Development of a coupled regional climate model for the Arctic

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Background

Recent observations and climate modelling results (Cubasch et al 2001, Serreze et al 2000) have highlighted the Arctic region as particularly vulnerable to potential anthropogenic climate change. Global model projections of the future climate show the largest surface warming over sea ice covered regions of the Arctic Ocean, where an initial climate warming is hypothesised to lead to sea ice melt, a reduction in the surface albedo and further melting and warming through increased absorption of solar radiation (i.e positive feedback). However, Global Climate Model simulations of the Arctic vary widely in quality and many of the key physical processes that must be parameterised are poorly understood.

One of the main objectives of the EU-sponsored GLIMPSE project (http://www.awi-potsdam.de/www-pot/atmo/glimpse/index.html) is to improve the description of physical processes in the Arctic and to develop parameterisations that can be used in climate models. As a contribution to GLIMPSE, the Rossby Centre at SMHI develops a coupled regional climate model for the Arctic based on the existing RCAO model (Döscher et al 2002) that combines the atmosphere model RCA (Rummukainen et al 2001) and the ocean model RCO (Meier et al 2003). The coupled model has been developed for mid-latitudes and therefore requires some adjustments for the relocation to the Arctic. Sea-ice and snow are important components of the Arctic climate – especially with regard to their role for the feedback with radiation – and the correct description of the melting, freezing and transport will be crucial for the coupled model and require special attention when setting up the model. Clouds are another important issue for the Arctic climate and we will study the interaction between clouds, radiation, and the underlying sea-ice to understand the complex dynamics and feedback between the various components.

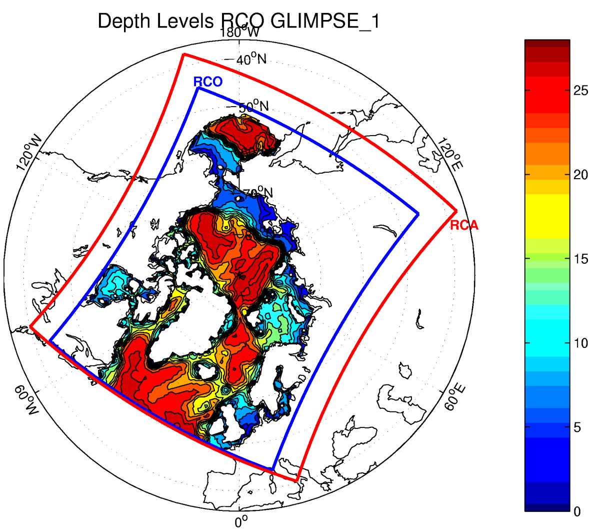

Figure 1 Setup of ocean (blue) and atmosphere (red) model domain for GLIMPSE. Color scale denotes depth for ocean model

Model setup

The setup of our coupled regional climate model for the Arctic is shown in Figure 1. The ocean model covers the central Arctic Ocean and the North Atlantic north of 50N. The Bering Sea is also included in order to realistically simulate the inflow variability through the Bering Strait. The horizontal resolution is 0.5 degrees or approximately 50 km in a rotated coordinate system centred over the North Pole. At the lateral boundaries sponge zones with relaxation to climatology are utilized. It is planned to replace these sponge zones with active open boundary conditions. The ocean model is coupled with a Hibler-type two-level (open water and ice) dynamic-thermodynamic sea ice model. The sea ice model utilizes the same horizontal grid as the ocean model.

The atmosphere model covers the same area as the ocean model and additionally some of the surrounding landmasses. The atmosphere and ocean model share the same horizontal grid in the common area. The present model configuration consists of 24 vertical levels but an increase to 31 levels is planned. At the boundaries, the atmosphere model is driven with 6-hourly ERA-40 fields.

The ocean and atmosphere models are coupled through the OASIS coupler that handles all data communication and – if necessary – interpolations between atmosphere and ocean grids (Terray et al. 1999). Ocean and atmosphere model time step are 10 and 30 minutes, respectively, and the coupling time step is 3 hours.

First results

First simulations with the atmosphere model alone have been performed to test the setup. As an example we show one year of monthly mean sea-level pressure over the central Arctic (north of 75N) from two runs compared to the observational ECMWF analyis (Fig. 2). The two model simulations differ in their description of the sea-ice, GL_OBS_ICE uses the sea-ice field from the ERA-40 analysis (derived from SSM/I observations) while GL_CLIM_ICE uses a climatological sea-ice field. None of the simulations shows a systematic bias. Neither simulation matches the observation in every month; sometimes GL_OBS_ICE is in better agreement and sometimes GL_CLIM_ICE. The difference between the two model simulations is of the same order as the difference between any of the simulations and the ECMWF analysis.

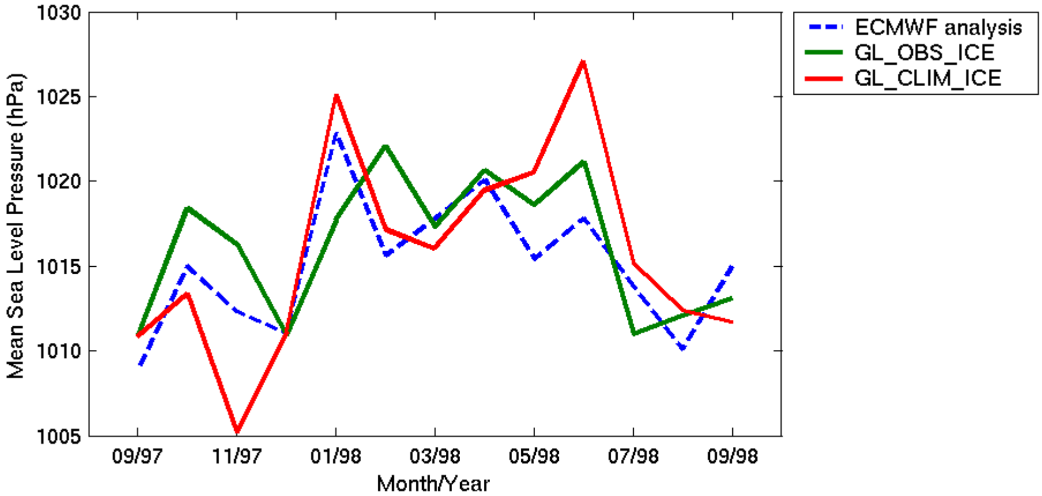

Figure 2 Monthly mean se level pressure in thecentral Arctic for 2 simulations (described in text) and ECMWF operational analaysis.

The example emphasises the role of the sea-ice for the variability of the Arctic climate. Future simulations with the coupled ocean-atmosphere model will include an interactive sea-ice description that will allow us to study the variability of the Arctic climate under consideration of the feedback between sea-ice and circulation.

References

Cubasch U, G.A.Meehl, G.J.Boer, R.J.Stouffer, M.Dix, A.Noda, C.A.Senior, S.Raper and K.S.Yap (2001). Projections of Future Climate Change. In *Climate Change 2001: The scientific basis. Contribution of Working Group 1 to the Third Assessment Report of the Intergovernmental Panel on Climate Change*. Cambridge University Press, 881pp.

Döscher R., U.Willén, C.Jones, A.Rutgersson, H.E.M.Meier, U.Hansson and L.P.Graham (2002). The development of the regional coupled ocean-atmosphere model RCAO. *Boreal Env. Res. 7*, 183-192.

Meier, H.E.M., R. Döscher, and T. Faxen (2003). A multiprocessor coupled ice-ocean model for the Baltic Sea: Application to salt inflow. *J. Geophys. Res. 108(C8)*, 3273.

Rummukainen M, J.Räisänen, B.Bringfelt, A.Ullerstig, A.Omstedy, U.Willén, U.Hansson and C. Jones (2001). A regional climate model for northern Europe: model description and results from the downscaling of twp GCM control simulations. *Clim. Dyn. 17*, 339-359.

Serreze M.C. and co-authors 2000. Observational evidence of recent changes in the northern high-latitude environment. *Climatic Change 46*, 159-20.

Terray L., S.Valcke and A.Piacentini (1999). *OASIS 2.3 Ocean Atmosphere Sea Ice Soil users guide*. CERFACS TR/CGMC/99-37, 82 pp.