Deconstructing Changes in the Strength of the Arctic Halocline and Nutrient Fluxes

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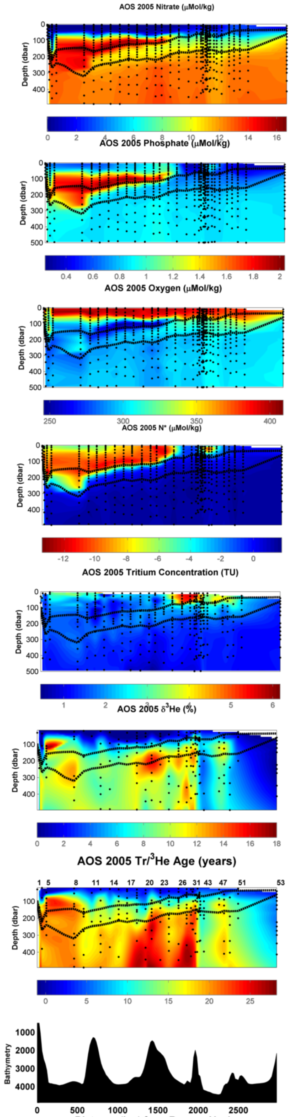
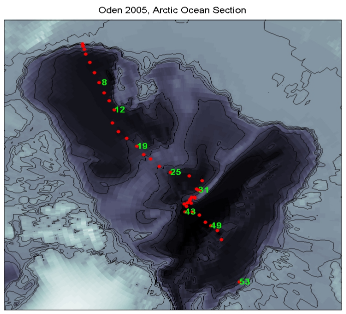
Nutrients fluxes from Tr/He tracer ages:



2005 Arctic Ocean Sciences Hydrological Stations

In 2005 Icebreaker Oden occupied 42 hydrographic stations between Barrow, Alaska, and the Barents Sea. Nutrients, stable isotopes, and transient tracers were collected, along with CTD traces of salinity, temperature, flourescence and transmissivity.. Here we combine tritium/helium ages with nutrient concentrations to estimate rates of nutrient regeneration below the mixed layer, in the Arctic Halocline.



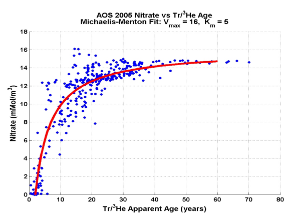
Freshwater from river runoff and ice melt are drawn to the Canadian Basin by anti-cyclonic wind patterns. Centered at about 350 meters depth is the "Atlantic" layer of relatively warm, salty water. The Atlantic and surface waters are separated by a strong halocline. The Upper Halocline, above about the 33.1 salinity isoline, is distinguished by high nutrient concentrations and is strongly influenced by North Pacific water detraining from the Chukchi shelf. The Lower Halocline, between about 33.1 and 34.5 psu, is a mixture of waters with their origins in the North Atlantic and on the Arctic shelves. We analyzed respiration and regeneration rates separately in the upper and lower haloclines and calculated water column averages. The result is basin-scale estimates of the export productivity.

	DOx/DAge	DN/DAge	DP/Dage
Upper Halocline	5.4	0.76	0.065
Lower Halocline	2.9	0.38	0.027
g C per sq. m.	3.2 - 6.4	3.3 - 6.6	4.1 - 8.2

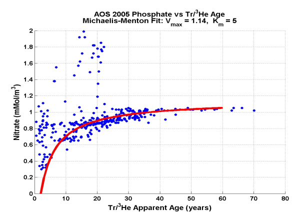
μMols/kg-year

Calculation of export production in grams of Carbon per square meter is based on:
- Polar mixed layer 20 meters thick.
- Average depth of the base of the Upper Halocline: 93 meters.
- Average depth of the base of the Lower Halocline: 180 meters.
- Average Regenerated-C::AOU ratio: 0.9.
- Standard (global average) Redfield ratios (106C : 16N : 1P)

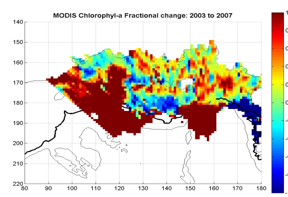
Nutrient regeneration rates are estimated from the correlation between nutrient concentrations and the "Tritium-Helium" age. This radioactive tracer age, is a biased estimator, systematically but non-linearly underestimating the mean time since last surface contact. Data from the Atlantic boundary current in the Canadian Basin indicates that the Tr/He age may be as low as half the mean age. Uncertainty in the true age and the variations in the nutrient regeneration ratios are the main sources of uncertainty.



Nitrate concentrations asymptote with time, indicating that regeneration is supply limited. We fit the nitrate/time relationship with a Michaelis-Menton rate equation, which indicates an asymptote of 16 microMols per kg. This value is a measure of the basin-averaged export production, much of which takes place on the shelves, and is advected isopycnally over the deep basin.

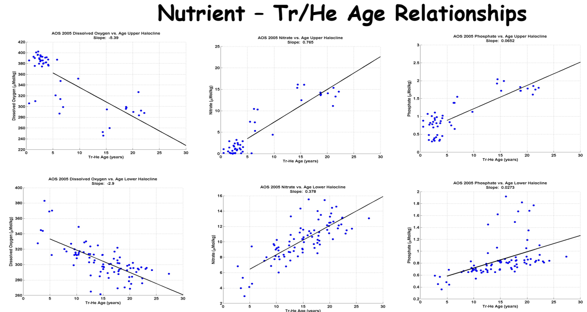


A scaled version of the Nitrate/Age M-M curve fits phosphate regeneration, except for a significant number of high phosphate samples. These are advected into the Canadian Basin from the Chukchi shelf. North Pacific water (aka: Bering Strait Inflow) is high in phosphate, but not as high as Lower Halocline Water, which also carries an indigenous Arctic shelf signal.

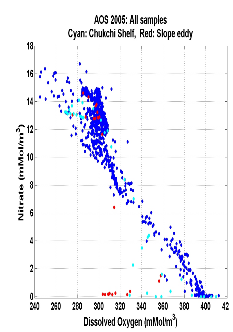


As the Arctic growing season lengthens, chlorophyll concentrations increase over the continental shelf and the southern Canadian Basin. With higher surface productivity, export is likely to rise and the nutrient asymptote should increase. Hydrographic and tracer cruises can track changes as integrated along isopycnals.

Nutrient – Tr/He Age Relationships

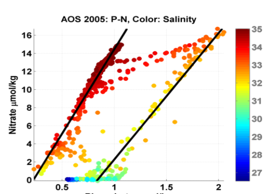


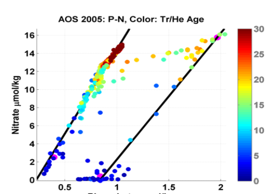
Plots above show changes in O2, NO3 and PO4 concentration with age in the Upper and Lower Halocline layers. (Mixed layer samples were excluded from correlation calculations.) Respiration rates are roughly twice as high in the Upper Halocline. Hi-PO4 anomalies are Chukchi Shelf water.



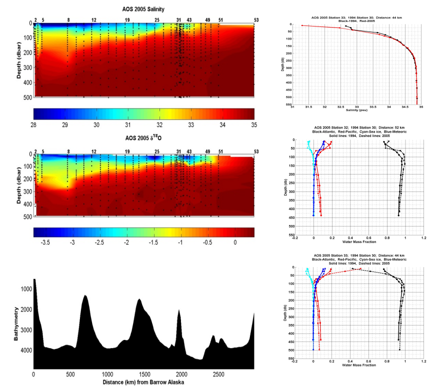
Dissolved-oxygen/nitrate ratios are consistent, except over the Chukchi shelf, and in a large eddy at the shelf break. The eddy is warm, fresh, nutrient-depleted, and carrying Chukchi Shelf plankton communities eastward along the continental shelf.

Nitrate/phosphate relationships are used in the Arctic to identify waters that have a significant fraction of North Pacific water. Clustered along the low-phosphate line are waters of mainly Atlantic origin; those near the high-phosphate line are heavily influenced by Pacific and/or shelf-water. Water moves along either of the black lines through photosynthesis/respiration and between them through mixing, nitrification or denitrification. The string of samples between the two hi-nutrient ends of the lines are in the Lower Halocline. Those between the lines at the low-nutrient end are near-surface samples near the boundary between the Canadian and Eurasian basins. Large gradients in the source regions over the shelves are smoothed by isopycnal mixing over the deep Canadian and Eurasian Basins, giving Arctic-wide averages.





Freshwater Content and Source Changes: 1994 - 2005



Using oxygen isotope ratios, salinity, and nutrient concentrations one can decompose the freshwater anomaly into Atlantic, Pacific, Sea-ice Melt and Meteoric components. Between 1994 and 2005 the upper waters of the Makarov Basin, where the two AOS cruises overlap, freshened significantly: by an average of 3.5 m total column freshwater inventory. The shift between Atlantic and Pacific derived ocean waters did not contribute to this freshening. 1 meter came from increased sea-ice melt (or decreased net sea-ice formation) and the major fraction, 2.5 meters, came from increased meteoric water: river runoff plus local precipitation.