Project: **903**

Project title: **Kohlenstoff im Permafrost: Bildung, Umwandlung und Freisetzung CarboPerm**

Project lead: **Victor Brovkin**

Report period: **1.1.2014 - 31.12.2015**

In 2014 and 2015, computing time on blizzard and mistral was used to perform a number of model experiments to support the development of model representations of a number of carbon cycle processes relevant in permafrost areas.

The processes include:

- A module for the determination of inundated area (wetland area) employing sub-gridscale topographic information
- Modifications to the soil organic matter decomposition routines to represent decomposition under anaerobic conditions and methane generation
- Methane transport through the soil
- A representation of soil carbon that is protected from decomposition due to frozen soil conditions
- Carbon accumulation in peatlands

The implementation of these processes is finished, though a final calibration is still required in some instances.

Wetland processes

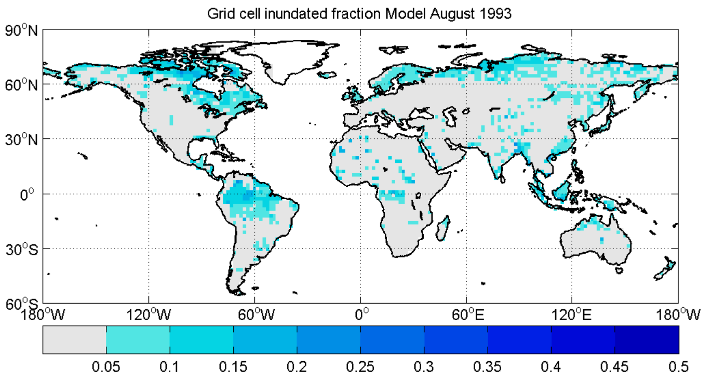

Figure 1: Grid cell fraction inundated for Aug. 1993

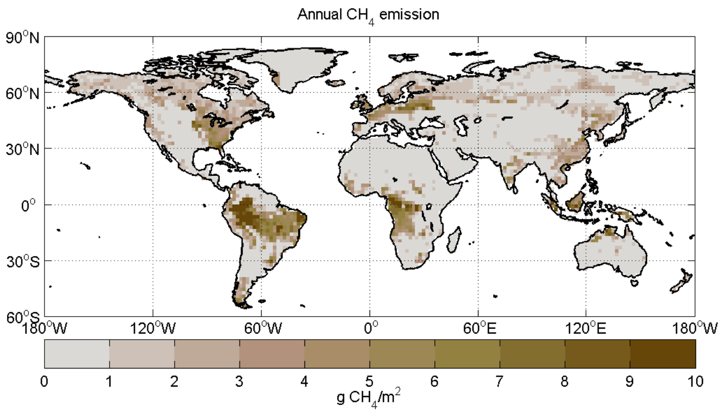

Figure 2: Annual CH_4 emissions for 1993

As an example of the determined inundated area, we show the grid cell fraction inundated for August 1993 in Fig. 1. The modelled inundation fraction is similar to remote sensing data in most areas, with the exception of the Amazon, where the model overestimates inundation extent, and the Sahara, where a numerical issue remains to be solved.

In inundated areas, methane is generated and transported through the soil. The annual emissions for 1993 are shown in Fig. 2. Total emissions are within the range of uncertainty, though the emission pattern still needs some further calibration.

Permafrost carbon storage

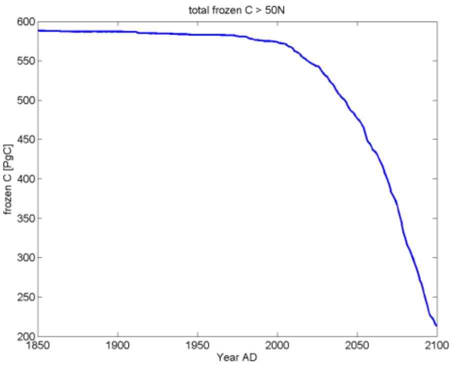

Figure 3: Total carbon stored in permanently frozen soil layers

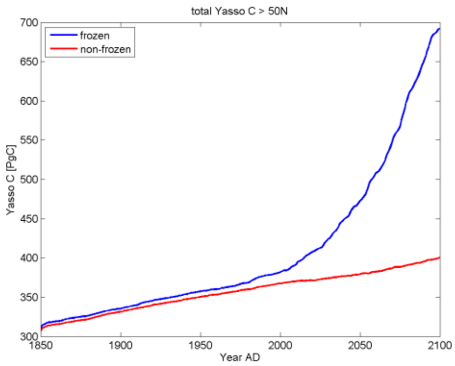

Figure 4: Total available to biospheric processes north of

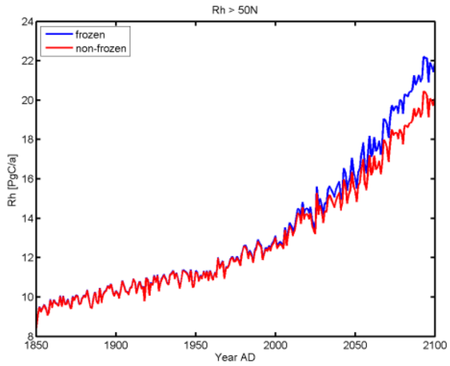

Figure 5: Total heterotrophic respiration north of 50°N

Until recently, land surface models did not represent frozen ground properly, and carbon cycle processes did not take the freezing state of the soil into account. We have developed a stratified soil carbon representation that represents the vertical distribution of soil organic matter in the soil and therefore allows the consideration of soil C storage in frozen soil layers.

This representation is based on prescribed carbon storages for the permafrost C pools. Figures 3-5 show results of two model experiments considering the historical period the time to 2100 using the RCP8.5 climate scenario. The model experiment shown in red does not contain the frozen carbon representation, while the experiment in blue does. Fig. 3 shows the total carbon stored in frozen soil layers north of 50°N, Fig. 4 shows the total soil carbon available to biospheric decomposition processes, and Fig. 5 shows the heterotrophic respiration, i.e., the carbon flux to the atmosphere from soil organic matter decomposition.

These results indicate the permafrost areas release additional carbon to the atmosphere, if the frozen carbon storage is considered. This does not play a role in the historical period and until 2050, but after 2050 this flux becomes significant and reaches 2 PgC/yr in the late 21st century.

Project publications

Not all results have been published yet, some results still require some final model experiments in 2016.

G.A. Alexandrov, V.A. Brovkin, T. Kleinen (submitted). Why there were no peatlands in Western Siberia during the Last Glacial Maximum?

Brovkin, V., Bruecher, T., Kleinen, T., Zaehle, S., Joos, F., Roth, R., Spahni, R., Schmitt, J., Fischer, H., Leuenberger, M., Stone, E. J., Ridgwell, A., Chappellaz, J., Kehrwald, N., Barbante, C., Blunier, T., & Dahl Jensen, D. (submitted). Comparative carbon cycle dynamics of past and present interglacials.

Cresto-Aleina, F., Runkle, B., Kleinen, T., Kutzbach, L., Schneider, J., & Brovkin, V. (2015). Modeling micro-topographic controls on boreal peatland hydrology and methane fluxes. Biogeosciences, 12, 5689-5704. doi:10.5194/bg-12-5689-2015

Bohn, T. J., Melton, J. R., Ito, A., Kleinen, T., Spahni, R., Stocker, B., Zhang, B., Zhu, X., Schroeder, R., Glagolev, M. V., Maksyutov, S., Brovkin, V., Chen, G., Denisov, S. N., Eliseev, A. V., Gallego-Sala, A., McDonald, K. C., Rawlins, M., Riley, W. J., Subin, Z. M., Tian, H., Zhuang, Q., & Kaplan, J. O. (2015). WETCHIMP-WSL: intercomparison of wetland methane emissions models over West Siberia. Biogeosciences, 12, 3321-3349. doi:10.5194/bg-12-3321-2015 [Fulltext] [Fulltext]

Kleinen, T., Brovkin, V., & Munhoven, G. (2015). Carbon cycle dynamics during recent interglacials. Climate of the Past Discussions, 11: Open Review, pp. 1945-1983. doi:10.5194/cpd-11-1945-2015