Holocene Climatic Changes in the Alaskan Arctic as Inferred from Sedimentological and Oxygen-Isotopic Analysis at Wahoo Lake

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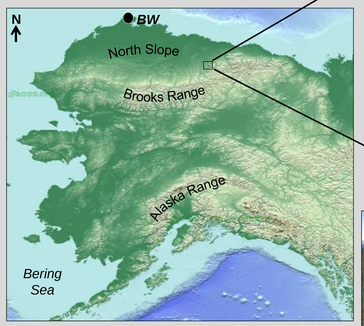
INTRODUCTION

Background and Rationale

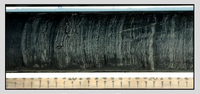
Reconstructions of Holocene climate in the Arctic have been accumulating, allowing for better understanding of how the region may respond to future climate changes. However, long-term records from the Alaskan Arctic are scarce. We conducted sedimentological and isotopic analyses at Wahoo Lake to infer Holocene climate variability in northern Alaska. Holocene variations in $\delta^{18}O$ from Wahoo Lake generally correspond to fluctuations in total solar irradiance, suggesting that solar variability may play an important role in the long-term climate of the Alaskan Arctic.

Study Site

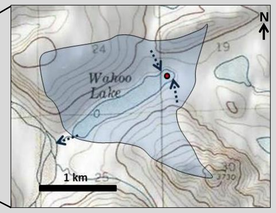
Wahoo (69° 4.612 N, 146° 55.676 W, 707 m a.s.l.)



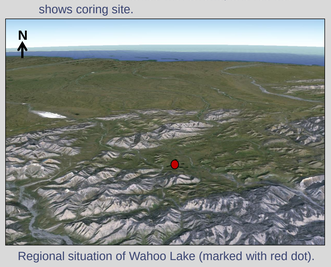
Map of Alaska with sites mentioned in text. Black dot = Barrow weather/GNIP station.



Sediment Core



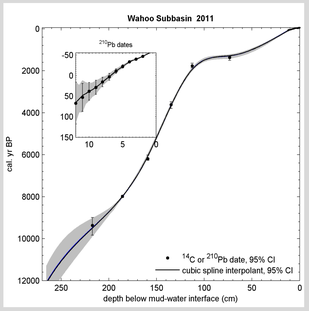
Wahoo Lake watershed shaded in blue, inlet and outlet streams marked with arrows, and red dot shows coring site.



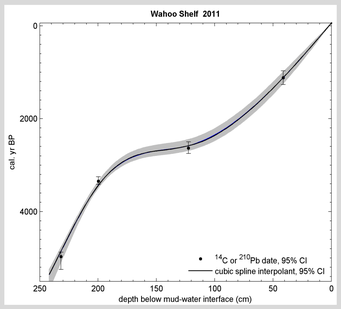
Regional situation of Wahoo Lake (marked with red dot).

- Small surface area (0.28 km^2) and large watershed (2.68 km^2, 282.3 ha)
- Cored subbasin (8.1 m water depth) and adjacent shelf (2.8 m)
- Open basin (2 inlets, 1 outlet)
- Max lake depth = 17.1 m
- Coring Date: July 5-7th 2011

Methods and Chronology



- Sediment core chronology
  - 11 ^{210}Pb ages from bulk sediment
  - 6 (subbasin) and 4 (shelf) calibrated ^{14}C ages from terrestrial macrofossils
  - Dates reported in calibrated years before CE 1950 (cal BP)
- Sedimentary and Isotopic Analysis
  - Loss-on-ignition (LOI) at 550° C and 950°C
  - *Pisidium* carbonate shells = $\delta^{18}O$ and $\delta^{13}C$



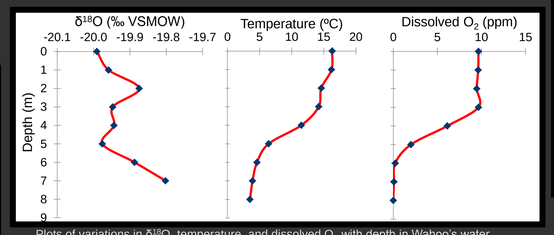
Age-depth model based on ^{14}C and ^{210}Pb dating. Black line = cubic spline interpolant; grey shading = 95% confidence envelope based on 1000 bootstraps.

- Water samples analyzed for δD and $\delta^{18}O$
  - inlet/outlet streams
  - every 1 m from subbasin water column
- Wahoo monthly precipitation modeled using the Online Isotopes in Precipitation Calculator
- Regional Meteoric Water Line (RMWL) defined by Global Network of Isotopes in Precipitation (GNIP) data from Barrow Weather Station

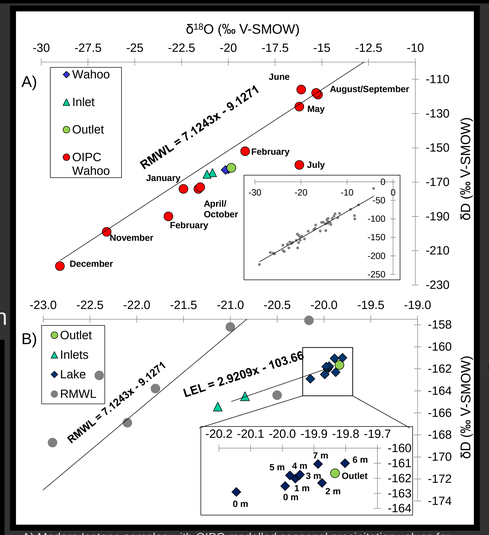
RESULTS and INTERPRETATION

Water Isotopes

- Modern $\delta^{18}O$ values provide interpretive framework for what environmental variations influenced variations in *Pisidium* record
- Samples indicate winter precipitation dominates lake water isotopic composition
- Evaporative enrichment between inlet and outlet water
- However, water column isotopic data is not indicative of evaporation, despite clear stratification



Plots of variations in $\delta^{18}O$, temperature, and dissolved O_2 with depth in Wahoo's water.



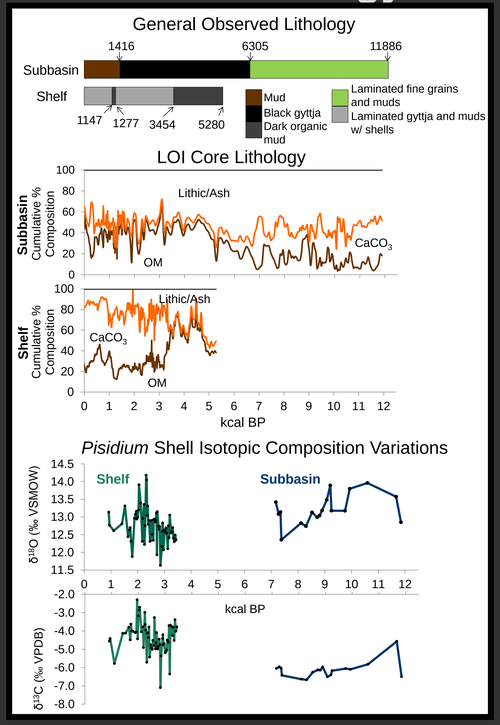
A) Modern Isotope samples with OIPC modelled seasonal precipitation values for Wahoo Lake plotted with RMWL. Inset: Barrow GNIP data used to construct RMWL.
B) Water-column samples from Wahoo Lake plotted with the RMWL and LEL.

Controls on $\delta^{18}O$ in *Pisidium*

	Post-Input Modification (Evaporative Enrichment)	Calcite Precipitation Temperature (summer)	Meteoric Precipitation Temperature	Meteoric Precipitation Seasonality
High $\delta^{18}O$	High Evaporation	Low Temperature	High Temperature	More Summer Precip
Low $\delta^{18}O$	Low Evaporation	High Temperature	Low Temperature-	More Winter Precip
Potential Impact	Several ‰	~0.2‰ per ºC	0.6-0.7 ‰ per ºC	Several ‰

- We interpret variations in the *Pisidium* $\delta^{18}O$ record as indicative of changes in evaporative enrichment and changes in temperature and/or seasonality of precipitation

Core Lithology and Carbonate Isotopes

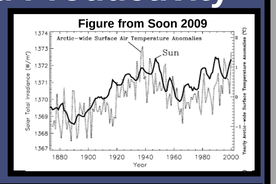


- Lithology suggests changes in lake level during the Holocene
- 11.5-8.5 kcal BP = high $CaCO_3$ content indicates closed-basin conditions and evaporative enrichment associated with a warm, dry Holocene Thermal Maximum
- Mid-Holocene = increasing lake-level suggested by *Pisidium* disappearance and reduction in calcite at ~6.5 kcal BP, as well as shelf-core basal date of 5.3 kcal BP
- 3.5-2.0 kcal BP = increased deposition of calcite during high lake level (i.e. open basin conditions) and increasing $\delta^{18}O$ indicates increasing temperature and/or increasing contribution of summer precipitation
- 2.0-1.0 kcal BP = $\delta^{18}O$ generally declines, indicating temperature decrease and/or increased contribution of winter precipitation
- High degree of $\delta^{18}O$ variability in late-Holocene suggests dramatic temperature changes (as much as 0.9 ºC)

DISCUSSION

Solar Forcing of Climate and Productivity

- Variability in solar output co-varies with Arctic annual mean surface temperature over the past ~120 years.
- Does this pattern exist throughout the Holocene?

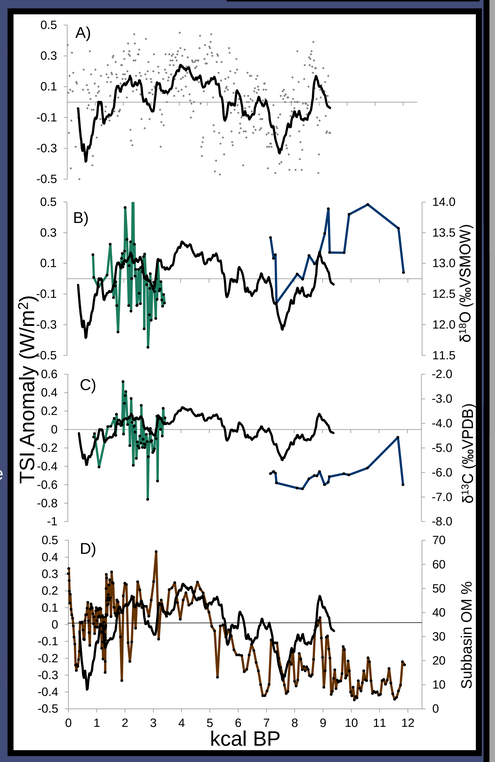


A. Record of Holocene Total Solar Irradiance (TSI) derived from cosmogenic nuclide Be^{10} in ice cores, plotted with 20-point moving average (Steinhilber et al. 2009).

B. *Pisidium* $\delta^{18}O$ record with TSI curve superimposed.

C. *Pisidium* $\delta^{13}C$ record with TSI curve.

D. LOI-derived organic matter (OM) variation with TSI curve.



Conclusions

Variations in solar output covary with the *Pisidium* $\delta^{18}O$ record, suggesting that solar irradiance may play an important role over the Holocene in the Alaskan Arctic.

TSI variability also corresponds to proxies of productivity at Wahoo Lake. Increases in $\delta^{13}C$ and LOI-derived OM during the Holocene suggest that Wahoo Lake became either a more productive lake or that increasing lake depth resulted in anoxic bottom waters that better preserved organic material.

Summary

- Isotopic and sedimentological analyses provide the first climate record from Alaska's North Slope.
- During the Holocene, Wahoo Lake changed from a relatively low-productivity, closed-basin lake to a more productive, open-basin lake as a result of regional climatic changes.
- Total solar irradiance seems to play an important role in the long-term climate of the Alaskan Arctic.
- Long-term trends in solar irradiance may also influence lacustrine productivity.

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