Data Assimilation of Arctic Ice Drift Using Single Evolutive Interpolated Kalman Filter in a Sea Ice Model

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Motivation

Arctic ice drift fields derived from satellite data are available as well as ice drift trajectories from deployed buoys. Therefore it is desirable to use these data for assimilation to validate a sea ice model. There are some points to examine: How realistic is the modelled ice drift? How significant are the differences between model and observational data? And last but not least: How long ice drift can be forecasted in a realistic is the modelled ice drift? How significant are the differences between model and observational data? And last but not least: How long ice drift can be forecasted in a realistic model? It is aspiring to reach a more realistic representation of consistent ice drift analysis with such a model by assimilating data can be done with the Single Evolutive Interpolated Kalman Filter (SEIK).

Preliminaries

In order to show the necessity of ice drift assimilation an arbitrary monthly mean drift field was examined. The ice drift means of March 2000 of the Arctic basin and its marginal seas are presented in Fig. 1. Averaging monthly, local patterns driving the ice drift, like low atmospheric pressure systems, vanish and drift represents regional patterns like the Beaufort Gyre. The latter is well pronounced in both drift data sets, even stronger in the model. This leads for example to a deviation in drift direction north of Greenland, hence resulting in a different ice export through Fram Strait, which is of climatic relevance. Differences in velocity and direction are presented in Fig. 3. Here, the deviation north of Greenland can clearly be seen (Fig. 3a). Problems right in the centre of the Beaufort Gyre are negligible due to low drift velocities (see Fig. 1). A comparison of both data sets shows a larger simulated drift velocity all over the Arctic basin as can be seen in Fig. 3b; this holds also for other months. Hopefully an assimilation scheme is capable to solve these problems.

Sea Ice Model

The model which is used is a dynamic-thermodynamic sea ice model with a viscous-plastic rheology based on the work of Hibler and Parkinson and Washington. Therefore the main two processes of sea ice are described: thermodynamic growth and advection of sea ice. Most important variables of the sea ice model are ice thickness (ice volume per surface area), ice concentration and ice drift (vector describes the horizontal drift velocity of the ice on the sea surface). The rotated spherical model grid covers the entire Arctic. It has a spatial resolution of 1/4 degree and a time resolution of six hours.

Ice Drift Observation

Fig. 1: Mean ice drift (March 2000) derived from satellite data (honey), yellow: temporal coverage of drift data of 50 to 90%, red: temporal coverage of drift data exceeding 90%.

Modelled Ice Drift without Assimilation

Fig. 2: Mean ice drift pattern in March 2000 derived from model result, only every fourth vector is displayed for clarity.

SEIK Algorithmus

A comparison of Kalman filter types (EnKF, SEEK and SEIK) done by L. Nerger showed advantages for the Singular Evolutive Interpolated Kalman Filter (SEIK) in computational time regarding large ensembles to reach superior performance of data assimilation.

Initialisation: Generating a state ensemble of minimum size whose ensemble statistics yield exactly the low rank covariance matrix in a decomposed form:

Forecast: Each ensemble member state evolves with the full numerical sea ice model.

Analysis: When observations are available compute the updated which only implicitly relates the model error to the observation error. The model state update finally is given analogue to analysis step of the Ensemble Kalman Filter (EnKF).

Resampling: Resample the state ensemble and compute the covariance Matrix, which contains the updated error statistics of the model error.

Outlook

The implementation of the Single Evolutive Interpolated Kalman Filter into the sea ice model delivers a new feature to assimilate data of several parameters in space and time simultaneously. That is possible because the filter framework is independent of the sea ice model. Therefore it is planned to assimilate ice thickness data from CryoSat and ice drift data together. Certainly this will lead to a more realistic sea ice model description.

References

2. C. L. Parkinson and W. M. Washington, A large-scale numerical model of sea ice, JGR, 84(C1):311-337, 1979