(comments of the referees are printed in blue, responses of authors are held in black)

Response letter to Anonymous Referee #3 (Author comment on Biogeosciences Discuss., 10, 19509-19540, 2013. C8263)

General comments

The authors performed a calibration and uncertainty analysis of the coupled CMF-PMF model using a Monte-Carlo approach. The topic fits very well into the scope of BGD, and the manuscript is well prepared. The text is well written, and I enjoyed to read the manuscript. The novelty of the presented 1D simulation runs is somewhat limited, because such model systems are available for more than 20 years, but I understand that a first step has to be done to parameterize such a new model framework. Technically the Monte-Carlo analysis was performed in an immaculate way. My major criticism, however, is that the plant model is behind the state-of-the-art. The model was calibrated for a winter cereal (winter wheat). The authors do not explicitly state that, but from reading the manuscript I got the impression that the crop model, besides senescence, does also not include vernalization. Simulating plant growth of winter wheat without vernalization and senescence is like simulating the hydrology of a catchment without considering snowfall in winter and capillary rise in summer. That are central plant physiological processes that must be captured by every crop model. At least, if the model is applied to a crop that has a vernalization requirement and is maturing at the end of the growing period. During the senescence phase of wheat (about 4 weeks) photosynthesis continuously declines and transpiration collapses. The crop stops growing, and assimilates are translocated from vegetative organs to grains. This period is highly dynamic and is crucial for simulating crop dynamics as well as the water fluxes, what should be also of interest for the hydrological model component. Such structural model deficiencies are in my view unacceptable and also not understandable. These two processes are-well understood and algorithms for including them into PMF are readily available from literature.

That the authors come up at the end nevertheless with good a fit is a "nice" example for a good fit for the wrong reason. The final yield, for example, is not matched well because during senescence assimilates are translocated from vegetative to generative organs but due to a continuously ongoing photosynthesis during a period where in the real world green living leaves are absent.

In my view, the authors must extend PMF for these two processes before this manuscript can be published. I would like to encourage the authors to revise the manuscript accordingly, because I am convinced that the concept to couple a 3D hydrological model with a process-based plant growth model has a high innovative potential.

PMF is not a new plant growth model, with a ready-made structure and predefined data sets that are needed to run the model. It is a model framework, which is based on existing modelling approaches. The basic idea is that the so-called process library of PMF can be extended in future with additional process representations without changing the abstract plant model. The strength of the framework is that PMF can be connected to any soil water balance and nutrient model by using a predefined interface. Its flexibility overcomes the problem of adapting a fixed model code to a site where not all required information to run the fixed model code are at hand. Rather, the model structure can be adapted to site specific conditions and available data.

Therefore, we did not activate the vernalization module in PMF for our case study, because of the lack of available phenological data. Additionally, switching the vernalization module on and running the model again would mean to re-run the entire analyses, including three months of computer run time at an HPC, which is out of the scope for testing one module, which we nonetheless could not calibrate with the available data. The important process vernalization will be tested in future when phenological data are at hand. In the work presented here, we test PMF in its early stage of model development and show that the GLUE analysis (or any other method to investigate model uncertainty) provides a tool for testing a fully coupled model system consisting of an individually developed hydrological and plant growth model.

We added in subchapter 2.1.2. "For our case study we did not activate the vernalization module, because of the lack of available phenological data. The important process of vernalization will be tested in future when phenological data are at hand."

We agree that the results do not give a good fit for the entire vegetation period, which is especially given for the leaf dry matter. This issue has been discussed in the article (p.19524, line27: "In the current model version PMF the model cannot represent a reduction of biomass during the growing season due to leave senescence."). We qualified our assessments about the plant modelling results in the paper from "good results" to "acceptable results" on several positions in chapter 3.2.2 and 3.3.

Nevertheless, we found an acceptable fit of our measured data, with addressing the missing leaf senescene process through the dual coefficient approach: "The transpiration and evaporation in PMF are simulated according to the dual coefficient approach described by Allen et al. (1998). The potential PET is adjusted with crop specific coefficients to account for different growing stages. This crop coefficient is low at the end of the growing period of winter wheat to account for a lower transpiration as a consequence of leaf senescene." (added in chapter 2.1.2). For this reason, the plant water balance and the hydrological model give a good fit to observed soil moisture data. Again, we agree that it is important to include additional plant physical processes in future.

Kraft, P., Vaché, K. B., Frede, H.-G., and Breuer, L.: CMF: a hydrological programming language extension for integrated catchment models, Environ. Modell. Softw., 26, 828–830, 2011.

Specific comments

p. 19512, line 11: You did not iterate simulation runs. You screened the hyperdimensional parameter space for behavioral model runs. Please rewrite!

Changed to: "Instead of calibrating single models step by step, we favour the use of a Monte Carlo algorithm to screen the hyper dimensional parameter space for behavioural model runs of the entire coupled model […]"

p. 19514, line19: This sentences is misleading. At the first view one gets the impression that you used two years for calibration (1993-1994), but what you actually did is that you tested the model for the growing season 1993/1994. Please rewrite!

Changed to: "To initiate the water content of CMF we used meteorological data for the year 1992 and calibrated it for the growing season 1993/1994."

p. 19514, line 25: Root, shoot etc. are not a physical component of the plant. Rewrite it as plant parts or organs.

Changed to: "The basic idea of PMF is to divide the plant into its parts root, shoot, stem, leaf and storage, which interact during the growth process."

p. 19515, line 1: Here it is unclear what you mean with "which interact on a numerical level". Please rewrite!
Sub-chapter 2.1.3: Here it remains vague how the dataflow between the models was organized in detail. A figure could help to make this point more clear here.

We have revised subchapter 2.1.3 completely for a detailed explanation of the coupling process:
Since both models contain Python interfaces which expose all states and fluxes, the implementation of "glue" code to connect the exchange of data is trivial. However, a major issue in model coupling is the definition of the functional boundary between the models, i.e. which processes are covered by which model. It needs to be ensured that processes are not simulated by both models. In this study, the problem is solved by the definition of interfaces in each model to transport information transparently.
The plant model contains methods for the connection to the environmental interfaces ("soil", "atmosphere") and the classes of the process library ("water", "ET"). The methods of the classes "soil" and "atmosphere" are implemented to query the state variables and parameters of CMF directly. Hence, at any code block, where PMF needs information about the actual matrix potential, water content and meteorological conditions, this information is routed through these classes to CMF, which sends the data back.
The class "ET" calculates the evapotranspiration and the class "water" estimates the plant´s water stress due to soil moisture conditions. During every day in the growing season, the plant model calls the class "ET" for the calculation of the potential transpiration (T_{pot}). A water stress value for each layer (ws) is calculated and contained in w_{stress}. Finally, the actual transpiration is determined by the sum of the stress driven water uptake from the rooting zone and the water uptake of the plant from each layer by the proportion of fine root content and water stress of each layer.
Each layer of the water transport model has an accessible Neumann boundary condition representing the system boundary between the soil and the roots. The flux of the boundary conditions is set by the coupling code to the water uptake calculated by PMF. Using the interface approach, the governing equation of water transport, plant growth and potential transpiration can be changed without changing the coupling system. An extension from plots to larger scales such as a hillslope, as shown for a virtual case by Kraft et al. (2011), or a full 3D landscape model is hence feasible without the need to change PMF and the coupling mechanism.
The two models are run consecutive after each time step using an operator split approach. First the plant growth model PMF simulates one time step *t*, using the states of the water transport model CMF at *t-1*. After that, CMF proceeds to *t*, using the water uptake of PMF as a loss term at each soil layer.

p. 19516, line 5-25: How are the assimilates are partitioned between the plant organs. Are the partitioning factors tabulated or do you use a more sophisticated approach such as the functional balance theory? Please explain and include it in the model description.
"Plant partitioning is done according to biomass fractions of each plant organ according to a table given by De Vries (1989). The fraction biomass which is allocated to each organ depends on the growing stage. Root growth and stem elongation occurs until anthesis. After that stage dry matter is only allocated to the above ground biomass. At the very end of the growing season the storage organs are filled." (added in subchapter 2.1.2)

De Vries, P., Balema, A., Jansen, D. M. and Ten Berge, H. F. M.: Simulation of ecophysiological process of growth in several annual crops, Center for agriculture publishing and documentation (Pudoc), Wageningen, 1989.

Subchapter 2.3: 1) I think this chapter would better fit at the very beginning of Chapter

The focus of our manuscript is on the models used and their inherent, coupled uncertainty. We therefore decided to place the case study description towards the end of the Material and Methods section. We think the placement is more a personal preference and suggest leaving the section where it is.

2. 2) I wonder why the authors did not use any phenological data in their calibration. I read the publication of Wegehenkel (2000). There it is stated that besides the above-ground biomass also the phenology was determined. Calibrating the phenology is usually the very first step in the calibration of a crop model calibration and that would already heavily distill the parameter space. That may explain also why the parameter space of the phenological plant parameters was not well-constrained (see p. 19521, line 3-4). The dataset does not contain information on phenology, so what should constrain the parameter space with regard to the different temperature sums? If phonological data are available the authors must include them in the calibration. They are of central importance!

Wegehenkel (2000) mentioned available phenological data, but only for the study site Krummbach. As far as we know, there are no phenological data available for the study site in Muencheberg, where we applied our coupled model. Consequently, phenological parameters could not be constrained.

p. 19525, line 21: It would be better to introduce the cross-validation method already earlier in Chapter 2.

This method is already introduced in chapter 2 at p.19519 l.18.

p. 19520, line 9: The growing season of winter wheat is from October until July. Please correct!

Changed to: "During the growing season (October-July), precipitation of 588 mm and an average temperature of 15.8°C were measured."

p. 19527, line 8: How was fertilization included in the crop growth model. Please explain?

We included the following sentences to clarify the model set up (added in chapter 3.3 on p.19527, line 8): "[…], the water balance of the soil has been simulated without a nutrient balance. For this reason, only water stress restricts crop growth. Fertilizer demand does not constrain plant growth in our model set up, as fertilizer is provided unlimited. In general, PMF is capable to account for active and passive nitrogen uptake."

p. 19528, line 16: Please add "at least under similar soil and weather conditions"

Changed as proposed.

Technical comments

Eq. (1): There is a typo. The minus sign must be replaced against a multiplication sign

Changed as proposed.

p. 19520, line 1: Cancel "primarily", p. 19520, line 1: Usually the texture fractions are give in percentage by weight and not volume. Please check!

Changed to "Sites are characterized by a primarily sandy *Eutric Cambisol*, with a homogenous volumetric sand content of 80 to 90% in a soil profile with 2.25 m depth. Silt and clay content contribute 5 to 10%. The soil is medium textured with good structural stability. The bulk density is around 1.5 g cm^{-1} and the organic matter content in the first 0.3 m amounts to 0.6%. An in depth description of soil physical and chemical properties is given by Mirschel (2007).“ (see also reply to Reviewer#1)

p. 19520, line 5: Replace “climate data” against “weather data“.
Changed as proposed.

Fig. 4 was not shown and plotted in my pdf.
The figure has been added again.