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Permafrost Degradation in the Representative Concentration Pathway RCP8.5

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Almost a quarter of the ice-free terrestrial area in the northern hemisphere is underlain by permafrost, i.e. ground whose temperature remains below the freezing point for a period of at least two years. But with global temperatures rising, these areas are loosing in size, especially as temperatures in the Arctic region increase twice as fast as the global mean. If the radiative forcing follows the RCP8.5 trajectory, it is only a question of time until permafrost has largely vanished.

Permafrost-affected soils have accumulated vast pools of organic carbon since the temperatures and the availability of liquid water that are characteristic for permafrost strongly inhibit the decomposition of organic material. In the northern hemisphere, these soils contain about 1300 - 1700 gigatons of carbon, which is more than all carbon held by global vegetation and Earth's atmosphere combined. When permafrost thaws, the degradation of the newly available organic material results in an increased formation of trace gases which will be released into the atmosphere, further increasing the green-house effect, hence temperatures. Thus, permafrost degradation has the potential to form an important positive feedback on climate warming, especially if a large fraction of the decomposing soil carbon is released in form of CH4 rather than the less potent CO_2, and is considered an important tipping element in the climate system.

For the range of the RCP8.5 trajectory, we investigate the long-term permafrost degradation corresponding to a given radiative forcing level, the resulting trace-gas emissions, i.e. CO_2 and CH4 emissions due to the decomposition of soil organic material, and their potential to contribute to a positive feedback. For this, we use an adapted version of JSBACH, the land-surface component of the Max-Planck-Institute for Meteorology's Earth System Model. In addition to the standard version of the model, we include the advanced soil physics, which represent the melting and freezing of water in the soil, and an improved characterization of the effect that soil organic material has on the soil thermal and hydrological properties. Furthermore, we use a new soil carbon model that represents the vertical structure of the organic material and accounts for depth dependent decomposition rates. Finally, we include a diagnostic wetland scheme and a scheme representing the formation and transport of gases in the soil, which allows us to determine the release of CH4 and CO_2 to the atmosphere.