# DATI CLIMATICI AD ALTA RISOLUZIONE (TEMPERATURE E PRECIPITAZIONI)

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**Consiglio Nazionale delle Ricerche**

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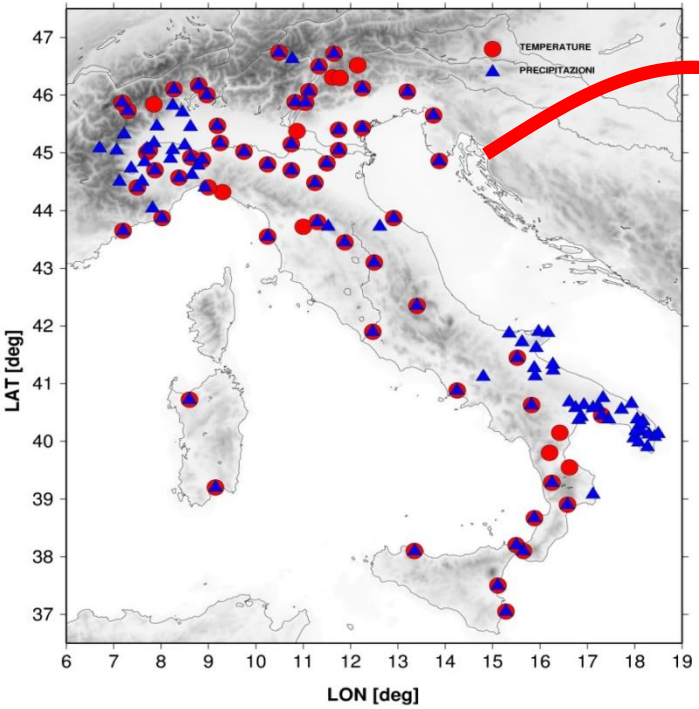
# CONTESTO GENERALE

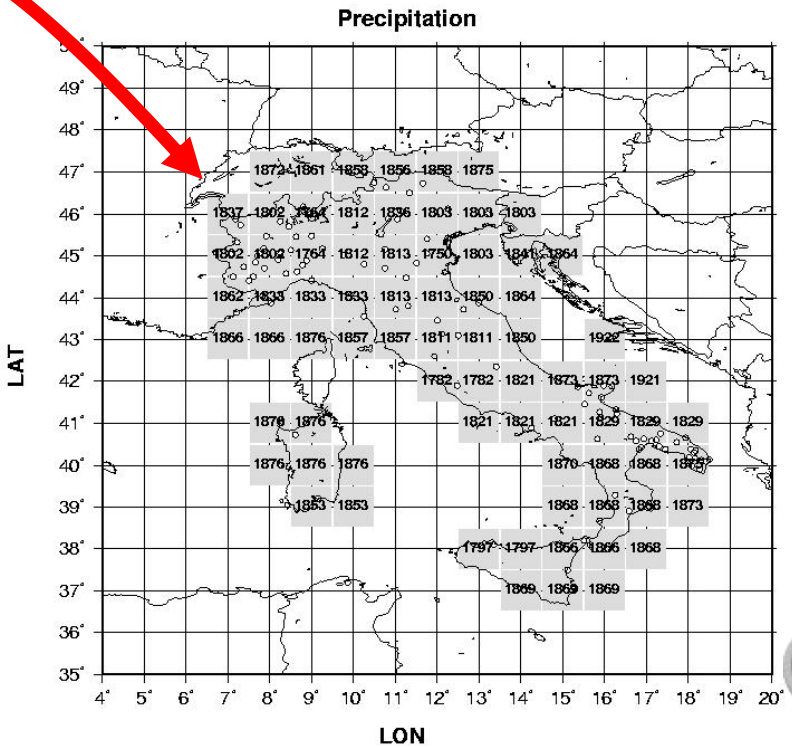
## ESISTE UN GROSSO GAP TRA L'INFORMAZIONE CLIMATICA ATTUALMENTE DISPONIBILE E CIÒ CHE IN PRATICA SERVIREBBE PER MEGLIO VALUTARE E AFFRONTARE GLI IMPATTI DEI CAMBIAMENTI CLIMATICI

**ATTIVITÀ ISAC-CNR/UNIMI SULLA RICOSTRUZIONE DELLE VARIAZIONI CLIMATICHE AVVENUTE IN ITALIA NEGLI ULTIMI DUE SECOLI**

DATABASE DI SERIE SECOLARI OMOGENEIZZATE



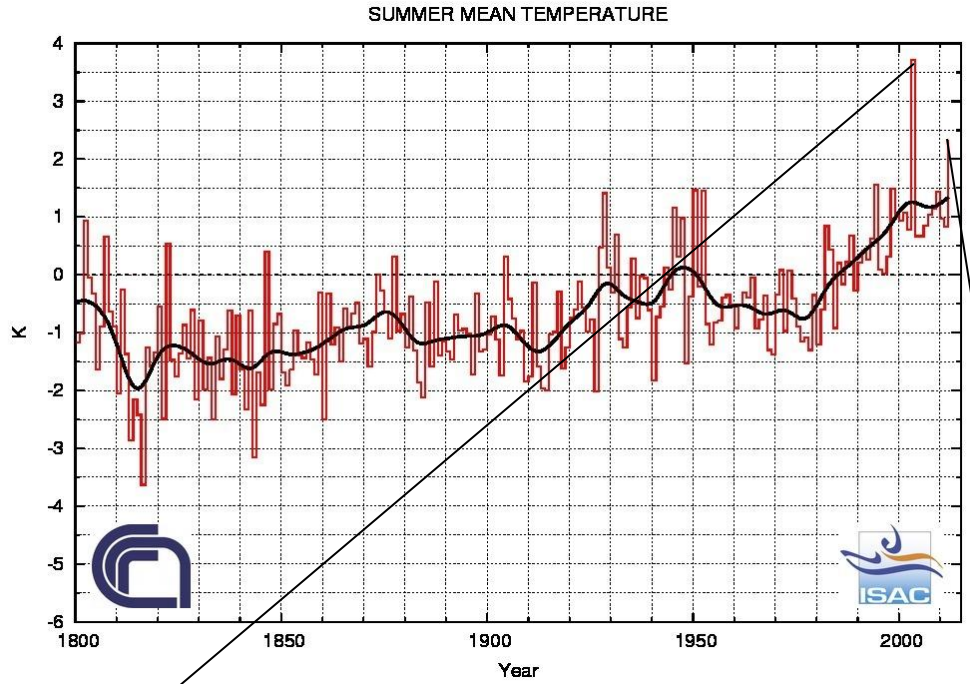

GRIGLIA DI **ANOMALIE** 1°X1° DI RISOLUZIONE PER GLI ULTIMI DUE SECOLI

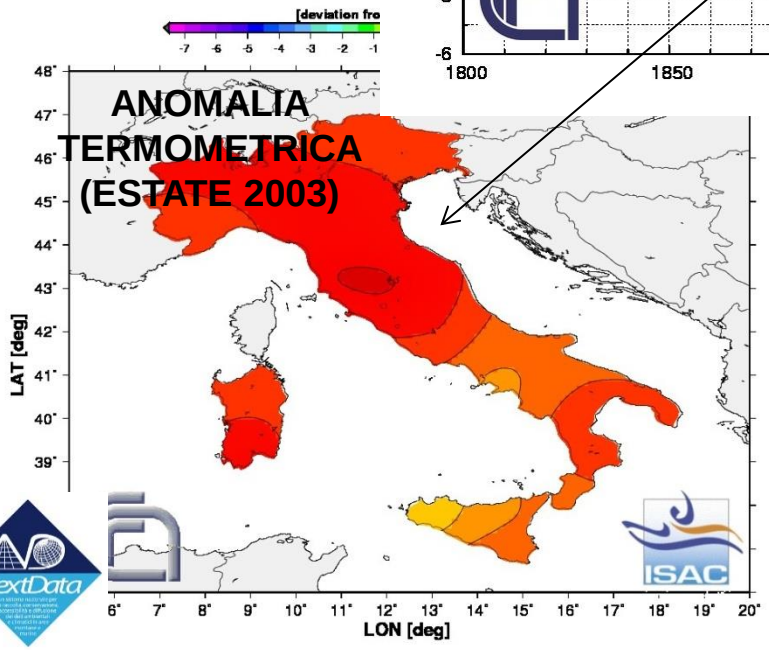


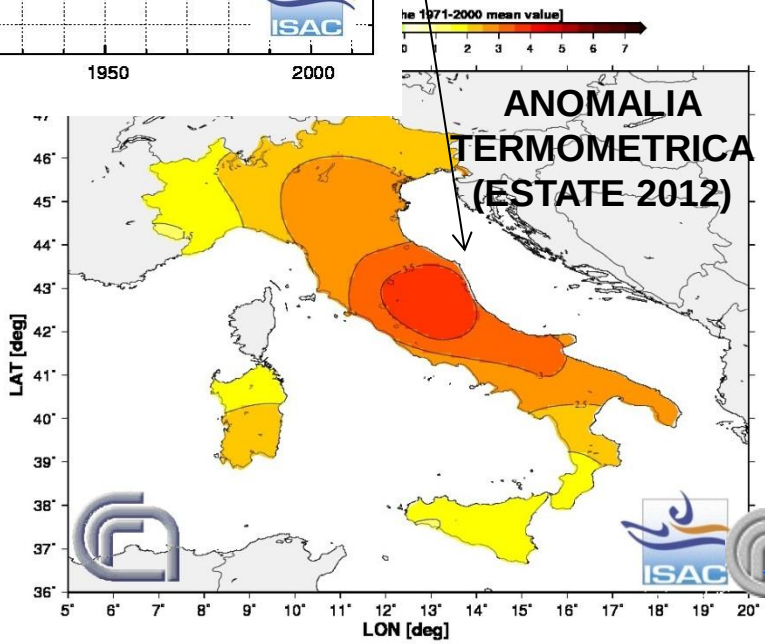

FROM: Brunetti et al., 2006. ***Int. J. Clim.***, **26**, 345-381

# CONTESTO GENERALE

**OTTIMO STRUMENTO PER LO STUDIO DELLA VARIABILITÀ E DEI CAMBIAMENTI CLIMATICI…**



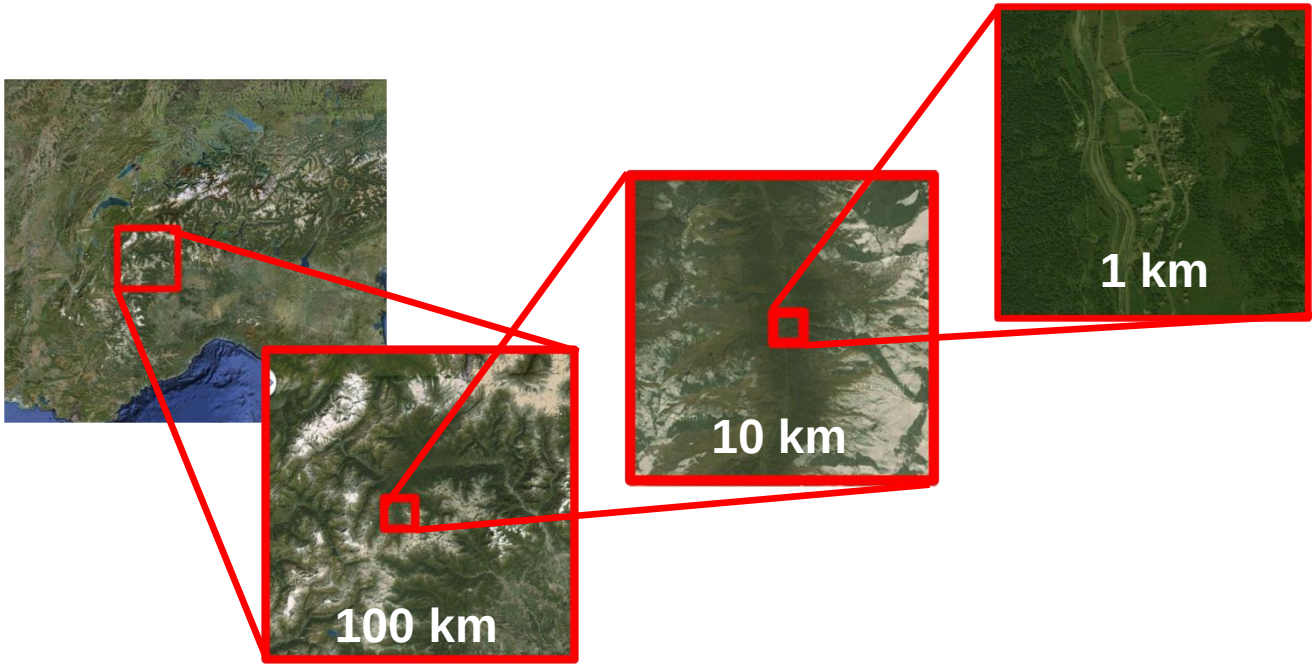



# CONTESTO GENERALE

…TUTTAVIA, DATI A BASSA RISOLUZIONE ESPRESSI IN TERMINI DI ANOMALIE NON CI PERMETTONO DI RISPONDERE A SPECIFICHE DOMANDE RILEVANTI PER LA VALUTAZIONE DEGLI IMPATTI DEI CAMBIAMENTI CLIMATICI.

Come è variata la temperatura media nell'arco dell'ultimo secolo in una particolare località (priva di stazione meteo)?




PER POTER RISPONDERE A RICHIESTE DI QUESTO TIPO OCCORREREBBE UNA SERIE OSSERVATIVA DI DATI METEOROLOGICI (CHE COPRA UN INTERVALLO TEMPORALE SUFFICIENTEMENTE LUNGO) PER OGNI CHILOMETRO QUADRATO DEL TERRITORIO.
IN ALTERNATIVA È NECESSARIO SVILUPPARE METODOLIGIE CHE PERMETTANO DI INTERPOLARE I DATI ESISTENTI SI DI UN GRIGLIATO AD ALTA RISOLUZIONE.

# APPROCCIO AL PROBLEMA

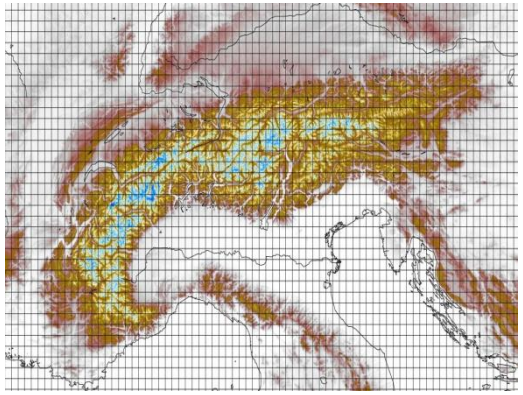
**<u>COSTRUIRE SEPARATAMENTE</u>: *- I VALORI NORMALI (CLIMATOLOGIE)***

(Mitchell and Jones, 2005. ***Int J Clim***, **25**, 693-712) ***- E LE DEVIAZIONI DA QUESTI***

- **LE CLIMATOLOGIE** SONO CARATTERIZZATE DA <u>FORTI GRADIENTI SPAZIALI</u>, QUINDI SERVIRA' UN'**ALTA DENSITA' DI STAZIONI** PER RAPPRESENTARLE, TUTTAVIA **SARA' SUFFICIENTE UN TRENTENNIO DI DATI** PER VALUTARLE

- **LE DEVIAZIONI** DA QUESTE SONO PIU' <u>COERENTI SPAZIALMENTE</u>, QUINDI SERVIRANNO **MENO STAZIONI** PER POTERLE RAPPRESENTARE, MA SARA' NECESSARIA UNA **PIU' LUNGA ESTENSIONE TEMPORALE** PER UNA PROFICUA ANALISI DI TENDENZE A LUNGO TERMINE

**Climatologia ad alta risoluzione (1kmX1km)**



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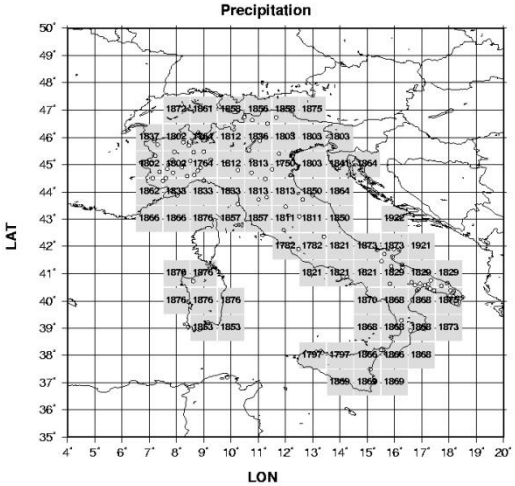
**Griglia anomalie da serie storiche (50-150 anni)**




**<u>Dalla sovrapposizione di climatologie e anomalie otteniamo griglie di risoluzione 1kmX1km di variabili meteorologiche in valori assoluti per gli decenni</u>**

# COSTRUZIONE DELLE CLIMATOLOGIE

# GLI STRUMENTI NECESSARI

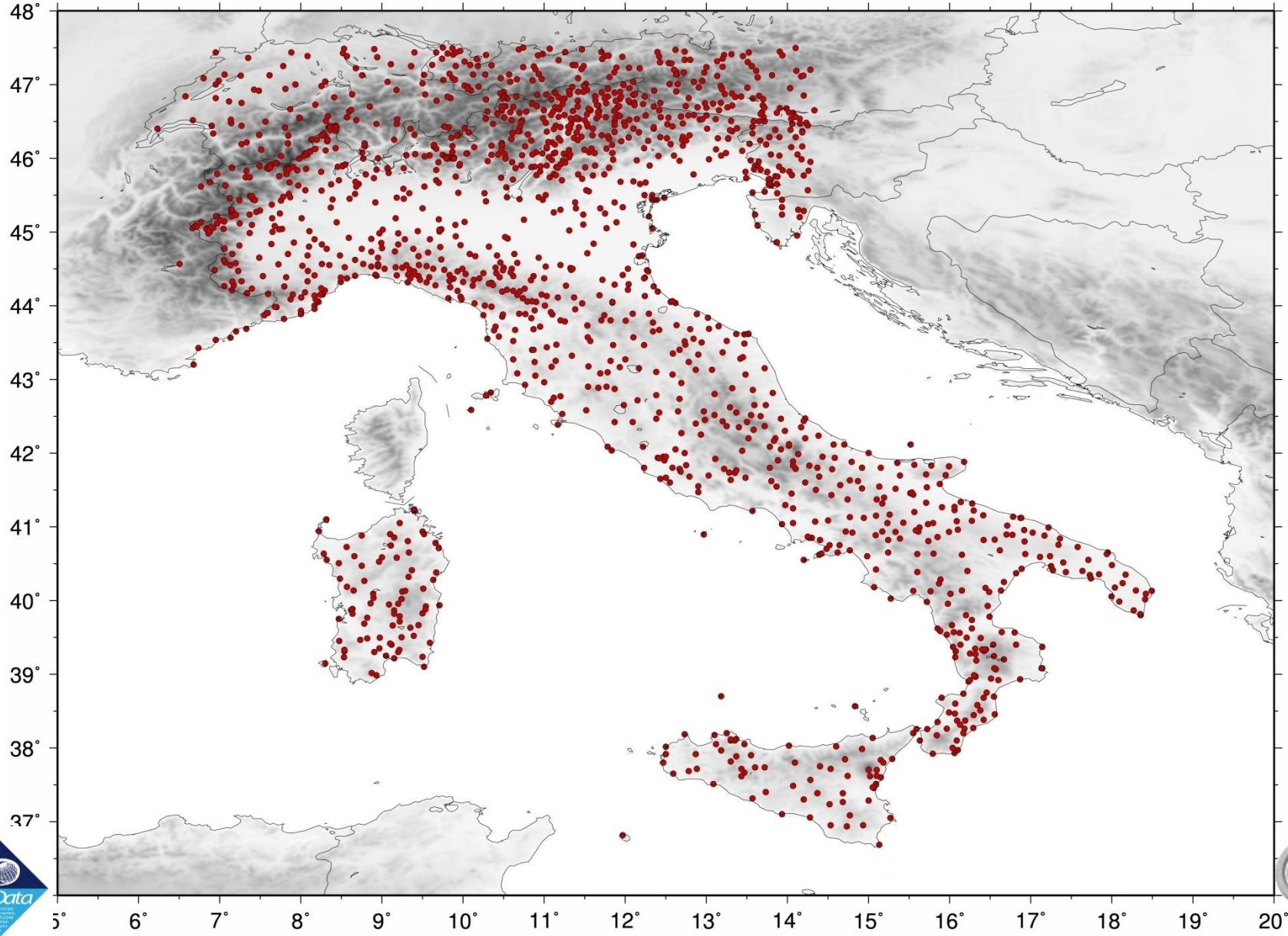
**PER LA COSTRUZIONE DI CLIMATOLOGIE AD ALTA RISOLUZIONE OCCORRONO**:

**- UN DATA SET ADEGUATO** CHE CI PERMETTA DI DESCRIVERE I GRADIENTI SPAZIALE ALLA RISOLUZIONE CHE ABBIAMO SCELTO

**- UNA PROCEDURA ADEGUATA** PER CATTURARE LA CORRETTA DIPENDENZA DELLA VARIABILE DAI PARAMETRI GEOMORFOLOGICI

# GLI STRUMENTI NECESSARI

## TEMPERATURE DATA SET FOR CLIMATE NORMAL EVALUATION



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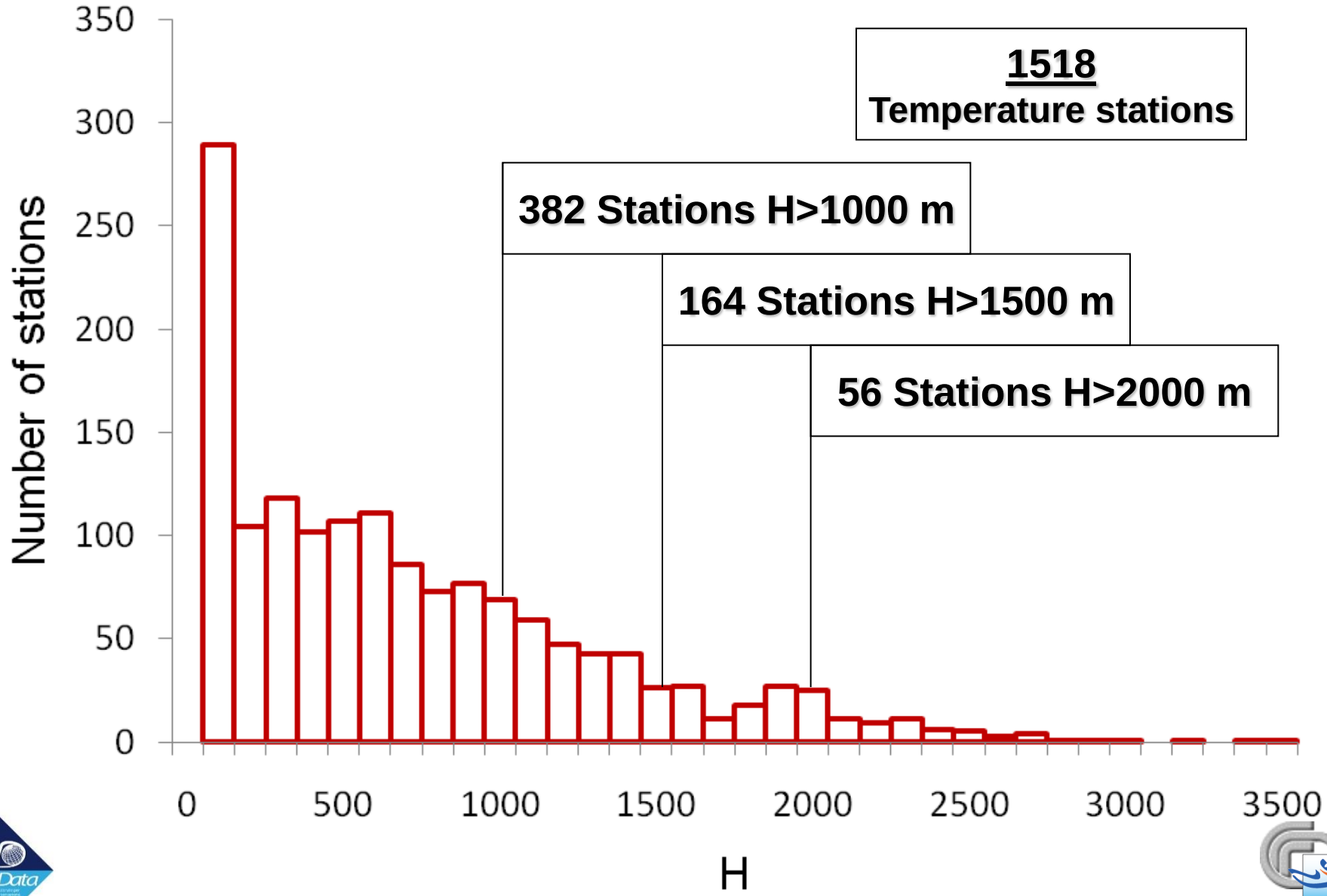
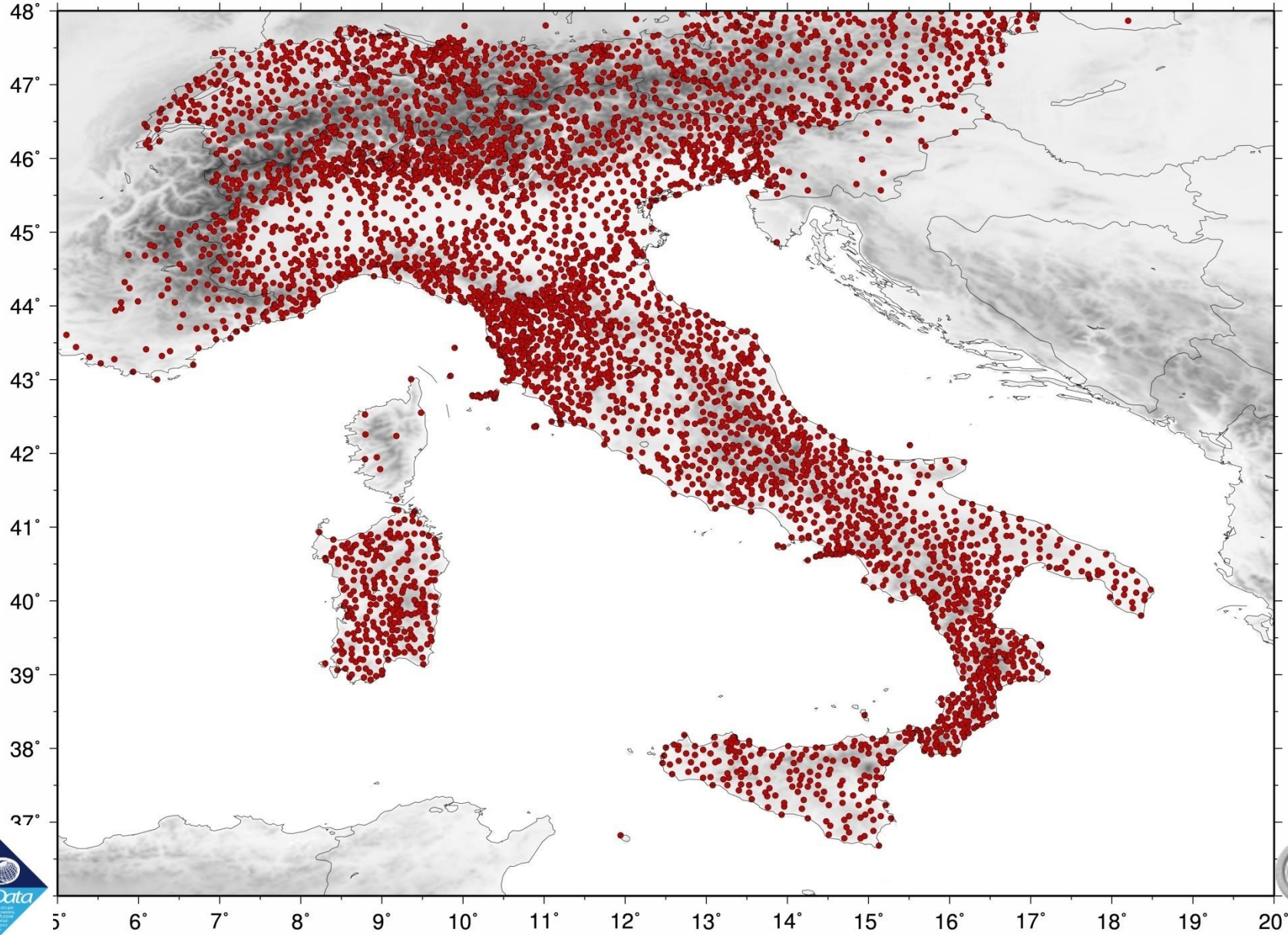


# GLI STRUMENTI NECESSARI

## PRECIPITATION DATA SET FOR CLIMATE NORMAL EVALUATION



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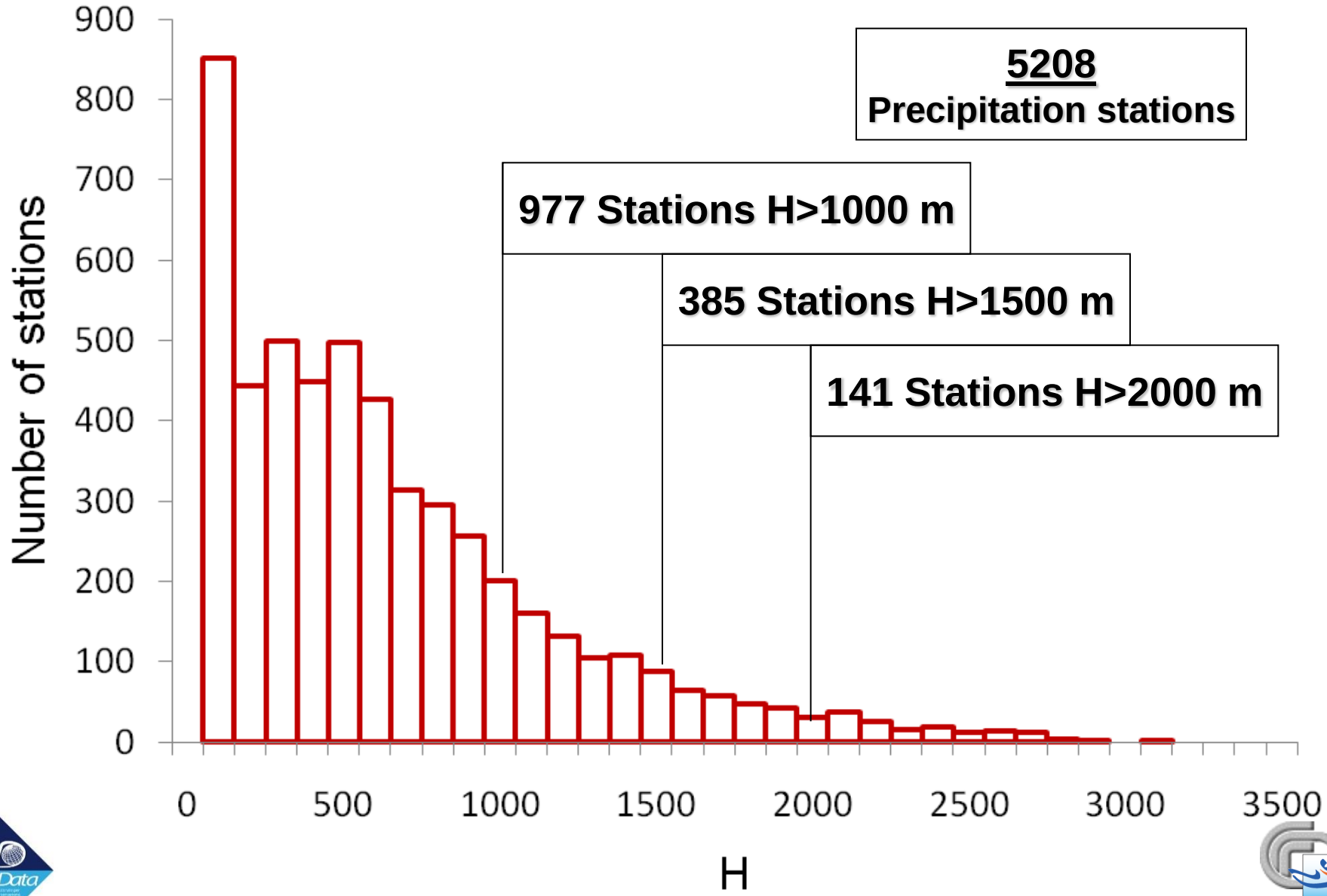
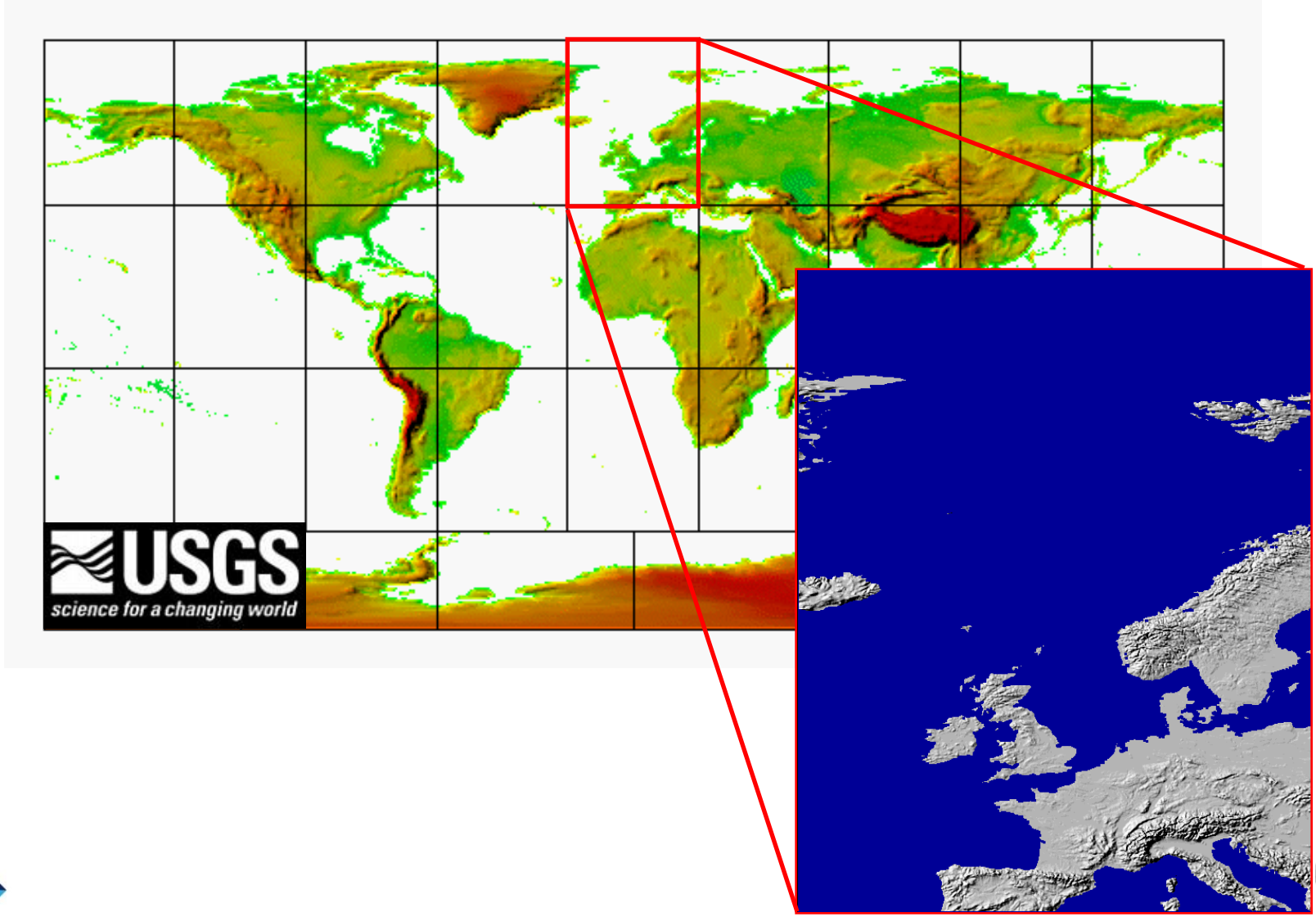
## PRECIPITATION DATA SET FOR CLIMATE NORMAL EVALUATION



# GLI STRUMENTI NECESSARI

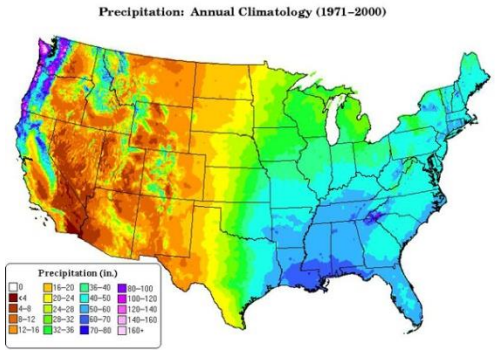
## 30 arcsecdonds Digital Elevation Model

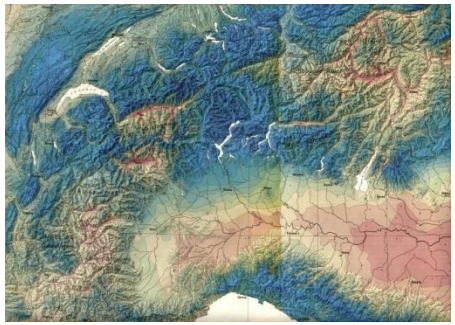


# LA METODOLOGIA PER LA COSTRUZIONE DELLE CLIMATOLOGIE

## THE MODEL

THE SELECTED MODEL IS SIMILAR TO **PRISM** (Parameter-elevation regression on independent slopes model) ALREADY USED FOR **US** (Daly et al., 1994) AND THE **ALPINE REGION** (Frei and Schär, 1998).



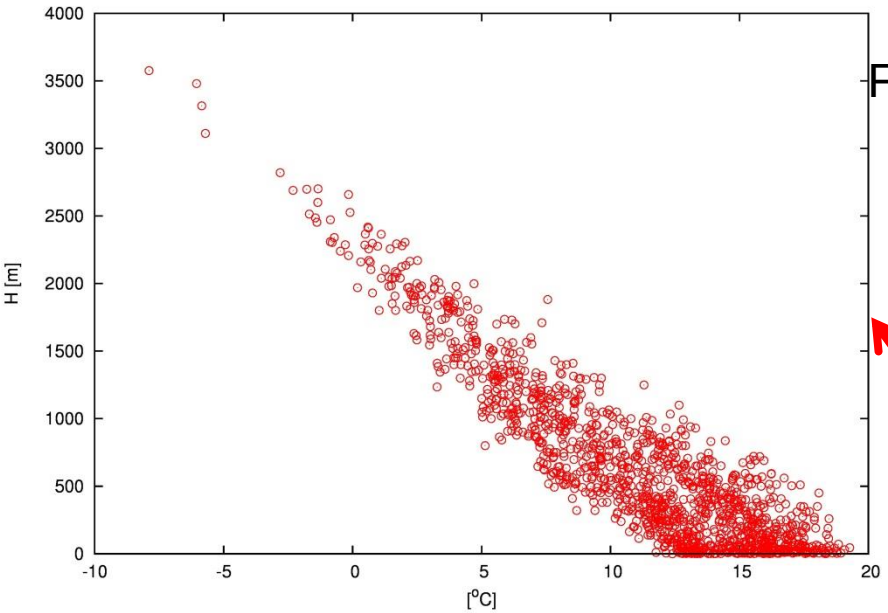
**LOCAL PARAMETER vs ELEVATION WEIGHTED LINEAR REGRESSION (LWLR)**

## WHY THIS MODEL?

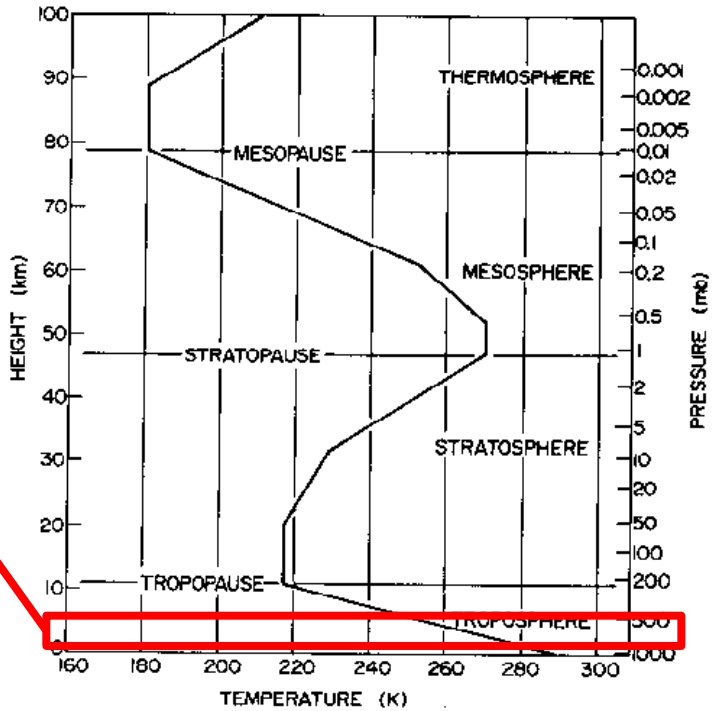

Daly C, Neilson RP, Philipps DL. 1994. Journal of Applied Meteorology, 33: 140–158

Frei C., Schär C. 1998. International Journal of climatology, 18: 873-900.

# TEMPERATURE




For temperature it is quite obvious. Temperature decrease with elevation in the troposphere.



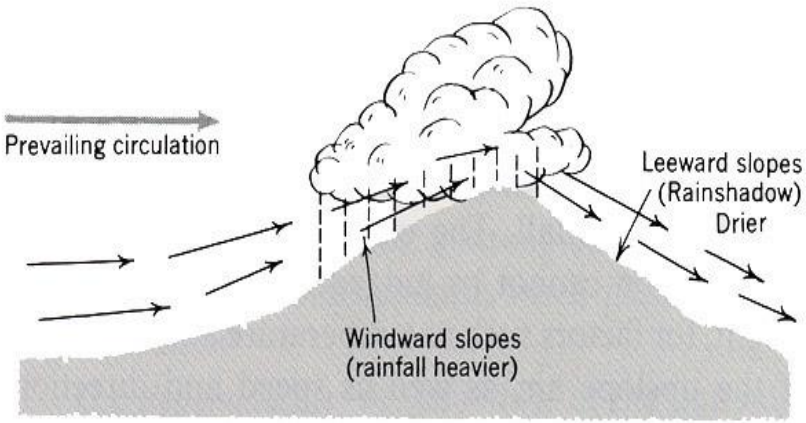

However the **lapse rate is locally different** depending on various factors:

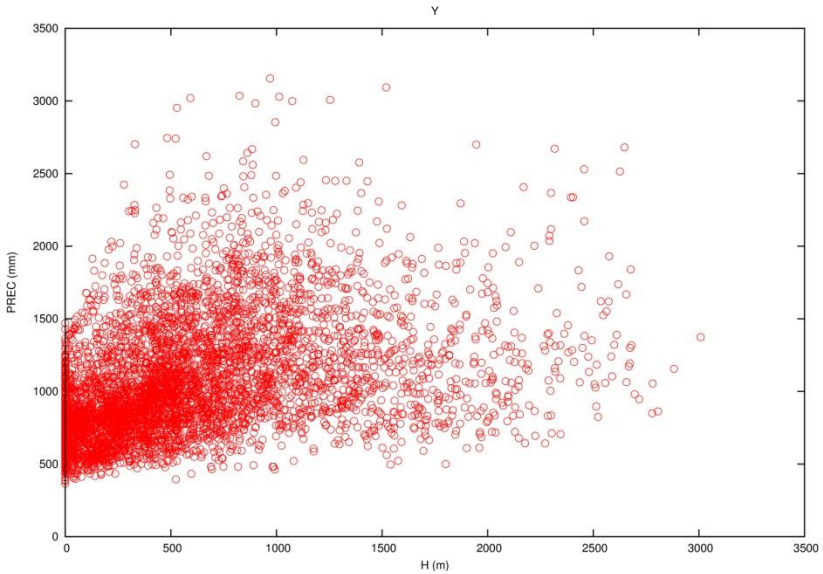
- Total solar radiation received (i.e. slope orientation and steepness)
- Sea mitigating effect
- Pool air cooling (i.e. temperature inversion effect)

**FOR THESE REASONS A GLOBAL T vs H RELATIONSHIP IS NOT APPROPRIATE, BUT A LOCAL ESTIMATION OF THE LAPSE RATE IS BETTER**

# PRECIPITATION

**Why this model?: because precipitation is strongly linked to orography, with a general increase of precipitation with elevation and with strong differences between windward and leeward slopes…. but….**

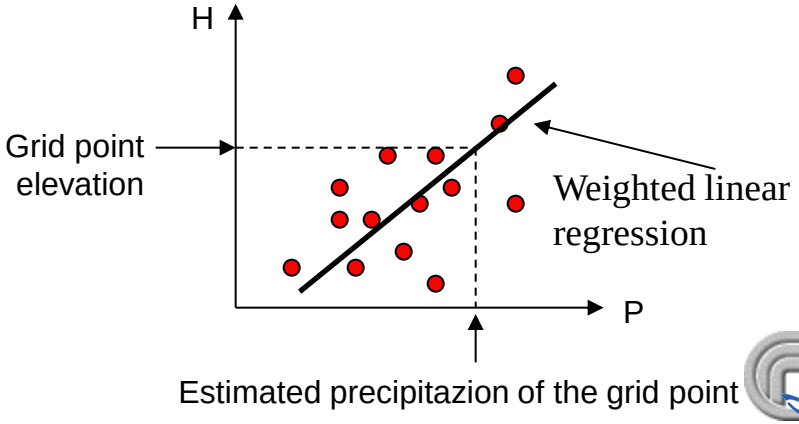



**… the link among precipitation and elevation is highly site dependent…**

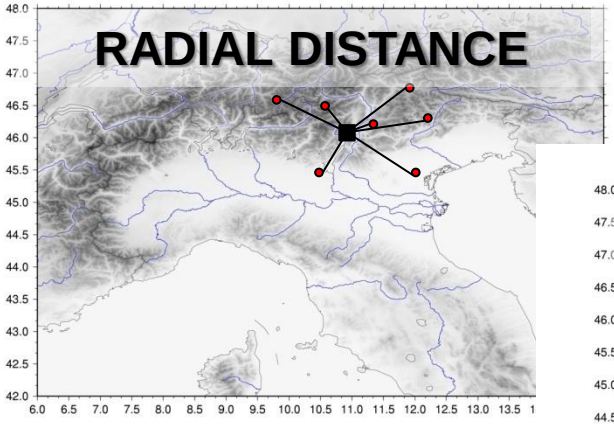
**So such a link has to be investigated on small spatial scales.**

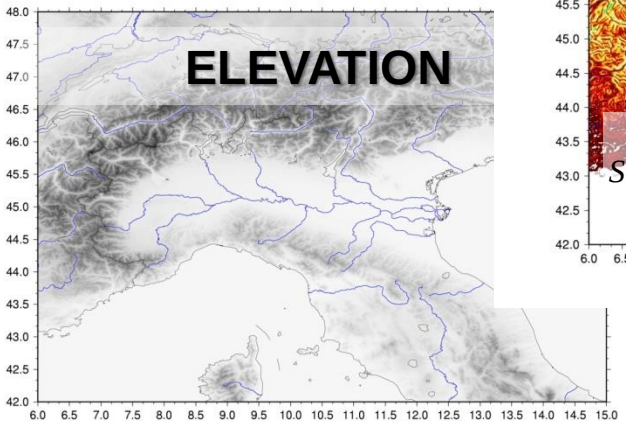
**How can such a study be performed? By means of a weighted linear regression of precipitation and elevation, being the weights given by the similarity between the geographic characteristics of each station and the grid cell.**

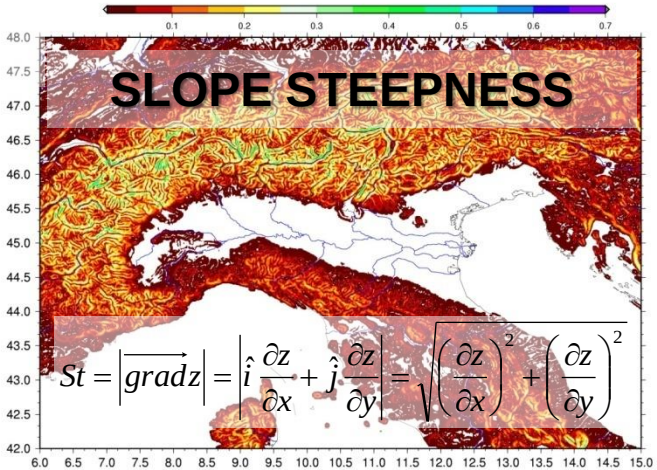


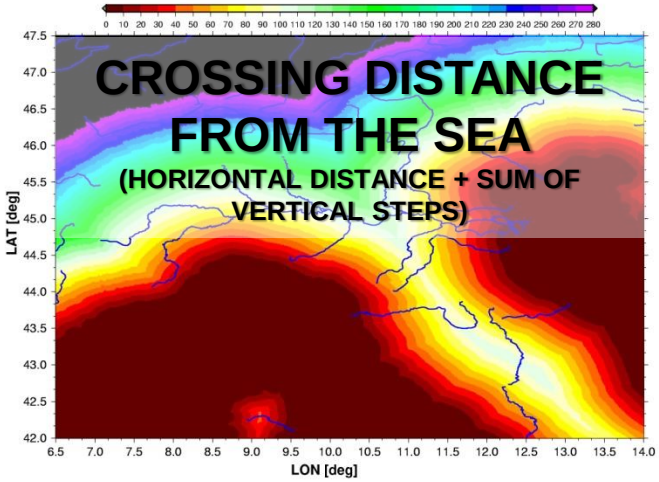
# LA METODOLOGIA PER LA COSTRUZIONE DELLE CLIMATOLOGIE

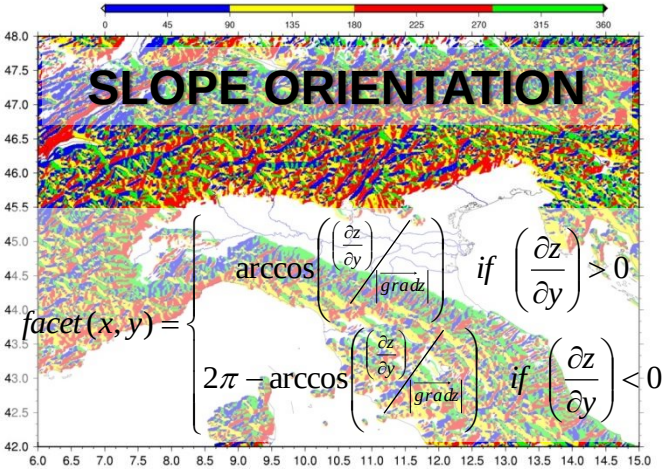
## THE WEIGHTS



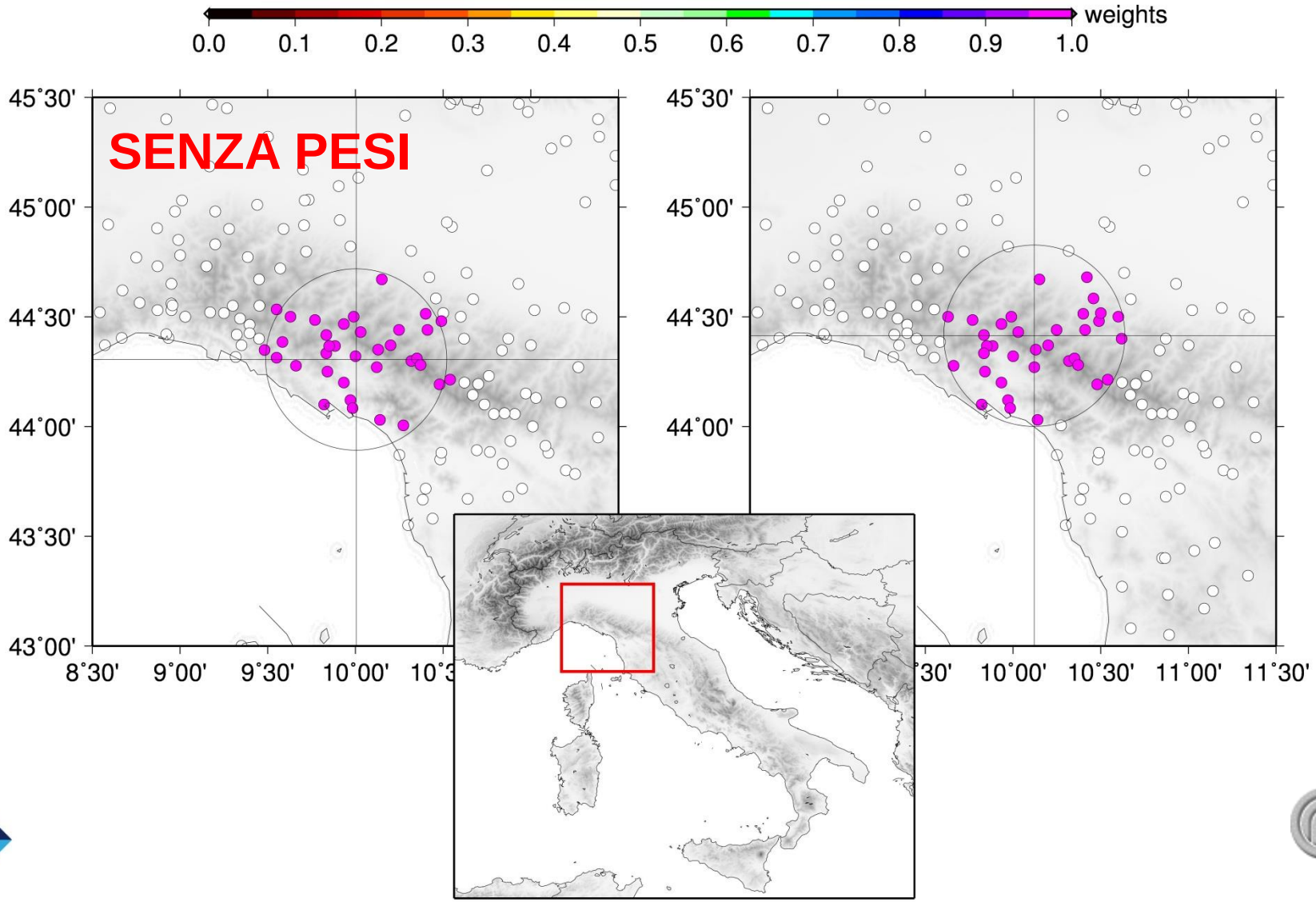




$$w_i(x,y) = w_i^{rad}(x,y) \cdot w_i^{h}(x,y) \cdot w_i^{St}(x,y) \cdot w_i^{facet}(x,y) \cdot w_i^{sea}(x,y)$$

# L'IMPORTANZA DEI PESI



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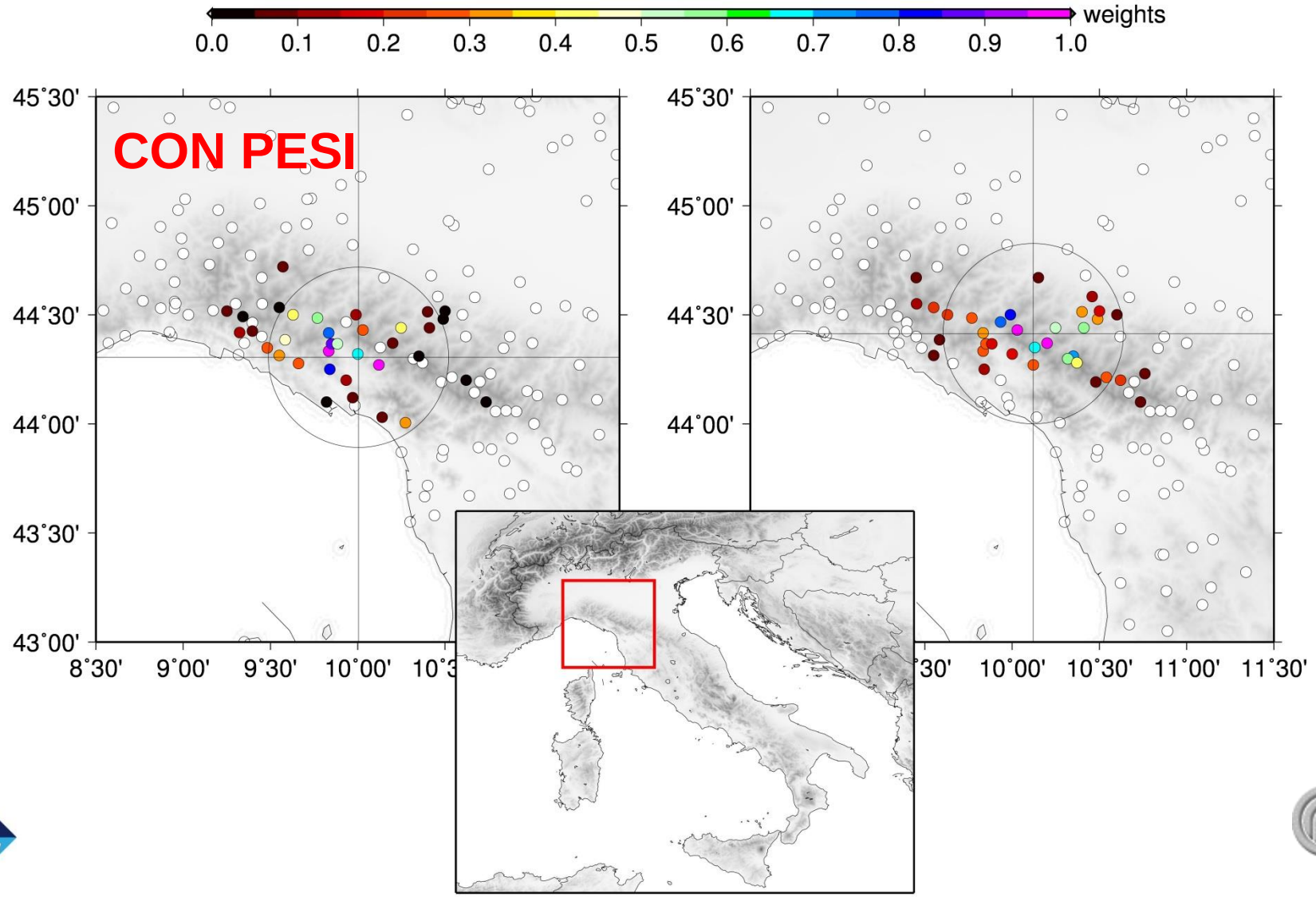

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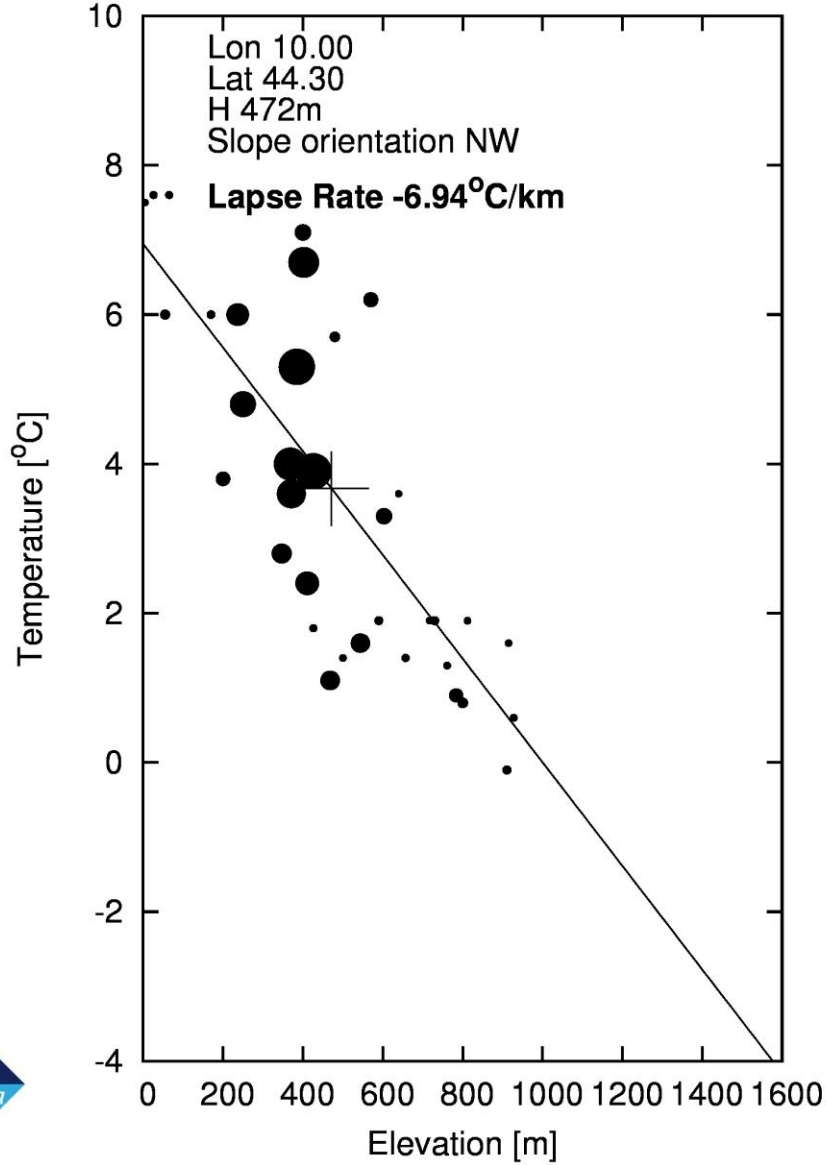
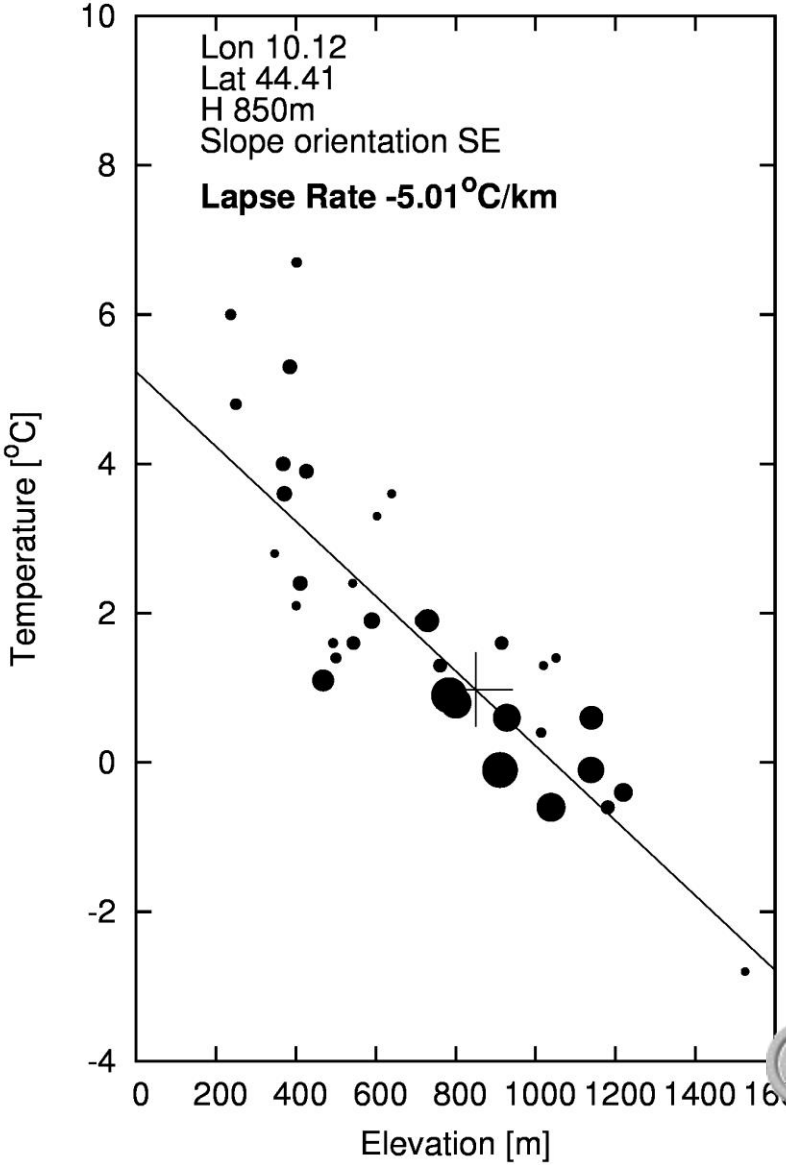
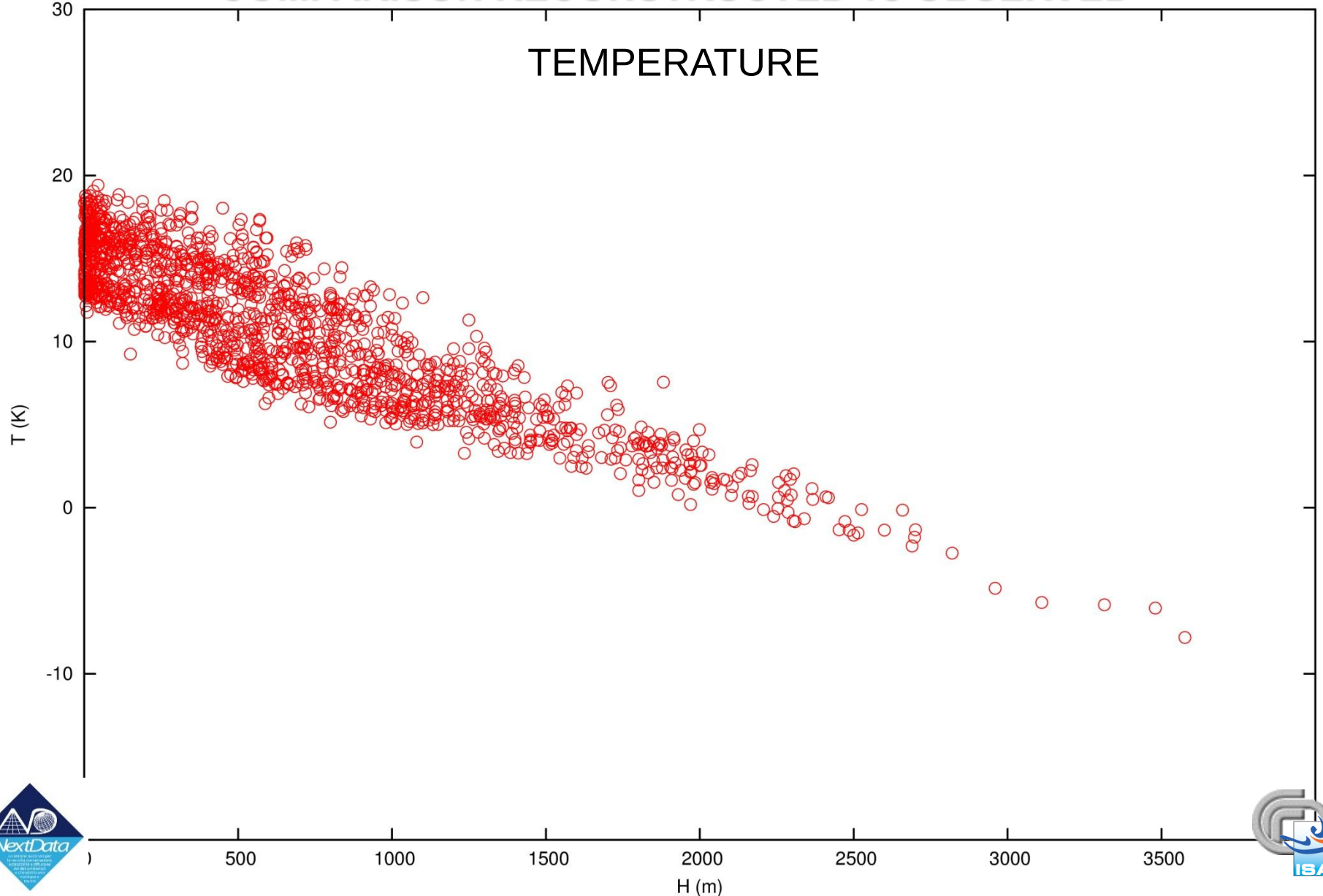


# VALUTAZIONE DELLE PRESTAZIONI

## COMPARISON RECONSTRUCTED vs OBSERVED



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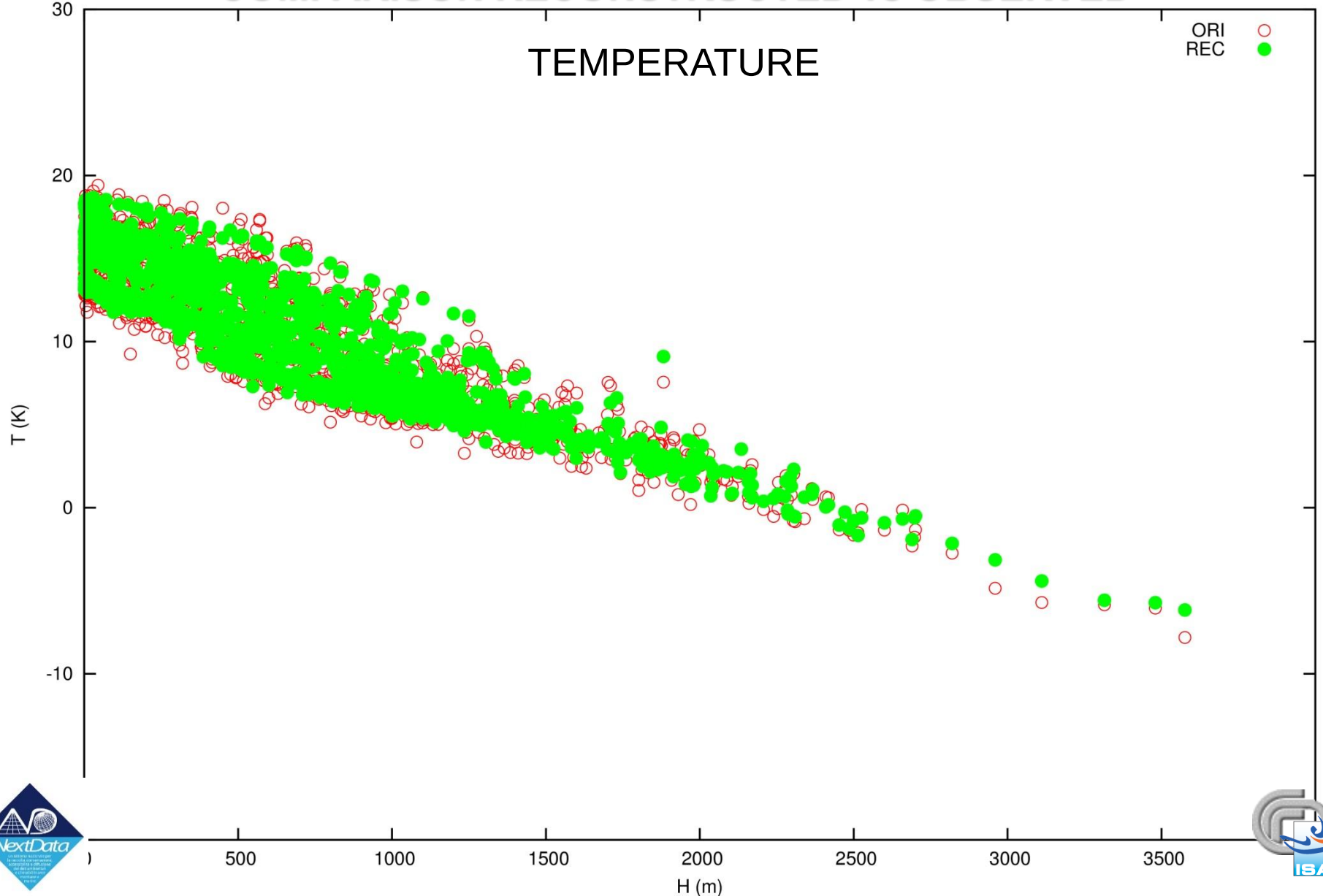
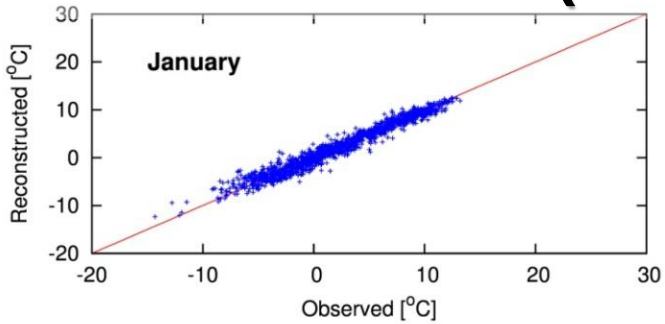
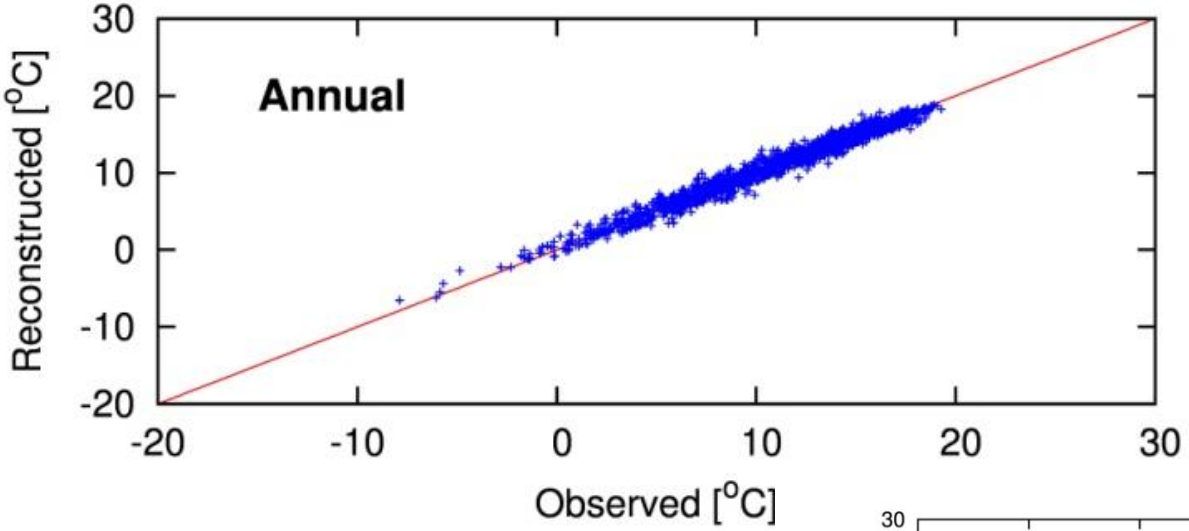
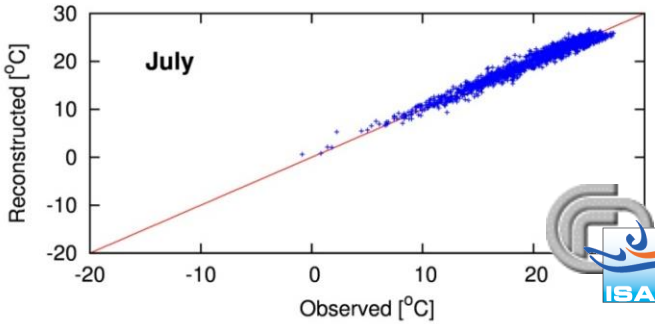


# RICOSTRUITO vs OSSERVATO
# (Tecnica leave-one-out)



# STIMA ERRORI (Tecnica leave-one-out)

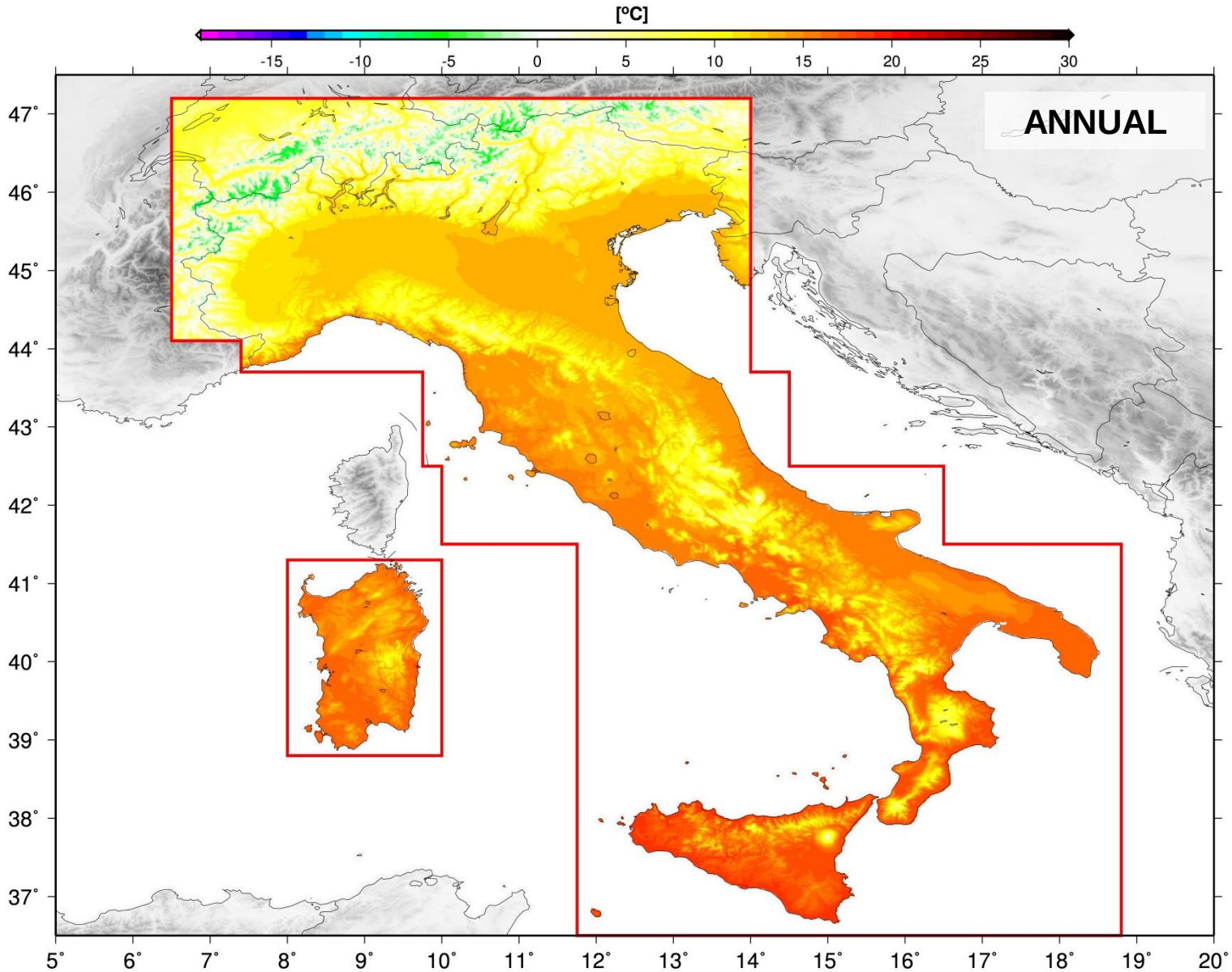
$$MAE = \frac{\sum_{i=1}^{N} \left| P_i^{est} - P_i^{obs} \right|}{N}$$

$$BIAS = \frac{\sum_{i=1}^{N} \left( P_i^{est} - P_i^{obs} \right)}{N}$$

$$RMSE = \sqrt{\frac{\sum_{i=1}^{N} \left( P_i^{est} - P_i^{obs} \right)^2}{N}}$$

| | MAE | BIAS | RMSE | $R^2$ |
|---|---|---|---|---|
| 1 | 0.772 | -0.037 | 1.013 | 0.960 |
| 2 | 0.691 | -0.035 | 0.896 | 0.965 |
| 3 | 0.603 | -0.029 | 0.781 | 0.971 |
| 4 | 0.578 | -0.026 | 0.738 | 0.973 |
| 5 | 0.585 | -0.018 | 0.740 | 0.972 |
| 6 | 0.619 | -0.011 | 0.790 | 0.970 |
| 7 | 0.665 | -0.016 | 0.847 | 0.967 |
| 8 | 0.654 | -0.017 | 0.835 | 0.970 |
| 9 | 0.617 | -0.021 | 0.791 | 0.971 |
| 10 | 0.629 | -0.025 | 0.807 | 0.969 |
| 11 | 0.673 | -0.031 | 0.864 | 0.969 |
| 12 | 0.782 | -0.038 | 1.027 | 0.960 |
| Y | 0.583 | -0.025 | 0.742 | 0.974 |

# LE CLIMATOLOGIE



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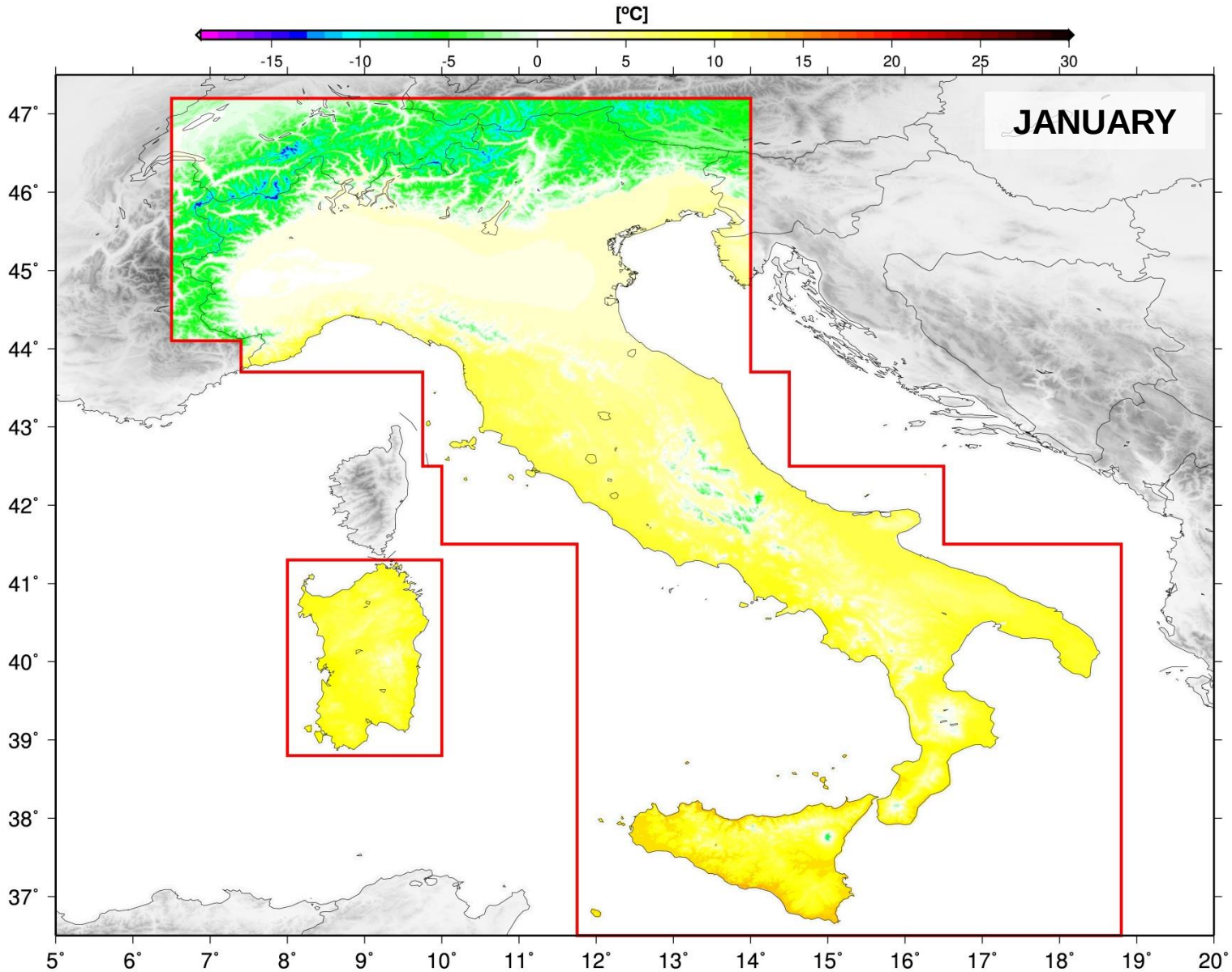

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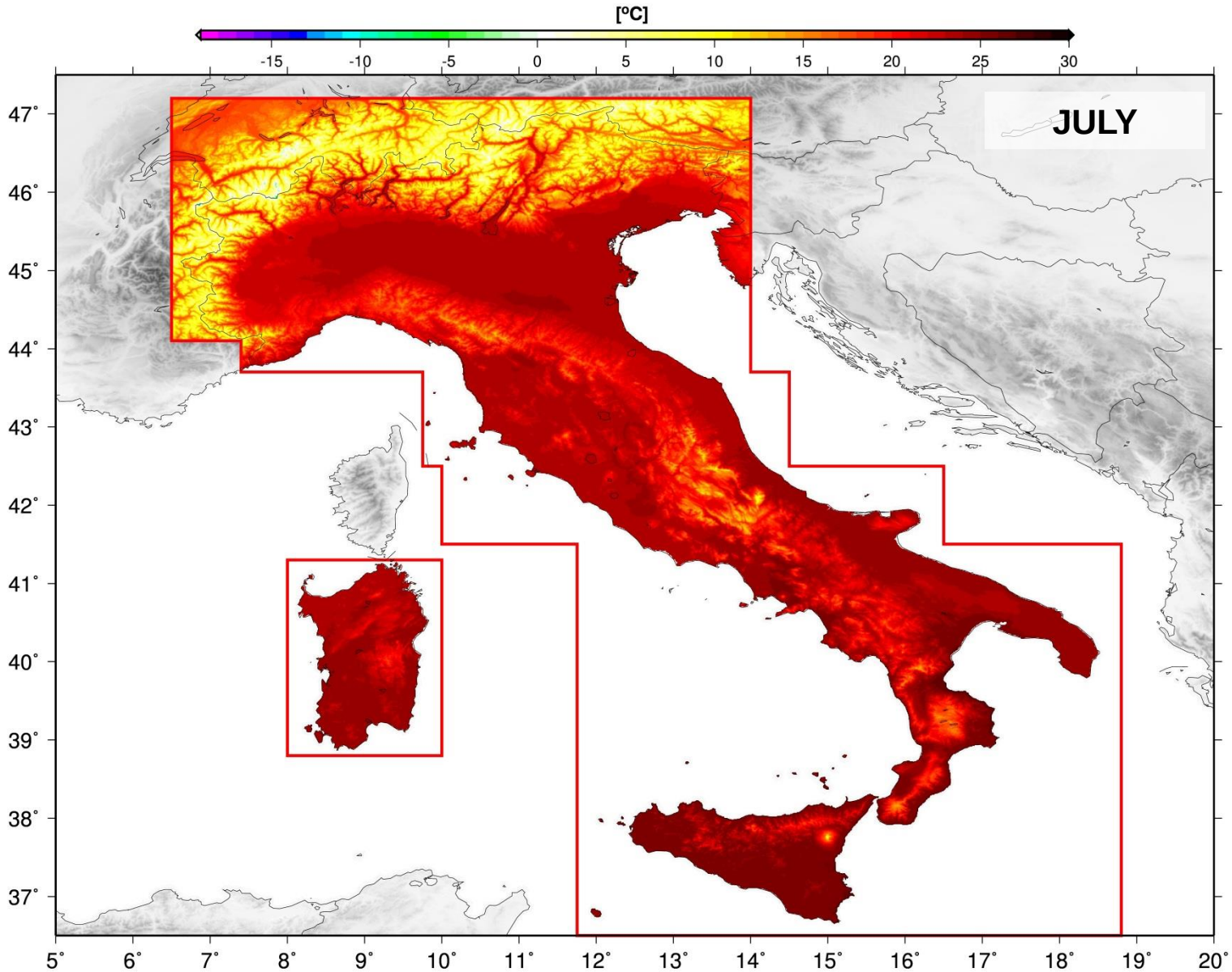


# INTERVALLO DI CONFIDENZA

IMPORTANT ADVANTAFGE OF **LWLR**: **CONFIDENCE INTERVAL**

$$S^2 = MSE + \frac{MSE}{\sum_{i=1}^{N} w_i} + MSE \frac{\left(h-\bar{h}\right)^2}{\sum_{i=1}^{N} w_i \left(h_i - \bar{h}\right)^2}$$

UNCERTANTY IN THE COEFFICIENT ESTIMATION

MEAN SQUARE ERROR

$$MSE = \frac{\sum_{i=1}^{N} w_i [T_i - T(x,y)]^2}{\sum_{i=1}^{N} w_i} \cdot \frac{N}{N-2}$$

UNCERTANTY IN THE MEAN VALUE ESTIMATION OF THE PREDICTAND FROM A FINITE SAMPLE

$w_i$ WEIGHTS

$\bar{h}$ WEIGHTED MEAN ELEVATION OF THE REGRESSION DATA SET

$h$ ELEVATION AT WHICH THE PARAMETER IS ESTIMATED

$h_i$ ELEVATION OF THE I$^{TH}$ STATION

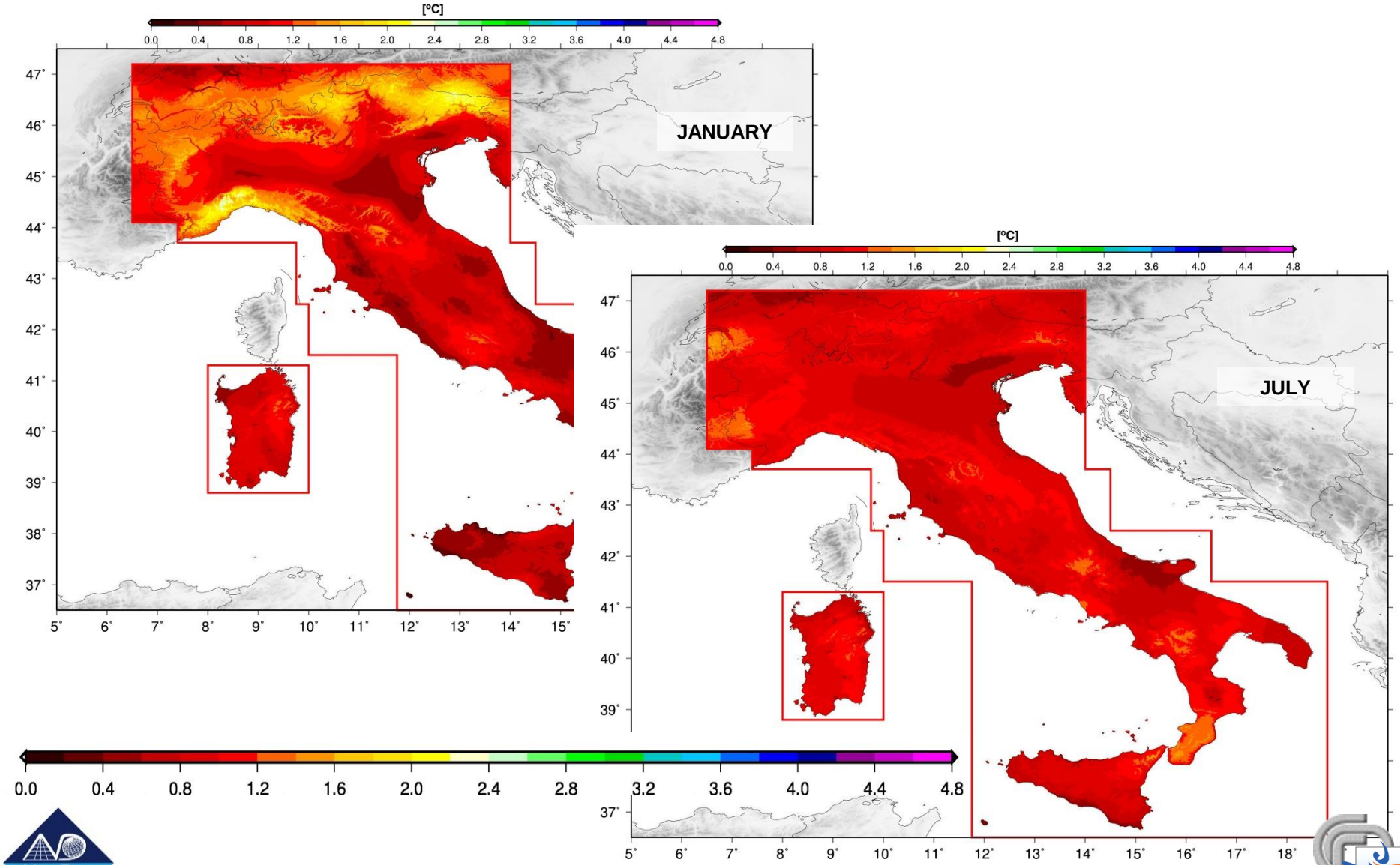
The prediction interval for the grid-point with elevation h is

$$T_h \pm t_{\frac{1-\alpha}{2},df} \cdot s\{T_h\}$$

where t is the value of a Student distribution with *df* degrees of freedom corresponding to cumulative probability (1-α)/2.

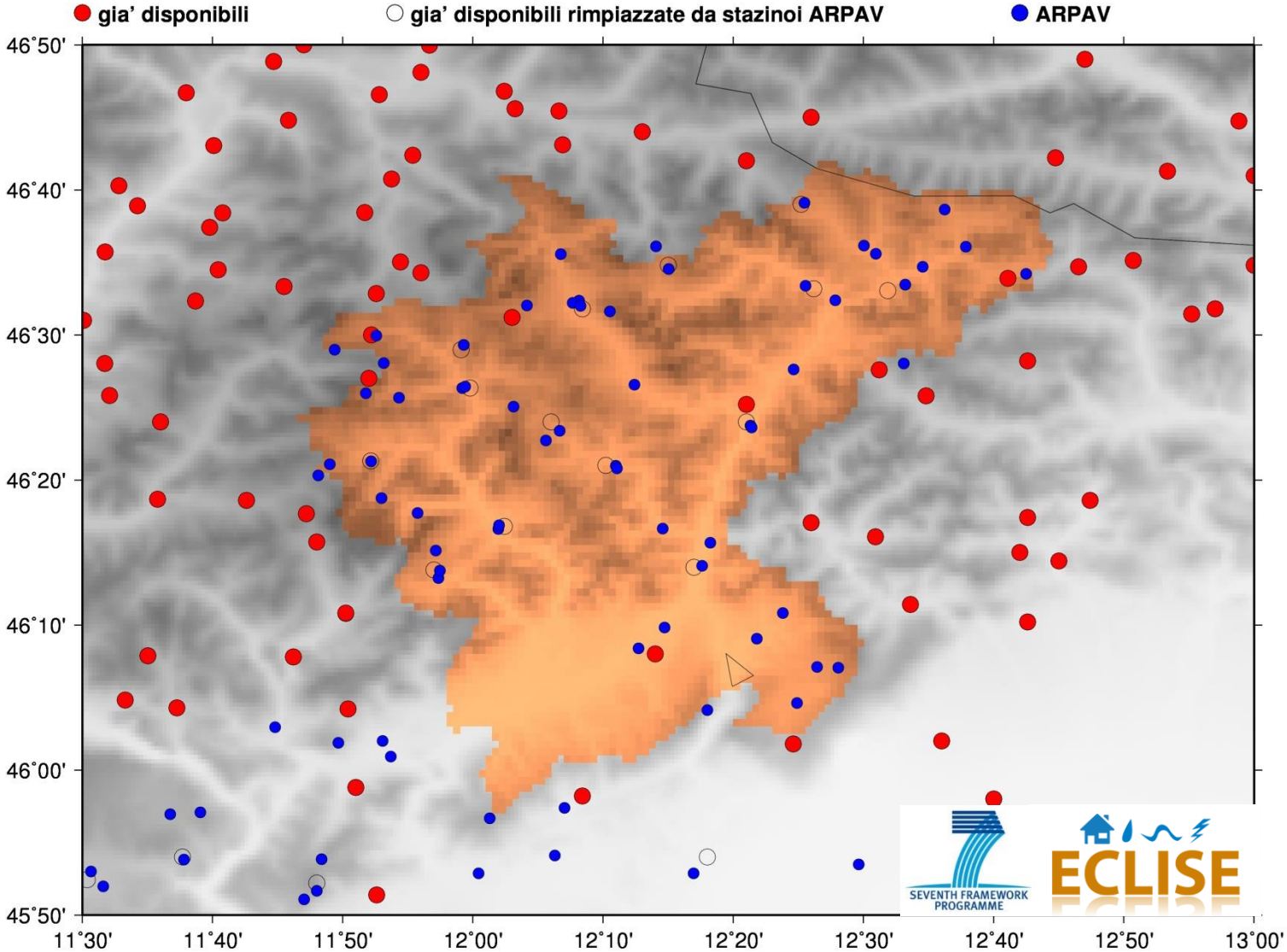
# INTERVALLO DI CONFIDENZA

α=0.6827



# ALCUNI RISULTATI

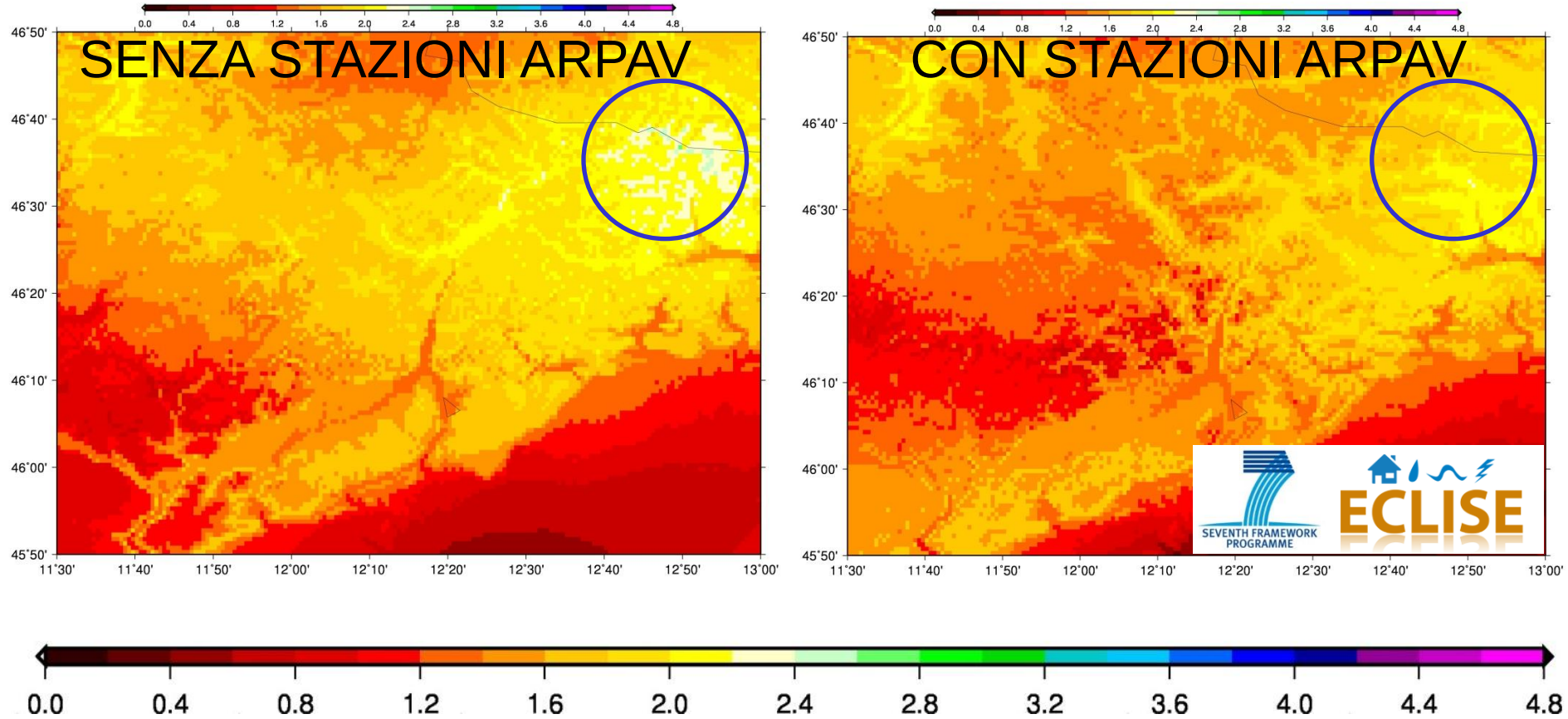
## Migliorando la disponibilità di dati...



# ALCUNI RISULTATI

## …migliora la qualità della ricostruzione e la confidenza sui risultati

**INTERVALLO DI CONFIDENZA** α=0.6827




La disponibilità delle stazioni di ARPA Veneto ha permesso un miglioramento dell'intervallo di confidenza.
Questo è particolarmente evidente nelle zone di alta quota, grazie soprattutto alla maggior rappresentatività delle stazioni ARPAV per quelle aree.

# COSTRUZIONE DELLE ANOMALIE

# COSTRUZIONE DELLE ANOMALIE

Thanks to the high spatial coherence of temporal fluctuations of meteorological variables, anomalies can be reconstructed on each point of a high resolution grid with a quite simple method.

$$w_i^{rad}(x,y) = e^{-\left(\frac{d_i^2(x,y)}{c_{rad}}\right)}$$

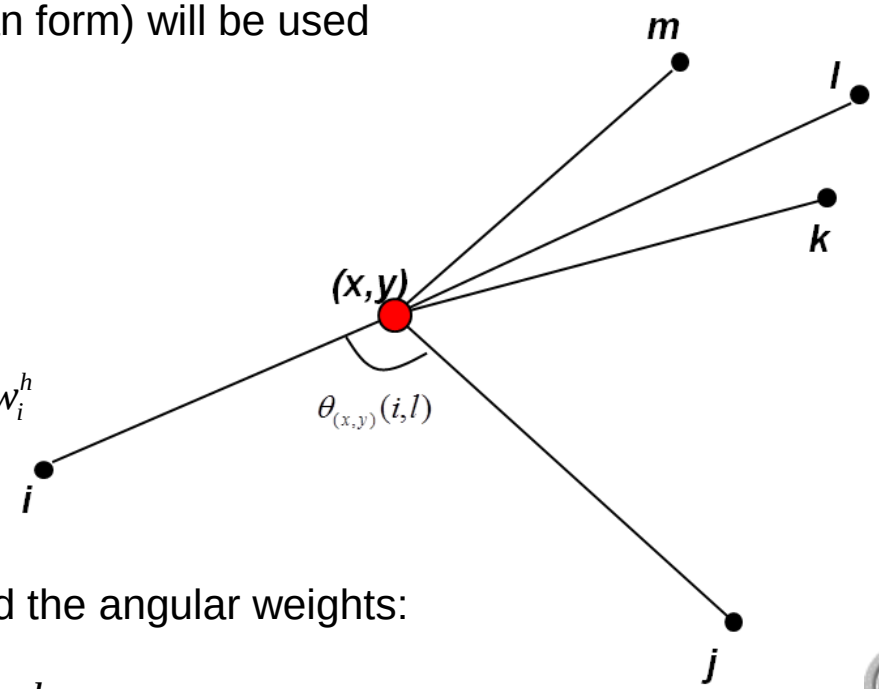
An inverse horizontal distance weighting function (of Gaussian form) will be used

$$w_i^{h}(x,y) = e^{-\left(\frac{\Delta h_i^2(x,y)}{c_h}\right)}$$

An inverse elevation distance weighting function (of Gaussian form) will be used

An angular weight is also used to take into account spatial anisotropy in station location:

$$w_i^{ang}(x,y) = 1 + \frac{\sum_{i=1}^{n} w_i^{'}\left[1-\cos\theta_{(x,y)}(i,l)\right]}{\sum_{i=1}^{n} w_i^{'}(x,y)}; \quad w_i^{'} = w_i^{rad} w_i^{h}$$



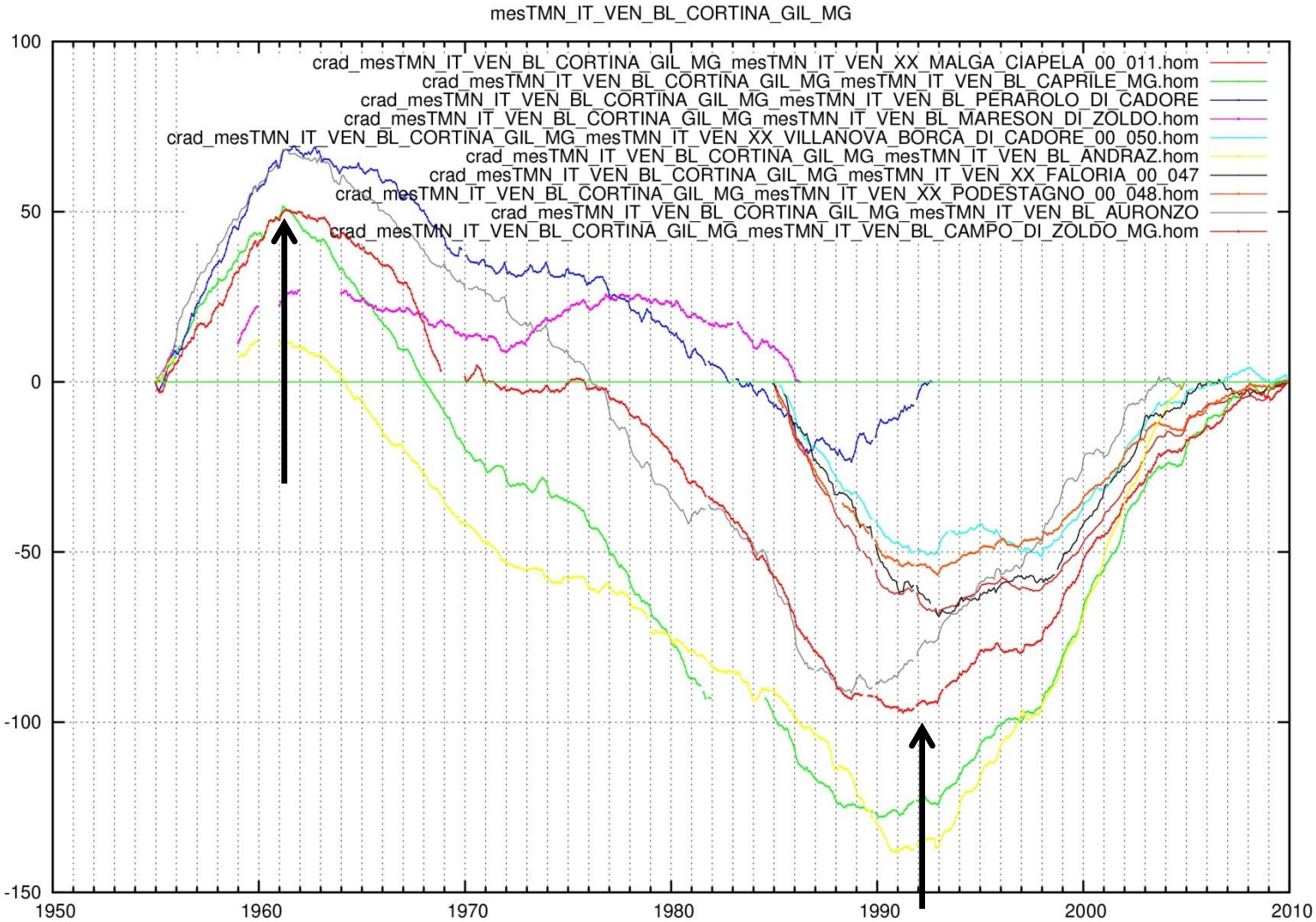

The final weight is the product of the radial and the angular weights:

$$w_i(x,y) = w_i^{rad}(x,y) \cdot w_i^{h}(x,y) \cdot w_i^{ang}(x,y)$$

# COSTRUZIONE DELLE ANOMALIE

## OMOGENEIZZAZIONE DELLE SERIE AVENTI SUFFICIENTE ESTENSIONE TEMPORALE

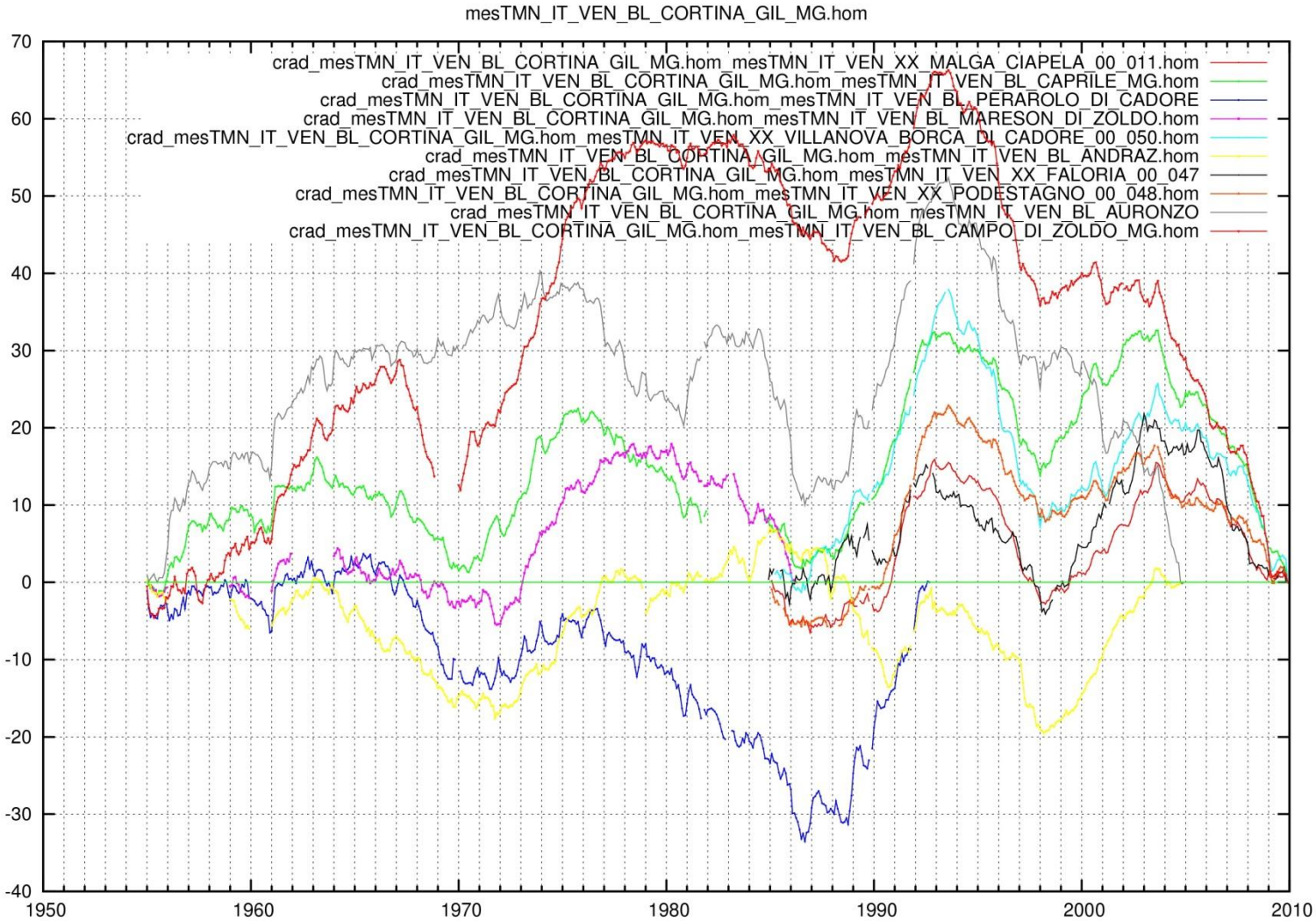
### CORTINA
### MERGING TRA CORTINA (1951-1992) E CORTINA GIL (1993-2009)



# COSTRUZIONE DELLE ANOMALIE

## OMOGENEIZZAZIONE DELLE SERIE AVENTI SUFFICIENTE ESTENSIONE TEMPORALE

### CORTINA



# ALCUNI RISULTATI

Let's show an example of the method. Let's suppose that we have to estimate a secular **temperature** record for the following point:

Latitude: 45.05 N; Longitude: 11.77 E; height: 9 m (i.e. Rovigo).

Step 1)

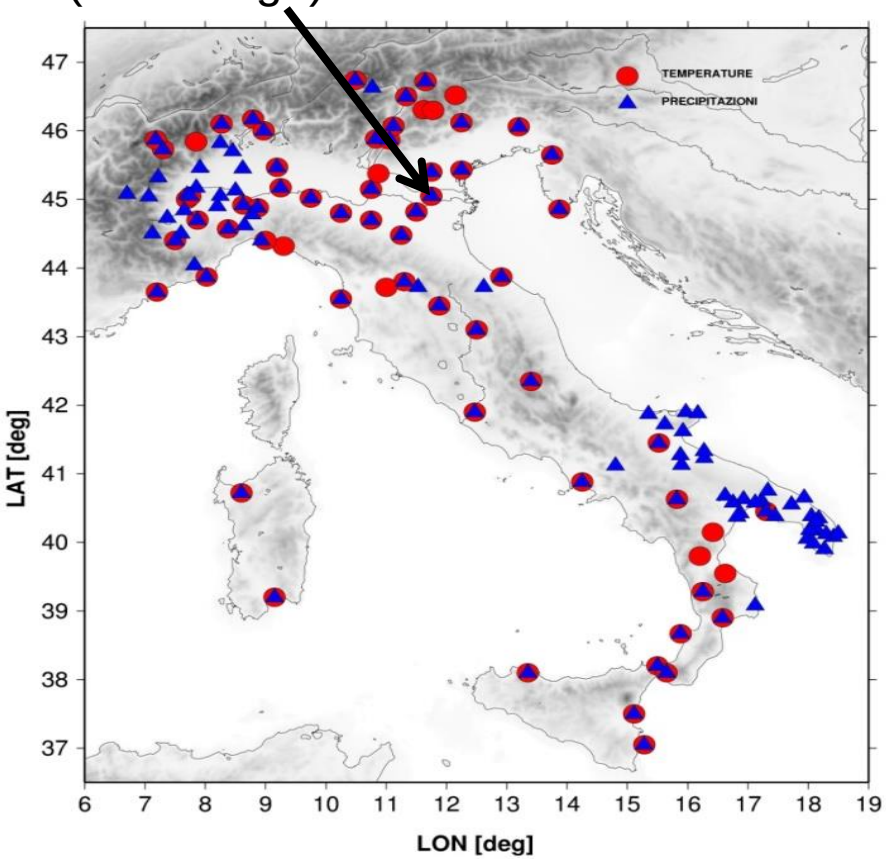
An anomalies **temperature** series is calculated for the grid point by means of the neighboring stations (excluding Rovigo from the dataset!!)

Step 2)

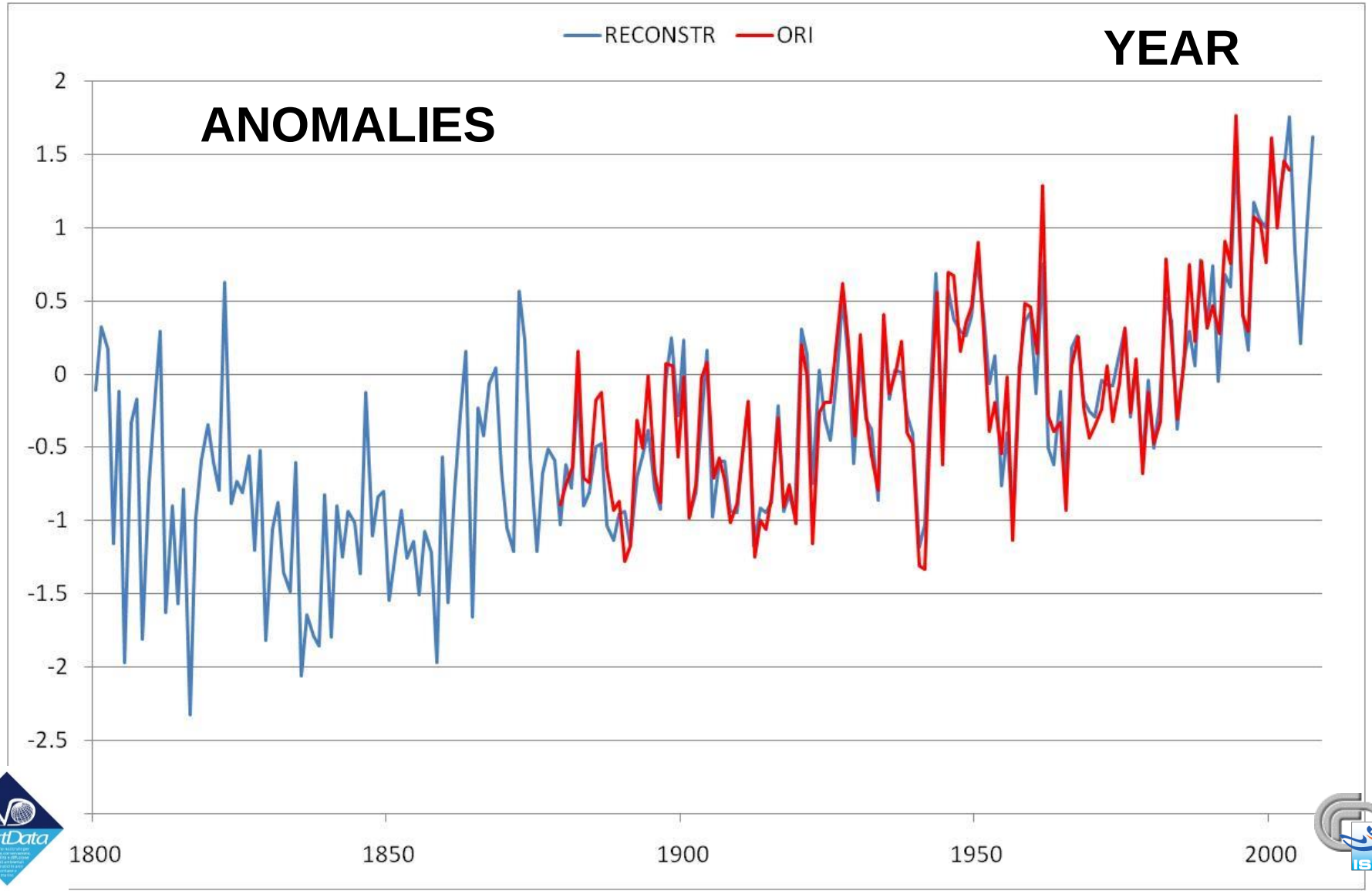
The 1961-1990 monthly normals are estimated by means of the **temperature/elevation model** (excluding Rovigo from the dataset!!).

Step 3)

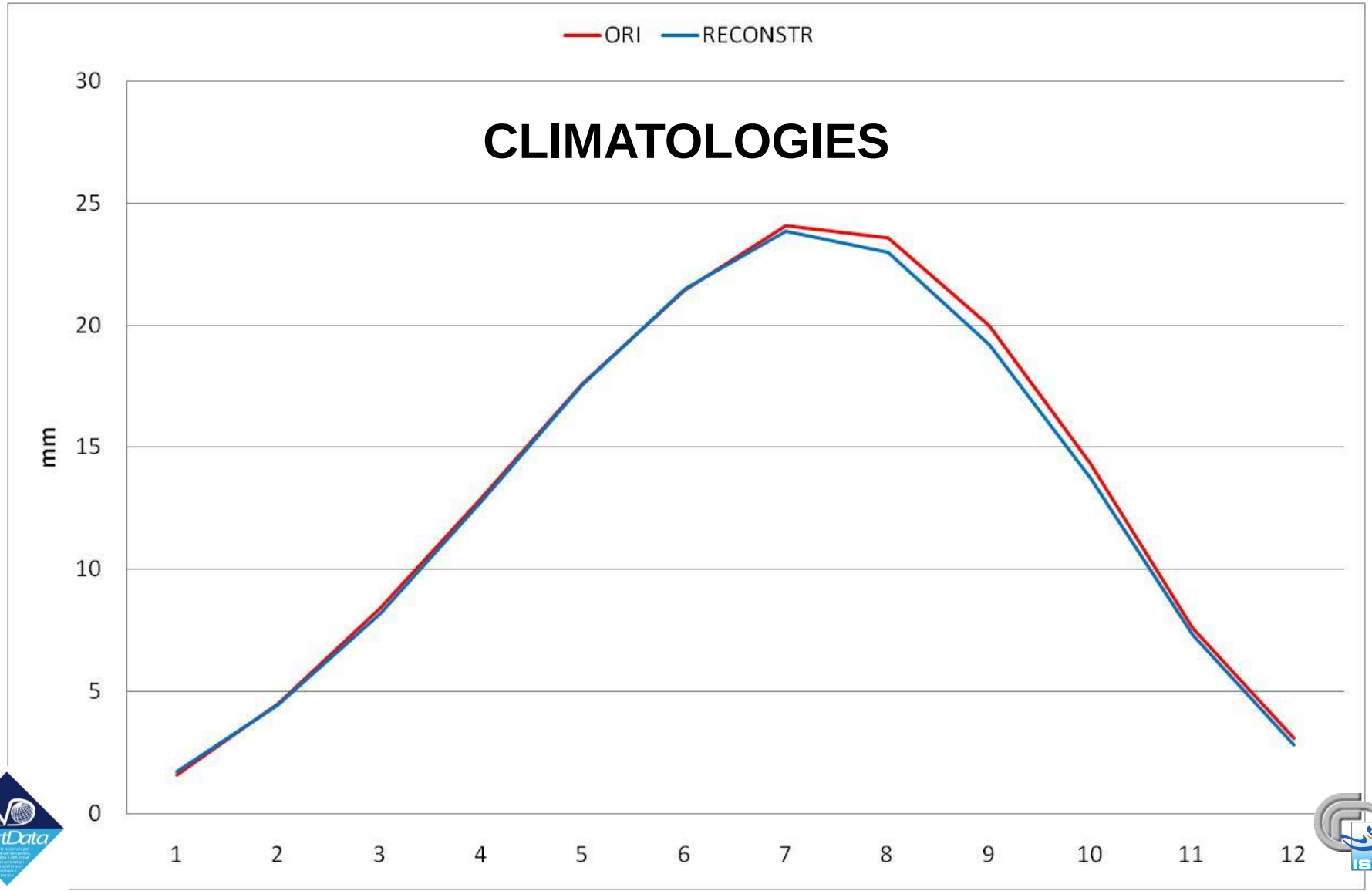
The 1961-1990 monthly normals are **added** to each corresponding monthly value of the anomalies series to finally get the absolute value series



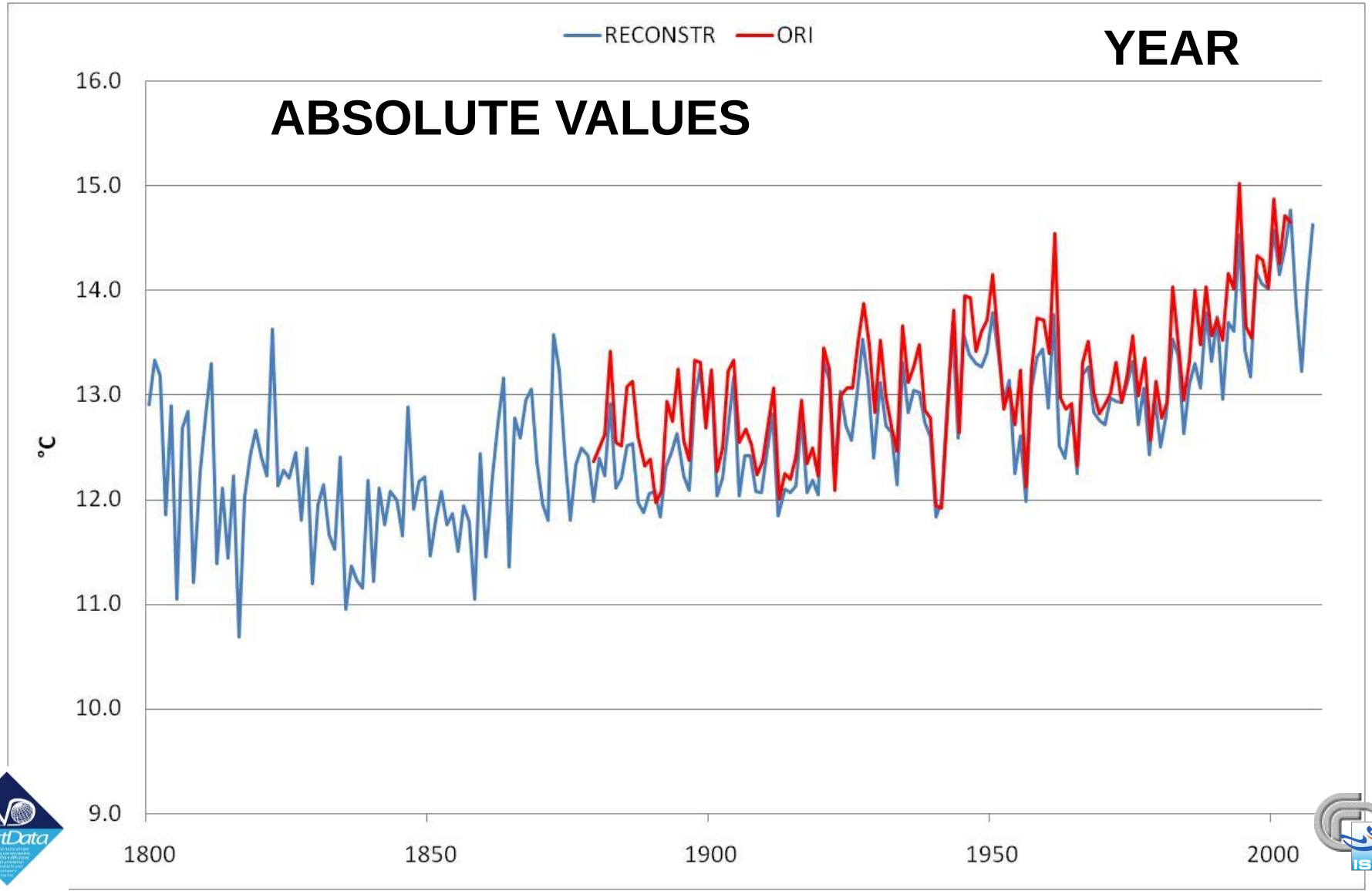
# ALCUNI RISULTATI



# ALCUNI RISULTATI



# ALCUNI RISULTATI



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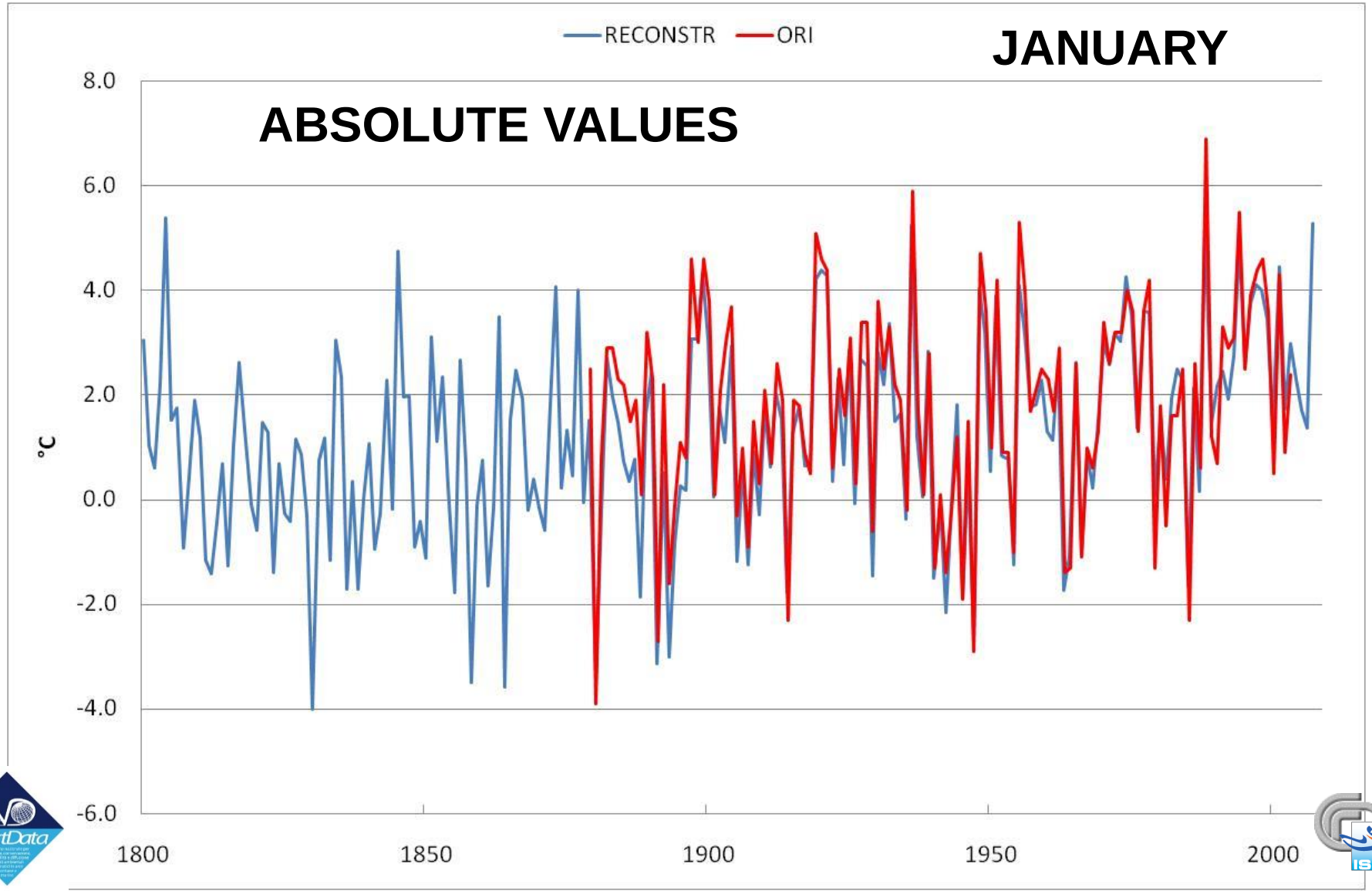
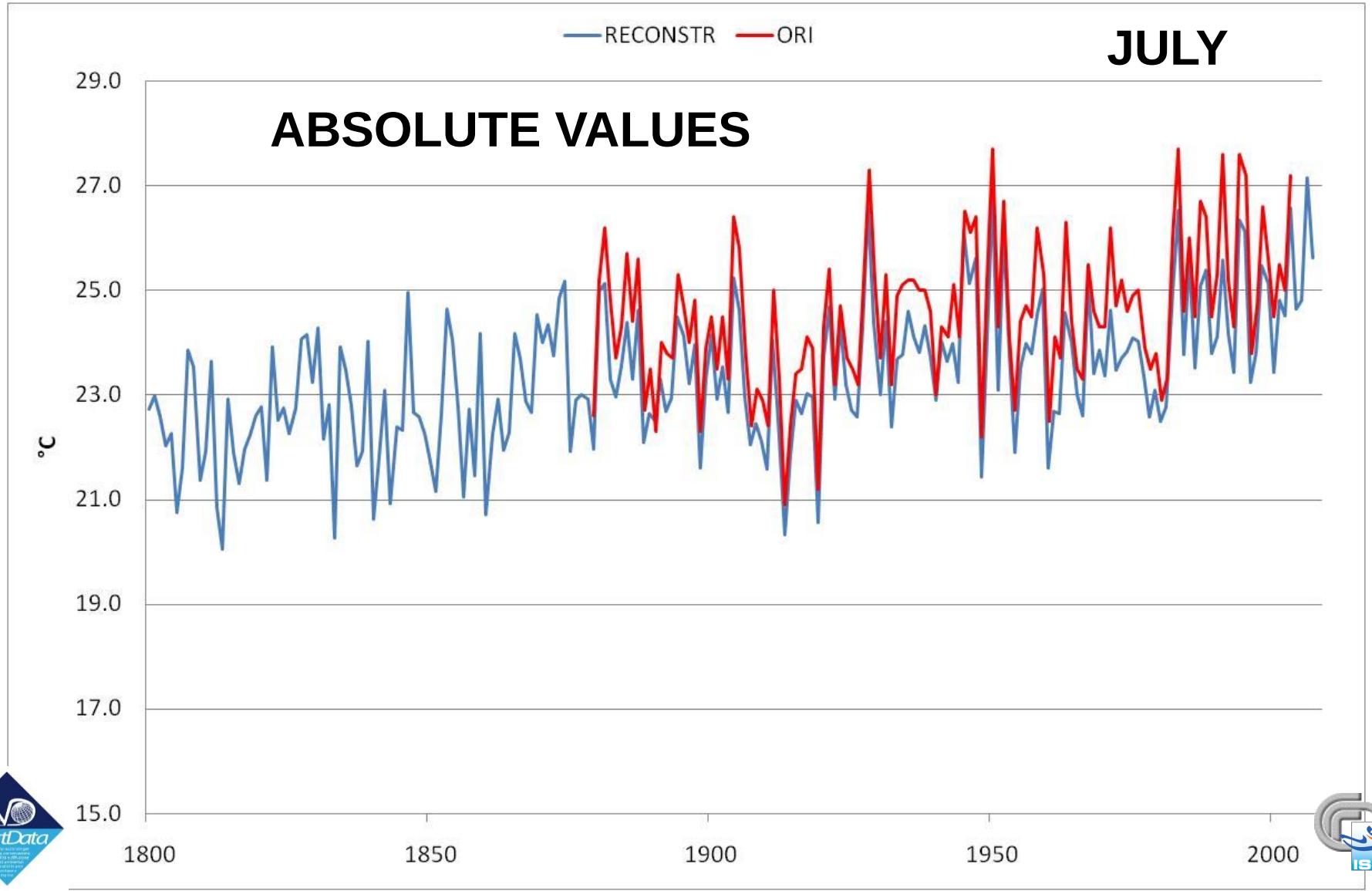
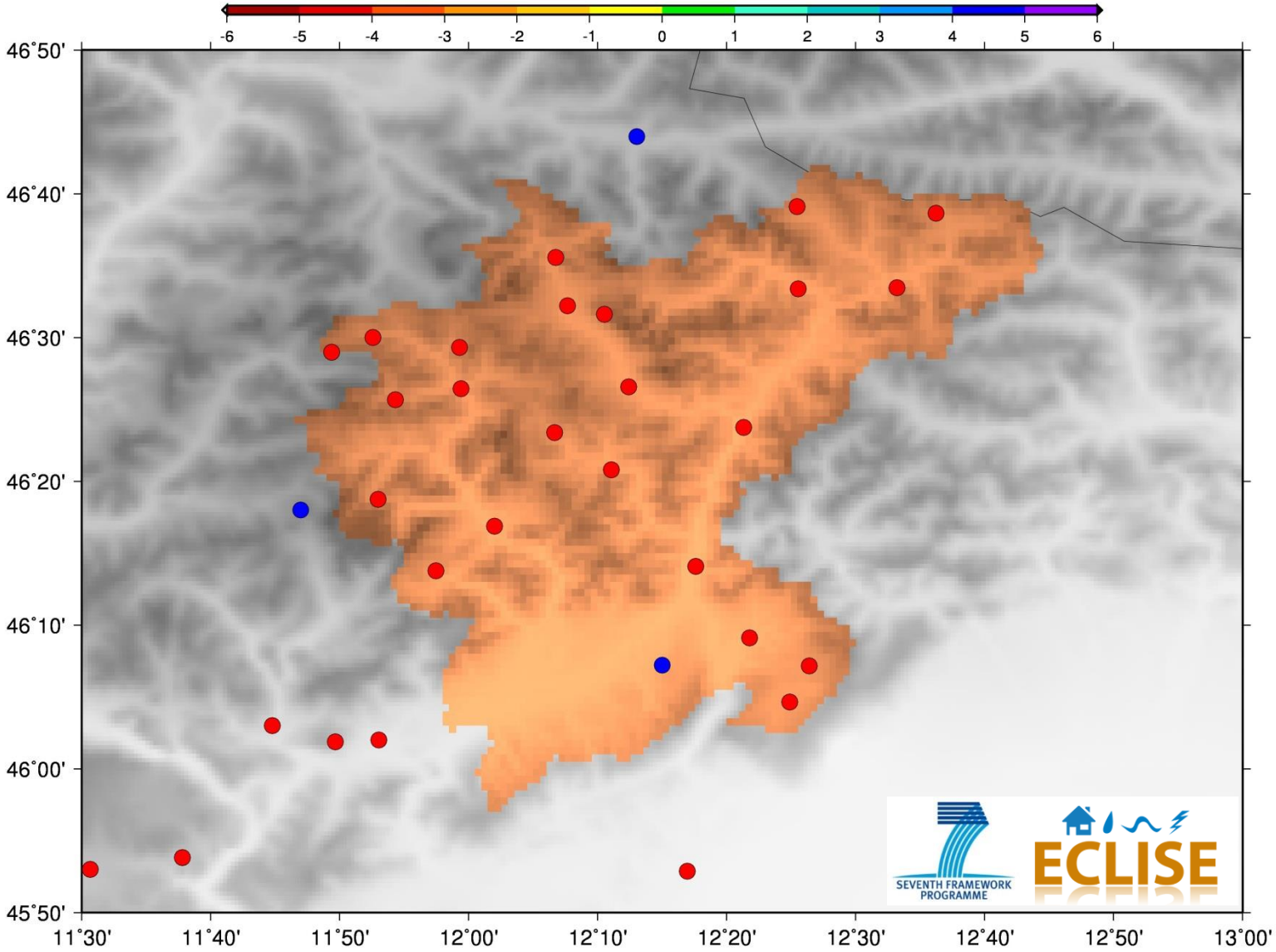


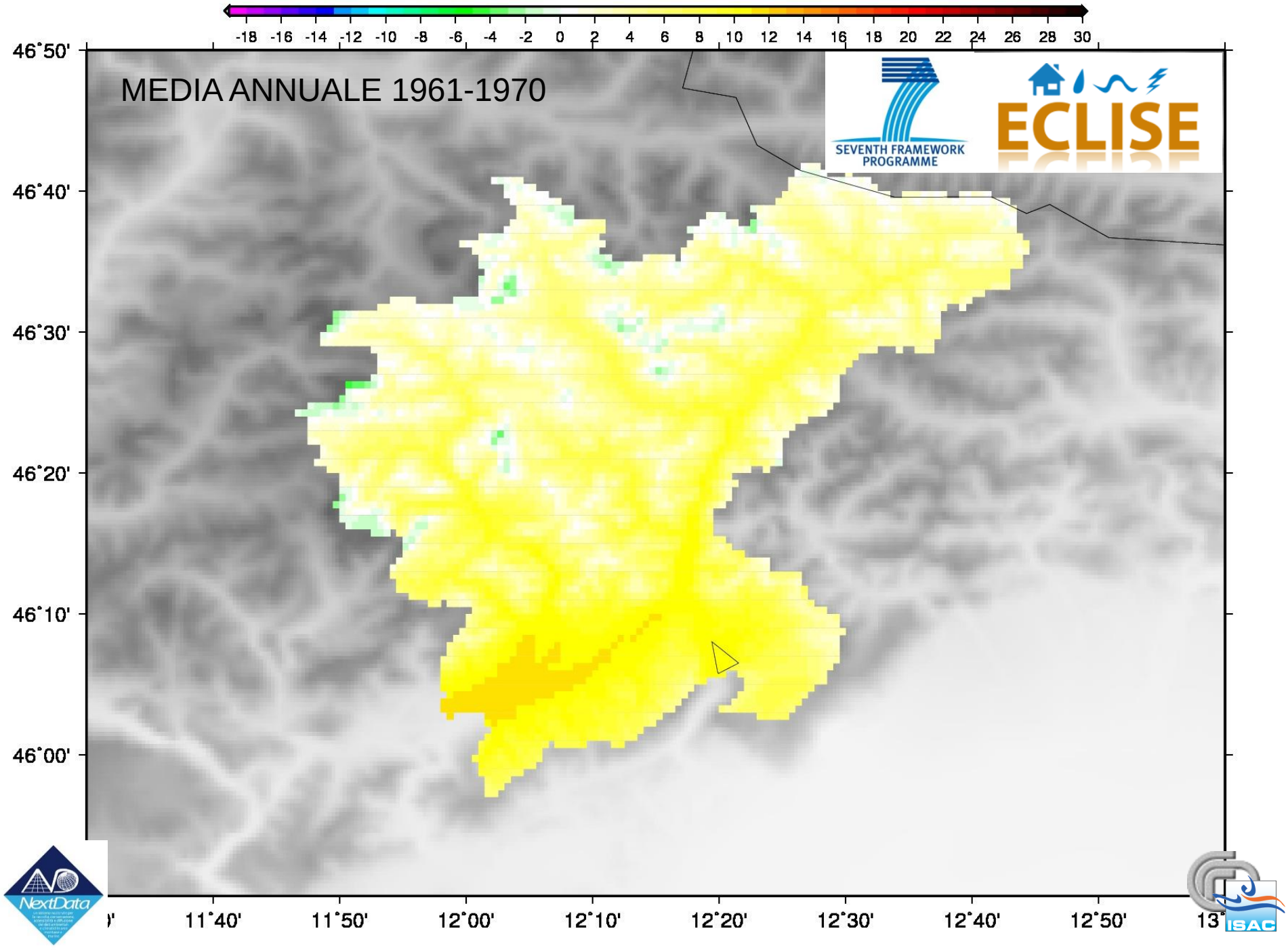
# ALCUNI RISULTATI

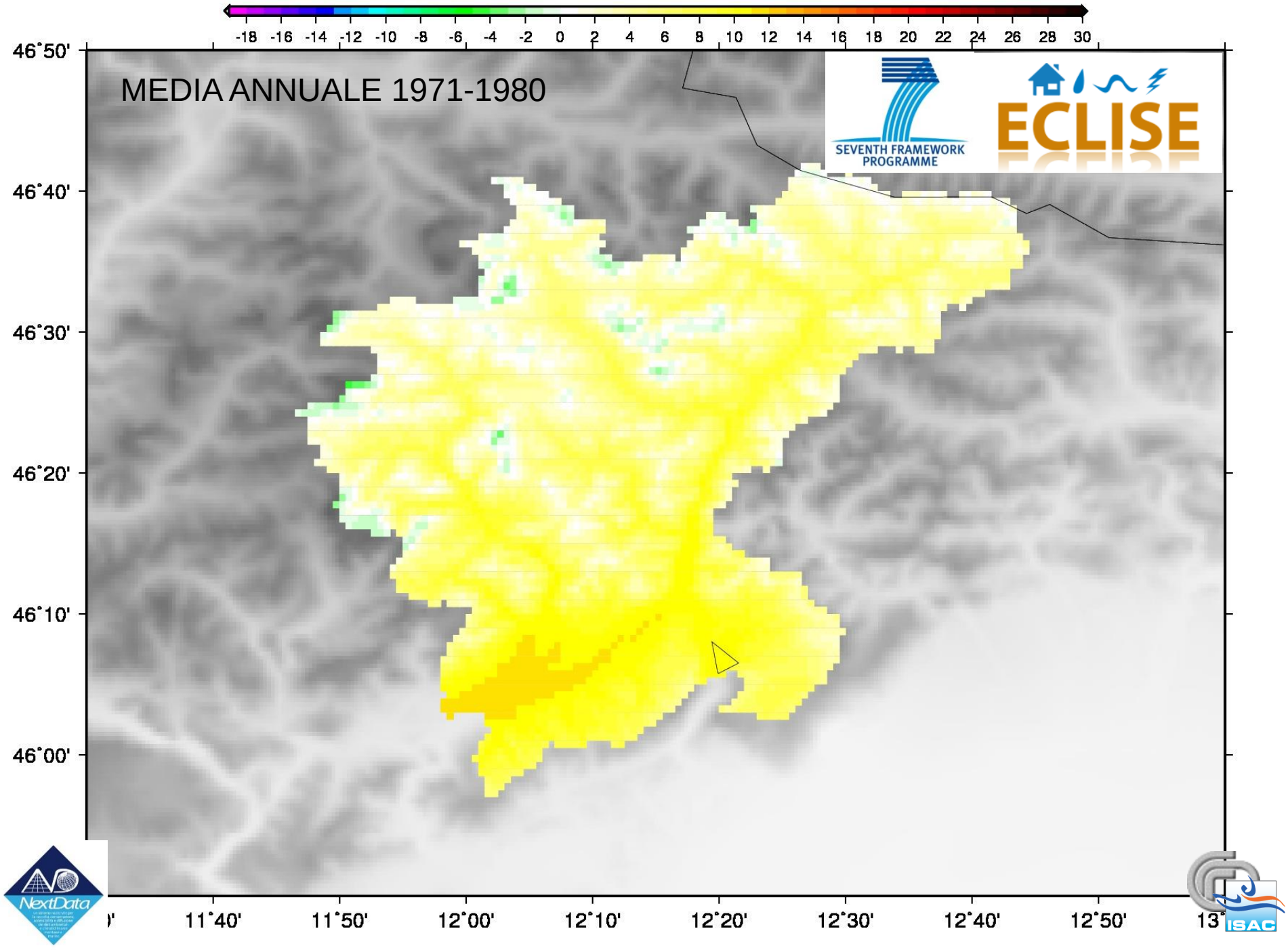


# COSTRUZIONE DELLE ANOMALIE

## SERIE AVENTI SUFFICIENTE ESTENSIONE TEMPORALE UTILIZZATE PER LA COSTRUZIONE DELLE ANOMALIE




MEDIA ANNUALE 1961-1970
-18 -16 -14 -12 -10 -8 -6 -4 -2 0 2 4 6 8 10 12 14 16 18 20 22 24 26 28 30
46°50'
46°40'
46°30'
46°20'
46°10'
46°00'
11°40'
11°50'
12°00'
12°10'
12°20'
12°30'
12°40'
12°50'
SEVENTH FRAMEWORK PROGRAMME
ECLISE
NextData
ISAC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-18 -16 -14 -12 -10 -8 -6 -4 -2 0 2 4 6 8 10 12 14 16 18 20 22 24 26 28 30
46°50'
46°40'
46°30'
46°20'
46°10'
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11°40'
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SEVENTH FRAMEWORK PROGRAMME
ECLISE
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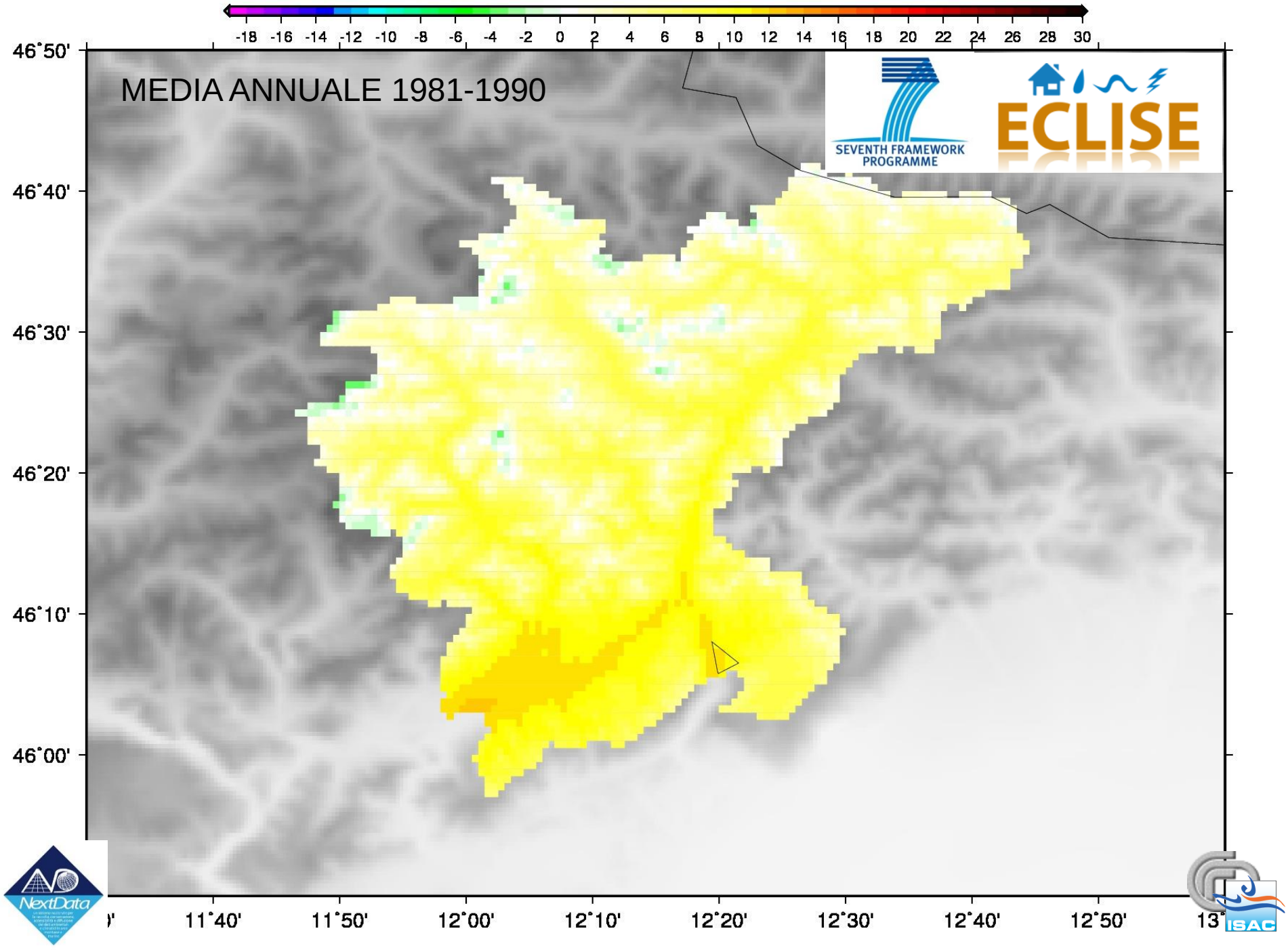
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SEVENTH FRAMEWORK PROGRAMME
ECLISE
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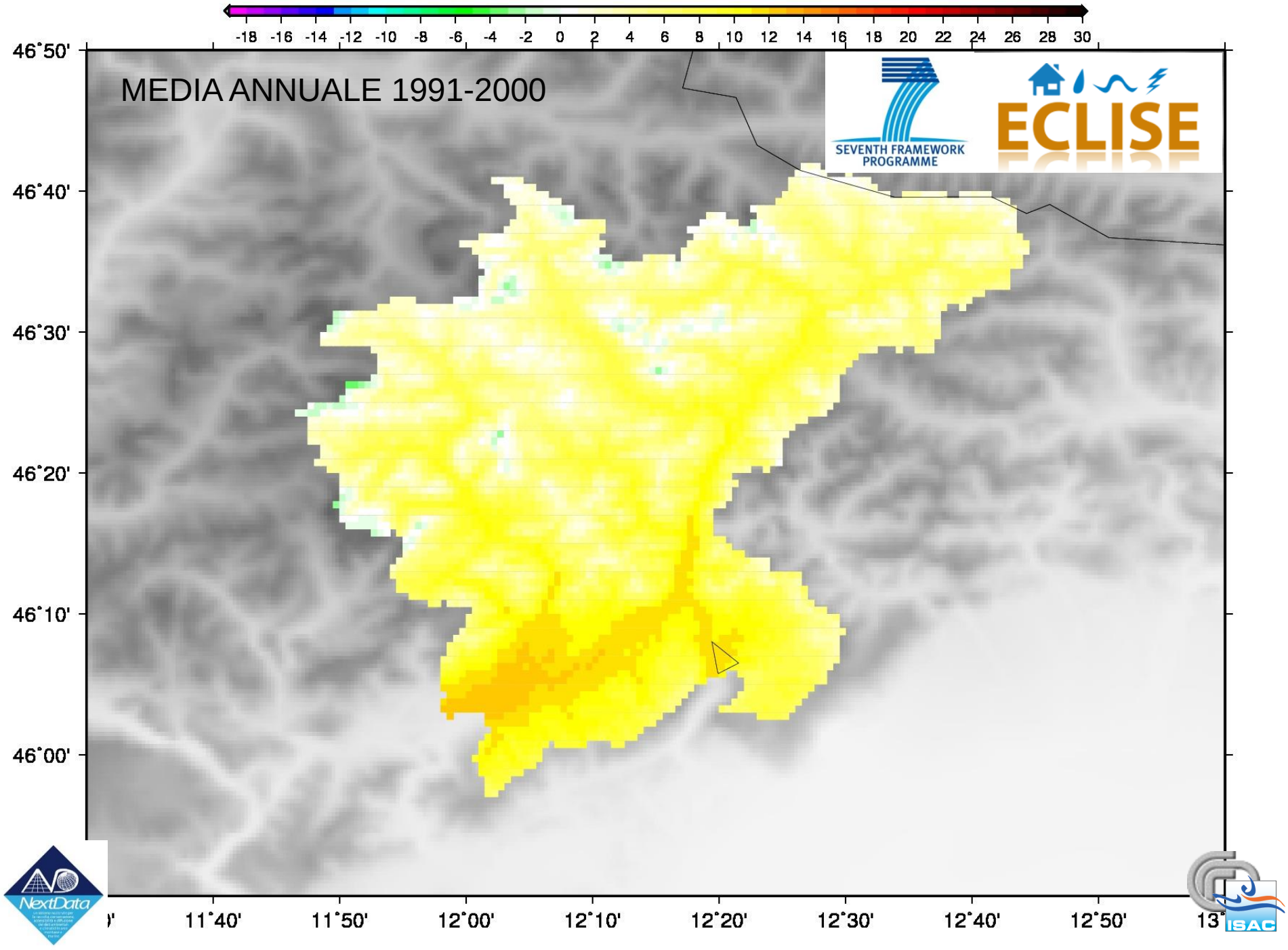
MEDIA ANNUALE 1991-2000
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SEVENTH FRAMEWORK PROGRAMME
ECLISE
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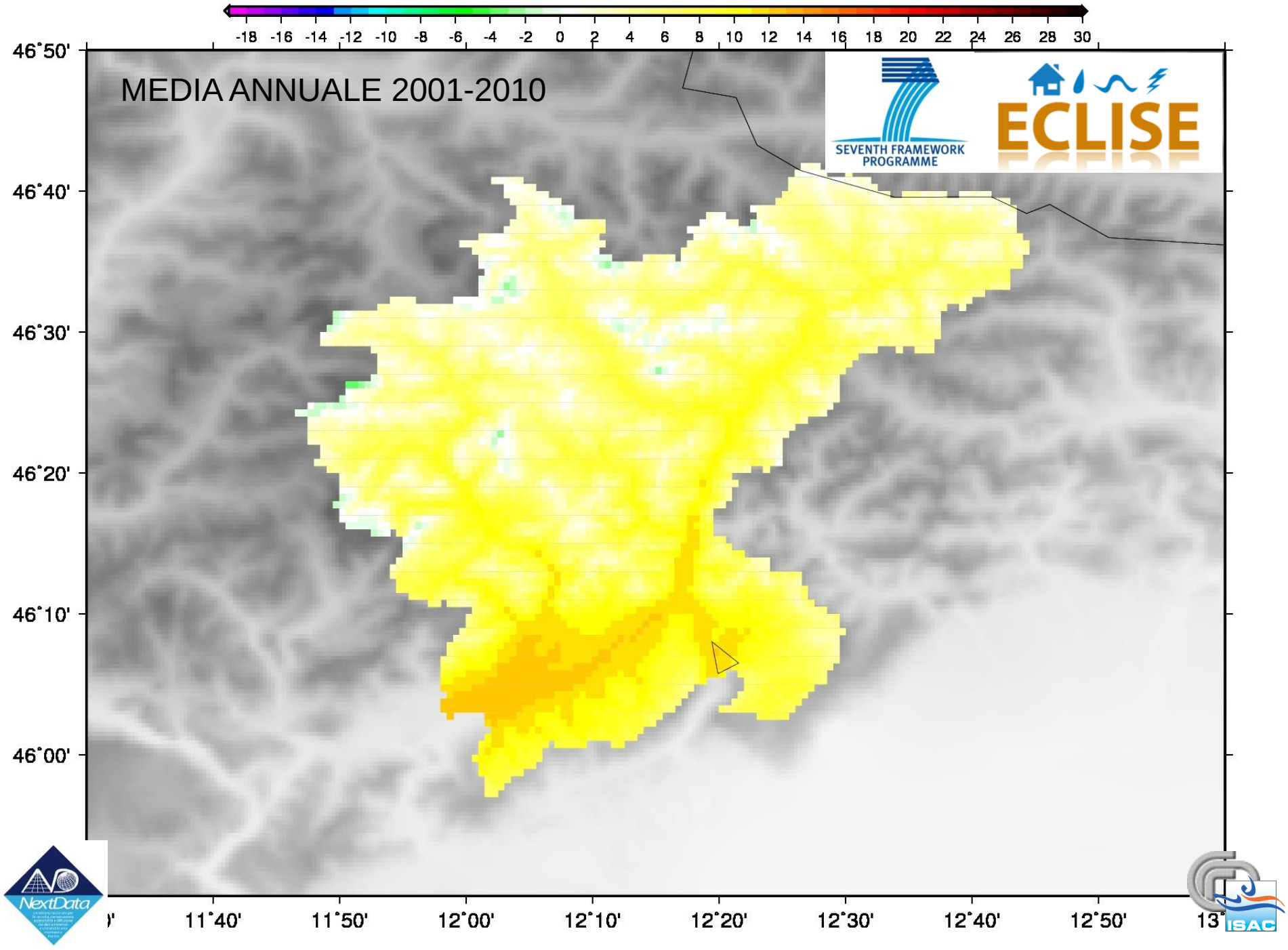
ISAC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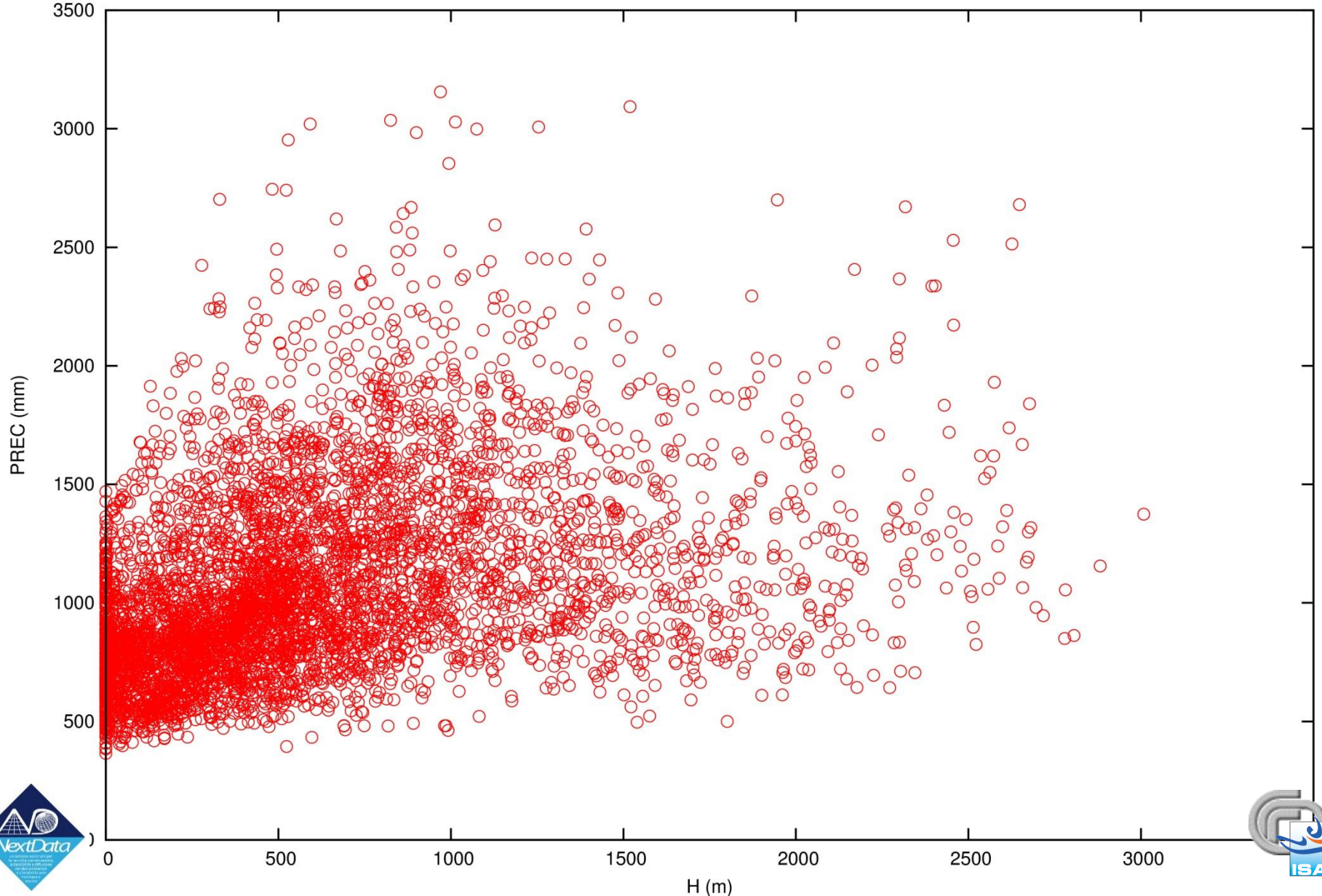
12°10'
12°20'
12°30'
12°40'
12°50'
SEVENTH FRAMEWORK PROGRAMME
ECLISE
NextData
ISAC

# PRECIPITAZIONI

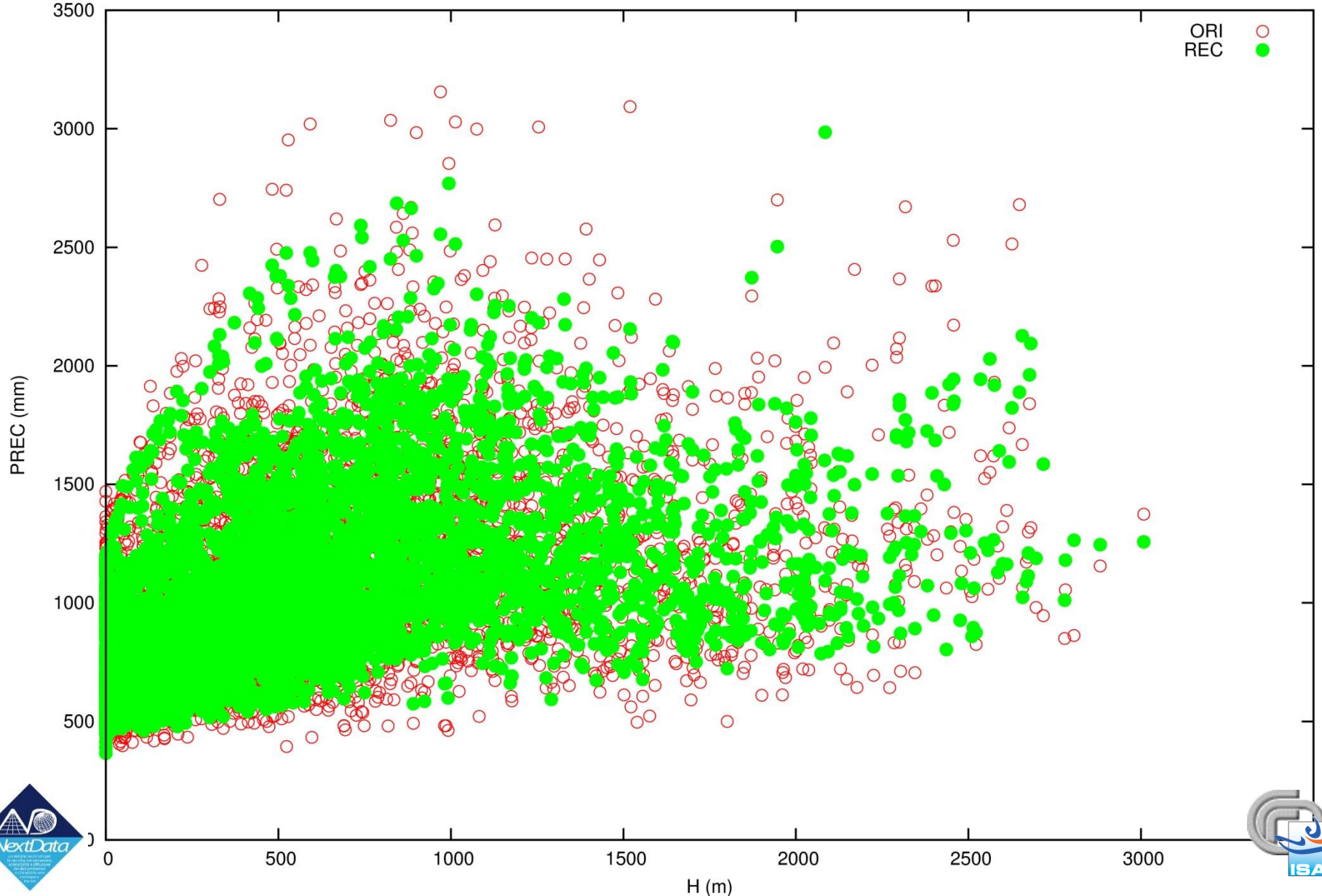
# VALUTAZIONE DELLE PRESTAZIONI

## RICOSTRUITO vs OSSERVATO



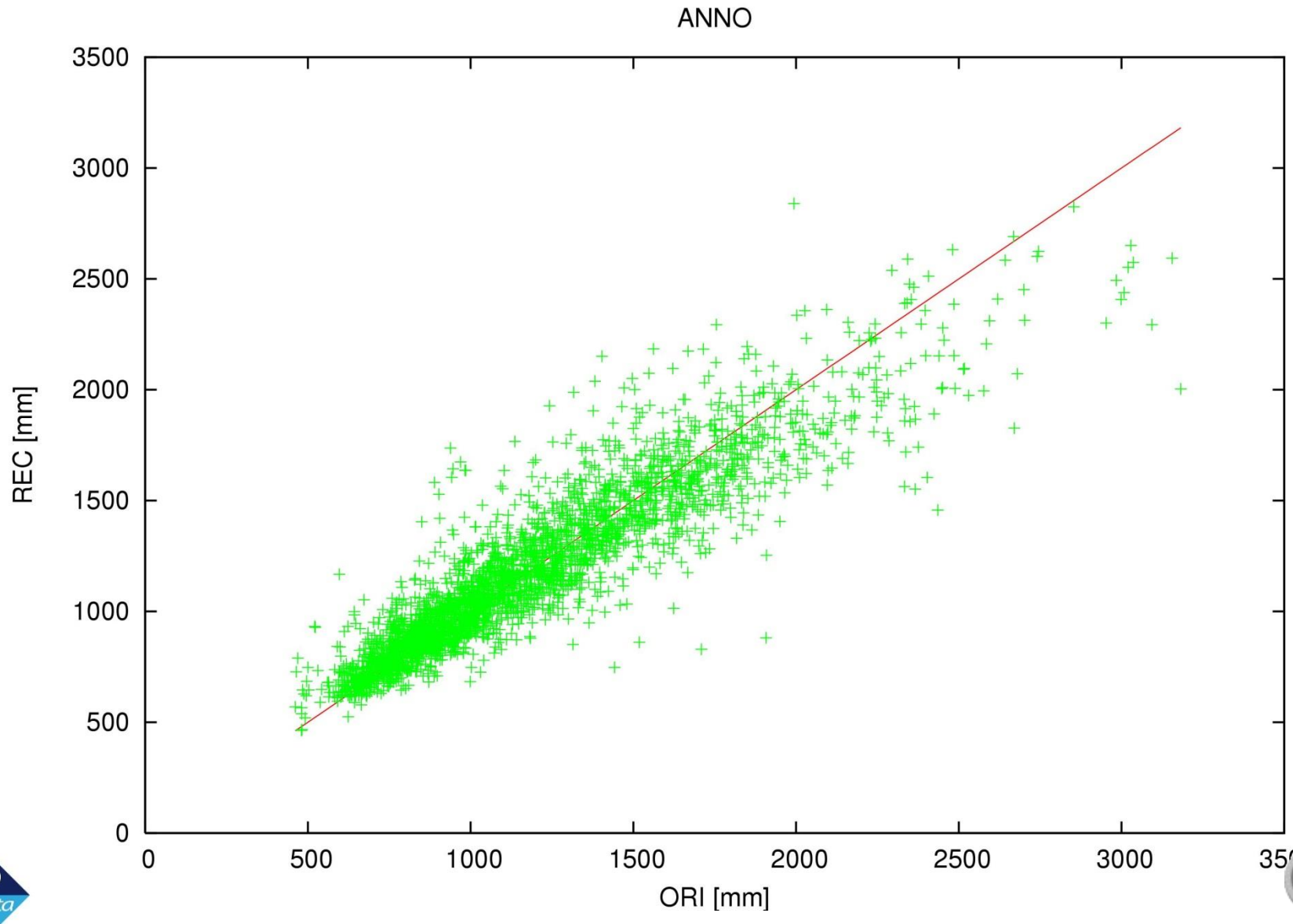
# VALUTAZIONE DELLE PRESTAZIONI

## RICOSTRUITO vs OSSERVATO



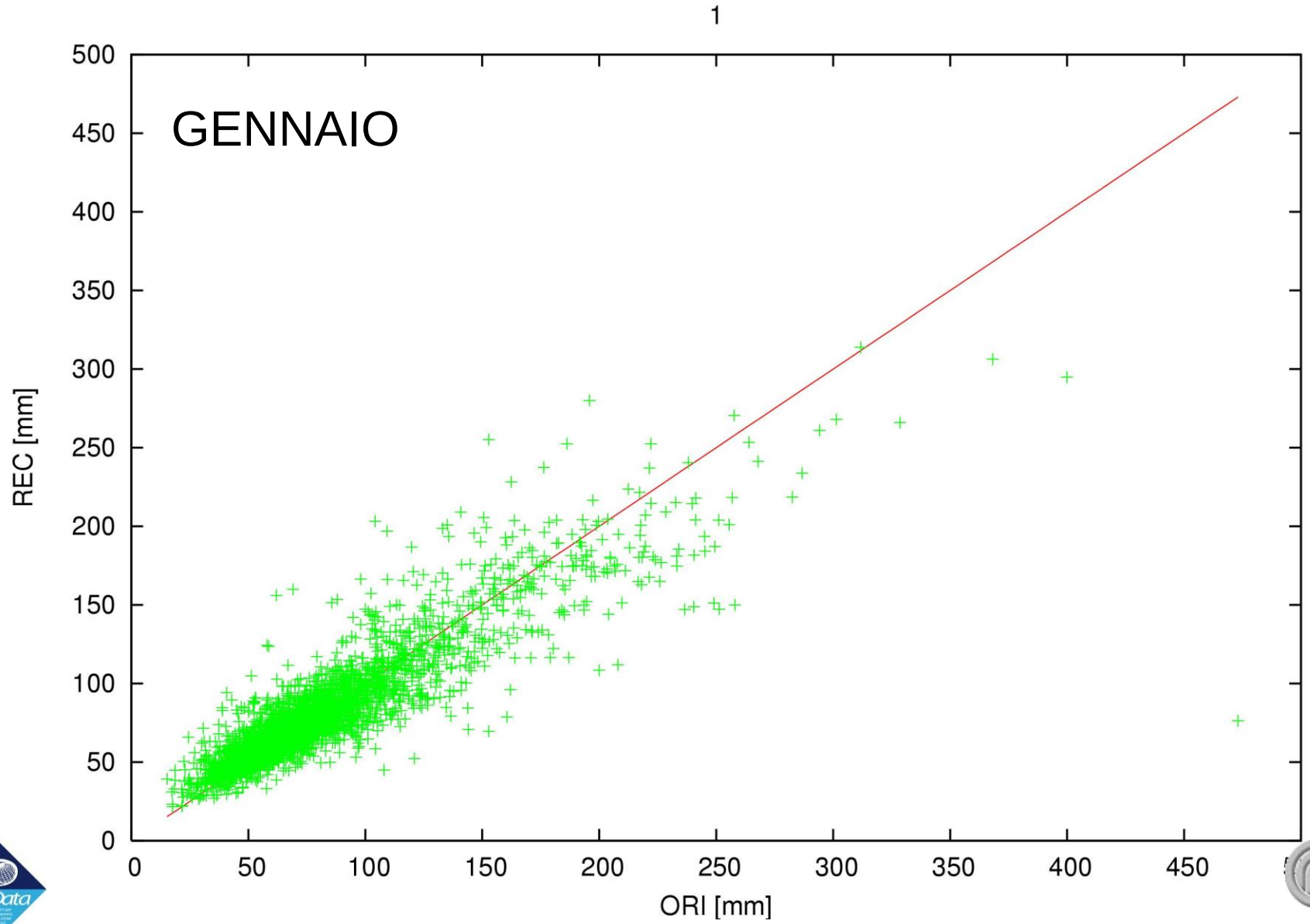
# VALUTAZIONE DELLE PRESTAZIONI

## RICOSTRUITO vs OSSERVATO



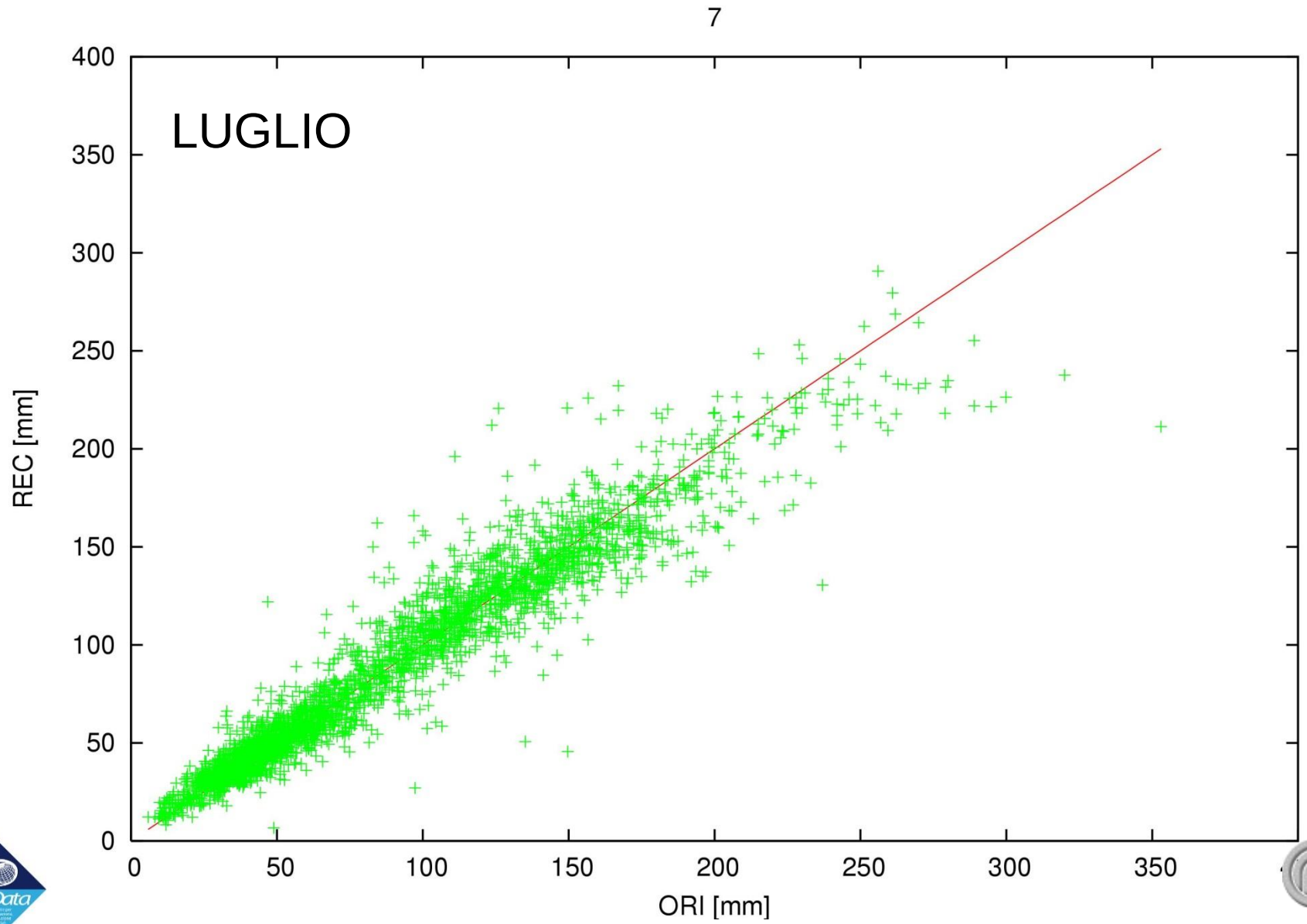
# VALUTAZIONE DELLE PRESTAZIONI

## RICOSTRUITO vs OSSERVATO



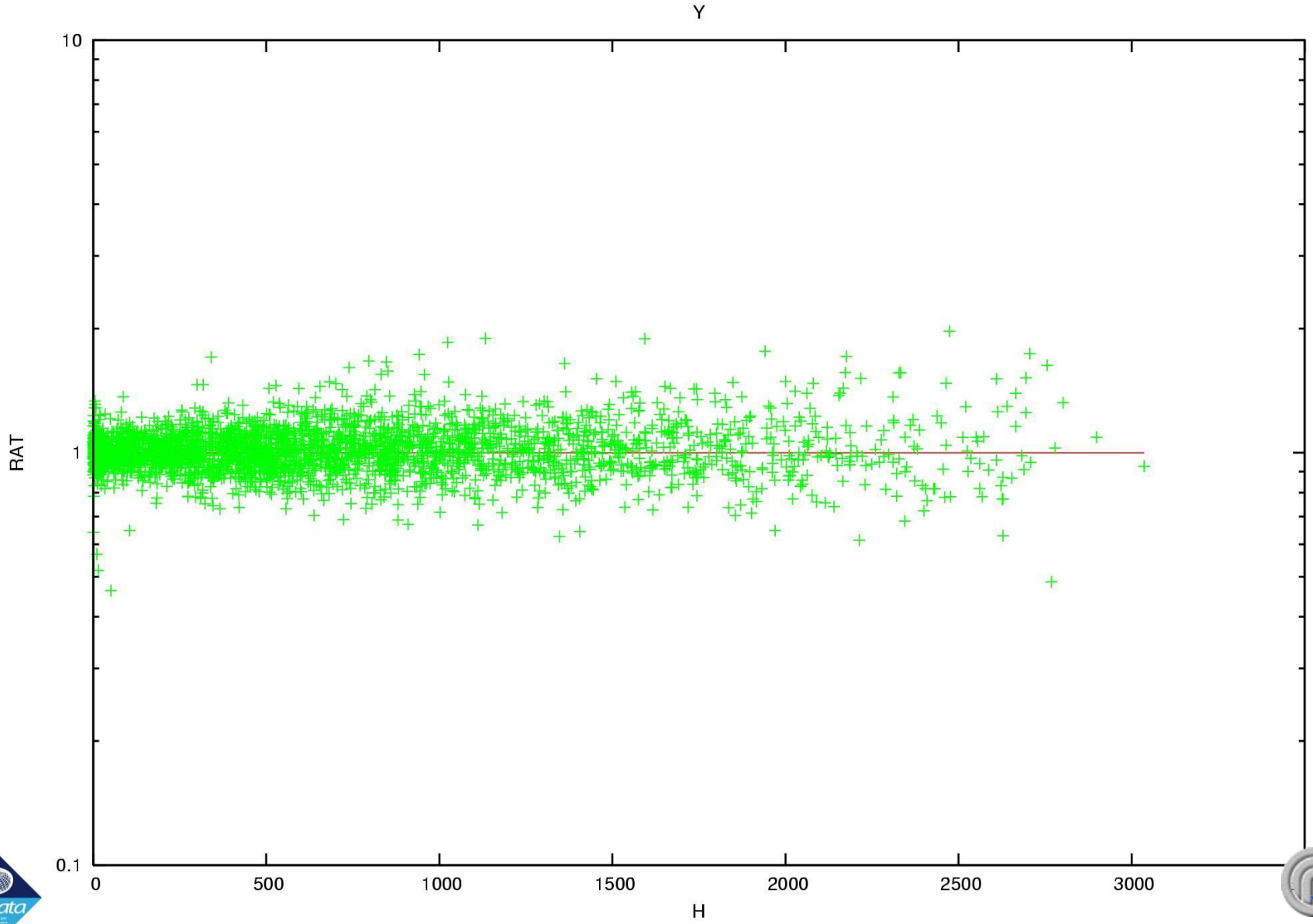
# VALUTAZIONE DELLE PRESTAZIONI

## RICOSTRUITO vs OSSERVATO



# VALUTAZIONE DELLE PRESTAZIONI

## RICOSTRUITO /OSSERVATO vs QUOTA



# STIMA ERRORI (Tecnica leave-one-out)

$$MAE = \frac{\sum_{i=1}^{N} \left| P_i^{est} - P_i^{obs} \right|}{N}$$

$$BIAS = \frac{\sum_{i=1}^{N} \left( P_i^{est} - P_i^{obs} \right)}{N}$$

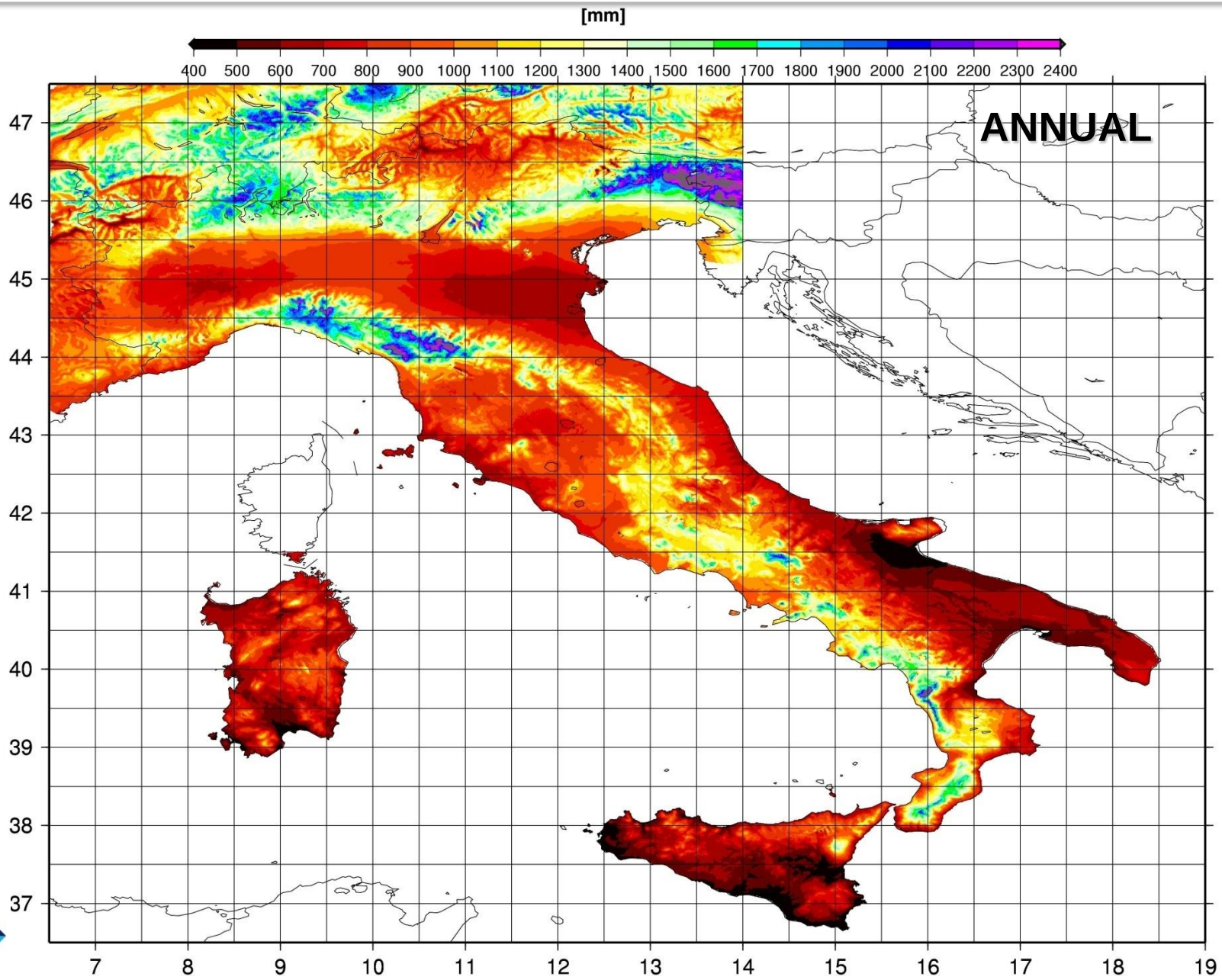
$$MAER = \frac{\sum_{i=1}^{N} \left| P_i^{est} / P_i^{obs} - 1 \right|}{N}$$

$$BIASR = \frac{\sum_{i=1}^{N} \left( P_i^{est} / P_i^{obs} - 1 \right)}{N}$$

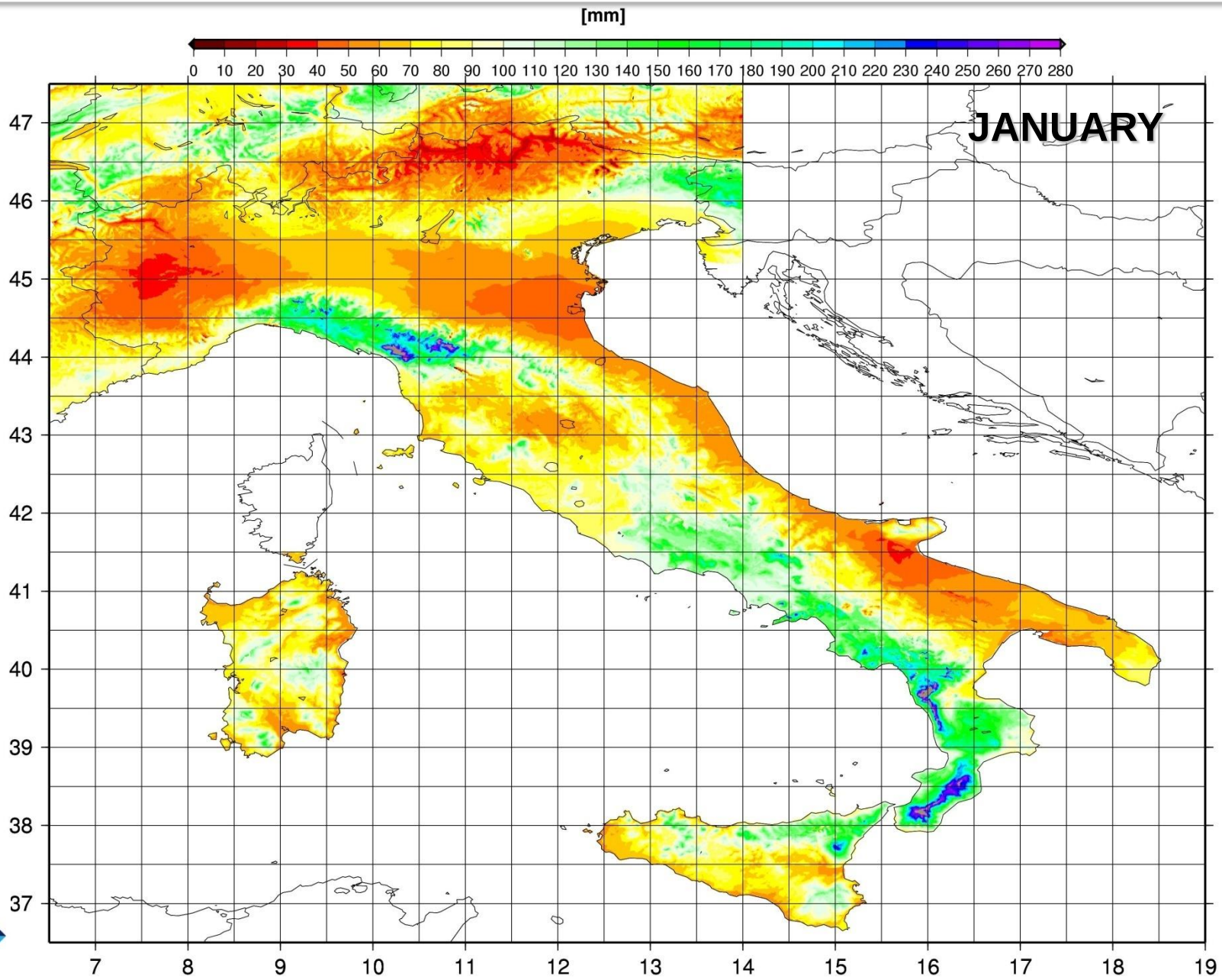
$$RMSE = \sqrt{\frac{\sum_{i=1}^{N} \left( P_i^{est} - P_i^{obs} \right)^2}{N}}$$

| | MAE (mm) | BIAS (mm) | MAER[%] | BIASR[%] | RMSE (mm) | R2 |
|---|---|---|---|---|---|---|
| 1 | 11.9 | 0.3 | 14.6 | 4.3 | 17.9 | 0.828 |
| 2 | 10.9 | 0.2 | 14.2 | 3.9 | 16.0 | 0.795 |
| 3 | 11.1 | 0.1 | 13.4 | 3.5 | 16.2 | 0.786 |
| 4 | 11.4 | 0.1 | 13.1 | 3.4 | 16.8 | 0.831 |
| 5 | 9.9 | 0.1 | 11.4 | 2.6 | 15.4 | 0.898 |
| 6 | 9.2 | 0.0 | 12.5 | 3.1 | 14.2 | 0.930 |
| 7 | 8.3 | 0.0 | 15.5 | 4.6 | 13.1 | 0.944 |
| 8 | 9.0 | 0.1 | 12.5 | 3.0 | 13.7 | 0.932 |
| 9 | 9.2 | 0.1 | 11.4 | 2.6 | 13.7 | 0.856 |
| 10 | 11.8 | 0.2 | 11.5 | 2.7 | 17.3 | 0.844 |
| 11 | 13.7 | 0.2 | 12.3 | 3.0 | 20.4 | 0.825 |
| 12 | 12.7 | 0.2 | 13.7 | 3.7 | 19.3 | 0.833 |

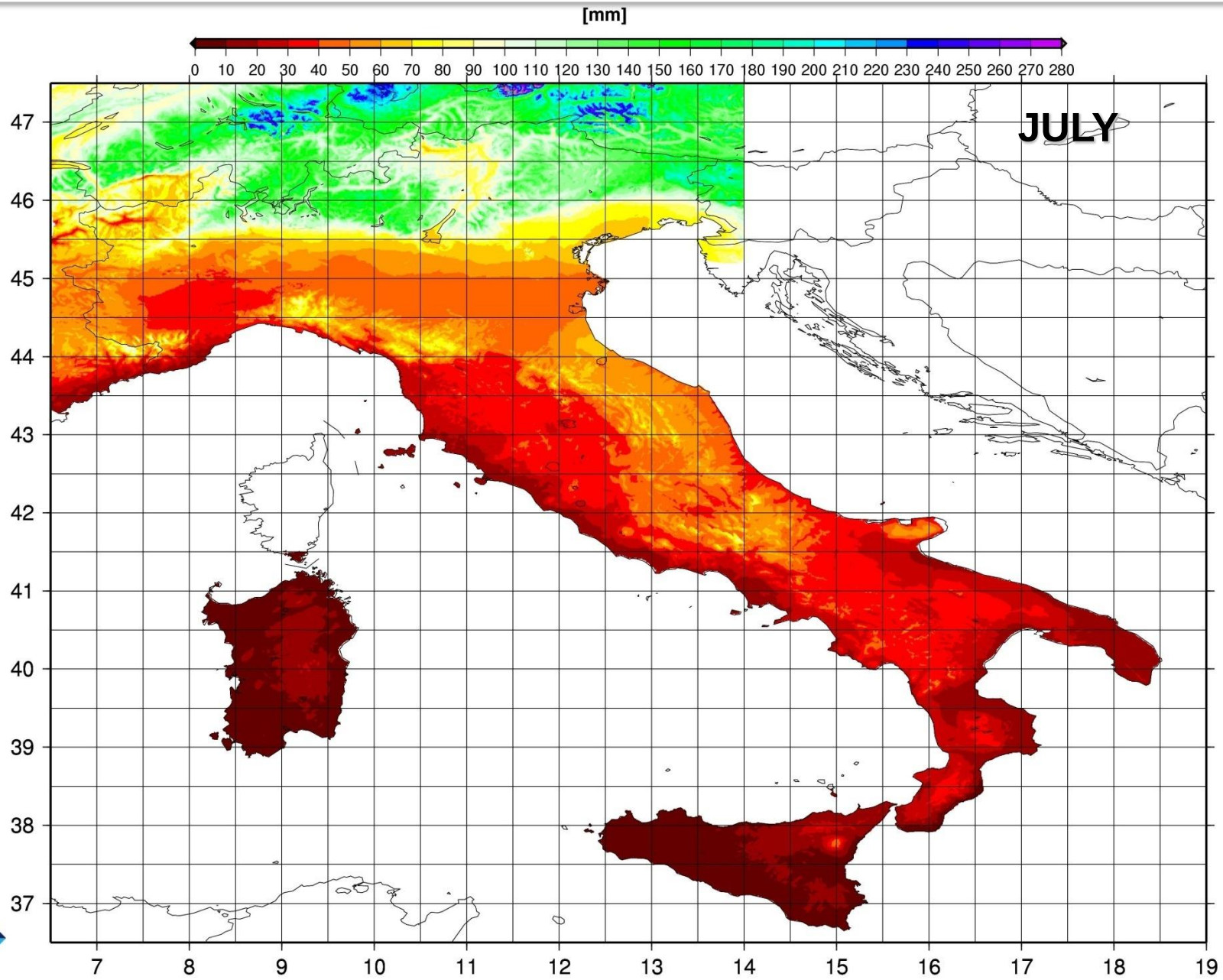
# ALCUNI RISULTATI



# ALCUNI RISULTATI



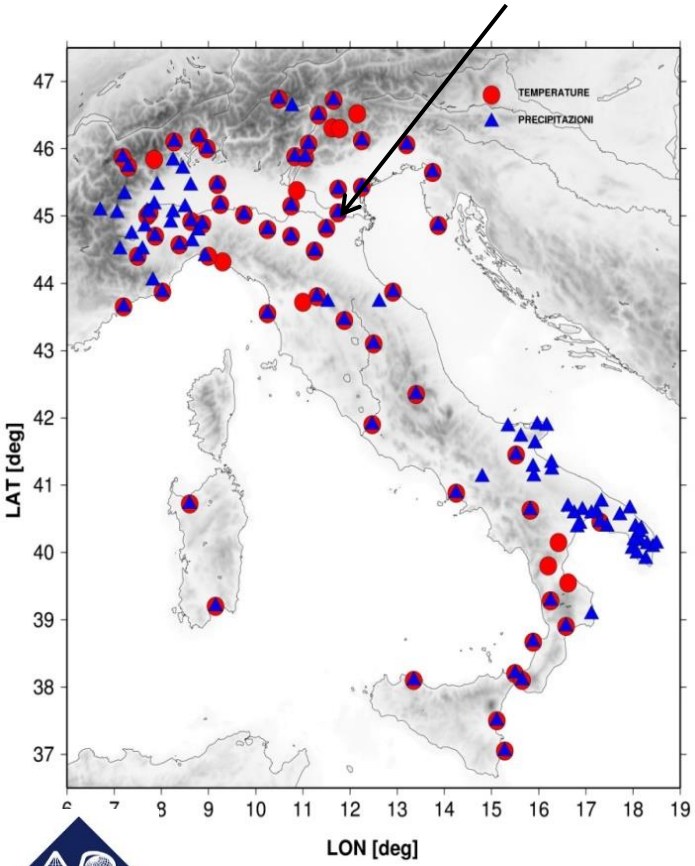
# ALCUNI RISULTATI



# ALCUNI RISULTATI

Let's show an example of the method. Let's suppose that we have to estimate a secular **precipitation** record for the following point:

Latitude: 45.05 N; Longitude: 11.77 E; height: 9 m (i.e. Rovigo).




Step 1)

An anomalies **precipitation** series is calculated for the grid point by means of the neighboring stations (excluding Rovigo!!)

Step 2)

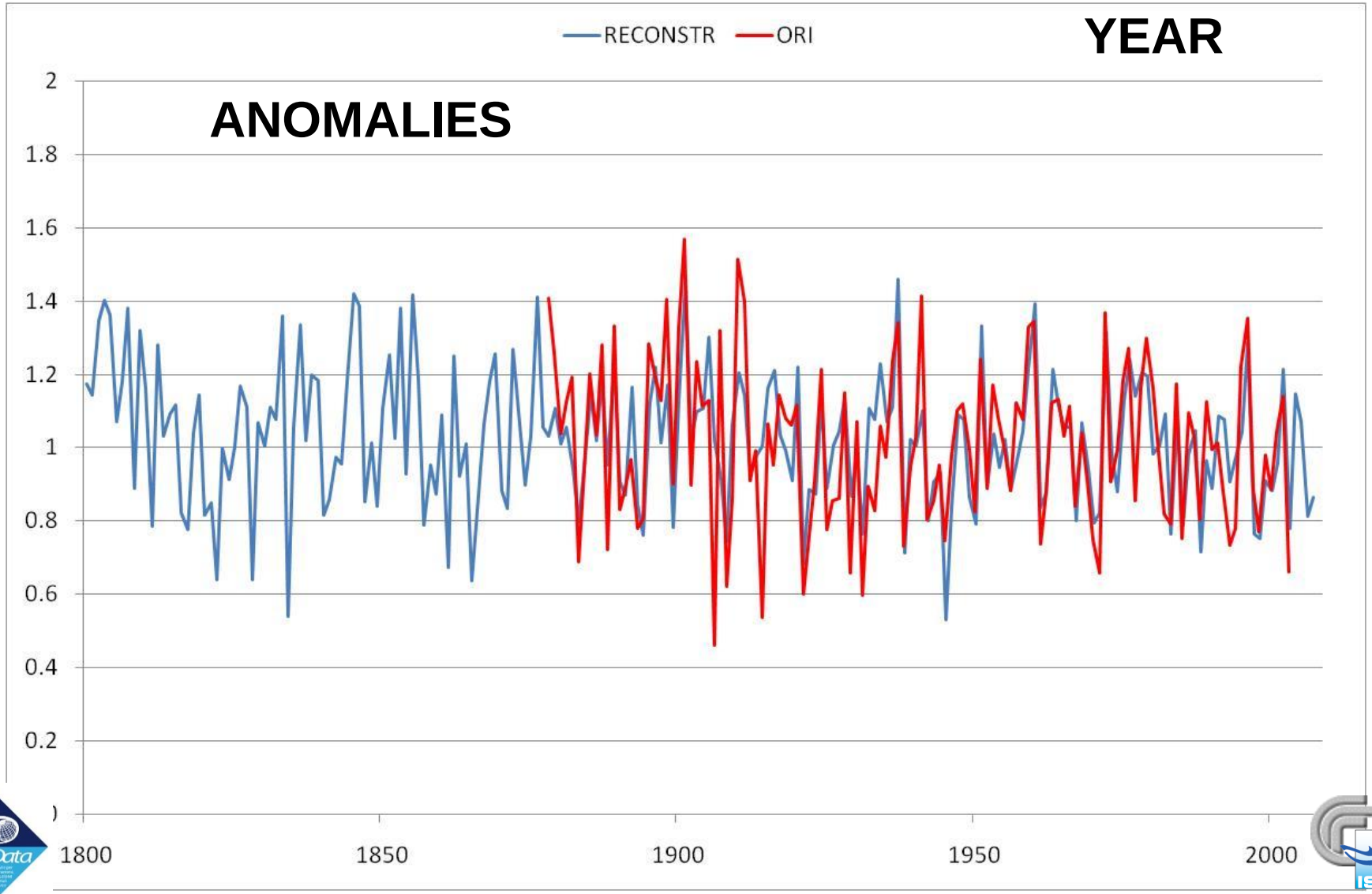
The 1961-1990 monthly normals are estimated by means of the **precipitation/elevation model**.

Step 3)

The 1961-1990 monthly normals are **multiplied** to each corresponding monthly value of the anomalies series to finally get the absolute value series

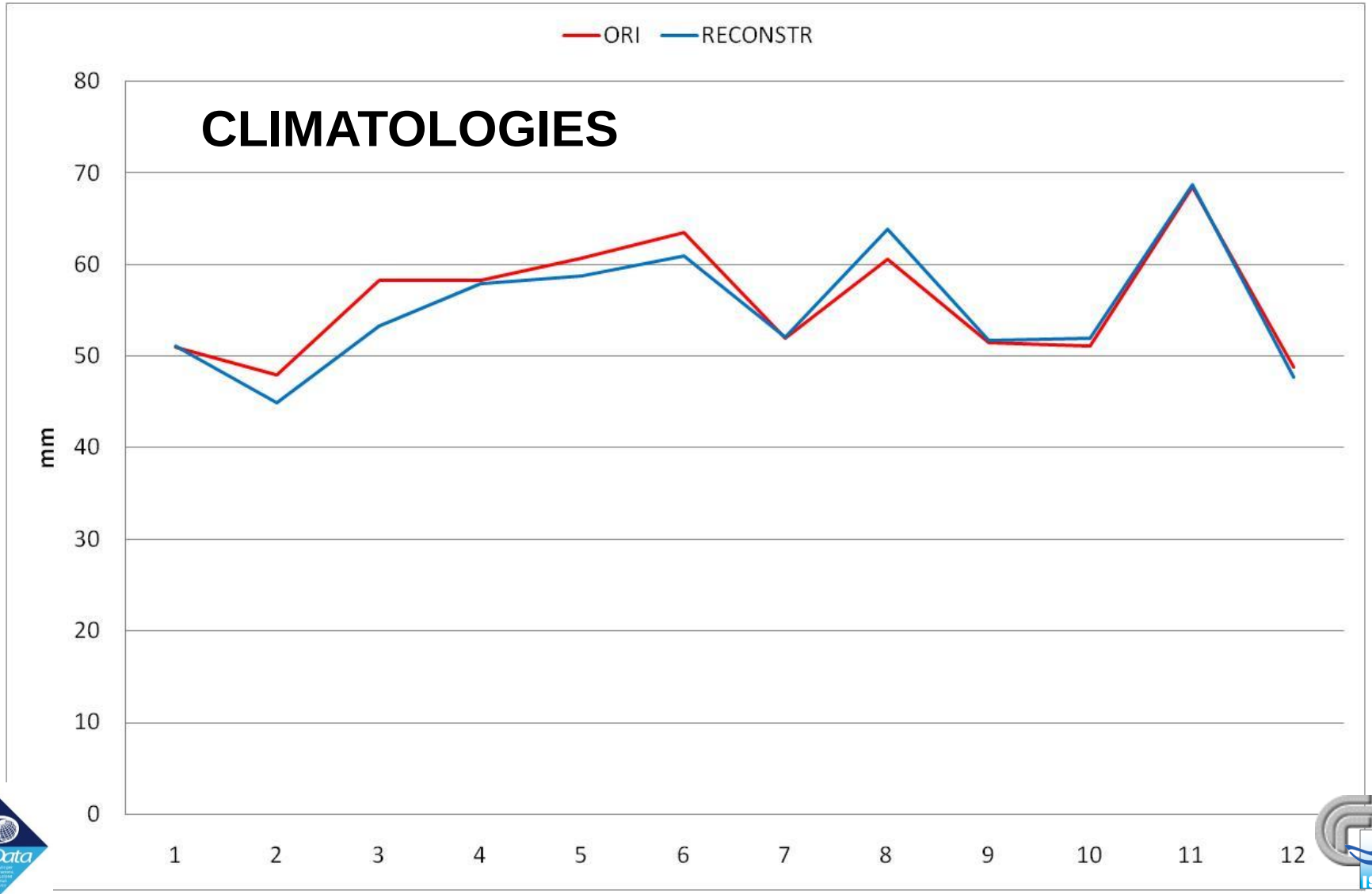
# ALCUNI RISULTATI

## SUPERIMPOSITION OF CLIMATE NORMALS AND ANOMALIES



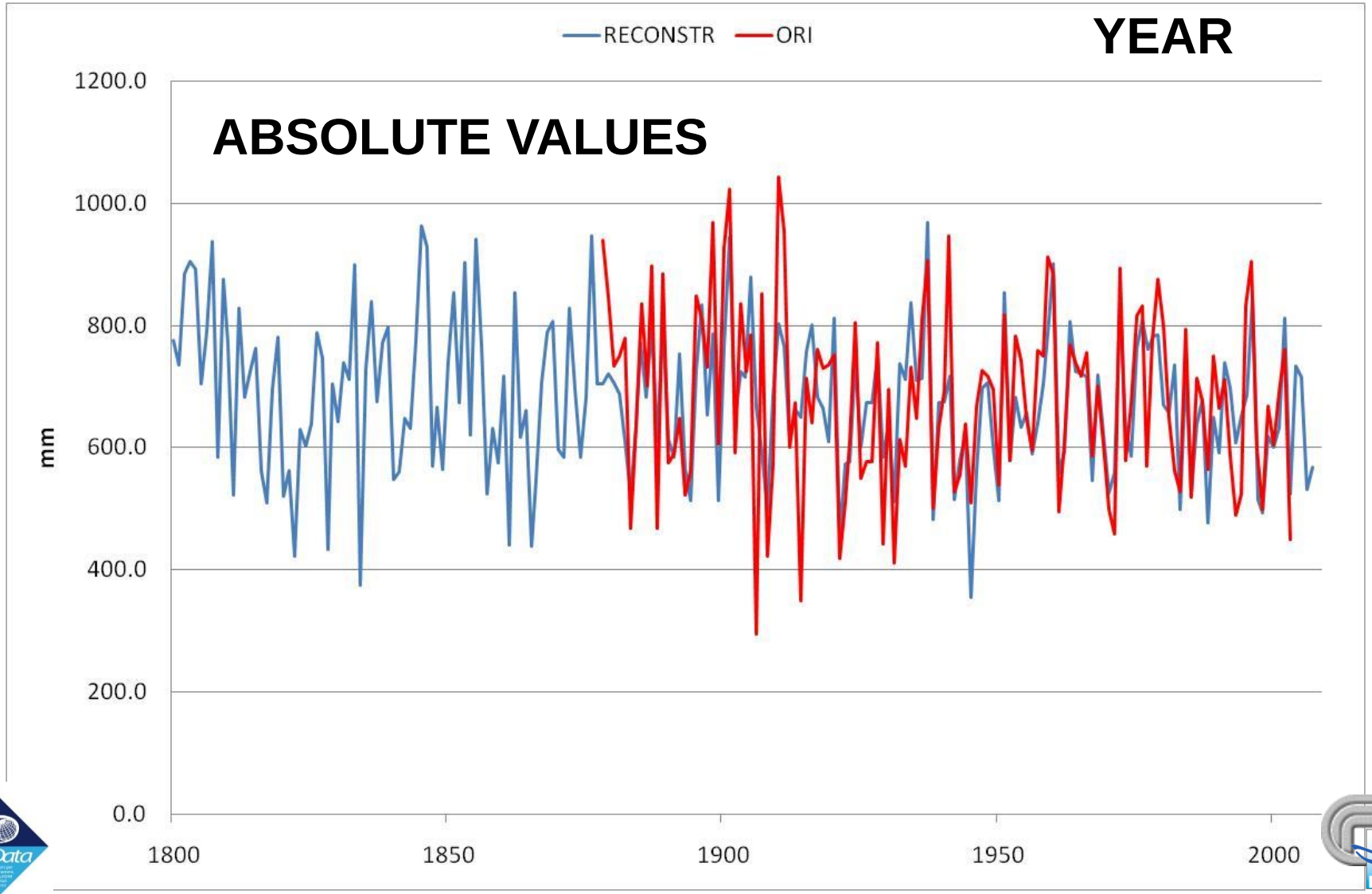
# ALCUNI RISULTATI

## SUPERIMPOSITION OF CLIMATE NORMALS AND ANOMALIES



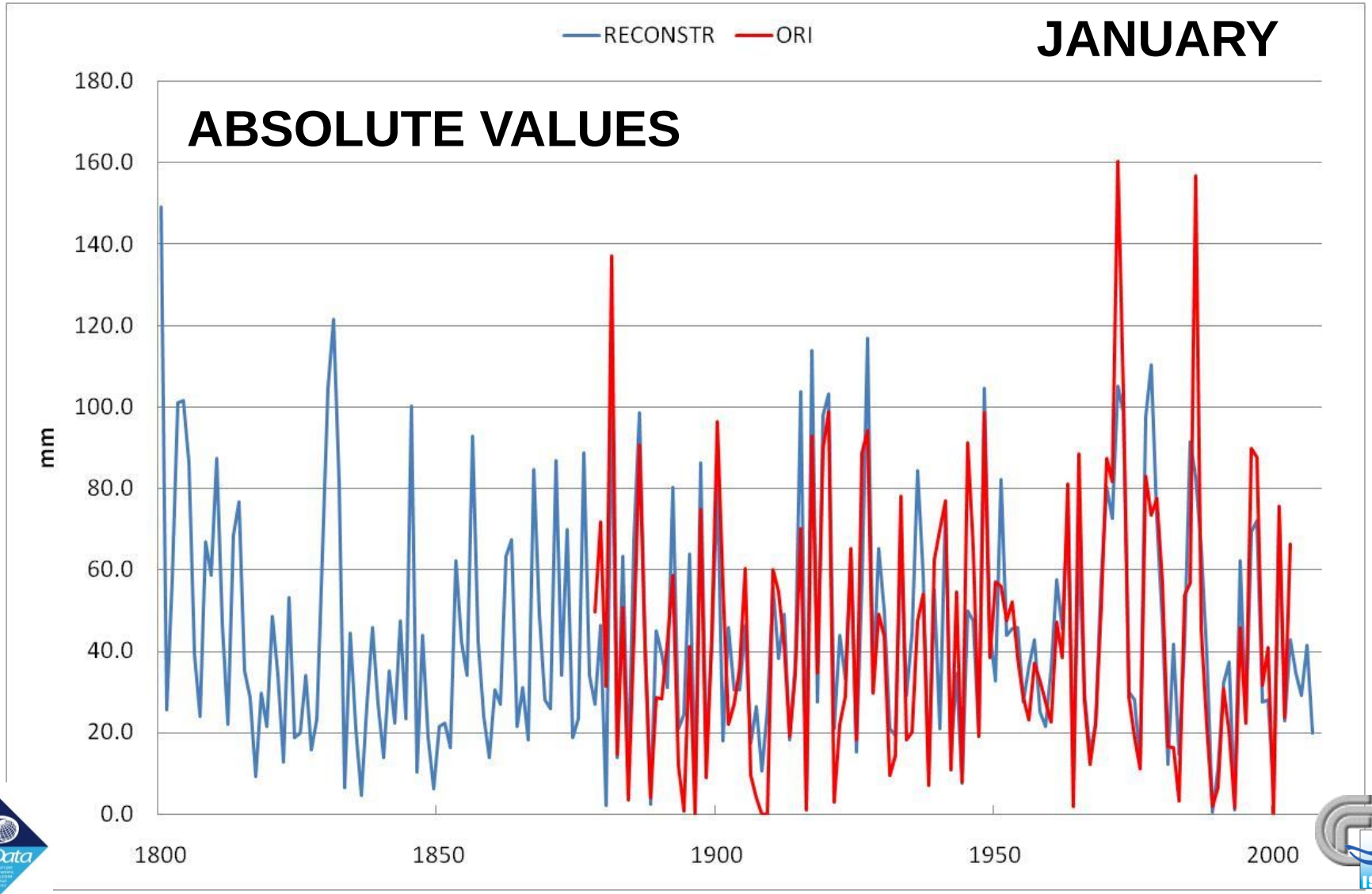
# ALCUNI RISULTATI

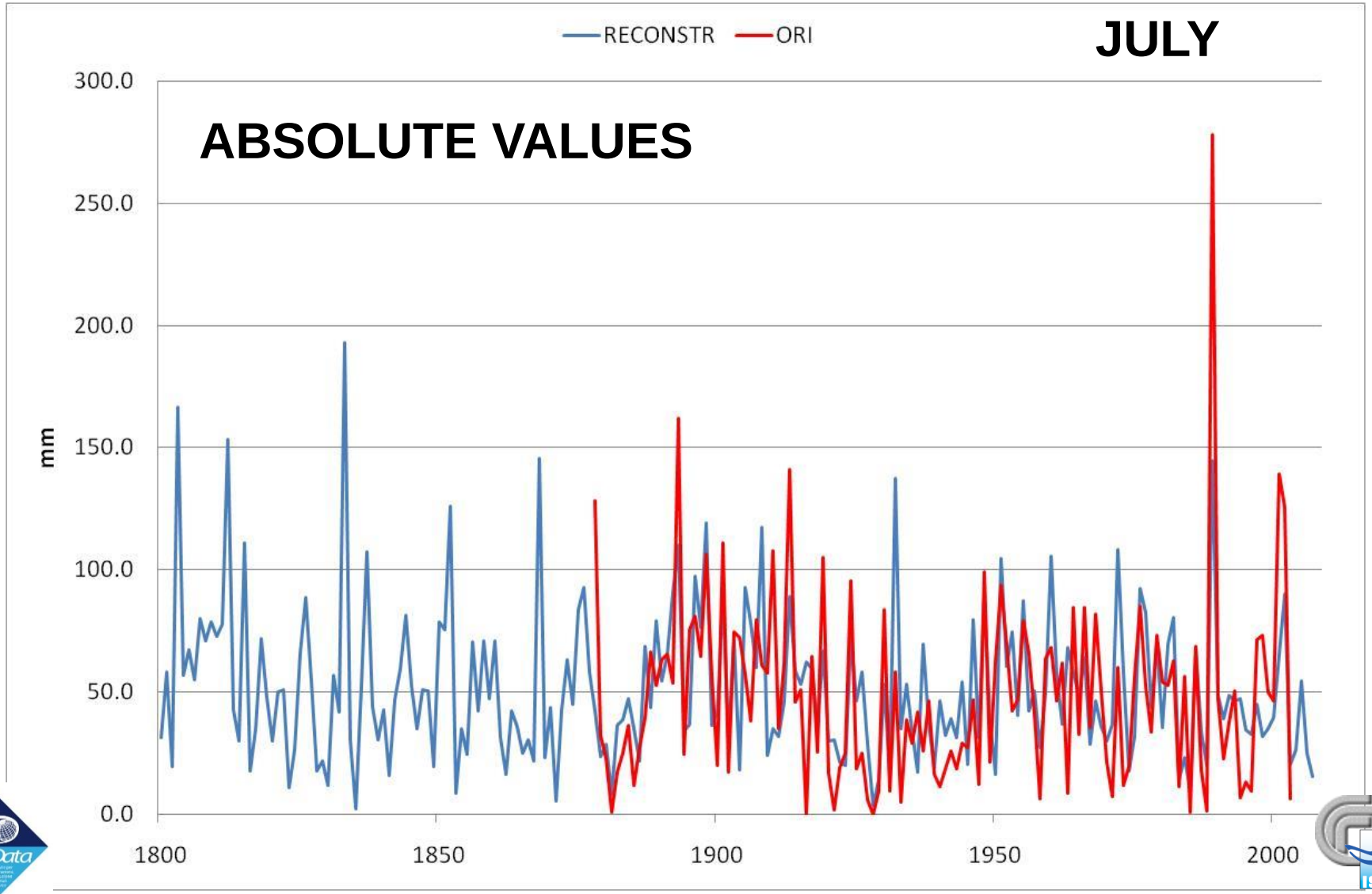
## SUPERIMPOSITION OF CLIMATE NORMALS AND ANOMALIES



# ALCUNI RISULTATI

## SUPERIMPOSITION OF CLIMATE NORMALS AND ANOMALIES



# ALCUNI RISULTATI

## SUPERIMPOSITION OF CLIMATE NORMALS AND ANOMALIES