Improved identification of convective cloud by the RDT product

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Abstract

The Rapid Developing Thunderstorm (RDT) product was developed by Météo-France in the framework of the SAF Nowcasting (EUMETSAT). Its objectives are the identification, monitoring and tracking of severe convective systems and the detection of rapidly developing convective clouds. This paper describes the new discrimination algorithm, convective and non-convective classification, developed for the next RDT version available in 2009. The convective discrimination is an original method based on a mix between statistical decisions and empirical rules. The statistical decisions are only processed to classify convective the non-convective cloud system whereas empirical rules are applied to declassified convective system.
This new algorithm significantly improves the discrimination skill (POD ~70%, POFD < 1%) and provides a subjectively correct depiction of convective phenomena, from triggering to mature stage.

1. Introduction

The Rapid Developing Thunderstorm (RDT) combines a cloud tracker and an algorithm to discriminate convective and non-convective cloud objects. The cloud objects defined by the RDT are cloud towers with a significant vertical extension (namely at least 6°C colder than the warmest pixels in its surroundings, these ones defining what is hereafter called the "cloud tower base").

The major benefit of an automatic tool like the RDT is the object and tracking approach. The representation of the convection process described by pixel-organized radiance information (images) is so synthesized in time and space into an object. Some new parameters associated to a cloud body can hence be derived (trend, extreme values over space and time, morphological attributes…).
Actually, even if a pixel approach well describes the severe convection, as the brightness temperature difference (BTD 6.2µm – 10.8µm) or RGB composite image for example, this is true only in the context of an expert interpretation of such images, while, in the context of an automated system, the use of simple threshold value into any severe convection detection tool leads to a high false alarms ratio. As depicted on *Figure 1*, a simple threshold on BTD could flag numerous non-convective pixels with BTD characteristics close to convective ones. The heavy unbalance between the two populations, in the order of 1 convective object for 100 non-convective ones, leads to generate numerous false alarms. Lastly, the pixel approach based on such temperature differences is applicable only to the mature stage and doesn't allow to detect the other stages of convection: triggering and development.

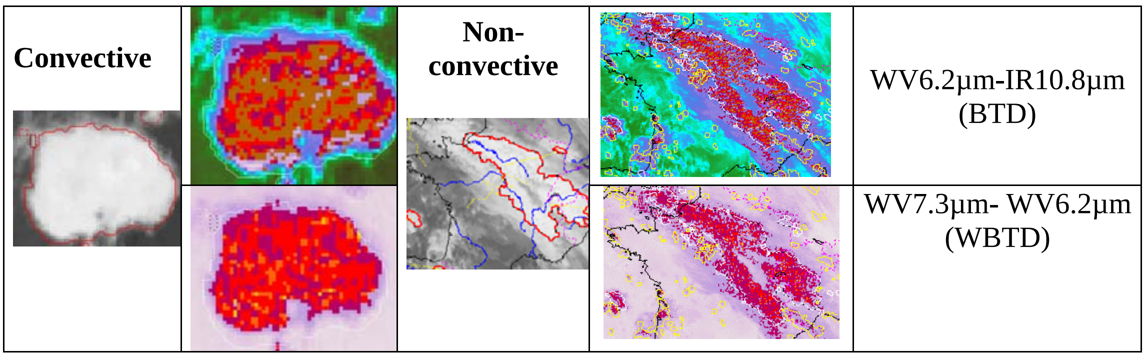

Figure 1 : Limitation of current convection indices in an automated detection approach

The current discrimination is only based on IR 10.8µm MSG channel and the algorithm doesn't allow to easily add new discrimination parameters. Moreover, the objective validation points out some weaknesses like an over-tuning on the learning database (*Guillou and Sénési, 2007*). These limitations lead to a complete re-design of the RDT discrimination scheme. This paper depicts the major principles of the new algorithm and outlines discrimination skill of RDT V2009. These improvements will be available in SAFNWC package version 2009 delivery.

2. The discrimination Algorithm

2.1 The major principles

The methodology and the statistical model choice have been defined with the support of Statistical Laboratory of Toulouse (*Ruiz and Villa, 2007, 2008*).

Unfortunatley (for a statistical approach), the two populations, convective and non-convective, are unbalanced. We can notice a ratio of one convective for more than one hundred non-convective over Europe.

Moreover, a convective object does not have 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 to identifiy deep convection, which is the occurrence of cloud to ground lightning detection, doesn't allow to diagnose the time of convection triggering or to depict the decaying period.

Therefore, the discrimination scheme has been designed as a mix between statistical decisions and empirical rules. The statistical decisions are only processed for short periods of the cloud life cycle defined after convection phases. They are only applied on non-convective objects to check their convective status. On the other hand, the empirical rules are defined to declassify convective objects (for managing convection decay or for correcting for false detections). They are based on cooling parameters for triggering and development phase, and make use in addition of the so-called "global convection index" for mature phase.

2.2 The statistical decision

The discriminating parameters associated to a cloud object are based on three MSG channels (IR 10.8 µm, WV 6.2 µm and WV 7.3 µm). For each channel, the cloud tracking allows to estimate the rate of change and extreme values for past periods of various durations, and both for average and maximum values over the cloud area. The list of discriminating parameters is provided in annex.

The statistical decision operates like a sieve, where the equivalent of the refinement of the mesh size is represented by the stage of vertical development of the convective clouds. It combines four interest moments defined on temperature threshold crossing, and a final step focused on mature population in order to classify all cloud systems not classified before (*Figure 2*):

- Warm 1: top temperature crossing –15°C **or** base of cloud tower crossing –5°C
- Warm2: top temperature crossing –25°C **or** base of cloud tower crossing –15°C
- Cold: top temperature crossing –35°C **or** base of cloud tower crossing –25°C
- Mature: top temperature crossing –40°C
- Final step (*Mature*): top temperature < -40°C

The statistical models defined on temperature threshold crossing are named transition models (MTD, CTD, WTD2, WTD1). The models defined on the mature population are named mature models (MD).

The transition models are defined for four possible durations of available cloud history: 15, 30 , 45 and 60 minutes. The mature ones are defined on a single history duration of 45 minutes.

In order to provide a classification for several configuration of channels availability, the statistical models are defined on three channel combinations:

- IR10.8 µm, WV6.2µm, WV7.3µm
- IR10.8 µm, WV6.2µm

- IR10.8 µm

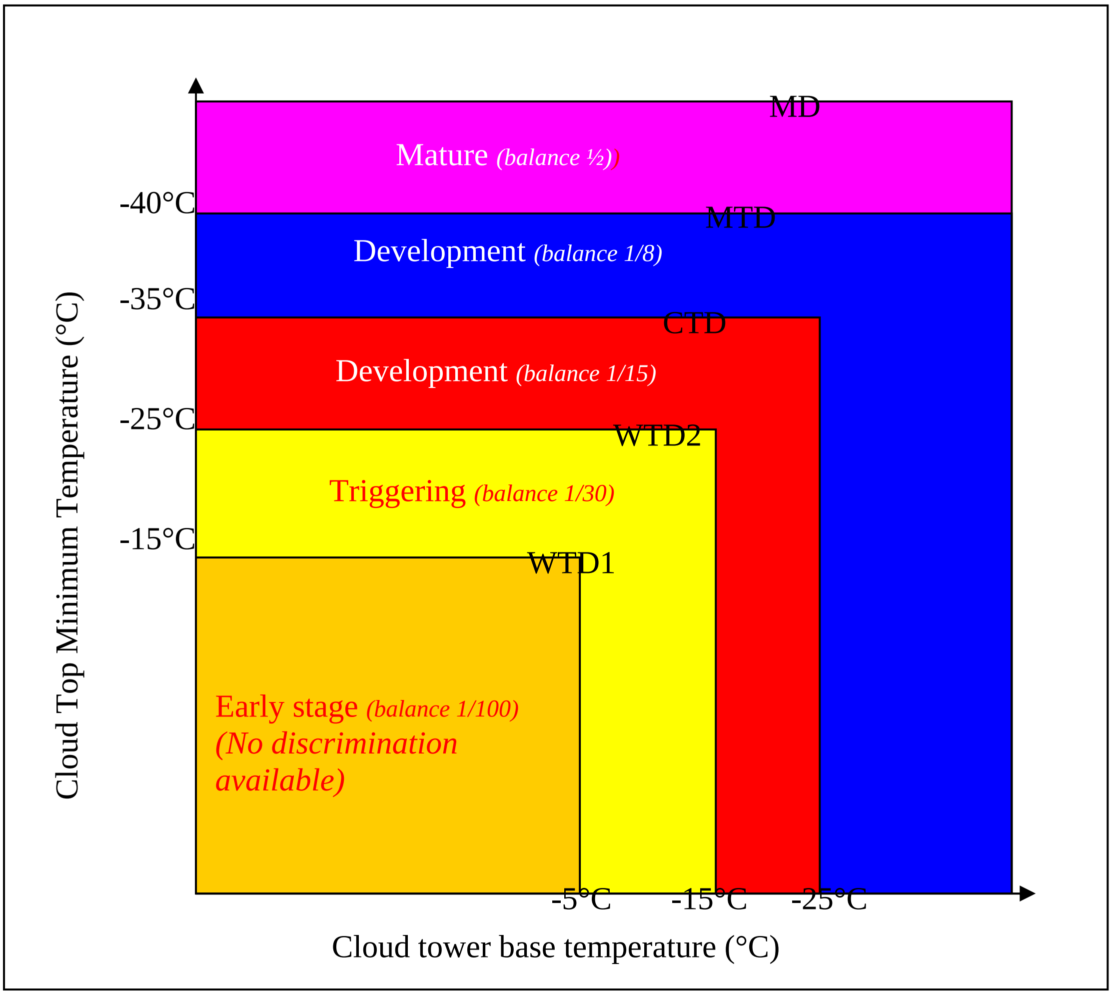

Figure 2 : Statistical Discrimination Scheme

All together, the discrimination scheme contains fifty one statistical models, or seventeen for each channels combination: four history durations for each of the four temperature thresholds, plus one for the mature population.

The choice of history duration of statistical models depends on the duration of the whole trajectory and duration following temperature threshold crossing (see figure below).

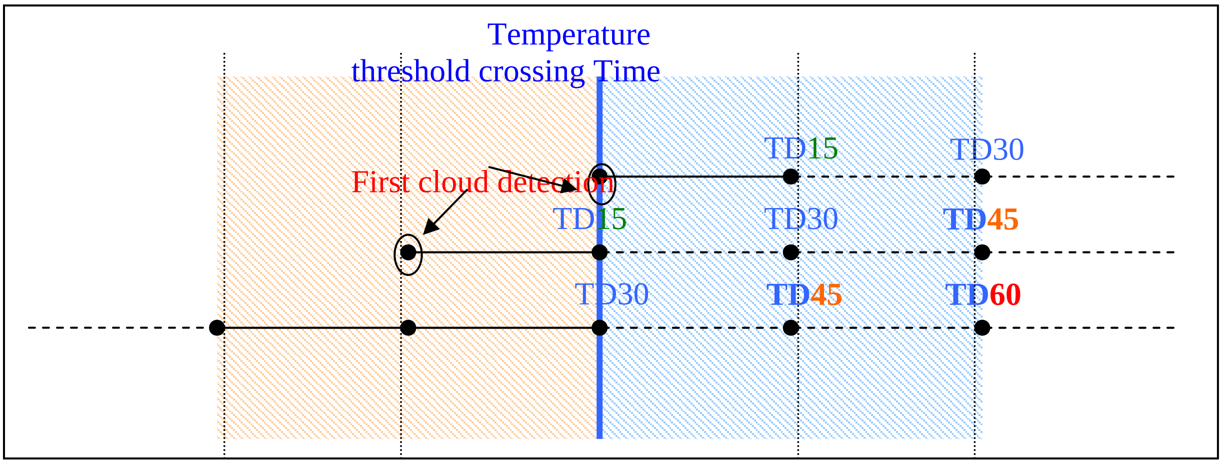

Figure 3 : Transition model choice (history duration from temperature crossing time)

Preliminary studies have been led to assess convective discriminating skill of linear and no linear statistical models (*Ruiz and Villa, 2007, 2008*) to be incorporate into the discrimination scheme. The best results are obtained with a random forest method (with 600 trees) and a simple Logistic Regression. The logistic regression has been chosen for implementation in the operational scheme, because this model is simple, fast and provides some information on discriminating parameters.

2.3 The statistical model tuning

The statistical models tuning gets organized around three databases:

- The learning database is built on summer 2004. The populations, convective and non-convective, have been balanced with a random sampling on non-convective population. This database is used to tune statistical models.
- The test database is built on summer 2004: This database was not balanced. It contains all convective and non-convective bodies. This database is used to assess discrimination skill on unbalanced populations configuration.
- The validation database is built on summer 2005: As the previous one, this base is unbalanced and contains all convective and non-convective body. This database provides an independent verification sample. The discrimination skill between test database and validation database should be comparable.

For each single logistic regression decision model, the discrimination skill is sensitive to the choice of a single parameter, the logistic function threshold chosen for the yes/no decision. This sensitivity can be depicted as a threat score /false alarm ratio curve, which allows to tune the trade-off between the false alarm rate and the global (threst score) skill. Figure 4 allows to compare the skill curves for four history durations for the nominal channels configuration and the “cold transition” case

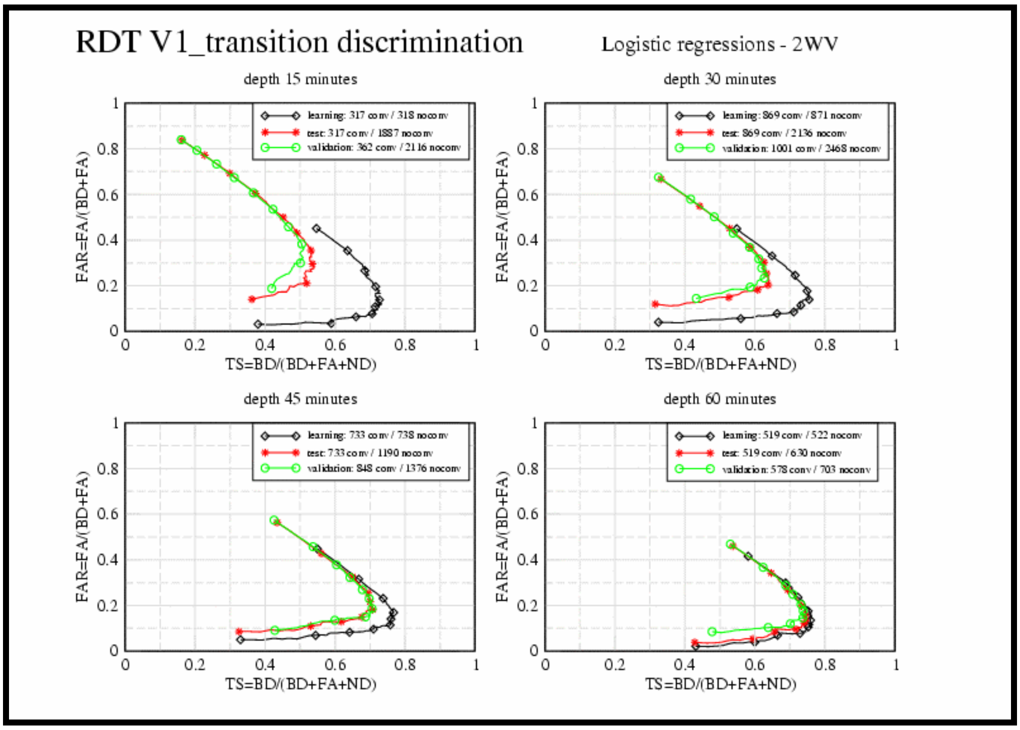

Figure 4 : Cold Transition Discrimination(CTD) – TS/FAR curves for model defined on IR10.8, WV6.2 and WV7.3 (2WV)

Generally, the models defined on short history durations generally show quite low score with a high false alarms ratio. Therefore, some of the 51 models, defined on short historic period, were not enabled in order to reduce false alarms. This result confirms the inability to define a convective classification using only one or two consecutive MSG images from IR10.8 and vapor channels only.

2.4 The empirical rules

2.4.1 Declassification rules

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

To manage change of RDT objects into discrimination scheme (*Figure 2*), the objects are characterized by temperature classes:

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

Class 2 is associated to discrimination of mature transition. Nevertheless, these objects are assumed mature (class 1) for declassification rules.

Except for class1, the convective object is declassified if it stays more than 45 minutes into the same class or upper class. Thus, the convective classification is assumed to remain valid for (no more than) 45 minutes. This feature allows to improve the stability of the diagnosis and smoothes some artefacts produced by the tracking algorithm (notably on the cloud tower base temperature).

Class 1 is associated to the mature phase. The declassification rules can not be defined on cooling rate only (development criteria). As for previous cases, the convective classification is kept valid for 45 minutes. After this period, the convective object is declassified if it changes of temperature class (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’ is negative.

2.4.2 Tracking rules

This paragraph depicts empirical rules defined on managing convective diagnosis in the tracking algorithm.

First, a newly detected cloud is always classified as non-convective.
The tracking algorithm allows to link an object to “father” objects defined on the previous image (based on overlapping). The “main father” is the father with the largest area (defined at a common temperature threshold). The so-called “convective father” is the coldest father with a convective classification. In some cases, the main father and the convective father do differ.

The discriminating parameters are processed on the “main” trajectory, which is the trajectory defined by the “main father” links. On the other hand, the “convective” trajectory, defined on the “convective father” links, allows to manage the convective duration and temperature class change used into the declassification rules.

If an object has a convective father, the object is classified as convective, and the declassification conditions are then processed on the convective trajectory.
In the case of decreasing temperature class change, the convective duration is initialized to zero for the new class. In the other cases, the convective duration is incremented.

3. The Discrimination skill

3.1 Validation methodology

3.1.1 Observations and limitations

The tracking algorithm allows to define convective and non-convective trajectories. A trajectory aggregates all RDT objects linked in time. The discrimination skill assessment at the scale of trajectories allows to provide gross scores. These scores do not depict all aspects of the skill of convection detection, especially for real-time operations, where one do not want to wait the diagnostic on convective nature until the end of cloud trajectory. Therefore, it is necessary to define for the evaluation of skill a statistical body more representative of deep convection triggering, here represented by lightning occurrence dynamics.

The use of lightning data matched to cloud objects is also questionable. The lightning data used is limited to cloud to ground strokes, and, the RDT cloud object depicts the cloud tower and not necessarily the whole cloud shield. Thus, some matching errors occur and have to be translated into a so-called “undefined” population which convective status cannot be decided for sure.

3.1.2 The ground truth

The definition used to classify a trajectory as convective is based on the total number of strokes spatially matched to the cloud area during the whole RDT cloud object life. Within a given limit of space tolerance in the matching process, we have defined three categories associated to lightning activity level:

- Low: for trajectories with one of more stroke matched
- Moderate: for a trajectory with at least 5 flashes matched
- Severe: for a trajectory with at least 20 flashes matched and a continuous lightning duration longer than 15 minutes.

The trajectories without lightning activity are labelled non-convective.
When analyzing a given lightning severity level, the trajectories without enough strokes are labelled as undefined and are not considered into score tables.

3.1.3 The statistical body

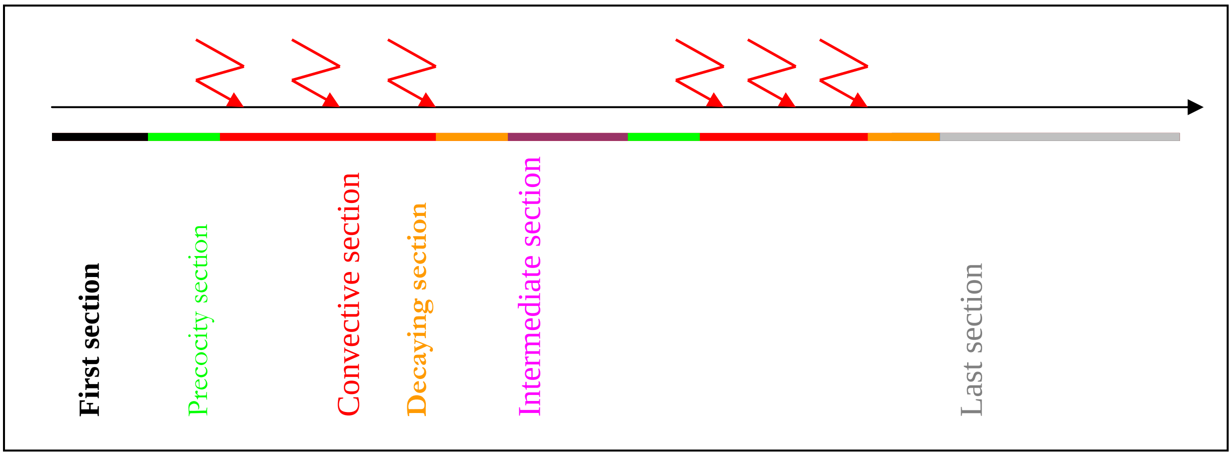

Figure 5 : Characterization of section bodies from a convective trajectory

The lightning activity is not necessarily continuous over a convective trajectory. We can define six types of trajectory section (*Figure 5*):

- The convective section: is composed of moments with lightning strokes “holes” shorter than 45 minutes(Red section)

- The precocity section. Such a section is defined before each convective section and with a duration of one hour (Green section)
- The decaying section: is defined as following each convective section, and has a duration of 45 minutes at most. The duration could be reduced in advantage to a precocity section. (Orange section)
- The intermediate section. The intermediate section is a non-lightning period between a decaying section and a precocity section(Purple section)
- The first section. The first section is a non-lightning period before the precocity section. (Black section)
- The last section. The last section is a no lightning period after the last decaying section. (Grey section)

The statistical body is defined from convective and non-convective trajectories. It can be either a single moment of the cloud cell life cycle, a section thereof (as defined above), or the whole life cycle duration (trajectory). The moment body has the same name than its section. The single moment approach is more relevant to real time operations of the discrimination, while the trajectory approach is more oriented toward climatology studies. The section approach allows to assess the true discrimination skill on convective phenomena. Indeed, this body is less sensitive to the duration of convective phenomena or false alarm classification than the single moment body.

3.1.4 The time tolerance

The section and single moment approaches allow to introduce a time tolerance on lightning activity. We consider three hypothesis:

H 1. The discrimination skill is assessed on all bodies from non-convective trajectory (yellow section or moment) and is limited to red bodies from convective trajectories (red section or moment).

H 2. The discrimination skill is assessed on all bodies from all trajectories. But, the classification decided for precocity and decaying period (green and orange bodies) is always counted like a good decision.

H 3. The discrimination skill is assessed on all bodies from all trajectories. The precocity and decaying period, green and orange bodies, are considered convective bodies.

3.1.5 Contingency tables

The verification is performed as follows, duly taking into account one of the three hypotheses defined above in selecting bodies:

A convective section is counted as a good detection if the algorithm discriminates a convective cell for at least one of the moments of the associated period.

A section other that convective is counted like a false alarm if the algorithm discriminates a convective cloud object on any moment of the associated period.

A convective moment is counted as a good detection if the algorithm actually discriminates as convective the corresponding RDT cloud cell.

A moment other than convective is counted like a false alarm if the algorithm discriminates as convective the corresponding cloud object.

Thus, the validation of RDT discrimination skill contains 21 contingency tables (3 electrical activity level x 3 kind of statistical bodies x 3 hypothesis for two bodies types).

The three table versions available for one electrical activity level and on one kind of statistical body are depicted below

Hypothesis 1:

Observation RDT classification	Convective	Non Convective
Convective discriminated	Good detection : Red bodies	False Alarm: Yellow bodies
Non discriminated	No detection: Red bodies	Good no detection Yellow bodies

Hypothesis 2:

Observation RDT classification	Convective	Non Convective
Convective discriminated	Good detection : Red + Green + Orange bodies	False Alarm: Yellow + Black + Grey + Violet bodies
Non discriminated	No detection: Red bodies	Good no detection Yellow + Black + Grey + Violet, Green + Orange bodies

Hypothesis 3:

Observation RDT classification	Convective	Non Convective
Convective discriminated	Good detection : Red + Green + Orange bodies	False Alarm: Yellow + Black + Grey + Violet bodies
Non discriminated	No detection: Red + Green + Orange bodies	Good no detection Yellow + Black + Grey + Violet bodies

3.2 Discrimination Score

Statistical body			Trajectory	Section			Single moment		
Hypothesis				H1	H2	H3	H1	H2	H3
Low lightning activity	Unbalanced Population	Cv	4988	5289 (red) 4059 (green) 3680 (orange) 1234 (black) 1710 (grey) and 76 (violet)			21777 (red) 10982 (green) 8919 (orange) 6449 (black) 10887 (grey) and 401 (violet)		
		Non Cv	62180	62180 (yellow)			419004 (yellow)		
	Score	POD	47	40	55	29	48	55	33
		POFD	2	2	2	2,5	<1	<1	1
		FAR	36	38	30	30	25	24	24
		TS	37	32	44	26	42	47	30
Moderate lightning activity	Unbalanced Population	Cv	2496	2715 (red) 1898 (green) 1677 (orange) 510 (black) 846 (grey) 57 (violet)			17964 (red) 4998 (green) 4211 (orange) 2715 (black) 5957 (grey) 336 (violet)		
		Non Cv	62180	62180 (yellow)			419004 (yellow)		
	Score	POD	66	60	71	42	55	59	43
		POFD	2	2	2	2	<1	<1	<1
		FAR	44	44	36	36	26	25	25
		TS	43	40	50	34	46	49	37,5
Severe lightning activity	Unbalanced Population	Cv	1354	1466 (red) 956 (green) 881 (orange) 253 (black) 488 (grey) 29 (violet)			13419 (red) 2500 (green) 2267 (orange) 1345 (black) 3713 (grey) 195 (violet)		
		Non Cv	62180	62180 (yellow)			419004 (yellow)		
	Score	POD	78	73	81	49	61	64	51
		POFD	2	2	2	3	<1	<1	<1
		FAR	56	55	45	45	30	29	29
		TS	39	38	47	34	48	50	42

Tab 1 Discrimination scores

The table above points out the high sensitivity of score values on the assumption used.
The analysis of sample size according to electrical activity level allows to understand how score values are governed by samples balance. The number of trajectory and of convective section (red) is divided by two between light and moderate lightning activity and also between moderate and severe lightning

activity. In the same time, the single convective moment (red) number decreases much less. So, the duration of convective section (red) from a trajectory with a low lightning activity is shorter than for the other activity levels. Therefore, the unbalance between convective and non-convective statistical bodies decreases more on trajectory and section bodies than on single moment. Thus, the discrimination skill are mechanically more improve, according to ground truth lightning activity level, on trajectory and section bodies than single moment one.
The limitation of score assessment on trajectory body is pointed out by the quite low score observed on section body and hypothesis one (convective population limited to red section): which shows that a good detection for a trajectory doesn't mean a good detection at the relevant time, i.e. during the convective period of that trajectory. Moreover, the scores assessed on single moment body are sensitive to the duration of convective period. Therefore, the discrimination skill assesses on section body is more relevant and provide realistic general scores for the discrimination algorithm.

The change in scores depending on the hypothesis on lightning time tolerance (H1, H2, H3 see paragraph 3.1.4) allows to characterize the discrimination skill around convective period. The highest score is logically reached under hypothesis 2. The weak difference between POD on hypothesis 1 and hypothesis 2 points out the weak discrimination skill on decaying and precocity period. Due to the short duration of these periods, the score variation between the three hypotheses remains small for single moment body.

Last, the false alarm ratio remains high whatever the validation assumption considered. As mentioned in paragraph 3.1.1, the ground truth used could lead to some matching error. At present time, it is not possible to assess the number of erroneous false detection due to a matching error or a lightning network detection weakness. Nevertheless, it is possible to check the sensitivity of the scores to filtering out the non-convective statistical bodies issued from non-convective trajectories which have a lightning stroke in the surrounding.

		Trajectory			**Section**			**Time step**		
Stroke proximity filter (km)	**Non-convective trajectory Number**	POFD	FAR	TS	POFD	FAR	TS	POFD	FAR	TS
0	62180	2	56	39	2	45	47	<1	29	50
60	51109	1	34	55	1	28	61	0,5	15	57
150	37963	1	22	63	1	20	67	0,5	10	59

Tab 2: Score and lightning proximity (hypothesis 2 and severe ground truth)

The false alarm ratio drops largely with flashes proximity filter. This means that the majority of false alarms are located near cloud to ground flashes.

3.3 <u>The precocity skill</u>

Let us define the discrimination precocity as duration of the time interval between first discrimination of the cloud and first lightning stroke matched to that cloud. Assessing the precocity depends on the capacity to actually track the cloud soon enough before the first flash. Nevertheless, even if the cloud tracker identifies cloud objects from warm cloud top temperature level (5°C), object splitting generates numerous "new" trajectories with a lost history. A subjective approach may be more efficient on this topic.

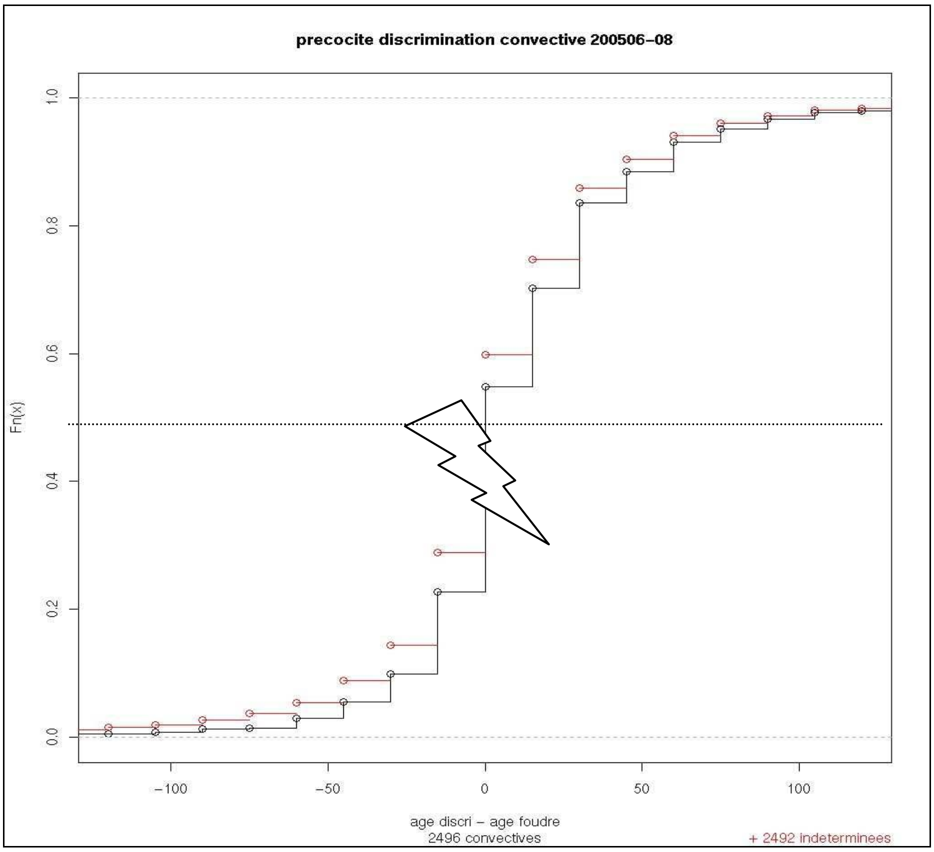

Figure 6: Precocity of discrimination (moderate ground truth (red mark, with undefined population)

The Figure 6 shows the histogram of precocity values on the verifications sample and for the low level of lightning activity; it points out that more than 50% of good detection are already performed at time of the first stroke occurrence, and 85 % thirty minutes after. Nevertheless, only 25% are discriminated before the first stroke.

The subjective approach points out a better precocity of detection for RDT V2009. Even if, the majority of systems are detected in the same time or one image before, we can notice some much earlier detection in the triggering phase or first phase of development. In these cases, the precocity is sometimes improved to one hour.

4. Examples

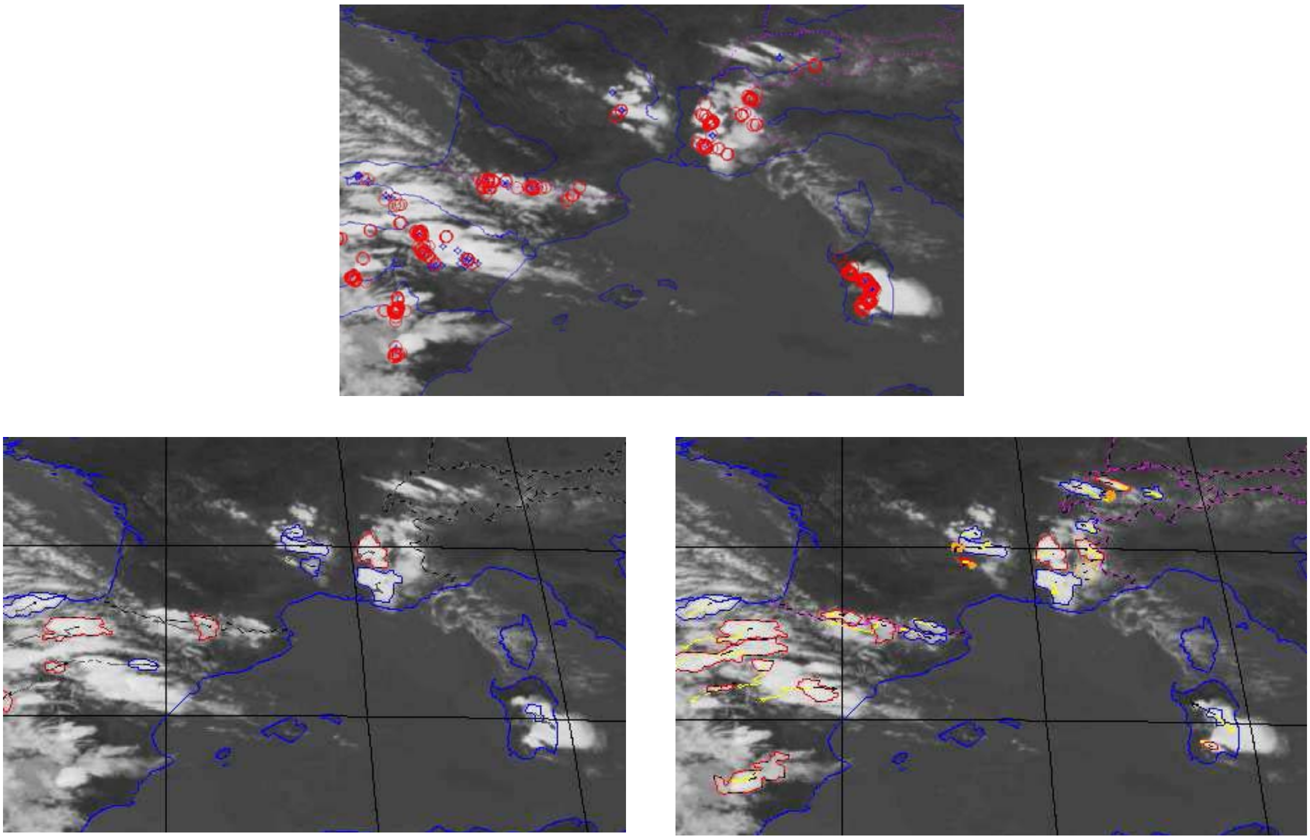

Figure 7 : RDT V2008 (left image) versus RDT V2009 (right image), lightning occurrence depicted on top image (18 July 2006)

The figure above shows the major improvement of discrimination skill. The new version detects all convective systems excepted two small ones in South-West. All objects classified as convective by the RDT actually show a lightning activity. The algorithm allows to discriminate all kind of convective systems: development phase in the north and mature phase in the south.
Meanwhile, the RDT version 2008 shows some difficulties to provide a right picture of whole convection. We can notice some mature systems not detected in the south and system in development in the north. The severe convection over Corsica is missed too.

Moreover, the new discrimination scheme waits 45 minutes before activating de-classification rules. This timeout allows to provide classification stability to the user. We can notice too the short past historic used by statistical model. In opposite to previous algorithm based on the whole cloud life, this modification discards the side effect (sensitive to region size).

5. Conclusion

The new RDT version improves the convective discrimination skill on various points. First, the probability of detection of the convective period (i.e. of the electrically active part of the cloud life cycle) reaches 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 weak (59%). Nevertheless, more than 80% of good detection are detected no more than 30 minutes after the first stroke.
Beyond objective scores, the new scheme provides a convective classification stable in time. The convective systems are duly de-classified during the decaying phase, hence avoiding to put the focus

on uninteresting objects. The false alarms are well diagnosed after a small track (45 minutes). We can notice the sensitive elimination of region size too.
Thus, the new version of RDT provides a right depicting of convective phenomena, from triggering phase to mature stage.. Even if the precocity versus the first lightning occurrence remains modest, it becomes subjectively useful when focusing on clouds with at least a moderate lightning activity.

Moreover, the new algorithm allows to add new discriminating parameters and assess their discriminating power. Further works is going on to improve early detection and decrease false alarm ratio. This includes the use of channel 3,9 µm and of NWP –derived convection-related diagnostic parameters. The use of MSG Rapid Scan mode data is also under study and should lead to a relevant tuning available for 2009SAF-NWC package delivery.

All documentations and software of the SAFNWC products are available on project web site http://nwcsaf.inm.es/. In advance of the next release of SAFNWC package, planned in January 2009, the RDT V2009 real time demonstration over Europe is available on the following web site: http://www.meteorologie.eu.org/RDT/.

6. References

1. Y. Guillou, S Sénési (November 2007), Validation report for "Rapid Development Thunderstorms (RDT-PGE11 v1.3) – SAF NWC documentation : http://nwcsaf.inm.es/

2. 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)

3. 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)

Annex - The Discriminating parameters

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

N°	Parameter	Meaning	Mature (45’)	Transition (15, 30, 45, 60)
1	Min_Tmin	minimum of top temperature	MD	
2	Max_TxTmin	Maximum of top temperature rate processed on two following images	MD	TD
3	Min_TxTmin	minimum of top temperature rate processed on two following images	MD	
4	Max_TxTmin2	Secondary maximum of top temperature rate processed on two following images		TD
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’)		TD
7	Max_TxTmin30	maximum of top temperature rate processed on 30’		TD
8	Max_TxTmin45	maximum of top temperature rate processed on 45’		TD
9	Max_TxTmin60	maximum of top temperature rate processed on 60’		TD
10	MinMaxPos	0 : continuous cooling on past historic taken care by statistical model 1 : other case		TD
11	MinMaxNeg	0 : continuous warming on past historic taken care by statistical model 1 : other case		TD
12	MinNegMaxPos	0 : warming before cooling on past historic taken care by statistical model 1: other case		TD
13	Max_TxTmoy	Maximum of mean temperature processed on two successive images	MD	
14	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	MD	
15	Max_DTmoyTmin	maximum mean temperature – top temperature	MD	TD
16	Min_DTmoyTmin	mimimum mean temperature – top temperature	MD	TD
17	Max_DTmoyTminST	maximum mean temperature, defined on ST, - top temperature	MD	
18	Max_DTsTmoy	Maximum temperature of base – mean temperature	MD	
19	Max_DTsTmoyST	Maximum temperature of base – mean temperature defined on ST	MD	
20	Max_Gpm	Maximum of the mean peripheral gradient processed on IR10.8	MD	TD
21	Max_QGP	Maximum of quantile 95% of peripheral gradient	MD	TD
22	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	MD	TD
23	Max_RapAspect	Maximum of long axe / small axe of ellipse enclosing	MD	TD
24	Max_SurfaceST	Maximum of the ST surface	MD	TD
25	Max_DSurfBTST	Maximum of cell surface – ST surface	MD	
26	Min_WVmin	Minimum of WV6.2	MD	TD
27	Min_WV2min	Minimum of WV7.3	MD	TD
28	Max_TxWV	Maximum WV6.2 rate processed on two following images	MD	TD

29	Max_TxWV10	Maximum WV6.2 rate processed on 10 minutes (Rapid Scan mode)		
30	Max_TxWV15	Maximum WV6.2 rate processed on 15 minutes		
31	Max_TxWV30	Maximum WV6.2 rate processed on 30 minutes		TD
32	Max_TxWV45	Maximum WV6.2 rate processed on minutes		TD
33	Max_TxWV60	Maximum WV6.2 rate processed on 60 minutes		TD
34	Max_TxWV2	Maximum WV7.3 rate processed on two following images		
35	Max_TxWV210	Maximum WV7.3 rate processed on 10 minutes (Rapid Scan mode)		
36	Max_TxWV215	Maximum WV7.3 rate processed on 15 minutes	MD	TD
37	Max_TxWV230	Maximum WV7.3 rate processed on 30 minutes		TD
38	Max_TxWV245	Maximum WV7.3 rate processed on 45 minutes		TD
39	Max_TxWV260	Maximum WV7.3 rate processed on 60 minutes		TD
40	Max_BTD	maximum of quantile 75% of WV6.2-IR10.8	MD	TD
41	Max_BTD90	maximum of quantile 90% of WV6.2-IR10.8	MD	TD
42	Max_BTDRatio	maximum of BTD index structure BTD=WV6.2 – IR10.8 Index structure is the ratio between contiguous BTD pixel >0 and BTD pixel > 0	MD	TD
43	Max_WBTD	maximum of quantile 75% of WV6.2- WV7.3	MD	TD
44	Max_WBTD90	maximum of quantile 90% of WV6.2- WV7.3	MD	TD
45	Max_WBTDRatio	Maximum of WBTD index structure WBTD= WV6.2- WV7.3 Index structure is the ratio between contiguous WBTD pixel > 0 and WBTD pixel > 0	MD	TD
46	Max_TxBTD	maximum of BTD rate processed on two following images		
47	Max_TxBTD10	maximum of BTD rate processed on 10 minutes (Rapid Scan Mode)		
48	Max_TxBTD15	maximum of BTD rate processed on 15 minutes	MD	TD
49	Max_TxBTD30	maximum of BTD rate processed on 30 minutes	MD	TD
50	Max_TxBTD45	maximum of BTD rate processed on 45 minutes	MD	TD
51	Max_TxBTD60	maximum of BTD rate processed on 60 minutes		TD
52	Max_TxWTD	maximum of WBTD rate processed on two following images		
53	Max_TxWTD10	maximum of WBTD rate processed on 10 minutes		
54	Max_TxWBTD15	maximum of WBTD rate processed on 15 minutes	MD	TD
55	Max_TxWBTD30	maximum of WBTD rate processed on 30 minutes	MD	TD
56	Max_TxWBTD45	maximum of WBTD processed on 45 minutes	MD	TD
57	Max_TxWBTD60	maximum of WBTD processed on 60 minutes		TD