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Back and forth nudging algorithm for data assimilation problems

D. Auroux (1), J. Blum (2)

(1) Laboratoire MIP, Université Paul Sabatier Toulouse 3, 31062 Toulouse cedex 9, France (auroux@mip.ups-tlse.fr); (2) Laboratoire J. A. Dieudonné, Université de Nice, Parc Valrose, 06108 Nice cedex 2, France

The standard nudging algorithm consists in adding to the state equations of a dynamical system a feedback term, which is proportional to the difference between the observation and its equivalent quantity computed by the resolution of the state equations. The model appears then as a weak constraint, and the nudging term forces the state variables to fit as well as possible to the observations. The backward nudging algorithm consists in solving the state equations of the model backwards in time. A nudging term, with the opposite sign compared to the standard nudging algorithm, is added to the state equations, and the final obtained state is in fact the initial state of the system.

The back and forth nudging algorithm (BFN) consists in solving first the forward nudging equation and then the direct system backwards in time with a feedback term. After resolution of this backward equation, one obtains an estimate of the initial state of the system. We repeat these forward and backward resolutions until convergence of the algorithm. The theoretical convergence of this algorithm can be obtained in the case of a linear system, or a very simple nonlinear ODE (Lorenz equations), under some observation hypothesis.

From a numerical point of view, we compared this algorithm to the 4D-VAR on nonlinear systems such as Lorenz, Burgers' equations, and a quasi-geostrophic ocean model. In all cases, the first iterations of the BFN algorithm were more efficient than the 4D-VAR ones. Moreover, it is still the case in presence of model or observation errors. Finally, its implementation is very easy because it requires neither the linearization of the equations nor any minimization process.