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 practice? It is aspired to reach a more realistic representation of ice dynamics consistent with observations and to reduce model error statistics using data assimilation. Thus, a consistent ice drift analysis with such a model by assimilating data can be done with the Single Evolutive Interpolated Kalman Filter (SEIK).

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[1] and Parkinson and Washington[2]. 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 ¼ degree and a time resolution of six hours.

[1] W. D. Hibler III, A Dynamic Thermodynamic Sea Ice Model, JPO, 9(4):815-864, 1979
[2] C. L. Parkinson and W. M. Washington, A large-scale numerical model of sea ice, JGR, 84(C1):311-337, 1979

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 and 2. The model results are compared to ice drift derived from satellite sensors QuickSCAT and SSM/I (courtesy of R. Ezraty, Ifremer). The daily satellite data sets show gaps due to technical reasons and atmospheric conditions. Therefore, only data points with a temporal coverage of at least 50% were included in the monthly mean (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 drift 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.

Ice drift observation

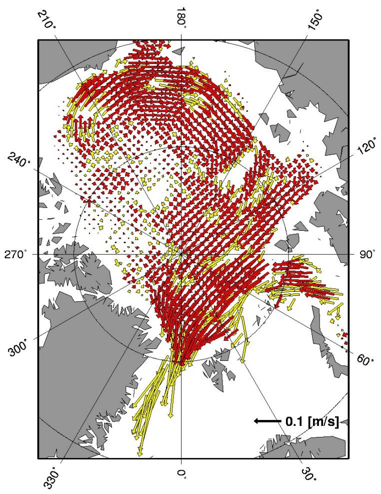

Fig. 1: Mean ice drift (March 2000) derived from satellite data (Ifremer); yellow: temporal coverage of drift data of 50 to 90 %; red: temporal coverage of drift data exceeding 90 %

Modelled ice drift without assimilation

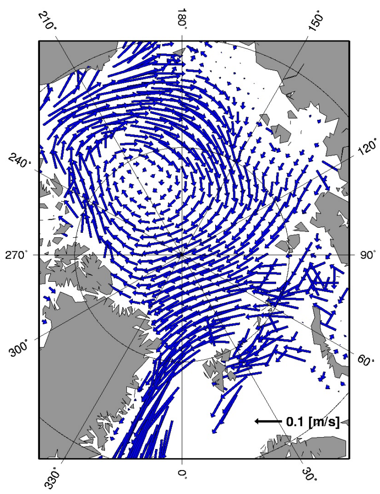

Fig. 2: Mean ice drift pattern in Mach 2000 derived from model result, only every fourth vector is displayed for clarity.

Ice Drift Comparison

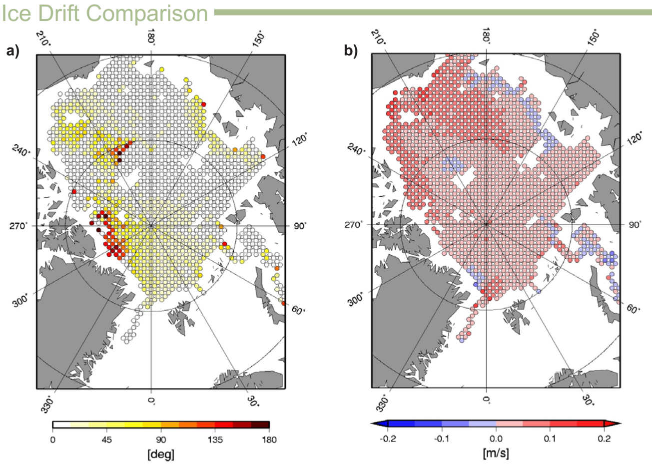

Fig. 3: Differences between model results and satellite derived drift data are presented. Model data were interpolated on the satellite data grid. Thus each circle represents a data point of the satellite data with a temporal coverage C>50%. **a)** Absolute deviation angles between model and satellite vectors. **b)** Difference of absolute ice drift velocity (model minus satellite).

SEIK Algorithmus

A comparison of Kalman filter types (EnKF[3], SEEK and SEIK[4]) done by L. Nerger[5] 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 P in a decomposed form:

$$\mathbf{P = LUL^T}$$

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

Analysis: When observations are available compute the updated **U** 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.

[3] G. Evensen, Sequential data assimilation with a nonlinear quasi-geostrophic model using Monte Carlo methods to forecast error statistics, J. Geophys. Res, 99(C5)10143,1994

[4] D.T. Pham, J. Veron, L. Gourdeau, Filtres de Kalman singuliers évolutif pour l'assimilation de donnes en océanographie, C.R. Acad.Sci Terre Planètres, 326, 255-260,1998

[5] L. Nerger, W. Hiller and J. Schröter, A Comparison of Error Subspace Kalman Filters, Part 1: Filter Algorithms, Tellus series a-dynamic meteorology and oceanography, accepted 2005

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.