The EUMETSAT Network of Satellite Application Facilities

NWC SAF

Support to Nowcasting and Very Short Range Forecasting

Algorithm Theoretical Basis Document for "Rapid Development Thunderstorms" (RDT-PGE11 v2.2)

SAF/NWC/CDOP/MFT/SCI/ATBD/11, Issue 2, Rev. 2

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Applicable to SAFNWC/MSG version 2011

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REPORT SIGNATURE TABLE

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2.0	01/10/2008		Chapter 3 – Algorithm description Discrimination algorithm change
2.1	01/10/2009		Update of the discrimination skill (statistical models)
2.2	*22 October 2010*		Use of NWP data, tuning of discrimination scheme over longer period

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1. INTRODUCTION

1.1 SCOPE OF THE DOCUMENT

The ATBD document provides the scientific description of the PGE11 algorithm. It points out assumptions done on algorithms and limitations of RDT products. Lastly, this document summarizes RDT validation result and describes RDT outputs.

1.2 SCOPE OF OTHER DOCUMENTS

The PUM (Product User Manual) provides all useful information to user (forecaster or research).

The VR (Validation report) depicts the accuracy of RDT to classify the convective cloud object. The discrimination skills are based on on lightning occurrences.

The Interface Control Documents ICD/1 (Interface Control Document n°1) describes the External and Internal Interfaces of the SAFNWC/MSG software.

The Interface Control Documents ICD/3 (Interface Control Document n°3) describes the input and output data formats of the SAFNWC/MSG software.

1.3 SOFTWARE VERSION IDENTIFICATION

This document is compliant with version v*2011*.of the SAFNWC software package.

1.4 IMPROVEMENT FROM PREVIOUS VERSION

- PGE11 can now take advantage of NWP data as input, for improving convective discrimination :
    - NWP data are used to compute convective indexes for synthesizing a "NWP convective mask".
    - NWP data are used to compute (CEP NWP) or identify (ARPEGE NWP) Tropopause characteristics, affected as extra attribute to cloud cells.
    - Gap to Tropopause and value of convective index affected to each cell are used as additional predictors for statistic models issued from PGE11 tuning.
    - PGE11 Tuning has benefit from the convective mask, ignoring trajectories in stable areas thus reducing the unbalance between convective and non convective populations, and taking into account new parameters in the logistic regressions

  - Real time processing : Convective diagnostic of PGE11 is attempted except in stable areas of this convective mask, thus avoiding non relevant diagnostic. It also benefits from a better tuning, especially in warm categories.

It is to note that PGE11 can still be processed without NWP data. The result will in this case be comparable to V2010, but it must be kept in mind that V2011 has benefit from a better tuning (see ATBD), even if NWP data are not available in real time. In any case, NWP data are strongly recommended.

- Minor improvement concern displacement estimation :
  - validity tests have been introduced, to invalid erroneous values. In this case persistence will be applied
  - displacement is estimate from the move of gravity center of Cloud tops
- A production number can be encoded in BUFR file, to identify RDT productions over various areas and/or satellites

1.5 DEFINITIONS, ACRONYMS AND ABBREVIATIONS

BUFR	Binary Universal Form for the Representation for Meteorological data
CMa	Cloud Mask (also PGE01)
ECMWF	European Centre for Medium-Range Weather Forecasts
EUMETSAT	European Meteorological Satellite Agency
GOES	Geostationary Operational Environmental Satellite
ICD	Interface Control Document
INM	Instituto Nacional de Meteorología
MSG	Meteosat Second Generation
MTR	Mid Term Review
NMS	National Meteorological Service
PGE	Product Generation Element
POD	PrObability of good Detection
POFD	PrObability of False Detection
RDT	Rapid Development Thunderstorms
SAF	Satellite Application Facility
SAF NWC	SAF to support NoWCasting and VSRF
SEVIRI	Spinning Enhanced Visible & Infrared Imager
CDOP	Continuous Development and Operation Phase
IOP	Initial Operation Phase

1.6 REFERENCES

1.6.1 Applicable documents

Reference	Title	Code	Vers
[AD.1.]	Product User Manual	SAF/NWC/CDOP/MFT/SCI/PUM/11	2.1
[AD.2.]	Validation report	SAF/NWC/CDOP/MFT/SCI/VR/11	2.1
[AD.3.]	Interface Control document for the External and Internal Interfaces	SAF/NWC/CDOP/INM/SW/ICD/1	2010
[AD.4.]	Interface Control Document for the input and output data formats	SAF/NWC/CDOP/INM/SW/ICD/3	2010
[AD.5.]	Software User Manual for the SAFNWC/MSG Application, Software Part	SAF/NWC/CDOP/INM/SW/SUM/2	2010

1.6.2 Reference documents

Reference	Title	Code	Vers
[RD 1]	Ruiz Gazen, A. Villa, N., (June 2007), RDT discrimination refining, intermediate report	Visiting scientist activities of the SAF NWC – http://nwcsaf.inm.es/VSA.html	2007
[RD 2]	Ruiz Gazen, A. Villa, N., (June 2008), RDT discrimination refining, final report	Visiting scientist activities of the SAF NWC – http://nwcsaf.inm.es/VSA.html	2008

1.7 GOAL OF THE RDT PRODUCT

The RDT, Rapid Development Thunderstorm, product has been developed by Meteo-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 are twofold:

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

The object-oriented approach underlying the RDT product allows to add value to the satellite image by characterizing convective, spatially consistent, entities through various parameters of interest to the forecaster : motion vector, cooling and expansion rate, cloud top height,…, and their time series. It supports easy and meaningful downstream data fusion (surface observations, NWP fields, radar data...).

Thereby, RDT is a tool for forecaster but can be used by research teams too, 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://www.zamg.ac.at/eumetrain/.

2. ALGORITHM OVERVIEW

2.1 OUTLINE OF THE ALGORITHM

The RDT algorithm could be divided into three parts:

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

2.1.1 The detection of cloud systems

The detection algorithm allows to define "cells" which represent the cloud systems. In the RDT 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.

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

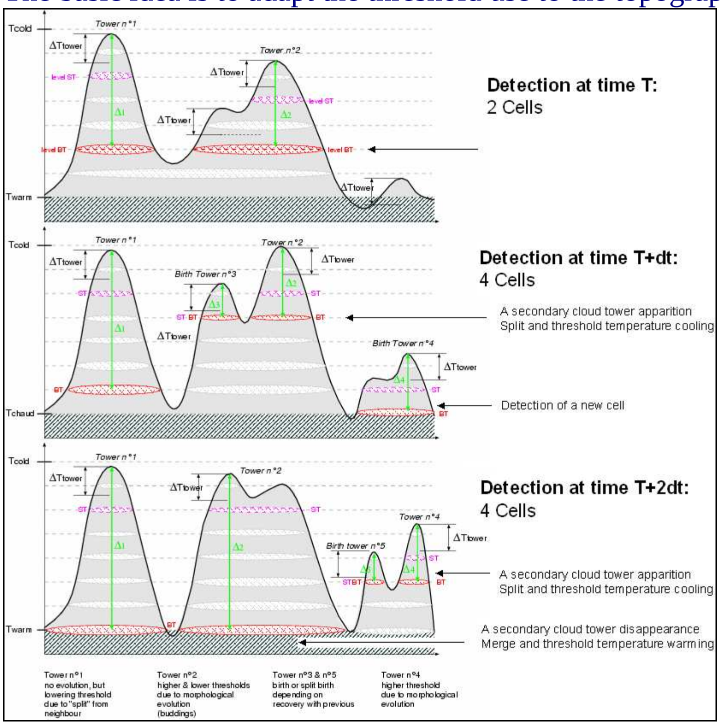


Figure 1: RDT cell definition

- 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)

Hence, the threshold use for a given cloud tower depends on the temperature pattern in the vicinity, and may evolve just because nearby towers do evolve (warmer zone or Deltat_tower=6°C for defining significant cloud towers, which contour are drawn in red).

Thus, the RDT cells linked in time to form a trajectory do not necessarily really depict the same phenomena along time. But the advantage of the method used (adaptative threshold) is to focus on convective parts of cloud systems, in order to perform the discrimination process.

Even if the cloud tracker is able to detect and track cloud object on pixel resolution, it is advised to limit at 60 squared kilometers (more or less 5 pixels with IR resolution over Europe) the minimum area of an object in order to improve quality of discriminating parameters processed. The minimum size of an object is defined into configuration file. On the other hand, a limitation to 200000 squared kilometers of the systems is enough to meet the objectives of RDT, and allow to avoid tracking huge non convective cloud systems.

2.1.2 The tracking of cloud systems

The adaptative threshold use makes complex the cell comparability due to various phenomena depicted. This method induces numerous merge and split too.

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 according to their (formerly analyzed) move and speed. 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
- *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 adaptative threshold temperature use, 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 link allows to compute move, speed and trend of all cloud objects. The time series of cloud's characteristics (peripheral gradient, volume, cooling rate...) are key input for the discrimination algorithm.

2.1.3 The discrimination of convective objects

As was mentioned previously, the RDT 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 objects among all cloud cells, adding a strong constraint which is that the discrimination should be effective as soon as possible after the first detection by RDT software.

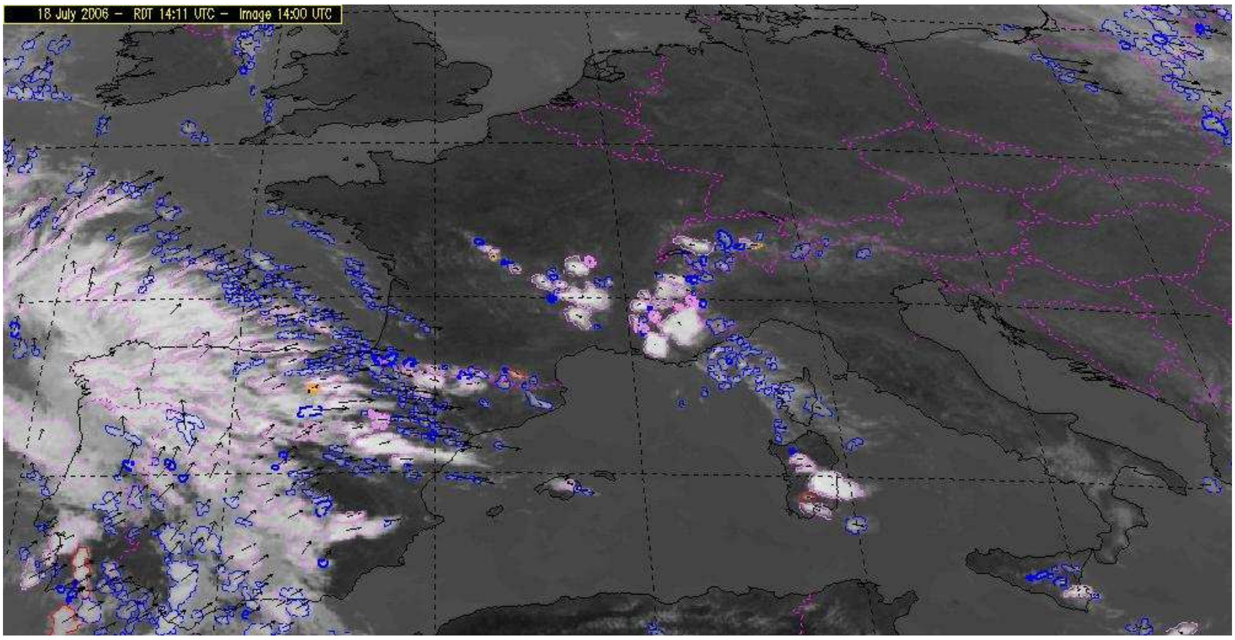


Figure 2: RDT objects before convective discrimination

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

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

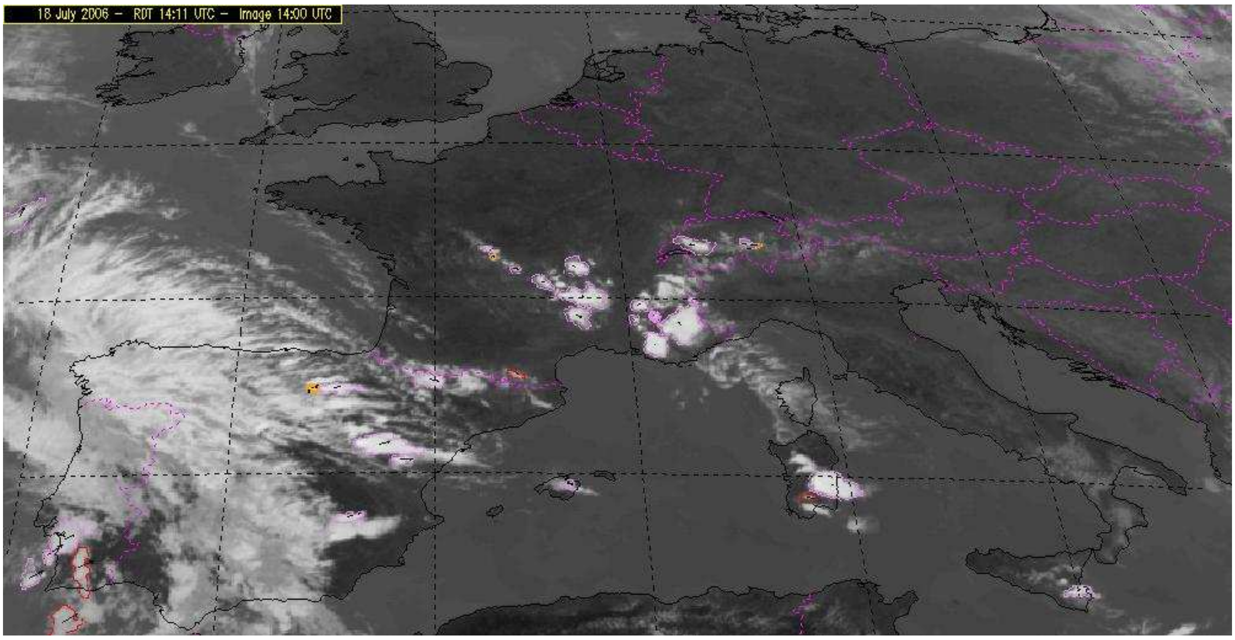


Figure 3: RDT objects after convective discrimination

The discrimination method makes use of discrimination parameters calculated from three MSG channels: IR 10.8µm, IR 8.7µm, IR 12µm, WV 6.2µm and WV 7.3µm. Two kinds of such discrimination parameters are computed:

- spatial characteristics (peripheral gradient, surface...)
- temporal characteristics (rate, extremes on various past period)

The discrimination scheme is a mix between empirical rules and statistical models tuned on a learning database.

The current learning data base is made over widened France. The ground truth used for building the data base is cloud to ground lightning occurrence.

3. ALGORITHM DESCRIPTION

3.1 THEORETICAL DESCRIPTION

3.1.1 Physics of the Problem

The thunderstorm detection by PGE11 is a mix of physical and statistical approach. The methodology is first to identify and track cloud system, then to define satellite characteristics of these cloud systems during different phases (triggering, development and mature). Learning data bases are then built on the most significant parts of the trajectories of the cloud systems, for a pre-conditional tuning.

3.1.2 Description of the Algorithm

3.1.2.1 The detection of cloud systems

The goal of the detection algorithm is to define "cells" which represent the cloud systems as seen in the infrared 10.8 µm channel. Once the "cells" are detected, a number of morphological (area, aspect ratio…) and radiative features (average and minimum brightness temperature,…) of the "cells" are computed in order to characterize the corresponding cloud systems. More precisely, "cells" are connected zones (8-connectivity) of pixels i) having a brightness temperature lower than a given temperature threshold T_{th} (which is not the same for all the "cells" detected in a given image) and ii) being larger than a given area threshold A_{min} (which is the same for all the detected "cells").

The use of a detection algorithm based on a fixed temperature thresholding is problematic. Indeed, the choice of a rather low temperature threshold leads to a late first detection of convective systems and the use of rather high temperature threshold leads to a merging of different convective systems into one single "cell" when these systems are embedded in a warm layer of clouds.

The RDT detection method is based upon an adaptative temperature thresholding of infrared images. Thus, each cloud system is represented by one or several cells defined by its own, cell-specific, temperature threshold, ranged between a warm threshold T_{warm} and a cold threshold T_{cold}. More precisely, possible temperature thresholds are : T_{warm}, $T_{warm} - \Delta T$, $T_{warm} - 2\Delta T$,… , T_{cold} where ΔT is the temperature step of possible temperature thresholds.

RDT Cells point out the bottom of cloud towers included inside cloud system. The temperature threshold used to define the bottom of an RDT object is the warmest one which allows to distinguish it from others nearby temperature extremes. As described in Figure 4, only strong enough temperature extremes are taken into account (...).

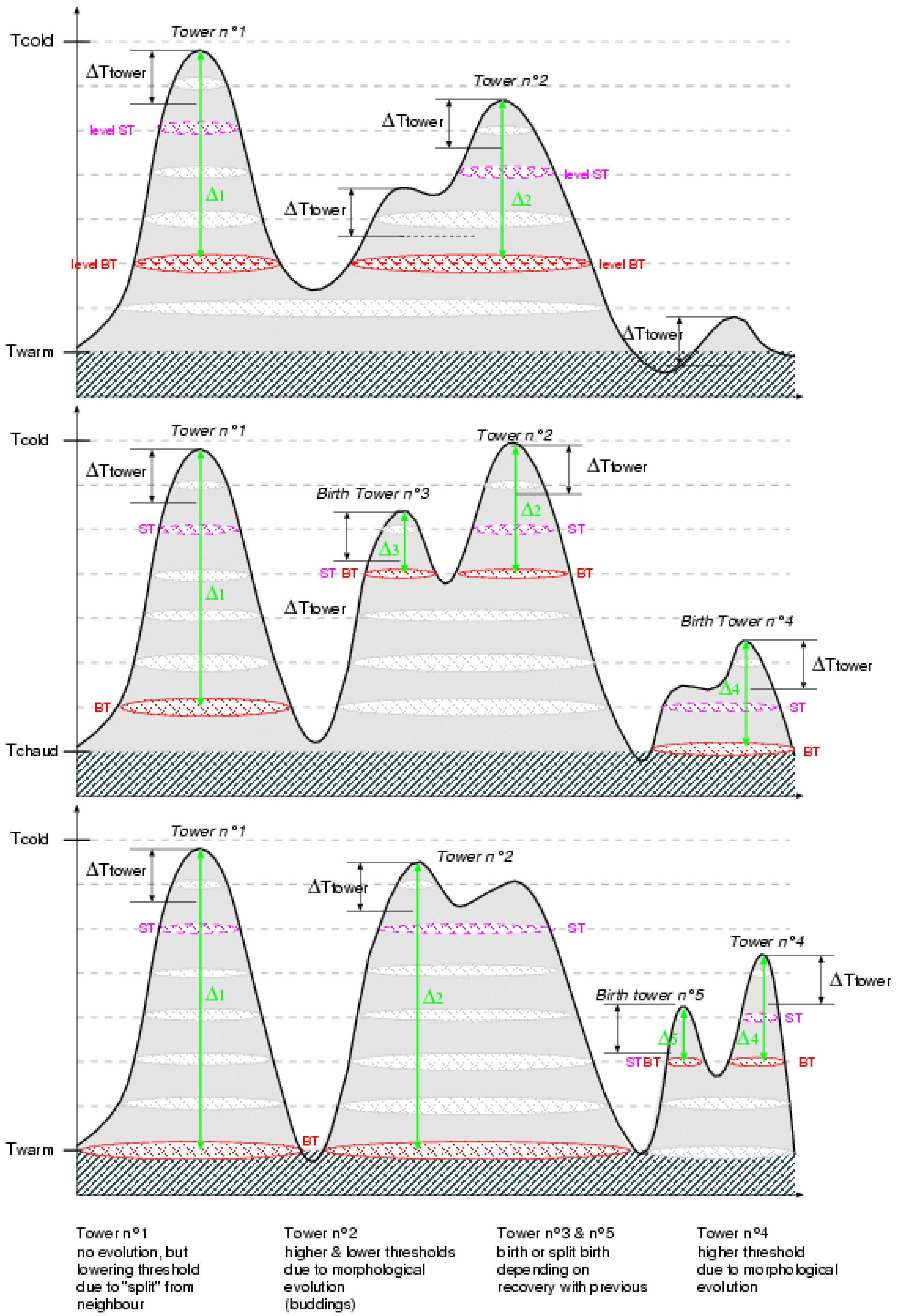


Figure 4: Diagram illustrating the principle of the detection algorithm

3.1.2.2 The tracking of cloud systems

Once the detection of cloud systems is performed, the tracking module of the RDT software is applied on the detected "cells" and allows to build trajectories of cloud systems from a sequence of infrared images. The tracking algorithm is based on the geographical overlapping of "cells" between two successive infrared images. It also handles splits and merges of cloud systems.

The main difficulty is the tracking of small cloud systems (typically less than 5 pixels). In order to improve the tracking of such small cloud systems, the RDT tracking algorithm takes into account an estimated velocity of "cells" to compute the overlapping between "cells".

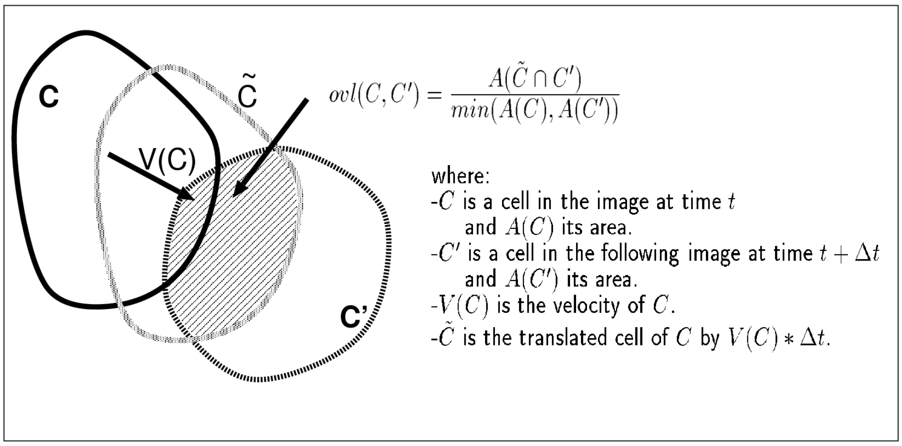


Figure 5: Definition of the overlapping between two cells

Briefly, the search for an overlapping between a cloud system C' detected in the image at time t+Δt and cloud systems detected in the previous image at time t is made as follows:

1. First, "cells" in the image at time *t* are advected using their estimated velocity. If at least one of these advected cells overlaps sufficiently with cloud system C' then a link is created between C' and this (these) cell(s).
2. If no overlapping is found, then the velocity of the cloud system C' is evaluated from cross-correlation technique.
3. The cloud system C' is then backward-advected from this estimated velocity. If at least one of the cells detected at time t overlaps sufficiently with the backward-advected cloud system C' then a link is created between C' and this (these) cell(s).
4. If no overlapping is found, then the backward-advected cloud system C' is enlarged and a last search for overlapping between this enlarged backward-advected cloud system C' and cells detected at time t is done. If at least one of the cells detected at time t overlaps sufficiently with the enlarged backward-advected cloud system C' then a link is created between C' and this (these) cell(s).
5. If no overlapping is found then cloud system C' is identified as the beginning of a new trajectory.

Figure 7 illustrates how the steps 2 and 3 of the tracking algorithm could improve the tracking of small cloud systems. In the diagrams of this figure, the "cells" of a given cloud system in two consecutive images are showed: C is its "cell" in the image at time *t* and C' is its "cell" in the image at time $t+\Delta t$.

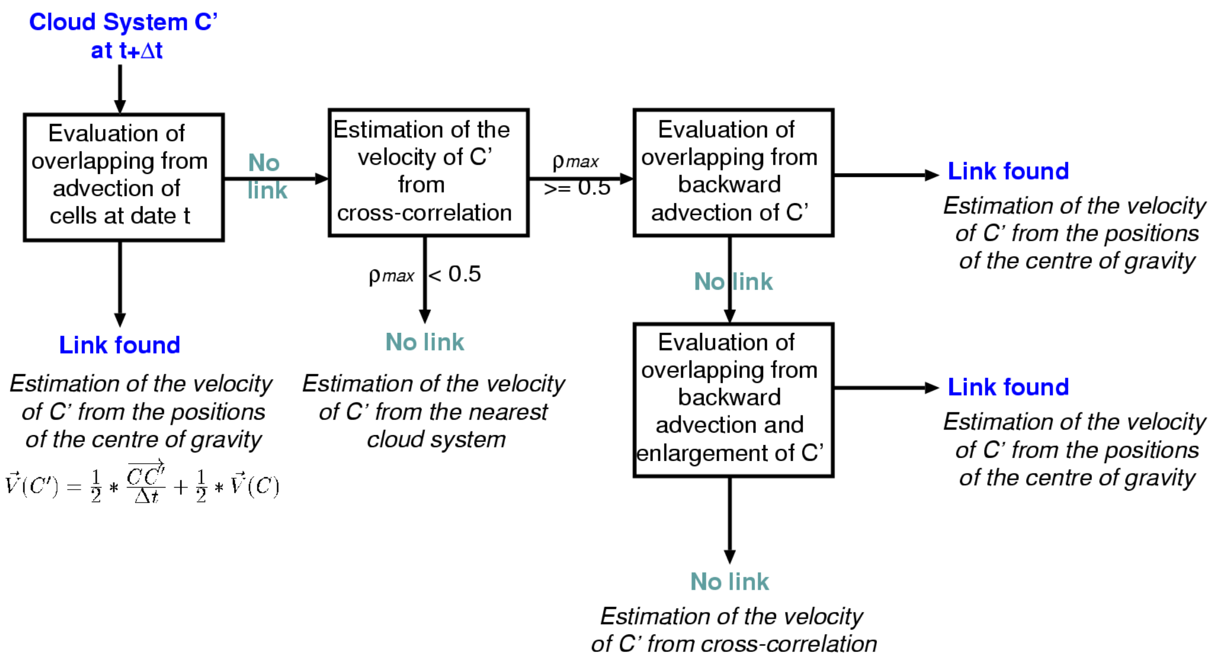


Figure 6: Main steps of the tracking algorithm

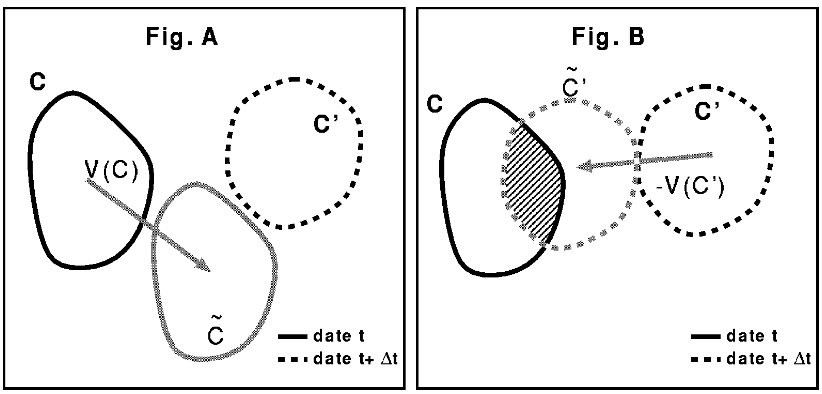


Figure 7: Principle of the tracking algorithm (steps 2 and 3)

In Figure 7 A, $\tilde{C}$ is the translated cell of C by $\vec{V}(C)\times\Delta t$ where $\vec{V}(C)$ is the estimated velocity of C, as computed in the previous tracking stage. In this case, the quality of the velocity was too low and lead to no overlapping between $\tilde{C}$ and C'. So, after step 1 of the tracking method, no link is created between "cells" C and C' and so, if steps 2 and 3 were not in the tracking algorithm, the tracking of this cloud system would have failed.

With the implemented RDT tracking algorithm, the following analysis is done:

- C' is a "cell" in the image at time *t+Δt* which overlaps with no "cell" of the previous image, consequently its velocity $\vec{V}(C')$ is evaluated using a cross-correlation technique.
- Figure 7 B displays the cell $\tilde{C}'$ which is the translated cell of C' by $-\vec{V}(C')\times\Delta t$, an overlapping is now existing between C and $\tilde{C}'$ and so, the tracking algorithm creates a link between "cells" C and C': the tracking is successful.

Step 4 of the tracking algorithm is an improvement for the tracking of very small cloud systems (less than 5 pixels). The enlargement of a cloud system consists of adding "pseudo-cloudy pixels" (see Figure 8) to the detected cells all along its edge in order to increase, artificially, the size of the cell and then to ease the occurrence of overlapping between consecutive cells corresponding to the same cloud system.

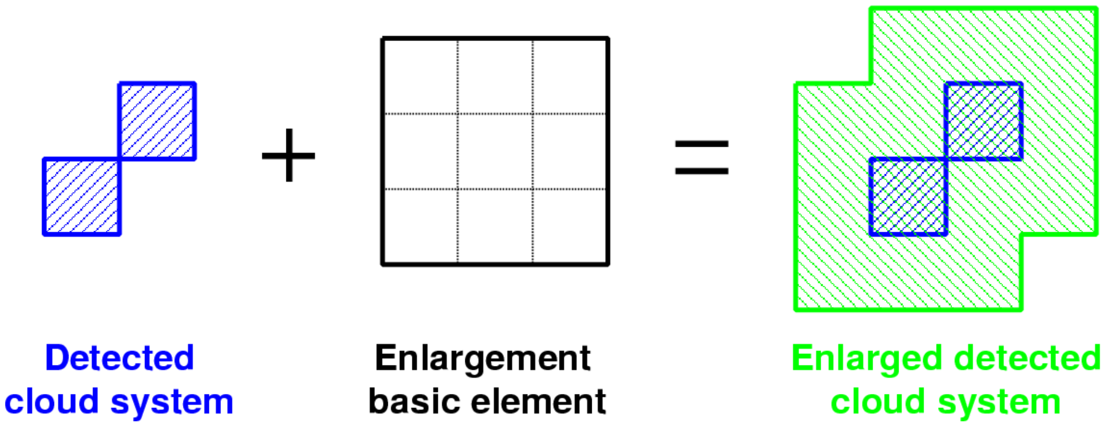


Figure 8: Principle of the enlargement of cloud systems (step 4)

3.1.2.3 The discrimination scheme

3.1.2.3.1 The major principles

The methodology and the statistical model choice have been defined with the support of Statistical Laboratory of Toulouse ([RD 1], [RD 2])

On statistical approach, the two populations, convective and no convective, are unbalanced. We can notice a ratio of one convective for more than one hundred convective over Europe.

Moreover, a convective object has not homogeneous characteristics during its life time. Thus, it is necessary to define several statistical bodies in order to take care of various stages of convective phenomena: triggering, development, mature and decaying phases.

At last, the ground truth used, cloud to ground occurrence, doesn't allow to diagnose the time of convection triggering or to depict the decaying period.

Therefore, the discrimination scheme is a mix between statistical decisions and empirical rules. The statistical decisions are only processed for a short period centred on several times of interest. They are only applied on no convective object to check their convective status. The empirical rules are defined to declassify convective object (convection decaying or false alarm diagnosis). They are based on cooling parameters for triggering and development phase and based on cooling and global convection index for mature phase.

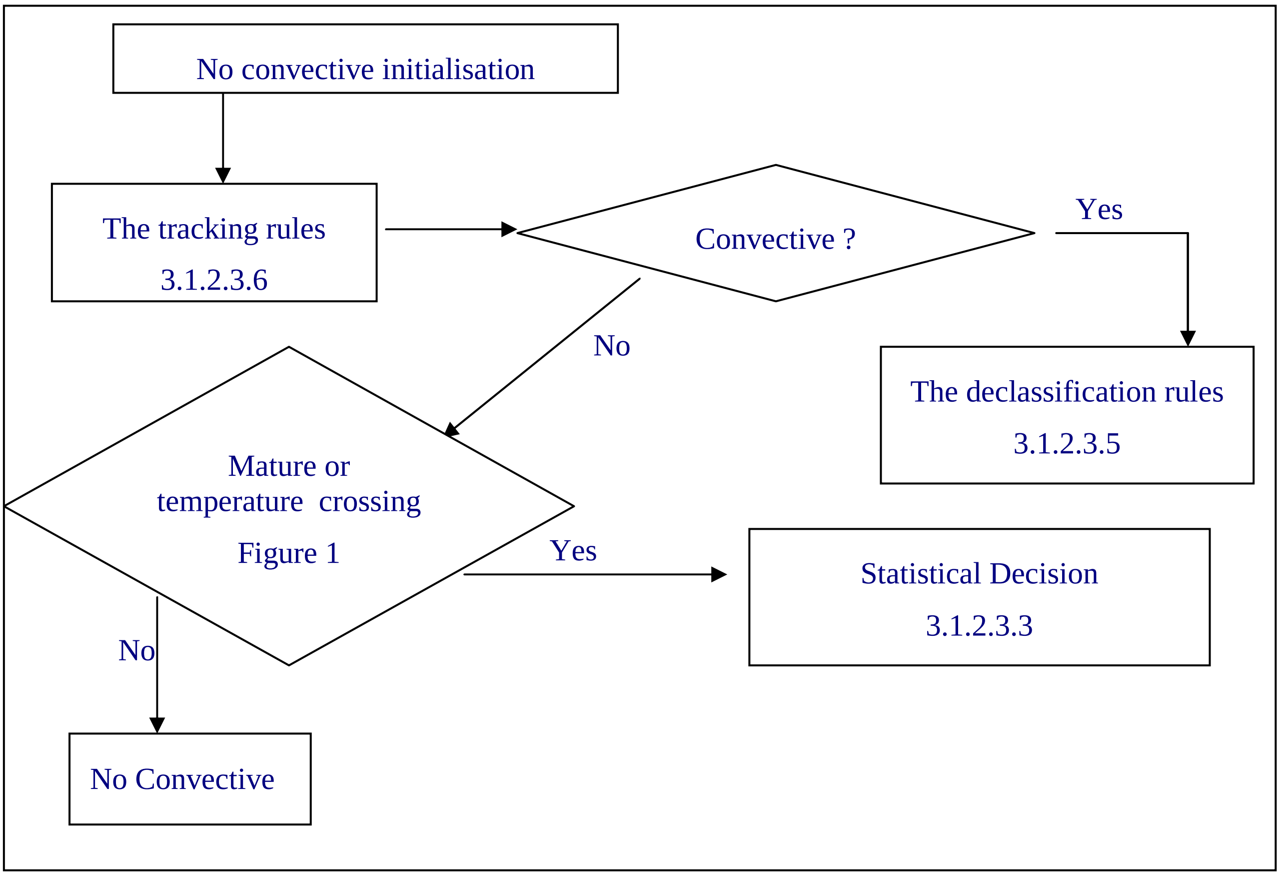


Figure 9: The discrimination schedule

3.1.2.3.2 NWP convective mask

The major improvement of PGE11v*2011* is to benefit from a NWP guidance before attempting a diagnostic.

NWP data are used to produce a convective mask through computation of several convective indexes : K index, Showalter index and Lifted index. The union of these indexes allow to identify stable areas where probability of convection will be very low. Values of this mask are 0 if all indexes are stable, 2 if at least one index is unstable, 1 in other cases. Regions with null (0) values are ignored by discrimination step.

Thus, PGE11 discrimination scheme focuses on convective regions, and avoid eventual false alarms, especially in winter or intermediate seasons.

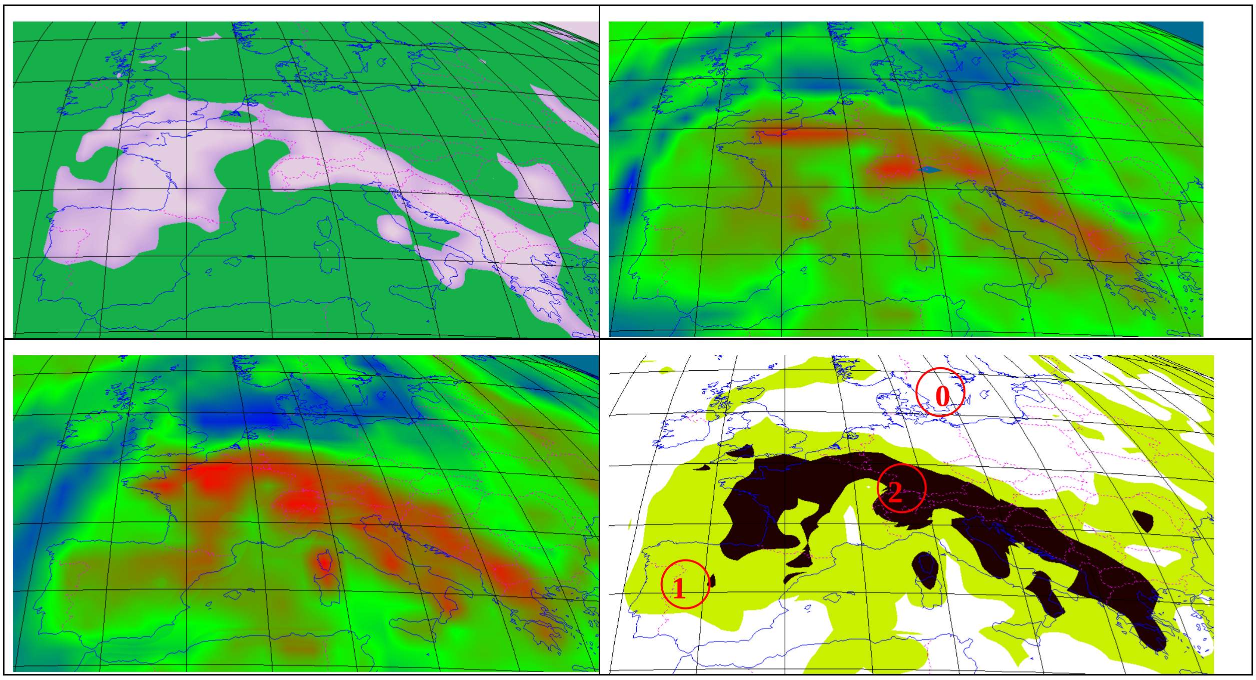


Figure 10: 25 May 2009, 12h15. Convective mask(bottom right), as a union of K index (top left), Showalter index (top right) and Lifted index (bottom left), from NWP data. Regions 1 and 2 are region of interest for PGE11 discrimination

Moreover, this approach has been applied during the tuning of PGE11 discrimination scheme, to exclude from the tuning areas and cloud systems without interest from a convective point of view.

Thus, this lead to a major improvement thanks to a strong decrease of the imbalance between convective and non convective populations, especially in the in warmest categories. The consequence is a better tuning in these categories, leading to a strong improvement concerning precocity.

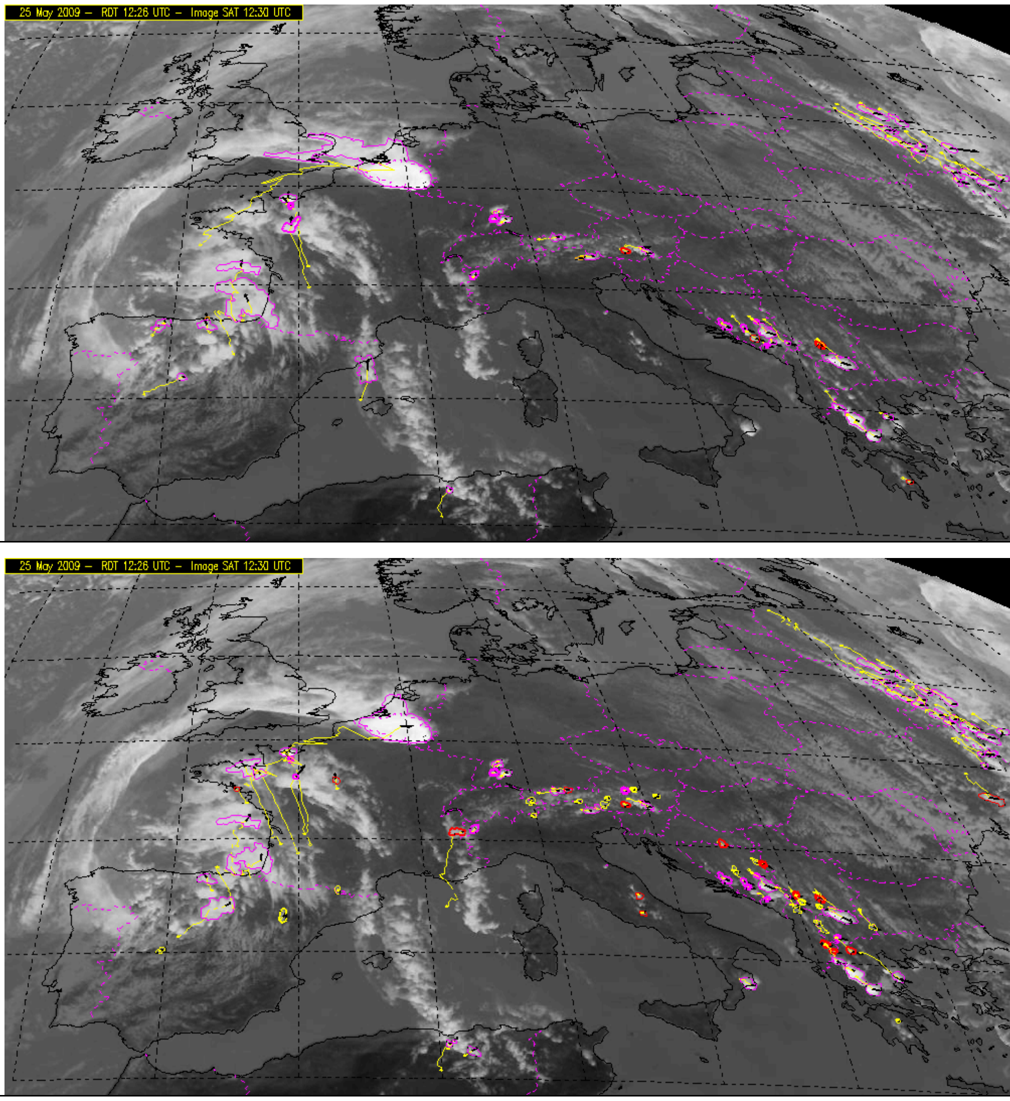


Figure 11 : 25 May 2009, 12h30 UTC. PGE11 v2010 (top) and v2011 (bottom). V2011 obviously benefits from a better tuning in warmer categories, with higher precocity (cells over Italy diagnosed 30 min previously)

3.1.2.3.3 The statistical decision

The discriminating parameters associated to a cloud object are processed on three MSG channels (IR 10.8µm, IR8.7µm, IR12µm, WV 6.2µm and WV 7.3µm). The cloud tracker allows to estimate rates and extremes on various past period. The list of discriminating parameters is provided in annex.

The statistical decision operates like a sieve with several level of accuracy. It combines several times of interest defined on temperature threshold crossing , a final step focused on mature stage , and a beginning step for initial developing stage

- Mature: top temperature < -40°C since at least 45min
- Mature transition: crossing top temperature –40°C
- Cold transition: crossing top temperature –35°C **or** base of cloud tower –25°C
- Warm2 transition: crossing top temperature –25°C **or** base of cloud tower –15°C
- Warm1 transition: crossing top temperature –15°C **or** base of cloud tower –5°C
- Warm : top temperature > -15° **and** base of cloud tower > –5°C, preceding Warm1 crossing

The statistical models defined on temperature threshold crossing are named transition models. The models defined on mature population are named mature models, and those defined on warm population warm models

The warm and transition models are defined for four depth, depending on available past historic: 15, 30 , 45 and 60 minutes. The mature ones are defined on period of at least 45 minutes, i.e. for 45 and 60 minutes depth.

In order to provide a classification for several configuration, the statistical models are defined on six available data hypothesis:

- IR10.8µm, IR8.7µm, IR12µm, WV6.2µm, WV7.3µm + NWP data
- IR10.8µm, WV6.2µm + NWP data (designed for GOES-12)
- IR10.8µm + NWP data (designed for METEOSAT-7)
- IR10.8µm, IR8.7µm, IR12µm, WV6.2µm, WV7.3µm
- IR10.8µm, WV6.2µm (designed for GOES-12)
- IR10.8µm (designed for METEOSAT-7)

It is to note that even if the user's configuration file does not correspond to the real time availability of data, PGE11 is able to adapt and detect automatically the best usable configuration among the ones listed above. For that reason, each mode has benefit from a specific tuning

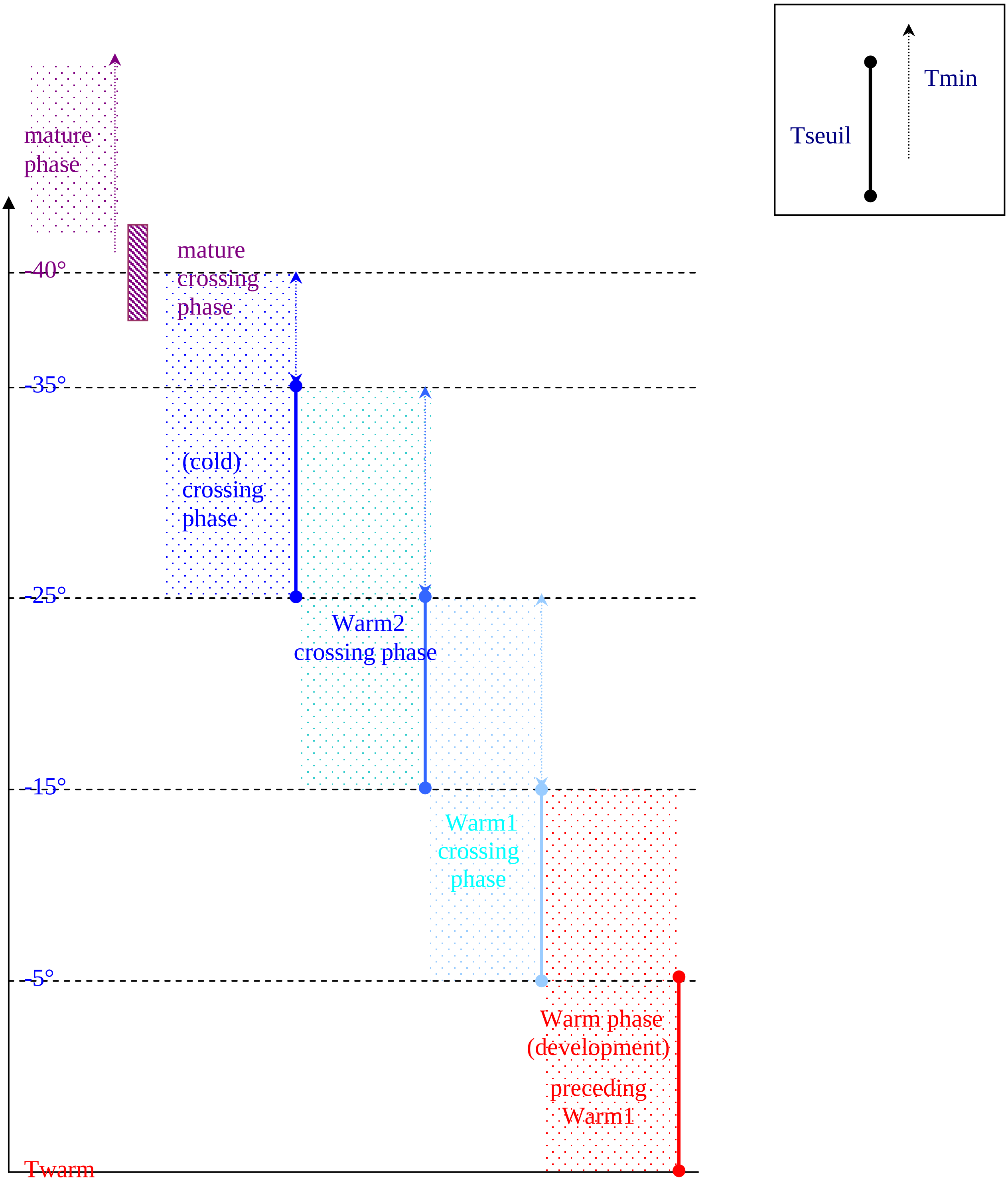


Figure 12: Vertical view : Categories of discrimination scheme and corresponding discrimination models

During the discrimination tuning for transition categories, 60min sections centred on transition time are extracted from cloud system trajectories, and models are defined on various depth, respecting the way those models are planned to be used in real time : the choice of a model correspond to a choice of depth, based on age in the category, age of first detection, and past historic in the warmer category.

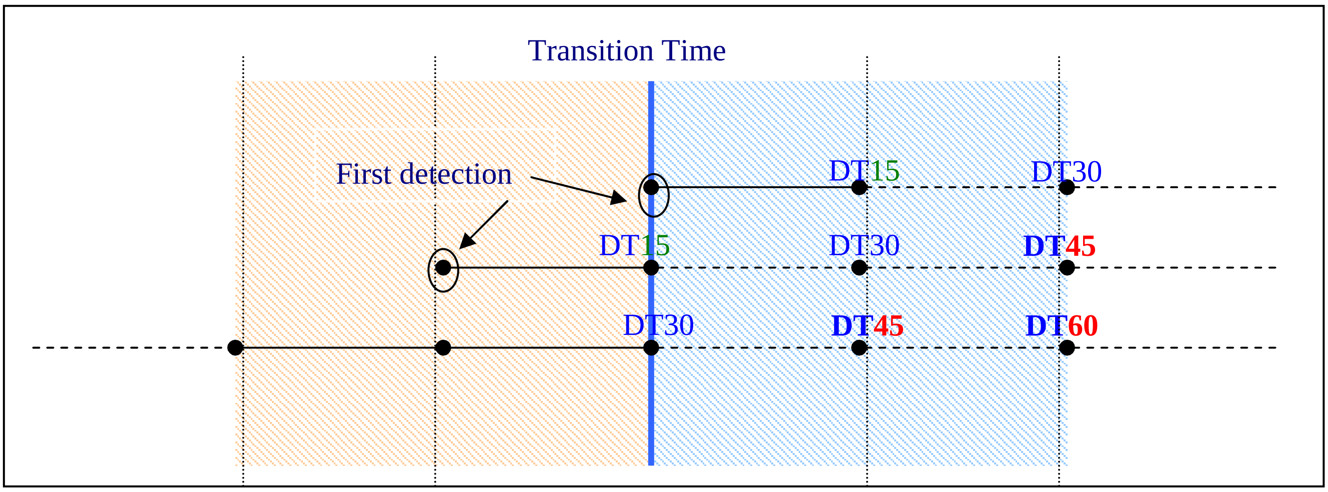


Figure 13: Temporal view : Transition model applicability depending on available historic. 3 cases depending on time of first detection. Transition time may be Tmin or Tseuil crossing their respective thresholds.

Warm category benefits from a specific approach, taking into account that the 60min section are extracted from cloud trajectories ahead a time of reference which is the Warm2 transition time, respecting the figure below.

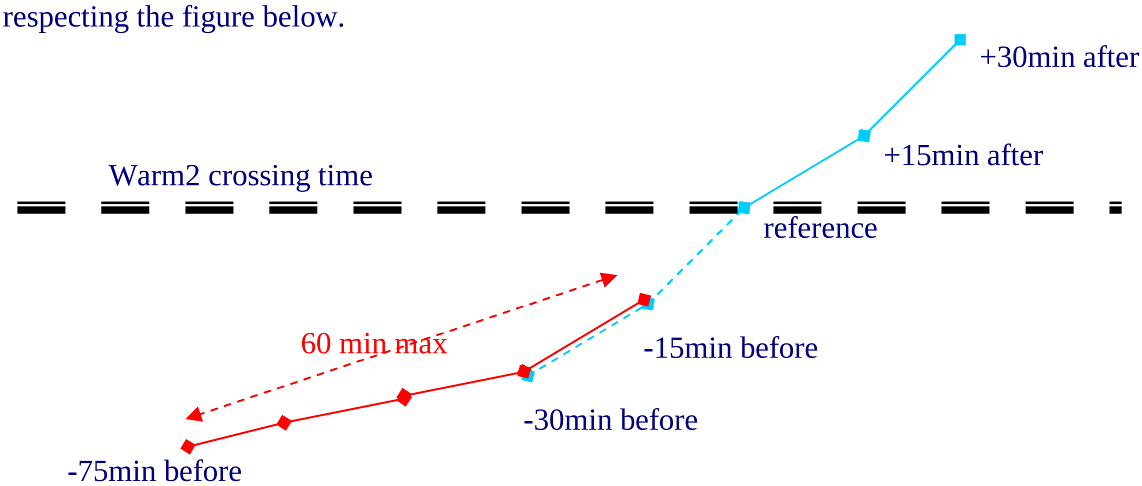


Figure 14: Spatial and temporal view for Warm category.

To summarize, the statistical scheme is based on four discriminations defined on crossing times and one discrimination for each mature and warm case. Each discrimination is defined on various time depth, depending on available historic data (15, 30, 45 and 60min) , except mature case defined for 45 and 60min only. Thus, the discrimination scheme rests on (5 categories x 4 depth + 1 category x 2 depth) x 6 configurations = 132 models. For that reason, the description of discrimination tuning in this document will give only a quick overview of the results obtained.

Preliminary studies had been led to assess convective discriminating skill of linear and no linear models (see [RD 1]) to be incorporate into the discrimination scheme. The best results were obtained with random forest method (with 600 tress) and simple Logistic Regression method. The logistic regression had been implemented into operational version from v2009 release. This model is simple and fast, and provide some information one discriminating parameters.

3.1.2.3.4 The statistical model tuning

The data used for discrimination were June-August 2008 and June-September 2009, for both MSG02 and MSG01-RapidScan, and corresponding NWP data from Meteo-France ARPEGE model, for 12h and 18h ranges (as for real time use).

The domain used for the tuning has been a little bit widened, to take into account last 2008 statistics of lightning data (provided by Météo-France Observation Department and concerning Météorage and partners network). An accuracy of 2-4km of detection has been taken into account.

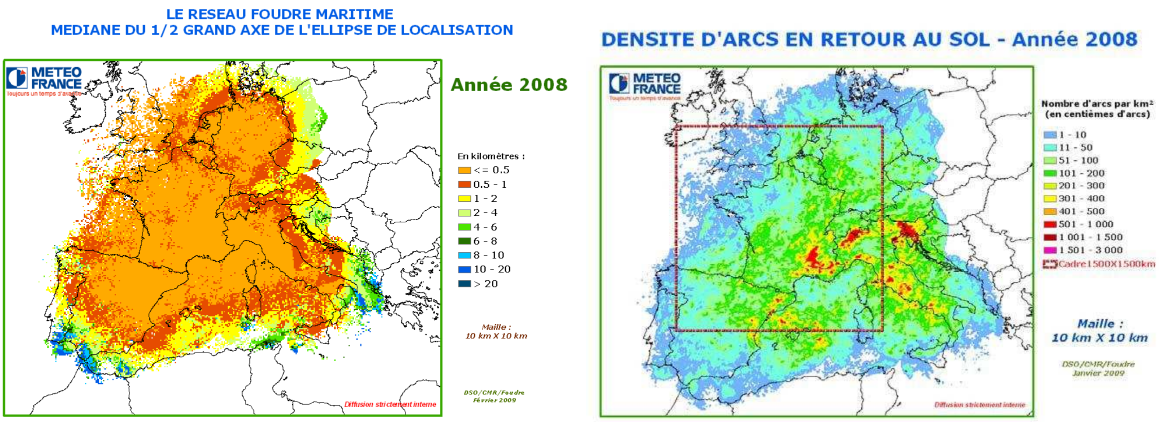


Figure 15: Extension and quality (precision left, density right) of Meteorage+partners network.Meteorage network coverage appears in red on right image

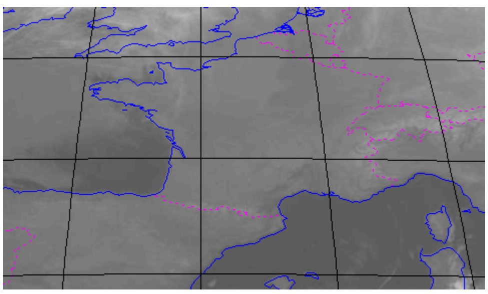


Figure 16:Domain used for RDT v2011 discrimination tuning

Thanks to the availability of more numerous 2008 and 2009 data, the discrimination tuning method has been modified for v2011 release in order to decrease the dependency to learning data set, and increase the stability (robustness) of statistical models.

1. The use of NWP data to exclude cloud systems in stable areas has allowed to reduce in the database the imbalance between electric and non electric systems. For that reason, the method has evolved in respect to "data mining" techniques : a large learning data set without modifications of the initial proportion of population.
2. The ground truth used rests on a moderate lightning data activity, even for mature and transition mature categories (based on strong activity for v2009 and v2010). But the proximity to lightnings has been taken into account to built a non polluted non-convective population , still decreasing the imbalance (non convective when 50 pixels far from flashes, i.e. about 150-200 km).
3. Cross validation method has been implemented to reduce the dependency to the learning data set. For each statistical model, the whole data base has been taken into account for a first tuning (except 4 weeks for a further independent validation) in order to obtain a selection of relevant parameters (predictors). The coefficients of these parameters have been then "adjusted" through the processing of fifty learning-validation steps, where learning and validation dataset where randomly choosen (with respect to a proportion 80%-20%). Thus, linear model will be less dependent on learning data set.
4. Finally, a validation step is undertaken on a independent data set : 4 weeks distributed among 2008 and 2009 , 20080713-20, 20080901-08, 20090617-24 and 20090821-28.

2008 and 2009 summers, except non electric days	4 distributed weeks
Learning dataset	Validation dataset

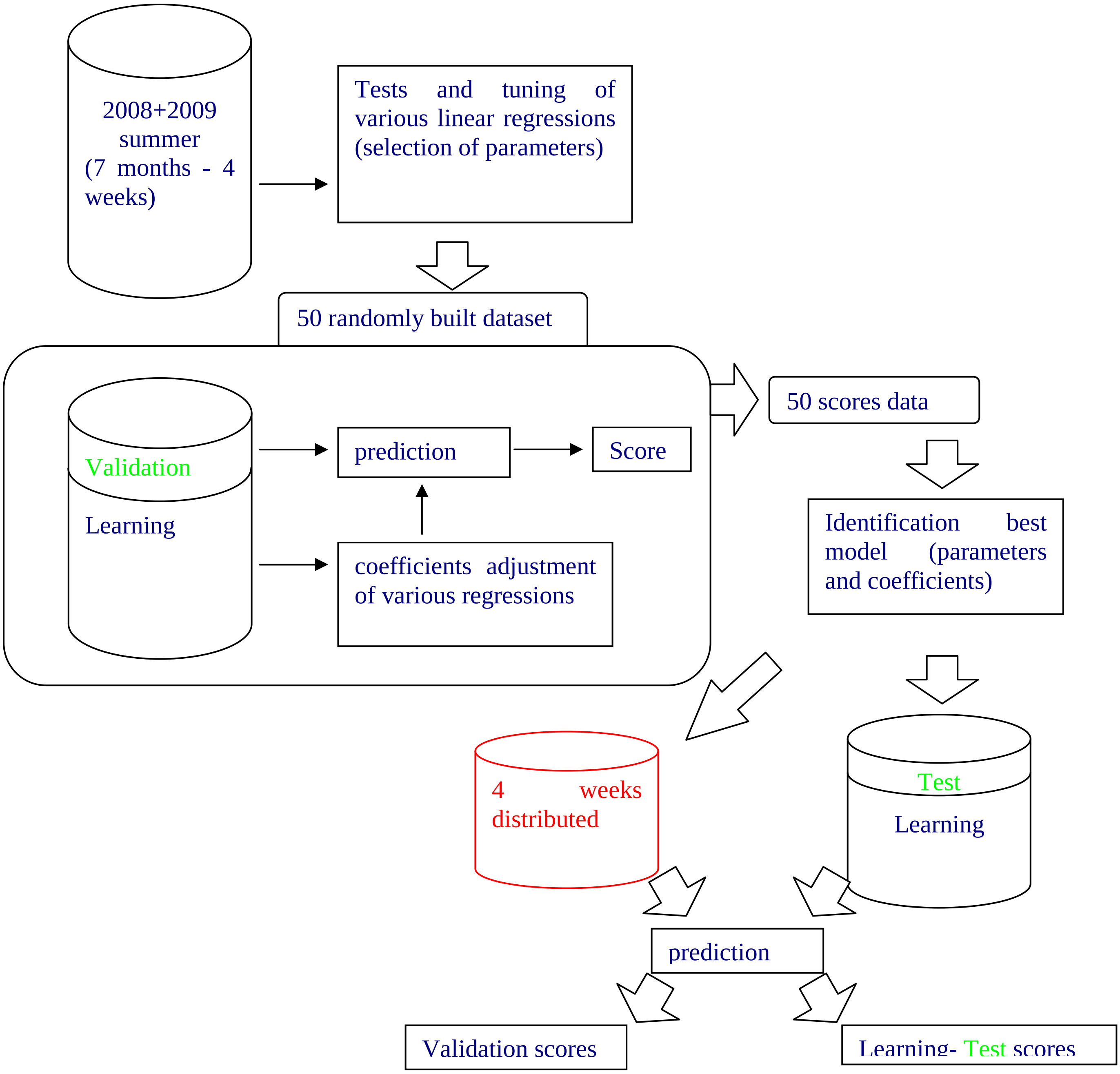


Figure 17: Discrimination tuning methodology.

The discrimination skill is depicted from threat score -false alarm distributions. This depicting allows to point out the inflexion point where the false alarm increase more than no detection decreasing, with respect to a maximum acceptable false alarm rate (varying from 5% to 15% depending on distributions).

The threat score /false alarm distributions are displayed in graphs like figure below, where learning data set appears in black (80% of learning data set), random test data set in green (remaining 20%), and validation data set in red. Minimum value of (TS-FAR) is marked as a cross. The automatic choice of decision threshold is made from red distribution, taking into account this marked point and a maximum value of FAR.

It has to be noted that a strict comparison of scores and graph with previous PGE11 release will be made difficult for several reasons :

- The constitution of database is quite different, with a NWP convective mask as a priori filter to cloud trajectories
- The methodology is quite different too, with a cross-validation process and a different manner to consider learning dataset, test dataset and validation dataset. Validation dataset in particular is quite restricted in comparison with learning one.
- The period of tuning is much larger, consequently the tuning more reliable
- The ground truth is slightly different, moderate for all categories but taking flashes proximity into account to constitute non convective population
- The area of tuning is a little bit wider

The comparison with previous version has been undertaken on a subjective basis, with topical case situations and real time situations, on a larger domain than for the tuning.

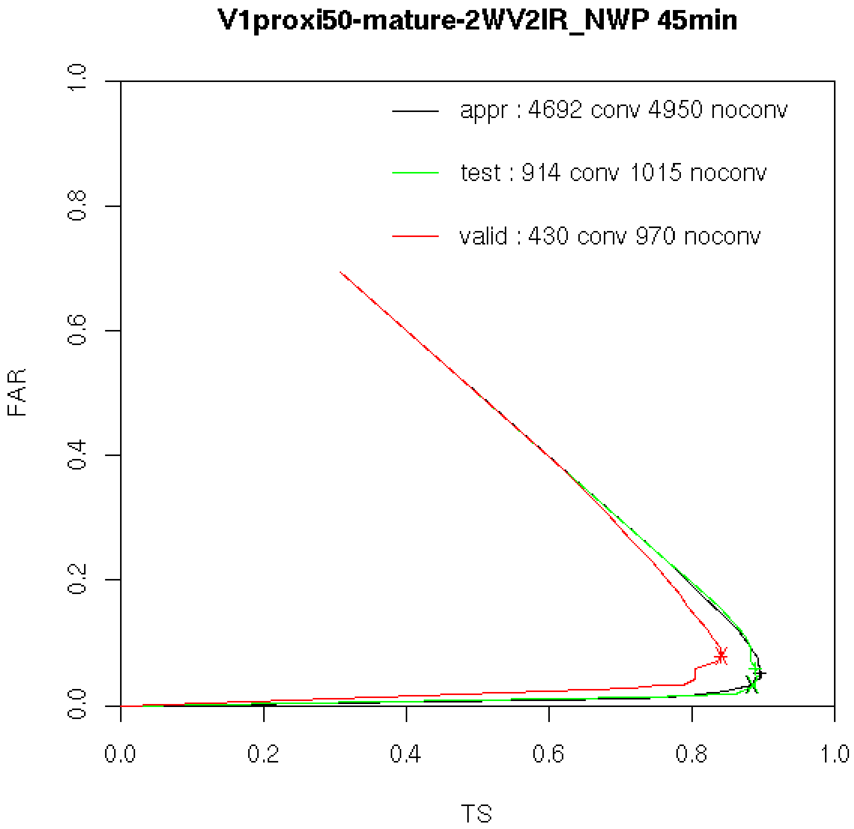


Figure 18: MSG V2011 tuning. TS/FAR curves for mature discrimination (DM), full configuration 6.2µm+7.3µm +8.7µm +10.8µm +12.0µm +NWP, 45 min depth, for a moderate ground truth with proximity to flashes taken into account

Learning database (black), random test database (green), Validation database(red)

The results issued from discrimination tuning (see graphs in next sections) allow to rank the configurations of PGE11 upon scores, whatever the categories :

1. "Full" configuration IR10.8µm+all additional channels (6.2µm+7.3µm +8.7µm +12.0µm) +NWP data
2. "All channels" configuration IR10.8µm+all additional channels (6.2µm+7.3µm +8.7µm +12.0µm)
3. "Limited with NWP" configuration IR10.8µm+WV6.2µm +NWP data
4. "Limited" configuration IR10.8µm+WV6.2µm
5. "Mono channel with NWP" configuration IR10.8µm+ NWP data
6. "Mono channel with NWP" configuration IR10.8µm

The automatic choice of configuration mode by PGE11 in the discrimination step, depending on available data (additional channels or not, NWP data or not), will respect this ranking.

Considering categories, the ranking upon scores is similar to the vertical ranking, as expected : cold categories offer better tuning and scores than warmest ones.

Considering past historic depth, larger depth most often get better scores than shorter ones, except for warmest categories, where significant signal is found and exploited even in shorter depth (15 and 30min), with systems is ascending phase remaining few time in these categories.

Synthesizing all the results leads to invalidate some models, when they present higher false alarms.

All invalidated models are listed in a specific file in $SAFNWC/import/Aux_data/PGE11/files_for_discri/ConvCoeffRegr_mask (ConvCoeffRegr_5_mask for rapidscan tuning) , sorted by configuration/category/depth. This file is read as a guidance in real time at the discrimination step of PGE11.

This is for example the case for warm category, for other configurations than the "full" configuration 2WV2IR+NWP : The use of NWP configuration allow to lower the false alarms, making those models usable for 15 and 30min depth essentially (Threat scores approaching 60% for False alarms less than 10%).

3.1.2.3.5 The declassification rules

The declassification is only applied on convective object in order to diagnose the false alarms or decaying phase. The declassification rules have been empirically defined on some case studies due to lack of ground truth to tune statistical models on these problematics.

To manage change of RDT objects into discrimination scheme (Figure 12), the objects are characterized by temperature classes:

- Category 1 : Top Temperature < -40°C
- Category 3: Top Temperature < -35°C or Base temperature < -25°C
- Category 4: Top Temperature < -25°C or Base temperature < -15°C
- Category 5: Top temperature < -15°C or Base temperature < -5°C
- Category 6: Top temperature > -15°C and Base temperature > -5°C

The Category 2 is associated to discrimination of mature transition. Nevertheless, these object are assumed mature (category1) for declassification rules.

The convective classification is supposed to be valid at least 45min for cloud systems, from the moment they do not present a strong warming. Due to a higher probability of false rate, this validity is only 30 min for the warmest category for cooling systems only.

Beyond this validity time, except category 1, a convective object is declassified if it stays into the same category. This schedule allows to improve the stability of diagnosis, and focus on cloud systems in ascending phase.

The category 1 is associated to mature phase. The declassification rules can not be defined on development criteria or cooling rate. As previous cases, the convective classification is assumed 45 minutes at least. After this period, The convective object is declassified if it changes of temperature category (Top temperature > -40 °C) or if the global convection index (WV6.2 – IR 10.8) verify the following conditions: GCD < -1 and trend on 45'< 0, or if another criteria based on the sum of all BTDs is satisfied.

3.1.2.3.6 The tracking rules

The previous paragraphs depict convective and no convective decision depending on object attributes. This paragraph depicts empirical rules defined on convective management associated to tracking algorithm.

At first, a new detection is always classified like no convective.

The tracking algorithm allows to link an object to objects defined on the previous image. The object matching are named "father". The main father is the father which the higher surface (defined at a common temperature). The convective father is the colder convective father. In some cases, the main father and the convective father could be the same.

The discriminating parameters are processed on main trajectory. The convective trajectory allows to manage the convective time and temperature category change used into the declassification rules.

If an object has a convective father, the object is classified like convective before to check declassification conditions on convective trajectory.

In the case of decreasing temperature category change, the convective time is initialised to zero for the new class. In the other cases, the convective time is raised.

3.1.2.3.7 The discrimination skill option

The statistical available by default are depicted on **Erreur ! Source du renvoi introuvable.**. Nevertheless, the user could reduce the false alarm ratio with option "precocite" of configuration file.

This option set to 0 deactivates the warmest discrimination of transition and all statistical models defined on a past historic shorter than 30 minutes.

3.1.2.3.8 The lightning discrimination

The object approach allows the data fusion with auxiliary data. The option "-lightning" of configuration file defines the lightning used. Set to N>0, the lightning is used to force convective characteristic of an object at the bufr writting step. Thus, an object not classified as convective by the discrimination scheme remains no convective for the algorithm of discrimination even if some flashes strokes are diagnosed.

3.1.2.3.9 The convective stage diagnosis

The diagnosis of convective phase is simply based on the temperature category depicted. The decaying stage is associated to a de-classification during a short period.

3.1.3 Error Budget Estimates

The improvement of cell definition, tracking and discriminating parameters computation lead to process a complete validation on convective discrimination accuracy. These validations have not been taken care into CDOP proposal.

3.2 PRACTICAL CONSIDERATIONS

3.2.1 Calibration and Validation

3.2.1.1 Objective validation

The objective validation has been done on summer 2008 over France (June to August). The lightning activity is used as ground truth.

The RDT V*2011* has not been validated on a large validation database but only on several cases study, and in real time configuration. Thus, the objective score defined on the previous version remains valid.

At first, the probability of detection of convective period is equal to 71%. The start of a convective period is defined on the first lightning occurrence on the convective section. Due to some delays on this reference, the probability of detection on convective single moment is smaller (59%). Nevertheless, more than 80% of good detection are detected before 30 minutes after the first occurrence.

More than objective score, the new version 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 small 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. Even if the precocity on the first lightning occurrence remains weak, the subjective evaluation confirms the precocity usefulness on moderate lightning activity.

3.2.1.2 Subjective validation

The subjective evaluation of the RDT V*2011* points out some improvements:

- False alarm reduced by the use of NWP data as a guidance (convective mask)
- Detection improvement by the use of NWP data for the tuning, improving the scores of statistical models in all categories.
- Early detection improvement due to score increasing on Warm1 and Warm statistical models.

V2011 tuning focuses on precocity of detection in warmest categories, by the use of a NWP convective mask to decrease the imbalance between convective and non convective systems, but also by the use of a convective index as additional parameter.

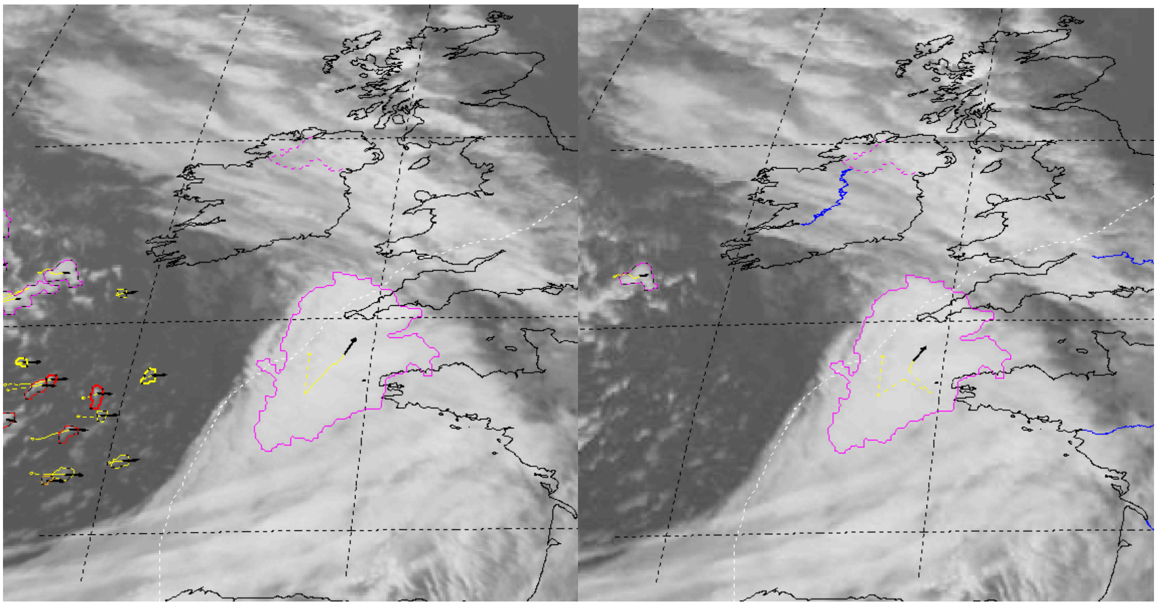
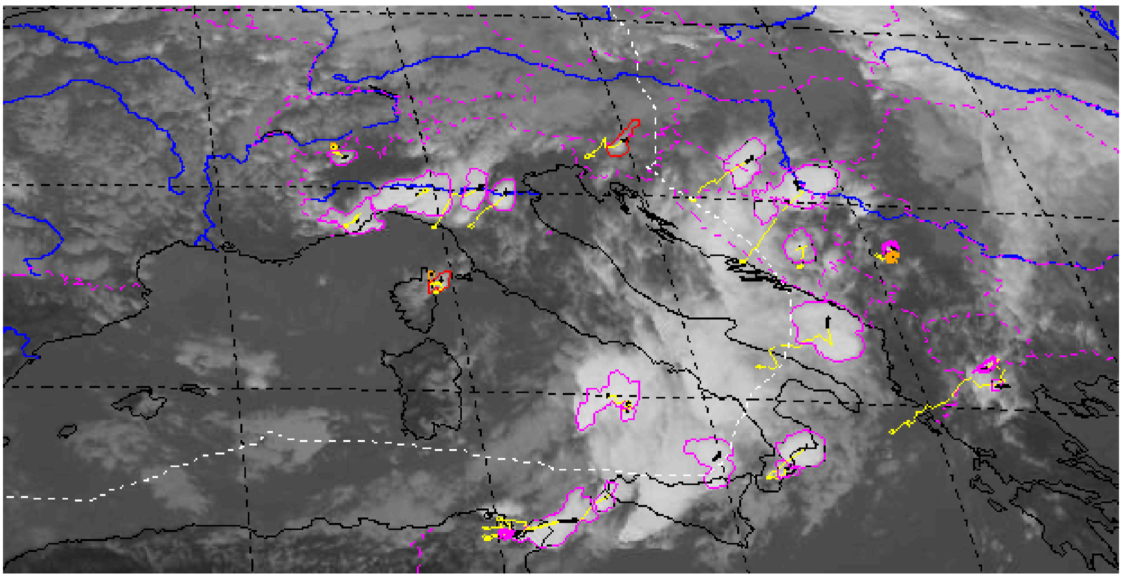


Figure 19:Comparison of RDT v2011 (with NWP data) vs V2010 (without NWP data).6 September 2010, 07h30

On the figure above , numerous small and warm convective systems are diagnosed by v2011 in the cold convective air mass behind cold front. All these systems are cooling convective clouds, even if not always leading to an electrical activity. On this picture, the only electric system is embedded in the cloud mass of the perturbation.



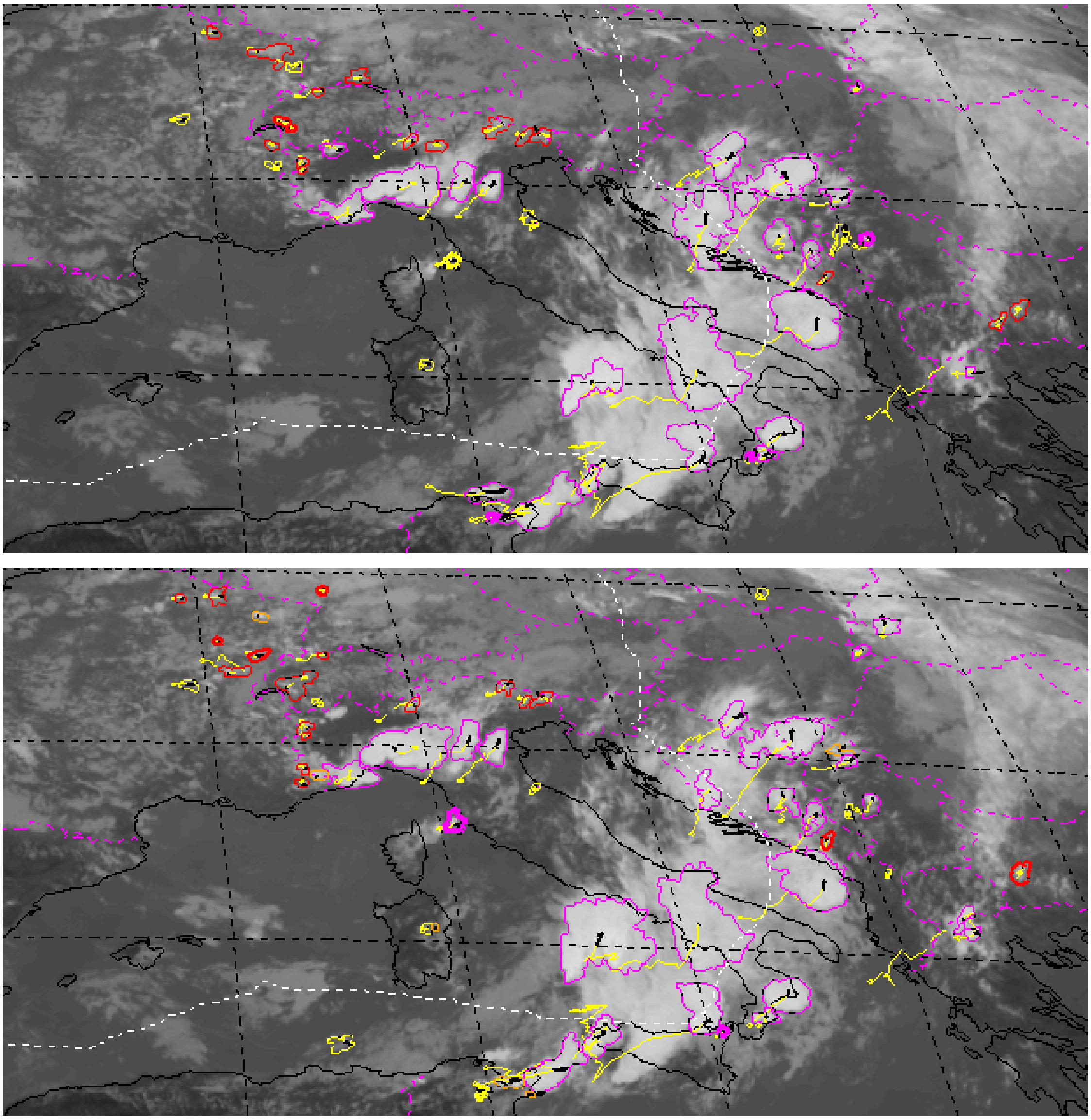


Figure 20:Comparison of RDT V2010 (top).vs v2011 9 September 2010, 13h15(middle) 13h30 (bottom). Yellow contours for Warm and Warm1 categories, red for Warm2 and Cold, violet for mature and transition mature.

The situation above not only displays the improvement with warm categories discrimination, but also higher detection of mature one.

Small systems on the eastern french frontier are all convective cooling systems, most of them associated with lightning flashes, and diagnosed by v2011 only. Other warm systems (yellow contours) are relevant (good precocity east of Corsica at 13h15), some others are not confirmed (French Alps).

Finally, v2011 allows to decrease false alarms and increase precocity of detection, thanks to a better tuning in all categories. Probability of detection is higher than previous version, especially in the warmest categories. Convective systems are thus more numerous , but it must kept in mind that the attempt to classify cloud systems in the warmest categories may lead to an increase of false alarms compensate the gain in the colder categories.

Thus, the activation of warm discrimination remains an (default) option of users (-precocite argument of PGE11 model configuration file), and can be eventually desactivated .

3.2.2 Quality Control and Diagnostics

The RDT doesn't process real time quality control on tracking or discrimination result.

3.2.3 Exception Handling

The RDT doesn't manage a quality of satellite data input due to lack of it. Nevertheless, RDT manages the flag quality of CTTH products.

Moreover, the RDT software produces some code error in exception cases.

Type (E/W)	Code Number	Code	Message	Comment	Recovery Action
E	11000	PGE11_SETREGION_ERROR	ERROR: BAD ALLOCATION OF THE REGION STRUCTURE (OUTPUT OF SETREGION SUBROUTINE)	The region structure of the HRIT processed image has been badly allocated (problem with the "setregion" routine of the NWCLIB).	Write a SPR
E	11001	PGE11_SEVINIT_ERROR	ERROR: BAD ALLOCATION OF THE IMAGE STRUCTURE (OUTPUT OF SEVINIT SUBROUTINE)	The image structure of the HRIT processed image has been badly allocated (problem with the "sevinit" routine of the NWCLIB).	Write a SPR
E	11002	PGE11_SEVREAD_ERROR	ERROR: PROBLEM WHEN READING THE INPUT SATELLITE IMAGE (OUTPUT OF SEVREAD SUBROUTINE)	An error occurs when reading the HRIT processed image (problem with the "sevread" routine of the NWCLIB).	Write a SPR
E	11003	PGE11_READ_IMAGE_CANAL_NULL	ERROR: WRONG CHANNEL NAME (PGE11_READ SUBROUTINE)	An error occurs when reading the HRIT processed image (bad channel name).	Write a SPR
E	11004	PGE11_READ_IMAGE_DONNEES_NULL	ERROR: WRONG DATE OF SATELLITE IMAGE (PGE11_READ SUBROUTINE)	An error occurs when reading the HRIT processed image (wrong date of the image).	Write a SPR
E	11005	PGE11_DUP_IMAGE_NULL_ENTRY	ERROR: WRONG IMAGE TO DUPLICATE (PGE11_DUP_IMAGE SUBROUTINE)	The image structure to duplicate was corrupted.	Write a SPR
W	11006	PGE11_SUPPRIME_DESCENDANCE_COHERENCE_PROBLEM	PB. WITH THE RELEASE OF CELL STRUCTURES (SUPPRIME_DESCENDANCE SUBROUTINE)	The release of a trajectory has failed.	Write a SPR
E	11007	PGE11_BUFR_NO_TABLES	ERROR: THE CONFIGURATION FILE PGE11_BUFR_table IS CORRUPTED OR NOT ACCESSIBLE. THE RDT PRODUCT IS NOT PROCESSED	A problem has occurred with the PGE11_BUFR_table	1. Ensure that the file PGE11_BUFR_table is located at the directory `$SAFNWC/import/Aux_data/PGE11`. 2. Ensure that this file has been adapted in accordance with the "Interface Control Document for the External and Internal Interfaces for the SAF NWC/MSG"
E	11008	PGE11_BUFR_CREATE_TEMP_FILE_ERROR	ERROR: CREATION OF A TEMP. FILE USED TO WRITE THE BUFR OUTPUT FILE FAILED. THE RDT PRODUCT IS NOT PROCESSED	The BUFR writing of the RDT product has failed (unable to create an internal file used to write the RDT product in BUFR format).	Write a SPR

Type (E/W)	Code Number	Code	Message	Comment	Recovery Action
E	11009	PGE11_BUFR_READ_TEMP_FILE_ERROR	ERROR: ACCESS TO A TEMP. FILE USED TO WRITE THE BUFR OUTPUT FILE FAILED. THE RDT PRODUCT IS NOT PROCESSED	The BUFR writing of the RDT product has failed (unable to read an internal file used to write the RDT product in BUFR format).	Write a SPR
W	11010	PGE11_CALCUL_POIDS_AVAL_PROBLEM	PB. WITH THE COMPUTATION THE INTERNAL PARAMETER POIDS_AVAL	The computation of an internal characteristic of a cloud system ("poids aval") has failed.	Write a SPR
W	11011	PGE11_COOLING_RATE_CALCULATION_PROBLEM	PB. WITH THE COMPUTATION THE COOLING RATE OF A CELL	The computation of the cooling rate of a cloud system has failed.	Write a SPR
W	11012	PGE11_CONTOURS_NO_GROUP	PB. WITH THE COMPUTATION OF CONTOURS (NO GROUP)	The computation of the contour of a cloud system has failed.	Write a SPR
W	11013	PGE11_CONTOURS_NO_CELLS	PB. WITH THE COMPUTATION OF CONTOURS (NO CELL)	The computation of the contour of a cloud system has failed.	Write a SPR
E	11014	PGE11_DICRIMINATION_WRONG_PARAM	ERROR: UNKNOWN DISCRIMINATION PARAMETER	The satellite-based method of the discrimination method has failed (an unknown discrimination parameter has been found)	Ensure that the content of the files located in the directory `$SAFNWC/import/Aux_data/PGE11/files_for_discri` and its subdirectories is the same as originally delivered with the SAFNWC/MSG software.
E	11015	PGE11_FOUDRE_WRONG_LINE	ERROR: LINE WITH WRONG FORMAT IN THE INPUT LIGHTNING DATA FILE	The corresponding line is not in the correct format	Ensure that the content of the file `$SAFNWC/import/Obs_data/PGE11_lightning_data` is filled according to the format given in the "Interface Control Document for the External and Internal Interfaces for the SAF NWC/MSG"
W	11016	PGE11_FOUDRE_INCORRECT_FILE	PB. WHEN OPENING THE INPUT LIGHTNING DATA FILE	The content of the input lightning data file is corrupted.	Ensure that the content of the file `$SAFNWC/import/Obs_data/PGE11_lightning_data` is filled according to the format given in the "Interface Control Document for the External and Internal Interfaces for the SAF NWC/MSG"
E	11017	PGE11_FOUDRE_FILE_NOT_FOUND	ERROR: INPUT LIGHTNING DATA FILE NOT FOUND	The file "PGE11_lightning_data" was not found.	Ensure that this file is located at the directory `$SAFNWC/import/Obs_data/`

Type (E/W)	Code Number	Code	Message	Comment	Recovery Action
E	11018	PGE11_UNKNOWN_PROGRAM_ARGUMENT	ERROR: PGE11 SOFTWARE UNKNOWN ARGUMENT. THE RDT PRODUCT IS NOT PROCESSED	An unknown input argument has been detected by the PGE11 software	1. Ensure that the corresponding model configuration file is filled in accordance to the Software User Manual. 2. Ensure that the file `$SAFNWC/bin/PGE11` is the same as the file `$SAFNWC/src/PGE11/PGE11` delivered within the SAFNWC/MSG software
E	11019	PGE11_INVALID_DISCRIMINATION_DIRECTORY	ERROR: INVALID DISCRIMINATION DIRECTORY	The directory $SAFNWC/import/Aux_data/PGE11/files_for_discri was not found.	Install this directory and its subdirectories delivered within the SAFNWC/MSG software
E	11020	PGE11_CONFIGURATION_FILE_NOT_FOUND	ERROR: MODEL CONFIGURATION FILE NOT FOUND. THE RDT PRODUCT IS PROCESSED WITH DEFAULT PARAMETER VALUES	The model configuration file specified by the user was not found.	1. Ensure that this file is located at the directory $SAFNWC/config 2. Ensure that there is no typo-mistake in the corresponding run configuration file.
W	11021	PGE11_TOO_MANY_IMAGES_MISSING	TOO MANY CONSECUTIVE SATELLITE IMAGES ARE MISSING: THE TRACKING IS REINITIALIZED	The PGE11 software has analysed that the time gap between the satellite image to process and the previously processed one was greater than 2h30.	1. No specific action when the time gap between the satellite image to process and the previously processed one is greater than 2h30. 2. Write a SPR if this warming message occurs in other circumstances.
W	11022	PGE11_COLD_START	INITIALIZATION OF THE TRACKING (FIRST IMAGE)	The tracking is initialzed.	1. No specific action when running the PGE11 software for the first time on a given region and with a given PGE11 model configuration file. 2. Write a SPR if this warming message occurs in other circumstances.

Type (E/W)	Code Number	Code	Message	Comment	Recovery Action
E	11023	PGE11_NO_IMAGE_TO_PROCESS	PB. WHEN READING THE INPUT SATELLITE IMAGE. THE RDT PRODUCT IS NOT PROCESSED	An error has occurred when reading the input satellite HRIT image.	1. Ensure that the corresponding HRIT file is correctly located at the directory `$SAFNWC/import/SEVIRI_data`. 2. Write a SPR if this error message occurs in other circumstances.
W	11024	PGE11_RESTORE_PROBLEM	PB. WHEN READING THE BACK-UP FILE OF CURRENT TRACKED TRAJECTORIES	The back-up of the speed of a given cloud system has failed.	Write a SPR
W	11025	PGE11_NO_SAVES_FILE	NO HISTORICAL FILE OF TRACKED TRAJECTORIES	The back-up file of tracked trajectories was not found.	1. No specific action when running the PGE11 software for the first time on a given region and with a given PGE11 model configuration file. 2. Write a SPR if this warming message occurs in other circumstances.
W	11026	PGE11_NO_SAVED_IMAGE	FILE OF THE PREVIOUS SATELLITE IMAGE NOT FOUND	The previous satellite image processed by the PGE11 software was not found	Ensure that the corresponding HRIT file is located at the directory `$SAFNWC/import/SEVIRI_data`
W	11027	PGE11_WRONG_DATAS_SAVE_FILE	PB. WITH THE HISTORICAL FILE OF TRACKED TRAJECTORIES	The back-up file of tracked trajectories was corrupted.	Write a SPR
W	11028	PGE11_SCANNING_PROBLEM	PB. WITH THE TEMPERATURE THRESHOLDING OF THE SATELLITE IMAGE	The detection algorithm of cloud systems has failed on a given satellite image pixel.	Write a SPR
W	11029	PGE11_SAT_INI_CARTE_ERROR	PB. WITH THE DETECTION OF CLOUD SYSTEMS (SAT_INI_CARTE SUBROUTINE)	Incoherence caused by the detection algorithm of cloud systems.	Write a SPR
E	11030	PGE11_MAX_NUM_CELL_TOO_LOW	PB. WITH THE DETECTION OF CLOUD SYSTEMS: TOO MANY CELLS ARE DETECTED	The detection algorithm of cloud systems has led an incoherence.	Write a SPR.
E	11031	PGE11_NUM_CELL_TOO_HIGH	ERROR: CORRUPTED CELLS AFTER THE DETECTION OF CLOUD SYSTEMS	The detection algorithm of cloud systems has led an incoherence.	Write a SPR.
E	11032	PGE11_MAP_NUM_TOO_HIGH	ERROR: CORRUPTED MAP AFTER THE DETECTION OF CLOUD SYSTEMS	The detection algorithm of cloud systems has led an incoherence.	Write a SPR.
W	11033	PGE11_COHERENCE_PROBLEM	PB. OF COHERENCE WITH THE OVERLAPPING OF CELLS	Incoherence caused by the tracking algorithm for the corresponding cloud systems.	Write a SPR
E	11034	PGE11_TAB_ERROR	ERROR: BAD COHERENCE BETWEEN MAP AND TEMP. TAB	The tracking algorithm of cloud systems has led to an incoherence	Write a SPR
E	11035	PGE11_NULL_CELL	ERROR: BAD COHERENCE BETWEEN DETECTED CELLS AND TEMP. TAB	The tracking algorithm of cloud systems has led to an incoherence	Write a SPR

Type (E/W)	Code Number	Code	Message	Comment	Recovery Action
E	11036	PGE11_WRONG_DETECTION_METHOD	ERROR: UNKNOWN DETECTION METHOD	Unknown name of the detection method used by the PGE11 software.	Ensure that the file `$SAFNWC/bin/PGE11` is the same as the file `$SAFNWC/src/PGE11/PGE11` delivered within the SAFNWC/MSG software
W	11037	PGE11_DISCRIMINATION_PROBLEM	PB OF COHERENCE IN THE DISCRIMINATION ALGORITHM	The discrimination algorithm has failed for a given cloud system.	Write a SPR
E	11038	PGE11_DISCRIMINATION_FILE_NOT_FOUND	ERROR: DISCRIMINATION FILES NOT FOUND	The file "qualities_disponibles" was not found.	Ensure that this file is located at the directory `$SAFNWC/import/Aux_data_PGE11/files_for_discri`.
E	11039	PGE11_CTTH_FILE_ERROR	ERROR: INPUT CTTH FILE NOT FOUND	The input CTTH file was not found	Ensure that the CTTH product is processed on the same region than the RDT product before running the PGE11 software
E	11040	PGE11_READ_CTTH_ERROR	ERROR: PROBLEM WHEN READING THE CTTH FILE (OUTPUT OF READUS SUBROUTINE)	An error occurs when reading the CTTH file.	Write a SPR
W	11041	PGE11_COHERENCE_DATE	PB OF COHERENCE WITH THE DATE OF THE IMAGE TO PROCESS: THE TRACKING IS REINITIALIZED		Write a SPR

Type (E/W)	Code Number	Code	Message	Comment	Recovery Action
W	11042	PGE11_LINE_DATATION	PB OF DATATION: LINE DATE SET TO IMAGE DATE	The HRIT data has no or wrong line datation The scanning date of RDT objects is set to the slot	Write a SPR
E	11043	PGE11_CT_FILE_ERROR	ERROR: INPUT CTTH FILE NOT FOUND	PGE 02 is not available	Ensure that PGE02 is processed
E	11044	PGE11_READ_CT_ERROR	ERROR: PROBLEM WHEN READING THE CTTH FILE (OUTPUT OF READUS SUBROUTINE)	An error occurs when reading the PGE02	Write a SPR
E	11045	PGE11_MASK_FILE_ERROR	ERROR: PROBLEM OPEN MASK FILE	An error occurs when opening the mask file (if available)	Write a SPR
E	11046	PGE11_READ_MASK_ERROR	ERROR: PROBLEM WHEN READING THE MASK FILE	An error occurs when reading the mask file (if available)	Write a SPR
E	11047	PGE11_INITPARAMNWP	ERROR: PROBLEM WHITH INITIALIZATING NWP PARAMETERS	An error occurs	Write a SPR
W	11048	PGE11_NWP_PB	WARNING: PROBLEMS WHEN ACCESSING NWP DATA	Not all NWP parameters or file are available. May be non relevant when concerns Meteo-France ARPEGE parameters, non available with ECMWF	Verify alimentation of NWP data. Eventually suppressing non available parameters with ECMWF from *.cfm
E	11049	PGE11_NWP_KO	ERROR: NWP DATA MISSING	Configuration file is not compliant with data providing, or NWP data are incomplete	Correct *.cfm file or provide full requested NWP data

Table 1: PGE11 Error / Warning messages

3.2.4 Outputs

The final product is numerical data which depict infrared characteristics (spatial and time) and move information associated to RDT cells. Numerical data are provided under BUFR format. Thus, **operating the RDT needs development of a visualization tool**.

RDT software is able to take in input flashes location. This additional data allows to improve discrimination skill (3.1.2.3.8). Moreover, the object approach of RDT allows to characterize the lightning activity associated to a convective cloud object and to build its time serie.

The BUFR format is described in the Interface Control Document n°3(# 1.6.1) of SAFNWC. The RDT offers two BUFR versions (1 and 2 configurable with -bufr argument in configuration file). The first version holds the full description of RDT cells without time series. The full RDT operating needs to build time series with previous outputs. The second version allows to limit on request the BUFR description to RDT objects discriminated as convective. This limitation leads to strongly reduce BUFR size. This version provides three time series (gravity center location, minimum temperature and lightning activity), allowing to make simpler the visualization tool development.Implementation of the product.

4. ASSUMPTIONS AND LIMITATIONS

4.1.1 Constraints and Limitations

The tuning has been carried out on summer period over a domain centred over France. The discrimination score during winter period could be weak.

ANNEX A – The Discriminating parameters

The acronym "ST" characterizes a cell defined at a ΔTtower (6°C) warmer than top temperature

Values are extremes over the section (15, 30, 45 or 60min depth)

N°	Parameter	Meaning
1.	Min_Tmin	minimum of top temperature
2.	Max_TxTmin	Maximum of top temperature rate processed on two following images
3.	Min_TxTmin	minimum of top temperature rate processed on two following images
4.	Max_TxTmin2	Secondary maximum of top temperature rate processed on two following images
5.	Max_TxTmin10	Maximum of top temperature rate processed on ten minutes (Rapid Scan mode)
6.	Max_TxTmin15	Maximum of top temperature rate processed on 15 minutes (equal to parameter n°2 for image frequency = 15')
7.	Max_TxTmin30	maximum of top temperature rate processed on 30'
8.	Max_TxTmin45	maximum of top temperature rate processed on 45'
9.	Max_TxTmin60	maximum of top temperature rate processed on 60'
10.	MinMaxPos	continuous cooling Boolean
11.	Max_TxTmoyST	Maximum of mean temperature, defined on ST, processed on two consecutives images. ST is a cell defined at a ΔTtower (6°C) warmer than top temperature
12.	Max_DTmoyTmin	maximum mean temperature – top temperature
13.	Max_DTseuilTmoy	Maximum temperature of base – mean temperature
14.	Max_DTseuilTmoyST	Maximum temperature of base – mean temperature defined on ST
15.	Max_Gpm	Maximum of the mean peripheral gradient processed on IR10.8
16.	Max_Qgp95	Maximum of quantile 95% of peripheral gradient
17.	Max_Volume	Maximum of system volume The volume is calculated on IR10.8 data. The base of volume is –25°C for mature object and +5°C for transition object
18.	Max_RapportAspect	Maximum of long axe / small axe of ellipse enclosing
19.	Max_SurfaceST	Maximum of the ST surface
20.	Max_DSurfaceBTST	Maximum of cell surface – ST surface
21.	Min_WV	Mini ofWV62
22.	Min_WV2	Mini of WV73
23.	Min_IR87	Mini of IR87

24.	Min_IR120	Mini of IR120
25.	Max_TxWV	Maximum WV6.2 rate processed on two following images
26.	Max_TxWV10	Maximum WV6.2 rate processed on 10 minutes (Rapid Scan mode)
27.	Max_TxWV15	Maximum WV6.2 rate processed on 15 minutes
28.	Max_TxWV30	Maximum WV6.2 rate processed on 30 minutes
29.	Max_TxWV45	Maximum WV6.2 rate processed on 45 minutes
30.	Max_TxWV60	Maximum WV6.2 rate processed on 60 minutes
31.	Max_TxWV2	Maximum WV7.3 rate processed on two following images
32.	Max_TxWV210	Maximum WV7.3 rate processed on 10 minutes (Rapid Scan mode)
33.	Max_TxWV215	Maximum WV7.3 rate processed on 15 minutes
34.	Max_TxWV230	Maximum WV7.3 rate processed on 30 minutes
35.	Max_TxWV245	Maximum WV7.3 rate processed on 45 minutes
36.	Max_TxWV260	Maximum WV7.3 rate processed on 60 minutes
37.	Max_TxIR87	Maximum IR8.7 rate processed on two following images
38.	Max_Tx IR8710	Maximum IR8.7 rate processed on 10 minutes (Rapid Scan mode)
39.	Max_Tx IR8715	Maximum IR8.7 rate processed on 15 minutes
40.	Max_Tx IR8730	Maximum IR8.7 rate processed on 30 minutes
41.	Max_Tx IR8745	Maximum IR8.7 rate processed on 45 minutes
42.	Max_Tx IR8760	Maximum IR8.7 rate processed on 60 minutes
43.	Max_TxIR120	Maximum IR120 rate processed on two following images
44.	Max_Tx IR12010	Maximum IR120 rate processed on 10 minutes (Rapid Scan mode)
45.	Max_Tx IR12015	Maximum IR120 rate processed on 15 minutes
46.	Max_Tx IR12030	Maximum IR120 rate processed on 30 minutes
47.	Max_Tx IR12045	Maximum IR120 rate processed on 45 minutes
48.	Max_Tx IR12060	Maximum IR120 rate processed on 60 minutes
49.	Max_BTDmax	Maximum of WV6.2-IR10.8
50.	Max_BTD	maximum of quantile 75% of WV6.2-IR10.8
51.	Max_BTD90	maximum of quantile 90% of WV6.2- IR10.8
52.	Max_BTDRatio	maximum of BTD structure BTD=WV6.2 – IR10.8 structure is the ratio between contiguous BTD pixel >-2 and BTD pixel > -2
53.	Max_WBTDmax	maximum of WV6.2- WV7.3
54.	Max_WBTD	maximum of quantile 75% of WV6.2- WV7.3

55.	Max_WBTD90	maximum of quantile 90% of WV6.2- WV7.3
56.	Max_WBTDRatio	Maximum of WBTD structure WBTD= WV6.2- WV7.3 structure is the ratio between contiguous WBTD pixel > -1 and WBTD pixel > -1
57.	Max_BTD4max	Maximum of IR87-IR108
58.	Max_BTD4Q1	maximum of quantile 75% of IR87-IR108
59.	Max_BTD4Q2	maximum of quantile 90% of IR87-IR108
60.	Max_BTD4Ratio	maximum of BTD structure BTD= IR8.7-IR10.8 structure is the ratio between contiguous BTD pixel >-2 and BTD pixel > -2
61.	Max_BTD5max	maximum of IR120-IR108
62.	Max_BTD5Q1	maximum of quantile 75% IR120-IR108
63.	Max_BTD5Q2	maximum of quantile 90% IR120-IR108
64.	Max_BTD5Ratio	maximum of BTD structure BTD= WV12-IR10.8 structure is the ratio between contiguous BTD pixel >0 and BTD pixel > 0
65.	Max_TxBTD	maximum of WV6.2-IR10.8 rate processed on two following images
66.	Max_TxBTD10	maximum of WV6.2-IR10.8rate processed on 10 minutes (Rapid Scan Mode)
67.	Max_TxBTD15	maximum of WV6.2-IR10.8 rate processed on 15 minutes
68.	Max_TxBTD30	maximum of WV6.2-IR10.8 rate processed on 30 minutes
69.	Max_TxBTD45	maximum of WV6.2-IR10.8 rate processed on 45 minutes
70.	Max_TxBTD60	maximum of WV6.2-IR10.8 rate processed on 60 minutes
71.	Max_TxWBTD	maximum of WV6.2- WV7.3 rate processed on two following images
72.	Max_TxWBTD10	maximum of WV6.2- WV7.3 rate processed on 10 minutes
73.	Max_TxWBTD15	maximum of WV6.2- WV7.3 rate processed on 15 minutes
74.	Max_TxWBTD30	maximum of WV6.2- WV7.3 rate processed on 30 minutes
75.	Max_TxWBTD45	maximum of WV6.2- WV7.3 processed on 45 minutes
76.	Max_TxWBTD60	maximum of WV6.2- WV7.3 processed on 60 minutes
77.	Max_NWPIndexConv	Maximum of Lifted index
78.	Max_NWPTtropo – Min_Tmin	Distance (°C) to tropopause

ANNEX B – The statistical model scores for MSG

1. MATURE DISCRIMINATION (DM)

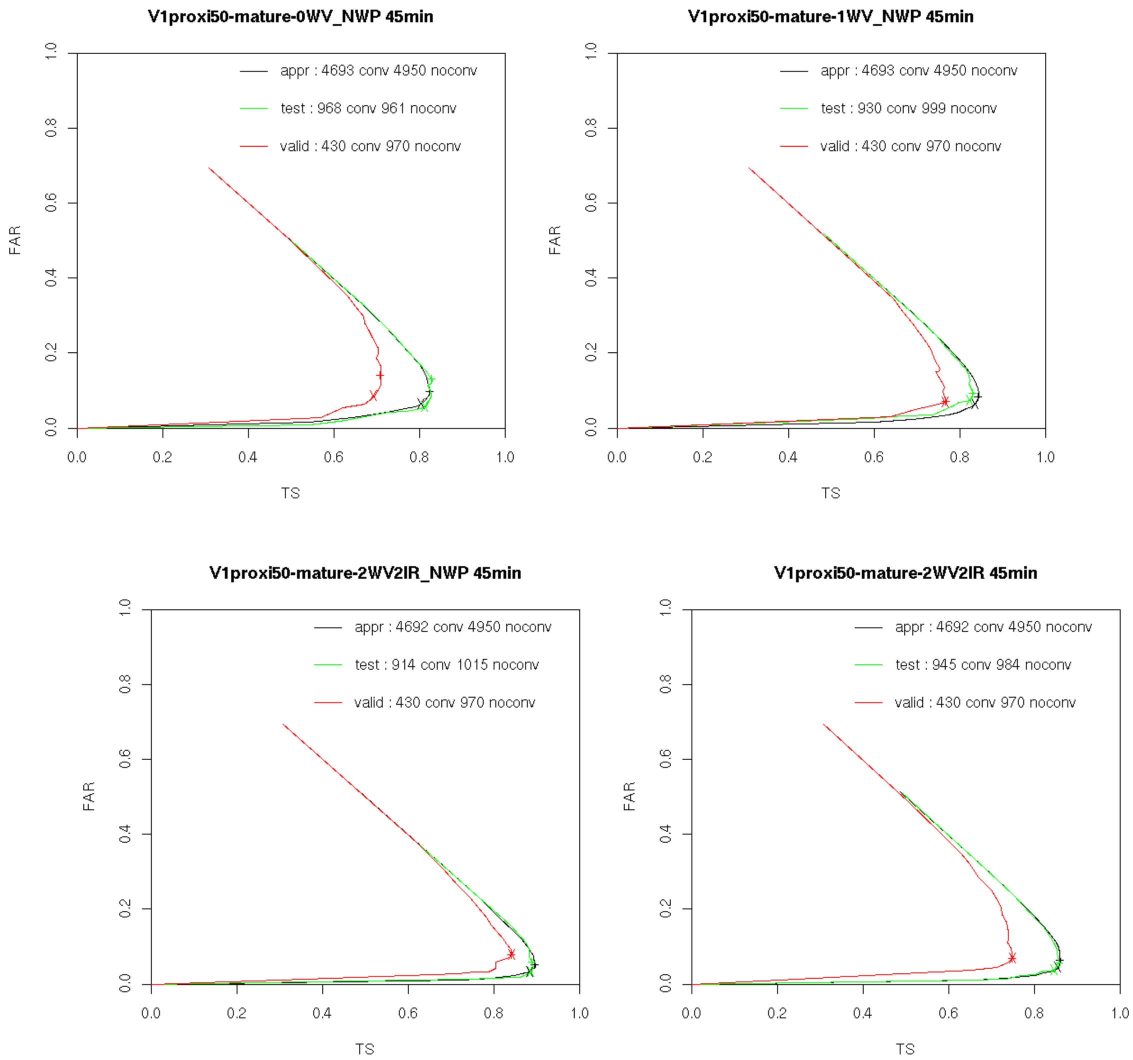


Figure 21: *MSG V2011 tuning for mature category, 45 min depth, for 4 configurations :* With NWP (top) with IR10.8 only (top left), IR10.8 and WV6.2 (top right), with 2 WV et 2 IR (bottom left) and with 2 WV et 2 IR without NWP (bottom right)

2. DISCRIMINATION ON MATURE TRANSITION (DTM)

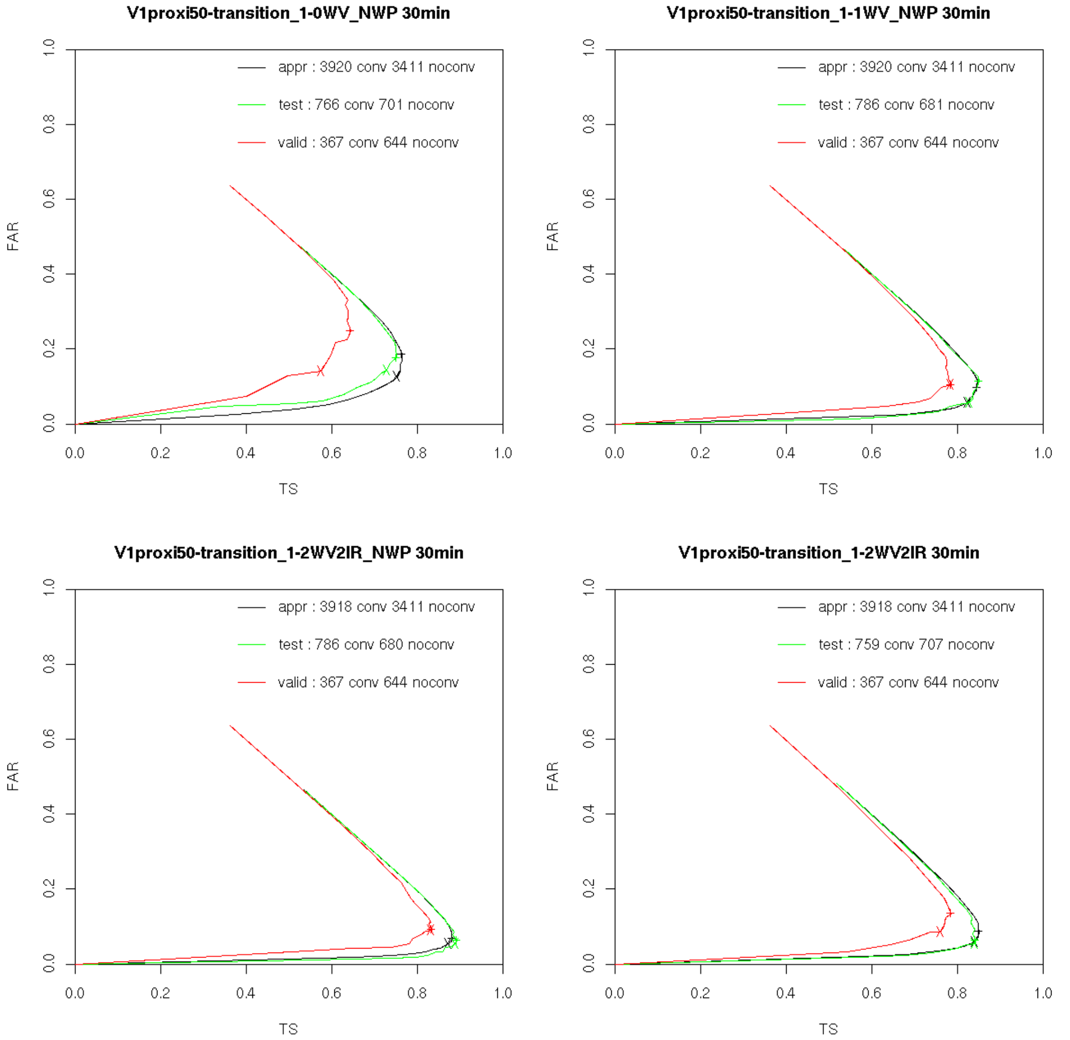


Figure 22: MSG V2011 tuning for transition mature category, 45 min depth, for 4 configurations : With NWP (top) with IR10.8 only (top left), IR10.8 and WV6.2 (top right), with 2 WV et 2 IR (bottom left) and with 2 WV et 2 IR without NWP (bottom right)

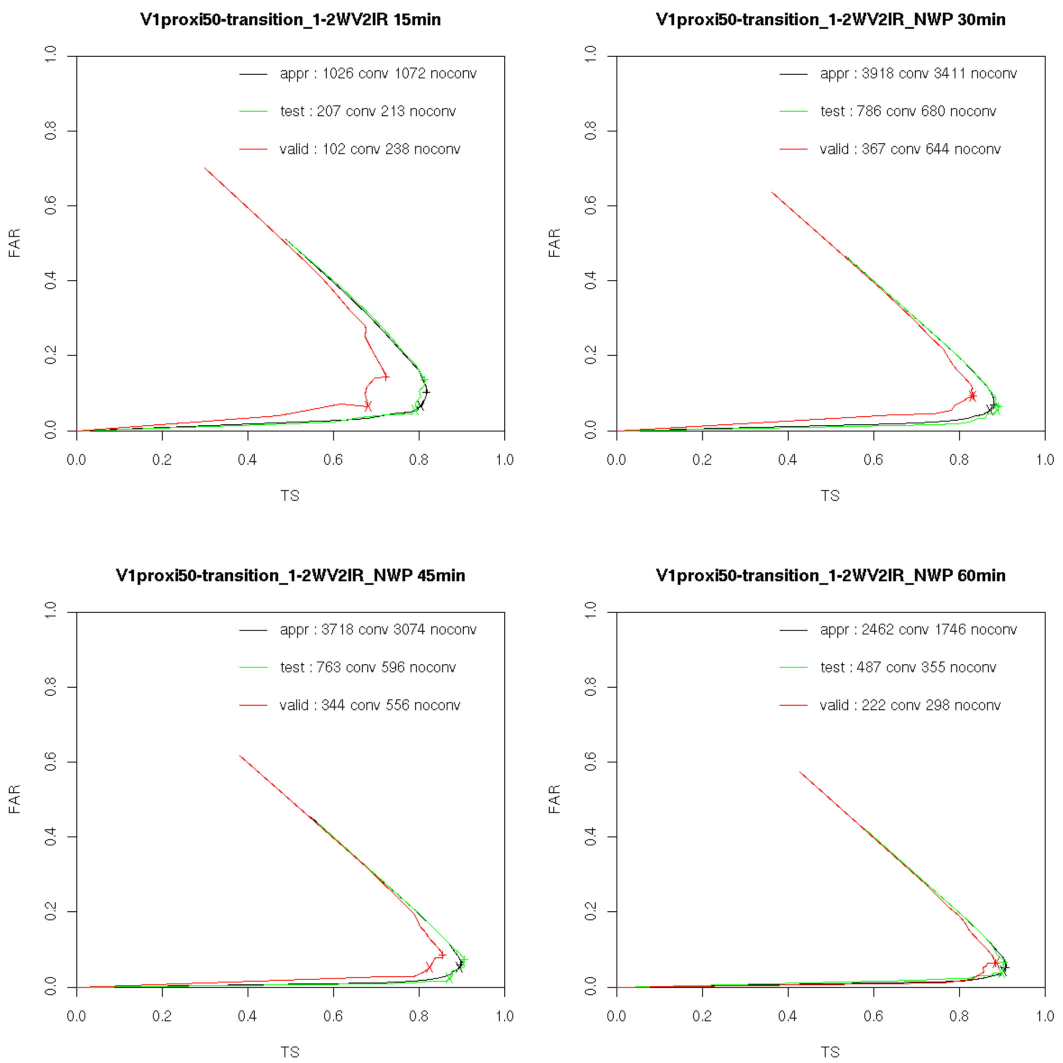


Figure 23: MSG V2011 tuning for transition mature category, full configuration, 4 available depth

3. DISCRIMINATION ON COLD TRANSITION (DTC)

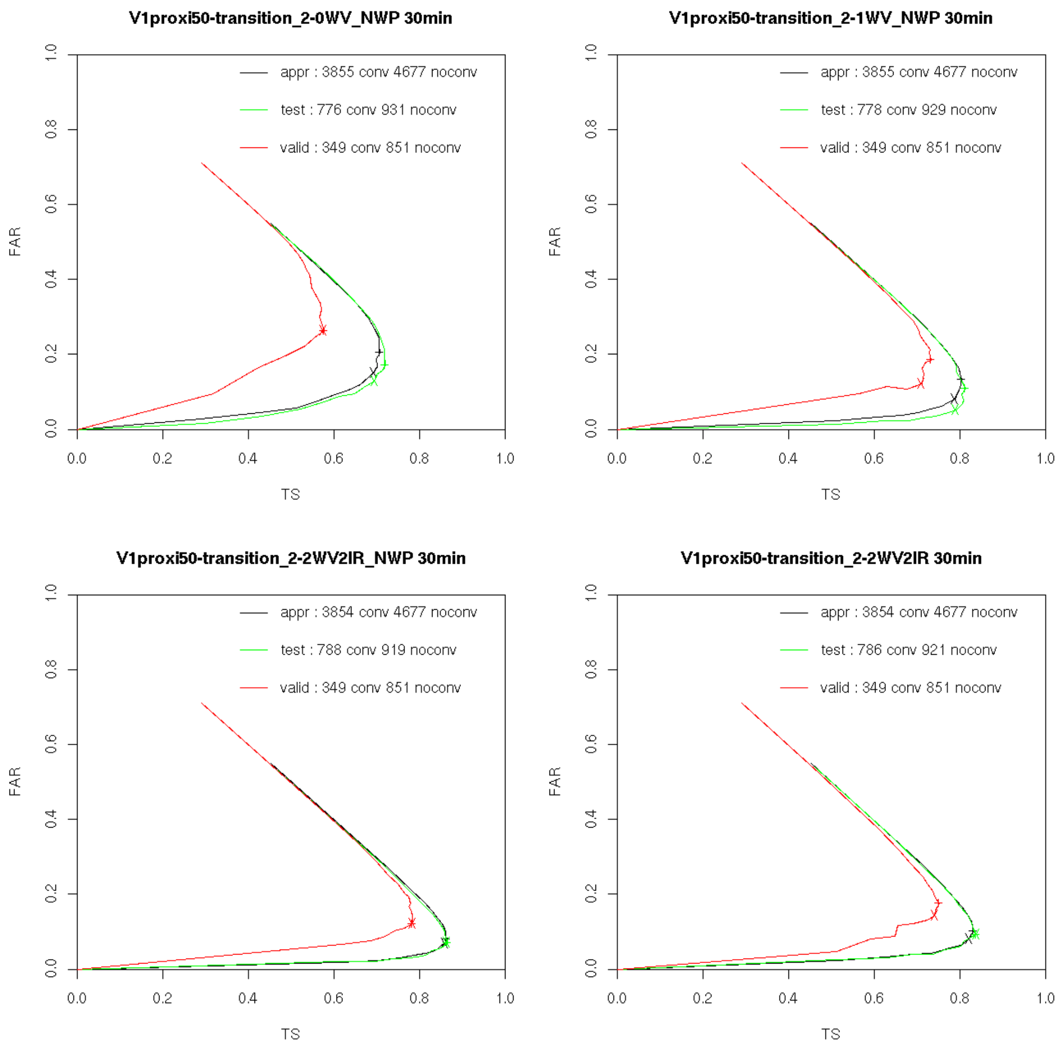


Figure 24: MSG V2011 tuning for cold transition category, 45 min depth, for 4 configurations : With NWP (top) with IR10.8 only (top left), IR10.8 and WV6.2 (top right), with 2 WV et 2 IR (bottom left) and with 2 WV et 2 IR without NWP (bottom right)

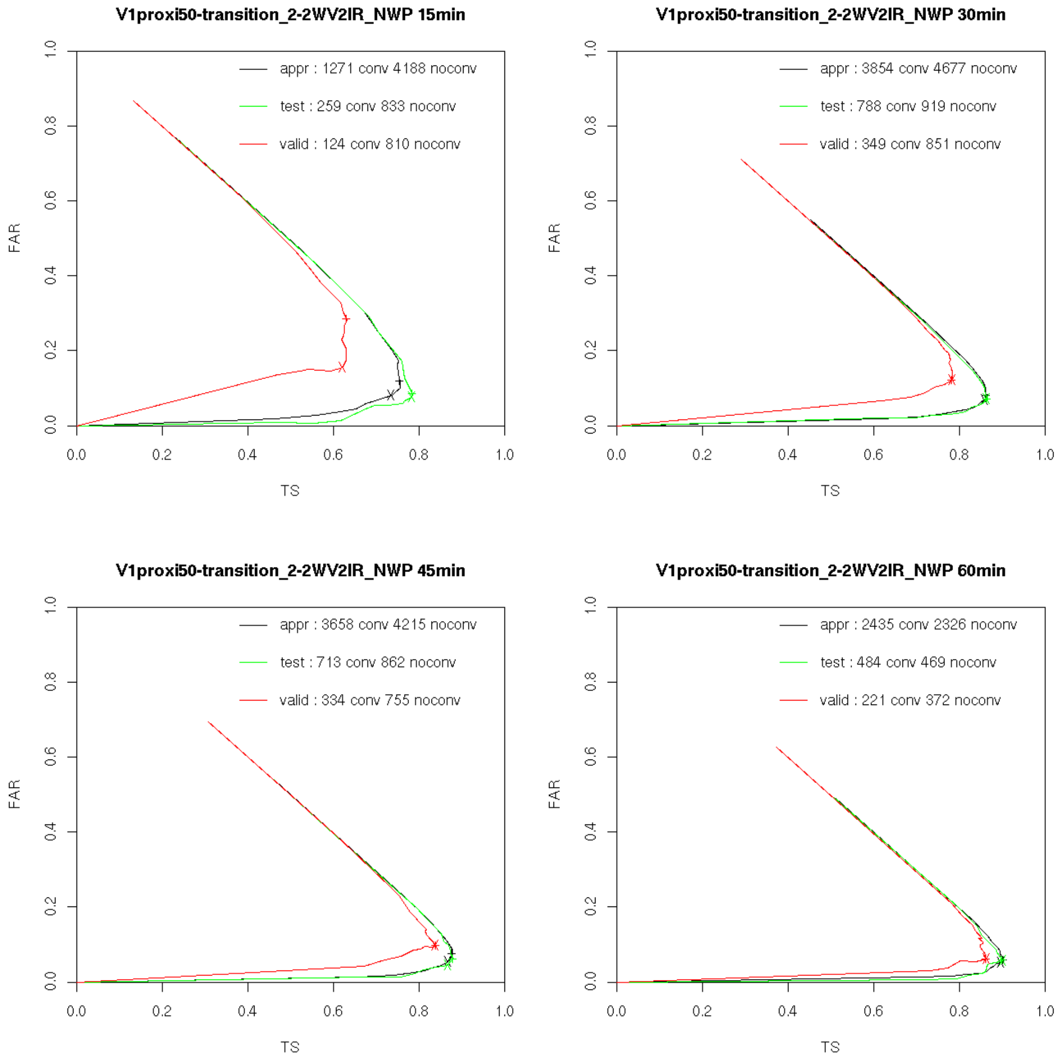


Figure 25 MSG V2011 tuning for cold transition category, full configuration, 4 available depth

4. DISCRIMINATION ON WARM2 TRANSITION (DTW2)

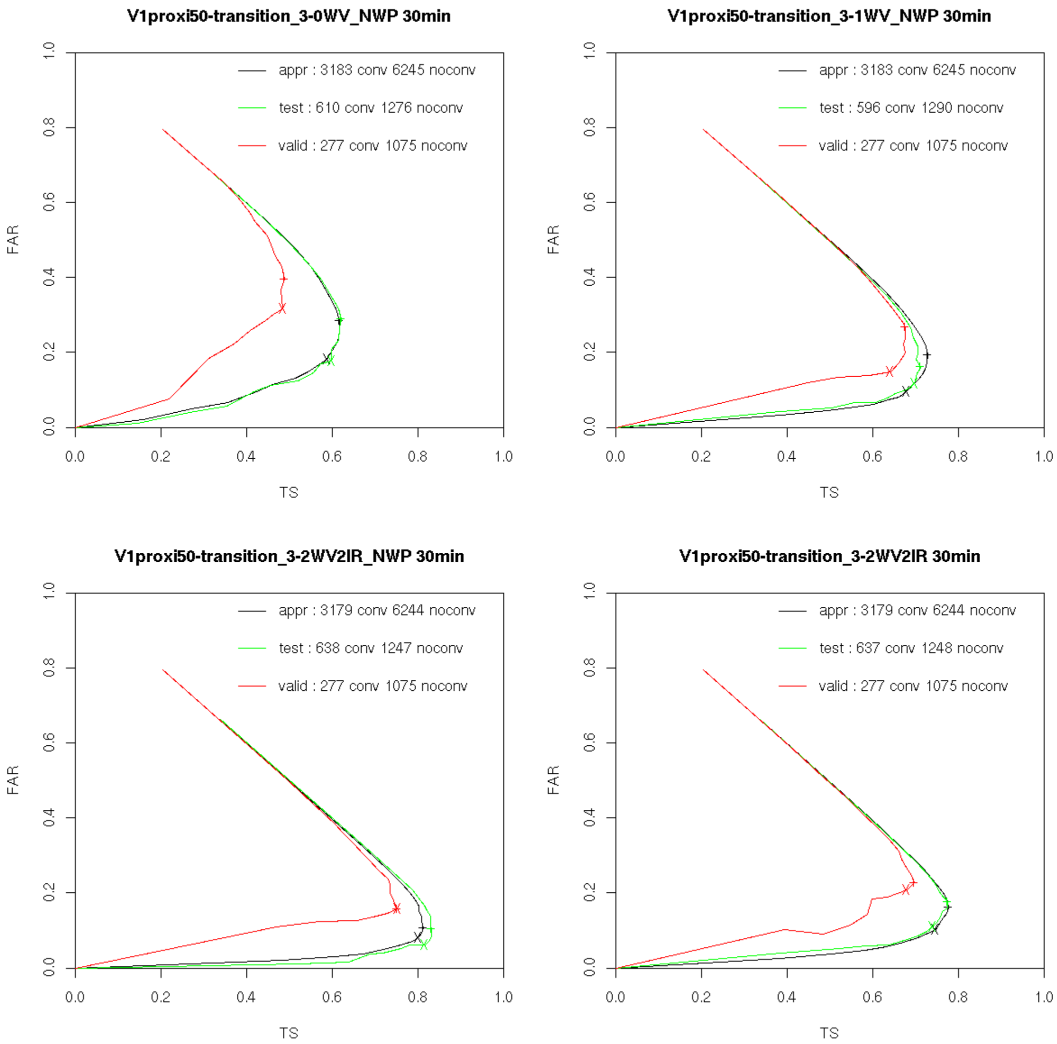


Figure 26: MSG V2011 tuning for Warm2 transition category, 45 min depth, for 4 configurations : With NWP (top) with IR10.8 only (top left), IR10.8 and WV6.2 (top right), with 2 WV et 2 IR (bottom left) and with 2 WV et 2 IR without NWP (bottom right)

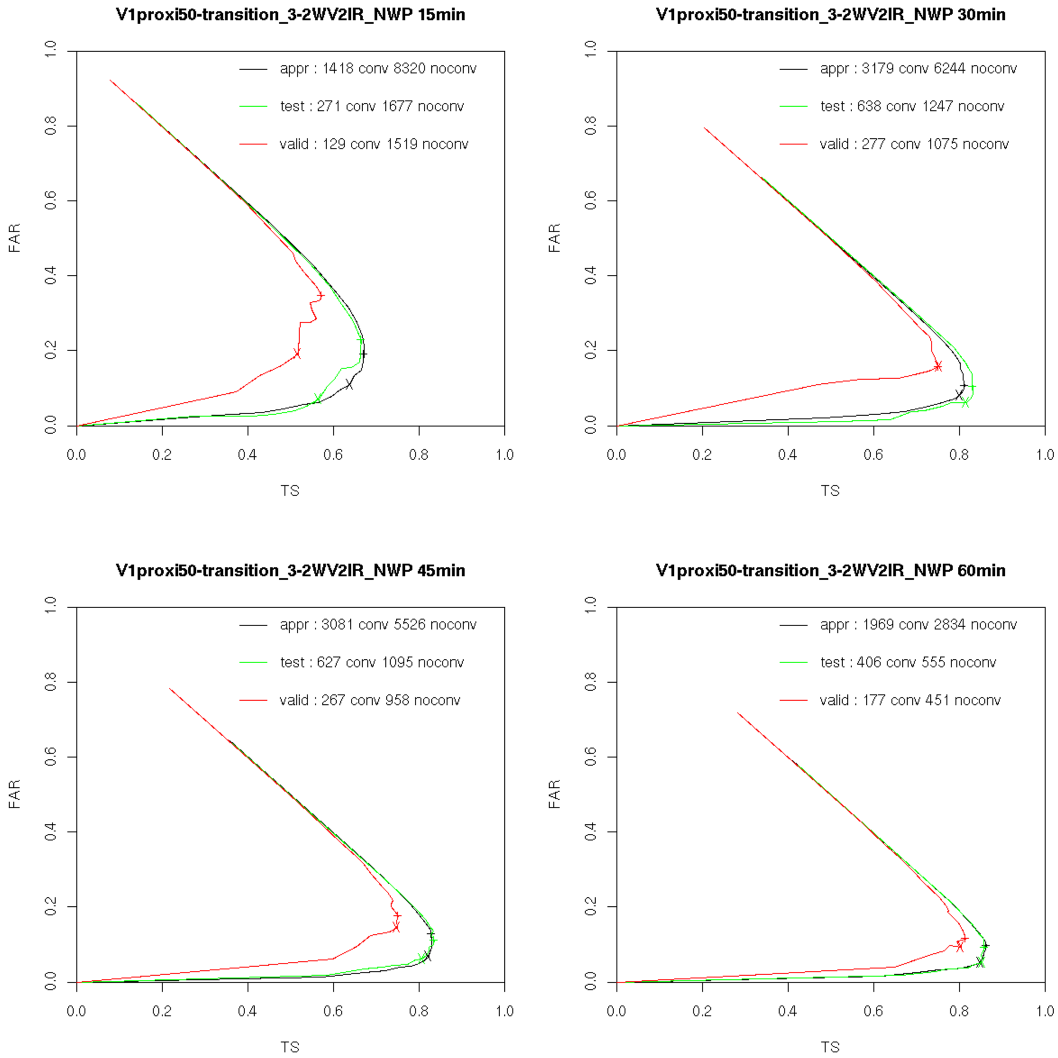


Figure 27 MSG V2011 tuning for Warm2 transition category, full configuration, 4 available depth

5. DISCRIMINATION ON WARM1 TRANSITION (DTW1)

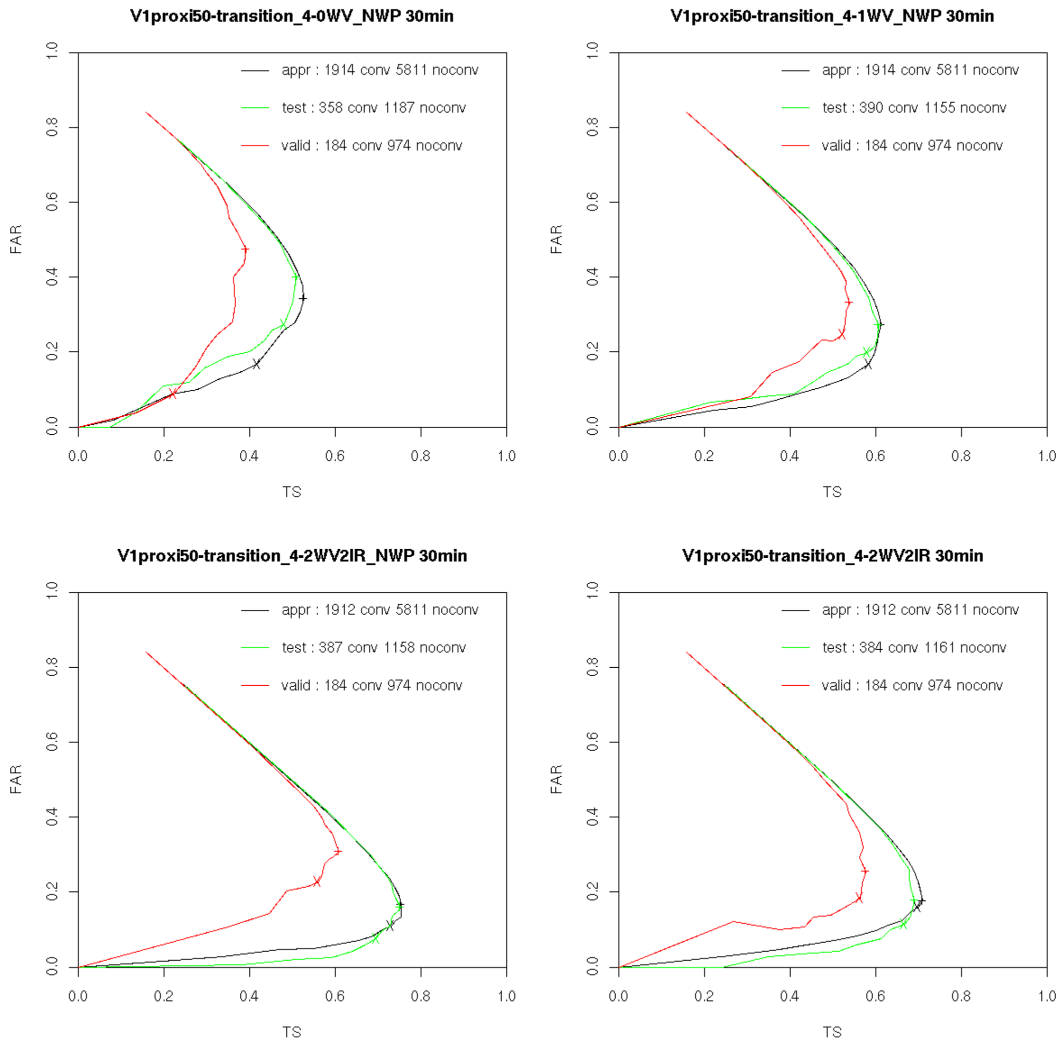


Figure 28: : MSG V2011 tuning for Warm1 transition category, 45 min depth, for 4 configurations : With NWP (top) with IR10.8 only (top left), IR10.8 and WV6.2 (top right), with 2 WV et 2 IR (bottom left) and with 2 WV et 2 IR without NWP (bottom right)

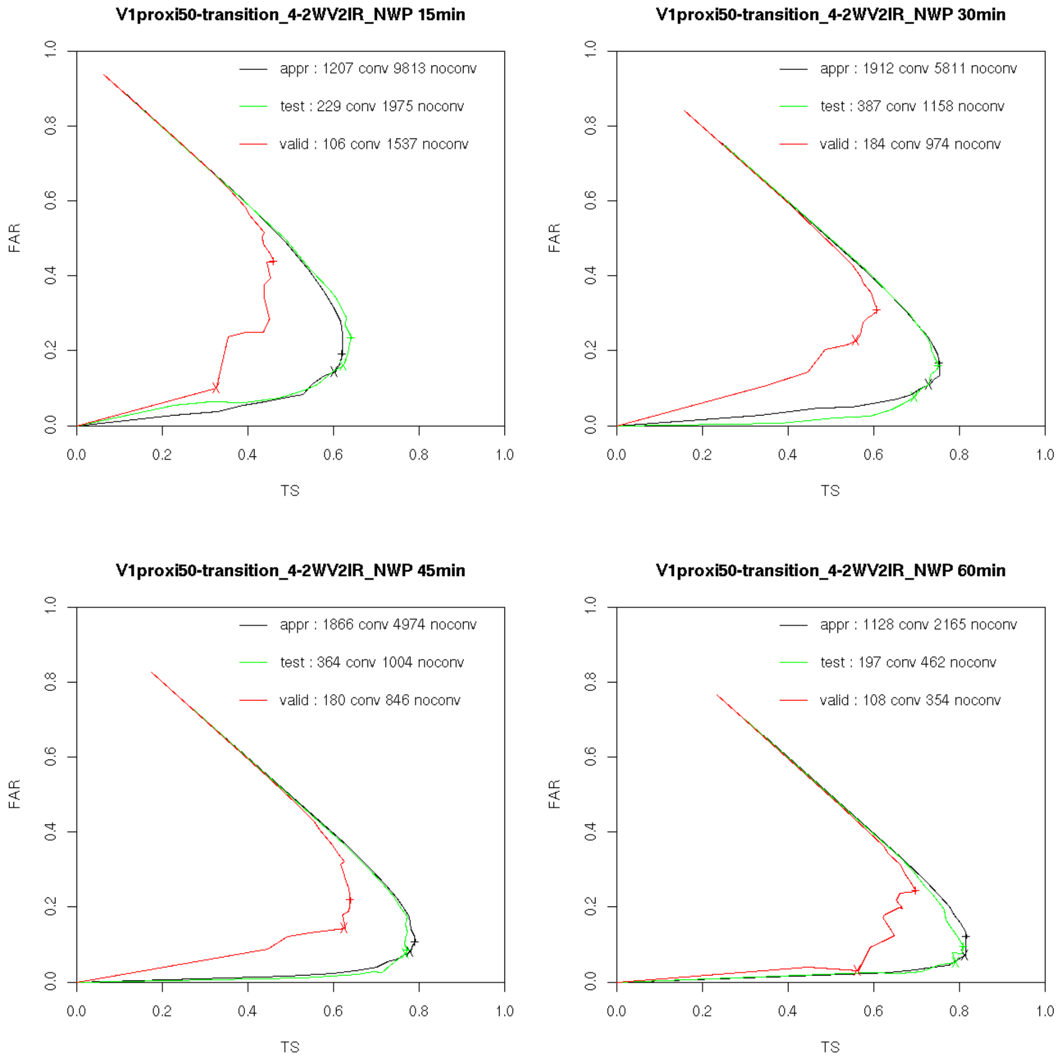


Figure 29 MSG V2011 tuning for Warm1 transition category, full configuration, 4 available depth

6. DISCRIMINATION ON WARM CATEGORY (DW)

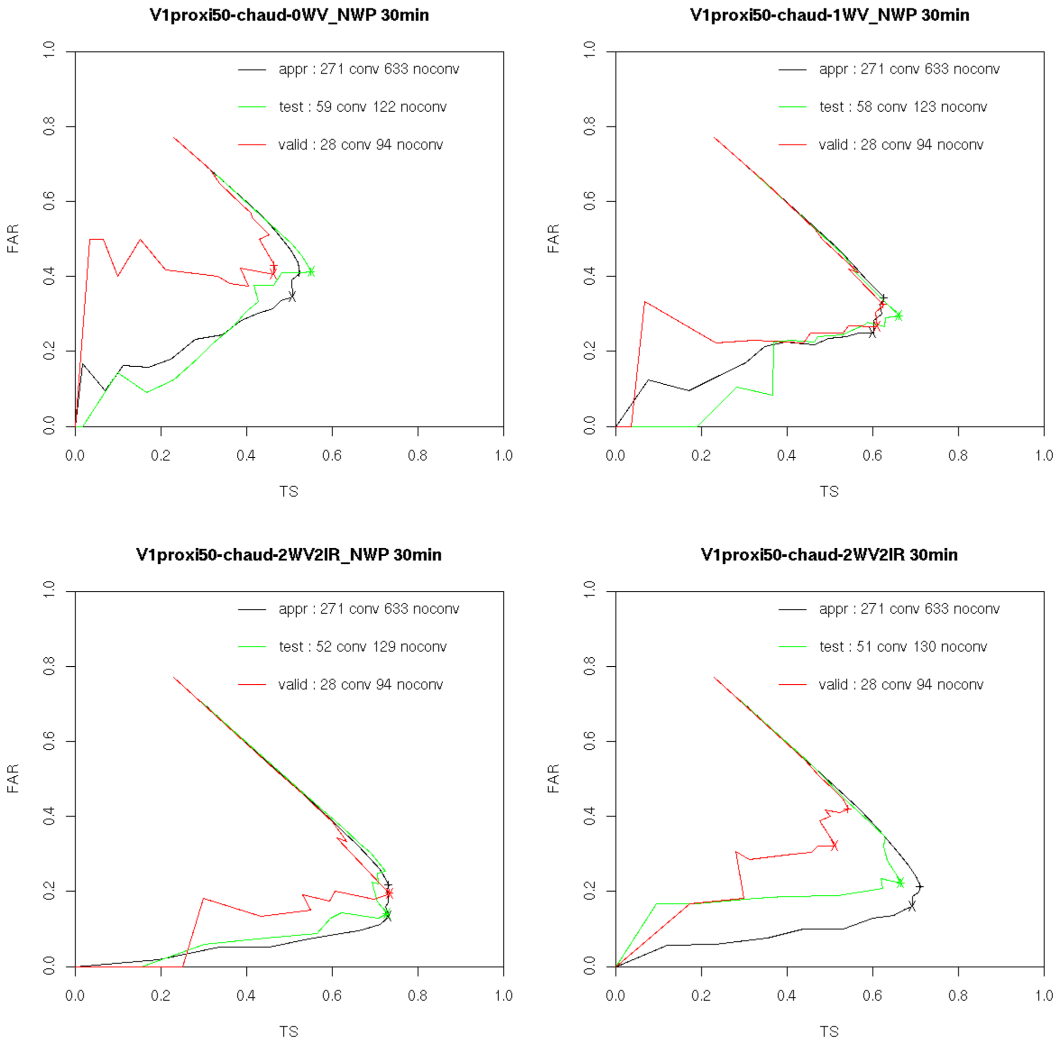


Figure 30: : MSG V2011 tuning for Warm category, 45 min depth, for 4 configurations : With NWP (top) with IR10.8 only (top left), IR10.8 and WV6.2 (top right), with 2 WV et 2 IR (bottom left) and with 2 WV et 2 IR without NWP (bottom right)

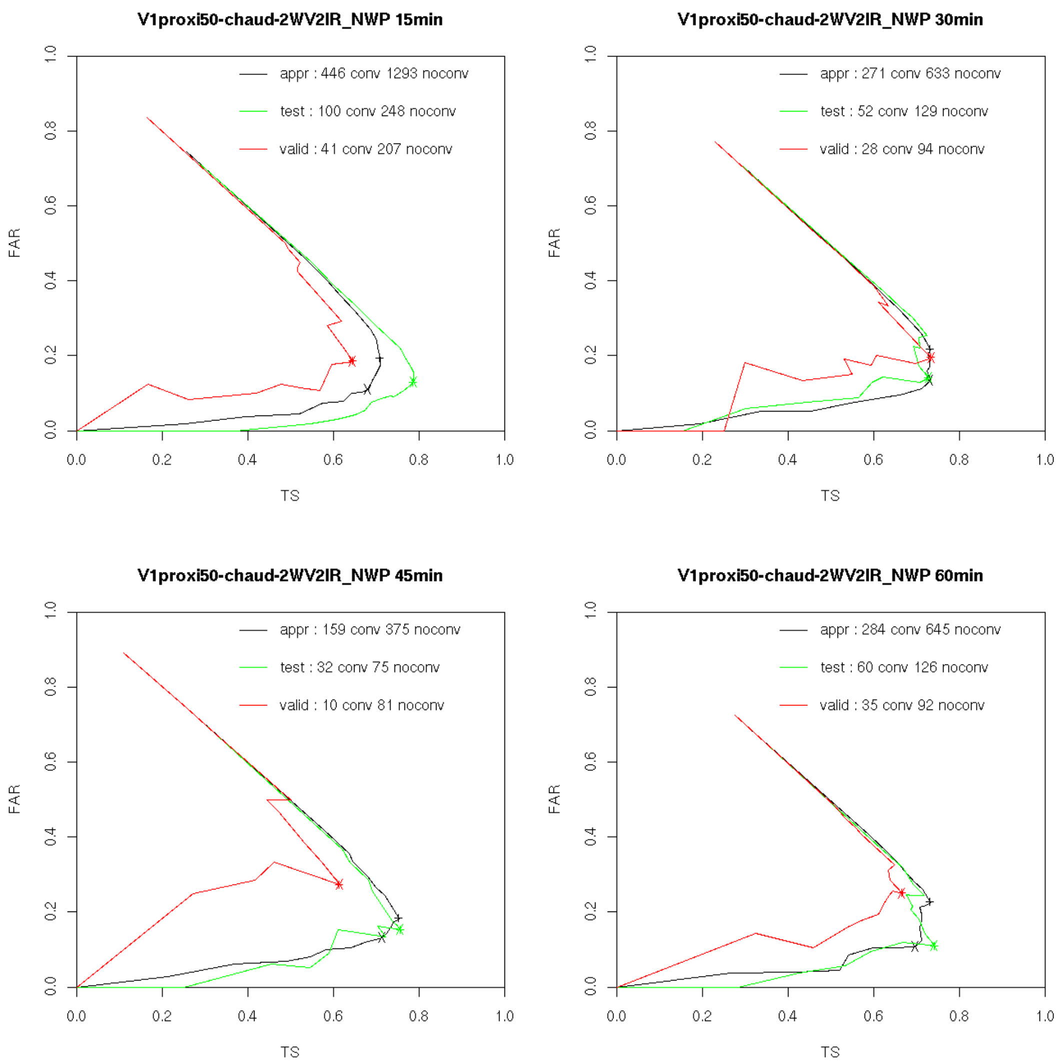


Figure 31 MSG V2011 tuning for Warm category, full configuration, 4 available depth

ANNEX C – The statistical model score for Rapid Scan

7. MATURE DISCRIMINATION (DM)

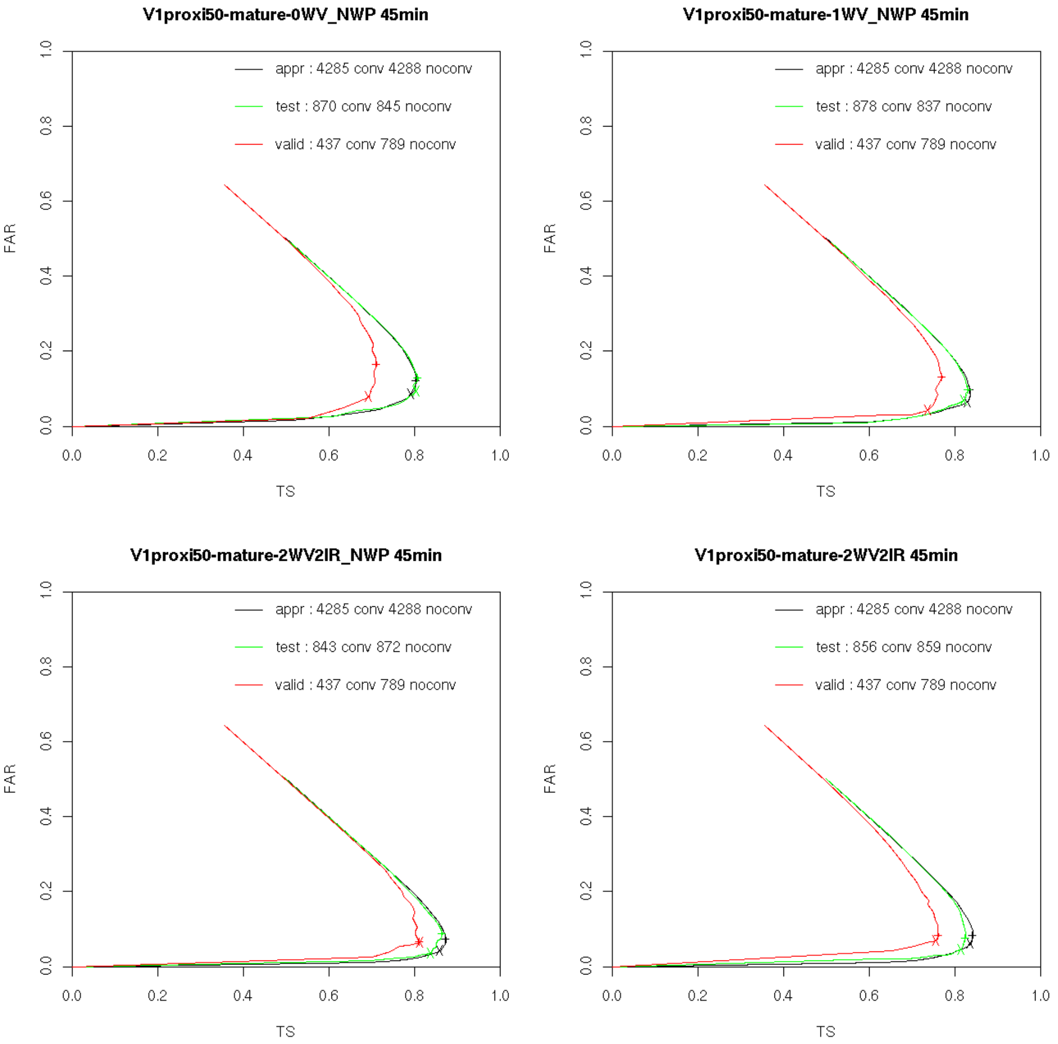


Figure 32: *RSS V2011 tuning for mature category, 45 min depth, for 4 configurations :*
With NWP (top) with IR10.8 only (top left), IR10.8 and WV6.2 (top right), with 2 WV et 2 IR (bottom left) and with 2 WV et 2 IR without NWP (bottom right)

8. DISCRIMINATION ON MATURE TRANSITION (DTM)

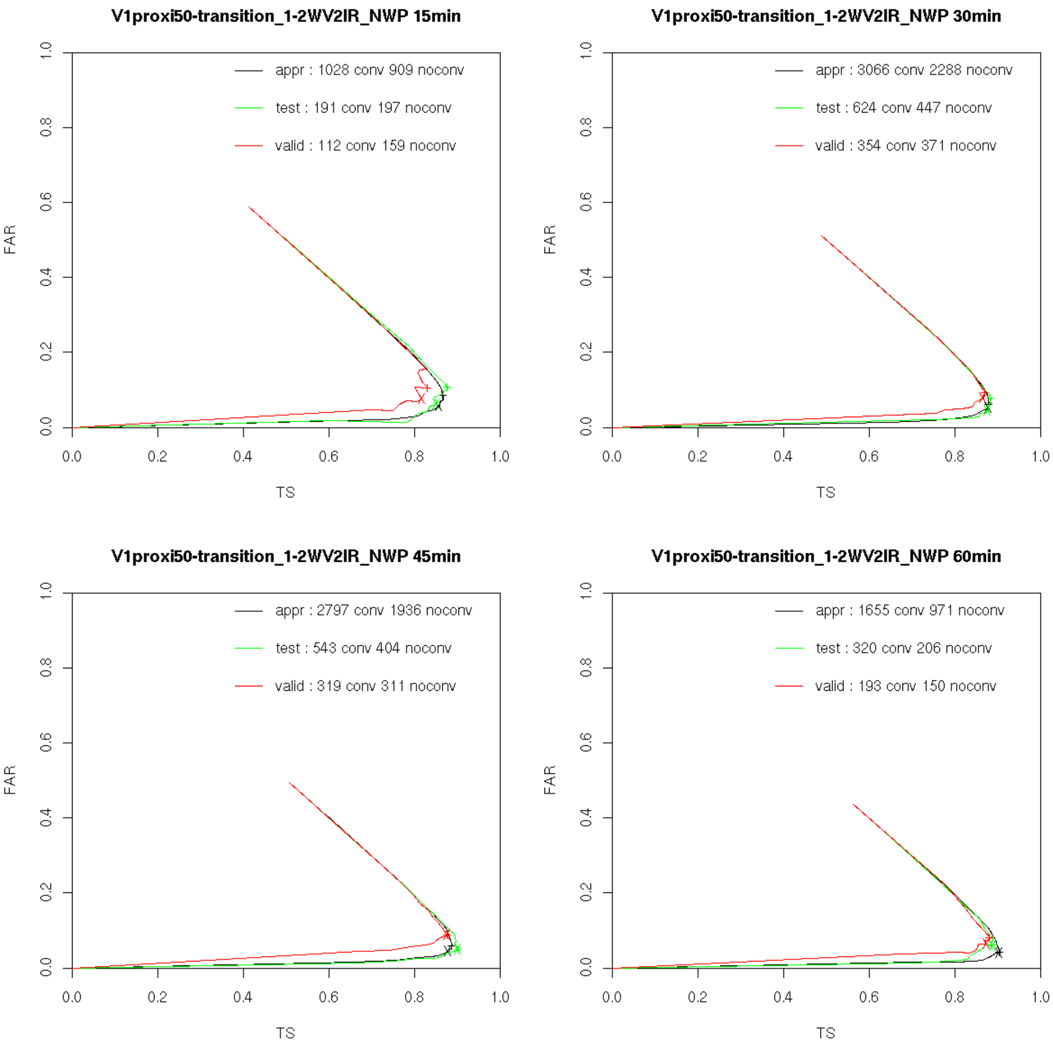


Figure 33: RSS V2011 tuning for transition mature category, full configuration, 4 available depths

9. DISCRIMINATION ON COLD TRANSITION (DTC)

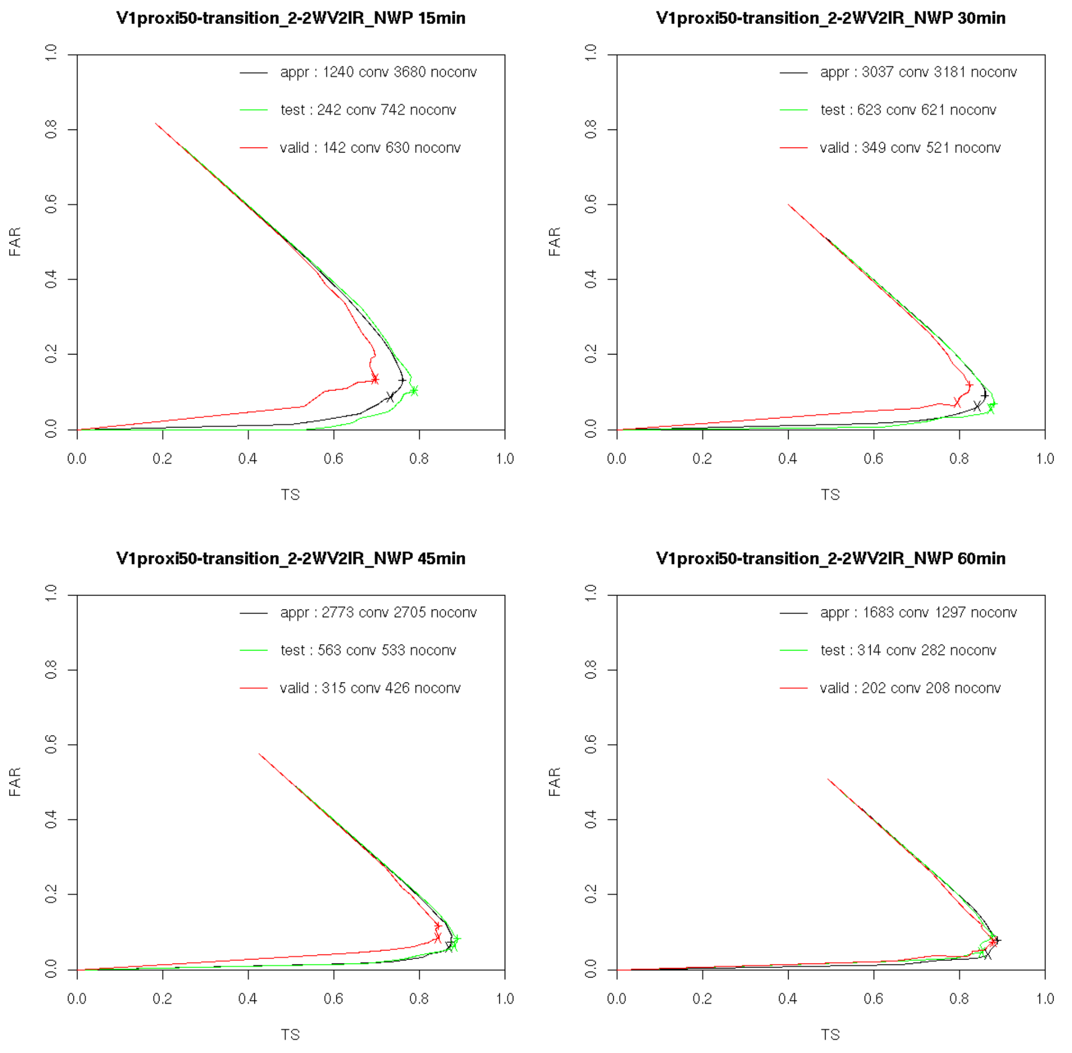


Figure 34: RSS V2011 tuning for cold transition category, full configuration, 4 available depths

10. DISCRIMINATION ON WARM2 TRANSITION (DTW2)

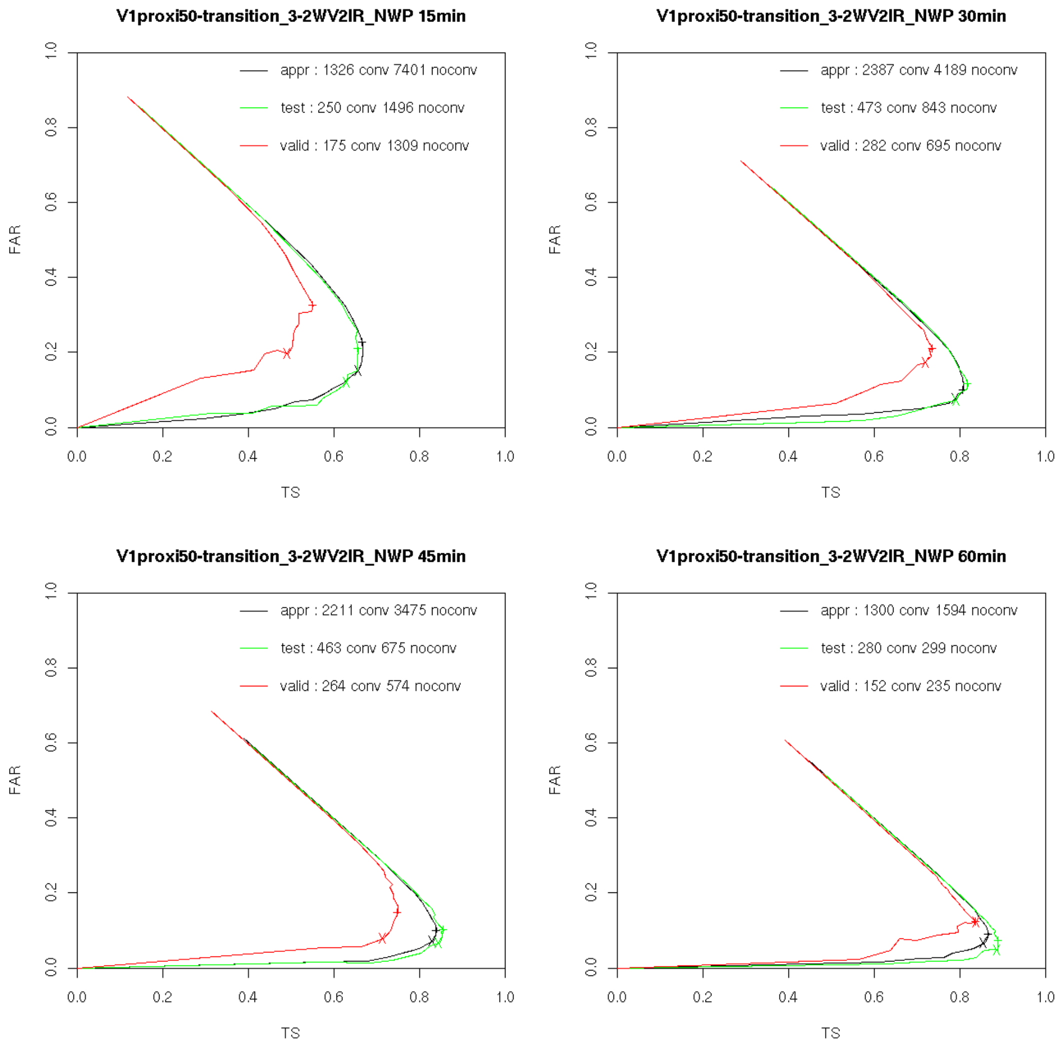


Figure 35: RSS V2011 tuning for Warm2 transition category, full configuration, 4 available depths

11. DISCRIMINATION ON WARM1 TRANSITION (DTW1)

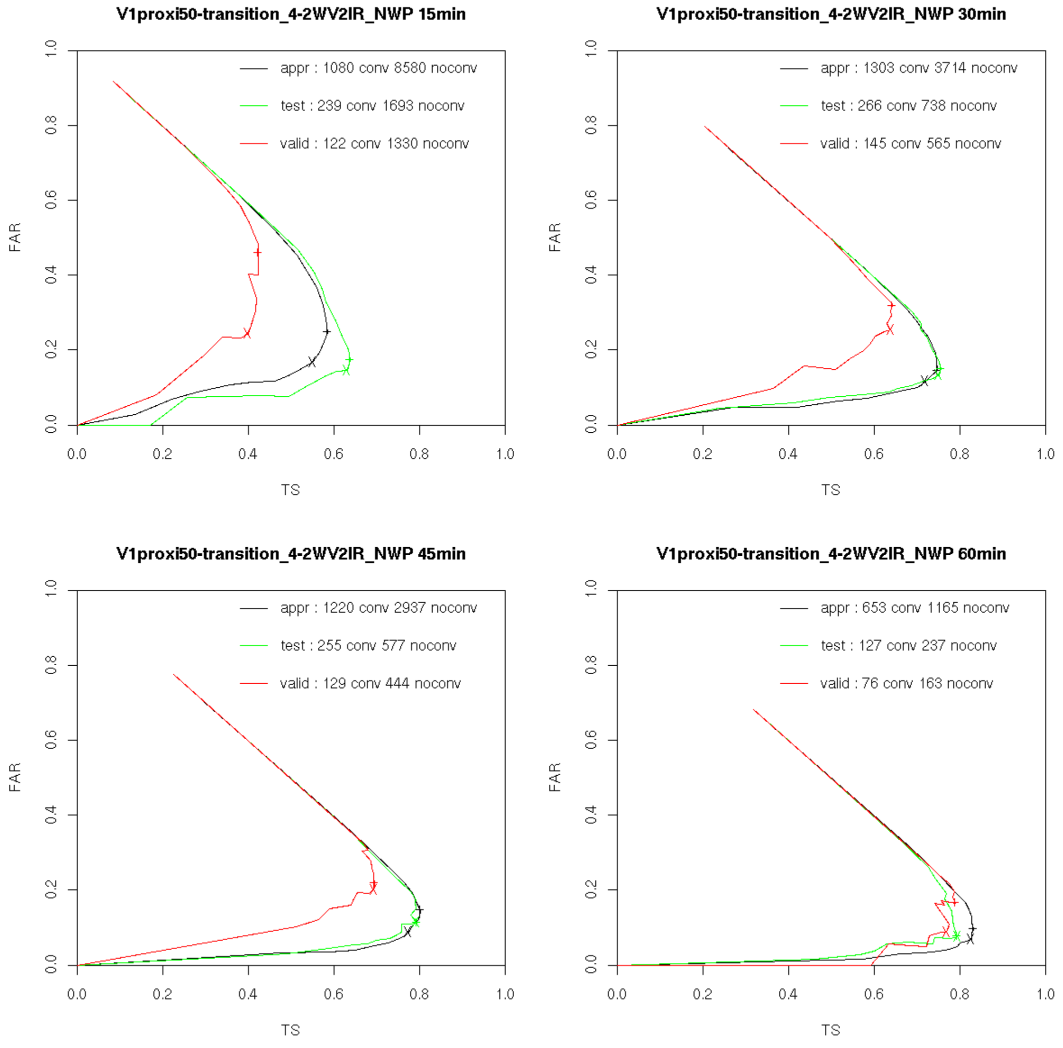


Figure 36: RSS V2011 tuning for Warm1 transition category, full configuration, 4 available depths

12. DISCRIMINATION ON WARM CATEGORY (DW)

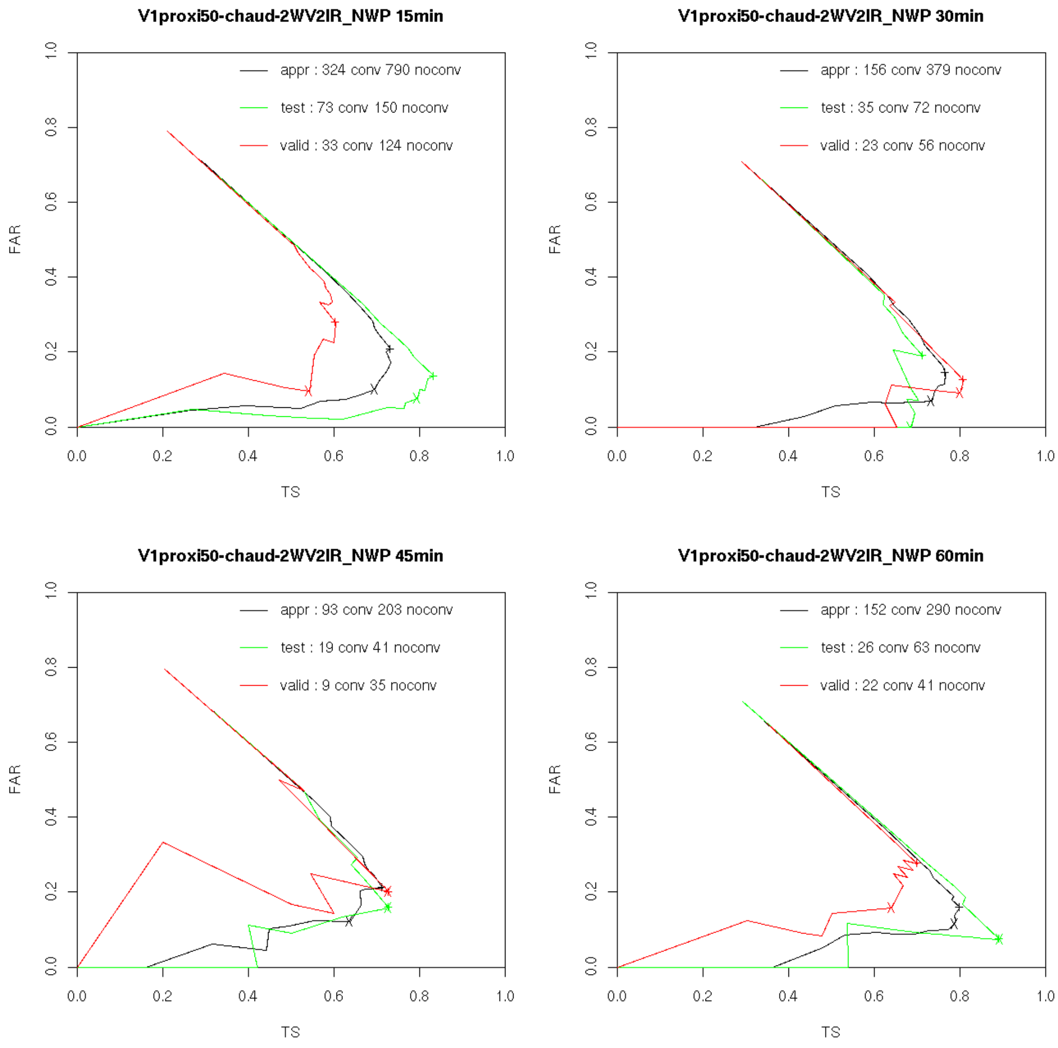


Figure 37: RSS V2011 tuning for Warm category, full configuration, 4 available depths