

Code: NWC/CDOP3/GEO/MF-CMS/SCI/UM/Cloud Issue: 2.0.1 Date: 22 February 2022 File: NWC-CDOP3-GEO-MF-CMS-SCI-UM-Cloud\_v2.0.1 Page: 1/61



SUPPORT TO NOWCASTING AND VERY SHORT RANGE FORECASTING

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

NWC/CDOP3/GEO/MF-CMS/SCI/UM/Cloud, Issue 2, Rev. 0.1 28<sup>th</sup> February 2022

*Applicable to* 

GEO-CMA-v5.1 (NWC-009)

GEO-CT-v4.1 (NWC-016)

GEO-CTTH-v4.1 (NWC-017)

GEO-CMIC-v2.1 (NWC-021)

Prepared by Météo-France / Centre d'études en Météorologie Satellitaire



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# DOCUMENT CHANGE RECORD

Version	Date	Pages	Changes
1.0d	15 June 2015	61	Draft version for STRR
1.0	15 Octobre 2016	61	Inclusion of STRR outcome
1.0d	31 October 2018	55	Applicable to v2018
1.0	21 January 2019	58	Final version for v2018 DRR
2.0	10 January 2022	61	Version for v2021 DRR
2.0.1	22 February 2022	61	Version for v2021 after DRR

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#### 1 INTRODUCTION

The Eumetsat "Satellite Application Facilities" (SAF) are dedicated centres of excellence for processing satellite data, and form an integral part of the distributed EUMETSAT Application Ground Segment (<a href="http://www.eumetsat.int">http://www.eumetsat.int</a>). 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, <a href="http://www.nwcsaf.org">http://www.nwcsaf.org</a>. This document is applicable to the NWC SAF processing package for geostationary meteorological satellites, <a href="http://www.nwcsaf.org">NWC/GEO</a>.

#### 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.7.]).

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.5.]) (for the External and Internal Interfaces of the SAFNWC/GEO) and ([AD.6.]) (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-v5.1 (Product Id NWC-009), GEO-CT-v4.1 (Product Id NWC-016), GEO-CTTH-v4.1 (Product Id NWC-017) and GEO-CMIC-v2.1 (Product Id NWC-021) implemented in the release 2021 of the NWC/GEO software package.

#### 1.4 IMPROVEMENT FROM PREVIOUS VERSION

Since 2018 release, the following improvements have been implemented:

- Technical improvements:
  - Use of NWP analysis for reprocessing activities
- Scientific improvements:



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 GEO-CT: better use of new channels (1.38μm) for semi-transparent and fractional clouds identification (this improvement applies to MTG and GOES-R, but not Himawari8 nor MSG.

#### 1.5 DEFINITIONS, ACRONYMS AND ABBREVIATIONS

Second Simulation of Satellite Signal in the Solar Spectrum

**BRDF** Bi-directional Reflectance Functions

CMA Cloud Mask

**CMIC** Cloud Microphysics

CEMS Centre d'étude en Meteorologie Satellitaire (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

**OSTIA** Operational Sea Surface Temperature and Sea Ice Analysis

**PGE** Product Generation Element

**R0.6** um 0.6 visible reflectance

**RTMOM** Radiative Transfer based on Matrix Operator Method

RTTOV Rapid Transmissions for TOVs
SAF Satellite Application Facility



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**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

TM Task Manager

**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	NWC/CDOP3/MGT/AEMET/PRO	1.0	11/04/2016
	Development and operation Phase (CDOP) march			
	2017 – February 2022			
[AD.2.]	Project Plan for the NWCSAF CDOP3 phase	NWC/CDOP3/SAF/AEMET/MGT/PP	1.6	01/12/2021
[AD.3.]	Configuration Management Plan for the	NWC/CDOP3/SAF/AEMET/MGT/CMP	1.1	15/04/2020
	NWCSAF			
[AD.4.]	NWCSAF Product Requirement Document	NWC/CDOP3/SAF/AEMET/MGT/PRD	1.5	28/02/2022
[AD.5.]	Interface Control Document for Internal and	NWC/CDOP3/GEO/AEMET/SW/ICD/1	2.0	01/09:2021
	External Interfaces of the NWC/GEO			
[AD.6.]	Data Output Format for the NWC/GEO	NWC/CDOP3/GEO/AEMET/SW/DOF	2.0	10/01/2022
[AD.7.]	Algorithm Theoretical Basis Document for the	NWC/CDOP3/GEO/MFL/SCI/ATBD/Clo	1.0.1	29/10/2021
	Cloud Product Processors of the NWC/GEO	ud		
[AD.8.]	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



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#### 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	NWC/CDOP3/GEO/MF-CMS/SCI/VR/Cloud	2.0.1	28/02//2022
	products processors of the NWC/GEO			
[RD.2.]	User Manual for the NWC/GEO application:	NWC/CDOP3/GEO/AEMET/SW/UM	2.0	10/01/2022
	Software part			

Table 2: List of Referenced Documents

 Code:
 NWC/CDOP3/GEO/MF-CMS/SCI/UM/Cloud

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# 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,  $T3.8\mu m$ ,  $T8.7\mu m$ ,  $T10.8\mu m$ ,  $T12.0\mu m$ ,  $R0.6\mu m$ ,  $R0.8\mu m$  and  $R1.6\mu m$ ), 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,



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- (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.7.]).

Daytime	Twilight	Nighttime
Snow detection	Snow detection	T10.8μm -T3.8μm
R0.6μm	R0.6μm	T10.8μm
T10.8μm	T10.8μm	T10.8μm -T12.0μm
T10.8μm-T12.0μm	T10.8μm-T12.0μm	T8.7μm-T10.8μm
T8.7μm-T10.8μm	Т10.8µm-Т3.8µm	Т3.8µm-Т10.8µm
Т10.8μm-Т3.8μm	T8.7μm-T10.8μm	Local Spatial Texture
Т3.8µm-Т10.8µm	Т3.8µm-Т10.8µm	Τ8.7μm-Τ3.8μm
R1.38μm	Local Spatial Texture	
Local Spatial Texture	T8.7μm-T3.8μm	

Table 3: Test sequence over land

Daytime	Daytime Sunglint Twilight		Nighttime
Ice detection	Ice detection	Ice detection	T10.8μm-T3.8μm
R0.8μm (R0.6μm)	SST	R0.8μm (R0.6μm)	SST
SST	T10.8μm-T12.0μm	T10.8μm-T3.8μm	T8.7μm-T10.8μm
R1.6µm	Т8.7µm-Т10.8µm	SST	T10.8μm-T12.0μm
T10.8μm-T12.0μm	Local Spatial Texture	R1.6μm	T12.0μm-T3.8μm
T8.7μm-T10.8μm	R0.8μm (R0.6μm)	T8.7μm-T10.8μm	T3.8μm-T10.8μm
Т10.8μm-Т3.8μm	Т10.8μm-Т3.8μm	Т10.8μm-Т12.0μm	Local Spatial Texture
Т3.8μm-Т10.8μm	Low Clouds in Sunglint	T12.0μm-T3.8μm	
R1.38µm		T3.8μm-T10.8μm	
Local Spatial Texture		Local Spatial Texture	

Table 4: Test sequence over sea



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[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, R1.6μm and R1.38μm stand for VIS/NIR bi-directional top of atmosphere reflectances at around 0.6, 0.8, 1.6 and 1.38 micrometer normalised for solar illumination; SST is the split-window (used for SST calculation) computed from T10.8μm and T12.0μm measurements. Low Clouds in Sunglint is a specific module for low clouds identification in sunglint areas. 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.6.]), a summary is given below:

Container			Content
GEO-CMA	SAFNWC GEO C	CMA Cloud N	
		Class	Cloud Mask category
		0	Cloud-free
		1	Cloudy
		FillValue	No data or corrupted data
GEO-CMA	SAFNWC GEO C	CMA Cloud a	nd Snow Mask
_CLOUDSNOW			
		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	SAFNWC GEO C	CMA Dust De	etection
_DUST			
		Class	<b>Dust Detection category</b>
		0	No dust
		1	Dust
		2	Undefined (separability problem)
		FillValue	No data or corrupted data
GEO-CMA	SAFNWC GEO C	CMA Volcani	c Plume Detection
_VOLCANIC		61	
		Class	Volcanic Plume Detection category
		0	No volcanic plume
		1	Volcanic plume
		2	Undefined (separability problem)
CEO CMA	CAENING CEO (	FillValue	No data or corrupted data
GEO-CMA	SAFNWC GEO C	JMA Smoke	Detection (not yet performed -> set to und
_SMOKE		Classic	Complex Detection of
		Class	Smoke Detection category
		0	No smoke Smoke
		2	
		FillValue	Undefined (separability problem)
		riiivaiue	No data or corrupted data



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Container	Content		
GEO-CMA	28 bits indic	ating (if set to 1)	
TESTLIST	20 ons mare	uning (it set to 1)	
	Bit 0:	R0.6μm (land) or R0.8μm (sea)	
	Bit 1:	R1.6µm (sea)	
	Bit 2:	Sunglint test using 3.8µm	
	Bit 3:	R1.38μm	
	Bit 4:	T10.8μm or SST	
	Bit 5:	T10.8μm – T12.0μm	
	Bit 6:	Τ10.8μm – Τ3.8μm	
	Bit 7:	T12.0μm – T3.8μm	
	Bit 8:	T3.8μm – T10.8μm	
	Bit 9:	$T10.8 \mu m - T8.7 \mu m$	
	Bit 10:	$T8.7 \mu m - T10.8 \mu m$	
	Bit 11:	$T8.7 \mu m - T3.8 \mu m$	
	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: Bit 27:	Spatial filtering: cloud reclassified as cloud-free Spatial filtering: cloud-free reclassified as cloud	
	Bit 27.	Spatial filtering, cloud-free reclassified as cloud	
GEO-CMA	10 bits indic	ating (if set to 1)	
status flag			
	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: Bit 8:	Sea ice map is available (not yet used) No method for dust	
	Bit 8:	No method for volcanic plume	
	Bit 10:	No method for smoke (not yet used)	
	2	and the same (not yet about)	



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# **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



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		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

Additionally the two following scores are available in the header of the Netcdf files:

- The product completeness is the ratio (in %) between the number of processed pixels and the number of "non space" pixels (ie, the pixels that should be processed).
- The product quality is the ratio (in %) between the number of good quality pixels and the number of "non space pixels (ie, the pixels that should be processed). The definition of good quality pixel is given in the ATBD.

## 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.]).

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



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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).]

- NWP\_ANALYSIS: the flag indicating if NWP analysis fields can be used. Its default value is FALSE. This flag has been made configurable to allow users to provide NWP analysis, in case of reprocessing activities. When it is set to TRUE, NWP fields with forecast time 00 are used by the PGE if they are available.
- 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 (defaut 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.7.]).]
- 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.]
- NP\_OMP\_CMA\_THREAD (default value: -1): The CMA is parallelized using openMP standard. If set to a strictly positive integer value, NB\_OMP\_CMA\_THREAD corresponds to the number of threads used by CMA. If NB\_OMP\_CMA\_THREAD is set to a negative value, the number if threads used by CMA will be monitored by the OMP\_NUM\_THREADS environment variable set at NWCSAF SW level.

#### 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.

The following command is used to process GEO-CMA manually, without the presence of the TM:

%GEO-CMA-v51 20211029T120000Z global.cfg safnwc CMA.cfm

This command executes GEO-CMA version 5.1 over the region global.cfg manually, without the presence of the TM

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# 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):

R0.6µm	R0.8µm	R1.38µm	R1.6µm	R2.25μm	Т3.8μm	T7.3μm	T8.7μm	T10.4µm	T10.8µm	T12.0µm	T13.4μm
Mandatory	Optional	Optional	Optional	Optional	Mandatory	Optional	Optional	Optional	Mandatory	Mandatory	Optional

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

hrvis
Optional

(hrvis is one visible channel at around 0.6µm (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 R1.6µm or T3.8µm; visible channel test over the ocean uses either R0.8µm or R0.6µm) and a result is available for this pixel. No results are provided for pixels where at least one mandatory channel is missing.

#### 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.

R0.6µm <sub>1h</sub>	T8.7μm <sub>1h</sub>	T10.8µm <sub>1h</sub>	T12.0µm <sub>1h</sub>	CMA <sub>1h</sub>	CT <sub>1h</sub>
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.

T8.7μm <sub>15mn</sub>	T10.8µm <sub>15mn</sub>	T12.0µm <sub>15mn</sub>	CMA <sub>15mn</sub>	CT <sub>15mn</sub>
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.



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hrvis<sub>15mn</sub>
Optional

(hrvis is one visible channel at around 0.6µm (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:

- o surface temperatures (required to get good quality results over land; but not mandatory)
- o air temperature at 950hPa (alternatively 925hPa). Used to check low level inversion.
- o total water vapour content of the atmosphere,
- o 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.

In case of reprocessing activities, NWP analysis can be used. To be remapped the NWP\_ANALYSIS flag has to be set to YES in the nwp conf file.

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 night time 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.



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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 nightime 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.7.]). 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 nightime conditions).

#### • Ancillary data sets:

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

- Land/sea atlas
- Land/sea/coast atlas
- o Elevation atlas
- o Monthly SST minimum and standard deviation values climatology
- O Monthly mean 0.6μm 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 μm, 0.67 μm and 0.86μm)
- Land cover database (BATS)
- o Monthly integrated atmospheric water vapor content climatology
- o Monthly climatology of mean air temperature at 1000 hPa
- o 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:



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Keyword	Description	Type	Default Value(s)
PGE_ID	Identifier of the PGE	Chain of	GEO-CMA
_		characters	
SEV_BANDS	SEVIRI channels to be used by CMA	Chain of	HRV, VISO6, VISO8, NIR13, NIR1
_	SEVIIII Chamicis to Se asea by Civil	characters	6,NIR22,R38,WV73,IR87,IR10
INT PRODUCT	Enables/disables the generation of		3,IR108,IR120, IR134 NO
	Enables/disables the generation of intermediate products	characters	
CMA SZSEG	Size of CMA segments expressed in	Integer	4
	SEVIRI coordinates (same value for lines	integer	
	and columns)		
HRV NEED	Flag to indicate if HRVIS band is to be used	Chain of	TRUE
_	riag to indicate if fix vis band is to be used	characters	
RTTOV USE	Flag to indicate if temporal information	Chain of	FALSE
	from previous scenes and products are to be	characters	
	used	Characters	
RTTOV USE COMPUTED	Flag defining if biases are to be monitored	Chain of	FALSE
BIAS	on line when RTTOV-based tests are used	characters	
IS ALREADY RECALIBR	Flag defining whether satellite data input by	Chain of	FALSE
ATED	the user are already recalibrated using post-	characters	
	launch and GSICS calibration coefficients	Characters	
NWP FREQUENCY PER D	Number of NWP forecast term per day	Integer	4
AY	input by user	integer	
NWP ANLYSIS	Flag to allow the use of NWP analysis	Chain of	FALSE
	Triag to allow the use of INWT allarysis	characters	
NB OMP CMA THREAD	Number of threads used by CMA (if set to	Integer	-1
	negative value, number of threads	integer	
	monitored by environment variable		
	OMP NUM THREADS		
NWP PARAM	Parameter :Temperature at surface level	Chain of	NWP ST
_	sampling rate: (=segment size CMA_SZSEG)	characters	4
	interpolation method.	Characters	BLM
NWP PARAM	Parameter: Temperature at pressure levels	Chain of	NWP T
_	sampling rate: (=segment size CMA SZSEG)	characters	4
	interpolation method.	characters	BLI
NWP PARAM	Parameter: Total column water vapour	Chain of	NWP TCWV
_	sampling rate: (=segment size CMA SZSEG)	characters	4
	interpolation method.	Jim wood	MAX
NWP_PARAM	Parameter :Altitude of the model at surface	Chain of	NWP_ALTM
_	sampling rate: (=segment size CMA SZSEG)	characters	4
	interpolation method.	311111111111111111111111111111111111111	BLI
NWP_PARAM	Parameter: Geopotential at surface	Chain of	NWP_SGEOP
	sampling rate: (=segment size CMA SZSEG)	characters	4 BLI
	interpolation method		DIII
RTS_PARAM	Parameter : Clear sky TOA radiance	Chain of	RTS_CLEAR
	sampling rate: (=segment size CMA SZSEG)	characters	4 BLI
	interpolation method		חחד
RTS_PARAM	Parameter: Transmittance from surface to	Chain of	RTS_TAUTOTAL
	TOA	characters	4 BLI
	sampling rate : (=segment size CMA SZSEG)		דחד
	interpolation method		
RTS_PARAM	Parameter : Clear sky down-welling	Chain of	RTS_DNCLEAR
	radiance	characters	4 BLI
	sampling rate : (=segment size CMA SZSEG)		חחד
	interpolation method		
			L

Table 5: CMa default Model Configuration File description



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#### 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.
- NWP\_ANALYSIS: the flag indicating if NWP analysis fields can be used. Its default value is FALSE. Information on how to change this flag 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.
- NP\_OMP\_CMA\_THREAD (default value: -1): The CMA is parallelized using openMP standard. If set to a strictly positive integer value, NB\_OMP\_CMA\_THREAD corresponds to the number of threads used by CMA. If NB\_OMP\_CMA\_THREAD is set to a negative value, the number if threads used by CMA will be monitored by the OMP\_NUM\_THREADS environment variable set at NWCSAF SW level.

# 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 for MSG. More details can be obtained from the validation report for cloud products ([RD.1.]).

GEO-CMA flags	Validated accuracy
<b>GEO-CMA cloud detection</b>	
If validated over European areas using SYNOP observations	POD: 97.1%
If validated over full disk using SYNOP and SHIP observations	POD: 94.5%



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<b>GEO-CMA dust flag</b>	
If relidated arranges and Africa for salan	POD:
If validated over sea and Africa for solar elevation larger than 20 degrees using	5 5 50 /
interactive targets	58.5% over land

Table 6: Summary of validation results of the current CMA version for MSG (POD stands for Probability Of Detection)

#### 2.4.2 Typical known problems and recommendation for use

The following problems may be encountered:

- Low clouds may be not detected in case low solar elevation, over both sea and land.
- It may happen that large areas of low clouds are not detected in night-time conditions over land. This can be the case in "warm sectors", but also in areas viewed with high satellite zenith angles or if the low clouds are surmounted by very thin cirrus.
- Snowy grounds are not detected at night-time and therefore may confused either with low clouds or cloud free surface. This drawback has been reduced with v3.1 in release 2011.
- 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



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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.

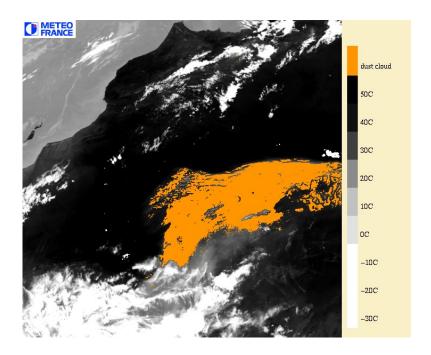


Figure 1: Example of SEVIRI dust cloud flag superimposed on a 10.8 µm infrared image: dust cloud over North Africa on 14th July 2003 at 13h00 UTC.

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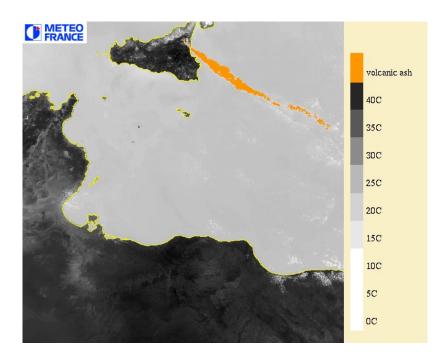


Figure 2: Example of MODIS volcanic ash cloud superimposed on a 10.8 µm infrared image: Etna eruption on 22th July 2001 at 9h55 UTC.

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# 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, T3.8µm, T8.7µm, T10.8µm, T12.0µm, R0.6µm, R0.8µm and R1.6µm), 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 (T10.8µm-T12.0µm, T8.7µm-T10.8µm or T3.9µm-T10.8µm) together with R0.6µm and R1.38µm (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



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compared to NWP forecast air temperatures at various pressure levels. Details are available in the algorithm theoretical basis document for cloud products ([AD.7.])

# 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.6.]), a summary is given below:

			Content	
GEO-CT	SAFNWC GEO CT Clo	ud Ty		
	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 moderately thick clouds	
	13		High semitransparent thick clouds	
	14		th semitransparent above low or medium clouds	
	FillValue		High semitransparent above snow/ice  No data or corrupted data	
GEO-CT			n/Cumuliform Cloud Detection	
CUMULIFORM	SAFNWC GEO CT Sura	шоп	n/Cumumorm Cloud Detection	
_COMOLIFORM	Cla	200	Stratiform/Cumuliform Cloud category	
	Cit	1	Stratiform status	
		2	Cumuliform status	
		3	Mixed status	
		4	Cloud-free	
		5	Undefined (separability problem)	
	FillV	FillValue No data or corrupted data		
GEO-CT	SAFNWC GEO CT Mu	ltilaye	<u> </u>	
_MULTILAYER				
	C	lass	Multilayer Cloud category	
		0	·	
		1	2	
		2		
		3		
		Value	No data or corrupted data	
GEO-CT	6 bits indicating (if set to	o 1)		
_status_flag	D'(0 - T - T	1.4	1' ' ' NIMID (" 11	
			mal inversion in NWP field	
			mperature available from NWP field	
			for cirrus identification n satellite data used	
			stratiform/cumuliform separation	
			multi-layer	
1	Bit 5. Tro metric	101		



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#### **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.



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

Additionally the two following scores are available in the header of the Netcdf files:

- The product completeness is the ratio (in %) between the number of processed pixels and the number of "non space" pixels (ie, the pixels that should be processed).
- The product quality is the ratio (in %) between the number of good quality pixels and the number of "non space pixels (ie, the pixels that should be processed). The definition of good quality pixel is given in the ATBD.

## 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.]).

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.
- NWP\_ANALYSIS: the flag indicating if NWP analysis fields can be used. Its default value
  is FALSE. This flag has been made configurable to allow users to provide NWP analysis, in
  case of reprocessing activities. When it is set to TRUE, NWP fields with forecast time 00 are
  used by the PGE if they are available



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• NP\_OMP\_CT\_THREAD (default value: -1): The CT is parallelized using openMP standard. If set to a strictly positive integer value, NB\_OMP\_CT\_THREAD corresponds to the number of threads used by CT. If NB\_OMP\_CT\_THREAD is set to a negative value, the number if threads used by CT will be monitored by the OMP\_NUM\_THREADS environment variable set at NWCSAF SW level.

# 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.

The following command is used to process GEO-CT manually, without the presence of the TM:

%GEO-CT-v41 20211029T120000Z global.cfg safnwc\_CT.cfm

This command executes GEO-CT version 4.1 over the region global.cfg manually, without the presence of the TM

# 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):

R0.6µm	R1.38µm	Т3.8μm	T7.3μm	T8.7μm	T10.4μm	T10.8µm	T12.0μm
Mandatory	Optional	Mandatory	Optional	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:



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

- surface temperatures
- o air temperature at 950hPa (alternatively 925hPa) (to check low level inversion), 850hPa, 700hPa, 500hPa and at tropopause level
- o total water vapour content of the atmosphere,
- o 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.

In case of reprocessing activities, NWP analysis can be used. To be remapped the NWP\_ANALYSIS flag has to be set to YES in the nwp\_conf\_file.

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
- o Monthly minimum SST climatology
- o Monthly mean 0.6μm atmospheric-corrected reflectance climatology (land)
- o Monthly integrated atmospheric water vapor content climatology
- o 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 lookup 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:



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Keyword	Description	Type	Default Value(s)
PGE_ID	Identifier of the PGE	Chain of	GEO-CT
		characters	
SEV_BANDS	SEVIRI channels to be used by CT	Chain of	VISO6, NIR13, IR38, WV73, IR87
	·	characters	,IR103,IR108,IR120
INT_PRODUCT	Enables/disables the generation of	Chain of	NO
	intermediate products	characters	
CT_SZSEG	Size of CT segments expressed in SEVIRI		
	coordinates (same value for lines and		
	columns)		
NB_OMP_CT_THREAD	Number of threads used by CT (if set to	Integer	-1
	negative value, number of threads		
	monitored by environment variable		
	OMP_NUM_THREADS		
NWP_ANLYSIS	Flag to allow the use of NWP analysis	Chain of	FALSE
amaa 1001100		characters	777.07
STSC_APPLIED	Enables the separation		FALSE
	stratiform/cumuliform. Not available in this	characters	
MIND DADAM	SW version		NEID OF
NWP_PARAM	Parameter :Temperature at surface level	Chain of	NWP_ST
	sampling rate : (=segment size CT_SZSEG)	characters	BLM
NUD DADAM	interpolation method.	- · · · ·	NIJD III
NWP_PARAM	Parameter :Temperature at pressure levels	Chain of NWP_T	
	sampling rate : (=segment size CT_SZSEG)	characters	BLI
NWP PARAM	interpolation method.	CI : C	NWP TT
IWE_FARAM	Parameter: Temperature at tropopause level	Chain of	4
	sampling rate : (=segment size CT_SZSEG)	characters	BLI
NWP PARAM	interpolation method.	Chain of	NWP TCWV
	Parameter: Total column water vapour sampling rate: (=segment size CT SZSEG)	characters	4
	interpolation method.	Characters	MAX
NWP PARAM	Parameter :Altitude of the model at surface	Chain of	NWP_ALTM
_	sampling rate: (=segment size CT SZSEG)	characters	4
	interpolation method.	Characters	BLI
NWP PARAM	Parameter : Geopotential at surface	Chain of	NWP SGEOP
_	sampling rate: (=segment size CT SZSEG)	characters	4
	interpolation method	Characters	BLI
	morpolation metroa	1	

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).
- NWP\_ANALYSIS: the flag indicating if NWP analysis fields can be used. Its default value is FALSE. Information on how to change this flag can be found in section 2.2.1.



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• NP\_OMP\_CT\_THREAD (default value: -1): The CT is parallelized using openMP standard. If set to a strictly positive integer value, NB\_OMP\_CT\_THREAD corresponds to the number of threads used by CT. If NB\_OMP\_CT\_THREAD is set to a negative value, the number if threads used by CT will be monitored by the OMP\_NUM\_THREADS environment variable set at NWCSAF SW level.

## 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 for MSG. More details can be obtained from the validation report for cloud products ([RD.1.]).

GEO-CT	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 for MSG.

#### 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

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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).

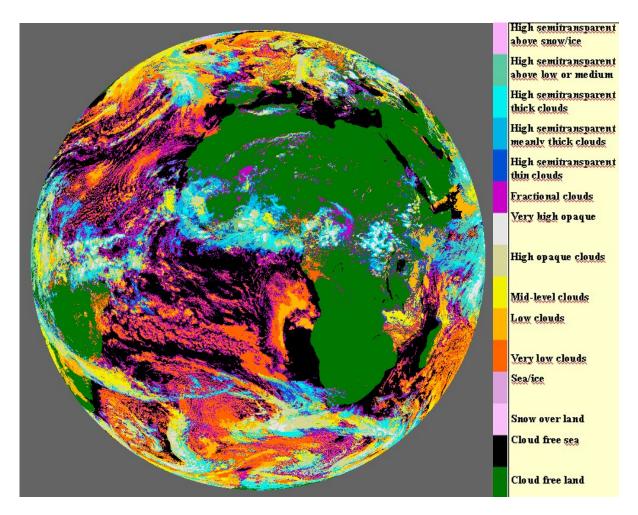


Figure 3: Example of SEVIRI CT cloud type using the colour palette included in CT NetCdF files.

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# 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, Rad6.2µm, Rad7.3µm, Rad13.4µm, T10.8µm, T12.0µm (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 (10.8μm, and 12.0μm) and sounding channels (6.2μm, 7.3μm, 13.4μm for MSG/SEVIRI). This process is performed in each segment of the image (the size of the segment is defined by the user, the default value being 4\*4



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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 H<sub>2</sub>O/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 H<sub>2</sub>O/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



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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.7.])

#### 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.6.]), a summary is given below:

Container	Content
GEO-CTTH PRES	SAFNWC GEO CTTH Cloud Top Pressure
	GEO-CTTH_PRES(Pa) = scale_factor * Counts + add_offset where:
	scale_factor = 10.0
	$add\_offset = 0.0$
GEO-CTTH ALTI	SAFNWC GEO CTTH Cloud Top Altitude
	GEO-CTTH_ALTI(m) = scale_factor * Counts + add_offset where:
	scale_factor = 1.0
	add_offset = -2000.0
GEO-CTTH TEMPE	SAFNWC GEO CTTH Cloud Top Temperature
_	GEO-CTTH_TEMPE(K) = scale_factor * Counts + add_offset where:
	scale_factor = 0.01
	add_offset = 130.0
GEO-CTTH EFFECTIV	SAFNWC GEO CTTH Cloud Effective Cloudiness
	GEO-CTTH_EFFECTIV = scale_factor * Counts + add_offset
	where: $scale\_factor = 0.01$
	$add\_offset = 0.0$



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Container		Content	
GEO-CTTH	14 bits indicating (if set to 1)		
_METHOD	Bit 0:	Cloud-free	
_	Bit 1:	No relieable 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 10.8μ7.0μm	
	Bit 12:	Radiance ratioing method 10.8µm/7.3µm	
	Bit 13:	Spatial smoothing (gap filling in semi-transparent cloud field)	
GEO-CTTH		ting (if set to 1)	
_status_flag	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	



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## **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.



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

Additionally the two following scores are available in the header of the Netcdf files:

- The product completeness is the ratio (in %) between the number of processed pixels and the number of "non space" pixels (ie, the pixels that should be processed).
- The product quality is the ratio (in %) between the number of good quality pixels and the number of "non space pixels (ie, the pixels that should be processed). The definition of good quality pixel is given in the ATBD.

# 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.
- RTTOV\_USE\_COMPUTED\_BIAS (default value:FALSE): a flag defining if biases are to be monitored on line [This key should be set to TRUE in case 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 thoses bias files (see [AD.7.]).]



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- NWP\_ANALYSIS: the flag indicating if NWP analysis fields can be used. Its default value
  is FALSE. This flag has been made configurable to allow users to provide NWP analysis, in
  case of reprocessing activities. When it is set to TRUE, NWP fields with forecast time 00 are
  used by the PGE if they are available
- NP\_OMP\_CTTH\_THREAD (default value: -1): The CTTH is parallelized using openMP standard. If set to a strictly positive integer value, NB\_OMP\_CTTH\_THREAD corresponds to the number of threads used by CTTH. If NB\_OMP\_CTTH\_THREAD is set to a negative value, the number if threads used by CTTH will be monitored by the OMP\_NUM\_THREADS environment variable set at NWCSAF SW level.

## 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.

The following command is used to process GEO-CTTH manually, without the presence of the TM:

%GEO-CTTH-v41 20211029T120000Z global.cfg safnwc\_CTTH.cfm

This command executes GEO-CTTH version 4.1 over the region global.cfg manually, without the presence of the TM

# 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):

Rad6.2µ m	Rad7.0µ m	Rad7.3µ m	Rad13.4 µm	Rad10.8µm	T10.8μm	T12.0µm
	ne of these one of these of the of th			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 T10.8µm brightness temperature is missing, no result is available. If T10.8µm brightness temperature is available, but mandatory channels are missing, only the cloud top temperature is computed using the method based on climatological atmospheric absorption correction.



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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:

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

Vertical pressure levels on which air temperature and humidity are defined by the user. All the surface and near-surface NWP informations and at least NWP informations every 210hPa on the vertical are mandatory to get full CTTH product. Otherwise only the cloud top temperature is retrieved using the method based on climatological atmospheric absorption correction. Furthermore, it is recommended to provide NWP information on levels at least up to 100hPa to ensure a good height retrieval quality for very high clouds.

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

In case of reprocessing activities, NWP analysis can be used. To be remapped the NWP\_ANALYSIS flag has to be set to YES in the nwp\_conf\_file.

#### • RTTOV simulations:

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

- 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.



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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.

#### • 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-CTTH (the processed region needs to contain large enough area covered by oceanic surfaces (see [AD.7.]). If this computation is not possible, the GEO-CTTH uses IR RTTOV simulation without bias correction).

#### • Ancillary data sets:

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

- Land/sea atlas
- Elevation atlas
- o Monthly minimum SST climatology
- o Monthly mean 0.6µm atmospheric-corrected reflectance climatology (land)
- o 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.

## 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:



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Keyword	Description	Type	Default Value(s)
PGE_ID	Identifier of the PGE	Chain of	GEO-CTTH
		characters	
SEV_BANDS	SEVIRI channels to be used by CTTH	Chain of characters	WV62,WV70,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	Integer	4
	SEVIRI coordinates (same value for lines and columns)	8	
RTTOV_USE_COMPUTED_ BIAS	Flag defining if biases are to be monitored on line	Chain of characters	FALSE
IS_ALREADY_RECALIBR	Flag defining whether satellite data input by	Chain of	FALSE
ATED	the user are already recalibrated using post- launch and GSICS calibration coefficients (not configurable in current version)	characters	
NB_OMP_CTTH_THREAD	Number of threads used by CTTH (if set to negative value, number of threads monitored by environment variable	Integer	-1
NWP ANLYSIS	OMP_NUM_THREADS Flag to allow the use of NWP analysis	Chain of	FALSE
_	Thag to allow the use of TVWT analysis	characters	
NWP_PARAM	Parameter :Temperature at surface level	Chain of	NWP_ST
	sampling rate : (=segment size CTTH_SZSEG) interpolation method.	characters	BLM
NWP_PARAM	Parameter :Temperature at surface level	Chain of	NWP_ST
	sampling rate : (=segment size CTTH_SZSEG) interpolation method.	characters	BLI
NWP_PARAM	Parameter :Pressure at surface level	Chain of	NWP_SP 4
	sampling rate : (=segment size CTTH_SZSEG) interpolation method.	characters	BLI
NWP_PARAM	Parameter :temperature at 2m	Chain of	NWP_2T
	sampling rate : (=segment size CTTH_SZSEG) interpolation method.	characters	BLI
NWP_PARAM	Parameter :relative humidity at 2m	Chain of	NWP_2RH 4
	sampling rate : (=segment size CTTH_SZSEG) interpolation method.	characters	BLI
NWP_PARAM	Parameter :Temperature at pressure levels	Chain of	NWP_T
	sampling rate : (=segment size CTTH_SZSEG) interpolation method.	characters	BLI
NWP_PARAM	Parameter :relative humidity at pressure	Chain of	NWP_RH 4
	levels	characters	BLI
	sampling rate : (=segment size CTTH_SZSEG) interpolation method.		
NWP_PARAM	Parameter :geopotential at pressure levels	Chain of	NWP_GEOP 4
	sampling rate : (=segment size CTTH_SZSEG)	characters	BLI
NWP PARAM	interpolation method.	Chain	NWP TT
	Parameter : Temperature at tropopause level sampling rate : (=segment size CTTH_SZSEG)	Chain of characters	4
	interpolation method.	Characters	BLI
NWP_PARAM	Parameter: Pressure at tropopause level	Chain of	NWP_TP
	sampling rate: (=segment size CTTH SZSEG)	characters	4 BLI
	interpolation method.		
NWP_PARAM	Parameter :Height at tropopause level	Chain of	NWP_TH 4
	sampling rate : (=segment size CTTH_SZSEG)	characters	BLI
	interpolation method.	j	



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

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.
- RTTOV\_USE\_COMPUTED\_BIAS: the flag defining if biases are to be monitored on line, is configurable (see its definition in section 4.2.1). Its default value is FALSE. Information on how to change this value can be found in section 4.2.1.
- NWP\_ANALYSIS: the flag indicating if NWP analysis fields can be used. Its default value is FALSE. Information on how to change this flag can be found in section 2.2.1
- NP\_OMP\_CTTH\_THREAD (default value: -1): The CTTH is parallelized using openMP standard. If set to a strictly positive integer value, NB\_OMP\_CTTH\_THREAD corresponds to the number of threads used by CTTH. If NB\_OMP\_CTTH\_THREAD is set to a negative value, the number if threads used by CTTH will be monitored by the OMP\_NUM\_THREADS environment variable set at NWCSAF SW level.

## 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 for MSG. More details can be obtained from the validation report for cloud products ([RD.1.]).



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GEO-CTTH products	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)

Table 10: Summary of validation results of the current CTTH version for MSG (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.

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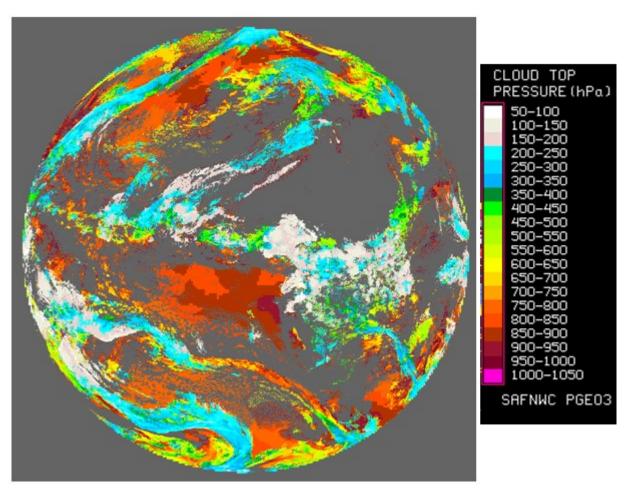


Figure 4: Example of SEVIRI CTTH cloud top pressure

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# 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 mycrophysics (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 T8.7μm-T10.8μm, T10.8μm and the CT cloud type itself complemented (only during daytime) by an combined analysis of the measured and simulated 0.6μm, 1.6μm and 2.25μm reflectances. The additional microphysics parameters are obtained only in daytime conditions through the comparison of measured and simulated 0.6μm and 1.6μm 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, T8.7μm, T10.8μm, R0.6μm, and R1.6μm), 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  $T8.7\mu m$ - $T10.8\mu m$ ,  $T10.8\mu m$  and the CT cloud type itself complemented by an combined analysis of  $0.6\mu m$  and  $1.6\mu m$  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".



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- Water clouds usually have low T8.7µm-T10.8µm 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 0.6μm ,1.6μm and 2.25 μm 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 0.6µm and 1.6µm 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.7.])

### 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.6.]), a summary is given below:

Container		Content		
GEO-CMIC	SAFNWC GEO CMIC Cloud Top Phase			
PHASE				
_	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	SAFNWC GEO CMIC Cloud I	Drop Effective Radius		
_REFF				
	GEO-CMIC_REFF(m	) = scale_factor * Counts + add_offset		
	where:			
	scale_factor = 10 <sup>-8</sup>			
	$add_{offset} = 0.0$			
	CAPANYC CEO CMC CL - 1 O C - 1 TL 1			
GEO-CMIC	SAFNWC GEO CMIC Cloud Optical Thickness			
_COT	CEO CMIC COT = seels feeten * Counts   add affect			
	GEO-CMIC_COT = scale_factor * Counts + add_offset			
	where:			
	$scale\_factor = 0.01$			
	$add\_offset = 0.0$			
GEO-CMIC	SAENWC GEO CMIC Cloud I	Liquid Water Dath		
LWP	SAFNWC GEO CMIC Cloud Liquid Water Path			
_L W I	GEO-CMIC LWP(kg.m <sup>-2</sup> ) = scale factor * Counts + add offset			
	where:	in j = scale_factor Counts + add_offset		
	scale factor $= 0.001$			
	add offset = 0.001			
	uuu_ojjsei — 0.0			
	<u> </u>			



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Container		Content	
GEO-CMIC	SAFNWC GEO CMIC Cloud Ice Water Path		
_IWP			
	GEO	O-CMIC_IWP(kg.m <sup>-2</sup> ) = scale_factor * Counts + add_offset	
	where:		
	scale factor	$\cdot = 0.001$	
	add_offset	= 0.0	
GEO-CMIC	11 bits indica	ting (if set to 1)	
_status_flag			
	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	
		, 1	



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## **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.



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

Additionally the two following scores are available in the header of the Netcdf files:

- The product completeness is the ratio (in %) between the number of processed pixels and the number of "non space" pixels (ie, the pixels that should be processed).
- The product quality is the ratio (in %) between the number of good quality pixels and the number of "non space pixels (ie, the pixels that should be processed). The definition of good quality pixel is given in the ATBD.

## 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



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should remain set to FALSE (defaut value). If set to TRUE (for example, CM-SAF may use this option), the CMIC does not perform its own recalibration of solar channels].

- NP\_OMP\_CMIC\_THREAD (default value: -1): The CMIC is parallelized using openMP standard. If set to a strictly positive integer value, NB\_OMP\_CMIC\_THREAD corresponds to the number of threads used by CMIC. If NB\_OMP\_CMIC\_THREAD is set to a negative value, the number if threads used by CMIC will be monitored by the OMP\_NUM\_THREADS environment variable set at NWCSAF SW level.
- NWP\_ANALYSIS: the flag indicating if NWP analysis fields can be used. Its default value
  is FALSE. This flag has been made configurable to allow users to provide NWP analysis, in
  case of reprocessing activities. When it is set to TRUE, NWP fields with forecast time 00 are
  used by the PGE if they are available

## 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.

The following command is used to process GEO-CMIC manually, without the presence of the TM:

%GEO-CMIC-v21 20211029T120000Z global.cfg safnwc CMIC.cfm

This command executes GEO-CMIC version 2.1 over the region global.cfg manually, without the presence of the TM

# 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):

R0.6µm	R1.6µm	R2.25μm	T8.7μm	T10.8µm
Mandatory	Mandatory	Optional	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.



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It is essential to use well calibrated 0.6μm and 1.6μm 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
- o 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.

In case of reprocessing activities, NWP analysis can be used. To be remapped the NWP\_ANALYSIS flag has to be set to YES in the nwp conf file

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
- o Elevation atlas
- o Monthly 0.6μm, 1.6μm and 2.25μm white-sky surface albedo climatology (land)
- o Monthly integrated atmospheric water vapor content climatology
- o 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 lookup 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 0.6µm and 1.6µm cloud radiative properties (beam bi-directional reflection, beam direct transmission, beam 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.



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#### 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	GEO-CMIC
		characters	
SEV_BANDS	SEVIRI channels to be used by CMIC	Chain of	VISO6, NIR16, NIR22, IR87, IR1
		characters	08
INT_PRODUCT	Enables/disables the generation of	Chain of	NO
	intermediate products	characters	
	(not configurable in current version)		
CMIC_SZSEG	Size of CMIC segments expressed in	Integer	4
	SEVIRI coordinates (same value for lines		
	and columns)		
IS_ALREADY_RECALIBR ATED	Flag defining whether satellite data input by	Chain of	FALSE
ALED	the user are already recalibrated using post-	characters	
	launch and GSICS calibration coefficients		
NB_OMP_CMIC_THREAD	Number of threads used by CMIC (if set to	Integer	-1
	negative value, number of threads		
	monitored by environment variable		
	OMP_NUM_THREADS		
NWP_ANLYSIS	Flag to allow the use of NWP analysis	Chain of	FALSE
		characters	
NWP_PARAM	Parameter :Total ozone content	Chain of	NWP_TOZ
	sampling rate : (=segment size CMIC_SZSEG)	characters	BLI
	interpolation method.		
NWP_PARAM	Parameter :Integrated water vapour above		NWP_AWV
	pressure level	characters	BLI
	sampling rate : (=segment size CMIC_SZSEG)		
	interpolation method.		
NWP_PARAM	Parameter :Integrated water vapour below	Chain of	NWP_BWV 4
	pressure level	characters	BLI
	sampling rate : (=segment size CMIC_SZSEG)		
	interpolation method.		

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.]).



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- NWP\_ANALYSIS: the flag indicating if NWP analysis fields can be used. Its default value is FALSE. Information on how to change this flag can be found in section 2.2.1
- NP\_OMP\_CMIC\_THREAD (default value: -1): The CMIC is parallelized using openMP standard.
   If set to a strictly positive integer value, NB\_OMP\_CMIC\_THREAD corresponds to the number of threads used by CMIC. If NB\_OMP\_CMIC\_THREAD is set to a negative value, the number if threads used by CMIC will be monitored by the OMP\_NUM\_THREADS environment variable set at NWCSAF SW level.

## 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 for MSG. More details can be obtained from the validation report for cloud products ([RD.1.]).

GEO-CMA flags	Validated accuracy
<b>GEO-CMIC</b> 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 <sup>2</sup> ; rsm: 38.46g/m <sup>2</sup>

Table 12: Summary of validation results of the current CMIC cloud phase and cloud liquid water path for MSG (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 nightime
  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.

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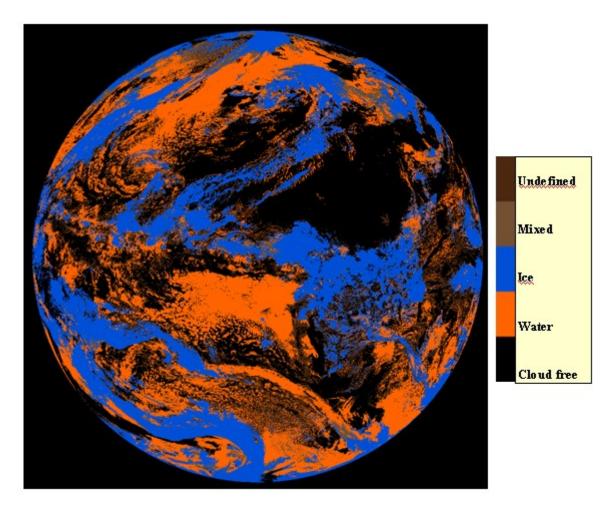


Figure 5 Example of SEVIRI cloud phase flag illustrated with the colour palette included in the CMIC NetCdF files.

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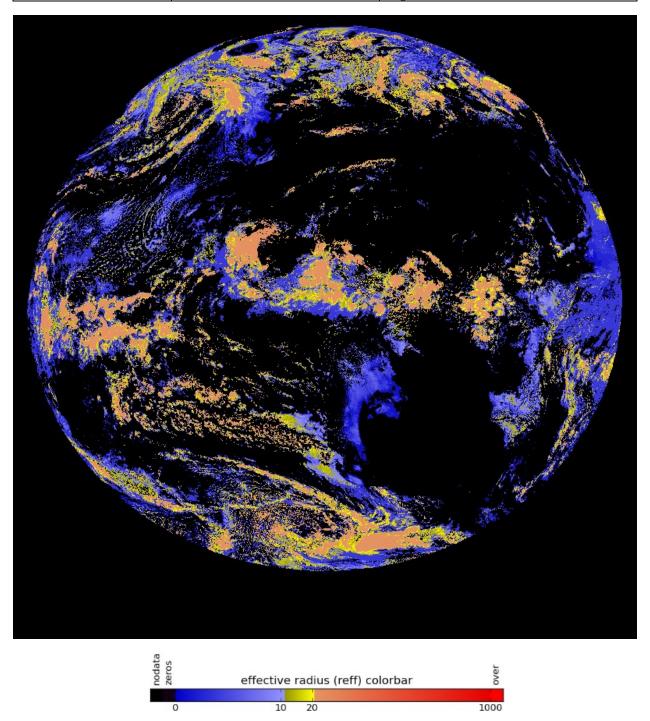


Figure 6 Example of SEVIRI cloud effective radius illustrated with the colour palette included in the CMIC NetCdF files.



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# **6 WARNING AND ERROR MESSAGES**

Code (E/W)	Message	Comment	Recovery action
È	"Usage:%sYYYYMMDDThhmmssZ region_conf_file model_conf_file"	Error when launching one cloud product	Check instruction for launching Cloud products
E	"NWC/GEO environment variable is not set"	\$SAFNWC is not set	Set \$SAFNWC
E	All messages related to NWCLIB time handling functions: NwcTimeSetStr, NwcTimeSetJR, NwcTimeAdd	Time input when launching PGE may be wrong.  Time string read in Gen_Info_MSG.asc file may be corrupted.	Check the slot time input when launching PGE. Check Gen_Info_sat.asc on \$SAFNWC/import/Aux_data/Cloud. If necessary, copy it form delivered SW.
Е	All messages including following string: "memory allocation" "allocation error" "Unable to allocate" "Error allocating" "not allocated" "cannot be allocated" "ERR NwcMemMalloc"	Problem of memory allocation	Check memory
Е	All messages containing following string: "Unable to open" "unable to create"	Problem to open an existing file or to create a new file.	Check permission and disk space on the directory.  Check presence of the requested file. The recovery actions depends on the type of file: for missing configuration files, copy them from delivered SW; for missing file to be input by user: check why they are missing; for new file, check permission/disk space on the directory.
Е	All messages containing the string: "NwcCFGetStr"	Problem when reading key in configuration file.	Check corresponding configuration file. If needed, copy them from delivered SW.
Е	Messages containing following string: "bad sat_ids" "bad key" "Tab name read expected" "pb key TAB_TYPE" "chn number pb read" "pb RANG_VIS"	Problem when reading ascii file on: \$SAFNWC/import/Aux_data/Cloud May be either requested key or table missing or unexpected, or incoherency with current satellite	Check the ascii file on \$SAFNWC/import/Aux_data/Cloud If necessary copy it from delivered SW.
Е	Messages containing the following string:  "ERR Sat_band"  "ERR nc_inq_varid varname"  "ERR namenc_inq_dimid status"  "ERR name nc_inq_dim status"  "ERR size length"  "ERR nc_get_vara_short status"	Problem when reading CMIC LUT in netcdf format	Ckeck the CMIC LUT netcdf file on \$SAFNWC/import/Aux_data/Cloud If necessary copy it from delivered SW.
Е	Messages containing the following string: "CldLibSegReadLSC: Error Reading landseacoast databuf file" "CldLibSegWriteLSC: Error Writing landseacoast databuf file"	Problem related to management of Land/Sea/Coast databuf file on \$SAFNWC/tmp.	Check permission and disk space on \$SAFNWC/tmp.  If file CLD_LANDSEACOAST_sat_region- n_m.raw exists on \$SAFNWC/tmp, it may be corrupted: delete this file (it will be created when sw is relaunched).



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Code (E/W)	Message	Comment	Recovery action
E	Messages containing following string: "Pb reading Ostia file" "No appropriate OSTIA file available on"	Problem when reading OSTIA netcdf file input by the user.	Check permission on \$SAFNWC/import/Aux_data/OSTIA. Check existence of OSTIA netcdf file input by the user on \$SAFNWC/import/Aux_data/OSTIA. If missing or corrupted file, download OSTIA file from ftp server as explained in Software User Manual.
Е	Messages containing following string:  "CldLibSegOstia : ERROR when reading OSTIA in databuf"  "CldLibSegReadOstiaDB: Error Reading OSTIA databuf file"  "CldLibSegOstia : ERROR when writing OSTIA in databuf"  "CldLibSegWriteOstiaDB: Error writing OSTIA databuf file"  "CldLibSegWriteOstiaDB: Error writing OSTIA databuf file"  "CldLibSegWriteOstiaDB: Error when removing OSTIA databuf file"	Problem related to management of OSTIA databuf	Check permission and space disk on \$SAFNWC/tmp. Remove OSTIA databuf from \$SAFNWC/tmp (if available).
Е	Messages containing following strings: "Error fgetpos when reading bias file" "Error when reading bias file" "PB reading bias file" "PB reading channel in bias file"	Problem related to reading rttov bias file monitored by cloud PGE.	Check permission and space disk on \$SAFNWC/tmp. Edit bias files to check their content If corrupted, remove rttov bias file
Е	CldLibReadRttovBias: the RTTOV Bias file is too old (%d days). Please load a valid file	The RTTOV bias file is too old to be used (maximum 35 day off from the validity range).	Download more recent rttov bias from AEMET ftp server
E	Messages containing following strings:  "CldCmaFinWriteSnowMap read error snow_hits on current_snow_file"  "CldCmaFinWriteSnowMap read error list_images on current_snow_file"  "CldCmaFinWriteSnowMap write error on"  "CldCmaFinWriteSnowMap write error on"	Problem related to management of snowmap databuf file (name in error message) on \$SAFNWC/tmp.	Check permission and space disk on \$SAFNWC/tmp. Remove snow map databuf (name in error message) from \$SAFNWC/tmp (if available).
Е	"in CldLibHandleResolution: incoherency in region order"	The spatial resolutions of the region initialised with NWCLIB functions are not ordered correctly: this is unexpected.	Should not happen. Contact developers on the helpdesk.
Е	"problem in decoding time string in CldLibInitCorDailyVis"	Time string read in Gen_Info_MSG.asc file may be corrupted.	Check Gen_Info_MSG.asc on \$SAFNWC/import/Aux_data/Cloud. If necessary, copy it from delivered SW.
Е	"Error due to incoherency in horizontal resolution" "incoherency of size"	Incoherency in spatial resolution or image size.	Should not happen. Contact developers on the helpdesk.
E	"CldLibSegCompAtlasClimSeg atlascode: unknown atlascode"	Unexpected atlas map code	Should not happen. Contact developers on the helpdesk.
W	"Not enough pixels to compute RTTOV bias"	Not enough cloud free oceanic pixel to compute RTTOV bias for current slot.	Check that your region allows the computation of the RTTOV bias (minimum number of oceanic pixels as explained in ATBD).  Do nothing if your region contains enough oceanic pixels. The RTTOV bias will be computed on other slots that are less cloudy.



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Code (E/W)	Message	Comment	Recovery action
Е	"Mandatory NWP fields are missing: height/pressure will not be computed"	5	Check why NWP remapped field are not available
Е	"Not enough pixel with mandatory input data available for CMA (or CT, CTTH,CMIC)"	Not enough pixel with mandatory data for CMA (or CT, CTTH,CMIC)  -> no output is computed	Check input data for CMA (or CT, CTTH,CMIC), especially NWP data.