Responses to comments of referee #2

Dear referee,

Thank you very much for your in-depth suggestions and constructive criticism. We appreciate the time you put into reviewing our manuscript. Below you can find a point by point reply to your comments, addressing your questions and indicating our revisions to the manuscript.

Comments

Comment:

1. I suggest to review the literature again for more data on poplar plantations to use for model validation. For example Searle et al. (2014, http://dx.doi.org/10.1016/j.biombioe.2014.01.001) provide a good overview and Nair et al. (2012) introduced the Biofuel Ecophysiological Trait and Yield Database (BETY-db) maintained by the University of Illinois. You should find enough information to validate ORCHIDEE-SRC under a range of climatic conditions.

Response:

We agree that the validation we provided was a not extensive enough to validate our model under a range of site conditions. Because more continuous SRC flux measurements were not available, we could only validate our modeled fluxes for one flux site. Biomass yield values are easier to acquire. Therefore, we added an extra section, where we compare model predictions and site measurements for a number of additional sites in a North-South gradient across Europe. We consulted the data sources you provided and the database looked promising, however, it did not contain many useful data on poplar. We used therefore used another recent source of SRC yield data (Njakou Djomo (2015)[1]; FIG A).

Comment:

2. Searle et al. (2014) also show that yields observed on small, intensively managed test sites may not be achieved at commercial scales. You could test the performance of simulated SRC crops using parameters of their corresponding plant functional types in natural vegetation (temperate broadleaf summergreen tree?).

Response:

The POPFULL site, which we used to calibrate part of our model and to validate the fluxes is run as a commercial scale plantation. Because the model performed well at this site, we think our model is suited to simulate commercial scale plantations. As requested, figure 2 of our manuscript shows a dotted line for the simulations using the standard parameterization, with only coppicing implemented. We also added this line to figure 3 of our manuscript (FIG B).

Comment:

3. Please explain in more detail the longer-term purpose of developing ORCHIDEEFM. As ORCHIDEE is part of a coupled earth system model do you plan to use the model in coupled

[1] S. Njakou Djomo, A. Ac, T. Zenone, T. De Groote, S. Bergante, G. Facciotto, H. Sixto, P. Ciria Ciria, J. Weger, R. Ceulemans, Energy performances of intensive and extensive short rotation cropping systems for woody biomass production in the EU, Renewable and Sustainable Energy Reviews, Volume 41, January 2015, Pages 845-854, ISSN 1364-0321, http://dx.doi.org/10.1016/j.rser.2014.08.058.

mode to study climatic feedbacks from changes in albeo, latent and sensible heat fluxes, CO2 and other greenhouse gas emissions? If this is a goal, then the problems with modelling surface heat fluxes need to be fixed first.

Response:

Our model will not be run in coupled mode. Our aim was to use this model to test a number of management scenarios across Europe to study the variation in the management effects on biomass production and CO2 uptake and find an optimal management. We expanded the section about the aim of our model development in the manuscript.

We agree that the discrepancy in sensible heat flux deserves more explanation. Therefore we extended the section on the sensible heat flux. The error is probably caused by a stable stratification that often develops in the dens plantation at night. Because of this stratification the measured sensible heat loss is lower than the simulated loss. We added an insert to figure 3 in the manuscript that shows the average diurnal pattern of the sensible heat flux, which clearly shows this (FIG B insert). To get a better fit, we tuned the leaf albedo and added this to the list of changed parameters (table 2). This modification only caused very minor changes to the other simulations, but we updated the graphs and values. cannot be represented correctly by the calculation of surface drag, in the way it is implemented in ORCHIDEE. This problem did already exist in the model, as described by Krinner (2005)[2].

Comment:

4. Changes in soil carbon under different land use options are an important determinant of the overall carbon effects of land use change. How do soil carbon pools change under SRC compared to natural vegetation and croplands in ORCHIDEE-SRC?

Response:

These data were not available for the Boom site. On the POPFULL site, the measured soil C loss was 703 g m^{-2} for the top 15 cm [3], while the model predicted a soil C loss of 744 g m^{-2} over the first rotation. We added this to the CO_2 flux validation section of our manuscript.

Comment:

5. Make sure to differentiate between calibration and validation. I think you used the eddy flux data from the POPFULL site to calibrate the model. If this is the case, it is clear why observed and simulated variables (Fig.3 and Fig.4) agree so closely.

Response:

Calibration and validation data were kept separate. We did use some measurements from the POPFULL site for the calibration of the model. These values where, however, not related to the flux data that were only used to validate the model. We changed a sentence in the manuscript to clarify this.

---

[2] Krinner, G., N. Viovy, N. de Noblet-Ducoudré, J. Ogée, J. Polcher, P. Friedlingstein, P. Ciais, S. Sitch, and I. C. Prentice (2005), A dynamic global vegetation model for studies of the coupled atmosphere-biosphere system, Global Biogeochem. Cycles, 19, GB1015, doi:10.1029/2003GB002199.

[3] Verlinden M.S., Broeckx L.S., Wei H. and Ceulemans R. (2013) Soil CO2 efflux in a bioenergy plantation with fast-growing Populus trees - influence of former land use, inter-row spacing and genotype. Plant and Soil, 369(1): 631-644.

Comment:

6. p.4028-4029: Please explain the spin-up procedure in more detail. What is the purpose of the different steps required to compute the soil carbon equilibrium? What does "the model was optimized to achieve a soil C equilibrium" mean in this context? How do you account for the land use history of the two test sites? Differences in previous land use may in part explain differences in simulated and observed carbon sources and sinks.

Response:

We updated the section on the spin-up procedure. A spinup was run to initialize the soil carbon pool. This spinup is performed by running the model with the input data repeatedly, until a soil carbon equilibrium is reached. Because this takes a very long time, a part of this spinup is executed with simplified versions of the model, i.e. teststomate and forcesoil. Teststomate deactivates sechiba, thus only running the daily processes, instead of half-hourly processes, hereby accelerating the model 48 times, reaching a steady state for the non-soil carbon pools. Forcesoil only uses the ORCHIDEE's soil carbon module, reaching a steady state for the soil carbon pools. The spinup scenario starts with three times 20 years of the full model, followed by 50 years of teststomate. Then 40 years of the full model, followed by 1000 years of forcesoil, and 260 more years of the full model. This gives a total of 1510 years, of which 360 are run with the full model. The end state of the spinups is then used as initial state for the actual simulations. This has been included in the main text of our manuscript.

Comment:

7. Table1: A more detailed explanation of the variables, equations and their function in the model would be helpful.

Response:

ORCHIDEE is a big leaf model and doesn't simulate individual trees. The functions f_{vol_bm}, f_{bm_vol}, f_{vol_circ}, and f_{circ_vol} are used to partition the biomass into circumference categories and to calculate the biomass of the initial hardwood cuttings from which the plantation is started. The function f_{height_circ} calculates the height from the circumference. This height is used to calculate LAI and roughness height. The roughness height is important in calculating the aerodynamic resistance. We updated the section on the allometric equations to include this.

Comment:

8. Figure 3 and figure 4 show similar information. Does figure 4 provide any additional information?

Response:

We agree that figure 4, which showed a de-trended version of figure 3, was partly redundant. We reduced figure 4 of our manuscript to only show the data for the latent heat flux and highlighted the data points corresponding to the dry spell, which shows the origin of the deviation in latent heat flux simulation, upon request of referee #1 (FIG C).

Comment:

9. Is irrigation possible on SRC plantations?

Response:

Yes. In Southern Europe, SRC is necessarily irrigated to achieve high yields. I mention this in the updated section of the biomass validation, where we validated yield simulations across

Europe. This will be further described in the follow up papers where we test different management scenarios. Sprinkler irrigation can be simulated in ORCHIDEE by adding the irrigation as precipitation.

Comment:

10. ORCHIDEE also simulates nitrogen fertilization. As N2O fluxes are an important element of the overall GHG balance of energy crop cultivation, does this also work for SRC plantations?

Response:

N_2O is an important GHG gas, also for SRC[4][5]. There is however no N simulation in ORCHIDEE-FM, and therefore also not in ORHCIDEE-SRC. The model assumes a sufficient pool of N in the soil and thus, depending on location and soil type, possibly fertilization. But, N loss in an SRC site is minimal, because most of the N is stored in the leaves, which are not harvested during coppicing. Therefore, the majority of the N stays on the site and only minimal N-fertilization is necessary. Moreover, Central Europe has high N deposition rates.

[4] Zona D., Janssens I.A., Aubinet M., Gioli B., Vicca S., Fichot R., Ceulemans R. (2013) Fluxes of the greenhouse gases (CO2, CH4 and N2O) above a short-rotation poplar plantation after conversion from agricultural land. Agricultural and Forest Meteorology, 169: 100-110.

[5] Zona D., Janssens I.A., Verlinden M.S., Broeckx L.S., Cools J., Gioli B., Zaldei A. and Ceulemans R. (2011) Impact of extreme precipitation and water table change on N2O fluxes in a bio-energy poplar plantation. Biogeosciences Discussions, 8: 2057-2092.

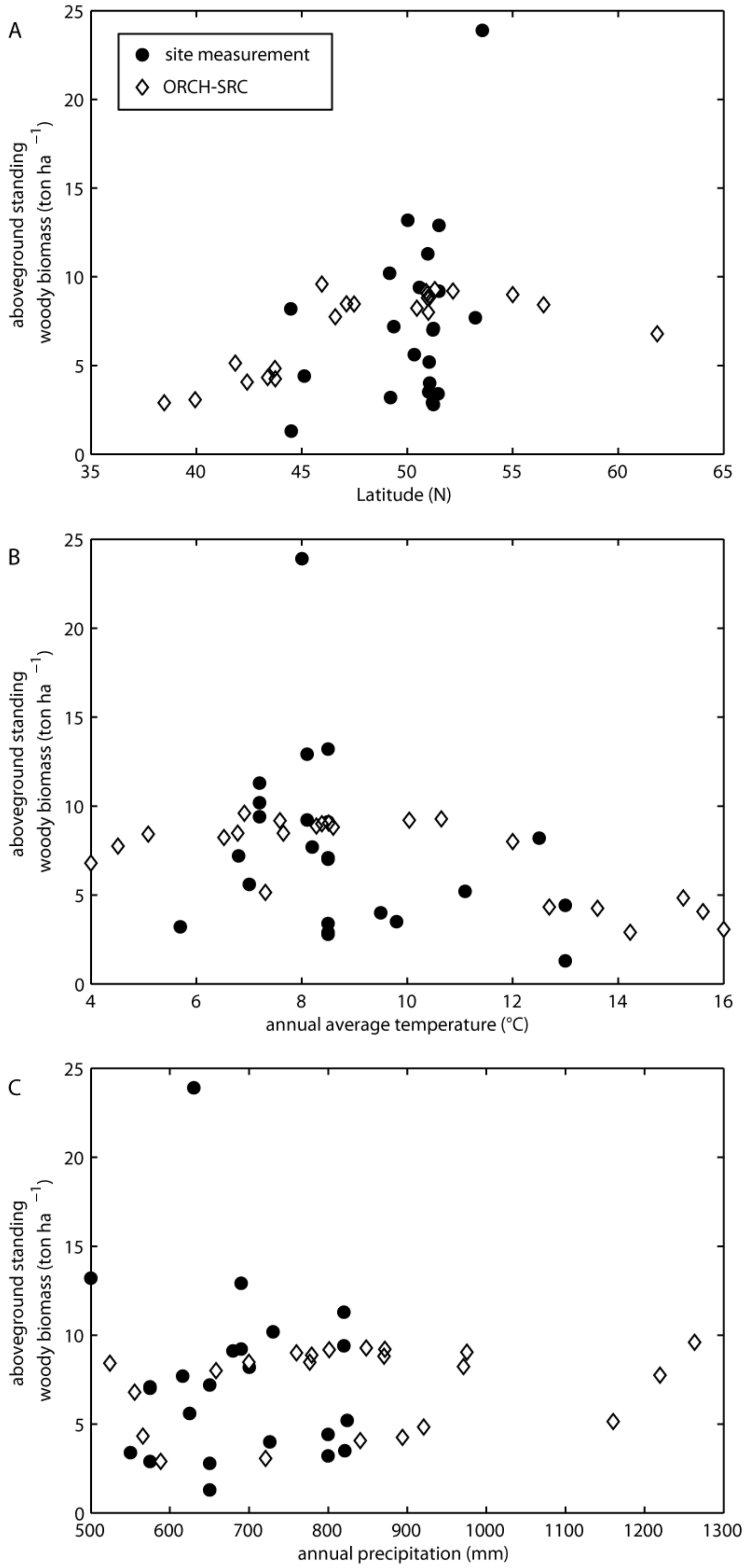

Fig. A: Comparison of aboveground standing woody biomass for ORCHIDEE-SRC simulations (open diamonds) across Europe with site measurements (black circles) across Europe. The biomass is plotted against (A) latitude, (B) annual average temperature and (C) annual precipitation.

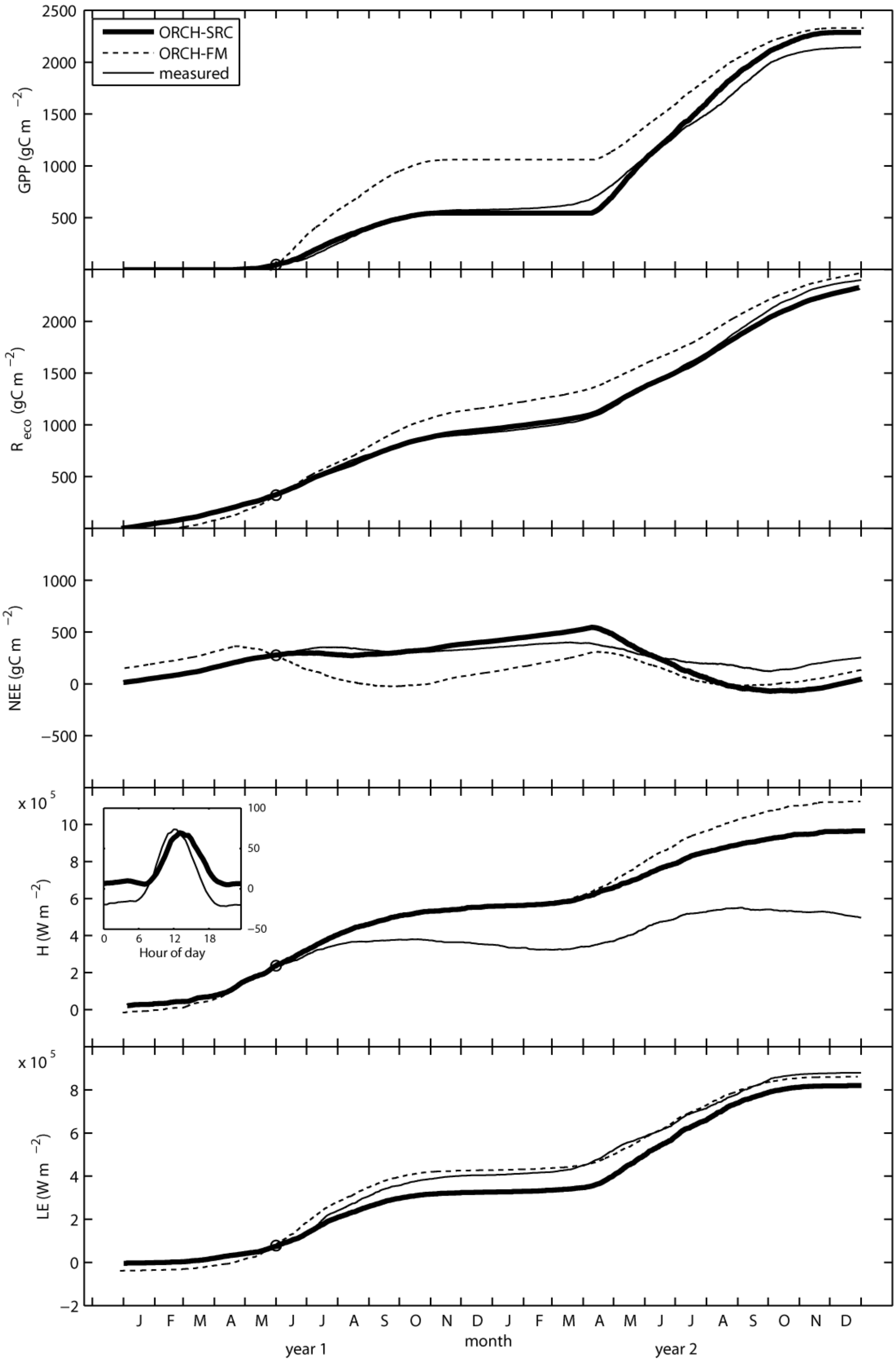

Fig. B: Cumulative fluxes of gross primary production (GPP), ecosystem respiration (Reco), net ecosystem exchange (NEE), sensible heat (H) and latent heat (LE) for the POPFULL site. The insert in the graph for sensible heat flux shows the average diurnal cycle of the sensible heat flux. Thin line:

measurements, fat line: simulations. The thin solid lines are the measured values from the eddy-covariance measurements or recalculated from these measurements using the flux-partitioning tool of the Max Planck Institute for Biogeochemistry (http://www.bgc-jena.mpg.de/~MDIwork/eddyproc/). The dashed lines are the model outputs using the standard model ORCHIDEE-FM. The solid thick lines are the model outputs using the modified model ORCHIDEE-SRC. Since there were no flux measurements before June 2010, both simulated and measured values coincide before that date.

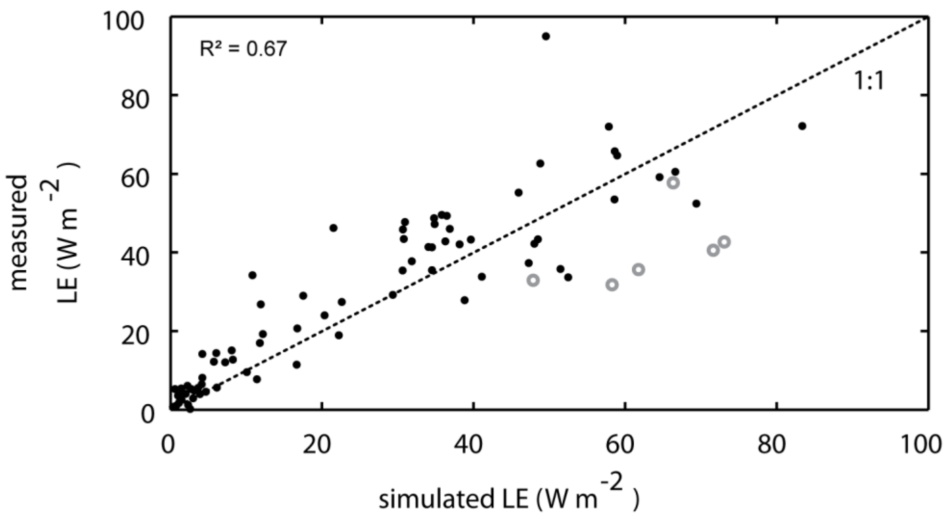

Fig. C: A 1-to-1 comparison of weekly averages of latent heat (LE)for the POPFULL site, between the model outputs and the measured values. The dotted line is the 1 : 1 line. Weeks 18-23 which represent the dry spell are highlighted as grey circles.