Implementation of Ensemble 3D-Var Data Assimilation for Sea Ice, Salinity and Temperature

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The history of ocean data assimilation is not long compared to atmospheric data assimilation. Popular methods used today in northern Europe include Optimal Interpolation (OI), Singular Evolutive Interpolated Kalman Filter (SEIK) and Ensemble Kalman Filter (EnKF). Another approach to data assimilation, popular by meteorologists and lately even oceanographers, is to use variational data assimilation. Here a quadratic cost function is minimized to produce a set of increments to the first-guess model field to make it fit available observations. The cost function depends on the misfit between the model trajectory and the observations. One advantage with variational data assimilation methods compared to other methods is that also unconventional observations can be used, as long as they can be included in the cost function. An example is brightness temperature measured from a satellite, which is not usually a model variable in an ocean model.

In ocean data assimilation, the horizontal background error covariances can be very complicated due to the complex bathymetry often found near coasts. This implies that horizontally homogeneous and isotropic correlation functions are not sufficient when trying to model the background error covariances. They may be parameterized a priori of course, using clever choices of correlation functions, in an attempt to mimic Nature. When it comes to ice data assimilation, however, the background error covariances should depend on the location of the ice edge as well which makes the parameterization more difficult.

An alternative to a priori determination of the correlation functions is to use ensemble data from earlier model runs. This method has been exploited in e.g. the Ensemble Kalman Filter method. Recently, it has been tested also with variational techniques, at least for the atmosphere. This presentation is about a very recent implementation of Ensemble 3D-Var for the ocean, with emphasis on sea ice and salinity and temperature. The main purpose are to improve initial conditions in short ocean and sea ice forecasts as well as for use in ocean and sea ice reanalyses.

Two different kinds of ensembles can be used. The first option is to use a static ensemble based on earlier model runs for earlier years. For example, a set of dates, from the same month of the year as the analysis, may be picked from a set of historical runs from earlier years. This ensures that a sufficient ensemble spread is obtained while still using ensemble statistics from the correct season. The advantage is that this kind of data is often already available at no additional computational cost.

The second option is to use a so-called dynamic ensemble, consisting of short forecasts from previous days, all valid at the assimilation date. A clear advantage with this type of ensemble is that the ensemble statistics is representative of the actual situation, including the current location of an ice edge for example. A drawback is that it requires the ensemble forecasts to be made before each assimilation cycle. This may be present already at some operational forecasting centers, but not necessarily for use in reanalyses. For the latter purpose the first option may be best.

In this presentation, the implementation of the Ensemble 3D-Var method at the Swedish Meteorological and Hydrological Institute will be described and some results will be shown. The new data assimilation system yields very promising results for sea ice when a dynamical ensemble is used. The multivariate nature of the implementation yields analysis increments which are consistent for all variables. E.g., removal of ice increases sea surface temperature in a manner which is consistent with the ensemble statistics. However, best results for salinity and temperature are obtained when a static ensemble is used instead of the dynamic ensemble. The challenge ahead is to create an ensemble which gives satisfactory results for all variables, for use in both operational oceanography and reanalyses.

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