ELDAS preliminary test-validation

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Dear Colleagues,

During the first ELDAS progress meeting we agreed upon the following course of action towards the ELDAS validation part as defined in WP 4100:

1) Initially, a first set of timeseries from the model output (TESSEL, TERRA, and ISBA) will be prepared by the ELDAS modelers. The structure of this preliminary dataset resembles the final output structure as much as is feasible for a *fast* production, but it will include at least several basic validation parameters (turbulent fluxes, net radiation components,…) as listed in the discussion of the validation plan. The timeseries will cover about 6 days. This dataset will allow us to start setting up a preliminary validation infrastructure.
2) Next, a larger dataset will be prepared, which will resemble the final model output products as close as possible. The dataset will comprise 2 months of timeseries, and also some spatial fields covering the ELDAS domain. This dataset is intended to be used to show the feasibility of the validation system and the tests we would like to perform.
3) Finally, using the experience obtained in phase 1 and 2, the "ultimate" validation dataset will be prepared.

We are still in phase 1 now. Recently, we received output from the DWD SVAT model TERRA (thanks, Martin!), for the period 1-6 June 2000. A *rough*, *preliminary test* (note this sequence of words!) validation was performed as an ELDAS validation appetizer, with the intention:

- to get an idea of some basic problems that might occur during the actual validation of the ELDAS soil moisture fields;
- to highlight some points that need attention in preparing the model output;
- to give the ELDAS project group a first flavor of the kind of analyses we plan to do within the validation work package;
- to involve you in the validation dinner and to encourage you to send us your phase 1 data as well;

To that end, we describe a comparison between the output from TERRA and observations from the "*Loobos Tower*", for a 6-day period, 1-6 June, in the year 2k.

Loobos Observations

The observations used here for the preliminary comparison are obtained at the Loobos site, established in the year 1995, and part of the CARBOEUROPE network of flux sites. The site is located near the town of Kootwijk in The Netherlands, at 52° 10' 00'' N, 5° 44' 38'' E. The area is quite flat, with an average elevation of 25 m above the mean sea level. Loobos is a forest site on sandy soil. The dominant tree species is *Pinus Sylvestris* and the average canopy height is 15.5 m. The Leaf Area Index (LAI) of the trees is about 2, and varies roughly between 0 and 1 for the undergrowth.

Turbulent fluxes are obtained using the eddy-correlation (EC) technique. The EC system (Figure 1) consists of a 3D ultrasonic anemometer (Solent, Gill) in combination with a fast infrared gas analyzer (Li-Cor 6262) placed on the top of a 26 m tower, with a fetch of 2-3 km. A full description of the system may be found in Moncrieff et al. (1997) and Aubinet et al. (2000). Additionally, CO_2 and H_2O concentrations are measured at five levels, (CIRAS-SC, PP systems), along with wind speed and temperature. The four components of the net radiation balance are observed separately: incoming and reflected short wave radiation are determined using two pyranometers (CM21, Kipp). The long wave components are measured by pyrgeometers (CG1, Kipp), with the sensor for the incoming long wave radiation being ventilated. At the top of the scaffolding tower at 26 m meteorological measurements of precipitation, horizontal wind speed, wind direction, relative humidity and air temperature are performed as well. Soil heat flux is measured using four heat flux sensors (TPD-TNO), under the litter layer at a depth of 3 cm in the mineral soil. Soil moisture and temperature are also measured in at five depths, but unfortunately, due to system failure these data are not available in the period investigated here. The averaging period of the observations is 30 minutes.

Model output

The output from TERRA applies to the grid point centered at 52° 9’ 27’’ N, and 5° 45’ 38’’ E, which is within 2-3 km from the Loobos site. The output is on an hourly basis: the energy fluxes are 60-minutes averages, while the other variables apply to the actual forecast time of the model. Some variables could not be provided as direct model output, but are obtained from post-processing the data. In some cases, an approximation has been used during the post-processing. An example is the shortwave radiation balance. The net shortwave radiation $SW_{net} = SWin + SWout$ was stored, but not its separate components $SWin$, incoming shortwave radiation, and $SWout$, outgoing shortwave radiation (note the convention that all downward fluxes are positive, and upward fluxes are negative). The latter two variables have been recomputed from the stored SW_{net}, using the approximation $SWout = -a_{dif}\, SWin$, in which a_{dif} is a soil-specific constant albedo for diffuse shortwave radiation. This is an approximation because in the model, $SWout$ is a function of direct (parallel) incoming radiation weighted by an albedo that depends upon zenith angle ($a(\theta)$), and downward diffuse shortwave radiation weighted by a_{dif}.

Table 1 lists the information provided by Martin Lange of DWD (Thanks again!), and provides the model output variables with an indication whether this is a direct output, and if not, whether the recomputed output is an approximation of the model code.

Figure 1. *Eddy correlation devices at the Loobos site. Left: Ultrasonic Anemometer and air inlet for CO_2 and H_2O measurements. Right: gas analyzer. See text and references for further information.*

Table 1. *Description of the output from TERRA.*

Variable	**Code**	**Direct Output**	**Approximated**	**Comment**
Operational soil moisture	*Smop(1), Smop(2)*	Yes	No	Soil moisture fields from operational forecasts, for two layers
Analysis increment	*Sminc(1), Sminc(2)*	no	no	Increment in *Smop* after analysis with observations from the previous day.
Net Radiation	*Netrad*	no	no	Re-computed as net shortwave radiation + net longwave radiation
Incoming shortwave radiation	*Swin*	no	yes	Approximation of albedo; $Swin = Swnet /(1-a_{dif})$
Outgoing shortwave radiation	*Swout*	no	yes	Approximation of albedo; $Swout = a_{dif}/(1-a_{dif})\ Swnet$
Incoming longwave radiation	*Lwin*	no	yes	Re-computed as *Lwnet* – *Lwout*, with *Lwnet* the net longwave radiation.
Outgoing longwave radiation	*Lwout*	no	yes	$Lwout=\varepsilon\sigma T_0^4$ with emissivity ε=1, Stefan-Boltzman constant σ=5.67•10^{-8} and T_0 the surface temperature
Latent heat flux	*Lhfl*	yes	no	
Sensible heat flux	*Shfl*	yes	no	
Air temperature	*T2m*	yes	no	No time average
Relative humidity	*Rh2m*	yes	no	Range 0-1, no time average
Windspeed, x	*U2m*	yes	no	At 10 m
Windspeed, y	*V2m*	yes	no	At 10 m

Comparison of data and model output

Timeseries

First, we compared with the data the timeseries of the net radiation and its individual components generated by the model. A relatively large difference is obtained for the reflected shortwave radiation. From the ratio *SWout/Swin* we derive an albedo of about 9% from the data, and of 16% for the approximated albedo of the model.

Clearly, the surface at the observation site and the average surface assumed in the model do not match. Similar problems probably occur for other surface characteristics like roughness, Leaf Area Index (LAI) *etcetera*, but we do not have the information to investigate this in more detail. This illustrates the need to describe the surface very carefully as well as the need to generate separate output for *all tiles* within a gridbox, so that measurements and model output can be compared for similar surfaces.

Another important feature in the present analysis is the overestimation of the incoming shortwave radiation on days 5 and 6, which were presumably cloudy days. At the same time, the incoming longwave radiation seems to be underestimated, from which we conclude that the model simulates a too low cloud cover. The net result is an overestimation of the net radiation, in spite of the higher albedo that causes too much reflected shortwave radiation.

Although from ELDAS perspective the cause of the differing net radiation is external, it is still important because it shows the reason why we will have to normalize in some way the fluxes related to soil moisture in order to have a fair comparison. Even in the case where model boundary conditions are standardized we will need such normalization to accommodate the differing “boundary conditions” of the observations. In the next section, we will consider some normalized atmospheric moisture indicators, which have of course their own problems.

A straightforward comparison of the sensible and latent heat fluxes is given in Figure 3. In can be seen that the latent heat flux is overestimated, while the sensible heat flux is underestimated. Our guess was that the differences are caused by the difference in the surface roughness and surface resistances between the model and the characteristics of the forest. To pursue this a little further, we tried to extract the aerodynamic and surface resistance (r_a and r_s, respectively) from the model output. As an intermediate step, we computed the surface-atmosphere differences of temperature and humidity, which were in the mean in reasonable agreement with those derived from the data. However, the scatter in the *model data* precluded a further investigation of the surface characteristics through r_a and r_s. This demonstrates why we need your own best estimates of quantities such as r_a and r_s on top of a careful definition of the model surfaces.

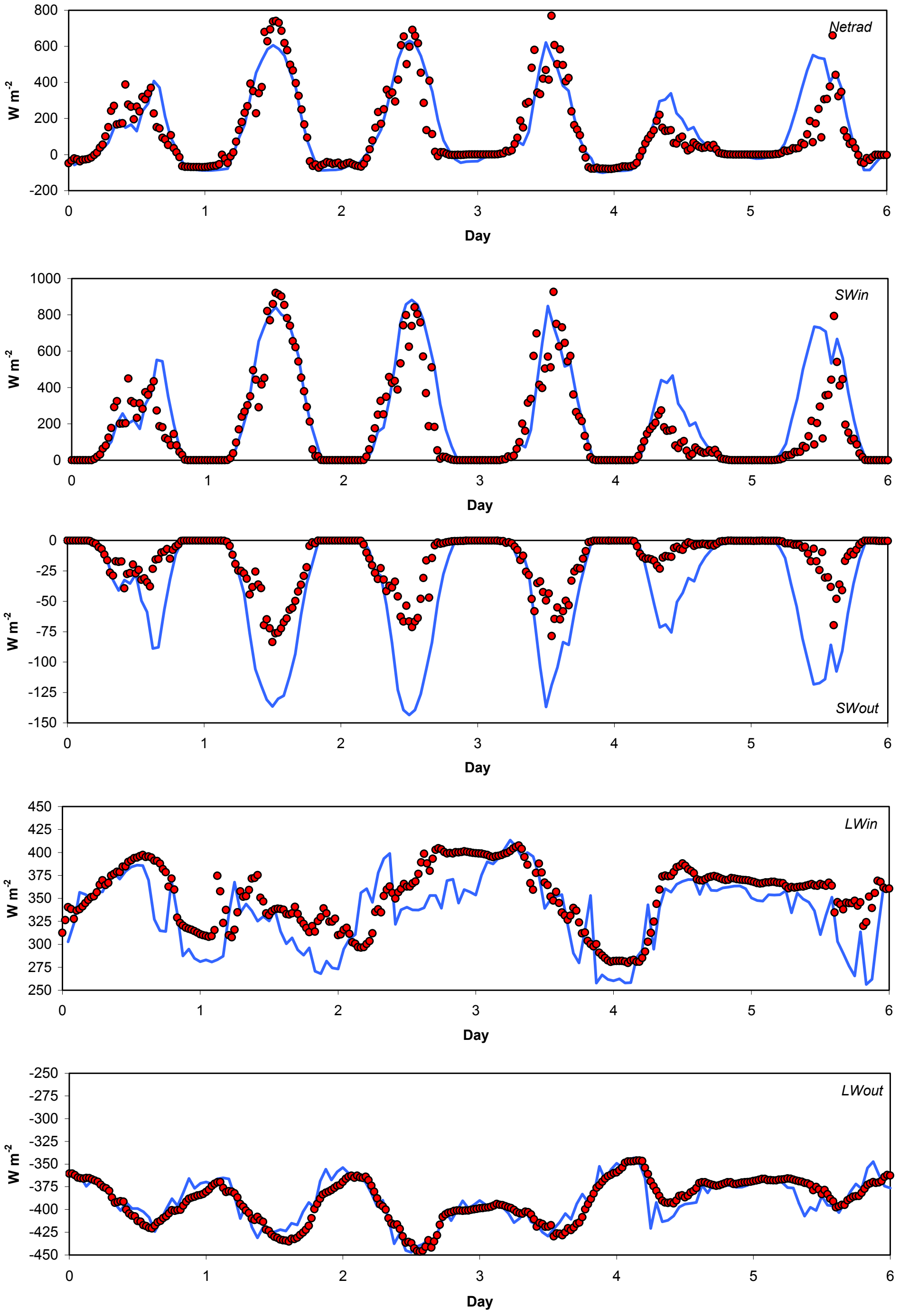

Figure 2. *Comparison between timeseries of the radiation fluxes from the model (blue lines) and from the observations (red circles). Labeling of the panels is according to Table 1.*

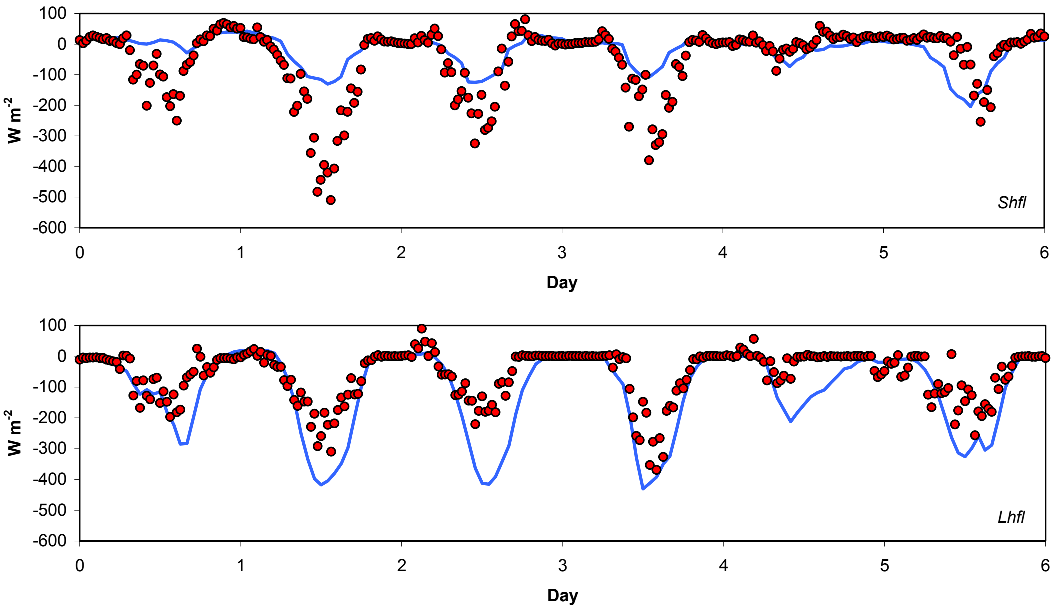

Figure 3. *Comparison between the timeseries of the sensible and latent heat fluxes from the model (blue lines) and the observations (red circles). Labeling of the graphs is according to Table 1.*

Moisture indicators

The most straightforward validation within ELDAS context is a direct comparison between the observed and modeled soil moisture fields. However, as in this preliminary validation, soil moisture might not always be available. In such cases especially, we will have to use atmospheric moisture indicators. We will be mainly interested in relatively slow, day-to-day variations that might be related to variations in soil moisture. Therefore, we computed around-noon averages (10-14 UTC) for these variables because their limited variation during this time of the day (Bastiaanssen, 1995). We computed these averages for all the model variables listed in Table 1 (except the daily increments of soil moisture) and for some derived variables, notably:

- the energy ratios *Lhfl*/*Netrad*, *Shfl*/*Netrad*, *G*/*Netrad*
- the surface temperature and water vapor pressure *T0* and *Es(T0)* respectively
- the water vapor pressure at the reference level *E(T2m)*
- the surface-atmosphere differences *DT=T0-T2m* and *DE=Es(T0)-E(T2)*
- the horizontal wind speed $Utot = \sqrt{(U2m^2 + V2m^2)}$
- the following atmospheric soil moisture indicators:
  - Bowen ratio $\beta = Shfl/Lhfl$ *(1)*
  - Evaporation fraction $\Lambda = Lhfl / (Lhfl+Shfl)$ *(2)*
  - Priestly and Taylor parameter $\alpha = [(s+\gamma)/s]\Lambda$ *(3)*

where s is the slope of the saturation vapor pressure curve and γ is the psychrometric constant.

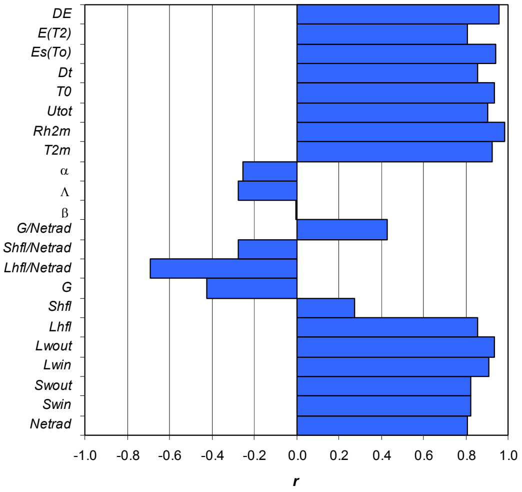

Figure 4. *Correlation between Loobos observations and TERRA model output for the quantities listed on the left axis. See Table 1 and main text for and explanation of the labels.*

We now computed the correlation matrices for the observed and modeled around-noon variables. Some results are given in Figure 4, showing the correlation between the Loobos observations and the TERRA model output, and Figure 5, showing the correlation between the simulated soil moisture (layer 1 and 2) and the other model-derived variables.

It can be seen that day-to-day observations of most variables within this six-day period are reasonably well reproduced by the model as long as they do not involve the sensible heat flux. Note that α contains *Shfl* via Λ in (3). Also, *G*/*Netrad* has been computed as the remainder in the energy budget and therefore contains *Shfl* as well.

The simulation of the moisture indicators is rather poor, except for *Lhfl*/*Netrad* that might also be interpreted as an atmospheric soil moisture indicator. Without further evidence, we would clearly have a problem in validating the soil moisture status.

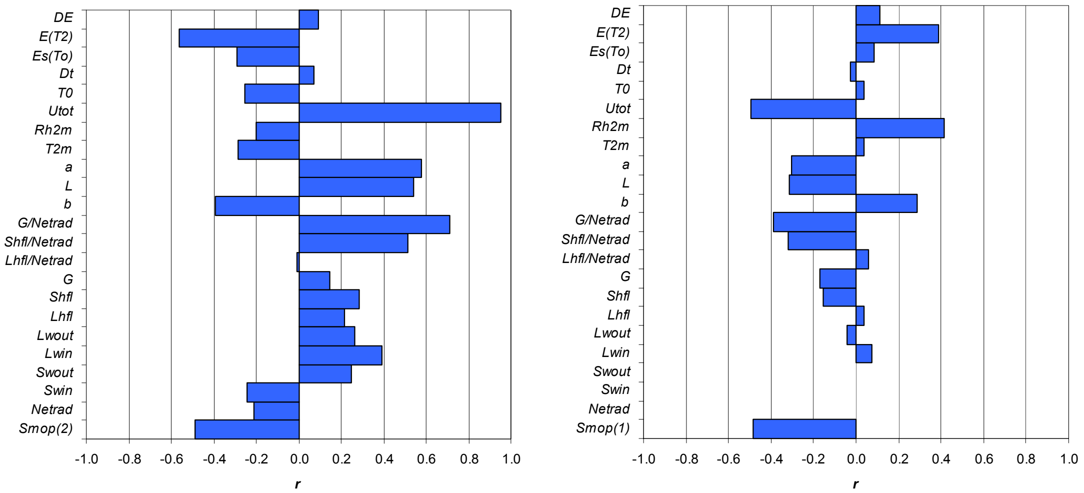

Figure 5. *Correlation* r *between the TERRA model variables (left axes) and the modeled soil moisture content for the upper soil layer (left panel), and the lower one (right panel).*

In this preliminary analysis we have no means to really check the validity of α, Λ and β as local soil moisture indicators, that is, using *observations* of soil moisture. But what we *can* do is to derive the soil moisture indicators that are *implicit* in the TERRA model by selecting the (combination of) variables with the highest correlation with the soil moisture content of the first and the second soil layer, *Smop*(1) and *Smop*(2), respectively (Figure 5). The most surprising result is that, according to TERRA, the wind speed *Utot* is the best soil moisture indicator for the upper soil layer, followed by the ratio *G*/*Netrad*. Furthermore, there seems to be no suitable moisture indicator for the second model layer… except the soil moisture *increment* after a data assimilation step (r=0.69, not included in the graph).

The results from the correlation matrices are further illustrated in Figure 6, where the day-to-day evolution of the observed around-noon values of the "moisture indicators" are compared with the modeled ones, and with the modeled soil moisture content of the upper layer (*Smos(1)*). Indeed,

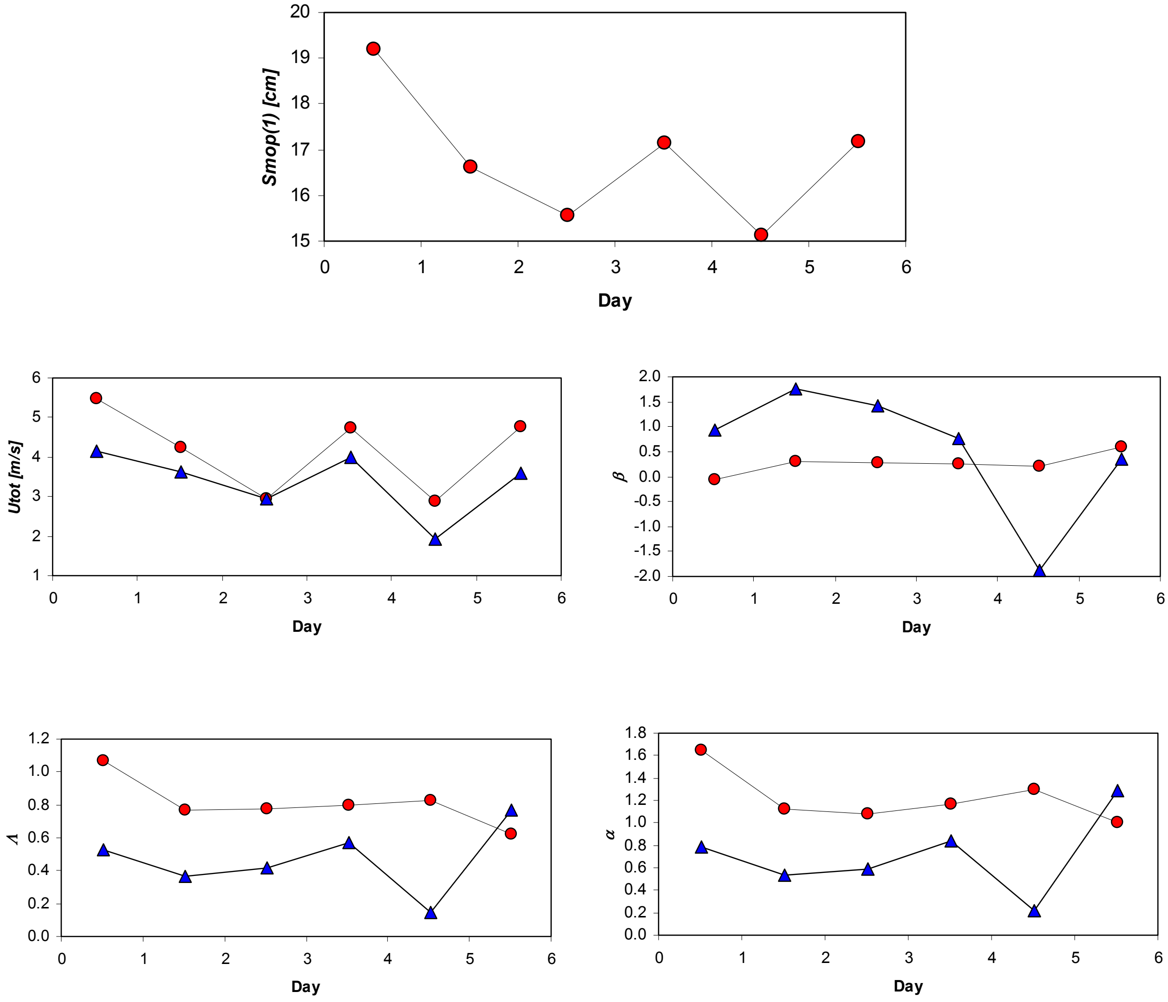

***Figure 6**. Evolution of modeled soil moisture content in the upper layer (Smop(1), upper panel), observed and modeled wind speed (U_{tot}, middle-left), Bowen ratio (β, middle-right), evaporative fraction (Λ, lower-left) and Priestley and Taylor α (lower-right). Observations are indicated with the blue triangles, model output by means of the red circles.*

Utot shows a remarkable correspondence with *Smop(1)*, while the “classical” moisture indicators reveal a disappointing performance of their “task”. Note that most problems appear to be related to the relatively poor simulation of day 5 and 6. Clearly, the present timeseries, although intriguing, are too short to draw definite conclusions.

Not yet the conclusion

We do not conclude that wind speed is a suitable soil moisture indicator to be used in the ELDAS validation study. Neither do we conclude that the moisture indicators perform badly. Our dataset is simply too limited to draw such conclusions. But we *do* conclude that for our validation study it is vital to have:

- Precise information on the model configuration, including the surface characteristics per gridpoint and per tile
- Separate model output of the fluxes per tile (if the tile-approach is used)
- Best estimates directly from the model of crucial parameters like r_a and r_s

References

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