Satellite-based Climate Atlas Manual

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Introduction

The Satellite Application Facility on Climate Monitoring (CM SAF) provides satellite-based climate information on a variety of parameters, which can help people find out something more about atmosphere and climate.

The climate atlas is a tool to help visualise climate datasets for Europe and Latvia. It is also a guide for working with satellite data in climatology. The atlas is based on the climate datasets provided by the CM SAF (Satellite Application Facility on Climate Monitoring), and it consists of maps providing climatological information of different meteorological parameters. These include:

- general climatic characteristics of meteorological parameters over Europe and Latvia;
- information on satellite data suitable for climatological studies, particularly datasets provided by the CM SAF;
- an example of the strengths and weaknesses of satellite data for climate applications;
- instructions for creating a satellite climatology atlas and beginning to work with satellite datasets in general.

This tool should be used for viewing example data from different CM SAF climate datasets. The complete instructions provided here will enable users to create their own atlas with only minor additional support in processing or climatological theory.

In order to start creating your own atlas (or other product of your own choice), you should:

1. Decide what you want to achieve.
2. No really - decide what you want to achieve.
3. Decide which CM SAF product is suitable for your application. In order to do this, you may want to consult the descriptions provided here and to visit the CM SAF web page http://www.cmsaf.eu/ and the Web User Interface http://wui.cmsaf.eu/
4. Order and download the data of interest by using the instructions for data ordering.
5. Install the software and get an idea of how it works, get acquainted with the scripts. Use the instruction files provided here for a basic overview and guidance.
6. Get acquainted with the work package (folder structure) that can be downloaded from the climate atlas viewer webpage and start working.
7. Pay attention to the results you get. Is there something suspicious or artificial in the data? You may need to decide if you are looking at something geophysical (real) or something from the data and data processing.

1. Data Sources

Table 1 shows an overview of the parameters used in the climate atlas and links to all the associated essential sources of information.

Table 1

Data used in the Climate Atlas

Parameter	Data provider	Dataset	Variable	Period	Description	Download
Cloudiness	CM SAF	CLARA-A1	Monthly mean Cloud Fractional Cover (CFC)	1982-2009	Product User Manual	CM SAF Web User Interface
Cloud Phase	CM SAF	CLARA-A1	• Monthly Mean Fraction of Liquid Water Clouds (CPH) • Monthly Mean Cloud Ice Water Path (IWP) • Monthly Mean Cloud Liquid Water Path (LWP)	1982-2009	Product User Manual	CM SAF Web User Interface
Cloud Top Parameters	CM SAF	CLARA-A1	Cloud Top Parameters (CTO) • Arithmetical Monthly Mean of Cloud Top Height Above Topography (cth_arith_mean) • Arithmetical Monthly Mean of Cloud Top Pressure (ctp_arith_mean) • Arithmetical Monthly Mean of Cloud Top Temperature (ctt_arith_mean)	1982-2009	Product User Manual	CM SAF Web User Interface
Cloud Optical Thickness	CM SAF	CLARA-A1	Monthly Mean Cloud Optical Thickness (COT) • Monthly Mean Cloud Optical Thickness of all Clouds (cot) • Monthly Mean Cloud Optical Thickness of All Ice Clouds (cot_ice) • Monthly Mean Cloud Optical Thickness of All Liquid Clouds (cot_liq)	1982-2009	Product User Manual	CM SAF Web User Interface
Solar Radiation	CM SAF	MVIRI data set	• Monthly Mean Solar Surface Irradiance (SIS) • Monthly Mean Direct Irradiance at Surface (SID)	1990-2005	Product User Manual	CM SAF Web User Interface
Daylight	CM SAF	Daylight data set	Daylight Intensity (DAL)	1990-2005	Product User Manual	CM SAF Web User Interface
Surface Albedo	CM SAF	CLARA-A1	Surface Albedo (SAL)	1982-2009	Product User Manual	CM SAF Web User Interface

2. Parameter Descriptions

This chapter contains detailed information on the parameters used in the Climate Atlas, their known disruptions, limitations and weaknessess and other issues to be taken into consideration.

Note that in the Climate Atlas, all the information is displayed over two areas – over Europe (defined as -30° to 35° E in longitude and 30° to 75° N in latitude) and over Latvia (defined as 20° to 29° E in longitude and 54° to 60° N in latitude). Information from Natural Earth was used for plotting the country borders.

2.1. Cloud Parameters

Information on sever cloud parameters can be found in the following sub-chapters. The se include the fractional cloud cover, cloud phase, cloud top parameters and cloud optical thickness.

2.1.1. Fractional Cloud Cover

For the characteristics of the cloud cover fraction (%) over both Europe and Latvia the CM SAF (*Satellite Application Facility on Climate Monitoring*) monthly mean product of fractional cloudiness (CFC) from the CLARA-A1 dataset was used. The dataset covers the period from 1982 to 2009, and provides information with a global coverage in 0.25*0.25° spatial resolution. The dataset is based on the measurements of Advanced Very High Resolution Radiometer (AVHRR) onboard the polar orbiting NOAA and the EUMETSAT MetOp satellites, and the specifics of the dataset can be found on the CM SAF webpage.

The atlas provides information on:

- Monthly mean cloud cover;
- Multi-year monthly mean, maximum and minimum cloud cover and monthly variations in cloudiness;
- Seasonal mean cloud cover with seasons representing the calendar seasons (September, October and November for autumn etc.);
- Multi-year seasonal mean, maximum and minimum cloud cover and seasonal variations in cloudiness;
- Annual mean cloud cover;
- Multi-year annual mean, maximum and minimum cloud cover and annual variations in cloudiness;
- Monthly, seasonal and annual anomalies in cloud cover.

Issues to be taken into consideration:

- Not all clouds are detected due to inherent limitations of the AVHRR imager as being a passive radiometer with a rather coarse field of view (here about 5 km in size). The current estimation is that clouds with optical thicknesses below 0.3 are generally not detected in AVHRR GAC datasets.
- Some thin clouds (particularly, ice clouds) over cold ground surfaces may remain undetected even if having cloud optical thicknesses higher than the above mentioned detection limit.
- Twilight conditions (Solar zenith angle between 80-95 degrees) are especially challenging to AVHRR cloud screening methods leading to some systematic underestimation of cloud amounts (especially for morning-evening satellites).
- The above deficiencies indicate that overall global CFC estimations are slightly negatively biased.

There are some gaps in the dataset:

- February 1985 – therefore the winter season values for the year 1985 were not calculated.
- October 1985 – therefore the autumn season values for the year 1985 were not calculated.

2.1.2. Cloud Phase

In the Climate Atlas, three parameters showing the climatology of cloud phase have been displayed – the fraction of liquid water clouds and cloud ice and liquid water paths. The data were obtained from the CM SAF CLARA A1 dataset based on the measurements of the AVHRR instrument onboard the polar-orbiting satellites. Detailed information on the cloud parameters included in the atlas is provided in the following chapters.

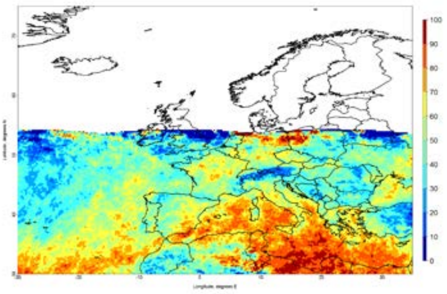
2.1.2.1. Fraction of Liquid Water Clouds

For the characteristics of the fraction of liquid water clouds (%) over both Europe and Latvia the CM SAF (*Satellite Application Facility on Climate Monitoring*) monthly mean product of fraction of liquid water clouds (CPH) from the CLARA-A1 dataset was used. The dataset covers the period from 1982 to 2009, and provides information with a global coverage in 0.25*0.25° spatial resolution. The dataset is based on the measurements of Advanced Very High Resolution Radiometer (AVHRR) onboard the polar orbiting NOAA and the EUMETSAT MetOp satellites, and the specifics of the dataset can be found on the CM SAF webpage.

The atlas provides information on:

- Monthly mean fraction of liquid water clouds for March-September;
- Multi-year monthly mean, maximum and minimum fraction of liquid water clouds and monthly variations in liquid water clouds for March-September;
- Spring and summer mean fraction of liquid water clouds with seasons representing the calendar seasons (March, April and May for spring etc.);
- Multi-year seasonal mean, maximum and minimum fraction of liquid water clouds and seasonal variations in liquid water clouds;
- Monthly and seasonal anomalies in fraction of liquid water clouds.

The reasons for excluding autumn and winter months from the atlas can be seen from the images below (example of the year 2002). All observations made under twilight conditions (solar zenith angles between 80-95 degrees) have been excluded from the product generation process in order to avoid being affected by specific cloud detection problems occurring in the twilight zone. The same applies for the low solar illumination at high latitudes in the winter season, and therefore no data is available over the northern part of Europe from October through February.



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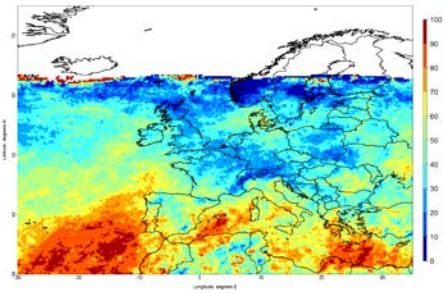

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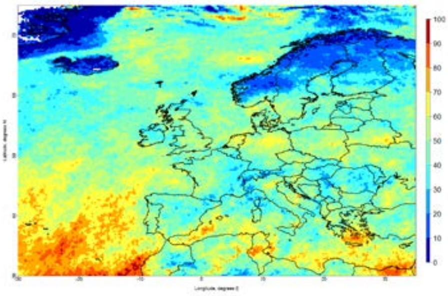

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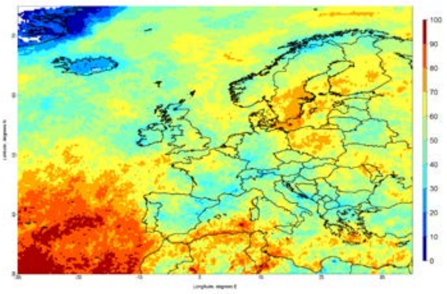

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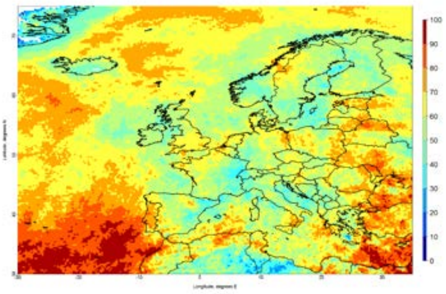

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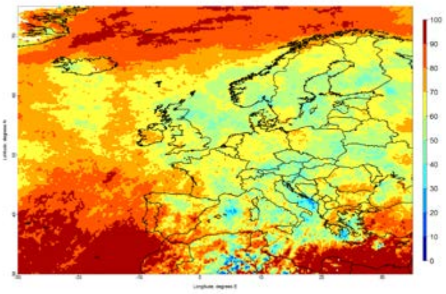

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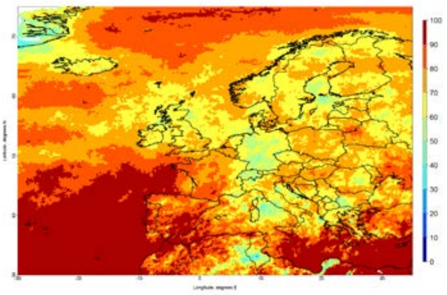

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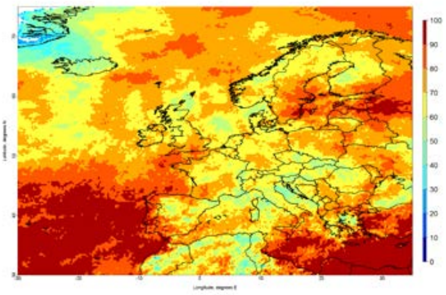

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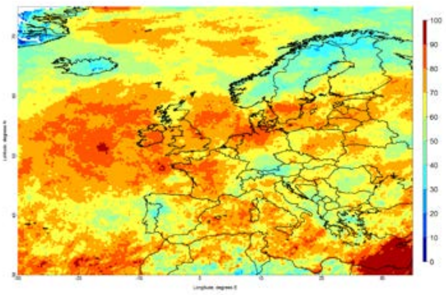

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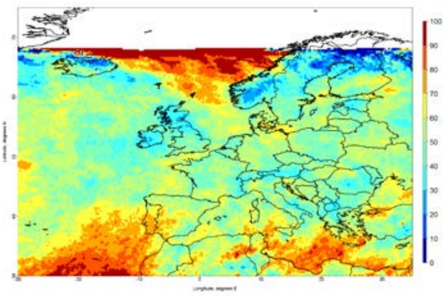

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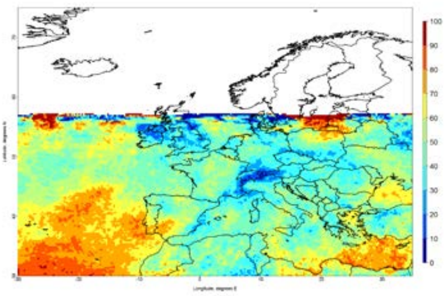

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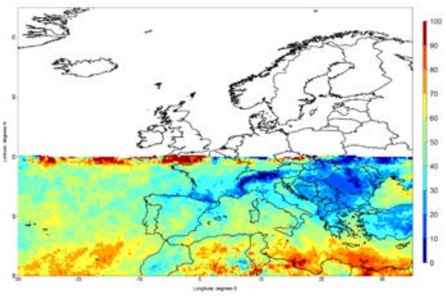


December

Other issues to be taken into consideration:

- Although the product is available from solar zenith angle of 80 degrees downwards, the derivation of cloud physical properties from reflected solar radiation is dependent on the availability of daylight. This means that no retrievals can be done during night time and in practice a maximum solar zenith angle of 72 degrees should be used.
- The data may show some problems over very bright surfaces, particularly ice and snow, as the visible reflectance from clouds is similar to that from the surface.
- In case of thin ice clouds over water clouds, the visible and near-infrared reflectances are dominated by the water cloud layer, which results in an erroneous water labelling. Validation results indicate that the water cloud occurrence might be overestimated by almost 100% at the expense of the corresponding ice cloud occurrence. The largest overestimations occur in case of very thin ice clouds over thick water clouds. Erroneous ice phase retrievals might also occur in case of broken or inhomogeneous overcast clouds, in particular over ocean surfaces.

There are also some gaps in the dataset:

- February 1985
- October 1985

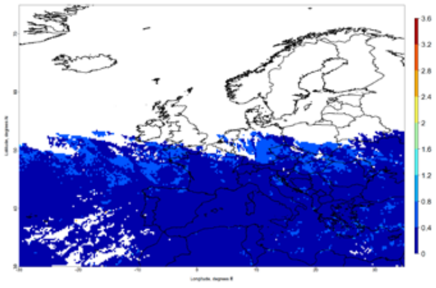
2.1.2.2. Cloud Ice Water Path

For the characteristics of the cloud ice water path (kg/m^2) over both Europe and Latvia the CM SAF (*Satellite Application Facility on Climate Monitoring*) monthly mean product of cloud ice water path (IWP) from the CLARA-A1 dataset was used. The dataset covers the period from 1982 to 2009, and provides information with a global coverage in 0.25*0.25° spatial resolution. The dataset is based on the measurements of Advanced Very High Resolution Radiometer (AVHRR) onboard the polar orbiting NOAA and the EUMETSAT MetOp satellites, and the specifics of the dataset can be found on the CM SAF webpage.

The atlas provides information on:

- Monthly mean cloud ice water path for March-September;
- Multi-year monthly mean, maximum and minimum cloud ice water path and monthly variations in cloud ice water path for March-September;
- Spring and summer mean cloud ice water path with seasons representing the calendar seasons (March, April and May for spring etc.);
- Multi-year seasonal mean, maximum and minimum cloud ice water path and seasonal variations in cloud ice water path;
- Monthly and seasonal anomalies in cloud ice water path.

The reasons for excluding autumn and winter months from the atlas can be seen from the images below (example of the year 1984). All observations made under twilight conditions (solar zenith angles between 80-95 degrees) have been excluded from the product generation process in order to avoid being affected by specific cloud detection problems occurring in the twilight zone. The same applies for the low solar illumination at high latitudes in the winter season, and therefore no data is available over the northern part of Europe from October through February.



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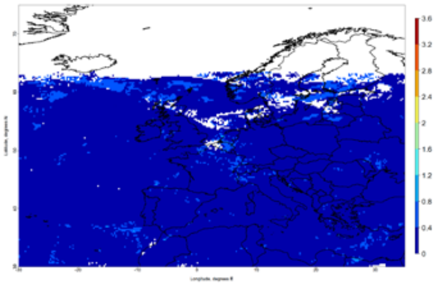

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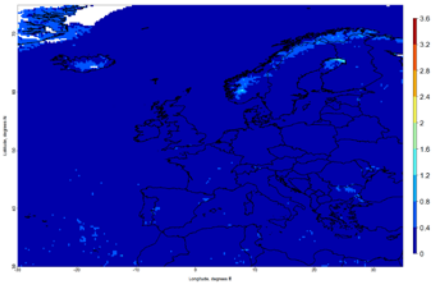

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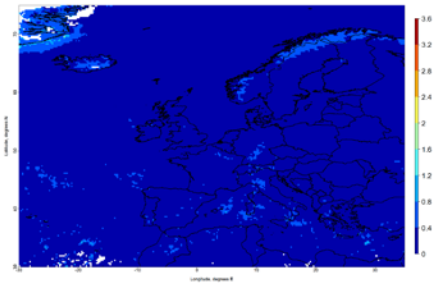

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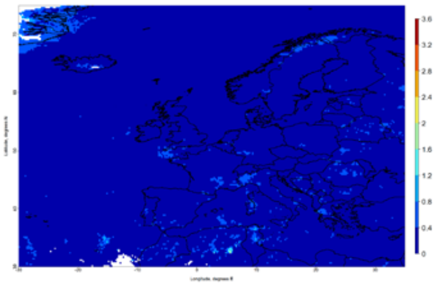

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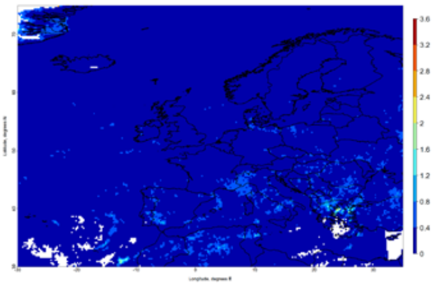

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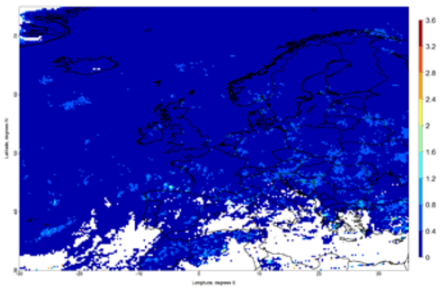

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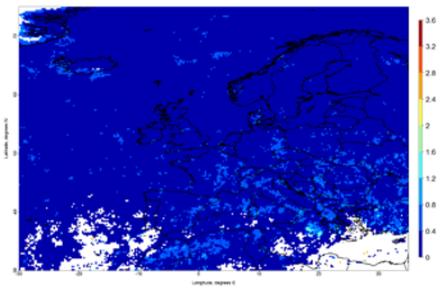

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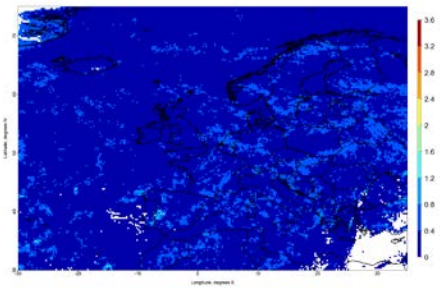

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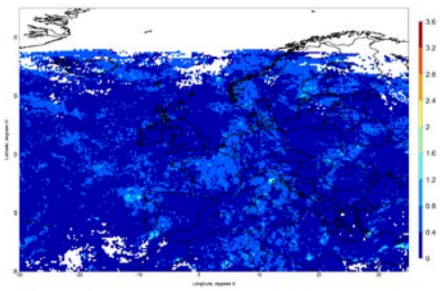

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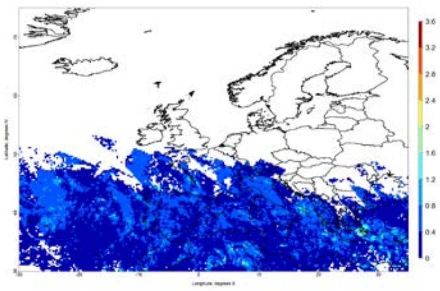

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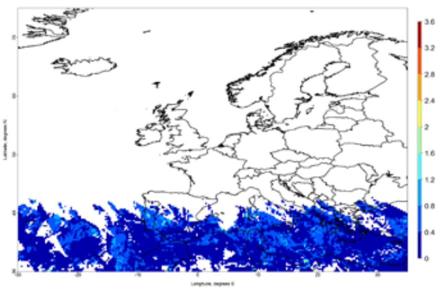


December

Other issues to be taken into consideration:

- Although the product is available from solar zenith angle of 80 degrees downwards, the derivation of cloud physical properties from reflected solar radiation is dependent on the availability of daylight. This means that no retrievals can be done during night time and in practice a maximum solar zenith angle of 72 degrees should be used.
- IWP is calculated from cloud optical thickness (please see the description file for COT), which implies that all limitations for COT are also limitations for IWP.
- Retrievals from passive satellite instruments are limited by the fact that the obtained signal emanates from the integrated profile. Since near-infrared radiation is only penetrating into the cloud to a certain depth (due to absorption by cloud particles), the retrieved cloud phase and effective radius are representative for the upper part of the cloud.

There are some gaps in the dataset:

- February 1985
- October 1985

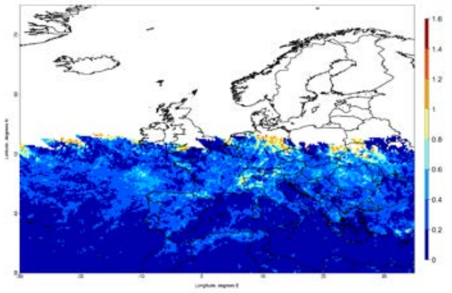
2.1.2.3. Cloud Liquid Water Path

For the characteristics of the cloud liquid water path (kg/m^2) over both Europe and Latvia the CM SAF (*Satellite Application Facility on Climate Monitoring*) monthly mean product of cloud liquid water path (LWP) from the CLARA-A1 dataset was used. The dataset covers the period from 1982 to 2009, and provides information with a global coverage in 0.25*0.25° spatial resolution. The dataset is based on the measurements of Advanced Very High Resolution Radiometer (AVHRR) onboard the polar orbiting NOAA and the EUMETSAT MetOp satellites, and the specifics of the dataset can be found on the CM SAF webpage.

The atlas provides information on:

- Monthly mean cloud liquid water path for March-September;
- Multi-year monthly mean, maximum and minimum cloud liquid water path and monthly variations in cloud liquid water path for March-September;
- Spring and summer mean cloud liquid water path with seasons representing the calendar seasons (March, April and May for spring etc.);
- Multi-year seasonal mean, maximum and minimum cloud liquid water path and seasonal variations in cloud liquid water path;
- Monthly and seasonal anomalies in cloud liquid water path.

The reasons for excluding autumn and winter months from the atlas can be seen from the images below (example of the year 1984). All observations made under twilight conditions (solar zenith angles between 80-95 degrees) have been excluded from the product generation process in order to avoid being affected by specific cloud detection problems occurring in the twilight zone. The same applies for the low solar illumination at high latitudes in the winter season, and therefore no data is available over the northern part of Europe from October through February.



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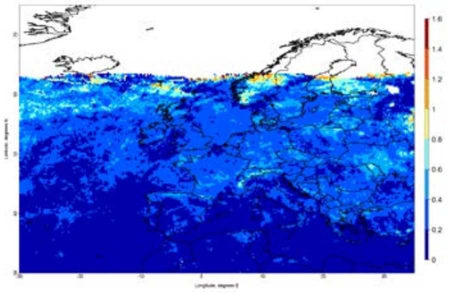

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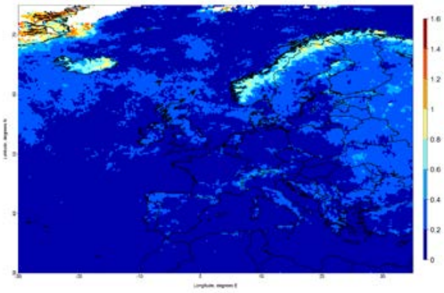

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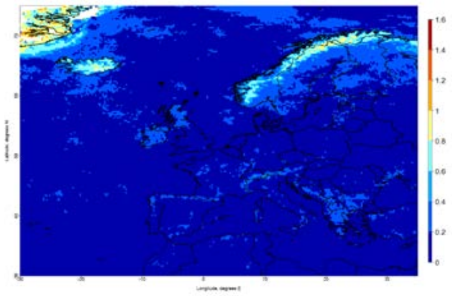

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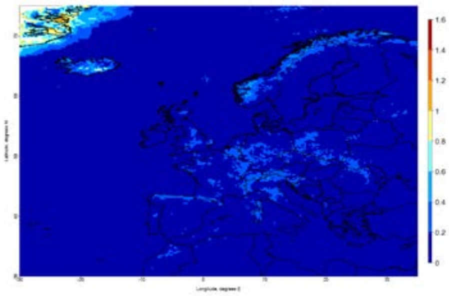

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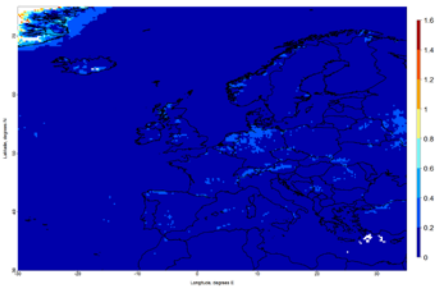

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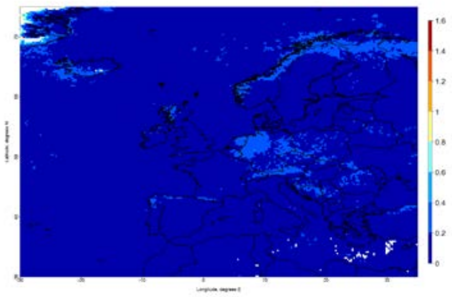

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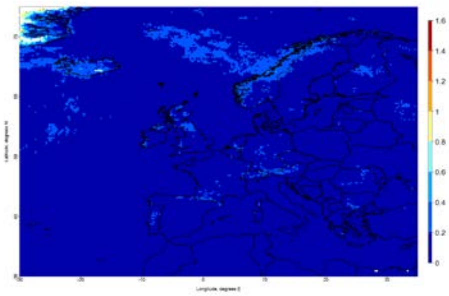

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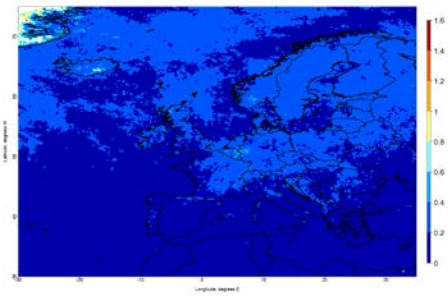

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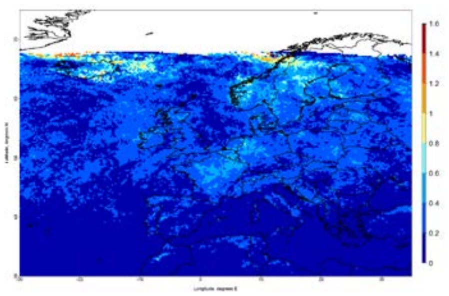

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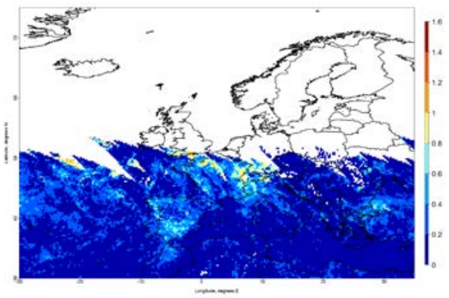

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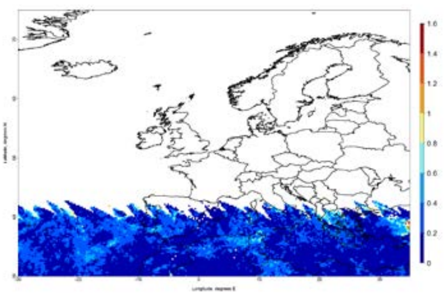


December

Other issues to be taken into consideration:

- Although the product is available from solar zenith angle of 80 degrees downwards, the derivation of cloud physical properties from reflected solar radiation is dependent on the availability of daylight.

This means that no retrievals can be done during night time and in practice a maximum solar zenith angle of 72 degrees should be used.

- LWP is calculated from cloud optical thickness (please see the description file for COT), which implies that all limitations for COT are also limitations for LWP.
- Retrievals from passive satellite instruments are limited by the fact that the obtained signal emanates from the integrated profile. Since near-infrared radiation is only penetrating into the cloud to a certain depth (due to absorption by cloud particles), the retrieved cloud phase and effective radius are representative for the upper part of the cloud.

There are some gaps in the dataset:

- February 1985
- October 1985

2.1.3. Cloud Top Parameters – Temperature, Pressure and Height

For the characteristics of the cloud top parameters over both Europe and Latvia the CM SAF (*Satellite Application Facility on Climate Monitoring*) monthly mean product of cloud top parameters (CTO) from the CLARA-A1 dataset was used. The dataset covers the period from 1982 to 2009, and provides information with a global coverage in 0.25*0.25° spatial resolution. The dataset includes information on the cloud top height above topography (cth_arith_mean) in metres, cloud top pressure (ctp_arith_mean) in hPa and cloud top temperature (ctt_arith_mean) in K. The dataset is based on the measurements of Advanced Very High Resolution Radiometer (AVHRR) onboard the polar orbiting NOAA and the EUMETSAT MetOp satellites, and the specifics of the dataset can be found on the CM SAF webpage.

The atlas provides the information on:

- Monthly mean cloud top temperature, pressure and height;
- Multi-year monthly mean, maximum and minimum cloud top temperature, pressure and height and monthly variations in these cloud top parameters;
- Seasonal mean cloud top temperature, pressure and height with seasons representing the calendar seasons (September, October and November for autumn etc.);
- Multi-year seasonal mean, maximum and minimum cloud top temperature, pressure and height and seasonal variations in these cloud top parameters;
- Annual mean cloud top temperature, pressure and height;
- Multi-year monthly mean, maximum and minimum cloud top temperature, pressure and height and monthly variations in these cloud top parameters;
- Monthly, seasonal and annual anomalies in cloud top temperature, pressure and height.

Issues to be taken into consideration:

- Cloud retrieval methods are unreliable in the presence of strong temperature inversions in the troposphere.
- As mentioned for the clod fractional cover (CFC) product, optically very thin clouds may not be detected at all. Even if being detected, it is very difficult to assign a correct cloud top level for the thinnest clouds. The semi-transparency correction method works only in cases of single-layer clouds

meaning that a significant fraction (up to about 20% of all clouds) may be left without a valid CTO value (e.g., multi-layer cloud cases).

- Clouds interpreted as being opaque are in reality often diffuse or multi-layered in their upper portions – this often leads to an underestimation of the true cloud top parameters of up to 2000 m.

There are some gaps in the dataset:

- February 1985 – therefore the winter season values for the year 1985 were not calculated.
- October 1985 – therefore the autumn season values for the year 1985 were not calculated.

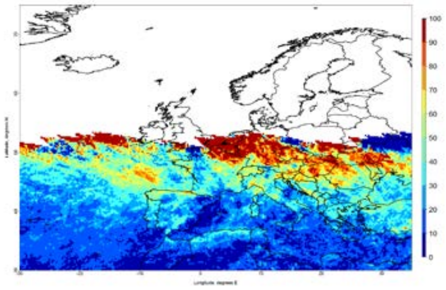
2.1.4. Cloud Optical Thickness

For the characteristics of the cloud optical thickness over both Europe and Latvia the CM SAF (*Satellite Application Facility on Climate Monitoring*) monthly mean product of cloud optical thickness (COT) from the CLARA-A1 dataset was used. The dataset covers the period from 1982 to 2009, and provides information with a global coverage in 0.25*0.25° spatial resolution. The dataset includes information on the cloud optical thickness for all clouds (cot) and separately for ice clouds (cot_ice) and liquid water clouds (cot_liq). The dataset is based on the measurements of Advanced Very High Resolution Radiometer (AVHRR) onboard the polar orbiting NOAA and the EUMETSAT MetOp satellites, and the specifics of the dataset can be found on the CM SAF webpage.

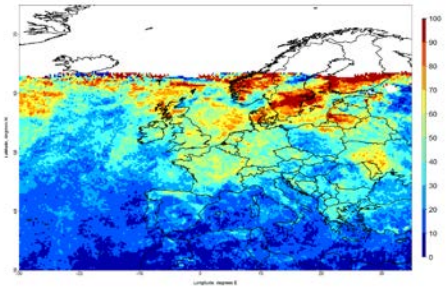
The atlas provides information on:

- Monthly mean cloud optical thickness for March-September;
- Multi-year monthly mean, maximum and minimum cloud optical thickness and monthly variations in cloud optical thickness for March-September;
- Spring and summer mean cloud optical thickness with seasons representing the calendar seasons (March, April and May for spring etc.);
- Multi-year seasonal mean, maximum and minimum cloud optical thickness and seasonal variations in cloud optical thickness;
- Monthly and seasonal anomalies in cloud optical thickness.

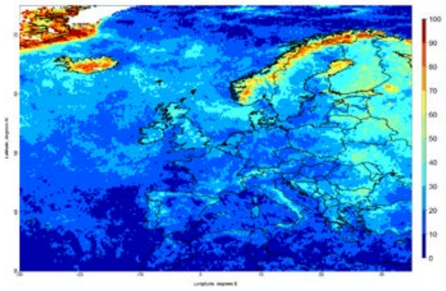
The reasons for excluding autumn and winter months from the atlas can be seen from the images below (example of the year 1984). All observations made under twilight conditions (solar zenith angles between 80-95 degrees) have been excluded from the product generation process in order to avoid being affected by specific cloud detection problems occurring in the twilight zone. The same applies for the low solar illumination at high latitudes in the winter season, and therefore no data is available over the northern part of Europe from October through February.



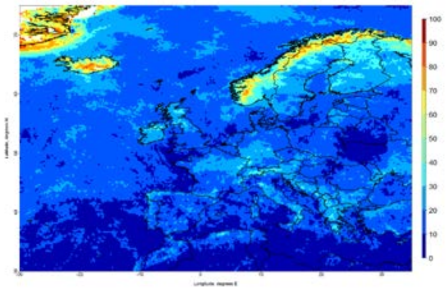
January



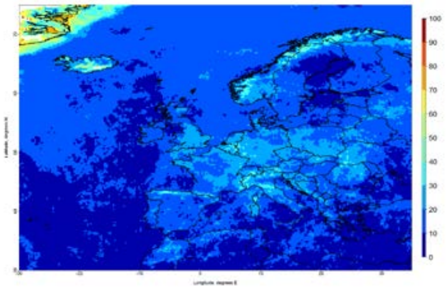
February



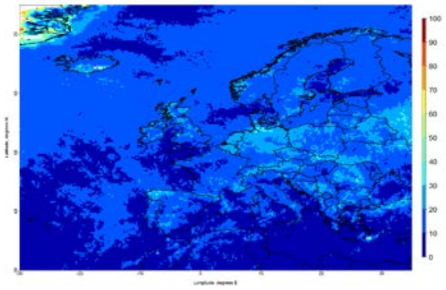
March



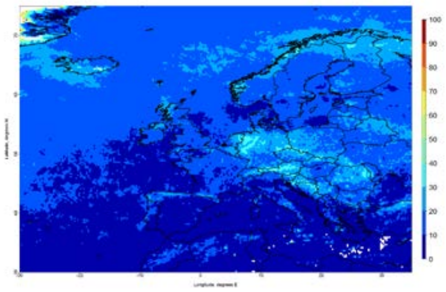
April



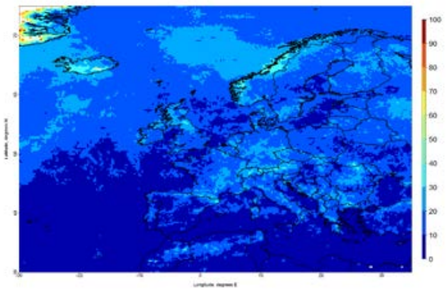
May



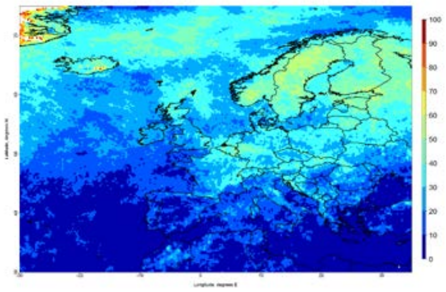
June



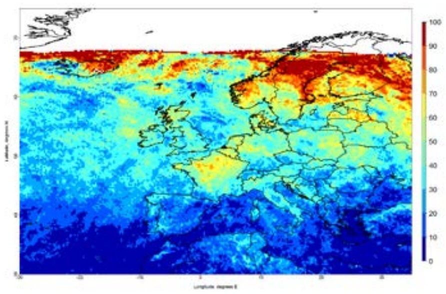
July



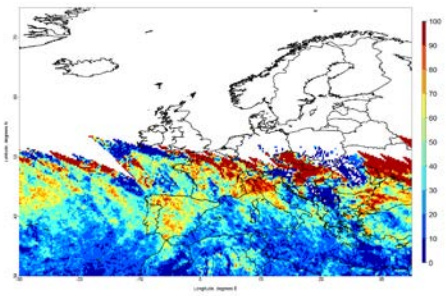
August



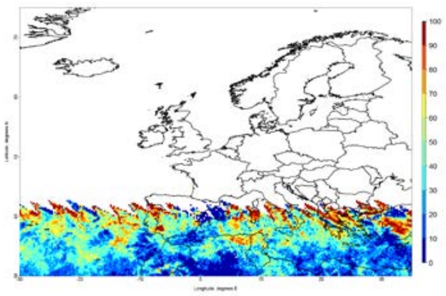
September



October



November



December

Other issues to be taken into consideration:

- Although the product is available from solar zenith angle of 80 degrees downwards, the derivation of cloud physical properties from reflected solar radiation is dependent on the availability of daylight. This means that no retrievals can be done during night time and in practice a maximum solar zenith angle of 72 degrees should be used.

- The retrieval is highly problematic over very bright surfaces, particularly ice and snow, as the visible reflectance from clouds is similar to that from the surface. You can see this effect over the Scandinavian mountains in the April image presented above.

There are also some gaps in the dataset:

- February 1985
- October 1985

2.2. Solar Radiation and Daylight

For the climatic characteristic of Solar radiation and daylight intensity, we used CM SAF datasets obtained from the measurements of the MVIRI instrument onboard the METEOSAT First generation satellites. Therefore, the information presented in the atlas is available on a very high spatial resolution, however due to technical reasons the time period used in the atlas is not as long as for the polar-orbiting satellite datasets.

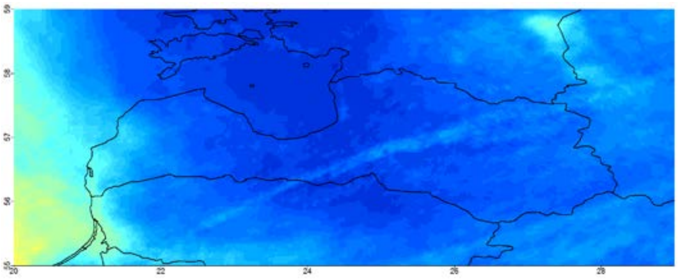
2.2.1. Surface Incoming Shortwave Radiation and Direct Irradiance at the Surface

For the characteristics of the surface incoming shortwave radiation and direct irradiance at the surface (W/m^2) over both Europe and Latvia the CM SAF (*Satellite Application Facility on Climate Monitoring*) monthly mean products of surface incoming shortwave radiation (SIS) and direct irradiance at the surface (SID) from a modified MVIRI dataset was used. The dataset covers the period from 1983 to 2005, and provides information for the METEOSAT full disc area in 0.05*0.05° spatial resolution. The dataset is based on the measurements of Meteosat Visible and Infrared Imager (MVIRI) instrument onboard the METEOSAT First generation satellites, and the specifics of the dataset can be found on the CM SAF webpage.

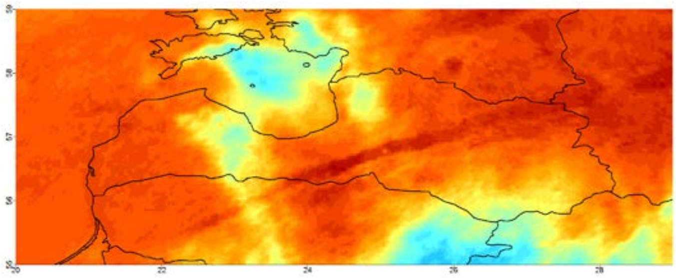
The atlas provides information on:

- Monthly mean surface incoming shortwave radiation and direct radiation at the surface;
- Multi-year monthly mean, maximum and minimum surface incoming shortwave radiation and direct radiation at the surface and monthly variations in solar radiation;
- Seasonal mean surface incoming shortwave radiation and direct radiation at the surface with seasons representing the calendar seasons (September, October and November for autumn etc.);
- Multi-year seasonal mean, maximum and minimum surface incoming shortwave radiation and direct radiation at the surface and seasonal variations in solar radiation;
- Annual mean surface incoming shortwave radiation and direct radiation at the surface;
- Multi-year annual mean, maximum and minimum surface incoming shortwave radiation and direct radiation at the surface and annual variations in solar radiation;
- Monthly, seasonal and annual anomalies in surface incoming shortwave radiation and direct radiation at the surface.

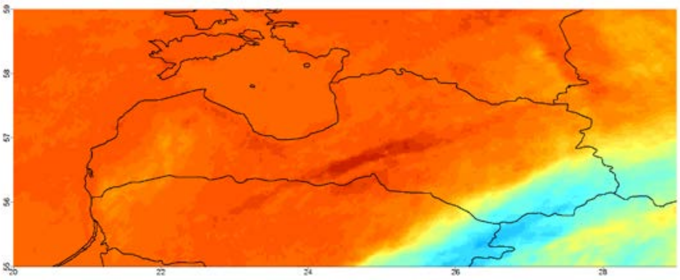
A modification of the MVIRI dataset has been used in creating the atlas, because a probably erroneous feature over Latvia, Lithuania and Eastern Russia has been found in the original dataset (see the example images from the year 2001 below). In order to avoid this error, it was chosen to use the EURO4M dataset with a 0.05*0.05° spatial resolution (Mueller et al. 2011).



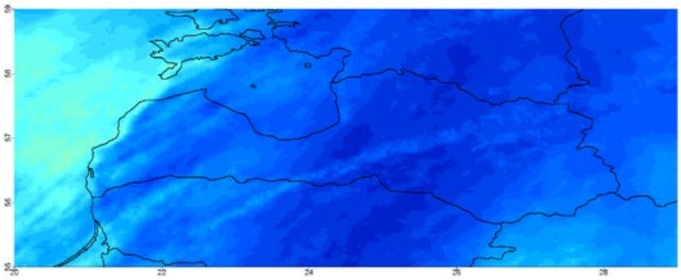
15.04.2001



25.06.2001



03.07.2001



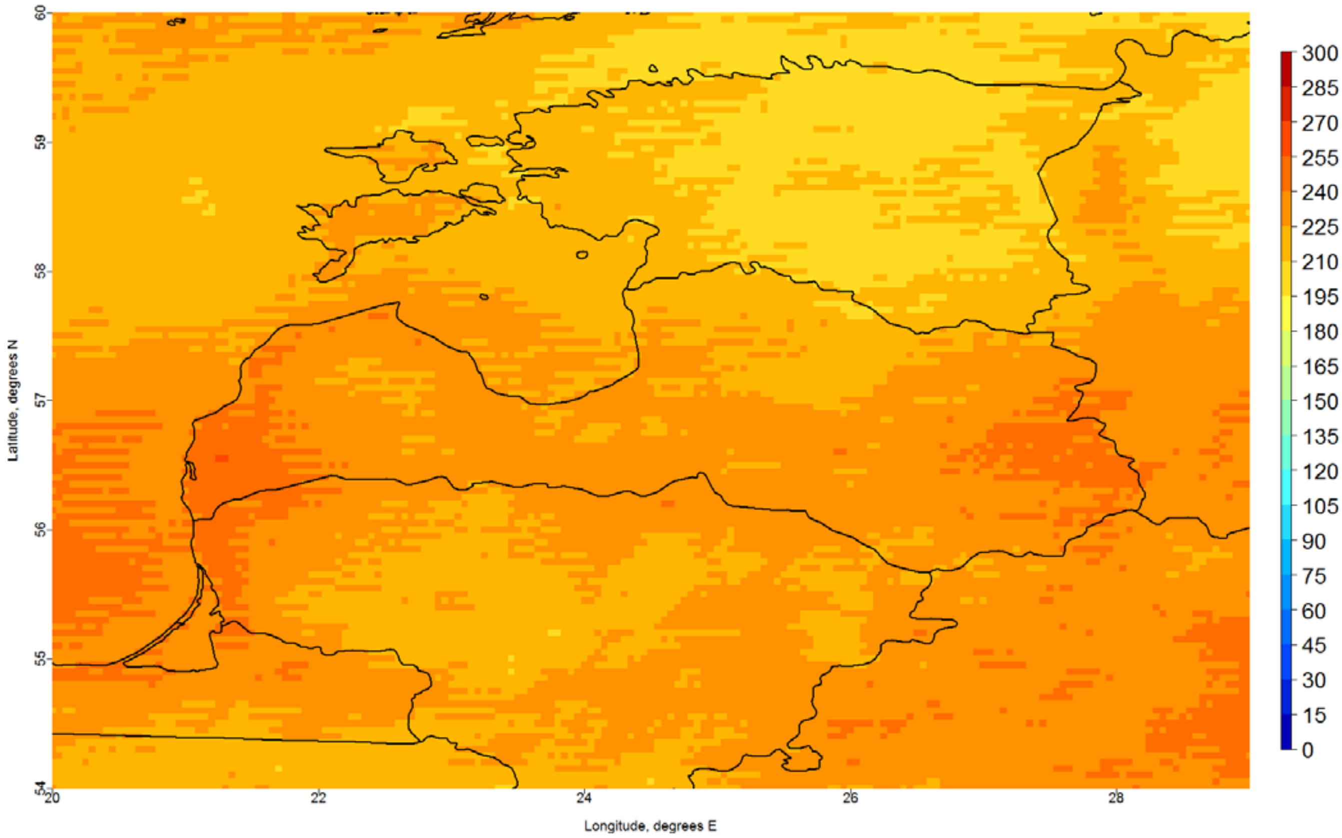
15.09.2001

Also the first years of the dataset have been excluded from the atlas because of missing information that produces spatially inhomogeneous and striped images (see image below – example of May 1985). This corresponds to products derived from MVIRI data onboard the satellites Meteosat 2-4.[1]

The hourly mean products are only affected for the early morning and late evening hours. The fields between 07:00 and 17:00 UTC are not involved and can be used without limitations. For the other times during the day the striping is very strong, therefore, the data for these time periods should not be used. For the SIS daily mean product the mean amplitude of the stripes is in the order of 5 W/m² (maximum in the order of 20 W/m²).

The CM SAF user feedback shows that the SIS and SID reveal a striping feature for the daily mean products before 1995, however in the creation of this atlas the information from 1990 to 2005 has been included.

[1] This striping is caused by disregarding the special night-time operation of the satellites (18:00-05:00UTC). During day-time the visible channel contained only half of the image (only every second line) for every even slot, whereas for the odd slots the whole image was available. The image at even slots was completed by copying the existing line onto the non-existing one. However, during night-time operation (even at odd time slots) every image contained only half of the image which resulted in empty lines (all zeros) for the odd slots because the copying routine was only applied to the even slots. Further artefacts and stripes are apparent in the raw data which was not documented and hence have not been corrected in the early METEOSAT satellites.



Other issues to be taken into consideration:

- The high clear-sky reflection over bright surfaces (e.g., desert regions) reduces the contrast between clear-sky reflection and cloudy-sky reflection. This leads to errors in the calculation of SIS and SID and the accuracy is significantly lower for snow covered surfaces.
- The accuracy of aerosol information is not known in several regions of the world due to missing ground measurements. SID and SIS are quite sensitive to the AOD (aerosol optical depth) in clear sky situations, which introduces a certain amount of uncertainty.

The information is displayed over two areas – over Europe (defined as -30° to 35° E in longitude and 30° to 75° N in latitude) and over Latvia (defined as 20° to 29° E in longitude and 54° to 60° N in latitude). Information from Natural Earth was used for plotting the country borders.

References:

Mueller, R., Trentmann, J., Träger-Chatterjee, C., Posselt, R., Stöckli, R. 2011. *The Role of the Effective Cloud Albedo for Climate Monitoring and Analysis*, Remote Sensing, doi:10.3390/rs3112305

2.2.2. Daylight Intensity

For the characteristics of the daylight intensity (kLux) over both Europe and Latvia the CM SAF (*Satellite Application Facility on Climate Monitoring*) monthly mean product of daylight intensity (DAL) from the Meteosat Surface Radiation Daylight Data Set was used. The dataset covers the period from 1983 to 2005, and provides information for the METEOSAT full disc area in 0.05*0.05° spatial resolution. The dataset is based on the measurements of Meteosat Visible and Infrared Imager (MVIRI) instrument onboard the METEOSAT First generation satellites, and specifics of the dataset can be found on the CM SAF webpage.

The atlas provides information on:

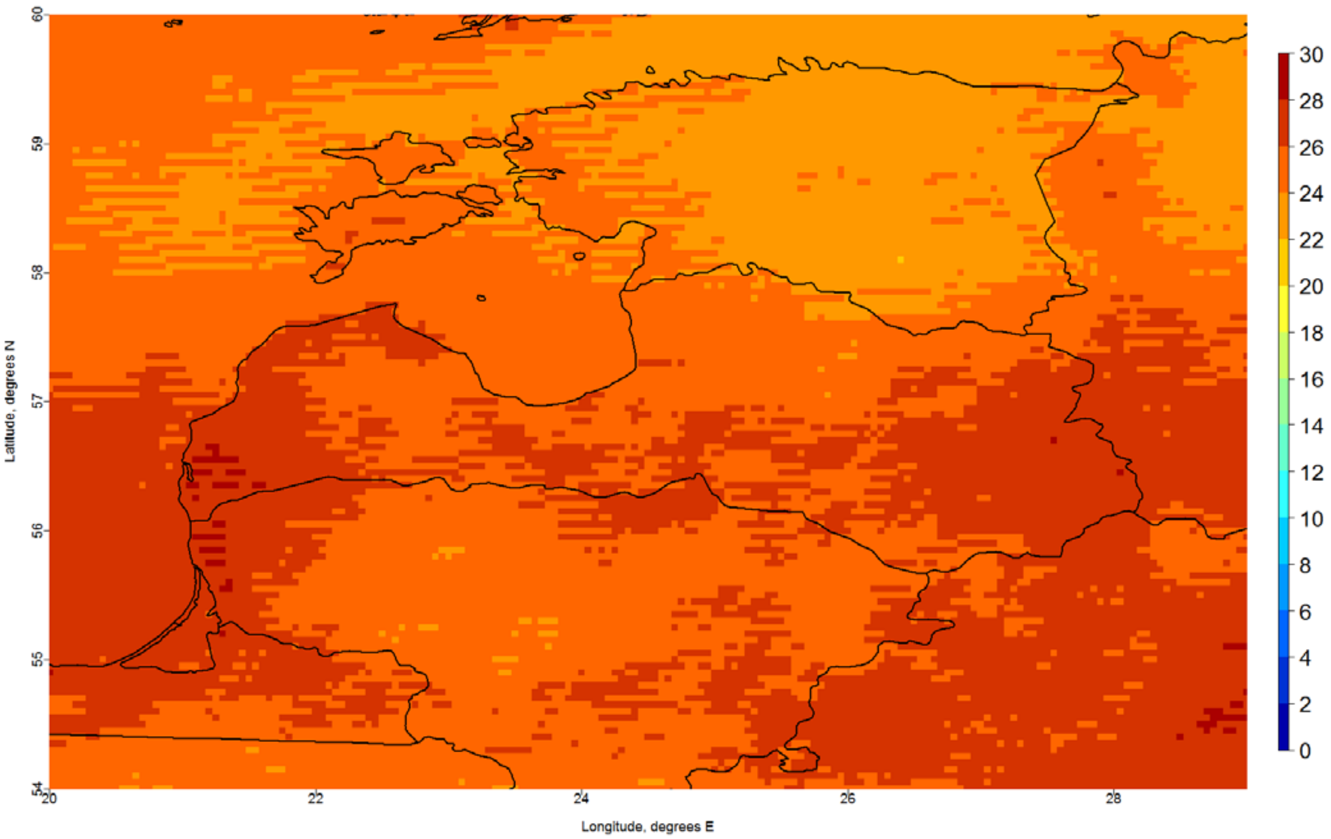
- Monthly mean daylight intensity;
- Multi-year monthly mean, maximum and minimum daylight intensity and monthly variations in daylight;
- Seasonal mean daylight intensity with seasons representing the calendar seasons (September, October and November for autumn etc.);
- Multi-year seasonal mean, maximum and minimum daylight intensity and seasonal variations in daylight;
- Annual mean daylight intensity;
- Multi-year annual mean, maximum and minimum daylight intensity and annual variations in daylight;
- Monthly, seasonal and annual anomalies in daylight intensity.

Also the first years of the dataset have been excluded from the atlas because of missing information that produces spatially inhomogeneous and striped images (see image below – example of May 1985). This corresponds to products derived from MVIRI data onboard the satellites Meteosat 2-4.[2]

The hourly mean products are only affected for the early morning and late evening hours. The fields between 07:00 and 17:00 UTC are not involved and can be used without limitations. For other times during the day the striping is very strong, therefore, the data for these time periods should not be used.

Due to the reasons mentioned above, only DAL data from 1990 to 2005 have been included in the creation of this atlas.

[2] This striping is caused by disregarding the special night-time operation of the satellites (18:00-05:00UTC). During day-time the visible channel contained only half of the image (only every second line) for every even slot, whereas for the odd slots the whole image was available. The image at even slots was completed by copying the existing line onto the non-existing one. However, during night-time operation (even at odd time slots) every image contained only half of the image which resulted in empty lines (all zeros) for the odd slots because the copying routine was only applied to the even slots. Further artefacts and stripes are apparent in the raw data which was not documented and hence have not been corrected in the early METEOSAT satellites.



Other issues to be taken into consideration:

- Over snow the uncertainty of daylight might be significantly higher than the estimated accuracies.
- The high clear-sky reflection over bright surfaces (e.g., desert regions) reduces the contrast between clear-sky reflection and cloudy-sky reflection. This leads to higher uncertainties in cloud albedo and errors in the calculation of DAL.
- In regions with long-lasting cloud cover the detection of a minimum which constitutes a clear sky situation might fail. This results in an underestimation of the effective cloud albedo and errors in DAL.

2.3. Surface Albedo

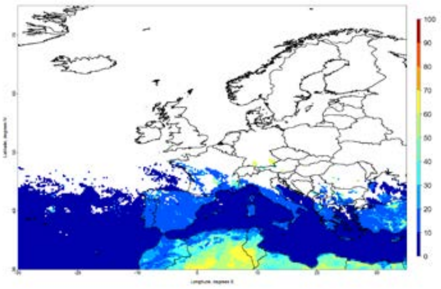
For the characteristics of the surface albedo (%) over both Europe and Latvia the CM SAF (*Satellite Application Facility on Climate Monitoring*) monthly mean product of surface albedo (SAL) from the CLARA-A1 dataset was used. The dataset covers the period from 1982 to 2009, and provides information with a global coverage in 0.25*0.25° spatial resolution. The dataset is based on the measurements of Advanced Very High Resolution Radiometer (AVHRR) onboard the polar orbiting NOAA and the EUMETSAT MetOp satellites, and the specifics of the dataset can be found on the CM SAF webpage.

The atlas provides information on:

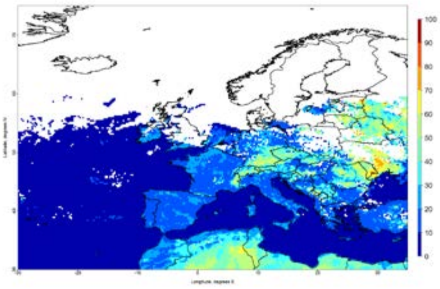
- Monthly mean surface albedo for March-September;
- Multi-year monthly mean, maximum and minimum surface albedo and monthly variations in surface albedo for March-September;

- Spring and summer mean surface albedo with seasons representing the calendar seasons (March, April and May for spring etc.);
- Multi-year seasonal mean, maximum and minimum surface albedo and seasonal variations in surface albedo;
- Monthly and seasonal anomalies in surface albedo.

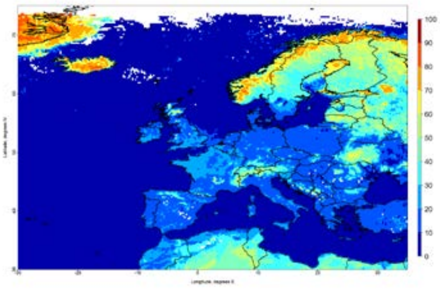
The reasons for excluding autumn and winter months from the atlas can be seen from the images below (example of the year 1984). All observations made under twilight conditions (solar zenith angles above 70 degrees) have been excluded from the product generation process. The same applies for the low solar illumination at high latitudes in the winter season, and therefore no data is available over the northern part of Europe from October through February.



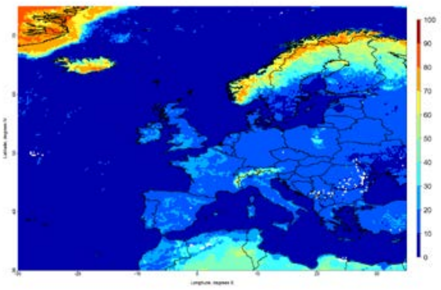
January



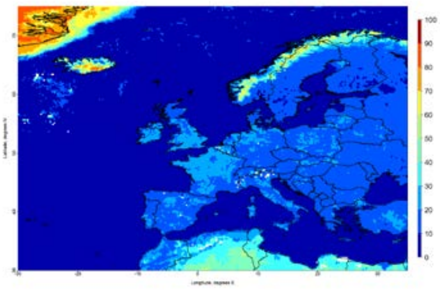
February



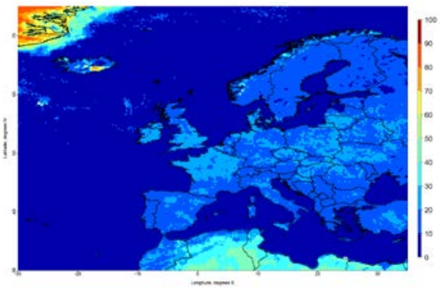
March



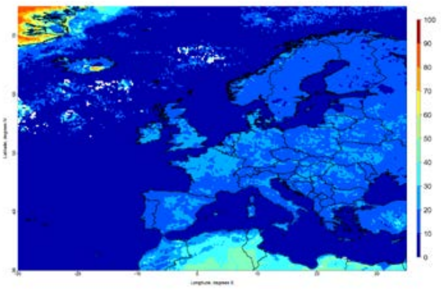
April



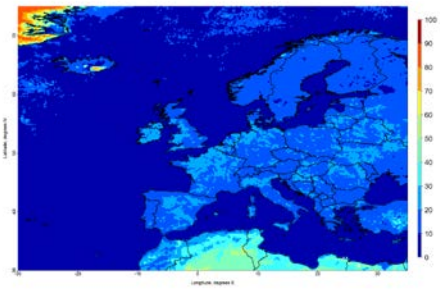
May



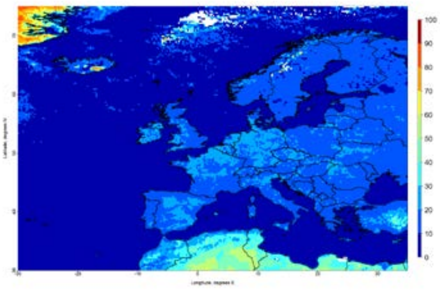
June



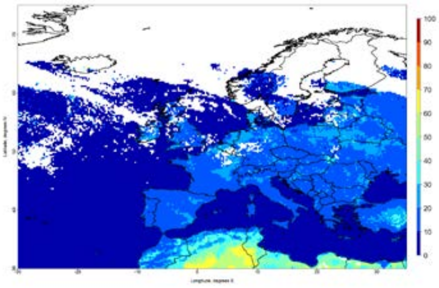
July



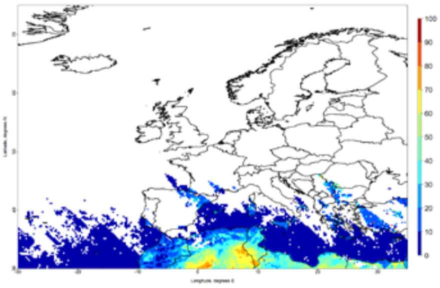
August



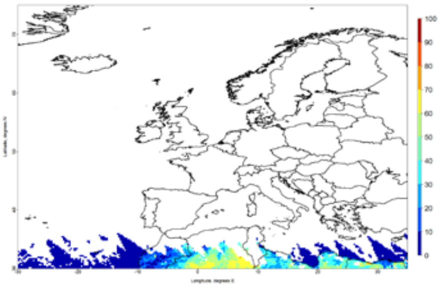
September



October



November



December

Other issues to be taken into consideration:

- The accuracy of the cloud mask is critical to the SAL product quality, since underestimation of clouds in the cloud mask may lead to sporadic instantaneous surface albedo retrieval overestimations of several hundred per cent (relative). Over snow-covered areas, the underestimation of cloud cover typically leads to an underestimation of the instantaneous surface albedo.
- The most important atmospheric variable affecting the surface albedo retrievals is the aerosol optical depth (AOD) in the atmosphere. Variations in AOD are both regional and global; their effect in space-observed surface reflectances is substantial. Yet an accurate derivation of AOD from satellite observations to support surface albedo retrievals requires assumptions on the albedo of the underlying surface. Currently a fixed AOD content is used in the dataset everywhere in the atmosphere.
- Errors in the land use classification data are another source of retrieval error that should be considered.

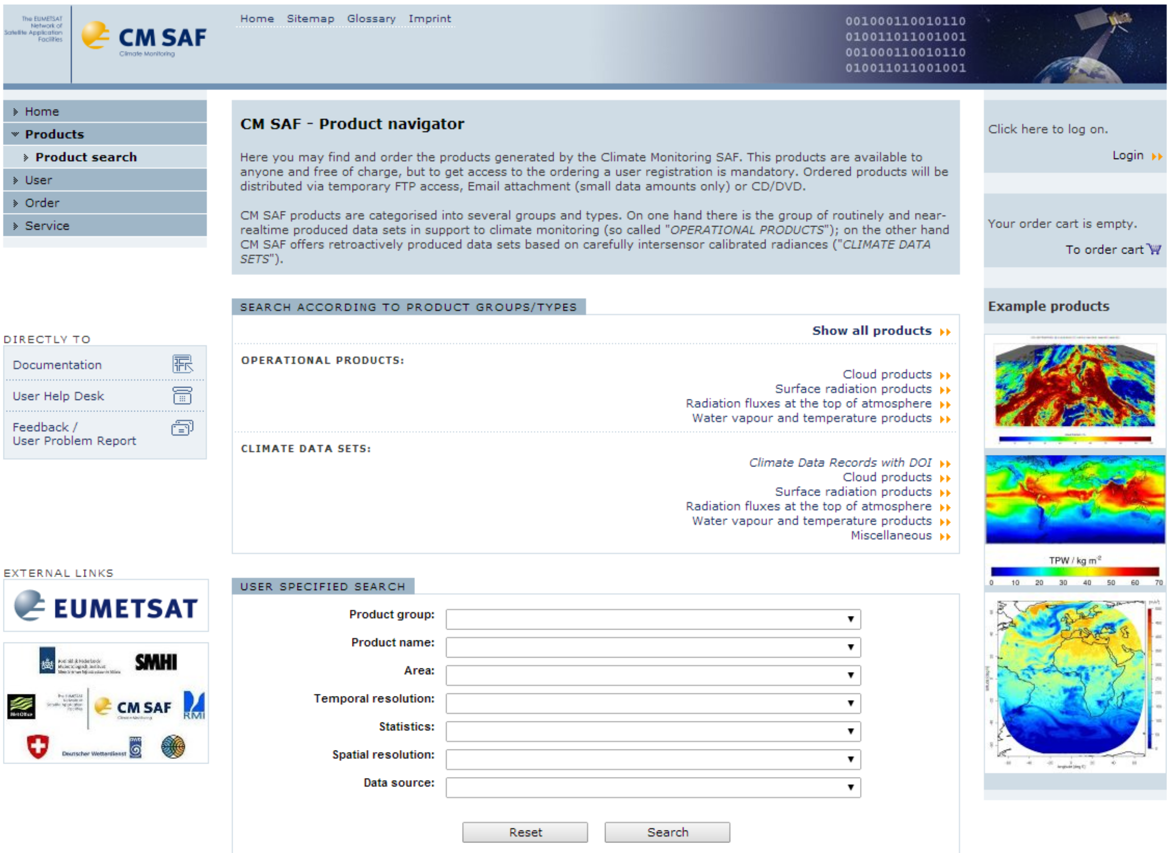
3. Instructions for Ordering Data from the CM SAF Web User Interface

CM SAF data can be downloaded from the Web User Interface: http://wui.cmsaf.eu/

Please contact CM SAF (contact.cmsaf@dwd.de) in case you have any questions or are experiencing problems with data ordering.

In order to download any data (in this case monthly mean Fractional Cloud Cover over the period 1982-2009 with a global coverage), please follow these instructions.

- Open http://wui.cmsaf.eu/
- You will see the front page (see the image below). You need to register in order to order any data. The registration can be found under *User → Registration* on the left side of the page.
  After registering and logging in go back to the *Products → Product Search* section of the front page where you will see the products divided into two groups: *Operational Products* and *Climate Data Sets*. The Operational Products are obtained in near real time and are disseminated with high timeliness (within 8 weeks after observation) to support operational climate monitoring application. Retroactively produced climate data sets are targeted on the provision of homogenous sets of high-quality data to investigate climate variability and long-term changes in the climate mean state and are based on carefully inter-sensor calibrated radiances.



- In this case you need to look for the climate data set.
- There are two ways to search for the desired data – by browsing through the products under the panel *Search According to Product Groups/Types* or by using the *User Specified Search*.
  <u>Option 1: To search according to product groups:</u>

- ✓ Select *Cloud Products* under *Climate Data Sets*
- ✓ A list containing all available cloud data sets will appear (see the image below), with giving additional information about the data source, time steps, statistics and area of coverage

List of products

Name	Data source	Time	Statistics	Area	
CAL - Cloud albedo, version 001	CAL from METEOSAT	Hourly	Mean	METEOSAT disk (70S-70N, 70W-70E)	
CAL - Cloud albedo, version 001	CAL from METEOSAT	Daily	Mean	METEOSAT disk (70S-70N, 70W-70E)	
CAL - Cloud albedo, version 001	CAL from METEOSAT	Monthly	Mean	METEOSAT disk (70S-70N, 70W-70E)	
CFC - Fractional cloud cover, version 001	CFC from METOP 02	Daily	Mean	Global	
CFC - Fractional cloud cover, version 001	CFC from METOP 02	Monthly	Mean	Global	
CFC - Fractional cloud cover, version 001	CFC from MSG	Instantaneous	(none)	MSG disk (CM SAF definition)	
CFC - Fractional cloud cover, version 001	CFC from MSG	Daily	Mean	MSG full disk (includes Europe, Afrika, Atlantic Ocean)	
CFC - Fractional cloud cover, version 001	CFC from MSG	Monthly	Mean	MSG full disk (includes Europe, Afrika, Atlantic Ocean)	
CFC - Fractional cloud cover, version 001	CFC from MSG	Monthly	Mean diurnal-cycle	MSG full disk (includes Europe, Afrika, Atlantic Ocean)	
CFC - Fractional cloud cover, version 001	CFC from NOAA 07	Daily	Mean	Global	
CFC - Fractional cloud cover, version 001	CFC from NOAA 07	Monthly	Mean	Global	
CFC - Fractional cloud cover, version 001	CFC from NOAA 09	Daily	Mean	Global	
CFC - Fractional cloud cover, version 001	CFC from NOAA 09	Monthly	Mean	Global	
CFC - Fractional cloud cover, version 001	CFC from NOAA 11	Daily	Mean	Global	
CFC - Fractional cloud cover, version 001	CFC from NOAA 11	Monthly	Mean	Global	
CFC - Fractional cloud cover, version 001	CFC from NOAA 12	Daily	Mean	Global	
CFC - Fractional cloud cover, version 001	CFC from NOAA 12	Monthly	Mean	Global	
CFC - Fractional cloud cover, version 001	CFC from NOAA 14	Daily	Mean	Global	
CFC - Fractional cloud cover, version 001	CFC from NOAA 14	Monthly	Mean	Global	
CFC - Fractional cloud cover, version 001	CFC from NOAA 15	Daily	Mean	Global	

195 Products found, displaying 1 to 20.
« ◄ 1 2 3 4 5 6 7 8 9 10 ► »

<u>Option 2: To search by using the user specified search:</u>

- ✓ Fill in the required information (see the image below) and hit *Search*.

USER SPECIFIED SEARCH

Product group:	Climate Data Sets
Product name:	CFC - Fractional cloud cover
Area:	Global
Temporal resolution:	Monthly
Statistics:	Mean
Spatial resolution:	Latitude/longitude grid (0.25x0.25 degree)
Data source:	Polar orbiting satellites

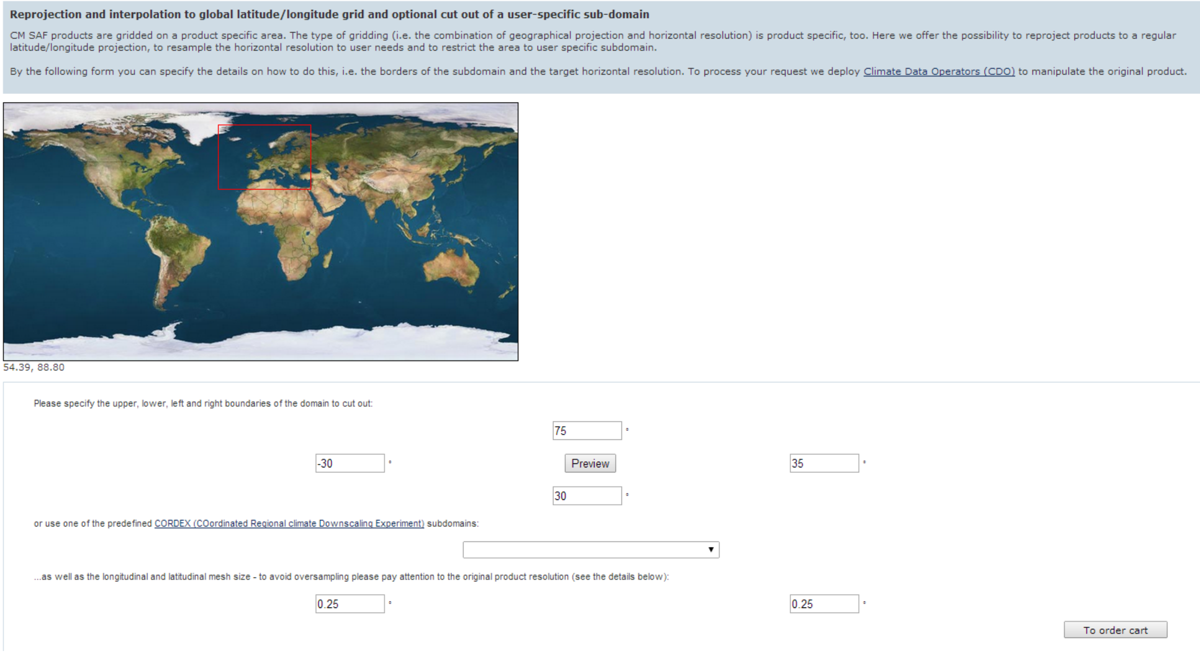
Reset Search

<u>Further proceed as follows regardless of the steps taken before:</u>

- ✓ Select the magnifying glass icon next to the monthly mean product of global fractional cloud cover data obtained from the polar orbiting satellites (see the image below)

CFC - Fractional cloud cover, version 001	CFC from polar orbiting satellites	Monthly	Mean	Global	

- ✓ It will bring you to a page with the product details
- ✓ The data files on a global scale are very big in size, therefore it is strongly (**!**) advised to chose a smaller area whenever it is possible. In order to do so proceed to *Change projection / spatial resolution / domain*
- ✓ That will bring you to a page where you can define the area of interest. However you are not supposed to change the resolution of the product.
- ✓ Press *Preview* to view the selected area (see image below)



- ✓ Proceed to *To order cart*
- ✓ You will be asked to specify the time range in the next step. Afterwards proceed to *To order cart*
- ✓ On the final page of the ordering you will see the size and estimated time of downloading the data, type of delivery (FTP would probably be the most convenient option) and order details. If the order satisfies your needs you can then proceed to *Place an order*

- ✓ You can view your orders under *Order → Order status*
- ✓ After successfully completing the order you should receive a Product request e-mail
- ✓ Also you will receive an e-mail with a link to the data after the order has been made available for you

4. Software Used for Creating the Satellite-based Climate Atlas

The choice for software used for creating the satellite climatology atlas was based on the experience of the CM SAF (*Satellite Application Facility on Climate Monitoring*). CM SAF uses R and CDO (*Climate Data Operators*) for statistical calculations and visualisation of the gridded satellite data. CM SAF provides a relatively simple and understandable toolbox for working with gridded satellite data. So it was decided to use the same technique for creating the satellite-based climate atlas, and several scripts created for R and CDO were used. This paper gives an introduction and instructions for working with these software tools in Windows environment. However CDO also works in Linux and R works on Mac.

It is advised to have the following software tools installed to be able to create a satellite climatology atlas in the most convenient way:

- Download and install the latest version of CDO (Climate Data Operators) here. This software tool will be used for calculations of the gridded data.
- Download and install the latest version of R. See the instructions provided here. This software tool will be used for the visualisation of the result data.
- Panoply, which can be downloaded here. This software tool is used for viewing NetCDF files, so also for viewing satellite data.
- Notepad++ is a software tool used for editing CDO and R scripts in a convenient way. You can download it here.
- NppToR can be downloaded from here. This software tool facilitates communication between R and Notepad++.
- 7zip is a useful tool for archiving and decompressing files. You can download it here.

4.1. CDO Installation Instructions for Windows (Obtained from the CM SAF)

Option 1 **-** Please follow this instruction if you do not have administrator rights on the computer.

- Put cdo.exe and pthreadGC2.dll into an arbitrary directory
- Create a new environment variable 'PATH' like that:
  a) Rightclick on 'My Computer',
  b) Choose 'Properties',
  c) Choose 'Advanced',
  d) Choose 'Environment Variables',
  e) Look for the User variable called 'PATH'. If it exists, edit it. Otherwise create a new variable 'PATH',
  f) Put the full directory name (where cdo.exe and pthreadGC2.dll have been put) into the PATH variable,
  g) Choose 'Ok' for all dialogs.

Option 2 **–** Please follow this instruction if you have administrator rights on the computer.

- Put cdo.exe and pthreadGC2.dll in C:\windows\system32. This directory should be in the PATH variable and CDO should work out of the box.

To check whether the installation of CDO has been successful please type 'cdo' at the command line prompt. You should get a list of available operators and the version number of CDO on the display and NOT a message saying 'command not found' (or anything comparable). In the latter case, please check the installation of CDO on your local system.

You might also want to get acquainted with the CDO Reference Card and the User's Guide.

4.2. R Installation Tips for Windows (Obtained from the CM SAF)

For the installation of *R*, please follow the instruction on the R-homepage.
For users of the Windows operating systems it is recommended to use the Notepad++ editor in combination with NppToR to develop and edit *R*-scripts under Windows. See the R Journal (Volume 2/1, June 2010, page 62) for a brief article on these useful tools: *Introducing NppToR: R Interaction for Notepad++*.

Here are some useful web pages regarding *R*:
http://cran.r-project.org/manuals.html
http://cran.r-project.org/faqs.html
http://cran.r-project.org/doc/contrib/Short-refcard.pdf

Additional packages required for R

The basic version of the software tool R already provides a wide range of functionalities. However, the strength of the open source software R is the opportunity for everybody to provide add-on packages that serve a special purpose. Most of these packages are distributed via the Comprehensive R Archive Network (CRAN), which provides identical mirrors all over the globe (see the list of CRAN mirrors). There are currently nearly 4000 packages available to extend the basic functionality of *R*. Each package contains a documentation that describes the additional commands available when the package is loaded. The installation of additional packages is described in the R Installation and Administration Guide. Under Windows, additional packages can be installed using the 'Packages'-option from the toolbar.

Here is the list of required add-on packages:

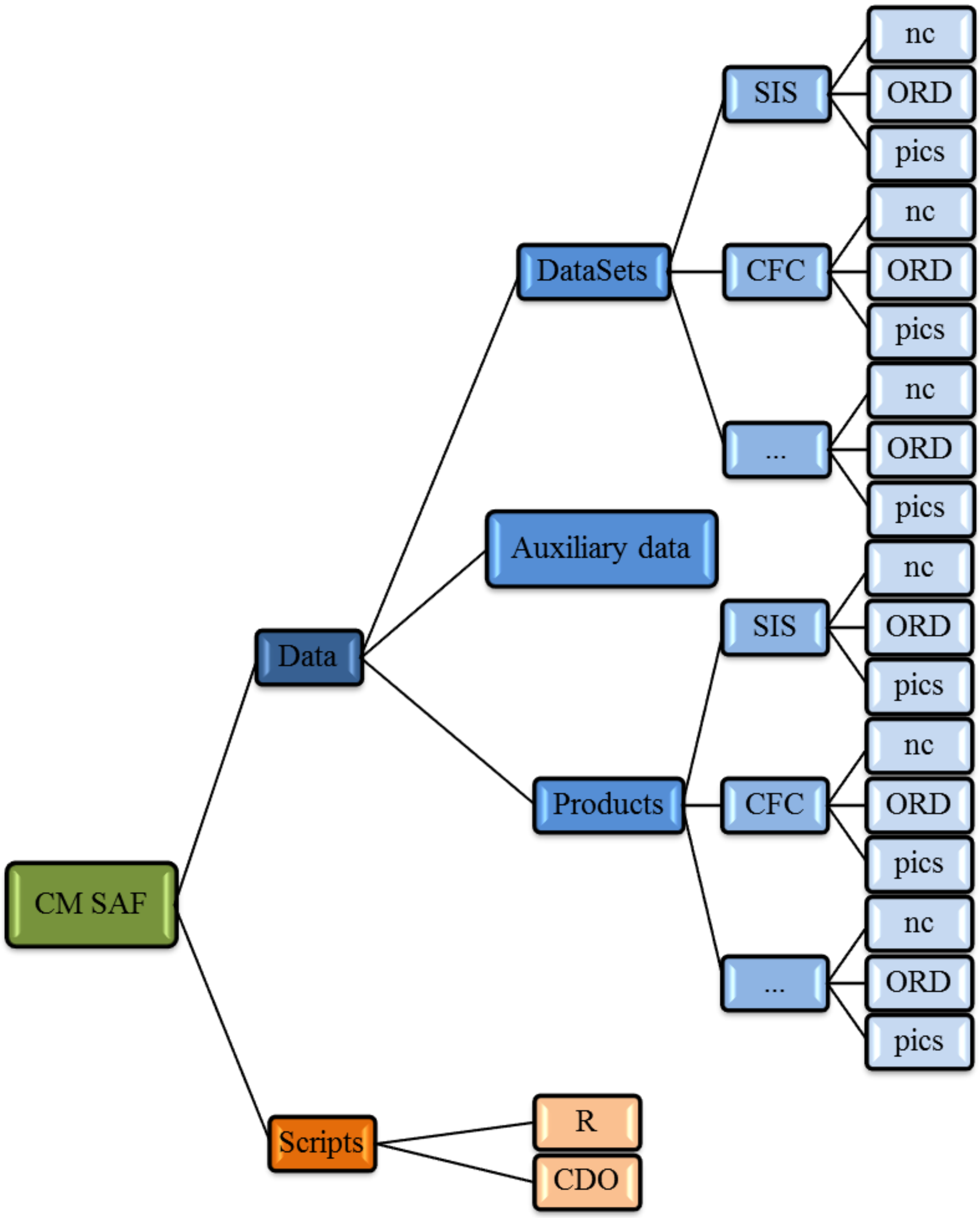
- ncdf: Interface to unidata netCDF data files;
- RNetCDF: R interface to NetCDF datasets;
- fields: Tool for spatial data;
- maptools: Tools for reading and handling spatial objects;
- RColorBrewer: ColorBrewer palettes;
- colorRamps: Builds colour tables;
- Hmisc: Contains many functions useful for data analysis, high-level graphics, utility operations, etc.
- solaR: Calculation methods of solar radiation and performance of photovoltaic systems from daily and intra-daily irradiation data sources;
- zoo: Infrastructure for regular and irregular time series;
- spam: Set of functions for sparse matrix algebra;
- sp: Provides classes and methods for spatial data;
- maps: Display of maps;
- lattice: A powerful high-level data visualization system, with an emphasis on multivariate data;
- latticeExtra: Extra graphical utilities based on lattice;
- hexbin: Binning and plotting functions for hexagonal bins.

5. Instructions for Using the Software Scripts

This chapter gives an introduction and instructions for manipulating with satellite data by using the suggested software tools (CDO and R) in Windows environment.

5.1. Setting up Working Directories

In order to be able to work with the provided scripts, the user will have to set up a definite order of directories (see the graph below).



The data should be organized so that the main folder *'CM SAF'* contains two subfolders – the *'Data'* subfolder and the *'Scripts'* subfolder[3]. The *'Scripts'* folder will contain two subfolders with data scripts for R and CDO. The *'Data'* folder will contain all the necessary datasets, while distinguishing between climate data sets (folder *'DataSets'*), operational climate products (folder *'Products'*) and additional data necessary for manipulating with the satellite data (folder *'Auxiliary Data'*). The folders *'DataSets'* and *'Products'* will contain the satellite data – the downloaded data should be placed in the *'ORD'* subfolder, then extracted to the *'nc'* subfolder, but the *'pics'* folder will be used for storing the newly generated images.

For the development of climate atlas, only the climate data sets will be used, but the operational products are useful for the everyday work with climate data.

5.2. After Downloading the Data

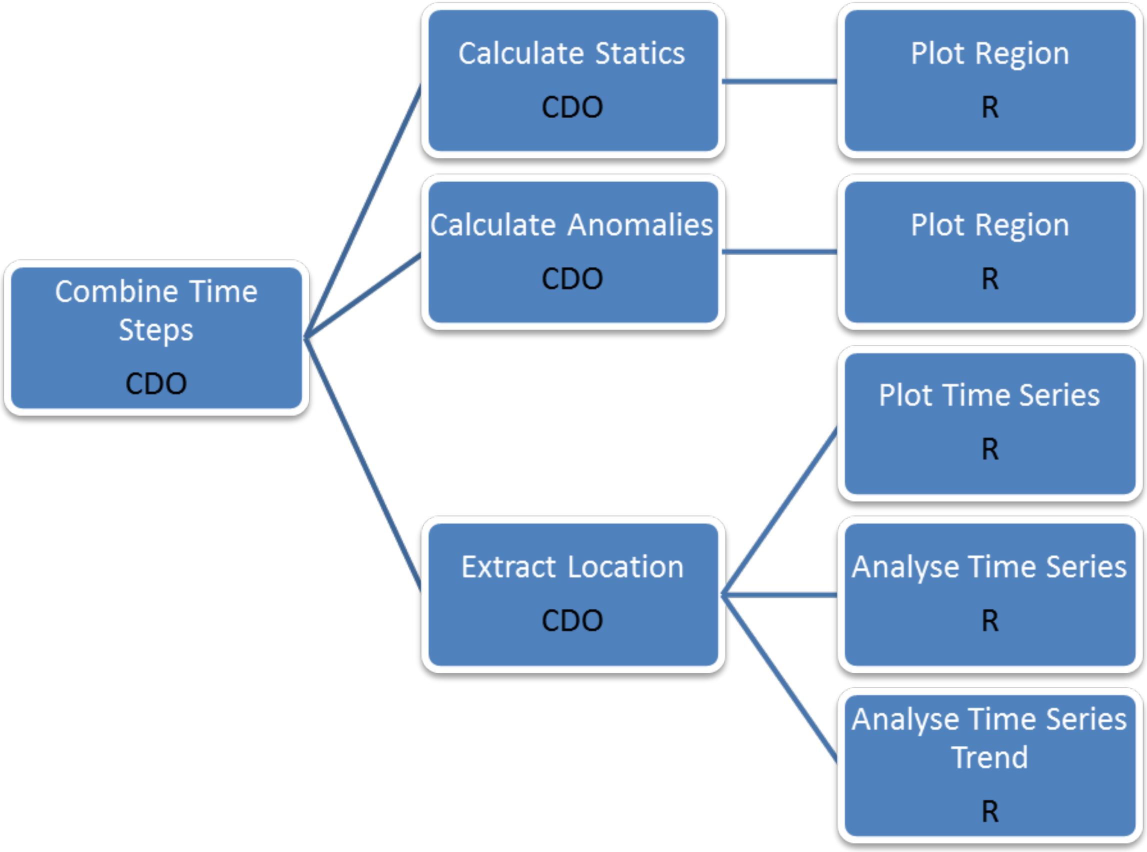
Once your order has arrived and you have downloaded the data to your computer in a .tar file, place the file in the *'ORD'* directory under the corresponding climate *'Products'* or *'DataSets'* directory (for example, the climate dataset data on SIS should be put in the folder ... /CM_SAF/Data/Datasets/SIS/ORD). Then unzip the file once in the same directory – it will give you a separate .nc.gz file for every time step of your data. Select all of the files (all of the time steps) and unzip them once again, but this time put the unzipped files in the *'nc'* directory. It is important to have the original .nc files in the *'nc'* directory, because this is the place where CDO scripts will look for the data.

5.3. The Order of Applying the Scripts

The next and really important step is understanding what you want to do with the data. For the development of the climate atlas the calculation of basic statistics and anomalies was chosen, but it is possible also to perform a deeper analysis by using these instructions in a slightly modified way. However the instructions provided here cover just the basic issues of manipulating with climate data.

The methodology is built up in a way, that there is a definite order in the application of the software scripts – in general at first using CDO for calculations, and then plotting the result with R. The general order of using the software scripts is presented in the graph below.

[3] The folder structure is important for the provided scripts to work.



Example. The order of scripts used for developing the climatology of cloudiness (CFC):

1. CDO script *Combine Time Steps* (combines all downloaded .nc files into one .nc file)
2. Apply CDO Operators to the file containing the combined time steps (in this case – monthly mean values) by using the *Calculate Statistics* script:
   - *timmean, timmin, timmax* – to obtain the maximum, minimum and mean values for every pixel over the whole period;
   - *yearmean*[4]- to obtain the annual mean (mean over the calendar year) values for every pixel for each year of the period. Apply the *timmin, timmean, timmax* and *timstd* operators to the output file of *yearmean* to obtain the multi-year annual minimum, maximum and mean values as well as the standard deviations.
   - *seasmean* - to obtain the seasonal mean (mean over the calendar season – JJA, SON, DJF, MAM) values for every pixel for each season over the period. Apply the *yseasmin, yseasmean, yseasmax* and *yseasstd* operators to the output file of *seasmean* or to the file containing the combined time steps to obtain the multi-year seasonal minimum, maximum and mean values as well as the standard deviations.
   - *ymonmean, ymonmin, ymonmax, ymonstd* – to obtain the multi-year monthly minimum, maximum and mean values as well as the standard deviations for every pixel for each month.

[4] There is a significant difference between using the *mean* and *avg* functions, as the *mean* function will calculate the value including missing values, but the *avg* function will only do the calculations in those pixels where all data steps contain data. In most cases the *mean* function is used, however it is advised to apply the *avg* function to the parameters that have inter-annual changes in the data coverage (like for example IWP)

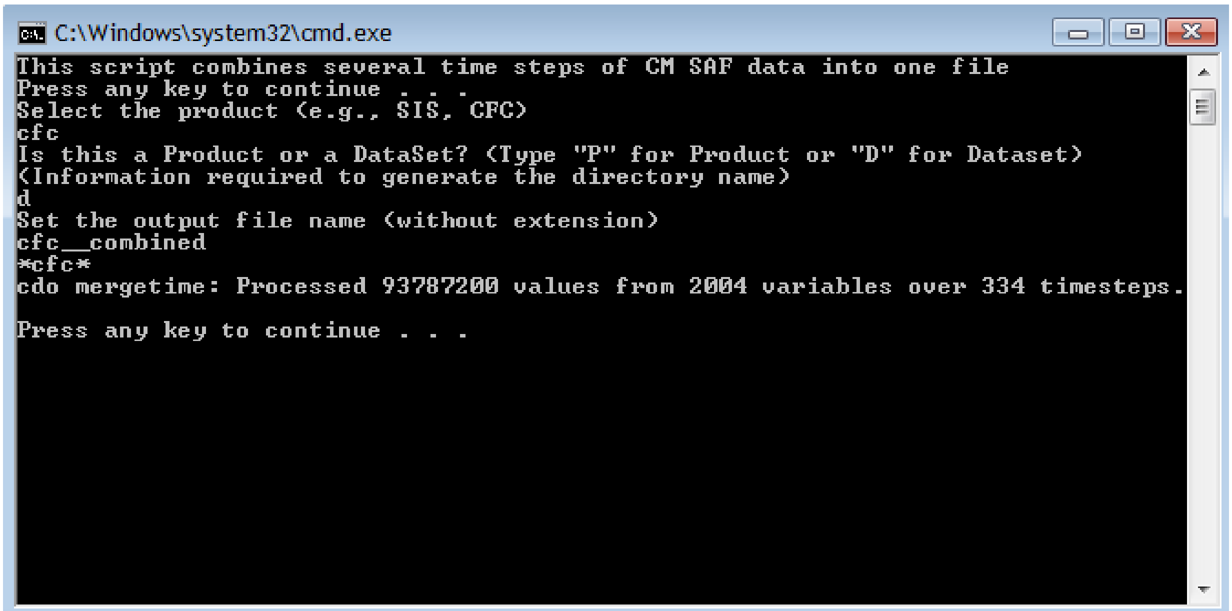
3. Apply the CDO script *Calculate Anomaly* to the output files containing the combined monthly time steps and the *seasmean* and *yearmean* operators.
4. Apply the R script *Plot Region* (or *Plot Region Multi*) to each output .nc file in order to obtain result images (.png files) of the statistical manipulations. The images will be put in the '*pics*' folder.

5.4. Software Scripts Used for Creating the Climate Atlas

5.4.1. CDO Script 'Combine Time Steps'

The script is used for combining the downloaded .nc files into one .nc file that contains several time steps. The output of this script will be the base of further statistical manipulations with the data.

The script is interactive (i.e. requires input from the user) and can be run by double-clicking on the corresponding .bat file. The script will open in a command prompt window and the user will be asked to add information on the dataset and set the name for the output file. CDO is not case-sensitive, so you can use both capital and small letters. Transition from one step to the other is done by pressing '*Enter*'. It will take some time for the script to work, but it will print out a completion message at the end of the process. See an example of a script window for the climate dataset of CFC in the image below.



The structure of the script can be seen below:

```
@echo off
SetLocal EnableDelayedExpansion

echo This script combines several time steps of CM SAF data into one file
PAUSE

REM Select the product here (e.g., "SIS", "CFC")
echo Select the product (e.g.., SIS, CFC)
set /p product=

set type=DEFAULT
REM Is this in Products or DataSets folder?
echo Is this a Product or a DataSet? (Type "P" for Product or "D" for Dataset)
echo (Information required to generate the directory name)
```

```
set /p typein=
set typein=%typein: =%
if /I %typein% EQU P (set type=Products)
if /I %typein% EQU D (set type=Datasets)
if /I %type% EQU DEFAULT (
echo Error: please type "P" or "D"
PAUSE
REM exit
)

REM Set the output file name
set outfile=OUTFILE
echo Set the output file name (without extension)
set /p outfile=

REM ----------------------------------------------------------------------

set Dataset=*%product%*
REM Remove all blanks
set product=%product: =%
set Dataset=%Dataset: =%
set type=%type: =%
set datset=%datset: =%

set datadir=..\..\Data\%type%\%product%\nc\

cd %datadir%

REM Select the input file name
echo %Dataset%
set infile=%Dataset%

cdo -b f32 mergetime %infile%.nc ..\%outfile%.nc

endlocal
PAUSE
```

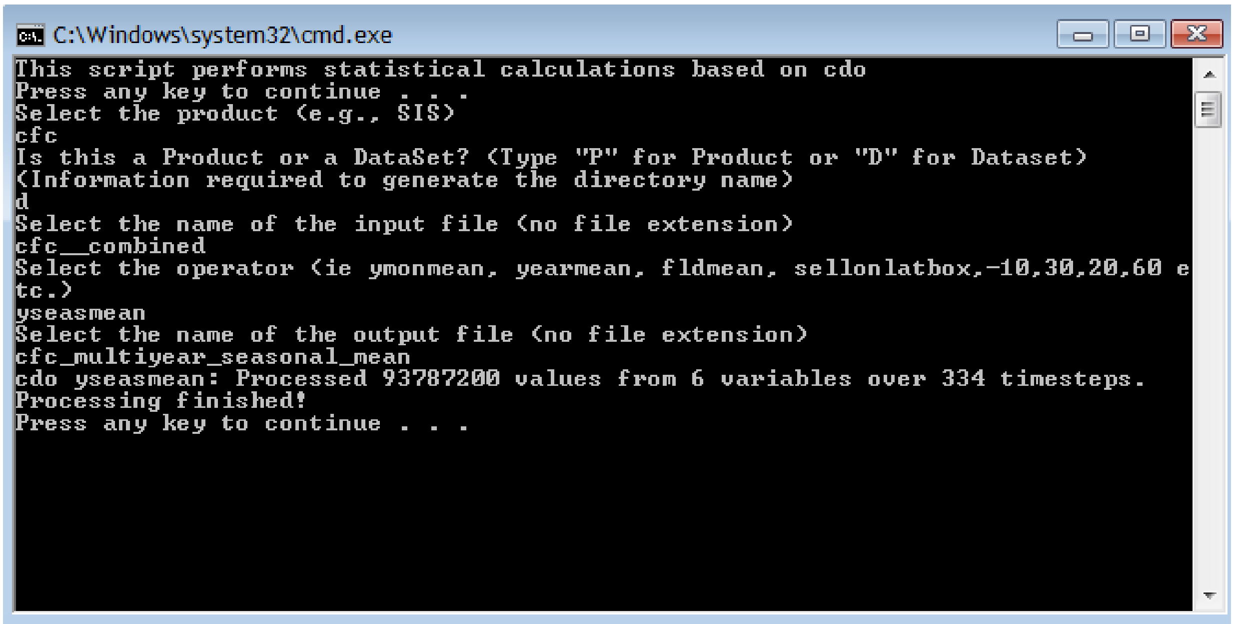
The output file will be written to the main directory of the particular Dataset/Product – in this case it would be ... /CM_SAF/Data/Datasets/CFC

5.4.2. CDO Script 'Calculate Statistics'

The script is used for performing statistical calculations (such as calculating the mean, minimum, maximum, standard deviation etc.) with the data. The file containing the combined time steps of the data is the input for this script, but the output of this script will contain the information on a statistical variable over a certain time step.

Similarly to the one presented before, this script is interactive. See an example of a script window for the calculation of the multiyear seasonal mean values of cloud cover (climate dataset of CFC) in the image below.

In comparison to the previous script, this one requires the input of a statistical operator. The available operators can be found in the CDO Reference Card.



The structure of the script can be seen below:

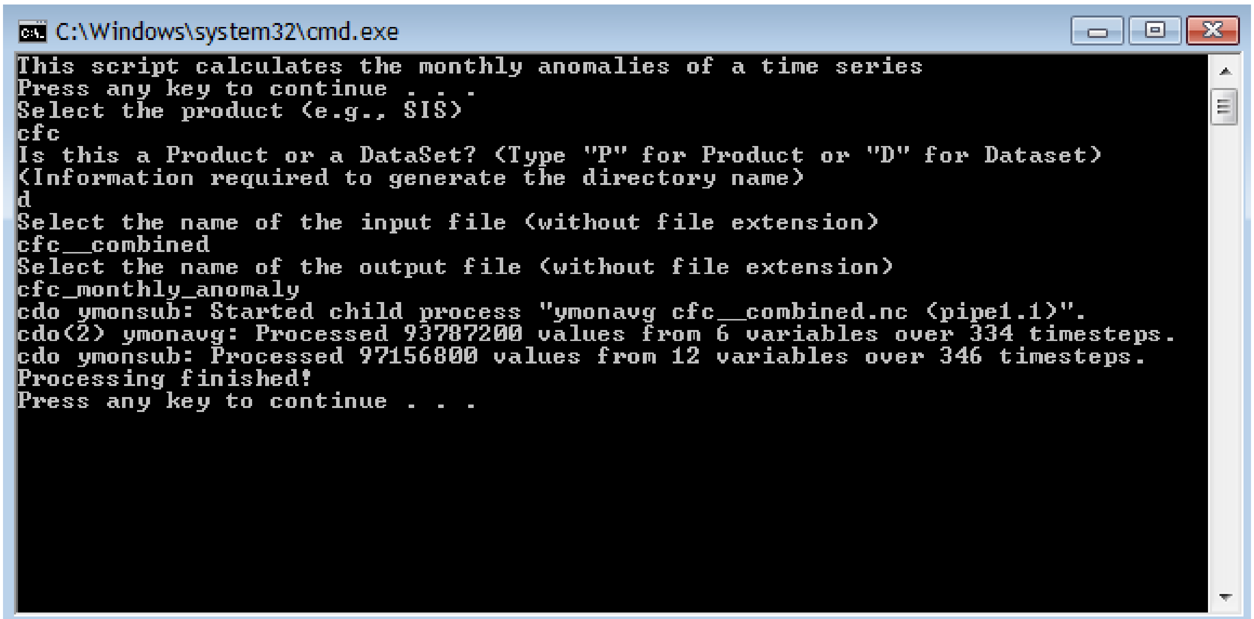
```
@echo off
REM This script performs some statistical calculations

echo This script performs statistical calculations based on cdo

PAUSE

REM Select the product here
echo Select the product (e.g., SIS)
set /p product=

set type=DEFAULT
REM Is this in Products or DataSets?
echo Is this a Product or a DataSet? (Type "P" for Product or "D" for Dataset)
echo (Information required to generate the directory name)
set /p typein=
set typein=%typein: =%
if /I %typein% EQU P (set type=Products)
if /I %typein% EQU D (set type=Datasets)
if /I %type% EQU DEFAULT (
echo Error: please type "P" or "D"
pause
exit
)

REM Select the input file
echo Select the name of the input file (no file extension)
set /p Datafile=

REM Select the Operator for statistical computing (ie ymonmean, ymonmax etc.)
REM timmean: temporal averaging
REM ymonmean: Multiyear-monthly average
echo Select the operator (ie ymonmean, yearmean, fldmean, sellonlatbox,-10,30,20,60 etc.)
set /p Operator=

REM Select output filename
echo Select the name of the output file (no file extension)
set /p Outfile=

REM Remove blanks
set product=%product: =%
set Datafile=%Datafile: =%
set type=%type: =%

REM Set the working directories
set datadir=..\..\Data\%type%\%product%\
```

```
cd %datadir%

cdo %Operator% %Datafile%.nc %Outfile%.nc

echo Processing finished!

PAUSE
```

5.4.3. CDO Script ‘Calculate Anomaly’

The script is used for calculating the anomalies, for example, to say how much did February 2003 differ from the long-term February mean. The script calculates the anomaly of each time step included in the input file, therefore if the input file contains information on a monthly scale, then monthly anomalies will be calculated, but for the calculation of the seasonal anomalies, an input file containing the seasonal mean values (calculated by applying the *seasmean* operator) should be provided. The time period covered in the input file is used as the reference or normal period for the anomalies.

The script is interactive and runs similarly to the previous two, but this time two operations take place at the same time – at first the script calculates the multi-year average value (child process), and then the anomalies around this value. See an example of a script window for the calculation of the monthly anomalies in cloud cover (climate dataset of CFC) in the image below.



The structure of the script can be seen below:

```
@echo off

echo This script calculates the monthly anomalies of a time series
PAUSE

REM Select the product here
echo Select the product (e.g., SIS)
set /p product=

set type=DEFAULT
REM Is this in Products or DataSets?
echo Is this a Product or a DataSet? (Type "P" for Product or "D" for Dataset)
echo (Information required to generate the directory name)
set /p typein=
set typein=%typein: =%
```

```
if /I %typein% EQU P (set type=Products)
if /I %typein% EQU D (set type=Datasets)
if /I %type% EQU DEFAULT (
echo Error: please type "P" or "D"
pause
exit
)

REM Select the input file
echo Select the name of the input file (without file extension)
set /p Datafile=

REM Select output filename
echo Select the name of the output file (without file extension)
set /p Outfile=

REM Remove blanks
set product=%product: =%
set Datafile=%Datafile: =%
set type=%type: =%

REM Set the working directories
set datadir=..\..\Data\%type%\%product%\
cd %datadir%

cdo -r -ymonsub %Datafile%.nc -ymonavg %Datafile%.nc %Outfile%.nc

echo Processing finished!

PAUSE
```

5.4.4. R Scripts 'Plot Region' and 'Plot Region Multi'

As mentioned before, R is used for plotting the results of the analysis and these particular scripts are used for visualising data over a predefined area. The *Plot Region* script can be used when plotting single images, however the *Plot Region Multi* script is useful when the output file contains several time steps to be plotted (such as for example anomalies).
The script can be edited in the text editor (Notepad ++), and can be either copied in the R console or transferred to it directly by pressing Ctrl+F8 (only works when NppToR is installed).
The structures of the scripts are presented below. There are several ways and approaches to R programming language, and therefore both scripts are quite different in the way they have been built up – the *Plot Region* script is a modified version of the scripts provided by the CM SAF, but the *Plot Region Multi* script was created from a scratch to show you a different way of working with R.
Basic things to keep in mind while working with R scripts are:

1. R is case sensitive.
2. The # sign in the beginning of a line makes it a comment and so inactive – R recognizes it as a comment and does not read it. Therefore use # signs to write comments or to activate/inactivate different parts of the script.
3. All errors while running the script will appear in blue in the R console window.

The structure of script *Plot Region:*

```
# This script displays a map of the selected product
# You can either specify a certain year / month from a data file with several time steps
# or plot one 2D field

# name of the input netcdf-file
filename <- "input_filename.nc"
# Name of the variable in the netcdf-file (note that some .nc files might contain several
variables)
varname <- "SIS"

# For Cloud Type (CTY) the following varnames are allowed:
# Data1 = Low Clouds, Data2 = Middle level clouds, Data3 = High opaque clouds
```

```
# Data4 = High Semitransparent clouds, Data5 = Fractional Clouds

# For HLW and HSH select the variable and the vertical level
# HLW: level: 1-5, varname: LPWm, RHWm, Tm
# HSH: level: 1-6, varname: Qm, Tm
level <- 6

# The following information is required to generate the name of the directory
# Select the name of the Products/DataSets as seen from the corresponding folder name
product <- "SIS"
# type = Products or DataSets as seen from the corresponding folder name
type <- "DataSets"

# If you want to create a png-file to be written in the ‘pics’ folder, you need to specify the filename. Otherwise the output will open in a new R window.
picout <- TRUE    # TRUE or FALSE
picfile <- "output_filename.png" # The begining will be the date

# In case you want to add something to the TITLE of the plot
add2title <- "CM SAF,MY TITLE"

# if your file has MULTIPLE times, then select the time here
# Make sure that the selected time is available in the data file,
year <- 2004
month <- 1

# here you may define your OWN DATE in the title (eg. in case of seasonal data)
# or if only one timestep is available in the data
own_date <- FALSE
owndate <- "January"

# if you want to choose the TIMESTEP instead of year and month,
# then set select_timestep="TRUE"
select_timestep <- FALSE
tstep <- 1

# select the plot region in degrees (set to NA for plotting full domain of data)
lonmin <- -20
lonmax <- 20
latmin <- 30
latmax <- 60

# Set the size of width or height of the output window (in # of pixels)
windowmax <- 1800

# Select to plot an anomaly in order to use of appropriate colour scale
plot.ano <- TRUE

# Set the breaks of the colour bar manually
# Suggested for plotting the anomalies, but can also be used for manually setting breaks for other output files
set.col.breaks <- TRUE
brk.set <- c(-10,-9,-8,-7,-6,-5,-4,-3,-2,-1,-0.5,0.5,1,2,3,4,5,6,7,8,9,10) # suggested for anomalies. Change values according to your needs
#brk.set <- c(0,10,20,30,40,50,100,150,200,250,300,350) # setting custom breaks manually
#brk.set <- seq(180,250,5) # setting a sequence from 180 to 250 with a step of 5 units

# select the range of the colour bar
# select -99 for flexible range
colmin0 <- -99
colmax0 <- 380
# Set the number of colours
ncol <- 19

# Set to true if higher resolution additional data is required
plotHighRes <- TRUE
plotVeryHighRes <- FALSE
# Switches to determine additional plot layers
plotCoastline <- TRUE
plotCountries <- TRUE
plotRivers <- FALSE
plotLakes <- FALSE
```

```
# Thickness of the additional lines
contour.thick <- 2.

# Switches to control the display of cities
plotCities <- FALSE
# Set to true if more cities should be displayed
plotCitiesHighRes <- FALSE
plotCitiesVeryHighRes <- FALSE
# symbol
pch.cities <- 2
# size of symbol
cex.cities <- 1.
# name next to the symbol?
label.cities <- TRUE
# size of the label
cex.label.cities <- 0.5
# lat offset of label
dlat <- 0.25

# Set the main data directory
#dir <- "YOURDATADIRECTORY"
dir <- ".../CMSAF/Data/"

#-----------------------------------------------------------------
# NO CHANGES REQUIRED BEYOND THIS POINT *although some useful things like changing the colour
scale can be done in the lower part of this script
#-----------------------------------------------------------------

datadir <- paste(dir,type,product,"",sep="/")
picdir <- paste(datadir,"pics",sep="")
file <- paste(datadir,filename,sep="/")

# make sure that you have the ncdf-, the fields- and the maps-package installed!
library(ncdf)
library(RNetCDF)
library(spam)
library(sp)
library(maps)
library(Hmisc)
library(fields)
library(maptools)
library(RColorBrewer)
library(colorRamps)
library(lattice)
library(latticeExtra)
library(hexbin)
library(zoo)

# below auxiliary data files used for plotting are listed
if (plotCoastline) {
aux.file <- "110m_coastline.shp"
if (plotHighRes) aux.file <- "50m_coastline.shp"
if (plotVeryHighRes) aux.file <- "10m_coastline.shp"
coastline.file <- paste(dir,"AuxiliaryData/coastline/",aux.file,sep="")
coastline <- readShapeSpatial(coastline.file)
coastline <- as(coastline,"SpatialLines")
}

if (plotCountries) {
aux.file <- "ne_110m_admin_0_countries.shp"
if (plotHighRes) aux.file <- "ne_50m_admin_0_countries.shp"
if (plotVeryHighRes) aux.file <- "ne_10m_admin_0_countries.shp"
countries.file <- paste(dir,"AuxiliaryData/countries/",aux.file,sep="")
countries <- readShapeSpatial(countries.file)
countries <- as(countries,"SpatialLines")
}

if (plotRivers) {
aux.file <- "110m-rivers-lake-centerlines.shp"
if (plotHighRes) aux.file <- "50m-rivers-lake-centerlines.shp"
if (plotVeryHighRes) aux.file <- "ne_10m_rivers_lake_centerlines.shp"
rivers.file <- paste(dir,"AuxiliaryData/rivers/",aux.file,sep="")
```

```
rivers <- readShapeSpatial(rivers.file)
rivers <- as(rivers,"SpatialLines")
}

if (plotLakes) {
aux.file <- "110m_lakes.shp"
if (plotHighRes) aux.file <- "50m-lakes.shp"
if (plotVeryHighRes) aux.file <- "ne_10m_lakes.shp"
lakes.file <- paste(dir,"AuxiliaryData/lakes/",aux.file,sep="")
lakes <- readShapeSpatial(lakes.file)
lakes <- as(lakes,"SpatialLines")
}

if (plotCities) {
aux.file <- "ne_110m_populated_places.shp"
if (plotCitiesHighRes) aux.file <- "ne_50m_populated_places.shp"
if (plotCitiesVeryHighRes) aux.file <- "ne_10m_populated_places.shp"
cities.file <- paste(dir,"AuxiliaryData/populated-places/",aux.file,sep="")
cities <- readShapeSpatial(cities.file)
lon.cities <- cities@data$LONGITUDE
lat.cities <- cities@data$LATITUDE
names.cities <- cities@data$NAME
}

# Open the netcdf-file
nc <- open.ncdf(file)

# Read the available variable in the file
nvars <- nc$nvars
varnames <- vector(mode="character",length=nvars)
for (n in 1:nvars) {
       varnames[n] <- nc$var[[n]]$name
}
if (varname %nin% varnames) {
print("Error, variable not in file!")
print("The following variables are available for selection:")
print(varnames)
stop("Please select one of the above variable! (varname)")
}

# Retrieve the unit, the missing_data-value, and the title of the data
unit <- att.get.ncdf(nc, varname,"units")$value
missval <- att.get.ncdf(nc,varname,"_FillValue")$value

if (att.get.ncdf(nc,varname,"title")$hasatt==TRUE) {
       name <- att.get.ncdf(nc,varname,"title")$value
       } else {
        name <- varname
       }

# The offset and the scalefactor is required because the Fill_Value attribute is not applied by
the ncdf-package
# The offset and scalefactor is automatically applied to all data
offset.value <- 0.
scale.factor <- 1.
if (att.get.ncdf(nc,varname,"add_offset")$hasatt==TRUE) {
       offset.value <- att.get.ncdf(nc,varname,"add_offset")$value }
if (att.get.ncdf(nc,varname,"scale_factor")$hasatt==TRUE) {
       scale.factor <- att.get.ncdf(nc,varname,"scale_factor")$value }

#---------------------------------------------------#

# determine the grid
londim <- nc$dim[["lon"]]
lon <- londim$vals
nx <- londim$len
latdim <- nc$dim[["lat"]]
lat <- latdim$vals
ny <- latdim$len
if (product == "HLW" || product =="HSH") {
       levdim <- nc$dim[["lev"]]
       level.out <- levdim$vals[level]
```

```
       }

# Set the plot ranges
if (is.na(lonmax) || is.na(latmax) || is.na(lonmin) || is.na(latmin)) {
       lonmin=lon[1]
       lonmax=lon[nx]
       latmin=lat[1]
       latmax=lat[ny]
       lonplot=c(lonmin,lonmax)
       latplot=c(latmin,latmax)} else {
       lonplot=c(lonmin,lonmax)
    latplot=c(latmin,latmax)}


#---------------------------------------------------#

# retrieve the time variable
timedim <- nc$dim[["time"]]
nt <- timedim$len
time.unit <- timedim$units
time <- timedim$vals

# Create a R-date-object
date.time <- as.Date(utcal.nc(time.unit,time,type="s")) # if the date is set as days since 1970-
01-01 00:00:00
#date.time <- as.Date(as.character(time),"%Y%m%d") # if the date is set in another format

itime <- 1
if (select_timestep != TRUE)
{
if (nt > 1) {
# determine the index of the selected time step
  timeout <- as.Date(paste(year,"-",month,"-1",sep=""))
  itime <- which(date.time==timeout)

# check if the time is included in the file
  if (length(itime) == 0) stop("Selected time not included in the file!")
  }
}

# if timestep is used instead of "year" and "month" ...
if (select_timestep== TRUE) {itime<- tstep}

# Read in the data
       if (product == "HLW" || product =="HSH") {
           field <- get.var.ncdf(nc, varname,start=c(1,1,level,itime),count=c(nx,ny,1,1))
              na.ind <- which(field < 0.)
              field[na.ind] <- NA
              } else {
              field <- get.var.ncdf(nc, varname,start=c(1,1,itime),count=c(nx,ny,1))
       }
# Set the missing data to NA
# Since the data has been corrected for the scalefactor and the offset,
# this has also to be considered for the FillValue
  na.ind <- which(field==(missval*scale.factor + offset.value))
  field[na.ind] <- NA

# Close the file
  close.ncdf(nc)

# Write formulas to change the units plotted
# field=(field*24)/1000

# FORMAT THE TIME step for plotting
if (own_date != TRUE)
{
if (nt > 1) {
  zdate <- paste(format(date.time[itime],"%Y%m"),sep=" ")
  if (nt == 12) zdate <- paste(format(date.time[itime],"%m"),sep=" ")
       } else zdate <- ""
}
if (own_date == TRUE) {zdate <- owndate}
```

```
# Set the variable to make the plot
  z <- field

# Invert the latitude dimension if necessary
  if (lat[ny] < lat[1]) {
    sort.out <- sort(lat,index.return=TRUE)
    lat <- sort.out$x
    z <- z[,sort.out$ix]
  }

# calulate the mean, min, max for the selected region only
  if (!is.na(lonmax) || !is.na(latmax) || !is.na(lonmin) || !is.na(latmin))
  {lon.reg <- which(lon >= lonmin & lon <= lonmax)
  lat.reg <- which(lat >= latmin & lat <= latmax)
  z.reg <- z[lon.reg,lat.reg]} else {z.reg <- z}

# print out the mean value of the field
  print(paste("Mean: ",mean(z.reg,na.rm=TRUE),sep=''))
  print(paste("Max: ",max(z.reg,na.rm=TRUE),sep=''))
  print(paste("Min: ",min(z.reg,na.rm=TRUE),sep=''))

# Set the title of the plot
title <- paste(name," (",unit,"), ",sep="")
       if (product == "HLW" || product == "HSH") {
       title <- paste(varname," (",unit,"), level: ",level.out,", ",sep="")
  }

#-----------------------------------------------------------
## Pic format is adjusted for the chosen plot region

lelo<-lonmax-lonmin
lela<-latmax-latmin
if (lelo >= lela)
{ width <- windowmax
  height <- round(windowmax* lela/lelo,0) }
if (lelo < lela)
{ width <- round(windowmax* lelo/lela,0)
  height <- windowmax }

# Open a png-file
time_picfile=paste(zdate,picfile,sep="_")
if (picout == TRUE) png(file=paste(picdir,time_picfile,sep="/"),height=height,width=width)

# set the number of rows and columns of the plot
par(mfrow = c(1,1))

  colmin <- colmin0
  colmax <- colmax0

  if ((as.integer(colmin) == -99) && (as.integer(colmax) == -99)) {
             colmin <- min(z.reg,na.rm=TRUE)
             colmax <- max(z.reg,na.rm=TRUE)
             }

  if (set.col.breaks) {
             brk <- brk.set
             } else {
             brk <- seq(colmin,colmax,length.out=ncol+1)
             }

# Set the colors and the color bar for the Difference plots
col.breaks <- brk
ncolor <- length(col.breaks)
at.ticks <- seq(1,ncolor)
names.ticks <- col.breaks[at.ticks]
zlim <- c(1,ncolor)

colors <- matlab.like(ncolor-1) # for the classical colour scale going from blue to red
#colors <- brewer.pal(ncolor-1,"Greys") # for one of the ColorBrewer palettes:
http://colorbrewer2.org/
```

```
#colors<-colorRampPalette(c("yellow", "red"))( 20 ) # for colour interpolation according to the colorRamp package
if (plot.ano) colors[as.integer(ncolor/2)] <- rgb(1,1,1)

# Generate the field to be plotted
field.plot <- matrix(ncol=ny,nrow=nx)
for (l in seq(1,ncolor-1) ) {
  idx <- which(z >= col.breaks[l] &
             z < col.breaks[l+1],arr.ind=TRUE)
  field.plot[idx] <- l + 0.1
}

# set some plot parameters (mainly plot margins)
par(mgp=c(3,0.5,0),mar=c(4,4,4,4),oma=c(3,3,3,3))

# make the plot including color bar
image.plot(lon,lat,field.plot,xlab="Longitude, degrees E",ylab="Latitude, degrees N",
cex.axis=1.5, cex.lab=1.5,
           main=paste(title,add2title,zdate,sep=""),
           legend.mar = 6, xlim=lonplot,ylim=latplot,zlim=zlim,
           nlevel=ncolor-1,col=colors,
                axis.args=list(at=at.ticks,labels=round(names.ticks,1), cex.axis=2.3))

# add rivers
if (plotRivers) {
plot(rivers, add=TRUE, col="blue", lwd=contour.thick)
}

# add lakes
if (plotLakes) {
plot(lakes, add=TRUE, col="blue", lwd=contour.thick)
}

# add coastline
if (plotCoastline) {
plot(coastline, add=TRUE, lwd=contour.thick)
}

# add country borders
if (plotCountries) {
plot(countries, add=TRUE, lwd=contour.thick)
}

# add cities
if (plotCities) {
points(lon.cities,lat.cities,pch=pch.cities,cex=cex.cities)
if (label.cities) text(lon.cities,lat.cities+dlat,names.cities,cex=cex.label.cities)
}

# close the jpg-file
if (picout == TRUE)
{
dev.off()
print("Plot created!")
}
```

The structure of script *Plot Region Multi*:

```
# This script displays a map of the selected product
# You can either specify a certain year / month from a data file with several time steps
# or plot one 2D field
# The script slightly differs from the original style of the CM SAF scripts

# name of the input netcdf-file
filename <- "input_filename.nc"
# Name of the variable in the netcdf-file (note that some .nc files might contain several variables)
varname <- "cfc"

# For Cloud Type (CTY) the following varnames are allowed:
# Data1 = Low Clouds, Data2 = Middle level clouds, Data3 = High opaque clouds
# Data4 = High Semitransparent clouds, Data5 = Fractional Clouds
```

```
# For HLW and HSH select the variable and the vertical level
# HLW: level: 1-5, varname: LPWm, RHWm, Tm
# HSH: level: 1-6, varname: Qm, Tm
level <- 6

# The following information is required to generate the name of the directory
# Select the name of the Products/DataSets as seen from the corresponding folder name
product <- "CFC"
# type = Products or DataSets as seen from the corresponding folder name
type <- "DataSets"

# If you want to create a png-file to be written in the 'pics' folder, you need to specify the
filename. Otherwise the output will open in a new R window.
picout <- TRUE    # TRUE or FALSE
picfile <- "output_filename.png" # The begining will be the date

# In case you want to add something to the TITLE of the plot
add2title <- "CM SAF,MY TITLE"

# here you may define your OWN DATE in the title (eg. in case of seasonal data)
# or if only one timestep is available in the data
own_date <- FALSE
owndate <- "January"

# select the plot region in degrees (set to NA for plotting full domain of data)
lonmin <- -20
lonmax <- 20
latmin <- 30
latmax <- 60

# Set the size of width or height of the output window (in # of pixels)
windowmax <- 1800

# Select to plot an anomaly in order to use of appropriate colour scale
plot.ano <- FALSE

# Set the breaks of the colour bar manually
# Suggested for plotting the anomalies, but can also be used for manually setting breaks for
other output files
set.col.breaks <- FALSE
brk.set <- c(-10,-9,-8,-7,-6,-5,-4,-3,-2,-1,-0.5,0.5,1,2,3,4,5,6,7,8,9,10) # suggested for
anomalies. Change values according to your needs
#brk.set <- c(0,10,20,30,40,50,100,150,200,250,300,350) # setting custom breaks manually
#brk.set <- seq(180,250,5) # setting a sequence from 180 to 250 with a step of 5 units

# select the range of the colour bar
# select -99 for flexible range
colmin0 <- 0
colmax0 <- 15
# Set the number of colours
ncol <- 15

# Set to true if higher resolution additional data is required
plotHighRes <- TRUE
plotVeryHighRes <- FALSE
# Switches to determine additional plot layers
plotCoastline <- TRUE
plotCountries <- TRUE
plotRivers <- FALSE
plotLakes <- FALSE
# Thickness of the additional lines
contour.thick <- 2.

# Switches to control the display of cities
plotCities <- FALSE
# Set to true if more cities should be displayed
plotCitiesHighRes <- FALSE
plotCitiesVeryHighRes <- FALSE
# symbol
pch.cities <- 2
# size of symbol
```

```r
cex.cities <- 1.
# name next to the symbol?
label.cities <- TRUE
# size of the label
cex.label.cities <- 0.5
# lat offset of label
dlat <- 0.25

# Set the main data directory
#dir <- "YOURDATADIRECTORY"
dir <- ".../CMSAF/Data/"

#-----------------------------------------------------------------
# NO CHANGES REQUIRED BEYOND THIS POINT *although some useful things like changing the colour scale can be done in the lower part of this script
#-----------------------------------------------------------------

datadir <- paste(dir,type,product,"",sep="/")
picdir <- paste(datadir,"pics",sep="")
file <- paste(datadir,filename,sep="/")

# make sure that you have the ncdf-, the fields- and the maps-package installed!
library(ncdf)
library(RNetCDF)
library(spam)
library(sp)
library(maps)
library(Hmisc)
library(fields)
library(maptools)
library(RColorBrewer)
library(colorRamps)
library(lattice)
library(latticeExtra)
library(hexbin)
library(zoo)

# below auxiliary data files used for plotting are listed
if (plotCoastline) {
aux.file <- "110m_coastline.shp"
if (plotHighRes) aux.file <- "50m_coastline.shp"
if (plotVeryHighRes) aux.file <- "10m_coastline.shp"
coastline.file <- paste(dir,"AuxiliaryData/coastline/",aux.file,sep="")
coastline <- readShapeSpatial(coastline.file)
coastline <- as(coastline,"SpatialLines")
}

if (plotCountries) {
aux.file <- "ne_110m_admin_0_countries.shp"
if (plotHighRes) aux.file <- "ne_50m_admin_0_countries.shp"
if (plotVeryHighRes) aux.file <- "ne_10m_admin_0_countries.shp"
countries.file <- paste(dir,"AuxiliaryData/countries/",aux.file,sep="")
countries <- readShapeSpatial(countries.file)
countries <- as(countries,"SpatialLines")
}

if (plotRivers) {
aux.file <- "110m-rivers-lake-centerlines.shp"
if (plotHighRes) aux.file <- "50m-rivers-lake-centerlines.shp"
if (plotVeryHighRes) aux.file <- "ne_10m_rivers_lake_centerlines.shp"
rivers.file <- paste(dir,"AuxiliaryData/rivers/",aux.file,sep="")
rivers <- readShapeSpatial(rivers.file)
rivers <- as(rivers,"SpatialLines")
}

if (plotLakes) {
aux.file <- "110m_lakes.shp"
if (plotHighRes) aux.file <- "50m-lakes.shp"
if (plotVeryHighRes) aux.file <- "ne_10m_lakes.shp"
lakes.file <- paste(dir,"AuxiliaryData/lakes/",aux.file,sep="")
lakes <- readShapeSpatial(lakes.file)
lakes <- as(lakes,"SpatialLines")
```

```
}

if (plotCities) {
aux.file <- "ne_110m_populated_places.shp"
if (plotCitiesHighRes) aux.file <- "ne_50m_populated_places.shp"
if (plotCitiesVeryHighRes) aux.file <- "ne_10m_populated_places.shp"
cities.file <- paste(dir,"AuxiliaryData/populated-places/",aux.file,sep="")
cities <- readShapeSpatial(cities.file)
lon.cities <- cities@data$LONGITUDE
lat.cities <- cities@data$LATITUDE
names.cities <- cities@data$NAME
}

# Open the netcdf-file
nc <- open.ncdf(file)

# Read the available variable in the file
nvars <- nc$nvars
varnames <- vector(mode="character",length=nvars)
for (n in 1:nvars) {
       varnames[n] <- nc$var[[n]]$name
}
if (varname %nin% varnames) {
print("Error, variable not in file!")
print("The following variables are available for selection:")
print(varnames)
stop("Please select one of the above variable! (varname)")
}

# Retrieve the unit, the missing_data-value, and the title of the data
unit <- att.get.ncdf(nc, varname,"units")$value
missval <- att.get.ncdf(nc,varname,"_FillValue")$value

if (att.get.ncdf(nc,varname,"title")$hasatt==TRUE) {
       name <- att.get.ncdf(nc,varname,"title")$value
       } else {
        name <- varname
       }

# The offset and the scalefactor is required because the Fill_Value attribute is not applied by
the ncdf-package
# The offset and scalefactor is automatically applied to all data
offset.value <- 0.
scale.factor <- 1.
if (att.get.ncdf(nc,varname,"add_offset")$hasatt==TRUE) {
       offset.value <- att.get.ncdf(nc,varname,"add_offset")$value }
if (att.get.ncdf(nc,varname,"scale_factor")$hasatt==TRUE) {
       scale.factor <- att.get.ncdf(nc,varname,"scale_factor")$value }

#---------------------------------------------------#

# determine the grid
londim <- nc$dim[["lon"]]
lon <- londim$vals
nx <- londim$len
latdim <- nc$dim[["lat"]]
lat <- latdim$vals
ny <- latdim$len
if (product == "HLW" || product =="HSH") {
       levdim <- nc$dim[["lev"]]
       level.out <- levdim$vals[level]
       }

# Set the plot ranges
if (is.na(lonmax) || is.na(latmax) || is.na(lonmin) || is.na(latmin)) {
       lonmin=lon[1]
       lonmax=lon[nx]
       latmin=lat[1]
       latmax=lat[ny]
       lonplot=c(lonmin,lonmax)
       latplot=c(latmin,latmax)} else {
       lonplot=c(lonmin,lonmax)
```

```
    latplot=c(latmin,latmax)}


#--------------------------------------------------#

# retrieve the time variable
timedim <- nc$dim[["time"]]
nt <- timedim$len
time.unit <- timedim$units
time <- timedim$vals

# Create a R-date-object
date.time <- as.Date(utcal.nc(time.unit,time,type="s")) # if the date is set as days since 1970-
01-01 00:00:00
#date.time <- as.Date(as.character(time),"%Y%m%d") # if the date is set in another format
DataEveryStep = array(-1, dim=c(nx,ny,nt))

for (timestep in 1:nt) {
print(timestep)

# Read in the data
       if (product == "HLW" || product =="HSH") {
           field <- get.var.ncdf(nc, varname,start=c(1,1,level,timestep),count=c(nx,ny,1,1))
              na.ind <- which(field < 0.)
              field[na.ind] <- NA
              } else {
              field <- get.var.ncdf(nc, varname,start=c(1,1,timestep),count=c(nx,ny,1))
       }
# Set the missing data to NA
# Since the data has been corrected for the scalefactor and the offset,
# this has also to be considered for the FillValue
  na.ind <- which(field==(missval*scale.factor + offset.value))
  field[na.ind] <- NA
  DataEveryStep[,,timestep] <- field
}

# Close the file
  close.ncdf(nc)

for (timestep in 1:nt) {

# FORMAT THE TIME step for plotting
  zdate <- paste(format(date.time[timestep],"%Y%m%d"),sep=" ")

# Set the variable to make the plot
  z <- DataEveryStep[,,timestep]

# Invert the latitude dimension if necessary
  if (lat[ny] < lat[1]) {
    sort.out <- sort(lat,index.return=TRUE)
    lat <- sort.out$x
    z <- z[,sort.out$ix]
  }

# calulate the mean, min, max for the selected region only
  if (!is.na(lonmax) || !is.na(latmax) || !is.na(lonmin) || !is.na(latmin))
  {lon.reg <- which(lon >= lonmin & lon <= lonmax)
  lat.reg <- which(lat >= latmin & lat <= latmax)
  z.reg <- z[lon.reg,lat.reg]} else {z.reg <- z}

# print out the mean value of the field
  print(paste("Mean: ",mean(z.reg,na.rm=TRUE),sep=''))
  print(paste("Max: ",max(z.reg,na.rm=TRUE),sep=''))
  print(paste("Min: ",min(z.reg,na.rm=TRUE),sep=''))

# Set the title of the plot
title <- paste(name," (",unit,"), ",sep="")
       if (product == "HLW" || product == "HSH") {
       title <- paste(varname," (",unit,"), level: ",level.out,", ",sep="")
  }

#----------------------------------------------------------
```

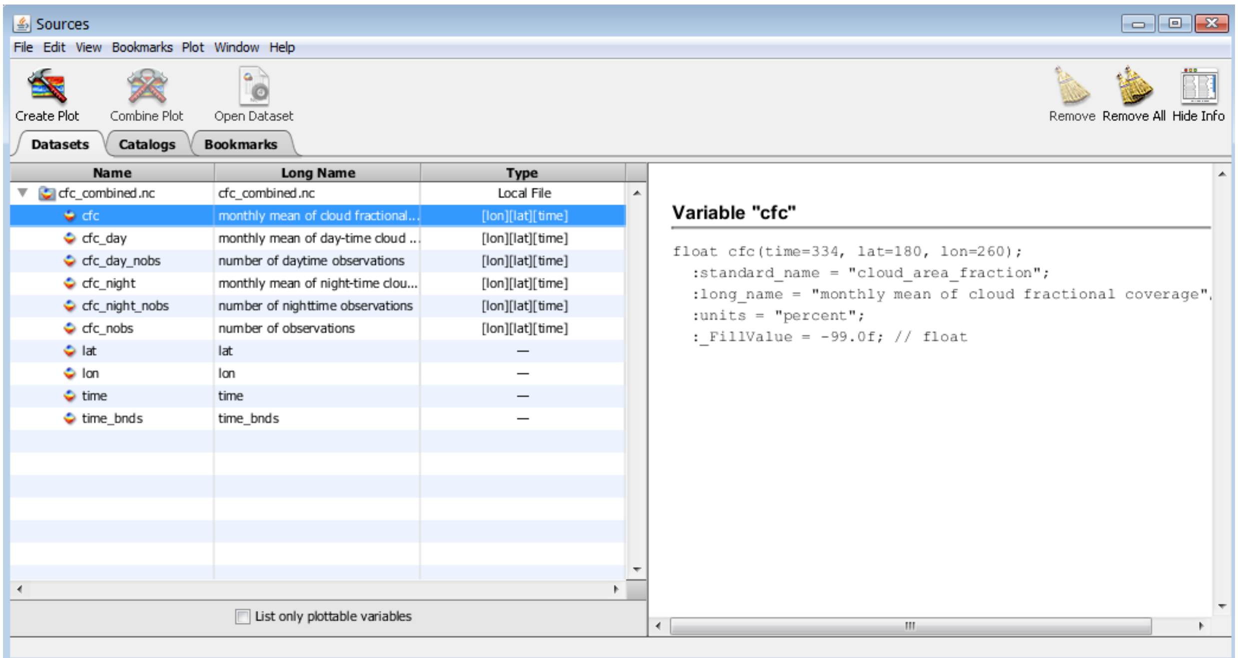
```
## Pic format is adjusted for the chosen plot region

lelo<-lonmax-lonmin
lela<-latmax-latmin
if (lelo >= lela)
{ width <- windowmax
  height <- round(windowmax* lela/lelo,0) }
if (lelo < lela)
{ width <- round(windowmax* lelo/lela,0)
  height <- windowmax }

# Open a png-file
time_picfile=paste(zdate,picfile,sep="_")
if (picout == TRUE) png(file=paste(picdir,time_picfile,sep="/"),height=height,width=width)

# set the number of rows and columns of the plot
par(mfrow = c(1,1))

  colmin <- colmin0
  colmax <- colmax0

  if ((as.integer(colmin) == -99) && (as.integer(colmax) == -99)) {
             colmin <- min(z.reg,na.rm=TRUE)
             colmax <- max(z.reg,na.rm=TRUE)
             }

  if (set.col.breaks) {
             brk <- brk.set
             } else {
             brk <- seq(colmin,colmax,length.out=ncol+1)
             }

# Set the colors and the color bar for the Difference plots
col.breaks <- brk
ncolor <- length(col.breaks)
at.ticks <- seq(1,ncolor)
names.ticks <- col.breaks[at.ticks]
zlim <- c(1,ncolor)

colors <- matlab.like(ncolor-1) # for the classical colour scale going from blue to red
#colors <- brewer.pal(ncolor-1,"Greys") # for one of the ColorBrewer palettes:
http://colorbrewer2.org/
#colors<-colorRampPalette(c("yellow", "red"))( 20 ) # for colour interpolation according to the
colorRamp package
if (plot.ano) colors[as.integer(ncolor/2)] <- rgb(1,1,1)

# Generate the field to be plotted
field.plot <- matrix(ncol=ny,nrow=nx)
for (l in seq(1,ncolor-1) ) {
  idx <- which(z >= col.breaks[l] &
             z < col.breaks[l+1],arr.ind=TRUE)
  field.plot[idx] <- l + 0.1
}

# set some plot parameters (mainly plot margins)
par(mgp=c(3,0.5,0),mar=c(4,4,4,4),oma=c(3,3,3,3))

# make the plot including color bar
image.plot(lon,lat,field.plot,xlab="Longitude, degrees E",ylab="Latitude, degrees N",
cex.axis=1.5, cex.lab=1.5,
           main=paste(title,add2title,zdate,sep=""),
           legend.mar = 6, xlim=lonplot,ylim=latplot,zlim=zlim,
           nlevel=ncolor-1,col=colors,
                axis.args=list(at=at.ticks,labels=round(names.ticks,1), cex.axis=2.3))

# add rivers
if (plotRivers) {
plot(rivers, add=TRUE, col="blue", lwd=contour.thick)
}

# add lakes
if (plotLakes) {
```

```
plot(lakes, add=TRUE, col="blue", lwd=contour.thick)
}

# add coastline
if (plotCoastline) {
plot(coastline, add=TRUE, lwd=contour.thick)
}

# add country borders
if (plotCountries) {
plot(countries, add=TRUE, lwd=contour.thick)
}

# add cities
if (plotCities) {
points(lon.cities,lat.cities,pch=pch.cities,cex=cex.cities)
if (label.cities) text(lon.cities,lat.cities+dlat,names.cities,cex=cex.label.cities)
}

# close the jpg-file
if (picout == TRUE)
{
dev.off()
print("Plot created!")
}
```

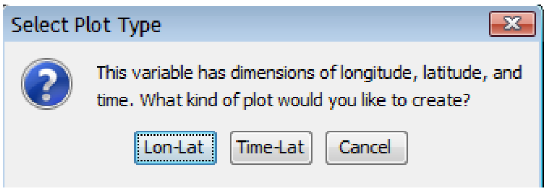
5.5. Additional Information Included in the .nc Files

The original and modified .nc files can be easily viewed by using Panoply. Panoply can be used to see which parameters are included in the file.

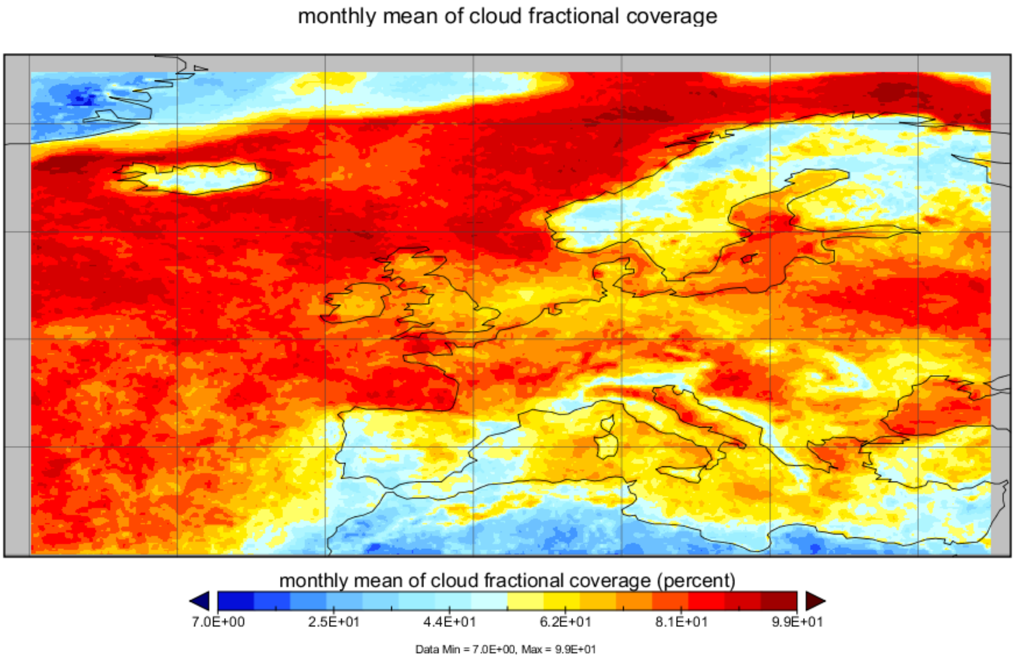
So for example in the image below you can see the information included in the combined (all time steps in one file) file for cloudiness – the left panel contains information about the variables (10 variables in this particular case), but the right panel shows additional information about each variable, such as the name, unit etc.

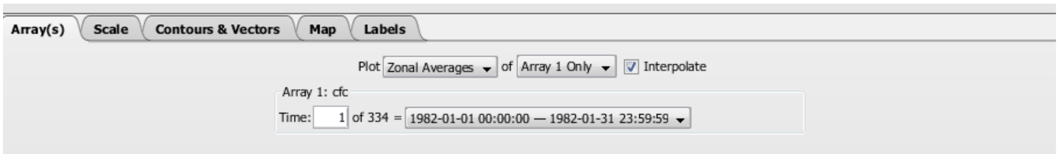


You can preview the data by double-clicking the variable name, and then choosing the appropriate plot type. You are supposed to select *Lon-Lat* for maps and areas, but *Time-Lat* for time-series data.



The image display window contains the world view by default, but you can zoom-in by holding down the Ctrl button and using the mouse to select the region. This particular .nc file contains 334 time steps, and you can navigate between them by using the menu at the bottom of the window.





6. Additional Sources to Help You

Below are listed some additional training and support materials that might be helpful for beginners in satellite climatology and computing:

- CM SAF Community Site will provide you with tutorial videos and useful scientific discussions of the current users of the data.
- CM SAF Event week, webcasts (can be found here and here) and Training Modules on the use of satellite data for climate monitoring.
- Online courses on computing and data analysis. You can find such courses on, for example, Coursera and Code School.

For additional information on the atlas please contact Zanita Avotniece from the Latvian Environment, Geology and Meteorology Centre (atlas@lvgmc.lv). For any additional support on the use of CM SAF data please contact the CM SAF (contact.cmsaf@dwd.de).

7. Copyright and Referencing

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