Sensitivity of near surface temperature model errors to the introduction of a prognostic snow density and a revised formulation of snow heat conductivity

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In the presence of snow on the ground the diurnal evolution of surface and near surface temperatures is governed not only by the forcing due to radiative and turbulent fluxes and the soil heat flux. In addition, heat conduction through the snow layer becomes important in situations when the soil surface temperatures deviate significantly from the values at the top of the snow layer. The contribution of this process to the energy budget at the interface between atmosphere and snow surface is controlled by the thickness of the snow layer and the associated heat conductivity.

In early spring 2005 the operational global model of DWD assumed a constant snow density of 250 kg/m^3 and a heat conductivity of approximately 0.2 W/(m K) with a weak dependence on the total water content of the snow layer. With these assumptions the decoupling of the snow surface from the underlying soil was overly efficient, leading to an excessive cooling at the snow surface at night and a corresponding error in near surface minimum temperatures. Fig.1a illustrates the distribution of near surface temperatures for a situation when a snow layer had been present for several days in most parts of Germany. Compared to observations the model was frequently too cold by more than 5 K. Overall the model simulated temperatures exhibited an excessive diurnal cycle above the snow. A revision of the formulation for the snow heat conductivity in conjunction with the introduction of a prognostic snow density alleviated the problem considerably. Snow heat conductivity is determined following the approach of Yen (1981) as a function of snow density. The impact of ageing on the density of existing snow itself follows the formulation proposed by Verseghy (1991). Even though the simulation of the snow density accounts for the metamorphosis of existing snow and the impact of freshly falling snow only in a very crude way, the formulation captures important aspects of the temporal evolution such as compaction due to processes like gravitational sedimentation and the reduction of the mean density, should fresh snow fall on an existing snow layer. Fig.1b illustrates the impact of these changes on the simulated nighttime temperatures. Compared to the operational model considerably higher temperatures were predicted and a better agreement with observations was achieved.

Despite these improvements the model still exhibits a significant negative temperature bias in wintertime situations when the atmosphere is characterised by a stable stratification near the surface. The remaining bias appears to be related to other model deficiencies since sensitivity experiments with further modifications affecting the heat flow through the snow layer had no significant impact on the problem. Further investigations will be performed with the turbulence scheme as a focal point of interest since the simulation of the stable boundary layer is generally a critical issue in NWP models.

References

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Yen, Y.-C., 1981: Review of thermal properties of snow, ice and sea ice. CCREL Rep.81-10, Cold Reg. Res. and Eng. Lab., Hanover, N.H.

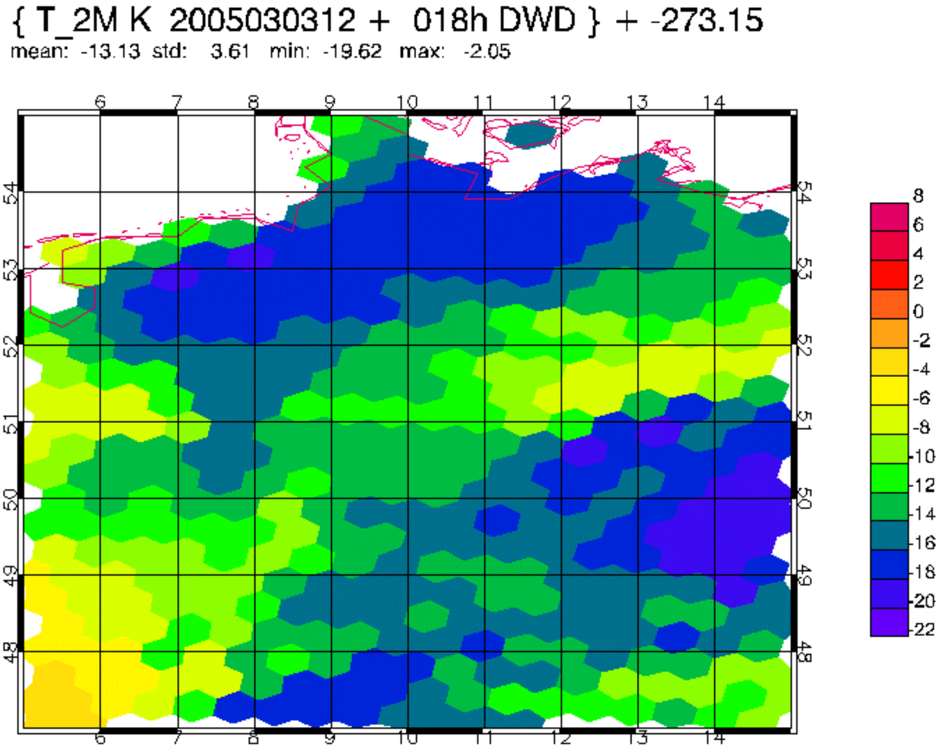

Fig.1a: Simulated near surface temperatures (°C) with operational model version for Central Europe based on initial data from March 3rd 2005 12 UTC

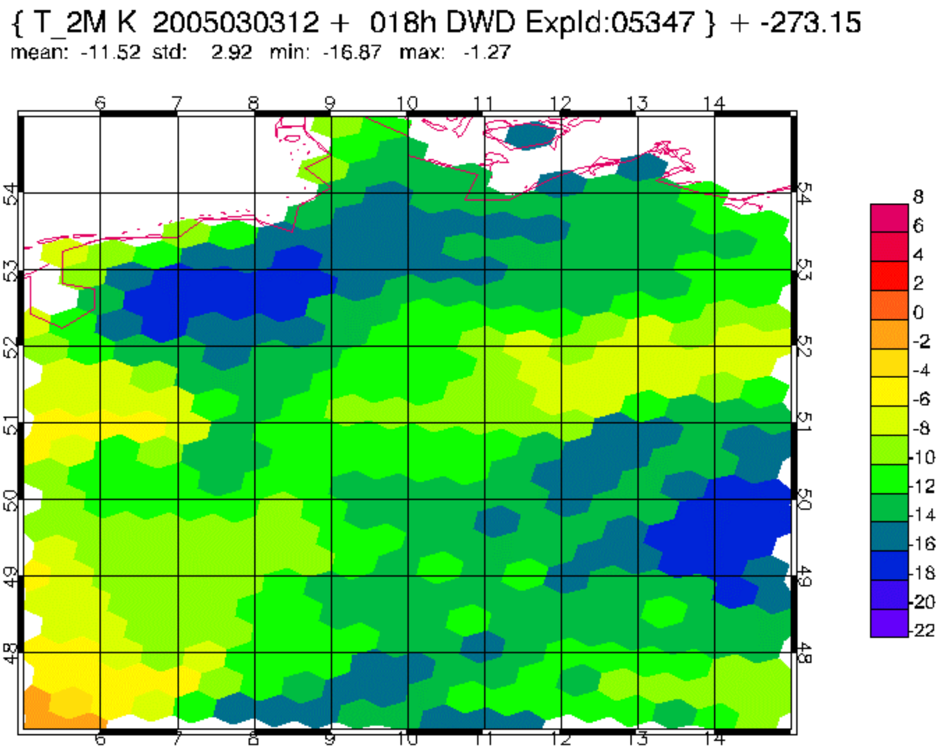

Fig.1b: Simulated near surface temperatures (°C) with experimental model version for Central Europe based on initial data from March 3rd 2005 12 UTC