Project: **903**

Project title (Jan. - Mai): **Kohlenstoff im Permafrost: Bildung, Umwandlung und Freisetzung – KoPf**

Project title (Jun. – Dec.):: **Kohlenstoff im Permafrost – Synthese**

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Report period: **2020-01-01 to 2020-12-31**

Model development

Historical / RCP85

In order to use the JSBACH version developed in the KoPf-project also for coupled simulations, the code was adapted to allow running the permafrost-specific physic-package only in a prescribed region (e.g. north of 60°N). With this model, a set of coupled simulations (land-atmosphere) was performed and it could be confirmed that with this model version the large-scale climate is similar to the climate simulated with the standard model, both in historical and in scenario simulations. Figure 1 shows the surface temperature difference between the historical simulations of the MPI-ESM with the updated permafrost scheme and the operational MPI-ESM 1.2 (CMIP6 version). It shows that the surface temperature bias for our focus region, i.e. the high northern latitudes, is reduced to around +/- ~1K, while it is negligible for the rest of the globe. Therefore, it is justified to use this approach to study the permafrost dynamics of high northern latitudes also using the fully coupled model.

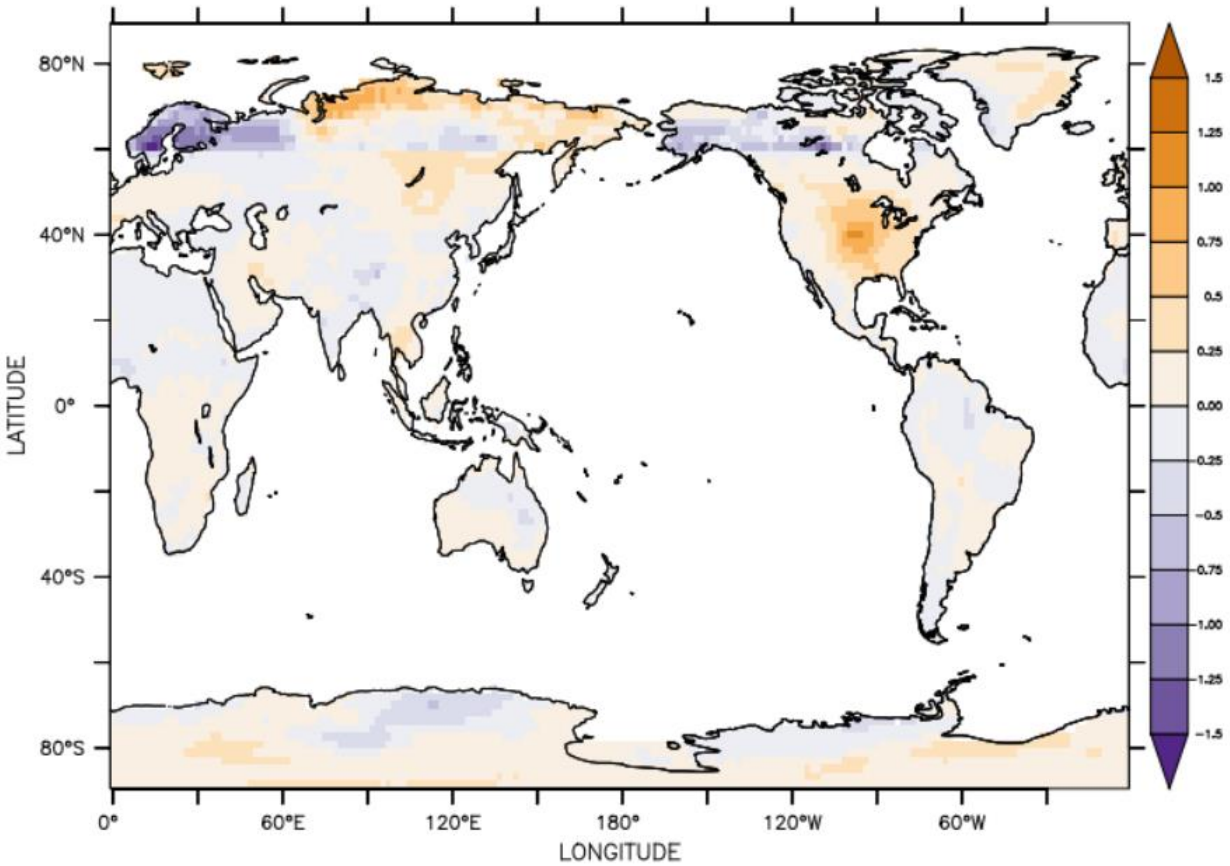

Fig. 1: Difference in surface temperatures for the 30-year mean (1974-2013) between the simulations with MPI-ESM-PF (with permafrost scheme) and MPI-ESM 1.2 (reference).

Simulations

1 Multistability

With idealized JSBACH (standalone) simulations, it could be shown that under nontransient atmospheric conditions (here corresponding to the Paris Agreement's long term goal of maintaining global mean temperatures at 1.5°C above pre-industrial levels PAT1.5.) parts of the high northern latitudes could be multistable, with the ensuing steady state depending on the initial soil organic matter concentrations (Fig. 2). Organic matter reduces the soil heat conductivity, lowering the soil temperatures, (liquid) water-availability and consequently decomposition rates deeper within the soil. As a result, the differences in soil organic matter, temperature and soil moisture could be sustained indefinitely. Finally, as a temperature overshoot (OS) of the PAT1.5, reduces the soil organic matter in the high latitudes, such an OS could have irreversible consequences for the state of the high northern latitudes.

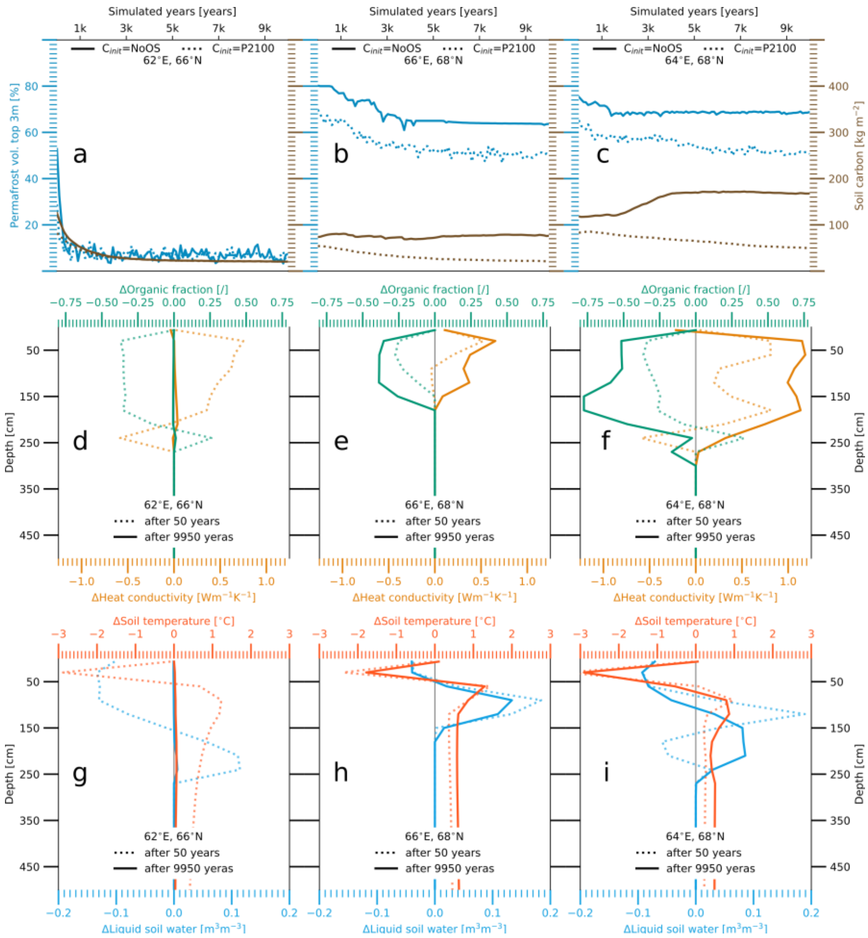

Figure 2: a) Dependency of steady-state conditions on the initial soil carbon concentrations. a) Simulated near-surface permafrost volume (blue lines, left y-axis) and soil carbon densities (brown lines, righty-axis) in a grid cell at 62◦E; 66◦N. Solid lines refer to a simulation which was initialized with soil carbon pools before an idealized temperature OS (NoOS), whereas dotted lines show a simulation that started from the pools after an OS that peaked in the year 2100 (P2100). Both simulations were initialized with the same soil temperature profile, soil water content and vegetation cover and were similarly forced with prescribed atmospheric conditions corresponding to the PAT1.5. All lines show 100-year averages. b) Same as abut for a grid cell at 66◦E; 68◦N.c)Same as abut for a grid cell at 64◦E; 68◦N. d) Difference in soil organic matter (green lines, top x-axis) and heat conductivity (yellow lines, bottom x-axis) between the two simulations (P2100-NoOS), at the beginning (dotted lines) and at the end (solid lines) of the10000-year period for a grid cell at 62◦E; 66◦N.e)Same as d but for a grid cell at 66◦E; 68◦N. f) Same as d but fora grid cell at 64◦E; 68◦N. g,h,i) Same as d,e,f but for the annual maximum of the monthly mean soil temperature(red lines, top x-axis) and liquid water content (blue lines, bottom x-axis)

2 Climate impact on abrupt thawing

Impact of climate patterns on deepening of active layer have been explored utilizing findings on basis of ERA-Interim atmospheric reanalysis and CALM database (Brown, 1998). Air temperature has been recognized as a major driver of active layer deepening, while changes in hydrological cycle (precipitation and snow cover) can modify impact of warming. In particular annual mean warming higher than previous 5-year running mean warming have been identified as the major driver of abrupt soil thawing events in high northern latitudes. Figure 5 shows similar analysis for historical run with MPI-ESM. It demonstrates qualitatively similar features as ERA-Interim analysis. That is increased warming after year 2000 and higher intensity of abrupt warming events. During the next phase of the project our objective is to evaluate model skill to reproduce interplay between climate and active layer thickness.

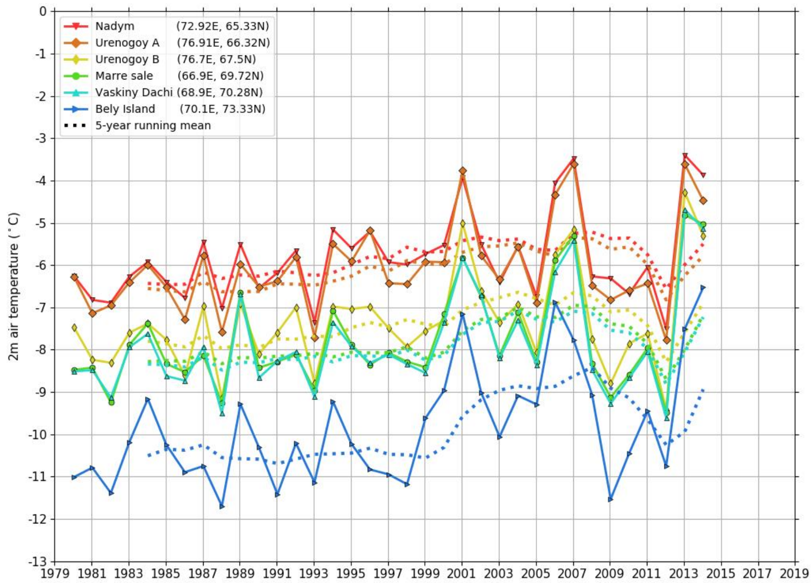

Figure 3: MPI-ESM simulated 2m air temperature showing abrupt warming events for several grids corresponding to geolocation of active layer monitoring sites in Western Siberia (Brown, 1998).

References:

Brown, J. 1998. Circumpolar Active-Layer Monitoring (CALM) Program: Description and data. In Circumpolar active-layer permafrost system, version 2.0. (ed.) M. Parsons and T. Zhang, (comp.) International Permafrost Association Standing Committee on Data Information and Communication. Boulder, CO: National Snow and Ice Data Center.