To the North Pole and back: a pan-Arctic barium synthesis

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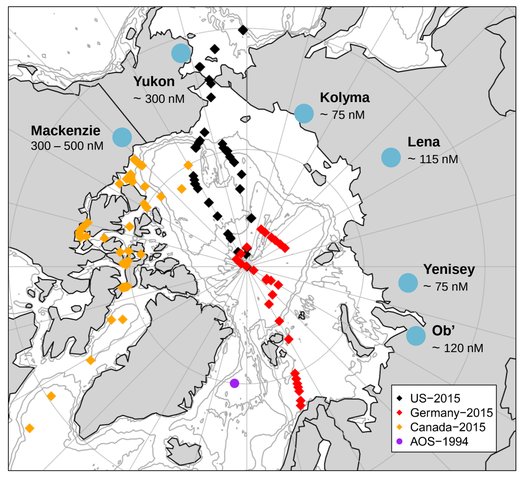
Background

Dissolved barium (dBa) has been used as a water mass tracer and Ba can be applied as a proxy for productivity due to a relationship between particulate Ba (pBa) and organic carbon. The utility of Ba depends on predictable behavior of the tracer.

We aim to describe and quantify non-conservative behavior (sources and sinks) of Ba in the Arctic marine system.

New data in this study are from GEOTRACES campaigns conducted throughout the Arctic Ocean from July – October 2015.



Take Home Messages

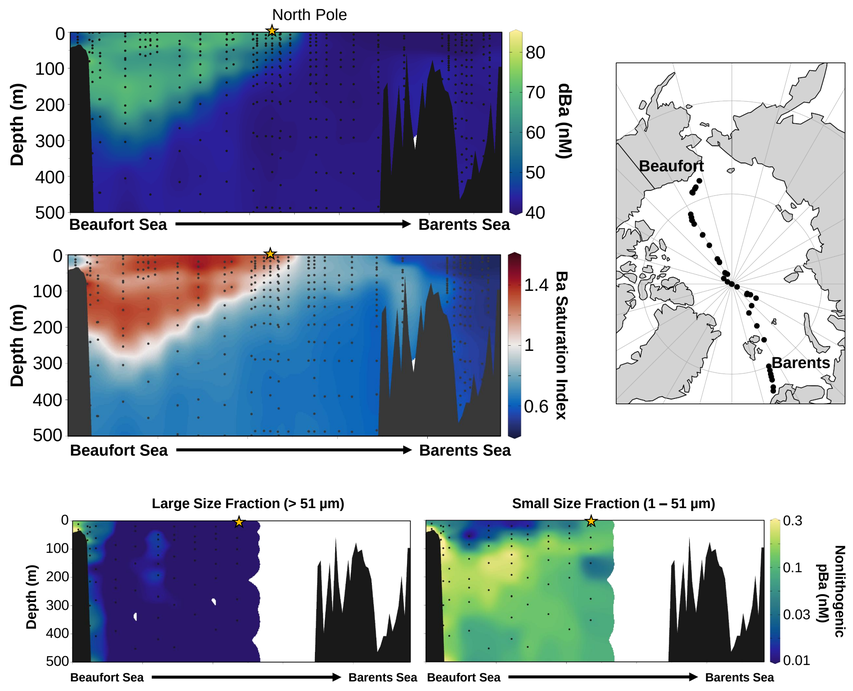
There are substantial non-conservative components to the dBa distribution in the Arctic Ocean.

- Ba flux from the shelf contributes the largest individual component to the surface 500 m of the basin.

We observed a large range of POC:pBa ratios and a log-linear relationship between pBa and POC; median and mean values from this study are higher than previous records.

A linear Ba isotope and 1/[dBa] trend indicates mixing is a dominant process, but mixing of what endmembers?

Barium Distributions

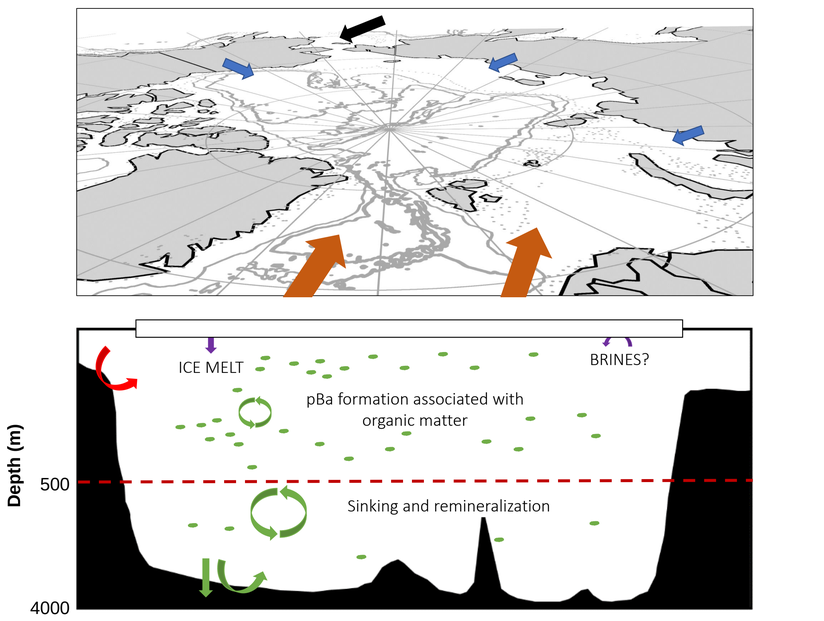


Mass Balance

Inputs

Outputs

$$f_{Pacific} + f_{Atlantic} + f_{Rivers} + f_{ice} + f_{shelves} = f_{pBa} + f_{ice} + f_{transport}$$



Ba distribution is controlled predominantly by inputs from Atlantic, Pacific, and riverine contributions. The role of ice, pBa, and shelves on the Ba mass balance is poorly constrained.

We assume that ice and pBa input and removal terms are small; we solve for the shelf flux considering only the surface 500 m:

Simplified Form

$$f_{shelves} = f_{transport} - f_{Pacific} - f_{Atlantic} - f_{Rivers}$$

Flux Term	Flux ($\mathbf{mol\ Ba\ y^{-1}}$)	Budget
$f_{transport}$	2.2×10^{10}	–
$f_{Pacific}$	2.0×10^{9}	9.1 %
$f_{Atlantic}$	9.4×10^{9}	42.3 %
f_{rivers}	8.1×10^{8}	3.6 %
f_{shelf}	$\mathbf{1.0 \times 10^{10}}$	**45.0 %**

Ra-based Arctic f_{shelf} estimate:

$$f_{shelf} = \frac{Ba}{Ra} \times f_{shelf\ (Ra)}$$

$$\mathbf{9.1 \times 10^{9}\ mol\ Ba\ y^{-1}}$$

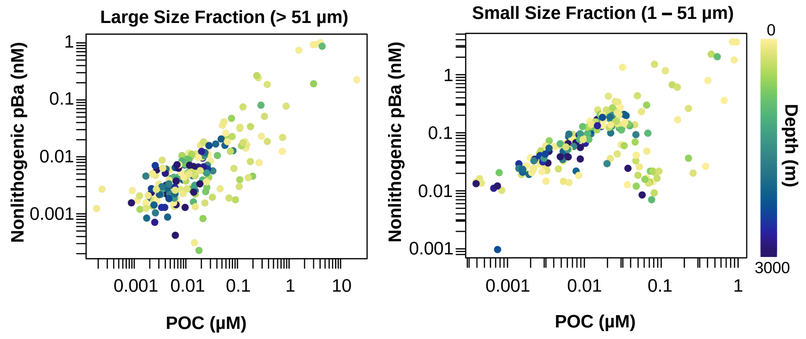
Ra flux from Kipp et al. (2018)

Area scaled benthic flux chamber estimate:

$$\mathbf{2.5 \times 10^{9}\ mol\ Ba\ y^{-1}}$$

California shelf benthic flux from McManus et al. (1994)

Carbon Proxy



C_{org}:$pBa_{nonlithogenic}$ (mol:mol)

Study	Range	Median	Mean
This Study	90 – 90,000	2,260	6,450
Thomas et al. (2011)	*Reported mean of literture values:*		2,575
Francois et al. (1995)	240 – 7,200	916	1,350
Dymond et al. (1992)	263 – 1,410	630	2,600

Barium Behavior

If dBa behaves conservatively then we expect:

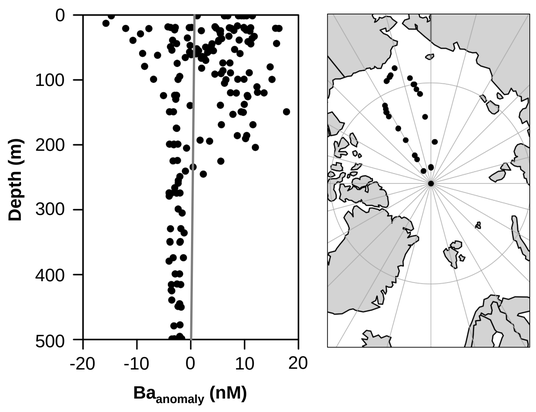
$$Ba_{pred} = Ba_{rivers}\ (f_{rivers}) + Ba_{Pac}\ (f_{Pac}) + Ba_{Atl}\ (f_{Atl}) + Ba_{ice}\ (f_{ice})$$

We define $Ba_{anomaly}$ as the difference between observed and predicted Ba:

$$Ba_{anomaly} = dBa_{obs} - dBa_{pred}$$

Using water mass fractions from Pasqualini et al. for the US transect, we observe a positive Ba anomaly between 25 and 250 m, which is consistent with Pacific-derived waters. **Is this evidence of a shelf Ba signal?**

Endmember	dBa (nM)
Pacific	57
Atlantic	45
Rivers	100
Ice	0



Isotopes

Barium isotopes have a linear relationship, which indicates mixing – although of what endmembers is unclear. Two low [dBa] shelf samples deviate from the trend.

A full water column profile from the Canada basin has an isotopic maximum around 500 m, likely indicating formation of barite. The particle maximum is above the isotopic maximum and likely indicates lateral transport of pBa off the shelves.

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