Geophysical Research Abstracts
Vol. 21, EGU2019-17425, 2019
EGU General Assembly 2019

Ancient carbon release from degrading, ice-rich permafrost deposits in NE Siberia: Evidence from radiocarbon analysis of CO_2

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Deep permafrost deposits that developed during the last glacial period and early Holocene in unglaciated lowlands of the circum-arctic region have been a carbon sink for millennia. This significant carbon pool is now being degraded because of increasing ground temperatures that particularly affect the ice-rich sediments in the Yedoma domain, also called ice complex deposits. The loess-like Yedoma deposits that still cover an area of about 1 million km^2 contain large syngenetic ice-wedges resulting in very high ground-ice contents (50–80% of the ground volume). This makes them particularly prone to disturbances such as thermokarst and thermo-erosion processes causing ground subsidence and sediment relocations processes by which the previously frozen organic matter is exposed to microbial decomposition. The complexity of processes and changes taking place in the thermokarst landscape complicates the prediction of greenhouse gas emissions resulting from the mineralization of the organic carbon (OC) stored in Yedoma deposits. To investigated the degradability of OC in thermokarst-affected Yedoma deposits, we designed a model study on a retrogressive thaw slump in the Lena River Delta (NE Siberia). The thawing of the ice wedges in the Yedoma exposed the sedimentary OC in the form of thaw mounds and mixes ancient and younger sediments, which contain ancient and younger organic matter of different age and stage of degradation. Using molecular sieves coupled with respiration chambers as well as depth- samplers, we collected CO_2 at different locations on the thaw slump for radiocarbon analysis providing information on different carbon sources (ancient, young) released from the different study sites. Additionally, we incubated sediment samples to identify substrates released preferentially.

Higher ^{14}C contents of the bulk OC in the near-surface sediment compared to the underlying sediment in two thaw mounds indicated the input of younger substrates potentially derived from younger sedimentary units or leachate of the ice wedges. Likewise, younger layers at another site suggest admixtures of Holocene active-layer material. These younger substrates are preferentially mineralized resulting in relatively high ^{14}C contents of the CO_2 collected with respirations chambers compared to bulk OC. Using depth samplers installed near the still frozen ground (50-60 cm) we collected very old CO_2, which has similar ^{14}C concentrations like the bulk sedimentary OC, indicating that the ancient (up to 30,000 yr BP old) Yedoma OC is mineralized if no younger substrates are available. This observation is confirmed by first $^{14}CO_2$ results of incubation experiments. Variable $^{14}CO_2$ results for three successive years further suggest that considerable changes are taking place in the sediment due to the rapid erosion of the thaw slump causing continuous sediment displacement, the formation of cracks, and the development of a sparse vegetation on the bare sediments. This in turn most probably caused changes in soil temperature, moisture, oxygen and nutrient contents (to be analysed) mirrored by younger CO_2 emissions at some sites. Overall the $^{14}CO_2$results reveal the complexity of the different deposits and of effects that may take place during their thawing complicating the prediction of future greenhouse gas releases from thawing Yedoma.