



CORE-CLIMAX
European ECV CDR
Capacity Assessment Report
Deliverable D2.25

Doc.No. : CC/EUM/REP/15/001
Issue : v1
Date : 26 July 2015
WBSDBS:

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Document History

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Viju John	EUMETSAT	Detailed outline finalised	12 January 2015
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Viju John	EUMETSAT	Final integration of individual consensus results for data records	29 January 2015
Viju John	EUMETSAT	Final update of graphical representation of results	7 April 2015
Jörg Schulz	EUMETSAT	Final Version	14 April 2015

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1 EXECUTIVE SUMMARY

This report addresses the outcome of an assessment of Europe's capacity to provide climate data records for Essential Climate Variables (ECV) as defined by the Global Climate Observing System (GCOS). The assessment was performed in the framework of the EU FP7 project CORE-CLIMAX to support European and international activities including the establishment of the Copernicus Climate Change Service.

The CORE-CLIMAX project has extended existing models for systematic assessment of best practises applied in the areas of science, information preservation, and usage of the data using the so-called System Maturity Approach. The extensions developed in CORE-CLIMAX allow the application not only for satellite data sets, but also for all climate data records (*in situ*, combined satellite and *in situ*, reanalyses). The project discussed its adapted approach with many leading initiatives in Europe such as the EUMETSAT network of Satellite Application Facilities (SAF) and the ESA Climate Change Initiative (CCI) and also internationally with WMO, the CEOS WG Climate, NOAA, and USGS to enable a broad participation in the assessment activity.

Enough major European climate data providers participated in the assessment (37 data records have been assessed) to allow conclusions about the applicability of the System Maturity Matrix for a capacity assessment. The assessment has been performed for satellite and in situ data records as well as weather prediction model-based reanalysis output. Among the data providers were EUMETSAT including its Satellite Application Facility Network, the ESA Climate Change Initiative, Copernicus Atmosphere, and Land Services.

It is emphasised that such an assessment has been performed for the first time for in situ data records and the great response from the dataset developers is highly appreciated. Major European players such as Met Office Hadley Centre being responsible for the Hadley Centre Observational data sets (HadObs), Deutscher Wetterdienst having international responsibility for the Global Precipitation Climatology Centre (GPCC), the Koninklijk Nederlands Meteorologisch Instituut leading the European Climate Assessment & Dataset (ECA&D) project, and the Alfred Wegener Institute hosting the Baseline Surface Radiation Network archive participated in the assessment. Their inputs have very much contributed towards adapting the initially satellite oriented assessment approach to one that is more generally applicable.

There is only one global reanalysis that is being produced in Europe (ERA Interim) and that has participated in the assessment. It is certainly possible to extent the assessment to regional reanalyses such as from the EU FP-7 UERRA project in the future. It is suggested to perform SMM assessments for such datasets in the framework of the Copernicus Climate Change Service.

Although the assessment was done in a self-assessment mode, an audit-type assessment for some of the randomly picked datasets revealed that most of the data providers have been very honest in assigning maturity scores to their products. This provides an overall large credibility of the self assessment results presented in this report.

The value of the self assessment has several aspects. Firstly, it provides a consistent view on strengths and weaknesses of the process of generating, preserving and improving CDRs to

each individual CDR producer, agencies and the EC. In particular, the assessment fulfilled its promise to be useful for the data providers by providing guidance to further development of their data products. The assessment made some data providers for the first time thinking about issues such as software maintenance which are a cost sensitive long-term item for an operational service, in particular for data records based on satellite data. Data providers are encouraged to repeat the self assessment periodically, e.g., annually, that enables progress monitoring of a guided development.

Secondly, the presented assessment provides detailed information where European activities to provide climate data records for GCOS ECVs stand. It may provide guidance for climate services where eventually to concentrate their investments into climate data record generation activities. For instance, data records showing maturity levels 3 and 4 (forming the initial operations capability) in many categories are certainly those that have good chance to be developed into full operations capability within the next 3-5 years. Others showing maturity levels 1 and 2 (being at research level) may be invested in but rather for doing more research and engineering development than transfer to operational services.

Thirdly, the assessment provides information to the general user community of CDRs, including science and services, on the status of individual records and the collective state of all records. It also provides this information for the first time across different observing systems, i.e., users can compare between satellite and in situ data sets on the different aspects covered by the maturity assessment. By this transparency and openness towards the users of CDRs has significantly be enhanced by the CORE-CLIMAX project.

Fourthly, the collective effort of the assessment to compile consistent descriptions of the participating data records has better facilitated Europe's contributions to international activities on the evaluation of climate models using observations such as Obs4Mips that require standardised data record descriptions.

Further realised systematic applications of the maturity matrix approach known today include:

- SMM is used in H2020 EUSTACE project to assess the maturity of data set development;
- SMM and APM were included in the Quality Assurance concept of FP7 QA4ECV project;
- SMM is used as a starting point in the Horizon 2020 project GAIA-CLIM to address the maturity of ground-based reference networks;
- CEOS-CGMS WG Climate uses SMM to assess status of data records in GCOS ECV inventory, which will be periodically repeated;
- The WMO initiative for Sustained and Coordinated Processing of Environmental Satellite Data for Climate Monitoring (SCOPE-CM, <http://www.scope-cm.org/>) uses the SMM as a progress monitoring tool in each of its dedicated internationally coordinated Climate Data Record projects.

Planned systematic applications include:

- Implementation in the Quality Assurance and Enhancement (QC&E) pillar of C3S;
- SMM results (e.g., graphical output shown in Figure 2) can be used as addition to the tools provided by the FP7 CHARMe project, i.e., the assessment results provided can become available through CHARMe nodes as annotations to participating data records.

2 INTRODUCTION

2.1 Purpose and Scope

The purpose of this report is to document the capacity assessment conducted on behalf of the Core-Climax consortium for the Essential Climate Variable (ECV) Climate Data Records (CDR) produced by European data providers and scientists.

The report addresses the European and international context of the capacity assessment, describes in detail the methods used for the assessment, provides an overview and detailed results per assessed data record, gives an outlook on future usages of the developed methodology, and provides some concluding remarks.

2.2 Reference Documents

RD-1	5th Space Council - Council Resolution - Taking forward the European Space Policy, 26 September 2008	COUNCIL OF THE EUROPEAN UNION, 13569/08
RD-2	Wilson, J., M. Dowell and A. Belward (2010): European capacity for monitoring and assimilating space based climate observations – Status and prospects. JRC Scientific and Technical Report	EUR 24273 EN, 46 pp., DOI: 10.2788/70393
RD-3	Dowell, M., P. Lecomte, R. Husband, J. Schulz, T. Mohr, Y. Tahara, R. Eckman, E. Lindstrom, C. Wooldridge, S. Hilding, J. J. Bates, B. Ryan, J. Lafeuille, and S. Bojinski (2013): Strategy towards and architecture for climate monitoring from space.	[available from: www.ceos.org , www.wmo.int/sat , www.cgms-info.org].
RD-4	Bates, J. J. and J. L. Privette, (2012), A maturity model for assessing the completeness of climate data records.	Eos Trans. AGU, 93(44), 441.
RD-5	Core-Climax System Maturity Matrix Instruction Manual (2014)	CC/EUM/MAN/13/002 [available at www.eumetsat.int]
RD-5	Tote, C., Coelst, F., Swinnen, E., Dong, Q (2014): CORE-CLIMAX Climate Data Record Assessment Web tool instruction manual	VITO internal document
RD-6	CORE-CLIMAX Dataset Descriptions (2015) Deliverable D2.25	EUM/OPS/REP/15/800971 [available at: www.eumetsat.int]

3 EUROPEAN AND INTERNATIONAL CONTEXT

Developing ECV climate data records poses many challenges because of the varied use of climate data, the complexities of data record generation, and the difficulties in sustaining the activities over extended periods of time. Therefore it is essential to assess the capability of the existing climate data record development activities to ensure the prolonged generation of high quality ECV climate data records so that they can help to produce the underpinning science that supports decisions on mitigation and adaptation for a changing Earth climate.

The European Union Council Resolution *"Taking forward the European Space Policy"*, as adopted by the Competitiveness Council meeting on 26 September 2008 was identifying Space and Climate Change as new priority area for the European Space Policy addressing the issue of climate change. The Council resolution [RD-1] invited the Commission "... to conduct a study to assess the needs for full access to standardised data and for increased computing power, and the means to fulfil them, taking into account existing capacities and networking in Europe."

Implementing this action the European Joint Research Centre conducted a workshop 2009 that did an ad hoc analysis of the European capacity on the means to provide these data and how Copernicus Services can effectively contribute to providing these data. The report by Wilson et al. [RD-2] is summarising the results of this workshop that identified 44 GCOS ECVs as the minimum set of standardised climate data that EC should be considering. This workshop did also a first attempt to analyse the capacity according to maturity, differentiating between sustained operational capacity and non-operational funded repetitive capacity and additional infrastructure needs in order to fill gaps identified.

Despite of these initial efforts a letter from GCOS and WCRP in May 2010 addressed the issue of ensuring transparency, traceability and good scientific judgement in the generation of climate data records that underpin climate research and climate change monitoring. This letter in particular stated:

"However, there is currently no systematic international approach to ensure transparency, traceability and sound scientific judgement in the generation of climate data records across all fields of climate science and related Earth observations, and there are no dedicated sustained resources in place to support such an objective. For example, there are currently eight sea-ice concentration products produced by different organizations globally that differ significantly in providing an estimate of sea-ice extent and concentrations, mostly due to differences in methodology and not the variability or dynamics of underlying phenomenon. It is very confusing and frustrating for the non experts as to which one of these products they can use in their research and analysis, and the necessary documents to describe their attributes in a comparative manner akin to the global model inter-comparisons do not exist."

This letter clearly asked for a structured approach to generate, evaluate and maintain climate data records and also communicate information to the scientific and climate service communities in an understandable way providing guidance to the user.

A global group of space agencies has answered this request by developing an architecture for climate monitoring from space [RD-3] that considers the whole value adding chain from making measurements to the development of policy and decision making. The report by Dowell et al. (2013) [RD-3] details two usage scenarios for such architecture:

- The promotion of a common understanding of the implementation implications of meeting the various climate monitoring requirements, and
- To support an assessment of the degree to which the current and planned systems that provide measurements from which climate data records are generated meet the requirements, and the generation of an action plan to address any identified shortfalls/gaps.

Essential for the second usage scenario is to assess what exists, what the degree of completeness and sustainability of the existing is, what quality the existing has and what is planned/committed for the future. The group of authors of the Dowell et al. [RD-3] report and the CEOS-CGMS Working Group Climate together with WMO established the so called GCOS ECV inventory (ecv-inventory.com) for climate data records derived from satellite measurements. Currently, the inventory consists of approximately 220 entries provided by space agencies around the world and provides a first basis for an analysis of the existing data records. Because the first call to populate the inventory was only directed to space agencies the current inventory holding is not complete and further work is needed to cover all relevant data records. In addition an analysis of the ‘fit for purpose’ of the data records needs to be done.

To support the international activities described above and the establishment of the Copernicus Climate Change Service one major objective of the CORE-CLIMAX project is to systematically assess the capacity of ongoing European activities in the area of generation and provision of climate data records. With respect to a Copernicus Climate Change Service also the role of in situ data and model-based reanalysis needs to be considered. As the in-situ data sets are generally under national responsibility the current assessment does not cover all relevant in situ data record generated by European providers. However, their inclusion in the assessment is demonstrating the value of the tools developed in CORE-CLIMAX and encourages more national managed data record to be included in a future assessment.

For an assessment of the European capacity in the most objective way possible we need tools that provide a basis for information preservation, expectations, and a metric for progress to completeness. The maturity matrix approach proposed by Bates and Privette [RD-4] offers a systematic mean to assess if the data record generation follows best practises in the areas science, information preservation and usage of the data. Some example uses of the matrix maturity are the assessments of data records developed in the NOAA Climate Data Record program and in the 2nd phase of SCOPE-CM to measure progress in the projects. For both these cases, maturity assessments were first done as self assessments. External assessments could be done in a form of audit.

The CORE-CLIMAX project’s proposition is based on [RD-4], but extending the model to more general so that it can be applied not only for satellite data sets, but for all climate data records (*in situ*, combined satellite and *in situ*, reanalyses). The project discussed its adapted approach with many leading initiatives in Europe such as the EUMETSAT network of

Satellite Application Facilities (SAF) and the ESA Climate Change Initiative but also internationally with WMO, the CEOS WG Climate, NOAA and USGS.

Basically, three different aspects of our capacity to generate data records need to be considered:

- Scientific, engineering and information preservation practises;
- Usage of products including feedback and update mechanisms ;
- Quality of products with respect to applications.

Assessing if data record generation follows best practises provides an internal view on strengths and weaknesses of the processes to generate, preserve and improve climate data records for agencies and each individual data record provider. It also provides a general information to the community concerning the status of individual data records as well as collective information on the state of all existing records, highlighting areas for development and improvement. The assessment of quality of products is facilitating an external view on data records trying to answer the most important user question: Is the quality good enough for my application?

The CORE-CLIMAX project defined three major elements for its capacity assessment:

- Data record descriptions that contain technical specifications and also information on quality, e.g., links to further documentation and/or inventories such as the CGMS-CEOS-WMO inventory (see <http://ecv-inventory.com/ecv-inventory>);
- A System Maturity Matrix (SMM) that evaluates if the production of a data record follows best practices for science, engineering, information preservation and facilitation of usage, and;
- An Application Performance Metric (APM) that attempts to evaluate the performance of an ECV CDR with respect to a specific application. To be able to apply the APM, user requirements for each application are needed to be compared to the actual technical specifications and validation results.

The three elements of the capacity assessment are designed to be independent of each other and represent means to support an assessment but do not provide the assessment results per se. The SMM is designed to principally be used without considering specific applications. With this the SMM does not depend on user requirements for specific applications and their change over time. In contrast the APM should facilitate a comparison of the real technical features of a data record and results of validation and other data quality assessment activities to user requirements for an application. It basically provides summary information on how close a specific data record is at fulfilling the requirements of a specific application. A prototype APM was developed during the capacity assessment workshop because the need of giving advice to data users what data record can be used for what application is needed. This need is manifested for instance in the huge amount of information provided on validation of data records that is unlikely to be processed by institutions that want to use the data records. The APM is intended to support institutions in making choices among different existing data records without the need to assess the full documentation of all potential data records. However, it shall be noted that the APM is a new concept that was used for the first time in the CORE-CLIMAX capacity assessment workshop. The development of an applicable tool was beyond the scope of the CORE-CLIMAX project. It is expected that the APM will be further adapted in the future to become fully functional.

4 ASSESSMENT TOOLS AND PROCEDURE

4.1 Data Set Description Template

A data record description template which is given below has been filled for each individual data record that entered in the CORE-CLIMAX assessment. The template is structured very similar to the template used for data sets entering the Climate Model Inter-comparison Project (CMIP) exercise. Only the part on the applications has been extended as the usage of most climate data records goes beyond the climate model comparison. Keeping these templates very similar was done purposefully to support the usage of the assessed data records in the CMIP-6 exercise with preparations being started during 2014. The Data Set Description Template contains advice on how to fill the individual sections. The overall aim is that these descriptions do not extend to more than five pages.

CORE-CLIMAX Data Set Description

(General Note: This data set description shall not become longer than 5 pages per data set described. Please stay to the most important facts and use tables and bullet lists to provide information where appropriate.)

(Type Data Set Name and if available digital identifier here):

- **Intent of the Document**

(Provide information on what data set is described and for what application(s) it was created. Keep in mind that the information is targeted at users of any level who wish to use the dataset for climate applications. Users may not be expected to be experts for in situ, remote sensing or reanalysis techniques.)

- **Point of Contact**

(Please provide a point of contact: Organisation and Contact details (at least a contact name, organisation and e-mail address)).

- **Data Field Description**

(Provide a link to an existing technical product specification or provide the information in a form of a table in this document. The specification shall at least include variable names and units (eventually including uncertainty estimates that come with the product), length of record, spatial coverage, spatial and temporal sampling.)

- **Data Origin**

(Provide a basic description of the methodology used to derive the product including the input data used and the source (provenance) of the data. Also provide a description of data processing methods such as (inter-satellite) calibration, algorithms employed, homogenization applied, mapping and averaging, etc. If the product makes heavily use of NWP and/or climate model data, e.g., as background fields this should be described as well.

In case of reanalysis data records please indicate what reanalysis system (coupled or single) has been used and name and version of the model(s).)

- **Validation and Uncertainty Estimate**

(Provide a summary of validation activities performed for the product and provide a summary of systematic and random uncertainty of the product and how these vary with space, time and state (tabulated form appreciated). In particular information on temporal stability of the data which is an indication of whether the data can be used for longer term variability and trend analysis is appreciated.)

- **Considerations for climate applications**

(Provide information on the applicability of the product for the planned application (stated in section 1) including limitations. In particular observational products applicable for model evaluation should state the different character when compared to model data. For instance for satellite-derived products it is important to describe limitations such as validity in specific areas (e.g., ocean or land only), unresolved diurnal cycles or diurnal cycle aliasing due to orbit drifts for polar orbiting satellites, sampling issues such as in the presence of clouds, sensitivity of the instrument, etc and their respective impacts on the application. For in situ measurements or gridded data sets derived from station data limitations due to the representativeness of the data, etc. and their effect for an application shall be provided.)

- **Instrument Overview**

(Provide information on the type of instruments (in situ/remote sensing) used to measure the variable provided including the measurement principle (e.g., infrared emission measured with a spectrometer) and give a description of the instrument science objective, capability, measurement principle, satellite and orbit characteristics or observation location and practice for in situ. Provide the strengths and weaknesses of the instrument measurement. If an instrument simulator is available, provide a short description and references later for details.

In the case of a re-analysis data set only indicate what instrument data relevant to the parameters considered have been assimilated. This can simply be a link to the information.)

- **References**

(Provide a complete list of references used in this document and may provide additional reading references on measurement principles, retrievals, modelling, validation, uncertainty characterisation, product, and applications.)

- **Revision History**

(Indicate the version number of this document, the date of writing and who has edited the document.)

4.2 System Maturity Matrix (SMM)

4.2.1 SMM description

The SMM is a tool to assess the system maturity of a CDR. SMM basically assesses whether CDR generation procedures have been compliant with best practices developed and accumulated by the scientific and engineering communities. The concept behind the CORE-CLIMAX system maturity matrix can be best illustrated as shown in Figure 1.

Creation of a climate data record is anchored on a number of assumptions and approximations, and thus is associated with significantly large uncertainties. This is mainly because the observing systems were designed to measure weather, but not for monitoring climate. Unless these assumptions and approximations are well understood and associated uncertainties are well characterized it is quite possible to misinterpret results of scientific analyses using these data records. Therefore uncertainty characterisation is a key area where CDRs need to achieve high levels of maturity.

Stable and easily maintainable software is one of the essential components of successful CDRs. It should be easy to diagnose deficiencies, to make changes to the software, and to test the software after modification. Non-maintainable software can result in unexpected increase in the production cost of data sets. The metadata, especially describing the input raw data are essential because development of a CDR is often an evolutionary process and repeated reprocessing of the input dataset is necessary. This also demands the archival of the raw data for reprocessing. CDRs shall be archived in a way that allows easy access to the users with varying requirements and skills. Therefore it demands less complicated file structures and provisions for read and analyses (e.g., sub-setting, plotting) software. Availability of comprehensive descriptions of technical and scientific aspects of the production chain is another essential characteristic of a mature CDR.

Above all the most important maturity characteristic of a successful CDR is the acceptance and usage by the user community and whether there are mechanisms to receive and incorporate feedbacks from the user community.

There are 6 major categories where assessments are made:

1. Software readiness
2. Metadata
3. User documentation
4. Uncertainty characterisation
5. Public access, feedback, and update
6. Usage

For each of these categories, the assessment will assign a range of score (1 – 6) that reflects the maturity of the CDR with respect to a specific category. Computing an overall score should be avoided and is useless. The real information is not in the overall scores, but in the details of the assessments, from which one can identify the needs or opportunities for improvements of the system which generates a CDR.

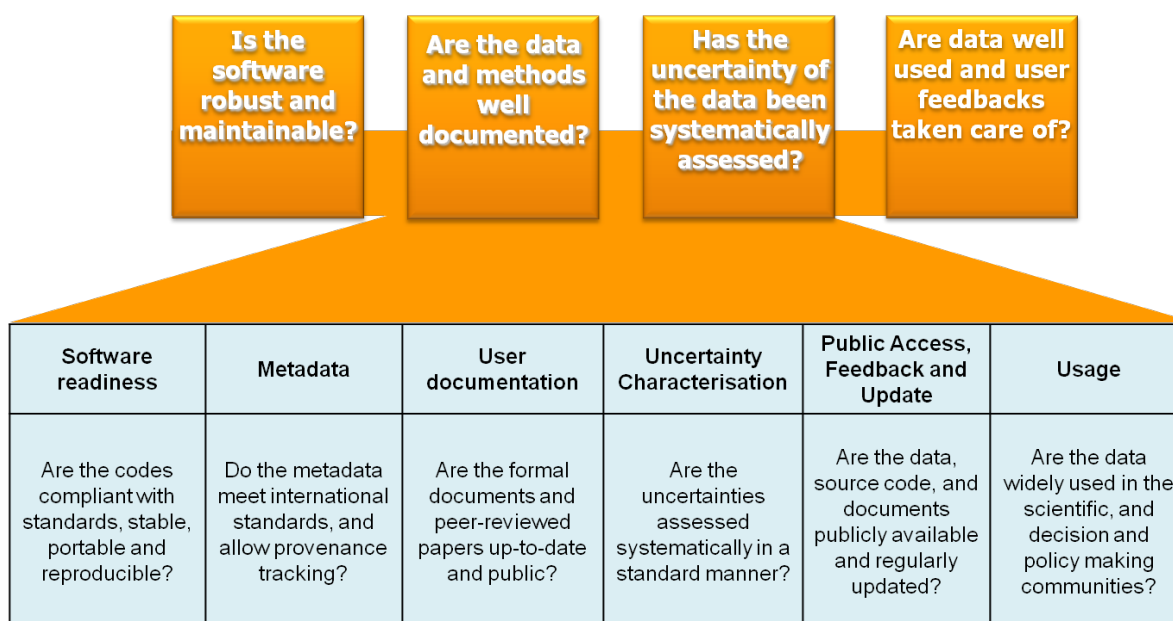


Figure 1: Illustration of CORE-CLIMAX system maturity matrix (SMM).

The maturity is also considered in three broad categories that give information on the grade of sustainment of the CDR generation process. The nomenclature for these broad categories has been imported from NOAA and follows [RD-4]: For a detailed description on how to fill an SMM, please refer to RD-5.

- Maturity scores 1 and 2 establish Research Capability (RC): All aspects of the CDR are still under development and with the PI most likely in projects.
- Maturity scores 3 and 4 establish an Initial Operations Capability (IOC): At this stage the CDR and associated material are available to the user community. The CDR has reached a status where its usefulness is completely demonstrated and decisions need to be made to sustain its maintenance and further development. At this stage so called transitions of CDR generation capabilities from research units to more operational oriented units are happening. Good examples for this are the import of the HOAPS data record (www.hoaps.org) from the Max-Planck Institute in Hamburg into the EUMETSAT Climate Monitoring Satellite Application Facility or the transition of the well known International Satellite Cloud Climatology Project (ISCCP) from NASA into NOAA-NCDC.
- Maturity scores 5 and 6: Full Operations Capability (FOC): At this stage the production of the CDR has been transitioned into operational environments, e.g., the whole processing process is under configuration management, fully automated and performance is monitored. The production chain meets the goal of acquiring capabilities to provide uninterrupted and indefinite data provision for climate monitoring. The data provider, e.g., a space agency takes complete responsibility for the maintenance and also further development of the CDR. The specific development activities still are performed by scientists within or external to the responsible agency or both. A current example for a full operations capability is the EUMETSAT CM-SAF.

The major categories of the SMM are subdivided into several minor categories and assessment scores are assigned based on scores in these minor categories. After a long deliberation at the workshop we have decided to take the range of scores (that is the minimum and the maximum) of the minor categories to represent a major category. The motivation for showing the minimum score is given by the fact that this score is informing about completeness of a major category. It directly points to an area for improvement. The maximum score will then indicate whether some minor categories have a higher score. It should be noted that the numbers need anyway an interpretation per assessed data record because the circumstances under which the data records were created hugely differ for satellite, in situ data records and reanalysis.

The minor categories sometimes include categories that cannot easily be assessed by an external assessor without asking the provider of the data which could be done in a formal audit type assessment but was not foreseen for the CORE-CLIMAX capacity assessment.

The SMM is provided as a multi-level Excel file where the scores shall be provided in the pages associated with the minor categories. These scores are then automatically be used to mark the range of scores for the major category highlighting the minimum score to directly point to an imminent issue. If a minor category is not filled a maturity of 1 will be set. There is one exception which is in the category Usage. In this category the usage of a data record is considered for applications in research and decision making. Which columns are taken into account depends on the intention of the data record. For instance, if the description is only pointing to use in research only that category shall be used to compute the overall maturity. It is planned to replace the Excel file with a web based tool and its availability will be communicated in due course of the project.

It is very important to use a unique CDR name and identification number (version) when the SMM is filled to assess a CDR. This shall match the name and identification information on the data set description form. Also a provision of the assessment date to follow the evolution in maturity of a particular CDR is very important.

4.2.2 SMM Web tool

A web tool has been designed so that CDR reviewers can perform the assessment of a CDR and thereby provide input to a database, from which information (statistics etc.) can be derived.

The purpose of this web tool instruction manual is to give a brief description specifically on how the web tool should be used. For a detailed description on the web tool please refer to RD-6.

Once all scores of the SMMs are entered one is able to generate overview of the maturity of the dataset. The overview shows the variable name, the assessment version, the earth-system which the dataset represents, the original project from where the variable is derived, type of assessment, and the minimum and the maximum scores as well as the time of the assessment.

The overview can be exported in a format of table where the red grids indicate the score between 1 and 2, the yellow grids represent the score between 3 and 4 while the green cells are those score between 5 and 6.

Software Readiness	Metadata	User Documentation	Uncertainty Characterisation	Public access, feedback, and update	Usage
Coding Standards	Standards	Formal description of scientific methodology	Standards	Public Access/Archive	Research
Software Documentation	Collection level	Formal validation report	Validation	Version	Decision support system
Numerical Reproducibility and portability	File level	Formal product user guide	Uncertainty quantification	User feedback mechanism	
Security		Formal description of operations concept	Automated quality monitoring	Updates to record	
Legend					
1	2	3	4	5	6

Figure 2: An example of SMM web tool generated overview of a dataset.

5 ASSESSMENT WORKSHOP

The CORE-CLIMAX Essential Climate Variable (ECV) Capacity Assessment Workshop was held at EUMETSAT Head Quarters in Darmstadt on 21 – 23 January 2014.

The workshop gathered about 40 participants representing all relevant European climate data record producers including EUMETSAT SAF network, ESA CCI projects, EC projects and EUMETSAT member state weather services as well as stakeholders (EC, CGMS, CEOS, WMO). The workshop covered data records for Land, Ocean, and Atmosphere constructed from satellite and in situ data as well as reanalysis. The workshop participants were asked to do a self assessment of their data records using the SMM prior to the workshop and there were 30 data sets (23 are based on satellite measurements, 6 are based on *in situ* measurements, and one is reanalysis based) with SMM results for analyses during the workshop.

First day of the workshop was dedicated to provide a big picture on the current status of international and European activities on the generation of ECV CDRs and the need of their sustained generation for effective climate services. The history, concepts, and initial feedbacks on the developed tools were also discussed to develop a common understanding on the assessment tools.

On the second day, the participants were divided into three subgroups (Land, Ocean, and Atmosphere themes) to discuss the SMM self assessments, to make more common understanding of the SMM, to reconcile the differences between different CDR communities, to come up with suggestions for improvements to the SMM, and to deliberate the idea of the APM.

The third day of the workshop presented and analysed the discussions from the three breakout groups and made recommendations and the way forward. The workshop participants endorsed the SMM as a useful tool for assessing completeness and identifying weaknesses in the development systems which produce CDRs from satellites and *in situ* measurements and reanalyses. The presentations and breakout group discussions provided a common understanding of most of the elements in the SMM among different communities and programs and based on these understandings further improvements have been proposed for the SMM and its instruction manual. However, the workshop suggested that the process of introducing the concept of SMM in different communities needs to be open and inclusive. As the SSM is based on “best practises”, reviews and changes to the SMM are expected on longer time scales (~10 years), but it is expected to have a review and eventual change prior to an implementation to a major service such as the Copernicus Climate Change Service. It was recommended to use the SMM in the review process of existing CDR programs such as EUMETSAT-SAF network and ESA-CCI. It was also recommended that SMM can be linked with the publication of CDRs in peer reviewed journals similar to the enforced use of unique digital object identifiers. The presentation of SMMs will follow the proposed colour coding (range of scores in each sub-category) and may include an interpretation of the scores.

After the workshop we further contacted European dataset developers who were not able to participate in the workshop for contributions and received inputs for 6 more datasets. All data set descriptions for the data sets contained in this report can be found in RD-6.

6 RESULTS OVERVIEW

The capacity assessment was performed as self assessment, i.e., all SMM scores for individual data sets presented in section 6 need to be considered with some care. The assessment workshop has very much improved the understanding of each individual category of the SMM but it cannot be excluded that a data provider misunderstood a specific entry and over- or underestimated the maturity of an assessed data set.

The main assessment results can be summarised as follows:

- For FCDRs a high variance in all scores is observed. The more operational the higher scores are for software readiness, meta data, documentation and public access;
- Operational TCDR get high scores for Meta Data, User Documentation, Public Access and Usage. Medium scores are sometimes observed for Software Readiness and Uncertainty Characterisation;
- Scientific TCDR get high scores for User Documentation, Uncertainty Characterisation, and Usage. Lower scores for Software Readiness and Public Access;
- From the differences between TCDRs produced in operational or scientific environments it can be deduced that getting consistently high scores in all categories takes approximately 5-10 years but can be achieved by a successful transfer of data record production from scientific to operational environments keeping the scientific expertise on board;
- The assessment of in situ datasets appears sometimes difficult because they are often updated continually and therefore the concept of versioning is very different to satellite datasets or not existing. An example to illustrate the problem was provided by Nick Rayner, Met Office: “As an example, let's take EN4, our sub-surface ocean data

set. We're about to release EN.4.1.2.0, where the version number is incremented either when there is a software change and/or when new individual batches of observations are included (in the past, not for a monthly extension of the data set). So, extending that to land station data (as we do for CRUTEM4, currently on CRUTEM.4.2.0.0) this means bringing in either (i) a new set of stations or (ii) a number of years that have recently been digitised from stations that we already had; this changes the version number. This is important because people can then trace their results or their gridded data set back to a particular version of the in situ observations and so know why their results or their data set might differ from someone else's who used a different version." The assessment workshop encouraged to use versioning of data sets for better reproducibility, transparency, and for easier understanding and use of the data;

- The maturity of *in situ* data largely depends on the selection of a set of stations or time period. If old and thus especially valuable data records would be excluded, this would immediately raise the maturity noticeably. In general, a more comprehensive data set will have a lower maturity compared to a selected subset, which might lead to misinterpretation;
- Uncertainty existed among the data providers on the applicability of Software Readiness category for in situ data. Data providers were not aware that cost for software maintenance can be substantial, e.g., when not-portable/not-documented;
- SMM assessment was not applied to measurement qualities such as traceability, measurement metrology and sustainability. Needed changes and application will be addressed in the EU H2020 GAIA-CLIM project;
- The assessment workshop discussed that the SMM was not used assessing source data, e.g., FCDRs, used to derive the ECV data sets. The SMM, in principle, is applicable to and can be applied to all kinds of climate data, including FCDR, so in the future there could be an SMM assessments for those data too that can be linked to the derived ECV data records;
- As the SMM is based on "best practises", review and changes to the SMM are only expected on longer time scales (~10 years). However, the workshop proposed to review and eventual change the SMM prior to an implementation, e.g., in the Copernicus Climate Change Service;
- During the assessment workshop it was encouraged to use SMM as a part of a peer-review process for data records. For instance in the process of publishing peer reviewed papers on data sets (in specialised journals) the existence of a maturity assessment could become mandatory.

7 ASSESSMENT RESULT PER DATASET

We conducted the assessment by categorising the datasets based on measurements target: Atmosphere, Ocean, Cryosphere, and Land. We treat fundamental climate records and reanalysis separately.

7.1 Fundamental Climate Data Records

We present SMM results of fundamental climate data records here. Fundamental Climate Data Records – FCDR – are sensor data that have been improved and quality controlled over time, together with ancillary data used to calibrate them. We treat them separately here

because they can be used to create Thematic Climate Data Records – TCDR – which can pertain to different earth systems.

7.1.1 STRATOSPHERIC SOUNDING UNIT (SSU) FCDR

Name	SSU Level 1b radiances
Origin	NCDC/CLASS; Cheng-Zhi Zou cheng-zhi.zou@noaa.gov
Spatial Characteristics	Global
Temporal Characteristics	Dec 1978 – Jan 2006; Instantaneous

Software Readiness	Metadata	User Documentation	Uncertainty Characterisation	Public access, feedback, and update	Usage
Coding Standards	Standards	Formal description of scientific methodology	Standards	Public Access/Archive	Research
Software Documentation	Collection level	Formal validation report	Validation	Version	Decision support system
Numerical Reproducibility and portability	File level	Formal product user guide	Uncertainty quantification	User feedback mechanism	
Security		Formal description of operations concept	Automated quality monitoring	Updates to record	
Legend					
1	2	3	4	5	6

The SSU level 1b radiances are stored at the NOAA-CLASS archive: <http://www.class.ncdc.noaa.gov/saa/products/welcome/>. They have been processed from the level 0 counts to calibrated radiances. The SSU observed radiances in the 15 micron carbon dioxide band, with three channels peaking at about 29 km, 35 km and 45 km in the stratosphere. The designation of these channels here is 1 to 3 respectively, although they are often referred to as channels 25 to 27 of the TOVS in the literature. The radiances originated from deep atmospheric layers. For nadir views the half-width varies from 16 km deep (channel 1) to about 22 km (channel 3). The SSU only flew on TIROS-N and NOAA's 6, 7, 8, 9, 11 and 14. In 1998 the AMSU-A instrument was launched which replaced the SSU in operations but measurements continued to be made by the SSUs until 2006. The data are stored as an orbit by orbit format with one record per scan line.

This is an important dataset for monitoring changes in stratospheric temperatures. However the current state of SSU level 1b radiance datasets still require work for climate monitoring (e.g., Thompson et al., 2012¹).

The software for this data set is in a preliminary stage which means a good effort is necessary to make this data set operational. All sub categories have score 1.

¹ Thompson et al., 2012: The mystery of recent stratospheric temperature trends, *Nature* 491, 692–697, doi:10.1038/nature11579.

Metadata are sufficient to understand and use the data at both collection and file levels (score 2 each), however no metadata standards are considered.

Formal documentations on scientific methods, validation are available in the peer reviewed literature and 2 recent papers describing the data processing have been accepted for peer reviewed publication. There is no description of operations concept, but a limited product user guide is available. Thus this category is primarily under research grade.

Significant efforts have been made recently to quantify uncertainties for this dataset and peer-viewed papers have been submitted or published.

Data and documentation are archived and available from NCDC, however there is no regular or standard mechanism established for collecting user feedbacks and updating the dataset.

The product has been moderately used for research and decision making.

7.1.2 SSM/I FCDR Edition 1.0

Name	SSM/I FCDR
Origin	CM SAF; contact.cmsaf@dwd.de
Spatial Characteristics	Pixel resolutions varying with channels.
Temporal Characteristics	Jul 1987 – Dec 2008

Software Readiness	Metadata	User Documentation	Uncertainty Characterisation	Public access, feedback, and update	Usage
Coding Standards	Standards	Formal description of scientific methodology	Standards	Public Access/Archive	Research
Software Documentation	Collection level	Formal validation report	Validation	Version	Decision support system
Numerical Reproducibility and portability	File level	Formal product user guide	Uncertainty quantification	User feedback mechanism	
Security		Formal description of operations concept	Automated quality monitoring	Updates to record	
Legend					
1	2	3	4	5	6

The CM SAF Fundamental Climate Data Record of SSM/I Brightness Temperatures provides homogenised and inter-calibrated brightness temperatures from the six SSM/I radiometers aboard F08, F10, F11, F13, F14, and F15.

Software used to generate the data set is in the initial operations capability except that security aspects of the software are not tested yet.

Metadata has the highest score for all categories. This implies that the dataset meets international standards for metadata and the compliance has been systematically tested and complete collection and file level metadata are available for the entire data period.

Formal scientific descriptions of the methods used to generate the data are available from the data provider. Data provider keeps updated validation report and user manual and comprehensive description of operations concept is available. More work on publishing the scientific methods will move the User Documentation category to full operational capability.

The dataset is in initial operations category for Uncertainty Characterisation category. The data set has not been participated in an international data assessment, but such assessments are generally not available for FCDRs.

Data and documentation are archived, under version control, and available from the data provider. However, the source codes which are used to generate the data are neither archived nor available to users. Regular mechanisms for collecting user feedbacks are established and the data are being regularly updated whenever new input data or new feedbacks are available.

These data are well received by users though the number of users is limited.

7.1.3 Baseline Surface Radiation Network (BSRN)

Name	Archive of the Baseline Surface Radiation Network (BSRN)
Origin	World Radiation Monitoring Center (WRMC); Gert.Koenig-Langlo@awi.de
Spatial Characteristics	Global stations, the number is varying over time, e.g., 9 stations 1992 and 58 stations 2014.
Temporal Characteristics	Selected research stations, which provide typically 1-minute averaged short- and long-wave surface radiation fluxes of the best possible quality currently available.

Software Readiness	Metadata	User Documentation	Uncertainty Characterisation	Public access, feedback, and update	Usage
Coding Standards	Standards	Formal description of scientific methodology	Standards	Public Access/Archive	Research
Software Documentation	Collection level	Formal validation report	Validation	Version	Decision support system
Numerical Reproducibility and portability	File level	Formal product user guide	Uncertainty quantification	User feedback mechanism	
Security		Formal description of operations concept	Automated quality monitoring	Updates to record	
Legend					
1	2	3	4	5	6

Main objectives of the Baseline Surface Radiation Network (BSRN; <http://bsrn.awi.de>) dataset are to monitor the shortwave and longwave surface radiative fluxes, to provide data for the calibration and validation of satellite-based estimates of the surface radiative fluxes and to produce high quality observational data for comparison with models and to derive long-term regionally representative climatologies.

As this dataset is generally a collection of raw measurements, the system for generating it does not require a robust software system, for example, as in case of a satellite data production system. However, a check of the website reveals that at the Data Warehouse, there must be some software to handle the data, to check, compress and format change, to produce station lists and maps, and some software for quality checks are provided to the users. Therefore, Software Readiness maturity of these components could have been rated.

The highest score for metadata represents the completeness of this category.

User documentations is not rated, however, users are guided in a convenient manner to their desired product via the web-pages. There are papers and other material explaining the methods of observations. Thus, this category could also have been rated.

Papers and reports on uncertainty information are linked, Validation using external reference data done for limited locations and times, a quality toolbox is provided, and limited information on uncertainty arising from systematic and random effects in the measurement.

Data and documents are archived and version controlled by the data provider. Regular mechanisms for user feedbacks are established and the product is regularly updated and interim data records are available.

The product has become a reference dataset for multiple applications and has been widely used for policy making.

7.2 Atmosphere

In this session we present assessment results of the atmospheric data sets.

7.2.1 ESA GHG-CCI datasets

Dataset attributes

Name	GHG-CCI; XCO ₂ and XCH ₄
Origin	ESA GHG-CCI; buchwitz@uni-bremen.de
Spatial Characteristics	Global, 30 x 60 km ² , global (land only for CO ₂)
Temporal Characteristics	2002 – 2012 (SCIAMACHY); 2009 – present (GOSAT); Instantaneous

System Maturity Matrix Scores

Software Readiness	Metadata	User Documentation	Uncertainty Characterisation	Public access, feedback, and update	Usage
Coding Standards	Standards	Formal description of scientific methodology	Standards	Public Access/Archive	Research
Software Documentation	Collection level	Formal validation report	Validation	Version	Decision support system
Numerical Reproducibility and portability	File level	Formal product user guide	Uncertainty quantification	User feedback mechanism	
Security		Formal description of operations concept	Automated quality monitoring	Updates to record	
Legend					
1	2	3	4	5	6

Climate prediction requires a good knowledge on the Greenhouse Gas (GHG) sources and sinks, in particular CO₂ and CH₄ and other GHG. The GHG-CCI (<http://www.esa-ghg-cci.org/>) data products contain information on regional CO₂ and CH₄ surface fluxes (emissions and uptake) and therefore can be used to improve our knowledge on GHG surface fluxes.

These products are generated with GHG-CCI “ECV Core Algorithm” (ECAs). ECAs are algorithms to retrieve dry-air column-averaged mole fractions of carbon dioxide (CO₂) and methane (CH₄), denoted XCO₂ (in ppm) and XCH₄ (in ppb) from currently two satellite instruments: SCIAMACHY onboard ENVISAT (2002-2012) and TANSO-FTS onboard GOSAT (2009-ongoing). The GHG-CCI products are Level 2 products, i.e., detailed information such as time and location is provided for each single satellite observation (ground pixel). Requirements are formulated in the corresponding User Requirements Document (URD, http://www.esa-ghg-cci.org/?q=webfm_send/173).

The software used to generate the dataset is under research grade, i.e., coding standards are not fully systematically applied, limited documentation of the code, and the software is not fully checked for portability, numerical reproducibility, and security.

Metadata are in initial operational capability, i.e., standards are defined but not systematically applied, collection level metadata are sufficient to use and understand the data without external assistance, and limited location level metadata are available. Recently the data format and documentation has been significantly improved (see, [http://www.esa-ghg-cci.org/-> Documents](http://www.esa-ghg-cci.org/->Documents) and -> CRDP (Data), in particular the PSD (http://www.esa-ghg-cci.org/index.php?q=webfm_send/160)).

User Documentation is in initial operational capability category. Comprehensive descriptions of scientific methods and validation are available on the GHG-CCI website ([http://www.esa-ghg-cci.org/-> Documents](http://www.esa-ghg-cci.org/->Documents) and -> CRDP (Data)) and journal papers are published on the methods and validation ([http://www.esa-ghg-cci.org/-> Publications](http://www.esa-ghg-cci.org/->Publications)). Product user guides are available ([http://www.esa-ghg-cci.org/-> CRDP \(Data\)](http://www.esa-ghg-cci.org/->CRDP(Data))) and the operations concept (http://www.esa-ghg-cci.org/?q=webfm_send/193).

The dataset falls into initial operational capability for Uncertainty Characterisation category (latest assessment: PVIR: http://www.esa-ghg-cci.org/index.php?q=webfm_send/160, AIECAR: http://www.iup.uni-bremen.de/~buch/ghgcci_public/AIECARv1_GHG-CCI_Final.pdf). The only sub-category under research grade is Automated Quality Monitoring which is only partially in place yet (see [http://www.esa-ghg-cci.org/-> CRDP \(Data\)](http://www.esa-ghg-cci.org/->CRDP(Data)))).

The data, documentation, and source code are archived by the data provider, which are version controlled by the PI. User feedback is collected and regular updates to dataset are made by the PI.

The data are extensively used for research ([http://www.esa-ghg-cci.org/-> Publications](http://www.esa-ghg-cci.org/->Publications)) but not yet for decision support system.

7.2.2 ESA-CCI Aerosol datasets

Name	ESA Aerosol_cci datasets
Origin	ESA Aerosol_cci; thomas.holzer-popp@dlr.de
Spatial Characteristics	Global, different resolution (0.1 to 10 degrees)
Temporal Characteristics	~weekly-monthly sampling (between 1995 and 2012)

Software Readiness	Metadata	User Documentation	Uncertainty Characterisation	Public access, feedback, and update	Usage
Coding Standards	Standards	Formal description of scientific methodology	Standards	Public Access/Archive	Research
Software Documentation	Collection level	Formal validation report	Validation	Version	Decision support system
Numerical Reproducibility and portability	File level	Formal product user guide	Uncertainty quantification	User feedback mechanism	
Security		Formal description of operations concept	Automated quality monitoring	Updates to record	
Legend					
1	2	3	4	5	6

Aerosol CCI provides following datasets after three years of intensive algorithm development, sensitivity analysis, validation and inter-comparison activities (Holzer-Popp, et al., 2013) and a round robin exercise of eight different algorithms (de Leeuw et al, 2013):

- AOD and Ångström exponent (AE)
- Stratospheric extinction profiles and aerosol optical depth
- Absorbing aerosol index (AAI)

AOD/AE datasets are provided for two main purposes: climate aerosol model evaluation, data assimilation into global aerosol re-analysis/forecasting model systems. The stratospheric dataset is provided as correction to the total column AOD retrievals (mostly relevant in case of major volcanic eruptions) and for stratospheric climate model evaluation. The AAI dataset (so far as only information for aerosol absorption, though qualitative) has been prepared for comparison to model datasets by developing a model AAI simulator and analyzing major sensitivities.

The software used to generate the datasets is partially compliant with coding standards and contains moderate documentation. However, the code is not evaluated for portability and numerical reproducibility, but the PI confirms of no security problems.

The metadata associated with the datasets are compliant with international standards and there is complete file level metadata and the collection level metadata are sufficient to understand and use the data.

The dataset falls into category of initial operational capability for User Documentation by maintaining comprehensive description and peer reviewed paper on scientific methods. Validation report is available from the PI and a paper on validation is submitted, user guide and limited operations concept are available from the data provider.

Uncertainty characterisation category is also in the initial operational capability. The data are inter-compared with other corresponding CDRs and quantitative estimates of uncertainty provided at location level. However, automatic quality monitoring is not in place.

Data, source code, and documentation are archived by the data provider with PI's versioning. The datasets are regularly being updated by using feedbacks from scientific community.

The data usage is on initial level (e.g. data assimilation test by ECMWF/MACC, trend and model comparison by AEROCOM).

7.2.3 GNSS Radio Occultation

Name	GNSS-RO DATA
Origin	ROM SAF
Spatial Characteristics	Global, 0-40 km (5 degrees in latitude, 200 m in vertical)
Temporal Characteristics	08/2001 to present

Software Readiness	Metadata	User Documentation	Uncertainty Characterisation	Public access, feedback, and update	Usage
Coding Standards	Standards	Formal description of scientific methodology	Standards	Public Access/Archive	Research
Software Documentation	Collection level	Formal validation report	Validation	Version	Decision support system
Numerical Reproducibility and portability	File level	Formal product user guide	Uncertainty quantification	User feedback mechanism	
Security		Formal description of operations concept	Automated quality monitoring	Updates to record	
Legend					
1	2	3	4	5	6

ROM SAF zonal monthly mean climate data products are publically available in the ROM SAF archives (<http://www.romsaf.org>). The data cover the troposphere and the lower and middle stratosphere, and are primarily intended for global climate monitoring and climate research applications, including model validation.

The software used to generate the dataset is under initial or full operational capability. The code is partially compliant with coding standards, moderately documented, portability and numerical reproducibility checked, and passed data provider's security review.

The metadata associated with the datasets are compliant with international standards and there is complete file level metadata and the collection level metadata are sufficient to understand and use the data.

The User Documentation category is in full operational capability with comprehensive documentation on methods, validation, user guide, and operations concept.

Uncertainty characterization category is in initial to full operational capability. The data sets have participated in multiple international data assessments. Uncertainties are quantified at location level, and automated quality monitoring feeding back to metadata or documentation.

Full operational capability is also achieved for Public Access, Feedback, and Update category with fully version controlled data, source code, and documentation are archived by the data provider. Regular feedback mechanisms are established and interim data records are being produced.

The GNSS-RO climate data have proven its utility in several studies but the data are not yet fully utilized, due to the limited temporal coverage of the time series and the relative novelty of this type of observational data. As the GNSS-RO time series lengthens, the potential usefulness and the number of possible applications increase.

7.2.4 Free Tropospheric Humidity (FTH)

Name	FTH edition 1.0
Origin	CMSAF; contact.cmsaf@dwd.de
Spatial Characteristics	(45W – 45E; 45S – 45N), gridded res. - 0.625°×0.625°
Temporal Characteristics	July 1983 to December 2009, 3 hourly sampling

Software Readiness	Metadata	User Documentation	Uncertainty Characterisation	Public access, feedback, and update	Usage
Coding Standards	Standards	Formal description of scientific methodology	Standards	Public Access/Archive	Research
Software Documentation	Collection level	Formal validation report	Validation	Version	Decision support system
Numerical Reproducibility and portability	File level	Formal product user guide	Uncertainty quantification	User feedback mechanism	
Security		Formal description of operations concept	Automated quality monitoring	Updates to record	
Legend					
1	2	3	4	5	6

FTH is an important climate variable due to its large sensitivity to outgoing longwave radiation (OLR) and thus a strong feedback factor in the Earth's climate system. Monitoring of FTH globally is therefore important to understand our changing climate. However, measuring humidity in the free troposphere is a challenge and there are only a few datasets available for FTH. One of these datasets is the FTH dataset produced by the EUMETSAT's CMSAF (http://wui.cmsaf.eu/safira/action/viewDoiDetails?acronym=FTH_METEOSAT_V001). FTH are derived from METOSAT 1st and 2nd generation geostationary satellites.

The dataset has highest score in Metadata sub-category, which meets Full Operational capability.

The scores are very high for User Documentation sub-category which is a reflection of rigorous documentation process in the SAF network. The scores are meeting Initial or Full Operational capability.

The Uncertainty Characterisation section is in the Initial Operational capability.

The Access, User Feedback and Update are also in Initial Operational capability.

The usage of this product is mainly for Research and it is under Initial Operational capability. The expectation is to have an impact on decision support system in the long run.

The dataset can potentially make some improvements in the Software Readiness category because the scores in this category are either in Research Grade or Initial Operational capability.

7.2.5 HOAPS release 3.2

Name	HOAPS release 3.2
Origin	CMSAF; contact.cmsaf@dwd.de
Spatial Characteristics	Only over the ice-free ocean surfaces; 0.5° x 0.5°
Temporal Characteristics	Monthly averages and 6-hourly composites

Software Readiness	Metadata	User Documentation	Uncertainty Characterisation	Public access, feedback, and update	Usage
Coding Standards	Standards	Formal description of scientific methodology	Standards	Public Access/Archive	Research
Software Documentation	Collection level	Formal validation report	Validation	Version	Decision support system
Numerical Reproducibility and portability	File level	Formal product user guide	Uncertainty quantification	User feedback mechanism	
Security		Formal description of operations concept	Automated quality monitoring	Updates to record	
Legend					
1	2	3	4	5	6

The Hamburg Ocean Atmosphere Parameters and Fluxes from Satellite (HOAPS) data set is a satellite-based climatology of precipitation, evaporation, freshwater budget (evaporation minus precipitation), related turbulent heat fluxes and atmospheric state variables as well as liquid water path and total column water vapour over the global ice free oceans.

The scores in the Software Readiness vary from research grade to full operations capability. Coding standards are applied, but not compliant to the standards yet. The software is portable and results are numerically reproducible, but security aspects of the code are not tested yet.

Metadata associated with this dataset is compliant with international standards and complete at file and collection levels. This implies full operational capability.

User Documentation falls under initial to full operational capability. Journal papers are published on methods and validation and comprehensive description of scientific methods is maintained by dataset developer. Report on inter-comparison with other CDRs available and the product user guide is regularly updated. Comprehensive description of the operations concept is also available.

The dataset generally falls under initial operational category for Uncertainty Characterisation. Standard uncertainty nomenclature is applied, comprehensive validation including comparisons against other CDRs are done, but there is only limited information available on uncertainties arising from systematic and random effects in the measurements. Automated quality monitoring is partially implemented.

The dataset generally falls under initial operational category for Public Access, feedback, and update. Data and documentation are under institution's version control, archived and publicly available. The dataset is regularly updated taking into account established user feedback mechanism.

The data have been used in research which is evidenced by citations.

7.2.6 Heleosat Surface Radiation

Name	CM SAF Surface Radiation MVIRI Data Set
Origin	CM SAF; contact.cmsaf@dwd.de
Spatial Characteristics	METEOSAT 0 deg disk; 0.03x0.03 degree grid
Temporal Characteristics	Hourly, daily, and monthly means; 1983-2005

Software Readiness	Metadata	User Documentation	Uncertainty Characterisation	Public access, feedback, and update	Usage
Coding Standards	Standards	Formal description of scientific methodology	Standards	Public Access/Archive	Research
Software Documentation	Collection level	Formal validation report	Validation	Version	Decision support system
Numerical Reproducibility and portability	File level	Formal product user guide	Uncertainty quantification	User feedback mechanism	
Security		Formal description of operations concept	Automated quality monitoring	Updates to record	
Legend					
1	2	3	4	5	6

The CM SAF Surface Radiation MVIRI Data Set is a satellite-based climatology of the surface irradiance, the surface direct irradiance and the effective cloud albedo derived from satellite-observations from the visible channel of the MVIRI instruments onboard the geostationary Meteosat satellites. The dataset was generated for climate applications.

Overall, this dataset is in the initial to full operational capability range, except for the "Security" category in the Software Readiness sub-matrix. This can be overcome by establishing a process to check security aspects in the SAF framework.

Scores in the Software Readiness could be improved by increasing compliance to coding standards and by completing the software documentation.

The dataset has high scores in Metadata and User Documentation, which are in full operational capability.

The scores for Uncertainty Characterisation are in the initial operational capability. Low scores in the Standards are only due to non-existence of procedures to achieve SI traceability. Participation in international data assessment(s), quantifying spatial and temporal error covariances, and full implementation of automated quality monitoring will take this dataset towards full operational capability.

The scores for Public Access, Feedback, and update are already in full operational capability. The dataset is regularly updated taking into account user feedbacks.

The dataset has high scores for usage which are corroborated by separate lists of research and decision support applications in the Data Record Description.

7.2.7 CLARA-A1 Surface Radiation

Name	CM SAF CLARA A1 surface radiation
Origin	CM SAF; contact.cmsaf@dwd.de
Spatial Characteristics	Global, 0.25x0.25 grid
Temporal Characteristics	daily and monthly mean, 1982-2009

Software Readiness	Metadata	User Documentation	Uncertainty Characterisation	Public access, feedback, and update	Usage
Coding Standards	Standards	Formal description of scientific methodology	Standards	Public Access/Archive	Research
Software Documentation	Collection level	Formal validation report	Validation	Version	Decision support system
Numerical Reproducibility and portability	File level	Formal product user guide	Uncertainty quantification	User feedback mechanism	
Security		Formal description of operations concept	Automated quality monitoring	Updates to record	
Legend					
1	2	3	4	5	6

CM SAF CLARA A1 surface radiation properties dataset is a global dataset of surface radiation derived from measurements of the series of Advanced Very High Resolution Radiometer (AVHRR) on the NOAA satellite series including METOP-A satellite.

Software readiness is generally in the initial operational category. Coding standards are partially applied, complete software installation/user manual available, reproducibility and portability confirmed by 3rd party, and the software passes data provider's security review.

Metadata are compliant with international standards, file and collection level metadata are sufficient to understand and use the data with enhanced discovery metadata and limited location level metadata. Thus this category is under initial operations category.

User documentation is under full operational capability. Comprehensive description on scientific methods and journal papers are published on this. Reports and peer-reviewed publications on comprehensive validation and inter-comparison are available from the data provider. Product user guide is regularly updated and maintained by data provider. Operations concept and description of practical implementation are available from the data provider.

Uncertainty characterisation falls into initial operations category. Standard uncertainty nomenclature is applied. Comprehensive validation is done and inter-comparisons against

other datasets have been performed. Comprehensive and quantitative estimates of uncertainty are provided with the product and automated quality monitoring is partially applied.

Public access, feedback, and update are fully operational with dataset, documentation, and source code being version controlled, archived by the data provider, and publicly available (except the software). The dataset is regularly updated taking into account user feedbacks.

The data are used for research and citations are occurring.

7.2.8 CLARA-A1 Cloud Properties

Name	CM SAF CLARA A1 cloud properties
Origin	CM SAF; contact.cmsaf@dwd.de
Spatial Characteristics	Global, 0.25 x 0.25 grid
Temporal Characteristics	daily and monthly mean, 1982 – 2009

Software Readiness	Metadata	User Documentation	Uncertainty Characterisation	Public access, feedback, and update	Usage
Coding Standards	Standards	Formal description of scientific methodology	Standards	Public Access/Archive	Research
Software Documentation	Collection level	Formal validation report	Validation	Version	Decision support system
Numerical Reproducibility and portability	File level	Formal product user guide	Uncertainty quantification	User feedback mechanism	
Security		Formal description of operations concept	Automated quality monitoring	Updates to record	
Legend					
1	2	3	4	5	6

CMSAF CLARA A1 cloud properties dataset is a global dataset of surface radiation derived from measurements of the series of Advanced Very High Resolution Radiometer (AVHRR) on the NOAA satellite series including METOP-A satellite.

Software readiness is generally in the initial operational category. Coding standards are partially applied, complete software installation/user manual available, reproducibility and portability confirmed by 3rd party, and the software passes data provider's security review.

Metadata are compliant with international standards, file and collection level metadata are sufficient to understand and use the data with enhanced discovery metadata and limited location level metadata. Thus this category is under initial operations category.

User documentation is under full operational capability. Comprehensive description on scientific methods and journal papers are published on this. Reports and peer-reviewed publications on comprehensive validation and inter-comparison are available from the data provider. Product user guide is regularly updated and maintained by data provider. Operations concept and description of practical implementation are available from the data provider.

Uncertainty characterisation falls into initial operations category. Standard uncertainty nomenclature is applied. Comprehensive validation is done and inter-comparisons against other datasets have been performed. Comprehensive and quantitative estimates of uncertainty are provided with the product and automated quality monitoring is partially applied.

Public access, feedback, and update are fully operational with dataset, documentation, and source code are version controlled and archived by the data provider and are publicly available (except the software). The dataset is regularly updated taking into account user feedbacks.

The data are used for research and citations are occurring.

7.2.9 GPCC Full Data Reanalysis Version 6

Name	GPCC Full Data reanalysis Version 6
Origin	Deutscher Wetterdienst; gpcc@dwd.de
Spatial Characteristics	0.5°, 1.0° and 2.5° regular lat-lon grid, global, over land, without Antarctica
Temporal Characteristics	1901-2010; monthly

Software Readiness	Metadata	User Documentation	Uncertainty Characterisation	Public access, feedback, and update	Usage
Coding Standards	Standards	Formal description of scientific methodology	Standards	Public Access/Archive	Research
Software Documentation	Collection level	Formal validation report	Validation	Version	Decision support system
Numerical Reproducibility and portability	File level	Formal product user guide	Uncertainty quantification	User feedback mechanism	
Security		Formal description of operations concept	Automated quality monitoring	Updates to record	
Legend					
1	2	3	4	5	6

The GPCC monthly gridded precipitation fields are calculated from internationally collected and quality controlled rain-gauge data (GTS-based and historical data). The objectives of the GPCC Full Data Reanalysis (GPCC_FD) are for verification of models, for analysis of historic global precipitation, for research concerning the global water cycle, e.g., trend and teleconnection. Full details are at ftp://ftp.dwd.de/pub/data/gpcc/html/fulldata_v6_doi_download.html.

Software readiness maturity ranges between 2 and 4, which are appropriate for the production of *in situ* datasets. Coding standards are identified, moderate documentation of the software is available, and PI affirms portability, numerical reproducibility, and no security issues.

Metadata maturity is self-assessed to highest scores. However, it is very ambitious for such a large collection of data including historical data.

Maturity of User Documentation is very high, except for the formal validation report, where maturity 2 is reached with limited validation available from the PI. Potential documentation on comprehensive validation and inter-comparisons would increase the maturity of category.

The maturity scores with respect to Uncertainty Characterization range from 2 to 6. SI traceability is established, comprehensive validation and inter-comparisons have been done, and automated quality monitoring is fully implemented. However, only limited information is available on uncertainties arising from systematic and random effects in the measurements.

Public Access, Feedback, Update is of adequate maturity (range 3-5), with data and documentation are version controlled and archived with public access. Feedbacks are collected from scientific community and they are used for regular update of the product.

The dataset is extensively used for research and policy making (for instance, it is used in the IPCC AR5 WG1 Summary for Policy Makers).

7.2.10 NKDZ

Name	NKDZ station data, historical version v002
Origin	Deutscher Wetterdienst; datenservice@dwd.de
Spatial Characteristics	Stations covering Germany
Temporal Characteristics	1/1/1781 to 31/12/2013; hourly, daily, monthly, annual

Software Readiness	Metadata	User Documentation	Uncertainty Characterisation	Public access, feedback, and update	Usage
Coding Standards	Standards	Formal description of scientific methodology	Standards	Public Access/Archive	Research
Software Documentation	Collection level	Formal validation report	Validation	Version	Decision support system
Numerical Reproducibility and portability	File level	Formal product user guide	Uncertainty quantification	User feedback mechanism	
Security		Formal description of operations concept	Automated quality monitoring	Updates to record	
Legend					
1	2	3	4	5	6

This is a national data set, produced by the Deutscher Wetterdienst (DWD). In July 2014, DWD had released its historical measurements of climatological parameters from the DWD climatological and meteorological stations together with station-specific metadata for free public access at ftp://ftp-cdc.dwd.de/pub/CDC/observations_germany.

The special value of this data set is in its comprehensive collection (back in time to 1781, and in the level of detail the station specific metadata (such as, e.g., known station history, instrument change or change in averaging formula).

Software Readiness ranges from research to initial operational capability. Coding standards are not used, moderate software documentation is available, and PI affirms no security issues. Third party affirms portability and numerical reproducibility.

Metadata standards are not systematically applied, but the data set is self assessed to have complete collection and file level metadata. However, this is ambitious in the light of lost metadata of historical measurements.

User Documentation is generally under research grade, that is, only limited documentation is available grade, which points to need for improvements in documentation.

In the Uncertainty Characterisation, automated quality monitoring has the highest score, but there is much room for improvement for standards, validation, and uncertainty quantification.

Public Access, Feedback, Update category is under initial to full operational capability with ICDRs being produced.

The dataset is widely used for research and policy making.

7.2.11 ECA&D

Name	ECA&D (European Climate Assessment & Dataset)
Origin	ECA&D Project Team, KNMI, eca@knmi.nl
Spatial Characteristics	10233 meteorological stations are collected throughout Europe and the Mediterranean, providing observations of up to 12 meteorological parameters each.
Temporal Characteristics	Time series of daily data

Software Readiness	Metadata	User Documentation	Uncertainty Characterisation	Public access, feedback, and update	Usage
Coding Standards	Standards	Formal description of scientific methodology	Standards	Public Access/Archive	Research
Software Documentation	Collection level	Formal validation report	Validation	Version	Decision support system
Numerical Reproducibility and portability	File level	Formal product user guide	Uncertainty quantification	User feedback mechanism	
Security		Formal description of operations concept	Automated quality monitoring	Updates to record	
Legend					
1	2	3	4	5	6

The European Climate Assessment & Dataset (<http://eca.knmi.nl/>) provides information on changes in weather and climate extremes, as well as the daily dataset needed to monitor and analyse these extremes. It is based on the contributions of long-term high quality daily observational data from 61 National Meteorological and Hydrological Services, observatories and universities from Europe and the Mediterranean. The special value of this data set is on one hand in the comprehensive collection, which makes it most useful for many applications, and on the other hand in derived indices.

The software used to produce this dataset consists of routines which perform rather simple calculations (averaging, finding max or min values etc.). Headers are available describing

these small routines, but, for example, portability, are not rated because the dataset developers feel they are 'not applicable'. Note that there is additional documentation of ECA&D in the form of an Algorithm Theoretical Basis Document (ATBD) which is made available via the website. With the stated limitations, the software system can be considered to have initial operational capability.

The Metadata is under research or initial operational capability with limited collection level metadata and sufficient file level metadata with location level metadata.

Maturity related to User Documentation spans the whole range 1 – 6. Some formal validation report would raise the minimum score to 3. However, such an approach to validate and/or document the validation results is not very common in the setting of data sets containing surface observations from meteorological stations. Comprehensive tools for cross-comparisons and plenty of scientific papers addressing specific parameters are available from the website.

In the Uncertainty Characterization, the low scores hinge on the input data. However, the automated quality monitoring is established and results are fed back to metadata.

Public Access, Feedback, Update is generally under full operational capability except that there is no version control established.

The dataset are extensively used for research and policy making.

7.2.12 EOBS

Name	E-OBS dataset (gridded data based on station observations in Europe) Version 9
Origin	ECA&D Project Team, KNMI, eca@knmi.nl
Spatial Characteristics	area: 25N-75N x 40W-75E; grids: 0.25 and 0.5 degree regular lat-lon grid, as well as 0.22 and 0.44 degree rotated pole grid
Temporal Characteristics	Daily, 1950-01-01 to 2013-06-30

Software Readiness	Metadata	User Documentation	Uncertainty Characterisation	Public access, feedback, and update	Usage
Coding Standards	Standards	Formal description of scientific methodology	Standards	Public Access/Archive	Research
Software Documentation	Collection level	Formal validation report	Validation	Version	Decision support system
Numerical Reproducibility and portability	File level	Formal product user guide	Uncertainty quantification	User feedback mechanism	
Security		Formal description of operations concept	Automated quality monitoring	Updates to record	
Legend					
1	2	3	4	5	6

E-OBS provides gridded fields based on the ECA&D station collection. More details at <http://eca.knmi.nl/>.

Software readiness scores vary from research to full operational capability. No coding standards are used, moderate software documentation is available, the software can be installed operationally by a third party and produces numerically reproducible results, and the PI confirms no security issues.

The Metadata for this dataset is in full operational grade.

Maturity for User Documentation is generally under full operational capability. Comprehensive descriptions and peer-reviewed papers on scientific methods, validation and inter-comparison are available. Product user guide and operations concept are regularly updated.

The uncertainty assessment refers to uncertainty of individual station observations. The uncertainty of the EOBS gridded product is mainly determined by the representativeness of the station observations, and the number of stations within a grid box. These error estimates are provided to the users, together with the data themselves. The automated quality monitoring is fully established.

Public Access, Feedback, Update is under full operational capability with data, documentation, and source code are archived and under fully established version control. ICDRs are being produced with fully established user feedback mechanisms.

The dataset is extensively used for research and policy making.

7.3 Oceanic datasets

In this session we present assessment results of the oceanic data sets.

7.3.1 Baltic Sea Automated Sea Ice

Name	SEAICE_BAL_SEAICE_L4_NRT_OBSERVATIONS_011_011/004
Origin	MyOcean, FMI, Juha.Karvonen@fmi.fi
Spatial Characteristics	1 km grid
Temporal Characteristics	Baltic Sea ice season

Software Readiness	Metadata	User Documentation	Uncertainty Characterisation	Public access, feedback, and update	Usage
Coding Standards	Standards	Formal description of scientific methodology	Standards	Public Access/Archive	Research
Software Documentation	Collection level	Formal validation report	Validation	Version	Decision support system
Numerical Reproducibility and portability	File level	Formal product user guide	Uncertainty quantification	User feedback mechanism	
Security		Formal description of operations concept	Automated quality monitoring	Updates to record	
Legend					
1	2	3	4	5	6

This dataset is a part of operational sea ice services in FMI and covers automated ice thickness and concentration charts which are produced by SAR data. Operational production is in FMI while data is provided by MyOcean project. The parameters are based on ice chart produced on daily basis during the Baltic Sea ice season and show the ice concentration in a 1 km grid. Ice thickness chart (ITC) is a product based on the most recent available ice chart (IC) and a SAR image.

Software Readiness is generally under initial operational capability: software is portable, and third party can install with numerically reproducible results. The software has moderate documentation. However, neither coding standards are applied nor security is evaluated.

The Metadata is under full operational capability.

User Documentation is from initial to full operational capability with reports and papers on scientific methods, comprehensive validation and data assessment, regularly updated product user guide, and comprehensive description of operations concept including practical implementation.

Uncertainty Characterisation is generally under initial operational capability with application of standard uncertainty nomenclature, partial establishment of SI traceability, comprehensive validation and inter-comparison, comprehensive information on uncertainties, and partially implemented automated quality monitoring.

Public Access, Feedback, and Archive category is also generally under initial operational capability with version controlled data and documentation are archived by the data provider. The data are regularly and operationally updated with feedbacks collected from scientific community.

The data are moderately used for research and extensively used for policy making.

7.3.2 ESA-SST-CCI-Analysis

Name	ESA SST CCI Analysis long-term product V 1.0
Origin	ESA-CCI; c.j.merchant@reading.ac.uk
Spatial Characteristics	Global; 0.05° lat-lon grid resolution
Temporal Characteristics	~20 years; Daily

Software Readiness	Metadata	User Documentation	Uncertainty Characterisation	Public access, feedback, and update	Usage
Coding Standards	Standards	Formal description of scientific methodology	Standards	Public Access/Archive	Research
Software Documentation	Collection level	Formal validation report	Validation	Version	Decision support system
Numerical Reproducibility and portability	File level	Formal product user guide	Uncertainty quantification	User feedback mechanism	
Security		Formal description of operations concept	Automated quality monitoring	Updates to record	
Legend					
1	2	3	4	5	6

ESA SST CCI Analysis long-term product version 1 are derived from infra-red imagery obtained from several Earth-observing satellite missions, combined to give daily, spatially complete information over the global oceans over 20 years. The principal recommended applications are for climate research applications requiring ~20 years of stable, low bias records of SST. The dataset is particularly valuable if a representation of global SST is required that is independent of in situ SST measurements.

The software used to produce this data set is under research to initial operational capability. Coding standards are not applied and security is not checked. Software is sufficiently documented and the PI affirms numerical reproducibility and portability.

The metadata for this dataset is generally under initial operational capability. International metadata standards are applied, collection level metadata are sufficient understand and use the data, and there are complete location level metadata at the file level.

User documentation is also generally under initial operational capability. Comprehensive documentation on scientific methods, validation, and operations concept is available from the PI. Product user guide is maintained by the data provider and is being regularly updated.

Uncertainty Characterisation generally is under initial operational capability. Standard uncertainty nomenclature is applied and procedures to establish SI traceability are defined. Comprehensive validation is done and the product is inter-compared with other CDRs. Qualitative information of uncertainty is provided with temporal and spatial error covariance. Automated quality monitoring is partially established.

Public Access, Feedback, and Update is also in the initial operational category. Data, documentation, and source code are under PI's versioning and archived by the data provider. The product is irregularly updated by using the feedbacks from scientific community collected by PI and data provider.

The benefits of using this dataset for research have been demonstrated.

7.3.3 ESA-SST-CCI-AVHRR

Name	ESA SST CCI AVHRR L2P long-term product V 1.0
Origin	ESA-CCI; c.j.merchant@reading.ac.uk
Spatial Characteristics	Global; ~4 km at nadir view
Temporal Characteristics	~20 years; Instantaneous

Software Readiness	Metadata	User Documentation	Uncertainty Characterisation	Public access, feedback, and update	Usage
Coding Standards	Standards	Formal description of scientific methodology	Standards	Public Access/Archive	Research
Software Documentation	Collection level	Formal validation report	Validation	Version	Decision support system
Numerical Reproducibility and portability	File level	Formal product user guide	Uncertainty quantification	User feedback mechanism	
Security		Formal description of operations concept	Automated quality monitoring	Updates to record	
Legend					
1	2	3	4	5	6

ESA SST CCI AVHRR L2P long-term product version 1.0 provides global Sea Surface Temperature (SST) as estimated from Advanced Very High Resolution Radiometer (AVHRR) imagery.

The principal recommended applications are climate research applications requiring ~20 years of global SSTs observed by satellite, with no gap-filling/interpolation. Since the SSTs are harmonized independently of in situ observations, use is recommended for applications where it is beneficial to have SST datasets that are independent. Skin and depth SSTs are distinguished and both are provided.

The software used to produce this data set is under research to initial operational capability. Coding standards are not applied and security is not checked. Software is sufficiently documented and the PI affirms numerical reproducibility and portability.

The metadata for this dataset is generally under initial operational capability. International metadata standards are applied, collection level metadata are sufficient understand and use the data, and there are complete location level metadata at the file level.

User documentation is also generally under initial operational capability. Comprehensive documentation on scientific methods, validation, and operations concept is available from the PI. Product user guide is maintained by the data provider and is being regularly updated.

Uncertainty Characterisation generally is under initial operational capability. Standard uncertainty nomenclature is applied and procedures to establish SI traceability are defined. Comprehensive validation is done and the product is inter-compared with other CDRs. Qualitative information of uncertainty is provided with temporal and spatial error covariance.

Public Access, Feedback, and Update is also in the initial operational category. Data, documentation, and source code are under PI's versioning and archived by the data provider. The product is irregularly updated by using the feedbacks from scientific community collected by PI and data provider.

The benefits of using this dataset for research have been demonstrated.

7.3.4 HadISST1

Name	HadISST1
Origin	Met Office – HadObs; nick.rayner@metoffice.gov.uk
Spatial Characteristics	Global oceans; 1 degree lat-lon grid
Temporal Characteristics	1870 to date; monthly

Software Readiness	Metadata	User Documentation	Uncertainty Characterisation	Public access, feedback, and update	Usage
Coding Standards	Standards	Formal description of scientific methodology	Standards	Public Access/Archive	Research
Software Documentation	Collection level	Formal validation report	Validation	Version	Decision support system
Numerical Reproducibility and portability	File level	Formal product user guide	Uncertainty quantification	User feedback mechanism	
Security		Formal description of operations concept	Automated quality monitoring	Updates to record	
Legend					
1	2	3	4	5	6

The HadISST1 data set is a blend of historical SST and modern SST observations from ships, buoys, drifters, satellites etc. and sea ice observations, partly from historical ship- and air-borne and partly from satellite data.

The code used produce the dataset is generally under research category. Coding standards are identified, but not applied, minimal documentation is available from the PI, portability and numerical reproducibility are confirmed by the PI, and the security is not evaluated.

Metadata is under initial operational capability. International standards are systematically applied, sufficient collection and file level metadata to understand and use the data without external assistance. Also, limited location-level metadata are available.

The scores for User Documentation vary from research to full operational capability. Highest score is for the formal description of scientific methods due to comprehensive description of methods maintained by the data provider and journal papers published when the product is updated. Comprehensive validation report, publications, and data assessment results are available. Limited description of operations concept is available, but there is no formal product user guide.

The uncertainty characterisation scores also range from research capability to full operational capability. Standard uncertainty nomenclature is applied, comprehensive validation is done and the data product has been part of international assessments, and automated quality monitoring is partially implemented.

Public Access, Feedback, and Update is under initial to full operational capability. The data, documentation, and source code are archived by the data provider and under institution's version control. The data set is irregularly updated following the updates collected from scientific community.

The dataset has been used for research and citations have been occurring. The dataset is extensively used for decision making and influence on policy making is demonstrated.

7.3.5 ESA Ocean Colour CCI

Name	Ocean Colour CCI
Origin	ESA-CCI; Shubha Sathyendranath, PML; help@esa-oceancolour-cci.org
Spatial Characteristics	Global; 4 km
Temporal Characteristics	1997 – 2014; daily composite

Software Readiness	Metadata	User Documentation	Uncertainty Characterisation	Public access, feedback, and update	Usage
Coding Standards	Standards	Formal description of scientific methodology	Standards	Public Access/Archive	Research
Software Documentation	Collection level	Formal validation report	Validation	Version	Decision support system
Numerical Reproducibility and portability	File level	Formal product user guide	Uncertainty quantification	User feedback mechanism	
Security		Formal description of operations concept	Automated quality monitoring	Updates to record	
Legend					
1	2	3	4	5	6

The ESA-CCI Ocean Colour ECV dataset provides ocean colour data, with a focus on Case 1 (Open Ocean, not Coastal) waters, which can be used by climate change prediction and assessment models. The dataset is created by band-shifting and bias-correcting atmosphere corrected MERIS and Aqua MODIS data to match SeaWiFS data, merging the datasets and computing per-pixel uncertainty estimates.

Software readiness is generally under initial operational capability: coding standards are partially applied and compliance results available, moderate description of the software available and PI affirms portability and numerical reproducibility. However, security aspects of the software are not evaluated.

The Metadata category is under full operational capability.

User Documentation is under initial or full operational capability. Comprehensive descriptions and papers on methods, validation, and operations concepts are maintained by data provider and product user guide is regularly updated.

Uncertainty Characterisation is also under initial or full operational capability. Standard uncertainty nomenclature is applied and SI traceability is partially established, comprehensive validation is done, quantitative estimates of uncertainty provided within the product characterising more or less uncertain data points, temporal and spatial error covariance are quantified, and automated quality monitoring is partially established.

Public Access, Feedback, Update is also from initial to full operational capability with data and documentation are under version control and archived by the data provider. ICDRs are being produced by taking into account user feedbacks.

The dataset is being moderately used.

7.3.6 ESA CCI Sea Ice Concentration

Name	ESA CCI Sea Ice Concentration				
Origin	ESA-CCI; stein.sandven@nersc.no and ltp@dmu.dk				
Spatial Characteristics	Global (polar regions); 25 km				
Temporal Characteristics	1992 – 2008; daily				
Software Readiness	Metadata	User Documentation	Uncertainty Characterisation	Public access, feedback, and update	Usage
Coding Standards	Standards	Formal description of scientific methodology	Standards	Public Access/Archive	Research
Software Documentation	Collection level	Formal validation report	Validation	Version	Decision support system
Numerical Reproducibility and portability	File level	Formal product user guide	Uncertainty quantification	User feedback mechanism	
Security		Formal description of operations concept	Automated quality monitoring	Updates to record	
Legend					
1	2	3	4	5	6

The ESA-CCI Sea Ice Concentration (SIC) dataset provides SIC and its uncertainties (both in % from 0 to 100) for Northern (NH) and Southern (SH) hemispheres, each file including: date and time for the daily product, latitude and longitude for each grid point, map of analyzed, daily averaged SIC, map of processing (*aka* status) flags, three maps of uncertainties as standard deviations of a gaussian uncertainty model (total, algorithm, and smear uncertainties), map of SIC values retrieved outside the physical range of 0%-100%, metadata information, both pertaining to the given date, and to the whole time-series.

Software readiness is generally under research capability: coding standards are partially applied and compliance results available, minimal description of the software available and PI affirms numerical reproducibility and no security problems.

The Metadata category is under full operational capability except for file level where metadata are available which are sufficient to use and understand the data independent of external assistance.

User Documentation is under initial operational capability. Comprehensive descriptions and papers on methods, validation, user guide, and operations concepts are maintained by data provider.

Uncertainty Characterisation is also under initial operational capability. Standard uncertainty nomenclature is applied, comprehensive validation is done, quantitative estimates of uncertainty provided within the product characterising more or less uncertain data points, and methods for automated quality monitoring is defined.

Public Access, Feedback, Update is also from initial to full operational capability with data and documentation are under version control and archived by the data provider. Dataset is irregularly updated by taking into account user feedbacks.

The dataset is being moderately used.

7.4 Cryosphere

We present the assessments of Cryosphere datasets here.

7.4.1 Sea Ice Volume Flux

Name		Sea Ice volume flux through Fram Strait 79N			
Origin		NERSC; kjetil.lygre@nersc.no			
Spatial Characteristics		At ~79 deg N latitude with 1 deg step from 5 deg E to 15 deg W			
Temporal Characteristics		6 Campaigns from 2005 to 2007			
Software Readiness	Metadata	User Documentation	Uncertainty Characterisation	Public access, feedback, and update	Usage
Coding Standards	Standards	Formal description of scientific methodology	Standards	Public Access/Archive	Research
Software Documentation	Collection level	Formal validation report	Validation	Version	Decision support system
Numerical Reproducibility and portability	File level	Formal product user guide	Uncertainty quantification	User feedback mechanism	
Security		Formal description of operations concept	Automated quality monitoring	Updates to record	
Legend					
1	2	3	4	5	6

Sea ice volume flux along 79 degrees north has been computed with a 1 degree longitudinal resolution. The flux was computed as a deliverable during the EU Monarch-A project to be compared to various climate parameters such as sea ice cover in the Arctic, ice thickness distribution, wind field etc. Grid cells for all data sets are centered on 79 deg N and from 5 deg E to 15 deg W. Ice area flux extracted from the time series of K. Kloster based on SAR and passive microwave observations. 4 columns contain: (1) ice concentration (%) (2) ice displacement per time interval 3-4 days (km), (3) azimuth angle (deg) (4) area ice flux (km²/day/deg). All values are given for ~79 deg N latitude with 1 deg step from 5 deg E to 15 deg W. Volume flux is computed by multiplying area flux and IceSAT sea ice thickness.

Software used to create this dataset is research grade.

Metadata is under initial operational capability with defined Standards and sufficient to use and understand the data and to extract discovery metadata.

User Documentation is under research grade with comprehensive scientific description of the methodology, report on limited validation, and limited product user guide available from PI.

Uncertainty Characterisation is also under research grade with Standard uncertainty nomenclature defined, limited validation done, and limited information.

Data are available from PI and irregular updates using feedback through scientific exchange which makes this dataset falls under initial operational capability for Public Access, Feedback, and Update.

The data are not very well used.

7.4.2 Cryoland Glacier Products

Name	Cryoland Glacier products
Origin	Cryoland Project; Dr. Thomas Nagler, ENVEO IT GmbH, thomas.nagler@enveo.at
Spatial Characteristics	Regional/local
Temporal Characteristics	Annual

Software Readiness	Metadata	User Documentation	Uncertainty Characterisation	Public access, feedback, and update	Usage
Coding Standards	Standards	Formal description of scientific methodology	Standards	Public Access/Archive	Research
Software Documentation	Collection level	Formal validation report	Validation	Version	Decision support system
Numerical Reproducibility and portability	File level	Formal product user guide	Uncertainty quantification	User feedback mechanism	
Security		Formal description of operations concept	Automated quality monitoring	Updates to record	
Legend					
1	2	3	4	5	6

Cryoland Glacier products datasets is a part of Cryoland Project, operational as a Copernicus service on snow and land ice. The product glacier outlines / area is provided on user request according to the internationally accepted GLIMS standards. The products are: Glacier Outlines/Area Map, Snow/Ice Maps, Glacier Lake, and Glacier Ice Velocity Map.

The software used to generate the dataset is under full operational capability except that the portability and numerical reproducibility are evaluated.

The metadata for the dataset is under full operational capability.

The scores for user documentation vary from research to full operational capability. Comprehensive descriptions and papers on scientific methods are available, but only limited documentation on validation exists. User guide and operations concepts have highest scores.

Uncertainty characterisation is generally under research capability.

Public Access, Feedback, Update scores are varying from research to full operational capability with fully version controlled dataset is available from the PI. The dataset is regularly updated by the PI using feedbacks obtained from established mechanisms.

Benefits for research are demonstrated by publications and potential benefits for decision making are identified.

7.5 Land surface

We present the assessments of land surface datasets here.

7.5.1 METEOSAT Surface Albedo

Name	Meteosat Surface Albedo
Origin	EUMETSAT; ops@eumetsat.int
Spatial Characteristics	METEOSAT first generation coverage; 2.5 km at sub-satellite point
Temporal Characteristics	1982 – 2011; 10 day composite

Software Readiness	Metadata	User Documentation	Uncertainty Characterisation	Public access, feedback, and update	Usage
Coding Standards	Standards	Formal description of scientific methodology	Standards	Public Access/Archive	Research
Software Documentation	Collection level	Formal validation report	Validation	Version	Decision support system
Numerical Reproducibility and portability	File level	Formal product user guide	Uncertainty quantification	User feedback mechanism	
Security		Formal description of operations concept	Automated quality monitoring	Updates to record	
Legend					
1	2	3	4	5	6

METEOSAT Surface Albedo (MSA) data set is derived from measurements of the METEOSAT Visible and Infra Red Imager (MVIRI) instrument on METEOSAT first generation satellites. Surface albedo is generally defined as the instantaneous ratio of surface-reflected radiation flux to incident radiation flux (dimensionless).

Scores for Software Readiness varies from research to full operational capability: coding standards are defined, but not applied, software documentation is complete, software can be installed by 3rd party with numerically reproducible results, and passes data providers security review.

Metadata is generally under initial operational capability. International standards are systematically applied, collection level metadata are sufficient to understand and use the data, and there is complete file level metadata.

User Documentation is also generally under initial operational capability. Comprehensive scientific description is maintained by data provider and journal papers are published. Report on comprehensive validation is available. Comprehensive user guide is available from the PI and description of operations concept is available.

Uncertainty characterisation is under initial operational capability. Standard uncertainty nomenclature is applied, comprehensive validation is done and quantitative uncertainty

estimates available characterising more or less uncertain data point. Automated quality monitoring is partially applied.

Public Access, archive and feedback is under initial or full operational capability. Data, documentation, and source code are under fully established version control and archived by the data provider. The dataset is irregularly updated using user feedbacks.

The product has been used for research and citations are occurring.

7.5.2 GEOV1 Leaf Area index (LAI)

Name	GEOV1 LAI
Origin	Copernicus Global Land Service; rl@hygeos.com
Spatial Characteristics	Global, 1 km grid
Temporal Characteristics	1999 to present; 10days frequency

Software Readiness	Metadata	User Documentation	Uncertainty Characterisation	Public access, feedback, and update	Usage
Coding Standards	Standards	Formal description of scientific methodology	Standards	Public Access/Archive	Research
Software Documentation	Collection level	Formal validation report	Validation	Version	Decision support system
Numerical Reproducibility and portability	File level	Formal product user guide	Uncertainty quantification	User feedback mechanism	
Security		Formal description of operations concept	Automated quality monitoring	Updates to record	
Legend					
1	2	3	4	5	6

The GEOV1 Leaf Area index (LAI) time series is provided by the European Copernicus Global Land Service and is based on SPOT-VEGETATION satellite observations, from 1999 until May 2014 (end of lifetime of SPOT-VGT). Since January 2014, the same data set is derived from the PROBA-V sensor, which is the successor of SPOT-VGT.

The Copernicus Global Land Service products LAI, FAPAR and surface albedo are processed using the same processing chain (except for the algorithm part) and distributed through the same portal. Also, the metadata and user documentation are treated in the same way. Therefore, the maturity of these products is very similar or even identical.

The software used to produce the dataset has highest maturity in all categories which means the codes are completely compliant with standards and which have been verified. The software is fully documented with complete installation/user manual and it is a turnkey system. Also the software has been checked for security issues and passed all the tests. This implies that the system is in a fully mature state and no improvements are needed.

The dataset has highest scores in the metadata category as well. It has compliance with international standards and the compliance is systematically checked by the data provider. The

dataset also has complete metadata collection and file levels. This implies that the system is in a fully mature state and no improvements are needed.

In the User Documentation category, the data set has highest scores for all but formal description of operations concept. This implies the dataset has all scientific documentation, describing algorithm and reporting results of quality assessment exercise, as complete as possible.

The data has highest scores for all sub-categories in Uncertainty Characterisation. This implies no more additional efforts are required for this.

Data, documentation, and source code are archived and fully under version control. Making the source code available to the public will make it achieve the highest scores. The data are produced in a continuous manner with availability of Interim Climate Data Records and there are regular mechanisms to obtain user feedbacks and incorporate them in updates.

The data set is used moderately for research and decision making.

7.5.3 GEOV1 fAPAR

Name	GEOV1 fAPAR
Origin	Copernicus Global Land Service, rl@hygeos.com
Spatial Characteristics	Global, 1km resolution
Temporal Characteristics	1999 to present; 10-days frequency

Software Readiness	Metadata	User Documentation	Uncertainty Characterisation	Public access, feedback, and update	Usage
Coding Standards	Standards	Formal description of scientific methodology	Standards	Public Access/Archive	Research
Software Documentation	Collection level	Formal validation report	Validation	Version	Decision support system
Numerical Reproducibility and portability	File level	Formal product user guide	Uncertainty quantification	User feedback mechanism	
Security		Formal description of operations concept	Automated quality monitoring	Updates to record	
Legend					
1	2	3	4	5	6

The GEOV1 fraction of Absorbed Photosynthetically Active Radiation (fAPAR) time series is provided by the European Copernicus Global Land Service and is based on SPOT-VEGETATION satellite observations, from 1999 until May 2014 (end of lifetime of SPOT-VGT). Since January 2014, the same data set is derived from the PROBA-V sensor, which is the successor of SPOT-VGT.

The Copernicus Global Land Service products fAPAR, LAI and surface albedo are processed using the same processing chain (except for the algorithm part) and distributed through the same portal. Also, the metadata and user documentation are treated in the same way. Therefore, the maturity of these products is very similar or even identical.

The software used to produce the dataset has highest maturity in all categories which means the codes are completely compliant with standards and which have been verified. The software is fully documented with complete installation/user manual and it is a turnkey system. Also the software has been checked for security issues and passed all the tests. This implies that the system is in a fully mature state and no improvements are needed.

The dataset has highest scores in the metadata category as well. It has compliance with international standards and the compliance is systematically checked by the data provider. The dataset also has complete metadata collection and file levels. This implies that the system is in a fully mature state and no improvements are needed.

In the User Documentation category, the data set has highest scores for all but formal description of operations concept. This implies the dataset has all scientific documentation, describing algorithm and reporting results of quality assessment exercise, as complete as possible.

The data has highest scores for all sub-categories in Uncertainty Characterisation. This implies no more additional efforts are required for this.

Data, documentation, and source code are archived and fully under version control. Like for the other Copernicus Global Land Service products, making the source code available to the public will make it achieve the highest scores. The data are produced in a continuous manner with availability of Interim Climate Data Records and there are regular mechanisms to obtain user feedbacks and incorporate them in updates.

The data set is used moderately for research and decision making.

7.5.4 GEOV1 Surface Albedo

Name	GEOV1 Surface Albedo
Origin	Copernicus Global Land Service, rl@hygeos.com
Spatial Characteristics	Global, 1km resolution
Temporal Characteristics	1999 to present; 10-days frequency

Software Readiness	Metadata	User Documentation	Uncertainty Characterisation	Public access, feedback, and update	Usage
Coding Standards	Standards	Formal description of scientific methodology	Standards	Public Access/Archive	Research
Software Documentation	Collection level	Formal validation report	Validation	Version	Decision support system
Numerical Reproducibility and portability	File level	Formal product user guide	Uncertainty quantification	User feedback mechanism	
Security		Formal description of operations concept	Automated quality monitoring	Updates to record	
Legend					
1	2	3	4	5	6

The GEOV1 Surface Albedo time series is provided by the European Copernicus Global Land Service and is based on SPOT-VEGETATION satellite observations, from 1999 until May 2014 (end of lifetime of SPOT-VGT). The processing line is currently under adaptation to continue the production using the PROBA-V sensor data, which is the successor of SPOT-VGT.

The Copernicus Global Land Service products surface albedo, LAI and fAPAR are processed using the same processing chain (except for the algorithm part) and distributed through the same portal. Also, the metadata and user documentation are treated in the same way. Therefore, the maturity of these products is very similar or even identical.

The software used to produce the dataset has highest maturity in all categories which means the codes are completely compliant with standards and which have been verified. The software is fully documented with complete installation/user manual and it is a turnkey system. Also the software has been checked for security issues and passed all the tests. This implies that the system is in a fully mature state and no improvements are needed.

The dataset has highest scores in the metadata category as well. It has compliance with international standards and the compliance is systematically checked by the data provider. The dataset also has complete metadata collection and file levels. This implies that the system is in a fully mature state and no improvements are needed.

In the User Documentation category, the data set has highest scores for all but formal description of operations concept. This implies the dataset has all scientific documentation, describing algorithm and reporting results of quality assessment exercise, as complete as possible.

The data has highest scores for all sub-categories in Uncertainty Characterisation, except for validation. Participating in international data set assessment(s) and incorporating feedbacks into the product development cycle would increase the maturity of the uncertainty characterisation.

Data, documentation, and source code are archived and fully under version control. Like for the other Copernicus Global Land Service products, making the source code available to the public will make it achieve the highest scores. The data are produced in a continuous manner, but without availability of Interim Climate Data Records and there are regular mechanisms to obtain user feedbacks and incorporate them in updates.

The data set is started being used for research and decision making, for which potential benefits have been identified.

7.5.5 ESA-CCI Soil Moisture

Name	ESA-CCI Soil Moisture
Origin	ESA CCI; ecv_sm_contact@ipf.tuwien.ac.at
Spatial Characteristics	Global; 0.25°~1.5°
Temporal Characteristics	1978 – 2013; between 1 and 3days

Software Readiness	Metadata	User Documentation	Uncertainty Characterisation	Public access, feedback, and update	Usage
Coding Standards	Standards	Formal description of scientific methodology	Standards	Public Access/Archive	Research
Software Documentation	Collection level	Formal validation report	Validation	Version	Decision support system
Numerical Reproducibility and portability	File level	Formal product user guide	Uncertainty quantification	User feedback mechanism	
Security		Formal description of operations concept	Automated quality monitoring	Updates to record	
Legend					
1	2	3	4	5	6

This Soil Moisture product is being developed and provided in the frame of the ESA Climate Change Initiative. The global soil moisture data set has been generated using active and passive microwave space borne instruments and covers the 35 year period from November 1978 to December 2013.

The software used to produce the Soil Moisture product has an overall maturity that corresponds with the level of Initial Operation Capability, which is in agreement with the data set development status.

The metadata associated with the products has a somewhat higher maturity, which is fully mature for the subcategory File level. Using international standards for the Collection level and regular update and checks of the metadata would increase the maturity of this category.

The User Documentation reaches the highest maturity for the formal description of the scientific methodology. The other user documentation subcategories have moderate maturity. Again, this is in line with the product development status. A formal description of the operations concept and its implementation, and regularly updates of the product user manual and validation results to the user would increase the maturity.

The Uncertainty characterization reaches nearly the highest maturity. Increasing the effort in international data assessments and organizing automated quality monitoring would result in the highest maturity.

The data and documentation are archived and available from the data provider and the version control is institutionalised. A gain in maturity could be reached by implementing a

full version control and archiving the source code. User feedback is requested, but no feedback mechanisms are put in place and only ad hoc updates to the data set is performed.

The data is used extensively in research and moderately in decision making.

7.5.6 ESA-CCI Land Cover datasets

Name	ESA LandCover_CCI datasets
Origin	ESA CCI; Pierre Defourny (UCLouvain, Belgium) contact@esa-landcover-cci.org
Spatial Characteristics	Global; 300-1000m, geographic lat-lon projection
Temporal Characteristics	1998 to present

1. Land Cover Maps

Software Readiness	Metadata	User Documentation	Uncertainty Characterisation	Public access, feedback, and update	Usage
Coding Standards	Standards	Formal description of scientific methodology	Standards	Public Access/Archive	Research
Software Documentation	Collection level	Formal validation report	Validation	Version	Decision support system
Numerical Reproducibility and portability	File level	Formal product user guide	Uncertainty quantification	User feedback mechanism	
Security		Formal description of operations concept	Automated quality monitoring	Updates to record	
Legend					
1	2	3	4	5	6

2. Land Surface Seasonality

Software Readiness	Metadata	User Documentation	Uncertainty Characterisation	Public access, feedback, and update	Usage
Coding Standards	Standards	Formal description of scientific methodology	Standards	Public Access/Archive	Research
Software Documentation	Collection level	Formal validation report	Validation	Version	Decision support system
Numerical Reproducibility and portability	File level	Formal product user guide	Uncertainty quantification	User feedback mechanism	
Security		Formal description of operations concept	Automated quality monitoring	Updates to record	
Legend					
1	2	3	4	5	6

3. Surface Reflectance

Software Readiness	Metadata	User Documentation	Uncertainty Characterisation	Public access, feedback, and update	Usage
Coding Standards	Standards	Formal description of scientific methodology	Standards	Public Access/Archive	Research
Software Documentation	Collection level	Formal validation report	Validation	Version	Decision support system
Numerical Reproducibility and portability	File level	Formal product user guide	Uncertainty quantification	User feedback mechanism	
Security		Formal description of operations concept	Automated quality monitoring	Updates to record	
Legend					
1	2	3	4	5	6

ESA - Land Cover CCI databases consist of:

- 1) 3 global LC maps at 300m spatial resolution for 3 epochs centred on the years 2010 (2008-2012), 2005 (2003-2007) and 2000 (1998-2002). The maps were obtained using the full MERIS archive (2003-2012) and the SPOT-Vegetation time series. The legend counts 22 classes defined using the FAO Land Cover Classification System (LCCS);
- 2) 3 global climatological 7-day time series over the 1998-2012 period representing typical seasonal dynamics of the land surface at the pixel level: the vegetation greenness as described by the Normalized Vegetation Index (NDVI), the snow occurrence and the Burnt Areas (BA) distribution. They are compiled from existing global datasets;
- 3) Global surface reflectance (SR) time series of the whole MERIS Full and Reduced Resolution archive (2002-2012) made of 7-day composites

The key characteristic of this global land cover database is that it distinguishes between the stable and the dynamic components of the land surface. The stable component is provided through a set of 3 successive maps consistent over time while the dynamics of the land surface is included in separate seasonality products. The principal recommended applications in the climate domain is the model evaluation and the use of the products as proxy for several land surface parameters assigned based on Plant Functional Types (e.g. surface albedo, latent and sensible heat fluxes, gross and net primary productivity).

The assessment is done taking into account the scores for the 3 datasets together.

The software used to generate these data is under research grade for LC maps and land surface seasonality products (coding standards are partially applied; a minimum documentation exists; PI affirms reproducibility under identical conditions; security is not checked). and generally under full operational capability for SR dataset (standards are systematically applied and compliance is systematically checked but improvement is needed to achieve full compliance; enhanced description of the process is available throughout the code and there is software installation/user manual; a 3rd party can install the code operationally; PI affirms no security problems).

The metadata scores are generally under initial operational capability for all datasets. Metadata standards are identified and/or defined but not systematically applied. Collection level metadata are limited for the LC maps and seasonality products while for the SR dataset, they are sufficient to use and understand the data independent of external assistance. There are complete location level metadata for all products except the seasonality ones.

The user documentation is also under initial operational capability for the 3 datasets: comprehensive scientific documentation on methods and validation available from data provider as well as a formal user guide; there is no or limited description of operation concepts.

The uncertainty characterisation: is under research to initial operational capability for LC maps and under initial operational capability for SR products. There is no uncertainty characterisation for the seasonality products.

Public Access, Feedback, Update is under research to initial operational capability. Data record and documentation are available from data provider; versioning is made by PI; feedback is collected by PI and data provider. Update is planned based on users feedback but up to now, there is none.

The benefits of these datasets for research applications identified for all datasets and publications demonstrating these are under review.

7.5.7 CLARA-A1-SAL (Surface Albedo)

Name	CLARA-A1-SAL (Surface Albedo) Edition 1
Origin	CMSAF, FMI; contact.cmsaf@dwd.de , aku.riihela@fmi.fi
Spatial Characteristics	Global; 0.25x0.25 degrees lat-lon grid
Temporal Characteristics	1982-2009; five-day and monthly mean

Software Readiness	Metadata	User Documentation	Uncertainty Characterisation	Public access, feedback, and update	Usage
Coding Standards	Standards	Formal description of scientific methodology	Standards	Public Access/Archive	Research
Software Documentation	Collection level	Formal validation report	Validation	Version	Decision support system
Numerical Reproducibility and portability	File level	Formal product user guide	Uncertainty quantification	User feedback mechanism	
Security		Formal description of operations concept	Automated quality monitoring	Updates to record	
Legend					
1	2	3	4	5	6

The CLARA-A1-SAL data set is derived from measurements of AVHRR visible/infrared imagers on NOAA and Metop-A satellites. The quantity described by the CLARA-A1-SAL dataset is the broadband Directional-Hemispherical Reflectance (DHR) of Earth's surface, also called Black-sky albedo.

The software used produce the dataset is generally under initial operational capability, but security issues are not evaluated yet.

The Metadata is under initial operational capability: International standards are systematically applied and there are sufficient file and collection level metadata to understand and use the data.

User Documentation is under initial or full operational capability. Comprehensive descriptions and journal papers available on scientific methods, reports on comprehensive validation and inter-comparisons are available, product user guide is regularly updated, and comprehensive operations concept is available.

Uncertainty Characterisation is under initial operational capability: Standard uncertainty nomenclature is applied, comprehensive validation is done and uncertainty arising from systematic and random effects in the measurement is available, and automated quality monitoring is partially applied.

Public Access, Feedback, Update is under initial or full operational capability: Data, documentation, and source code are under fully established version control and archived by the data provider. The dataset is regularly being updated by using feedback through established mechanisms.

Benefits for research applications are demonstrated in publications.

7.5.8 GlobSnow Snow Extent

Name	GlobSnow Snow Extent (SE) version 1.2
Origin	FMI; kari.luojuus@fmi.fi
Spatial Characteristics	Global; 1 km
Temporal Characteristics	1995 – present;

Software Readiness	Metadata	User Documentation	Uncertainty Characterisation	Public access, feedback, and update	Usage
Coding Standards	Standards	Formal description of scientific methodology	Standards	Public Access/Archive	Research
Software Documentation	Collection level	Formal validation report	Validation	Version	Decision support system
Numerical Reproducibility and portability	File level	Formal product user guide	Uncertainty quantification	User feedback mechanism	
Security		Formal description of operations concept	Automated quality monitoring	Updates to record	
Legend					
1	2	3	4	5	6

The European Space Agency (ESA) Data User Element (DUE) GlobSnow Snow Extent (SE) product set version 1.2 for the Northern Hemisphere represents information on snow coverage retrieved from ERS-2 ATSR-2 and Envisat AATSR from 1995 until present.

The software used to generate this dataset is fully compliant with the coding standards, moderately documented, portable and results are numerically reproducible, no security issues are found. These make the Software Readiness suitable for initial operational capability.

Metadata and User Documentation get highest scores for all aspects.

Uncertainty Characterisation is under initial to full operational capability. Standard uncertainty nomenclature is used and SI traceability is partially established, comprehensive validation and inter-comparison were done. Quantitative estimates of uncertainty provided within the product characterising more or less uncertain data points. Automated monitoring is fully established and results fed back to metadata.

Public Access, feedback and update is also under initial to full operational capability. Data and documentation are under fully established version control and archived and available to the public from Data Provider. The dataset is regularly updated using fully established feedback mechanisms.

The data are extensively used for research and for decision making.

7.5.9 H-SAF Daily Snow Cover (H10)

Name	H-SAF Daily Snow Cover (H10/SN-OBS-1)
Origin	H-SAF, FMI; matias.takala@fmi.fi
Spatial Characteristics	The H-SAF area [25-75°N lat, 25°W - 45° E lon]
Temporal Characteristics	2004 – present; Daily

Software Readiness	Metadata	User Documentation	Uncertainty Characterisation	Public access, feedback, and update	Usage
Coding Standards	Standards	Formal description of scientific methodology	Standards	Public Access/Archive	Research
Software Documentation	Collection level	Formal validation report	Validation	Version	Decision support system
Numerical Reproducibility and portability	File level	Formal product user guide	Uncertainty quantification	User feedback mechanism	
Security		Formal description of operations concept	Automated quality monitoring	Updates to record	
Legend					
1	2	3	4	5	6

H-SAF Daily Snow Cover (H10/SN-OBS-1) data set is a product under H-SAF Project of EUMETSAT SAF Network. As the hydrological project of the SAF Network, snow parameters are the key parameters to the project. H10 dataset gives the snow information on a pixel basis for SAF Europe area as a snow mask, having binary information for the snow coverage on cloud-free and non-dark locations.

Software Readiness varies from research grade to full operational capability: partially compliant to coding standards, minimal documentation is available, PI affirms portability and numerical reproducibility, and continues to pass data provider's security review.

Metadata and User Documentation are under full operational capability.

Uncertainty Characterisation is under initial to full operational capability: Standard uncertainty nomenclature is applied, comprehensive validation and inter-comparison are done, comprehensive quantification of more or less uncertain points are available, and temporal and spatial error covariance are quantified. Automated monitoring is fully established and results fed back to metadata.

Public Access, feedback and update is also under initial to full operational capability. Data and documentation are under institution's version control and archived and available to the public from Data Provider. The dataset is regularly updated using fully established feedback mechanisms.

The data are not well utilised for research and policy making.

7.5.10 H-SAF Daily Effective Snow Cover (H12)

Name	H-SAF Daily Effective Snow Cover (H12/SN-OBS-3)
Origin	H-SAF, FMI; matias.takala@fmi.fi
Spatial Characteristics	The H-SAF area [25-75°N lat, 25°W - 45° E lon]
Temporal Characteristics	Daily

Software Readiness	Metadata	User Documentation	Uncertainty Characterisation	Public access, feedback, and update	Usage
Coding Standards	Standards	Formal description of scientific methodology	Standards	Public Access/Archive	Research
Software Documentation	Collection level	Formal validation report	Validation	Version	Decision support system
Numerical Reproducibility and portability	File level	Formal product user guide	Uncertainty quantification	User feedback mechanism	
Security		Formal description of operations concept	Automated quality monitoring	Updates to record	
Legend					
1	2	3	4	5	6

H-SAF Daily Effective (Fractional) Snow Cover (H12/SN-OBS-3) data set gives the snow information on a pixel basis for SAF Europe area as a snow mask, having fractional information for the snow coverage on cloud-free and non-dark locations.

Software Readiness varies from research grade to full operational capability: partially compliant to coding standards, minimal documentation is available, PI affirms portability and numerical reproducibility, and continues to pass data provider's security review.

Metadata and User Documentation are under full operational capability.

Uncertainty Characterisation is under initial to full operational capability: Standard uncertainty nomenclature is applied, comprehensive validation is done, comprehensive quantification of more or less uncertain points are available, and temporal and spatial error covariance are quantified. Automated monitoring is fully established and results fed back to metadata.

Public Access, feedback and update is also under initial to full operational capability. Data and documentation are under institution's version control and archived and available to the public from Data Provider. The dataset is regularly updated using fully established feedback mechanisms.

The data are not well utilised for research and policy making.

7.5.11 LSA-SAF Daily Snow Cover

Name	LSA-SAF Daily Snow Cover
Origin	LSA-SAF, FMI; Niilo.Siljamo@fmi.fi
Spatial Characteristics	3 km at sub-satellite point
Temporal Characteristics	Daily

Software Readiness	Metadata	User Documentation	Uncertainty Characterisation	Public access, feedback, and update	Usage
Coding Standards	Standards	Formal description of scientific methodology	Standards	Public Access/Archive	Research
Software Documentation	Collection level	Formal validation report	Validation	Version	Decision support system
Numerical Reproducibility and portability	File level	Formal product user guide	Uncertainty quantification	User feedback mechanism	
Security		Formal description of operations concept	Automated quality monitoring	Updates to record	
Legend					
1	2	3	4	5	6

LSA-SAF Daily Snow Cover data set are snow cover map produced from MSG data contains a classification of each surface pixel or resolution cell into one (and only one) of the following classes:

- totally snow covered;
- partially snow covered;
- no snow;
- unclassified;
- non-processed;
- water (sea, lake, river etc.).

An additional set of quality/processing flags for each pixel indicates the certainty of the classification and integration and also gives information on the processing and conditions.

The software used to generate this dataset is under research category: coding standards are not applied, minimal software documentation is available, PI affirms portability and numerical reproducibility, and security issues are not evaluated.

Metadata and User Documentation are under full operational capability.

Uncertainty Characterisation is under initial to full operational capability: Standard uncertainty nomenclature is applied and SI traceability is partially established, comprehensive validation and inter-comparison are done, comprehensive quantification of more or less uncertain points are available, and temporal and spatial error covariance are quantified. Automated monitoring is fully established and results fed back to metadata.

Public Access, feedback and update is also under initial to full operational capability. Data and documentation are under institution's version control and archived and available to the public from Data Provider. The dataset is regularly updated using fully established feedback mechanisms.

The dataset is widely used for research and decision making.

7.5.12 Global Fire Assimilation System

Name	Global Fire Assimilation System
Origin	Copernicus Atmosphere Monitoring Service (CAMS); j.kaiser@mpic.de
Spatial Characteristics	Global, .1 and .5 deg
Temporal Characteristics	2000 – present; Daily

Software Readiness	Metadata	User Documentation	Uncertainty Characterisation	Public access, feedback, and update	Usage
Coding Standards	Standards	Formal description of scientific methodology	Standards	Public Access/Archive	Research
Software Documentation	Collection level	Formal validation report	Validation	Version	Decision support system
Numerical Reproducibility and portability	File level	Formal product user guide	Uncertainty quantification	User feedback mechanism	
Security		Formal description of operations concept	Automated quality monitoring	Updates to record	
Legend					
1	2	3	4	5	6

Global Fire Assimilation System (GFAS) provides global daily estimates of open biomass burning, a.k.a. vegetation fires with 0.5deg and 0.1deg resolutions. It is based on satellite observations of Fire Radiative Power (FRP), currently by NASA's two polar orbiting MODIS

instruments. The dataset is primarily intended as lower boundary condition input for atmospheric composition and air quality modeling in real time and retrospectively.

The software used is under research to initial operational capability. Coding standards are partially applied, moderate documentation is available, and PI affirms portability, numerical reproducibility, and of no security issues.

Metadata are under initial to full operational capability with full compliance to international standards. Sufficient collection level metadata and complete file level metadata are available.

User Documentation scores are varying from research grade to full operational capability. Comprehensive descriptions and journal publications are available on scientific methods. Limited descriptions of validation and operations concepts are available. However, there is no product user guide available.

Uncertainty Characterisation is either under research grade or initial operational capability. Standards are not applied, but comprehensive validation and inter-comparison are done. Limited information is available on uncertainty arising from systematic and random effects in the measurement. Automated quality monitoring is partially implemented

Public Access, Feedback, Update is under initial or full operational capability. Data and documentation are under institution's version control and archived and available to the public from Data Provider. Interim Climate Data Records are being produces using feedbacks through established mechanisms.

The dataset is widely used for research and citations are occurring. Use in decision making is occurring and benefits are emerging.

7.6 Reanalysis

This subsection discusses the ERA-Interim data set which is the only reanalysis data which is assessed in this report.

7.6.1 ERA-Interim

Name	ERA-Interim
Origin	ECMWF; Data.Services@ecmwf.int
Spatial Characteristics	Global, gridded
Temporal Characteristics	1979 – now; 6-hourly, with daily and monthly averages

Software Readiness	Metadata	User Documentation	Uncertainty Characterisation	Public access, feedback, and update	Usage
Coding Standards	Standards	Formal description of scientific methodology	Standards	Public Access/Archive	Research
Software Documentation	Collection level	Formal validation report	Validation	Version	Decision support system
Numerical Reproducibility and portability	File level	Formal product user guide	Uncertainty quantification	User feedback mechanism	
Security		Formal description of operations concept	Automated quality monitoring	Updates to record	
Legend					
1	2	3	4	5	6

The ERA-Interim dataset comes from a comprehensive global reanalysis based on data assimilation, i.e. a process that blends model forecasts with a range of observational data, taking into account their respective uncertainty characteristics. Originally created to support both numerical weather prediction and climate studies, ERA-Interim has subsequently been adopted in other applications including climate monitoring and earth-system science.

Coding standards are partially applied to the software used to generate the ERA-Interim dataset, the software documentation is substantially more than minimal with header and process description (comments) in the code but it lacks a README needed for the next maturity level, the PI affirms numerical reproducibility and portability under identical conditions, and the security problems are not evaluated. The software category is thus rated as research grade.

Metadata category is rated as initial operational grade. Standards are identified and applied at the file level, but there are only limited collection-level metadata available. The file-level metadata are often sufficient to use and understand the ERA-Interim data.

User Documentation is initial operational grade except for the lack of a description of the operations concept.

The ERA-Interim dataset is extensively validated for the principal parameters (e.g., temperature, humidity, precipitation). The data provider (ECMWF) has participated in

multiple international data assessments and the results have been fed back to the product development cycle.

The ERA-Interim dataset, documentation, and source code are under institutional version control and archived. Data and documentation are available to the public. The data provider collects feedback from the scientific community and this is used for irregular updates to the dataset. This category falls into initial operational capability.

Improvements in all these categories are achievable given sufficient resourcing.

ERA-Interim data are used extensively in research and decision support systems.

8 SUPPORTING DATASET USERS TO MAKE THE RIGHT CHOICE

Another tool developed in the project, the Application Performance Matrix (APM), attempts to evaluate the performance of an ECV CDR with respect to a specific application. The APM was added to the capacity assessment during the discussions about the SMM because it became clear that the SMM cannot answer the question on how good a data record is for a specific application. To be able to assess suitability of a data record with the APM, user requirements for each considered application are needed to compare the actual technical specifications and validation results to them.

APM is basically posing a set of typical questions which a user may ask when a data record is being searched for. Whereas questions towards the spatiotemporal coverage may be easy to answer from the technical specifications of a data record, questions towards results of uncertainty analysis are more difficult and a suggestion on the suitability of a data record for an application may need interaction between the application and data record experts. Key for any suggestion for usage based on this is an understanding of the user requirements for an application. For instance GCOS provides useful requirements for its ECVs which can be used as guidelines for suggestions of data records for applications in climate system analysis. However, a detailed analysis of user requirements per application would be useful to enhance the usability of the APM in the future.

The basic principle of the APM is easy as it evaluates how well the data record's technical specifications and accessible validation results, which should be listed in a Product Specification Table (PST), match the user requirements for the application considered, which should be listed in a User Requirement Table (URT). The (PST) is a database that consists of all relevant details on the climate data record, such as the technical specifications (e.g. period covered, temporal and spatial resolution/sampling, temporal and spatial coverage, etc) and a summary of validation results (e.g. uncertainty arising from systematic and random effects, temporal stability, etc). The PST ideally is part of a climate data record inventory where all PSTs are coming together.

The User Requirement Table (URT) consists of the user query of requirements expressed in parameters that are provided in the PST. Essentially, the APM evaluation process refers to performing a query on the PST. When such a query is made on several data records simultaneously, the search query result that is returned comprises the APM and a suggestion on which data records are matching requirements for the application.

These concepts were discussed in the workshop and the participants endorsed further developments to the APM concept which will be pursued in the near future.

9 CONCLUSIONS

9.1 Completeness of the assessment

The assessment tried to be as comprehensive as possible. Enough major European climate data providers participated in the assessment to allow conclusions about the applicability of the SMM for a capacity assessment. The assessment has been performed for satellite and in situ data records as well as weather prediction model-based reanalysis output. Among the satellite data providers are EUMETSAT including its Satellite Application Facility Network, the ESA Climate Change Initiative, Copernicus Atmosphere and Land Services.

It has to be emphasised that such an assessment had been done for the first time for in situ data records and the great response from the dataset developers is highly appreciated. Major European players such as Met Office Hadley Centre being responsible for the Hadley Centre Observational data sets (HadObs), Deutscher Wetterdienst having international responsibility for the Global Precipitation Climatology Centre (GPCC), the Koninklijk Nederlands Meteorologisch Instituut leading the European Climate Assessment & Dataset (ECA&D) project, and the Alfred Wegener Institute hosting the Baseline Surface Radiation Network archive participated in the assessment. Their inputs to the fruitful discussions have very much contributed towards adapting the initially satellite oriented SMM to a matrix that is more generally applicable.

There is only one global reanalysis that is being produced in Europe (ERA Interim) and that has participated in the assessment. It is certainly possible to extend the assessment to regional reanalyses such as from the EU FP-7 UERRA project in the future. It is suggested to perform SMM assessments for such datasets in the framework of the Copernicus Climate Change Service.

Although the assessment was done in a self-assessment mode, an audit-type assessment for some of the randomly picked datasets revealed that most of the data providers have been very honest in assigning SMM scores to their products. This provides an overall large credibility of the self assessment results presented here.

9.2 Value and potential usage

The value of the self assessment has several aspects. Firstly, it provides a consistent view on strengths and weaknesses of the process of generating, preserving and improving CDRs to each individual CDR producer, agencies and the EC. In particular, the assessment fulfilled its promise to be useful for the data providers by providing guidance to further development of their data products. The assessment made some data providers for the first time thinking about issues such as software maintenance which are a cost sensitive long-term item for an operational service, in particular for data records based on satellite data. Data providers are encouraged to repeat the self assessment periodically, e.g., annually, that enables progress monitoring of a guided development.

Secondly, the presented assessment provides detailed information where European activities to provide climate data records for GCOS ECVs stand. It may provide guidance for climate services where eventually to concentrate their investments into climate data record generation activities. For instance, data records showing maturity levels 3 and 4 (forming the initial operations capability) in many categories are certainly those that have good chance to be developed into full operations capability within the next 3-5 years. Others showing maturity levels 1 and 2 (being at research level) may be invested in but rather for doing more research and engineering development than transfer to operational services.

Thirdly, the assessment provides information to the general user community of CDRs, including science and services, on the status of individual records and the collective state of all records. It also provides this information for the first time across different observing systems, i.e., users can compare between satellite and in situ data sets on the different aspects covered by the maturity assessment. By this transparency and openness towards the user of CDRs has significantly be enhanced by the CORE-CLIMAX project.

Fourthly, the collective effort of the assessment to compile consistent descriptions of the participating data records has better facilitated Europe's contributions to international activities on the evaluation of climate models using observations such as Obs4Mips that require standardised data record descriptions.

Further realised systematic applications of the maturity matrix approach known today include:

- SMM is used in H2020 EUSTACE project to assess the maturity of data set development;
- SMM and APM were included in the Quality Assurance concept of FP7 QA4ECV project;
- SMM is used as a starting point in the Horizon 2020 project GAIA-CLIM to address the maturity of ground-based reference networks;
- CEOS-CGMS WG Climate uses SMM to assess status of data records in GCOS ECV inventory, which will be periodically repeated;
- The WMO initiative for Sustained and Coordinated Processing of Environmental Satellite Data for Climate Monitoring (SCOPE-CM, <http://www.scope-cm.org/>) uses the SMM as a progress monitoring tool in each of its dedicated internationally coordinated Climate Data Record projects.

Planned systematic applications include:

- Implementation in the Quality Assurance and Enhancement (QC&E) pillar of C3S;
- SMM results (e.g., graphical output shown in Figure 2) can be used as addition to the tools provided by the FP7 CHARMe project, i.e., the assessment results provided can become available through CHARMe nodes as annotations to participating data records.

Core-Climax Climate Data Record Capacity Assessment Report

APPENDIX A SYSTEM MATURITY MATRIX AND ITS SUB-MATRICES

		CDR Name Here			maturity level as of mm/dd/yyyy	
CORE-CLIMAX System Maturity Matrix						
Maturity	SOFTWARE READINESS	METADATA	USER DOCUMENTATION	UNCERTAINTY CHARACTERISATION	PUBLIC ACCESS, FEEDBACK, UPDATE	USAGE
1	Conceptual development	None	Limited scientific description of the methodology available from PI	None	Restricted availability from PI	None
2	Research grade code	Research grade	Comprehensive scientific description of the methodology, report on limited validation, and limited product user guide available from PI; paper on methodology is submitted for peer-review	Standard uncertainty nomenclature is identified or defined; limited validation done; limited information on uncertainty available	Data available from PI, feedback through scientific exchange, irregular updates by PI	Research: Benefits for applications identified DSS: Potential benefits identified
3	Research code with partially applied standards; code contains header and comments, and a README file; PI affirms portability, numerical reproducibility and no security problems	Standards defined or identified; sufficient to use and understand the data and extract discovery metadata	Score 2 + paper on methodology published; comprehensive validation report available from PI and a paper on validation is submitted; comprehensive user guide is available from PI; Limited description of operations concept available from PI	Score 2 + standard nomenclature applied; validation extended to full product data coverage, comprehensive information on uncertainty available; methods for automated monitoring defined	Data and documentation publically available from PI, feedback through scientific exchange, irregular updates by PI	Research: Benefits for applications demonstrated. DSS: Use occuring and benefits emerging
4	Score 3 + draft software installation/user manual available; 3rd party affirms portability and numerical reproducibility; passes data providers security review	Score 3 + standards systematically applied; meets international standards for the data set; enhanced discovery metadata; limited location level metadata	Score 3 + comprehensive scientific description available from data provider; report on inter comparison available from PI; paper on validation published; user guide available from data provider; comprehensive description of operations concept available from PI	Score 3 + procedures to establish SI traceability are defined; (inter)comparison against corresponding CDRs (other methods, models, etc); quantitative estimates of uncertainty provided within the product characterising more or less uncertain data points; automated monitoring partially implemented	Data record and documentation available from data provider and under data provider's version control; Data provider establishes feedback mechanism; regular updates by PI	Score 3 + Research: Citations on product usage in occurring DSS: societal and economical benefits discussed
5	Score 4 + operational code following standards, actions to achieve full compliance are defined; software installation/user manual complete; 3rd party installs the code operationally	Score 4+ fully compliant with standards; complete discovery metadata; complete location level metadata	Score 4 + comprehensive scientific description maintained by data provider; report on data assessment results exists; user guide is regularly updated with updates on product and validation; description on practical implementation is available from data provider	Score 4 + SI traceability partly established; data provider participated in one inter-national data assessment; comprehensive validation of the quantitative uncertainty estimates; automated quality monitoring fully implemented (all production levels)	Score 4 + soure code archived by Data Provider; feedback mechanism and international data quality assessment are considered in periodic data record updates by Data Provider	Score 4+ Research: product becomes reference for certain applications DSS: Societal and economic benefits are demonstrated
6	Score 5 + fully compliant with standards; Turnkey System	Score 5 + regularly updated	Score 5 + journal papers on product updates are and more comprehensive validation and validation of quantitative uncertainty estimates are published; operations concept regularly updated	Score 5 + SI traceability established; data provider participated in multiple inter-national data assessment and incorporating feedbacks into the product development cycle; temporal and spatial error covariance quantified; Automated monitoring in place with results fed back to other accessible information, e.g. meta data or documentation	Score 5 + source code available to the public and capability for continuous data provisions established (ICDR)	Score 5 + Research: Product and its applications becomes references in multiple research field DSS: Influence on decision and policy making demonstrated
1 & 2	Research Capability (RC)				CORE-CLIMAX V4 (EUM/USC/DOC/13/701166, 19/11/2013)	
3 & 4	Initial Operations Capability (IOC)					
5 & 6	Full Operations Capability (FOC)					

Figure 3: Top level view of the Core-Climax System Maturity Matrix (SMM).

Core-Climax Climate Data Record Capacity Assessment Report

Maturity	SOFTWARE READINESS	Coding standards	Software Documentation	Numerical Reproducibility and Portability	Security
1	Conceptual development	No coding standard or guidance identified or defined	No documentation	Not evaluated	Not evaluated
2	Research grade code	Coding standard or guidance is identified or defined, but not applied	Minimal documentation	PI affirms reproducibility under identical conditions	PI affirms no security problems
3	Research code with partially applied standards; code contains header and comments, and a README file; PI affirms portability, numerical reproducibility and no security problems	Score 2 + standards are partially applied and some compliance results are available	Header and process description (comments) in the code, README complete	PI affirms reproducibility and portability	Submitted for data provider's security review
4	Score 3 + draft software installation/user manual available; 3 rd party affirms portability and numerical reproducibility; passes data providers security review	Score 3 + compliance is systematically checked in all code, but not yet compliant to the standards.	Score 3 + a draft Software Installation/User Manual	3 rd party affirms reproducibility and portability	Passes data provider's security review
5	Score 4 + operational code following standards, actions to achieve full compliance are defined; software installation/user manual complete; 3 rd party installs the code operationally	Score 4 + standards are systematically applied in all code and compliance is systematically checked in all code. Code is not fully compliant to the standards. Improvement actions to achieve full compliance are defined.	Score 4 + enhanced process descriptions throughout the code; software installation/user manual complete	Score 4 + 3 rd party can install the code operationally	Continues to pass the data provider's review
6	Score 5 + fully compliant with standards; Turnkey System	Score 5 + code is fully compliant with standards.	As in score 5	Score 5 + Turnkey system	As in score 5

Figure 4: Sub-matrix of SMM which evaluates Software Readiness.

Core-Climax Climate Data Record Capacity Assessment Report

Maturity	METADATA	Standards	Collection level	File level
1	None	No standard considered	None	None
2	Research grade	No standard considered	Limited	Limited
3	Standards defined or identified; sufficient to use and understand the data and extract discovery metadata	Metadata standards identified and/or defined but not systematically applied	Sufficient to use and understand the data independent of external assistance; Sufficient for data provider to extract discovery metadata from meta data repositories	Sufficient to use and understand the data independent of external assistance
4	Score 3 + standards systematically applied; meets international standards for the data set; enhanced discovery metadata; limited location level metadata	Score 3 + standards systematically applied at file level and collection level by data provider. Meets international standards for the dataset	Score 3 + Enhanced discovery metadata	Score 3 + Limited location (pixel, station, grid-point, etc.) level metadata
5	Score 4+ fully compliant with standards; complete discovery metadata; complete location level metadata	Score 4 + meta data standard compliance systematically checked by the data provider	Score 4 + Complete discovery metadata meets international standards	Score 4 + Complete location (pixel, station, grid-point, etc.) level metadata
6	Score 5 + regularly updated	Score 5	Score 5 + Regularly updated	Score 5

Figure 5: Sub-matrix of SMM which evaluates Metadata.

Core-Climax Climate Data Record Capacity Assessment Report

Maturity	USER DOCUMENTATION	Formal description of scientific methodology	Formal Validation Report	Formal Product User Guide	Formal description of operations concept
1	Limited scientific description of the methodology available from PI	Limited scientific description of methodology available from PI	None	None	None
2	Comprehensive scientific description of the methodology, report on limited validation, and limited product user guide available from PI; paper on methodology is submitted for peer-review	Comprehensive scientific description available from PI and Journal paper on methodology submitted	Report on limited validation available from PI	Limited product user guide available from PI	None
3	Score 2 + paper on methodology published; comprehensive validation report available from PI and a paper on validation is submitted; comprehensive user guide is available from PI; Limited description of operations concept available from PI	Score 2 + Journal paper on methodology published	Report on comprehensive validation available from PI; Paper on product validation submitted	Comprehensive User Guide available from PI	Limited description of operations concept available
4	Score 3 + comprehensive scientific description available from data provider; report on inter comparison available from PI; paper on validation published; user guide available from data provider; comprehensive description of operations concept available from PI	Score 3 + Comprehensive scientific description available from Data Provider	Report on inter-comparison to other CDRs, etc. Available from PI and data Provider; Journal paper on product validation published	Score 3 + available from data provider	Comprehensive description of operations concept available
5	Score 4 + comprehensive scientific description maintained by data provider; report on data assessment results exists; user guide is regularly updated with updates on product and validation; description on practical implementation is available from data provider	Score 4 + Comprehensive scientific description maintained by data provider	Score 4 + Report on data assessment results exists	Score 4 + regularly updated by data provider with product updates and/or new validation results	Operations concept and description of practical implementation available
6	Score 5 + journal papers on product updates are and more comprehensive validation and validation of quantitative uncertainty estimates are published; operations concept regularly updated	Score 5 + Journal papers on product updates published	Score 5+ Journal papers more comprehensive validation, e.g., error covariance, validation of qualitative uncertainty estimates published	Score 5	Score 5 + Operations concept regularly updated

Figure 6: Sub-matrix of SMM which evaluates User Documentation.

Core-Climax Climate Data Record Capacity Assessment Report

Maturity	UNCERTAINTY CHARACTERISATION	Standards¹	Validation	Uncertainty quantification	Automated Quality Monitoring
1	None	None	None	None	None
2	Standard uncertainty nomenclature is identified or defined; limited validation done; limited information on uncertainty available	Standard uncertainty nomenclature is identified or defined	Validation using external reference data done for limited locations and times	Limited information on uncertainty arising from systematic and random effects in the measurement	None
3	Score 2 + standard nomenclature applied; validation extended to full product data coverage, comprehensive information on uncertainty available; methods for automated monitoring defined	Score 2 + Standard uncertainty nomenclature is applied	Validation using external reference data done for global and temporal representative locations and times	Comprehensive information on uncertainty arising from systematic and random effects in the measurement	Methods for automated quality monitoring defined
4	Score 3 + procedures to establish SI traceability are defined; (inter)comparison against corresponding CDRs (other methods, models, etc); quantitative estimates of uncertainty provided within the product characterising more or less uncertain data points; automated monitoring partially implemented	Score 3 + Procedures to establish SI traceability are defined	Score 3 + (Inter)comparison against corresponding CDRs (other methods, models, etc)	Score 3 + quantitative estimates of uncertainty provided within the product characterising more or less uncertain data points	Score 3 + automated monitoring partially implemented
5	Score 4 + SI traceability partly established; data provider participated in one inter-national data assessment; comprehensive validation of the quantitative uncertainty estimates; automated quality monitoring fully implemented (all production levels)	Score 4 + SI traceability partly established	Score 4 + data provider participated in one inter-national data assessment	Score 4 + temporal and spatial error covariance quantified	Score 3 + monitoring fully implemented (all production levels)
6	Score 5 + SI traceability established; data provider participated in multiple inter-national data assessment and incorporating feedbacks into the product development cycle; temporal and spatial error covariance quantified; Automated monitoring in place with results fed back to other accessible information, e.g. meta data or documentation	Score 5 + SI traceability established	Score 4 + data provider participated in multiple inter-national data assessment and incorporating feedbacks into the product development cycle	Score 5 + comprehensive validation of the quantitative uncertainty estimates and error covariance	Score 5 + automated monitoring in place with results fed back to other accessible information, e.g. meta data or documentation

Figure 7: Sub-matrix of SMM which evaluates Uncertainty Characterisation.

Core-Climax Climate Data Record Capacity Assessment Report

Maturity	PUBLIC ACCESS, FEEDBACK, UPDATE	Public Access/Archive	Version¹	User Feedback Mechanism	Updates to Record
1	Restricted availability from PI	Data may be available through request to PI	None	None	None
2	Data available from PI, feedback through scientific exchange, irregular updates by PI	Data available through PI	Preliminary versioning by PI	PI collects and evaluates feedback from scientific community	Irregularly by PI following scientific exchange and progress
3	Data and documentation publically available from PI, feedback through scientific exchange, irregular updates by PI	Data and documentation archived and available to the public from PI	Versioning by PI	PI and Data provider collect and evaluate feedback and from scientific community	Irregularly by PI following scientific exchange and progress
4	Data record and documentation available from data provider and under data provider's version control; Data provider establishes feedback mechanism; regular updates by PI	Data and documentation archived and available to the public from Data Provider	Version control institutionalised	Data provider establishes feedback mechanism such as regular workshops, advisory groups, user help desk, etc. and utilises feedback jointly with PI	Regularly by PI utilising input from established feedback mechanism
5	Score 4 + source code archived by Data Provider; feedback mechanism and international data quality assessment are considered in periodic data record updates by Data Provider	Score 4 + source code archived by Data Provider	Fully established version control considering all aspects	Established feedback mechanism and international data quality assessment results are considered in periodic data record updates	Regularly operationally by data provider as dictated by availability of new input data or new methodology following user feedback
6	Score 5 + source code available to the public and capability for continuous data provisions established (ICDR)	Score 5 + source code available to the public from Data Provider	Not used	Score 5 + Established feedback mechanism and international data quality assessment results are considered in continuous data provisions (Interim Climate Data Records)	Score 5 + capability for fast improvements in continuous data provisions established (Interim Climate Data Records)

Figure 8: Sub-matrix of SMM which evaluates Public Access, Feedback, and Update.

Core-Climax Climate Data Record Capacity Assessment Report

Maturity	USAGE	Research	Decision Support System
1	None	None	None
2	Research: Benefits for applications identified DSS: Potential benefits identified	Benefits for research applications identified	Potential benefits identified
3	Research: Benefits for applications demonstrated. DSS: Use occurring and benefits emerging	Benefits for research applications demonstrated by publication	Use occurring and benefits emerging
4	Score 3 + Research: Citations on product usage in occurring DSS: societal and economical benefits discussed	Score 3 + Citations on product usage occurring	Score 3 + societal and economical benefits discussed
5	Score 4+ Research: product becomes reference for certain applications DSS: Societal and economic benefits are demonstrated	Score 4 + product becomes reference for certain applications	Score 4 + societal and economical benefits demonstrated
6	Score 5 + Research: Product and its applications becomes references in multiple research field DSS: Influence on decision and policy making demonstrated	Score 5 + Product and its applications becomes references in multiple research field	Score 5 + influence on decision (including policy) making demonstrated

Figure 9: Sub-matrix of SMM which evaluates Usage.

APPENDIX B LIST OF ACRONYMS

GCOS	Global Climate Observing System
AMSU	Advanced Microwave Sounding Unit
APM	Application Performance Metric
AWI	Alfred Wegener Institute
C3S	Copernicus Climate Change Service
CCI	Climate Change Initiative
CDR	Climate Data Record
CEOS	Committee on Earth Observation Satellite
CGMS	Coordination Group for Meteorological Satellites
CLASS	Comprehensive Large Array-data Stewardship System
CMIP	Climate Model Inter-comparison Project
CMSAF	Satellite Application Facility on Climate Monitoring
EC	European Commission
ECMWF	European Centre for Medium-Range Weather Forecasts
ECV	Essential Climate Variable
ESA	European Space Agency
EUMETSAT	European Organisation for the Exploitation of Meteorological Satellites
EUSTACE	EU Surface Temperature for All Corners of Earth
FCDR	Fundamental Climate Data Record
GCOS	Global Climate Observing System
GHG	Greenhouse Gas
GPCC	Global Precipitation Climatology Centre
H2020	Horizon 2020
HOAPS	Hamburg Ocean Atmosphere Parameters and Fluxes from Satellite
ICDR	Interim Climate Data Record
IOC	Initial Operational Capability
IPCC	Intergovernmental Panel on Climate Change
ISCCP	International Satellite Cloud Climatology Project
MACC	Monitoring Atmospheric Composition and Climate
METOP	Meteorological Operational Satellite
MVIRI	Meteosat Visible Infra-Red Imager
NCDC	National Climate Data Centre
NOAA	National Oceanic and Atmospheric Administration
PI	Principal Investigator
RC	Research Capability
RO	Radio Occultation
SAF	Satellite Application Facility
SCOPE-CM	Sustained and coordinated processing of environmental satellite data for Climate Monitoring
SEVIRI	Spinning Enhanced Visible and Infrared Imager
SMM	System Maturity Matrix
SSM/I	Special Sensor Microwave Imager
SST	Sea Surface Temperature

SSU	Stratospheric Sounding Unit
TIROS	Television and InfraRed Observation Satellite
UERRA	Uncertainties in Ensembles of Regional ReAnalyses
USGS	U.S. Geological Survey
WCRP	World Climate Research Programme
WG	Working Group
WMO	World Meteorological Organization



CORE-CLIMAX
Dataset Descriptions
Deliverable D2.25

Doc.No. : CC/EUM/REP/15/002
Issue : v1
Date : 26 July 2015
WBS/DBS :

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1 INTRODUCTION

1.1 Purpose

The purpose of this document is to provide consistent descriptions for the data records that participated in the assessment of the European Essential Climate Variable (ECV) climate data record (CDR) capacity conducted on behalf of the CORE-CLIMAX consortium.

1.2 Scope

1.3 Reference Documents

RD-1	CORE-CLIMAX European ECV CDR Capacity Assessment Report	EUM/OPS/REP/15/800965
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1.4 Document Structure

Section 1 General information (this section)

Section 2 Provides standardised descriptions for all data records that participated in the capacity assessment.

2 DATA SET DESCRIPTIONS

2.1 Fundamental Climate Data Records

2.1.1 Stratospheric Sounding Unit (SSU) FCDR

2.1.1.1 Intent of the Document

This document summarizes essential information needed for users of any level who wish to use the stratospheric sounding unit (SSU) radiance data set for climate applications. The SSU was mounted on the TIROS-N and some of the NOAA polar orbiters.

2.1.1.2 Point of Contact

Roger Saunders, Met Office, U.K. roger.saunders@metoffice.gov.uk

2.1.1.3 Data Field Description

The SSU level 1b radiances are stored at the NOAA-CLASS archive:

<http://www.class.ncdc.noaa.gov/saa/products/welcome>. They have been processed from the level 0 counts to calibrated radiances. The SSU observed radiances in the 15 micron carbon dioxide band, with three channels peaking at about 29 km, 35 km and 45 km in the stratosphere. The designation of these channels here is 1 to 3 respectively, although they are often referred to as channels 25 to 27 of the TOVS in the literature. The radiances originated from deep atmospheric layers. For nadir views the half-width varies from 16 km deep (channel 1) to about 22 km (channel 3). The SSU only flew on TIROS-N and NOAA's 6, 7, 8, 9, 11 and 14 as detailed in Table 1. In 1998 the AMSU-A instrument was launched which replaced the SSU in operations but measurements continued to be made by the SSUs until 2006. The data are stored as an orbit by orbit format with one record per scan line. The formats are described on the CLASS web site.

<i>Space-craft</i>	<i>Data available</i>	<i>SSU channel used</i>	<i>SSU Status</i>	<i>Comments</i>
<i>TIROS-N</i>	Dec 78- July 80	1,2	Operational	Channel 3 very noisy , systematic bias unstable
<i>NOAA-6</i>	Dec 79 – April 83 Sept 84 - June 85 Nov 85- Oct. 86	1,2,3	Operational *SSU collected *SSU collected	No HIRS-2 after April 1983
<i>NOAA-7</i>	Jan. 82 - July 83 Aug 83 – Feb 85	1,2,3 1,3	Operational *SSU collected	Self calibration of channel 2 not valid after July 1983
<i>NOAA-8</i>	May 83 - Jun84 Jul 85 – Sept 85	1,2,3 2,3	Operational *SSU collected	Channel 1 very noisy in 1985, because of pickup of 3 rd harmonic from PMC 3
<i>NOAA-9</i>	Mar 85 - Feb 87 Mar 87 – Jan 89	1,2,3	Operational *SSU collected	Data from Oct 1988 onwards not retained in archive.
<i>NOAA-11</i>	Oct 88- Jan 95 Feb-95 – Nov03	1,2,3	Operational *SSU collected	Small data gap in UK time series archive in May1995
<i>NOAA-14</i>	Feb 95- Jan 00 Feb 00 – Jan 06	1,2,3	Operational *SSU collected	Small data gap in UK archive in time series May 1995

*SSU still transmitting and being received by NOAA at lower priority than operational, in some cases data were processed at NOAA by the usual software and in a limited number of cases the raw data were transmitted to the Met Office for processing.

Table 1. SSU instruments producing useful information for the time series of atmospheric brightness temperatures.

2.1.1.4 Data Origin

The procedure for the basic calibration of the TOVS radiometers, including the SSU, is outlined in Lauritson *et. al.* (1979) and essentially converts counts to radiances with the calibration coefficients included in the raw data. Radiances were converted to equivalent black body brightness temperatures (hereafter referred to as brightness temperatures) using the inverse of Planck's radiation equation. The earth-located brightness temperatures were stored as the level 1b dataset for SSU in the CLASS archive. It was found however there was an anomaly with the SSU space views used for the calibration and so a correction has to be applied for each SSU to give the correct radiance. To date this has not been done to the radiances in the CLASS archive. A detailed description of the SSU processing steps is given in Nash and Saunders (2013). The coverage of the data was near global with two overpasses a day. Another factor to consider is the cell pressure as this changes the spectral response of the channel and hence the height of the layer being observed in the stratosphere. Immediately after launch the pressure can change quite rapidly as the water vapour in the cell escapes but after 6-12 months the pressure usually settles down (see Fig. 1). The forward model for the channel has to take this pressure change into account. The RTTOV fast radiative transfer model (Saunders *et. al.* 2013) has a correction for the cell pressure changes on the SSU to try and accurately model the change in spectral response of each channel.

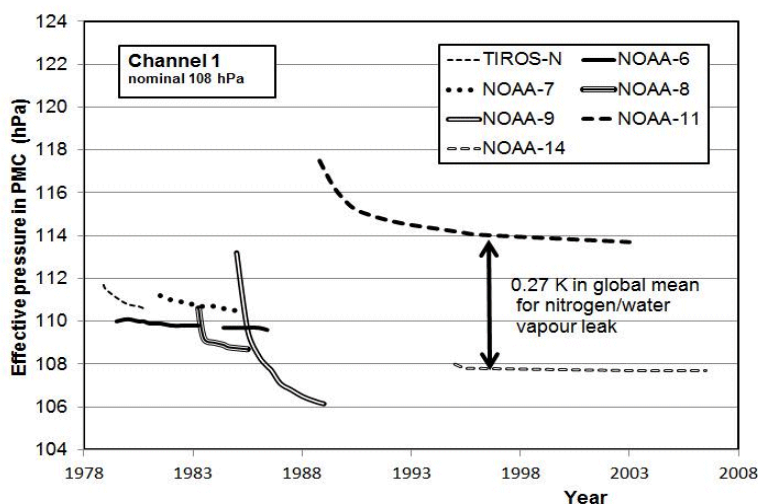


Figure 1. Changes in PMC cell pressures derived from changes in PMC frequencies during operation in space. Effect on global radiances for channel 1 for a typical pressure change is shown, for a typical water vapour PMC leak.

2.1.1.5 Validation and Uncertainty Estimate

An estimate of the uncertainties of the use of the SSU radiances as brightness temperatures is given in the table below. More details in Nash and Saunders (2013). The SSU radiance uncertainties were validated by comparing 2 satellites with SSU instruments on which overlapped at the same time over periods of greater than 6 months. Examination of the Obs minus FG values in the ERA-40 reanalysis were also used to give further confidence in the measurements (Kobayashi *et. al.* 2009).

	Channel 1 [K]	Channel 2 [K]	Channel 3 [K]
--	---------------	---------------	---------------

	Channel 1 [K]	Channel 2 [K]	Channel 3 [K]
Self-calibration	0.1	0.09	0.08
Non-Linearity	0.05	0.042	0.04
Space view offset	0.02	0.026	0.03
In orbit short term change	0.05	0.042	0.11
Radiometric offset due to water vapour in the PMC changing spectral response	0.02	0.04	0.08
Overall radiometric precision	0.13	0.12	0.17
Random error in individual earth observation	0.3	0.4	0.5

Table 2. Error budget of SSU Radiance observations (for averages in space or time) in brightness temperature after Nash and Brownscombe (1982), given a correct space view offset correction.

2.1.1.6 Considerations for climate applications

During the early years of the SSU the temperature retrievals were primarily used by centres involved in real-time monitoring of the stratosphere (Pick and Brownscombe, 1981, Bailey *et. al.*, 1993). More recently, as the record has reached over 25 years, interest has moved to using the measurements for monitoring stratospheric climate trends as an independent dataset. The main factor that has to be considered for SSU radiances to be used for a stratospheric time series analysis is the solar tide in the upper atmosphere. This has to be corrected and Nash and Saunders (2013) describe one way to do this.

An important application of the SSU dataset has been the assimilation of the SSU radiances directly in reanalyses (e.g. ERA-40 and ERA-Interim, Uppala *et. al.* 2005). Exploiting the SSU measurements in this way requires a homogenous radiance dataset based on the best knowledge of the calibration and uses all scan angles but doesn't require a tidal correction. There have been some studies on this and also on comparing the consistency of SSU radiances with AMSU-A stratospheric channel radiances using the ERA-40 reanalysis (e.g. Kobayashi *et. al.* 2009).

2.1.1.7 Instrument Overview

The SSU used the selective chopping technique developed by Houghton and Smith (1970), combined with the pressure modulator technique used in the Pressure Modulator Radiometer on Nimbus-6, Curtis *et. al.* (1974). A schematic of the optics for one channel of the SSU channels is shown in Figure 1. Radiation centred at 665 cm⁻¹ was filtered through a Pressure Modulator Cell (PMC) and a supplementary interference filter of bandwidth 60 cm⁻¹. Radiation from spectral regions where pressure modulation of the cell did not result in a transmission modulation through the PMC was rejected. This corresponded to regions of

strong absorption close to the carbon dioxide line centres and regions of negligible absorption in the line wings. The regions of transmission modulation were further away from the line centres in a high pressure PMC than in a low pressure PMC. Channel 1 with a high pressure PMC sensed radiation with a lower carbon dioxide absorption coefficient overall and hence lower down in the atmosphere than that sensed in channel 3 with a lower pressure PMC. The PMCs were connected to a sealed titanium cylinder, where modulation of the pressure was induced by the oscillation of a closely fitting piston, suspended on two diaphragm springs. This piston was maintained in oscillation at its resonant frequency by pulses of current passed through a coil mounted on the piston's shaft and lying in the gap of a magnet. An electronic servo system, which sensed the back-e.m.f. in the coil, controlled the length of the current pulse and kept the amplitude constant. The current to drive the piston was fed into the coil via a ceramic lead-through, see Figure 1. The frequency of the PMC depended on the PMC pressure and the mechanical constants of the spring (assumed to be constant.) The PMC was operated at a stable temperature, normally close to 30°C. The signal channel electronics amplified and selected the signal component from the detector in phase with the pressure modulation. The three PMCs in the SSU were mounted close to each other, in parallel facing the plane scan mirror.

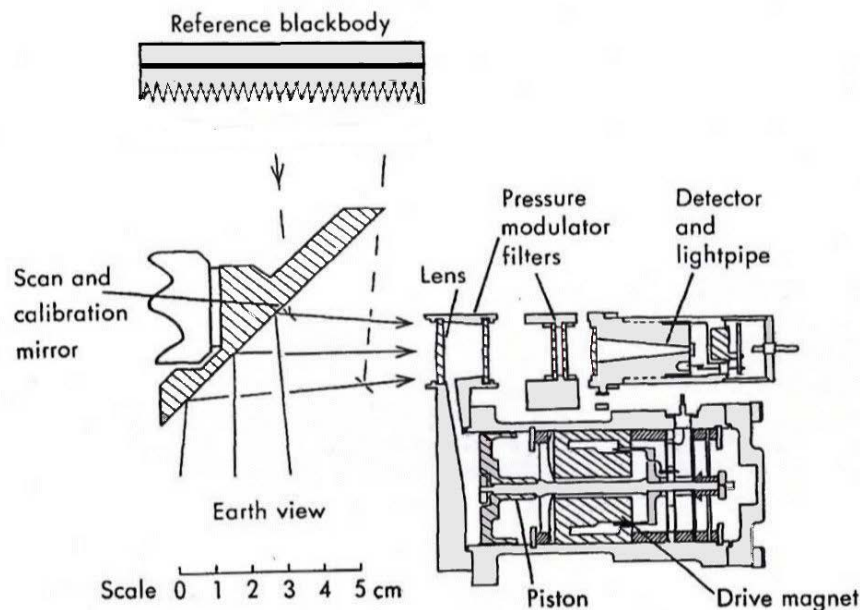


Figure 1. Schematic of the optics and pressure modulator for one cell. All three PMCs used the same mirror. Lens and light pipe windows were coated germanium.

A plane mirror scanned sideways in 8 steps of 10 degrees up to 35° either side of nadir. Each view lasted 4s, with data integrated for 3.4s. Every 256s, the mirror rotated to observe an internal reference blackbody at a temperature around 295K for 16s and then a space view for 16s. Earth view radiances were derived from a linear interpolation between the space view radiance and the internal black body radiance. The SSU signal was smallest for the internal blackbody view radiance and largest for the space view radiance. If the output of the signal channel was X_{sc} counts, and the radiance viewed was R_{sc} , then:

$$R_{sc} = -A \cdot X_{sc} + B \quad (1)$$

Where A, and B were constants over a 4 minute calibration cycle. A depended on the detector performance, the electrical amplification, and the amplitude of the pressure modulation, and B included the amplitude of the pressure modulation and the electrical offset for cell temperature modulation.

2.1.1.8 References

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2.1.1.9 Revision History

12 Jan 2014 - Version 1 – Initial draft created by Roger Saunders

2.1.2 EUMETSAT CM SAF SSM/I FCDR Edition 1.0

2.1.2.1 Intent of the Document

This document summarizes essential information needed for users of any level who wish to use the CM SAF Fundamental Climate Data Record of SSM/I for climate applications and climate service.

2.1.2.2 Point of Contact

EUMETSAT Satellite Application Facility for Climate Monitoring

Deutscher Wetterdienst
Frankfurter Straße 135
60594 Offenbach, Germany

Email: contact.cmsaf@dwd.de

2.1.2.3 Data Field Description

Information on technical specifications, the retrieval, the limitations, the file name convention and the data file contents such as variable names and units are given in the CM SAF Product User Manual, available at

http://www.cmsaf.eu/bvbw/generator/CMSAF/Content/Publication/SAF_CM_DWD_PUM_FCDR_SSMI_1_0.templateId=raw,property=publicationFile.pdf/SAF_CM_DWD_PUM_FCDR_SSMI_1_0.pdf

2.1.2.4 Data Origin

The CM SAF Fundamental Climate Data Record of SSM/I Brightness Temperatures covers the time period from July 1987 to December 2008 including all available data from the six SSM/I radiometers aboard F08, F10, F11, F13, F14, and F15. It provides homogenised and inter-calibrated brightness temperatures in a user friendly data format. The improved homogenization and inter-calibration procedure ensures the long term stability of the FCDR for climate related applications. All available raw data records have been reprocessed to a common standard, starting with the calibration of the raw Earth counts to ensure a completely homogenized data record. The new inter-calibration model incorporates a scene dependent inter satellite bias correction and a non-linearity correction to the instrument calibration. Furthermore, the data processing accounts for several known issues with the SSM/I instruments and corrects calibration anomalies due to along scan inhomogeneity, moonlight intrusions, and sunlight intrusions. The data files contain all available original sensor data and metadata to provide a completely traceable climate data record. Inter-calibration and Earth incidence angle normalization offsets are available as additional layers within the data files in order to keep this information transparent to the users. The data record is complemented with radiometer sensitivities, quality flags, surface types, and Earth incidence angles. The data record is fully independent from model information.

2.1.2.5 Validation and Uncertainty Estimate

The SSM/I FCDR has been compared to the raw data and the results after individual inter-sensor calibration steps. It has further been compared to the SSM/I FCDR from Remote Sensing Systems (version 6, Semunegus, 2011). A comprehensive validation report is available from

http://www.cmsaf.eu/bvbw/generator/CMSAF/Content/Publication/pdf/SAF_CM_DWD_VAL_FCDR_SSMI_1_0,templateId=raw,property=publicationFile.pdf/SAF_CM_DWD_VAL_FCDR_SSMI_1_0.pdf.

The overall mean difference between the different sensors has been reduced to below 0.1 K.

2.1.2.6 Considerations for climate applications

The intersensor calibration method used here to homogenize the SSM/I brightness temperature time series does not account for an absolute radiometric offset. The reference target is the SSM/I aboard DMSP F11, which means that any absolute offset in the F11 TBs will be transferred to the other radiometers. However, one reason to choose the F11 as the reference target was a good performance when validating against collocated in-situ wind speed measurements from buoy observations (Andersson et al., 2010). This should at least minimize the remaining absolute error in the brightness temperature data record.

The intersensor calibration is determined over ocean, sea-ice and cold scenes over land because of a lower variability, smaller diurnal cycle and better behaved error characteristics. Due to this restriction, not the complete range of possible TBs is covered for all channels. It is assumed that the intersensor differences can be characterized as a linear problem and the derived correction coefficients can be used over warm land as well.

The incidence angle normalisation TB offsets are only available over water. Geophysical retrievals over land and ice should always account for varying EIAs within their procedures.

During the time period from April 1988 to December 1991, the 85 GHz channel on DMSP F08 were defective. A replacement algorithm has been developed to estimate the 85 GHz measurements from the lower frequencies. However, this reconstruction is limited to the variability observed in the lower frequencies and can not fully recover the missing 85 GHz channel characteristics. Over land and ice surfaces this general approach is not applicable due to the strongly varying surface emissivity.

2.1.2.7 Instrument Overview

SSM/I sensors have been carried aboard the DMSP satellite series since 1987. Up to three radiometers have been in orbit simultaneously. An extensive description of the instrument and satellite characteristics has been published by Hollinger et al. (1990) and Wentz (1991). The DMSP satellites fly in a near-circular, sun-synchronous orbit, with an inclination of 98.8° at an approximate altitude of 860 km. The Earth's surface is sampled with a conical scan at a constant local zenith angle of 53.1° and a 1400 km wide swath. A nearly complete coverage of the Earth by one SSM/I is achieved within two to three days. Due to the orbit inclination and swath width, the regions poleward of 87.5° are not covered. To date, six

SSM/I instruments have been successfully launched aboard the F08, F10, F11, F13, F14 and F15 spacecraft. All satellites have a local equator crossing time between 5 and 10 A.M./P.M. for the descending/ascending node. The F08 had a reversed orbit with the ascending node in the morning. Also, the Earth observing portion of the scan on this satellite is, differently from the others, centred to the aft. Most of the DMSP satellites have a very stable orbit. The temporal variation of the equator crossing times is less than three hours for all satellites. At the end of the time period the orbits of F14 and F15 begin to decay noticeably, but are still within 2-3 hours of original time.

The SSM/I is a seven channel total power radiometer measuring emitted microwave radiation at four frequency intervals centred at 19.35, 22.235, 37.0, and 85.5 GHz. All frequencies are sampled at horizontal and vertical polarization, except for the 22.235 GHz channel, which measures only vertically polarized radiation.

The spatial resolution varies from 69 km by 43 km with a sampling frequency of 25 km for the 19 GHz channel to 15 km by 13 km with 12.5 km sampling frequency for the 85 GHz channel. The 85 GHz channels are sampled for each rotation of the instrument (A and B-scans) with a resolution of 128 uniformly spaced pixels, while the remaining channels are sampled every other scan (A-scans) with a resolution of 64 pixels. A fixed cold space reflector and a reference black body hot load are used for continuous onboard two point calibration.

2.1.2.8 References

A. Andersson, K. Fennig, C. Klepp, S. Bakan, H. Graßl, and J. Schulz, 2010: The Hamburg Ocean Atmosphere Parameters and Fluxes from Satellite Data - HOAPS-3, *Earth Syst. Sci. Data*, 2, 215-234, doi:10.5194/essd-2-215-2010.

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2.1.2.9 Revision History

First issue: version 1.0, 13 January 2014, Marc Schröder (DWD)

2.1.3 Baseline Surface Radiation Network (BSRN)

2.1.3.1 Intent of the Document

The objective of the BSRN is to provide, using a high sampling rate, observations of the best possible quality, for short- and long-wave surface radiation fluxes. These readings are taken from a small number of selected stations, in contrasting climatic zones, together with collocated surface and upper air meteorological data and other supporting observations.

The uniform and consistent measurements throughout the BSRN network are used to:

- monitor the background (least influenced by immediate human activities which are regionally concentrated) short-wave and long-wave radiative components and their changes with the best methods currently available,
- provide data for the validation and evaluation of satellite-based estimates of the surface radiative fluxes and
- produce high-quality observational data for comparison to climate model (GCM) calculations and for the development of local regionally representative radiation climatologies.

2.1.3.2 Point of Contact

Director of the World Radiation Monitoring Center WRMC (BSRN archive):

Dr. Gert König-Langlo
Alfred Wegener Institute for Polar and Marine Research
Postfach 120161, D-27515 Bremerhaven
e-mail: Gert.Koenig-Langlo@awi.de
web: <http://www.bsrn.awi.de>
phone: +49 471 4831 1806

Interim project manager of the BSRN:

Dr. Joseph Michalsky
NOAA/ESRL
325 Broadway, GMD
Boulder, Colorado 80305
e-mail: Joseph.Michalsky@noaa.gov
phone: +1 303 497 6360

2.1.3.3 Data Field Description

As of mid 2013, 58 BSRN stations have submitted data to the WRMC (Fig. 1). The data import is organized in so called station-to-archive files which contain all the data from one station collected during one month. Currently a total of over 7000 station-month datasets from 58 stations are available in the WRMC, although only 9 stations have delivered their data back to 1992. The measurements from BSRN stations are expected to be submitted to the WRMC with no more than about one year delay, however, the most recent data from

some stations are being submitted with much longer delay (for an overview of available surface radiation data see http://www.pangaea.de/PHP/BSRN_Status.php?q=LR0100).

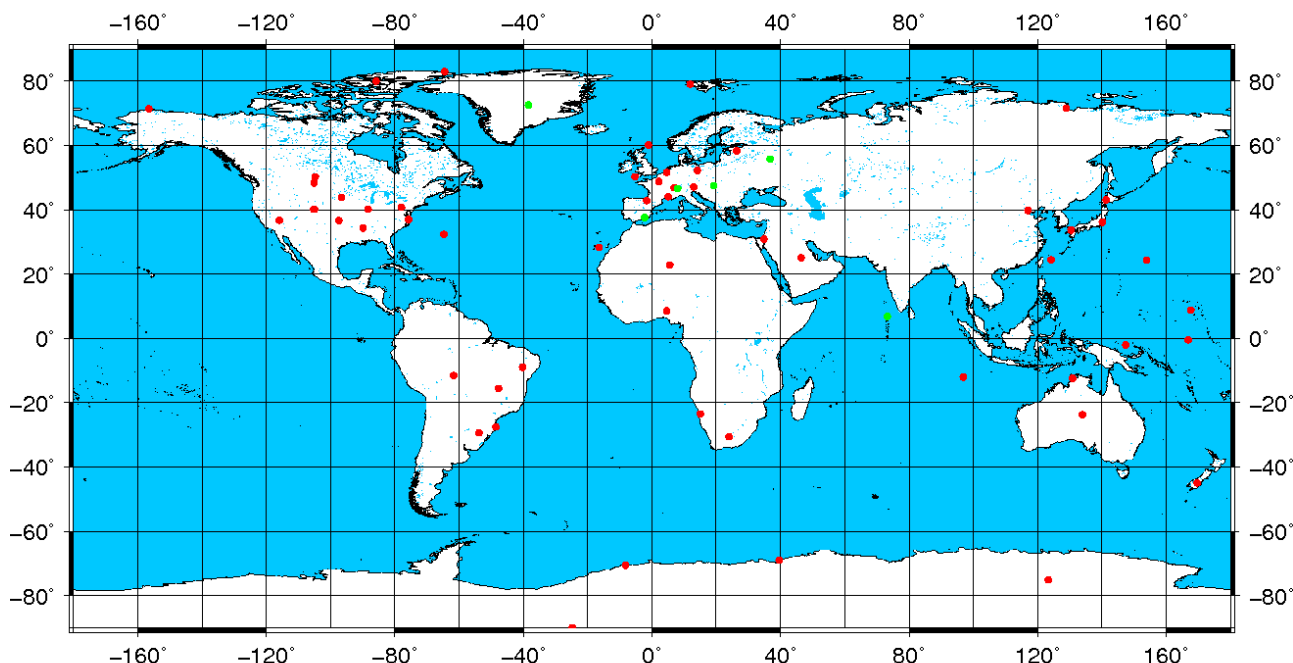


Fig. 1. Active BSRN stations (red) and candidates (green) mid 2013.

The WRMC archives many parameters observed at the BSRN stations. Because the stations provide different parameters, the station-to-archive file is organized in logical records (LR) according to various groups of measurements. An overview of all supported LRs and the comprising parameters is given in Table 1. The mandatory parameters are included in the logical record LR 0100; these are global, direct, diffuse, downward long-wave radiation, air temperature, relative humidity, and air pressure at instrument height. Other parameters like the upward radiation fluxes and ancillary data such as upper-air soundings and basic meteorological observations are optional.

Table 1. The datasets available in the WRMC mid 2013		
Logical Record	Stations	Months
LR 0100: (Global, Diffuse, Direct, Long-wave down)	58	7294
LR 0300: (Reflex, Long-wave up, net radiation)	11	1905
LR 0500: (UV)	14	1613
LR 1000: (Synoptic observations)	13	1731
LR 1100: (Upper air soundings)	29	3699
LR 1200: (Total ozone)	9	1447
LR 1300: (Ceilometer data)	3	614
LR 3010: (Radiation measurements from 10 m height)	10	1568
LR 3030: (Radiation measurements from 30 m height)	2	259
LR 3300: (Radiation measurements from 300 m height)	1	218

2.1.3.4 Data Origin

The BSRN stations need to meet several basic requirements. The most important requirement is a long-term involvement of an expert in surface radiation measurements for each measurement site, who is designated as the BSRN station scientist. The BSRN station scientists are responsible for the data quality of their station. All the BSRN station scientists are instructed to readily provide acquired data to the WRMC in a timely manner and in the specified ASCII-format, according to the station-to-archive file format, see: <http://www.wmo.int/pages/prog/gcos/Publications/gcos-174.pdf>.

2.1.3.5 Validation and Uncertainty Estimate

The station scientists are responsible for the quality of their submitted data. Within the archive all incoming data are format-checked and visualized. Files with the most obvious errors are not imported into the archive but are returned to submitter.

The quality of many BSRN data can be controlled individually by using the BSRN Toolbox (Schmithüsen et al. 2012) which was released in the beginning of 2012. The tool is rather flexible. It can handle:

- station-to-archive freshly created by a station scientists prior to submission,
- files downloaded from the ftp-archive (<ftp://ftp.bsrn.awi.de/>),
- files downloaded from PANGAEA (<http://www.pangaea.de>).

The quality checks offered by the BSRN Toolbox can help

- the station scientists to test station-to-archive files before they get submitted,
- the data curator from the WRMC before archiving submitted data (this gets done routinely since December 2011), and
- any user of the WRMC testing extracted data from the WRMC.

At the moment the BSRN Toolbox offeres the BSRN Global Network recommended QC tests, V2.0 (Long, C. N., and E. G. Dutton, 2002). In future, more quality check options will be developed and implemented. More detailed information are given at: http://wiki.pangaea.de/wiki/BSRN_Toolbox#Quality_Check.

Any user who finds questionable data should inform the WRMC staff (Gert.Koenig-Langlo@awi.de) about the problem so the data can be double checked. If the problem is severe, the WRMC staff will contact the corresponding station scientists for corrections. If the corrected data cannot be submitted within a reasonable period of time, the questionable data will be deleted from PANGAEA, and a warning will be given in the corresponding station directory of the ftp-archive.

2.1.3.6 Considerations for climate applications

Not filled.

2.1.3.7 Instrument Overview

Within the Operations Manual of the Baseline Surface Radiation Network (McArthur L.J.B., 2005) detailed information is given how a BSRN station has to be instrumented and maintained. Each dataset is assigned with the instrument used including information about the calibration.

2.1.3.8 References

König-Langlo, G. , Sieger, R. , Schmithüsen, H. , Bücker, A. , Richter, F. and Dutton, E. (2013): The Baseline Surface Radiation Network and its World Radiation Monitoring Centre at the Alfred Wegener Institute, <http://www.wmo.int/pages/prog/gcos/Publications/gcos-174.pdf>

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Schmithüsen, H., R. Sieger, and G. König-Langlo, 2012: BSRN Toolbox - a tool to create quality checked output files from BSRN datasets and station-to-archive files. Alfred Wegener Institute, Helmholtz Centre for Polar and Marine Research, Bremerhaven, doi:10.1594/PANGAEA.774827.

Wild, M., D. Folini, C. Schär, N. Loeb, E. G. Dutton, and G. König-Langlo, 2013: The global energy balance from a surface perspective. Climate Dynamics, Volume 40, Issue 11-12, pp 3107-3134, doi:10.1007/s00382-012-1569-8.

2.1.3.9 Revision History

Version 1: Gert König-Langlo, Bremerhaven 2014-01-08

2.2 Atmospheric Datasets

2.2.1 ESA CCI GHG datasets

2.2.1.1 Intent of the Document

This document provides an overview about the core satellite-derived greenhouse gas (GHG) data products as generated within the ESA project GHG-CCI (<http://www.esa-ghg-cci.org/>). These products are generated with GHG-CCI “ECV Core Algorithm” (ECAs). ECAs are algorithms to retrieve dry-air column-averaged mole fractions of carbon dioxide (CO₂) and methane (CH₄), denoted XCO₂ (in ppm) and XCH₄ (in ppb) from currently two satellite instruments: SCIAMACHY onboard ENVISAT (2002-2012) and TANSO-FTS onboard GOSAT (2009-ongoing).

The GHG-CCI products are Level 2 products, i.e., detailed information such as time and location is provided for each single satellite observation (ground pixel).

In addition to the ECA products GHG-CCI also delivers several other products referred to as “Additional Constraints Products” (ACAs). For information on ACAs please visit <http://www.esa-ghg-cci.org/>.

2.2.1.2 Point of Contact

Overall contact for GHG-CCI is: Michael Buchwitz, Institute of Environmental Physics (IUP), University of Bremen, Germany (buchwitz@uni-bremen.de).

2.2.1.3 Data Field Description

The GHG-CCI data products are continuously being improved. The first ECV data generated within GHG-CCI is called Climate Research Data Package (CRDP) number 1, CRDP#1. CRDP#1 was released in October 2013.

The next release will be CRDP#2, which will be available in October 2014. For CRDP#2 the data format will be significantly improved in terms of better metadata, meeting of data standards and improved data product harmonization. See: Product Specification Document version 3 (PSDv3, available from <http://www.esa-ghg-cci.org/> -> “Documents” or directly: from

http://www.esa-ghg-cci.org/index.php?q=webfm_send/160).

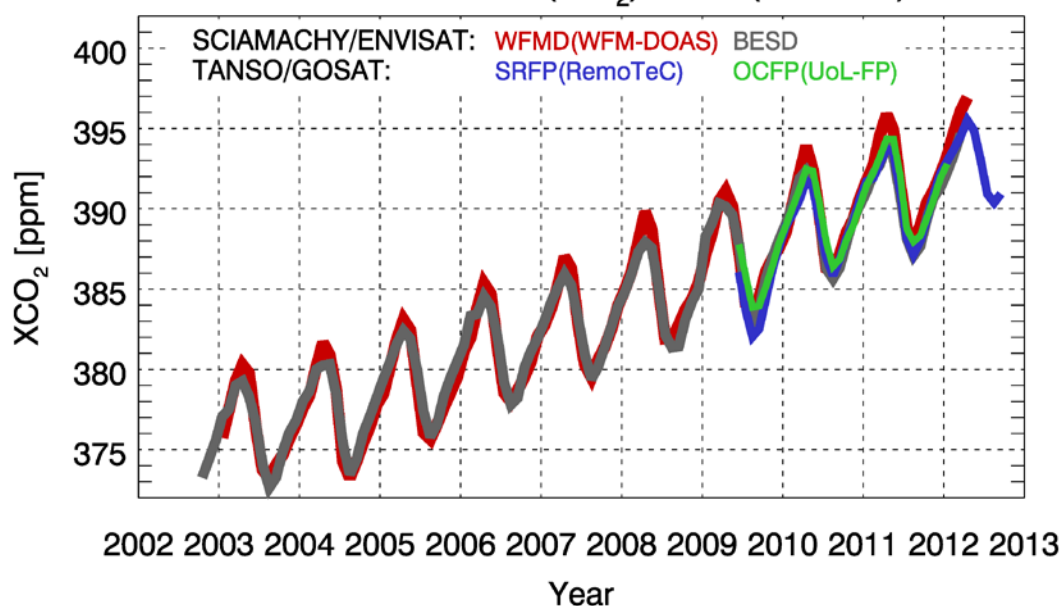
The following table summarizes the main characteristics of the core GHG-CCI datasets. Please visit <http://www.esa-ghg-cci.org/> -> “CRDP (Data)” to get information on the latest version of each product and time period covered.

product	sensor	responsible provider(s)	Resolution & coverage	period
XCO ₂	SCIAMACHY on ENVISAT	IUP, Univ. Bremen	30x60 km ² , global (land only)	2002-2012
XCO ₂	TANSO on GOSAT	Univ. Leicester and SRON/KIT	10 km, global	2009-2011+
XCH ₄	SCIAMACHY on ENVISAT	IUP, Univ. Bremen, and SRON/JPL	30x60 km ² , global	2002-2012
XCH ₄	TANSO on GOSAT	Univ. Leicester and SRON/KIT	10 km, global	2009-2011+

A time series of XCO₂ using data products contained in CRDP#1 is shown in the following figure. Clearly visible is the CO₂ increase and its seasonal cycle. Also clearly visible is the good consistency of the SCIAMACHY and GOSAT XCO₂.

GHG-CCI CRDP#1

Carbon Dioxide (CO₂) - NH (0°-60°N)



2.2.1.4 Data Origin

The GHG-CCI core data products are generated using XCO₂ and XCH₄ retrieval algorithms optimized for the sensors SCIAMACHY/ENVISAT (nadir mode) and TANSO-FTS/GOSAT (see Buchwitz et al., 2013, and publications listed given on <http://www.esa-ghg-cci.org/>). These algorithms, which are based on radiative transfer modelling and Optimal Estimation (OE) and/or Differential Optical Absorption Spectroscopy (DOAS) methods, convert the measured radiance spectra (Level 1 products or Fundamental Climate Data Records (FCDR)) into atmospheric CO₂ and/or CH₄ information in terms of XCO₂ and XCH₄. The FCDRs are the operational Level 1 products of SCIAMACHY (generated by DLR/ESA) and TANSO/GOSAT (generated by JAXA).

2.2.1.5 Validation and Uncertainty Estimate

Validation of the data (see Buchwitz et al., 2013, Dils et al., 2013, and for CRDP#1 the GHG-CCI “Product Validation and Intercomparison Report” (PVIR) available on <http://www.esa-ghg-cci.org/> -> “Documents”. The validation has been performed by comparison with ground-based data of the Total Carbon Column Observing Network (TCCON, www.tccon.caltech.edu/). The following tables summarize the validation of the CRDP#1 (see “Product Validation and Intercomparison Report” version 2 (PVIRv2; link: http://www.esa-ghg-cci.org/index.php?q=webfm_send/152) for details):

Estimates of achieved data quality (all values 1-sigma): CRDP#1 XCO₂ (in ppm)				
Sensor	Algorithm	Random error ("Single measurement precision")	Systematic error ("Relative accuracy")	Comments
SCIAMACHY on ENVISAT	BESD v02.00.04	2.1	0.7 – 1.2 (RA – SRA)	Details see Section 3: Precision: "Scat" Tab. 3.4.1; Accuracy: "RA-SRA" Tab. 3.4.1.
SCIAMACHY on ENVISAT	WFMD 3.3	4.0	1.2 – 1.7	- " -
TANSO on GOSAT	OCFP v4.0 (UoL-FP)	2.2	0.7 – 0.8	- " -
TANSO on GOSAT	SRFP v2.1 (RemoTeC)	2.0	0.4 – 0.7	- " -
SCIAMACHY & GOSAT merged	EMMA v1.5x (x = a, b, c)	x=a: 2.7 x=b: 2.0 x=c: 1.9	0.6 – 1.2 0.6 – 1.1 0.6 – 1.0	- " -
Required:	G / B / T	< 1 / 3 / 8	< 0.2 / 0.3 / 0.5	/URD GHG-CCI v1/

Table S-1: Estimated quality of the satellite XCO₂ data products obtained from comparisons with ground-based TCCON XCO₂ retrievals. Green numbers indicate that at least the corresponding Threshold (T) user requirement has been met (but not necessarily the more demanding Breakthrough (B) or Goal (G) requirement). Note that the reported errors of the satellite data are relative to TCCON data, which have an uncertainty of approx. 0.4 ppm, and that in addition also the estimated parameters are to some extent uncertain (see main text for details).

Estimates of achieved data quality (all values 1-sigma): CRDP#1 XCH₄ (in ppb)				
Sensor	Algorithm	Random error ("Single measurement precision")	Systematic error ("Relative accuracy")	Comments
SCIAMACHY on ENVISAT	WFMD v3.3 (WFM-DOAS)	86 (*) < Nov. 2005: 30	8 – 16 (*) (RA – SRA)	Details see Section 3: Precision: "Scat" Tab. 3.4.1; Accuracy: "RA-SRA" Tab. 3.4.1. See also Sect. 6.2.1.
SCIAMACHY on ENVISAT	IMAP v.6.0	51 (*) < Nov. 2005: 30	18 – 18 (*)	Details see Section 3: Precision: "Scat" Tab. 3.4.1; Accuracy: "RA-SRA" Tab. 3.4.1. See also /Buchwitz et al., 2013/.
TANSO on GOSAT	OCPR v4.0 (UoL-PR)	14	3 - 4	Details see Section 3: Precision: "Scat" Tab. 3.4.1; Accuracy: "RA-SRA" Tab. 3.4.1
TANSO on GOSAT	SRFP v2.1 (RemoTeC)	14	4 - 6	- " -
Required:	G / B / T	< 9 / 17 / 34	< 1 / 5 / 10	/URD GHG-CCI v1/

Table S-2: Estimated quality of the satellite XCH₄ data products obtained from comparisons with ground-based TCCON XCH₄ retrievals. For details, see caption of **Table S-1**. (*) Note that the SCIAMACHY data quality suffers from detector degradation after October 2005. Green numbers indicate that at least the corresponding Threshold (T) user requirement has been met (but not necessarily the more demanding Breakthrough (B) or Goal (G) requirement). Note that the reported errors of the satellite data are relative to TCCON data, which have an uncertainty of approx. 3.5 ppb, and that in addition also the estimated parameters are to some extent uncertain (see main text for details).

2.2.1.6 Considerations for climate applications

Climate prediction requires a good knowledge on the GHG sources and sinks, in particular CO₂ but also CH₄ and other GHG. The GHG-CCI data products contain information on regional CO₂ and CH₄ surface fluxes (emissions and uptake) and therefore can be used in order to improve our knowledge on GHG surface fluxes (e.g., Alexe et al., 2014, Basu et al., 2013, Chevallier et al., 2014, Guerlet et al., 2013, Schneising et al., 2013, 2014).

The GHG-CCI are also useful to improve climate models (e.g., Hayman et al., 2014, Shindell et al., 2013) and for other applications related to climate such as obtaining wild fire emission ratios (e.g., Ross et al., 2013).

The GHG-CCI CRDP#1 has been assessed by the GHG-CCI Climate Research Group (CRG) and the results are documented in the first version of a document called "Climate Assessment Report" (CAR), which is also available via the GHG-CCI website (link: http://www.esa-ghg-cci.org/index.php?q=webfm_send/153).

2.2.1.7 Instrument Overview

See Sect. 4. For a detailed description of SCIAMACHY see Bovensmann et al., 1999, and for GOSAT see Kuze et al., 2009.

2.2.1.8 References

Data: Datasets are openly available at <http://www.esa-ghg-cci.org/?q=node/106> -> “GHG-CCI Data Products Main Website” (online access after (short) registration; registered users will get an automatically generated e-mail with login information).

Documents: All relevant documents are publicly available via the GHG-CCI website <http://www.esa-ghg-cci.org/> -> “Documents”, e.g., User Requirements Document (URD) and Product Validation and Intercomparison Report (PVIR). Links to product specific documents such as Product User Guide (PUG) and Algorithm Theoretical Baseline Document (ATDB) are given in the product tables on <http://www.esa-ghg-cci.org/?q=node/106> -> “GHG-CCI Data Products Main Website”.

Peer-reviewed publications: An up to date list including links to pdf versions is maintained at <http://www.esa-ghg-cci.org/> -> “Publications”.

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2.2.1.9 Revision History

This document is the first version (v1.0) issued on 20-June-2014 by Michael Buchwitz, IUP, Univ.Bremen, Science Leader of the GHG-CCI project.

2.2.2 ESA CCI Aerosol

2.2.2.1 Intent of the Document

Following datasets are provided from Aerosol_cci after three years of intensive algorithm development, sensitivity analysis, validation and inter-comparison activities (Holzer-Popp, et al., 2013) and a round robin exercise of eight different algorithms (de Leeuw et al, 2013):

- AOD and Ångström exponent (AE)
- Stratospheric extinction profiles and aerosol optical depth
- Absorbing aerosol index (AAI)

AOD / AE datasets are provided for two main purposes: climate aerosol model evaluation, data assimilation into global aerosol re-analysis / forecasting model systems. The stratospheric dataset is provided as correction to the total column AOD retrievals (mostly relevant in case of major volcanic eruptions) and for stratospheric climate model evaluation. The AAI dataset (so far as only information for aerosol absorption, though qualitative) has been prepared for comparison to model datasets by developing a model AAI simulator and analyzing major sensitivities.

2.2.2.2 Point of Contact

Overall contact for Aerosol_cci is: Thomas Holzer-Popp, DLR, thomas.holzer-popp@dlr.de

2.2.2.3 Data Field Description

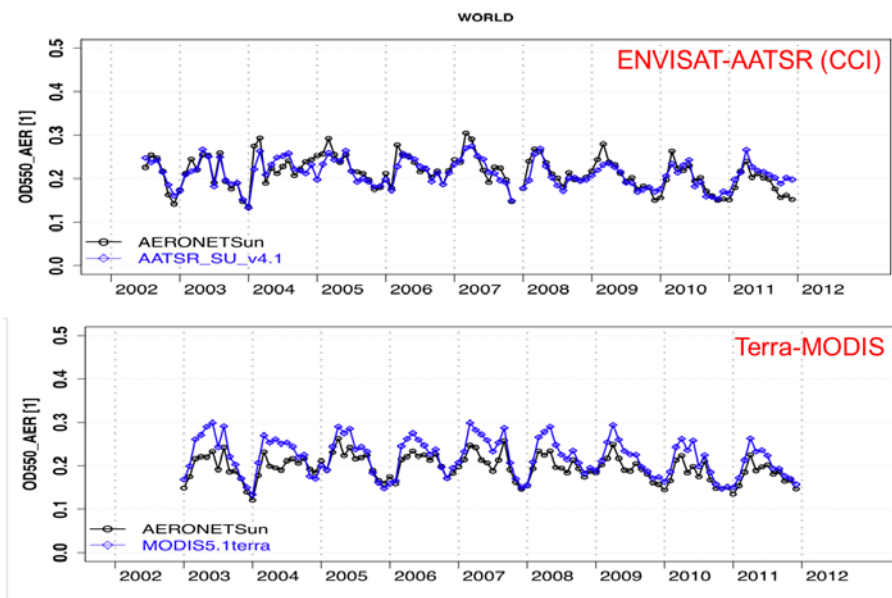
The following table summarizes the main characteristics of the Aerosol_cci mature datasets.

algorithm	version	sensor(s)	responsible provider	Main aerosol parameters	Resolution coverage	period(s)
ADV / ASV	1.42 / 1.43	AATSR ATSR-2	FMI	AOD, AE	10km, 1° global	2007- 2010 2000
ORAC	2.02	AATSR ATSR-2	UOxford / RAL	AOD, aerosol type	10km, 1° global	2008 2000
SU	4.1 4.2	AATSR ATSR-2	USwansea	AOD, AE	10km, 1° global	2002-2012 1995-2002
ALAMO	2.2	MERIS	HYGEOS ICARE	AOD, AE	10km, 1° global ocean	2008
AAI	1.01	OMI	KNMI	AAI	0,25° global	2005, 2008
Star occultation	2.1	GOMOS	BIRA	stratosphere ext. profiles, AOD+AE	10x2,5° global	2008

Further experimental datasets have been produced in preparation for future datasets.

The longest time series from Aerosol_cci currently available is shown (global average) in comparison to AERONET and MODIS-Terra in the following figure. Note that the earlier

part of the time series (1995-2002 from ATSR-2) is currently under evaluation – this is why it is not (yet) shown in this plot.



2.2.2.4 Data Origin

AOD / AE are retrieved from several satellite sensors (ATSR series, MERIS provided from ESA) using dual view (ATSR) or multi-spectral techniques - this accounts for their different information content (e.g. different coverage or angular / spectral sampling). In the case of the ATSR instrument also different algorithms are used, which make different approaches to a smart use of auxiliary / a priori information required for the underlying ill-posed retrieval problem – this allows estimating the uncertainty of the retrieval results. All algorithms have benefited and significantly improved from the round robin exercise and intensive algorithm experiments conducted. For the combined ATSR time series exploiting 2 instruments (ATSR-2 and AATSR) no specific inter-calibration (beyond operational calibration and drift corrections provided by ESA) has been applied. AAI is derived from the OMI instrument (data provided from NASA / KNMI). Stratospheric extinction profiles and stratosphere column integrated AOD and AE are derived by a star occultation method and aggregated to gridded products. All methods are described in the different Algorithm Theoretical Baseline Documents (see references). The datasets are available in sensor projection and as gridded daily / monthly datasets.

2.2.2.5 Validation and Uncertainty Estimate

Validation was conducted by comparing sensor-projection and gridded daily data to external references (AERONET for AOD / AE; NDAAC ground-based lidar for stratospheric profiles). Standard metrics (stdv, bias, linear fit, Pearson correlation) were calculated and a scoring metric was applied which combines evaluation of the bias with temporal and spatial correlations for different regions of the world. Validation was separated for different regions (with limited availability of AERONET data over open oceans and in the Southern

hemisphere) and for land / coast / sea sites. Additionally, inter-comparison to other satellite datasets (MODIS, MISR, SeaWIFS for AOD / AE, CALIOP, OSIRIS for stratospheric AOD) was conducted. The results are described in the Product Validation and Intercomparison Report with its annexes (see references; a publication is in preparation). Validation of the AAI is not possible, since this is not a measurable quantity. All products contain pixel level uncertainties based on error propagation and in some cases parameterizations (using a posteriori validation results). These uncertainties have statistically been compared to true errors against AERONET which showed that absolute uncertainty values are too large in most cases - therefore only using relative uncertainties (across regions, seasons) can be recommended at this point. Harmonization in absolute values of uncertainties is required and is planned for phase 2 of Aerosol_cci (2014-2016). A global overview of the validation results for 2008 / 2000 is given in the following table.

algorithm	version	sensor(s)	responsible provider	parameters	rmse/bias land	rmse/bias ocean
ADV	1.42	AATSR	FMI	AOD	0.09 / -0.02	0.10 / + 0.04
	1.43	ATSR-2			0.15 / - 0.06	0.13 / + 0.04
ORAC	2.02	AATSR	UOxford / RAL		0.10 / + 0.01	0.14 / + 0.07
		ATSR-2			0.19 / + 0.10	0.19 / + 0.08
SU	4.1	AATSR	USwansea		0.14 / 0.00	0.08 / + 0.01
	4.2	ATSR-2			0.17 / 0.00	0.11 / - 0.01
ALAMO	2.2	MERIS	HYGEOS / ICARE		-	0.10 / + 0.03
Star occultation	2.1	GOMOS	BIRA	stratospheric AOD	< 10 – 25% (depending on altitude)	

2.2.2.6 Considerations for climate applications

Validation of AOD showed good accuracy. Validation of the Ångström exponent showed much weaker performance, so that its use cannot (yet) be recommended. The overlap between the ATSR-2 and AATSR datasets in 2002 / 2003 has not (yet) been assessed.

All AOD algorithms use a common definition of 4 basic aerosol components (fine mode extremes of weak and strong absorption, sea salt and mineral dust [de Leeuw et al, 2013]) externally mixed following each algorithm's strategy.

The consistency of the cloud masks used in Aerosol_cci against Cloud_cci (AATSR AOD) was assessed showing that the fraction of mutually inconsistent pixels is smaller than 1% (analyzed erroneously as at the same time fully cloudy and fully cloud-free) and that the fraction of neglected pixels is about 20% (containing twilight zone of mixed cases, but also missed pixels for safety from cloud contamination).

Additional aerosol (e.g. mixing fractions between the 4 components, non-spherical AOD fraction, effective radius, aerosol altitude) and diagnostic (e.g. cloud, surface fit quality) parameters are contained in the product files, but have not been validated and are therefore not listed.

AAI has major sensitivities to aerosol layer height, cloud contamination and surface albedo. All products implement the technical requirements (format, grid, open access) from the Aerosol_cci User Requirements Document. Requirements for content and accuracy are fulfilled as far as possible (e.g. fine mode AOD has not yet been evaluated).

Major user feedback received summarizes utility and limitations of the products:

The systematic harmonized storage and public availability of Aerosol_cci products will facilitate usage. Level 2 and level 3 data are available in a consistent manner. Documentation is still a little bit scattered (note: this was optimized afterwards, so that the documentation and its availability at the Aerosol_cci website has improved). Reference papers have been produced in peer-reviewed literature open-access journals, which contain the most essential information.

The satellite aerosol dataset from AATSR (2002-2012) provides a new interesting benchmark dataset for the evaluation of climate models AOD. Spatio-temporal coverage of the AATSR dataset is at best half of what one obtains with current MODIS retrievals. That should not prevent too much the utility of ATSR for deriving global AOD fields given the excellent low bias to Aeronet. However, the impact of smaller coverage on global bias and uncertainty requires further research. While the AATSR record from 2002-2012 shows to be a rather reliable source of information for multi-annual trends, its prolongation into earlier ATSR-2 data is promising if the quality can be shown to resemble that of the latter period. A first comparative evaluation of the year 2000 (ATSR) and 2008 (AATSR), using the FMI (ADV) retrieval results, show somewhat larger errors (at less available reference measurements) against Aeronet.

The long term 2002-2012 ATSR bias against Aeronet has been established regionally, and on average ranges from -17% (East Asia) to +5% (N-America), which is judged as being rather small. ATSR AOD errors are convincingly documented for instance via the PVIR.

Whereas AATSR with its swath width of 512 km offers limited coverage (global every ~6 days), the MERIS instrument with 1150 km swath width has potential for better coverage (every ~3 days). However, we can only recommend use of MERIS ALAMO datasets over ocean, but currently none of the MERIS products tested over land.

Stratospheric AOD established based on GOMOS appears to be useful for evaluating models and other retrievals in particular in combination with CALIOP. The scarcity of data in the stratosphere makes the new data addition very valuable.

In general the independent nature of the Aerosol_cci products make them a valuable addition to the currently available suite of satellite data sets used for model evaluation. An important step has also been made to make the aerosol absorption index accessible for model evaluation through a simulator.

2.2.2.7 Instrument Overview

The Aerosol_cci datasets are derived from polar orbiting satellite instruments in the UV/VIS spectral range with the addition of thermal spectral bands for cloud masking. Retrieval algorithms use a priori information on aerosol type from an AEROCOM (model) / AERONET (ground-based sun photometer) annual mean climatology (prepared by Stefan Kinne, summarized in Holzer-Popp, et al., 2013). More detail to the methodology is summarized in section 4.

2.2.2.8 References

Datasets are openly available at <http://www.icare.univ-lille1.fr/archive/?dir=CCI-Aerosols> (unrestricted online access: account: cci; password: cci)

Analysis of datasets is openly available at the AEROCOM website aerocom.met.no/cgi-bin/aerocom.

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All relevant documentation is publicly available at the project website <http://www.esa-aerosol-cci.org/>. In particular the following reference documents are provided:

- User requirements document: http://www.esa-aerosol-cci.org/?q=webfm_send/482
- Archive of ATBDs: http://www.esa-aerosol-cci.org/?q=webfm_send/512 and http://www.esa-aerosol-cci.org/?q=webfm_send/511
- Uncertainty characterisation report: http://www.esa-aerosol-cci.org/?q=webfm_send/536
- Product validation and intercomparison report: http://www.esa-aerosol-cci.org/?q=webfm_send/535 (with appendices contained in http://www.esa-aerosol-cci.org/?q=webfm_send/539 and http://www.esa-aerosol-cci.org/?q=webfm_send/540)
- a (draft) report on analysis of the consistency of cloud masks between Aerosol_cci and Cloud_cci: http://www.esa-aerosol-cci.org/?q=webfm_send/507
- Product user guide: http://www.esa-aerosol-cci.org/?q=webfm_send/534 (with appendices contained in http://www.esa-aerosol-cci.org/?q=webfm_send/537 and http://www.esa-aerosol-cci.org/?q=webfm_send/538)
- Climate Assessment Report: http://www.esa-aerosol-cci.org/?q=webfm_send/542
- User requirements update form: http://www.esa-aerosol-cci.org/?q=webfm_send/224

2.2.2.9 Revision History

This document provides a first updated version 1.1 issued on 27/06/2014 by Thomas Holzer-Popp.

2.2.3 EUMETSAT ROM SAF GNSS-RO DATA

2.2.3.1 Intent of the document

This document describes the ROM SAF monthly climate data products publically available in the ROM SAF archives (<http://www.romsaf.org>). The data cover the troposphere and the lower and middle stratosphere, and are primarily intended for global climate monitoring and climate research applications, including model validation. The intent of the present document is to provide a brief description of the data for use in the CORE-CLIMAX Climate Data Record (CDR) assessment.

2.2.3.2 Point of contact

Hans Gleisner, Danish Meteorological Institute, Lyngbyvej 100, Copenhagen, Denmark.
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URL: <http://www.romsaf.org>

2.2.3.3 Data Field Description

Radio Occultation (RO) is a measurement technique that derives vertical profiles of the refractive index (or, refractivity) of the atmosphere from the observed bending of radio waves emitted by GPS satellites (see Sections 4 and 7). Hence, the climate variables include not only the common meteorological variables, but also bending angle and refractivity:

- ^{1.}
 - Bending angle (radians)
 - Refractivity (N-units)
 - Temperature (K)
 - Geopotential height (gpm)
 - Specific humidity (g/kg)
 - Dry temperature (K)
 - Dry pressure (hPa)

^{2.} The climate variables are provided as zonal monthly means on 2D latitude-height grids with a nominal resolution of 5 degrees by 200 meters [1]. Zonal averaging means there is no longitudinal dimension. The type of vertical grid (impact altitude, mean-sea level altitude, or pressure height) depends on the variable. The impact altitude and the mean-sea level altitude are referenced to the Earth's geoid, while the pressure height is simply a logarithmic measure of pressure.

The ROM SAF provides two types of climate data records: *offline* climate data (Table 1) and *reprocessed* climate data (Table 2). The offline climate data are suitable for climate monitoring applications, while the reprocessed climate data provide a homogeneous data set suitable for climate research applications.

Core-Climax Climate Data Record Capacity Assessment Descriptions

Detailed data product specifications are found at: http://www.romsaf.org/product_archive.php

Climate data record	Unit	Time resol.	Lat-Height resolution	Length of record	Horizontal coverage	Vertical coverage	Mission
GRM-17: bending angle	radians	month	5° x 200 m	2006/09 – present	90°S–90°N	0-40 km	COSMIC
GRM-18: refractivity	N-units	month	5° x 200 m	2006/09 – present	90°S–90°N	0-40 km	COSMIC
GRM-19: temperature	K	month	5° x 200 m	2006/09 – present	90°S–90°N	0-40 km	COSMIC
GRM-20: humidity	g/kg	month	5° x 200 m	2006/09 – present	90°S–90°N	0-12 km	COSMIC
GRM-21: geopot. height	m	month	5° x 200 m	2006/09 – present	90°S–90°N	0-40 km	COSMIC
GRM-22: dry temperature	K	month	5° x 200 m	2006/09 – present	90°S–90°N	0-40 km	COSMIC
GRM-23: dry pressure	hPa	month	5° x 200 m	2006/09 – present	90°S–90°N	0-40 km	COSMIC

Table 1. Overview of ROM SAF offline climate data records (used for continuous climate monitoring), showing temporal and spatial resolution, length of data records, and spatial coverage.

Climate data record	Unit	Time resol.	Lat-Height resolution	Length of record	Horizontal coverage	Vertical coverage	Mission
GRM-28, GRM-29: <i>bending angle, refractivity, temperature, humidity*, geopot. height, dry temperature, dry pressure</i>	radians N-units K g/kg m K hPa	month	5° x 200 m	2007/06 – 2013/12	90°S–90°N	0-40 km *0-12 km	Metop-A Metop-B
GRM-30: <i>bending angle, refractivity, temperature, humidity*, geopot. height, dry temperature, dry pressure</i>	radians N-units K g/kg m K hPa	month	5° x 200 m	2006/09 – 2013/12	90°S–90°N	0-40 km *0-12 km	COSMIC
GRM-32: <i>bending angle, refractivity, temperature, humidity*, geopot. height, dry temperature, dry pressure</i>	radians N-units K g/kg m K hPa	month	5° x 200 m	2001/08 – 2008/09	90°S–90°N	0-40 km *0-12 km	CHAMP
GRM-33: <i>bending angle, refractivity, temperature, humidity*, geopot. height, dry temperature, dry pressure</i>	radians N-units K g/kg m K hPa	month	5° x 200 m	2007/03 – 2013/12	90°S–90°N	0-40 km *0-12 km	GRACE-A

Table 2. Overview of ROM SAF reprocessed climate data records (homogenized data records suitable for scientific studies), showing temporal and spatial resolution, length of data records, and spatial coverage.

2.2.3.4 Data origin

The monthly climate data products are computed from the *bending angles* and from the vertical profiles of *refractivity*, *temperature*, *pressure*, and *specific humidity* that are obtained from the *excess phase* of radio signals travelling through the atmosphere along horizontal paths (see Fig 1) [2]. The two GPS radio frequencies (L1 and L2) received by an RO instrument onboard a LEO satellite are characterised by their amplitude and phase values. The bending angle profiles are obtained using the positions and velocities of the GPS and LEO satellites. The raw bending angle profiles are first subject to a correction in order to eliminate the effect of the ionosphere on the signals. In the case of single ray propagation the phase contains all the necessary information in order to derive the bending angle, whereas in the case of multiple ray propagation (multipath), caused by strong vertical gradients in the atmosphere, both the amplitude and the phase are needed to obtain a bending angle profile free of multipath artifacts.

The observed, raw bending angles undergo *ionospheric correction* and *statistical optimization*, whereby the observed data are smoothed and merged with an MSIS-90 profile mapped to bending angle space. A refractivity profile is then obtained through an inversion using the Abel transform. To retrieve the ROM SAF products temperature, pressure and humidity, ancillary data are needed. These data are obtained from ECMWF forecasts, appropriate to the time and location of the occultation. In combination with the observed refractivity, the ECMWF background is used in a 1D-Var algorithm to simultaneously estimate the temperature, humidity and pressure profiles, together with surface pressure. The solution is constrained by the assumption that the atmosphere is in hydrostatic equilibrium. Note that unique humidity profiles cannot be obtained from radio occultation measurements without using some source of ancillary information on temperature.

The starting point for the ROM SAF climate processing is thus vertical profiles of *bending angle* (α) as a function of *impact parameter*, microwave *refractivity* (N) as a function of *mean-sea level altitude* (H ; geometric height above the geoid), and *temperature* (T), *pressure* (p), and *specific humidity* (q) as functions of mean-sea level altitude, H . The *geopotential height* (Z) as a function of pressure or *pressure height* (H_p) is an alternative formulation of the pressure profile. The bending angles and the refractivities are provided on relatively dense vertical grids reaching up to altitudes around 100 km. i.e. above the region where the RO technique provides useful information on the neutral atmosphere. The temperature, pressure, and specific-humidity profiles are given on a standard set of ECMWF model levels ranging from the surface up to around 80 km.

The monthly mean climate data are generated from these RO atmospheric profiles through rather straight-forward *binning and averaging* [3]. A set of equal-angle latitudinal bands, or grid boxes, are defined and all valid, quality controlled observations that fall within a latitude

band and calendar month undergo a weighted averaging to form a zonal mean for that latitude and month. The weighting is done by dividing each latitudinal grid box into two sub-grid boxes, average into each of these, and by computing the mean of the two averages. This is done to more closely approximate an area-weighted average.

2.2.3.5 VALIDATION AND UNCERTAINTY ESTIMATE

The quality of the zonal monthly means is indicated by the estimated errors delivered as a part of the ROM SAF climate data products. The validation report related to climate data provides an in-depth discussion on how the data were validated, and tabulates the formal requirements that are met by the data products [4].

As a part of the operational climate processing, the observational uncertainty and the sampling error associated with the monthly means are estimated. Detailed descriptions of these estimates and the underlying assumptions are found in [2].

The sampling errors are estimated from sampling an ECMWF analysis field at the nominal time and locations of the observations. A weighted average is generated from the sampled ECMWF data and the difference to the true mean, obtained from averaging the full grid, provides an estimate of the sampling error.

As described in the ATBD [2], the two errors – observational and sampling – are independent and can be formally combined into a total error in a *root-mean-square* sense. Both errors show a considerable variation with latitude and height, reflecting variations in data numbers, in the atmospheric variability, and in the observational noise levels. In general, the sampling errors are roughly an order of magnitude larger than the observational errors.

2.2.3.6 CONSIDERATIONS FOR CLIMATE APPLICATIONS

RO climate data exhibit properties that make them ideally suited to climate applications: all weather capability, calibration free operation, high accuracy, and high vertical resolution. Unlike techniques based on radiance measurements, it is expected to have an excellent intrinsic long-term stability. Some of the limitations include: low horizontal resolution (~300 km), short time series (“operational” measurements started in 2001), lower spatial sampling than some other remote-sensing techniques (global data numbers from ~200 per day in 2001, increasing to ~3000 per day after 2006).

2.2.3.7 INSTRUMENT OVERVIEW

The RO technique is based on highly accurate GPS (or more generally, GNSS) satellite-borne receivers. The RO instruments operate in a limb-sounding geometry whereby radio signals emitted from the GPS satellites, orbiting some 20,000 km above the Earth surface, are received by a satellite in low-Earth orbit (LEO), e.g. the GRAS instrument onboard the Metop satellites. The GPS radio signals scan the atmosphere until they are occulted by the Earth (setting occultation) or from the moment they appear behind the Earth (rising

occultation). During this scan, the amplitude and the phase delay as a function of time are measured.

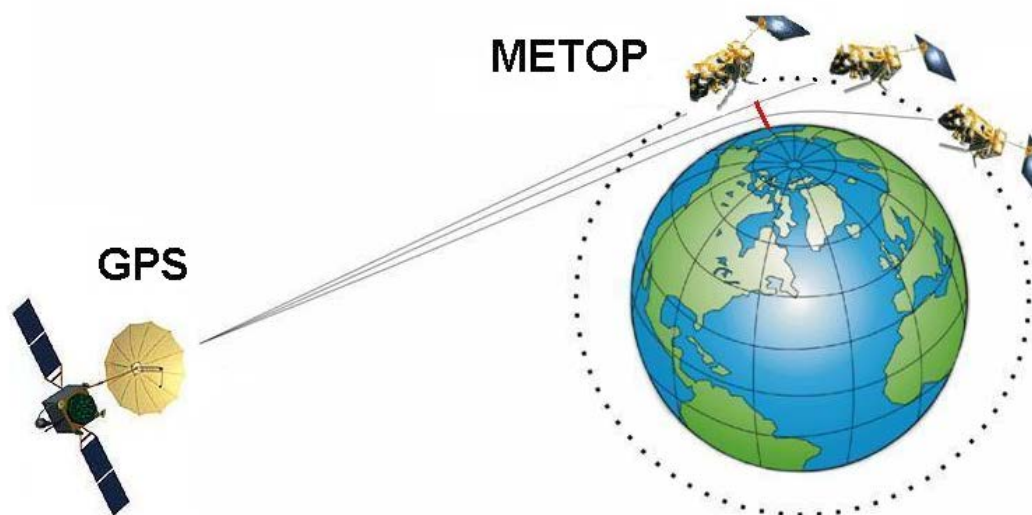


Figure 1. Schematic representation of the RO observing geometry during an occultation. It is shown how the GRAS instrument onboard Metop receives radio signals from a GPS satellite.

The main characteristics of the RO measurements are consequences of the operating frequencies of the radio waves (microwaves in the L-band, 1 to 2 GHz), the limb sounding geometry, and the fact that it is based on measuring time differences rather than radiances (in the form of phase delays). Hence, the main characteristics are: all weather capability, calibration free operation, high accuracy, and high vertical resolution. The fact that we measure time differences is important for climate applications – it removes the need for inter-satellite calibration and provides an excellent long-term stability of the data records.

2.2.3.8 REFERENCES

- [1] ROM SAF Product User Manual: Offline Level 3 Climate Data, Ref: SAF/ROM/DMI/UG/CLM/001.
- [2] ROM SAF ATBD: Climate algorithms, SAF/ROM/DMI/ALG/CLM/001.
- [3] Gleisner, H., Latitudinal binning and area-weighted averaging of irregularly distributed radio occultation data, GRAS SAF Report 10, 2010.
- [4] ROM SAF Validation Report: Offline Level 3 Climate Data, GRM-17, 18, 19, 20, 21, Ref: SAF/ROM/DMI/REP/CLM/001.
- [5] ROM SAF ATBD: 1DVAR algorithms, Ref: SAF/ROM/DMI/ALG/1DV/002.

2.2.3.9 REVISION

HISTORY

Version	Date	By	Description
ver 0.1	10/1 2014	Hans Gleisner	1 st draft for the self assessment.
Ver 0.2	15/1 2014	Hans Gleisner	Updated draft for the self assessment.

2.2.4 EUMETSAT CM SAF FTH Edition 1.0

2.2.4.1 Intent of the Document

This document summarizes essential information needed for users of any level who wish to use the Free Tropospheric Humidity (FTH) data set for climate applications and climate service.

doi: 10.5676/EUM_SAF_CM/FTH_METEOSAT/V001

2.2.4.2 Point of Contact

Satellite-Application Facility for Climate Monitoring

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Offenbach, Germany

Email: contact.cmsaf@dwd.de

2.2.4.3 Data Field Description

Information on technical specifications, the retrieval, the limitations, the file name convention and the data file contents such as variable names and units are given in the CM SAF Product User Manual, available at

http://www.cmsaf.eu/bvbw/generator/CMSAF/Content/Publication/SAF_CM_DWD_PUM_FTH_1.1,templateId=raw,property=publicationFile.pdf/SAF_CM_DWD_PUM_FTH_1.pdf.

2.2.4.4 Data Origin

The CM SAF Free Tropospheric Humidity (FTH) data set from METEOSAT2-5 and METEOSAT7-9 provides the mean relative humidity over a deep layer of the troposphere within $\pm 45^\circ$ longitude and $\pm 45^\circ$ latitude. The retrieval was developed at Centre National de la Recherche Scientifique (CNRS) and is similar to the retrieval described in Soden and Bretherton (1996). In contrast to Soden and Bretherton (1996) the Jacobian with respect to relative humidity is applied during the training of the statistical retrieval and during validation. After transfer to CM SAF, CM SAF and CNRS jointly extended the time series into the SEVIRI era. The brightness temperatures and the cloud information are taken from ISCCP-DX (Rossow and Schiffer, 1999), except for SEVIRI observations after December 2005 which are taken from DWD archive. Temperature profiles from ECMWF are used to slightly improve the performance of the inversion. Homogenisation and inter-calibration is described in Brogniez et al. (2006) and Picon et al. (2003). The product is defined under clear sky and low level cloud conditions and is available at 3-hourly temporal resolution and as monthly averages (straightforward averages over all valid observations) on a regular latitude/longitude grid with a spatial resolution of $0.625^\circ \times 0.625^\circ$. The temporal coverage of the data sets ranges from July 1983 to December 2009. The METEOSAT6 period, March

1997-May 1998, is not covered. The FTH layer position and thickness depends on atmospheric condition, in particular water vapour content in the free troposphere. The clear sky radiance is provided as auxiliary information layer.

2.2.4.5 Validation and Uncertainty Estimate

The FTH data set has been compared against in-situ and two independent satellite data records, namely UTH from HIRS (Shi and Bates, 2011) and from AMSU-B (Bühler et al., 2008). A comprehensive validation report is available from

http://www.cmsaf.eu/bvbw/generator/CMSAF/Content/Publication/pdf/SAF_CM_DWD_VAL_FTH_1.2,templateId=raw,property=publicationFile.pdf/SAF_CM_DWD_VAL_FTH_1.pdf.

The quality can be summarised as follows: bias=-3.2%, RMSD=16.8% and stability 0.5%±0.45%.

2.2.4.6 Considerations for climate applications

The validation of the FTH product exhibited an increase in bias between summer 1988 and summer 1990 and a maximum in bias in January 1996, with generally spurious biases in 1996. Therefore and though significant efforts have been dedicated to the homogenisation of the METEOSAT time series, the quality of the FTH retrieval would benefit from a recalibrated and inter-calibrated FCDR of METEOSAT. The recovery of METEOSAT 6 data would close data gaps in the time series.

The identification of clear sky and low level clouds relies on ISCCP-DX data, and the FTH quality depends on the cloud classification quality. Strongest quality degradation can be expected when high level clouds are not correctly identified. For data until February 1997 coastal areas exhibit spurious quality due to issues in cloud detection.

It could be shown that the quality of the retrieval decreases when applied to observations in mid-latitudes. Therefore, the application of the retrieval is restricted to the tropics, i.e., to an area within ±45°N/S and ±45°E/W.

The retrieval is not reliable over elevated terrain with surface pressures less than 700 hPa because the weighting function might reach the surface.

2.2.4.7 Instrument Overview

The Meteosat Visible and Infrared Imager (MVIRI) is a three channel imaging radiometer flown consecutively on Meteosat-2 to Meteosat-7 from the first generation of Meteosat satellites. It observes the Earth from a geostationary orbit at 0° latitude orbit every 30 minutes between 1982 and 2006. The spatial sampling distance of the observations is approximately 5 km at nadir and increases with distance from sub-satellite point.

The Spinning Enhanced Visible and Infrared Imager (SEVIRI) carries out observations at 12 channels which cover the visible and thermal infrared spectral wavelength range. SEVIRI is on board Meteosat-8 and -9 (Meteosat second generation), which is a geostationary satellite at 0° latitude. SEVIRI full disc observations are repeated every 15 minutes between 2004 and

present. The spatial sampling distance of brightness temperature (BT) observations is 3 km, again increasing with distance from sub-satellite point.

The inversion is based on the water vapour channel located at 6.3 microns.

2.2.4.8 References

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Shi, L., and J. J. Bates (2011), Three decades of intersatellite-calibrated High-Resolution Infrared Radiation Sounder upper tropospheric water vapor, J. Geophys. Res., 116, D04108, doi:10.1029/2010JD014847.
Soden, B. and F. Bretherton, Interpretation of TOVS water vapor radiances in terms of layer-average relative humidities: method and climatology for the upper, middle and lower troposphere, J. Geophys. Res., 101, 9333-9343, 1996.

2.2.4.9 Revision History

First issue: version 1.0, 10 January 2014

2.2.5 EUMETSAT CM SAF HOAPS release 3.2

2.2.5.1 Intent of the Document

This document summarizes essential information needed for users of any level who wish to use the Hamburg Ocean Atmosphere Parameters and Fluxes from Satellite (HOAPS) data set for climate applications and climate service.

2.2.5.2 Point of Contact

Satellite-Application Facility for Climate Monitoring
Deutscher Wetterdienst
Frankfurter Straße 135
60594 Offenbach, Germany

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2.2.5.3 Data Field Description

Information on technical specifications, the retrieval, the limitations, the file name convention and the data file contents such as variable names and units are given in the CM SAF Product User Manual, available at

http://www.cmsaf.eu/bvbw/generator/CMSAF/Content/Publication/SAF_CM_DWD_PUM_HOAPS_1_1,templateId=raw,property=publicationFile.pdf/SAF_CM_DWD_PUM_HOAPS_1_1.pdf.

With the Digital Object Identifier: 10.5676/EUM_SAF_CM/HOAPS/V001.

2.2.5.4 Data Origin

The Hamburg Ocean Atmosphere Parameters and Fluxes from Satellite (HOAPS) data set is a satellite-based climatology of precipitation, evaporation, freshwater budget (evaporation minus precipitation), related turbulent heat fluxes and atmospheric state variables as well as liquid water path and total column water vapour over the global ice free oceans. All variables are derived from SSM/I passive microwave radiometers on-board the Defense Meteorological Satellite Program (DMSP) satellites, except for the SST, which is taken from AVHRR measurements. All retrievals are of statistical nature and model independent and are described in Schlüssel and Emery (1990), Bauer and Schlüssel (1993), and Andersson et al. (2010). Figure 2 in Andersson et al. (2010) shows temporal coverage and equator crossing time of the individual DMSP satellite. The data set includes multi-satellite averages, inter-sensor calibration, and an efficient sea ice detection procedure. All HOAPS products are defined over the ice-free ocean surface. The products are available as monthly averages and 6-hourly composites on a regular latitude/longitude grid with a spatial resolution of 0.5° x 0.5° degrees.

2.2.5.5 Validation and Uncertainty Estimate

The HOAPS products have been compared against various satellite, in-situ and reanalysis data (Andersson et al., 2010 and Schröder et al., 2013). A comprehensive validation report is available from

http://www.cmsaf.eu/bvbw/generator/CMSAF/Content/Publication/pdf/SAF_CM_DWD_VAL_HOAPS_1_1,templateId=raw,property=publicationFile.pdf/SAF_CM_DWD_VAL_HOAPS_1_1.pdf. A summary is given in Table 5-1.

Integrated total water path has not been intensively validated yet.

Table 0-1: Overview of achieved accuracy.

Product Name	Achieved accuracy
Vertically integrated water vapour	Bias: 0.5 kg/m ² RMSD: 2 kg/m ² stability: 0.05%/dec
Near surface specific humidity	Bias: -0.4 g/kg RMSD: 0.1 g/kg stability: -0.1%/dec
Near surface wind speed	Bias: 0.24 m/s RMSD: 0.15 m/s stability: 0.09 m/s/dec
Latent heat flux	Bias: 1 W/m ² RMSD: 3.7 W/m ² stability: 2.7 W/m ² /dec
Precipitation	Bias: 0.12 mm/d RMSD: 0.14 mm/d stability: -0.01 mm/d/dec
Evaporation	Bias: 0.04 mm/d RMSD: 0.13 mm/d stability: 0.09 mm/d/dec
Freshwater flux	Bias: 0.4 mm/d RMSD: 0.2 mm/d stability: 0.1 mm/d/dec

2.2.5.6 Considerations for climate applications

The HOAPS retrieval results are not valid over land surfaces and ice covered regions. Thus all HOAPS products are restricted to ice-free oceanic conditions. This results in temporally varying sampling density in the polar regions, where the retrieval is only possible during ice-free summer months.

The number of DMSP satellite platforms available throughout the years covered by the data set varies between 1 and 3. The first months of the data set are derived from only on one

satellite, which leads to a greater uncertainty in the mean fields due to the insufficient sampling.

The sun synchronous orbit of the DMSP satellites does not allow resolving a detailed diurnal cycle of a parameter. Hence, systematic biases may occur in regions where a parameter exhibits a strong, non-sinusoidal, diurnal cycle dependency.

The training data base may not be sufficient to fully represent the extremes of the true atmospheric variability.

2.2.5.7 Instrument Overview

SSM/I sensors have been carried aboard the DMSP satellite series since 1987. Up to three radiometers have been in orbit simultaneously. An extensive description of the instrument and satellite characteristics has been published by Hollinger et al. (1990) and Wentz (1991). The DMSP satellites fly in a near-circular, sun-synchronous orbit, with an inclination of 98.8° at an approximate altitude of 860 km. The Earth's surface is sampled with a conical scan at a constant local zenith angle of 53.1° and a 1400 km wide swath. A nearly complete coverage of the Earth by one SSM/I is achieved within two to three days. Due to the orbit inclination and swath width, the regions poleward of 87.5° are not covered. To date, six SSM/I instruments have been successfully launched aboard the F08, F10, F11, F13, F14 and F15 spacecraft. All satellites have a local equator crossing time between 5 and 10 A.M./P.M. for the descending/ascending node. The F08 had a reversed orbit with the ascending node in the morning. Also, the Earth observing portion of the scan on this satellite is, differently from the others, centred to the aft. Most of the DMSP satellites have a very stable orbit. The temporal variation of the equator crossing times is less than three hours for all satellites. At the end of the time period the orbits of F14 and F15 begin to decay noticeably, but are still within 2-3 hours of original time.

The SSM/I is a seven channel total power radiometer measuring emitted microwave radiation at four frequency intervals centred at 19.35, 22.235, 37.0, and 85.5 GHz. All frequencies are sampled at horizontal and vertical polarization, except for the 22.235 GHz channel, which measures only vertically polarized radiation.

The spatial resolution varies from 69 km by 43 km with a sampling frequency of 25 km for the 19 GHz channel to 15 km by 13 km with 12.5 km sampling frequency for the 85 GHz channel. The 85 GHz channels are sampled for each rotation of the instrument (A and B-scans) with a resolution of 128 uniformly spaced pixels, while the remaining channels are sampled every other scan (A-scans) with a resolution of 64 pixels. A fixed cold space reflector and a reference black body hot load are used for continuous onboard two point calibration.

2.2.5.8 References

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2.2.5.9 Revision History

First issue: version 1.0, 10 January 2014

2.2.6 EUMETSAT CM SAF Heliosat Surface Radiation

2.2.6.1 Intent of the Document

This document summarizes essential information needed for users of any level who wish to use the CM SAF Surface Radiation MVIRI Data Set for climate applications. The CM SAF Surface Radiation MVIRI Data Set is a satellite-based climatology of the surface irradiance, the surface direct irradiance and the effective cloud albedo derived from satellite-observations from the visible channel of the MVIRI instruments onboard the geostationary Meteosat satellites.

2.2.6.2 Point of Contact

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2.2.6.3 Data Field Description

The MVIRI instrument onboard the Meteosat First Generation satellites is a passive imaging radiometer with three spectral channels: a visible channel covering 500-900 nm, and infra-red channels covering 5.7-7.1 microns and 10.5-12.5 microns. MVIRI comes with a spatial resolution of 2.5km for the visible and 5km for the IR channels, sub-satellite point respectively. The Meteosat processing provides climate data sets of effective cloud albedo, solar surface irradiance and direct irradiance. The applied method, i.e., MAGIC SOL described in detail in the Algorithm Theoretical Baseline document (SAF/CM/DWD/ATBD/MVIRI_HEL), provides also information on the clear sky reflection which can be used to derive the surface albedo and the surface solar net budget. These records enable the calculation of the surface shortwave net radiation budget. The effective cloud albedo, the solar surface irradiance and the direct irradiance are available on a regular 0.03x0.03 degree grid. The spatial coverage covers the Meteosat disk up to a scanning angle of 70° (Figure 1). The data sets are available as hourly, daily and monthly means. All MAGIC SOL data sets are introduced in Table 1 with associated acronyms and units.

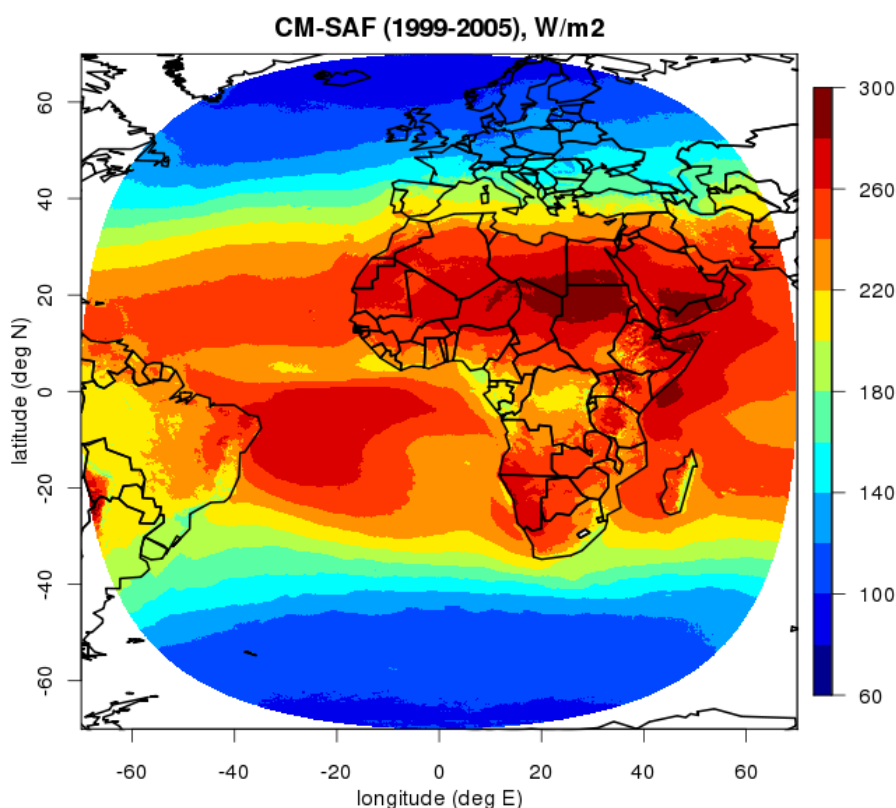


Figure 1: Area coverage for CM SAF Meteosat climate data sets, illustrated here for SIS.

Table 1: Overview of MVIRI based data sets retrieved with MAGIC SOL.

Acronym	Product title	Unit
SIS	Surface Incoming Shortwave Irradiance	W m ⁻²
CAL	Effective Cloud Albedo	Dimensionless
SID	Direct Irradiance at surface	W m ⁻²

2.2.6.4 Data Origin

The processing of the MVIRI data is done in satellite projection. The results are transferred to the regular latitude-longitude-grid using climate data operators (cdo, <https://code.zmaw.de/projects/cdo>). For the retrieval of the effective cloud albedo, the Heliosat algorithm is used (Hammer et al., 2003). The original version of the Heliosat method has been modified to generate a data set that meets climate quality. The effective cloud albedo derived with the modified Heliosat version is used in combination with the clear-sky surface radiation model MAGIC (Mueller et al., 2009) to derive the surface radiation products from the geostationary Meteosat satellites number 2 to 7. The complete model (cloud and clear sky) is called MAGIC SOL and described in more detail in the CM-SAF ATBD (SAF/CM/DWD/ATBD/MVIRI_HEL).

The Heliosat method does not require calibrated radiances as input, but is directly based on image counts. To consider the aging of the satellite instruments and the transitions between the satellites of the Meteosat series a self-calibration method has been developed and applied. The self-calibration method overcomes the need for well calibrated radiances, which are not

available for Meteosat First Generation. The MAGIC SOL algorithm uses the satellite image information in order to retrieve the effective cloud albedo. From the Heliosat algorithm the effective cloud albedo is derived. Together with information about the atmospheric clear sky state (water vapour, aerosols, ozone) the effective cloud albedo is used as input for the MAGIC method to calculate the direct irradiance and the solar surface irradiance.

2.2.6.5 Validation and Uncertainty Estimate

The solar irradiance (SIS = Surface Incoming Solar radiation) and the direct irradiance (SID = Surface Incoming Direct radiation) derived from the Meteosat first generation satellites (Meteosat 2 to 7, 1982-2005) have been validated using ground based observations from the Baseline Surface Radiation Network (BSRN) as a reference. The validation target values for the mean absolute difference between satellite-derived and surface-measured radiation is defined by the target accuracy for monthly/daily means of 10/20 W/m² for SIS and 15/25 W/m² for SID plus an uncertainty of the ground based measurements of 5 W/m².

The mean absolute differences of the monthly mean surface incoming solar (SIS) and surface incoming direct radiation (SID) are 7.8 W/m² and 11.0 W/m², respectively, i.e., well below the respective targets of 15 and 25 W/m² for all sites. Moreover, nearly 90 % and about 85 % of the monthly mean absolute difference values of surface solar and direct irradiance are below the target values.

The daily mean data of the surface incoming solar radiation (global irradiance) have a mean absolute difference of 15 W/m², which is below the target value of 20 W/m². The mean absolute difference of the daily mean direct irradiance (SID) is 21 W/m², i.e. smaller than the target value of 30 W/m².

2.2.6.6 Considerations for climate applications

The target accuracy is achieved for monthly and daily means. No trends in the bias are detectable, demonstrating the stability and homogeneity of the surface incoming solar radiation and the surface incoming direct radiation products. For the effective cloud albedo the accuracy is derived from the SIS accuracy. The target value of 0.1 is reached with exception of the winter period for latitudes above 55 degree, where higher uncertainties might occur. Low monthly/daily mean clear sky irradiance (<70/100 W/m²) usually occur during wintertime above a latitude of +/-55°. The target accuracy might not be reached for these regions and period. More over, for slant geometries (border of Heliosat coverage) it is expected that the target accuracy is not met and even higher uncertainties might occur. Higher uncertainties might also occur for snow covered regions.

In general for SIS, SID and CAL higher uncertainties are expected over regions with long lasting snow cover and desert regions with (bright) sand surface. For SID, higher uncertainties are also expected in regions with high variation in aerosol properties.

2.2.6.7 Research Applications

- Polytechnic University of Bucharest, Bucharest, Romania
- ETH Zurich, Institute of Environmental Engineering

- Institut für Atmosphäre und Umwelt, Goethe-Universität, Frankfurt am Main, Germany
- Institute for Atmospheric and Climate Science, ETH Zurich, Zurich, Switzerland
- UCAR Climate Data Guide

2.2.6.8 Decision Support Applications

- PV-GIS, Joint Research Centre, Ispra, Italy
- Meteonorm, Meteotest, Bern, Switzerland
- ARPA Lombardia Weather Service, Milan, Italy
- Solar Radiation Atlas of Spain, Spanish Meteorological Agency, Madrid, Spain
- EU MARS Crop Yield Forecasting System, Joint Research Centre, Ispra, Italy
- Solar Resource Assessment in Benelux, Royal Meteorological Institute of Belgium, Brussels, Belgium
- Climate Suitability Maps for Agriculture, Agroscope, Zürich, Switzerland

2.2.6.9 Instrument Overview

The MVIRI instrument onboard the Meteosat First Generation satellites is a passive imaging radiometer with three spectral channels: a visible channel covering 500-900 nm, and infra-red channels covering 5.7-7.1 microns and 10.5-12.5 microns. MVIRI comes with a spatial resolution of 2.5km for the visible and 5km for the IR channels, sub-satellite point respectively. The second generation of Meteosat satellites is equipped with the Spinning Enhanced Visible and InfraRed Imager (SEVIRI) and the Geostationary Earth Radiation Budget (GERB) instrument. However, retrieval algorithms that have been developed in order to use the additional information gained by the improved spectral information of MSG can not be applied to the MVIRI instrument, as they use spectral information that is not provided by MFG (NWC SAF cloud algorithm, CM-SAF radiation algorithm). Hence, in order to be able to provide a long time series covering more than 20 years there is a need for a specific climate algorithm that can be applied to the satellites from the Meteosat First and Second Generation. Moreover, the retrieved climate variable must have climate quality. The MAGIC SOL method in combination with the gnu-public license version of MAGIC does meet the above mentioned requirements.

2.2.6.10 References

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R. Posselt, R.W. Mueller, R. Stöckli, J. Trentmann, Remote sensing of solar surface radiation for climate monitoring — the CM-SAF retrieval in international comparison, *Remote Sensing of Environment*, Volume 118, 15 March 2012, Pages 186-198, ISSN 0034-4257, <http://dx.doi.org/10.1016/j.rse.2011.11.016>.

CM-SAF documentation reports (to be found under

http://dx.doi.org/10.5676/EUM_SAF_CM/RAD_MVIRI/V001):

SAF/CM/DWD/ATBD/MVIRI_HEL/1.2: Algorithm Theoretical Basis Document (ATBD) - Meteosat (MVIRI) Solar Solar Irradiance and effective Cloud Albedo Climate Data Sets.

SAF/CM/DWD/PUM/MVIRI_HEL/1.4: Product User Manual (PUM) - Meteosat (MVIRI) Solar Surface Irradiance and effective Cloud Albedo Climate Data Sets.

SAF/CM/DWD/VAL/MVIRI_HEL/1.1: Validation Report - Meteosat (MVIRI) Solar Surface Irradiance and effective Cloud Albedo Climate Data Sets.

2.2.6.11 Revision History

10-01-2014 - Version 1 – Initial draft created by Rainer Hollmann.

16-01-2014 – Version 1 – Update of initial draft by Oliver Sus.

16-01-2014 – Version 1 – Inclusion of Applications by Reto Stöckli

2.2.7 EUMETSAT CM SAF CLARA-A1 Surface Radiation

2.2.7.1 Intent of the Document

This document summarizes essential information needed for users of any level who wish to use the CM SAF CLARA A1 cloud properties data set for climate applications. CLARA A1 is derived from measurements of the series of Advanced Very High Resolution Radiometer (AVHRR) on the NOAA satellite series including METOP-A satellites.

2.2.7.2 Point of Contact

Satellite-Application Facility for Climate Monitoring
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Frankfurter Straße 135
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2.2.7.3 Data Field Description

The CLARA-A1 dataset is a global dataset of cloud, surface albedo and surface radiation products derived from measurements of the Advanced Very High Resolution Radiometer (AVHRR) onboard the polar orbiting NOAA and Metop satellites (Figure 1). Monthly and daily mean products have been compiled over a time period of 28 years starting in 1982 and ending in 2009. Results are available for individual satellites as well as aggregated for all satellites through intercalibration. Results are provided on two types of grids: one global regular latitude-longitude grid with 0.25 degrees resolution and two equal-area grids covering the polar regions with 25 km resolution (products on the polar grids are restricted to cloud amount and surface albedo). Further extensions, e.g. single- and multi-parameter histograms, and subsets, e.g. daytime-only and night-time only results, are also included. Observations from polar orbiting sun synchronous satellites are made at the same local solar time at each latitude band. A specific problem with the observation nodes for the NOAA satellites has been the difficulty to keep observation times stable for each individual satellite. Some compensation for this has been attempted in the CM SAF dataset but not for all parameters.

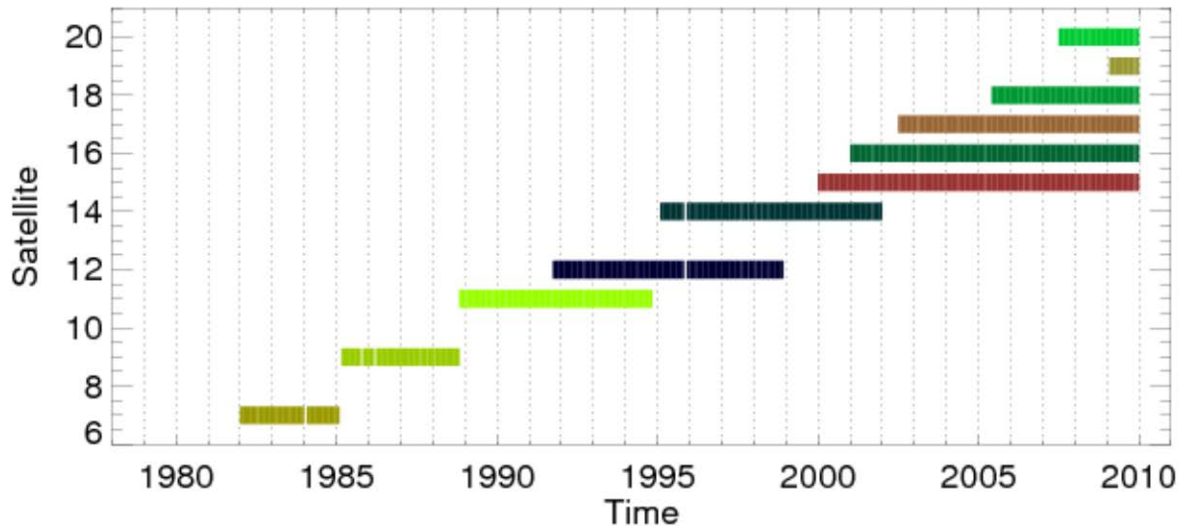


Figure 1: Visualisation of the used NOAA-satellites showing satellite numbers on Y-axis and the length of the observation period for each satellite. Notice that number 20 denotes Metop-A. Some data gaps are present but only for some isolated months for NOAA-7, NOAA-9, NOAA-12 and NOAA-14.

The CLARA-A1 data set contains multiple surface radiation parameters derived from AVHRR, which are:

- Shortwave surface radiation products: the surface radiation in the wavelength region between 200 nm and 4000 nm. It is further distinguished between the surface incoming solar radiation (SIS) and the net surface solar radiation (SNS). The underlying fundamental assumption of retrieving the surface solar irradiance from satellite observations is that the reflected radiance, as measured by the satellite instrument, is related to the broadband atmospheric transmission, T . From the atmospheric transmission the surface incoming solar radiation, SIS, can be derived by $SIS = E_0 \cos(\Theta_0) T$, where E_0 is the incoming solar flux at the top-of-the-atmosphere ($E_0 = 1368 \text{ W/m}^2$) and Θ_0 the solar zenith angle. The net surface solar radiation is defined as the difference between the incoming and the reflected surface solar radiation. $SNS = SIS - SOS$, where SNS is the net surface solar irradiance and SOS the reflected surface solar radiation.
- Longwave surface radiation products: the surface longwave radiation products of the CM SAF GAC data set are the surface downwelling longwave radiation (SDL), the surface outgoing longwave radiation (SOL), and the surface net longwave radiation (SNL).
 - o SDL: The CM SAF algorithm to derive the surface downwelling longwave (SDL) radiation from the AVHRR GAC data set is based on the monthly mean surface downwelling longwave radiation data from the ERA-Interim data set. The CM SAF GAC cloud fraction (CFC) data set and high-resolution topographic information are used to generate the CM SAF GAC SDL data set on the global 0.25° grid.
 - o SOL: The surface outgoing longwave radiation (SOL) is primarily determined by the surface temperature and the emissivity of the surface. In the longwave

spectral region, the emissivity of the Earth surface is close to unity, resulting in a very small contribution of the reflected surface downwelling longwave radiation to the surface outgoing longwave radiation.

- o SNL: The surface net longwave radiation is defined as the sum of the downwelling and the upwelling longwave surface radiation. Since, in the case of the CM SAF GAC surface longwave radiation data sets, the surface outgoing longwave radiation is positively defined, the surface net longwave radiation is calculated by the difference between the downwelling and the upwelling longwave surface radiation.
- Surface radiation budget (SRB): The surface radiation budget is calculated as the sum of the shortwave and the longwave net surface radiation fluxes and can be derived directly from the corresponding monthly mean CM SAF GAC data sets: $SRB = SNS + SNL$. The calculation is based on the monthly mean CM SAF GAC data sets of the net surface longwave (SNL) and shortwave (SNS) and available on the 0.25 deg global grid.
- Cloud radiative effect: The shortwave cloud radiative effect (CFS) is defined as the difference between the net shortwave surface radiation fluxes under all-sky and under clear sky conditions. The longwave cloud radiative effect (CFL) is defined as the difference of the net longwave surface radiation fluxes under all-sky and under clear-sky conditions.

2.2.7.4 Data Origin

The CM SAF GAC surface radiation data set from AVHRR (Table 1) satellite observations provides global coverage. The instantaneous AVHRR observations are used to derive the spatio-temporal averaged data sets. The products are available as monthly averages on a regular latitude/longitude grid with a spatial resolution of $0.25^\circ \times 0.25^\circ$ degrees. For the surface solar irradiance (SIS: surface incoming solar radiation) also daily averages are available. The temporal coverage of the data sets ranges from 1 January 1989 to 31 December 2009.

Table 2: Spectral channels of the Advanced Very High Resolution Radiometer (AVHRR). The three different versions of the instrument are described as well as the corresponding satellites. Notice that channel 3A was only used continuously on NOAA-17 and Metop-1. For the other satellites with AVHRR/3 it was used only for shorter periods.

Channel Number	Wavelength (micrometers) AVHRR/1 NOAA-6,8,10	Wavelength (micrometers) AVHRR/2 NOAA-7,9,11,12,14	Wavelength (micrometers) AVHRR/3 NOAA-15,16,17,18 NOAA-19, Metop-A
1	0.58-0.68	0.58-0.68	0.58-0.68
2	0.725-1.10	0.725-1.10	0.725-1.10
3A	-	-	1.58-1.64
3B	3.55-3.93	3.55-3.93	3.55-3.93
4	10.50-11.50	10.50-11.50	10.50-11.50
5	Channel 4 repeated	11.5-12.5	11.5-12.5

The retrieval of the surface incoming solar radiation is based on the method presented in Mueller et al., (2009). As auxiliary data sources, the integrated water vapour from the ERA-Interim data set (Dee et al., 2011), aerosol information from the GADS/OPAC data base (Hess et al., 1998) and the surface albedo from the SARB/CERES team (<http://www-surf.larc.nasa.gov/surf/>) are used. The monthly-averaged surface radiation budget is derived as the sum of the CM SAF GAC data sets of the surface net shortwave radiation (SNS) and the surface net longwave radiation (SNL), which corresponds to the definition of the surface radiation budget. The surface shortwave cloud radiation effect is derived from the monthly-averaged data sets of the surface incoming shortwave radiation and the surface albedo, and the monthly-averaged clear-sky surface downward shortwave radiation. The latter is derived in the processing of the surface incoming solar radiation. The monthly mean surface longwave cloud radiation effect is determined as the product of the cloud correction factor and the cloud fraction determined by CM SAF GAC.

2.2.7.5 Validation and Uncertainty Estimate

For the surface incoming solar radiation (SIS), the surface outgoing longwave radiation (SOL), and the surface downward longwave radiation (SDL) the accuracy of the data set is validated with available surface observations from the Baseline Surface Radiation Network (BSRN, Ohmura et al., 1998, Figure 2). For the other parameters, the accuracy is tested based on the accuracy of the input data using the method of propagation of uncertainty.

The accuracy requirements applicable for this validation report are mainly derived from the Global Climate Observing System (GCOS) in 2004, which have been updated in December 2011. All products in the GAC surface radiation dataset fulfil the updated GCOS requirements regarding the horizontal resolution (100 km). The GCOS accuracy requirements are partly fulfilled for the surface radiation products; the requirements on stability have yet to be assessed.

Table 3: Summary of the accuracy of the CM SAF GAC surface radiation data sets.

Data Set	Threshold / Target / Optimal Accuracies in W/m²	Dataset Accuracy in W/m²
SIS	15 / 10 / 8 30 / 25 / 20 (daily averages)	10 20
SNS	20 / 15 / 12	15
SOL	15 / 10 / 8	14
SDL	15 / 10 / 8	8
SNL	20 / 15 / 12	22
SRB	25 / 20 / 15	42
CFS	15 / 10 / 8	15
CFL	15 / 10 / 8	5

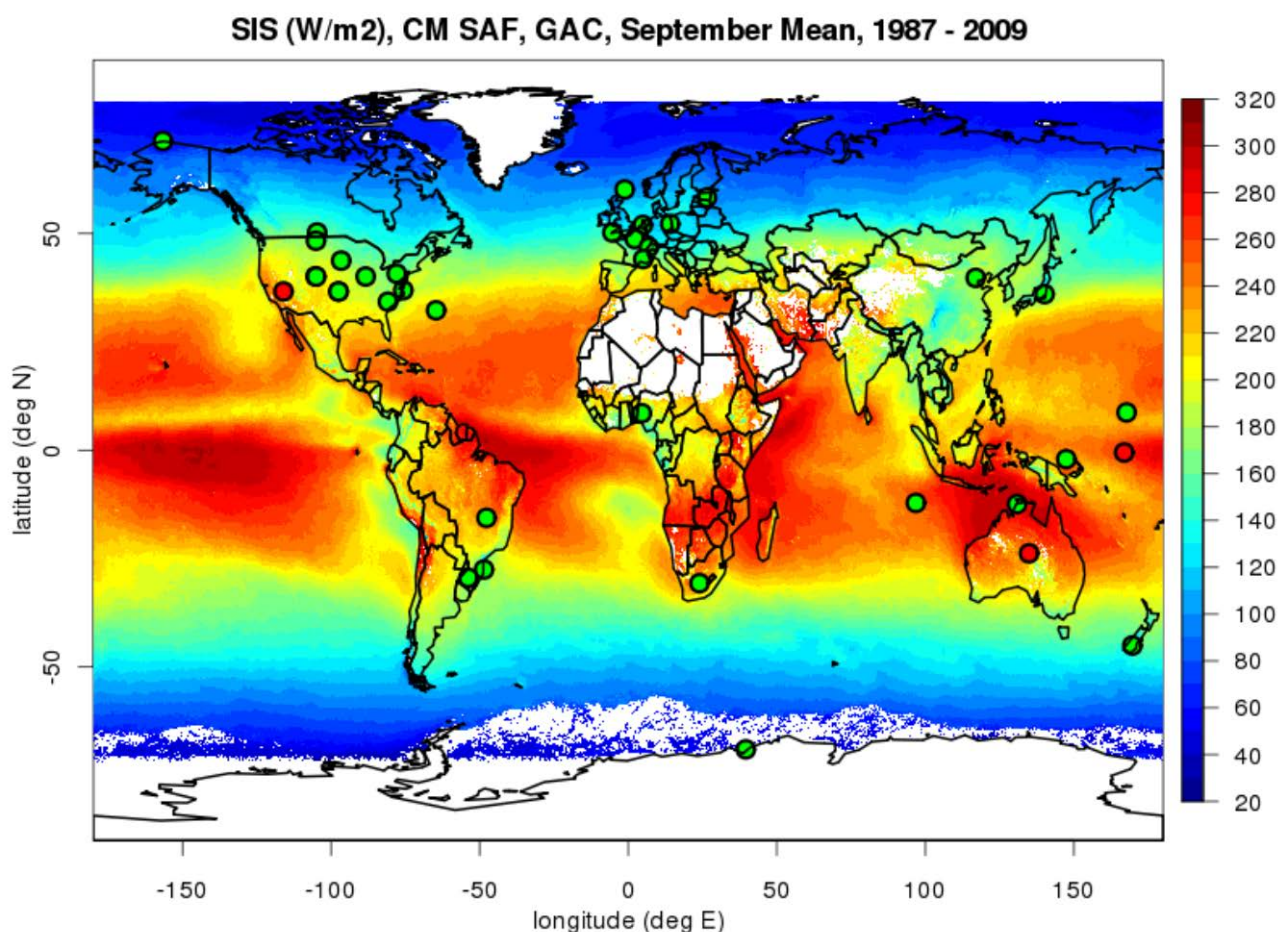


Figure 2: Multi-year average of the CM SAF GAC surface solar irradiance data set for the month of September and validation results obtained by comparison with available BSRN surface measurements. Green dots represent surface stations where the GAC SIS data set is within the target accuracy, red dots correspond to surface stations, where the GAC SIS data set does not meet the target accuracy.

2.2.7.6 Considerations for climate applications

The suitability of these data sets for climate applications depends strongly on the specific application. The general accuracy of the data sets has been shown by validation with reference measurements and by uncertainty assessments. The data sets of the surface shortwave radiation quantities (SIS, SNS, CFS) have been shown to have a high quality and are mainly derived from satellite observations. The quality of the up- and downwelling longwave surface fluxes is also within the expectations, however, since these data sets use substantial information from reanalysis and should not be used for the validation of reanalysis and other model-derived data sets. Due to the error propagation, the accuracy of the net longwave radiation and the total surface radiation might exceed the target accuracy and without further validation with reference measurements these data should be used with care.

Please note, that the temporal stability and homogeneity of these data sets have not yet been fully evaluated. While all possible measures have been taken in the generation of these data sets, artificial shifts or trends in the final data sets cannot be excluded. Application of these

data sets for the analysis of temporal changes / trend is recommended only after a careful evaluation of the temporal behaviour of these data sets.

2.2.7.7 Instrument Overview

Measurements from the Advanced Very High Resolution Radiometer (AVHRR) radiometer onboard the polar orbiting NOAA satellites and the EUMETSAT METOP satellites have been performed since 1978. Figure 1 gives an overview over all satellites carrying the AVHRR instrument until 2009 (the final year covered by the new CM SAF GAC dataset). Notice that also data from NOAA-19 and Metop-A have been used for the last two years in the CM SAF dataset. The instrument only measured in four spectral bands in the beginning (AVHRR/1) but from 1982 a fifth channel was added (AVHRR/2) and in 1998 even a sixth channel was made available (AVHRR/3), although only accessible if switched with the previous third channel at 3.7 micron (Table 1).

2.2.7.8 References

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Mueller, R., C. Matsoukas, A. Gratzki, H. Behr, and R. Hollmann (2009), The CM-SAF operational scheme for the satellite based retrieval of solar surface irradiance - A LUT based eigenvector hybrid approach, *Remote Sensing of Environment*, 113(5), 1012-1024.
Ohmura, A., et al. (1998), Baseline Surface Radiation Network (BSRN/WCRP): New precision radiometry for climate research, *Bulletin of the American Meteorological Society*, 79(10), 2115-2136.

CM-SAF documentation reports

(to be found under http://dx.doi.org/10.5676/EUM_SAF_CM/CLARA_AVHRR/V001):

SAF/CM/DWD/ATBD/GAC/RAD/1.2: Algorithm Theoretical Basis Document (ATBD) - AVHRR GAC surface radiation, Edition 1.

SAF/CM/DWD/PUM/GAC/RAD/1.2: Product User Manual (PUM) - AVHRR GAC surface radiation, Edition 1.

SAF/CM/DWD/VAL/GAC/RAD/1.2: Validation Report - AVHRR GAC surface radiation, Edition 1

2.2.7.9 Revision History

10-01-2014 - Version 1 – Initial draft created by Rainer Hollmann.

16-01-2014 – Version 1 – Update of initial draft by Oliver Sus.

2.2.8 EUMETSAT CM SAF CLARA-A1 Cloud Properties

2.2.8.1 Intent of the Document

This document summarizes essential information needed for users of any level who wish to use the CM SAF CLARA A1 cloud properties data set for climate applications. CLARA A1 is derived from measurements of the series of Advanced Very High Resolution Radiometer (AVHRR) on the NOAA satellite series including METOP-A satellites.

2.2.8.2 Point of Contact

Satellite-Application Facility for Climate Monitoring
Deutscher Wetterdienst
Frankfurter Straße 135
60594 Offenbach, Germany

Email: contact.cmsaf@dwd.de

2.2.8.3 Data Field Description

The CLARA-A1 dataset is a global dataset of cloud, surface albedo and surface radiation products derived from measurements of the Advanced Very High Resolution Radiometer (AVHRR) onboard the polar orbiting NOAA and Metop satellites (Figure 1). Monthly and daily mean products have been compiled over a time period of 28 years starting in 1982 and ending in 2009. Results are available for individual satellites as well as aggregated for all satellites through intercalibration. Results are provided on two types of grids: one global regular latitude-longitude grid with 0.25 degrees resolution and two equal-area grids covering the polar regions with 25 km resolution (products on the polar grids are restricted to cloud amount and surface albedo). Further extensions, e.g. single- and multi-parameter histograms, and subsets, e.g. daytime-only and night-time only results, are also included. Observations from polar orbiting sun synchronous satellites are made at the same local solar time at each latitude band. A specific problem with the observation nodes for the NOAA satellites has been the difficulty to keep observation times stable for each individual satellite. Some compensation for this has been attempted in the CM SAF dataset but not for all parameters.

The CLARA-A1 data set contains multiple cloud parameters derived from AVHRR, which are:

- Cloud Fractional Cover (CFC): the fraction of cloudy pixels per grid square compared to the total number of analysed pixels in the grid square [%]
- Joint Cloud property histogram (JCH): This two-dimensional histogram gives the absolute numbers of occurrences for specific cloud optical thickness and cloud top pressure combinations defined by specific bins
- Cloud Top level (CTO): Three versions of the CM SAF Cloud Top product exist: 1. Cloud Top Temperature, CTT [Kelvin]; 2. Cloud Top Height (CTH), expressed as altitude over ground topography [m]; 3. Cloud Top Pressure (CTP), expressed in pressure co-ordinates [hPa].

- Cloud Optical Thickness (COT): is retrieved from a comparison of the measured 0.6 μm reflectance to pre-calculated Lookup Table values
- Cloud Phase (CPH): determines cloud thermodynamic phase, i.e. ice or water (mixed phase is not retrieved)
- Liquid Water Path (LWP): is computed from the retrieved cloud optical thickness and cloud particle effective radius
- Ice Water Path (IWP): as above, but using the retrieved effective radius of ice crystals and the density of ice

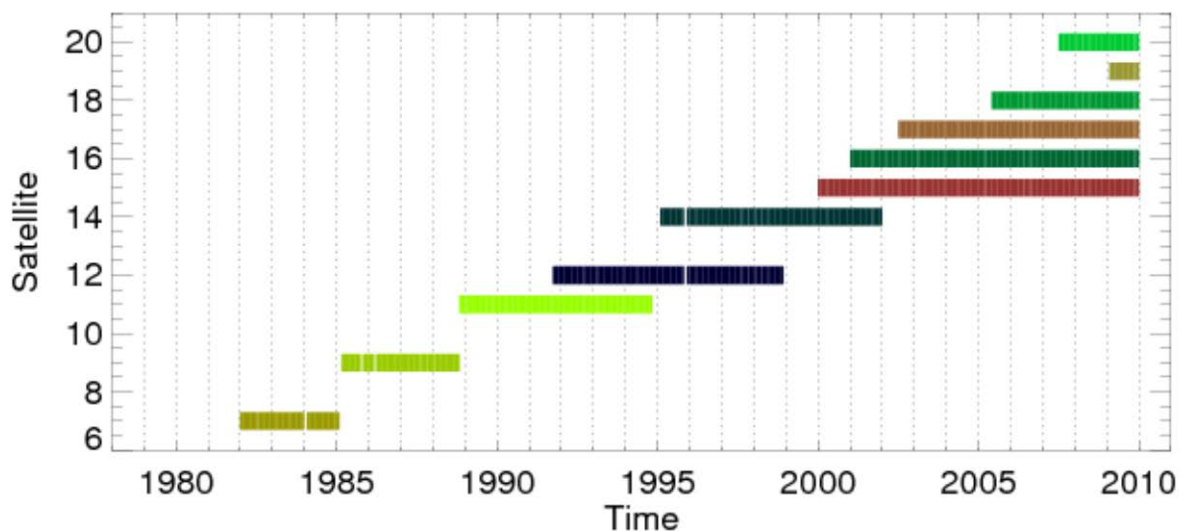


Figure 3: Visualisation of the used NOAA-satellites showing satellite numbers on Y-axis and the length of the observation period for each satellite. Notice that number 20 denotes Metop-A. Some data gaps are present but only for some isolated months for NOAA-7, NOAA-9, NOAA-12 and NOAA-14.

2.2.8.4 Data Origin

The CLARA-A1 dataset spans the time period 1982-2009. Retrieval methods have been dependent on the access to two infrared (split-window) channels at 11 and 12 microns meaning that only data from satellites carrying the AVHRR/2 or AVHRR/3 instruments have been used (Table 1). The algorithms applied are the PPS (Polar Platform System) cloud processing package (Dybbroe et al., 2005a and Dybbroe et al., 2005b), which is used to determine cloud fraction and cloud top properties, and the CPP (Cloud Physical Properties) algorithm (Roebeling et al. 2006), which retrieves cloud thermodynamic phase, cloud optical thickness, cloud particle effective radius, and liquid/ice water path. The algorithms used to produce the CLARA-A1 cloud properties dataset are explained in detail in the ATBD (cite).

As input for the L2 to L3 processing environment serve pixel level retrieval results of the Level 2 algorithm software of PPS and CPP. The final outputs produced are global fields of daily and monthly averages. Before creation of L3 data, the pixel-based data are re-projected onto a $(0.05^\circ)^2$ latitude-longitude grid. Building on these remapped fields, the Level-3 data (daily and monthly means) are aggregated and averaged on the final $(0.25^\circ)^2$ grid.

Table 4: Spectral channels of the Advanced Very High Resolution Radiometer (AVHRR). The three different versions of the instrument are described as well as the corresponding satellites. Notice that channel 3A was only used continuously on NOAA-17 and Metop-1. For the other satellites with AVHRR/3 it was used only for shorter periods.

Channel Number	Wavelength (micrometers) AVHRR/1 NOAA-6,8,10	Wavelength (micrometers) AVHRR/2 NOAA-7,9,11,12,14	Wavelength (micrometers) AVHRR/3 NOAA-15,16,17,18 NOAA-19, Metop-A
1	0.58-0.68	0.58-0.68	0.58-0.68
2	0.725-1.10	0.725-1.10	0.725-1.10
3A	-	-	1.58-1.64
3B	3.55-3.93	3.55-3.93	3.55-3.93
4	10.50-11.50	10.50-11.50	10.50-11.50
5	Channel 4 repeated	11.5-12.5	11.5-12.5

In addition, results are also prepared on two equal-area polar grids at 25 km resolution for the Arctic and Antarctic regions, respectively. This is done to facilitate usage of results over the poles where the converging longitudes make the use of regular latitude-longitude grids problematic. Here, initial results are defined in a 5 km resolution grid on these regions before averaged into 25 km L3 products. These grids are centred at the poles and cover areas of 1000 km x 1000 km. However, notice that this only concerns the two cloud parameters Fractional Cloud Coverage and Cloud Top Level.

2.2.8.5 Validation and Uncertainty Estimate

An extensive validation of cloud products from the CM SAF GAC Edition 1 dataset has been performed. The reference datasets were taken from completely independent and different observation sources (e.g. SYNOP, CALIPSO-CALIOP, SSM/I and AMSR-E) as well as from similar satellite-based datasets from passive visible and infrared imagery (MODIS, ISCCP and PATMOS-x). A distinction was made between results from completely independent references (SYNOP, CALIPSO-CALIOP, SSM/I and AMSR-E) and results from datasets based on similar satellite sensors (PATMOS-x, MODIS and ISCCP). Highest credibility was given to results from the first group while results from the second group were used as consistency checks.

Validation was performed for both accuracy (i.e. bias) and precision estimates (Table 2). The validation through MODIS data showed that accuracy target requirements are met for CTP, COT, LWP, and IWP, but bias is larger than required for CFC and CPH. Precision requirements are fulfilled for CTP and COT, but not for CFC, CPH, LWP, and IWP.

2.2.8.6 Considerations for climate applications

CFC: The CFC dataset is still not of sufficient quality for offering global climate trend analysis. However, good validation results were found for mid- to high-latitude regions, except for near-Polar regions and Polar winter.

CTO: Similar recommendations as for CFC products. Many cloud tops of boundary layer clouds appear to be overestimated.

COT: Most reliable at solar zenith angles $<65^\circ$. Surfaces with snow or ice cover are problematic. Care should be taken when using the dataset for long-term trend analysis (orbital drifts, inter-satellite discontinuities).

CPH: As for COT.

LWP: As for COT. Also, significant differences are observed between the parts of the dataset relying on the 1.6- μm and 3.7- μm channels. It is recommended that those parts are not combined but used separately for analyses.

IWP: As for LWP.

Table 5: Summary of validation results compared to target accuracies and precisions for each cloud product. Notice that accuracies are given as mean errors or biases (both terms being equivalent) valid for both negative and positive deviations. Unless stated otherwise, values are shown for comparison against MODIS only.

Cloud Product	Accuracy requirement (mean error or bias)	Achieved accuracies	Precision requirement (RMS)	Achieved precisions
CFC	10 % (absolute)	-10 % to -20 %	20 % (absolute)	20 % to 27 %
CTH	1200 m	-2661 m (CALIPSO)	2000 m	n/a
CTP	110 hPa	-40 hPa to -50 hPa	130 hPa	80 hPa
COT	15 %	-5 % to -10 %	30 %	30 %
CPH	5 % (absolute)	3 % to 20 %	10 %	12 % to 25 %
LWP	15 %	15 %	30 %	35 % to 45 %
IWP	25 %	0 % to 80 %	50 %	45 % to 90 %
JCH	n/a	n/a	n/a	n/a

2.2.8.7 Instrument Overview

Measurements from the Advanced Very High Resolution Radiometer (AVHRR) radiometer onboard the polar orbiting NOAA satellites and the EUMETSAT METOP satellites have been performed since 1978. Figure 1 gives an overview over all satellites carrying the AVHRR instrument until 2009 (the final year covered by the new CM SAF GAC dataset). Notice that also data from NOAA-19 and Metop-A have been used for the last two years in the CM SAF dataset. The instrument only measured in four spectral bands in the beginning (AVHRR/1) but from 1982 a fifth channel was added (AVHRR/2) and in 1998 even a sixth channel was made available (AVHRR/3), although only accessible if switched with the previous third channel at 3.7 micron (Table 1).

2.2.8.8 References

Dybbroe, A., A. Thoss and K.-G. Karlsson, 2005a: NWC SAF AVHRR cloud detection and analysis using dynamic thresholds and radiative transfer modeling - Part I: Algorithm description, J. Appl. Meteor, 44, pp. 39-54.

Dybbroe, A., A. Thoss and K.-G. Karlsson, 2005b: NWC SAF AVHRR cloud detection and analysis using dynamic thresholds and radiative transfer modeling - Part II: Tuning and validation, J. Appl. Meteor, 44, 55-71.

Karlsson, Karl-Göran; Riihelä, Aku; Müller, Richard; Meirink, Jan Fokke; Sedlar, Joseph; Stengel, Martin; Lockhoff, Maarit; Trentmann, Jörg; Kaspar, Frank; Hollmann, Rainer; Wolters, Erwin (2012): CLARA-A1: CM SAF Clouds, Albedo and Radiation dataset from AVHRR data - Edition 1 - Monthly Means / Daily Means / Pentad Means / Monthly Histograms. Satellite Application Facility on Climate Monitoring. DOI:10.5676/EUM_SAF_CM/CLARA_AVHRR/V001.

http://dx.doi.org/10.5676/EUM_SAF_CM/CLARA_AVHRR/V001

Karlsson, K.-G., Riihelä, A., Müller, R., Meirink, J. F., Sedlar, J., Stengel, M., Lockhoff, M., Trentmann, J., Kaspar, F., Hollmann, R., and Wolters, E.: CLARA-A1: a cloud, albedo, and radiation dataset from 28 yr of global AVHRR data, Atmos. Chem. Phys., 13, 5351-5367, doi:10.5194/acp-13-5351-2013, 2013.

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Roebeling, R.A., A.J. Feijt and P. Stammes, 2006, Cloud property retrievals for climate monitoring: implications of differences between SEVIRI on METEOSAT-8 and AVHRR on NOAA-17, J. Geophys. Res., 111, D20210, doi:10.1029/2005JD006990.

CM-SAF documentation reports

(to be found under http://dx.doi.org/10.5676/EUM_SAF_CM/CLARA_AVHRR/V001):

SAF/CM/DWD/ATBD/GAC/CLD/1.1: Algorithm Theoretical Basis Document (ATBD) - AVHRR GAC cloud products, Edition 1.

SAF/CM/KNMI/ATBD/GAC/PPP/1.1: Algorithm Theoretical Basis Document (ATBD) - Cloud Physical Products AVHRR.

SAF/CM/SMHI/ATBD/CTO_AVHRR/2.0: Algorithm Theoretical Basis Document (ATBD) - CM-SAF Product CM-15 and CM-16 Cloud Top (Temperature, Pressure, Height) from AVHRR.

SAF/CM/SMHI/ATBD/PCH/1.1: Algorithm Theoretical Basis Document (ATBD) - Joint Cloud property Histogram products AVHRR / SEVIRI.

SAF/CM/DWD/PUM/GAC/CLD/1.2: Product User Manual (PUM) - AVHRR GAC cloud products, Edition 1.

SMHI/VAL/GAC/CLD/1.2: Validation Report - AVHRR GAC cloud products, Edition 1

2.2.8.9 Revision History

10-01-2014 - Version 1 – Initial draft created by Rainer Hollmann.

16-01-2014 – Version 1 – Update of initial draft by Oliver Sus.

2.2.9 GPCC Full Data Reanalysis Version 6

2.2.9.1 Intent of the Document

This document describes the Full Data Reanalysis of the Monthly Land-Surface Precipitation dataset provided by the Global Precipitation Climatology Centre (GPCC, <http://gpcc.dwd.de/>). The dataset is of higher-accuracy compared to the near-real-time products of GPCC and is recommended for hydrometeorological model verifications and water cycle studies (Becker et al. 2013, Schneider et al. 2013).

2.2.9.2 Point of Contact

Dr. Andreas Becker
Global Precipitation Climatology Centre (GPCC)
c/o Deutscher Wetterdienst
E-mail: gpcc@dwd.de

2.2.9.3 Data Field Description

Product specifications:

Geographic region:	global, over land (0-360°E, 90°S-90°N) without Antarctica
Dimension:	720 columns, 360 rows for 0.5° resolution, 360 columns, 180 rows for 1.0° resolution, 144 columns, 72 rows for 2.5° resolution
Spatial resolution:	0.5°, 1.0° and 2.5°
Temporal resolution:	monthly
Temporal coverage:	1901-2010
Projection:	regular lat-lon grid
Format:	NetCDF, ASCII

Parameters:

Parameter	Unit
Precipitation totals	mm/month
Number of gauges per grid	number

DOI for Scientific and Technical Data:

10.5676/DWD_GPCC/FD_M_V6_050 (for 0.5° resolution)

10.5676/DWD_GPCC/FD_M_V6_100 (for 1.0° resolution)

10.5676/DWD_GPCC/FD_M_V6_250 (for 2.5° resolution)

2.2.9.4 Data Origin

As described in Becker et al. (2013) GPCC uses rain gauge data from two major sources:

- a) near real-time data received through the Global Telecommunication System (GTS)
- b) offline data received through data acquisition (by WMO support letters and bilateral contacts)

Monthly data coverage ranges between less than 10,000 and more than 47,000 stations. Figure 1 shows the growth of the GPCC database for the Full Data Reanalysis.

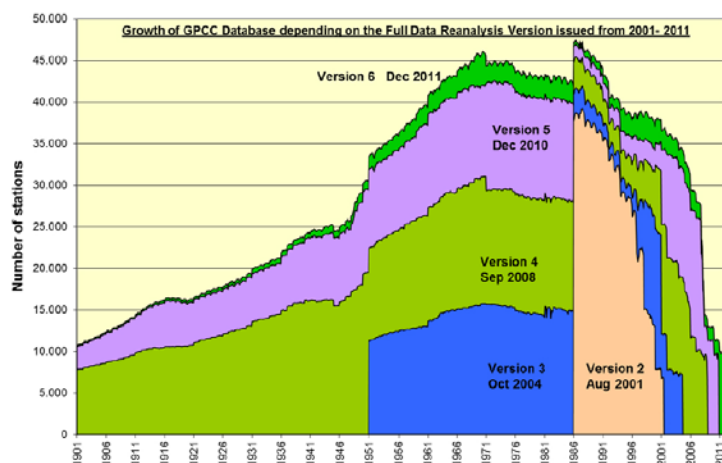


Fig.1: Temporal evolution of number of stations in the GPCC Full Data Reanalysis dataset (from Becker et al. 2013).

GPCC data processing methodology is illustrated in Figure 6 in Schneider et al. (2013). The GPCC Full Dataset is updated at irregular time intervals subsequent to significant data base improvements.

2.2.9.5 Validation and Uncertainty Estimate

Information on data accuracy can be found in the [GPCC product description document](#):

The two major error sources are: (1) The systematic measuring error which results from evaporation out of the gauge and aerodynamic effects, when droplets or snow flakes are drifted by the wind across the gauge funnel, and (2) the stochastic sampling error due to a sparse network density. The relative sampling error of gridded monthly precipitation is between +/-

7 to 40% of the true area-mean, if 5 rain gauges are used, and with 10 stations the error can be expected within the range of $\pm 5\%$ and 20% (Rudolf et al. 1994).

Figure 2 shows the spatial distribution of the number of stations per $2.5^\circ \times 2.5^\circ$ grid for July.

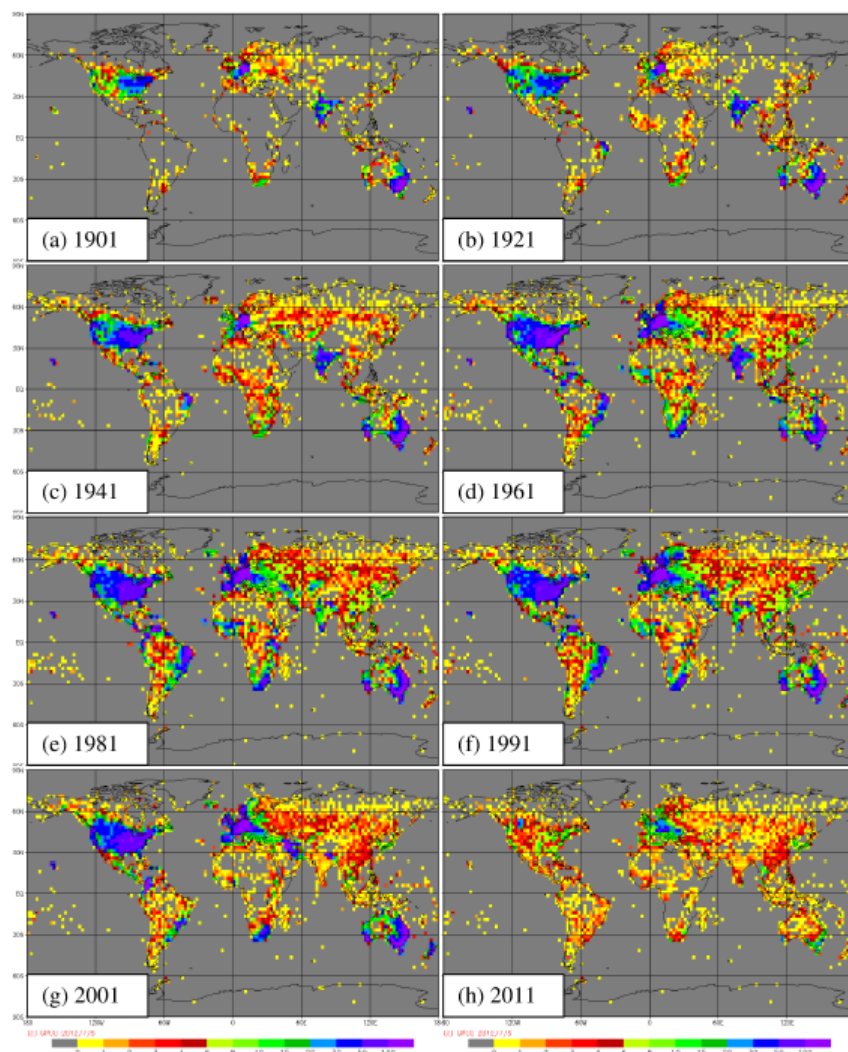


Fig. 2: Number of stations per $2.5^\circ \times 2.5^\circ$ grid for July (from Becker et al. 2013).

2.2.9.6 Considerations for climate applications

Among all GPCP datasets the Full Data Reanalysis is built for its best accuracy. It is recommended for the following applications (according to Becker et al. 2013):

- a) verification of reanalysis products
- b) analysis of historic global precipitation and the global water cycle
- c) diagnosis of regions sensitive to precipitation-related circulation indices (e.g. NAO, SOI)
- d) trend analysis (using methods robust against inhomogeneities)

The quality of the interpolated precipitation totals decrease with decreasing station density.

2.2.9.7 Instrument Overview

Description of rain gauge measurement principles can be found in:

WMO Catalogue of National Standard Precipitation Gauges:

<http://www.wmo.int/pages/prog/www/IMOP/publications/IOM-39.pdf>

WMO CIMO Guide (Chapter 6: Measurement of Precipitation):

ftp://ftp.wmo.int/Documents/MediaPublic/Publications/WMO8_CIMOguide/Part-I/WMO8_Ed2008_PartI_Ch6_Up2010_en.pdf

2.2.9.8 References

Becker, A., Finger, P., Meyer-Christoffer, A., Rudolf, B., Schamm, K., Schneider, U., and Ziese, M (2013): A description of the global land-surface precipitation data products of the Global Precipitation Climatology Centre with sample applications including centennial (trend) analysis from 1901–present, Earth Syst. Sci. Data, 5, 71-99, doi: [10.5194/essd-5-71-2013](https://doi.org/10.5194/essd-5-71-2013).

Fuchs, T., J. Rapp, F. Rubel and B. Rudolf (2001): Correction of Synoptic Precipitation Observations due to Systematic Measuring Errors with Special Regard to Precipitation Phases. Phys.Chem. Earth Pt. B), 26, 689-693.

Legates, D. R., and C. J. Willmott (1990): Mean seasonal and spatial variability in gauge-corrected, global precipitation. Int. J. Climatol., 10, 111-127.

Schneider, U., Becker, A., Finger, F., Meyer-Christoffer, A., Ziese, M., and Rudolf, B (2013): GPCC's new land-surface precipitation climatology based on quality-controlled in-situ data and its role in quantifying the global water cycle, Theor. Appl. Climatol, doi: [10.1007/s00704-013-0860-x](https://doi.org/10.1007/s00704-013-0860-x)

2.2.9.9 Revision History

CORE-CLIMAX Data Set Description Version 1.0, 6 September 2013: André Obregón (DWD) with input from Dr. Markus Ziese (DWD).

2.2.10 NKDZ

2.2.10.1 Intent of the Document

This document describes the publicly released Nationales Klimadatenzentrum (NKDZ) station data comprising hourly, daily, monthly and multi-annual values derived from temperature, precipitation, wind, cloud cover and sunshine measurements recorded at stations of DWD.

Historical measurements of climatological parameters from the DWD climatological and meteorological stations are provided together with station-specific metadata (such as, e.g., known station history, instrument change or change in formula) for free public access at ftp://ftp-cdc.dwd.de/pub/CDC/observations_germany/. Note the terms of use at ftp://ftp-cdc.dwd.de/pub/CDC/Terms_of_use.pdf.

2.2.10.2 Point of Contact

Dr. Frank Kaspar
Head of National Climate Data Centre (NKDZ)
Deutscher Wetterdienst
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63067 Offenbach
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Fax: 069 - 8062-4499
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2.2.10.3 Data Field Description

Product specifications: These are data as measured and quality controlled. Note the unit of measurement can vary between stations and change over time. Also, the time of observations had changed. Time units are given as recorded at each station (i.e., are not constant for hourly data). This time effect was cared for in derivation of daily values. For aggregated values (daily, monthly), note the calculation formula has changed over time according to measurements availability.

Spatial coverage: Stations covering Germany

Temporal coverage: 1/1/1781 to 31/12/2013

Temporal resolution: hourly, daily, monthly and multi-annual

Parameters: maximum, mean and minimum of air temperature and humidity at 2m height, mean wind speed and direction at 10m height, cloud cover, sunshine duration, sum of precipitation.

Not all stations measure all parameters, and not all temporal resolutions are given. Refer to <ftp://ftp-cdc.dwd.de/pub/CDC/help/> for the different station collectives covering specific parameters at specific resolution.

Format(s): The data are given in ascii within files *product_*.txt*. Station specific metadata are given (in German only) in the files *Beschreibung_*.html* which gives units, measurement times, time units, measurement procedures, algorithm changes, instrument changes and other

noteworthy information. *Protokoll_*.txt* lists bad or missing data, *Stationsmetadaten*.txt* contains the station history (e.g., change of location,). All files are zipped according to station.

2.2.10.4 Data Origin

As explained in *Kaspar et al., 2013*, in the early years, various meteorological services were founded in various parts of today's Germany. After the establishment of the International Meteorological Organization (IMO) in 1873, the different standards were continuously adjusted to this specification and from 1934 unified instrumentation and observer instruction were applied. In the divided Germany, different instrumentation and observation practices have been developed from 1945 onwards. After the reunification in 1990 these practices were again harmonized.

2.2.10.5 Validation and Uncertainty Estimate

Considerations of quality assurance are explained in *Kaspar et al., 2013*: several steps of quality control, including automatic tests for completeness, temporal and internal consistency, and against statistical thresholds based on the software QualiMet (see *Spengler, 2002*) and manual inspection result in a quality which can be considered as reasonably good, but there are still doubtful values, especially in data prior to 1979 (in the order of about 0.1–1 %).

2.2.10.6 Considerations for climate applications

Data are provided “as observed”, no homogenization has been carried out. The history of instrumental design, observation practice, and possibly changing representativity has to be considered for the individual stations when interpreting changes in the statistical properties of the time series. It is strongly suggested to investigate the records of the station history which are provided together with the data. Note that in the 1990s many stations had the transition from manual to automated stations, entailing possible changes in certain statistical properties.

2.2.10.7 Instrument Overview

Description of measurement and observation principles are maintained in the *DWD Beobachterhandbuch*.

2.2.10.8 References

DWD Vorschriften und Betriebsunterlagen Nr. 3 (VuB 3), *Beobachterhandbuch* (BHB) für

Wettermeldestellen des synoptisch-klimatologischen Mess- und Beobachtungsnetzes, März 2014.

Kaspar, F., G. Müller-Westermeier, E. Penda, H. Mächel, K. Zimmermann, A. Kaiser-Weiss, T. Deutschländer: Monitoring of climate change in Germany – data, products and services of Germany's National climate Data Centre. *Adv. Sci. Res.*, 10, 99–106, 2013.

Spengler, R.: The new Quality Control- and Monitoring System of the Deutscher Wetterdienst. Proceedings of the WMO Technical Conference on Meteorological and Environmental Instruments and Methods of Observation, Bratislava, 2002.

2.2.10.9 9. Revision History

The described data set version v002 was released on 24th July 2014. Improved and extended versions data are planned in approximately annual intervals to take into account the historical data rescued in the meantime and with improved flagging of known data quality issues. More recent data (which are not versioned and not fully quality controlled) can be found in subdirectories /recent/ under ftp://ftp-cdc.dwd.de/pub/CDC/observations_germany/climate/ .

This document is maintained by the Nationales Klimadatenzentrum (NKDZ) of DWD, last edited 19 Sept 2014 AKW.

2.2.11 EACD

2.2.11.1 INTENT OF THE DOCUMENT

The website of the European Climate Assessment & Dataset (www.ecad.eu) project provides information on changes in weather and climate extremes, as well as the daily dataset needed to monitor and analyse these extremes.

2.2.11.2 POINT OF CONTACT

ECA&D Project Team
Royal Netherlands Meteorological Institute (KNMI)
P.O. Box 201
3730 AE De Bilt
The Netherlands
e-mail: eca@knmi.nl
fax: + 31 30 2204614

2.2.11.3 DATA FIELD DESCRIPTION

The table with daily station data provided by ECA&D can be downloaded:
http://www.ecad.eu/utis/downloadfile.php?file=work/138970615895/ECAD_elements.pdf

2.2.11.4 DATA ORIGIN

The Algorithm Theoretical Basis Document (ATBD):
<http://www.ecad.eu/documents/atbd.pdf>

The ECA dataset consists of daily station series obtained from climatological divisions of National Meteorological and Hydrological Services and station series maintained by observatories and research centres throughout Europe and the Mediterranean. For details of the individual data providers see the participants list (<http://www.ecad.eu/dailydata/datadictionaryparticipants.php>). A comprehensive overview of all available data is provided in the data dictionary (<http://www.ecad.eu/dailydata/datadictionary.php>).

2.2.11.5 VALIDATION AND UNCERTAINTY ESTIMATE

The series are quality controlled and flags (“OK”, “suspect” or “missing”) for individual data are attached. Homogeneity testing has resulted in classification of series in “useful”, “doubtful” or “suspect”. Note that these categories only hold for the particular time intervals for which the tests were applied. It is recommended to use the results of the homogeneity tests for selecting appropriate series and time intervals. The series have not been homogenized in the sense that values are changed.

No specific uncertainty estimate is given for the data provided.

2.2.11.6 CONSIDERATIONS FOR CLIMATE APPLICATIONS

Please look at <http://www.ecad.eu/FAQ/index.php> for specific questions on the data and its use. For comparison with model data, a gridded product is available for precipitation, temperature and sea level pressure in Europe

2.2.11.7 INSTRUMENT OVERVIEW

All daily data in the ECA&D database are daily in-situ observations. The instrumentation may vary per data provider. The data dictionary provides for each station the data provider and a short station description. For detailed information on instrumentation the data provider should be contacted.

2.2.11.8 REFERENCES

For a complete list of publications see <http://www.ecad.eu/publications/index.php>

2.2.11.9 REVISION HISTORY

Version 1: Gé Verver, KNMI, 14 January 2014

2.2.12 EOBS

2.2.12.1 INTENT OF THE DOCUMENT

Description of a daily gridded observational dataset for precipitation, temperature and sea level pressure in Europe called E-OBS.

2.2.12.2 POINT OF CONTACT

ECA&D Project Team
Royal Netherlands Meteorological Institute (KNMI)
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fax: + 31 30 2204614

2.2.12.3 DATA FIELD DESCRIPTION

E-OBS datafiles 1950-01-01 to 2013-06-30 Version 9

The data files contain gridded data for 5 elements (daily mean temperature TG, daily minimum temperature TN, daily maximum temperature TX, daily precipitation sum RR and daily averaged sea level pressure PP). They cover the area: 25N-75N x 40W-75E. The data files are in compressed NetCDF format and range in size from 26Mb - 1.1Gb. There are 4 different versions: 2 grid resolutions x 2 grid flavours. Data is made available on a 0.25 and 0.5 degree regular lat-lon grid, as well as on a 0.22 and 0.44 degree rotated pole grid, with the north pole at 39.25N, 162W. The regular grid is the same as the monthly CRU data grids available from the Climatic Research Unit. The rotated grid is the same as used in many ENSEMBLES Regional Climate Models. Besides 'best estimate' values, separate files are provided containing daily standard errors and elevation. See Haylock et al. (2008) and van den Besselaar et al. (2011) for further details. The Global 30 Arc-Second Elevation Data Set (GTOPO30), a global raster Digital Elevation Model (DEM) with a horizontal grid spacing of 30 arc seconds (approximately 1 kilometer) developed by USGS is used for the elevation file.

Version 9.0	Best estimate	Daily standard error	Elevation
0.25 deg. regular grid	TG TN TX RR PP	TG TN TX RR PP	all elements
0.50 deg. regular grid	TG TN TX RR PP	TG TN TX RR PP	all elements
0.22 deg. rotated grid	TG TN TX RR PP	TG TN TX RR PP	all elements
0.44 deg. rotated grid	TG TN TX RR PP	TG TN TX RR PP	all elements

2.2.12.4 DATA ORIGIN

The gridded fields are based on the daily station data available in ECA&D (www.ecad.eu): daily station series obtained from climatological divisions of National Meteorological and Hydrological Services and station series maintained by observatories and research centres throughout Europe and the Mediterranean. For details of the individual data providers see the participants list. A comprehensive overview of all available data is provided in the data dictionary.

2.2.12.5 VALIDATION AND UNCERTAINTY ESTIMATE

The daily station observations on which E-OBS are based have not been homogenized before gridding.

Separate files are provided containing daily standard errors and elevation. See Haylock et al. (2008) and van den Besselaar et al. (2011) for further details. This estimation does not include the potential measurement errors, but only takes into account the interpolation errors by the gridding procedure.

2.2.12.6 CONSIDERATIONS FOR CLIMATE APPLICATIONS

Please look at <http://www.ecad.eu/FAQ/index.php> for specific questions on the data and its use.

Gridded datasets derived through interpolation of station data have a number of potential inaccuracies and errors. These errors can be introduced either by the propagation of errors in the station data or by limitations in the ability of the interpolation method to estimate grid values from the underlying station network. As part of the ENSEMBLES project, MeteoSwiss has evaluated the homogeneity of the station data (see Begert et al. 2008 under Project info) and Oxford University has evaluated the gridded E-OBS dataset (see Hofstra et al. 2009a,b under Project info). An important finding of the latter evaluation is that, in areas where relatively few stations have been used for the interpolation, both precipitation and temperature are over-smoothed. This leads to reduced interpolated values relative to the "true" area-averages, in particular for extremes.

2.2.12.7 INSTRUMENT OVERVIEW

The E-OBS data product is based on ECA&D data. All daily data in the ECA&D database are daily in-situ observations. The instrumentation may vary per data provider. The data dictionary provides for each station the data provider and a short station description. For detailed information on instrumentation the data provider should be contacted.

2.2.12.8 REFERENCES

For a complete list of publications see <http://www.ecad.eu/publications/index.php>

2.2.12.9 REVISION HISTORY

Version 1: Gé Verver, KNMI, 14 January 2014

2.3 Oceanic Datasets

2.3.1 Baltic Sea Automated Sea Ice

2.3.1.1 Intent of the Document

This document summarizes essential information needed for users of any level who wish to use the SEAICE_BAL_SEAICE_L4_NRT_ OBSERVATIONS_011_011/004 dataset for climate applications. This product(s) is a part of operational sea ice services in FMI and covers automated ice thickness and concentration charts which are produced by SAR data. Production is in FMI while data is provided by MyOcean project.

2.3.1.2 Point of Contact

Juha Karvonen, Finnish Meteorological Institute, Juha.Karvonen@fmi.fi

2.3.1.3 Data Field Description

For the Baltic Sea- The operational sea ice service at FMI provides ice parameters over the Baltic Sea. The parameters are based on ice chart produced on daily basis during the Baltic Sea ice season and show the ice concentration in a 1 km grid. Ice thickness chart (ITC) is a product based on the most recent available ice chart (IC) and a SAR image. The SAR data is used to update the ice information in the IC. The ice regions in the IC are updated according to a SAR segmentation and new ice thickness values are assigned to each SAR segment based on the SAR backscattering and the ice IC thickness range at that location.

The concentration is in %, thickness in cm, and ice deformation (0=no deformation, 1= rafted ice, 2= mildly ridged ice, 3= ridged ice, 4= extremely ridged ice, 5= brash ice barrier).

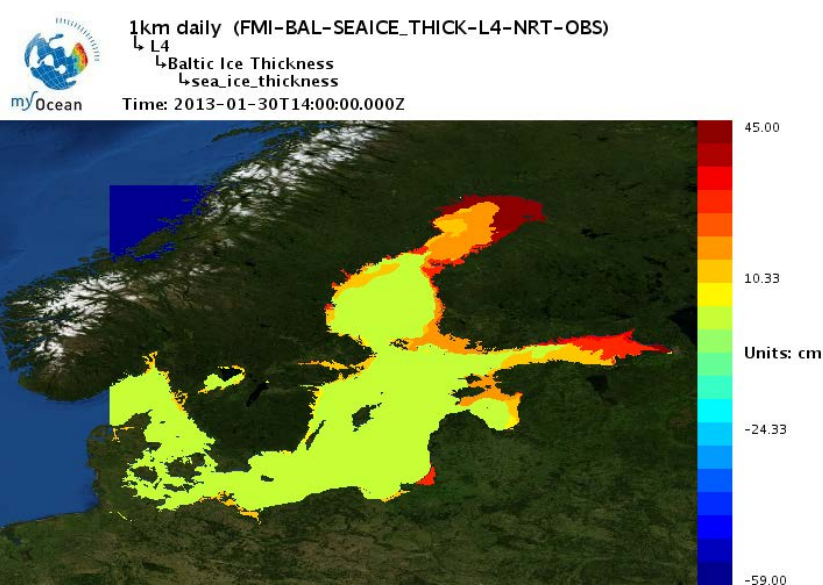


Figure 1: Sea Ice Thickness example on the date 30-01-2013

2.3.1.4 Data Origin

Sea ice concentration:

The operational sea ice service at FMI produces sea ice parameters based on a manual interpretation of satellite data and ground truth. The satellite data used are Synthetic Aperture Radar data from RADARSAT-2 and Envisat (until its failure in April 2012) and visual and infrared data from MODIS and NOAA. Ground truth is origin from Finnish and Swedish icebreakers, ships, ice observation stations of the Baltic ice services, ports, etc. The RADARSAT-2 data are in ScanSAR Wide mode dual polarization and each scene covers an area of about 500 x 500 km and is resampled to a spatial resolution of 100 meter. The scenes are mainly focused to the Baltic Sea, Kattegat and Skagerrak east of 9° E. The Envisat data were in WideSwath mode with a swath width of 450 km and were resampled to a spatial resolution of 150 meters. The data covered same area as RADARSAT-2 data. The MODIS and NOAA data covers the charting area several times each day and are resampled to 500 x 500 meter. The operator uses the latest available satellite data and ground truth producing the ice chart in an Ice Map production system. New gridded sea ice parameters are available every day during the Baltic Sea ice season around 14:00 UTC winter time and 13:00 UTC summer time at a spatial resolution of 1000 meter.

Sea ice thickness chart (ITC):

An ITC is produced after receiving a SAR image either from Envisat ASAR (until its failure in April 2012) or RADARSAT-2. The HH channel wide swath images are used to generate the product. The product covers the sea ice area covered by the SAR image. The resolution of the product is 500m. The product is based on the sea ice thickness history from the most recent IC available before the SAR. The SAR data are preprocessed by performing an incidence angle correction and speckle filtering. After this preprocessing a segmentation is performed and a segmentwise image autocorrelation feature is computed for the image. This textural feature is used to locate the open water areas. From the IC, ice thickness range is assigned to each SAR segment, i.e., a mapping of the SAR segments to IC segments is performed. This improves the spatial accuracy of the IC segments. After this, an ice thickness value is assigned to each SAR segment. This thickness value is dependent on the ice thickness range adopted from the IC and on the mean SAR segment backscattering such that higher SAR backscattering corresponds to thicker ice. Finally, the open water areas are updated according to the SAR open water classification.

PARAMETERS:

Inputs: IC (ice thickness history), georeferenced Envisat ASAR WSM or Radarsat-2 SCW (level 1b data) Resolution: 500m Coverage: SAR area (in the area of Baltic Sea) Since: Dec 2010 (depending on the existence of the Baltic Sea ice cover) Temporal resolution: Dependent on the received SAR data Units: cm For more information: J. Karvonen, M. Simila, I. Heiler, Ice Thickness Estimation Using SAR Data and Ice Thickness History, Proceedings of the IEEE International Geoscience and Remote Sensing Symposium 2003 (IGARSS 03), v. I, pp. 74-76, Toulouse, France, 2003.

2.3.1.5 Validation and Uncertainty Estimate

FMI validates ice thickness data and ice concentration data. Ice thickness is validated with ice thickness measurements made on board Finnish icebreakers. Ice concentration validation is made against the ASI algorithm (by the University of Bremen). The validation is performed twice for each season: the early winter validation in February (Dec-Jan data), and the late winter validation in May (Feb-Apr data), this six month period covers a typical Baltic ice season rather well. Detailed information on the validation can be found in Karvonen et al.

As the ice charts use 10% classes for the ice concentrations, the ice concentration subtractions between Finnish (FI) and Bremen (BR) ice concentration data were also classified in to 10% classes from $[-100, -90[$ to $[90, 100]$. The figure below shows the ice concentration distribution of the subtractions at individual dates and the mean distribution. Positive values mean that FI-product has provided higher concentrations than BR-product and vice versa. Therefore the fatter right tail indicates that the BR-product gives lower concentration values as the FI-product. However, the majority of the subtractions are between -10% and 10%. Hence, FI-product and BR-product results provide rather similar results.

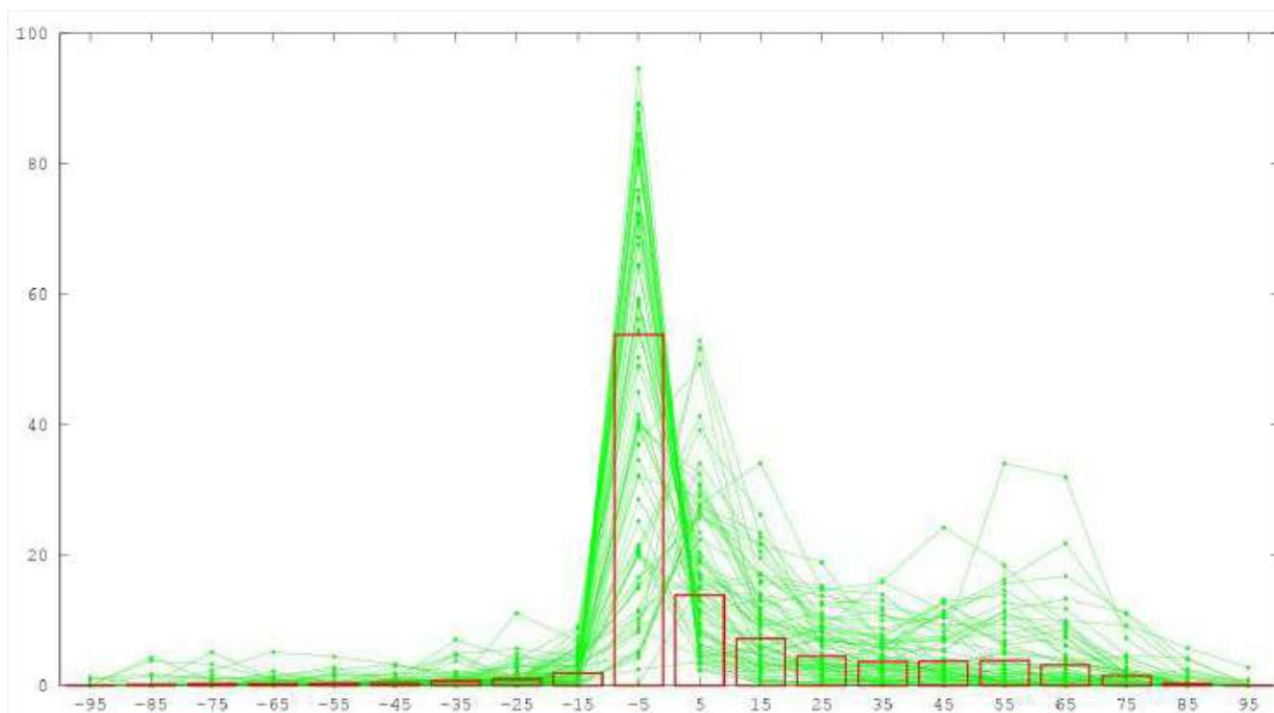


Figure 2: Distributions of the ice concentration subtractions between FMI-product and BR-product. Positive values indicate that FI-product is providing higher concentrations than BR-product and vice versa. At x-axis are the class centers of the 10% wide classes and y-axis values are in percentages.

The ice chart based ice thickness results were compared with ice thickness results measured on icebreakers. The SAR-based ice thickness results were compared with ice thickness results measured on Icebreakers. Several icebreaker measurements were excluded, because no matching SAR image was available.

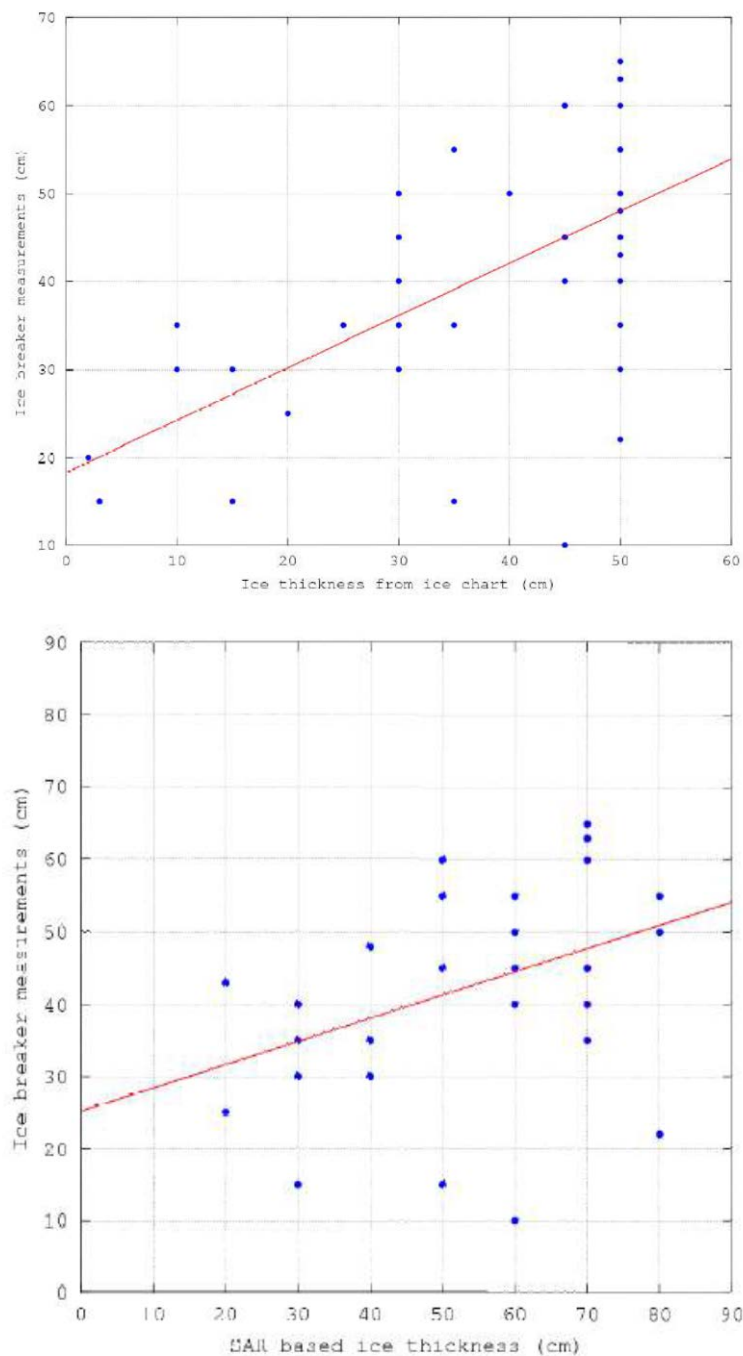


Figure 3: Ice thickness values from ice charts and ice breaker measurements in centimeters (up), SAR based ice thicknesses and ice breaker measurements in centimeters (down). Solid line is the fitted regression line by the least squares method.

2.3.1.6 Considerations for climate applications

While sea ice information can be used to validate climate models, the main purpose of the product is to supply information for the vehicles in Baltic Sea. Detailed information on sea ice conditions is crucial for navigation in ice-covered waters. The most important sea ice variables are the ice concentration, ice thickness, and the amount and height of ridges. Hence,

national operational ice services try to collect all available information on present ice conditions (ice analysis) and, with the help of prognostic dynamic–thermodynamic models, to forecast future ice conditions.

2.3.1.7 Instrument Overview

ASAR on Envisat:

An Advanced Synthetic Aperture Radar (ASAR), operating at C-band, ASAR ensures continuity with the image mode (SAR) and the wave mode of the ERS-1/2 AMI. It features enhanced capability in terms of coverage, range of incidence angles, polarisation, and modes of operation. This enhanced capability is provided by significant differences in the instrument design: a full active array antenna equipped with distributed transmit/receive modules which provides distinct transmit and receive beams, a digital waveform generation for pulse "chirp" generation, a block adaptive quantisation scheme, and a ScanSAR mode of operation by beam scanning in elevation.

Accuracy:

Radiometric resolution in range: 1.5-3.5 dB, Radiometric accuracy: 0.65 dB

Spatial Resolution:

Image, Wave and Alternating Polarisation modes: approx 30m x 30m. Wide Swath mode: approx 150m x 150m. Global Monitoring mode: approx.. 1000m x 1000m.

Swath Width:

Image and alternating polarisation modes: up to 100km, Wave mode: 5km, Wide swath and global monitoring modes: 400 km or more

Waveband:

Microwave: C-band, with choice of 5 polarisation modes (VV, HH, VV/HH, HV/HH, or VH/VV)

RADARSAT-2 SAR:

Launched in December 2007, Canada's next-generation commercial radar satellite offers powerful technical advancements that will enhance marine surveillance, ice monitoring, disaster management, environmental monitoring, resource management and mapping in Canada and around the world.

Active Antenna: C-Band

Centre Frequency: 5.405 Ghz

Bandwidth: 100 MHz

Antenna Dimensions: 15m x 1.5m

Polarization: HH, HV, VH, VV

Polarization Isolation: > 25 dB

Aperature Length: 15 m

Aperature width: 1,37 m

Mass: 750 kg

Deployment Mechanism: Extendable support structure

2.3.1.8 References

MyOcean Product Catalogue Overviews, MyOcean Website, www.myocean.met.no, 2014

MyOcean (2012), Product User Manual for Baltic Sea – Sea Ice Observations, Version 2.2.

MyOcean (2013), Quality Information Document for OSI TAC Sea Ice products, Version 1.5.

Karvonen, J-, Cheng, B., Vihma, T., Arkett, M., Carrieres, T., 2012. A method for sea ice thickness and concentration analysis based on SAR data and a thermodynamic model, *The Cryosphere*, Vol 6, 1507-1526.

Canadian Space Agency, RADARSAT-2, <http://www.asc-csa.gc.ca>, 2014

ESA, Earthnet Online – ASAR, <http://earth.esa.int>, 2014

2.3.1.9 Revision History

09-01-2014 – Version 1 – Context has changed for FMI Sea Ice products by Cemal Melih Tanis.

2.3.2 ESA-CCI SST Analysis

2.3.2.1 Intent of the Document

This document summarizes essential information for users of the ESA SST CCI Analysis long-term product version 1.0. The principal content of this dataset is global Sea Surface Temperature (SST).

The SST data are derived from infra-red imagery obtained from several Earth-observing satellite missions, combined to give daily, spatially complete information over the global oceans over 20 years.

The principal recommended applications are for climate research applications requiring ~20 years of stable, low bias records of SST. The dataset is particularly valuable if a representation of global SST is required that is independent of in situ SST measurements.

2.3.2.2 Point of Contact

Prof. Christopher Merchant, University of Reading, science.leader@sst-cci.org / c.j.merchant@reading.ac.uk.

2.3.2.3 Data Field Description

Full descriptions of the file data and metadata fields are given in the SST CCI Product User Guide (SST_CCI-PUG-UKMO-001) available from www.esa-sst-cci.org.

The key data content and the variable names are:

- Latitudes of the data points, *lat*
- Longitudes of the data points, *lon*
- Infilled (i.e., optimal interpolated) daily-mean estimates of sea surface temperature at a depth of 20 cm, *analysed_sst*
- Total uncertainty of the sea surface temperature at 20 cm depth, *analysis_error*

The geophysical fields are global, daily, at 0.05° latitude-longitude grid resolution.

Note: fill-values should be checked for, and scales and offsets need to be applied to obtain data in geophysical units.

2.3.2.4 Data Origin

Appendix 1 of the SST CCI Product User Guide (Good and Rayner, 2013) gives a six-page summary of how SST CCI data were produced. References to the scientific literature can also be found there, justifying the brief summary below.

Step 1. Retrieval of SST from satellite measurements.

Infra-red imagery is obtained from two series of sensors: the Advanced Very High Resolution Radiometers (AVHRRs) and the Along-Track Scanning Radiometers (ATSRs). The images are processed to exclude cloud pixels and sea-ice pixels, using a physics-based, probabilistic (Bayesian) method. For clear-sky pixels, the satellite observations (brightness temperatures) are used to infer sea surface temperature (SST), using a method based on radiative transfer calculations (optimal estimation). Thus, both cloud screening and SST estimation use simulations informed by numerical weather prediction fields (ERA-Interim re-analyses), although the influence of the prior fields on the SST retrieval is close to zero by design. The SST obtained reflects the temperature of the skin temperature of the ocean surface at the instant of observation. The optimal estimation retrievals from both the ATSRs and AVHRRs are cross-referenced / harmonized for mutual consistency to coefficient-based SSTs from an earlier ATSR-series dataset (described in Merchant et al., 2012, and references therein). All SSTs are thus independent from in situ observations (they are not tuned to any in situ data set).

Step 2. (ATSR only) Aggregation to 0.05° latitude-longitude cells.

The full resolution (1 km) SSTs from clear sky pixels are averaged within each 0.05° cell, which brings the ATSR and AVHRR-derived SSTs to comparable resolution. (AVHRR radiance data are both averaged and sub-sampled spatially prior to creation of the Level 1 input files used as input in SST CCI, and have a resolution of ~4 km at best.)

Step 3. Adjustments to depth SST at a standard local time.

The ocean surface has a daily cycle of temperature, with respect to which the satellite overpass times are not constant (particularly for AVHRRs). Unless adjusted for, aliasing of the diurnal cycle could cause trend artefacts in the record. Therefore, a physical model of the diurnal cycle is used to adjust the SST to a standard time, namely, the nearest of 1030 h or 2230 h local time for the longitude of the observation. At these local times, the diurnal cycle is on average close to the daily mean. Moreover, to facilitate use of the dataset in the longer historical context, the same physical model at the same time is used to give an adjustment from the skin SST to the SST at 20 cm, which is chosen to be representative of in situ measurements such as from drifting buoys and ships' buckets.

Step 4. Create spatially complete daily mean fields ("analysis")

The ATSR and AVHRR datasets are combined and interpolated/extrapolated in space and time as necessary to create the infilled dataset. This process is referred to in the relevant meteorological community as "analysis" and creates a dataset that may be referred to as an "L4" dataset. The SST analysis is performed by a sophisticated system for optimal interpolation ("OSTIA") run at the UK Met Office. Unlike the operational OSTIA products from the Met Office, the SST CCI analysis does not use in situ observations, and is therefore an independent satellite-only analysis. The SST depth fields are used as input, and the result is considered as an estimate of daily mean SST at a depth compatible with drifting buoy data.

2.3.2.5 Validation and Uncertainty Estimate

An uncertainty estimate is provided in the product for every SST. The uncertainty estimate is context-specific is not derived from or linked to validation activities for this dataset. Instead, both SST and SST uncertainty are validated. The validation results for both SST and SST uncertainty are fully reported in the SST CCI Product Validation and Intercomparison Report (Corlett et al., 2014). The validation was performed by SST CCI team members not involved in algorithm development and dataset production, and includes comparison against wholly independent SST datasets.

Validation activities:

1. Comparison of SSTs matched to various validation data sets (“reference data” in the PVIR). These include drifting buoys (“drifters”), the global tropical moored buoy array (GT MBA), the uppermost measurements from Argo profiling floats, and ship-borne radiometer measurements. (Skin-to-depth and time differences are accounted for such as to make comparisons like-for-like.) Summary statistics of differences are given below. Here “iDrifters” are a subset of drifting buoy measurements that were reserved within the project only for validation and not used at any other stage. GT MBA, Argo and radiometer measurements were also reserved data. (Other drifting buoy data were used earlier within the project for algorithm selection, but note that algorithms were not tuned to this data. The use of robust statistics downweights the influence of outliers, which may arise from either validation or satellite datasets; the PVIR gives more detail on the discrepancy distributions.)

Validation data	Number	Median (K)	Robust Std Deviation (K)
Drifters	2392462	+0.05	0.28
iDrifters	142902	+0.06	0.25
GT MBA	25492	+0.09	0.22
Argo	8867	+0.04	0.26
Radiometers	696	+0.05	0.46

2. Validation of the SST uncertainty estimates by considering the standard deviation of discrepancy relative to drifting buoys as a function of SST uncertainty. In the plot below, the standard deviation bars should line up with the dashed line if the uncertainty estimates are realistic. This shows that the uncertainty field does discriminate more and less certain data. (See PVIR for full explanation.)

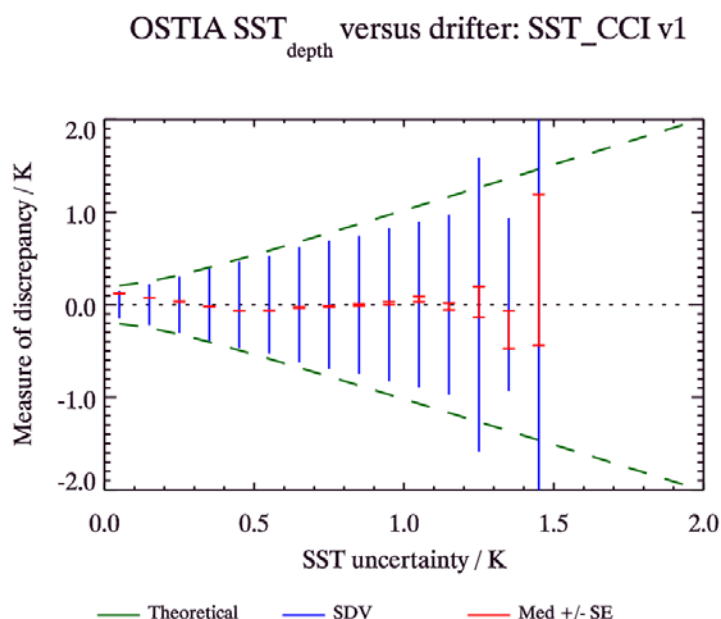


Fig 1. Validation of uncertainty estimates. Dashed line shows the envelope the data should fill for perfect SST uncertainty estimates in the products, given knowledge of the uncertainty of the validation data. Vertical lines show ± 1 standard deviation of satellite-validation differences as a function of estimate uncertainty in the SST analysis product. Vertical 'error bars' show the range of one standard error around the median for each bin.

3. Assessment of temporal stability of SST analysis against GTMBA. For the period 1995 to 2010 the SST CCI analysis is found to be stable relative to GTMBA to between 0.0001 and 0.0032 K yr^{-1} (95% confidence interval from fitting uncertainty of differences in dataset). An exception is a period of instability at the end of life of the first ATSR (early 1996). Prior to 1995, there is a trend associated with diminishing retrieval artifacts following the eruption of Mt Pinatubo. The timeseries of deseasonalised discrepancy is shown below. The lines are least-squares fits after and prior to 1995.

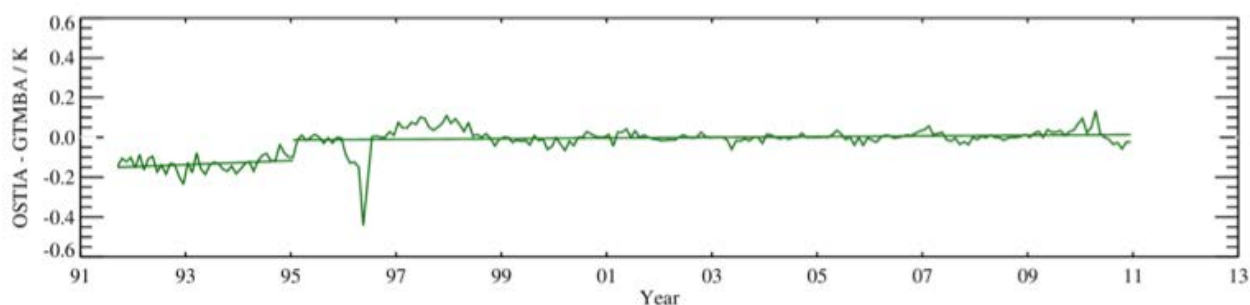


Fig 2. Stability of SST CCI analysis relative to the global tropical moored buoy array (calibrated moorings).

2.3.2.6 Considerations for climate applications

Experiences from trial climate applications are reported fully in the SST CCI Climate Assessment Report (Rayner et al., 2014). The report covers:

- Comparison of trends and variability in SST with other datasets
- Utility of the dataset for climate model assessment (example of the Hadley Centre)

- Utility for European Northwest Shelf Ocean Reanalysis
- Impact on high resolution atmospheric modelling (prescribed SST runs)
- Assessment of SST feature resolution in the dataset
- Utility for assessing modes of SST variability
- Utility in investigating links of SST variability to hydrological cycle
- Utility in diagnosis of ocean model errors

Uncertainty of the SST varies (e.g., uncertainty increases for times and places where persistent cloud limits the number of underlying ATSR and AVHRR observations). However, this variability in uncertainty is captured realistically by the associated SST uncertainty field (see above §3). Note that, conversely, SST values that have very low uncertainty (e.g., <0.2 K) are identified, which may be useful in identifying biases in other data sets and/or models.

The data set is intended to be free of issues related to aliasing of the diurnal cycle, an adjustment for which has been made. The assessment activities suggest that the SST analysis gives a very “clean” picture of SST variability on monthly to inter-annual time scales.

2.3.2.7 Instrument Overview

The ATSRs and AVHRRs are imaging radiometers, including wavelengths sensitive to the thermal emission from the sea surface (broad channels centred on 3.7, 11 and 12 μm). The ATSRs are improved relative to the older AVHRR design for climate applications, in that (i) they have two-point calibration using highly stable black bodies, and (ii) view the surface through the atmosphere at two different angles to increase the information content on SST.

2.3.2.8 References

Corlett, G. K., Atkinson, C. and others (2014). Product Validation and Intercomparison Report (PVIR). Doc Ref SST_CCI-PVIR-UoL-001. Available from www.esa-sst-cci.org.
Good, S., and Rayner, N. (2013). SST CCI Product User Guide. Doc Ref SST_CCI-PUG-UKMO-001. Available from www.esa-sst-cci.org.
Merchant, C. J., O. Embury, N. A. Rayner, D. I. Berry, G. Corlett, K. Lean, K. L. Veal, E. C. Kent, D. Llewellyn-Jones, J. J. Remedios, and R. Saunders (2012), A twenty-year independent record of sea surface temperature for climate from Along Track Scanning Radiometers, J. Geophys. Res., 117, C12013, doi:10.1029/2012JC008400.
Rayner, N., Kennedy, J., and others (2014). ESA SST CCI Climate Assessment Report. Doc Ref SST_CCI-CAR-UKMO-001. Available from www.esa-sst-cci.org.

2.3.2.9 Revision History

Version	Date	Author	Reviewed by
0.1	13/1/2014	C J Merchant	G K Corlett

2.3.3 ESA CCI SST AVHRR

2.3.3.1 Intent of the Document

This document summarizes essential information for users of the ESA SST CCI AVHRR L2P long-term product version 1.0. The principal content of this dataset is global Sea Surface Temperature (SST) as estimated from Advanced Very High Resolution Radiometer (AVHRR) imagery.

The principal recommended applications are climate research applications requiring ~20 years of global SSTs observed by satellite, with no gap-filling/interpolation. Since the SSTs are harmonized independently of in situ observations, use is recommended for applications where it is beneficial to have SST datasets that are independent. Skin and depth SSTs are distinguished and both are provided.

2.3.3.2 Point of Contact

Prof. Christopher Merchant, University of Reading, science.leader@sst-cci.org / c.j.merchant@reading.ac.uk.

2.3.3.3 Data Field Description

Full descriptions of the file data and metadata fields are given in the SST CCI Product User Guide (SST_CCI-PUG-UKMO-001) available from www.esa-sst-cci.org.

The key data content and the variable names are:

- Latitudes of the data points, *lat*
- Longitudes of the data points, *lon*
- Sea surface temperature of the skin at time of satellite observation, *sea_surface_temperature*
- Total uncertainty of the skin sea surface temperature, *sses_standard_deviation*
- Sea surface temperature at 20 cm depth and standardized local time (1030 h or 2230 h), *sea_surface_temperature_depth*
- Total uncertainty of the sea surface temperature at 20 cm depth, *sst_depth_total_uncertainty*
- Standard flags for quality, location type

The SSTs are given on the satellite projection at the resolution of “Global Area Coverage” (GAC) files from AVHRR, which is a best resolution ~4 km at nadir view.

Note: fill-values should be checked for, and scales and offsets need to be applied to obtain data in geophysical units.

2.3.3.4 Data Origin

Appendix 1 of the SST CCI Product User Guide (Good and Rayner, 2013) gives a six-page summary of how SST CCI data were produced. References to the scientific literature can also be found there, justifying the brief summary below. An algorithm theoretical basis document (Merchant et al., 2013) is also available.

Infra-red imagery is obtained from the Advanced Very High Resolution Radiometers (AVHRRs) in the form of GAC orbit files. The images are processed to exclude cloud pixels and sea-ice pixels, using a Bayesian method. For clear-sky pixels, the satellite observations (brightness temperatures) are used to infer sea surface temperature (SST), using a method based on radiative transfer calculations (optimal estimation). Thus, both cloud screening and SST estimation use simulations informed by numerical weather prediction fields (ERA-Interim re-analyses), although the influence of the prior fields on the SST retrieval is close to zero by design. The SST obtained reflects the temperature of the skin temperature of the ocean surface at the instant of observation. The optimal estimation retrievals from AVHRRs are cross-referenced / harmonized for mutual consistency to coefficient-based SSTs from an earlier ATSR-series dataset (described in Merchant et al., 2012, and references therein). All SSTs are thus independent from in situ observations (they are not tuned to any in situ data set).

The ocean surface has a daily cycle of temperature, with respect to which the satellite overpass times are not constant (particularly for AVHRRs). Unless adjusted for, aliasing of the diurnal cycle could cause trend artefacts in the record. Therefore, a physical model of the diurnal cycle is used to adjust the SST to a standard time, namely, the nearest of 1030 h or 2230 h local time for the longitude of the observation. At these local times, the diurnal cycle is on average close to the daily mean. Moreover, to facilitate use of the dataset in the longer historical context, the same physical model at the same time is used to give an adjustment from the skin SST to the SST at 20 cm, which is chosen to be representative of in situ measurements such as from drifting buoys and ships' buckets.

2.3.3.5 Validation and Uncertainty Estimate

An uncertainty estimate is provided in the product for every SST. The uncertainty estimate is context-specific and is not derived from validation activities. Instead, both SST and SST uncertainty are validated. The validation results for both SST and SST uncertainty are fully reported in the SST CCI Product Validation and Intercomparison Report (Corlett et al., 2014). The validation was performed by SST CCI team members not involved in algorithm development and dataset production, and includes comparison against wholly independent SST datasets.

Validation activities:

1. Comparison of SSTs matched to various validation data sets ("reference data" in the PVIR). These include drifting buoys, the results for which are shown below. The drifting buoy data were used earlier within the project for algorithm selection, but note that selected algorithms were not tuned to any in situ data. The results are presented per sensor. The use of robust statistics downweights the influence of outliers, which may arise from either validation or satellite datasets; the PVIR gives full detail on the discrepancy distributions.

AVHRR	Retrieval	Number	Median (K)	RSD (K)
Metop A	<i>Day</i>	130150	-0.02	0.37
	<i>Night</i>	133619	+0.08	0.26
NOAA 18	<i>Day</i>	203490	-0.05	0.43
	<i>Night</i>	167294	+0.14	0.29
NOAA 17	<i>Day</i>	335985	+0.03	0.40
	<i>Night</i>	305926	+0.08	0.28
NOAA 16	<i>Day</i>	189813	+0.05	0.47
	<i>Night</i>	172481	+0.16	0.33
NOAA 15	<i>Day</i>	70214	+0.04	0.52
	<i>Night</i>	66446	+0.12	0.43
NOAA 14	<i>Day</i>	26933	+0.09	0.49
	<i>Night</i>	22856	+0.19	0.38
NOAA 12	<i>Day</i>	12852	+0.08	0.58
	<i>Night</i>	6430	+0.04	0.54

2. Validation of the SST uncertainty estimates is done by considering the standard deviation of discrepancy relative to drifting buoys as a function of SST uncertainty. In the plot below, the standard deviation bars should line up with the dashed line if the uncertainty estimates are realistic. This shows that the uncertainty field does effectively discriminate more and less certain data obtained at night (right), but generally over-estimates the uncertainty for SSTs obtained during daytime. (See PVIR for full discussion.) This analysis is for the series of AVHRRs as a whole.

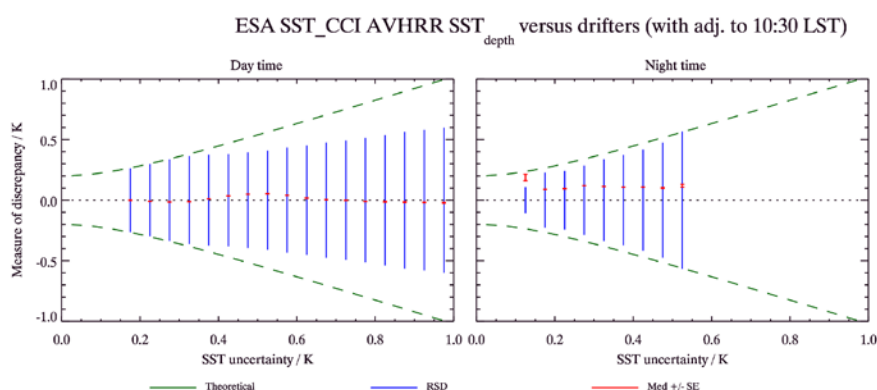


Fig 1. Validation of uncertainty estimates. Dashed line shows the envelope the data should fill for perfect SST uncertainty estimates in the products, given knowledge of the uncertainty of the validation data. Vertical lines show ± 1 standard deviation of satellite-validation differences as a function of estimate uncertainty in the SST analysis product. Vertical 'error bars' show the range of one standard error around the median for each bin.

3. Assessment of temporal stability of SST analysis against GTMBA. For the period 1995 to 2010 the SST CCI analysis is found to be stable relative to GTMBA as follows:

Daytime SSTs: 95% confidence interval is -0.012 to -0.007 K yr⁻¹
Night-time SSTs: 95% confidence interval is -0.002 to $+0.002$ K yr⁻¹
(95% confidence interval is from fitting uncertainty of differences in dataset). An exception is a period of instability at the end of life of the first ATSR (early 1996). Prior to 1995, there is a trend associated with diminishing retrieval artifacts following the eruption of Mt Pinatubo and also effects of significant periodic instability of the NOAA-12 AVHRR. The timeseries of deseasonalised discrepancy is shown below. The lines are least-squares fits after and prior to 1995.

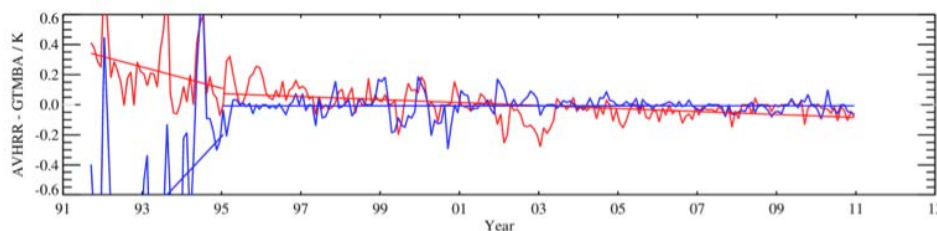


Fig 2. Stability of SST CCI AVHRR L2P relative to the global tropical moored buoy array (calibrated moorings).

2.3.3.6 Considerations for climate applications

Experiences from trial climate applications are reported fully in the SST CCI Climate Assessment Report (Rayner et al., 2014). The report covers:

- Comparison of trends and variability in SST with other datasets
- Utility of the dataset for climate model assessment (example of the Hadley Centre)
- Utility for European Northwest Shelf Ocean Reanalysis
- Impact on high resolution atmospheric modelling (prescribed SST runs)
- Assessment of SST feature resolution in the dataset
- Utility for assessing modes of SST variability
- Utility in investigating links of SST variability to hydrological cycle
- Utility in diagnosis of ocean model errors

The unresolved instability of NOAA-12 calibration suggests use of data from NOAA-14 (1995) onwards for this version of the SST CCI AVHRR dataset.

2.3.3.7 Instrument Overview

The AVHRRs are imaging radiometers, including wavelengths sensitive to the thermal emission from the sea surface (broad channels centred on 3.7, 11 and 12 μm). The calibration design is not optimized for climate application of the data, hence the need to cross-reference the AVHRR data to the ATSR-series data and/or undertake other means of harmonization to improve stability.

2.3.3.8 References

Corlett, G. K., Atkinson, C. and others (2014). Product Validation and Intercomparison Report (PVIR). Doc Ref SST_CCI-PVIR-UoL-001. Available from www.esa-sst-cci.org.
Good, S., and Rayner, N. (2013). SST CCI Product User Guide. Doc Ref SST_CCI-PUG-UKMO-001. Available from www.esa-sst-cci.org.

Merchant, C. J., O. Embury, N. A. Rayner, D. I. Berry, G. Corlett, K. Lean, K. L. Veal, E. C. Kent, D. Llewellyn-Jones, J. J. Remedios, and R. Saunders (2012), A twenty-year independent record of sea surface temperature for climate from Along Track Scanning Radiometers, *J. Geophys. Res.*, 117, C12013, doi:10.1029/2012JC008400.

Merchant, C. J., and others (2013). SST CCI Algorithm Theoretical Basis Document v2. Doc Ref SST_CCI-ATBDV2-UOE-001. Available from www.esa-sst-cci.org.

Rayner, N., Kennedy, J., and others (2014). ESA SST CCI Climate Assessment Report. Doc Ref SST_CCI-CAR-UKMO-001. Available from www.esa-sst-cci.org.

2.3.3.9 Revision History

Version	Date	Author	Reviewed by
0.1	13/1/2014	C J Merchant	

2.3.4 HadISST1

2.3.4.1 Intent of the Document

This document summarizes essential information for users of the Met Office Hadley Centre's sea ice and sea surface temperature (SST) data set, HadISST1. It is a combination of monthly globally-complete fields of SST and sea ice concentration on 1 degree latitude-longitude grid from 1870 to date. Fields for the month-before-last are added to the data set on the 2nd of every new month (for users who need faster updates, there is a preliminary version available earlier). The principal recommended application is climate research.

2.3.4.2 Point of Contact

John Kennedy, Met Office Hadley Centre, john.kennedy@metoffice.gov.uk

2.3.4.3 Data Field Description

Full description of HadISST1 is available at <http://www.metoffice.gov.uk/hadobs/hadisst/>

2.3.4.4 Data Origin

The SST data are taken from the Met Office Marine Data Bank (MDB), which from 1982 onwards also includes data received through the Global Telecommunications System (GTS). In order to enhance data coverage, monthly median SSTs for 1871-1995 from the Comprehensive Ocean-Atmosphere Data Set (COADS) (now ICOADS) were also used where there were no MDB data. The sea ice data are taken from a variety of sources including digitized sea ice charts and passive microwave retrievals.

HadISST1 temperatures are reconstructed using a two stage reduced-space optimal interpolation procedure, followed by superposition of quality-improved gridded observations onto the reconstructions to restore local detail. The sea ice fields are made more homogeneous by compensating satellite microwave-based sea ice concentrations for the impact of surface melt effects on retrievals in the Arctic and for algorithm deficiencies in the Antarctic, and by making the historical in situ concentrations consistent with the satellite data. SSTs near sea ice are estimated using statistical relationships between SST and sea ice concentration.

2.3.4.5 Validation and Uncertainty Estimate

No formal uncertainty estimates are provided with the HadISST1 fields.

Formal uncertainty estimates are provided with successors of components of HadISST1, e.g. the gridded in situ measurements contained within HadSST3 (see <http://www.metoffice.gov.uk/hadobs/hadsst3/>). These can be used as an indication of where HadISST1 is based on actual observations and where it is inferred and can be used to indicate the uncertainty in those gridded observations. (A new version of the HadISST analysis, HadISST2 is under development and does indicate uncertainty through the provision of an ensemble of ten interchangeable realisations of the analysis for each month, or pentad.)

Validation of various aspects of the fields is provided by the many uses to which HadISST1 has been put, e.g. in driving atmosphere-only simulations and reproducing past climate which can be independently verified by comparison to independent land air temperature data. Indeed, direct comparisons to independent marine air temperature data have also verified long term changes seen in HadISST1.

The journal paper describing the data set (Rayner et al., 2003) includes comparison to other climate SST analyses, which support the variations seen in HadISST1.

2.3.4.6 Considerations for climate applications

Many users have found the SST and sea ice fields in HadISST1 to be of benefit to their research. At the time of writing, the journal paper describing it has been cited over 2,800 times, according to the Web of Science.

Despite efforts during the development of HadISST1, various discontinuities exist in the sea ice fields, particularly in the last two decades. Documentation of these is found on <http://www.metoffice.gov.uk/hadobs/hadisst/>. These have largely been introduced as the data set has been updated with new data sources. A new sea ice analysis is currently under development and a prototype is documented in Titchner and Rayner (2014).

2.3.4.7 Instrument Overview

Instruments used in the construction of HadISST1 are many and various, both measuring in situ and remotely, and include:

For SST

- Voluntary Observing Ships
- Drifting buoys
- Moored buoys
- Sub-surface observing platforms such as XBTs, CDTs, etc
- Advanced Very High Resolution Radiometer

For sea ice

- Scanning Multichannel Microwave Radiometer
- Special Sensor Microwave Imager
- Advanced Microwave Scanning Radiometer
- Manually constructed sea ice charts based on various observations, e.g. from ships and aircraft.

Measurements from these diverse sources have been brought together and made into a homogeneous record through the application of corrections to account for relative biases between them.

2.3.4.8 References

Rayner, N. A.; Parker, D. E.; Horton, E. B.; Folland, C. K.; Alexander, L. V.; Rowell, D. P.; Kent, E. C.; Kaplan, A., 2003: Global analyses of sea surface temperature, sea ice, and night marine air temperature since the late nineteenth century. J. Geophys. Res., Vol. 108, No. D14, 4407 10.1029/2002JD002670.

Titchner, H.A. and N. A. Rayner, 2014: The Met Office Hadley Centre Sea Ice and Sea-Surface Temperature data set, version 2, part 1: Sea ice concentrations. Geophys. Res –Atmospheres, Vol. 119, Issue: 6, 2864-2889, doi: 10.1002/2013JD020316.

2.3.4.9 Revision History

Version	Date	Author	Reviewed by
0.1	04/05/2015	Viju John	Nick Rayner
1.0	03/06/2015	Nick Rayner	Jörg Schulz

2.3.5 ESA CCI Ocean Colour

2.3.5.1 Intent of the Document

This document summarizes essential information needed for use of the ESA OC CCI data set for climate applications. The Ocean Colour ECV is providing ocean colour data, with a focus on Case 1 waters, which can be used by climate change prediction and assessment models. The dataset is created by band-shifting and bias-correcting atmosphere corrected MERIS and Aqua MODIS data to match SeaWiFS data, merging the datasets and computing per-pixel uncertainty estimates.

2.3.5.2 Point of Contact

Science lead: Shubha Sathyendranath, PML
General e-mail contact: help@esa-oceancolour-cci.org

2.3.5.3 Data Field Description

The OC CCI data set is described in the Product User Guide (PUG) that can be found at <ftp://oc-cci-data:ELaiWai8ae@ftp.rsg.pml.ac.uk/occci-v1.0/documentation/>

The outputs of the OC CCI processing chain are level 3 mapped daily composites, generated from multiple sensors, with a spatial resolution of 4 km/pixel. The data are multiple sensor merged with input data: SeaWiFS 1997-2010, MERIS 2002-2012 and Aqua MODIS 2002-2014. The products produced are shown in the following table

Name	Description	Unit
CHLOR_A	Phytoplankton chlorophyll- concentration	mg Chl-a m ⁻³
RRS	Remote sensing reflectance at 6 wavelengths Rrs and water class product subset	sr ⁻¹
IOP	Inherent optical properties (absorption and backscatter) at 6 wavelengths	m ⁻¹
K_490	Vertical attenuation coefficient at 490nm (Kd490)t	m ⁻¹

Further details can also be found in the Products Specification Document at <http://www.esa-oceancolour-cci.org/?q=documents#4>

2.3.5.4 Data Origin

A very brief overview of the major CCI processing stages is given here; for more detail, please refer to the OC CCI SPD and DPM.

The input EO datasets were MERIS L1b 3rd reprocessing (including OCL fixes), MODIS R2013.1 level 3 binned (4km) on a sinusoidal grid, SeaWiFS level 1a GAC (4km) R2010.0.

MERIS was processed with the POLYMER algorithm (v2.7.0) to level 2 and binned to level 3 4km (sinusoidal grid) with the BEAM binner, and flagged using the IDEPIX cloud and land masks.

SeaWiFS L1a was processed to level 3 binned (4km) with SeaDAS 7.0, since no 4km download was available. Standard SeaDAS flags were used. MODIS was not processed, as a suitable 4km level 3 binned dataset was available from NASA.

MODIS and MERIS were band shifted to the six main SeaWiFS bands (412, 443, 490, 510, 555, 670nm) by computing QAA IOPs and back computing the Rrs bands using a high-resolution spectral model. The output Rrs for 412-555nm were cleaned of any negative values, with the data items removed. Negative Rrs values in the 670nm band frequently occur due to low signal levels, and these were clamped to zero. Nothing was done to the SeaWiFS data.

The band shifted MERIS and MODIS Rrs were corrected to remove gross differences (biases) against SeaWiFS Rrs. The correction was done on a per-pixel basis using a 2003-2007 climatology to compute bias adjustments at every location where all sensors had gathered data.

The individual sensor data were merged with a simple average.

A range of products were computed from the merged Rrs, directly using the algorithms in SeaDAS (with the exception of Kd490, which was implemented independently for v1.0). Algorithms were selected from the best performers in the round-robin evaluation.

All data are re-projected onto a geographic grid, metadata added, product subsets created, PNG quicklooks created.

2.3.5.5 Validation and Uncertainty Estimate

A detailed description of the Uncertainty characterisation is available in the OC CCI Uncertainty Characterisation Document (UCD) and product validation is described in the Product Validation and Intercomparison Report (PVIR) available at <http://www.esa-oceancolour-cci.org/?q=documents#>. Note that both documents will be updated during January 2014

Per-pixel uncertainty estimates were computed following Moore et al (2009). In short, the membership of every pixel in 9 water classes was computed, then a pixel-specific total uncertainty was computed using these memberships and a table of uncertainties per class. The uncertainty tables were computed from matchups between the CCI V1 data and a database in-situ data for each of the products noted above.

2.3.5.6 Considerations for climate applications

The suitability of the OC CCI products for climate applications is given in detail in the Climate Assessment Report that should be ready by the end of January. This included comparison with in situ data; time series analysis; comparison with other ocean colour products; data assimilation into ecosystem models; and model skill assessment.

A number of issues with the current version 1 of the product is given in section 5 of the PUG. Furthermore, it should be noted the V1 product is optimized for case 1 water (open ocean and stratified shelf waters) and is less accurate at high latitudes where the air mass (between the satellite pixel and sensor) is high.

2.3.5.7 Instrument Overview

Briefly, sensors in space measure radiance exiting the atmosphere. This signal must be corrected for atmospheric scattering and atmospheric absorption to retrieve the signal leaving the ocean. Algorithms then use the relative magnitude of radiance (or remote sensing reflectance) in differing wavelengths to infer in-water properties such as chl-a. A full description of the measurement principle for ocean colour can be found at the IOCCG web site via the report series http://www.ioccg.org/reports_ioccg.html.

2.3.5.8 References

Moore, TS, Campbell, JW, Dowell, MD, 2009. A class-based approach to characterizing and mapping the uncertainty of the MODIS chlorophyll product. Remote Sensing of Environment, 113: 2424-2430

2.3.5.9 Revision History

21-01-2014 - Version 1 – Initial draft created by PML.

2.3.6 ESA CCI Sea-Ice-Concentration

2.3.6.1 Intent of the Document

This document introduces the Sea Ice Concentration (SIC) data set processed in the ESA CCI Sea Ice project in 2014 (SICCI). Contribution of the EUMETSAT OSISAF to the production of this data set is acknowledged. It is a global SIC product with per-grid cell uncertainties, covering 1992-2008. The main user groups are climate scientists and modelers. Since sea ice is a sensitive climate indicator with large seasonal and regional variability, the climate research community requires long-term and regular observations of the key ice parameters in both Arctic and Antarctic. Although it is shorter than the SIC data set delivered by the EUMETSAT OSISAF, it was shown to be more accurate in the overlap period. It can be useful for process studies or research that does not require the full time-series from 1978 to recent years.

2.3.6.2 Point of Contact

CCI Sea Ice Project Leader:

Stein Sandven, Nansen Environmental and Remote Sensing Centre, Bergen, Norway,
stein.sandven@nersc.no.

SIC Principal Investigator: Leif Toudal Pedersen, Danish Meteorological Institute, Copenhagen, Denmark, lt@dmu.dk

2.3.6.3 Data Field Description

Technical product specification is given in the Product User Guide (Laverne and Rinne, 2014) available at http://esa-cci.nersc.no/?q=webfm_send/170.

Variable name	Sea Ice Concentration
Units	%
Temporal coverage	1992 – 2008
Spatial Coverage	Global (polar regions)
Temporal Sampling	Daily
Spatial Sampling	25 km
Per-pixel uncertainty	yes

The distributed product contains daily gridded maps of SIC and its uncertainties (both in % from 0 to 100) for Northern (NH) and Southern (SH) hemispheres, each file including:

- Date and time for the daily product;
- Latitude and longitude for each grid point;
- Map of analyzed, daily averaged SIC;
- Map of processing (*aka* status) flags;

- Three maps of uncertainties as standard deviations of a gaussian uncertainty model (total, algorithm, and smear uncertainties);
- Map of SIC values retrieved outside the physical range of 0%-100%;
- Metadata information, both pertaining to the given date, and to the whole time-series.

2.3.6.4 Data Origin

SIC was estimated from Earth brightness temperatures (Tbs) retrieved by satellite sensors at 19 GHz vertical polarization (19V) and 37 GHz vertical and horizontal polarizations (37V and 37H). These channels have been available since 1979, allowing for consistent SIC time-series.

The OSISAF/SICCI processing SIC scheme features:

- An optimal blending of two well-known algorithms: Bootstrap frequency mode at low SIC values (Comiso, 1986) and Bristol (Smith, 1996) at high SIC.
- Dynamic tuning of the algorithms coefficients (aka dynamic tie-points).
- Atmospheric correction of the Tbs with Radiative Transfer Model (RTM) and selected ERA Interim fields (see below).
- Per-pixel transfer uncertainty from satellite measurements to final gridded product (see next section).

RTM-based correction of the Tbs, using ERA-Interim re-analysis data

In order to reduce the noise due to atmospheric and surface processes, the input Tbs were undergone atmospheric correction based on RTM (Meissner and Wentz, 2012; Wentz, 1997). 3-hourly fields of 10 m wind speed, total columnar water vapour, and 2 m air temperature from the ECMWF ERA-Interim Numerical Weather Prediction (NWP) re-analysis were used in this process.

Dynamic tuning of the tie-points

For coping with synoptic, seasonal, and inter-annual variations of the typical sea ice emissivities, the processing method includes a dynamic tuning of the algorithms coefficients (aka tie-points) against known targets. This technique is also meant to reduce the impact of sensor drift, inter-mission calibration, and trends in the ERA-Interim fields.

Input data

The SIC data set was processed from the SSM/I Fundamental Climate Record of the EUMETSAT Climate SAF V001 (1987-2008) (Fennig, et al. 2013). Data from the F08 satellite was not processed due to some flagging issues in the FCDR (since then corrected). The resulting SIC time-series thus covers 1992-2008.

2.3.6.5 Validation and Uncertainty Estimate

Validation against ground truth

SICCI SIC data were validated for / compared with: SIC = 0% and SIC = 100% (NH and SH), Landsat optical imagery (NH), and ASPeCt protocol visual ship-based observations (SH).

Table 5.1: Validation results* for daily SICCI SIC 1992-2008, SSM/I **

		Accuracy	Precision	Uncertainty
Northern Hemisphere	Open water	$0.4 \pm 0.1\%$	$2.2 \pm 0.3\%$	2.6%
	Sea ice	-1.3%	2.8 to 3.1%	3.1%
Southern Hemisphere	Open water	$0.1 \pm 0.1\%$	$1.9 \pm 0.2\%$	2.7%
	Sea ice	- 0.3%	3.1 to 3.4%	3.6%

* Note that these results are based on the full distribution of SIC values, i.e. include the off-range values (see product description).

** Special Sensor Microwave Imager

SICCI SIC agrees with Landsat SIC within 1% when taking the thin ice fraction into account. The SIC and uncertainties do not have inconsistencies due to sensor changes. The uncertainties are free of a trend, but have a seasonal cycle, which can be explained by the influencing environmental factors.

Per-grid cell uncertainties

The maps of uncertainties are obtained as a combination of two error sources:

1. The algorithm uncertainty (aka *tie-point* uncertainty). This term takes into account the uncertainty in the coefficients to the SIC algorithms. At low SIC, the uncertainties are mainly due to remaining atmospheric noise, due to an imperfect correction scheme or input (ERA-Interim) data. At high SIC, ice types, snow depth and snow layering are the main source of uncertainties. All these contributions are summarized in the tie-point uncertainties, and propagated through the SIC algorithms to the algorithm uncertainty. This uncertainty is computed on swath satellite data, thus before gridding and averaging into daily maps.
2. The smearing + gridding + geolocation error. This groups the effects of antenna mismatch (the 19 GHz and 37 GHz do not image exactly the same area on the Earth surface), the geolocation uncertainty (uncertainty on where the satellite exactly points to), and the gridding uncertainty (transforming a set of swath-based SIC values into a single daily gridded $25 \text{ km} \times 25 \text{ km}$ value). All these three contributions will have most effects in regions with strong gradients, typically along the ice edge and marginal ice zone. This term is thus parametrized by the local 3×3 standard deviation of the gridded SIC field, and has largest values at the ice edge.

2.3.6.6 Considerations for climate applications

Coastal SIC values

The SIC values were used to compute sea ice area (SIA) and extent (SIE). The resulting time series were compared with independent estimates of SIA and SIE. SICCI SIA and SIE are smaller than computed, for instance, from the NSIDC SIC CDR, particularly during summer. Largest differences in the SIA and SIE between SICCI and other products occur near coasts. These are caused by different land masks and different yet sub-optimal approaches to correct for the land-spillover effect. SIC estimates close to the coast are recommended to be used with caution and are flagged accordingly in the SICCI SIC product.

Residual noise over open water

SICCI does not categorically filter away artificial SIC patches over open water caused by weather effects because the aim is to keep low SIC where it actually occurs. These artificial SIC patches may occur in the belt of open water bordering with the ice cover. These patches may cause a residual non-zero average SIC over open water when averaged and could also contribute to SIA and SIE if the SIC threshold used to compute these is set to $< 15\%$. These SIC patches cannot be flagged yet by the additional information (uncertainty, flags) provided with the SICCI SIC product. It should be noted that these patches are statistical realization of the gaussian uncertainty model with standard deviation provided in the uncertainty variables. Such gaussian model will allow events of large SIC (0.01% events above $3 \times \text{sigmas}$).

Summer ice concentration and melt-ponding

Virtually all SIC algorithms based on the passive microwave (PMR) channels around 19GHz, 37GHz, and 90GHz are very sensitive to melt-pond water on top of the ice. This data set is no exception. The depth of the emitting layer at these wavelengths indeed do not allow for distinguishing between ocean water (in leads) and melt water (in ponds). This is the main reason why these SIC data sets are underestimating SIC during summer. They actually provide ice surface fraction, i.e. area of ice not covered with melt ponds.

Thin sea ice

Concentration of thin sea-ice (5-30cm) is underestimated by most of the “classic” PMR SIC algorithms, due to the radiometric contribution of water below the ice. A complete, 100% cover of thin sea-ice indeed does not act as a radiometric insulator for the PMR frequencies around 19 and 37 GHz that are the base for this SICCI data set, and many others.

Interpolation of missing values

The SICCI SIC data set aims at addressing needs from all users needing access to climate sea ice concentration data, from interested general public to climate modelers. Like for the OSISAF data set, it was decided to provide interpolated, temporally and spatially, SIC values in places where original input satellite data were missing, aiming at most complete daily maps. Interpolated grid cells are clearly identified in the status_flag layer (see later section). These values should generally not be used for scientific applications, especially the ones obtained from spatial interpolation.

Grid spacing and resolution

The SICCI SIC products are delivered with a grid spacing of 25 km. Since the footprint of the SSM/I channel at 19.35 GHz is roughly an ellipse of 45 km $\times$ 70 km diameter, and since no attempt was made in the SICCI data set to use “Resolution Enhancement” techniques, the true resolution of the SSM/I data set is expected to be larger than the 25 km grid spacing.

2.3.6.7 Instrument Overview

SSM/I was used to produce the data set. The instrument is carried onboard satellites of the Defense Meteorological Satellite Program (DMSP). The SSM/I is a seven-channel, four-frequency, orthogonally polarized, passive microwave radiometric system that measures atmospheric, ocean and terrain microwave Tbs at 19.35, 22.2, 37.0, and 85.5 GHz frequencies in vertical and horizontal polarizations (except 22.2 GHz available only in

vertical). The SSM/I rotates continuously about an axis parallel to the local spacecraft vertical and measures the upwelling scene Tbs. The absolute Tb of the scene incident upon the antenna is received and spatially filtered by the antenna to produce an effective input signal or antenna temperature at the input of the feed horn antenna. The DMSP F10-11 and F13-15 satellites, used to produce this data set, are flown in a near-circular, sun-synchronous, polar orbit with altitude of 728–878 km, inclination of 98.8° – 98.9° , period of 100.5–102.0 minutes and swath width of 1400–1500 km [source National Snow and Ice Data Center (NSIDC)]. When retrieving sea ice parameters from SSM/I Tbs the main advantages are: daily coverage of the entire Arctic and Antarctica, light- and cloud-independent, long time-series. The main weakness is relatively coarse resolution and sensitivity to atmospheric constituents (more pronounced at 85.5 GHz frequency).

2.3.6.8 References

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2.3.6.9 Revision History

Version 1.0, 25 June 2015: N. Ivanova, T. Laverne, and S. Kern.

2.4 Cryosphere datasets

2.4.1 Sea Ice Volume Flux

2.4.1.1 Intent of the Document

(Sea ice volume flux along 79 degrees north has been computed with a 1 degree longitudinal resolution. The flux was computed as a deliverable during the EU Monarch-A project to be compared to various climate parameters such as sea ice cover in the Arctic, ice thickness distribution, wind field etc.

Grid cells for all data sets are centered on 79 deg N and from 5 deg E to 15 deg W. Ice area flux extracted from the time series of K. Kloster based on SAR and passive microwave observations. 4 columns contain:

(1) ice concentration (%) (2) ice displacement per time interval 3-4 days (km), (3) azimuth angle (deg) (4) area ice flux (km²/day/deg). All values are given for ~ 79 deg N latitude with 1 deg step from 5 deg E to 15 deg W. Volume flux is computed by multiplying area flux and IceSAT sea ice thickness.

2.4.1.2 Point of Contact

Kjetil Lygre, Nansen Environmental and Remote Sensing Center, Norway,
kjetil.lygre@nersc.no phone +47 55 20 58 00

2.4.1.3 Data Field Description

<http://monarch-a.nersc.no/node/70>

(variable names and units (eventually including uncertainty estimates that come with the product), length of record, spatial coverage, spatial and temporal sampling.)

2.4.1.4 Data Origin

http://monarch-a.nersc.no/sites/monarch-a.nersc.no/files/D2.6.2%20Ice%20volume%20flux%20Fram%20Strait_0.pdf

Sea ice volume flux is computed by multiplying estimates of **ice area flux** with ice thickness. Ice area flux time series data across 79°N by Kloster (2011) have been used. This is a product of measurements of profiles of : 1) ice displacement by Envisat WS-mode ASAR images and 2) ice concentration by DMSP SSMI and Aqua AMSR-E , made in consecutive time intervals, generally each of 3 days duration. The data spans the interval August 2004 to July 2011. The displacement is found by visually tracking of features between pairs of images. Although this in some cases can be difficult, for most image pairs it is possible to find reliable displacements vectors in the scene-overlapping area with a spacing of about 30 – 50 km, normally excluding the off-the-fast-ice zone and the ice edge zone. The uncertainty is estimated to +-5%.

The displacement profile is tabulated in 21 intervals (bins), each of one degree longitude with centers from 15W to 5E along 79N, by interpolation between the measured vectors nearest to this line. In the shear zone, linear interpolation from zero motion in the stable fast ice to the first measured motion vector is made. Ice concentration is measured on the dates of the SAR images along the same profile at 79N, and a mean ice concentration is computed from the values at the start date and the end date of the displacement interval. An early version of the computed ice flux was seen to agree with other analyses of the Arctic sea ice system (Smedsrud et al., 2008)

Ice thickness

Ice thickness data are downloaded from the NSIDC web-site and taken from six specific ICESat campaigns lasting approximately one month each from where good laser altimetry data are available (Kwok and Cunningham, 2008). The underlying freeboard to thickness conversion factor is contributing to the uncertainty of the measurements. To reduce the noise level the data were binned and averaged over 40km by 40 km boxes centered along 79N and at each 1 degree longitude.

Combining ice thickness with ice concentration and ice area flux one obtains sea ice volume flux.

2.4.1.5 Validation and Uncertainty Estimate

The flux values are found to be comparable to Spreen et al., 2009, although somewhat on the high side and with considerable interannual variability. A bimodal pattern is apparent during February 2006 and October 2007, indicative of an ice edge jet separate from an inner jet. The outer maximum is influenced by a maximum in ice thickness near the ice edge (not shown). High values near the edge could indicate compaction by surface waves or a contamination of the signal of the same waves. Hence, the results for the outer 5-6 data points should be interpreted with caution.

The data only spans the interval October 2005 to October 2007 and covering the six iceSAT campaigns that took place. Computations of the area flux has continued (and having a higher temporal resolution), so new estimates will be done, depending on resources, based on the more recent altimetry campaigns, noting potential intercalibration issues. For uncertainties of the iceSAT data, see <http://nsidc.org/data/icesat/>. The ice area flux uncertainty is estimated to 5% (see above).

2.4.1.6 Considerations for climate applications

The current data set based on IceSAT is short (2 years), even if the temporal variability observed is consistent with independent studies. The mean value and longitudinal profile may be valuable for model validation. Prolongation of the time series with more recent ice thickness products will make the time series more climatically relevant. The data have high longitudinal (1 deg) resolution, and covers a climatically important region (Fram Strait), although it cannot be generalized outside 79 deg N.

2.4.1.7 Instrument Overview

Ice thickness:

Laser altimetry: <http://nsidc.org/data/icesat/>

The main uncertainty lies in the computation of ice thickness from freeboard, assuming an ice density.

Ice concentration:

Passive microwave. See Koster, 2011

Ice displacement:

Manual inspection of images / ASAR, see Kloster (2011)

2.4.1.8 References

<http://monarch-a.nersc.no/node/70>

http://monarch-a.nersc.no/sites/monarch-a.nersc.no/files/D2.6.2%20Ice%20volume%20flux%20Fram%20Strait_0.pdf

http://nsidc.org/data/icesat/data_releases.html

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2.4.1.9 Revision History

Version 1.0 of this document on [Sea Ice volume flux through Fram Strait 79N](#)

2014-01-20

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2.4.2 Cryoland Glacier Products

2.4.2.1 Intent of the Document

This document summarizes essential information needed for users of any level who wish to use the Cryoland Glacier product datasets for climate applications. This product(s) is a part Cryoland Project, operational as a Copernicus service on snow and land ice.

2.4.2.2 Point of Contact

Dr. Thomas Nagler, ENVEO IT GmbH, thomas.nagler@enveo.at

2.4.2.3 Data Field Description

Glacier Outlines/Area Map:

The product glacier outlines / area is provided on user request according to the internationally accepted GLIMS standards. The detailed specification of the CryoLand glacier outline / area product is summarized in Table 3.1. An example of glacier outlines/area of the Hohe Tauern Mountain Group, Austria, derived from SPOT-5 data acquired in 2009 is shown in Figure 3.1. This example shows the intermediate glacier area map product automatically derived from SPOT-5 data indicated by red lines, as well as the final glacier area map manually corrected for debris cover in black lines. For intercomparison the glacier extents mapped from orthophotos in 1999 within the Austrian Glacier Inventory is shown in white (Lambrecht and Kuhn, 2007), revealing changes of the glacier extent in a 10 years period.

Information about glaciers, including for example glacier area, elevation information, surface classifications and changes to previous investigations are stored in a table associated to the polygons. A detailed description about the storage of information according to GLIMS standards is given in the Product Design Document (CryoLand, 2011).

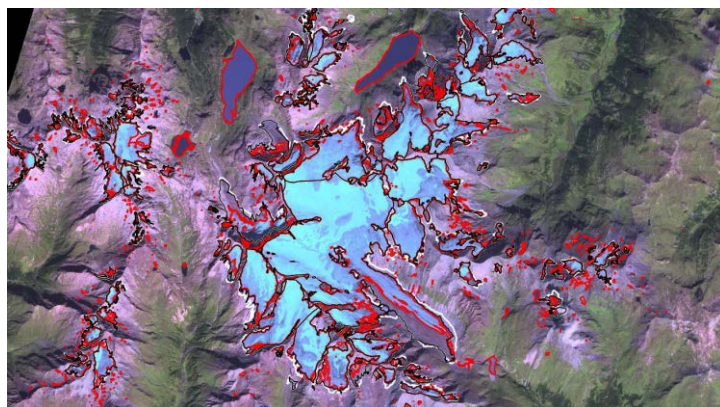


Figure 3.1: Comparison of glacier outlines in the National Park Hohe Tauern in Salzburg Land, Austria, of 1999 (white), the binary glacier outline product derived from the SPOT 5 scene of 2009 (red), and the manually corrected glacier outlines of 2009 (black). The RGB 413 composite of SPOT 5 image of 2009/09/01, overlaid with the semi-transparent panchromatic band is used as background.

Table 3.1: Description of the glacier outline product.

<i>Parameter</i>	<i>Specification</i>
Thematic variable	Glacier Outlines (GLO) / Glacier Area (GLA)
Thematic resolution	N/A
Thematic range	Glacier area, internal rocks
Thematic accuracy	3 % aiming at 1 %
Thematic uncertainty estimate	N/A
Spatial coverage	Regional, on demand
Delivery time period	01 August – 15 November (end of ablation period, varies with geographic location)
Temporal frequency	Annually
Spatial resolution	10 – 25 meters
Geometric accuracy	< 50 meters aiming at < 15 meters
Projection/Datum	Lat, Lon / WGS84
Sensor	SPOT, Landsat, Ikonos, Formosat, Quickbird
Required Auxiliary data	Very high resolution Digital Elevation Model, Glacier Outlines of previous years (optional)
File format	Shapefile
Developed by	ENVEO
Service provider	ENVEO
<i>CryoLand</i> priority	1 (primary product)
<i>CryoLand</i> status	Prototype / validation

Snow/Ice Maps

The snow / ice area maps are created based on optical satellite imagery acquired as close as possible to the date with the maximum extent of the ablation areas on the investigated glaciers. The retrieved maps can be combined with a DEM in order to get a 3-D snow map and extract the area–altitude distribution of the snow and ice areas. Figure 3.2 shows an example of snow/ice areas on glaciers in the Ötztal Alps, Austria, derived semi-automatically from a Landsat 5 TM scene of 2009-08-31. Table 3.2 summarizes the specifications for the snow/ice area product.

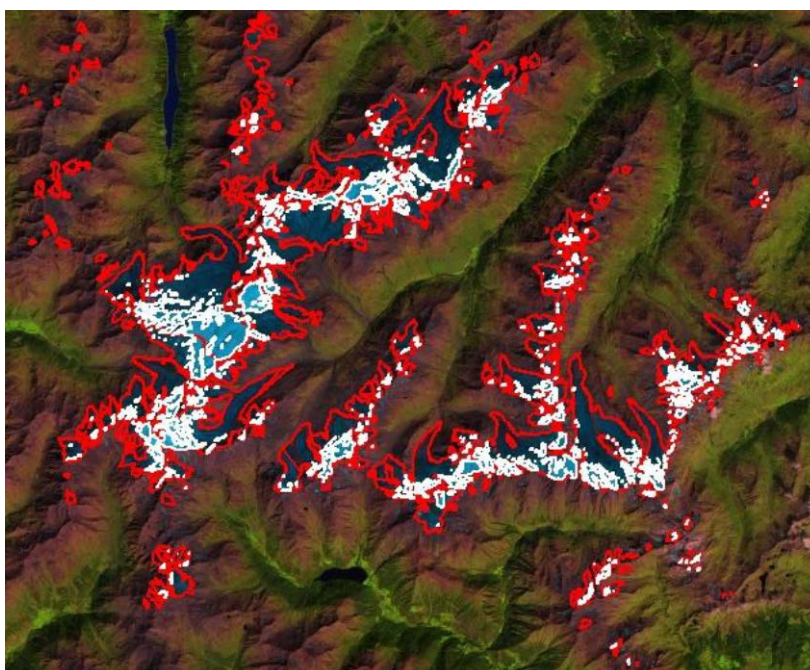


Figure 3.2: Snow areas (white) and outlines (red) of glaciers in the Ötztal Alps, Austria / Italy. The background image is a subset of the Landsat 5 TM (193/027) RGB composite of the bands 5-4-3 of 31 August 2009, which is used as data base.

Table 3.2: Description of the product snow/ice area on glaciers.

<i>Parameter</i>	<i>Specification</i>
Thematic variable	Glacier snow/ice areas (GLS)
Thematic resolution	N/A
Thematic range	Snow, Glacier Ice
Thematic accuracy	3 % aiming at 1 %
Thematic uncertainty estimate	N/A
Spatial coverage	Regional, local, on demand
Delivery time period	01 August – 30 September (summer, end of ablation period)
Temporal frequency	Annually
Spatial resolution	10 – 25 meters
Geometric accuracy	< 100 meters, aiming at < 30 meters
Projection/Datum	Lat, Lon / WGS84, UTM / WGS84 (optionally)
Sensor	Envisat ASAR, TerraSAR-X, SPOT, Landsat, Ikonos, Formosat, Quickbird
Required Auxiliary data	Very high resolution Digital Elevation Model, Glacier Outlines
File format	Shapefile, GeoTIFF
Developed by	ENVEO
Service provider	ENVEO
CryoLand priority	2 (candidate product)
CryoLand status	Prototype / validation

Glacier Lake:

In order to observe changes, glacier lakes are detected from optical or SAR data all over the year. The final product is provided as closed polygons. A product example of glacier lakes in Kyrgyz Tien Shan derived from Formosat-2 scene of 22 September 2012 is shown in Figure 3.3. Information related to the glacier lakes, basic statistics as well as observed area changes can be added in the associated attribute table which meets the GLIMS standards. The product specifications for glacier lakes are summarized in Table 3.3.

Table 3.3: Description of the glacier lake product.

<i>Parameter</i>	<i>Specification</i>
Thematic variable	Glacier Lake (GLL)
Thematic resolution	N/A
Thematic range	Glacier lake water, internal island
Thematic accuracy	3 % aimed at 1 %
Thematic uncertainty estimate	N/A
Spatial coverage	N/A
Delivery time period	Regional, local, on demand
Temporal frequency	Annually
Spatial resolution	10 – 25 meters
Geometric accuracy	< 50 meters aiming at < 15 meters
Projection/Datum	Lat, Lon / WGS84, UTM / WGS 84 (optionally)
Sensor	SPOT, Formosat, Landsat, TerraSAR-X, Envisat ASAR, Radarsat-2
Required Auxiliary data	Very high resolution Digital Elevation Model
File format	Shapefile
Developed by	ENVEO and GAMMA
Service provider	ENVEO and GAMMA

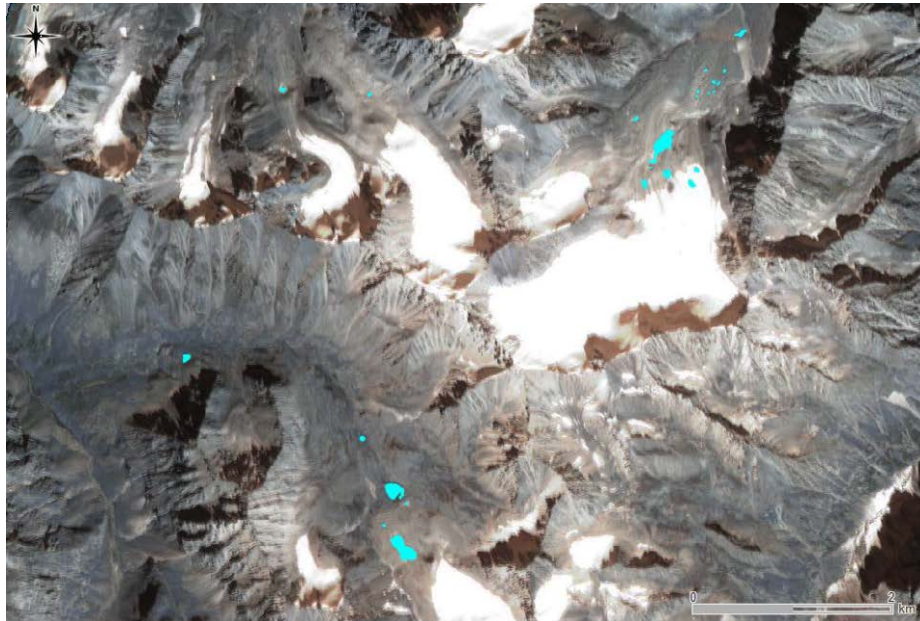


Figure 3.3: Examples for glacier lakes and glacier lake formations (blue areas) in Kyrgyz Tien Shan, near Golubina Glacier, mapped from Formosat-2 scene of 22 September 2012.

Glacier Ice Velocity Map:

The retrieval of ice velocity maps on glaciers is based on repeat pass SAR data, digital elevation models (DEM), and binary masks of water and glaciers. Currently, two methods are available at ENVEO and GAMMA for the retrieval of ice motion maps, the InSAR processing and the Offset Tracking procedure.

The InSAR analysis results in an absolute motion phase (range displacement) in the satellite line-of-sight direction. After geocoding of the absolute motion phase, and making assumptions on the ice flow, velocity profiles and ice motion maps can be retrieved.

Table 3.4 summarizes the product specifications. Figure 3.4 shows two product examples at Skeidararjökull, Iceland.

The Offset Tracking procedure results in an ice displacement in slant and azimuth direction. Additional products in slant-range geometry are a plot of the correlation values, a plot of the Signal-to-Noise-Ratio (SNR), a quiver plot with colour coded ice motion magnitude and arrows indicating direction and magnitude, and a further plot showing the colour coded ice motion magnitude. All products derived from the Offset Tracking procedure can be geocoded in order to retrieve orthorectified maps.

Table 3.4: Description of the glacier velocity product.

Parameter	Specification
Thematic variable	Glacier Velocity (GLV)
Thematic resolution	N/A
Thematic range	N/A
Thematic accuracy	5 % aimed at 1 %
Thematic uncertainty estimate	N/A
Spatial coverage	Regional, on demand
Delivery time period	N/A
Temporal frequency	Annually
Spatial resolution	10 – 25 meters
Geometric accuracy	20 meters, aimed at 10 meters
Projection/Datum	Lat, Lon / WGS84
Sensor	Cosmo-SkyMed, Radarsat-2 and TerraSAR-X
File format	Shapefile, GeoTIFF
Developed by	ENVEO & GAMMA
Service provider	ENVEO & GAMMA
CryoLand priority	3 (candidate product)
CryoLand status	Prototype / validation

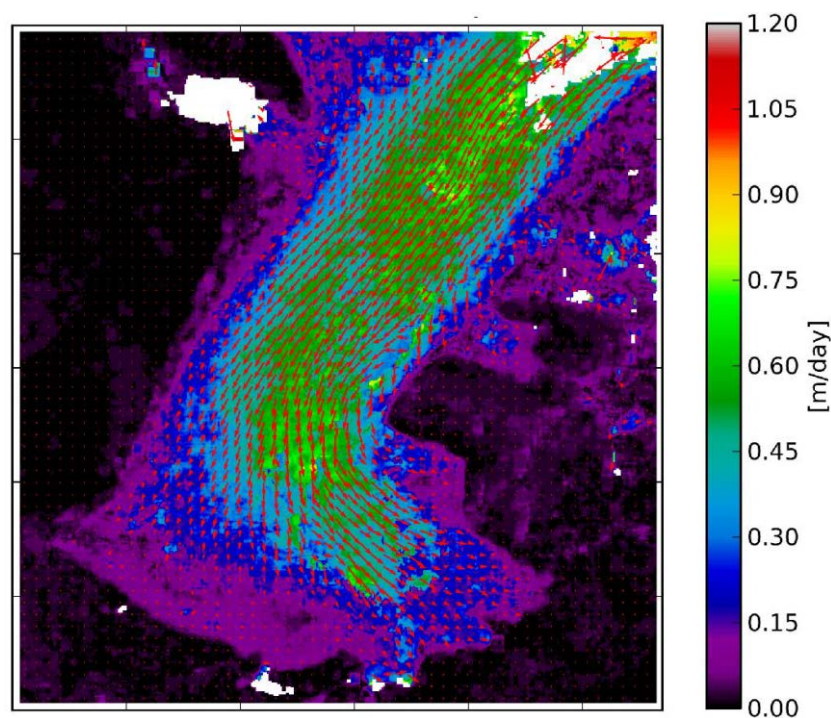


Figure 3.4: Quiver plot of TerraSAR-X image combination 2010/09/18 (master) and 2010/09/07 (slave) at Skeidararjökull, Vatnajökull, Iceland, indicating the ice flow direction and magnitude via arrows during this period.

2.4.2.4 Data Origin

Glacier Outlines/Area Map:

For the retrieval of glacier outlines/areas from high resolution optical satellite data with spectral bands in the visible and shortwave infrared acquired at end of summer, the Normalized Difference Snow Index (NDSI) introduced by Hall et al. (1995) is used as basic algorithm for the preliminary differentiation of snow, ice, and other surfaces. Depending on the sensor, an additional band can be used to refine the NDSI match or to classify glacier areas in cast shadowed areas.

The NDSI is calculated from the top of atmosphere reflectances and the Ekstrand correction (Ekstrand, 1996) is applied in order to normalize illumination effects due to topography and atmospheric propagation. This topographic correction requires a slope and an aspect map as input, which are derived from a digital elevation model (DEM). The topographically corrected top of atmosphere reflectances (R_p) of a visible (VIS) and a mid-infrared (MIR) band are used to calculate the NDSI.

The derived ratio map is scaled between -1.0 and $+1.0$. A threshold is applied on the resulting ratio map where a first guess of 0.40 often results in proper snow / ice maps, but can also be different due to scene dependent illumination effects or topographic properties. Thus, a stepwise approximation combined with visual comparison is helpful to reduce the possible thresholds to a range of $5 - 10$ values. Within this threshold range a refined stepwise approximation is applied, using a step size of 0.01 for retrieving the best match of the preliminary glacier mask compared with a RGB composite where glacier areas can be identified.

The snow / ice map retrieved by the selected threshold is combined with a water mask to eliminate water bodies, which often have similar NDSI values as snow or ice. Over Europe, a water mask with 100 m spatial resolution is available from the Corine Land Cover Map of 2006 (CLC2006), released by the European Environment Agency (EEA) in April 2012. Outside of Europe, the ESA GlobCover 2009 data set with a spatial resolution of 1 km can be used for a rough preliminary water classification. Clouds and cloud shadows have to be masked to eliminate such areas. Further misclassified surfaces, for example bright agricultural areas, can be eliminated by combining the resulting map with a digital elevation model and selecting a minimum glacier elevation. All areas located at elevations lower than the selected minimum glacier elevation are thus classified as non-glacier areas. This data combination results in a preliminary glacier map.

This map is converted into a vector file storing the outlines of the snow / ice classified areas as polygons using predefined templates meeting GLIMS standards as reference. To derive the glacier area map, the retrieved vector layer usually requires some manual post-processing (e.g. dust or rocks at the glacier tongue, adjacent snow fields, Nunataks and internal rocks, etc.). Furthermore, glaciers with common accumulation areas have to be separated using hydrological basins derived from a DEM. The resulting final map of glacier outlines additionally stores glacier related information according to the internationally accepted

GLIMS (Global Land Ice Measurements from Space) standards in the associated attribute table.

Snow/Ice Map:

The retrieval of snow / ice area maps on glaciers from optical satellite data is based on the different reflectance properties of snow and ice in the near infrared spectral range. Cloud free images acquired close to the date with the maximum extent of the ablation area, an accurate high resolution digital elevation model (DEM), and glacier outlines, preferably mapped from the same image or data acquired close to the basic satellite image, are required as input. The bands of the selected image are radiometrically calibrated and converted into top of atmosphere reflectance, before Ekstrand's (Ekstrand, 1996) method for correcting topographically induced illumination effects and atmospheric propagation is applied. For this correction, slope and aspect maps derived from the DEM are required as input.

After combining the resulting map with rasterized glacier outlines, a histogram of the topographically corrected TOAR values on the remaining areas is created. Defining a minimum and maximum threshold value based on the histogram, the cutting threshold is selected by a stepwise approximation and cross-comparison with auxiliary maps, as RGB composites, as described in detail by Bippus (2011).

If a band of the blue spectral range is available, the detection of snow in cast shadowed areas can be improved. Otherwise, such areas or further misclassifications have to be corrected manually during the post-processing.

Glacier Lake:

The retrieval of glacier lakes is mainly based on manual mapping from high or very high resolution optical satellite data or SAR imagery. A preliminary water classification can help to identify glacier lakes. ENVEO tested the Normalized Difference Snow Index for the generation of a preliminary water mask based on very high and high resolution optical satellite data. This approach worked quite well for a preliminary glacier lake mask derived from the Formosat scene over the Kyrgyz Tien Shan. If the location of a glacier lake is known in advance, as for example for the Lake Tininnilik in West-Greenland, calculating the NDSI as auxiliary map is not necessary.

Scenes with cloud cover or cloud shadows over the area of interest have to be excluded from the data base, as clouds obscure the earth surfaces and cloud shadows make the discrimination of different surfaces difficult.

Glacier Ice Velocity Map:

Deriving glacier velocity maps from repeat pass SAR imagery is currently mainly based on Offset Tracking. The displacements between two scenes in slant range geometry can be estimated by an amplitude cross correlation.

The resulting image shows offsets in range and azimuth direction. Geocoding these displacement images results in ice motion maps and velocity profiles.

InSAR analysis is only performed for selected glaciers, as the retrieval of ice motion maps by this technique requires a number of assumptions. By the InSAR procedure the ice displacement only in line of sight (LOS) between the time 1 and 2 can be retrieved.

The InSAR analysis results in several slant-range ice motion products, including the coherence level, the motion and the topographic phase. Assumptions on the ice flow at the glacier surface are required to retrieve velocity profiles and ice motion maps after geocoding the slant-range ice motion map.

2.4.2.5 Validation and Uncertainty Estimate

Glacier Outlines:

The currently available validation of the glacier outline product is carried out in collaboration with the user ZAMG. The glacier outlines of Hohe Tauern, Austria, derived from a SPOT-5 image acquired on 1 September 2009 were compared by the user ZAMG Vienna with glacier outlines analysed from very high resolution orthophotos acquired on 31 August 2009. The delay of only 1 day between the image acquisitions allows the direct intercomparison of the outlines mapped from different sources. An example of the glacier outline comparison is illustrated in 5.1.

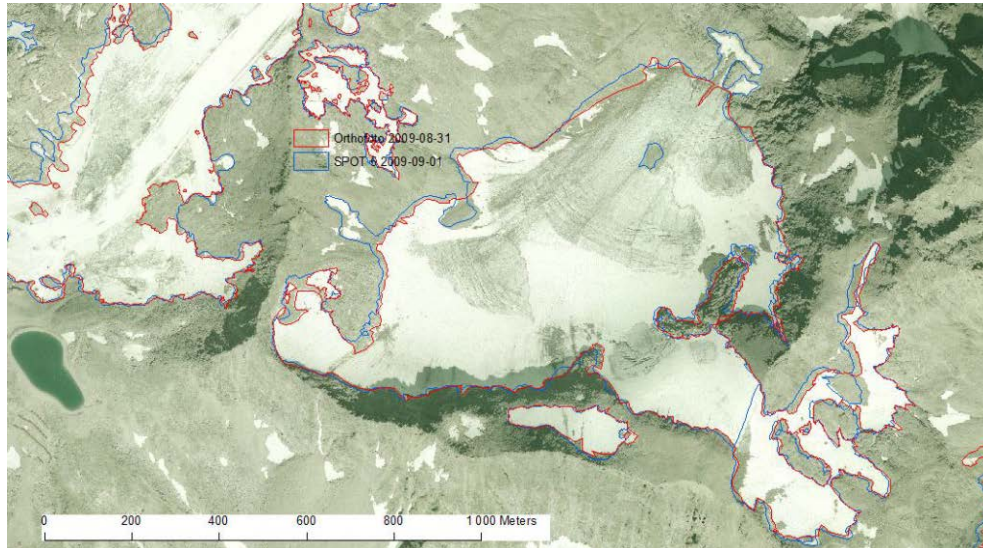


Figure 5.1: Comparison of glacier outlines in the Goldberggruppe, Austria, on an orthophoto of 2009-08-31. Red outlines were mapped by ZAMG based on this Orthophoto. Blue outlines are derived semi-automatically by ENVEO from the SPOT-5 scene of 2009-09-01.

For major parts of the region used for validation activities, the glacier outlines derived from different sources using different mapping methods match rather well. A small shift of the outlines derived from SPOT-5 compared to these from the orthophoto was locally detected, which probably result from different digital elevation models and ground control points used for the orthorectification of the SPOT-5 scene and the orthophoto, respectively. Together with the user ZAMG a set of ground control points located all over the SPOT-5 scene was

identified for new orthorectification of the scene. Further, a new DEM provided by the EU was used for the new orthorectification. Reviewing the accuracy of the glacier outlines derived from the newly orthorectified SPOT-5 scene is ongoing. Some debris covered parts on glaciers were also misclassified by the semi-automated mapping method from the SPOT-5 scene. These areas are manually corrected in the revised version derived from the newly orthorectified scene.

The associated glacier areas as well as area changes in terms of km² and percentage are given in Table 5.1. The derived area reductions are in line with regularly field observations and measurements on glaciers of the Glocknergruppe by members of the Universities of Salzburg and Graz, Austria, reporting a continuous retreat of glaciers in the Glocknergruppe, Austria (<http://www.uni-graz.at/geowww/pasterze/>). A direct comparison of the derived glacier areas is not possible because no other absolute values for the recent areas of the analysed glaciers are published yet.

Table 5.1: Areas and area changes between 1998 and 2009 of selected glaciers in the Glocknergruppe, Austrian Alps, derived from orthophotos of 1998 (Lambrech and Kuhn, 2007) and from SPOT-5 scene of 2009.

No	Glacier name	Area 1998 [km ²]	Area 2009 [km ²]	Area change [km ²]	Area change [%]
a	Pasterzen Kees	18.37	17.21	-1.16	-6.31
b	Wasserfallwinkel	1.86	1.69	-0.17	-9.14
c	Bockkar Kees	3.26	3.14	-0.12	-3.68
d	Karlinger Kees	3.78	3.42	-0.36	-9.52
e	Ödenwinkel Kees	2.26	1.89	-0.37	-16.37
f	Laperwitz Kees	2.18	1.95	-0.23	-10.55
g	Fruschnitz Kees	2.69	2.62	-0.07	-2.60
h	Teischnitz Kees	1.93	1.79	-0.14	-7.25
i	Ködnitz Kees	1.41	1.29	-0.12	-8.51

Snow/Ice Map:

Currently, the validation of snow areas from optical satellite imagery is mainly based on comparisons to snow areas manually derived from very high resolution orthophotos. Due to the high variability of snow areas it is crucial for the validation that the data sets are acquired on the same day or within a few days if no significant meteorological events occur in meantime.

Snow areas derived by the described processing line from Landsat 5 TM and Landsat 7 ETM+ data were validated during the ESA project GlobGlacier on selected glaciers in Austria and Norway, where orthophotos meeting approximately the acquisition dates of the Landsat images were available. The retrieved snow areas show the largest differences on glacier parts located in cast shadows and on glacier ice directly illuminated by the sun.

Glacier Lake:

For comparison and evaluation, the outlines of the glacier Lake Tininnilik in West-Greenland mapped from a Landsat 7 ETM+ scene of 17 August 2010 are compared with the lake outlines mapped from an Envisat ASAR image of 15 August 2010. Multiple Envisat ASAR scenes were acquired between 2006 and 2011 over this region and were available at Norut, but this is the only available data set with an almost coincident acquisition date from Landsat 7 ETM+ and Envisat ASAR. The location of the Lake Tininnilik is in the central part of the particular Landsat 7 ETM+ scene coverage, which is not affected by data gaps due to the failed Scan Line Corrector.

The glacier lake extents mapped from Landsat 7 ETM+ and Envisat ASAR scenes acquired with only two days delay show an overall good agreement. But, due to the coarser spatial resolution of the Envisat ASAR image some narrow streams connecting further water bodies with the main lake could not be identified. Thus, the overall area derived from the Envisat ASAR scene for the glacier lake is significantly smaller compared to the area mapped from the Landsat scene. The comparison is shown in Figure 5.2.



Figure 5.2: Comparison of outlines of glacier Lake Tininnilik, West-Greenland, derived from Landsat 7 ETM+ scene of 2010-08-17 (white outlines) and an Envisat ASAR scene of 2010-08-15 (red outlines). A RGB composite of the Landsat 7 ETM+ scene is used as background.

Additionally, estimations of the water surface level are available from field observations of Frank Nielsen including GPS measurements and photogrammetry in multiple years since 1995, online available at <http://www.sydforsifjorden.dk/xtinnilik.html>. As the satellite imagery used for mapping the lake extent was acquired only since 2000, the observations made between 2000 and 2006 are used for intercomparison. Based on the multi-temporal field observations, the water surface level of this lake can be set in relation with its area extent. At a maximum water surface level, the lake extends over more than 40 km², while at minimum water surface level the area is only about 20 km², as also shown in Figure 5.3.

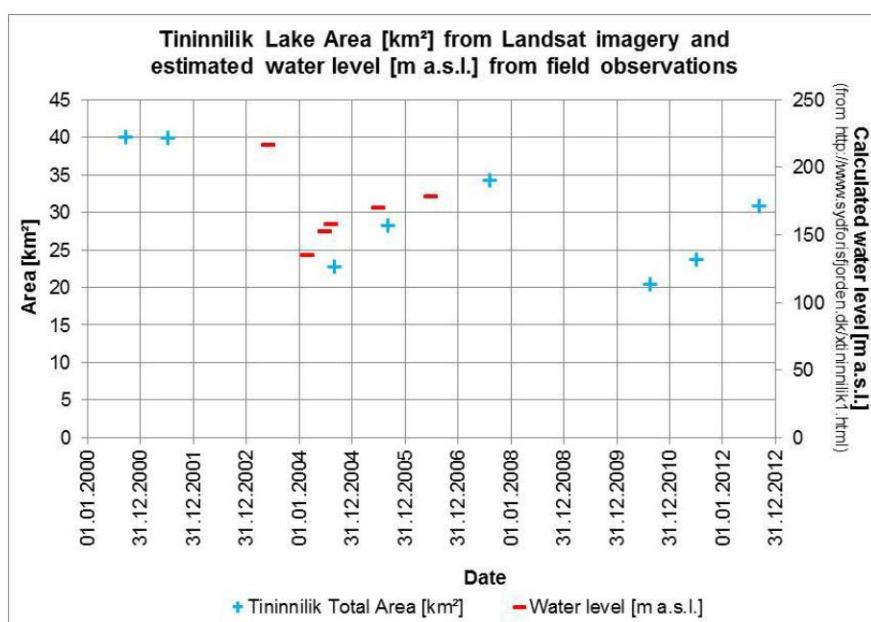


Figure 5.3: Comparison of lake area of Tininnilik derived from multiple Landsat images acquired between 2000 and 2012 and observations of lake surface water levels in several years.

Glacier Ice Velocity Map:

Ice motion maps can be validated by comparison with GPS in-situ measurements. For interpreting the validation results, the different spatial resolutions of the measurements have to be considered: GPS measurements resemble point measurements, while ice displacements derived from SAR imagery usually have a typical window size of a few hundred meters. Thus, the in-situ GPS measurements and the satellite based ice motion retrieval cannot be identical by theory.

Glacier velocities data over Vestfonna (Svalbard) computed from ERS-2 SAR data were validated against DGPS surveys from Pohjola et al. (2011). The ERS-2 SAR data set, acquired in 2011 with a 3 days' time interval, was posing a series of challenging processing issues, including decorrelation over the outlet glaciers, incomplete coverage with ascending and descending SAR data, and high Doppler centroid and baseline values. Integration of InSAR and OT was thus required to obtain the ice velocity map presented in Figure 5.4.

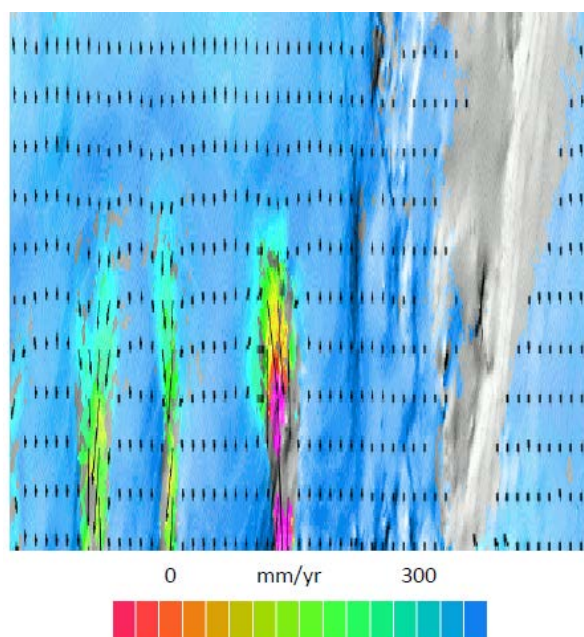


Figure 5.4: Ice surface velocity map of Nordaustlandet from ERS-2 SAR acquisitions of March-April 2011.

InSAR was considered in the central part of Nordaustlandet, where both ascending and descending data are available, and coherence is high, i.e. excluding the outlet glaciers. Over the five outlet glaciers in the northern part of Vestfonna dual-azimuth OT was considered. Over the North and East of Austfonna and over the South of Vestfonna range-azimuth OT was employed. Because DGPS data from the geodetic survey campaigns in 2007-2010 are available as horizontal ice surface velocity component, the ERS-2 SAR displacements in the satellite line-of-sight direction were transformed to horizontal ice surface speeds. This assumption might not be entirely valid as the SAR based ice motion is also sensitive to vertical displacement. Considering that the ERS-2 SAR data are from the winter – early spring season we can however at least exclude ablation as a source of surface vertical ice

motion. The pixels corresponding to the GPS stakes were considered in the comparison. Results are shown in Figure 5.5. for InSAR, dual-azimuth OT (i.e. where OT in the azimuth direction from ascending and descending passes were combined), and standard OT (i.e. slant-range and azimuth).

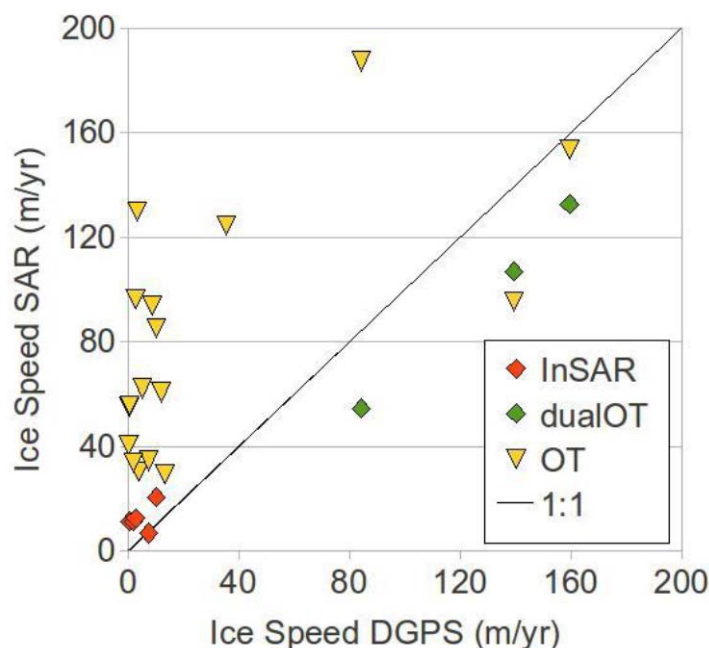


Figure 5.5: Comparison of ERS-2 SAR and geodetic (DGPS) ice velocities.

The agreement between DPGS and InSAR over the slowest moving part of the ice cap is satisfactory, considering all the problems related to the validation of glacier velocity data against in-situ measurements explained at the beginning of the section. The average of the absolute difference between DGPS and InSAR results is 8.2 m/yr and the maximum difference is 10.8 m/yr. Over the fast moving parts of the outlet glaciers the average of the absolute difference between DGPS and dual-azimuth OT results is 29.7 m/yr and the maximum difference is 32.4 m/yr. Finally, the absolute difference between DGPS and OT results is 72.1 m/yr and the maximum difference is 310.2 m/yr.

In addition, glacier velocities from repeat image data can be compared against those from image data of equal or better resolution, accuracy and precision and matching stable ground in the image set, if present, gives a good indication for the overall co-registration of the repeat images, and some general idea of the matching accuracy under the specific image conditions. We extracted the ground-range and azimuth displacements over areas on stable ground with the ERS-2 SAR data of Figure 2.15 and obtained the following standard deviations: 6-12 m/yr for InSAR, 70 m/yr for dual-azimuth OT, and 100 m/yr for OT.

2.4.2.6 Considerations for climate applications

Within the project glacier products are generated on request from users contributing to many application fields including climate change assessment, hydrological runoff forecasting and simulations in areas where glacier melt is important for example with respect to natural hazards due to glacier lake outburst floods or for geotechnical planning in regions with

glacier melt. The CryoLand glacier service prepares the basis for a Copernicus Glacier Service within the Copernicus Land Service.

Glacier outlines and thereof derived glacier areas are the most basic information on glaciers. As glaciers are sensitive on climate, regular observations of glacier areas are useful to detect changes, and thus enable assessing inferences on climate changes. In some regions, changing glacier areas is a crucial factor for geotechnical planning and the runoff forecasting in the hydrological basins of glaciers. Knowing the area of a glacier is also mandatory for all glacier related investigations, as for example the estimation of a glacier's mass balance. Glacier outlines are further needed for analysing other glacier parameters from satellite data, as snow / ice areas on glaciers, or ice surface velocity.

Knowledge on glacier ice velocity will provide a better understanding of a wide range of processes related to glacier dynamics, for example glacier mass flux, flow modes and flow instabilities (e.g. surges), sub-glacial processes (e.g. erosion), supra- and intra-glacial mass transport, and the development of glacier lakes and associated hazards. In addition, the comparison of the spatio-temporal variations of glacier velocities both within and between regions will improve understanding of climate change impacts.

2.4.2.7 Instrument(s) Overview

SPOT-5:

Launch Date	May 3, 2002
Launch Vehicle	Ariane 4
Launch Location	Guiana Space Centre, Kourou, French Guyana
Orbital Altitude	822 kilometers
Orbital Inclination	98.7°, sun-synchronous
Speed	7.4 Km/second (26,640 Km/hour)
Equator Crossing Time	10:30 AM (descending node)
Orbit Time	101.4 minutes
Revisit Time	2-3 days, depending on latitude
Swath Width	60 Km x 60 Km to 80 Km at nadir
Metric Accuracy	< 50m horizontal position accuracy (CE90%)
Digitization	8 bits
Resolution	Pan: 2.5m from 2 x 5m scenes Pan: 5m (nadir) MS: 10m (nadir) SWI: 20m (nadir)
Image Bands	Pan: 480-710 nm Green: 500-590 nm Red: 610-680 nm Near IR: 780-890 nm Shortwave IR: 1,580-1,750 nm

LANDSAT-5 TM:

Landsat TM has 7 spectral bands; 3 in the visible range and 4 in the infrared range. Band 6 is specifically sensitive to thermal infrared radiation to measure surface temperature. The band wavelengths were chosen for their value in discriminating vegetation type, water penetration, plant and soil moisture measurements, and identification of hydrothermal alteration in certain rock types. All of the bands have a 30m pixel size except band 6 which has a spatial resolution of 120m.

Spectral Bands/Wavelengths

Band	Resolution	Wavelength μm	Description
1	30m	0.45-0.52	Blue
2	30m	0.53-0.61	Green
3	30m	0.63-0.69	Red
4	30m	0.78-0.90	Near Infrared
5	30m	1.55-1.75	Short-wave Infrared
6	60m	10.4-12.5	Thermal Infrared
7	30m	2.09-2.35	Short-wave Infrared

Image footprint or swath width

Landsat TM data is delivered in scenes that measure 115 miles (185km) by 106 miles (170km).

Return Interval

Landsat 4 and 5 are on the WRS-2 orbit path and revisits the same spot on the earth every 16 days. Because Landsat 4 and 5 are in a sun-synchronous orbit, they cross the equator between 9:30am and 10:00am each day.

IKONOS

Launch Date	24 September 1999 at Vandenberg Air Force Base, California, USA
Operational Life	Over 7 years
Orbit	98.1 degree, sun synchronous
Speed on Orbit	7.5 kilometers per second
Speed Over the Ground	6.8 kilometers per second
Revolutions Around the Earth	14.7, every 24 hours
Altitude	681 kilometers
Resolution at Nadir	0.82 meters panchromatic; 3.2 meters multispectral
Resolution 26° Off-Nadir	1.0 meter panchromatic; 4.0 meters multispectral
Image Swath	11.3 kilometers at nadir; 13.8 kilometers at 26° off-nadir
Equator Crossing Time	Nominally 10:30 AM solar time
Revisit Time	Approximately 3 days at 40° latitude
Dynamic Range	11-bits per pixel
Image Bands	Panchromatic, blue, green, red, near IR

QuickBird

Core-Climax Climate Data Record Capacity Assessment Descriptions

Launch Date	October 18, 2001
Launch Vehicle	Boeing Delta II
Launch Location	Vandenberg Air Force Base, California, USA
Orbit Altitude	450 Km / 482 Km - (Early 2013)
Orbit Inclination	97.2°, sun-synchronous
Speed	7.1 Km/sec (25,560 Km/hour)
Equator Crossing Time	10:30 AM (descending node)
Orbit Time	93.5 minutes
Revisit Time	1-3.5 days, depending on latitude (30° off-nadir)
Swath Width (Nadir)	16.8 Km / 18 Km - (Early 2013)
Metric Accuracy	23 meter horizontal (CE90)
Digitization	11 bits
Resolution	Pan: 65 cm (nadir) to 73 cm (20° off-nadir) MS: 2.62 m (nadir) to 2.90 m (20° off-nadir)
Image Bands	Pan: 450-900 nm Blue: 450-520 nm Green: 520-600 nm Red: 630-690 nm Near IR: 760-900 nm

Envisat ASAR

Accuracy	Radiometric resolution in range: 1.5-3.5 dB, Radiometric accuracy: 0.65 dB
Spatial Resolution	Image, Wave and Alternating Polarisation modes: approx 30m x 30m. Wide Swath mode: approx 150m x 150m. Global Monitoring mode: approx 1000m x 1000m.
Swath Width	Image and alternating polarisation modes: up to 100km, Wave mode: 5km, Wide swath and global monitoring modes: 400km or more
Waveband	Microwave: C-band, with choice of 5 polarisation modes (VV, HH, VV/HH, HV/HH, or VH/VV)

TerraSAR-X

Resolution	HighResolution Spotlight: 1m SpotLight: 2m StripMap: 3m ScanSAR: 18m
Nominal Swath Width	HS Spotlight: 5 to 10 km x 5 km (width x length) SpotLight: 10 km x 10 km StripMap: 30 km x 50 km ScanSAR: 100 km x 150 km
Bands	Active X- band Microwave
Archive Availability	From 2007
Programmability	YES
Minimum Area Of Purchase	One scene

Core-Climax Climate Data Record Capacity Assessment Descriptions

Stereo Available?	Yes, Interferometric and Radargrammetric
Best Scale	Upto 1:3000

Cosmo-SkyMed

Inclination angle (degrees)	97.86
Orbital period (minutes)	95 min
Mean local time at descending node	06:00 ± 15 min
Mean altitude (km)	619.6 km
Orbits per day	14 13/16
Repeat cycle (days)	16 days (237 orbits)
Constellation of Satellites	4 at 90° phasing
Polarization (selectable)	HH, VV, HV, VH
Beam Mode and Nominal Resolution	
SpotLight	1 m
StripMap Mode	
HighImage	3 m
PingPong	5 m
ScanSAR Mode	
Wideregion	30 m
Hugeregion	100 m

Radarsat-2

Inclination angle (degrees)	98.6
Orbital period (minutes)	100.7
Mean local time at ascending node	18:00 ± 5 min
Altitude (km)	798
Orbits per day	14 7/24
Repeat cycle (days)	24 days (343 orbits)
Polarization	HH,HV,VH,VV
Beam Modes and Nominal Resolution	
Fine Beam	Spotlight,single pol: 3 m x 18 km
Standard Beam	10 m x 50 km
ScanSAR	25 m x 100 km
	300 m x 50 km (narrow)

2.4.2.8 References

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2.4.2.9 Revision History

10-08-2013 - Version 1 – Initial draft created by Viju John and edited by Alessio Lattanzio.

17-08-2014 – Version 1 – Context has changed for Cryoland Glacier products by Cemal Melih Tanis.

2.5 Land Datasets

2.5.1 EUMETSAT METEOSAT Surface Albedo

2.5.1.1 Intent of the Document

This document summarizes essential information needed for users of any level who wish to use the METEOSAT Surface Albedo (MSA) data set for climate applications. MSA data set is derived from measurements of the METEOSAT Visible and Infra Red Imager (MVIRI) instrument on METEOSAT first generation satellites.

2.5.1.2 Point of Contact

EUMETSAT Help desk ops@eumetsat.int

2.5.1.3 Data Field Description

Surface albedo is generally defined as the instantaneous ratio of surface-reflected radiation flux to incident radiation flux (dimensionless). The MSA data product contains Directional Hemispherical Reflectance factor (DHR) and isotropic Bi-Hemispherical Reflectance factor (BHR_{iso}). The DHR represents the surface albedo when only direct illumination is considered. The DHR (or “*black sky albedo*”) corresponds to the albedo in the absence of any atmosphere. It depends on the angular position of the light source and surface properties. The BHR_{iso} (or “*white sky albedo*”) represents the surface albedo of a surface when the illumination is isotropic. The albedo of a surface under an overcast homogeneous cloud deck would be a good BHR_{iso} approximation. It depends on surface properties and sun angle. The actual albedo (or “*blue sky albedo*”) is a linear combination of DHR and BHR_{iso} (see Pinty et al., 2005 for more details).

The spatial and temporal coverage of MSA product is shown in Figure 1. Nominal operational position for METEOSAT platforms is 0 deg east. METEOSAT 5 and 7 satellites were moved over to Indian Ocean respectively in July 1998 and November 2006. METEOSAT-3 was also moved to the west, at first to 50° W and early in 1993 to 75° W. Examples of the three different coverage are shown in Figure 2.

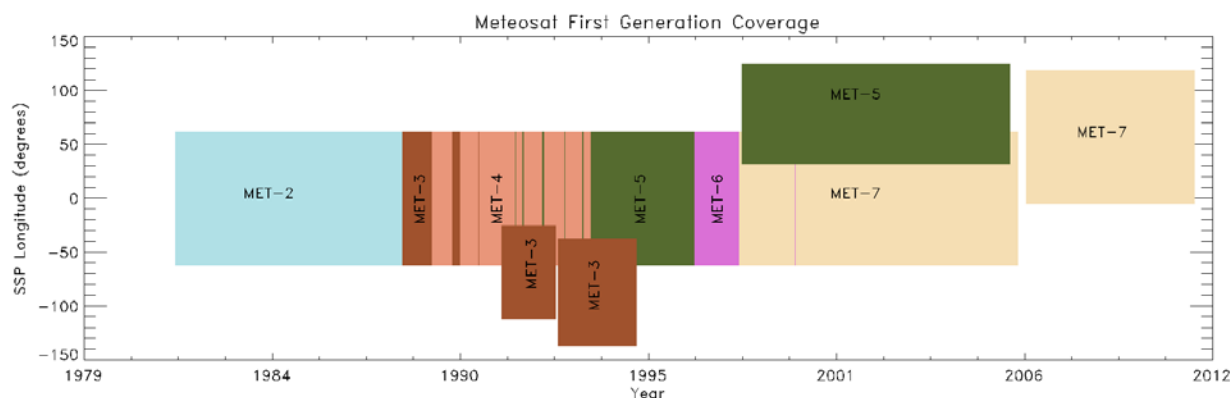


Figure 5: Spatial and temporal coverage of METEOSAT first generation (MFG) satellites.

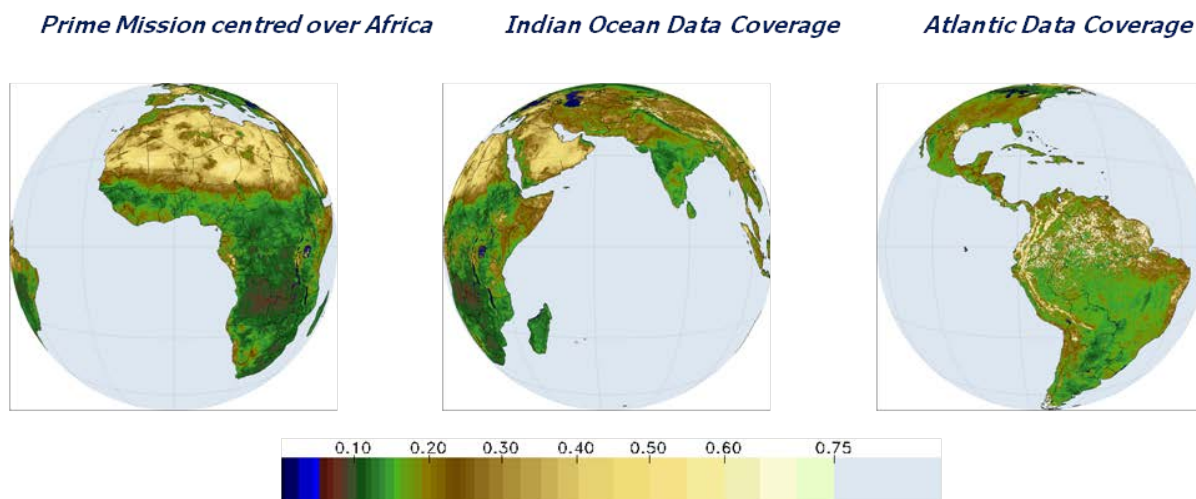


Figure 6: Examples for 3 different coverages of MSA product.

The albedo retrieval is performed for each processed day but, in order to minimize the impact of cloud coverage, each MSA product is generated every 10-day compositing periods. These compositing periods are defined with the Julian day number. The first period runs from day 1 to day 10, the second from day 11 to day 20, and so on. The last period of the year is therefore slightly shorter than the other periods and runs from day 361 to 365 (or to day 366 in a leap year). There is a maximum of 37 products per year.

The retrieval is performed on the visible band of MVIRI resulting in a spectral albedo value. In order to be compared with albedo retrieved using measurements taken by other instruments a conversion to broad band is needed as described in Loew and Govaerts [2010].

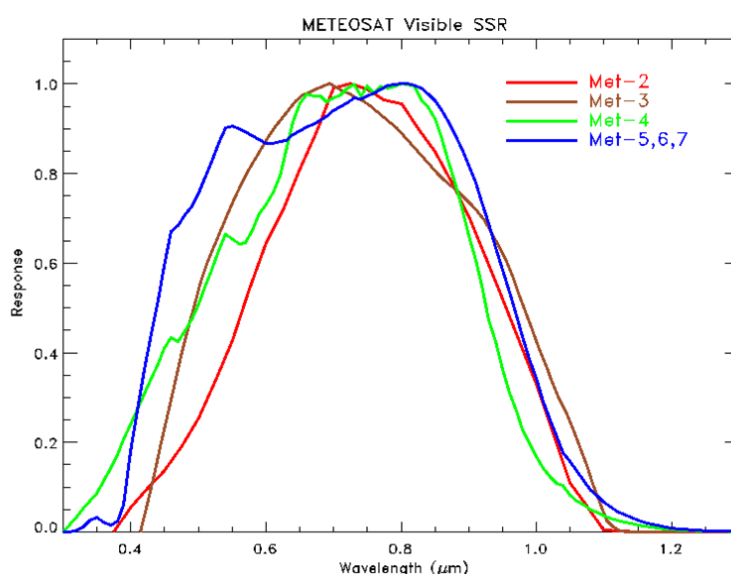


Figure 7: Spectral response functions of the visible band of MVIRI instruments on-board MFG satellites.

The MSA product is derived over the land portion in the METEOSAT disk (as shown in Figure 2) even if no sea mask is applied during the generation process and some values over sea or lakes are included in the retrieval. The albedo for those water bodies should not be considered. The spatial resolution of the MSA product is equal to the one of the METEOSAT VIS band. The distance between two adjacent pixels at the sub-satellite point is equal to 2.5 km.

2.5.1.4 Data Origin

The MVIRI Visible (VIS) band (extends from 0.45 μm to 1.0 μm with a central wavelength at 0.70 μm (see Figure 3)) data from EUMETSAT archive is used as the main input for MSA algorithm. Atmospheric gases are fairly transparent to incoming and outgoing (reflected) solar radiation in this spectral range. The MSA algorithm relies on an approach proposed by Pinty et al. [1997, 2000a, 200b]. During the course of the day, observations acquired different illumination conditions are accumulated (see Figure 4). Ultimately, it retrieves the surface anisotropy and the atmospheric aerosol load through the inversion of a Radiative Transfer Model (RTM) as shown in Figure 4. The elements of the model are an absorbing layer (gases absorption), a scattering layer (aerosol scattering) and an anisotropic surface (coupled with the scattering layer). The proposed algorithm will use ozone and water vapor contents from other sources (currently reanalyses) as input data to reduce the problem: from a radiation transfer problem to a surface-aerosol scattering problem. The level of confidence in the retrieval depends on the size of the measurement vector that can change from pixel to pixel according to cloud and illumination conditions (for details refer to Lattanzio [2013]). The algorithm also estimates the retrieval parameter error (for details refer to Govaerts Lattanzio [2007]). A 10-day temporal compositing technique is applied to maximize the spatial coverage of cloud-free pixels. Finally, the retrieved surface state variables are used to derive the Directional Hemispherical Reflectance (DHR) corresponding to a sun position of 30° together with its respective error (see Govaerts Lattanzio [2007]). The estimated retrieval error and the probability of the solution are the two key elements that permits a meaningful comparison of surface albedo derived from different radiometers.

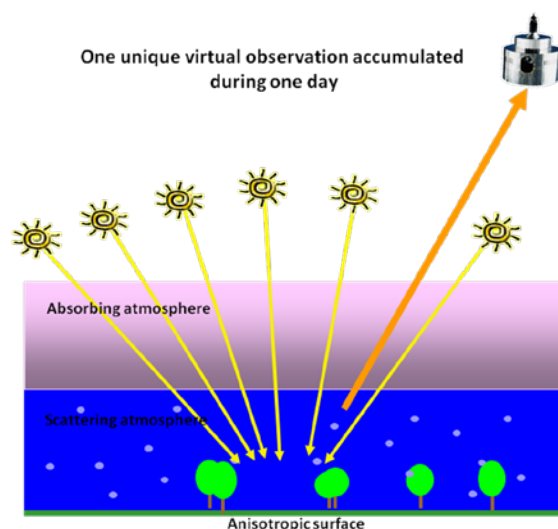


Figure 0: MSA Retrieval scheme. The observations accumulated during the day are used as an angular sampling of the surface. The elements of the model are an absorbing layer, a scattering layer and an anisotropic surface.

2.5.1.5 Validation and Uncertainty Estimate

A detailed validation of MSA product is reported in Fell et al., [2012]. They found that MSA long-term observations are very consistent and have been shown to match the GCOS stability requirement of 1% per decade for a number of desert reference surfaces (see Fig. 5, for example).

The MSA data record agrees well with corresponding values from both satellite-derived and ground-based observing systems under many observation conditions

No significant artefacts are observed at satellite to satellite transitions when applying the new spectral-to-broadband conversion factors provided by Loew and Govaerts [2010]

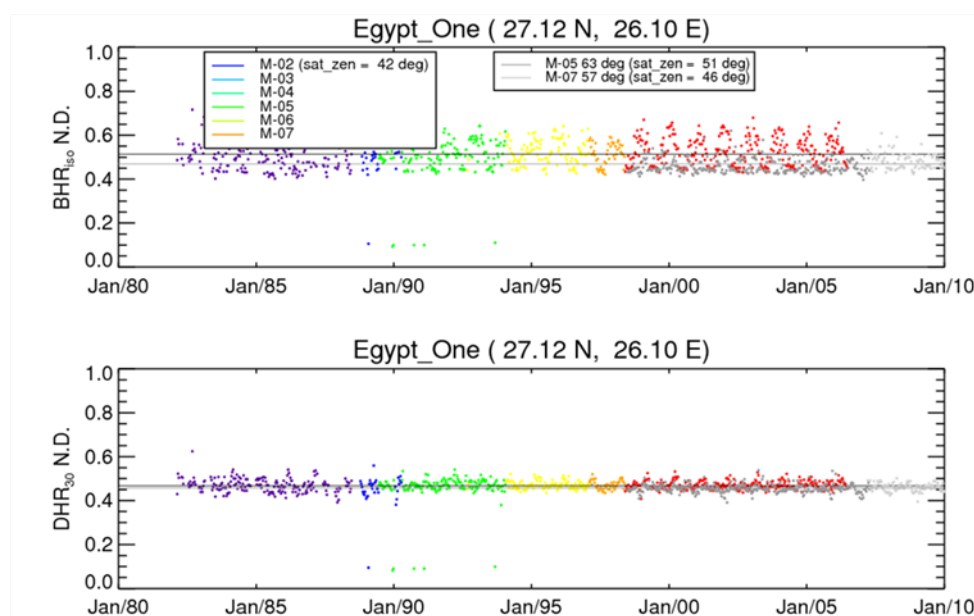


Figure 5: An example showing the stability of MSA product.

2.5.1.6 Considerations for climate applications

MSA product is spectral albedo which has to be converted to broadband albedo using the spectral response function for the corresponding satellite before using in applications. The spectral conversion is based on a 3rd order polynomial as $y = d + c x + b x^2 + a x^3$. The coefficients (a-d) are given in EUMETSAT [2007].

The ability for satellite-based surface albedo retrieval is generally reduced due to insufficient illumination at higher latitudes in the winter months and, more importantly, due to frequent cloud cover in several parts of the world, such as the mid-latitudes in winter and tropical areas in the ITCZ;

Undetected clouds usually result in an overestimation of the surface albedo and may thus create a systematic bias

Some surfaces show large MSA differences between ODEG and IODC observation geometries. Aside aerosol related effects; we infer insufficiently characterised surface anisotropy as the main reason for the observed behaviour

2.5.1.7 Instrument Overview

The MVIRI instruments are on-board METEOSAT geostationary satellites 1-7. MVIRI operates in three spectral bands, chosen in accordance with METEOSAT's primary task of mapping the distribution of clouds and water vapour. Radiance data from the full earth disc are acquired during a 25 minute scan period. This is followed by a five minute re-trace and stabilization interval, so that one complete set of full earth disc images is available every half an hour. Scanning from East to West is achieved by the spin of the satellite and scanning from South to North is achieved by small incremental steps in the pointing of the radiometer telescope.

2.5.1.8 References

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2.5.1.9 Revision History

30-08-2013 - Version 1 – Initial draft created by Vijju John and edited by Alessio Lattanzio.

2.5.2 GEOV1 Leaf Area index (LAI)

2.5.2.1 Intent of the Document

The objectives of this document are to (1) describe the GEOV1 Leaf Area index (LAI) time series provided by the European Copernicus Global Land Service using SPOT-VEGETATION satellite observations, from 1999 to present, (2) assess its usability in climate reanalysis studies.

2.5.2.2 Point of Contact

Roselyne Lacaze (HYGEOS), rl@hygeos.com

2.5.2.3 Data Field Description

The GEOV1 Leaf Area index (LAI) time series is provided by the European Copernicus Global Land Service and is based on SPOT-VEGETATION satellite observations, from 1999 to present. LAI is a land ECV and is expressed in units of m^2m^{-2} . Both the archive and the near real time GEOV1 LAI are available at a global scale, on a 10-daily basis and at a spatial resolution of 1 km, under the HDF5 format on a latlon grid. The near real time data are provided no more than three days after the last observation. No restriction applies on the use of the product, which can be used for any application, included for commercial purposes.

The GEOV1 LAI product is described on the CEOS ECV inventory web site:

http://ecv-inventory.com/ecv-inventory/ceos?_dm_flow=user2&_dm_event=actions
(the record name of GEOV1 LAI is "CDR_ECV25_2")

and on the Copernicus Global Land Service web site:

<http://land.copernicus.eu/global/products/LAI>

On the latter, the following technical documents are provided:

Algorithm Theoretical Basis Document

(http://land.copernicus.eu/global/sites/default/files/products/GIO-GL1_ATBD_LAIV1_I1.00.pdf)

Product User Manual (http://land.copernicus.eu/global/sites/default/files/products/GIO-GL1_PUM_LAIV1_I1.00.pdf)

Validation Report (http://land.copernicus.eu/global/sites/default/files/products/GIO-GL1_VR_LAIV1_I1.00.pdf)

2.5.2.4 Data Origin

The SPOT-VEGETATION data used as input to the GEOV1 algorithm come from the VITO processing and archiving centre in Mol (Belgium). The GEOV1 LAI is produced by a neural network trained with the existing CYCLOPES V3.1 and MODIS C5 products which were fused to improve the LAI estimates by benefiting of the respective advantages of each product (Baret et al., 2013). The inputs of the neural network correspond to the directionally normalized top of canopy reflectance in the red, NIR and SWIR bands, as derived from the CYCLOPES V3.1 algorithm, and the median value of the sun zenith angle over the composition window of 30 days. The pre-processing steps include cloud screening, atmospheric correction based on a climatology of aerosols, and directional normalization using a robust fit of Roujean's model (Hagolle et al., 2004; Roujean et al., 1992). Details about the pre-processing can be found in the literature (Baret et al., 2007).

2.5.2.5 Validation and Uncertainty Estimate

The GEOV1 product was extensively validated through the comparison of the product to pre-existing LAI products (indirect validation) and to in situ LAI observations (direct validation). The latter were derived from a global network of homogeneous sites. The GEOV1 LAI presents reliable spatial distribution, smooth temporal profiles which are stable from year to year, good dynamic range with reliable magnitude for bare areas and dense forests, and optimal performances with ground-based maps. GEOV1 outperforms the quality of reference global products in most of the examined criteria. In particular, the direct validation indicates that, overall, the GEOV1 LAI is better than the MODIS Collection 5 LAI (r^2 value of 0.807 against 0.729, and RMSE of 0.74 against 0.92). The validation process is detailed in the Validation Report, and the results are published in the open peer-reviewed literature (Camacho et al., 2013). The temporal consistency of the product was assessed over a short period of time (2003-2005) by Camacho et al. (2013). Barbu et al. (2013) compared the GEOV1 LAI with values simulated by a land surface model over France, for the 2008-2011 period (Fig. 1).

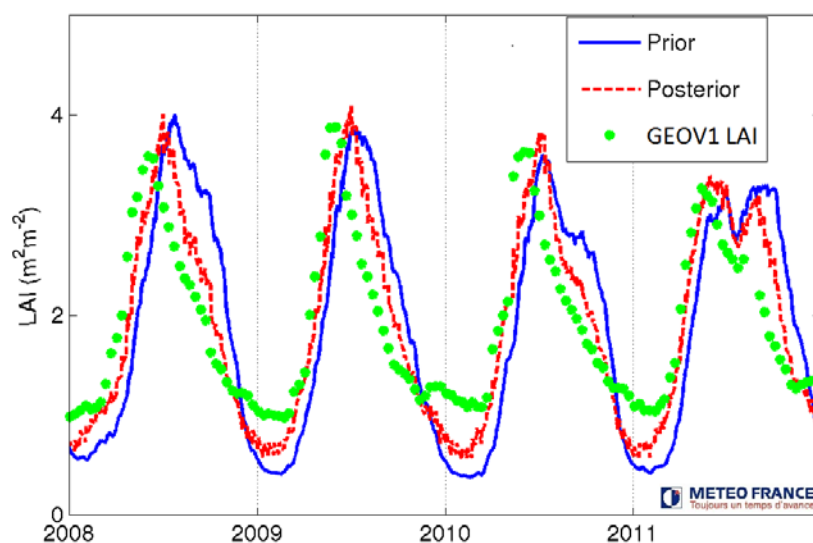


Figure 1 - Time series of modelled (blue), observed (green) and analyzed (red) LAI (m^2m^{-2}) averaged over France from 2008 to 2011 (adapted from Barbu et al., 2013).

2.5.2.6 Considerations for climate applications

The period of time covered by the product (1999-2013) is too short to analyse trends. An attempt was made by CNES to merge GEOV1 with historical AVHRR data using the NASA Long Term Data Record data set (<http://ltdr.nascom.nasa.gov>), over the period 1981-1998, at a spatial resolution of 5 km. The idea was to adapt the neural network algorithm used to produce GEOV1 to the AVHRR dataset. The obtained 1981-2013 harmonized time series is described on the CEOS ECV inventory web site (record name "CDR_ECV25_4"). However, it is not recommended to use the resulting merged product as is. A discontinuity in the time series is clearly visible at many locations from 1998 to 1999 (see Fig. 2). The AVHRR-derived LAI presents lower values than the GEOV1 time series starting in 1999. This problem should be solved in a new revised version of the product (GEOV2). For the time being, an alternative is to use the 30-yr GIMMS LAI3g product derived from AVHRR and MODIS observations (Zhu et al., 2013), or to use the extended GEOV1 data set to analyse the seasonal and interannual variability, only (not trends).

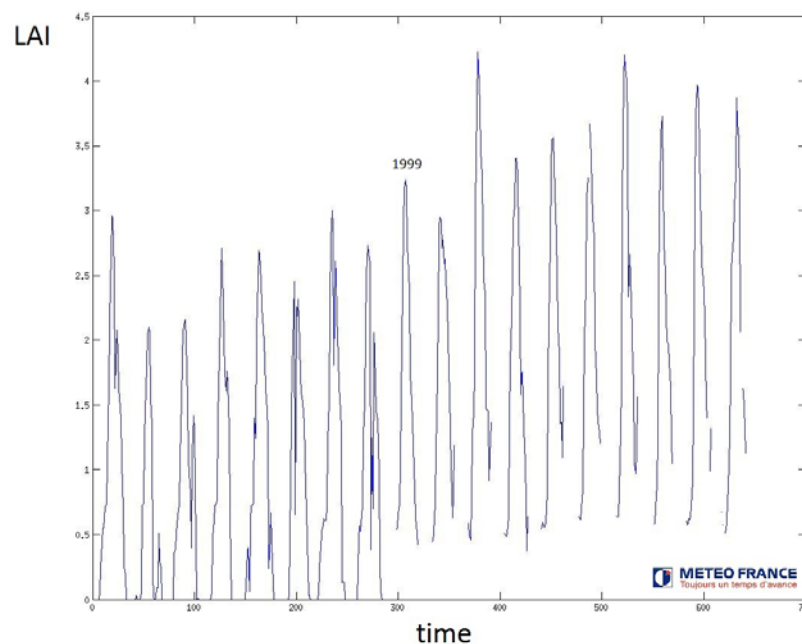


Figure 2 - Time series of the merged CDR_ECV25_4 AVHRR-GEOV1 product from 1991 to 2008 over a 5km x 5km location in Europe presenting a large contrast between the AVHRR-derived LAI (1991-1998) and the SPOT-VEGETATION-derived GEOV1 LAI (1999-2008).

2.5.2.7 Instrument Overview

The first VEGETATION European sensor was launched in 1998 aboard SPOT4. A second instrument was launched in 2002 aboard SPOT5 to ensure the continuity of observations. The two instruments are identical and provide global observations of the surface from a sun-synchronous orbit at 822 km altitude, with an inclination of 96.7°, a period of 26 days and an equatorial crossing time of 10:30. Because of the large swath (101°, equivalent to 2200 km),

about 90% of the equatorial areas are imaged each day, the remaining 10% being imaged the next day. For latitudes higher than 35° (North and South), all regions are acquired at least once a day. The instrumental concept relies on a linear array of 1728 CCD detectors providing a spatial resolution around 1.15 km with minimum variations for off-nadir pixel size thanks to the telecentric design of the optics. Four spectral bands are available: B0 (450 nm, $\Delta\lambda=40$ nm); B2 (645 nm, $\Delta\lambda=70$ nm); B3 (835 nm, $\Delta\lambda=110$ nm); SWIR (1165 nm, $\Delta\lambda=170$ nm). The stability of the platform, the accurate knowledge on its position and attitude and post processing of the images allow to achieve a multi-temporal registration accuracy around 200 m (rms) (Baret et al., 2007).

2.5.2.8 References

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2.5.2.9 Revision History

Version 1.0, 2 September 2013, Jean-Christophe Calvet (Meteo-France).

2.5.3 GEOV1 fAPAR

2.5.3.1 Intent of the Document

The objectives of this document are to (1) describe the GEOV1 fraction of absorbed photosynthetic radiation (fAPAR) time series provided by the European Copernicus Global Land Service using SPOT-VEGETATION satellite observations, from 1999 to present, (2) assess its usability in climate reanalysis studies.

2.5.3.2 Point of Contact

Roselyne Lacaze (HYGEOS), rl@hygeos.com

2.5.3.3 Data Field Description

The GEOV1 fraction of the absorbed photosynthetically active radiation (fAPAR) time series is provided by the European Copernicus Global Land Service and is based on SPOT-VEGETATION satellite observations, from 1999 to present. fAPAR is a land ECV, ranges between 0 and 1 and is unitless. Both the archive and the near real time GEOV1 fAPAR are available at a global scale, on a 10-daily basis and at a spatial resolution of 1 km, under the HDF5 format on a latlon grid. The near real time data are provided no more than three days after the last observation. No restriction applies on the use of the product, which can be used for any application, included for commercial purposes.

The GEOV1 fAPAR product is described on the CEOS ECV inventory web site:

http://ecv-inventory.com/ecv-inventory/ceos?_dm_flow=user2&_dm_event=actions
(the record name of GEOV1 fAPAR is "CDR_ECV24_3")

and on the Copernicus Global Land Service web site:

<http://land.copernicus.eu/global/products/FAPAR>

On the latter, the following technical documents are provided:

Algorithm Theoretical Basis Document

(http://land.copernicus.eu/global/sites/default/files/products/GIO-GL1_ATBD_FAPAR_I1.00.pdf)

Product User Manual (http://land.copernicus.eu/global/sites/default/files/products/GIO-GL1_PUM_FAPAR_I1.00.pdf)

Validation Report (http://land.copernicus.eu/global/sites/default/files/products/GIO-GL1_VR_FAPAR_I1.00.pdf)

2.5.3.4 Data Origin

The SPOT-VEGETATION data used as input to the GEOV1 algorithm come from the VITO processing and archiving centre in Mol (Belgium). The GEOV1 fAPAR is produced by a neural network trained with the existing CYCLOPES V3.1 and MODIS C5 products which were fused to improve the fAPAR estimates by benefiting of the respective advantages of each product (Baret et al., 2013). The inputs of the neural network correspond to the directionally normalized top of canopy reflectance in the red, NIR and SWIR bands, as derived from the CYCLOPES V3.1 algorithm, and the median value of the sun zenith angle over the composition window of 30 days. The pre-processing steps include cloud screening, atmospheric correction based on a climatology of aerosols, and directional normalization using a robust fit of Roujean's model (Hagolle et al., 2004; Roujean et al., 1992). Details about the pre-processing can be found in the literature (Baret et al., 2007).

2.5.3.5 Validation and Uncertainty Estimate

The GEOV1 product was extensively validated through the comparison of the product to pre-existing fAPAR products (indirect validation) and to in situ fAPAR observations (direct validation). The latter were derived from a global network of homogeneous sites. The GEOV1 fAPAR presents reliable spatial distribution, smooth temporal profiles which are stable from year to year, good dynamic range with reliable magnitude for bare areas and dense forests, and optimal performances with ground-based maps. GEOV1 outperforms the quality of reference global products in most of the examined criteria. In particular, the direct validation indicates that, overall, GEOV1 fAPAR products are the most similar products to the reference maps, reaching an overall performance (RMSE) better than 0.1 for with no bias and a correlation (R^2) of 0.80. When comparing against other global fAPAR data sets, GEOV1 provides overall uncertainties below 0.1 with CYC and MOD products, with no systematic differences with MODIS. However, the systematic uncertainties are very large (close to 0.2) with JRC product.

The validation process is detailed in the Validation Report, and the results are published in the open peer-reviewed literature (Camacho et al., 2013). The temporal consistency of the product was assessed over a short period of time (2003-2005) by Camacho et al. (2013).

2.5.3.6 Considerations for climate applications

The period of time covered by the product (1999-2013) is too short to analyse trends. An attempt was made by CNES to merge GEOV1 with historical AVHRR data using the NASA Long Term Data Record data set (<http://ltdr.nascom.nasa.gov>), over the period 1981-1998, at a spatial resolution of 5 km. The idea was to adapt the neural network algorithm used to produce GEOV1 to the AVHRR dataset. The obtained 1981-2013 harmonized time series is described on the CEOS ECV inventory web site (record name "CDR_ECV24_4"). However, it is not recommended to use the resulting merged product as is. A discontinuity in the time series is clearly visible at many locations from 1998 to 1999 (see Fig. 2). The AVHRR-derived fAPAR presents lower values than the GEOV1 time series starting in 1999. This problem should be solved in a new revised version of the product (GEOV2). For the time being, an alternative is to use the 30-yr GIMMS fAPAR3g product derived from AVHRR

and MODIS observations (Zhu et al., 2013), or to use the extended GEOV1 data set to analyse the seasonal and interannual variability, only (not trends).

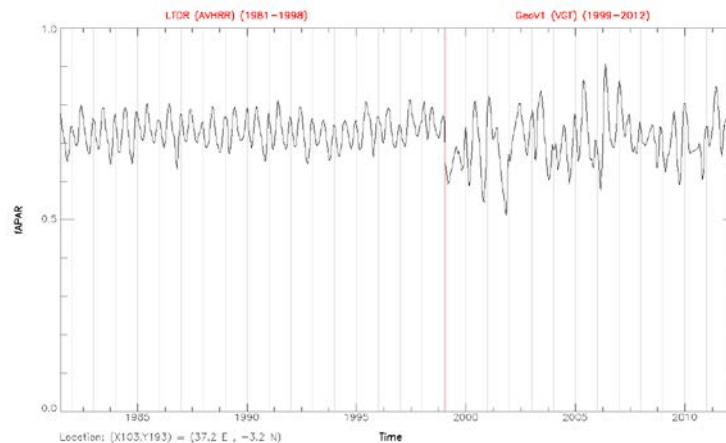


Figure 2 - Time series of the merged CDR_ECV24_4 AVHRR-GEOV1 product from 1991 to 2008 over a 5km x 5km location in Europe presenting a large contrast between the AVHRR-derived fAPAR (1991-1998) and the SPOT-VEGETATION-derived GEOV1 fAPAR (1999-2008).

2.5.3.7 Instrument Overview

The first VEGETATION European sensor was launched in 1998 aboard SPOT4. A second instrument was launched in 2002 aboard SPOT5 to ensure the continuity of observations. The two instruments are identical and provide global observations of the surface from a sun-synchronous orbit at 822 km altitude, with an inclination of 96.7°, a period of 26 days and an equatorial crossing time of 10:30. Because of the large swath (101°, equivalent to 2200 km), about 90% of the equatorial areas are imaged each day, the remaining 10% being imaged the next day. For latitudes higher than 35° (North and South), all regions are acquired at least once a day. The instrumental concept relies on a linear array of 1728 CCD detectors providing a spatial resolution around 1.15 km with minimum variations for off-nadir pixel size thanks to the telecentric design of the optics. Four spectral bands are available: B0 (450 nm, $\Delta\lambda=40$ nm); B2 (645 nm, $\Delta\lambda=70$ nm); B3 (835 nm, $\Delta\lambda=110$ nm); SWIR (1165 nm, $\Delta\lambda=170$ nm). The stability of the platform, the accurate knowledge on its position and attitude and post processing of the images allow to achieve a multi-temporal registration accuracy around 200 m (rms) (Baret et al., 2007).

2.5.3.8 References

Baret, F., Hagolle, O., Geiger, B., Bicheron, P., Miras, B., Huc, M., Berthelot, B., Nino, F., Weiss, M., Samain, O., Roujean, J.-L., and Leroy, M.: LAI, fAPAR and fCover CYCLOPES global products derived from VEGETATION, Part 1: Principles of the algorithm, *Remote Sens. Environ.*, 110: 275–286, 2007.

Baret, F., Weiss, M., Lacaze, R., Camacho, F., Makhmara, H., Pacholczyk, P., and Smets, B.: GEOV1: LAI and FAPAR essential climate variables and FCOVER global time series capitalizing over existing products. Part1: Principles of development and production, *Remote Sens. Environ.*, (2013)
<http://dx.doi.org/10.1016/j.rse.2012.12.027>.

Camacho, F., Cernicharo, J., Lacaze, R., Baret, F., and Weiss, M.: GEOV1: LAI and FAPAR essential climate variables and FCOVER global time series capitalizing over existing products. Part2: Validation and intercomparison with reference products, Remote Sens. Environ. (2013)
<http://dx.doi.org/10.1016/j.rse.2013.02.030>.

Hagolle, O., Nicolas, J. -M., Fournie, B., Cabot, F., & Henry, P.: Absolute calibration of VEGETATION derived from an interband method based on the sun glint over ocean. IEEE Transactions on Geoscience and Remote Sensing, 42, 1472–1481, 2004.

Roujean, J. L., Leroy, M., & Deschamps, P. Y.: A bidirectional reflectance model of the Earth's surface for the correction of remote sensing data, Journal of Geophysical Research, 97, 20455–20468, 1992.

Zhu, Z., Bi, J., Pan, Y., Ganguly, S., Anav, A., Xu, L., Samanta, A., Piao, S., Nemani, R.R., and Myneni, R.: Global data sets of vegetation Leaf Area Index (LAI)3g and Fraction of Photosynthetically Active Radiation (FPAR)3g derived from Global Inventory Modeling and Mapping Studies (GIMMS) Normalized Difference Vegetation Index (NDVI3g) for the period 1981 to 2011, Remote Sens., 5, 927-948, doi:10.3390/rs5020927, 2013.

2.5.3.9 Revision History

Version 1.0, 10 January 2014, Else Swinnen (VITO).

2.5.4 GEOV1 Surface Albedo

2.5.4.1 Intent of the Document

The objectives of this document are to (1) describe GEOV1 Surface Albedo (SA) time series produced by the European Copernicus Global Land service, based on SPOT-VEGETATION satellite observations, from 1999 to May 2014, (2) assess its usability in climate reanalysis studies.

2.5.4.2 Point of Contact

Roselyne Lacaze (HYGEOS), rl@hygeos.com

2.5.4.3 Data Field Description

The Copernicus Global Land GEOV1 Surface Albedo (SA) time series is based on SPOT-VEGETATION satellite observations, from 1999 to May 2014. The post-SPOT continuity will be ensured using PROBA-V observations and when available by Sentinel-3 observations. SA is a land ECV and is dimensionless. Two values are provided : directional SA ("black sky" SA) and hemispherical SA ("white sky" SA). Both the archive and the near real time SA are available at the global scale, on a 10-daily basis and at a spatial resolution of 1 km, under the HDF5 format on a regular latlon grid ("plate-carrée"). The near real time data are provided no more than three days after the last observation. No restriction applies on the use of the product, which can be used for any application, included for commercial purposes, according to the Copernicus data policies.

The SA product is described on the CEOS ECV inventory web site:

http://ecv-inventory.com/ecv-inventory/ceos?_dm_flow=user2&_dm_event=actions
(the record name of SA is "CDR_ECV22_2")

and on the Copernicus Global Land Service web site:

<http://land.copernicus.eu/global/products/SA>

On the latter, the following technical documents are provided:

Algorithm Theoretical Basis Document
(http://land.copernicus.eu/global/sites/default/files/products/GIO-GL1_ATBD_SAV1_I1.00.pdf)

Product User Manual
(http://land.copernicus.eu/global/sites/default/files/products/GIO-GL1_PUM_SAV1_I1.00.pdf)

Validation Report

(http://land.copernicus.eu/global/sites/default/files/products/GIO-GL1_VR_SAV1_I1.00.pdf)

2.5.4.4 Data Origin

The SPOT-VEGETATION data used as input to the SA algorithm come from the VITO processing and archiving centre in Mol (Belgium). The algorithm has been defined by Météo-France (Centre National de Recherches Météorologique) in the framework of the FP5/CYCLOPES project which first has elaborated a surface albedo from the SPOT/VEGETATION sensor data. It follows the approach separating atmospheric correction, directional reflectance normalization, and albedo determination. The inputs of the algorithm correspond to the directionally normalized top of canopy reflectance in the red, NIR and SWIR bands, as derived from the CYCLOPES V3.1 algorithm, and the median value of the sun zenith angle over a composition window of 30 days. The pre-processing steps include cloud and snow screening, and atmospheric correction based on a climatology of aerosols. , The directional normalization uses a robust fit of Roujean's model (Hagolle et al., 2004; Roujean et al., 1992). Details about the processing can be found in the literature (Baret et al., 2007).

2.5.4.5 Validation and Uncertainty Estimate

The SA product was extensively validated through the comparison of the product to pre-existing SA products (indirect validation) and to in situ SA observations (direct validation). The latter were derived from global networks of homogeneous sites. Except for high latitudes and equatorial regions, the SA presents reliable spatial distribution, smooth temporal profiles which are stable from year to year, good dynamic range with reliable magnitude for bare areas and dense forests, and optimal performances with ground-based observations. For high latitudes and equatorial regions the lack of spatial continuity is very high, especially during winter in the northern hemisphere. This is one of the main drawbacks of the GEOV1 SPOT/VGT Albedo and of other polar orbiting satellite products, in contrast to products derived from geostationary sensors. GEOV1 SA scores with respect to in situ observations are slightly less than for the MODIS products. The validation process is detailed in the Validation Report.

2.5.4.6 Considerations for climate applications

The period of time covered by the product (1999-2014) is too short to analyse trends.

2.5.4.7 Instrument Overview

The first VEGETATION European sensor was launched in 1998 aboard SPOT4. A second instrument was launched in 2002 aboard SPOT5 to ensure the continuity of observations. The two instruments are identical and provide global observations of the surface from a sun-synchronous orbit at 822 km altitude, with an inclination of 96.7°, a period of 26 days and an equatorial crossing time of 10:30. Because of the large swath (101°, equivalent to 2200 km), about 90% of the equatorial areas are imaged each day, the remaining 10% being imaged the next day. For latitudes higher than 35° (North and South), all regions are acquired at least once a day. The instrumental concept relies on a linear array of 1728 CCD detectors providing a spatial resolution around 1.15 km with minimum variations for off-nadir pixel size thanks to the telecentric design of the optics. Four spectral bands are available: B0 (450

nm, $\Delta\lambda=40$ nm); B2 (645 nm, $\Delta\lambda=70$ nm); B3 (835 nm, $\Delta\lambda=110$ nm); SWIR (1165 nm, $\Delta\lambda=170$ nm). The stability of the platform, the accurate knowledge on its position and attitude and post processing of the images allow to achieve a multi-temporal registration accuracy around 200 m (rms) (Baret et al., 2007).

2.5.4.8 References

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2.5.4.9 Revision History

Version 1.0, 24 June 2014, Jean-Christophe Calvet (Meteo-France).

Version 1.1, 25 June 2014, Roselyne Lacaze (HYGEOS).

2.5.5 ESA-CCI Soil Moisture

2.5.5.1 Intent of the Document

The objectives of this document are to (1) describe the ESA CCI soil moisture product provided by Technische Universitaet Wien (TU Wien) using multiple satellite/sensors, from 1978 to 2010 and (2) assess its usage for climate change science.

2.5.5.2 Point of Contact

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2.5.5.3 Data Field Description

The ESA CCI Soil Moisture is provided globally by Technische Universitaet Wien (TU Wien).

- Spatial domain: global
- Temporal domain: 1978-2010
- Spatial resolution: 0.25°~1.5°
- Temporal resolution: between 1 and 3 days
- Layer depth: 0.5-10 cm
- Accuracy: will only be available after Aug. 2014
- Stability: will only be available after Aug. 2014
- Quality and confidence flags: snow, frozen soil, topography, water, etc.
- Data format: NetCDF
- Available metadata: global soil porosity map
- Delivery mechanism: <http://www.esa-soilmoisture-cci.org/node/145>

The product is described on the CEOS ECV inventory web site:

http://ecv-inventory.com/ecv-inventory/ceos?_dm_flow=user2&_dm_event=actions (the record name is "CDR_ECV28_1")

and on the ESA CCI Soil Moisture website: <http://www.esa-soilmoisture-cci.org/>. From the website, the following technical documents are provided:

- User Requirement Document
(http://www.esa-soilmoisture-cci.org/sites/default/files/documents/public/Deliverables/CCI_Soil_Moisture_D1.1_URD_v.2.0.pdf)
- Comprehensive Error Characterisation Report (CECR)
(http://www.esa-soilmoisture-cci.org/sites/default/files/documents/public/Deliverables/20120521_CCI_Soil_Moisture_D1.2.1_CECR_v.0.7.pdf)
- Data Access Requirements Document (DARD)
(http://www.esa-soilmoisture-cci.org/sites/default/files/documents/public/Deliverables/20120413_CCI_Soil_Moisture_D1.3_DARD_v.1.2.PDF)
- Product Validation Plan (PVP)
(http://www.esa-soilmoisture-cci.org/sites/default/files/documents/public/Deliverables/20120830_CCI_Soil_Moisture_D2.1_PVP_v.1.1.pdf)
- Algorithm Theoretical Basis Document (ATBD)
(http://www.esa-soilmoisture-cci.org/sites/default/files/documents/public/Deliverables/20130214_CCI%20Soil%20Moisture%20ATBD1.v1.0.pdf)
- Product Validation and Algorithm Selection Report (PVASR)
(http://www.esa-soilmoisture-cci.org/sites/default/files/documents/public/Deliverables/CCI_Soil_Moisture_D2.5_PVASR_v1.0.pdf)
- Detailed Processing Models
(http://www.esa-soilmoisture-cci.org/sites/default/files/documents/public/Deliverables/20121126_CCI_Soil_Moisture_D2.7_DPM_v.1.0.pdf)
- Input Output Data Definition (IODD)
(http://www.esa-soilmoisture-cci.org/sites/default/files/documents/public/Deliverables/20121221_CCI_Soil_Moisture_D2.8_IODD_v1.0.pdf)
- System Prototype Description (SPD)
(http://www.esa-soilmoisture-cci.org/sites/default/files/documents/public/Deliverables/CCI_Soil_Moisture_D3.1_SPD_v.1.0.pdf)
- System Verification Report (SVR)
(http://www.esa-soilmoisture-cci.org/sites/default/files/documents/public/Deliverables/CCI_Soil_Moisture_D3.2_SVR_v.1.0.pdf)
- Database for Task 3

(http://www.esa-soilmoisture-cci.org/sites/default/files/documents/public/Deliverables/CCI_Soil_Moisture_Database_Task3_v1.0.pdf)

- System Requirements Document (SRD)
(http://www.esa-soilmoisture-cci.org/sites/default/files/documents/public/Deliverables/20121221_CCI_Soil_Moisture_D5.1_SRD.pdf)

2.5.5.4 Data Origin

The soil moisture merging scheme, for generating ESA CCI soil moisture, can be subdivided into three components: error characterisation, rescaling, and merging. Characterising the uncertainty of the individual data sets is required to decide for each location which data set provides the most reliable soil moisture estimates and, therefore, should be favoured in the merged product. Rescaling of the different data sets is needed to bring the different data sets into a common observation space. The merging itself combines the different data sets into a single product. It was decided to merge the data sets in two successive stages: First, all radiometer-based soil moisture observations are merged to a single passive soil moisture time series and all scatterometer-based soil moisture observations are merged to a single active soil moisture time series; Second, the resulting active and passive time series are combined into a final multi-sensor product (Dorigo et al. 2011; Liu et al. 2011).

The soil moisture ECV is generated within the WACMOS and soil moisture CCI project. For the time being, the inter-satellite calibration on Level 1B data has not been implemented. The ECV data is generated based on Level 2 data (from both active and passive microwave sensors). The algorithms used for soil moisture retrieval are TU Wien Change Detection Algorithm for scatterometer and Land Parameter Retrieval Method for radiometer. The homogenization/rescaling approach adapts CDF (cumulative distribution function) matching method.

2.5.5.5 Validation and Uncertainty Estimate

The ESA CCI soil moisture product (ECVSM) has been extensively validated through the comparison of the product to reanalysis data (e.g. ERA-Interim/Land, GLDAS) and to in-situ soil moisture observations (e.g. International Soil Moisture Network). Although the strategy introduced in section 4 is expected to allow a selective use of the most accurate measurements and increases the temporal density of the observations available, the final product cannot effectively provide soil moisture information for high-elevation regions (Zeng et al. 2014).

The low retrieval rate of soil moisture over high-elevation regions is mainly due to the limitation inherent to the used microwave data (e.g. the signal of liquid water content is difficult to be retrieved over frozen ground) (Owe et al. 2008; Wagner et al. 2013). Both AMSR-E and ASCAT-L2 data have advisory flags for frozen soil, which partially leads to the sparse temporal retrieval of soil moisture. The rescaling and merging strategies itself

contribute to another aspect of explanation of the low retrieval rate. The merging strategy deploys AMSR-E and ASCAT-L2 data only over the sparsely and moderately vegetated regions of the globe and combines them only when the CDF matched AMSR-E and ASCAT-L2 data are highly correlated (e.g. correlation coefficient is greater than 0.65) (Liu et al. 2011). On the other hand, the rescaling strategy adapted output of a land surface model (e.g. Noah) as the reference, by which the soil property used may not be representative over TP. Last but not least, the freezing/thawing treatment in land surface model may partially contribute to the low rate of retrieval as well (Su et al. 2013).

Most recently, Loew et al. (2013) found that the inter-annual soil moisture dynamics as represented by ECVSM is in general good anomaly correlations with different global precipitation products and has skill to represent soil moisture dynamics independent from the precipitation forcing. The highest skill in representing soil moisture dynamics was observed in areas that are not affected by dense vegetation or snow and ice. In terms of data homogeneity, the data density of ECVSM is limited due to snow cover and frozen ground conditions, which is also found by Zeng et al (2014). The ECVSM shows discontinuities in its time series as showed below:

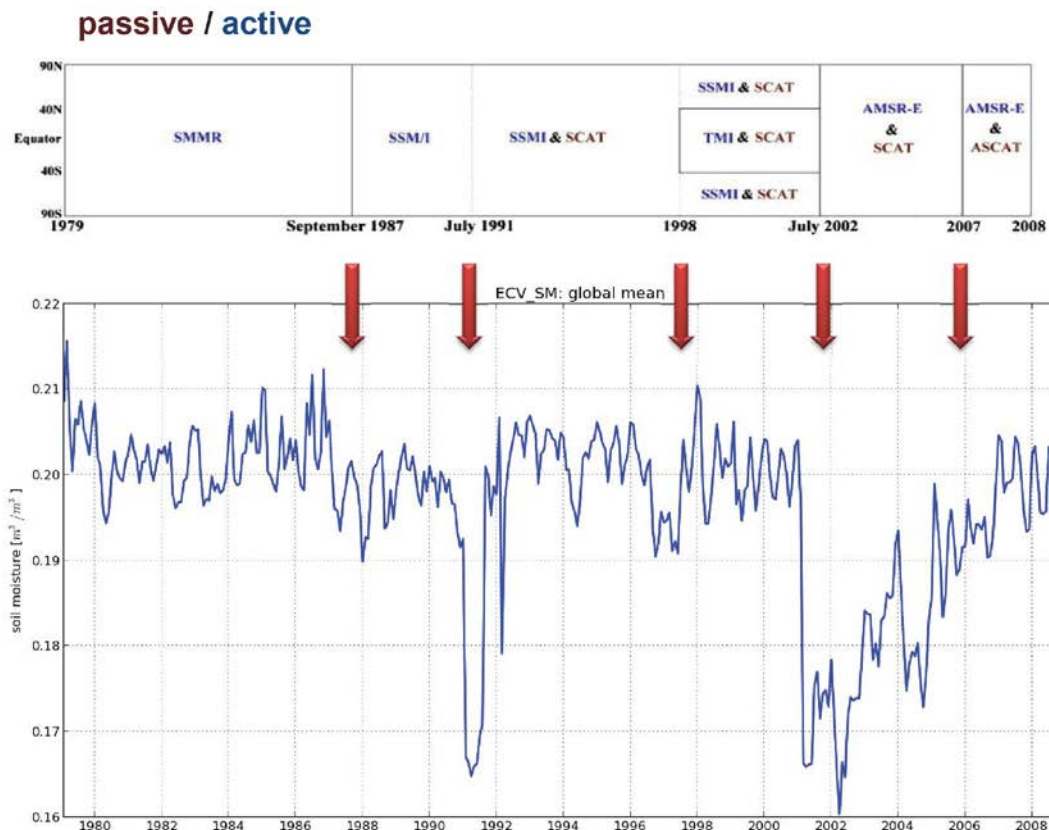


Figure 1 The discontinuities may be caused by a change in the observing system, which affects the absolute soil moisture values as well as the temporal sampling of the data. (Adopted from Loew 2013)

2.5.5.6 Considerations for climate applications

ECVSM has been used to detect trends worldwide. Dorigo et al. (2012) found that 27% of the area covered by the dataset showed significant trends ($p=0.05$), of those, 73% were negative and 27% positive. The most prominent trend patterns in remotely sensed surface moisture were also found in GLDAS-Noah and ERA-Interim soil moisture and GPCP precipitation. However, the relationship with trends in GIMMS-NDVI is more complex. One note is that ECVSM is generated based on GLDAS-Noah soil moisture climatology. This leads to the probability density function is dependent on GLDAS-Noah and therefore does not provide a model independent dataset for soil moisture percentile distribution (see table 1 below from Loew et al 2013). It is indicated that although ECVSM does not provide an independent measure the temporal dynamics is not affected.

Most recently, ECVSM has been used to detect the links between ENSO cycle and trends in continental evaporation (Miralles et al. 2013), the decline trends of land evapotranspiration (Jung et al. 2010), the trend of precipitation over drier soil (Taylor et al. 2012), the global patterns in base flow index (Beck et al. 2013) and the global vegetation biomass change (Liu et al. 2013).

Table 1. Summary of potential and limitations of ECVSM for climate modeling applications.

Potential	Current limitations
Climate model evaluation	
Percentile statistics are useful tool for model evaluation	ECVSM soil moisture probability density function is dependent on Noah GLDAS and therefore does not provide a model independent dataset for soil moisture percentile distribution
ECVSM shows consistent temporal trend patterns with precipitation and ancillary soil moisture data	ECVSM shows discontinuities in the long-term time series, which are likely to be the result from changing observing systems. Any conclusions from trend analysis therefore need to be taken very carefully.
	Time series not homogeneous due to different data rescaling approaches before and after 1988; see Liu et al. (2012), Sect. 3.1.2 for details Limited data coverage in early years (< 1990)
Process and regional studies	
Good representation of intra- and interannual soil moisture anomalies at global to regional scale	Risk of regionally missing soil moisture information due to binary-like blending technique applied; example: missing Europe's 2003 heat wave
Suitable soil moisture information for land-atmosphere interactions in the Sahel	High latitude limitation due to snow cover and frozen soil conditions

(from Loew et al. 2013)

2.5.5.7 Instrument Overview

The generation of ECVSM focuses on C-band scatterometers (ERS-1/2 scatterometer, METOP Advanced Scatterometer) and multi-frequency radiometers (SMMR, SSM/I, TMI, AMSR-E, Windsat) as these sensors are characterized by their high suitability for soil

moisture retrieval and a long technological heritage. Other microwave sensors suitable for soil moisture retrieval, including the Soil Moisture and Ocean Salinity (SMOS) mission, Synthetic Aperture Radars (SARs), Aquarius and radar altimeters, are not considered in the first phase of the CCI programme.

2.5.5.8 References

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2.5.5.9 Revision History

Version 1.0, 08/01/2014, Yijian Zeng (ITC) Version 1.1, 09/01/2014, Yijian Zeng (ITC)

2.5.6 ESA CCI LandCover datasets

2.5.6.1 Intent of the Document

At the end of a first 3-year phases, the ESA LandCover_CCI project delivers the following datasets:

- Global land cover (LC) databases made of :
 - o 3 global LC maps at 300m spatial for 3 epochs centered on the years 2010 (2008-2012), 2005 (2003-2007) and 2000 (1998-2002);
 - o 3 LC condition products which describe the natural variability of the land surface. They correspond to three aggregated land surface seasonality products: the NDVI, the Burned Areas (BA) and the snow.
- Global surface reflectance (SR) time series made of 7-day composites from 2003 to 2012.

2.5.6.2 Point of Contact

Contact for all LandCover_CCI is Pierre Defourny from UCLouvain-Geomatics (Belgium) (pierre.defourny@uclouvain.be)

2.5.6.3 Data Field Description

The LC maps describe the stable elements of the land surface, using a typology made of 22 classes defined using the UN Land Cover Classification System (LCCS). This LCCS typology is compatible with the Plant Functional Types used in climate modelling studies. At this stage, only macroscopic forest changes have been identified to derive the 3 epochs.

The LC condition products provide, on a per pixel basis, climatological variables which depict the reference behaviour for the vegetation greenness, the snow and the BA at global scale. This behavior is characterized by the average trajectory and the intra-annual variability over the 1998-2012 period.

The global SR time series delivered in the project are the ones which served as input for generating the global LC maps. They are made of temporal syntheses obtained over a 7-day compositing period.

The following tables summarize the main characteristics of the ESA LandCover_CCI datasets. More detailed information about the technical specifications of these 3 products can be found in the Product Specification Document (v1.10) available on the project website (<http://www.esa-landcover-cci.org/>).

Table 6: Main characteristics of the global LC maps

PRODUCT	MEASUREMENTS	SPATIAL COVERAGE AND RESOLUTION	TEMPORAL COVERAGE	TEMPORAL RESOLUTION	DATA VOLUME
Global LC maps	– LC classification in LCCS – Pixel processed or not – Pixel status – Number of valid observations – Overall LC assessment	Global – 300 m	1998-2002 2003-2007 2008-2012	5 years	~ 350 MB

Table 7: Main characteristics of the LC condition products

CLIMATOLOGICAL DATASET	MEASUREMENTS	SPATIAL COVERAGE AND RESOLUTION	TEMPORAL COVERAGE	TEMPORAL RESOLUTION	DATA VOLUME
NDVI	– Mean – Standard deviation – Number of valid weekly composites – Status	Global - 1000m	1999-2012	Weekly	~ 30GB
Burned Areas	– Percentage of occurrence – Number of valid weekly composites	Global - 500m	2000-2012	Weekly	~ 5GB
Snow	– Percentage of occurrence – Number of valid weekly composites	Global - 500m	2000-2012	Weekly	~ 8GB

Table 8: Main characteristics of the SR time series

PRODUCT	MEASUREMENTS	SPATIAL COVERAGE AND RESOLUTION	TEMPORAL COVERAGE	TEMPORAL RESOLUTION	DATA VOLUME
Top of Canopy SR time series in 13 spectral bands in visible and near infrared (NIR)	– SR mean – SR uncertainties – Mean of vegetation index – Number of contributing observations over clear sky land in aggregation period – Number of observations with water / snow and ice / cloud / cloud shadow coverage in aggregation	Global – 300 m (Full Resolution) Global – 1000 m (Reduced Resolution)	2003-2012	7-days	~ 350 MB

	period – Pixel status				
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2.5.6.4 Data Origin

The SR time series made of 7-day composites are derived from the full archive of the ESA Envisat MERIS sensor (2003-2012). The spectral content encompasses the 13 (without band 11 and 15) of the 15 MERIS spectral channels and the spatial resolution is of 300 m for MERIS FR and 1000m for MERIS RR. These 7-day composites were obtained by pre-processing the MERIS L1B products using several modules: radiometric and geometric correction, pixel identification, atmospheric correction with aerosol retrieval and compositing and mosaicking procedures.

The global LC maps are derived from those MERIS global SR time series, as well as from SPOT-Vegetation time series from 1998 to 2012. First, a baseline LC map is generated by running machine learning and unsupervised classification algorithms on the entire MERIS SR time series from 2003 to 2012. This 10-year baseline LC map is then updated using SPOT-Vegetation time series from 1998 to 2012 to detect the annual forest changes.

The LC condition products are built from existing long-term global datasets with high temporal frequency and moderate spatial resolution (250m-1km). They result from a compilation of 13 years of 7-day instantaneous observations into 1 temporarily aggregated yearly profile of reference.

Table9: Input data used to compile the land surface seasonality products.

CLIMATOLOGICAL SERIES	INPUT DATA
NDVI	14 years (1999-2012) of daily S1 SPOT-VGT surface reflectance time series and related quality flags [www: http://www.vgt.vito.be/indexIE.html]
Burned Areas	13 years (2000-2012) of the Global Fire Emissions Database version 3 (GFED.v3) products [Giglio et al., 2010]. Its spatial resolution is 500m.
Snow	13 years (2000-2012) of the "MODIS/Terra Snow Cover 8d L3 Global 500m SIN Grid" product (MOD10A2) [Riggs and Salomonson, 2006]

The methodology for the **NDVI land surface seasonality** consists in 5 steps: production of 7-day composites; NDVI computation; aggregation, 7-day period by 7-day period, of the resulting 14 annual time series over years; NDVI profiles smoothing; quality flags computation.

The **burned areas land surface seasonality** product is made in 2 steps: a splitting algorithm converts the monthly aggregated input data into 7-day composites and then, BA observations are aggregated over the 13 years to generate the BA land surface seasonality product itself.

The processing chain leading to the **snow land surface seasonality** product includes 4 steps: spatial filtering to reduce NaN observations; temporal aggregation of snow observations over 13 years to obtain the percentages of snow occurrence; temporal resampling from the original

8-day period to the required 7-day period; application of a temperature filter to reduce commission errors.

Finally, as the land surface seasonality products are built from various independent data sources, post-edition steps were applied to reach **compliance** between all land surface seasonality products.

2.5.6.5 Validation and Uncertainty Estimate

The LC maps were validated following international standards in an independent process (using validation datasets that were not used during the production of the LC maps and carried out by external parties). The validation process included three different steps: elaborating the sampling strategy, collecting reference data sources and assessing the products accuracy. A contingency matrix was built by comparing the maps with the validation dataset. When considering the entire validation dataset (2308 samples), the accuracy level is found to be 70.8% and it increases up to 74.4% when using only the 1484 validation samples located in homogeneous areas. Producers and users accuracy values have also been computed in order to provide more information about the accuracy of the different thematic classes. Classes like “Cropland”, “Forest”, “Bare Areas”, “Broadleaved Evergreen Forest”, “Water” and “Snow and Ice”. On the other hand, classes such as “Shrubland”, “Grassland”, “Sparse vegetation” and “Wetlands” can be more affected by errors. Finally, it shall be mentioned that the quality of the map varies according to the region of interest. Looking at the number of valid observations available over a region (information which is provided as a quality flag) gives a first indication about the input data quality and the expected classification reliability.

For the LC condition, no formal validation or uncertainty estimates were performed. Nonetheless, the spatial consistency and the products’ limitations were evaluated. In addition, discrepancies between condition products were assessed for the 3 following pairs: BA vs Snow, BA vs NDVI and Snow vs NDVI. In all cases, few discrepancies were observed on average: less than 1% of the burnt surface, 2% of the burnt surface and 3% of the snow covered surface for the respective above-mentioned 3 pairs.

The quality of the global SR time series was first visually assessed, showing improvements compared to previous versions in other projects. In addition, the discrimination potential of the time series was evaluated by computing (i) the intra- and inter-annual reflectance dynamics (range and standard deviation) from the overall spectral reflectance distribution for each spectral band, (ii) the temporal variance at the pixel level for the various spectral reflectance values and (iii) the local variance for the various spectral reflectance values within a LC class and across LC classes. Finally, reflectance values were compared against in-situ data (mean spectra retrieved from time series of the CEOS LANDNET site Dunhunag, La Crau, Negev and Railroad Valley Playa) and the geometric accuracy was evaluated to be 70-m.

2.5.6.6 Considerations for climate applications

LC indeed refers to one of the most obvious and commonly used indicators for land surface parameterization and is much associated to the human activities and natural processes, while also playing a significant role in climate forcing. The unique and new property of the ESA

LandCover_CCI dataset is the distinction between the stable and the dynamic components of the land surface, which was a key requirement of the climate modellers involved in the project. The LC concept has been revisited to deliver both LC maps that are stable and consistent and a set of three climatological 7-day time series representing several seasonal dynamics of the land surface.

This innovative concept clearly opens new opportunities in the climate domain. This ESA LandCover_CCI dataset corresponds to a first version, which is already considered as mature even if there are limitations.

The main limitations of the 3 global LC maps are of 2 types. First, the mapping of the boreal region and more precisely, of the transition between the grassland, sparse vegetation and bare areas, is of lower quality. Second, the changes between the 3 maps only concern the forest classes in this version. Other classes will be considered in the next products delivery.

For the LC condition, a discrepancy analysis was carried out between them and showed that, although based on independent sensors, various spatio-temporal resolutions and algorithms, they can be used together to further describe the land surface in a consistent manner. There is therefore no known evidence against using them in climate modelling. Yet, it shall be mentioned that the reliability of the products is spatially variable and dependant on the number of valid and cloud-free weekly composites which is to be used as a quality indicator. The lowest numbers of valid and cloud-free observations are found over the western coast of central Africa and extreme latitudes. One of the drawbacks with using optical time series for global mapping is the inconsistency of the valid coverage along the year. Data are missing over high latitudes during winter time when there is no solar illumination. The lack of validation and uncertainty estimates is also a limitation.

2.5.6.7 Instrument Overview

More information about the input data is given in section 4.

2.5.6.8 References

Datasets are openly available after registration at <http://maps.elie.ucl.ac.be/CCI/viewer/>.

Deliverables and other information about the project are available on the project website <http://www.esa-landcover-cci.org/>.

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2.5.6.9 Revision History

This document provides a first draft version (1.0) issued on 02/07/2014 by the project consortium.

2.5.7 EUMETSAT CM SAF CLARA-A1-SAL

2.5.7.1 Intent of the Document

This document summarizes essential information needed for users of any level who wish to use the CLARA-A1-SAL data set for climate applications. The CLARA-A1-SAL data set is derived from measurements of AVHRR visible/infrared imagers on NOAA and Metop-A satellites.

2.5.7.2 Point of Contact

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2.5.7.3 Data Field Description

The quantity described by the CLARA-A1-SAL dataset is the broadband Directional-Hemispherical Reflectance (DHR) of Earth's surface, also called *Black-sky albedo*. While surface albedo in general is defined as the dimensionless ratio of surface-reflected radiation flux to incident radiation flux, DHR specifically defines the incoming radiation flux as unidirectional so that there are no atmospheric effects included. Therefore, DHR describes only the inherent optical properties of the reflecting surface (as a function of Solar Zenith Angle). For a full discussion on various reflectance quantities and their relationships, please see e.g. Schaepman-Strub et al., (2006).

The dataset has a global coverage, spanning 1982-2009. The CLARA-A1-SAL dataset is a part of the CLARA-A1 dataset family (Karlsson et al., 2013). The input data for CLARA-A1-SAL is formed based on a Fundamental Climate Data Record (FCDR) of AVHRR radiances, which employs a state-of-the-art homogenization and intercalibration of the instrument-observed radiances (Heidinger et al., 2010). AVHRR data coverage per satellite is illustrated in Figure 1 (from Karlsson et al., 2013). The reference paper of the CLARA-A1-SAL covering processing aspects and validation results is available by Riihelä et al., (2013).

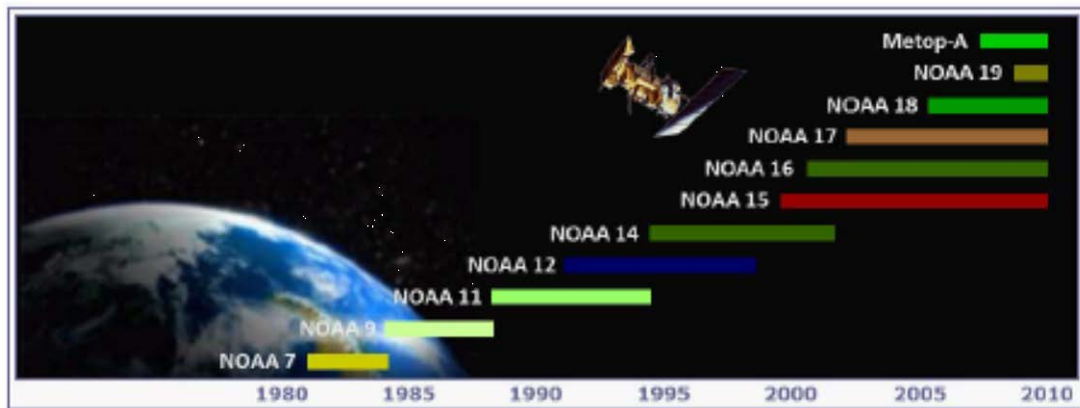


Figure 8: Temporal coverage of AVHRR data in CLARA-A1-SAL.

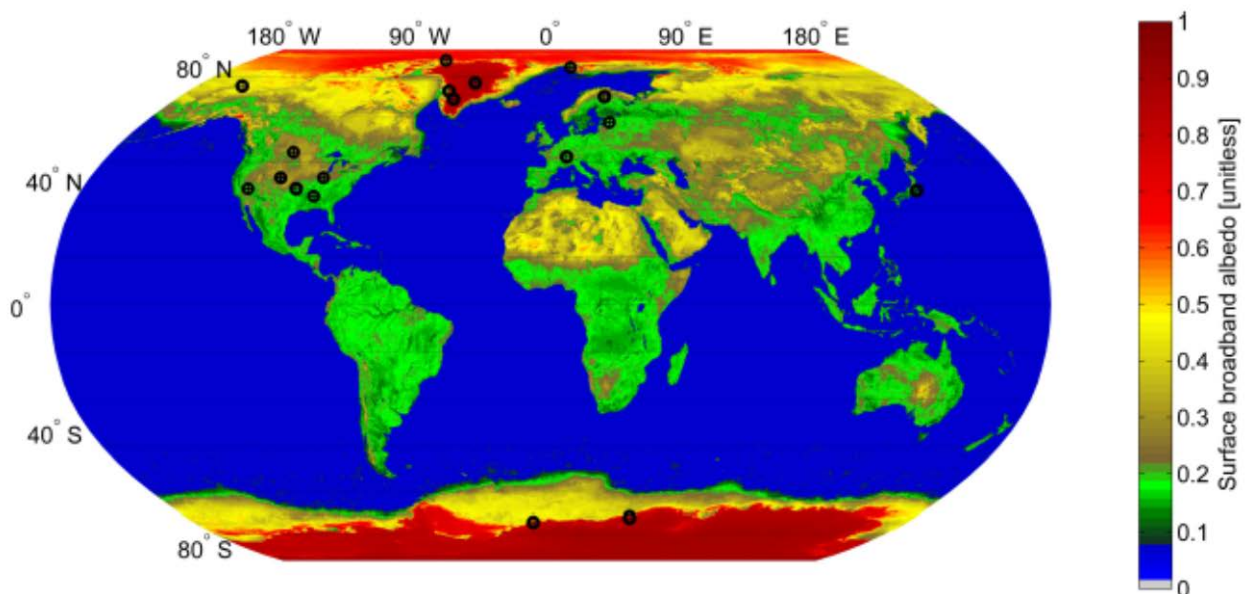


Figure 9: Annual mean observable DHR of the Earth in 2007, composed from monthly mean CLARA-A1-SAL products. Black cross-in-circle markers indicate dataset validation sites.

The products provided to end users are the five-day mean albedo and the monthly mean albedo. Global products are provided in a regular latitude-longitude grid with a cell resolution of 0.25 degrees. For cryospheric applications, the Polar regions' data have been subsetting from the original swath-level retrievals into 25 km resolution pole-centric Lambert Equal Area projections. Figures 2 and 3 illustrate the coverage and retrieved DHR from CLARA-A1-SAL for the global and Arctic products (from Riihelä et al., 2013).

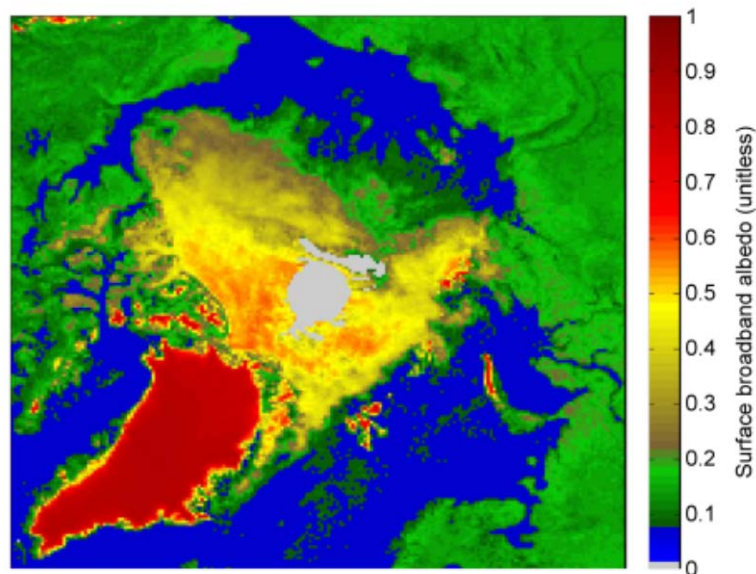


Figure 10: Arctic monthly mean surface albedo [DHR] from CLARA-A1-SAL for August 2007.

2.5.7.4 Data Origin

In CLARA-A1-SAL, the SAL algorithm retrieves broadband DHR from intercalibrated AVHRR imager data from bands 1 and 2. Cloud identification and calculation of satellite and illumination geometry is performed by the Polar Platform System software (Dybbroe et al., 2005). The albedo retrievals follow distinct paths according to the land cover class of each area in question, as shown in Figure 4.

The processing paths for snow and water surfaces are different from the more traditional path for vegetated surfaces. For water, a LUT is used to directly infer open water broadband albedo at a fixed SZA regardless of satellite-observed reflectance. For snow, the instantaneous overpasses are kept as directional-directional reflectances, temporal averaging forms the desired hemispherical-directional reflectances (by sampling of the full hemispheric reflectance signature). A full treatment of the processing is available in the CLARA-A1-SAL Algorithm Theoretical Basis Document (ATBD), downloadable through http://dx.doi.org/10.5676/EUM_SAF_CM/CLARA_AVHRR/V001

2.5.7.5 Validation and Uncertainty Estimate

The CLARA-A1-SAL dataset was validated against in situ albedo observations from the Baseline Surface Radiation Network (BSRN), Greenland Climate Network (GC-Net), and the SHEBA and Tara floating ice camps by Riihelä et al. (2013). Steps were taken to minimize the representativeness problems of comparing point-like in situ observations to coarse scale satellite retrievals. CLARA-A1-SAL was generally capable of achieving a 10-15% relative retrieval uncertainty versus land/seasonal snow in situ observations. For snow and ice surfaces, the demonstrated relative retrieval uncertainty was 5-10%. For illustration, Figure 5 shows the CLARA-A1-SAL validation results over Arctic sea ice against in situ observations from two ice camps.

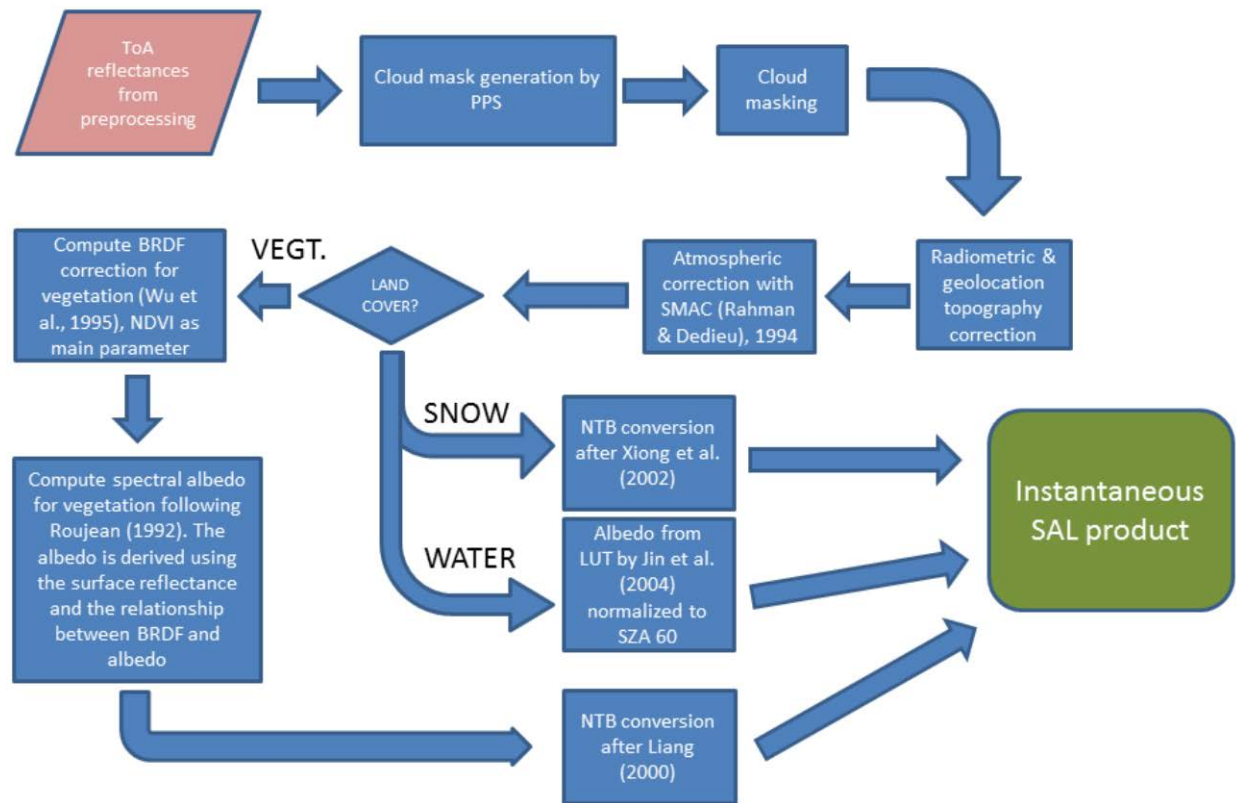


Figure 11: The SAL processing scheme used in CLARA-A1-SAL generation.

It should be noted that the static background AOD (of 0.1 at 550 nm) used in CLARA-A1-SAL creates larger retrieval biases in areas with natural high aerosol loading conditions, such as Sahel or Southeast Asia. Therefore, we have created a post-processing correction scheme for users who possess accurate AOD data over their region and period of interest and who wish to correct CLARA-A1-SAL for any unaccounted aerosol effects in the retrieved albedo. Details on the method are available from Manninen et al. (2013).

The stability of the dataset was assessed by calculating the maximum deviations from the 28-year mean DHR at Summit camp on the Greenland ice sheet and Dome-C on Antarctica. These sites were chosen for their high natural albedo stability. The results from these sites were similar; a maximum deviation of 6.8% (relative) was found at Summit and 5.5% at Dome-C. This finding also supports the good quality of the AVHRR radiance intercalibration used as input.

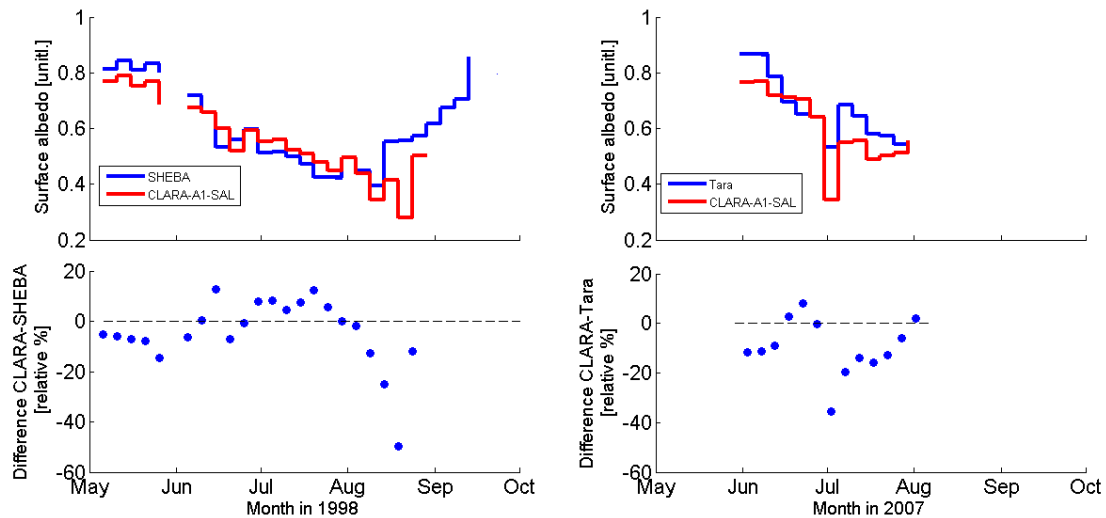


Figure 12: Upper plots: CLARA-A1-SAL five-day mean DHR against in situ albedo observations from the SHEBA (left) and Tara (right) floating ice camps on the Arctic Ocean. Lower plots: Relative difference of the retrievals against reference.

2.5.7.6 Considerations for climate applications

The quality of cloud screening is paramount for optical imager-based albedo retrievals. While the PPS-based cloud mask has been shown to be quite accurate (Karlsson et al., 2013), cloud misclassifications inevitably occur. These misclassifications can lead to a substantial bias in a single overpass, but generally their effect on the five-day and particularly monthly mean CLARA-A1-SAL products is assessed to be minor. Exceptions may occur particularly in low Sun elevation conditions when there is a very limited amount of AVHRR data available for averaging.

The quality of the dataset has been shown to be good for cryospheric applications, demonstrated by first published applications on the Arctic sea ice albedo part of the dataset (Riihelä et al., 2013, Karlsson and Svensson, 2013, Koenigk et al., 2013).

Potential for CLARA-A1-SAL use in global energy budget studies also exists but will require a careful postprocessing of remaining AOD variation effects following e.g. Manninen et al. (2013), as well as a quantitative accounting of the effects of varying land cover usage on the albedo retrievals, as CLARA-A1-SAL uses the USGS land cover classification of 1992/93 throughout the 28-year coverage.

2.5.7.7 Instrument Overview

The initial AVHRR instrument only measured in four spectral bands (AVHRR/1), but from 1982 a fifth channel at 12 μm was added (AVHRR/2). Further, a sixth channel at 1.6 μm was added in 1998 (AVHRR/3); however, this channel was only accessible if switched with the channel at 3.7 μm .

The AVHRR instrument measures at a horizontal resolution close to 1 km at nadir but only data at a reduced resolution of approximately 4 km (Global Area Coverage, GAC) are permanently archived and currently available with global coverage since the onset of measurements.

2.5.7.8 References

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2.5.7.9 Revision History

10-01-2014 - Version 1 – Initial draft created by Aku Riihelä.

2.5.8 ESA GlobSnow Snow Extent

2.5.8.1 Intent of the Document

This document summarizes essential information needed for users of any level who wish to use the GlobSnow Snow Extent data set for climate applications. The European Space Agency (ESA) Data User Element (DUE) GlobSnow Snow Extent (SE) product set version 1.2 for the Northern Hemisphere represents information on snow coverage retrieved from ERS-2 ATSR-2 and Envisat AATSR from 1995 until present.

2.5.8.2 Point of Contact

Kari Luojus, Finnish Meteorological Institute, kari.luojus@fmi.fi

2.5.8.3 Data Field Description

Snow extent, or fractional snow cover, is the classification of the snow covered area in the mean of graduation. While this graduation can be defined as percentage, it can be classified as a few levels of coverage. GlobSnow SE product covers four types of products. Daily Fractional Snow Cover (DFSC) defines the snow covered area as a percentage in a daily temporal sampling. Daily 4-classes Snow Cover classifies the snow covered area into 4 classes, which is derived from DFSC. Weekly Aggregated Fractional Snow Cover (WFSC) is derived from the snow information of seven consecutive days for the best estimation and cloud-free results. Monthly Aggregated Fractional Snow Cover (MFSC) is the monthly version of WFSC.

GlobSnow SE is a global product and the input data is taken from both ERS-2 ATSR-2 and Envisat AATSR. ATSR-2 and AATSR operating onboard of ERS-2 and ENVISAT since 1995 and 2002, respectively, provide a 15 years data set for producing global snow extent maps at a resolution of about 1 km. The spectral characteristics and resolution of ATSR-2 and AATSR are summarized in Table 1.

Table1:
Characteristics of ERS-2 ATSR-2 and ENVISAT AATSR.

<i>ATSR-2, AATSR Specifications</i>	
Spectral Channels [μm]	0.55, 0.66, 0.87, 1.6, 3.7, 11.0
Resolution	1.03 x 1.03 km at nadir
Swath Width	500 km, 555 pixels
Global Coverage	35 and 168 day cycles
Signal Quantization	12-bit

Both sensors provide VIS and SWIR channels which is especially important for snow / cloud discrimination. The swath width is ca 500 km. As an example Figure 1 shows the coverage of AATSR for the Northern Hemisphere on 24 May 2008. Figure 2 and Figure 3 show detailed

views of the 3 and 6 days coverage of Europe. Within 6 days Europe is covered by about 99%, only small diamond shaped data gaps are found south of ca 40°N.

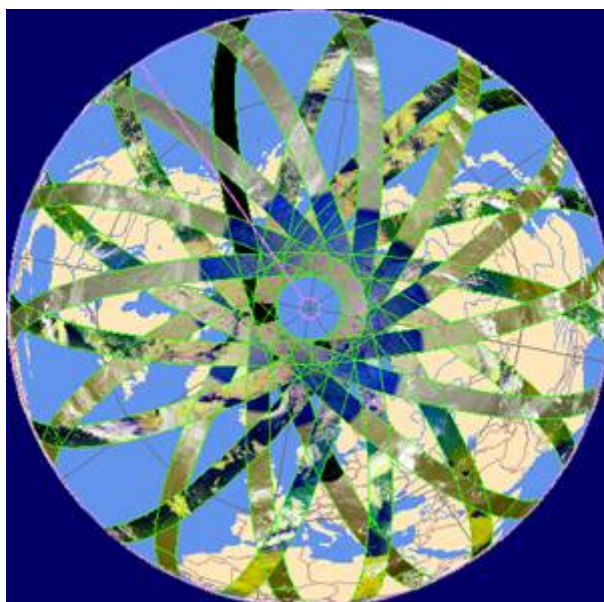


Figure 1: 1 day coverage of AATSR, Northern Hemisphere, 24 May 2008.

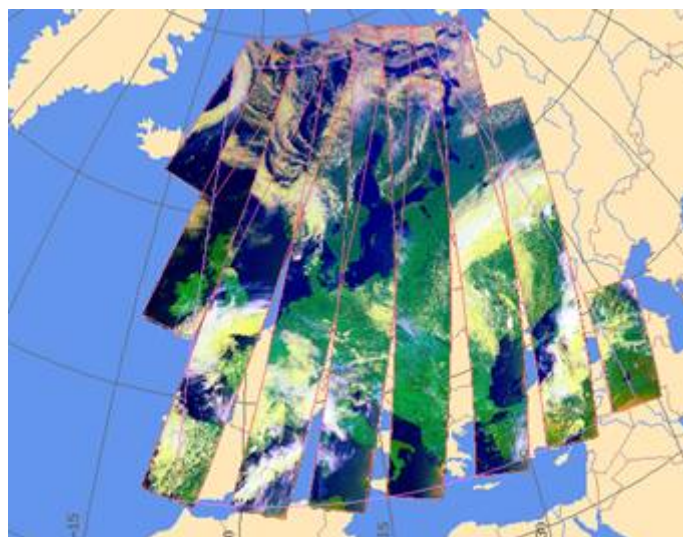


Figure 2: 3 days coverage of AATSR, Europe, 24 -26 May 2008.

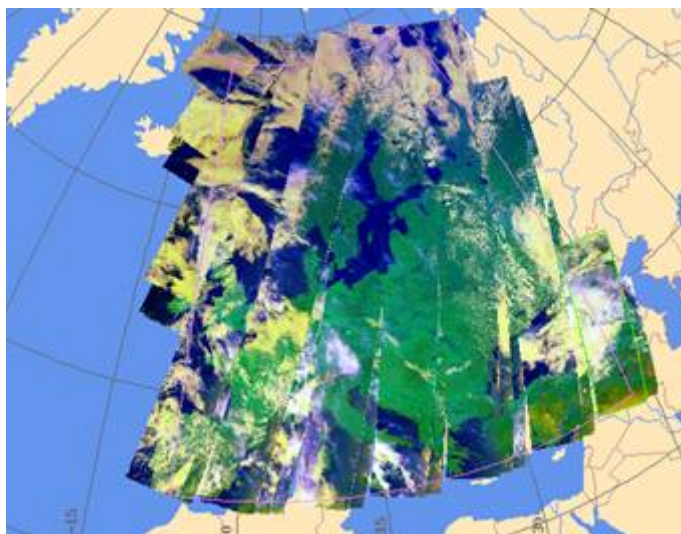


Figure 3: 6 days Coverage of AATSR, Europe, 24 – 29 May 2008

2.5.8.4 Data Origin

The GlobSnow SE processing system applies optical measurements in the visual-to-thermal part of the electromagnetic spectrum acquired by the ERS-2 sensor ATSR-2 and the Envisat sensor AATSR. Clouds are detected by a cloud-cover retrieval algorithm (SCDA) and masked out. Large water bodies (oceans, lakes and rivers) and glaciers are also masked out. The snow cover information is retrieved by two algorithms, one for high-mountain areas of steep topography above the tree line (NLR) and another for forested and open areas (SCAmod). The domains of the algorithms are determined by the thematic masks, and the retrieval results are merged. The resulting snow cover map is the basis of the generation of the four product types.

The SCAmod algorithm is based on a semi-empirical reflectance model, where reflectance from a target is expressed as a function of the snow fraction. The average generally applicable reflectance values for wet snow, forest canopy and snow-free-ground serve as model parameters. A transmissivity map provides the amount of reflected sunlight that could be observed from a satellite in forest areas. The transmissivity is an expression of the effect of forest on local reflectance observations. FSC can then be derived from observed reflectance based on the given reflectance constants and the transmissivity values. The method is described

in detail in Metsämäki et al. 2005. The algorithm has been developed and is intended for forested and non-forested, non-mountainous regions, particularly for the boreal forest zone and tundra belt. Currently, band 1 (555 nm) and 4 (1.6 μm) is used by the algorithm.

The NLR algorithm is based on the assumption that there is a linear relationship between snow coverage and measured top-of-atmosphere (TOA) reflectance (or radiance). When this relationship is established, the fractional snow cover percentage value of each pixel can be calculated. The relationship is established by an automatic calibration procedure using calibration targets. Populations of 100% snow covered pixels are identified and determine the reflectance for 100% snow coverage. A corresponding procedure is followed for 0% snow

coverage. The algorithm is often referred to as the Norwegian Linear-Reflectance-to-snow cover (NLR) algorithm, and is actually a two-endmember case of linear spectral unmixing. The algorithm was originally developed for analysis of NOAA AVHRR data (Solberg and Andersen, 1994), and has later been tailored to MODIS data (Solberg et al. 2006). A special version of the NLR algorithm has been developed for the GlobSnow project. Currently, band 2 (670 nm) is used by the algorithm.

2.5.8.5 Validation and Uncertainty Estimate

A detailed validation of GlobSnow SE product is reported in S. Metsämäki et al., [2012]. The validation against ground-observed fractional snow cover in Finland showed an RMSE of 0.11 for SCAMod applied to Terra/MODIS, while for NASA MOD10_L2 an RMSE of 0.20 was obtained. Validation against Finnish weather station data with four categories for snow coverage (100%, 0% and two fractional categories), showed an overall accuracy of 65.9% for SCAMod applied to MODIS, 65.1% for SCAMod applied to AATSR and 46.4% for MOD10_L2 product. The omission error for presence of snow – full or partial – was 16.0% for SCAMod_{AATSR}, 12.8% for SCAMod_{MODIS} and 25.7% for MOD10_L2. Hence, SCAMod shows clearly better performance when compared to MOD10_L2, particularly for forests as was proven. Comparison between FSC from SCAMod and FSC from high-resolution Landsat TM/ETM+ data representing the ‘truth’ showed a good agreement in general.

2.5.8.6 Considerations for climate applications

The presence of snow cover exerts a specific and strong influence on the energy and water budgets of the lower atmosphere. For this reason, large-scale automated snow cover mapping from satellite images is very useful. Snow cover maps can be used as input for numerical weather prediction (NWP) models. Accurate snow cover is also important for hydrological forecasting of river runoff during the melting season. Additionally, remote sensing of other surface parameters requires information on whether or not the surface is snow covered.

The European Space Agency (ESA) Data User Element (DUE) funded GlobSnow project aims at creating a global database of snow parameters for climate research purposes. The main objective is to create a long term dataset on two essential snow parameters. The project will provide information concerning the areal extent of snow (SE) on a global scale and snow water equivalent (SWE) for the Northern Hemisphere.

2.5.8.7 Instrument Overview

The primary mission of ATSR on ERS-1 and ERS-2 is to obtain sea surface temperature data sets for climate studies, but the high-quality image data collected by the instruments has application to a wide range of EO activities. Careful pre-flight and in-flight calibration is a major feature of the ATSR instruments and their data are particularly suited to applications where high radiometric accuracy and stability is required. Each of the ATSR instruments carries two infrared calibration targets, and the ATSR-2 and the future ATSR instruments carry an on-board visible calibration system for their visible channels.

ATSR-1, launched as part of the payload of ESA's ERS-1 satellite on 17th July 1991, was the test-bed for the "along track scanning" concept. It carries infrared channels at 1.6, 3.7, 10.8 and 12.0 μm , and has no visible channels. The instrument operated from August 1991, until routine ERS-1 operations stopped (when the satellite was put into hibernation) in June 1996. Data from the 3.7 μm was not available after May 1992 when this channel failed. The ATSR-2, for ERS-2, and Advanced ATSR (AATSR) instruments are developments of the ATSR-1 which, in addition to the standard ATSR infrared channels, carry visible channels for vegetation, aerosol and cloud remote sensing. These channels each have a spectral width of 20nm, and are centred at 0.55, 0.67, and 0.87 μm , respectively. These narrow bands have been chosen to maximise the sensor's sensitivity, whilst avoiding significant atmospheric absorption features that would otherwise distort the signals from the ground. ATSR-2 is the current operational ATSR and is flying on the ESA ERS-2 satellite which was launched in April 1995.

ATSR's field of view comprises two 512 km-wide curved swaths, with a nominal pixel size of 1 km² at the centre of the nadir swath, and 1.5 km – 2 km at the centre of the forward swath. This viewing geometry produces 512-km wide high-resolution infrared and, from ATSR-2, visible images of the Earth's surface from which SST and other geophysical products can be retrieved.

The other key features of the ATSR instruments are their low-noise detectors, high-quality calibration and longterm stability. The noise performance of both the flight ATSR instruments is extremely good, and even after several years in-flight ATSR-1 was achieving a better noise performance than is seen in typical AVHRR instruments soon after launch.

2.5.8.8 References

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2.5.8.9 Revision History

10-08-2013 - Version 1 – Initial draft created by Viju John and edited by Alessio Lattanzio.
09-01-2014 – Version 1 – Context has changed for GlobSnow products by Cemal Melih Tanis.

2.5.9 EUMETSAT H-SAF Daily Snow Cover (H10)

2.5.9.1 Intent of the Document

This document summarizes essential information needed for users of any level who wish to use the H-SAF Daily Snow Cover (H10/SN-OBS-1) data set for climate applications. H10 is a product under H-SAF Project of EUMETSAT SAF Network. As the hydrological project of the SAF Network, snow parameters are the key parameters to the project. H10 dataset gives the snow information on a pixel basis for SAF Europe area as a snow mask, having binary information for the snow coverage on cloud-free and non-dark locations.

2.5.9.2 Point of Contact

Matias Takala, Finnish Meteorological Institute, matias.takala@fmi.fi

2.5.9.3 Data Field Description

The product is an output of image classification processing. The snow signature is recognised as differential brightness in more short-wave channels, intended to discriminate snow from no-snowed land and snow from clouds. Both radiometric signatures are used (specifically, the 1.6 micron channel as compared with others), and time-persistence (for cloud filtering by the "minimum brightness" technique applied over a sequence of images). The Meteosat/SEVIRI contribution is mostly for southern Europe (including mountainous regions) and minimum brightness technique application. For mountainous regions multispectral threshold technique implemented on VIS and IR satellite reflectance values is used in order to get maximum daily snow coverage.

Contours of snow-covered areas, presented as mask-like maps (binary image). VIS/IR images from both LEO and GEO are used. The product may be processed in different ways and have different quality depending on the surface being flat, forested or mountainous.

- **Coverage:** The H-SAF area [25-75°N lat, 25°W-45°E long]
- **Cycle:** Daily
- **Resolution:** 1 to 5 km, depending on the instrument providing the retained pixel (best for MODIS, worst for SEVIRI)
- **Accuracy:** POD 95 %, FAR 10 % - Depending on geographical situation (flat/forested areas, mountainous regions)
- **Timeliness:** Fixed time of the day, product updated to account for data available until 1 h before delivery
- **Dissemination:** By dedicated lines to centres connected by GTS - By EUMETCast to most other users, especially scientific

- **Formats:** Values in fixed grid points of the Meteosat projection (GEO satellites) or fixed latitude-longitude grid (WGS 84) representing the resolution of the used satellite (polar orbiting satellites). Also JPEG or similar for quick-look.

2.5.9.4 Data Origin

Product SN-OBS-1 (Snow detection (snow mask) by VIS/IR radiometry) is based on multi-channel analysis of the SEVIRI instrument onboard Meteosat satellites. The SEVIRI IFOV at nadir is 4.8 km and sampling is performed at 3 km intervals. These figures degrade over Europe to ~ 8 km IFOV and ~ 5 km sampling. The observing cycle (15 min) enables continuous monitoring of the cloud situation, searching for time instants of cloud-free conditions in a given time interval (e.g., 24 h). However, since short-wave channels play an essential role in the retrieval algorithm, the useful range of hours (i.e. day light time) depends on the time of year and location of observation.

The SN-OBS-1 product for flat/forested areas has been developed and integrated in the operational environment of FMI. It has a long-standing heritage over Scandinavia, where it was extensively validated. Over other European areas, validation has started in late 2007. The product for mountainous areas has been developed by METU and thereafter transferred on the operational environment of TSMS in late 2007. Products have been available for validation starting from mid-November 2007. The products from FMI and from TSMS both cover the full H-SAF area, but thereafter are merged at FMI by blending the information on flat/forest areas from the FMI product and that one on mountainous areas from the TSMS product.

The SEVIRI channels at 0.64, 1.6, 3.9 and 10.8 μm were selected for the snow recognition algorithm and most important, cloud discrimination. The 0.64 μm channel is most suitable to detect clouds because of their high reflectance. Channels in this spectral region are commonly used for cloud detection (e.g. Rossow and Garder 19931). Compared to the reflectivity of snow, the reflectivity of clouds is substantially higher at 1.6 μm . The 10.8 μm channel is suitable for detecting clouds due to their temperature which is generally lower than the temperature of the surface beneath. Distinguishing low clouds from cold surfaces with the same temperature is very difficult when using only thermal information around 10.8 μm (Ernst 19752). For this task, IR 3.9 provides an important additional information at daytime as well as at night-time. Comparing the algorithms for flat/forested and mountainous areas it is noted that the second better exploits multispectral features. Corrections for sun zenith angle are applied. Atmospheric corrections are not applied.

2.5.9.5 Validation and Uncertainty Estimate

Whereas the previous operational characteristics have been evaluated on the base of system considerations (number of satellites, their orbits, access to the satellite) and instrument features (IFOV, swath, MTF and others), the evaluation of accuracy requires validation, i.e. comparison with the ground truth or with something assumed as “true”. SN-OBS-1, as any other H-SAF product, has been submitted to validation entrusted to a number of institutes.

The accuracy of the snow detection product has been assessed by comparison with meteorological bulletins and in-field measurements in properly equipped sites.

Prototypes of SN-OBS-1 have been available since winter 2006-2007, and validated by case studies. The product has been regularly distributed starting from end-2007 for systematic validation. The current release makes use of the Land-SAF product, available since April 2008. In next table the results from the last validation cycle, winter 2009/2010 (i.e. 1st October 2009 - 31 March 2010), are reported. Comparisons are recorded separately for flat/forested areas and mountainous areas. Combined statistics of results (averages weighed by the number of samples) are provided for both flat/forested and mountainous areas, although this information mixing inhomogeneous situation is of doubtful use.

Score	Non-mountainous areas						Mountainous areas					
	IRM	FMI	BfG	IMWM	METU	Total	IRM	FMI	BfG	IMWM	METU	Total
N. samples	612	5803	207711	6205	0	220331	0	0	18760	2661	1221	22642
POD	0.91	0.89	0.75	0.80	-	0.75	-	-	0.60	0.55	0.93	0.60
FAR	0.29	0.05	0.03	0.07	-	0.03	-	-	0.00	0.07	0.16	0.01
CSI	0.67	0.85	0.73	0.76	-	0.74	-	-	0.60	0.52	0.79	0.60
POFD	0.03	0.08	0.02	0.14	-	0.02	-	-	0.05	0.20	0.10	0.12
ACC	0.97	0.90	0.86	0.82	-	0.86	-	-	0.61	0.59	0.91	0.62
HSS	0.78	0.79	0.72	0.61	-	0.72	-	-	0.05	0.20	0.81	0.14

Table 1: Statistical scores for SN-OBS-1 - Winter 2009-2010 - Threshold snow/no-snow for flat/forested areas: 1 cm depth

For detailed information one can look for the Product Validation Report (PVR) on H-SAF website.

2.5.9.6 Considerations for climate applications

Snow is one of the major water resources in many regions of the world; therefore monitoring and estimating the snow parameters play an important role in predicting discharges during melting seasons. Snow covered area information is one of the inputs for distributed snow models. The use of snow products retrieved from satellite images in hydrological applications and observation of the impact of such products in hydrological models are key issues in the Hydrological Satellite Facility (HSAF) Project, which is financially supported by the European Organization for the Exploitation of Meteorological Satellites (EUMETSAT).

2.5.9.7 Instrument Overview

The primary mission of MSG is the continuous observation of the Earth's full disk. This is achieved with the Spinning Enhanced Visible and Infrared Imager (SEVIRI) imaging radiometer, a twelve channel imager observing the Earth-atmosphere system with a spatial sampling distance of 3 km in eleven channels. A high-resolution visible (HRV) channel covers half of the full disk with a 1 km spatial sampling. The actual field of view of the channels is about 4.8 km and 1.67 km. A repeat cycle of 15 minutes for full-disk imaging provides unprecedented multi-spectral observations of rapidly changing phenomena (e.g. deep convection) and provides better and more numerous wind observations from the tracking of cloud features. Rapid scans of limited latitude belts are possible with shorter time intervals.

The imaging is performed by combining the satellite spin with the rotation (stepping) of the scan mirror. The images are taken from South to North and East to West. The nominal spin rate is 100 revolutions per minute. The spin axis is nominally parallel to the North-South axis of the Earth. The scan from South to North is achieved with 1250 E-W scans; this provides 3750 image lines for channels 1 through 11 (see Table 1) since 3 detectors for each channel are used for the imaging. For the HRV (channel 12) 9 detectors sweep the Earth for one line scan. The number of line scans is programmable such that shorter repeat cycles can be performed. A full disk image is obtained within about 12 minutes (see Figure 1). This is followed by the calibration of thermal IR channels.

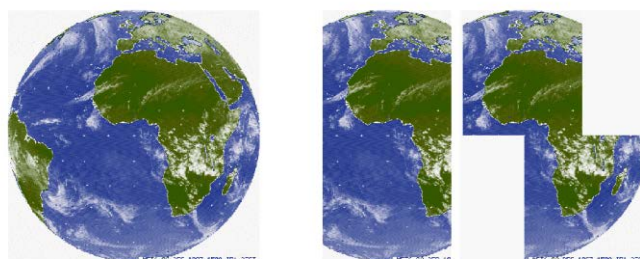


Figure 1: Coverage of MSG for the repeat cycle of 15 minutes for channels 1 through 11. The High resolution Visible (HRV), i.e. channel 12, covers only half the Earth in E-W, however the area of imaging can be selected.

Most SEVIRI spectral channels build upon the heritage from other satellites which has the great advantage that the operational user community can readily use existing know-how to utilise SEVIRI radiance observations.

2.5.9.8 References

EUMETSAT, H-SAF Website, 2014.

EUMETSAT (2011), HSAF Product User Manual for product H10 – SN-OBS-1, SAF/HSAF/PUM-10/1.1, Version 1.1.

EUMETSAT (2011), HSAF Product Validation Report for product H10 – SN-OBS-1, SAF/HSAF/PVR-10/1.1, Version 1.1.

Schmetz, J., Pili, p., Ratier, A., Rota, S., Tjemkes, S., no date. Meteosat Second Generation (MSG): Capabilities And Applications, *American Meteorological Society*, retrieved from <https://ams.confex.com/ams/pdfpapers/23827.pdf>

2.5.9.9 Revision History

10-08-2013 - Version 1 – Initial draft created by Viju John and edited by Alessio Lattanzio.
09-01-2014 – Version 1 – Context has changed for H-SAF Snow products by Cemal Melih Tanis.

2.5.10 EUMETSAT H-SAF Daily Effective Snow Cover (H12)

2.5.10.1 Intent of the Document

This document summarizes essential information needed for users of any level who wish to use the H-SAF Daily Effective (Fractional) Snow Cover (H12/SN-OBS-3) data set for climate applications. H12 is a product under H-SAF Project of EUMETSAT SAF Network. As the hydrological project of the SAF Network, snow parameters are the key parameters to the project. H12 dataset gives the snow information on a pixel basis for SAF Europe area as a snow mask, having fractional information for the snow coverage on cloud-free and non-dark locations.

2.5.10.2 Point of Contact

Matias Takala, Finnish Meteorological Institute, matias.takala@fmi.fi

2.5.10.3 Data Field Description

The product differs from SN-OBS-1 in so far as, in the snow map, the resolution elements report the fractional snow coverage instead of being binary (snow/snow-free). The possibility of appreciating fractional coverage stems from the lack of observed brightness in respect of what would be if the pixel were fully filled by snow. The forest canopy obscuring the full visibility to the ground is accounted for by applying certain a priori transmissivity information, which must be generated using satellite-borne reflectance data acquired under full dry snow cover conditions. These reflectances must be measured by the same instrument as which is used in the fractional snow coverage estimation. This means that the product can be generated for areas where full dry snow cover stays at least for some period and that during that period, cloud-free reflectance data are gained. Since the transmissivity approach may not work well for bare ground and vegetative lands (different from forest area) on mountainous regions, subpixel reflectance model is used. The topographic normalization is performed preferably, in order to eliminate the terrain effects on the reflectances of the features in the mountainous regions.

Combined effect, within a product resolution element, of fractional snow cover and other reflective contributors is used to estimate the fractional cover at resolution element level. The product may be processed in different ways and have different quality depending on the surface being flat, forested or mountainous.

- **Coverage:** The H-SAF area [25-75°N lat, 25°W-45°E long]
- **Cycle:** Daily
- **Resolution:** 5 to 10 km (0.05 degrees), depending on the location (best for northern parts, worst for southern parts of the H-SAF area)
- **Accuracy:** Around 20 % - Depending on geographical location (flat/forested areas, mountainous regions)
- **Timeliness:** Fixed time of the day, product updated to account for data available until 1 h before delivery

- **Dissemination:** By dedicated lines to centres connected by GTS - By EUMETCast to most other users, especially scientific
- **Formats:** Values in fixed latitude-longitude grid representing a resolution element of the used instrument. Also JPEG or similar for quick-look.

2.5.10.4 Data Origin

Product SN-OBS-3 (Effective snow cover by VIS/IR radiometry) is based on multi-channel analysis of the AVHRR instrument onboard NOAA and MetOp satellites. The AVHRR radiometer has an IFOV of 1.1 x 1.1 km² at nadir degrading to ~ 2 x 6 km² at the edge of the 2900 km cross-track swath. Computing fractional cover would in principle require segmenting the image in arrays of pixels (typically ~ 32 x 32) and counting those classified as snow. This would lead to unacceptable product resolution. For H-SAF, fractional cover is generated at pixel resolution, by exploiting the brightness intensity that is the convolution of the snow signal (highest) and the fraction of snow within the pixel ("effective" cover").

The retrieval algorithm is somewhat different for flat or forested area and for mountainous regions. SNOBS- 3 is generated in Finland by FMI and in Turkey by TSMS. The products from FMI and from TSMS both cover the full H-SAF area, but thereafter are merged at FMI by blending the information on flat/forested areas from the FMI product and that one on mountainous areas from the TSMS product. The SEVIRI channels at 0.64, 1.6, 3.9 and 10.8 μm were selected for the snow recognition algorithm and most important, cloud discrimination. The 0.64 μm channel is most suitable to detect clouds because of their high reflectance. Channels in this spectral region are commonly used for cloud detection (e.g. Rossow and Garder 19931). Compared to the reflectivity of snow, the reflectivity of clouds is substantially higher at 1.6 μm . The 10.8 μm channel is suitable for detecting clouds due to their temperature which is generally lower than the temperature of the surface beneath. Distinguishing low clouds from cold surfaces with the same temperature is very difficult when using only thermal information around 10.8 μm (Ernst 19752). For this task, IR 3.9 provides an important additional information at daytime as well as at night-time. Comparing the algorithms for flat/forested and mountainous areas it is noted that the second better exploits multispectral features. Corrections for sun zenith angle are applied. Atmospheric corrections are not applied.

The observing cycle of the complex of NOAA and MetOp satellites over Europe is about 3 h. For a single satellite pass, several areas in the scene would provide no useful measurements because of clouds. Therefore, the complex of passes is multi-temporally analysed to search for time instants of cloud-free conditions in a given time interval (e.g., 24 h). However, since short-wave channels play an essential role in the retrieval algorithm, the useful range of hours is in daylight.

2.5.10.5 Validation and Uncertainty Estimate

Whereas the previous operational characteristics have been evaluated on the base of system considerations (number of satellites, their orbits, access to the satellite) and instrument features (IFOV, swath, MTF and others), the evaluation of accuracy requires validation, i.e.

comparison with the ground truth or with something assumed as “true”. SN-OBS-3, as any other H-SAF product, has been submitted to validation entrusted to a number of institutes. The accuracy of the snow detection product has been assessed by comparison with meteorological bulletins and in-field measurements in properly equipped sites.

In case studies H12 product is compared with RGB composites of METOP-AVHRR data. The snow cover area classification performance of the product can be visually interpreted. The algorithm sometimes misclassifies high clouds as snow. The cloud/snow discrimination in operational snow products is still a very challenging subject. H12 product is also compared with another snow product, namely MODIS snow product. MODIS-Terra has better spatial resolution compared to METOP-AVHRR. From the results it is observed that both products are consistent. The consistency is high during full snow coverage in January (over all accuracy=92%), it decreases in melting season (March, over all accuracy =79%). It is observed that MODIS finds more 100% snow cover compared to fractional snow cover compared to H12 snow product. The user’s and producer’s accuracies for March 26, 2011 are high for no snow and snow 50%-100% classes, whereas for January 27, 2010 the user’s accuracy for 0% snow cover class is low. 142 pixels of 50%-100% snow cover in MODIS product was classified as no-snow in H12 product. As the number of the samples in each class increases the accuracies also increases.

The overall accuracy has been evaluated for the period October, 2010 – April, 2011 in Finland and Turkey. The averaged overall accuracy obtained is equal to 66%. As shown in the Table 16 the statistical scores obtained by the validation of H12 in SPVG are really close to the thresholds stated in the Product requirements.

Product requirements		H12	
threshold	target	optimal	total
45%	65%	95%	66%

H-SAF Accuracy requirements for H12 (Overall Accuracy)

For detailed information one can look for the Product Validation Report (PVR) on H-SAF website.

2.5.10.6 Considerations for climate applications

Snow is one of the major water resources in many regions of the world; therefore monitoring and estimating the snow parameters play an important role in predicting discharges during melting seasons. Snow covered area information is one of the inputs for distributed snow models. the use of snow products retrieved from satellite images in hydrological applications and observation of the impact of such products in hydrological models are key issues in the hydrological satellite facility (hsaf) project, which is financially supported by the european organization for the exploitation of meteorological satellites (eumetsat).

2.5.10.7 Instrument Overview

The AVHRR is a radiation-detection imager that can be used for remotely determining cloud cover and the surface temperature. Note that the term surface can mean the surface of the Earth, the upper surfaces of clouds, or the surface of a body of water. This scanning

radiometer uses 6 detectors that collect different bands of radiation wavelengths as shown below.

The first AVHRR was a 4-channel radiometer, first carried on TIROS-N (launched October 1978). This was subsequently improved to a 5-channel instrument (AVHRR/2) that was initially carried on NOAA-7 (launched June 1981). The latest instrument version is AVHRR/3, with 6 channels, first carried on NOAA-15 launched in May 1998. The AVHRR/3 instrument weighs approximately 72 pounds, measures 11.5 inches X 14.4 inches X 31.4 inches, and consumes 28.5 watts power. Measuring the same view, this array of diverse wavelengths, after processing, permits multi spectral analysis for more precisely defining hydrologic, oceanographic, and meteorological parameters. Comparison of data from two channels is often used to observe features or measure various environmental parameters. The three channels operating entirely within the infrared band are used to detect the heat radiation from and hence, the temperature of land, water, sea surfaces, and the clouds above them.

2.5.10.8 References

EUMETSAT, H-SAF Website, 2014.

EUMETSAT (2012), HSAF Product User Manual for product H12 – SN-OBS-3, SAF/HSAF/PUM-12, Version 1.0.

EUMETSAT (2012), HSAF Product Validation Report for product H12 – SN-OBS-3, SAF/HSAF/PVR-12, Version 1.2.

NOAA, Advanced Very High Resolution Radiometer – AVHRR, NOAA Satellite Information System Website, 2014.

2.5.10.9 Revision History

10-08-2013 - Version 1 – Initial draft created by Viju John and edited by Alessio Lattanzio.

09-01-2014 – Version 1 – Context has changed for H-SAF Snow products by Cemal Melih Tanis.

2.5.11 EUMETSAT LSA-SAF Daily Snow Cover

2.5.11.1 Intent of the Document

This document summarizes essential information needed for users of any level who wish to use the LSA-SAF Daily Snow Cover data set for climate applications. The Satellite Application Facility (SAF) on Land Surface Analysis (LSA) is part of the SAF Network, a set of specialized development and processing centers, serving as EUMETSAT (European organization for the Exploitation of Meteorological Satellites) distributed Applications Ground Segment. The main purpose of the LSA SAF is to take full advantage of remotely sensed data; particularly those available from EUMETSAT sensors, to measure land surface variables, which will find primarily applications in meteorology. Snow cover is one of the key parameters of the project.

2.5.11.2 Point of Contact

Niilo Siljamo, Finnish Meteorological Institute, Niilo.Siljamo@fmi.fi

2.5.11.3 Data Field Description

The SEVIRI/Meteosat derived products are generated for 4 different geographical areas within Meteosat disk (Figure 1):

- Euro – Europe, covering all EUMETSAT member states;
- NAfr – Northern Africa encompassing the Sahara and Sahel regions, and part of equatorial Africa.
- SAfr – Southern Africa covering the African continent south of the Equator.
- SAmE – South American continent within the Meteosat disk.

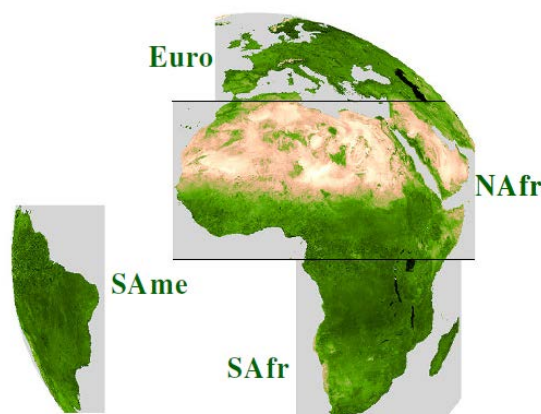


Figure 1: The LSA SAF geographical areas

The product has the spatial and temporal resolution of the instrument; as a daily production at 3 km resolution.

The resulting snow cover map produced from MSG data contains a classification of each surface pixel or resolution cell into one (and only one) of the following classes:

- totally snow covered
- partially snow covered
- no snow
- unclassified
- non-processed
- water (sea, lake, river etc.)

An additional set of quality/processing flags for each pixel indicates the certainty of the classification and integration and also gives information on the processing and conditions.

2.5.11.4 Data Origin

The MSG snow cover (SC) retrieval is based on multispectral threshold technique applied to each pixel of the image. Detailed description of the snow detection algorithm is in Algorithm Theoretical Basis Document. In the algorithm MSG/SEVIRI radiance and brightness temperatures of several channels are used together with land surface temperature (LST) and solar and satellite angles to classify each pixel of the land areas. For example, snow and ice can be separated from water clouds by their low reflectance at 1.6 μm or at 3.9 μm channels. Cirrus clouds can be separated using the difference between brightness temperatures at 10.8 μm and 12.0 μm channels. A combination of these and similar characteristics are used to separate snow covered and snow free pixels. One example of the different characteristics is in a scatter plot in Figure 2. This and other similar figures have been used for the development of the classification algorithm.

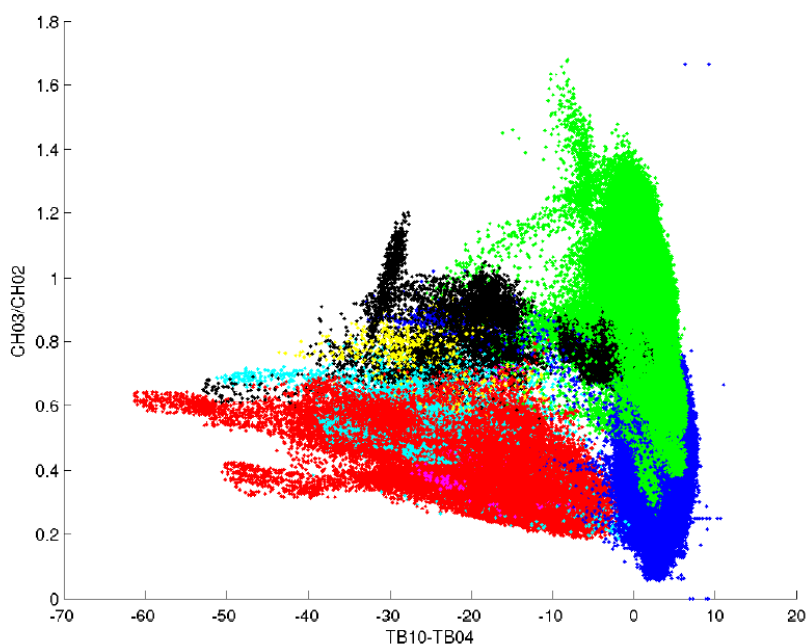


Figure 2: Radiance ratio of the SEVIRI channels 3 and 2 vs. brightness temperature difference of the channels 10 and 4. Blue (snow) and green (snow free) are quite clearly separated from different cloudy pixel types. Red (ice clouds), black (water clouds) and cyan (mixed clouds) mark the cloud types which are totally opaque. Yellow (snow free) and magenta (snow covered) mark the pixels which are cloud covered, but the clouds are still transparent.

The algorithm is not intended for use in mountain areas. Pixels in these areas are determined using the elevation data and a flag indicating high terrain is set. Forests make the detection of snow more difficult. Preliminary product validation shows that the amount of snow pixels is slightly overestimated for non-forest land types, while it is underestimated for forest classes.

2.5.11.5 Validation and Uncertainty Estimate

The adopted strategy for validation of SC product consists of two main steps: 1) comparison with in situ measurements; 2) inter-comparison with other satellite derived SC products. The current SC product is not yet validated using SYNOP or other surface observations.

Automatic Quality Control (QC) is performed on SC data and the quality information is provided on a pixel basis. As shown in Appendix A, SC QC contains general information about input data. However the part of the SC algorithm used for quality analysis will be changed.

As specified in the Product Requirements Document the target for the accuracy of the snow cover product is less than 15% of false alarms and over 80% hit rate. The optimal accuracy target is less than 5% of false alarms and over 90% hit rate. The strategy adopted for confirming the achievement of this goal is documented in the Scientific Validation Plan Document. Preliminary results are given in the Validation Report.

Figure 3 show that version 2.05 of the LSA SC produces very good results during the winter and spring.

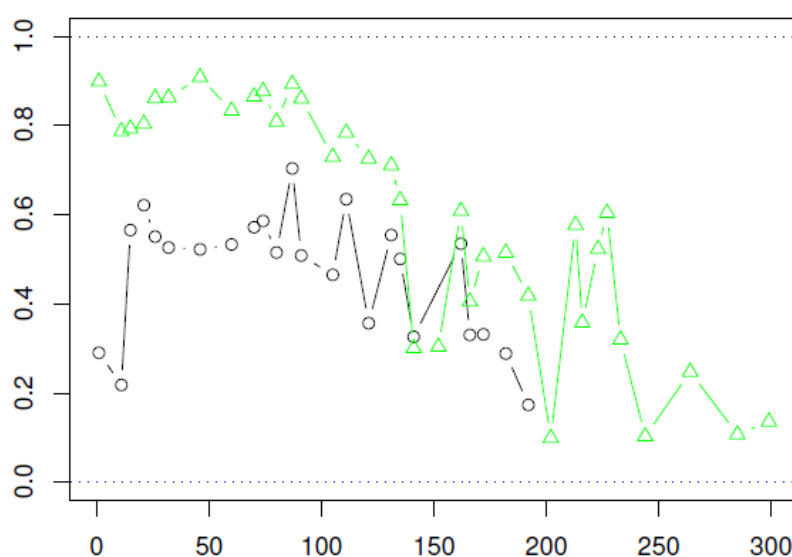


Figure 3 – Heidke Skill Score of LSA SC versions 1.12 (black) and 2.05 (green) when compared to NOAA/NESDIS snow product. For this test NOAA/NESDIS snow cover is assumed to be observed truth at surface. During the summer the HSS drops because the number of snow covered pixels is too low for reliable analysis.

2.5.11.6 Considerations for climate applications

The presence of snow cover exerts a specific and strong influence on the energy and water budgets of the lower atmosphere. For this reason, large-scale automated snow cover mapping from satellite images is very useful. Snow cover maps can be used as input for numerical weather prediction (NWP) models. Accurate snow cover is also important for hydrological forecasting of river runoff during the melting season. Additionally, remote sensing of other surface parameters requires information on whether or not the surface is snow covered.

2.5.11.7 Instrument Overview

The primary mission of MSG is the continuous observation of the Earth's full disk. This is achieved with the Spinning Enhanced Visible and Infrared Imager (SEVIRI) imaging radiometer, a twelve channel imager observing the Earth-atmosphere system with a spatial sampling distance of 3 km in eleven channels. A high-resolution visible (HRV) channel covers half of the full disk with a 1 km spatial sampling. The actual field of view of the channels is about 4.8 km and 1.67 km. A repeat cycle of 15 minutes for full-disk imaging provides unprecedented multi-spectral observations of rapidly changing phenomena (e.g. deep convection) and provides better and more numerous wind observations from the tracking of cloud features. Rapid scans of limited latitude belts are possible with shorter time intervals.

The imaging is performed by combining the satellite spin with the rotation (stepping) of the scan mirror. The images are taken from South to North and East to West. The nominal spin rate is 100 revolutions per minute. The spin axis is nominally parallel to the North-South axis of the Earth. The scan from South to North is achieved with 1250 E-W scans; this provides 3750 image lines for channels 1 through 11 (see Table 1) since 3 detectors for each channel are used for the imaging. For the HRV (channel 12) 9 detectors sweep the Earth for one line scan. The number of line scans is programmable such that shorter repeat cycles can be performed. A full disk image is obtained within about 12 minutes (see Figure 4). This is followed by the calibration of thermal IR channels.

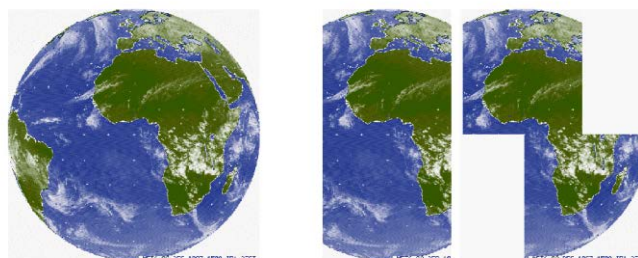


Figure 4: Coverage of MSG for the repeat cycle of 15 minutes for channels 1 through 11. The High resolution Visible HRV), i.e. channel 12, covers only half the Earth in E-W, however the area of imaging can be selected.

Most SEVIRI spectral channels build upon the heritage from other satellites which has the great advantage that the operational user community can readily use existing know-how to utilise SEVIRI radiance observations.

2.5.11.8 References

EUMETSAT (2011), Product User Manual Snow Cover, SAF/LAND/FMI/PUM/SC/2.8, Version 2.8.

EUMETSAT (2011), LSA SAF Validation Report Snow Cover, SAF/LAND/FMI/VR_SC/1.1, Version 1.2.

Schmetz, J., Pili, p., Ratier, A., Rota, S., Tjemkes, S., no date. Meteosat Second Generation (MSG): Capabilities And Applications, *American Meteorological Society*, retrieved from <https://ams.confex.com/ams/pdfpapers/23827.pdf>

2.5.11.9 Revision History

10-08-2013 - Version 1 – Initial draft created by Viju John and edited by Alessio Lattanzio.

09-01-2014 – Version 1 – Context has changed for LSA-SAF Snow Cover product by Cemal Melih Tanis.

2.5.12 Global Fire Assimilation System

2.5.12.1 INTENT OF THE DATASET

GFAS provides global daily estimates of open biomass burning, a.k.a. vegetation fires with 0.5deg and 0.1deg resolutions. It is based on satellite observations of Fire Radiative Power (FRP), currently by NASA's two polar orbiting MODIS instruments. The dataset is primarily intended as lower boundary condition input for atmospheric composition and air quality modeling in real time and retrospectively. It is the main fire emission dataset used throughout the *Copernicus Atmosphere Monitoring Services*, e.g. in the MACC reanalysis (Inness et al., 2014). Since the dataset is consistent in time and it is also suitable for climate applications. It has thus been used since 2010 to monitor the ECV *fire disturbance* in NOAA's annual *State of the Climate* reports, which are published in BAMS (Kaiser & van der Werf, 2010/2011/2012/2013/2014).

2.5.12.2 POINT OF CONTACT

PI: Dr. Johannes W. Kaiser, Max Planck Institute for Chemistry, Hahn-Meitner-Weg 1, D-55128 Mainz, Germany, <mailto:j.kaiser@mpic.de>

helpdesk of data provider: <http://atmosphere.copernicus.eu/contact/>

help desk of additional archive:
http://eccad.sedoo.fr/eccad_extract_interface/JSF/page_contact.jsf

2.5.12.3 DATA FIELD DESCRIPTION

The dataset is described at <http://atmosphere.copernicus.eu/fire> and the its linked pages.

A technical product specification that was prepared in 2012 can be found at the ECCAD archive at http://eccad.sedoo.fr/eccad_extract_interface/JSF/page_metadata.jsf?exportpdf=83 (minimal registration with email address required).

The dataset has since been extended to start in March 2000 and it is updated in real time with a time lag of seven hours. The dataset has global coverage and a temporal resolution of one day. The default spatial resolution is 0.5deg. A version with 0.1deg resolution is available on request. The following variables are included:

longName	shorName	units	GRIB paramID
Wildfire flux of Carbon Dioxide	co2fire	kg m ⁻² s ⁻¹	210080
Wildfire flux of Carbon Monoxide	cofire	kg m ⁻² s ⁻¹	210081
Wildfire flux of Methane	ch4fire	kg m ⁻² s ⁻¹	210082
Wildfire flux of Non-Methane Hydro-Carbons	nmhcfire	kg m ⁻² s ⁻¹	210083
Wildfire flux of Hydrogen	h2fire	kg m ⁻² s ⁻¹	210084
Wildfire flux of Nitrogen Oxides NOx	noxfire	kg m ⁻² s ⁻¹	210085
Wildfire flux of Nitrous Oxide	n2ofire	kg m ⁻² s ⁻¹	210086
Wildfire flux of Particulate Matter PM2.5	pm2p5fire	kg m ⁻² s ⁻¹	210087
Wildfire flux of Total Particulate Matter	tpmfire	kg m ⁻² s ⁻¹	210088

longName	shorName	units	GRIB paramID
Wildfire flux of Total Carbon in Aerosols	tcfire	kg m ⁻² s ⁻¹	210089
Wildfire flux of Organic Carbon	ocfire	kg m ⁻² s ⁻¹	210090
Wildfire flux of Black Carbon	bcfire	kg m ⁻² s ⁻¹	210091
Wildfire overall flux of burnt Carbon	cfire	kg m ⁻² s ⁻¹	210092
Wildfire fraction of area observed	offire	dimensionless	210097
Wildfire radiative power	frpfire	W m ⁻²	210099
Wildfire combustion rate	crfire	kg m ⁻² s ⁻¹	210100
Wildfire radiative power maximum	maxfrpfire	W	210101
Wildfire flux of Sulfur Dioxide	so2fire	kg m ⁻² s ⁻¹	210102
Wildfire Flux of Methanol (CH₃OH)	ch3ohfire	kg m ⁻² s ⁻¹	210103
Wildfire Flux of Ethanol (C₂H₅OH)	c2h5ohfire	kg m ⁻² s ⁻¹	210104
Wildfire Flux of Propane (C₃H₈)	c3h8fire	kg m ⁻² s ⁻¹	210105
Wildfire Flux of Ethene (C₂H₄)	c2h4fire	kg m ⁻² s ⁻¹	210106
Wildfire Flux of Propene (C₃H₆)	c3h6fire	kg m ⁻² s ⁻¹	210107
Wildfire Flux of Isoprene (C₅H₈)	c5h8fire	kg m ⁻² s ⁻¹	210108
Wildfire Flux of Terpenes (C₅H₈)_n	terpenesfire	kg m ⁻² s ⁻¹	210109
Wildfire Flux of Toluene lump (C₇H₈+ C₆H₆ + C₈H₁₀)	toluenefire	kg m ⁻² s ⁻¹	210110
Wildfire Flux of Higher Alkenes (C_nH_{2n}, C_n≥4)	hialkenesfire	kg m ⁻² s ⁻¹	210111
Wildfire Flux of Higher Alkanes (C_nH_{2n+2}, C_n≥4)	hialkanesfire	kg m ⁻² s ⁻¹	210112
Wildfire Flux of Formaldehyde (CH₂O)	ch2ofire	kg m ⁻² s ⁻¹	210113
Wildfire Flux of Acetaldehyde (C₂H₄O)	c2h4ofire	kg m ⁻² s ⁻¹	210114
Wildfire Flux of Acetone (C₃H₆O)	c3h6ofire	kg m ⁻² s ⁻¹	210115
Wildfire Flux of Ammonia (NH₃)	nh3fire	kg m ⁻² s ⁻¹	210116
Wildfire Flux of Dimethyl Sulfide (DMS) (C₂H₆S)	c2h6sfire	kg m ⁻² s ⁻¹	210117
Wildfire Flux of Ethane (C₂H₆)	c2h6fire	kg m ⁻² s ⁻¹	210118

The variable *offire* is a quantitative accuracy/uncertainty indicator: A value of zero indicates that the other variables contain no information (and are set to zero by default), increasingly larger values indicate increasing accuracy of the other variables.

2.5.12.4 DATA ORIGIN

The dataset is based on fire radiative power (FRP) observations provided by NASA based on its MODIS instruments aboard the Terra and Aqua satellites. The FRP observation from NASA's MOD14/MYD14 products are gridded and corrected for faulty observations, cloud cover, other observations gaps, partial snow and water cover of the grid cells, and availability of observations from only one satellite. The corrections employ data assimilation with a Kalman filter. FRP is then converted to the dry matter combustion rate of the fires (*crfire*), which is in turn converted to emissions of the different smoke constituents and the carbon flux (*cfire*). All conversions are fire type / land cover dependent. The details are described in Kaiser et al. (2012) and Remy & Kaiser (2014).

2.5.12.5 VALIDATION AND UNCERTAINTY ESTIMATE

The dataset has been validated against the GFED3.1 dataset, see Kaiser et al. (2012). It has also been validated by its various users in MACC-II project reports and scientific publications. An overview of the validation results and detailed accuracy assessment is provided by Andela et al. (2013). The dataset is by design free from errors with longer-term trends for the period of 2003-2014, when both MODIS instruments are available. 2000-2002 have been corrected for biases as much as possible. It can thus be used for longer term

variability and trend analysis over this 15-year period.

2.5.12.6 CONSIDERATIONS FOR CLIMATE APPLICATIONS

The product provides state-of-the-art fire disturbance and emission estimates for air quality and climate applications. It should, however, be noted that all such estimates have large systematic and random errors on the order of up to 100% for individual events and 20-30% for continental-scale estimates. Furthermore, fires have a strong diurnal cycle with often vanishing values during nighttime, which is not resolved by the dataset. The validation of fire activity in climate models is currently moving towards the characterization of several different properties of fires: carbon consumption, fire severity, emissions of different species, burnt area, and others. The dataset directly provides values for the first three properties. Information on burnt area can only be derived indirectly, using additional assumptions on fuel load and combustion completeness.

2.5.12.7 INSTRUMENT OVERVIEW

The dataset is based on the MOD14/MYD14 products which are derived from the MODIS instruments aboard NASA's Terra and Aqua satellites. Most quantitative information is derived from the fire-dedicated MIR (3.7 μ m) channel. The fire detection also uses other channels. The satellites are in sun-synchronous orbits without drifts.

2.5.12.8 REFERENCES

- [1] J. W. Kaiser, N. Andela, J. Atherton, M. de Jong, A. Heil, R. Paugam, S. Remy, M. G. Schultz, G. R. van der Werf, T. T. van Leeuwen, and M. J. Wooster, "Recommended fire emission service enhancements," Tech. Memo. 724, European Centre for Medium-range Weather Forecasts (ECMWF), Reading, UK, 2014.
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2.5.12.9 REVISION HISTORY

version 1, 12/8/214, Johannes Kaiser

2.6 Reanalysis

2.6.1 ERA-Interim

2.6.1.1 Intent of the Document

This document is aimed at potential users of the ECMWF Interim Reanalysis dataset (hereafter ERA-Interim) in climate applications; it provides a high-level description of ERA-Interim and links to further information.

Originally created to support both 1) Numerical Weather Prediction and 2) Climate Studies, ERA-Interim has subsequently been adopted in other applications including climate monitoring and earth-system science.

The ERA-Interim dataset comes from a comprehensive global reanalysis based on data assimilation, i.e. a process that blends model forecasts with a range of observational data, taking into account their respective uncertainty characteristics.

2.6.1.2 Point of Contact

Data Services
European Centre for Medium-Range Weather Forecasts
Shinfield Park
Reading
RG2 9AX
UNITED KINGDOM

Email: Data.Services@ecmwf.int

2.6.1.3 Data Field Description

Length of record: January 1979 to present

Temporal sampling: typically 6-hourly, with daily and monthly averages also available

Horizontal extent: global, gridded fields

Vertical extent: surface to 0.1 hPa

Spatial sampling: about 80 km horizontally, and 60 vertical levels

Main variables: Air Temperature, Geopotential Height, Precipitable water, Precipitation

For further details, see Berrisford (2011a) “The ERA-Interim archive Version 2.0”, available at: <http://www.ecmwf.int/publications/library/do/references/show?id=90276>

See also <https://climatedataguide.ucar.edu/climate-data/era-interim> (follow link to Metadata).

2.6.1.4 Data Origin

See Dee et al. (2011) in the references below for a full description of the ERA-Interim reanalysis system.

It uses a December 2006 version of the ECMWF Integrated Forecast Model (IFS Cy31r2, atmosphere-only).

The data assimilation is based on a 12-hourly four-dimensional variational analysis (4D-Var) with adaptive estimation of biases in satellite radiance data (VarBC). The spectral resolution is T255 (about 80 km) and there are 60 vertical levels, with the model top at 0.1 hPa (about 64 km).

2.6.1.5 Validation and Uncertainty Estimate

Many peer-reviewed publications are readily available, supplemented by “grey literature”. At the time of writing, recent evaluations include

Upper Air temperature record	Simmons et al (2013)
Water cycle	Balsamo (2012) Simmons et al (2010)
Soil Moisture	Albergel (2013)
Near-surface Fluxes	Kral (2011)
Ozone	Dragani (2010a,b)
Energy/momentum budgets	Berrisford (2011b)

For the known issues about temporal jumps and inconsistencies, see for example the sections “Specific problems in ERA-Interim” and “Assessing the quality of reanalysis data” under <https://climatedataguide.ucar.edu/climate-data/era-interim>

Because validation and uncertainty activities are on-going in the form of scientific research and inter-comparisons, users are advised to keep abreast of latest developments via <http://www.ecmwf.int/research/era>.

2.6.1.6 Considerations for climate applications

Keep abreast of latest information via <https://climatedataguide.ucar.edu/climate-data/era-interim> (follow link to Guidance) and <http://www.ecmwf.int/research/era/do/get/index/QualityIssues>.

2.6.1.7 Instrument Overview

Details in Poli (2010) “List of observations assimilated in ERA-40 and ERA-Interim (V1.0)” available at <http://www.ecmwf.int/publications/library/do/references/show?id=89965>

With some exceptions, ERA-Interim uses input observations prepared for ERA-40 until 2002, and data from ECMWF's operational archive thereafter. See Dee et al. (2011) in the references below for a full description of the ERA-Interim instrumental inputs.

2.6.1.8 References

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2.6.1.9 Revision History

09-Jan-2014 - Version 0.3 – Initial draft created by David Tan and Paul Poli.