



The influence of thermal soil and vegetation characteristics on the ground heat flux and temperature

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The problem ...

Verifications have shown that the ground heat flux computed by the land surface scheme of the COSMO Numerical Weather Prediction model of the German Weather Service tends to be systematically overestimated. Since this flux is part of the surface energy balance it affects the other components like the turbulent heat fluxes or the surface temperature.

This means, an overestimation of the ground heat flux during daytime leads to an underestimation of the other surface fluxes and a reduced surface warming. During afternoon and night this behaviour is reversed.

SRNWP Data Exchange Programme

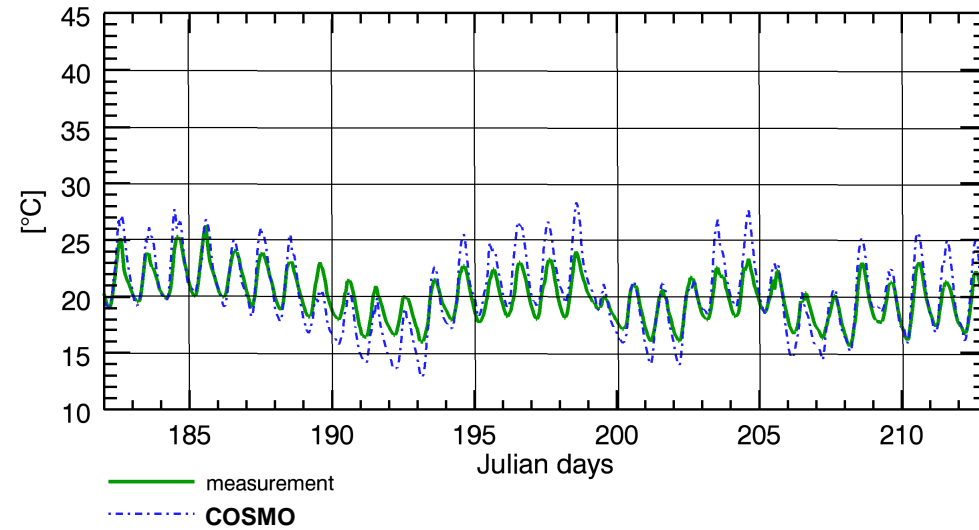
The data pool is an initiative by the Short Range Numerical Weather Prediction (SRNWP) Programme of EUMETNET to promote collaboration between the five European limited area modelling consortia. The COSMO consortium has the responsibility for the collection and provision of these data.

Six European sites are selected in order to evaluate the operational COSMO model simulations.

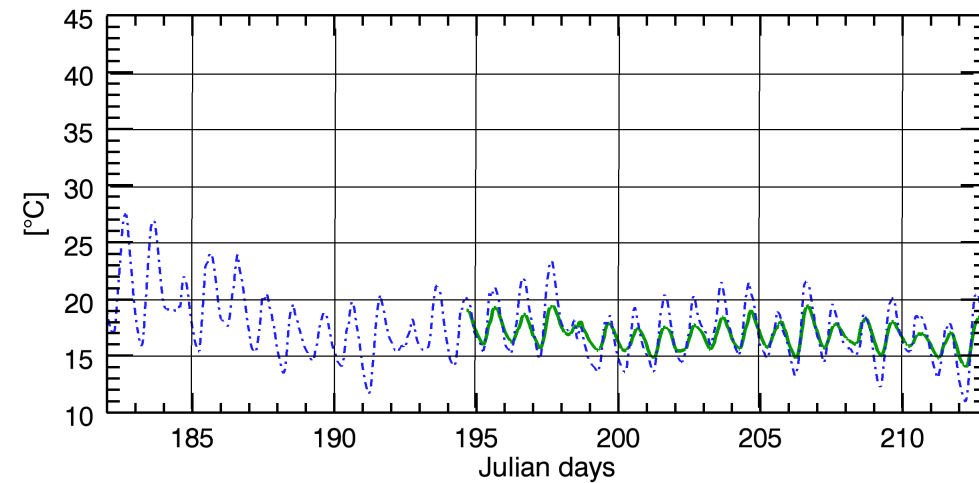
They all show a systematic overestimation of the amplitude of the diurnal cycles of the soil temperature. This behaviour becomes more enhanced the further south the observational site is located.

Soil temperature (-6 cm) : July 2009

Lindenberg
(Falkenberg)

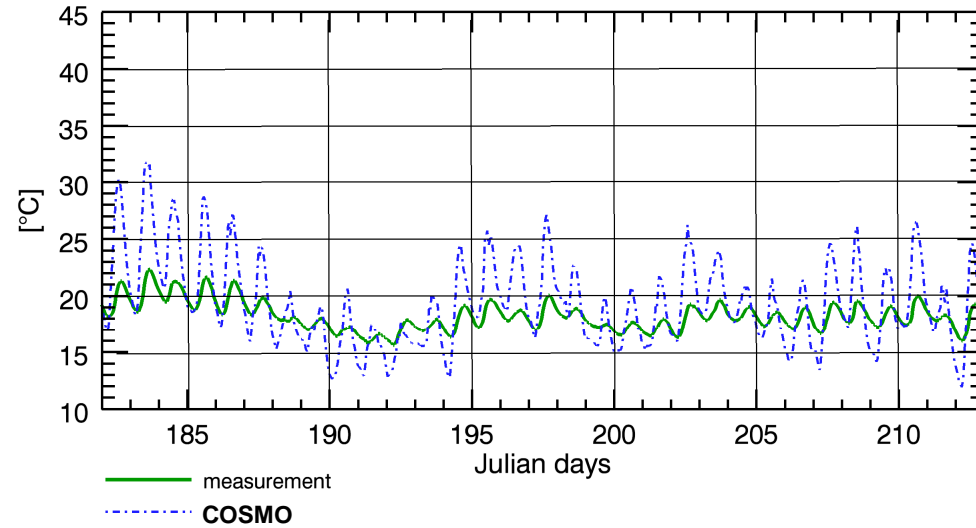


Cardington

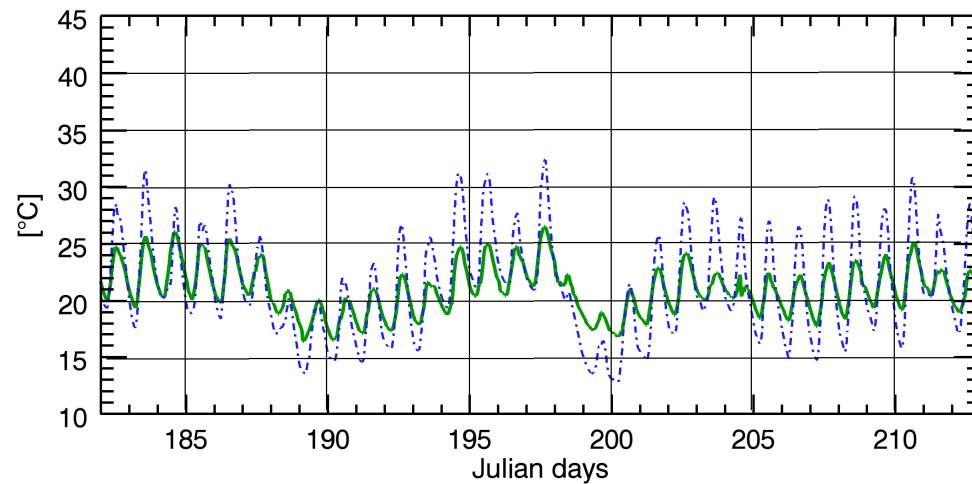


Soil temperature (-6 cm) : July 2009

Cabauw

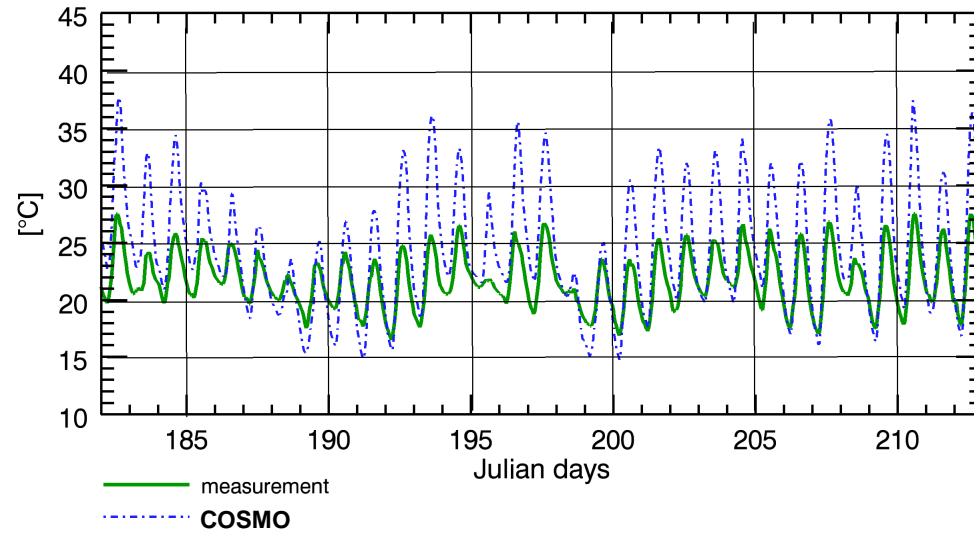


Payerne

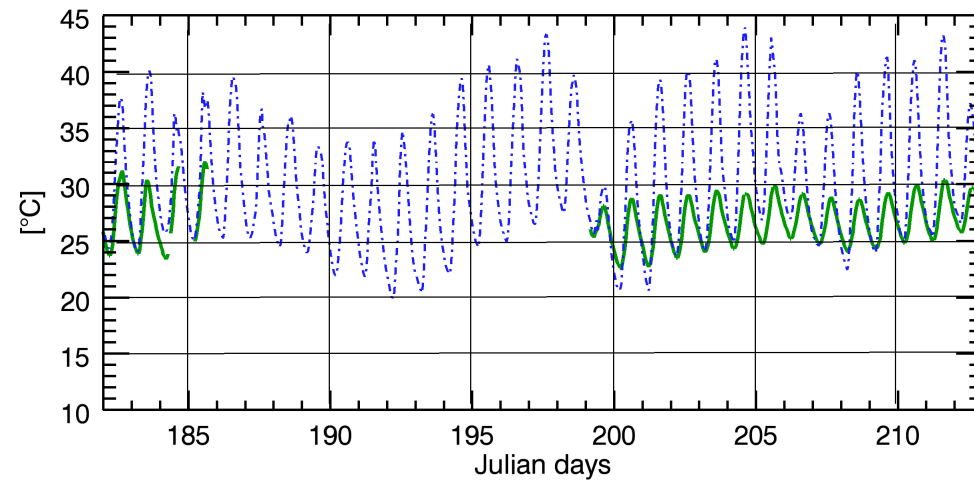


Soil temperature (-6 cm) : July 2009

Toulouse
(Fauga-Mauzac)



San Pietro
Capofiume



Hypothesis

The results have shown that the ground heat flux in the COSMO model is systematically overestimated (in summer). Therefore, it should be reduced. There are two main reasons for this overestimation:

- The shading effect of the vegetation is not represented in the model
- The thermal conductivity of the soil is too large (in summer)

Solution

- Introduce a simple shielding factor in the model
- Reduce the thermal conductivity of the soil (in summer), here by introducing its strong dependency on the soil moisture content

Experiments

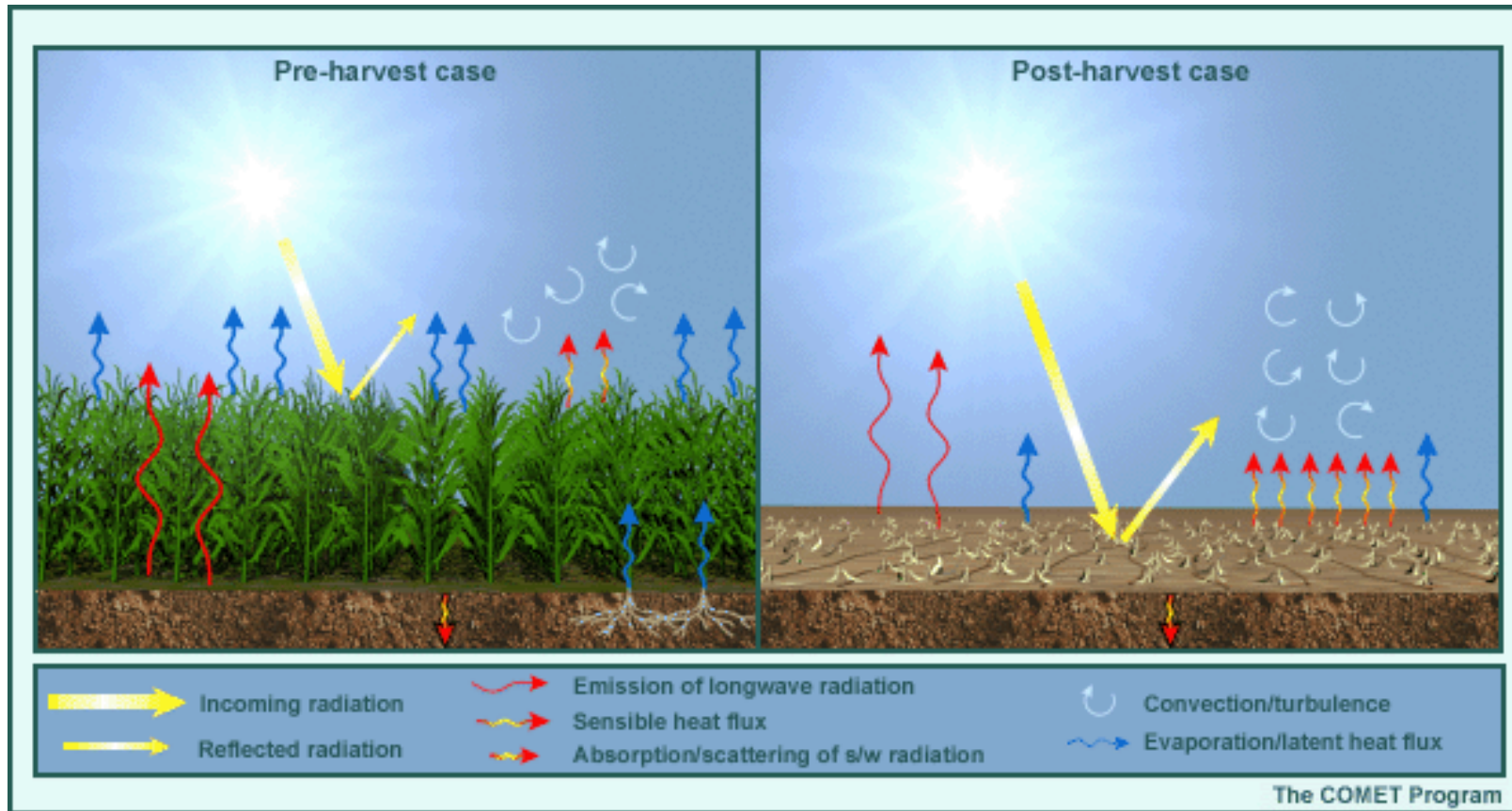
The two effects

- **Shading**
- **Thermal conductivity dependent on soil moisture content**

were tested in sensitivity experiments with the offline version of the multi-layer land surface scheme TERRA in order to study their impact on the ground heat flux and the soil temperature.

The shading was described by e.g. Deardorff (1978), Avissar and Pielke (1989) or Schädler et al. (1990). They introduced a shielding factor which is related to the vegetation cover. Furthermore, Schulz et al. (1998) have demonstrated that introducing a separate energy budget for the canopy improves the surface temperature simulated by the soil-vegetation system.

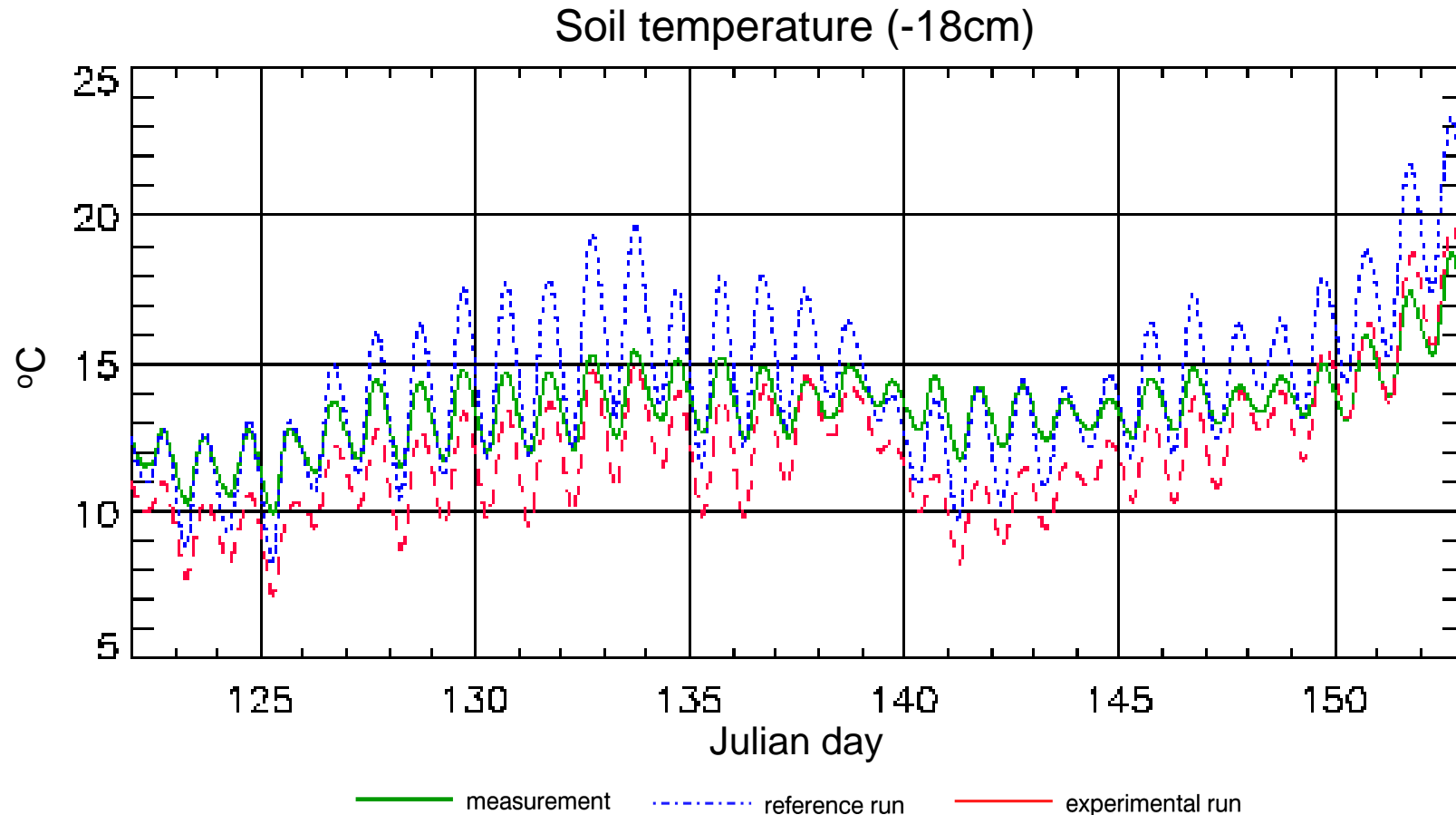
Shading



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

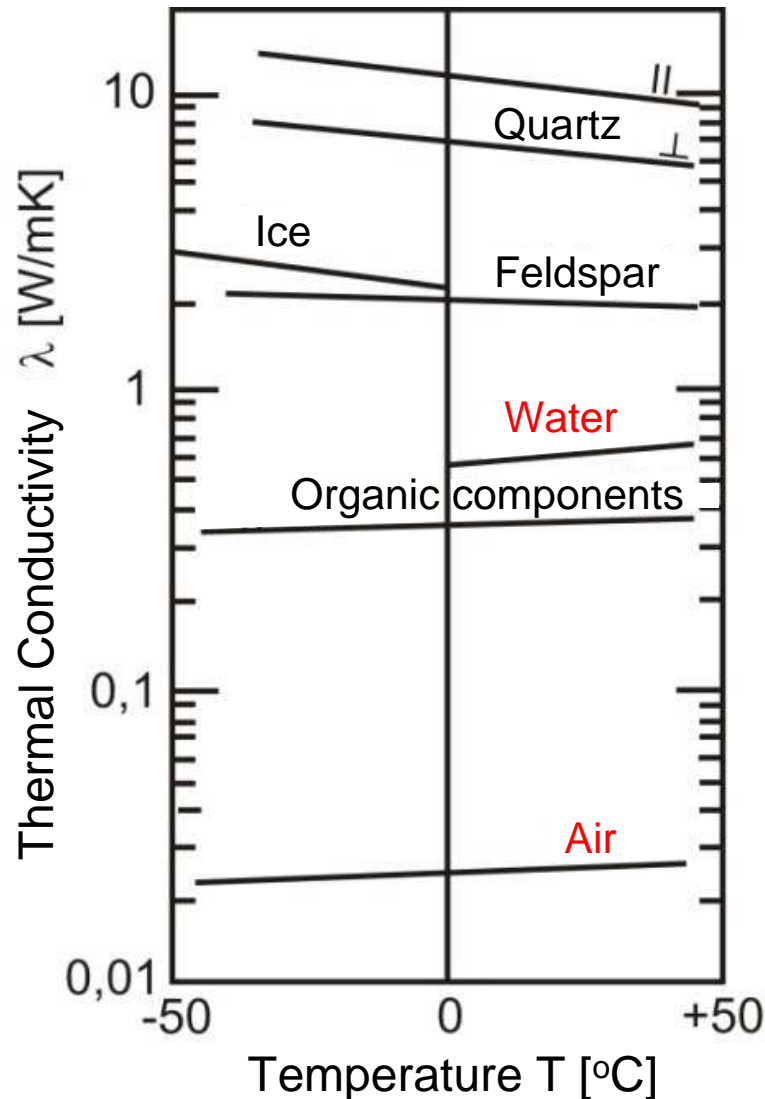
Offline TERRA: Falkenberg May 2008

Shading with plant cover 0.7



The soil temperature and its diurnal cycles are reduced in the experiment, in particular the latter fits better to the observation.

Thermal Conductivity



The thermal conductivity of water is about a factor of 25 larger than that of air!

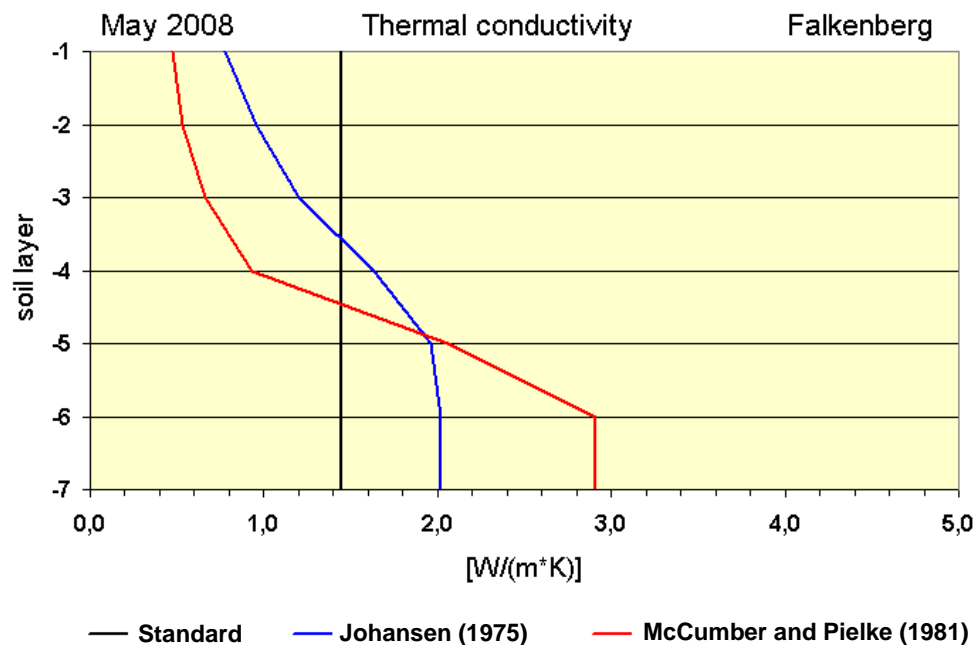
This means, replacing the air in the pores of a soil by water increases the thermal conductivity of the soil system dramatically.

In other words:

A wet soil (in winter) has a much larger thermal conductivity than a dry soil (in summer).

Baier (2008), after Frivik (1981)

Thermal Conductivity



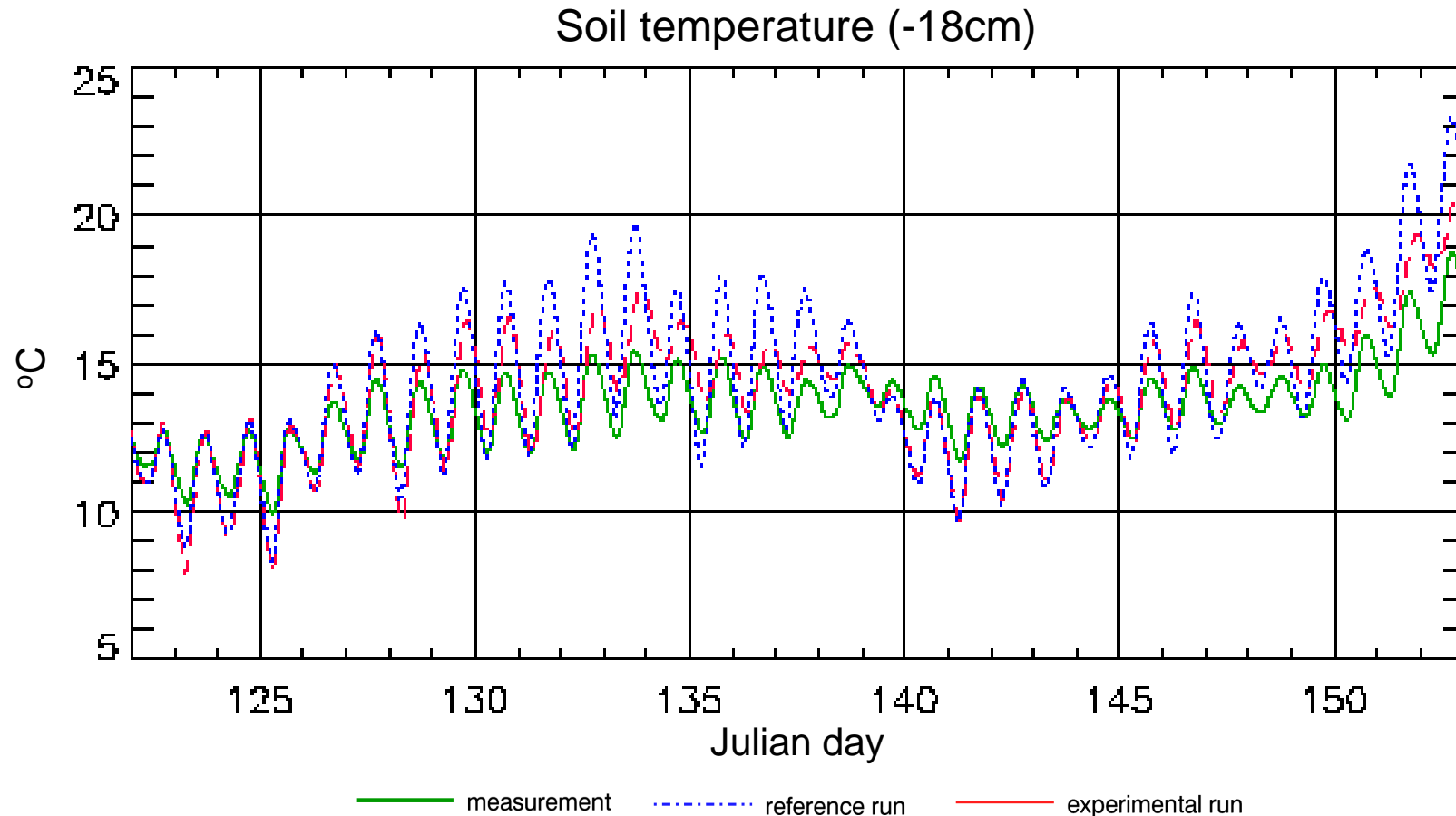
In the soil component of the COSMO model, the multi-layer TERRA scheme, the thermal conductivity is constant in time. It represents a medium soil wetness, shown by the black line in the figure.

The blue and red curve show the vertical profile of the thermal conductivity, computed for the mean soil moisture profile for Falkenberg in May 2008.

Two different approaches were used, relating thermal conductivity to soil moisture content. In our offline simulation we used McCumber and Pielke (1981).

Offline TERRA: Falkenberg May 2008

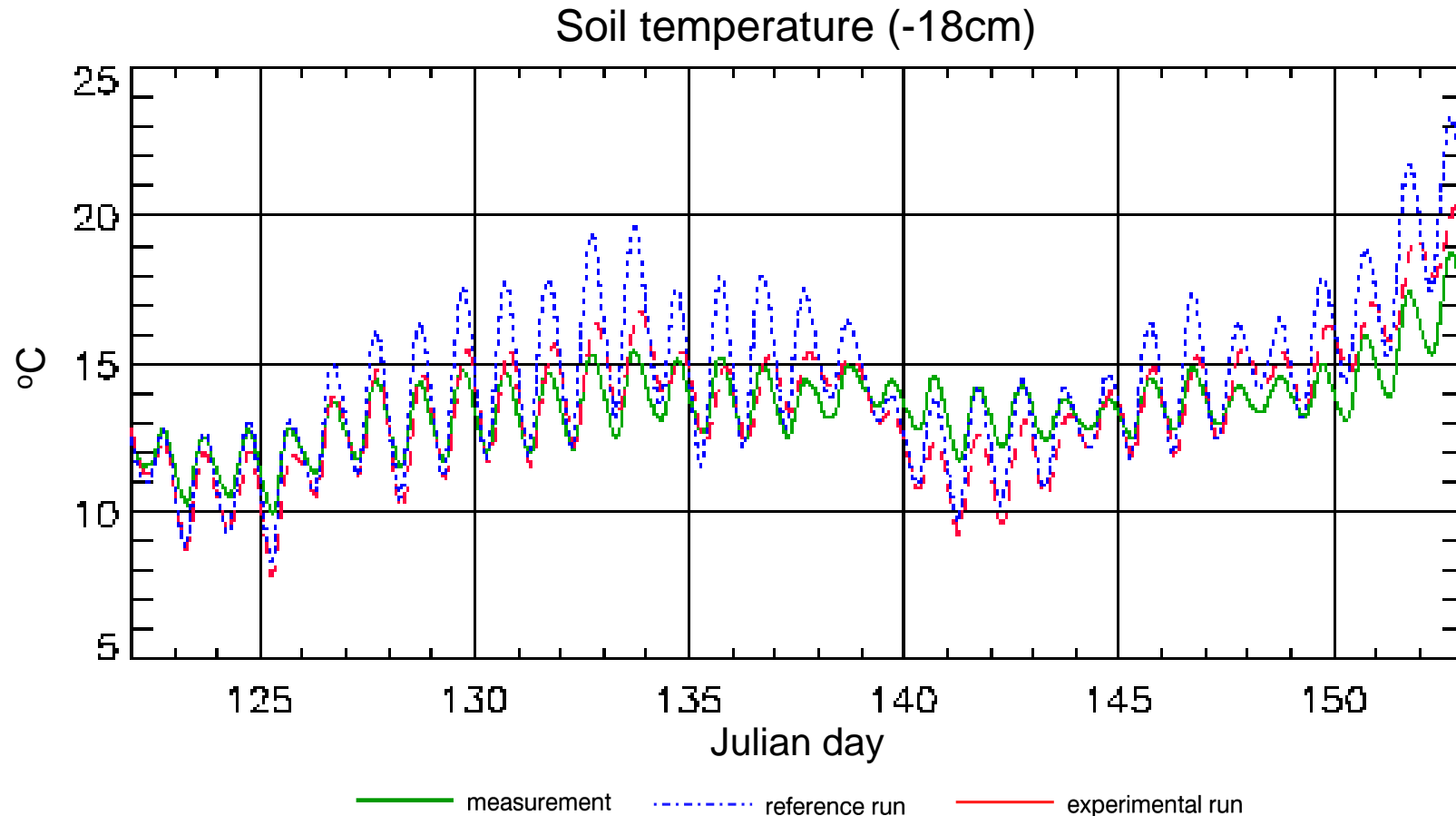
Thermal conductivity depending on soil moisture



The diurnal cycles of the soil temperature are much reduced in the experiment and fit better to the observation.

Offline TERRA: Falkenberg May 2008

Shading and variable thermal conductivity



The combination of both model modifications gives the best result for the soil temperature and its diurnal cycles.

Conclusions

- The ground heat flux in the COSMO model is systematically overestimated (in summer).
- This can affect also the other components of the surface energy balance like the turbulent heat fluxes or the surface temperature in terms of phase or amplitude of their diurnal cycles.
- Observations from the SRNWP data pool are very valuable for analysing this model behaviour. The offline version of TERRA is a very useful tool for developing model changes and improvements.
- The shading by the vegetation and the thermal conductivity of the soil are very good candidates for explaining the presented model deficiencies. Further work on this subject is needed.

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