An improved representation of the surface temperature including the effects of vegetation in the land surface scheme TERRA
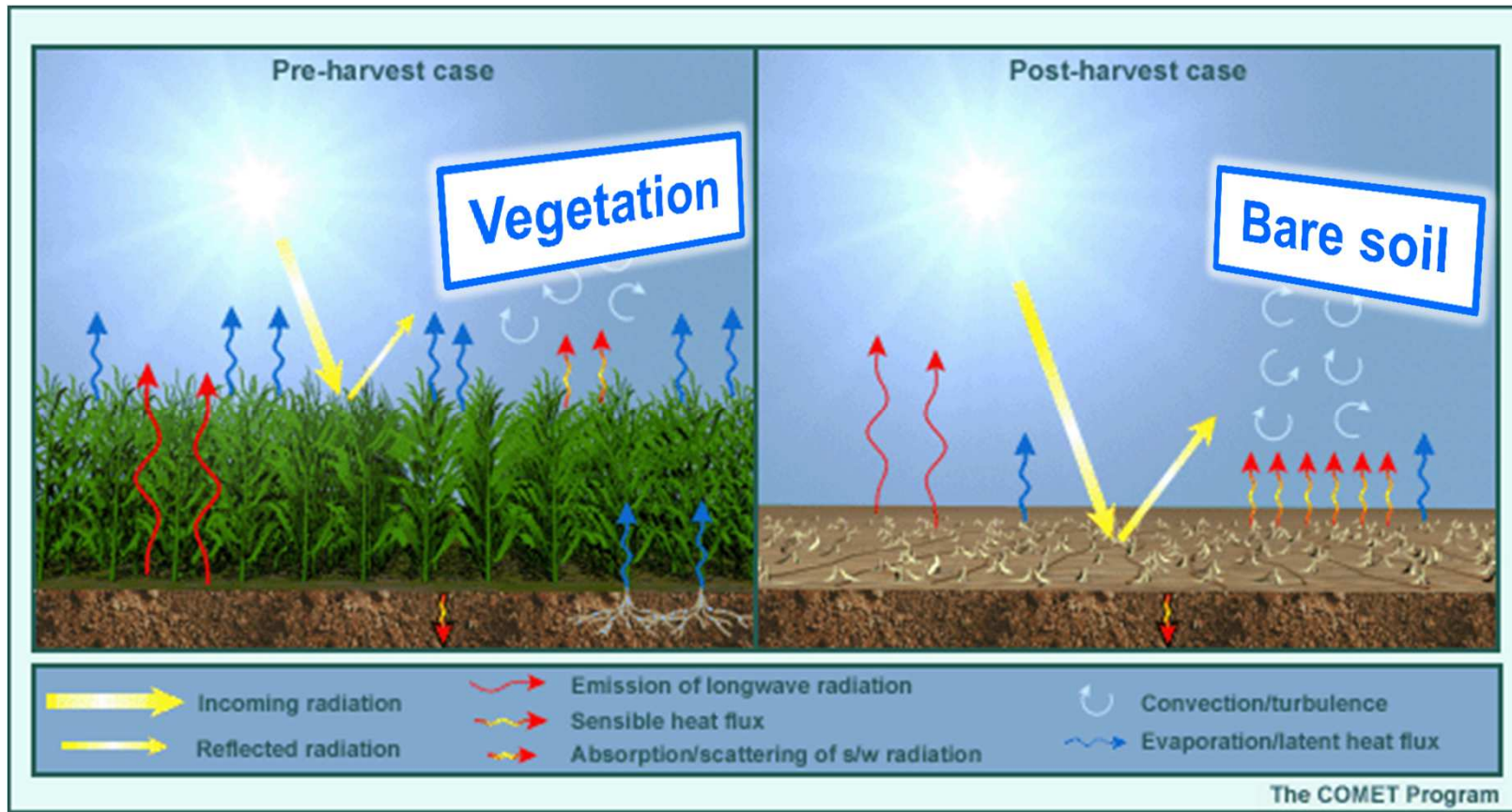
Jan-Peter Schulz[1] and Gerd Vogel[2]

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[2]Deutscher Wetterdienst, Lindenberg, Germany

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

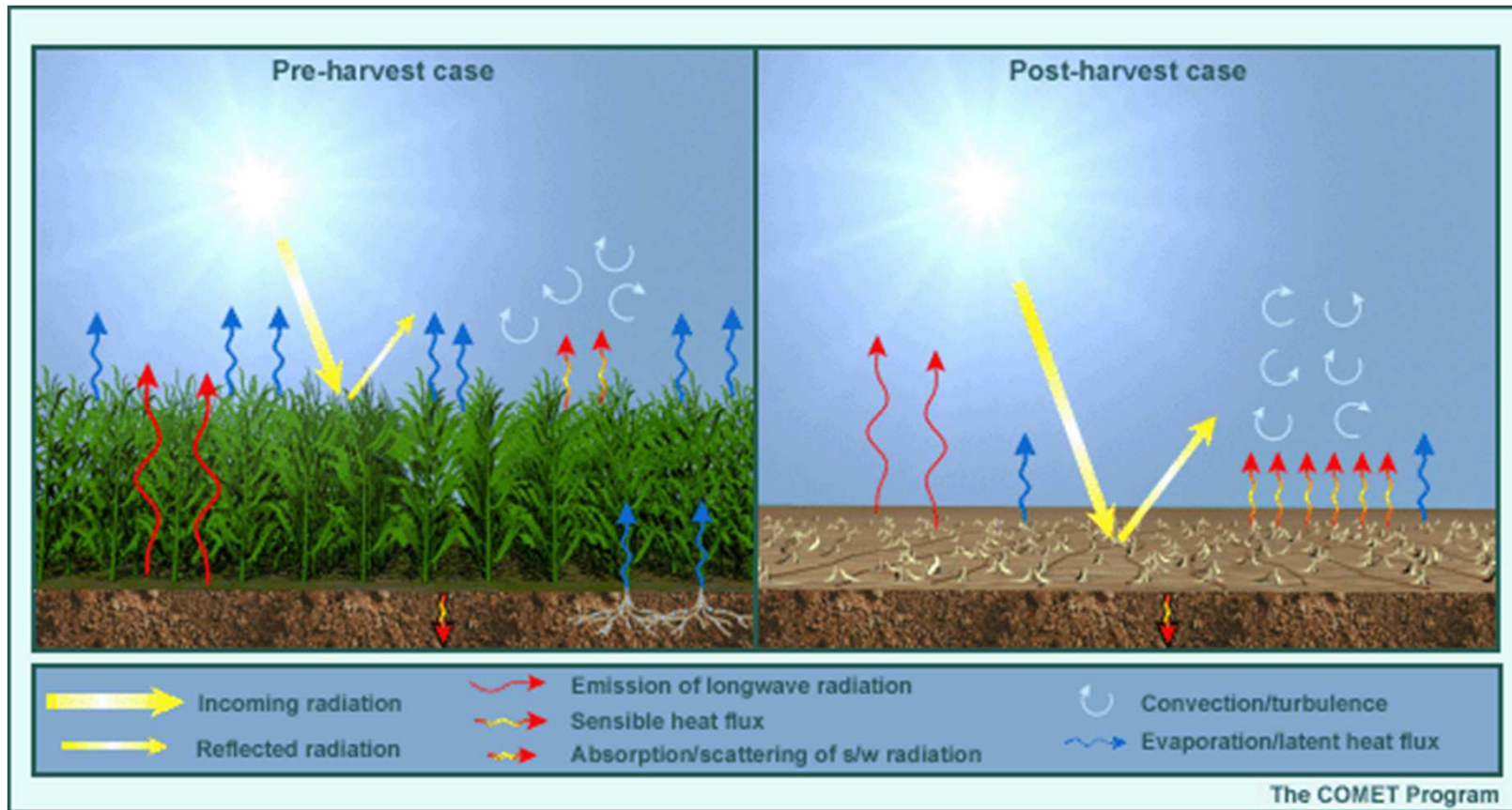# What is the surface temperature in TERRA?

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

Pre-harvest case   Post-harvest case

|	
Incoming radiation	Emission of longwave radiation
Reflected radiation	Sensible heat flux
	Absorption/scattering of s/w radiation
	Convection/turbulence
	Evaporation/latent heat flux

The COMET Program

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.
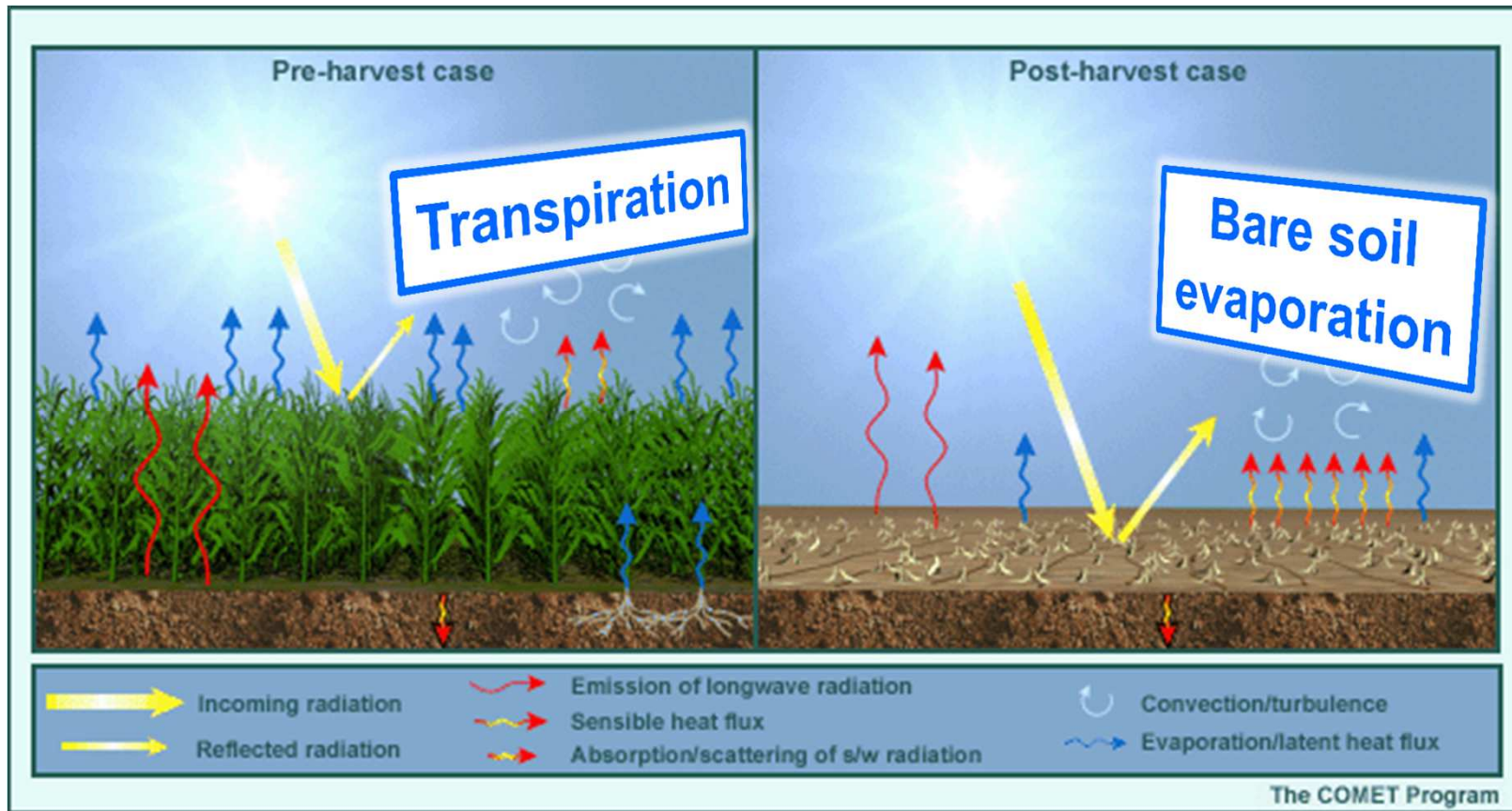
Offline TERRA: Falkenberg 2 - 4 July 2010
Thermal conductivity: Johansen

Soil temperature, grass (-6cm) Bare soil temperature (-6cm)
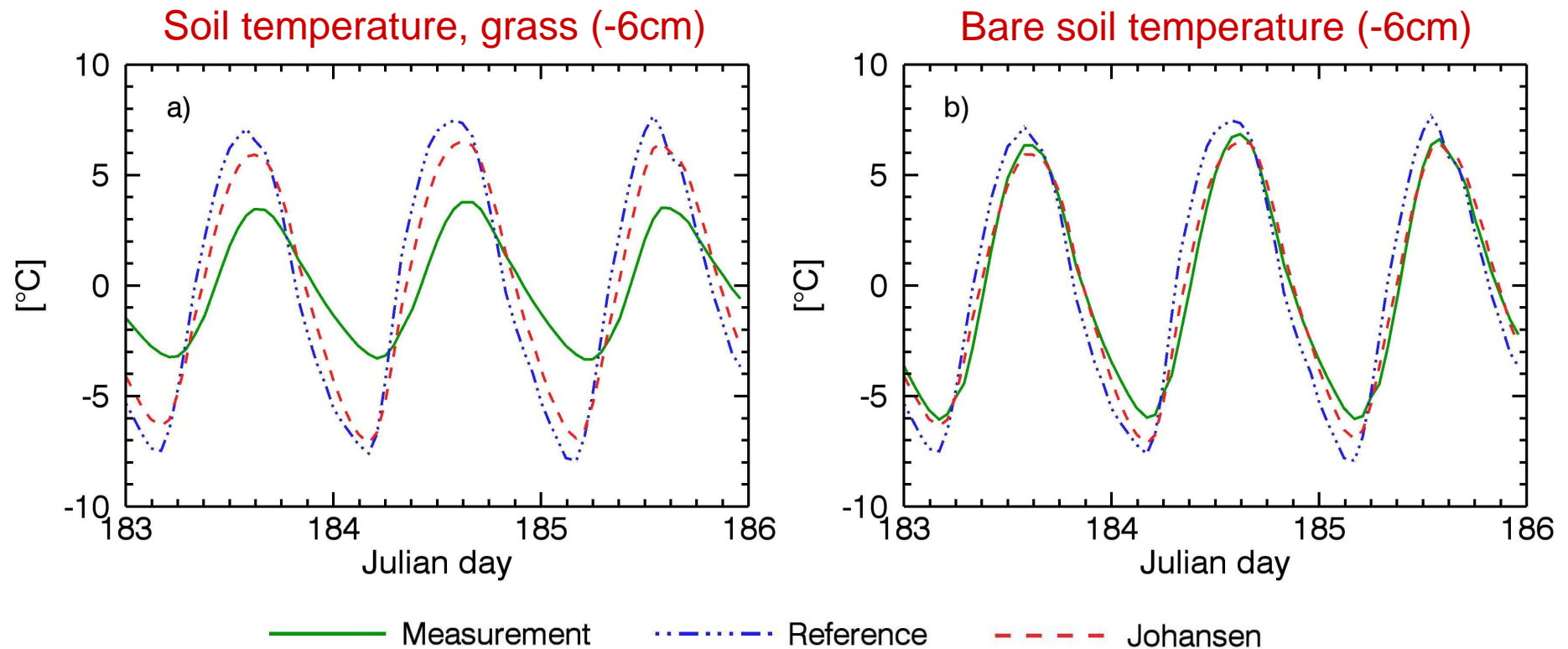
- Bare soil temperature is well represented by TERRA
- Measurements: Diurnal temperature range reduced by shading by factor of 2, this is not captured by TERRA
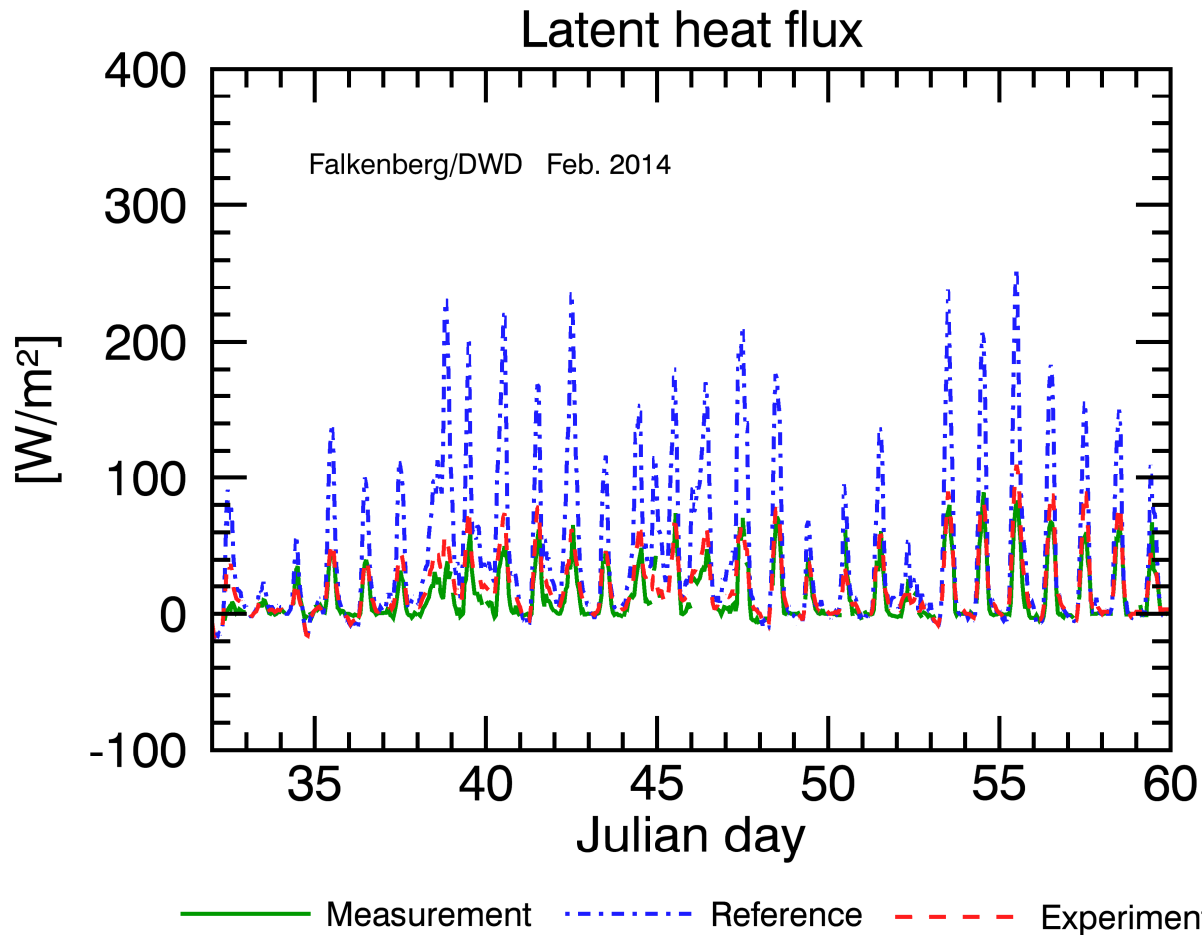
Bare soil evaporation

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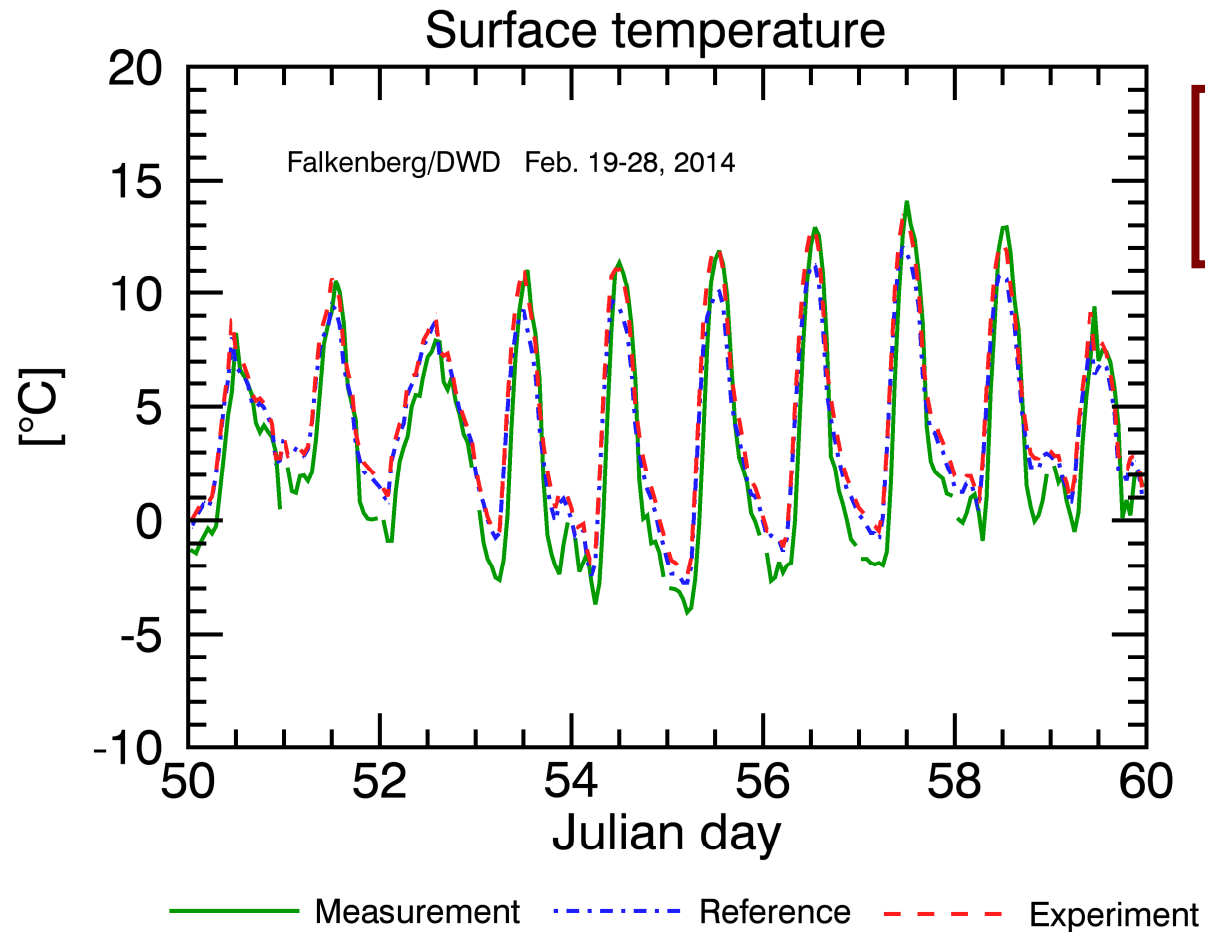
Reduced bare soil evaporation simulated by resistance method improves the total latent heat flux in TERRA substantially compared to BATS
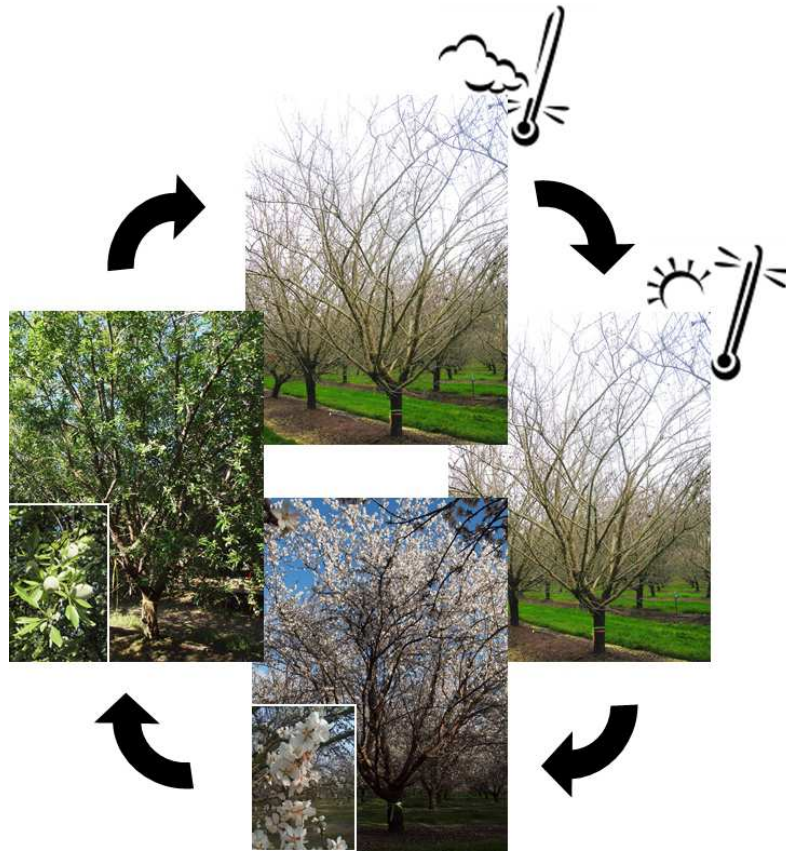
Surface temperature

Falkenberg/DWD   Feb. 19-28, 2014

19-28 Feb. 2014

Legend: Measurement · Reference · Experiment

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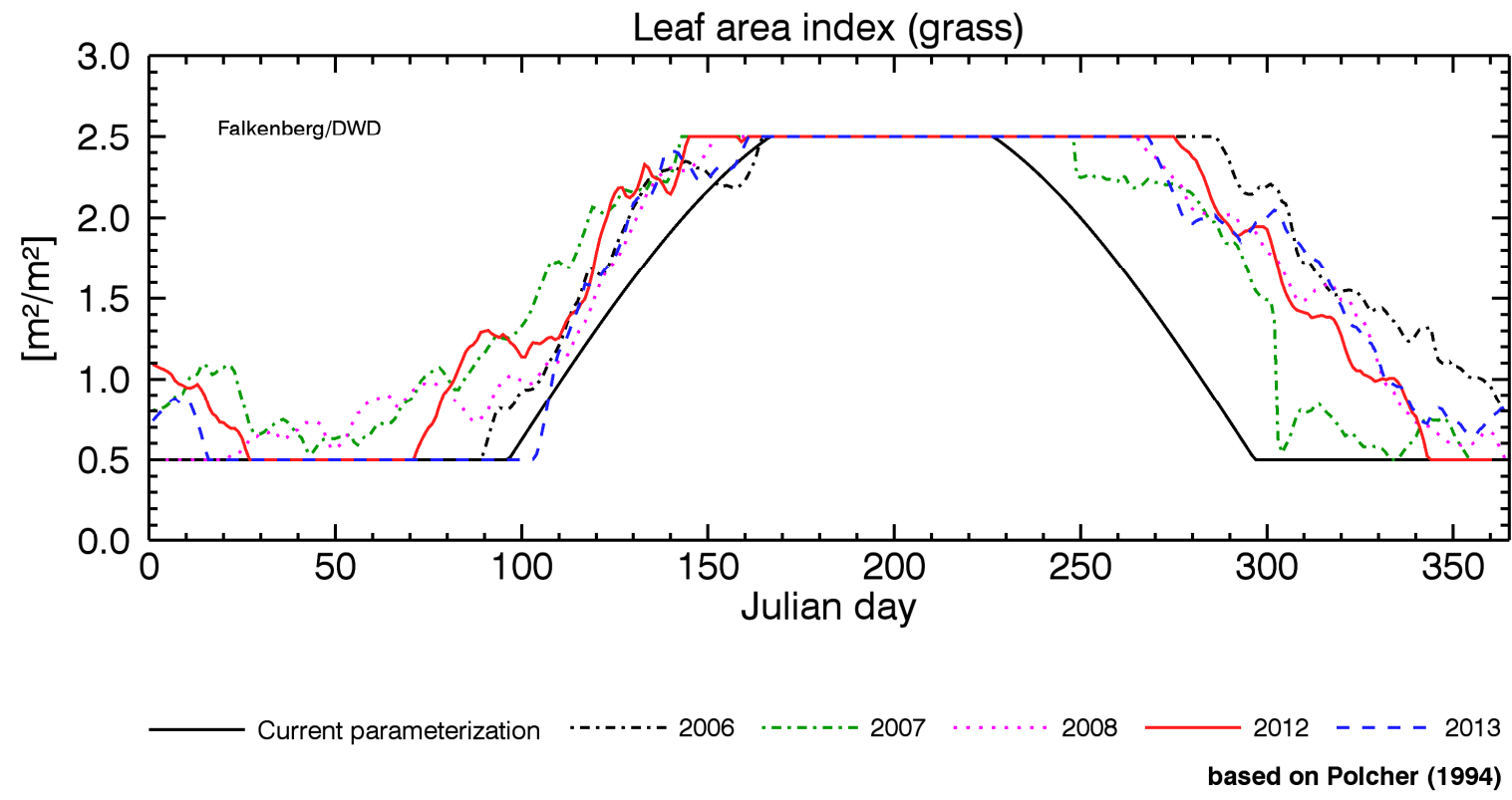
Phenology

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.

Leaf area index (grass)

Falkenberg/DWD
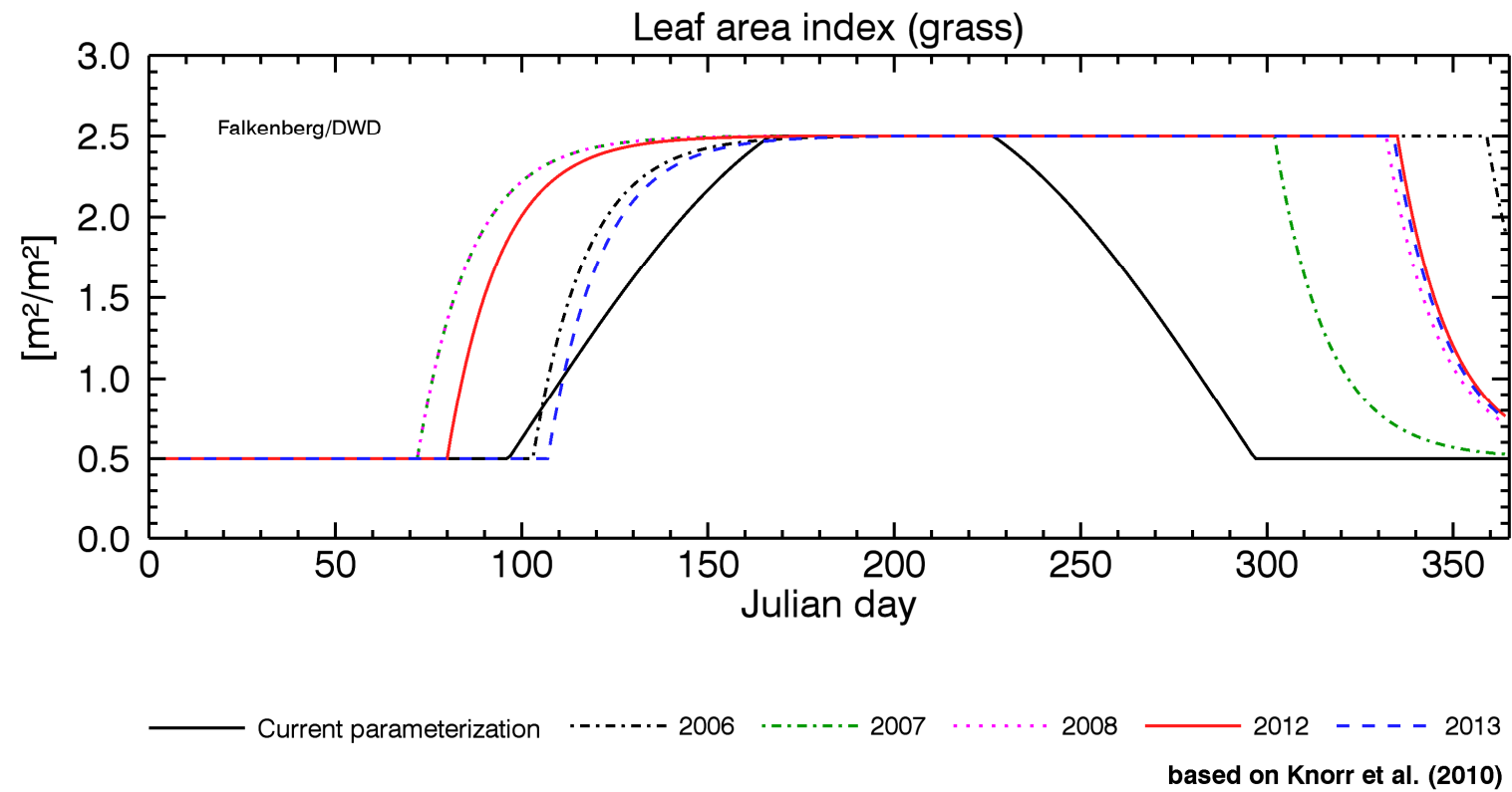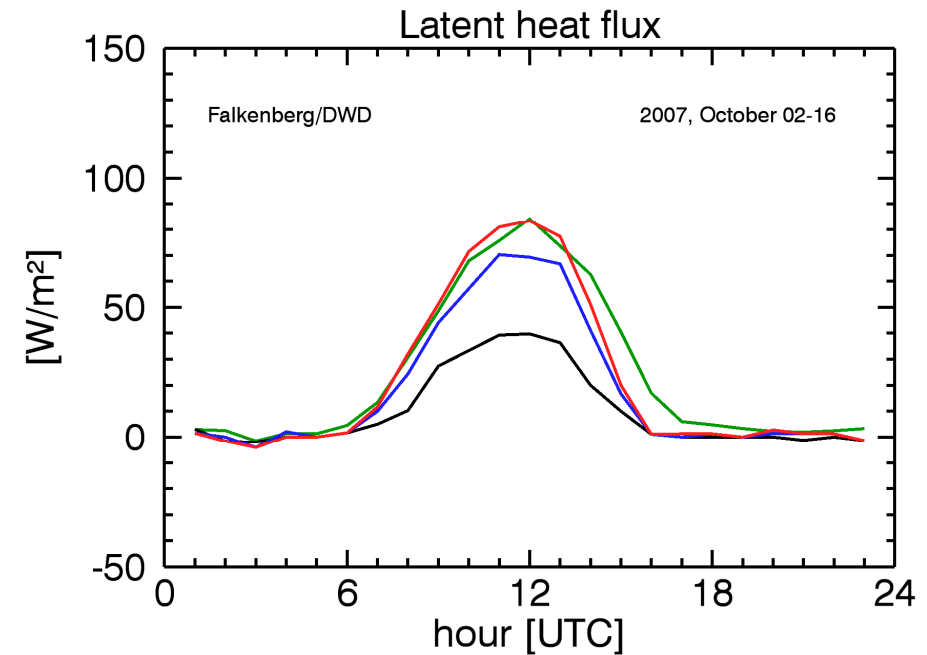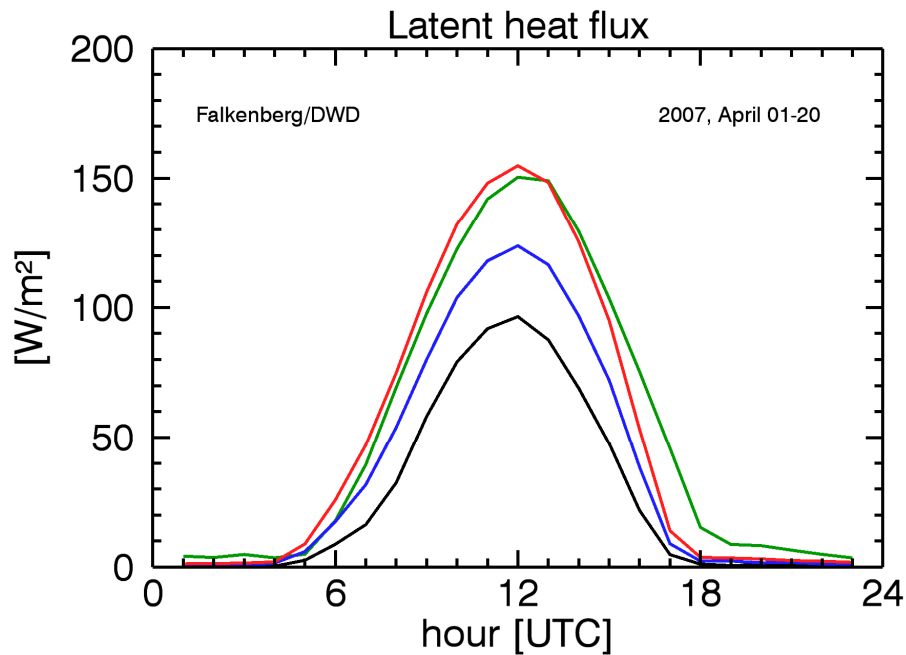
Legend: Current parameterization — 2006 — 2007 — 2008 — 2012 — 2013

based on Polcher (1994)

Leaf area index (grass)

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
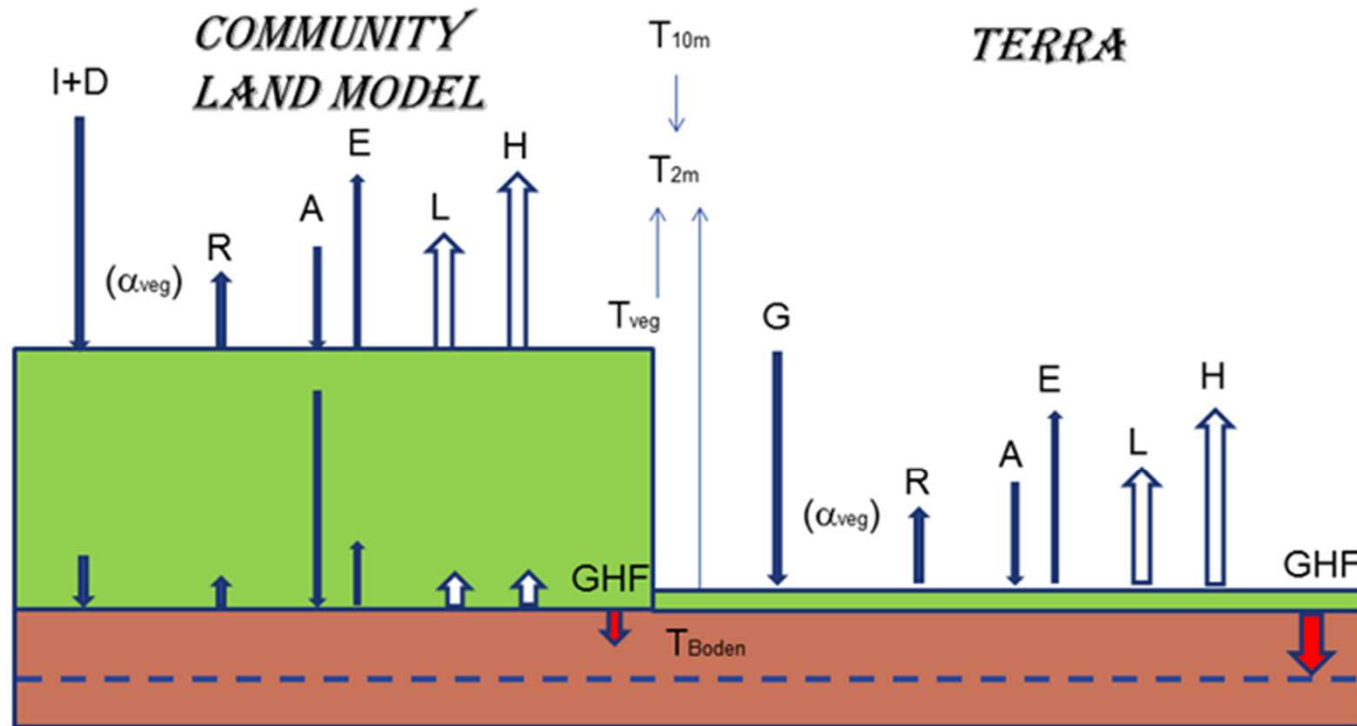
The problem …

➢ 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.
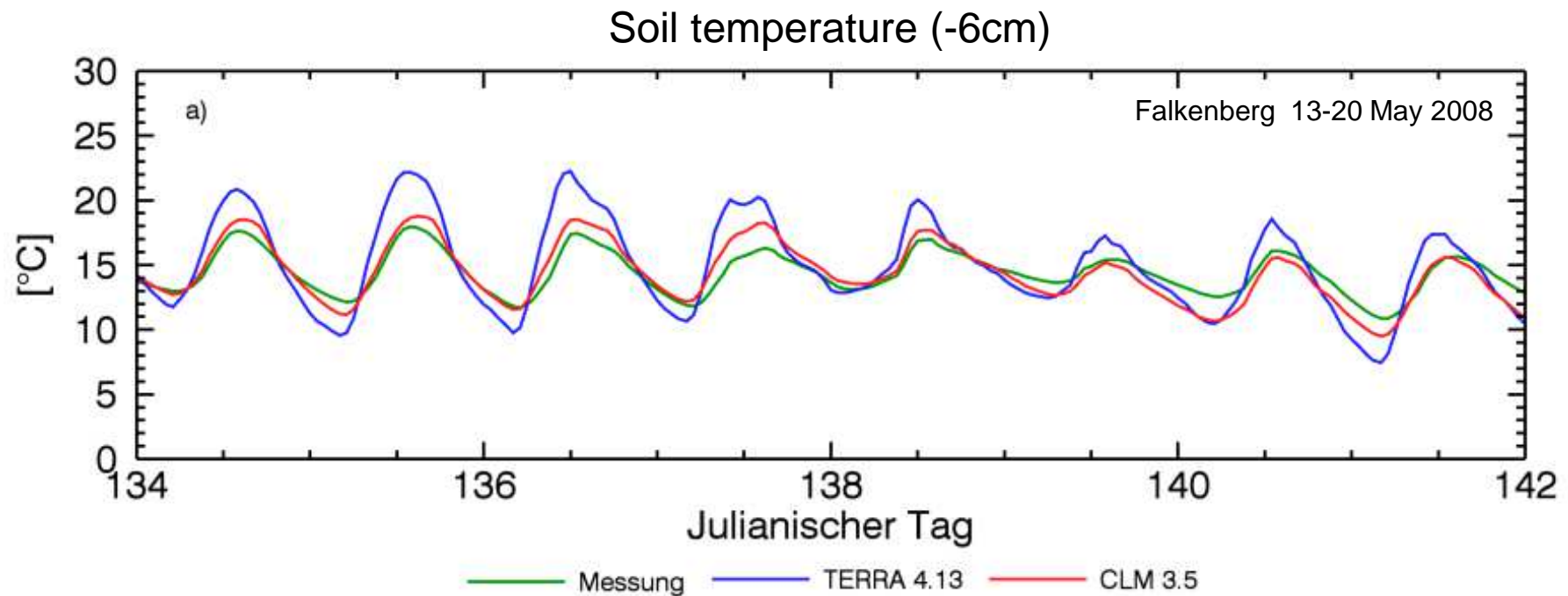
Offline TERRA vs. CLM
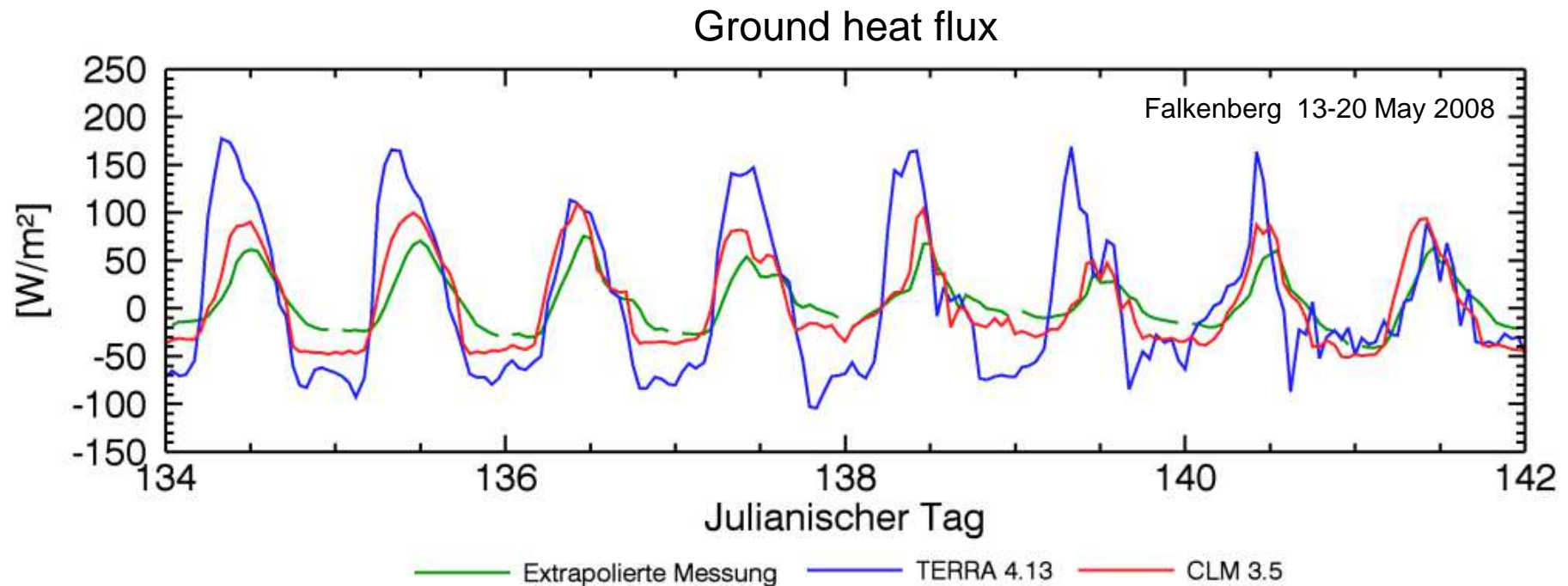
Ground heat flux

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

Offline TERRA vs. CLM

Soil temperature (-6cm)

a)   Falkenberg 13-20 May 2008
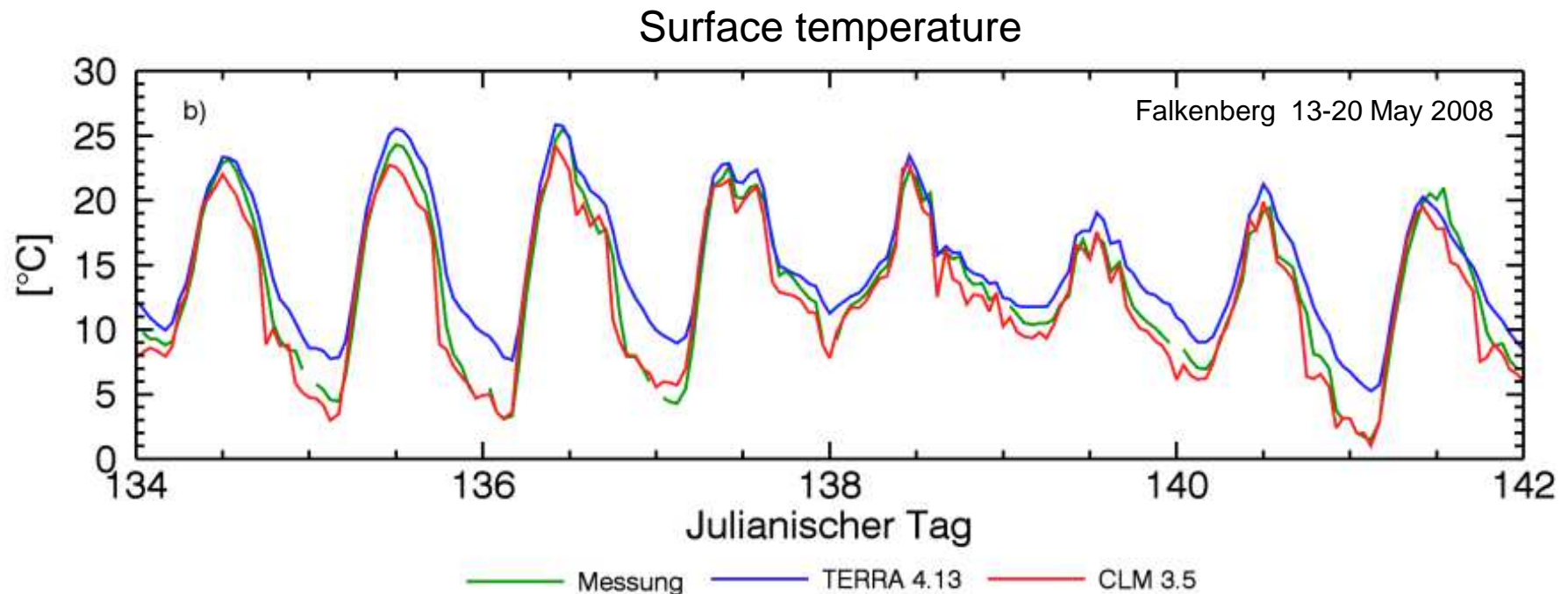
Messung — TERRA 4.13 — CLM 3.5

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

Surface temperature

Falkenberg 13-20 May 2008

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
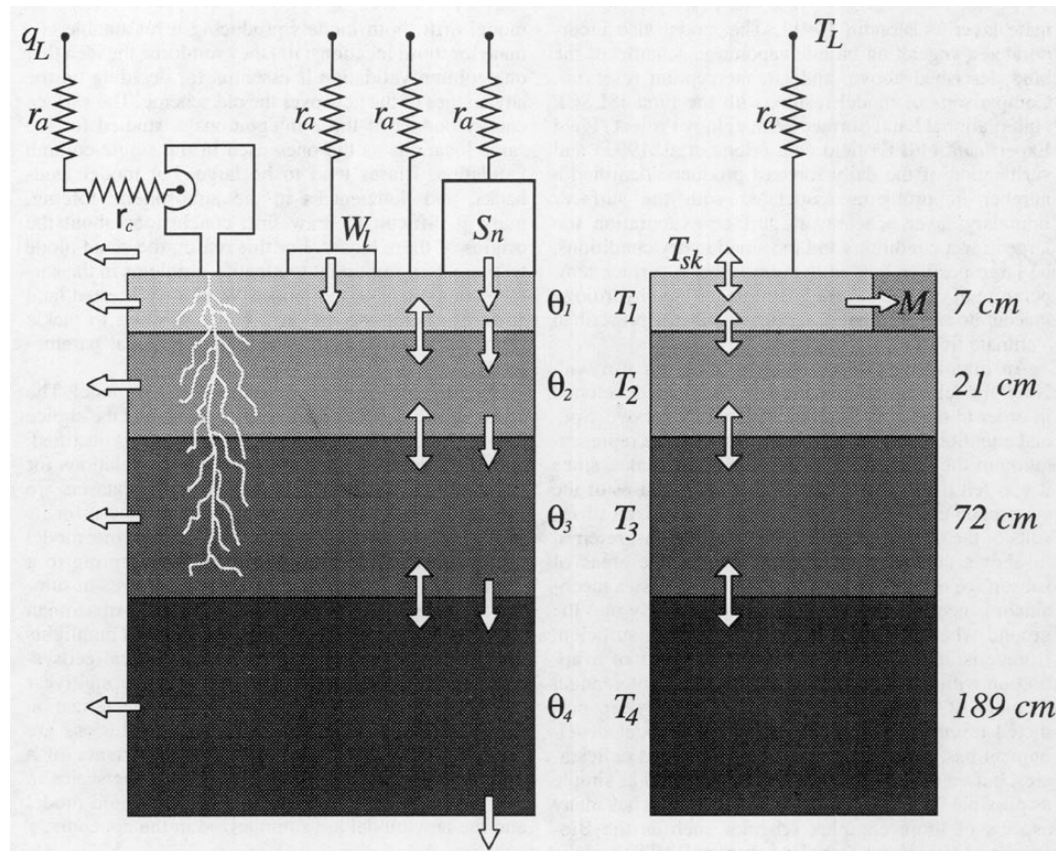
Λ_{sk} : skin layer conductivity

R_{SW}, R_{LW} : net shortwave radiation flux, net longwave radiation flux
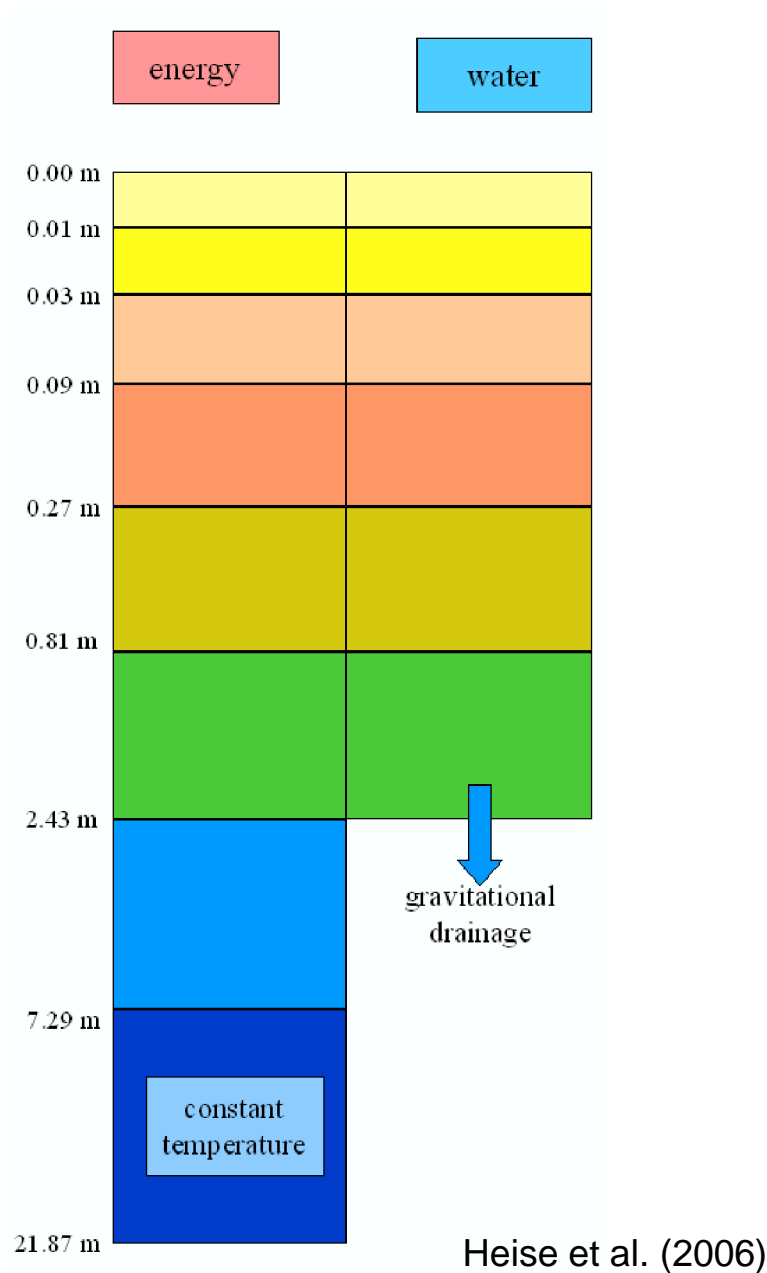
LE, H : latent heat flux, sensible heat flux

Skin temperature in IFS
## (Viterbo and Beljaars 1995)

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
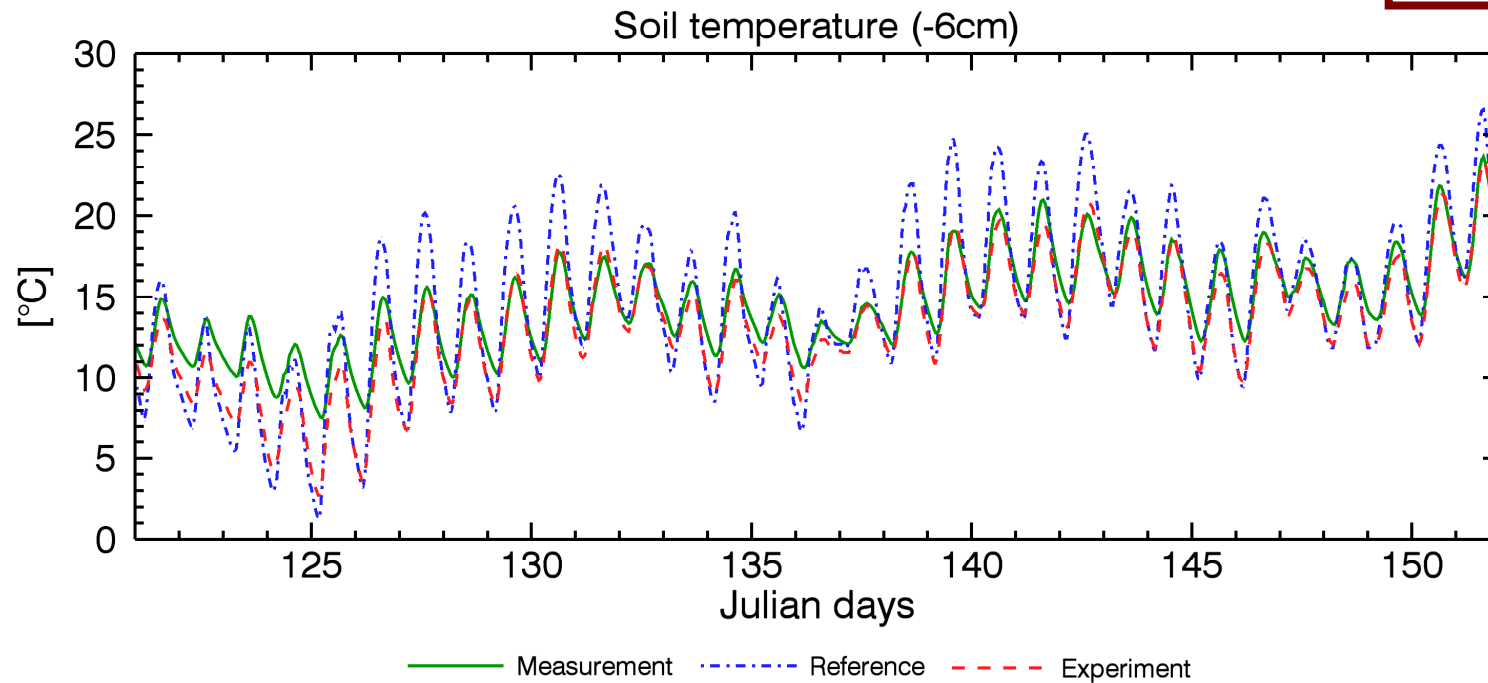
Heise et al. (2006)

Ground heat flux at surface
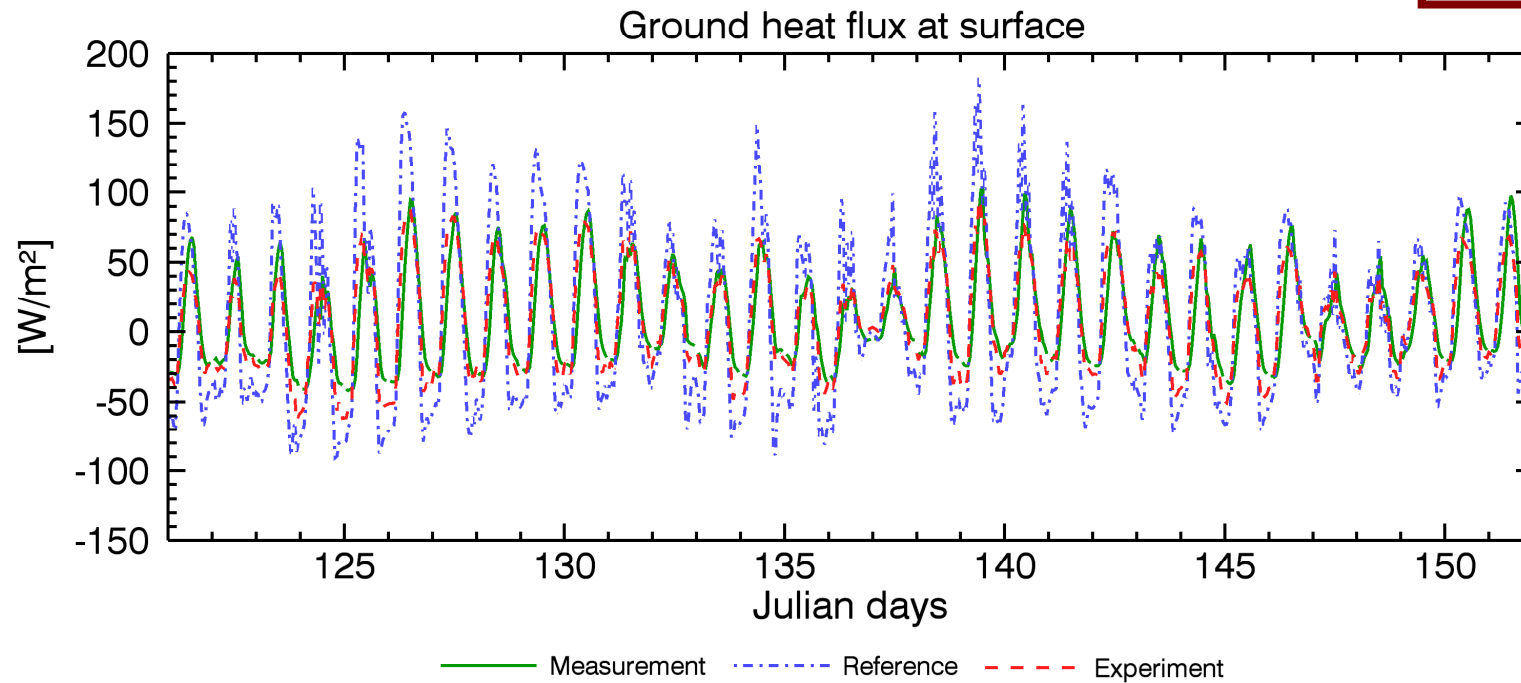
Ground heat flux substantially overestimated by TERRA, with the skin temperature formulation it is significantly reduced and much closer to the measurements
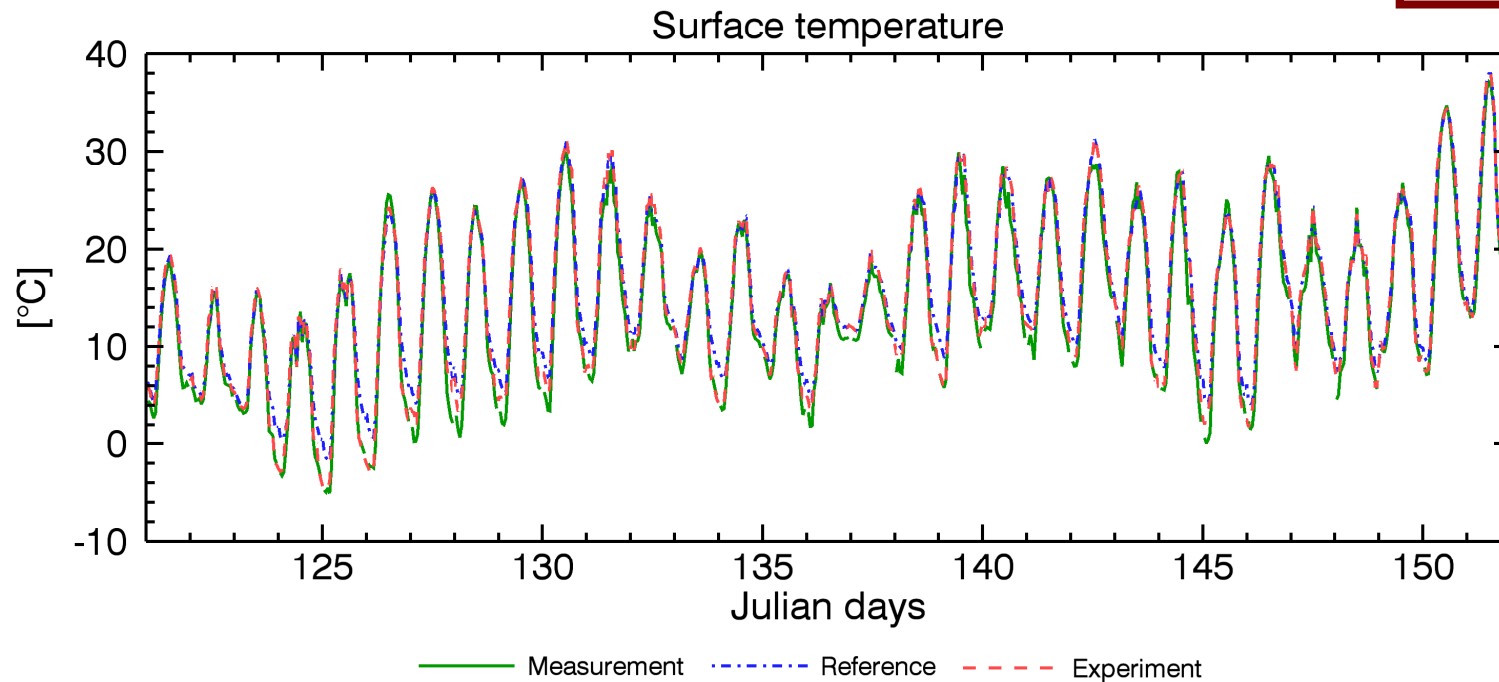
May 2011

Soil temperature (-6cm)

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
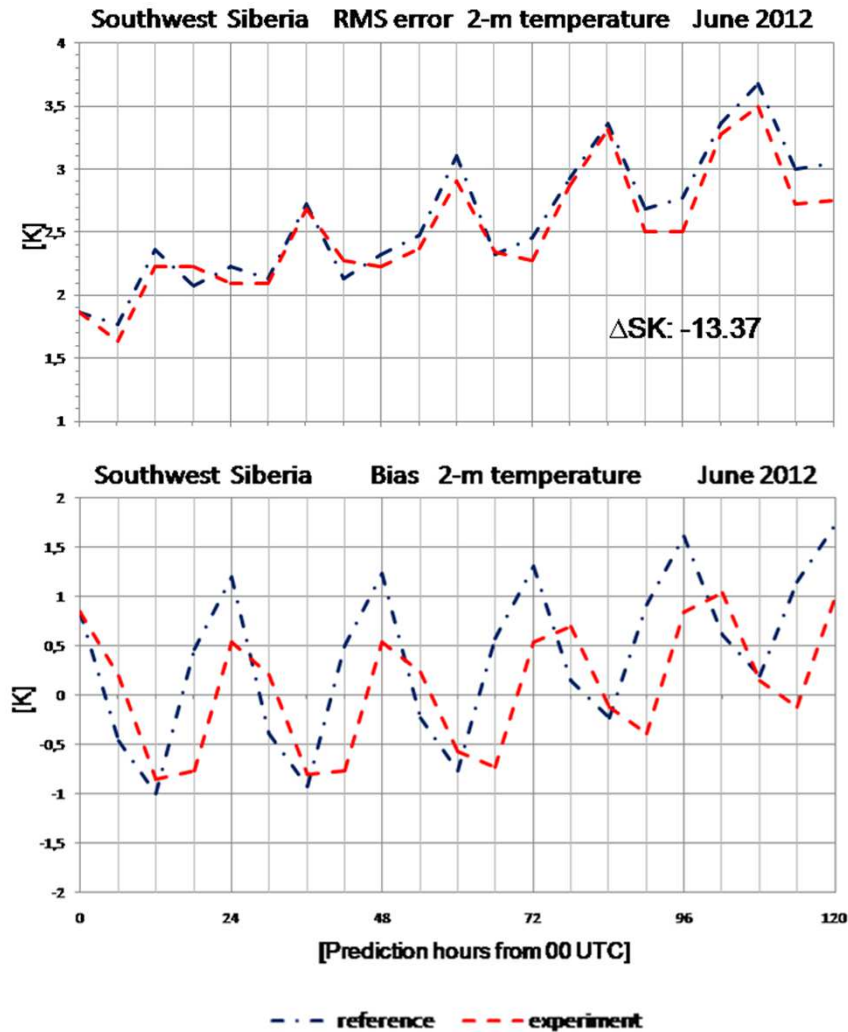
Surface temperature

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
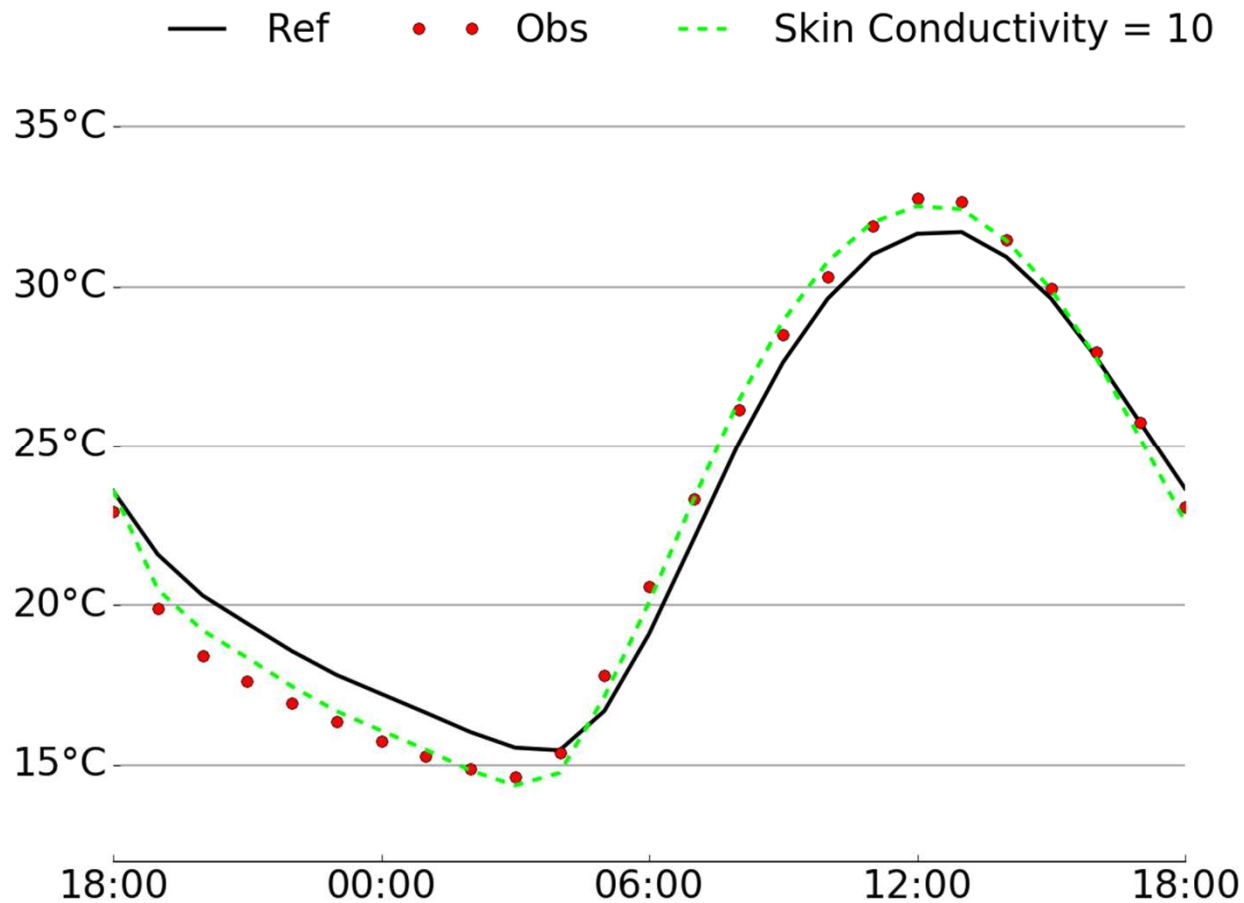
ICON: SW Siberia, June 2012, 00 UTC

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)
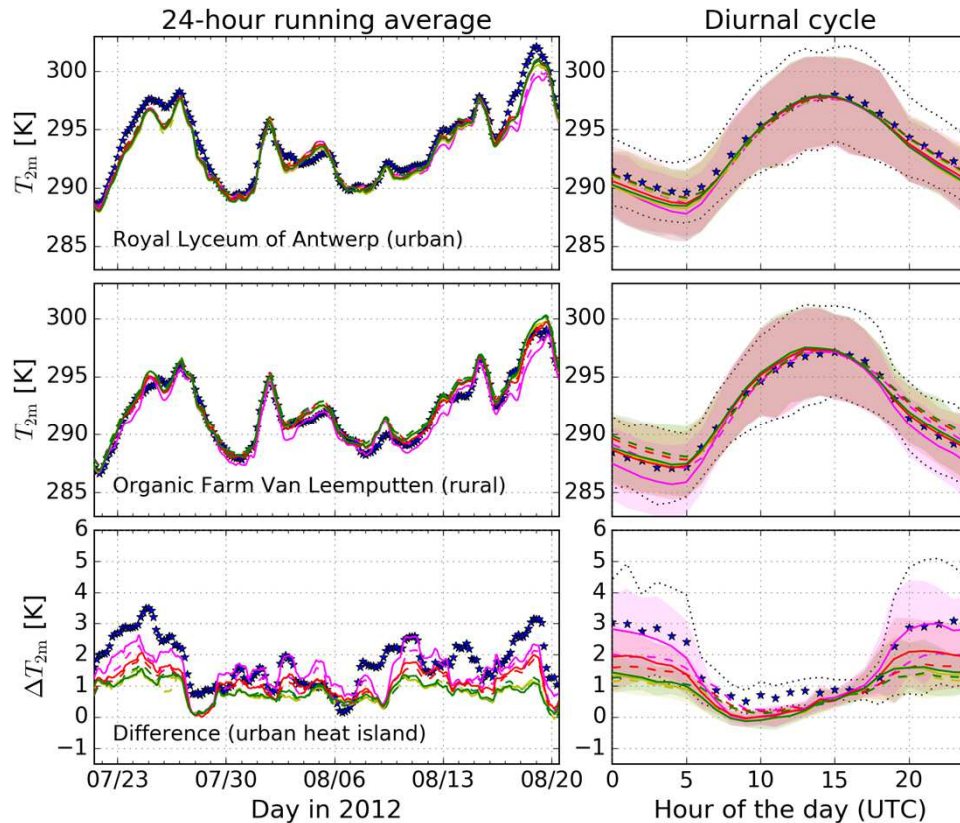
- ➢ Green line: IFS skin temperature

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.