An Evaluation of Cloud and Radiation Processes Simulated by GEM-LAM for the Arctic SHEBA Year

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Due to the unique conditions prevailing in the Arctic (e.g. extreme low temperature and water vapor mixing ratios, highly reflective sea-ice/snow surfaces, low-level inversions and the absence of solar radiation for extended periods) the macro physical and microphysical processes controlling cloud formation and cloud-radiation interactions are complex. The difficulty of simulating these processes was recently highlighted during the Arctic Regional Climate Model Intercomparison Project (ARCMIP). The objective of this study is to evaluate the new Canadian Regional Climate Model (the limited area version of the Global Environmental Multiscale model (GEM-LAM)) for the period September 1997 to October 1998 over the Western Arctic Ocean. This period was coincident with the Surface Heat Budget of the Arctic Ocean (SHEBA) field experiment. Surface downwelling shortwave (SWD) and longwave (LWD) radiation, surface albedo (SFC albedo), vertically integrated water vapor, liquid water path (LWP) and cloud cover simulated by GEM-LAM are evaluated against the SHEBA observation data. GEM-LAM is also compared to the eight other ARCMIP participating models.

The simulation domain is approximately the same as the one used during ARCMIP and covers Alaska, the Beaufort and Chukchi Seas and the Western Arctic. The simulation covers the period of September 1st 1997 to August 31st 1998 with a one-year spin-up. Initial and boundary conditions are provided by the ERA40 re-analysis and the Atmospheric Model Intercomparison Project 2 (AMIP2) for sea ice cover and sea-surface temperature.

Figure 1 shows that, in general, all models represent reasonably well the annual cycle of LWD with a maximum during summer and minimum during winter. Most models tend to underestimate LWD throughout the year. However, GEM reproduces quite well this variable with the largest underestimation during January 98 with a relative error of 10% (~-14 Wm^{-2}) and an overestimation in April 98 with a relative error of 7% (~+9 Wm^{-2}).

The inter-model spread is much larger for SWD. The intensity and time of maximum insolation substantially vary between models. GEM reproduces the SWD peak in June 1998, which is not the case for some other models with a simulated SWD peak earlier in May. GEM is also very close to observations with the largest error occurring in May 98 with a small relative error of 9% (~22 Wm^{-2}) with respect to observations.

The observed vertically integrated water vapor (figure 1c) reflects the annual cycle of temperature: low in winter and high in summer. Most models reproduce the observed annual cycle of this variable quite well. GEM-LAM tends to underestimate the vertically integrated water vapor during winter and overestimate during summer. This is likely to be related to a warm atmospheric bias in summer and a cold atmospheric bias during summer.

Observed surface albedo is around 0.70 during winter and decreases significantly during summer down to 0.35 in August 1998. GEM - LAM overestimates the surface albedo for all seasons in this experiment. It has the largest overestimation in June 1998 with relative error of 33%. The presence of melt pounds and leads, which are not considered in the simulation, is probably a factor explaining the large albedo differences between models and observations.

Observations show that cloud cover is approximately 50% during winter and 95% during summer with a steep increase (decrease) during spring (autumn). Most of the participating models are unable to capture both the annual cycle and absolute values of cloud cover. GEM systematically overestimates cloud cover during winter (September 97 – April 98). The model underestimation of winter clouds can be related to the difficulties of observing optically thin clouds in the Arctic during winter (Wyser and Jones, 2005). When these thin clouds are filtered out, the simulated cloud cover is much closer to satellite observations as shown on Figure 1e.

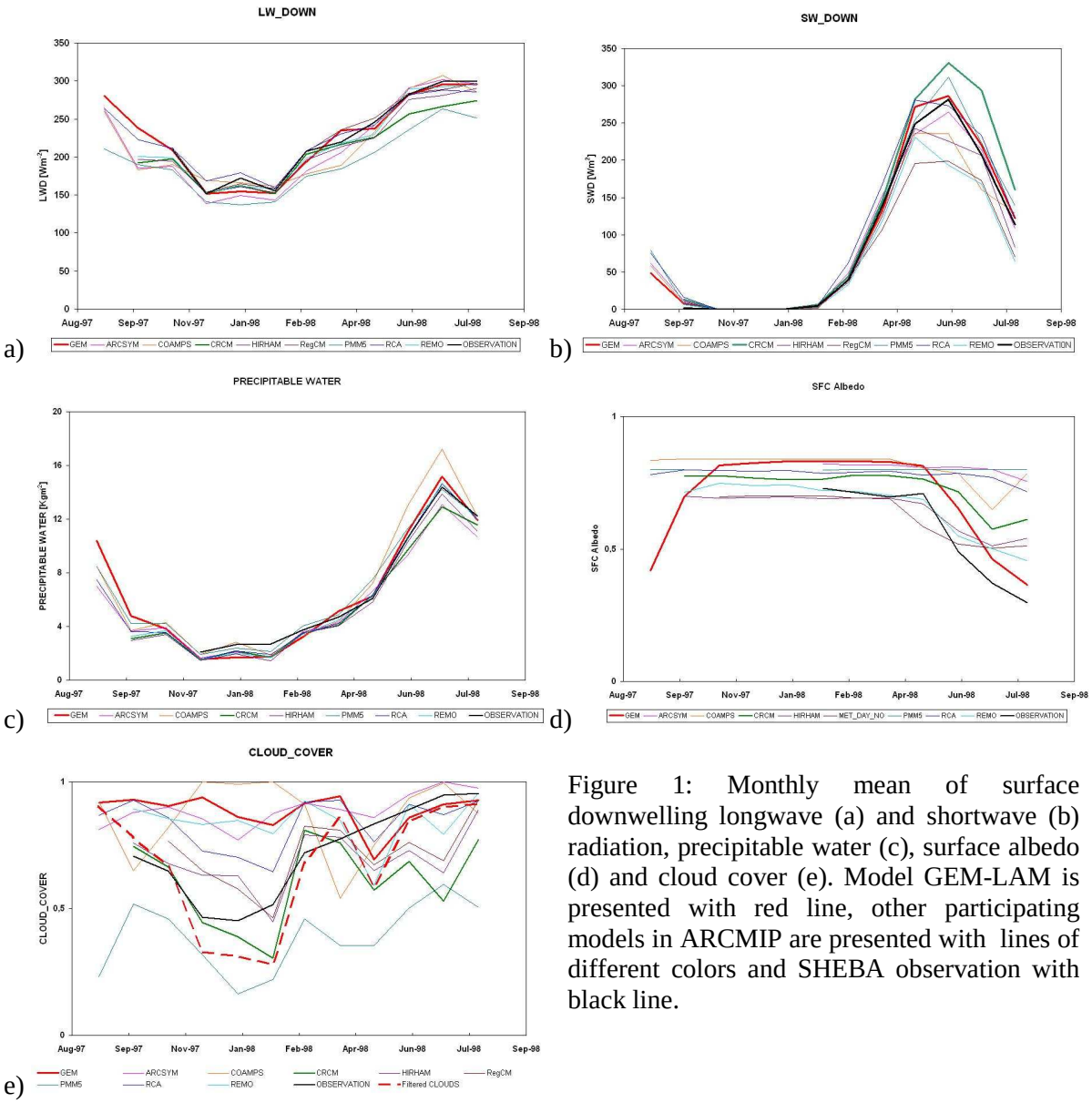

Figure 1: Monthly mean of surface downwelling longwave (a) and shortwave (b) radiation, precipitable water (c), surface albedo (d) and cloud cover (e). Model GEM-LAM is presented with red line, other participating models in ARCMIP are presented with lines of different colors and SHEBA observation with black line.

References:

Wyser, K. 2007 : An Evaluation of Arctic Cloud and Radiation processes during the SHEBA year: Simulation results from 8 Arctic Regional Climate Models.

Rinke, A. 2004 : Climate Dynamics: Evaluation of an Ensemble of Arctic Regional Climate Models: Spatial Patterns and Height Profiles

Klaus Wyser, Colin G. Jones; 2005; Journal of geophysical research; Modeled and observed clouds during Surface Heat Budget of the Arctic Ocean (SHEBA); vol 110