	User Manual for the Cloud Product Processors of the NWC/GEO: Science Part	Code: NWC/CDOP2/GEO/MFL/SCI/UM/Cloud Issue: 1.0 Date: 15 October 2016 File: NWC-CDOP2-GEO-MFL-SCI-UM-Cloud_v1.0 Page: 1/56
---	---	---	--

The EUMETSAT
Network of
Satellite
Application
Facilities



NWC SAF

Support to Nowcasting and
Very Short Range Forecasting

User Manual for the Cloud Product Processors of the NWC/GEO: Science Part

NWC/CDOP2/GEO/MFL/SCI/UM/Cloud, Issue 1, Rev. 0

15 October 2016

Applicable to


GEO-CMA-v4.0 (NWC-002)

GEO-CT-v3.0 (NWC-006)

GEO-CTTH-v3.0 (NWC-010)



GEO-CMIC-v1.0 (NWC-013)

Prepared by Météo-France / Centre de Météorologie Spatiale

		User Manual for the Cloud Product Processors of the NWC/GEO: Science Part	Code: NWC/CDOP2/GEO/MFL/SCI/UM/Cloud Issue: 1.0 Date: 15 October 2016 File: NWC-CDOP2-GEO-MFL-SCI-UM-Cloud_v1.0 Page: 2/56
---	---	---	--

REPORT SIGNATURE TABLE

Function	Name	Signature	Date
Prepared by	Herve Le Gleau MF/DP/CMS		15 October 2016
Reviewed by	Hervé Le Gléau MF/DP/CMS		15 October 2016
Authorised by	NWC SAF Project Manager		15 October 2016

		User Manual for the Cloud Product Processors of the NWC/GEO: Science Part	Code: NWC/CDOP2/GEO/MFL/SCI/UM/Cloud Issue: 1.0 Date: 15 October 2016 File: NWC-CDOP2-GEO-MFL-SCI-UM-Cloud_v1.0 Page: 3/56
---	---	---	--

DOCUMENT CHANGE RECORD

Version	Date	Pages	Changes
1.0d	15 June 2015	56	Draft version for STRR
1.0	15 October 2016	56	Inclusion of STRR outcome



		User Manual for the Cloud Product Processors of the NWC/GEO: Science Part	Code: NWC/CDOP2/GEO/MFL/SCI/UM/Cloud Issue: 1.0 Date: 15 October 2016 File: NWC-CDOP2-GEO-MFL-SCI-UM-Cloud_v1.0 Page: 4/56
---	---	---	--



Table of Contents

1	INTRODUCTION	7
1.1	SCOPE OF THE DOCUMENT	7
1.2	SCOPE OF OTHER DOCUMENTS	7
1.3	SOFTWARE VERSION IDENTIFICATION	7
1.4	IMPROVEMENT FROM PREVIOUS VERSION	7
1.5	DEFINITIONS, ACRONYMS AND ABBREVIATIONS	8
1.6	REFERENCES	9
1.6.1	Applicable documents	9
1.6.2	Reference documents	10
2	CLOUD MASK (GEO-CMA) PRODUCT	11
2.1	DESCRIPTION OF CLOUD MASK (GEO-CMA) PRODUCT	11
2.1.1	Goal of Cloud Mask (GEO-CMA) product	11
2.1.2	Description of Cloud Mask (GEO-CMA) algorithm	11
2.1.3	Description of Cloud Mask (GEO-CMA) output	13
2.2	IMPLEMENTATION OF CLOUD MASK (GEO-CMA)	16
2.2.1	Manual preparation of Cloud Mask (GEO-CMA) model configuration file for each region	16
2.2.2	Cloud Mask (GEO-CMA) execution step	17
2.3	INPUTS AND CONFIGURABLE PARAMETERS FOR CLOUD MASK (GEO-CMA)	17
2.3.1	List of inputs for Cloud Mask (GEO-CMA)	17
2.3.2	CMA Model Configuration File	20
2.3.3	Configurable parameters for Cloud Mask (GEO-CMA)	21
2.4	CLOUD MASK (GEO-CMA) VALIDATION	22
2.4.1	Summary of Cloud Mask (GEO-CMA) validation results	22
2.4.2	Typical known problems and recommendation for use	23
2.5	EXAMPLE OF CLOUD MASK (GEO-CMA) VISUALISATION	23
3	CLOUD TYPE (GEO-CT) PRODUCT	25
3.1	DESCRIPTION OF CLOUD TYPE (GEO-CT) PRODUCT	25
3.1.1	Goal of Cloud Type (GEO-CT) product	25
3.1.2	Outline of Cloud Type (GEO-CT) product	25
3.1.3	Description of Cloud Type (GEO-CT) output	26
3.2	IMPLEMENTATION OF CLOUD TYPE (GEO-CT)	28
3.2.1	Manual preparation of Cloud Type (GEO-CT) model configuration file for each region	28
3.2.2	The Cloud Type (GEO-CT) execution step	28
3.3	INPUT AND CONFIGURABLE PARAMETERS FOR CLOUD TYPE (GEO-CT)	29
3.3.1	List of inputs for Cloud Type (GEO-CT)	29
3.3.2	CT Model Configuration File	30
3.3.3	Configurable parameters for Cloud Type (GEO-CT)	31
3.4	CLOUD TYPE (GEO-CT) VALIDATION	31
3.4.1	Summary of Cloud Type (GEO-CT) validation results	31
3.4.2	Typical known problems and recommendation for use	31
3.5	EXAMPLE OF CLOUD TYPE (GEO-CT) VISUALISATION	31
4	CLOUD TOP TEMPERATURE AND HEIGHT (GEO-CTTH) PRODUCT	33
4.1	DESCRIPTION OF CLOUD TOP TEMPERATURE AND HEIGHT (GEO-CTTH) PRODUCT	33
4.1.1	Goal of Cloud Top Temperature and Height (GEO-CTTH) product	33
4.1.2	Outline of Cloud Top Temperature and Height (GEO-CTTH) algorithm	33
4.1.3	Description of Cloud Top Temperature and Height (GEO-CTTH) output	35
4.2	IMPLEMENTATION OF CLOUD TOP TEMPERATURE AND HEIGHT (GEO-CTTH)	38
4.2.1	Manual preparation of Cloud Top Temperature and Height (CTTH) model configuration file for each region	38

4.2.2	<i>The Cloud Top Temperature and Height (GEO-CTTH) execution step.....</i>	38
4.3	INPUTS AND CONFIGURABLE PARAMETERS FOR CLOUD TOP TEMPERATURE AND HEIGHT (GEO-CTTH)	39
4.3.1	<i>List of inputs for Cloud Top Temperature and Height (GEO-CTTH).....</i>	39
4.3.2	<i>CTTH Model Configuration File</i>	41
4.3.3	<i>Configurable parameters for Cloud Top Temperature and Height (GEO-CTTH)</i>	43
4.4	CLOUD TOP TEMPERATURE AND HEIGHT (GEO-CTTH) VALIDATION	43
4.4.1	<i>Summary of Cloud Top Temperature and Height (GEO-CTTH) validation results.....</i>	43
4.4.2	<i>Typical known problems and recommendation for use.....</i>	44
4.5	EXAMPLE OF CLOUD TOP TEMPERATURE AND HEIGHT (CTTH) VISUALISATION	44
5	CLOUD MICROPHYSICS (GEO-CMIC) PRODUCT.....	46
5.1	DESCRIPTION OF CLOUD MICROPHYSICS (GEO-CMIC) PRODUCT.....	46
5.1.1	<i>Goal of Cloud Microphysics product.....</i>	46
5.1.2	<i>Outline of Cloud Microphysics (GEO-CMIC) algorithm.....</i>	46
5.1.3	<i>Description of Cloud Microphysics (GEO-CMIC) output</i>	47
5.2	IMPLEMENTATION OF CLOUD MICROPHYSICS (GEO-CMIC).....	50
5.2.1	<i>Manual preparation of Cloud Microphysics (GEO-CMIC) model configuration file for each region.....</i>	50
5.2.2	<i>The Cloud Microphysics (GEOCMIC) execution step</i>	51
5.3	INPUTS AND CONFIGURATION PARAMETERS FOR CLOUD MICROPHYSICS (GEO-CMIC).....	51
5.3.1	<i>List of inputs for Cloud Microphysics (GEO-CMIC).....</i>	51
5.3.2	<i>CMIC Model Configuration File</i>	52
5.3.3	<i>Configurable parameters for Cloud Microphysics (GEO-CMIC).....</i>	53
5.4	CLOUD MICROPHYSICS (GEO-CMIC) VALIDATION.....	53
5.4.1	<i>Summary of Cloud Microphysics (GEO-CMIC) validation results.....</i>	53
5.4.2	<i>Typical known problems and recommendation for use.....</i>	54
5.5	EXAMPLE OF CLOUD MICROPHYSICS (CMIC) VISUALISATION.....	54

List of Tables and Figures

<i>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.....</i>	<i>24</i>
<i>Figure 2: Example of MODIS volcanic ash cloud superimposed on a 10.8μm infrared image: Etna eruption on 22th July 2001 at 9h55 UTC.....</i>	<i>24</i>
<i>Figure 3: Example of SEVIRI CT cloud type using the colour palette included in CT NetCdF files.</i>	<i>32</i>
<i>Figure 4: Example of SEVIRI CTTH cloud top pressure.....</i>	<i>45</i>
<i>Figure 5 Example of SEVIRI cloud phase flag illustrated with the colour palette included in the CMIC NetCdF files.....</i>	<i>55</i>
<i>Figure 6 Example of SEVIRI cloud effective radius illustrated with the colour palette included in the CMIC NetCdF files.....</i>	<i>56</i>
<i>Table 1: List of Applicable Documents.....</i>	<i>10</i>
<i>Table 2: List of Referenced Documents.....</i>	<i>10</i>
<i>Table 3: Test sequence over land.....</i>	<i>12</i>
<i>Table 4: Test sequence over sea.....</i>	<i>12</i>
<i>Table 5: CMA default Model Configuration File description.....</i>	<i>21</i>
<i>Table 6: Summary of validation results of the current CMA version (POD stands for Probability Of Detection)</i>	<i>22</i>
<i>Table 7: CT default Model Configuration File description.....</i>	<i>30</i>
<i>Table 8: Summary of validation results of the current CT version.....</i>	<i>31</i>
<i>Table 9: CTTH default Model Configuration File description.....</i>	<i>43</i>
<i>Table 10: Summary of validation results of the current CTTH version (std stands for standard deviation).....</i>	<i>44</i>
<i>Table 11: CMIC default Model Configuration File description.....</i>	<i>53</i>
<i>Table 12: Summary of validation results of the current CMIC cloud phase and cloud liquid water path (POD stands for Probability Of Detection).....</i>	<i>54</i>

		User Manual for the Cloud Product Processors of the NWC/GEO: Science Part	Code: NWC/CDOP2/GEO/MFL/SCI/UM/Cloud Issue: 1.0 Date: 15 October 2016 File: NWC-CDOP2-GEO-MFL-SCI-UM-Cloud_v1.0 Page: 7/56
---	---	---	--

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, NWC SAF. The main objective of NWC SAF 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 NWC SAF webpage, <http://www.nwcsaf.org>. This document is applicable to the NWC SAF processing package for geostationary meteorological satellites, NWC/GEO.

1.1 SCOPE OF THE DOCUMENT

This document is the Product User Manual for the Cloud Products components PGE01 (GEO-CMA, Cloud Mask), PGE02 (GEO-CT, Cloud Type), PGE03 (GEO-CTTH, Cloud Top Temperature and Height) and PGE15 (GEO-CMIC, Cloud Microphysics) of the NWC/GEO software package.

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

1.2 SCOPE OF OTHER DOCUMENTS

The algorithms used to extract the GEO Cloud Products are detailed in the algorithm theoretical basis document for cloud products ([AD.11.]).

The validation of the algorithms used to extract the GEO Cloud Products is reported in the validation report for cloud products ([RD.1.]).

Instructions to install, configure and execute the SAFNWC/GEO software in order to extract the GEO Cloud Products are detailed in the software user manual ([RD.2.]).

The interface control documents ([AD.6.]) (for the External and Internal Interfaces of the SAFNWC/GEO) and ([AD.8.]) (GEO Output Product Format Definition) detail the input and output data format for the SAFNWC/GEO software.

1.3 SOFTWARE VERSION IDENTIFICATION

This document describes the products obtained from the GEO-CMA-v4.0 (Product Id NWC-002), GEO-CT-v3.0 (Product Id NWC-006), GEO-CTTH-v3.0 (Product Id NWC-010) and GEO-CMIC-v1.0 (Product Id NWC-013) implemented in the release 2016 of the NWC/GEO software package.

1.4 IMPROVEMENT FROM PREVIOUS VERSION



Since 2013 release, the following improvements have been implemented:

- Technical improvements: interface to updated NWCLIB, new output format, technical adaptation to process other meteorological geostationary satellites than MSG
- Scientific improvements:

- GEO-CMA: use of RTTOV on line to improve some thresholds, reduction of fire/cloud confusion
- GEO-CT: none
- GEO-CTTH: none
- GEO-CMIC: new product based on cloud phase and cloud optical thickness and effective particle size respectively output and internally computed in CT from 2013 release. The main improvement since 2013 release is the availability of new outputs (cloud optical thickness, effective particle size, liquid and ice water path) and the use by the retrieval algorithm of cloud reflectance simulations based on DISORT instead RTMOM.

1.5 DEFINITIONS, ACRONYMS AND ABBREVIATIONS

6S	Second Simulation of Satellite Signal in the Solar Spectrum
BRDF	Bi-directional Reflectance Functions
CMA	Cloud Mask
CMIC	Cloud Microphysics
CMS	Centre de Meteorologie Spatiales (Météo-France, satellite reception centre in Lannion)
CTTH	Cloud Top Temperature and Height
CT	Cloud Type
DISORT	Discrete Ordinates Radiative Transfer Program
ECMWF	European Centre for Medium range Weather Forecast
EUMETSAT	European Meteorological Satellite Agency
FOV	Field Of View
GEO	Meteorological Geostationary Satellite
HDF	Hierarchical data Format
HRIT	High Rate Information Transmission
IR	Infrared
K	Kelvin
LUT	Look-Up Table
MODIS	Moderate-Resolution Imaging Spectroradiometer
MSG	Meteosat Second Generation
NIR	Near Infra-Red
NOAA	National Oceanic and Atmospheric Administration
NWC SAF	SAF to support NoWCasting and VSRF
NWCLIB	NWC/GEO common library
NWP	Numerical Weather Prediction
OSI SAF	Ocean and Sea Ice SAF

		User Manual for the Cloud Product Processors of the NWC/GEO: Science Part	Code: NWC/CDOP2/GEO/MFL/SCI/UM/Cloud Issue: 1.0 Date: 15 October 2016 File: NWC-CDOP2-GEO-MFL-SCI-UM-Cloud_v1.0 Page: 9/56
---	---	---	--

OSTIA	Operational Sea Surface Temperature and Sea Ice Analysis
PGE	Product Generation Element
R0.6μm	0.6 visible reflectance
RTMOM	Radiative Transfer based on Matrix Operator Method
RTTOV	Rapid Transmissions for TOVs
SAF	Satellite Application Facility
SEVIRI	Spinning Enhanced Visible & Infrared Imager
SST	Sea Surface Temperature
SUM	Software User Manual
SW	Software
T11μm	11 micrometer infrared brightness temperature
TIGR	Tovs Initial Guess Retrieval
TOA	Top Of Atmosphere
VIS	Visible

1.6 REFERENCES

1.6.1 Applicable documents

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

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

Current documentation can be found at the NWC SAF Helpdesk web: <http://www.nwcsaf.org>

Ref	Title	Code	Vers	Date
[AD.1.]	Proposal for the Second Continuous Development and operation Phase (CDOP) march 2012 – February 2017	NWC/CDOP2/MGT/AEMET/PRO	1.0	15/03/2011
[AD.2.]	NWCSAF Project Plan	NWC/CDOP2/SAF/AEMET/MGT/PP	1.9	15/10/2016
[AD.3.]	Configuration Management Plan for the NWCSAF	NWC/CDOP2/SAF/AEMET/MGT/CMP	1.4	15/10/2016
[AD.4.]	NWCSAF Product Requirement Document	NWC/CDOP2/SAF/AEMET/MGT/PRD	1.9	15/08/2016
[AD.5.]	System and Components Requirements Document for the NWC/GEO	SAF/NWC/CDOP2/AEMET/SW/SCRD	1.2	15/10/2016
[AD.6.]	Interface Control Document for Internal and External Interfaces of the NWC/GEO	NWC/CDOP2/GEO/AEMET/SW/ICD/1	1.1	15/10/2016
[AD.7.]	Interface Control Document for the NWCLIB of the NWC/GEO	NWC/CDOP2/GEO/AEMET/SW/ICD/2	1.1	15/10/2016
[AD.8.]	Data Output Format for the NWC/GEO	NWC/CDOP2/GEO/AEMET/SW/DOF	1.1	15/10/2016
[AD.9.]	Architectural Design Document for the NWC/GEO	NWC/CDOP2/GEO/AEMET/SW/ACDD	1.1	15/10/2016
[AD.10.]	Component Design Document for the Cloud Product Processors of the NWC/GEO	NWC/CDOP2/GEO/MFL/SW/ACDD/Cloud	1.1	15/10/2016
[AD.11.]	Algorithm Theoretical Basis Document for the Cloud Product Processors of the NWC/GEO	NWC/CDOP2/GEO/MFL/SCI/ATBD/Cloud	1.1	15/10/2016
[AD.12.]	The Nowcasting SAF glossary	NWC/CDOP2/SAF/AEMET/MGT/GLO	2.0	18/2/2014

Table 1: List of Applicable Documents

1.6.2 Reference documents

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

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

Current documentation can be found at the NWC SAF Helpdesk web: <http://www.nwcsaf.org>.

Ref	Title	Code	Vers	Date
[RD.1.]	Scientific and Validation report for the cloud products processors of the NWC/GEO	NWC/CDOP2/GEO/MFL/SCI/VR/Cloud	1.0	15/10/2016
[RD.2.]	User Manual for the NWC/GEO application: Software part	NWC/CDOP2/GEO/AEMET/SW/UM	1.0	15/10/2016

Table 2: List of Referenced Documents

2 CLOUD MASK (GEO-CMA) PRODUCT

2.1 DESCRIPTION OF CLOUD MASK (GEO-CMA) PRODUCT

2.1.1 Goal of Cloud Mask (GEO-CMA) product

The cloud mask (GEO-CMA), developed within the NWC SAF 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, instability indices, land or sea surface temperatures, snow/ice cover delineation) may be computed. It also allows identifying cloudy areas where other products (cloud types, cloud top temperature/height, cloud microphysic, precipitation) 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, volcanic plumes.

2.1.2 Description of Cloud Mask (GEO-CMA) algorithm

The algorithm has been designed to be applicable to imagers on board meteorological geostationary satellites. The imagers may have different set of channels possibly at different horizontal resolutions. The lowest native resolution of the radiometer (3km at nadir for MSG/SEVIRI), which is for most imagers on board present and future meteorological geostationary satellites the horizontal resolution of all IR channels and some solar channels, will be chosen as the default horizontal resolution. Solar channels may be available at higher horizontal resolution (1km at nadir for HRV). In this release, the process is applied to all useful channels at the default horizontal resolution (high resolution channels being averaged at this resolution), the high resolution channels being additionally used at their native resolution to detect sub-pixels clouds inside pixels at default horizontal resolution. We use generic labels in this document (for example, T3.8 μ m, T8.7 μ m, T10.8 μ m, T12.0 μ m, R0.6 μ m, R0.8 μ m and R1.6 μ m), the exact central wavelengths of the corresponding channels depending on the satellite. The list of available labels depends on the satellite; the list of mandatory channels is listed in 2.3.1 .

A first process allows the identification of clouds or snow/ice. It consists in the following steps which are applied to all pixels at default horizontal resolution:

- a first set of multispectral tests with thresholds computed from Look-Up Tables (LUT) allows detecting most of the pixels containing cloud or snow,
- (optional step) a second limited set of multispectral tests with thresholds computed from RTTOV applied on-line to NWP vertical profiles allows by a more accurate threshold computation a detection of low or thin high clouds that remained undetected when using LUTs,
- an analysis of the temporal variation (on a short period of time around 15 minutes) of some spectral combination of channels allows detecting rapidly moving clouds,
- a specific treatment combining temporal coherency analysis and region growing technique allows the improvement of low clouds detection in twilight conditions,

- (optional step) an analysis of solar channels at high spatial resolution (HRV for MSG) allows detecting sub-pixel clouds inside pixel at default horizontal resolution,
- a spatial filtering is finally applied to cold areas, cloud edges (over ocean), isolated cloud pixel (land) and snow-area edges

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

Details on the tests are given in the algorithm theoretical basis document for cloud products ([AD.11.]).

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

Table 3: Test sequence over land

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

Table 4: Test sequence over sea



[T3.8µm, T8.7µm, T10.8µm and T12.0µm are labels that stand for brightness temperatures at around 3.8, 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 around 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 Sunlint is a specific module for low clouds identification in sunglint areas. It must be noted that labels (T3.8µm, T8.7µm, T10.8µm, T12.0µm, R0.6µm, R0.8µm and R1.6µm) are generic, the exact central wavelength of the corresponding channel depending on the satellite]

2.1.3 Description of Cloud Mask (GEO-CMA) output

The content of the GEO-CMA output (in NetCDF format) is described in the Data Output Format document ([AD.8.]), a summary is given below:

Container	Content												
GEO-CMA	SAFNWC GEO CMA Cloud Mask <table border="1"> <tr> <th>Class</th><th>Cloud Mask category</th></tr> <tr> <td>0</td><td>Cloud-free</td></tr> <tr> <td>1</td><td>Cloudy</td></tr> <tr> <td>FillValue</td><td>No data or corrupted data</td></tr> </table>	Class	Cloud Mask category	0	Cloud-free	1	Cloudy	FillValue	No data or corrupted data				
Class	Cloud Mask category												
0	Cloud-free												
1	Cloudy												
FillValue	No data or corrupted data												
GEO-CMA _CLOUDSNOW	SAFNWC GEO CMA Cloud and Snow Mask <table border="1"> <tr> <th>Class</th><th>Cloud and Snow Mask category</th></tr> <tr> <td>0</td><td>Cloud-free</td></tr> <tr> <td>1</td><td>Cloud (except thin ice cloud over snow)</td></tr> <tr> <td>2</td><td>Thin ice cloud over snow/ice</td></tr> <tr> <td>3</td><td>Snow/Ice</td></tr> <tr> <td>FillValue</td><td>No data or corrupted data</td></tr> </table>	Class	Cloud and Snow Mask category	0	Cloud-free	1	Cloud (except thin ice cloud over snow)	2	Thin ice cloud over snow/ice	3	Snow/Ice	FillValue	No data or corrupted data
Class	Cloud and Snow Mask category												
0	Cloud-free												
1	Cloud (except thin ice cloud over snow)												
2	Thin ice cloud over snow/ice												
3	Snow/Ice												
FillValue	No data or corrupted data												
GEO-CMA _DUST	SAFNWC GEO CMA Dust Detection <table border="1"> <tr> <th>Class</th><th>Dust Detection category</th></tr> <tr> <td>0</td><td>No dust</td></tr> <tr> <td>1</td><td>Dust</td></tr> <tr> <td>2</td><td>Undefined (separability problem)</td></tr> <tr> <td>FillValue</td><td>No data or corrupted data</td></tr> </table>	Class	Dust Detection category	0	No dust	1	Dust	2	Undefined (separability problem)	FillValue	No data or corrupted data		
Class	Dust Detection category												
0	No dust												
1	Dust												
2	Undefined (separability problem)												
FillValue	No data or corrupted data												
GEO-CMA _VOLCANIC	SAFNWC GEO CMA Volcanic Plume Detection <table border="1"> <tr> <th>Class</th><th>Volcanic Plume Detection category</th></tr> <tr> <td>0</td><td>No volcanic plume</td></tr> <tr> <td>1</td><td>Volcanic plume</td></tr> <tr> <td>2</td><td>Undefined (separability problem)</td></tr> <tr> <td>FillValue</td><td>No data or corrupted data</td></tr> </table>	Class	Volcanic Plume Detection category	0	No volcanic plume	1	Volcanic plume	2	Undefined (separability problem)	FillValue	No data or corrupted data		
Class	Volcanic Plume Detection category												
0	No volcanic plume												
1	Volcanic plume												
2	Undefined (separability problem)												
FillValue	No data or corrupted data												

Container	Content
GEO-CMA _TESTLIST	<p>28 bits indicating (if set to 1)</p> <ul style="list-style-type: none"> Bit 0: R0.6µm (land) or R0.8µm (sea) Bit 1: R1.6µm (sea) Bit 2: Sun glint test using 3.8µm Bit 3: R1.38µm Bit 4: T10.8µm or SST Bit 5: T10.8µm – T12.0µm Bit 6: T10.8µm – T3.8µm Bit 7: T12.0µm – T3.8µm Bit 8: T3.8µm – T10.8µm Bit 9: T10.8µm – T8.7µm Bit 10: T8.7µm – T10.8µm Bit 11: T8.7µm – T3.8µm Bit 12: Snow with only T3.8µm Bit 13: Snow with R1.6µm Bit 14: Snow with combined use of R1.6 µm and R2.2µm Bit 15: Local Spatial Texture Bit 16: T10.8µm with RTTOV Bit 17: T3.8µm with RTTOV Bit 18: T8.7µm – T3.8µm with RTTOV Bit 19: T10.8µm – T12.0µm with RTTOV Bit 20: T10.8µm – T8.7µm with RTTOV Bit 21: T10.8µm – T3.8µm with RTTOV Bit 22: Temporal-differencing Bit 23: Stationary cloud in twilight Bit 24: Spatial extension of stationary clouds in twilight Bit 25: Use of high resolution visible Bit 26: Spatial filtering: cloud reclassified as cloud-free Bit 27: Spatial filtering: cloud-free reclassified as cloud
GEO-CMA _status_flag	<p>10 bits indicating (if set to 1)</p> <ul style="list-style-type: none"> Bit 0: Low level thermal inversion in NWP field Bit 1: Cold snowy ground suspected Bit 2: Temporal algorithm passed Bit 3: High resolution satellite data used Bit 4: RTTOV on line-used Bit 5: SST analysis available Bit 6: Snow map available (not yet used) Bit 7: Sea ice map is available (not yet used) Bit 8: No method for dust Bit 9: No method for volcanic plume

 	User Manual for the Cloud Product Processors of the NWC/GEO: Science Part	Code: NWC/CDOP2/GEO/MFL/SCI/UM/Cloud Issue: 1.0 Date: 15 October 2016 File: NWC-CDOP2-GEO-MFL-SCI-UM-Cloud_v1.0 Page: 15/56
---	---	---

Geophysical Conditions

Field	Type	Description
Space	Flag	Set to 1 for space pixels
Illumination	Parameter	Defines the illumination condition 0: N/A (space pixel) 1: Night 2: Day 3: Twilight
Sunglint	Flag	Set to 1 if Sunglint
Land_Sea	Parameter	0: N/A (space pixel) 1: Land 2: Sea 3: Coast
Rough_terrain	Flag	Set to 1 if rough terrain
High_terrain	Flag	Set to 1 if high terrain

Processing Conditions

Field	Type	Description
Satellite_input_data	Parameter	Describes the Satellite input data status 0: N/A (space pixel) 1: All satellite data are available 2: At least one useful satellite channel is missing 3: At least one mandatory satellite channel is missing
NWP_input_data	Parameter	Describes the NWP input data status 0: N/A (space pixel or NWP data not used) 1: All NWP data are available 2: At least one useful NWP field is missing 3: At least one mandatory NWP field is missing
Product_input_data	Parameter	Describes the Product input data status 0: N/A (space pixel or Auxiliary data not used) 1: All input Product data are available 2: At least one useful input Product is missing 3: At least one mandatory input Product is missing
Auxiliary_input_data	Parameter	Describes the Auxiliary input data status (includes products used as input to PGE) 0: N/A (space pixel or Auxiliary data not used) 1: All Auxiliary data are available 2: At least one useful Auxiliary field is missing 3: At least one mandatory Auxiliary field is missing

Quality

Field	Type	Description
Nodata	Flag	Set to 1 if pixel is NODATA
Internal_consistency	Flag	Set to 1 if an internal consistency check has been performed. Internal consistency checks will be based in the comparison of the retrieved meteorological parameter with physical limits, climatological limits, neighbouring data, NWP data, etc.
Temporal_consistency	Flag	Set to 1 if a temporal consistency check has been performed Temporal consistency checks will be based in the comparison of the

		retrieved meteorological parameters with data obtained in previous slots.
Quality	Parameter	Retrieval Quality 0: N/A (no data) 1: Good 2: Questionable 3: Bad 4: Interpolated

2.2 IMPLEMENTATION OF CLOUD MASK (GEO-CMA)

CMA is extracted by PGE01 (GEO-CMA) component of the NWC/GEO software package. Detailed information on how to run this software package is available in the software user manual (RD.2.1).

When a new region is defined the user has to manually prepare the CMA model configuration files for this new region using a default CMA model configuration file provided in the NWC/GEO software package (see its content in section 2.3.2).

The CMA execution step is the real-time processing of the satellite images over the region. This process consists in the launch of the command: GEO-CMA by the Task manager.

2.2.1 Manual preparation of Cloud Mask (GEO-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 GEO-CMA model configuration files by adapting the GEO-CMA default model configuration file available in the SAFNWC/GEO software package (see its content in section 2.3.2).

The following parameters are configurable in the default GEO-CMA model configuration file:

- **CMA_SZSEG** (default value: 4): the size of the segment for CMA. [Segments are square boxes in the satellite projection, whose size is expressed as the number of default horizontal resolution pixels (3km at nadir for MSG) 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 RTTOV simulations, 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 default horizontal resolution, allowing the identification of the surface type (land or sea) of all pixels, whatever the segment size. The quality is not very much dependent of the segment size (if lower than 4). Decreasing the segment size will increase the execution time]. Note that sampling rate of NWP_PARAM and RTS_PARAM (see 2.3.2) should be modified accordingly.
- **NWP_FREQUENCY_PER_DAY** (default value: 4): the number of NWP forecast term per day input by the user. [By default, it is set to 4 (corresponds to NWP fields every 6 hours which is the minimum number authorized by the NWCSAF software). If the user inputs more frequent NWP fields, the NWP_FREQUENCY_PER_DAY key should be changed (for example 8 per day in case NWP fields every 3hours). This key allows to use the NWP fields input by the user avoiding hidden temporal interpolation. In fact, the computation of some IR threshold may need to analyse how NWP parameters has change before and after current slot. This require that the NWP parameters (before and after current slot) should be those input by the user without temporal linear interpolation (which is automatically performed by NWCSAF NWP handling routines).]

- **IS_ALREADY_RECALIBRATED** (default value: FALSE): a flag defining whether satellite data input by the user are already recalibrated using post-launch calibration coefficients (solar channels) and GSICS IR calibration coefficients. [For nearly all users, it shall remain set to FALSE (default value). If set to TRUE (for example, CM-SAF may use this option), the RTTOV on line option is desactivated because RTTOV infrared bias files may not be adequate].
- **RTTOV_USE** (default value: FALSE): a flag defining if the set of tests using thresholds computed on-line with RTTOV should be applied. [RTTOV_USE flag is checked at the execution step. GEO-CMA applies the set of tests using thresholds computed on-line with RTTOV if its value is TRUE. This flag has been made configurable to allow users being blocked by hardware resources to still run GEO-CMA by assigning it to FALSE in the configuration file.]
- **RTTOV_USE_COMPUTED_BIAS** (default value: FALSE): a flag defining if biases are to be monitored on line when RTTOV-based tests are used. [This key should be set to TRUE in case RTTOV_USE is set to TRUE and RTTOV bias files are not available for the NWP model used by the user (AEMET provides bias files for ECMWF only). But there are some constraints to create those bias files (see [AD.11.]).]
- **HRVIS_NEED** (default value: TRUE): a flag indicating whether the hrvis analysis should be done. [HRVIS_NEED flag is checked at the execution step. GEO-CMA applies the hrvis analysis if its value is TRUE. This flag has been made configurable to allow users being blocked by hardware resources to still run GEO-CMA by assigning it to FALSE in the configuration file.]

2.2.2 Cloud Mask (GEO-CMA) execution step

The GEO-CMA execution step consists in the launch of the command: GEO-CMA by the Task manager with the required parameters: time of slot, region and configuration file name.

2.3 INPUTS AND CONFIGURABLE PARAMETERS FOR CLOUD MASK (GEO-CMA)

2.3.1 List of inputs for Cloud Mask (GEO-CMA)

The input data to the GEO-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:**

For the current slot (H+00):

The following bi-directional reflectances or brightness temperatures are needed at default horizontal resolution (3km at nadir for MSG/SEVIRI):

R0.6 μ m	R0.8 μ m	R1.6 μ m	T3.8 μ m	T7.3 μ m	T8.7 μ m	T10.8 μ m	T12.0 μ m	T13.4 μ m
Mandatory	Optional	Optional	Mandatory	Optional	Optional	Mandatory	Mandatory	Optional

and at high spatial resolution (1km at nadir for MSG) :

hrvis
Optional

(hrvis is one visible channel at around 0.6 μ m (HRV for MSG))

The GEO-CMA software checks the availability of 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 T3.8 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.

For the slot one hour earlier (H-60min):

The following bi-directional reflectances or brightness temperatures or CMA or CT of the scene analysed one hour earlier are optionally needed (at default horizontal resolution) to improve the cloud detection in day-night transition. If one of them misses this improvement is not performed.

R0.6 μ m _{1h}	T8.7 μ m _{1h}	T10.8 μ m _{1h}	T12.0 μ m _{1h}	CMA _{1h}	CT _{1h}
Optional	Optional	Optional	Optional	Optional	Optional

For the slot around 15 minutes earlier (H-15min, exact delay depending on the satellite):

The following brightness temperatures or CMA or CT of the scene analysed around 15 minutes earlier (exact delay depending satellite) are optionally needed (at default horizontal resolution) to improve the cloud detection of fast moving clouds. If one of them misses this improvement is not performed.

T8.7 μ m _{15mn}	T10.8 μ m _{15mn}	T12.0 μ m _{15mn}	CMA _{15mn}	CT _{15mn}
Optional	Optional	Optional	Optional	Optional

The hrvis bi-directional reflectance of the scene analysed around 15 minutes earlier (exact delay depending satellite) is optionally needed to improve the sub-pixel cumulus cloud detection. If not available this improvement is not performed.

hrvis _{15mn}
Optional

(hrvis is one visible channel at around 0.6 μ m (HRV for MSG))

The channels are input by the user in specified format (HRIT for MSG), and extracted on the processed region by NWC/GEO software package.

• Sun and satellite angles associated to satellite 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 NWC/GEO software package from the NWP fields input by the user in GRIB format.

 	User Manual for the Cloud Product Processors of the NWC/GEO: Science Part	Code: NWC/CDOP2/GEO/MFL/SCI/UM/Cloud Issue: 1.0 Date: 15 October 2016 File: NWC-CDOP2-GEO-MFL-SCI-UM-Cloud_v1.0 Page: 19/56
---	---	---

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.

- **RTTOV simulations:**

The following parameters simulated by RTTOV are used as input:

- Clear sky top of atmosphere radiance
- Transmittance from surface to TOA
- Clear sky downwelling radiance

These remapped fields are elaborated by the NWC/GEO software package by applying RTTOV to the NWP fields input by the user in GRIB format.

The RTTOV simulations are not mandatory: if not available, the GEO-CMA software does not apply corresponding tests, the GEO-CMA quality being then slightly lower (especially in nighttime conditions).

- **OSTIA fields:**

The following parameters are used as input:

- OSTIA SST and local estimated error

High resolution global daily bulk SST fields (OSTIA) are input by the user who can obtain them from MyOcean service desk (see <http://www.myocean.eu.org>). They are used in conjunction with RTTOV simulations.

These OSTIA fields are not mandatory: if not available the RTTOV simulations are not used over ocean and the CMA software does not apply corresponding tests, the GEO-CMA quality being then slightly lower (especially in nighttime conditions).

- **RTTOV bias files:**



Rttov bias files are used as input. They can be downloaded from AEMET ftp server. They are valid only for ECMWF model.

These files are not mandatory. If not available, the bias can be computed by GEO-CMA (the processed region needs to contain large enough area covered by oceanic surfaces (see [AD.11.]). If this computation is not possible, the GEO-CMA does not apply test using RTTOV simulation and the GEO-CMA quality being then slightly lower (especially in nighttime conditions).

- **Ancillary data sets:**

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

- Land/sea atlas
- Land/sea/coast atlas
- Elevation atlas
- Monthly SST minimum and standard deviation values climatology
- Monthly mean 0.6 μ m atmospheric-corrected reflectance climatology (land)
- Monthly mean visible surface reflectance climatology for hrvis processing (land, (for MSG: HRV large band surface reflectance)) (derived from monthly MODIS black-sky albedos at 0.55 μ m, 0.67 μ m and 0.86 μ m)
- Land cover database (BATS)
- Monthly integrated atmospheric water vapor content climatology

		User Manual for the Cloud Product Processors of the NWC/GEO: Science Part	Code: NWC/CDOP2/GEO/MFL/SCI/UM/Cloud Issue: 1.0 Date: 15 October 2016 File: NWC-CDOP2-GEO-MFL-SCI-UM-Cloud_v1.0 Page: 20/56
---	---	---	---

- Monthly climatology of mean air temperature at 1000 hPa
- Monthly thermal emissivity at IR wavelength

These ancillary data are available in the NWC/GEO software package on a global scale; a SAFNWC tool allows their remapping on full disk for each new satellite; they are finally 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 NWC/GEO software package, and are needed by the CMA software.

2.3.2 CMa Model Configuration File

The CMA model configuration file contains all the coefficients and constants required for the derivation of the GEO-CMA product. The model configuration file must be placed in the \$SAFNWC/config directory. The file contains the following information:

Keyword	Description	Type	Default Value(s)
PGE_ID	Identifier of the PGE	Chain of characters	GEO-CMA
SEV_BANDS	SEVIRI channels to be used by CMA	Chain of characters	HRV,VIS06,VIS08,NIR16,IR38,WV73,IR87,IR108,IR120,IR134
INT_PRODUCT	Enables/disables the generation of intermediate products	Chain of characters	NO
CMA_SZSEG	Size of CMA segments expressed in SEVIRI coordinates (same value for lines and columns)	Integer	4
HRV_NEED	Flag to indicate if HRVIS band is to be used	Chain of characters	TRUE
RTTOV_USE	Flag to indicate if temporal information from previous scenes and products are to be used	Chain of characters	FALSE
RTTOV_USE_COMPUTED_BIAS	Flag defining if biases are to be monitored on line when RTTOV-based tests are used	Chain of characters	FALSE
IS_ALREADY_RECALIBRATED	Flag defining whether satellite data input by the user are already recalibrated using post-launch and GSICS calibration coefficients	Chain of characters	FALSE
NWP_FREQUENCY_PER_DAY	Number of NWP forecast term per day input by user	Integer	4
NWP_PARAM	Parameter :Temperature at surface level sampling rate : (=segment size CMA_SZSEG) interpolation method.	Chain of characters	NWP_ST 4 BLM
NWP_PARAM	Parameter :Temperature at pressure levels sampling rate : (=segment size CMA_SZSEG) interpolation method.	Chain of characters	NWP_T 4 BLI
NWP_PARAM	Parameter :Total column water vapour sampling rate : (=segment size CMA_SZSEG) interpolation method.	Chain of characters	NWP_TCWV 4 MAX
NWP_PARAM	Parameter :Altitude of the model at surface sampling rate : (=segment size CMA_SZSEG) interpolation method.	Chain of characters	NWP_ALTM 4 BLI
NWP_PARAM	Parameter : Geopotential at surface sampling rate : (=segment size CMA_SZSEG) interpolation method	Chain of characters	NWP_SGEOP 4 BLI
RTS_PARAM	Parameter : Clear sky TOA radiance sampling rate : (=segment size CMA_SZSEG) interpolation method	Chain of characters	RTS_CLEAR 4 BLI
RTS_PARAM	Parameter : Transmittance from surface to TOA sampling rate : (=segment size CMA_SZSEG) interpolation method	Chain of characters	RTS_TAUTOTAL 4 BLI
RTS_PARAM	Parameter : Clear sky down-welling radiance sampling rate : (=segment size CMA_SZSEG) interpolation method	Chain of characters	RTS_DNCLEAR 4 BLI

Table 5: CMA default Model Configuration File description

2.3.3 Configurable parameters for Cloud Mask (GEO-CMA)

The following configurable parameters are available in the default CMA model configuration file:

- **CMA_SZSEG:** the size of the segment is configurable (see its definition in section 2.2.1). Its default value is 4. Information on how to change the size of the segment can be found in section 2.2.1.
- **NWP_FREQUENCY_PER_DAY:** the number of NWP forecast term per day is configurable (see its definition in section 2.2.1). Its default value is 4. Information on how to change this number of NWP can be found in section 2.2.1.
- **IS_ALREADY_RECALIBRATED:** the flag, defining whether satellite data input by user are already recalibrated with post-launch calibration coefficients (solar channels) and GSICS IR calibration coefficients, is configurable (see its definition in section 2.2.1). Its default value is FALSE. Information on how to change this value can be found in section 2.2.1.
- **RTTOV_USE:** the flag defining if RTTOV is to be used on line (to allow a better detection of low or thin clouds) is configurable (see its definition in section 2.2.1). Its default value is FALSE. Information on how to change this value can be found in section 2.2.1.
- **RTTOV_USE_COMPUTED_BIAS:** the flag defining if biases are to be monitored on line, is configurable (see its definition in section 2.2.1). Its default value is FALSE. Information on how to change this value can be found in section 2.2.1.
- **HRVIS_NEED:** the flag indicating if hrvis data have to be used (to allow enhanced sub-pixel cumulus detection) is configurable (see its definition in section 2.2.1). Its default value is TRUE. Information on how to change this value can be found in section 2.2.1.



2.4 CLOUD MASK (GEO-CMA) VALIDATION

2.4.1 Summary of Cloud Mask (GEO-CMA) validation results

The following table summarises the validation results of the current version. More details can be obtained from the validation report for cloud products ([RD.1.]).

<i>GEO-CMA flags</i>	Validated accuracy
GEO-CMA cloud detection If validated over European areas using SYNOP observations If validated over full disk using SYNOP and SHIP observations	POD: 97.1% POD: 94.5%
GEO-CMA dust flag If 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 6: Summary of validation results of the current CMA version (POD stands for Probability Of Detection)

		User Manual for the Cloud Product Processors of the NWC/GEO: Science Part	Code: NWC/CDOP2/GEO/MFL/SCI/UM/Cloud Issue: 1.0 Date: 15 October 2016 File: NWC-CDOP2-GEO-MFL-SCI-UM-Cloud_v1.0 Page: 23/56
---	---	---	---

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

The only aim of snow detection by CMA is to limit the confusion with clouds. The users interested in snow cover should rather use H-SAF daily snow products and not the CMA snow category which should be considered as an additional information to help the image interpretation.

2.5 EXAMPLE OF CLOUD MASK (GEO-CMA) VISUALISATION

It is important to note that the GEO-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 NWC SAF products (CT for example).

Colour palettes are included in CMA NetCDF files, allowing an easy visualisation of CMA main categories, dust and volcanic ash 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.

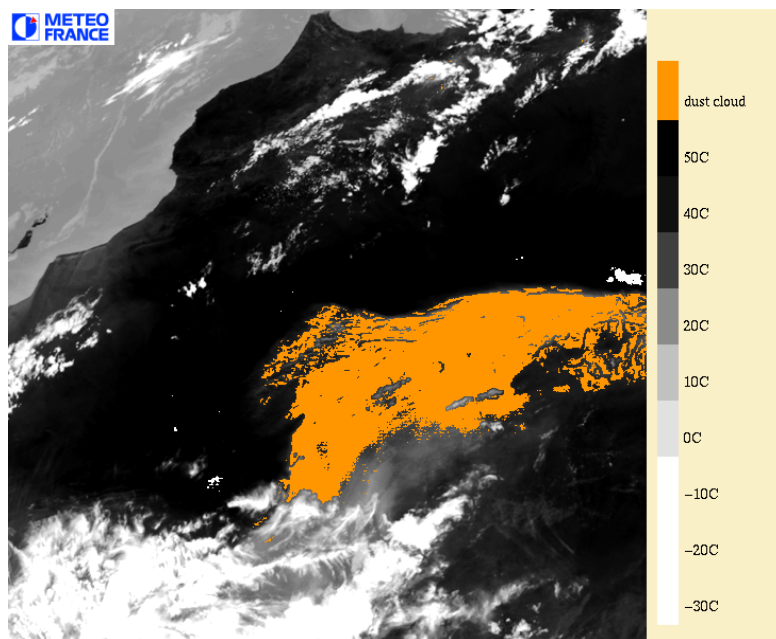


Figure 1: Example of SEVIRI dust cloud flag superimposed on a 10.8 μ m infrared image: dust cloud over North Africa on 14th July 2003 at 13h00 UTC.

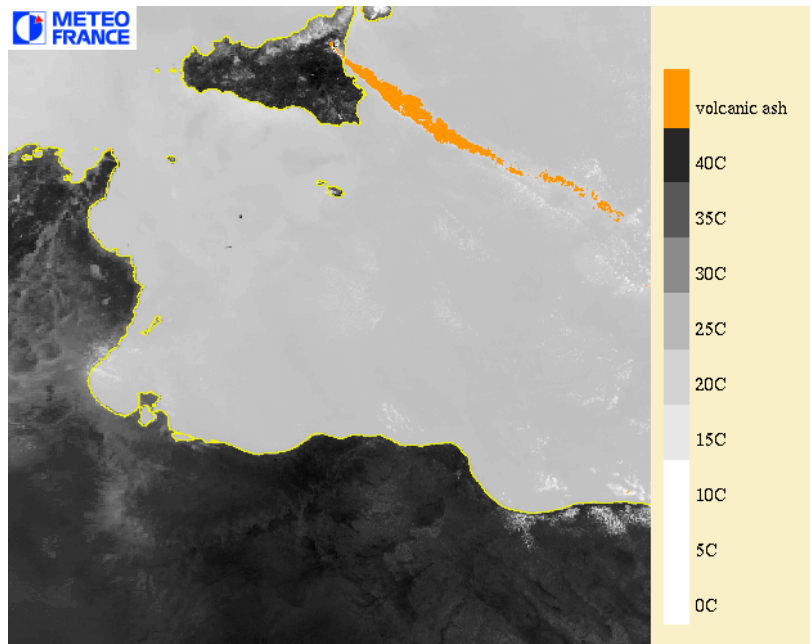


Figure 2: Example of MODIS volcanic ash cloud superimposed on a 10.8 μ m infrared image: Etna eruption on 22th July 2001 at 9h55 UTC.

3 CLOUD TYPE (GEO-CT) PRODUCT

3.1 DESCRIPTION OF CLOUD TYPE (GEO-CT) PRODUCT

3.1.1 Goal of Cloud Type (GEO-CT) product

The cloud type (CT), developed within the NWC SAF 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, cloud microphysics 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 2017).

3.1.2 Outline of Cloud Type (GEO-CT) product

The algorithm has been designed to be applicable to imagers on board meteorological geostationary satellites. The imagers may have different set of channels possibly at different horizontal resolutions. The lowest native resolution of the radiometer (3km at nadir for MSG/SEVIRI), which is for most imagers on board present and future meteorological geostationary satellites the horizontal resolution of all IR channels and some solar channels, will be chosen as the default horizontal resolution. Solar channels may be available at higher horizontal resolution (1km at nadir for HRV). In this release, the process is applied to all useful channels at the default horizontal resolution (high resolution channels being averaged at this resolution). We use generic labels in this document (for example, T3.8 μ m, T8.7 μ m, T10.8 μ m, T12.0 μ m, R0.6 μ m, R0.8 μ m and R1.6 μ m), the exact central wavelengths of the corresponding channels depending on the satellite. The list of available labels depends on the satellite; the list of mandatory channels is listed in 3.3.1.

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 μ m-T12.0 μ m, T8.7 μ m-T10.8 μ m or T3.9 μ m-T10.8 μ m) and R0.6 μ 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.11.])

3.1.3 Description of Cloud Type (GEO-CT) output

The content of the CT output (in NetCdF format) is described in the Data Output Format document ([AD.8.]), a summary is given below:

Container	Content																																		
GEO-CT	SAFNWC GEO CT Cloud Type <table border="1"> <thead> <tr> <th>Class</th><th>Cloud Type category</th></tr> </thead> <tbody> <tr><td>1</td><td>Cloud-free land</td></tr> <tr><td>2</td><td>Cloud-free sea</td></tr> <tr><td>3</td><td>Snow over land</td></tr> <tr><td>4</td><td>Sea ice</td></tr> <tr><td>5</td><td>Very low clouds</td></tr> <tr><td>6</td><td>Low clouds</td></tr> <tr><td>7</td><td>Mid-level clouds</td></tr> <tr><td>8</td><td>High opaque clouds</td></tr> <tr><td>9</td><td>Very high opaque clouds</td></tr> <tr><td>10</td><td>Fractional clouds</td></tr> <tr><td>11</td><td>High semitransparent thin clouds</td></tr> <tr><td>12</td><td>High semitransparent meanly thick clouds</td></tr> <tr><td>13</td><td>High semitransparent thick clouds</td></tr> <tr><td>14</td><td>High semitransparent above low or medium clouds</td></tr> <tr><td>15</td><td>High semitransparent above snow/ice</td></tr> <tr><td>FillValue</td><td>No data or corrupted data</td></tr> </tbody> </table>	Class	Cloud Type category	1	Cloud-free land	2	Cloud-free sea	3	Snow over land	4	Sea ice	5	Very low clouds	6	Low clouds	7	Mid-level clouds	8	High opaque clouds	9	Very high opaque clouds	10	Fractional clouds	11	High semitransparent thin clouds	12	High semitransparent meanly thick clouds	13	High semitransparent thick clouds	14	High semitransparent above low or medium clouds	15	High semitransparent above snow/ice	FillValue	No data or corrupted data
Class	Cloud Type category																																		
1	Cloud-free land																																		
2	Cloud-free sea																																		
3	Snow over land																																		
4	Sea ice																																		
5	Very low clouds																																		
6	Low clouds																																		
7	Mid-level clouds																																		
8	High opaque clouds																																		
9	Very high opaque clouds																																		
10	Fractional clouds																																		
11	High semitransparent thin clouds																																		
12	High semitransparent meanly thick clouds																																		
13	High semitransparent thick clouds																																		
14	High semitransparent above low or medium clouds																																		
15	High semitransparent above snow/ice																																		
FillValue	No data or corrupted data																																		
GEO-CT _CUMULIFORM	SAFNWC GEO CT Stratiform/Cumuliform Cloud Detection <table border="1"> <thead> <tr> <th>Class</th><th>Stratiform/Cumuliform Cloud category</th></tr> </thead> <tbody> <tr><td>1</td><td>Stratiform status</td></tr> <tr><td>2</td><td>Cumuliform status</td></tr> <tr><td>3</td><td>Mixed status</td></tr> <tr><td>4</td><td>Cloud-free</td></tr> <tr><td>5</td><td>Undefined (separability problem)</td></tr> <tr><td>FillValue</td><td>No data or corrupted data</td></tr> </tbody> </table>	Class	Stratiform/Cumuliform Cloud category	1	Stratiform status	2	Cumuliform status	3	Mixed status	4	Cloud-free	5	Undefined (separability problem)	FillValue	No data or corrupted data																				
Class	Stratiform/Cumuliform Cloud category																																		
1	Stratiform status																																		
2	Cumuliform status																																		
3	Mixed status																																		
4	Cloud-free																																		
5	Undefined (separability problem)																																		
FillValue	No data or corrupted data																																		
GEO-CT _MULTILAYER	SAFNWC GEO CT Multilayer Cloud Detection <table border="1"> <thead> <tr> <th>Class</th><th>Multilayer Cloud category</th></tr> </thead> <tbody> <tr><td>0</td><td>No multilayer detected</td></tr> <tr><td>1</td><td>Multilayer detected</td></tr> <tr><td>2</td><td>Cloud free</td></tr> <tr><td>3</td><td>Undefined (separability problem)</td></tr> <tr><td>FillValue</td><td>No data or corrupted data</td></tr> </tbody> </table>	Class	Multilayer Cloud category	0	No multilayer detected	1	Multilayer detected	2	Cloud free	3	Undefined (separability problem)	FillValue	No data or corrupted data																						
Class	Multilayer Cloud category																																		
0	No multilayer detected																																		
1	Multilayer detected																																		
2	Cloud free																																		
3	Undefined (separability problem)																																		
FillValue	No data or corrupted data																																		
GEO-CT _status_flag	6 bits indicating (if set to 1) <ul style="list-style-type: none"> Bit 0: Low level thermal inversion in NWP field Bit 1: Tropopause temperature available from NWP field Bit 2: R1.38μm used for cirrus identification Bit 3: High resolution satellite data used Bit 4: No method for stratiform/cumuliform separation Bit 5: No method for multi-layer 																																		

Geophysical Conditions

Field	Type	Description
Space	Flag	Set to 1 for space pixels
Illumination	Parameter	Defines the illumination condition 0: N/A (space pixel) 1: Night 2: Day 3: Twilight
Sunglint	Flag	Set to 1 if Sunglint
Land_Sea	Parameter	0: N/A (space pixel) 1: Land 2: Sea 3: Coast
Rough_terrain	Flag	Set to 1 if rough terrain
High_terrain	Flag	Set to 1 if high terrain

Processing Conditions

Field	Type	Description
Satellite_input_data	Parameter	Describes the Satellite input data status 0: N/A (space pixel) 1: All satellite data are available 2: At least one useful satellite channel is missing 3: At least one mandatory satellite channel is missing
NWP_input_data	Parameter	Describes the NWP input data status 0: N/A (space pixel or NWP data not used) 1: All NWP data are available 2: At least one useful NWP field is missing 3: At least one mandatory NWP field is missing
Product_input_data	Parameter	Describes the Product input data status 0: N/A (space pixel or Auxiliary data not used) 1: All input Product data are available 2: At least one useful input Product is missing 3: At least one mandatory input Product is missing
Auxiliary_input_data	Parameter	Describes the Auxiliary input data status (includes products used as input to PGE) 0: N/A (space pixel or Auxiliary data not used) 1: All Auxiliary data are available 2: At least one useful Auxiliary field is missing 3: At least one mandatory Auxiliary field is missing

Quality

Field	Type	Description
Nodata	Flag	Set to 1 if pixel is NODATA
Internal_consistency	Flag	Set to 1 if an internal consistency check has been performed. Internal consistency checks will be based in the comparison of the retrieved meteorological parameter with physical limits, climatological limits, neighbouring data, NWP data, etc.
Temporal_consistency	Flag	Set to 1 if a temporal consistency check has been performed. Temporal consistency checks will be based in the comparison of the retrieved meteorological parameters with data obtained in previous slots.

Quality	Parameter	Retrieval Quality
		0: N/A (no data) 1: Good 2: Questionable 3: Bad 4: Interpolated

3.2 IMPLEMENTATION OF CLOUD TYPE (GEO-CT)

CT is extracted by PGE02 (GEO-CT) component of the NWC/GEO software package. Detailed information on how to run this software package is available in the software user manual (RD.2.1).

When a new region is defined the user has to manually prepare the CT model configuration files for this new region using a default CT model configuration file provided in the NWC/GEO software package (see its content in section 3.3.2).

The CT execution step is the real-time processing of the satellite images over the region. This process consists in the launch of the command: GEO-CT by the Task manager.

3.2.1 Manual preparation of Cloud Type (GEO-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 GEO-CT model configuration files by adapting the GEO-CT default model configuration file available in the SAFNWC/GEO software package (see its content in section 3.3.2).

The following parameter is configurable in the default GEO-CT model configuration file:

- **CT_SZSEG** (default value: 4): the size of the segment. This default value may be manually changed. [Segments are square boxes in the satellite projection, whose size is expressed as the number of default horizontal resolution pixels (3km for MSG) 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 default horizontal resolution, allowing the identification of the surface type (land or sea) of all pixels, whatever the segment size. The quality is not very much dependent on the segment size (if lower than 4). Decreasing the segment size will increase the execution time]. Note that sampling rate of NWP_PARAM and RTS_PARAM (see 2.3.2) should be modified accordingly.

3.2.2 The Cloud Type (GEO-CT) execution step

The GEO-CT execution step consists in the launch of the command: GEO-CT by the Task manager with the required parameters: time of slot, region and configuration file name.

3.3 INPUT AND CONFIGURABLE PARAMETERS FOR CLOUD TYPE (GEO-CT)

3.3.1 List of inputs for Cloud Type (GEO-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 bi-directional reflectances or brightness temperatures are needed at default horizontal resolution (3km at nadir for MSG):

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

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

The channels are input by the user in specified format (HRIT for MSG), and extracted on the processed region by NWC/GEO software package.

- **CMA cloud categories**

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

- **Sun and satellite angles associated to satellite 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 NWC/GEO 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 vapor content climatology
- Monthly climatology of mean air temperature at 1000hPa, 850hPa, 700hPa, 500hPa.

These ancillary data are available in the NWC software package on a global scale; a SAFNWC tool allows their remapping on full disk for each new satellite; they are finally extracted on the processed region by the CT software itself.

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

3.3.2 CT Model Configuration File

The CT model configuration file contains all the coefficients and constants required for the derivation of the GEO-CT product. The model configuration file must be placed in the \$SAFNWC/config directory. The file contains the following information:

Keyword	Description	Type	Default Value(s)
PGE_ID	Identifier of the PGE	Chain of characters	GEO-CT
SEV_BANDS	SEVIRI channels to be used by CT	Chain of characters	VIS06,IR38,WV73,IR87,IR108,IR120
INT_PRODUCT	Enables/disables the generation of intermediate products	Chain of characters	NO
CT_SZSEG	Size of CT segments expressed in SEVIRI coordinates (same value for lines and columns)	Integer	4
NWP_PARAM	Parameter :Temperature at surface level sampling rate : (=segment size CT_SZSEG) interpolation method.	Chain of characters	NWP_ST 4 BLM
NWP_PARAM	Parameter :Temperature at pressure levels sampling rate : (=segment size CT_SZSEG) interpolation method.	Chain of characters	NWP_T 4 BLI
NWP_PARAM	Parameter :Temperature at tropopause level sampling rate : (=segment size CT_SZSEG) interpolation method.	Chain of characters	NWP_TT 4 BLI
NWP_PARAM	Parameter :Total column water vapour sampling rate : (=segment size CT_SZSEG) interpolation method.	Chain of characters	NWP_TCWV 4 MAX
NWP_PARAM	Parameter :Altitude of the model at surface sampling rate : (=segment size CT_SZSEG) interpolation method.	Chain of characters	NWP_ALTM 4 BLI
NWP_PARAM	Parameter : Geopotential at surface sampling rate : (=segment size CT_SZSEG) interpolation method	Chain of characters	NWP_SGEOP 4 BLI

Table 7: CT default Model Configuration File description

3.3.3 Configurable parameters for Cloud Type (GEO-CT)

The following configurable parameters is available in the default CT model configuration file:

- **CT_SZSEG:** the size of the segment is configurable (see its definition in section 3.2.1). Its default value is 4. Information on how to change the size of the segment can be found in section 3.2.1).

3.4 CLOUD TYPE (GEO-CT) VALIDATION

3.4.1 Summary of Cloud Type (GEO-CT) validation results

The following table summarises the validation results of the current version for the CT cloud type. More details can be obtained from the validation report for cloud products ([RD.1.]).

<i>GEO-CT</i>	Validated accuracy
GEO-CT cloud type If validated over full disk (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 79% and 96% depending on illumination

Table 8: Summary of validation results of the current CT version

3.4.2 Typical known problems and recommendation for use

The following problems may be encountered (for wrong cloud detection, please refer to paragraph 2.4.2):

- 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.

As already stated in 2.4.2, the users interested in snow cover should rather use H-SAF daily snow products and not the CT snow category which should be considered as an additional information to help the image interpretation.

3.5 EXAMPLE OF CLOUD TYPE (GEO-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, multilayer, stratiform/cumuliform (not yet available))) as input to mesoscale analysis models, objective Nowcasting schemes, but also in the extraction of other NWC SAF products (CTTH or CMIC for example).

Colour palettes are included in CT NetCdF 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 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).

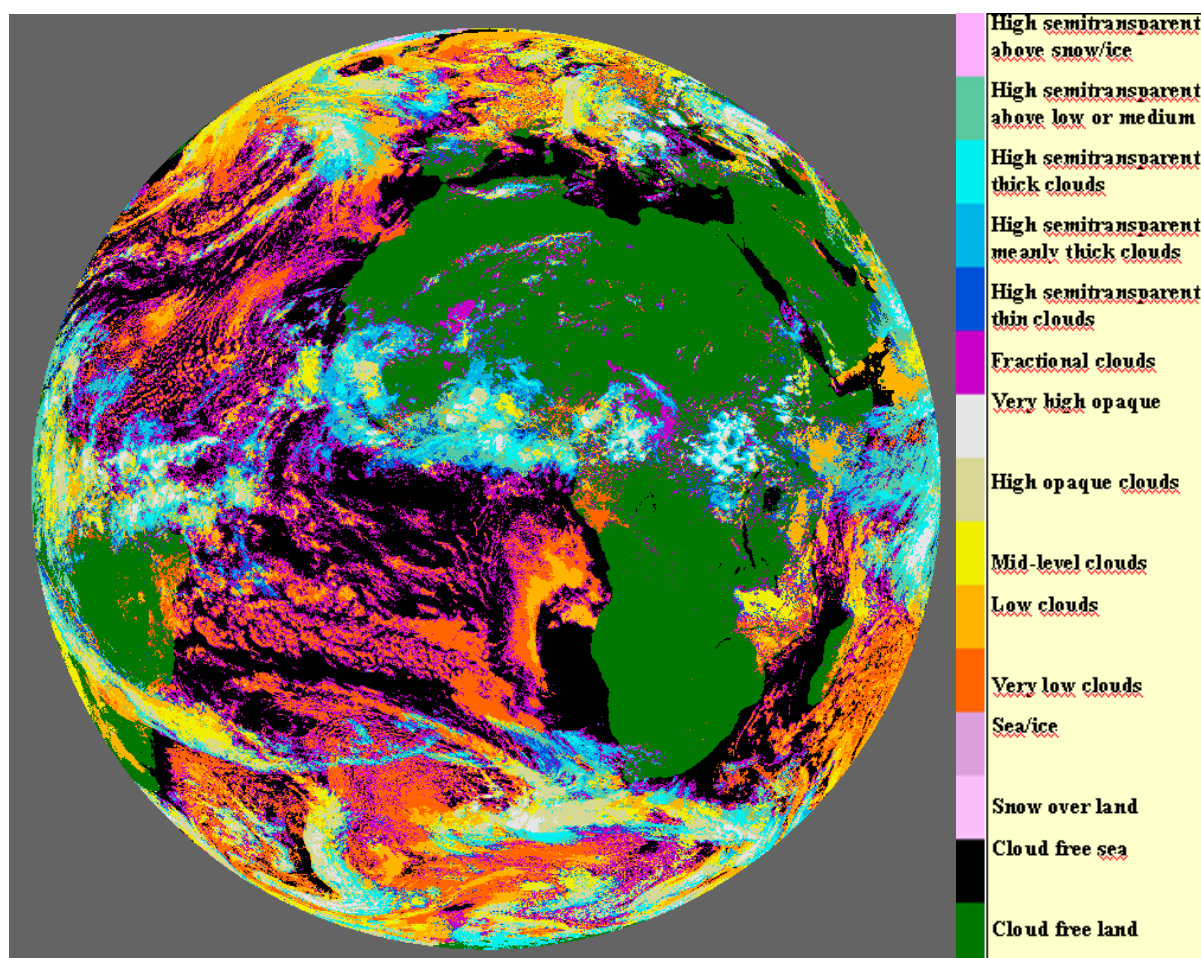


Figure 3: Example of SEVIRI CT cloud type using the colour palette included in CT NetCdF files.

4 CLOUD TOP TEMPERATURE AND HEIGHT (GEO-CTTH) PRODUCT

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

4.1.1 Goal of Cloud Top Temperature and Height (GEO-CTTH) product

The cloud top temperature and height (CTTH), developed within the NWC SAF 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 NWC SAF 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 (GEO-CTTH) algorithm

The algorithm has been designed to be applicable to imagers on board meteorological geostationary satellites. The imagers may have different set of channels possibly at different horizontal resolutions. The lowest native resolution of the radiometer (3km at nadir for MSG/SEVIRI), which is for most imagers on board present and future meteorological geostationary satellites the horizontal resolution of all IR channels and some solar channels, will be chosen as the default horizontal resolution. Solar channels may be available at higher horizontal resolution (1km at nadir for HRV). In this release, the process is applied to all useful channels at the default horizontal resolution (high resolution channels being averaged at this resolution). We use generic labels in this document (for example, Rad6.2 μ m, Rad7.3 μ m, Rad13.4 μ m, T10.8 μ m, T12.0 μ m (Rad and T stand for radiance and brightness temperatures)), the exact central wavelengths of the corresponding channels depending on the satellite. The list of available labels depends on the satellite; the used and mandatory channels are listed in 4.3.1.



Cloud top pressure or height are derived from their IR brightness temperatures by comparison to simulated IR brightness temperatures computed from temperature and humidity vertical profiles forecast by NWP using a IR radiative transfer model (RTTOV). Exact retrieval method depends on cloud type as semi-transparency correction using window and sounding IR channels may be needed.

The different steps of the processing, applied to cloud-classified image at default horizontal resolution (3km at nadir for MSG), are summarized below. The exact process applied to each pixel depends on the availability of NWP and satellite imagery data.

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

The following process is then applied:

- RTTOV radiative transfer model (Eyre, 1991) is applied using NWP temperature and humidity vertical profile to simulate cloud free and overcast (clouds successively on each vertical pressure levels) radiances and brightness temperatures for window channels (10.8 μ m, and 12.0 μ m) and sounding channels (6.2 μ m, 7.3 μ m, 13.4 μ m for MSG/SEVIRI). This process is performed in each

 	User Manual for the Cloud Product Processors of the NWC/GEO: Science Part	Code: NWC/CDOP2/GEO/MFL/SCI/UM/Cloud Issue: 1.0 Date: 15 October 2016 File: NWC-CDOP2-GEO-MFL-SCI-UM-Cloud_v1.0 Page: 34/56
---	---	---

segment of the image (the size of the segment is defined by the user, the default value being 4*4 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 temperatures 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: the 10.8µm window channel and a sounding (6.2µm, 7.3µm, 13.4µm for MSG) channel. 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 (10.8µm) and sounding (13.4µm, 7.3µm or 6.2µm for MSG) radiance bi-dimensional histogram analysis, is first applied. The histograms are built in boxes of 32*32 pixels centred on each segment of the image (whose size is defined by the user, the default value being 4*4 pixels). It therefore allows the retrieval of cloud top pressure at the segment horizontal resolution (i.e., by default 4*4 pixels). This method is successively applied using the radiances of sounding channels (7.3µm, 6.2µm and 13.4µm for MSG), the final retrieved cloud pressure being the minimum cloud top pressures obtained using single sounding channel.
 - If no result can be obtained with the H₂O/IRW intercept method, the radiance ratioing method is then applied at a pixel basis to retrieve the cloud top pressure from the radiances of two channels: a window channel (10.8µm) and a sounding channel (for MSG, successively 7.3µm, 6.2µm and 13.4µm).
 - 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 each box of 32x32 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 altitude (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 satellite data are missing (see list of inputs for CTTH):

Cloud top temperatures 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.

Details are available in the algorithm theoretical basis document for cloud products ([AD.11.]

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

The content of the CTTH output (in NetCDF format) is described in the Data Output Format document ([AD.8.]), a summary is given below:

Container	Content
GEO-CTTH _PRES	SAFNWC GEO CTTH Cloud Top Pressure $\text{GEO-CTTH_PRES(Pa)} = \text{scale_factor} * \text{Counts} + \text{add_offset}$ where: $\text{scale_factor} = 10.0$ $\text{add_offset} = 0.0$
GEO-CTTH _ALTI	SAFNWC GEO CTTH Cloud Top Altitude $\text{GEO-CTTH_ALTI(m)} = \text{scale_factor} * \text{Counts} + \text{add_offset}$ where: $\text{scale_factor} = 1.0$ $\text{add_offset} = -2000.0$
GEO-CTTH _TEMPE	SAFNWC GEO CTTH Cloud Top Temperature $\text{GEO-CTTH_TEMPE(K)} = \text{scale_factor} * \text{Counts} + \text{add_offset}$ where: $\text{scale_factor} = 0.01$ $\text{add_offset} = 130.0$

Container	Content
GEO-CTTH_EFFECTIV	SAFNWC GEO CTTH Cloud Effective Cloudiness $\text{GEO-CTTH_EFFECTIV} = \text{scale_factor} * \text{Counts} + \text{add_offset}$ where: $\text{scale_factor} = 0.01$ $\text{add_offset} = 0.0$
GEO-CTTH_METHOD	14 bits indicating (if set to 1) Bit 0: Cloud-free Bit 1: No reliable method Bit 2: Opaque cloud, RTTOV not available Bit 3: Opaque cloud, using RTTOV Bit 4: Opaque cloud, using RTTOV, in case thermal inversion Bit 5: Intercept method 10.8μm/13.4μm Bit 6: Intercept method 10.8μm/6.2μm Bit 7: Intercept method 10.8μm/7.0μm Bit 8: Intercept method 10.8μm/7.3μm Bit 9: Radiance ratioing method 10.8μm/13.4μm Bit 10: Radiance ratioing method 10.8μm/6.2μm Bit 11: Radiance ratioing method 10.8μm/7.0μm Bit 12: Radiance ratioing method 10.8μm/7.3μm Bit 13: Spatial smoothing (gap filling in semi-transparent cloud field)
GEO-CTTH_status_flag	6 bits indicating (if set to 1) Bit 0: Cloud-free Bit 1: Low level thermal inversion in NWP field Bit 2: Opaque clouds Bit 3: Fractional clouds : no retrieval method Bit 4: Too thin clouds : no retrieval method Bit 5: Multilayer suspected

Geophysical Conditions



Field	Type	Description
Space	Flag	Set to 1 for space pixels
Illumination	Parameter	Defines the illumination condition 0: N/A (space pixel) 1: Night 2: Day 3: Twilight
Sunglint	Flag	Set to 1 if Sunglint
Land_Sea	Parameter	0: N/A (space pixel) 1: Land 2: Sea 3: Coast
Rough_terrain	Flag	Set to 1 if rough terrain
High_terrain	Flag	Set to 1 if high terrain

Processing Conditions

Field	Type	Description
Satellite_input_data	Parameter	Describes the Satellite input data status 0: N/A (space pixel) 1: All satellite data are available 2: At least one useful satellite channel is missing 3: At least one mandatory satellite channel is missing
NWP_input_data	Parameter	Describes the NWP input data status 0: N/A (space pixel or NWP data not used) 1: All NWP data are available 2: At least one useful NWP field is missing 3: At least one mandatory NWP field is missing
Product_input_data	Parameter	Describes the Product input data status 0: N/A (space pixel or Auxiliary data not used) 1: All input Product data are available 2: At least one useful input Product is missing 3: At least one mandatory input Product is missing
Auxiliary_input_data	Parameter	Describes the Auxiliary input data status (includes products used as input to PGE) 0: N/A (space pixel or Auxiliary data not used) 1: All Auxiliary data are available 2: At least one useful Auxiliary field is missing 3: At least one mandatory Auxiliary field is missing

Quality

Field	Type	Description
Nodata	Flag	Set to 1 if pixel is NODATA
Internal_consistency	Flag	Set to 1 if an internal consistency check has been performed. Internal consistency checks will be based in the comparison of the retrieved meteorological parameter with physical limits, climatological limits, neighbouring data, NWP data, etc.
Temporal_consistency	Flag	Set to 1 if a temporal consistency check has been performed. Temporal consistency checks will be based in the comparison of the retrieved meteorological parameters with data obtained in previous slots.

		User Manual for the Cloud Product Processors of the NWC/GEO: Science Part	Code: NWC/CDOP2/GEO/MFL/SCI/UM/Cloud Issue: 1.0 Date: 15 October 2016 File: NWC-CDOP2-GEO-MFL-SCI-UM-Cloud_v1.0 Page: 38/56
---	---	---	---

Quality	Parameter	Retrieval Quality
		0: N/A (no data) 1: Good 2: Questionable 3: Bad 4: Interpolated

4.2 IMPLEMENTATION OF CLOUD TOP TEMPERATURE AND HEIGHT (GEO-CTTH)

CTTH is extracted by PGE03 (GEO-CTTH) component of the NWC/GEO software package. Detailed information on how to run this software package is available in the software user manual ([RD.2.]).

When a new region is defined the user has to manually prepare the CTTH model configuration files for this new region using a default CTTH model configuration file provided in the NWC/GEO software package (see its content in section 4.3.2).

The CTTH execution step is the real-time processing of the satellite images over the region. This process consists in the launch of the command: GEO-CTTH by the Task manager.

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 GEO-CTTH model configuration files by adapting the GEO-CTTH default model configuration file available in the SAFNWC/GEO software package (see its content in section 4.3.2).

The following parameter is configurable in the default GEO-CTTH model configuration file:

- **CTTH_SZSEG** (default value: 4): the size of the segment. [Segments are square boxes in the satellite projection, whose size is expressed as the number of default horizontal resolution pixels (3km at nadir for MSG) 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 every segment.]. Note that sampling rate of `NWP_PARAM` and `RTS_PARAM` (see 2.3.2) should be modified accordingly.

4.2.2 The Cloud Top Temperature and Height (GEO-CTTH) execution step

The GEO-CTTH execution step consists in the launch of the command: GEO-CTTH by the Task manager with the required parameters: time of slot, region and configuration file name.

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

4.3.1 List of inputs for Cloud Top Temperature and Height (GEO-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 satellite brightness temperatures and radiances are needed at default horizontal resolution (3km at nadir for MSG):

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 satellite brightness temperatures and radiances for each pixel. Full CTTH product is computed only if all mandatory satellite 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 satellite channels are input by the user in requested format (HRIT for MSG), and extracted on the processed region by NWC/GEO 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 satellite 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, relative humidity and geopotential on vertical pressure levels
- tropopause temperature, pressure and geopotential
- 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,

		User Manual for the Cloud Product Processors of the NWC/GEO: Science Part	Code: NWC/CDOP2/GEO/MFL/SCI/UM/Cloud Issue: 1.0 Date: 15 October 2016 File: NWC-CDOP2-GEO-MFL-SCI-UM-Cloud_v1.0 Page: 40/56
---	---	---	---

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 NWC software package from the NWP fields input by the user in GRIB format.

- **RTTOV simulations:**

The following parameters simulated by RTTOV are used as input for 10.8 μ m and 12.0 μ m window channels and all sounding channels (for MSG: 6.2 μ m, 7.3 μ m and 13.4 μ m)

- Clear sky top of atmosphere radiance
- Transmittance from surface to TOA
- Clear sky downwelling radiance
- Clear+cloudy TOA radiance for given cloud top pressure and fraction (run RTTOV with black cloud at surface level)
- Level to space overcast radiance given black cloud for each vertical level defined by the user

These remapped fields are elaborated by the NWC/GEO software package by applying RTTOV to the NWP fields input by the user in GRIB format.

The RTTOV simulations are mandatory to get full CTTH product. Otherwise only the cloud top temperature is retrieved using the method based on climatological atmospheric absorption correction.

- **OSTIA fields:**

The following parameters are used as input:

- OSTIA SST

High resolution global daily bulk SST fields (OSTIA) are input by the user who can obtain them from MyOcean service desk (see <http://www.myocean.eu.org>). They are used in conjunction with RTTOV simulations.

These OSTIA fields are not mandatory: if not available the RTTOV simulations will be performed using NWP skin surface temperature.



- **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 thermal emissivity at IR wavelength



These ancillary data are available in the NWC software package on a global scale; a SAFNWC tool allows their remapping on full disk for each new satellite; they are finally extracted on the processed region by the CTTH software itself.

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

 NWC SAF	 METEO FRANCE	User Manual for the Cloud Product Processors of the NWC/GEO: Science Part	Code: NWC/CDOP2/GEO/MFL/SCI/UM/Cloud Issue: 1.0 Date: 15 October 2016 File: NWC-CDOP2-GEO-MFL-SCI-UM-Cloud_v1.0 Page: 41/56
---	--	---	---

4.3.2 CTTH Model Configuration File

The CTTH model configuration file contains all the coefficients and constants required for the derivation of the GEO-CTTH product. The model configuration file must be placed in the \$SAFNWC/config directory. The file contains the following information:

 	User Manual for the Cloud Product Processors of the NWC/GEO: Science Part	Code: NWC/CDOP2/GEO/MFL/SCI/UM/Cloud Issue: 1.0 Date: 15 October 2016 File: NWC-CDOP2-GEO-MFL-SCI-UM-Cloud_v1.0 Page: 42/56
---	---	---

Keyword	Description	Type	Default Value(s)
PGE_ID	Identifier of the PGE	Chain of characters	GEO-CTTH
SEV_BANDS	SEVIRI channels to be used by CTTH	Chain of characters	WV62,WV73,IR108,IR120,IR134
INT_PRODUCT	Enables/disables the generation of intermediate products	Chain of characters	NO
CTTH_SZSEG	Size of CTTH segments expressed in SEVIRI coordinates (same value for lines and columns)	Integer	4
RTTOV_USE_COMPUTED_BIAS	Flag defining if biases are to be monitored on line when RTTOV-based tests are used (not configurable in current version)	Chain of characters	FALSE
IS_ALREADY_RECALIBRATED	Flag defining whether satellite data input by the user are already recalibrated using post-launch and GSICS calibration coefficients (not configurable in current version)	Chain of characters	FALSE
NWP_PARAM	Parameter :Temperature at surface level sampling rate : (=segment size CTTH_SZSEG) interpolation method.	Chain of characters	NWP_ST 4 BLM
NWP_PARAM	Parameter :Temperature at surface level sampling rate : (=segment size CTTH_SZSEG) interpolation method.	Chain of characters	NWP_ST 4 BLI
NWP_PARAM	Parameter :Pressure at surface level sampling rate : (=segment size CTTH_SZSEG) interpolation method.	Chain of characters	NWP_SP 4 BLI
NWP_PARAM	Parameter :temperature at 2m sampling rate : (=segment size CTTH_SZSEG) interpolation method.	Chain of characters	NWP_2T 4 BLI
NWP_PARAM	Parameter :relative humidity at 2m sampling rate : (=segment size CTTH_SZSEG) interpolation method.	Chain of characters	NWP_2RH 4 BLI
NWP_PARAM	Parameter :Temperature at pressure levels sampling rate : (=segment size CTTH_SZSEG) interpolation method.	Chain of characters	NWP_T 4 BLI
NWP_PARAM	Parameter :relative humidity at pressure levels sampling rate : (=segment size CTTH_SZSEG) interpolation method.	Chain of characters	NWP_RH 4 BLI
NWP_PARAM	Parameter :geopotential at pressure levels sampling rate : (=segment size CTTH_SZSEG) interpolation method.	Chain of characters	NWP_GEOP 4 BLI
NWP_PARAM	Parameter :Temperature at tropopause level sampling rate : (=segment size CTTH_SZSEG) interpolation method.	Chain of characters	NWP_TT 4 BLI
NWP_PARAM	Parameter :Pressure at tropopause level sampling rate : (=segment size CTTH_SZSEG) interpolation method.	Chain of characters	NWP_TP 4 BLI
NWP_PARAM	Parameter :Height at tropopause level sampling rate : (=segment size CTTH_SZSEG) interpolation method.	Chain of characters	NWP_TH 4 BLI
NWP_PARAM	Parameter :Altitude of the model at surface sampling rate : (=segment size CTTH_SZSEG) interpolation method.	Chain of characters	NWP_ALTM 4 BLI

Keyword	Description	Type	Default Value(s)
NWP_PARAM	Parameter : Geopotential at surface sampling rate : (=segment size CTTH_SZSEG) interpolation method	Chain of characters	NWP_SGEOP 4 BLI
RTS_PARAM	Parameter : Clear sky TOA radiance sampling rate : (=segment size CTTH_SZSEG) interpolation method	Chain of characters	RTS_CLEAR 4 BLI
RTS_PARAM	Parameter : Transmittance from surface to TOA sampling rate : (=segment size CTTH_SZSEG) interpolation method	Chain of characters	RTS_TAUTOTAL 4 BLI
RTS_PARAM	Parameter : Clear sky down-welling radiance sampling rate : (=segment size CTTH_SZSEG) interpolation method	Chain of characters	RTS_DNCLEAR 4 BLI
RTS_PARAM	Parameter : TOA radiance for given cloud top pressure and fraction sampling rate : (=segment size CTTH_SZSEG) interpolation method	Chain of characters	RTS_TOTAL 4 BLI
RTS_PARAM	Parameter : Level to space overcast radiance given black cloud for each layer sampling rate : (=segment size CTTH_SZSEG) interpolation method	Chain of characters	RTS_OVERCAST 4 BLI

Table 9: CTTH default Model Configuration File description

4.3.3 Configurable parameters for Cloud Top Temperature and Height (GEO-CTTH)

The following parameter is configurable in the default CTTH model configuration file:

- CTTH_SZSEG: the size of the segment is configurable (see its definition in 4.3.1). Its default value is 4. Information on how to change the size of the segment can be found in section 4.2.1.

4.4 CLOUD TOP TEMPERATURE AND HEIGHT (GEO-CTTH) VALIDATION

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

The following table summarises the validation results of the current version for CTTH. More details can be obtained from the validation report for cloud products ([RD.1.]).

<i>GEO-CTTH products</i>	Validated accuracy: bias(std)
Top height of opaque low, mid-level and high cloud :	
If validated over full disk using satellite based lidar	-0.49km(0.99km)
If validated over full disk using satellite based radar	-0.35km(0.82km)
Top height of semi-transparent cloud :	
If validated over full disk using satellite based lidar	-1.44km(1.97km)
If validated over full disk using satellite based radar	0.21km(1.88km)



		User Manual for the Cloud Product Processors of the NWC/GEO: Science Part	Code: NWC/CDOP2/GEO/MFL/SCI/UM/Cloud Issue: 1.0 Date: 15 October 2016 File: NWC-CDOP2-GEO-MFL-SCI-UM-Cloud_v1.0 Page: 44/56
---	---	---	---

Table 10: Summary of validation results of the current CTTH 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:
 - 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.
- 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 NWC SAF products.

Colour palettes are included in CTTH NetCDF 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.

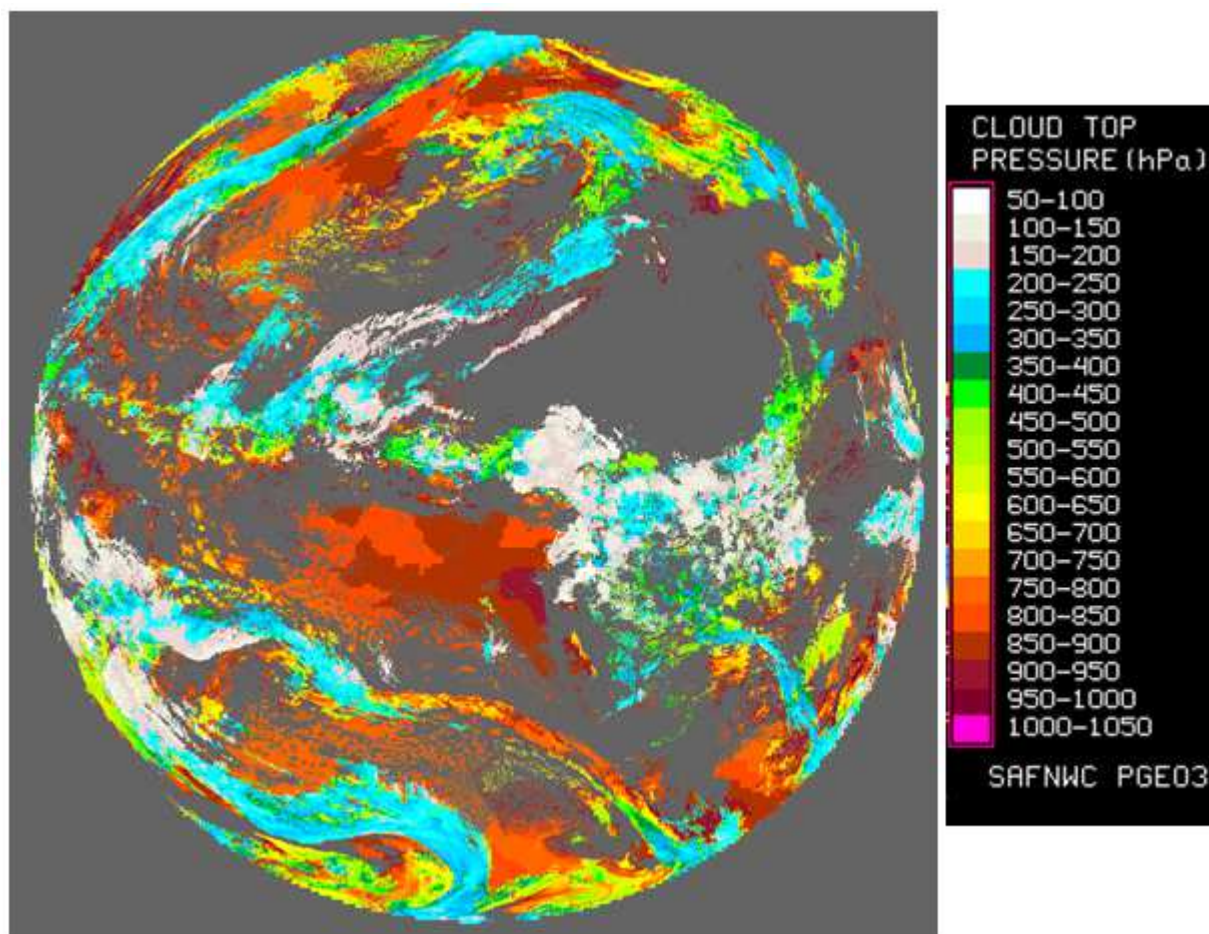


Figure 4: Example of SEVIRI CTTH cloud top pressure

5 CLOUD MICROPHYSICS (GEO-CMIC) PRODUCT

5.1 DESCRIPTION OF CLOUD MICROPHYSICS (GEO-CMIC) PRODUCT

5.1.1 Goal of Cloud Microphysics product

The cloud microphysics (CMIC), developed within the NWC SAF context, mainly aims to support nowcasting applications. The main objective of this product is to provide detailed information on the cloud microphysics. 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 (such as precipitation), or as a final image product for display at a forecaster's desk. The CMIC product is useful for the identification of precipitation clouds and useful for characterisation of rapidly developing thunderstorm.

The CMIC product contains information relevant to the cloud top (thermodynamical phase, cloud particle size) or integrated on the full vertical extent (optical depth, liquid and ice water path).

5.1.2 Outline of Cloud Microphysics (GEO-CMIC) algorithm

The CMIC retrieval algorithm first retrieves the thermodynamical phase through an empirical use of T8.7 μ m-T10.8 μ m, T10.8 μ m and the CT cloud type itself complemented (only during daytime) by an combined analysis of the measured and simulated 0.6 μ m and 1.6 μ m reflectances. The additional microphysics parameters are obtained only in daytime conditions through the comparison of measured and simulated 0.6 μ m and 1.6 μ m reflectances.

The algorithm has been designed to be applicable to imagers on board meteorological geostationary satellites. The imagers may have different set of channels possibly at different horizontal resolutions. The lowest native resolution of the radiometer (3km at nadir for MSG/SEVIRI), which is for most imagers on board present and future meteorological geostationary satellites the horizontal resolution of all IR channels and some solar channels, will be chosen as the default horizontal resolution. Solar channels may be available at higher horizontal resolution (1km at nadir for HRV). In this release, the process is applied to all useful channels at the default horizontal resolution (high resolution channels being averaged at this resolution). We use generic labels in this document (for example, T8.7 μ m, T10.8 μ m, R0.6 μ m, and R1.6 μ m), the exact central wavelengths of the corresponding channels depending on the satellite. The list of available labels depends on the satellite; the list of mandatory channels is listed in 5.3.1.

The cloud top phase is first retrieved by an empirical use of T8.7 μ m-T10.8 μ m, T10.8 μ m and the CT cloud type itself complemented by an combined analysis of 0.6 μ m and 1.6 μ m measured and simulated reflectances, as summarized below:

- Warm (respectively cold) opaque clouds are supposed to be constituted of water (respectively ice) particles, whereas the temperature range between 0°C and –40°C may correspond to both (or a mixture) of water or ice clouds.
- Cloud classified as semi-transparent in CT cloud type are supposed be constituted of ice particles. Cloud classified as fractional may correspond to thin cirrus or sub-pixel low clouds; their retrieved cloud phase is therefore set “undefined”.

- Water clouds usually have low $T8.7\mu\text{m}$ - $T10.8\mu\text{m}$ and ice clouds rather high values. Simple viewing angle-dependant thresholds subjectively defined from SEVIRI observations are applied to identify obviously water or ice clouds.
- If the cloud top phase is still not determined, the comparison of observed and simulated $0.6\mu\text{m}$ and $1.6\mu\text{m}$ reflectances for cloudy pixels may allow retrieving the cloud top phase (but ambiguous situations may still exists).



Once the cloud phase has been determined, the optical depth and the particle size are obtained using the measured and the simulated $0.6\mu\text{m}$ and $1.6\mu\text{m}$ reflectances. Finally liquid and ice water path are obtained by empirical formula.

Details are available in the algorithm theoretical basis document for cloud products ([AD.11.])

5.1.3 Description of Cloud Microphysics (GEO-CMIC) output

The content of the CMIC output (in NetCDF format) is described in the Data Output Format document ([AD.8.]), a summary is given below:

Container	Content														
GEO-CMIC _PHASE	SAFNWC GEO CMIC Cloud Top Phase <table border="1"> <thead> <tr> <th>Class</th><th>Cloud Top Phase category</th></tr> </thead> <tbody> <tr> <td>1</td><td>Liquid</td></tr> <tr> <td>2</td><td>Ice</td></tr> <tr> <td>3</td><td>Mixed</td></tr> <tr> <td>4</td><td>Cloud-free</td></tr> <tr> <td>5</td><td>Undefined (separability problem)</td></tr> <tr> <td>FillValue</td><td>No data or corrupted data</td></tr> </tbody> </table>	Class	Cloud Top Phase category	1	Liquid	2	Ice	3	Mixed	4	Cloud-free	5	Undefined (separability problem)	FillValue	No data or corrupted data
Class	Cloud Top Phase category														
1	Liquid														
2	Ice														
3	Mixed														
4	Cloud-free														
5	Undefined (separability problem)														
FillValue	No data or corrupted data														
GEO-CMIC _REFF	SAFNWC GEO CMIC Cloud Drop Effective Radius <p> $\text{GEO-CMIC_REFF(m)} = \text{scale_factor} * \text{Counts} + \text{add_offset}$ where: $\text{scale_factor} = 10^{-8}$ $\text{add_offset} = 0.0$ </p>														
GEO-CMIC _COT	SAFNWC GEO CMIC Cloud Optical Thickness <p> $\text{GEO-CMIC_COT} = \text{scale_factor} * \text{Counts} + \text{add_offset}$ where: $\text{scale_factor} = 0.01$ $\text{add_offset} = 0.0$ </p>														
GEO-CMIC _LWP	SAFNWC GEO CMIC Cloud Liquid Water Path <p> $\text{GEO-CMIC_LWP(kg.m}^{-2}\text{)} = \text{scale_factor} * \text{Counts} + \text{add_offset}$ where: $\text{scale_factor} = 0.001$ $\text{add_offset} = 0.0$ </p>														

		User Manual for the Cloud Product Processors of the NWC/GEO: Science Part	Code: NWC/CDOP2/GEO/MFL/SCI/UM/Cloud Issue: 1.0 Date: 15 October 2016 File: NWC-CDOP2-GEO-MFL-SCI-UM-Cloud_v1.0 Page: 48/56
---	---	---	---

Container	Content
GEO-CMIC_IWP	SAFNWC GEO CMIC Cloud Ice Water Path $\text{GEO-CMIC_IWP}(\text{kg.m}^{-2}) = \text{scale_factor} * \text{Counts} + \text{add_offset}$ where: $\text{scale_factor} = 0.001$ $\text{add_offset} = 0.0$
GEO-CMIC_status_flag	11 bits indicating (if set to 1) Bit 0: Cloud-free Bit 1: High resolution satellite data used Bit 2: Combined use of 1.6µm & 2.2µm for phase retrieval Bit 3: No retrieved phase: no reliable Reff/Cot retrieval Bit 4: Mixed phase : no reliable Reff/Cot retrieval Bit 5: Measurement incoherent with simulation: no reliable Reff/Cot retrieval Bit 6: Too much overlap in simulation : no reliable Reff/Cot retrieval Bit 7: 1.6µm used for reff/cot retrieval Bit 8: 2.2µm used for reff/cot retrieval Bit 9: 3.8µm used for reff/cot retrieval Bit 10: Multilayer cloud suspected

Geophysical Conditions



Field	Type	Description
Space	Flag	Set to 1 for space pixels
Illumination	Parameter	Defines the illumination condition 0: N/A (space pixel) 1: Night 2: Day 3: Twilight
Sunglint	Flag	Set to 1 if Sunglint
Land_Sea	Parameter	0: N/A (space pixel) 1: Land 2: Sea 3: Coast
Rough_terrain	Flag	Set to 1 if rough terrain
High_terrain	Flag	Set to 1 if high terrain

Processing Conditions

Field	Type	Description
Satellite_input_data	Parameter	Describes the Satellite input data status 0: N/A (space pixel) 1: All satellite data are available 2: At least one useful satellite channel is missing 3: At least one mandatory satellite channel is missing
NWP_input_data	Parameter	Describes the NWP input data status 0: N/A (space pixel or NWP data not used) 1: All NWP data are available 2: At least one useful NWP field is missing 3: At least one mandatory NWP field is missing
Product_input_data	Parameter	Describes the Product input data status 0: N/A (space pixel or Auxiliary data not used) 1: All input Product data are available 2: At least one useful input Product is missing 3: At least one mandatory input Product is missing
Auxiliary_input_data	Parameter	Describes the Auxiliary input data status (includes products used as input to PGE) 0: N/A (space pixel or Auxiliary data not used) 1: All Auxiliary data are available 2: At least one useful Auxiliary field is missing 3: At least one mandatory Auxiliary field is missing

Quality

Field	Type	Description
Nodata	Flag	Set to 1 if pixel is NODATA
Internal_consistency	Flag	Set to 1 if an internal consistency check has been performed. Internal consistency checks will be based in the comparison of the retrieved meteorological parameter with physical limits, climatological limits, neighbouring data, NWP data, etc.
Temporal_consistency	Flag	Set to 1 if a temporal consistency check has been performed Temporal consistency checks will be based in the comparison of the retrieved meteorological parameters with data obtained in previous slots.

 	User Manual for the Cloud Product Processors of the NWC/GEO: Science Part	Code: NWC/CDOP2/GEO/MFL/SCI/UM/Cloud Issue: 1.0 Date: 15 October 2016 File: NWC-CDOP2-GEO-MFL-SCI-UM-Cloud_v1.0 Page: 50/56
---	---	---

Quality	Parameter	Retrieval Quality
		0: N/A (no data) 1: Good 2: Questionable 3: Bad 4: Interpolated

5.2 IMPLEMENTATION OF CLOUD MICROPHYSICS (GEO-CMIC)

CMIC is extracted by PGE15 (GEO-CMIC) component of the NWC/GEO software package. Detailed information on how to run this software package is available in the software user manual ([RD.2.]).

When a new region is defined the user has to manually prepare the CMIC model configuration files for this new region using a default CMIC model configuration file provided in the NWC/GEO software package (see its content in section 5.3.2).

The CMIC execution step is the real-time processing of the satellite images over the region. This process consists in the launch of the command: GEO-CMIC by the Task manager.

5.2.1 Manual preparation of Cloud Microphysics (GEO-CMIC) 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 GEO-CMIC model configuration files by adapting the GEO-CMIC default model configuration file available in the SAFNWC/GEO software package (see its content in section 5.3.2).

The following parameters are configurable in the default GEO-CMIC model configuration file:

- **CMIC_SZSEG** (default value: 4): the size of the segment. This default value may be manually changed. [Segments are square boxes in the satellite projection, whose size is expressed as the number of default horizontal resolution pixels (3km at nadir for MSG) 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 cloud simulations, the atlas values 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 default horizontal resolution, allowing the identification of the surface type (land or sea) of all default horizontal resolution pixels, whatever the segment size. The quality is not very much dependent on the segment size (if lower than 16)]. Note that sampling rate of NWP_PARAM and RTS_PARAM (see 2.3.2) should be modified accordingly.
- **IS_ALREADY_RECALIBRATED** (default value: FALSE): this flag defines whether satellite data input by the user are already recalibrated with post-launch calibration coefficients (solar channels) and GSICS IR calibration coefficients. [For nearly all users, it should remain set to FALSE (default value). If set to TRUE (for example, CM-SAF may use this option), the CMIC does not perform its own recalibration of solar channels].

5.2.2 The Cloud Microphysics (GEOCMIC) execution step

The GEO-CMIC execution step consists in the launch of the command: GEO-CMIC by the Task manager with the required parameters: time of slot, region and configuration file name.

5.3 INPUTS AND CONFIGURATION PARAMETERS FOR CLOUD MICROPHYSICS (GEO-CMIC)

5.3.1 List of inputs for Cloud Microphysics (GEO-CMIC)

The input data to the CMIC 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 bi-directional reflectances or brightness temperatures are needed at default horizontal resolution (3km at nadir for MSG):

R0.6 μ m	R1.6 μ m	T8.7 μ m	T10.8 μ m
Mandatory	Mandatory	Mandatory	Mandatory

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

The channels are input by the user in requested format (HRIT for MSG), and extracted on the processed region by NWC/GEO software package.

It is essential to use well calibrated 0.6 μ m and 1.6 μ m reflectances: calibration coefficients provided by KNMI are used by CMIC to recalibrate these channels during CMIC computation.

- **CT cloud categories**

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

- **CTTH cloud categories**

The CTTH cloud top pressure are optional. They are computed by the CTTH software. If they are not available, default values are used for water (800hPa) or ice clouds (300hPa)

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



This information is mandatory. It is computed by the CMIC 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 :

- Total ozone content
- Integrated water vapour content above and below pressure levels defined by user

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

		User Manual for the Cloud Product Processors of the NWC/GEO: Science Part	Code: NWC/CDOP2/GEO/MFL/SCI/UM/Cloud Issue: 1.0 Date: 15 October 2016 File: NWC-CDOP2-GEO-MFL-SCI-UM-Cloud_v1.0 Page: 52/56
---	---	---	---

The NWP fields are not mandatory. The CMIC software replaces missing NWP fields by climatological values extracted from ancillary dataset. The quality of CMIC is lower if NWP fields are missing.

- **Ancillary data sets:**

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

- Land/sea atlas
- Elevation atlas
- Monthly 0.6 μ m and 1.6 μ m white-sky surface albedo climatology (land)
- Monthly integrated atmospheric water vapor content climatology
- Monthly ozone content climatology

These ancillary data are available in the NWC/GEO software package on a global scale; a SAFNWC tool allows their remapping on full disk for each new satellite; they are finally extracted on the processed region by the CMIC software itself.

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

One file (netcdf format) containing offline DISORT simulations of 0.6 μ m and 1.6 μ m cloud radiative properties (beam bi-directional reflection, beam direct transmission, beam diffuse transmission, diffuse transmission, diffuse reflection flux) performed for a set of water and ice clouds, is available in the NWC/GEO software package, and is needed by the CMIC software.

5.3.2 CMIC Model Configuration File

The CMIC model configuration file contains all the coefficients and constants required for the derivation of the GEO-CMIC product. The model configuration file must be placed in the \$SAFNWC/config directory. The file contains the following information:

Keyword	Description	Type	Default Value(s)
PGE_ID	Identifier of the PGE	Chain of characters	GEO-CMIC
SEV_BANDS	SEVIRI channels to be used by CMIC	Chain of characters	VIS06,NIR16,IR87,IR108
INT_PRODUCT	Enables/disables the generation of intermediate products (not configurable in current version)	Chain of characters	NO
CMIC_SZSEG	Size of CMIC segments expressed in SEVIRI coordinates (same value for lines and columns)	Integer	4
IS_ALREADY_RECALIBRATED	Flag defining whether satellite data input by the user are already recalibrated using post-launch and GSICS calibration coefficients	Chain of characters	FALSE
NWP_PARAM	Parameter :Total ozone content sampling rate : (=segment size CMIC_SZSEG) interpolation method.	Chain of characters	NWP_TOZ 4 BLI
NWP_PARAM	Parameter :Integrated water vapour above pressure level sampling rate : (=segment size CMIC_SZSEG) interpolation method.	Chain of characters	NWP_AWV 4 BLI
NWP_PARAM	Parameter :Integrated water vapour below pressure level sampling rate : (=segment size CMIC_SZSEG) interpolation method.	Chain of characters	NWP_BWV 4 BLI

Table 11: CMIC default Model Configuration File description

5.3.3 Configurable parameters for Cloud Microphysics (GEO-CMIC)

The following configurable parameter are available in the default CMIC model configuration file:

- **CMIC_SZSEG:** The size of the segment is configurable (see its definition in section 5.3.1). Its default value is 8. Information on how to change the size of the segment can be found in section 5.2.1.
- **IS_ALREADY_RECALIBRATED:** this flag, defining whether satellite data input by the user are already recalibrated with post-launch calibration coefficients (solar channels) and GSICS IR calibration coefficients, is configurable (see its definition in section 5.3.1). Its default value is FALSE. Information on how to change this value can be found in section 5.3.1 and in the software user manual ([RD.2.]).

5.4 CLOUD MICROPHYSICS (GEO-CMIC) VALIDATION

5.4.1 Summary of Cloud Microphysics (GEO-CMIC) validation results

The following table summarises the validation results of the current version. More details can be obtained from the validation report for cloud products ([RD.1.]).

GEO-CMA flags	Validated accuracy
GEO-CMIC cloud phase	
If validated over full disk using space born	

lidar observation	For water phase: POD: 93.78% FAR: 5.40% For ice phase: POD: 96.59% FAR: 3.94%
GEO-CMIC cloud liquid water path If validated over full disk over ocean using AMSR micro-wave imagery	Bias: -0.96g/m^2 ; rsm: 38.46g/m^2

Table 12: Summary of validation results of the current CMIC cloud phase and cloud liquid water path (POD stands for Probability Of Detection)

5.4.2 Typical known problems and recommendation for use

The following problems may be encountered:

- No CMIC is available for cloud classified as fractional
- No optical thickness, drop effective radius and liquid/ice water path are retrieved at nighttime or twilight, or at daytime for “mixed phase” or “undefined phase”

5.5 EXAMPLE OF CLOUD MICROPHYSICS (CMIC) VISUALISATION

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

Colour palettes are included in CMIC NetCdF files, thus allowing an easy visualisation of CMIC different parameters such as the cloud phase, cloud optical thickness (as illustrated in Figure 5), cloud effective radius (as illustrated in Figure 6), cloud liquid or ice water path.

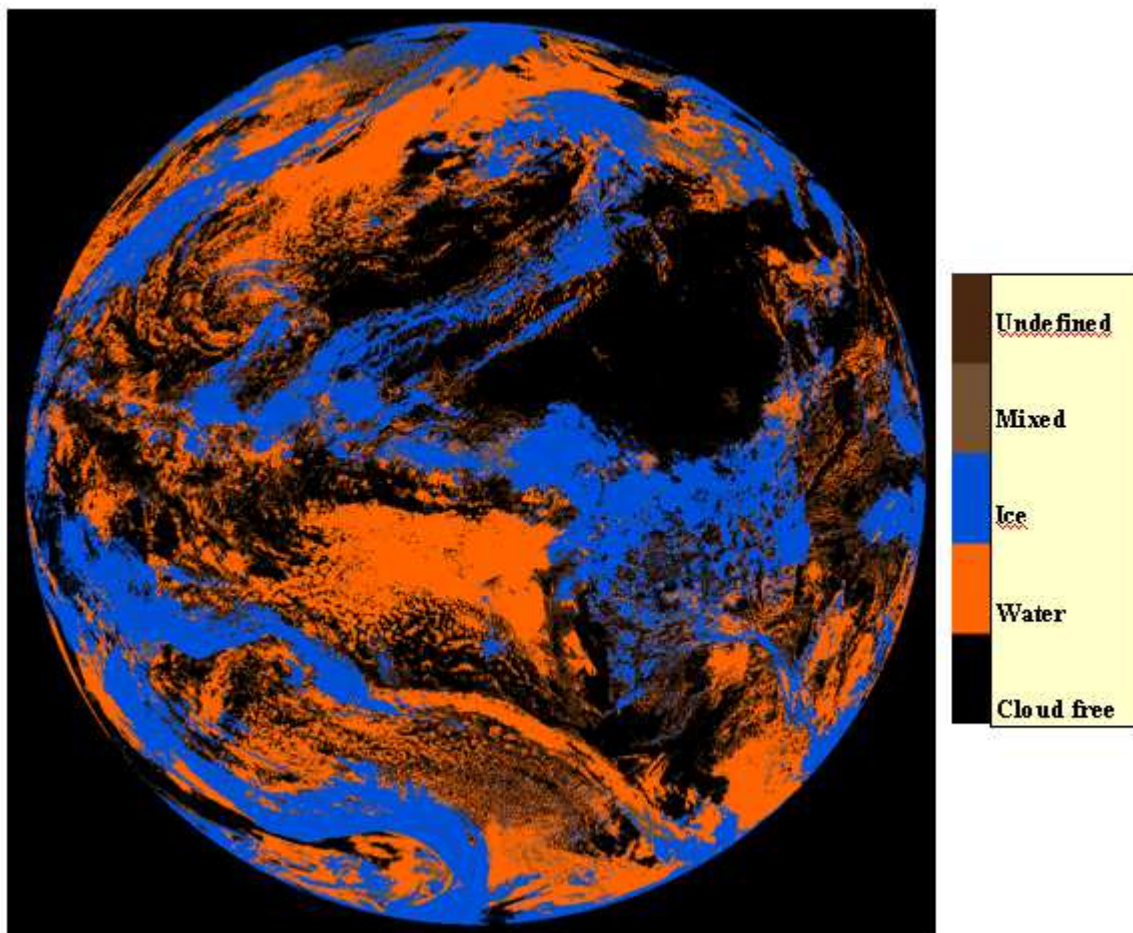


Figure 5 Example of SEVIRI cloud phase flag illustrated with the colour palette included in the CMIC NetCdF files.

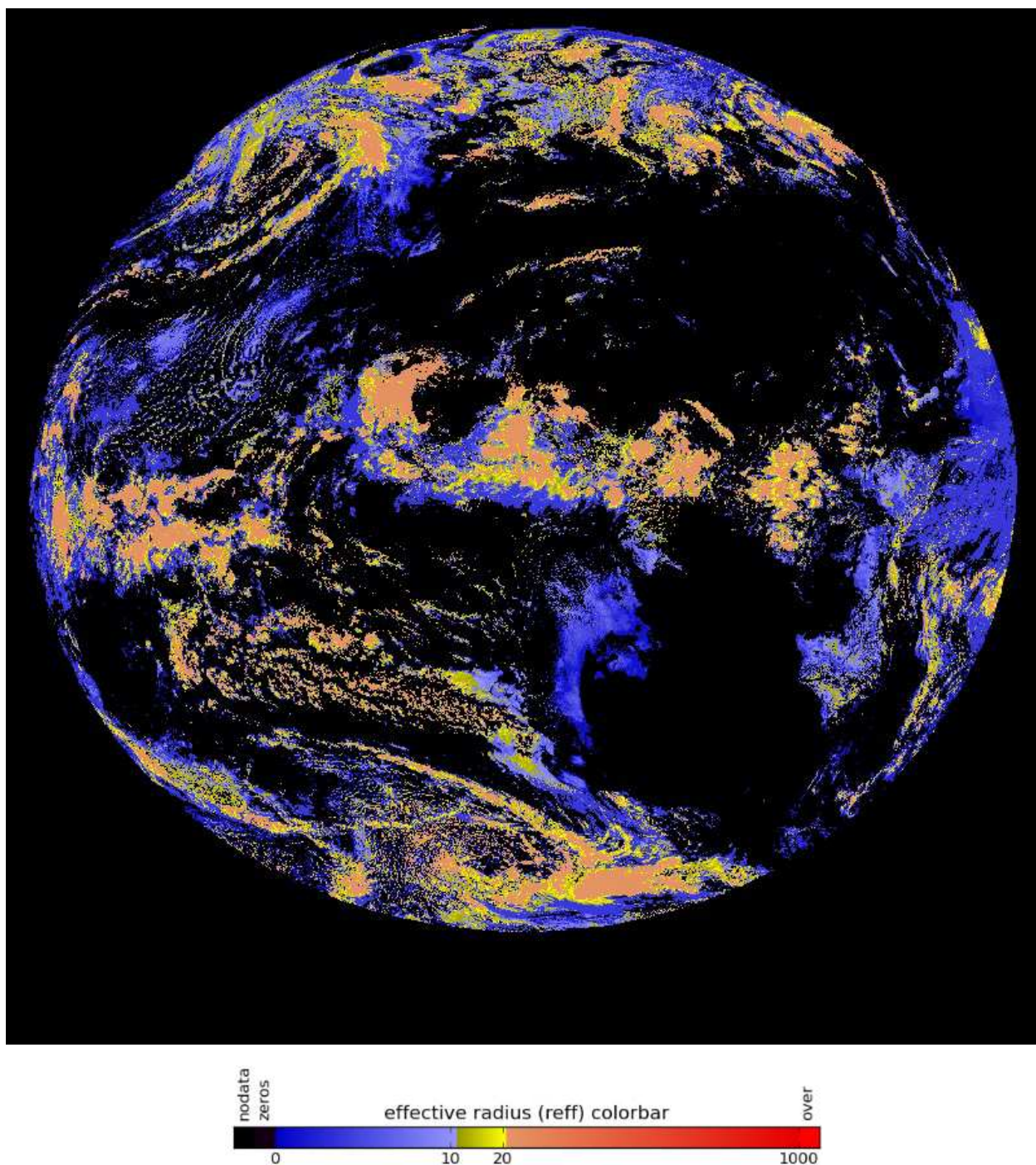


Figure 6 Example of SEVIRI cloud effective radius illustrated with the colour palette included in the CMIC NetCdF files.