Gallium vs. Nutrients to Separate Atlantic and Pacific Source Waters

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The 2015 Arctic GEOTRACES cruise (GN01) provided the first basin-scale transect of trace elements and isotopes across the central Arctic Ocean. Samples from similar tracks (AOS94, AOS2005) have been decomposed into four water masses: meteoric water, sea-ice melt/brine, and two salt-water end members: Atlantic inflow and shelf-modified Pacific inflow. This separation has been performed in a phase space defined by oxygen isotope ratios, salinity, and one of several quasi-conservative combinations of nutrients, based on their Redfield ratios. Crudely speaking, salinity separates fresh from salty water and oxygen isotopes separate meteoric water from sea ice melt or brine. Salt water has been separated into high- and low-nutreint end-members, with higher concentrations associated with Pacific and lower concentrations with Atlantic inflows. Known problems include endogenous Arctic nutrient sources, varying Redfield ratios, and non-Redfield sources and sinks (nitrification, de-nitrification, phosphate dissolution). We explore the potential of gallium concentrations (high in Atlantic and low in Pacific waters) as a more conservative alternative.

The comparison reveals qualitative agreement, but with a systematic difference. The gallium-based decomposition yields a smooth transition between the halocline and Atlantic layers, while nutrient based solutions have abrupt transitions. To explore the physical implications we apply a 1-D advection-diffusion model to estimate an apparent vertical mixing coefficient. We assume the Arctic water column is in steady state, fed from below by slow bottom-water formation, and mixed by a background diffisivity. The best match of the model to the nutrient-based profiles is at the low end of plausible mixing coefficients: $1x10^{-6}$ m^2s^{-1}. Gallium-based profiles require approximately an order of magnitude more mixing, which is also plausible, but at the high-end of observed mixing rates away from rough topography. Interestingly, salinity and temperature yield similarly different coefficients ($K_{z\text{-temp},} > K_{z\text{-salt}}$). We discuss the implications of these results for ventilation of the upper and lower Arctic halocline layers.