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Some problems for the application of inverse techniques to environmental modelling

One of the most important steps in the development and application of an environmental model is the model calibration, i.e. the determination of the values of the model parameters that permit the best fitting between model results and measured data. This is a typical example of inverse problem. At every phase of the model development and application, we must consider the goals of the model and the (space and time) scales at which the phenomena are described by the model. These aspects have strong impact on the solution to the inverse problem.

In particular the choice of the model scales is of paramount importance, because it controls the ability of the model to reproduce real features and the discretization of the domain for the numerical model. Moreover, a necessary condition to be confident on model forecast is that the model scales are consistent with the space and time distribution of the field measurements. Decreasing the grid spacing can improve the ability of the model to reproduce fine-scale features. However, this requires a detailed knowledge of the physical system, which could be a difficult task if the natural system is heterogeneous or anisotropic, as is often the case for geological formations or turbulent flows. Therefore the modeler of the physical system must work with numerical techniques that provide "good solutions" even for grids with "large spacing". "Good solutions" are solutions which satisfy the physical principles that are at the base of the model, i.e. the conservation principles. "Large spacing" means that (1) the grid elements or cells could be larger than the optimal value coming from the purely mathematical theory, but consistent with the distribution of the available measurements and (2) the grid elements could be larger than the volume over which phenomenological laws are validated with laboratory or field experiments.

These remarks are important for model calibration and therefore for the solution to the inverse problem, above all in the discrete case, which is the most important for applications. In particular, stability is usually an overwhelming problem for continuous domains, but numerical instability is often linked to ill conditioning. Moreover, ill conditioning depends upon the model scale, which is strictly linked to the grid spacing and the spatial data distribution.

Furthermore, in the last decades, several works, dealing with both statistical and deterministic inverse techniques, have shown the importance of using several independent data sets to reduce uncertainty in the model. This is very important because, in principle, the parameters of the discrete models are non local quantities, in the sense that they depend upon the space distribution in a region wider than the area to which the parameters refers to and on the flow direction. Therefore, parameters obtained from data sets corresponding to different flow situations are more confident and, as a consequence, this improves the reliability of model forecasting.