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

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[3]Centro Nazionale di Meteorologia e Climatologia dell'Aeronautica militare

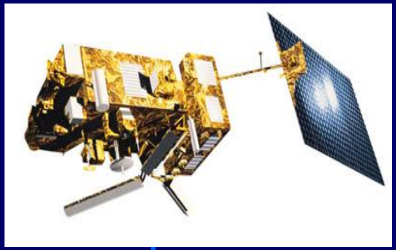
Topic

- 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)

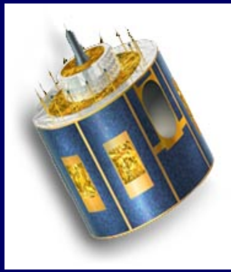
This task will be performed under a Visiting Scientist (VS) project sponsored by EUMETSAT within the Hydrological-SAF program.

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

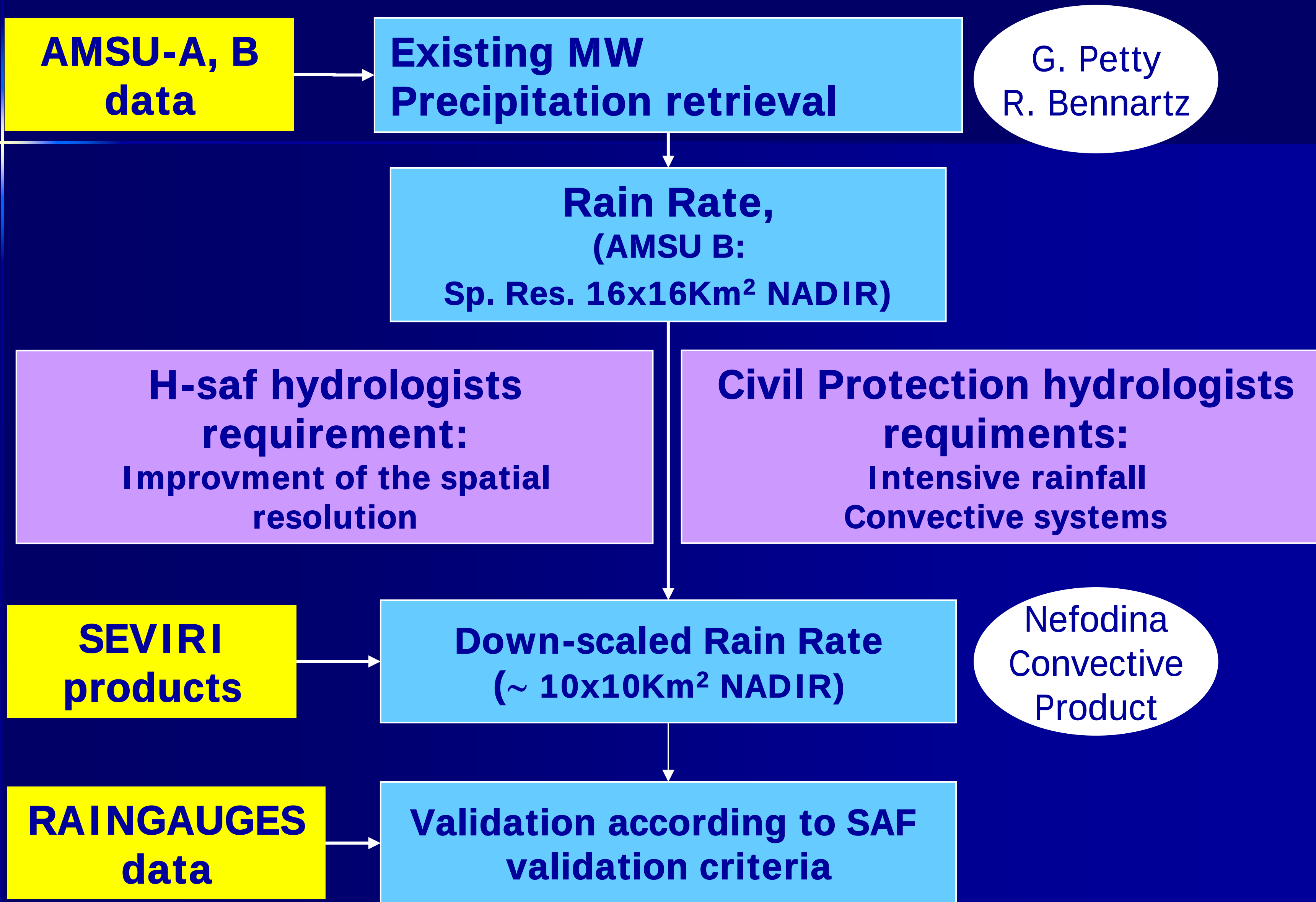
Visiting Scientist: Paolo Antonelli

- *Space Science Engineering Center – UW-Madison*

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

- MW, IR, and real-time processing

Strategy


AMSU-A, B data
Existing MW Precipitation retrieval
G. Petty
R. Bennartz
Rain Rate,
(AMSU B:
Sp. Res. 16x16Km^2 NADIR)
H-saf hydrologists requirement:
Improvment of the spatial resolution
Civil Protection hydrologists requiments:
Intensive rainfall
Convective systems
SEVIRI products
Down-scaled Rain Rate
(~ 10x10Km^2 NADIR)
Nefodina Convective Product
RAINGAUGES data
Validation according to SAF validation criteria

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)*

Courtesy of R. Bennartz

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

Courtesy of R. Bennartz

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.

Courtesy of R. Bennartz

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

Courtesy of G. Petty

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)

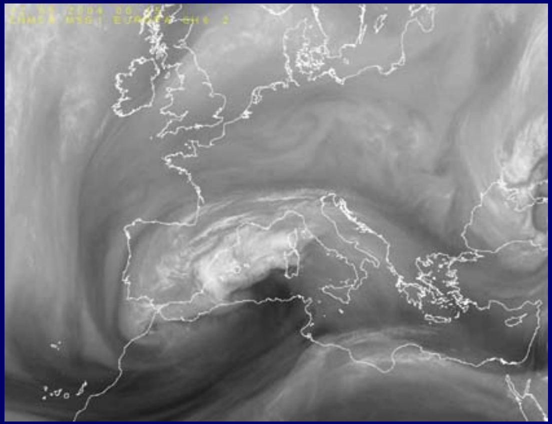
PART II

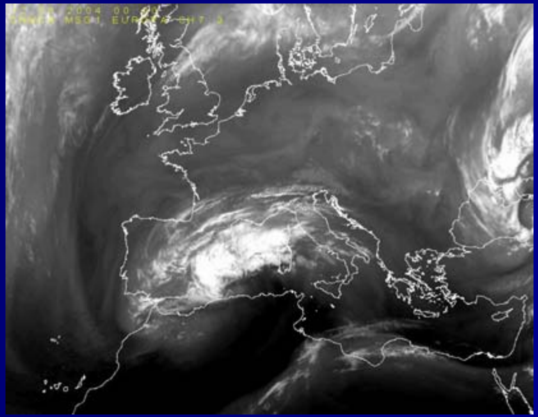
AMSU RR Down-scaling with SEVIRI products

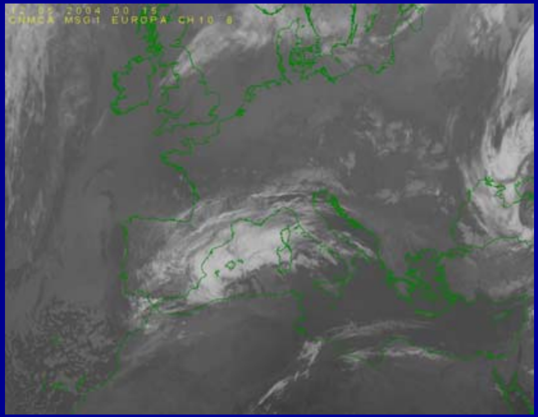
METHOD TO AUTOMATICALLY DETECT CONVECTIVE CLOUD SYSTEMS AND MONITOR THEIR LIFE CYCLE USING MSG DATA

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 μm and absorption channels 6.2 μm and 7.3 μm.



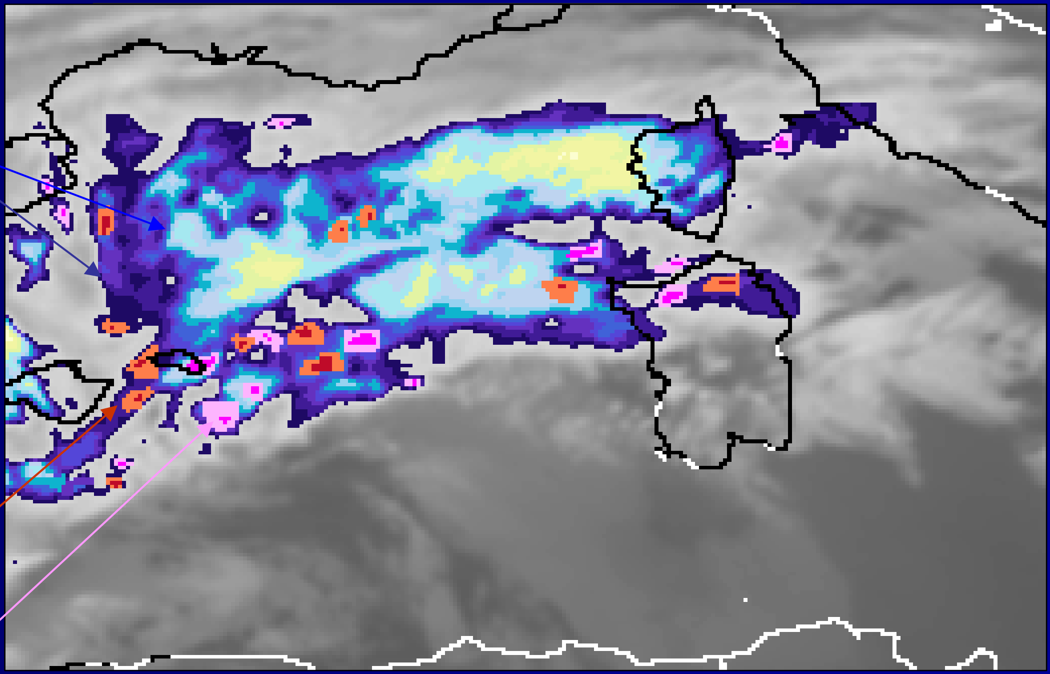




MODEL OUTPUT: the last 10.8 μm IR image over the Mediterranean area where the convective objects and their forecasts are represented.

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

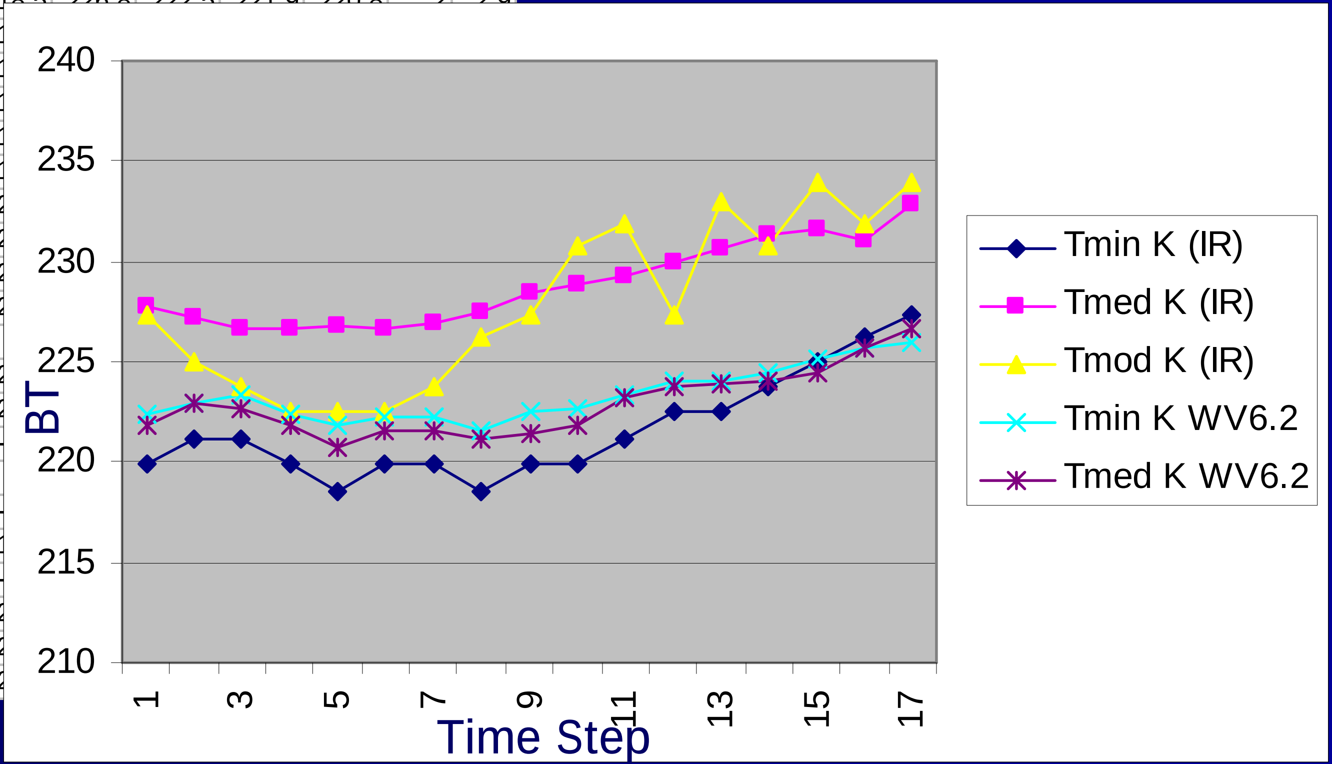
- **Blue shades are used to show the cloud which we are interested in. Dark blue is used for lowest cloud and light blue/yellow for highest clouds.**



- **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 sostitue	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	218,5	226,8	222,5	221,9	220,8	2	2,9
27	5 2 15	11	15	244	355	21						
27	5 2 15	11	0	247	353	21						
27	5 2 15	10	45	248	354	21						
27	5 2 15	10	30	248	354	21						
27	5 2 15	10	15	248	354	21						
27	5 2 15	10	0	247	354	22						
27	5 2 15	9	45	246	355	22						
27	5 2 15	9	30	245	355	22						
27	5 2 15	9	15	246	357	22						
27	5 2 15	9	0	247	358							
27	5 2 15	8	45	248	360	22						
27	5 2 15	8	30	251	362	22						
-999	###########	-999	-999	-999	-999	-						
28	5 2 15	12	30	240	149							
-999	###########	-999	-999	-999	-999	-						
30	5 2 15	12	30	277	139	21						
-999	###########	-999	-999	-999	-999	-						
32	5 2 15	12	30	265	512	22						
32	5 2 15	12	15	266	508	22						
32	5 2 15	12	0	266	502	22						

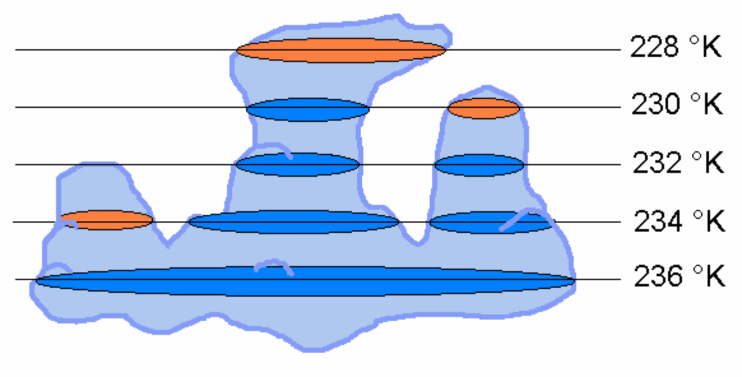


Convection: Main phases

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

  - FIRST DETECTION
  - ALREADY DETECTED

- PARENTAL RELATIONSHIP
  between two slots



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

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

- LIFE PHASE FORECAST BY NEURAL NETWORK
  DEVELOPING or DISSOLVING

- DISSOLVING TIME FORECAST BY NEURAL NETWORK

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.

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

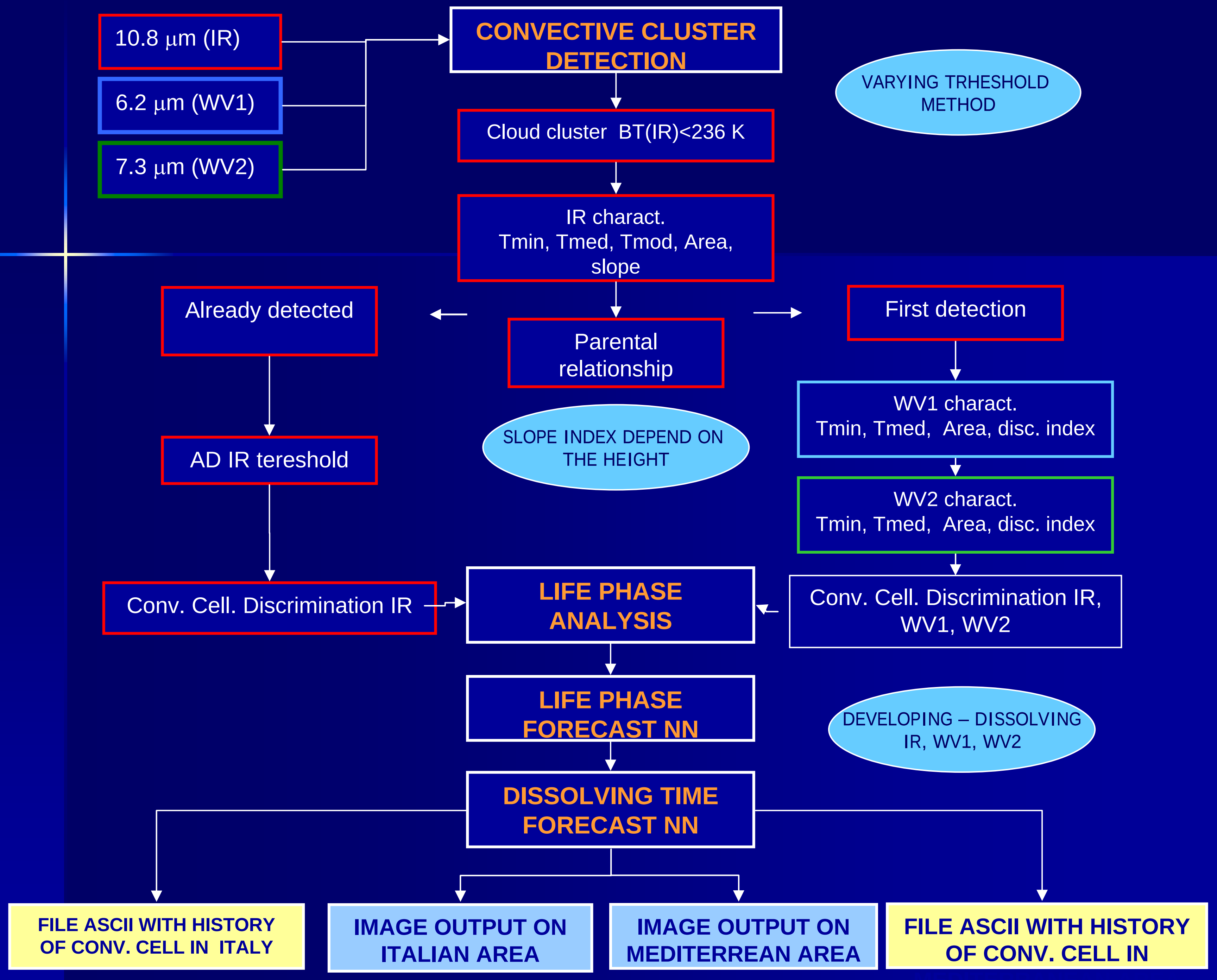
- It is so possible to classify the COs as *first detection* or *already detected* and then apply a threshold method to the static parameters of the cloud cell with a different tuning

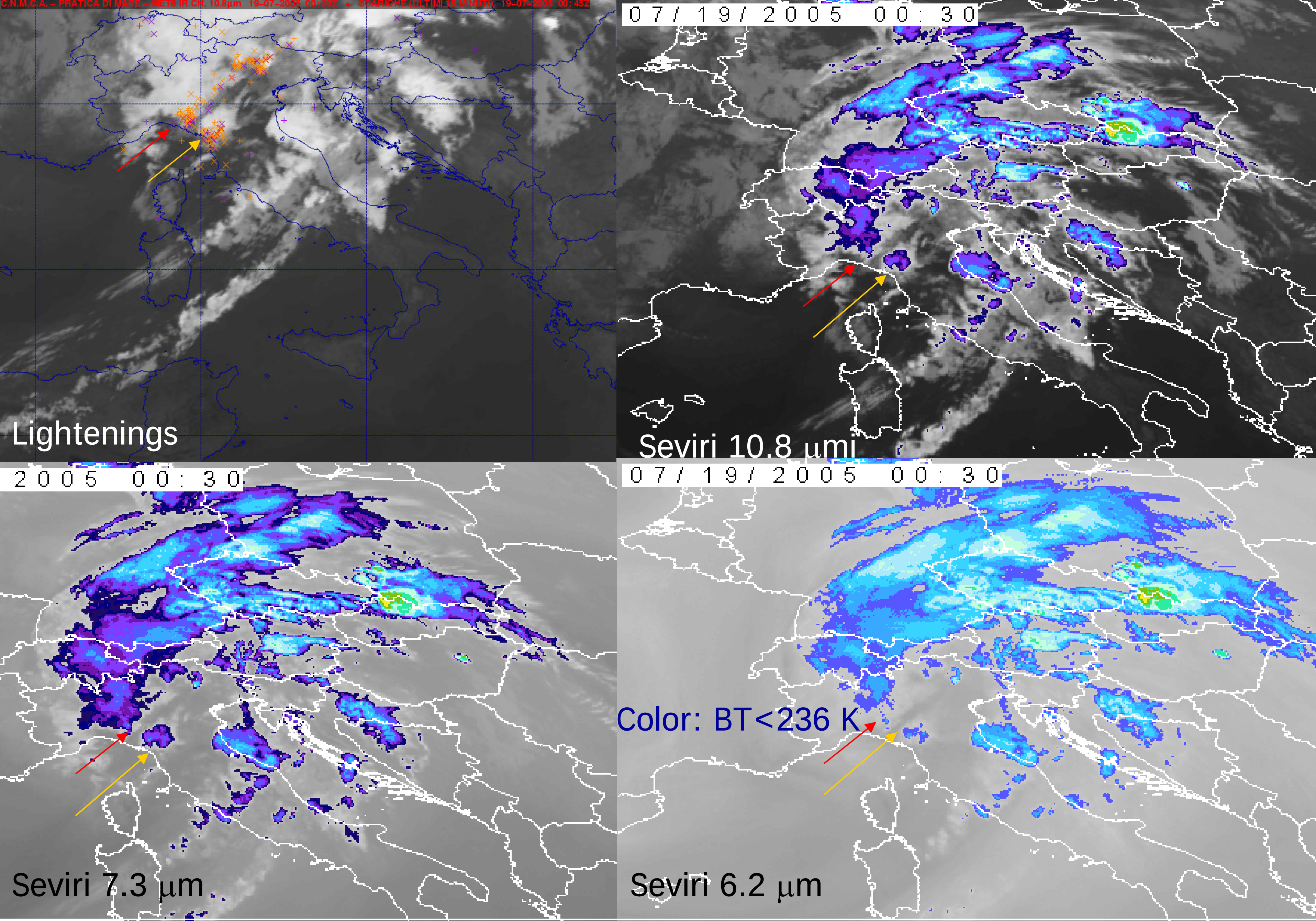
- FIRST DETECTION or ALREADY DETECTED:
  - The investigation and the thresholds for the convective discrimination are different;
  - If it is a convective object already detected the probability to be still convective is high, we have only to investigate the IR area and slope:

    → IR thresholds

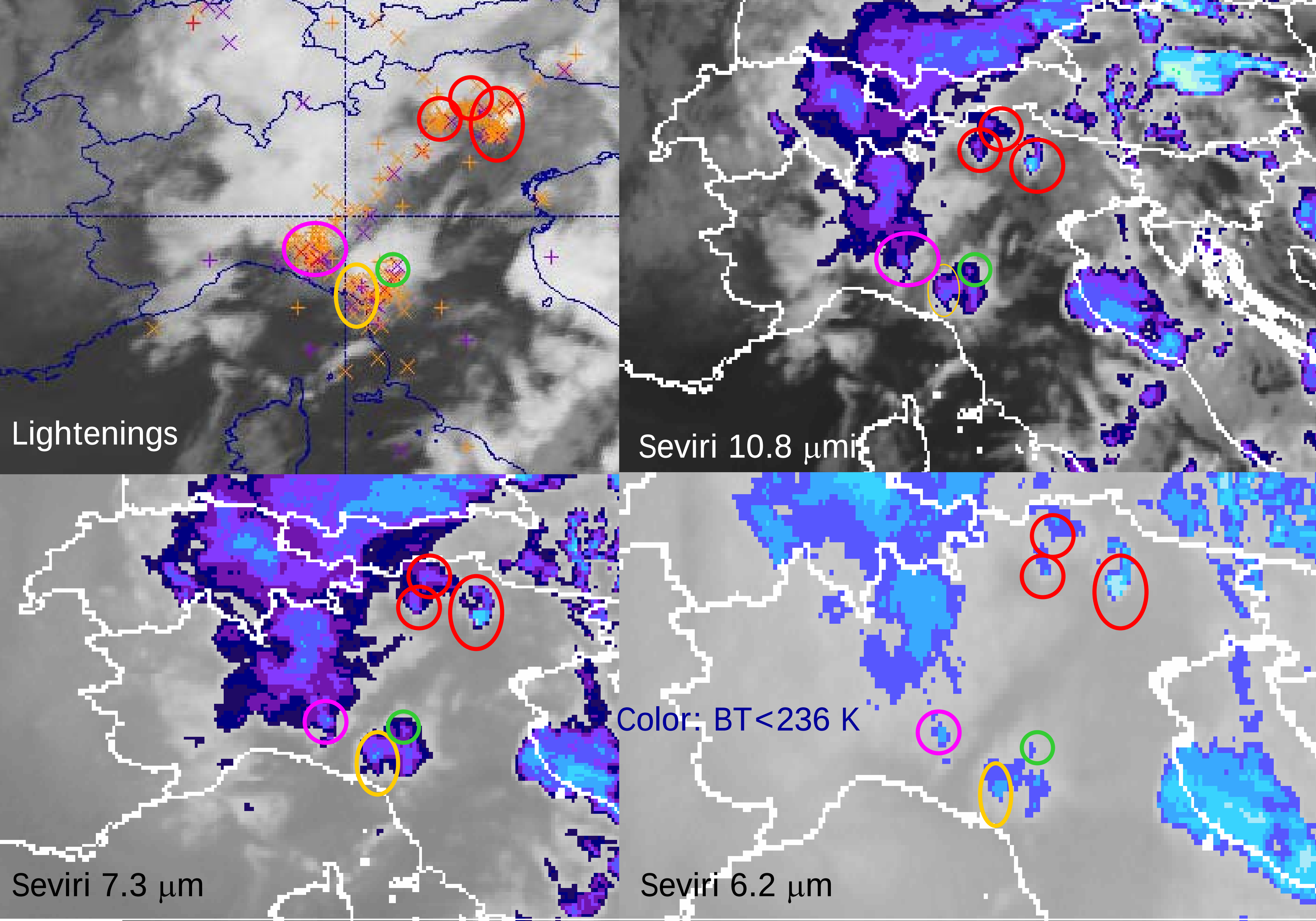
  - If it is the first detection the IR information are not enough.

    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:


10.8 µm (IR)
6.2 µm (WV1)
7.3 µm (WV2)
CONVECTIVE CLUSTER DETECTION
VARYING TRHESHOLD METHOD
Cloud cluster BT(IR)<236 K
IR charact. Tmin, Tmed, Tmod, Area, slope
Already detected
Parental relationship
First detection
WV1 charact. Tmin, Tmed, Area, disc. index
AD IR tereshold
SLOPE INDEX DEPEND ON THE HEIGHT
WV2 charact. Tmin, Tmed, Area, disc. index
Conv. Cell. Discrimination IR
LIFE PHASE ANALYSIS
Conv. Cell. Discrimination IR, WV1, WV2
LIFE PHASE FORECAST NN
DEVELOPING – DISSOLVING IR, WV1, WV2
DISSOLVING TIME FORECAST NN
FILE ASCII WITH HISTORY OF CONV. CELL IN ITALY
IMAGE OUTPUT ON ITALIAN AREA
IMAGE OUTPUT ON MEDITERREAN AREA
FILE ASCII WITH HISTORY OF CONV. CELL IN



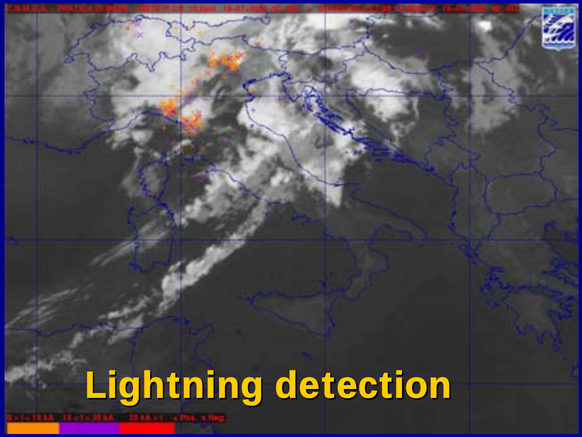
Lightenings
07/ 19/ 2005 00: 30
Seviri 10.8 µm
2005 00: 30
Seviri 7.3 µm
07/ 19/ 2005 00: 30
Color: BT<236 K
Seviri 6.2 µm


Lightenings
Seviri 10.8 µm
Seviri 7.3 µm
Color: BT<236 K
Seviri 6.2 µm

Validation phase: lightning detection an automatic tool

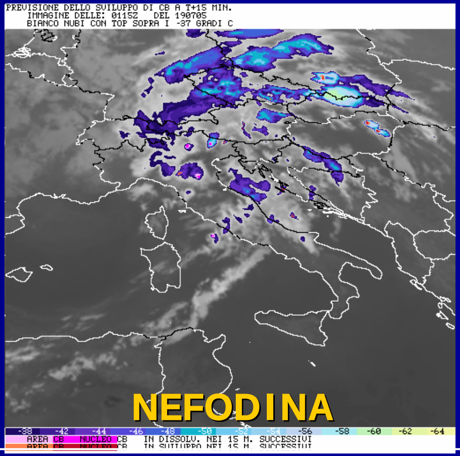
lightning → nefodina

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

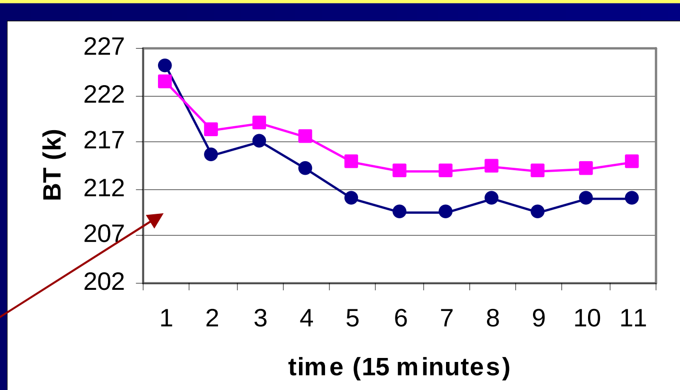
*A convective cell is considered in a **developing phase** if its top is growing or if the IR temperature has not a substantial change and the water vapor is increasing :*

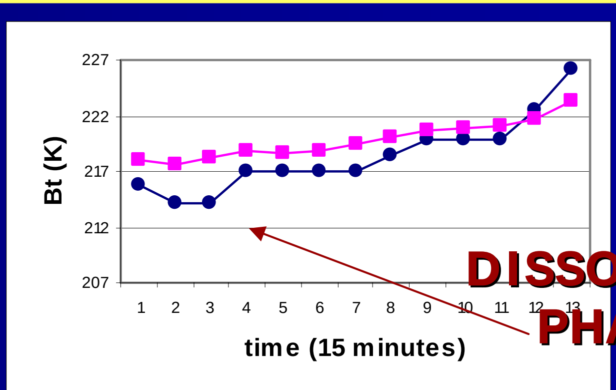
$$[\Delta \mathbf{T}^{IR} /dt < 0] \quad or \quad [(\Delta \mathbf{T}^{IR} /dt < \alpha , \alpha \text{ small}) \text{ and } \Delta \mathbf{T}^{WV} /dt < 0].$$

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

*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:

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

where with IR, WV1 and WV2 are indicated the 10.8μm, the 6.2μm and the 7.3μm channel respectively. The same transfer function has been used obtaining the following results:

Ep= 10.6%	**VAR=7%**	**CORR=0.8**

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**

Forecast by neural network of dissolving time of the convective cell

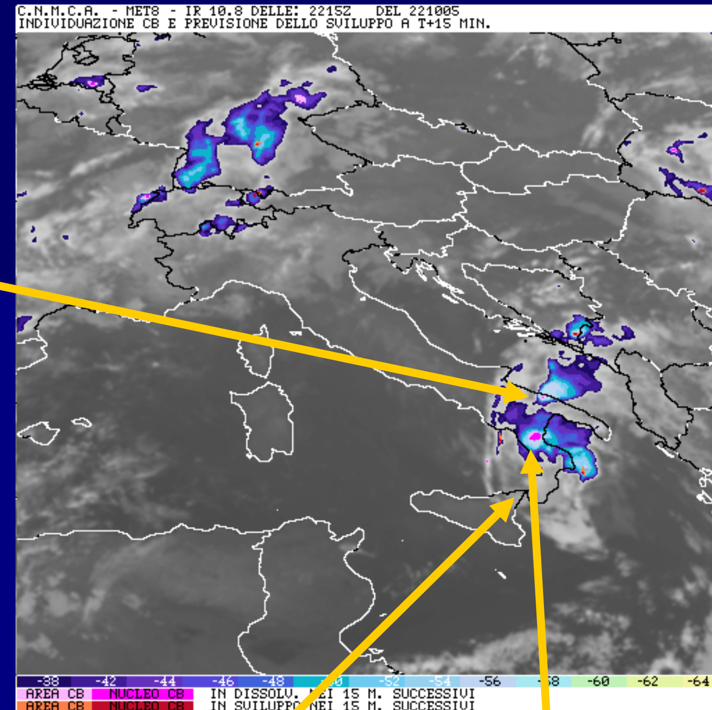
'Dissolving time' : how long the convective activity will last?
15 min, 30 min, ..1 hour?

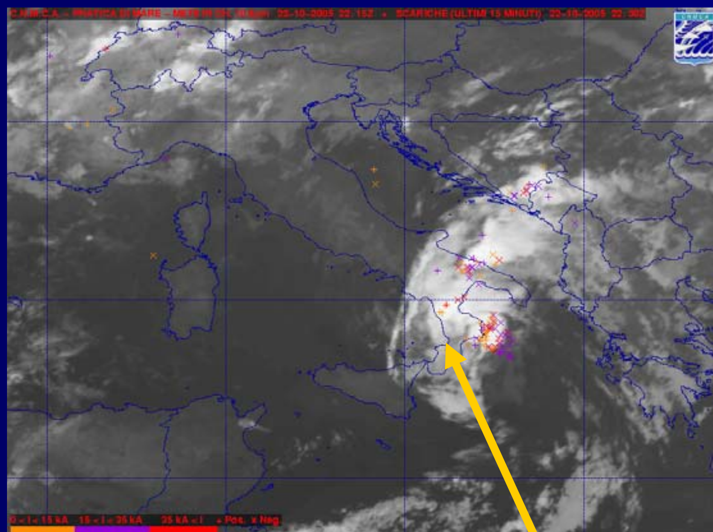
- data set of 12000 data (January '05– September '05) — learning set = 8000 data; testing set = 4000 data
- a three layers back propagation network with 12 neurons in the input layers, 12 neurons in the first hidden layer, 12 neurons in the second hidden layers and a neuron in the output layer.
- The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


C.N.M.C.A. - MET8 - IR 10.8 DELLE: 2215Z DEL 221005
INDIVIDUAZIONE CB E PREVISIONE DELLO SVILUPPO A T+15 MIN.
-38 -42 -44 -46 -48 -52 -54 -56 -60 -62 -64
AREA CB NUCLEO CB IN DISSOLV. NEI 15 M. SUCCESSIVI
AREA CB NUCLEO CB IN SVILUPPO NEI 15 M. SUCCESSIVI



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 (6.2μm and 7.3μm) 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

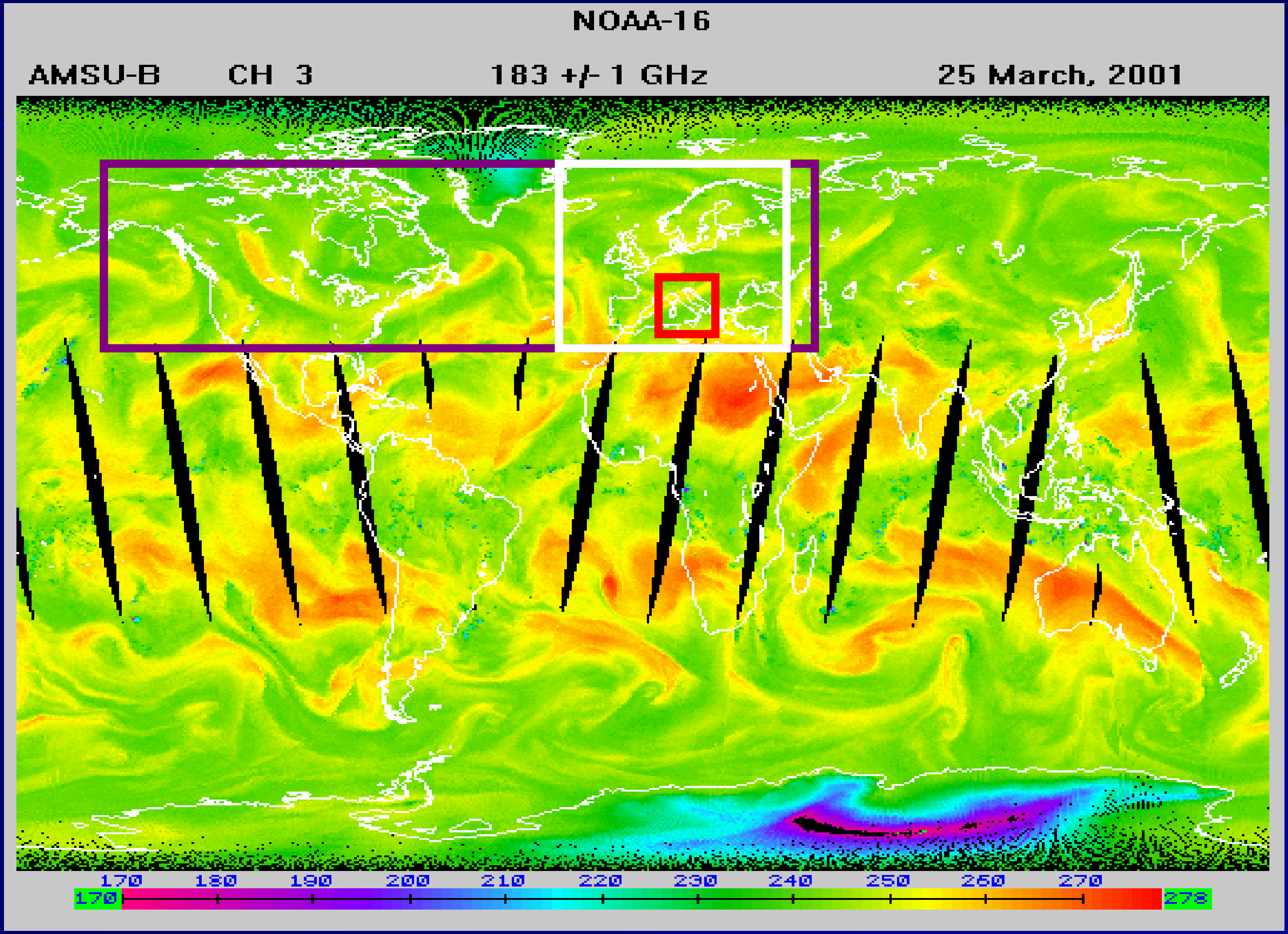
Starting:
Feb 1st 2006

Coverage:
Europe,
North Atlantic,
North America

AMSU coverage

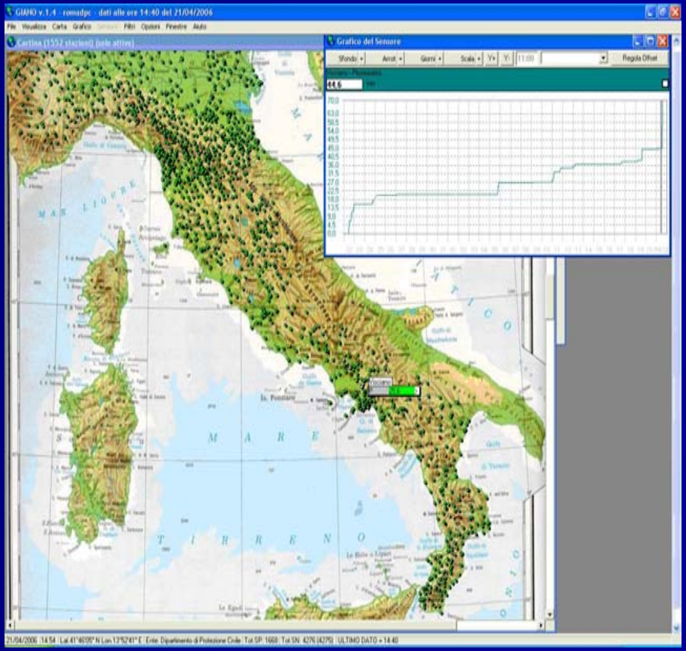
Raingauges coverage

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 km^2 to 100 km^2) currently available RR retrieval algorithms for AMSU data to higher special 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.

International TOVS Study Conference, 15th, ITSC-15, Maratea,Italy, 4-10 October 2006
Madison, WI, University of Wisconsin-Madison, Space Science and Engineering Center,
Cooperative Institute for Meteorological Satellite Studies, 2006.