

Product User Manual for “Cloud Products” (CMA-PGE01, CT-PGE02 & CTTH-PGE03 v1.4)

SAF/NWC/CDOP/MFL/SCI/PUM/01, Issue 1, Rev. 4

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Applicable to SAFNWC/MSG version 2008

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Reviewed by	MF/DP/CMS		<i>07 November 2007</i>
Authorised by	L. F. López Cotín SAFNWC Project Manager		<i>7 November 2007</i>

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1.4	7 November 2007	30	Initial version (content derived from “User manual for PGE01-02-03 v1.3 (Cloud Products) of the SAFNWC/MSG: scientific part”)


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1. INTRODUCTION

1.1 SCOPE OF THE DOCUMENT

This document is the Product User Manual for MSG cloud products PGE01 (CMa), PGE02 (CT) and PGE03 (CTTH).

This document contains practical information on the characteristics of the above mentioned products, on their applicability and limitations.

1.2 SCOPE OF OTHER DOCUMENTS

The algorithms used to extract the MSG Cloud Products PGE01 (CMa), PGE02 (CT) and PGE03 (CTTH) are detailed in an Algorithm Theoretical Basis Document ([AD. 4]).

The validation of the algorithms used to extract the MSG Cloud Products PGE01 (CMa), PGE02 (CT) and PGE03 (CTTH) is reported in a validation report ([AD. 5]).

Instructions to install, configure and execute the SAFNWC/MSG software in order to extract the MSG Cloud Products PGE01 (CMa), PGE02 (CT) and PGE03 (CTTH) are detailed in a Software User Manual (AD. 3).

The Interface Control Documents (AD. 1) (for the External and Internal Interfaces of the SAFNWC/MSG) and (AD. 2) (MSG Output Product Format Definition) detail the input and output data format for the SAFNWC/MSG software.

1.3 SOFTWARE VERSION IDENTIFICATION


This documents describes the products obtained from the PGE01-02-03 version v1.4 of the 2008 SAFNWC/MSG software package delivery.

1.4 IMPROVEMENT FROM PREVIOUS VERSION

No algorithm improvement has been implemented since previous version, just a tuning to account for Eumetsat plans to change in 2008 the currently disseminated SEVIRI IR “spectral radiances” into “effective radiance” (see [AD. 6]).

1.5 DEFINITIONS, ACRONYMS AND ABBREVIATIONS

CMa	Cloud Mask (also PGE01)
CMS	Centre de Meteorologie Spatiales (Météo-France, satellite reception centre in Lannion)
CTTH	Cloud Top Temperature and Height
CT	Cloud Type
ECMWF	European Centre for Medium range Weather Forecast
EUMETSAT	European Organisation for the Exploitation of Meteorological Satellites
HDF	Hierarchical data Format
HRIT	High Rate Information Transmission
ICD	Interface Control Document
MSG	Meteosat Second Generation
NWP	Numerical Weather Prediction
PGE	Product Generation Element

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PUM	Product User Manual
R0.6μm	0.6 visible reflectance
RTTOV	Rapid Transmissions for TOVs
SAF	Satellite Application Facility
SAF NWC	SAF on support to NoWCasting and VSRF
SAF O&SI	Ocean and Sea Ice SAF
SEVIRI	Spinning Enhanced Visible & Infrared Imager
SW	Software
T11μm	11 micrometer infrared brightness temperature

1.6 REFERENCES

1.6.1 Applicable Documents


Reference	Title	Code	Vers	Date
[AD. 1]	Interface Control Document for the External and Internal Interfaces of the SAFNWC/MSG	SAF/NWC/IOP/INM/SW/ICD/1	2.0	
[AD. 2]	SAFNWC/MSG Output Products Format Definition	SAF/NWC/IOP/INM/SW/ICD/3	2.0	
[AD. 3]	Software User Manual for the SAFNWC/MSG application	SAF/NWC/IOP/INM/SW/SUM/2	2.0	
[AD. 4]	Algorithm Theoretical Basis Document for "Cloud Products" (CMA-PGE01, CT-PGE02 & CTTH-PGE03 v1.4)	SAF/NWC/CDOP/MFL/SCI/ATB D/01	1.4	07/11/07
[AD. 5]	Validation Report for "Cloud Products" (CMA-PGE01, CT-PGE02 & CTTH-PGE03 v1.4)	SAF/NWC/CDOP/MFL/SCI/VR/02	1.4	07/11/07
[AD. 6]	Change to the MSG Level1.5 Image product Radiance Definition	EUM/STG-OPS/21/07/DOC/04		20/02/07

Table 1: List of Applicable Documents

1.6.2 Reference Documents

Reference	Title	Code	Vers	Date
[RD.1]				
[RD.2]				

Table 2: List of Referenced Documents

 <p>SAF NWC METEO FRANCE Toujours un temps d'avance</p>	<p>Product User Manual for "Cloud Products" (CMa-PGE01, CT-PGE02 & CTTH-PGE03 v1.4)</p>	<p>Code: SAF/NWC/CDOP/MFL/SCI/PUM/01 Issue: 1.4 Date: 7 November 2007 File: SAF-NWC-CDOP-MFL-SCI-PUM-01_v1.4.doc Page: 9/30</p>
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2. CMA PRODUCT

2.1 DESCRIPTION OF CMA PRODUCT

2.1.1 Goal of CMa product

The cloud mask (CMa), developed within the SAF NWC context, aims to support nowcasting applications, and additionally the remote-sensing of continental and oceanic surfaces. The CMa allows identifying cloud free areas where other products (total or layer precipitable water, land or sea surface temperatures, snow/ice cover delineation) may be computed. It also allows identifying cloudy areas where other products (cloud types and cloud top temperature/height) may be derived.

The central aim of the CMa is therefore to delineate all cloud-free pixels in a satellite scene with a high confidence. In addition, the product provides information on the presence of snow/sea ice, dust clouds and volcanic plumes.

2.1.2 Outline of CMa algorithm

The algorithm is based on multispectral threshold technique applied to each pixel of the image.

A first series of tests allows the identification of pixels contaminated by clouds or snow/ice; this process is stopped if one test is really successful (i.e., if the threshold is not too close to the measured value). The characteristics of this set of tests are summed up below:

- The tests, applied to land or sea pixels, depend on the solar illumination and on the viewing angles and are presented in Table 3 and Table 4.
- Most thresholds are determined from satellite-dependent look-up tables (available in coefficients' files) using as input the viewing geometry (sun and satellite viewing angles), NWP forecast fields (surface temperature and total atmospheric water vapour content) and ancillary data (elevation and climatological data). The thresholds are computed at a spatial resolution (called "segment size") defined by the user as a number of SEVIRI infra-red pixels. Some thresholds are empirical constant or satellite-dependent values (available in coefficients' files).
- The quality of the cloud detection process is assessed.
- A spatial filtering is applied, allowing to reclassify pixels having a class type different from their neighbours.
- A test is applied to cloud contaminated pixels to check whether the cloud cover is opaque and completely fills the FOV.

This first series of tests allows to determine the cloud cover category of each pixel (cloud-free, cloud contaminated, cloud filled, snow/ice contaminated or undefined/non processed) and compute a quality flag on the processing itself. Moreover, the tests that have allowed the cloud detection (more that one test are possible, if some tests were not really successful) are stored.

A second process, allowing the identification of dust clouds and volcanic ash clouds, is applied to all pixels (even already classified as cloud-free or contaminated by clouds). The result is stored in the dust cloud and volcanic ash cloud flags.

Details on the tests are given in [AD. 4].

Daytime	Twilight	Nighttime
---------	----------	-----------

Snow detection	Snow detection	T10.8 μ m
T10.8 μ m	T10.8 μ m	T10.8 μ m-T12.0 μ m
R0.6 μ m	R0.6 μ m	T8.7 μ m-T10.8 μ m
T10.8 μ m-T12.0 μ m	T10.8 μ m-T12.0 μ m	T10.8 μ m-T8.7 μ m
T8.7 μ m-T10.8 μ m	T8.7 μ m-T10.8 μ m	T10.8 μ m-T3.9 μ m
T10.8 μ m-T3.9 μ m	T10.8 μ m-T8.7 μ m	T3.9 μ m-T10.8 μ m
T3.9 μ m-T10.8 μ m	T10.8 μ m-T3.9 μ m	Local Spatial Texture
Local Spatial Texture	T3.9 μ m-T10.8 μ m	T8.7 μ m-T3.9 μ m
	Local Spatial Texture	
	T8.7 μ m-T3.9 μ m	

Table 3: Test sequence over land

Daytime	Sunglint	Twilight	Nighttime
Ice detection	Ice detection	Ice detection	SST
SST	SST	SST	T10.8 μ m-T12.0 μ m
R0.8 μ m (R0.6 μ m)	T10.8 μ m-T12.0 μ m	R0.8 μ m (R0.6 μ m)	T8.7 μ m-T10.8 μ m
R1.6 μ m	T8.7 μ m-T10.8 μ m	R1.6 μ m	T10.8 μ m-T3.9 μ m
T10.8 μ m-T12.0 μ m	Local Spatial Texture	T10.8 μ m-T12.0 μ m	T12.0 μ m-T3.9 μ m
T8.7 μ m-T10.8 μ m	R0.8 μ m (R0.6 μ m)	T8.7 μ m-T10.8 μ m	T3.9 μ m-T10.8 μ m
T10.8 μ m-T3.9 μ m	T10.8 μ m-T3.9 μ m	T10.8 μ m-T3.9 μ m	Local Spatial Texture
T3.9 μ m-T10.8 μ m	Low Clouds in Sunglint	T12.0 μ m-T3.9 μ m	
Local Spatial Texture		T3.9 μ m-T10.8 μ m	
		Local Spatial Texture	

Table 4: Test sequence over sea

[T3.9 μ m, T8.7 μ m, T10.8 μ m and T12.0 μ m stand for brightness temperatures at 3.9, 8.7, 10.8 and 12.0 micrometer; R0.6 μ m, R0.8 μ m and R1.6 μ m stand for VIS/NIR bi-directional top of atmosphere reflectances at 0.6, 0.8 and 1.6 micrometer normalised for solar illumination; SST is the split-window (used for SST calculation) computed from T10.8 μ m and T12.0 μ m measurements. Low Clouds in Sunglint is a specific module for low clouds identification in sunglint areas.]

2.1.3 Description of CMA output

The description of CMA output (in HDF format) is detailed in AD. 2. This section summarizes the CMA output fields (a colour palette is also included in the HDF CMA output file for each field, see 2.5).

- **The main product output consists in the following six categories coded on 3 bits**

0	Non-processed	containing no data or corrupted data
1	cloud-free	no contamination by snow/ice covered surface, no contamination by clouds ;

- | | | |
|---|-----------------------|---|
| 2 | Cloud contaminated | but contamination by thin dust/volcanic clouds not checked partly cloudy or semitransparent. May also include dust clouds or volcanic plumes. |
| 3 | Cloud filled | opaque clouds completely filling the FOV. May also include thick dust clouds or volcanic plumes. |
| 4 | Snow/Ice contaminated | |
| 5 | Undefined | has been processed but not classified due to known separability problems |

- **16 bits to describe which test was successful**

For each cloudy pixel, the bits corresponding to the successful tests are activated. More than one bit may be activated, if tests were not really successful (measurement too close to thresholds).

- 0 T10.8 μ m or SST
- 1 R0.6 μ m (land) or R0.8 μ m (sea)
- 2 Sunlint test using 3.9 μ m
- 3 Local Spatial Texture
- 4 T10.8 μ m - T12.0 μ m
- 5 T10.8 μ m - T3.9 μ m or T12.0 μ m - T3.9 μ m
- 6 T3.9 μ m - T10.8 μ m
- 7 Spatial smoothing (reclassify isolated cloud-free pixels)
- 8 T8.7 μ m - T3.9 μ m
- 9 R1.6 μ m (sea)
- 10 T8.7 μ m - T10.8 μ m or T10.8 μ m - T8.7 μ m
- 11 Snow using R1.6 μ m
- 12 Snow using T3.9 μ m
- 13-15 spare

- **9 bits for quality**

3 bits to define illumination and viewing conditions:

- 0 Undefined (space)
- 1 Night
- 2 Twilight
- 3 Day
- 4 Sunlint

2 bits to describe NWP input data

- 0 Undefined (space)
- 1 All NWP parameters available (no low level inversion)
- 2 All NWP parameters available (low level inversion)
- 3 At least one NWP parameter missing


2 bits to describe SEVIRI input data

- 0 Undefined (space)
- 1 All useful SEVIRI channels available ;
- 2 At least one useful SEVIRI channel missing
- 3 A least one mandatory SEVIRI channel missing

2 bits to describe the quality of the processing itself:

- 0 Non processed (containing no data or corrupted data)
- 1 Good quality (high confidence)
- 2 Poor quality (low confidence)
- 3 Reclassified after spatial smoothing (very low confidence)

- **2 bits for dust detection**

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- 0 Non processed (containing no data or corrupted data)
- 1 dust
- 2 non dust
- 3 undefined (due to known separability problems)

- **2 bits for volcanic plume detection**

- 0 Non processed (containing no data or corrupted data)
- 1 volcanic plume
- 2 non volcanic plume
- 3 undefined (due to known separability problems)

2.2 IMPLEMENTATION OF CMA

CMA is extracted by PGE01 of the SAFNWC/MSG software package. Detailed information on how to run this software package are available in AD. 3.

Three main steps are identified. The user manually interacts with the CMA software during the installation step, the CMA preparation and execution steps being automatically monitored by the Task Manager (if real-time environment is selected).

2.2.1 The CMA installation step:

When a new region is defined and added in system and run configuration files, the user launches (only once) the command `mfcms_inst_pge01`. This command allows:

- The automatic elaboration of monthly climatological and atlas maps, as well as latitude/longitude and satellite angles information on the new region at the full IR horizontal resolution. These regional atlas and maps are extracted from maps available on the whole MSG disk.
- The automatic elaboration of the model configuration file. In this file, a default value of 4 is given to the size of segments (`Cma_szseg`). This default value may be manually changed. [Segments are square boxes in the satellite projection, whose size is expressed as the number of IR pixels of one edge of the square box. The size of the processed regions must be a multiple of the segment size. All the solar and satellite angles, the NWP model forecast values, the atlas values and the thresholds will be derived over all the processed regions at the horizontal resolution of the segment. Note also that the land/sea atlas will be available at the full IR resolution, allowing the identification of the surface type (land or sea) of all IR pixels, whatever the segment size. The quality is not very much dependent of the segment size (if lower than 4). A segment size of 4 allows the preparation step to be 9 times faster than if a segment size of 1 was used]
- The automatic set of pre-defined time scheduling (of the preparation step) in Programmed Task Definition Files.

2.2.2 The CMA preparation step:

The preparation step is performed by the command `mfcms_next_pge01` which is launched in advance of satellite data reception according to a pre-defined time scheduling set during the installation step.

This preparation step includes the computation on the region at the segment spatial resolution of:

- the solar & satellite angles,
- the monthly climatological & atlas maps,
- the thresholds for the CMA algorithm

2.2.3 The CMA execution step:

The execution step is the real-time processing of the SEVIRI images itself over the region. This process consists in the launch of the command: PGE01 by the Task manager. The cloud masking is then performed, using the thresholds prepared during the preparation step.

2.3 INPUTS AND CONFIGURABLE PARAMETERS FOR CMA

2.3.1 List of inputs for CMA

The input data to the CMA algorithm are described in this section. Mandatory inputs are flagged, whereas the impact of missing non-mandatory data on the processing are indicated.

- **Satellite imagery:**

The following SEVIRI bi-directional reflectances or brightness temperatures are needed at full IR spatial resolution:

R0.6 μ m	R0.8 μ m	R1.6 μ m	T3.9 μ m	T8.7 μ m	T10.8 μ m	T12.0 μ m	T13.4 μ m
Mandatory	Optional	Optional	Mandatory	Optional	Mandatory	Mandatory	Optional

The CMA software checks the availability of SEVIRI channels for each pixel. If non mandatory channels are missing for one pixel, the tests using these channels are not applied, or applied differently (for example, snow detection uses either R1.6 μ m or T3.9 μ m; visible channel test over the ocean uses either R0.8 μ m or R0.6 μ m) and a result is available for this pixel. No results are provided for pixels where at least one mandatory channel is missing.

The SEVIRI channels are input by the user in HRIT format, and extracted on the processed region by SAFNWC software package.

- **Sun and satellite angles associated to SEVIRI imagery**

This information is mandatory. It is computed by the CMA software itself, using the definition of the region and the satellite characteristics.

- **NWP parameters:**

The forecast fields of the following parameters, remapped onto satellite images, are used as input :

- surface temperatures (required to get good quality results over land ; but not mandatory)
- air temperature at 950hPa (alternatively 925hPa). Used to check low level inversion.
- total water vapour content of the atmosphere,
- altitude of the NWP model grid (alternatively surface geopotential on the NWP model grid). Required if NWP fields are used as input.

These remapped fields are elaborated by the SAFNWC software package from the NWP fields input by the user in GRIB format.

The NWP fields are not mandatory: the CMA software replaces missing NWP surface temperatures or total water vapour content of the atmosphere by climatological values extracted from ancillary dataset, but the quality of CMA is then lower.

- **Ancillary data sets:**

The following ancillary data, remapped onto satellite images, are mandatory :

- Land/sea atlas
- Land/sea/coast atlas
- Elevation atlas

- Monthly minimum SST climatology
- Monthly mean 0.6µm atmospheric-corrected reflectance climatology (land)
- Monthly integrated atmospheric water vapor content climatology
- Monthly climatology of mean air temperature at 1000 hPa

These ancillary data are available in the SAFNWC software package on MSG full disk in the default satellite projection at full IR resolution; They are extracted on the processed region by the CMa software itself.

Coefficients’s file (also called threshold tables), containing satellite-dependent values and look-up tables for IR thresholds and for solar channels’ thresholds, are available in the SAFNWC software package, and are needed by the CMa software.

2.3.2 Configurable parameters for CMa

The only configurable parameter is the size of the segment (see its definition in 2.2.1). Its default value is 4. Information on how to change the size of the segment can be found in the PGE01 pre-operation section of AD. 3.

2.4 CMA VALIDATION

2.4.1 Summary of CMA validation results

Table 5 summarises the validation results of the current version. More details can be obtained from [AD. 5].

PGE01 flags	Validated accuracy
<p>PGE01 cloud detection If validated over European areas using SYNOP observations</p>	<p>POD: 95.90%</p>
<p>PGE01 dust flag If validated over sea and Africa for solar elevation larger than 20 degrees using interactive targets</p>	<p>POD: 38.5% over sea 58.5% over land</p>

Table 5: Summary of validation results of the current PGE01 version (POD stands for Percentage Of Detection).[AD. 5]

2.4.2 Typical known problems and recommendation for use

The following problems may be encountered:

- Low clouds may be not detected in case low solar elevation, over both sea and land.
- It may happen that large areas of low clouds are not detected in night-time conditions over land. This can be the case in “warm sectors”, but also in areas viewed with high satellite zenith angles or if the low clouds are surmounted by very thin cirrus.
- Snowy grounds are not detected at night-time and are therefore confused either with low clouds or cloud free surface.
- False detection of volcanic ash clouds happens especially in daytime conditions (over low clouds and deserts surfaces), but also in night-time (over cold clouds). The volcanic ash clouds detection is not performed in case low solar elevation.

- Dust cloud detection is performed only at daytime. Over land, dust clouds are not well detected when the sun is low or if they are too thin. Over sea, large areas of dust may not be detected if their thermal signature is not strong enough. Moreover, wrong detection may be observed in oceanic regions.

The CMa product may be used to identify cloud-free surfaces for oceanic or continental surface parameters retrieval. Nevertheless, as some clouds remains undetected and to account for artefacts such as shadows or aerosols, the user should apply a post-processing which could include:

- the spreading of the cloud mask that should allow to detect cloud edges and mask shadows or moist areas near cloud edges
- the use of the cloud mask quality flag not to compute surface parameters in bad quality cloud free areas
- the implementation of an additional filtering based on the temporal variation around the current slot

2.5 EXAMPLE OF CMA VISUALISATION

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

Colour palettes are included in CMa HDF files, allowing an easy visualisation of CMa main categories, dust and volcanic ash clouds flags.

No example of CMa main categories's visualisation are given, as it is thought that the user will be more interested to visualize the CT product which can be seen as a refinement.

Example of visualisation of the dust cloud and the volcanic ash cloud flags superimposed on infrared images are given in Figure 1 and Figure 2 , using SEVIRI and MODIS imagery.

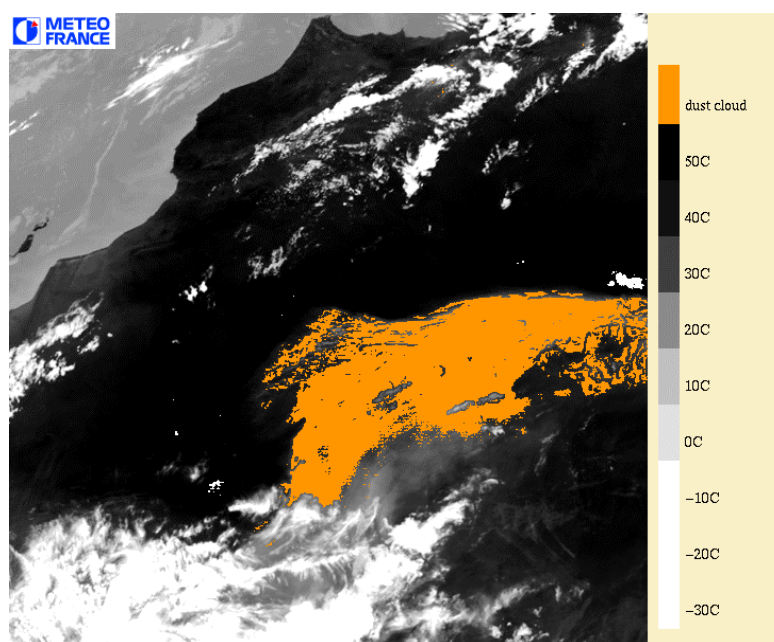


Figure 1: Example of SEVIRI dust cloud flag superimposed on a 10.8 μ m infrared image: dust cloud over North Africa on 14th July 2003 at 13h00 UTC.

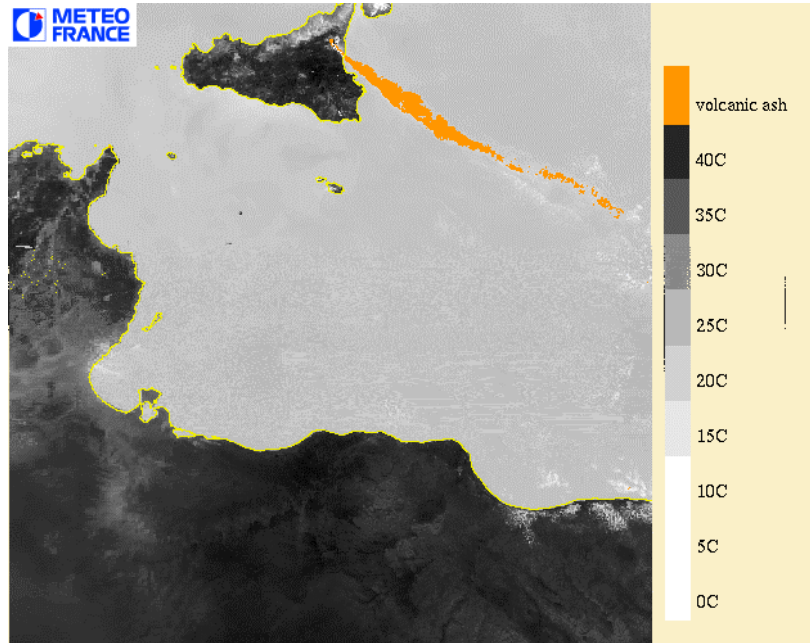



Figure 2: Example of MODIS volcanic ash cloud superimposed on a 10.8µm infrared image: Etna eruption on 22th July 2001 at 9h55 UTC.

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3. CT PRODUCT

3.1 DESCRIPTION OF CT PRODUCT

3.1.1 Goal of CT product

The cloud type (CT), developed within the SAF NWC context, mainly aims to support nowcasting applications. The main objective of this product is to provide a detailed cloud analysis. It may be used as input to an objective meso-scale analysis (which in turn may feed a simple nowcasting scheme), as an intermediate product input to other products, or as a final image product for display at a forecaster's desk. The CT product is essential for the generation of the cloud top temperature and height product and for the identification of precipitation clouds. Finally, it is also essential for the computation of radiative fluxes over sea or land, which are SAF Ocean & Sea Ice products.

The CT product therefore contains information on the major cloud classes : fractional clouds, semitransparent clouds, high, medium and low clouds (including fog) for all the pixels identified as cloudy in a scene. A second priority is the distinction between convective and stratiform clouds (implementation not planned before 2012), and the identification of clouds for which the top mainly consists of water droplets.

3.1.2 Outline of CT algorithm

The CT algorithm is a threshold algorithm applied at the pixel scale, based on the use of CMA and spectral & textural features computed from the multispectral satellite images and compared with a set of thresholds.

The set of thresholds to be applied depends mainly on the illumination conditions, whereas the values of the thresholds themselves may depend on the illumination, the viewing geometry, the geographical location and NWP data describing the water vapour content and a coarse vertical structure of the atmosphere.

Opaque clouds are first separated from semi-transparent and from fractional (sub-pixel) clouds using brightness temperature differences ($T_{10.8\mu m} - T_{12.0\mu m}$, $T_{8.7\mu m} - T_{10.8\mu m}$ or $T_{3.9\mu m} - T_{10.8\mu m}$) and $R_{0.6\mu m}$ (at daytime). Opaque clouds are then separated in very low, low, mid-level, high or very high clouds using their $T_{10.8\mu m}$ brightness temperatures which are compared to NWP forecast air temperatures at various pressure levels. Details are available in [AD. 4].

3.1.3 Description of CT output

The description of CT output (in HDF format) is detailed in AD. 2. This section summarizes the CT output fields (a colour palette is also included in the HDF CT output file for each field, see 3.5).

- **The main product output consists in the following twenty-one categories coded on 5 bits**

0	non-processed containing no data or corrupted data
1	cloud free land no contamination by snow/ice covered surface, no contamination by clouds ; but contamination by thin dust/volcanic clouds not checked
2	cloud free sea no contamination by snow/ice covered surface, no contamination by clouds ;

but contamination by thin dust/volcanic clouds not checked

- 3 land contaminated by snow
- 4 sea contaminated by snow/ice
- 5 very low and cumuliform clouds
- 6 very low and stratiform clouds
- 7 low and cumuliform clouds
- 8 low and stratiform clouds
- 9 medium and cumuliform clouds
- 10 medium and stratiform clouds
- 11 high opaque and cumuliform clouds
- 12 high opaque and stratiform clouds
- 13 very high opaque and cumuliform clouds
- 14 very high opaque and stratiform clouds
- 15 high semitransparent thin clouds
- 16 high semitransparent meanly thick clouds
- 17 high semitransparent thick clouds
- 18 high semitransparent above low or medium clouds
- 19 fractional clouds (sub-pixel water clouds)
- 20 undefined (undefined by CMA)

In the current version of CT, the separation between cumuliform and stratiform is not performed: low, medium or high clouds will be classified as stratiform, and a specific bit indicating whether the separation between stratiform and cumuliform clouds has been attempted, will be set to zero (see below quality flag).

- **10 bits for quality**

3 bits to define illumination and viewing conditions:

- 0 Undefined (space)
- 1 Night
- 2 Twilight
- 3 Day
- 4 Sunlint

2 bits to describe NWP input data

- 0 Undefined (space)
- 1 All NWP parameters available (no low level inversion)
- 2 All NWP parameters available (low level inversion)
- 3 At least one NWP parameter missing

2 bits to describe SEVIRI input data


- 0 Undefined (space)
- 1 All useful SEVIRI channels available ;
- 2 At least one useful SEVIRI channel missing
- 3 At least one mandatory SEVIRI channel missing

2 bits to describe the quality of the processing itself:

- 0 Non processed (containing no data or corrupted data)
- 1 Good quality (high confidence)
- 2 Poor quality (low confidence)
- 3 Reclassified after spatial smoothing (very low confidence)

1 bit set to 1 to indicate that the separation between cumuliform and stratiform clouds has been performed.

In the current version of CT, the separation between cumuliform and stratiform is not performed: this bit will be set to zero and the low, medium or high clouds will be classified as stratiform.

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- **2 bits for cloud phase**

- 0 Non processed (containing no data or corrupted data)
- 1 water cloud
- 2 ice cloud
- 3 undefined (due to known separability problems)

In the current version, the cloud phase is set to Non processed

3.2 IMPLEMENTATION OF CT

CT is extracted by PGE02 of the SAFNWC/MSG software package. Detailed information on how to run this software package are available in AD. 3.

Three main steps are identified. The user manually interacts with the CT software during the installation step, the CT preparation and execution steps being automatically monitored by the Task Manager (if real-time environment is selected).

3.2.1 The CT installation step:

When a new region is defined and added in system and run configuration files, the user launches (only once) the command `mfcms_inst_pge02`. This command allows:

- The automatic elaboration of monthly climatological and atlas maps, as well as latitude/longitude and satellite angles information on the new region at the full IR horizontal resolution. These regional atlas and maps are extracted from maps available on the whole MSG disk.
- The automatic elaboration of the model configuration file. In this file, a default value of 4 is given to the size of segments (Cma_szseg). This default value may be manually changed, but must be the same as for CMa. [Segments are square boxes in the satellite projection, whose size is expressed as the number of IR pixels of one edge of the square box. The size of the processed regions must be a multiple of the segment size. All the solar and satellite angles, the NWP model forecast values, the atlas values and the thresholds will be derived over all the processed regions at the horizontal resolution of the segment. Note also that the land/sea atlas will be available at the full IR resolution, allowing the identification of the surface type (land or sea) of all IR pixels, whatever the segment size. The quality is not very much dependent on the segment size (if lower than 4). A segment size of 4 allows the preparation step to be 9 times faster than if a segment size of 1 was used]
- The automatic set of pre-defined time scheduling (of the preparation step) in Programmed Task Definition Files.

3.2.2 The CT preparation step:

The preparation step is performed by the command `mfcms_next_pge02`. which is launched in advance of satellite data reception according to a pre-defined time scheduling set during the installation step.

This preparation step includes the computation on the region at the segment spatial resolution of:

- the solar & satellite angles,
- the monthly climatological & atlas maps,
- the thresholds for the CT algorithm

3.2.3 The CT execution step:

The execution step is the real-time processing of the SEVIRI images itself over the region. This process consists in the launch of the command: PGE02 by the Task manager. The CT is then performed, using the thresholds prepared during the preparation step.

3.3 INPUTS AND CONFIGURABLE PARAMETERS FOR CT

3.3.1 List of inputs for CT

The input data to the CT algorithm are described in this section. Mandatory inputs are flagged, whereas the impact of missing non-mandatory data on the processing are indicated.

- **Satellite imagery:**

The following SEVIRI bi-directional reflectances or brightness temperatures are needed at full IR spatial resolution:

R0.6 μ m	R1.6 μ m	T3.9 μ m	T7.3 μ m	T8.7 μ m	T10.8 μ m	T12.0 μ m
Mandatory	Optional	Mandatory	Optional	Optional	Mandatory	Mandatory

The current version of CT software does not use the 1.6 μ channel.

The CT software checks the availability of SEVIRI channels for each pixel; no results are available for pixels where at least one mandatory channel is missing.

The SEVIRI channels are input by the user in HRIT format, and extracted on the processed region by SAFNWC software package.

- **CMA cloud categories**

The CMA cloud categories are mandatory. They are computed by the CMA software.

- **Sun and satellite angles associated to SEVIRI imagery**

This information is mandatory. It is computed by the CT software itself, using the definition of the region and the satellite characteristics.

- **NWP parameters:**

The forecast fields of the following parameters, remapped onto satellite images, are used as input :

- surface temperatures
- air temperature at 950hPa (alternatively 925hPa) (to check low level inversion), 850hPa, 700hPa, 500hPa and at tropopause level
- total water vapour content of the atmosphere,
- altitude of the NWP model grid (alternatively surface geopotential of the NWP model grid). Required if NWP fields are used as input.

These remapped fields are elaborated by the SAFNWC software package from the NWP fields input by the user in GRIB format.

The NWP fields are not mandatory. The CT software replaces missing NWP surface temperatures, air temperature at 850hPa, 700hPa, 500hPa or total water vapour content of the atmosphere by climatological values extracted from ancillary dataset. An alternative method is used in case of missing NWP air temperature at tropopause level. The quality of CT is lower if some NWP fields are missing.

- **Ancillary data sets:**

The following ancillary data, remapped onto satellite images, are mandatory :

- Land/sea atlas
- Elevation atlas
- Monthly minimum SST climatology
- Monthly mean 0.6 μ m atmospheric-corrected reflectance climatology (land)
- Monthly integrated atmospheric water vapour content climatology
- Monthly climatology of mean air temperature at 1000hPa, 850hPa, 700hPa, 500hPa.

These ancillary data are available in the SAFNWC software package on MSG full disk in the default satellite projection at full IR resolution; They are extracted on the processed region by the CT software itself.

One coefficients' file (also called threshold table), containing satellite-dependent values and look-up tables for thresholds, is available in the SAFNWC software package, and is needed by the CT software.

3.3.2 Configurable parameters for CT

The only configurable parameter is the size of the segment (see its definition in 3.2.1). Its default value is 4. Information on how to change the size of the segment can be found in the PGE02 pre-operation section of AD. 3.

3.4 CT VALIDATION

3.4.1 Summary of CT validation results

Table 6 summarises the validation results of the current version. More details can be obtained from [AD. 5].

PGE02	Validated accuracy
<p>PGE02 cloud type</p> <p>If validated over European areas and adjacent seas using interactive targets (the user accuracy is defined as the probability of a pixel being classified into a category to really belong to this category)</p>	<p>User accuracy for low opaque, high opaque, semi-transparent high clouds : between 78% and 96% depending on illumination</p>

Table 6: Summary of validation results of the current PGE02 version.[AD. 5]

3.4.2 Typical known problems and recommendation for use

The following problems may be encountered (for wrong cloud detection, please refer to paragraph 2.4):

- Very thin cirrus are classified as fractional clouds.
- Very low clouds may be classified as medium clouds in case strong thermal inversion.
- Low clouds surmounted by thin cirrus may be classified as medium clouds.

3.5 EXAMPLE OF CT VISUALISATION

It is important to note that the CT product is not just an image, but numerical data. At first hand, the CT is rather thought to be used digitally (together with the appended flags (quality, cloud phase)) 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 CT HDF files, thus allowing an easy visualisation of CT categories as illustrated on Figure 3.

The user may be interested in visualising all the available classes (please keep in mind that the separation between stratiform and cumuliform clouds is not performed in the current CT version) as displayed on a SEVIRI example in Figure 3, or highlight one or a few categories suitable for the application of interest. Product's animation will be a help for the user to interpret the visualized CT, and to identify artefacts (for example, the replacement of a snowy area by a low cloud between two successive pictures may be due only to the transition from day to night, as the snow detection is not possible at nighttime).

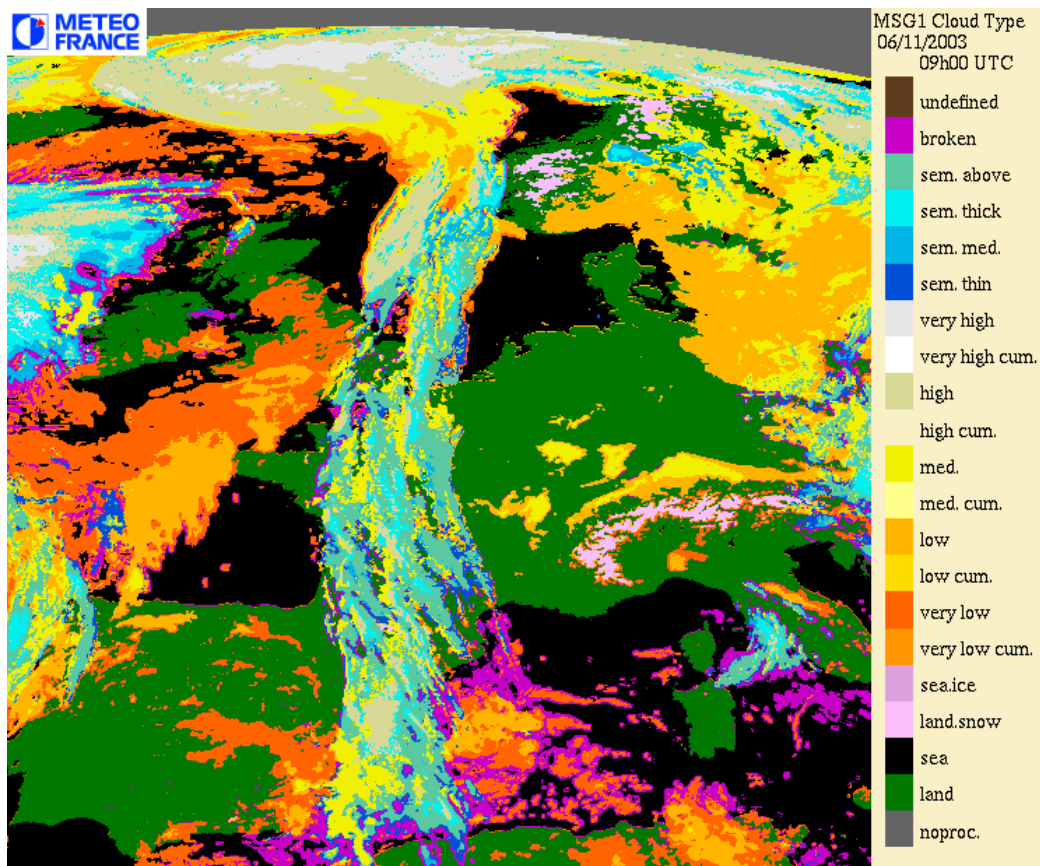



Figure 3: Example of SEVIRI CT using the colour palette included in CT HDF files.

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4. CTTH PRODUCT

4.1 DESCRIPTION OF CTTH PRODUCT

4.1.1 Goal of CTTH product

The cloud top temperature and height (CTTH), developed within the SAF NWC context, aims to support nowcasting applications. This product contributes to the analysis and early warning of thunderstorm development. Other applications include the cloud top height assignment for aviation forecast activities. The product may also serve as input to mesoscale models or to other SAF NWC product generation elements.

The CTTH product contains information on the cloud top temperature and height for all pixels identified as cloudy in the satellite scene.

4.1.2 Outline of CTTH algorithm

The different steps of the processing, applied to cloud-classified image, are listed below. The exact process applied to each pixel depend on the availability of NWP and SEVIRI data.

If all mandatory NWP and SEVIRI data are available (see list of input for CTTH):

The following process is then applied:

- RTTOV-7 radiative transfer model is applied using NWP temperature and humidity vertical profile to simulate 6.2 μ m, 7.3 μ m, 13.4 μ m, 10.8 μ m, and 12.0 μ m cloud free and overcast (clouds successively on each RTTOV vertical pressure levels) radiances and brightness temperatures. This process is performed in each segment of the image (for the CTTH product, the segment is a box of 32*32 SEVIRI IR pixels). The vertical profiles used are temporally interpolated to the exact slot time using the two nearest in time NWP fields input by the user.
- The techniques used to retrieve the cloud top pressure depend on the cloud's type (as available in CT product):
 - For very low, low, medium or high thick clouds : The cloud top pressure is retrieved on a pixel basis and corresponds to the best fit between the simulated and the measured 10.8 μ m brightness temperatures. The simulated brightness temperature, initially computed at the segment resolution, are spatially interpolated to individual pixels during this process. In case of the presence of a low level thermal inversion in the forecast NWP fields, the very low, low or medium clouds are assumed to be above the thermal inversion only if their brightness temperatures are colder than the air temperature below the thermal inversion minus an offset whose value depends on the nature of thermal inversion (dry air above the inversion level or not).
 - For high semi-transparent clouds: The 10.8 μ m infrared brightness temperatures are contaminated by the underlying surfaces and cannot be used as for opaque clouds. A correction of semi-transparency is applied, which requires the use of two infrared channels: a window (10.8 μ m) and a sounder (13.4 μ m, 7.3 μ m or 6.2 μ m) channels. The basis is that clouds have a stronger impact in a window channel than in a sounding channel. The following process is implemented:
 - The H₂O/IRW intercept method, based on a window (10.8 μ m) and sounding (13.4 μ m, 7.3 μ m or 6.2 μ m) radiance bi-dimensional histogram analysis, is first applied. It allows the retrieval of cloud top pressure at the segment horizontal

resolution (i.e., 32*32 SEVIRI IR pixels). This method is successively applied using the 13.4 μ m, 7.3 μ m and 6.2 μ m radiances, the final retrieved cloud pressure being the averaged cloud top pressures obtained using single sounding channels.

- If no result can be obtained with the H₂O/IRW intercept method, the radiance ratioing method is then applied to the 10.8 μ m and 7.3 μ m radiances to retrieve the cloud top pressure at a pixel basis. If no result can be obtained, the method is applied to 6.2 μ m and finally to 13.4 μ m radiances.
- If the radiance ratioing technique leads to cloud top temperatures warmer than the corresponding 10.8 μ m brightness temperatures, the method for thick clouds is used instead.
- For fractional clouds : No technique is proposed in the current version for low broken clouds. The sounding channels are nearly unaffected by broken low clouds and are therefore useless; the infrared channels at 10.8 μ m and 12.0 μ m are contaminated by the surface and cannot therefore be used as for opaque clouds.
- Cloud top temperature and height (above sea level) are then computed from their pressure using general modules. During these processes, the atmospheric vertical profiles are temporally interpolated to the exact slot time using the two nearest in time NWP outputs fields, and spatially interpolated to individual pixels.
- Effective cloudiness (defined as the fraction of the field of view covered by cloud (the cloud amount) multiplied by the cloud emissivity in the 10.8 μ m window channel) is also computed during the processing. It is equal to 1.0 for thick clouds and takes a value between 0. and 1. for semi-transparent clouds.

In case some mandatory NWP or SEVIRI data are missing (see list of inputs for CTTH):

Cloud top temperature of very low, low, medium and high clouds are then computed by applying a climatological atmospheric absorption correction to the 10.8 μ m brightness temperature using look-up tables. The cloud top pressure and height are not retrieved.

More details can be found in [AD. 4].

4.1.3 Description of CTTH output

The description of CTTH output (in HDF format) is detailed in AD. 2. This section summarizes the CTTH output fields (a colour palette is also included in the HDF output CTTH file for each field, see 4.5).

- **6 bits for the cloud top pressure**

Linear conversion from count to pressure : $\text{Cloud_Pressure} = \text{gain} * \text{Count}_{6\text{bits}} + \text{intercept}$
(correspond to pressures ranging between Cloud_Pressure and Cloud_Pressure+25hPa)

Gain	Intercept	Special count
25 hPa/count	-250hPa	0 (no pressure available)

- **7 bits for the cloud top height**

Linear conversion from count to height : $\text{Cloud_Height} = \text{gain} * \text{Count}_{7\text{bits}} + \text{intercept}$
(correspond to heights ranging between Cloud_Height and Cloud_Height+200m)

Gain	Intercept	Special count

200 m/count	-2000 m	0 (no height available)
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- **8 bits for the cloud top temperature**

Linear conversion from count to temperature : $\text{Cloud_Temperature} = \text{gain} * \text{Count}_{8\text{bits}} + \text{intercept}$
(correspond to temperatures ranging between Cloud_Temperature and Cloud_Temperature+1K)

Gain	Intercept	Special count
1 K/count	150 K	0 (no temperature available)

- **5 bits for effective cloudiness**

Linear conversion from count to effective cloudiness : $\text{Cloudiness} = \text{gain} * \text{Count}_{5\text{bits}} + \text{intercept}$
(correspond to cloudiness ranging between Cloudiness and Cloudiness+5%)

Gain	Intercept	Special count
5 %/count	-50 %	0 (no cloudiness available)

- **14 bits for quality**

2 bits to define processing status:

0 non-processed. encompasses :

-CMA and/or CT Non-processed or undefined,

-Image areas that may not be processed [when the images' size is not a multiple of the PGE03 segment size]

1 non-processed because FOV is cloud free

2 processed because cloudy, but without result

3 processed because cloudy, with result

1 bit set to 1 when RTTOV IR simulations are available

3 bits to describe NWP input data

0 undefined (space)

1 All NWP parameters available, no thermal inversion

2 All NWP parameters available, thermal inversion present

3 Some NWP pressure levels missing, no thermal inversion

4 Some NWP pressure levels missing, thermal inversion present

5 At least one mandatory NWP information is missing

2 bits to describe SEVIRI input data

0 undefined (space)

1 all SEVIRI useful channels available

2 at least one SEVIRI useful channel missing

3 at least one SEVIRI mandatory channel is missing

4 bits to describe which method has been used

0 Non-processed

1 Opaque cloud, using rtov

2 Opaque clouds, not using rtov


3 Intercept method 10.8 μm /13.4 μm

4 Intercept method 10.8 μm /6.2 μm

5 Intercept method 10.8 μm /7.3 μm

6 Radiance Ratioing method 10.8 μm /13.4 μm

7 Radiance Ratioing method 10.8 μm /6.2 μm

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- 8 Radiance Ratioing method 10.8 μ m/7.3 μ m
 - 9 Intercept method averaged value:10.8 μ m/6.2 μ m and 10.8 μ m/7.3 μ m
 - 10 Intercept method averaged value: 10.8 μ m/6.2 μ m and 10.8 μ m/13.4 μ m
 - 11 Intercept method averaged value: 10.8 μ m/7.3 μ m and 10.8 μ m/13.4 μ m
 - 12 Intercept method averaged value: 10.8 μ m/13.4 μ m, 10.8 μ m/6.2 μ m and 10.8 μ m/7.3 μ m
 - 13 Opaque cloud, using RTTOV, in case thermal inversion
 - 14-15 Spare for not yet defined methods
- 2 bits to describe quality of the processing itself
- 0 No result (Non-processed, cloud free, no reliable method)
 - 1 Good quality (high confidence)
 - 2 Poor quality (low confidence)

4.2 IMPLEMENTATION OF CTTH

CTTH is extracted by PGE03 of the SAFNWC/MSG software package. Detailed information on how to run this software package are available in AD. 3.

In order to prepare the remapping of NWP fields by the SAFNWC software, the user has to manually prepare (once for ever) the NWP configuration file:

- he defines the NWP vertical pressure levels on which he will input air temperature and relative humidity. For CTTH purposes, vertical levels must be at least be available every 210hPa.
- he defines the codes (depending on local EMOS table) of needed parameters.

Three main steps related to the CTTH software are identified. The user manually interacts with the CTTH software during the installation step, the CTTH preparation and execution steps being automatically monitored by the Task Manager (if real-time environment is selected).

4.2.1 The CTTH installation step:

When a new region is defined and added in system and run configuration files, the user launches (only once) the command `mfcms_inst_pge03`. This command allows:

- The automatic elaboration of monthly climatological and atlas maps, as well as latitude/longitude and satellite angles information on the new region at the full IR horizontal resolution. These regional atlas and maps are extracted from maps available on the whole MSG disk.
- The automatic elaboration of the model configuration file. In this file, the value of 32 is given to the size of segments. It cannot be changed by the user.
- The automatic set of pre-defined time scheduling (of the preparation step) in Programmed Task Definition Files.

4.2.2 The CTTH preparation step:

The preparation step is performed by the command `mfcms_next_pge03` which is launched in advance of satellite data reception according to a pre-defined time scheduling set during the installation step.

This preparation step includes the computation on the region at the segment spatial resolution of:

- the solar & satellite angles,
- the monthly climatological & atlas maps,

- the simulated cloud free & opaque cloud radiances with RTTOV

4.2.3 The CTTH execution step:

The execution step is the real-time processing of the SEVIRI images itself over the region. This process consists in the launch of the command: PGE03 by the Task manager. The CTTH is then performed, using the simulated radiances prepared during the preparation step.

4.3 INPUTS AND CONFIGURABLE PARAMETERS FOR CTTH

4.3.1 List of inputs for CTTH

The input data to the CTTH algorithm are described in this section. Mandatory inputs are flagged, whereas the impact of missing non-mandatory data on the processing are indicated.

- **Satellite imagery:**

The following SEVIRI brightness temperatures and radiances are needed at full IR spatial resolution:

Rad6.2 μ m	Rad7.3 μ m	Rad13.4 μ m	Rad10.8 μ m	T10.8 μ m	T12.0 μ m
At least one of these channels is mandatory, the two others are then optional			Mandatory	Mandatory	Optional

The CTTH software checks the availability of SEVIRI brightness temperatures and radiances for each pixel. Full CTTH product is computed only if all mandatory SEVIRI radiances and brightness temperatures are available. If T10.8 μ m brightness temperature is missing, no result is available. If T10.8 μ m brightness temperature is available, but mandatory channels are missing, only the cloud top temperature is computed using the method based on climatological atmospheric absorption correction.

The SEVIRI channels are input by the user in HRIT format, and extracted on the processed region by SAFNWC software package.

- **CMa and CT cloud categories**

The CMa and CT cloud categories are mandatory. They are computed by the CMa and CT software.

- **Satellite angles associated to SEVIRI imagery**

This information is mandatory. It is computed by the CTTH software itself, using the definition of the region and the satellite characteristics.

- **NWP parameters:**

The forecast fields of the following parameters, remapped onto satellite images, are used as input :

- surface temperature
- surface pressure
- air temperature and relative humidity (alternatively dew point temperature) at 2m
- air temperature and relative humidity on vertical pressure levels
- altitude of the NWP model grid (alternatively surface geopotential on the NWP model grid). Required if NWP fields are used as input.

Vertical pressure levels on which air temperature and humidity are defined by the user. All the surface and near-surface NWP informations and at least NWP informations every 210hPa on the vertical are mandatory to get full CTTH product. Otherwise only the cloud top temperature is

retrieved using the method based on climatological atmospheric absorption correction. Furthermore, it is recommended to provide NWP information on levels at least up to 100hPa to ensure a good height retrieval quality for very high clouds.

These remapped fields are elaborated by the SAFNWC software package from the NWP fields input by the user in GRIB format.

- **Ancillary data sets:**

The following ancillary data, remapped onto satellite images, are mandatory :

- Land/sea atlas
- Elevation atlas
- Monthly minimum SST climatology
- Monthly mean 0.6 μ m atmospheric-corrected reflectance climatology (land)

These ancillary data are available in the SAFNWC software package on MSG full disk in the default satellite projection at full IR resolution; They are extracted on the processed region by the CTTH software itself.

RTTOV-7 coefficients' file, mandatory for RTTOV radiative transfer calculation, is available in the SAFNWC software package. If RTTOV model cannot be launched, only the cloud top temperature is computed using the method based on climatological atmospheric absorption correction.

One coefficients' file, containing satellite-dependent values and one look-up table for climatological atmospheric absorption correction, is available in the SAFNWC software package, and is needed by the CTTH software.

4.3.2 Configurable parameters for CTTH

PGE03 has no configurable parameter.


4.4 CTTH VALIDATION

4.4.1 Summary of CTTH validation results

Table 7 summarises the validation results of the current version. More details can be obtained from [AD. 5].

PGE03 products	Validated accuracy: bias(std)
<p>Top height of opaque low, mid-level and high cloud If validated over European areas using ground-based radar/lidar</p>	50m (1170m)
<p>Top height of semi-transparent cloud If validated over European areas using ground-based radar/lidar</p>	1090m (1090m)

Table 7: Summary of validation results of the current PGE03 version (std stands for standard deviation).[AD. 5]

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4.4.2 Typical known problems and recommendation for use

The following problems may be encountered:

- CTTH will be wrong if the cloud is wrongly classified:
 - Underestimation of cloud top height/pressure for semi-transparent clouds classified as low/medium
 - Over estimation of cloud top height/pressure for low/medium clouds classified as semi-transparent
- No CTTH is available for clouds classified as fractional.
- CTTH may be not computed for thin cirrus clouds.
- CTTH for cirrus clouds may have a square-like appearance due to the use of histogram analysis in the retrieval process.
- Retrieved low cloud top height may be overestimated (to be confirmed during validation).

4.5 EXAMPLE OF CTTH VISUALISATION

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

Colour palettes are included in CTTH HDF files, thus allowing an easy visualisation of cloud top pressure (as illustrated with the SEVIRI example on Figure 4), height, temperature and effective cloudiness.

The product, if used as an image on the forecaster desk, may be visualized (together with CT) in an interactive visualisation system, where individual pixel values (top temperature, height and pressure, cloudiness) may be displayed while moving the mouse over the image.

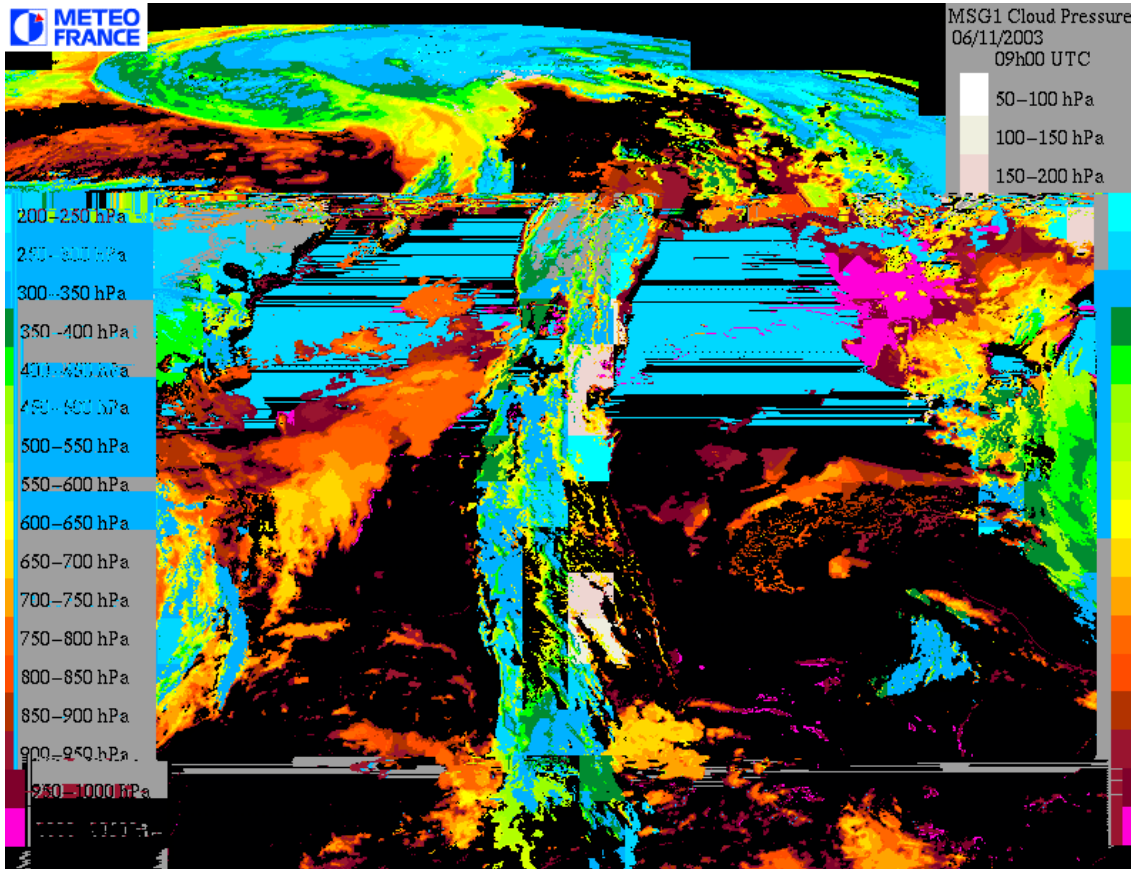


Figure 4: Example of SEVIRI CTTH cloud top pressure