A Prognostic Graupel Microphysics Scheme For High-Resolution NWP

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Introduction

For LM, an additional optional microphysical parameterization scheme which takes into account also graupel has been developed. This scheme is derived from DWD's currently operational microphysics scheme (Doms and Schättler, 1999; Doms and Majewski, 2004; Doms et al., 2005; for 3d-transport of the precipitation species see Baldauf and Schulz, 2004) which is used in the global model GME (40 km mesh size) and the mesoscale limited-area model LM (7 km mesh size). It considers the mixing ratios of cloud water, cloud ice, rain, snow, and now additionally graupel as prognostic condensate categories. The purpose of this scheme is to represent more realistically the cloud microphysical processes in explicitly resolved deep convection. It is intended to be used in LMK ("LM-Kürzestfrist", see Doms and Förstner, 2004), the high-resolution short-range version of LM.

Method

For the graupel particles, an exponential size distribution is assumed: $f_g(D_g) = N_0^g \exp(-\lambda_g D_g)$ with $N_0^g = 4 \times 10^6$ m^{-4} (Rutledge and Hobbs, 1984), D_g: diameter of graupel particle. The properties of single graupel particles in the form of power laws are taken from Heymsfield and Kajikawa (1986) for their (low density, $\rho_g \approx 0.2\,\mathrm{g/cm^3}$) lump graupel: For the mass-size relation, it is assumed: $m_g = a_m^g\, D_g^{3.1}$ with a_m^g =169.6; and for the terminal fall velocity depending on size: $v_T^{gp}(D_g) = v_0^g D_g^{0.89}$ with $v_0^g = 442.0$ (all in the corresponding SI units).

Graupel is initiated from freezing of raindrops and from conversion of snow to graupel due to riming. Water vapor deposition, sublimation, melting, and collection of cloud droplets and cloud ice crystals is parameterized for graupel in a way analogous to snow. In contrast to the present scheme, for the (Kessler-type) autoconversion from cloud water to rain water, a cloud water threshold is applied (currently 0.2 g/kg).

Figure 1 shows the microphysical processes considered in the parameterization scheme.

Results

Single cases with LMK

Figure 2 shows west-east cross-sections of hydrometeor distributions for two LMK cases: A stratiform snowfall event from March 2004 (left) and a spring/summer convective event from May 2004. On the one hand, in the stratiform snowfall event most precipitation ice is simulated as snow, with about only 10 percent graupel. On the other hand, in the convective event, most precipitation ice is simulated as graupel, with snow occuring mostly in the upper part (and also in an anvil-like part) of the cloud. These seem to be reasonable results. Therefore, it can be concluded that the scheme simulates graupel principally in a plausible way.

Testsuite 2004-07-16 to 2004-09-30

A comparison (two 18-h forecasts daily, starting 00 UTC and 12 UTC, for Jul 16 to Sep 30, 2004) of LMK results computed with the new scheme shows a small (5 %) decrease in total precipitation compared to the present microphysics scheme. Generally, standard verification scores (against synop observations) were not affected significantly. The positive frequency bias for small (0.1–2 mm/h) precipitation events was slightly reduced which might be caused by the introduction of the threshold for cloud water autoconversion. It can be concluded that the scheme behaves well also for a large series of forecasts, but significant improvements in forecast skill could not be found yet from the preliminary verification carried out up to now.

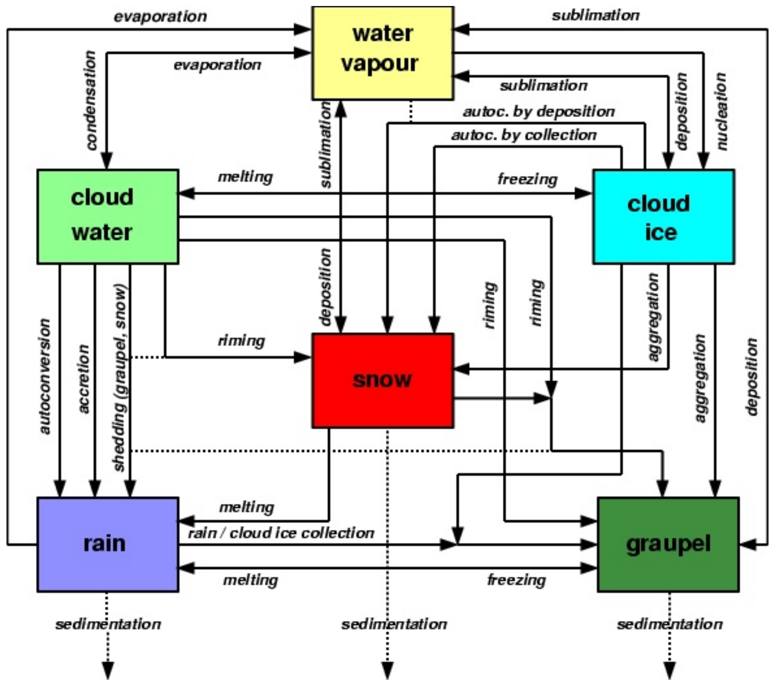

Figure 1: Cloud microphysical processes considered in the graupel scheme.

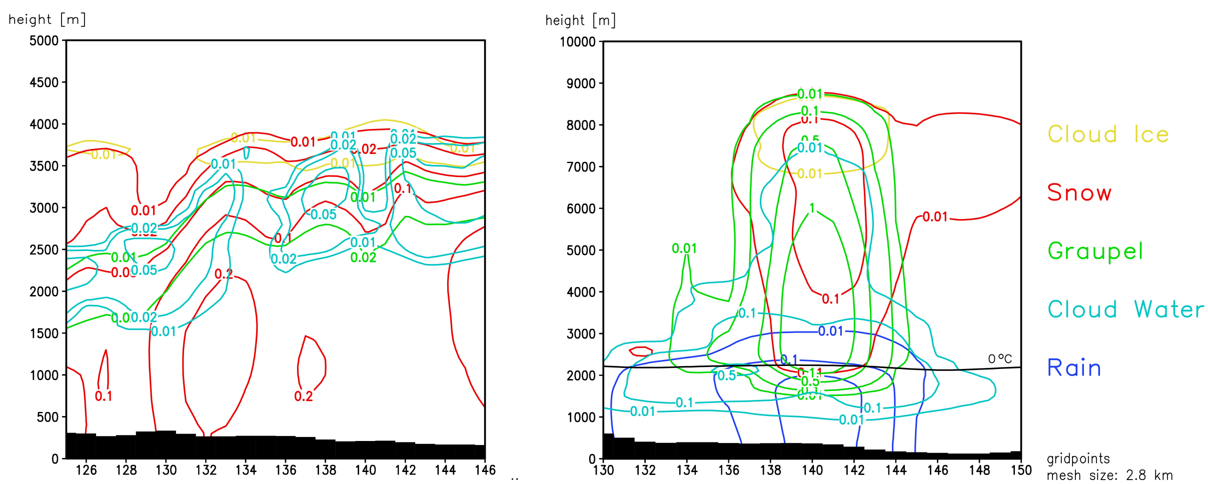

Figure 2: West-east cross-sections of hydrometeor distributions (mixing ratios in g/kg) for two cases simulated with LMK. Left: stratiform snowfall (2004-03-09 00 UTC + 08 h), isolines: 0.01, 0.02, 0.05, 0.1, 0.2. Right: convective cell (2004-05-11 00 UTC + 13 h), isolines: 0.01, 0.1, 0.5, 1.

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