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Evaluation of rainfall spatial interpolation methods, assessment on different places and times: a small urban area (France), a large rural water catchment (Senegal) and the northern Atlantic region

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The aim of this comparative analysis is to determine the rainfall spatial interpolation method which is the most efficient, based on three different study fields, each one having their own characteristics in terms of size or pluviometer density. The first study area is the urban area of Greater Lyon, in the North of the Rhône valley, in France. This is a small area, with a very dense rain gauge network. The second one is a vast rural water catchment (Ferlo), with few rain gauges, in Senegal, while the third area deals with a huge territory: the northern Atlantic region.

Greater Lyon possesses one of the densest rain gauge networks in an urban area within Europe, having 52 gauges in a flat area of 464 km^2. Most of the pluviometers belong to the urban community of Grand Lyon, with 29 tipping bucket rain gauges working in this area. This creates a density of about 1 pluviometer for every 10 km^2. They are spread all over the Grand Lyon area, although with a lower density in the eastern part of the agglomeration. Analysis shown in this paper is completed using this network data.

The Ferlo, a vast agro pastoral territory is located in the north region of Senegal between 16 degree 15 and 14 degree 30 north of latitude and 12 degree 50 and 16 degree west of longitude. This territory, situated on an intermediary area scale between Greater Lyon and the northern Atlantic region has a sparse measure network of 13 rain gauges in an area of approximately 55000 km^2.

Reconstructing rainfall patterns at a palaeoclimatic scale is a complex exercise because raw data are not available so they must be interpreted from periglacial or botanical proxy. A first step is necessary to reconstruct a "palaeo" rain gauge network by inferring these palaeoclimatic data in rainfall threshold values (mm/y). Currently, this network is composed of about 60 sites all widespread in the northern Atlantic region. This creates a relatively low density of stations, which imposes limits to the efficiency of the interpolation process.

The purpose of this analysis is to choose a method which combines the quality of interpolation and convenience of use (time, calculus and computation). Four spatial interpolation methods have been chosen and used on a sample of rainfall events which gather 18 years of annual precipitation, from 1998 to 2005 for the Greater Lyon area and Ferlo water catchment. The palaeoclimatic work on the northern Atlantic region is focused on the period best known as the Lateglacial/Holocene transition.

Rainfall spatial interpolation methods range from simple estimations to complex procedures and can be grouped in many typology. The one that will be used in this article is based on two categories, the determinist methods and the stochastic methods. The determinist methods consist of the barycenter techniques like the Inverse Distance Weighting technique, the area division techniques, and the Spline techniques. The stochastic methods include the classic regression techniques such as the Trend Surface, the local regression techniques, and the Kriging techniques. Many different methods of spatial interpolation exist and they are widely described in the specialised literature, so a precise explanation of them will not be carried out in this paper.

Methodological principles of analysis:

Four spatial interpolation methods have been chosen for this article: Inverse Distance Weighting method and the Spline (completely regularized) as the determinist methods; Global Polynomial Interpolation (trend surface) and Ordinary Kriging as the stochastic methods.

In order to analyze the interpolation quality, an evaluation by cross validation has been carried out. The cross validation starts by eliminating one of the available gauges. The four different spatial interpolation methods are then applied to estimate the missing value on the basis of the remaining observed ones. This process has been carried out on each rain gauge. For each interpolation test on the four methods, the rainfall observed values $Z(x)$ have been considered, the estimated values $\check{Z}(x)$, and the errors $e(x)=Z(x)-\check{Z}(x)$. The mean of the errors and its standard deviation was then calculated for each interpolation method.

Essential conclusion on results:

The results obtained by cross validation lead to these conclusions. Estimations reveal significant differences depending on the interpolation methods used, and show a clear hierarchy by types of methods. Indeed, the stochastic methods seem more accurate than the determinist ones.

Inverse Distance Weighting method and the Spline are the less efficient interpolation methods. On the contrary, Ordinary Kriging is the method which allows the sharpest interpolation and is the most representative. However, Global Polynomial Interpolation method is able to supply very precise interpolation, without needing a lot of decision making and parameter choices, although being less flexible than Kriging.

Despite the differences in results, the four interpolation techniques provide relatively sharp estimation, as shown with cross validation. To conclude, Global Polynomial Interpolation method is sharp and can be preferred to the time consuming kriging method which needs a lot of geostatistical knowledge, parameter decision, and requires more computation.

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