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/CDOP2/GEO/MFT/SCI/UM/Convection, Issue 1, Rev. 1

15th October 2016

Applicable to

GEO-CI v1.0 (NWC-052)

GEO-RDT-CW v4.0 (NWC-055)

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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.nwcsaf.org. This document is applicable to the NWC SAF processing package for geostationary meteorological satellites, NWC/GEO.

1.1 SCOPE OF THE DOCUMENT

This document is the User Manual for the Convection Products components PGE18 (GEO-CI, Convection Initiation) and PGE19 (GEO-RDT-CW, Rapid Developing Thunderstorm – Convection Warning) of the NWC/GEO software package.

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

1.2 SCOPE OF OTHER DOCUMENTS

The algorithms used to extract the GEO 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 External and Internal Interfaces of the SAFNWC/GEO) and ([AD.8.]) (GEO Output Product Format Definition) detail the input and output data format for the SAFNWC/GEO software.

1.3 SOFTWARE VERSION IDENTIFICATION

This document describes the products obtained from the PGE18 GEO-CI v1.0 (Product Id NWC-052) from the PGE19 GEO-RDT-CW v4.0 (Product Id NWC-055) implemented in the release 2016 of the NWC/GEO software package.

1.4 IMPROVEMENT FROM PREVIOUS VERSION

PGE18 (GEO-CI) v2016 is the first release of the product. CI software takes advantage of common modules with RDT-CW, and shares some aspects of cell detection and tracking, over which movement analysis and pixel analysis superimpose to complete the processing.

PGE19 (GEO-RDT-CW) is a continuation of CDOP-PGE11 (RDT). The main changes implemented in v2016 concern:

- Adaptation to new v2016 NWCLIB interfaces and structures
- More optional inputs: new CMIC product for microphysics, HRW for movement analysis, NWP wind component as additional inputs for NWP parameters.
- Processing of a 2D movement field as guess field (from HRW and NWP winds) for initialization of cloud cell motion
- Improvement of spatial and temporal coherence of cloud cell motion, improvement of expansion rate processing
- Additional attributes related to CMIC product (phase, microphysics parameters), basic related icing index at high altitude, lightning trend, top pressure trend, synthetic multisource severity index
- Improvement of discrimination modules that change a "No" convection diagnosis issued from statistical discrimination step of algorithm (for example in case of OT detection or, according to user's configuration, lightning activity or high CRR). Product keeps memory of "forced" convection diagnosis too, and this characteristic is taken into account in the next slots. Improvement of the de-classification step.
- Optional parallax correction inserted before product encoding
- The compliance with NetCDF format for encoding SAFNWC v2016 outputs *(BUFR output may additionally be produced for non regression purposes, depending on user's configuration)*. NetCDF encoding refers to bulletin-like structure, but optional 2D map of type/phase of convective cells may be available into the output of analyzed cloud cells, depending on user's configuration.
- The development of a nowcast (+1h) module, activated through user's configuration, and leading to maximum four forecast products (+15', +30', +45', +60') additional to the analyzed one.
- The implementation of CTRAJ product an intermediate output.

1.5 DEFINITIONS, ACRONYMS AND ABBREVIATIONS

1.5.1 NWC SAF glossary

See [RD.1] for a complete list of acronym 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.nwcsaf.org

Ref	Title	Code	Vers	Date
[AD.1.]	Proposal for the Second Continuous Development and operation Phase (CDOP) march 2012 – February 2017	NWC/SCDOP2/MGT/AEMET/PRO	1.0	15/3/2016
[AD.2.]	NWCSAF Project Plan	NWC/CDOP2/SAF/AEMET/MGT/PP	1.9	15/10/206
[AD.3.]	Configuration Management Plan for the NWCSAF	NWC/CDOP2/SAF/AEMET/MGT/CM P	1.4	15/10/2016
[AD.4.]	NWCSAF Product Requirement Document	NWC/CDOP2/SAF/AEMET/MGT/PR D	1.9	Aug 2016
[AD.5.]	System and Components Requirements Document	NWC/CDOP2/GEO/AEMET/SW/SCR D	1.2	15/10/2016
[AD.6.]	Interface Control Document for Internal and External Interfaces of the NWC/GEO	NWC/CDOP2/GEO/AEMET/SW/ICD/ 1	1.1	15/10/2016
[AD.7.]	Interface Control Document for the NWCLIB of the NWC/GEO	NWC/CDOP2/GEO/AEMET/SW/ICD/ 2	1.1	15/10/2016
[AD.8.]	Data Output Format for the NWC/GEO	NWC/CDOP2/GEO/AEMET/SW/DOF	1.1	15/10/2016
[AD.9.]	Architectural Design Document for the NWC/GEO	NWC/CDOP2/GEO/AEMET/SW/ACD D	1.1	15/10/2016
[AD.10.]	Component Design Document for the Convection Product Processors of the NWC/GEO	NWC/CDOP2/GEO/MFT/SW/ACDD/ Convection	1.1	15/10/2016
[AD.11.]	Algorithm Theoretical Basis Document for the Convection Product Processors of the NWC/GEO	NWC/CDOP2/GEO/MFT/SCI/ATBD/ Convection	1.1	15/10/2016
[AD.12.]	Interface Control Document for the input and output data formats	SAF/NWC/CDOP/INM/SW/ICD/3	1.1	15/10/2016

Table 1: List of Applicable Documents

1.6.2 Reference documents

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

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

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

Ref	Title	Code	Vers	Date
[RD.1.]	The Nowcasting SAF Glossary	NWC/CDOP2/SAF/AEMET/MGT/GLO	2.0	18/2/2014
[RD.2.]	Validation report for of the Convection products processors of the NWC/GEO	NWC/CDOP2/GEO/MFT/SCI/VR/01	1.0	15/10/2016
[RD.3.]	User Manual for the NWC/GEO application: Software par	NWC/CDOP2/GEO/AEMET/SW/UM	1.0	15/10/2016

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 by PGE18 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

Note: relevant parameters, thresholds and some part of the algorithm are inspired from « Best Practice Document, 2013, for EUMETSAT Convection Working Group, Eds J.Mecikalski, K. Bedka and M. König », especially SATCAST methodology for the definition of pre-CI pixels.

2.1.2.1 Area of interest

Convective mask from NWP data, Cloud mask from GEO-CT product, and IR10.8 Brightness temperature thresholding (warmer than -25°C) allow ignoring large non relevant areas and pixels of a region, and restricting the analysis to a limited set of pixels.

2.1.2.2 Movement field

A 2D movement field is estimated in optimum configuration with blending NWP wind field in the low level (850hPa) and last available HRW wind observations, remapped on grid-field and selected versus the corresponding pixel's brightness temperature.

This blended field is one side used as guess movement in the following object tracking process , and on the other side updated with those object diagnosed speeds.

This field will be considered as a pixel tracker for following trends calculations.

2.1.2.3 Object detection and tracking

An object analysis process has been adapted to detect and track warm cloud cells from lowest surfaces. The objectives of this step are

- to take benefit from techniques allowing to catch cloud cells movement
- to access cloud cells' parameters variations over long history

For more details on detection and tracking techniques, see 3.1.2.2 in this document and [AD.11.].

2.1.2.4 Pixel analysis

Brightness Temperature Differences are processed for each *eligible-CI* pixel from various available channels, for current data and data from previous slot.

Then, BT (IR10.8) and BTD trends are calculated for each eligible-CI pixel using the speed and direction of updated 2D movement field as guidance for identifying pairs of current and corresponding pixels in previous image. When available, trends from object tracking are preferred to trends calculated from retro-advected pixels.

2.1.2.5 Pre-CI pixels

Each *eligible-CI* has got then a list of BT and BTD values and trends. According to previous studies about convection initiation, parameters are grouped as Interest fields, referring to cloud top glaciation, cloud vertical extension and cloud growth.

Pre-CI pixels are pixels which get at least one significant relevant value of those fields.

2.1.2.6 Diagnosis

Each pre-CI pixel is associated with a list of Interest fields' values, used as input for CI diagnosis.

CI-diagnosis should be derived from statistical models using those values. The tuning of such models has been postponed to the next release

The CI probability is estimated with empirical rule defined by count of relevant criteria. The v2016 version proposes this possibility only. The principle is to sum up the number of relevant parameters by group, giving greater importance to *growth* family parameters, then *glaciation* parameters, and finally vertical extension (height) group.

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

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 SEVIRI image file in HRIT format (mandatory input) is available in the directory $SAFNWC/import/Sat_data/. To process CI in real-time, the user has to refresh this file every 15 minutes with the most up-to-date data.
4. Ensure that the directory $SAFNWC/import/NWP_data has been provided with latest NWP multigrib 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 undertake a tracking of small warm cloud cells from one image to the following. 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 analyze trends on 15 and 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.

2.3 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 file located in the directory $SAFNWC/import/Aux_data/CI. This file is delivered with the SAFNWC/MSG software and must not be modified by the user.

2.3.1.2 Optional inputs

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

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 compliant with either ARPEGE or ECMWF NWP data. Some parameters that are not available in one case 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 PGE18 are :

- instability indexes: previously computed and saved as DATABUF for other PGEs or recomputed by PGE18
- 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. **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 and that:

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

3. **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'stracking). 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.
CMa	Flag for using (1) or not (0) CT as mask	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
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 Summary of validation results

Up to now, validation process has not been completed. It will be undertaken once tuning on all missing lead periods ([0-60mn] and [0-90min]) will have been achieved, and thus the forecast process fully implemented.

Up to now validation has been performed on case studies for the [0-30] forecast range.

2.4.2 Typical known problems and recommendation for use

This first 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.

2.5 EXAMPLE OF CI VISUALISATION

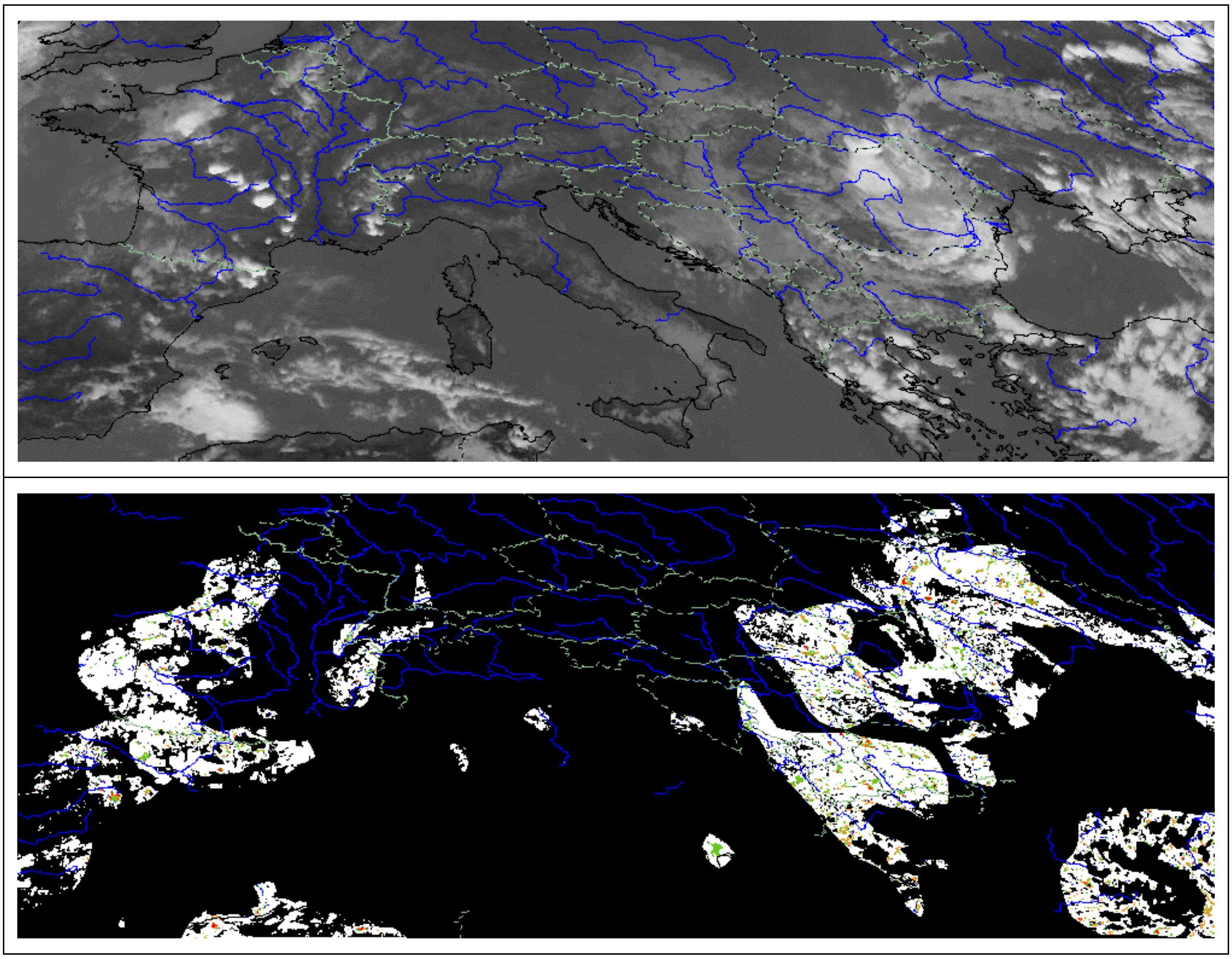
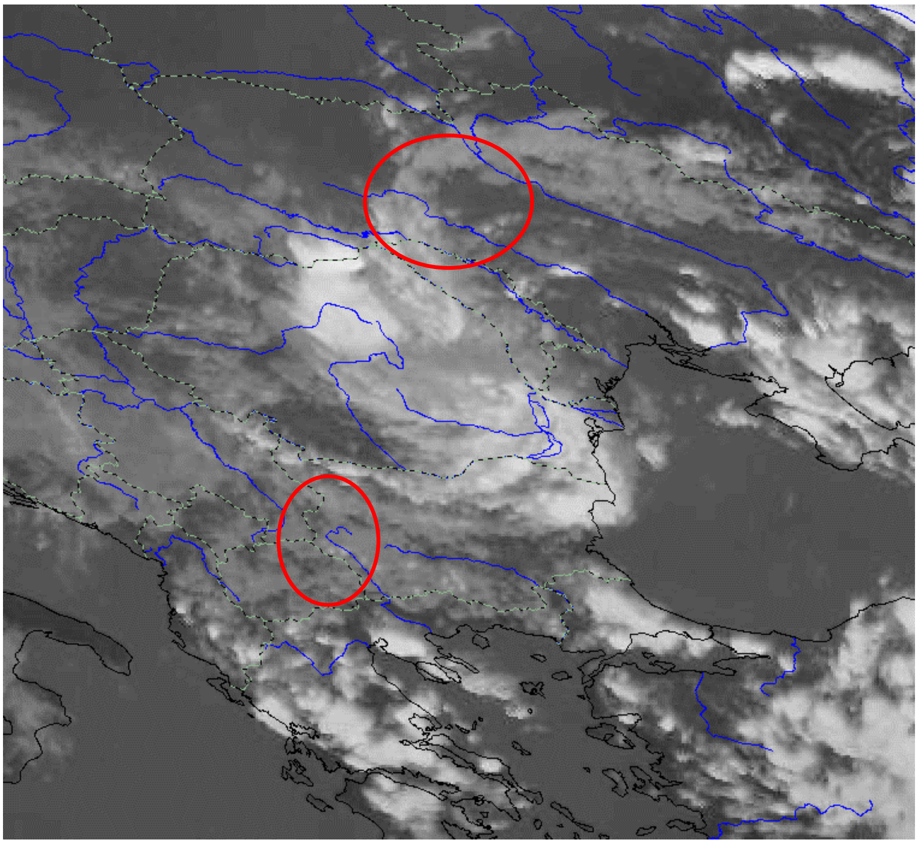


Figure 1: 28/06/2010 12Z – IR image (top) - CI prob30 container using the colour palette included in NetCdF files (bottom). White areas represent areas of interest with eligible-CI



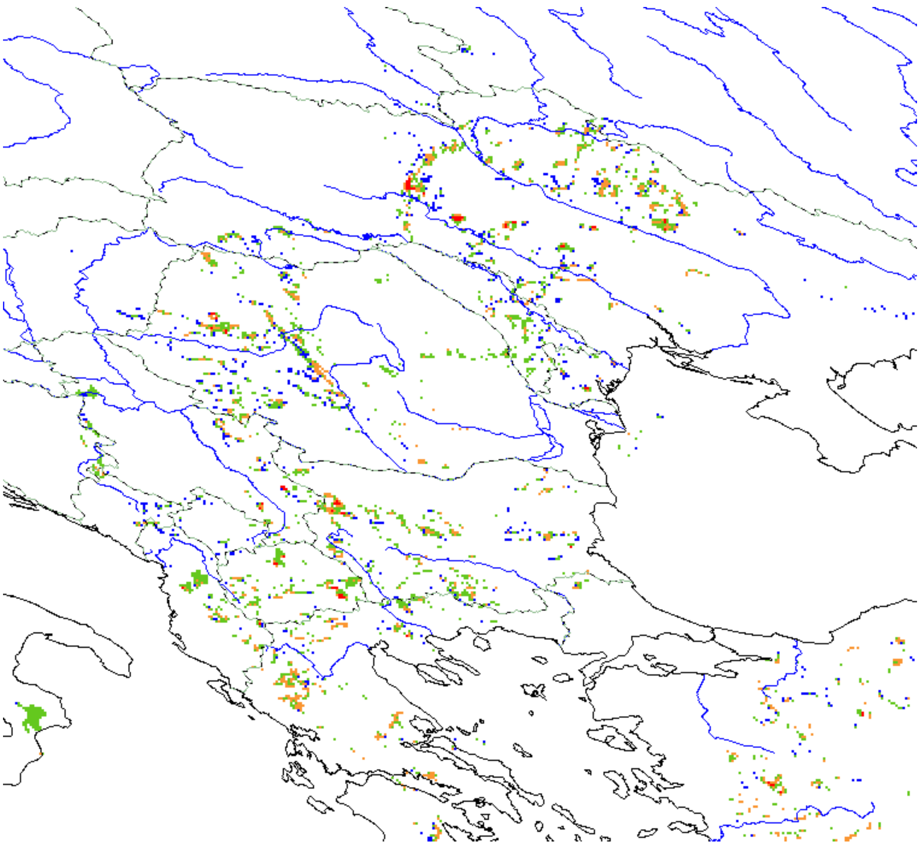


Figure 2: 28/06/2010 12Z – top: IR image - bottom: CI prob30 container displaying 4 classes of probability (blue/ green/ orange/ red). Most likely active areas highlighted (red ellipses)

3 RAPID 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 geostationnary 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). It is provided to users in the form of numerical data stored in a BUFR format file. 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

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, 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 Meteosat-based real-time demonstration is available for registered NMS on the Internet, at this address: http://www.meteorologie.eu.org/RDT/index.html. A training material is 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 three parts:

- 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"

3.1.2.1 The detection of cloud systems

The detection algorithm allows to define "cells" which represent the cloud systems. In the RDT_CW algorithm, "cells" are defined on infrared images (channel IR10.8) by applying a threshold which is specific to each cloud system, and which chosen based on local brightness temperature pattern. A good understanding of this process is essential to make the best use of RDT-CW.

The main idea is to adapt the threshold use to the topography of the cloud tops:

- In the case of simple topography (like the simple, isolated, cloud associated to a single convective cell in clear air, at development stage), the threshold chosen corresponds to the outer limits of the cloudy zone
- In more complex cases, the principle is to use the warmest temperature threshold which allows to get one cell for each cloud "tower". A cloud tower is here formally defined as a local brightness temperature minima which is separated from the other, nearby, minima by a sufficiently warmer zone (6°C warmer)

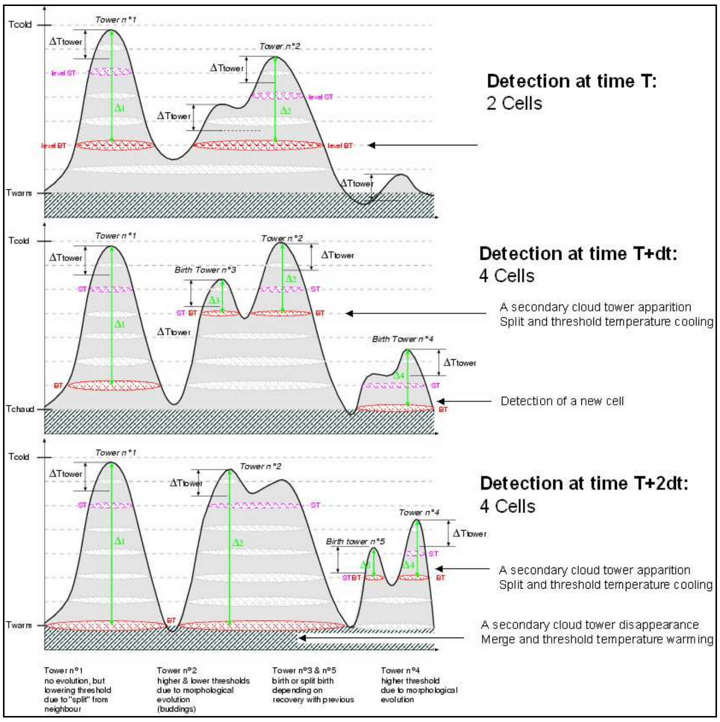


Figure 3: RDT-CW cell definition

Hence, the threshold used for a given cloud tower depends on the temperature pattern in the vicinity, and may evolve because nearby towers do evolve, merging or separating cloudy budding.

Please note that the RDT cells linked in time to form a trajectory do not necessarily really depict the same phenomena along time. The advantage of the “adaptative threshold” method is to focus on convective parts of cloud systems and to facilitate the discrimination process.

3.1.2.2 The tracking of cloud systems

The use of an adaptive threshold makes the cell comparison complex because of a wide variety of phenomena that are described. This method induces numerous merges or splits.

The tracking algorithm is mainly built on the overlapping between cells in two successive images. Before the cells overlap processing, the previous cells are moved in the speed and direction analyzed earlier. Nevertheless, correlation or neighborhood methods are applied when overlapping method doesn't succeed. The temporal links are processed as follow:

- *No match*: the current cell is a new one and begins a new trajectory is created
- *Merge*: more than one former cell match with one current cell. The trajectory of the "largest" former cell is kept; the other ones are closed. Due to the use of the “adaptative threshold” method the largest former cell is not directly defined on its area attribute but on a area defined at a common threshold.
- *Split*: One former cell match with several current cells. The "largest" current cell carries out the time series. The other ones are processed like new cells.
- *Merge and split*: Several former cells match witch several current cells: In this case (less than 3% of trajectories), all trajectories are closed and the current cells are processed like new cells.

The temporal links allows computing move, speed and trends of all cloud objects.

- Speed estimate relies on successive positions (weighted gravity centres) of linked previous and current cells
- When no temporal link has been found, moving speed is initiated from movement guess field previously initiated by blending HRW observations and mid-level U/V NWP winds.

Once the main temporal link has been identified, time series of cloud's characteristics (peripheral gradient, volume, cooling rate...) may be used as key input for the discrimination algorithm.

3.1.2.3 The discrimination of convective objects

As it was mentioned previously, the RDT-CW detection algorithm is able to detect cloud structure from meso-alpha scale (200 to 2000 km) down to pixel scale. The goal of the discrimination method is to identify the convective RDT-CW objects among all cloud cells, adding a strong constraint that is that the discrimination should be effective as soon as possible after the first detection by RDT-CW software.

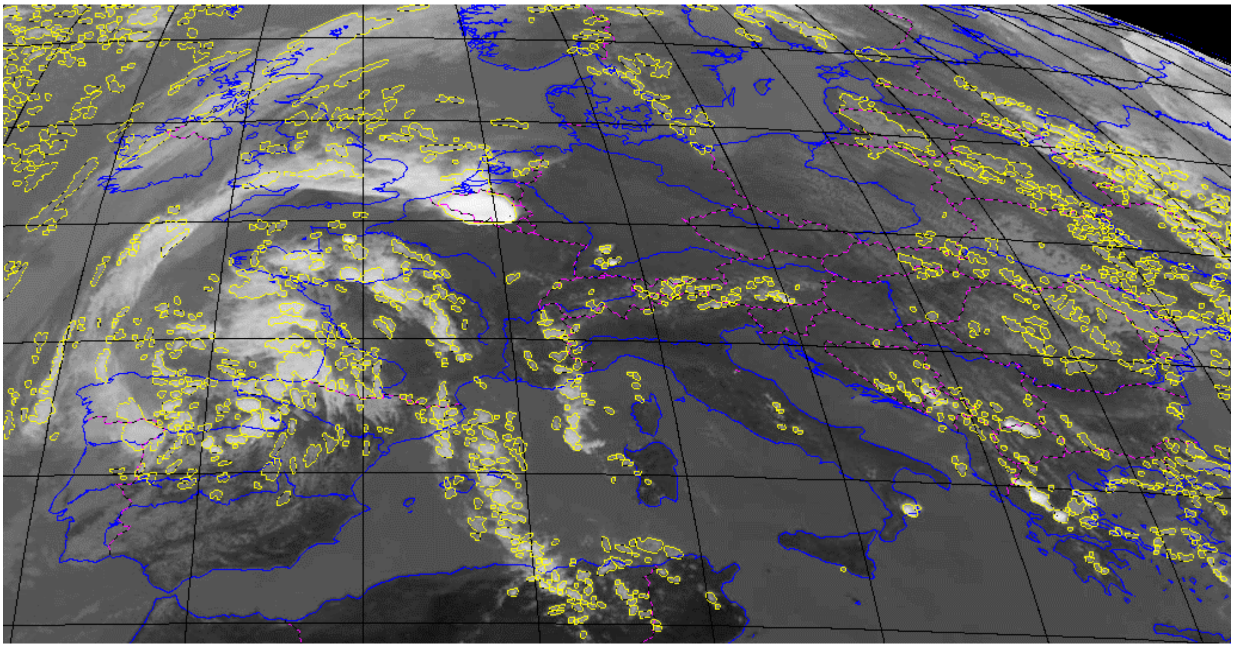


Figure 4: 25th May 2009, 12UTC – RDT-CW objects (yellow outline) before convective discrimination

The picture above displays all RDT-CW detected cells. This picture points out the detection and tracking efficiency of RDT-CW. We can notice the phenomena and scale diversity of RDT-CW objects.

The next image displays convective objects only. The ratio between no convective and convective objects is about 100.

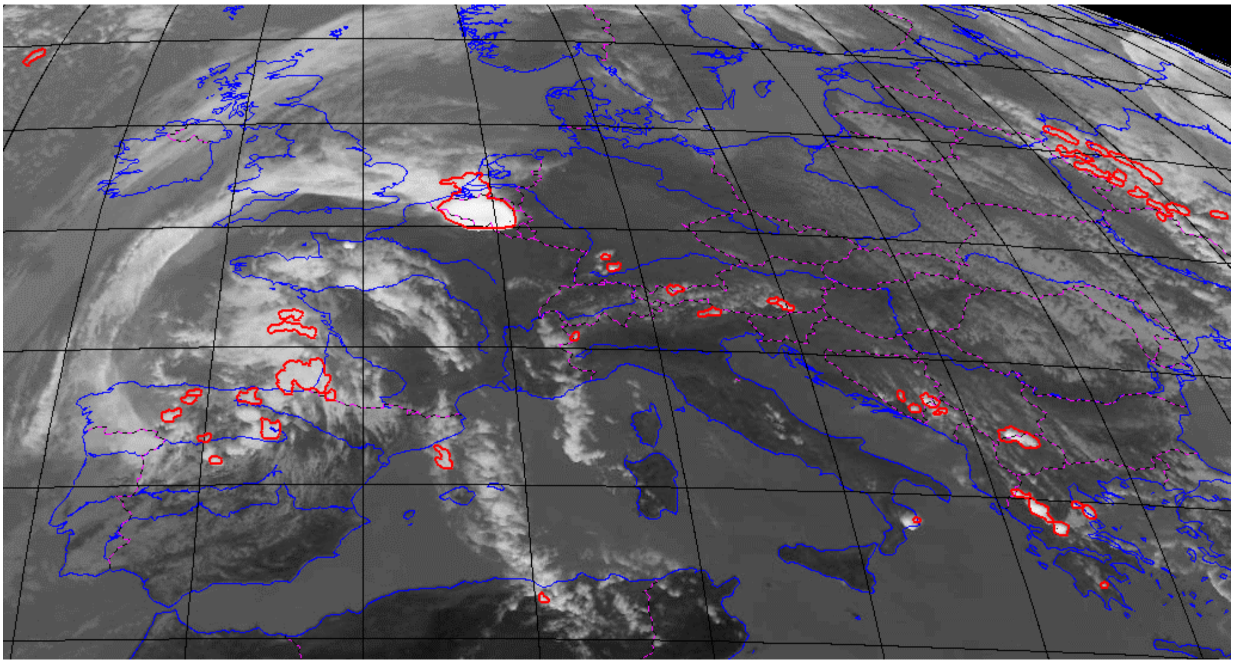


Figure 5: 25th May 2009, 12UTC – RDT-CW objects (red outline) after convective discrimination

The discrimination method makes use of discrimination parameters calculated from infrared 10.8, IR12.0, IR8.7 and two vapour channels (WV6.2 and WV7.3) characteristics. Two kinds of such discrimination parameters are computed:

- Spatial characteristics (extremes, peripheral gradient, surface)
- Temporal characteristics (cooling rate, parameters trend)

The discrimination scheme relies on statistical models tuned on a learning database. The current learning database is made over widened France. The ground truth used for building the database is cloud to ground lightning occurrence.

The imbalance between number of convective and non-convective objects may lead to strong increase of false detection for small improvement of detection efficiency. For that reason NWP data have been used to restrict the region of interest to areas of moderate or high instability. Numbers of electric and non electric systems become closer even in low layer (warm categories), which allows a more robust tuning of statistical models.

The ground truth used to build the database is lightning occurrence (cloud to ground or intra-cloud). For that reason the current learning database used to tune RDT discrimination algorithm is made over widened France, where accuracy and efficiency of detection are reliable. The tuning domain of RDT-CW takes into account the former improvements of detection efficiency and precision from Meteorage lightning network.

In order to process RDT-CW on others satellites, the discrimination scheme has been tuned for two others configurations than the “nominal” one:

- IR10.8 and WV6.2 (defined for GOES data)
- IR10.8 (defined for METEOSAT 7)

Taking into account the possibility or not to use NWP data as optional input, six modes of processing (configurations) are finally made available:

- IR10.8, IR12.0, IR8.7, WV6.2, WV7.3 and NWP data (default configuration for MSG)
- IR10.8, WV6.2 and NWP data
- IR10.8 and NWP data
- IR10.8, IR12.0, IR8.7, WV6.2, WV7.3
- IR10.8, WV6.2
- IR10.8

Even if the user’s configuration file does not correspond to the real time availability of data, RDT-CW is able to adapt and detect automatically the best usable configuration among the ones listed above. For that reason, each mode is associated with a specific tuning.

3.1.2.3.1 "Yes" convection diagnosis follow-up

The discrimination scheme will be applied to non convective cloud system which reveal an ascending/growing trajectory. Once the statistical method has lead to identify a system as convective, this diagnosis will be later examined through empirical rules in the next slots:

- First, the convective diagnosis is inherited from one “father” cell to its “daughter”, to initiate a temporal continuity for a convective system
- But when this diagnosis lasts more than a given period (default 45min), it is checked against vertical evolution of the cloud system (did the cloud system continue to grow, or did this growth stop or invert ?) or against other parameters (temperature trends, BTD values or trends for mature systems). This step may lead to a de-classification of the convective characteristic

Thus, the operational implementation of convective discrimination is a mix between statistical models for identifying convective systems, and empirical rules for confirming or removing this characteristic by analyzing the temporal evolution of a cloud system.

3.1.2.3.2 Use of additional/external data for "Yes" convection diagnosis

In some cases, discrimination scheme does not allow producing an early diagnosis, or has lead to a too early de-classification. For that reason, external or additional available data may be used to consolidate, or even initiate convective diagnosis. This possibility, derived from the data blending capabilities of RDT-CW, is mostly under user’s control through configuration file.

- Overshooting Top Detection processed by RDT-CW is an additional characteristic of cloud cell which is automatically used to consolidate the convective diagnosis, and prevent too-early de-classification of mature cloud systems.
- Lightning data, when available and precise enough, may greatly consolidate to the diagnosis of convection. LGH argument drives this possibility, taking into account the number of lightning flashes associated with a cloud cell
- Convective Rain Rate product allows estimating maximum precipitation amount over cloud cell horizontal extension. Highest values can be associated with thunderstorms. CRRDISCRI argument drives this possibility, activating a threshold of 50mm/h or defining a new threshold for “forcing” the diagnosis
- Tropical and equatorial regions present the deepest convective systems, with coldest minimum temperatures. This feature may be used to consider as convective coldest systems at low latitudes . TROPICALDISCRI argument drives this possibility with an adequate temperature threshold.

3.1.2.4 The forecast of convective objects

Before v2016, RDT is an analysis tool. In order to improve its usefulness in forecasting application (CW) a forecast up to 1 hour has been proposed for each slot since v2016, depending on user’s configuration.

The forecast relies on the moving speed estimate of each cloud cell object, representative of its dynamic. For that reason moving estimate has been improved in RDT-CW, to get a better coherence with environmental movement field, and also to improve temporal continuity.

- NWP winds in low-mid levels and HRW AMV estimates are taken into account and blended to provide a movement “guess” field prior to cell tracking. Cold start cases and new or orphan cells can take benefit of this guess field for initiating a reliable movement diagnosis even without cloud cell tracking

- Then, in order to avoid non-representative or erratic speed estimate and in order to propose a useful forecast, the motion vector temporal coherence is checked against previous estimates, and again checked against guess field.

The resolution of forecast is 15 minutes whatever the time-resolution of satellite data input.

3.1.2.5 Additional and synthesis attributes of convective objects

3.1.2.5.1 Phase of development

RDT output product includes a specific attribute named "phase of life" or "phase of development", ranging from "triggering" (or "split") to "growing", "mature" then "decaying" values. This attribute is an attempt to diagnose the stage of development of the tracked cloud system, and is a mix between history, vertical development and activity of the cloud system.

The true development stage of a convective system is difficult to diagnose: conceptual models do not always spread over the same period of time, and depend on the way the convection is organized.

- This attribute was initially (IOP) exclusively based on cooling and expansion rates, but was very variable for a given cloud system from one slot to the other
- The following versions of RDT (v2009=>v2012) made this attribute rather correspond to vertical "categories", the "mature" label corresponding to the coldest one. The diagnosis was simpler, but stable.
- However, some developed cloud systems may reveal signs of variable and strong activity. It lead us to take again into account additional parameters linked to the activity of the system (expansion rate, cooling rate, lightning activity, overshoots) and get a more relevant and realistic diagnosis, which becomes a short mix of history, vertical extension and activity.

The tables below synthesize the modifications.

History	*Vertical category (based on Tmin)*	*Type*	*Encoded phase*
birth			***0 = Triggering***
Split			***4 = Triggering from a Split***
continued	***Warm***	***Conv***	***0 = Triggering***
		not Conv	*3 = decaying*
	Warm Transition	***Conv***	***0 = Triggering***
		not Conv	*3 = decaying*
	Warm transition2	***Conv***	***1 = growing***
		not Conv	*3 = decaying*
	Cold Transition	***Conv***	***1 = growing***
		not Conv	*3 = decaying*
	Mature		***2 = mature***

Table 1 - diagnostic of phase of development - V2009 => V2012

History	*Cooling*	*Vertical category (based on Tmin)*	*Expansion*	*Activity: Type, lightning, OTD*	***Encoded phase***
birth					***0 = Triggering***
Split					***4 = Triggering from a Split***
continued	*Cooling*	***Warm***			***1 = growing***
		Warm Transition			***1 = growing***
		Warm transition2			***1 = growing***
		Cold Transition			***1 = growing***
		Mature	*no expansion*		***2 = mature***
			expansion		***1 = growing***
	~same T°	***Warm***	*expansion*	*or **Conv** or Light.*	***1 = growing***
			no expansion +	*not Conv + no Light.*	*3 = decaying*
		Warm Transition	*expansion*	*or **Conv** or Light.*	***1 = growing***
			no expansion +	*not Conv + no Light.*	*3 = decaying*
		Warm transition2	*expansion*	*or **Conv** or Light.*	***1 = growing***
			no expansion +	*not Conv + no Light.*	*3 = decaying*
		Cold Transition	*expansion*	*or **Conv** or Light.*	***1 = growing***
			no expansion +	*not Conv + no Light.*	*3 = decaying*
		Mature			***2 = mature***
	Warming	***Warm***		*Lightning or (**Conv** and low warming)*	***1 = growing***
				else	*3 = decaying*
		Warm Transition		*Lightning or (**Conv** and low warming)*	***1 = growing***
				else	*3 = decaying*
		Warm transition2		*Lightning or (**Conv** and low warming)*	***1 = growing***
				else	*3 = decaying*
		Cold Transition		*Lightning or (**Conv** and low warming)*	***1 = growing***
				else	*3 = decaying*
		Mature		*Lightning or (**Conv** and low warming) or OTD*	***2 = mature***
				else	*3 = decaying*

Table 2 - Diagnostic of phase of development from V2013

Default configuration of RDT-CW handles those improvements. Nevertheless, if the user prefers the previous diagnosis based on vertical categories, it is possible to de-activate the modifications and return to the previous diagnostic, by changing one argument in the configuration file.

3.1.2.5.2 Severity

A new attribute has been added to RDT-CW output, in order to point to users, when possible, the most active convective cloud systems taking into account a set of characteristics. Four levels of activity (low, moderate, high, very high), very may be encoded, depending on the number of thresholds crossed by a set of parameters.

Most of parameters used for “activity” part of “phase of development” attribute are here taken into account, using various thresholds for estimating a level of intensity of this activity.

- Overshoot: (Y/N)
- Cooling rate:
  - Extreme (> 100°/h i.e. 25°/15’)
  - strong (> 50°/h i.e. 12°/15’)
  - moderate (> 20°/h i.e. 5°/15’)
- BTD trend (wv6.2-IR10.8): strong values (>20°/15’)
- Expansion rate: strong values (+100% / 15’)
- Lightning:
  - Intense (>50/15’)
  - moderate (>20/15’)
- Convective rain rate: strong values > 50mm/h

⇒

unknown

Low

Moderate

High

Very high

3.1.3 Description of RDT-CW outputs

The default output format of RDT-CW product is NetCDF. Nevertheless, for a matter of compatibility with operational and distributed interfaces and tools, and depending on user configuration, the previous BUFR format may still be produced **additionally**, being compliant with previous v2013 RDT version. Finally the additional Trajectory ASCII output has been maintained as an intermediate optional output, depending on user configuration .

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.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 PGEs …).

- The *vertical surface description part* lists for each cloud system pairs of threshold brightness temperature / 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 products for each given lead range. The maximum lead range may be configurable, but cannot exceed 1h. Forecast products are available each 15min. So there can be up to 5 output files produced, one for the analysis, and 4 for +15, +30, +45 and +60min lead ranges.

3.1.3.2 Previous BUFR output

This CDOP BUFR output format has been kept optionally available for compatibility purposes with operational visualization tools. In that case both NetCDF and BUFR output are produced.

The product is numerical data which depicts characteristics (spatial and time) and displacement information associated to RDT-CW cells. When provided in BUFR format, **operating the RDT needs a specific visualization tool**.

The BUFR format was described in the v2013 Interface Control Document n°3 of SAFNWC ([AD.12.]). The RDT-CW offers four BUFR encoding possibilities corresponding to different versions (1 to 4 for "BUFR" argument in RDT-CW model configuration file).

The initial version holds the full description of cloud cells (convective or not) without time series. The full RDT-CW operating needs to build time series from previous outputs, and to select convective ones.

The second version provides time series for three parameters (gravity center location, minimum temperature and lightning activity), allowing to make simpler the visualization tool development. This version also may allow to limit the BUFR description to RDT-CW objects discriminated as convective. This limitation leads to strongly reduce BUFR size.

The third version has BUFR structure closer to initial version (parameters time series are given up), but includes additional attributes. It offers the possibility to benefit from CT and CRR data with RDT-CW. Depending on cloud morphology, additional relevant area may be described through additional 2nd level cell (closer to cloud top tower). On user's request, output can be limited to significant cells: convective ones and/or electric and/or those associated with high rain rates. For newly significant cells, historical genealogy is provided through full description of previous cells , allowing to process time series for all parameters.

The fourth version of BUFR is very similar to the third one, the structure is almost identical. Overshooting tops are analyzed in RDT-CW. This version allow to encode a short description of overshooting tops for the corresponding cells. On user's request, output can be limited to significant cells, among which those with overshoot will be considered.

It is to note that this format does not handle new parameters developed for v2016: severity, lightning trend, top pressure trend …

3.1.3.3 CTRAJ intermediate output

The RDT-CW processes an intermediate output, CTRAJ, in ASCII format. This file describes all cloud trajectories ended during the time slot. 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.11.] 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 are available in repository "$SAFNWC/import/Aux_data/RDT-CW/files_for_discri":
    a. ConvCoeffRegr and ConvCoeffRegr_mask for MSG
    b. ConvCoeffRegr_5 and ConvCoeffRegr_5_mask for Rapid Scan

4. When optional additional BUFR output has to be implemented, user has to update the files "$SAFNWC/import/Aux_data/RDT-CW/RDT-CW_BUFR_table" , "$SAFNWC/import/Aux_data/RDT-CW/RDT-CW_BUFR_table_Nprod", "$SAFNWC/import/Aux_data/RDT-CW/RDT-CW_BUFR_table2" , "$SAFNWC/import/Aux_data/RDT-CW/RDT-CW_BUFR_table2_Nprod", , "$SAFNWC/import/Aux_data/RDT-CW/RDT-CW_BUFR_table3", and "$SAFNWC/import/Aux_data/RDT-CW/RDT-CW_BUFR_table4" if needed.
5. Ensure that the SEVIRI image file in HRIT format (mandatory input) is available in the directory $SAFNWC/import/Sat_data/. To process RDT-CW in real-time, the user has to refresh this file every 15 minutes with the most up-to-date data.
6. Ensure that the directory $SAFNWC/import/NWP_data has been provided with latest NWP multigrib 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.
7. 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 a kind of 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 analyze trends on various depth.
- 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.

3.3 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:

4. **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 when possible, optimal processing of RDT-CW will be obtained with the use of current VIS06, WV6.2, WV7.3, IR8.7 and IR12.0 channels.

5. **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 files 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.
- If additional BUFR output is requested by user, files "RDT-CW_BUFR_table*" are requested. They allow managing the version of BUFR descriptors for the RDT product suitable for the user. These files are delivered with the SAFNWC/MSG and have to be updated by the user. They have to be located in the $SAFNWC/import/Aux_data/RDT-CW directory. They allow the user to set the BUFR edition number, the version number of master tables used, the version number of local tables used, the code of the originating centre and the values of local descriptors defined in the RDT product (see the Interface Control Documents ICD/1 for the External and Internal Interfaces of the SAFNWC/MSG for more details on this file).

6. **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:

4. **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 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 compliant with either ARPEGE or ECMWF NWP data. Some parameters that are not available in one case 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 PGE19 are

- Instability indexes: previously computed and saved as DATABUF for other PGEs or recomputed by PGE19
- Tropopause temperature diagnosis: previously computed and saved as DATABUF for other PGEs or recomputed by PGE19
- 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.

5. 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) related to the processed satellite image and in accordance with the chosen values of the parameters "LGHDTANT" and "LGHDTPOST" of the model configuration file (see next section). More precisely, for a given SEVIRI slot:

- let D_{first} be the scanning time of the first pixel scanned by the SEVIRI radiometer in the processed region.
- let D_{last} be the scanning time of the last pixel scanned by the SEVIRI radiometer in the processed region.

Then, the lightning data file corresponding to this slot should include all the lightning data detected beetwen the times D_{first} – “-dt_light_before” and D_{last} + “-dt_light_after”.

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).

6. 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.

The quality of this pressure is also estimated from the number of pixels of the cloud system which are considered, and to their quality from CTTH product itself. More precisely, the quality takes into account CTTH_EFFECTIVE and CTTH_QUALITY parameters to select the pixels used for determining cloud top pressure:

7. 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

iii. the CT product is generated on the desired region and that:

iv. the parameter “CMa” 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:

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

iv. 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.

The quality of Cloud Type attribute is related to the number of pixels of the cloud system which are considered, and to their quality from CT product itself.

8. 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.

This integration is optional. In order to use the CMIC product as input to the RDT-CW software for masking clear pixels, 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 integration of the Cloud Phase value into the RDT-CW product is done as follows:

- 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 $1/5^{th}$ 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 Wateer Path (IWP) and Liquid Water Path (LWP) over cloud cell extension

Those microphysic parameters will be later used for estimating a risk index for High Altitude Icing.

The quality of Phase attributes is related to the number of pixels of the cloud system which are considered, and to their quality derived from CMIC product itself.

9. CRR 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 CRR 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

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

ii. the parameter “CRR” 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 CRR intensity over the cell’s horizontal extension.

The quality of rain rate attribute is related to the number of pixels of the cloud system which are considered, and to their quality derived from CRR product itself.

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 10mm/h. It can be customized through parameter “CRR” of the model configuration file

When the confidence in CRR product is good, it is also possible to “force” the convective diagnostic when rain rate exceeds a given threshold. The default threshold is 50mm/h. This option is activated only when the parameter “CRRDISCRI” is set to 1 in the model configuration file. The threshold can be customized with an argument greater than 1 to the parameter “CRRDISCRI”. This configuration has not been evaluated.

10. 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

i. The HRW product is generated on the desired region and that

ii. 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	200000.
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)
HRW	Flag for using (1) or not (0) HRW	integer	1 (yes)
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

Keyword	Description	Type	Default Value(s)
DBG	Flag for activating (1) or not (0) debug mode	integer	0
FCST	Maximum lead range for advected products– 0 (no advection), 15, 30, 45 or 60 (minutes)	integer	60
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 RDT-CW product	integer	1
BUFR	Number for activating or not (0) BUFR output. Number refers to version of RDT BUFR. Negative value means convective cells encoded only.	integer	0
NUMPROD	Optional production number for RDT-CW product	integer	
PHASE	Processing mode for phase of life attribute 0= v2009-v2012 approach (categories) 1= multisource approach	integer	1
CRRDISCRI	Convective Rain rate threshold for forcing discrimination – recommanded 50mm/h	float	Not activated
TROPICALDISCRI	Temperature threshold for forcing discrimination in tropical regions – recommanded -75°C	float	Not activated

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

3.4 RDT-CW VALIDATION

3.4.1 Summary of validation results

The validation of RDT-CW v2016 has been limited on case studies. No modification has been brought to the discrimination scheme. Thus, the discrimination skill processes on the previous version remains totally valid.

An objective validation of PGE11-RDT v2011 had been lead over Europe for summer and intermediate seasons (April to October). The lightning activity issued from EUCLID database has been used as ground truth.

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 RDT has also been validated on several case studies, and in real time configuration. It has been analyzed that PGE11 provides a convective classification stable in time. The discrimination algorithm is focused on convective period. The convective systems are de-classified in time during decaying phase, avoided the tracking of un-interest objects. The false alarms are well diagnosed after a short track (45 minutes).

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 diagnosed before lightning activity occurs.

3.4.2 Known problems and recommendation for use

The tuning have been carried out on summer period and focused on RDT objects associated with moderate to high electrical activity. The discrimination score during winter period could be weak, but 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**.

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 colored contour** which defines cloud system edges. The **color** of this contour is related to the phase of life of the system which is highly linked to its category (developing, transition, mature) and 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.

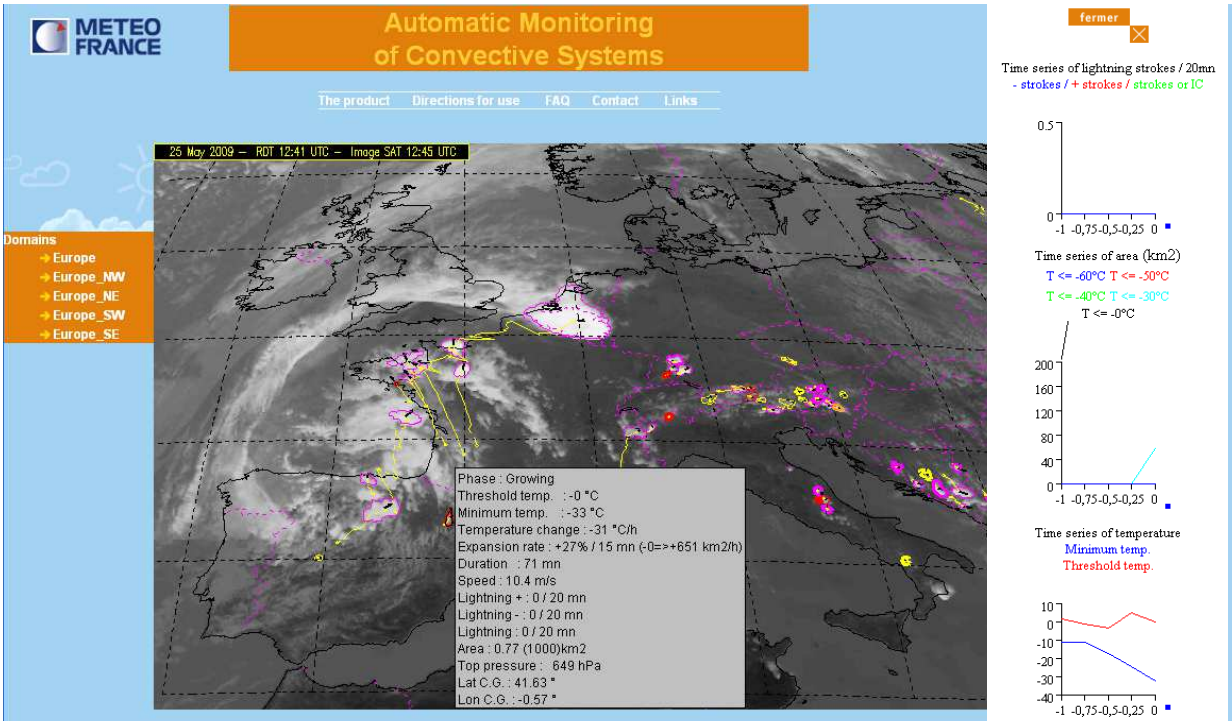


Figure 6: Example of product visualisation

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 simple visualization of additional parameters

Additional information appears in examples below on 1st visualization step, with an additional contour centred on top of cloud tower, a very interesting point for large systems.

On the 2nd visualization step, cloud type and phase attributes, and maximum rain rate are displayed in the popup window

The additional contour is also associated with dedicated parameters, which can be displayed in a dedicated popup window too.

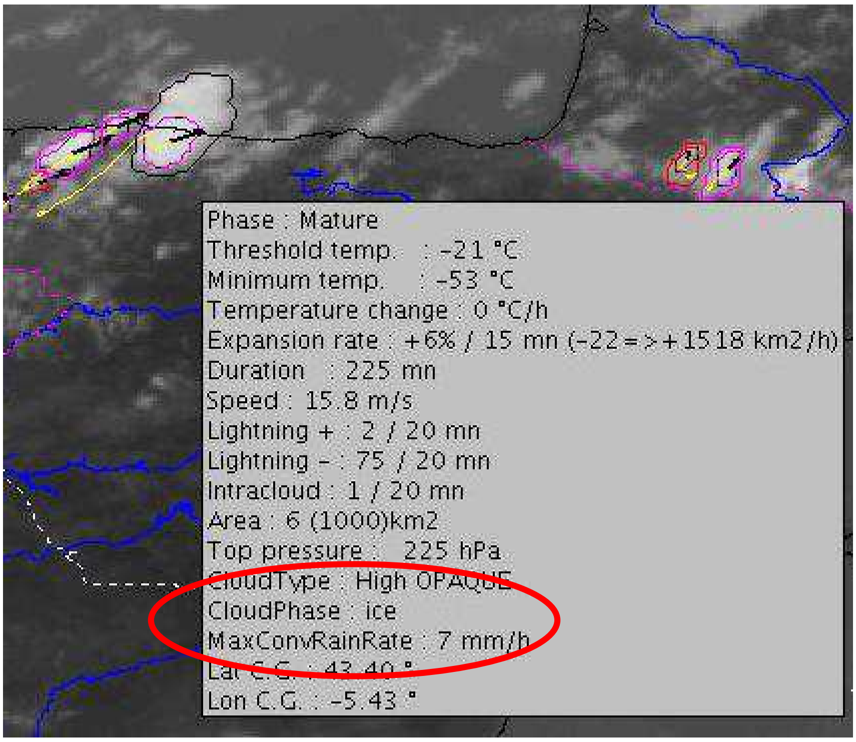


Figure 7: 15/09/2011 14h15. Example of RDT-CW product visualisation, with Cloud Type, Phase and Rain rate information.

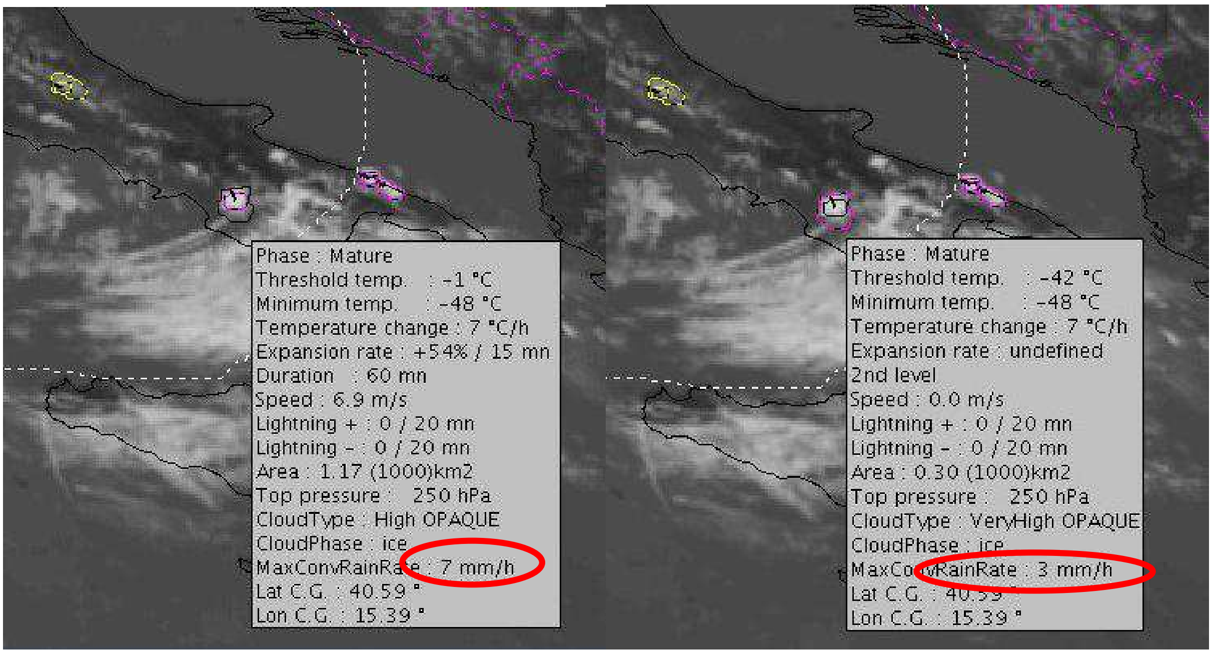


Figure 8: 13/09/2011 12h15. Example of RDT-CW product visualisation. Main cell (left) and 2nd level (right) attributes

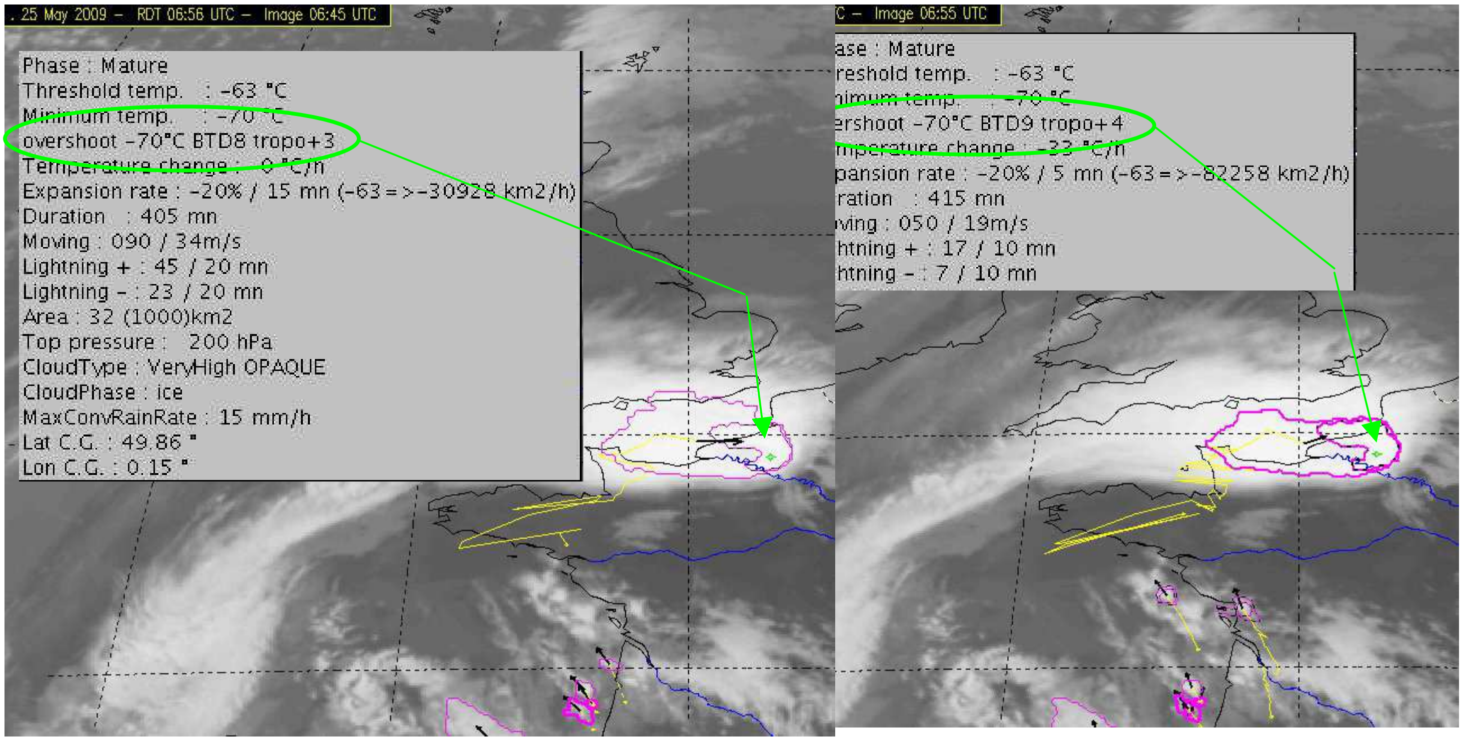


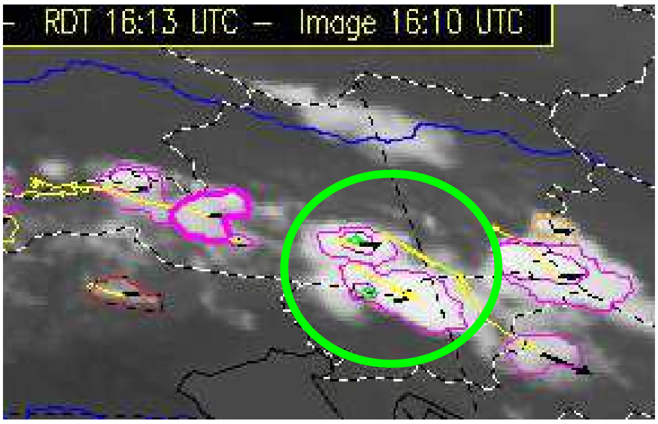
Figure 9: 25/05/2009 valid around 07 UTC: Example of v2013 RDT-CW product visualisation for MSG2 FDSS (left)- and MSG1 RSS (right). Main cell and 2nd level contours, main cell attributes, and overshoot localizations (green diamond)

Figure above illustrates the multi-dimensional approach of convection with RDT-CW for both nominal and rapid scan service. Please note that the identification and tracking of cells in RSS and FDSS are obviously slightly different because temporal-frequency differences influences recovery processing and dates of validity are not strictly the same. Nevertheless, the way the top of the system is characterized and represented is the same, whatever the examined attribute, 2nd level contour or overshoot.

The overshooting top has a very low temperature (-70°C) and is associated with a very high BTD (WV6.2-IR10.8) around 8/9 °C. The temperature difference between overshooting top and and ARPEGE NWP diagnostic of tropopause is moderate, but remains of interest.

One can note the near U-like shape of 2nd level contour.

Figure below illustrates for the same day a convective cloud system with two overshoots near Austrian-Slovenia frontier. The southern overshoot has a top temperature approaching -70°C but its other characteristics are not noteworthy (light BTD and moderate temperature difference between overshot and tropopause) The identification of this convective system through an enclosing contour as well as a quite different 2nd level, whose activity is confirmed by the detection of an overshoot, is a first step for a synthetic representation of significant objects.



Phase : Mature
Threshold temp. : -56 °C
Minimum temp. : -69 °C
overshoot -69°C BTD3 tropo+3
Temperature change : -22 °C/h
Expansion rate : +36% / 5 mn (-56=>+11383 km2/h)
Duration : 285 mn
Moving : 230 / 7m/s
Lightning + : 22 / 10 mn
Lightning - : 283 / 10 mn
Area : 4 (1000)km2
Top pressure : 175 hPa
CloudType : VeryHigh OPAQUE
CloudPhase : ice
MaxConvRainRate : 18 mm/h
Lat C.G. : 46.41 °
Lon C.G. : 14.71 °

Southern cell characteristics

Phase : Mature
Threshold temp. : -56 °C
Minimum temp. : -67 °C
overshoot -67°C BTD1 tropo+3
Temperature change : 33 °C/h
Expansion rate : +15% / 5 mn (-56=>+2479 km2/h)
Duration : 35 mn
Moving : 090 / 8m/s
Lightning + : 16 / 10 mn
Lightning - : 182 / 10 mn
Area : 1.56 (1000)km2
Top pressure : 175 hPa
CloudType : VeryHigh OPAQUE
CloudPhase : ice
MaxConvRainRate : 17 mm/h
Lat C.G. : 46.97 °
Lon C.G. : 14.38 °

Northern cell characteristics

Figure 10: 25/05/2009 valid around 16h15 UTC: Example of RDT-CW product visualisation for MSG1 Rapid Scan. Main cells and 2nd level contours, main cells attributes, and overshoot localizations (green diamonds)

3.5.3 Examples of visualization of forecast products

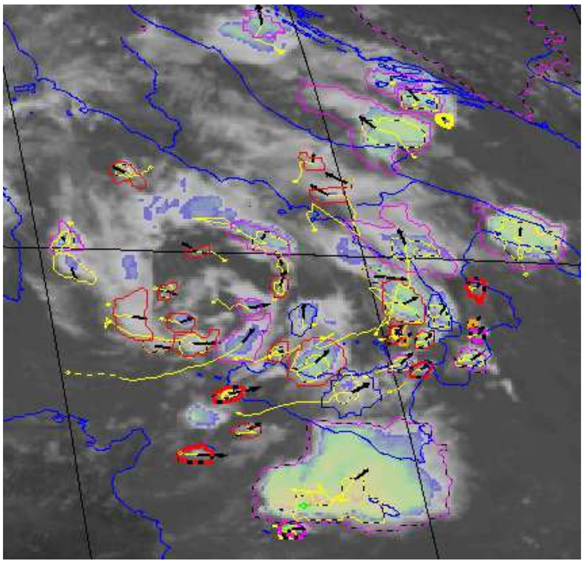
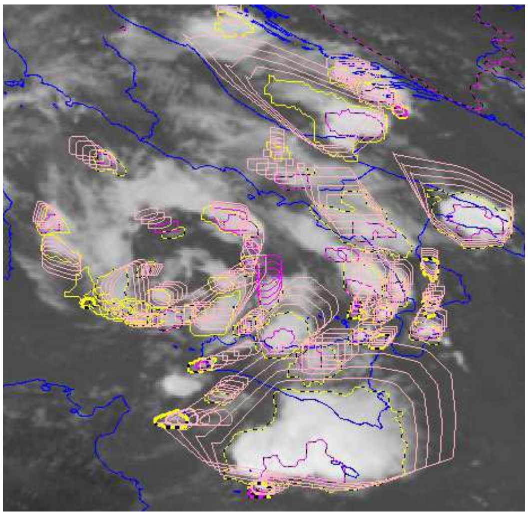
	
Analyzed RDT-CW cells with motion vectors	RDT-CW +15, +30, +45 and +60 smoothed and dilated forecast cells

Figure 11: 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 11, where smoothing and dilatation options have been activated. Even if those latter options may obviously insert a touch of uncertainty, they also can sometimes lead to excessive dilated contours when large cells are associated with high expansion rates. That's why RDT-CW default configuration file keeps those options non active.