Validation Report for "Rapid Development Thunderstorms" (RDT-PGE11 v3.0)

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REPORT SIGNATURE TABLE

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2.1	1 October 2009	19	No scientific updates. Adapted date, issue and rev. to v2010
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3.0	*15th July 2013*	46	Main results of validation applicable to v***2013*** (POD, FAR, precocity, etc.). Cases studies for overshooting tops detection, PGE11-RDT v2013 new attribute

Table of contents

List of Tables and Figures

1. INTRODUCTION

1.1 PURPOSE

The discrimination (see Glossary section 1.4) method of PGE11 identifies convective objects in the whole population of cloud cells.. This diagnosis is particularly useful over regions where lightning detection data are not available or reliable. Moreover, PGE11 aims to identify convective systems before lightning occurs. Thanks to discrimination scheme, PGE11 is more than a cloud-tracker. The tuning of PGE11-RDT discrimination scheme is necessary each time new input data are taken into account (additional channels, NWP data, etc.). Thus, the discrimination scheme is a key point of RDT algorithm and each change in discrimination scheme implies a new validation process, objective or subjective. If no modification is added to discrimination scheme, the validation relies on possible new case study and verification of new attributes of RDT.

Version 2009 of PGE11-RDT had been validated in an objective way in the following conditions (see *RD2*):

- ✓ Domain France
- ✓ Period June-August 2005
- ✓ Lightning Météorage data as verifying data (ground truth)

The validation over France only and over summer season only has been considered too restrictive. For that reason RDT-PGE11 was not qualified as fully operational. The most recent PGE11-RDT discrimination tuning has been undertaken for version 2011, the main improvement compared to version 2009 is the use of NWP data. NWP data help to eliminate stable areas and provide predictors to statistical scheme. This tuning has used French lightning data of the 2008 and 2009 summer seasons.

The extended objective validation of RDT has been undertaken for v2011, with following characteristics:

- ✓ Domain Europe
- ✓ Period June-August 2008 and April-October 2009
- ✓ Lightning EUCLID data as verifying data (ground truth)

The validation period was not the same as the tuning period, which is a good point in a statistical point of view.

Validation results of v2011 are fully applicable to the following releases up to v*2013* because the discrimination scheme hasn't change.

Subjective validation of the latest versions are illustrated by some case studies. The aim is focus on additional characteristics of RDT.

1.2 REQUIREMENTS

Skill requirements had been expressed in PRD Table for RDT (see *RD1*). Target accuracy were mainly fixed for precocity (see Glossary section 1.4):

25% of convective cloud systems diagnosed before first lightning occurrence

50% % of convective cloud systems diagnosed 30min after first lightning occurrence

70% of thunderstorms diagnosed

Those objectives were initially expressed with a corresponding POFD of 1%, in the initial conditions of distribution of convective and non convective populations of cloud cell trajectories (see Glossary section 1.4, and section 2.2).

1.3 Scope of the document

The assessment of discriminating accuracy is very sensitive to numerous parameters such as statistical criteria chosen, ground truth, season, area, etc. Therefore, the document is divided into three parts.

The first chapter briefly describes the input data necessary to this validation

The second one details the methodology of validation and the different hypothesis made to draw up the score tables

The third one presents the discrimination skill of RDT version 2011 processed on the complete validation database, compares validation skills to the previous one (v2009), and evaluates the skills for different region and period.

1.4 Glossary, Acronyms and Abbreviations

1.4.1 Glossary

Cell	PGE11 "object" representation of a Cloud system in a satellite image
Convective mask	Identification of stable/ neutral/unstable/ areas from NWP data. Used by PGE11 to ignore stable areas
Detection	PGE11 algorithm that identifies cloud cells in IR10.8 image
Detection Mask	Mask derived from EUCLID data detection in order to define validation area and ignore trajectories out of these area
Discrimination	PGE11 diagnosis process to distinguish convective systems from the others
Flash proximity	Distance to nearest electric flash for non convective systems
Overshooting Top	Budding of a convective system rising above tropopause level, generally associated to a strong updraft activity
Precocity	Capacity of PGE11 to diagnose the convection before the first flash appears
Section	Period of a cloud cell trajectory defined from the lightning activity.
Time step	Elementary time-element of a given satellite image (15 minutes for FDSS).
Tracking	PGE11 process that associates cloud cells in two successive images
Trajectory	Ensemble of temporal-linked cloud cells representing the whole life cycle of a given cloud system

1.4.2 Acronyms and Abbreviations

BTD	Brightness Temperature Difference
EUCLID	European Cooperation for LIghtning Detection
FAR	False alarm rate
GOES	Geostationary Operational Environmental Satellite
MSG	Meteosat Second Generation
OT(D)	Overshooting Top (Detection)

POD	Percentage of detection
POFD	Percentage of false detection
RDT	Rapid Development Thunderstorms
SEVIRI	Spinning Enhanced Visible and InfraRed Imagery
TS	Threat score

1.5 REFERENCES

1.5.1 Applicable Documents

Reference	*Title*	*Code*	*Version*
[AD.1.]	*Algorithm Theorical Basis Document*	*SAF/NWC/CDOP/MFT/SCI/ATBD/11*	*3.0*
[AD.2.]	*Product Use Manual*	*SAF/NWC/CDOP/MFT/SCI/PUM/11*	*3.0*
[AD.3.]	*Interface Control document for the External and Internal Interfaces*	*SAF/NWC/CDOP/INM/SW/ICD/1*	*2011*
[AD.4.]	*Interface Control Document for the input and output data formats*	*SAF/NWC/CDOP/INM/SW/ICD/3*	*2011*
[AD.5.]	*Software User Manual for the SAFNWC/MSG Application, Software Part*	*SAF/NWC/CDOP/INM/SW/SUM/2*	*2011*

Table 1: List of Applicable Documents

1.5.2 Reference Documents

Reference	*Title*	*Code*	*Version*	*Date*
RD1	NWCSAF Product Requirements Document	SAF/NWC/CDOP/INM/MGT/PRD	*1.2*	*17/11/2011*
RD2	Validation Report for "Rapid Development Thunderstorms"		*2.2*	*31/01/2011*

Table 2: List of Referenced Documents

2. VALIDATION DATA

2.1 ELECTRIC EUCLID DATA

Those data concern stroke returns of Cloud-to-Ground flashes, collected from several interconnected national lightning detection networks over Europe.

Available parameters are: time of the event, impact point coordinates (Latitude and longitude), Current intensity and polarity.

Database has been explored to assess the geographical and temporal coverage of the data.

The requested period is fully covered, with high continuity, as illustrated for example in the figure below for summer 2008.

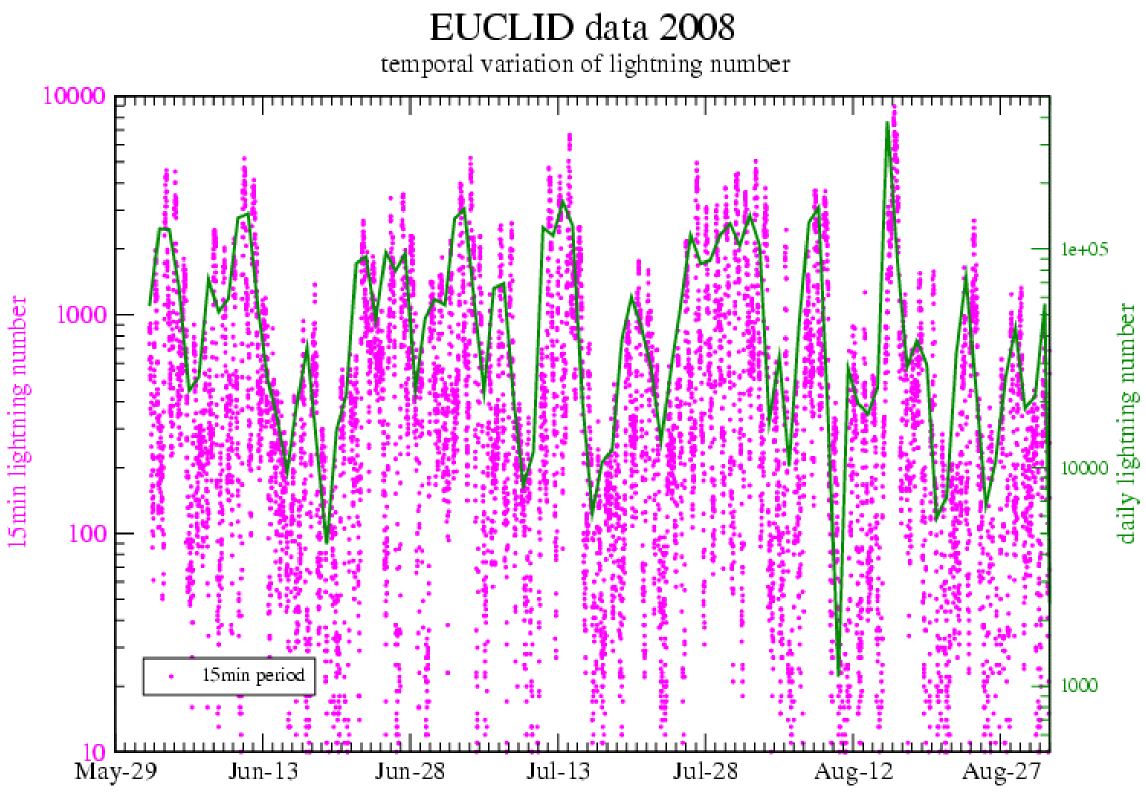


Figure 1: June-August 2008 - Temporal series of lightning impacts, cumulated over 15min (pink) or daily (green)

On the other hand, monthly and total density charts have pointed the most active areas, as well as the lack of coverage (following figure).

There are very few data over United Kingdom. Network at the time of validation were sparser than nowadays (cf EUCLID source). Consequently, although in the present nominal coverage area (see Annex I), this area has to be considered carefully when lightning data is used as ground truth (a lightning detection weakness should lead to bad scores for RDT).

The Iberic peninsula shows also a relatively weak electrical activity over the period, but no additional element allows ignoring this region. We have assumed that EUCLID data are representative of a rather low convective activity during 2008 and 2009 periods over this region.

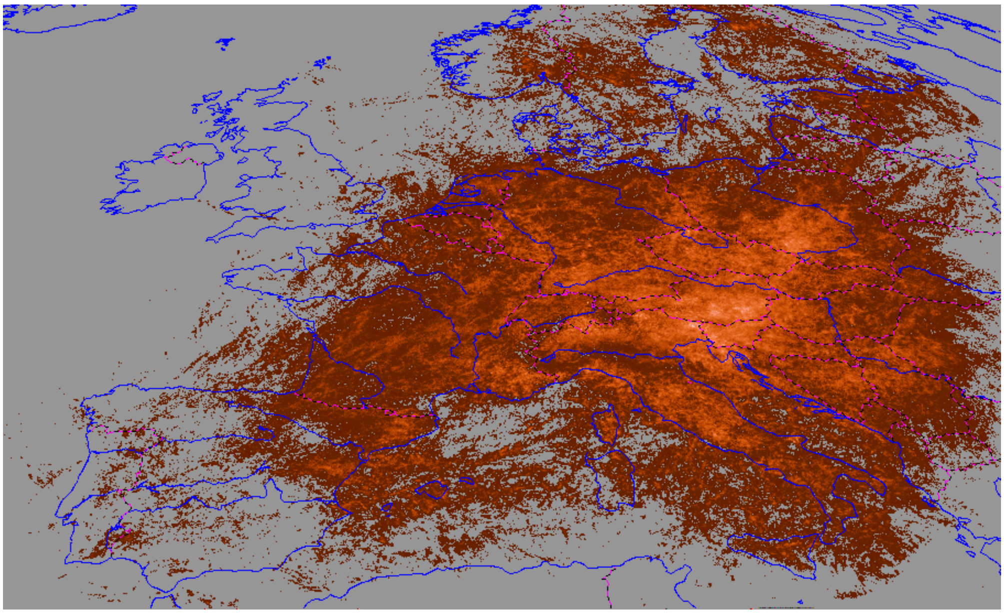


Figure 2: Total geographical density (nb / pixel) of EUCLID lightnings over customized region (summer 2008 + April-October 2009)

This exploration lead to define a new domain for the validation, as the intersection between EUCLID coverage data and local MSG archived data.

Moreover, a mask of non-detection has also been defined, merged from nominal detection area (see Annex I) and the observed availability of data over the period. This mask allows ignoring suspicious areas (from detection point of view) in the validation process.

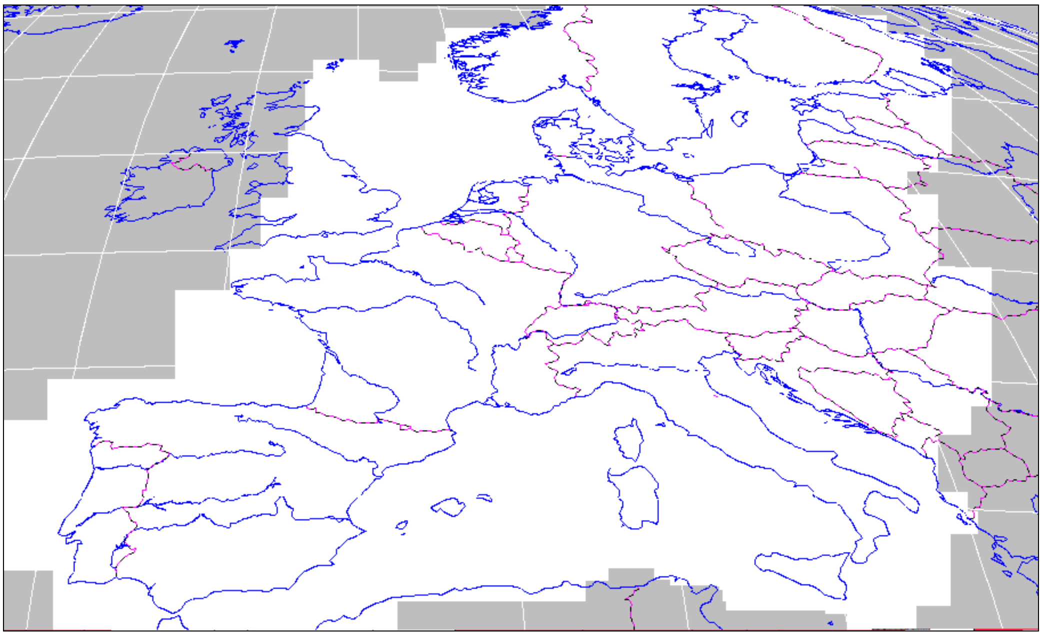


Figure 3: Domain and detection mask defined and applied for validation purpose

2.2 RDT CLOUD TRAJECTORIES

Validation needs Cloud cell trajectories, processed over the period and the domain described above. A trajectory aggregates all RDT objects linked in time. PGE11-RDT Discrimination diagnosis is activated for each cloud cell using satellite information only, and a passive matching with lightning data is undertaken at this stage for further evaluation.

Concerning the matching between cloud cells and lightning flashes, some limitations have to be taken into account: on one side, the lightning location is limited to cloud to ground flashes strokes; on the other side, the RDT object depicts cloud tower and not the whole cloud system. Thus, some matching misses between lightning data and cloud object are possible. Thus, a spatial tolerance of about 10 km has been taken into account, and a proximity distance to the nearest flash evaluated.

An illustration of the process result is proposed below, by comparing lightning and cloud cell data. The figure describes:

- Total lightning number over the region for each slot, number of paired flashes (association lightning – cloud cell), number of orphan flashes (despite a 10 km spatial tolerance), number of flashes out of domain or temporal range (slot ± 8min)
- Total number of detected and tracked cloud cells, number of convective RDT-diagnosed cells, and repartition of total cloud cell number against NWP convective environment (result of NWP guidance)

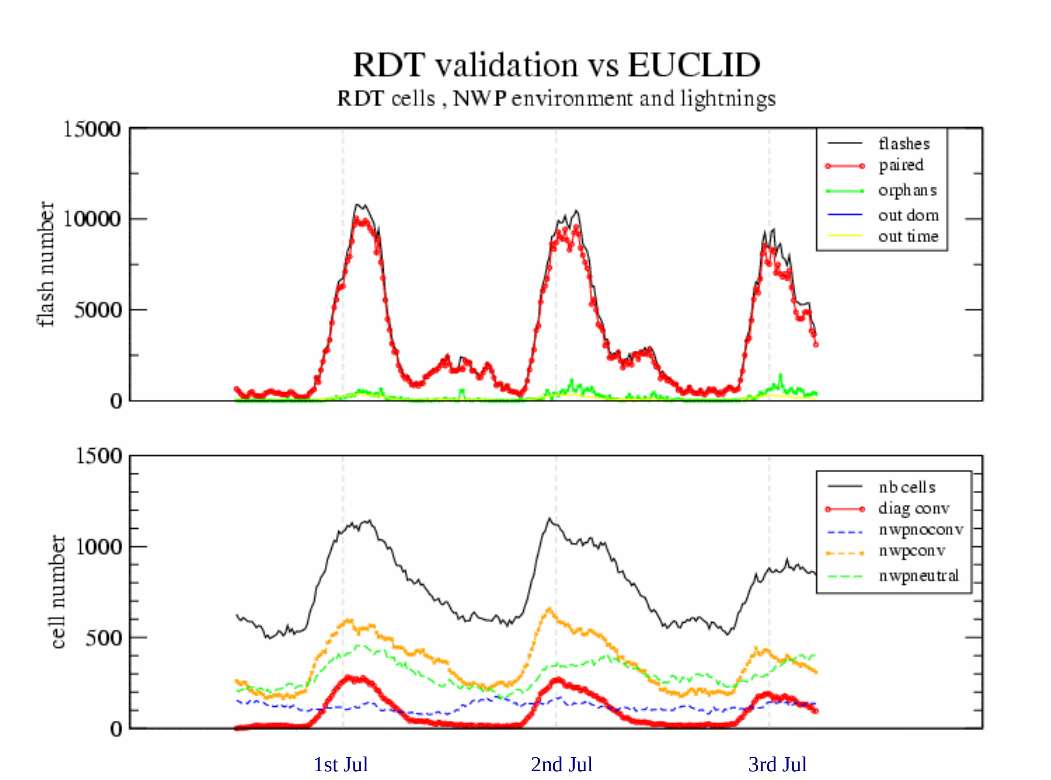


Figure 4: Example 1-3rd July 2009. Total, paired and orphans lightning number for each slot (top). Total and convective Cloud cell number for each slot (bottom)

3. VALIDATION METHODOLOGY

The validation process relies on a detailed analysis of the electrical activity of cloud trajectories. This electrical activity analyzed over the life of the cloud systems constitutes the "ground truth".

3.1 THE GROUND TRUTH

3.1.1 The Ground truth for trajectories

The definition retained to identify a trajectory as "observed" convective or non-convective is seen globally as a first step, based on the total number of flashes strokes paired during the whole RDT object life.

In order to ignore eventual less reliable cases due to wrong matching, several level of intensity are considered. Three levels of ground truth have been defined:

- **Low**: a trajectory is assumed convective if it is matching with one flash stroke at least
- **Moderate**: a trajectory is assumed convective if it is matching with 5 flashes strokes at least
- **Severe**: a trajectory is assumed convective if it is matching with more than 20 flashes strokes, and if it reveals a continuous activity

Considering a higher intensity for ground truth implies

- that the number of trajectories observed as convective decreases
- that the number of undetermined trajectories, which are not enough electrically active, increases.

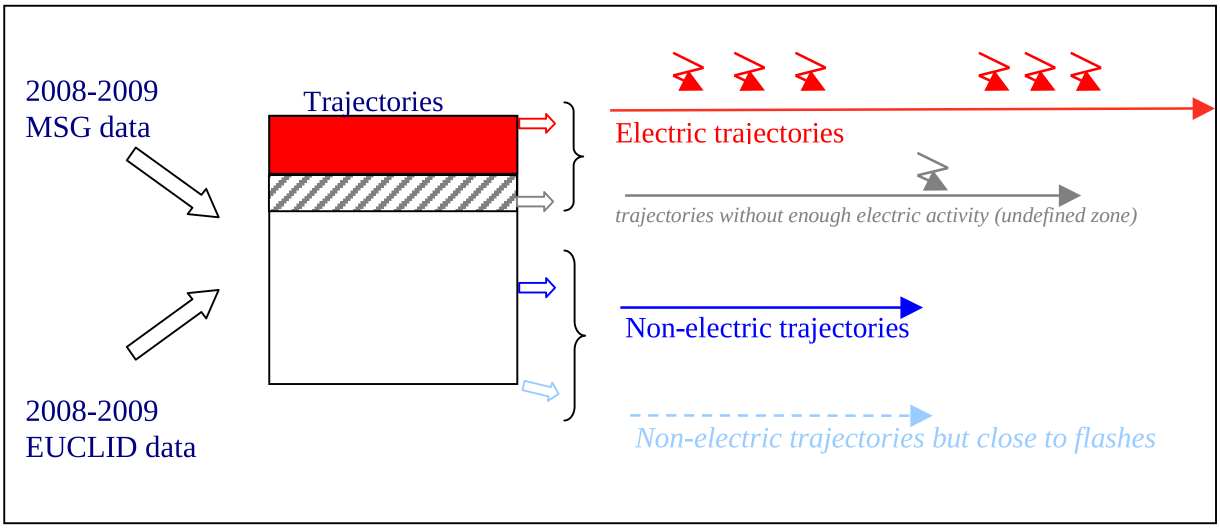


Figure 5: Full-trajectory approach. Population are split considering ground truth and flashes proximity

When the level is fixed at "low", there is no undetermined trajectory. When the level is fixed at "severe", the number of undetermined trajectories is maximum. The trajectory without lightning activity are assumed non convective. Indeterminate trajectory are eliminated of the validation

Here again the uncertainty of cloud-flash matching may be taken into account, by the use of distance to nearest flash (called here **proximity to flashes**). Some cumuliform cloud systems are in the nearest of active thunderstorms but do not degenerate themselves to thunderstorms. Do these clouds have to be considered as convective or not ? Depending on the sense given to a False Alarm (would in that case a RDT convective diagnosis be unacceptable?), it can be useful to ignore ambiguous non-electric trajectories close to flashes. Several levels of filters (distance to flashes) have been evaluated.

3.1.2 Detailed analysis of activity on sections and time steps

This full-trajectory ground truth does not take into account the variability of electric activity, neither its time of occurrence. An assessment of RDT discrimination with this approach allows providing only gross scores. Moreover, it neglects the synchronicity between RDT discrimination and lightning occurrence. A similar limitation appears at finest time scale if we consider each single moment of a trajectory independently of the others.

In order to focus on most active periods of cloud systems or on precocity characteristics prior to first flashes, a more conceptual approach is necessary.

A ground truth is here defined closer to convective periods. The cloud trajectories will be cut in several homogeneous periods, depending on the occurrence, intensity and continuity of electrical activity.

3.1.2.1 Definition of sections and time steps

The lightning activity is not permanent on an electric (or undefined) trajectory. Six kinds of homogeneous periods may be defined as sections and time steps:

- Black: first non-electric period of an electric trajectory, preceding first flash of more than one hour.
- Green: The precocity section. Non-electric period of 1 hour, preceding an electric period. The length of this period is empirically sized to include the growing stage of convective systems.
- Red: The electric section. Electrically active period including all time steps continuously electric or surrounded by electric time steps spaced out of less than 45 minutes. The lapse time of 45 minutes corresponds to the pre-supposed validity of convective diagnosis in the PGE11 code, beyond which a de-classification test is undertaken.
- Orange: The decaying section. Non-electric period of 45 minutes following an electric period (same remark as above concerning the value of 45 min). Its duration could be reduced in advantage to another following precocity section.
- Violet: The intermediate section. Non electric period between two electric sections excepted precocity and decaying section.
- Gray: last non electric period following the last decaying section.

A non-electric trajectory can define only one kind of section and time steps:

- Yellow: unique non electric period of a non electric trajectory

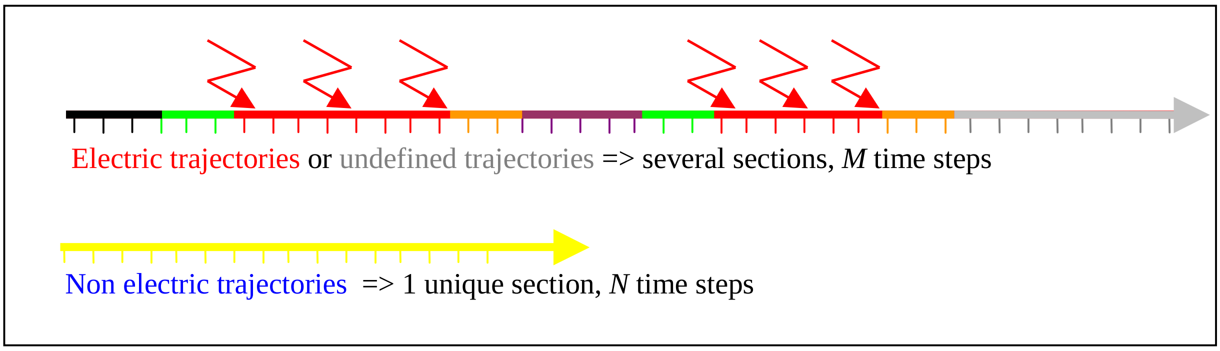


Figure 6: Section and time step examples for an electric trajectory (top) and for a non electric trajectory (bottom)

3.1.3 Conclusion on ground truth

The statistical elements evaluated in this report will be either the whole life cycle duration (so called "trajectory"), a part of this life cycle (so called "section"), or a single moment of the cloud cell life cycle (so called "time step"). Those elements have to be examined against RDT diagnosis.

- Convective "observation" for Trajectory elements = full-trajectory ground truth (total electric activity)
- Convective "observation" for Section elements = "colour" of the section
- Convective "observation" for Time step" elements = "colour" of the corresponding section

3.2 RDT DIAGNOSIS OF STATISTICAL ELEMENTS

The PGE11-RDT discrimination scheme allows a convective diagnosis for each detected and tracked cloud cell, i.e. for each time step. This diagnosis is the result of a statistical model, or is inherited from previous diagnosis.

- RDT Diagnosis for Time step element = result of discrimination scheme (type of cell)

Concerning sections of trajectories, all RDT diagnosis of all time steps of a section have to be taken into account. A convective diagnosis of a single cell at any given time of this section will apply the whole section that cell belongs to.

- RDT diagnosis for Section element = convective if at least one time step of section has convective RDT diagnosis, non convective in other case

As for section elements, all RDT diagnosis of all time steps of a trajectory have to be taken into account. A convective diagnosis of a single cell at any given time will apply to the entire trajectory of that cell.

- RDT diagnosis for Trajectory element = convective if at least one time step of trajectory has convective RDT diagnosis, non convective in other case

3.3 EVALUATION METHODOLOGY

3.3.1 Full trajectory approach

In this case, RDT diagnosis is directly assessed against YES or NO electric characteristics, while these characteristics are modulated with the ground truth intensity or the flashes proximity.

This leads to contingency tables, from which POD, POFD, FAR or other skills can be derived.

	Convective « Observed »	Non convective « Observed »
Convective diagnosis	Good Detection: **GD** *Trajectory*: electric	False Alarm: **FA** *Trajectory*: non electric
Non convective diagnosis	Miss: **MI** *Trajectory*: electric	Correct Rejection: **CR** *Trajectory*: non electric

Probability of detection (hit rate): POD= GD/(GD+MI)

Fraction of the observed "yes" events correctly forecast
Characteristics: Range: 0 to 1. Perfect score: 1. Sensitive to hits, but ignores false alarms. Very sensitive to the climatological frequency of the event. Good for rare events. Can be artificially improved by issuing more "yes" forecasts to increase the number of hits. Should be used in conjunction with the FAR Source : The Centre for Australian Weather and Climate Research, http://www.cawcr.gov.au/projects/verification/).

False alarm ratio : FAR= FA/(GD+FA)

Fraction of the predicted "yes" events which did not occur (i.e., were false alarms)
Characteristics: Range: 0 to 1. Perfect score: 0. Sensitive to false alarms, but ignores misses. Very sensitive to the climatological frequency of the event. Should be used in conjunction with POD.

Probability of false detection (false alarm rate) POFD= FA/(FA+CR)

Fraction of the observed "no" events incorrectly forecast as "yes"
Characteristics: Range: 0 to 1. Perfect score: 0. Sensitive to false alarms, but ignores misses. Can be artificially improved by issuing fewer "yes" forecasts to reduce the number of false alarms.

Threat Score : TS= GD/(GD+FA+MI)

Combination of hits, false alarms and misses
Characteristics: Range: 0 to 1. Perfect score: 1. Sensitive to false alarms and misses. Relatively frequently used because a more balanced score. Somewhat sensitive to the climatology of the event, tending to give poorer scores for rare events.

In order to increase the readability of the report, the numbers associated to the scores will be listed in percentage (%).

3.3.2 Section and time steps approach

In this case, diagnosis is assessed against the « color », which represents the "observed" characteristic. Here again, this can be modulated upon ground truth intensity (ignoring some electric trajectories, and corresponding sections and time steps) and/or flashes proximity (ignoring some non electric trajectories, and corresponding sections and time steps).

But precocity and decaying sections, even if non electric, must not be systematically considered as non convective « observed »:

- Example 1: a convective RDT diagnosis during precocity (green) section is an early alert (goal of RDT product), and must not be seen as a false alarm. But a non-convective RDT diagnosis may correspond to a further late or missed diagnosis depending on following elements' characteristics
- Example 2: a convective RDT diagnosis in a decaying (orange) section may either be a late diagnosis or a coherent continuous diagnosis, never a false alarm. A non-convective RDT diagnosis should be seen as a correct rejection, except if none previous convective diagnosis had been issued.
- Example 3: black, violet, or grey sections can on the contrary be considered as non convective, when coherent behaviour of RDT diagnosis has to be assessed

Thus, following hypothesis have been considered for sections and time steps contingency tables:

1. H1: only red or yellow sections and time steps are taken into account for RDT quality assessment, thus focusing on electrical activity only
2. H2: green and orange sections and time steps discriminated as convective are considered as good detections. They are considered as correct rejection if discriminated as non convective. Thus, higher tolerance is given to convective diagnosis: green and orange are always correct
   Black, violet or grey sections and time steps are considered as non convective
3. H3: green and orange sections and time steps discriminated as convective are considered as good detections. They are considered as misses if discriminated as non convective. Thus, skills depend on precocity performance of RDT diagnosis.
   Black, violet or grey sections and time steps are still considered as non convective

H1 hypothesis	Convective « Observed »	Non convective « Observed »
Convective diagnosis	Good detection: **GD** *Sections and time steps*: red	False Alarm: **FA** *Sections and time steps*: yellow
Non convective diagnosis	Miss: **MI** *Sections and time steps*: red	Correct rejection: **CR** *Sections and time steps*: yellow

H2 hypothesis	Convective « Observed »	Non convective « Observed »
Convective diagnosis	Good detection: **GD** *Sections and time steps*: red + (green, orange)	False Alarm: **FA** *Sections and time steps*: yellow + (black, violet, grey)
Non convective diagnosis	Miss: **MI** *Sections and time steps*: red	Correct rejection: **CR** *Sections and time steps*: yellow + (green, orange) + (black, violet, grey)

H3 hypothesis	Convective « Observed »	Non convective « Observed »
Convective diagnosis	Good detection: **GD** *Sections and time steps*: red + (green, orange)	False Alarm: **FA** *Sections and time steps*: yellow + (black, violet, grey)
Non convective diagnosis	Miss: **MI** *Sections and time steps*: red + (green, orange)	Correct rejection: **CR** *Sections and time steps*: yellow + (black, violet, grey)

In order to illustrate those different approaches and hypothesis, a detailed example of electric trajectory analysis for RDT diagnosis assessment is given in Annex II.

4. DISCRIMINATION SKILLS

4.1 CONTINGENCY TABLES

4.1.1 Extended domain and period

Statistical element			Trajectory	Section			Time step (cell)		
Hypothesis				H1	H2	H3	H1	H2	H3
Low lightning activity	Population	Conv	40351	46400 (red) 34841 (green) 32184 (orange) 11771 (black) 15958 (grey) and 1350 (violet)			249940 (red) 97368 (green) 81449 (orange) 77981 (black) 124054 (grey) and 8018 (violet)		
		NoConv	292544	292544 (yellow)			2653671 (yellow)		
	Score	POD	61	52	66	40	57	63	42
		POFD	3.5	3.5	4	4.5	1	1.5	1.5
		FAR	29	29	26	26	18	20	20
		TS	49	43	54	34	50	54	38
Moderate lightning activity	Population	Conv	26079	30853 (red) 21566 (green) 19720 (orange) 6155 (black) 9731 (grey) 1127 (violet)			220241 (red) 57789 (green) 50875 (orange) 38494 (black) 79466 (grey) 6860 (violet)		
		NoConv	292544	292544 (yellow)			2653671 (yellow)		
	Score	POD	74	66	77	49	60	65	50
		POFD	3.5	3.5	4	4.5	1	1.5	1.5
		FAR	34	33	28	28	19	20	20
		TS	53	50	59	40	53	56	44
Severe lightning activity	Population	Conv	17066	20146 (red) 13268 (green) 12329 (orange) 3481 (black) 6413 (grey) 751 (violet)			183681 (red) 35025 (green) 32380 (orange) 21408 (black) 54648 (grey) 4778 (violet)		
		NoConv	292544	292544 (yellow)			2653671 (yellow)		
	Score	POD	81	75	83	55	65	69	56
		POFD	3.5	3.5	4	4.2	1	1.4	1.4
		FAR	42	40	33	33	21	21	21
		TS	51	50	58	43	56	58	48

Tab 1: RDT v2011 Discrimination skill table over Europe for full period (June-August 2008 + April-October 2009)

Results are firstly analysed on full validation domain for the complete period. There are presented in the table above for the three levels of ground truth, and for the three hypothesis concerning sections and time steps.

The sensitivity of score values depending on the various cases or approaches is discussed here.

The unbalance between "observed" convective and non-convective trajectory population is around 10%: from 9% and 6% for high intensities of ground truth to 14% for lower intensities. A comparable ratio can be observed in section and time steps approaches. This limited unbalance gives more reliability to the results.

Considering the dependency of scores on ground truth intensities, it can be noted that:

- POD increases with ground truth intensity, especially for trajectories and sections elements
- FAR increases with ground truth intensity,
- TS is minimum for low lightning activity.

Considering the dependency of scores on hypothesis for assessing sections and time step RDT discrimination, it can be noted that:

- H2 exhibits logically better scores, due to the tolerance given to precocity and decaying sections
- H3 POD differs from H2 ones: when the number of precocity sections diagnosed as convective is not high, POD is low
- Variations between H1 and H2 scores are less stressed, with lower POD, POFD and TS and higher FAR

Considering various statistical elements for a given ground truth, moderate for example, it can be noted that:

- POD and TS are both comparable between trajectories and sections, FAR are a little bit lower with section approach
- FAR is much lower for time steps (cells). POD is also lower. TS does not vary between sections and time step approaches. Despite a comparable ratio between convective and non convective populations, POFD is much lower for this approach

As a first analysis of these results, we can note that the section approach, which is close to the real time use of RDT product, exhibits very good results with a limited FAR and satisfying POD and TS. The results remain correct at trajectory time scale. When comparing with time step scores, better POD and TS has associated to higher FAR.

The moderate ground truth, represents a reliable "observation" point of view, ignoring less active cloud systems.

We consider that RDT follow the requirements .

4.1.2 Impact of the extension of the validation period on scores

The behaviour of RDT v2011 during intermediate seasons can be evaluated by the comparison of scores elaborated over the full validation period (June-August 2008 + April-October 2009, see par 4.1.1) and the results obtained below on summer months only (summer 2008+2009).

Statistical element			Trajectory	Section	Time step (cell)
Low lightning activity	Population	Conv	40351 ⬂ 28753		
		NoConv	292544 ⬂ 171390		
	Score	POD	61⬀63	66⬀68	63⬀64
		POFD	3.5⇨3.5	4⇨4.5	1.5⇨1.5
		FAR	29⬂27	26⬂24	20⬂18
		TS	49⬀51	54⬀56	54⬀56
Moderate lightning activity	Population	Conv	26079 ⬂ 19127		
		NoConv	292544 ⬂ 171390		
	Score	POD	74⬀75	77⬀78	65⬀66
		POFD	3.5⇨3.5	4⇨4.5	1.5⇨1.5
		FAR	34⬂31	28⬂27	20⬂18
		TS	53⬀56	59⬀61	56⬀57
Severe lightning activity	Population	Conv	17066 ⬂ 12799		
		NoConv	292544 ⬂ 171390		
	Score	POD	81⬀82	83⇨83	69⇨69
		POFD	3.5⇨3	4⇨4.5	1.4⇨1.5
		FAR	42⬂38	33⬂31	21⬂19
		TS	51⬀54	58⬀60	58⬀59

Tab 2: RDT v2011 Discrimination skill Table over full period (left green figures) vs summer period (right red figures), H2 hypothesis for sections and time steps. Arrows illustrate the changes (increasing, stable, decreasing) of the results between two periods.

On can note a light but very limited improvement of false alarms scores: the gain is limited to a maximum of 2 points when the assessment of PGE11-RDT discrimination is limited to summer period. TS takes benefit of the gain in FAR.

A consequence is that ***the behaviour of RDT is quite good, relatively homogeneous and comparable whatever the months selected for the validation even*** with an increase of unbalance between convective/non convective population with an extended period of validation (about 50% more non electric cases vs 30% more electric).

The explanation of this good result is ***due to the use of NWP as guidance*** by PGE11, which prevents diagnosis attempt on "uninteresting" areas like for example frontal zones. Those zones revealed in the past some false alarms cases, which has been a limit to the use of RDT product during intermediate seasons.

4.1.3 Impact of the extension of validation area on scores

In this part, we compare our result with the results of the previous validation. The differences between the two validations exercises are

- The version of RDT (v2009 / v2011)
- The domain (France / Europe)
- The period: always summer but 2008+2009 in one case and 2005 in the other

Considering the results above and our experience of RDT behaviour, we consider that the main impacts we will have to analyse will come from differences of version of RDT.

Statistical element			Trajectory	Section	Time step (cell)
Low lightning activity	Population	Conv	28753⇖ 4988		
		NoConv	171390⇖ 62180		
	Score	POD	63⇖47	68⇖55	64⇖55
		POFD	3.5⇖2	4.5⇖2	1.5⇖1
		FAR	27⇙36	24⇙30	18⇙24
		TS	51⇖37	56⇖44	56⇖47
Moderate lightning activity	Population	Conv	19127⇖ 2496		
		NoConv	171390⇖ 62180		
	Score	POD	75⇖66	78⇖71	66⇖59
		POFD	3.5⇖2	4.5⇖2	1.5⇖1
		FAR	31⇙44	27⇙36	18⇙25
		TS	56⇖43	61⇖50	57⇖49
Severe lightning activity	Population	Conv	12799⇖ 1354		
		NoConv	171390⇖ 62180		
	Score	POD	82⇖78	83⇖81	69⇖64
		POFD	3⇖2	4.5⇖2	1.5⇖1
		FAR	38⇙56	31⇙45	19⇙29
		TS	54⇖39	60⇖47	59⇖50

Tab 3: RDT Discrimination skill Table for summer periods v2011 over Europe (red figures) vs v2009 over France (grey figures) only. H2 hypothesis for sections and time steps. Arrows illustrate the changes (increasing, stable, decreasing) of the results between two domains

The much better behaviour of PGE11-RDT v2011 than v2009 appears here in all cases: PODs are strongly increased (about 10 points for light or moderate activity, except for severe ground truth), false alarms strongly reduced (sometimes more than 10 points!), TS much largely increases.

Looking at observed population numbers, it appears that the unbalance convective/non convective was much marked with the previous validation: the ratio was [8%, 4%, 2%] for various ground truth, the ratio are [16%, 11%, 7%] for this validation. We propose the following explanation: the NWP convective mask (see ATBD) filters the non convective systems to consider. This filter explains higher POFD when v2011 is compared to v2009. Regarding the slight increase of POFD with the strong decrease of FAR, skills exhibit an high improvement of RDT behaviour: there are less false convective diagnosis, even if those represent a larger proportion of non convective observed trajectories.

RDT discrimination of v2011 shows a much better behaviour than discrimination of v2009, with scores largely beyond the requested requirements.

4.1.4 Impact of changes in flashes proximity on scores

As referred into previous paragraph, the ground truth that we use may lead to some matching error or ambiguous cases between cloud cells and lightning flashes. Once a detection mask has been taken into account, the errors may come from:

- Lightning sensors measurements uncertainty: sensors point some flashes outside the tolerance area of 10km, leading to ignore electric activity of convective cells
- Real ambiguous cases of cumuliform cloud systems developing in a thunderstorm zone without evolution to a cumulonimbus
- Failure of matching algorithm of PGE11-RDT. Cloud cells are representative of the base of cloud towers but some lightning flashes are likely to occur on the edge of large cloud system, more than 10km away from top tower

Analysis of RDT trajectories allow to take into account the flashes in the surrounding: PGE11 computes for each cloud cell the minimum distance to nearest flash, called flashes proximity.

- Below the tolerance value, this proximity is set to zero (matching cell-flash) for "observed" convective population.
- Beyond, it may be used for filtering statistical elements considered as non convective from "ground truth" point-of-view.

Thus, it is possible to check the sensitivity of the scores to this filter, and evaluate RDT performance despite the mentioned matching errors or limitations. .

		Trajectory			**Section**			**Time step**		
Flashes proximity filter (km)	**No conv trajectory number**	*POFD*	FAR	TS	*POFD*	FAR	TS	*POFD*	FAR	TS
0	292544	*3.5*	34	53	*4*	28	59	*1.5*	20	56
21	278426	*2.5*	27	58	*3.4*	23	62	*1*	16	58
35	266711	*2*	22	61	*3*	21	64	*1*	14	59
70	241178	*1.4*	15	65	*2.5*	17	66	*<1*	11	60

105	218678	*1*	11	68	*2*	15	68	*<1*	9	61
140	198995	*<1*	8	70	*2*	13	69	*<1*	8	62
175	181162	*<1*	6	70	*2*	12	70	*<1*	7	62

Tab 4: dependency of scores on lightning proximity (hypothesis 2 and moderate ground truth)

The false alarm ratio rapidly drops when flashes proximity filter is more permissive. FAR is divided by two when one considers a 70km filter area, which can be seen as a reasonable exclusion zone. A large part of false alarms are located beyond 70km of cloud-to-ground flashes.

When flashes exclusion area and intensity of the ground truth are considered together, it is possible to get a realistic idea of RDT discrimination true skills. Intensity of ground truth has a positive impact on POD. Flashes proximity filter have a positive impact on POFD and FAR, like illustrated in the table below:

Flashes proximity filter (km)	Trajectory Light GT			Trajectory **Moderate GT**			Trajectory Severe GT		
	POD 61			POD **74**			POD 81		
	POFD	FAR	TS	*POFD*	FAR	TS	*POFD*	FAR	TS
0	*3.5*	29	49	*3.5*	34	53	*3.5*	42	51
21	*2.5*	22	52	*2.5*	27	58	*2.5*	33	57
35	*2*	18	53	***2***	**22**	**61**	*2*	28	62
70	*1.4*	12	56	*1.4*	15	65	*1.5*	20	68
105	*1*	9	57	*1*	11	68	*1*	15	72
140	*<1*	6	58	*<1*	8	70	*<1*	11	74
175	*<1*	5	59	*<1*	6	70	*<1*	8	76

Tab 5: Dependency of Full-Trajectory scores on lightning proximity and on ground truth intensity

With a moderate ground truth (defined by 5 flash impacts at least during a trajectory) and non convective trajectories defined by being away from flashes of more than about 35km, satisfying skills are reached for full-trajectory approach: POD of 74% together with 2% POFD, FAR 22% and a TS of 61%.

4.2 THE DISCRIMINATION PRECOCITY

One of the goals of RDT is to detect as early as possible convective systems evolving in thunderstorms. The precocity (earliness) of this diagnostic will be measured against the age of first lightning flash paired with a cloud cell of a convective trajectory.

When cloud systems are first detected in the low levels of the troposphere, one may expect that the tracking capacity of PGE11-RDT correctly monitors the evolution of the cloud system, and anticipates its thunderstorm state.

But among the detected and tracked cloud cells, a large part is first depicted in mid or high levels. Moreover, because morphological evolution lots of trajectories are split by the algorithm at cold temperatures. For those cloud systems, it will be difficult to correctly anticipate a thunderstorm state. Therefore, precocity results should be regarded against those limitations.

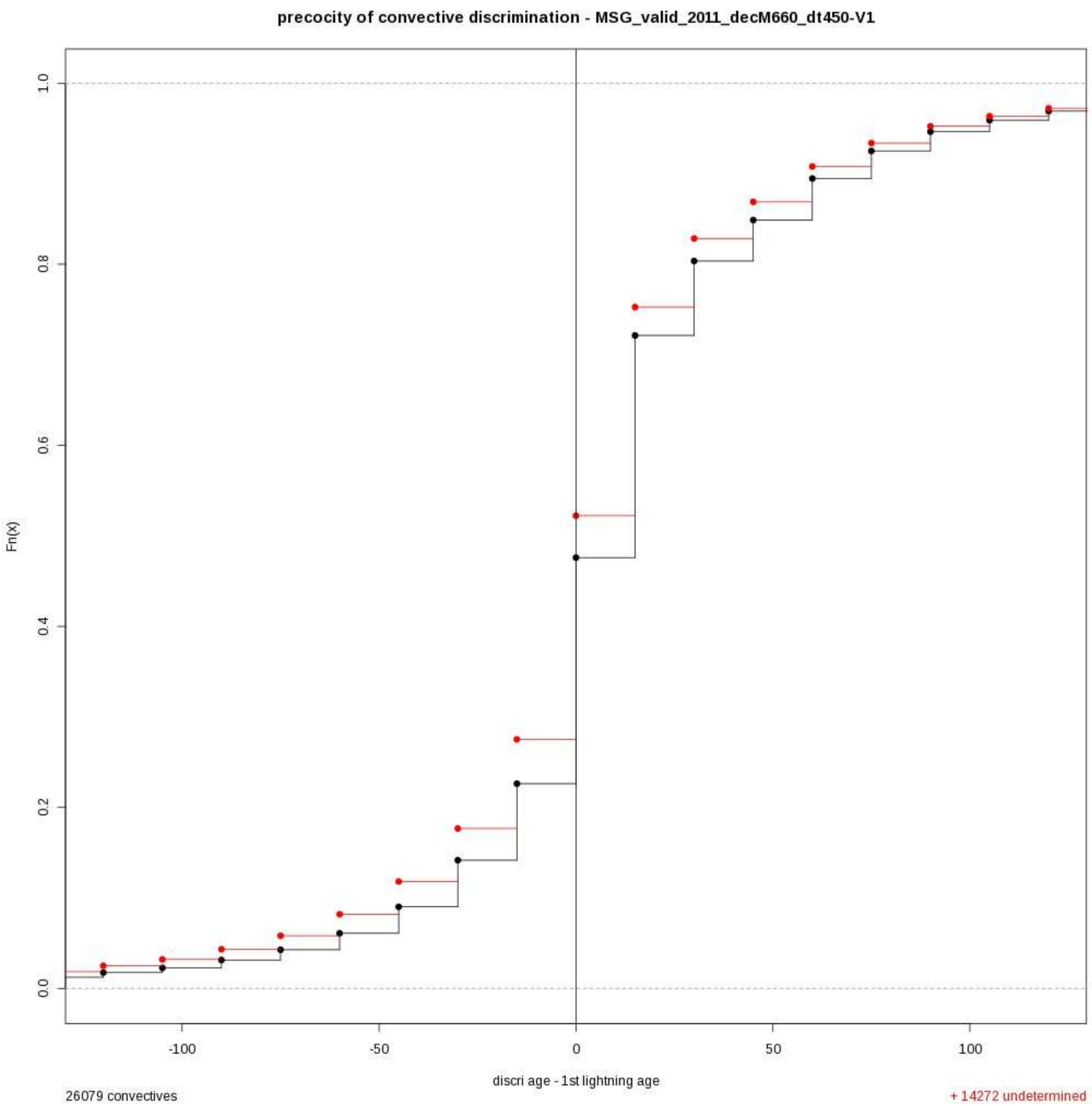


Figure 7: Precocity of RDT v2011 discrimination for moderate (black) and low (red marks) ground truths.

The figure above points out that more than 50% of good detection are already classified at the time of the first lightning occurrence, 80 % thirty minutes after. Nevertheless, only 25% are classified before the first flashes stroke (15 min before).

No major improvement appears when we compare the precocity of v2011 with the precocity of v2009. The precocity increases on the left part of the graph, but without modification of the overall score.

One can deduce a "shift" of previously early-diagnosed systems, taking all the benefit of improvement. Other systems do not seem to have got full advantage of this RDT version. This is illustrated on the graph below, where precocity is linked to the category of the first RDT diagnosis.

Categories used in PGE11 code are detailed in ATBD document (section **3.1.2.3.3)**

- Mature systems (value 0, here labeled "Mat") beyond -40°C
- Mature Transition systems (value 1) when crossing -40°C : not used here because systems are switched to mature category when convective
- Cold Transition system (value 2, here labeled "TCold") when crossing -35°C
- Warm Transition 2 system (value 3, here labeled "TWarm2") when crossing -25°C
- Warm Transition 1 system (value 4, here labeled "TWarm") when crossing -15°C
- Warm systems (value 5, here labeled "Warm") above -15°C preceding TWarm state

Warmest categories ("Warm" and "TWarm") correspond to the earliest diagnosis of RDT v2011. Compared to v2009, the v2011 version has taken advantage of a correct discrimination tuning in these categories (thanks to NWP guidance), where RDT v2009 did not. Early diagnosed systems of v2009 seem consequently to have been diagnosed earlier, in warmer categories, with v2011.

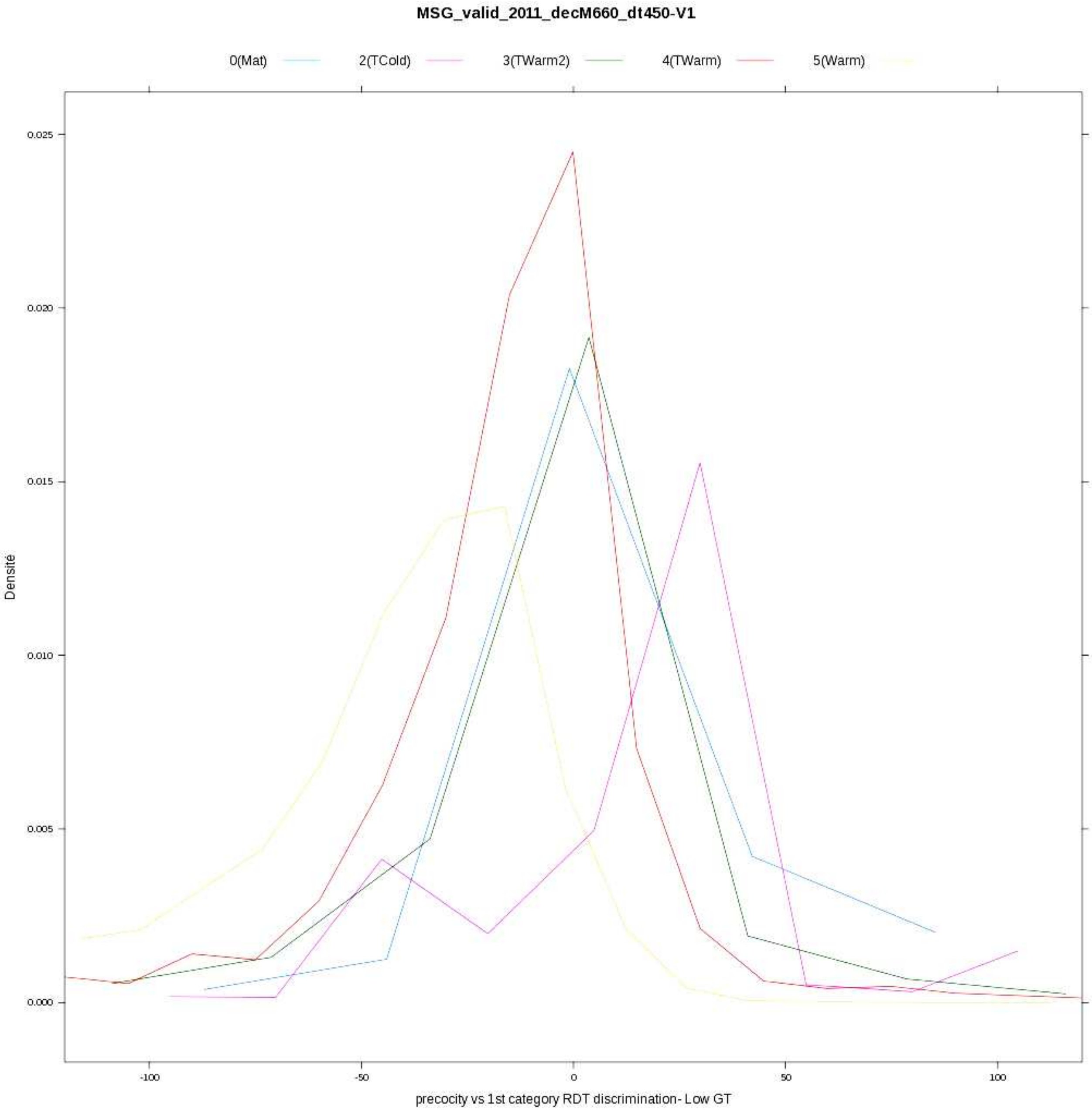


Figure 8: Precocity of discrimination for low ground truth, displayed for each category of first diagnosis. Left part of the graph corresponds to early diagnosis, right part to late diagnosis.

5. CASE STUDY EVALUATION

Main improvement of PGE11-RDT v2011, compared to previous version, is the use of NWP data as input. The goal of this change was to improve convective discrimination. In order to elaborate a synthesis convective mask, NWP data are used to compute convective indexes. The use of the convective mask has a positive impact on both tuning and real-time processing.

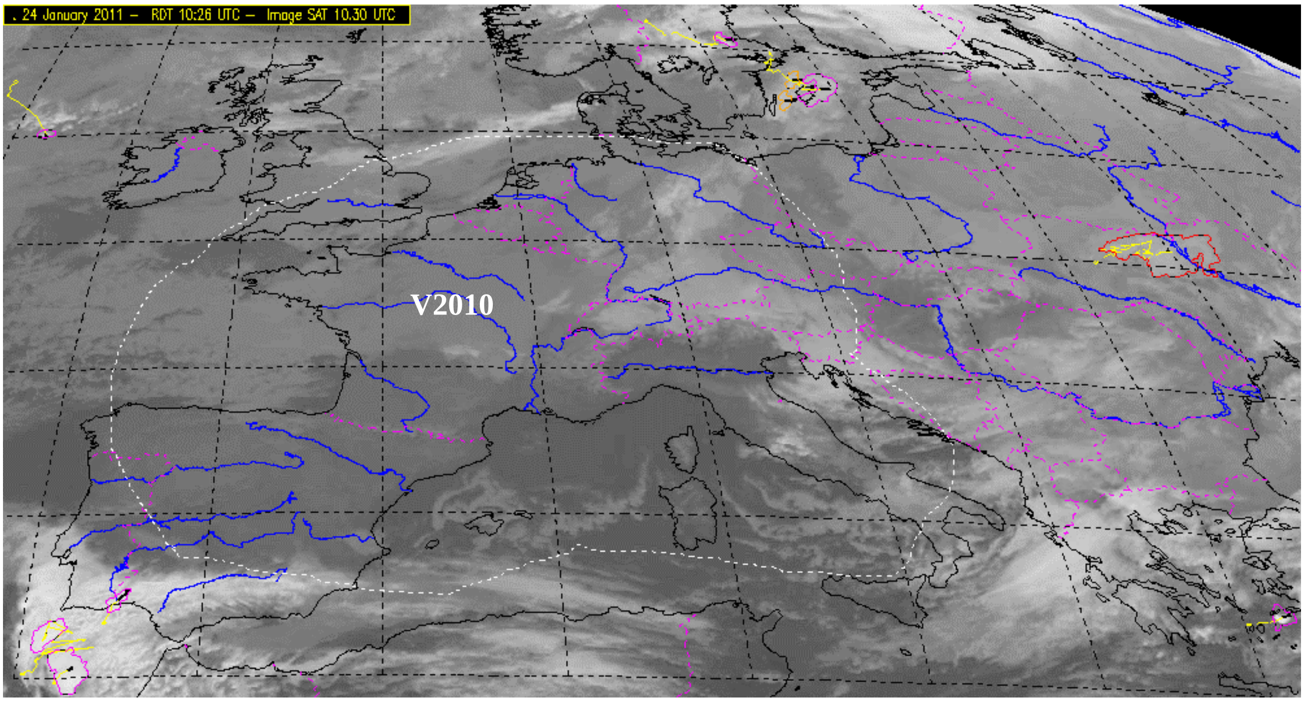
- Tuning: PGE11 Tuning has taken benefit from the convective mask, ignoring trajectories in stable areas thus reducing the unbalance between convective and non convective populations when processing statistics, giving more reliable and robust statistical models
- Real time processing: Convective diagnosis of PGE11 is attempted except in stable areas of this "NWP convective mask", thus avoiding non relevant diagnosis

5.1 NWP CONVECTIVE MASK: LOWERING FALSE ALARMS

Since the RDT is tuned over France with summer season satellite data, it may sometimes reveal false alarm cases when applied over winter or intermediate seasons.

NWP data allow undertaking guidance before attempting a diagnosis. Thus, PGE11 discrimination scheme may focus on convective regions, and avoid eventual false alarms.

Figure below illustrates the benefit of this approach, by filtering occasional false alarms in a winter. PGE11 v2011 focuses on the real convective areas in south-east and south-west corners of the region.



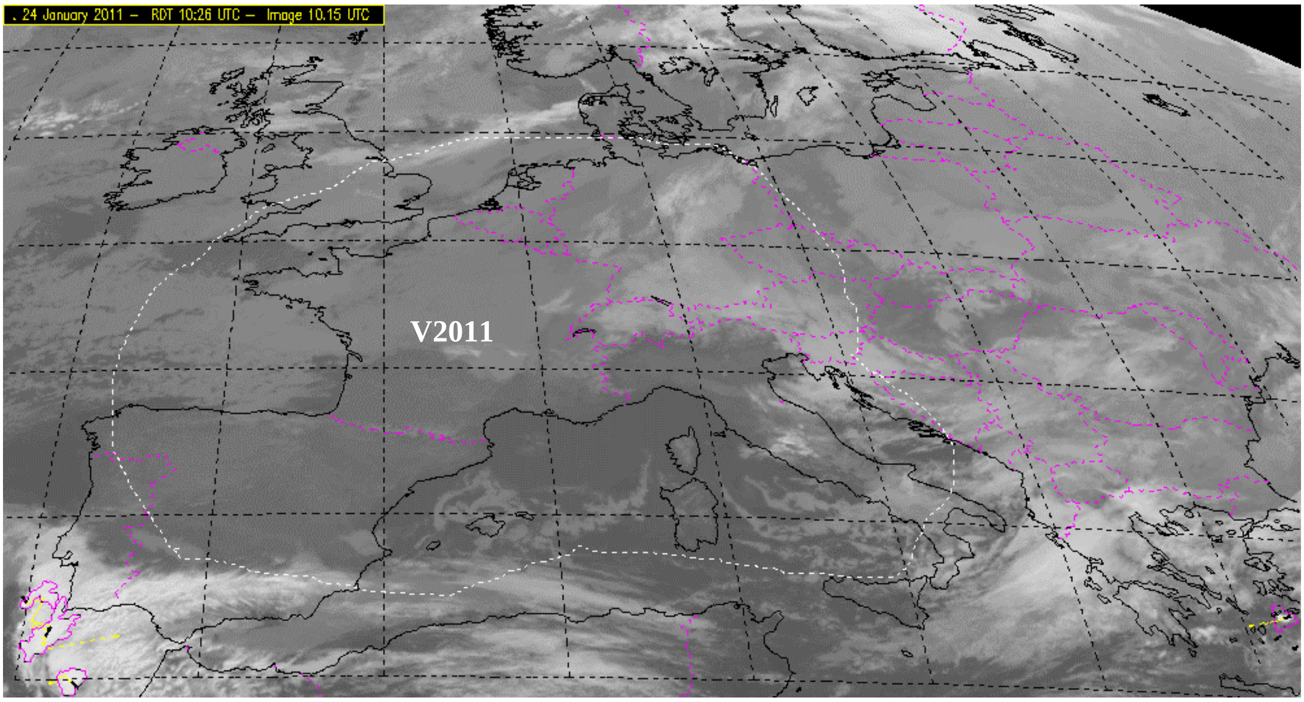


Figure 9 : 24 January 2011 - slot 10h15 - RDT v2010 (top) VS v2011 (bottom)

PGE11 v2010 exhibits obvious false alarms over Europe, while it is not the case for v2011. Convective diagnosis on real unstable areas are similar with v2010 and 2011.

5.2 Impact of NWP mask and data on discrimination Tuning

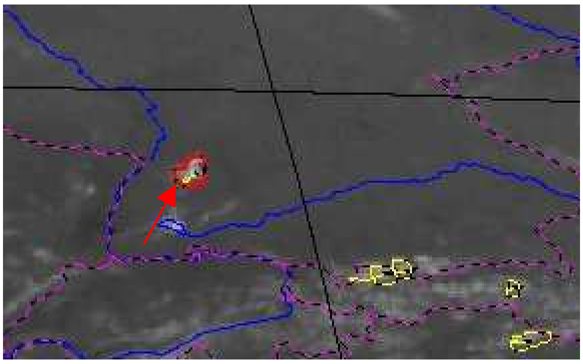
In order to exclude from the learning data bases areas and cloud systems without interest from a convective point of view, NWP mask approach has been applied during the tuning of PGE11 discrimination scheme..

Thus, this leads to an improvement thanks to a strong decrease of the imbalance between convective and non-convective populations, especially in the warm categories. The consequence is a better tuning in these categories, and consequently a potential improvement concerning precocity, which is illustrated below.

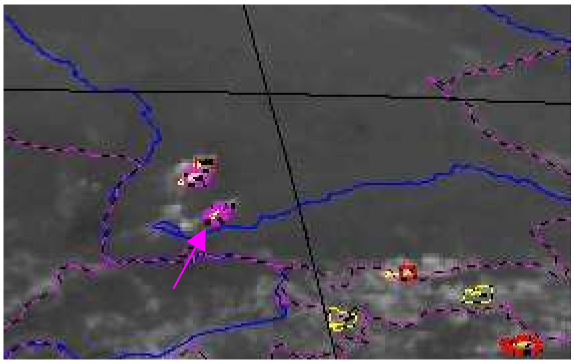
5.2.1 Locally earlier convective diagnosis

On 25th May 2009 ("Topical case" situation), convective cells are growing and merging in the south-west of Germany between 11h and 17h UTC. They are early depicted and diagnosed as convective by RDT v2011, even if those cells are already well developed (minimum temperatures of the cells are cold).

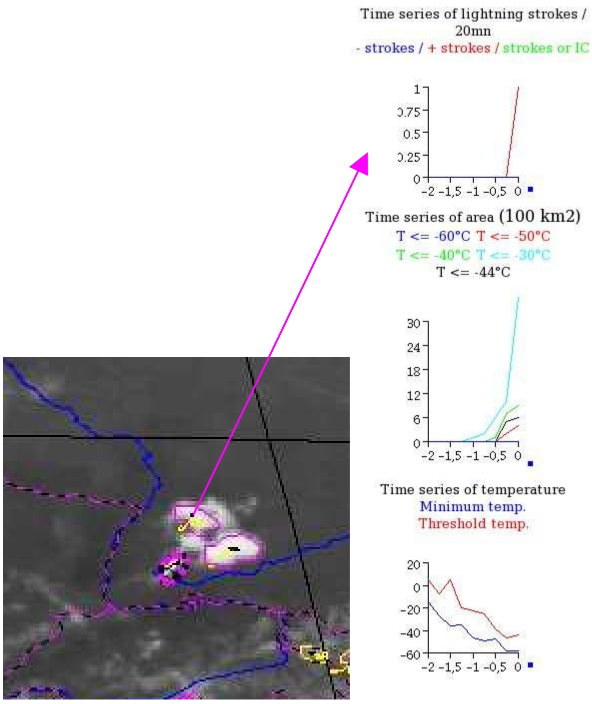
The precocity varies from 0 to 90 minutes for individual cells, but the value to retain is 45 minutes between first diagnosed cell and first paired flash in the neighborhood. The first cell is diagnosed at 11h15 UTC, 30 minutes after its first detection, but 90 minutes before a lightning flash be paired with this cell. But the first paired flashes really appear at 12h UTC. All those cells finally merge together, and dissipate around 16h45. The lighting activity ends at 15h15.



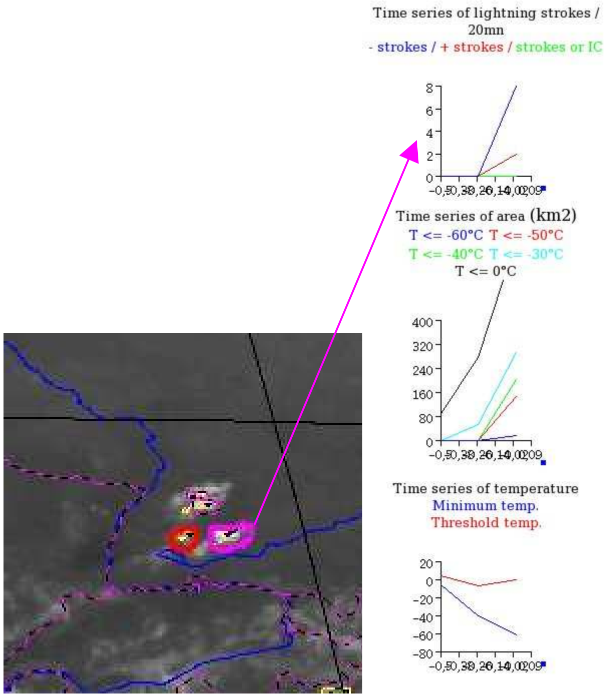
11h15: 1st convective cell diagnosed (Tmin -36°)



11h45: 2nd cell diagnosed (future main cell) in mature category



12h45: 1st lightning in 1st cell (see historical parameters on the right)



12h00: 1st lightning in 2nd cell (see historic parameters on the right), 3rd cell diagnosed synchronous with lightning

Figure 10: 25th May 2009 RDT v2011, zoom over SW-Germany. slots from 11h15 to 12h45. Trajectories, cells and motion vectors, cell history.

The figure below illustrates a detailed analysis of this situation, compared with a similar analysis done with RDT v2010 and Météorage data.

- When compared to previous RDT v2010, all cells have been diagnosed 15 min earlier with v2011.
- EUCLID data seem to be more numerous and earlier in this case than Meteorage data, but RDT v2011 keeps advantage on convective diagnosis when compared to lightning data

Conclusions about precocity are kept unchanged: there is an improvement of precocity thanks to the use of NWP data.

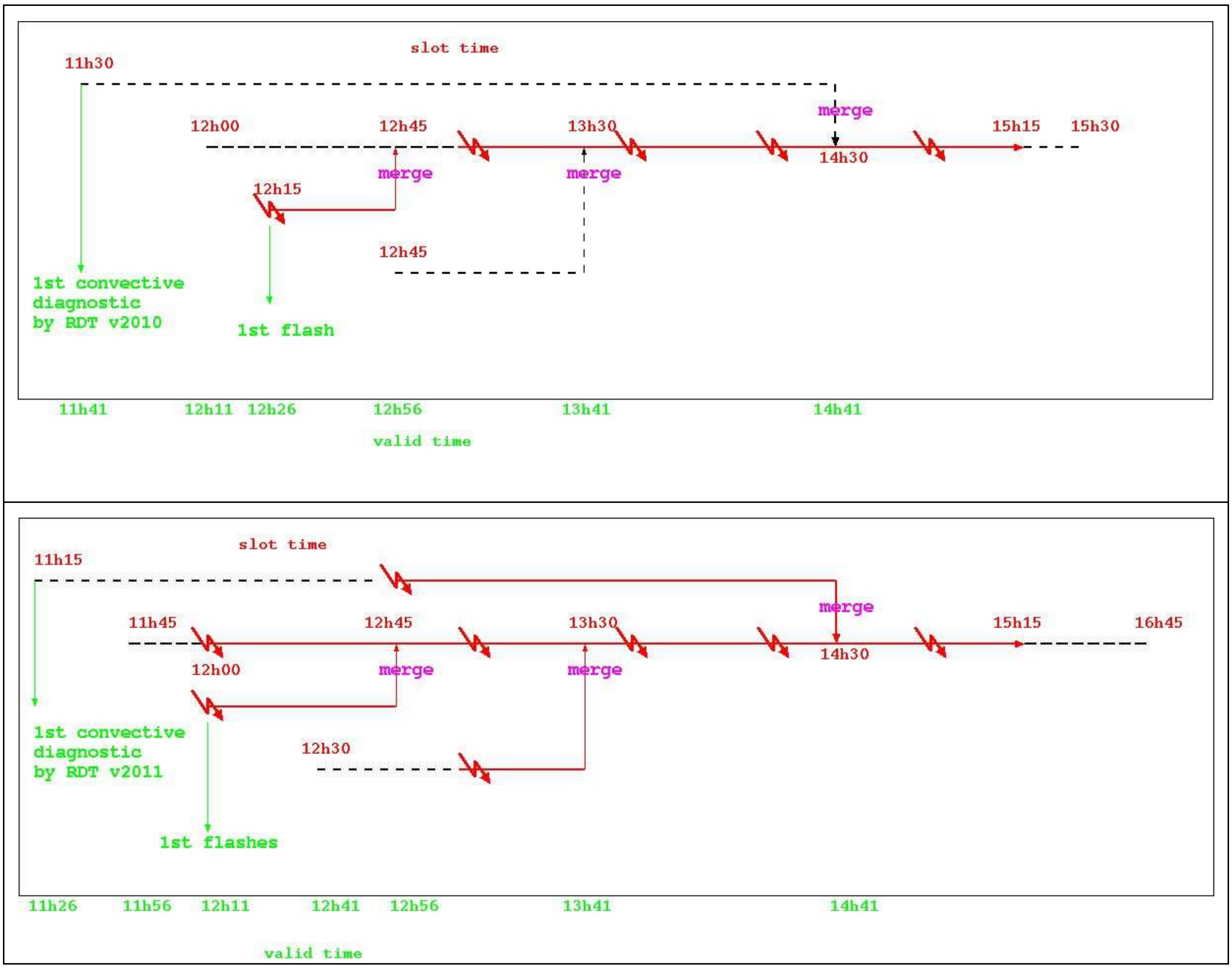


Figure 11: 25 May 2009, 11h15 to 16h45, zoom over SW-Germany. RDT v2010 analysis vs Météorage data (top) .RDT v2011 analysis vs EUCLID data (bottom).

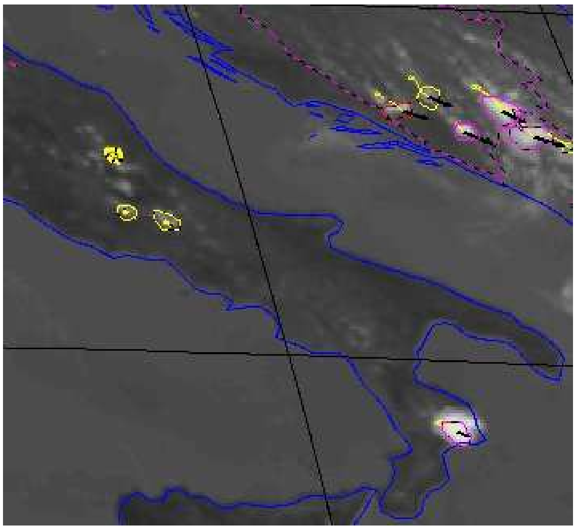
5.2.2 Improvement of discrimination:

All categories have taken benefit from this approach, with suitable statistical models even in warm categories.

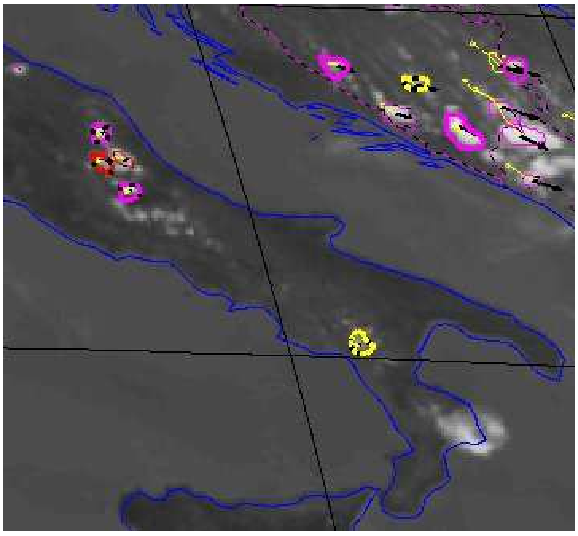
In the example below, v2011 obviously benefits from a better tuning in warmer categories, with better precocity for un-embedded convective systems. Cells over Italy are diagnosed 30 minutes previously to v2010. Sometimes mature convective systems are also depicted with v2011 earlier than v2010.

Here again one can note a good precocity of individual cell: 30 minutes for the southern cell, about 60 minutes in central part of Italy. But in the last case the effect of orography has to be taken into account

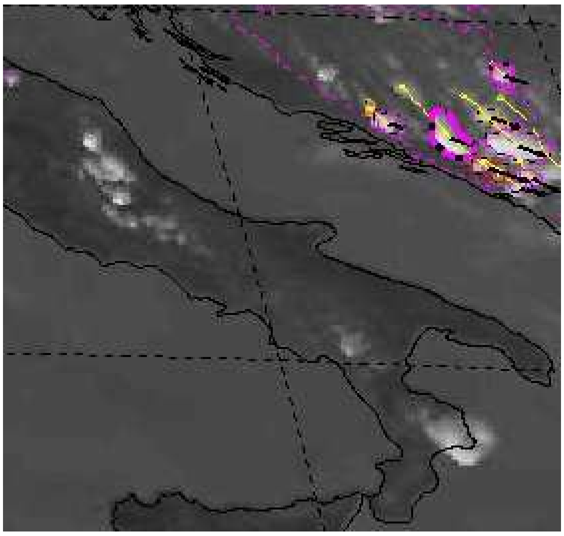
It is to note that false alarms increase when more numerous systems are diagnosed in the warmest categories. Among the three cells diagnosed in the centre of Italy, only one will evaluate towards an electric system. The two others will dissipate, even if they have exhibited convective characteristics in the growing stage. The question could be raised to know what is really to be considered as a false alarm, when looking at the further convective evolution in the same zone.



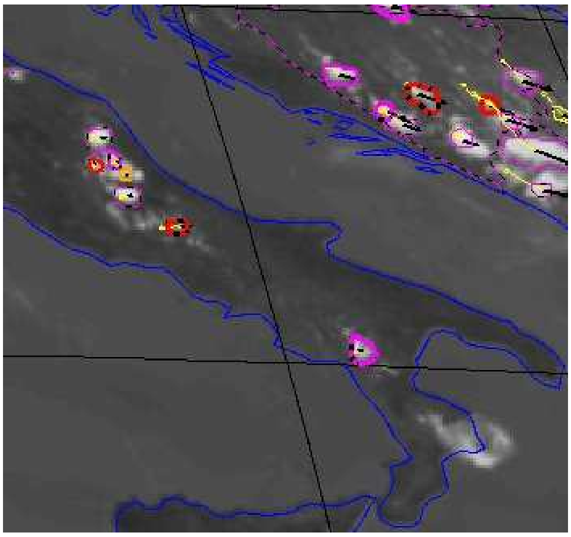
11h45: RDT **v2011** - First cells diagnosed (~ -20°C)



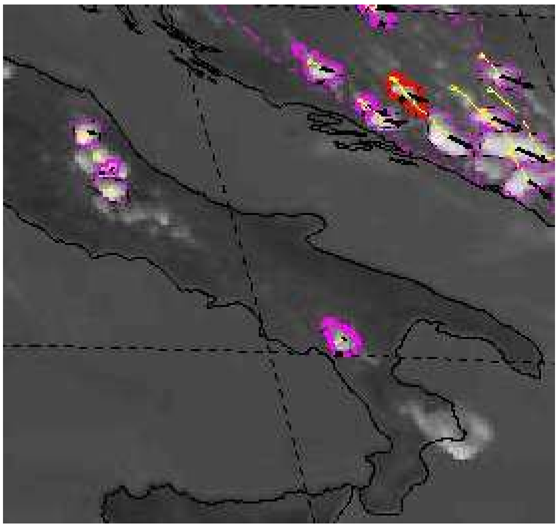
12h30: RDT **v2011** - new diagnosed cell in the south (-20°C, strong cooling -14°C in 15min)



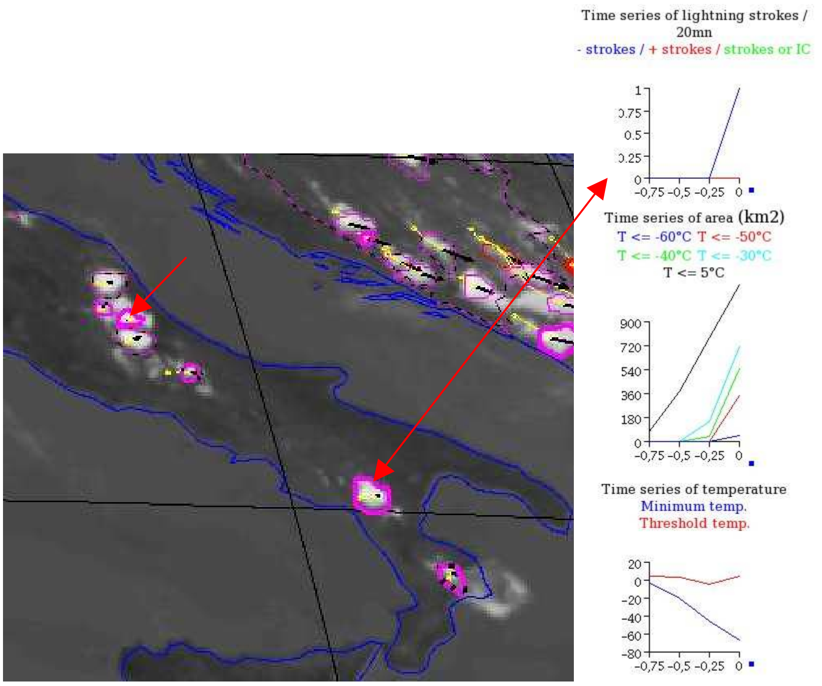
12h30: no cells with RDT v2010



12h45: RDT **v2011**



12h45: RDT v2010 – 1st cells diagnosed



13h00: RDT **v2011** – first lightings paired north and south cells (historic parameters on the right)

Figure 12: 25th May 2009, slots 11h45-13h00 UTC. RDT v2011 (central and left), v2010 (right).

5.3 OVERSHOOTING TOP DETECTION

As detailed in AD.1., Overshooting Top Detection (OTD) of PGE11 is undertaken in two steps. First, morphological analysis of cloud cells allows identifying cell's list of so-called "OT-candidates". Then, OT candidates are eliminated or confirmed examinating gap to tropopause or criteria more severe than those in first step.

Criteria are inspired from existing bibliography about OTD, and have been adjusted on case studies. With OTD, we have the first use of visible channel in RDT algorithm (VIS 0.6). Hereafter are some examples of these subjective tuning and validations. The expert subjective validation requires HRV images (that are not use in OTD).

5.3.1 Pre selection step

The static thresholds used for IR10.8 BT and BTD=WV6.2-IR10.8, and the morphological analysis of cloud cell top lead to identify possible overshoots for convective systems. A balance had to be found between restrictive or more tolerant values of thresholds. The first option lead to missing some overshoots, the second one implied a necessary further confirmation through additional criteria. The second option has been chosen and the step are called "pre-selection" and "confirmation"

The figure below illustrates a case study over Austrian-Slovenian border, on the 25th of May, 2009. Only PGE11 OT pre-detection are plotted, superimposed on an enhanced IR image. The convective system containing several convective cells exhibits some OT signatures. The corresponding OT's extensions vary from one to a tenth of pixels, all located on an extremum of IR10.8 BT.

A comparable approach concerning overshoots was also examined, for cross comparison. The same case study has been analysed by Bedka and al (here extracted from "Best Practice Guide" of Convection Working Group - CWG), figure below exhibits HRV channel with result of OT detection. In this case, all four OTD appear also inside the PGE11 OT pre-selection set. Some more interesting points are proposed with PGE11, these points need a confirmation, which is the aim of next step of the algorithm.

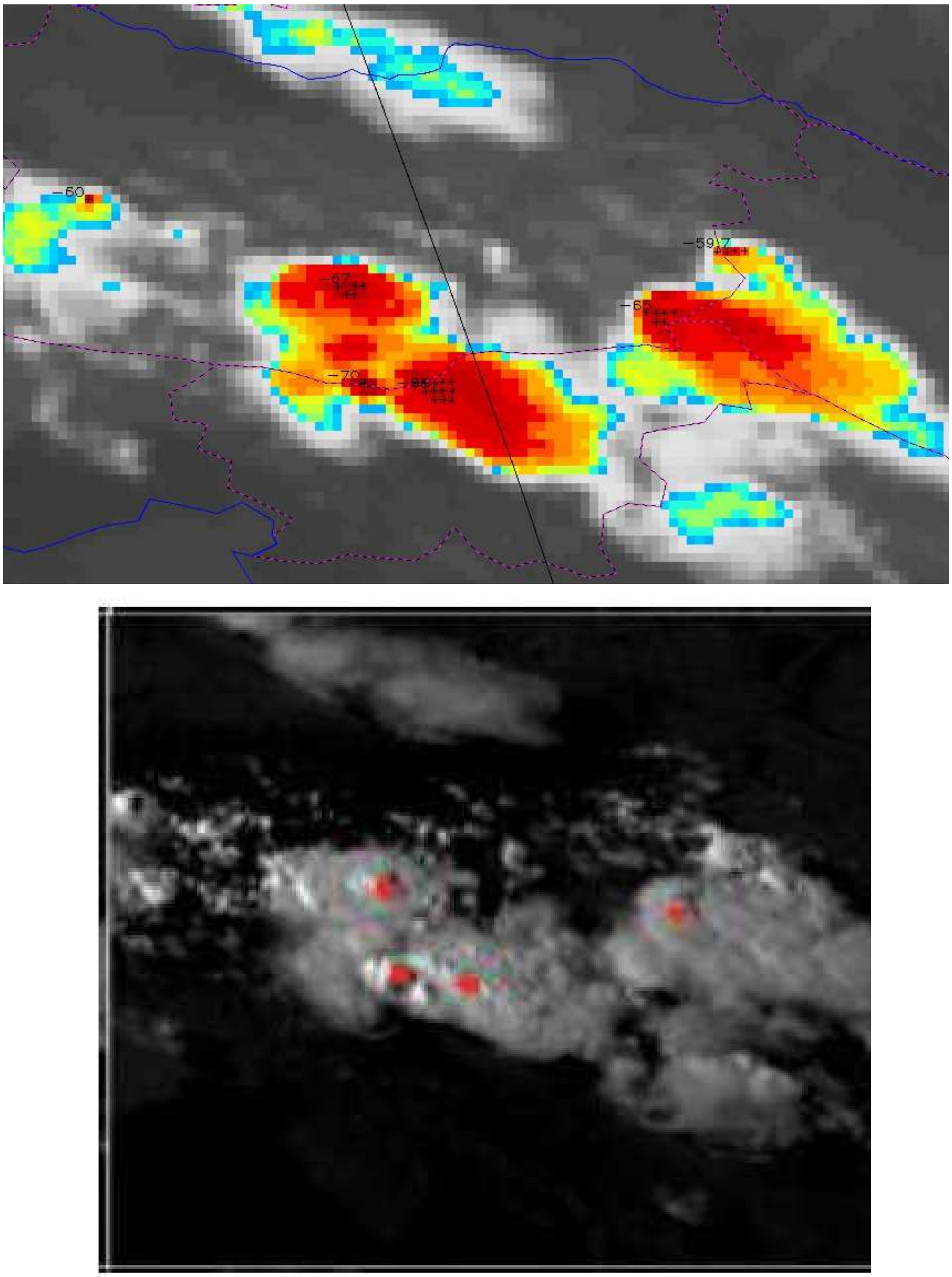


Figure 13: 25th May 2009, slot 16h00 UTC. Zoom over Austrian-Slovenian frontier. Top: Enhanced IR10.8 image with plotted pre-selected PGE11 OT. Bottom: HRV image with highlighted OTD from Bedka and al

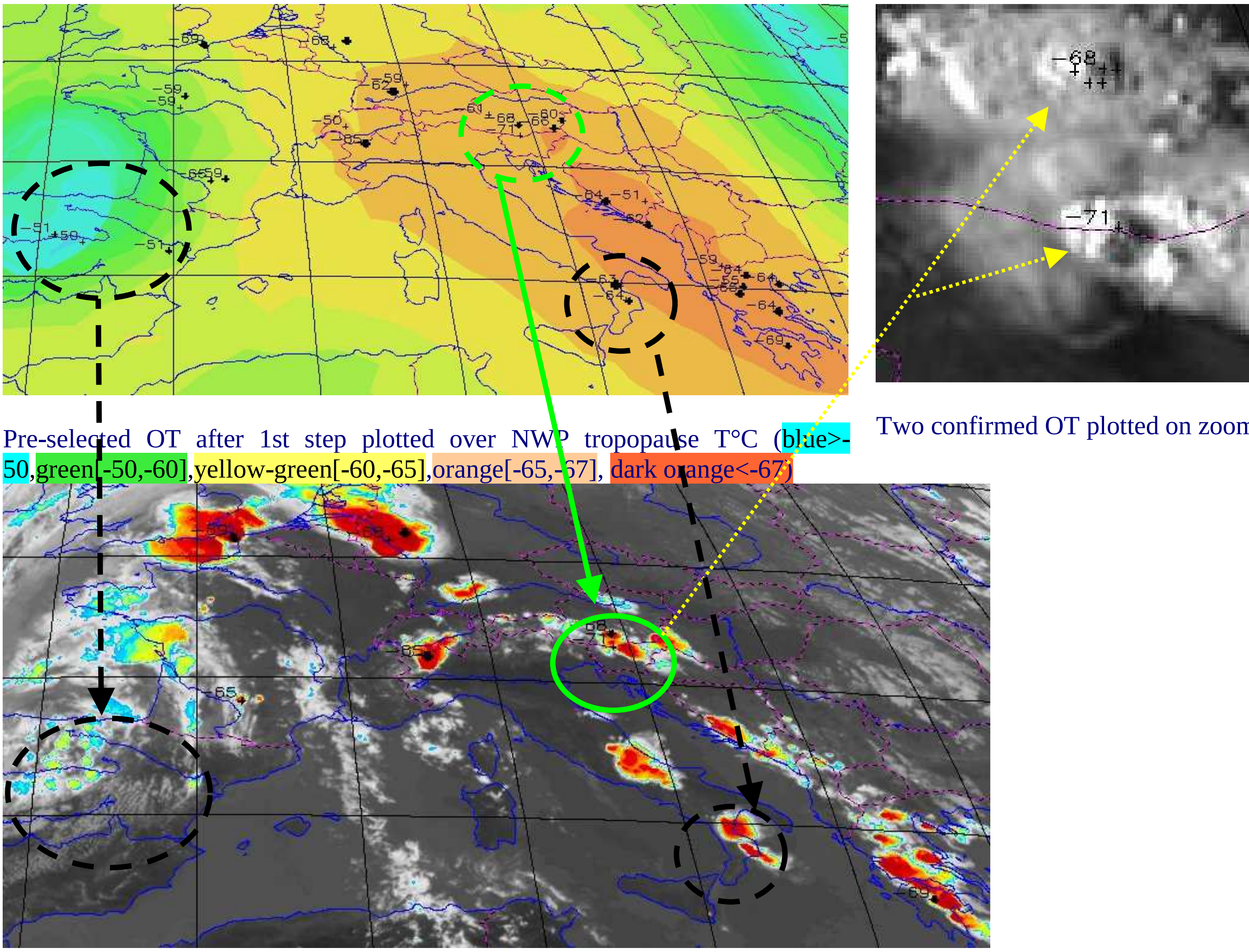
5.3.2 Confirmation step

NWP input is used by PGE11 for guidance and for a more efficient discrimination step. With OTD, NWP data have now a new role in RDT. Tropopause pressure and temperature are read or re-processed (diagnosed) during the managing phase of NWP data. This parameter is a key attribute for confirming or filtering overshooting top candidates, since a relevant gap over tropopause is generally expected and observed with overshoots.

Several attempts and case studies, based on ARPEGE NWP data over Europe, have lead to set a first threshold to a value of 5°C to define what is a significant gap over tropopause. The value of 10°C, generally admitted, would filter almost all OTs from this situation.

For pixels only slightly above tropopause level (i.e. gap between 0° and 5°), a complementary set of criteria mixing high BTD, high reflectance and large gap between average and minimum temperature of cloud cell, allows to keep some overshoots with different marked signatures

The figure below illustrates the differences between pre-selection and confirmation steps, highlighting in particular how the OTD takes advantage of tropopause diagnosis.



Pre-selected OT after 1st step plotted over NWP tropopause T°C (blue>-50,green[-50,-60],yellow-green[-60,-65],orange[-65,-67], dark orange<-67)

Two confirmed OT plotted on zoom

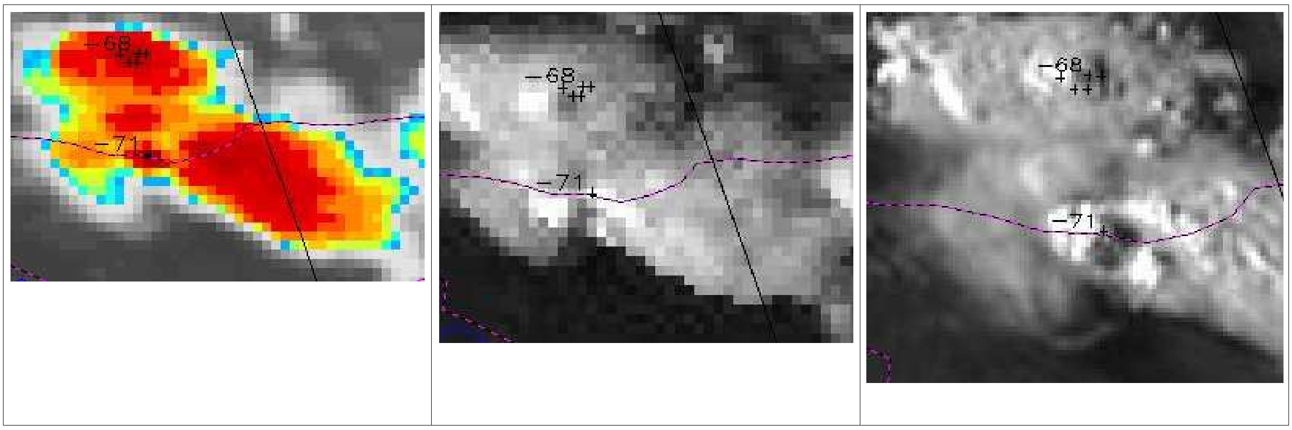
Confirmed OT after 2nd step plotted over enhanced IR10.8

Figure 14: 25th May 2009, slot 16h00 UTC.
Top left: NWP tropopause temperature superimposed with all PGE11 OT candidates.
Bottom: confirmed PGE11 OTD superimposed on enhanced IR10.8
Top right: HRV zoom confirming the 2 remaining PGE11 OTD

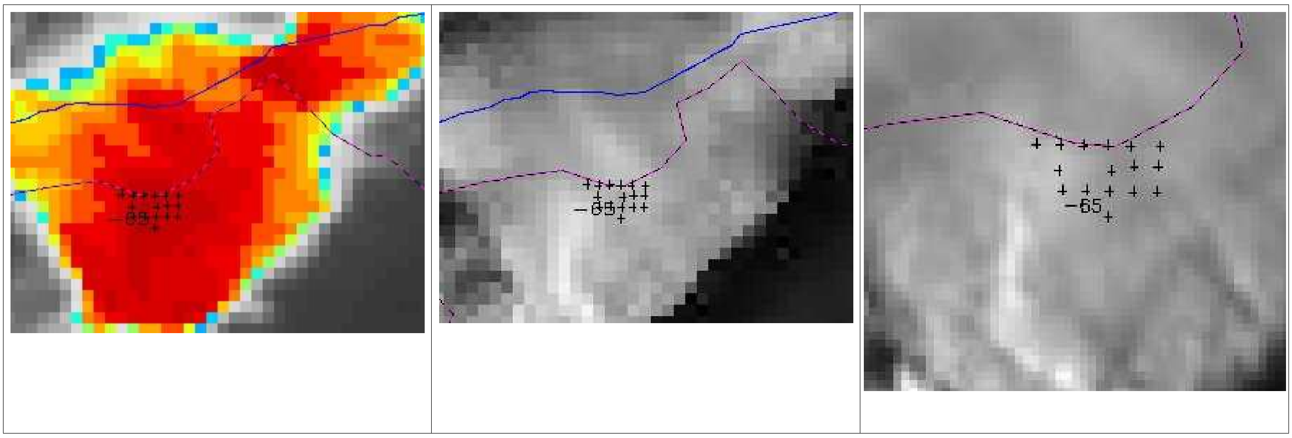
5.3.3 Subjective validation

We only consider in this chapter the OT confirmed after the confirmation step. Only these OT are available in PGE11 output. Mainly low resolution visible, HRV and IR10.8 enhanced images have been used to validate the OT.

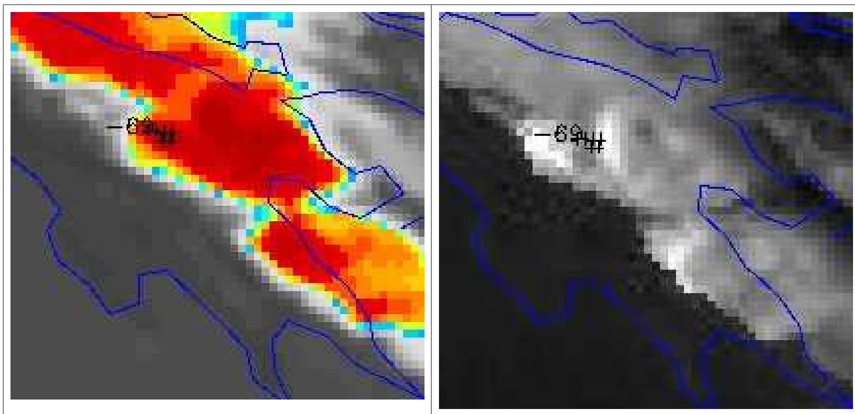
On the following examples, OTD are plotted on raw IR10.8 enhanced images (left), on low resolution VIS parallax-corrected images (middle), and on raw HRV image (right). For most cases, overshooting top detection appears close to high reflectance spot, and can be considered as validated.



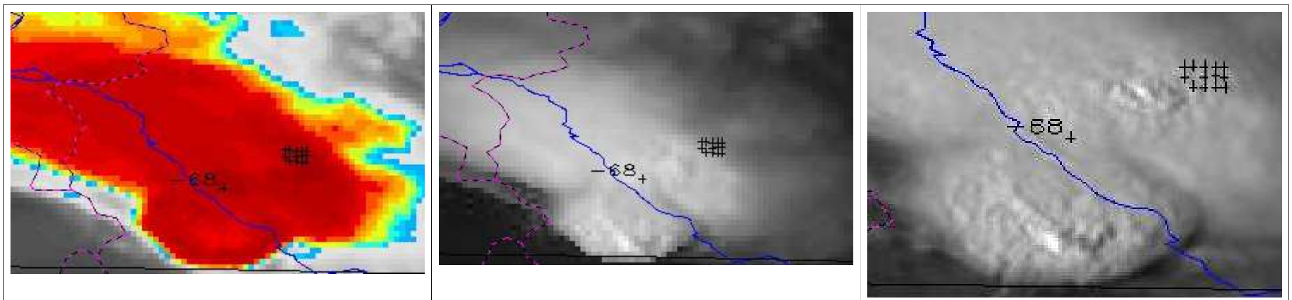
Two OT have a temperature of 3-4°C above tropopause. They are associated with high values of reflectance, even if those "spots" are not exactly colocated on paralax-corrected images. Detection can be considered as validated when looking at buddings on HRV images



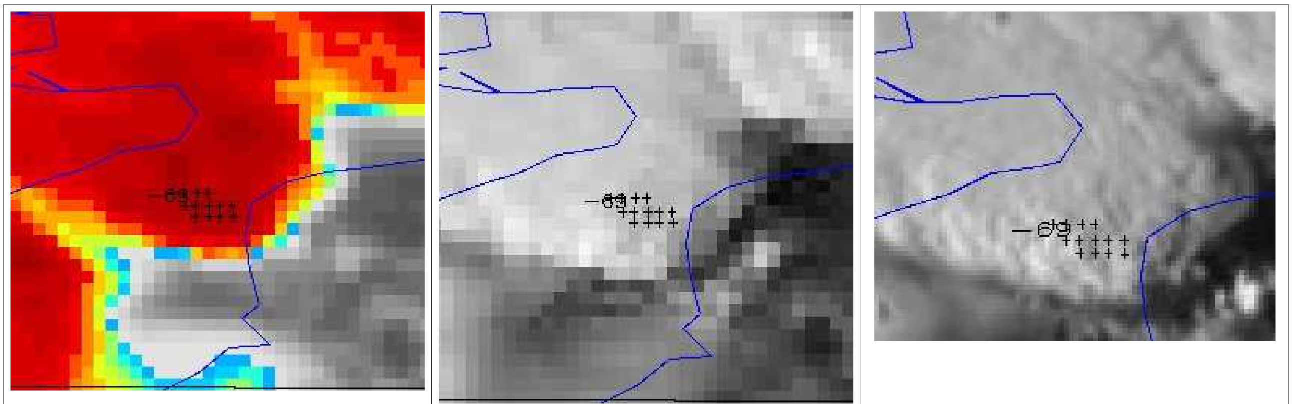
Reflectance values are not very high on LR and HR VIS images, and located rather southward of the detected OT. This one is slightly above tropopause level but largely colder than surrounding pixels.



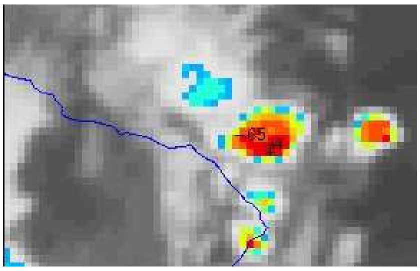
OTD is confirmed by high VIS reflectance in the vicinity, even if the OT temperature is only 1.5°C above NWP tropopause

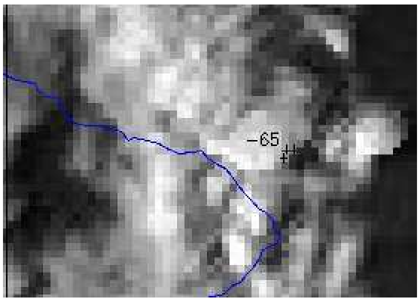


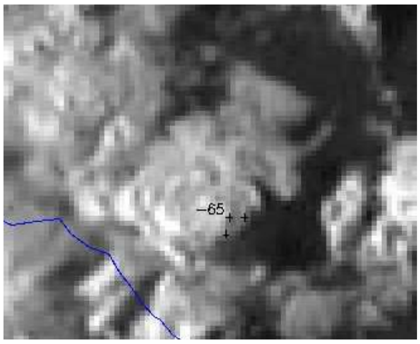
Theses "twin" OT, both with temperature extrema and BTD maximum, does not show high colocated reflectances (except one pixel close to the eastern one), even if the texture seem obviously above an anvil. One can suspect a secondary extremum on the southern edge of the cloud cell, where white spot in HR visible appears.



Moderate reflectances appear here slightly south of the IR-detected OT, on the edge of the cloud system. Visible channels hardly confirm this detection. .







OT is associated with high value of LR VIS reflectance. HRV signal appears more on the western edge of the cloud cell. The cell is quite small, but clearly above tropopause (gap of 5°), justifying the OT detection.

To conclude, the Overshooting Top Detection implemented in PGE11 seems to fit its objective for the cases studies which have been analyzed. The first step allows selecting all kind of interesting pixels and the confirmation step allow to focus on the most relevant ones.

5.3.4 Applicability to tropical regions

Brightness temperature, but also size and distance thresholds have been adapted when applying PGE11 OT detection to tropical regions. Deep convection associated with high and cold tropopause has lead to consider rather at least double-size OT for the morphology analysis. indeed, the initial values of thresholds did not allow to fulfil the conditions for most cases.

Thus temperature threshold of -70°C and typical OT size of 100km have set for latitudes below 30°. Below is an illustration of the result, with single pixel and extended OT which are compliant with morphology and tropopause value.

A more detailed subjective validation is undertaken over those regions by Météo-France oversea territories forecasters (in progress), which will extend to OTD when the corresponding release will be in operation.

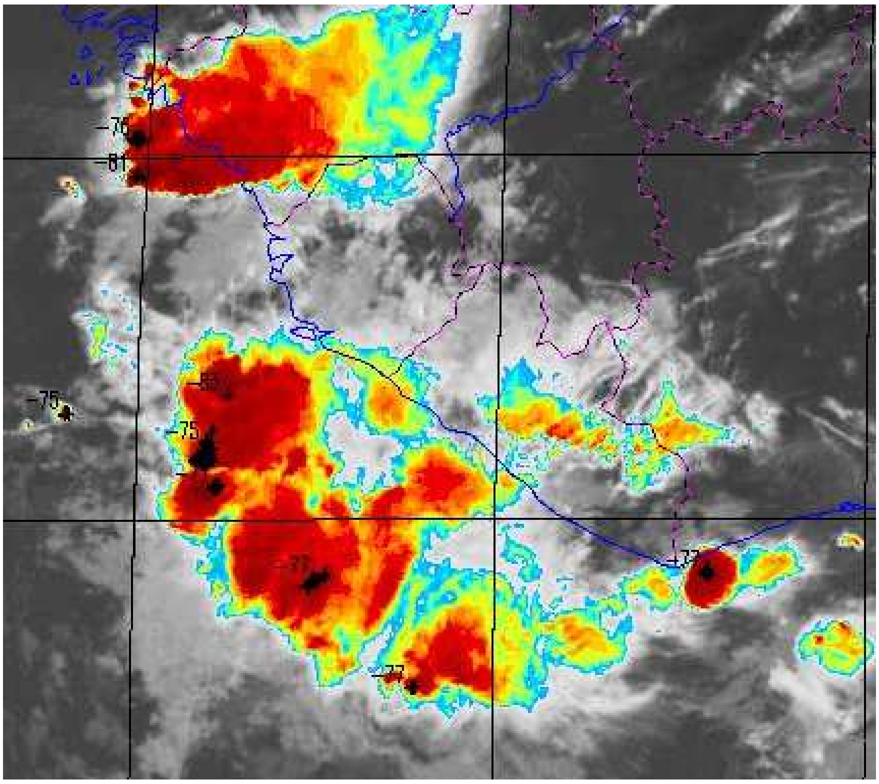


Figure 15: 06/06/2012 12h00 UTC, south-west Africa: PGE11 OTD on enhanced IR image.

6. END-USERS FEEDBACKS

RDT, a very satisfying product widely used for Research and Operations, by Météo-France and its partners.

The use of RDT concerns for example

- Forecasters of Météo-France, in France and overseas territories (La Réunion, Antilles, Polynésie, Wallis et Futuna). RDT provides a significant help for regions not covered by radars.
- AMMA experiments (http://aoc.amma-international.org/observation/mcstracking/)
- Hymex project (http://www.hymex.org/RDT/)
- Analysis of Rio-Paris AF447 crash (2009).

Collaboration concerns

- NOAA for a RDT GOES (Operation + Research)
- ACMAD for a RDT-Africa
- European FlySafe Project with RDT software adapted to radar data

RDT will be used in the framework of SESAR project and HAIC project.

Survey distributed to SAF/NWC users early July 2008 : RDT is mainly used for Research activities (7 answers) and operations for forecasting issues (8). Results are quite the same for the 2010 survey. The judgment of overall quality of RDT product is very satisfying: 6 High, 4 Medium, 1 Low.

7. CONCLUSION

From a subjective point of view, the use of NWP data with PGE11-RDT v2011 has allowed an improving gap of the discrimination efficiency. False alarms are lowered thanks to a "NWP convective mask" used as a guidance for the diagnosis, and precocity is increased with early diagnosis in warmest categories, thanks to a new tuning with NWP data and mask.

The objective validation over a wide region thanks to EUCLID data detailed in this report has confirmed this first analysis. It has been undertaken through various approaches from time step cell to the full life cycle of a cloud system, and taking into account the limitations of the ground truth.

With a moderate ground truth (defined by 5 flash impacts at least during a trajectory) and non convective trajectories defined by being away from flashes of more than about 35km, satisfying skills are reached for full-trajectory approach: POD of 74% together with 2% POFD, FAR 22% and a TS of 61%. Scores are even better when considering sections of trajectories or cloud cells individually.

RDT keeps good performances when taking into account intermediate season period Of course RDT scores are better for summer.

Moreover, the skills obtained with EUCLID data, over Europe and for v2011 are better in all configurations and for all approaches than for the previous validation.

This improvement does not appear so clearly concerning the precocity of RDT discrimination. It is limited to systems which are able to be early discriminated, i.e. with isolated convective system depicted from low levels.

Finally, those results fulfil the target accuracy requirements (see 1.2) over a large domain and for an extended period, i.e. 70% of detection and 25% of convective systems diagnosed before lightning activity.

We consider nevertheless that progress can still be made to lower the false alarm and the number of misses cases, and to still improve the precocity.

RDT provides an accurate depiction of convective phenomena, from triggering phase to mature stage. The RDT object allows pointing out some areas of interest of a satellite image. It provides relevant information on triggering and development clouds and on mature systems. Even if the precocity on the first lightning occurrence remains to be improved, the subjective evaluation confirmed the precocity usefulness on moderate lightning activity.

Thanks to these good results the status of RDT has been set up to "operational" by EUMETSAT in 2012.

The new part of the algorithm concerns OTD for v2013. Subjective validation exhibits very good results. It is a major point to improve RDT by focusing on the areas of more severe and intense convection. Now, depending on cloud system morphology, RDT is able to present a kind of multidimensional description of convective systems, thanks to second level identification and overshooting top detection. It completes the data fusion approach with other PGEs of SAFNWC.

ANNEX I: EUCLID DATA

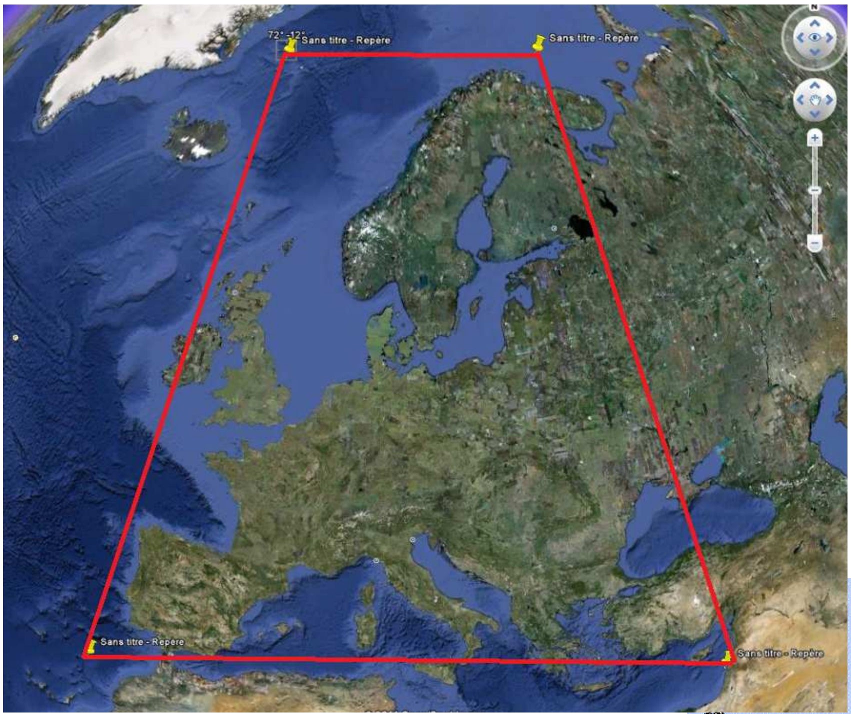


Figure 16: initial area of EUCLID data

Figure 17: Detection zone of EUCLID network for 2008-2009 period

ANNEXE II: EXAMPLE OF ELECTRIC TRAJECTORY ANALYSIS

The figure below illustrates the validation methodology described in the present report. An electric trajectory, considered as convective whatever the ground truth intensity (about hundred flashes paired), is analyzed against its RDT diagnosis.

Top figure points electric activity at each time step (black histogram), section and time step « colours » (maroon cf ***correspondance***), and discrimination result of RDT (magenta cf ***correspondance***).

Bottom figure illustrates the temporal evolution of temperatures (threshold and minimum)

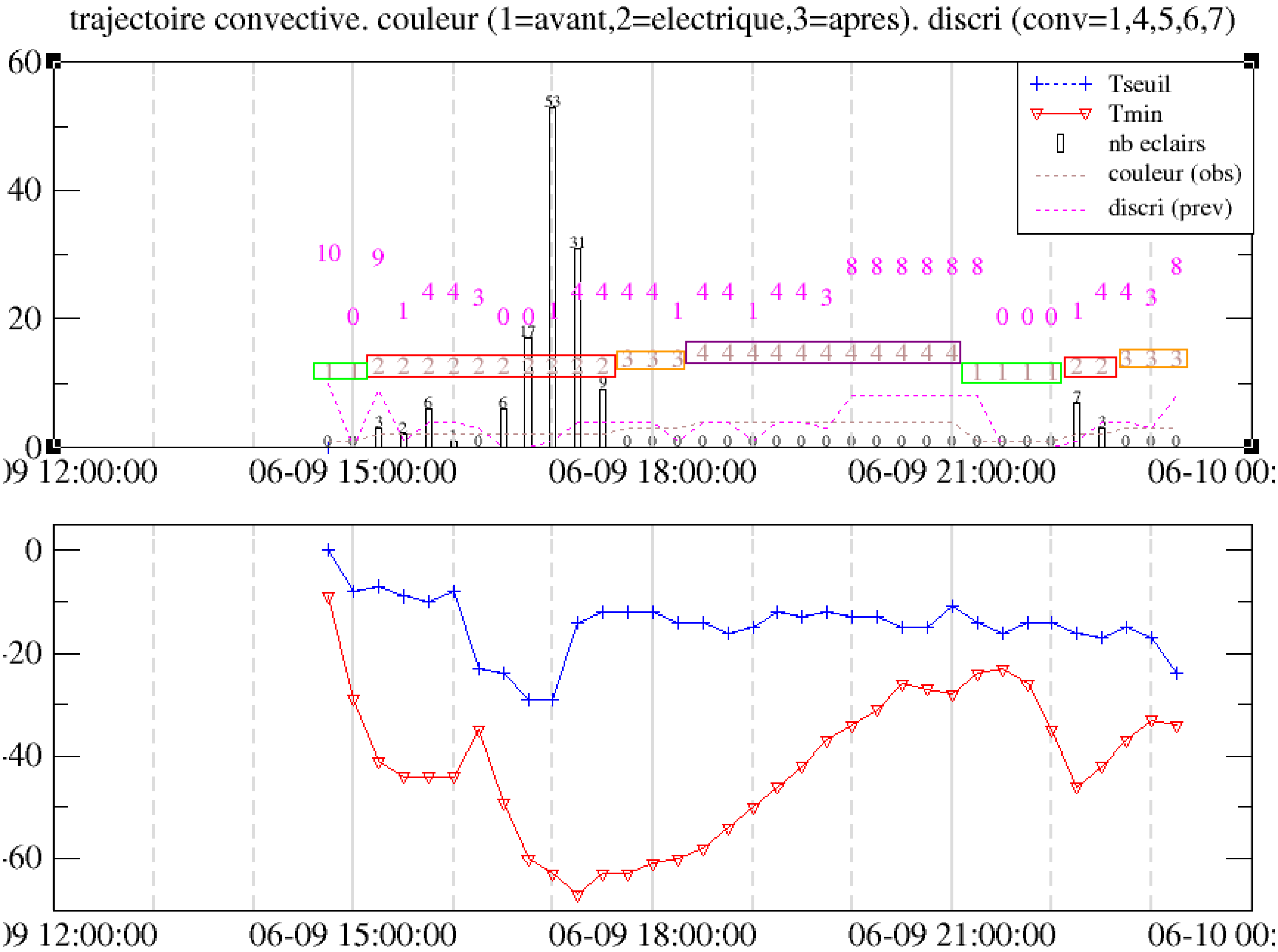


Figure 18: Evolution of a convective / electric trajectory

« Trajectory »: good detection: convective observation, and convective discrimination at forth time step (not a good precocity here).

« Sections »: trajectory cut in 7 sections, among which 2 electric (code 2 red), with respective precocity (code 1 green) and decaying (code 3 orange) sections, and a transition section (code 4 violet).

Hypothesis 1:

2 « red » sections, each one with at least one convective discrimination: 2 good detections

Hypothesis 2:

2 « green » sections with non-convective diagnosis: 2 correct rejections.
2 « red » sections, each one with at least one convective discrimination: 2 good detections
2 « orange » sections, each one with at least one convective discrimination: 2 good detections (persistence of diagnosis, late declassification)
1 « violet » section with some convective discrimination: 1 false alarm

4GD + 2CR + 1FA => **POD=100%** **FAR=20%** **POFD=33%** **TS=80%**

Hypothesis 3:

2 « green » sections with non-convective diagnosis: 2 misses.
2 « red » sections, each one with at least one convective discrimination: 2 good detections
2 « orange » sections, each one with at least one convective discrimination: 2 good detections (persistence of diagnosis, late declassification)
1 « violet » section with some convective discrimination: 1 false alarm

4GD + 2MI + 1FA => **POD=67%** **FAR=20%** **POFD=100%** **TS=57%**

« <u>Time steps</u> »: 36 time steps for 9h duration:

12 « red» time steps, among which <u>8 discriminated as convective</u> and 4 non convective (2 non convective, 1 undefined et 1 declassified)
6 « green» time steps, among which 4 discriminated as non convective and 2 non convective (undefined)
6 « orange» time steps, among which <u>4 discriminated as convective</u>, and 2 non convective (1 declassified and 1 undefined)
11 « violet » time steps, among which <u>5 discriminated as convective</u>, and 6 non convective (1 declassified and 5 undefined)

Hypothesis 1: 8GD+4MI => **POD=67%, FAR=0%, POFD=0%, TS=67%**

Hypothesis 2: 12GD+4MI+14CR+5FA => **POD=75%, FAR=29%, POFD=26%, TS=57%**

Hypothesis 3: 12GD+12MI+6CR+5FA => **POD=50%, FAR=29%, POFD=45%, TS=41%**

« Color » classes of sections :

- *0 =black = non electric cell preceding first flash of more than 1h*
- *1 =green= non electric cell preceding first flash*
- *2 =red= electric cell or cell in electric section*
- *3 =orange= non electric cell following electric section*
- *4 =violet= non electric cell between 2 electric sections*
- *5 =grey= non electric cell following last electric period*
- *6 =yellow= no activity*

RDT diagnosis classes :

- ***1 = diagnosis <u>convective</u> from statistical model***
- ***4 = diagnosis <u>convective</u> inherited from main link***
- ***5 = diagnosis <u>convective</u> inherited ascending***
- ***6 = diagnosis <u>convective</u> split inherited***
- ***7 = diagnosis <u>convective</u> split inherited ascending***
- *0 = diagnosis non convective from statistical model*
- *3 = de-classification of previous convective system*
- *8 = statistical model not applied, previously de classified*
- *9 = statistical model not applied, previously non convective*
- *10 = statistical model never applied*