

Interactive comment on “An improved land biosphere module for use in reduced complexity Earth System Models with application to the last glacial termination” by Roland Eichinger et al.

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Received and published: 24 January 2017

Comment on “An improved land biosphere module for use in reduced complexity Earth System Model with application to the last glacial termination”

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The study presents developments of the DCESS earth system model, for vegetation zones and for a permafrost carbon pool. They present some validation for the vegetation zones, and then go on to perform and discuss the simulation of the last glacial termination. I focus on the permafrost module here.

The amount of carbon stored in the area defined as permafrost in the model is

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30kg/m², an approximation from present-day near surface soil organic carbon data in Schuur et al 2015. The approach to define where is the permafrost, is to use the latitude L_{snow} (or L_{ice}, whichever is lower) at the 0degC global temperature (page 9 line 6: is this a typo? Do you mean L_{snow} is at the 0degC latitude? Perhaps this needs to be re-written).

Whilst this would indeed create a dynamic pool of carbon sensitive to changes in the area of L_{snow}/ice, I am not convinced that this is a good representation of permafrost-carbon. If the concentration in this pool is fixed at 30kg/m², then it cannot be properly taking account of the long time-to-equilibrium that would be seen in a permafrost-like carbon pool. Low accumulation and low decay rates means that the rate of change of area becomes important for soil carbon content. This is true for both release from “thawed” (i.e. no longer in L_{ice}/snow) or newly permafrost (i.e. new L_{ice}/snow) areas. They assume that this 30kg/m² is instantaneous for new areas, and is instantly released in thawed areas (is this the case in the model?). As such it is entirely dependent on the parametrisation of L_{snow} (and not soil carbon dynamics or decay rates).

The mean value of 30kg/m² also does not take account of the true spatial heterogeneity of carbon content in permafrost soils. For example, some areas which underlay peatlands contain on the order of 100kg/m²+ organic carbon contents, and others far less than 30kg/m². The spatial location of higher or lower-than-mean carbon content soils would make a big difference to carbon release rates. However, this is not possible to treat in this model (due to how it is set up) but should be mentioned.

I understand that this is a reduced complexity model, but it is important to incorporate accumulation and decay rates into a permafrost carbon pool model. This is especially true if the aim is to consider changing climates. At least this needs to be discussed in the text. See Zimov et al 2009 for example of the dynamic response of a permafrost-carbon model soil.

The authors say they tuned their model to a last glacial climate state, but this doesn't

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appear to include the amount of carbon on land. Although the total change of -408GtC from LGM to PI is in alignment with recent estimates, the starting point at LGM from 1800GtC (fig 1) is far lower than Ciais et al 2012 estimate (at 3640+-400GtC). The authors do state p18 line10 that their permafrost pool is underestimated (compared to Ciais et al 2012), but they need to quantify this. It makes a big difference to the LGM simulation discussion. For example, with a far larger LGM permafrost carbon pool it is unlikely that regrowth of the terrestrial biosphere would compensate permafrost thawing for land carbon flux. It would also pull their LGM-PI land carbon change out. This needs to be discussed.

The authors have put a lot of effort into improving the land biosphere module for vegetation zones, but the permafrost pool representation is less well developed and not well explored, and is not validated. They need to consider whether representing permafrost carbon dynamics in this way, assuming an instant equilibrium with climate of soil carbon, is appropriate (I think it's not). And if not, then to instead develop a separate permafrost model for use with DCESS.

Zimov, N. S., et al. "Carbon storage in permafrost and soils of the mammoth tundra-steppe biome: Role in the global carbon budget." *Geophysical Research Letters* 36.2 (2009).

Interactive comment on Geosci. Model Dev. Discuss., doi:10.5194/gmd-2016-306, 2017.