Short note on the diurnal disaggregation of the Earth2Observe forcing by land surface models

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Rational :

Land surface models (LSM) solve the surface energy balance at sub-hourly time steps but the Earth2Observe forcing (E2OFD) only provides atmospheric conditions every 3 hours. Thus a temporal disaggregation is needed before the data is given to the LSMs. This is typically done in the driver of the model. If the disaggregation is not done in the same way by all models, differences in the imposed potential evaporation could result leading to discrepancies in simulated fluxes. Such differences in the interpretation of forcing data can have consequences on the WRR2 data which is produced by Earth2Observe.

Making this step more difficult than necessary is the convention used by ECMWF when attributing a date to an average quantity. This issue has been discussed before during the preparation of the WFD and WFDEI forcing and is documented in the papers by Weedon et al. In the ECMWF re-analysis, which is the basis for E2OFD, fluxes (Rainf, Snowf, SWdwon and LWdown) are provided as mean values over 3hourly intervals and they are attributed the last date of the averaging interval. On the other hand, scalar variables (Tair, Qair, U, V, Psurf) are provided as instantaneous values and have a unambiguous date.

In this analysis we do not discuss the precipitation fluxes (Rainf and Snowf) as they are disaggregated differently. Either the 3hourly cumulated flux is distributed homogeneously over the entire interval or only over a faction of that period. The impact on the simulated surface processes is difficult to asses as it depends on the complexity of the scheme used by each LSM for computing infiltration into the soil.

Experiment :

The 4 LSMs participating in the WRR2 exercise have been asked to provide time step values for one year (2006) over the Iberian Peninsula.

The analysis was performed over a few days in June on a point where it had not rained in the previous days (5.25 West, 41.75 North) and over the entire region for some characteristics of the diurnal cycle. These choices were made to ensure diurnal cycle difference could clearly be attributed to differences in the disaggregation method used.

Data provided by land surface models :

JULES : Provided hourly values for all forcing variables and a few of the fluxes computed by the LSM. No potential evaporation was provided.

Météo-France (MF) : Provided 15 minute values. Potential evaporation is not provided as it is not explicitly computed in the model.

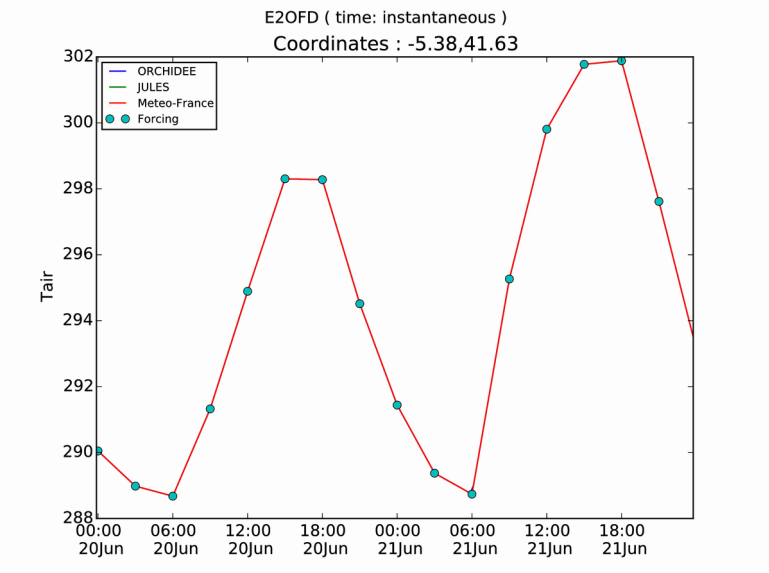
ORCHIDEE : All variables of the model were available at the 15 minute time step of the model.

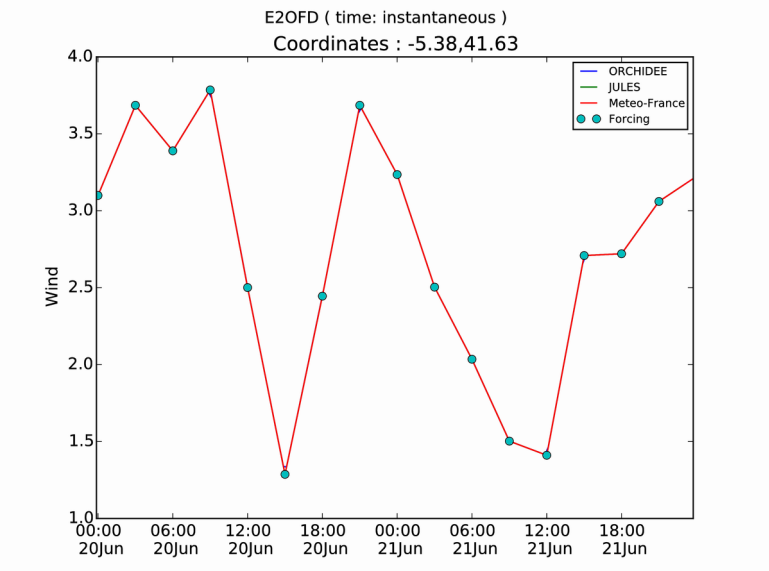
ECMWF : No data provided

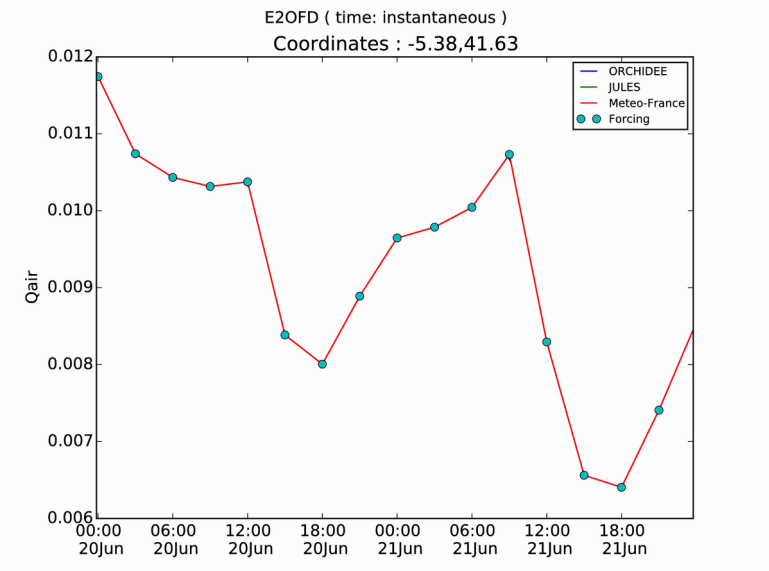
Preliminary analysis

Scalar variables

For the scalar variables, which are given as instantaneous values in E2OFD, all models produce the same values at their time step and they go exactly through the points provided by the forcing. All three models have used a simple linear interpolation.

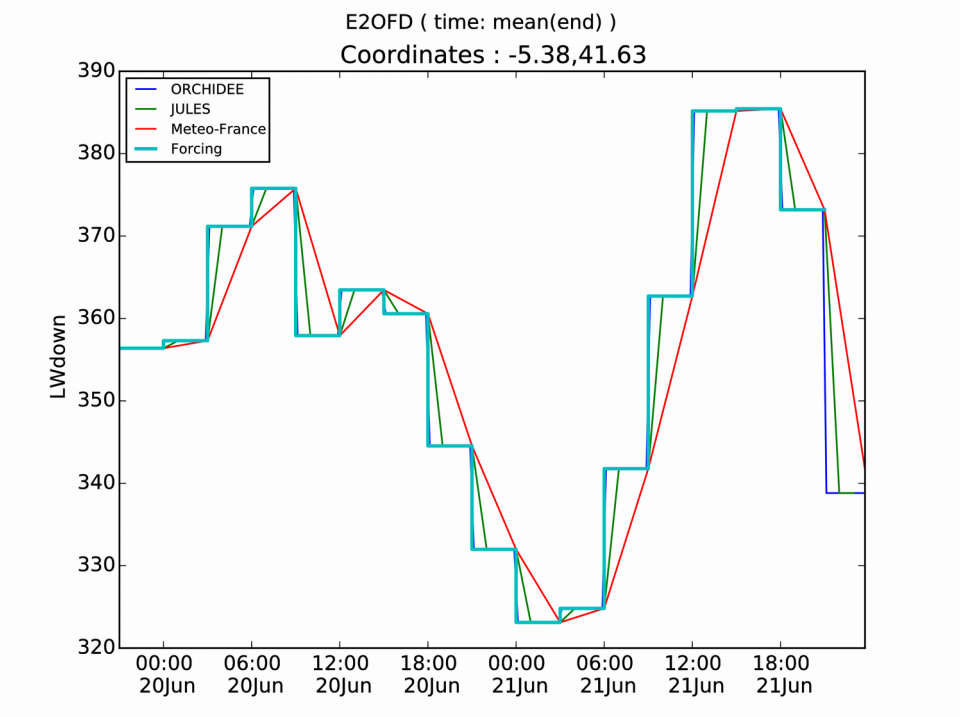






Long-wave radiation

Long-wave downward is the simplest flux to interpolate as it has relatively slow variations. As we wish to preserve the average flux provided by E2OFD during the temporal disaggregation, most models will simply maintain the given value during the validity period of the E2OFD data. Thus the flux given at 03:00 is maintained from 00:00 to 03:00.

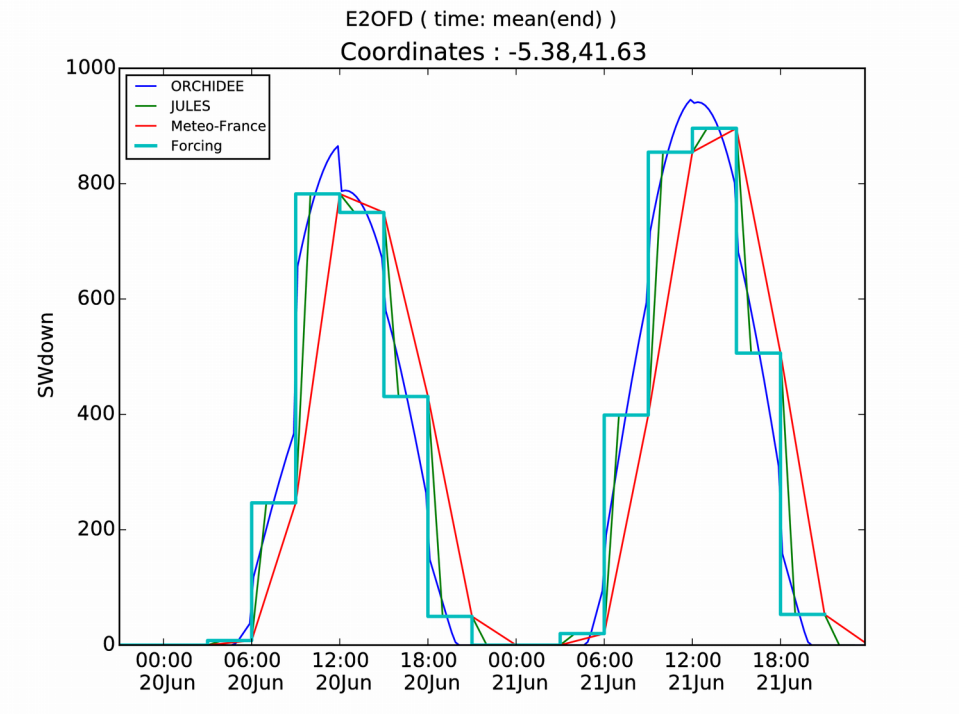


This is done correctly within JULES and ORCHIDEE. One can see that in JULES the line rejoins the forcing data a little later than ORCHIDEE. This is only due to the fact that JULES has provided the data at hourly time steps.

On the other hand we can see that MF does a linear interpolation of LWdown and furthermore treats the values provided by E2OFD as if they were instantaneous values, which was a mistake. This may have an impact on the flux conservation and may introduce a de-phasing up to 3 hours.

Short-wave radiation

For short-wave downwelling radiation the situation is much more complex as not only do we wish to preserve the flux, we also would like to reconstruct the mid-day peak at the maximum solar zenith angle.

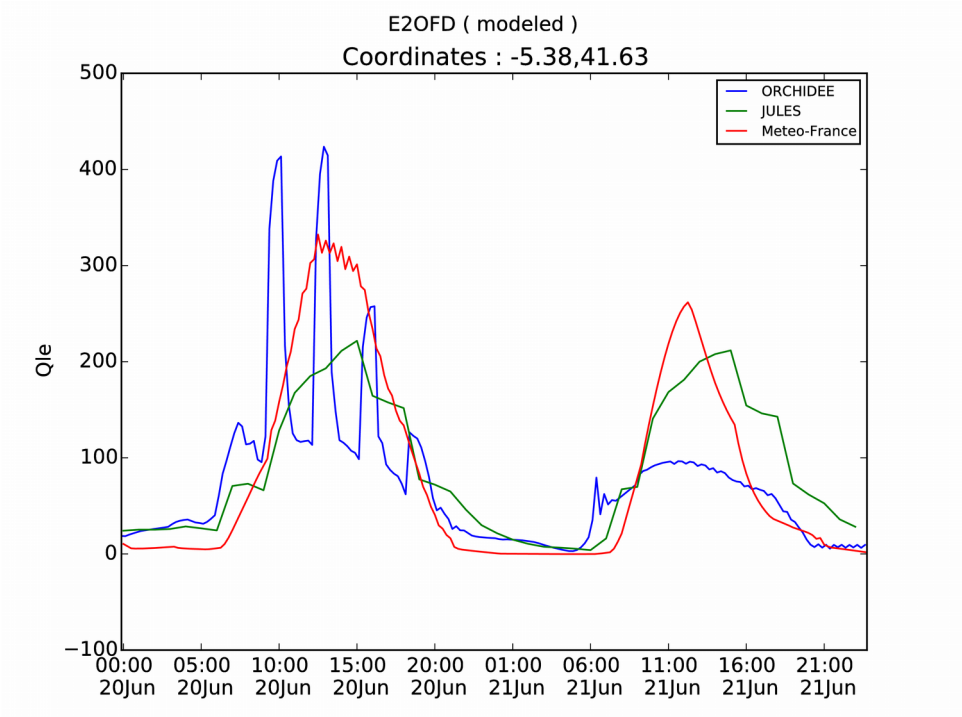


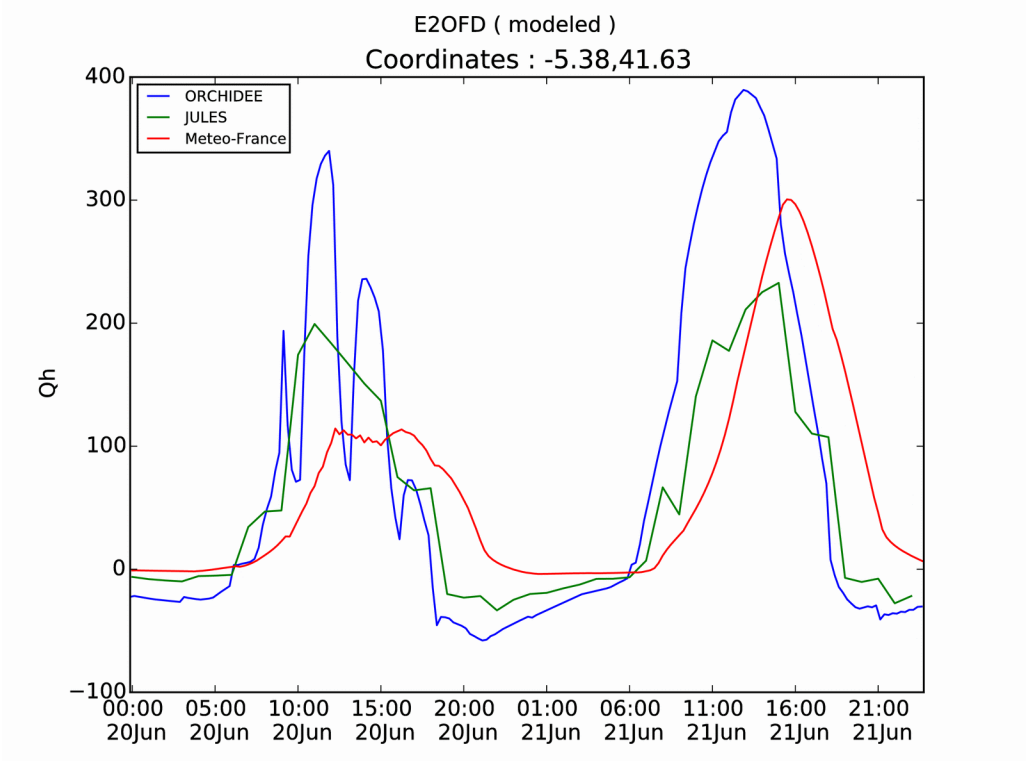
The diagnostic shows that only ORCHIDEE attempts to reconstruct the mid-day peak. This is not very successful as it produces some discontinuities as can be seen on the 20th of June. The discontinuity comes from the fact that the conservation of the total flux is done over the 3 hourly forcing interval and not the full diurnal cycle. JULES on the other hand maintains the flux provided by E2OFD during the 3 hourly interval over which it is valid. Thus, it misses the mid-day peak but conserves the flux.

Again MF misinterprets the fluxes in E2OFD and uses a linear interpolation. The diurnal cycle is shifted by up to 3 hours. On the other hand the linear interpolation produces a mid-day peak, but it is too low and not at the right time of day (On the 21st of June it occurs at 15:00). This disaggregation probably does not conserve the total downward solar radiation either. Note that contrarily to shortwave and longwave incoming radiation, the two other forcing fluxes (rainfall and snowfall) were correctly interpreted as constant values over the previous 3 hours (step functions instead of linear interpolation).

Does the temporal disaggregation of the forcing have consequences ?

Ideally we should explore this question with potential evaporation as it sums-up well the atmospheric demands. But as not all models could provide this variable, we compare here the latent (Qle), sensible (Qh) heat fluxes and surface temperature.


E2OFD (modeled)
Coordinates : -5.38,41.63
ORCHIDEE
JULES
Meteo-France
Qle
500
400
300
200
100
0
−100
00:00 20Jun
05:00 20Jun
10:00 20Jun
15:00 20Jun
20:00 20Jun
01:00 21Jun
06:00 21Jun
11:00 21Jun
16:00 21Jun
21:00 21Jun


E2OFD (modeled)
Coordinates : -5.38,41.63
ORCHIDEE
JULES
Meteo-France
Qh
400
300
200
100
0
−100
00:00 20Jun
05:00 20Jun
10:00 20Jun
15:00 20Jun
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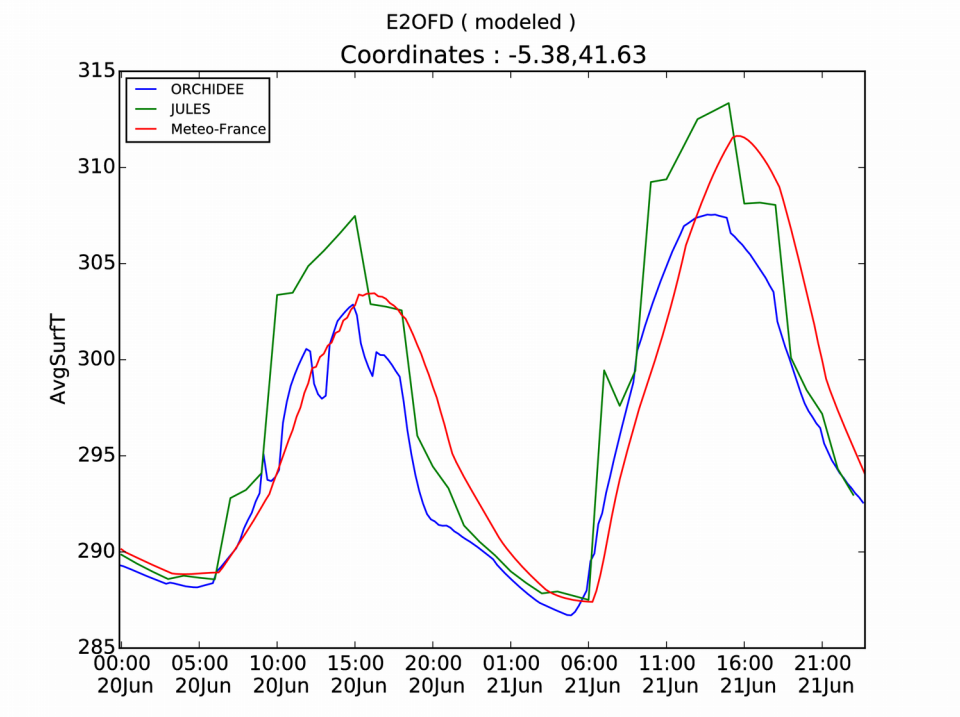


MF

It is clearly visible in the surface temperature that the disaggregation leads to a delay in the surface energy balance of about 3 hours (judging from surface temperature). At least in this region and season, when surface temperature is driven by the incoming solar radiation. This is bound to have consequences on the turbulent fluxes as the atmospheric variables (Tair and Qair) are out of phase with the surface quantities. Thus the gradients between the surface and lower atmospheric levels will follow another evolution than one would expect.

On the 21st of June the two other models have a much smaller phase shift for sensible and latent heat fluxes than MF.

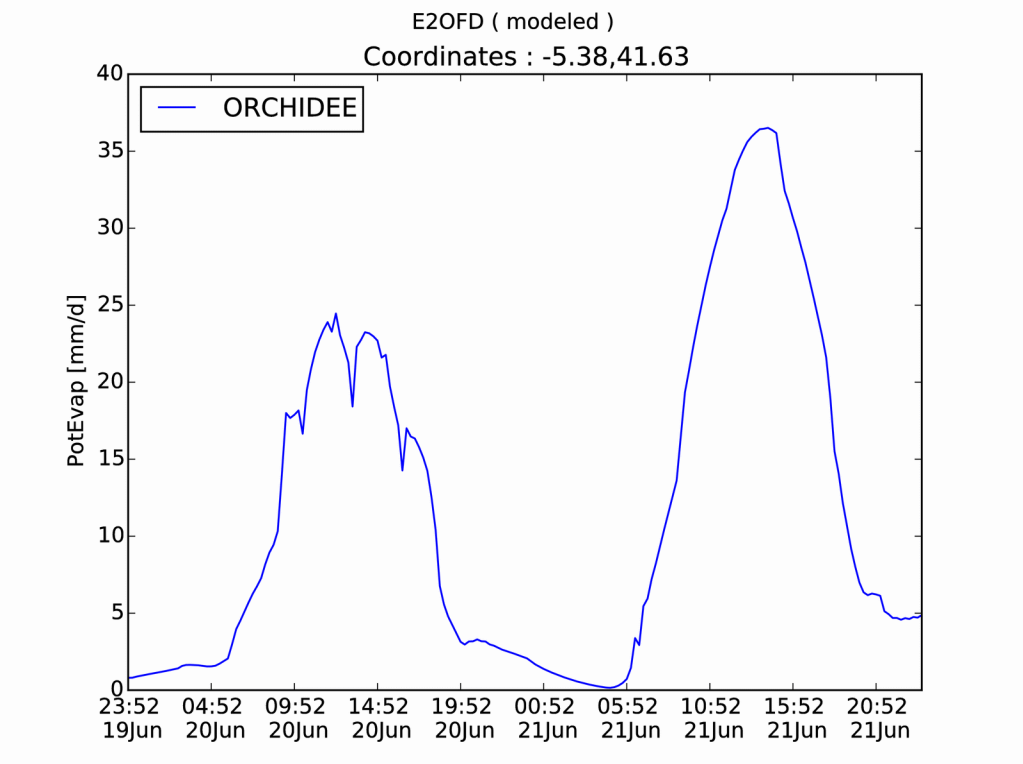
Jules

The step functions in the disaggregated forcing computed by JULES has a visible impact on the surface temperature and turbulent fluxes.

ORCHIDEE

The usage of the zenith angle for the interpolate of SWdown over the 3-hourly forcing interval leads to discontinuities, especially on the 20th of June. This impacts the potential evaporation as shown below. This signal then gets amplified by the stress function for evaporation. So the entire surface energy balance is perturbed by these discontinuities.

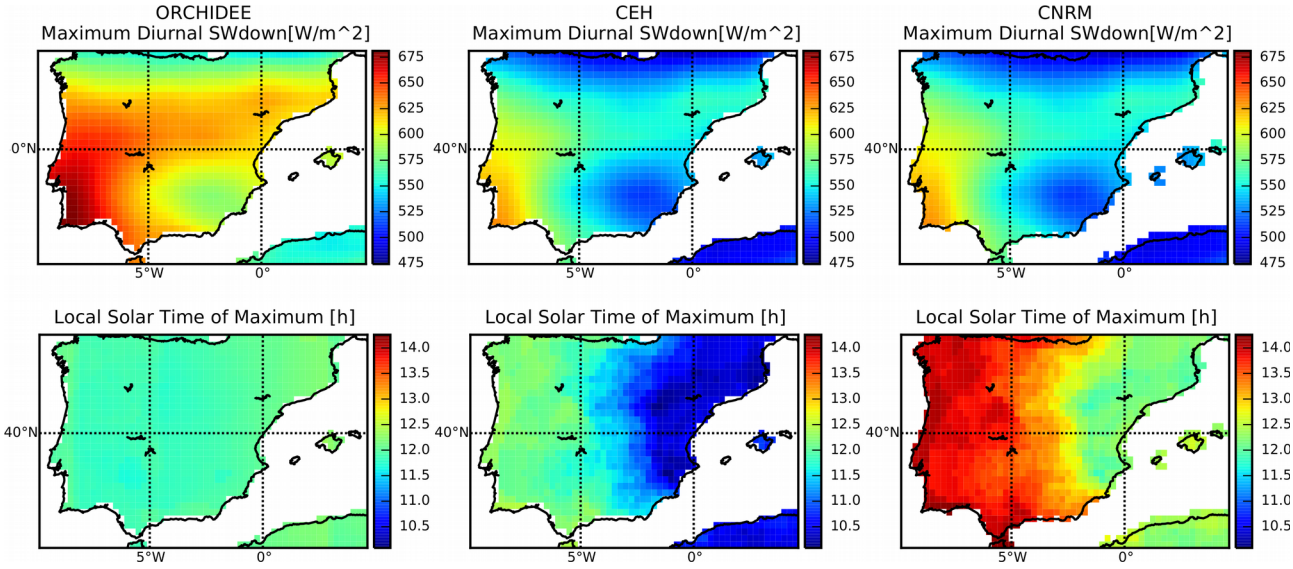
The discontinuities are most visible on the 20th of June as the 3-hourly SWdown averaged from 9:00 to 12:00 is larger than the following one (Probably because of afternoon clouds). On the other hand, the averaged solar zenith angle is larger for the 12:00 to 15:00 time period. Thus the flux conservation over the 3-hourly interval creates a large discontinuity at 12:00. This is not the case on the 21st of June and the interpolation provides a smoother transition at noon.



Regional Analysis

We have extended the analysis to the Iberian Peninsula and the 3 month of data available (May-July). It allows in particular to see the spatial extent of the issues identified above with the three disaggregation methods.

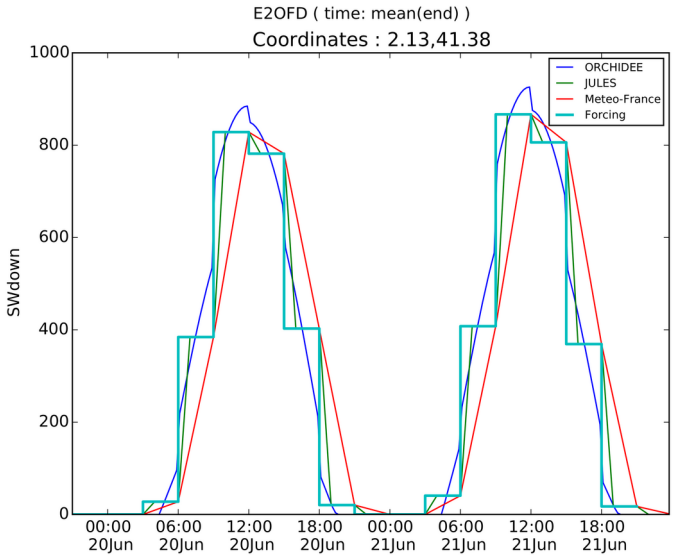
Downward Solar flux :

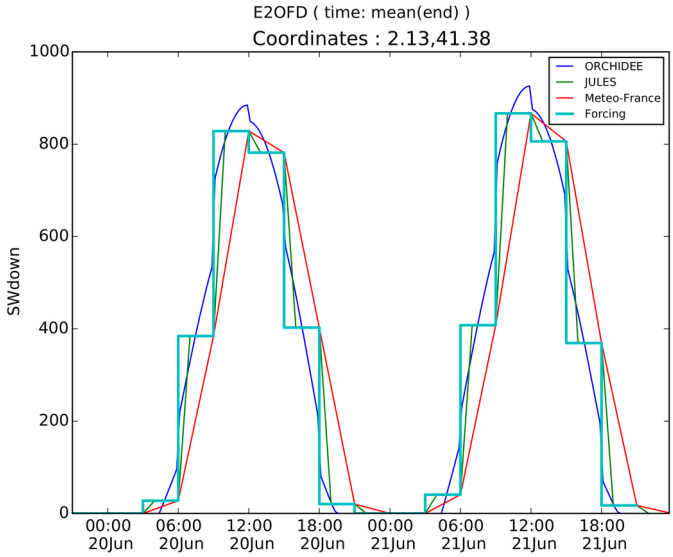


It can be noted that some of the above described characteristics of the SWdown disaggregation can be generalized to this region. We discuss here the above figures which are for the month of May :

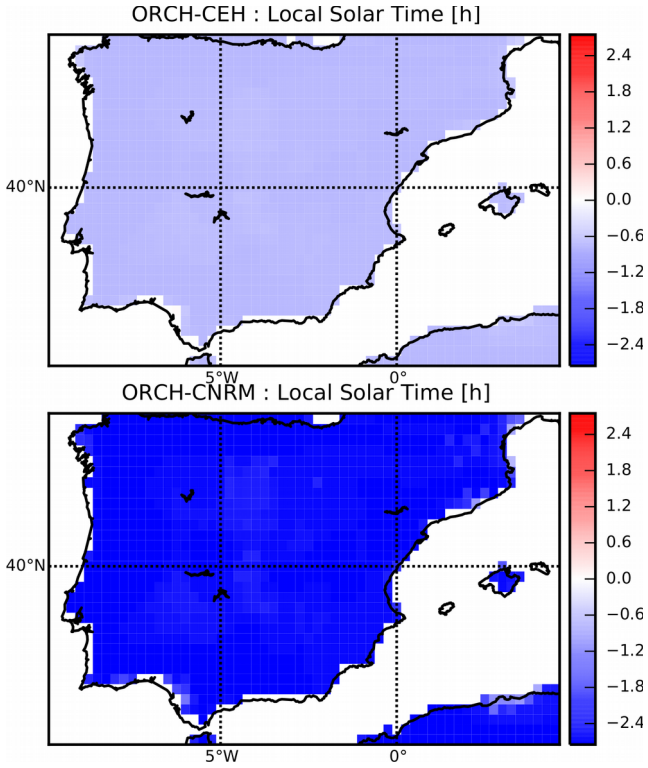
- ORCHIDEE has larger values of SWdown (up to 670W:m²) than the 2 other models as it attempts to reconstruct the mid-day peak. CEH and MF are limited to maximum values of 630W/m².
- Maximum solar flux is always around 12:00 local solar time in ORCHIDEE.
- Because of the step function in CEH, there are regions where the maximum is already at 9:00. This occurs because here the E2OFS specifies that the average solar downward flux is larger over the 9:00 to 12:00 time interval than over the consecutive period. Thus the first maximum value is found at 9:00. Taking into account the solar zenith angle in ORCHIDEE avoids this effect.
- In the regions where the maximum of SWdown is over the 9:00 to 12:00 period, MF (CNRM) has the right timing. Else, the maximum is up to 3 hours late (Around 14:30 local solar time).

To illustrate the maximum SWdown time at 9:00 found for some models, the time series of this variable for Barcelona are shown below. It can be noted that in this case MF has a maximum SWdown at the time of maximum zenith angle.





Downward longwave

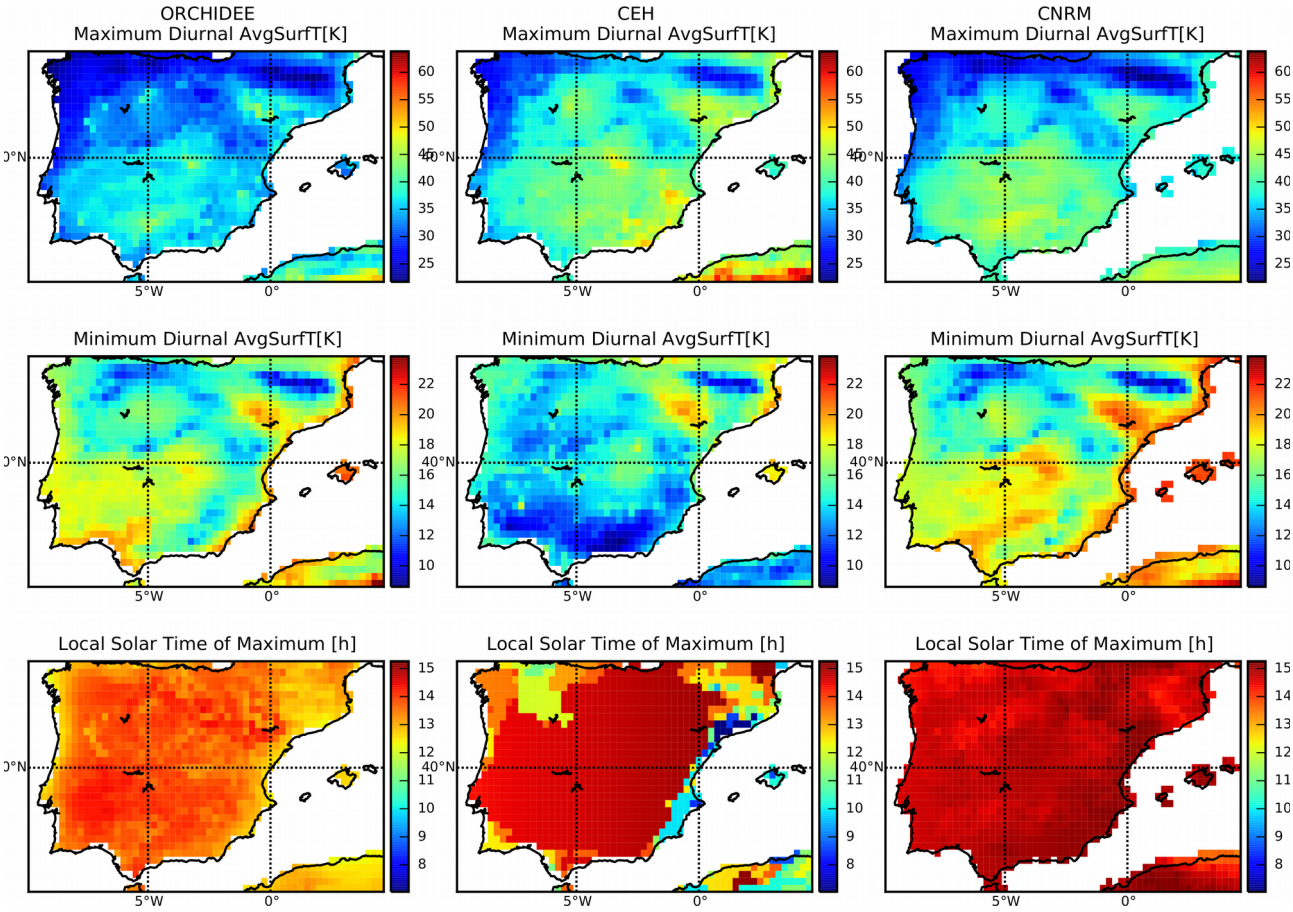


The above figure shows the difference in the local solar time of the maximum value for Lwdown between ORCHIDEE and CEH in the upper panel and ORCHIDEE and MF in the lower panel.

There is a systematic difference of 1 houre between ORCHIDEE and CEH because of the lower sampling frequency in the latter model.

On the other hand the difference in timing between ORCHIDEE and MF is 3 hours as expected from the above analysis of the flux interpolation.

Surface temperature



The above maps of average surface temperature amplitude (maximum top row, minimum middle row) for the three models (columns from left to right : ORCHIDEE, CEH and MF) are for the month of July. They show that some strong differences exist. They are probably mostly linked to differences in the surface energy balance simulated by the three models (different drivers).

The lower row provides the local solar time of the surface temperature maximum and shows some characteristics which can be attributed directly to the way the forcing data are disaggregated. ORCHIDEE mostly has the maximum temperature at 14h. Some regional differences can probably be explained by local processes like afternoon clouds or surface properties.

On the other hand for CEH the maximum surface temperature is reached at very different moments of the day. In the morning when there is a clear maximum of SWdown over the 9:00-12:00 averaging period of the forcing. For instance over Catalonia and the Mediterranean coast. Maximum is at about noon in the north-western part and in the afternoon over the rest of the Peninsula. So the step function of the SWdown of the forcing leaves clear spatial structures in the diurnal cycle of the surface temperature.

For MF the maximum surface temperature is systematically reached after 14:00 because of the interpolation of the fluxes is performed with the same methodology as the instantaneous values.