A multi-layer soil model including freezing/melting processes

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In the present operational models of the German Weather Service the soil heat and water transport processes are calculated by an economic two-layer soil model. The upper layer of this model has a thickness of the order of 0.1 m. In winter large amounts of water/ice available in such a thick layer would result in an exaggerated suppression of temperature changes in the soil - and therefore also in the lowest atmospheric layer - if freezing/melting processes were included. Therefore they were neglected in the present model versions. But, conversely, this leads to daily temperature amplitudes being considerably too large in winter, if freezing/melting processes occur in reality.

To reduce this deficiency, a multi-layer soil model was implemented in the non-hydrostatic limited area model LM of the German Weather Service (Heise and Schrodin, 2002). It allows the choice of thin layers close to the soil surface. In this model the freezing/melting processes are included in two different versions: In the first version complete freezing/melting of soil water/ice occurs at the freezing point temperature. But even with rather thin upper layers the freezing/melting process still seems to be exaggerated. Therefore, in the second version some amount of liquid water may remain in the soil even at temperatures well below the freezing point. The temperature of complete freezing of water is determined dependent on the soil type. This approach basically follows Flerchinger and Saxton (1989).

First experiments simulated a situation of significantly decreasing temperatures in the north-eastern part of Germany (see Figure 1). The prediction of 2m temperatures was verified by observations (obs) at the Meteorological Observatory Lindenberg of the German Weather Service. In the first experiment (mlv) the freezing/melting process in the soil was neglected, leading to temperatures being significantly lower than the observations after 30 h forecast time. In the second experiment (fr0) with total freezing/melting at the freezing point temperature, the diurnal change of temperature is extremely reduced especially in the first 24 hours, showing the too large effect of this version. Only the second version with a variable temperature of complete freezing (frv) yields acceptable diurnal courses of temperature.

References

Heise, E. and R. Schrodin, 2002: Aspects of snow and soil modelling in the operational short range weather prediction models of the German Weather Service. Journal of Computational Technologies. Submitted.

Flerchinger, G. N. and K. E. Saxton, 1989: Simultaneous heat and water model of a freezing snow-residue-soil system. I. Theory and development. Transactions ASAE, Vol. 32(2), 565-571.

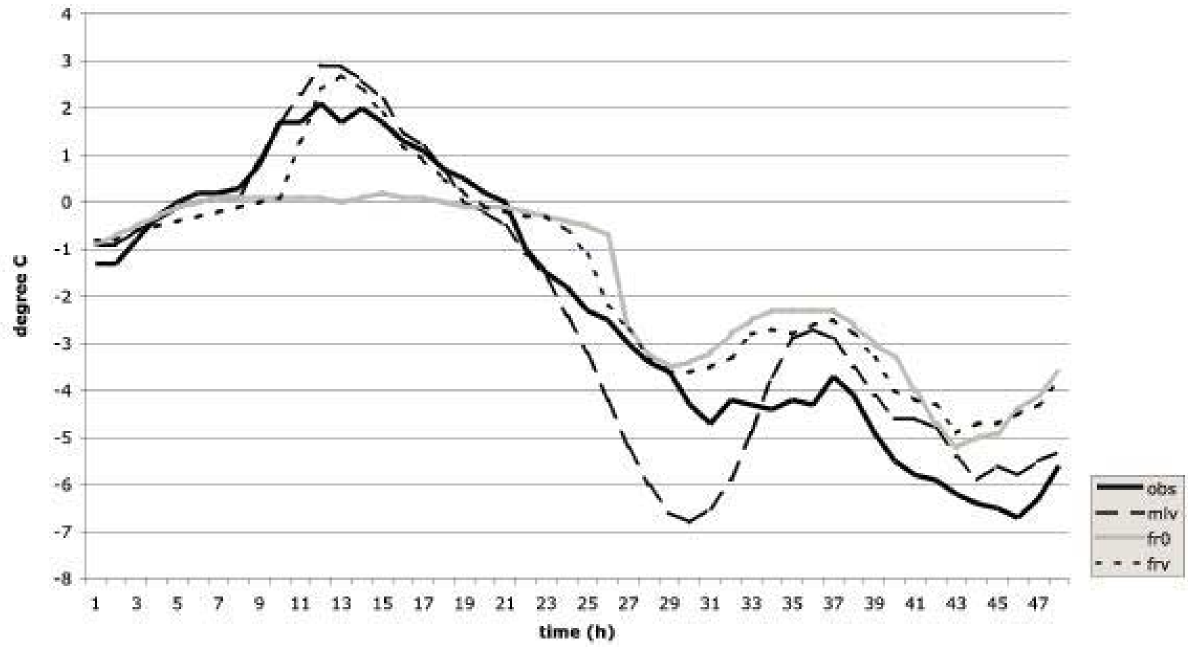

Figure 1: Observed (obs) and predicted 2m temperatures at the Meteorological Observatory Lindenberg of the German Weather Service. 0h corresponds to 28 January 1999 00.00 UTC. See text for details of the three simulations.