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High-Northern-latitudes permafrost extend in MPI-ESM simulations of SSP126 and SSP585

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The representation of permafrost related processes in Earth System Models (ESM) remains a challenge. A recent collaboration between two related projects (Kohlenstoff im Permafrost (Carbon in Permafrost) – KoPf, and Study Of the Development of Extreme Events over Permafrost areas – SODEEP) yielded a new vertical structure of the soil column in JSBACH, the land component of the Max Planck Institute (MPI) for Meteorology ESM (MPI-ESM). This feature resulted in a better representation of the vertical soil moisture dynamics and the energy transfer due to soil freezing and thawing, which is particularly relevant for the high northern latitudes.

Although, air temperatures are simulated reasonably well with the MPI-ESM, care must be taken not to introduce a bias when implementing new processes in the model or changing existing parametrizations. Here we investigate the permafrost extent in two Shared Socioeconomic Pathways (SSP) simulations (SSP126 and SSP585) with the MPI-ESM using prescribed ocean surface boundary conditions. Our results show a consistency between terrestrial and atmospheric dynamics, when comparing the permafrost extent determined on basis of simulated active layer thickness (soil variable) and Day Degree Thaw Index (DDTI; atmospheric variable). The latter is calculated as the annual sum of positive average daily 2m air temperatures and its square root can be used as an indicator of annual maximum thaw depth.

The SSP126 simulation shows that both DDTI and thaw depth stabilize within the range of the present-day interannual variability, while SSP585 indicates a substantial deepening of the active layer – resulting in a complete disappearance of near-surface permafrost in large parts of the high northern latitudes - and DDTI in SSP585 simulation increases in excess of 2000°C. These values at present characterize northern mid-latitudes i.e. landscapes not underlined by permafrost. A preliminary analysis indicates that the decline of the permafrost extent in SSP585 occurs mostly during the second half of 21st century. Furthermore, the SSP585 simulation also shows an increase in the number of extreme events relevant for permafrost degradation. The investigated extreme climate patterns (as defined in the frame of the SODEEP project) include abrupt warming (defined as occurrence of annual mean temperature above 5-year running mean) and increase in seasonal precipitation anomalies, as well as changes in specific snow characteristics.