Data assimilation for geophysical problems: variational and sequential techniques.

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Data assimilation consists in combining informations coming from numerical models and from observations, in order to reconstruct in an optimal way the state of the system in the past, in the present and also to forecast the future. In external geophysics (for example meteorology and oceanography), data assimilation consists in identifying the initial state of the dynamical system from observations, as the dependence on this initial state is fundamental for chaotic and turbulent systems.

There are two classes of numerical techniques that can achieve this goal: variational methods and sequential ones based on filtering.

The variational methods are based on optimal control theory and consider the initial state as the control vector(ref 1). They require to compute the linearized state and the adjoint state, and use a minimization algorithm in order to minimize the cost-function. This algorithm is usually very performing, but it is difficult to implement on sophisticated models.

The most popular sequential data assimilation method is the Kalman filter, which means that the model is integrated forward in time and, whenever measurements are available, these are used to reinitialize the model before the integration continues. The Ensemble Kalman filter has been proposed by Evensen (ref 2) and uses the representation of error statistics based on an ensemble of model states. An alternative to the traditional error covariance equation is proposed for the prediction of error statistics. This algorithm is relatively easy to implement.

Finally a new algorithm that is intermediate between the two approaches will be presented, called the back and forth nudging algorithm (ref 3), that consists in adding to the equation of the model a newtonian relaxation term that fits the model to the observations and in performing back and forth resolutions of the system in order to incorporate these observations in the model. Examples and comparisons with variational methods will be given for simple models, such as Lorenz, Burgers,...

References:

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