A Global Compilation of size-fractionated POC, $CaCO_3$, and Opal Concentration Profiles in the Mesopelagic

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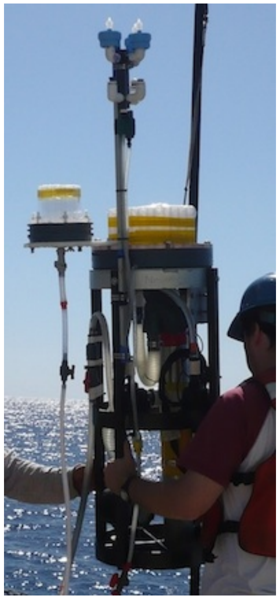
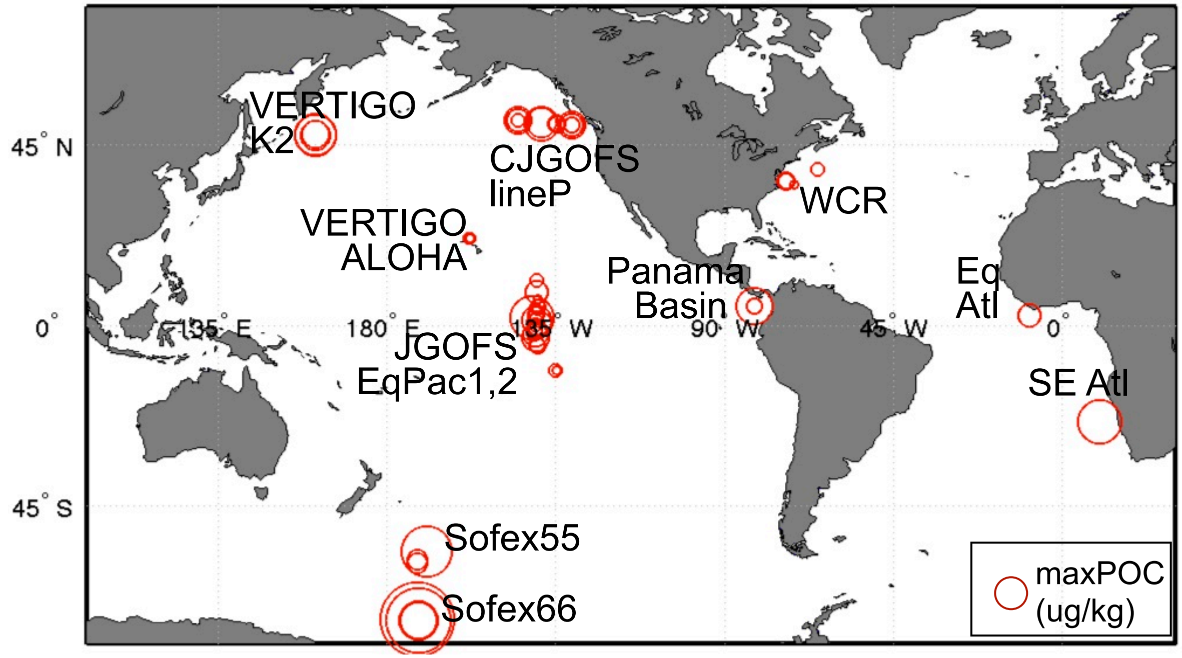
Objectives of this session

1. Discuss existing observational approaches to measure the concentration and size distribution of particles in the ocean
   – Large volume in-situ filtration for collection of size fractionated particles (>53um; 1-53um)
2. The spatial variations in particle concentration and size distribution which these instruments have so far documented
   – Compilation of major particle composition (POC, opal, $CaCO_3$) from the global MULVFS dataset



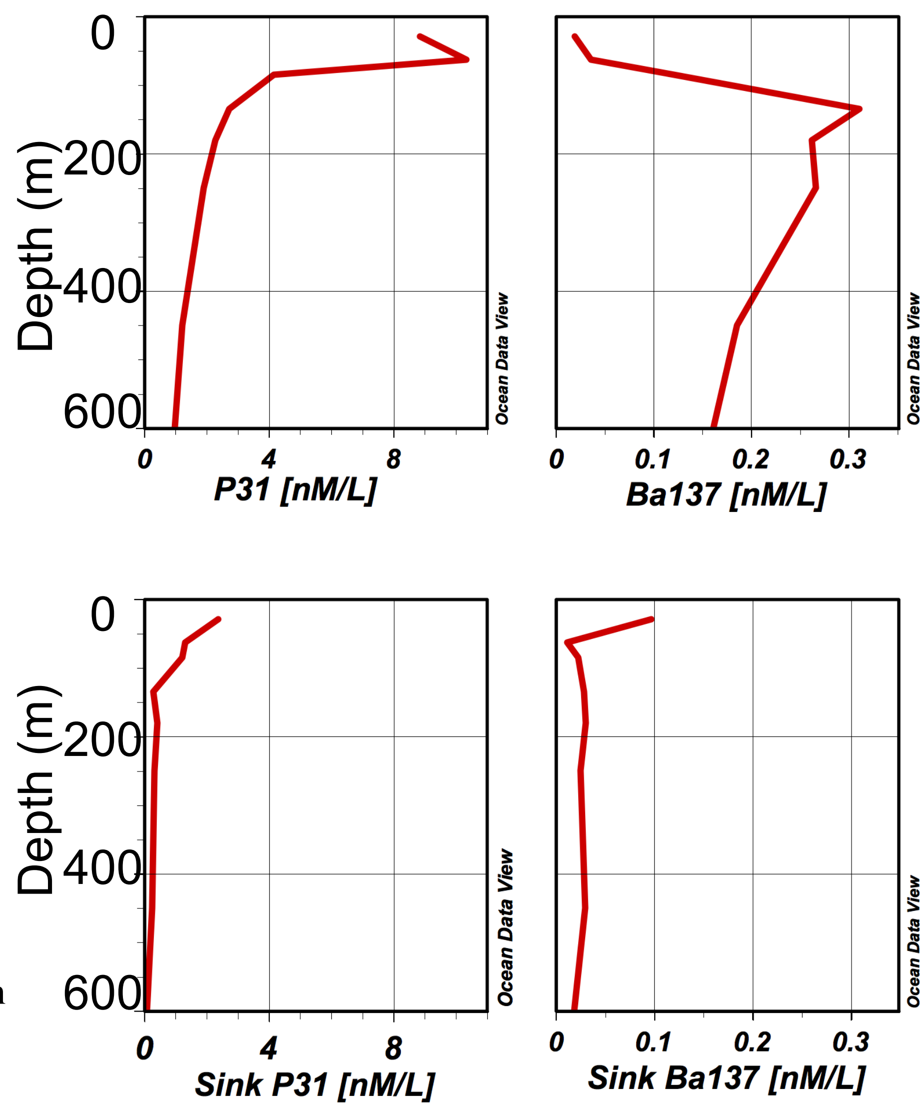


Motivation for size-fractionation: Particle dynamics (via geochemistry, USGT NAZT stn 11)

Part. Phosphorus   Part. Barium

Suspended (1-51um) size fraction

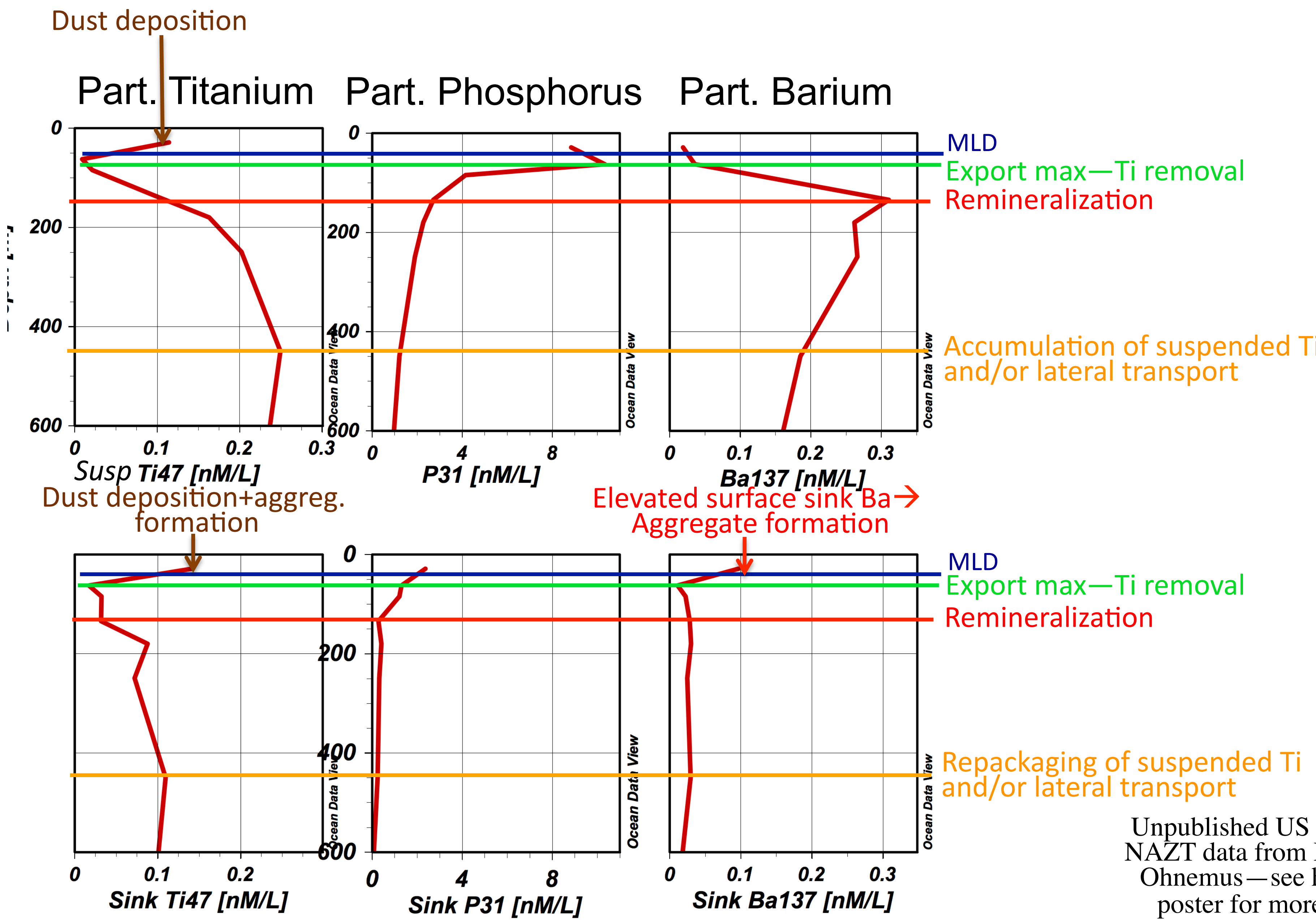
Sinking (>51um) size fraction



Unpublished US GT NAZT data from Dan Ohnemus—see his poster for more!

- Production of 1-51um P by photosynthesis near surface
- >51um P near surface from aggregate formation
- µm-sized barite particles formed in micro-environments of aggregates near surface → max in >51um Ba near surface
- As organic matter remineralizes (gradient in P), aggregates fragment and release barite into small size fraction
- Maximum in remineralization in P coincides with max in 1-51um Ba

Why care about particle dynamics for GEOTRACES?



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Why study major particle composition for GEOTRACES?

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www.elsevier.com/locate/epsl

The influence of particle composition and particle flux on scavenging of Th, Pa and Be in the ocean

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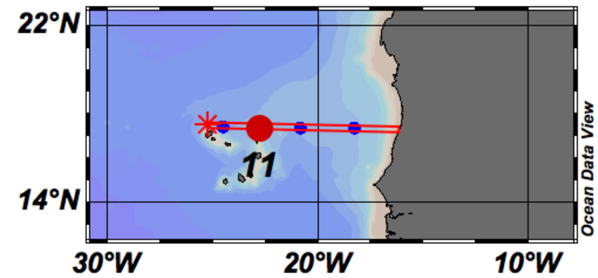
Abstract

We have examined the relative affinity of Th, Pa and Be for sorption from seawater onto particles of variable composition (opal, carbonate, lithogenic particles and organic carbon). Nuclide concentrations in particles collected from time-series sediment traps were normalized by the dissolved nuclide concentration in the overlying water column in order to compute partition coefficients under conditions spanning a wide range of particle flux and particle composition. Our results suggest that the affinity of particles for Pa and Be increases with their increasing opal content and decreasing carbonate content, while the affinity of particles for Th increases with increasing carbonate content, and decreases with increasing opal content. We find no correlation between the aluminosilicate content of

Might particle composition be important for other trace metals?

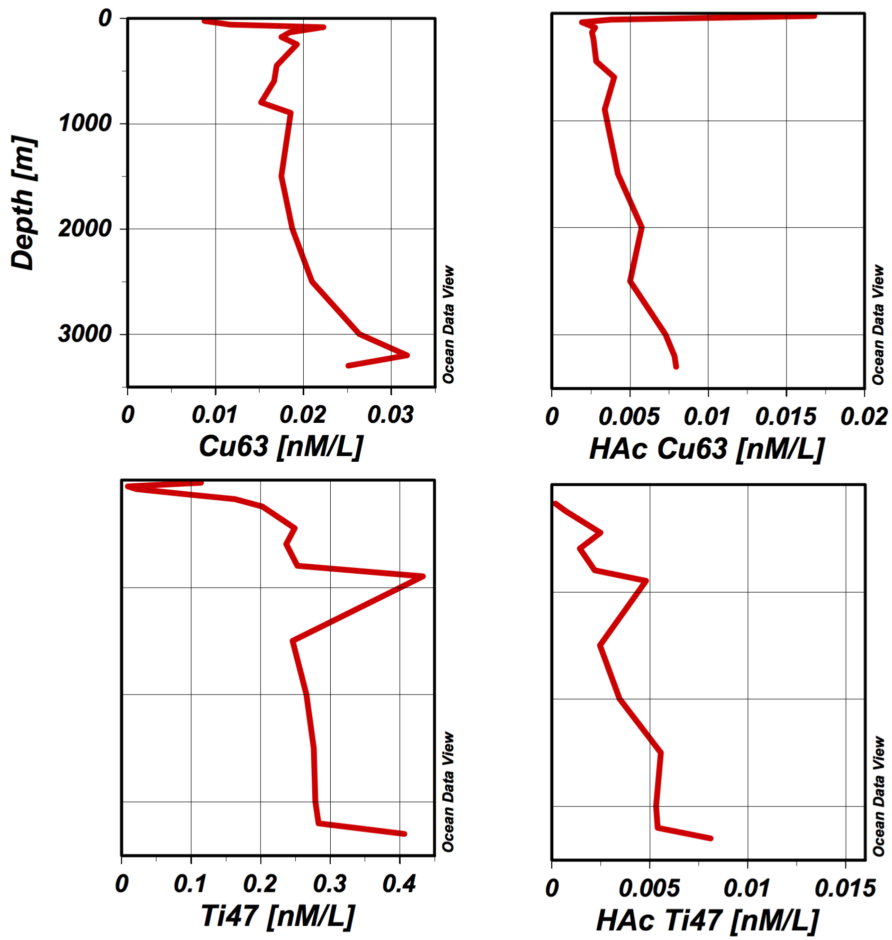


Total particulate fraction--source

Acid Leachable —scavenged fraction

pCu

pTi



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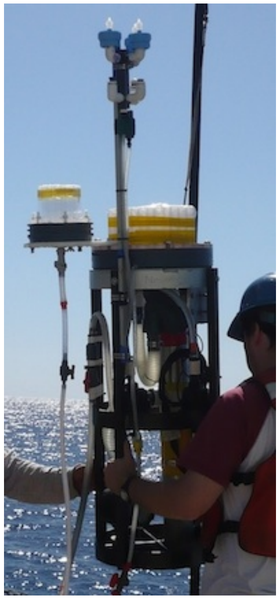
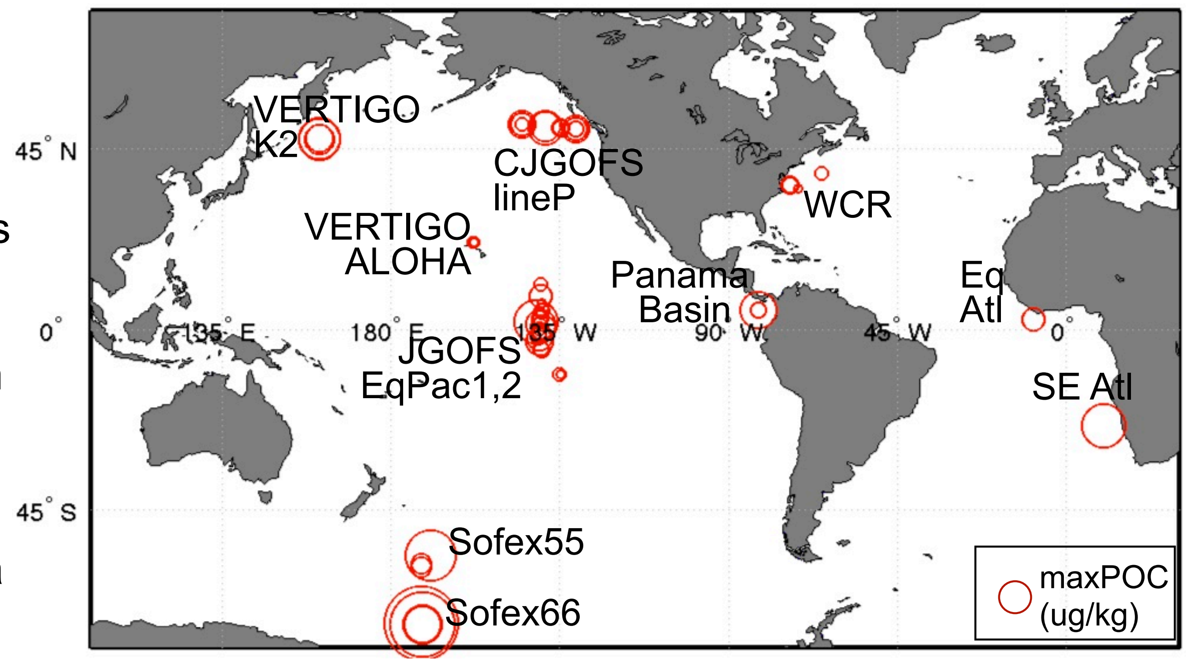
A Global Compilation of size-fractionated POC, $CaCO_3$, and Opal Concentration Profiles in the Mesopelagic

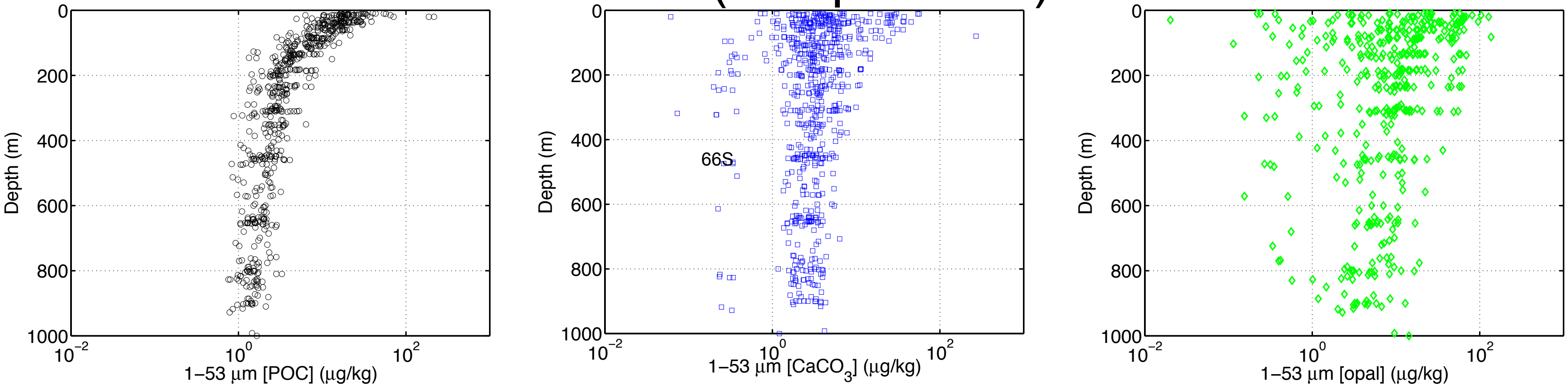


- Particle samples collected using the Multiple Unit Large Volume in-situ Filtration System (MULVFS) between 1973 and 2005 by Jim Bishop
- Size fractionated particles (<1μm, 1-53μm, >53μm)
- >53μm size fraction = sinking size class
  - *POC Flux* = *particle sinking speed* x >53μm *POC concentration*
- 1-53μm size fraction = suspended size class
- Dataset benefits:
  - 62 open ocean profiles with wide geographic coverage in many regimes
  - High depth resolution in the mesopelagic (up to 12 depths in upper 1000m)
  - POC, $CaCO_3$, opal measurements on all > 53μm particles, and many 1-53μm particles
  - Consistency! All samples collected and processed by a single PI (Jim Bishop)

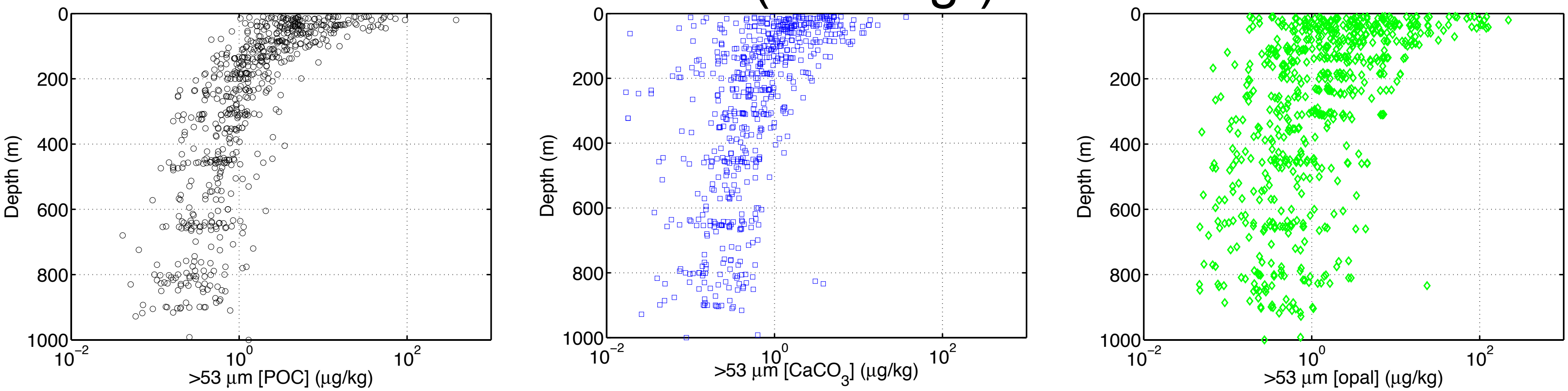


POC $CaCO_3$ Opal (bSi)

The 1-53um ("suspended") dataset



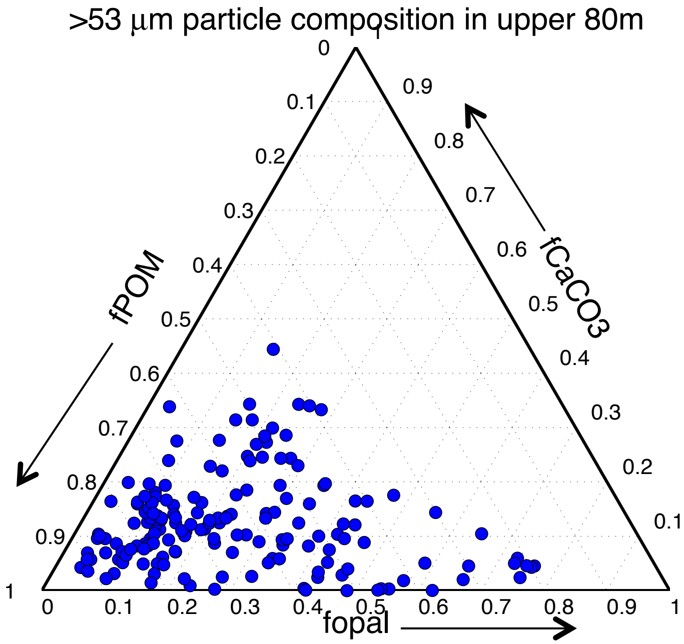
The >53um ("sinking") dataset



- Variability is smaller in the 1-53um size fraction, especially for POC
- The 1-53um size fraction has higher concentrations of all three components

1-53um CaCO3 and opal data compilation not yet published; rest available at Lam et al. 2011 GBC, v25, GB3009

>53um particles become relatively more $CaCO_3$ and opal rich with depth as POC attenuates faster with depth

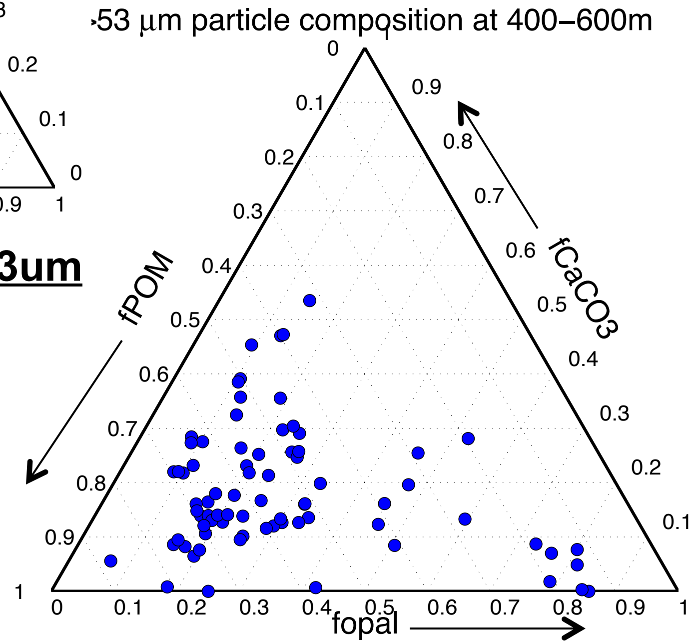


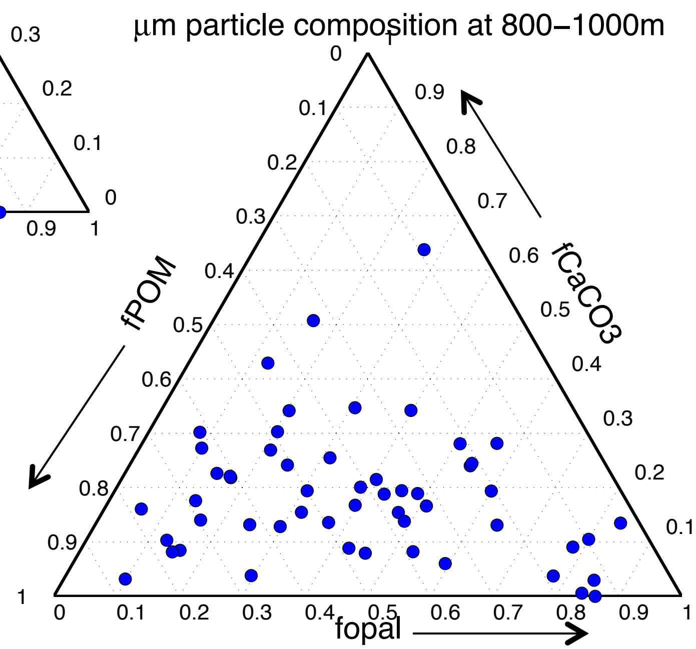
Relative composition of >53um surface particles

Dominated by POM

fOpal ranges from from 0-0.8

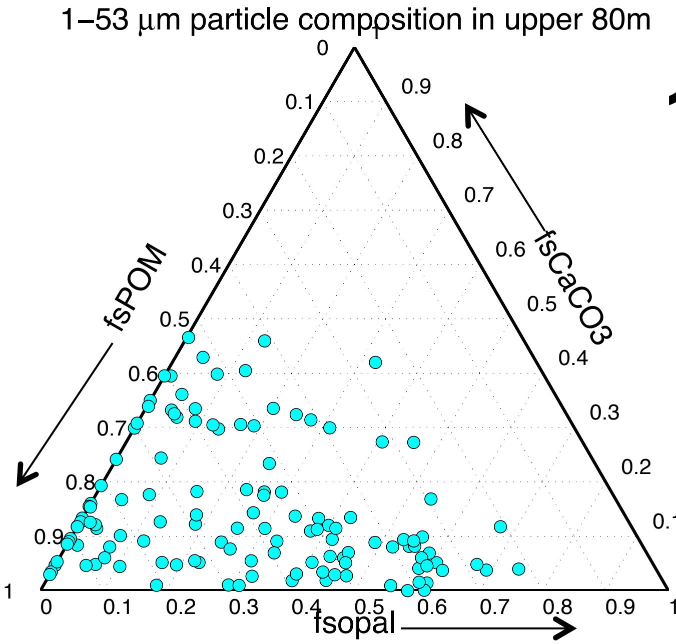
$fCaCO_3$ ranges from 0-0.45

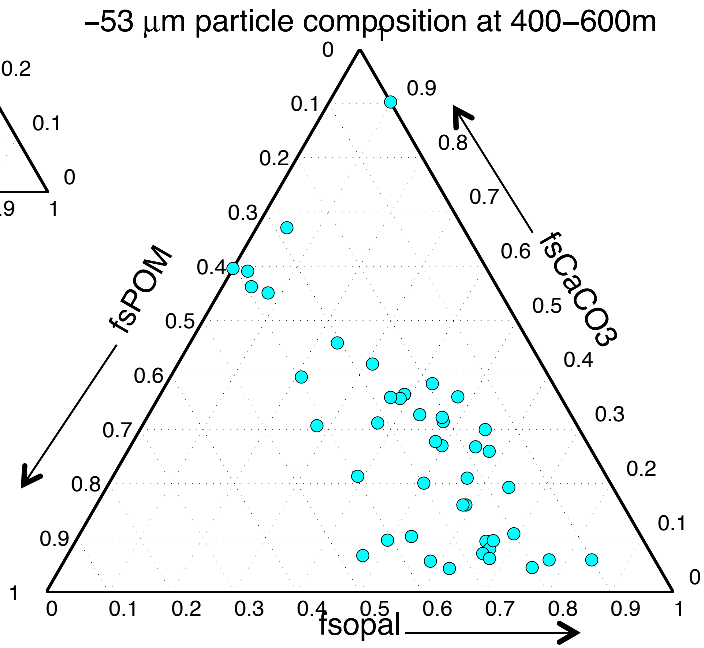


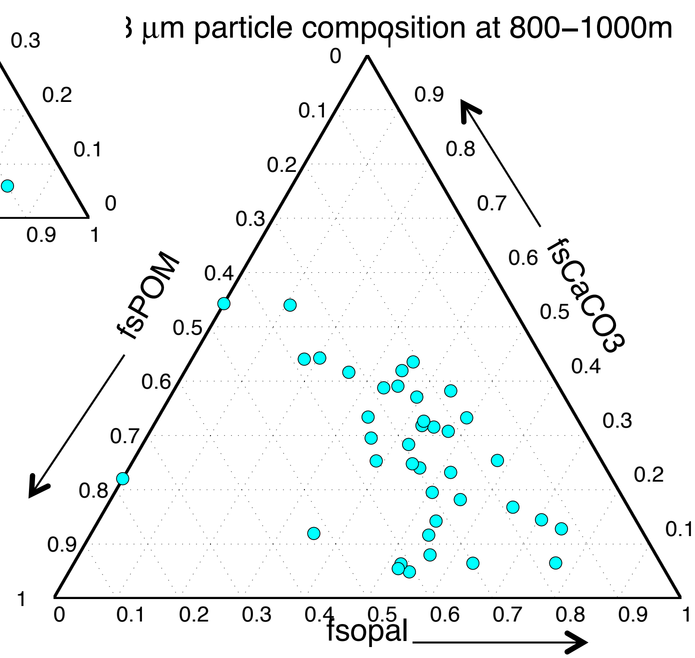


Data available at Lam et al. 2011 GBC, v25, GB3009

1-53um particles become relatively more opal rich with depth

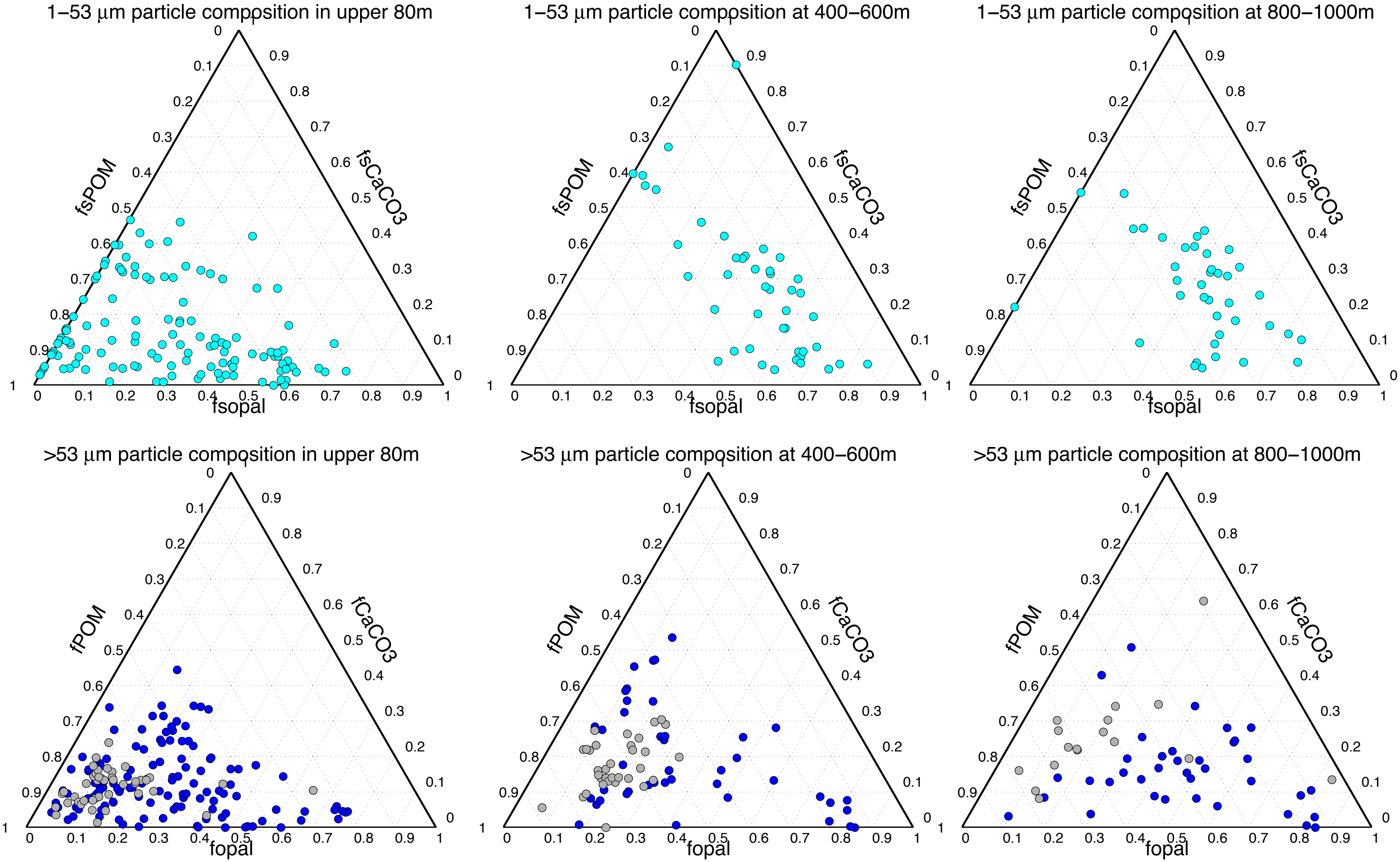




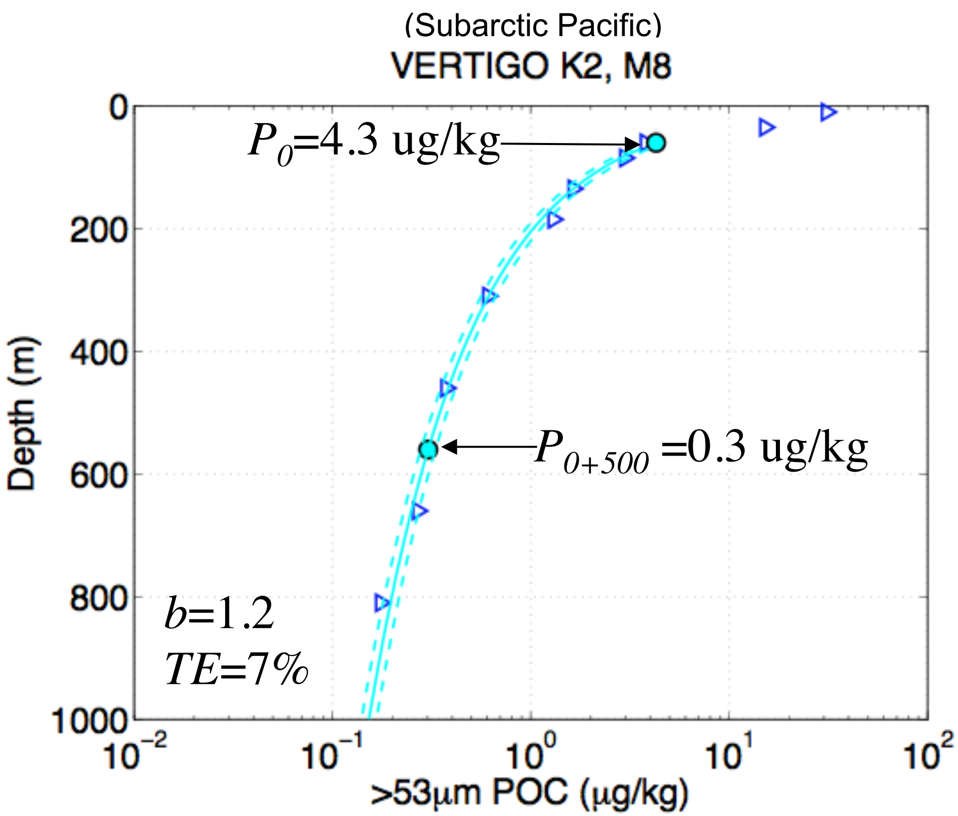


1-53um CaCO3 and opal data compilation not yet published; rest available at Lam et al. 2011 GBC

1-53um particles change with depth more than >53um particles



Representing and comparing the variability in POC profiles



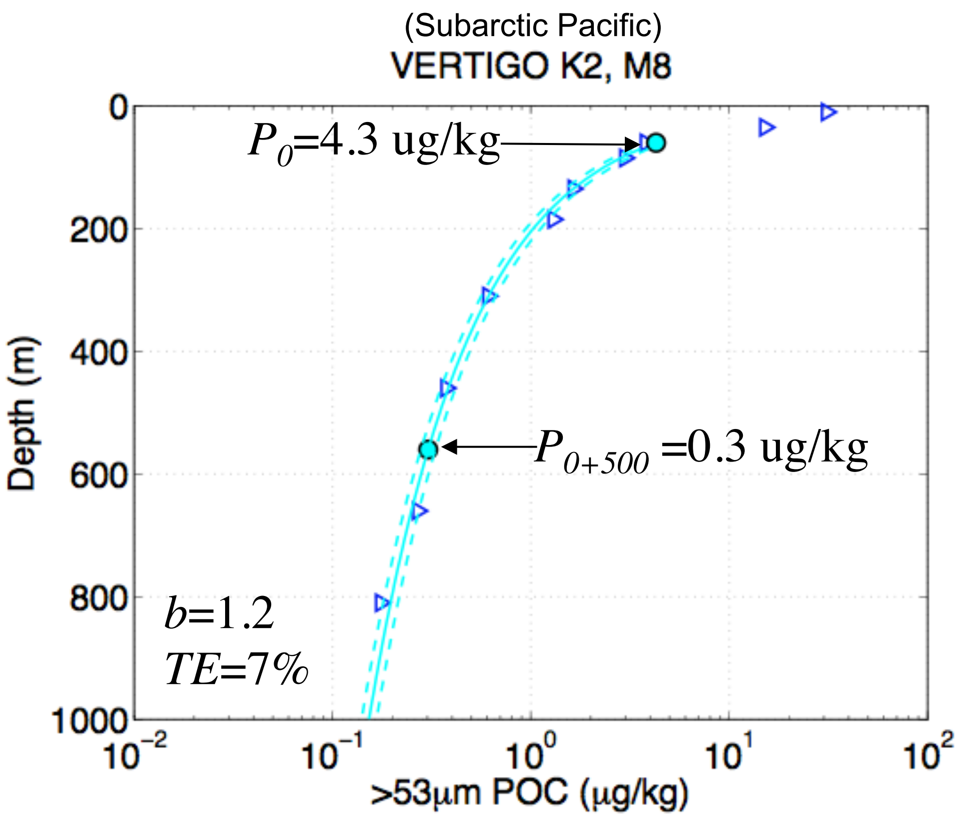
- All >53µm and 1-53µm POC profiles were fit with a power law function (55/62 well fit)

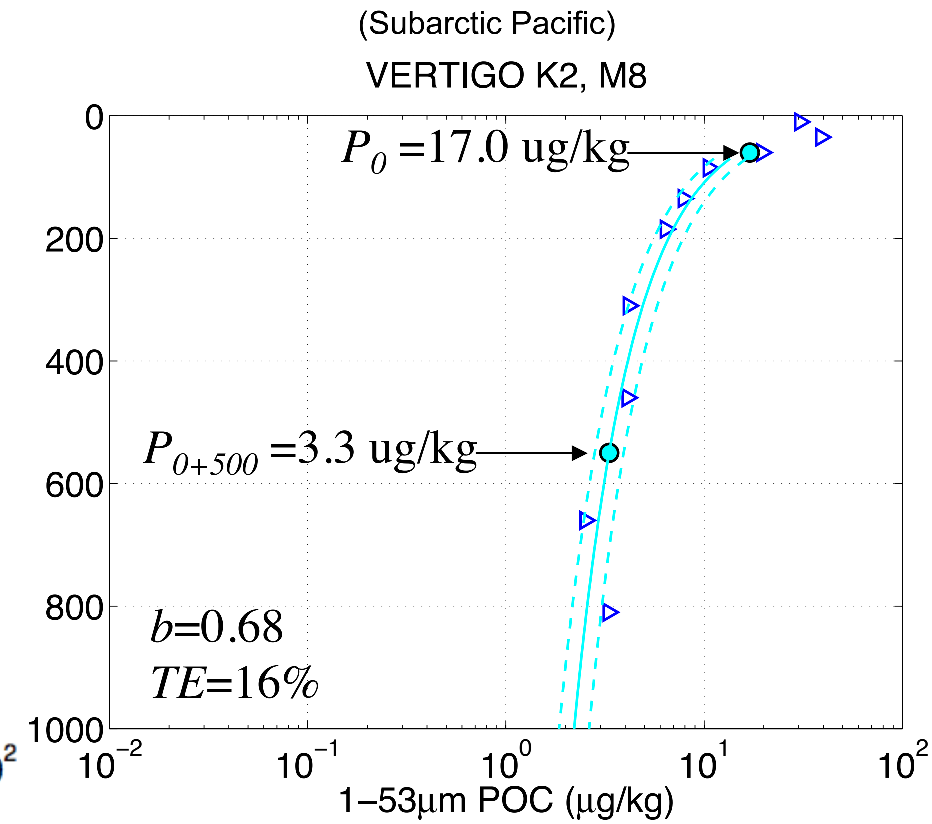
$$P_z = P_0 \left(\frac{z}{z_0} \right)^{-b}$$

- z_0 is the export depth
- P_0 is the fitted POC concentration at z_0
  - "Strength of shallow pump"
- b is the power law exponent
  - "attenuation of POC"

- P_{0+500} is the fitted POC concentration 500m below z_0
  - "Strength of deep pump"
- TE is the Transfer Efficiency between P_0 and P_{0+500}, another measure of attenuation

Example fits to the sinking (>53 um) and suspended (1-53um) size fractions

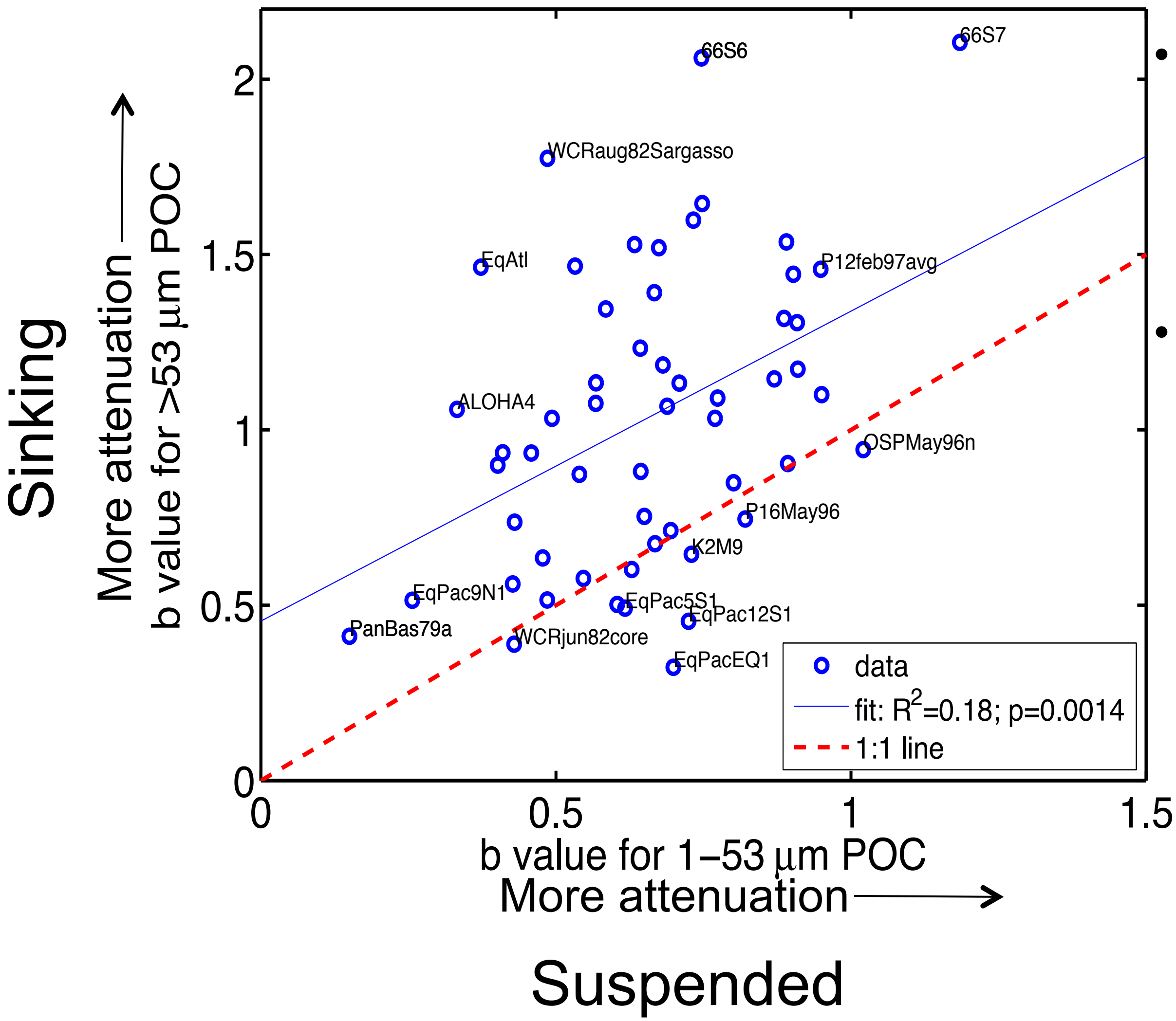




Sinking (>53um) particles

Suspended (1-53um) particles

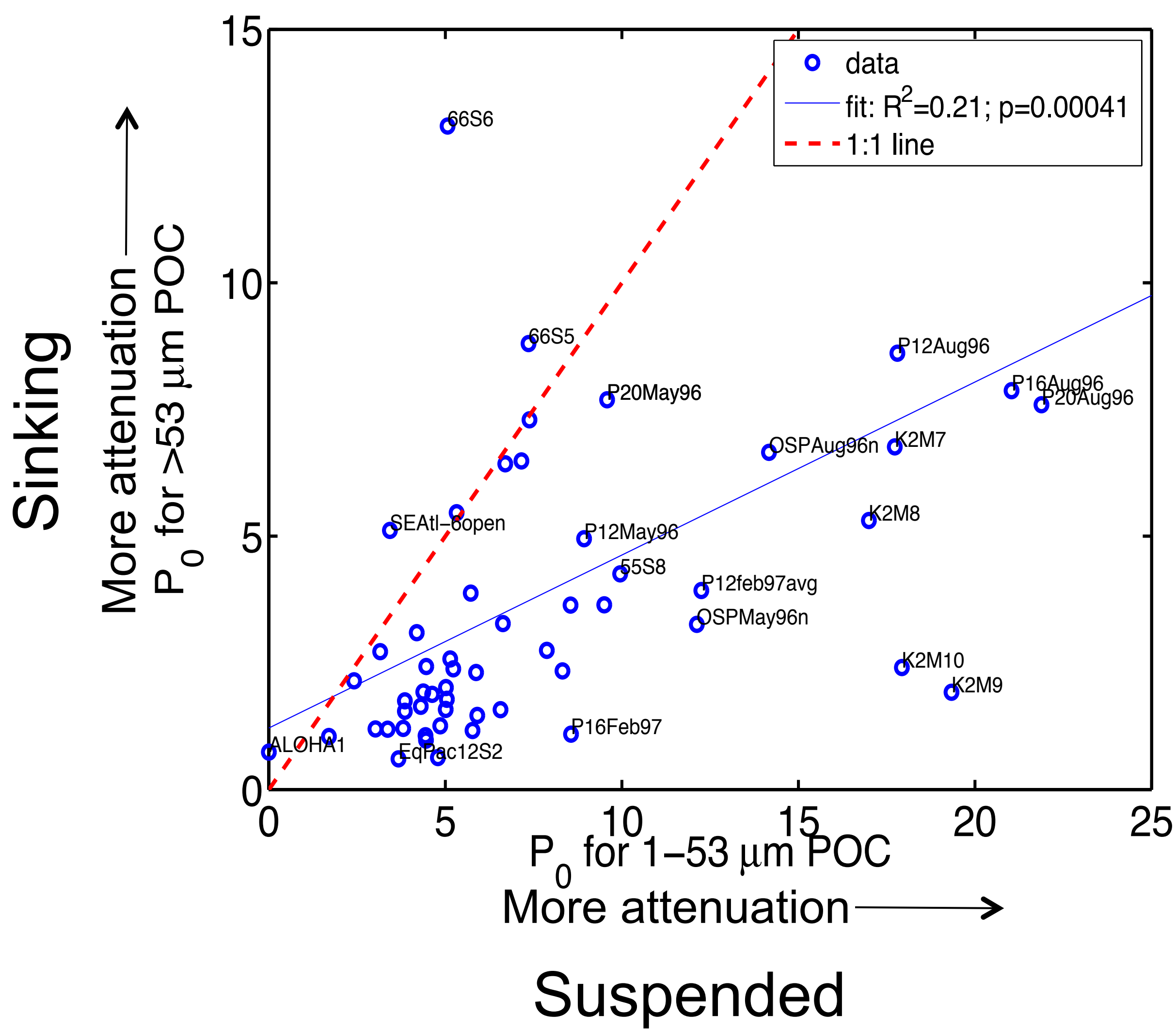
Suspended POC has a lower attenuation with depth than sinking POC



- Weak correlation between the attenuation ("b value") of the sinking (>53um) and suspended (1-53um) size fractions (R^2=0.18)
- Attenuation of POC in the sinking size fraction exhibits a greater range and is almost always greater than the suspended size fraction

Lam et al., unpublished.

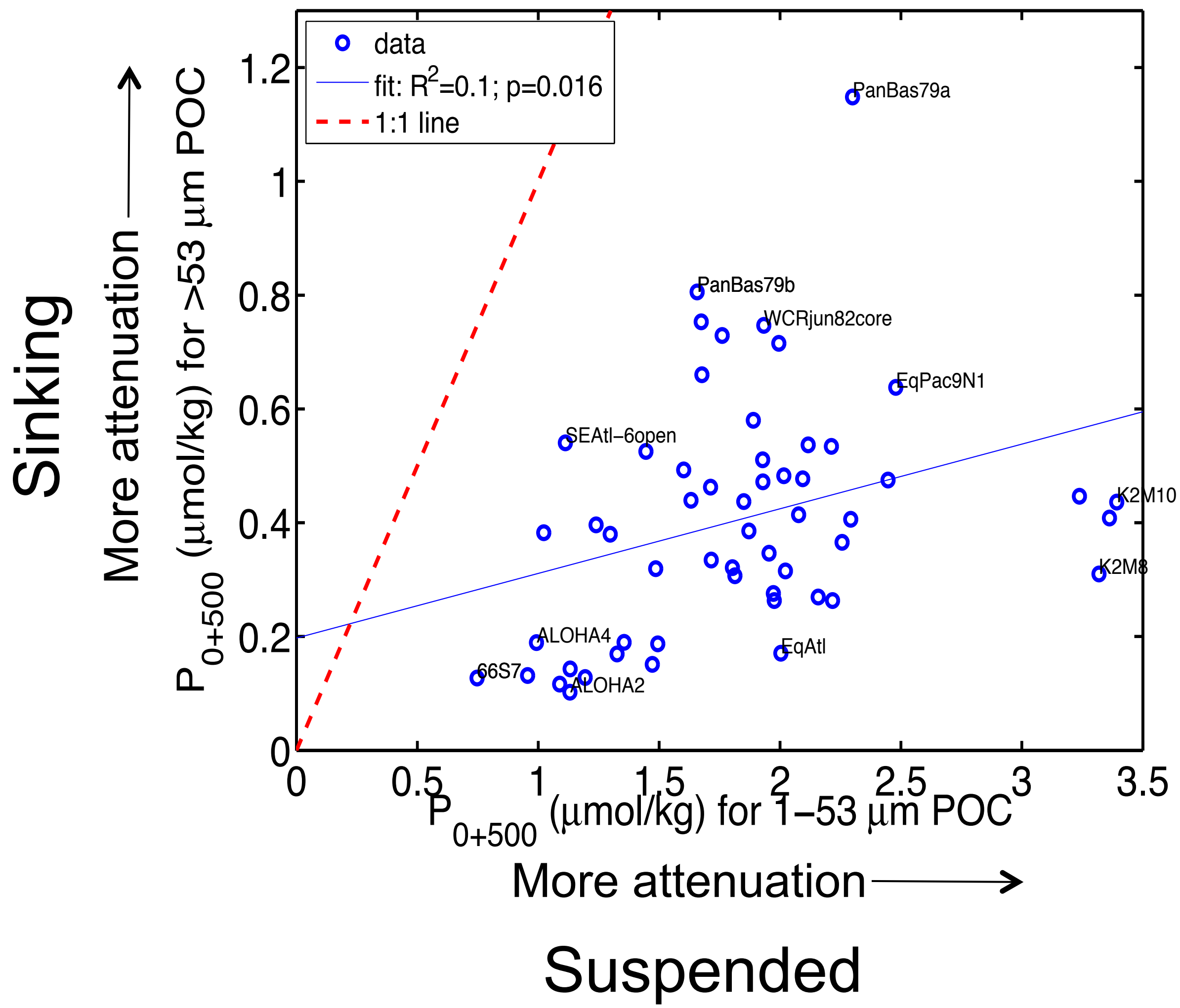
POC at the base of the euphotic zone (P_0) is usually but not always higher in the suspended size fraction



- P_0 of the sinking size fraction is typically ~30% of the suspended size fraction
- The exception is in blooms, where >53um particles can equal or even exceed the suspended size fraction

Lam et al., unpublished.

POC 500m below the base of the euphotic zone (P_{0+500}) is always higher in suspended size fraction



- Even weaker correlation between P_{0+500} of the sinking (>53um) and suspended (1-53um) size fractions (R^2=0.1)

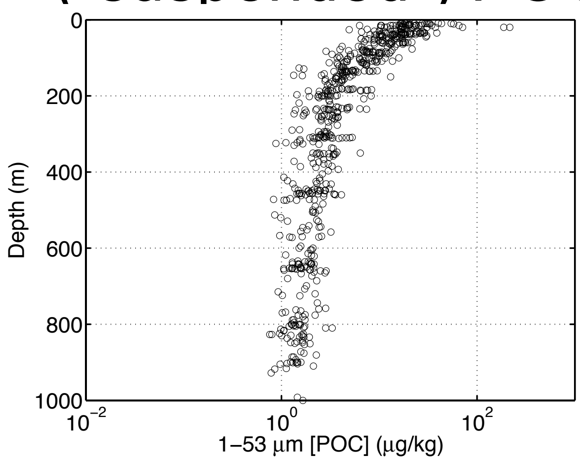
Lam et al., unpublished.

Summary (1): Particle composition in sinking vs. suspended size fractions

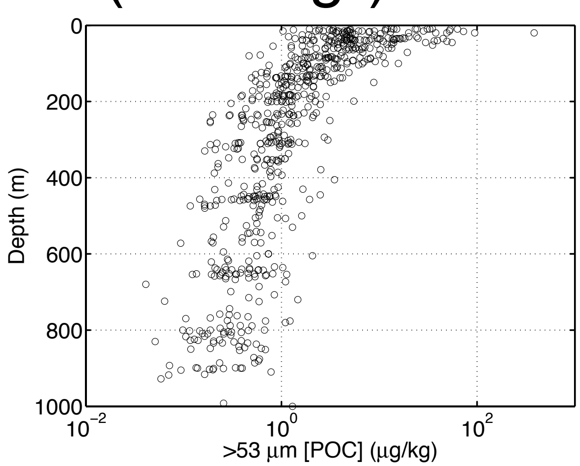
- The attenuation of POC is stronger in the sinking compared to the suspended size fraction
- POC concentrations at the base of the euphotic zone are usually higher for suspended compared to sinking size fractions
- POC 500m below the base of the euphotic zone (P_{0+500}) is always higher in suspended size fraction
- The relative composition of suspended particles changes more with depth than sinking particles—a reflection of decreasing POC but almost conservative $CaCO_3$ and opal with depth
- Large variability in particle composition: how will this affect scavenging of dissolved TEIs?

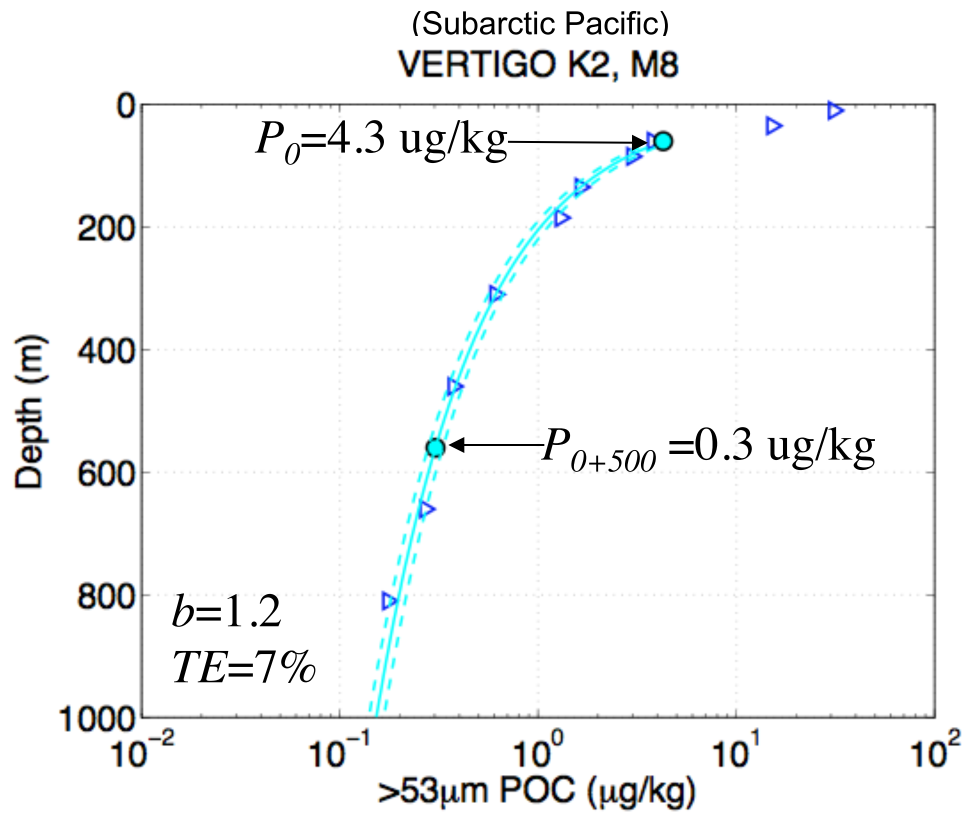
Making sense of the large variability in >53um ("sinking") POC

1-53um ("suspended") POC

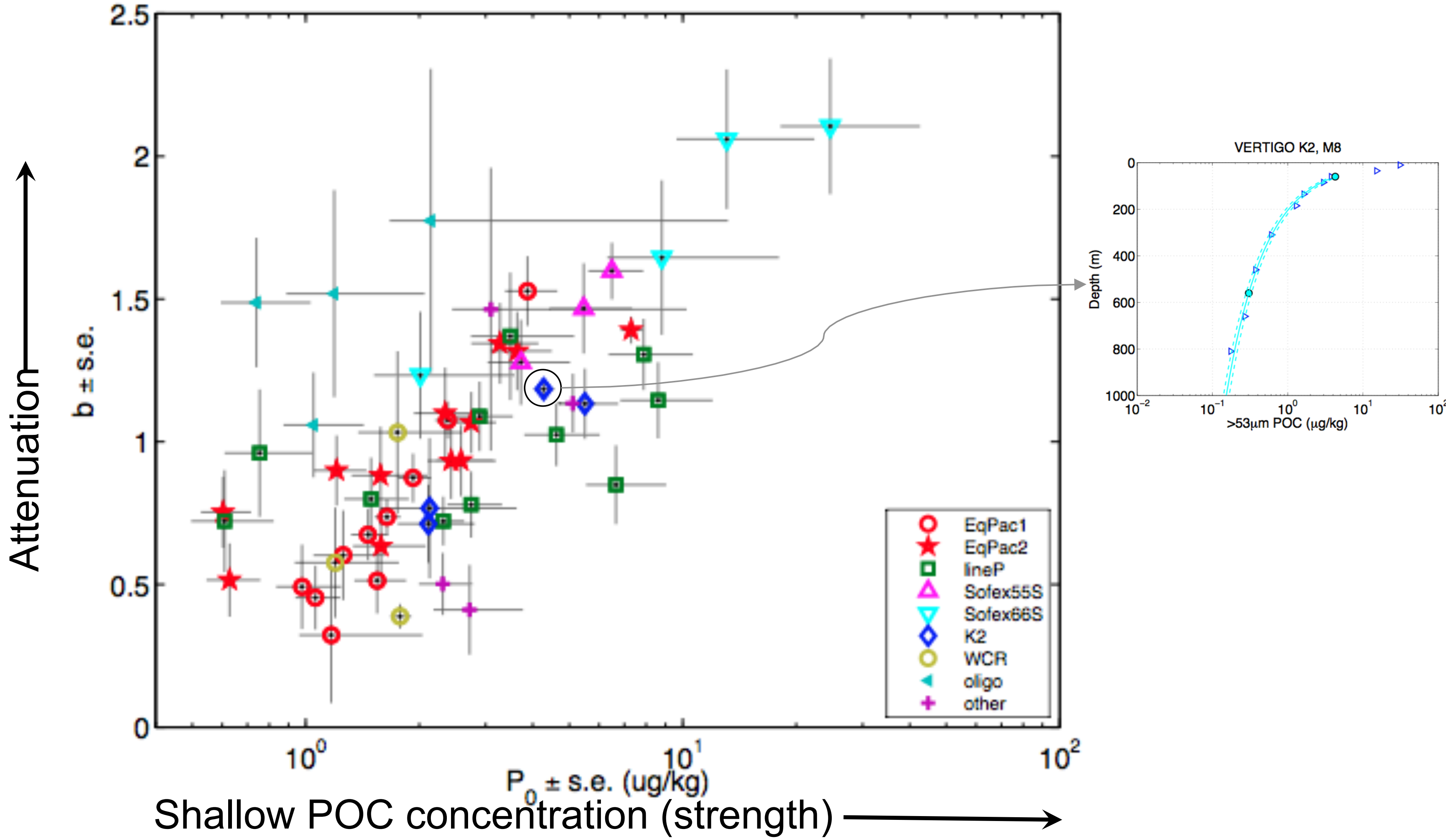


The >53um ("sinking") POC



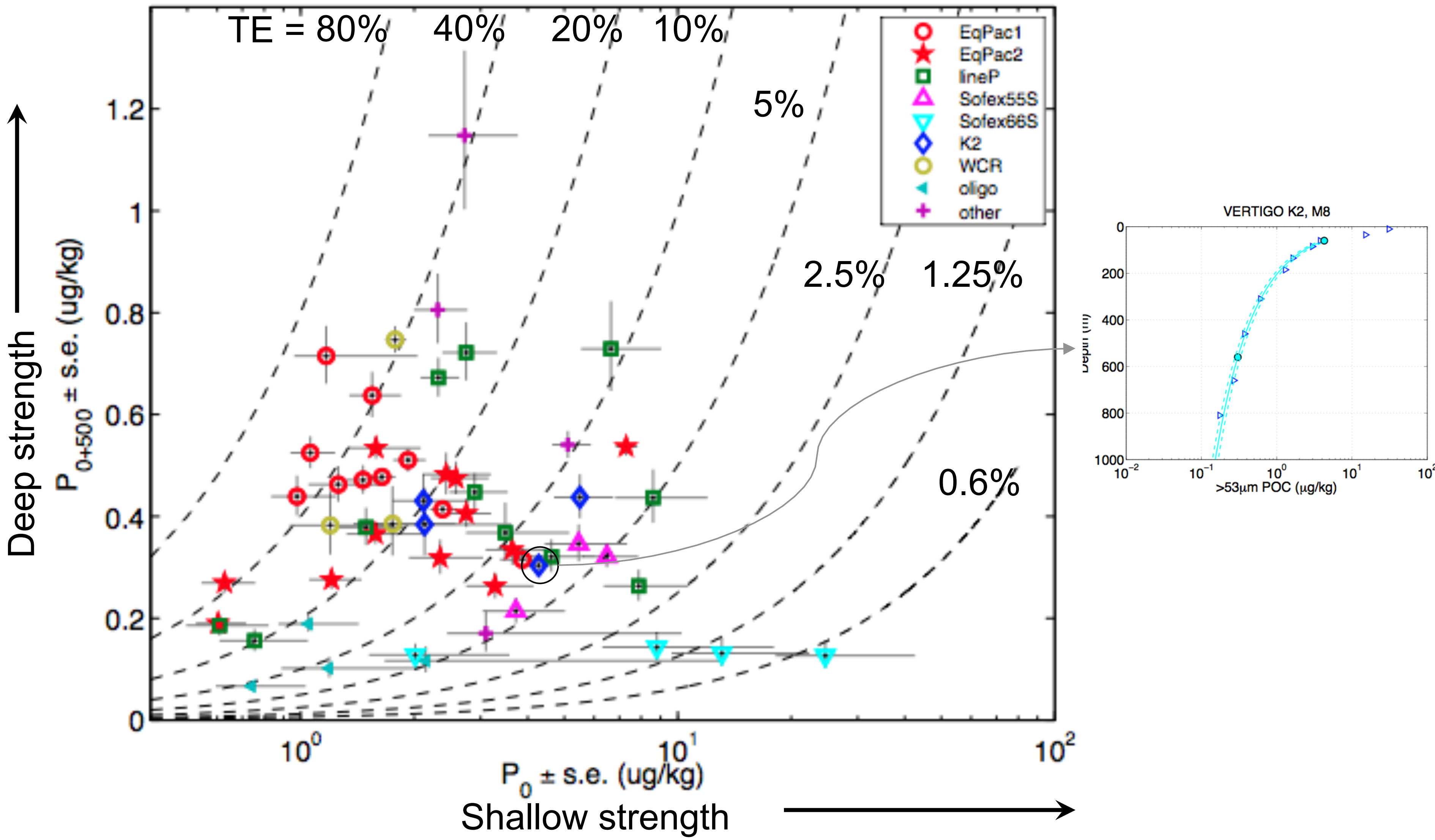


Sinking (>53um) POC: Higher P_0 (shallow POC concentration) is correlated with higher b (attenuation)



Lam et al. 2011 GBC, v25, GB3009

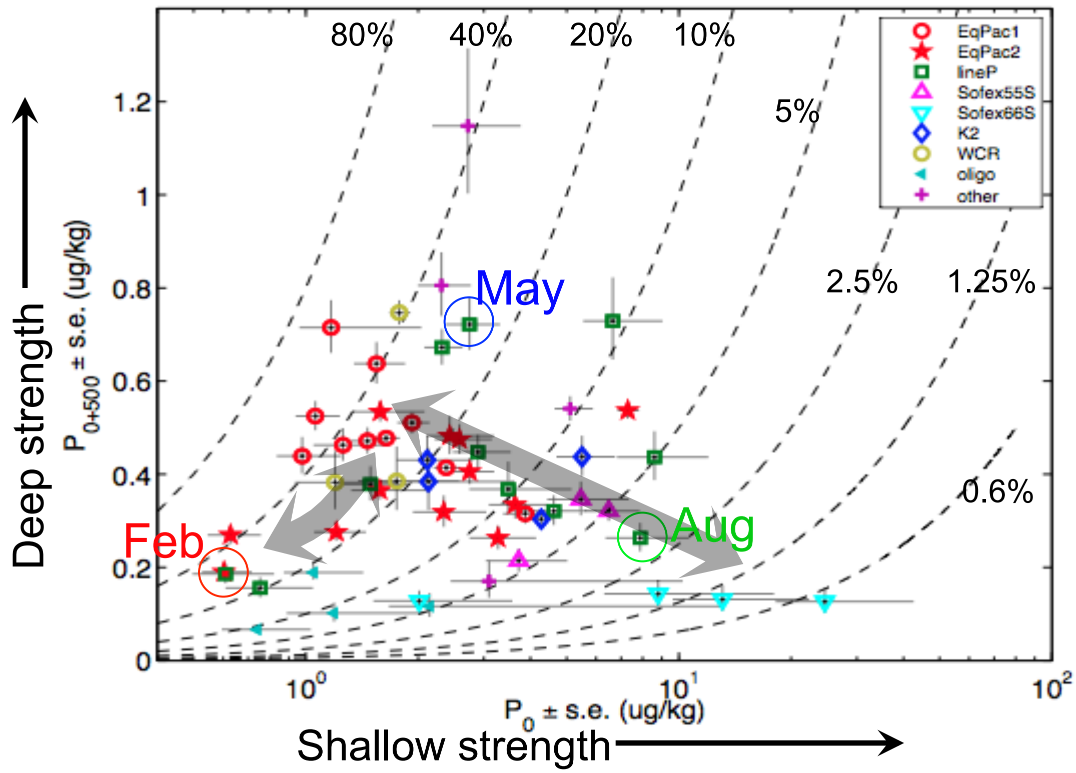
Sinking (>53um) size fraction: Global P_0 vs P_{0+500}

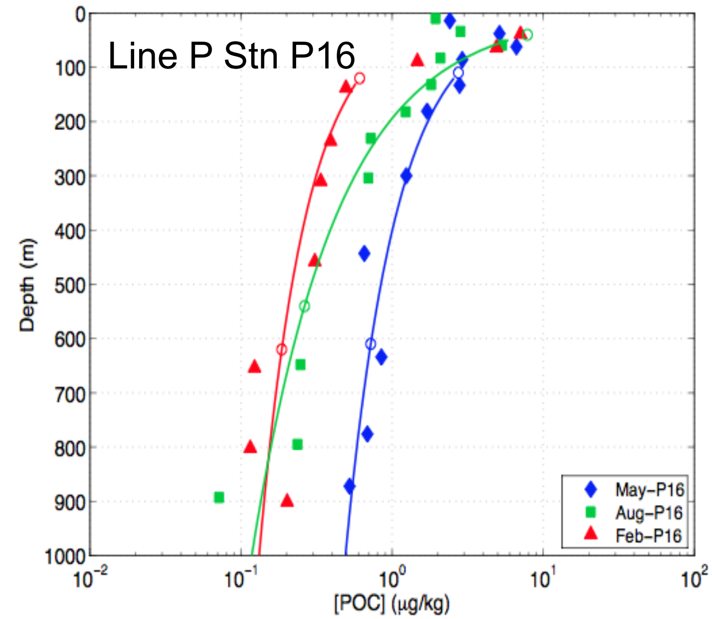


Concentrations of shallow and deep >53um POC are decoupled

Lam et al. 2011 GBC, v25, GB3009

The strength and efficiency of the biological pump are dynamic

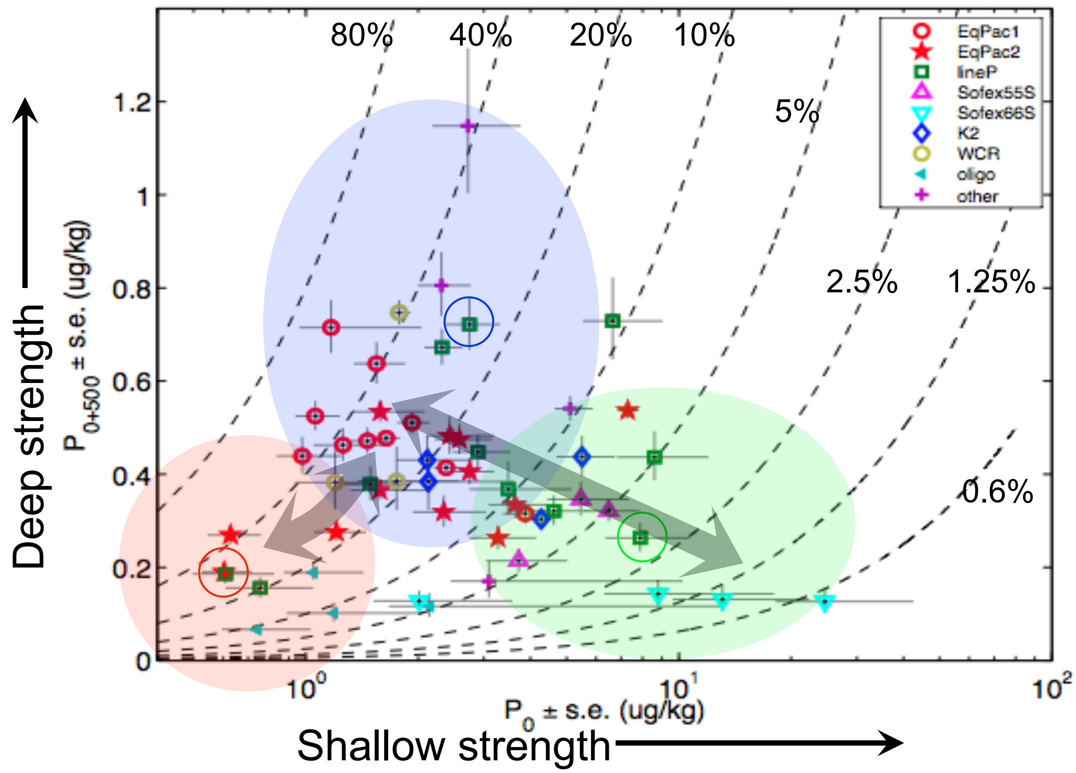


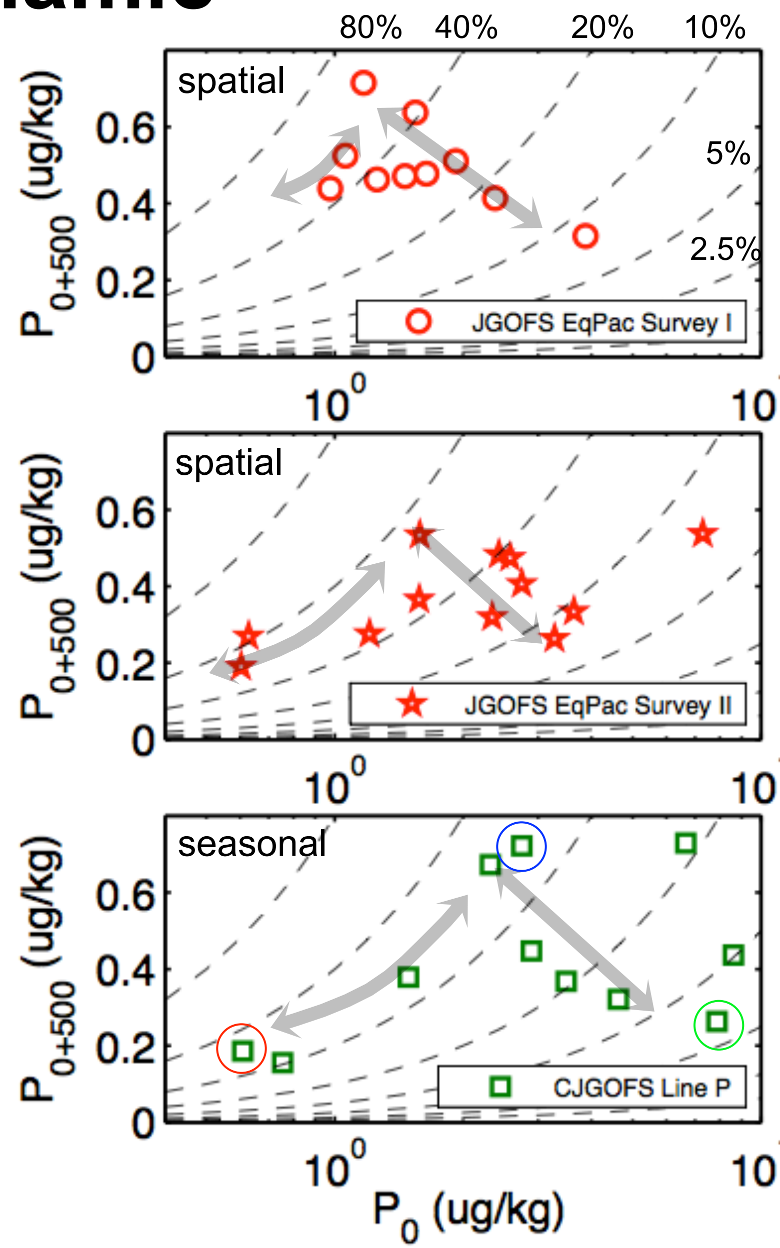


- A single station can span the entire range in pump strength and efficiency over a seasonal cycle
- At low to moderate P_0, P_0 and P_{0+500} increase concurrently, maintaining constant TE
- The biological pump strength and efficiency are maximized at moderate P_0
- From moderate to high P_0, P_{0+500} decreases with increasing P_0, decreasing TE

Lam et al. 2011 GBC, v25, GB3009

The strength and efficiency of the biological pump are dynamic





- Pattern holds over temporal and spatial gradients

Lam et al. 2011 GBC, v25, GB3009

Summary (2): the dynamic biological pump

- The biological pump is dynamic:
  - At low to moderate P_0, P_0 and P_{0+500} increase concurrently, maintaining constant TE
  - **The biological pump strength and efficiency are maximized at moderate P_0**
  - From moderate to high P_0, P_{0+500} decreases with increasing P_0
- This dynamism is visible in the global snapshot, but also within a region across spatial gradients (eg. EqPac) and across seasonal gradients (eg. CJGOFS line P)

"steady state" communities

"bloom" communities

Conclusions

- Sampled particles need to be interpreted based on their typical residence times
- For >53um size fraction:
  - This size fraction has short residence times (sinking speeds ~ 100 m/d) and large spatial and temporal variability
  - Sampled >53um particles are a snapshot (days) of the water column
- For 1-53um size fraction:
  - Longer residence time (sinking speeds ~ 1 m/d) allows more exchange with solutes in the water column
  - Sampled 1-53um particles can integrate over a longer time (weeks—many months)
- How to interpret the role of particles in governing the dissolved TEI distributions given that they are snapshots