Geophysical Research Abstracts
Vol. 13, EGU2011-6570, 2011
EGU General Assembly 2011

Late Holocene winter warming reconstructed from 14C-dated ice wedges, central Lena Delta, Northern Siberia

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In the permafrost regions of Northern Siberia, paleoclimate investigations are mainly restricted to lakes and permafrost profiles and, in many cases, based upon paleoecological (thus, summer) indicators (i.e. pollen). Here, we present data from ice wedges as the most abundant type of ground ice in the ice-rich permafrost deposits of Northern Siberia. Stable water isotopes in ice wedges are a direct paleo-precipitation proxy and considered to be an excellent winter temperature tracer due to: (1) temperature-dependent isotope fractionation during precipitation, (2) timing of frost cracking and of the infill of frost cracks, (3) no significant post-depositional modifications of the isotope composition. The organic matter inclusions in ice wedges can be dated by Radiocarbon methods, thus, allowing to assessing the age of discrete parts within an ice wedge.

In the frame of the field campaign "Lena Delta 2005", Holocene ice wedges and enclosing sediments were studied and sampled in detail. Key sites of the first Lena River terrace with Holocene ice wedge activity were selected with a height of $>$ 10 m when possible to avoid river flooding processes influencing ice wedges during or after their growth. The main objective of this project is to link the isotope composition of ice wedges (and by that the winter temperature) to the time of their formation by AMS-dating of organic matter enclosed in ice wedges, and hence, to establish a Holocene ice wedge-based winter isotope thermometer. Since organic matter within the ice may be derived from either allochthonous or autochthonous peat, a careful selection of the samples to be dated is a prerequisite for a successful application of the ^{14}C dating technique to ice wedges.

In this paper, we present data on the stable isotope composition (δ^{18}O, δD, d excess) of Holocene ice wedges and recent ice veins based upon 25 AMS-dates of organic matter enclosed in ice wedges. The data show that the ground ice on the first terrace of the Lena Delta was mainly formed in the second half of the Holocene between about 6 kyr BP and today, thus mostly contemporaneously to sediment accumulation. In general, ice wedge-growth was particularly active in the past 2000 years. Holocene ice wedges are remarkably variable in their isotopic composition (δ^{18}O from –26.8 to –22.8‰) reflecting varying winter conditions in the second half of the Holocene. Warmest winter conditions were observed in the most recent centuries and about 1000 years BP, whereas between 4000 and 5500 years BP winter climate was significantly colder. We observe a general winter warming trend in the Late Holocene, contrasting with the Late Holocene cooling known from most reconstructions of the middle and high northern latitudes, which are, however, mostly based upon summer temperature proxies. In summary, a detailed ^{14}C-based study on the stable isotope composition of Late Holocene ice wedges reveals the winter climate history of the last about 6000 years in Northern Siberia at about centennial-scale resolution.