EUMETSAT Satellite Application Facility on
Support to Operational Hydrology and Water Management

Algorithm Theoretical Baseline Document (ATBD) for product H43

Snow detection MTG/FCI

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0.1	12/01/2017	Preliminary version prepared for MTG PDR
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1 Introduction to product H43

1.1 Sensing principle

The Flexible Combined Imager (FCI) on the MTG-I satellite will continue the very successful operation of the Spinning Enhanced Visible and Infrared Imager (SEVIRI) on Meteosat Second Generation (MSG). The satellite's three axes stabilised platform will be capable of providing additional channels with better spatial, temporal and radiometric resolution, compared to the current MSG satellites.

Requirements for the FCI have been formulated by regional and global Numerical Weather Prediction (NWP) and nowcasting communities. These requirements are reflected in the design which allows for Full Disk Scan (FDS), with a basic repeat cycle of 10 minutes, and a European Regional-Rapid-Scan (RRS) which covers one-quarter of the full disk with a repeat cycle of 2.5 minutes.

The FCI takes measurements in 16 channels, of which eight are placed in the solar spectral domain between 0.4 µm to 2.1 µm, delivering data with a 1 km spatial resolution. The additional eight channels are in the thermal spectral domain between 3.8 µm to 13.3 µm, delivering data with a 2 km spatial resolution. In the RSS mode there will be two additional channels in the solar domain, with a spatial resolution of 0.5 km, and two in the thermal domain, with a spatial resolution of 1 km.

The visual and IR channels can be used for snow cover detection only in cloud free conditions. Different surfaces have different reflectance properties which suggest that these differences can be used to separate different surfaces. Typical spectral properties of different surfaces have been measured in laboratory and in situ (see e.g. Baldridge et al, 2008) although these cannot be used directly as a basis for satellite algorithms. There is always lots of variability in natural surface types. The grain size of the snow cover changes over time and space, the wetness of snow is changing and the reflecting properties change when the surface is viewed from different angles and in different lighting conditions. Also the vegetation is highly variable even in winter. This natural variability makes it quite difficult to develop a general classification algorithm for snow cover. Finally, there is also the atmosphere which must be taken in account when surface and laboratory measurements are compared to satellite measurements.

Figure 1 shows as an example three surface types: fine snow, coniferous trees and pale brown silty loam. These are based on laboratory measurements and models. Some commonly used satellite instrument channels are also presented. The figure shows that the SEVIRI channels 1, 2 and 3 and AVHRR channel 1, 2 and 3A can be used for snow classification at least if the type of snow is known. This has been shown in practise in LSA SAF and later in H SAF, when excellent snow detection products have been developed for MSG/SEVIRI and Metop/AVHRR.

Earlier experience shows that geostationary satellites are not the best option for snow detection because the spatial resolution is usually quite low in high latitudes i.e. in the areas most often covered by snow. However, excellent temporal resolution (15 minutes) is an advantage when the algorithm is based on visual and IR channels of the MSG/SEVIRI instrument. The H31 (MSG/SEVIRI) snow extent product is described in Siljamo and Hyvärinen (2011). The advantage of cloud clearing with H10 snow product is presented by Surer et al. (2014). They found that the MSG/SEVIRI snow product (H10) contains significantly less pixels classified as clouds than MODIS, particularly in the mountains. The merging of 32 MSG-SEVIRI images per day reduces cloud coverage between 15 and 29% for the period November–June from 2008-2012 as compared to the MODIS-combined product

(Terra and Aqua combined snow product). Polar satellites can produce images from specified regions 2-4 times each day if the area is cloud free about the same time each day. Geostationary instruments such as MSG/SEVIRI produce images every 15 minutes and it is much more likely that at least some of the images are cloud free. If the cloud free period is longer the changing lighting conditions can help the classification. Similar benefit can be expected from MTG/FCI.

Cloud cover is also a severe limitation on optical channels. Active and passive microwave methods would be better suited for cloud covered areas, but the spatial resolution of the passive microwave instruments is quite poor when compared to optical channels. Active microwave instruments i.e. radars have better resolution, but unfortunately these instruments need much more processing before the data is in practical form.

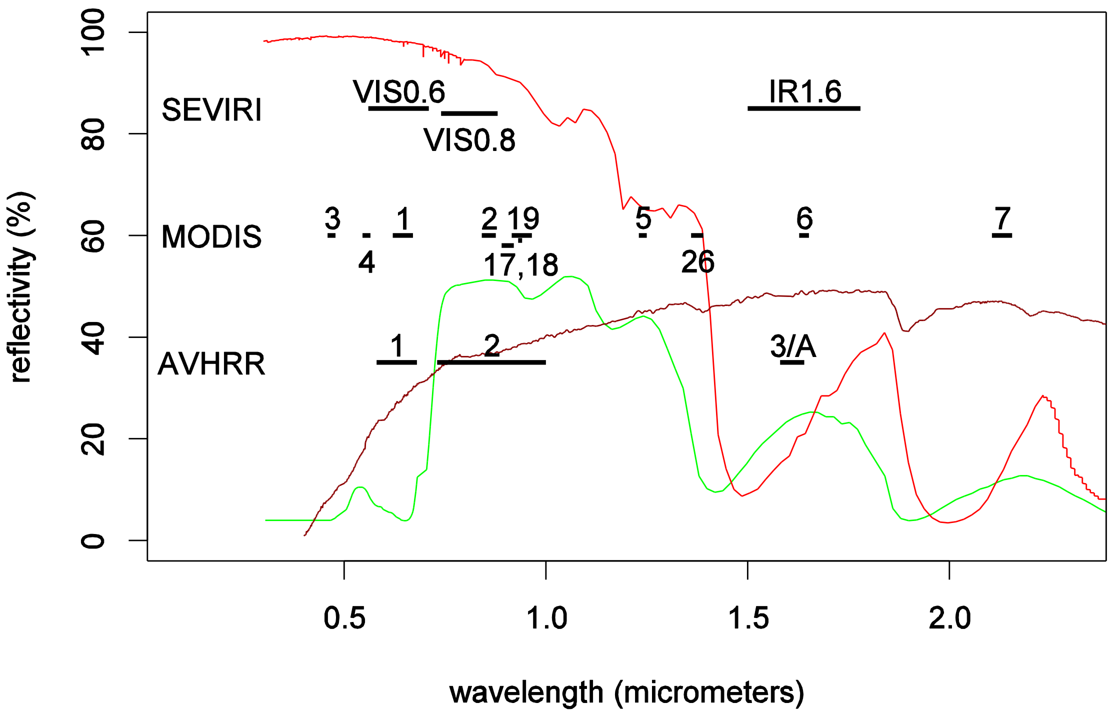

Figure 1 *Example of reflectances of three different surfaces and commonly used satellite instrument channels. Surface reflectances (snow (red), vegetation (green) and bare earth (brown)) based on ASTER Spectral Library v 2.*

1.2 Main operational characteristics

The H SAF MTG/FCI snow extent algorithm is basically a thresholding method based on the different properties of the snow covered and snow free surfaces and clouds. The daily product will be produced in two separate phases. Phase 1 is the SC1 snow cover product which is based on one cycle of FCI images. All of the SC1 products are used to produce the daily MTG/FCI snow extent product (SC2).

In the phase 1 pixels in the FCI image are classified either to several classes (at least snow, snow free, water, unclassified, no process) or fractional snow coverage will be estimated.

Once per day the daily Snow Cover (SC2) product is calculated using the SC1 products of the day. Again the system classifies each pixel or snow cover fraction is estimated. For the daily MTG/FCI snow extent product, all snow cover maps which are produced in phase 1 are merged. Simplified view of the product generation is presented in the Figure 2.

The similar production chain running for MSG SEVIRI snow products (H10 and H34) will be implemented for H43 too. The product files will include flat/forest area product from FMI and mountainous area product from TSMS, which both cover the full MTG disk. In addition, a merged version produced at FMI by blending the information from flat/forest area product (FMI) and mountain area product (TSMS) for users preferring merged version.

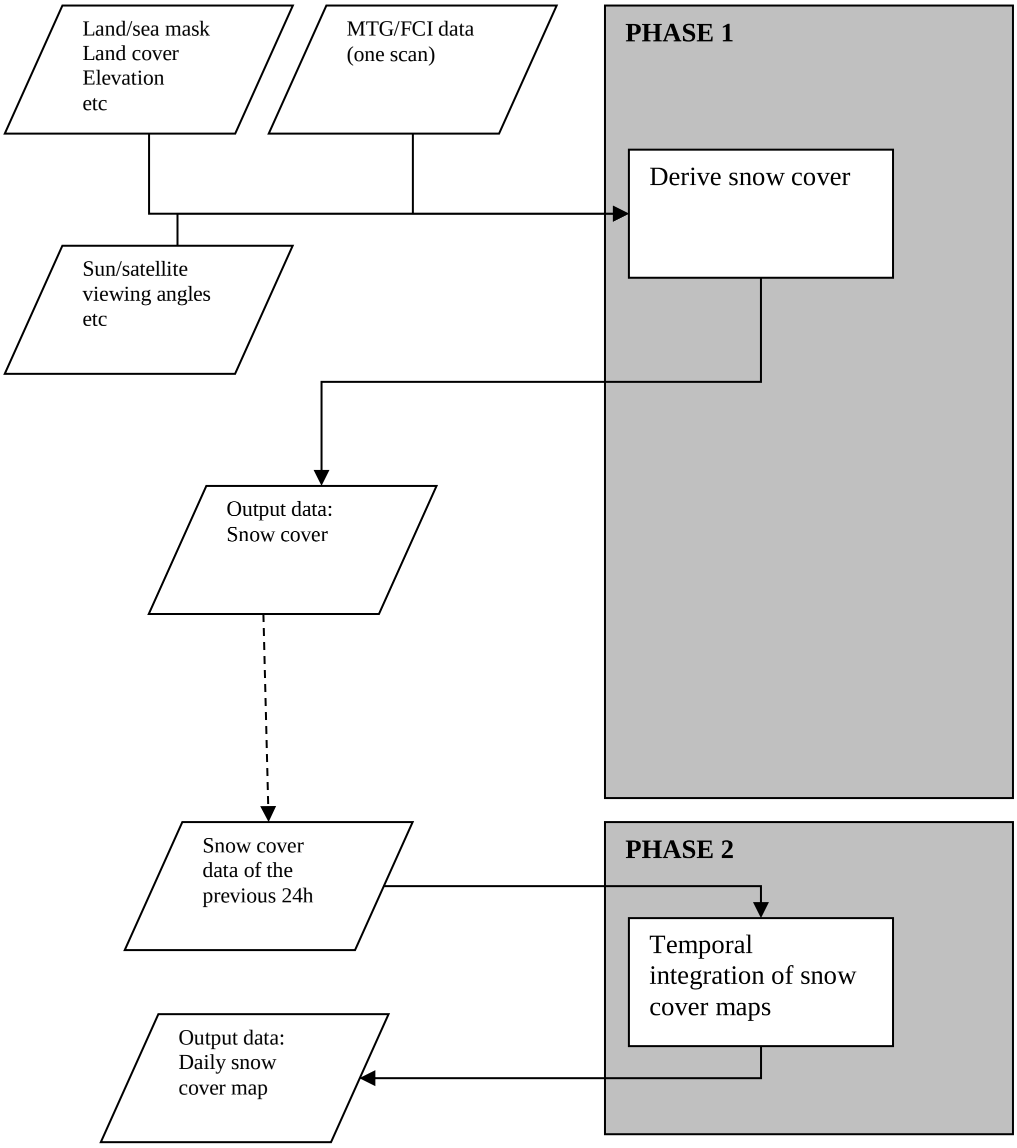

Figure 2 *Flowchart of the H SAF MTG/FCI snow extent algorithm (product H43).*

1.3 Architecture of the products generation chain

MTG/FCI data will be received through EUMETCAST or from other sources if necessary. The processing takes mainly place in FMI premises in Sodankylä where an Arctic satellite data center is located.

1.4 Product development team

Names and references of the main participants for H43 algorithm development and integration are listed in following table:

Table 1: Development team for product H43

Niilo Siljamo	Finnish Meteorological Institute (FMI)	Finland	niilo.siljamo@fmi.fi
Matias Takala			matias.takala@fmi.fi
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Erdem Erdi	Turkish State Meteorological Service (TSMS)		erdem.erdi@mgm.gov.tr

2 Processing concept

MTG/FCI data will be used to product daily snow detection data (e.g. snow extent maps). Details see chapter 1.

3 Algorithms description

3.1 The Processing details

The algorithm for the flat/forest areas is expected to be developed using the same principles as was used for the development of the products H31 (MSG/SEVIRI snow extent) and H32 (Metop/AVHRR snow extent). In the first phase, single images will be processed and then daily product will be generated by merging the data collected during one day.

This approach has produced very good results using MSG/SEVIRI and Metop/AVHRR data for snow detection. See the documentation of the H SAF/LSA SAF MSG/SEVIRI and Metop/AVHRR snow extent products for details.

The algorithm for the mountain areas is expected to be developed using the same principles as was used for the development of products H10 and H34.

3.2 The Algorithm validation

Product validation will be based on surface observations of snow cover (snow depth and state of the ground observations) and/or other satellite snow products (e.g. Sentinel, MODIS, VIIRS, IMS, etc.)

3.3 Examples of product H43

Since the MTG/FCI instrument is in development, there are not yet any example products. However, the H43 product is expected to be similar or better than existing H SAF snow products H31 and H34 (MSG/SEVIRI instrument).

4 Applicable documents

1- CDOP3 PRD – H-SAF CDOP3 Product Requirement Document Rel. 1.0, Ref: SAF/HSAF/CDOP3/PRD/1.0

5 References

Baldridge, A. M., Hook, S. J., Grove, C. I. and G. Rivera, 2008(9). The ASTER Spectral Library Version 2.0. Remote Sensing of Environment.

MTG design: http://www.eumetsat.int/website/home/Satellites/FutureSatellites/MeteosatThirdGeneration/MTGDesign/index.html#fci

Siljamo, N. and Hyvärinen, O., 2011. New Geostationary Satellite-Based Snow-Cover Algorithm. Journal of Applied Meteorology and Climatology. 50. DOI: 10.1175/2010JAMC2568.1.

Surer,S., J. Parajka, and Z. Akyurek, 2014. Validation of the operational MSG-SEVIRI snow cover product over Austria, Hydrol. Earth Syst. Sci. 18, 763–774.

Annex 1: Introduction to H-SAF

The EUMETSAT Satellite Application Facilities

H-SAF is part of the distributed application ground segment of the "*European Organization for the Exploitation of Meteorological Satellites (EUMETSAT)*". The application ground segment consists of a "*Central Application Facilities*" located at EUMETSAT Headquarters, and a network of eight "*Satellite Application Facilities (SAFs*)", located and managed by EUMETSAT Member States and dedicated to development and operational activities to provide satellite-derived data to support specific user communities (see Figure 13):

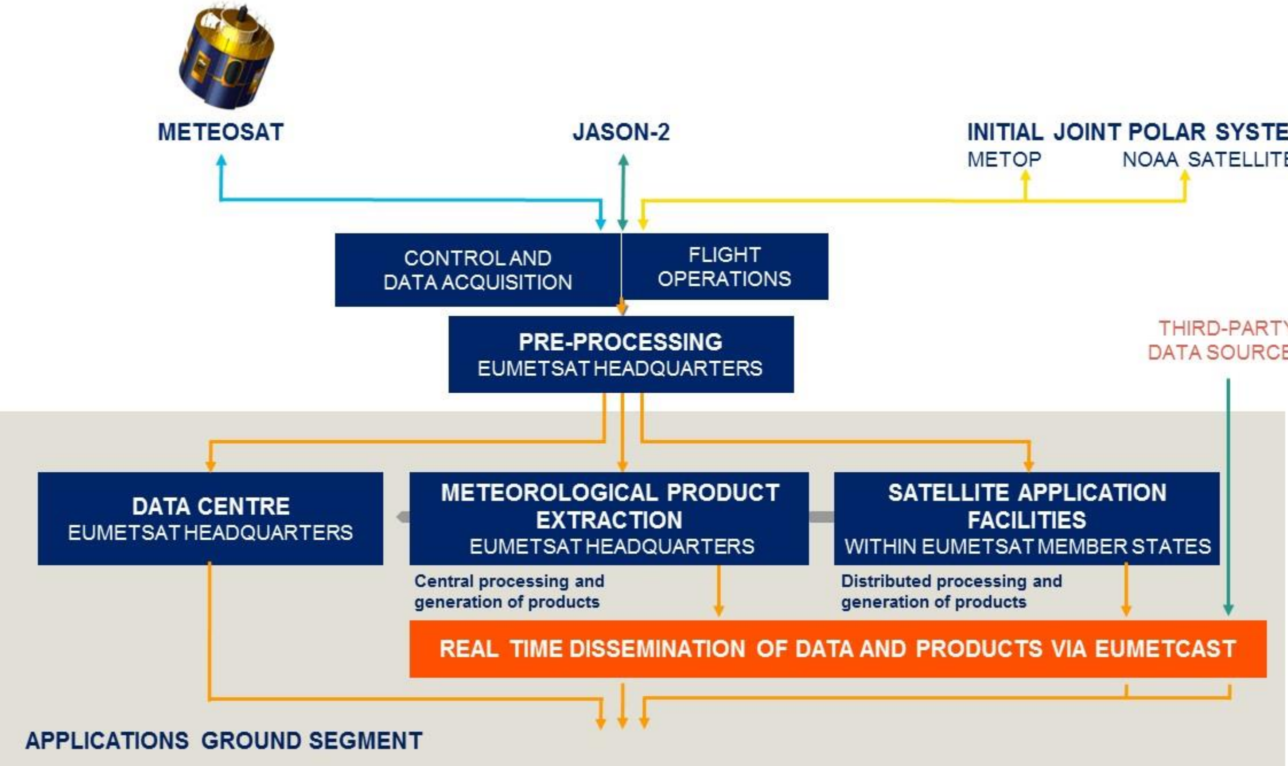

Figure 13: Conceptual scheme of the EUMETSAT Application Ground Segment

Figure 14 depicts the composition of the EUMETSAT SAF network, with the indication of each SAF's specific theme and Leading Entity.

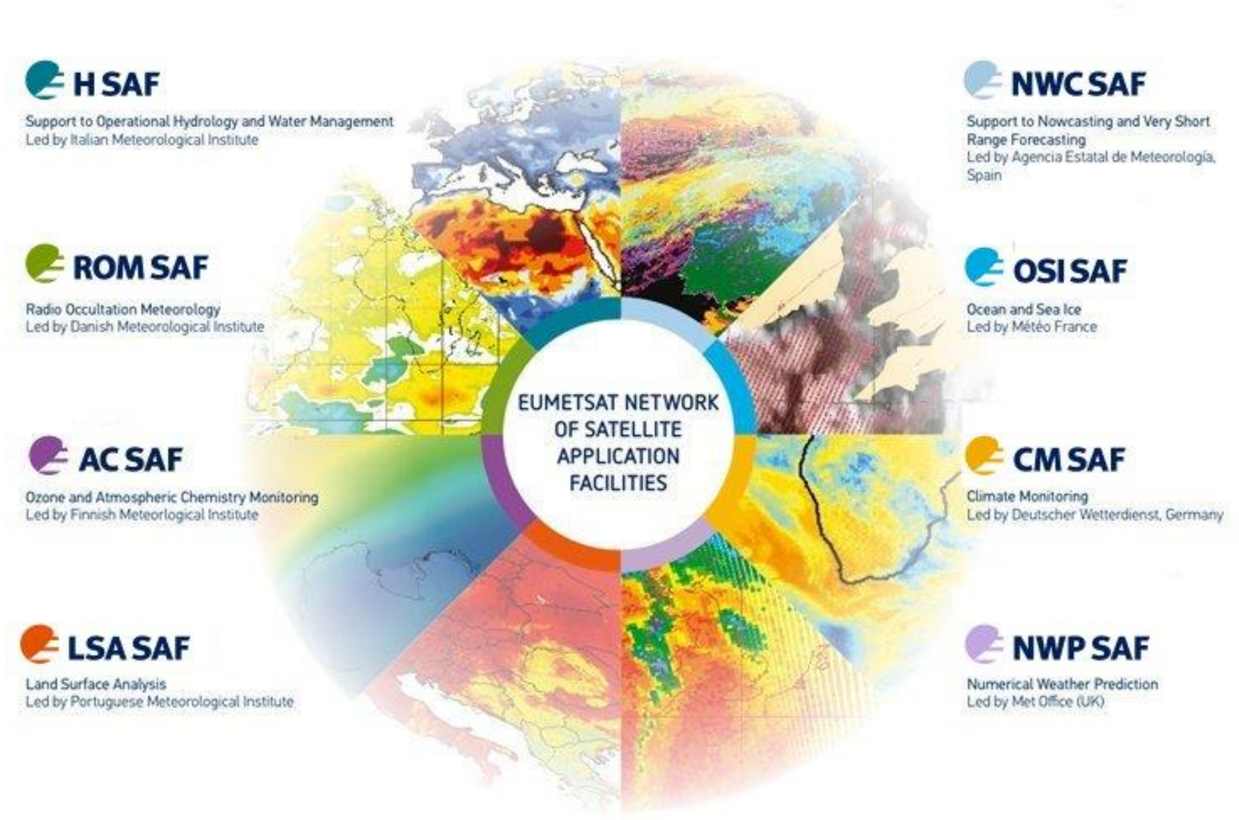

Figure 14: Current composition of the EUMETSAT SAF Network

Purpose of the H-SAF

The main objectives of H-SAF are:

a. ***to provide new satellite-derived products*** from existing and future satellites with sufficient time and space resolution to satisfy the needs of operational hydrology, by generating, centralizing, archiving and disseminating the identified products:
   - precipitation (liquid, solid, rate, accumulated);
   - soil moisture (at large-scale, at local-scale, at surface, in the roots region);
   - snow parameters (detection, cover, melting conditions, water equivalent);

b. ***to perform independent validation of the usefulness of the products*** for fighting against floods, landslides, avalanches, and evaluating water resources; the activity includes:
   - downscaling/upscaling modelling from observed/predicted fields to basin level;
   - fusion of satellite-derived measurements with data from radar and raingauge networks;
   - assimilation of satellite-derived products in hydrological models;
   - assessment of the impact of the new satellite-derived products on hydrological applications.

Products / Deliveries of the H-SAF

For the full list of the Operational products delivered by H-SAF, and for details on their characteristics, please see H-SAF website hsaf.meteoam.it.
All products are available via EUMETSAT data delivery service (EUMETCast, http://www.eumetsat.int/website/home/Data/DataDelivery/EUMETCast/index.html), or via ftp download; they are also published in the H-SAF website hsaf.meteoam.it.
All intellectual property rights of the H-SAF products belong to EUMETSAT. The use of these products is granted to every interested user, free of charge. If you wish to use these products, EUMETSAT's copyright credit must be shown by displaying the words "copyright (year) EUMETSAT" on each of the products used.

System Overview

H-SAF is lead by the Italian Air Force Meteorological Service (ITAF USAM) and carried on by a consortium of 21 members from 11 countries (see website: hsaf.meteoam.it for details)
Following major areas can be distinguished within the H-SAF system context:

- Product generation area
- Central Services area (for data archiving, dissemination, catalogue and any other centralized services)
- Validation services area which includes Quality Monitoring/Assessment and Hydrological Impact Validation.

Products generation area is composed of 5 processing centres physically deployed in 5 different countries; these are:

- for precipitation products: ITAF CNMCA (Italy)
- for soil moisture products: ZAMG (Austria), ECMWF (UK)
- for snow products: TSMS (Turkey), FMI (Finland)

Central area provides systems for archiving and dissemination; located at ITAF CNMCA (Italy), it is interfaced with the production area through a front-end, in charge of product collecting.
A central archive is aimed to the maintenance of the H-SAF products; it is also located at ITAF CNMCA.
Validation services provided by H-SAF consists of:

- Hydrovalidation of the products using models (hydrological impact assessment);
- Product validation (Quality Assessment and Monitoring).

Both services are based on country-specific activities such as impact studies (for hydrological study) or product validation and value assessment.
Hydrovalidation service is coordinated by IMWM (Poland), whilst Quality Assessment and Monitoring service is coordinated by DPC (Italy): The Services' activities are performed by experts from the national meteorological and hydrological Institutes of Austria, Belgium, Bulgaria, Finland, France, Germany, Hungary, Italy, Poland, Slovakia, Turkey, and from ECMWF.

Annex 2: Glossary

AMSR2	Advanced Microwave Scanning Radiometer 2
AMSU	Advanced Microwave Sounding Unit (on NOAA and MetOp)
ATDD	Algorithms Theoretical Definition Document
ATMS	Advanced Technology Microwave Sounder
AU	Anadolu University (in Turkey)
BfG	Bundesanstalt für Gewässerkunde (in Germany)
CAF	Central Application Facility (of EUMETSAT)
CDOP	Continuous Development-Operation Phase
CESBIO	Centre d'Etudes Spatiales de la BIOsphere (of CNRS, in France)
CGMS	Coordination Group for Meteorological Satellites
CMAP	Climate Prediction Center Merged Analysis of Precipitation
CM-SAF	SAF on Climate Monitoring
COMet	Centro Operativo per la Meteorologia (in Italy)
CNR	Consiglio Nazionale delle Ricerche (of Italy)
CNRS	Centre Nationale de la Recherche Scientifique (of France)
COSMO-ME	Consortium for Small-Scale Modelling - version for Mediterranean
DMSP	Defence Meteorological Satellite Program
DPC	Dipartimento Protezione Civile (of Italy)
EARS	EUMETSAT Advanced Retransmission Service
ECMWF	European Centre for Medium-range Weather Forecasts
EDC	EUMETSAT Data Centre, previously known as U-MARF
EUM	Short for EUMETSAT
EUMETCast	EUMETSAT's Broadcast System for Environmental Data
EUMETSAT	European Organisation for the Exploitation of Meteorological Satellites
FMI	Finnish Meteorological Institute
FTP	File Transfer Protocol
GEO	Geostationary Earth Orbit
GPCP	Global Precipitation Climatology Project
GPI	GOES Precipitation Index
GPM	Global Precipitation Measurement
GRAS-SAF	SAF on GRAS Meteorology
H-SAF	SAF on Support to Operational Hydrology and Water Management
IMWM	Institute of Meteorology and Water Management (in Poland)
IPF	Institut für Photogrammetrie und Fernerkundung (of TU-Wien, in Austria)
IPWG	International Precipitation Working Group
IR	Infra Red
IRM	Institut Royal Météorologique (of Belgium) (alternative of RMI)
ISAC	Istituto di Scienze dell'Atmosfera e del Clima (of CNR, Italy)
ITU	İstanbul Technical University (in Turkey)
LATMOS	Laboratoire Atmosphères, Milieux, Observations Spatiales (of CNRS, in France)
LEO	Low Earth Orbit
LHN	Latent Heat Nudging
LSA-SAF	SAF on Land Surface Analysis
Météo France	National Meteorological Service of France
METU	Middle East Technical University (in Turkey)
MHS	Microwave Humidity Sounder (on NOAA 18 and 19, and on MetOp)
MW	Micro Wave
NMA	National Meteorological Administration (of Romania)
NOAA	National Oceanic and Atmospheric Administration (Agency and satellite)
NWC-SAF	SAF in support to Nowcasting & Very Short Range Forecasting
NWP	Numerical Weather Prediction
NWP-SAF	SAF on Numerical Weather Prediction
O3M-SAF	SAF on Ozone and Atmospheric Chemistry Monitoring
OMSZ	Hungarian Meteorological Service
OSI-SAF	SAF on Ocean and Sea Ice
PMW	Passive Micro-Wave
PP	Project Plan
PUM	Product User Manual

PVR	Product Validation Report
QPF	Quantitative Precipitation Forecast
REMET	Reparto di Meteorologia (in Italy)
RMI	Royal Meteorological Institute (of Belgium) (alternative of IRM)
SAF	Satellite Application Facility
SEVIRI	Spinning Enhanced Visible and Infra-Red Imager (on Meteosat from 8 onwards)
SHMÚ	Slovak Hydro-Meteorological Institute
SSM/I	Special Sensor Microwave / Imager (on DMSP up to F-15)
SSMIS	Special Sensor Microwave Imager/Sounder (on DMSP starting with S-16)
STD	Standard Deviation
SYKE	Suomen ympäristökeskus (Finnish Environment Institute)
TKK	Teknillinen korkeakoulu (Helsinki University of Technology)
TSMS	Turkish State Meteorological Service
TU-Wien	Technische Universität Wien (in Austria)
U-MARF	Unified Meteorological Archive and Retrieval Facility
UniFe	University of Ferrara (in Italy)
URD	User Requirements Document
UTC	Universal Coordinated Time
VIS	Visible
WMO	World Meteorological Organization
ZAMG	Zentralanstalt für Meteorologie und Geodynamik (of Austria)