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Discussions

Interactive comment on "Modelling LAI, surface water and carbon fluxes at high-resolution over France: comparison of ISBA-A-gs and ORCHIDEE" *by* S. Lafont et al.

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RESPONSE TO REVIEWER #2

The authors thank the anonymous reviewer #2 for his/her review of the manuscript and for the fruitful comments.

2.1 [This is a well-written and nicely designed model-model-data-data experiment, assessing the ability of two land surface models to simulate the leaf area dynamics over France. Simulated carbon fluxes are also presented. The models and data display some pleasing similarities, but also some rather worrying differences. The methodology is excellent, and the analysis of the results and their interpretation largely well

done. We learn much about where there are differences between the models and between the models and the data. However, we do not learn much, if anything, about the causes of these differences. As such, this is more of a technical report than a scientific paper. The work will be acceptable for publication if the model descriptions are expanded to include details about how carbon fluxes and leaf area dynamics are simulated, and more on how these details impact on the results.]

RESPONSE 2.1

Yes, more details should be given about how the main differences between the models impact the results. We think that the paper shows clearly that the differences between simulations at a regional scale are caused by contrasting parameterizations at the PFT level. Such differences can be partially masked when comparing simulations using different vegetation maps. In this study, they appear more clearly as the same vegetation map is used by the two models. In the absolute, local studies are much more adapted to the analysis of individual sub-processes embedded in complex models representing many interacting processes. The two models used in this study share the same general structure, allowing the description of the same biophysical processes. However, they have been developed independently, and the way the processes are represented can differ greatly. Those relevant to this study include the photosynthesis module and the phenology (see below). Also note that other processes may impact photosynthesis and the vegetation biomass, such as the representation of the soil hydrology, the surface albedo, the resolution of the surface energy budget, etc. ISBA-A-gs uses a CO2 responsive parameterization of photosynthesis based on the model of Goudriaan et al. (1985) modified by Jacobs (1994) and Jacobs et al. (1996). This parameterization is derived from the set of equations used in ORCHIDEE (Farquhar et al., 1980 for C3 plants and Collatz et al., 1992 for C4 plants), and it has the same formulation for C4 plants as for C3 plants, differing only by the input parameters. Moreover, the slope of the response curve of the light-saturated net rate of CO2 assimilation to the internal CO2 concentration is represented by the mesophyll conductance (gm). Therefore, the value of the gm parameter is related to the activity of the Rubisco enzyme (Jacobs et al., 1996), while in the Farquhar model, this quantity is represented by a maximum carboxylation rate parameter (Vc,max). The model also includes a detailed representation of the soil moisture stress. Two different types of drought responses are distinguished for both herbaceous vegetation (Calvet, 2000) and forests (Calvet et al., 2004), depending on the evolution of the water use efficiency (WUE) under moderate stress: WUE increases in the early soil water stress stages in the case of the drought-avoiding response, whereas WUE decreases or remains stable in the case of the drought-tolerant response. ORCHIDEE has an explicit phenology model which computes leaf onset and leaf offset dates. This phenology submodel was calibrated globally using remote sensing data (Botta et al., 2000). For deciduous forests, the leaf onset is controlled by air temperature, only, while a dual constraint on soil moisture availability and air temperature is used for grasslands and crops. The temperature dependence is based on temperature sums, in units of Growing Degree Days and of Chilling Days. The senescence model is based on two criteria. First, the leaf turnover rate increases sharply when the mean leaf age exceeds a maximum leaf age. Second, environmental conditions are accounted for, using air temperature for the forest PFT and air temperature and soil moisture availability for grasslands. Maignan et al. (2011) have recently improved the ORCHIDEE phenology model for crops, using specific parameter values for crops instead of using the same parameters for crops and for grasslands. A typical seasonal cycle simulated by ORCHIDEE presents (1) a dormancy phase, (2) a sharp increase of LAI over a few days at the leaf onset, (3) a more gradual growth governed by photosynthesis, until a maximum LAI value has been reached, (4) stable maximum LAI values until the senescence date has been reached, (5) a senescence phase presenting an exponential decline of LAI. The ISBA-A-gs growth model currently used in the SURFEX modelling platform (www.cnrm.meteo.fr/surfex/) is described in Gibelin et al. (2006). No specific phenology model is used, as the vegetation growth and senescence are entirely driven by photosynthesis. However, the LAI values are maintained above a minimum LAI threshold (1 m2m-2 for coniferous forest, 0.3 m2m-2 for other

PFTs). At wintertime, such low values may be reached, and prescribing minimum LAI values allows plant growth to start as soon as photosynthesis exceeds leaf respiration (i.e. net assimilation of CO2 is positive). The leaf biomass turnover increases when the ratio of the actual photosynthesis to the maximum photosynthesis decreases. This usually triggers a decrease of LAI corresponding to the senescence. A typical seasonal cycle of LAI simulated by ISBA-A-gs starts with LAI at its minimum value. At springtime, LAI gradually increases, in relation with the rise in net assimilation values and with lower turnover rates. At summertime, when the soil moisture stress increases, the leaf biomass mortality tends, first, to counterbalance net assimilation and LAI reaches a maximum value or a plateau (at a value which is not predefined and which may vary from one year to another). In more marked summer drought conditions, the leaf biomass mortality exceeds net assimilation and LAI declines, down to the minimum value. Compared with the ORCHIDEE model simulation, the ISBA-A-gs LAI is more continuous, with a smoother evolution.

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Goudriaan, J., van Laar, H.H., van Keulen, H., and Louwerse, W.: Photosynthesis, CO2 and plant production, edited by: Day, W. and Atkin, R. K., in: Wheat growth and modelling, NATO ASI Series, Plenum Press, New York, Series A, 86, 107–122, 1985.

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Meteorol., 80, 111–134, 1996.

2.2 [7404.8-10 PFT parameters are mentioned, but no details. More information is required about how the models work and the differences between them.]

RESPONSE 2.2

Yes, the description of the models' parameters should be made in the model description Sections. ISBA-A-gs has nine main parameters listed in Brut et al. (2009) for various PFTs. The photosynthesis model is governed by four key parameters: the mesophyll conductance in well-watered conditions (gm), the cuticular conductance, the critical extractable soil moisture content, and the response to drought (drought-avoiding or drought-tolerant). Plant growth is characterized by five parameters: the maximum leaf span time, the minimum leaf area index, the leaf nitrogen concentration NL, the SLA (specific leaf area) sensitivity to NL, and SLA at NL =0%. The PFT-dependent parameters of ORCHIDEE are detailed in Krinner et al. (2005) and in Le Maire et al. (2010). The main photosynthesis parameter is Vc,max (see RESPONSE 2.1), and the computation of stomatal conductance uses the parameters (slope and intercept) of Ball et al. (1987). The phenology model uses nine parameters: the mean leaf span time, the maximum LAI beyond which there is no allocation of biomass to leaves, the SLA, a daily temperature threshold for summing cumulated degree days, three parameters to compute the threshold cumulative degree day for leaf onset, a weekly temperature below which leaves are shed if seasonal temperature trend is negative, a weekly moisture stress below which leaves are shed.

REFERENCE

Le Maire, G., Delpierre, N., Jung, M., Ciais, P., Reichstein, M., Viovy, N., Granier, A., Ibrom, A., Kolari, P., Longdoz, B., Moors, E. J., Pilegaard, K., Rambal, S., Richardson, A. D. and Vesala, T.: Detecting the critical periods that underpin interannual fluctuations in the carbon balance of European forests, J. Geophys. Res., 115, G00H03, 16 pp., doi:10.1029/2009JG001244, 2010.

2.3 [7406.1 How does this 30 day composite window impact on the interpretation of seasonality?]

RESPONSE 2.3

The 30-d composite window is a narrow Gaussian filter (Baret et al., 2007) centred on the date of interest. It is used to smooth the LAI signal in case of missing dates, caused for example by the presence of clouds. Weiss et al. (2007) have shown that the temporal profile of the CYCLOPES LAI presents the same timing than the MODIS product.

2.4 [7407.16 Need much more information on how leaf area dynamics are modelled in ORCHIDEE. Also, no useful information about leaf area dynamics for ISBA-A-gs. Also, no information about photosynthesis parameterisations in either model.]

RESPONSE 2.4

Yes. See RESPONSES 2.1 and 2.2.

2.5 [7410.14 "In summer, the highest values of the modelled LAI are located over the coniferous forest of Les Landes (southwestern coast), and the lowest values are located over the mountainous areas. In contrast, the MODIS LAI maximum values are located over the mountainous grasslands." Surely there must be independent observations to see which is correct.]

RESPONSE 2.5

This sentence could be rephrased as: The main difference between the modelled and the satellite-derived LAI is observed for the Massif Central grasslands in April. While many simulated values are still lower than 1 m2m-2, most satellite-derived values are higher than 2 m2m-2, especially for MODIS. A few independent in situ LAI observations were presented by Vuichard et al. (2007). They reported low LAI values at springtime (1 m2m-2 or less) followed by a rapid rise in June, up to 2.5 m2m-2.

REFERENCE

Vuichard, N., Soussana, J.-F., Ciais, P., Viovy, N., Ammann, C., Calanca, P., Clifton-Brown, J., Fuhrer, J., Jones, M., and Martin, C.: Estimating the greenhouse gas fluxes of European grasslands with a process-based model: 1. Model evaluation from in situ measurements, Global Biogeochem. Cy., 21, GB1004, doi:10.1029/2005GB002611, 2007.

2.6 [7411.2 I do not see the similarity between the models. ORCHIDEE looks much closer to the data. In Figure 1, ORCHIDEE LAI in northwestern France falls much earlier (July onwards) than ISBA-A-gs, and is similar in this respect to the satellite products. I would expect much of this region to be dominated by C3 crops. However, in Figure 6, C3 crop mean LAI falls to almost 0 by July, whereas ORCHIDEE remains higher for the whole year. This seems rather odd. Having read the description, the C3 crop panel in Figure 6 clearly has incorrect colour assignments. Grassland must be wrong as well]

RESPONSE 2.6

Despite the temporal shift between the models, they present rather similar spatial patterns at summertime, especially at the boundary between senescent and growing areas. From this point of view, both models differ from the satellite products. Concerning Fig. 6, there is indeed an error in the colour labelling. Thanks for spotting it. In Figs. 6-8, and 10, the blue lines correspond to ORCHIDEE simulations and the red lines correspond to ISBA-A-gs simulations. A corrected Fig. 6 will be included in the final version of the paper.

2.7 [Why no satellite products on Figure 6?]

RESPONSE 2.7

Yes. The average satellite-derived LAI annual cycle will be added to the "ALL PFT" sub-figure of Fig. 6. In the figure caption, it will be mentioned that the model simulation

are averaged over the period 1994-2007, while the satellite data are averaged over the period 2000-2007. The two satellite products (CYCLOPES and MODIS) present a LAI seasonal cycle with a smaller (lower maximum and higher minimum) amplitude than the simulated one.

2.8 [7414.12 First mention of this difference in LAI definition between the models. Needs more information on the modelled LAI to enable the results to be interpreted (need explanation, not just description – need to learn something!)]

RESPONSE 2.8

Yes. See RESPONSES 2.1 and 2.2.

2.9 [7415.16. "The differences in simulated fluxes between models are directly linked to the PFT types (Figs. 7 and 8)": I would not agree - the PFT types all display approximately the same offset]

RESPONSE 2.9

Indeed, the PFT impact on the differences in simulated fluxes is more visible on a seasonal basis (Fig. 8), than on an annual basis (Fig. 7). In Fig. 8, it can be observed that the two NEE simulations are more or less consistent, from one PFT to another.

2.10 [7416 There is too little information on how the models treat photosynthesis and respiration to enable meaningful interpretation of the differences in NEE.]

RESPONSE 2.10

Yes. See RESPONSES 2.1 and 2.2. It must be noticed that Figs. 7-8 present average results over a 14-yr period, aggregated at the country level. The interpretation of NEE differences at this scale is not easy. However, a striking feature is that differences in NEE values are much smaller than differences in GPP and LAI values. Figure 9 presents additional information about the spatial and seasonal distribution of the average monthly NEE values, on a grid-cell basis. Consistent with Fig. 8, the land uptake of

CO2 is more marked in ORCHIDEE simulations than for ISBA-A-gs simulations from March to May. While no spatial correlation is observed between the two models in September and in October, excellent spatial correlations are observed at wintertime (December, January, February), with r2 values higher than 0.55. Fair spatial correlations are observed during the rest of the year (November, and from June to August) with monthly r2 values ranging from 0.24 to 0.46.

2.11 [7417 The discussion now gives important information about how LAI is modelled. This should have been in the model descriptions to help interpret the results as one read the ms.]

RESPONSE 2.11

Yes. See RESPONSES 2.1 and 2.2.

2.12 [7417.24 Written in this way it sounds as if ORCHIDEE is less good in terms of mechanisms, but surely it performs better in this regard when compared to the data (e.g. Figure 1)?]

RESPONSE 2.12

The phenology sub-model of ORCHIDEE permits to simulate the seasonal variability of LAI as observed from space (Fig. 1) better than ISBA-A-gs. The lack of a phenology sub-model in ISBA-A-gs triggers more differences between modelled and satellite-derived seasonal cycles. However, the differences of the two models with the satellite-derived products are less contrasting in terms of interannual variability (Fig. 3) and of scaled anomaly (Fig. 5).

2.13 [7418.28 'Shultze' spelt incorrectly?]

RESPONSE 2.13

This is a typo. One should read "Schulze et al. (2009)".

2.14 [7419.19 Sudden mention of farming practices. This needs to be invoked earlier.

Where has this affected the comparisons? 7420.7 This conclusion could not be drawn from this paper without invoking management earlier and bringing it into the analysis of the simulation results!]

RESPONSE 2.14

Yes, it must be made clear that the two model versions used in this study do not include a representation of farming practices per se. This may explain why most NEE differences between the two models are observed for crop PFTs (Figs. 6-8).

2.15 [7420 Last paragraph: The main conclusion from this work should be that we need better validation data and ways to assess the process representations in the models directly. Benchmarking is reliant on data, not model inter-conformity!]

RESPONSE 2.15

Yes. Using a common forcing and input land cover maps permits avoiding discrepancies in the simulated vegetation biomass that would lead to wrong conclusions regarding the intrinsic model performances. However, benchmarking in not only a matter of intercomparison methodology. Relevant data sets, as accurate as possible, have to be used. For example, Calvet et al. (2011) have tested the use of agricultural yield statistics to compare several parameter configurations of the ISBA-A-gs model. They show that, even if ISBA-A-gs does not simulate specific processes related to agricultural practices, the agricultural statistics have potential to evaluate the impact of key model parameters, in particular those related to the plant response to drought. Finally, new LAI and FAPAR products (BIOPAR-V1) are being prepared by the GEOLAND-2 project. As they will be available in near-real-time, they will permit a continuous quality control of model-based monitoring systems. Ultimately, they could be assimilated in land surface models, as shown by Barbu et al. (2011).

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