

Abstract

Clouds are an important regulator of the Earth's radiation budget and represent a major link between radiation and the hydrological cycle. In contrast to the "standard" method of comparing the model results with long-term climatologies, a different approach to validate clouds and cloud systems in ECHAM4 T106 is used by investigating the representation of synoptic-scale cloud systems. The aim is to explore whether the realistically reproduced mean cloud amounts are the result of a realistic representation of clouds in a higher temporal resolution. To enable a validation against observations, a dynamical adjustment approach based on the so-called Newtonian relaxation technique (nudging) is used, which relaxes the model state towards reanalysis data by adding a non-physical relaxation term to the model equations. In the simulations vorticity, divergence, temperature and the logarithm of surface pressure are adjusted to ECMWF reanalysis fields. The strength of the forcing is controlled by an adjustment time scale which is different for each adjusted variable.

The development of an extraordinary strong cyclone along the East Coast of the U.S.A. and a North Atlantic blocking situation are chosen as case studies. The synoptic systems have been selected to cover a large range of typical phenomena. A third situation, namely tropical convection in the western Pacific warm pool region, has been excluded from the cloud validation, since the Newtonian relaxation cannot force the model to the observed state for single convective events.

Compared to observations, the synoptic-scale features are well reproduced by the model. This is true even for variables which are not adjusted to the observed state. The general features of the horizontal and vertical cloud distribution are well reproduced for both synoptic systems. Nevertheless, systematic differences occur. The model underestimates clouds in low and middle levels of the troposphere and therefore total cloud amounts. Low-level clouds are most obviously underestimated in the blocking situation and behind the cold front of the developing cyclone, while the underestimation of mid-level cloudiness seems to be a more general feature which appears in both cases. On the other hand, thin upper-level cirrus anvils in pre-frontal regions seem to be overestimated. For the blocking situation, in addition, the horizontal distribution of clouds is different compared to ISCCP observations.

Sensitivity studies are carried out to confirm the findings of the cloud validation in order to study the effects of changes in the description of clouds and other processes, which will be included into the upcoming model version ECHAM5. Such experiments are an AMIP2 simulation, a more sophisticated stratiform cloud scheme PCI, developed by Lohmann and Roeckener (1996a), and the new advection scheme SPITFIRE (Rasch and Lawrence, 1997). With an experiment using a changed profile of the "critical relative humidity", the effect of small changes on the representation of clouds is investigated. All experiments lead to larger cloud amounts in the lower troposphere and a slight increase in mid-level cloud amounts. Small changes occur in the upper troposphere, except for the PCI scheme, which clearly reduces the upper-level cloudiness. Encouraging is that the changed condensation profile in the experiment RHCRIT, which is only a small modification compared to the other experiments, clearly improves the representation of clouds in the blocking situation and even slightly improves the cloud distribution in the extratropical cyclone. In short, the modified profile of the critical relative humidity and the more sophisticated stratiform cloud scheme PCI lead to considerable improvements in the blocking situation, while the representation of frontal cloudiness in the East Coast storm is mainly improved by AMIP2 and SPITFIRE.