Das COSMO-D2-Experiment 10805: Bare soil evaporation und skin temperature formulation after Viterbo and Beljaars (1995)

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A new parameterisation of bare soil evaporation for the land surface scheme TERRA of the COSMO atmospheric model

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The problem …

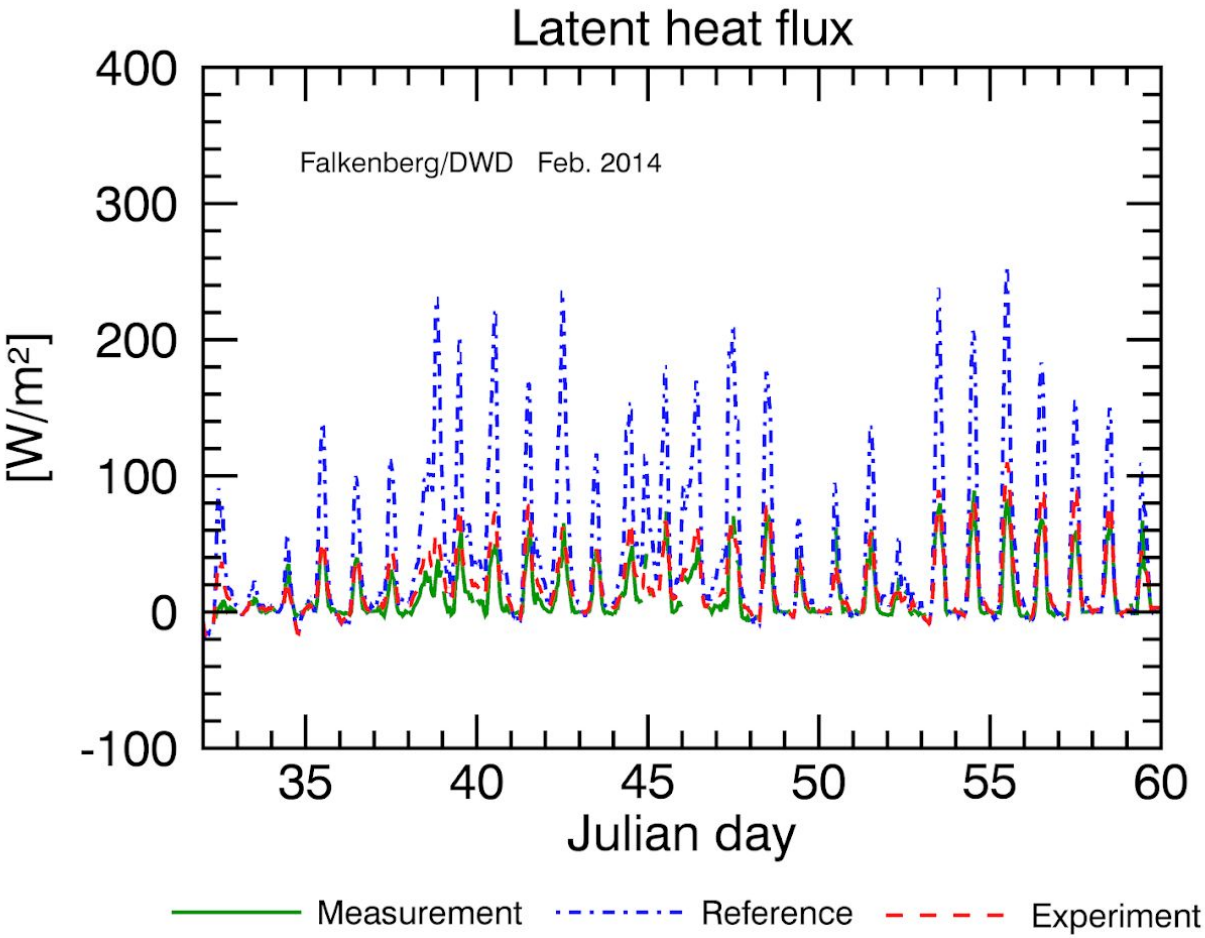
- The bare soil evaporation in TERRA is systematically overestimated under medium-wet to wet conditions.
- This creates a
  - dry bias in the soil,
  - moist bias of near-surface humidity,
  - cold bias of near-surface temperature (daytime),
  - reduced diurnal near-surface temperature range.
- The bare soil evaporation in TERRA is systematically underestimated under medium-dry to dry conditions.

Present BATS scheme bare soil evaporation replaced by resistance formulation

$$E_{bs} = (1 - f_{intercept})(1 - f_{snow})\, f_{bare\_soil}\, \beta E_{pot}(T_{sfc})$$

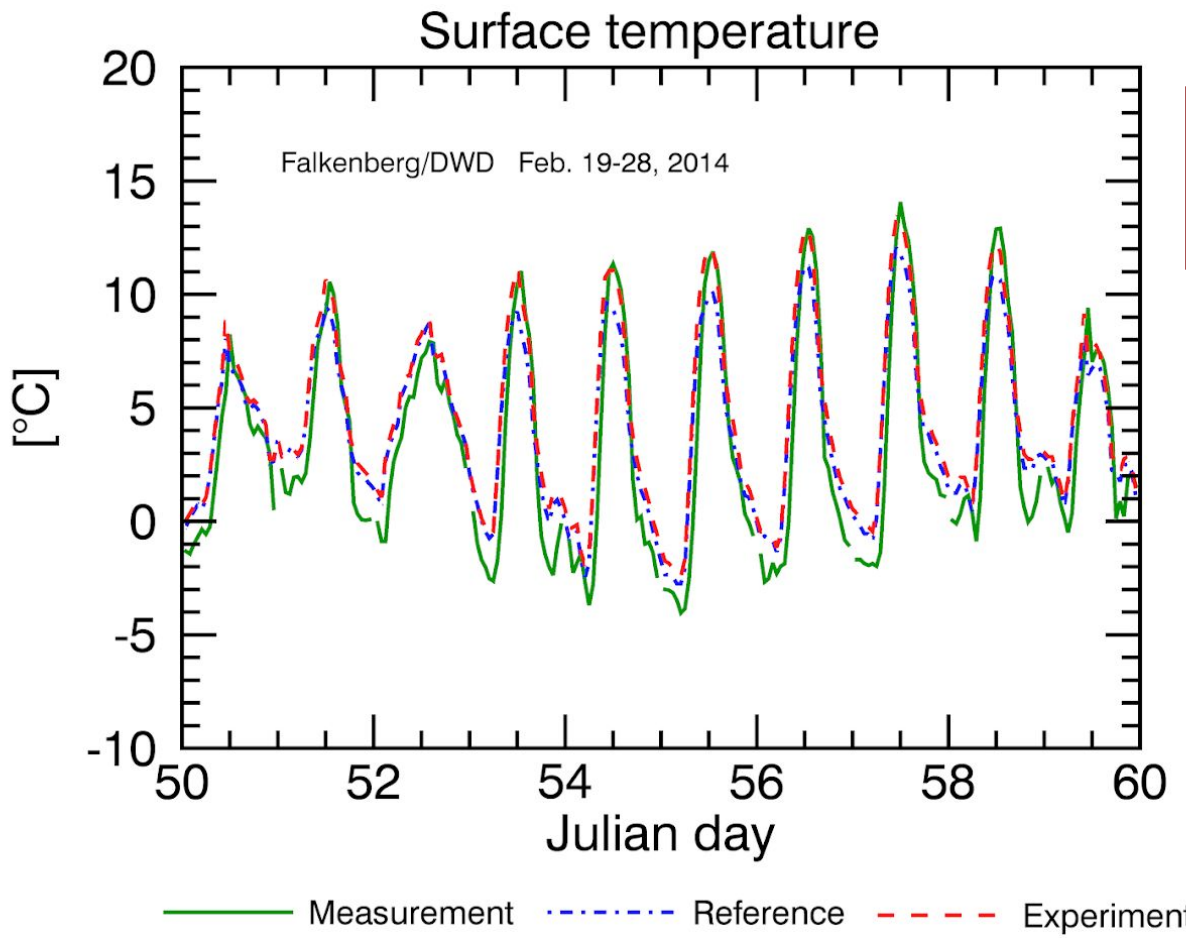
$$\beta = \frac{1}{1 + 50\, \frac{w_{fcap} - w_{adp}}{w_{soil} - w_{adp}} c_h u}$$

Model forcing with observations from Lindenberg site



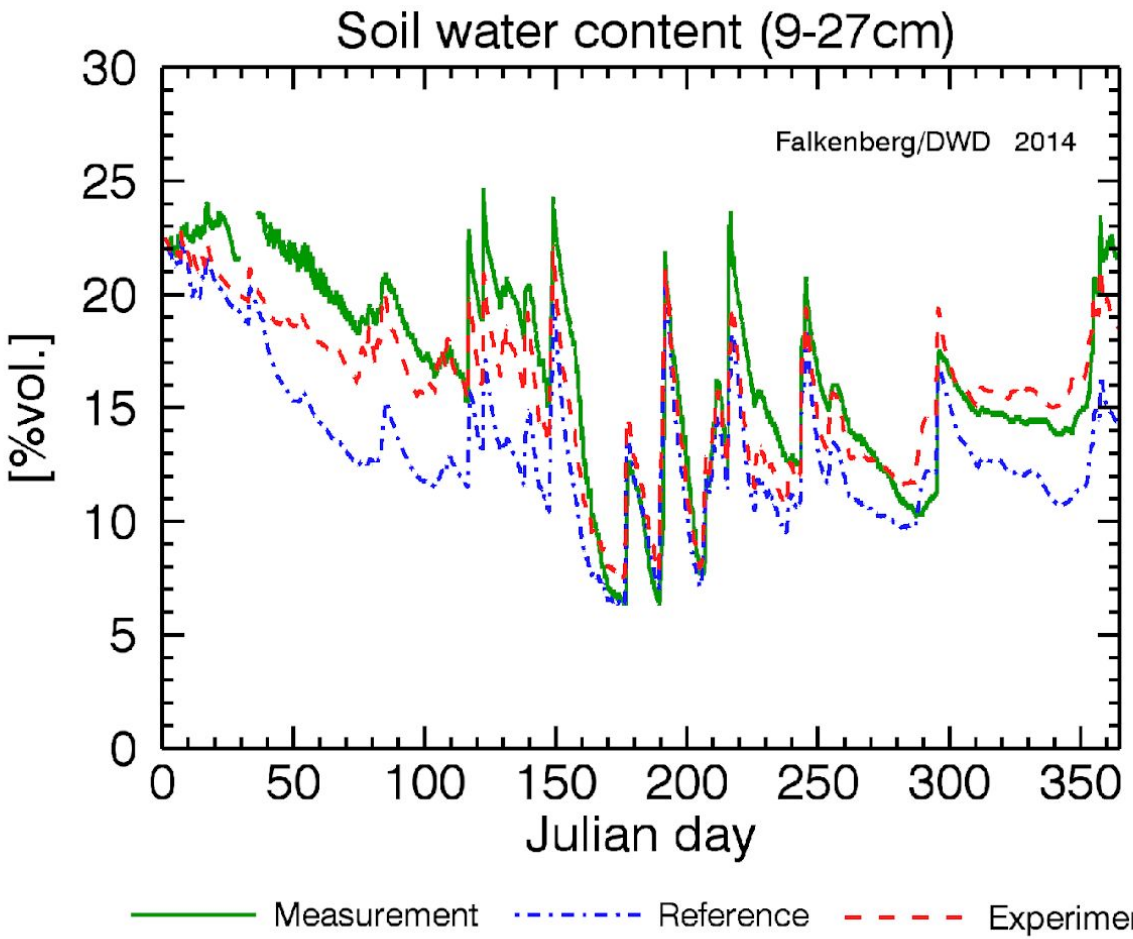
Feb. 2014

Reduced bare soil evaporation simulated by resistance method improves the total latent heat flux substantially compared to BATS



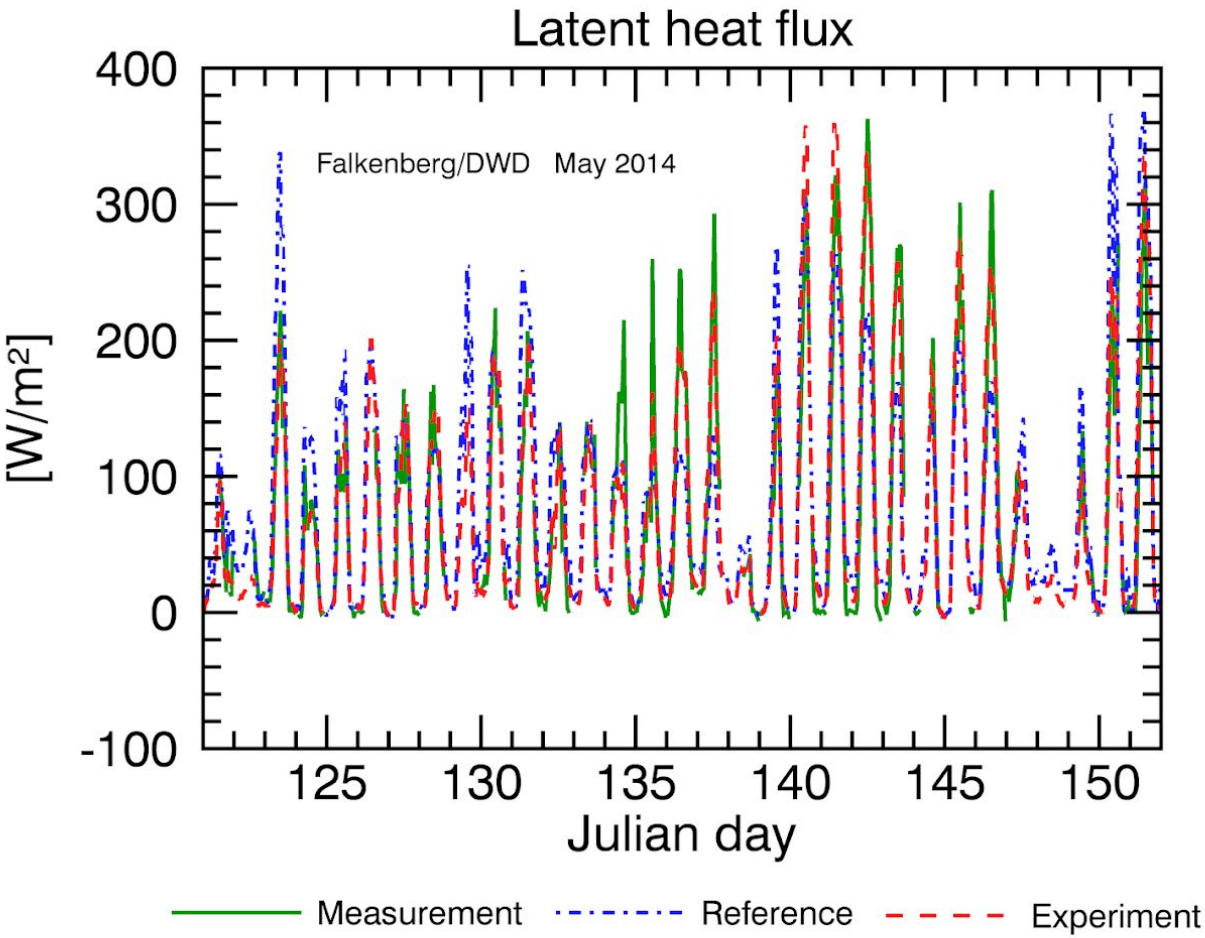
19-28 Feb. 2014

Reducing latent heat flux by the resistance method increases daily maximum surface temperatures, correcting for a cold bias by BATS



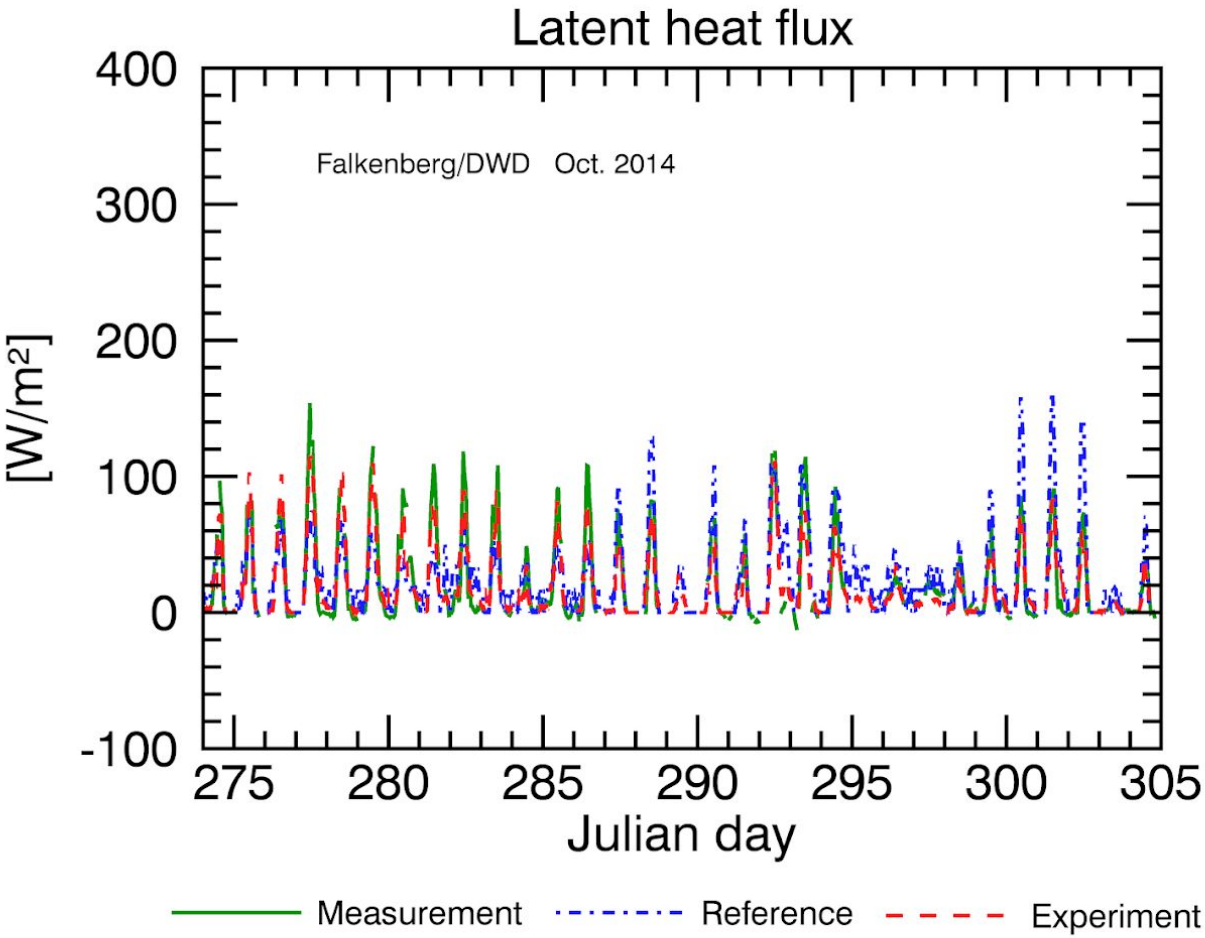
2014

Reduced bare soil evaporation simulated by resistance method reduces drying of the soil considerably, annual cycle of soil moisture much improved compared to BATS



May 2014

Latent heat flux improved by resistance method both under wet conditions (reduced) as well as under dry conditions (increased) compared to BATS


Latent heat flux
Falkenberg/DWD Oct. 2014
[W/m²]
400
300
200
100
0
-100
275
280
285
290
295
300
305
Julian day
Measurement
Reference
Experiment

Oct. 2014

Conclusions

- The bare soil evaporation in TERRA, simulated by the BATS scheme, is systematically overestimated under medium-wet to wet conditions. This behaviour is reversed under medium-dry to dry conditions.
- An overestimated evaporation and latent heat flux, respectively, lead to a dry bias in the soil, moist and cold biases in the near-surface atmosphere, and an underestimated diurnal near-surface temperature range.
- A new formulation of the bare soil evaporation, based on the resistance method, was developed and implemented in TERRA. Experiments in offline mode, utilizing measurements of the Lindenberg/Falkenberg site, show substantial improvements with respect to moisture and temperature errors.
- Experiments in coupled mode, with ICON, show improvements as well.

An improved representation of the surface temperature including the effects of vegetation in the land surface scheme TERRA

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The problem …

- 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.
- In TERRA, there is no representation of the vegetation in the surface energy balance. This means, there is no energy budget including a temperature for the vegetation layer (canopy temperature missing).
- The insulating effects by the vegetation at the sub-canopy level are missing.
- Including these two effects in TERRA can improve the simulation of surface and of soil temperatures (see e.g. Deardorff 1978, Schulz et al. 1998, or Vogel et al. 2015).

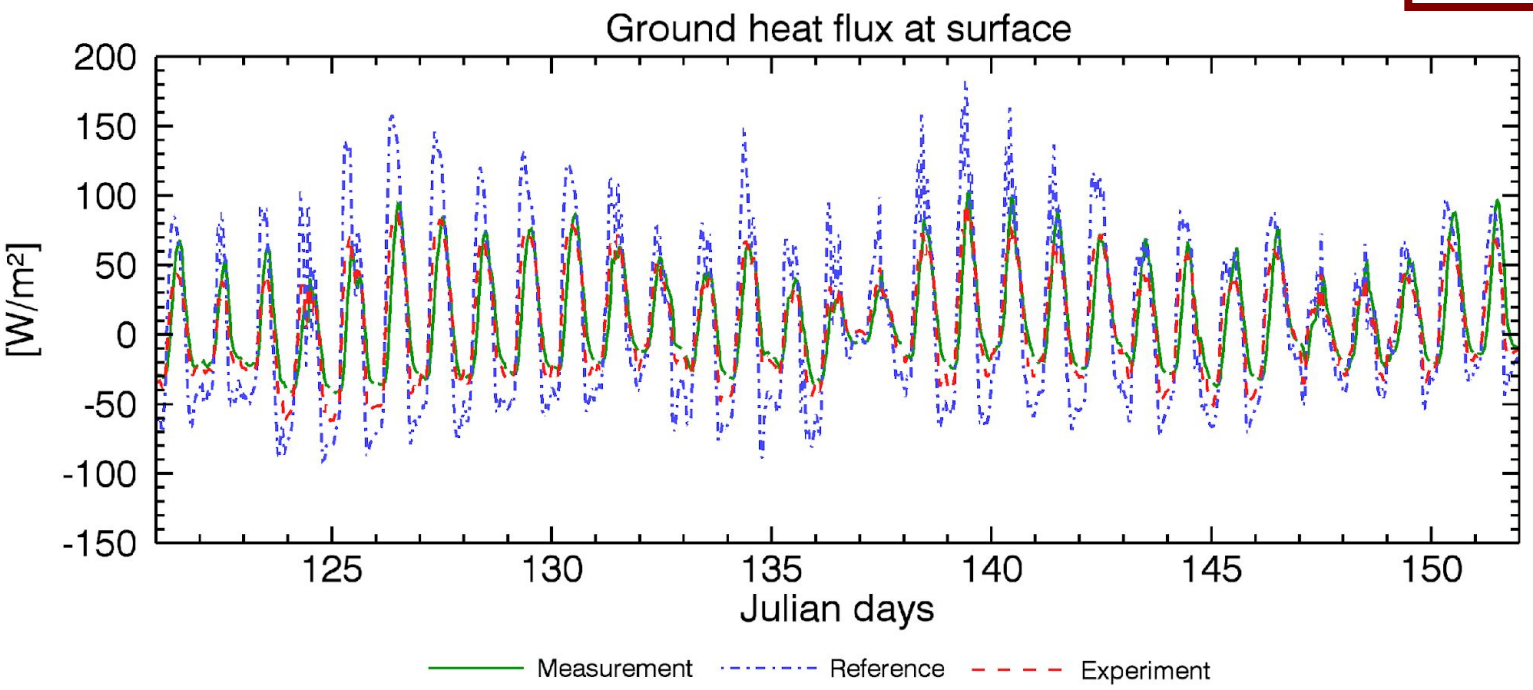
Conductivity relates ground heat flux to temperature difference between skin layer and lowest atmospheric level

$$R_{net} + Lhfl_s + Shfl_s = \lambda_c(T_{sk} - T_1)$$

After Viterbo and Beljaars (1995)

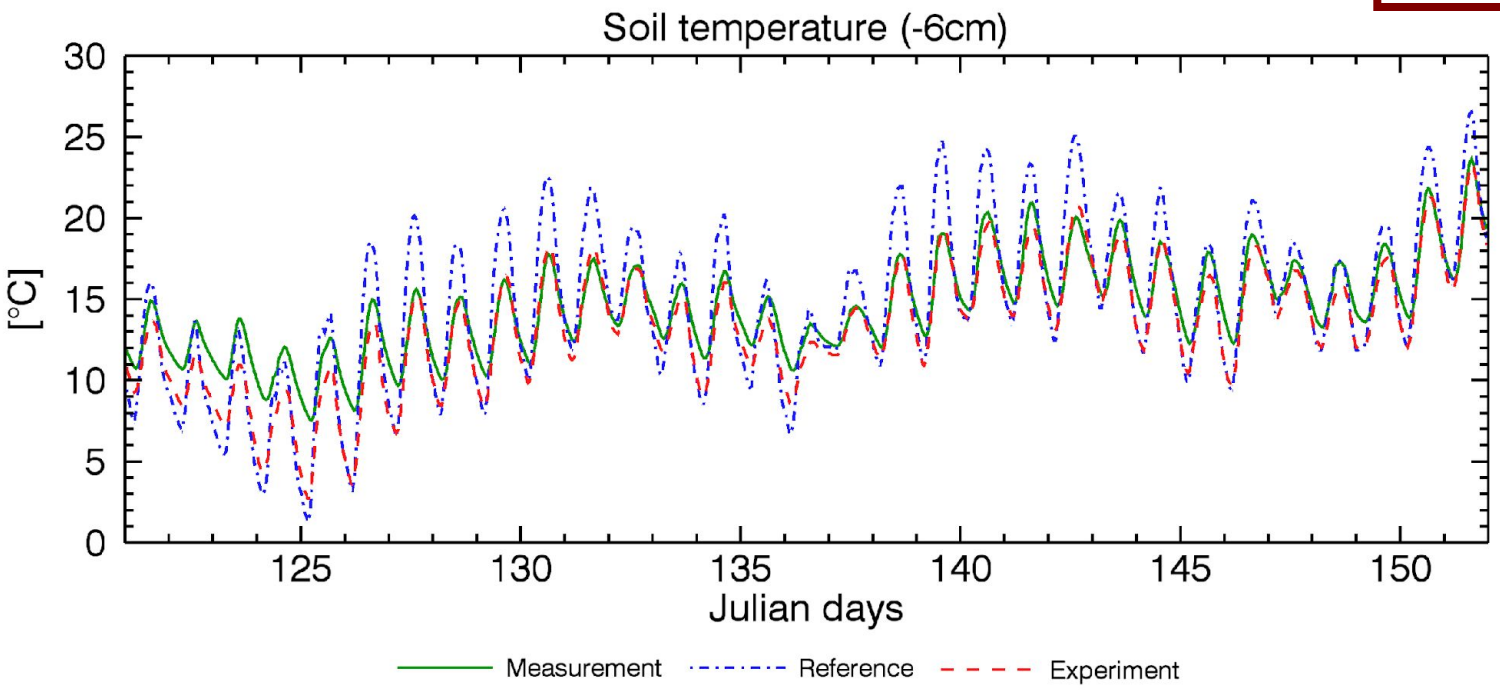
Model forcing with observations from Lindenberg site

May 2011



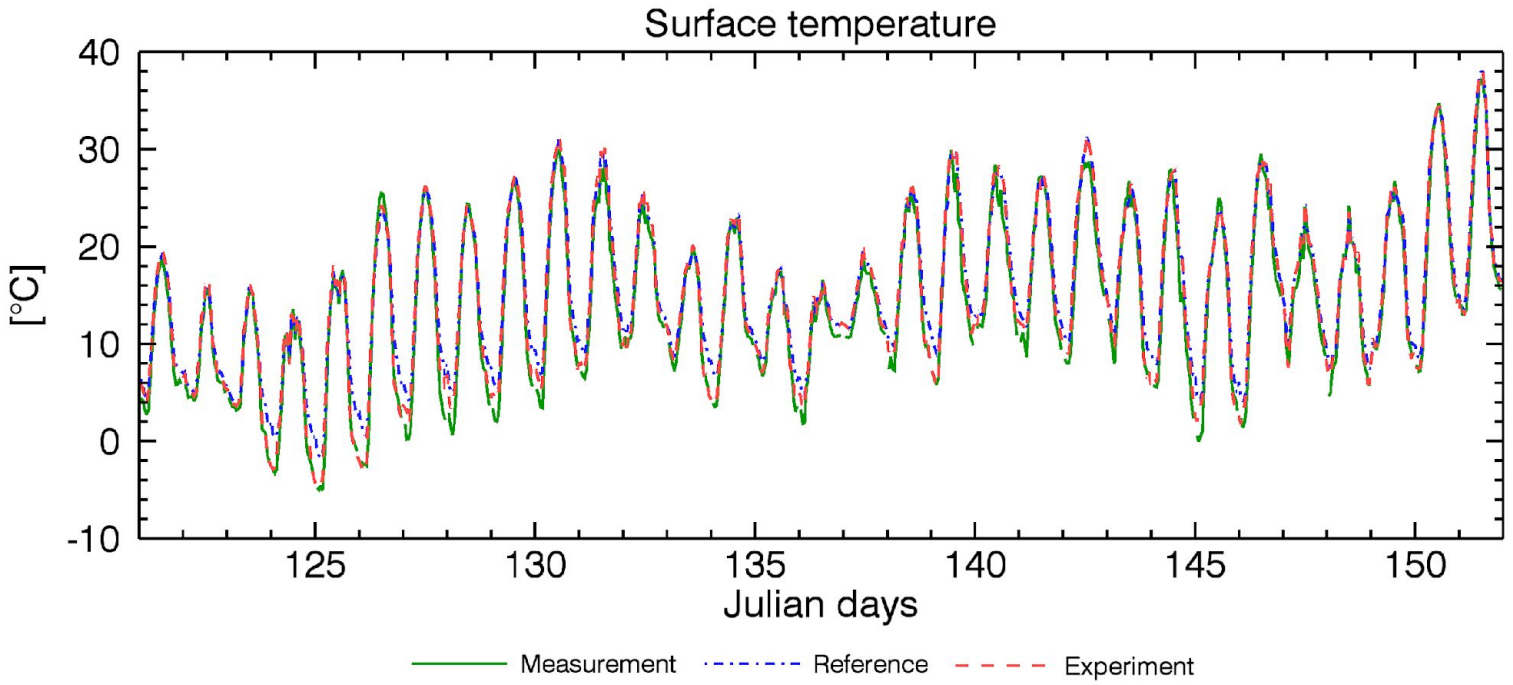
Ground heat flux substantially overestimated by TERRA, with the skin temperature formulation it is significantly reduced and much closer to the measurements

May 2011



Amplitudes of the diurnal cycles of the soil temperatures in TERRA are systematically overestimated, with the skin temperature formulation they are considerably reduced and therefore improved

May 2011



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

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, COSMO-DE, COSMO-CLM) show improvements as well.
- There are two alternative canopy formulations in TERRA by M. Raschendorfer and J. Helmert which can be used for comparison.