ISDA-Online

February 11, 2022 / 15 – 17 UTC

"History of Data Assimilation"

Session Chairs: Javier Amezcua, Lars Nerger, Ting-Chi Wu, Nora Schenk, Tobias Necker

Program:

15:00 – 15:05 **Welcome**

15:05 – 15:50 **A Brief History of Data Assimilation**
Olivier Talagrand

15:50 – 16:00 **Questions / Discussion (10 min.)**

16:00 – 16:45 **Data Assimilation: From an Eventful Past to a Bright Future**
Michael Ghil

16:45 – 16:55 **Questions / Discussion (10 min.)**

16:55 – 17:00 **Closing / Information on upcoming events**

Please note:

- The times in UTC are approximate. In case of technical problems, we might have to change the order of the presentations.
- Login to the session is possible from 20 minutes before the event starts. When you login before 15:00 UTC, and everything is quiet, this is most likely because we muted the microphones.

Time zones: 15 – 17 UTC

Europe:	03 – 05 pm GMT (London)	04 – 06 pm CET (Berlin)	
Asia/Australia:	11 – 01 am CST (Shanghai)	00 – 02 am JST (Tokyo)	02 – 04 am AEDT (Sydney)
Americas:	07 – 09 am PST (San Fran.)	08 – 10 am MST (Denver)	10 – 12 am EST (NewYork)

A Brief History of Data Assimilation

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Data Assimilation (DA) originated from the apparently minor and rather trivial task of defining initial conditions for numerical weather forecasts. It gradually turned out to be linked to many fundamental questions, and has now become a major tool of the numerical science of the atmosphere, the ocean and the climate.

The ultimate purpose of DA can be stated as defining the state of the atmosphere from all the available relevant information. The latter essentially consists of the observations *stricto sensu*, which vary in nature, as well as and spatial and temporal distribution, and of the physical laws governing the flow, available in practice in the form of a discretized numerical model. These various pieces of information are all affected with some uncertainty.

DA is actually one of the many inverse problems that are encountered in many fields of science of technology. As such, it can conveniently be stated as a problem in Bayesian Estimation, viz., determine the probability distribution for the state of the flow, conditioned by the available information. But, among inverse problems, DA has its own specific features: very large numerical dimensions, nonlinear (actually chaotic) underlying dynamics, and, in the case of weather prediction, need for the forecast to be reliably delivered in time. These features have strongly influenced the development of methods and algorithms for DA.

Most assimilation methods can be described as more or less heuristic and pragmatic extensions, to moderately nonlinear and non-Gaussian situations, of linear and Gaussian statistical estimation. These methods are described in the talk, together with how they have contributed to the progress of meteorology and atmospheric science. Because of the large numerical dimensions, and of the need to better represent nonlinearity, ensemble methods, in which the required probability distribution is represented by a number of points in state space, have gradually been developed, and are the subject of active research.

From its specific origins in numerical weather prediction, DA has gradually extended to various fields of science and technology, in geophysics and elsewhere: oceanography, hydrology, climatology, plate tectonics, terrestrial and solar magnetism, and others. It has also extended to various applications, among which, e.g., definition and a priori evaluation of observing systems, ‘reanalyses’ of past observations, validation of numerical models and parameter estimation.

**Data Assimilation:
From an Eventful Past to a Bright Future**

Michael Ghil
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V. Bjerknes first described weather prediction as an initial-value problem in 1904. As J. von Neumann and associates started using computers to implement this idea immediately after World War II, it quickly became apparent that the requisite initial data available then were incomplete. The appearance of weather satellites in the 1960s led further on to the concept of time-continuous assimilation of remote-sensing data. Nowadays, data assimilation (DA) is being applied across all the areas of the climate sciences and much beyond.

This talk traces the evolution of DA methodology from the successive corrections and polynomial interpolation of the beginnings through the development of sequential-estimation ("Kalman filtering") and control-theoretical ("variational" or "adjoint") methods to today's machine-learning–aided methods. Key concepts, such as information transfer between variables and between regions, as well as parameter estimation and new areas of application will be emphasized. Cutting-edge progress to be covered will touch upon the application of concepts and tools from nonautonomous and random dynamical systems theory, as well as upon combining machine learning with DA and with knowledge-based models for weather and climate prediction.