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Comment on gmd-2021-263

Anonymous Referee #2

Referee comment on "A new approach to simulate peat accumulation, degradation and stability in a global land surface scheme (JULES vn5.8_accumulate_soil) for northern and temperate peatlands" by Sarah E. Chadburn et al., Geosci. Model Dev. Discuss., <https://doi.org/10.5194/gmd-2021-263-RC2>, 2021

This manuscript is presenting a version of JULES that include a vertically discretize accumulation of organic and mineral soil. This version is also capable of simulating soil carbon aging. Capability of the soil organic accumulation scheme is demonstrated for various simulation set up that aim at showing sensitivity of the model to soil properties. Simulation results are compared with the standard JULES version and to peatland profiles at 216 sites. The paper also discusses the capability of the model to reproduce processes specific of peatlands formation, and stability. The novelty of this scheme is to be able to consider the resilience of peatland soil to increase atmospheric temperature and the instability of peatland soil to drainage. Thus, this manuscript represents a significant contribution to modelling science and is within the scope of Geoscientific Model Development. Model description (section 2) is well structured and the model is sorely described. Further than developing a new model for peatlands, this scheme has been designed for global scale simulations using Earth System Model (ESM). Therefore, I am convinced that the new features proposed in JULES-Peat will provide a complementary view on peatland functioning in the literature.

I have some comments that I think will help to ease the reading of the paper and I hope render the study even more appealing. Those modifications do not require to run some more simulations but aim at emphasis results that demonstrate the capability of the model to simulate resilience behaviors of peatland soil and the faster degradation of the peat soil due to a significant decrease in soil humidity.

I hope the authors find my suggestions useful and I am looking forward to read a revised version of the manuscript.

General comments:

- The present land surface model JULES-peat in this manuscript is evaluated for tundra, boreal and temperate regions however there are no evaluation in tropical regions. Therefore, the title should be modified to mention that it is only for peat accumulation in the North hemisphere or also named northern peatlands. This should also be specified in the introduction and in the other parts of the manuscript.

- Section 3 present a series of simulations and the dataset that is employed for model evaluation. Almost all simulations defined in Table 2 are described in this section except for JULES-Peat-W-drain and JULES-Peat-W10-drain. Few sentences about these two simulations are needed to fully discuss Table 2 and the whole set of simulations.

- Section 4 describes and discusses simulation results. While results are very interesting the structure/organization of this section is a little confusing:

- I feel like those sections 4.1 and 4.2, are more like a results part and section 4.3 to 4.5 a discussion part. Therefore, I would recommend to split this section 4 results and discuss in two sections. The first one with the results described in sections 4.1 and 4.2 on the accumulation scheme and soil aging. The second section that will discuss results described in section 4.3, 4.4 and 4.5.

- At first, it has been surprising to me to start the result section of a model on peat (organic rich soil) by a paragraph on the representation of mineral soil. In addition, the following section is titles "JULES-Peat evaluation" which could mislead the reader in thinking that results in section 4.1 are not from JULES-Peat but only from JULES therefore current section 4.2 needs a different title.

- Although, the authors should add a paragraph explaining how the different parts of this new scheme serves in representing vertical profiles of organic and mineral soils and their response to environment changes. For instance, how is the model performed a transition from mineral soil to organic soil or the other way around and which part(s) of the model is involved in this process. This paragraph can be placed either as introduction or as a sub-section of section 4: results and will aim at presenting the different components (refereeing to section 2 and equations) of the scheme. Emphasis needs to be made on the new functionality of the model. For example, line 407 to 412 can be moved to this new part.

- Results could be organized into more sub-sections such as "Evaluation of intrinsic conditions" that will include results on carbon profile, age and bulk density and "Evaluation of environmental conditions" that will include results on JULES-Peat-W and initial conditions.

- In section 4.1, at the place of discussing the validation of each vertical profile, I would rather argue that in the top soil JULES-PEAT version provide more realistic carbon density. However, in soil layers deeper than 0.5m JULES-PEAT largely overestimate carbon content compare to JULES base case. Surprisingly while considering all the soil profile JULES_PEAT generate a carbon profile that fit better the observation. May be a RMSE or R2 will help quantifying the difference between observations and simulations?

- I like stand-alone figures it helps me capture the overall content and structure of a paper therefore additional information need to be added to all figure captions. Figure captions should define all the element of the figure in order for the reader to be able to understand the aim and content of the figure without relying on the main discussion in the manuscript (see details comments for each figure and table).

- It is sometimes difficult in the manuscript to distinguish between JULES the model and the simulation therefore the name of the simulation can me changed. It can be called after the reference number of the JULES version employed or JULES-BaseCase or JULES-ReferenceRun.

- In a few places, the authors are confusing ESM and land surface models. For instance, in line 7, 59 and 520 whereas in line 82 they explained that "JULES includes a vertically-resolved soil carbon scheme (Burke et al., 2017a), although this hasn't yet been used in the Earth System Model configuration." Since this study was conducted on stand-alone version (offline conditions), ESMs line 7, 59 and 520 should be replaced by land surface model.

- Citations "in prep.":

I do think it is not appropriate to have among references papers in preparation e.i. Gao et al., in prep., Smith et al., in prep. In a manuscript in preparation many things can change from the reference authors, title, journal that later on, it gets difficult to figure which paper you were refereeing to. In addition, these references are not part of references listed at the end of the paper. Please remove these citations that appear in table 1, line 535 and line 290.

Detailed comments for figures and tables:

Figure 1: Panel F should be removed from this figure to be in a separate figure since you discuss figure 1F first in line 105 and 125 and later figure 1A-E line 183.

In panel 1F that should be the new figure 1, the legend is not very clear. It is a little confusing to have on one side line color and on the other line types. I recognize that it takes more room but it is also easier to understand having a legend like: green solid line JULES, wilt=0.1; green dashed line JULES, wilt=0.5; blue solid line JULES-peat, wilt=0.1; blue dashed line JULES-peat, wilt=0.1;

Then for the new figure 2 that will show panels A to E, only one legend for all panels can be displayed outside of panels or at the place of former panel F.

In the new figure captions, the vertical dotted lines or the region between dotted lines and the purple crosses 'compiled data' need to be defined. For example, line 265-267 can be placed in the figure caption to define the purple crosses.

Figure 2 and 3: There are some elements of the figure that have not be defined neither in the figure caption nor in the legend. For instance, crosses and diamond markers are not defined as well as in panel entitled "All", the black solid line and the grey area. Also, it will be easier for the reader whether in the figure caption there will be a brief description of the main difference between JULES-Peat and JULES-Peat10 such as at line 347-348 and of JULES-Peat-W and JULES-Peat-W10 such as in line362-363. I would prefer to have the legend outside of any panels so we can see the full vertical profile for Svalbard_Ny site even though it is easy to guess. It would be interesting to display in each panel the RMSD value of each site. These values will provide a quantitative evaluation of the fit for each simulation. It will be easier to refer to specific panels in each figure if each panel is labeled with a letter.

Figure 4, 5 and 6: The grey area is not defined neither in the caption nor in the legend. Here the same, I would rather have a full view of the vertical profile for Tundra sites and have the legend outside of panels. In the panel title boreal and temperate are displayed in capital letter and no tundra, I guess all region name should be displayed in the same manner. If I understand correctly figure 4, for example each red line corresponds to the simulation using JULES at a different site within the considered region then site names should be given in the figure caption. Also, I do not understand why there are no simulation of JULES in the Tundra region? In the figure caption "against **typical** profile for peat cores" typical can be removed resulting in "against profile for peat cores".

Figure 9: In the figure caption, it should be explained why is there different line styles for the four panels on the left than for those on the right?

Figure 10: May be "Demonstration of peat accumulating / not accumulating" could be replaced by "Demonstration of peat accumulation efficiency". The horizontal solid line in all four bottom panels needs to be defined somehow.

Table 4: There is no need for the second column "Colour in Fig.7" since there is a legend in Figure 7 that already defines that.

Detailed comments for the manuscript:

Line 17-21: "peatlands. In particular the best performing configurations had root mean squared error (RMSE) in carbon density for peat sites of 7.7–16.7 kgC m⁻³ depending on climate zone, when compared against typical peat profiles based on 216 sites from a global dataset of peat cores. This error is considerably smaller than the soil carbon itself (around 30–60 kgC m⁻³) and reduced by 35–80% compared with standard JULES. The RMSE at mineral soil sites is also smaller in JULES-Peat than JULES itself (reduced by 30–50%)." This part is not clear when it is read for the first time

Line 23-24: "This provides a new approach for improving the simulation of organic and peatland soils, and associated carbon-cycle feedbacks in ESMs, which other land surface models could follow." I believe that it is wiser to let the reader decide whether or not they want to use the same or a different implementation. I would remove the last part of the sentence "which other land surface models could follow"

Line 90-94: "These changes were made based on well-known principles: Firstly, that microbial activity drops to zero in completely dry conditions (Yan et al., 2018); secondly that respiration in anaerobic conditions is known to be no higher than 20% of the maximum rate in aerobic conditions (Schuur et al., 2015); and finally that when microbes lack nitrogen, they tend to decompose plant litter faster in order to 'mine' for nitrogen (Craine et al., 2007) in contrast to the original scheme introduced by Wiltshire et al. (2021) in which the decomposition of litter is inhibited when nitrogen is in short supply." This sentence is very long and can be split into multiple sentences by removing the semi-column and word "that" after firstly, secondly and finally.

Line 95: "as follows:" can be removed.

Line 165: "See original JULES version on Figure 4, red lines" please add a reference or

"Figure 4 of the present study" if it is what you mean.

Line 202: "if there is a '**corner**' in the function" I believe that it is name a 'discontinuity' in a function rather than a 'corner'.

Line 260: "firstly" can be removed.

Line290-292: "along with Scotty Creek (Helbig et al., 2016, 2017a, b), Pleistocene Park (Euskirchen et al., 2017b), Imnavait (Euskirchen et al., 2017a), and Eight Mile Lake (Celis et al., 2019)." Why did you add these sites for the present study? Are they more recent measurements? Are they complementary of your initial sites? If yes in which way? Do they add some representation of boreal or tundra sites?

Line 293: "Some of the sites, namely Abisko, Seida and Imnavait, **are split into** different landscape types," ; "are split into" can be replaced by "have".

Line 303: "layered soil carbon and nitrogen are **switched on**; a bedrock column is included below the soil to simulate heat conduction. Starting from this baseline simulation, we then **switched on** the new processes in JULES-Peat "; the first "switched on" can be replaced by "considered" and the second one by "activated".

Line 321: ", or in other words more of the plant litter added to the surface layers." can be remove, it is already explained right above line 319.

Line 327: "the fraction of organic matter that is carbon" can be replace by "the fraction carbon in soil organic matter" And "For this calculation we **required**" can be replaced by "selected".

Line 328-330: "the datapoints that were **essentially organic material** with minimal mineral content, **so we removed any datapoints** for which the percent carbon (by mass) was less than 30%, leaving only data where the vast majority of the soil by volume is organic material. This left over 24,500 datapoints. "can be replace by "the datapoints that were **organic rich** with minimal mineral content, for which the percent carbon (by mass) was **higher** than 30%, leaving only data, **over 24,500 datapoints**, where the vast majority of the soil by volume is organic material."

Line 378: "32% and 56% for the configurations that perform best in terms of carbon profile (Table 3)." Could you name the configurations that performed best?

Line 385: "Since peat generally forms in wetter places, the fact that the simulations without lateral water flow out of the soil (-W and -W10) compare best against observations is an indication that the model behaviour is reasonable." Could it be an indication that the hydrology module is not well calibrated or that some processes are missing for peatland soil?

Line 392: "JULES-Peat was **only** able to accumulate peat **from scratch** at one of the tundra sites" can be modified to "JULES-Peat was **sometimes** able to accumulate peat **starting with no carbon in the soil at t=0** at one of the tundra sites"

Line 422: "Liu et al. (2020) tracked the surface subsidence rate over time following drainage in two different ecosystem types – forest and agriculture." Please explain a little more this study my understanding of this sentence was that Liu et al studied the subsidence of forest and agricultural lands and not of peatlands.

Line 427: "the mechanical raising and lowering of the peat surface" Could you provide the order of magnitude of height change during bog breathing process?

Line 447: "It is significant that the UK **are** Ireland sites" I think "are" need to be replaced by "and".

Supplementary information:

In equation 1 and 4: does dz has the same definition than $\hat{\square}\square dz = z - z_{\text{eff}}$ or is it dz_{eff} ?

In section 1: "The $\hat{\square}\square$ first order derivative (second term on **RHS** of Equation 1)" please defined RHS.

For all figures, I would recommend to place the legend outside of any panels for example above or below the figure. For Figure S7 to S10, please add the legend, it is quite annoying when you are looking at figure S10 and that you have to scroll back 3 or 4 pages to check the legend in Figure S5 and S6.