Evaluation of rainfall spatial interpolation methods : the case of the urban area of Greater Lyon (France)

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Greater Lyon possesses one of the densest rain gauge networks in an urban area within Europe, having 52 gauges in an area of 460 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 more than 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. The first rain gauges were set up in 1985, but the actual network density of the present day was reached in 1989. The data is available every 6 minutes although this is variable according to the tip of the bucket. Analysis shown in this paper is made with this network data. Rainfall spatial interpolation methods range from simple estimations to complex procedures and can be gathered in many typology. The one which will be used in this article is based on two categories, the determinist methods and the stochastic methods, themselves subdivided in three categories each. The determinist methods gather the barycenter techniques with Inverse Distance Weighting method for example, the area division techniques like the Thiessen polygons method, and the spline techniques (regularized and tension). The stochastic methods include the classic regression techniques with amongst them the trend surface analysis technic, the local regression techniques, and the kriging techniques. Many different methods of spatial interpolation exist and they are widely described in the specialized literature, so a precise explanation of them will not be carried out in this paper.

Methodological principles of analysis :

The aim of this comparative analysis is to determine the spatial interpolation method which is the most adequate for the urban area of Greater Lyon (which is a small area of 460 km^2, with a very dense rain gauge network) from two criteria: quality of estimation and how difficult it may be to carry out (time, calculus and computation). Thus, the purpose of this analysis is to choose a method which combines the quality of interpolation and convenience of use. Four spatial interpolation methods have been chosen and used on a large sample of rainfall events, but only one event is shown as a reference in this paper (Comparative analysis were carried out on 158 rainfall events, selected in function of three criterion : intensity (of 6 min, 20 min, 1 h, 2 h and 6 h range surface intensity and lifetime event), nuisances and disturbances recorded during the rainfall event, and presence or not of a convective meso-scale system). The chosen rainfall event occurred during the 1st and 2nd of December 2003 and affected the entire south-east region of France. In addition, this rainfall event is the most significant in terms of damage and rainfall total during the last 5 years in the Lyon region consisting of 20.3 % of the annual mean rainfall (in addition, the choice of this rainfall event is justified because the presented results are very representative from these obtained during the tests done on the other event). Four spatial interpolation methods have been chosen for this article: Inverse Distance Weighting method and Thiessen polygons interpolation method for the determinist methods; Trend Surface interpolation method with a 3rd polynomial order and ordinary kriging whose linear model has been chosen as best to fit a line to the semi-variogram for the stochastic methods. In order to analyze the interpolation quality of the four methods chosen, two evaluations were carried out: an evaluation by visual observation, and an evaluation by cross validation. Concerning the visual observation evaluation, the rainfall event selected has been drawn with the four spatial interpolation methods, from the 28 greater Lyon rain gauges. Interpolations were carried out for different time ranges: 6 min, 20 min, 1 h and 2 h, and on the rainfall total of the event that was chosen for this article. The cross validation starts by randomly eliminating half of the available gauges. The four different spatial interpolation methods are then applied to estimate the missing values on the basis of the remaining observed ones. In this study, half of the gauges have been eliminated randomly, and this operation has been repeated 20 times in order to get more precision on the mean results. For each interpolation tests on the four methods, we have considered the rainfall observed values Z(x), the estimated values E(x), the errors e(x)=Z(x)- E(x), the absolute errors |e(x)| and the relative errors |e(x)|/Z(x). Then, the global mean of the relative errors and its standard deviation was calculated for each interpolation method.

Essential conclusion on results :

The results obtained, by visual observation evaluation and by cross validation lead to these conclusions. Estimations show significant differences depending on the interpolation methods used, but they do not traduce a clear hierarchy by types of methods (determinist and stochastic). Thiessen polygon method (determinist) and Trend surface method (stochastic) are the less efficient interpolation methods, with respectively 14.02 % and 15.75 % of global mean of relative errors. On the contrary, ordinary kriging (stochastic method) is the method which allows the sharpest interpolation and is the most representative (with 7.54 % of global mean of relative errors). However, IDW method (stochastic method) is able to supply very precise interpolation, shown by a global mean of relative errors of 8.52 %. The extreme density of measure network is the principal explanation. It explains that despite the result differences, the four interpolation techniques provide relatively sharp estimation, as shown with cross validation. To finish, the IDW method, that is sharp as a result of the high density measure network, can be preferred to the kriging method which is less convenient to use and requires more computation.

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