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# Innovative graphical-numerical methods to investigate compositional changes in groundwater systems

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Groundwater systems are typical dissipative structures and their evolution can be affected by non-linear dynamics. In this framework, geochemical and hydrological processes are often characterized by random components mixed with intermittency and presence of positive feedbacks between fluid transport and mineral dissolution. Therefore, in these cases, complex variability structures in the chemical signature of waters are recognized. Large fluctuations in intermittent processes are not rare as in normal and log-normal processes and significantly contribute to the statistical moments, thus moving the physicochemical data from the Euclidean geometry to fractals and multifractals.

Since the knowledge of dynamics in water systems has substantial implications in the management of the water resource, groundwater chemistry can better be understood by using innovative graphical and numerical methods in the light of the Compositional Data Analysis Theory (CoDA, Aitchison, 1986), which is particularly suitable to explore the whole composition and the relationships between its parts.

The whole compositional change, characterizing each sample with respect to some end-members (i.e. rain waters, pristine waters and sea water), is modeled by using the perturbation operator in the simplex geometry (Pawlowsky-Glahn and Buccianti, 2011). Perturbation factors are calculated and then analyzed by investigating their cumulative distribution function (Pr[X>=x]) with the aim of registering the presence of power laws (fractal and multifractal dynamics) and forecasting a possible spatial behavior.

Results obtained for some aquifers from Tuscany (central Italy) are presented and discussed in the framework of the GEOBASI project (Nisi et al., 2016). Preliminary evaluations indicate that perturbation factors are sensible tools to: 1) identify the different components (random, deterministic, fractal) contributing to the variability of the geochemical data, 2) discriminate the role of additive and multiplicative phenomena in time and/or space, 3) highlight the presence of

non-linear dissipation with the energy exchanges between different scales.[Office1]

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