An extreme value model for maximum wave heights based on weather types

A. Rueda, P. Camus, F. Méndez, A. Tomás, A. Luceño

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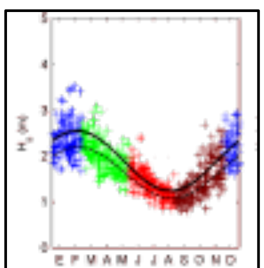
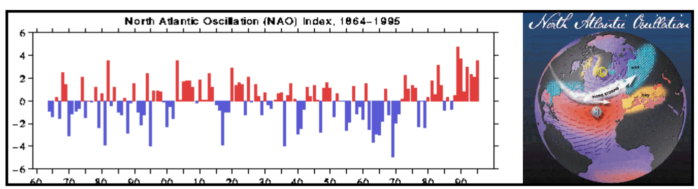
Motivation

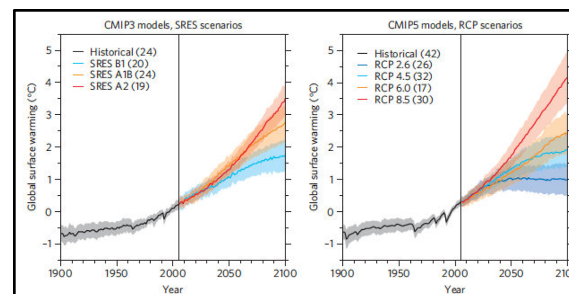
- Interest on the upper tail of the distribution of HS ➡ Extreme value theory

$$F(y) = \exp\left\{-\left[1 + \xi\left(\frac{y-\mu}{\psi}\right)\right]^{\frac{-1}{\xi}}\right\}$$

- Non-stationarity of the climate system



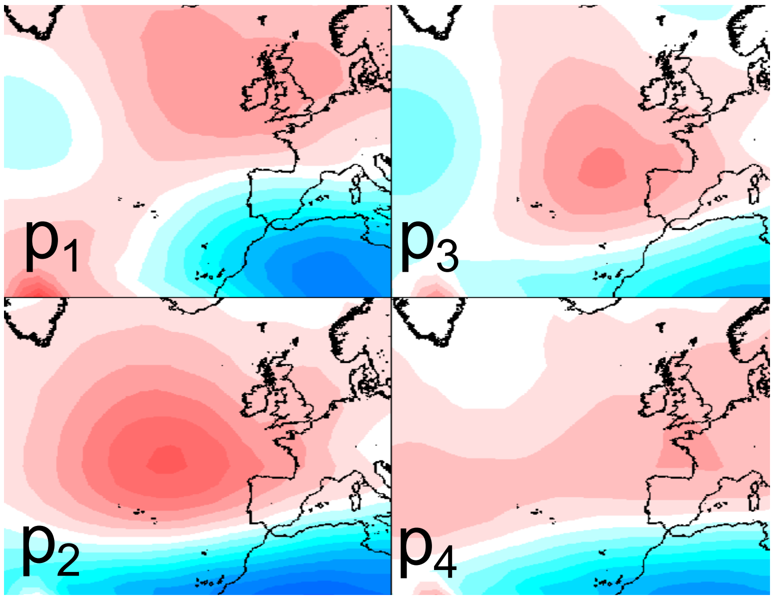


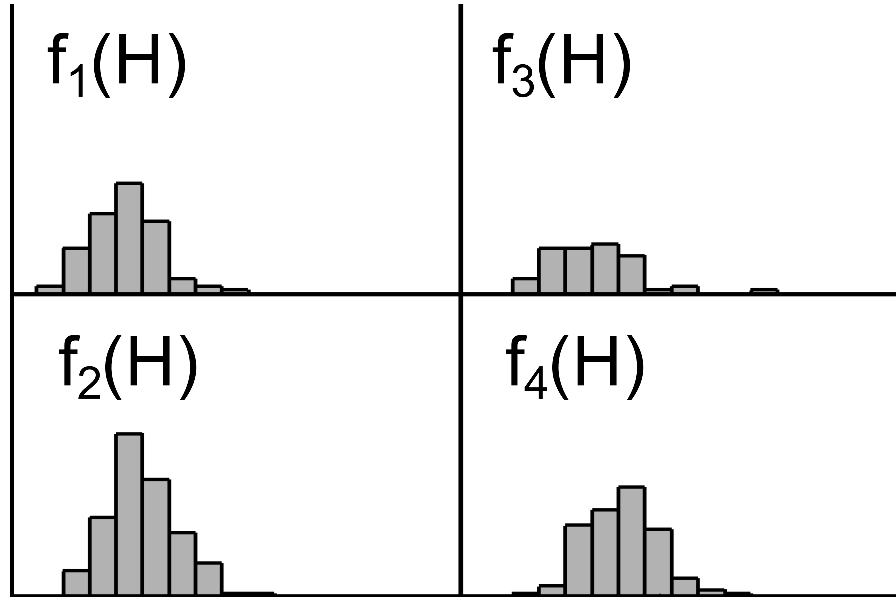


- Statistical downscaling of extremes

SD based on Weather Types

$X=(WT_1,WT_2,WT_3,WT_4)$ Y



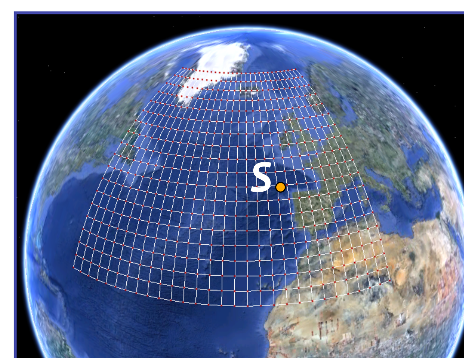


WT= Weather-type

p_i=ocurrence probability of WT_i

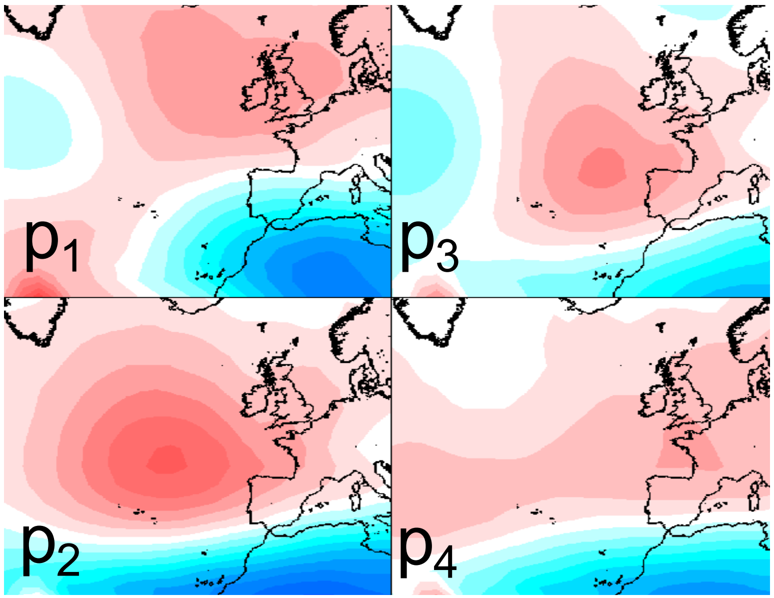
Regression model /Stat. Downscaling:

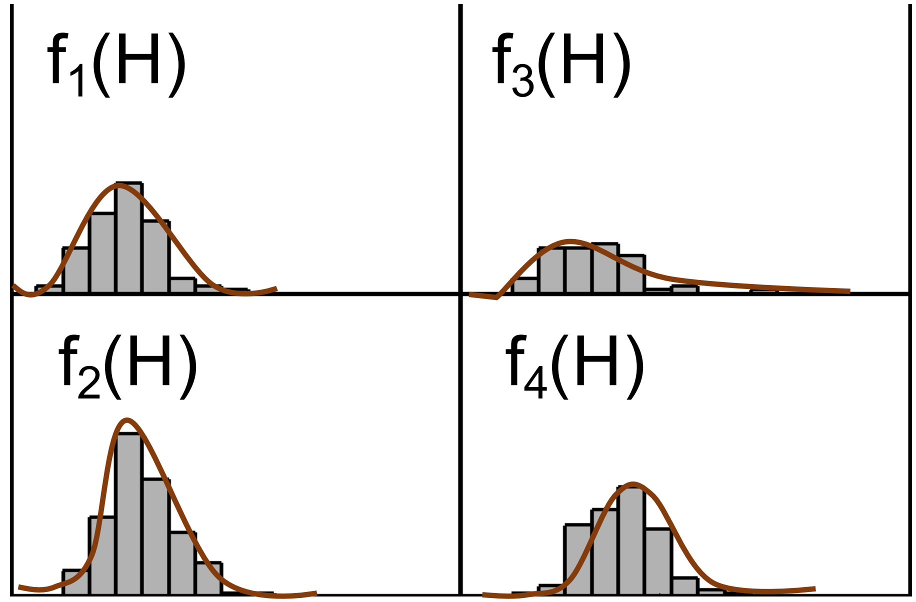
$Y=g(X)$



Daily max - SD based on Weather Types

$X=(WT_1,WT_2,WT_3,WT_4)$ $\qquad$ Y



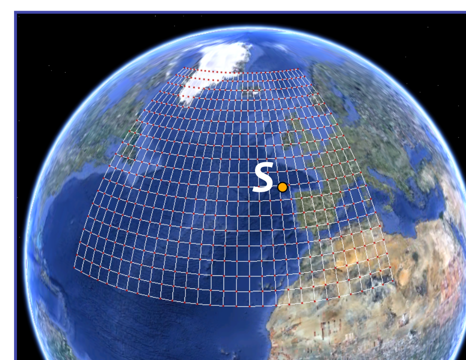


p_i=ocurrence probability of WT_i

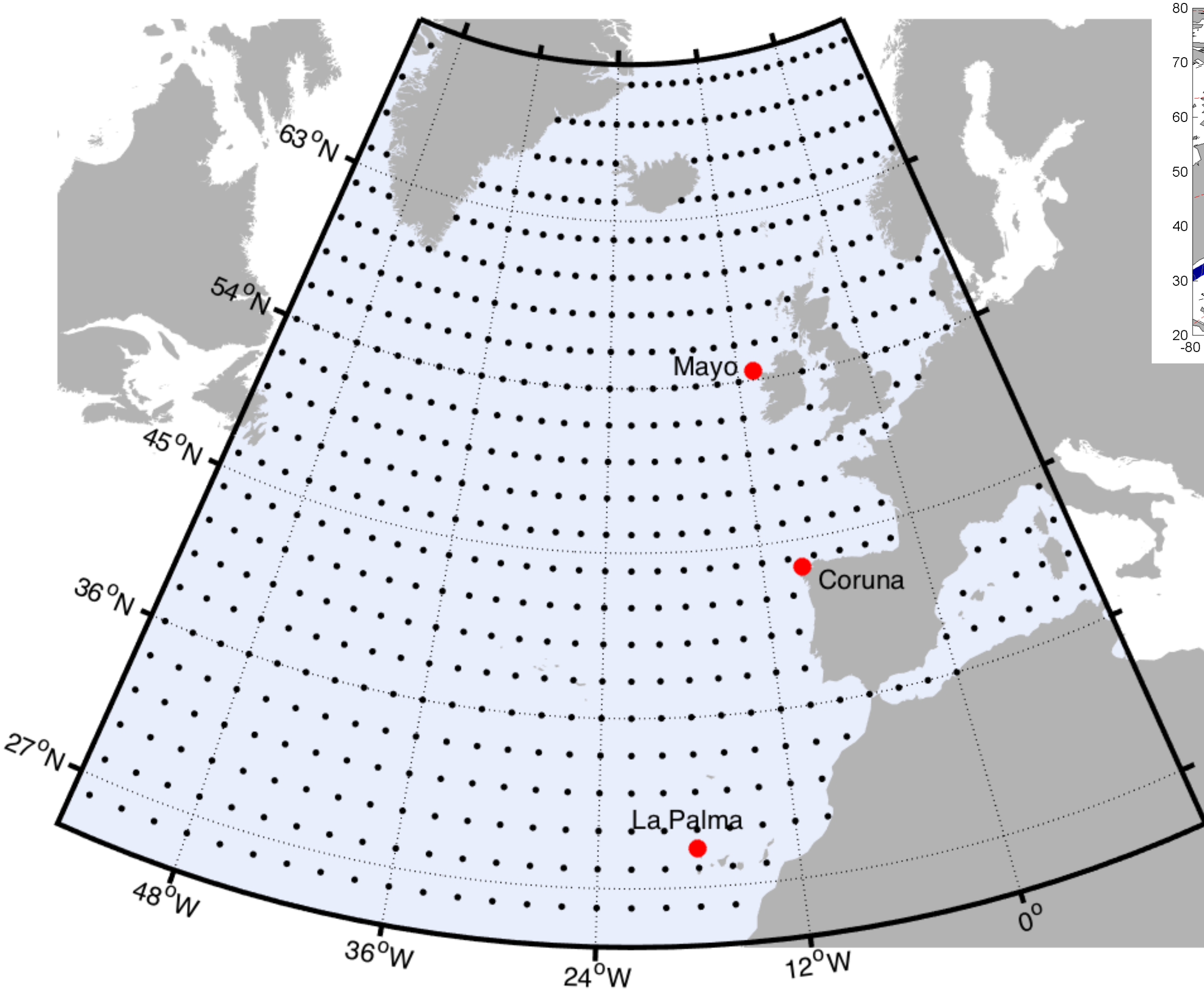
$p_1+p_2+p_3+p_4=1$

N = number of block maxima ; θ_i = extremal index

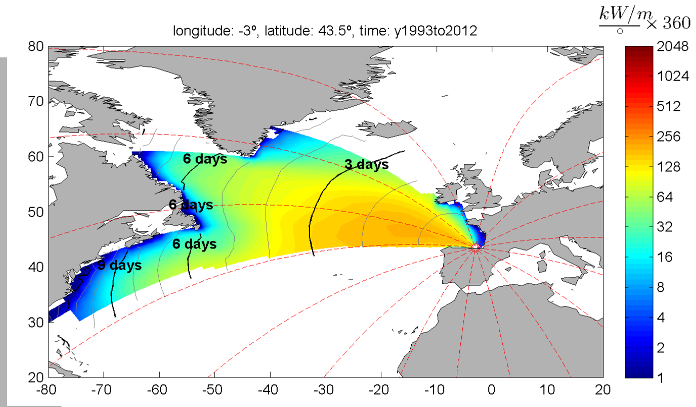
$F_S(H)=F_1(H)^{Np_1\theta_1}\cdot F_2(H)^{Np_2\theta_2}\cdot F_3(H)^{Np_3\theta_3}\cdot F_4(H)^{Np_4\theta_4}$



Study Locations - Predictor



SLP fields from CFSR, Saha et al., 2010



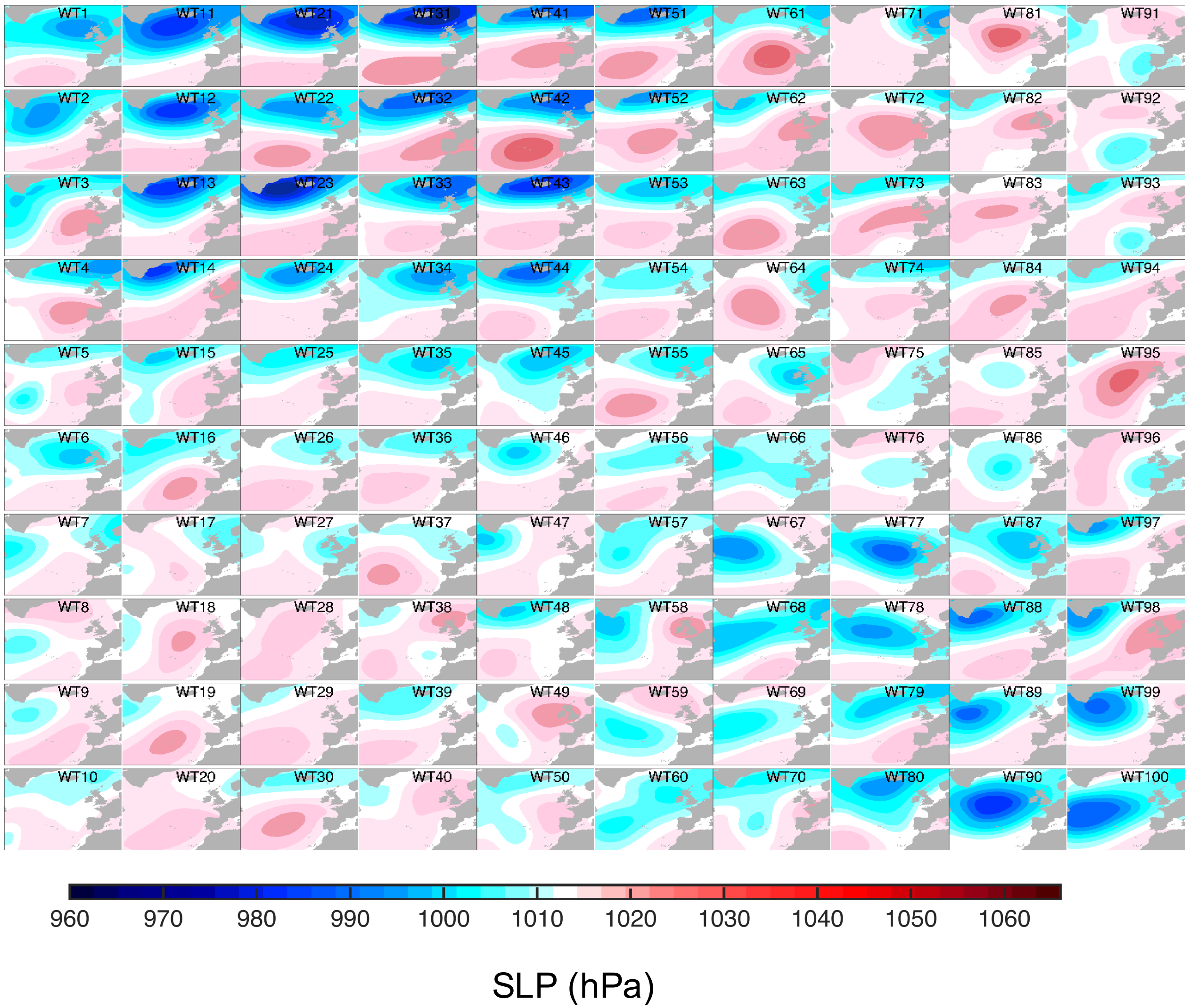
(Perez et al., O.D. 2014)

SLP, SLPGrd

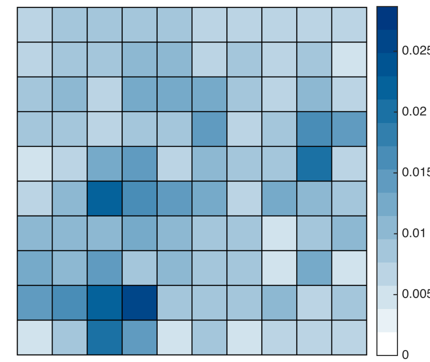
PREDICTOR PRE-PROCESS:
Historical temporal coverage

(Camus et al., O.D. 2014)

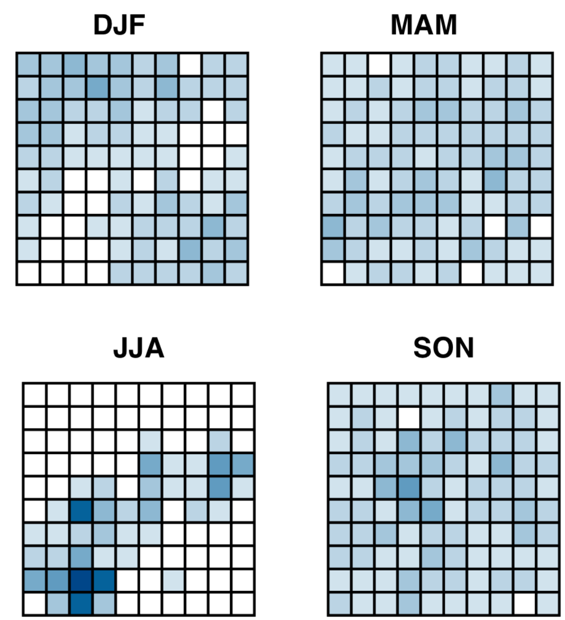
Weather Types Classification



Annual probability



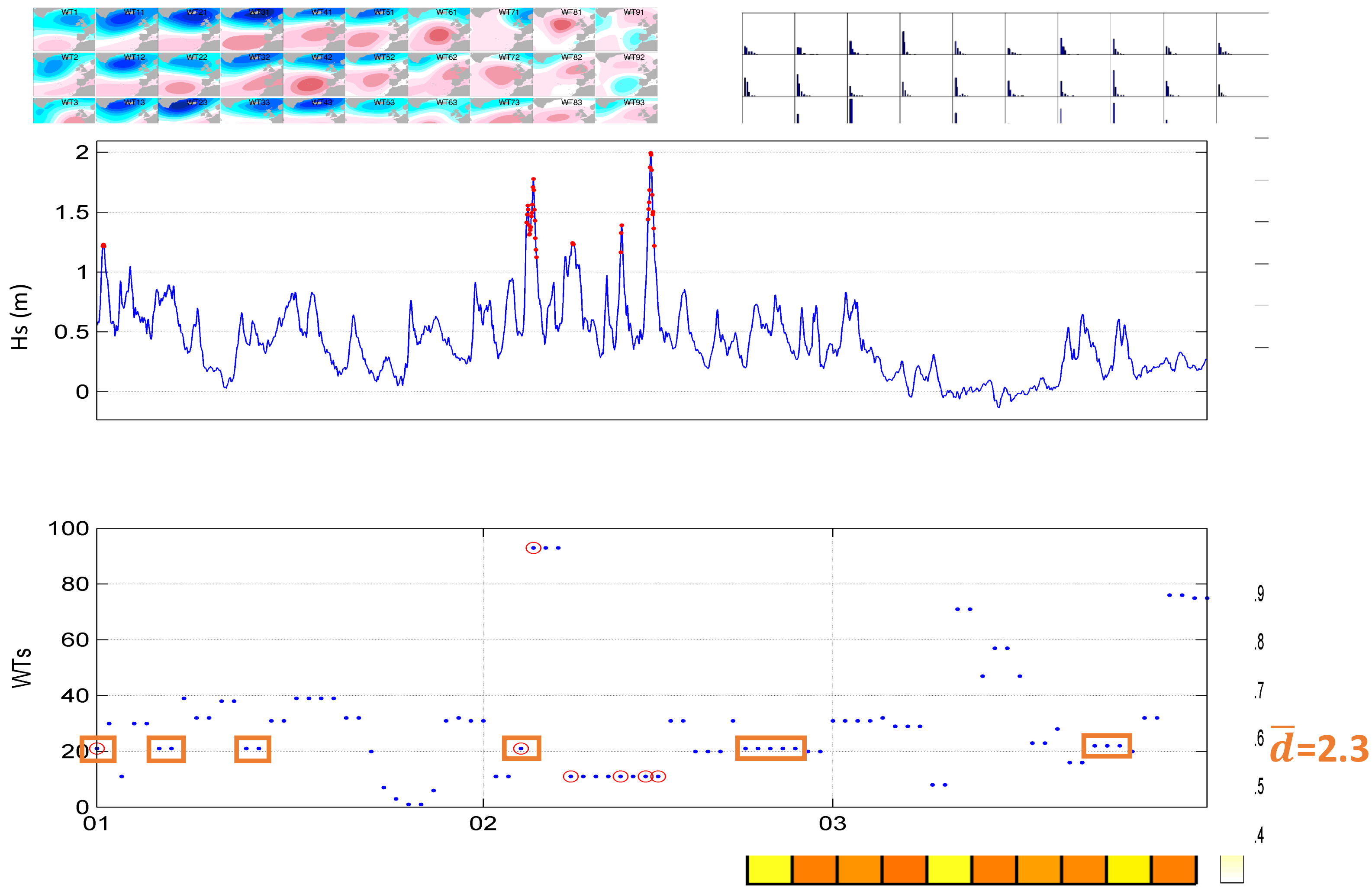
Seasonal probability



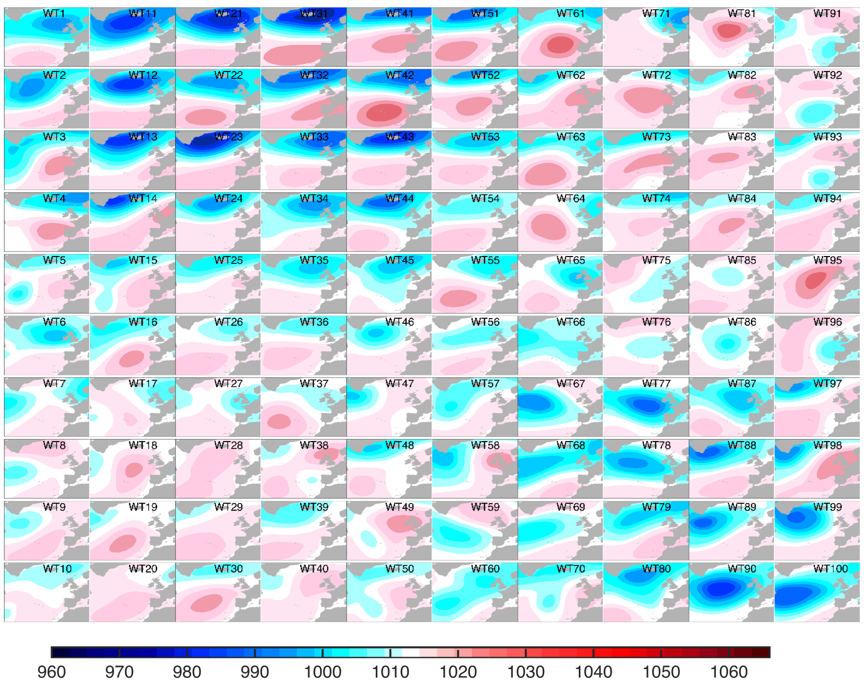
Climate-related Extremal Index

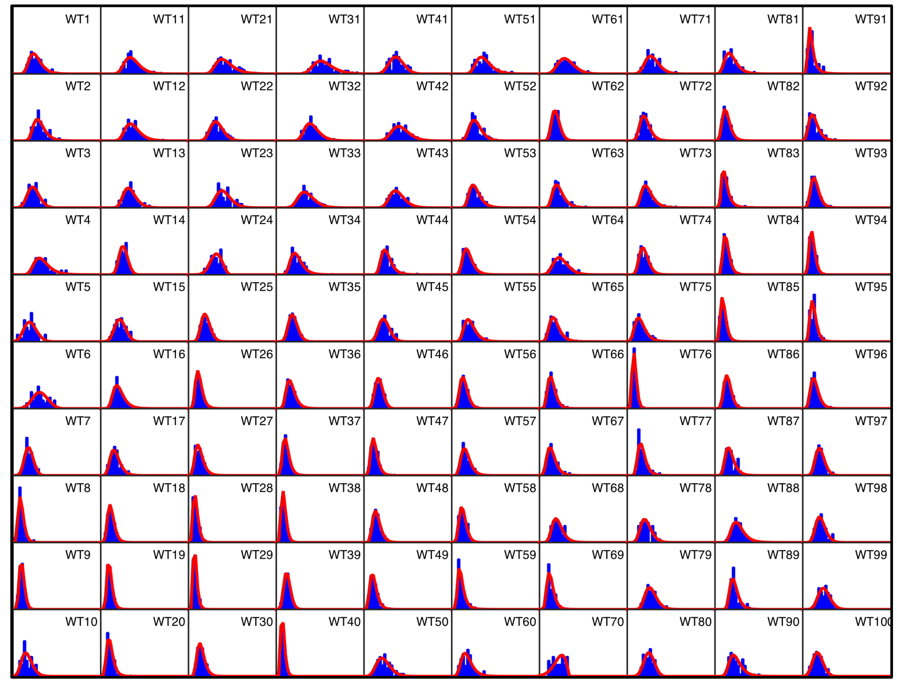
$$F_y^{Max}(y) = F_y(y)^{N \cdot \theta}$$

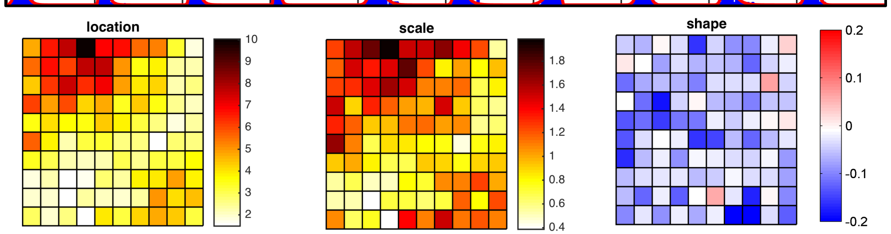
Duration histograms



GEV distribution associated to each WT







$$F(y) = \exp\left\{-\left[1 + \xi\left(\frac{y-\mu}{\psi}\right)\right]^{\frac{-1}{\xi}}\right\}$$

μ ψ ξ

Wave hindcast from Perez et al. 2015

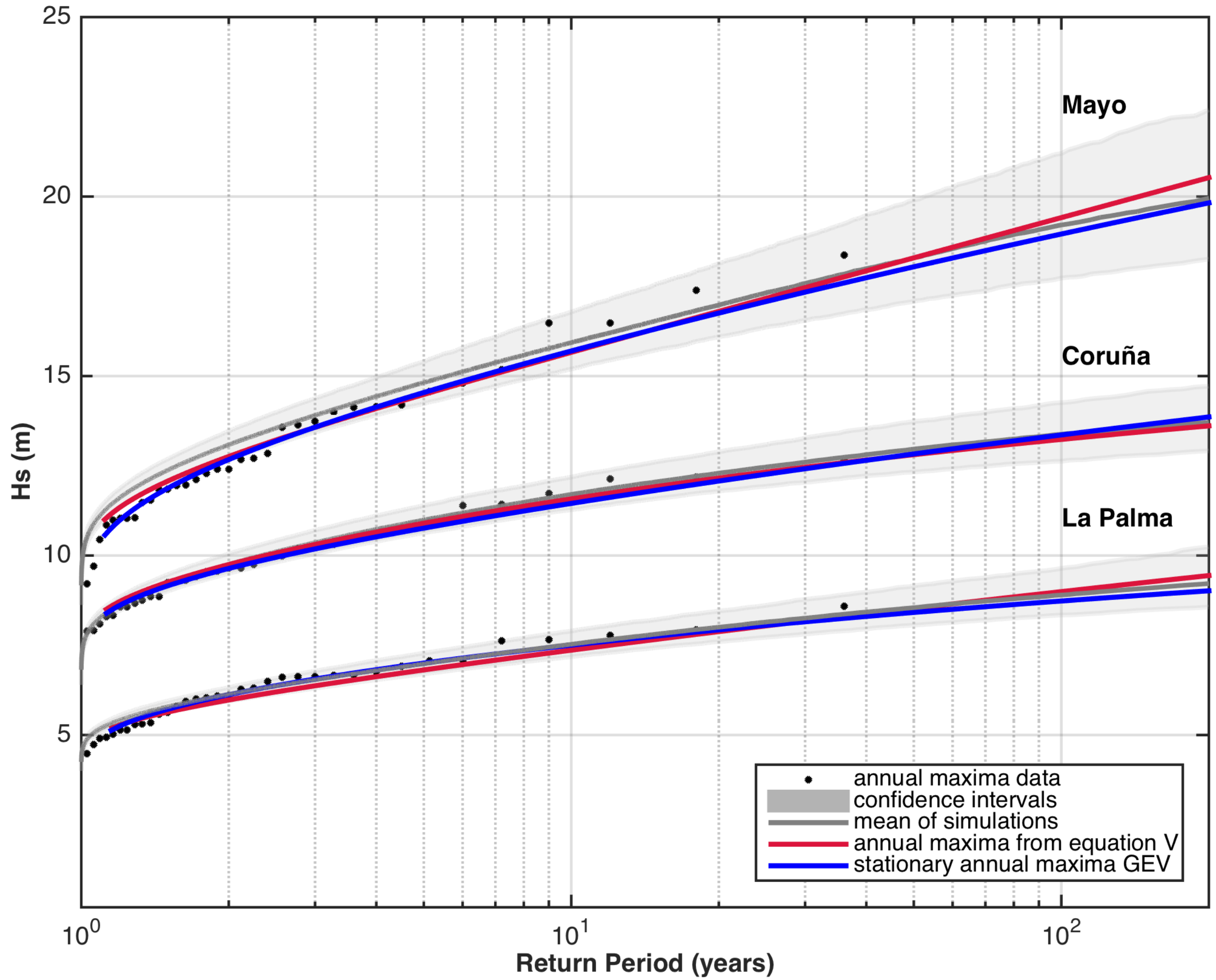
Annual maxima

$$F\,(y) = \prod_{i=1}^{Nwt} F_i\,(y)^{N \cdot P_i \cdot \theta_i}$$

N =365

P_i = annual probability

$$P_i, \{i = 1, \dots, Nwt\}$$



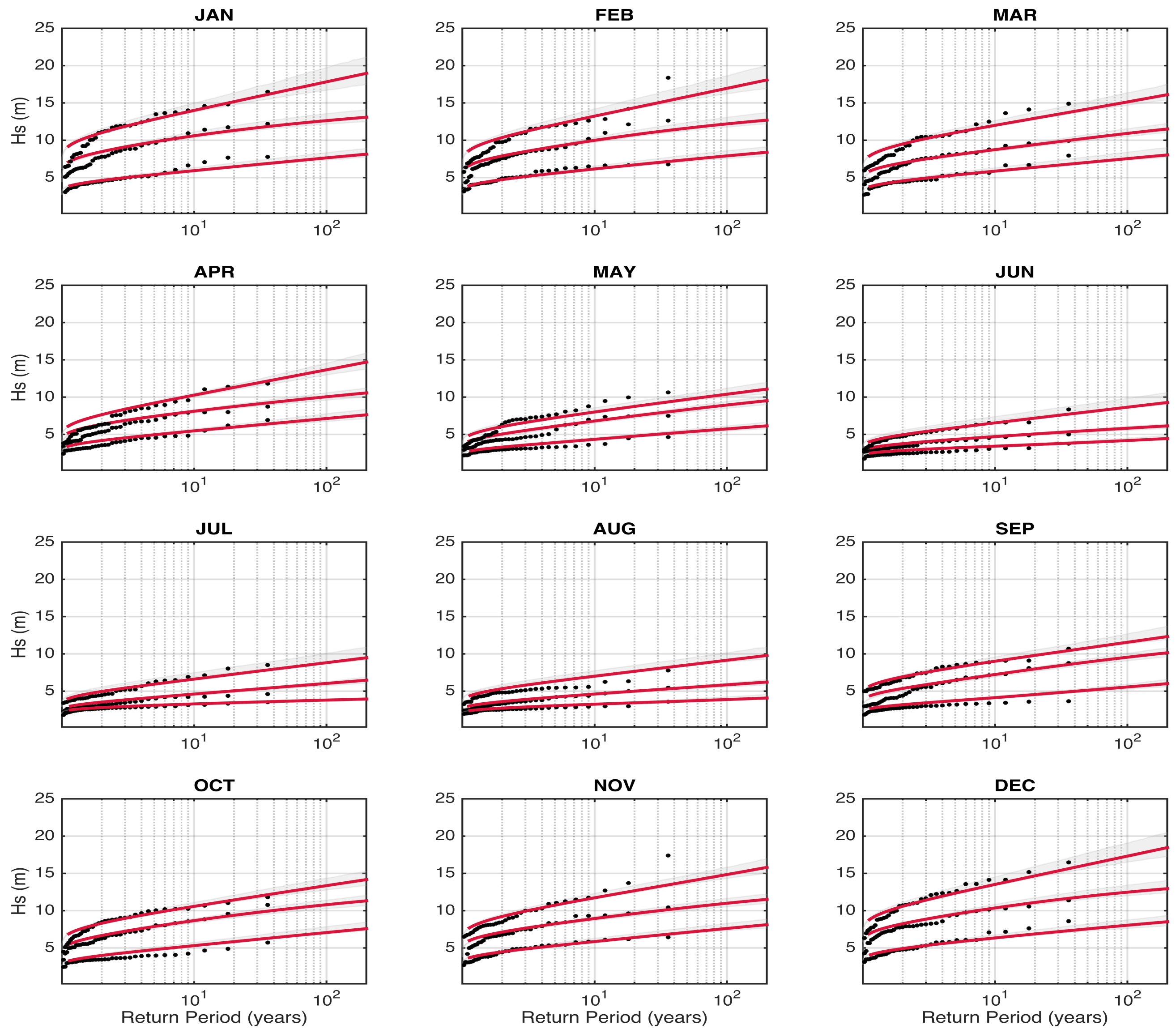
Monthly maxima

$$F(y) = \prod_{i=1}^{Nwt} F_i(y)^{N \cdot P_i \cdot \theta_i}$$

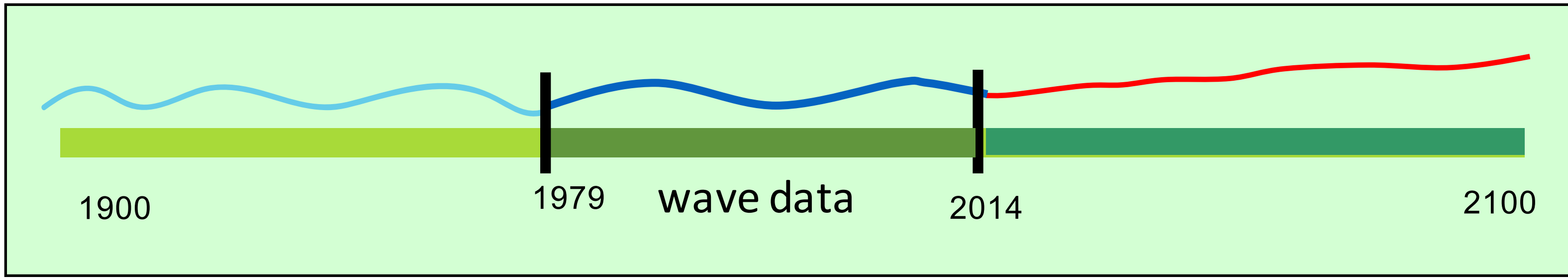
N =30

P_i = monthly probability

$P_i, \{i = 1, \ldots, Nwt\}$

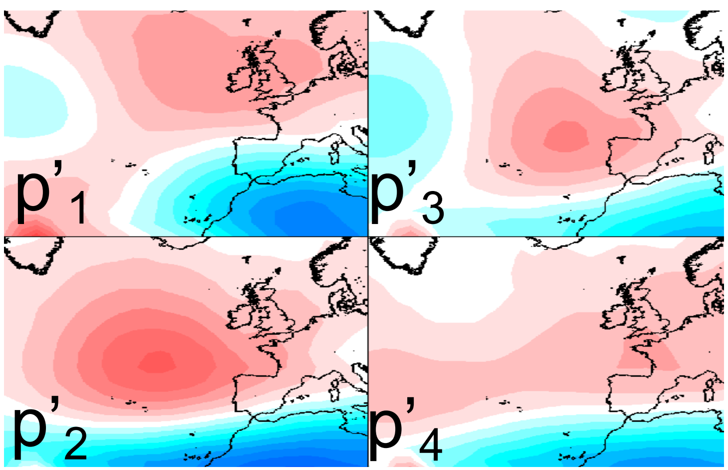


Assessing Climate Variability



X'=new predictor

Y = g(X')

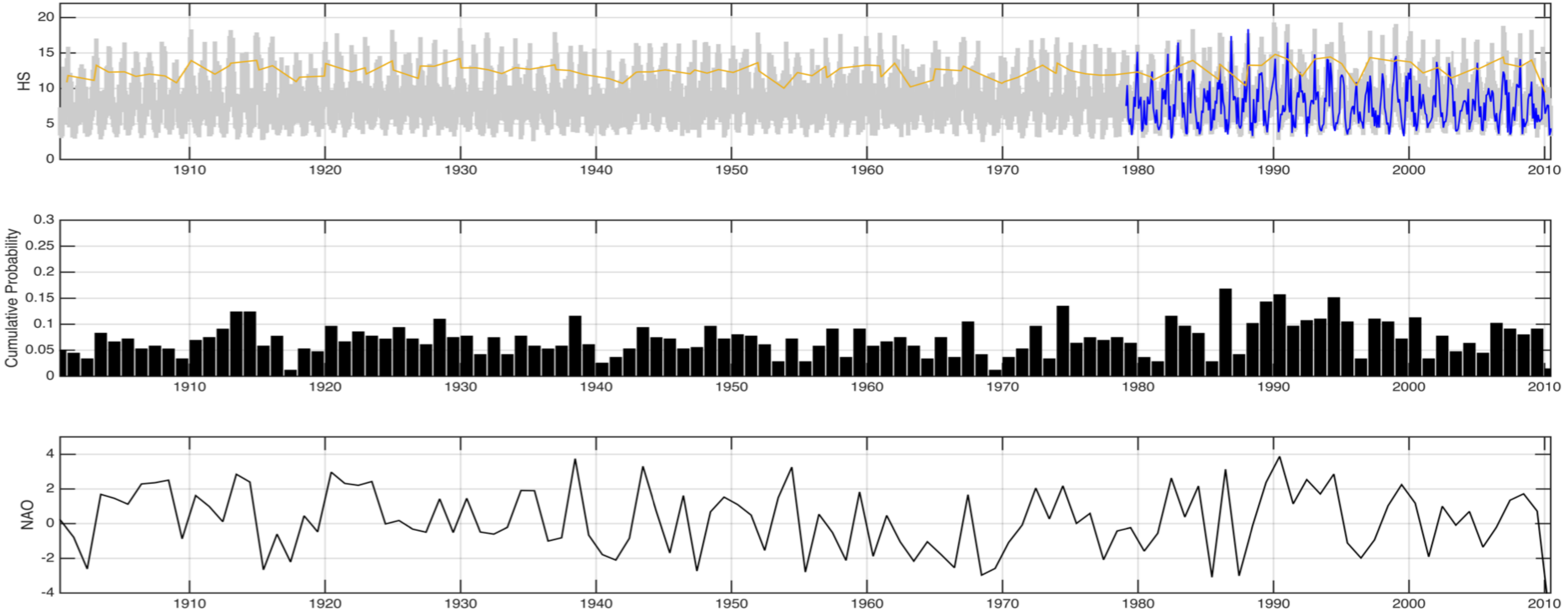


$p'_1+p'_2+p'_3+p'_4=1$

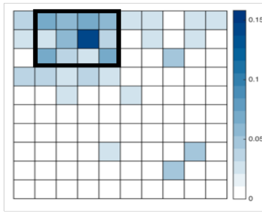
$F'_S(H) = F_1(H)^{Np'_1\theta'_1} \cdot F_2(H)^{Np'_2\theta'_2} \cdot F_3(H)^{Np'_3\theta'_3} \cdot F_4(H)^{Np'_4\theta'_4}$

Assessing Climate Variability

20CR atmospheric reanalysis (Compo et al., 2011) → Monthly HS maxima



NAO>3



Conclusions

- A statistical downscaling model based on **weather types** is able to reproduce the **distribution of maxima significant wave height for different time periods**.
- The **non-stationarity** is introduced in the model by means of changes on the occurrence probability of the associated weather types.
- An example with the 20th century atmospheric reanalysis reveals the **importance of large scale patterns** such the NAO on the recorded wave height maxima.

Acknowledgement

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Thank you for your attention!

ruedaac@unican.es

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Weather Types Regression-Guided Classification

$$X_i(x)=\{SLP(x),SLPG(x)\},\quad i=1,\ldots,n$$

$$X_i(x)=EOF_i\cdot PC_i+\ldots+EOF_d\cdot PC_d\,,$$

$$X_{EOF}=\{PC_i\,,\ldots,PC_d\}$$

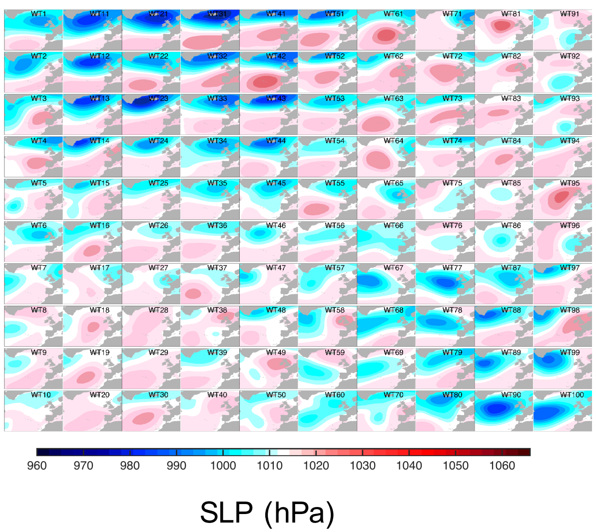
$$Y=X_{EOF}\cdot B+E$$

$$\hat{Y}=X_{EOF}\cdot B$$

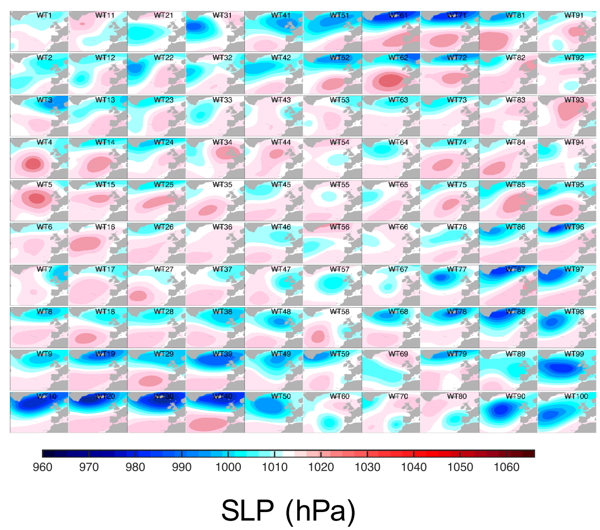
K-Means

$$\boldsymbol{Z}=[(\boldsymbol{1}-\boldsymbol{\alpha})\cdot\boldsymbol{X_{EOF}}+\boldsymbol{\alpha}\cdot\hat{Y}];$$

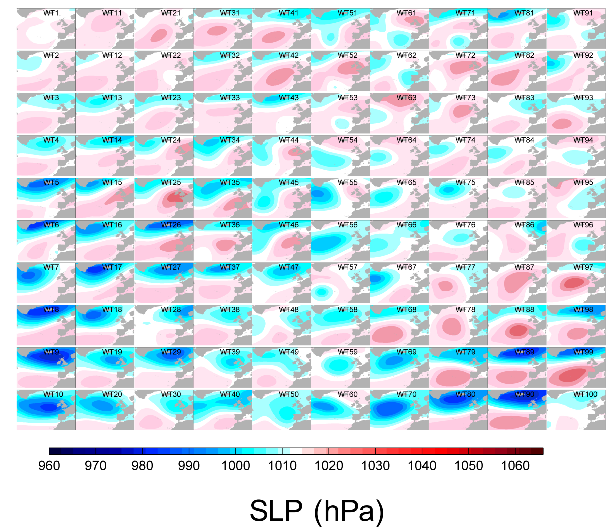
Mayo α = 0.3



La Palma α = 0.2



Coruña α = 0.6



Wave data from Perez et al. (2015)

$N_{WT}=100$

Cannon et. al (2012)
Camus et al. OD (submitted)