# Ice wedges as winter paleotemperature proxies: is it feasible?

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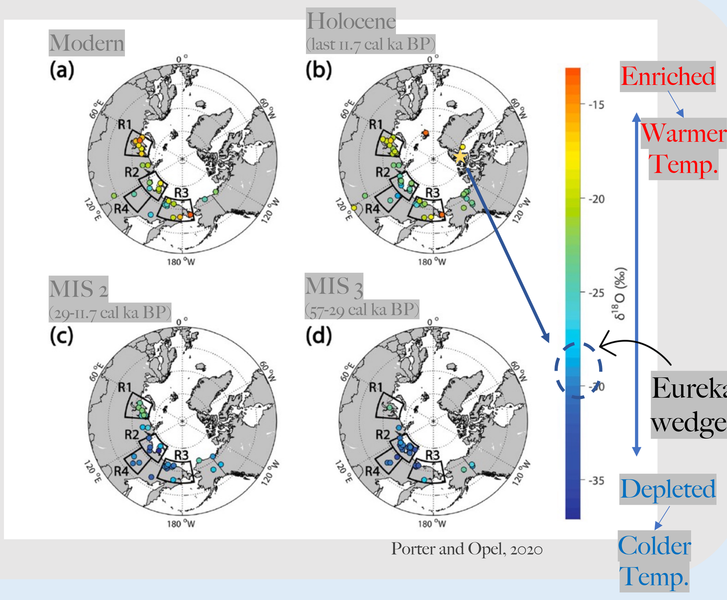
## Background

Ice wedges as winter paleotemperature proxy:

- Use the δ[18]O signature of wedges to identify Arctic winter warming

However, these studies *do not* consider:

1. Snowpack metamorphoses in the winter (2-4‰; Taylor et al., 2001)
2. Ice wedge activity - peripheral cracking, frequency of cracking, and isotopic fractionation within the wedge




Porter and Opel, 2020

## Research Objective

We wanted to understand:

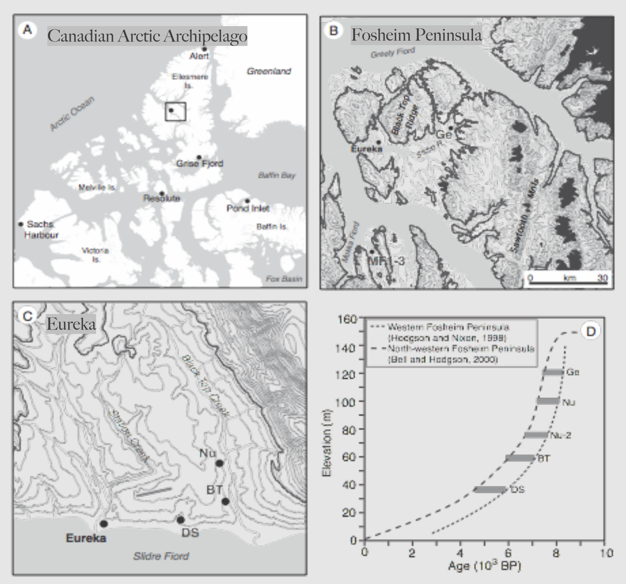
Does the D-[18]O signature of ice wedges *accurately* record winter temperatures?

And this is how we did it:

(1) Identify the effect of sampling position and depth within ice wedges on their δ[18]O composition.

(2) Compare the δ[18]O of ice wedges with the Agassiz ice core record.

## Study Site

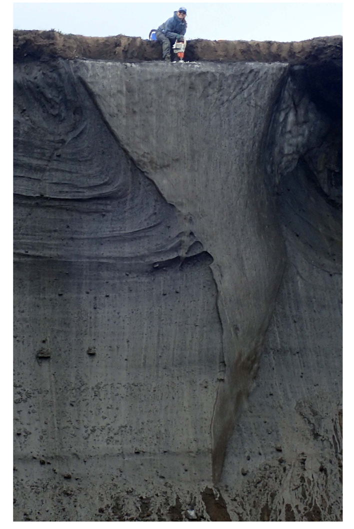



- Glaciation and Surficial sediments:
  - Innuitian Ice sheet (IIS) deglaciated 10.3-8.7 kyr BP
  - Marine limit at Eureka Weather Station: 146 m a.s.l.
- Climate:
  - Annual: -18.5±1.4°C; ppt: 77.6 ± 25.8 mm y[-1]
  - Winter: -38.5±1.7°C; snow depth: 14.9 ± 6.3 cm
  - Summer: 4.3±1.3°C; rainfall events: low (<0.03 mm).
- Permafrost:
  - >500 m thick
  - Active layer is between 10-100 cm thick
  - Ground temperature at ZAA remains <-10°C

## Methods

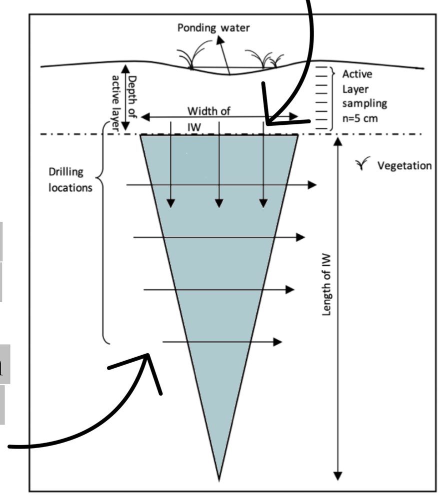
### Sampling

Ice wedges were sampled horizontally in 2018 and vertically in 2019



3-5 vertical surface cores extracted from 8 wedges in 2019 across the wedge to a depth of ~30cm

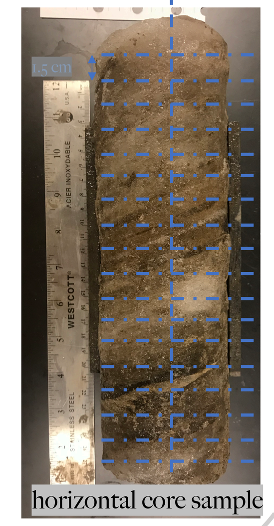
2-4 cores extracted from 4 wedges at depth in 2018 at an interval of ~30 cm using a CRREL coring kit



### Laboratory Analysis

- Horizontal cores were cut in half along their length then sub-sampled at 1.5cm intervals along the growth axis using a sterile tile saw.
- Thawed at room temperature and sampled for δD and δ[18]O.
- Vertical cores were thawed at room temperature in sterile glass beakers and sealed to ensure *no* potential evaporation.
- Samples were then filtered (pre-rinsed 0.45 um nitrate cellulose filters) into 20ml plastic vials for δD - δ[18]O; 40ml plastic vials for geochemistry, and DOC; and 1L amber vials for [14]C DOC.

vertical core sample




horizontal core sample

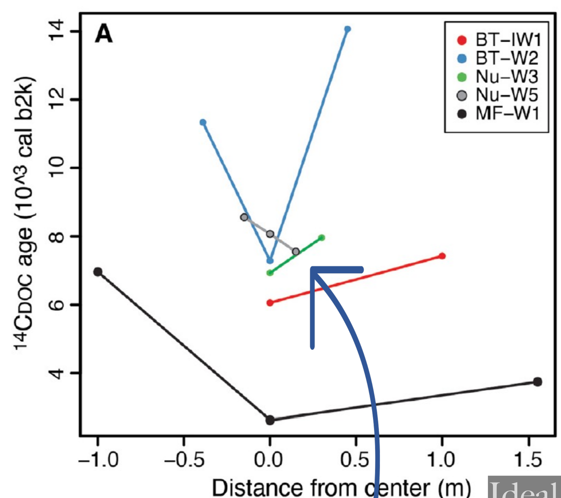
### Statistical Analysis

- Shaprio-Wilk test for normality on the [18]O and D-excess data from the horizontal cores.
  - Ice wedge data should be natural-log transformed to meet the assumption of normality.
- An ANOVA within subjects test was conducted to determine whether the means of [18]O and D-excess between depths of sampling in each ice wedge was statistically different.
- Covariance computed to determine the ratio of signal to noise in the horizontal [18]O records at the same depth on both sides of the wedge.

## Results and Discussion

### Ice wedge irregular growth:

Majority of samples show regular growth with younger ages in the centre.



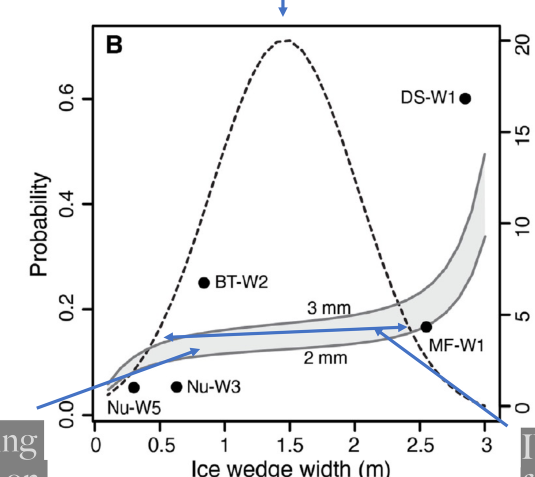

Ideal sampling width based on growth curve

Nu-W5 showed irregular growth.

Indicates peripheral cracking is occurring in *some* ice wedges.

### Probability of cracking:

Modelling and radiocarbon dates (EU) from Ice wedges showed that ice wedges of medium width (1-1.5 m) have the highest cracking probability.

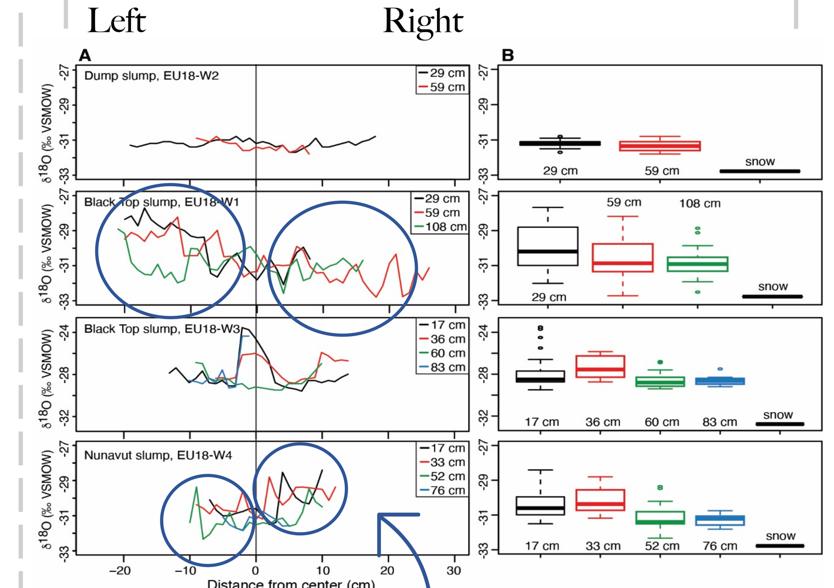



IW Width X Age following 2mm and 3mm growth

These medium wedges likely preserve a higher temporal resolution due to their higher cracking probability and are likely better for paleoclimate reconstructions.

### Variations within an ice wedge:

Left Right

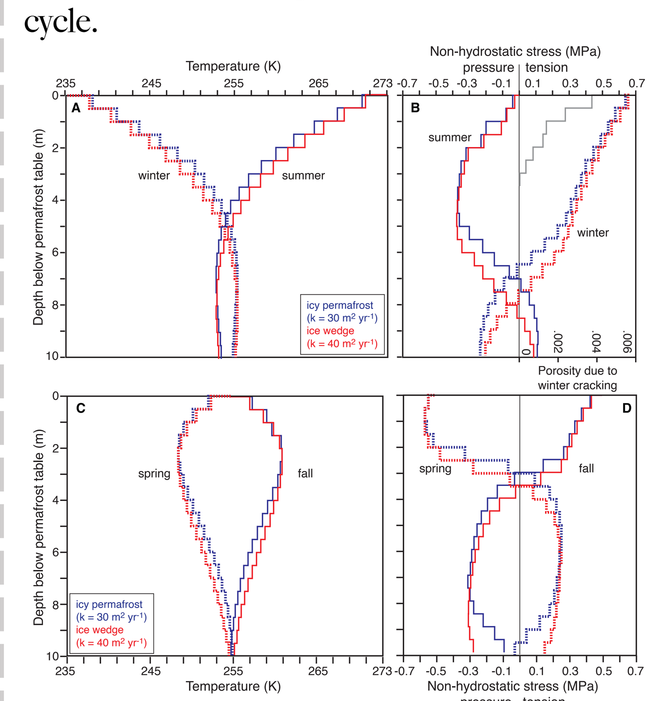



The δ[18]O of one side of a wedge is *observed* to be different than the other.

Ice wedge reconstructions which rely on one side of an ice wedge may be incorrectly interpreted.

### Ice wedge and permafrost interaction:

We modelled temperature and non-hydrostatic stress profiles in an ice wedge and adjacent icy permafrost following a seasonal temperature cycle.

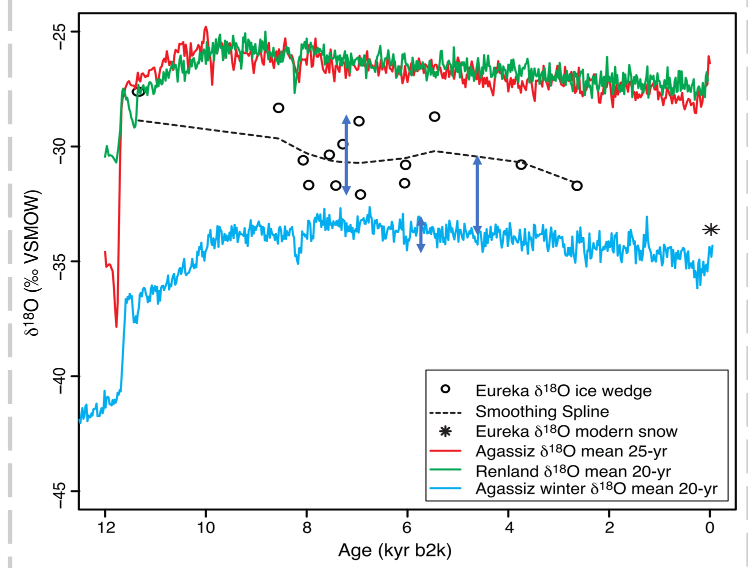



Revelled water migration at maximum speeds of c. 2.0 x 10[-5] m yr[-1] (0.02 mm yr[-1]) at 0.5 m depth in the *summer*.

*Therefore*, caution must be exhibited when sampling ice wedge edges.

### Comparison with glacial ice:

Ice wedge δ[18]O records showed a higher-than-expected degree of variability against the winter δ[18]O for the Agassiz ice cap.




As a result, a smoothing spline filter was used to reduce noise caused by the evolution of δ[18]O during snowmelt.

We also see a 4-5‰ difference between Agassiz winter reconstruction and the Eureka ice wedge reconstruction.

Temperature reconstructions using ice wedge δ[18]O will reflect warmer temperatures than what actually occurred.

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## What does this mean for the future?

Currently, ice wedges *are not* accurate proxies for winter paleoclimate.

Modern methods used to sample ice wedges for paleotemperature reconstructions do not account for the complexity of ice wedge growth.

We suggest establishing an ice wedge chronology of multiple ice wedges to create an *accurate* paleoclimate reconstruction.

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Interested in reading the paper? Scan this QR Code using your phone's camera.

Works cited:

Porter, T. J., & Opel, T. (2020). Recent advances in paleoclimatological studies of Arctic wedge- and pore-ice stable-water isotope records. *Permafrost and Periglacial Processes*, (February), 1–13. https://doi.org/10.1002/ppp.2052

Taylor, S., Feng, X., Renshaw, C. E., & Kirchner, J. W. (2002). Isotopic evolution of snowmelt 2. Verification and parameterization of a one-dimensional model using laboratory experiments. *Water Resources Research*, *38*(10), 36-1–36–38. https://doi.org/10.1029/2001wr000815