Influence of different vertical and horizontal model resolutions on the simulated hydrological cycle of the GCM ECHAM5

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A new version of the atmospheric general circulation model (GCM) ECHAM has recently become operational at the Max Planck Institute for Meteorology. For the validation of the hydrological cycle simulated by this new ECHAM5 model (Roeckner et al. 2003), a special focus was set on the influence of different horizontal and vertical resolutions of the ECHAM5 model grid on the quality of the simulated hydrological cycle. The resolutions investigated comprise the spectral horizontal resolutions T42, T63, T106, and T159 as well as two vertical resolutions with 19 (L19) and 31 (L31) vertical levels. The horizontal resolutions correspond to grid sizes of about 2.8°, 1.9°, 1.1° and 0.75° or rather 300 km, 200 km, 110 km and 80 km, respectively. The validation of the simulated hydrological cycle was conducted from the global scale to the regional scale. For the latter, several large catchments are selected which are representative for different climate zones. The validation has shown that increases in vertical and horizontal resolution have a significant impact on the accuracy of the simulated hydrological cycle of ECHAM5. It turned out that an increase in vertical resolution from 19 to 31 levels generally has a larger impact on the simulated hydrological cycle than an increase in horizontal resolution. Despite of the uncertainties of observational estimates over the ocean it seems that the simulated hydrological cycle over the ocean is slightly worsening with an increased resolution. But over land increases in horizontal resolution and especially in vertical resolution have a positive impact on the quality of the simulated hydrological cycle. For some catchments, such as for the Amazon and the Amur catchment with regard to the simulated 2m temperature, only the combined effect of increases in both kinds of resolution lead to a significant improvement. This indicates that the increase of resolution in only one dimension (either vertical or horizontal) may not be sufficient to yield a considerable improvement in the hydrological cycle simulated by a GCM in general. An increase of horizontal resolution from T106 to T159 does not noticeably improve the simulated hydrological cycle. Therefore it is recommended to use T106L31 for future ECHAM5 studies involving the hydrological cycle if computing time is not a limiting factor.

Fig. 1 shows the annual mean biases of the simulated precipitation over selected large catchments that represent various regions from different climates. Over a specific catchment, the bias was calculated from the difference of the simulated precipitation minus GPCP data (Huffman et al. 1997). For most of the catchments, the finer vertical resolution in the L31 simulations leads to a reduction in the precipitation bias. A slight increase of a positive bias is only shown in the Baltic Sea and Arctic Ocean catchment. The effect of an increased horizontal resolution is much smaller than the effect of an increased vertical resolution. A significant bias reduction occurs only in a few catchments (Amur, Baltic Sea, Danube, Nile, Yangtze Kiang), which is most prominent in the Yangtze Kiang catchment. This is clearly related to the much better resolved orography in the very narrow region of the upper catchment part of the Yangtze Kiang river.

The increased vertical resolution causes a reduction of the evaporation bias (not shown) in the majority of catchments. Here, the observed evaporation was calculated from the difference of GPCP precipitation data minus the observed climatological discharge (Dümenil Gates et al. 2000). A relatively large reduction is occurring over the Ganges/Brahmaputra catchment although the bias is still large. This suggests that the increased vertical resolution has a positive effect on the simulation of the Indian monsoon circulation. A significant worsening of the evaporation bias is only seen over the Arctic Ocean catchment. As for precipitation, the effect of an increased horizontal resolution is comparatively small, thereby significantly increasing the positive bias over the Arctic Ocean catchment and slightly reducing the bias over the Congo, Mississippi and Yangtze Kiang catchments.

The combined effect of the precipitation and evaporation biases results in the runoff biases shown in Fig. 2. Here, the runoff bias was calculated by the difference of simulated runoff minus the observed climatological discharge. The increased vertical resolution significantly reduces the runoff biases over almost all catchments. In the Nile catchment, a lot of water is taken from the river for irrigation. As no irrigation information enters the ECHAM5 model this is not simulated. For the Murray, the positive runoff bias is increased with vertical resolution but the Murray catchment covers a very dry area with an annual discharge of only 8 km^3/a (= 258 m^3/s). As there are negative biases in precipitation and evaporation for all model resolutions, even comparatively small deviations (ranging from 2 to 6 km^3/a) of *P-E* (= runoff) from the observed discharge may cause larger runoff bias percentages. The effect of an increased horizontal resolution on the runoff bias is, although mostly smaller than the effect of an increased vertical resolution, more prominent than for precipitation and evaporation. It generally tends to reduce the runoff bias, especially over the catchments of Amur, Baltic Sea, Danube, Parana and Yangtze Kiang. Only the large runoff bias over the Ganges/Brahmaputra catchment is increased with finer horizontal resolutions.

References

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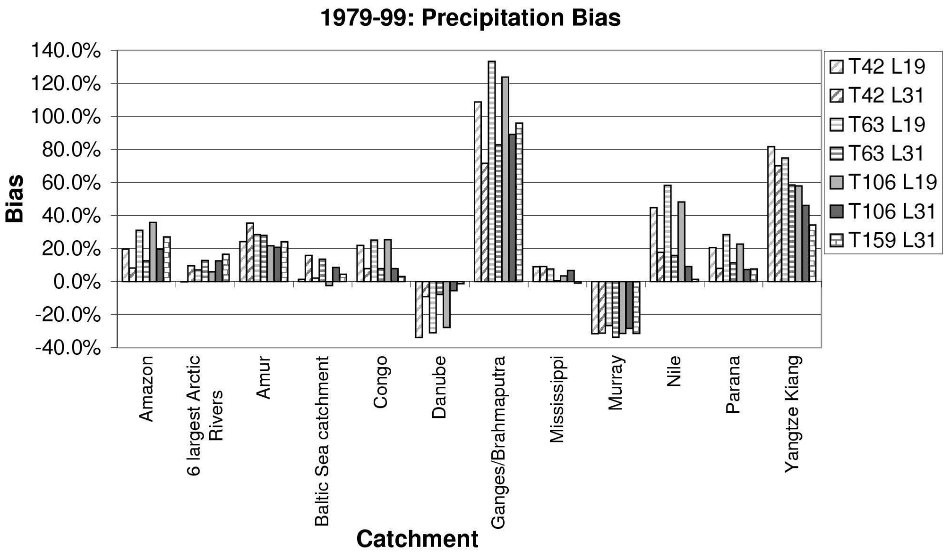

Figure 1 Annual mean bias in simulated precipitation over several catchments. Over a specific catchment, the bias was calculated from the difference of the simulated precipitation minus GPCP data.

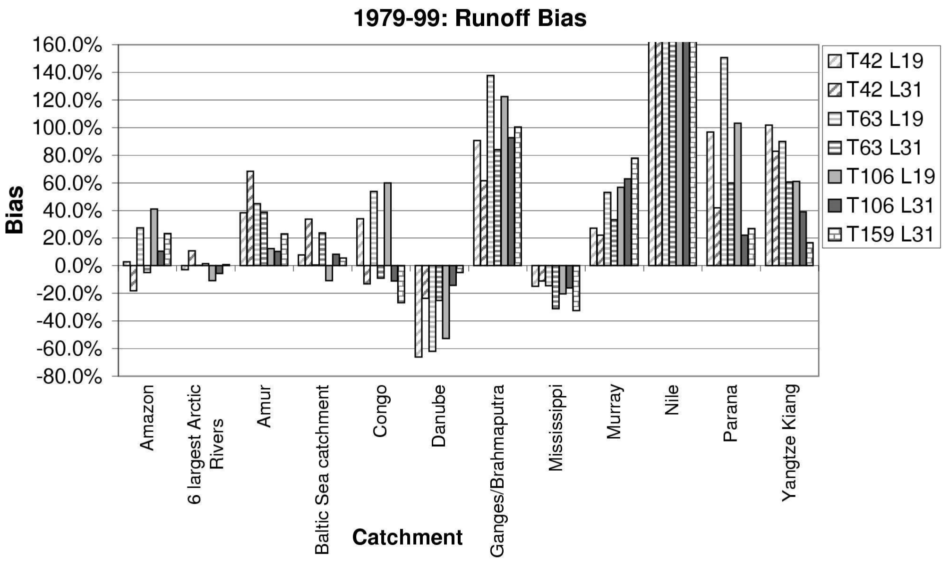

Figure 2 Annual mean bias in simulated runoff over several catchments. The runoff bias was calculated from the difference of the simulated runoff minus the observed climatological discharge.