Facets of UNCERTAINTY

Kos Island, Greece 17-19 october 2013

STAHY '13

Areal distribution of extreme short rainfall evaluated using meteorological information

Salvatore Gabriele
CNR-IRPI
Rende Italy
salvatore.gabriele@irpi.cnr.it

OUTLINE

1. Possible weakness of short rainfall series used in standard regional analysis (Italian case).
2. Search regional rainfall homogeneity using atmospheric fields (*)
3. Proposition of an areal distribution for maximum annual short rainfall of 1hour.
4. Vibo Valentia flood case study

(*) S.Gabriele – Chiaravalloti F.
APPLICAZIONI METEOCLIMATICHE NELLA REGIONALIZZAZIONE DELLE PRECIPITAZIONI –pp 254 - CNR IRPI 2012
gabriele@irpi.cnr.it

Point 1 :Possible weakness of short rainfall series in standard regional analysis (Italian case).

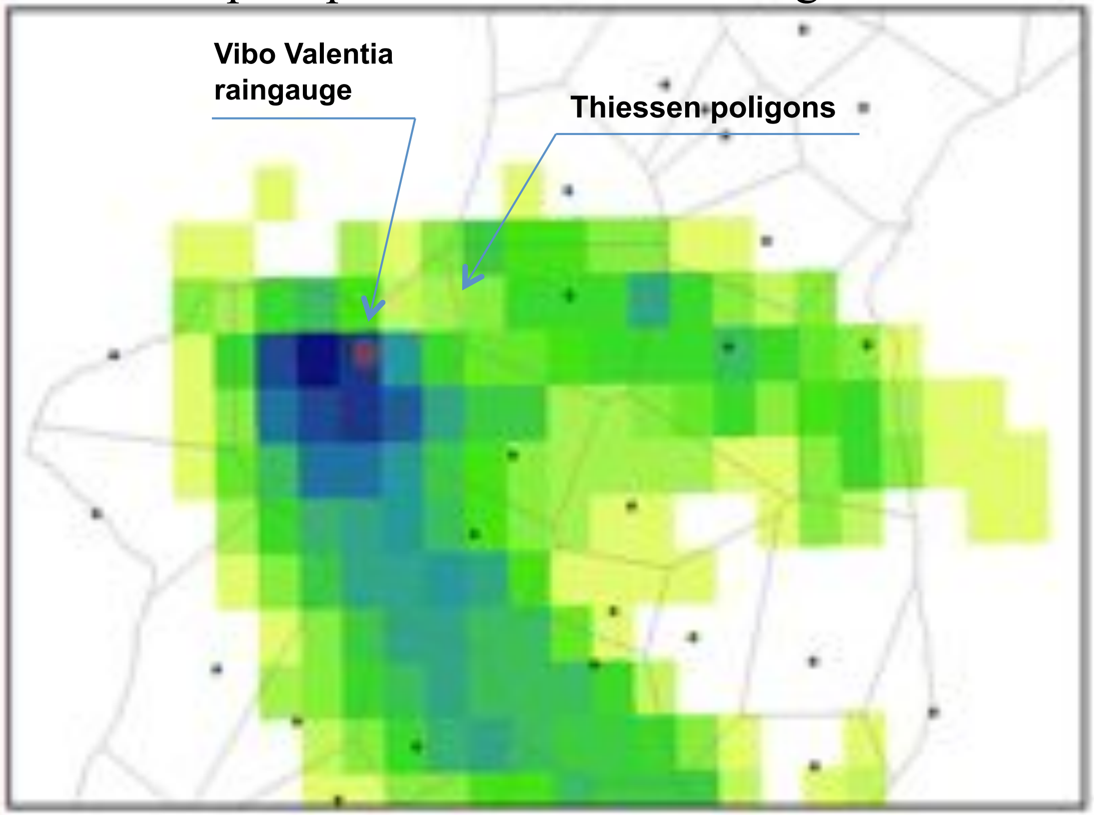
HOW ARE SIGNIFICANT THE HISTORICAL SERIES OF SHORT RAINFALLS

(Calabria region, Italy)

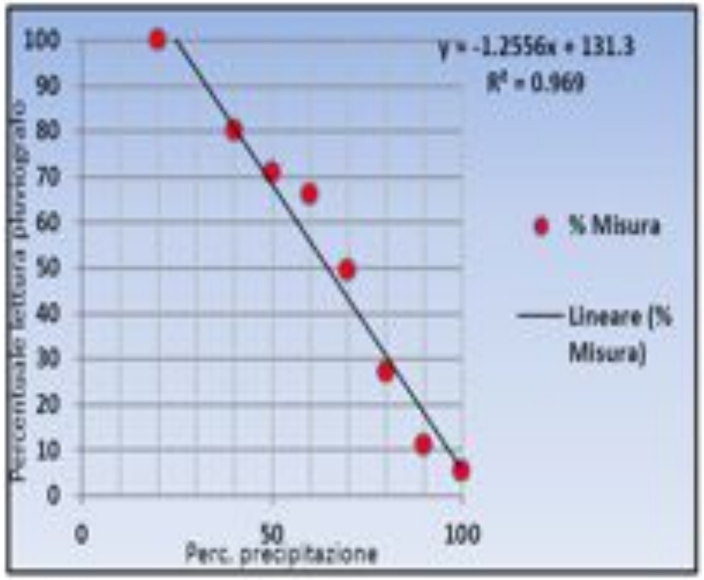
- Short heavy rainfall are mainly due to convective phenomena
- Core of convective cumulonimbus normally not exceed 15-25 kmq
- With a rain-gauge density of 1x200 kmq the probability to register the maximum intensity is about 10% which decrease with intensity

Value	Percentu.
100	5.5
90	11
80	27
70	49.5
60	66.0
50	71.0
40	0.8
20	100

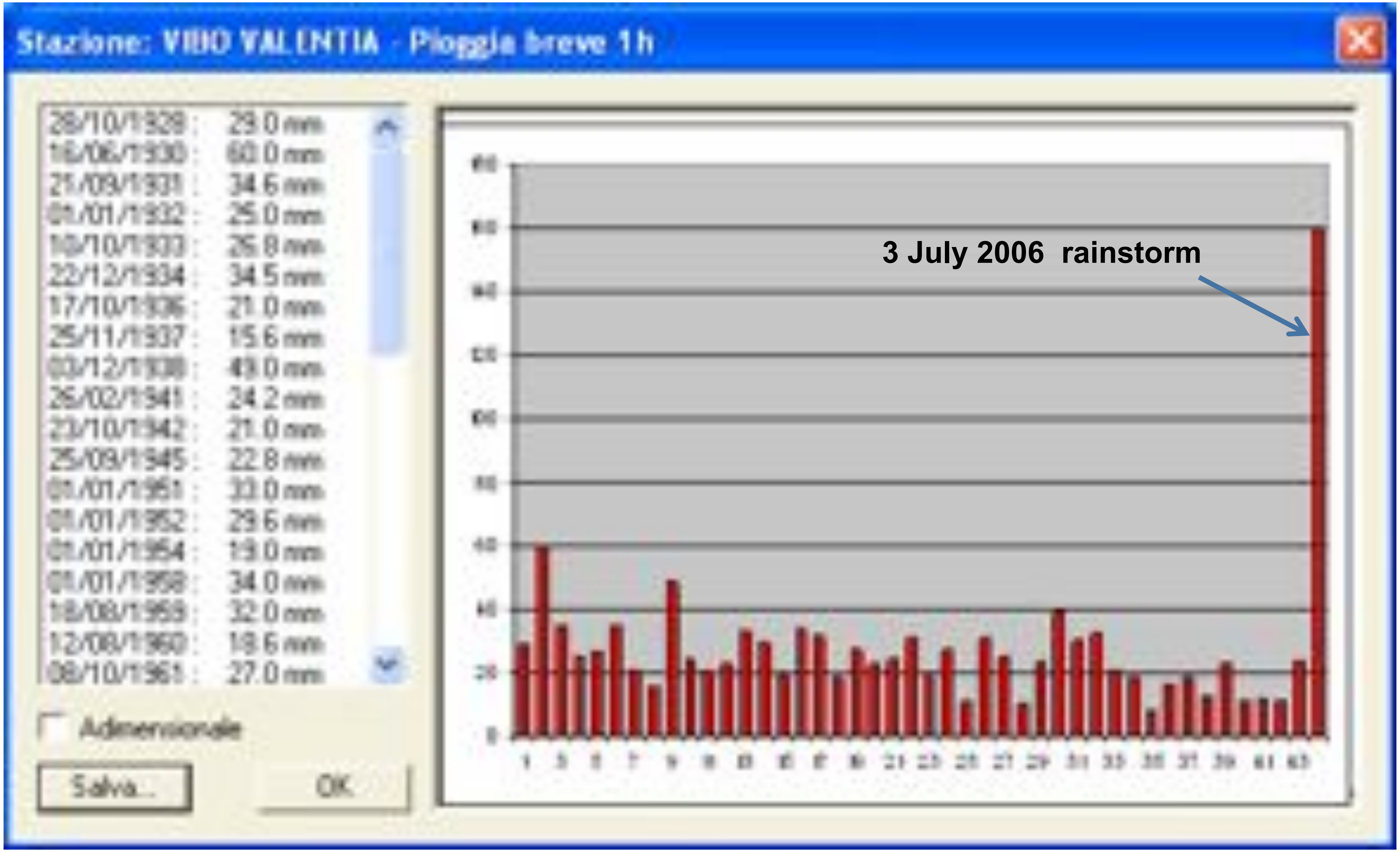
Total areal precipitations evaluated using MSG8



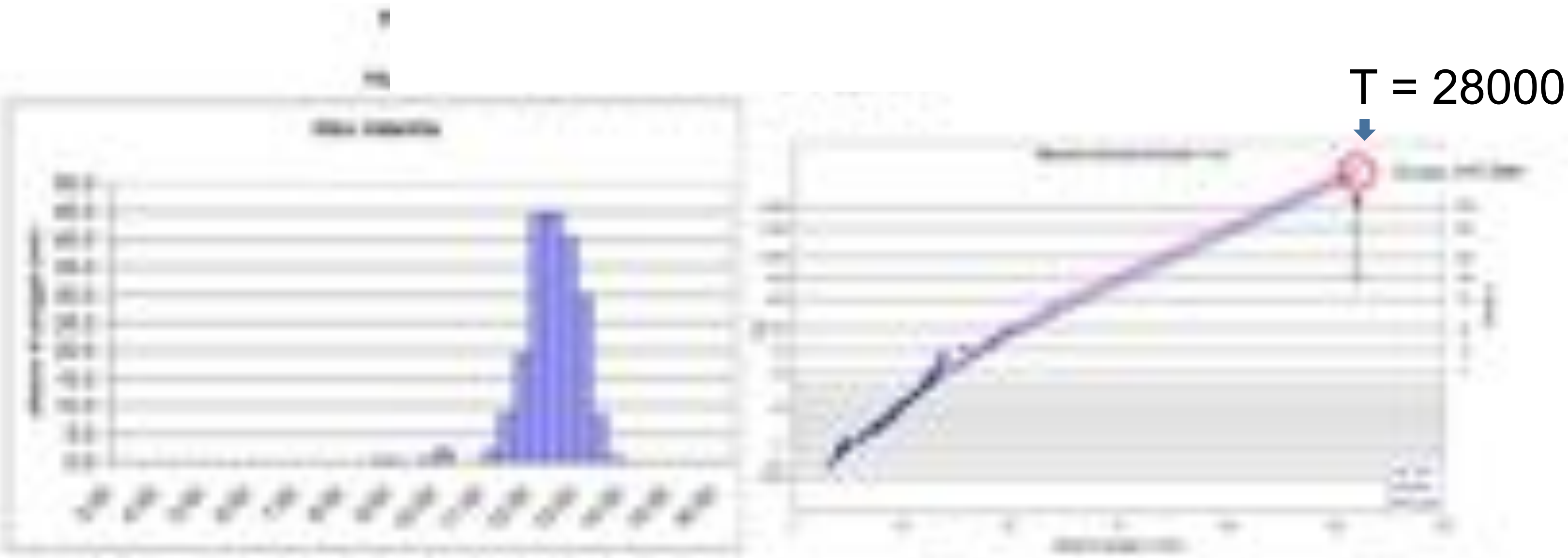
Percentage of precipitation versus raingauge measure



Vibo Valentia historical data for maximum annual rainfall of 1hour



Evaluation of the Return Period for different rainfall duration, using two regional Models: VAPI and PAI based on the index method and TCEV distribution.

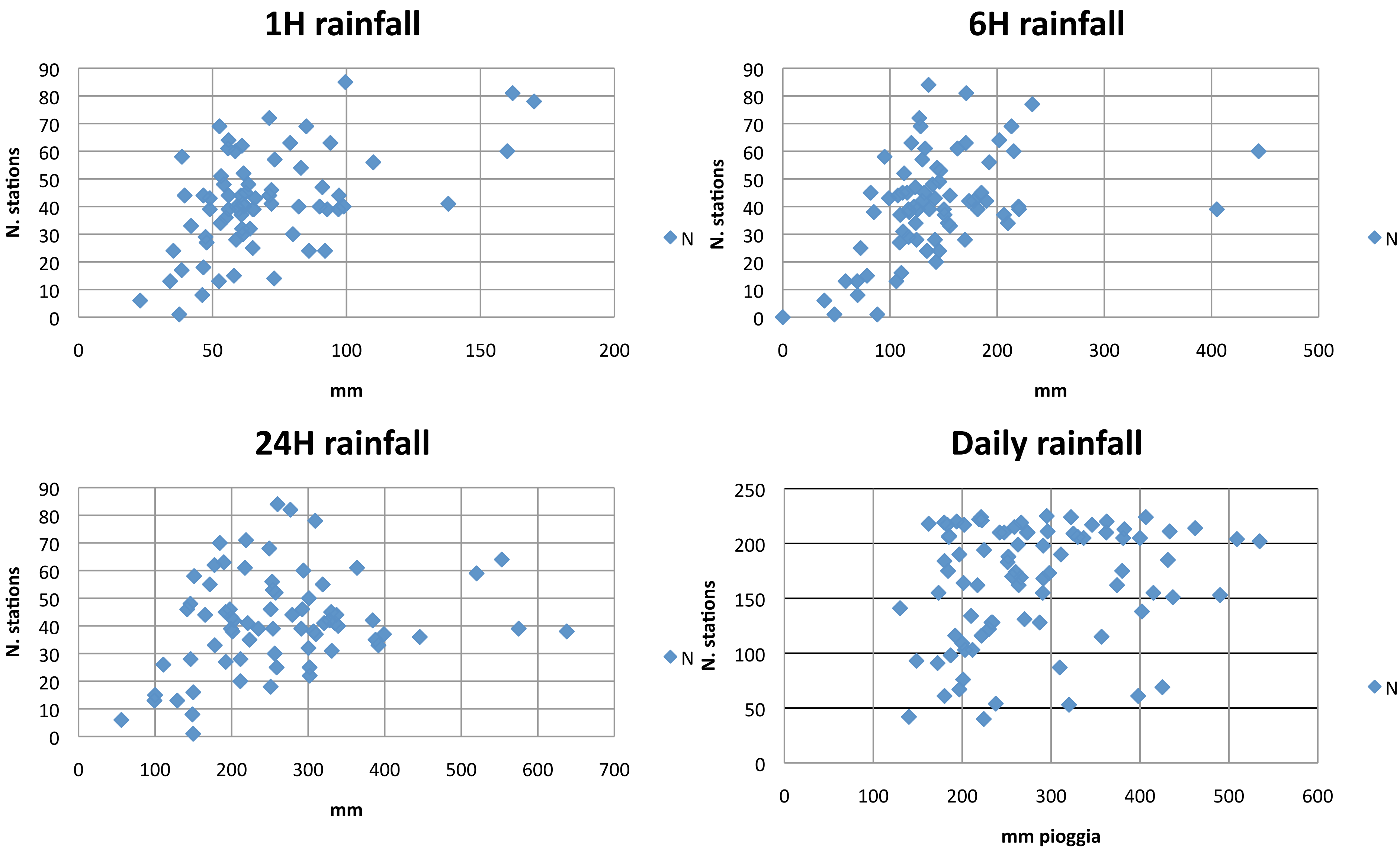


Stazione	Piogge su 20 min		Piogge su 1 h		Piogge su 3 h		Piogge su 6 h	
	PAI	VAPI	PAI	VAPI	PAI	VAPI	PAI	VAPI
Mongiana	*	*	1	1	1	1	1	1
Monterosso	*	*	3	3	20	25	10	10
Pizzoni	12	15	40	60	80	120	120	150
Serra San Bruno	2.5	2.5	8	8	36	36	20	20
Vibo Valentia	120	320	>1000	>1000	>1000	>1000	>1000	>1000

Tab. 5. Tempi di ritorno (anni) dell'evento studiato. (*) per le stazioni di Mongiana e Monterosso Calabro.

T = 28000

RELATION BETWEEN RAINFALL INTENSITY AND NUMBER OF STATIONS
(Calabria region, Italy)



Point 1 conclusion:(Possible weakness of short rainfall series in standard regional analysis (Italian case).

- For short rainfall series, also in presence of a sufficient number of stations, regional rainfall information may be much smaller than the appearences: about 10-15% of the total. (obviously depending on rain gauges density).

- As consequence, selection of homogeneous regions and statistical inference may lead to meaningless results.

- Failure to evaluate real maximum rainfall, expecially for small basins, may lead to overstimate the return period (or understimate rainfall) with serious consequences in planning and design.

REGIONAL HOMOGENEITY AND METEOROLOGICAL INDEXES

In the case of poor rainfall historical series, selection of homogeneous region may be pursued using meteorological indexes.

Meteorological indexes must be selected according to:

- the ability to represent physical features
- continuity in time and easy computation
- possibility to build sampling data series which can be inferred with geo-statistical tools

Selected meteorological indexes are: (from ERA40 ECMWF archive, 21 layers 0.25 x 0.25 degree resolution))

- **CAPE: Convective Available Potential Energy (convective rainfall)**
- QD : Q-Vector Divergence (frontal rainfall)
- VIMF : Vertically Integrated Moisture Flux (mean direction and intensity)

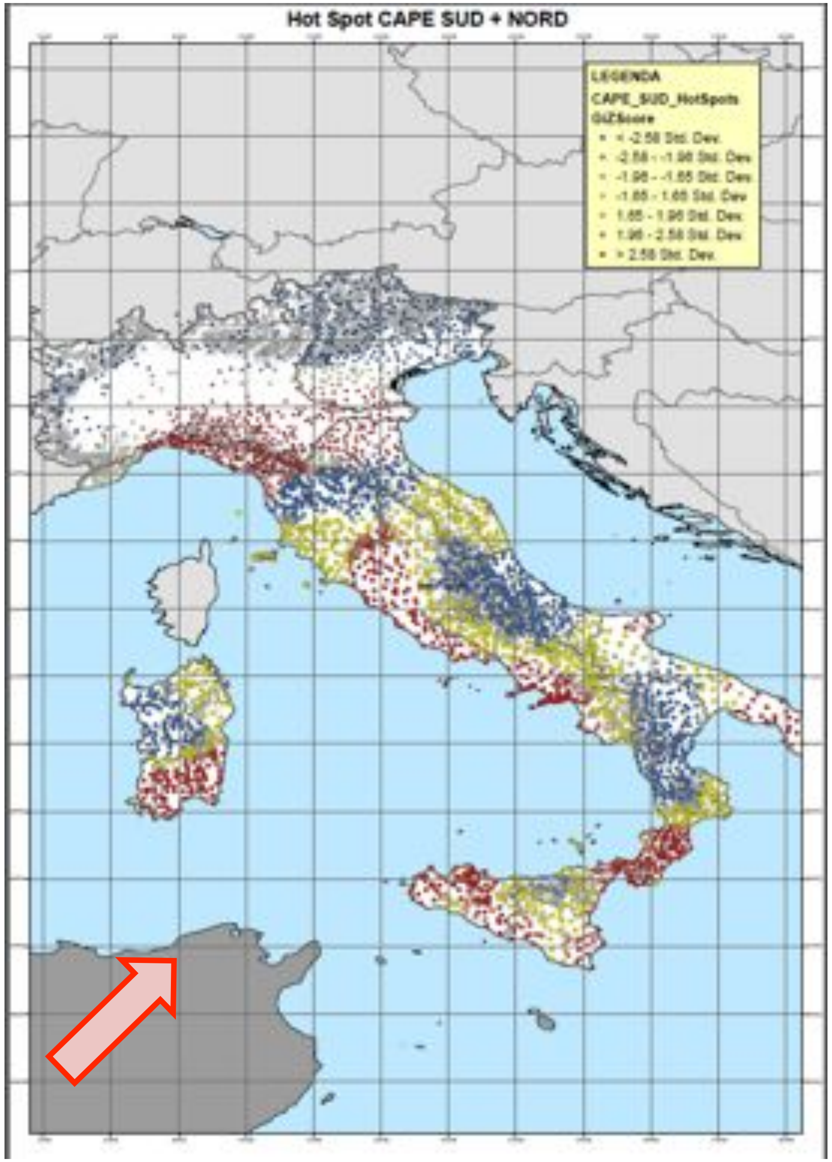
CAPE: Convective Available Potential Energy

$$CAPE = g \int_{LFC}^{EL} \frac{T_p - T_e}{T_e} dz \cong g \sum_{LFC}^{EL} \frac{T_p - T_e}{T_e} \qquad [J/kg]$$

$$T_v = T \cdot (1 + w \frac{R_v}{R_d}) / (1 + w)$$

<u>Index able to quantify the thermodynamic instability of deep convection associated with convective rainfalls</u>

Hot Spot results for frequency over the median values of CAPE .
Sampling data from 1959 to 1992

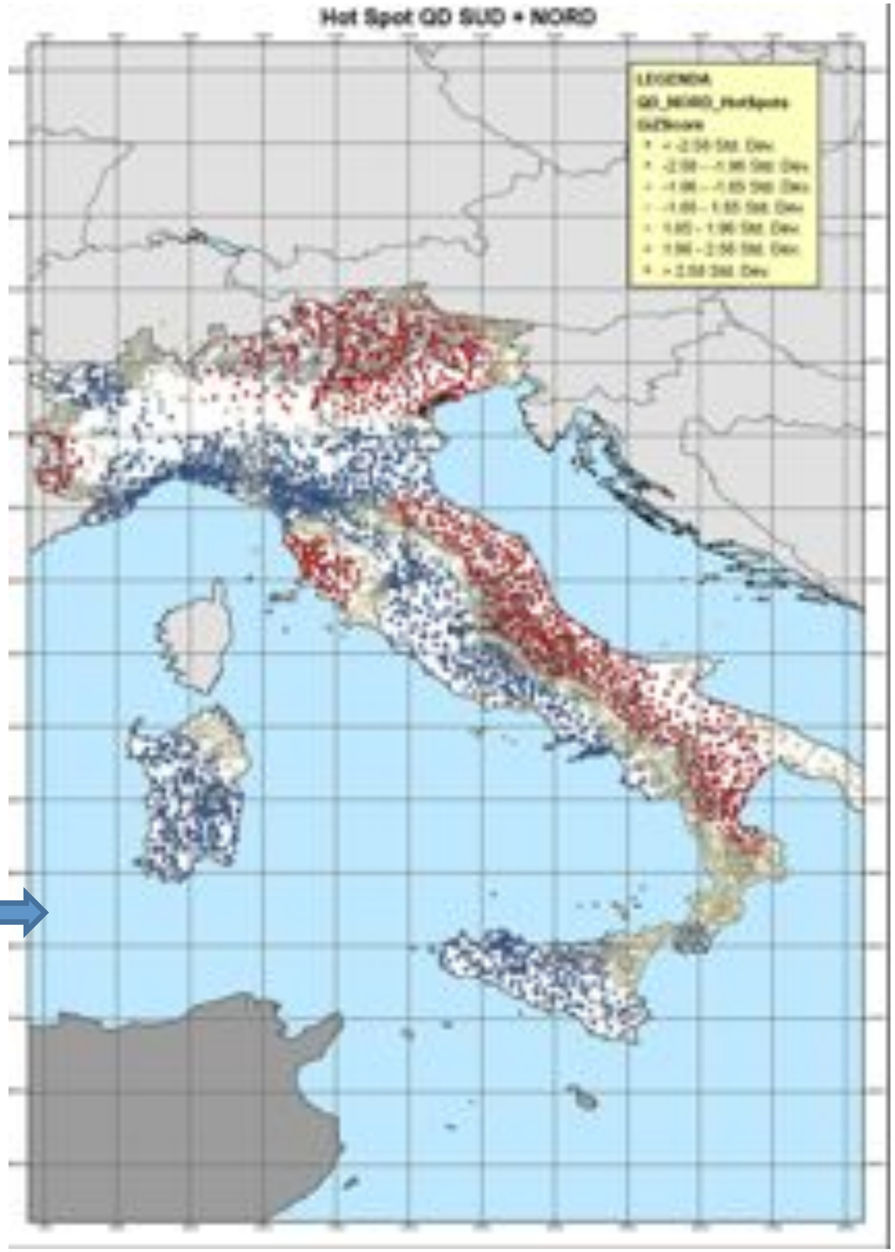


QD: Divergence of the vector Q

$$Q_x = -\frac{R}{\rho}\frac{\partial v_g}{\partial x}\cdot\nabla T \quad Q_y = -\frac{R}{\rho}\frac{\partial v_g}{\partial y}\cdot\nabla T$$

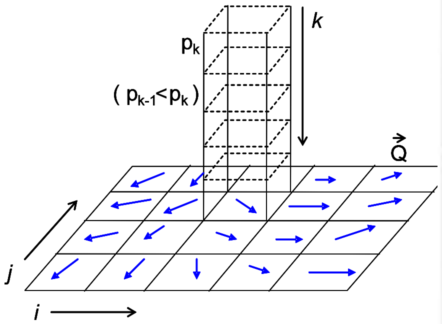
QD evaluate the presence of dynamic instability.

Hot Spot results for frequency over the median values of QD .
Sampling data from 1959 to 1992



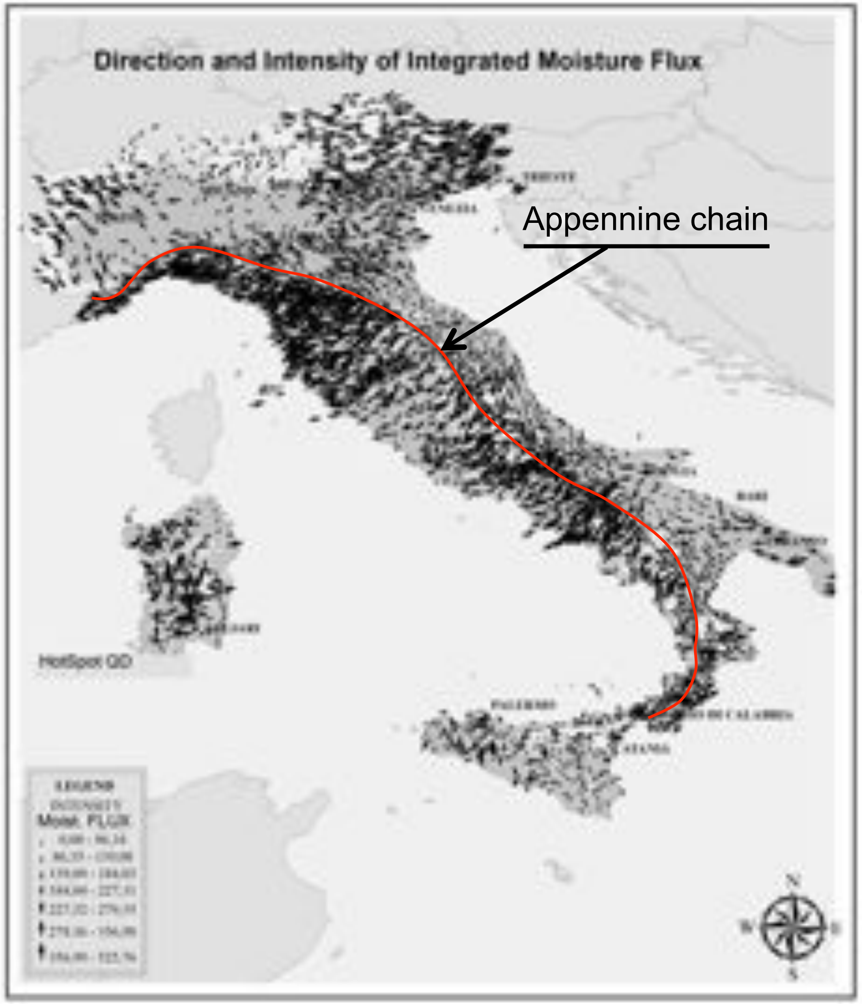
VIMF: Vertically Integrated Moisture Flux

$$\vec{Q} = (Q_u, Q_v) = -\frac{1}{g}\int_{p_S}^{p_T} q\,\vec{V}\,dp$$



The Vertically Integrated Atmospheric Moisture Flux, describe the synoptic transport of vapor in the atmosphere. It is a fundamental parameter in the hydrological balance and for the feeding of extreme events.

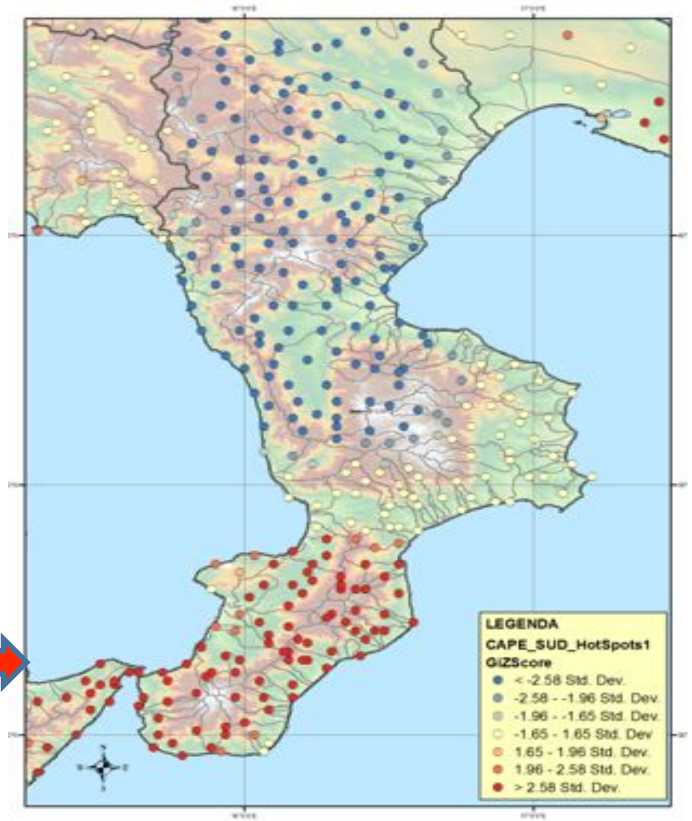
Direction and intensity of VIMF based on wind maximum direction frequency.



Point 3: (Proposition of an areal distribution for maximum annual 1H short rainfall)

Results of Hot Spot analysis on CAPE index are used to delimitate <homogeneous areas> for short rainfall of 1H.

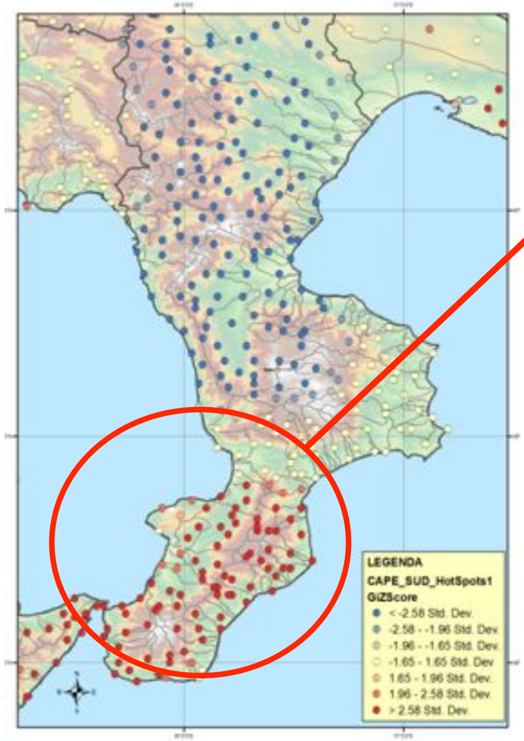
Frequency spatial distribution of max annual rainfall of 1H over median value



Hot Spot results for frequency over the median value of CAPE index

- High Z-score (HOT SPOT intense clustering of high values)
- Low Z-score (COLD SPOT intense clustering of low values)

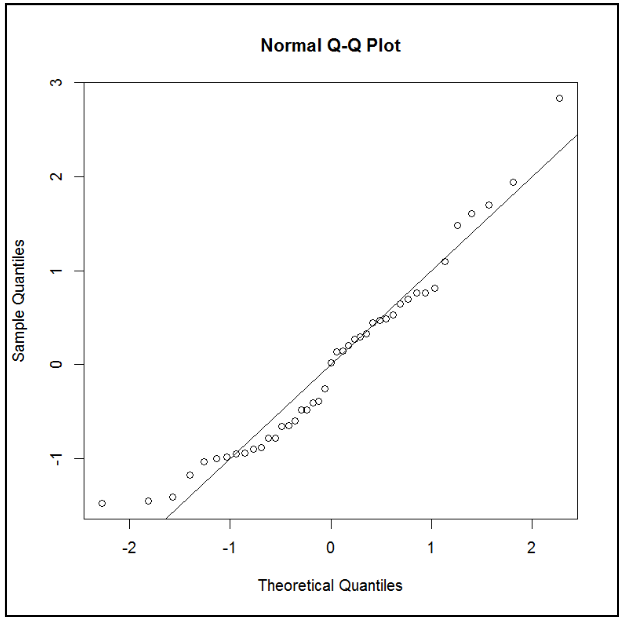
Results of homogeneity test for selected homogeneous region using CAPE index for 15 rainfall series



STANDARDIZED TEST VALUE H(1)	-0.44
STANDARDIZED TEST VALUE H(2)	-2.00
STANDARDIZED TEST VALUE H(3)	-2.06

GEN. LOGISTIC	L-KURTOSIS= 0.216	0.06 *
GEN. EXTREME VALUE	L-KURTOSIS= 0.183	-2.03
GEN. NORMAL	L-KURTOSIS= 0.169	-2.93
PEARSON TYPE III	L-KURTOSIS= 0.144	-4.57
GEN. PARETO	L-KURTOSIS= 0.103	-7.13
TCEV DISTRIBUTION	L-KURTOSIS= 0.201	-0.91 *

Normality test for CAPE



While CAPE index, in the delimited region is normally distributed with low s.d., we consider it CONSTANT.

The hypothesis of constancy of CAPE, if transfer - red to rainfall, **means that also extreme short rainfall have the same distribution all over the region**.

SUPER-HOMOGENEITY AND AREAL DISTRIBUTION

If the mean of maximum annual short rainfalls is CONSTANT too (*), we may define a UNIQUE distribution all over the super-homogeneous region.

- The regional sampling data set is build considering, year-by-year, the maximum short rainfall height recorded in the region.

- Areal parameters are estimated from a single sample site with length equal to the recorded number years.

- The distribution $F_A(X)$ represent the probability of not excideence of X all over the region A.

- To evaluate the at-site probability we need to introduce the dimension of cell rainfall associated to the X rainfall.

(*) High values of CAPE identify high frequency of convective rainfall associated with cumulonimbus. The rainfall intensity associated to this kind of cloud, which can reach the stratosphere is poorly affected by orography, so far, we may consider frequency and distribution of extreme rainfall constant too.

RELATION BETWEEN CELL SIZE AND RAINFALL INTENSITY

Distribution of rainstorm cells dimension is of great interest in attenuation models of radio transmission.

For a cell of radius D, relation rainfall intensity X versus D are commonly presented in literature as a power function:

$$D = \alpha X^{\beta}$$

α and β are related to the clime of the region and may be estimated using radar data.

$$A(X_i) = \pi D^2$$

The cell dimension $A(X_i)$ for a rainfall event of height X_i, is used to evaluate the area of the "active region" equal to the mean value of $A(X_i)$ multiplied for the yearly mean number of stations ;

$$A_c = \overline{A} * NS$$

A_c represent the real portion of the regional area, interested by maximum rainfall events, which is used to evaluate distribution parameters.

At-site estimation $F_P(X)$ starting from areal distribution F(X)

Estimation of $F_P(X)$ starting from the areal distribution is here pursued in a simple way (it is under revision)

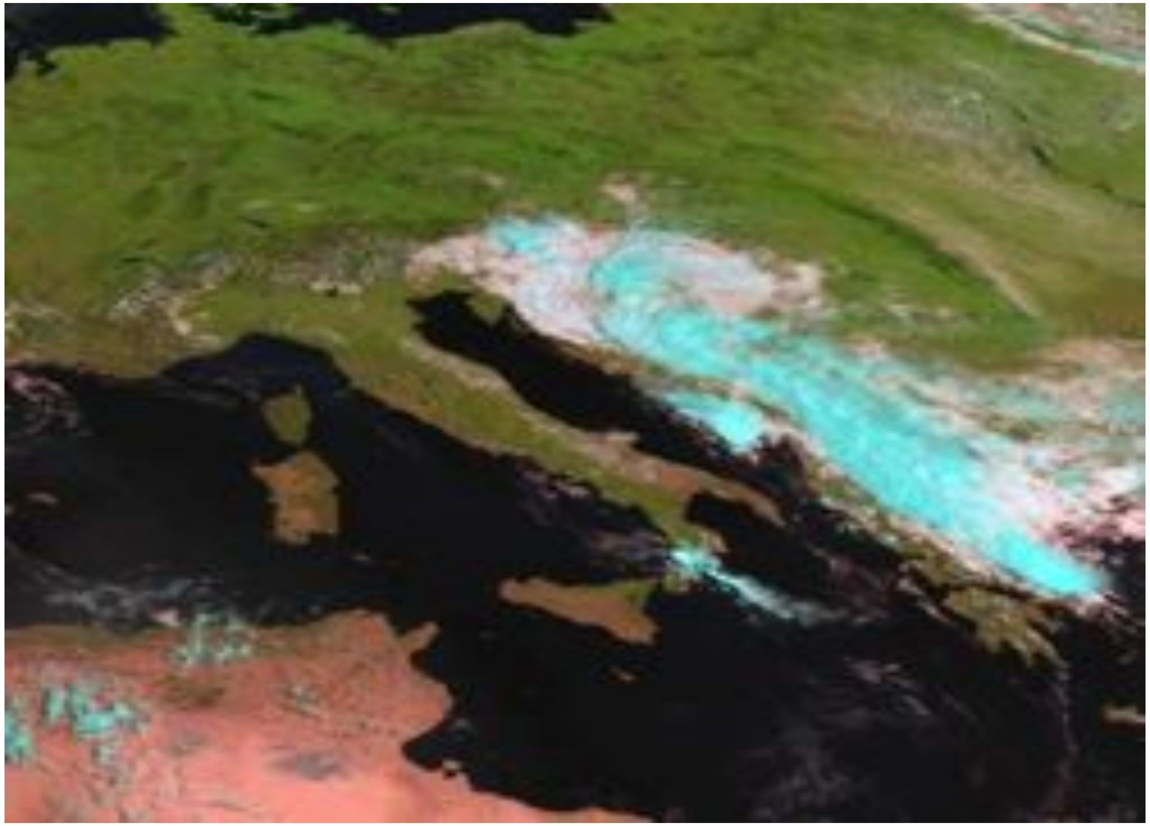
- given X, the corresponding cell area A_P is evaluated using the relation:

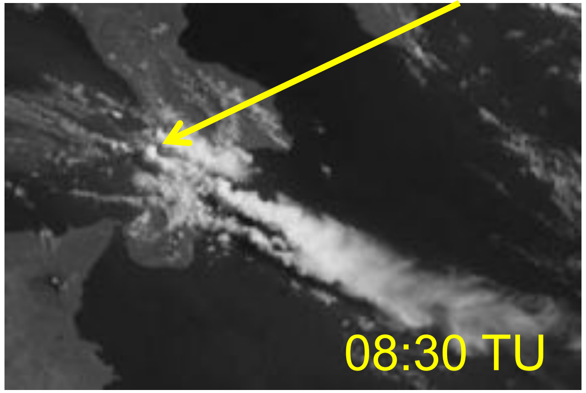
$$D = \alpha X^{\beta}$$
$$A_P = \pi D^2$$

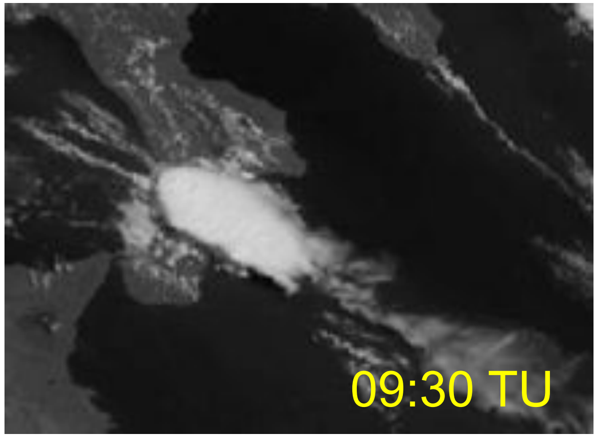
If the areal distribution F(X) is evaluated using the "active areal distribution" A_C then the probability that event hit an area equal A_P is:

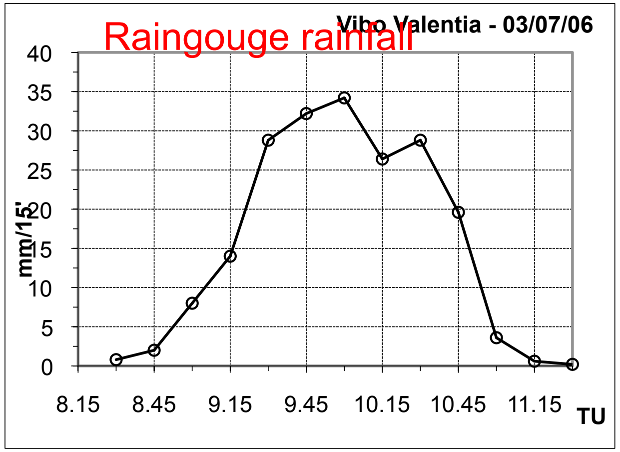
$$F_P(X) = F(X) * A_P / A_C$$

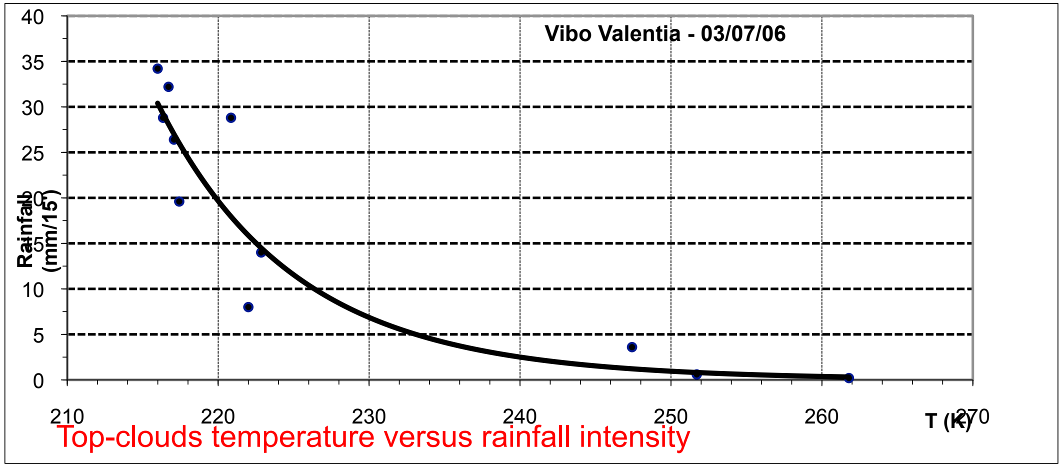
POINT 4. (Vibo Valentia flood events 3/7/2006)











Vibo Valentia results

AREAL ESTIMATION

TCEV parameters (evaluated considering 71 years) Mean number of station for year: NS = 25

$\vartheta 1$ = 13.456
$\vartheta 2$ = 39.457
$\lambda 1$ = 34.195
$\lambda 2$ = 1.568

Areal return period: $F_A(X <= 132.2)) = 0.96$ $T = 1/(1-F) = T_{132.2} =$ **25** years

Area of the active region: A_c = 554 kmq

$\mathbf{T_A}$ = **25** years (*)

AT-SITE ESTIMATION

Cell size: D(130.2) $55 * R^{-0.455}$

Cell area: A_P = 28.26 kmq

$T_p = T_a * Ac/A_P$ = **490** **(<< 28.000)**

(*) In the homogeneous region, in the last past 90 years we had 4 events with intensity greater than 132 mm.

CONCLUSION

- Due to the small dimension of the rain cells associated with extreme events, the probability of a rain gauge to intercept the maximum rainfall is very low.

- Index method procedure for short rainfall, may overestimate return period of extreme precipitation .

- Use of meteorological information my be very useful to select homogeneous regions in presence of scarce rainfall data.

- For short rainfall, if the CAPE index may be considered constant, it is possible to hypothesize, a super-homogeneity and than a unique areal distribution all over the region.

- To evaluate at-point probability, a simply relation between rainfall intensity versus cells area is adopted for an attempted.

- The proposed procedure shows more realistic results in the case of very intense short precipitation.

- For the case of Vibo Valentia flood, the return period T, evaluated with the index-method is greater than **28000** years while with the proposed procedure is less than **500** years.