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

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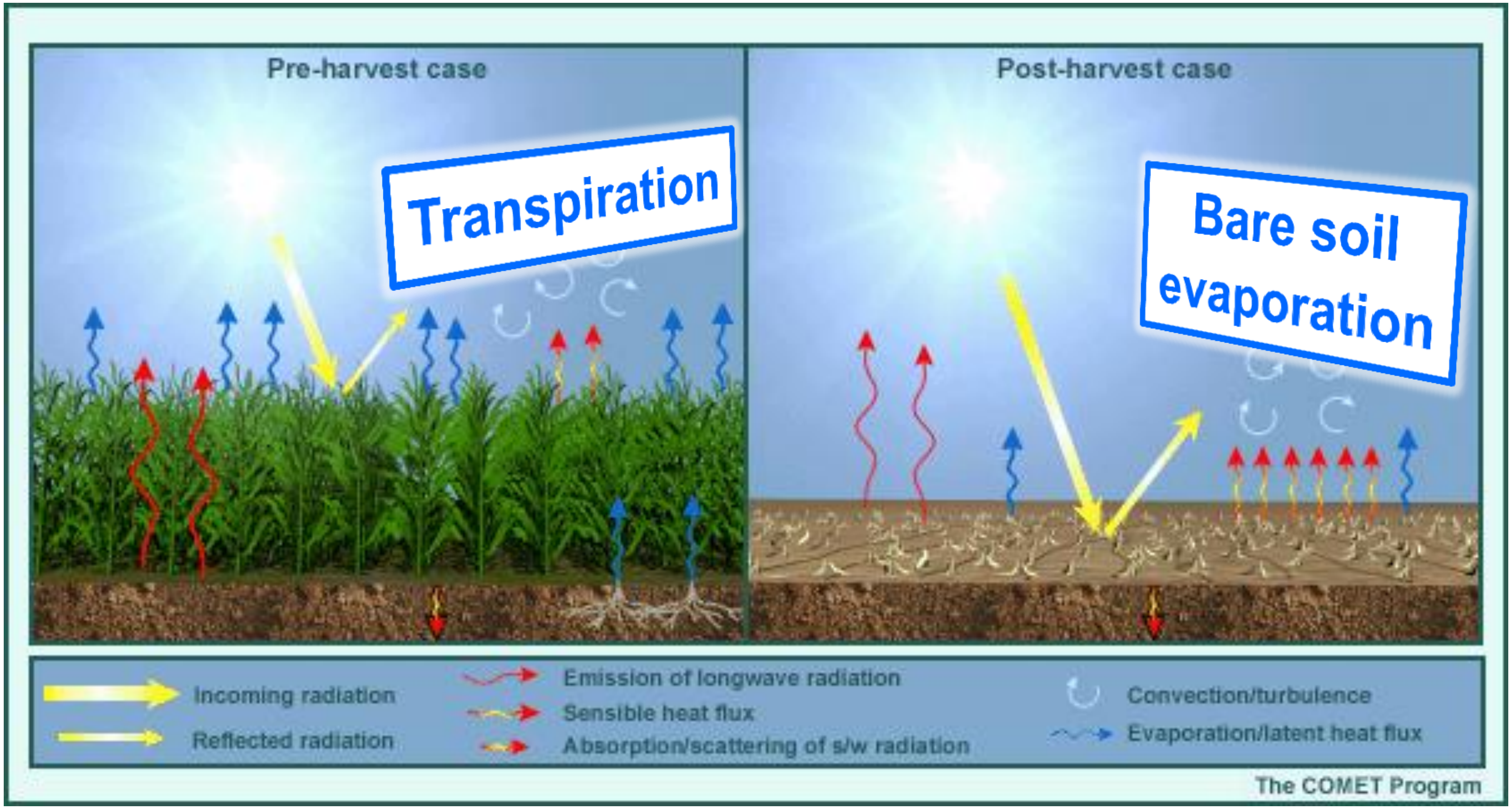
COSMO / CLM / ART User Seminar, 7 - 9 Mar. 2016, Offenbach

What is bare soil evaporation?

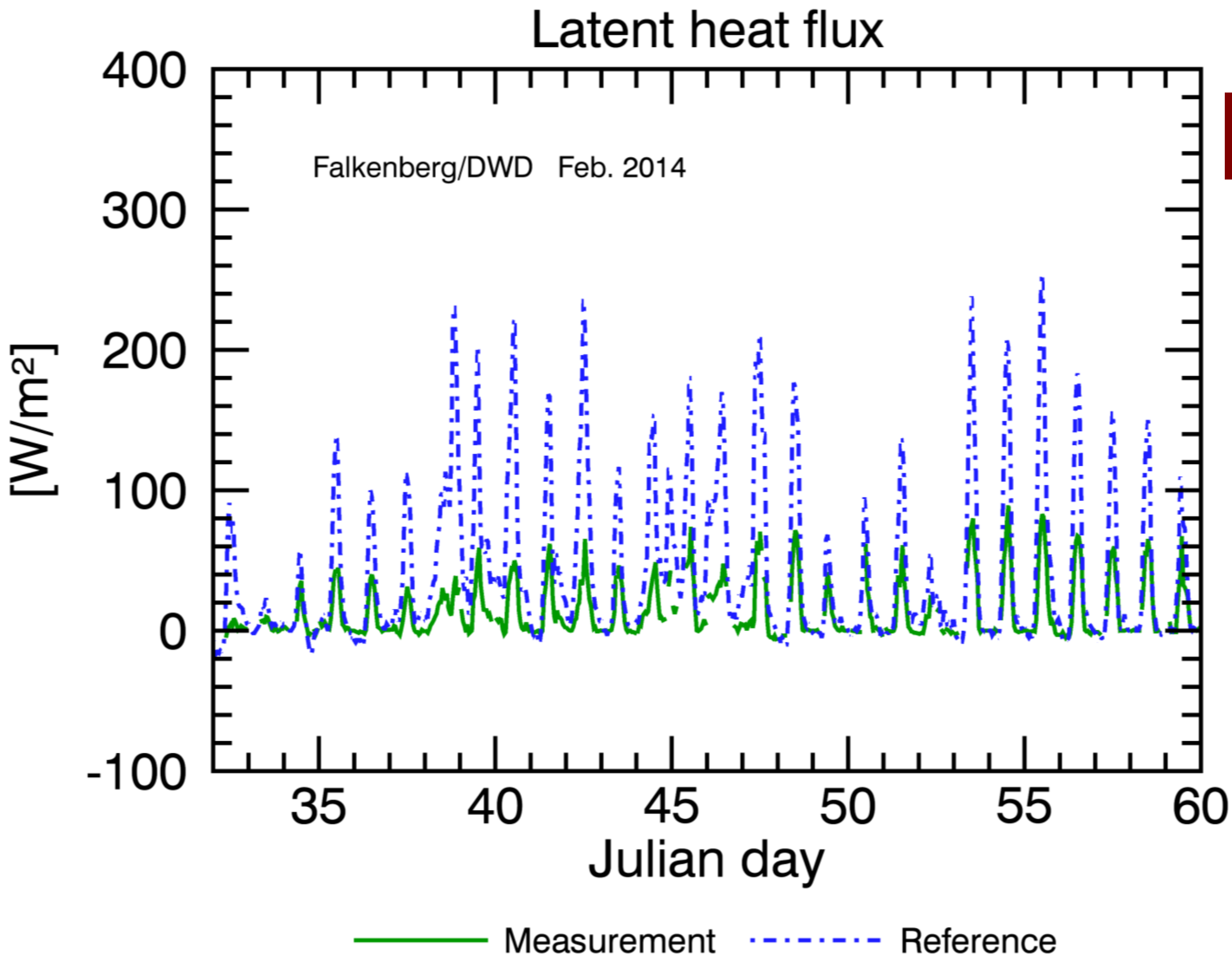


The problem …

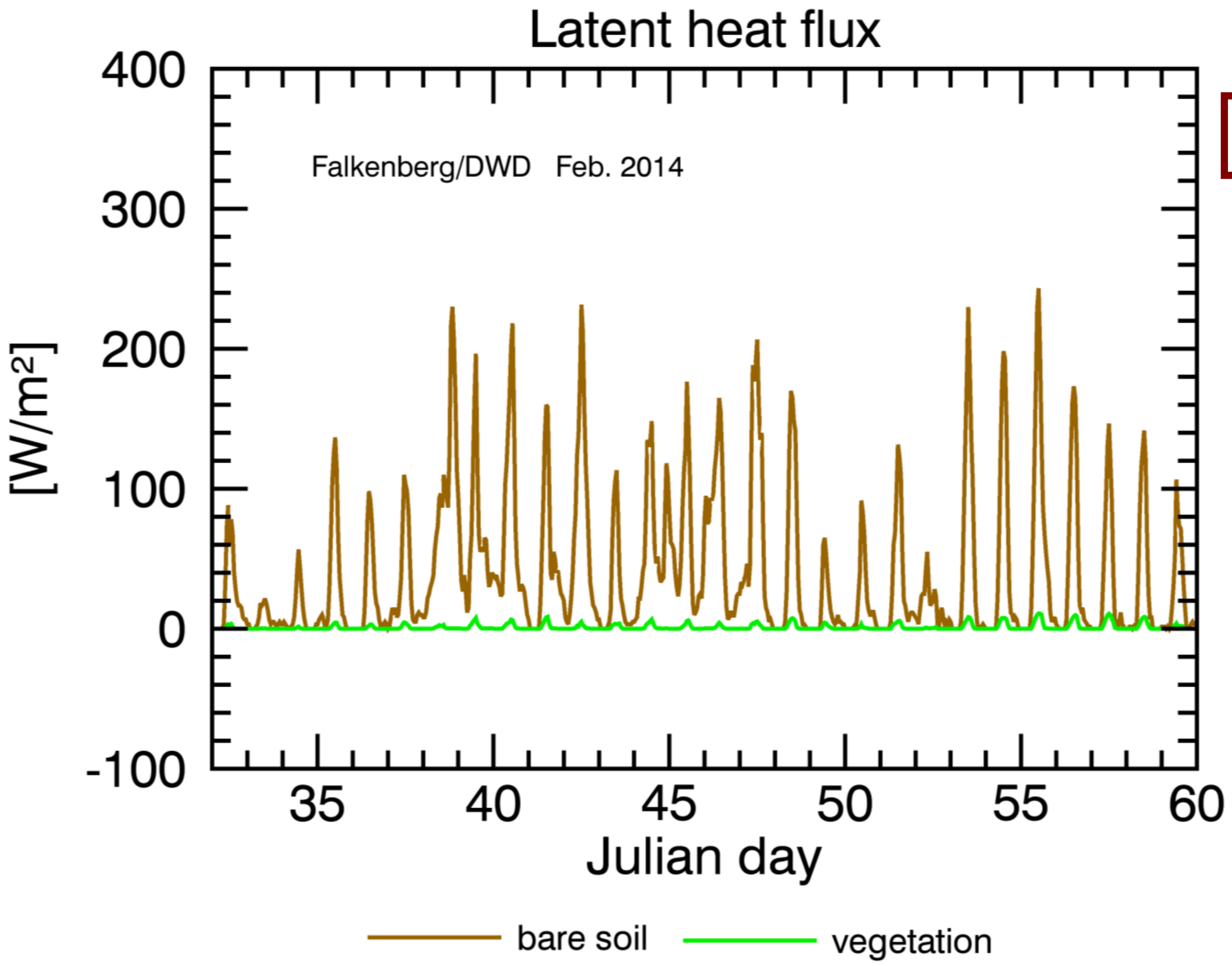
- The bare soil evaporation in TERRA is systematically overestimated under medium-wet to wet conditions.

- 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.


Latent heat flux
Falkenberg/DWD Feb. 2014
400
300
200
100
0
-100
[W/m²]
35
40
45
50
55
60
Julian day
Measurement
Reference

Feb. 2014


Latent heat flux
Falkenberg/DWD Feb. 2014
[W/m²]
400
300
200
100
0
-100
35
40
45
50
55
60
Julian day
bare soil
vegetation

Feb. 2014

Bare soil evaporation

based on the Biosphere-Atmosphere Transfer Scheme (BATS; Dickinson, 1984)

$$E_{bs} = \rho_w C_k D \frac{s_t}{(z_u z_t)^{1/2}}$$

ρ_w: density of water
s_u : average soil water content in upper $z_u = 0.09$ m
s_t : average soil water content in upper $z_t = 0.81$ m

Bare soil evaporation

based on the Biosphere-Atmosphere Transfer Scheme (BATS; Dickinson, 1984)

where C_k is calculated by

(11.18)

(11.19)

(11.20)

m and the fraction depend on the soil

(11.21)

The scheme was adapted, or tuned, to the two-layer land surface scheme (Jacobsen and Heise, 1982) of the former model generation. Apparently, this can not directly be transferred to the current multi-layer land surface scheme.

B_f is given by

$$B_f = 5.5 - 0.8B\left[1 + 0.1(B-4)log_{10}\frac{K_0}{K_R}\right] \quad , \qquad (11.22)$$

with $K_R = 10^{-5} m/s$.

ρ_w: density of water

s_u : average soil water content in upper $z_u = 0.09$ m

s_t : average soil water content in upper $z_t = 0.81$ m

Bare soil evaporation

based on a resistance formulation analogue to Ohm´s law

(for a review see e.g. Schulz et al., 1998)

$$E_{bs} = \rho \frac{1}{r_a + r_s} (q_v - q_{sat})$$

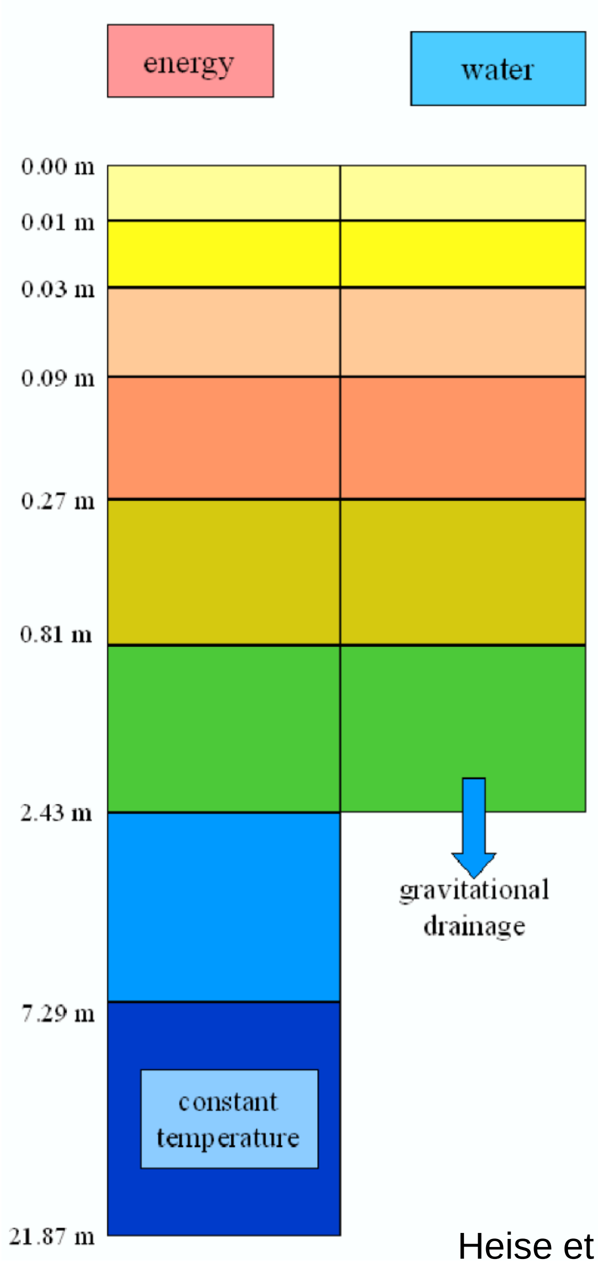
$$r_s = r_{s,\min} \left(\frac{\theta_1 - \theta_{\min}}{\theta_{\max} - \theta_{\min}} \right)^{-1}$$

ρ : density of air

q_v, q_{sat} : specific humidity of air, and saturation specific humidity at surface

r_a, r_s, $r_{s,\min}$: aerodynamic resistance, soil resistance, and minimum soil resistance

θ_1, $\theta_{\min}$, $\theta_{\max}$: volumetric soil water content of top layer, min. and max. value of θ



Heise et al. (2006)

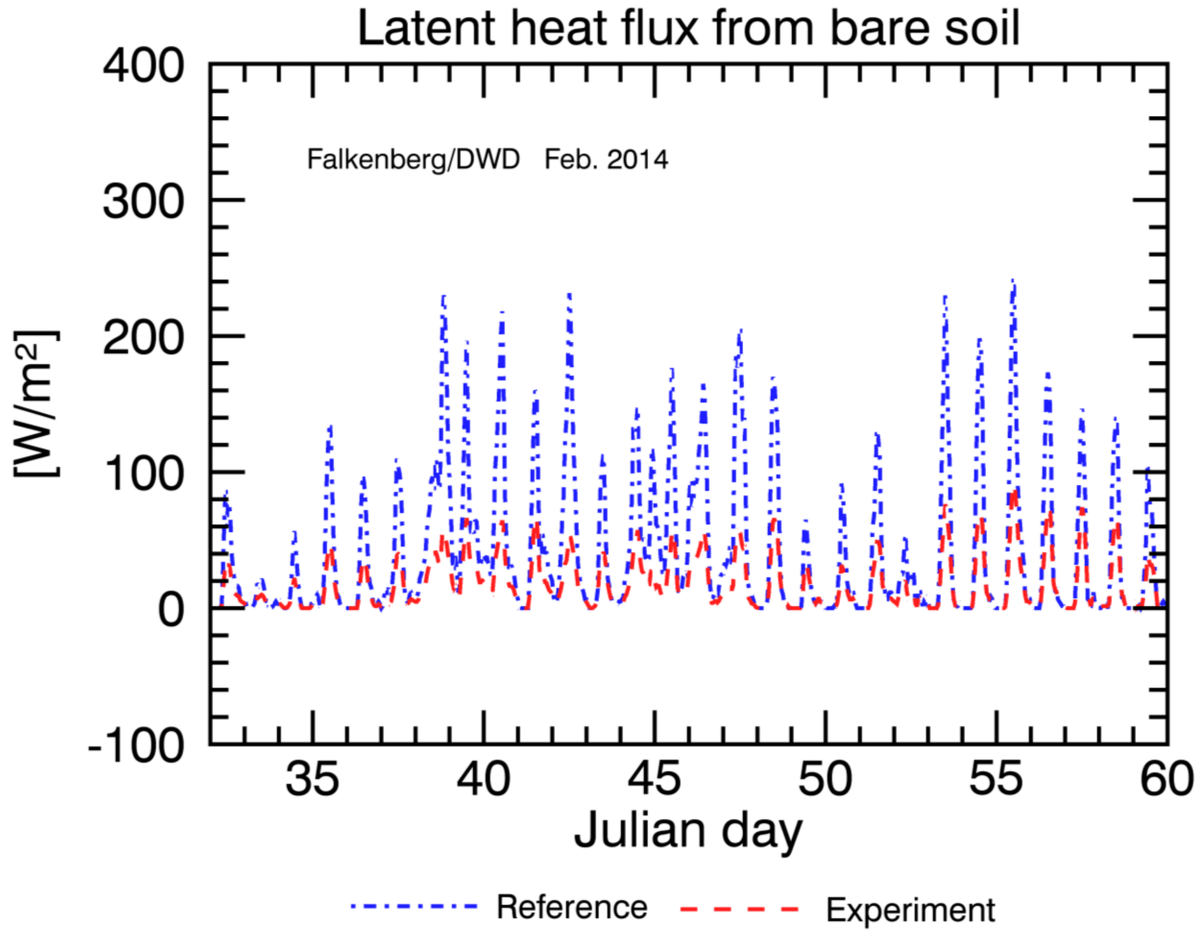
Land surface scheme TERRA

Layers for temperature and soil water content

Experiments:

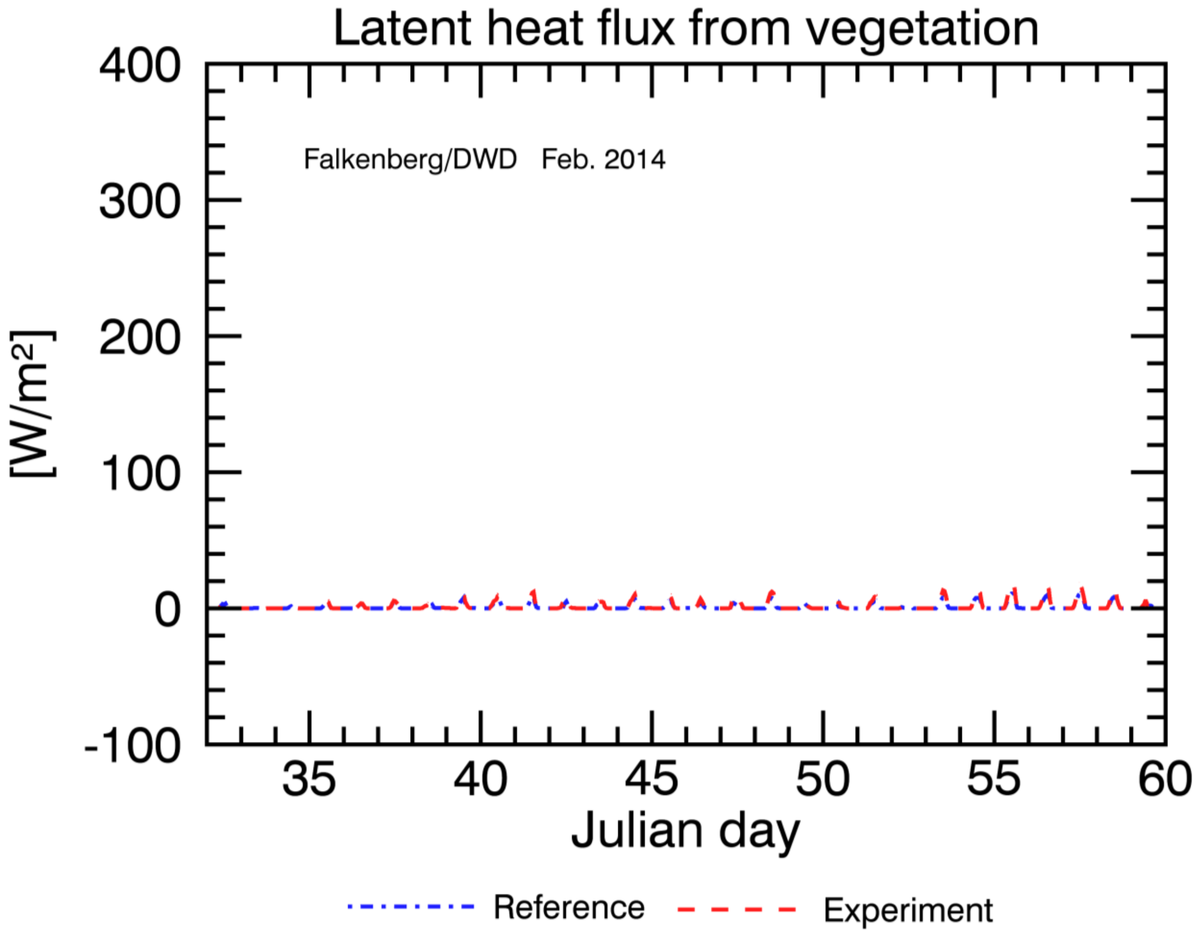
- Use atmospheric forcing to run TERRA in offline mode
- Here, observed forcing from DWD observatory Lindenberg is used (Falkenberg site)

- Reference : BATS
- Experiment : Resistance



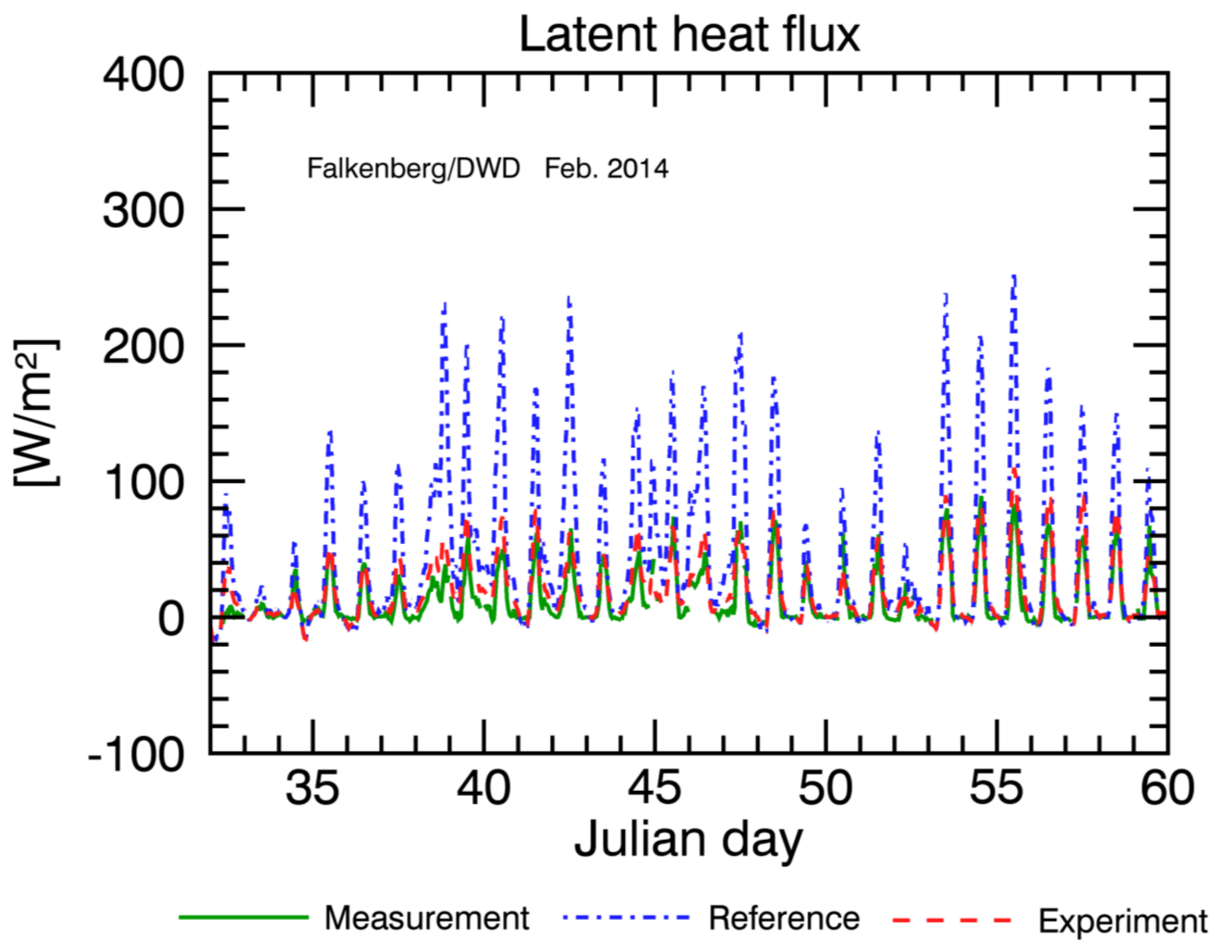
Feb. 2014

Bare soil evaporation substantially reduced by resistance method compared to BATS



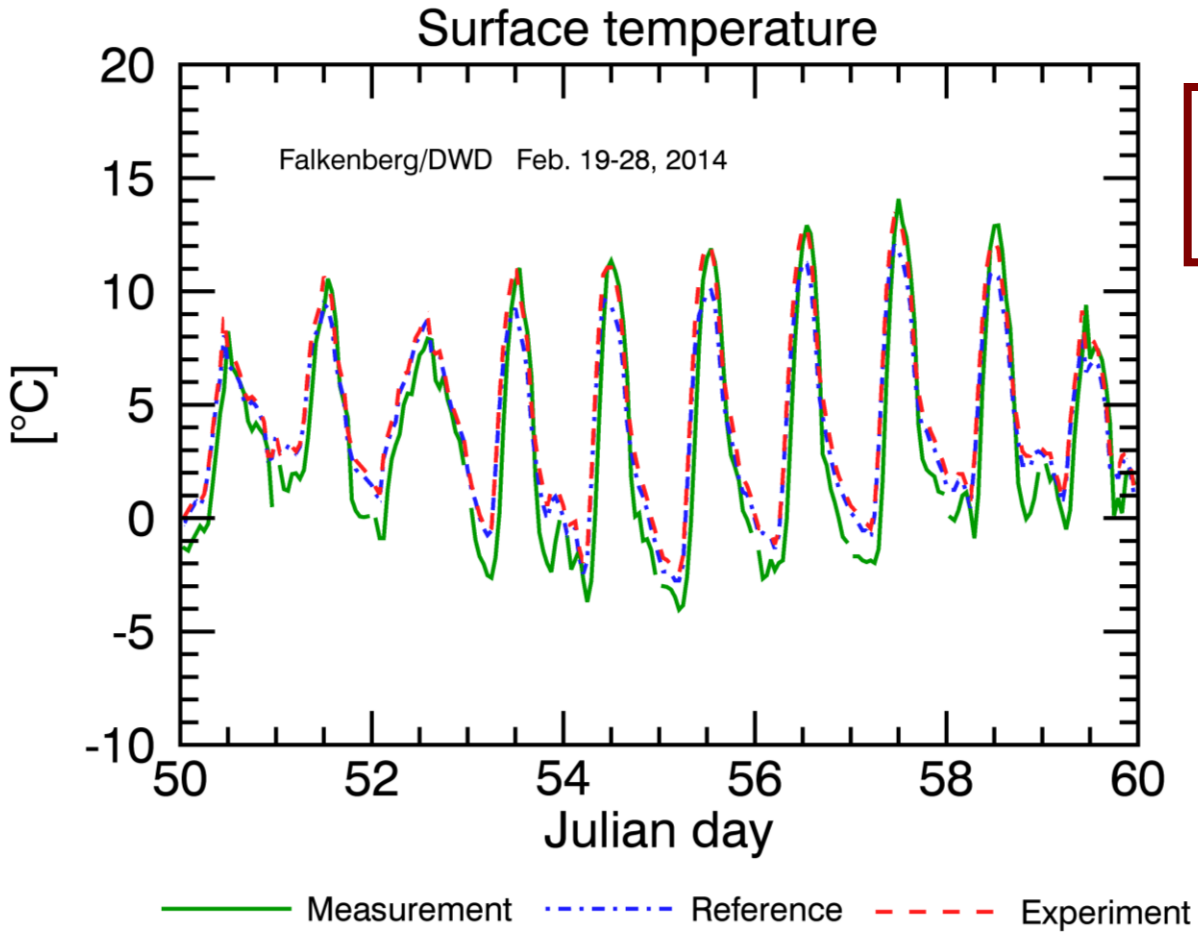
Feb. 2014

Transpiration very close to zero in February at Falkenberg in both model versions



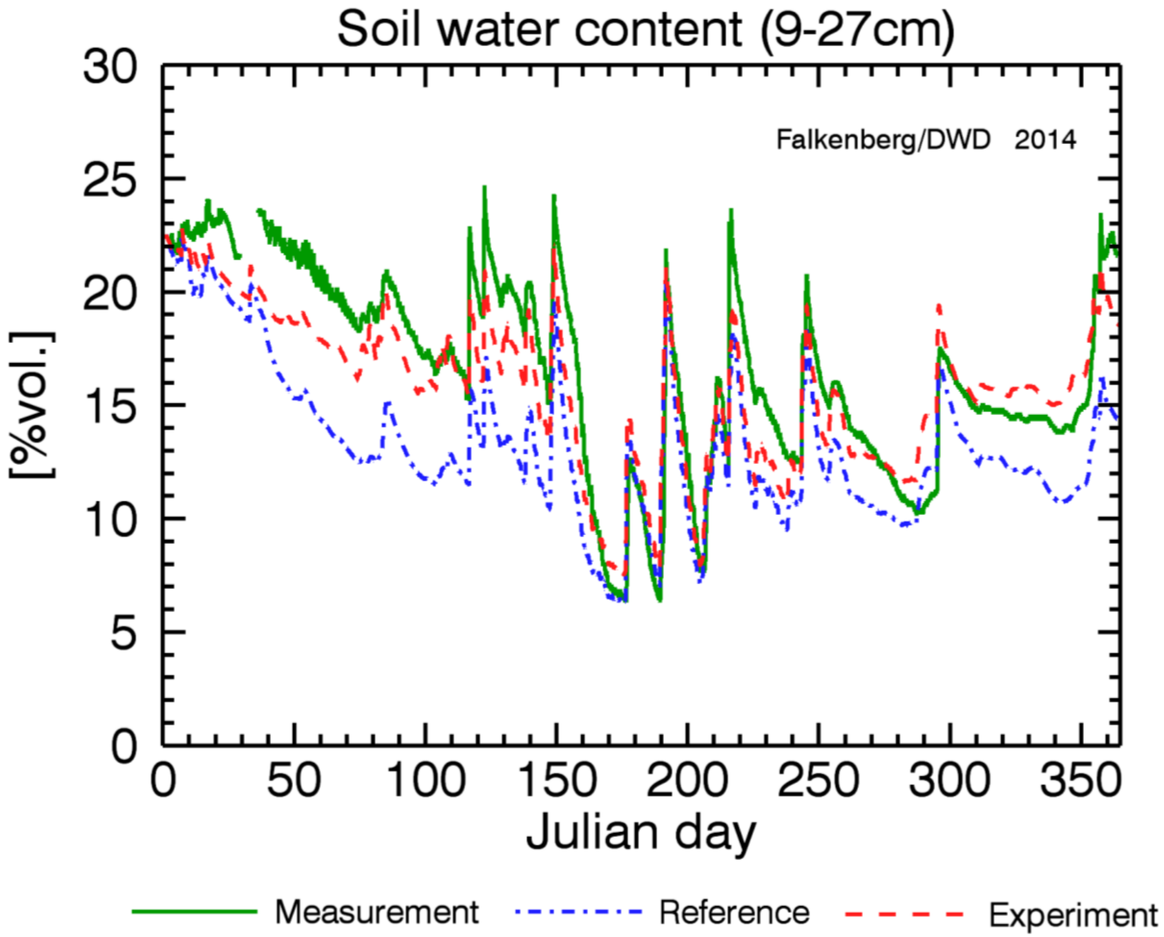
Feb. 2014

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



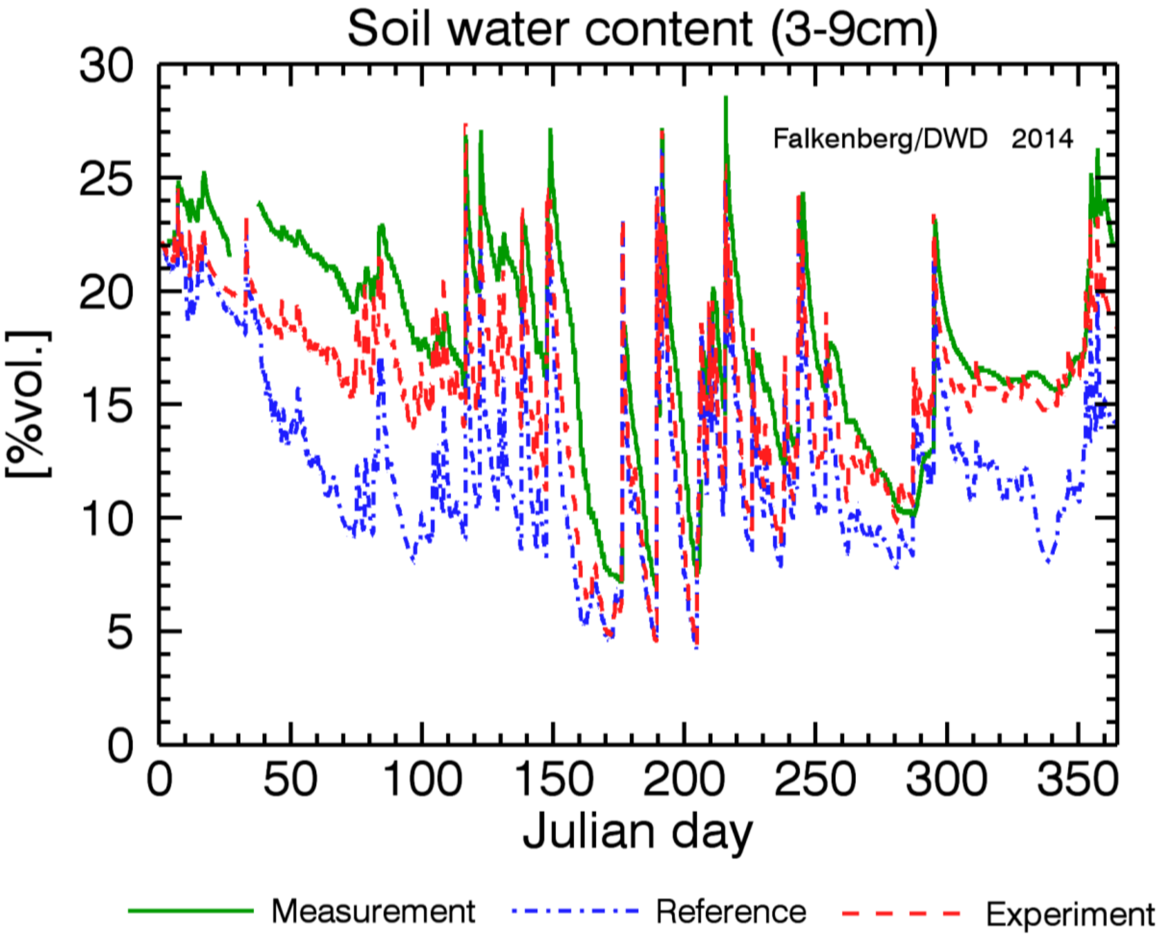
19-28 Feb. 2014

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



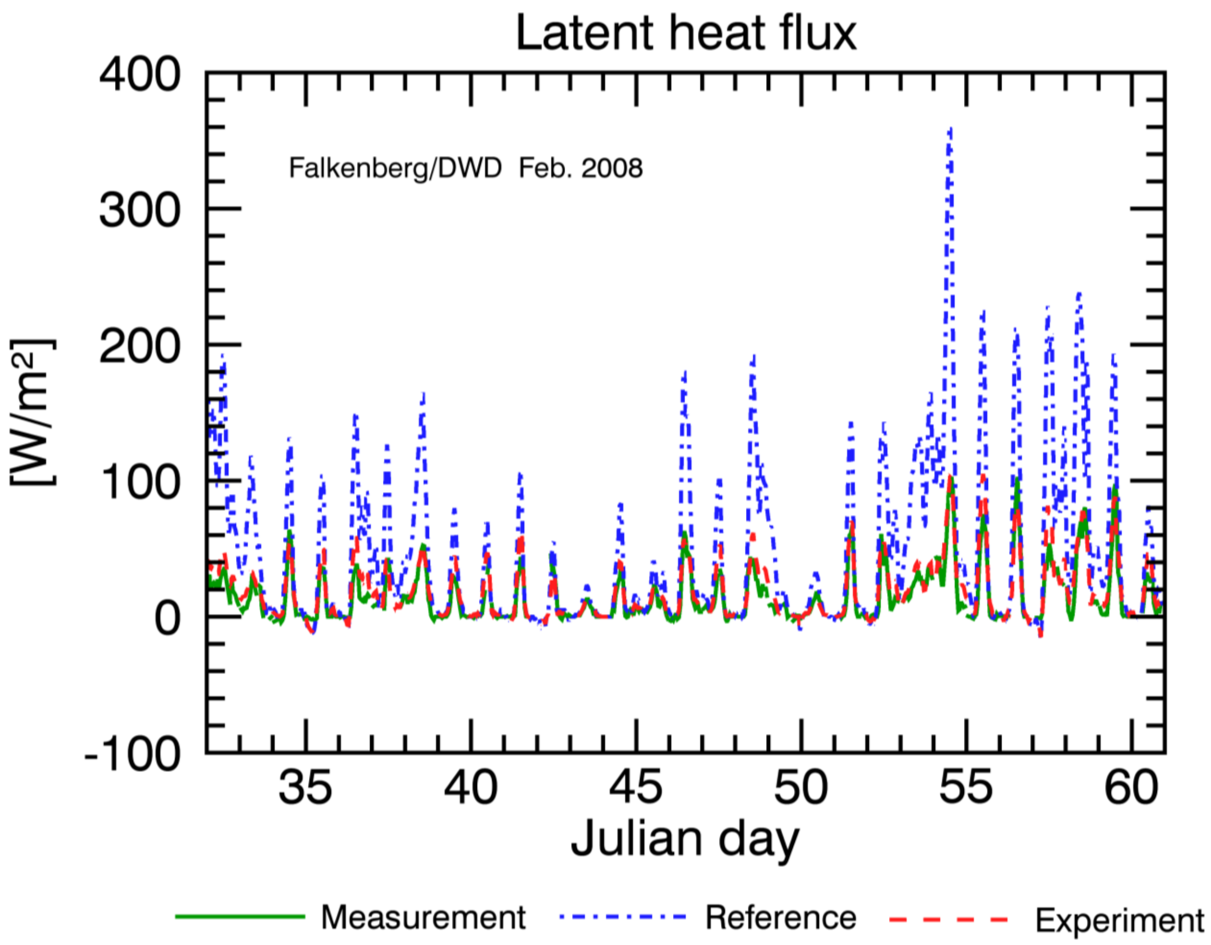
2014

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



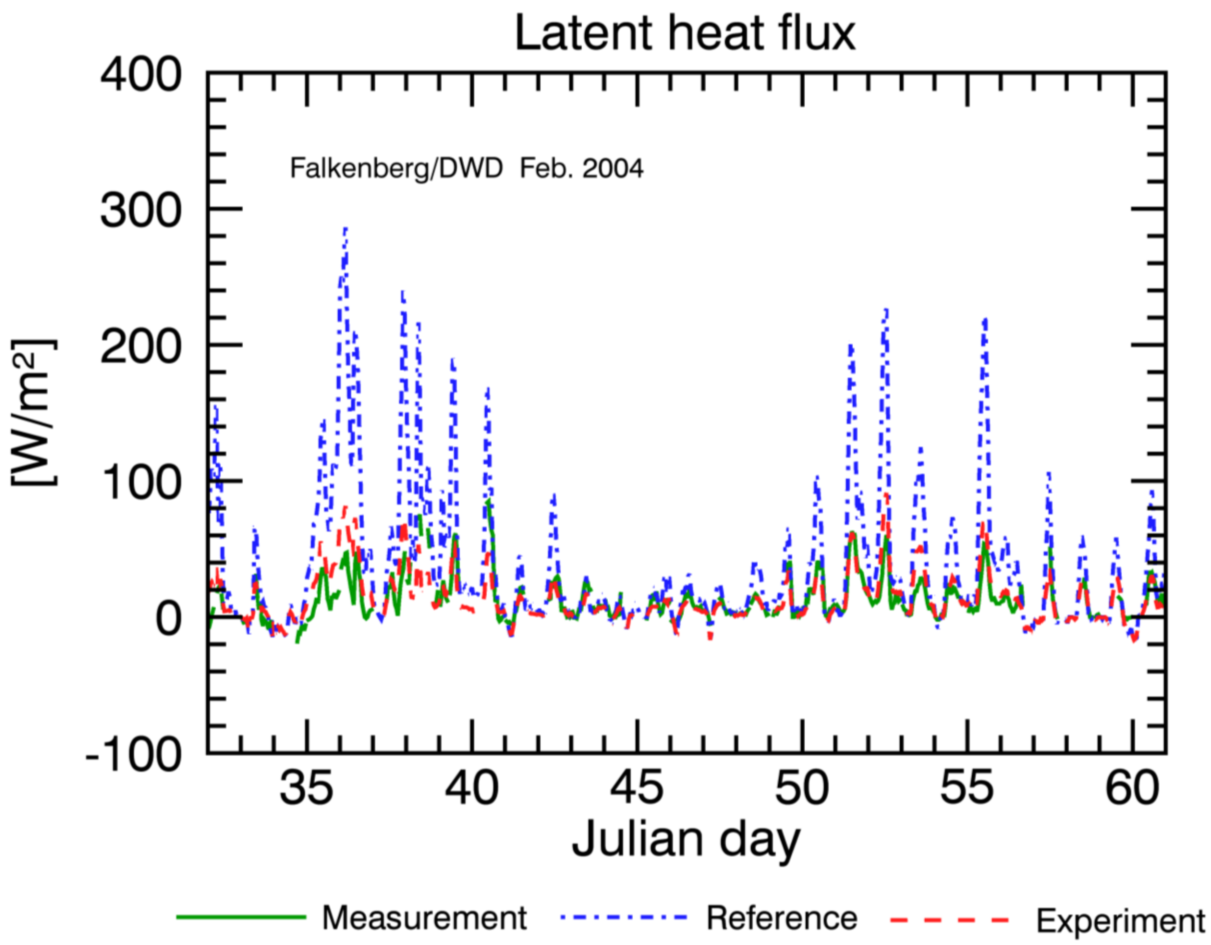
2014

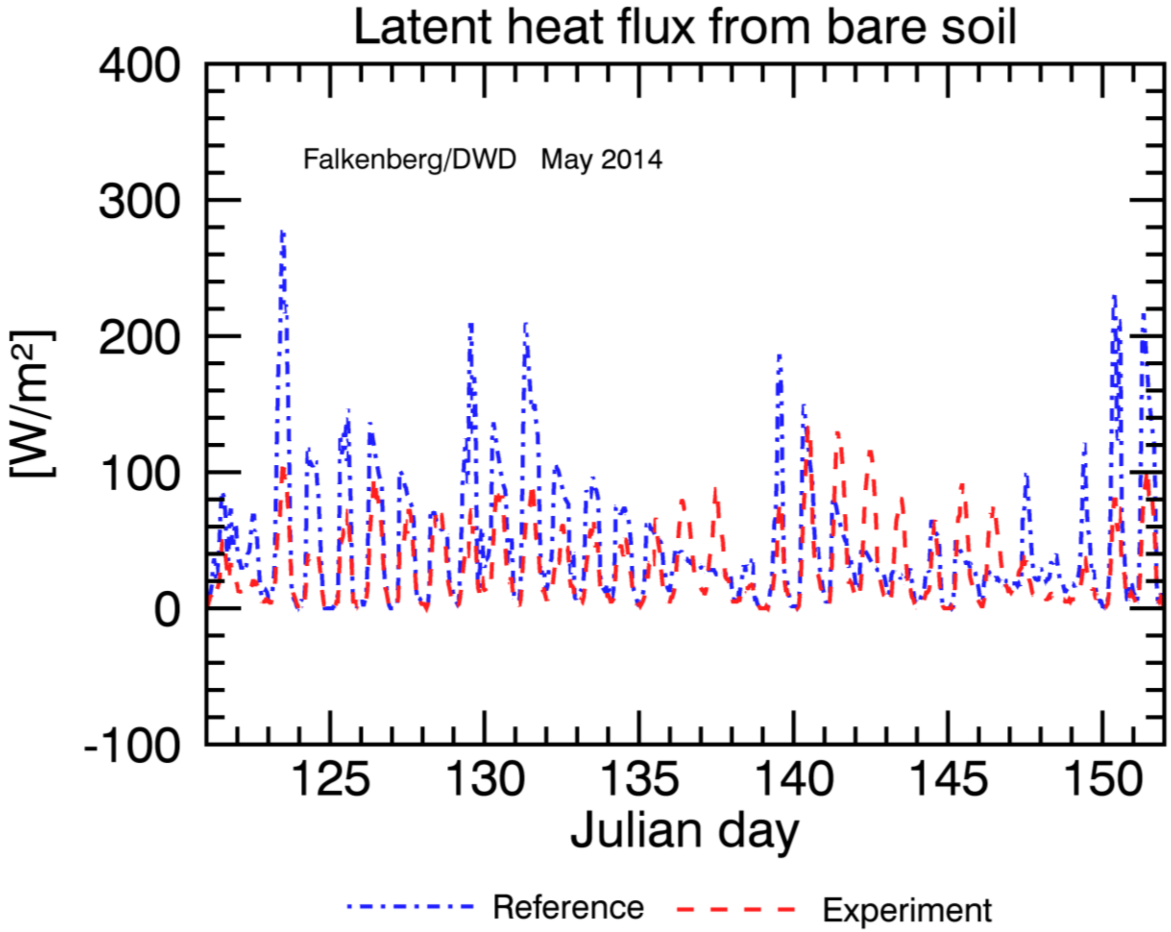
Reduced bare soil evaporation simulated by resistance method reduces drying of the soil considerably, annual cycle of soil moisture much improved compared to BATS


Latent heat flux
Falkenberg/DWD Feb. 2008
400
300
200
100
0
-100
[W/m²]
35
40
45
50
55
60
Julian day
Measurement
Reference
Experiment

Feb. 2008

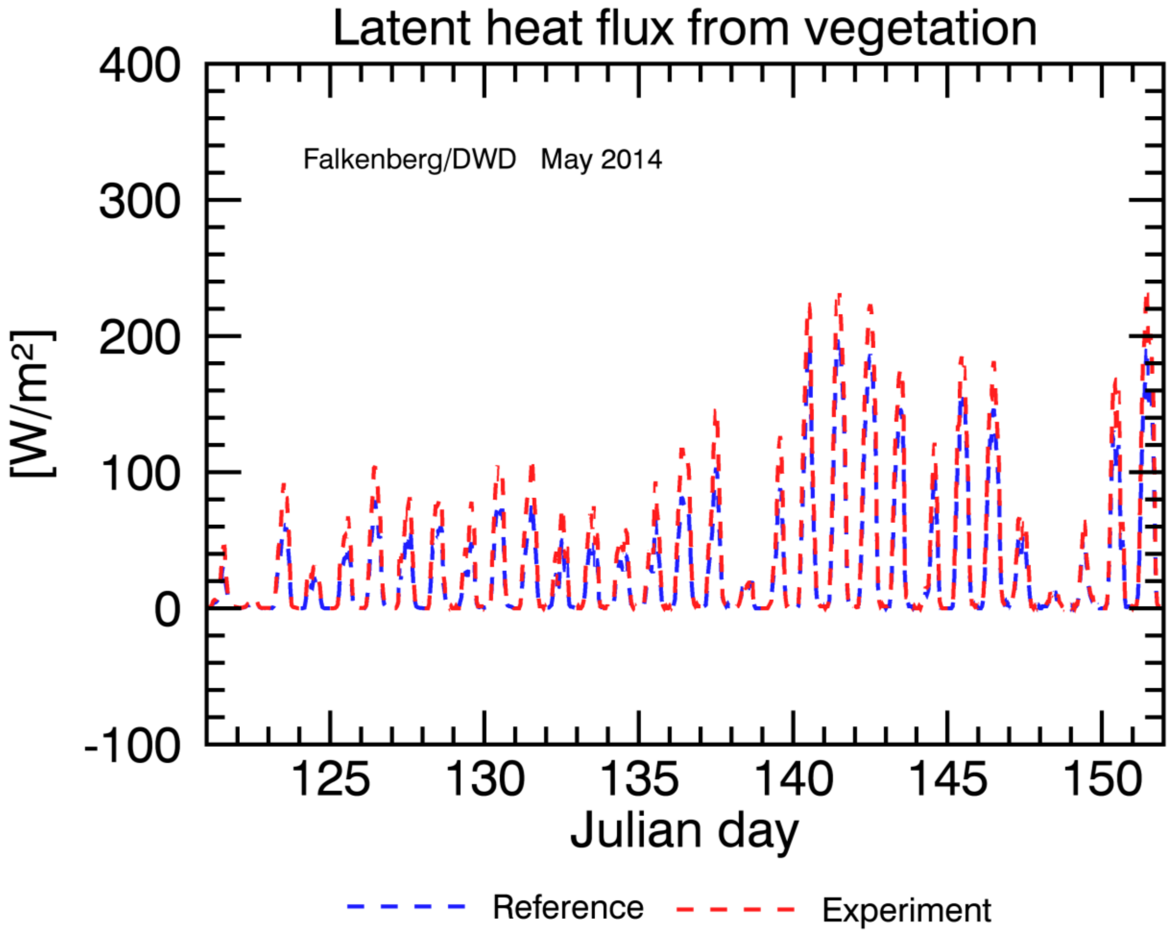
Feb. 2004


Latent heat flux
Falkenberg/DWD Feb. 2004
400
300
200
100
0
-100
[W/m²]
35
40
45
50
55
60
Julian day
Measurement
Reference
Experiment



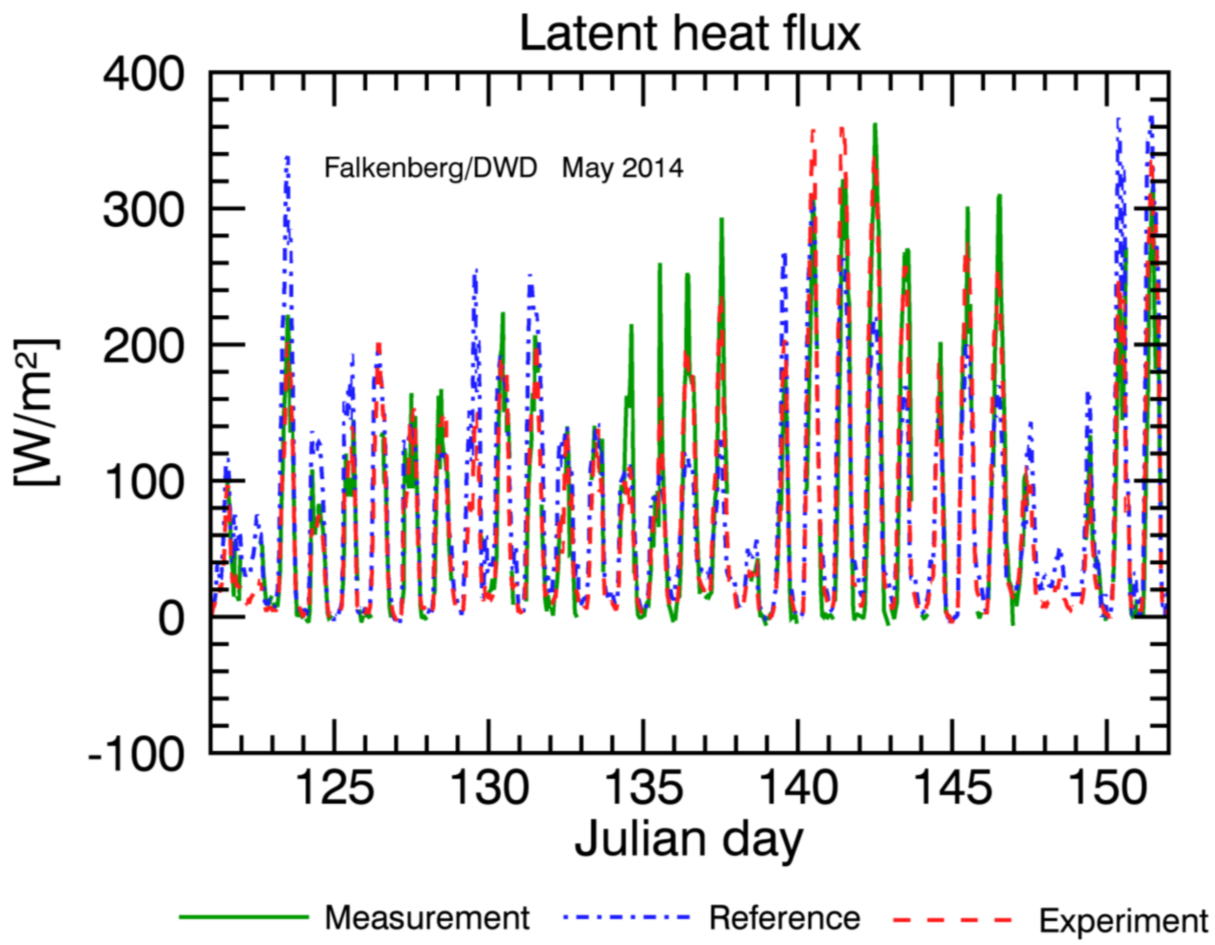
May 2014

Bare soil evaporation not always reduced by resistance method compared to BATS, under dry conditions it is increased



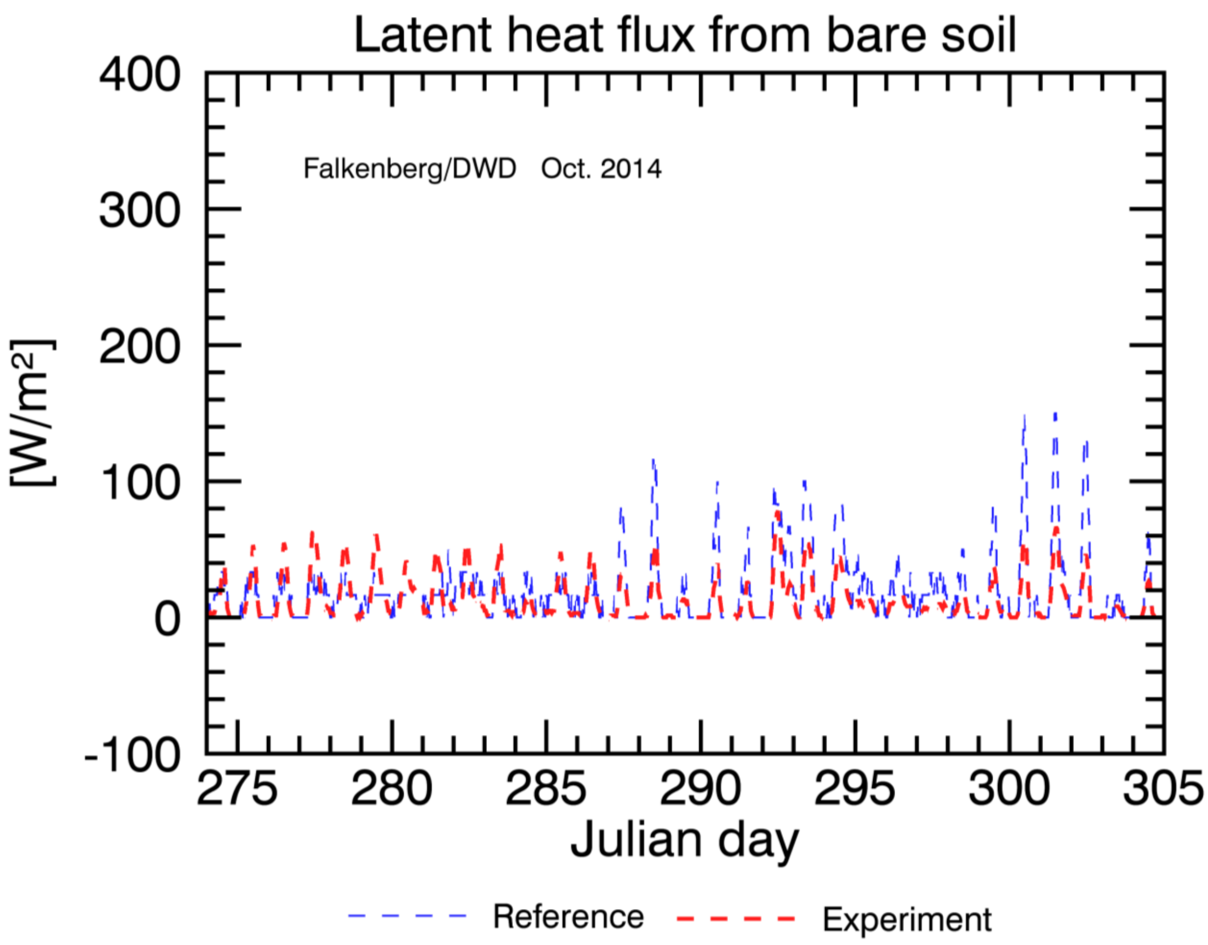
May 2014

Transpiration much higher in May than in February, following the phenological cycle

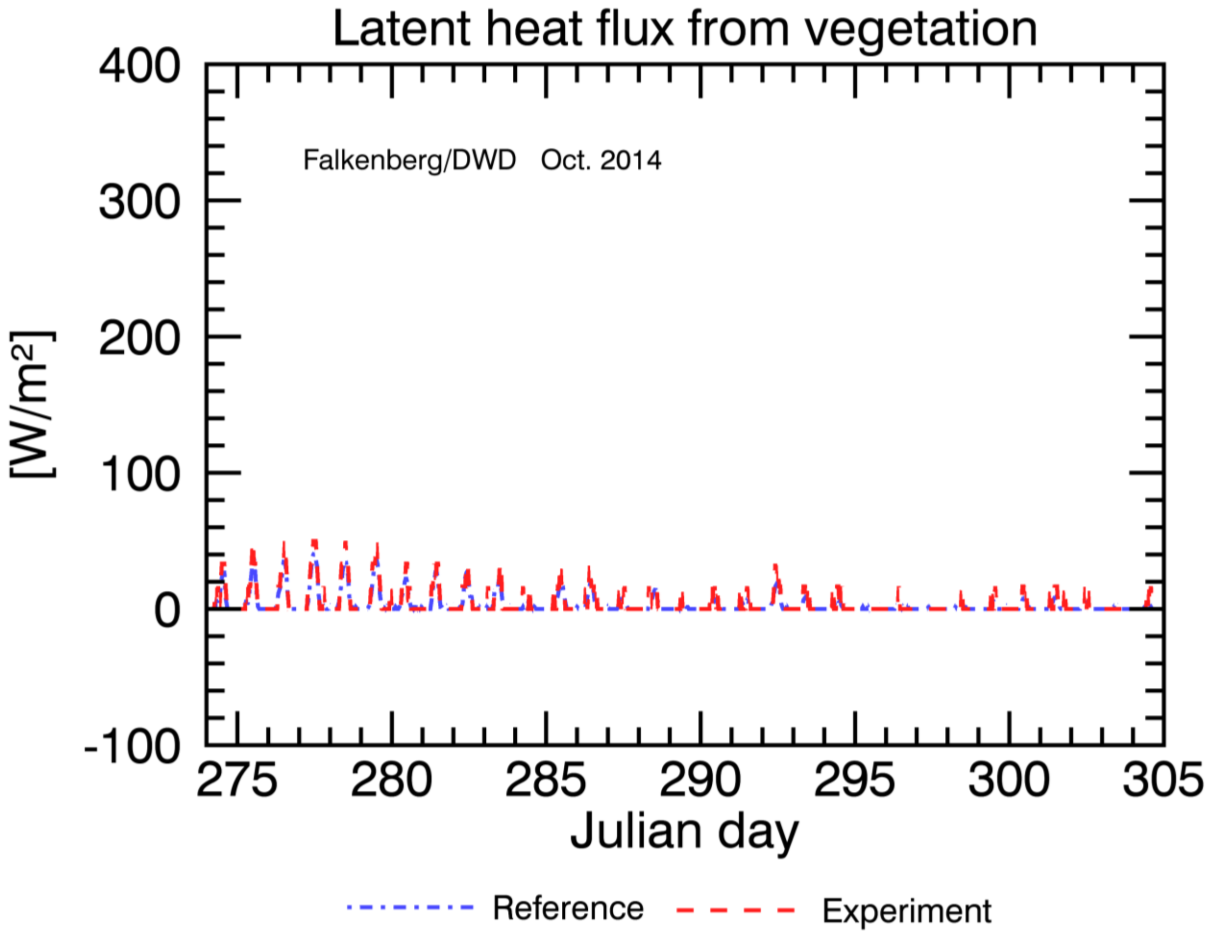


May 2014

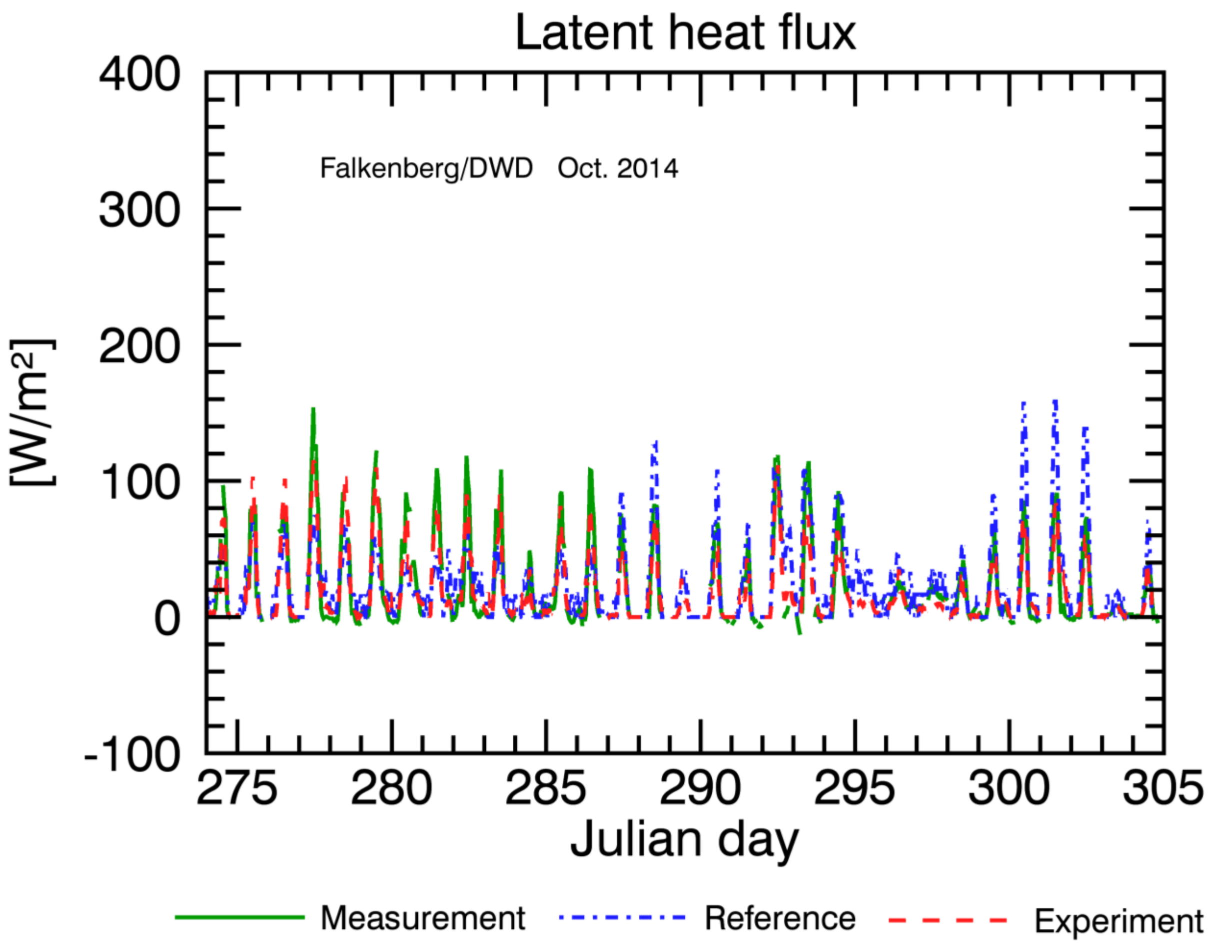
Latent heat flux improved by resistance method both under wet conditions (reduced) as well as under dry conditions (increased) compared to BATS


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

Oct. 2014

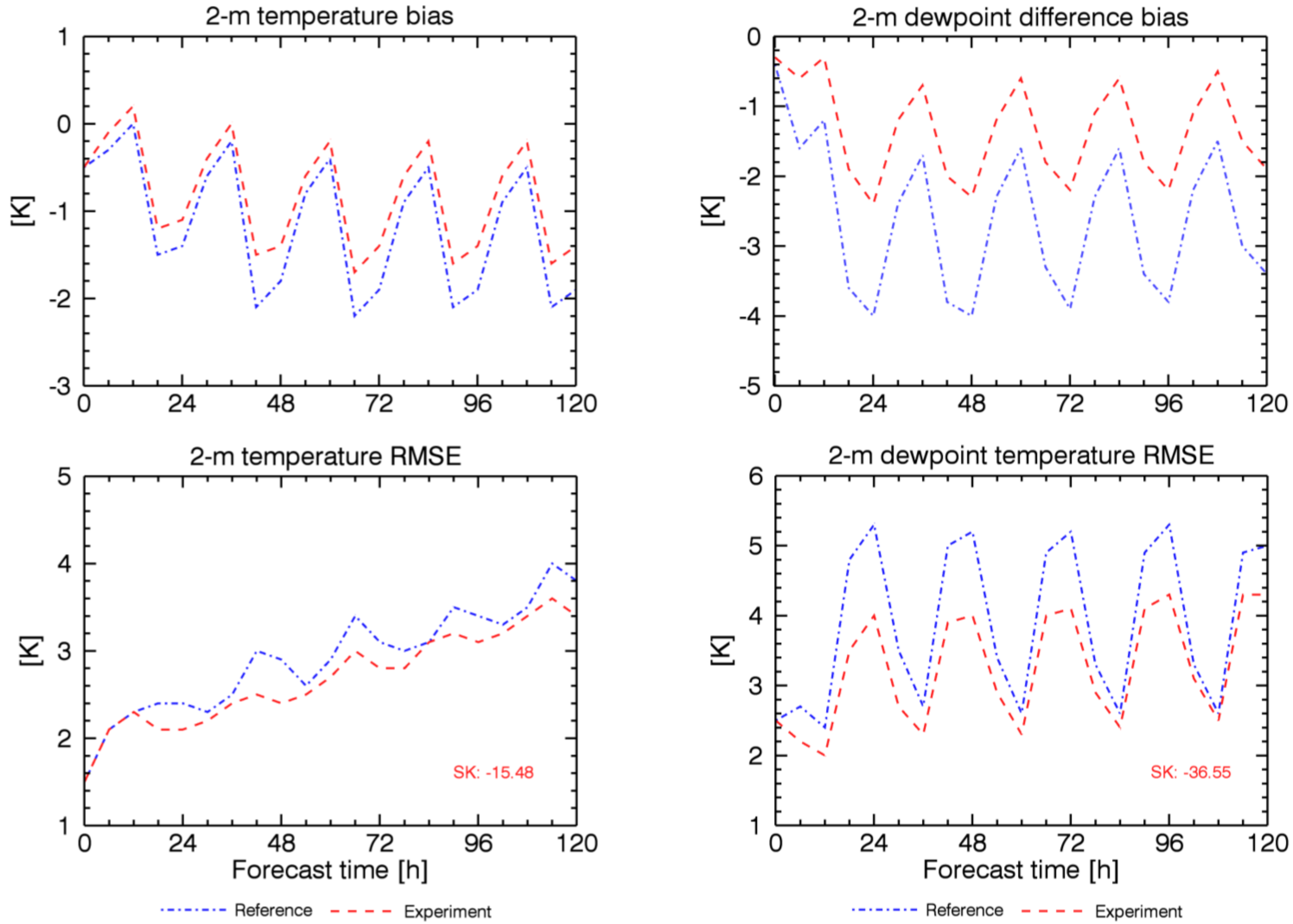

Latent heat flux from vegetation
Falkenberg/DWD Oct. 2014
400
300
200
100
0
-100
[W/m2]
275
280
285
290
295
300
305
Julian day
Reference
Experiment

Oct. 2014


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

ICON: NE America, January 2012, 00 UTC



- Cold bias and RMSE of 2-m temperature significantly reduced by resistance equ.
- Moist bias and RMSE of 2-m dewpoint difference substantially reduced

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.