We have developed a comprehensive description of the climatic and environmental changes in the eastern Taimyr (TAY) (, 102E) during extremely warm BC 4111 to 3850, AD 900-1100, AD 1950-2006 and cold AD 516-560, AD 1600-1650, AD 1800-1850 periods in the Holocene using tree ring parameters and stable isotope (13C and 18O) data.

A new cell wall (CWT), maximum late wood density (MXD) and tree-ring width (TRW) chronologies, as well as 13C and 18O of whole wood and cellulose chronologies were obtained from TAY, which showed declining trends mainly in the late wood density and carbon isotopes during the period from 1950 to 2006. The 13C of wood and cellulose chronologies from YAK (69N, 149 E) [Sidorova et al. 2008] did not show such declining trends as we found for 13C cellulose chronologies from TAY and Finland (FIN) [Sidorova et al. 2009, 2011]. This could indicate that forest ecosystems in the northeastern Siberia (YAK) are still less impacted by global warming than in the northern parts of central Siberia (TAY). The climatological analysis revealed that the stable isotope data show a significant correlation with July precipitation, which is not observed in tree-ring widths. Complementary, latewood density chronology obtained from TAY shows similar correlations as stable isotopes, while CWT chronologies show stronger correlations with climatic data. The stable isotope chronologies from the northern Siberian sites carry information on large-scale climate patterns. In particular, the 18O signal from the eastern site YAK proved to have many wide-ranging connections, reaching as far as to Greenland and even responding to the North Atlantic Oscillation (NAO). This indicates that this location is ideal for capturing a representative climate signal for a large area, which is important in the context of climate reconstructions over millennia which are possible for this site [Sidorova et al., 2008, 2013]. On the other hand, we found that the climatic signals inferred from tree-ring width and 13C of whole wood and cellulose from TAY and YAK show inverse (negative correlations) response. This suggests a cautionary note that climate variations are not uniform over northern Eurasia, but that different modes of atmospheric circulation can result in complex warming and cooling patterns. The signal obtained from 18O wood and cellulose from TAY and YAK show similar trends for the common period from 1900 to 2004. The 18O data could be considered as a climatic indicator for long-term climatic changes, which is confirmed by other proxies such as 18O in Greenland ice core data (GISP2) and NAOs. The temperature signal reflected in tree-ring width, latewood density and stable isotope chronologies from both Siberian regions show widespread dimension patterns from east to west (latitude effect) and from north to south (longitude effect).

Tree-ring widths, cell wall thickness and 13C and  18O in tree ring cellulose from TAY indicate that the period from BC 4111 to 3850 was warmer and drier compared to the present period from 1900 to 2008 AD [Sidorova et al. 2013]. Tree-ring index and stable isotope data of the present period show similarities with the period from BC 3906 to 3806. In contrast, the “Medieval Warm Period” (MWP) AD 900-1150 was wetter compared to both the period from BC 4111 to 3850 and from AD 1791 to 2008. A common signal was revealed between July temperature and precipitation reconstructions obtained from pollen data and 18O data derived from GISP2 data for the three studied periods. While they showed divergent trends during the MWP with 18O data from ice cap Severnaya Zemlya (SZ), all these proxies are in a good agreement during the recent period.

Good agreement between stable carbon, oxygen isotope chronologies as well as July temperature and precipitation reconstructions obtained from pollen data and 18O data of ice cores from GISP2 and SZ recorded strong temperature and precipitation signals indicating warm and wet climatic conditions during the MWP. The MWP is differently recorded in tree rings along the subarctic circle from TAY to Sweden (SWE). MWP and RP on TAY started earlier and showed higher tree-ring fluctuations compared to YAK and SWE. Stable isotope data from annual tree ring cellulose and MXD chronology from TAY for the MWP indicated wetter climate conditions than in YAK and SWE. However, during the recent period trees from TAY, YAK and SWE recorded dryer climate conditions than during the MWP. We showed that the 20th century warming is not unprecedented in the Siberian north, neither regarding the absolute temperature nor the rate of change. Similar climate conditions to the present were recorded by tree-ring parameters, stable isotopes, pollen and ice core data about 6000 years ago [Sidorova et al. 2013].

At the two sites closest to the northern limit of tree growth on the TAY and YAK, there are sharp declines of already narrow tree-ring widths and of cell-wall thicknesses in AD 536, AD 1258, AD 1641, AD 1815 and AD 1992 accompanied by simultaneous drops in cellulose δ13C. Significant decrease in δ13C indicates cold conditions with low vapour pressure deficit during the growing season, which is strongly enhanced by light reduction (due to dust veils) at the sites and reducing photosynthesis. A gradual course of decline for δ13C in Altai (ALT), more southern site goes along with tree-ring width (TRW), caused by the same delayed effectiveness of light reduction. There were very low values of δ18O at ALT in AD 536 only, and reduced cell wall thicknesses in AD 536 and AD 537 as well as frost ring formation in AD 536-538. Significant rapid decreasing 18O values (-4.8σ) for the year AD 536 are a result of low condensation temperatures of atmospheric water vapor, together with a low vapor pressure deficit due to low temperatures, which controls needle water fractionation, leading to a diminished needle H218O enrichment. The discrepancy in 18O between the high latitude and the high altitude sites most likely has its cause in a different hydraulic regime: While trees in ALT rely predominantly on precipitation water throughout the growing season, the northern trees utilize to a large part a mix of precipitation water, and water originating from melted permafrost. Therefore the variability in 18O is strongly dampened in TAY and YAK.

The combination of classical dendrochronological methods with stable isotope analysis improves our knowledge about climatic and environmental changes; in particular, the multiple signals stored in isotope data of tree rings. The multi-proxy approach based on a combination of high and low- time resolution proxies improves the quality of climatic reconstructions.

Results of this project give new interesting insights on the problem of global warming in the north. In the context of past climatic changes, recent warming is not extraordinary in the Siberian north and has analogues in the past [Sidorova et al. 2013]. However, during the last decades trees from Siberian north started to respond to developing of water shortage [Sidorova et al. 2009, 2011]. If the warming trend will continuously increase, as it was during the recent decades, we could expect that trees would be exposed to a severe drought stress; the number of fire events will increase as well as insect’s attacks. Our improved knowledge from this project gives us the tools to develop the right directions and strategies for the Russian forest management, which undoubtedly will impact the socio-economic environment.

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