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Prognostic equations for rain in the ECHAM5 GCM: Global simulations

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Clouds and precipitation play an important role in the hydrological cycle of the earth. Changing precipitation patterns due to climate change will result in shifted vegetation zones, will have an influence on water quality, soil structure/erosion and runoff into rivers and oceans. Through feedback processes, these changed precipitation rates have an impact on cloud formation and microphysical processes which, on their part, influence the precipitation rates. The prediction of precipitation is, therefore, an important issue for the climate modeling community.

Furthermore, clouds play an important role in the energy budget of the earth. Aerosol particles and their precursors resulting from human activity are thought to change the physical and optical properties of clouds. The first indirect effect refers to an increasing cloud albedo due to decreasing cloud droplet sizes as the concentration of (anthropogenic) aerosols increase. For those smaller cloud droplets it is harder to grow into precipitation sized drops. This results in less precipitation at the surface and presumably a prolonged lifetime of clouds within the atmosphere and is referred to as second aerosol indirect effect. In contrast to most of the (small) aerosols that act as Cloud Condensation Nuclei (CCN), Giant CCN (e.g., sea salt and dust) are suggested to have an enhancing effect on the formation of precipitation (i.e., drizzle) and, therefore, might lower the second indirect effect, especially over the oceans. However, the size of both of these aerosol indirect effects is still very uncertain.

In order to improve the representation of rain within the ECHAM5 general circulation model prognostic equations for rain mass mixing ratio and rain drop number concentration were introduced. In the standard version of the ECHAM5 rain is reaches the surface within one model time step or evaporates in the cloud-free air below the cloud.

This approach is only true for relatively large rain drops. Smaller drops (i.e., drizzle) also sediment but may not reach the surface within one time step. Therefore, to calculate the actual rain flux from one model level to the next a fall velocity of rain drops is introduced. In order to account for the microphysical processes in which rain is involved, especially accretion of cloud droplets with rain drops, the model time step is split into several sub-time steps.

Simulations with the ECHAM5 Single Column Model showed that the precipitation pattern changes depending on the number of sub-time steps. Changes in the precipitation amount as well as a slight prolongation of the precipitation events results from rain water staying in the atmosphere and, therefore, higher accretion rates.

The impact of the prognostic rain treatment on global precipitation patterns will be the subject of this presentation. Therefore, global simulations with the ECHAM5 will be compared to either the standard ECHAM5 version as well as to observations from the Global Precipitation Climatology Project (GPCP). Special attention is, thereby, drawn on the changes over the ocean where sea salt as a giant CCN might have a large effect on precipitation.