

Interactive comment on “Ground-ice stable isotopes and cryostratigraphy reflect late Quaternary palaeoclimate in the Northeast Siberian Arctic (Oyogos Yar coast, Dmitry Laptev Strait)” by Thomas Opel et al.

T.J. Porter (Referee)

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Dear Trevor Porter,

Thank you for your thorough review which has raised a couple of good points to improve our manuscript. Please find our replies to your referee comments below in → blue italics.

General comments:

Water isotopes from ice cores are one of the most important climate proxies in Quaternary paleoclimate research. But long ice core records have significant spatial limitations. Relict ground ice in continuous permafrost regions has great potential to fill spatial and temporal gaps in the water isoscape. The manuscript reviewed here, in my view, represents an important contribution to the Quaternary literature. It provides new relict ice isotope data from Oyogos Yar (Dimitry Laptev Strait region) and compares with existing data from the nearby Bol’shoy Lyakhovsky Island locality. Together this regional dataset offers an impressive cross-section of climate-isotope variability over the last ~ 200 ka. Many of the deposits pre-date the limits of the radiocarbon method, and are notoriously challenging to constrain. The authors have done a commendable job establishing a regional chronostratigraphic framework that is both well illustrated and simple to understand. The manuscript was generally well written – some editorial type corrections are needed as outlined below. The data appear to be of high quality and were thoughtfully interpreted, and reasonable conclusions were ultimately drawn. I have only a few specific comments that I feel the authors should address. Following the suggested revisions, I would strongly recommend this manuscript is accepted.

→ Thank you!

Specific comments:

- Abstract describes ‘cold to very cold’, ‘very cold to moderate’, ‘very cold’ and ‘extremely cold’ winter conditions during several key timeslices, but the benchmark is not clearly defined. Please state what the paleoclimate end members are (e.g., LGM to Late Holocene).

→ For this climate interpretation we use the following tentative classification of mean ice wedge $\delta^{18}O$ values with six classes (extremely cold: -38‰ to -35‰, very cold: -35‰ to -32‰, cold: -32‰ to -29‰, moderate -29‰ to -26‰, warm: -26‰ to -23‰, very warm: -23‰ to -20‰). This classification uses roughly the Last Glacial Maximum and modern climate conditions as end-members.

We added this information to the discussion (section 5.2).

- P14, L10: What is meant by ‘. . .fits good to a maximum in modelled summer temperatures. . .’? Are you referring to how the water isotope data match the modelled temperatures? If so, this comparison is perhaps unjustifiable since the ice wedge isotope values are from snowmelt and should therefore be compared with modelled winter temperatures. Considering uncertainties of age

and seasonality (all winter months, or just some) of the relict ice, the data seem to compare reasonably well with modelled winter temperatures. I would recommend revising this bit so that the reader is not confused about the seasonality of the water.

→ In this paragraph we do not discuss ice-wedge isotope data. Instead we discuss the presence of extensive thermokarst lakes dated to 102.4 ± 9.7 kyr (MIS5c), formerly ascribed to the Eemian (MIS5e). Nevertheless, the general warm temperatures inferred from the presence of the thermokarst lake deposits coincide with a maximum in modeled summer temperatures around 105 kyr b2k.

We changed the wording accordingly.

- P15, L24-25: This statement is a bit too strong and lacks accuracy – as it is currently written, it appears to say the primary signal in texture ice relates to secondary fractionation. However, the subsequent sentence contradicts that. Alternatively, you might say that climatic interpretation of water isotopes in texture ice is confounded by partial overprinting of the original meteoric signal by secondary fractionation processes associated with active layer freeze-thaw cycles, and that the degree of overprinting may depend heavily on the environmental context given contrasting variances across different units.

→ Thanks for this advice. We changed the sentence using to your suggestion.

- In section 5, tentative links are made between isotope variations in the Siberian study region and some of the high-amplitude (Dansgaard-Oeschger 'style') fluctuations in North Greenland, NGRIP ice core record. I would caution the authors about doing this so liberally. First, NGRIP is a different seasonality. Second, Greenland is a very special place, and most of these very strong climate oscillations in the NGRIP record are linked to local variability in the vigor of the North Atlantic heat pump (AMOC). While I can understand the appeal in making this comparison, since it may help to explain why the Siberian isotope data do not always compare well with the local modelled temperatures, I think more care is needed when attempting to correlate paleoclimate in the North Atlantic and East Siberian Arctic. My proposed solution would be to acknowledge these complex issues, re: seasonality, and also correlating high-amplitude events across such large distances. Finally, I would also suggest re-iterating that age uncertainties in the Siberian data are sufficient in most cases to bring the data in accord with the modelled temperatures.

→ You are completely right. It is challenging and probably to straightforward to compare the different datasets without referring to different seasonality, climate regime and age uncertainties. Nevertheless we think that comparing the different datasets add additional value for palaeoclimatic interpretation.

We added a sentence acknowledging the mentioned issues.

Technical corrections:

- P3, L17: no need for 'see e.g. discussion in' – this is already implied by citing the paper.

→ Changed accordingly.

- P3, L31-32: I understand the intended meaning of this sentence, but as it is currently written it suggests humans have been conducting field studies in this region since the mid-Pleistocene.

→ *Changed accordingly.*

- P4, L4: should be 'less extensively'

→ *Changed accordingly.*

- P4, L12: should be 'spatially and temporally'

→ *Changed accordingly.*

- P4, L26: mounds = colluvium?

→ *Thermokarst mound (baydzherakh) refers to the remaining sedimentary polygon center filling after melting of ice wedges surrounding an ice-wedge polygon.*

We added this explanation.

- P6, L17-18: is 12.5% (+/-0.5%) potassium content is a reasonable assumption? Please elaborate.

→ *Of course K contents in feldspars vary considerably, but due to our sample processing including feldspar flotation and density separation, we are confident to have extracted K-rich feldspar. In the cited study, Huntley and Baril (1997) found a K content for K-feldspars of 11.5 – 13.5% within a confidence interval of 95%. Based on that, the value of 12.5% ± 0.5% became a standard value used in IRSL dating. The need for more precise values arises when measuring single grains, because then the varying K content plays a role for statistical analyses of results, but in our study we used multiple grain aliquots that average over 100 – 500 grains approximately.*

- P6, L20-21: revise sentence structure, or break into 2 sentences. Example. The equilibrium technique was used to prepare ice-wedge and texture-ice samples for stable isotope analysis. Stable oxygen and hydrogen isotope ratios were measured on a Finnigan 215 MAT Delta-S at AWI Potsdam.

→ *Changed accordingly.*

- P6, L24: It is odd that the measurement precision hasn't changed in 17 years (i.e., since Meyer et al., 2000). Perhaps a more recent citation would be appropriate here, or simply ask the IRMS lab manager at AWI what the value is today, and report that.

→ *The measurement precision of mass spectrometry has actually not changed within the last 17 years for water isotopes. The equilibrium technique is still the most precise on the market and not been surpassed by new developments in the field of mass spectrometry (i.e. the gas bench). So, there is actually no need for a newer reference. The new laser-optical techniques may reach similar precision, but these have not been used for our paper. Hanno Meyer is the lab manager and co-author of this manuscript.*

- P10, L13-15: Communication error. 'Holocene cracking' was not observed in the Yedoma Ice Complex. Rather, 'milky white ice veins' were observed in the YIC. Please revise the sentence.

→ *Changed accordingly.*

- P10, L22: when specific units are referred to (e.g., Unit II), 'Unit' should be capitalised. There are many instances of this spelling error throughout section 4. Please correct in the final manuscript.

→ *Changed accordingly.*

- P13, L25: revise to “. . .and have isotopic values that are depleted compared to ice wedges on Bol’shoy. . .’

→ *Changed accordingly, but ... “less depleted”...*

- P14, L8-9: revise to “The IRSL age for Unit III (102.4+/-9.7 kyr) points to a MIS5c origin rather than MIS5e (Eemian) as suggested previously (Wetterich et al., 2009; Kienast et al., 2011).’

→ *Changed accordingly.*

- P14, L20-21: I am not sure what is meant here. Please clarify this sentence.

→ *We rewrote the sentence and followed the suggestion of Reviewer 1.*

- P15, L1: ‘. . .factors such as. . .’

→ *Changed accordingly.*

- P16, L2-3: revise to ‘As soil water migrates to a freezing front, the first ice. . .’

→ *We changed the wording considering your suggestion.*

- P16, L10-12: I am not sure what is meant here. Please clarify this sentence.

→ *We deleted this sentence.*

- P16, L24: ‘. . .according to. . .’

→ *Changed to “corresponding”.*

- P19, L1-3: if it adds value, why not add the Laskar winter insolation curve?

→ *We added the insolation curves for both summer (JJA) and extended winter (NDJFMA) to Figure 7 and changed the text and figure captions accordingly.*

- P19, L13: ‘All in all, *our* data. . .’

→ *Changed accordingly.*

- P19, L23: ‘. . .pollen data from. . .’

→ *Changed accordingly.*

- P19, L34-35: please rephrase the sentence beginning with ‘However,. . .’ As it is currently written, I am not entirely sure what is meant.

→ *We rewrote the sentence.*

- P20, L1: please remind the reader (in brackets) how much d-excess increased.

→ *We added the numbers (about 1‰ for Bol’shoy Lyakhovsky Island and about 2‰ for Oyogos Yar).*

- P20, L12: '. . .in addition *to* and. . .'

→ *Changed accordingly.*

– Figure 7: Please specify if the standard error bars are 1 or 2 sigma.

→ *The age uncertainties refer to the maximum age range from Table 1 (i.e. refer to respective minimum and maximum age not to standard error).*

This is now stated in the figure caption.