The EUMETSAT Network of Satellite Application Facilities

NWC SAF
Support to Nowcasting and Very Short Range Forecasting

User Manual for the NWC/PPS Application: Science Part

NWC/CDOP2/PPS/SMHI/SCI/UM/1, Issue 1, Rev. 0

15 September 2014

Applicable to SAFNWC/PPS version 2014

Applicable to the following PGE:s:

PGE	Acronym	Product ID	Product name	Version number
PGE01	CMa	NWC-062	Cloud Mask	4.0
PGE02	CT	NWC-065	Cloud Type	2.0
PGE03	CTTH	NWC-068	Cloud Top Temperature and Height	4.0
PGE04	PC	NWC-073	Precipitating Clouds	1.6
PGE05	CPP	NWC-071	Cloud Physical Properties	1.1

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REPORT SIGNATURE TABLE

Function	Name	Signature	Date
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DOCUMENT CHANGE RECORD

Version	Date	Pages	Changes
1.0d	27 June 2014	53	Replacing CDOP-document: SAF/NWC/CDOP/SMHI-PPS/SCI/PUM/1 First version for SAFNWC/PPS v2014. Implemented RIDs from PCR-v2014: -Action8 (note on new output format) General changes: -updates for PPS v2014, eg.: updated validation, more input to CPP, removed Task Manager, no special descriptions for VIIRS (as VIIRS is an integrated part now). -New datasets: CMa binary cloudmask, CT multi-layer, CPP cwp and cph_extended.
1.0	15 September 2014	53	Implemented RIDs from DRR-v2014: -LSc04, TH: Typos -LSc05: Added a limitation: LWP not validated over sea.

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1. INTRODUCTION

The EUMETSAT "Satellite Application Facilities" (SAF) are dedicated centres of excellence for processing satellite data, and form an integral part of the distributed EUMETSAT Application Ground Segment (http://www.eumetsat.int). This documentation is provided by the SAF on Support to Nowcasting and Very Short Range Forecasting, SAFNWC. The main objective of SAFNWC is to provide, further develop and maintain software packages to be used for Nowcasting applications of operational meteorological satellite data by National Meteorological Services. More information can be found at the SAFNWC webpage, http://www.nwcsaf.org . This document is applicable to the SAFNWC processing package for polar orbiting meteorological satellites, SAFNWC/PPS, developed and maintained by SMHI (http://nwcsaf.smhi.se).

1.1 PURPOSE

This document is intended for the end-user, i e the forecaster.

For the person in charge of building and installing the PPS software package, thus the sys-admin we refer to the Software User Manual ([RD.9]), which will of course also be relevant for the science-admin.

For the person interested in the algorithms in detail we refer to the ATBD documents ([RD.2], [RD.3], [RD.4], [RD.5] and [RD.6]).

1.2 SCOPE

This document is the Product User Manual for the SAFNWC Polar Platform System (PPS) based cloud and precipitation products. The document describes how to use the products after installation. It is meant to support the interpretation as well as describe the possibilities and limitations.

1.3 DEFINITIONS AND ACRONYMS

Acronym	Explanation
ACPG	AVHRR/AMSU Cloud Product Generation software (A major part of the SAFNWC/PPS s.w., including the PGE:s.)
AHAMAP	AMSU-HIRS-AVHRR Mapping Library (A part of the SAFNWC/PPS s.w.)
AMSU	Advance Microwave Sounding Unit
AVHRR	Advanced Very High Resolution Radiometer
CALIOP	Cloud-Aerosol Lidar with Orthogonal Polarization
CALIPSO	Cloud-Aerosol Lidar and Infrared Pathfinder Satellite
CDOP	Continuous Development and Operational Phase
CLIWA-NET	Cloud Liquid Water Network
CMa	Cloud Mask (also PGE01)
CM-SAF	Climate Monitoring SAF
COT	Cloud Optical Thickness
CPH	Cloud Phase
CPP	Cloud Physical Properties
CT	Cloud Type (also PGE02)
CTTH	Cloud Top Temperature and Height (also PGE03)
CWP	Cloud Water Path
ECMWF	European Centre for Medium-range Weather Forecasts
EPS	EUMETSAT Polar System
EUMETSAT	European Organisation for the Exploitation of Meteorological Satellites
FAR	False Alarm Rate
FOV	Field of View
GIS	Geographic Information System
GOES	Geostacionary Operational Environmental Satellite
HDF5	Hierarchical Data format version 5
HIRLAM	High Resolution Area Model
IR	Infrared
IASI	Infrared Atmospheric Sounding Interferometer
IWP	Ice Water Path
LUT	Look-Up-Table
LWP	Liquid Water Path
MHS	Microwave Humidity Sounding Unit
MODIS	Moderate Resolution Imaging Spectrometer
NIR	Near Infrared
NOAA	National Oceanic and Atmospheric Administration
NORDRAD	Nordic Weather Radar Network
NWP	Numerical Weather Prediction
OSISAF	Ocean and Sea Ice SAF
PC	Precipitating Cloud (also PGE04)
PCPN	Precipitation
PGE	Process Generating Element
POD	Probability Of Detection
POFD	Probability Of False Detection
PPS	Polar Platform System
RGB	Red Green Blue
REFF (reff)	Effective Radius
RMS	Root Mean Square Deviation
RTTOV	Radiative Transfer for TOVs

Acronym	Explanation	Acronym	Explanation
SAF	Satellite Application Facility		Hydrological Institute
SAFNWC	Satellite Application Facility for support to NoWcasting	**SW**	SoftWare
		UTC	Universal Time Co-ordinated
SEVIRI	Spinning Enhanced Visible InfraRed Imager	**VIIRS**	Visible Infrared Imaging Radiometer Suite
SI	scattering index	**VIS**	Visible
SMHI	Swedish Meteorological and		

See [RD.1.] for a complete list of acronyms for the SAFNWC project.

1.4 REFERENCES

1.4.1 Applicable documents

The following documents, of the exact issue shown, form part of this document to the extent specified herein. Applicable documents are those referenced in the Contract or approved by the Approval Authority. They are referenced in this document in the form [AD.X]

For dated references, subsequent amendments to, or revisions of, any of these publications do not apply. For undated references, the current edition of the document referred applies.

Current documentation can be found at SAFNWC Helpdesk web: http://www.nwcsaf.org

Ref	Title	Code	Vers	Date
[AD.1.]	NWCSAF Project Plan	NWC/CDOP2/SAF/AEMET/MGT/PP	1.5	05/06/14
[AD.2.]	NWCSAF Product Requirements Document	NWC/CDOP2/SAF/AEMET/MGT/PRD	1.5	05/06/14
[AD.3.]	System and Components Requirements Document for the SAFNWC/PPS	NWC/CDOP2/PPS/SMHI/SW/SCRD	1.0	15/09/14

Table 1: List of Applicable Documents

1.4.2 Reference documents

The reference documents contain useful information related to the subject of the project. These reference documents complement the applicable ones, and can be looked up to enhance the information included in this document if it is desired. They are referenced in this document in the form [RD.X]

For dated references, subsequent amendments to, or revisions of, any of these publications do not apply. For undated references, the current edition of the document referred applies

Current documentation can be found at SAFNWC Helpdesk web: http://www.nwcsaf.org

Ref	Title	Code	Vers	Date
[RD.1.]	The Nowcasting SAF Glossary	NWC/CDOP2/SAF/AEMET/MGT/GLO	2.0	18/02/2014
[RD.2]	Algorithm Theoretical Basis Document for the Cloud Mask of the NWC/PPS	NWC/CDOP2/PPS/SMHI/SCI/ATBD/1	1.0	15/09/14
[RD.3]	Algorithm Theoretical Basis Document for the Cloud Type of the NWC/PPS	NWC/CDOP2/PPS/SMHI/SCI/ATBD/2	1.0	15/09/14
[RD.4]	Algorithm Theoretical Basis Document for the Cloud Top Temperature, Pressure and Height of the NWC/PPS	NWC/CDOP2/PPS/SMHI/SCI/ATBD/3	1.0	15/09/14
[RD.5]	Algorithm Theoretical Basis Document for the Precipitating Clouds of the NWC/PPS	NWC/CDOP2/PPS/SMHI/SCI/ATBD/4	1.0	15/09/14
[RD.6]	Algorithm Theoretical Basis Document for the Cloud Physical Properties of the NWC/PPS	NWC/CDOP2/PPS/SMHI/SCI/ATBD/5	1.0	15/09/14
[RD.7]	Interface Control Document for Internal and External Interfaces NWC/PPS	NWC/CDOP2/PPS/SMHI/SW/ICD/1	1.0	15/09/14
[RD.8]	Datat Output Format of the NWC/PPS	NWC/CDOP2/PPS/SMHI/SW/SW/DOF	1.1	15/09/14
[RD.9]	User Manual for the NWC/PPS Application: Software Part, 1. Installation	NWC/CDOP2/PPS/SMHI/SW/UM/1	1.0	15/09/14
[RD.10]	User Manual for the NWC/PPS Application: Software Part, 2. Operations	NWC/CDOP2/PPS/SMHI/SW/UM/2	1.0	15/09/14
[RD.11]	Scientific and Validation Report for the Cloud Product Processors of the NWC/PPS	NWC/CDOP2/PPS/SMHI/SCI/VR/Cloud	1.0	15/09/14

Table 2: List of Referenced Documents

1.5 DOCUMENT OVERVIEW

This document contains the description of usage of the SAF NWC PPS-based application and its products. To cover these objectives the present document has been structured in the following sections:

- Section 1 contains the current introduction along with the list of used acronyms and applicable and reference documents.
- Section 2 describes which products there are, their algorithms and their outputs.
- Section 3 describes shortly how to run the products.
- Section 4 describes which input is needed, and that the s.w. can be configured.
- Section 5 gives a summary of the validation
- Section 6 gives some examples of visualization of the products.

1.6 SCOPE OF OTHER DOCUMENTS

The algorithms used to extract the PPS Cloud Products PGE01 (CMa), PGE02 (CT), PGE03 (CTTH), PGE04 (PC) and PGE05 (CPP) are detailed in Algorithm Theoretical Basis Documents ([RD.2], [RD.3], [RD.4], [RD.5], and [RD.6]).

The validation of the algorithms used to extract the PPS Cloud Products PGE01 (CMa), PGE02 (CT), PGE03 (CTTH), PGE04 (PC) and PGE05 (CPP) is reported in a validation report ([RD.11]).

Instructions for install, configure and execute the SAFNWC/PPS software, in order to extract the PPS Cloud Products, are detailed in a Software User Manuals ([RD.9] and [RD.10]).

The Interface Control Documents ([RD.7]) (for the External and Internal Interfaces of the NWC/PPS) and ([RD.8]) (Data Output Format) details the input and output data format for the NWC/PPS software.

1.7 LICENSE AND CONDITIONS OF USE

The software accompanying this Users Manual is provided under license. Rights to use, copy, or modify, this software follows EUMETSAT policy of the SAFNWC/PPS software, and is specified in the dedicated license agreement.

A Help Desk facility is available for the registered user. The exact coordinates of this Help Desk web-site is http://www.nwcsaf.org .

2. DESCRIPTION OF THE PRODUCT

These are the five cloud and precipitation product generation elements (PGEs), that are derived from AVHRR/VIIRS/AMSU data:

PGE01- Cloud Mask (CMa)

PGE02- Cloud Type (CT)

PGE03- Cloud Top Temperature and Height (CTTH)

PGE04- Precipitating Clouds (PC)

PGE05- Cloud Physical Properties (CPP)

From here the product generation element will be referred to by their names.

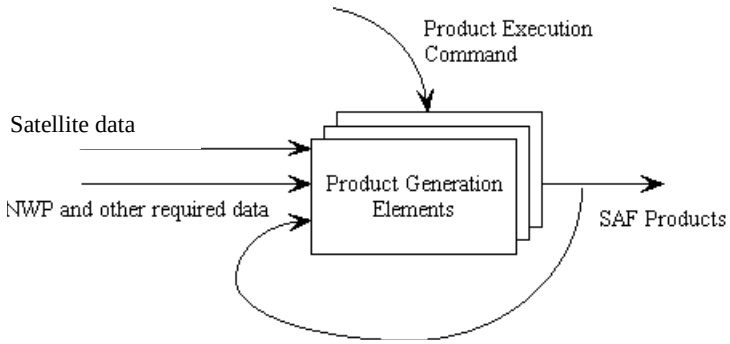


Figure 1: Simplified SAFNWC/PPS design

The CT product requires the output of CMa as input, the CTTH and the PC products require output from both CMa and CT. CPP uses input from CMa and CTTH, though the input from CTTH is optional.

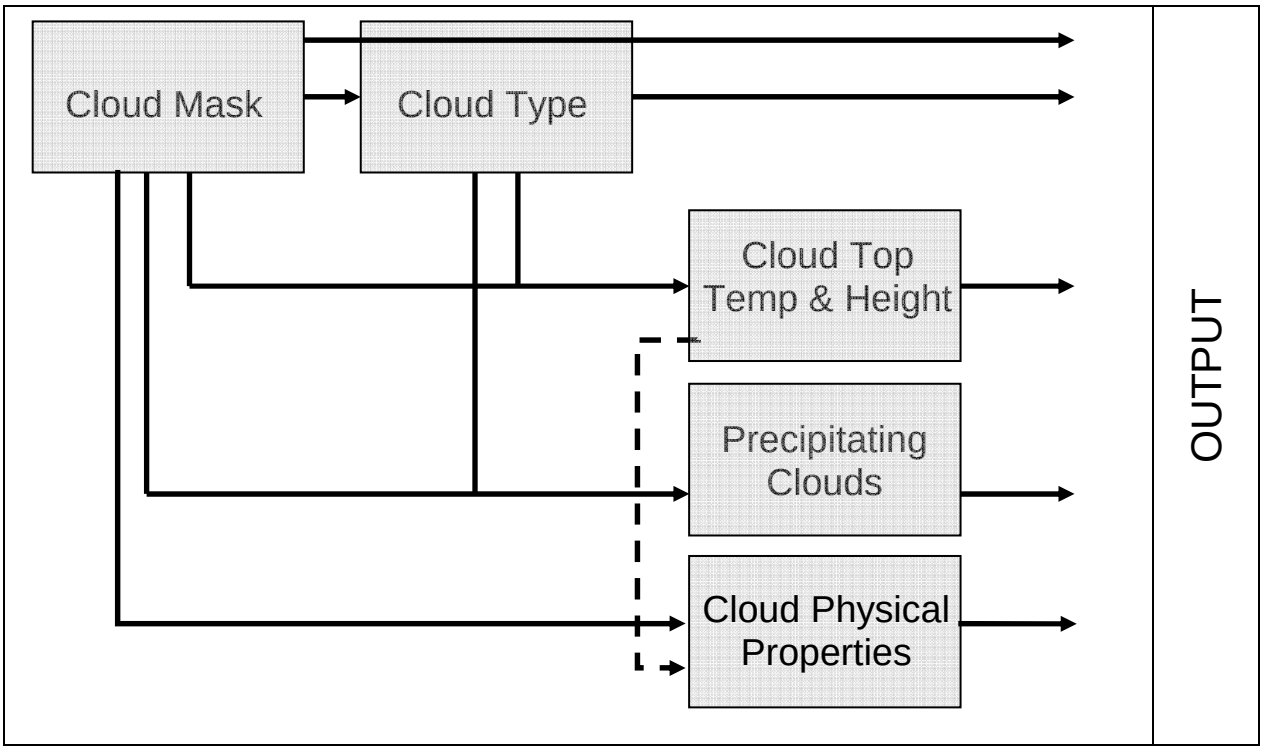


Figure 2: Internal dependence of the products

The different products have been designed in such a way as to allow individual execution as stand alone applications.

2.1 SUMMARY OF CHANGES SINCE SAFNWC/PPS VERSION 2012

Major changes in version 2014 are:

- CMa algorithm: Solar contribution is included explicitly in day-land look-up tables, embracing the 3.7µm channel.
- CMa algorithm: Threshold offsets have been carefully retuned and test logic has been cleaned. This makes the algorithm much more precise.
- CMa algorithm: Test for high terrain has been replaced by a test for rough terrain since it turned out that the algorithm is more sensitive to roughness than to height.
- CT algorithm: The dataset *multi-layer clouds* has been added.
- CTTH product has been improved in a way that errors are reduced and more results are assigned to cloudy pixels (i.e. less 'no data' pixels).
- Cloud Physical Properties Product has been revised completely and comes with a new algorithm and new look-up tables.
- The output file format is changed, both for filename and for content.

2.2 GOAL OF THE PRODUCTS

2.2.1 Cloud Mask

This product attempts to delineate all absolutely cloud-free pixels in a satellite scene with a high confidence. In addition, it will identify cloud free snow or ice contaminated pixels when illumination allows.

Coverage and resolution:

- Coverage is depending on the coverage of the polar satellites.
- The algorithm will work anywhere, but the product quality depends on the geographical area. The quality is at its best over Central Europe, somewhat decreasing over Scandinavia, and further decreasing over the Arctic; also going to the south (southern Spain and north Africa) will decrease the quality.
- Full AVHRR (1 km) resolution. Or full VIIRS (750 m) resolution.

2.2.2 Cloud Type

The main objective of the Cloud Type product is to distinguish between thin and opaque clouds and provide a rough estimate of the cloud top height, and try to distinguish between water particle clouds and ice particle clouds. The highest priority is given to the reliable identification of the major cloud categories: low, medium, high, and semi-transparent cirrus.

Coverage and resolution:

- Coverage is depending on the coverage of the polar satellites.
- The algorithm will work anywhere, but the product quality depends on the geographical area. The quality is at its best over Central Europe, somewhat decreasing over Scandinavia, and further decreasing over the Arctic; also going to the south (southern Spain and north Africa) will decrease the quality.
- Full AVHRR (1 km) resolution. Or full VIIRS (750 m) resolution.

2.2.3 Cloud Top Temperature and Height

The output provides information on the temperature, pressure and height of clouds. The height assignment is done separately for opaque clouds and semi-transparent and sub-pixel cloud tops and is provided in separate output fields.

Coverage and resolution:

- Coverage is depending on the coverage of the polar satellites.
- The algorithm will work anywhere, but the product quality depends on the geographical area.
- Full AVHRR (1 km) resolution. Or full VIIRS (750 m) resolution.

2.2.4 Precipitating Clouds

The online-processing for the Precipitating Clouds product derives the precipitation likelihood from AVHRR and microwave data. (It can use VIIRS data, but it can not make use of the microwave data from the same satellite, so the quality of the product would be degraded.)

The objective of the PC product is to support detailed precipitation analysis for nowcasting purposes, especially in areas for which no radar data is available. The focus is on the delineation of non-precipitating and precipitating clouds and on giving a rough indication on expected intensity. The output is the likelihood of precipitation in three intensity intervals of light precipitation (0.1-0.5mm/h), moderate precipitation (0.5-5.0mm/h) and heavy precipitation (>5mm/h). The sum of those three classes is the total likelihood of precipitation. The likelihood of no precipitation is calculated by 100% - total likelihood of precipitation.

Coverage and resolution:

- Coverage is depending on the coverage of the polar satellites.
- The algorithm will in principle work in mid-latitudes and sub-arctic latitudes, but has been locally tuned for Scandinavia and only been verified qualitatively for other European regions.
- Nominally at full AVHRR (1 km) resolution, but microwave information which is dominating the product output has a resolution of 15km in the sub-satellite point.

2.2.5 Cloud Physical Properties

The official products are liquid water path and cloud phase. The additional products are ice water path, cloud optical thickness and effective radius.

Images of the liquid and ice water path are useful to analyse the structure of the atmosphere. These products show the pattern of and help to distinguish between different air-masses (e.g. in large low pressure systems). Effective radius together with cloud phase helps to complete information about the character of a cloud. They provide valuable support in the identification of fog and areas of potential precipitation. The optical thickness on the other hand is most important for energetic considerations since it is the most important atmospheric measure for variations in the earth's energy budget.

Coverage and resolution:

- Coverage is depending on the coverage of the polar satellites.
- The algorithm will work anywhere, but the product quality depends on the geographical area.
- Full AVHRR (1 km) resolution. Or full VIIRS (750 m) resolution.

2.3 OUTLINE OF THE ALGORITHM

2.3.1 Cloud Mask

The Cloud Mask scheme is a threshold-based algorithm, utilising all 5/6 spectral channels of the AVHRR/2 or AVHRR/3 sensor, or 7 spectral channels from the VIIRS sensor, NWP short range forecast data, emissivity maps and 1 km GIS (digital elevation model and landuse) data. The scheme makes use of off-line radiative transfer simulations (6S and RTTOV) of cloud free atmospheres, to estimate, prior to the reception of satellite data, the optimal thresholds valid for the given satellite scene.

2.3.2 Cloud Type

The Cloud Type algorithm takes as input the Cloud Mask output, and utilise all 5/6 spectral channels of the AVHRR/2 or AVHRR/3 sensor, or corresponding channels from the VIIRS sensor, NWP short range forecast data, and 1 km GIS (digital elevation model and landuse) data. The algorithm distinguishes different cloud types using thresholds defined by off-line radiative transfer calculations and a database of interactively collected training targets.

2.3.3 Cloud Top Temperature and Height

The Cloud Top Temperature and Height will take as input the Cloud Type, and utilise the 11 and 12 micron channels of the AVHRR/VIIRS sensor, NWP short range forecast data, and 1 km GIS (digital elevation model and landuse) data. To compensate for the atmospheric attenuation above the opaque clouds, and for the semi-transparency correction, radiative transfer calculations (RTTOV) using NWP short range forecast output of the vertical temperature and humidity profiles will be used.

The algorithm for the opaque clouds differs from the algorithm for the semi-transparent clouds. This means CTTH will be generated in two separate processes.

For semi-transparent clouds the estimation of cloud top height products is more complex since part of the temperature signal originates from lower clouds or the surface. For the processing of semi-transparent clouds a windowing technique is used where information in a larger area is used to estimate the contribution of lower clouds and surface to the total signal and to correct for it. There is an option called ‘moving window’ where the area is moved stepwise in an overlapping manner. This method achieves more valid CTTH estimates for semi-transparent clouds. Moving window processing will slow down the CTTH-processing and therefore it can be turned off.

2.3.4 Precipitating Clouds

The algorithm(s) to retrieve information on the presence (including rough intensity estimations) of precipitation is based on the Cloud Type output, and use either or both the spectral information in the VIS/IR of the AVHRR and the MW information of the AMSU-B or MHS. For the VIS/IR the day-algorithm relies additionally on the microphysical information available in the 1.6 micron or 3.7 micron channels, and the night-time algorithm relies on the 11 and 12 micron channels alone. The AMSU-algorithm will utilise the scattering signal of precipitation sized ice particles. Due to a careful treatment of different surface emissivities over land and sea and a weighted blending of the retrieval according to actual land/sea fraction in every field of view, the algorithm works seamlessly over coastal areas.

The VIS/IR and MW estimates are merged in the final product. AVHRR is mostly used in a quality control of the MW algorithm for spurious light rain and to fill areas where no MW estimate is available, as between MW pixels and on the sides of the swath. Information on intensity is mostly introduced by the

MW data. When the algorithm is configured to use MW data, it is recommended to configure use of IR algorithm only for both day and night, as to guarantee a uniform and seamless performance of the algorithm

2.3.4.1 Sources for Precipitating Clouds

- AVHRR/3 - all channels, or just IR channels
- AMSU-B 89.0 and 150.0 GHz or MHS 89GHz and 157GHz

2.3.5 Cloud Physical Properties

The Cloud Physical Properties algorithm takes as input the Cloud Mask and CTTH outputs, and utilises all 5/6 spectral channels of the AVHRR/2 or AVHRR/3 sensor, or corresponding channels from the VIIRS sensor, NWP short range forecast data, OSISAF ice maps, and 1 km GIS (digital elevation model and landuse) data. The algorithm uses lookup-tables, pre-calculated with a plane-parallel radiative transfer model. Visible and near-infrared channels are used to derive the basic quantities optical thickness and effective radius. Cloud phase and liquid water path are then calculated from those quantities.

2.4 DESCRIPTION OF THE OUTPUT

Please notice that the v2014 of PPS will give output in a different format than PPS v2012. The file names will differ, as well as the names of the dataset, the class definitions (CMa, CT and CPP-phase), the processing flags and the attributes. Though, the products will be the same, and all dataset that were in v2012 (except processing flags) will also be produced in v2014.

2.4.1 Cloud Mask

The AVHRR/VIIRS Cloud Mask output consist of

- a five category cloud mask
- a binary cloud mask
- three quality/conditions flags

2.4.1.1 Main output

The main output is the cloud mask, which is presented in two ways: either a binary cloud mask (cloud free/cloudy) or an extended cloud mask with more categories described.

The extended cloud mask values are given by the five categories listed below. Cloud free land and cloud free sea are originally only one cloud free category, so in order to make an output image like Figure 3 the user will have to apply a land/sea mask herself, or use the information available in the conditions flag (bit number 4 and 5 – see 2.4.1.2.1).

The binary cloud mask (Figure 4) has only got the values: cloud free and cloudy. Which means that cloud contaminated is classified as cloudy, and snow/ice is classified as cloud free. The separation in cloud free land and cloud free sea is applied afterwards, as for the extended cloud mask image.

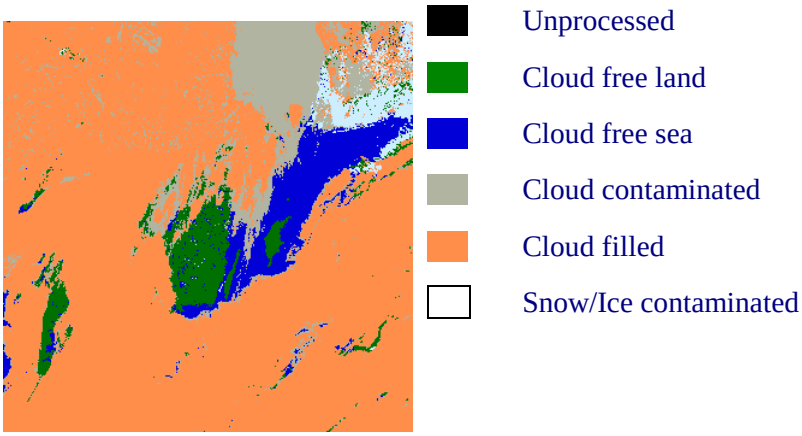


Figure 3: Extended Cloud Mask Classification

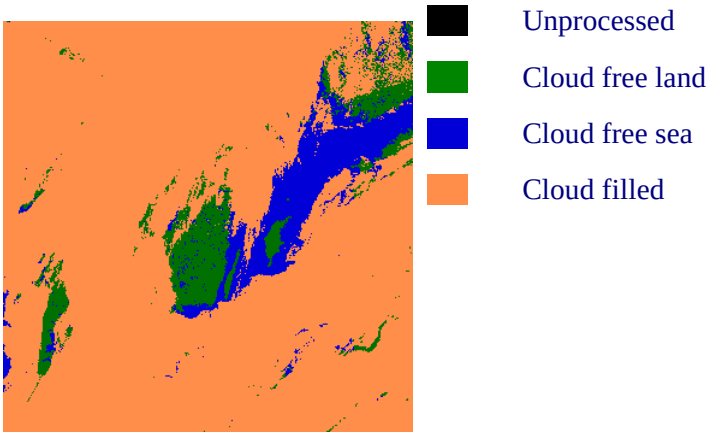


Figure 4: Binary Cloud Mask Classification

Table 3: Cloud Mask, extended

value	class

0	Cloud free
1	Cloud filled
2	Cloud contaminated
3	Snow/Ice contaminated
255	No data

Table 4: Cloud Mask, binary

value	class
0	Cloud free
1	Cloud filled
255	No data

2.4.1.2 Quality and condition flags

There are three flags available in the product files: the condition flag and the quality flag, which are common for all the pge:s, and a statusflag, which is specific for each pge. Each flag occupies 16 bits, and provide the user with valuable information on the conditions under which the processing was performed, and on the quality of the product. For cloud mask there might also be two flags describing which threshold tests that have been performed (not described here). The exact outline of the flags is given below.

2.4.1.2.1 Common flags: condition flag and quality flag

The condition flag describes environmental and illumination conditions, as well as the availability of input data. The first part of the flag describes the conditions:

Table 5: Condition flag, environmental conditions

Illumination & environmental conditions	
bit number	**meaning of the bit**
0	Outside swath/In swath
1-2	Illumination: 0 N/A, 1 night, 2 day, 3 twilight
3	Sunglint/No sunglint
4-5	Land/sea: 0 N/A, 1 land, 2 sea, 3 coast
6	High terrain/Low terrain

7	Rough terrain/Not rough terrain

A number of bits describe the use/availability of various kinds of input data, eg. NWP fields and the availability of the AVHRR/VIIRS channels:

Table 6: Condition flag, input data

Missing data	
bit number	**meaning of the bit**
8-9	Satellite data: 0 N/A, 1 Data available, 2 Useful data missing, 3 Mandatory data missing
10-11	NWP-data: 0 N/A, 1 Data available, 2 Useful data missing, 3 Mandatory data missing
12-13	PGE-data: 0 N/A, 1 Data available, 2 Useful data missing, 3 Mandatory data missing (This flag is not relevant for Cloud Mask, which has no other PGE as input)
14-15	Auxiliary data: 0 N/A, 1 Data available, 2 Useful data missing, 3 Mandatory data missing

The quality flag describes information related to the product quality.

Table 7: Quality flag

Thresholding quality and smoothing	
bit number	**meaning of the bit**
0	This pixel has been assigned to no data
1-2	*These bits are not used*
3-5	Quality: 0 N/A 1 Good 2 Questionable 3 Bad 4 Reclassified or interpolated

For cloud mask the quality (bit number 3-5) is set to bad (=3) for pixels with low quality results. This happens when the value of a pixel in some feature is close to the threshold determining the output. Bit number 3-5 is set to reclassified/interpolated (=4) when an isolated pixel has been changed from

cloudy to cloud free (or vice-versa) after applying spatial smoothing. This spatial smoothing will only be applied when the T11-T37 test was the one determining the output value.

2.4.1.2.2 Status flag for Cloud Mask

The status flag has got different meanings for different PGE:s. Here is described the meaning of the status flag for the cloud mask. Two bits are used to describe the usage of sea-ice input information. The ice concentration maps that can be used are produced by OSISAF.

Table 8: Cloud Mask, status flag

Status flag	
bit number	**meaning of the bit**
0	Low level inversion present
1	Suspected low quality of the NWP data.
2	External sea-ice information used. .
3	Sea-ice cover, according to external sea ice maps.
4	There is no method applied for a separate aerosol data set.
5	There is suspected heavy aerosol. (Can be set un-according to flag 4).

A flag is set to 1 if the condition described (e.g. Low level inversion) applies; otherwise it is set to 0.

2.4.2 Cloud Type

The AVHRR/VIIRS Cloud Type output consist of

- a 15 category main output (Cloud classification)
- a multi-layer cloud dataset
- three quality/condition flags

It can also be configured for, though we do not recommend to use it:

- a cloud particle phase flag

2.4.2.1 Main output

Except when outside the swath, or when processing is stopped due to erroneous input data, a pixel may take one of 4 cloud free values (depending on the underlying surface being land or sea and snow/ice covered or not) or one of 10 cloudy values in the current implementation. The cloudy values can be sub-divided into 5 opaque categories depending on the height of the cloud top, 4 semi-transparent cloud categories (*very thin*, *thin* and *thick cirrus*, and *cirrus over medium and low clouds*) and a *fractional clouds* category. There is no separation between cumiliform and stratiform clouds.

The colour legend applied for the Cloud Type presentations has been agreed upon between SMHI and Meteo-France, CMS-Lannion, who are developing the SEVIRI Cloud Type product. At the Meteo-France server you may access the latest images from their prototype Cloud Type based on GOES data.

The choice of colours is based first of all on the idea that the meteorological interesting features (clouds and snow) should be easily detected against the background (clear). Secondly it shall be possible to identify the individual cloud classes (in terms of height, opaqueness, and dominating particle phase) from each other, and from cloud free snow or ice on the ground or sea.

Therefore dark colours (black and green) have been chosen for the (clear) background. The semi-transparent cirrus clouds are kept in blue-cyan. Opaque clouds go from orange over yellow, and grey-greenish to white for increasing height (and increasing amount of ice-particles in the cloud). Fractional cloud is dark purple, whereas ice/snow is bright violet and pink.

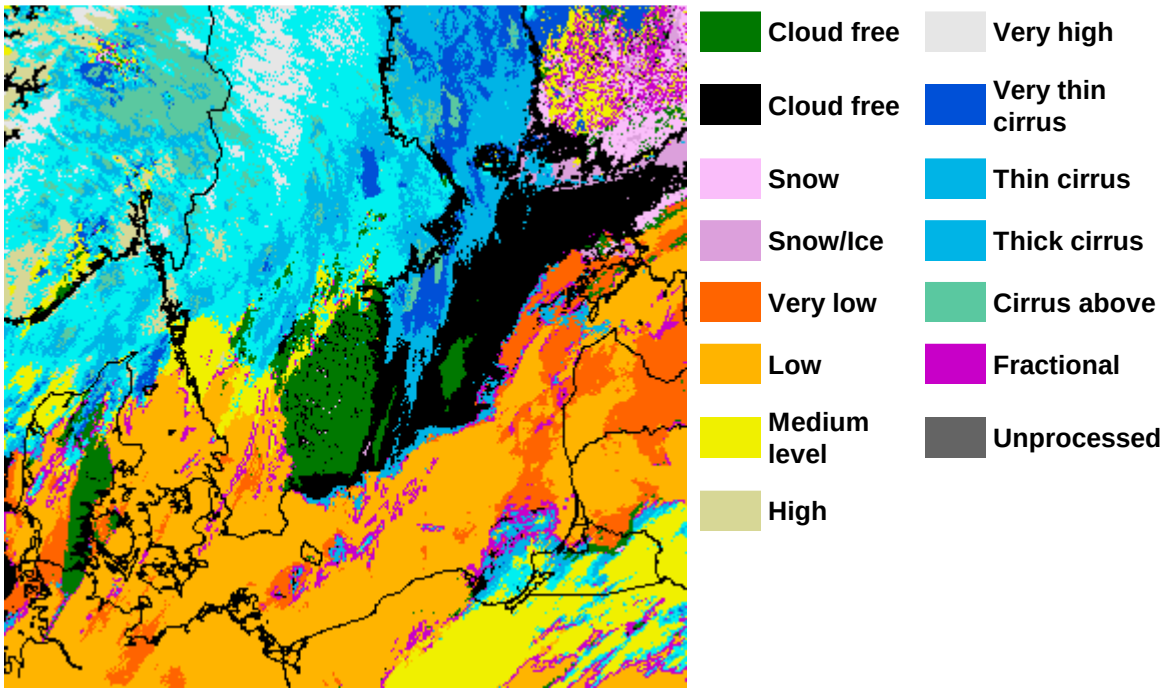


Figure 5: Cloud Type Classification

Table 9: Cloud Type, main output

value	class	value	Class
1	Cloud free land	9	Very High
2	Cloud free sea	10	Fractional
3	Snow/Ice land	11	High semi-transparent very thin cirrus
4	Snow/Ice sea	12	High semi-transparent thin cirrus
5	Very low	13	High semi-transparent thick cirrus
6	Low	14	High semi-transparent above low clouds
7	Medium	15	Not used for PPS. (For GEO: High semi-transparent above snow/ice)
8	High opaque clouds	Fill Value	No data or corrupted data

Table 10: Cloud Type, multi-layer clouds

value	class
0	Single layer cloud
1	Multi-layer cloud
255	No data (including cloud free)

2.4.2.2 Quality and condition flag

The quality flag and the conditions flag are the same for all pge:s, see description as for the Cloud Mask (2.4.1.2.1). For the Cloud Type product, the flag for bad quality is set when cloud mask flags for bad quality, while the reclassified/interpolated value is not used for the cloud type product.

The status flag has got different meanings for different PGE:s. Here is described the meaning of the status flag for the cloud type. Two of its bits are used to describe the usage of sea-ice input information. The ice concentration maps that can be used are produced by OSISAF.

Table 11: Cloud Type, status flag

Status flag	
bit number	**meaning of the bit**
0	Low level inversion present
1	Suspected low quality of the NWP data.
2	External sea-ice information used.
3	Sea-ice cover, according to external sea ice maps.

A flag is set to 1 if the condition described (e.g. Low level inversion) applies; otherwise it is set to 0.

2.4.2.3 Cloud particle phase flag

In the cloud type product, there can be produced a phase flag; though *as default is it switched off*. If you want data about cloud phase, we recommend you to use the Cloud Physical Properties product Cloud Phase (see 2.4.5).

Radiative transfer modelling will be used in the definition of this flag. Water/ice phase distinction using only one of the two AVHRR/3 channels 3a or 3b are rather ambiguous, so this information is likely only to serve as a rough guideline.

2 bits to describe the dominating cloud phase. If cloud phase information is not possible to retrieve with any skill none of the two bits will be set.

Table 12: Cloud Type, cloud phase flag

Cloud phase categories	
bit number	**class name**
0	Non-processed (containing no data or corrupt data) or unclassified
1	Water cloud
2	Ice cloud

2.4.3 Cloud Top Temperature and Height

2.4.3.1 Main output

The output provides information on the temperature, pressure and height of opaque and semi-transparent cloud tops.

- Temperature is given in Kelvin

- Pressure is given in Pa
- Height is given in meter

Following example shows the cloud top height output.

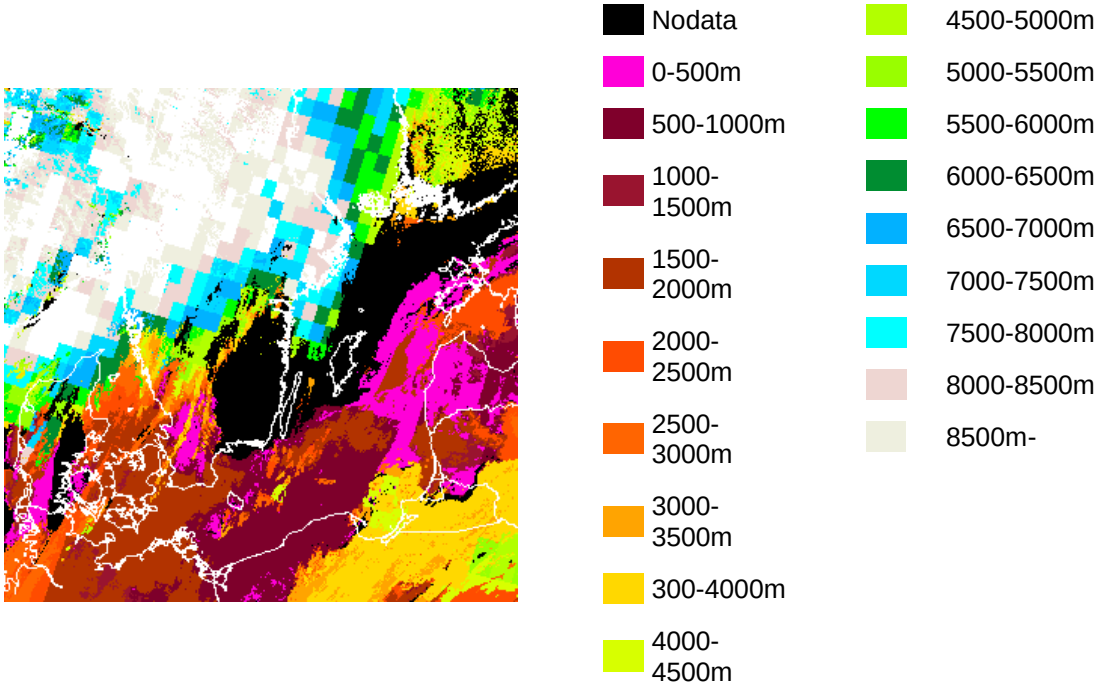


Figure 6: CTTH product, example from cloud top height output

2.4.3.2 Flags

The quality flag and the conditions flag are the same for all pge:s, see description as for the Cloud Mask (2.4.1.2.1). For the CTTH product, the flag for bad quality is set when there is a low level inversion in a cloud pixel. The reclassified/interpolated flag is set in pixels which have been assigned values after spatial interpolation.

The status flag has got different meanings for different PGE:s. Here is described the meaning of the status flag for the cloud top temperature and height. The exact outline of the flag is given below.

Table 13: CTTH, status flag

Status flag	
bit number	**meaning of the bit**
0	Cloud free
1	No reliable method

2	Opaque cloud
3	Multi-layer cloud suspected
4	Low level inversion present
5	Suspected low quality of the NWP data.
6	RTTOV IR simulations applied
7	Windowing technique applied

2.4.4 Precipitating Clouds

2.4.4.1 Main output

The PC product consists of a numerical value for the likelihood of precipitation within the following four precipitation intensity classes:

- no precipitation (R < 0.1 mm/hr)
- risk for (light) precipitation: 0.1 mm/hr < R < 0.5 mm/hr
- light/moderate precipitation: 0.5 mm/hr < R < 5.0 mm/hr
- intensive (convective) precipitation: 5.0 mm/hr < R

The following probability classes will be used:

0% (= 0-5%)

10% (= 5-15%)

20% (= 15-25%)

30% (= 25-35%)

40% (= 35-45%)

50% (= 45-55%)

60% (= 55-65%)

70% (= 65-75%)

80% (= 75-85%)

90% (= 85-95%)

100% (= 95-100%)

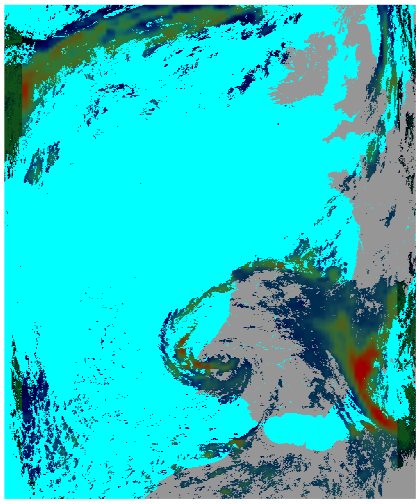


Image derived from the AVHRR/AMSU Precipitating Clouds output by assigning the red colour to the probabilities for heavy precipitation the green colour to the probabilities for moderate precipitation and the blue colour to the probabilities for light precipitation.

Figure 7: Precipitating Cloud, main output

2.4.4.2 Flags

No separate uncertainty estimate is included in the PC product. Provision of the probability of precipitation in each of the intensity classes will give an indication of the uncertainty of the estimate, mixed colours in the png-images indicate that intensity classes are overlapping (for example brownish colour indicates that precipitation might either be moderate or heavy).

The quality flag and the conditions flag are the same for all pge:s, see description as for the Cloud Mask (2.4.1.2.1).). For the Precipitating Clouds product, the flag for bad quality is set when there is only AVHRR/VIIRS data, and no AMSU data available, the quality flag is also set to bad when there is no Cloud Type data available. The reclassified/interpolated flag is not used for the Precipitating Clouds product.

The status flag has got different meanings for different PGE:s. Here is described the meaning of the status flag for the precipitating clouds. Table 14: PC, status flag

Status flag	
bit number	**meaning of the bit**
0	Suspected low quality of the NWP data
1	No method for precipitation rate
2	AMSU estimate used
3	AVHRR estimate used
4	Solar channels used

2.4.5 Cloud Physical Properties

The AVHRR/VIIRS Cloud Physical properties output consist of

- Two main output products:
  - Liquid water path, given in kg/m^2
  - Cloud Phase, in 3 categories
- Five additional output products: (not committed)
  - Ice water path, given in kg/m^2
  - Cloud water path (i.e. both liquid and ice water path)
  - Cloud Optical Thickness –a dimensionless quantity from 0 and up
  - Effective radius, given in m
  - Extended cloud phase, in 8 categories
- Six data sets for quality and processing information:
  - Error estimates for: cloud water path, cloud optical thickness and effective radius.
  - Three quality/condition flags

2.4.5.1 Main output

The liquid water path is given in kg/m^2, displayed in the figure below. The cloud phase is given in 3 categories: nodata (including cloud free), water and ice –as is also displayed in the figure below.

It is also worth to notice that while the cloud phase product works at any time of the day, the liquid water path only works at daylight. Processing a scene at night time will give a liquid water path product of only no-data. Processing a scene, which is partly in bad lighting conditions, will give part of the scene as no-data.

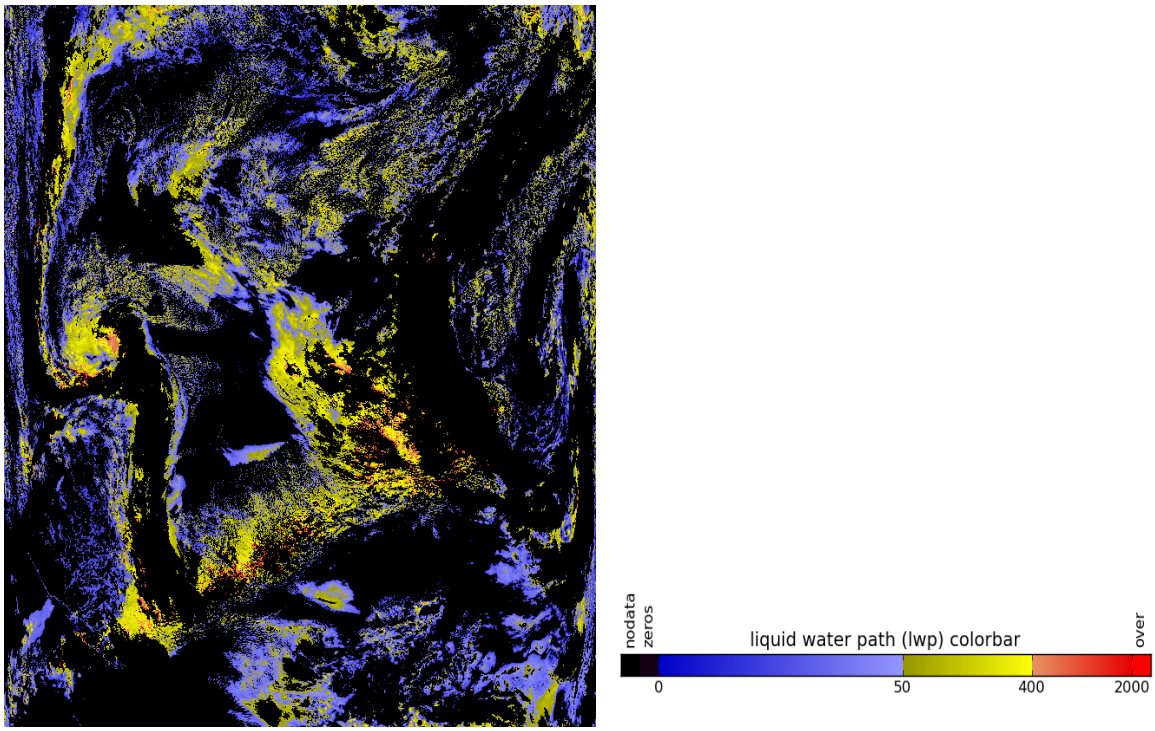


Figure 8 Cloud Physical Properties products: Liquid Water Path (colour scale in g/m^2)

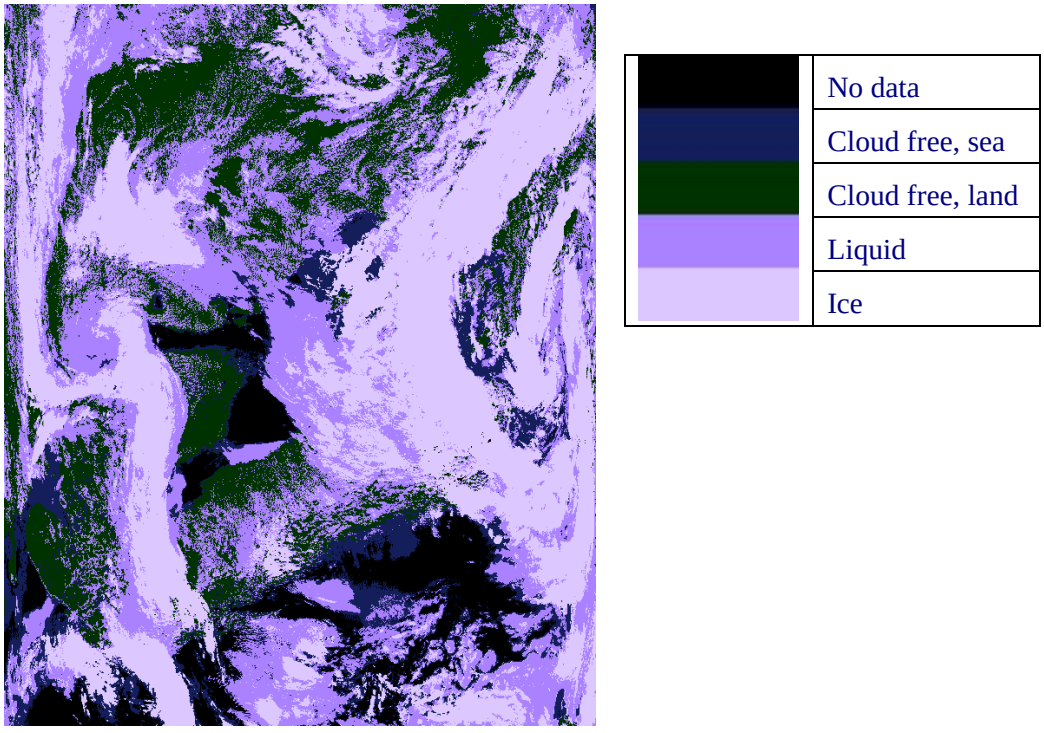


Figure 9 Cloud physical properties product: Cloud Phase

Table 15: Cloud Physical Properties, cloud phase classes

value	class
1	Cloud phase: liquid
2	Cloud phase: ice
255	No data

2.4.5.2 Additional output

The liquid water path and the ice water path (additional product) are kind of complementary. Liquid water path only has values in locations where cloud phase is 'water', while ice water path only has values in location where cloud phase is 'ice'. While the product cloud water path displays both liquid water path and ice water path.

The effective radius is given in m. But please note that the typical values are in the scale of µm. The cloud optical thickness is a dimensionless quantity with values from 0 and up.

It is also worth to notice that ice water path, cloud optical thickness and effective radius only works at daylight. –Just as for the liquid water path, described above.

The extended cloud phase, with more classes than the normal cloud phase, is described in Table 16.

Table 16: Cloud Physical Properties, extended cloud phase classes

value	class
2	Fog
3	Cloud phase: liquid
4	Super cooled
5	Mixed cloud phases
6	Opaque
7	Cirrus
8	Overlap
255	No data

2.4.5.3 Quality and condition flag

The quality flag and the conditions flag are the same for all pge:s, see description as for the Cloud Mask (2.4.1.2.1). For the CPP product, the flag for bad quality is set when the retrieval quality of cloud optical thickness and effective radius is bad. The flag for questionable quality is set when there is snow or ice on

the ground, or when the cloud phase value was changed during processing. The reclassified/interpolated flag is set when cloud phase value is changed to clear during processing.

The status flag has got different meanings for different PGE:s. Here is described the meaning of the status flag for the cloud physical properties product.

Table 17: CPP, status flag

Status flag	
bit number	**meaning of the bit**
0	Cloud free
1	Bad optical conditions (e.g. night)
2	Suspected snow or ice
3	1.6 µm channel used
4	3.8 µm channel used

A flag is set to 1 if the condition described (e.g. cloud free) applies; otherwise it is set to 0.

3. IMPLEMENTATION OF THE PRODUCTS

Three main steps are identified. The preparation and execution steps are always needed. If wanted, the products can afterwards be remapped to regions.

More about the implementation can be found in Software User Manual ([RD.9] and [RD.10]).

3.1.1 The preparation step:

Good to know is that before the execution of the cloud products a preparation step must be run. This preparation step includes the computation for the specific scene of:

- AVHRR/VIIRS data
- the solar & satellite angles
- the monthly climatological & atlas maps
- NWP data
- the thresholds for the algorithm
- emissivity data (configurable)
- OSISAF ice maps (configurable)

Most of the preparations are required for all products. For Cloud Mask and Cloud Type there is an additional common preparation step. The Cloud Top product and Precipitating Clouds each have their own additional preparation step.

3.1.2 The execution step:

The execution step is the processing of the algorithms for each product. It is using the data and thresholds prepared during the preparation step. Some of the PPS products depend on other PPS products, e.g. Cloud Type requires Cloud Mask as input.

3.1.3 Products on region

The product processing is performed in satellite projection. If the products are wanted on a certain region, a script has to be run after the execution step, to remap the products on the region. The user can define the region(s) he wants to have; instructions can be found in Software User Manual ([RD.10]).

4. INPUTS AND CONFIGURABLE PARAMETERS

4.1 LIST OF INPUTS

The package is built for real-time processing on AVHRR (1 km full resolution) data from NOAA- and Metop-scenes. For version 2012 and later it is also possible to process 750m resolution data from the VIIRS instrument on-board the NPP satellite, and planned for the JPSS satellites. VIIRS processing applies to all products except for the Precipitating Clouds product.

It is also possible to process 1km resolution data from the MODIS instrument on-board the EOS satellites Terra and Aqua. This applies to the Cloud Mask, Cloud Type and Cloud Top products. This processing, however, is neither supported nor is it possible to apply in real-time operations.

Additional input data needed is NWP-data (from ECMWF or Hirlam) and ice maps from OSISAF. The package can also be run without ice cover data.

Read more about the input in Software User Manual ([RD.10]) and in the ATBD documents ([RD.2], [RD.3], [RD.4], [RD.5] and [RD.6]).

4.1.1 Cloud Mask

Following input is used for the generation of Cloud Mask:

- NWP surface temperature
- NWP 950 hPa temperature
- NWP Total precipitable water
- Sun zenith, satellite view zenith, and sun-satellite view relative azimuth difference angle
- 1km Landuse data (including land/sea mask)
- 1km Digital elevation map
- OSISAF ice maps
- AVHRR/VIIRS data
- Emissivity maps

4.1.2 Cloud Type

Following input is used for the generation of Cloud Type:

- NWP surface temperature
- NWP temperature at several vertical levels (e.g. 950,850,700,500, and tropopause)
- Sun zenith, satellite view zenith, and sun-satellite view relative azimuth difference angle
- 1km Landuse data (including land/sea mask)

- 1km Digital elevation map
- Output from Cloud Mask
- AVHRR/VIIRS data

4.1.3 Cloud Top Temperature and Height

Following input is used for the generation of Cloud Top Temperature and Height:

- NWP temperature at several vertical pressure levels
- NWP relative humidity at several vertical pressure levels
- NWP temperature and pressure at tropopause
- Sun zenith, satellite view zenith, and sun-satellite view relative azimuth difference angle
- 1km Landuse data (including land/sea mask)
- 1km Digital elevation map
- Output from Cloud Mask
- Output from Cloud Type
- AVHRR/VIIRS data

4.1.4 Precipitating Clouds

Following input is used for the generation of Precipitating Clouds:

- NWP surface temperature
- Sun zenith, satellite view zenith, and sun-satellite view relative azimuth difference angle
- 1km Landuse data (including land/sea mask)
- 1km Digital elevation map
- Output from Cloud Type
- AVHRR data
- MW data (optional)

4.1.5 Cloud Physical Properties

Following input is used for the generation of Cloud Physical Properties:

- NWP surface temperature
- NWP total integrated water vapour

- NWP snow depth and snow albedo (both are optional)
- OSISAF ice maps (optional)
- Sun zenith, satellite view zenith, and sun-satellite view relative azimuth difference angle
- 1km Landuse data (including land/sea mask)
- AVHRR/VIIRS data
- Output from PPS Cloud Mask
- Output from PPS CTTH (optional)

4.2 CONFIGURABLE PARAMETERS

SAFNWC/PPS has been designed to allow a full configuration. That means that the implementation of the application includes minimum information about processing of the PGEs and secondary actions. All this data is submitted in several configuration files, and therefore it can be configured according to the user's preferences.

Possible configuration is for example:

- Processing methods configuration. Examples: Which product should be generated and for which satellites, generation of flags, log files etc.
- Input and output: Examples: Where to find/put it, what kind of input should be used for the generation.

The possible configurable parameters are described in the Software User Manual ([RD.10]).

5. VALIDATION

5.1 SUMMARY OF VALIDATION RESULTS

The latest validation of CMa, CT and CTTH is made for SAFNWC/PPS v2014 with matchup data from two hundred scenes of NOAA/NPP, matched with CloudSat/CALIPSO data. The validation result shows that quite some of the threshold accuracies are reached, though not all. For CMa, v2014, there has also been made validation against synop data, globally.

For PC latest validation was made for SAFNWC/PPS v2008. It showed that all threshold accuracies are reached, and mostly target accuracy too. Anyhow, few changes in PGE04 are made since.

For CPP the latest validation is made for SAFNWC/PPS v2014 with matchup data from fifty scenes of NOAA, matched with CloudSat/CALIPSO and AMSR-E data. The validation result shows that for CPP all threshold accuracies are reached, and also quite some of the target accuracies.

5.1.1 Cloud Mask

In Table 18 we see the results of the PPS Cloud Mask version 2014, validated with CloudSat/CALIPSO data. As a reference and for comparison we present the results also for the MODIS Cloud Mask against CALIPSO.

Table 18 Accuracy measures and verification scores for the PPS cloudmask (version 2014) as compared to CALIPSO and the MODIS Cloud Mask (available in the CALIPSO files). Shown are the grand total findings, accuracies divided by lighting conditions, as well as the required accuracies. HR denotes the hit rate and N the number of matching pixels

Observed Accuracy							
	BIAS %	HR	POD-cloudy%	FAR-cloudy %	POD-clear %	FAR-clear %	N
PPS (all)	-10.2	0.84	82.4	4.5	88.9	36.4	775229
MODIS (all)	-4.6	0.87	89.0	5.1	81.7	33.7	
PPS day	-5.5	0.87	88.0	5.1	85.6	30.1	296104
MODIS day	-5.2	0.88	89.0	4.3	86.4	29.9	
PPS night	-12.3	0.83	79.5	4.0	91.5	36.3	336888
MODIS night	-4.9	0.87	88.7	5.4	76.8	40.2	
PPS twilight	-15.2	0.80	77.2	4.0	88.6	47.4	142307
MODIS twilight	-2.1	0.88	90.3	6.6	82.2	24.6	

Requirement Accuracy		
Threshold POD	Target POD	Optimal POD
85%	95%	98%
Threshold FAR	Target FAR	Optimal FAR
20%	10%	5%

In Table 19we see the results of the PPS Cloud Mask version 2014, validated with synop data. The Cloud Mask has been produced with GAC-data, thus they are spread out globally.

Table 19 Accuracy measures and validation scores for the PPS CMa (version 2014) for 99 GAC orbits against global Synop reports

Observed Accuracy									
	RMS	**MAE**	**Hit rate**	**Bias (%)**	**Pod cloudy**	**Far cloudy**	**Pod clear**	**Far clear**	**N**
All	2.26	1.49	0.901	0.41	0.935	0.058	0.765	0.260	20298
Day	1.96	1.31	0.933	-0.62	0.950	0.030	0.845	0.238	12861
Night	2.77	1.83	0.841	4.01	0.908	0.123	0.667	0.265	5966
Twilight	2.58	1.71	0.870	-4.56	0.896	0.055	0.746	0.403	1471
Target Accuracy (globally)									
		MAE	Hit rate	**Bias (%)**	**Pod cloudy**	Far cloudy	Pod clear	Far clear	N
Threshold Accuracy					**> 0.85**	**< 0.20**			
Target Accuracy					**> 0.90**	**< 0.15**			
Optimal Accuracy					**> 0.95**	**< 0.10**			

5.1.2 Cloud Type

For a validation of the cloud type, we use the classification provided with the CALIPSO data. The CALIPSO cloud types can be condensed into three height classes, which are low level, medium level and high level clouds (low level clouds > 680hPa, medium level 680-440hPa, high level <440hPa).

Table 20 Basic accuracy descriptors for the cloud classes of low, medium and high clouds. Bc RMS denotes the bias corrected RMS and HR the hit rate.

Observed Accuracy					
	Bias %	bc RMS%	POD %	FAR %	HR
All: Low	-11.43	45.6	53.5	26.5	0.86
Medium	-2.81	43.7	38.1	61.5	0.79
High	-1.33	46.4	69.4	39.1	0.82
Day: Low	-14.16	46.3	51.1	22.7	0.83
Medium	-3.43	43.9	41.1	54.0	0.75
High	2.63	45.2	68.0	45.0	0.83
Night: Low	-7.85	58.4	58.4	31.3	0.89
Medium	-0.44	35.8	35.8	70.8	0.82
High	-5.44	71.2	71.2	32.2	0.82
Twilight: Low	-13.09	46.8	50.4	25.0	0.87
Medium	-6.67	46.1	34.9	58.7	0.82
High	-1.53	49.1	66.8	45.4	0.80

Required Accuracy			
	Threshold	Target	Optimal
POD	50%	70%	80%
FAR	60%	40%	20%

In Table 20 is seen that the threshold requirements are met for low and high clouds. But the detection level of medium level clouds misses somewhat.

5.1.3 Cloud Top Height

The validation of the cloud top height is investigated and Table 21 present result and requirements.

Table 21 Observed and required accuracies for the cloud top heights

Observed Accuracy						
	Semi-transparent			Opaque		
Bias	177 m			-421 m		
bc-RMS	2037 m			1896 m		
Required Accuracy						
	Semi-transparent			Opaque		
	Threshold	Target	Optimal	Threshold	Target	Optimal
Bias	2000 m	1500 m	200 m	1000 m	500 m	200 m
bc-RMS	2000 m	1500 m	500 m	2000 m	1500 m	500 m

From the Table 21 we can see that the CTTH product, both semi-transparent and for opaque clouds, reaches or just misses the threshold accuracy in terms of RMS. For the semi-transparent product the optimal accuracy is reached in terms of bias, and for the opaque product the threshold accuracy is reached.

5.1.4 Precipitating Clouds

Only minor technical changes have been done in PGE04, as well for version 2009, as for versions 2010, 2012 and 2014. Therefore we refer to the extensive validation of PGE04 that was done for the release 2008. From Table 22, it is clear that version 1.3 (i.e. the release of 2008) meets and exceeds the threshold accuracy in all classes. The product requirement is Table 23, is the requirements valid for PPS v2014, and they are fulfilled.

Users visualizing the PC product using probability alone can use a threshold for precipitation of 20% for class 1 through 3. This was found to impact the product only minimally.

Table 22 PGE04 statistics, POD per intensity class, for all seasons, satellites and entire year

Precipitation Class	Probability of Detection
No PCPN	83%
Light PCPN	55%
Moderate + Heavy PCPN	68%

Table 23 PGE04 statistics, compared to product requirements

	POD	FAR
Achieved performance	0.62	0.67
Threshold accuracy	> 0.55	> 0.70
Target accuracy	> 0.65	> 0.65
Optimal accuracy	> 0.80	> 0.50

5.1.5 Cloud Physical Properties

The validation of the CPP cloud phase and liquid water path show that both algorithms met the specified requirements. While the cloud phase product has been validated over both land and sea, the LWP product has only been properly validated over sea. Though there has been made a comparison with MODIS liquid water path, split in land and sea, and it show about as good performance over land as over sea.

The CPP cloud phase is validated against the CALIOP instrument on board the CALIPSO platform. The threshold accuracy, POD and FAR, is met for all scores under investigation, see Table 24.

The validation of the CPP liquid water path is made against the Advanced Microwave Scanning Radiometer for EOS (AMSR-E) instrument on board the Aqua satellite. This validation is only made over sea. The root mean square deviation (RMS) error for all four studies months are under the threshold accuracy. The general tendency is an underestimation of low values and overestimation of high LWP values. The bias lies under the threshold accuracy. See Table 25.

For all details, we refer to the Product Validation Report ([RD.11]).

Table 24 Validation results, and required accuracies, for CPP Cloud Phase. Verified against CALIOP data

	Hit rate	POD liquid	FAR liquid	POD solid	FAR solid
Achieved performance	0.76	0.73	0.18	0.80	0.30
Threshold accuracy		≥ 0.70	≤ 0.35	≥ 0.60	≤ 0.35
Target accuracy		≥ 0.80	≤ 0.20	≥ 0.80	≤ 0.20

Optimal accuracy		≥ 0.90	≤ 0.10	≥ 0.90	≤ 0.10

Table 25Validation results, and required accuracies, for CPP Liquid Water Path. Verified against AMSR-E data. Validation only over sea.

	RMS [g/m²]	Bias [g/m²]
Achieved accuracy	45.4	3.6
Threshold accuracy	≤ 100.	≤ 20.
Target accuracy	≤ 50.	≤ 10.
Optimal accuracy	≤ 20.	≤ 5.

5.2 KNOWN PROBLEMS AND LIMITATIONS

There are not yet any methods in PPS to extract useful micro-wave information from the NPP satellite. Therefor the Precipitating Clouds product can not be produced on NPP data with full quality.

The Cloud Physical Properties product only give a product while day light (sun zenith angle below 72 degrees), except for the cloud phase which works at all time of the day.

The Liquid Water Path (part of Cloud Physical Properties product) is not validated over land, only over sea.

6. EXAMPLE OF PRODUCT VISUALISATION

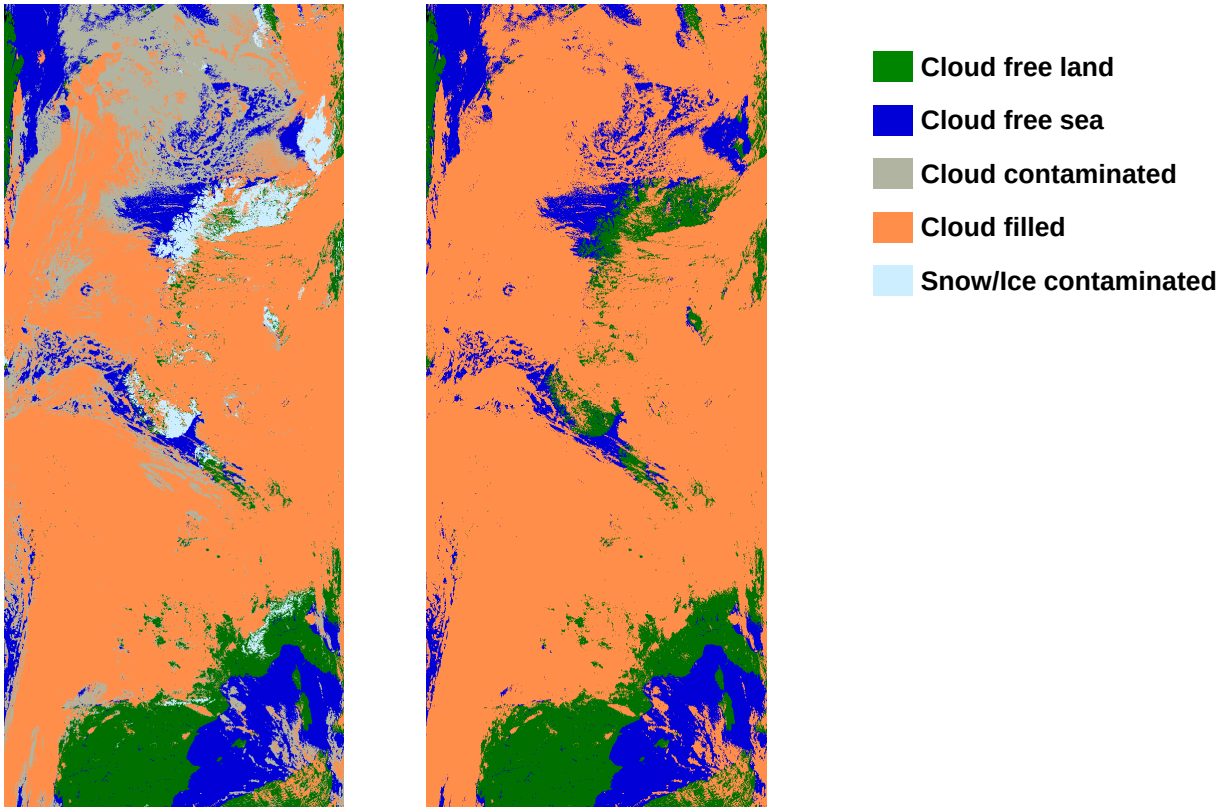
It is important to note that the products are not just images, but numerical data. At first hand, for example the CT is rather thought to be used digitally (together with the appended flags) as input to mesoscale analysis models, objective Nowcasting schemes, but also in the extraction of other SAFNWC products (CTTH for example).

Colour palettes are included in HDF files, allowing an easy visualisation. And while processing the product, png/jpg files can be produced at the same time, for an even easier visualisation.

Following examples is all from January 13th over southern Scandinavia. They are all produced by version 2.0 of SAFNWC/PPS, which was operational at that time.

6.1 CLOUD MASK

Some news for the Cloud Mask for PPS v2014 is a binary cloud mask, which will be produced side-by-side with the since before existing cloud mask (a.k.a. extended cloud mask). The binary cloud mask has only two classes: cloudy and cloud free (and also no data, e.g. if missing input data). For an example of both products see Figure 10.



extended cloud mask binary cloud mask

Figure 10 Cloud Mask and Binary Cloud Mask

The output and the quality flag is visualised together. This example is from 1015UTC. In the north-western part is the snow covered area well presented.

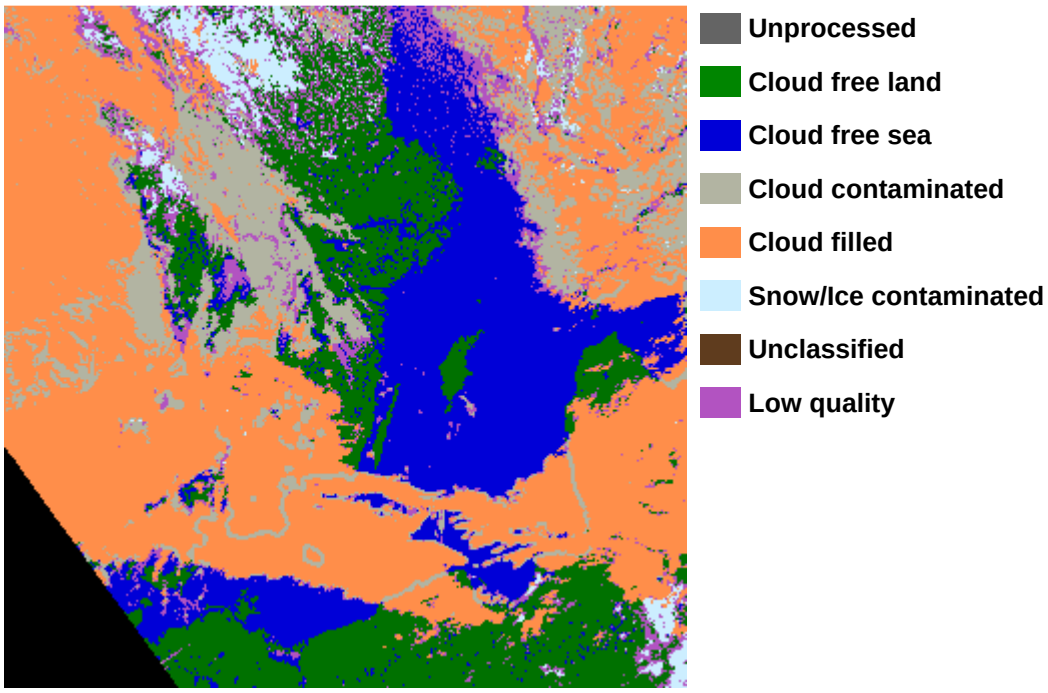
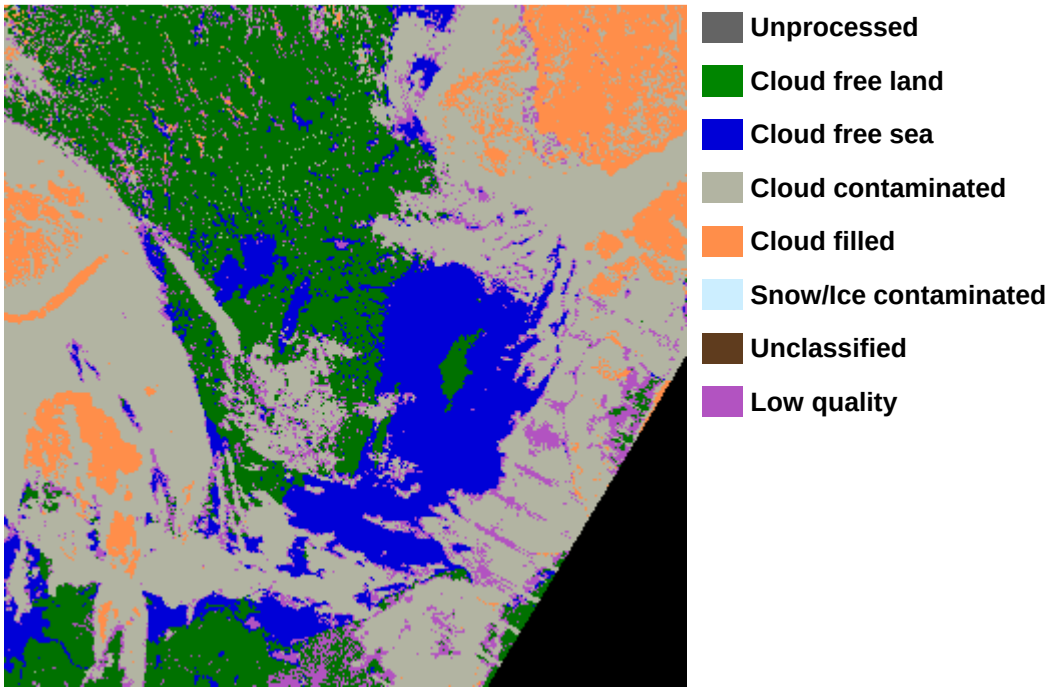
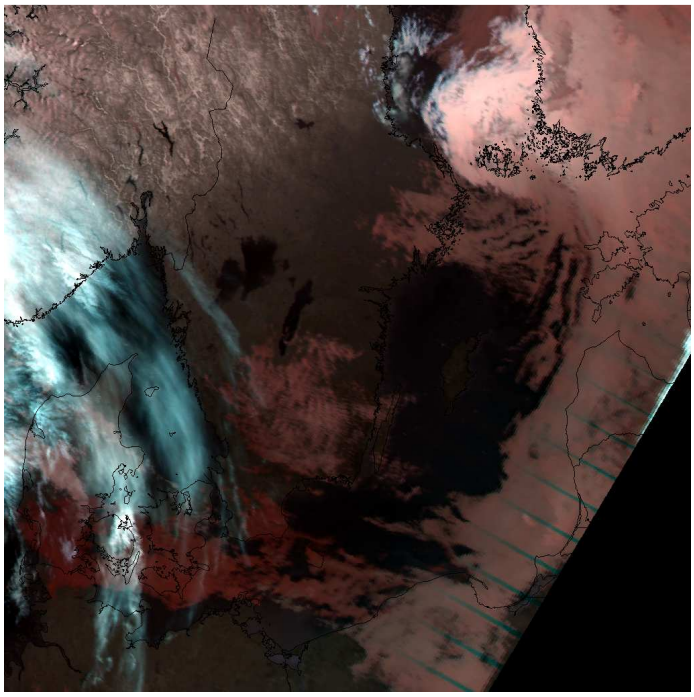


Figure 11: Cloud Mask UTC1015, main output and quality flag

Earlier in the morning with a very low sunzenith angle the Cloud Mask product has some problem to identify the snow:





Reference image

RGB Ch 3,4,5

Figure 12: Cloud Mask,UTC 0805-twilight

6.2 CLOUD TYPE

The cloud type classification works good, except for in certain situations: at twilight and in winter conditions with very cold surface temperatures.

First is the Cloud Type product output for UTC 1015:

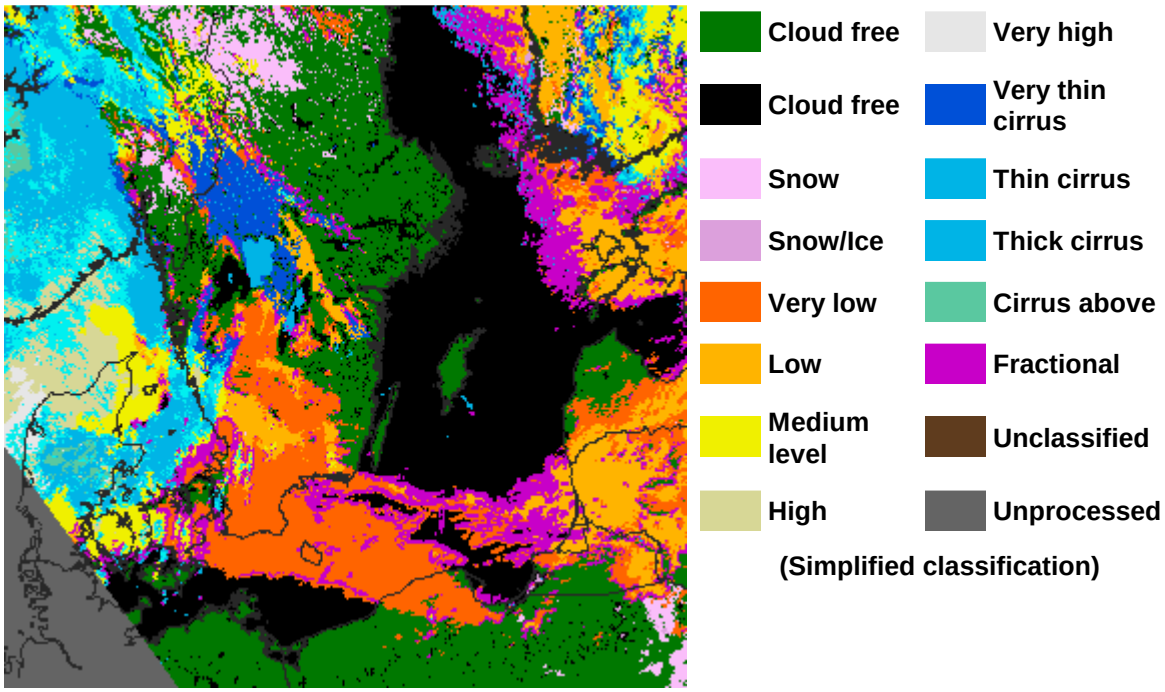


Figure 13: Cloud Type UTC1015

But, also for Cloud Type, snow is missing for low sun zenith angle situations (UTC0805). To be compared to the example for Cloud Mask. The low clouds over southern Sweden however are captured.

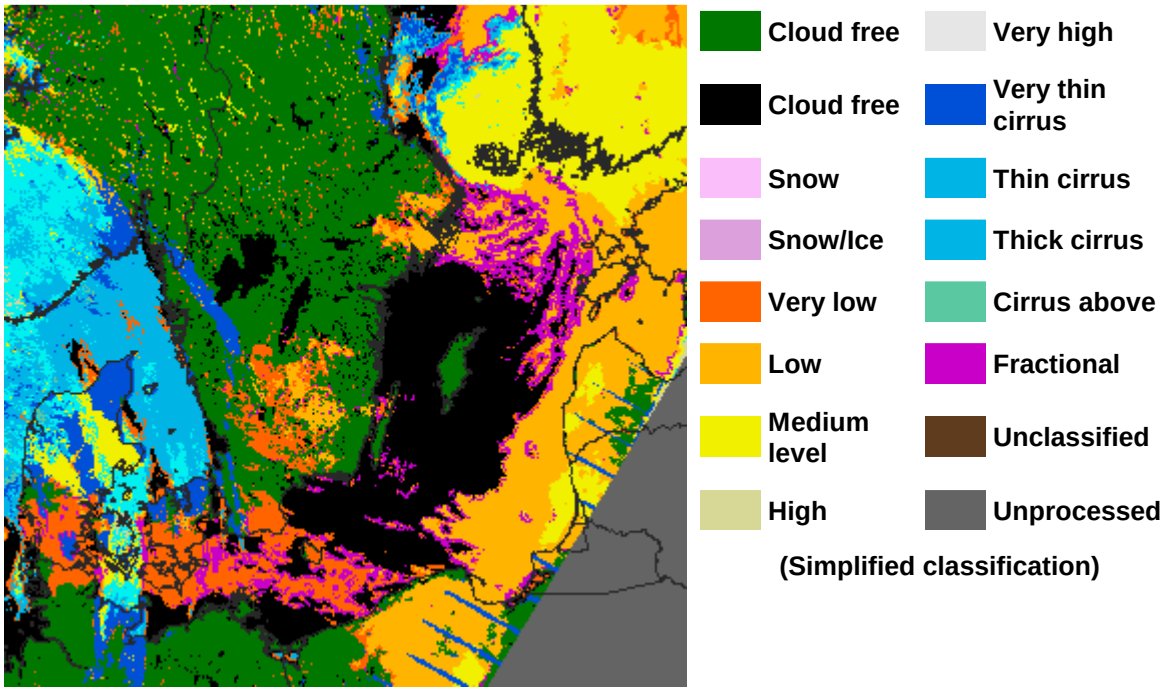
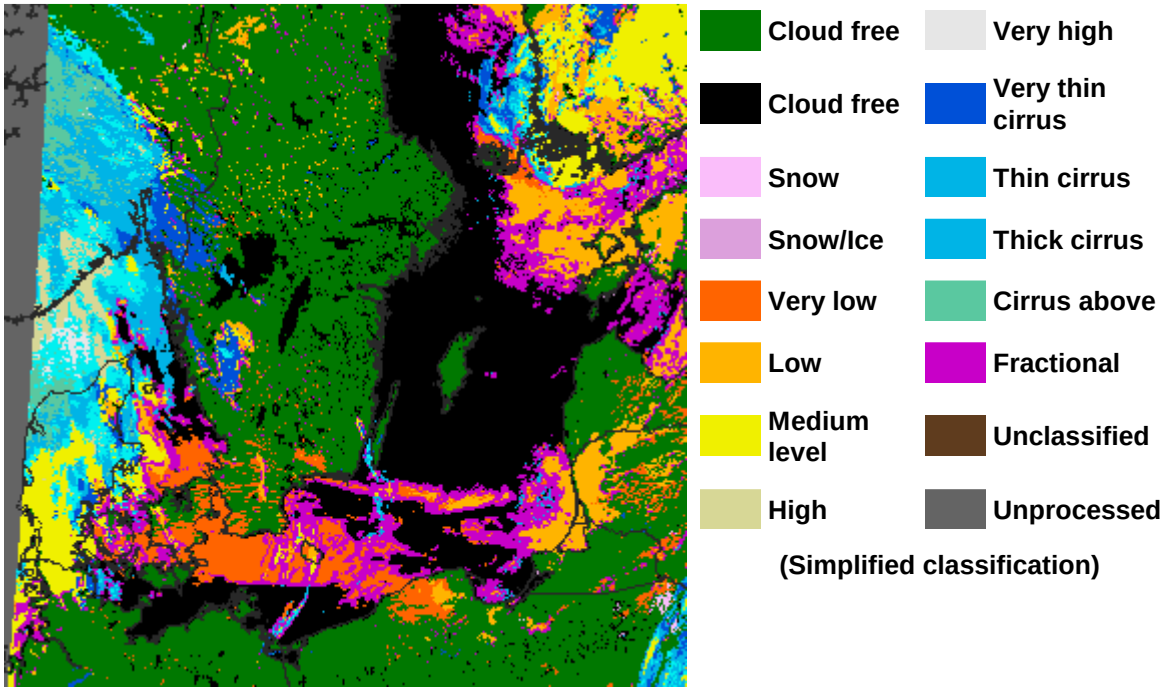
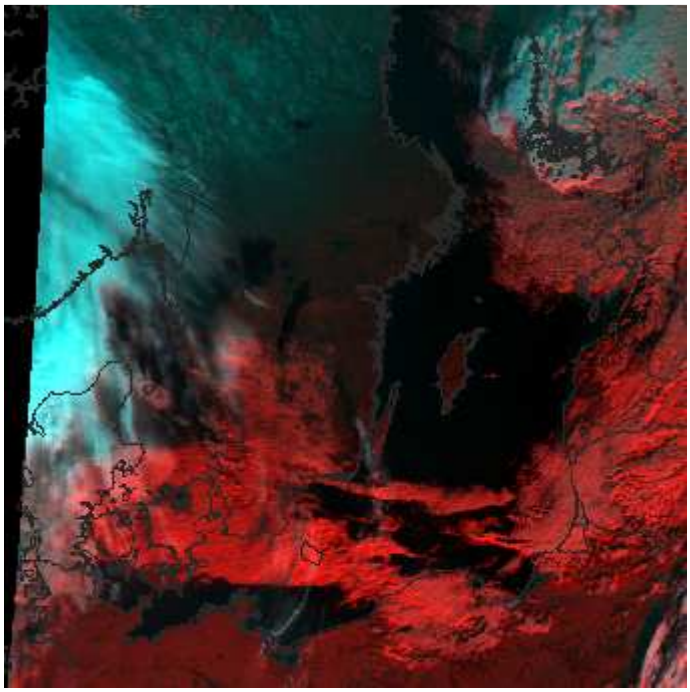


Figure 14: Cloud Type UTC0805- twilight

A bit later in the morning, but still low sun zenith angle, the low clouds over cold surface (southern Sweden) are not captured as expected. Compare the CT cloud classification to the RGB (ch 3,4,5).





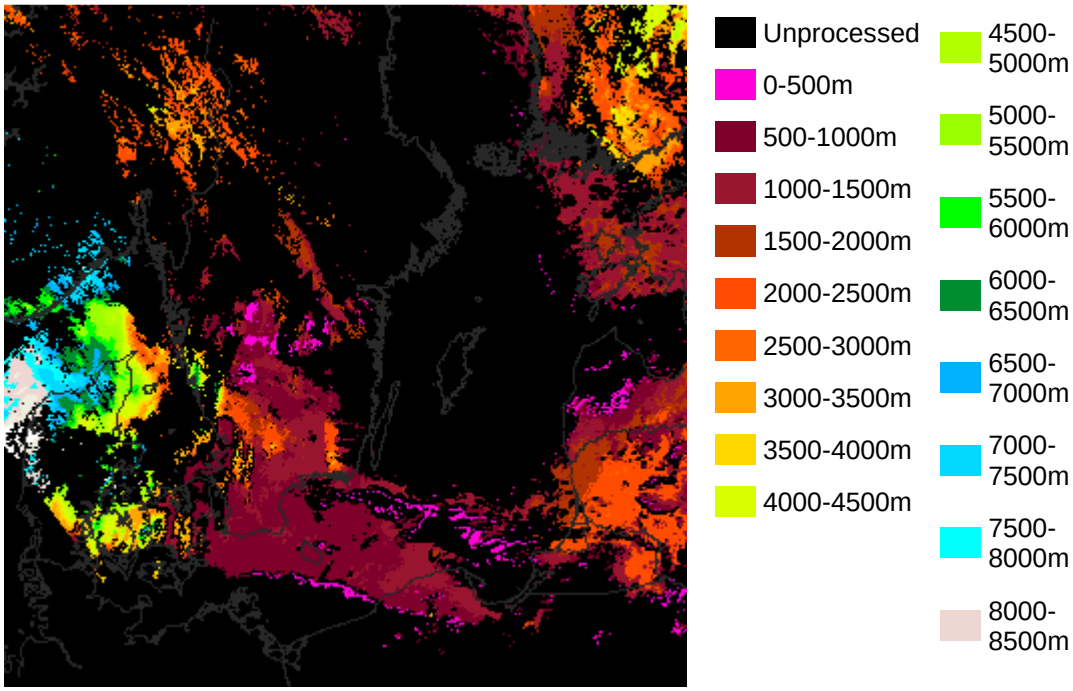
Reference image

RGB Ch 3,4,5

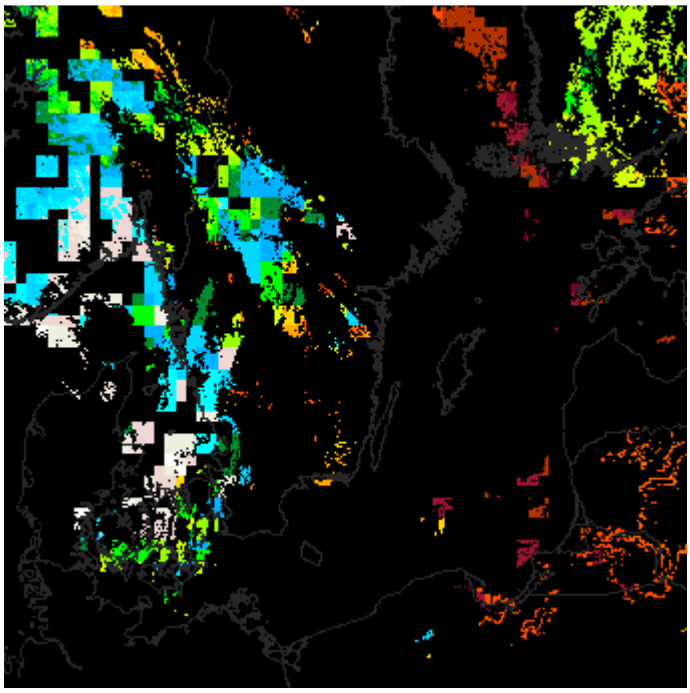
Figure 15: Cloud Type UTC0840

6.3 CLOUD TOP TEMPERATURE AND HEIGHT

The Cloud Top Temperature and Height is generated based on the output from the Cloud Mask and the Cloud Type. The Cloud Top Height is generated separately for the Opaque clouds and for the Semi-transparent clouds. You can look at the images for each of them, but they are also combined to an image containing both. The results are shown below, corresponding to the examples for CMa and CT.



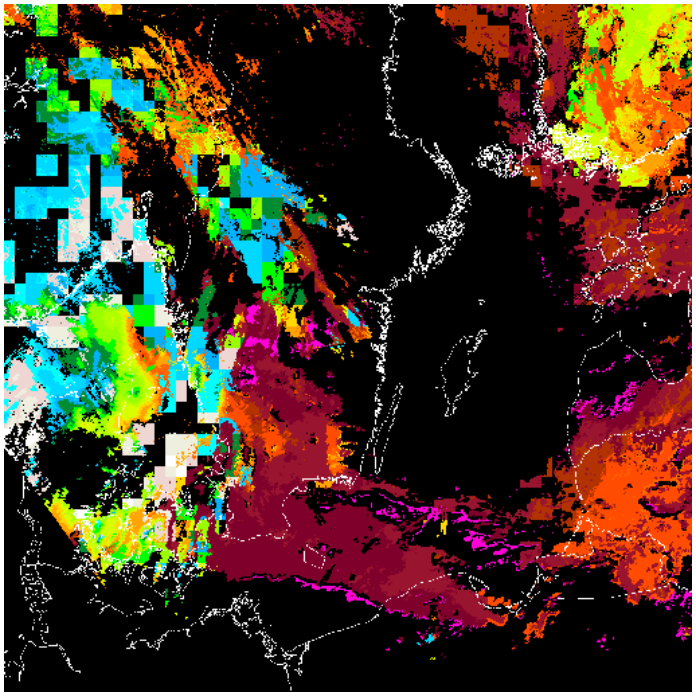
8500m-



Height of opaque clouds (above) and semi-transparent clouds (below).

Note the effect of the windowing technique for the semi-transparent clouds.

Figure 16: Cloud Top Temperature and Height UTC1015

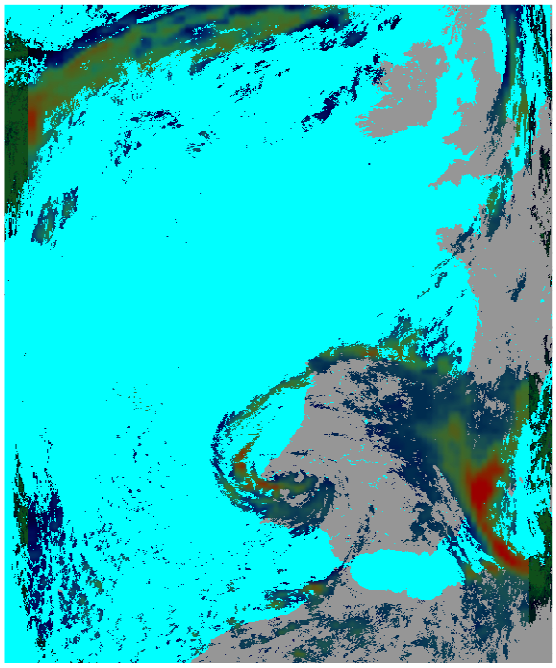


Cloud top height, a combination of opaque clouds and semi-transparent clouds. Compare with the two images above

Figure 17: Cloud Top Temperature and Height UTC1015, combined product

6.4 PRECIPITATING CLOUDS

An example of a visualisation of the Precipitating Cloud product is shown here. (To be exact, this is not the same scene as for the products above, but it is the same scene as for the Cloud Physical Properties product.)



Colour coding:
The image of the precipitating clouds product is created as a colour composite where:

- **layer 1 (red) is assigned to the probability for precipitation intensity class 3, *intensive precipitation*,**
- **layer 2 (green) is assigned to the probability for precipitation intensity class 2, *light/moderate precipitation*, and**
- **layer 3 (blue) is assigned to the probability for class 1, *risk for precipitation*.**

Figure 18: Precipitating Clouds UTC1336

6.5 CLOUD PHYSICAL PROPERTIES

There are two official products within the Cloud Physical Properties product and three additional products. An example of visualisation for each of them is shown here.

This example is in late November at 13:36. We can see it as an example of the need for daylight. Upper right part is over England and Ireland while the central part is off the coast of Spain. Over England the daylight is in this case not enough for the Cloud Physical Properties product, thus being no-data there.

The same colour bar is used for liquid water path and ice water path:

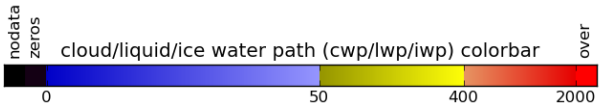


Figure 19: Colour scale used for liquid water path, as well as ice water path (ing/m^2)

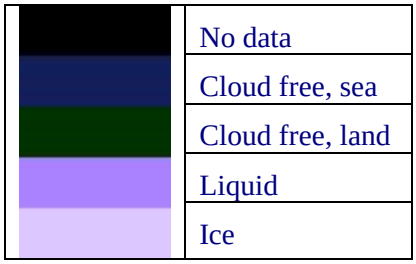
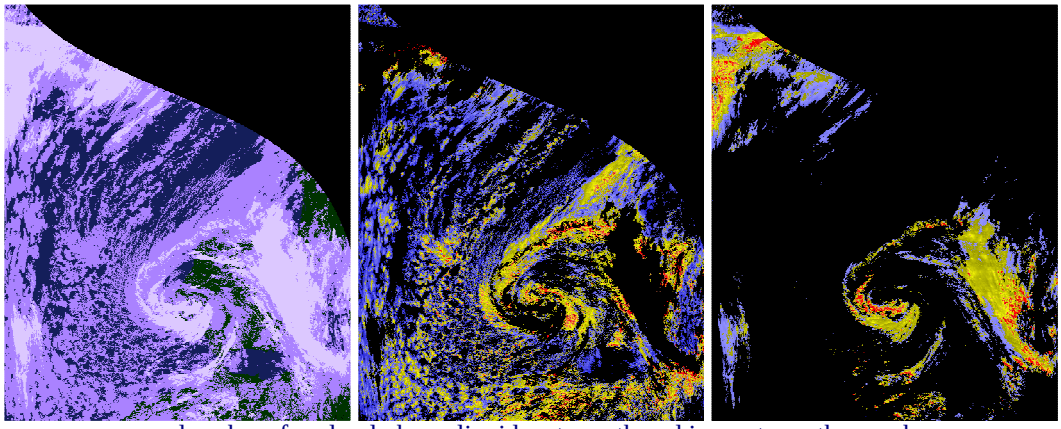


Figure 20 Colour scale used for cloud phase

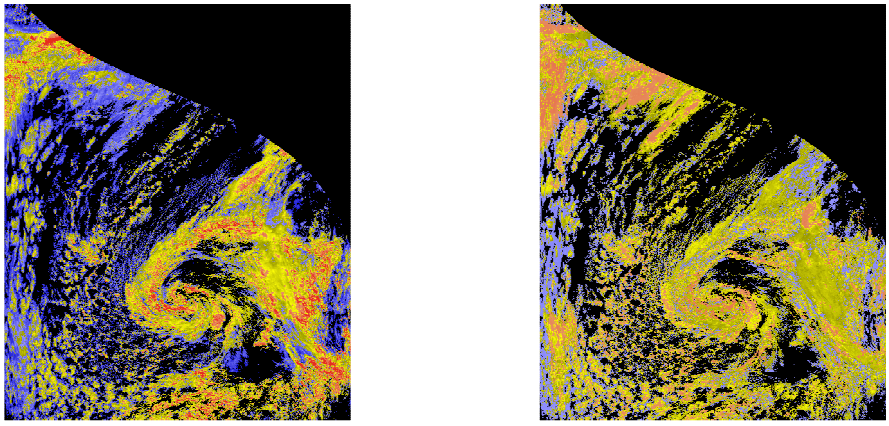
Below all outputs Cloud Physical Properties products are displayed. Also a Cloud Type and an RGB (0.6µm, 0.8µm, 11µm) are displayed, for comparison.

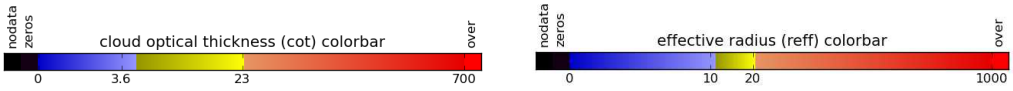
cloud phase ***liquid water path*** ***ice water path***



colour bars for cloud phase, liquid water path and ice water path, see above

cloud optical thickness ***effective radius***





cloud type ***rgb***

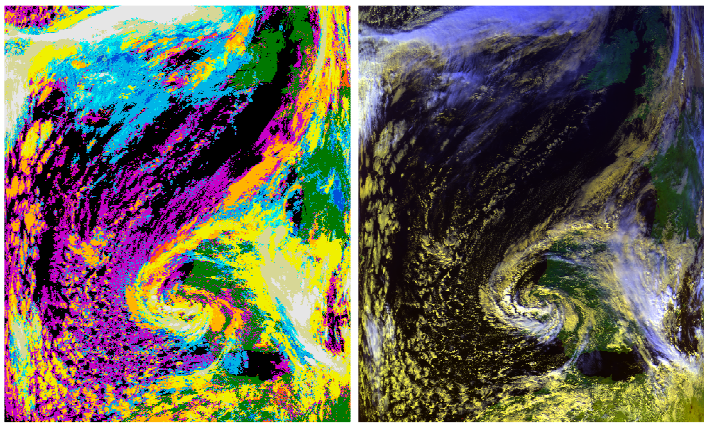


Figure 21: Cloud Physical Properties UTC1336

ANNEX A. List of TBC, TBD, Open Points and Comments

TBD/TBC	Section	Resp.	Comment