Exploring Spatial and Temporal Variations of Arctic Circulation Using Oxygen Isotopes of Seawater

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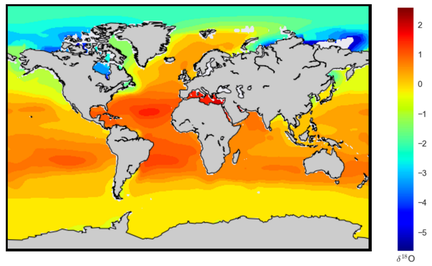
Introduction

Observations from the past sixty years of seawater $\delta^{18}O$ and salinity were compiled into a database by Schmidt et al. (1999) and used to calculate a three-dimensional 1°x1° $\delta^{18}O$ global gridded dataset by LeGrande and Schmidt (2006; LS06) (fig 1.1).

Fig 1.1 LS06 v1.2 Global $\delta^{18}O$



Because freshwater processes impact the isotopic composition of seawater as they impact salinity, regional linear regressions (Craig and Gordon, 1965) can be leveraged to trace hydrology. This study updates the Schmidt et al. (1999) database, examines discrepancies between estimated and calculated $\delta^{18}O$ using the Arctic Ocean as a case study (fig 1.2.), and recalculates LS06.

Fig 1.2 Arctic $\delta^{18}O$ Discrep.

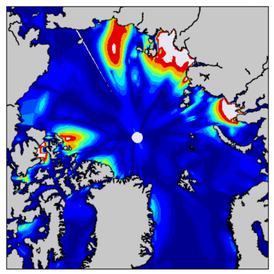
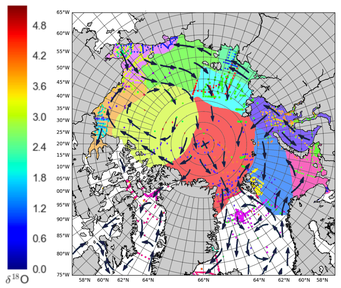


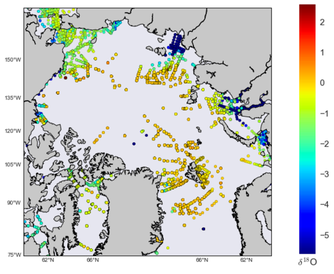
Fig 1.3 10 Arctic Regions



The Arctic Ocean is parsed, QC'd and analyzed according to geography, surface currents (fig 1.3) and seasonality (fig 2.1a,b).

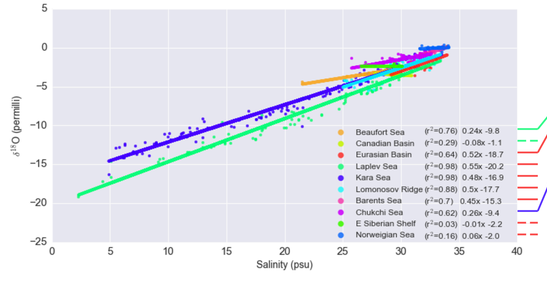
Quality Checks and Water Mass Consolidation

Fig 2.1a Melt Season (MJJASO) $\delta^{18}O$ Dist.



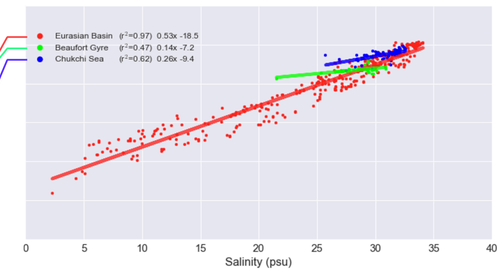
Strong spatial distribution and freshwater gradients from coastal meteoric sources to open ocean.

Fig 2.2a Melt Season $\delta^{18}O$-Sal Relationship of 10 Regions



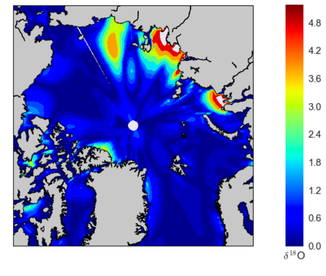
Compatible mixing gradients (slope) and freshwater end-members (y-int) marked with solid ticks (right) and merged (fig 2.3a). Poorly sampled regions with low R^2 denoted with a dashed tick and aggregated with nearest neighboring region.

Fig 2.3a Melt Season $\delta^{18}O$-Sal Relationship of 3 Regions



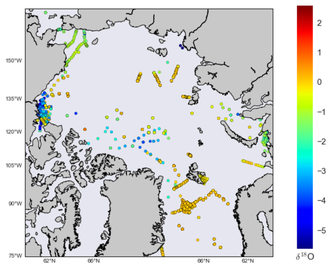
Unique $\delta^{18}O$-Sal relationships represent three Arctic freshwater sources visible in fig 2.1a gradients–Bering Strait (purple) and Russian (red) and Canadian (green).

Fig 2.4a Melt Arctic Discrepancy 3 Regions



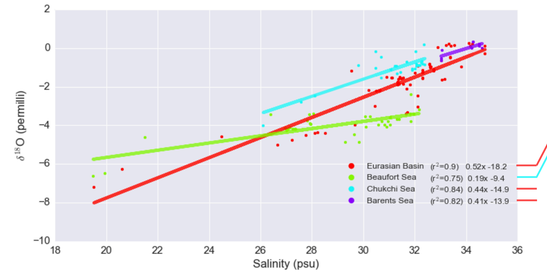
Discrepancy reduced by 700 $\delta^{18}O$ compared to fig 1.2. Beaufort Gyre discrepancy eliminated. East Siberian Shelf more accurate despite lack of sampling coverage.

Fig 2.1b Frozen Season (JFMAOND) $\delta^{18}O$ Dist.



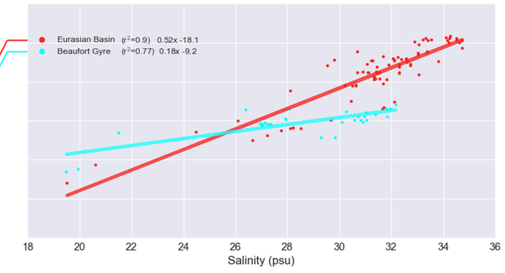
Sea ice limits regions to: Chukchi, Beaufort, Barents and Eurasian Basin. Gradients weaker.

Fig 2.2b Frozen Season $\delta^{18}O$-Sal Relationship of 4 Regions



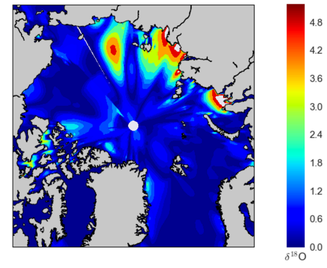
Less dynamic hydrology when freshwater flux is low from 3 freshwater sources in fig 2.3a and sample distribution is poor.

Fig 2.3b Frozen Season $\delta^{18}O$-Sal Relationship of 2 Regions



Eurasian Basin consistent seasonally (fig 2.3a), with addition of Chukchi in colder months. Beaufort Gyre highly variable seasonally.

Fig 2.4b Frozen Arctic Discrepancy 2 Regions



Discrepancy reduced by 500 $\delta^{18}O$ compared to fig 1.2. The Melt 3 WM is more accurate, calculate LS06

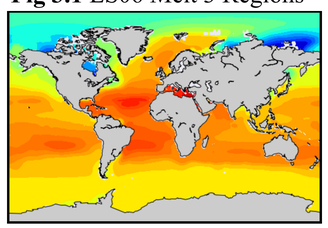
Methods

- Added 3k (10% increase) to Schmidt et al. (1999) database.
- LS06 method to update global gridded dataset (fig 1.1).
- Measured Arctic discrepancies (estimated-calculated $\delta^{18}O$) from 0-10m integrated above 66 N (fig 1.2) ~2992 $\delta^{18}O$.
- Explored 10 regions of the Arctic Ocean parsed by geography and surface currents (Brown 2001, fig 1.3) for root cause of discrepancies.
- Jackknife slope analysis to QC each region (fig 2.6).
- Linear regression to find regions of unique $\delta^{18}O$-sal relationships under two temporal regimes—frozen (4 regions in JFMAOND) and melt (10 regions in MJJAS).
- Regions consolidated using similar $\delta^{18}O$-Sal relationships.
- Recalculated global gridded dataset (LS06) and analyzed discrepancies for each regime.

Conclusion

The Arctic is a small land-enclosed body of water with complex circulation and diverse inputs. Transient meteoric water from river discharge leaves a lasting imprint. To reflect this, LS06 is calculated using 3 regions in Melt season (right) and 2 regions in Frozen season (not pictured). Despite the variable hydrology in the Beaufort Gyre, discrepancies are. Due to poor spatial distribution of Frozen season, calculated $\delta^{18}O$ is disproportionately shaped by few measurements.

Fig 3.1 LS06 Melt 3 Regions



Future Work

Use Jackknife to QC globally and along isopycnals.

How does sea ice dampen the relationship?
How will these trends change as Arctic warms?

Acknowledgements

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References

Bauch, D., et al. (2010), Changes in distribution of brine waters on the Laptev Sea shelf in 2007. *Journal of Geophysical Research 115*, C11.

Bauch, D., P. Schlosser, and R. Fairbanks (1995), Freshwater balance and the source of deep and bottom waters in the Arctic Ocean inferred from the distribution of H218O. *Progress in Oceanography 35*: 53-80.

Craig, H., and L. I. Gordon (1965), Deuterium and oxygen 18 variations in the ocean and the marine atmosphere. In E. Tongiori (Ed.) *Proceedings of a Conference on Stable Isotopes in Oceanographic Studies and Paleotemperatures,* Spoleto, Italy.

Dansgaard, W. (1964), Stable isotopes in precipitation. *Tellus 16*, 436-468.

Grabs, W. E., F. Portmann, and T. De Couet (2000), Discharge Observation Networks in Arctic Regions: Computation of the River Runoff into the Arctic Ocean, Its Seasonality and Variability. In Lewis, E.L., Jones, E.P., Lemke, P., Prowse, T.D., and P. Wadhams (Eds.), *Freshwater Budget of the Arctic Ocean*. Boston: Kluwer Academic Publishers, 249-65.

Létolle, R., et al. (1993), ^{18}O abundance and dissolved silicate in the Lena delta and Laptev Sea (Russia). *Marine Chemistry 43*, 47-64.

LeGrande, A.N., and G. A. Schmidt (2006), Global gridded data set of the oxygen isotopic composition in seawater. *Geophysical Research Letters 33*.

Schmidt, G. A., G. R. Bigg, and E. J. Rohling (1999), Global seawater oxygen-18 database - v1.21. http://data.giss.nasa.gov/o18data/