EUMETSAT NWC SAF
SUPPORT TO NOWCASTING AND VERY SHORT RANGE FORECASTING

User Manual for the Convection Product Processors of the NWC/GEO MTG-I Day1

NWC/CDOP3/MTG/MF-PI/SCI/UM/Convection, Issue 1, Rev. 2.1

30th May 2025

Applicable to

GEO-CI v3.0 (NWC-054)

GEO-RDT-CW v6.0 (NWC-057)

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REPORT SIGNATURE TABLE

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DOCUMENT CHANGE RECORD

Version	*Date*	*Changes*
1.0	31st January 2021	After STRR
1.1	3rd February 2024	After ORR1
1.2.0	31th March 2025	Minor update for final v2025 delivery, inclusions of all changes non linked with MTG up to 2021.3
1.2.1	30th May 2025	Updated after ORR2 first round

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1 INTRODUCTION

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

1.1 Scope of the document

This document is the User Manual for the Convection Products components GEO-CI (Convection Initiation) and GEO-RDT-CW (Rapidly Developing Thunderstorm – Convection Warning) of the NWC/GEO software package.

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

1.2 Scope of other documents

The algorithms used to extract the GEO Convection Products are detailed in the algorithm theoretical basis document for Convection products.

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

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

The interface control documents ([AD.7.]) (for the Internal and External Interfaces of the SAFNWC/GEO) and ([AD.8.]) (GEO Output Product Format Definition) detail the input and output data format for the SAFNWC/GEO software.

1.3 Software Version Identification

This document describes the products obtained from the GEO-CI v3.0 (Product Id NWC-054) from the GEO-RDT-CW v6.0 (Product Id NWC-057) implemented in the release v2025 of the NWC/GEO software package.

1.4 Improvement from previous version

Main improvement from previous release v2021 is MTG-I1 compliance (FCI and LI instruments)

Also to note : some functionalities associated to the v2021 patches

- CI addition of a filter to remove pixels belonging to a large cell (over 10 000 km²).
- CI: the cloud type at previous slots is taken into account when computing parameters' trends.
- RDT improvement of the cell detection
- RDT and CI : code optimization

- Support to GOES-18 satellite

Also to note: the format of dates has changed in execution lines (please refer to paragraphs "operations")

Also to note: support to GOES-19 satellite

1.5 Definition, Acronyms and Abbreviations

See [AD.5] for a complete list of acronyms for the NWC SAF project.

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://nwc-saf.eumetsat.int

Ref	***Title***	***Code***	***Vers***	***Date***
[AD.1.]	*Proposal for the Fourth Continuous Development and operation Phase (CDOP) march 2022 – February 2027*	*/NWC/SAF/AEMET/MGT/CDOP4Proposal*	*1.0*	*12/03/2021*
[AD.2.]	*Project Plan for the NWCSAF CDOP4 phase*	*NWC/CDOP4/SAF/AEMET/MGT/PP*	*3.0.0*	*21/10/2024*
[AD.3.]	*Configuration Management Plan for the NWCSAF*	*NWC/CDOP4/SAF/AEMET/MGT/CMP*	*1.2.0*	*29/03/2024*
[AD.4.]	*NWCSAF Product Requirement Document*	*NWC/CDOP4/SAF/AEMET/MGT/PRD*	*3.0.0*	*21/10/2024*
[AD.5.]	*The Nowcasting SAF glossary*	*NWC/CDOP4/SAF/AEMET/MGT/GLO*	*1.0.0*	*31/10/2023*
[AD.6.]	*System and Components Requirements Document for the NWC/GEO MTG-I day-1*	*NWC/CDOP2/MTG/AEMET/SW/SCRD*	*1.3.1*	*31/3/2025*
[AD.7.]	*Interface Control Document for Internal and External Interfaces of the NWC/GEO*	*NWC/CDOP3/MTG/AEMET/SW/ICD/1*	*1.4.0*	*31/3/2025*
[AD.8.]	*Interface Control Document for the NWCLIB of the NWC/GEO*	*NWC/CDOP2/MTG/AEMET/SW/ICD/2*	*1.4.0*	*31/3/2025*
[AD.9.]	*Data Output Format for the NWC/GEO*	*NWC/CDOP2/MTG/AEMET/SW/DOF*	*1.4.0*	*31/3/2025*
[AD.10.]	*Architecture Design Document for the NWC/GEO v2025*	*NWC/CDO2/MTG/AEMET/SW/ACDD*	*1.3.0*	*31/3/2025*
[AD.11.]	*User Manual for the Tools of the NWC/GEO*	*NWC/CDOP3/MTG/AEMET/SCI/UM/Tools*	*1.2.0*	*31/3/2025*

Table 1: List of Applicable Documents

1.6.2 Reference documents

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

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

Current documentation can be found at the NWC SAF Helpdesk web: http://nwc-saf.eumetsat.int.

Ref	***Title***	***Code***	***Vers***	***Date***
[RD.1.]	*Validation report for of the Convection products processors of the NWC/GEO*	*NWC/CDOP3/GEO/MF-PI/SCI/VR*	*1.1*	*18/12/2019*
[RD.2.]	*User Manual for the NWC/GEO application: Software part*	*NWC/CDOP2/GEO/AEMET/SW/UM*	*1.0*	*15/10/2016*
[RD.3.]	*Karagiannidis, A., 2016, Final Report on Visiting Scientist Activity for the validation and improvement of the Convection Initiation (CI) product of NWC SAF v2016 and v2018, Visiting Scientist Activity followed in Nowcasting Department of Météo France, Toulouse, France Period June-December 2016*	available *on NWCSAF Website*		*2016*
[RD.4.]	*Scientific Report on verification of RDT forecast*	NWC/CDOP3/GEO/MFT/SCI/RP/01	1.1	2018
[RD.5.]	*Visualization specifications for Convection Products*	NWC/CDOP2/GEO/MFT/SCI/RP/06	1.2	2016
[RD.6.]	*Lenk, S. Senf, F., Deneke, H., 2018, validation of the Convection Initiation product (CI) of NWCSAF v2018, Associated scientist activity*	NWCSAF/CDOP3/SAF/MF-PI/SCI/RP/Ci_Improv_Tropos avalaible on NWCSAF Website		2018

Table 2: List of Referenced Documents

2 CONVECTION INITIATION (GEO-CI) PRODUCT

2.1 DESCRIPTION OF GEO-CI PRODUCT

2.1.1 Goal of CI product

CI provides the probability for a cloudy pixel to become a thunderstorm in a given following period (30, 60 or 90 minutes). The product aims to catch the first steps of initiation of convection, when the first convective signs occur after the formation of clouds, or when those signs appear revealing a modification of environmental conditions.

2.1.2 Description of CI process and analysis

The CI is a mix of object and pixel analysis, of physical and statistical approach. The methodology is

1. to identify areas of interest, which are areas of ***eligible-CI*** pixels
2. to determine a guess of ***2D movement field*** to be representative of cloudy pixel movement
3. to undertake, over areas of interest, ***cloud cell detection and tracking*** in order to
   - *correct, update and complete* the 2D movement field
   - increase the number of slots from which the pixel is tracked
4. to calculate satellite characteristics of these pixels, including historic of the pixel thanks to 2D movement field (***static and dynamic characteristics***)
5. finally to determine ***CI*** pixels using relevant thresholds of parameters and evaluate convection through probability assessment

The algorithm is described in ATBD. Some improvements from v2016 to v2018 have been defined in [RD.3.].

Relevant parameters, thresholds and some part of the algorithm are inspired from « Best Practice Document » [RD.3.], especially SATCAST methodology for the definition of CI pixels. Major improvements of versions following the first v2016 release have been defined during the Visiting Scientist activity in the period June-December 2016 [RD.4.] and a first objective validation has been performed during a AS activity [RD.6].

2.1.3 Description of output

The content of the output in NetCDF format is described in the Data Output Format document ([AD.9.]). The product is an image-like product, whose target structure contains three main containers dedicated to the three specified periods [0-30mn], [0-60mn] and [0-90mn].

Container	***Content***
ci_prob30	*NWC GEO CI Probability next 30 minutes* *Class 0: no probability to become thunderstorm* *Class 1: 0-25% probability to become thunderstorm in the next 30minutes* *Class 2: 25-50% probability to become thunderstorm in the next 30minutes* *Class 3: 50-75% probability to become thunderstorm in the next 30minutes* *Class 4: 75-100% probability to become thunderstorm in the next 30minutes* *FillValue: No data or corrupted data*

Container	***Content***
ci_prob60	*NWC GEO CI Probability next 60 minutes* *Same classes and meaning than for ci_prob30, but referred to the next 60 minutes*
ci_prob90	*NWC GEO CI Probability next 90 minutes* *Same classes and meaning than for ci_prob30, but referred to the next 90 minutes*
ci_quality	*Value 8: good* *Value 16: questionable* *Value 24: bad*
ci_status_flag	*6 bits indicating (if set to 1)* *Bit 0: High_resolution_satellite_data_used* *Bit 1: Visible_data_used* *Bit 2: IR3.9µm_data_used* *Bit 3: Cloud_type_data_used* *Bit 4: Cloud_Microphysic_data_used* *Bit 5: NWP_data_used*

Table 3: CI NetCDF output containers

Note : The common attributes product_quality and product_completeness are filled as follow:

- Completeness = percentage of usable pixels compared to total number of pixels (usable means non space and available data)
- Quality = percentage of available data, processed as weighted average of available data. Weights are following
  - 50% from mandatory data (current and previous IR10.8 channel)
  - 50% from optional data
    - 25 % from NWP data
    - 25 % from other NWC SAF products (CT, HRW, CMIC)

2.2 Implementation of CI

The implementation of the CI software follows the general implementation of components of the SAFNWC/MSG software.

Basically, the following steps are needed to proceed:

1. Create or update configuration files (system, region, and run configuration files) according to their format (see the Interface Control Document ICD/1 for the External and Internal Interfaces of the SAFNWC/MSG).
2. Update, if necessary, the CI configuration file
3. Ensure that the satellite image - SEVIRI file in HRIT format or SAFNWC-compliant FSD file in netcdf format- (mandatory input) is available in the directory $SAFNWC/import/Sat_data/. To process CI in real-time, the user has to refresh this directory with the most up-to-date data.
4. Ensure that the directory $SAFNWC/import/NWP_data has been provided with latest NWP multiple GRIB data (not mandatory but recommended), and that these data have been remapped by the TM on the specified region (remapped NWP data available in the $SAFNWC/tmp directory). CI configuration file is used as guidance for the use and remapping of NWP data.

Then, the processing of CI is automatically monitored by the task manager (see the Software Users Manual for the Task Manager of the SAFNWC/MSG software).

2.2.1 CI reprocessing cases

Like RDT-CW software, CI undertakes a tracking of cloud cells from one image to the following, but focused here on small warm ones. In real-time there is a kind of continuity. But in reprocessing cases, the starting point has to be clearly defined, as explained hereafter.

If a user wants to focus on a specific period, he has to run CI software at least one hour before: it helps to have a stabilized tracking and reliable cloud cell motion estimation.

- Cloud speed estimate takes into account the speed at previous step. At the beginning, only guess field, neighbouring cells and correlation process allow to estimate speed movement. Then, overlapping technique and previous track allow to improve the estimate.
- Diagnostic scheme needs at least 30min recent historic to analyse trends on first slots and up to 30min depths.
- When CI software runs, it creates backup files identified for each slot. They will be used for the next step. Those backup files get information from several previous steps.

Cases starting point will be defined according to the situation the user wants to study.

2.2.2 CI monitoring

End-users may define several criteria in order to monitor a CI production chain. Classical criteria are processing time or auxiliary files availability. One additional criteria the developers would recommend is to use the number of pixels with a probability of 0%, the number of pixels associated with a probability between 0 and 50% and the number of pixels associated with a probability between 50 and 100%. It is the criteria used in monitoring system on NWCSAF website.

2.3 Input and configurable parameters for CI

2.3.1 List of inputs

2.3.1.1 Mandatory inputs

Three different kinds of mandatory inputs are needed by the CI software in order to proceed correctly:

2.3.1.1.1 Satellite images

These images are provided as input to the CI software by the user. These images must be located in the relevant directory ${SAFNWC}/import/Sat_data, (for more details please refer to the Software Users Manual for the NWC/GEO software).

Mandatory channels are IR10.8, WV6.2, WV7.3, IR8.7, IR12.0 and 13.4µm channels, and are to be available also for the previous slot. Channel #15 (IR 10.3µm) is recommended to be used for GOES16 satellite.

2.3.1.1.2 Configuration file

Beside the SAFNWC general configuration files (system, run and region configuration files, see the Interface Control Document ICD/1 for the External and Internal Interfaces of the NWC/GEO), the following configuration file must be created or updated in order to process CI on a region. CI model configuration file is composed of keywords and values which will be used by the CI software. It must be located in the $SAFNWC/config directory. The list of keywords and their significance is described into the next paragraph.

2.3.1.1.3 Auxiliary files

In order to perform a convective initiation analysis, the CI software makes use of coefficients file located in the directory $SAFNWC/import/Aux_data/CI. Those files are delivered with the NWC/GEO software and must not be modified by the user.

2.3.1.2 Optional inputs

Up to four optional inputs should be provided to CI software for an optimal product:

2.3.1.2.1 NWP data

Even if optional from a technical and functional point of view, NWP data is strongly recommended for a more efficient result. Most recent NWP data has to be located in the directory $SAFNWC/import/NWP_data. When remapped in $SAFNWC/tmp directory, NWP data is used for two objectives:

- Read or re-compute instability indexes, to synthesize a “NWP convective mask” valid for the slot date. This mask allows to exclude stable areas from analysis process.
- Extract 850hPa U/V wind component as guess for movement field for cold start or for orphan cloud cells for which no tracking allowed to compute displacement.

The CI configuration file is used as guidance for the use and remapping of NWP data, by listing all desired parameters (see next section). The CI default configuration file of NWC SAF package lists parameters needed from compliant NWP data. Some parameters that are not initially available, may be estimated from others: humidity at 2m (ARPEGE relative humidity or ECMWF dew point temperature), orography (ARPEGE ground height or ECMWF geopotential).

The NWP elements that will be taken into account by GEO-CI are:

- Instability indexes: previously computed and saved as DATABUF for other products or recomputed
- U/V wind component

CI has been designed so that the dependence of NWP is limited. It allows mainly to take advantage from movement guess field and convective environment. CI performances should not be highly impacted by changing horizontal and temporal resolution of NWP fields. But of course, the lower horizontal and temporal resolutions are, the more detailed the analysis of convective environment and atmospheric motion are.

2.3.1.2.2 CT product.

In the CI software, it is possible to take benefit from CT product of the NWC/GEO. This integration is optional. It allows using CT product as mask product for ignoring cloud-free areas and for filtering relevant pixels in CI process.

In order to use the CT product as input to the CI software for masking clear pixels, the user has to ensure that:

i. the CT product is generated on the desired region
ii. the parameter “CT” of the model configuration file (see next section) is set to 1.

2.3.1.2.3 CMIC product

In the CI software, it is possible to take benefit from CMIC product of the SAFNWC/GEO. This integration is optional. It allows using CMIC product for filtering relevant pixels in CI process, and micro-physics parameter's values for CI diagnosis in day configuration.

In order to use the CMIC product as input to the CI software, the user has to ensure that

i. The CMIC product is generated on the desired region
ii. And the parameter “CMIC” of the model configuration file (see next section) is set to 1.

The use of CMIC in CI software is done as follows:

- The Cloud Top Phase parameter of CMIC product is used for filtering "ice" cases, and focus on pixels/cloud systems in liquid or mixed phase
- In daily conditions, micro-physics parameters Cloud Optical Thickness, Liquid Water Path and Ice Water Patch are used for an additional filtering to exclude non significant pixels, and for a final diagnosis using additional specific tuning

2.3.1.2.4 HRW product

In the CI software, it is possible to take into account HRW Atmospheric Motion Vectors to process, with U/V NWP winds, a guess for movement field.

This integration is optional. In order to use the HRW product as input to the CI software for improving the cloud cell motion estimation, the user has to ensure that

i. The HRW product is generated on the desired region
ii. The parameter “HRW” of the model configuration file (see next section) is set to 1.

The use of HRW into the CI software is done as follows:

- Predictor winds available for the current slot are read in temporary directory of SAFNWC
- Those observations are remapped with a defined tolerance onto region definition in order to fill a movement field
- This movement field is completed from U/V NWP winds read from low-mid NWP levels (for areas where no HRW retrievals are available)
- This guess movement field is made available for cloud-cell tracking, which allows a better initiation of cloud cell movement.

- Then, cloud cell tracking allows improving this field with update by motion vectors related to objects, leading to an optimal blending (NWP+HRW+cell's tracking). This movement field will be used as pixel tracker for following purposes of CI software.

2.3.2 Model Configuration File and configurable parameters

The CI model configuration file contains all the flags and values required for the derivation of the product. The model configuration file must be placed in the $SAFNWC/config directory. The file contains the following information, among which user's configurable parameters are highlighted:

Keyword	*Description*	*Type*	*Default Value(s)*
PGE_ID	Identifier of the PGE	Chain of characters	GEO-CI
SEV_BANDS	SEVIRI channels to be used	Chain of characters	WV62 WV73 IR87 IR108* IR120 IR134 *IR103 for GOES16
NWP_PARAMxx(*)	U component of wind at various pressure levels	Chain of characters	NWP_UW 1 BLI
NWP_PARAMxx(*)	V component of wind at various pressure levels	Chain of characters	NWP_VW 1 BLI
NWP_PARAM	Lifted index	Chain of characters	NWP_LI 1 BLI
NWP_PARAM	K index	Chain of characters	NWP_KI 1 BLI
NWP_PARAM	Showalter index	Chain of characters	NWP_SHW 1 BLI
PGE arguments			
TCOLD	cold temperature threshold when multiple thresholding, deg Celsius	float	-75.
TWARM	warm temperature threshold when multiple thresholding deg Celsius	float	10
DELTATEMPE	temperature step between Tcold and Twarm, deg Celsius	float	1.
DELTATTOUR	minimum gap between Base and top temperat-ures to define a cloud tower to be taken into account	float	3
SMIN	Minimum detection area, km2	float	1.
SMAX	Maximum detection area, km2	float	400000.
NWPMVTLVL	U/V NWP Pressure level to use - hPa	integer	850
Optional inputs			
CT	Flag for using (1) or not (0) CT product	integer	1 (yes)
CMIC	Flag for using (1) or not (0) CMIC product	integer	1 (yes)
HRW	Flag for using (1) or not (0) HRW	integer	1 (yes)
User options			
CANAL_UTIL	channel number for main IR window to use (detection, tracking and discrimination)	integer	16 (IR108 default) 15 (IR103 for GOES16)
OMP_NBTHREAD	when using openmp for parallelization mode, number of thread to be used	integer	3
LICONV	convective threshold	integer	-3 (default)
LINOCONV	non convective threshold	integer	0 (default)
KICONV	convective threshold	integer	30 (default)
KINOCONV	non convective threshold	integer	20 (default)
SHWCONV	convective threshold	integer	-3 (default)
SHWNOCONV	non convective threshold	integer	+3 (default)
DBG	Flag for activating (1) or not (0) debug mode	integer	0

Table 4: default CI Model Configuration File description

2.4 CI OPERATIONS

2.4.1 Procedure

2.4.1.1 Input data files needed for GEO-CI product generation

- Mandatory input data like satellite data configuration files and auxiliary files as listed in paragraph 2.3.1.1

- Optional input data (NWP, other NWCSAF products) as listed in paragraph 2.3.1.2

- PGE configuration file as detailed in paragraph 2.3.2

2.4.1.2 Output files obtained from GEO-CI product generation

The following output files are generated if GEO-CI runs successfully:

- GEO-CI product
  `S_NWC_CI_satellite_region-VISIR_YYYYMMDDThhmmssZ.nc`
  in the directory `$SAFNWC/export/CI`
- Backup files
  `GEO-CI_regionname_Carte_sauvegarde_YYYYMMDDHHmm,` and
  `GEO-CI_regionname_sauvegarde_YYYYMMDDHHmm`

  `MFT_regionname_dx_0_YYYYMMDDHHmm`

  `MFT_regionname_dy_0_YYYYMMDDHHmm`

  `MFT_regionname_umvt_0_YYYYMMDDHHmm`

  `MFT_regionname_vmvt_0_YYYYMMDDHHmm`
  in the directory `$SAFNWC/tmp`

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

```
GEO-CI-v30 <time_of_slot> <region_configuration_file>
         <CI model_configuration_file>
```

2.4.2 Examples

`GEO-CI-v30 20150407T120000Z safnwc_MSGN.cfg safnwc_CI.cfm`

This command executes GEO-CI over the region `safnwc_MSGN.cfg` manually, without the presence of the TM

2.4.3 Caution and warning messages

See paragraph 4 for the list of error messages

If everything is correct then the following message is received:

`CPU time Slot YYYYMMDDTHHmmssZ end GEO-CI` : <time> secs

2.4.4 Known errors, causes and solutions

None.

2.5 CI VALIDATION

2.5.1 Validation results

Validation report [RD.1.] fully describes the validation results.

2.5.1.1 MSG case

As it was already highlighted in the previous CI version, false alarms in CI are the main issue. In this objective validation, thanks to the transformation of CI pixels into CI objects and to the focus on ideal case studies, false alarms are significantly reduced without degrading POD. However, results are highly dependent on the type of ground truth considered (median FAR varies between 0.15 and 0.65 for CI operated with SEVIRI in Rapid Scan).

The best scores are obtained by taking entire radar trajectories as GTs, indicating that the CI product is not only triggered by the initial phase of the convection, but also by more advanced stages. The median POD of 0.5 for CI operated with SEVIRI in Rapid Scan shows that there is still room for improvement to make CI diagnosis more sensitive to convection initiation phases.

This validation highlighted CI properties such as its high temporal persistence and its 20-30 minutes anticipation of the majority of radar trajectories. This work has also shown that MSG_RSS yields better scores due to his higher scan frequency.

2.5.1.2 MTG case

The validation scores for MTG are very similar to those of SEVIRI (POD around 0,6 for two situations, FAR around 0,4 for one situation and FAR around 0,5 for the other one) and the outputs are comparable. Nevertheless it shall be noted, that the current validation prepared for the v2025 validation report has been performed with very limited amount of cases of convective activity over Europe/France as well as preliminary tuning of some NWCSAF cloud products used as input by CI. See [RD.1.]for details

2.5.1.3 Other satellites (GOES-E, GOES-W, Himawari-9)

For the other satellites the analysis has been performed on a subjective basis, confirming the usefulness of the product.

2.5.2 Typical known problems and recommendation for user

- More false alarms during night-time as CMIC product is not available.
- No diagnosis in case of thin cirrus layer
- Dependency of movement fields
- CI signal may persist on the edge of mature convective systems.
- Higher FAR but higher POD with CI operated with FCI (compared to CI operated with SEVIRI). Day-2 mitigation expected

Situations with day-time isolated and unorganized convection with clear sky and without strong movement field are the best conditions for CI to operate. These situations are the ones where the CI performs best and brings the most value to users.

Example of CI behaviour in non-ideal cases can be found in chapter 3.5.2.1 of [RD.1.]

- At 17:00 UTC when some false alarms begin to appear due to the absence of CMIC filtering
- At 13:10 UTC when some CI signal appear at the edge of a well-established convective system

2.6 EXAMPLES OF VISUALISATION

Examples of CI visualisation are proposed hereafter.

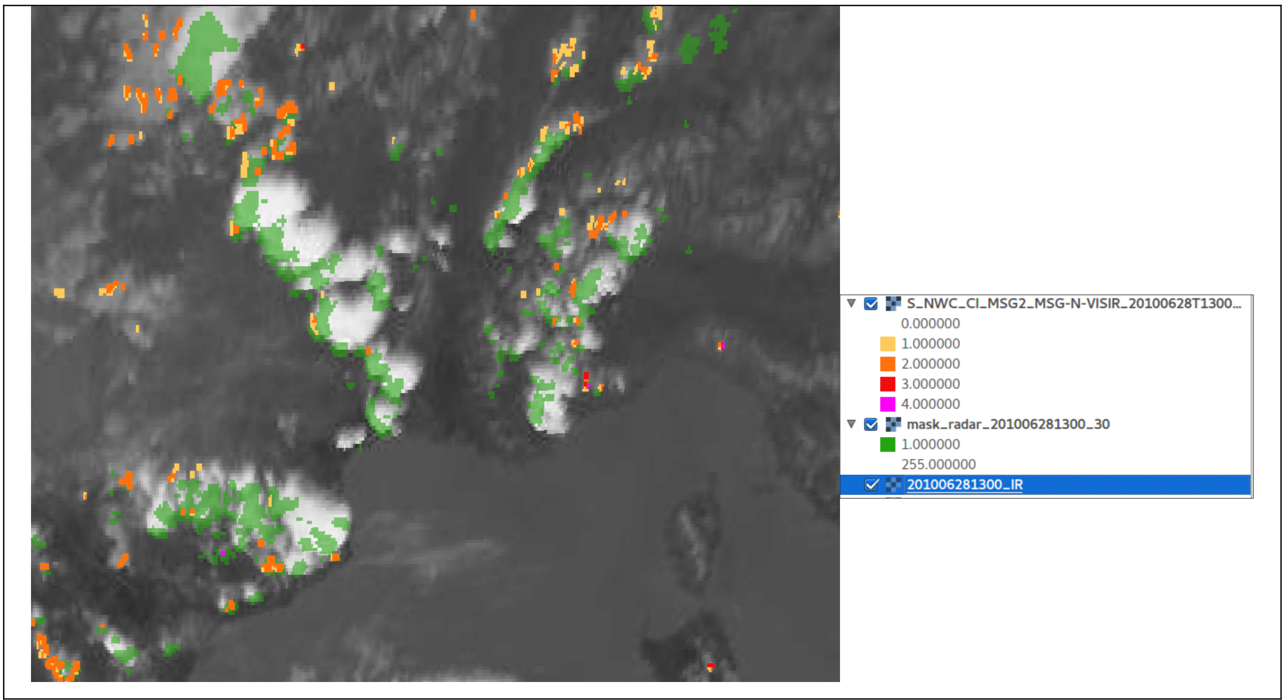


Figure 1: 28/06/2010 - 13Z IR image - accumulated Radar signal >35dBZ over [13-13h30Z] - CI prob30 container valid for [13-13h30Z]. New colour palette included in NetCdF files (bottom).

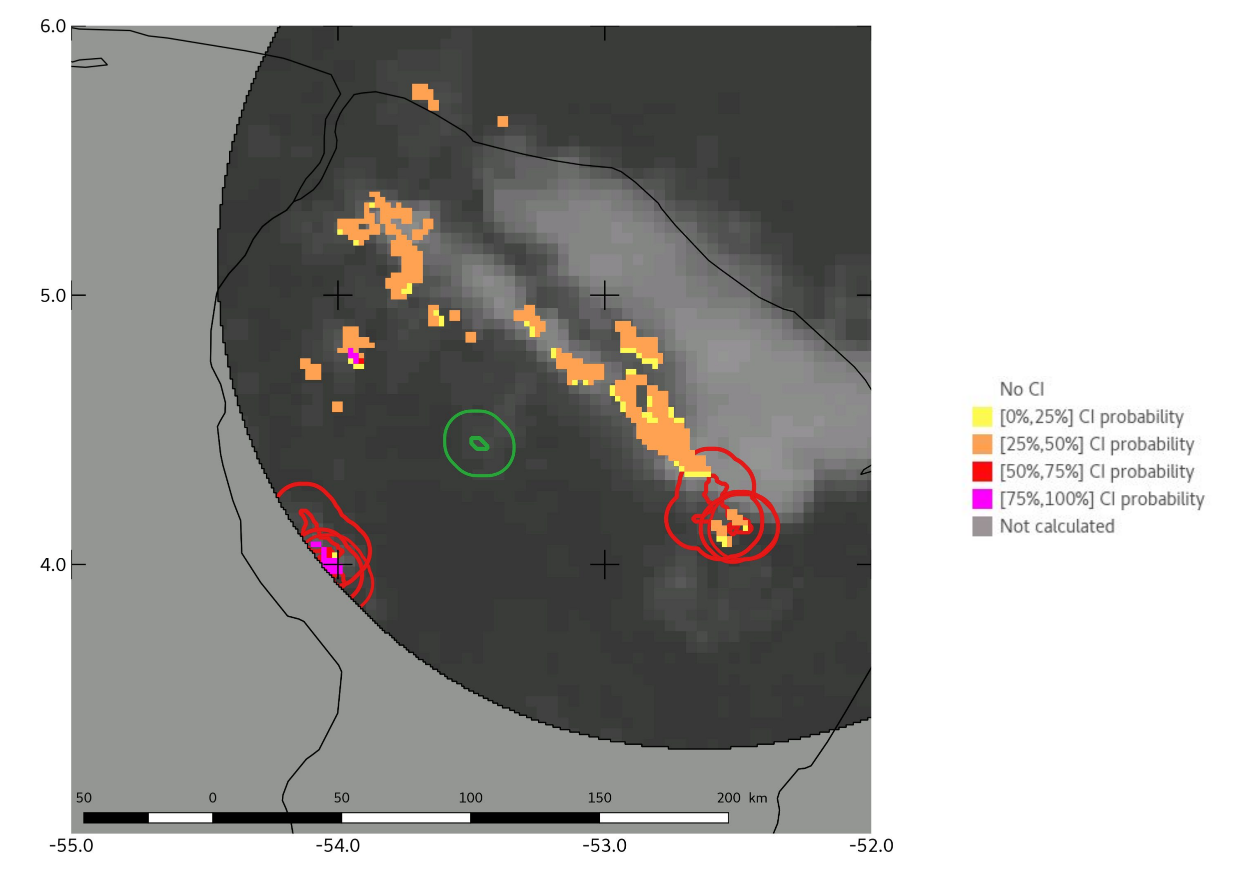


Figure 2: 2018-10-02T19:00:00Z, French Guiana. IR10.8 satellite imagery at t, CI at [t+0,t+30min] forecast production (from yellow to magenta according to the class of probability to assess the forecast capacity of CI). Radar-convective objects (Ground Truths) at t= 0 in blue contours, at [t+5;t+30 min] in green contours. Ground Truths at [t-30;t+0min[and their evolution at t+0min and t+30min in red contours to assess the signage capacity of CI.

3 RAPIDLY DEVELOPING THUNDERSTORM – CONVECTION WARNING (GEO-RDT-CW) PRODUCT

3.1 Description of the RDT-CW product

3.1.1 Goal of RDT-CW product

The RDT-CW product has been developed by Météo-France in the framework of the EUMETSAT SAF in support to Nowcasting. Using mainly geostationary satellite data, it provides information on clouds related to significant convective systems, from meso scale (200 to 2000 km) down to smaller scales (tenth of km). The objectives of RDT-CW are:

- The identification, monitoring and tracking of intense convective system clouds
- The detection of rapidly developing convective cells, where IR sensor allows for
- The forecast of the convective cells

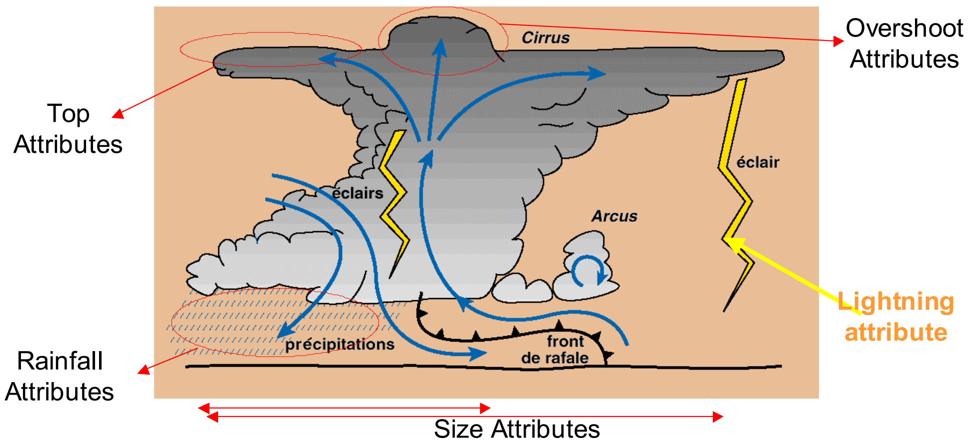


Figure 3: RDT-CW scheme

The object-oriented approach underlying the RDT-CW product allows to add value to the satellite image by characterizing convective systems with various parameters of interest for the forecaster: motion vector, cooling and expansion rate, cloud top height,…, and associated time series of these parameters. It supports easily and meaningfully downstream data fusion (surface observations, NWP fields and radar data).

Thereby, RDT-CW is a tool for forecaster but can also be used by research teams, and end-users like aeronautical users.

Finally, a NWC SAF real-time demonstration is available on the Internet, at this address: http://nwc-saf.eumetsat.int. Some training materials are available on EUMETrain Website http://eumetrain.org.

3.1.2 Description of RDT-CW process and analysis

The RDT-CW algorithm could be divided into four steps:

- The detection of cloud systems
- The tracking of cloud systems
- The discrimination of convective cloud objects
- The forecast of convective cloud objects

Detection, tracking and discrimination can be grouped together in "analysis part". The algorithm is described in ATBD

It is to note that GEO-RDT-CW discrimination step has been revised since v2018: an additional discrimination scheme labelled as "calibrated" (CAL) is based on satellite-calibrated coefficients, available for some current geostationary satellites. Previous discrimination scheme, labelled as "generic" (GEN), remains available in all cases.

3.1.3 Description of RDT-CW outputs

The default output format of RDT-CW product is NetCDF. Depending on user configuration, an intermediate optional output is possible with Trajectory ASCII output.

3.1.3.1 NetCDF output

The content of the GEO-RDT-CW output in NetCDF format is described in the Data Output Format document ([AD.9.]). A very brief summary is given below, taking into account that this mainly bulletin-like file lists a large number of variables/attributes, taking into account horizontal, vertical and temporal description of each cloud cell. But this output may also include an image part.

- The *bulletin-like part* of the product relies on several dimensions: number of cells, number of contour points for horizontal description, number of levels, slices and overshooting tops for vertical description, number of trajectory points for a temporal description.
- The *overview part* of the output lists some characteristics of cloud cell population. It may also include an additional optional *map of type and phase* of cloud cells (not the default mode). It is possible to activate the encoding of this map (user action with NCMAPINCLD argument of configuration file set to 1)
- The *cell part* details the spatial and temporal description of the cloud system
  - The *main description part* lists for each cloud system identity characteristics, date type and other characteristics (type, movement, cooling rate, severity …) which concern the whole cloud system
  - The *level and contour description part* lists for each cloud system and each "bottom" and "top" threshold level the localization parameters (contour and gravity centre), satellite characteristics, morphological characteristics and data fusion parameters (lightning, other products, etc.).
  - The *vertical surface description part* lists for each cloud system pairs of threshold brightness temperature and surface allowing vertical morphological description
  - The *historical description part* lists for each cloud system a limited set of characteristics of its recent past (maximum 12 time steps corresponding to satellite refresh rate): localization of gravity centre, satellite and morphology characteristics, movement and trends. This part makes the RDT-CW output independent of previ-

ous outputs, when users want to manage trajectory of the cloud system and main temporal characteristics. A more complete temporal description will imply to manage previous outputs.

  - The *overshooting top description part* lists all detected overshooting tops, their localization, characteristics and reference to the corresponding cloud system

- Forecast products
  - Forecast products are only bulletin-like product, without map container. Moreover, the set of variables/attributes is more restricted: only main and bottom level description.
  - There is one forecast product for each given lead range. The maximum lead range may be configurable, but cannot exceed 1h. Forecast step is also configurable, and is set by default to the satellite update rate. For example the default configuration with MSG leads for a 1-hour forecast to 5 output files produced, one for the analysis, and 4 for +15, +30, +45 and +60min lead ranges.

Note: The common attributes product_quality and product_completeness are filled as follow:

- Completeness = percentage of usable pixels compared to total number of pixels (usable means non space and available data)
- Quality = percentage of available data, processed as weighted average of available data, Weights are following
  - 50% from mandatory data (current and previous IR10.8 channel)
  - 50% from optional data
    - 25 % from NWP data
    - 10 % from LGH data
    - 15 % from other NWC SAF products (CT, CTTH, CMIC, CRRPh)

3.1.3.2 CTRAJ intermediate output

The RDT-CW may process an intermediate output, CTRAJ, in ASCII format. This file describes all cloud trajectories ended during the time slot (description of the past tracking of achieved cloud systems). The format of this file is updated with new optional additional data. This output is updated at each slot, in a dedicated, daily or monthly file depending on user's model configuration file.

Content of this file is described in [AD.9.] documentation.

3.2 IMPLEMENTATION OF RDT-CW

3.2.1 General Considerations

The implementation of the RDT-CW software follows the general implementation of components of the SAFNWC/MSG software.

Basically, the following steps are needed to proceed:

1. Create or update configuration files (system, region, and run configuration files) according to their format (see the Interface Control Document ICD/1 for the External and Internal Interfaces of the NWC/GEO).
2. Update, if necessary, the RDT-CW configuration file

3. Ensure that files for convective discrimination (coefficient matrix and matrix mask) are available in repository "$SAFNWC/import/Aux_data/RDT-CW/files_for_discri":
    a. Generic discrimination:
        i. ConvCoeffRegr and ConvCoeffRegr_mask applicable for all satellites
        ii. ConvCoeffRegr_5 and ConvCoeffRegr_5_mask for MSG Rapid Scan
    b. Calibrated discrimination

        ConvCoeffRegr.*satellitename.updaterate* and ConvCoeffRegr.*satellitename.updaterate*_mask where *satellitename* is the name of geostationary satellite that is intended to be used by the user, and *updaterate* is expressed in minutes [1]

        ConvCoeffRegr.*satellitename.updaterate.15* and ConvCoeffRegr.*satellitename.updaterate.15*_mask when channel #15 is preferred for IR window main channel, and specific tuning available (i.e. GOES-16/18/19 and HIMAWARI08/09 family satellites essentially)
4. Ensure that the satellite data is available in the directory $SAFNWC/import/Sat_data/ (SEVIRI image file in HRIT format or netcdf format for Foreign Satellite Data). To process RDT-CW in real-time, the user has to refresh this directory with the most up-to-date data.
5. Ensure that the directory $SAFNWC/import/NWP_data has been provided with latest NWP multiple GRIB data (not mandatory but recommended), and that NWP data has been remapped by the TM on the specified region (remapped NWP data available in the $SAFNWC/tmp directory). RDT-CW configuration file is used as guidance for the use and remapping of NWP data.
6. Depending on user's specifications, ensure that the lightning data file (optional input) is available in the directory $SAFNWC/import/Obs_data/Lightning. The name of this file and its content must be compliant with the Interface Control Document ICD/1 for the External and Internal Interfaces. To process RDT-CW in real-time, the user has to refresh this directory with the most up-to-date data. It is also recommended not to include unnecessary (old) lightning data in order to avoid useless processing.

Then, the processing of RDT-CW is automatically monitored by the task manager (see the Software Users Manual for the Task Manager of the SAFNWC/MSG software).

3.2.2 RDT-CW reprocessing cases

This is a particularity of the RDT-CW software to undertake a tracking of cloud cells from one image to the following. In real-time there is continuity. But in reprocessing cases, the starting point has to be clearly defined:

If user wants to focus on a specific period, he has to run RDT-CW software at least one hour before, and ideally 2 hours.

- Cloud speed estimate takes into account the speed at previous step. At the beginning, only guess field, neighbouring cells and correlation process allow to estimate speed movement. Then, overlapping technique and previous track allow improving the estimate.

[1] Note for GOES16 and HIMAWARI08: when the satellite nominal update rate, as mentioned in satellite configuration file, is different from the dataset available for the tuning, both values are mentioned for identifying discrimination matrices, even if those matrices are identical.

- Discrimination scheme needs also a recent historic to calculate trends on various depths.
- When RDT-CW software runs, it creates backup files identified for each slot, which will be used for the next step. These backup files get information from several previous steps.

Cases starting point will be defined according to the situation the user wants to study.

3.2.3 RDT-CW monitoring

End-users may define several criteria in order to monitor a RDT production chain. Classical criteria are processing time or auxiliary files availability. One additional criteria the developers would recommend is to use the number of cells over a domain and the number of convective ones'. It is the criteria used in monitoring system on NWCSAF website. One can see in figure below a normal variation of the criteria over the reference domain (northern part of MSG disk), with

- A stable number of cells,
- A normal ratio convective/non convective cells (around one in ten). Note: the ratio is lower in nature but after a NWP filter (instability indices) RDT-CW is operated on unstable areas only
- A normal increase of convection during day-time

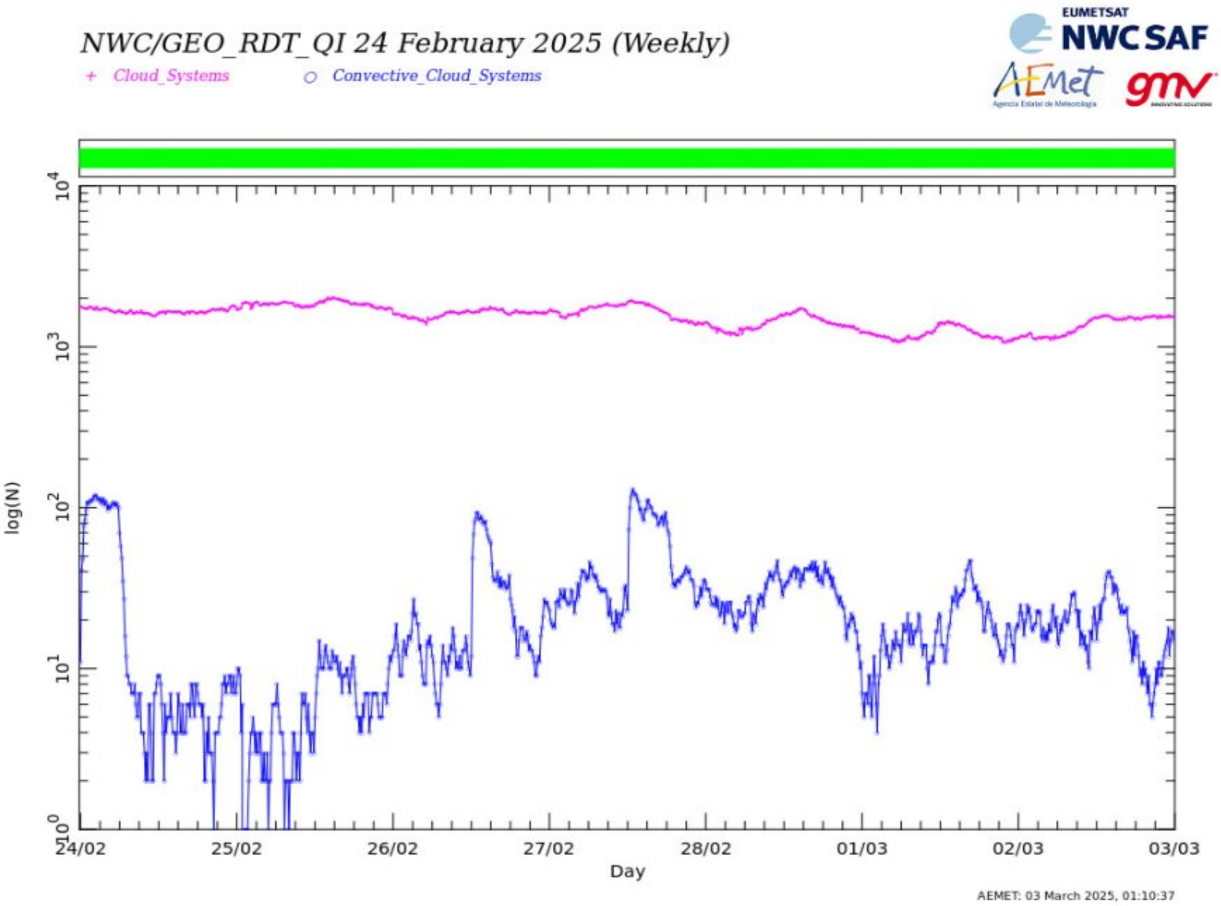


Figure 4: Weekly monitoring of RDT-CW

3.3 Inputs and configurable parameters for RDT-CW

3.3.1 List of inputs

3.3.1.1 Mandatory inputs

Three different kinds of mandatory inputs are needed by the RDT-CW software in order to proceed correctly:

3.3.1.1.1 Satellite images.

These images are provided as input to the RDT-CW software by the user. These images must be located in the relevant directory ${SAFNWC}/import/Sat_data, (for more details please refer to the Software Users Manual for the NWC/GEO software).

Mandatory channel is #16 (IR 10.8µm channel for MSG satellites) or #15 (IR 10.3µm for GOES and HIMAWARI satellites) as main channel, and has to be available also for the previous slot. Channels#(15 or 16) and WV6,2 are mandatory for discrimination. Optimal processing of RDT-CW for convective discrimination will be obtained with the use of VIS0.6, IR1.6, IR2.2, IR3.8, WV7.3, IR8.7 and IR12.0 channels.

In order to improve overshooting top detection efficiency, it is possible to take benefit from HR in visible channels, when available. For that purpose, HR_VIS argument has to be set to 1 in configuration file. Depending on satellites, HR_VIS argument set to 1 will lead to:

- For MSG satellites, HRV channel will be used additionally to normal resolution VIS0.6µm channel.
- For other satellites, VIS0.6µm will be read at high resolution. Please note that RDT discrimination scheme relies, among others, on channel reflectance difference RD=NIR16-VIS06 during daytime. In the case of HR_VIS set to 1 and NIR16 channel not available at high resolution, VIS06 will not be used at high resolution

Moreover, channels IR97 and IR134 are used for BTD computation with IR108 in the algorithm to detect overshooting tops, and they are available in CTRAJ intermediate product for further studies.

3.3.1.1.2 Configuration files.

Beside the NWC SAF general configuration files (system, run and region configuration files, see the Interface Control Document ICD/1 for the External and Internal Interfaces of the NWC/GEO), the following configuration file must be created or updated in order to process RDT-CW on a region:

RDT-CW model configuration file is composed of keywords and values which will be used by the RDT-CW software. It must be located in the $SAFNWC/config directory. The list of keywords and their significance is described into the next paragraph.

3.3.1.1.3 Auxiliary files

In order to perform a discrimination of convective systems, the RDT-CW software makes use of discrimination files located in the directory $SAFNWC/import/Aux_data/RDT-CW/files_for_discri. These files are delivered with the NWC/GEO software and must not be modified by the user. For more details on these files, please refer to the Interface Control Documents ICD/1 for the External and Internal Interfaces of the NWC/GEO.

3.3.1.2 Optional inputs

Up to seven optional inputs should be provided to RDT-CW software for an optimal product:

3.3.1.2.1 NWP data

Even if optional from a technical and functional point of view, NWP data is strongly recommended for a more efficient result. Most recent NWP data has to be located in the directory $SAFNWC/import/NWP_data. When remapped in $SAFNWC/tmp directory, NWP data is used for following purposes:

- Read or re-compute instability indexes, to synthesize a "NWP convective mask" valid for the slot date. This mask allows to exclude stable and neutral areas from discrimination process, and thus to avoid eventual false alarms.
- Read or re-compute tropopause temperature, to be provided to discrimination scheme with Lifted Index.
- Take benefit from Tropopause temperature to validate Overshooting Top detection.
- Extract 700hPa U/V wind component as guess for movement field for cold start of RDT-CW or for orphan cloud cells for which no tracking is possible.

The RDT-CW configuration file is used as guidance for the use and remapping of NWP data, by listing all desired parameters (see next section). The RDT-CW default configuration file of NWCSAF package lists parameters needed from compliant NWP data. Some parameters that are not initially available may be estimated from others: humidity at 2m (ARPEGE relative humidity or ECMWF dew point temperature), orography (ARPEGE ground height or ECMWF geopotential), tropopause characteristics (available with ARPEGE, reprocessed with ECMWF).

The NWP elements that will be taken into account by RDT-CW are

- Instability indexes: previously computed and saved as DATABUF for other products or recomputed
- Tropopause temperature diagnosis: previously computed and saved as DATABUF for other products or recomputed
- U/V wind component

RDT-CW has been designed so that the dependence of NWP is limited. It allows mainly to take advantage from better statistical models. RDT-CW performances should not be highly impacted by changing horizontal and temporal resolution of NWP fields. But of course, the lower horizontal and temporal resolutions are, the more detailed the analysis of NWP convective environment is.

3.3.1.2.2 Lightning data file

In order to characterize electrical activity of convective systems (counting of lightning flashes detected below the cloud systems) and eventually to force the discrimination of convective systems using lightning data, the RDT-CW software may use data issued from ground lightning network and/or from satellite sensor.

Lightning data files have to be created or supplied, and regularly updated in the directory $SAFNWC/import/Obs_data/Lightning/. Files content must be lightning data (see the Interface Control Documents ICD/1 for the External and Internal Interfaces of the NWC/GEO to have details on the format and the naming of this file) applicable to the processed region.

The values of the parameters "LGHDTANT" and "LGHDTPOST" (respectively "SLGHDTANT" and 'SLGHDTPOST") of the model configuration file (see next section) allow GEO-RDT-CW to extract just what is necessary from the available ground-based lightning files (respectively GEO lightning sensors' files). More precisely, for a given time slot, all the lightning data detected between the times slot-LGHDTANT and slot+LGHDTPOST are extracted from the available lightning data files.

To process RDT-CW in real-time, the user has to provide $SAFNWC/import/Obs_data/Lightning/ with the most up-to-date data. It is also recommended not to include unnecessary (old) lightning data in order to avoid useless processing.

If such data is not provided as input, the only consequences are that the discrimination of convective systems is based only on satellite characteristics of the cloud systems and that the electrical characterization of convective systems is set to missing values.

The choice to use or not lightning data as optional input to the RDT-CW software and/or as forcing data for its discrimination scheme, is controlled by the parameters "LGH" for ground lightning data or "SLGH" for data issued from satellite sensor of the model configuration file (see next section).

3.3.1.2.3 CTTH product

In the RDT-CW software, it is possible to document the cloud top pressure of cloud systems detected and tracked by the software. This is done through the integration of the CTTH product of the NWC/GEO into the RDT-CW product.

This integration is optional. In order to use the CTTH product as input to the RDT-CW software the user has to ensure that i) the CTTH product is generated on the desired region and that ii) the parameter "CTTH" of the model configuration file (see next section) is set to 1.

The integration of this CTTH into the RDT product is done as follows:

For a given detected cloud system, the corresponding cloud top pressure is defined as the Q10 value of the distribution of the CTTH pressure product over the horizontal extension of the cloud system.

3.3.1.2.4 CT product

In the RDT-CW software, it is possible to document the type of cloud systems detected and tracked by the software. This is done through the integration of the CT product of the NWC/GEO into the RDT product.

This integration is optional. It allows also using CT product as mask product for ignoring cloud-free areas in RDT-CW processing.

In order to use the CT product as input to the RDT-CW software for masking clear pixels, the user has to ensure that:

- the CT product is generated on the desired region and that:
- the parameter "CMa" or the parameter "CT" of the model configuration file (see next section) is set to 1.

In order to use the CT product as input to the RDT-CW software for additional attributes to RDT cloud cells, the user has to ensure that:

- the CT product is generated on the desired region and that

- the parameter “CT” of the model configuration file (see next section) is set to 1.

The integration of the Cloud Type class value into the RDT product is done as follows: for a given detected cloud system, the corresponding cloud type is defined as the highest proportion of processed cloud type class over the cell’s horizontal extension.

3.3.1.2.5 CMIC product.

In the RDT-CW software, it is possible to document phase (water or ice) and microphysics (Cloud Optical Thickness, Radius effective, Cloud Water Path) of cloud systems detected and tracked by the software. This is done through the integration of the CMIC product of the NWC/GEO into the RDT-CW product. Moreover, micro-physic parameters are used to estimate a high altitude ice crystal risk over the cloud cell extension

This integration is optional. In order to use the CMIC product as input to the RDT-CW software, the user has to ensure that

- The CMIC product is generated on the desired region and that
- The parameter “CMIC” of the model configuration file (see next section) is set to 1.

The integration and use of the micro-physic values into the RDT-CW product is done as follows:

- Cloud Optical Thickness (COT), Liquid Water Path (LWP) and Ice Water Path (IWP) 2D fields are used to determine a 2D temporary field of high altitude ice crystal risk
- For a given detected cloud system, the corresponding cloud phase is defined as the highest proportion of processed cloud phase value (water or ice) over the cell’s horizontal extension. The information on phase is given only if the ratio of cloud phase processed pixels is greater than 1/5th of RDT cell’s pixels, otherwise it is set to “unknown”. It is corrected to “mixed” if the highest proportion of phase value is below 60%, or if this mixed value represents the highest proportion.
- The Cloud Optical Thickness (COT) value corresponds to the highest value over cloud cell extension
- The Radius Effective (Reff) value corresponds to the highest value over cloud cell extension
- The Cloud Water Path (CWP) value corresponds to the sum of the highest value of Ice Water Path (IWP) and Liquid Water Path (LWP) over cloud cell extension
- The High altitude Icing Hazard (HIcgHzd) value corresponds to the highest value (0 or 1) of Ice Crystal risk 2D field over cloud cell extension

3.3.1.2.6 CRRPh product.

In the RDT-CW software, it is possible to document a rain rate of cloud systems detected and tracked by the software. This is done through the integration of the CRRPh product of the NWC/GEO into the RDT product. This integration is optional.

In order to use the CRRPh product as input to the RDT-CW software for evaluating a maximum rain rate attribute, the user has to ensure that

- the CRRPh product is generated on the desired region and that
- the parameter “CRRPh” of the model configuration file (see next section) is set to a value equal or greater to 1.

The integration of the convective rain rate value into the RDT product is done as follows: for a given detected cloud system, the corresponding maximum convective rain rate is defined as the 99th percentile of processed rain rate intensity over the cell's horizontal extension.

The convective rain rate is also considered for qualifying RDT cells as "significant", independently of RDT-CW convective discrimination result. The default threshold for that purpose is 30mm/h. It can be customized through parameter "CRRPh" of the model configuration file.

3.3.1.2.7 HRW product

In the RDT-CW software, it is possible to take into account HRW Atmospheric Motion Vectors to process, with U/V NWP winds, a guess for movement field.

This integration is optional. In order to use the HRW product as input to the RDT-CW software for improving the cloud cell motion estimation, the user has to ensure that:

- The HRW product is generated on the desired region and that
- The parameter "HRW" of the model configuration file (see next section) is set to 1.

The use of HRW into the RDT software is done as follows:

- Predictor winds available for the current slot are read in temporary directory of $SAFNWC
- Those observations are remapped with a defined tolerance onto region definition to fill a movement field
- This movement field is completed from U/V NWP winds read from low-mid NWP levels, where no HRW observations are available

Thus, a guess movement field is made available for cloud cell tracking, which allows a better initiation of cloud cell movement.

3.3.2 Model Configuration File and configurable parameters

The RDT-CW model configuration file, placed in the $SAFNWC/config directory, contains flags and values required for the processing. The file contains the following information, among which user's configurable parameters are highlighted:

Keyword	*Description*	*Type*	*Default Value(s)*
PGE_ID	Identifier of the PGE	Chain of characters	RDT-CW
SEV_BANDS	SEVIRI channels to be used	Chain of characters	VIS06 WV62 WV73 IR87 IR97 IR108* IR120 IR134 *IR103 for GOES and HIMAWARI satellites)
NWP_PARAMxx(*)	U component of wind at various pressure levels	Chain of characters	NWP_UW 1 BLI
NWP_PARAMxx(*)	V component of wind at various pressure levels	Chain of characters	NWP_VW 1 BLI
NWP_PARAM	Temperature of Tropopause	Chain of characters	NWP_TT 1 BLI
NWP_PARAM	Pressure of Tropopause	Chain of characters	NWP_TP 1 BLI
NWP_PARAM	Lifted index	Chain of characters	NWP_LI 1 BLI
NWP_PARAM	K index	Chain of characters	NWP_KI 1 BLI

Keyword	Description	Type	Default Value(s)
NWP_PARAM	Showalter index	Chain of characters	NWP_SHW 1 BLI
INT_PRODUCT	Enables/disables the generation of CTRAJ intermediate product	Chain of characters	YES
TRAJ	Selection of the kind of information to be included in CTRAJ product	Chain of characters	TISXOLH
PGE arguments			
TCOLD	cold temperature threshold when multiple thresholding, deg Celsius	float	-75.
TWARM	warm temperature threshold when multiple thresholding deg Celsius	float	5.
DELTATEMPE	temperature step between Tcold and Twarm, deg Celsius	float	1.
DELTATTOUR	minimum gap between Base and top temperatures to define a cloud tower to be taken into account	float	6.
SMIN	Minimum detection area, km2	float	60. (200. recommended for higher satellite nominal resolution)
SMAX	Maximum detection area, km2	float	400000.
NWPMVTLVL	U/V NWP Pressure level to use - hPa	integer	700
Optional inputs			
CT	Flag for using (1) or not (0) CT	integer	1 (yes)
CTTH	Flag for using (1) or not (0) CTTH	integer	1 (yes)
CMIC	Flag for using (1) or not (0) CMIC	integer	1 (yes)
CRRPh	value for using (≥1) or not (0) CRRPh when >1, value is used for labelling significant cloud cells (default value=30mm/h)	integer	1 (yes)
HRW	Flag for using (1) or not (0) HRW	integer	1 (yes)
LGH	Flag or number for using (-1 or number≥1) or not (0) lightning data -1: use without forcing discrimination result N: use with forcing discrimination result from Nth impact	integer	1
LGHDTANT	time step (sec) before image date for associating lightning flashes	integer	900 (to be adapted depending on satellite update rate and user needs)
LGHDTPOST	time step (sec) after image date for associating lightning flashes	integer	300
LGHTLR	maximum distance (nb. sat pixel) between cell and flash to associate both	integer	3
LGHPROXI	Maximum value(km) to compute distance between flash and cloud cell, and to try pairing with including cell	integer	50
SLGH	Flag or number for using (-1 or number≥1) or not (0) lightning flashes -1: use without forcing discrimination result N: use with forcing discrimination result from Nth impact	integer	0 or 1 (MTG-LI or GOES-GLM cases)
SLGHDTANT	time step (sec) before image date for associating lightning flashes from GEO lightning sensors	integer	0 (to be adapted depending on satellite update rate and user needs)
SLGHDTPOST	time step (sec) after image date for associating lightning flashes from GEO lightning sensors	integer	600
SLGHPROXI	Maximum value(km) to compute distance between flash and cloud cell, and to try pairing with including cell	integer	50
SLGHTLR	maximum distance (nb. sat pixel) between cell and flash to associate both	integer	3
HR_VIS	Flag for activating (1) or not (0) the management of VIS HR channels when available	integer	0
User options			
CANAL_UTIL	channel number for main IR window to use (detection, tracking and discrimination)	integer	16 (IR108 default) 15 (IR103 for GOES and HIMAWARI satellites)

Keyword	*Description*	*Type*	*Default Value(s)*
FCST	*Maximum lead range for advected products- 0 (no advection), up to 60 (minutes)*	*integer*	*60 (to be adapted depending on satellite update rate and user needs)*
FCSTEP	*lead range step in minutes*	*integer*	*15 (to be adapted depending on satellite update rate and user needs)*
PARALLAX	*Flag for activating (1) or not (0) parallax correction in RDT-CW product*	*integer*	*1*
SMOOTHPTS (**)	*Flag for smoothing (1) or not (0) advected contours*	*integer*	*0*
DILAT (**)	*Flag for inflating/contracting (1) or not (0) advected contours vs expansion rate and lead range*	*integer*	*0*
NCMAPINCLD	*Flag for encoding (1) or not (0) image map into analysed RDT-CW product*	*integer*	*0 (default)*
BTLIMIT	*upper limit of threshold temperature (°C) to define "Base of Tower" (BT) level for cloud cells*	*float*	*-70*
OMP_NBTHREAD	*when using openmp for parallelization mode, number of threads to be used*	*integer*	*3*
LICONV	*convective threshold*	*integer*	*-3 (default)*
LINOCONV	*non convective threshold*	*integer*	*0 (default)*
KICONV	*convective threshold*	*integer*	*30 (default)*
KINOCONV	*non convective threshold*	*integer*	*20 (default)*
SHWCONV	*convective threshold*	*integer*	*-3 (default)*
SHWNOCONV	*non convective threshold*	*integer*	*+3 (default)*
DBG	*Flag for activating (1) or not (0) debug mode*	*integer*	*0*
OUTPUT_CELLS	*Type of cells to describe and output in the NetCDF file*	*integer*	*0 (all cells) 1 (default, significant cells) 2 (convective cells) 3 (convective and electric cells) 4 (electric cells) 5 (convective cells with significant CRRPh values) 6 (cells with significant CRR values) 7 (cells with detected overshooting tops)*

Table 5: default RDT-CW Model Configuration File description

(*) Temperature and relative humidity are requested to be remapped for each pressure level of AV_PRESSURE_LEVELS covering ECMWF and ARPEGE levels.

(**) Smoothing and dilatation options for advected cloud cells only - To be used preferentially in case study mode

3.4 RDT-CW OPERATIONS

3.4.1 Procedure

3.4.1.1 Input data files needed for RDT-CW product generation

- Mandatory input data like satellite data configuration files and auxiliary files as listed in paragraph 3.3.1.1

- Optional input data (NWP, lightning data, other NWCSAF products) as listed in paragraph 3.3.1.2
- PGE configuration file as detailed in paragraph 3.3.2

3.4.1.2 Output files obtained from GEO-RDT-CW product generation

- GEO-RDT-CW analyzed product and, depending on user's configuration (FCST and FCSTEP arguments in configuration file), forecast products
  `S_NWC_RDT-CW_satellite_region-VISIR_YYYYMMDDThhmmssZ.nc`
  `S_NWC_RDT-CW_satellite_region-VISIR_YYYYMMDDThhmmssZ_0EE.nc`
  `where EE is the forecast range, in minutes (recommended to be limited to 60)`

  for example with default configuration for MSG nominal rate
  `S_NWC_RDT-CW_MSGi_region-VISIR_YYYYMMDDThhmmssZ_015.nc`
  `S_NWC_RDT-CW_MSGi_region-VISIR_YYYYMMDDThhmmssZ_030.nc`
  `S_NWC_RDT-CW_MSGi_region-VISIR_YYYYMMDDThhmmssZ_045.nc`
  `S_NWC_RDT-CW_MSGi_region-VISIR_YYYYMMDDThhmmssZ_060.nc`
  in the directory `$SAFNWC/export/RDT`
- Depending on user's configuration, intermediate products:
  `S_NWC_CTRAJ_MSGi_region_YYYY-MM-DDThh:mm:ssZ`
  or `S_NWC_CTRAJ_MSGi_region_YYYY-MM-DD`
  or `S_NWC_CTRAJ_MSGi_region_YYYY-MM`
  `by default in` in the directory `$SAFNWC/tmp`
- Backup files
  `GEO-RDT-CW_regionname_Carte_sauvegarde_YYYYMMDDHHmm` and
  `GEO-RDT-CW_regionname_sauvegarde_YYYYMMDDHHmm`
  in the directory `$SAFNWC/tmp`

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

```
GEO-RDT-CW-v60 <time_of_slot> <region_configuration_file>
             <RDT-CW model_configuration_file>
```

3.4.2 Examples

```
GEO-RDT-CW-v60 20150407T120000Z safnwc_MSGN.cfg safnwc_RDT-CW.cfm
```

This command executes GEO-RDT-CW over the region safnwc_MSGN.cfg manually, without the presence of the TM.

3.4.3 Caution and warning messages

See paragraph 4 for the list of error messages

If everything is correct then the following message is received:

```
CPU time Slot YYYYMMDDTHHmmssZ end GEO-RDT-CW : <time> secs
```

3.4.4 Known errors, causes and solutions

None

3.5 RDT-CW Validation

3.5.1 Summary of validation results

Validation report RD.1 fully describes the validation results. Objective and subjective validations have been undertaken for several satellites. Results presented in validation report have to be considered regarding the various geographical regions and various lightning network detection efficiencies.

3.5.1.1 MSG case

Previous validation results for v2016 for MSG are still applicable. RDT-CW v2016 subjective validation are detailed in v2016 validation reports. Considering a moderate electrical activity, the overall probability of detection is 74%, and reaches 77% on convective periods over Europe using Euclid lightning data. The start of a convective period is defined on the first lightning occurrence on the convective section. When considering convective cells at single moments, the probability of detection is smaller (65%) but still satisfying with about 20% of false alarms. Nevertheless, 25% of good detections are detected before the first lightning occurrence, and more than 80% within following 30 minutes.

It has been analysed that RDT-CW provides a convective classification stable in time. The discrimination algorithm is focused on convective periods, is managed through a controlled heritage process to guarantee this stability. The convective systems are declassified in time during decaying phase, avoiding the tracking of uninteresting objects. Thus, the RDT provides a right depicting of convective phenomena, from triggering phase to mature stage. The RDT object allows to point out the interest area of a satellite image. The subjective and objective evaluations exhibit that convection can be sometimes diagnosed before lightning activity occurs.

3.5.1.2 MTG case

MTG and MSG output are similar.

Over the European domain when LI data are used for a situation in September 2024, for the criteria "is the trajectory convective or not RDT operated with MTG/FCI exhibits POD of 86% (76% for MSG3) and a FAR of 47% (14% for MSG3). For the 20250421 case, RDT is operated with LI data providing an excellent detection regarding the validation method: the use of LI helps now to mitigate the non-detection for electric systems. FAR for RDT operated with MTG/FCI are correct but remain the highest: 40% for the full disk (against 27 % for the RDT operated with MSG/SEVIRI data)

POD scores are much better for the RDT operated with MTG/FCI, but FAR remains an issue to solve in future with specific fine-tuning.

Detection of warm systems is kept.

A under-detection of overshooting top has also been noted and discussed in [RD.1]

3.5.1.3 Other satellites (GOES-E, GOES-W, Himawari-9)

Lightning is required for RDT-CW validation and the upcoming of GOES 19 was late regarding the v2025 delivery.

Concerning GOES16 with GLM, the scores were obtained taking as a reference the period from 20200901 to 2020929 (13 cases). The POD ranges from 59,3 to 83,4% (median 73,0) and the FAR ranges from 16,6 to 56,3% (median 40,7%) when the moderate ground truth is considered.

For the other satellites (GOES-18, Himawari-9) the analysis has been performed on a subjective basis, confirming the usefulness of the product.

3.5.2 Known problems and recommendation for user

- The tunings have been carried out on a limited set of days for each satellite, with a light to moderate electrical activity with the best dataset available.
- The discrimination scores during winter period are weaker.
- Warm systems are more difficult to detect.
- Regarding MTG the v2025 is Day-1 approach without specific tuning, explaining some false alarms. Day-2 mitigation expected
- Low detection capability of OT for RDT operated with MTG/FCI. Day-2 mitigation expected
- Forecast don’t take into account orographic effects, no creation or dissipation of cells
- Active areas sometimes difficult to isolate
- Tracking issues: anvil vs. active part

3.6 Example of RDT-CW visualisation

The final product is numerical data which depict infrared characteristics (spatial and time) and move information associated to RDT cells. Thus, operating the RDT needs a specific visualisation tool.

Some specification about RDT visualisation for a tool developed by AEMET has been provided in a scientific report [RD.5.] and can be adapted for some end-users.

The study case below gives an example of a simple RDT operating tool from bulletin-like information only. More elaborate systems with downstream data fusion could take advantage of object approach like these of RDT product.

3.6.1 Example of simple visualization

This visualization is a simple display of RDT-CW on a web page. The background image is satellite infrared data. The different characteristics of convective object are displayed through three steps of visualization:

- The first step corresponds to the superposition of graphical attributes on the corresponding infrared image. These graphical attributes are:
  - **At least one coloured contour** which defines cloud system edges. The **colour** of this contour is related to the phase of life of the system which is highly linked to its category (developing, transition, mature) and also to its activity (convective, cooling, expansion …). A second included contour, with same characteristics, corresponds to a “top of tower” level which has enough different extension than main level.

    - **The thickness** of this contour is related to the temperature tendency of systems: the greater the cooling, the thicker the contour.
    - **The style** of the contour (dashed/plain) indicates whether the system is electrically active or not: dashed when no lightning paired or available, plain for lightning occurrence. If –lightning argument of RDT-CW configuration file is >0, the electrical information is used to force the convective diagnostic. When –lightning argument is <0, flashes are paired without impact on convective diagnostic of the cell (visualization tool has to take into account this possibility of "non-detection" of electric cells).
    - **A yellow line** shows the trajectory of the system (all previous locations of the centre of gravity of the system in past images).
    - **A black arrow** shows the expected move of the system for the next half hour.
    - **One (several) green diamond(s)** points the eventual overshoot(s) associated to the system.
- The second step allows to access numerical values of some characteristics of the RDT-CW object. These values are displayed into an interactive popup window. Its visualisation is activated by moving the mouse inside the contour of the corresponding cloud system.
- The third step allows visualizing historical time series of some characteristics. The visualisation of these series, as it was mentioned previously, is interactive and is activated by simple-click inside the contour of the corresponding RDT-CW object:
    - Number of positive and negative lightning impacts registered below the convective system.
    - Area of the system at various brightness temperature thresholds.
    - Threshold temperature and minimum temperature of cell.

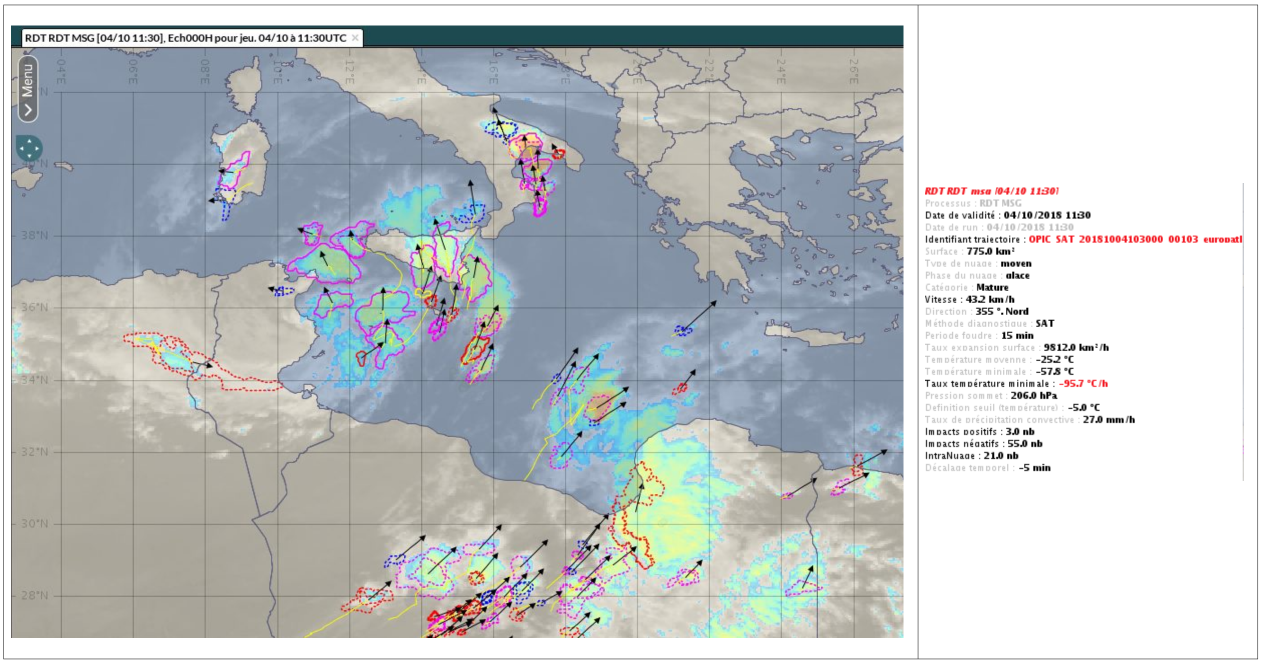


Figure 5: Example of product visualisation, RDT cells on the left, gauge for one cell on the right (pop-up window)

3.6.2 Examples of visualisation of forecast products

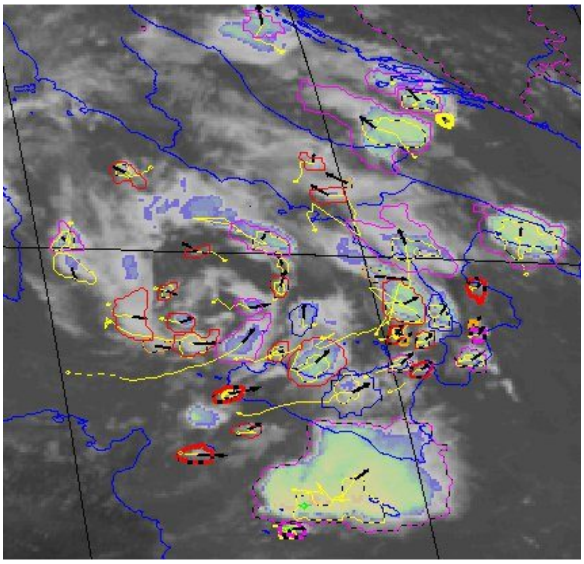
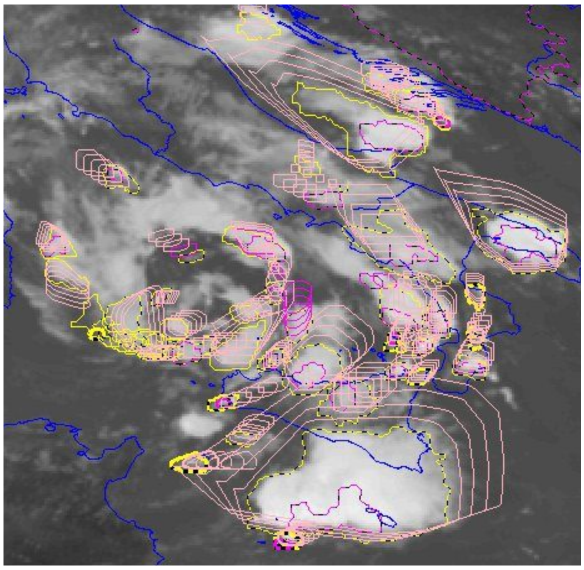
	
Analysed RDT-CW cells with motion vectors	RDT-CW +15, +30, +45 and +60 smoothed and dilated forecast cells

Figure 6: 11th August 2015 09h00 UTC slot –illustration of RDT advection scheme

The advection scheme takes benefit from an improving quality of cell’s motion. It is illustrated in Figure 6, where smoothing and dilatation options have been activated.

3.6.3 Other examples of visualisation

Météo-France has developed a new visualisation tool, using map web services that provide very light files. Figure 7 exhibits large convective cells over France, an overshooting top is described.

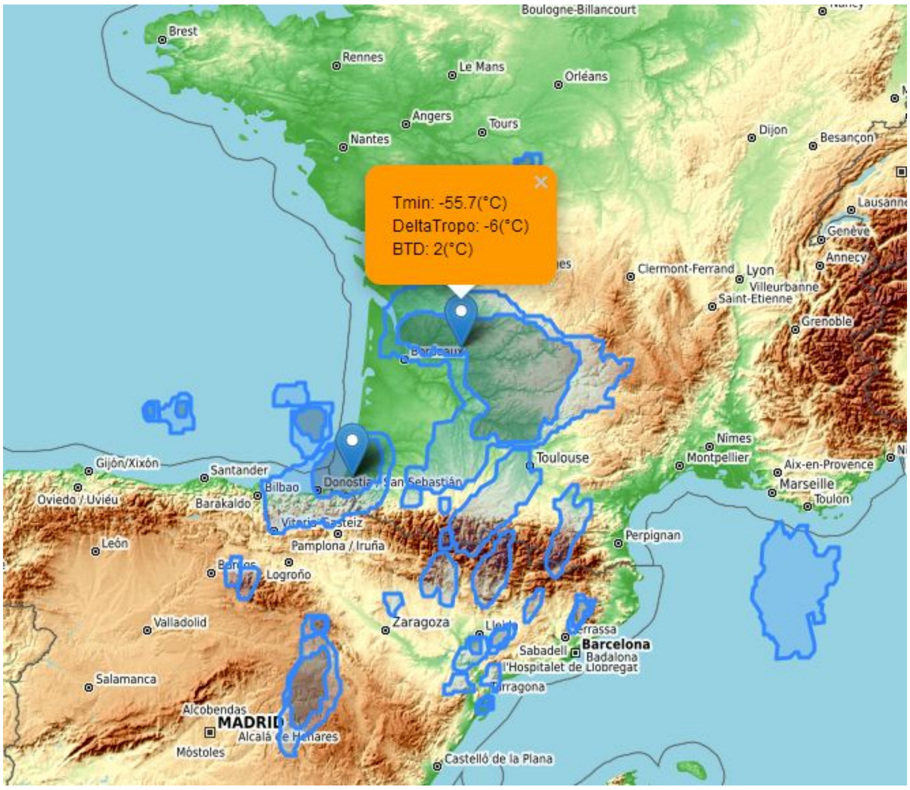


Figure 7: RDT visualisation example with OT depicted near Bordeaux

RDT is also provided to Météo-France forecasters through Synopsis system with various possibility of superposition with other data (Figure hereafter).

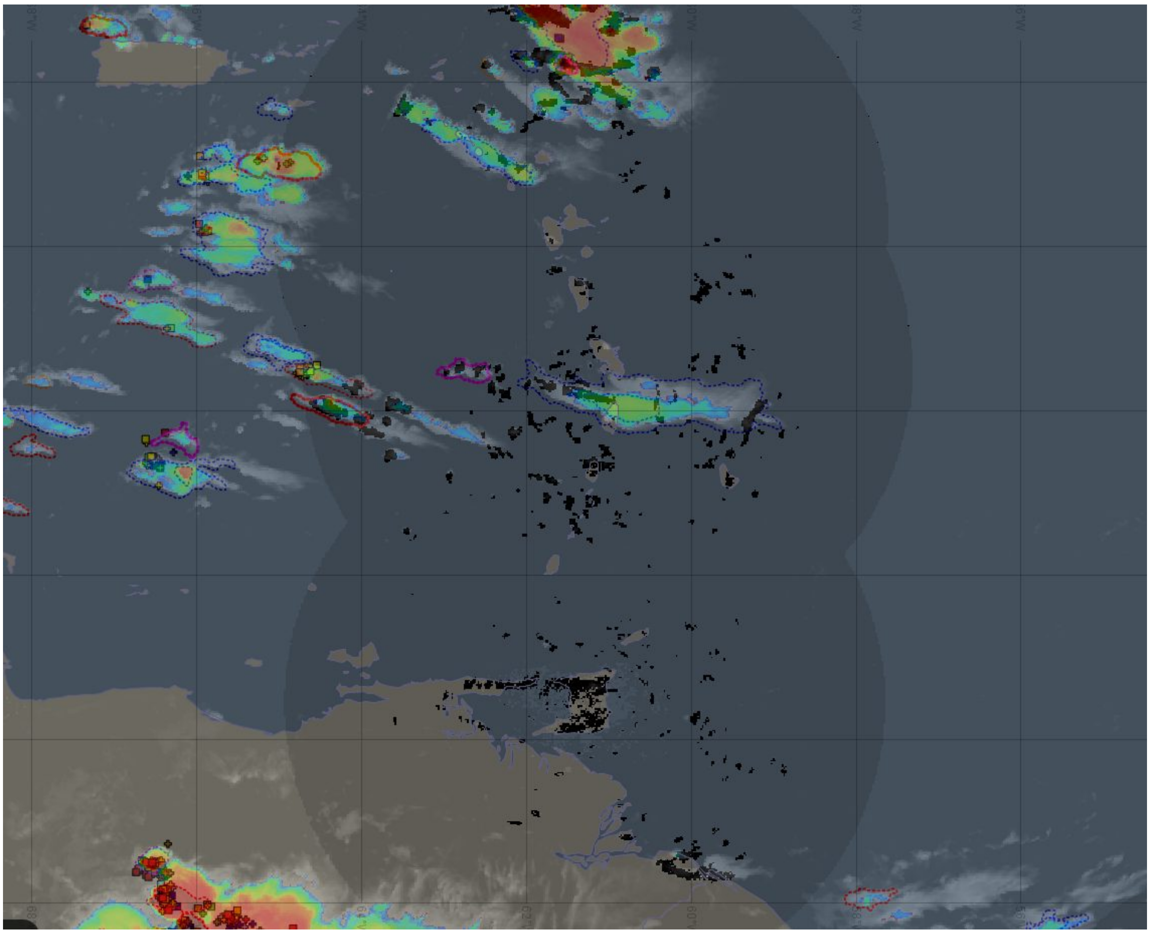


Figure 8: Illustration of several information superimposed on Synopsis system. RDT (operated with GOES data) outlines (blue, red magenta) over the Caribbean. French radar data reflectivities (black points and radar coverage in grey), GOES-16 enhanced IR image (convection palette: colder temperature in red), GLD360 lightning network (circles in green orange and red)

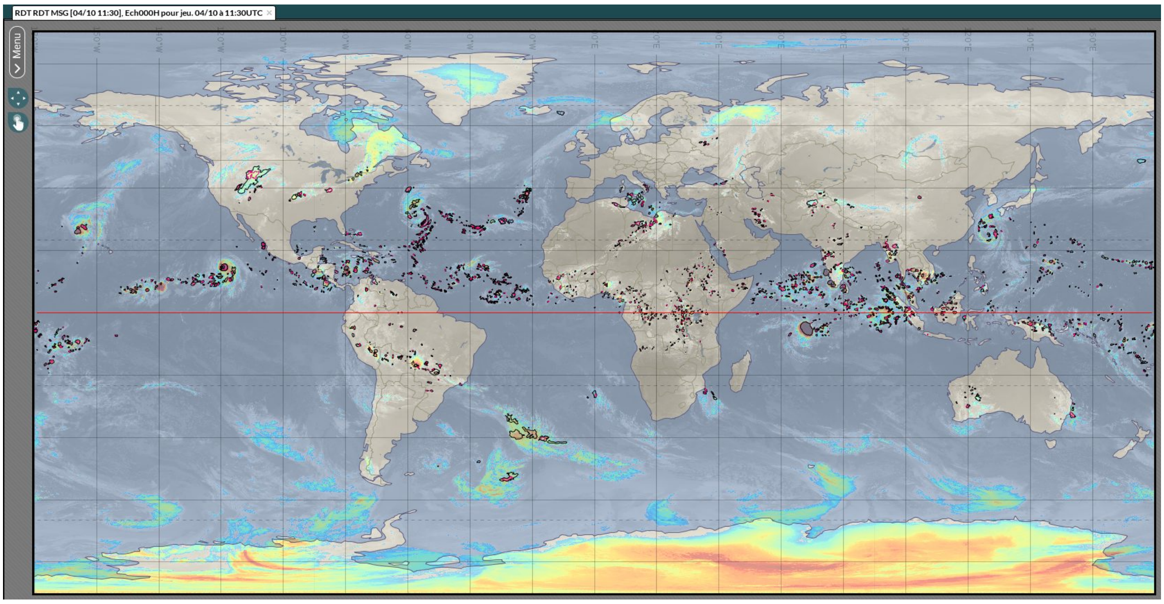
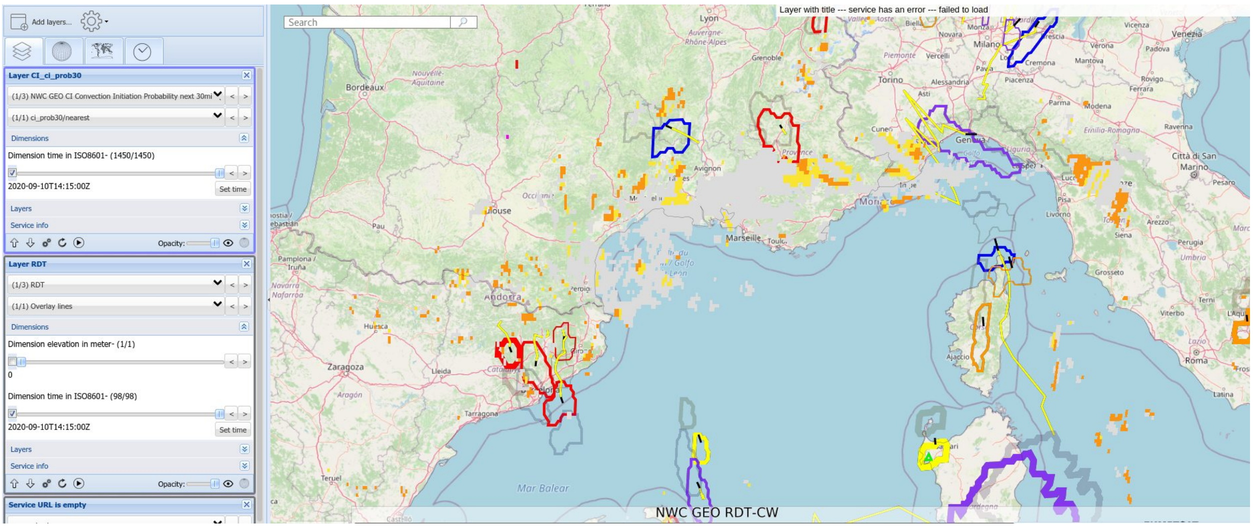


Figure 9: RDT-CW (operated with 5 GEO satellites) outlines (black) with Synopsis. Superposition with mosaic of IR satellite images

There are other tools used or developed for NWC SAF products visualisation, for example

- AEMET has developed a real time visualisation tool, on the website http://nwc-saf.eumetsat.int
- ADAGUC functionalities was also developed by AEMET and has been used for users Test-bed



- For ESSL TestBed, a html-based data display has been developed to display NWCSAF products.

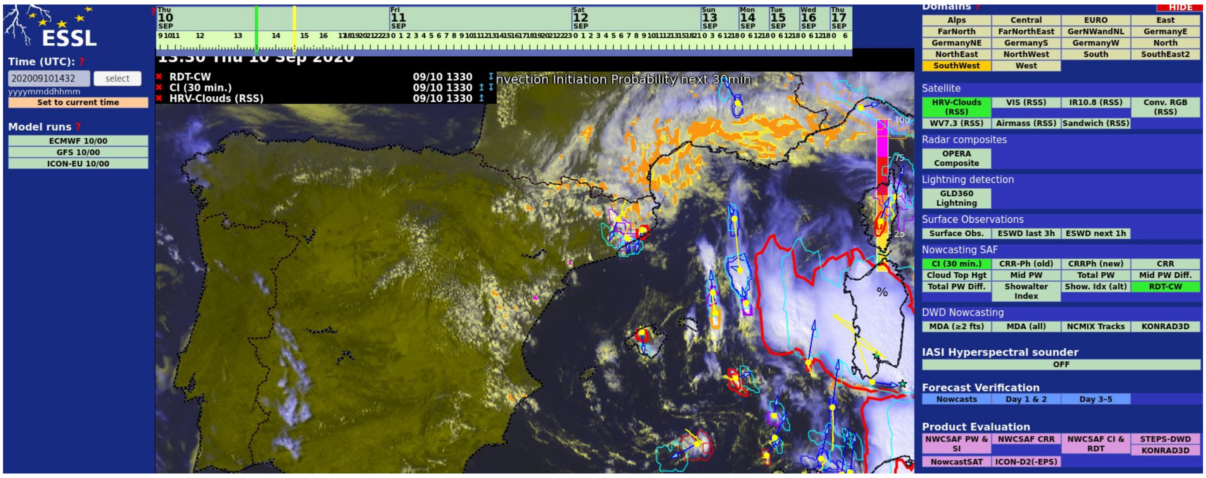


Figure 10: ESSL visualization

4 WARNING AND ERROR MESSAGES FOR RDT AND/OR CI

Code (E/W)	Message including following strings	Comment	Recovery action
E	“Initialisation error” “Error setting the region”	Error during initialization process when launching PGE	Check arguments and configuration file for launching PGE
E	“read Error in date format “, “Slot already processed - Task Stopped” “dt ERROR In analyse_recouvrement” , “Pb processing time gap”	Slot time when launching PGE may be wrong.	Check the slot time input when launching PGE. Check or remove backup files in `$SAFNWC/tmp` directory for a cold start, or launch for a next slot
E	“NO_IMAGE_TO_PROCESS” “IMAGE NULL” “read Error Init reading of Satellite Data”	Missing Satellite data	Check `$SAFNWC/import/Sat_data` directory or slot time input
E	“MALLOC_ERROR” “allocation error” “Unable to allocate“, “unable to initialize” “Error allocating“ “PB alloc” “not allocated” “ERR NwcMemMalloc” “unable to initialize”	Problem of memory allocation	Check memory
E	“Error computing lat/lon data”	Bad return status of NwcNavGetLatLon routine	Check memory. Contact Helpdesk
E	“PB NwcProdGetName not OK”	Bad return status of NwcProdGetName routine	Check memory. Contact Helpdesk
E	“HRW_ERROR_*”	Read problem of HRW predecessor winds	Check presence of corresponding files in `$SAFNWC/tmp` directory
E/W	“Unable to open” , “unable to create”, “not found” , “PB List2MapObsHrw : TABpixhrw NULL” , “FILE_NOT_FOUND” , “ … read …” , “error reading”, “FILE_ERROR” , “pb filin” ,“OPEN_ERROR”, “FILE_ERROR”, “READ_* error”, “write ERROR”, “pb access filin” , “PB read …”, “ERROR * Lightning”	Problem to open an existing file or to create a new file, or to read an existing file	Check permission and disk space on the directory. Check presence of the requested file, of the relevant directory. 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.
E	“INITPARAMNWP” , “Unable to read the number of available NWP levels”	Pb in initialization of NWP data	Check compliance between nwp_conf_file , NWP parameter in cfm file and NWP data
E	“NWP_* PB for level”	Missing required data	Check availability of corresponding data/parameter
E	“PB with BTD of ”	Problem for creating memory for image analysis	Check memory. Contact developers on the helpdesk
E	“dimensions map and imageBTD differ”, “imTrendBTD or imageBTD NULL”	Incoherency in image analysis and/or difference	Contact developers on the helpdesk.
E	“PB in BTDimageTrend”	Error when computing trends of channel differences	Contact developers on the helpdesk.
E	“PB in CIpixofiParam”	Error when computing pixel parameters for CI	Contact developers on the helpdesk.
E	“ERROR in Seuillage_MultiT”	Bad return status of thresholding routine	Check other error messages. Contact developers on the helpdesk
E	« analyse_recouvrement » « In calcul_coupure_s »	Incoherency in recovery and spatial analysis	Should not happen. Contact developers on the helpdesk.
E	“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.

Code (E/ W)	Message including following strings	Comment	Recovery action
E	"RDT interrupted after suit_cellules"	Bad return status of tracking routine	Check other error messages and availability of data in `$SAFNWC/tmp directory`. Contact developers on the helpdesk
E	"STOP AdvectionCell NULL target dat " "Error in AdvectionScheme()"	Bad return status of advection routine	Check other error messages. Contact developers on the helpdesk
E	"Error in *_WriteProduct()", "Error initiating * product for writing" , "Error writing * container" , "Error finalizing the product"	Bad return status of writing routines	Check other error messages linked to output writing, check PRODIO configuration file. If needed, copy them from delivered SW. Eventually contact developers on the helpdesk
E	"PB READING GENERIC DISCRIMINATION_FILE", "DISCRIMINATION NOT POSSIBLE", "INVALID_DISCRIMINATION_DIRECTORY", "DISCRIMINATION_PROBLEM ReadConvCoeffRegr"	Missing or corrupted coefficient matrix files or directory for discrimination	Check installation content from delivered SW
W	"cold start"	Run without backup files	
W	"PB Reading previous image" "imAnt NULL"	Previous image missing	Eventually check datas
W	"No HRW obs read"	No available HRW data despite option in cfm file	Check configuration file and/or HRW processing
W	"NWPGuide non successful" "PB NWP_*"	No available NWP data or parameter despite option in cfm file	Check configuration files and/or NWP data
W	"COHERENCE Pb date of image", "Pb restoring datas", "saved and current regions are not the same" , "NO_SAVES_FILE" , "NO_SAVED_IMAGE" , "WRONG_DATAS_SAVE_FILE"	Pb with backup files. Switch to cold start	If necessary stop and re initialize process
W	"imTrendBTD not available"	trend images not available (missing movement field).	
W	"RESTORE_PROBLEM speed "	Incoherence of read parameters	Eventually re initialize process from cold start
W	"MAX_NUM_CELL_TOO_LOW"	Max number of cell exceeded, not taken into account	Eventually reduce region size and/or thresholding parameters and/or cell area ranges
W	"PB pixel size coord"	Edge pixel => default nominal pixel size	
W	"calcul …." "…incalculable…"	Processing parameters not effective => set to missing	
W	"recupere_surfT..."	Missing information for vertical description	
W	" … no Mvt field", "no external input"	Missing data for processing mvt field	
W	"TOO_MANY_IMAGES_MISSING"	Missing images	Check data flow input
W	"Error computing …"	Bad return status of NwcNavGetSatAngles or NwcNavGetSunAngles routine	
W	"PB enleve_les_cellules_incluantes »		
W	"PB in Parallax correction"	Bad return status of ParallaxCorrection routine – option desactivated	
W	"PB analyse_recouvrement" "calcul_poids_aval problem", "Pb Calcul_coupures_s", "COHERENCE_PROBLEM "	problem in group cell recovery	Eventually Contact developers on the helpdesk.
W	"PB READING CALIBRATED DISCRIMINATION_FILE"	Discrimination not calibrated for this satellite	Automatic switch towards generic discrimination scheme. Check installation

Code (E/ W)	Message including following strings	Comment	Recovery action
W	"…predictor … missing …"	Data discontinuity allowing processing discriminant parameters	Check data input
W	"PB write NetCDF"	Bad return status of generic writing routine	Check PRODIO configuration file , check output product