An improved representation of the land surface temperature including the effects of vegetation in the COSMO model

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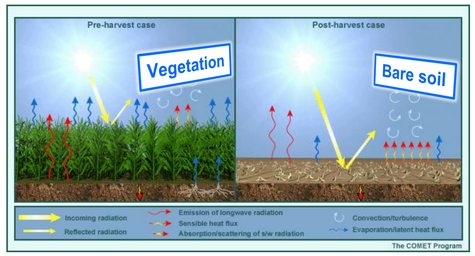
Surface temperature in TERRA?



The problem ...

- The amplitude of the diurnal cycle of the surface temperature simulated by the land surface scheme TERRA (Schulz et al. 2016) of the DWD global and regional atmospheric models is systematically underestimated.
- This typically creates a
  – cold bias of near-surface day temperature,
  – or warm bias of near-surface night temperature,
  – or both.
- The amplitudes of the diurnal cycles of the soil temperatures in TERRA are systematically overestimated.
- This means that the other components of the surface energy balance are biased as well, for instance, the surface turbulent heat fluxes or the ground heat flux.

Experiments

In TERRA, there is no representation of the vegetation in the surface energy balance. An energy budget including a canopy temperature for the vegetation is missing. The insulating effects by the vegetation at the sub-canopy level are missing as well. In extensive tests it turned out that including the skin temperature scheme by Viterbo and Beljaars (1995) can efficiently improve the TERRA simulations.

Experiments comparing TERRA (Reference) and the skin temperature formulation (Experiment) in

- Offline mode: TERRA with atmospheric forcing from DWD observatory Lindenberg (Falkenberg site)
- Coupled mode: Global model ICON for numerical weather prediction at DWD

Offline TERRA: Falkenberg May 2011

Surface temperature represented by

Temperature of top soil layer in TERRA (Doms et al. 2011)

$$C_s \frac{\partial T_s}{\partial t} = R_{SW} + R_{LW} + LE + H + G$$

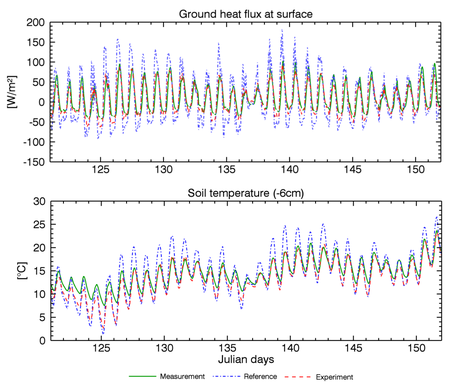
T_s : surface temperature
C_s, t : heat capacity per unit area, time
R_{SW}, R_{LW} : net shortwave radiation flux, net longwave radiation flux
LE, H, G : latent heat flux, sensible heat flux, ground heat flux

Skin temperature in IFS (Viterbo and Beljaars 1995)

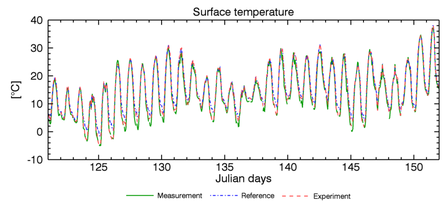
$$\Lambda_{sk}(T_{sk} - T_s) = R_{SW} + R_{LW} + LE + H$$

T_{sk}, T_s : skin temperature, surface temperature
Λ_{sk} : skin layer conductivity
R_{SW}, R_{LW} : net shortwave radiation flux, net longwave radiation flux
LE, H : latent heat flux, sensible heat flux

Positive consequences for surface and soil temperatures and ground heat flux

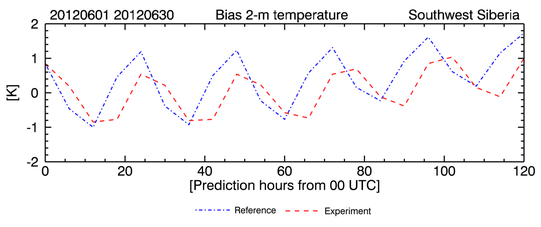


The ground heat flux and correspondingly the amplitudes of the diurnal cycles of the soil temperatures in TERRA are systematically overestimated, with the skin temperature formulation they are considerably reduced and much closer to the measurements.

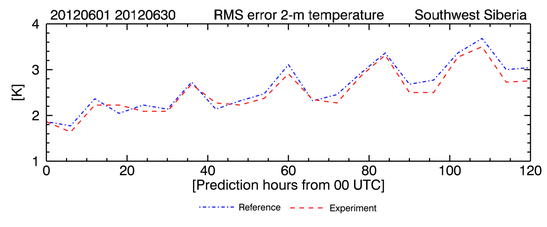


The amplitude of the diurnal cycle of the surface temperature in TERRA is systematically underestimated (clear nocturnal warm bias), with the skin temperature formulation it is substantially increased and much closer to the measurements.

ICON over Southwest Siberia: June 2012, 00 UTC, horiz. res.: 40 km



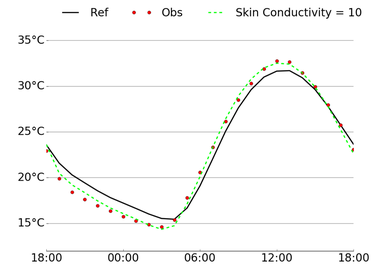
The nocturnal warm bias of the 2-m temperature is significantly reduced by the skin temperature formulation.



The RMSE of the 2-m temperature is significantly reduced by the skin temperature formulation. SK: -13.37

COSMO-DE: 1–2 July 2015

- COSMO-DE is the operational NWP model at DWD. Its domain covers mainly Germany and the Alpine region with a grid spacing of 2.8 km.



- Obs: Meteosat, cloud free pixels in satellite and model
- Black line: TERRA surface temperature (COSMO-DE)
- Green line: IFS skin temperature

Sgoff et al. (2017)

The amplitude of the diurnal cycle of the surface temperature in TERRA is systematically underestimated (clear warm bias during night and cold bias during day), with the skin temperature formulation it is substantially increased and much closer to the observations.

Conclusions

- The amplitude of the diurnal cycle of the surface temperature in TERRA is systematically underestimated.
- The amplitudes of the diurnal cycles of the soil temperatures in TERRA are systematically overestimated.
- The IFS skin temperature formulation was adapted and implemented in TERRA. It provides an additional energy budget for and insulating effects by the vegetation. Experiments in offline mode show substantial improvements with respect to temperature and heat flux errors.
- Experiments in coupled mode (ICON and COSMO-DE) show improvements as well.

References

Doms, G. et al., 2011: A description of the nonhydrostatic regional COSMO model. Part II: Physical parameterization. Deutscher Wetterdienst, Offenbach, 154 pp.

Schulz, J.-P., G. Vogel, C. Becker, S. Kothe, U. Rummel and B. Ahrens, 2016: Evaluation of the ground heat flux simulated by a multi-layer land surface scheme using high-quality observations at grass land and bare soil. *Meteor. Z.*, **25**, 607–620.

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