Long-term warming of Holocene winter temperatures in the Canadian Arctic recorded in stable water isotope ratios of relict ice wedges

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Basic theory

1. **Ice wedges** contain a record of winter-spring precipitation in the form of discrete ice veins, each representing a ‘year’ of growth.
2. Ice veins may not form every year, but several millennia can be recorded in an ice wedge.
3. In Arctic regions, stable isotope ratios of precipitation (δD and $\delta^{18}O$) are strongly influenced by mean air temperature (Porter et al., 2016).
4. Siberian ice wedges have been used to reconstruct Holocene winter-spring temperatures (e.g., Meyer et al., 2015; Opel et al., 2017), a seasonality rarely captured by other proxies.
5. Knowledge of Holocene cold-season climate change in the Canadian Arctic is largely lacking.

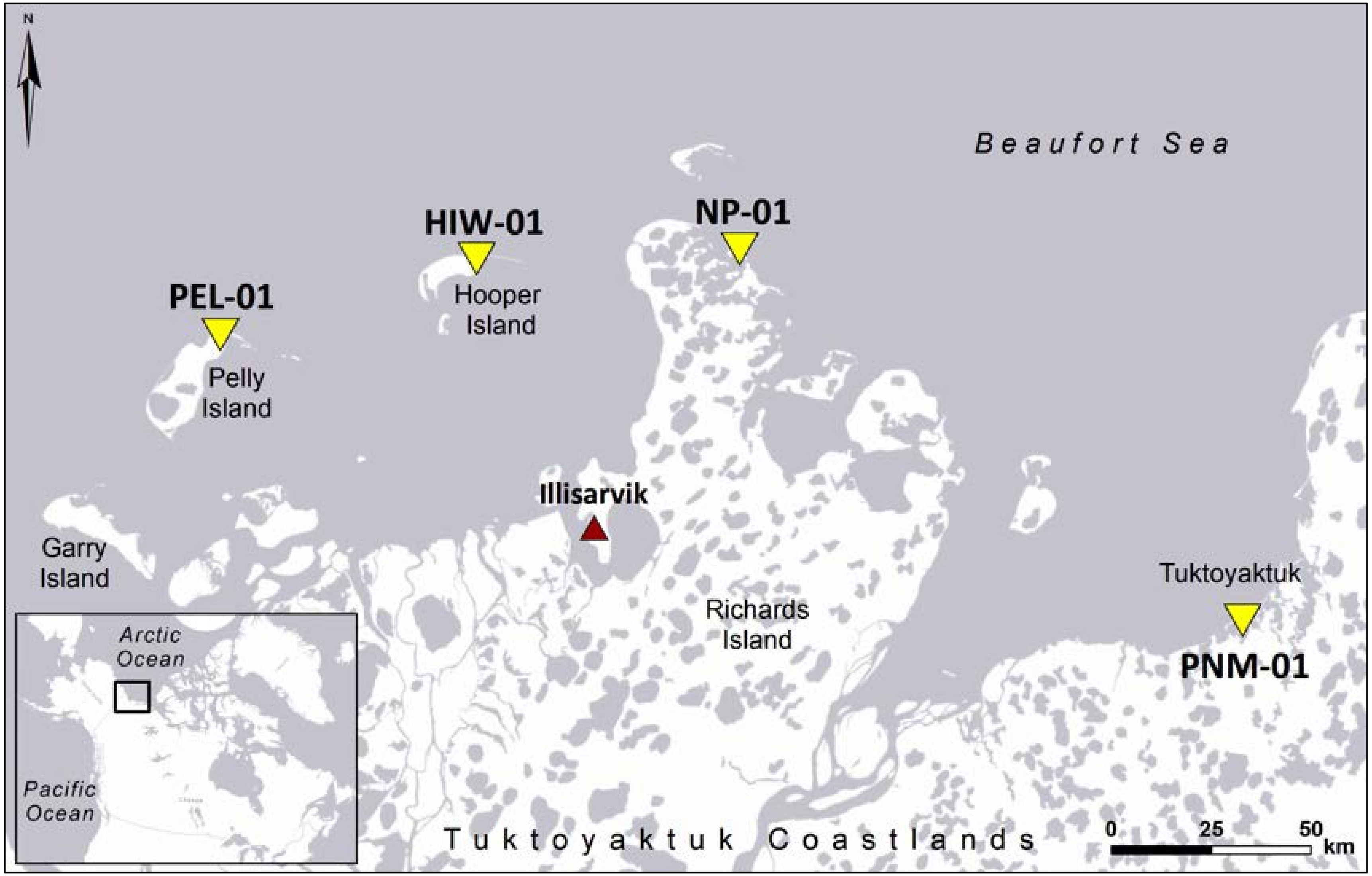
Study objective

1. Develop a Holocene ice-wedge $\delta^{18}O$ record to better understand cold-season climate in the Canadian Arctic

Tuktoyaktuk Coastlands (Canada) sites

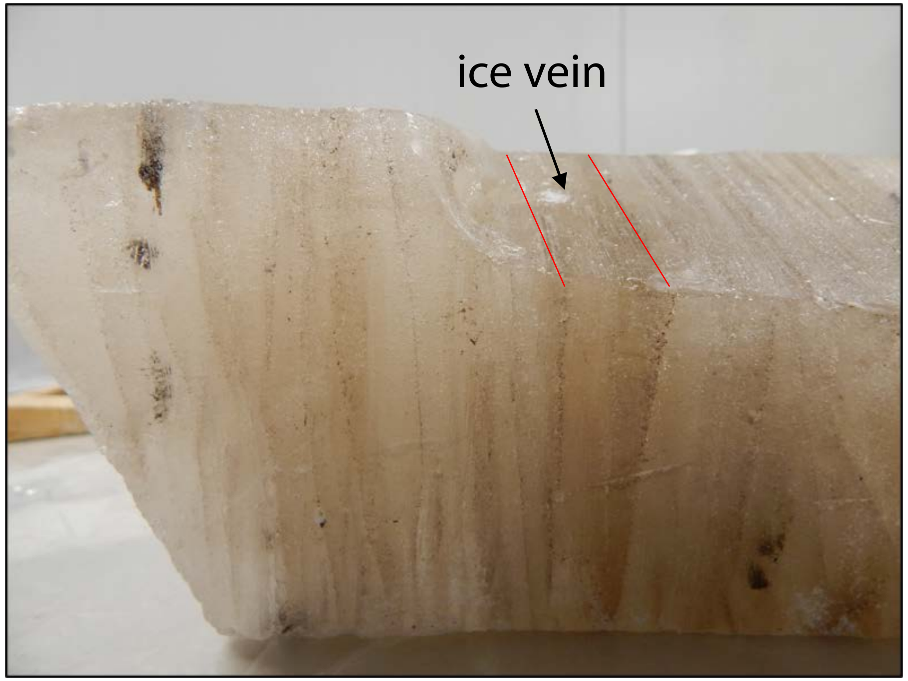
4 Holocene-age ice wedges (yellow triangles) from retrogressive thaw slumps

1 modern ice wedge at Illisarvik (Michel, 1990) is included in the analysis



Methods

1. Fieldwork: blocks were cut from ice wedges with a chainsaw and stored in field coolers
2. Lab work: ice veins were sub-sampled (1-3 veins per sample) with a bandsaw
    - Water isotope composition (δD and $\delta^{18}O$) of the ice samples was analysed with a Picarro l2130-i
3. ^{14}C dating: the DOC content of select ice samples was AMS radiocarbon dated (e.g., Lachniet et al., 2012)
4. $\delta^{18}O$ record: a 7,400-yr composite record was created from $\delta^{18}O$ of the ^{14}C-dated ice-wedge samples



Results/discussion

1. The TC ice-wedge record shows a long-term δ¹⁸O increase, similar to Siberian ice wedges (e.g., Meyer et al. 2015; Opel et al. 2017).

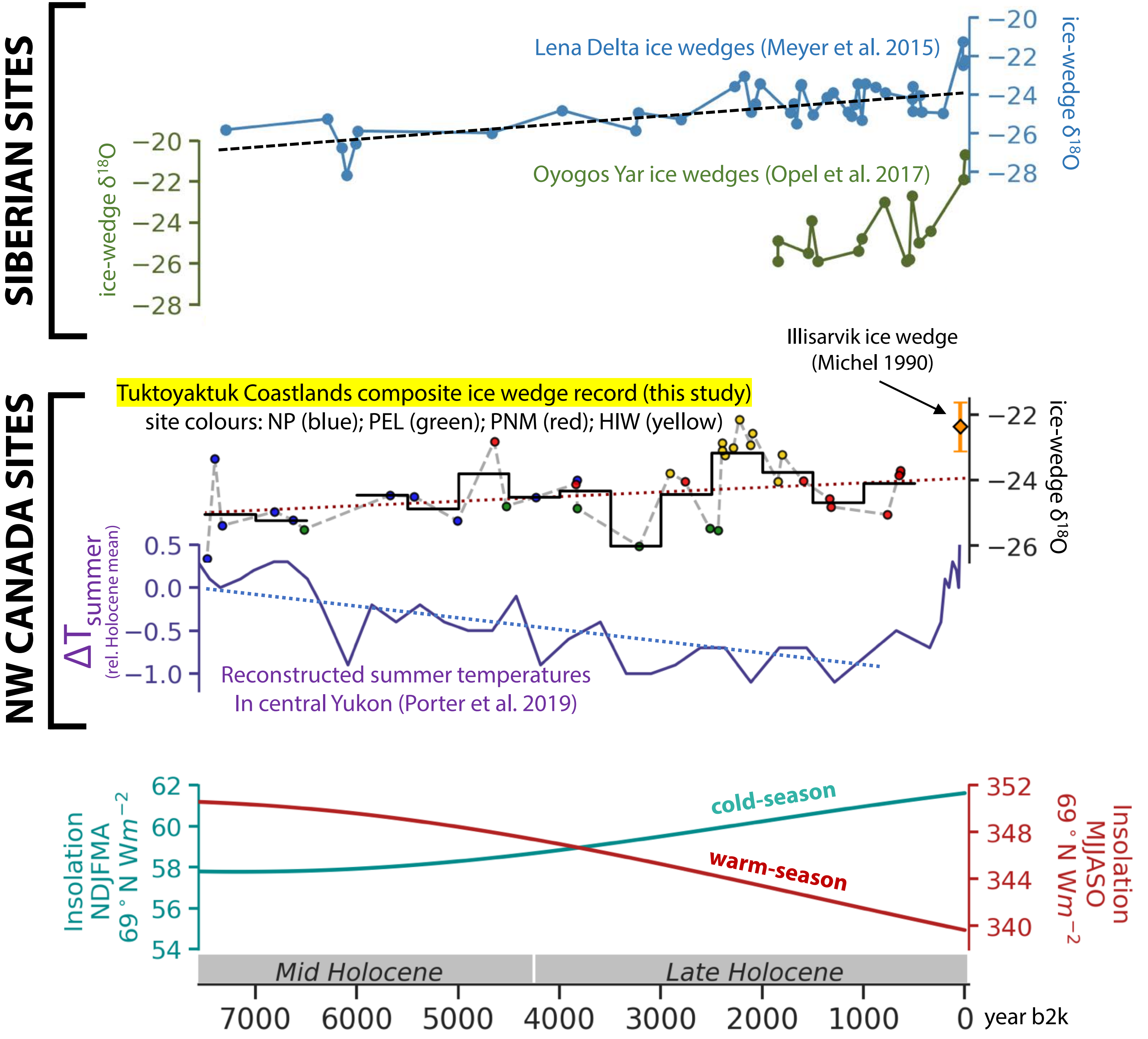
2. The δ¹⁸O increase reflects a cold-season warming trend driven by increasing cold-season insolation through the Holocene.

3. Conversely, reconstructed summer temperatures in the region (e.g,. Porter et al. 2019) show an opposite cooling trend through most of the Holocene, explained by decreasing warm-season insolation.

Concluding remarks

1. Ice wedges provide a unique water isotope archive for constraining winter paleoclimate

2. The TC record confirms Holocene warming in the Western Arctic, in agreement with climate model simulations and ice-wedge studies in the Siberian Arctic.



References

1. Lachniet MS, Lawson DE, Sloat AR. Revised 14C dating of ice wedge growth in interior Alaska (USA) to MIS 2 reveals cold paleoclimate and carbon recycling in ancient permafrost terrain. Quatern Res. 2012;78(2):217-225.
2. Meyer H, Opel T, Laepple T, Dereviagin AY, Hoffmann K, Werner M. Long-term winter warming trend in the Siberian Arctic during the mid- to late Holocene. Nat Geosci. 2015;8(2):122-125.
3. Michel FA. Isotopic composition of ice-wedge ice in northwestern Canada. Proc 5th Can Permafr Conf. 1990:5–9.
4. Opel T, Laepple T, Meyer H, Dereviagin AY, Wetterich S. Northeast Siberian ice wedges confirm Arctic winter warming over the past two millennia. The Holocene. 2017;27(11):1789-1796.
5. Porter TJ, Froese DG, Feakins SJ, et al. Multiple water isotope proxy reconstruction of extremely low last glacial temperatures in eastern Beringia (Western Arctic). Quat Sci Rev. 2016;137:113-125.
6. Porter TJ, Schoenemann SW, Davies LJ, Steig EJ, Bandara S, Froese DG. Recent summer warming in northwestern Canada exceeds the Holocene thermal maximum. Nat Commun. 2019;10(1): 1–10. 1631. https://doi.org/10.1038/s41467-019-09622-y

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