Product User Manual for "Cloud Products" (CMa-PGE01 v3.2, CT-PGE02 v2.2 & CTTH-PGE03 v2.2)

SAF/NWC/CDOP2/MFL/SCI/PUM/01, Issue 3, Rev. 2.3

4 December 2014

Applicable to SAFNWC/MSG version 2013

Prepared by Météo-France / Centre de Météorologie Spatiale

REPORT SIGNATURE TABLE

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DOCUMENT CHANGE RECORD

Version	Date	Pages	CHANGE(S)
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")
2.0	23 August 2008	31	Content adapted to version v2.0
3.0	17 may 2010	33	Content adapted to version v3.0
3.1	24 march 2011	32	Content adapted to version v3.1
3.2	15 February 2012	32	Content adapted to version v3.2
3.2.1	15 July 2013	32	Content adapted to NWP management change
3.2.2	15 November 2013	32	See RID OR9 (0BJ1_Ops201301_Nicola_011)
3.2.3	4 December 2014	34	See RID OR2014 (OBJ1_MBL_Kotro_006)

Table of contents

	Product User Manual for "Cloud Products" (CMa-PGE01 v3.2, CT-PGE02 v2.2 & CTTH-PGE03 v2.2)	**Code:** SAF/NWC/CDOP2/MFL/SCI/PUM/01
NWC SAF / METEO FRANCE Toujours un temps d'avance		**Issue:** 3.2.3 **Date**: *4 December 2014*
		File: SAF-NWC-CDOP2-MFL-SCI-PUM-01_v3.2.3
		Page: *5/34*

List of Tables and Figures

	Product User Manual for "Cloud Products" (CMa-PGE01 v3.2, CT-PGE02 v2.2 & CTTH-PGE03 v2.2)	**Code:** SAF/NWC/CDOP2/MFL/SCI/PUM/01
NWC SAF / METEO FRANCE *Toujours un temps d'avance*		**Issue:** 3.2.3 **Date**: *4 December 2014*
		File: SAF-NWC-CDOP2-MFL-SCI-PUM-01_v3.2.3
		Page: 7/34

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://nwcsaf.org . This document is applicable to the SAFNWC processing package for Meteosat Second Generation satellites, SAFNWC/MSG.

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 the algorithm theoretical basis document for cloud products ([AD. 4]).

The validation of the algorithms used to extract the MSG Cloud Products PGE01 (CMa), PGE02 (CT) and PGE03 (CTTH) is reported in the validation report for cloud products ([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 the 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 document describes the products obtained from the CMa-PGE01 V3.2, CT-PGE02 v2.2 and CTTH-PGE03 v2.2 implemented in the release2013 of the SAFNWC/MSG software package.

1.4 IMPROVEMENT FROM PREVIOUS VERSION

CMa, CT and CTTH algorithms remain unchanged since previous version (v2012).

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
FOV	Field Of View
HDF	Hierarchical data Format
HRIT	High Rate Information Transmission
HRV	High Resolution Visible
ICD	Interface Control Document
MSG	Meteosat Second Generation
NWP	Numerical Weather Prediction
PGE	Product Generation Element
PUM	Product User Manual
R0.6μm	0.6 visible reflectance
RTMOM	Radiative Transfer based on Matrix Operator Method
RTTOV	Rapid Transmissions for TOVs
SAF	Satellite Application Facility
SAF NWC	SAF on support to NoWCasting and VSRF
SAF OSI	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 v3.2, CT-PGE02 v2.2 & CTTH-PGE03 v2.2)	SAF/NWC/CDOP/MFL/SCI/ATBD/01	3.2.1	20/09/12
[AD. 5]	Validation Report for "Cloud Products" (CMa-PGE01 v3.2, CT-PGE02 v2.2 & CTTH-PGE03 v2.2)	SAF/NWC/CDOP/MFL/SCI/VR/06	1.0	15/02/12
[AD. 6]	Validation report for the PGE01-02-03 (v1.2) (Cloud Products) of the SAFNWC/MSG	SAF/NWC/IOP/MFL/SCI/VAL/01	1.2	17/01/07

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

2. CLOUD MASK (CMA) PRODUCT

2.1 DESCRIPTION OF CLOUD MASK (CMA) PRODUCT

2.1.1 Goal of Cloud Mask (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 Cloud Mask (CMa) algorithm

The algorithm is based on multispectral threshold technique applied to each pixel of the image. A first process allows the identification of cloudy pixels. It consists in a first set of multispectral threshold tests (summed up below) which is complemented by an analysis of the temporal variation (on a short period of time: 15 minutes) of some spectral combinations of channels (to detect rapidly moving clouds), a specific treatment combining temporal coherency analysis and region growing technique (to improve the detection of low clouds) and a temporal analysis of the HRV channel (to detect sub-pixel cumulus clouds).

The 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 and to reduce known defaults as cloud false alarms in coastal area and in edges of snowy areas.

- 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 the algorithm theoretical basis document for cloud products ([AD. 4]).

Daytime	Twilight	Nighttime
Snow detection	Snow detection	T10.8μm
T10.8μm	T10.8μm	T10.8μm-T12.0μm
R0.6μm	R0.6μm	T8.7μm-T10.8μm
T10.8μm-T12.0μm	T10.8μm-T12.0μm	T10.8μm-T8.7μm
T8.7μm-T10.8μm	T8.7μm-T10.8μm	T10.8μm-T3.9μm
T10.8μm-T3.9μm	T10.8μm-T8.7μm	T3.9μm-T10.8μm
T3.9μm-T10.8μm	T10.8μm-T3.9μm	Local Spatial Texture
Local Spatial Texture	T3.9μm-T10.8μm	T8.7μm-T3.9μm
	Local Spatial Texture	
	T8.7μm-T3.9μm	

Table 3: Test sequence over land

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

Table 4: Test sequence over sea

[T3.9μm, T8.7μm , T10.8μm and T12.0μm stand for brightness temperatures at 3.9, 8.7, 10.8 and 12.0 micrometer ; R0.6μm,R0.8μm and R1.6μm 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 T10.8μm and T12.0μm measurements. Low Clouds in Sunglint is a specific module for low clouds identification in sunglint areas.]

2.1.3 Description of Cloud Mask (CMa) output

The description of CMa output (in HDF format) is detailed in the output products format definition document (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 ; but contamination by thin dust/volcanic clouds not checked
2	Cloud contaminated	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   T10.8µm or SST
1   R0.6µm (land) or R0.8µm (sea)
2   Sunglint test using 3.9µm
3   Local Spatial Texture
4   T10.8µm - T12.0µm
5   T10.8µm - T3.9µm or T12.0µm - T3.9µm
6   T3.9µm - T10.8µm
7   Spatial smoothing (reclassify isolated cloud-free pixels)
8   T8.7µm - T3.9µm
9   R1.6µm (sea)
10   T8.7µm –T10.8µm or T10.8µm –T8.7µm
11   Snow using R1.6µm or T3.9µm
12   HRV-based test
13   Stationary cloud in twilight
14   Spatial expansion of stationary cloud in twilight
15   Temporal-differencing

- **11 bits for quality**

3 bits to define illumination and viewing conditions:
0   Undefined (space)
1   Night
2   Twilight
3   Day
4   Sunglint

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)

1 bit for temporal processing indicator (significant for cloud-free pixels)

0   Not performed
1   Performed

1 bit for HRV processing indicator (significant for cloud-free pixels)

0   Not performed
1   Performed

- **2 bits for dust detection**

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 CLOUD MASK (CMA)

CMa is extracted by PGE01 of the SAFNWC/MSG software package. Detailed information on how to run this software package is available in the software user manual (AD. 3).

The software architecture of PGE01 has been strongly modified in version v2010 (to make the life easier for the user). It is now very similar to the other PGEs.

When a new region is defined the user has now to manually prepare the CMa model configuration files for this new region using a default CMa model configuration file provided in the SAFNWC/MSG software package.

There is an option for the user to monitor the so-called CMa preparation step before SEVIRI images are available (to speed up the process). By default, this preparation step is performed during the CMa execution step.

The CMa execution step (which includes the CMa preparation step in case it has not been launched before) is automatically launched by the Task Manager (if real-time environment is selected).

	Product User Manual for "Cloud Products" (CMa-PGE01 v3.2, CT-PGE02 v2.2 & CTTH-PGE03 v2.2)	**Code:** SAF/NWC/CDOP2/MFL/SCI/PUM/01
NWC SAF / METEO FRANCE *Toujours un temps d'avance*		**Issue:** 3.2.3 **Date**: *4 December 2014*
		File: SAF-NWC-CDOP2-MFL-SCI-PUM-01_v3.2.3
		Page: *13*/34

2.2.1 Manual preparation of Cloud Mask (CMa) model configuration file for each region

When a new region is defined and added in system and run configuration files, the user must manually prepares the CMa model configuration files by adapting the CMa default model configuration file available in the SAFNWC software package. Three parameters are configurable in the default CMa model configuration file:

- CMA_SZSEG (default value: 4): the size of the segment for CMa. The new segment size must also be updated in the lines NWP_PARAMxx [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]

- TEMPORAL_USE (default value: TRUE): a flag defining if the temporal analysis should be done. [TEMPORAL_USE flag is checked at the execution step. PGE01 applies the temporal analysis if its value is TRUE. This flag has been made configurable to allow users being blocked by hardware resources to still run the PGE01 by assigning it to FALSE in the configuration file.]

- HRV_NEED (default value: TRUE): a flag indicating whether the HRV analysis should be done. [HRV_NEED flag is checked at the execution step. PGE01 applies the HRV analysis if its value is TRUE. This flag has been made configurable to allow users being blocked by hardware resources to still run the PGE01 by assigning it to FALSE in the configuration file.] When required and when the 2 HRV images required by the algorihm are not available the PGE01 is processed without this enhancement. For regions being partially covered by HRV measurements, only the SEVIRI pixels having HRV benefit from enhancement.

Moreover as the content of NWP_CONF_FILE is dependent on the local installation, the user must make the NWP_PARAMXX consistent with the local NWP_CONF_FILE when the standard one is not used (for details see section dedicated to NWP data files in SAF/NWC/CDOP/INM/SW/SUM/2 [AD. 3]) .

2.2.2 The Cloud Mask (CMa) preparation step (optional)

By default, this CMa preparation step is performed during the CMa execution step (see 2.2.3).

But to speed up the CMa processing, this preparation step can performed by the command mfcms_next_pge01 which can be launched in advance of satellite data reception according to a pre-defined time scheduling to be manually set by the user.

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 Cloud Mask (CMa) execution step

The CMa execution step (which by default includes the CMa preparation step see 2.2.2) 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.

	Product User Manual for "Cloud Products" (CMa-PGE01 v3.2, CT-PGE02 v2.2 & CTTH-PGE03 v2.2)	**Code:** SAF/NWC/CDOP2/MFL/SCI/PUM/01
NWC SAF / METEO FRANCE Toujours un temps d'avance		**Issue:** 3.2.3 **Date**: *4 December 2014*
		File: SAF-NWC-CDOP2-MFL-SCI-PUM-01_v3.2.3
		Page: *14*/34

2.3 INPUTS AND CONFIGURABLE PARAMETERS FOR CLOUD MASK (CMA)

2.3.1 List of inputs for Cloud Mask (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 of the scene to be analysed are needed at full IR spatial resolution (at HRV spatial resolution for HRV):

HRV	R0.6µm	R0.8µm	R1.6µm	T3.9µm	T7.3µm	T8.7µm	T10.8µm	T12.0µm	T13.4µm
Optional	Mandatory	Optional	Optional	Mandatory	Optional	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 R1.6µm or T3.9µm; visible channel test over the ocean uses either R0.8µm or R0.6µm) and a result is available for this pixel. No results are provided for pixels where at least one mandatory channel is missing.

The following SEVIRI bi-directional reflectances or brightness temperatures or Cma or CT of the scene analysed one hour sooner are optionally needed to improve the cloud detection in day-night transition. If one of them misses this improvement is not performed.

R0.6µm$_{1h}$	T8.7µm$_{1h}$	T10.8µm$_{1h}$	T12.0µm$_{1h}$	CMa$_{1h}$	CT$_{1h}$
Optional	Optional	Optional	Optional	Optional	Optional

The following SEVIRI brightness temperatures or Cma or CT of the scene analysed 15 minutes sooner are optionally needed to improve the cloud detection of fast moving clouds. If one of them misses this improvement is not performed.

T8.7µm$_{15mn}$	T10.8µm$_{15mn}$	T12.0µm$_{15mn}$	CMa$_{15mn}$	CT$_{15mn}$
Optional	Optional	Optional	Optional	Optional

The HRV bi-directional reflectance of the scene analysed 15 minutes sooner are optionally needed to improve the sub-pixel cumulus cloud detection. If not available this improvement is not performed.

HRV$_{15mn}$
Optional

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.

	Product User Manual for "Cloud Products" (CMa-PGE01 v3.2, CT-PGE02 v2.2 & CTTH-PGE03 v2.2)	**Code:** SAF/NWC/CDOP2/MFL/SCI/PUM/01
NWC SAF METEO FRANCE *Toujours un temps d'avance*		**Issue:** 3.2.3 **Date**: *4 December 2014*
		File: SAF-NWC-CDOP2-MFL-SCI-PUM-01_v3.2.3
		Page: *15*/34

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.

CMa has been designed so that the dependency of NWP is limited to the amount that is absolutely necessary. The impact of missing NWP data has been analyzed in details and reported in [AD. 6]. Provided requested NWP fields are input by the user, the impact of changing horizontal and temporal resolution will be limited.

- **Ancillary data sets:**

The following ancillary data, remapped onto satellite images, are mandatory :
   o Land/sea atlas
   o Land/sea/coast atlas
   o Elevation atlas
   o Monthly minimum SST climatology
   o Monthly mean 0.6μm atmospheric-corrected reflectance climatology (land)
   o Monthly mean large band visible surface reflectance climatology (land, for HRV processing)
   o Monthly integrated atmospheric water vapour content climatology
   o 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 Cloud Mask (CMa)

Three configurables parameters are available in the default CMa model configuration file:

- CMA_SZSEG: The size of the segment is configurable (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 software user manual (AD. 3) and in section 2.2.1.

- TEMPORAL_USE: The flag defining if temporal information is to be used (to allow a better detection of fast moving clouds and low clouds in twilight conditions) is configurable (see its definition in 2.2.1). Its default value is TRUE. Information on how to change this value can be found in the software user manual (AD. 3) and in section 2.2.1.

- HRVNEED: The flag indicating if HRV data have to be used (to allow enhanced sub-pixel cumulus detection) is configurable (see its definition in 2.2.1). Its default value is TRUE. Information on how to change this value can be found in the software user manual (AD. 3) and in section 2.2.1.

2.4 CLOUD MASK (CMA) VALIDATION

2.4.1 Summary of Cloud Mask (CMa) validation results

Table 5 summarises the validation results of the current version. More details can be obtained from the validation report for cloud products ([AD. 5]). The impact of missing NWP data has been analyzed in details and reported in [AD. 6]

PGE01 flags	Validated accuracy
PGE01 cloud detection validated over European areas using SYNOP observations	POD:96.5%
PGE01 dust flag validated over sea and Africa for solar elevation larger than 20 degrees using interactive targets	POD: 55.5% over sea 58.5% over land

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

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 therefore may confused either with low clouds or cloud free surface. This drawback has been reduced with v3.1 in release2011.

- False detection of volcanic ash clouds happens especially in daytime conditions (over low clouds and desertic surfaces), but also in night-time (over cold clouds). The volcanic ash clouds detection is not performed in case low solar elevation.

- Over land, 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, some dust areas may not be detected (especially the thinnest parts). Moreover, some wrong detection may be observed in oceanic regions, especially at nighttime near Namibia coast and occasionally over the South Atlantic (at latitude larger than 50 degrees).

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

	Product User Manual for "Cloud Products" (CMa-PGE01 v3.2, CT-PGE02 v2.2 & CTTH-PGE03 v2.2)	**Code:** SAF/NWC/CDOP2/MFL/SCI/PUM/01
NWC SAF / METEO FRANCE *Toujours un temps d'avance*		**Issue:** 3.2.3 **Date**: *4 December 2014*
		File: SAF-NWC-CDOP2-MFL-SCI-PUM-01_v3.2.3
		Page: *17*/34

2.5 EXAMPLE OF CLOUD MASK (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.
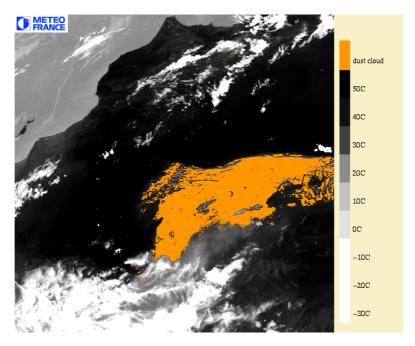

Figure 1: Example of SEVIRI dust cloud flag superimposed on a 10.8μm infrared image: dust cloud over North Africa on 14th July 2003 at 13h00 UTC.

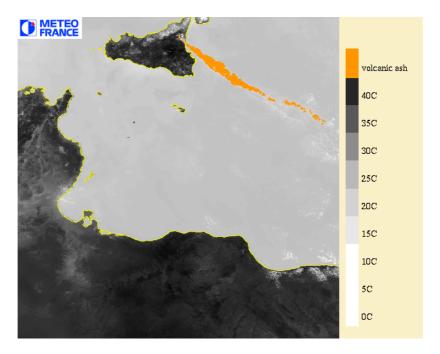*Figure 2: Example of MODIS volcanic ash cloud superimposed on a 10.8µm infrared image: Etna eruption on 22th July 2001 at 9h55 UTC.*

3. CLOUD TYPE (CT) PRODUCT

3.1 DESCRIPTION OF CLOUD TYPE (CT) PRODUCT

3.1.1 Goal of Cloud Type (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 Cloud Type (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 ($T10.8\mu m$-$T12.0\mu m$, $T8.7\mu m$-$T10.8\mu m$ or $T3.9\mu m$-$T10.8\mu m$) and $R0.6\mu m$ (at daytime). Opaque clouds are then separated in very low, low, mid-level, high or very high clouds using their T10.8mm brightness temperatures which are compared to NWP forecast air temperatures at various pressure levels. Details are available in the algorithm theoretical basis document for cloud products ([AD. 4]).

A separate processing is applied to compute the cloud phase flag, based on the use of CT cloud type, $T8.7\mu m$,$T10.8\mu m$ (all illumination), $R0.6\mu m$ and $R1.6\mu m$ (at daytime).

3.1.3 Description of Cloud Type (CT) output

The description of CT output (in HDF format) is detailed in the output products format definition document (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	Sunglint

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.

- **2 bits for cloud phase**

0   Non processed (containing no data or corrupted data) or no cloud

1   water cloud

2   ice cloud

3   undefined (due to known separability problems)

3.2 IMPLEMENTATION OF CLOUD TYPE (CT)

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

The software architecture of PGE02 has been strongly modified in version v2010 (to make the life easier for the user). It is now very similar to the other PGEs.

When a new region is defined the user has now to manually prepare the CT model configuration files for this new region using a default CT model configuration file provided in the SAFNWC/MSG software package.

There is an option for the user to monitor the so-called CT preparation step before SEVIRI images are available (to speed up the process). By default, this preparation step is performed during the CT execution step.

The CT execution step (which includes the CT preparation step in case it has not been launched before) is automatically launched by the Task Manager (if real-time environment is selected).

3.2.1 Manual preparation of Cloud Type (CT) model configuration file for each region

When a new region is defined and added in system and run configuration files, the user must manually prepares the CT model configuration files by adapting the default CT model configuration file available in the SAFNWC software package.

Three parameters are configurable in the default CT model configuration file:

- CT_SZSEG (default value: 4): the size of the segment. This default value may be manually changed, but must be the same as for CMa (CMA_SZSEG)). The new segment size must also updated in the lines NWP_PARAMxx [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]

- PHASE_COMPUTATION (default value: TRUE): a flag defining if the cloud phase flag should be computed.[PHASE_COMPUTATION flag is checked at the execution step. It should be assigned to TRUE or FALSE. PGE02 computes the cloud phase flag if its value is TRUE. This flag has been made configurable to allow users being blocked by hardware resources to still run the PGE02 by assigning it to FALSE in the configuration file.]

- CT_PHASE_SZSEG (default value: 8): the size of the segment for the cloud phase flag computation. This default value may be manually changed independently from CMA_SZSEG or CT_SZSEG or the size available in the lines NWP_PARAMxx. [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. The simulated R0.6μm and R1.6μm cloud reflectances for various clouds used during the processing are computed at the segment resolution. The cloud phase flag quality is not very much dependent on the segment size.]

Moreover as the content of NWP_CONF_FILE is dependent on the local installation, the user must make the NWP_PARAMXX consistent with the local NWP_CONF_FILE when the standard one is not used (for details see section dedicated to NWP data files in SAF/NWC/CDOP/INM/SW/SUM/2 [AD. 3]) .

3.2.2 The Cloud Type (CT) preparation step (optional)

By default, this CT preparation step is performed during the CT execution step (see 3.2.3).

But to speed up the CT processing, this preparation step can performed by the command mfcms_next_pge02 which can be launched in advance of satellite data reception according to a pre-defined time scheduling to be manually set by the user.

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
- the simulated R0.6μm and R1.6μm cloudy reflectances

3.2.3 The Cloud Type (CT) execution step

The CT execution step (which by default includes the CT preparation step see 3.2.2) 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 and simulations prepared during the preparation step.

3.3 INPUTS AND CONFIGURABLE PARAMETERS FOR CLOUD TYPE (CT)

3.3.1 List of inputs for Cloud Type (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:

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

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. If T8.7μm or R1.6μm are missing, the cloud phase flag is not computed.

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.

CT has been designed so that the dependency of NWP is limited to the amount that is absolutely necessary. Provided requested NWP fields are input by the user, the impact of changing horizontal and temporal resolution will be limited.

- **Ancillary data sets:**

The following ancillary data, remapped onto satellite images, are mandatory :
- Land/sea atlas
- Elevation atlas
- Monthly minimum SST climatology
- Monthly mean 0.6μm atmospheric-corrected reflectance climatology (land)
- Monthly 0.6μm and 1.6μm white-sky surface albedo 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.

One file containing offline simulations of 0.6μm and 1.6μm reflectances performed for a set of four water clouds and four ice clouds using RTMOM radiative transfer model is available in the SAFNWC software package, and is needed by the CT software.

3.3.2 Configurable parameters for Cloud Type (CT)

Three configurables parameters are available in the default CT model configuration file:

- CT_SZSEG: The size of the segment is configurable (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 software user manual (AD. 3) and in section 3.2.1.

- PHASE_COMPUTATION: The flag defining if the cloud phase flag should be computed is configurable (see its definition in 3.2.1). Its default value is TRUE. Information on how to change this value can be found in the software user manual (AD. 3) and in section 3.2.1.

- CT_PHASE_SZSEG: The size of the segment for cloud phase flag computation is configurable (see its definition in 3.2.1). Its default value is 8. Information on how to change the size of the segment can be found in the software user manual (AD. 3) and in section 3.2.1.

3.4 CLOUD TYPE (CT) VALIDATION

3.4.1 Summary of Cloud Type (CT) validation results

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

PGE02	Validated accuracy
PGE02 cloud type 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)	User accuracy for low opaque, high opaque, semi-transparent high clouds : between 78% and 96% depending on illumination
PGE02 cloud phase flag validated over European areas using ground-based radar/lidar	Hit Rate (HR) : 0.83 Kuiper Skill Score KSS: 0.62

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 often 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 CLOUD TYPE (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 cloud type 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).
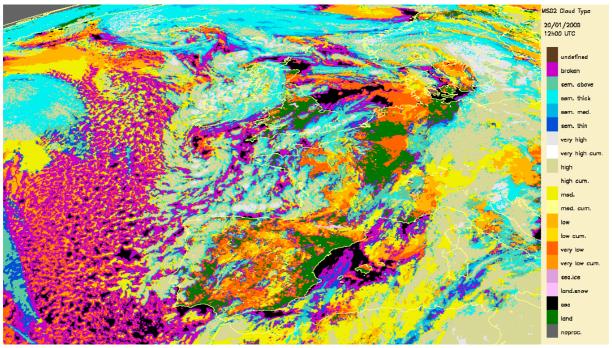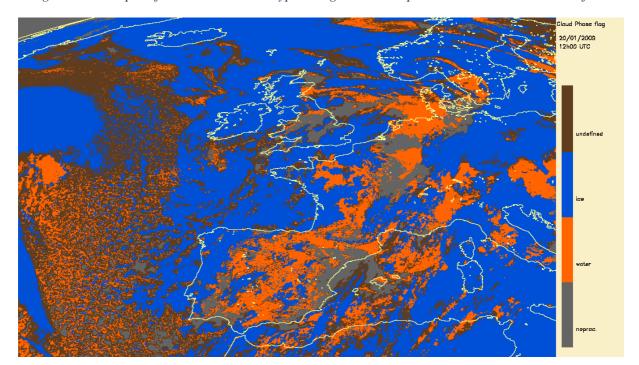

Figure 3: Example of SEVIRI CT cloud type using the colour palette included in CT HDF files.

Figure 4 Example of SEVIRI CT cloud phase using the colour palette included in CT HDF files.

4. CLOUD TOP TEMPERATURE AND HEIGHT (CTTH) PRODUCT

4.1 DESCRIPTION OF CLOUD TOP TEMPERATURE AND HEIGHT (CTTH) PRODUCT

4.1.1 Goal of Cloud Top Temperature and Height (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 Cloud Top Temperature and Height (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-9 radiative transfer model (developed by NWP SAF) is applied using NWP temperature and humidity vertical profile to simulate 6.2µm, 7.3µm, 13.4µm, 10.8µm, and 12.0µm cloud free and overcast (clouds successively on each vertical pressure levels) radiances and brightness temperatures. This process is performed in each segment of the image (the size of the segment is defined by the user, the default value being 16*16 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 or medium thick clouds : The cloud top pressure is retrieved on a pixel basis and corresponds to the best fit between the simulated and the measured 10.8µm brightness temperatures. The simulated brightness temperature are available at the segment resolution. 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 thick clouds: a method called the radiance ratioing method (see the next bullet for further explanation of this method) is first applied to remove any remaining semi-transparency that could have been undetected by the cloud type scheme. In case of failure, the method defined for medium opaque clouds is then applied.

  - For high semi-transparent clouds: The 10.8µm 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 (10.8µm) and a sounder (13.4µm, 7.3µm or 6.2µm) 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 H_2O/IRW intercept method, based on a window (10.8μm) and sounding (13.4μm, 7.3μm or 6.2μm) radiance bi-dimensional histogram analysis, is first applied. The histograms are built in boxes of 32*32 SEVIRI IR pixels centred on each segment of the image (whose size is defined by the user, the default value being 16*16 SEVIRI IR pixels). It therefore allows the retrieval of cloud top pressure at the segment horizontal resolution (i.e., by default 16*16 SEVIRI IR pixels). This method is successively applied using the 7.3μm, 6.2μm and 13.4μm radiances, the final retrieved cloud pressure being the minimum cloud top pressures obtained using single sounding channels.

- If no result can be obtained with the H_2O/IRW intercept method, the radiance ratioing method is then applied to the 10.8μm and 7.3μm radiances to retrieve the cloud top pressure at a pixel basis. If no result can be obtained, the method is applied to 6.2μm and finally to 13.4μm radiances.

- If the radiance ratioing technique leads to cloud top temperatures warmer than the corresponding 10.8μm 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 10.8μm and 12.0μm are contaminated by the surface and cannot therefore be used as for opaque clouds.

- A gap-filling procedure is applied in semi-transparent cloud top pressure field: in boxes of fixed size (32x32 SEVIRI IR pixels), a cloud top pressure is computed as the average pressure of all pixels containing semi-transparent clouds inside the current and the eight surrounding boxes. This average cloud top pressure is then assigned to all pixels of the current box containing semi-transparent clouds and having no retrieved cloud top pressure.

- 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.

- Effective cloudiness (defined as the fraction of the field of view covered by cloud (the cloud amount) multiplied by the cloud emissivity in the 10.8μm 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 10.8μm brightness temperature using look-up tables. The cloud top pressure and height are not retrieved.

More details can be found in the algorithm theoretical basis document for cloud products ([AD. 4]).

4.1.3 Description of Cloud Top Temperature and Height (CTTH) output

The description of CTTH output (in HDF format) is detailed in the output products format definition document (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 : Cloud_Pressure = gain * Count_{6bits} + intercept
(corresponds 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 : Cloud_Height = gain * Count_{7bits} + intercept
(corresponds to heights ranging between Cloud_Height and Cloud_Height+200m)

Gain	Intercept	Special count
200 m/count	-2000 m	0 (no height available)

- **8 bits for the cloud top temperature**

Linear conversion from count to temperature : Cloud_Temperature = gain * Count_{8bits} + intercept
(corresponds 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 : Cloudiness = gain * Count_{5bits} + intercept
(corresponds 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 rttov
2   Opaque clouds, not using rttov
3   Intercept method 10.8μm/13.4μm
4   Intercept method 10.8μm/6.2μm
5   Intercept method 10.8μm/7.3μm
6   Radiance Ratioing method 10.8μm/13.4μm
7   Radiance Ratioing method 10.8μm/6.2μm
8   Radiance Ratioing method 10.8μm/7.3μm
9   Spare
10   Spare
11   Spare
12   Spare
13   Opaque cloud, using RTTOV, in case thermal inversion
14   Spatial smoothing (gap filling in semi-transparent cloud field)
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 CLOUD TOP TEMPERATURE AND HEIGHT (CTTH)

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

The software architecture of PGE03 has been strongly modified in version v2010 (to make the life easier for the user). It is now very similar to the other PGEs.

When a new region is defined the user has now to manually prepare the CTTH model configuration files for this new region using a default CTTH model configuration file provided in the SAFNWC/MSG software package.

There is an option for the user to monitor the so-called CTTH preparation step before SEVIRI images are available (to speed up the process). By default, this preparation step is performed during the CTTH execution step.

The CTTH execution step (which includes the CTTH preparation step in case it has not been launched before) is automatically launched by the Task Manager (if real-time environment is selected).

4.2.1 Manual preparation of Cloud Top Temperature and Height (CTTH) model configuration file for each region

When a new region is defined and added in system and run configuration files, the user must manually prepares the CTTH model configuration files by adapting the default CTTH model configuration file available in the SAFNWC software package.

Only one parameter is configurable in the default CTTH model configuration file:

- CTTH_SZSEG (default value: 16): the size of the segment. This default value may be manually changed independently of CMA_SZSEG and CT_SZSEG The new segment size must also updated in the lines NWP_PARAMxx. [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. The NWP model forecast values and RTTOV simulations will be derived over all the processed regions at the horizontal resolution of the segment. A small ctth_szseg will decrease the box aspect in the retrieved cloud top pressure and will be especially useful if the NWP fields have a high horizontal resolution. But it may become very time consuming as RTTOV is launched for every segment.]

Moreover as the content of NWP_CONF_FILE is dependent on the local installation, the user must make the NWP_PARAMXX consistent with the local NWP_CONF_FILE when the standard one is not used (for details see section dedicated to NWP data files in SAF/NWC/CDOP/INM/SW/SUM/2 [AD. 3]).

4.2.2 The Cloud Top Temperature and Height (CTTH) preparation step (optional)

By default, this CTTH preparation step is performed during the CTTH execution step (see 4.2.3).

But to speed up the CTTH processing, this preparation step can performed by the command mfcms_next_pge03 which can be launched in advance of satellite data reception according to a pre-defined time scheduling to be manually set by the user.

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 Cloud Top Temperature and Height (CTTH) execution step

The CTTH execution step (which by default includes the CTTH preparation step see 4.2.2) 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 CTHT is then performed, using the simulated radiances prepared during the preparation step.

4.3 INPUTS AND CONFIGURABLE PARAMETERS FOR CLOUD TOP TEMPERATURE AND HEIGHT (CTTH)

4.3.1 List of inputs for Cloud Top Temperature and Height (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:

Rad6.2μm	Rad7.3μm	Rad13.4μm	Rad10.8μm	T10.8μm	T12.0μm
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 T10.8μm brightness temperature is missing, no result is

available. If T10.8µm 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 :
  - o surface temperature
  - o surface pressure
  - o air temperature and relative humidity (alternatively dew point temperature) at 2m
  - o air temperature and relative humidity on vertical pressure levels
  - o 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.

Additionally, the quality of the CTTH for low level clouds is dependent on the description by NWP fields of the low level thermal inversion, which can be improved by increasing spatial, temporal and especially near-surface vertical resolution.

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 :
  - o Land/sea atlas
  - o Elevation atlas
  - o Monthly minimum SST climatology
  - o Monthly mean 0.6µm 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-9 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 Cloud Top Temperature and Height (CTTH)

Besides the NWP parameters to be used (the levels may be changed by the user), only one parameter is configurable in the default CTTH model configuration file:

- CTTH_SZSEG: The size of the segment is configurable (see its definition in 4.2.1). Its default value is 16. Information on how to change the size of the segment can be found in the software user manual (AD. 3) and in section 4.2.1.

4.4 CLOUD TOP TEMPERATURE AND HEIGHT (CTTH) VALIDATION

4.4.1 Summary of Cloud Top Temperature and Height (CTTH) validation results

Table 7 summarises the validation results of the current version. More details can be obtained from the validation report for cloud products ([AD. 5]).

PGE03 products	Validated accuracy: bias(std)
Top height of opaque low, mid-level and high cloud validated over European areas using ground-based radar/lidar	120m(1050m)
Top height of semi-transparent cloud validated over European areas using ground-based radar/lidar	1020m(940m) (intercept method) 100m(1050m) (radiance ratioing technique)

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

4.4.2 Typical known problems and recommendation for use

The following main problems may be encountered:

- CTTH will be wrong if the cloud is wrongly classified:
  - o Underestimation of cloud top height/pressure for semi-transparent clouds classified as low/medium
  - o 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.
- Retrieved low cloud top height may be overestimated.

4.5 EXAMPLE OF CLOUD TOP TEMPERATURE AND HEIGHT (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 5), 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.
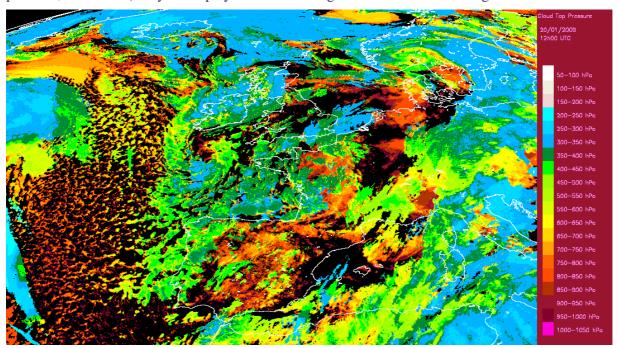

Figure 5: Example of SEVIRI CTTH cloud top pressure