Interactive Discussion on 6, C1070-C1075, 2013

Reply to anonymous Referee #3

Thank you a lot for your detailed review and your constructive comments and suggestions with regard to language and content, we modified the manuscript accordingly.

Specific comments:

Titel:
Dynamic Coupling of Regional Atmosphere with Biosphere in the New Generation Regional Climate System Model REMO-iMOVE

Abstract

Reply:
Many thanks for the comments on technical and content-related shortcomings.
We revised the abstract:

Abstract.
The main objective of this study is the coupling of the regional climate model REMO with a 3rd generation land surface scheme and the evaluation of the new model version called REMO with interactive MOsaic-based VEgetation: REMO-iMOVE. The representation of vegetation is based on plant functional types, which distinctly change the biophysical land surface properties in the new model. New vegetation processes and dynamic interactions between atmosphere and vegetation are introduced. The coupled system now incorporates direct feedbacks between land and atmosphere on regional scale at model time step basis .

Attention is paid to the documentation of the technical aspects of the new model constituents and the coupling mechanism. We compare simulation results of REMO-iMOVE and of the reference version REMO2009 in order to investigate the sensitivity of the regional model to the new land surface scheme. With both model versions, climate simulations for the time period 1995-2005 were carried out. The regional model domain covers Europe on a horizontal resolution of 0.44°. The regional model simulations are forced with ECMWF ERA-Interim reanalyses data as lateral boundary conditions.
The results of these experiments are compared to multiple observation data sets of temperature, precipitation, latent heat flux and leaf area index observation data in order to evaluate the performance of both model versions.

The interactive coupling of REMO with the vegetation scheme captures dynamic changes of vegetation properties like leaf area index and photosynthetic activity due to atmospheric and soil conditions. In particular, the new crop phenology module is able to represent a more realistic annual cycle of vegetation cover. Further, the new model version has the ability to model net primary productivity for the given plant functional types. This new feature is thoroughly evaluated against literature values of net primary productivity of different plant species in European climatic regions.

REMO-iMOVE is able to simulate the European climate in the same quality as the parent model REMO2009. Differences in surface climate parameters can be restricted to some regions and are mainly related to the new representation of vegetation phenology, which directly influences surface heat and moisture fluxes. The simulated inter-annual variability of vegetation phenology as well as the net primary productivity lays in the range of observations and literature values for most European regions. This study also reveals the need for a more sophisticated soil moisture scheme in REMO-iMOVE, which is able to simulate horizontal soil water dynamics and thus differentiate the access of plants to water due to different rooting depths. This gets especially important if the model will be used in dynamic vegetation studies.

Referee #2 stated shortcomings of the evaluation of the model phenology. Therefore we put in a new chapter to emphasis this part of the results. So a new chapter (5.2.1) is introduced:

5.2.1 Evaluation of the interactive phenological scheme

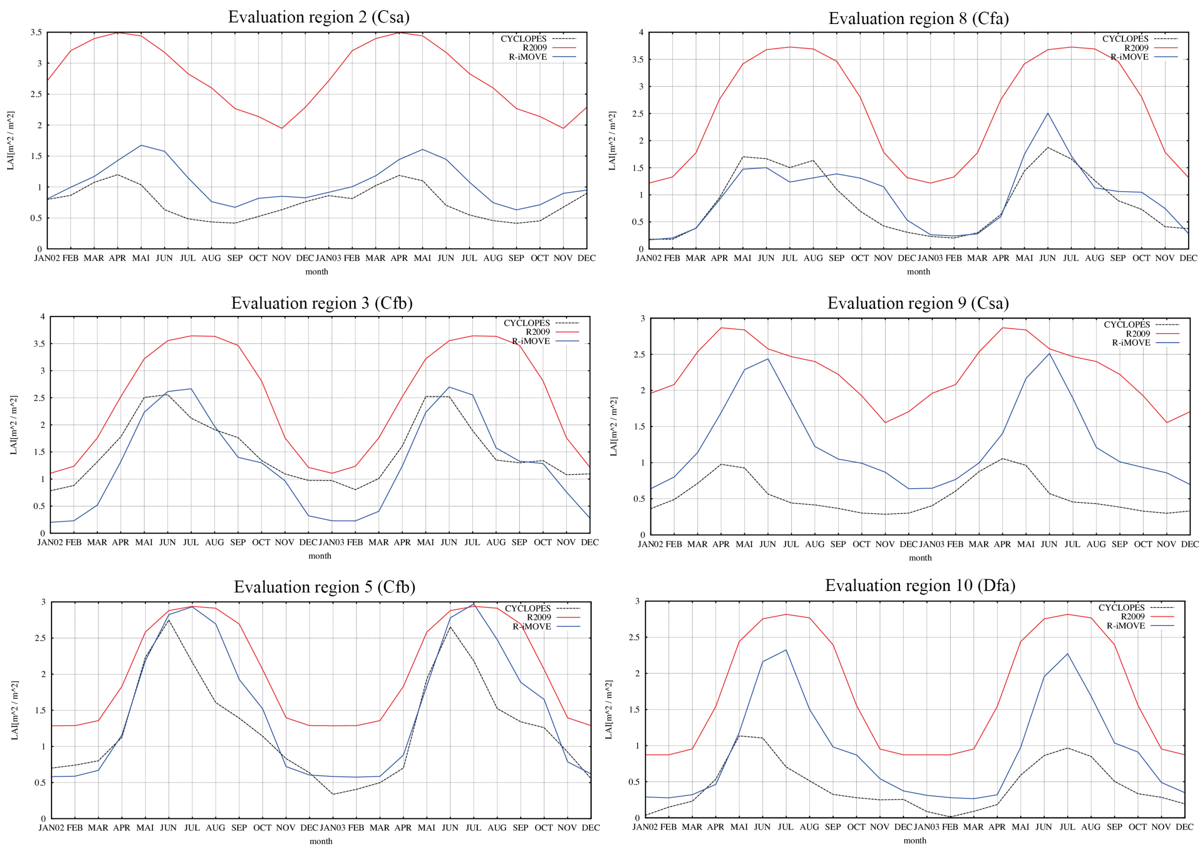
The vegetation and therefore the phenological scheme of REMO-iMOVE is solely driven by the atmospheric forcing and soil moisture characteristics. In REMO the phenology was prescribed and could not represent inter-annual variability. Figures 11 shows the LAI courses of REMO-iMOVE and REMO2009 in comparison to CYCLOPES observation data for the years 2002 and 2003. With the collection of evaluation regions shown, we give an overview for regions with high LAI dynamics. Despite some inaccuracies in the length of the vegetative period, the LAI courses of REMO-iMOVE match well to the observation data for the evaluation regions 2, 3, 5 and 8. The LAI maximum is a month late in region 2. The length of the vegetation period is overestimated by a month in region 5. The vegetation period is shifted by a month in region 3, but the magnitudes of LAI match well the observations. The LAI magnitude of evaluation region 9 and 10 is highly overestimated by both models, however the timing of the onset of vegetation is modeled well in REMO-iMOVE. Since the phenology is now driven by atmospheric forcing and soil moisture dynamics and vegetation distribution and the phenology model logic, many factors interact to model the LAI course. The onset of vegetation greening of summergreen PFTs is mainly driven by the mean day temperature, so these PFTs are dependent on the atmospheric forcing. Grass PFTs always grow if sufficient moisture is available and the temperature is high enough, so shortcomings will surely be dependent on the bucket soil scheme and the atmospheric forcing. The findings also do clearly show that in comparison to REMO2009, the new model is not only able to react to inter-annual changes in vegetation cover, but also emends some shortcomings in the LAI courses of REMO2009.

Chapter 6

P. 3110, L. 9:

The interactive coupling of REMO with the vegetation scheme captures dynamic changes of vegetation properties like the annual cycle of LAI and photosynthetic activity due to atmospheric and soil conditions. Chapter 5.2.1 shows that REMO-iMOVE is able to reproduce the observed annual cycle of vegetation in most evaluated regions. Shortcomings still exist in some semi-arid and continental climate regions. The observed LAI values in the evaluation regions 9 and 10 do not exceed the limit of 1 (Figure 11). The simulated values show maximum of nearly 2.5. The plant growth in these regions is m limited by water. Figure XY shows the soil water dynamics for evaluation regions 9 and 10. A value below 35% of the bucket fill means, that the wilting point in the soil is reached and no more water is available to plants. If the value is above 35%, water is available for plant growth. It is clearly seen, that the bucket fill never drops below 35% in region 9, even if it is located partly in semi-arid environment. In evaluation region 10, we would also expect strong plant water stress in summer due to the continental climate characteristics. But the bucket fill always exceeds 35%, meaning that water is available for plant growth. As stated earlier, the bucket soil water scheme of REMO is not able to represent horizontal soil moisture dynamics. Since that would be needed for a near realistic image of plant growth in these regions, we also can see that in the overestimated LAI value. Another factor towards an overestimation of the LAI magnitudes is the model bias in summer precipitation, which can be up to 40 to 60% in the referred regions.

New Figure – figure 11



Introduction

Reply:
Many thanks for the remarks on technical and content-related shortcomings.

Methods

Reply:

- PFT table: done
- Table 1: the value in the parenthesis is just a consecutive numbering and is being deleted, since it leads to confusion
- The equation is based on the observation, that soil gets darker when it is wetted and tries to put this empirically described relationship into the model, based on the stated literature. It is valuated by off-line experiments. The exponential scaling is needed to meet model soil moisture representation.
- P3093 L 1-3: we put that together with the following paragraph
- Grass PFT LAI: we could not see such behaviour, since the vegetation dynamics is rather slow and minor in magnitude, compared to the atmospheric variables
- fAPAR: the general functionality is described. For detailed answers please consider the stated BETHY model by Knorr, 1998
- Coupling concept: In general we do not want to change the picture, but we put more effort in the explanation. To clarify some of the stated points, we put the part of the figure we meant in capital letters behind each paragraph:

  REMO and JSBACH are technically very similar. This similarity made it possible to implement subroutines of JSBACH directly into the REMO model code. Therefore the coupling between the two models could be realized on a model time step basis without

significant loss of computational performance. Figure 1 shows the concept of the coupling and the computations done by the iMOVE (JSBACH) sub-model. Here we show only the most important parameters and processes. In the left box the directly concerned processes and parameters of standard REMO are shown in blue and grey. On the right hand side the new processes and parameters are shown in green, yellow and grey. Green parameters mean that a quantity is processed for each PFT of a grid cell. Yellow parameters are accumulated as a weighted PFT average for the grid cell and reported back to REMO.
The canopy absorption model of iMOVE gets the photosynthetically active radiation of REMO and together with the LAI for each PFT the fAPAR is computed (ABSORPTION IN CANOPY). fAPAR is used together with atmospheric CO_2, pressure, temperature, atmospheric moisture and LAI to derive the water unlimited photosynthesis rate and unstressed stomatal conductance (PHOTOSYNTHESIS water unlimited). The water stress factor is computed using the soil water content of REMO (the hydrological soil parametrization in REMO and ECHAM6 are similar). The photosynthesis rate and stomatal conductance is computed using unstressed quantities combined with the computed water stress factor (PHOTOSYNTHESIS water limited). The actual photosynthesis rate is the basis for NPP. The actual stomatal conductance is given back to REMO to compute the surface evaporation fluxes. NPP, soil moisture, temperature and the model time are used in the phenology model to derive the updated LAI (PHENOLOGY). The surface vegetation ratio (VGR) is derived from the LAI via Beers extinction law for each PFT. The VGR for the whole grid cell is based on weighted PFT values. The grid cell albedo is updated using soil albedo, vegetation albedo, snow cover and the water fraction, if open water is present in the grid cell. The grid cell roughness length (Z0) is computed using vegetation and soil roughness length on weighted PFT basis (UPDATE LAND SURFACE). The updated and accumulated physical surface parameters for each grid cell VGR, LAI, albedo and Z0 are passed to the surface flux computations of REMO. The direct coupling of surface and vegetation processes to the atmosphere represents interactions between land and atmosphere and hence adjusts the surface parameters based on the atmospheric forcing. In turn the surface and vegetation feeds back to the atmospheric state.

Experiments

Reply:

For us it was interesting how the vegetation reacts to the soil water spin up. Since we have a bucket scheme in REMO, which is spinning up sufficiently in one year we wanted to show the arid and semi-arid vegetation behaviour on soil water. In chapter 3 we describe the experiment, which includes the years 1995-2005 (P3097, L.26). In chapter 5.1 we describe the evaluation characteristics and state, that we compare the climatic variable for the period 1996 to 2005 (P.3099, L.11), so the first year is not included in the model inter-comparison.

The orography of the model region is shown to introduce the extent of the model domain to the reader.

Results

Referee: Rather than showing month, what about showing three-month seasons?
Reply: We explicitly decided to evaluate monthly values, to really show what the model is doing and to give detailed information on the abilities.

Referee: section of evaluation LAI to satellite data
Reply: is included now

Referee: Evaluation regions should be used.
Reply: we included this in all relevant sections where it makes sense to us.

Referee: soil moisture needs to be addressed
Reply: Soil moisture can only be addressed through the use of proxy data, since local soil moisture measurements are not very representative for broader regions and the horizontal resolution of the model is 50 km! Our focus is the soil moisture in semi-arid and arid region. To evaluate this we included the hydrological spin up in the relevant sections (NPP). To show the effects we used the NPP as proxy.

Referee: Precipitation
Reply: We crossed out slight.

Referee: color scale figure 7
Reply: the color scheme depicts the value REMO-FLUXNET. It is confusing since values of fluxes are defined negative, if they are directed away from the surface into the atmosphere. If REMO shows a value of -5 and Fluxnet shows a value of -10. A value of 5 is resulting, meaning REMO models 5 W/m2 too less latent heat flux → red. We added an explanation of this in the text: “It should be stated that fluxes are defined negative when the flux direction is from the surface to the atmosphere."

Referee: warm bias section confusing:
Reply & changes in the text:
Mainly the areas of the Balkans region, the Hungarian lowlands and the west coast of the Black Sea are under the influence of a distinct increase in 2m temperatures in REMO-iMOVE from July until October (evaluation region 8 - Cfa and Cfb climate). The areas showing the warm deviation, correlate with a drop in LAI and vegetation ratio (vegetation covered part of the grid cell - VGR) in REMO-iMOVE (Fig. 10). This decrease in vegetated area decreases the effective amount of transpiration and thus evaporative cooling. This causes an increase in temperature and sensible heat flux (please note: fluxes are defined negative when directed away from the surface). The increased Bowen ratio causes a drying of the lower atmosphere. The lower atmospheric moisture provides an important part to the whole atmospheric moisture content. Especially in summer, when the local moisture recycling is the main source for precipitation, the decrease in atmospheric moisture is the reason for a reduction in precipitation.
The reason for the changes in the vegetation surface parameters LAI and VGR is the improvement in the phenology scheme for crops. In REMO2009, the crops are “harvested” at a fixed date every year, which is decoupled from the climatic drivers and occurs in late September. The crop phenology in REMO-iMOVE is closely coupled to the atmospheric forcing and thus is able to model the harvest date dynamically. Figure 11 shows the LAI annual cycles of both model versions and the CYCLOPES observation data in 2002 and 2003 for the Cfa climate in evaluation region 8 (compare Fig. 3). Evaluation region 8 is located in the area of the described warm bias. The simulated LAI in REMO-iMOVE depicts very much the characteristics of the observational data, not only in magnitude but also in the timing of maximum and minimum values, which is not the case in REMO2009.

Referee: NPP calculation and highly structured terrain
Reply: Not the NPP is important, but the model resolution. We clarified the section:
P. 3105, L. 19: To model NPP directly in a regional climate model, driven by all important forcing variables enables the modelers to conduct carbon cycle experiments on high resolution. This enhancement in resolution brings opportunities in regions of highly structured or heterogeneous terrain.

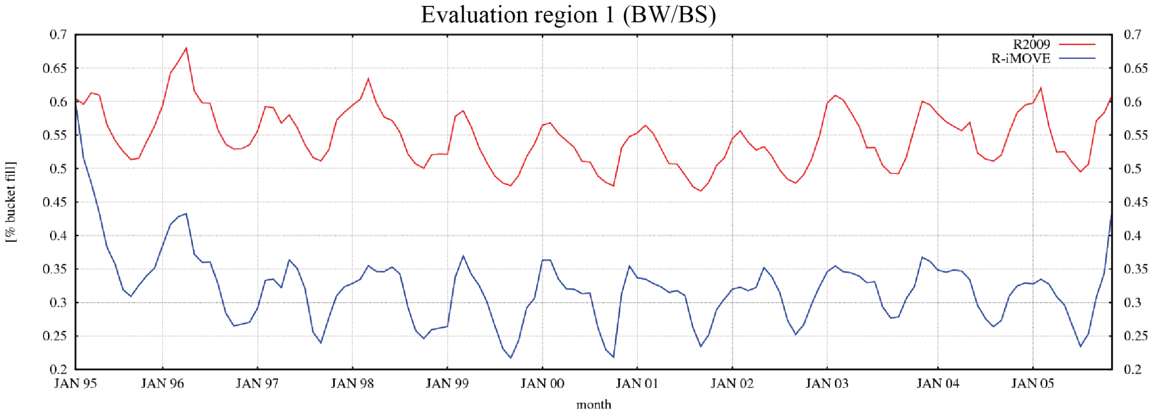
Referee: NPP section.
Reply:
- Figure 12 is decomposed into subfigures.
- The sentence also is proved by Roy et al. 2001, we will add that.
- We just have one NPP flux – it is not possible to have above ground and below ground values.
- P. 3109, L.7: But the spread in the measurements of below ground root productivity is huge, ranging between 3 to 60\% of total productivity (Roy et al., 2001).

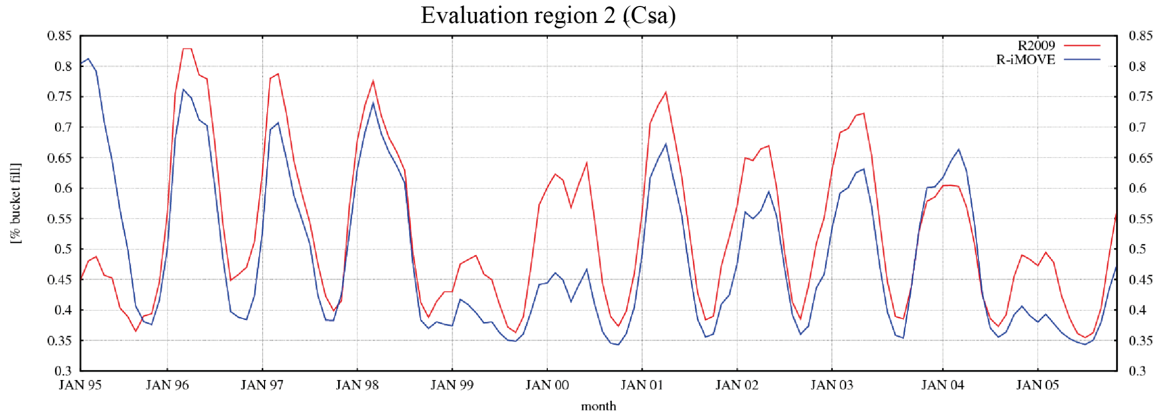
Discussion

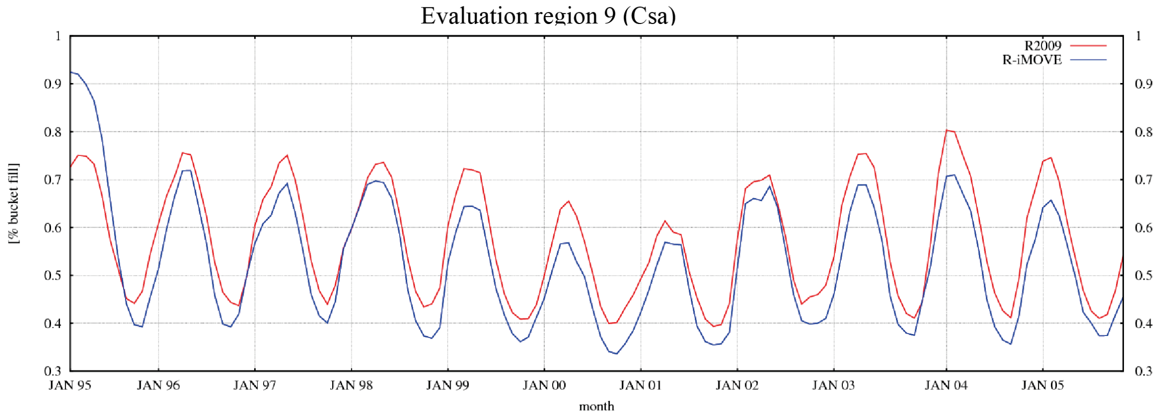
Referee: productivity in dry regions
Reply: We rephrased the section and put in a paragraph discussing the soil moisture problem in dry areas and also a new picture.

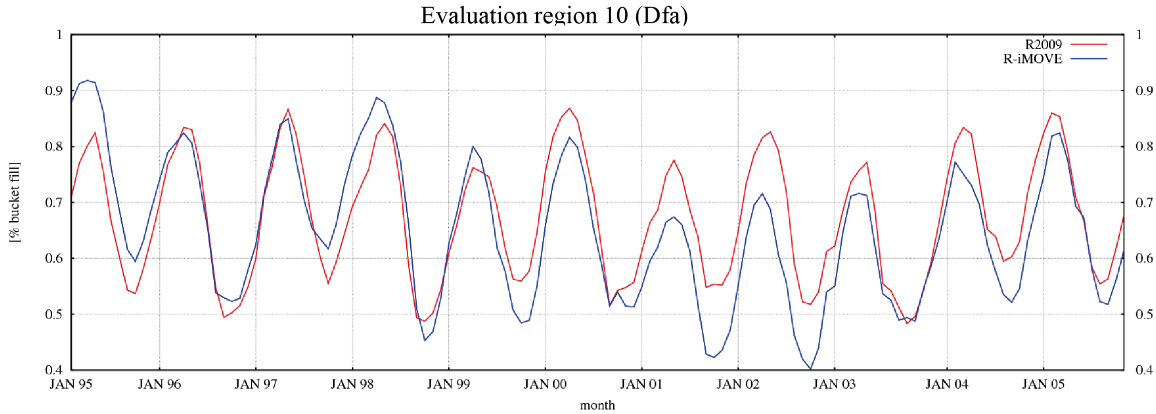
Changes in the text:
The productivity dependence on soil water in an extreme case is given in the first year of the model run, where the hydrological soil spin-up took place. Here the annual NPP rate in all arid environments (evaluation region 1 BW/BS) is very high, compared to all other years where no productivity takes place to the lack of soil water. Also in evaluation region 2 Csa the NPP rate drops to minimum values in exceptionally dry years (1999, 2000). In figure 12 we depicted the soil water courses for region 1 (BW/BS) and region 2 (Csa) for comparison. So it is clear for region 1 in the first year (spin-up), that the productivity values are high, because water is available in the soil. After the soil spin up the productivity values drop, since only in very few months in some years the soil water exceeds 35 \% of the bucket fill and is available for the plants. In evaluation region 2 we can correlate the distinctive drop in NPP in the years 1999, 2000 and 2005 to the exceptionally dry state of the soil. So we can state that the overestimated grass PFT productivity is mainly due to missing horizontal soil water dynamics, which would differentiate the access of plants to water due to different rooting depths.

New figure – figure 12









Conclusions

Referee: Focus on lakes
Reply: The focus on lakes comes from the misunderstanding, that we consider the higher resolution of

the RCM important for structured and heterogeneous terrain – not the NPP – we clarified that.

Referee: Phenology
Reply: We hope this is clarified due to the introduction of the LAI results and discussion section

Referee: Soil scheme
Reply: We state the importance of the multi layer soil scheme for solely water limited PFTs and hope to clarify that, by introducing the soil water courses of some evaluation regions. See the introduced figure showing the soil moisture in some evaluation regions.