Project: **1117**

Project title: **Study Of the Development of Extreme Events over Permafrost areas - SODEEP**

Principal investigator: **Stefan Hagemann**

Report period: **2019-07-01 to 2020-06-30**

Model Development and sensitivity simulations

In the frame of the SODEEP project, we utilized MPI-ESM with its land component JSBACH, and the regional Earth System model ROM with its atmospheric component REMO. Several modifications and improvements were needed in particular related to soil hydrology and thermodynamics of both JSBACH and REMO.

JSBACH

Various sensitivity tests were conducted to develop a new vertical structure in the discretization of the soil column in JSBACH. On the one hand, this was done to improve the vertical dynamics of moisture and energy transport. On the other hand this should enable a better representation of soil carbon processes in regions that are underlain by permafrost. Figure 1 demonstrates the importance of vertical discretization in particular for the presentation of processes related to permafrost degradation. Top panel of the Figure 1 shows a grid box at 77°E and 66°N for which the deepening of the active layer thickness after year 2003 depends on the vertical discretization. In the contrary, the grid box at 82°E and 70°N (Fig. 1, bottom panel) indicates only a weak sensitivity of the active layer thickness to the vertical discretization. Therefore, these results suggest that resolving top vertical layers down to 3m with 15-30 cm layer thickness might be crucial for studies focusing on active layer depth in high northern latitudes.

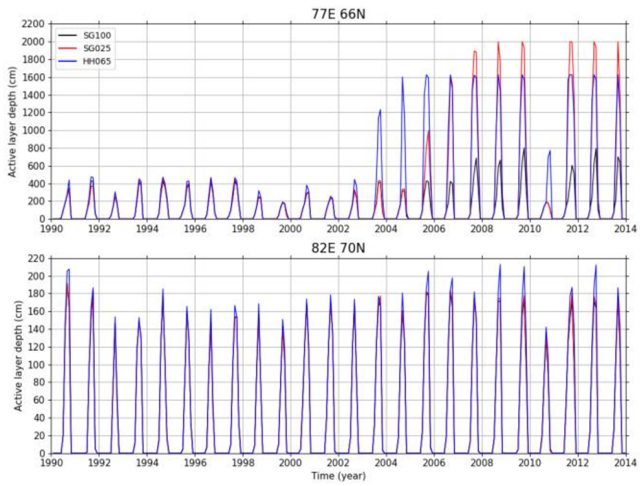

Figure 1: Active layer depth for 3 JSBACH experiments with different vertical discretization.

REMO

In this phase of the project, settings for regional downscaling simulations over the Arctic domain with 5-layer hydrology have been developed. Figure 2 shows annual 2m temperature differences between test simulations with 5-layer and bucket hydrology, which were driven by ERA-interim boundary conditions for the period 1981-1990, at 1° resolution. The 5-layer scheme leads to an improved representation of soil hydrology and land atmosphere processes. The comparison to the bucket simulation reveals similar features as described in the global study of Hagemann and Stacke (2015) with MPI-ESM. In both cases, the improved hydrology led to a warming over North America and northern Eurasia and a cooling over southern Europe and central Eurasia. The implementation of the permafrost scheme by Blome (2014) is ongoing work.

Conducted and further simulations

Apart from developing a coherent framework for the identification of extreme climate conditions relevant for permafrost degradation, another major task in our project comprises the further improvement of permafrost related processes in numerical models. In the project, we consider the

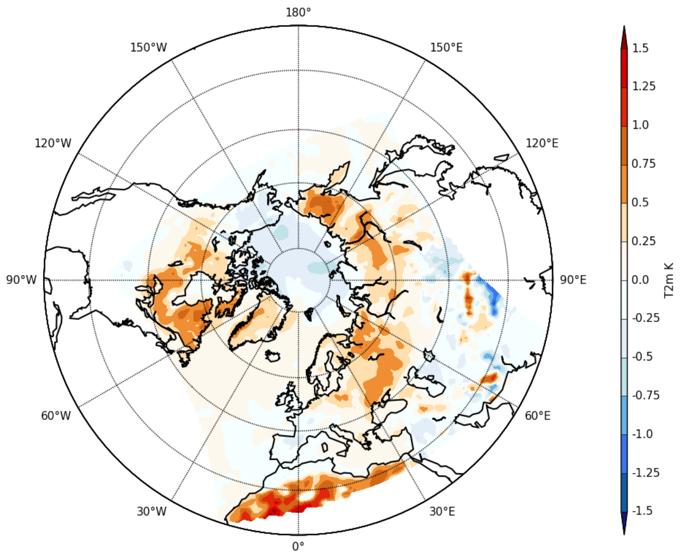

Figure 2: Difference of annual mean 2m temperature between REMO simulations with 5-layer and bucket hydrology for the 10 years period of 1981-1990.

whole hierarchy of numerical models from the process-study model GIPL (Geophysical Institute Permafrost Laboratory), via the regional Earth System Model (ESM) ROM and its atmosphere/land component REMO, to the global MPI-ESM and in particular its land component JSBACH. In the project, apart from updating soil processes related to permafrost dynamics, our objectives related to numerical modelling are twofold. Firstly, we aim to compare numerical models and evaluate their skills to simulate permafrost related processes for present day climate i.e. driven by ERA-Interim reanalysis. For that purpose ERA-Interim as well as WFDEI (WATCH forcing data based on bias corrected ERA-Interim data) forcing driven simulations have been conducted with JSBACH (with improved soil freezing and thawing processes, as well as improved vertical discretization) and REMO (with 5-layer soil hydrology implemented). To complete this study, an ERA-Interim driven REMO simulation with improved soil freezing and thawing processes is needed. Our second aim related to modelling comprises of comparative analysis of past, present and future extreme events relevant for permafrost degradation. Therefore, historical and future scenario simulations with MPI-ESM are needed. Originally, these simulations were planned with MPI-ESM2, however no official release was available by the time needed to complete tasks proposed in our project. Therefore, we decided to conduct our simulations with MPI-ESM 1.2. Unfortunately, this version of the model is known for its considerable warm bias in combination with the permafrost-ready version of JSBACH. This bias originates from the interplay of the ECHAM atmosphere with the changed representation of land surface processes, which would lead to an unrealistic melting of sea ice in the fully coupled model. An elimination of this bias would require an extensive tuning of MPI-ESM 1.2, which was neither in the scope for the SODEEP project team nor desired by MPI-M. Therefore, we decided to conduct AMIP-type simulations with MPI-ESM 1.2, where SST and sea ice are prescribed from existing CMIP6 historical and scenario simulations conducted with the operational MPI-ESM 1.2 wich will then be downscaled. Up to now, we completed historical simulations with the operational MPI-ESM1.2 and the version with the permafrost-ready version of JSBACH and the improved vertical discretization. In addition, we conducted a regional downscaling simulations with REMO driven by a historical AWI-CM simulation. It is also planned to conduct downscaling of MPI-ESM1.2 simulations (historical and scenarios). We are currently screening available scenarios (since we need boundary conditions sea surface temperature and sea-ice for AMIP type simulations).

References:

Blome, T (2014) Influence of different permafrost processes on the large-scale energy and water cycles over Siberia. Reports on Earth System Science 150/2014. https://mpimet.mpg.de/fileadmin/publikationen/Reports/WEB_BzE_150.pdf

Hagemann, S. & Stacke (2015), T. Impact of the soil hydrology scheme on simulated soil moisture memory. Clim Dyn 44: 1731. https://doi.org/10.1007/s00382-014-2221-6