Geosci. Model Dev. Discuss.,
doi:10.5194/gmd-2016-235-AC1, 2016

Geoscientific Model Development Discussions
Open Access
EGU

Interactive comment on "A vertical representation of soil carbon in the JULES land surface scheme with a focus on permafrost regions" *by* Eleanor J. Burke et al.

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Received and published: 14 December 2016

A vertical representation of soil carbon in the JULES (vn4.3_permafrost) land surface scheme with a focus on the permafrost regions.

The title has been changed to the above as requested by the editor.

The authors thank the reviewers for the clear and interesting reviews. Their comments will be addressed in the following manner.

Referee 1

Equation 6 and related text: Indeed the soil moisture used in Equation 6 reduces when

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the soil freezes and hence provides an additional constraint on the temperature sensitivity. As with many other models, JULES has a proportion of unfrozen water even at temperatures below freezing (Cox et al., 1999, Figure 3a). This is dependent on the soil type as is the wilting point, so the minimum soil moisture threshold will vary with location as well as time of year. This paper has only tested a couple of the many available parameterisations of the control of temperature and soil moisture on respiration. It would be very informative to carry out a systematically sensitivity study of these parameterisations in order to get a more definitive suggestion as to which are most suitable. This will be the subject of further work. I have changed the order of Equations 6 to 8 and added information on the freeze inhibition as a function of temperature and the additional constraint on the temperature sensitivity by the moisture function.

Intro to section 2.3: The prognostic soil carbon does not feedback onto the organic soil characteristics. This is in the queue of further developments. This lack of feedback has been made clearer on line 20 of page 8.

Figure 3 and associated text: We agree, the NPP of the northern high latitudes is not clear in this figure. The colour bar has been changed to clarify this.

Figure 5: We have added the NCSCD data as a new subplot to Figure 4. (It wasn't there because in an earlier draft we showed the soil carbon scaled by the global mean and couldn't do an equivalent thing with the NCSCD). The caption has been expanded to clarify the Figure and the discussion at the top of page 10 expanded. Page 13, line 1: Yes the partitioning of the soil carbon between pools was done by interpolating the observations to the model depths and partitioning per soil level. This is clarified in the revised document.

Figure 11: In the permafrost the deep soil carbon has a very slow turnover times. This is slow enough for it to be assumed to be inert on timescale of 100-1000 years. Therefore in an equilibrium simulation there is little exchange of soil carbon between the deep soil and the shallower soil. However, the climate and CO2 changes during a 20th

century transient run mean that there is some transfer between the deep and shallow soil carbon as is described here. This is a simple representation of ‘old’ permafrost carbon which is traced when permafrost thaws in a changing climate and is used in Burke et al., (2017. to be submitted to Bogeosciences) to identify the soil carbon related to the permafrost feedback. There is also great potential for a model tracer such as the one discussed here to be used for model evaluation using radioisotopes (He, Y., Trumbore, S.E., Torn, M.S., Harden, J.W., Vaughn, L.J., Allison, S.D. and Randerson, J.T., 2016. Radiocarbon constraints imply reduced carbon uptake by soils during the 21st century. Science, 353(6306), pp.1419-1424.). The discussion and caption around Figure 11 have been modified to clarify the fact that the time series of deep soil carbon shown only includes the original deep carbon, not the increase in the soil carbon at depth, analogous to the loss of permafrost carbon.

Initialising soil carbon: A discussion of the issue of benchmarking models given that they have already used the observed data set for initialisation is added to the text. This paper mainly evaluates the model using the observed soil carbon. However, we feel that there is a better method of constraining models based on metrics such as turnover times. This is the subject of on going work.

Referee 2

The description of the vertical transfers in the soil carbon model is expanded and clarified. In particular equations for the soil carbon mixing are added and the depth dependence for each function in Equation 14 more clearly defined. FT and Fs are dependent on the soil temperature and moisture profile calculated within JULES.

The transport of the respired carbon through the system is not yet included in this model version. Once respired the carbon is assumed to be instantly transferred to the atmosphere. Given that the soil carbon is assumed to be emitted as CO_2 rather than CH_4, its form is unlikely to change in the soil column, so the amount will be roughly correct. However, there will be some delay from time of decomposition to time of emission from the soil surface. This delay will increase with increasing depth. In addition some gas may be temporarily or more permanently held within the soil structure. We are uncertain as to how much impact adding this process will have on the model results and this is another development in the pipeline for the future. This will become more important when the respired carbon is differentiated between CO2 and CH4. CH4 is readily oxidised as it is transported through the soil profile. This is another required model development.

Any old carbon respired will also be instantly released to the atmosphere. The old soil carbon moves throughout the profile in a similar way to the rest of the soil carbon i.e. via mixing. This is clarified in the document.

P1, L11: more details added on the missing processes such as peat accumulation.

P4, Eq 7 & 8: order flipped

P4, L25: Only a limited evaluation of the different functions limiting respiration is discussed here. As discussed in "Equation 6 and related text" above the soil moisture function also includes some indirect temperature sensitivity. Although beyond the scope of this current paper, a fuller analysis using a large model ensemble with a range of FT and Fs would enable a range of simulated soil carbon distributions to be assessed more carefully. I think one of the conclusions which should be added to this paper (see also "Initialising soil carbon") is that alternative methods of constraining the present day soil carbon distribution need to be developed in order to more rigorously assess model output.

P5, Eq 12, 13: Beta_R has no depth dependence. Rtot has depth dependence because it is the sum of the respiration from all of the pools, i.e. the sum of the Ri in Equation 14. There is no explicit treatment of transfer of the respired carbon to the atmosphere – this is discussed above in more detail.

P5, L26: diffusion rate is changed to diffusion coefficient.

P6, L20: The ‘old’ carbon transfers through the profile in the same manner as the rest of the soil carbon. The respired ‘old’ carbon is instantly transferred tot he atmosphere.

P7, L5: PFT – Plant Functional Type – is defined.

P7, L10: This sentence is reworded to “Two different model simulations were carried out using two alternative parameterisations of soil respiration.”

P7, L23: These are the same factors the diffusion coefficients and rate constant were scaled by. This is added to the text.

P9, L15: too high NPP means too much input of organic carbon to the soil resulting in a high soil carbon.

P9, L25: The equilibrium state of soil carbon depends on a balance between the inputs and the decomposition rate. The model take a long time to reach this equilibrium because the decomposition rates and the diffusion rates of the 4th pool are very slow (hence the need to accelerate the soil carbon spinup), but a significant amount of soil carbon is built up in the deeper soils. A sentence elaborating the difference between spin up and 20th century climate is added.

P9, L30: JULES generates its soil carbon stocks by running for many years until the soil carbon is in steady state. The input (NPP) is balanced by the output (respiration). The observations contain this equilibrium soil carbon plus further non-equilibrium soil carbon such as is in peatland and waterlogged soils. JULES is not expected to be able tor represent this non-equilibrium soil carbon (Hugelius et al., in preparation). The last sentence on page 9 has been updated to more carefully reflect this discussion.

P11, L5: As discussed above, we have not yet included the transport of respired carbon to the atmosphere but plan on including this and exploring its impact in the future.

P12, L5: There is an interesting interrelationship between tau_resp and FT and how they relate to the modelled soil carbon. This is discussed in more detail in this section and in the discussion of Figure 5. tau_resp exerts strong control over the amount of

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soil carbon in the profile. It does not impact the difference between the tropics and the northern high latitudes. In contrast FT affects the relative amounts of soil carbon in the cold and the warm regions.

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