



Refinement and operational implementation of a rain rate algorithm based AMSU/MHS, and SEVIRI data within the Hydrological-SAF

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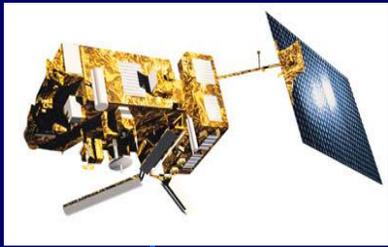
Topic

- Description of the strategy designed to adapt existing satellite (AMSU) based **rain-rate estimation** algorithms to **hydrologist needs** with the use of **ancillary satellite products** (SEVIRI)

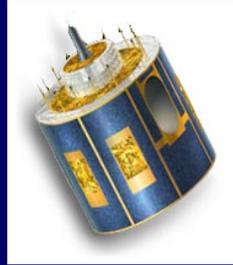
This task will be performed under a Visiting Scientist (VS) project sponsored by EUMETSAT within the Hydrological-SAF program.

Outline

- VS program, Institutes involved;
- Precipitation retrieval from AMSU data (PART I);
- Convective systems discrimination from SEVIRI data (PART II);
- Rain gauges use for the calibration and validation (PART III);
- Conclusions.



SAFs (Satellite Application Facilities) EUMETSAT



- aimed to develop and deliver meteorological services and products
- mainly derived by Satellite (geostationary/polar) data;
- considered to be a common need of all, or the least a majority, of Member States
- use of data for applications
- Inter- saf activity/exchange desirable.

H-SAF (Hydrological SAF)



Precipitation (Develop. CNR- Italy), snow cover (Develop. Turkey and Finland), soil moisture (Develop. Austria)



Hydrologist requirements

Visiting Scientist proposal:

Refinement and operation implementation of a rain rate algorithm based AMSU/MHS and raingauges data over the H-SAF

Proposal developed by:

Dipartimento della Protezione Civile Italiana, (S. Puca)

Corina A., Gioia A., Giordano P., Rossi L. - hydrology, satellite

Centro Nazionale di Meteorologia e Climatologia dell'Aeronautica militare, (F. Zauli);

De Leonibus L., Melfi D., Biron D., Bonavita M.

– satellite, real-time processing

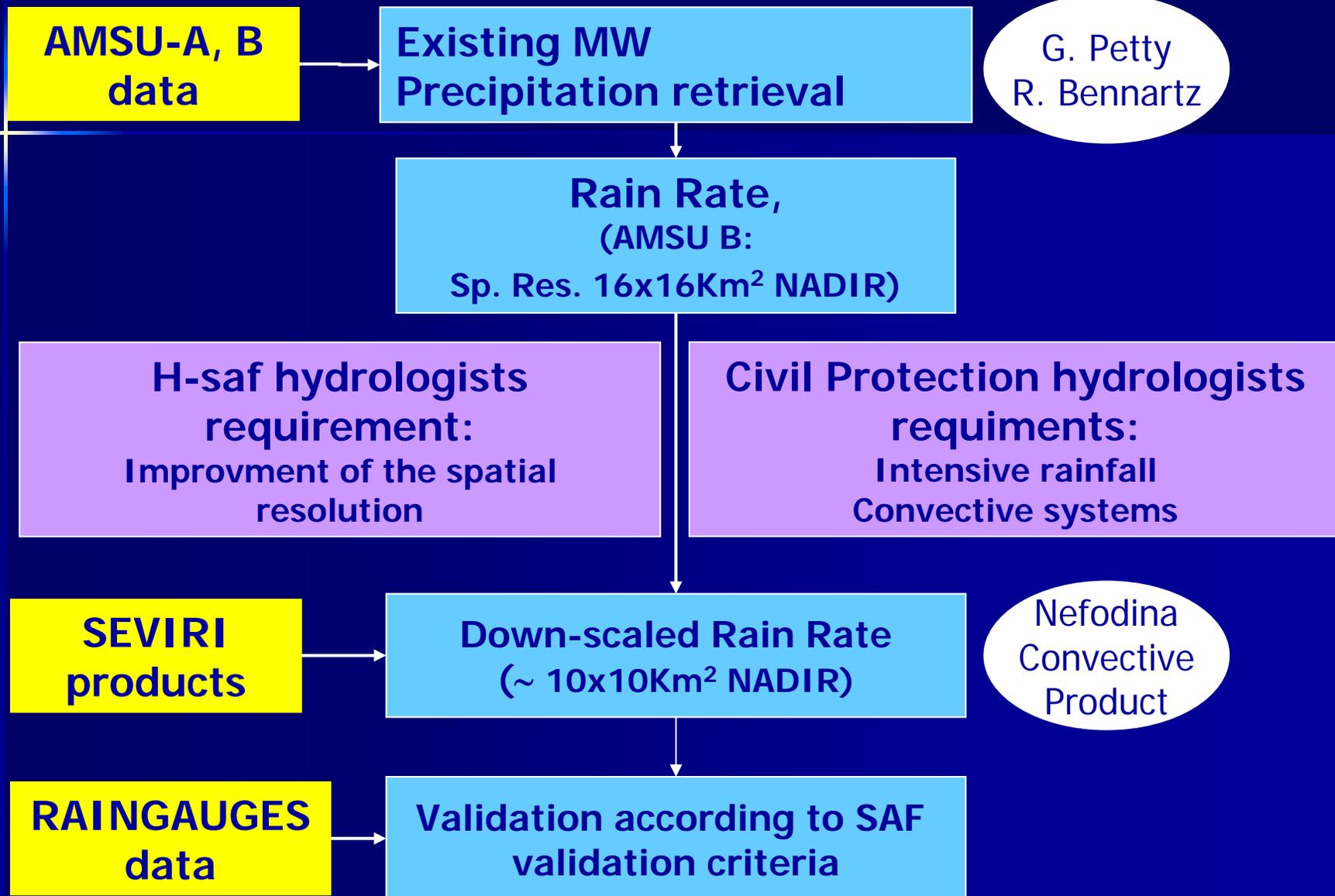
Visiting Scientist: Paolo Antonelli

• *Space Science Engineering Center – UW-Madison*

Petty G., Bennartz R., Woolf H.,

- MW, IR, and real-time processing

Strategy



PART I

Rain Rate Estimation from AMSU data

Existing Precipitation Algorithm PC product (operative at SMHI)

- *Algorithm set-up: Uses differential scattering BT 89 GHz and 150 GHz hereafter Scattering Index (SI)*
- *Discriminate 4 classes of precipitation according to rainrate intensity for 3 kinds of background:*
 - *AMSU-A water or coast, AMSU-B land:
SI = T89-T150-CORR*
 - *AMSU-A land (and AMSU-B land):
SI = T23-T150-CORR*
 - *AMSU-B water: SI = T89-T150-CORR*
- *Developed within the NWC-SAF, the algorithm is already operative at the Swedish Meteorological and Hydrological Institute (SMHI)*

Four classes of precipitation intensity from co-located radar data

	Rain rate
Class 1: Precipitation-free	0.0 - 0.1 mm/h
Class 2: Risk for precipitation	0.1- 0.5 mm/h
Class 3: Light/moderate precipitation	0.5 - 5.0 mm/h
Class 4: Intensive precipitation	5.0 - ... mm/h

Note: severe precipitation events can not be discriminated

Current status of the PC product

- PC product running operationally at SMHI within NWCSAF software package;
- Product can be run independently on AAPP ingested level 1 C AMSU data;
- Adjustment for MHS versus AMSU-B included;
- Product tuned to collocated radar data;
- Provides likelihoods for four different intensity classes of precipitation;
- Accounts for different surface types (land/water/coast);
- User requirements to extend algorithm output to Rain Rate (RR) plus uncertainty were formulated.

Single Channel Approach to extend PC product to RR

- The algorithm identifies AMSU-B FOVs with T_b depressions, and translate these depressions in rain rate
 - $\delta T_b = \langle T_{b,150} \rangle - T_{b,150}$ (where $\langle T_{b,150} \rangle$ is clear sky T_b)
- Precipitation generally creates T_b depressions ranging from 15 K to approximately 150 K;
- Calibration curves that relate T_b depressions to rain-rate values are derived from a training set of co-located AMSU and NEXRAD data

Critical Points

- Coastal Areas (different solutions already tested)
- No retrieval over Ocean (not an issue for H-SAF)
- Poor retrieval over snow covered FOVs (possibility of using snow product derived within H-SAF)
- Rugged terrain not suited for radar meteorology (not an issue if also rain-gauges are used in the training set instead of radar data only)
- High values of RR (>20 mm/hr) not observable because of saturation

Single Channel Approach: Algorithm Strengths

- Reliable (preliminary tests proved that the 1channel approach has very similar performances as NESDIS operational physically-based algorithm)
- Relatively easy integration with NWC-SAF approach (PC product)

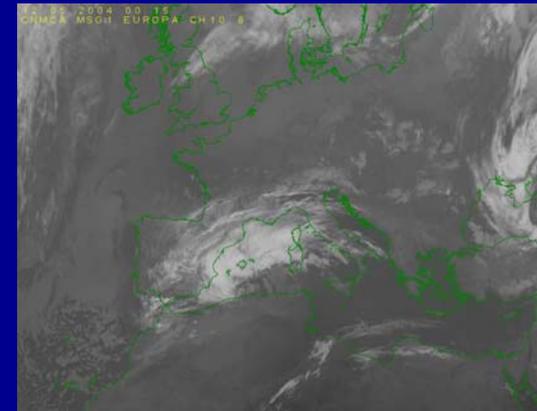
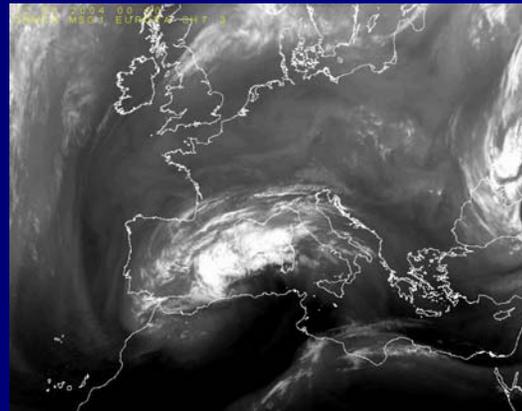
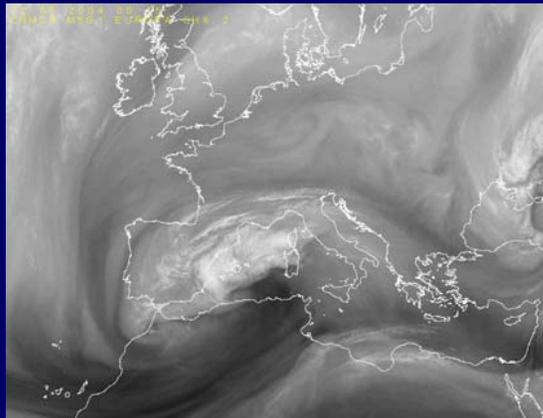
PART II

AMSU RR Down-scaling with SEVIRI products

METHOD TO AUTOMATICALLY DETECT CONVECTIVE CLOUD SYSTEMS AND MONITOR THEIR LIFE CYCLE USING MSG DATA

At the Italian Meteorological Service of the Air Force an automatic model, called NEFODINA, has been developed to check the main convective nucleus.

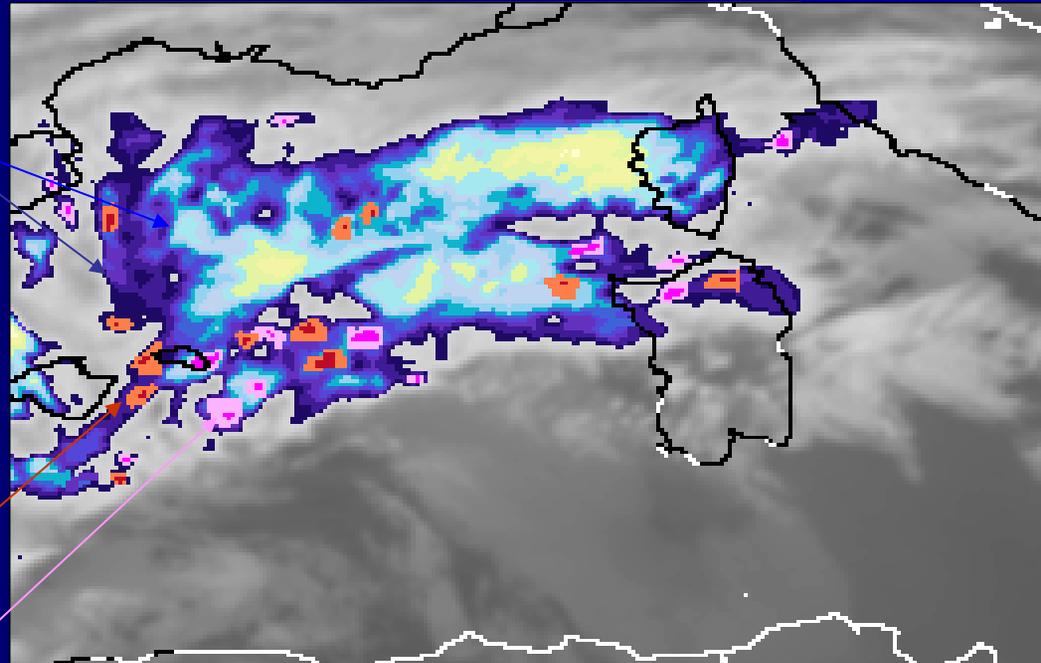
MODEL INPUT: the last infrared images of the window channel $10.8 \mu\text{m}$ and absorption channels $6.2 \mu\text{m}$ and $7.3 \mu\text{m}$.



MODEL OUTPUT: the last $10.8 \mu\text{m}$ IR image over the Mediterranean area where the convective objects and their forecasts are represented.

MODEL OUTPUT: the last infrared image (ch10.8) over the Italian area where the convective cells and their forecasted evolution are represented.

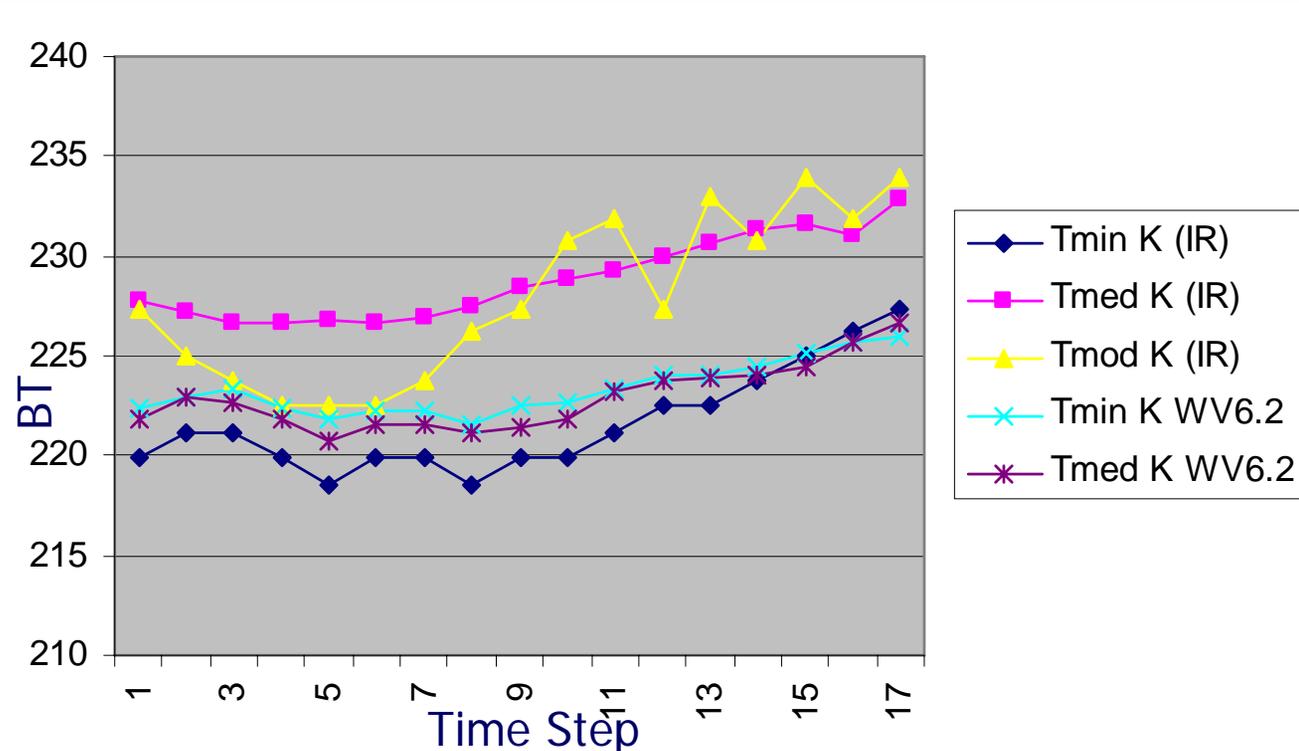
■ Blue shades are used to show the cloud which we are interested in. Dark blue is used for lowest cloud and light blue/yellow for highest clouds.



- With **red shades** the cloud top of the detected convective cell forecasted in growing phase is indicated
- With **pink shades** the cloud top of the detected convective cell forecasted in decreasing phase is indicated.
- The dark **red** and dark **pink** colors are used to indicate the most intensive convective regions.

convective history is recorded from the first detection

numero identificativo de	AA	MM	GGG	ora	minuti	riga (stiamo sostituendo	colonna (stiamo sostituendo	Tmin K (IR)	Tmed K (IR)	Tmod K (IR)	Tmin K WV6.2	Tmed K WV6.2	Area (IR) (ora fissa)	slope index (IR)
27	5	2	15	12	30	243	346	219,9	227,8	227,4	222,4	221,9	2	3,6
27	5	2	15	12	15	241	346	221,2	227,2	225	223	223	2	2,4
27	5	2	15	12	0	241	352	221,2	226,7	223,8	223,3	222,7	2	3
27	5	2	15	11	45	242	353	219,9	226,6	222,5	222,4	221,8	2	3,6
27	5	2	15	11	30	244	354	219,5	226,8	222,5	221,9	220,8	2	2,9
27	5	2	15	11	15	244	355	219,5	226,8	222,5	221,9	220,8	2	2,9
27	5	2	15	11	0	247	353	219,5	226,8	222,5	221,9	220,8	2	2,9
27	5	2	15	10	45	248	354	219,5	226,8	222,5	221,9	220,8	2	2,9
27	5	2	15	10	30	248	354	219,5	226,8	222,5	221,9	220,8	2	2,9
27	5	2	15	10	15	248	354	219,5	226,8	222,5	221,9	220,8	2	2,9
27	5	2	15	10	0	247	354	219,5	226,8	222,5	221,9	220,8	2	2,9
27	5	2	15	9	45	246	355	219,5	226,8	222,5	221,9	220,8	2	2,9
27	5	2	15	9	30	245	355	219,5	226,8	222,5	221,9	220,8	2	2,9
27	5	2	15	9	15	246	357	219,5	226,8	222,5	221,9	220,8	2	2,9
27	5	2	15	9	0	247	358	219,5	226,8	222,5	221,9	220,8	2	2,9
27	5	2	15	8	45	248	360	219,5	226,8	222,5	221,9	220,8	2	2,9
27	5	2	15	8	30	251	362	219,5	226,8	222,5	221,9	220,8	2	2,9
-999	#####	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999
28	5	2	15	12	30	240	149	219,5	226,8	222,5	221,9	220,8	2	2,9
-999	#####	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999
30	5	2	15	12	30	277	139	219,5	226,8	222,5	221,9	220,8	2	2,9
-999	#####	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999	-999
32	5	2	15	12	30	265	512	219,5	226,8	222,5	221,9	220,8	2	2,9
32	5	2	15	12	15	266	508	219,5	226,8	222,5	221,9	220,8	2	2,9
32	5	2	15	12	0	266	502	219,5	226,8	222,5	221,9	220,8	2	2,9



Convection: Main phases

- CONVECTIVE NUCLEUS DETECTION
IR 10.8 μm , WV 6.2 μm , WV 7.3 μm

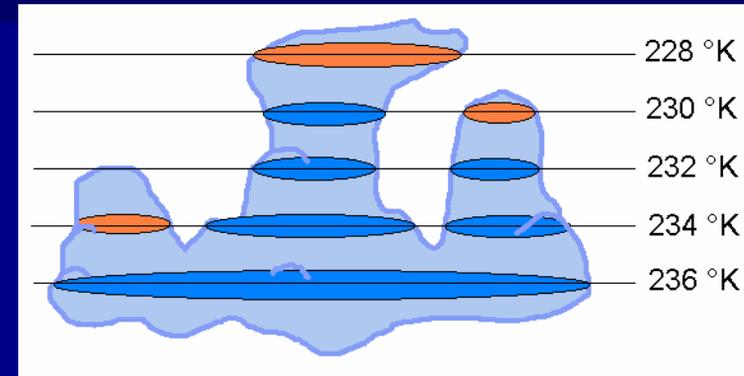
- FIRST DETECTION
- ALREADY DETECTED

- PARENTAL RELATIONSHIP
between two slots

- CHARACTERISATION OF THE Convective Objects' (CO)
LIFE PHASE;

- LIFE PHASE FORECAST BY NEURAL NETWORK
DEVELOPING or DISSOLVING

- DISSOLVING TIME FORECAST BY NEURAL NETWORK



The cloud objects are identified using a varying threshold method on IR BT with a step of 1 K.

Convective Objects (CO)

- **PARENTAL RELATIONSHIP:** The Cross Correlation (CC) between the cloud cells detected at time t and the CCs detected at time $(t-1)$, is so evaluated minimizing the distance function based on the position of the centre of gravity, minimum temperature and modal temperature.

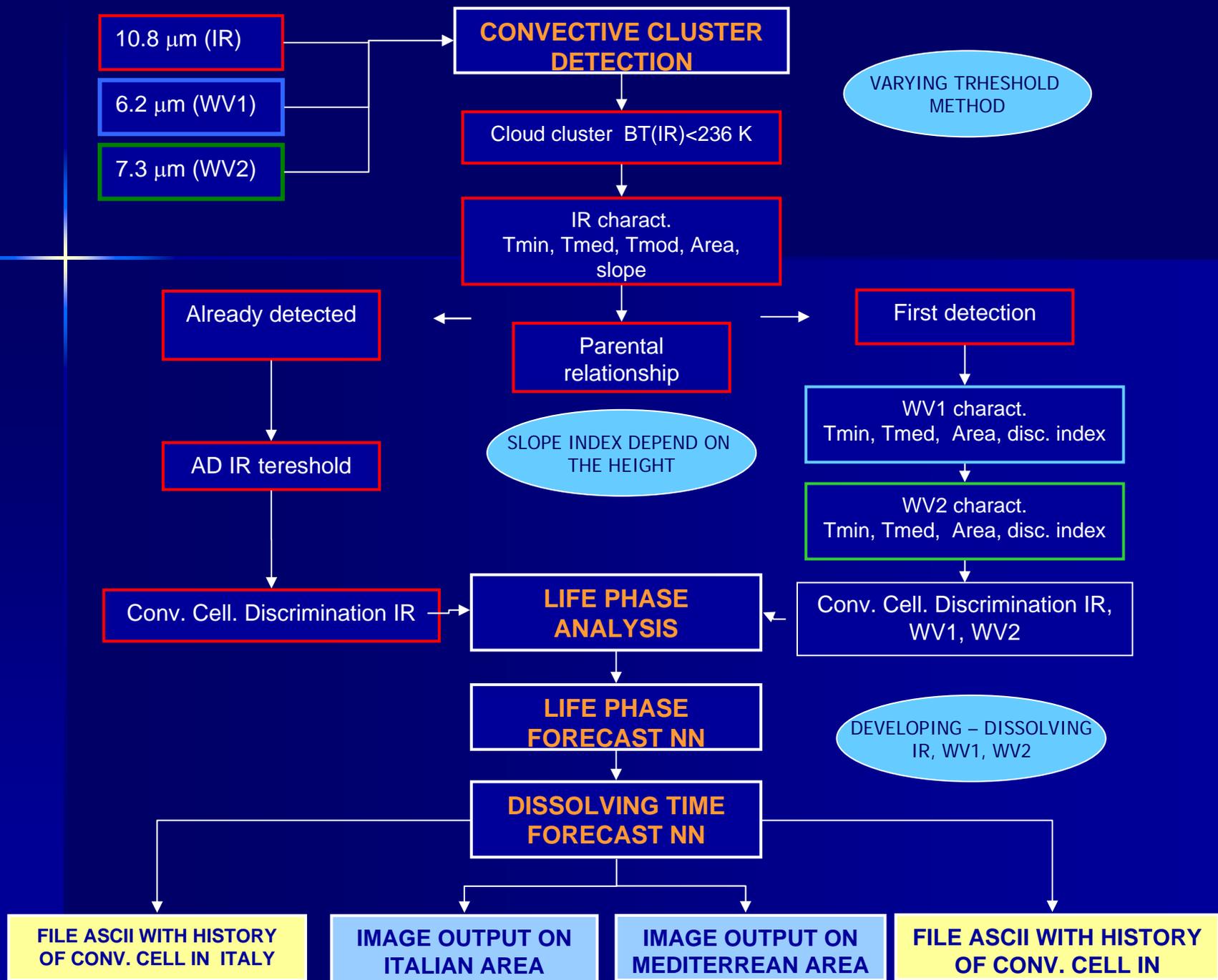
$$\sqrt{d_1^2 + d_2^2 + d_3^2 + d_4^2 + d_5^2}$$

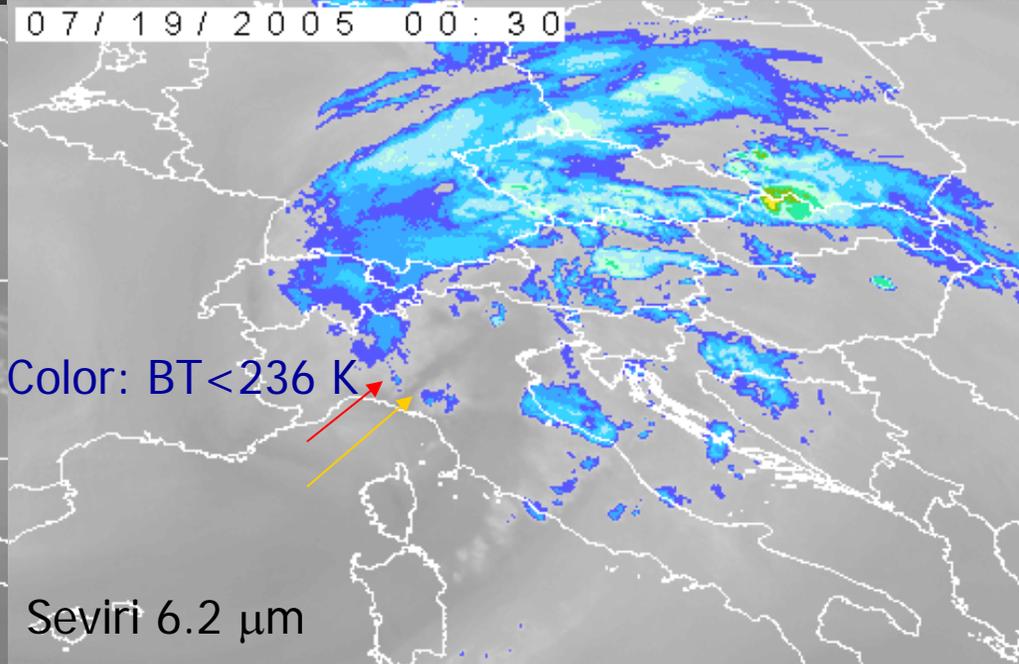
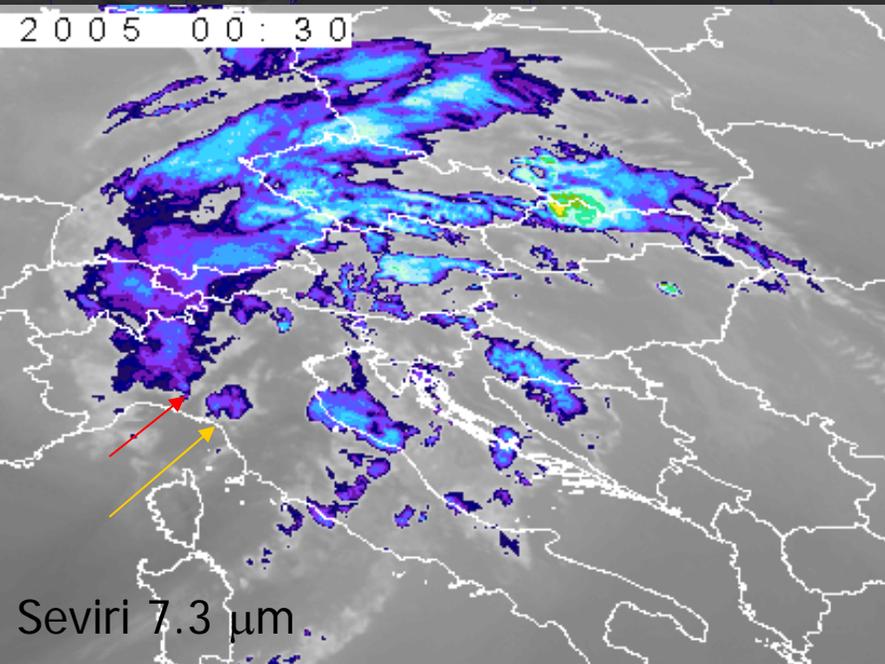
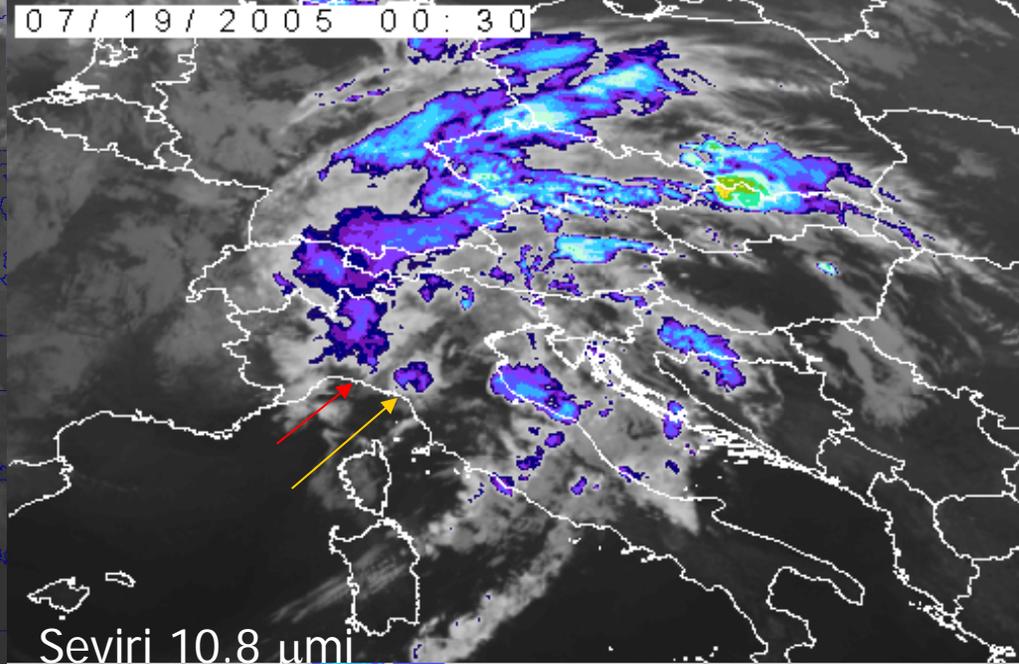
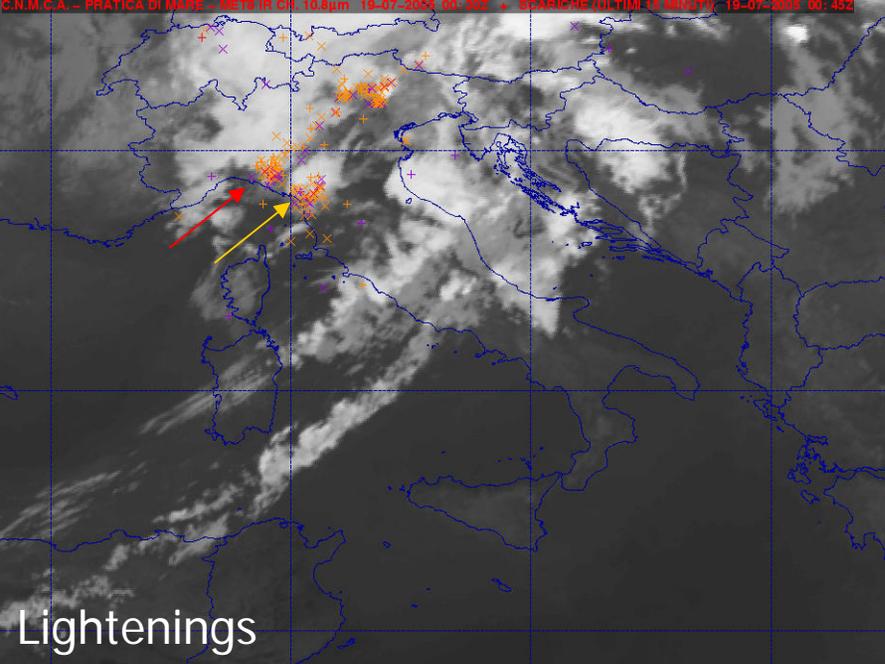
- It is so possible to classify the COs as *first detection* or *already detected* and then apply a threshold method to the static parameters of the cloud cell with a different tuning
- **FIRST DETECTION or ALREADY DETECTED:**
 - The investigation and the thresholds for the convective discrimination are different;
 - If it is a convective object already detected the probability to be still convective is high, we have only to investigate the IR area and slope:

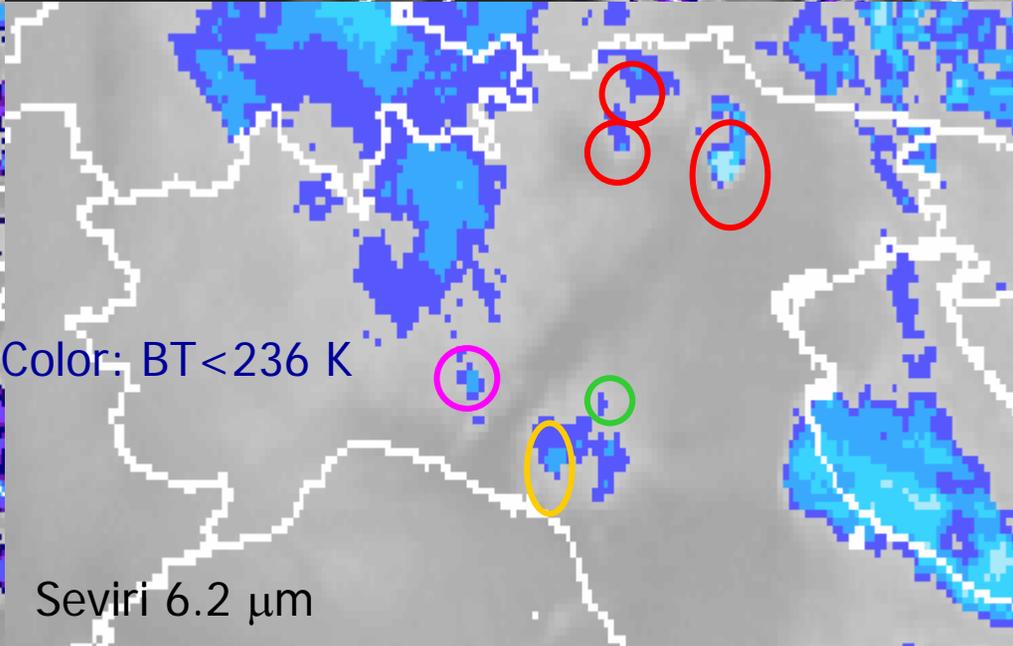
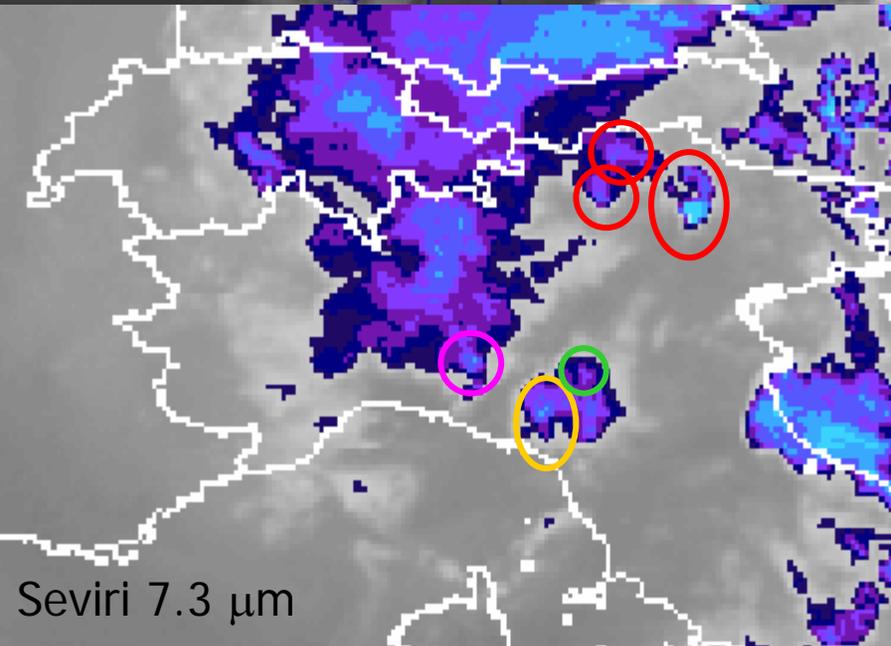
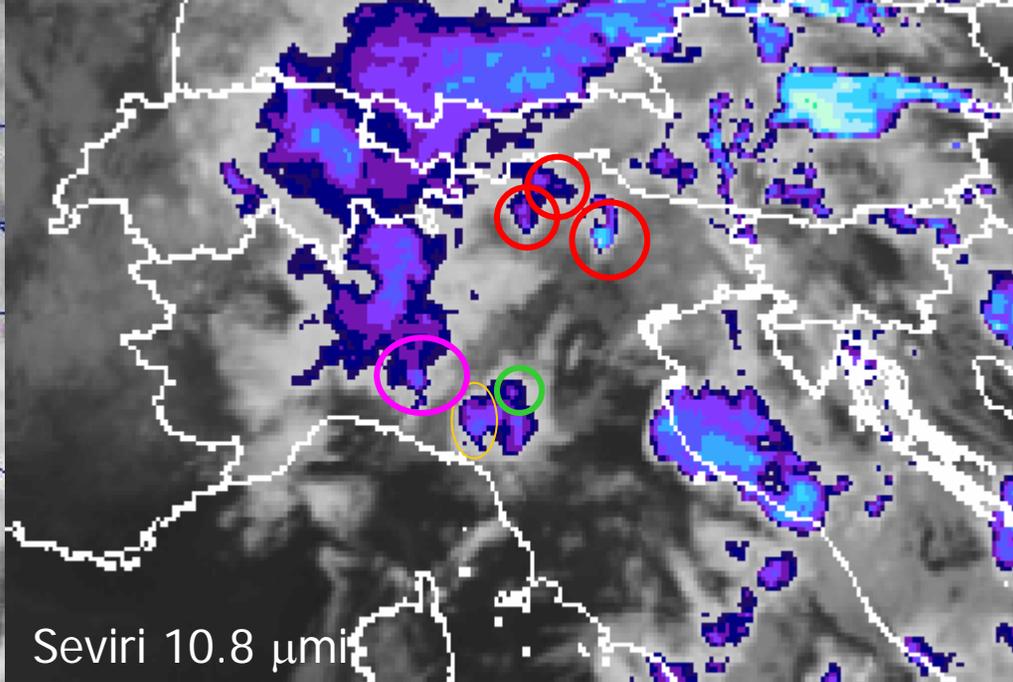
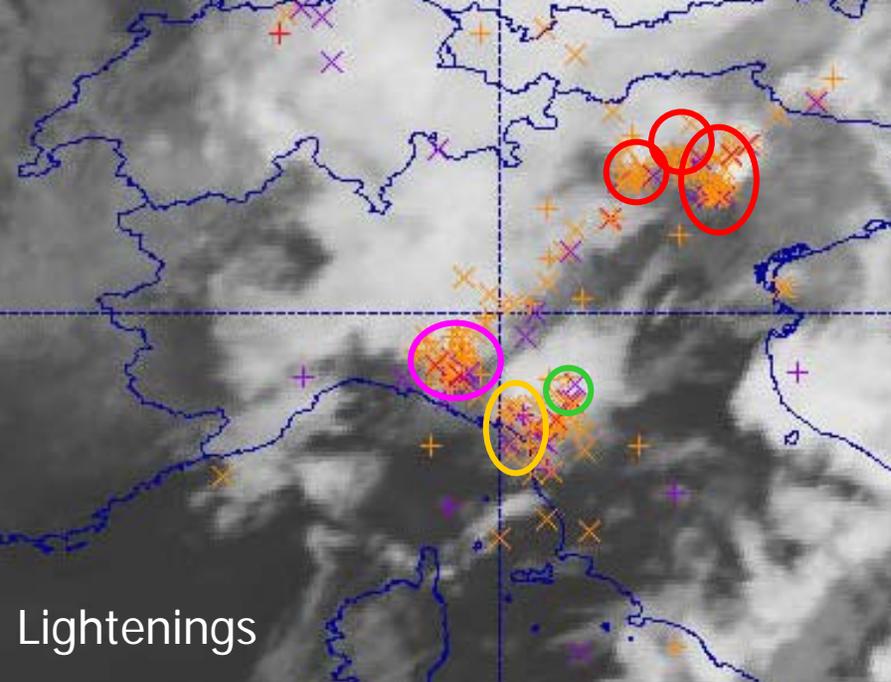
IR thresholds



- If it is the first detection the IR information are not enough.
There is then an analysis of the WV1 BT and the WV2 BT spatial distribution. The idea is that if the cloudy object is convective a defined structure has to be present also in the WV1 WV2 channels:



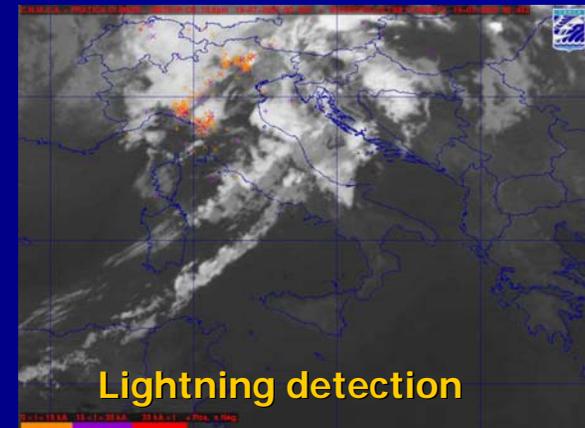




Validation phase: lightning detection an automatic tool

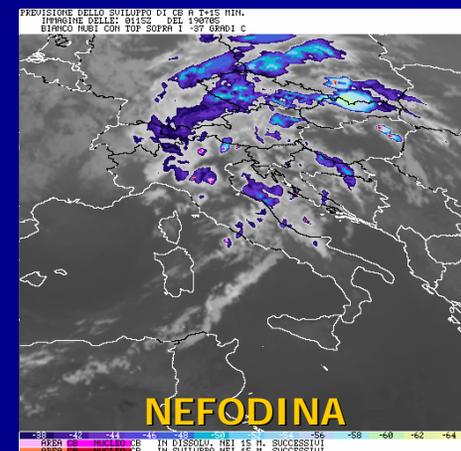
lightning → nefodina

Regions where the lightning network measures an electric activity and the top temperature of the cloud is below the temperature threshold (236 K), nefodina has to single out convective area. (previous and next 15 minutes).



nefodina → lightning

Regions where nefodina detects convective area and during the development of the cloudy cluster an electric activity is measured.



→ **POD=0.84 FAR=0.17**

Definition of developing and dissolving phase with IR and WV data

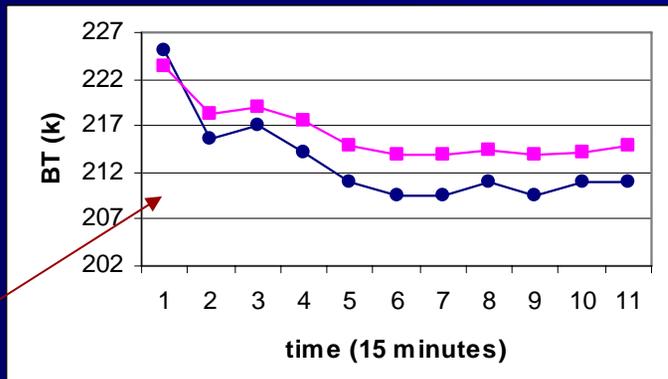
A convective cell is considered in a **developing phase** if its top is growing or if the IR temperature has not a substantial change and the water vapor is increasing :

$$[\Delta T^{IR} / dt < 0] \quad \text{or} \quad [(\Delta T^{IR} / dt < \alpha, \alpha \text{ small}) \text{ and } \Delta T^{WV} / dt < 0].$$

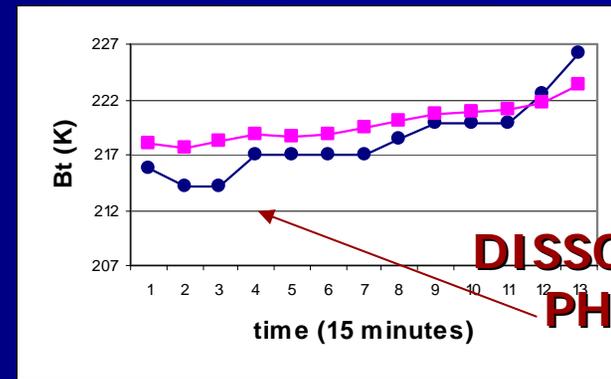
where $T^{IR} = (T^{IR}(t) - T^{IR}(t-1))/2$ and $T^{WV} = (T^{WV}(t) - T^{WV}(t-1))/2$

In all the others cases the convective cell is **dissolving**.

GROWING PHASE



DISSOLVING PHASE



Forecast with neural network of the phase of the convective cell at time $t+15$ min with MSG data

- two layers back propagation network with 6 neurons in the input layers, 60 neurons in the hidden layer and a neuron in the output layer.
- The input vector is:

$$\mathbf{X}^t = (T^{IR}(t), T^{IR}(t-1), T^{WV1}(t), T^{WV1}(t-1), T^{WV2}(t), T^{WV2}(t-1))$$

where with IR, WV1 and WV2 are indicated the $10.8\mu\text{m}$, the $6.2\mu\text{m}$ and the $7.3\mu\text{m}$ channel respectively. The same transfer function has been used obtaining the following results:

Ep= 10.6%	VAR=7%	CORR=0.8
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Forecast with neural network of the phase of the convective cell at time $t+30$ min with MSG data

Ep= 13%	VAR=8%	CORR=0.78
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Forecast by neural network of dissolving time of the convective cell

'Dissolving time' : how long the convective activity will last?

15 min, 30 min, ..1 hour?

- data set of 12000 data (January '05– September '05) learning set = 8000 data
testing set = 4000 data
- a three layers back propagation network with 12 neurons in the input layers, 12 neurons in the first hidden layer, 12 neurons in the second hidden layers and a neuron in the output layer.
- The input vector is:

$$\mathbf{X}^t = (T^{IR}(t), T^{IR}(t-1), sl, ph, age, DT^{IR}(t), T^{WV1}(t), T^{WV1}(t-1), D T^{WV1}(t), T^{WV2}(t), T^{WV2}(t-1), D T^{WV2}(t))$$



MAD= 17 min

MD= 1 min

METHOD TO AUTOMATICALLY DETECT CONVECTIVE CLOUD SYSTEMS AND MONITOR THEIR LIFE CYCLE USING MSG DATA

- A multi channel approach based on IR window channel (10.8 μm) and the two WV absorption channels (6.2 μm and 7.3 μm) are used during the detection phase to discriminate the convective objects and to represent their life phase.
- the IR window channel 10.8 μm and the two WV channels (6.2 μm and 7.3 μm) are also used to forecast the evolution of the convective cell life for next 15 minutes and 30 minutes with an efficiency of 89% and of 87% respectively.
- A three layers back propagation neural network, using the IR and WV parameters, is used to forecast the dissolving time of the CO with MAD of 17 minutes and MD equal of 1 minute.
- NEFODINA runs in 1 minute in operational mode at the Italian Meteorological Service of the Air Force. This is an important support for forecasters of the IAFMS who test every day the performance and the reliability of this product.

AMSU RR DOWN-SCALING

- AMSU derived RR will be down-scaled simply assuming that all the precipitation within the AMSU FOV occurs in the convective cell identified by NEFODINA
- Among the others Problems related to the accuracy of co-location between AMSU and NEFODINA (SEVIRI) are anticipated.

PART III

- Data set and strategy for algorithm calibration and validation
- Down-scaled AMSU RR will be validated according to the SAF Validation Group guidelines using available raingauges.

Calibration Data-set AMSU-A, AMSU-B/MHS NOAA 16/18, RAINGAUGES and NEFODINA

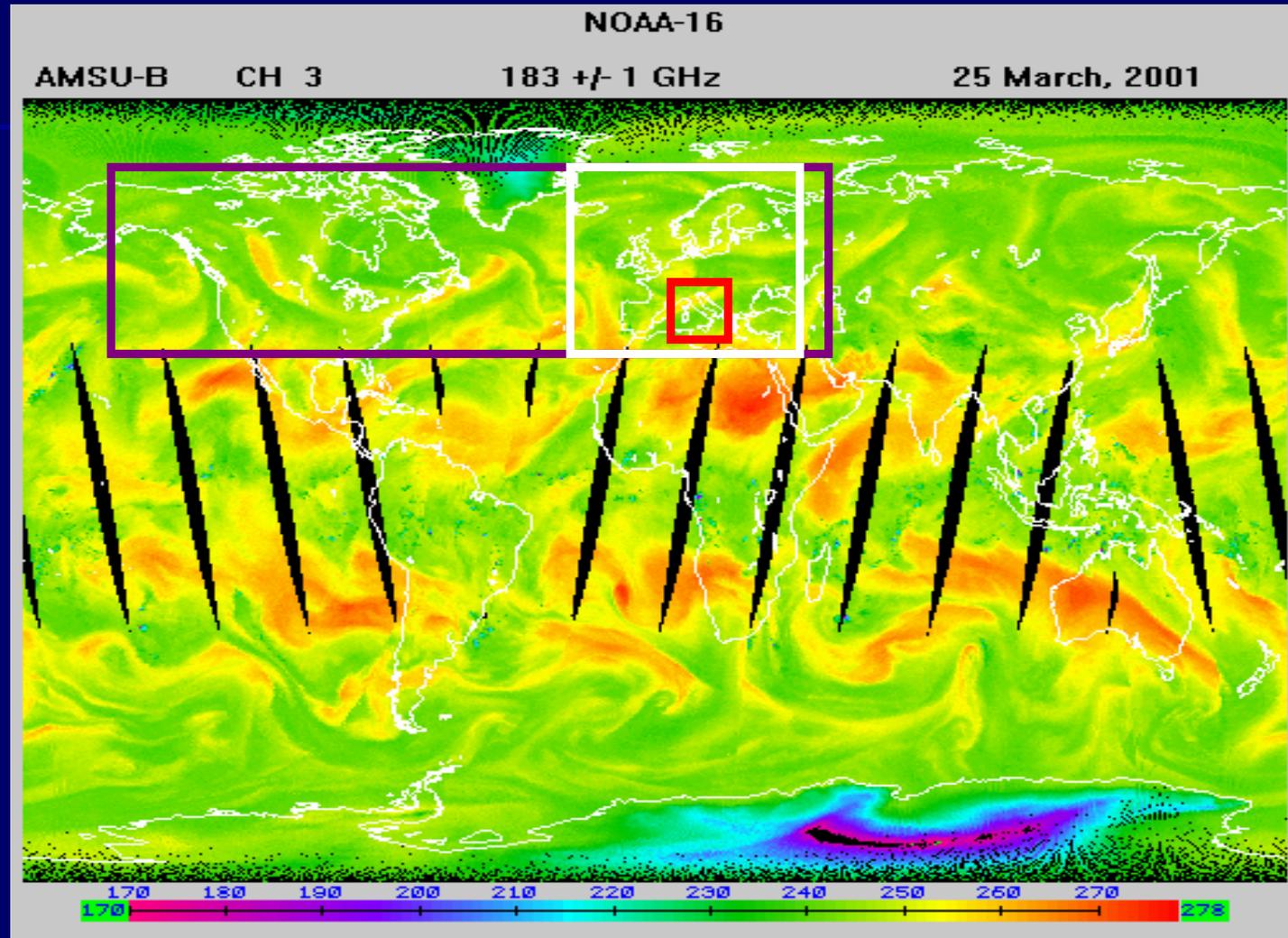
Starting:
Feb 1st 2006

Coverage:
Europe,
North Atlantic,
North America

AMSU coverage

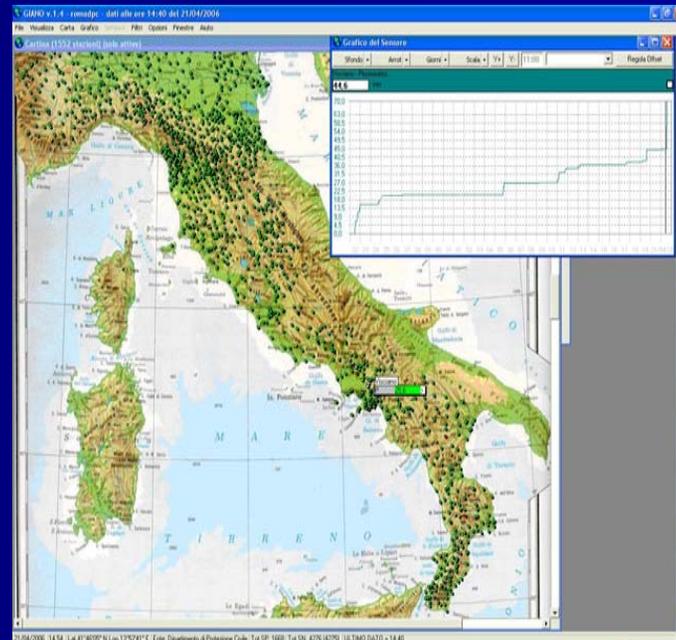
Raingauges
coverage

NEFODINA
coverage



RAIN GAUGES

- About 2000 rain gauges are currently operating in Italy
 - Cumulated rain data available every 15, 30 minute
 - Data available starting from 2004
 - Actual distribution:



Conclusions

- In order to respond to the needs of the hydrological community we planned an activity to down-scale (from 256 km² to 100 km²) currently available RR retrieval algorithms for AMSU data to higher spatial resolution RR, using SEVIRI products;
- Accuracy for convective systems;
- The activity will be carried over by a Visiting Scientist within the H-SAF program and within an international collaboration;
- The validation will be based on rain gauges because they are spatially well distributed over Europe and they represent the best estimate of the precipitation on the ground for hydrologists;
- Results are expected before May 2007.