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Evaluation of the ground heat flux simulated by a multi-layer land surface scheme using high-quality observations at grass land and bare soil

Jan-Peter Schulz (1), Gerd Vogel (2), Claudia Becker (2), Steffen Kothe (3), and Bodo Ahrens (3)

(1) Deutscher Wetterdienst, Research and Development, Offenbach am Main, Germany (jan-peter.schulz@dwd.de), (2) Deutscher Wetterdienst, Meteorological Observatory Lindenberg, Germany, (3) Goethe University Frankfurt, Frankfurt am Main, Germany

Two parameterisations for the dependence of the soil thermal conductivity on the soil water content are compared, using the multi-layer land surface scheme TERRA of the Consortium for Small-scale Modeling (COSMO) atmospheric model. The simulations were carried out in offline mode with identical atmospheric forcing data from the Meteorological Observatory Lindenberg of the German Meteorological Service (Deutscher Wetterdienst). The results show that the ground heat flux computed by the reference version of TERRA is systematically overestimated under dry conditions. In this version, the thermal conductivity does not depend on the simulated water content of the soil. Since the ground heat flux is part of the surface energy balance it affects the other components such as turbulent heat fluxes and surface temperature. An overestimation of the ground heat flux during daytime leads to an underestimation of the other surface fluxes and to a reduced surface warming, during afternoon and night this behaviour is reversed. The two formulations for soil thermal conductivity, presented by O. Johansen on the one hand and M. C. McCumber and R. A. Pielke on the other hand, both reduce the ground heat flux in TERRA under dry conditions, the former yielding good results while the latter is even leading to underestimations. In addition to this, the former is also applied in coupled mode in the climate version of the COSMO model, the COSMO-CLM, for Africa, resulting in improved diurnal cycles of near-surface temperature in dry regions. Furthermore, it is shown with the Lindenberg measurements that the soil temperature and hence the ground heat flux are particularly influenced by the effects of shading of the incoming solar radiation due to the vegetation cover, leading to a significantly reduced solar radiation at the sub-canopy land surface, even under a layer of grass. For future improvements of TERRA these effects should be represented.