How good is the boundary-layer in current atmospheric climate models?

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The problem

Global climate models (GCM) support an amplified climate warming in the Arctic. An ensemble of 19 CMIP models suggests an amplification on average of about 2.5 times the global average. Recent analysis of observations also indicate a more rapid warming in the Arctic, at least over land. In the models, a main reason for the polar amplification of the warming is likely a strong ice/sea-albedo feedback. The inter-model spread in the climate-change sensitivity is, however, for larger in the Arctic than elsewhere also on Earth. To elaborate further on Arctic climate change, the models must deal adequately with the energy fluxes at the surface and how they may change.

Simulation summary

- 1 1 year simulation (2 Sep 1997 – 1 Oct 1998)
- 6-hourly lateral forcing by the ECHAM4 analyses
- Lower boundary forcing by satellite data of SST and air-sea temperature
- and ice fraction
- Domain size 950 x 2750 km
- Model resolution 50 km
- Computing model results on 12 processors
- Calculations of the SHEBA ice camp
- Meteorological test for 6 variables for

Near-surface parameters

It is not immediately evident that models will follow the parameterized at the surface and lateral boundary

Modelled turbulent fluxes

Modelled momentum fluxes are often too large, ranging from only slightly low to about a factor of two to large, but the correlation to the observations is acceptable. That modelled momentum fluxes are too large is interesting as it is directly related to development of synoptic scale systems.

Vertical structure

Bias in the model simulated vertical structure was estimated by comparison to sounding data from SHEBA and it is illustrated as an ensemble average for each model, for temperature and specific humidity. Several things are clear from this comparison:
- There is a significant difference in the error structure, above and below 1 km. The error below 1 km is much larger, indicating problems with the boundary layer in broad sense.
- Even with “perfect” lateral boundary conditions, the error in the free troposphere is significant and different between models.
- The error structure in the boundary layer is indicative of problems with low clouds, specially in winter. The observed cold bias in the surface temperature is still evident in almost all models, presumably due to too thick or too much clouds and thus overestimated cloud top cooling.

Conclusions

Six models boundary-layer models are compared for a year-long simulation of the 2005 SHEBA year. The relatively small domain ensures that all models have a significant development of synoptic scale systems. The vertical structure is then well constrained.

Sensible heat flux shows the least correspondence to the observations. The model sensitivity to resolved-scale variables is very large for latent heat flux.