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MEASURING CONCENTRATION OF DAILY PRECIPITATION: A METHOD COMPARISON STUDY

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The temporal concentration of precipitation may be characterised using several methods. For climate-scale precipitation, concentration measures are usually performed by means of dimensionless indices related with the Lorenz curve (Shaw and Wheeler, 1994, Martin-Vide, 2004). Other disciplines employ information entropy formulae such as the Theil Index (*TI*), derived from the Shannon Index (Cowell, 2000; Jost, 2006).

Some authors use fractal theory to describe the self-similarity of rainfall, according to the box-counting method or the Hurst exponent (Taouti and Chettih, 2014). Rainfall irregularity in time is also described using the Maximum Average Intensity (MAI) and the Intensity Duration Frequency (IDF) curves (Ghahraman and Hosseini, 2005). In particular, the rate of decline of the MAI curve can be analysed using the *n* index, which is related to the temporal distribution of precipitation (Monjo, 2016).

This study seeks to analyse the main techniques for measuring the temporal concentration of daily precipitation in time series. To this end, several indices and their relationships are examined: the Theil Index (*TI*), the Gini Index (*GI*), the Concentration Index (*CI*), the classic *n* index (n_δ) and an ordered version of the *n* index (n_{or}) (Martin-Vide, 2004, Monjo and Martin-Vide, 2016). The n_{or} and n_δ, indices were obtained by using the Profile Log-Likelihood (PLL) approach (Raue *et al.*, 2009). All indices were analysed to obtain a general intercomparison statistic and to determine their spatial distribution around the world.

A total of 66,409 daily time series were analysed for the period 1950-2014. Data were taken from the Global Historical Climatology Network-Daily Database (GHCN-Daily) (Menne *et al.*, 2012).

Results showed a very high correspondence between the *CI* and the *GI*, with a Pearson correlation of R = 0.994 and a Mean Normalised Absolute Error (MNAE) of 0.8% (Fig. 3a). In 95% of cases, absolute error is less than 2%. Therefore, for practical purposes, they are indistinguishable, at least for daily precipitation.

Regarding the other indices, strong connections were found (Table 2), and therefore just one can be used for most comparative analyses. In particular, we recommend using the *GI* due to its simplest estimation and its highest correlation (R > 0.7) with the other indices. Taking this index as a basis for comparison, some mathematical features can be gleaned. According to its similarity with the *CI*, the Lorenz curve can be simulated using an exponential function. In addition, on account of the mathematical relationship between the *GI* and the n_{or} index, it can be said that the n_{or} index is related to the shape of the Lorenz curve.

Comparing	*GI*	n_{or}	n_δ	*TI*
GI	-	**0.98**	0.71	0.76
n_{or}	**0.98**	-	0.63	0.76
n_δ	0.71	0.63	-	0.55
TI	0.75	**0.76**	0.55	-

Table 1.- Pearson correlation of the indices used. All values present a very low level of significance (p-value < $2\cdot 10^{-16}$).

The high concentration of precipitation is linked to the rapid pace of physical processes such as convection. In fact, regions with the highest concentration correspond to areas with a high degree of insolation (arid or semi-arid regions) or are influenced by warm seas, such as the Gulf of Mexico, the Western Mediterranean and the Arabian Sea (Fig. 1).

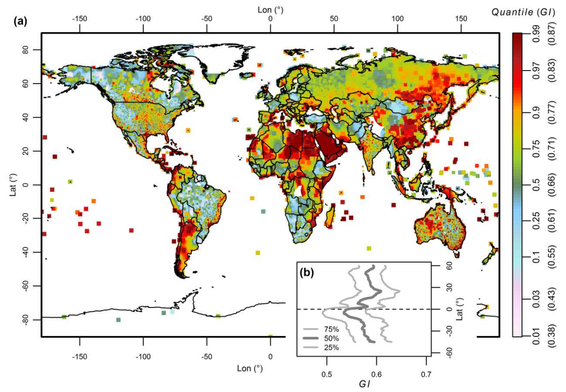

Fig. 1. Spatial distribution of the *GI* (a) and its latitudinal profile (b).

In general, low rainfall concentration can be interpreted as a consequence of regular patterns such as large-scale maritime flows (advective processes) or repetitive patterns such as a successive passage of lows or storms. Examples of the repetitive passage of lows are France and parts of Canada, whilst cases of recurrent storms occur in Brazil and Eastern Peru. Desert regions can be classified into two types according to their high or low precipitation concentration during the few days of rain. In particular, the highest concentration for deserts is observed in coastal areas (e.g. west of the Sonora, Atacama and Thar deserts), whilst the lowest concentration is located in inland areas (e.g. east of the Sonora, Thar and central Sahara deserts). The Asian monsoon also presents two different types: the Indian Summer Monsoon (with moderate rainfall concentration values) and the East Asian Monsoon (with very high concentration values), according to the higher or lower persistence of rainfall events.

The correlation between the number of rainy days and the concentration indices depends on the region analysed. For example, the regions with uneven rainfall (e.g. the Mediterranean Basin and South-Eastern China) present higher rainfall concentration when less rainy days occur (negative correlation). However, the regions with regular rainfall patterns (e.g. Brazil and India) show a higher concentration when more rainy days are reported (positive correlation).

This study could serve to characterise the world's climates according to rainfall concentration and the physical mechanisms governing this behaviour. In fact, the concentration indices analysed prove useful for measuring climate changes in rainfall patterns and their influence on erosivity.

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