On the coupling of a 3D Baltic Sea model to a regional atmospheric model

Ralf Döscher[1], Ulrika Willén, Colin Jones, Anna Rutgersson, H.E. Markus Meier, Ulf Hansson and Phil Graham

Rossby Centre, Swedish Meteorological and Hydrological Institute (SMHI), S-60176 Norrköping, Sweden

Regional coupled ocean-atmosphere-ice-landsurface models represent a major element on the way to assess the energy budget and water cycle over the Baltic Sea catchment area and to understand interaction across interfaces. To approach that goal, coupled regional models with the capability to run decades need to be developed and verified. This is currently done at the Rossby Centre within the Swedish Meteorological and Hydrological Institute (SMHI) for a northern European domain including the Baltic Sea (Fig. 1). The Rossby Centre Atmosphere Ocean model RCAO has been developed within the framework of the Swedish Regional Climate Modeling Program (SWECLIM) in order to perform downscaling of global climate scenarios and nowtime data. The latter is in accord with the goals of the GEWEX subprogram BALTEX. A description of the coupling and first evaluation of fluxes is given by Döscher et al. (2002). Meier and Döscher (2002) give a description of Baltic Sea flux budgets.

The interactively coupled ocean within RCAO is limited to the Baltic Sea. The remaining ocean areas are represented by a one-way data transfer of sea surface quantities to the atmosphere. The component models of RCAO are the Rossby Centre models for ocean (RCO, including sea ice) and atmosphere (RCA, including land surface). RCO is a 3D ocean model described by Meier al. (2002). RCA is described in detail by Rummukainen et al. (2001) and Jones et al. (2001). River runoff to the Baltic Sea is represented by a river routing scheme connecting the land runoff with river mouths. RCAO features a resolution of 44 km for the atmosphere and 6 nautical miles for the ocean. The coupling interval is 30 minutes. The ocean and atmosphere models are interactively coupled via the OASIS coupler (Valcke et al., 2000). The coupled system is parallel which enables efficient integrations on climate related timescales.

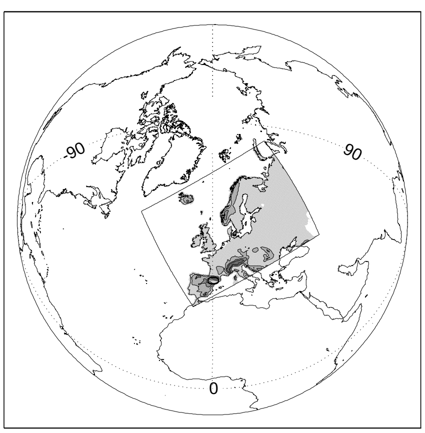

Figure 1: RCAO model domain for hindcast runs, covering most of Europe and parts of the North Atlantic Ocean and Nordic Seas. Only the Baltic Sea is interactively coupled.

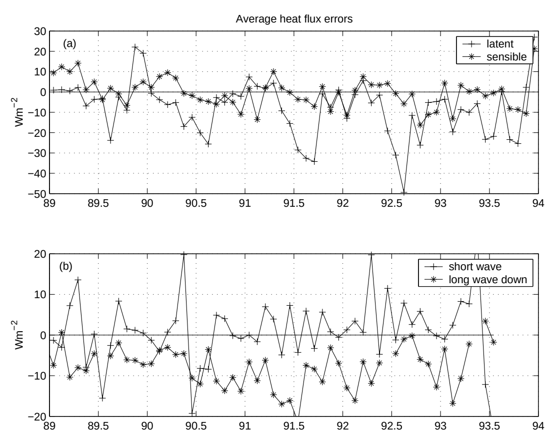

Figure 2: Heat flux errors. (a): latent/sensible heat flux over the Baltic - observation (daSilva), (b): shortwave/longwave heat flux over land - observation (SMHI station data)

A validation of RCAO is carried out by comparing 5-year long coupled hind-cast runs with observations and an ocean stand-alone run. The coupled system is forced with ECMWF reanalysis data (ERA15) at the atmosphere's lateral boundaries. The system does not use flux corrections. The coupled sea surface temperature (SST) matches observations well for five years in a row. SST's are statistically equivalent

[1]Corresponding author's email: ralf.doescher@smhi.se

to the uncoupled ocean model forced by observations (Mean error amplitude is close to 0.3 K for both). Despite this statistical similarity, differences occur contributing to an overestimation of sea ice extent throughout the winters in the coupled ocean. The ice area is especially overestimated during strong winters. This problem can be related to incorrect fluxes before and during winter. Negative biases are seen in the latent heat fluxes over sea and in downward longwave radiation (Fig. 2) The latent heat flux differs from observations by up to 50 Wm^{-2}. Largest differences are negative and occur during late summer and fall. Thus, the coupled ocean loses too much heat before the beginning of the ice period. The surface turbulent fluxes of sensible and latent heat in the RCA-model are calculated using mean model parameters and transfer coefficients as described by Rutgersson et al. (2001), modified by Makin and Perov (1997). Our results show that further improvement is needed for the latent heat flux, while sensible heat flux of the coupled run fits well with observations. Fig. 2b shows a good agreement of model and observation regarding shortwave radiation. The longwave downward radiation shows a clear negative bias, thus leading to the overestimation of sea ice. Newer model runs indicate that the negative bias disappears on longer timescales. The atmospheric formulation of the surface long-wave downward radiation depends on assumptions about the vertical overlap of clouds in a grid column. "maximum overlap" (Savijärvi 1990) is used in our coupled run. A more physically based assumption, "maximum-random overlap" (Weare 2001), was tested in an additional coupled run. This gives better wintertime SST's and sea-ice extent, since the effective cloud cover was increased leading to increased long-wave radiation towards the surface and a reduced long-wave surface bias. However, a summertime warm bias became worse. The stability of the coupled ocean's surface temperature appears robust on the annual timescale. Flux errors of the magnitude discussed above are always compensated by the response of SST and accordingly adjusted fluxes. In the 5-year mean, the total heat content of coupled and uncoupled ocean are similar within 4% without a trend. In that sense, the coupled system is free of drift. Thus, the coupled system is suitable for multi-year runs. The ocean surface elevation variability is significantly more realistic for stand-alone ocean runs.

We conclude that the coupled model performance is good with respect to most fluxes and longterm stability. However, a coupled forcing for the ocean model cannot completely replace observation-based forcing for hind-cast runs. For longer forecast and scenario runs, of course, the atmosphere model provides the only possible forcing. A 3D Baltic Sea ocean model as RCO provides the best currently possible lower boundary condition for the coupled regional atmosphere in hind-cast mode, as it provides high resolution for surface quantities in good quality. This is not available from observations. This is even more true for longterm forecast runs as sea surface quantities can only be delivered by an ocean model. Future work needs to address the issues of latent and longwave heat flux. Moreover, a more detailed evaluation for longer simulation periods is planned. Further, interaction of sub-basin scale ocean processes with ocean-atmosphere fluxes will be examined.

References

Döscher R., Willen U., Jones J., Rutgersson A., Meier H.E.M. & Hansson U 2002: The development of the coupled ocean-atmosphere model RCAO. *Boreal Env. Res.*, submitted.

Jones C. 2001: A brief description of RCA2. *SWECLIM Newsletter* 11, November, 9-14.

Makin V. K. & Perov V. 1997: On the Wind Speed Dependence of Momentum, Sensible Heat and Moisture Exchange Coefficients Over Sea in the HIRLAM Model-a case study, *Hirlam Newsletter*, 29, pages 26-31. SMHI, SE-601 76 Norrköping, Sweden.

Meier H.E.M., Döscher R. & Faxén T. 2002: A multiprocessor coupled ice-ocean model for the Baltic Sea: application to salt inflow. *J. Geophys. Res.*, submitted.

Meier H.E.M. & Döscher R. 2002: Simulated water and heat cycles of the Baltic Sea using a 3D coupled atmosphere-ice-ocean model. *Boreal Env. Res.*, submitted.

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

Rutgersson A., Smedman A.-S. & Omstedt A. 2001: Measured and simulated latent and sensible heat fluxes at two marine sites in the Baltic Sea, *Bound.-Layer Meteor.*, 99, 53-84.

Savijärvi H. 1990: Fast radiation parametrization schemes for mesoscale and short-range forecast models. *J. Appl. Meteor.*, 29, 437-447.

Valcke S., Terray L., and & Piacentini A., 2000: Oasis 2.4, Ocean atmosphere sea ice soil: user's guide. *Technical Report TR/CMGC/00/10*, CERFACS, Toulouse, France, 58 pp.

Weare B.C. 1989: Effects on cloud overlap on radiative feedbacks. *Clim. Dyn.*, 17, 143-150.