

**Review:** Dynamic Coupling of Regional Atmosphere to Biosphere in the New Generation Regional Climate System Model REMO-iMOVE

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**General Remarks:**

This paper introduces and evaluates the coupled biosphere-atmosphere model REMO-iMOVE. The authors describe the advances in the coupled model compared to previous versions, with the most significant change being the introduction of plant functional types (PFTs). An interactive phenological scheme predicts the state of the vegetation, which feeds back to influence the surface albedo, the surface and canopy radiation calculations, and the surface energy and carbon fluxes. Using the newly developed model, the authors present results from an eleven-year simulation. In comparisons against previous versions, the new model performs at least as well, if not better, and now includes the capability to calculate and compare carbon fluxes. In conclusion, the authors identify the importance of soil moisture and suggest the development of a multi layer soil scheme to further improve the model.

This paper presents a new model that has the potential to be utilized in a variety of applications to advance modeling science and to address scientific questions. In general, the model development, description, and evaluation are clearly outlined. I believe that the authors provide sufficient background information and references to previous work, while clearly stating the new material in this study. Although the description is thorough, it has substantial errors in grammar. Fixing the English errors would greatly improve the manuscript, including altering the title of the paper as well as the abstract. I found the figures in the paper to be too small, and I feel that showing seasonal differences rather than monthly comparisons would be better. Overall, I think that this paper is suitable for publication in Geoscientific Model Development; however, I think it could benefit from substantial modifications.

**Specific Comments:**

**Title**

Although I did understand what was meant by the title and what would be included in the paper, the wording is not a proper English phrase.

**Abstract**

I think the abstract could be clearer and more concise. I would suggest rearranging the order to introduce the changes in the model in the beginning of the paragraph, and I think it would be helpful to outline the exact changes in the model, including not only the use of PFTs, but also mentioning the resulting changes in the phenological state, the albedo, the radiation and the surface fluxes. The authors also mention that the modeled inter-annual variability in the phenology compared well to literature values; however, I feel that this needed to be explained more in the paper. While they did indeed show improvement in two years of LAI values and also improvement in the variability in the carbon fluxes, I felt that more justification than two years was needed to extend the improvement in the inter-annual variability statement to the phenology. Finally, the authors state the need for improvement in the soil moisture calculation, but I feel that the emphasis on soil moisture needed to be explained more in the paper.

There are numerous errors in comma usage, specific words, and in phrases. Here are some specific examples:

- The phrase on line 10 “to represent present day European climate” is unnecessary
- The word “result” in line 11 needs to be “results”
- The word “further” in line 13 is placed in a confusing place and can be removed
- The preposition “by” in line 14 should be changed to “against”
- The use of “these” at the beginning of line 20 is confusing: what is being referenced? There aren’t any parameters listed in the proceeding sentences, just changes in the model and the vegetation.

## **Introduction**

Overall, I found the background information sufficient; however, there are several errors in grammar:

- Remove the comma between “models” and “by” in line 11
- Add “not only” in line 14 (after “heterogeneity”) to go along with the “but also” used later in the sentence
- Add a comma after “on the one hand” (line 15) and after “on the other hand” (line 16)
- Remove “mainly” in line 22
- Remove the comma between “study” and “that” in line 24
- Remove the comma between “conductance” and “because” in line 25
- Change the “or” to an “and” in line 26
- Add the phrase “to describe and evaluate” after “The aim of this study is” to clarify that sentence

## **Methods**

Overall I found the methods section to be a thorough description of the model and the changes made; however, I have several suggestions below that I think would improve this paper:

- I would recommend putting the PFTs into a table, as I think this would be helpful for future reference throughout the paper.
- In Table 1, what is the value in parenthesis? This needs to be defined in the caption.
- In the description of the soil albedo including litter, it is unclear where the equation came from. Perhaps cite a reference for the equation and the PFT values of the litter scaling factor.
- The equation for the soil albedo including soil moisture uses an exponential relationship; however, the reference cited describes a linear relationship. Please provide a description of the exponential relationship that is used instead.
- In the description of the canopy radiation, the first sentence is separate (page 3093, lines 1-3). I found it confusing to have a paragraph of only a single sentence. From reading it, I would recommend combining this sentence with the following paragraph (lines 4-18), which I believe describes the radiation scheme in JSBACH.
- In the description of the grass PFTs, I was wondering that since the LAI is allowed to change daily if that introduced spurious “wiggles” in the LAI? You could consider including an example of the seasonal cycle to show the magnitude of the daily and seasonal changes in LAI.
- The text describes the calculation of LAI, but does not give the relationship back to the fAPAR that is used in the model. I assume the fAPAR is calculated from the LAI? If so, I think including a short statement and perhaps the equation would be helpful.
- Figure 1 depicts the coupling concept of REMO-iMOVE; however, I found this figure to be more confusing than helpful and would suggest reworking it. I recommend putting the

color descriptions in the figure caption to make it easier to quickly see what each box refers to, rather than having to flip back to the main text. The arrowheads are also too small to see which direction is indicated. I found the arrows to photosynthesis confusing, with arrows to water limited coming both from climate variables and also from unlimited photosynthesis. From my understanding, I think it would be better to rearrange this to have the photosynthesis on a single line, with both the water limited and unlimited pointing directly to NPP (rather than having to go through limited, as from my understanding this may not be the case if water is available). I also found the fAPAR and LAI boxes confusing; isn't the LAI used to calculate fAPAR? There is no link between these. Also, the only input to phenology was time; however, the climate variables are also involved in the calculation. I was also confused as to what was meant by heat conversion and wondered where the energy and carbon fluxes fit in. I believe they should be gray boxes along with evapotranspiration; and since these are very important model output, they need to be included in the diagram.

- I found the description of the calculation of the grid cell surface vegetation ratio confusing (page 3097, lines 12-16). I think that the grid cell values are weighted means of the PFT contributions, but this should be clarified.

There are also numerous errors in grammar and some instances where clarification in the text would improve the manuscript. Here is a list of the most significant errors I noticed:

- Remove the apostrophe from "it's" on page 3089, line 14
- Add an "s" to "scheme" on page 3089, line 20
- Add an "s" to "advancement" on page 3090, line 7
- Add "the" after "on" on page 3090, line 9
- Rearrange the second half of the sentence on page 3090, line 10 (perhaps to something like: "the division of a single grid cell into 16 PFTs")
- Add an "s" to "sum" on page 3091, line 3
- Add a comma after "Table 1" on page 3091, line 7
- Change "splitted" to "split" on page 3091, line 12
- Fix incorrect PFTs listed on page 3091, line 14
  - C3/C4 grass are PFTs 9 and 10 (not the printed 3/4)
- Remove the comma after "tables" on page 3091, line 15
- Remove the paragraph break for the sentence starting with "All the allocation" (page 3091, line 15), as this continues on with the description of the previous paragraph
- Change "compare" to "see" on page 3092, lines 1 and 14
- Change "were" to "where" on page 3092, line 4
- Change the phrase "albedo decrease to soil wetting" to "albedo decreases with soil moisture"
- Remove the comma after "above" on page 3092, line 20
- Remove the comma after "computed" on page 3092, line 19
- Put the phenological characteristic list in the same order that they are described (page 3094, lines 7-8)
- Remove the comma after "supplementary" (page 3094, line 24)
- Remove the comma after "0.1" on page 3095, line 6
- Change "begin" to "beginning" on page 3095, line 16
- Remove the comma after "is" on page 3096, line 15
- Change "is" to "are" on page 3097, lines 9 and 20
- Remove the "s" from "adjusts" on page 3097, line 21

## **Experiments**

I would suggest removing the phrase “so-called perfect” and adding “from” after conditions (page 3098, lines 27-28).

I found it interesting that you left the soil hydrological conditions out of equilibrium. Is this necessary to include in the paper? This could be a helpful test, but I’m not sure if it’s necessary to publish. And why consider just the hydrological conditions but not the soil thermal properties, as don’t those adjust faster than the hydrological state? If you do include the first year of un-equilibrium, I think you need a further description as to the purpose of this test and then further explanations of the results of this test, perhaps in a separate section in the results so that it’s easy to identify. And since the first year is not in equilibrium, then for the model inter-comparisons and climate results that year of simulation should not be included.

Figure 2 depicts the orography, but I didn’t find that useful. I think it would be more helpful to show something like the dominant vegetation coverage.

## **Results**

Overall I thought the results section was well organized and a useful evaluation of the new model; however, I have several suggestions that I think would improve the manuscript. First, the figures are too small and too numerous. Rather than showing months, what about showing three-month seasons? I think that would be much clearer, especially since the text primarily uses seasonal descriptions. Second, what about adding a section on the inter-annual variability of LAI and comparing to satellite data? Since this is discussed in the conclusions, I think it needs to be explored as thoroughly as the NPP. Third, I would suggest using the regions as much as possible in the text explanations. Some of the descriptions are confusing, and it would be simpler to use the regions to point out geographical areas as much as possible, since they are defined and even depicted in Figure 3. Fourth, I think the importance of soil moisture needs to be addressed. In the conclusions the authors state that the soil moisture is the most vital improvement necessary in the model; however, I feel that the results shown do not fully substantiate this statement.

In addition to the above general comments, I also have several specific suggestions. Starting with the general model comparison paragraph, I did not like the use of the phrase “surface parameters” on line 7: stomatal conductance and plant available soil water are not parameters, but rather are diagnostic variables calculated by the model.

In the precipitation overview, I thought that the authors underestimated the severity of the precipitation errors by using the adjective “slight”. To me, a 40-60% difference isn’t slight (and honestly it looked close to 80-100% to me in some areas, from what I could tell in the figure). I also didn’t see the underestimation in parts of Europe for December to March (page 3101, line 27) and don’t think this sentence needed to be included. The final paragraph of that section was difficult to see from the figures as well.

In the latent heat flux section, I believe the color scale on Figure 7 is backwards. From what the figure shows, it appears that REMO underestimates the latent heat flux in European summer (the region is blue, indicating the REMO is less than FLUXNET, not overestimated as stated in the text). Please make sure to clarify this.

I found the warm bias section confusing and needing more explanation. First, the authors show the vegetation ratio but do not describe what this is. Please include a description of what is meant by

the vegetation ratio. The LAI is quite reduced in REMO-iMOVE (Figure 11) and I think this needs further explanation as to why. With crops, I would actually expect the LAI to be higher in the summer, which would then decrease the Bowen ratio and temperatures, rather than causing both to increase as described in the text. I would also expect more seasonal change in LAI, rather than a complete offset in these regions. Given these thoughts, I found the author's argument for the warm bias difficult to follow and suggest re-working this section.

In the new model features section, the authors state that the NPP calculation is especially important for areas with highly structured terrain or with many lakes. It is unclear to me why this would be the case and I would appreciate a further explanation of that statement.

In the NPP section, the authors state that the connection between NPP and soil water is evident in the appendix. What is being referred to? I did not see an appendix and did not know what was meant by this statement. The figure of NPP inter-annual variability (Figure 12) is not readable. Please reduce the number of mini-figures and make them bigger and clearer. Mid-section, the authors state that NPP measurements vary due to different species and nitrogen contents, but I think references for these statements are necessary. The authors also provide literature values of below and above ground productivity separately. Would it be possible to directly compare these values to model output (i.e. compare below as well as above ground productivity)? Finally, at the end of this section, the numbers on the figure are too small to compare to the values stated in the text, and the authors state that the magnitude is huge (page 3109, line 7), but it is unclear what they are referring to. I am assuming they mean the range in below ground root productivity, but this needs to be clarified.

Grammar errors:

- Add a comma after "insight" and remove the commas after "areas" on page 3099, line 14
- Fix the sentence order of the sentence starting with "in a second step" on page 3099, line 15
- Change "till" to "until" on page 3100, lines 1 and 4 and on page 3101, line 7
- Remove "partly" from page 3100, line 3
- Add "in that region" to the end of the sentence on page 3100, lines 11-12
- Add an "s" to "version" on page 3100, line 12
- Start a new paragraph with the sentence "Beginning in July" (page 3100, line 14)
- Add an "s" to "month" on page 3100, line 22
- Change the sentence "In May, the conform picture for both models change", as I'm not sure what is meant here (page 3101, line 13)
- Add an "s" to "version" on page 3102, line 19
- Remove the comma after "identified" on page 3102, line 27
- Remove the "n" from "ratio" in the Figure 10 caption
- Remove the comma after "processes" on page 3105, line 2
- Remove the comma after "models" on page 3105, line 7
- Remove the commas after "detail" on page 3105, line 10
- Add commas after "(NPP)" and "grid cell" on page 3105, lines 18-19
- Remove the sentence "Usually NPP is measured..." on pages 3105-3106 as it is unnecessary as long as the units are included in the figures
- Remove the comma after "year" on page 3107, line 6
- Add an "s" to "zone" on page 3108, line 11
- Remove the comma after "values" on page 3108, line 12
- Add an "s" to "range" on page 3108, line 27

- Combine the sentence starting with “Below ground” with the previous paragraph (page 3108, line 23)
- Add an “s” to “region” on page 3109, line 1
- Add an “s” to “range” on page 3109, line 2

## Discussion

The authors state that the productivity in dry regions is dominantly limited by soil moisture availability, but I felt that this was not shown sufficiently in the results section, as no other explanations were offered and no correlations nor any statistical relationships were shown.

Since all three final paragraphs in this section all discuss productivity in various climate zones, these should be combined into a single paragraph.

Grammar errors:

- Remove the comma after “REMO2009” on page 3109, line 11
- Change “in” to “is” on page 3109, line 18
- Remove “if” on page 3109, line 19
- Remove the comma after “parameterization” on page 3110, line 4
- Remove “near” on page 3110, line 7
- Change “vital” to “vitality” on page 3110, line 9
- Change the use of “parameter” on page 3110, line 12 to something like “model features”, since NPP is not a fixed parameter but rather a new diagnosed variable
- Fix the second sentence of the paragraph beginning “One of the most” (page 3110, lines 12-13), as it does not make sense
- Change “insufficient” to “insufficiently” on page 3110, line 22

## Conclusions

In discussing the importance of NPP, the authors focus on lakes, yet no results including lakes were shown. I feel this statement needs further explanation or needs to be removed.

As one of the conclusions, the authors state that the modeled inter-annual variability in phenology is in the range of observations for most European regions examined; however, they only looked at two regions for two years. Since for NPP they looked at more regions with longer time frames, would it be possible to include an extended analysis of LAI, perhaps using satellite data, to further justify this conclusion?

The authors end by stating that importance should be put in developing the soil scheme. While this is likely important, is it possible to list other factors that may be causing errors or to further substantiate this claim that the main problem is related to the soil moisture?

Grammar errors:

- Remove the comma after “approach” on page 3111, line 17
- Fix the second sentence in the paragraph starting with “NPP is an...” as it doesn’t make sense
- Remove the comma after “REMO-iMOVE” on page 3112, line 1
- Remove the comma after “show” on page 3112, line 9