

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

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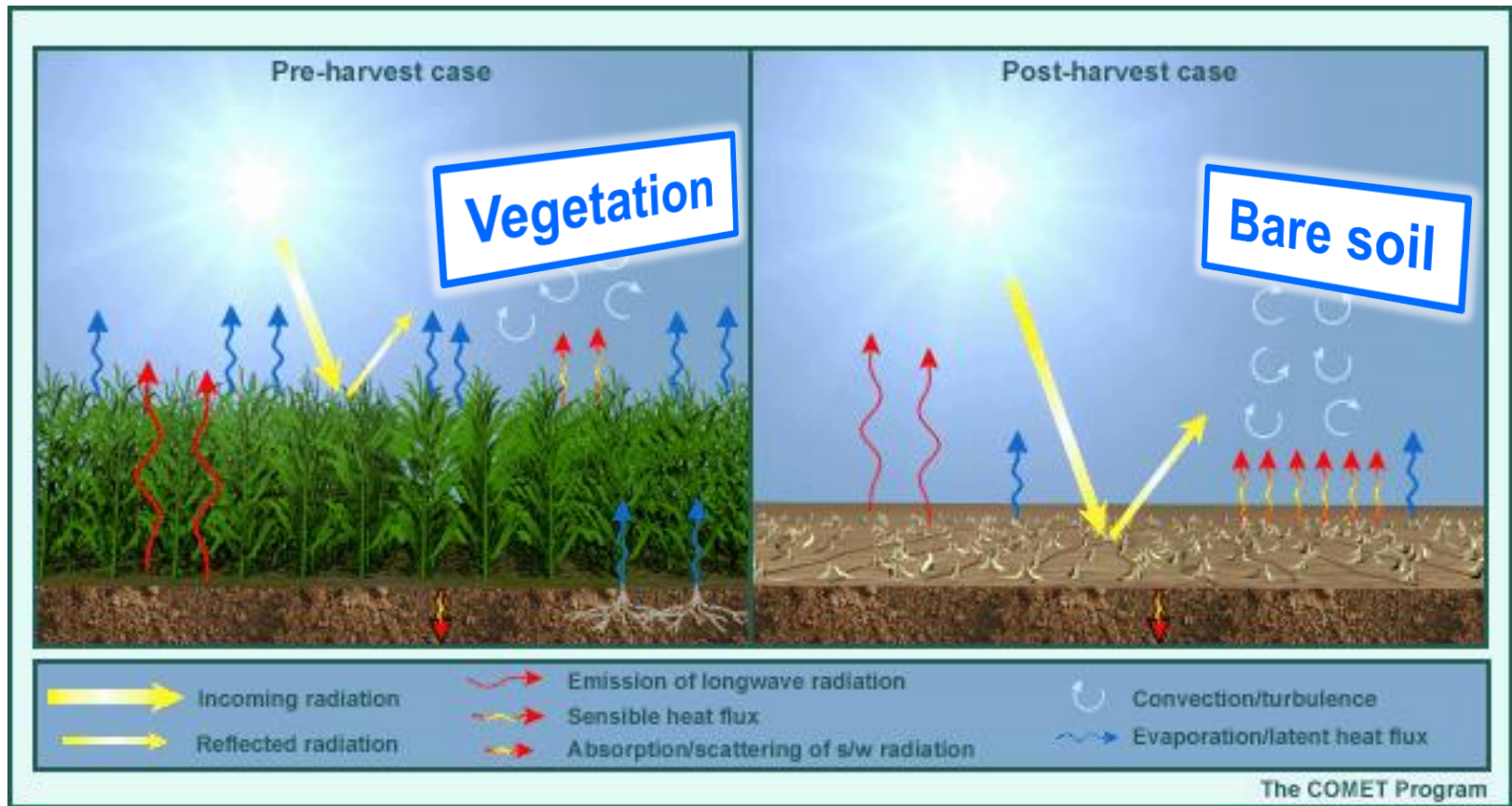
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COSMO / CLM / ICON / ART User Seminar, 6 - 8 Mar. 2017, Offenbach



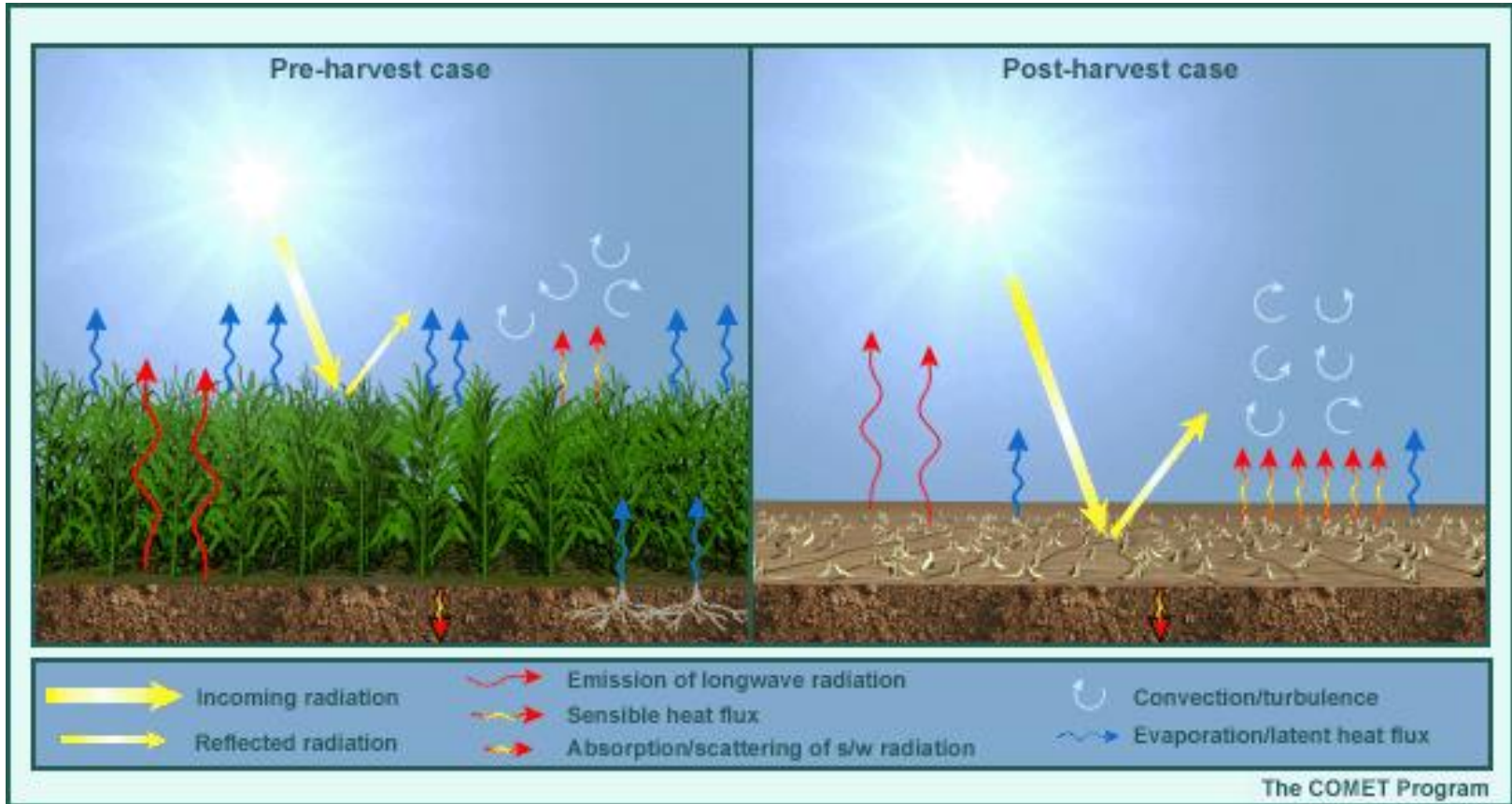
What is the surface temperature in TERRA?



The problem ...

- The amplitude of the diurnal cycle of the **surface temperature** in TERRA is systematically **underestimated**.
- This typically creates a
 - **cold** bias of near-surface temperature during daytime,
 - or a **warm** bias of near-surface temperature during nighttime,
 - 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**.

Shading



In TERRA the insulating effects by the vegetation at the sub-canopy land surface are not represented. The incoming solar radiation is directly used in the surface energy balance, modifying the other energy terms in an unrealistic way.

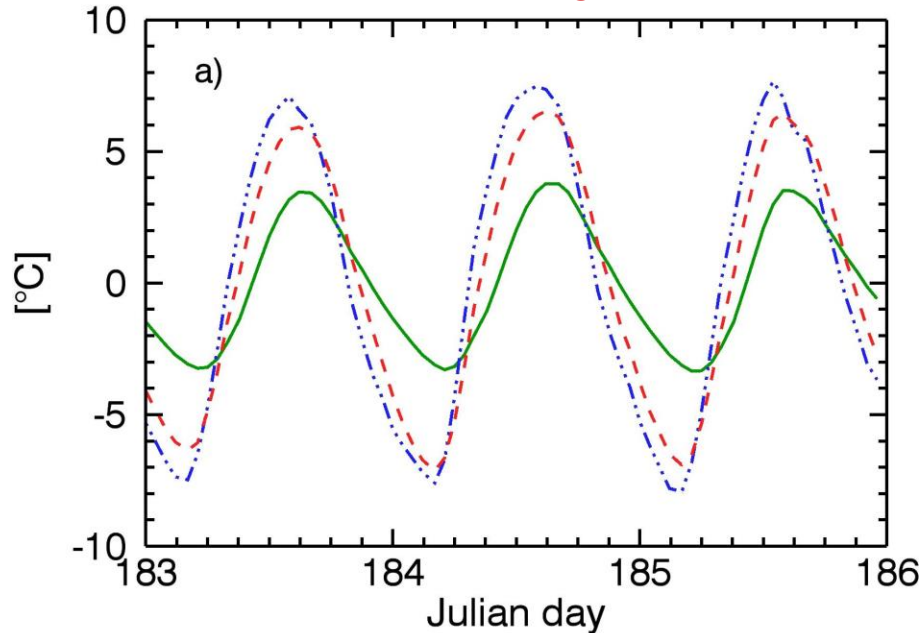
Schulz, J.-P., G. Vogel, C. Becker, S. Kothe, U. Rummel and B. Ahrens, 2016: Evaluation of the ground heat flux simulated by a multi-layer land surface scheme using high-quality observations at grass land and bare soil. Meteor. Z., 25, 607-620.



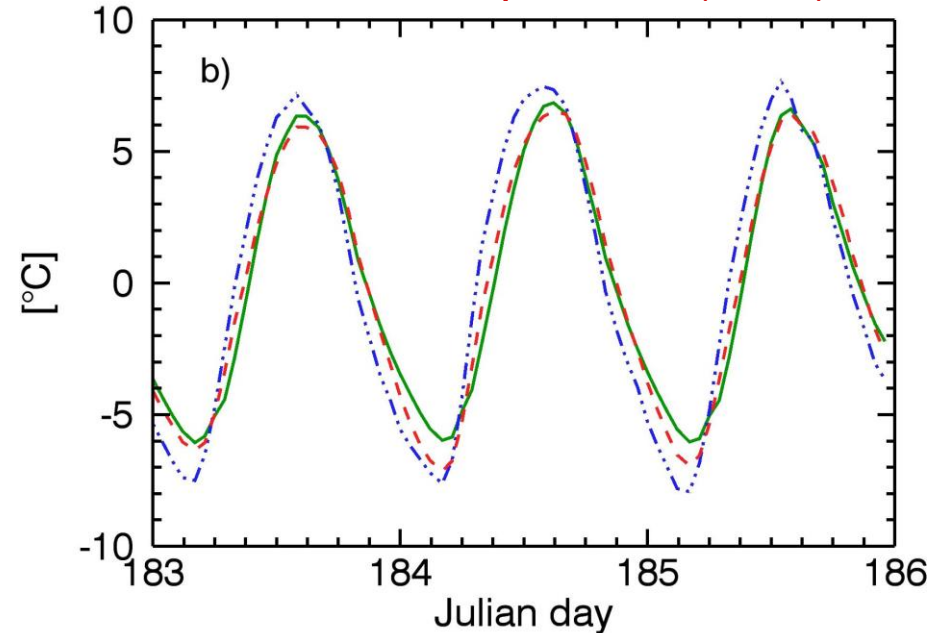
Offline TERRA: Falkenberg 2 - 4 July 2010

Thermal conductivity: Johansen

Soil temperature, grass (-6cm)



Bare soil temperature (-6cm)

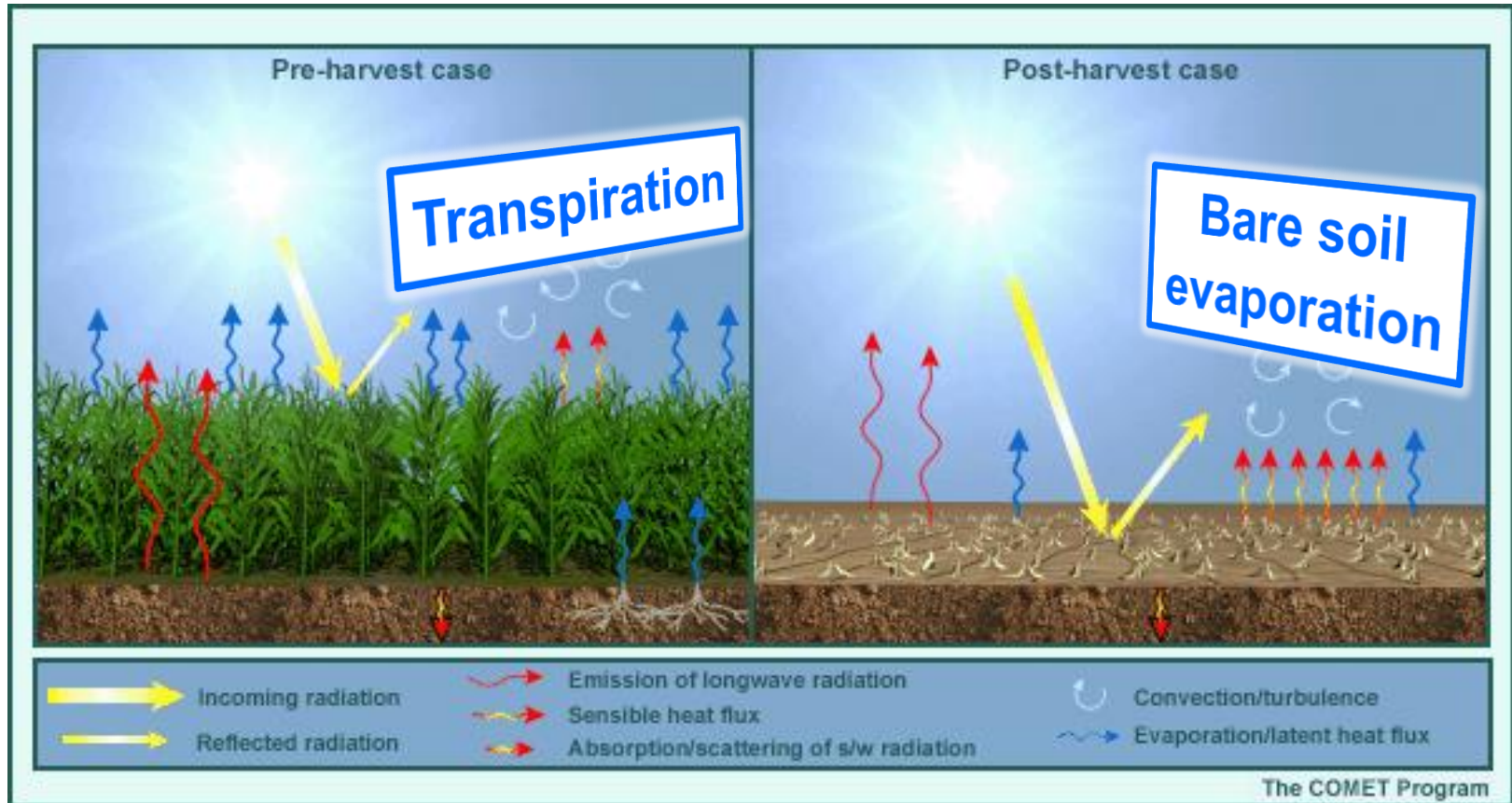


— Measurement ····· Reference - - - Johansen

- Bare soil temperature is well represented by TERRA
- **Measurements**: Diurnal temperature range reduced by shading by factor of 2, this is not captured by TERRA



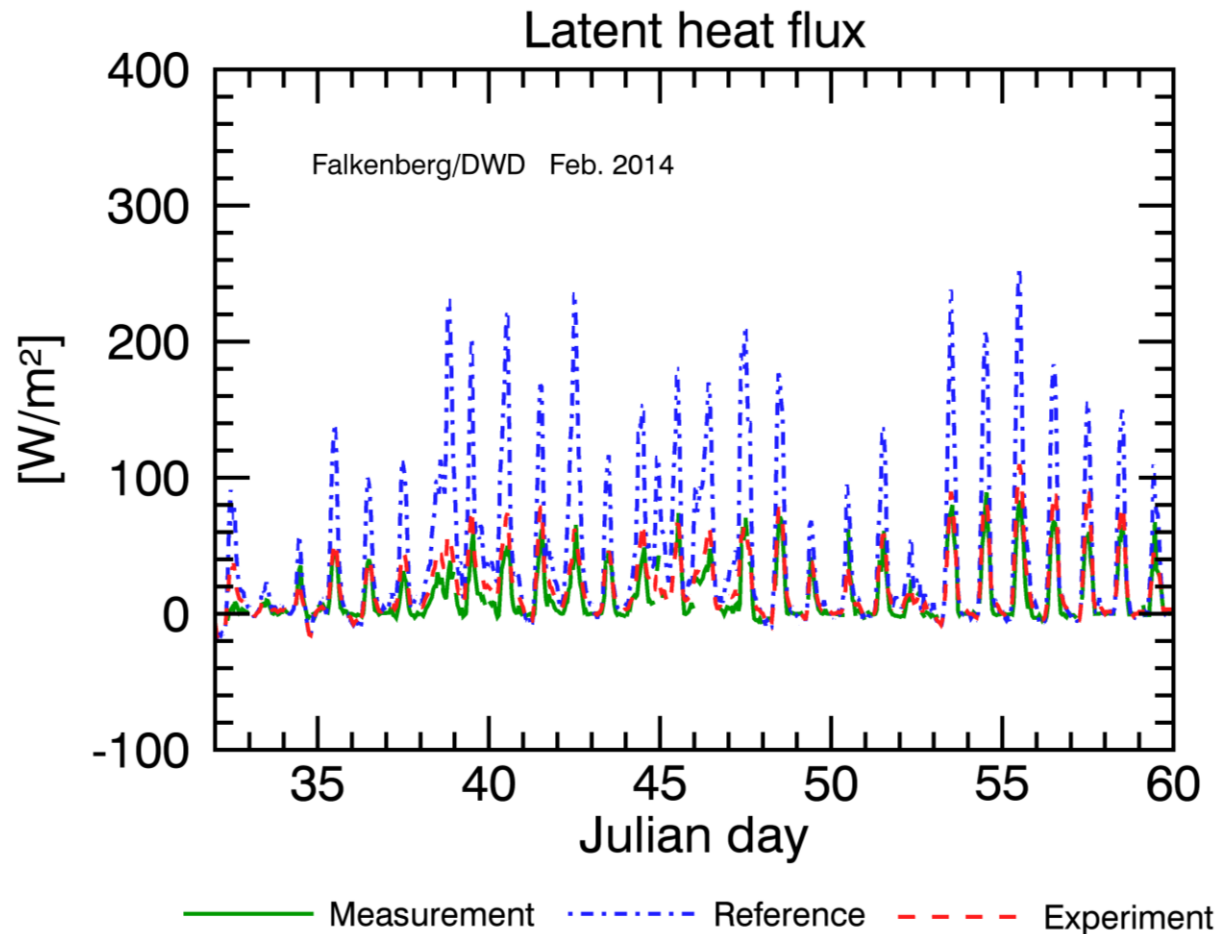
Bare soil evaporation



A new formulation of the bare soil evaporation, based on the resistance method, was developed and implemented in TERRA. Experiments show substantial improvements with respect to moisture and temperature errors.

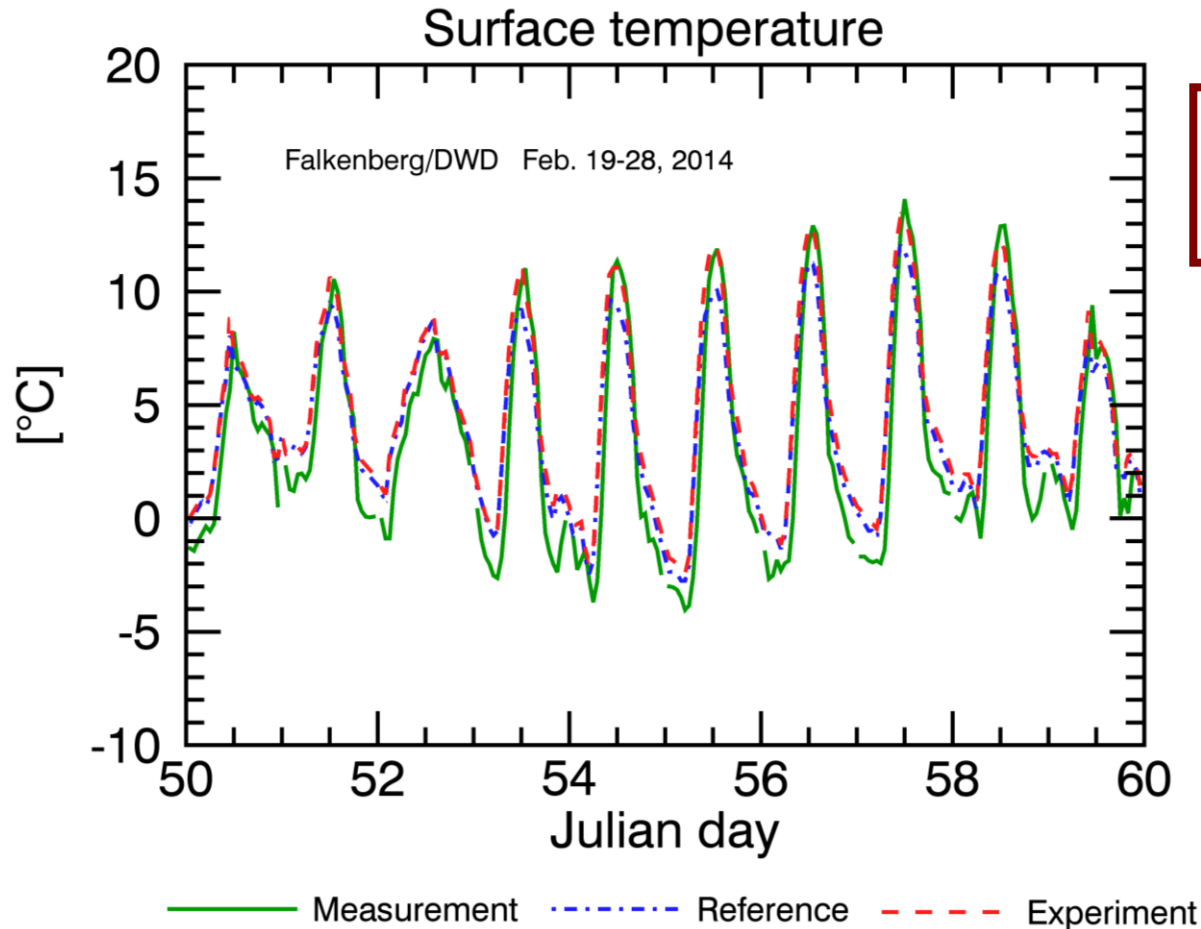
Schulz, J.-P. and G. Vogel, 2016: A new parameterisation of bare soil evaporation for the land surface scheme TERRA of the COSMO atmospheric model. COSMO / CLM / ART User Seminar 2016.





Feb. 2014

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

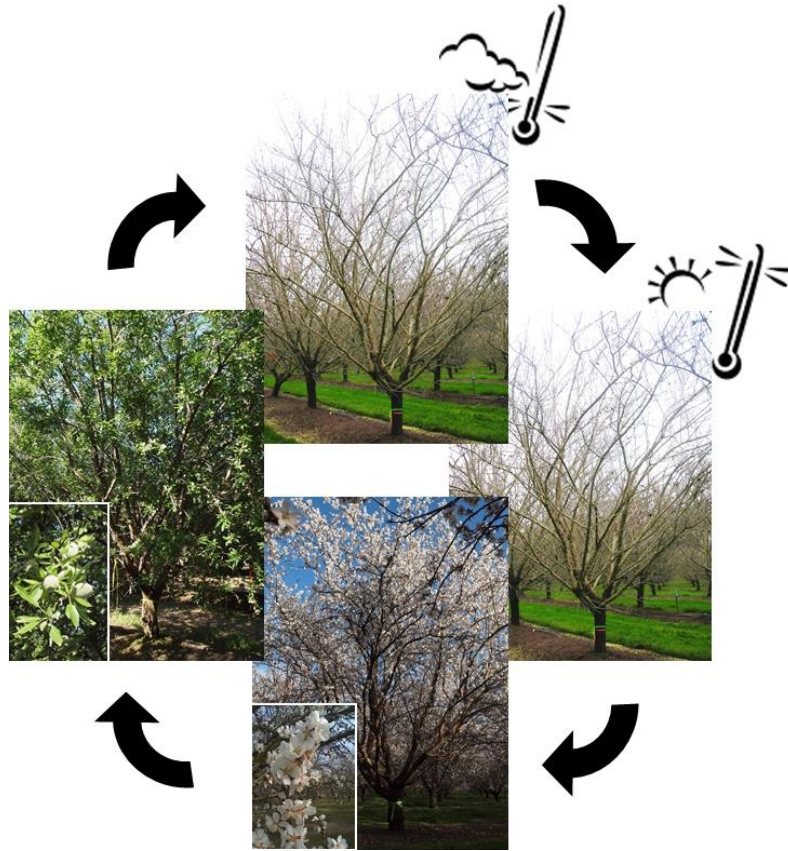


**19-28 Feb.
2014**

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

Phenology

Phenological stages in the production of almonds

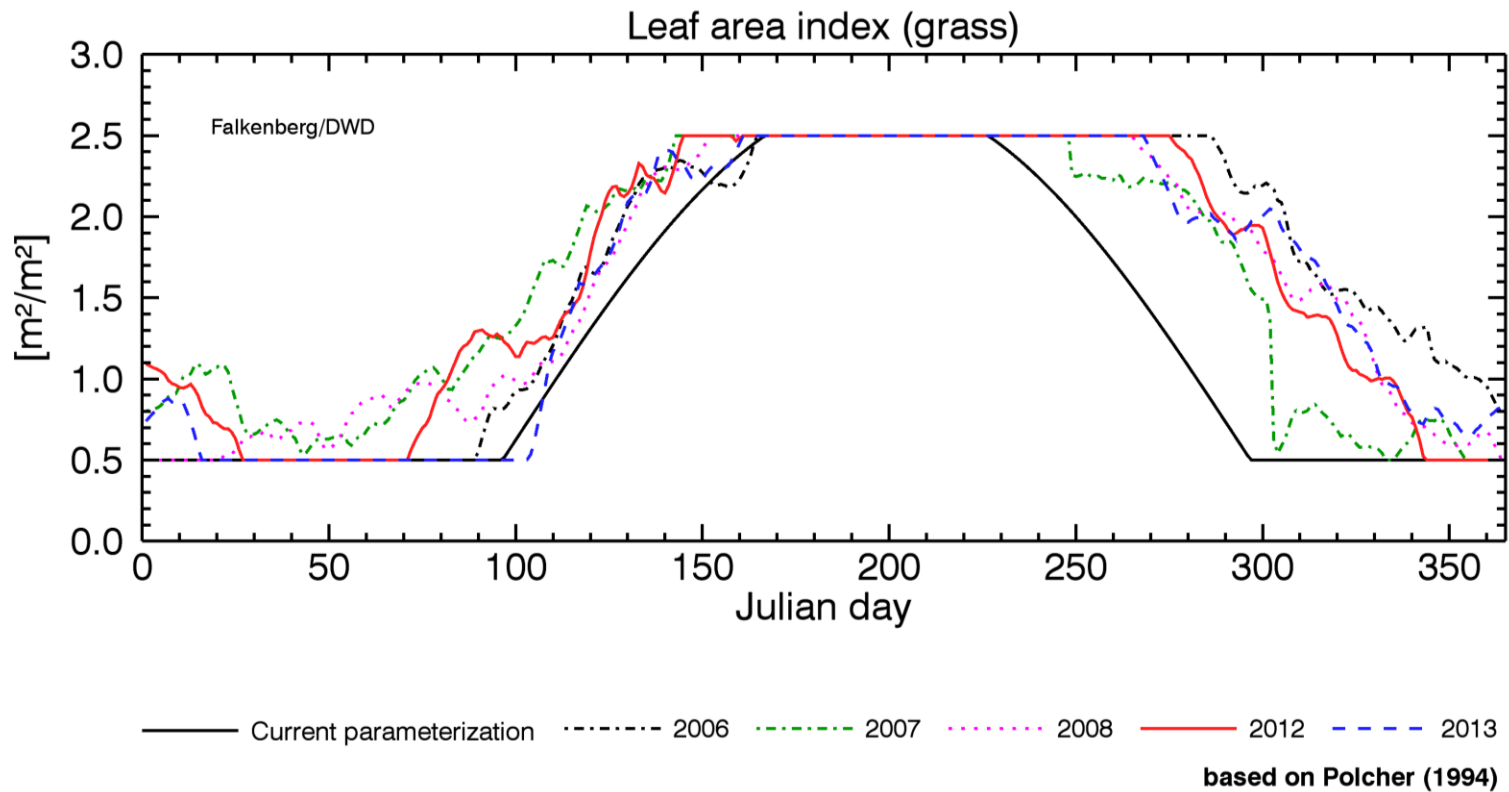


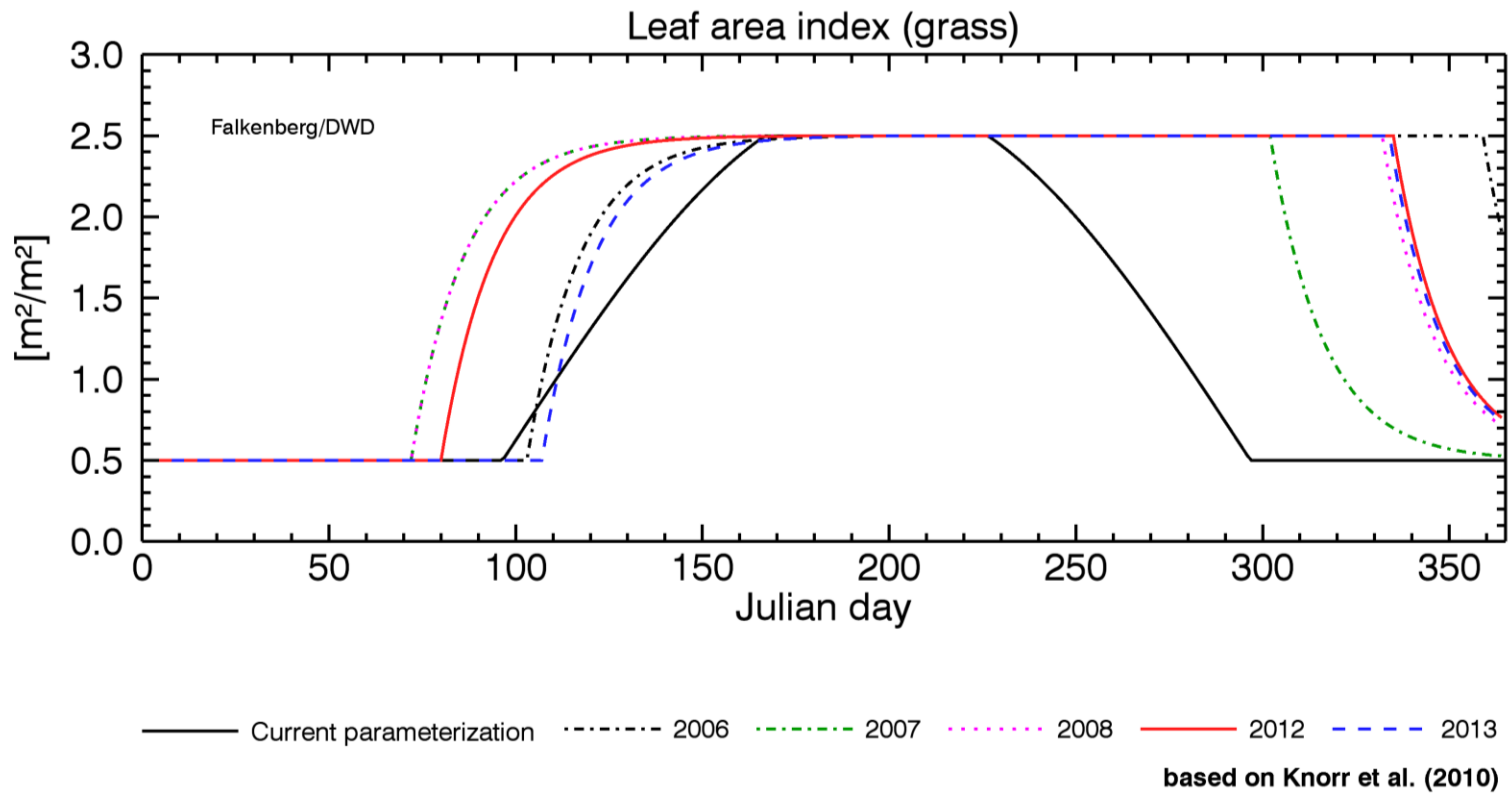
<http://treephenology.ucdavis.edu/>

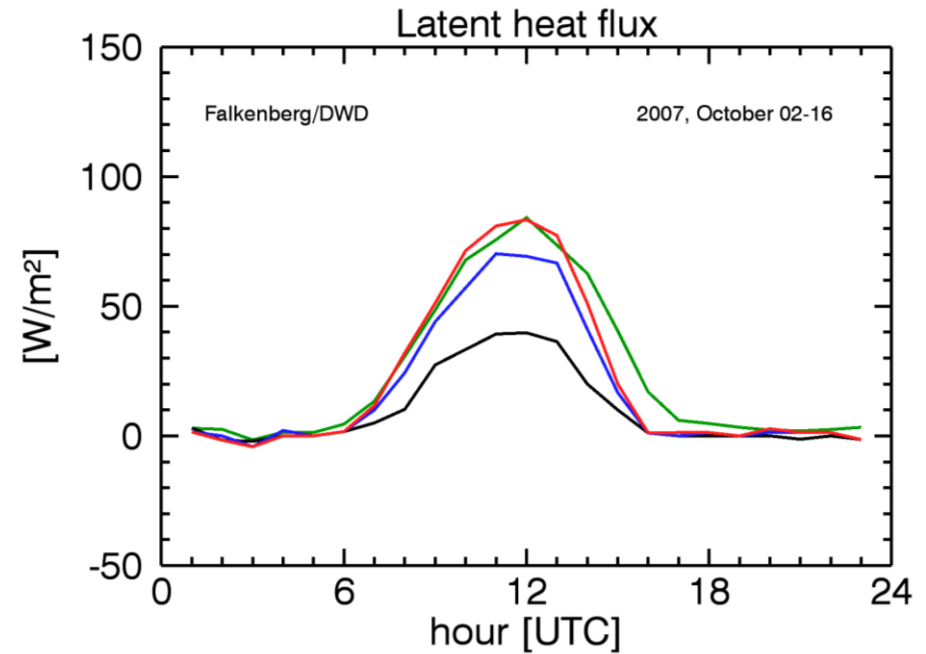
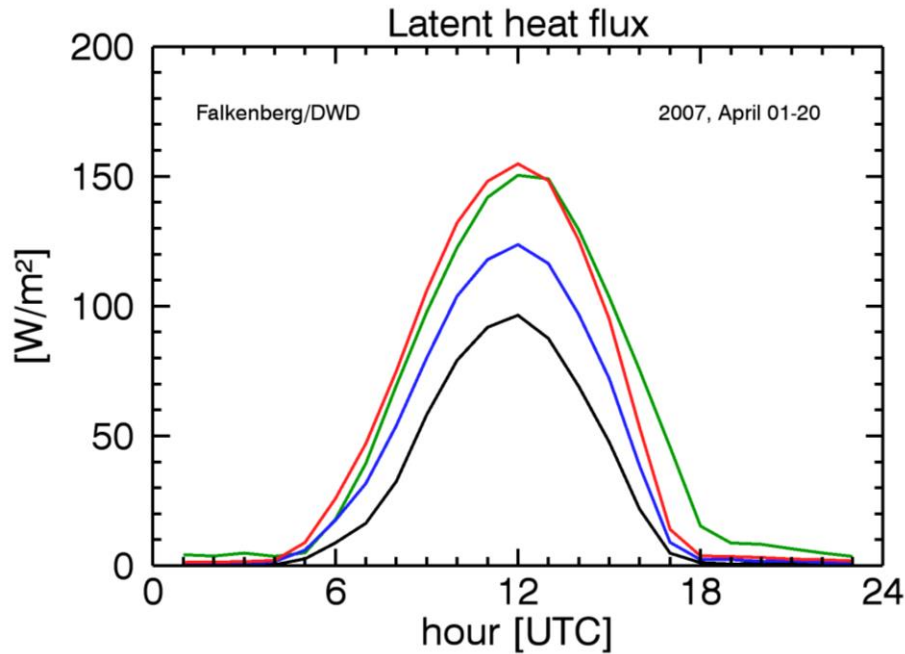
With the current parameterisation TERRA can not account for the inter-annual variability of the phenology. Different approaches for simulating the seasonal cycle of phenology were implemented and tested in TERRA.

Schulz, J.-P., G. Vogel and B. Ahrens, 2015: A new leaf phenology for the land surface scheme TERRA of the COSMO atmospheric model. COSMO Newsletter, 15, 21-29.









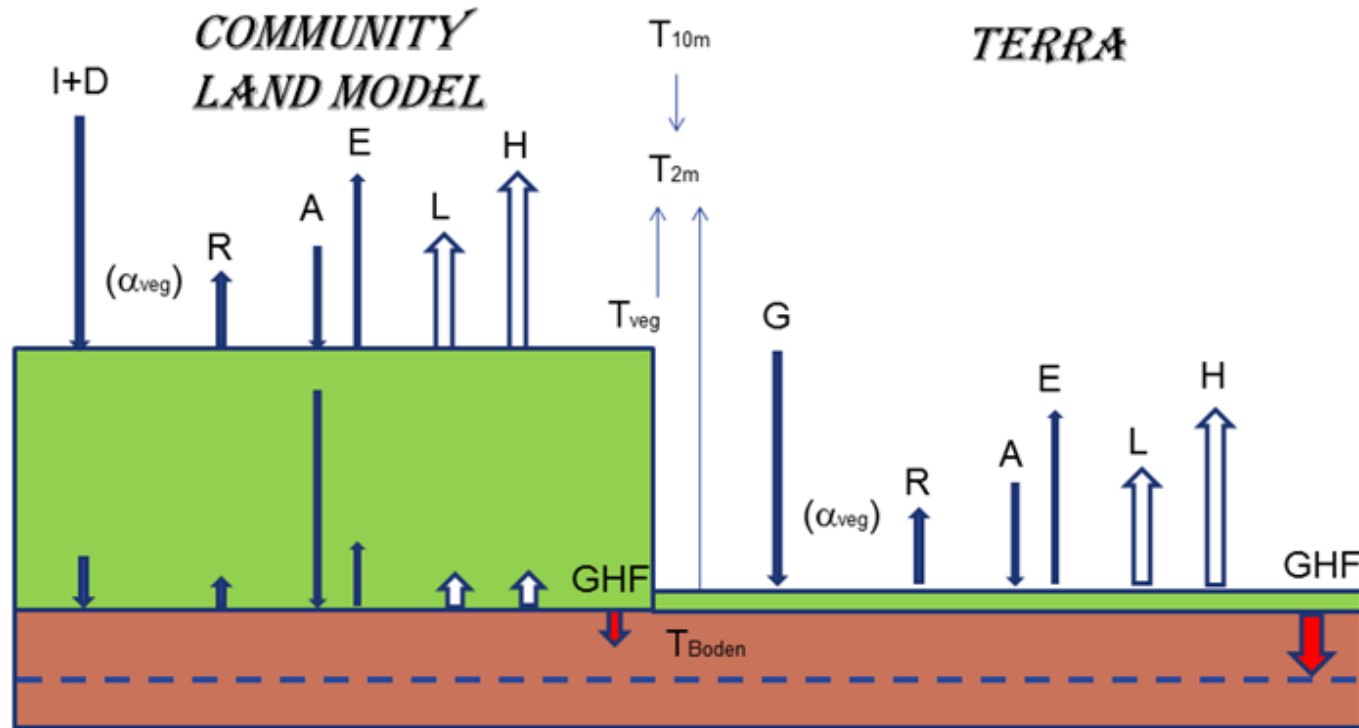
- Measurement
- LAI current parameterization
- LAI adopted from Polcher (1994)
- LAI adopted from Knorr et al. (2010)

A more realistic leaf phenology in TERRA providing a more realistic leaf area index improves the simulated total latent heat flux substantially, having a positive effect also for the surface temperature

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).

TERRA vs. Community Land Model (CLM)



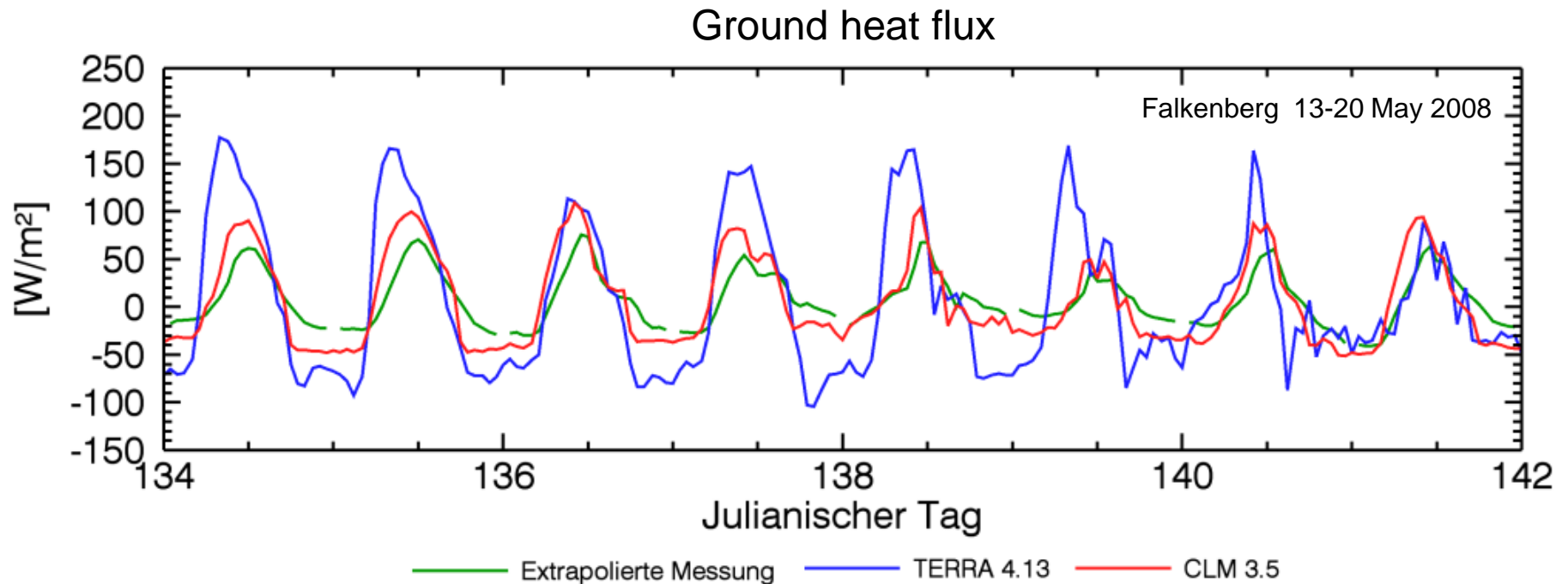
CLM includes:

- Energy budget for vegetation, including T_{veg}
- Insulation by vegetation

Vogel, G., P. Shrestha, J.-P. Schulz, C. Becker und U. Rummel, 2015: Modelluntersuchungen zum Einfluss der solaren Abschattung auf die Erdbodentemperaturen in Falkenberg. Deutscher Wetterdienst, MOL-RAO Aktuell 3/2015, Lindenberg, 2 pp.

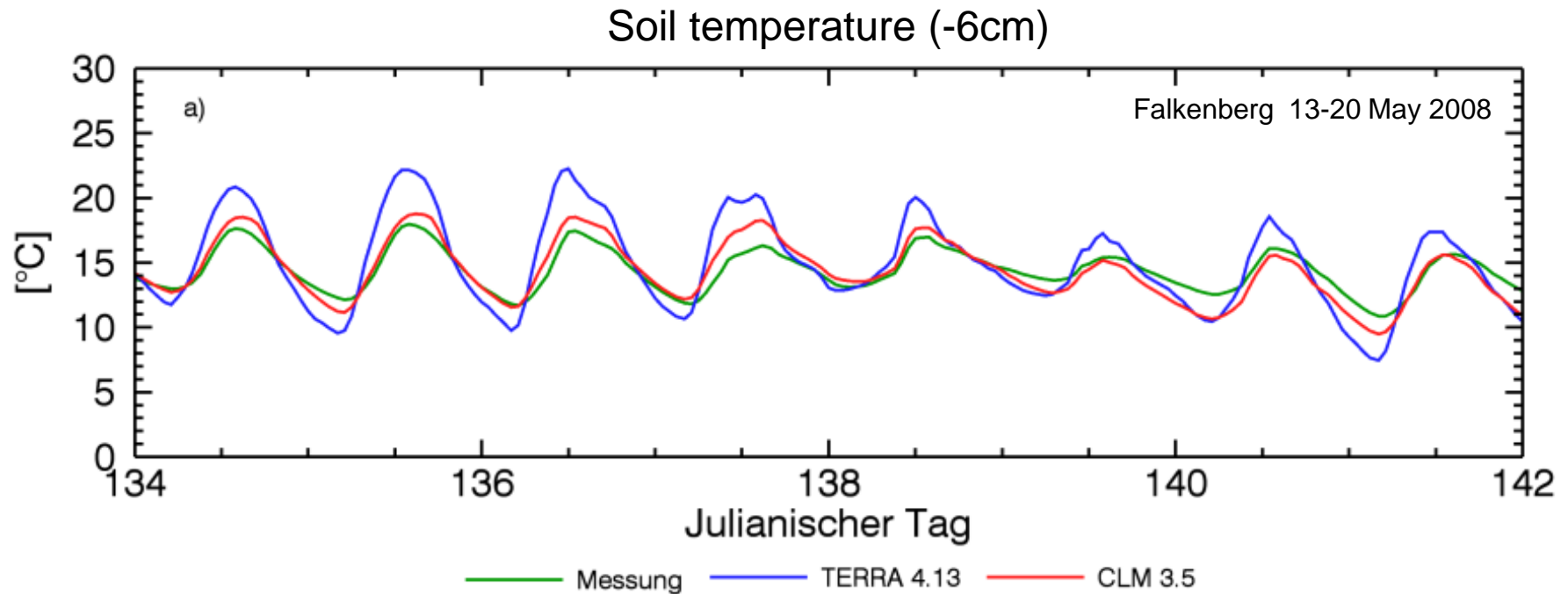


Offline TERRA vs. CLM



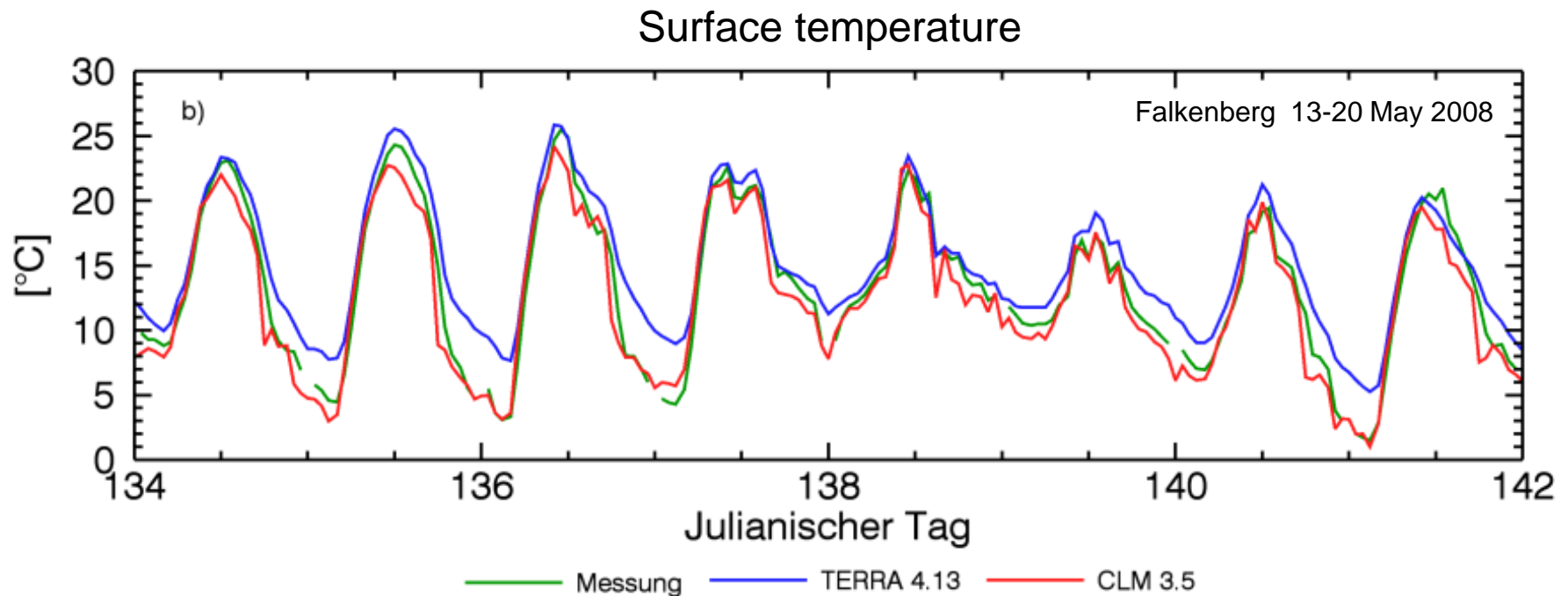
Ground heat flux substantially overestimated by TERRA, in CLM it is significantly reduced and much closer to the measurements

Offline TERRA vs. CLM



Amplitudes of the diurnal cycles of the soil temperatures in TERRA are systematically overestimated, in CLM they are considerably reduced and therefore improved

Offline TERRA vs. CLM



Amplitude of the diurnal cycle of the surface temperature in TERRA is systematically underestimated, with a nocturnal warm bias of up to 5 K, in CLM it is substantially increased and much closer to the measurements

Surface temperature 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

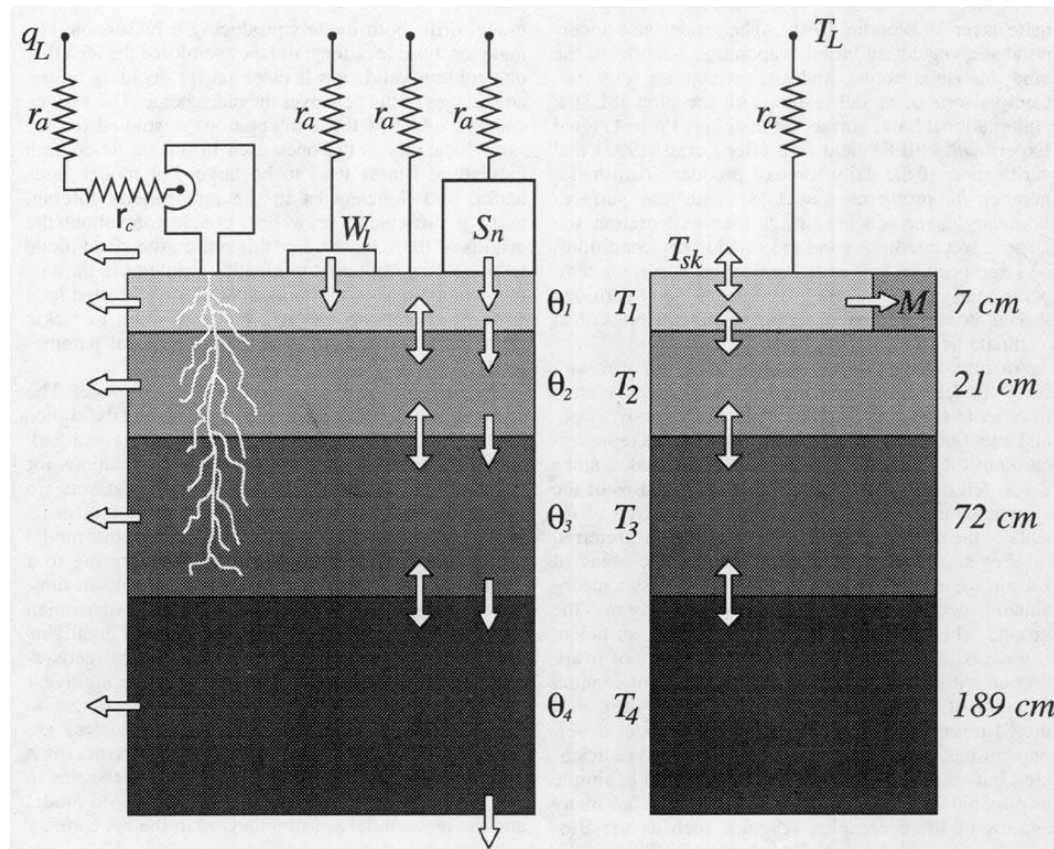
Λ_{sk} : skin layer conductivity

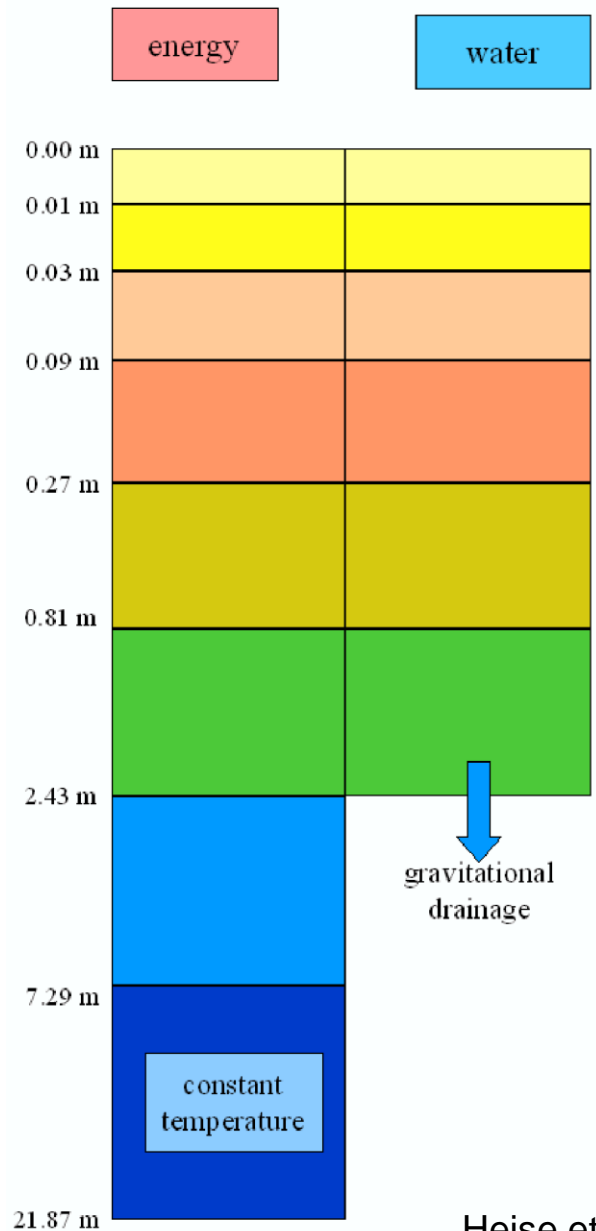
R_{SW}, R_{LW} : net shortwave radiation flux, net longwave radiation flux

LE, H : latent heat flux, sensible heat flux

Skin temperature in IFS

(Viterbo and Beljaars 1995)





Heise et al. (2006)

Land surface scheme TERRA

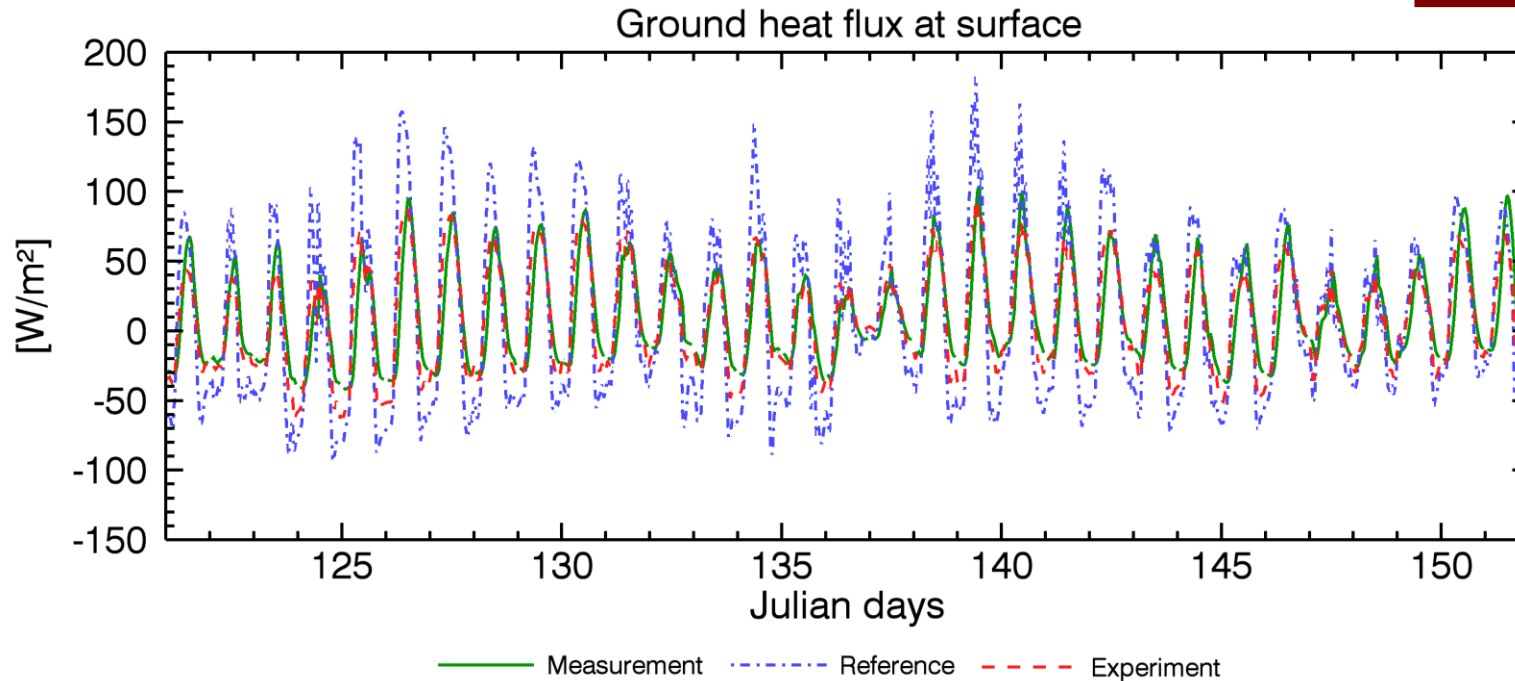
Layers for temperature and
soil water content

Experiments:

- Use atmospheric forcing to run
TERRA in offline mode
- Here, observed forcing from DWD
observatory Lindenberg is used
(Falkenberg site)
- **Reference** : TERRA surface temperature
- **Experiment**: IFS skin temperature

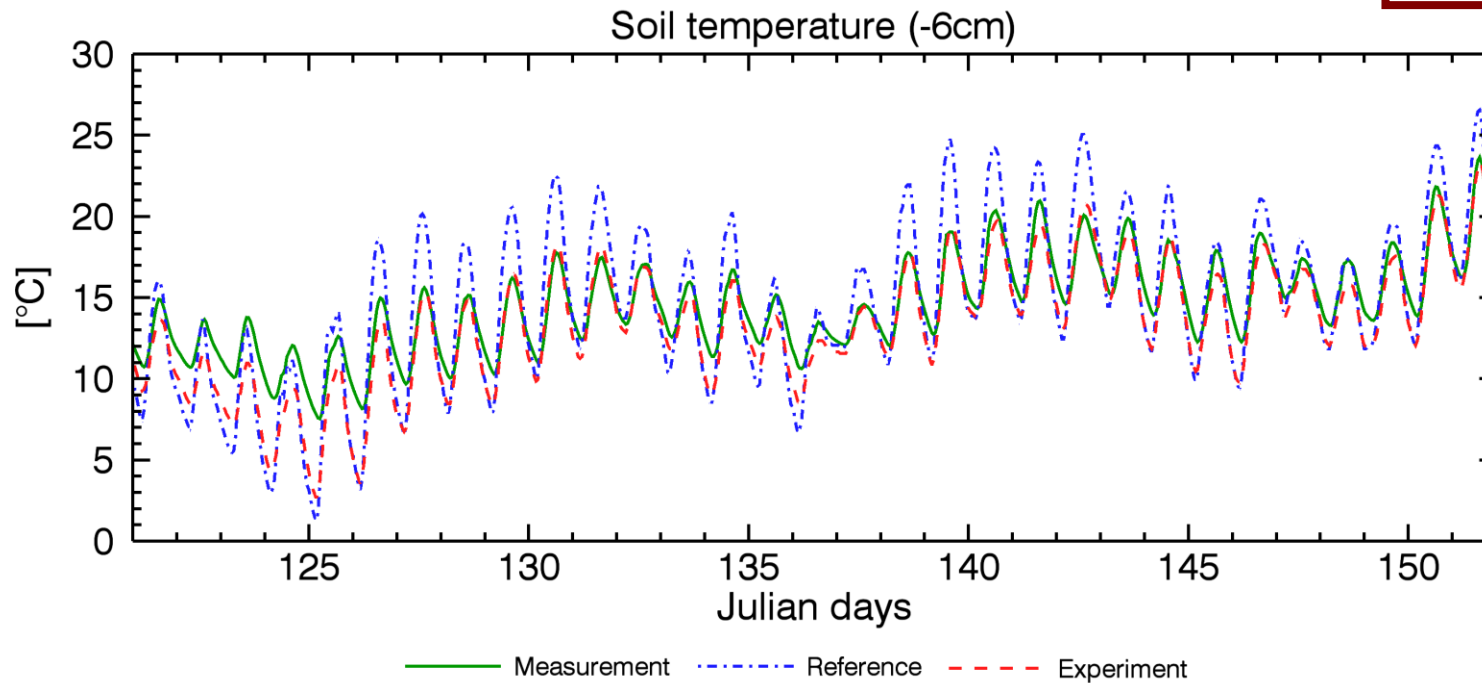


May 2011



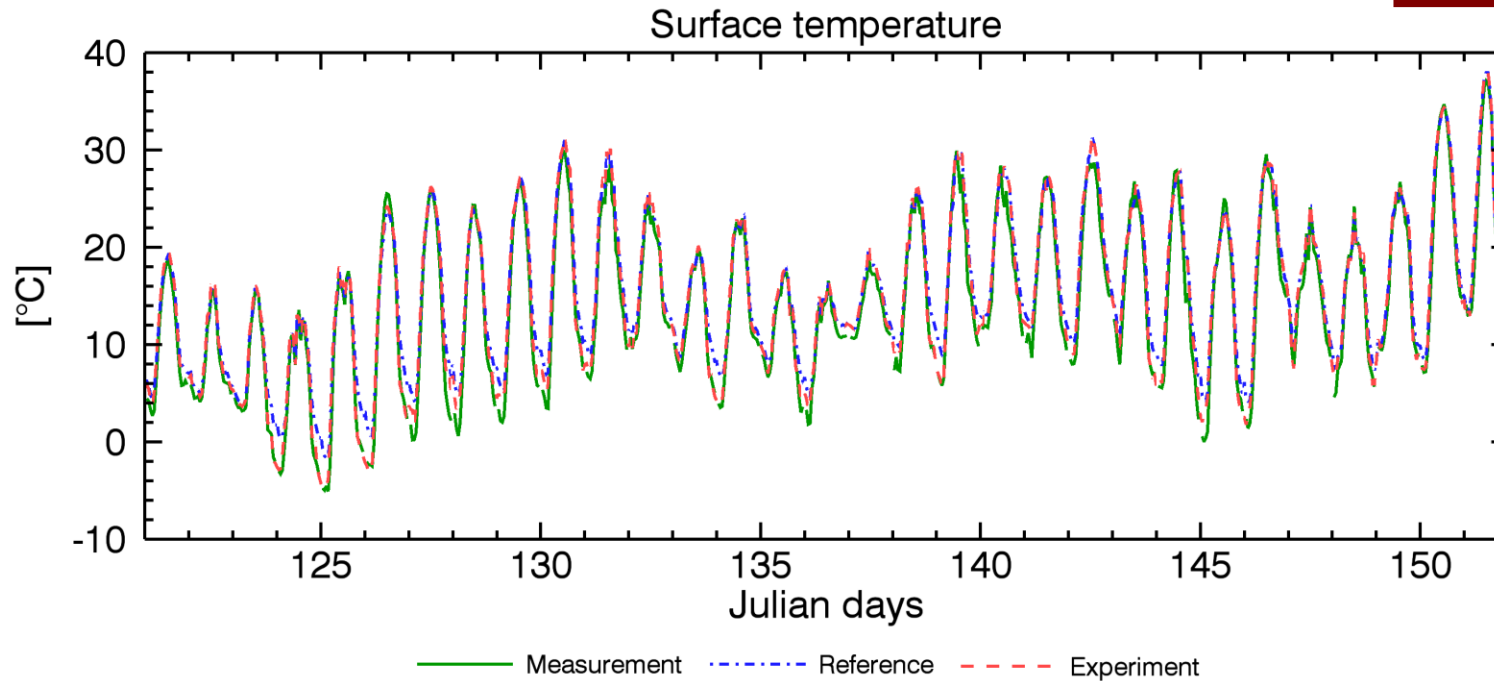
Ground heat flux substantially overestimated by TERRA, with the skin temperature formulation it is significantly reduced and much closer to the measurements

May 2011



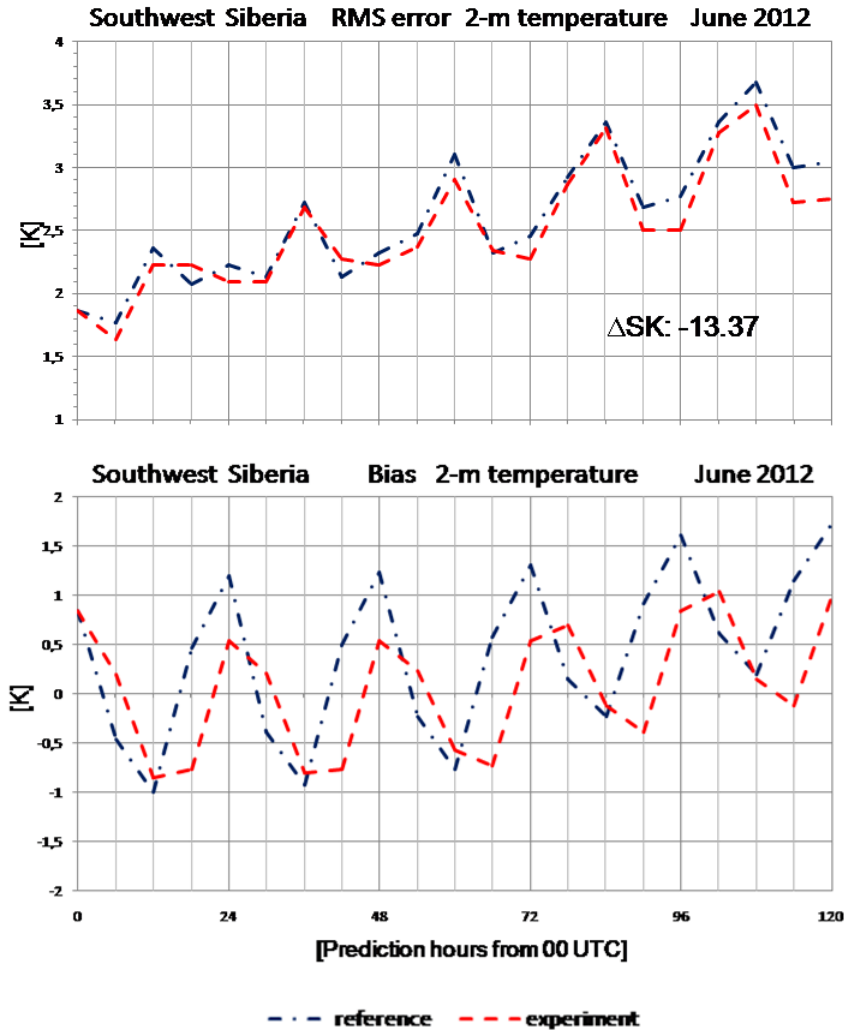
Amplitudes of the diurnal cycles of the soil temperatures in TERRA are systematically overestimated, with the skin temperature formulation they are considerably reduced and therefore improved

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

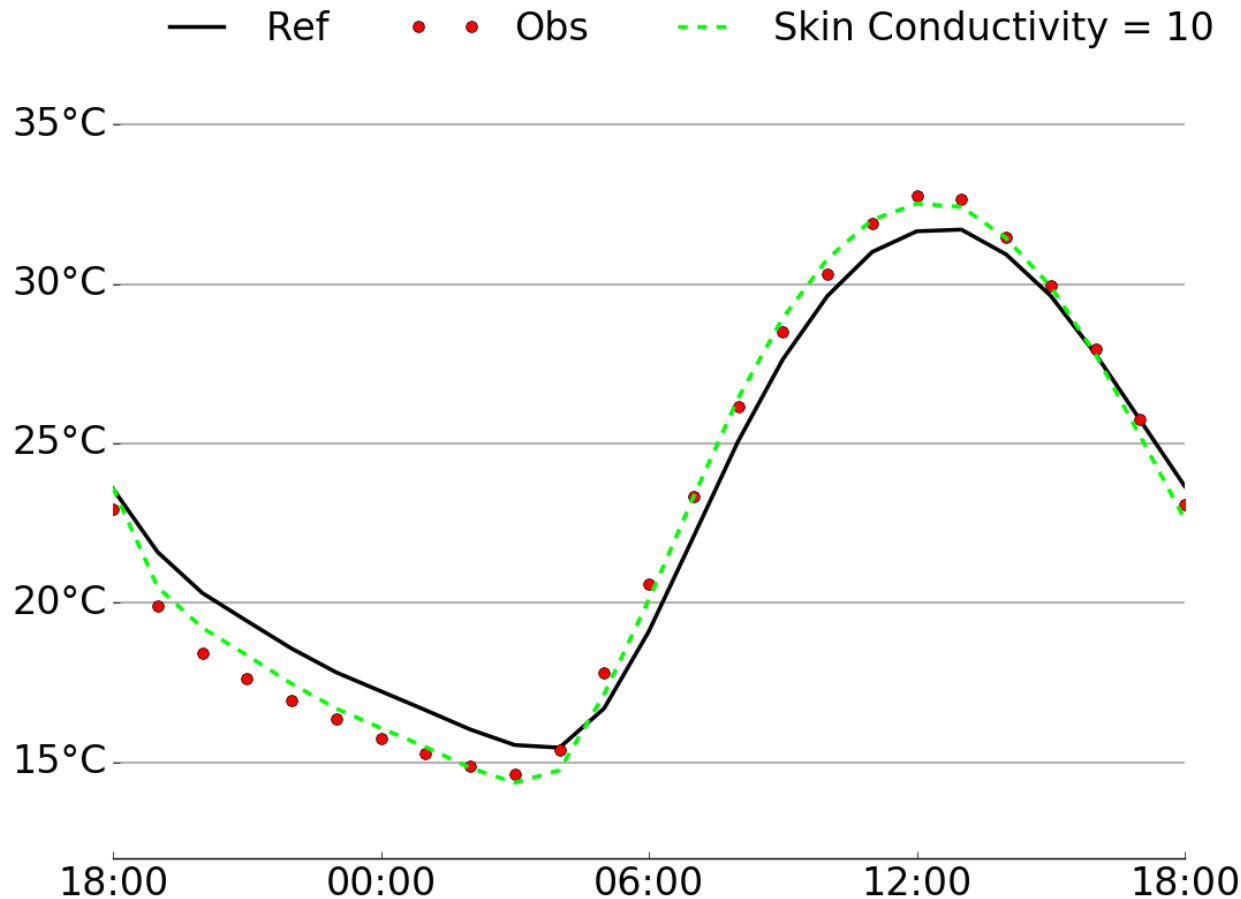
ICON: SW Siberia, June 2012, 00 UTC



Nocturnal warm bias and RMSE of 2-m temperature significantly reduced by skin temperature formulation



COSMO-DE: 1 - 2 July 2015



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

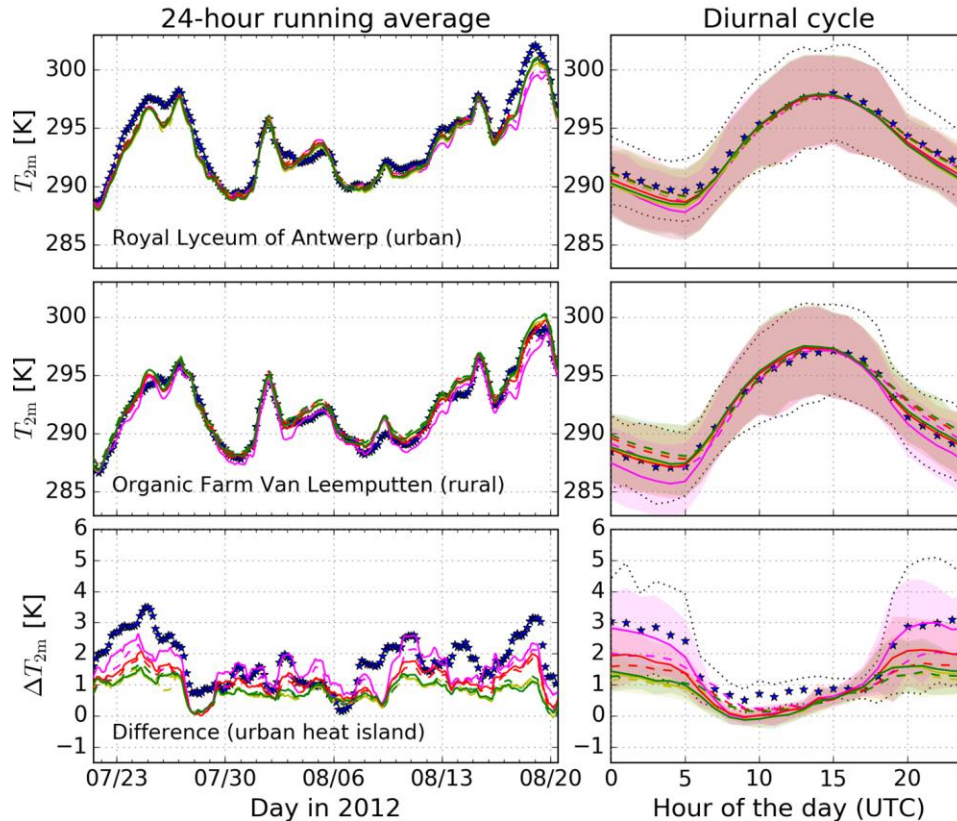
Christine Sgoff, HErZ Frankfurt

Amplitude of the diurnal cycle of the surface temperature in TERRA is systematically underestimated, with the skin temperature formulation it is substantially increased and much closer to the measurements



COSMO-CLM with TERRA-URB: Belgium

21 Jul. - 20 Aug. 2012, mesh size 2.8 km



- **Obs:** Station measurements (urban vs. rural)
- **Dashed lines:** TERRA surface temperature (TERRA-URB)
- **Solid lines:** IFS skin temperature

Hendrik Wouters, KU Leuven, U. Ghent

Amplitude of the diurnal cycle of the surface temperature in TERRA is systematically underestimated, 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.

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