Recent and ongoing sea ice modeling activities at UCL-ASTR

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Recently, a hindcast simulation of the Arctic and Antarctic sea ice variability over the period 1955–2001 has been performed with the UCL-ASTR gobal ice-ocean model [*Fichefet et al.*, 2003a, 2003b]. In this experiment, the model was driven by the National Centers for Environmental Prediction (NCEP) – National Center for Atmospheric Research (NCAR) reanalysis daily surface air temperatures and winds. The other atmospheric input fields consisted of climatologial surface relative humidities, cloud fractions, and precipitation rates. Both the mean state and variability of the ice packs over the satellite observing period are reasonably well reproduced by the model. Over the 47-year period, the simulated ice area in each hemisphere experiences large decadal variability together with a decreasing trend of ~1% per decade. In the Southern Hemisphere, this trend is mostly caused by an abrupt retreat of the ice cover during the second half of the 1970s and the beginning of the 1980s. The modeled ice volume also exhibits pronounced decadal variability, especially in the Northern Hemisphere. Beside these fluctuations, we detected a downward trend in Arctic ice volume of 1.8% per decade and an upward trend in Antarctic ice volume of 1.5% per decade.

The UCL-ASTR sea ice model (LIM) has also been coupled to the French ocean general circulation model OPA. The coupled model was then run on a global domain with a 2 degree mean resolution (ORCA2-LIM configuration). The same forcing as above was used. The model performance has been evaluated with respect to the representation of sea ice and high latitude oceans. The seasonal growth and decay of the sea ice is fairly well simulated in both hemispheres, with ice extent, thickness, and drift in general agreement with observations. The locations of the main sites of deep convection (Labrador and Greenland Seas, and continental shelves of marginal seas of the Southern Ocean) are also well reproduced. Model deficiencies include a slight overstimation of the summer ice extent in the Arctic and a significant underestimation of multiyear ice in the Weddell Sea. Furthermore, the widths of the Arctic Ocean Boundary Current and Antarctic Circumpolar Currents are somewhat overestimated. Sensitivity studies have revealed that the use of a combined forcing dataset is crucial to achieve a reasonable summer sea ice coverage and that the direct utilization of the NCEP–NCAR wind stress data leads to an overestimation of the sea ice velocity. We also showed that a sea surface salinity restoring is necessary to avoid spurious open ocean convection in the Weddell Sea. For further details, see *Timmermann et al.* [2003a, 2003b].

In parallel, we have started to revise LIM in order to remain in the forefront of large-scale sea ice modeling. First, we have replaced the thermodynamic component of the model (which had only three layers) by a multilayer model that explicitly takes into account the effects of sea ice salinity on the specific heat, thermal conductivity, and latent heat of the ice. For this, we basically followed the approach of *Bitz and Lipscomb* [1999]. In addition, we have incoporated in the model the formulation proposed by *Vancoppenolle and Fichefet* [2003] for the spatial and temporal evolution of the sea ice salinity. Given the strong dependence of the ice growth/melt rate on the ice thickness and since the physical properties of sea ice vary widely from one ice type to the other, the inclusion of various ice types and ice thickness categories in LIM is imperative. The relevant ice types that can be present in 100-km-wide oceanic areas (which is the typical size of grid cells of large-scale sea ice models) are : open water, frazil ice, pancake ice, level and ridged first year ice, and level and ridged multiyear ice. We plan to modify LIM so that each grid cell can accomodate these various ice types. Each ice type will be characterized by its own snow and ice thickness distributions and surface and bottom properties (e.g., surface albedo and drag coefficients). Evolution equations for each ice type and thickness category will have to be formulated, and redistribution functions between the different ice types and thickness categories will have to be designed. This work will be done in collaboration with the University of Helsinki, Finland.

Another way of improving the performance of LIM is to assimilate data into the model. This takes adavantage of the great advances that have been made in polar observational capabilities during the last two decades. These advances have led to a rich collection of data on sea ice, including, among others, satellite passive microwave observations of ice motion and concentration. Since it is only very recently that the assimilation of data into large-scale sea ice models has been initated, we propose here to test some of the simplest and low cost data assimilation techniques such as nudging, optimal interpolation, and Kalman filter. In order to reduce as much as possible the computational cost, we plan to evaluate these techniques in a simplified version of LIM using twin experiments (numerical experiments that assimilate model outputs instead of real observations). On the basis of these experiments, we will select the most suitable method and will implement it into the full version of ORCA2-LIM. Previous studies on the assimilation of data into sea ice models showed that problems can arise when assimilating ice motion data alone or ice concentration data alone. Therefore, we project to assimilate both types of data. Two experiments will be then conducted with the coupled model over the last two decades, during which satellite data are available : one with data assimilation and the other without data assimilation. Comparison between results of the two experiments and observations will allow us to evaluate the performance of the data assimilation system.

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References

Bitz, C.M., and W.H. Lipscomb, An energy-conserving thermodynamic model of sea ice, *J. Geophys. Res*., *104*, 15,669-15,677, 1999.

Fichefet, T., H. Goosse, and M.A. Morales Maqueda, A hindcast simulation of Arctic and Antarctic sea ice variability, 1955-2001, *Polar Res*., *22*, 91-98, 2003a.

Fichefet, T., B. Tartinville, and H. Goosse, Antarctic sea ice variability during 1958-1999: A simulation with a global ice-ocean model, *J. Geophys. Res.*, *108 (C3)*, doi: 10.1029/2001JC001148, 2003b.

Timmermann, R., H. Goosse, G. Madec, T. Fichefet, C. Ethé, and V. Dulière, On the representation of high latitude processes in the ORCA-LIM global coupled sea ice–ocean model, *Ocean Modell.*, revised, 2003a.

Timmermann, R., A. Worby, H. Goosse, and T. Fichefet, Utilizing the ASPeCt sea ice thickness dataset to validate a global coupled sea ice–ocean model, *J. Geophys. Res.*, submitted, 2003b.

Vancoppenolle, M., and T. Fichefet, 2004 : An empirical one-dimensional parameterization of the sea ice salinity evolution, In *Proceedings of the ACSYS Final Science Conference (Arctic and Antarctic Research Institute, St. Petersburg, 11–14 November 2003)*, submitted, 2003.