ULMOi: A NEW TELECONNECTION INDEX FOR RAINFALL PREDICTABILITY IN THE MEDITERRANEAN BASIN

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ABSTRACT

- **Motivation**:
  - •Improvement of seasonal and multiannual rainfall projections for Mediterranean Basin.
  - •Increase the resilience to extreme weather and climatic events.
- **Objective**:
  To design a new index to explain the climate variability and to analyze the predictability of precipitation anomalies along Mediterranean Basin for monthly and annual time scales.
- **Materials**:
  - 45 meteorological observatories (up to 150 years length).
  - A 500 hPa geopotential global reanalysis by NCEP/NCAR (65 years).
  - Another 11 teleconnection indexes were considered to relate to the new index.
- **Methods**:
  - •**Design of index**: it was used seven windows instead of isolated points.
  - •**Analysis of predictability, interdependence, and climatic variability**: FFT, ANOVA, Backward elimination stepwise, Pearson Correlation, SSE, SAE, and prevailing patterns.
- **Results**:
  - **For the study period 1950-2015**: Relationship between ULMOi and observatories is negative in most stations, except for some stations on the eastern edge.
  - •All predictions show **lower errors than** the reference prediction based on the climatic average.

MATERIALS

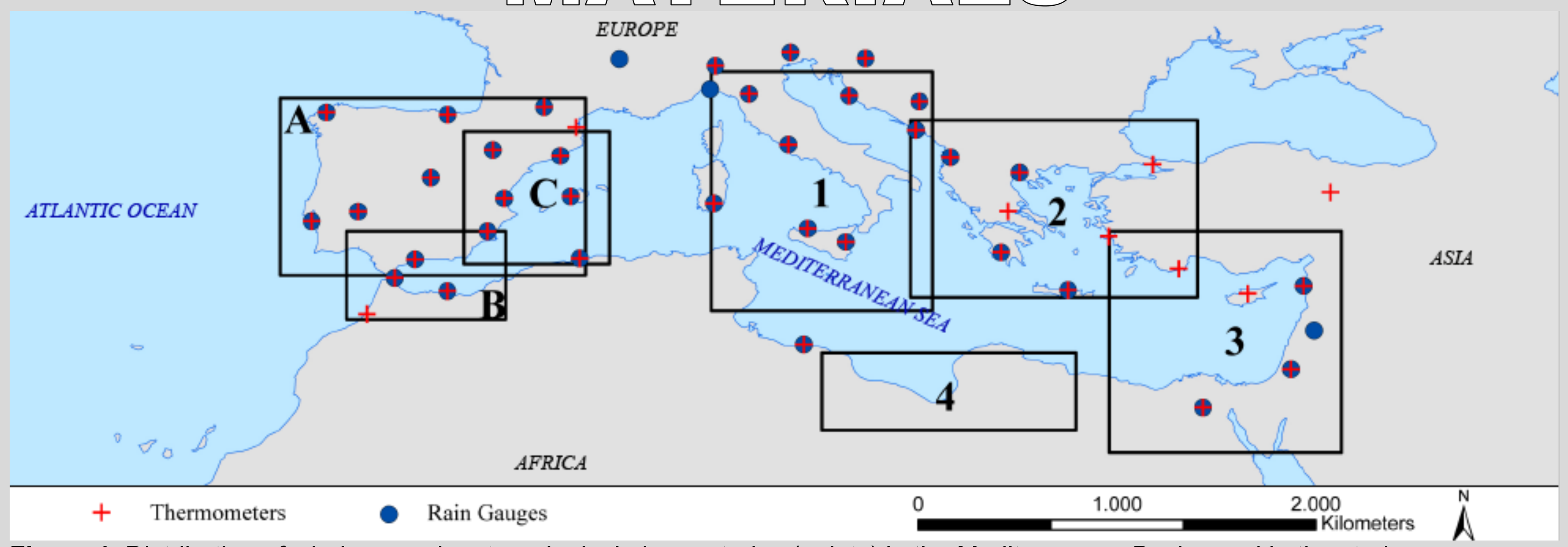

Figure 1. Distribution of windows and meteorological observatories (points) in the Mediterranean Basin used in the study.

- •**45 meteorological stations** (Fig 1).
  - **European Climate Assessment (ECA) and Dataset**
  - 34 with thermopluviometric time-series.
  - 3 with precipitation time-series.

Data from the NCEP/NCAR reanalysis:
- 6 hour temporal frequency.
- 500hPa Geopotential height .
- Spatial resolution of 25 km × 25 km.

Additional indexes: AOi, NAOi, MOi, WeMOi, ENSOi, PDOi, AMOi, SAHEL-Pi, GSNWi, GJSL and AJSL.

METHODS

ULMOi was defined as **the difference between the anomaly in the western area** (windows A, B and C) **and the anomaly in the eastern area of the Mediterranean** (windows 1 to 4) **, West-East: 3 x 4 versions**

Simulations of precipitation was performed using the ULMOi as predictor.

$$ULMOi_{ab} = \frac{D500_{ab} - \overline{(D500_{ab})}}{\sqrt{\frac{\sum_{i=1}^{N}\left(\overline{D500_{ab}} - D500_{ab}\right)^2}{N-1}}}$$

$$SAE = \frac{\sum_{i=1}^{N}|s_i - o_i|}{\sum_{i=1}^{N}|\bar{o}_i - o_i|}$$

$$SSE = \sqrt{\frac{\sum_{i=1}^{N}(s_i - o_i)^2}{\sum_{i=1}^{N}(\bar{o}_i - o_i)^2}}$$

where s_i is the simulation, o_i is the observation, and $\bar{o}_i$ is the mean of the observations.

The **best ULMOi** version was selected according to different statistical measures **such as standardized absolute error** (SAE) and **standardized mean squared error** (SSE), among others.

In order to rank the 3 x 4 versions of ULMOi according to ability, a Fractional Order (*FO*) was assigned.

$$FO_{ij} = 1 + 11\frac{E_{ij} - \min_{1\le i\le 12}(E_{ij})}{\max_{1\le i\le 12}(E_{ij}) - \min_{1\le i\le 12}(E_{ij})}$$

Fractional order FOi of the i-version ULMOi, considering *n* statistical measures E_{ij} is:

$$FO_i = \frac{1}{n}\sum_{j=1}^{n} FO_{ij}$$

RESULTS AND DISCUSSION

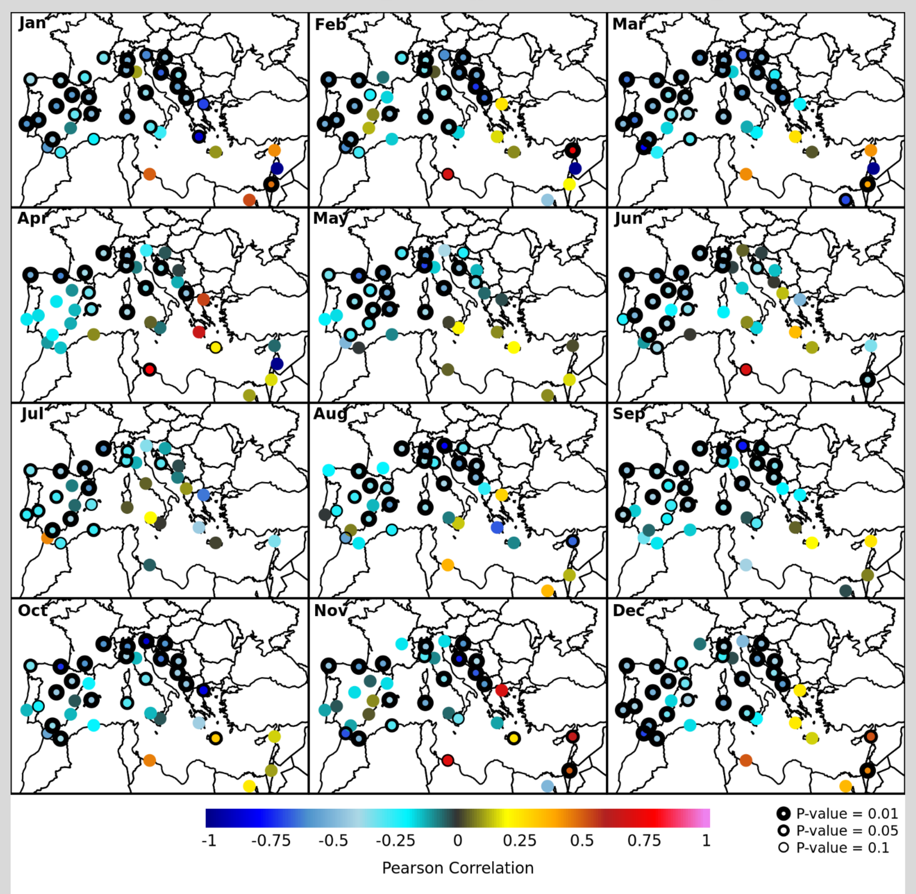

Figure 2. *R* and its p-value obtained comparing simulated and observed precipitation for each month of the year.

According to the SAE, the best window is **C4**, corresponding to Balearic Sea and North Libya.

We found **statistically significant and negative correlation coefficients** in the west and center of basin. Neutral or positive coefficents were obtained in south and east (Fig. 2).

This is primarily due to an **atmospheric blocking** generated in the western Mediterranean, where westerlies are reduced and storm tracks along the eastern Mediterranean are favored.

The observed spatial distribution of correlation coefficients is also caused by the atmospheric blocking (which generates high pressure over the Iberian Peninsula) over the Mediterranean Basin in the positive phase of the ULMOi, producing subsidence that inhibit the largely favorable upward movement to generate precipitation.

The weather stations with the most statistically significant *p*-value for annual precipitation according to the ULMOi are located in Spain and Italy: Madrid, Milan, A Coruña, Genoa, and Bilbao. For winter, a major variability of all versions of ULMOi is detected in all observatories (Fig 3).

Overall, statistic shows that ULMOi explains most of precipitation variability (see Figs 4 and 5)

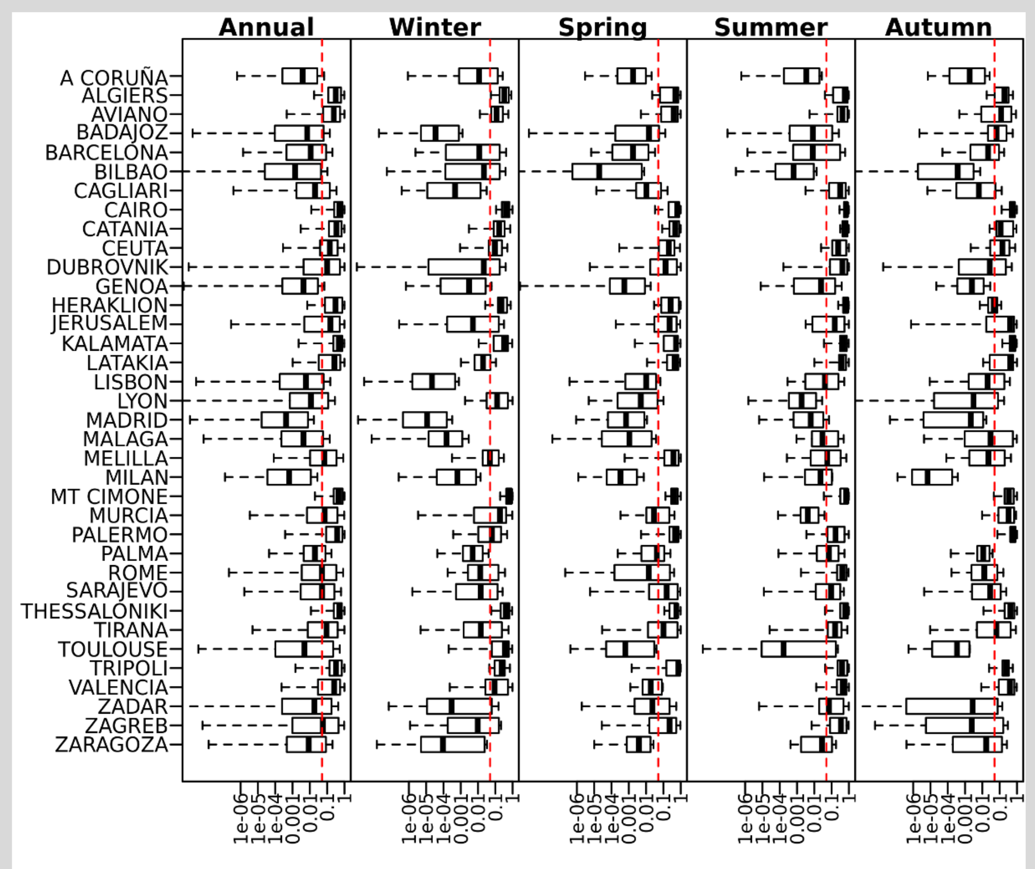

Figure 3. Pearson Correlation P-value obtained comparing seasonal simulation from C4 ULMOi and the observed anomaly in rainfall.

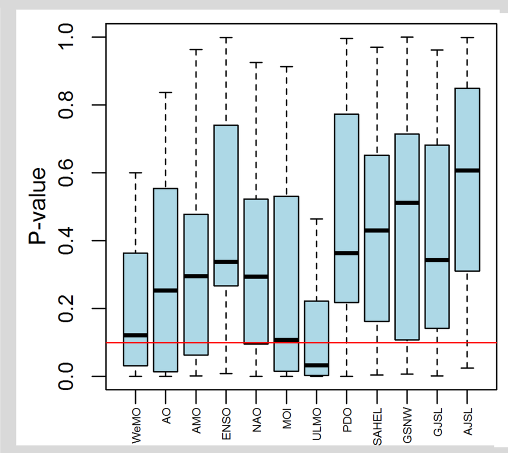

Figure 4. Pearson Correlation *P*-value obtained comparing seasonal simulation from studied indexes and the observed anomaly in rainfall.

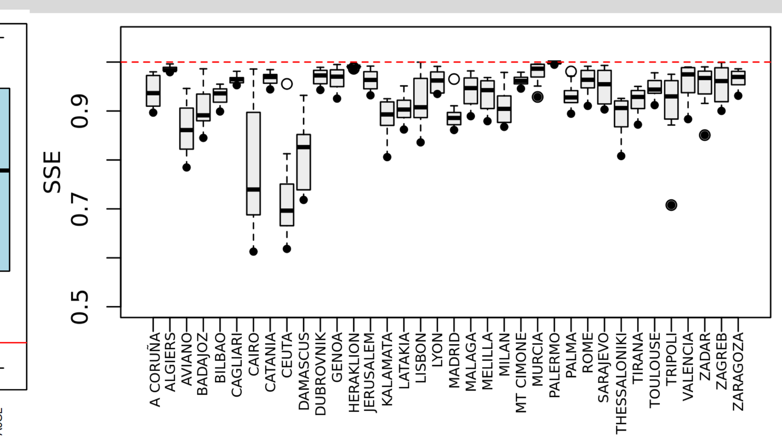

Figure 5. Standardized mean squared error (SSE) of the precipitation prediction using the ULMOi C4 calculated for each month of the year and for each observatory.

Three multiyear cycles were detected according to the FFT analysis for the time-series of ULMOi (figure 6a): **2.5 ± 0.5, 7 ± 1, and 25 years.**

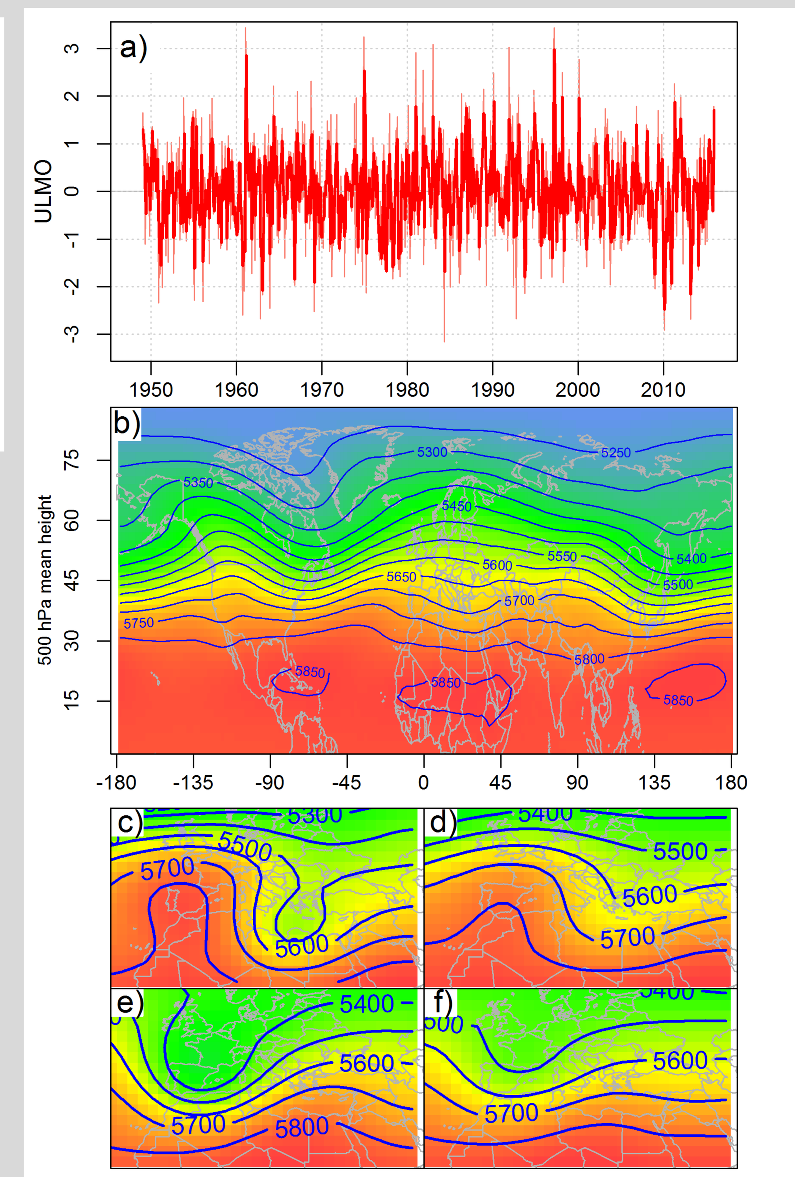

Figure 6. Evolution of monthly ULMOi C4 normalized with standard deviation (light red) and 10 months moving average (dark red) (a). Mean Z500 (b) and ULMOi phases of C4 version: positive (c, d) (3 & 1 SD), and negative (e, f) (3 & 1 SD).

The representatives of each of the phases of C4 version are (figure 6b and 6c):

1. **Neutral phase**: is characterized by zonality of geopotential. The figure shows the mean 500 hPa height for NH as a reference of normal.
2. **Positive phase**: is characterized by the incursion of a ridge in the Iberian Peninsula, which causes high geopotential values and low values of geopotential in the central sector. It leads to episodes of stability in the western and wet weather in east (c & d).
3. **Negative phase**: the lowest values of geopotential are found in Iberian Peninsula due to the position of a through over it; thus, it favors unstable weather (e & f).

CONCLUSIONS

1. This work explores to expand the definition of MOi by using an index represented by areas instead of observatories or specific points and focusing at 500 hPa geopotential height: ULMOi. The new index has reported lower errors than the MOi for points located in the same windows.
2. The relationship between ULMOi and precipitation, is negative in most of the basin, except for some stations on the eastern edge. High geopotential levels around west side inhibits upward movement to generate precipitation, it means atmospheric stability over these regions.
3. The best individual predictors are ULMOi and MOi. The low dependence between WeMOi and ULMOi explains that their combination optimizes the prediction of precipitation anomalies for most stations, with an error in the range of 15-25%

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