Project: **903**

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

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Report period: **2016-01-01 to 2016-12-31**

In 2016, work in CarboPerm focused on production experiments to evaluate the carbon storage in permafrost areas under climate change and the further development of the land surface model JSBACH to build up carbon stores in permafrost.

## Permafrost carbon buildup

Since carbon in permafrost does not decompose unless warmed, the permafrost carbon stocks represent a very long-term storage in the earth system. Present day carbon stocks date mostly to the deglaciation after the last glacial maximum, though substantially older stocks can be found in areas that were not glaciated.

Modelling these carbon stores therefore requires spinup experiments at least from the LGM. We therefore developed a module for the buildup of carbon in permafrost areas and used the EMIC CLIMBER2 to provide climate anomalies for spinup experiments from LGM to the present. Model development and spinups are nearly finished, though no results are available yet.

## Permafrost carbon release under future climate

By prescribing permafrost carbon stocks, we were able to evaluate the carbon release from permafrost areas under future climate conditions. In comparison to the results in last year's report, we were able to refine the model estimate by considering different depth horizons of carbon storage and by including a $CH_4$ emission model that allows the determination of methane emissions from thawed permafrost carbon stocks.

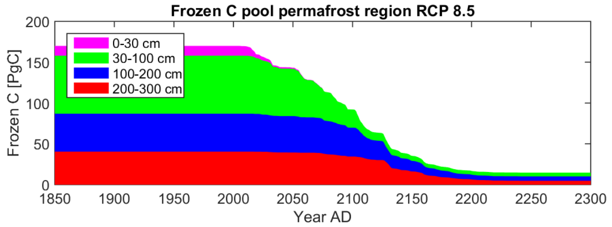


**Figure 1: frozen carbon stocks in permafrost**

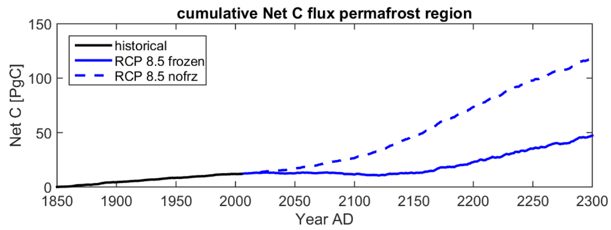


**Figure 2: cumulative net carbon flux to permafrost region**

Figure 1 shows the development of frozen carbon stocks in a model experiment covering the historical period 1850-2005 and the future following an rcp 8.5 climate forcing scenario. C stocks begin decreasing significantly after 2020, by 2100 most of the permafrost carbon to a depth of 1m will be degraded, and the deeper permafrost carbon degrades over the course of the 22nd century. Figure 2 shows how this affects the net carbon flux: If permafrost carbon is not considered (dashed line), the present-day permafrost region is a strong sink for carbon, increasing substantially into the future, while the region will turn into a temporary source of carbon during the late 21st century, if permafrost C stocks are considered.

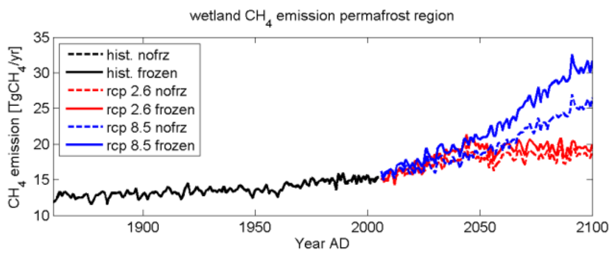


**Figure 3: Wetland $CH_4$ emissions, permafrost region**

With regard to $CH_4$ emissions, the effect of the frozen C stocks is even larger. $CH_4$ emissions from the permafrost region are shown in Fig. 3. These become substantially larger if permafrost C stocks are considered (solid line) than if they are not represented (dashed line).

### Effects of permafrost on climate

An unforeseen result of our experiments was that the inclusion of permafrost in MPI-ESM led to a strong modification of surface climate.

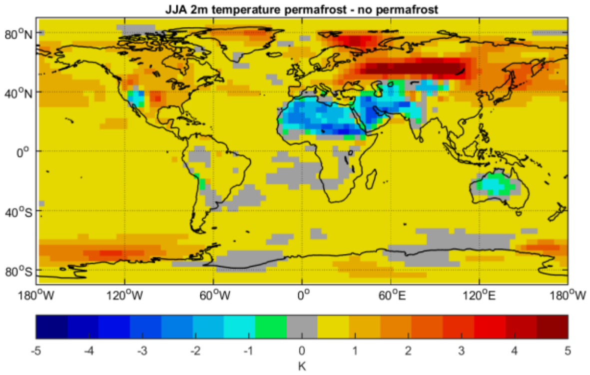


**Figure 4: JJA surface air temperature difference between permafrost and no permafrost**

Fig. 4 shows the difference in summer surface air temperature between an experiment with permafrost and an experiment without permafrost. Shown is the near-equilibrium state reached in a coupled model experiment after 1000 years. Clearly, the inclusion of permafrost leads to a strong warming. This warming is initially confined to northern Canada and Siberia, but affects global climate over a centennial time scale through the warming of Arctic Ocean waters. The warming is due to a reduction in evapotranspiration (and thus evaporative cooling) because water cannot infiltrate into the frozen ground during snowmelt. This strong climatic bias prevented us from performing the coupled carbon cycle experiments originally planned for 2016. Removing this bias will require a re-calibration of the atmosphere model, requested for 2017.

### Project publications

Saunois, M., ..., ., Kleinen, T. & et al, . (submitted). The global Methane budget: 2000-2012.

Kaiser, S., Beer, C., Göckede, M., Castro-Morales, K., Knoblauch, C., Ekici, A., Kleinen, T., Zubrzycki, S., Sachs, T. & Wille, C. (submitted). Process-based modelling of the methane balance in periglacial landscapes with JSBACH.

Alexandrov, G., Brovkin, V. & Kleinen, T. (2016). The influence of climate on peatland extent in Western Siberia since the Last Glacial Maximum. Scientific Reports, 6 , doi:10.1038/srep24764

Brovkin, V., Brücher, T., Kleinen, T., Zaehle, S., Joos, F., Roth, R., Spahni, R., Schmitt, J., Fischer, H., Leuenberger, M., Stone, E., Ridgwell, A., Chappellaz, J., Kehrwald, N., Barbante, C., Blunier, T. & Dahl Jensen, D. (2016). Comparative carbon cycle dynamics of the present and last interglacial. Quaternary Science Reviews, 137, 15-32 , doi:10.1016/j.quascirev.2016.01.028

Cresto-Aleina, F., Runkle, B., Brücher, T., Kleinen, T. & Brovkin, V. (2016). Upscaling methane emission hotspots in boreal peatlands. Geoscientific Model Development, 9, 915-926 , doi:10.5194/gmd-9-915-2016