Geosci. Model Dev. Discuss., 7, C2104–C2108, 2014
www.geosci-model-dev-discuss.net/7/C2104/2014/

Geoscientific Model Development Discussions
Open Access

GMDD
7, C2104–C2108, 2014

Interactive Comment

Interactive comment on "A simplified permafrost-carbon model for long-term climate studies with the CLIMBER-2 coupled earth system model" *by* K. A. Crichton et al.

K. A. Crichton et al.

kcrichton@lgge.obs.ujf-grenoble.fr

Received and published: 24 October 2014

> Processes

The complex processes associated with permafrost and related soil carbon cannot be individually accounted for on the very large grid cell size of CLIMBER-2. When modelling these processes at high resolution, the local conditions become very important and create heterogeneity in model output across grid cells. However, by using a mean value to represent these processes on a very large grid size much of the heterogeneity "disappears".

The main assumption for our treatment is that the driver of high soil carbon in permafrost soils is a reduced soil decomposition. A further assumption is that there is proportionality between climate, permafrost extent and active layer thickness at this grid cell size. I will make this clearer in the revised version.

For other processes, such as: talik formation, ice content, carbon export via water runoff etc. we do not individually take account of these. We assume that these processes are present in all climates (i.e glacial and interglacial). They are represented (although not all) in the rate of soil decomposition/accumulation. These are accounted for in the permafrost-carbon dynamics setting, which can be "selected" in transient simulations using model-data comparison.

The transient behaviour of permafrost soil carbon is very important for our model. The main difference in soil carbon dynamics spatially is the partition of this carbon between "fast" or "slow" soil C pools. For example, in Siberia locations much of the soil carbon is in the slow pool. In Canada, more of it (proportionally) is in the fast pool. This is due to the fact that soils in Canada have had a much shorter time to accumulate carbon since glacial termination 1.

Overall, given that this is the first attempt at implementing a permafrost carbon-mechanism in a coupled earth system model, keeping it simple was imperative.

> Tunable parameters

There are a total of four tunable parameters in the permafrost-carbon mechanism, the values for "a" and "b" in the tau_perm equation (eqn 3) (applied each to the fast and slow carbon pools). In order to find the permafrost extent, I did tune the sigmoid function that relates frost-index to permafrost area. Whilst finding the values of "a" and "b" it was clear that total permafrost area is important in determining total land carbon stocks. Only one of the permafrost extent models was suitable and then was fixed (so, now permafrost extent is no longer tunable, but seen as an input for the carbon cycle part of the model).

> Subgrid vs re-mixed

The reviewer is correct that the subgrid represents the separation of permafrost and non-permafrost soil carbon in a grid cell, and the re-mixing model mixes them. The re-mixing model was implemented because it is far simpler, and lighter for processing. As well as this, the fluxes between land and atmosphere are calculated for a full grid cell, so even with a subgrid approach the separation of permafrost and non-permafrost soils would "disappear." The sub-grid approach described does not include any downscaling of the atmospheric model input, so each subgrid "sees" the same temperature, rainfall etc etc. I wanted to create a mechanism that did not significantly increase model run-speed, nor required large scale changes in the model, or was too complicated.

Conceptually for the re-mixing model: a part of carbon accumulated in the permafrost soil is treated as standard soil (i.e. Unfrozen). This is somewhat similar to what occurs in the active layer in the summer months. Overall, I will improve the description of these two methods, with a focus on how the re-mixing model actually works. This will also include the evidence for the relationship between climate and permafrost related processes at this grid size.

> Grid scales

The grid cell size is important for our model, and using the exact same treatment for other grid scales/resolutions is not appropriate. All the relationships are for the CLIMBER-2 grid scale. Our model shows indeed that the relationship between frost-index and permafrost fraction is non-linear (sigmoid) – so this would need to be re-tuned for other grid scales. Also, the relationship between permafrost-fraction in a grid cell and soil carbon content is non-linear, so values for "a" and "b" would also need to be re-tuned. Our treatment of permafrost-carbon for CLIMBER is not intended to be used with GCMs at all. We developed the model for CLIMBER-2 and its GDVM (based on Vecode), it is not intended to be used for other models. I will make this clearer in the discussion section.

GMDD

7, C2104–C2108, 2014

Again, this is intended to be a “simple” treatment of permafrost of the same complexity as other components in CLIMBER-2. In the end, we have a spatially distributed permafrost soil carbon pool covering around 11 points - 11 grid cells (for the pre-industrial climate). The heterogeneity of permafrost processes at the small scale add up to a mean relationship at the very large scale which we consider to be approriately treated in our simplified representation. I will try to emphasise this and provide clear evidence in the revised version.

> Questions, answers

CLIMBER timestep for the land biosphere model is 1 year, for the atmospheric model it is 1 day. This is why using frost index is particularly suitable as it accounts for changes in seasonality (orbit around the sun), and can be easily calculated using the atmospheric model. Given the one year timestep for the land biosphere model, heat-diffusion approach is very inappropriate.

Term "b" in equation 3 is a constant (like "a"). "a" is also multiplied by Frost index. "b" is just a constant that is not multiplied by frost index. Equation 3 is applied to the permafrost fraction of the soil carbon in a grid cell. So, for a very cold soil (100% permafrost, high frost index) the soil decomposition rate is very small. For a medium cold soil (for example 20% permafrost, lower frost index) the decomposition rate for the permafrost fraction is slightly larger. Equation 3 is only applied to the permafrost fraction of a grid cell, the non-permafrost fraction is treated with equation 2. The concept for our model is that soil decay is lower in permafrost soils. So we have a multiplier for tau. This multiplier is eqn 3. The multiplier is also dependent (slightly) on frost index. This means that in 100% permafrost soils, there is an extra amplifier as conditions get more severe (i.e. higher frost index).

The slow C pool is one thing. The "slow" permafrost-carbon dynamic setting is another. I will make this clearer in the revised version by identifying when I mean soil pool and when I mean dynamic setting.

GMDD
7, C2104–C2108, 2014

Thank you for your review.

Interactive comment on Geosci. Model Dev. Discuss., 7, 4931, 2014.

GMDD

7, C2104–C2108, 2014