Sensitivity of model climate to physical parameterizations in climate models

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Different climate models usually give different atmospheric general circulation patterns that often differ considerably from observations. These differences in model climatology are associated with the differences in physics and numerics in climate models. However, due to the nonlinear nature and complexity of the models, it is difficult to identify the sources causing model deficiencies in the simulated climatology and variability. In order to attribute the model errors to specific modelling assumptions, many studies considered GCMs as being decomposed into modules that can be tested and compared independently. Held and Suarez (1994) proposed a benchmark calculation for evaluating the dynamical cores of GCMs independently of the physical parameterizations. Deque (1999) studied the intrinsic capacity of Eularian and Semi-Lagrangian advection by using model configuations that only changed model dynamics while using the same physical parameterization package. Numerous efforts are also made to evaluate the parameterization schemes of specific physical process such as radiation (Ellingson et al. 1991; etc.) and land surface process (Henderson-Sellers et al. 1992).

In this study we investigate the influence of the physical paramterization as a whole package on model climatology. Two atmospheric climate models are used: the climate version of ARPEGE (v4) and the Danish climate model (DKCM). The atmospheric DKCM is developed at the Danish Meteorological Institute for applications in climate simulations at relatively high resolution. It was constructed by combining the ARPEGE/IFS dynamical core developed at ECMWF and Meteo-France, and the ECHAM5 physical parameterization package that is designed for climate simulations (Yang 2004). The model is characterized by the efficiency advantage of ARPEGE/IFS and may perform extended simulations efficiently even at high resolution. The two models in comparison here thus differ only in physical parameterizations. Two 30-year simulations forced with climatological boundary conditions were carried out using DKCM and ARPEGE at resolution of T63 and 31 vertical layers. The simulations were evaluated using ERA40 re-analysis.

Fig. 1 shows the winter time (DJF) 500 hPa geopotential height (contour lines) and their systematic errors with respect to ERA40 re-analysis (color shadings) for the two models. It can be seen that in extra tropics, the systematic errors in DKCM are generally smaller than that in ARPEGE, in particular in north Pacific-north America sector. The reduction of systematic errors in DKCM compared to ARPEGE is also significant in the zonal mean circulation in upper troposphere and stratosphere (not shown). The wintertime variability (not shown) is also better represented in DKCM than in ARPEGE in comparison with ERA40. The maximun variabily in north Atlantic seen in ERA40 is completly missing in ARPEGE, while it is reproduced in DKCM with the maximun area somewhat smaller than seen in ERA40. The above differences may be associated with the differences in diabatic forcing associated with physical parameterizations. Fig. 2 shows the difference of the verticlly averaged diabatic forcing between the DKCM and the ARPEGE. Extrema are seen in the northern high latitudes along the edges of sea ice, indicating its cause from the differences in the treatment of sea ice in the two models. In the low and midlatitudes, the major differeces between the diabatic forcings in the two models seem to be coinsident with the differences between the precipitations in the two models (not shown), implying possible connections with the cloud related process and convective activities. More detailed analyses are undergoing along this line to determine the most crucial physical processes responsible for the above differences in model climatology and variability.

References

Deque, M., 1999: Eulerian versus Semi-Lagrangian in climate simulation: verdic of the nudging technique. CAS/JSC working group on Numerical experimentation: Research Activities in Atmospheic and Oceanic Modelling. Edited by H. Ritchie. Report No. 28. 7.21-7.22.

Ellingson, R. G., J. Ellis and S.B. Feis, 1991: The intercomparison of radiation codes used in climate models: Longwave results. J. Geophys. Res., 96, 8925-8953.

Held, I. M. and M. J. Suarez, 1994: A proposal for the intercomparison of the dynamical cores of atmospheric general circulation models. Bull. Amer. Meteor. Soc., 75, 1825-1830.

Henderson-Sellers, A., Z.-L. Yang and R.E. Dickinson, 1992: The project for intercomparison of land-surface parameterization schemes. Bull. Amer. Meteor. Soc., 74, 1335-1349.

Shuting Yang, 2004: The DKCM atmospheric model: The atmospheric component of the Danish climate model, Danish Climate Center report 04-05, 23pp.

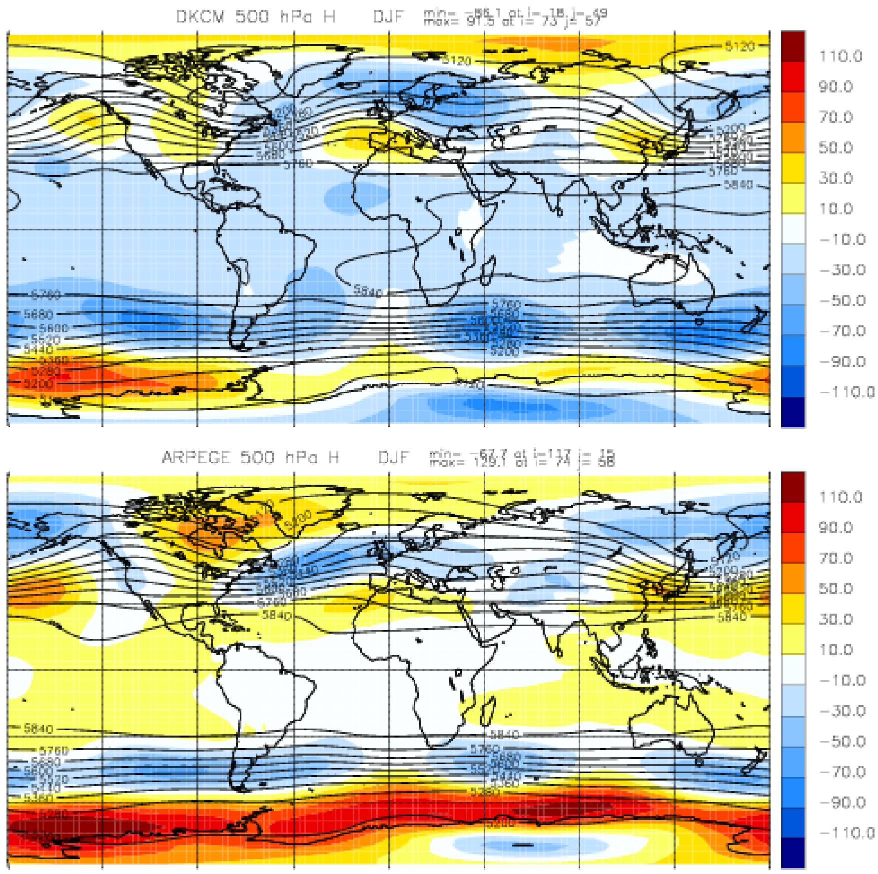

Figure 1. Seasonal mean 500 hPa geopotential height (contour lines) and its systematic errors with respect to ERA40 (color shading) for DJF for DKCM (top) and ARPEGE (middle), respectily. Unit: gpm.

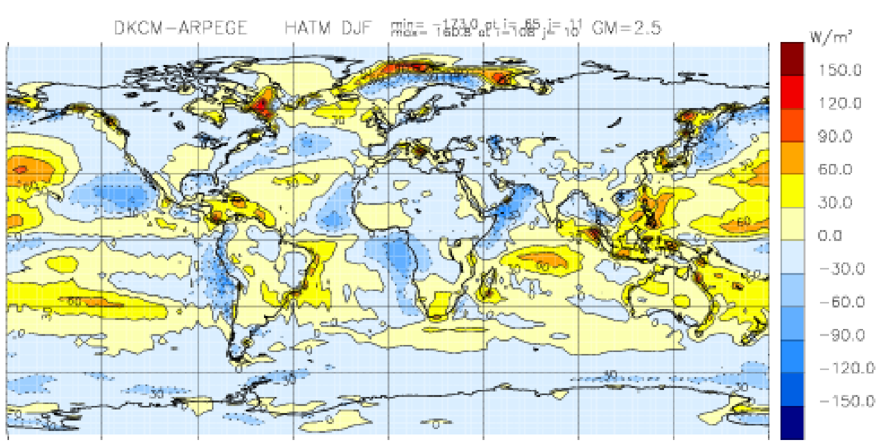

Figure 2. The difference of the vertically averaged diabatic forcing between DKCM and ARPEGE for DJF.