Spatial Patterns of Daily Precipitation Intensity in Southern Portugal, 1940–1999

Ana Cristina Costa[1], Tiago Oliveira[1], Sara Dias[1,2], Marco Painho[1]
[1]Instituto Superior de Estatística e Gestão de Informação, Universidade Nova de Lisboa
[2]Faculdade de Ciências Médicas, Universidade Nova de Lisboa
{ccosta@isegi.unl.pt; sdias@isegi.unl.pt; toliveira@isegi.unl.pt; painho@isegi.unl.pt}

INTRODUCTION

The south of continental Portugal is a drought prone area characterized by scarce precipitation, little runoff and water availability (e.g., Paulo *et al*, 2003;). As other southern European regions, the rainfall regime in southern Portugal is Mediterranean, and so highly variable in both the spatial and temporal dimensions, with very intense flood peaks and with frequent drought periods. Fragoso and Gomes (2008) concluded that the most southern region (Algarve) is the one where episodes of heavy rainfall are most frequent and exhibits the strongest torrential character. The Alentejo area, north of Algarve, is mainly an agro-silvo-pastoral region and the most affected by desertification and drought (Pereira *et al*., 2006).

A number of studies focus on the spatial interpolation of precipitation fields in Portugal (e.g. Goovaerts 2000; Nicolau *et al*., 2002). Recent publications by Costa and Soares (2007) and Costa *et al*. (2008) provide space-time analyses of the frequency and magnitude of extreme precipitation in the south of Portugal based on geostatistical simulation algorithms. This study evaluates space-time patterns in daily precipitation intensity by calculating a climate index (SDII) at stations with records within the 1940–1999 period in the south of Portugal. Annual scenarios of the SDII were produced from 1940 to 1999 using direct sequential simulation. Those scenarios were then used to produce an additional set of maps of indicators summarizing their underlying space-time patterns.

METHODS

Interpolation typically leads to an overestimation of small values and underestimation of large ones. To overcome this limitation, geostatistical stochastic simulation has become a widely accepted procedure to obtain a set of equiprobable simulated realizations of variables from natural phenomena, consistent with the data and its statistical characteristics (e.g., Costa *et al*., 2008).

For the spatial interpolation of precipitation intensity, we explore the application of direct sequential simulation (DSS), proposed by Soares (2001), which has the fundamental advantages of simulating directly in the original data space and not relying on multi-Gaussian assumptions. This characteristic allows its application in high-skewed variables or in non-stationary fields reproduction.

For each year, one simulated realization was generated through the DSS algorithm on 800m×800m grids using different exponential space-time semivariogram models for each decade. Summary maps were produced based on those sixty scenarios of the 1940/99 period, namely probability and trend maps. At each grid cell, the probability of exceeding a given threshold value was evaluated as the proportion of the sixty yearly estimates that are equal or greater than that threshold. The local trend map was obtained by applying a nonparametric estimator of the trend slope magnitude (Modarres and Silva, 2007) at each grid cell using the simulated values for 1940/99.

STUDY REGION AND DATA

The study region is located in the South of continental Portugal, and 105 monitoring stations with daily precipitation data were selected (Figure 1). Each station series data was previously quality controlled and studied for homogeneity (Costa and Soares, 2008). The Simple Precipitation Intensity Index (SDII) is based on the average precipitation amount on wet days, with a wet day defined as a day with at least 1 mm of precipitation.

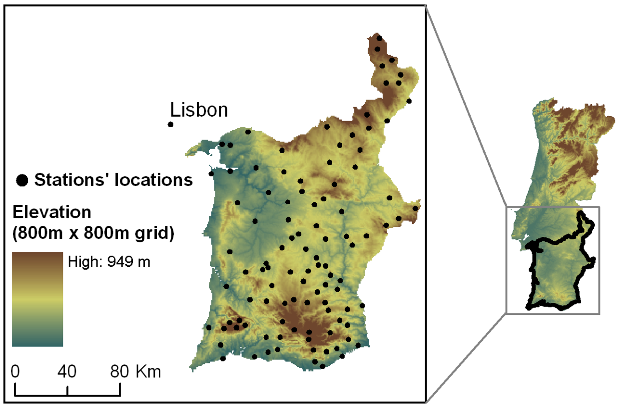

Figure 1: Elevation of the study region in the south of Portugal and stations' locations.

RESULTS AND DISCUSSION

A variogram measures the spatial-temporal correlation of an observed variable. The parameters estimated for each exponential variogram (Table 1) show that there are no relevant tendencies in what concerns the temporal component. Regarding the spatial component, the estimated values of the range parameter are generally increasing along the decades. This means that the daily precipitation intensity tends to be more spatially homogeneous through time in this region. This is likely to have profound implications for agricultural planning and water supply management. This evidence is consistent with the findings of Costa and Soares (2007) and Costa *et al*. (2008) for other extreme precipitation indices.

Decades	**Spatial range** (m)	**Temporal range** (years)	**Sill**
1940-49	45000	3.5	9.8
1950-59	55000	3	5.8
1960-69	70000	3	5.9
1970-79	50000	3	5.8
1980-89	140000	4	9.6
1990-99	110000	2	6.9

Table 1: Parameters of the space-time exponential variograms for each decade of SDII.

For illustration purposes, the simulated scenarios of 1949 and 1984 are presented since they correspond, in average, to the wettest and driest years as measured by the SDII (Figure 2). The mountainous regions of Algarve and of the northeast area have high probability of extremely intense rainfall events (Figure 3), as expected (Costa *et al*., 2008). Most of the study region exhibits weak negative trend signals in the daily precipitation intensity, while few areas show weak positive signals, particularly in the northeast (Figure 4).

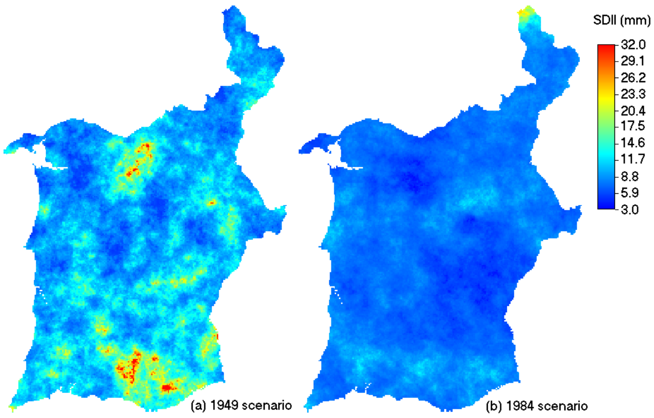

Figure 2: Simulated realizations of daily precipitation intensity for (a) 1949 and (b) 1984.

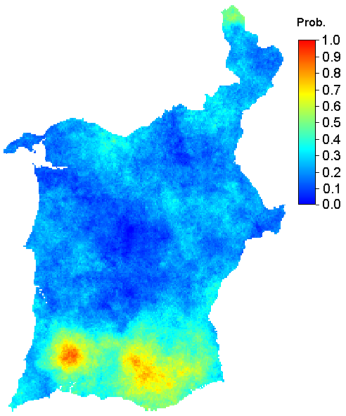

Figure 3: Probability of the daily precipitation intensity (SDII) to be equal or greater than 10.9 mm (75^{th} percentile of the regional histogram of the climate normal 1961/90).

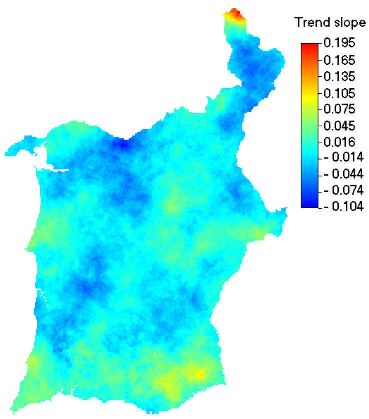

Figure 4: Local trends in the daily precipitation intensity (SDII).

BIBLIOGRAPHY

Costa A. C., Soares, A., Space-time interpolation and uncertainty assessment of an extreme precipitation index using geostatistical cosimulation. In: *Seventh IEEE International Conference on Data Mining Workshops (ICDMW 2007)*, IEEE Computer Society: 589-594, 2007.

Costa, A. C., Soares A., 2008. Trends in extreme precipitation indices derived from a daily rainfall database for the South of Portugal. *Int. J. Climatol.*, DOI: 10.1002/joc.1834.

Costa A. C., Durão R., Pereira M. J., Soares, A., 2008. Using stochastic space-time models to map extreme precipitation in southern Portugal. *Nat. Hazard Earth Sys.* 8(4): 763-773.

Fragoso M., Gomes P. T., 2008. Classification of daily abundant rainfall patterns and associated large-scale atmospheric circulation types in Southern Portugal. *Int. J. Climatol.* 28(4): 537-544.

Goovaerts P., 2000. Geostatistical approaches for incorporating elevation into the spatial interpolation of rainfall. *J. Hydrol.* 228: 113-129.

Modarres R., Silva V. P. R., 2007. Rainfall trends in arid and semi-arid regions of Iran. *J. Arid. Environ.* 70(2): 344-355.

Nicolau R., Ribeiro L., Rodrigues R. R., Pereira H. G., Câmara A. S., Mapping the spatial distribution of rainfall in Portugal. In: Kleingeld W. J., Krige D. G. (eds.), *Geostatistics 2000*, Cape Town, Vol. 2, Geostatistical Association of Southern Africa, South Africa: 548-558, 2002.

Paulo A. A., Pereira L. S., Matias P. G., Analysis of local and regional droughts in southern Portugal using the theory of runs and the Standardised Precipitation Index. In: Rossi G., Cancelliere A., Pereira L. S., Oweis T., Shatanawi M., Zairi A. (eds.), *Tools for Drought Mitigation in Mediterranean Regions*, Kluwer, Dordrecht: 55-78, 2003.

Pereira L. S., Louro V., Rosário L., Almeida A., Desertification, territory and people, a holistic approach in the Portuguese context. In: Kepner W. G., Rubio J. L., Mouat D. A., Pedrazzini F. (eds.), *Desertification in the Mediterranean Region: a Security Issue*, NATO Sc.Com., AK/Nato Publishing Unit, Springer-Verlag, Dordrecht: 269-289, 2006.

Soares A., 2001. Direct sequential simulation and cosimulation. *Math. Geol.* 33(8): 911-926.