First validation of the prognostic cloud ice scheme in the global model GME

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The operational parameterization scheme of GME for the formation of grid-scale clouds and precipitation is based on a Kessler-type bulk formulation and uses a specific grouping of various cloud and precipitation particles into broad categories of water substance. The particles in these categories interact by various microphysical processes which are parameterized in terms of the mixing ratios as the dependent model variables. Four categories of water substance are considered: water vapour, cloud water, rain and snow. Cloud water is treated as bulk phase with no appreciable terminal fall velocity relative to the airflow, whereas single-parameter exponential size-spectra and empirical size-dependent terminal fall velocities are assumed for raindrops and snow crystals. The calculation of cloud water condensation and evaporation is based on instantaneous adjustment to water saturation. This leads to a number of drawbacks of the scheme, namely

- Clouds will always exist at water saturation independent of temperature.
- The cloud ice-phase is neglected by assuming a fast transformation from cloud water to snow.
- Contrary to observations high level humidity exceeding ice saturation is often predicted by GME.

To overcome these problems, a new scheme including prognostic cloud ice has been developed.

This parameterization scheme was designed to take into account cloud ice by a separate prognostic budget equation. Cloud ice is assumed to be in the form of small hexagonal plates that are suspended in the air and have no appreciable fall velocity. As a novel feature of the scheme, we formulate the depositional growth of cloud ice as a non-equilibrium process and require, at all temperatures, saturation with respect to water for cloud liquid water to exist. Ice crystals which are nucleated in a water saturated environment will then grow very quickly by deposition at the expense of cloud droplets. Depending on local dynamic conditions, the cloud water will either evaporate completely, or saturation will be maintained, resulting in a mixed phase cloud. In case of a comparatively weak forcing, the cloud will rapidly glaciate to become an ice cloud existing at or near ice saturation. Fig. 1 gives an overview on the hydrological cycle and the microphysical processes considered by the scheme.

For a first validation the operational model (Routine) and GME with prognostic cloud ice (Experiment) have been compared with observations (NOAA 15 measurements) for the period September 2000 until August 2001. On the first of each month for this period 30-day GME forecasts starting from analysed initial conditions with fixed SST have been performed. The twelve 30-day runs have been averaged to form an annual mean value. Fig. 2 compares the zonal average of the outgoing longwave radiation (OLR, W/m^2) at the top of the atmosphere of both model versions (Routine and Experiment) with the observations. The inclusion of prognostic cloud ice greatly improves the quality of the simulated OLR due to the different radiative properties of cloud ice compared to supercooled cloud water. The globally averaged annual radiation balance (OLR plus solar radiation balance) at the top of the atmosphere is almost closed in GME with prognostic cloud ice (+2.1 W/m^2) compared with -19.7 W/m^2 for the current operational model. Since January 2, 2002 a parallel test suite of GME with prognostic cloud ice has been established, and an operational introduction is scheduled for April 2002. At the same time prognostic cloud ice will be introduced in DWD's regional model LM as well as in LMs at Meteo Swiss (Switzerland), SMR-ARPA (Italy), HNMS (Greece) and IMGW (Poland), and in ten HRMs (High resolution Regional Model of the DWD) running world wide e.g. in Brazil, China, Israel, Italy, Oman, Romania, Spain and Vietnam.

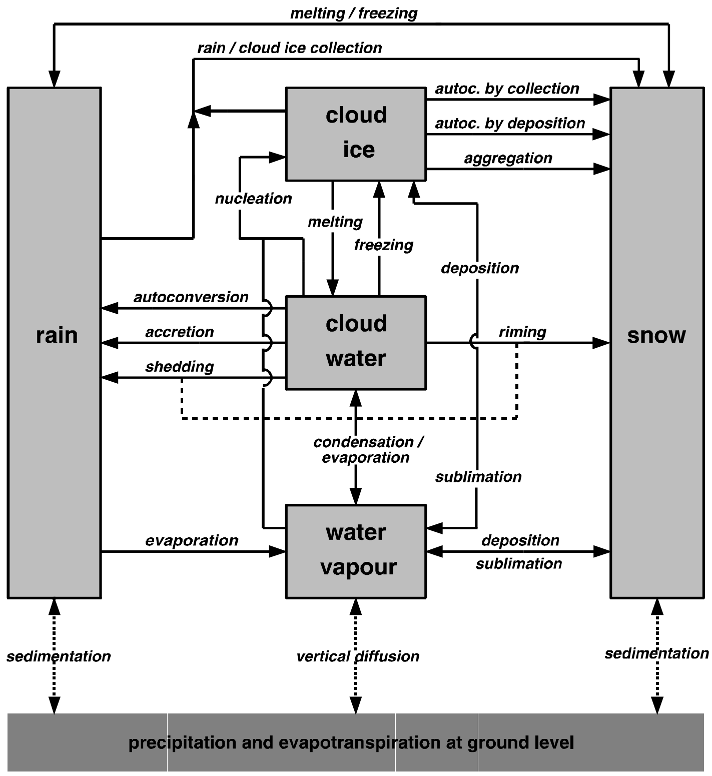

Fig. 1 Hydrological cycle and microphysical processes in the cloud ice scheme

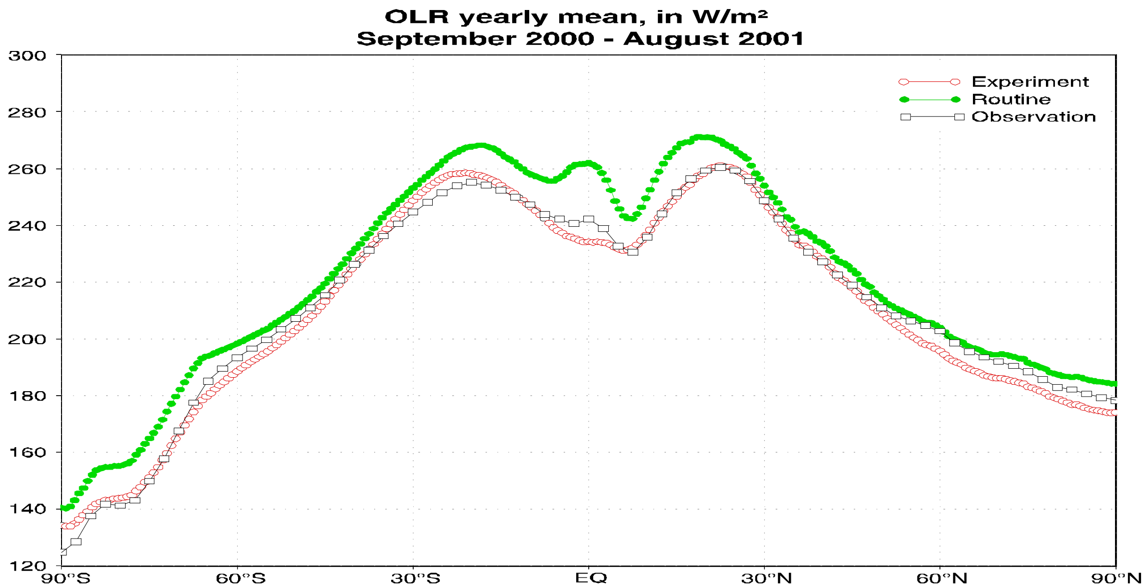

Fig. 2 Zonal mean of outgoing longwave radiation (W/m^2) at the top of the atmosphere