Geophysical Research Abstracts
Vol. 13, EGU2011-10748, 2011
EGU General Assembly 2011

Sea-ice data assimilation in coupled climate models – are ice concentration observations sufficient?

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Sea-ice initial conditions contribute to decadal predictability of polar climate. For skilful predictions, coupled climate models hence need to be initialised with sea-ice conditions that are both close to observations, and compatible with model dynamics.

Here, we investigate the feasibility of sea-ice data assimilation in the coupled climate model ECHAM/MPI-OM. In particular, we examine how observations of Northern Hemisphere sea-ice concentration can be used to improve the simulated ice volume and ocean surface properties. We employ a simple nudging approach for ice concentration, and the analysis increments for ice volume, sea surface salinity and temperature are prescribed as a function of the concentration analysis increments.

Although the simulation of ice concentration is almost always improved, we find that the quality of the simulated ice volume depends critically on the choice for the functional dependence between the analysis increments of concentration and volume. Schemes that conserve ice volume or ice thickness, as they have been suggested in other studies, do not give satisfying results in our data assimilation framework.

We show that the problems in those schemes arise when the dynamics of the coupled model provide a too strong negative feedback on the analysis increments. For the thickness-conserving scheme, the internal sea-ice stress can cause unrealistic ice advection in summer, and for the volume-conserving scheme the strong dependence of surface heat flux on ice concentration can cause unrealistic ice growth in winter.

We suggest a new scheme for sea-ice data assimilation with volume analysis increments that are proportional to concentration analyis increments. This scheme provides a volume correction that mitigates the adverse effects introduced by negative model feedbacks, and is able to significantly improve the analysed sea-ice state using only observations of ice concentration. Therefore, this scheme is a promising candidate to be combined with atmospheric and oceanic data assimilation in order to initialise the model for seasonal to decadal predictions.