Minisymposium *Operational Applications of Data Assimilation*

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Data Assimilation is a general set of methods, of various complexities, for computing the optimal estimate of the true state of a system over time. It uses values obtained both from observations and *a priori* models, and information about their errors. Its main improvements have resulted from its wide spread use in meteorological and ocean models applied to weather forecast, although its come originally from control theory.

An important aim of this symposium was to show that there are other fields in science and technology, where the effective use of observed but incomplete data is crucial. Applications in robotics and nuclear sciences, as well as meteorology were featured in the symposium. Indeed Data Assimilation is becoming a cross-domain tool. In this symposium, experts from various fields presented Data Assimilation for specific applications, and compare recent advances and new ideas emerging from their different points of view.

The goal of modern Data Assimilation methods is to make optimal estimates of the initial or time developing state of variables in a model, by putting together information from all available observations and from previous forecasts. Basically, Data Assimilation can be considered as an extension of the least square method. The method of the Best Linear Unbiased Estimation (BLUE) filter is the simplest, both theoretically and computationally. But Data Assimilation is also valid for dynamical or time-varying data sets and models. The Kalman Filter is one of the general methods that provides optimal evaluation of data in relation to a model. Both BLUE and Kalman Filter are very efficient as long as the space of observed data has a limited size, but other methods need to be used for large set of data. Four-dimensional Variational Data Assimilation (4DVAR) based on this principle is currently the most widely used assimilation method for operational weather prediction. Using 4DVAR in meteorology improves accuracy of the forecasts typically by up to a few percent for 2–5 days. Instead of 4DVAR, it is equivalent applying a Kalman Filter to the data as the observation window-length increases.

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As in many complex systems, some (but not all) dynamics of the atmosphere are very sensitive to the initial state, and the model errors. It is helpful that the dynamical equations limit the magnitude of errors in this case, because the equations effectively correlate the variables. The errors and their correlations can be further reduced by ensuring that the initial data, when it is introduced into the processes, satisfies dynamic of balance relationships given by previous equations.

These mathematical and computations procedures for making the best evaluation of incomplete data are not limited to meteorology. An autonomous robot needs to collect as much data as possible to evaluate its position and status in real time. As explained, to build real-time precise representations (maps) of its environment, it uses different filtering methods, and switches from one to another to improve the overall system fault-tolerance. Data Assimilation is applied in the same way as in meteorology and oceanography, but here the technique is called filtering and/or data fusion.

A new application has emerged in the critical field of modelling and evaluating of the core of a nuclear reactor. In this case, Data Assimilation improves operational security and optimal utilisation of resources. Two kinds of applications have been demonstrated. The aim of the first one is to collect information coming from several instruments, in order to estimate the state of the whole system. The second one is to evaluate optimally the parameters of the nuclear core model. In both applications the essential elements is to use data and modelling to make optimal estimates of the required evaluations, and continually reduce error on them.

The Data Assimilation techniques are evolving along time to new techniques in operational computation, and in design. Striking examples are the recent developments using ensemble methods for very large dimension models and for imprecise systems. Data Assimilation improves the reliability of these models, including those where the models for the same process (e.g. weather) are based on different parametrisation, and where many computation are performed simultaneously to allow for noisy predictions in highly non linear processes. At the same time, Data Assimilation schemes are becoming more accurate and faster by incorporating greater physical understanding into the simpler models.

In all fields of science and technology the objectives are to make better and faster use of the increasing volume of measured data, even though it is always incomplete. In order to improve the accuracy of the models with increasing power of computation, Data Assimilation is becoming progressively more essential in computation and observation, and also in control and design of complex systems.

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