On the detection of climate change by using simple scaling analysis on temporal rainfall series

María del Carmen Casas-Castillo[1] and Raül Rodríguez-Solà[2]

[1]Department of Physics, ESEIAAT, Universitat Politècnica de Catalunya, Colom 1, 08222 Terrassa (Barcelona), Spain

m.carmen.casas@upc.edu, raul.rodriguez@upc.edu

[2]Department of Physics, ETSEIB, Universitat Politècnica de Catalunya, Avda. Diagonal 647, 08028 Barcelona, Spain

UNIVERSITAT POLITÈCNICA DE CATALUNYA BARCELONATECH

In nature it is common to observe **fractal self-similarity**, whereby the division of some structures gives rise to parts that have a similar shape to the original, showing what is known as **scale invariance**. In natural processes the fractal self-similarity usually has a statistical character.

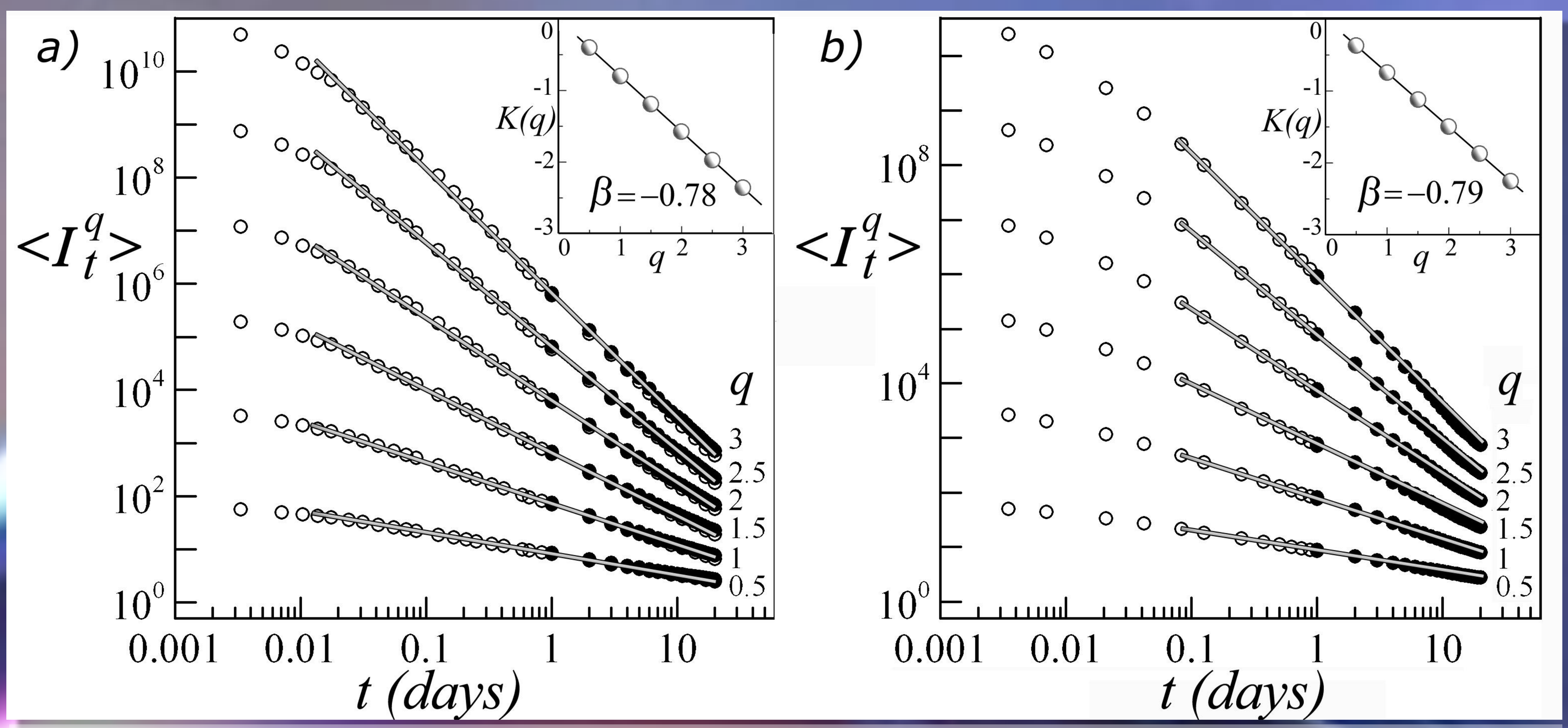


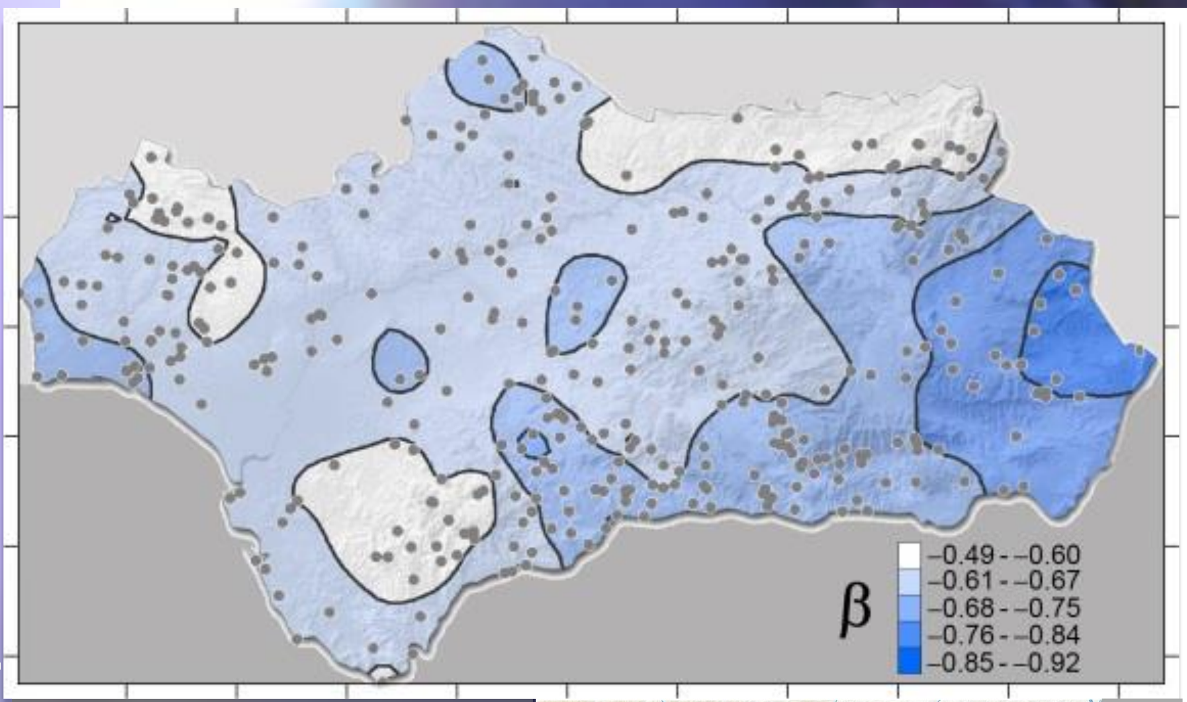
Fig. 1: Statistical moments corresponding to the simultaneous registers of the pluviographs (white circles) and the total pluviometers (black circles) [1] from *a) Fabra Observatory* of *Barcelona*, and *b) Ebre Observatory*. The inserted figures show the lineal functions $K(q) = \boldsymbol{\beta} q$ obtained from the slopes of the straight lines fitting the moments for every q

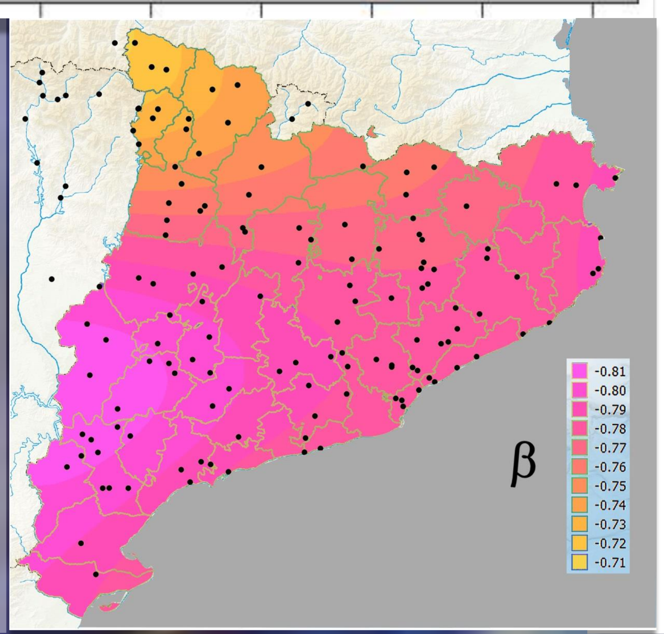
The development of theories based on **scale invariance** has allowed some natural extremely complex patterns to show an underlying simplicity that facilitates their study. The process of **rainfall generation** is a **complex nonlinear dynamic process** easier to analyse by studying the scaling relationships of one of its manifestations, the **rainfall intensity time series**.

The annual maximum rainfall intensity fulfils $I_t \overset{dist}{=} \lambda^{K(q)} I_{\lambda t}$, a **scaling relationship** that indicates that both members of the equation can be described by the same statistical distribution, where I_t is the rainfall intensity for a duration t and $I_{\lambda t}$ corresponds to a duration λt. When the scaling function of the q-order statistical moments is linear, $K(q) = \boldsymbol{\beta} q$, the distribution is describing a **monofractal** magnitude or of **simple scale** (figure 1).

The **scaling** parameter $\boldsymbol{\beta}$ is usually a good indicator of the **pluviometric** regime **irregularity**. [1-3] Higher values are observed for rainy locations with regular registers, while $\boldsymbol{\beta}$ is closer to the limit value -1 for the most irregular.

The **trend** towards **irregularity** in the rainfall patterns, possibly due to **global warming**, might be detected by the study of the evolution through time of $\boldsymbol{\beta}$, using moving temporal intervals [2,3].





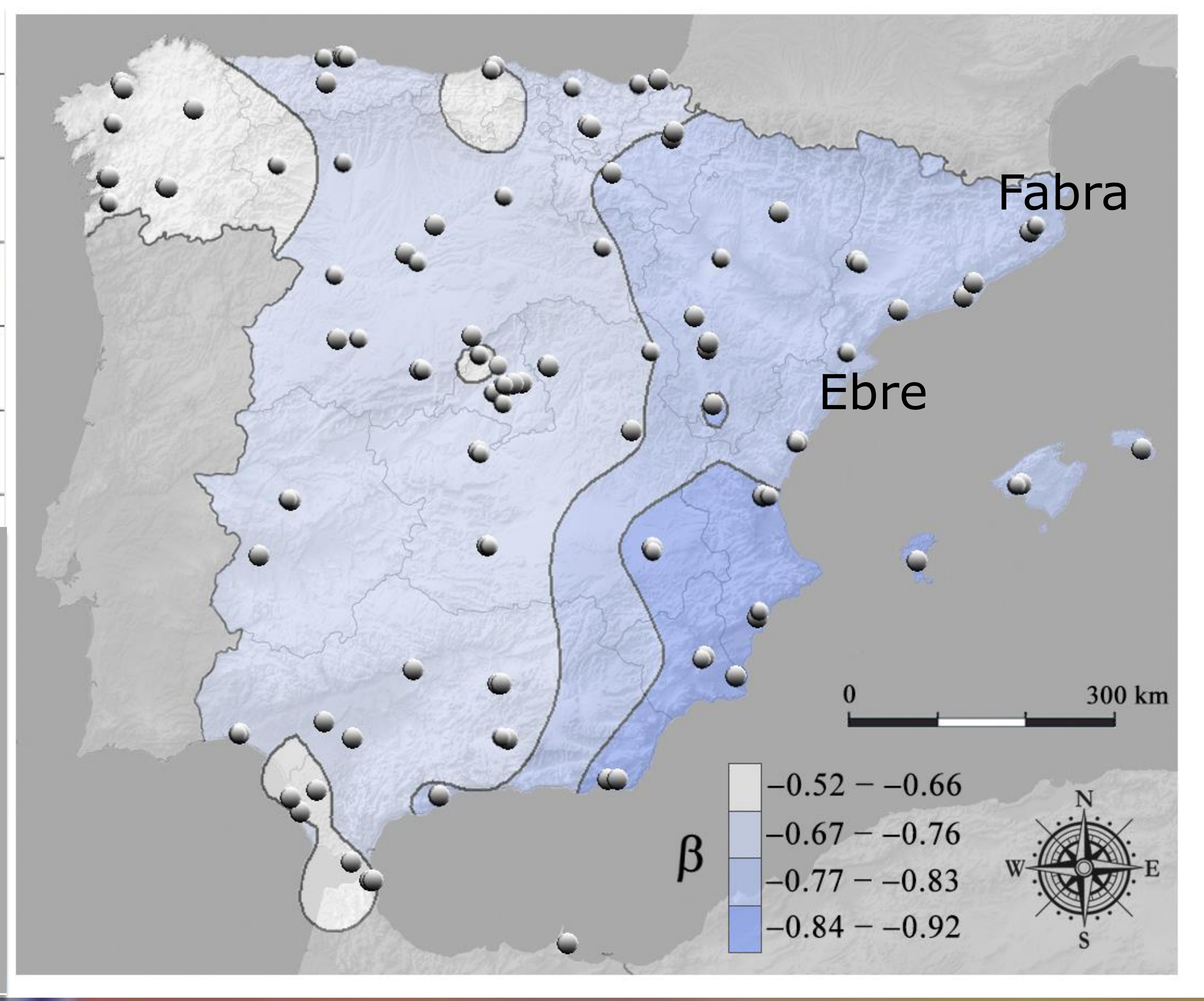


Fig. 2: Spatial distribution of the scaling parameter $\boldsymbol{\beta}$ for the Iberian Peninsula (right, [1]) and smaller regions as Andalusia (up left, [2]) and Catalunya (down left, [3]).

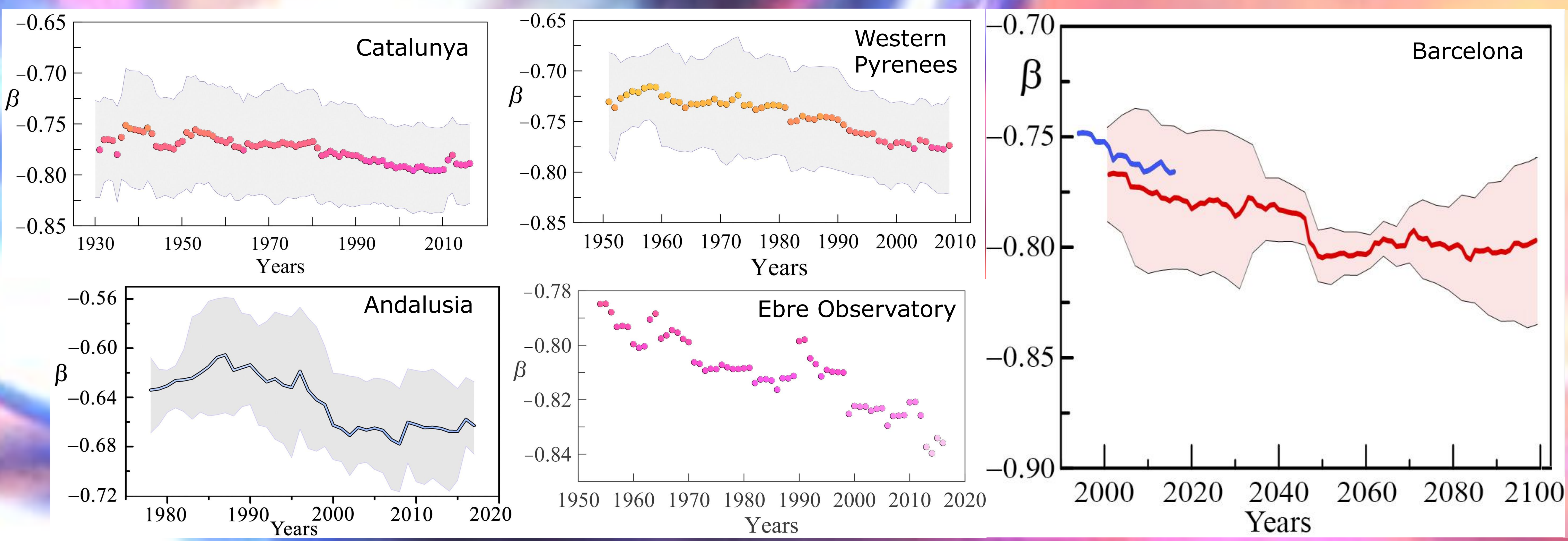


Fig. 3: Decreasing evolution of $\boldsymbol{\beta}$ in Barcelona calculated from historical series for the last 25 years and from simulated series for the 21st century under some IPCC4-A2 climate scenarios, both with a similar decreasing rate of -0.003/decade, the same rate observed under IPCC5 scenarios, and for the historical dataset of Andalusia, for Western Pyrenees and *Ebre Observatory*

[1] Rodríguez-Solà R, Casas-Castillo MC, Navarro X, Redaño Á (2017) A study of the scaling properties of rainfall in Spain and its appropriateness to generate intensity-duration-frequency curves from daily records. *Int J Climatol* **37**(2):770–780. https://doi.org/10.1002/joc.4738

[2] Casas-Castillo MC, Rodríguez-Solà R, Llabrés- Brustenga A, García-Marín AP, Estévez J, Navarro X (2022) A Simple Scaling Analysis of Rainfall in Andalusia (Spain) under Different Precipitation Regimes. *Water* **14**, 1303. https://doi.org/10.3390/w14081303.

[3] Casas-Castillo MC, Llabrés-Brustenga A, Rius A, Rodríguez-Solà R, Navarro X (2018) A single scaling parameter as a first approximation to describe the rainfall pattern of a place: application on Catalonia. *Acta Geophys* **66**(3): 415-424. https://doi.org/10.1007/s11600-018-0122-5.

WEATHER AND CLIMATE EXTREMES AND THEIR PREDICTABILITY

CAFE FINAL CONFERENCE

27 TO 29 SEPTEMBER, 2022 (BARCELONA, SPAIN)