CERFACS

Centre Européen de Recherche

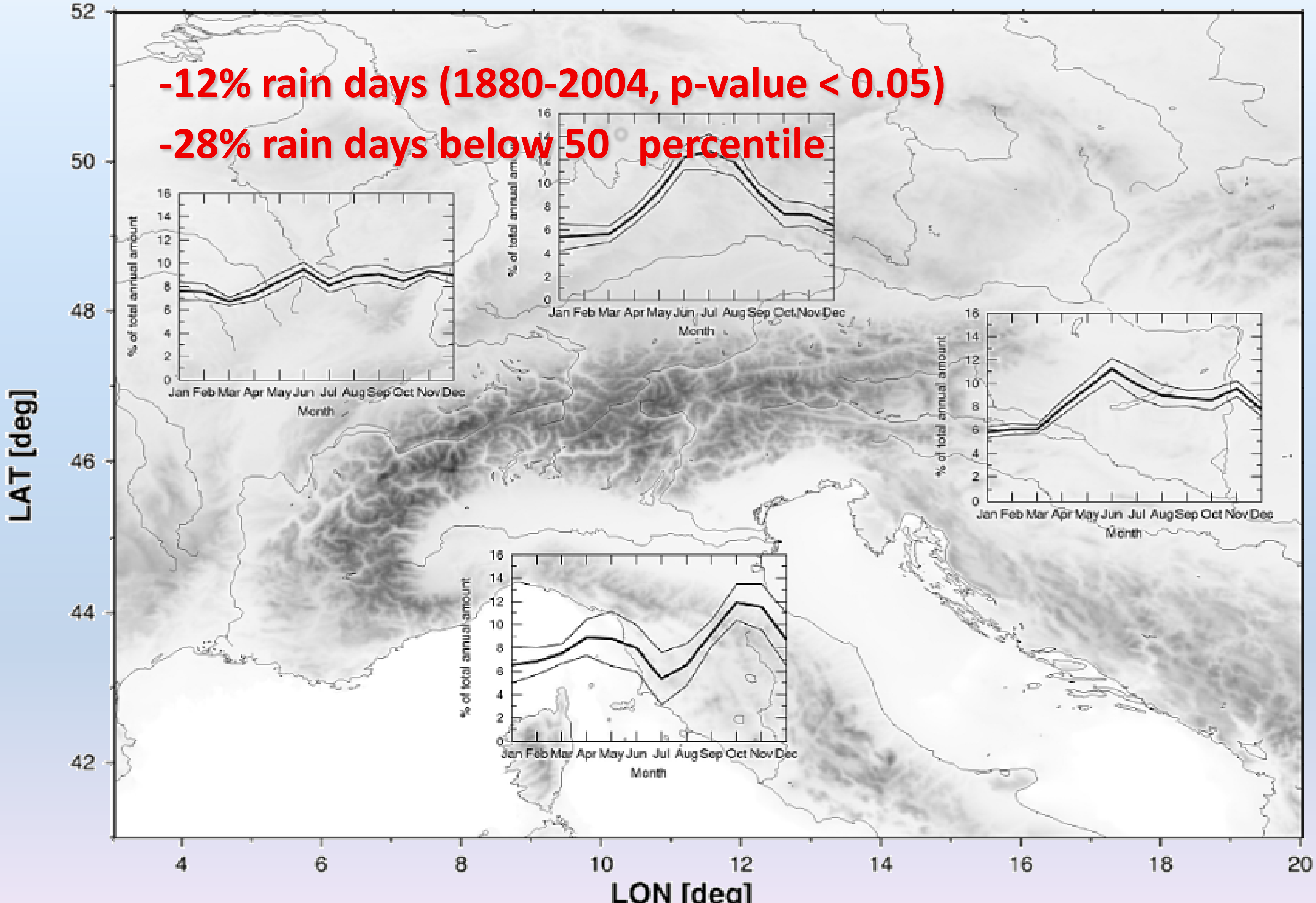
et de Formation Avancée en Calcul Scientifique

WEATHER TYPES AND PRECIPITATION IN THE IBERIAN PENINSULA

NICOLA CORTESI

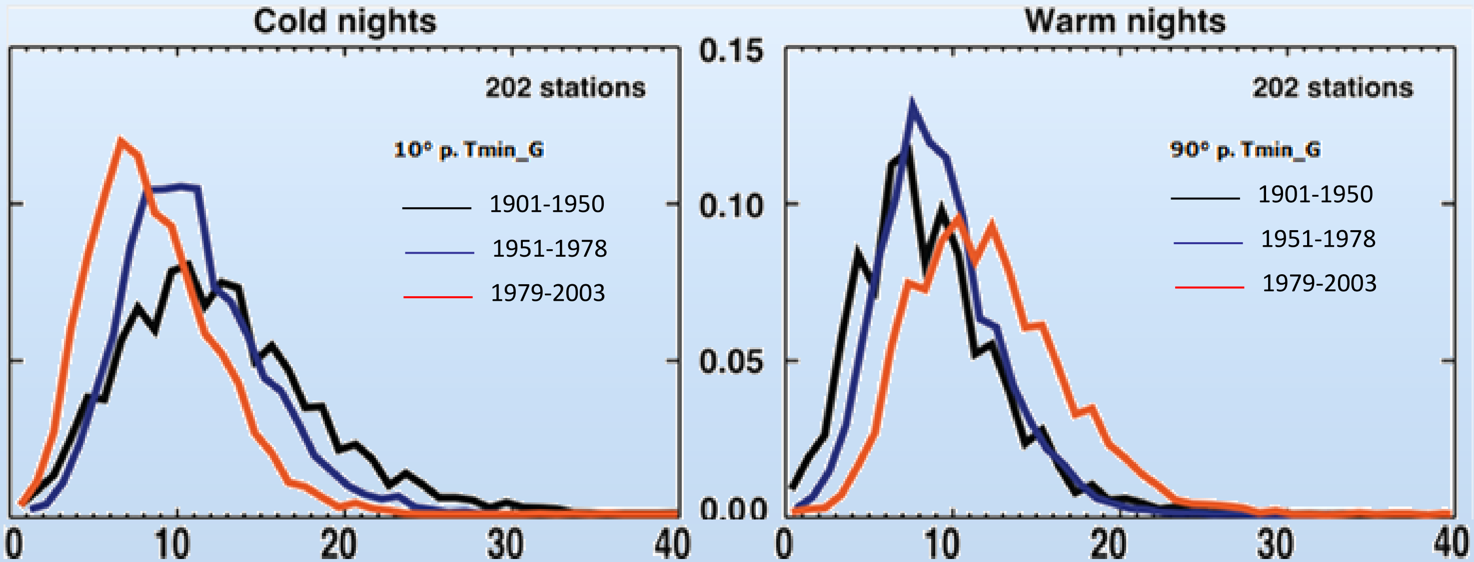
TOULOUSE, 19TH FEBRUARY 2014

2007: Bachelor degree at Milan University on Daily Precipitation Variability

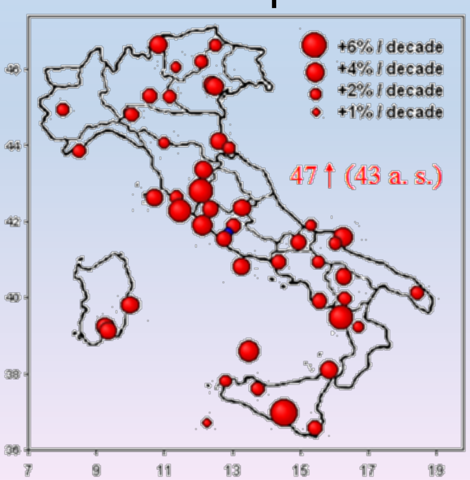


Precipitation annual cycles representative of different subregions of the Great Alpine Region

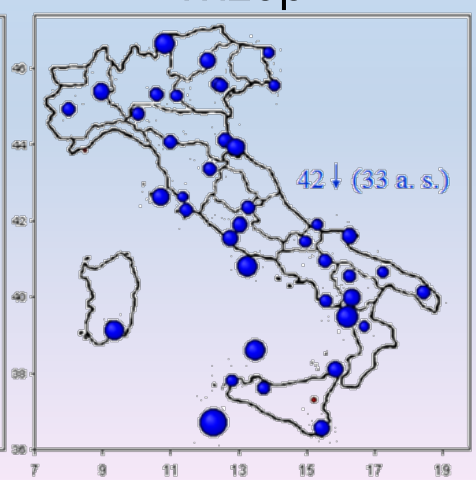
2008: Stage at CESI Ricerca on improving forecasts of electrical demand



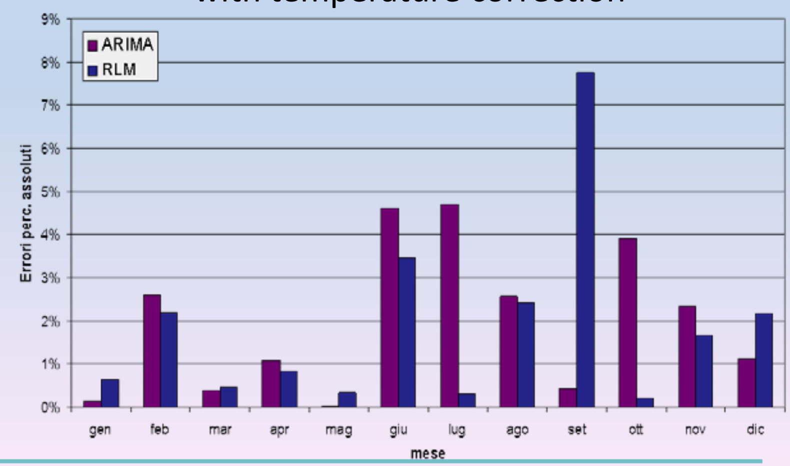
Tx90p



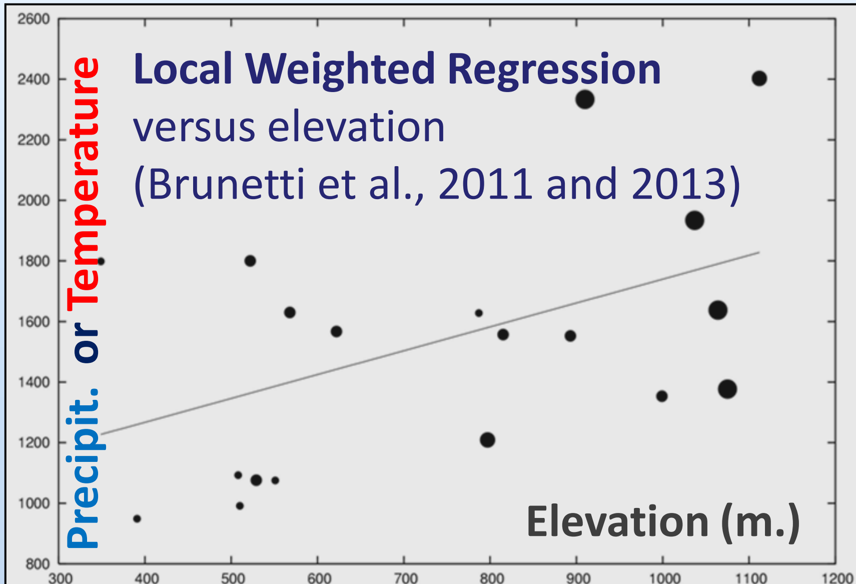
Tx10p

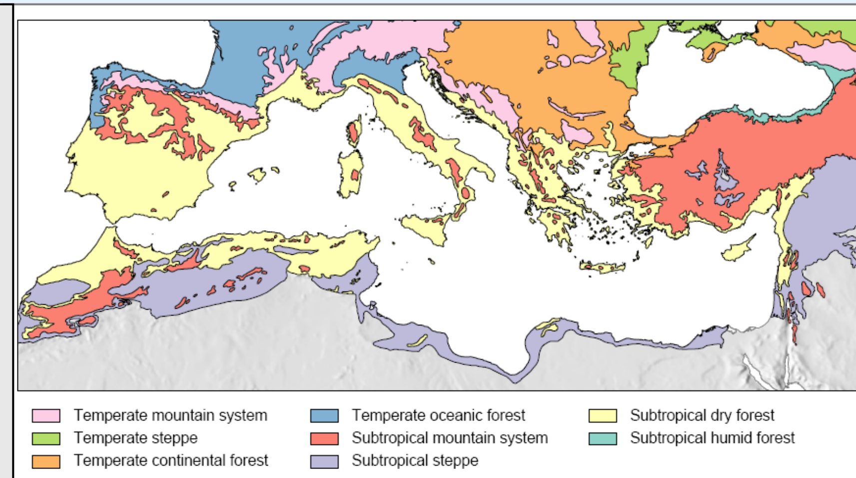


Improvement of MAE% of ARIMA models with temperature correction



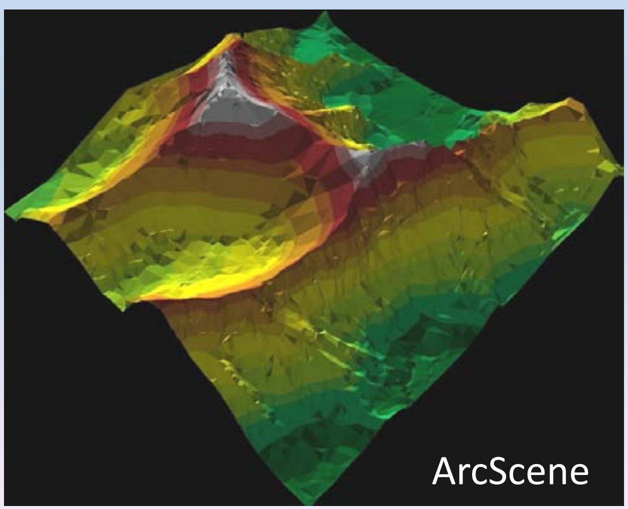
2009: Master at Zaragoza University on Geographic Information Systems (GIS)

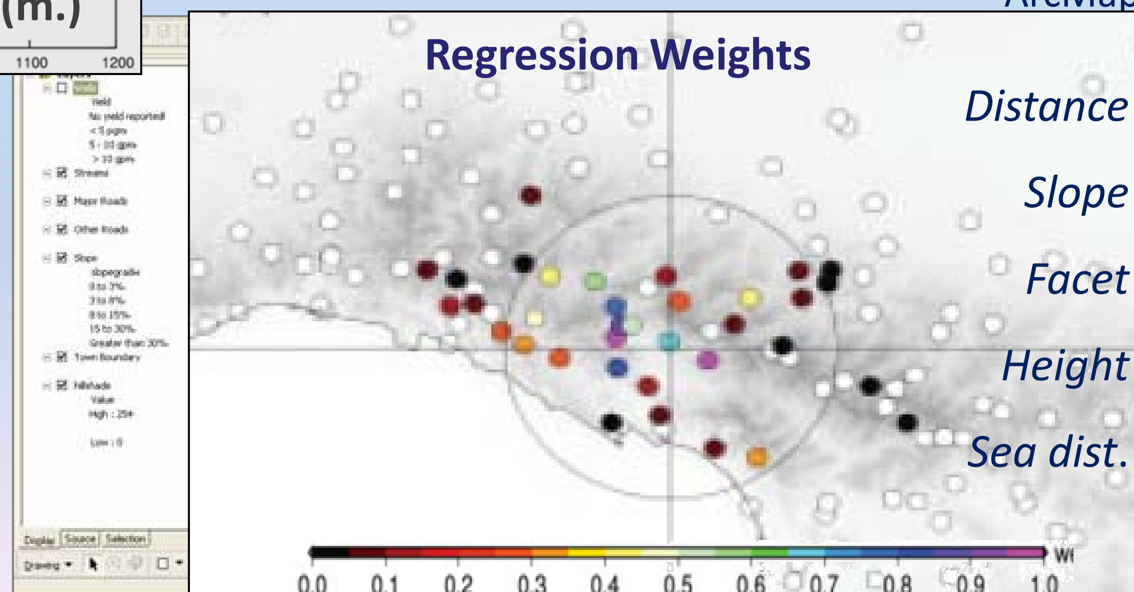




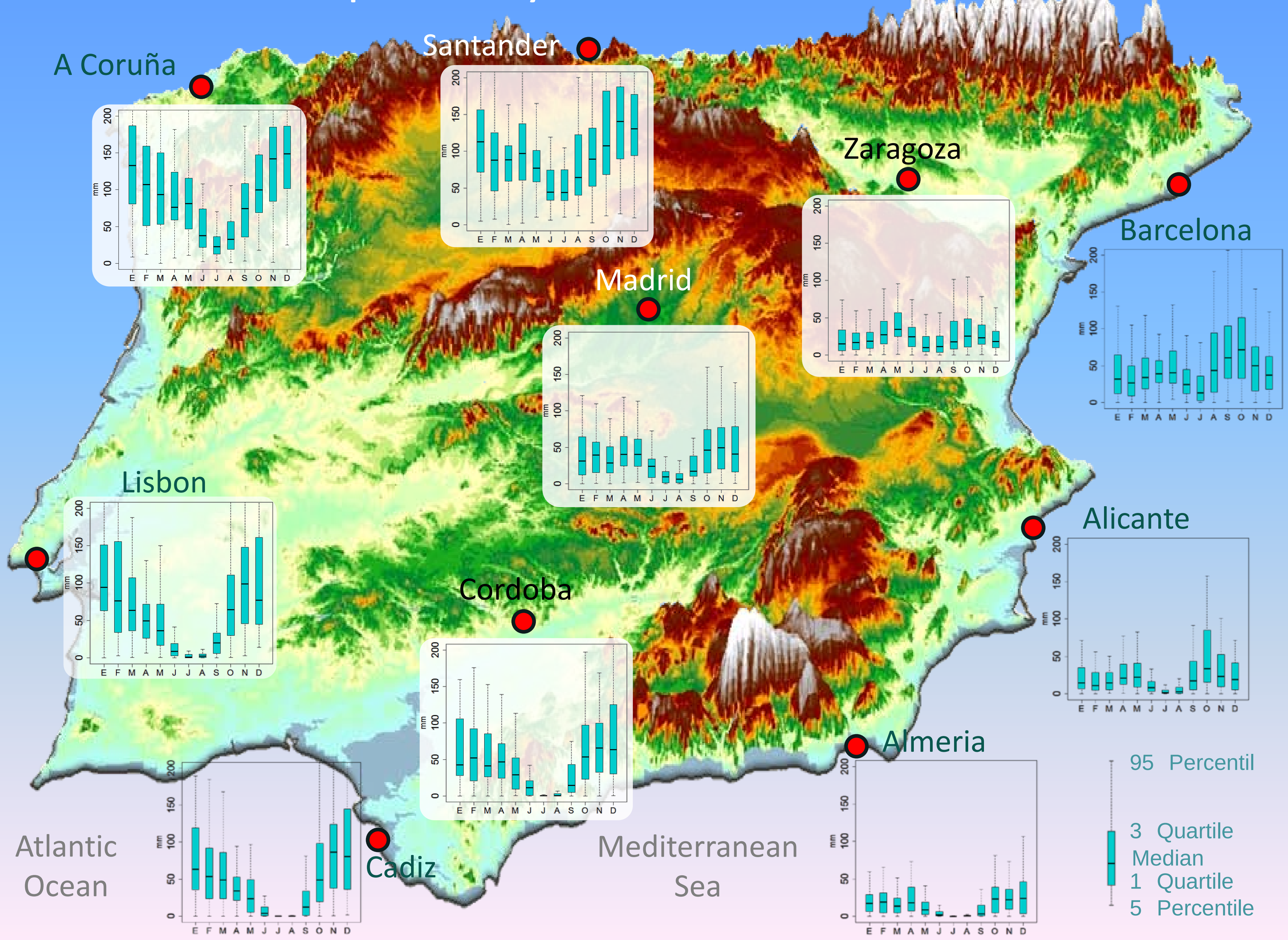
GRASS GIS

ArcMap





2011-2013: PhD on Precipit.Variability in the Iberian Peninsula



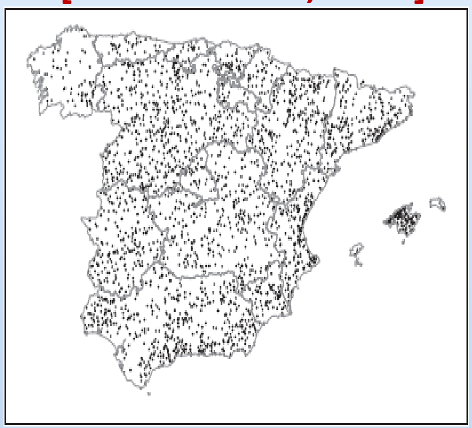
Iberian precipitation datasets

PT02
[Belo-Pereira, 2011]

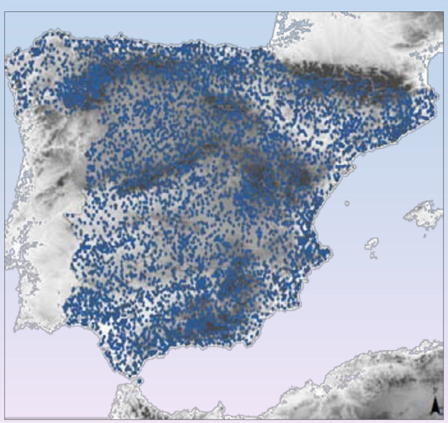
806 Portuguese series

\+

Spain02
[Herrera et al., 2010]



2756 Spanish series



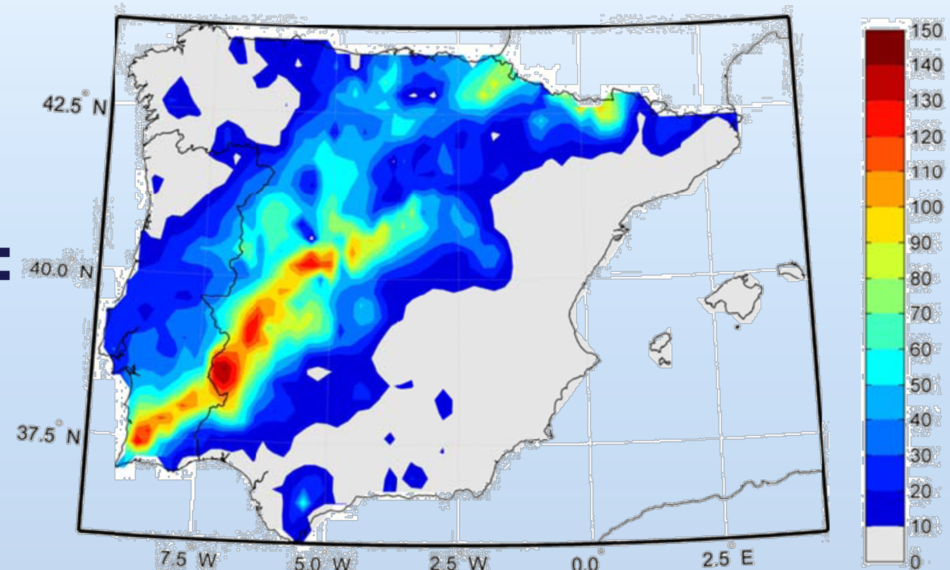
Agencia Estatal de Meteorología

>10 000 series
(6821 with 10+ yrs.)

=

Iber02 (1950-2003)

[Ramos and Trigo, 2011]



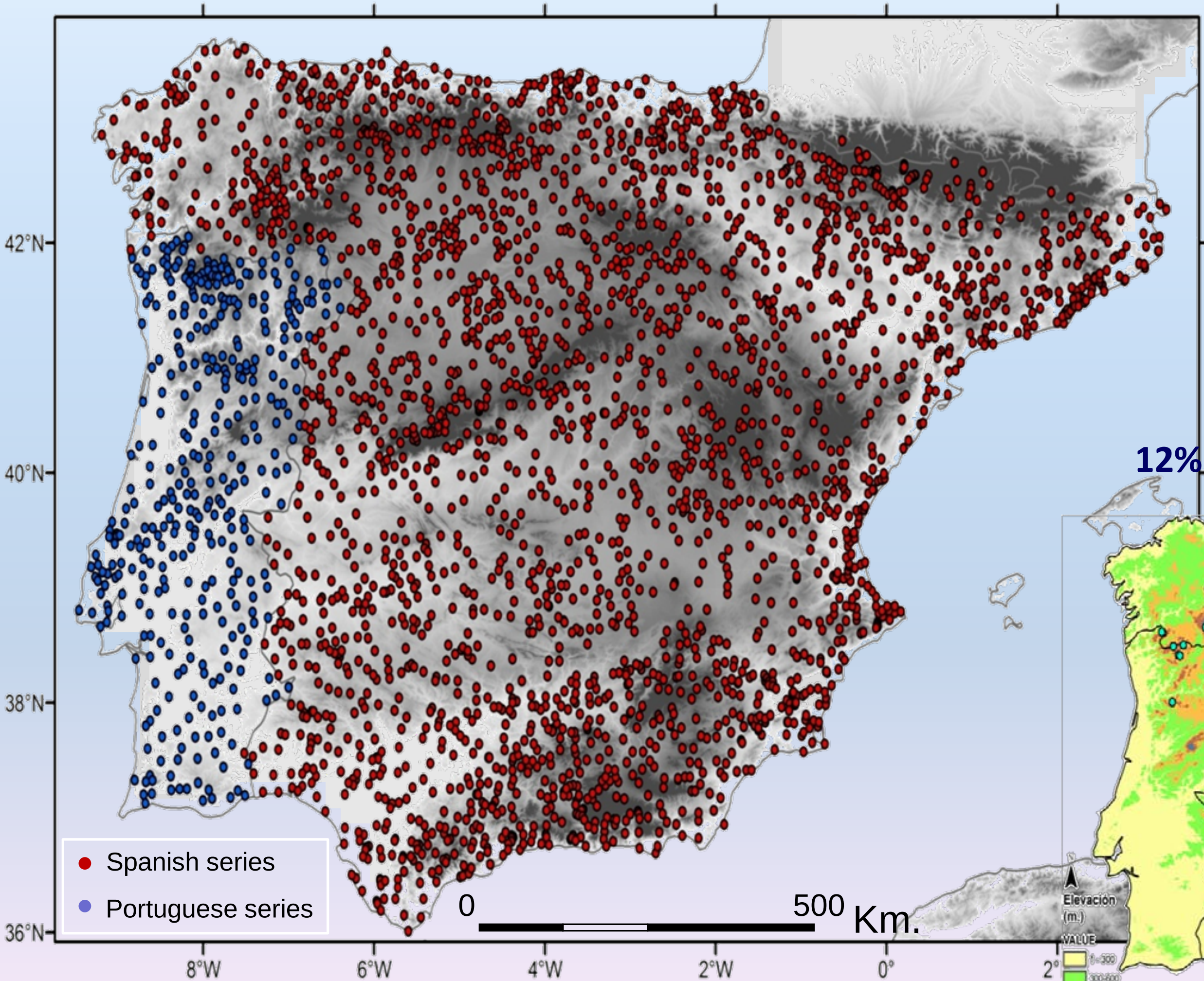
Daily precipitation sum (mm) for the 5 of November of 1997

+ Daily gridded precipit.
+ Fully homogenized
+ High density (>3000 orig. series)

- Only gridded data publicy available
- Resolution of 0.2 somewhat coarse
- Temporal gaps (each year was interp. with different series)

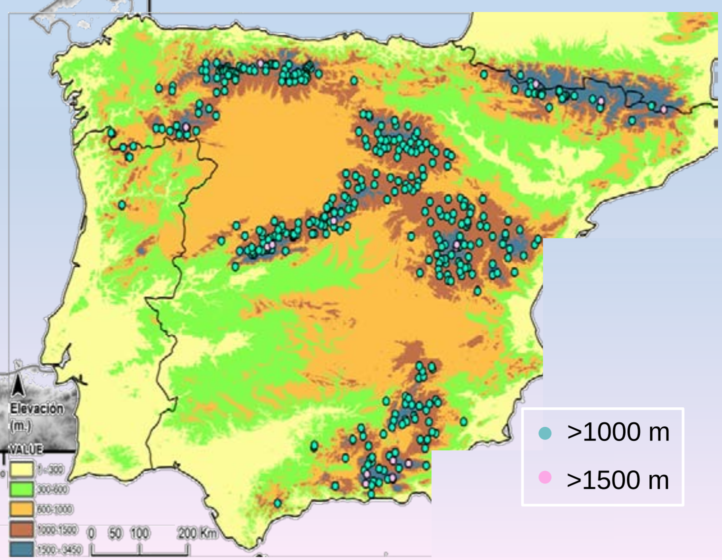
Mopredasp (1948-2003)

[MOnthly PRecipitation DAtabase for Spain and Portugal of ***3030*** monthly series]
(González-Hidalgo et al., 2011 and Lorenzo-Lacrúz et al., 2011)



- \+ Fully homogenized
- \+ Point series, not grid
- \+ High density (3030 series)
- \+ No temporal gaps (reconstructed series)
- \- Monthly resolution

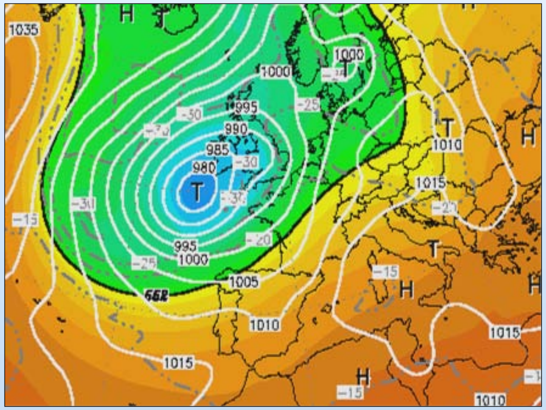
12% of series with altitude > 1000 m.



Weather Type (WT) Classification

Lamb classification modified by Jenkinson and Collison
(Trigo and DaCamera, 2002)

Mean Daily Pressure Field



Southerly Flow: $\mathbf{S} = 1.305\,[0.25\,(p_5 + 2p_9 + p_{13}) - 0.25\,(p_4 + 2p_8 + p_{12})]$

Westerly Flow: $\mathbf{W} = [0.5\,(p_{12} + p_{13}) - 0.5\,(p_4 + p_5)]$

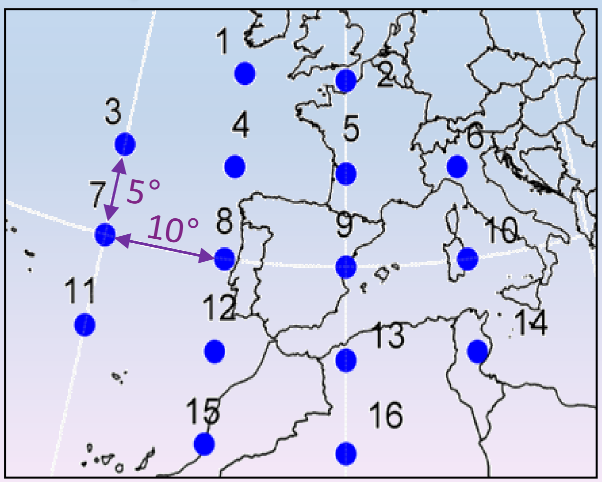
Total Flow: $\mathbf{F} = (\mathbf{S}^2 + \mathbf{W}^2)^{1/2}$ **Flow Direction:** $\mathbf{D} = \mathrm{arctg}\,(\mathbf{W/S})$

Southerly Vorticity: $\mathbf{ZS} = 0.85\,[0.25\,(p_6 + 2p_{10} + p_{14}) - 0.25\,(p_5 + 2p_9 + p_{13}) - 0.25\,(p_4 + 2p_8 + p_{12}) + 0.25\,(p_3 + 2p_7 + p_{11})]$

Westerly Vorticity: $\mathbf{ZW} = 1.12\,[0.5\,(p_{15} + p_{16}) - 0.5\,(p_8 + p_9)] - 0.91\,[0.5\,(p_8 + p_9) - 0.5\,(p_1 + p_2)]$

Total Vorticity: $\mathbf{Z} = \mathbf{ZS} + \mathbf{ZW}$ (>0: Cyclonic ; <0: Anticyclonic)

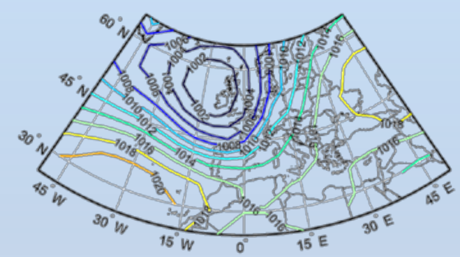
Selection of 16 grid points $p_1, \ldots, p_{16}$:



Extraction of point values

Calculation of Geostrophical Indexes

Ex: ***Westerly*** *WT:* $|\mathbf{Z}| < \mathbf{F}$, $248 < \mathbf{D} < 292$

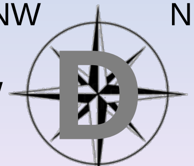


WTs Classification

Selection of WTs (26):

8 Directionals

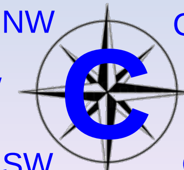
N
NW NE
W E
SW SE
S



$|\mathbf{Z}| < \mathbf{F}$

9 Cyclonic

C.N
C.NW C.NE
C.W C.E
C.SW C.SE
C.S



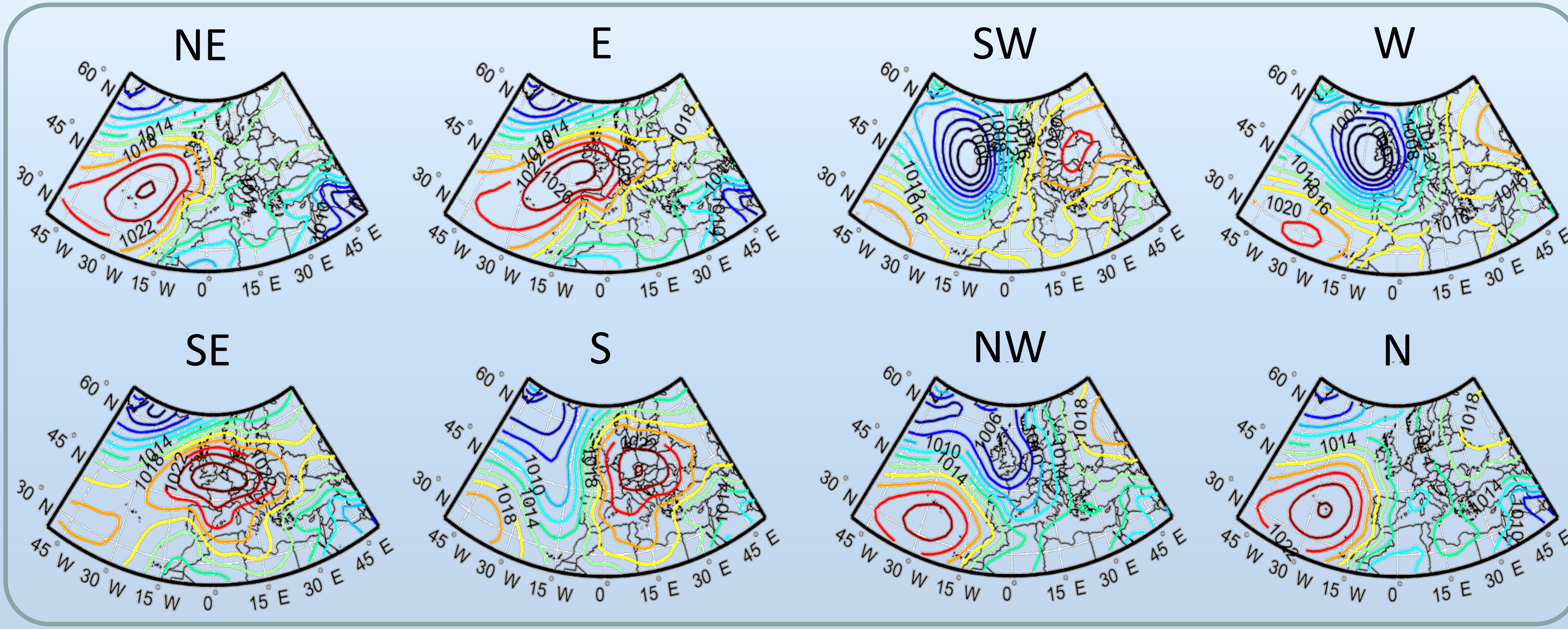
$|\mathbf{Z}| > \mathbf{F}, \mathbf{Z} > 0$

9 Anticyclonic

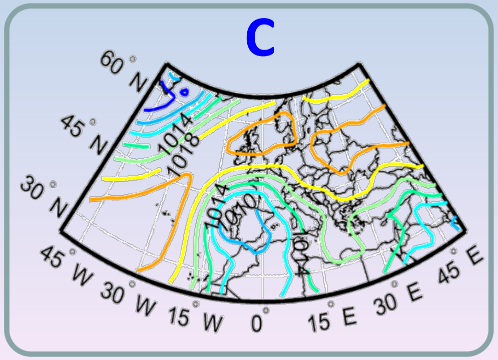
A.N
A.NW A.NE
A.W A.E
A.SW A.SE
A.S

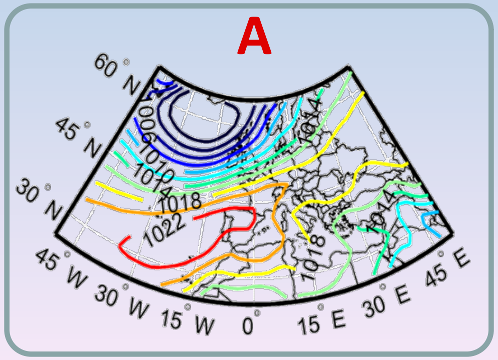
$|\mathbf{Z}| > \mathbf{F}, \mathbf{Z} < 0$

Mean annual SLP field for each directional WT



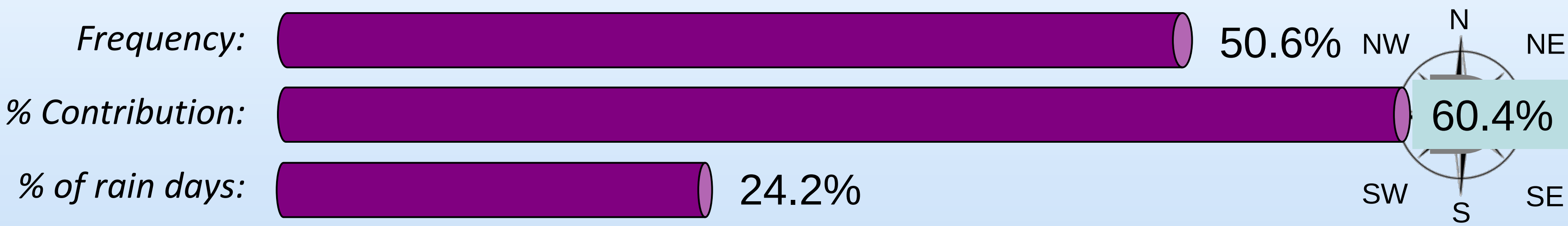
SLP:
20th Century Reanalysis



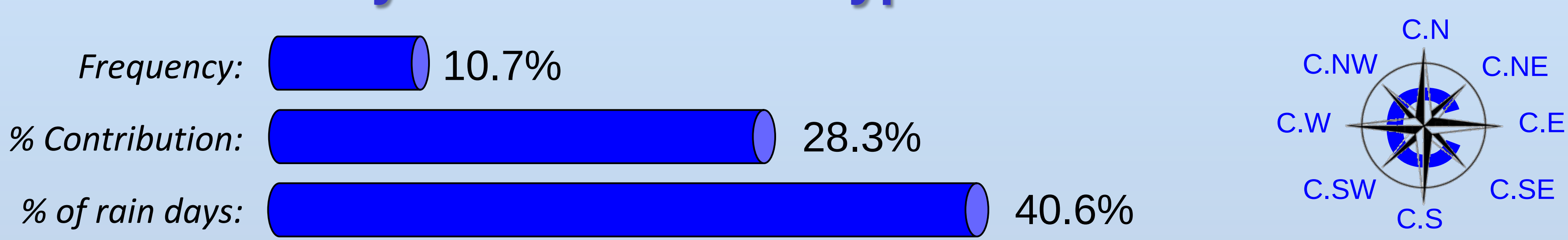


Period:
1948-2003

Directional Weather Types

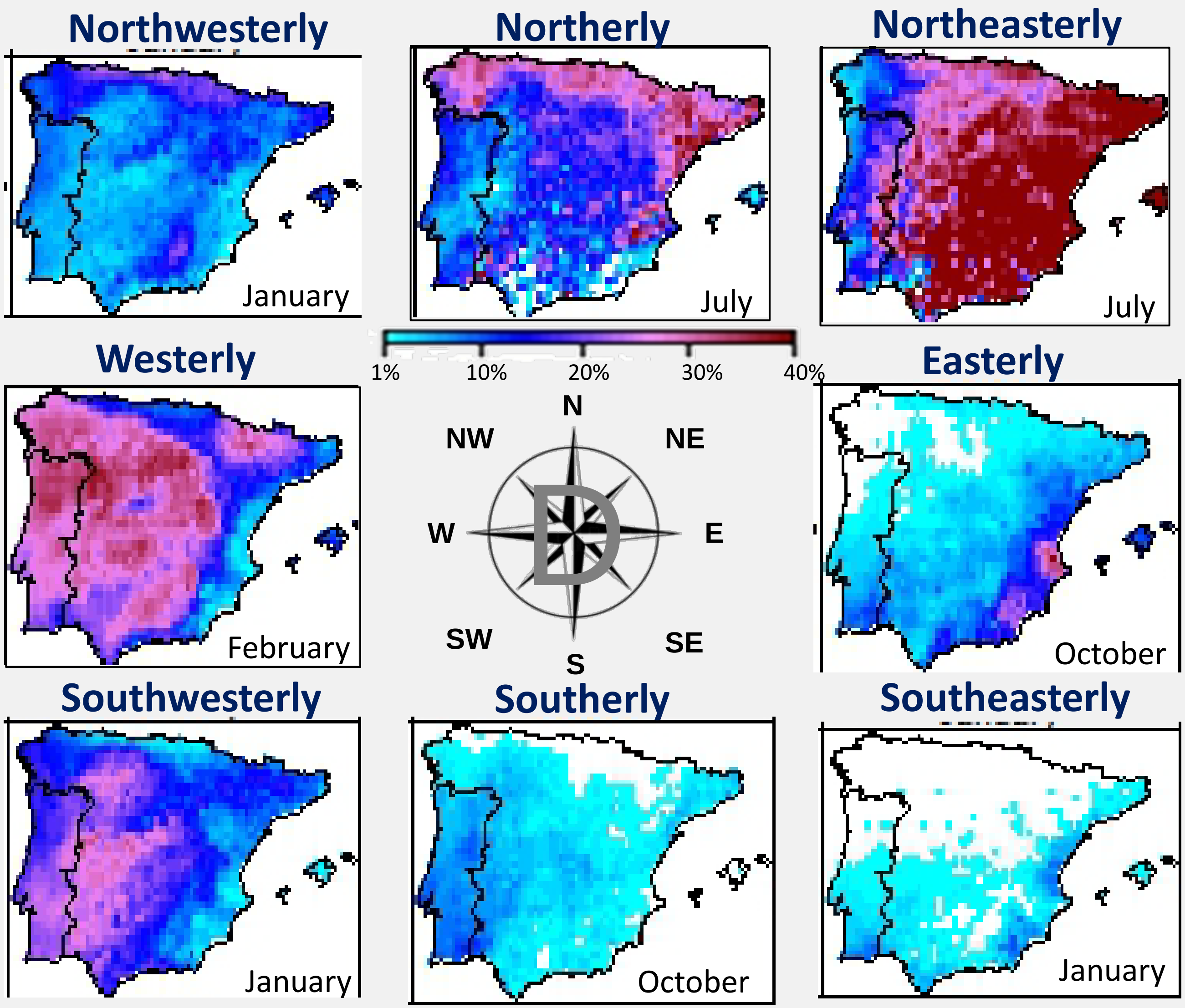


Cyclonic Weather Types

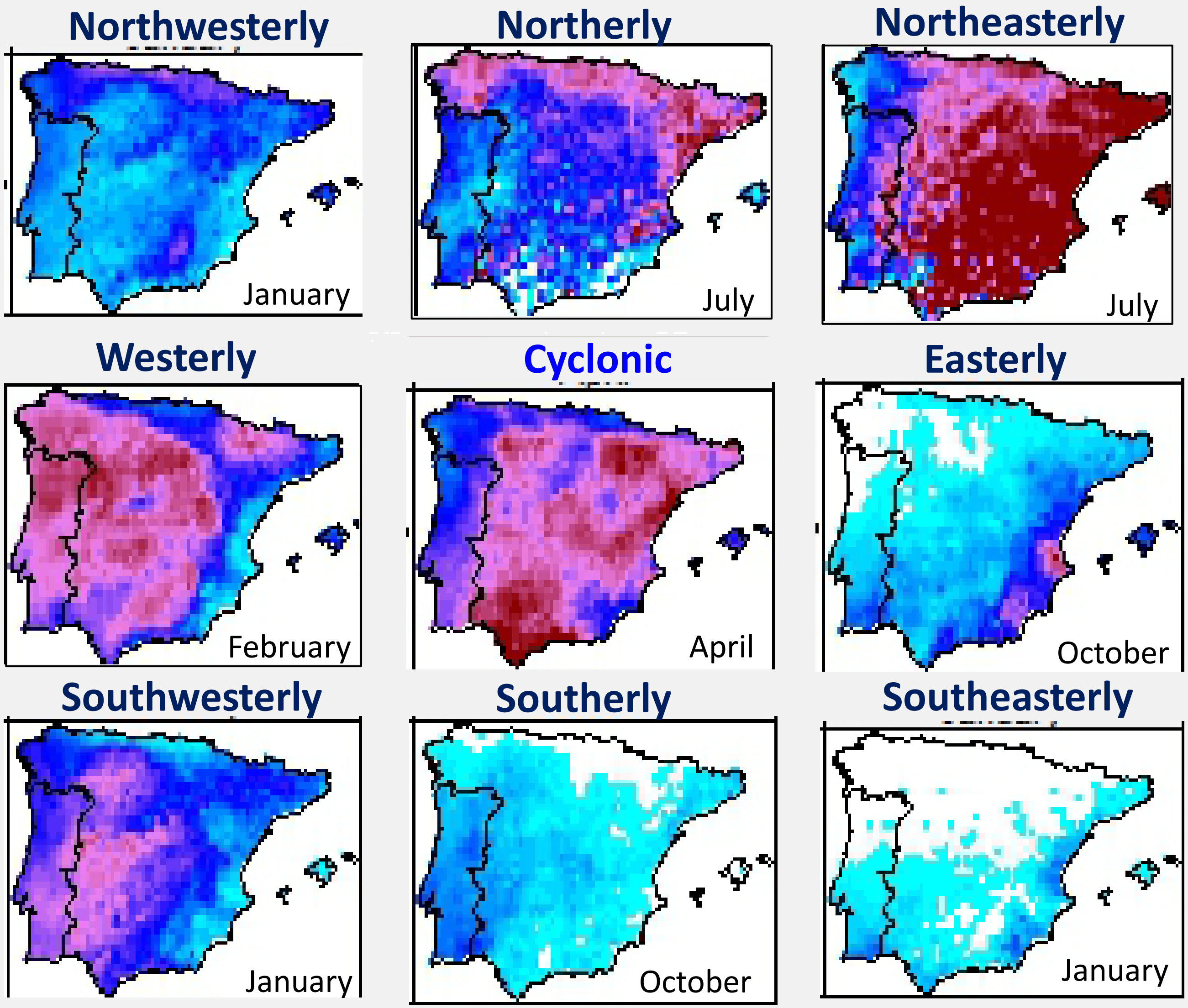


Anticyclonic Weather Types

% Contribute of the 8 Directional WT to Monthly Prec.

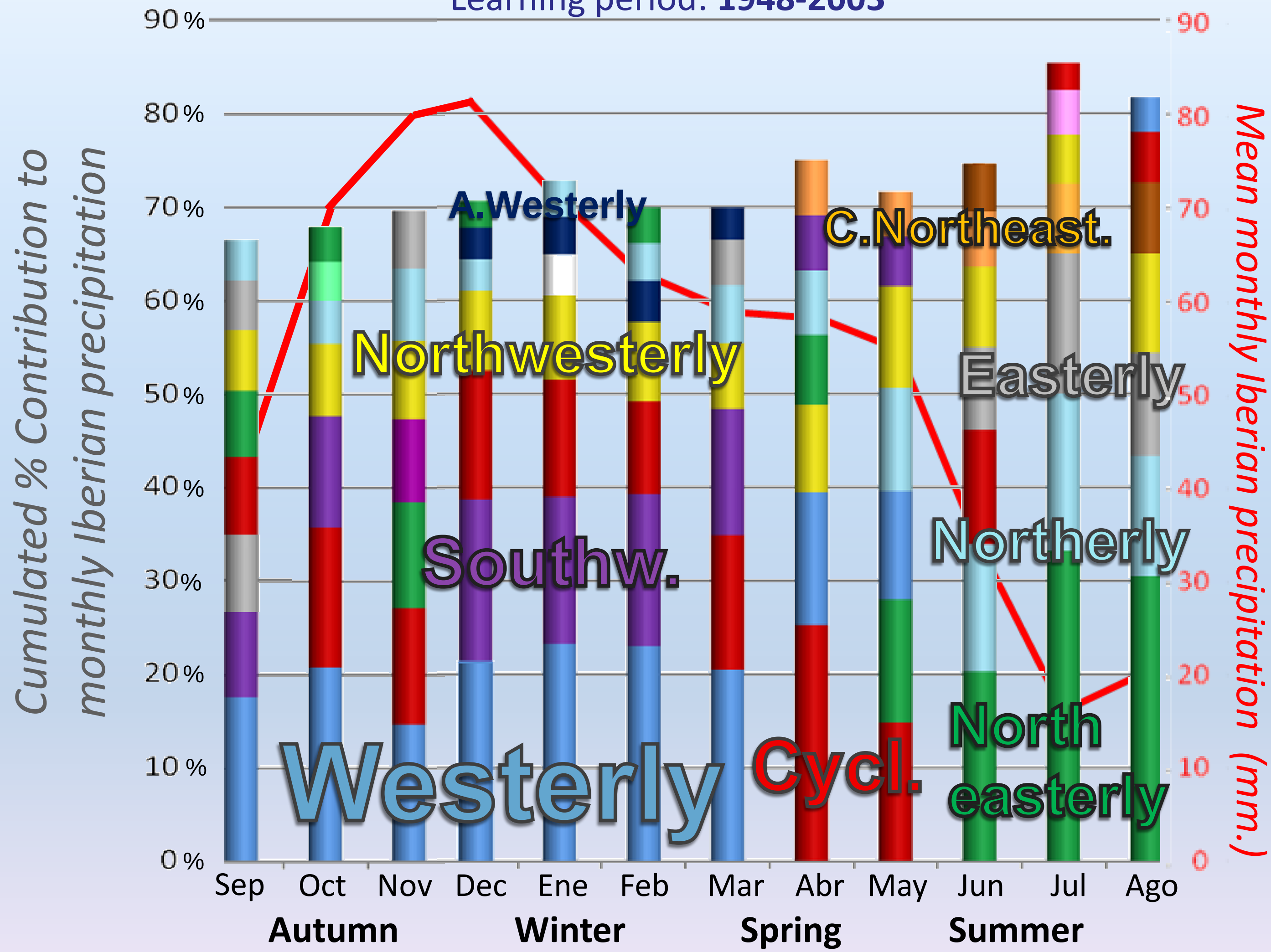


% Contribute of the 8 Directional WT to Monthly Prec.



% Contribution of each WT to monthly Iberian precipitation

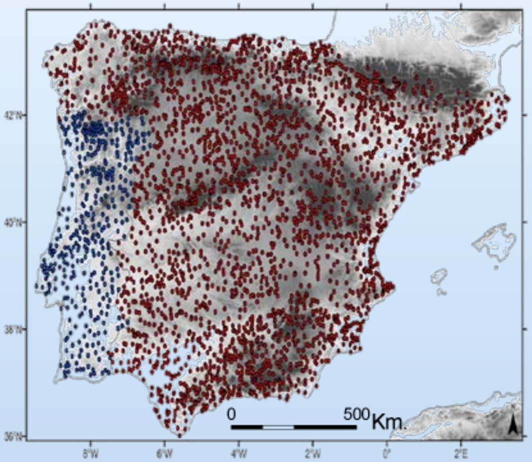
Learning period: **1948-2003**



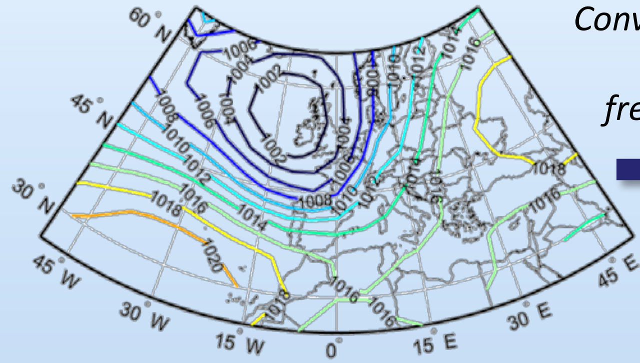
Weather Types with the highest % contribution are at bottom

Precipitation Downscaling

Mopredasp dataset

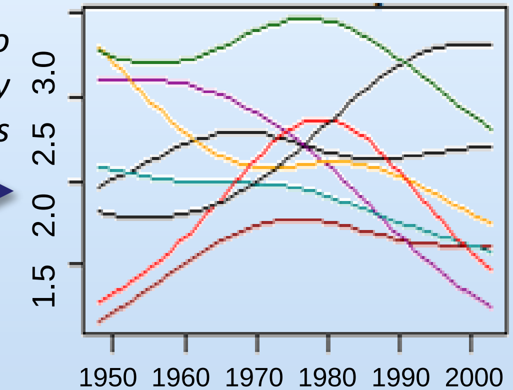


Daily Weather Types (WTs) Classification



Conversion to monthly frequencies

WTs Monthly Frequencies



Forward Stepwise Regression Model

Ex: *January:*

P_{tot} (mm) ***Fr. WT_1*** ***Fr. WT_2*** ***Fr. WT_{26}***

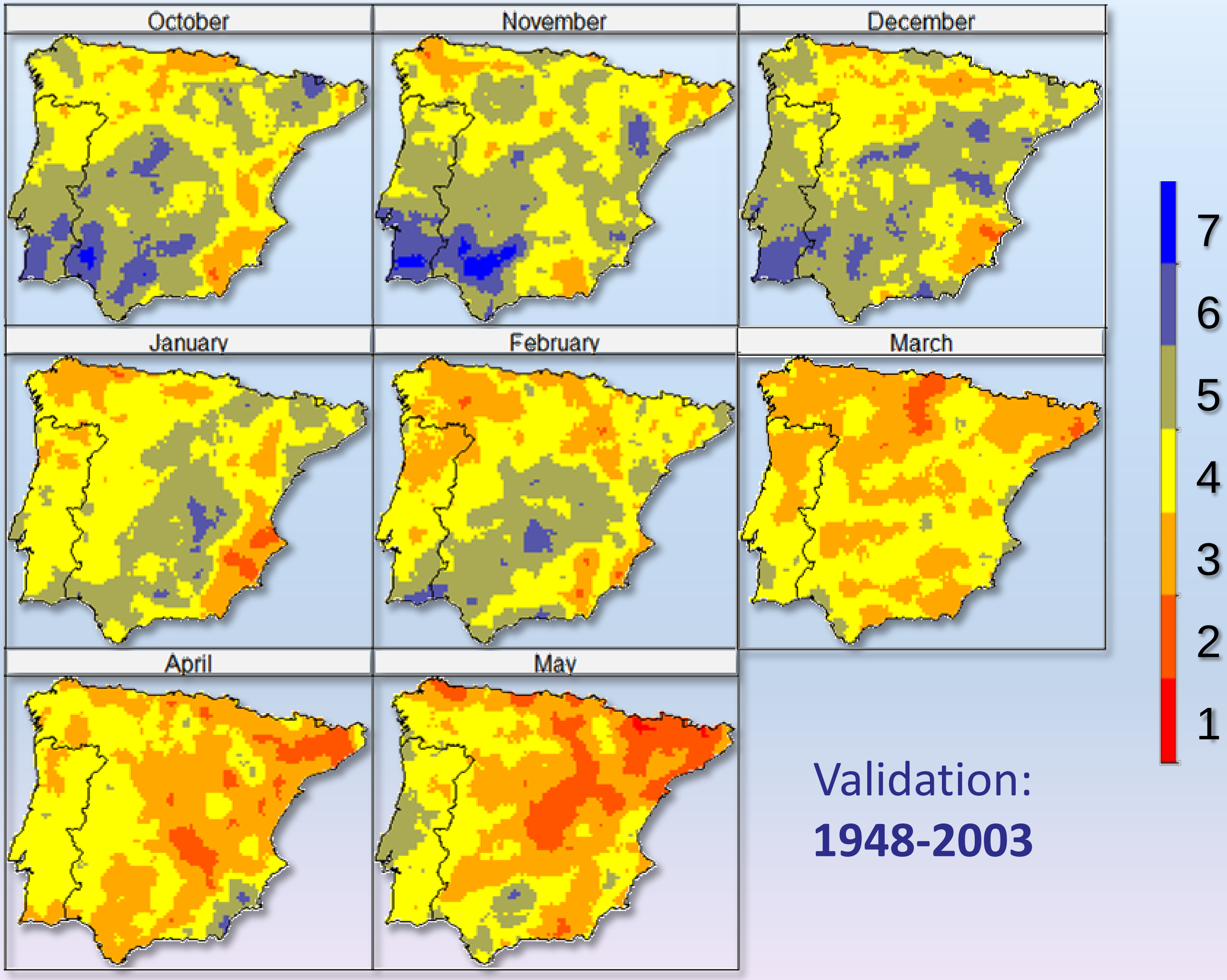
$$\begin{matrix} 1948: \\ 1949: \\ \ldots \\ 2003: \end{matrix} \begin{pmatrix} 149.0 \\ 116.7 \\ \ldots \\ 138.8 \end{pmatrix} = \alpha_0 + \alpha_1 \cdot \begin{pmatrix} 9 \\ 14 \\ \ldots \\ 8 \end{pmatrix} + \alpha_2 \cdot \begin{pmatrix} 17 \\ 12 \\ \ldots \\ 20 \end{pmatrix} + \ldots + \alpha_{26} \begin{pmatrix} 1 \\ 5 \\ \ldots \\ 3 \end{pmatrix}$$

$$\alpha_0 \geq 0 \quad const.term \qquad \alpha_1 \ldots \alpha_{26} \geq 0 \quad coef.\,de\,cada\;WT$$

Learning and validation period: ***1948-2003*** *(Validation:* ***leave-one-out*** *cross validation)*

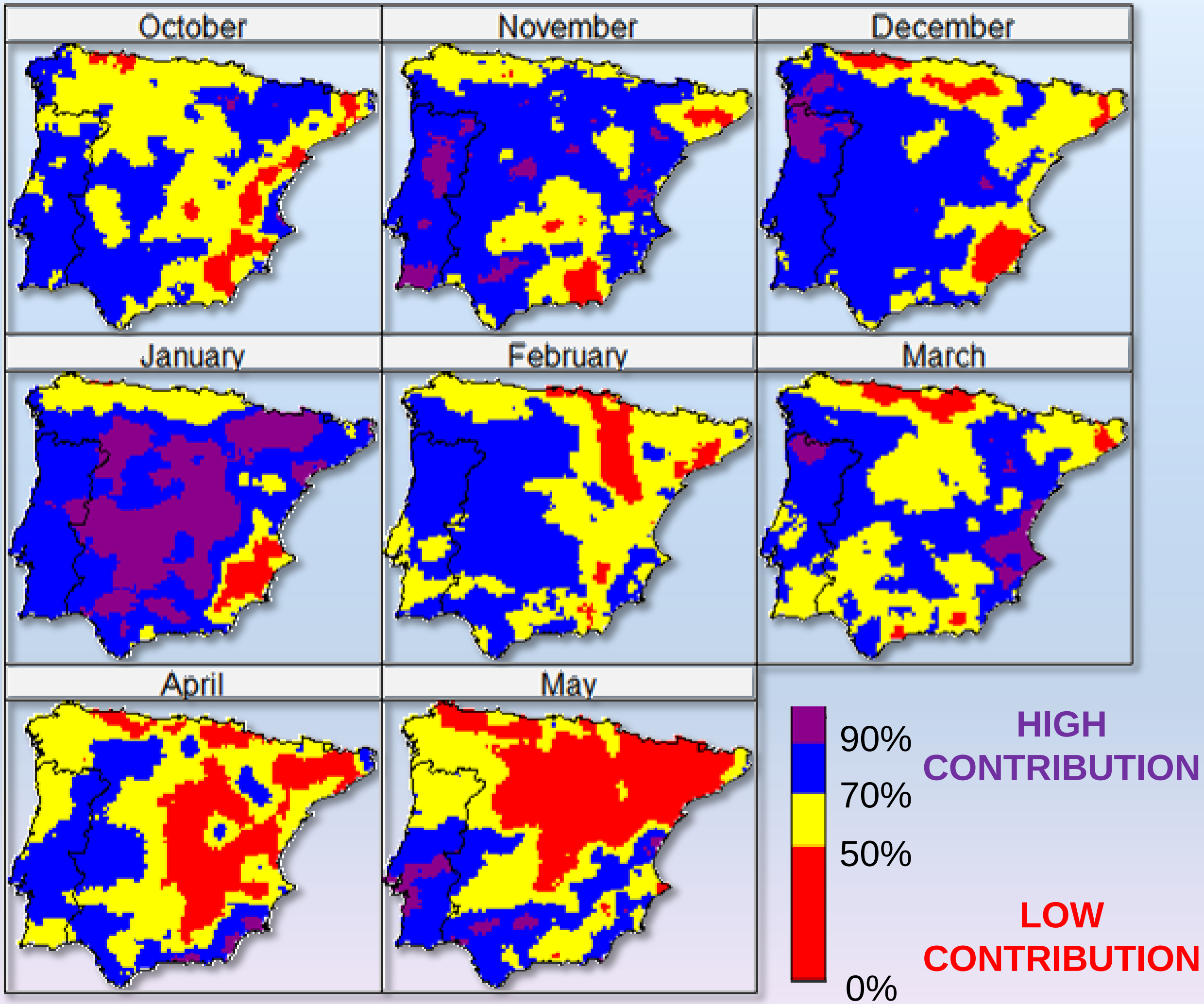
For each month and each series we will have a different model

Number of predictor Weather Types:

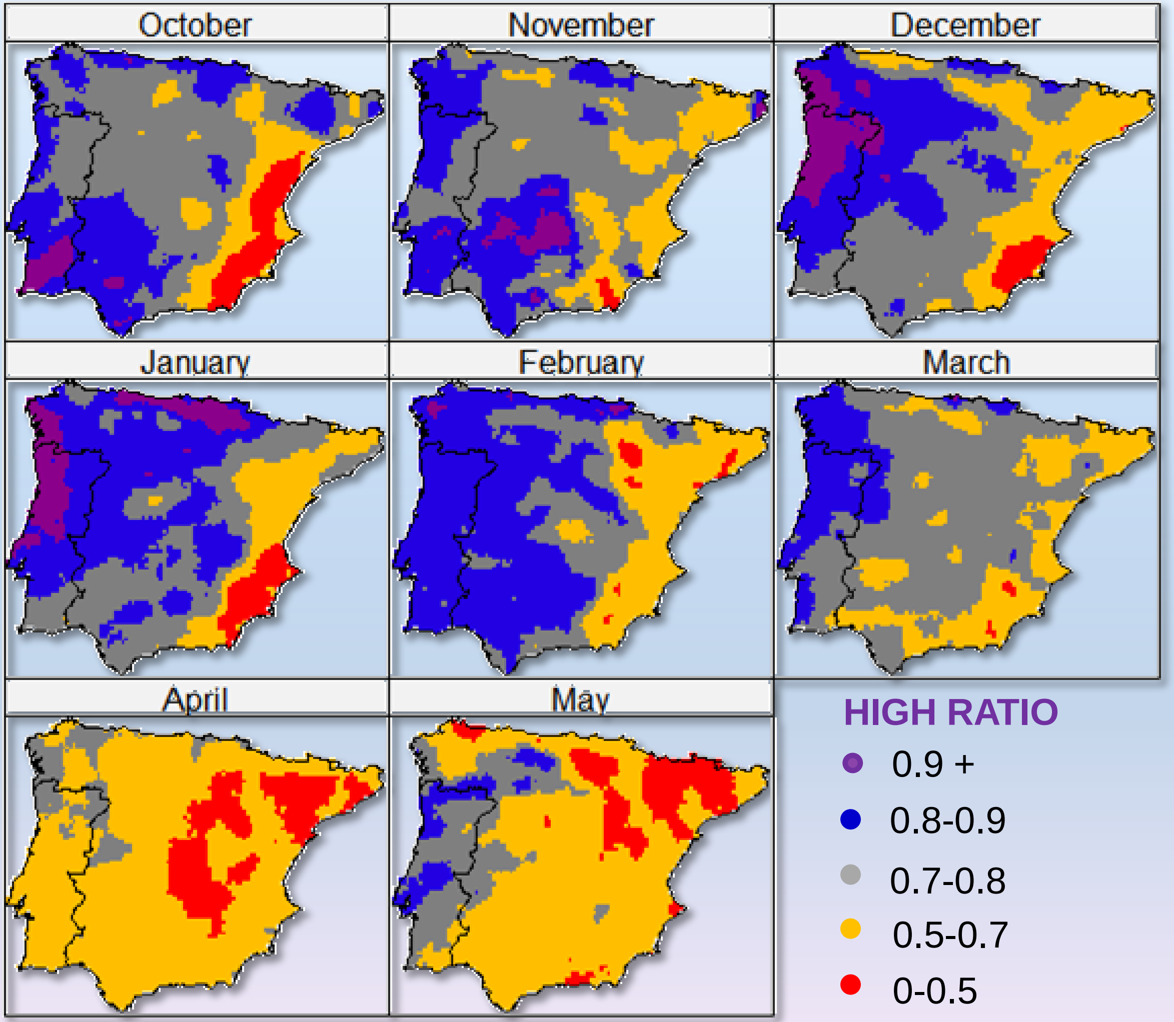


Validation:
1948-2003

% Contribution of all 26 Weather Types to total monthly prec.



Predicted Standard Dev. / Observed Standard Dev.

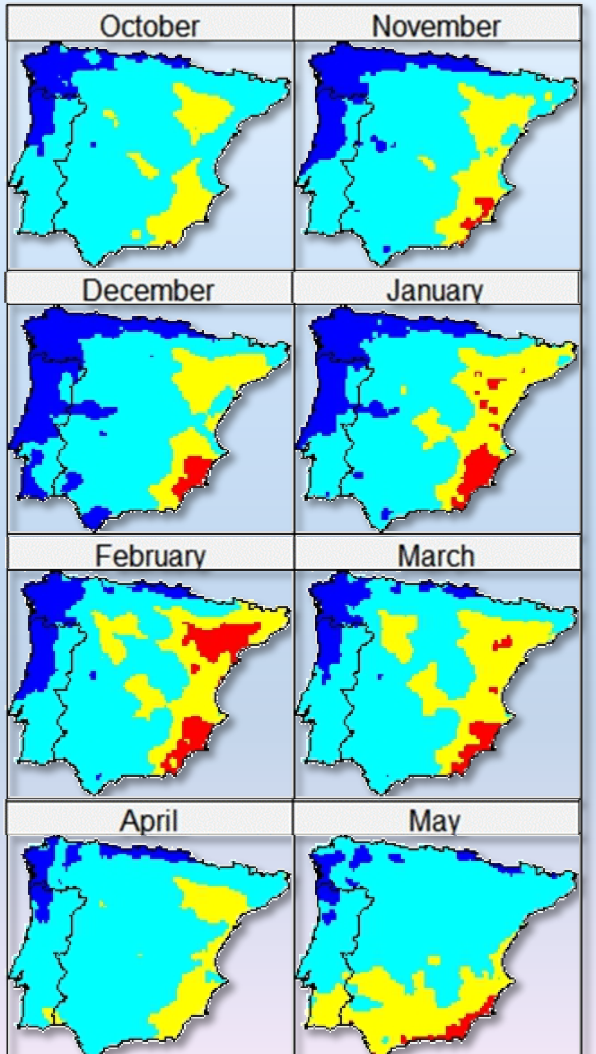


HIGH RATIO

- 0.9 +
- 0.8-0.9
- 0.7-0.8
- 0.5-0.7
- 0-0.5

LOW RATIO

Normalized Mean Absolute Error
MAE % = |P – O| / O



Validation:
1948-2003

LOW ERROR

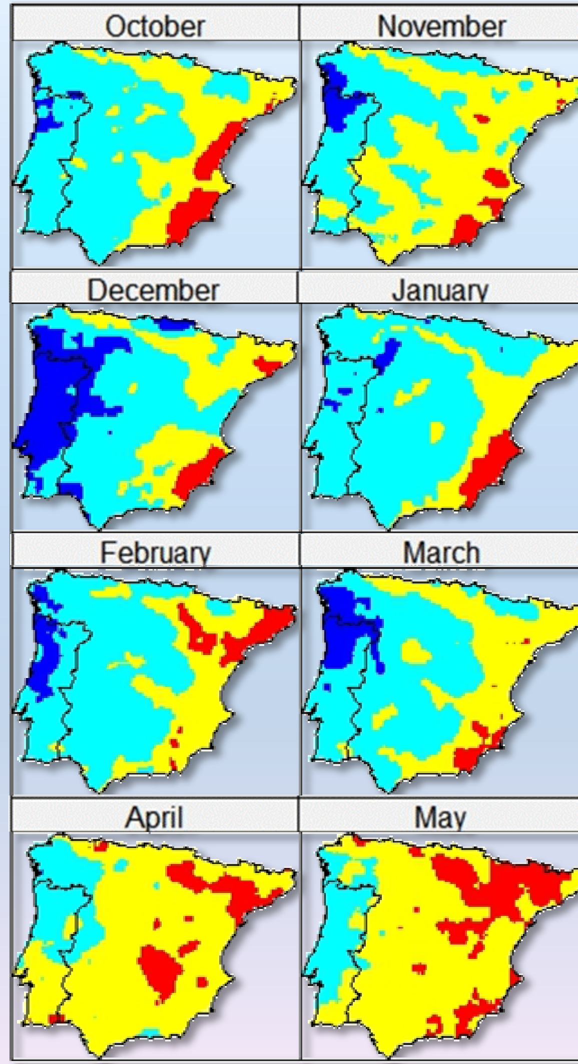
- 0-5%
- 5-10%
- 10-15%
- > 15%

HIGH ERROR

Summer months not shown (very high errors)

Index of Agreement
(D de Willmott)

$$d = 1 - \frac{\sum_{i=1}^{n} |P_i - O_i|}{2 \sum_{i=1}^{n} |O_i - \overline{O}|}$$



Validation:
1948-2003

LOW ERROR

- 0.7-1
- 0.6-0.7
- 0.5-0.6
- 0-0.5

HIGH ERROR

Summer months not shown (very high errors)

Stationarity assumption

20th Century Rean. (SLP 1850-2003) — *Derive* → **26 Lamb WTs (1850-2003)**

26 Lamb WTs (1850-2003) — *Derive* → **Relationships between Weather Types and Iberian precipitation**

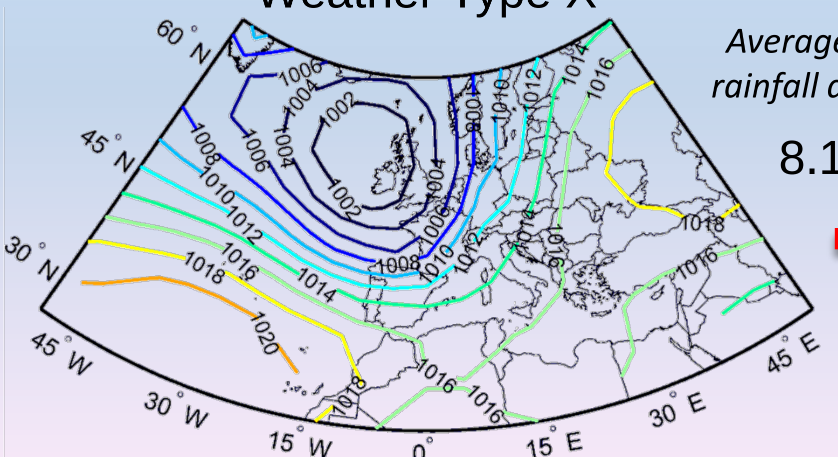
Mopredasp monthly Iberian prec. (1948-2003) ↔ *Calibration* ↔ **Relationships between Weather Types and Iberian precipitation**

Relationships between Weather Types and Iberian precipitation — *Fore cast* → **Predicted gridded precipitation (1850-1947)**

130 Long monthly precip. series from 1915 — *Stability testing* *(1915-1949 vs. 1950-2003)* → **Predicted gridded precipitation (1850-1947)**

The underlying forecasting hypothesis is that, for a chosen serie and month, each WT **always produces the *same* mean daily rainfall amount.**

Weather Type X



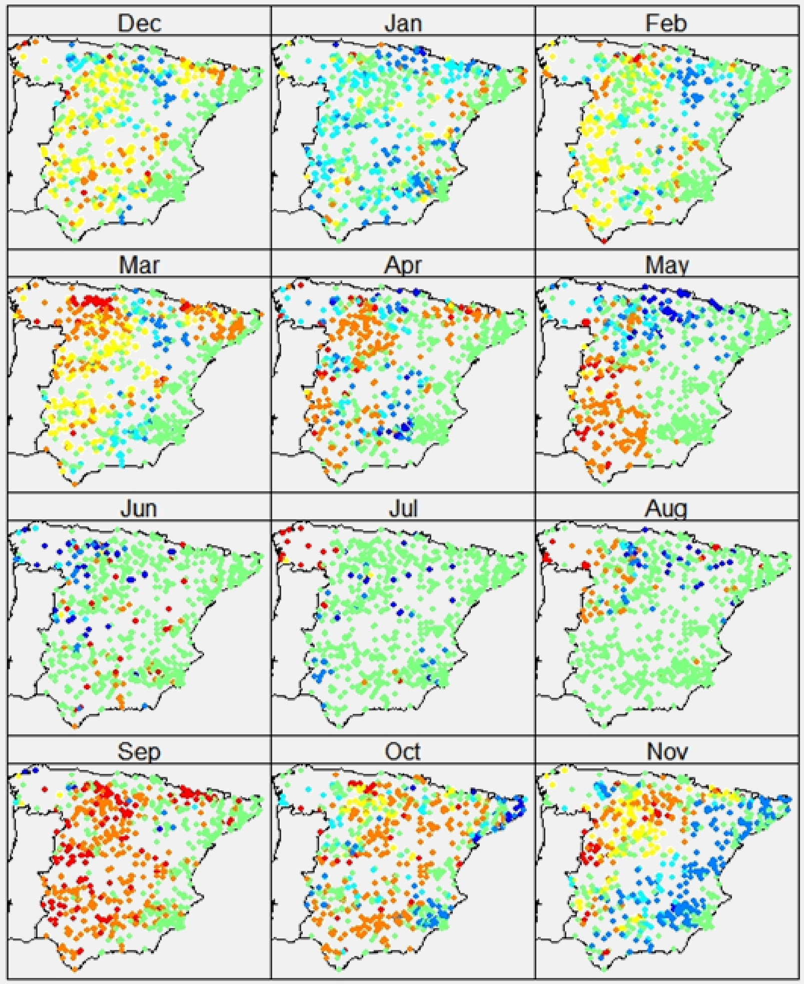
Average daily rainfall amount

8.1 mm.

Toulouse in January

Must be similar both in 1915 -1947 both in 1948-2003

Comparison between Average Daily Rainfall Amount (Ω) of Westerly weather type for two periods 1915-1947 and 1948-2003



P-value < 5% (Stationary relationship)

P-value > 5% and
$\Omega_{\text{1st period}} > \Omega_{\text{2nd p.}}$

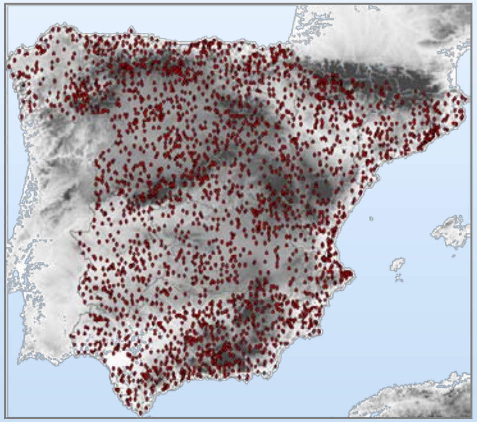
- >100%
- >50%
- >20%

P-value > 5% and
$\Omega_{\text{1st period}} < \Omega_{\text{2nd p.}}$

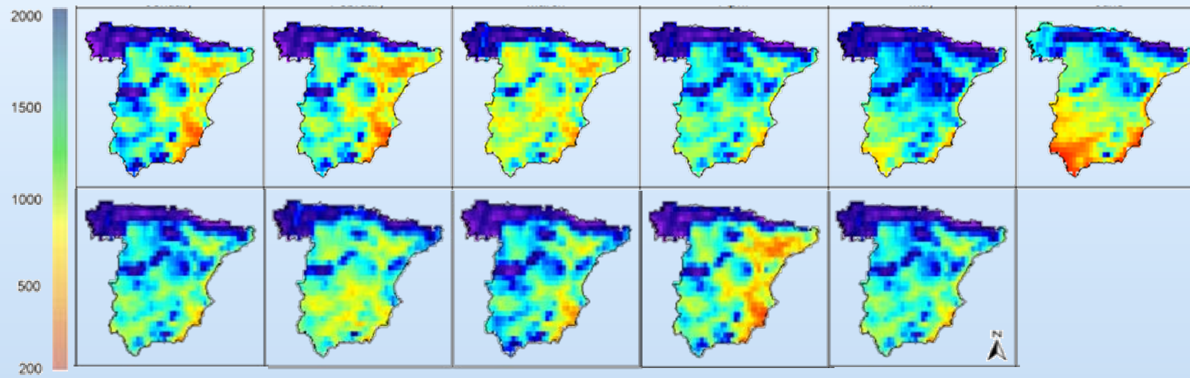
- <100%
- <50%
- <20%

Ensemble Validation

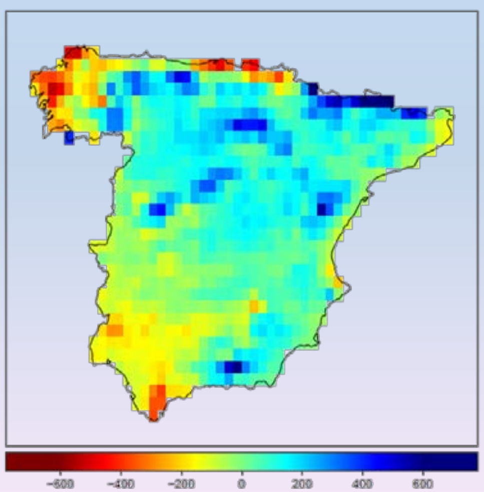
Monthly MOPREDASP



Interpolation on a 25 km² grid (Local weighted regress.)



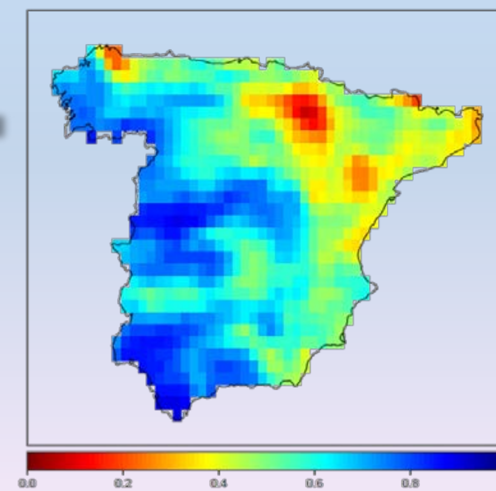
11 RCMs at **25** km² from the *Ensemble Project*
Parametrization: **ECHAM4 GCM**
Boundary: **ERA40**



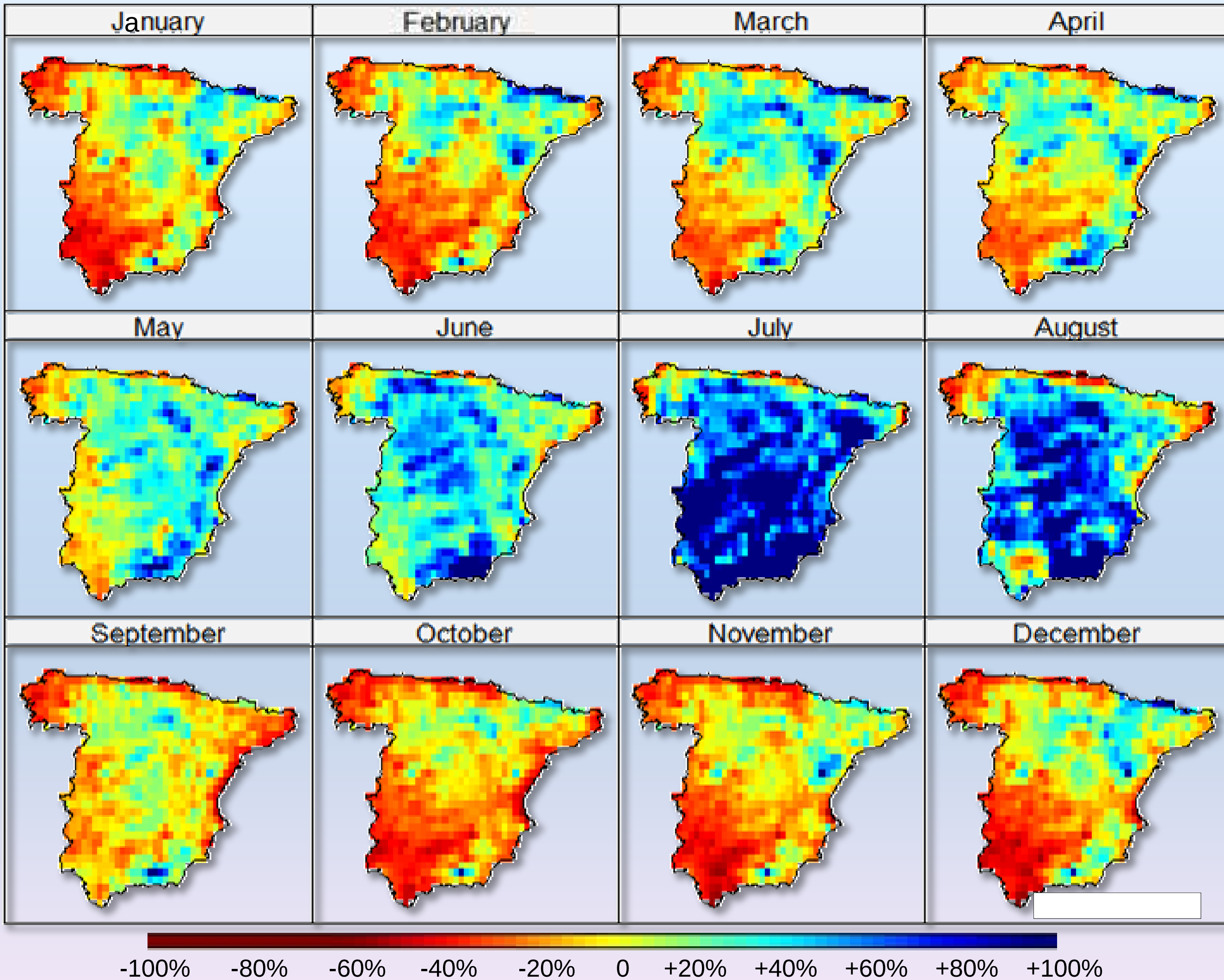
VALIDATION 1961-2000

Error Indexes:
Bias, MAE, RMSE, R^2, …

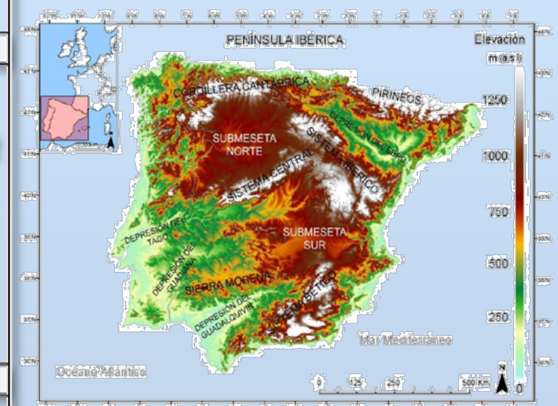
Ensemble Mean Model



Mean Bias Error in % **(MBE %)** of the Ensemble Model



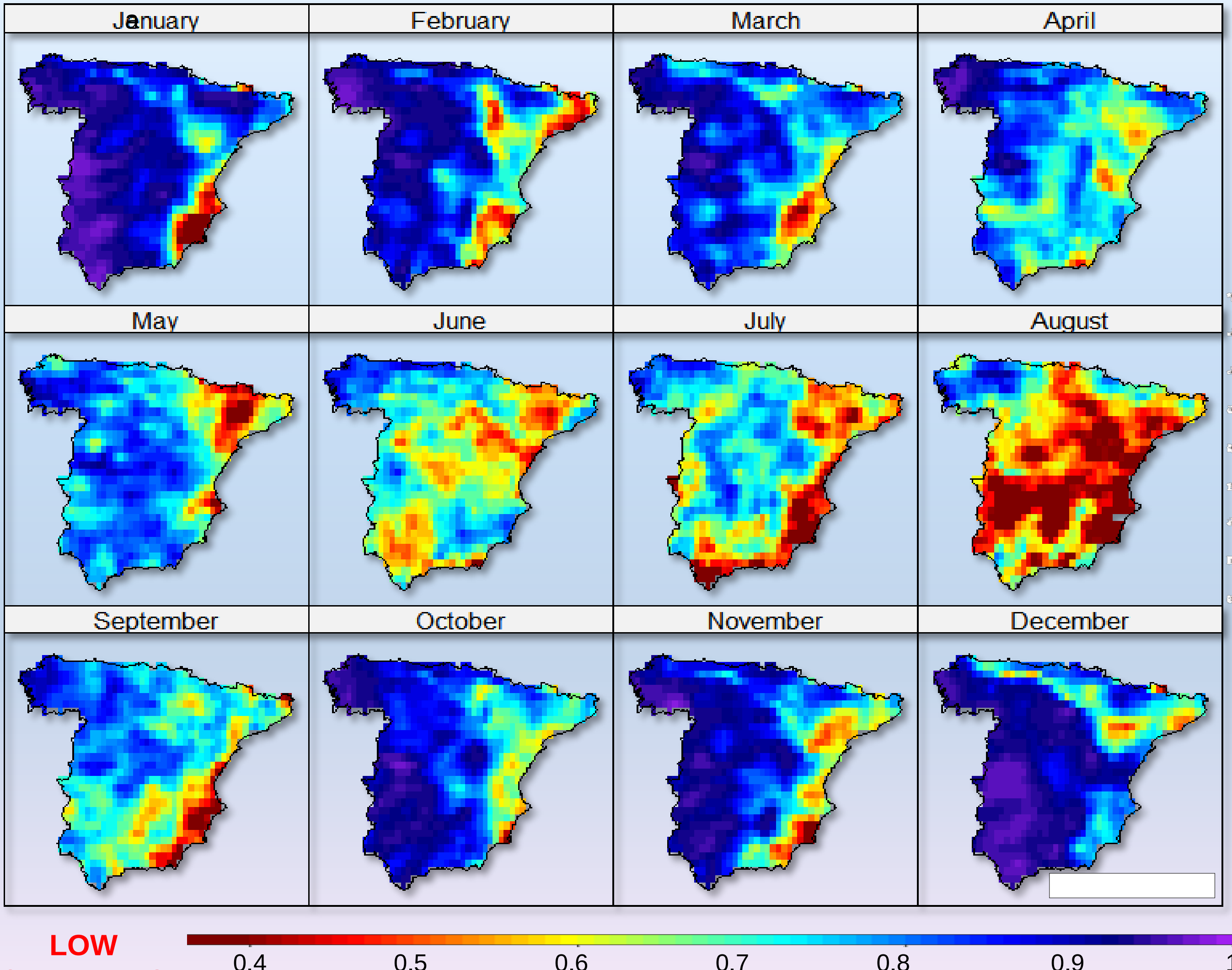
Ensemble validation



Validation:
1961-2000

Monthly Ensemble of 15 RCMs

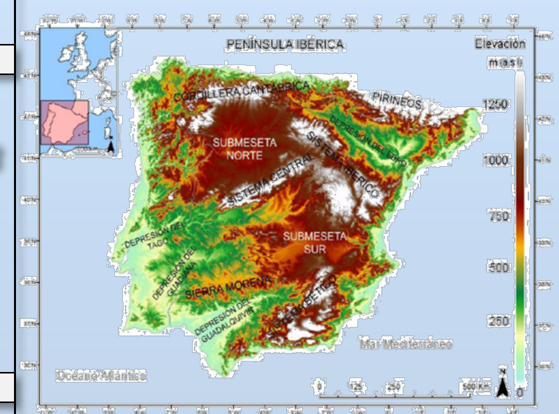
Detrended Pearson's Correlation Coefficient



LOW CORRELATION

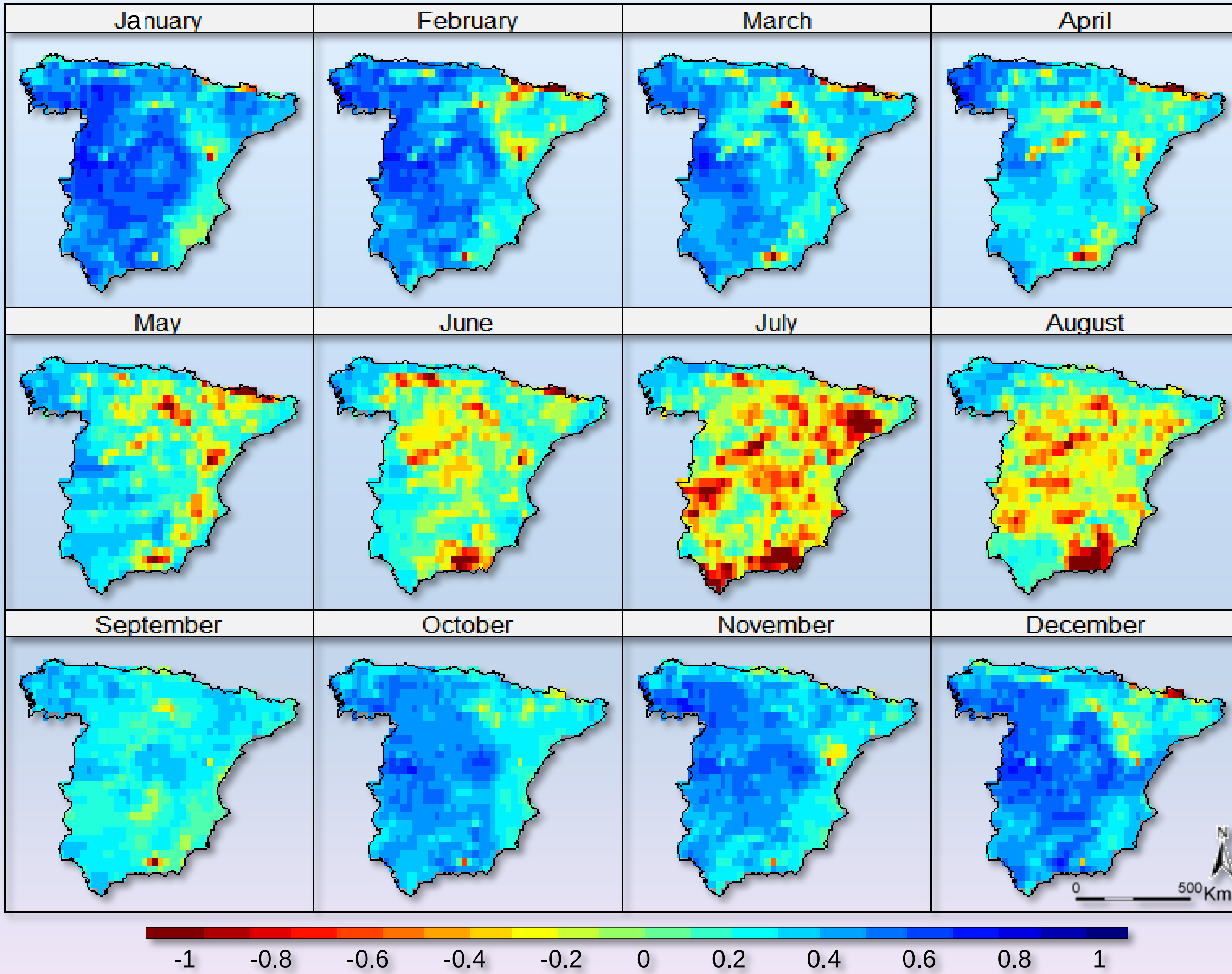
HIGH CORRELATION

Ensemble validation



Validation:
1961-2000

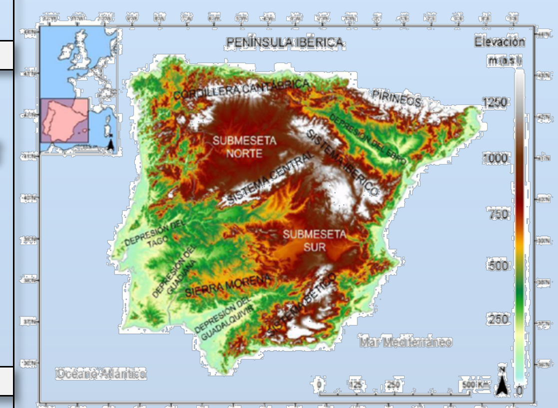
Skill Score of the RMSE $(RMSE_{ENSEMBLE} - RMSE_{CLIMATOL.}) / -RMSE_{CLIMATOL.}$



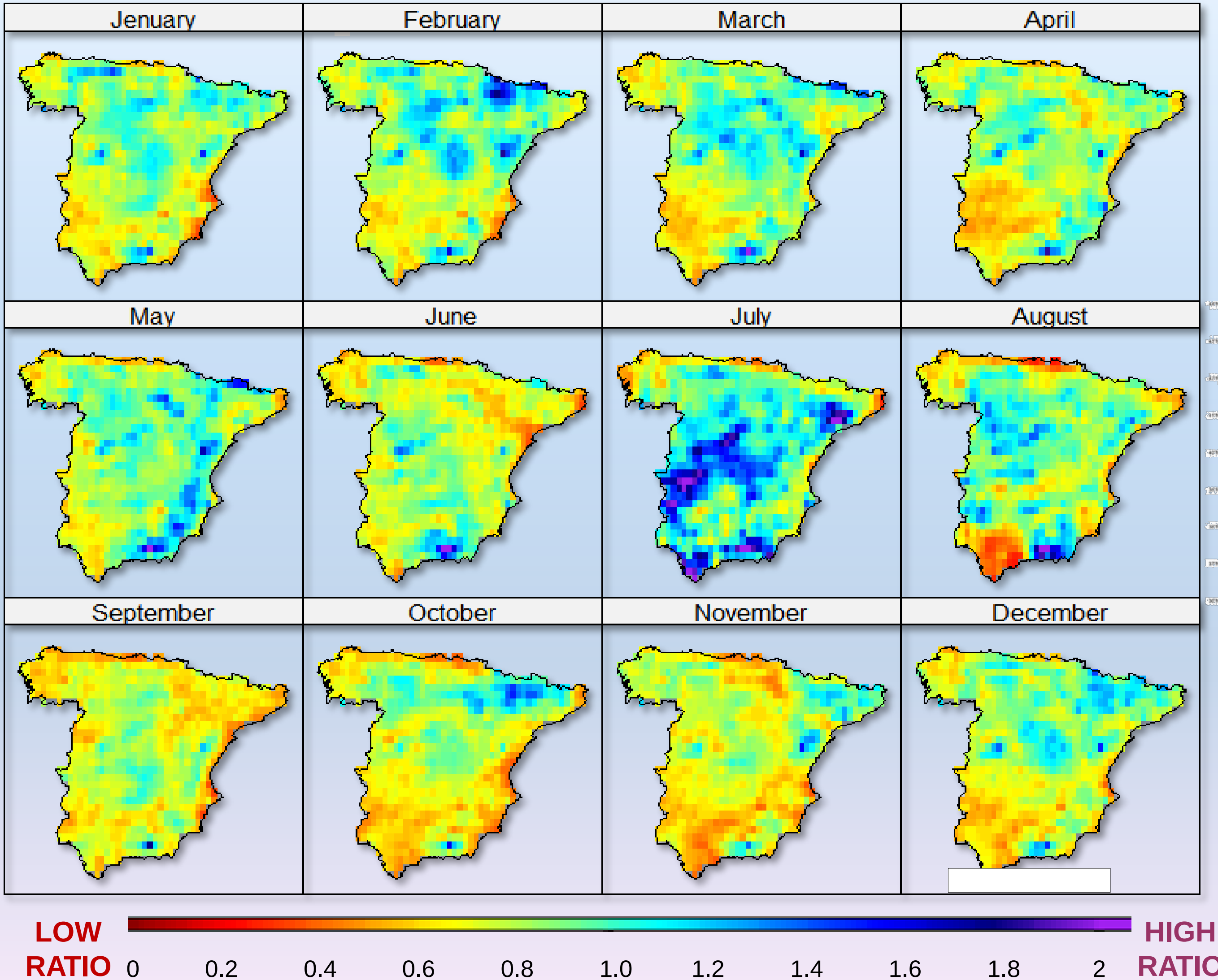
CLIMATOLOGICAL MODEL IS BETTER

ENSEMBLE MODEL IS BETTER

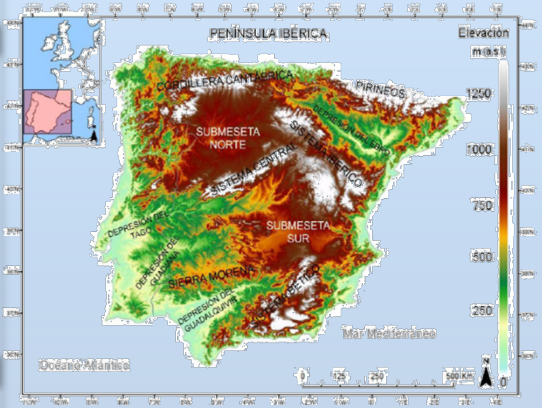
Ensemble validation



Ratio between Modelled and Observed Standard Deviation



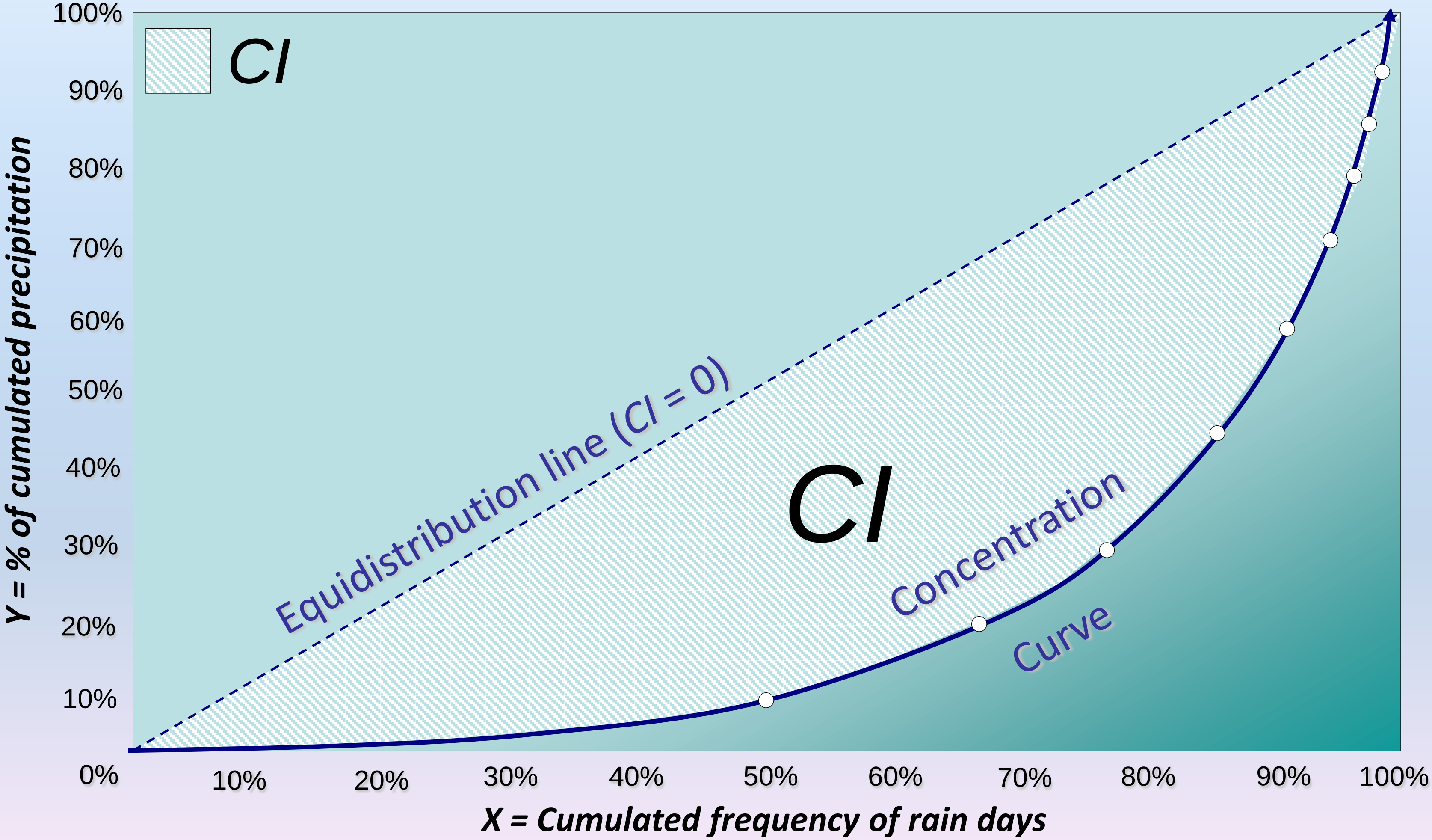
Ensemble validation



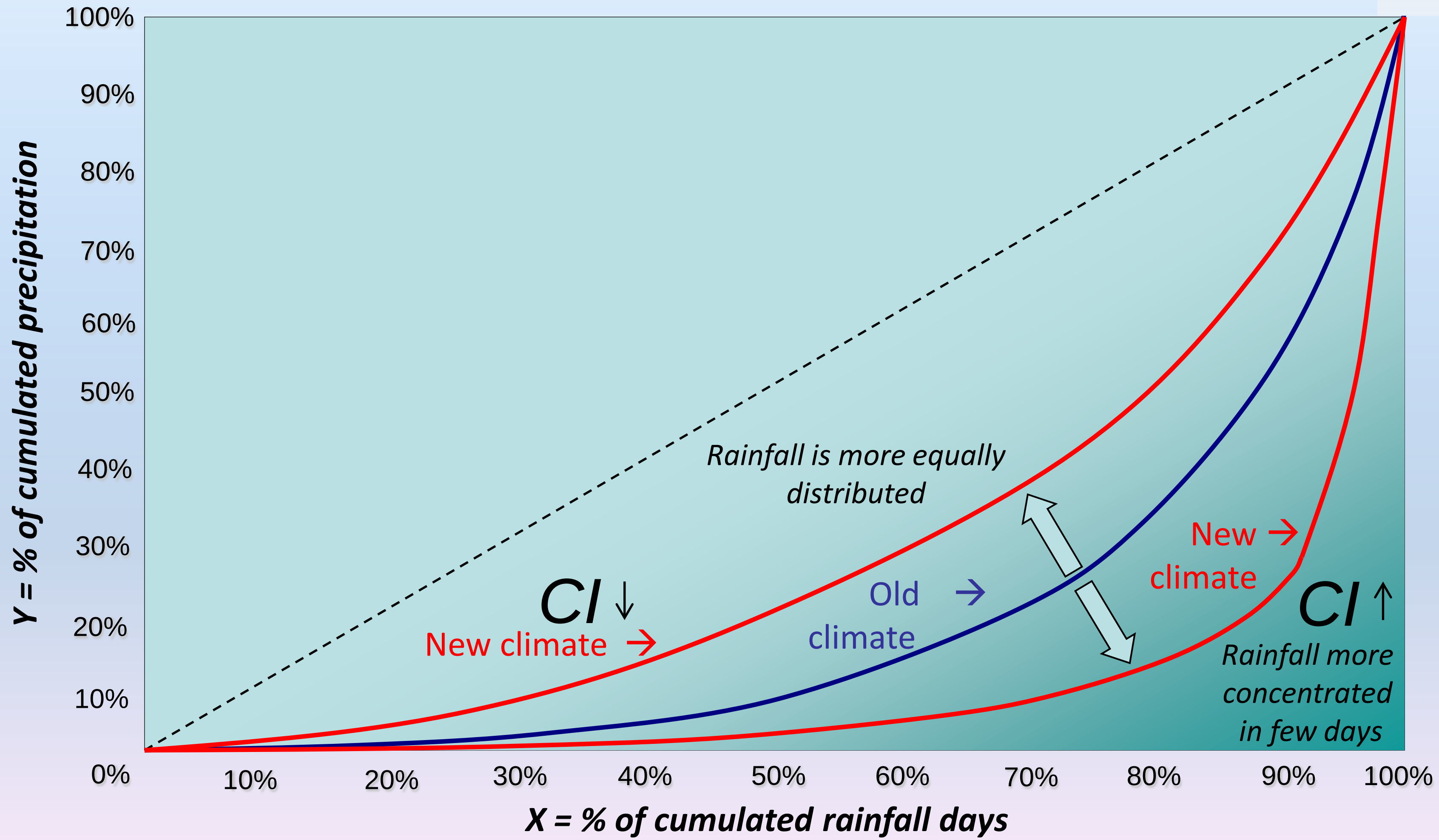
Validation:
1961-2000

Concentration Index (CI)

(Martín-Vide, 2004)

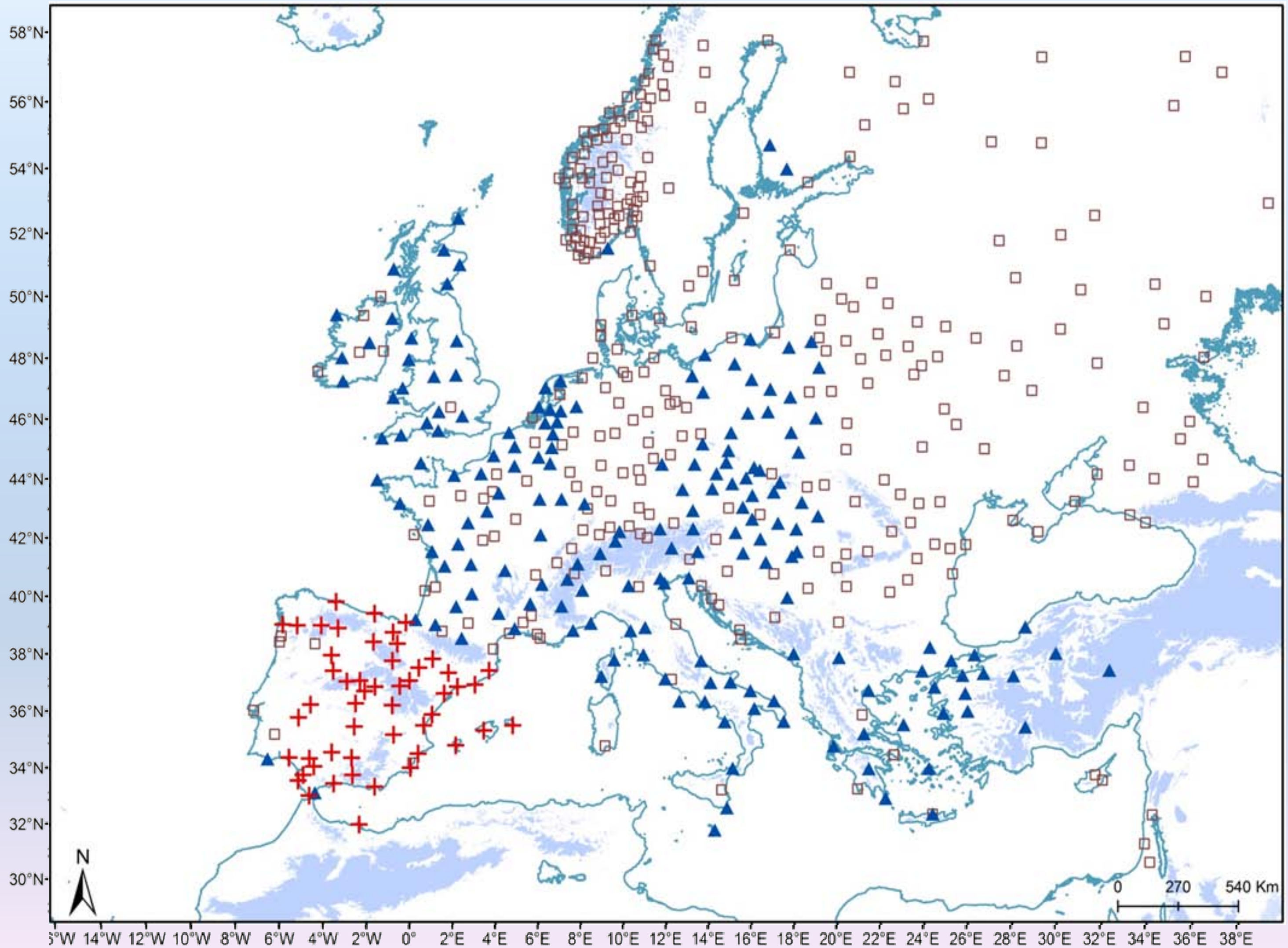


Change in the Concentration Index (*CI*)



Distribution of the 530 selected daily series

(with at least 90% of data during 1971-2010)



Database:

AEMet Agencia Estatal de Meteorología

+ 51 series

ECA&D

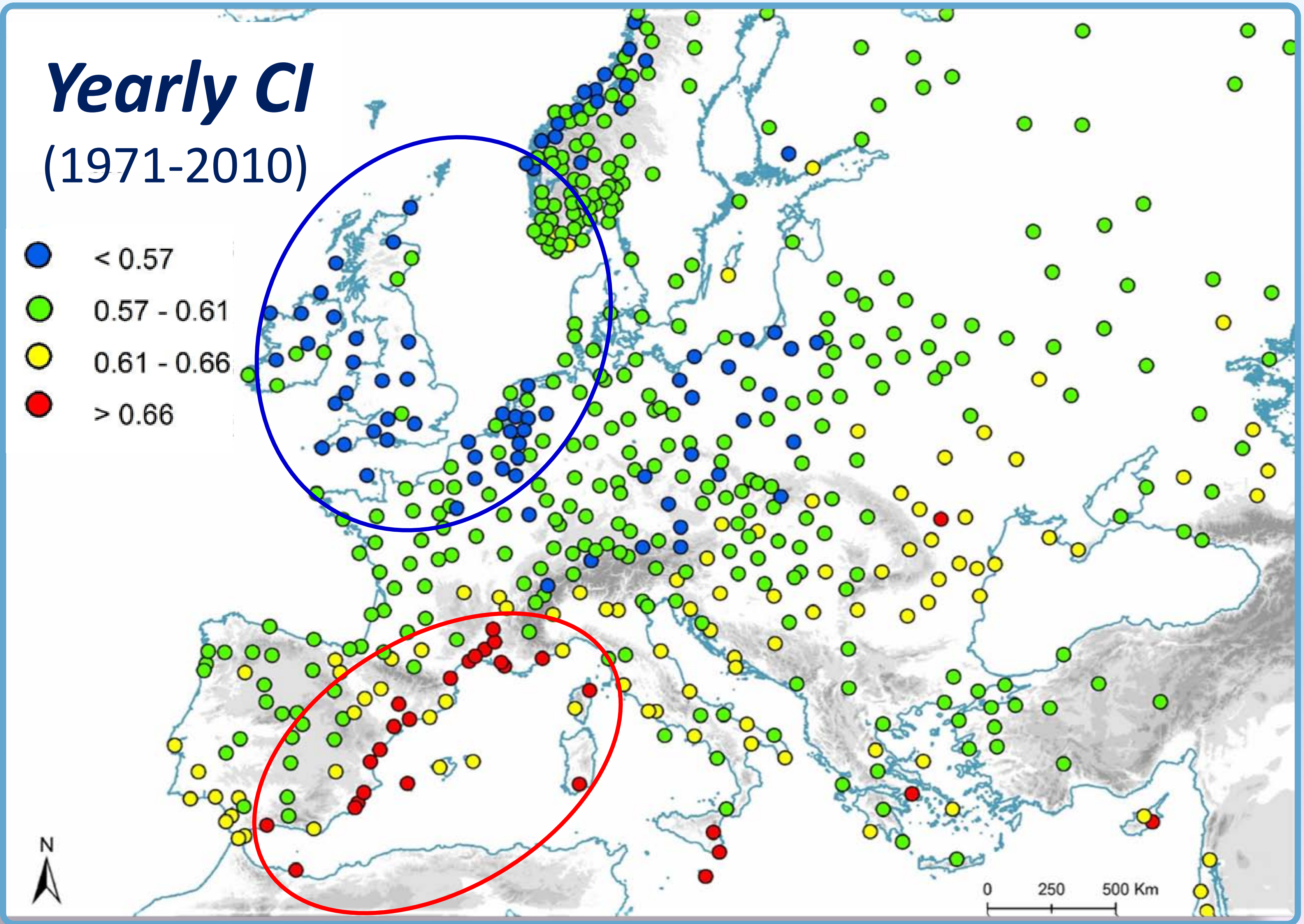
□ 298 series

NOAA

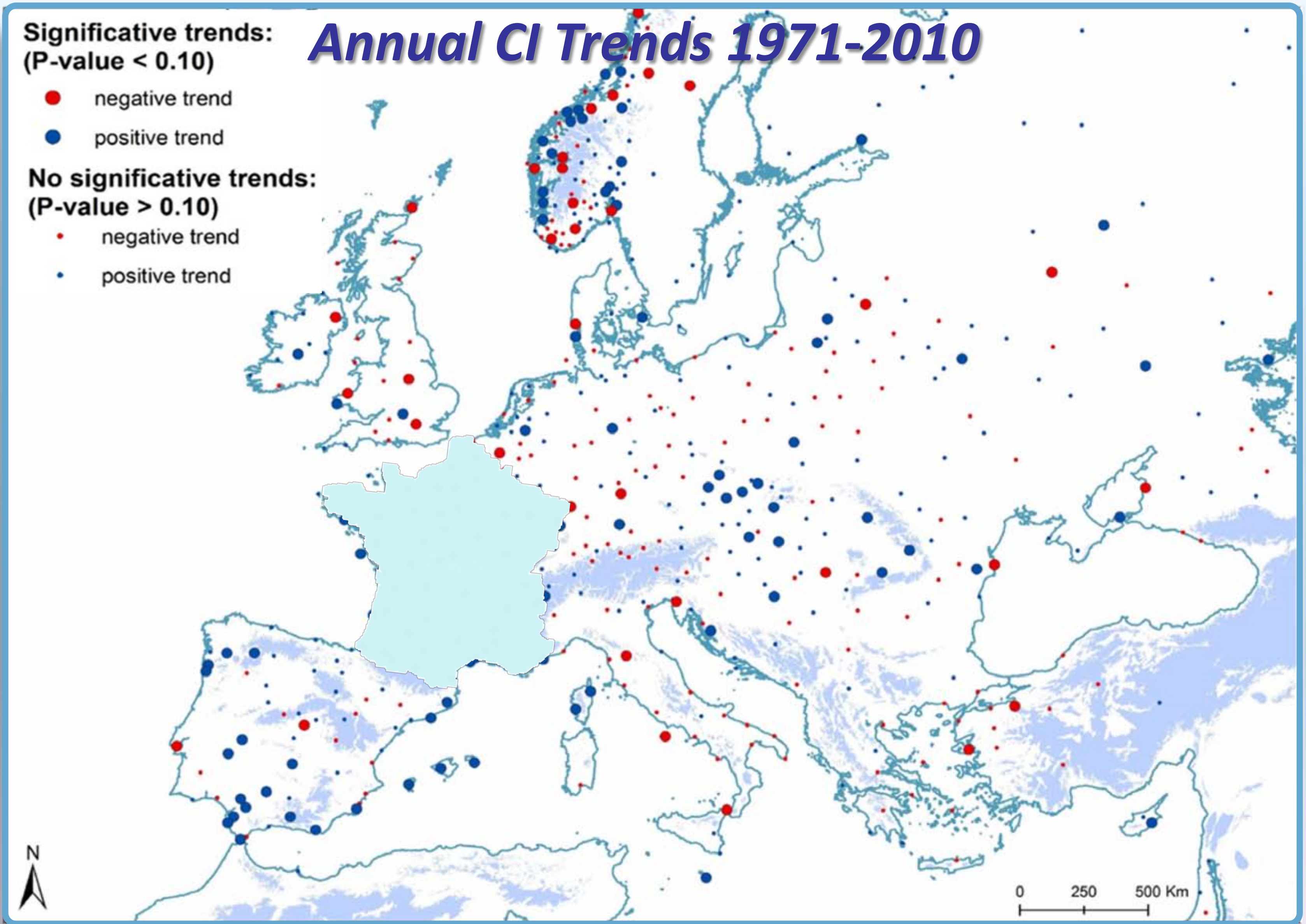
▲ 181 series

Yearly CI

(1971-2010)

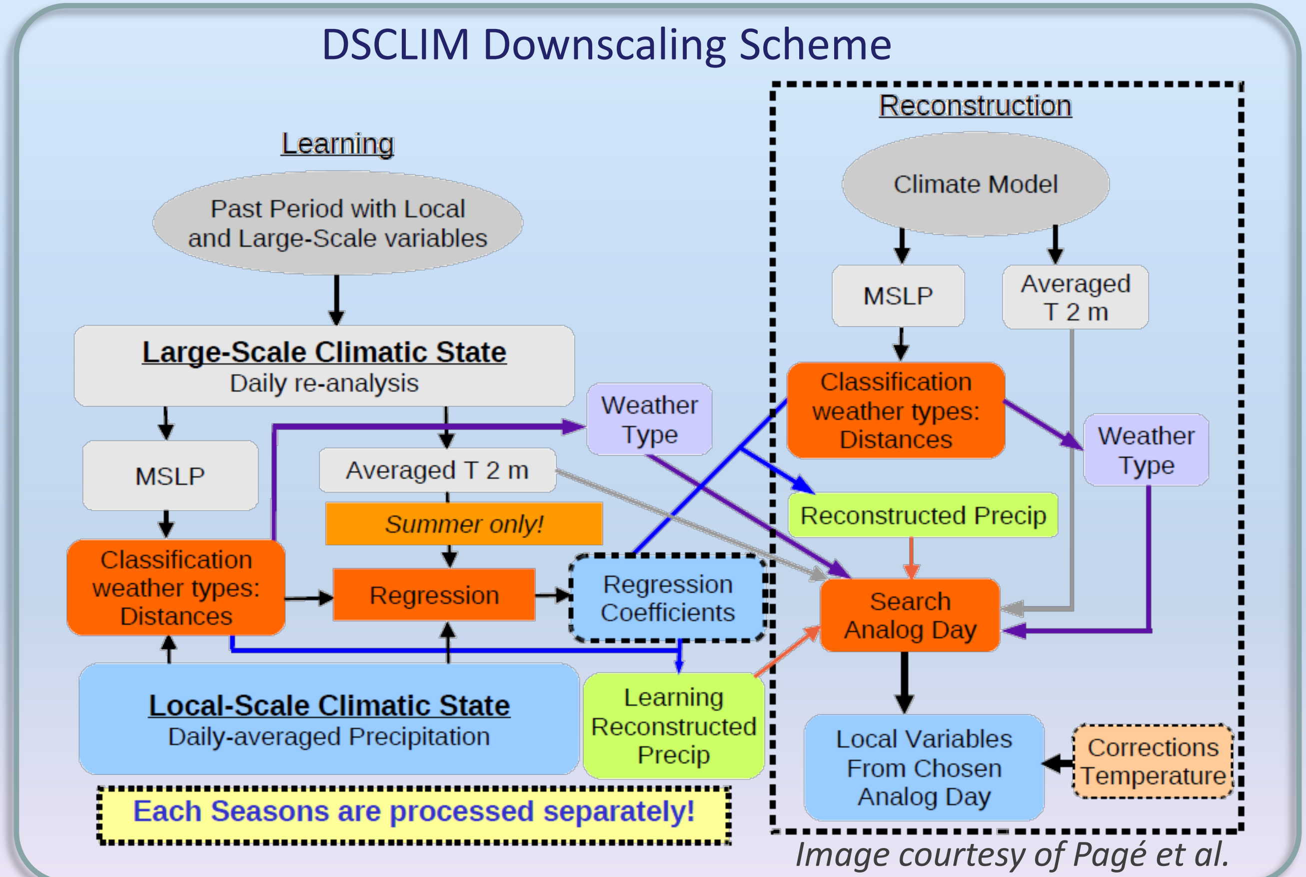


Annual CI Trends 1971-2010



Future Work – Postdoc (2014)

- Extending DSCLIM Downscaling Method developed at CERFACS from France to the whole European region



Supervisor: *Dr.Christan Pagé*

- **Articles with Peer Review:**

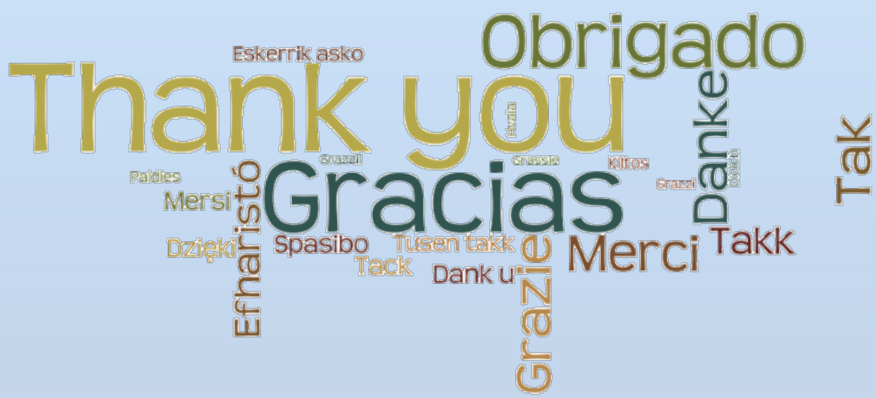
1. Cortesi N, González-Hidalgo JC, Trigo R, Ramos A (2013), **Weather Types and spatial variability of precipitation in the Iberian Peninsula**, *International Journal of Climatology.* Published online in Wiley Online Library (wileyonlinelibrary.com) (doi: 10.1002/joc.3866)
2. Cortesi N, Trigo R, González-Hidalgo JC, Ramos A (2013) **Modelling monthly precipitation with circulation weather types for a dense network of stations over Iberia**. *Hydrology and Earth System Sciences 9, 6935-6977* (doi:10.5194/hessd-9-6935-2012).
3. Cortesi N, González-Hidalgo JC, Brunetti M, de Luis M (2013) **Spatial variability of precipitation in Spain**. *Regional Environmental Change* (doi: 10.1007/s10113-012-0402-6).
4. Nadal-Romero E, González-Hidalgo JC, Cortesi N (2013) **Weather Types, runoff and sediment yield in a Mediterranean Mountain landscape**, *Earth Surface Processes and Landforms* (doi: 10.1002/esp.3451).
5. Cortesi N, González-Hidalgo JC, Cabos W, de Luis M (2012) **Precisión e incertidumbres de las precipitaciones estimadas por modelos ENSEMBLES en la España peninsular (1961-2000). Variaciones espaciales y temporales.** In *Cambio climático: extremos e impactos. Actas 8 Congreso AEC, 53-62* (ISBN 978-84-695-4331)
6. Cortesi N, González-Hidalgo JC, Brunetti M, Martin-Vide J (2012) Daily precipitation concentration across Europe 1971-2010. *Natural Hazards 12: 2799-2810* (doi:10.5194/nhess-12-1-2012).
7. González-Hidalgo JC, Cortesi N, Nadal E, Brunetti M, Stepaneck P, De Luis M (2013) **Las tendencias de las precipitaciones en España en el periodo 1945-2005,** In *Fenomenos Meteorologicos adversos en España, 281-297* (ISBN 978-84-96709-88-1).
8. Lorenzo-Lacruz J, Vicente S, González-Hidalgo JC, Lopez JI, Cortesi N (2012) **Evaluación regional de la respuesta hidrológica a las condiciones de sequía climática a distintas escalas temporales en la Península Ibérica**. En Cambio climático: extremos e impactos. *Actas 8 Congreso AEC, 819-829 (ISBN 978-84-695-4331-3).*
9. 9. Apadula F, Cortesi N, Negri A, (2010) **National Electrical Demand and Climatic Variables.** *Associazione elettronica ed elettrotecnica Italiana (AEIT),* num 3, pagg. 42-48.

May I help? ☺

- <u>Subjects</u>
  - Climatology
  - Statistical Downscaling
  - Synoptic Meteorology
  - Geostatistics
  - Interpolation Techniques
  - High Perf. Computing
  - RCMs bias-correction & validation

- <u>Software</u>
  - R
  - C / C++
  - Fortran
  - ArcGIS
  - GRASS
  - VBA

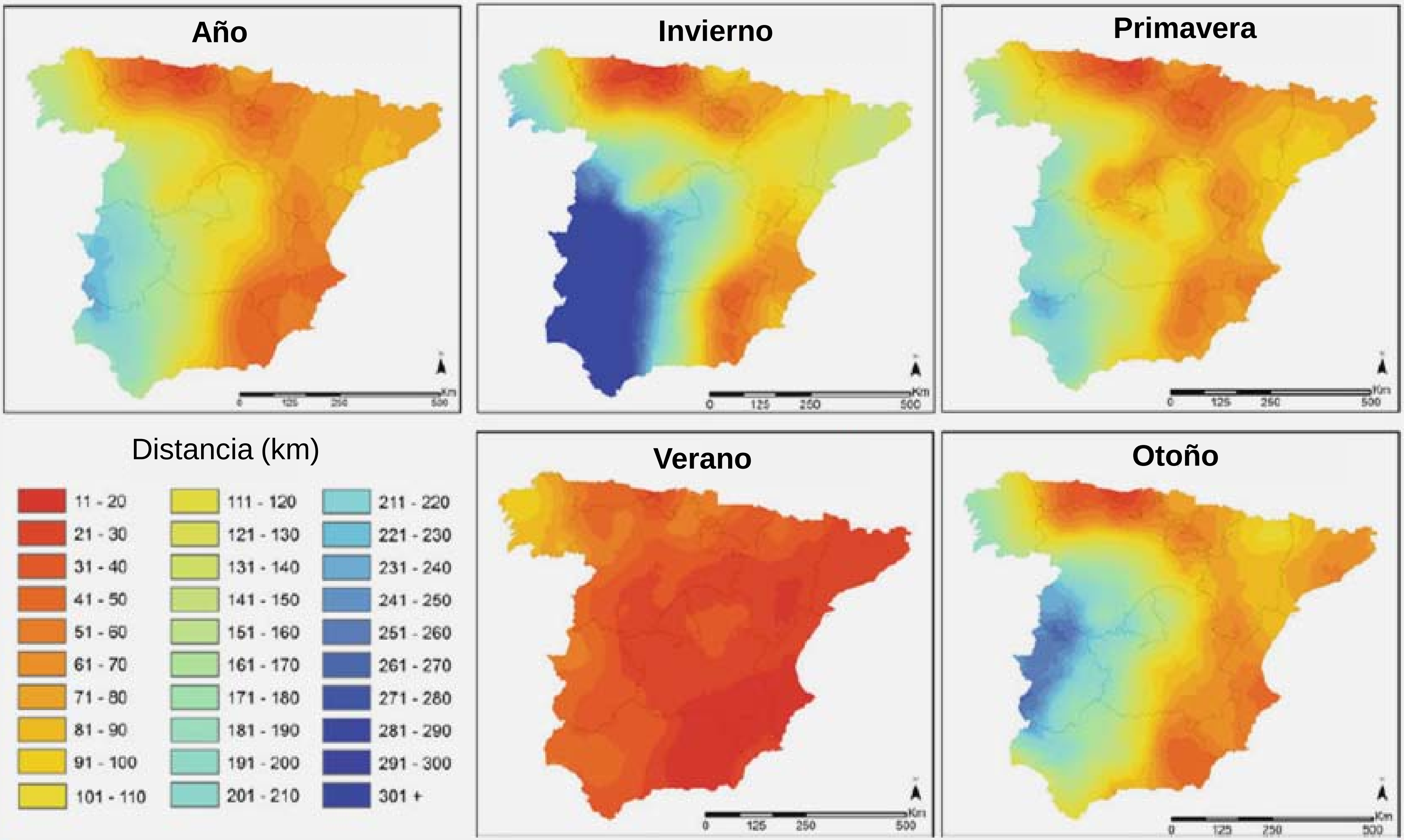
Merci de votre attention!



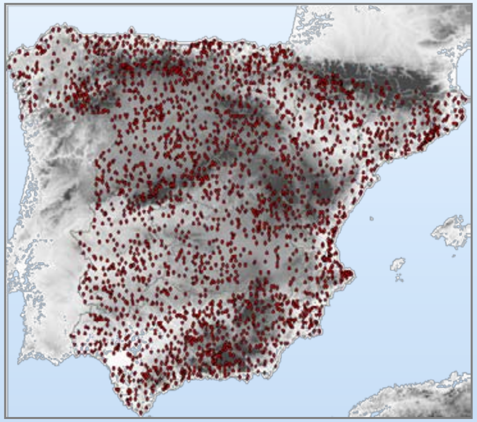
Any comments and questions are welcome

cortesi@cerfacs.fr

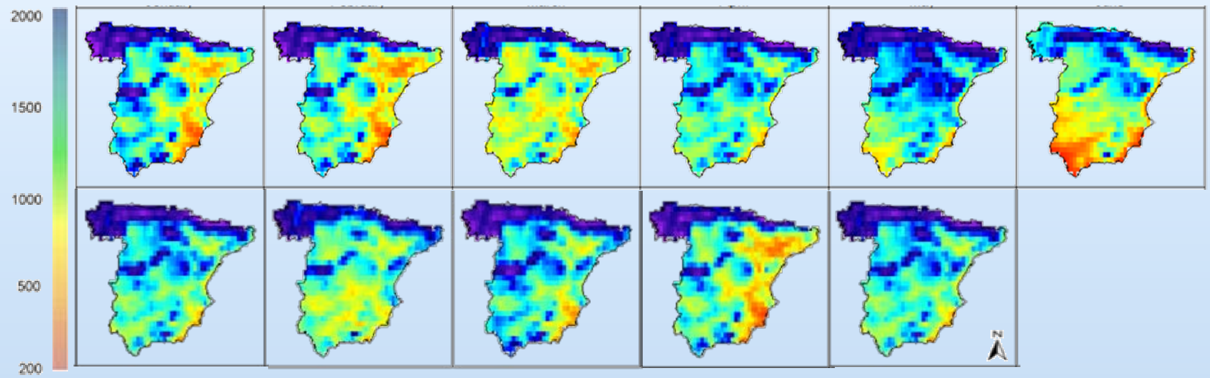
Distancia de Decorrelación (1956-2005)



MOPREDAS mensual



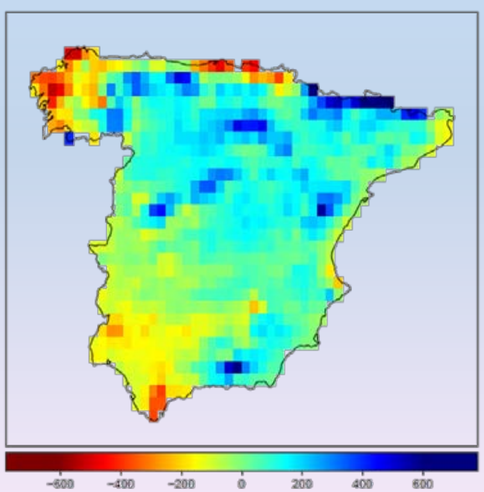
11 RCMs a 25 km^2 (1961-2000) del *Ensemble Project*



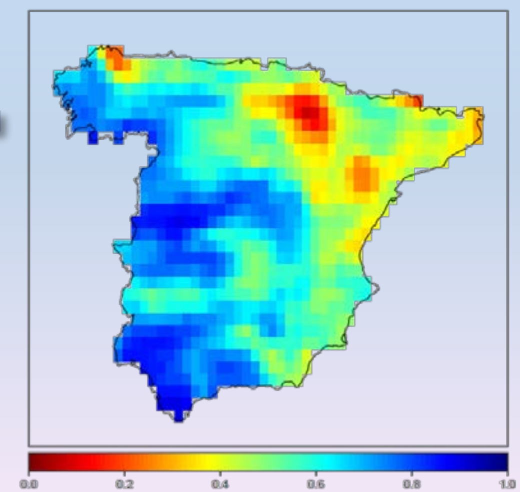
Resultados de cada modelo individual promediados pixel por pixel para crear el:

Interpolación malla de 25 km^2 (Kriging ordinario)

Modelo de referencia



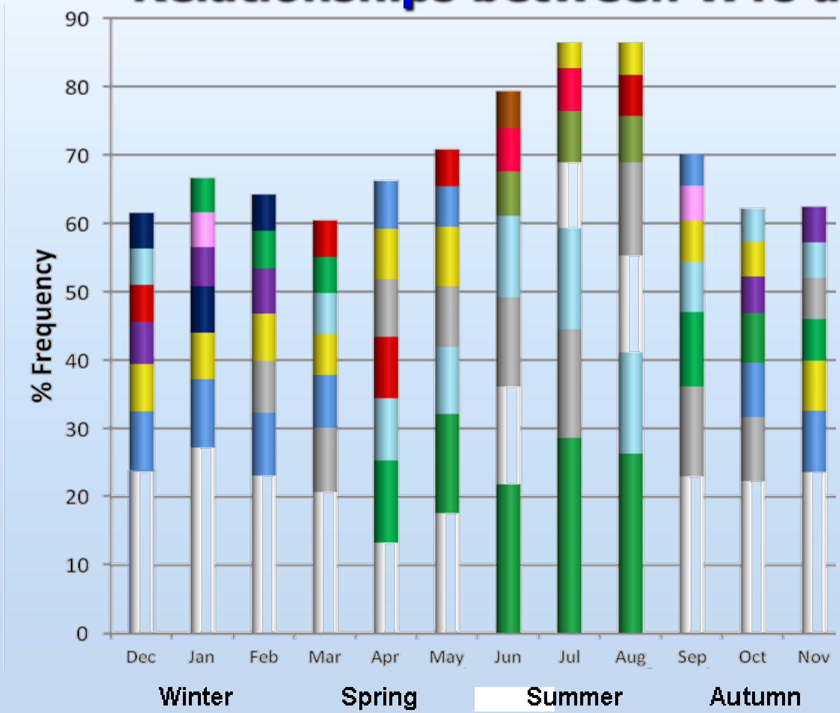
Validación estacional



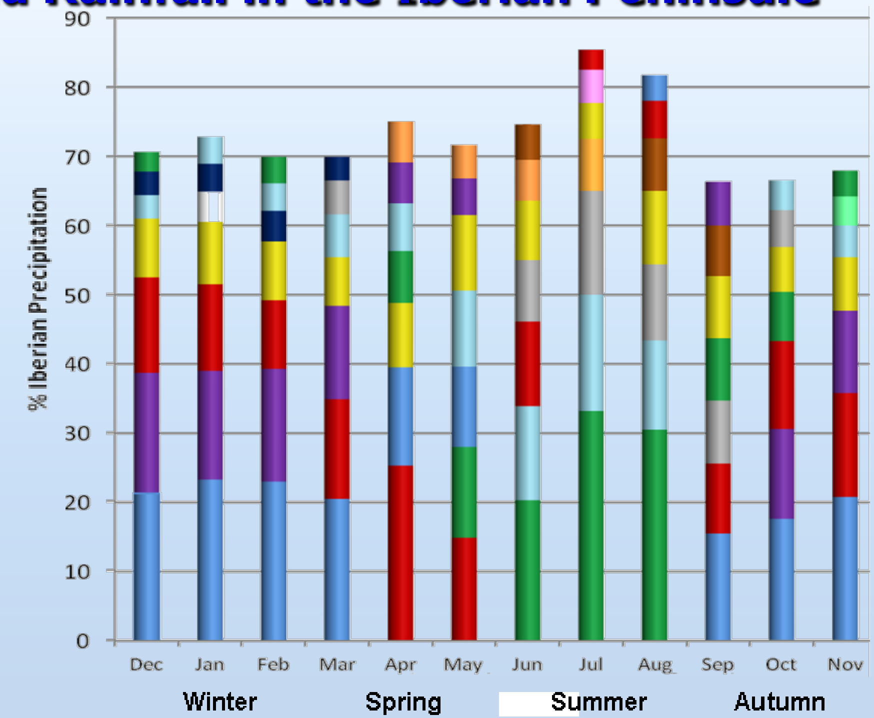
Índices de error:

MBE, MAE, RMSE, R^2, CV, …

Relationships between WTs and Rainfall in the Iberian Peninsule



WTs monthly Frequency (%)

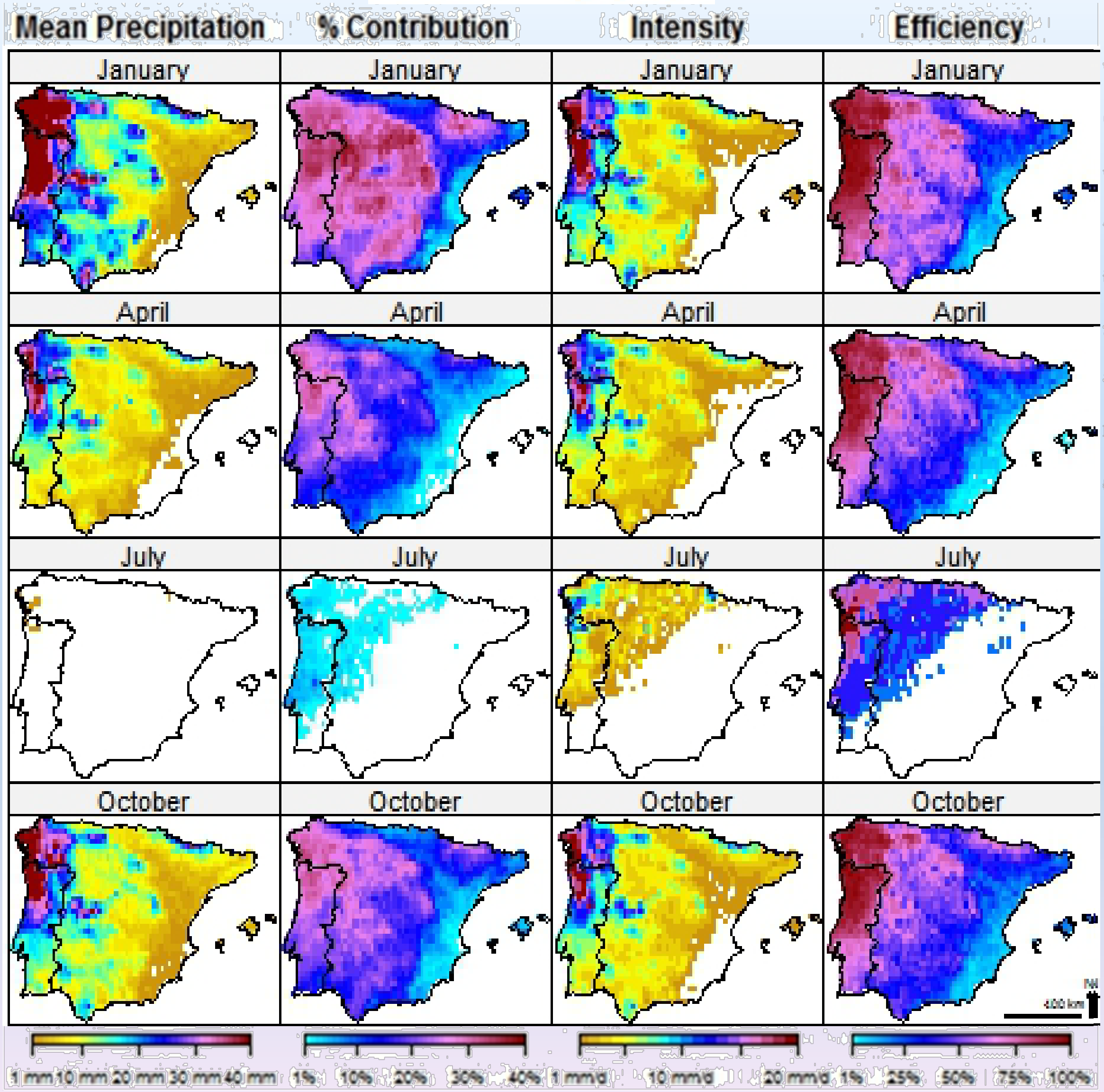


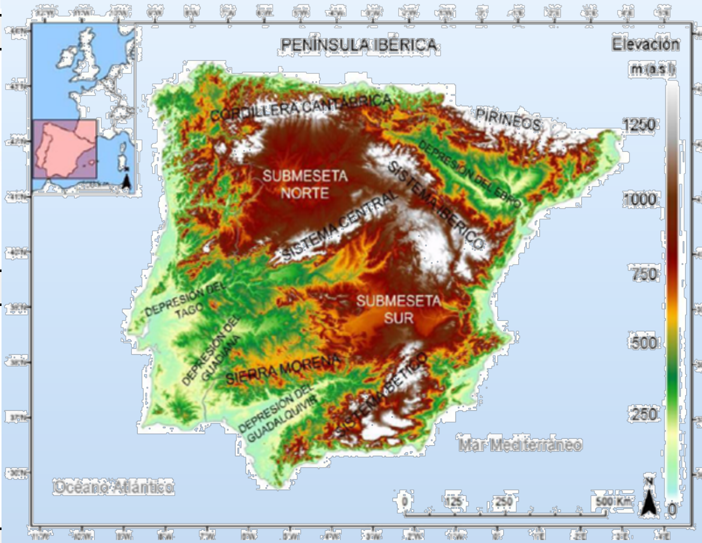
% Contribute to monthly IP prec.

WTs monthly Frequency (%)		% Contribute to monthly IP prec.	
1	A (Pure Anticyclonic)	1	W (Westerly)
2	NE (North Easterly)	2	C (Pure Cyclonic)
3	E (Easterly)	3	NE (North Easterly)
4	N (Northerly)	4	SW (South Westerly)
5	NW (North Westerly)	5	NW (North Westerly)
6	W (Westerly)	6	N (Northerly)
7	C (Pure Cyclonic)	7	E (Easterly)

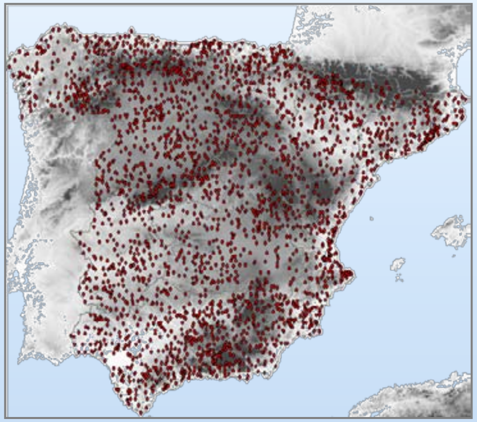
Other WTs: A.W (Anticyclonic Westerly), A.NW (Anticycl.Northwesterly), A.NE (Anticyclonic Northeasterly), C.SE (Cyclonic Southeasterly), C.NE (Cyclonic Northeasterly), C.E (Cyclonic Easterly)

Westerly (W)

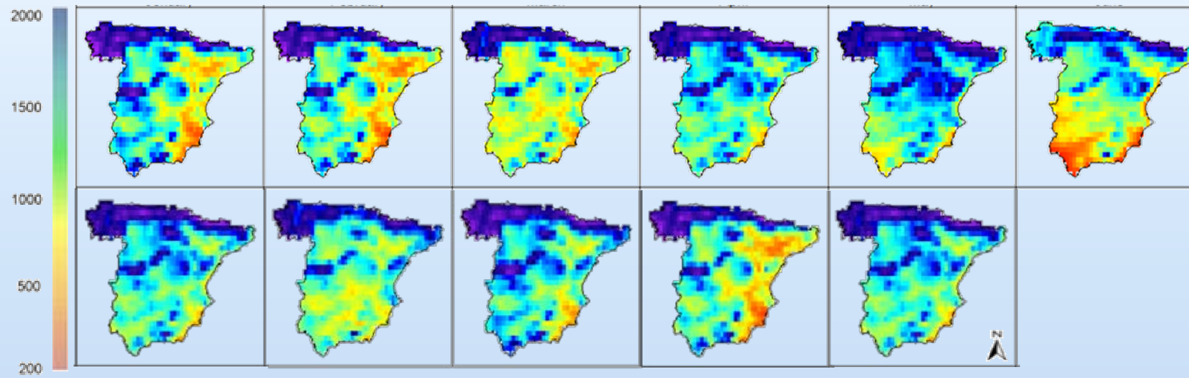

Mean Precipitation
% Contribution
Intensity
Efficiency
January
April
July
October
1 mm
10 mm
20 mm
30 mm
40 mm
1%
10%
20%
30%
40%
1 mm/d
10 mm/d
20 mm/d
1%
25%
50%
75%
100%
400 km


PENINSULA IBERICA
Elevación
m (a.s.l)
1250
1000
750
500
250
0
CORDILLERA CANTABRICA
PIRINEOS
SUBMESETA NORTE
SISTEMA CENTRAL
SISTEMA IBERICO
SUBMESETA SUR
SIERRA MORENA
Mar Mediterráneo
Océano Atlántico

Monthly obs.precipitation



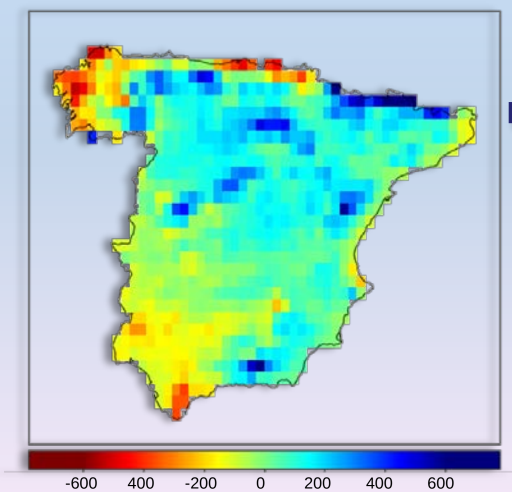
11 RCMs a 25 km² (1961-2000) from *Ensemble Project*



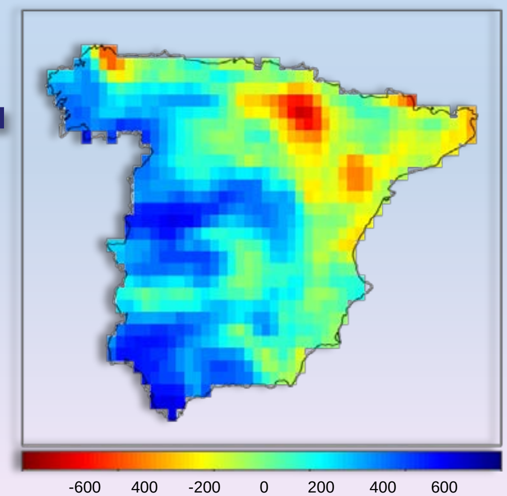
Interpolation
grid 25 km²

A multi-model was also created
to reduce dispersion:

Mean Model

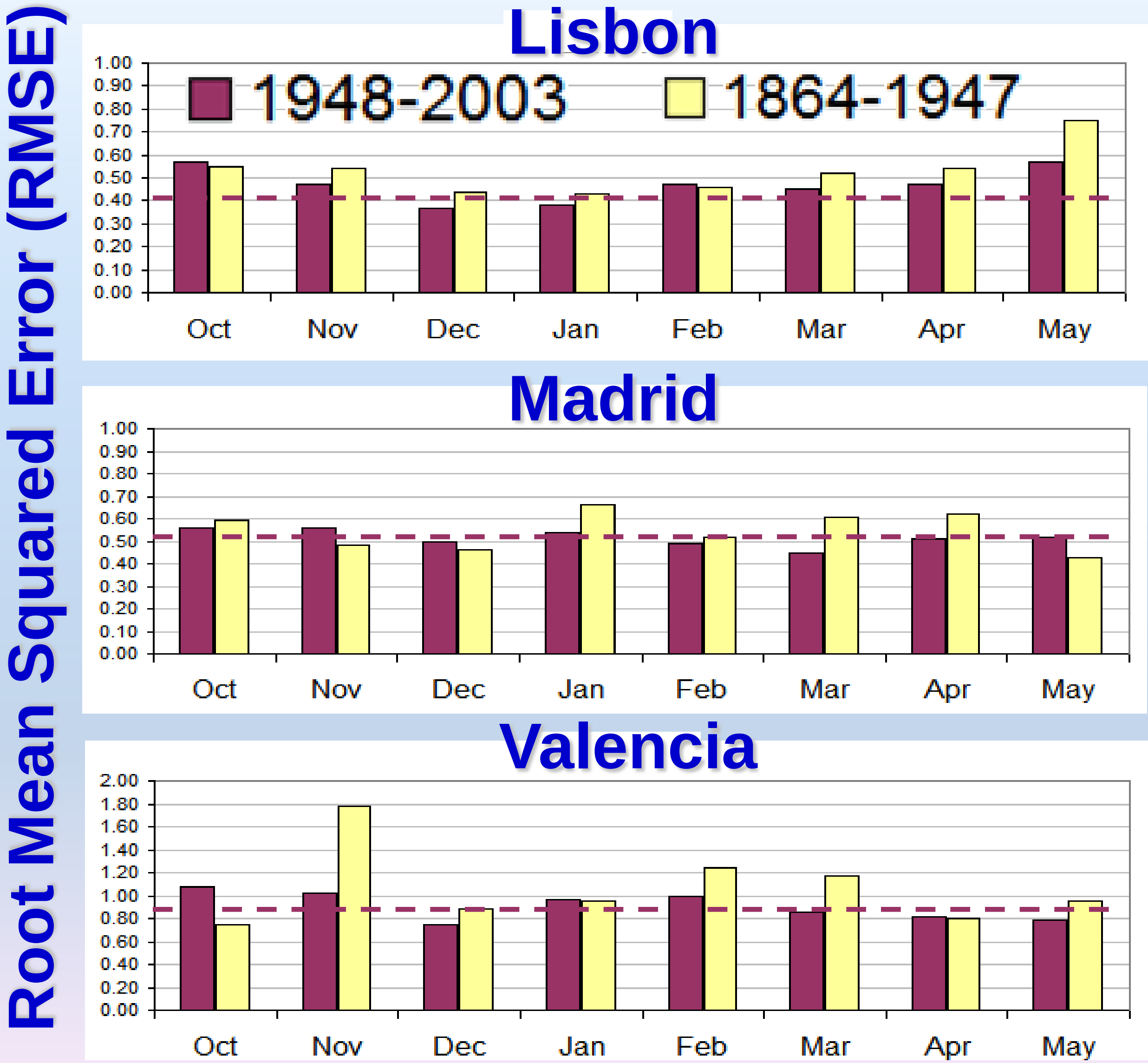


Validation

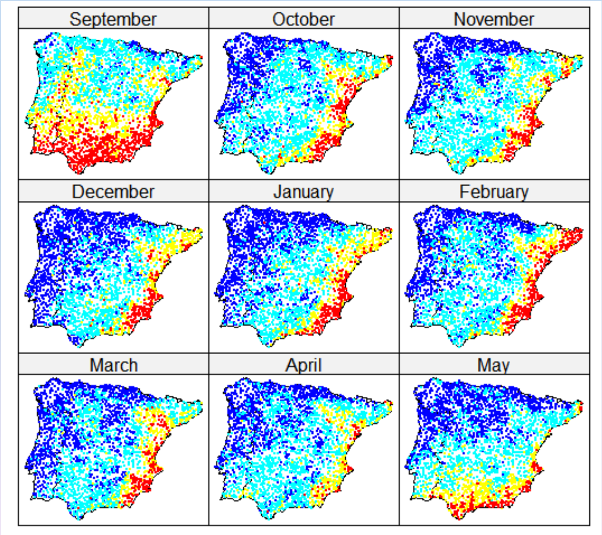


Error Indexes:
MBE, MAE, RMSE, R^2, SD, …

Hypothesis testing (1864-1947)

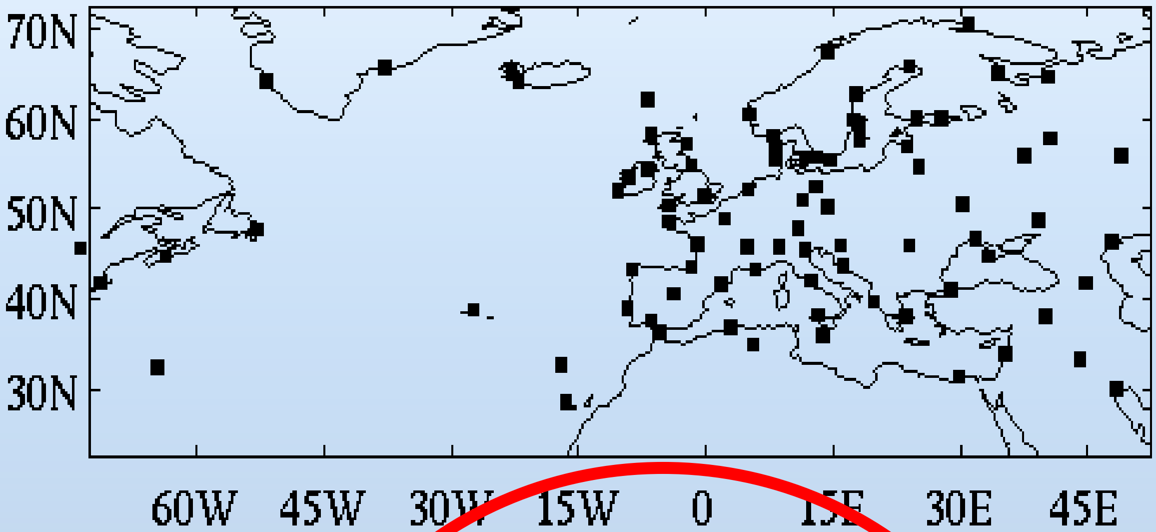


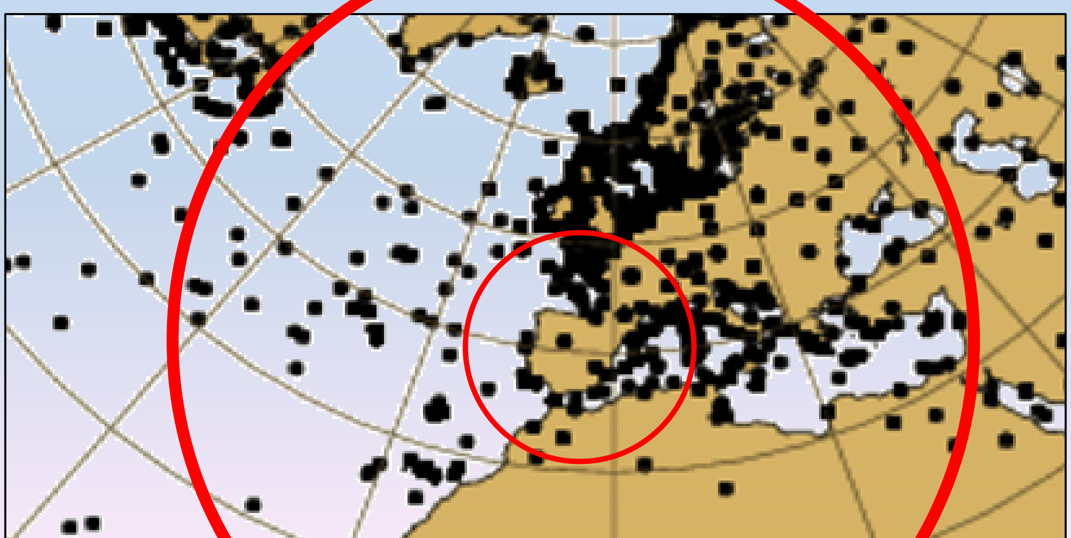
RMSE (1948-2003)



Very Long European Reanalysis Dataset

SLP Surface Network Observations





EMSLP dataset (EMULATE Project)

+ Very long (**1850**-2003)

+ Reconstruction, not reanalysis

- Low sp. resolution (5)

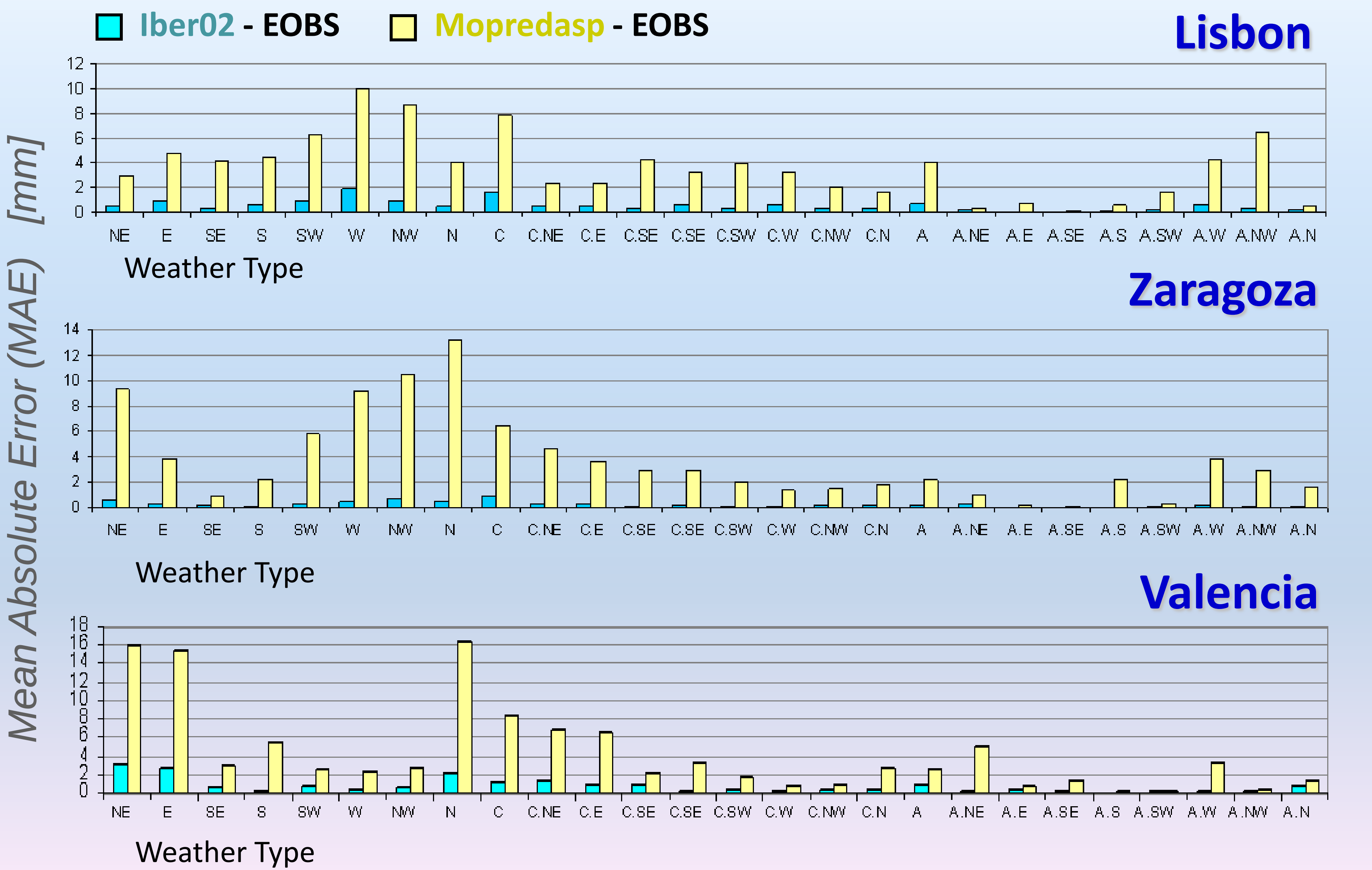
20th Century Reanalysis

+ Good sp. resolution (2)

+ More stations than EMSLP along the Mediterranean coast of Spain

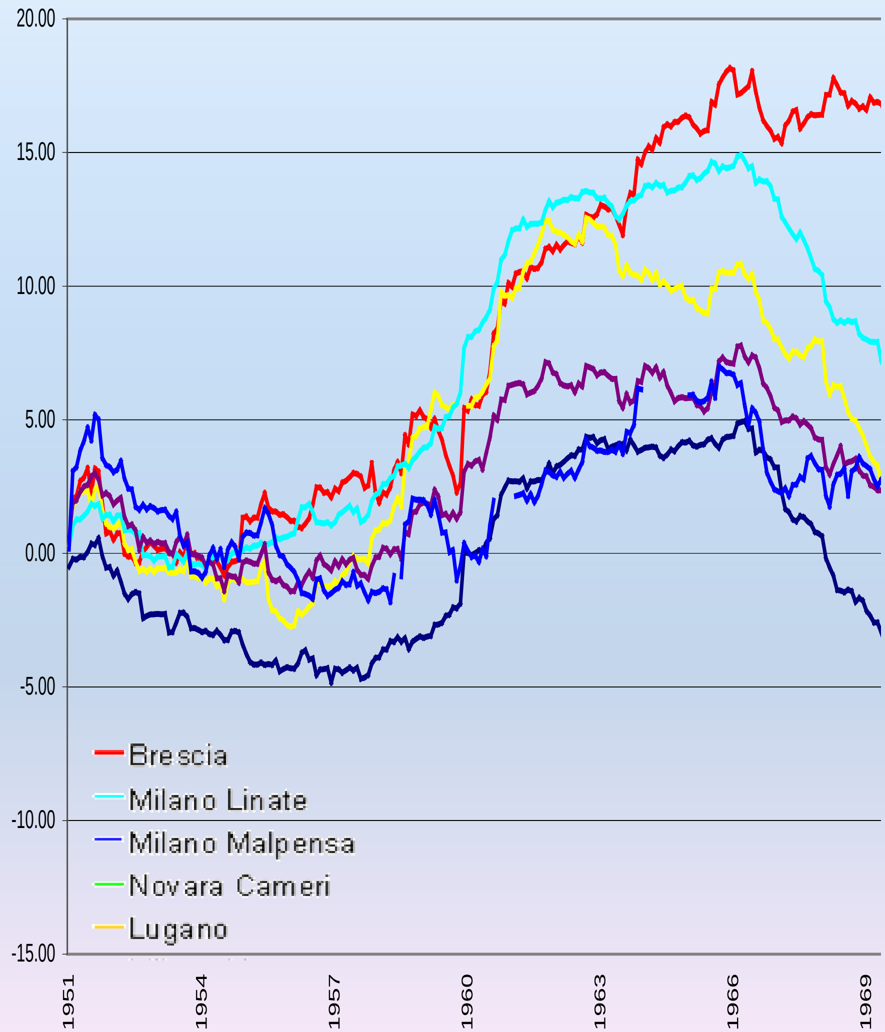
- Shorter than EMSLP (**1871**-2008)

Daily vs. Monthly precip.data

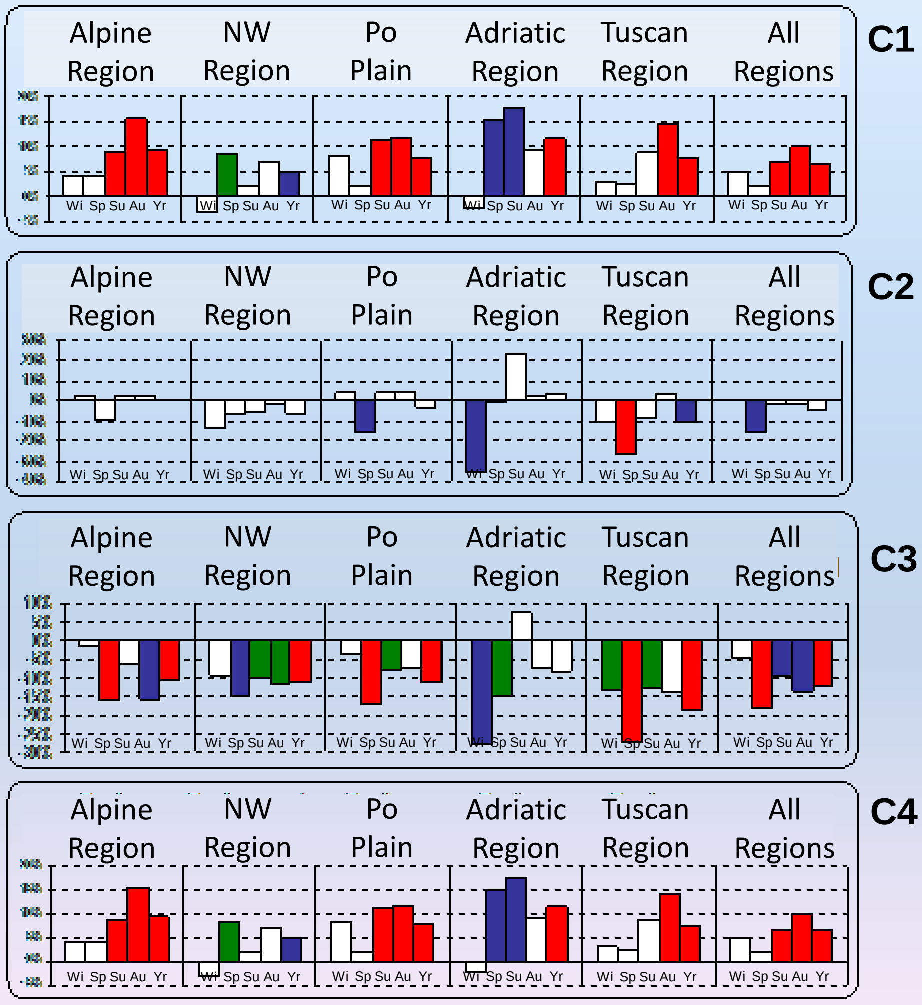


2007: Physic degree at IFGA (Institute for Atmospheric Physic, University of Milan)

Craddock Test



% Trend of Wet Days Index from 1951 to 2006



Precipitation Downscaling

Calculate the *Average daily rainfall amount* associated to each WT:
(i.e: the precipitation intensity of the WT)

$$\overline{P}_{WT}(x,m) = \frac{\sum_{y=1950}^{2003} \sum_{d \in \{WT\}} P(x,m,y,d)}{\sum_{y=1950}^{2003} N_{WT}(m,y)}$$

Prec.data from **Iber02** dataset

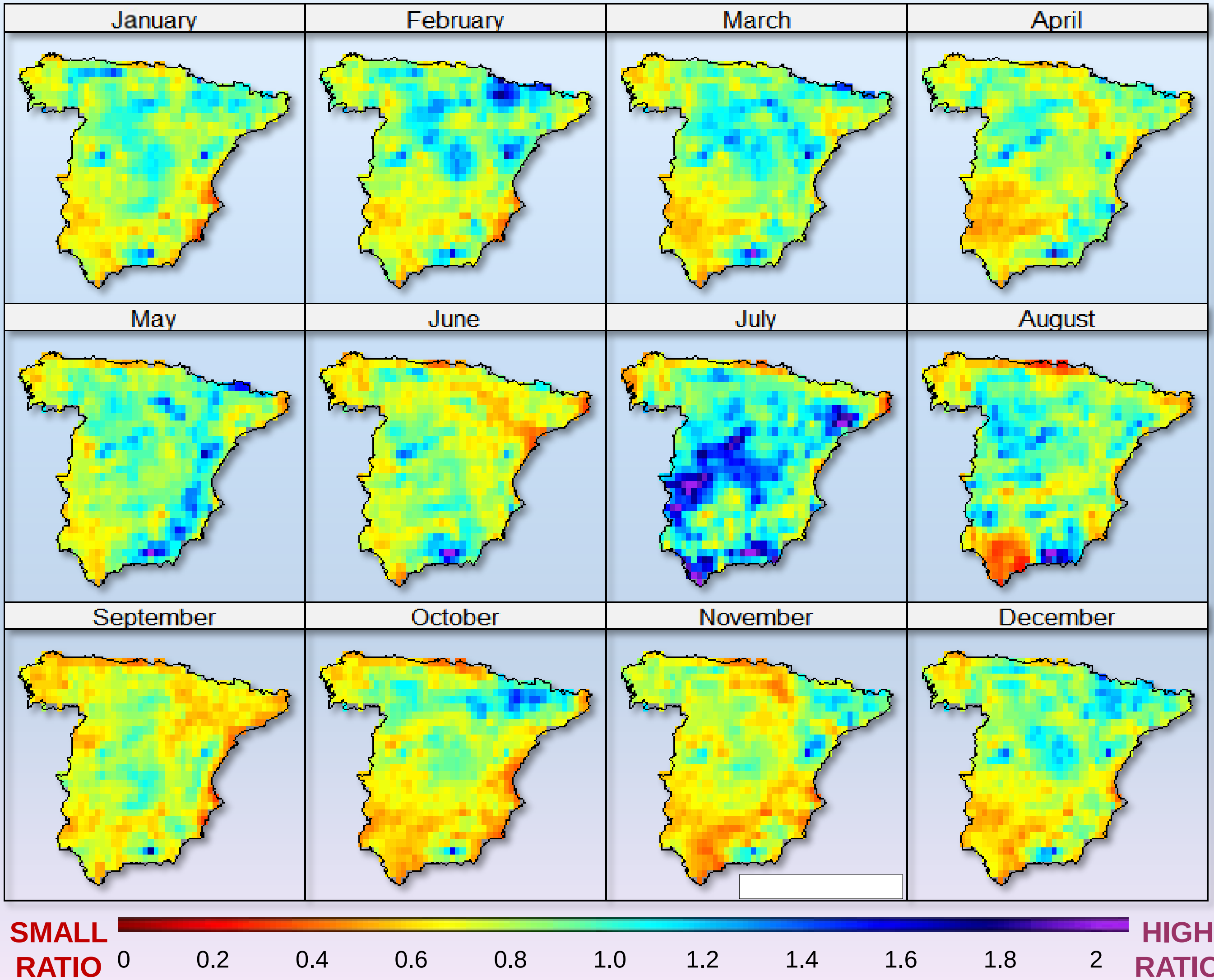
Learning period: **1950-2003**

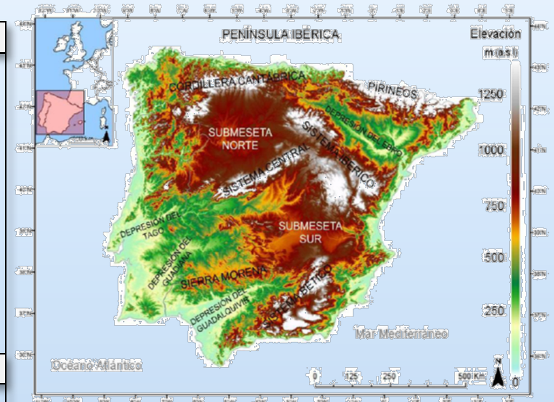
being:

being:	*x*	*grid pixel*
	m = 1,…,12	*month*
	y = 1950,…,2003	*year*
	P(x,m,y,d)	*observed precipitation* for pixel *x*, month *m*, year *y* and day *d.*
	$N_{WT}(m,y)$	*number of days* belonging to that WT during month *m* of year *y*

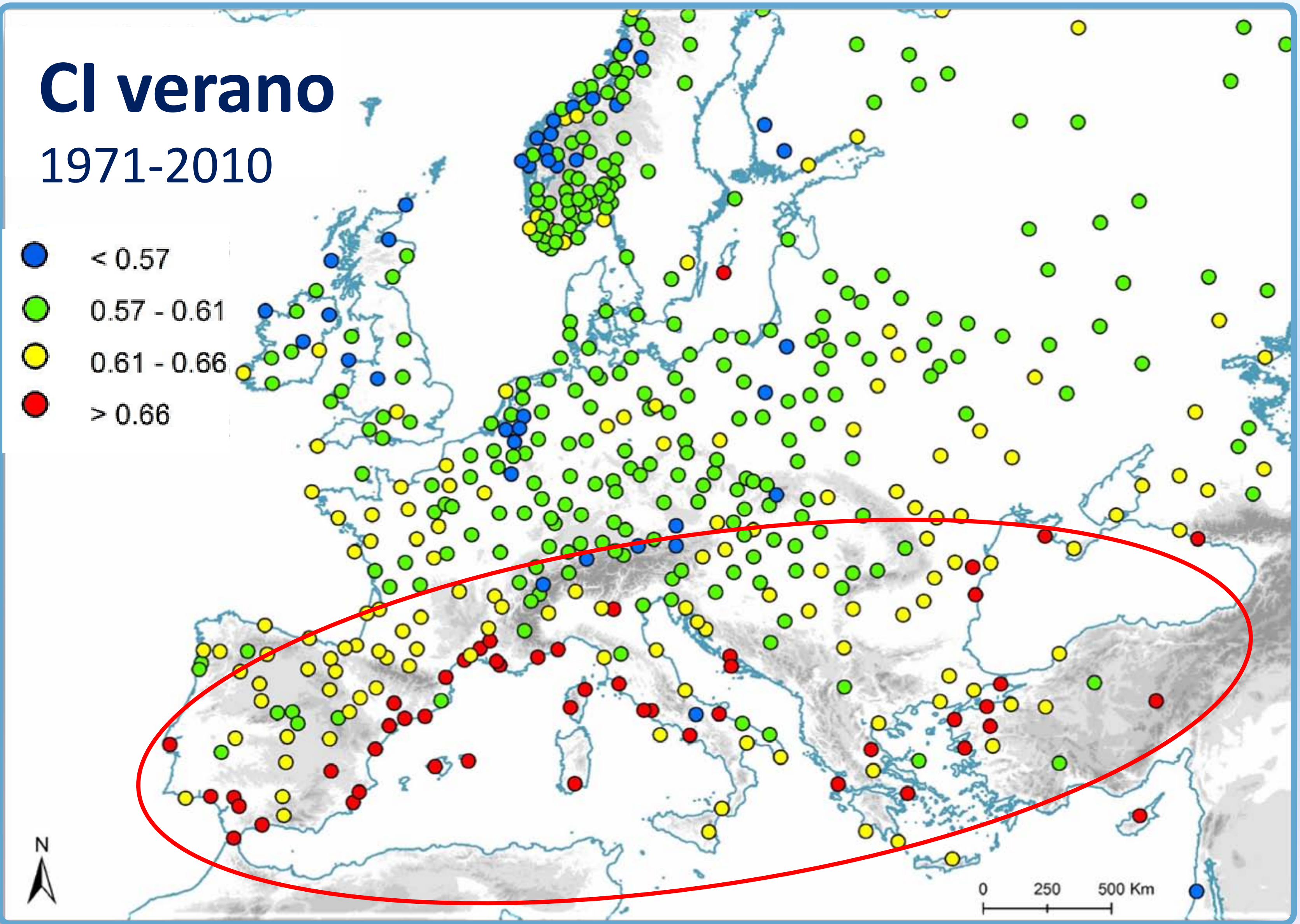
For each month and each grid point we will have a different model

Ratio between modelled and observed Standard Deviation

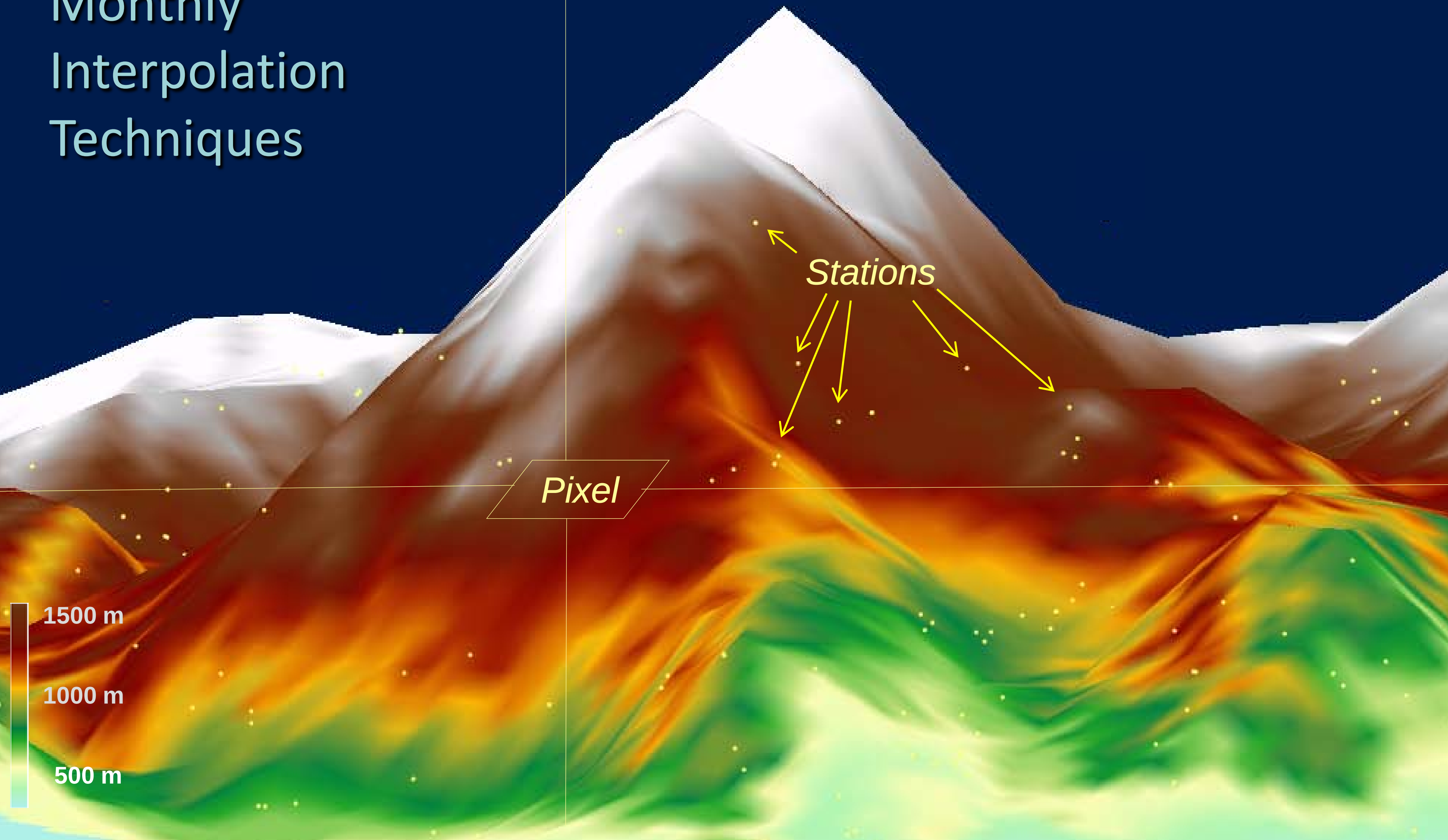




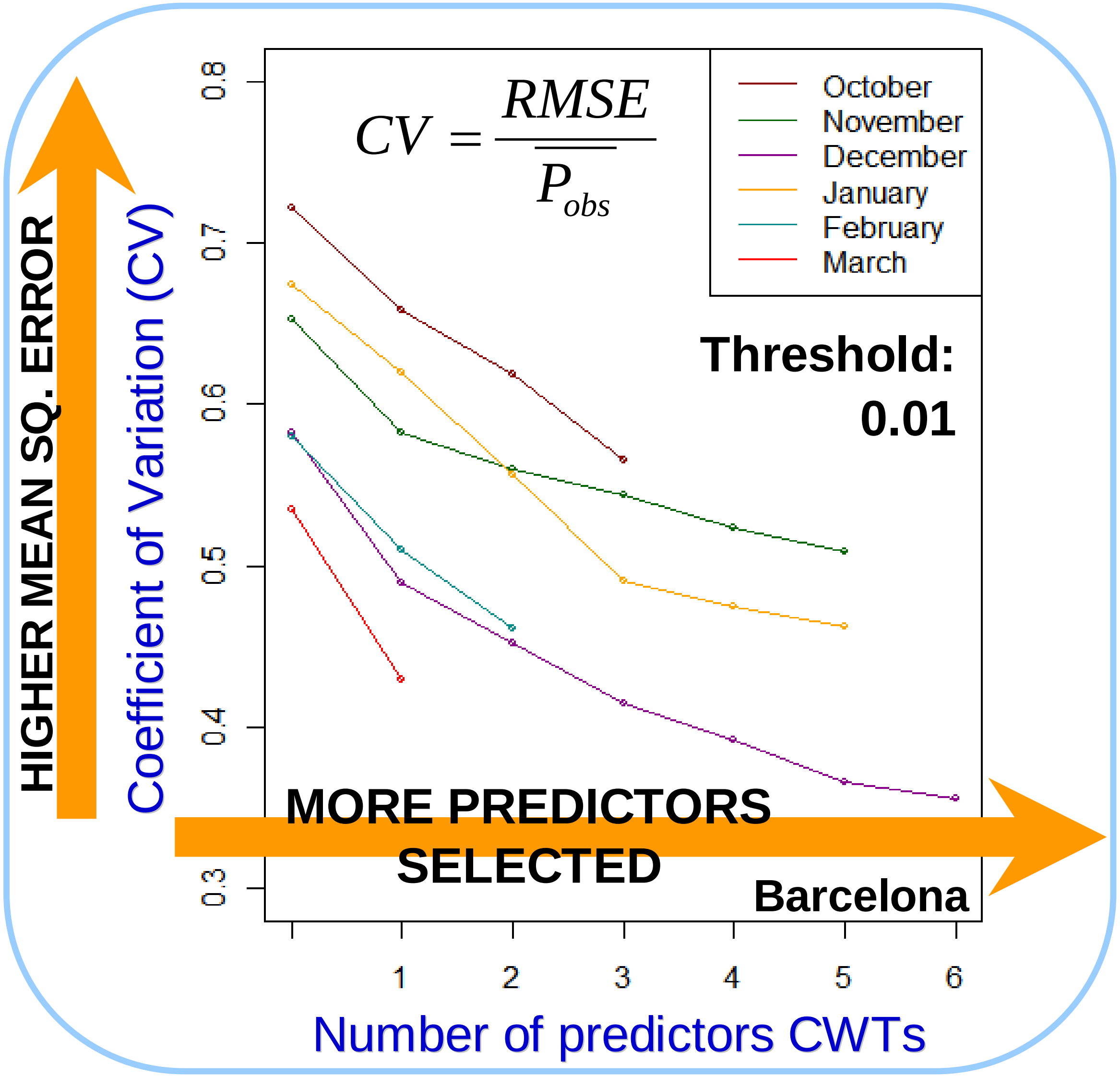
CI verano
1971-2010



Monthly Interpolation Techniques



Forward Stepwise selection



Merci de votre attention!

nicolacortesi@ymail.com

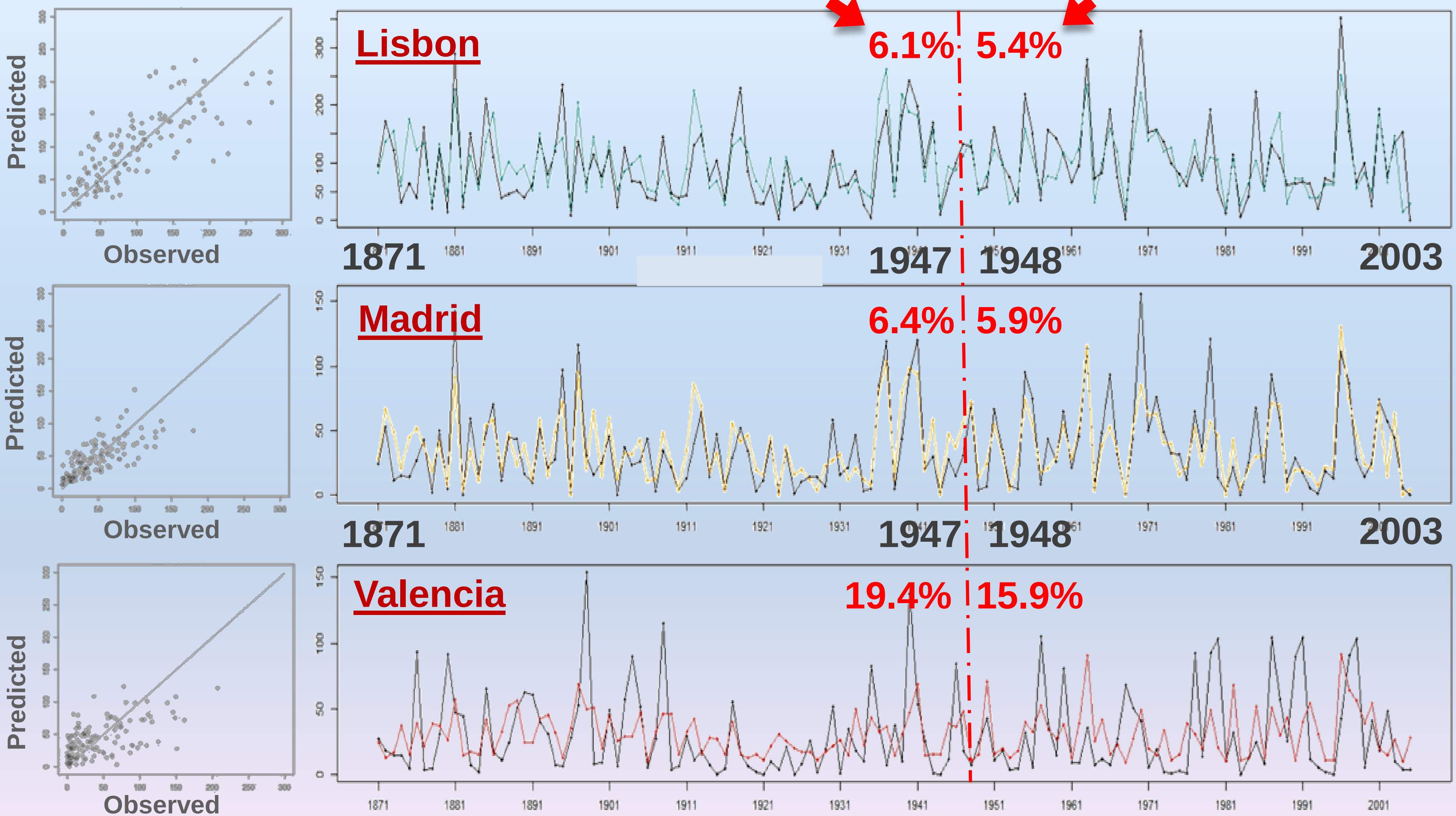
Thank you for the attention!

nicolacortesi@ymail.com

Monthly prec. downscaling with 20th Century R. for January

MAE (downscaling period 1871-1947)

MAE (learning period 1948-2003)



Observed monthly precipitation (**black** lines) and downscaled (**coloured** lines)