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3D mapping and simulation of Geneva Lake environmental data

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The Geneva Lake is the biggest alpine and subalpine lake in central Europe. The depth of this lake is 309 meters and its total volume of water is 89 billions m3. It takes, on average, around twelve years so that waters of the lake are completely brewed. Furthermore the Geneva lake waters are rich in dissolved substances as carbonate, sulfate. The quantity of particles in suspension in the lake, which mainly arrived from the Rhône, is nowadays around height million of tones. The International Commission for the Leman Lake (CIPEL) works about the improvement of the quality of this lake since 1962. In the present study three dimensional environmental data (temperature, oxygen and nitrate) which cover the period from 1954 to 2008, for a total of 27'500 cases are investigated. We are interested to study the evolution of the temperature of the lake because there is an impact on the reproduction of fishes and also because the winter brewing of the water makes the re-oxygenation of deep-water. In order that biological balance is maintained in a lake, there must be enough oxygen in the water. Moreover, we work on nitrate distribution and evolution because contributions in fertilizers cause eutrophication of lake. The data are very numerous when we consider the time series, some of them with more than 300 occurrences, but there are between 2 and 15 data available for spatial cartography.

The basic methodology used for the analysis, mapping and simulations of 3D patterns of environmental data is based on geostatistical predictions (family of kriging models) and conditional stochastic simulations. Spatial and temporal variability, 3D monitoring networks changing over time, make this study challenging. An important problem is also to make interpolation/simulations over a long period of time, like ten years. One way used to overcome this problem, consists in using a weighted average of ten variograms during this period. 3D mapping was carried out using environment data for several depths.
Applying all data comprehensive analysis both in space and in time was performed. The evolution of the distribution of environmental parameters and their difference in space between two periods and also several times series were studied. Furthermore with the analysis of temporal measurements depending on spatial coordinates (x, y, z) the trends, periodicity, and seasonal variation or cycles were evaluated. First results demonstrate no global warming in such environment. However certain currents and their evolution in the lake were identified. Then, we can see the movement of cold and hot waters in the lake during time and in space.
A main question posed by ecologists is: is there any global warming of the lake? According to the results based on date 1954-1980, no global warming either of the "Small Lake" (Geneva) or the whole lake was put into evidence. However the temperatures of the different parts of the lake vary from one year to another year with significant differences of warming, respectively cooling of different areas and at different depths. The graphical representations of time series of temperature at one location for different depths show clearly the annual rhythm and also other frequencies (11 years). The historical well known "cold years" are well identified. At some years, one can observe an inversion of temperature when the cold water in the depth comes upwards to the surface. Spatial patterns are also found for the nitrate content in water. The future developments deal with multivariate analysis and simulations of environmental and pollution data in the lake.