Proxies of particle flux: from the modern ocean to the $^{231}Pa_{st}$

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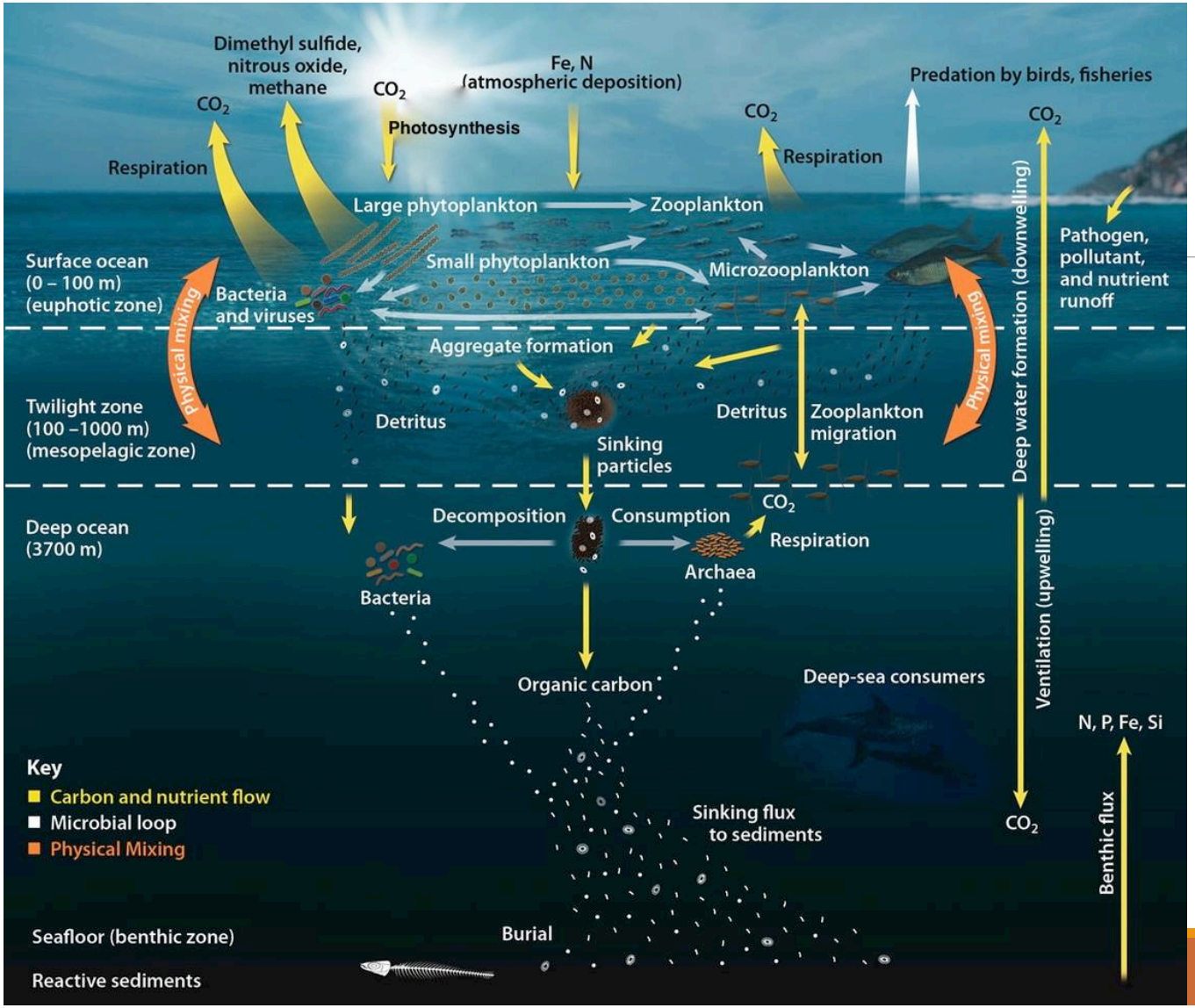
Motivation: Quantifying the deep ocean receptacle

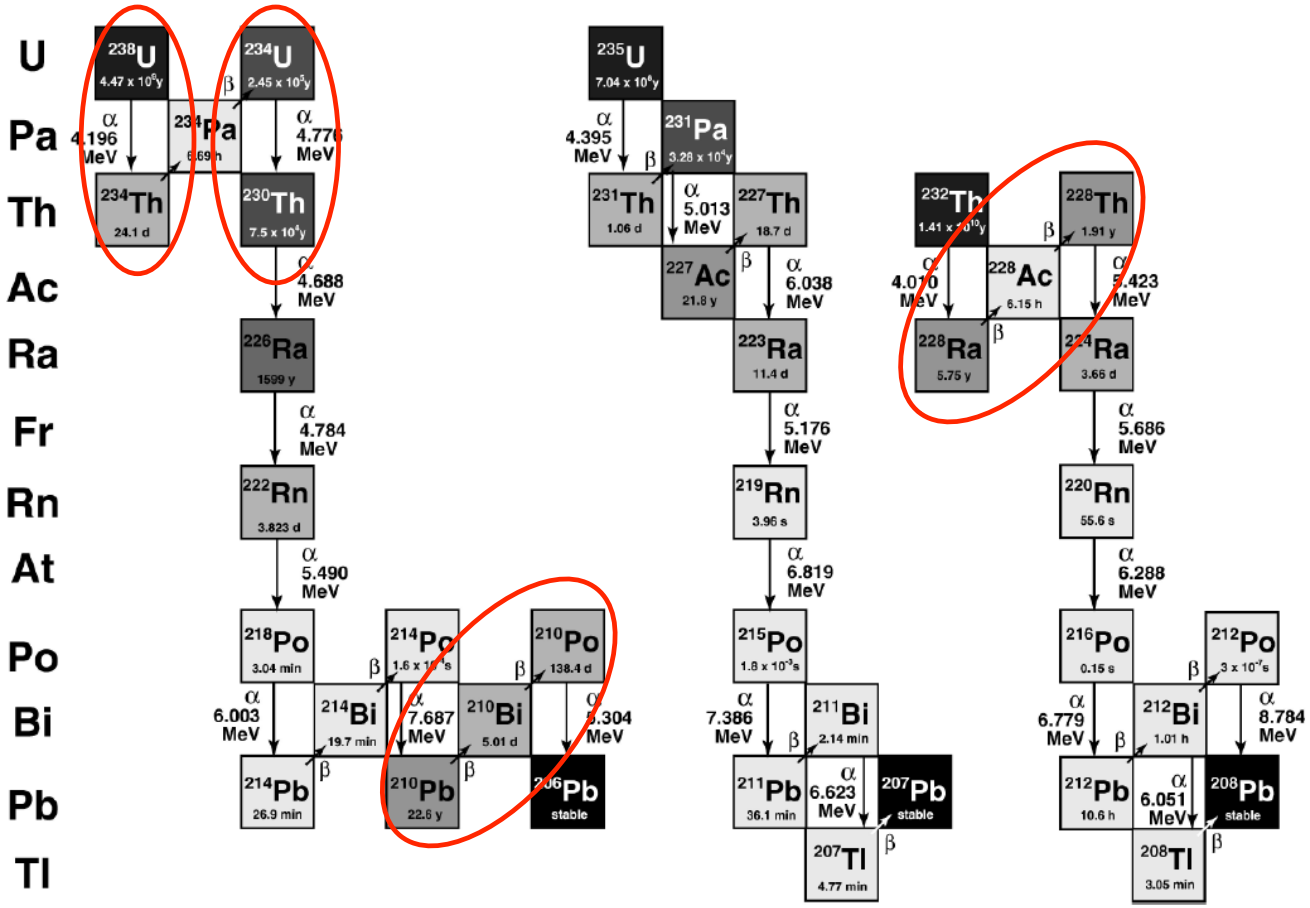


- Important to quantify:
  - Carbon storage
  - Nutrient/trace metal availability

- Radionuclides as sediment traps for the past

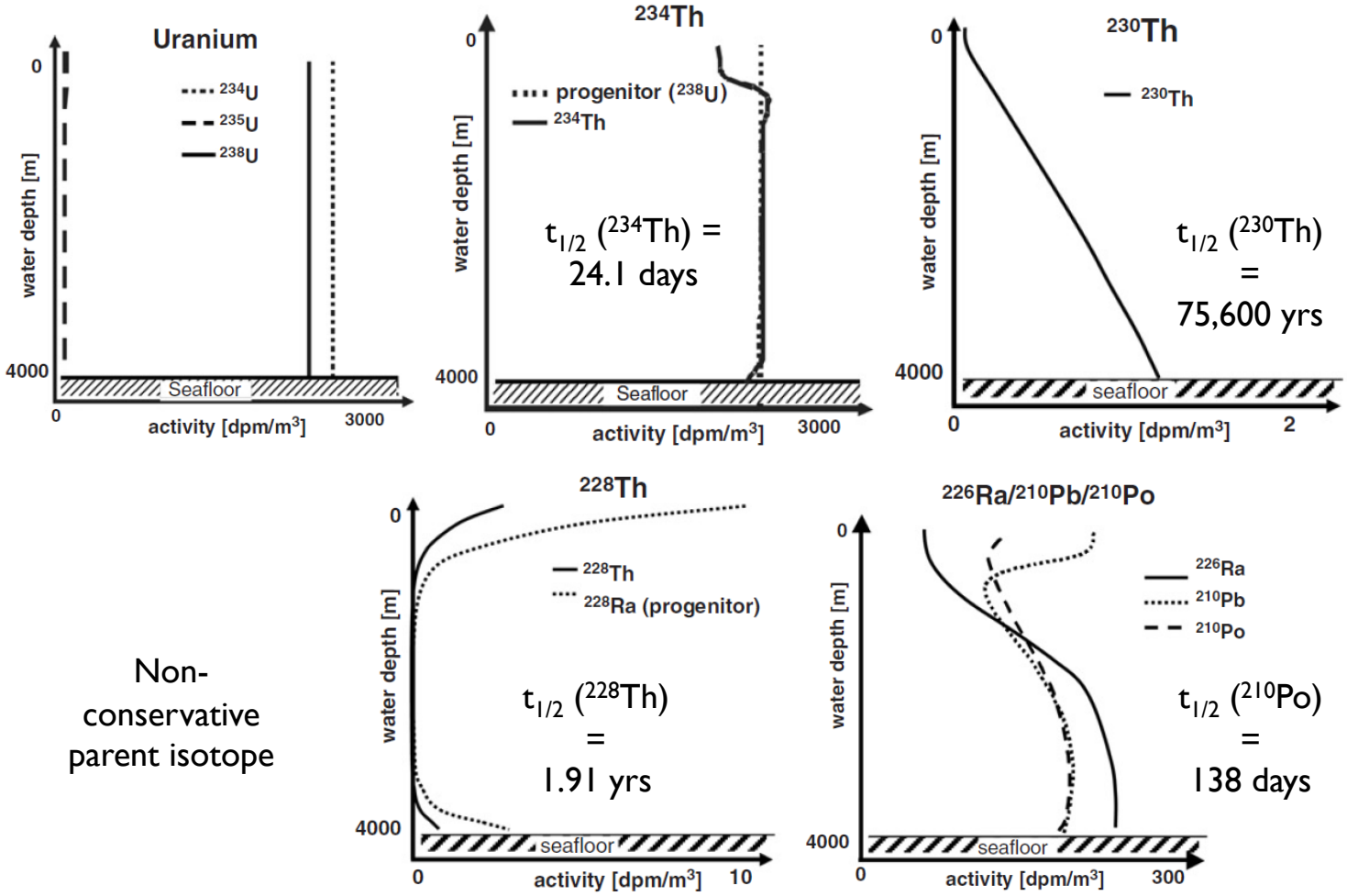
DOE report, 2008 (genomicscience.energy.gov)

Nuclide Pairs Tracing Particle Export



Typical Oceanic Profiles

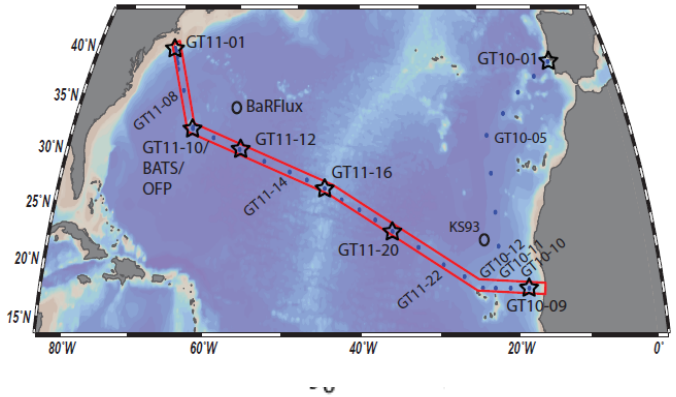
Soluble, homogeneous parent isotope

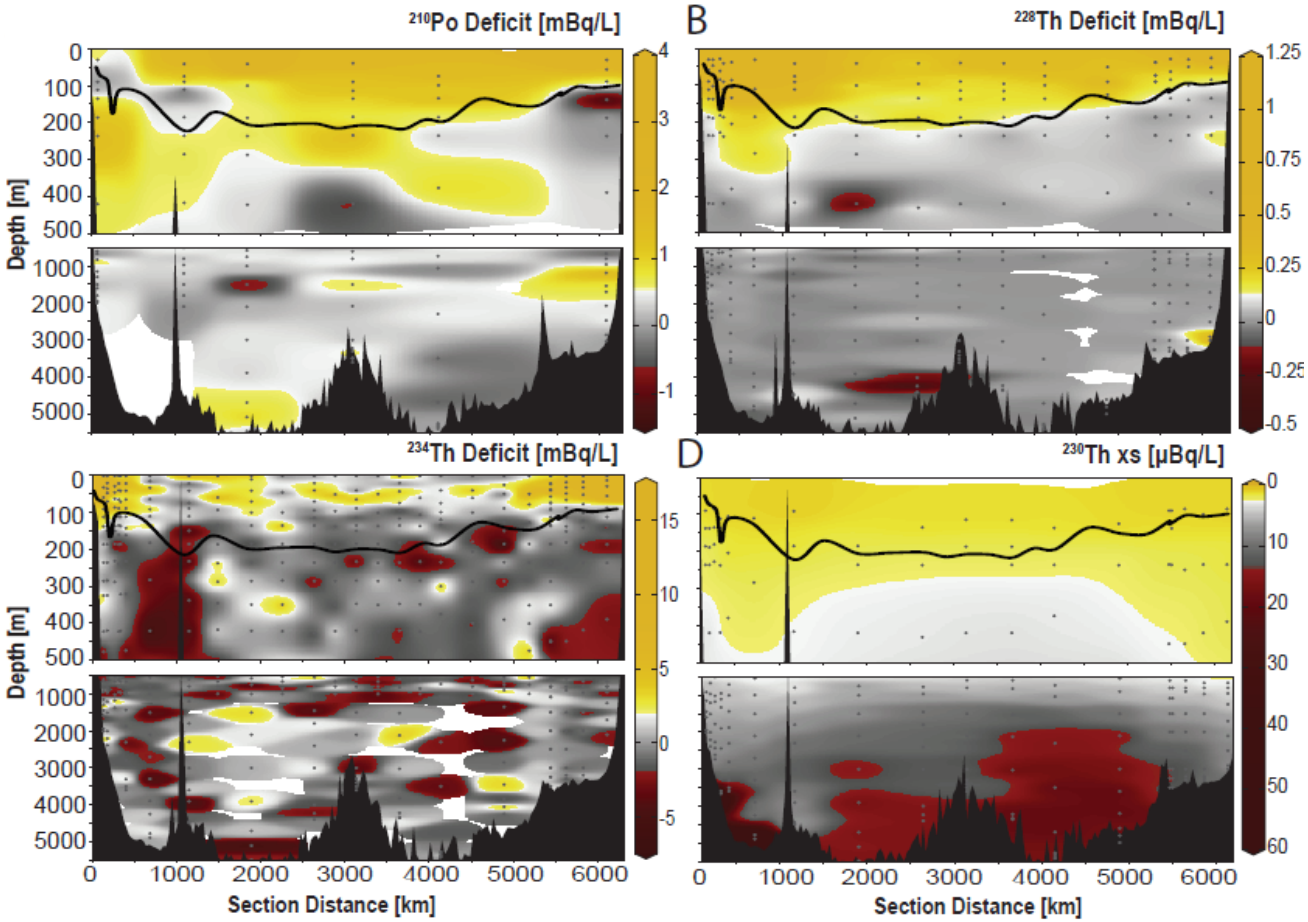


Non-conservative parent isotope

Radionuclide Deficits Due to Sinking Particles

GA03 GEOTRACES Section





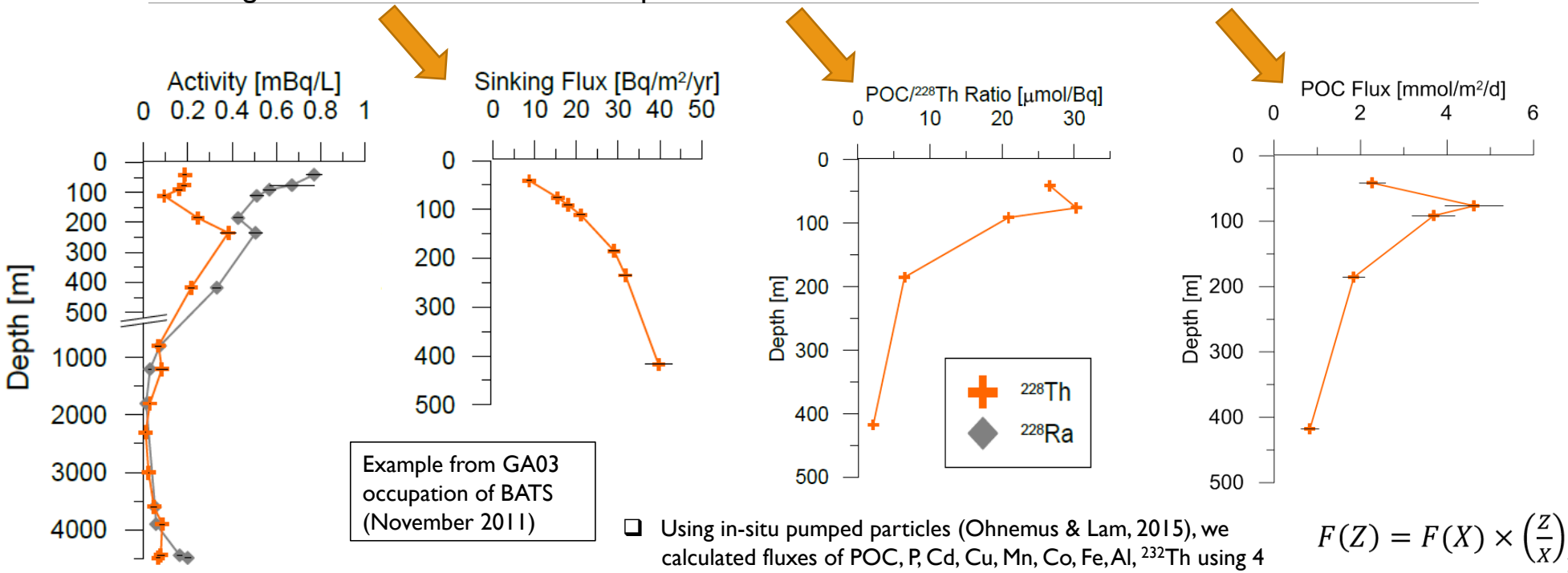
Hayes et al., 2019 *Global Biogeochemical Cycles*
data from: Owens et al., 2015 *DSR-II;* Charette et al., 2015 *Mar Chem;* Maiti et al., 2015 *Mar Chem;* Rigaud et al., 2015 *DSR-II;* Hayes et al., 2015a+b, *DSR-II + Mar Chem*

Converting from Radionuclide to Elemental Flux

1. Integrate nuclide deficit to get flux

2. Determine element/nuclide ratio in particles

3. Multiply ratio by nuclide flux to get elemental flux

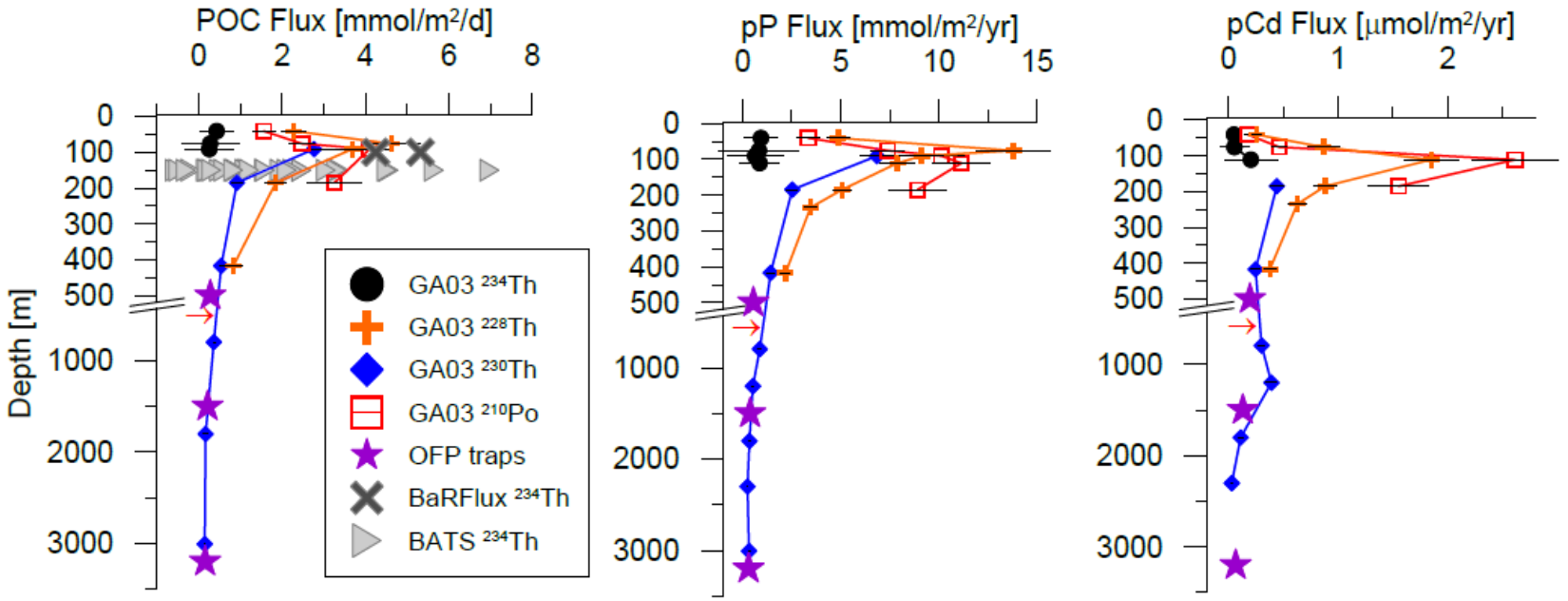


Example from GA03 occupation of BATS (November 2011)

- Using in-situ pumped particles (Ohnemus & Lam, 2015), we calculated fluxes of POC, P, Cd, Cu, Mn, Co, Fe, Al, ^{232}Th using 4 radionuclide methods

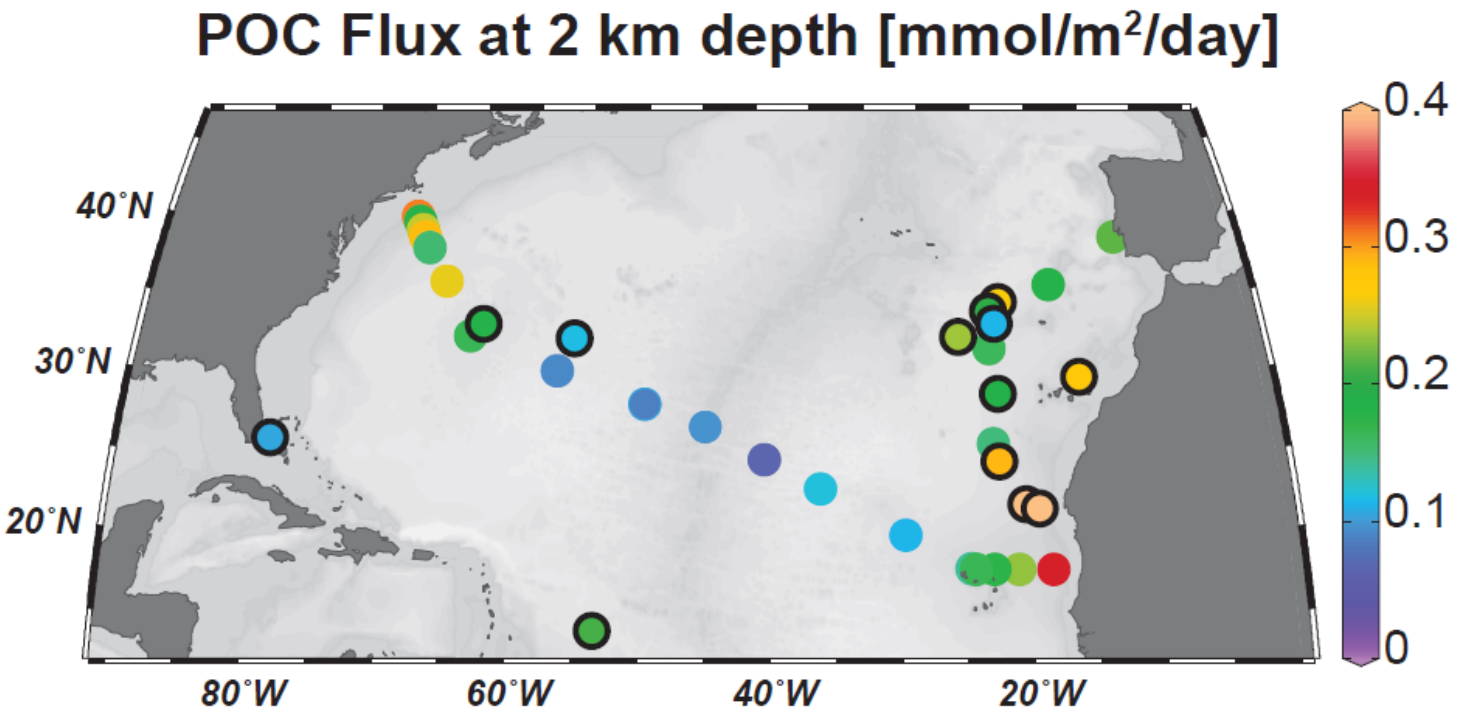
$$F(Z) = F(X) \times \left(\frac{Z}{X}\right)_p$$

Multi-method particle flux comparison at BATS: 1. Biogenic Elements



Hayes et al., 2019 *Global Biogeochemical Cycles*
OFP from Huang & Conte, 2009 *GCA*; BATS ^{234}Th time-series: Sweeney et al, 2003 *DSR-II* + Buesseler et al., 2008 *DSR-II*

Thorium-based carbon fluxes are consistent with and extend knowledge of deep sea sediment traps



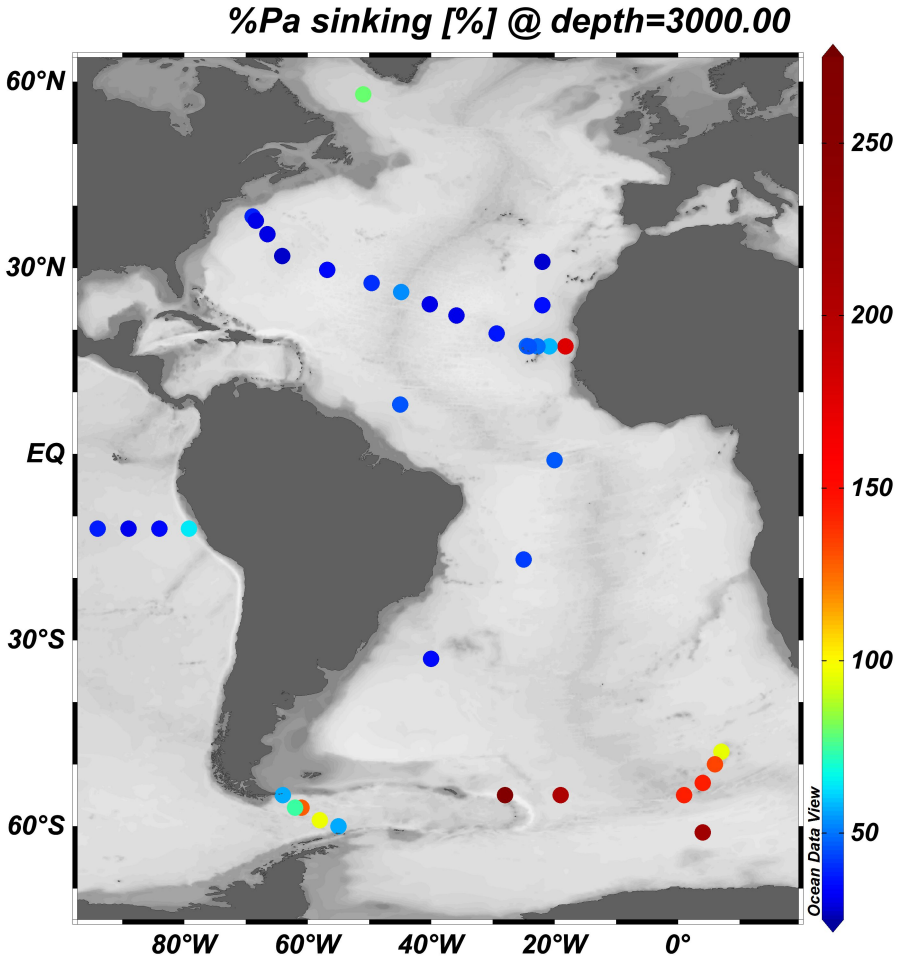
- Deep sediment trap data outlined in black

Hayes et al., 2019 *Global Biogeochemical Cycles;* Honjo et al., 2008 *Progress in Oceanography*

Implications

- ^{230}Th can be used to reconstruct preserved particle rain to the seafloor over the past ~400,000 years for any element or component of the sediments
  - Caveats relate to grain-size and circulation effects, uncertainty generally <30%
- Many applications for reconstructing particle rain of biological components, mineral components, trace metals…

- Can we reconstruct the global sinking flux of ^{231}Pa to demonstrate the nature of its lateral transport?
  - Use particulate ^{230}Th to get deep sinking flux
  - Multiply by particulate ^{231}Pa/^{230}Th to get sinking particulate ^{231}Pa flux
  - Sinking flux divided by its production rate is a measure of how much removed to the seafloor in that location



Making the budget of ^{231}Pa

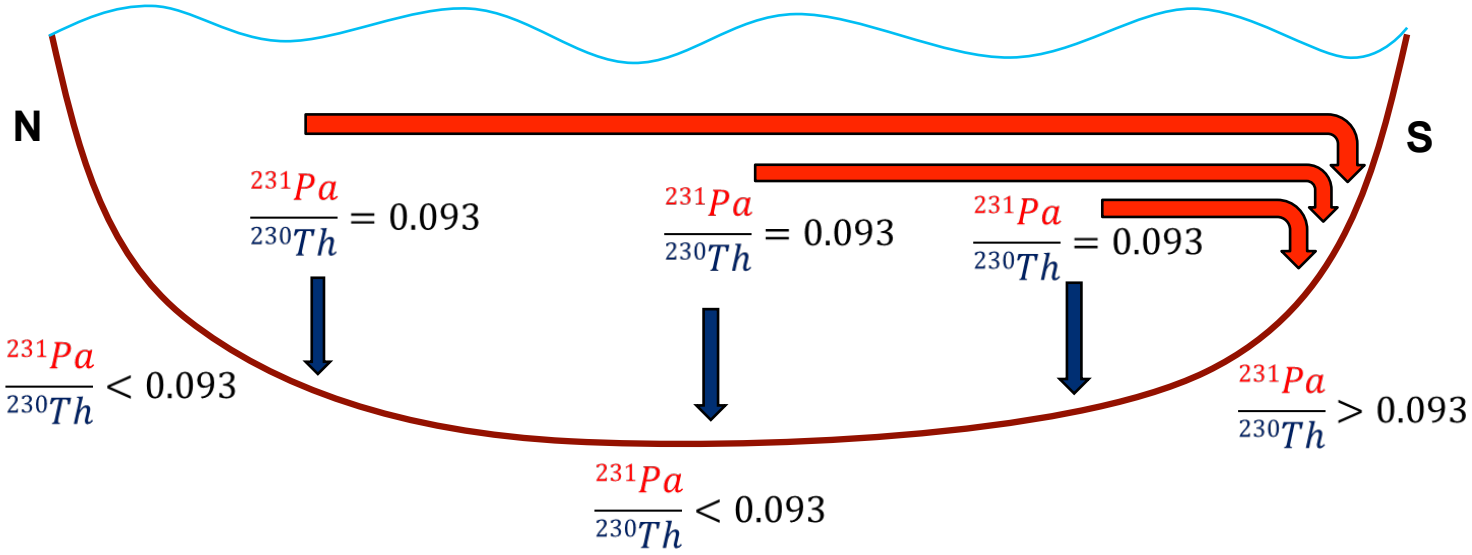
% of water column ^{231}Pa production sinking across 3 km depth

$$= \frac{Sinking^{231}Pa\ flux(z)}{\int_0^z {}^{235}U * \lambda_{231}\ dz}$$

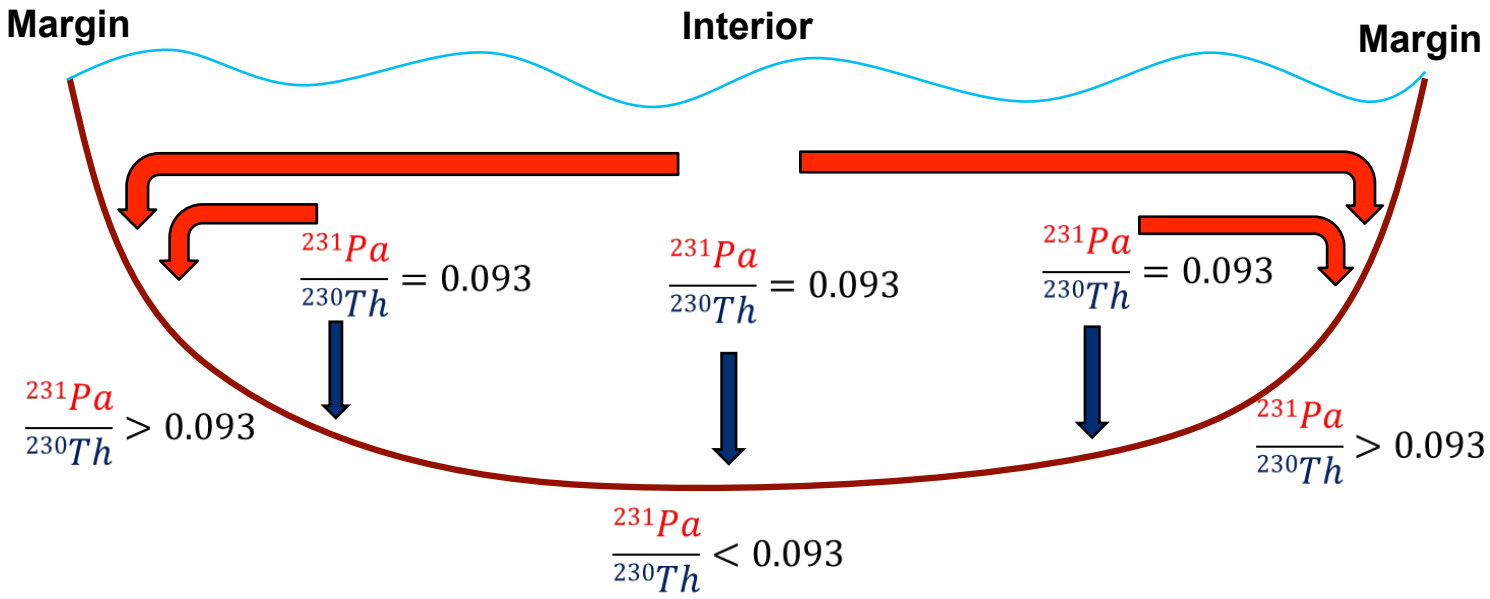
- Can all of the ^{231}Pa produced be accounted for in the Atlantic?
- Is it all moved to the Southern Ocean or is some moved north or to the margins?

Hayes et al., *for this* meeting; Hayes et al., 2015 *Marine Chemistry*; Pavia et al., 2018 *Marine Chemistry*; Henderson database: Venchiarutti et al., 2011 *Deep Sea Research II;* Moran et al, 2002 *Earth and Planetary Science Letters*; Rutgers van der Loeff et al., 1993 *Deep Sea Research I*

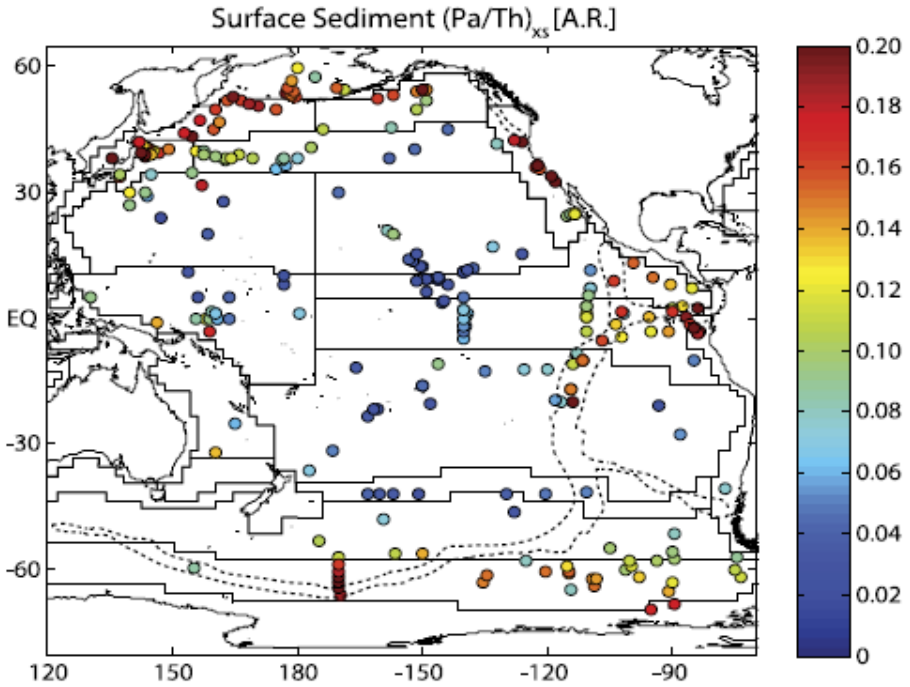
The Atlantic Pa Regime:
Southern Ocean scavenging



The Pacific Pa Regime:
boundary scavenging

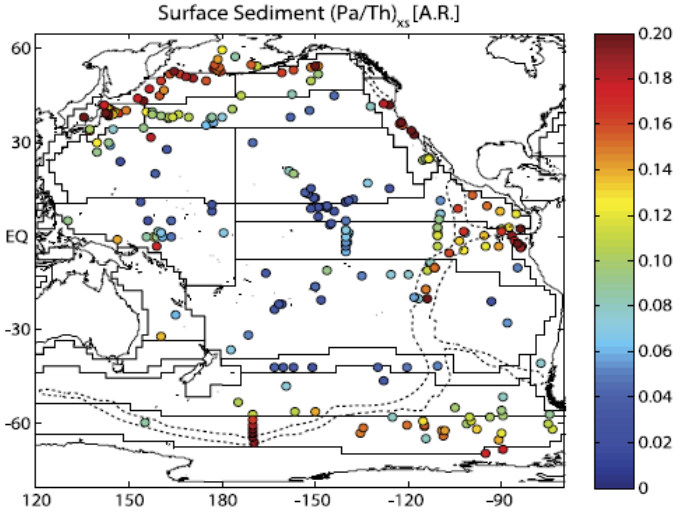


The Pacific Pa Regime:
biogeographic province scavenging

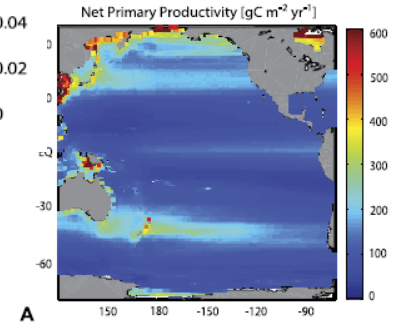


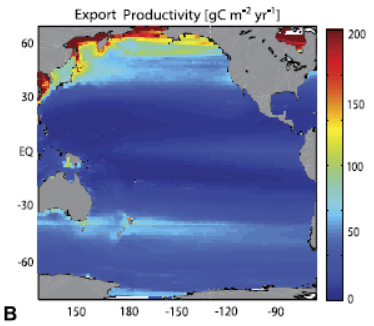
- Excess Pa burial occurs across provinces that support higher export/ opal productivity

Hayes et al., 2014 *Earth and Planetary Science Letters*

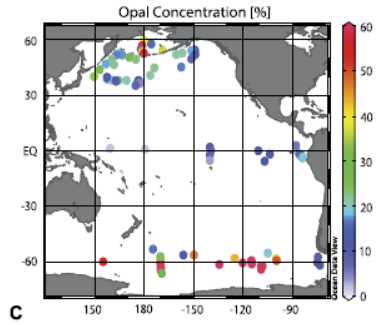


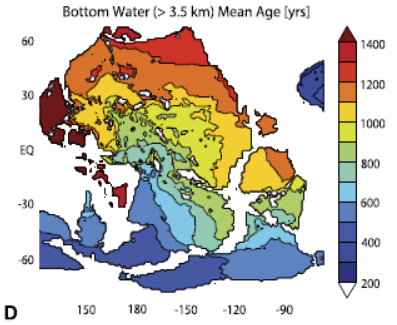
Result: Pa/Th surface sediment ratios

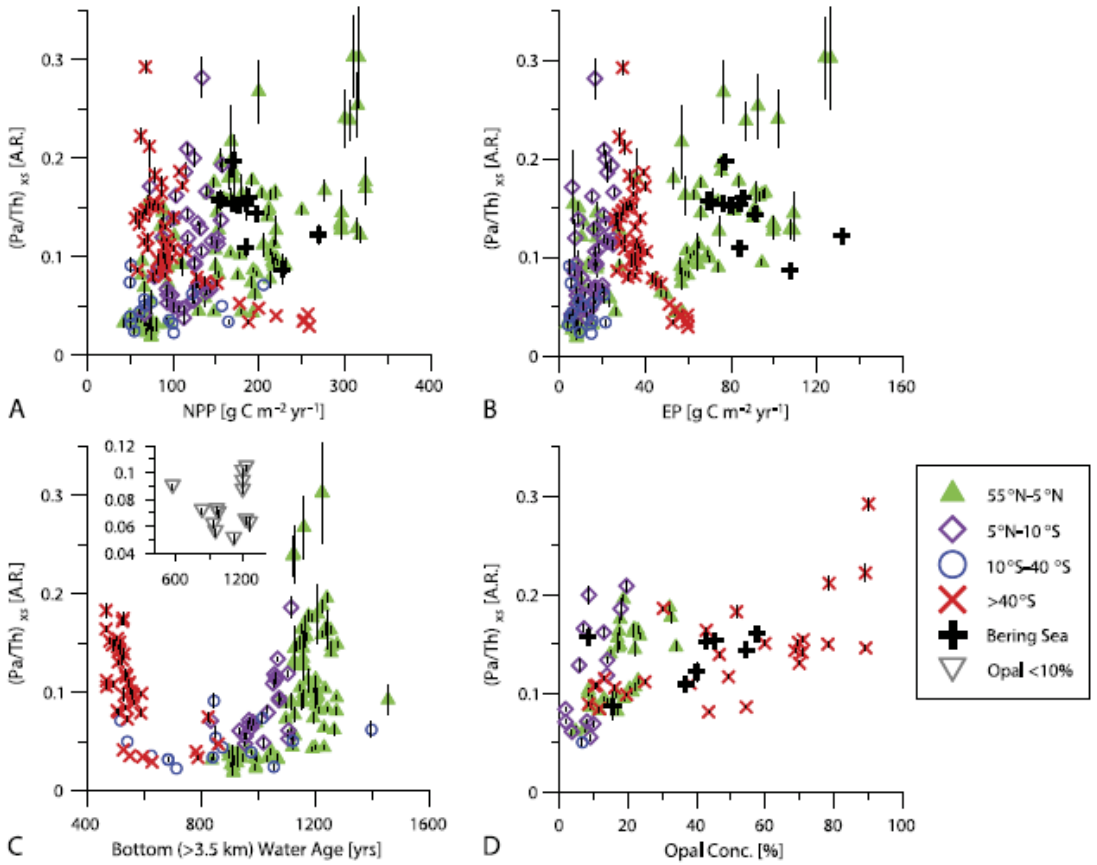




Potential Controls: NPP, EP, opal%, bottom water age





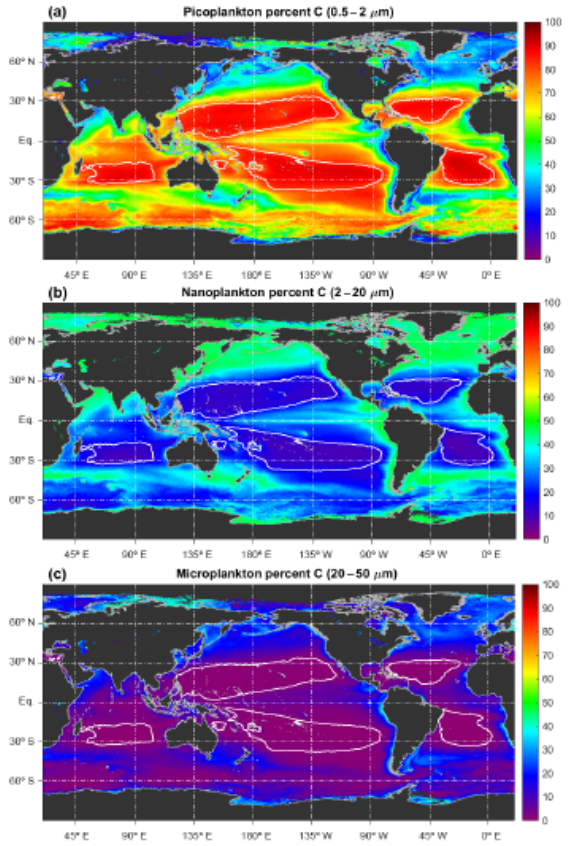


Opal has the best correlations…

Biogeographic provinces

Provinces have distinct phytoplankton groups

Hypothesis is that this is the source of contrast in particle flux and particle composition



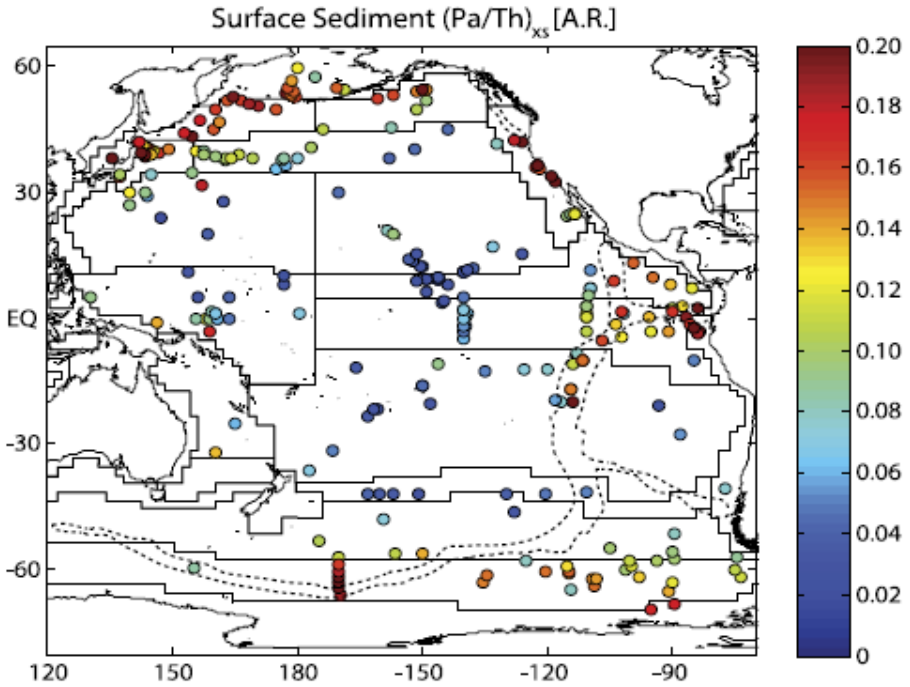
Pico (cyanos::poor exporter)

nano

Micro (diatoms::good exporter)

Kostadinov et al., 2016 *Ocean Sci.*

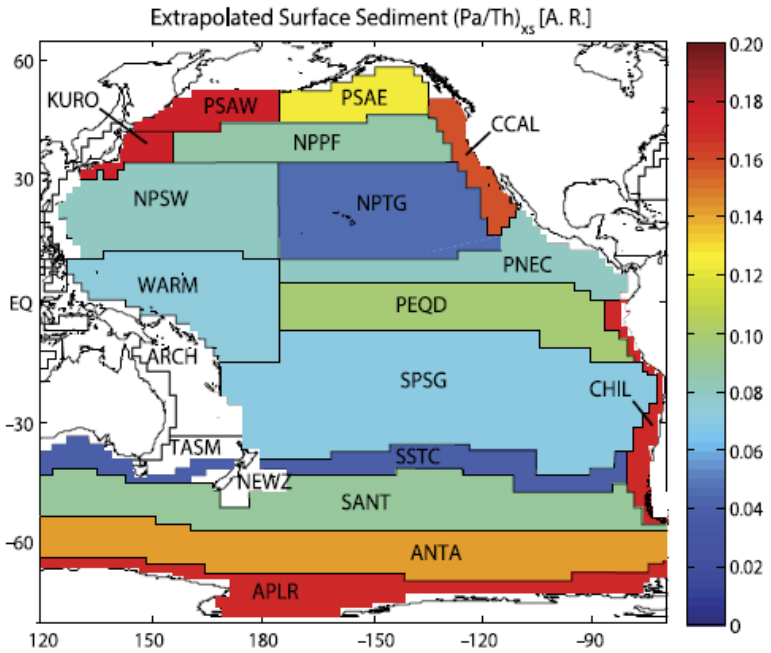
The Pacific Pa Regime:
biogeographic province scavenging



- Let's use the provinces to extrapolate the unknown areas and fill in the basin budget

Hayes et al., 2014 *Earth and Planetary Science Letters*

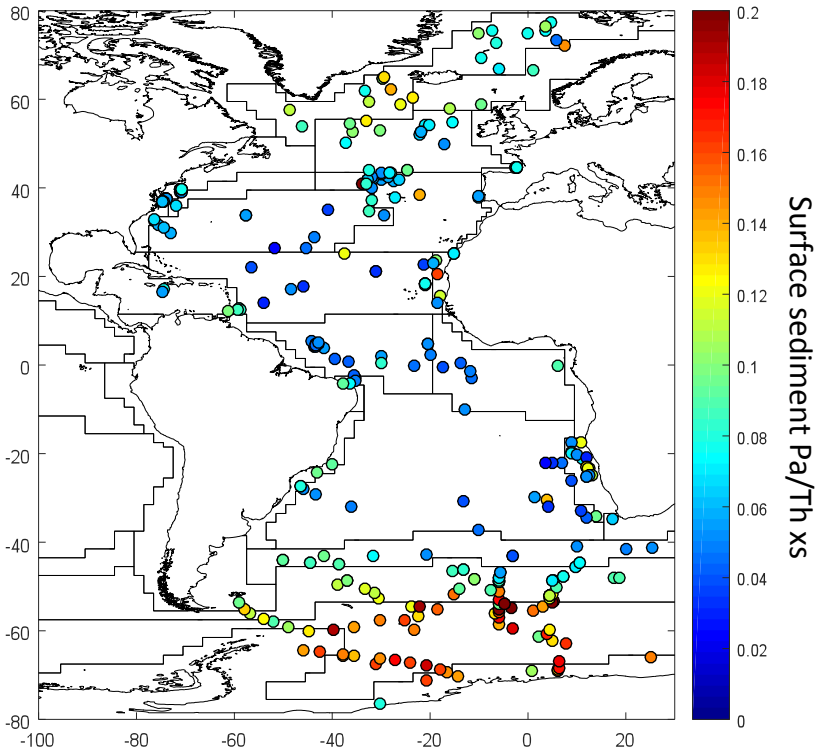
The Pacific Pa Regime:
biogeographic province scavenging



- Assume flux of ^{230}Th is equal everywhere
- We can account for ~93 ± 3% of the Pa production with observed surface sediments
- The Pacific Pa budget is in balance

Hayes et al., 2014 *Earth and Planetary Science Letters*

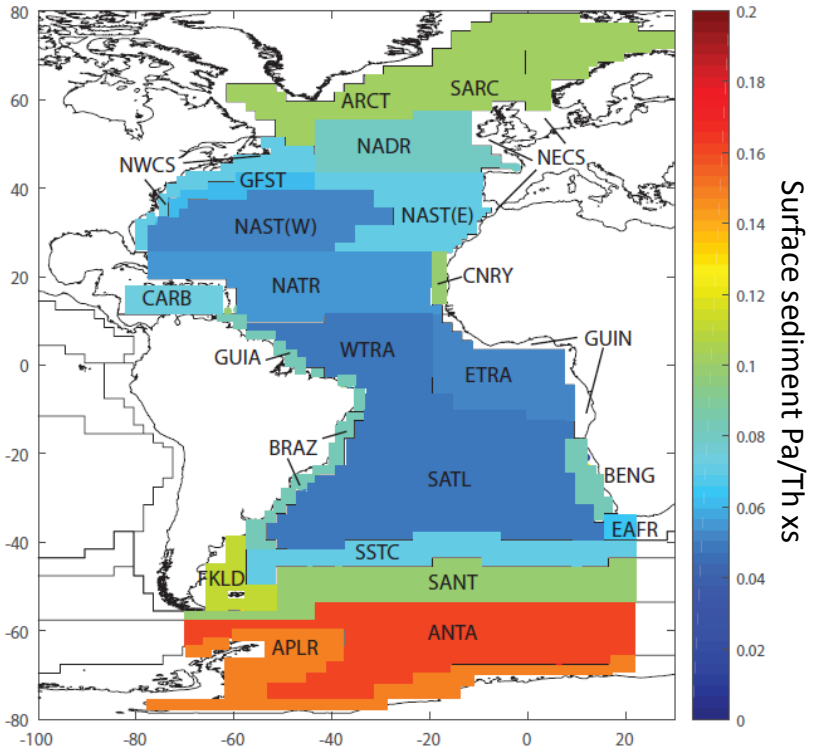
The Atlantic Pa Regime:



- Large depletion of Pa/Th in North Atlantic
- Overall, the Atlantic high productivity provinces are less enriched in Pa
- Little obvious zonal gradients

Hayes et al., *for this meeting*; Henderson compilation; also Bradtmiller et al., 2014 *Nat. Comm.*

The Atlantic Pa Regime:



- About 80±5% of Atlantic Pa production is accounted for in surface sediments (missing Pa sinks?)
- The Pa deficit in the South Atlantic is larger than the North (cf. Deng et al., 2014)
- Is Pa/Th distribution is a combination of transport and regional contrast in particle flux?
  - How to disentangle?

Hayes et al., *for this meeting*

Some other ideas for the working groups…

- What is the true geographic representativeness of your core?
- The ocean is divided into particle flux regimes, largely due to fundamental productivity patterns, availability of nutrients, light & physical fronts
- Are there other modern distributions we should take advantage of to interpolate sparse sites?
  - Dust deposition regimes?
  - Sediment composition regimes?
  - Hydrothermal regimes?