The EUMETSAT Network of Satellite Application Facilities

NWC SAF
Support to Nowcasting and Very Short Range Forecasting

User Manual for the Convection Product Processors of the NWC/GEO

NWC/CDOP3/GEO/MF-PI/SCI/UM/Convection, Issue 1, Rev. 0

21 January 2019

Applicable to
GEO-CI v2.0 (NWC-053)
GEO-RDT-CW v5.0 (NWC-056)

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DOCUMENT CHANGE RECORD

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1.1	*16th October 2016*	Applicable to v2016
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1.0	*21st January 2019*	Final version, applicable to v2018

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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://www.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 ([AD.11.]).

The validation of the algorithms used to extract the GEO Convection Products is reported in the validation report for Convection products ([RD.2.]).

Instructions to install, configure and execute the SAFNWC/GEO software in order to extract the GEO Convection Products are detailed in the software user manual ([RD.3.]).

The interface control documents ([AD.6.]) (for the Internal and External Interfaces of the SAFNWC/GEO) and ([AD.7.]) (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 v2.0 (Product Id NWC-053) from the GEO-RDT-CW v5.0 (Product Id NWC-056) implemented in the release 2018 of the NWC/GEO software package.

1.4 IMPROVEMENT FROM PREVIOUS VERSION

The main changes implemented in GEO-CI v2018 cover the following aspects:

- Use of CMIC and Cloud type (taking into account VSA recommendation ([RD.4.]) for the identification of areas of interest.

- New tuning, including a mode for day-time and one for night-time.
- Tracking improvement
- Forecast horizon extension
- Parallelization capabilities
- Increased validation effort, especially work with Leibniz Institute

The main changes implemented in GEO-RDT-CW v2018 concern:

- Additional discrimination scheme with different set of predictors, generic depth ranges adapted to all satellite update rates, day/night calibration with use of VIS and NIR channels, calibration with Himawari-8, GOES16, MSG4.
- Use of new channels for convective discrimination (day mode 1.6 µm, 2.2 µm, 3.8 µm)
- Lightning jump diagnosis inside each RDT cell
- Additional Lightning pairing rules
- Use of CMIC
- Improved declassification rules for mature systems
- Limitation of contour level for mature systems thanks to the use of tropopause temperature or optional temperature threshold
- Improved calculation of high IWC hazard inside convective cells
- Use of CRR-Ph as optional input for RDT description
- Parallelization capabilities

1.5 Definitions, Acronyms and Abbreviations

1.5.1 NWC SAF glossary

See [RD.1] 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://www.nwc-saf.eumetsat.int

Ref	Title	Code	Vers	Date
[AD.1.]	Proposal for the Third Continuous Development and Operations Phase (CDOP-3) March 2017-February 2022	NWC SAF: CDOP-3 proposal	1.0	11/4/2016
[AD.2.]	Project Plan for the NWCSAF CDOP3 phase	NWC/CDOP3/SAF/AEMET/MGT/PP	1.0	6/3/2018
[AD.3.]	Configuration Management Plan for the NWCSAF	NWC/CDOP3/SAF/AEMET/MGT/CMP	1.0	21/2/2018
[AD.4.]	NWCSAF Product Requirement Document	NWC/CDOP3/SAF/AEMET/MGT/PRD	1.0	January 2018
[AD.5.]	System and Components Requirements Document	NWC/CDOP2/GEO/AEMET/SW/SCRD	2.1d	21/1/2019
[AD.6.]	Interface Control Document for Internal and External Interfaces of the NWC/GEO	NWC/CDOP3/GEO/AEMET/SW/ICD/1	1.0	21/1/2019
[AD.7.]	Interface Control Document for the NWCLIB of the NWC/GEO	NWC/CDOP3/GEO/AEMET/SW/ICD/2	1.0	21/1/2019
[AD.8.]	Data Output Format for the NWC/GEO	NWC/CDOP3/GEO/AEMET/SW/DOF	1.0	21/1/2019
[AD.9.]	Component Design Document for the NWCLIB of NWC/GEO	NWC/CDOP2/GEO/AEMET/SW/ACDD/NWCLIB	2.0	27/2/2017
[AD.10.]	Component Design Document for the Convection Product Processors of the NWC/GEO	NWC/CDOP2/GEO/MFT/SW/ACDD/Convection	2.1	21/1/2019
[AD.11.]	Algorithm Theoretical Basis Document for the Convection Product Processors of the NWC/GEO	NWC/CDOP2/GEO/MFT/SCI/ATBD/Convection	2.1	21/1/2019
[AD.12.]	User Manual for the Tools of the NWC/GEO	NWC/CDOP3/GEO/AEMET/SW/UM/Tools	1.0	21/1/2019
[AD.13.]	NWC SAF CDOP3 Project Plan Master Schedule	NWC/CDOP3/SAF/AEMET/MGT/PP/MasterSchedule	1.1	28/2/2018

Table 1: List of Applicable Documents

1.6.2 Reference documents

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

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

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

Ref	Title	Code	Vers	Date
[RD.1.]	The Nowcasting SAF Glossary	NWC/CDOP2/SAF/AEMET/MGT/GLO	2.1	3/2/2017
[RD.2.]	Validation report for of the Convection products processors of the NWC/GEO	NWC/CDOP3/GEO/MF-PI/SCI/VR-Convection_v1.0d	1.0	21/1/2019
[RD.3.]	User Manual for the NWC/GEO application: Software part	NWC/CDOP2/GEO/AEMET/SW/UM	1.0	15/10/2016
[RD.4.]	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	avalaible on NWCSAF Website		2016
[RD.5.]	Scientific Report on verification of RDT forecast	NWC/CDOP3/GEO/MFT/SCI/RP/01	1.1	2018
[RD.6.]	Visualization specifications for Convection Products	NWC/CDOP2/GEO/MFT/SCI/RP/06	1.2	2016
[RD.7.]	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 range. 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. to determine ***pre-CI*** pixels using relevant thresholds of parameters
6. finally to evaluate convection through probability assessment, and localize corresponding ***CI*** pixels

The algorithm is described in [AD.11.]. Some improvement from v2016 to v2018 have been defined in [RD.4.].

Relevant parameters, thresholds and some part of the algorithm are inspired from « Best Practice Document » [RD.4.], especially SATCAST methodology for the definition of pre-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.5.]. These improvements concern more specifically the tuning (thresholding, split of the algorithm in day and night parts), the use of CMIC. Learning data relies on case studies and features representative of convection triggering. It is dedicated to tune interest fields' thresholds and coefficients to evaluate a diagnosis of convection initiation.

2.1.3 Description of output

The content of the output in NetCdF format is described in the Data Output Format document ([AD.8.]). The product is an image-like product, whose target structure content three main containers dedicated to the three specified periods [0-30mn], [0-60mn] and [0-90mn]. Even if for this first release only the first period is filled, the containers have same structure. [0-60mn] and [0-90mn] containers are both set to FillValue.

<table>
<tr><th>Container</th><th>Content</th></tr>
<tr><td>ci_prob30</td><td>NWC GEO CI Probability next 30 minutes
<table>
<tr><th>Class</th><th>Cloud Type category</th></tr>
<tr><td>0</td><td>no probability to become thunderstorm</td></tr>
<tr><td>1</td><td>0-25% probability to become thunderstorm in the next 30minutes</td></tr>
<tr><td>2</td><td>25-50% probability to become thunderstorm in the next 30minutes</td></tr>
<tr><td>3</td><td>50-75% probability to become thunderstorm in the next 30minutes</td></tr>
<tr><td>4</td><td>75-100% probability to become thunderstorm in the next 30minutes</td></tr>
<tr><td>FillValue</td><td>No data or corrupted data</td></tr>
</table></td></tr>
<tr><td>ci_prob60</td><td>NWC GEO CI Probability next 60 minutes
Same classes and meaning than for ci_prob30, but referred to the next 60 minutes</td></tr>
<tr><td>ci_prob90</td><td>NWC GEO CI Probability next 90 minutes
Same classes and meaning than for ci_prob30, but referred to the next 90 minutes</td></tr>
<tr><td>ci_status_flag</td><td>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</td></tr>
</table>

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 nbnumber of pixels (usable means non space and available data)
- Quality = percentage of available data, processed as weighted average of available data. Weights are following
  - 70% from mandatory data (current and previous IR10.8 channel)
  - 30% from optional data (CT, NWP, 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 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 a backup file which will be used for the next step. This 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 auxilary files availability, One additional criteria the developers would recommend is to use the number of pre-CI pixels, 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:

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 SAFNWC/MSG software).

   Mandatory channels are IR10.8, WV6.2 and IR13.4µm channels, and are to be available also for the previous slot. But when possible, optimal processing of CI will be obtained with the use of current WV7.3, IR8.7 , IR12.0 channels.

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 SAFNWC/MSG), the following configuration file must be created or updated in order to process CI on a region:

   - CI model configuration file. It 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. **Auxiliary files**

In order to perform a convective initiation analysis, the CI software makes use of coefficient files located in the directory $SAFNWC/import/Aux_data/CI. Those files are delivered with the SAFNWC/MSG 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, those data are strongly recommended for a more efficient result. Most recent NWP data have to be located in the directory $SAFNWC/import/NWP_data. When remapped in $SAFNWC/tmp directory, NWP data are 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 SAFNWC 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 take benefit from CT product of the SAFNWC/MSG. 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 and that:

ii. 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 allow 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
NWP_PARAM	Surface Pressure	Chain of characters	NWP_SP 1 BLI
NWP_PARAM	Temperature at 2m	Chain of characters	NWP_2T 1 BLI
NWP_PARAM	Relative humidity at 2m	Chain of characters	NWP_2RH 1 BLI
NWP_PARAM	Dew point temp. at 2m	Chain of characters	NWP_2D 1 BLI
NWP_PARAM	Altitude	Chain of characters	NWP_ALTM 1 BLI
NWP_PARAM	Geopotential at surface	Chain of characters	NWP_SGEOP 1 BLI
NWP_PARAMxx(*)	Temperature at various pressure levels	Chain of characters	NWP_T 1 BLI
NWP_PARAMxx(*)	Relative humidity at various pressure levels	Chain of characters	NWP_RH 1 BLI
NWP_PARAMxx(*)	Geopotential at various pressure levels	Chain of characters	NWP_GEOP 1 BLI
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
TCOLD	cold temperature threshold when multiple thresholding, deg Celsius	float	-25.
TWARM	warm temperature threshold when multiple thresholding deg Celsius	float	10
DELTATEMPE	temperature step between Tcold and Twarm, deg Celsius	float	1.
SMIN	Minimum detection area , km2	float	1.
SMAX	Maximum detection area, km2	float	10000.
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)
NWPMVTLVL	U/V NWP Pressure level to use - hPa	integer	850
OMP_NBTHREAD	when using openmp for parallelization mode, number of thread to be used	integer	3
DBG	Flag for activating (1) or not (0) debug mode	integer	0

Table 4: default CI Model Configuration File description

2.4 CI VALIDATION

2.4.1 Validation results

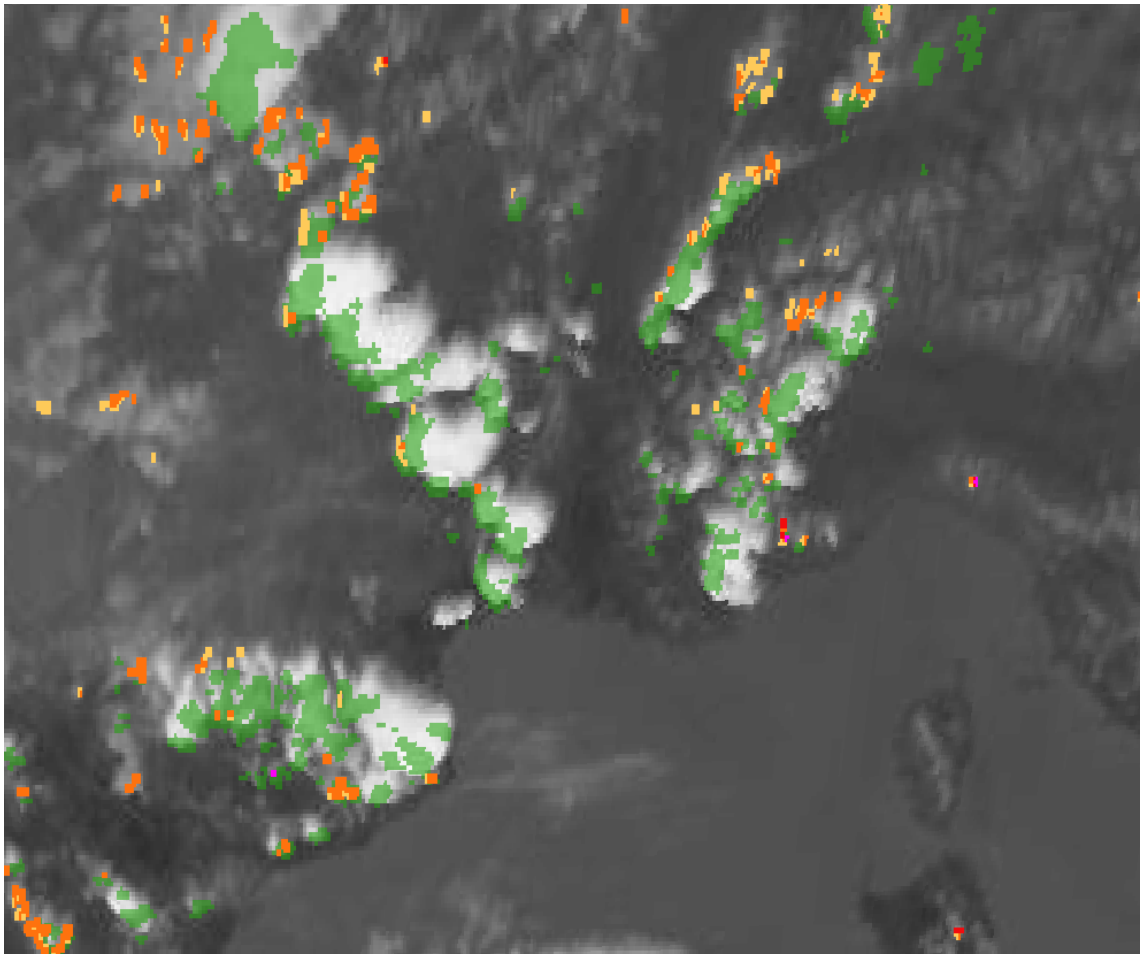
Validation report [RD.2.] fully describe the validation results. Some validation results of GEO-CI v2018 relies on the work undertaken in the AS activity [RD.7.]

Typical known problems and recommendation for use

This version of GEO-CI offers a basic approach with most relevant parameters which have been previously identified by others studies for this topic. However, the objective is not to exactly clone the previous approaches, but to offer a different use of the output for nowcasting purposes, with the wish to take into account uncertainty of the forecast through probability information.

GEO-CI focuses on warm and cloudy pixels, in an unstable environment, ignoring growing and already mature convection. Thus, when displaying GEO-CI product, most pixels have no information or non significant signal.

Example of CI visualisation



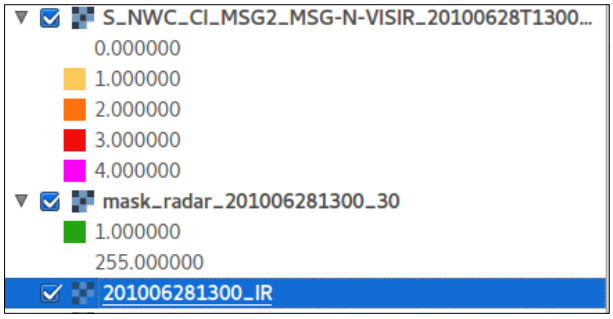


Figure 1: 28/06/2010 - 13Z IR image - accumulated Radar signal >35dBZ over [13-13h30Z] - CI prob30 container valid for [13-13h30Z]. New colour palette included in NetCdF files (bottom).

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

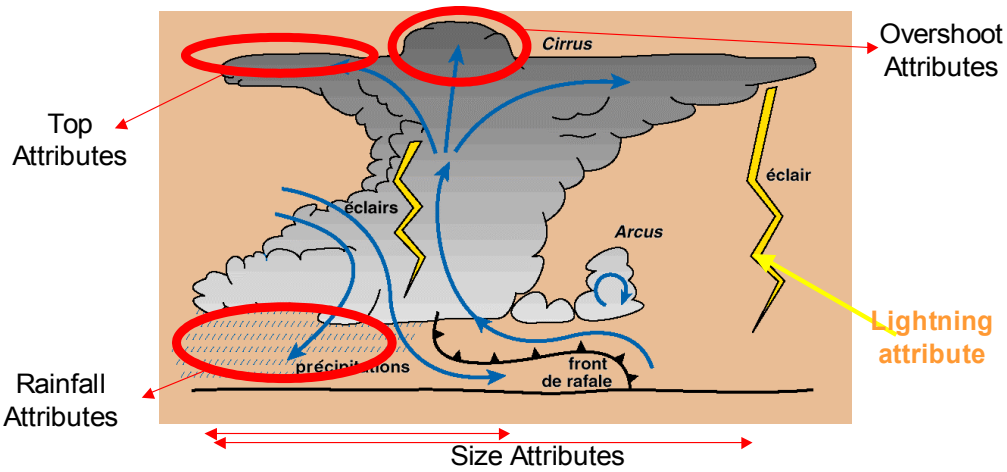


Figure 2: RDT-CW scheme

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 SAFNWC real-time demonstration is available on the Internet, at this address: http://www.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 [AD.11.]

It is to note that GEO-RDT-CW discrimination step has been revised for 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.

Description of RDT-CW outputs

The default output format of RDT-CW product is NetCDF. The previous BUFR format is no more produced. Depending on user configuration, an intermediate optional output is possible with Trajectory ASCII output .

3.1.2.1 NetCDF output

The content of the GEO-RDT-CW output in NetCdF format is described in the Data Output Format document ([AD.8.]). 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 cells. 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 overshoots 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 (default mode). It is possible to de-activate the encoding of this map, and keep bulletin-like structure only (user action with NCMAPINCLD argument of configuration file set to 0)
  - 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 previous 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 overshoots, 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 nb of pixels (usable means non space and available data)
- Quality = percentage of available data, processed as weighted average of available data, Weights are following
  - 80% from mandatory data (current and previous IR10.8 channel)
  - 20% from optional data (CT, CTTH, CMIC, CRR, HRW, LGH, NWP)

3.1.2.2 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.8.]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 SAFNWC/MSG).
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]
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 these data have 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).

[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.

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.
- Discrimination scheme needs also a recent historic to calculate trends on various depths.
- When RDT-CW software runs, it creates a backup file which will be used for the next step. This 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 auxillary 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 cell,
- 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 not operated on stable areas
- A normal increase of convection during daytime

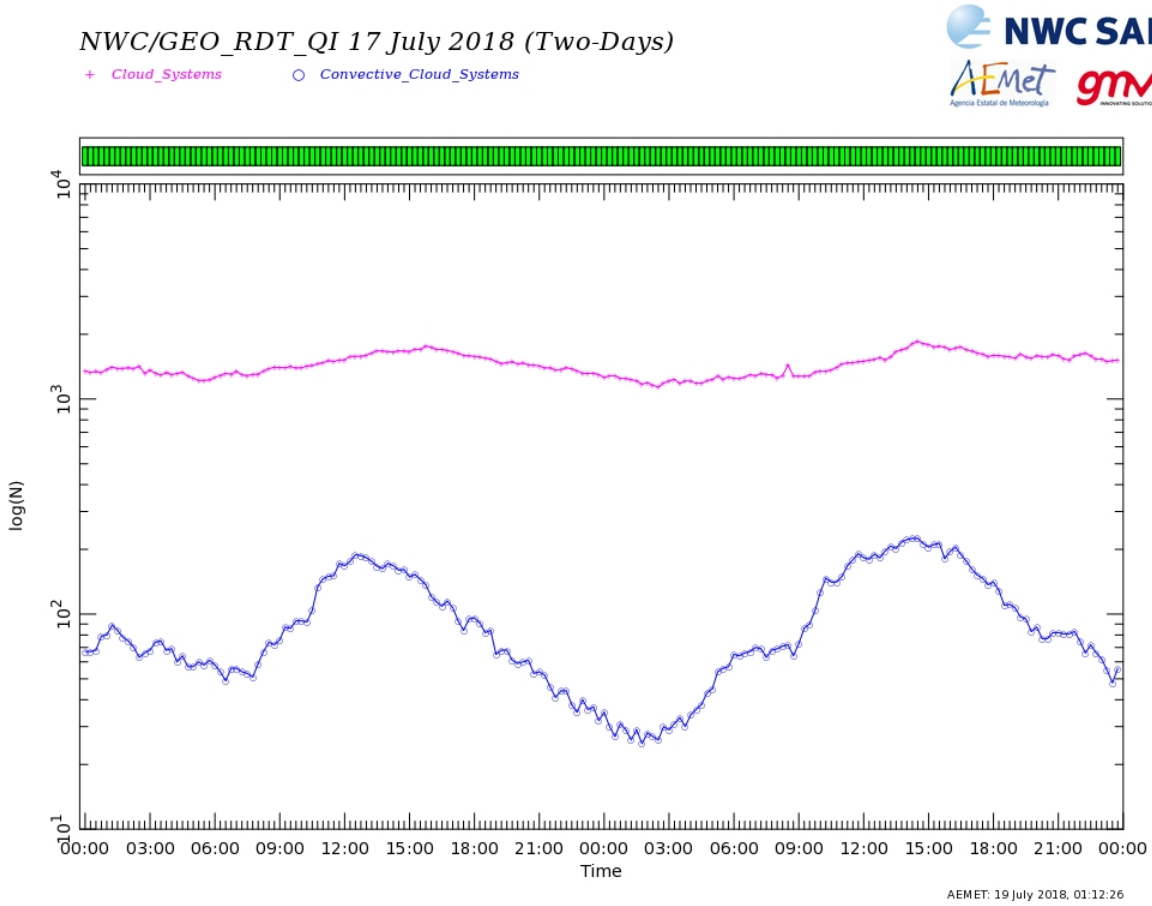


Figure 3: 2-days monitoring of RDT-CW

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 SAFNWC/MSG software).

Mandatory channel is IR 10.8µm channel, and has to be available also for the previous slot. But optimal processing of RDT-CW will be obtained with the use of current VIS06, IR16, IR38, WV6.2, WV7.3, IR8.7 and IR12.0 channels.

3.3.1.1.2 Configuration files.

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 SAFNWC/MSG), the following configuration file must be created or updated in order to process RDT-CW on a region:

RDT-CW model configuration file. It 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 SAFNWC/MSG 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 SAFNWC/MSG.

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, those data are strongly recommended for a more efficient result. Most recent NWP data have to be located in the directory $SAFNWC/import/NWP_data. When remapped in $SAFNWC/tmp directory, NWP data are 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 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 SAFNWC 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 as input an ASCII file of lightning detection data. This file has to be created and regularly updated in the directory $SAFNWC/import/Obs_data/Lightning/.

Its content must be lightning data (see the Interface Control Documents ICD/1 for the External and Internal Interfaces of the SAFNWC/MSG 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” of the model configuration file (see next section) allow GEO-RDT-CW to extract just what is necessary from the available lightning 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 are 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 parameter “LGH” 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 SAFNWC/MSG 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 minimum 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 SAFNWC/MSG 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 microphysic (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 SAFNWC/MSG 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

CRR and/or CRR-Ph products.

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 CRR and/or the CRRph product of the SAFNWC/MSG into the RDT product. This integration is optional.

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

iii. the CRR product is generated on the desired region and that

iv. the parameter "CRR" of the model configuration file (see next section) is set to a value equal or greater to 1.

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

v. the CRR-Ph product is generated on the desired region and that

vi. 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:

- When CRR-Ph and CRR are processed, available and configured as input to RDT-CW, CRR-Ph values are used preferentially to CRR values.
- 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.

As an additional attribute, 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 "CRR" or "CRRph" of the model configuration file

3.3.1.2.6 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 IR108 IR120 (IR134)
NWP_PARAM	Surface Pressure	Chain of characters	NWP_SP 1 BLI
NWP_PARAM	Temperature at 2m	Chain of characters	NWP_2T 1 BLI
NWP_PARAM	Relative humidity at 2m	Chain of characters	NWP_2RH 1 BLI
NWP_PARAM	Dew point temp. at 2m	Chain of characters	NWP_2D 1 BLI
NWP_PARAM	Altitude	Chain of characters	NWP_ALTM 1 BLI
NWP_PARAM	Geopotential at surface	Chain of characters	NWP_SGEOP 1 BLI
NWP_PARAMxx(*)	Temperature at various pressure levels	Chain of characters	NWP_T 1 BLI
NWP_PARAMxx(*)	Relative humidity at various pressure levels	Chain of characters	NWP_RH 1 BLI
NWP_PARAMxx(*)	Geopotential at various pressure levels	Chain of characters	NWP_GEOP 1 BLI
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
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
TRAJPROD	Availability of CTRAJ product 0 = monthly 1 = daily 2 = each slot	integer	2
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.
SMIN	Minimum detection area , km2	float	60.
SMAX	Maximum detection area, km2	float	400000.
BTLIMIT	upper limit of threshold temperature (°C) to define "Base of Tower" (BT) level for cloud cells	float	-60
LIMITTROPO	Flag for using NWP tropopause temperature as upper limit of threshold temperature (°C) to define "Base of Tower" (BT) level for cloud cells	integer	1 (yes)
DISCRI	Discrimination scheme mode: no(0) generic(1), calibrated(2), both(3=CAL, GEN if CAL not available)	integer	3
CMa	Flag for using (1) or not (0) CT as mask	integer	1 (yes)
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)
CRR	value for using (≥1) or not (0) CRR	integer	1 (yes)
CRRph	value for using (≥1) or not (0) CRRph	integer	1 (yes)
HRW	Flag for using (1) or not (0) HRW	integer	1 (yes)

Keyword	Description	Type	Default Value(s)
NWPMVTLVL	U/V NWP Pressure level to use - hPa	integer	700
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
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
DBG	Flag for activating (1) or not (0) debug mode	integer	0
FCST	Maximum lead range for advected products- 0 (no advection), up to 60 (minutes)	integer	60
FCSTEP	lead range step in minutes	integer	15
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	1
TROPICALDISCRI	Temperature threshold (°C) for forcing discrimination in tropical regions –recommanded -75°C	float	Not activated
OMP_NBTHREAD	when using openmp for parallelization mode, number of thread to be used	integer	0

Table 5: RDT-CW default Model Configuration File description

(*) Temperature and relative humidity are requested to be remapped for each iiii 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 VALIDATION

3.4.1 Summary of validation results

Since Generic Discrimination scheme (GEN mode) may remain active when no calibration has been made available for a given satellite, or when a calibrated statistical model is not validated, or depending on user's configuration, previous validation results for v2016 are still applicable.

RDT-CW v2016 subjective validation with case studies or RDT v2011 objective validation and corresponding discrimination skills are detailed in v2016 validation reports, and summarized hereafter :

> Considering a moderate electrical activity, the overall probability of detection is 74%, and reaches 77% on convective periods. 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 whith 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.

The tuning of the new Calibrated Discrimination scheme has been undertaken on several geostationary satellites, running GEO-RDT-CW over various geographical regions for several days each. Therefore, the use of a global lightning dataset was necessary to be used as ground truth. GLM dataset from GOES16 and WWLLN lightning network for other satellites were used.

Tuning datasets were submitted to a cross validation process (with independent learning/validation sets). Thus results can be considered as reliable and representative. But a complete objective validation like for GEN discrimination scheme for each satellite would need a much larger dataset. Results presented in validation report have to be considered regarding the various geographical regions and various lighting network efficiencies.

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 de-classified in time during decaying phase, avoided the tracking of un-interest 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. It provides interest information on triggering and development clouds and on mature systems. The subjective and objective evaluations exhibit that convection can be sometimes diagnosed before lightning activity occurs.

3.4.2 Known problems and recommendation for use

The tunings have been carried out on a limited set of days for each satellite, with a light to moderate electrical activity from global network.

The discrimination scores during winter period are weaker, but RDT process will take full benefit from the use of NWP data to avoid false alarms.

3.5 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 visualization tool**.

Some specification about RDT visualization for a tool developed by AEMET has been provided in a scientific report [RD.6.] 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.

3.5.1 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 visualization 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 visualization 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.

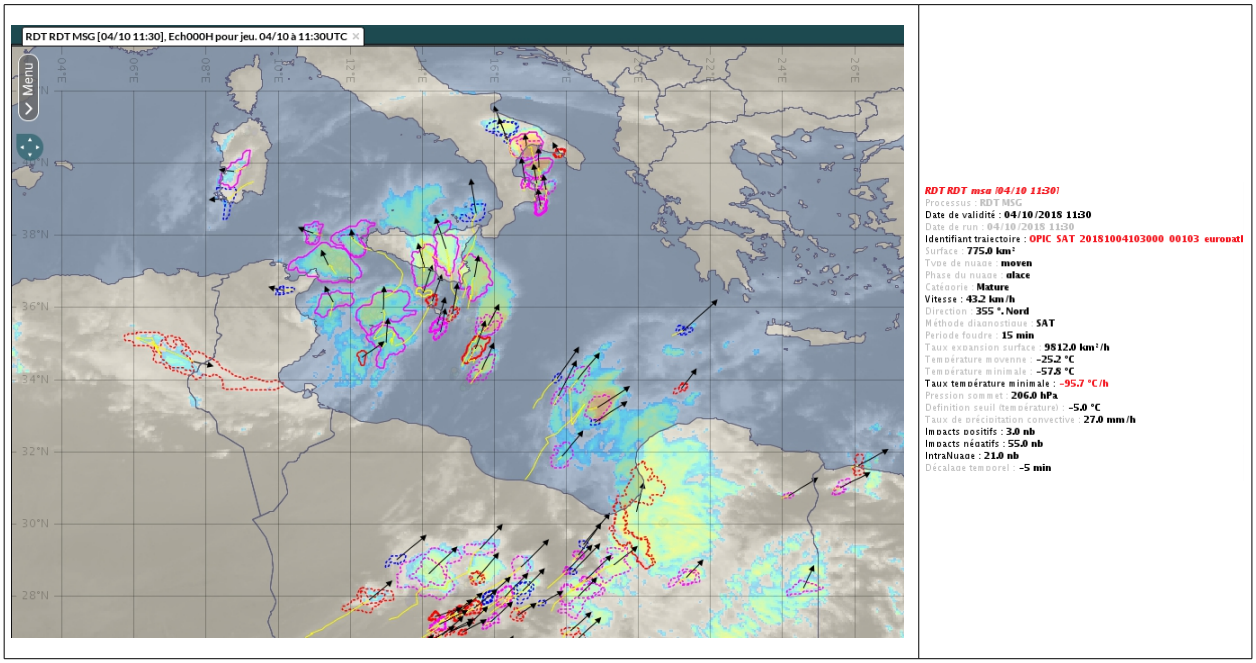
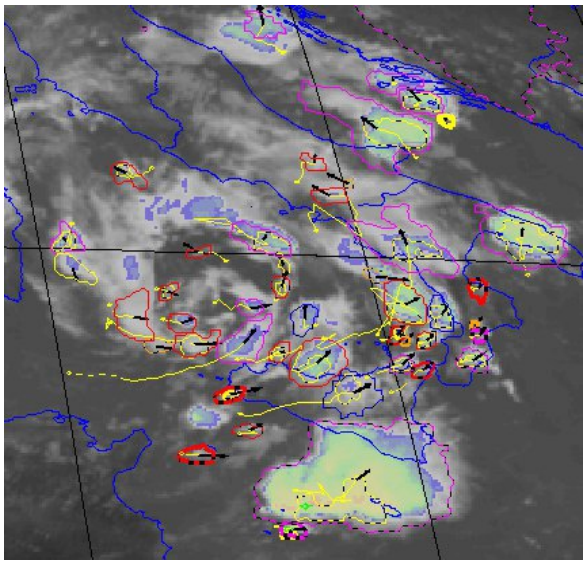


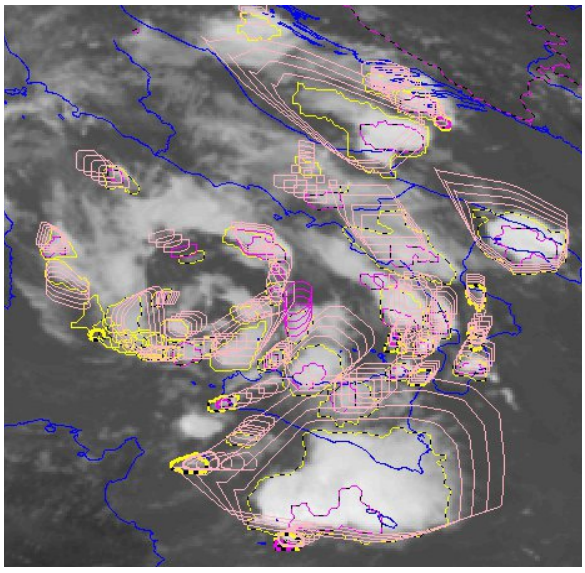
Figure 4: Example of product visualisation, RDT cells on the left, gauge for one cell on the right (pop-up window)

The EUMETRAIN website provides studies cases on convective triggering over France and Africa (http://www.zamg.ac.at/eumetrain/NWCSAF_WS_June2004/Update/main.htm).

3.5.2 Examples of visualization of forecast products



Analyzsd RDT-CW cells with motion vectors



RDT-CW +15, +30, +45 and +60 smoothed and dilated forecast cells

Figure 5: 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 5, where smoothing and dilatation options have been activated.

3.5.3 Other examples of visualisation

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

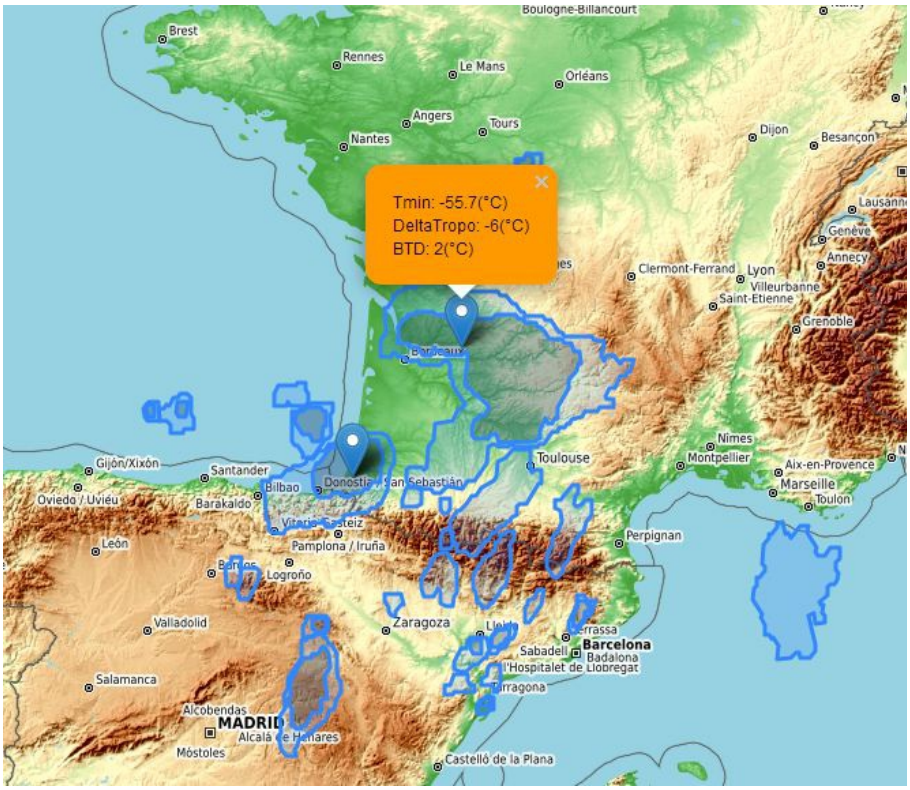


Figure 6: RDT visualisation example with OT depicted near Bordeaux

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

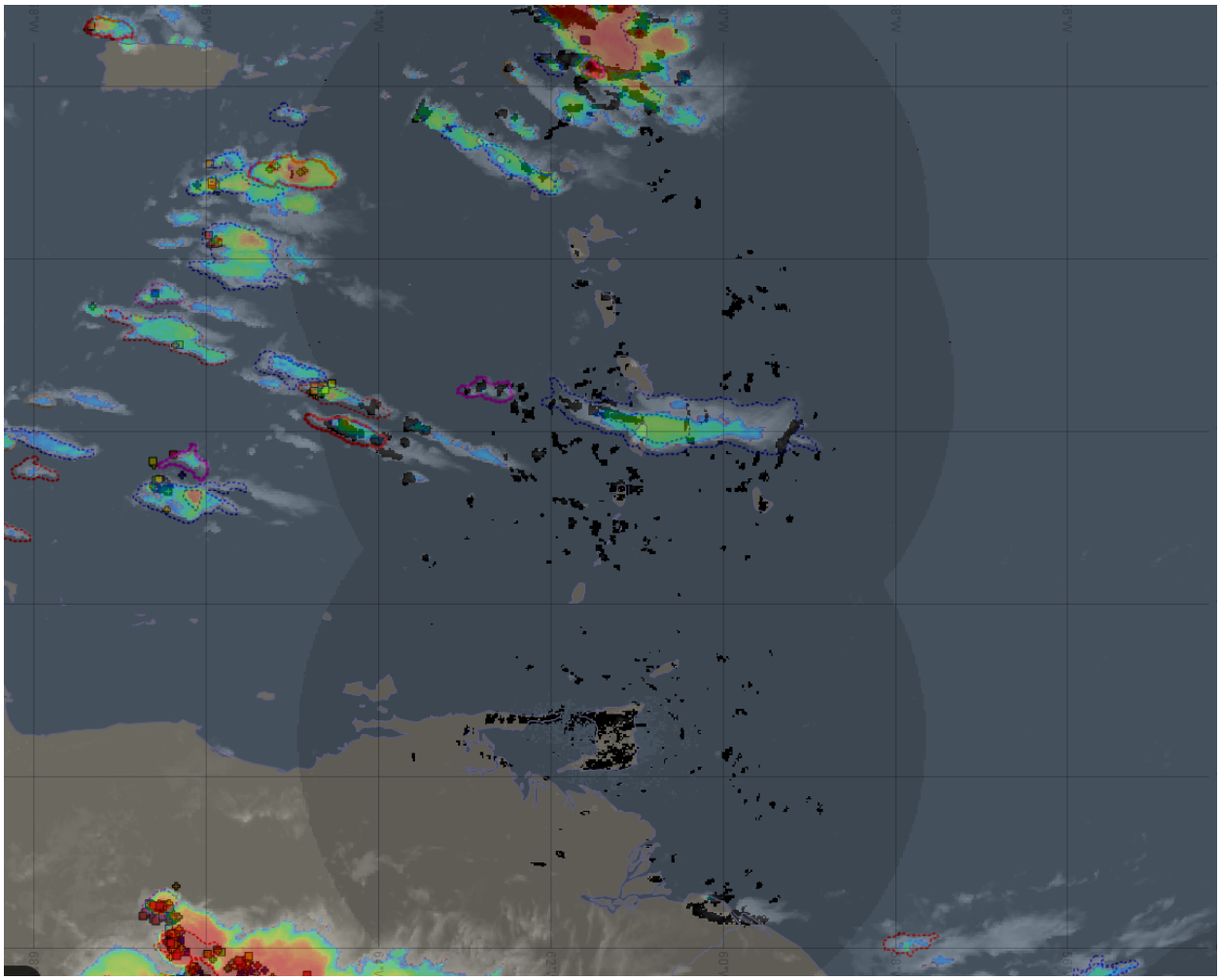


Figure 7: Illustration of several information superimposed on Synopsis system. RDT (operated with GOES data) outlines (blue, red magenda) over the Caribbean. French radar data reflectivities (black points and radar covergae in grey), GOES-16 enhanced IR image ,(convection palette: colder temperature in red), GLD360 lightning network (circles in green orange and red)

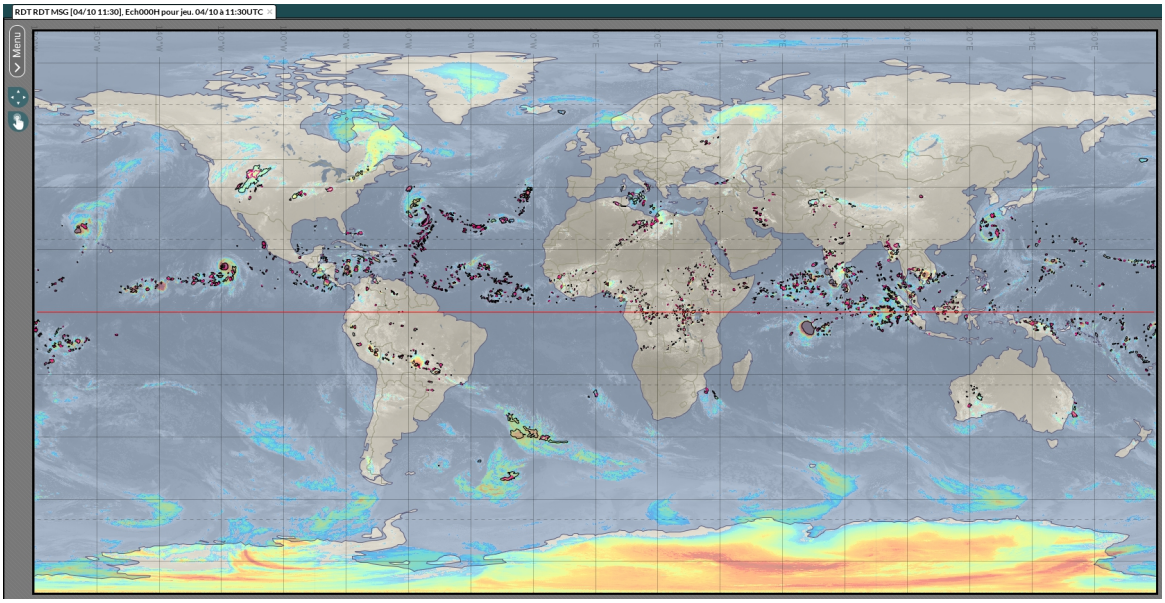


Figure 8: RDT (operated with 5 GEO satellites) outlines (black) with Synopsis. Superposition with mosaic of IR satellite images

There are many tools used or developed for RDT visualisation and for example

- AEMET has developed a visualisation tool, on the website http://www.nwc-saf.eumetsat.int
- For ESSL TestBed, a html-based data display has been developed to display NWCSAF products.