Theme 3: Export and Regeneration

Can do now (have the data)
Intermediate time scale (have some data)
Longer term time scale (scoping)

1. **How do export and regeneration processes and rates vary with depth?**

Talks:

- Alan Shiller:
  - Variability in rare earth profiles is related to mixing of water masses with different preformed values
  - Some trends in Nd and AOU (but some trends independent of it)
  - Cerium anomaly may not be due to reductive dissolution, but corresponds better with Th-232 (suggesting a terrigenous signal)
  - Biological signal associated with La in the Deepwater horizon methane plume (light rare earths are required for some methane dehydrogenases)
- Dave Kadko:
  - ^{7}Be to get shallow intense respiration rates at BATS
  - important to discern the mechanism of the DOC source to the derived OUR
  - if you integrate over the whole layer you can get a net rate (but miss out on mechanisms)
- Greg Cutter:
  - Nitrite signal (nM) matches hot spots in AOUR (µmol m^2/yr)
    - Need to assume a stoichiometry
- Erin Black:
  - ^{234}Th data from 3 basins (can also use ^{228}Th in Arctic)
  - question 4 (how does Th in large fraction related to small size fraction)
- Bob Anderson
  - ^{230}Th is all removed on particles (can apply paleo principles to the water column)
    - can see flux gradients in the upper water column that match multi-year trap data
    - spatial variability of POC flux across the eastern NAZT from station 9 to 16
    - compare to other isotopes to see if we agree at that depth interval
  - need to account for upwelling as a cross-check

Notes:

- How can we better define the depth dependence of export and regeneration?
- Does the depth dependence of processes and rates vary with environmental conditions?
- Horizontal versus vertical processes (sinking versus subduction)

- What are particle sinking rates?
- Changes to TEI/C ratios with depth
- What are the controls on the different regeneration length scales of different TEIs?
  - (e.g. depth of ferricline versus nitricline)
- Do different data sets give us the same answer?

2. **How do processes and rates vary with time and space (e.g. different biogeochemical and physical regimes)?**

Talks:

- Bill Smethie:
  - age of water on the N Atlantic GA03 transect, OMP analysis
  - Ideal mean age (deep waters= 400 years; surface = 20 years)
  - Arctic cruise: deep water in Canadian basin is about 450 years old from C-14, but really its older (hundreds of years), implications for scavenging
  - Arctic surface waters are young (3-6 years)
- Rob Sherrell:
  - Sedimentary sources of TEIs from an ocean margin that are advected offshore (and modified by scavenging while moving offshore) will look like a regeneration signal in profiles offshore even when they might not be
    - Mn peak is slightly shallower than the Fe peak, likely reflecting a combination of depth of the source and scavenging processes
  - When comparing dissolved metal distributions and cell quotas, there is an advantage to exploring horizontal drawdown variation in surface water rather than in the twilight zone (within certain regimes). This avoids differential regeneration and scavenging in the twilight zone.
    - Can get net regeneration in the mixed layer when compare to the cell quotas from the cells that are contributing to export
- Pete Sedwick: process studies and looking at seasonal scales
  - dFe at BATS shows a strong seasonal variability which can be related to mechanisms (Langrangian fashion)
  - subsurface min associated with DCM, and surface dust feature
  - subsurface max could be associated with a regeneration feature below the DCM (intensity of this seems to be associated with the intensity of the chl max)
- Alyson Santoro: what is the relationship between metal distributions and rates/amount of nitrification
  - Steep gradients in biological processes around the DCM (50 fold increase in the remineralization rate around the DCM)
  - METZYME data: how is the high abundance of organisms in the deep ocean related to the abundance of metals in the surface ocean (or history of the water mass)
    - Can now map organisms (AOA- with Cu based respiratory chain, as well as an Fe requirement) over large spatial scales (similar to GEOTRACES)

- Alakendra Roychoudhury
    - Seasonal data in Southern Ocean shows biological draw down in the surface for Cd and Co compared to winter
    - Interesting Fe peak subsurface in the summer
    - Seasonal differences in dust sources to Southern Ocean
        - Also dust has a different composition depending on the season
        - Metals are mobilized from dust quickly (24 hours) and over longer time scales (5 days)
        - Impact of trace metals in dust to phytoplankton growth (can impact community structure and ultimately export)
- Molly Martin
    - OMZ age in EPZT is about 30 years
    - Take AOU combine with tracers to get OUR values (OUR= AOU/transient tracer age)
    - OUR max in the top of the oxygen minimum zone (could be an advective feature)

Notes:

- Seasonal? Longer term scales (global change) to be used for prediction?
- What are the bounds on some ocean circulation rate processes (overturning of upper thermocline, subduction) in different spatial regimes?
- How does circulation rates relate to export and regeneration rates?
- Why are there apparent regional differences in TEI regeneration?
- How do we separate the effects of regeneration (J) from mixing and transport signals?
    - Can we de-convolve J into its component processes (regeneration/scavenging)?
    - Can we use multiple TEIs?
    - How do we better constrain export using multiple strategies?
    - Compare Th, Ba, TEIs
    - How much is exported, regenerated, recycled
- What is the relationship between OUR and dissolved TEI distributions?
    - What is the regional dependence?
    - What is the difference between the vertical and horizontal processes
    - Can you differentiate these processes with modeling?
- What are the mechanisms and rates of regeneration of TEIs in the upper ocean and their sensitivity to environmental conditions?
- What is the effect of lithogenic inputs on export and regeneration?
    - Source vs. ballast

3. What is the relative importance of biotic versus abiotic processes and rates on export and regeneration?

Talks:

- Maeve Lohan:

    - LpFe vs. dFe gives you a kink in the data
    - In the open ocean the dFe is higher than the LpFe (vice versa in coastal region)
    - When add DFB to see that more dFe is remobilized (could indicate microbial activity in the oligotrophic region with high recycling)
        - AOU explains 60% of dFe
    - Enrichment of pFe/pAl (above crustal ratio) in the DCM
- Max Grand and Mariko Hatta
    - AOU vs. dFe if different ocean basins (needs to be done very systematically)
    - Good relationship in Indian Ocean until Bay of Bengal (means the high Fe is not only remineralization)
        - Can get net remineralization (Fe:C)
    - South of equator below dust input area (has lower dFe compared to AOU)
        - Some clustering of S. Atlantic data with higher dFe compared to AOU
    - Pacific zonal transect also falls along this plot
        - Can use all of this to classify individual regeneration rates and preformed Fe (compare net regeneration rate with cell stoichiometry data)
    - Does scatter represent scavenging, plasticity in stoichiometry, or depth integral integration(?)
- Barbeau/Maldonado
    - Shrimp can vertically migrate over 1400m
    - Other organisms can go very deep (thousands of meters, different seasonal time scales)
    - Important implications for organic matter export (important in high latitudes regions and in highly productive regions)

Notes:

- Elemental stoichiometry (regeneration length scales)
- What is the relative role of biota (bacteria vs. algal vs. zooplankton) in export and regeneration?
    - Zooplankton (euphausids vs. salps)?
    - Type of grazing/migration
    - Fecal pellets
- How do we better represent the role of ligands in regeneration of TEIs in models?
    - Tease out intermediate phases (leachable particulate)
    - Reversible scavenging of ligands?

4. **How do processes and rates vary along dissolved-particulate continuum?**

<u>Talks</u>:

- Steve Emerson:

- Change in DOC from preformed value as it relates to AOU can tell you how much of this respiration is due to DOC (over depth of 100-250m) compared to total respiration
- ΔDOC/AOU = 0.46
- 70% of respiration is fueled by DOC degradation (DOC from the top) at HOT
- 13% of respiration is due to DOC at BATS
- 14% at OSP
- fraction of annual NCP (mol m^2/ yr) due to DOC flux out of the ocean is 70% at HOT, 10% at OSP (particles main player, then zooplankton), 10% at BATS (particles, but very advective)

- Adrian Burd
  - Full size spectrum model of aggregation rates
    - 2 size class model with first order aggregation does not work
    - can still have 2 size classes but need interaction between the two size classes of particles

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Notes:

- What is the relationship between sinking and suspended material?
- Do the small slow-sinking particles have a role in buffering dissolved distributions
  - K_d
- How do we de-couple disaggregation (breakup) of particles versus remobilization?
- How do organic ligands mediate exchange between dissolved and particulate TEI distributions ?
  - Can we parameterize this in models?
  - Do they buffer leachable particulate metals (instead of "free" metals)

5. Do we understand the processes well enough to make predictions about the future and interpret paleorecords?

Talks:

- Katsumi Matsumoto: plasticity in P:N:C can buffer changes in POC export
  - Ratio is higher in subtropical regions
  - Climate change: expect increased stratification, fewer upwelled nutrients (can effect export)
  - Cellular allocation model solves for the optimal allocation of P:N for maximal growth (trying to add Fe, DOP, and temperature)
    - Gyres have highest C:P ratio (250-300)
  - Global carbon export from 1750-2200
    - Starts from about 10 PgC/yr in 1750 and decreases to 9.2 PgC (but is not as low if you have plasticity and 1% buffer)

Notes:

- How would we better represent particle dynamics in models?
  - Parameterizing aggregation/disaggregation dynamics in global models (20 size classes, 1um-)
  - Export (different than martin curve)
  - Integrals of the size distributions (5 or 6 moments): difficult to related to the TEIs
  - Can relate 2nd moment to TEIs scavenging
- How do we incorporate simple biological processes to better constrain TEI cycling?
- Sensitivity of export and regeneration to climate change (and vice versa)
- What are the mechanisms and rates of regeneration of TEIs in the upper ocean and their sensitivity to environmental conditions?
  - Changes in krill, salps abundance (changes to export efficiency)