COMPARATIVE STUDY OF SEA ICE RESPONSE FROM NEMO-LIM3 TO TWO ATMOSPHERIC FORCINGS

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Abstract

We investigate the influence of using different atmospheric forcing fields as boundary conditions for the ocean-sea ice model NEMO-LIM3, with a focus on the sea ice response. Two experiments (corresponding to two atmospheric reanalyses) are conducted. While the trends in sea ice area agree well with observations for one of the forcings, both runs underestimate summer sea ice area, due to an underestimation of ice thickness. Also, unexpected oceanic convection is observed in the Bellingshausen and Ross Seas for one of the simulations.

Method

NEMO-LIM3 is a well-known Oceanic General Circulation Model (OGCM) (Madec, 2008; Fichefet and Morales Maqueda, 1997; Vancoppenolle et al., 2009)[1]. Its sea ice component (LIM3) include different ice thickness categories, brine entrapment and explicit drainage modelling, and a snow ice formation scheme (among others) in order to capture the complex coupling between sea ice dynamics and thermodynamics.

While NEMO-LIM3 is part of many General Circulation Climate Models, it is also often used in “forced” mode, i.e. prescribing the air-ocean and air-sea ice fluxes using atmospheric reanalyses. Two such reanalyses are tested:

- The first experiment, denoted hereafter “DFS4”, is based on 6h values of wind, temperature and humidity (ERA40 reanalysis), monthly climatologies of precipitation and daily climatologies of radiative fluxes. See Brodeau et al. (2009) for a complete description.
- The second experiment, denoted hereafter “NCEP”, is based on daily values of wind and temperature (NCEP/NCAR reanalysis) and monthly climatologies of humidity, precipitation and cloudiness. See Vancoppenolle et al. (2009) for additional details.

Both experiments run on a tripolar ORCA1 grid (1 degree resolution), spanning the period 1979-2006. They have been spun up for 50 years each.

Results

[1] See also www.nemo-ocean.eu and www.climate.be/lim

a. Northern Hemisphere

a.1. DFS4 Experiment

The DFS4 experiment reproduces almost perfectly the observed trend during the past three decades (Fig. 1, left). However, while the winter area is slightly underestimated, the summer ice area for this experiment exhibits a clear offset from observations (Fig. 2); the amplitude of the simulated cycle exceeds the observations by about 40%.

Reasonable values for areal sea ice export through Fram Strait (Fig.3) and underestimation of volume export (not shown here) indicate that the simulated sea ice is too thin. This explains the underestimation of summer ice area discussed above: as a matter of fact, thinner ice enhances conductive heat fluxes and thus reinforces thinning (see e.g. Ebert and Curry, 1993).

a.2. NCEP Experiment

The NCEP experiment overestimates the observed trend but presents a reasonable interannual variability, particularly during the last two decades of the simulation (Fig. 1, right). Absolute values of ice area are consistent during winter but depart from observations in summer (Fig. 2).

Again, we claim that sea ice is too thin and is responsible for the shrinking in ice area during summer months.

a.3. Comparison

The two gray curves in Fig. 1 have a correlation of 0.69. From this figure, we can measure the signature of the model itself, which is quite strong in this case. Ice export (Fig. 3) as well as ice thickness distribution[2] both suggest stronger winds for NCEP.

b. Southern Hemisphere

b.1. DFS4 Experiment

As in the Northern Hemisphere, the trend in ice area matches observations, particularly well between 1994 and 2004 (Fig. 4). Again (not shown here), the amplitude of the mean seasonal cycle of sea ice area is overestimated with respect to observations by about 21%, leading to a nearly sea ice free basin in February and March.

b.2. NCEP Experiment

As suspicious trends in ice area were simulated in the 90's for this experiment, we realized that the mixed layer of the ocean reached about 4000 m in the Bellingshausen and Ross Seas, i.e. convection took place from the bottom of the ocean. Warm waters brought upwards accordingly have led to a massive melting of southern sea ice (Fig. 5). The physical processes responsible for triggering this undesirable convection have not been identified yet.

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[2] Not shown here ; ice thickness distributions exhibit a stronger gradient for NCEP experiment along the Northern Greenland coast and of f the Canadian Arctic Archipelago.

b.3. Comparison

The sensitivity of NEMO-LIM3 to the atmospheric forcing is clearly visible here. As the two experiments have been run using the same model, with same initial conditions but with different atmospheric reanalyses, we attribute the deep convection observed in the NCEP experiment to the atmospheric forcing itself. However, using the same atmospheric forcing, such convection has not been observed on a coarser grid (ORCA2, see Vancoppenolle et al., 2009).

Conclusions

These first runs of NEMO-LIM3 on an ORCA1 grid (1 degree resolution) yield three conclusions regarding the use of atmospheric reanalyses as boundary condition for this OGCM:

- DFS4 experiment is more accurate in terms of trends but produces thinner ice than NCEP experiment. In general, sea ice is too thin in both experiments; in the near future, attention will be paid to the calibration of thermodynamical parameters, e.g. melting ice albedo.
- Winds seem to play an important role, especially concerning the ice thickness distribution. Future work will be devoted to quantify the impact of the wind fields on ice export and thickness.
- Unexpected convection takes place in the Bellingshausen and Ross Seas in the NCEP experiment. Again, stronger winds could be responsible for that behaviour but this phenomenon has still to be assessed.

Acknowledgements

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References

Brodeau, L., Barnier, B., Treguier, A.-M., Penduff, T.,Gulev, S., *An ERA40-based atmospheric forcing for global oceanic circulation models*, Ocean Modelling 31 88-104 (2010)

Comiso, J.C., Bootstrap *sea ice concentrations from NIMBUS-7 SMMR and DMSP SSM/I*, 1979–2006. Boulder, Colorado USA: National Snow and Ice Data (2007)

Ebert, E., Curry, A., An intermediate One-Dimensional Thermodynamic Sea Ice Model for Investigating Ice-Atmosphere Interactions , Journal of Geophysical Research 98 10085-10109 (1993)

Fichefet, T., Morales Maqueda, M. A., *Sensitivity of a global sea ice model to the treatment of ice thermodynamics and dynamics*, Journal of Geophysical Research 102 pp. 12609-12646 (1997)

Kwok, R., Cunningham, G.F., Pang, S.S., *Fram Strait sea ice outflow*. Journal of Geophysical Research 109 (2004)

Madec, G., *NEMO ocean engine* . Note du Pole de modélisation, Institut Pierre-Simon Laplace (IPSL), France, No 27 ISSN No 1288-1619. NEMO_book_v3_2 (2008)

Vancoppenolle, M., Fichefet, T., Goosse, H., Bouillon, S., Madec, G., Morales Maqueda, M. A., Simulating *the mass balance and salinity of Arctic and Antarctic sea ice. 1. Model description and validation*, Ocean Modelling 27 33-53 (2009)

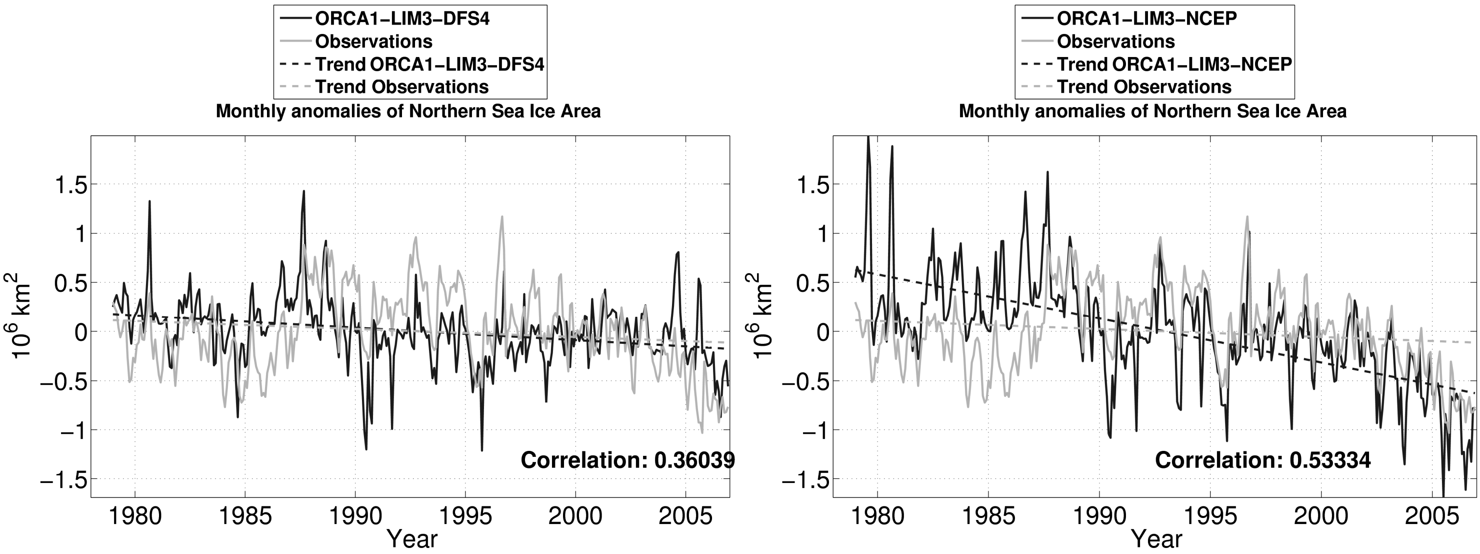

Fig. 1 *: Monthly anomalies of Northern Sea Ice Area for DFS4 (left) and NCEP (right) experiments. Observations : Comiso, 2007*

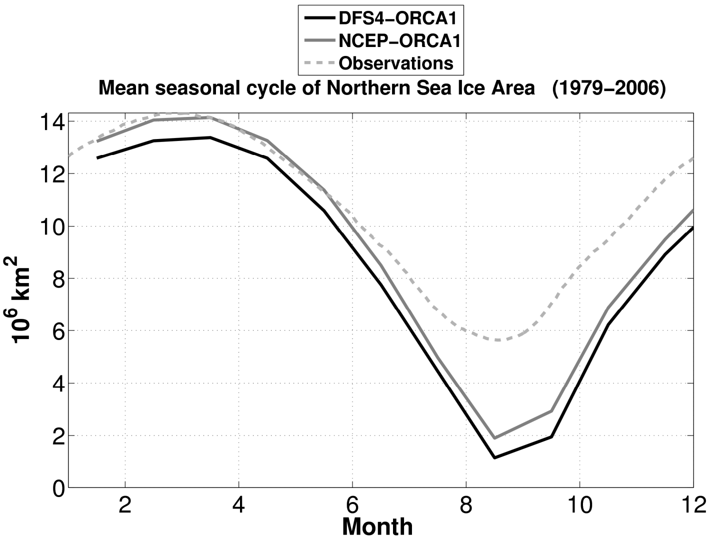

Fig. 2 *: Mean seasonal cycle of Northern Sea Ice Area from model simulations (solid) and observations (dashed ; Comiso, 2007)*

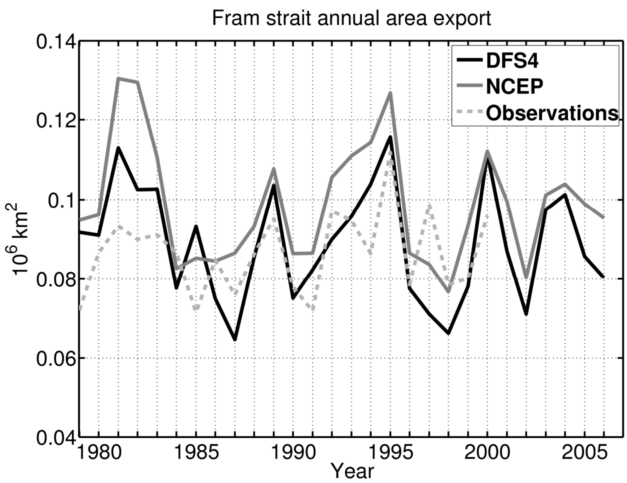

Fig. 3 *: Areal export of sea ice through Fram Strait from model simulations (solid) and observations (dashed ; Kwok et al., 2004)*

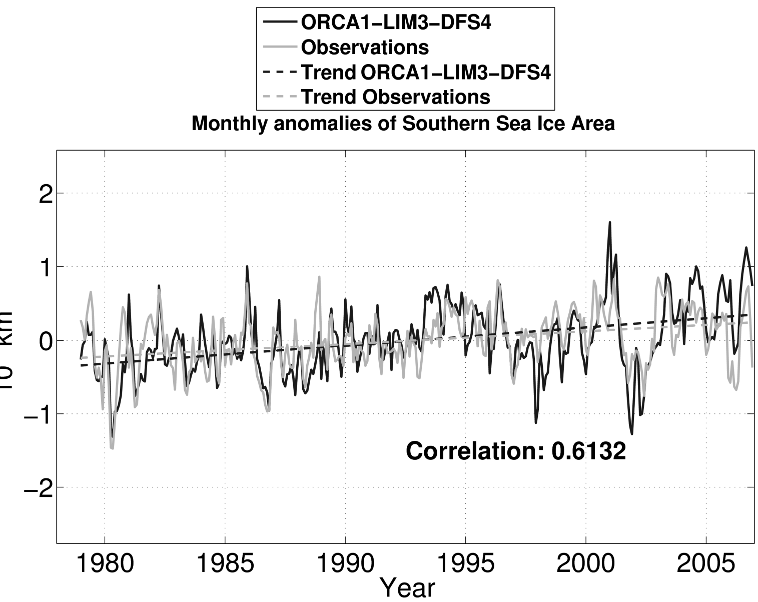

Fig. 4 *: Monthly anomalies of Southern Sea Ice Area for DFS4 experiment. Observations : Comiso, 2007.*

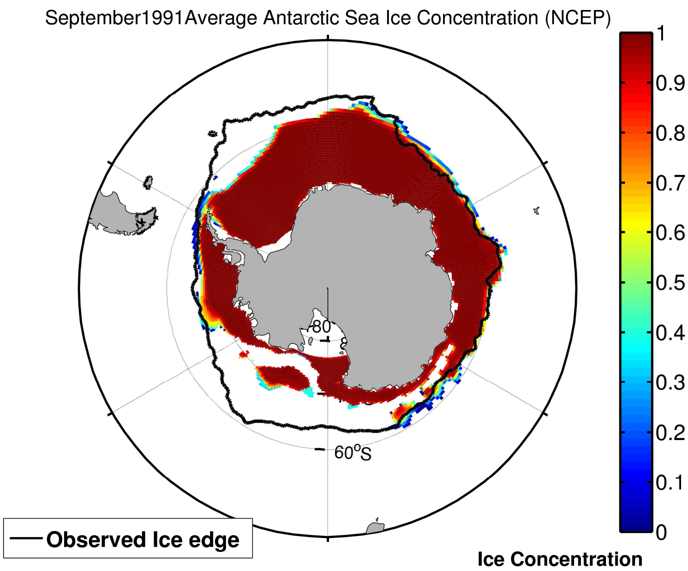

Fig. 5 *: September 1991 average Sea Ice concentration for NCEP experiment, and observed ice edge (Comiso, 2007).*