# Validation of ORCHIDEE in January 2017

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## 1 Model version

The model used is version #4030 of the ORCHIDEE-ROUTING branch. This corresponds to the merge of the trunk at release #3959 (8th December 2016) with the new routing scheme. After this merger a number of bugs needed to be fixed to be able to run with orchideedriver and coupled to WRF.

- ORCHIDEE needs at least release #1010 of XIOS to work well (Change needed in modipsl).
- Compilation issues on the IPSL Mesocentre were fixed by introducing architecture environment files in makeorchidee_fcm. This implements the procedures already in use in XIOS.
- some errors in the field IDs in the file_def_orchidee.xml
- soilth_lev was not correctly allocated in orchideedriver.f90
- The time counting in slowproc is not general enough and fails for cases others than integration time steps starting at 00:00:00 each day.
- the **xios_init** function did not work for curvilinear grids.
- The setting of nbvmax in interpweight.f90 needed some adjustment for higher resolution grids.

The orchideedriver is used as it is the only one which works correctly with the forcing data set used here.

## 2 Forcing and validation data used

We used the Earth2Observe forcing data set (E2OFD) which has been prepared by ECMWF. This is **ERA_Int** downscaled statistically to a 0.25 deg. resolution and then bias corrected with high resolution data.

The treatment to the data is as follows :

- Radiation fluxes (SWdown & LWdown) : bilinear interpolation;
- Tair, Quair, PSurf: corrected for altitude differences using a time/space varying lapse rate;

- Rainfall & Snowfall: corrected using the GPCCv7 until 2013 & GPCC monitoring until 2015. CHPclim to downscale from 0.5x0.5 to 0.25 ;

Correction performed for WFDEI and that are not included in E2OFD :

- No correction for Tair using CRU mean and diurnal range
- No correction to SWdown using cloud cover & aerosols
- Rainf / Snowfall: No correction using CRU number of wet days, no under-catch rainfall/snowfall correction

Corrections in E2OFD that were not included in WFDEI :

- Tair adjustment using a new orography and temporal/spatial varying lapse rates
- Downscaling of the GPCC 0.5 climate to 0.25 using CHPclim (`http://chg.ucsb.edu/data/CHPclim/index.html`)

The E2OFD 3-hourly fields are available in the WCI server `https://wci.earth2observe.eu/thredds/catalog/ecmwf/met_forcing_v1/catalog.html`. On the IPSL Mesocentre these files are available at /bdd/ORCHIDEE_Forcing/BC/OOL/OL2/E2OFD/ ready to be used by ORCHIDEE.

The simulations will be compared to the monthly river discharge observations obtained from Global Runoff Data Centre (GRDC). There are 5723 stations over the entire globe and the time series cover up to 2013. The data are available at the IPSL Mesocentre: /bdd/ORCHIDEE_Forcing/Validation/GRDC/GRDC_Monthly_June14.nc"

# 3 configurations

In order to explore the last significant evolutions of ORCHIDEE toward CMIP6 a number of configurations were tested :

### 3.0.1 EU_Merge_start :

- Started from default values and ran from 1979 to 1995.
- Vegetation taken from map PFTmap_IPCC_2000.nc but we would have preferred to start with carteveg5km.nc. This is not possible as there is still a bug in interpweight when a point does not get any information from the file.
- LAI is read from file lai2D.nc.
- The Zobler soil classification and bare soil albedo are taken from file soils_param.nc.
- Photosynthesis is used : STOMATE_OK_CO2 = TRUE.

## 3.1 EU_Merge_startdv :

This simulation is exactly the same as above except that we have replaced the LAI read from a file by STOMATE, i.e. STOMATE_OK_STOMATE = n.

To avoid any initialisation issues it is also started in 1979 with default values.

### 3.2 EU_Merge_suetal :

This simulation starts from the 1st of January 1990 restart of EU_Merge_start and ran until 1995 with Su et al. activated (ROUGH_DYN = TRUE).

It is considered that the roughness parametrisation does not need a major spin-up.

### 3.3 EU_Merge_newsurf :

This simulation starts from the 1st of January 1988 restart of EU_Merge_start and ran until 1995 with the aim to test the various improvements introduced in the ancillary data for CMIP6. To ensure all soil and vegetation variables are re-initialised they were removed from the restart file.

- The ESA CCI vegetation maps with FracNobio are used : SRF/PFTMAPS/CMIP6/ESA-LUH2/historical/v1/withNoBio/13PFTmap_2000_ESA_LUH2v2h_withNoBio_v1.nc.
- The USDA soil classification in soils_param_usdatop.nc is used.
- The MODIS based background albedo is used from file alb_bg_modisopt_2D_ESA.nc
- The new albedo parameters are used as proposed at `https://forge.ipsl.jussieu.fr/orchidee/wiki/ReferenceSimulations/3934`

### 3.4 EU_Merge_snfrz :

This simulation aims at testing the new snow scheme and soil freezing. To achieve this the restart of 1st of January 1988 of simulation EU_Merge_start needed to be simplified so that the thermal soil depth could be increased to 20m (DEPTH_MAX_T = 20).

The simulation was started in 1987 to give the soil more time to spin-up its temperature.

The following flags were set :

- OK_EXPLICITSNOW = TRUE
- OK_FREEZE = TRUE
- READ_REFTEMP = FALSE

All simulations are performed over Mediterranean region on a domain which goes from 19.25W to 61.25E in longitude and -6.25S to 58.75N in latitude. The domain is chosen so that all rivers contributing freshwater to the Mediterranean sea have their basins fully included.

## 4 Basin scale water balance

The resolution and the new routing scheme allow to place correctly 307 GRDC stations in the model output. It thus provides a powerful tool to evaluate the basin scale water balance over a large spectrum of climates and spatial scales. The stations cover catchments from very small and dry ones, like the Aude with less than $50m^3/s$ up to continental scale basins such as the Danube.

New developments under-way will allow to extract even more stations from the model in the future.

One should note that the short period over which the model ran (1990-1995) does not always overlap with the available observations. Thus 2 curves are plotted : i) GRDC Obs. is the mean annual cycle for period of overlap of the simulation and the observations; ii) GRDC Clim. is the average annual cycle over the entire time series available for the station. The difference between both curves has to be interpreted as the deviation of the simulated years from the long term climatology. The graphs also include the annual mean discharge as a tick mark on the vertical axis.

The lower graphs of the figures displayed here show the annual anomalies. This will not be discussed here as the 6 years simulated are not enough for a fair analysis.

Only a few stations out of the 307 will be presented and they are classified by climate as this seems to best separates systematic model biases.

## 4.1 High latitudes

The rivers of northern and central Europe show similar biases. We chose to focus on the following ones : Rhone, Rhine, Elbe, Loire, and Danube (Fig. 1, 2, 3, 4 and 5).

General points to be noted :

- Systematically in this region the model has less water in the rivers than observed.
- If the precipitation of GPCC is to be believed then this can be interpreted as an overestimation of evaporation over Europe. This is an old and well known bias of ORCHIDEE.
- The shape of the annual cycle and the timing of peak discharge is well simulated in all basins. This indicates that the new routing scheme is working as designed. Please keep in mind that the 3 time constants of the reservoirs were not adjusted at this resolution.
- In many of the largest catchment of this region, the simulated low-flows are too low. This could be a result of human regulation aimed at navigation.

Come comments specific to the 5 simulation :

- **EM_Merge_start**

  This simulation is always among the ones with the lowest discharge indicating that in this configuration the model has the strongest evaporation.

- **EM_Merge_startdv**

  The evaporation estimation is in most cases higher in this configuration thus leading to even lower discharge values.

- **EM_Merge_suetal**

  The addition of the Su et al. parametrization of the roughness length leads to a reduction of evaporation and thus to a significant improvement of the discharge values.

- **EM_Merge_newsurf**

  The new description of the surfaces also leads to a reduction of evaporation which is welcome. The impact is not as large as the Su et al. parametrization. For most rivers this is clearly the best configuration of ORCHIDEE.

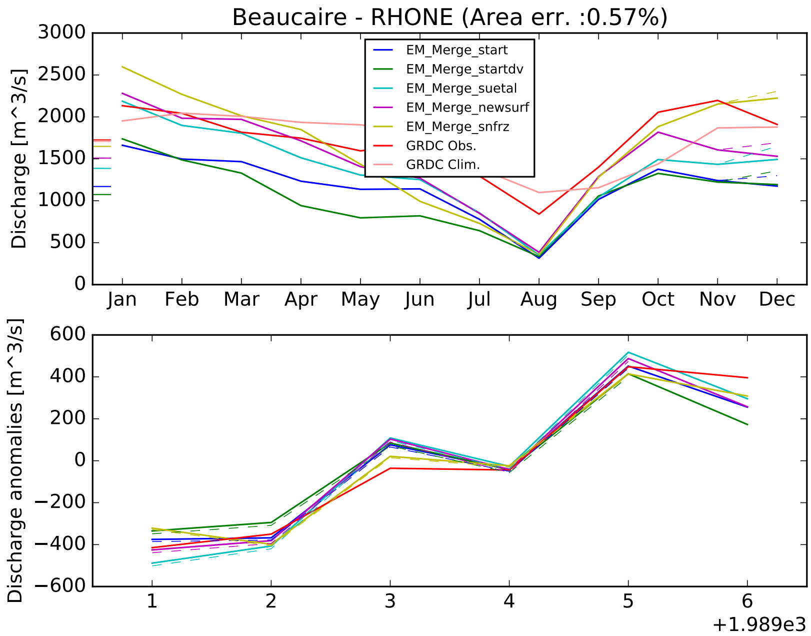


Figure 1: Beaucaire, Rhone

- **EM_Merge_snfrz**

  Introducing the new snow parametrization degrades the simulation mostly during the winter month in this region. The discharge strongly increases in autumn to reach its peak in January or February. This does not appear to be an improvement in any of the stations analysed. On the other hand this configuration further decreases evaporation in central Europe and thus improves the annual mean discharge.

## 4.2 Mediterranean climate

Rivers in the Mediterranean climate are more difficult to analyse because of the strong water usage which is not currently included in the routing scheme. Furthermore a severe drought has occurred over the Iberian Peninsula (IP) during the 90s and thus the simulated period is not very representative of the climatology.

In the Duero basin (North West of the IP) the impact of the various configuration of ORCHIDEE is weak, except for snow and soil freezing (Fig. 6. The model has too little water in the rivers and in this area it is unlikely to be entirely attributable to human intervention. It would appear that over semi-arid areas the underestimation of evaporation is not corrected in any of the tests.

The Guadalquivir is one of the rivers where the impact of the drought is most clearly visible (Fig. 7). The model there overestimates slightly the annual discharge and this is in all likelihood due to the lack of representation of irrigation and other water uses.

The Sidi Belatara station clearly shows even more clearly the lack of human water usage in the discharge (Fig. 8). As we do not simulate irrigation the model strongly underestimates evaporation and thus carries too much water in the rivers.

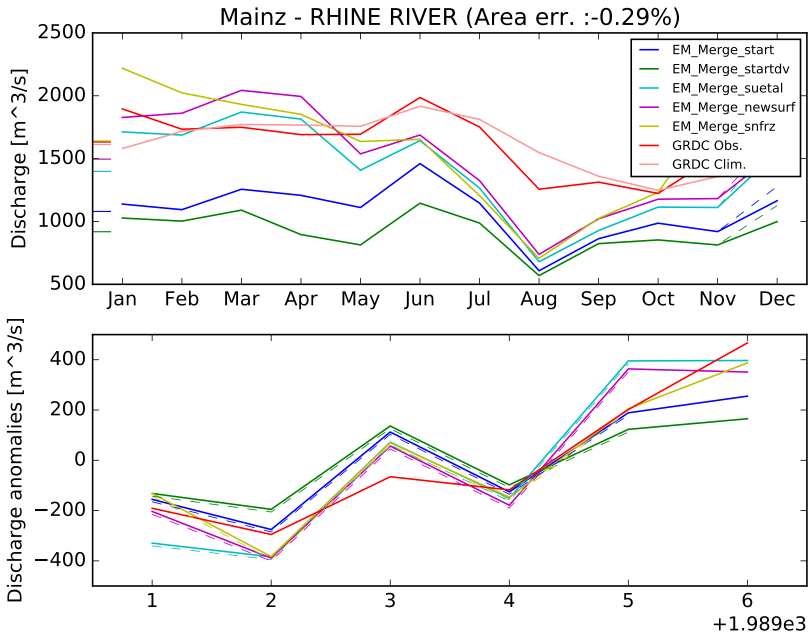


Figure 2: Mainz, Rhine

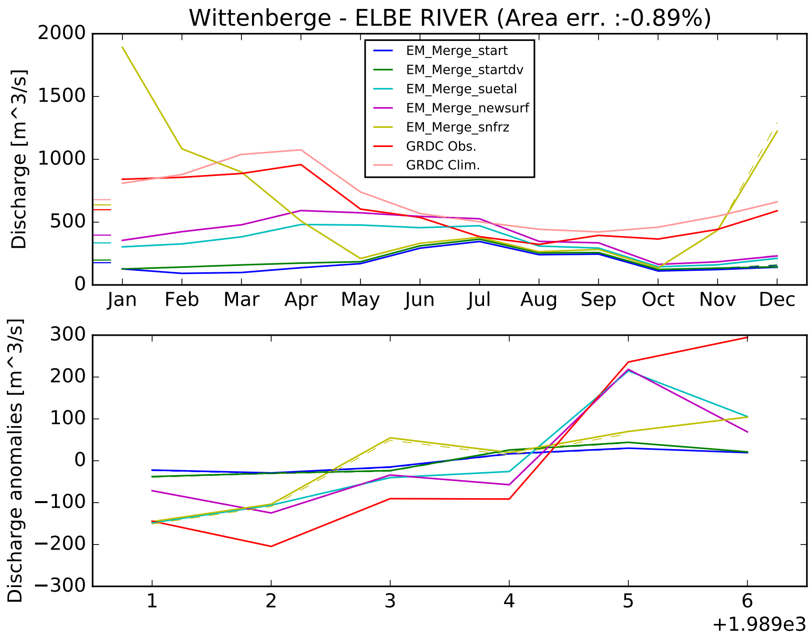


Figure 3: Wittenberg, Elbe

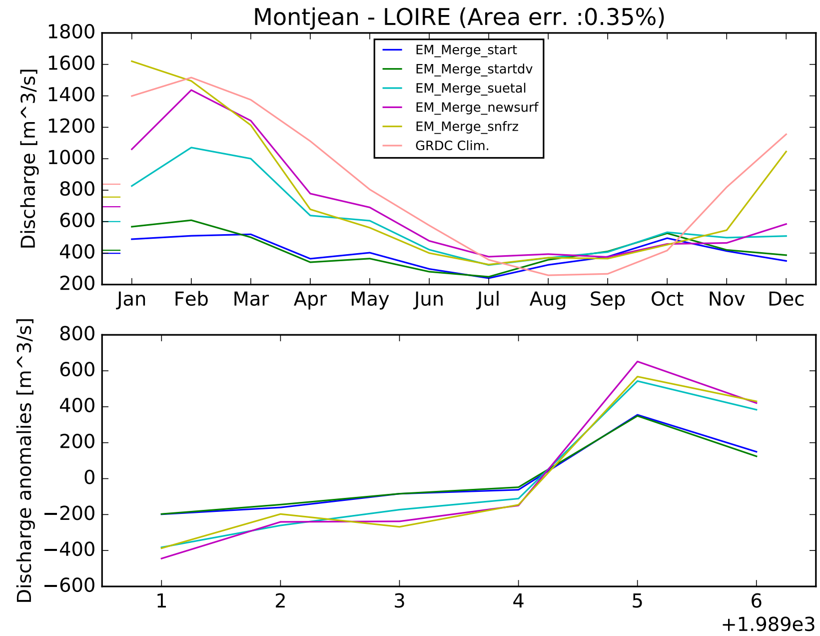


Figure 4: Montjean, Loire

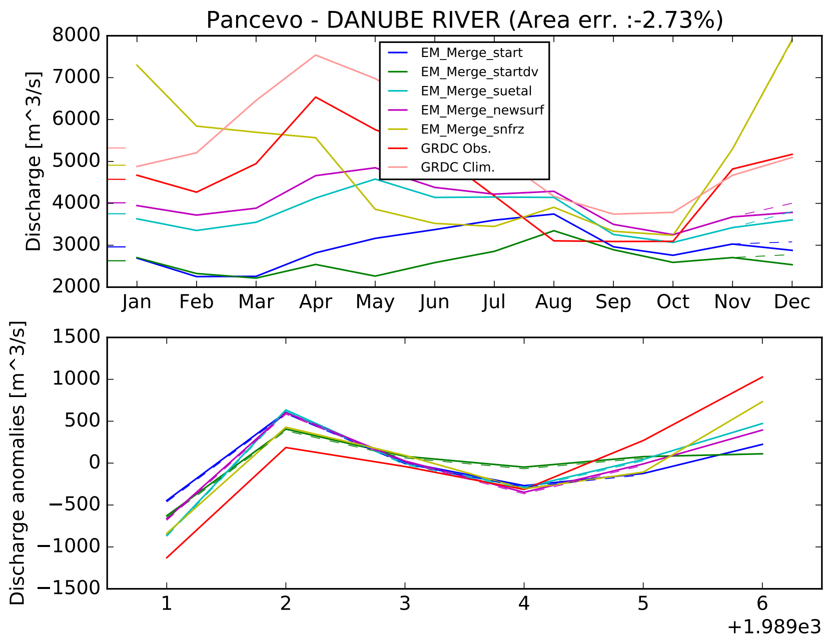


Figure 5: Pancevo, Danube

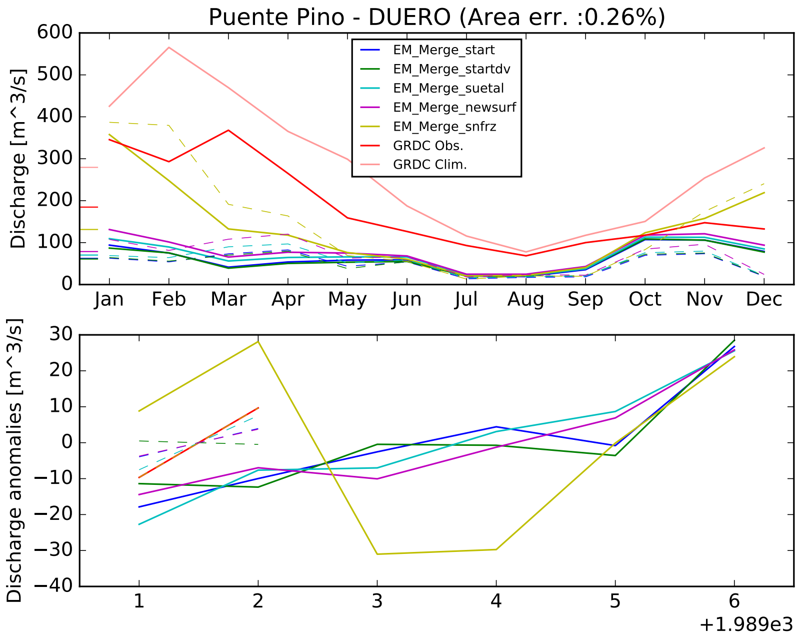


Figure 6: Puente Pino, Duero

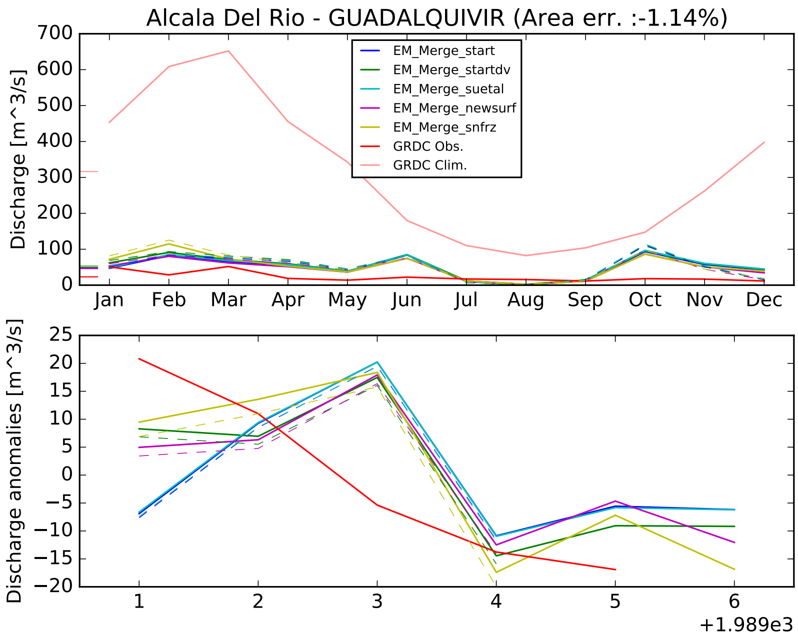


Figure 7: Alcala Del Eio, Guadalquivir

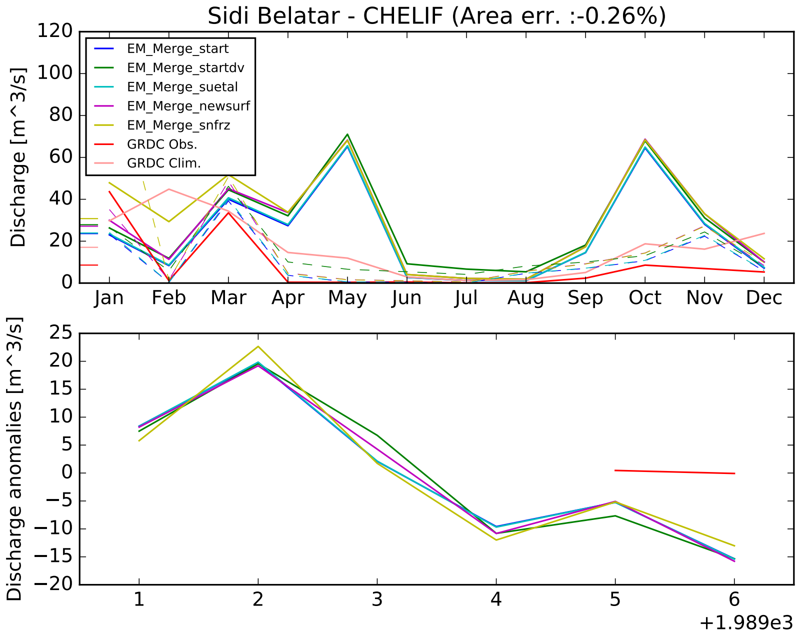


Figure 8: Sidi Belatar, Chelif

In all three cases chosen to illustrate this region, but in the other semi-arid river basins as well, the introduction of the snow model and soil freezing does not improve the simulated discharge. Please note that all these rivers take their source in mountains where snow processes are still active.

## 4.3 Tropical regions

The African rivers of the domain are more difficult to analyse as the rainfall estimates are probably affected by larger errors than in Europe. Furthermore the large rivers in the domain (Nile and Niger) include large floodplains which are not yet modelled in the new routing scheme. With the Nile having on top of that a large human water usage. So we limit our discussion to two medium size rivers : i) The Corubal flowing through Burkina Faso and Ivory Coast (Fig. 9) and ii) the Gambia in the most Western part of the continent (Fig. 10).

In these very different climates the routing scheme is also able to reproduce well the annual cycle. This clearly points to the value of the high resolution.

In the case of the Corubal (Fig. 9) the discharge is correct and for the Gambia it is overestimated (Fig. 10). In view of the rainfall uncertainty it is difficult to conclude much on the evaporation over this region.

## 4.4 Evaporation changes

The evaporation maps and in particular the annual difference between EM_Merge_start and EM_Merge_newsurf (Fig. 11) show that the reduction of evaporation is generalised. This maps allows confirms and generalise the basin scale water cycle diagnostics presented above.

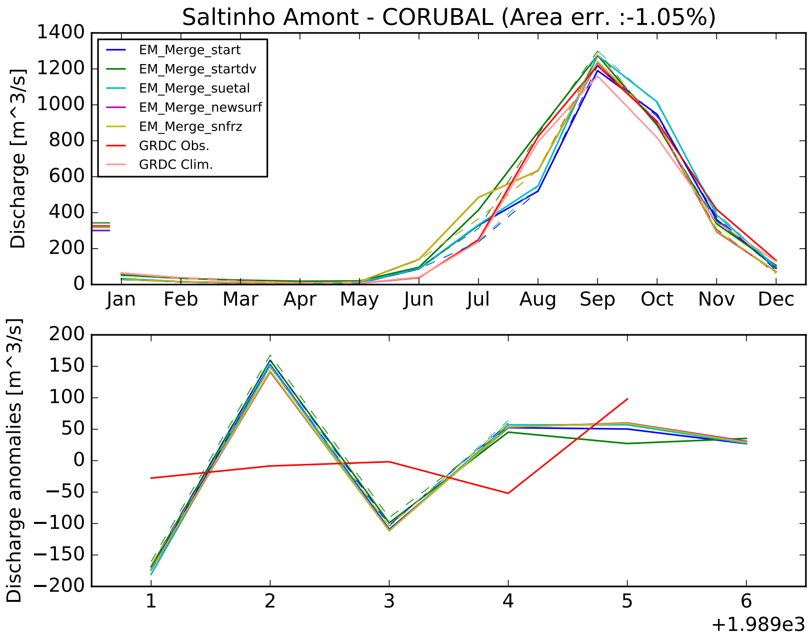


Figure 9: Saltinho Amont, Corubal

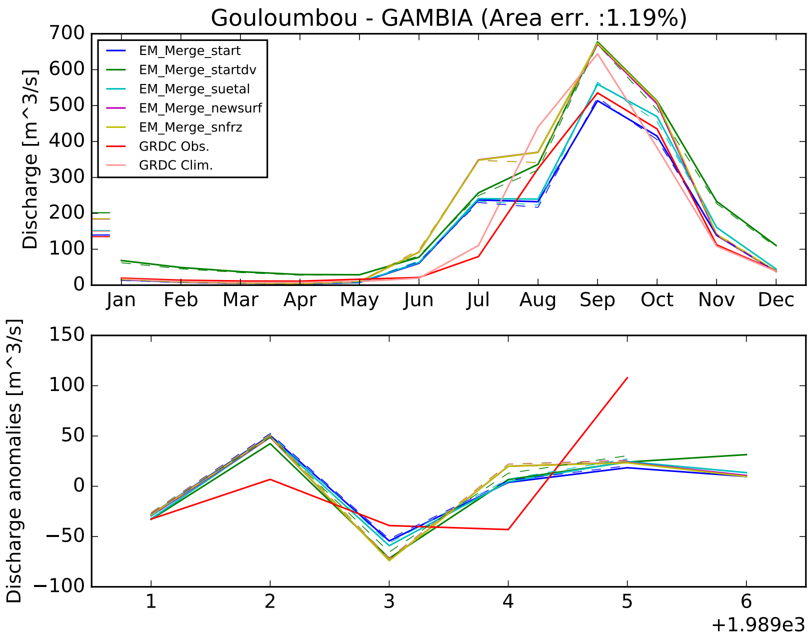


Figure 10: Gouloubou, Gambia

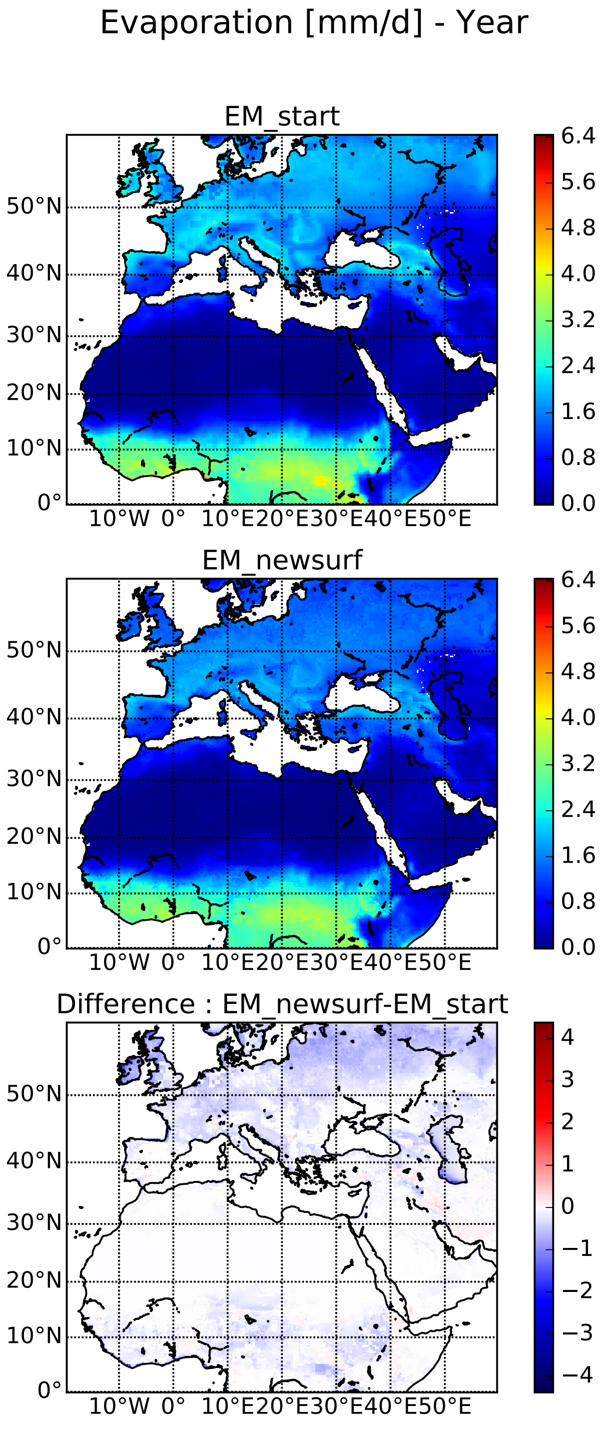


Figure 11: Annual mean evaporation difference between EM_Merge_start and EM_Merge_newsurf

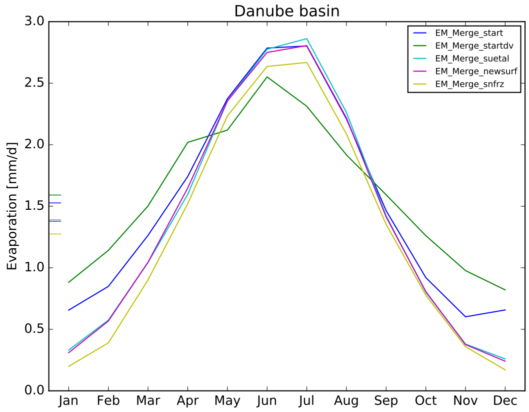


Figure 12: Average evaporation over the Danube basin.

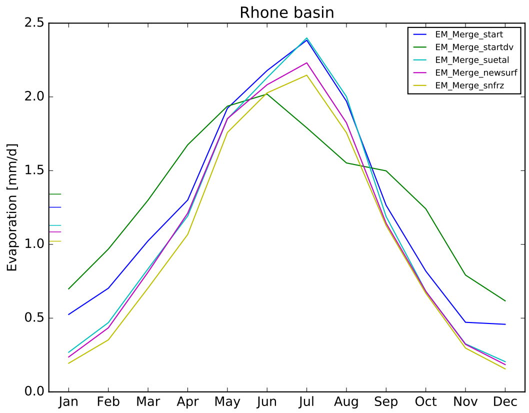


Figure 13: Average evaporation over the Rhone basin.

If we take a look at the basin average evaporation of the basins analysed above we note that the reduction brought by Su et al. in evaporation in concentrated in winter (Fig. 12, 13, 14). This reduction then leads in some regions to even some evaporation increases in summer (Fig. 14).

In general the activation of the dynamic LAI calculation leads to an increase in evaporation in winter and reduction in summer. This probably explains the worse comparisons of the river discharge with the GRDC data.

# 5 To freeze or not to freeze

As the simulation EM_Merge_snfrz did not prove of very good quality we tried not to activate the freezing of the soil. Only the explicit snow option is activated and this simulation is labelled EM_Merge_snow.

We examine the impact of this simplification in the configuration of ORCHIDEE at 3 other stations of the GRDC database : Bratislava on the Danube (Fig. 15), Razdorskaya

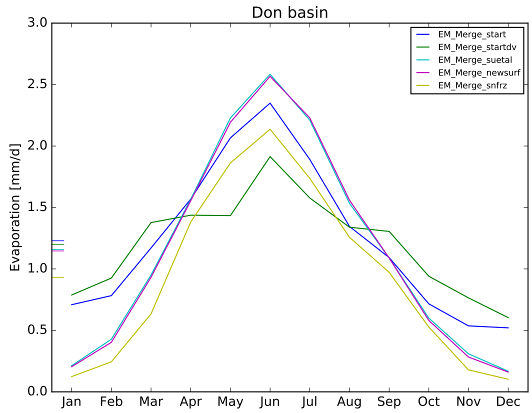


Figure 14: Average evaporation over the Don basin.

on the Don (Fig. 16) and Pontelagoscuro on the Po (17).

From these 3 stations it appears that not using the soil freezing improves the simulated discharge and gives also better results than the EM_Merge_newsurf. The main improvement come from a stronger discharge in spring at snow melt and a large amount of water throughout the year. This is observed on all 3 stations presented here but it is quite general for all rivers with significant snow processes. The upper Danube which is sampled here in Bratislava shows the most spectacular improvement.

The higher annual mean discharge can be explained by a decrease of winter evaporation produced by the explicit snow scheme. This is illustrated in Fig. 18 for the Don.

It must be concluded from these results that the soil freezing option in ORCHIDEE degrades the hydrological cycle simulated by the model.

# 6 Adequacy of ancillary data

The issue we wish to examine here is the adequacy of the resolution of ancillary data for the usage of ORCHIDEE in regional applications. We first examine albedo which has seen the evolution of the background albedo. We look in particular at the Iberian Peninsula to be able to distinguish more details.

It appears that the background albedo is too coarse (Fig. 19). The 1/2 degree resolution of the grid at which the product was derived from MODIS is clearly visible. Furthermore the treatment of the coastline is not appropriate for higher resolution.

Either the land/sea mask used for the derivation of the background albedo was too coarse. This will need to be re-examined as these sharp contrast of albedo can generate local circulations in the regional model.

The 1/2 degree of the ESA-CCI PFT map seem adequate for 20km resolution grids. But again the coast appears as a weak point. There are strong discontinuities on the coastal points (Fig. 20, 21).

Probably all ancillary data should be derived on land/sea masks with fractional coverage so that even on grid boxes only partly covered by land the original information (from ESA-CCI or MODIS) can be preserved and then exploited by ORCHIDEE when

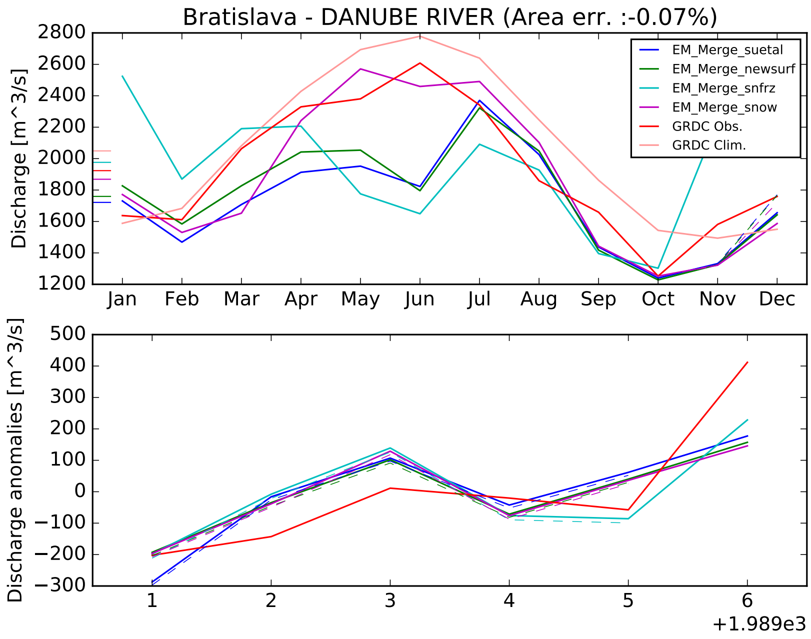


Figure 15: Bratislava, Danube

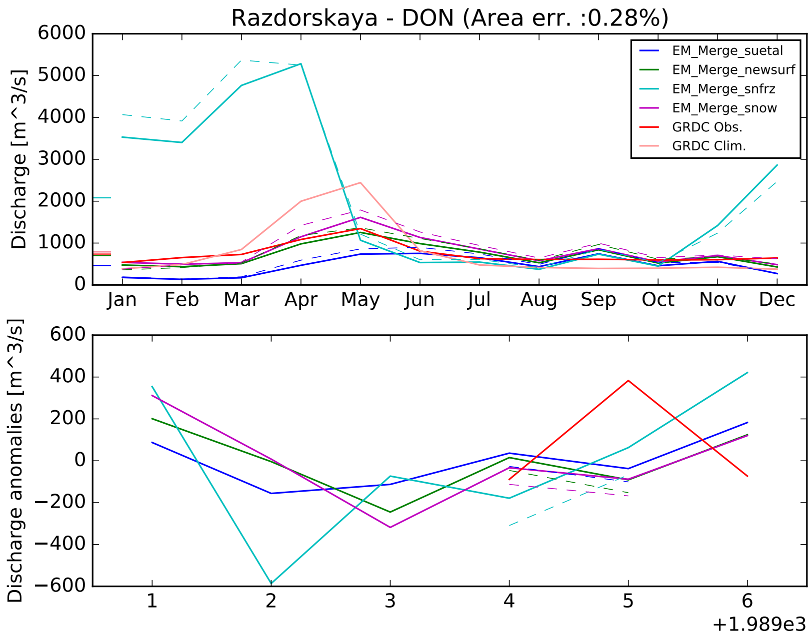


Figure 16: Razdorskaya, Don

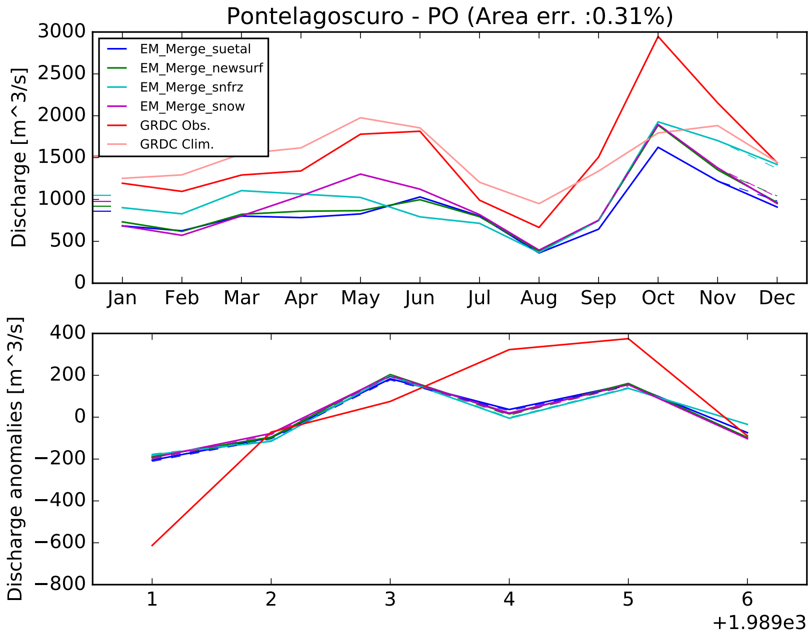


Figure 17: Pontelagoscuro, Po

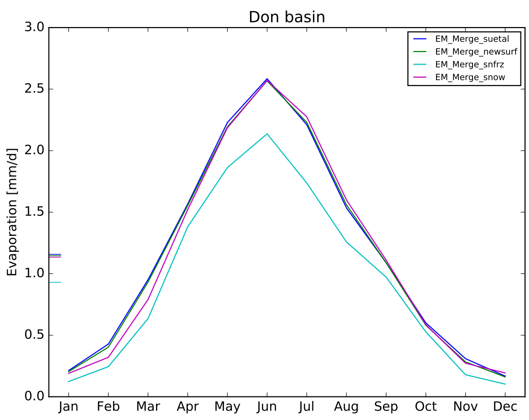


Figure 18: Average evaporation over the Don basin.

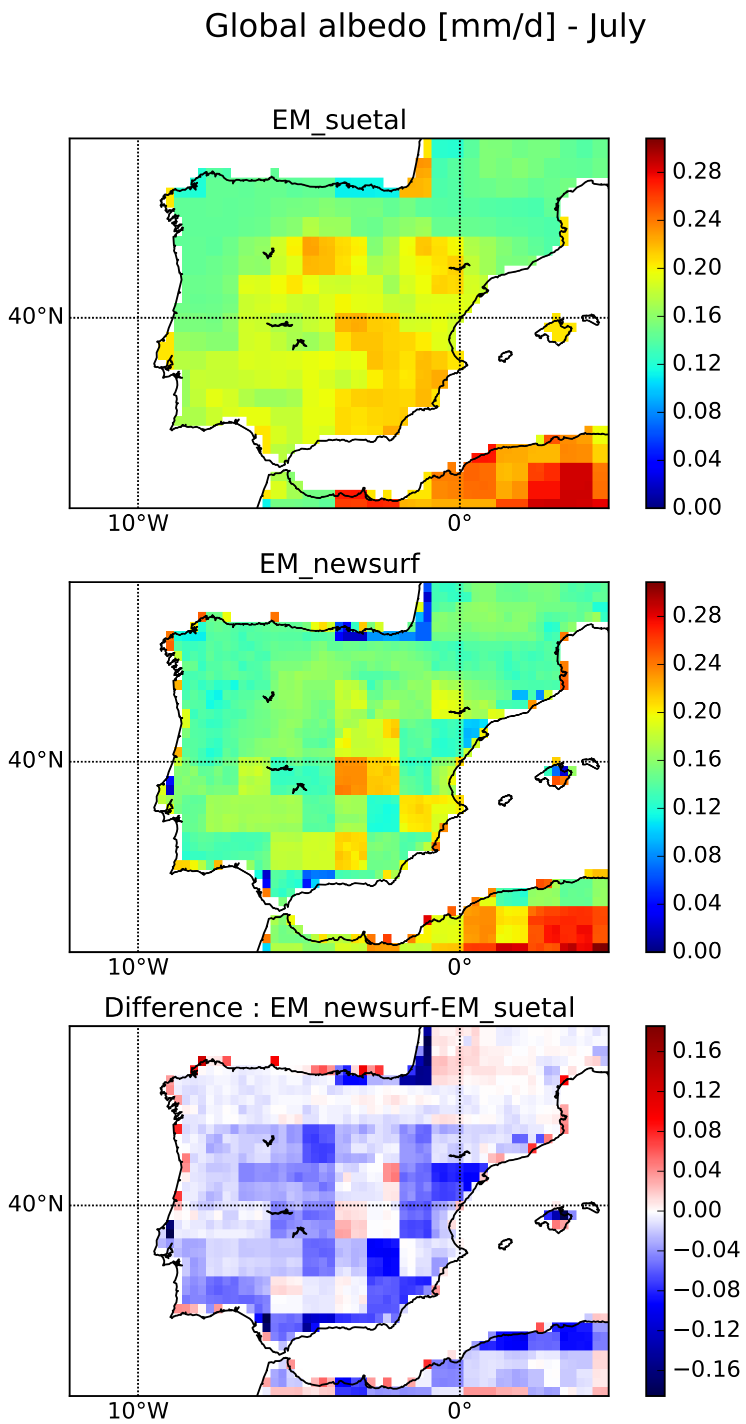


Figure 19: July albedo over the Iberian Peninsula.

it runs on high resolution grids.

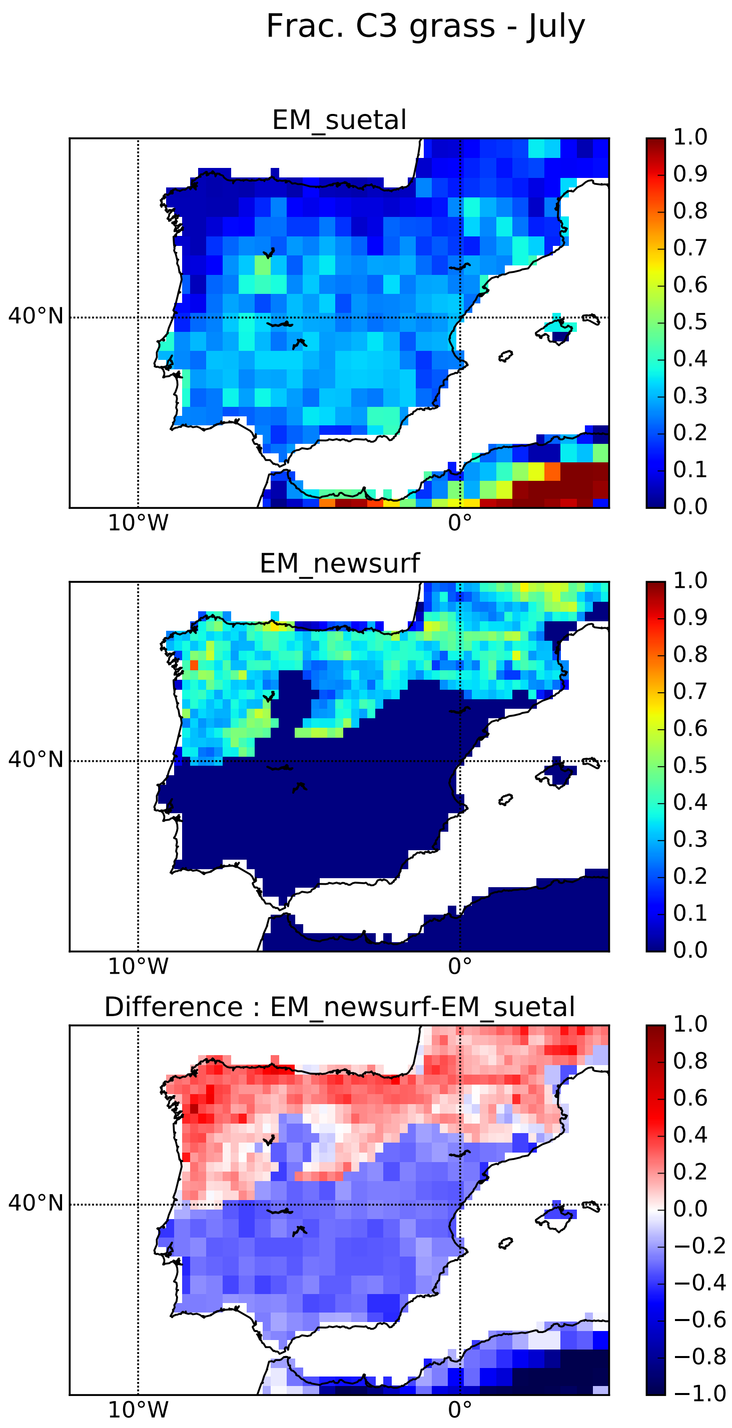


Figure 20: C3-grass maximum fraction over the Iberian Peninsula.

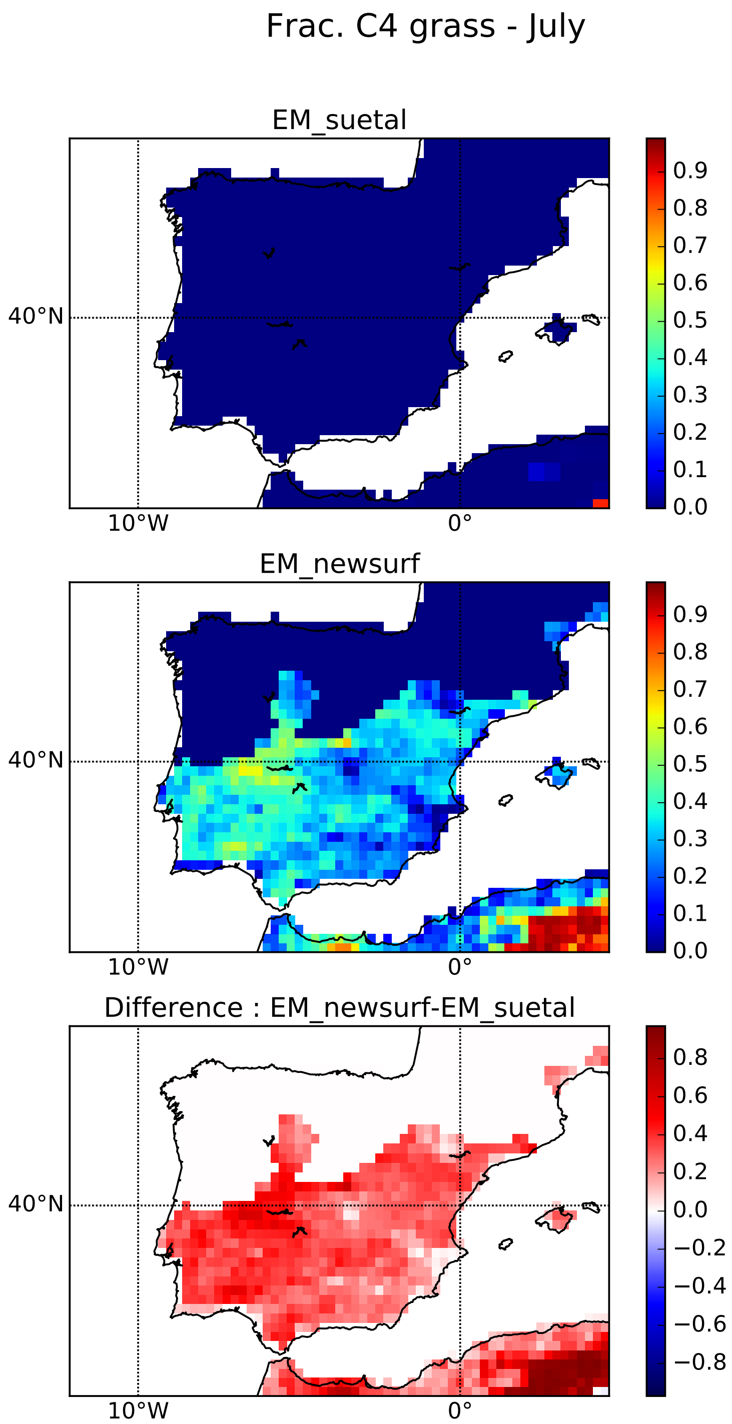


Figure 21: C4-grass maximum fraction over the Iberian Peninsula.