Southern Ocean (and beyond) Particle Fluxes:

Efficiency of shallow POC export and export to mesopelagic

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WHOI

OCB 2009 Summer Workshop

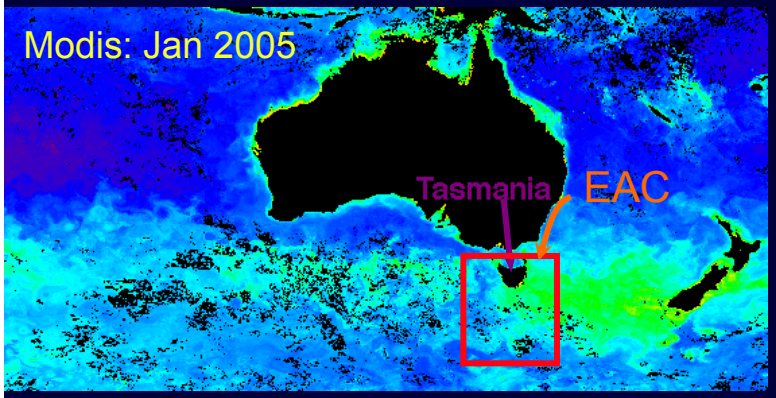
Outline

- Shallow carbon export fluxes from Subantarctic and Polar Frontal Zones from SAZ-Sense project
- POC profiles from Subantarctic and Antarctic Zones from SOFeX (MULVFS)
- Global compilation of POC profiles from (MUL)VFS

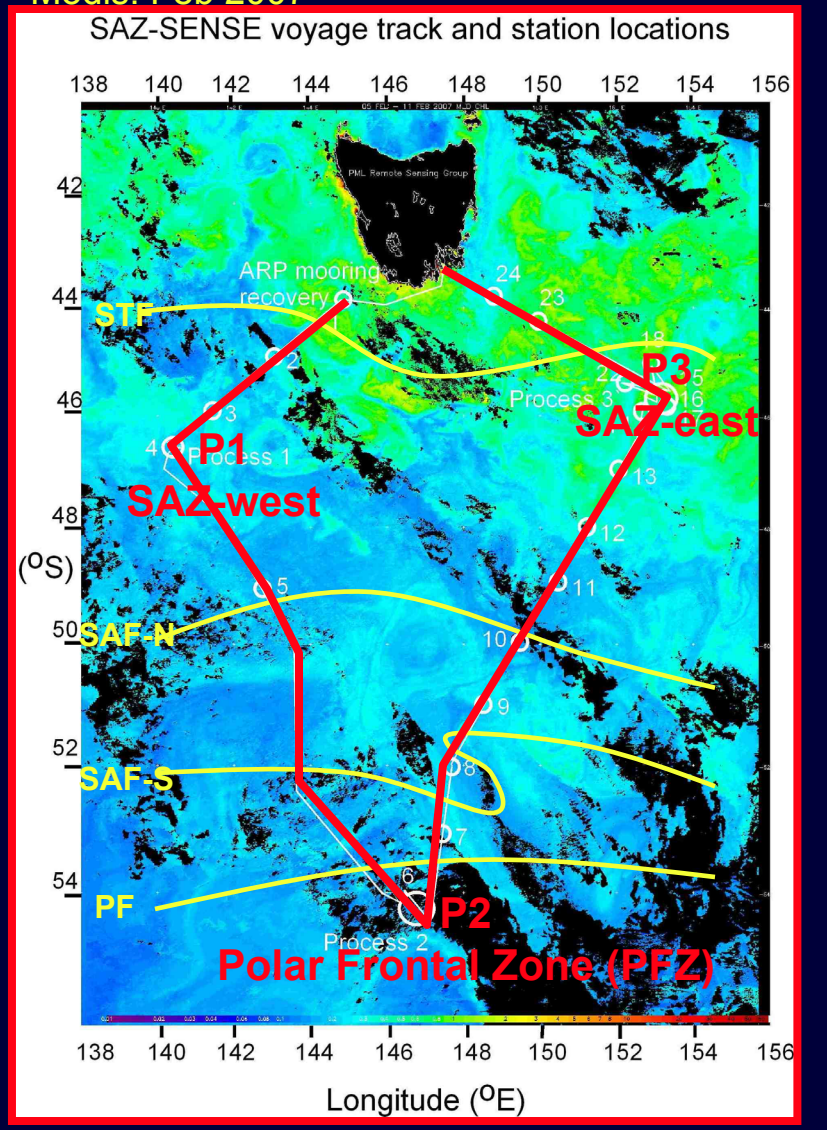
Acknowledgements

- People
  - SAZ Sense ^{234}Th:
    - **Stephanie Jacquet, Frank Dehairs, VUB**
    - Tom Trull, Diana Davies, ACE-CRC
    - Ken Buesseler, WHOI
    - Brian Griffiths, Karen Westwood, CSIRO
    - Simon Wright, Australian Antarctic Division
    - Captain and crew of R/V Aurora Australis
  - (MU)LVFS data (POC concentration profiles):
    - **Jim Bishop, UC Berkeley/LBNL**
- Funding
  - SAZ Sense: Antarctic Climate and Ecosystems Cooperative Research Center (ACE-CRC)
  - SAZ Sense ^{234}Th: Belgian Federal Science Policy (Belspo), ACE-CRC
  - SOFeX: NSF, DOE
  - (MU)LVFS over the years: NSF, DOE
  - Compilation: WHOI Ocean and Climate Change Institute (OCCI), WHOI postdoctoral scholar award

Sub-Antarctic Zone Sensitivity to environmental change (SAZ-Sense) Project



Modis: Feb 2007



SAZ-Sense hypotheses (subset):

H1-SAZ east of Tasmania has observed higher biomass than SAZ west because of:

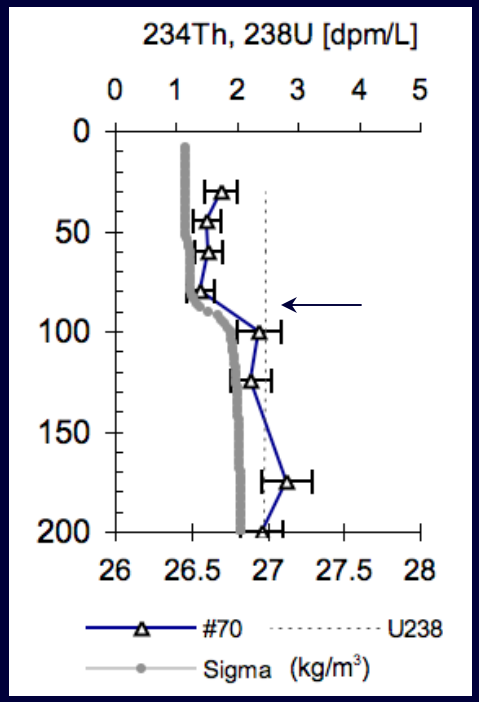
H1a-influence from EAC

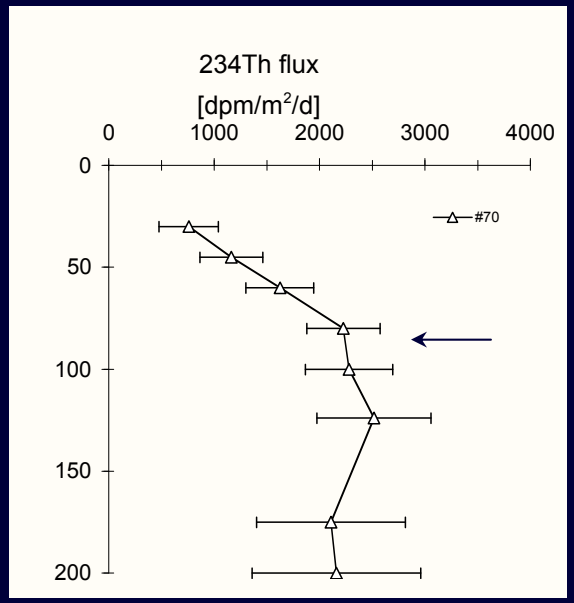
H1b-higher natural iron supply

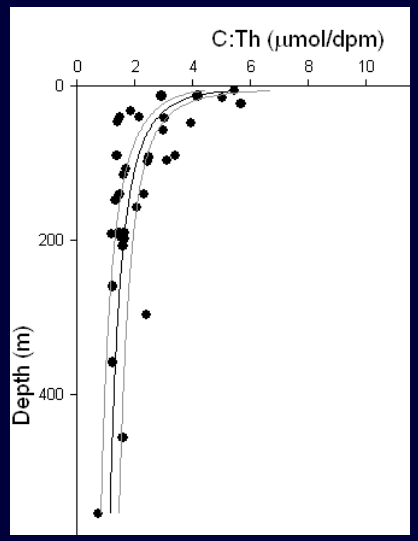
H2-Organic carbon export is in simple proportion to primary production

^{234}Th-derived shallow POC fluxes (Export Production)

Deficit in ^{234}Th activity relative to ^{238}U ⟶ **^{234}Th flux** ⟶ x POC:Th ⟶ POC flux



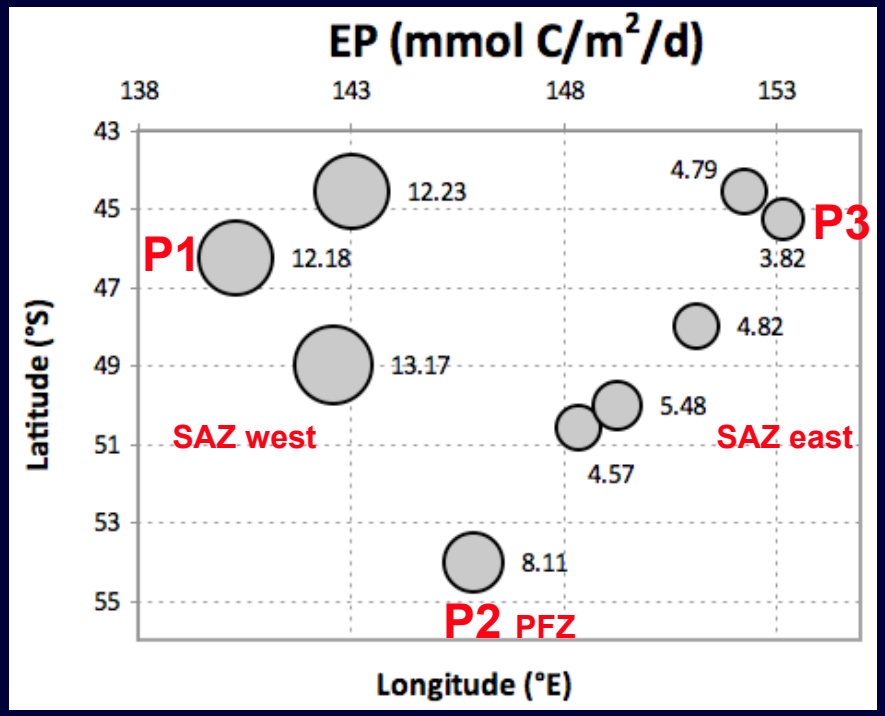


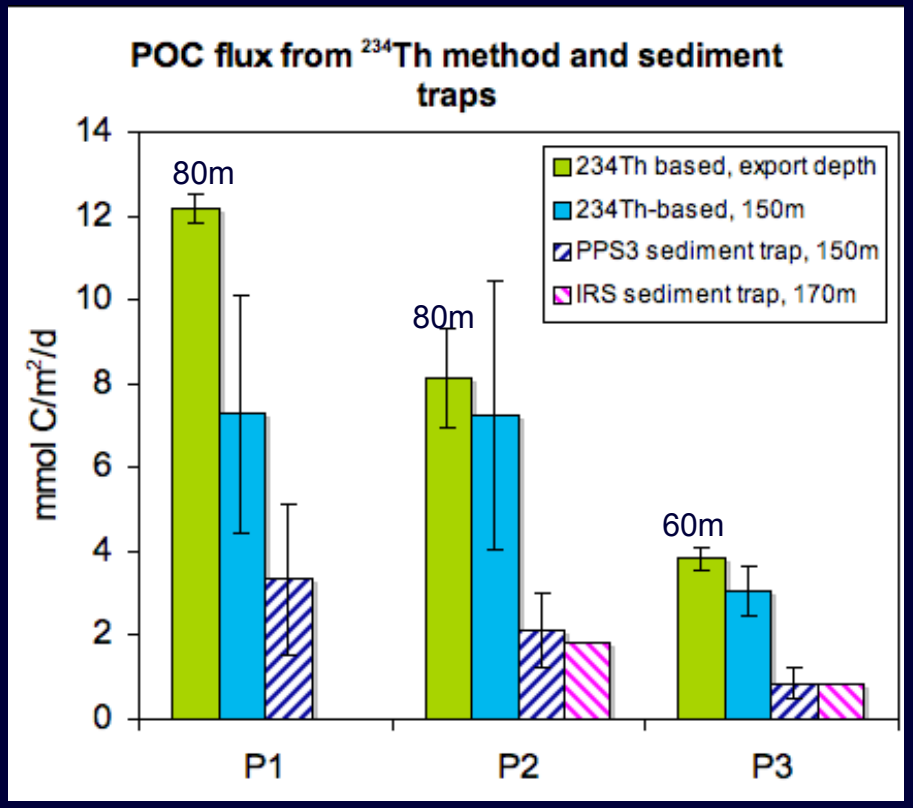


Jacquet, Lam, Trull, Dehairs, DSR2 almost submitted

Shallow export highest in SAZ west

^{234}Th-derived POC fluxes (Export Production)





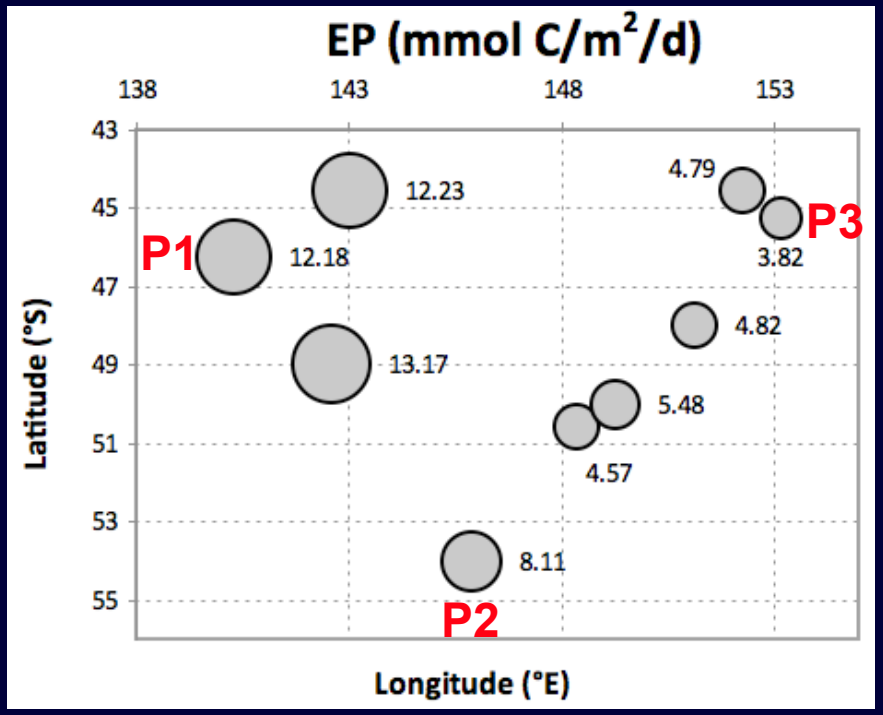
P1 SAZ west

P2 PFZ

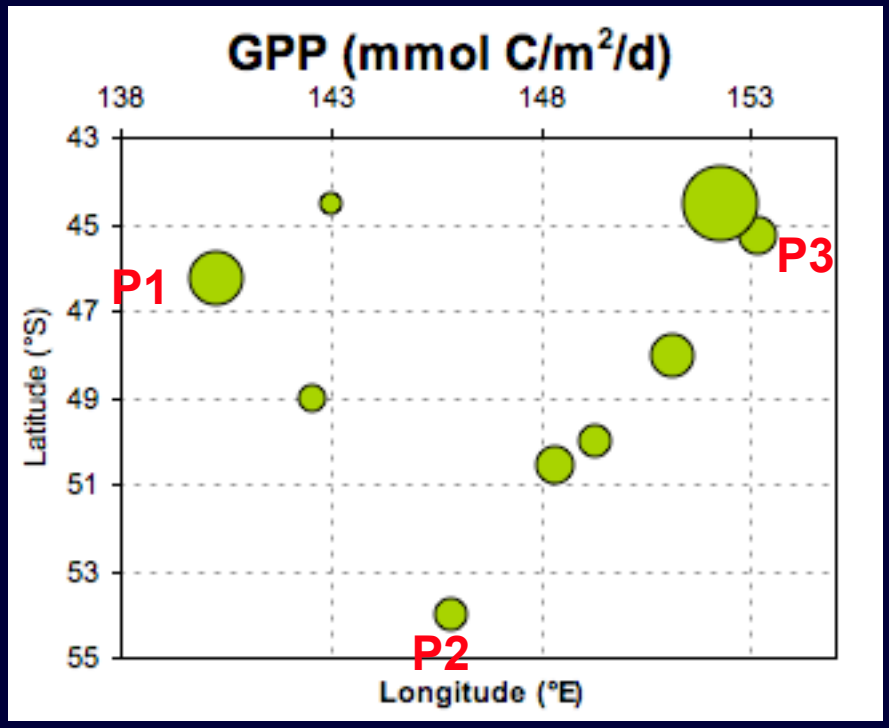
P3 SAZ east

Jacquet, Lam, Trull, Dehairs, DSR2 almost submitted

How do export fluxes compare to Gross Primary Production (GPP)?



Jacquet, Lam, Trull, Dehairs, DSR2

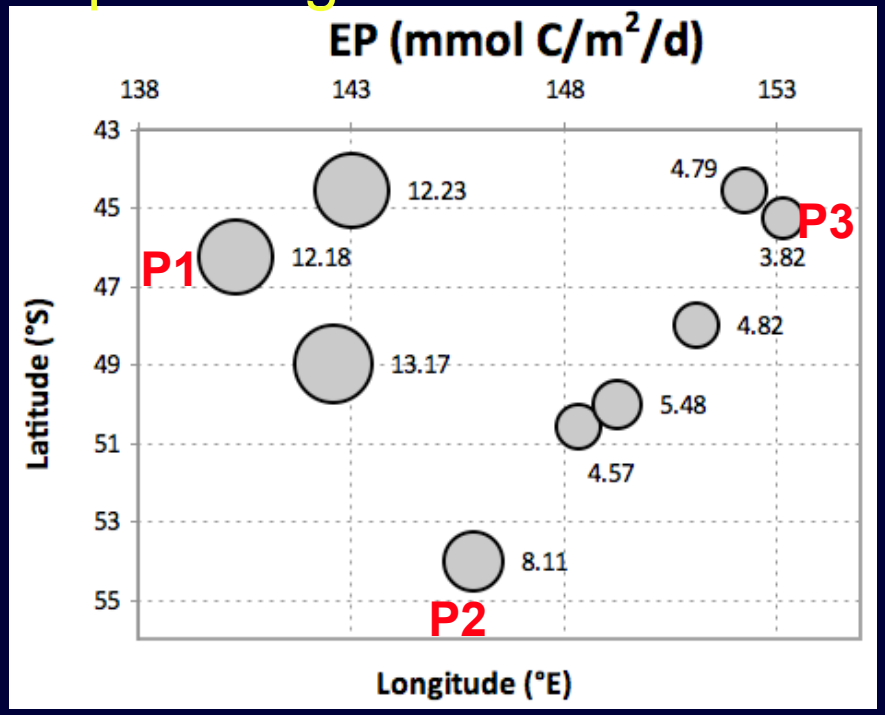


Data from Westwood et al., DSR2

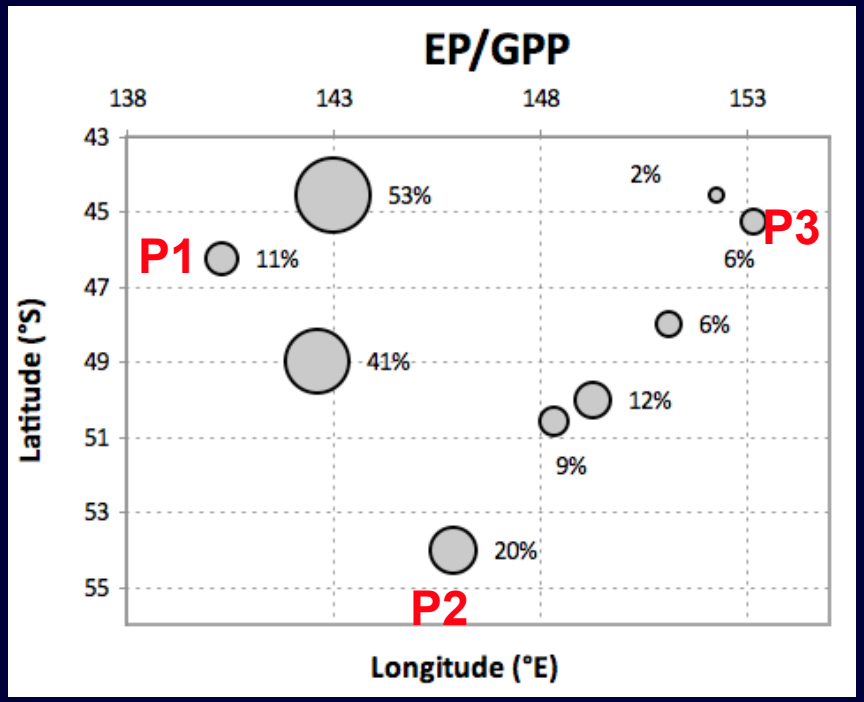
Generally higher GPP in SAZ-east

SAZ west has higher export *magnitude* and *efficiency* out of surface

Export magnitude



Export efficiency

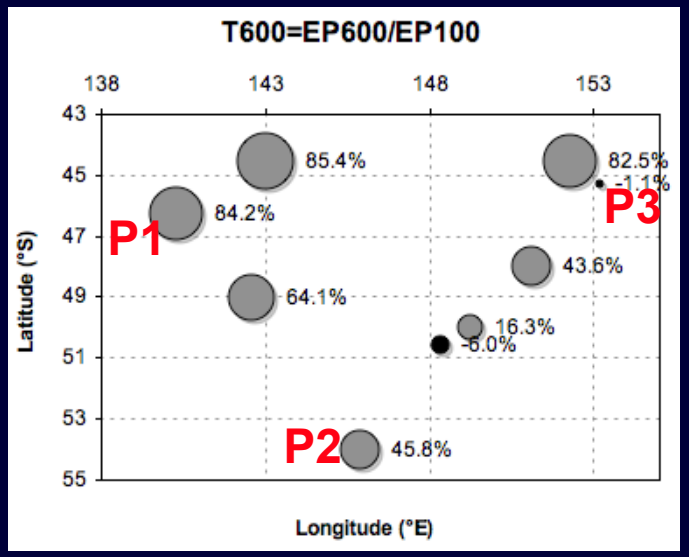


Jacquet, Lam, Trull, Dehairs, DSR2

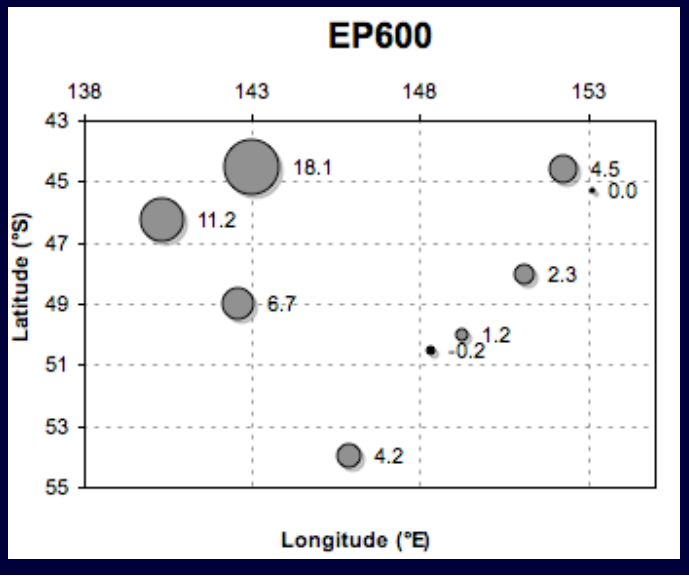
~~H2-Organic carbon export is in simple proportion to primary production~~

What's going on below shallow export?

Mesopelagic transfer efficiency



Flux at 600m



Mesopelagic (100-600m) Remineralization (MR) estimated using excess barite as proxy (Jacquet, Dehairs, et al. DSR2). Use MR to estimate transfer efficiency between 100-600m.

SAZ west has generally higher mesopelagic transfer efficiency (lower remineralization)

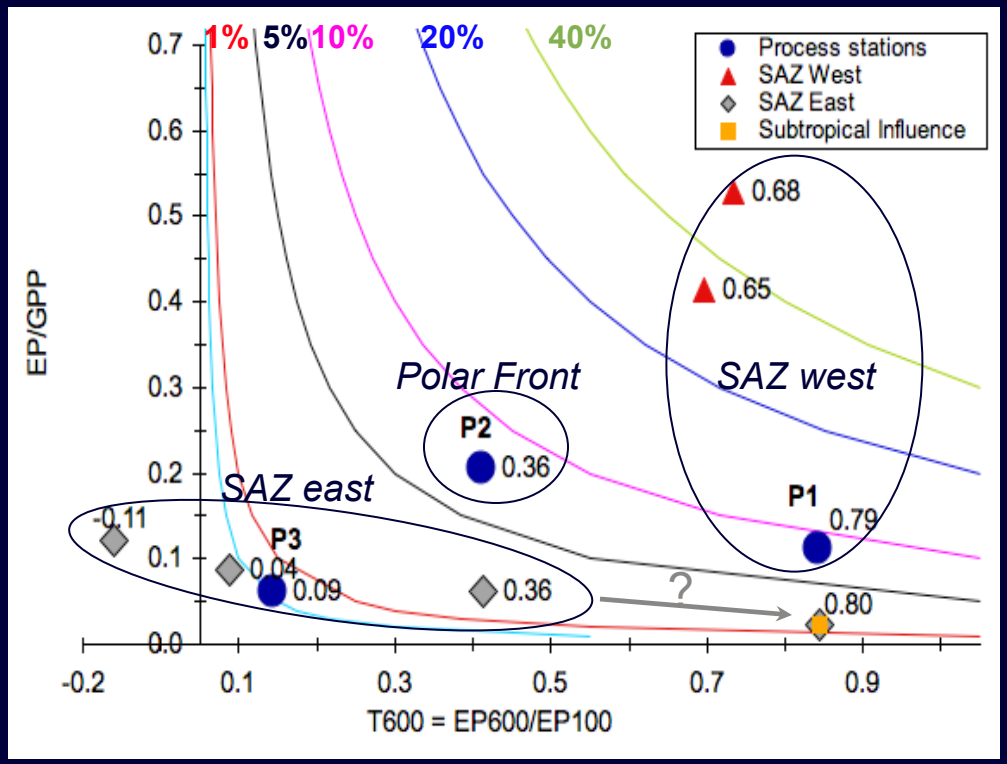
SAZ west has higher shallow and mesopelagic export efficiencies.

These overwhelm lower GPP, leading to higher flux at 600m

MR data from Jacquet, Dehairs, et al. DSR2

Relating shallow export and mesopelagic transfer efficiencies

Shallow export efficiency



Mesopelagic transfer efficiency

Contours are lines of constant EP600/GPP = efficiency of transfer of GPP to 600m. Higher EP600/GPP = longer remineralization length scale

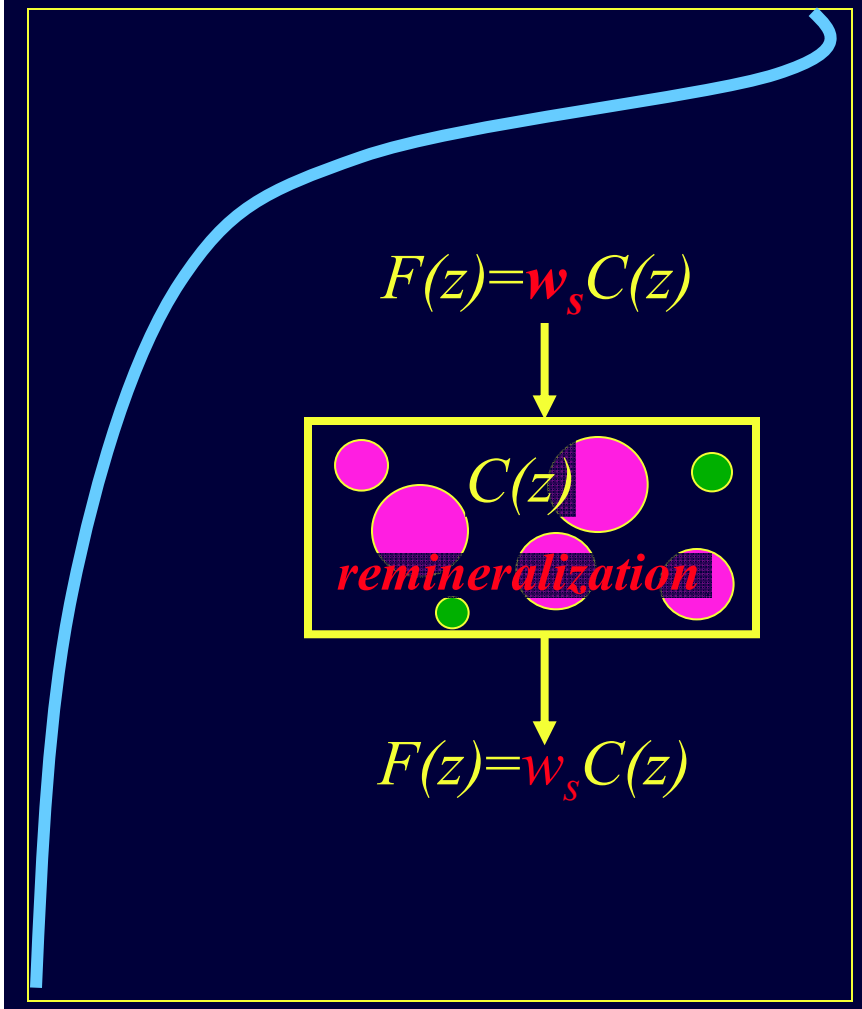
SAZ east has higher Fe (Bowie et al.) and more dinoflagellates and cyanobacteria (Wright et al.) than SAZ west

PFZ has the lowest Fe and more diatoms

High Fe subtropical influence in SAZ east--> a preview of the future?

Jacquet, Lam, Trull, Dehairs, DSR2
Jacquet, Dehairs, et al. DSR2
After Buesseler and Boyd 2009 L&O

Relating POC flux, concentration, sinking, and remineralization



$$\frac{\partial F(z)}{\partial z} = \frac{\partial \left(w_s C(z)\right)}{\partial z} = -rC(z)$$

Divergence of Flux = Internal sink from remineralization, r

If assume w_s, r constant with depth, then solution is:

$$C(z) = C_{80} \exp\left[-\frac{z}{w_s / r}\right]$$

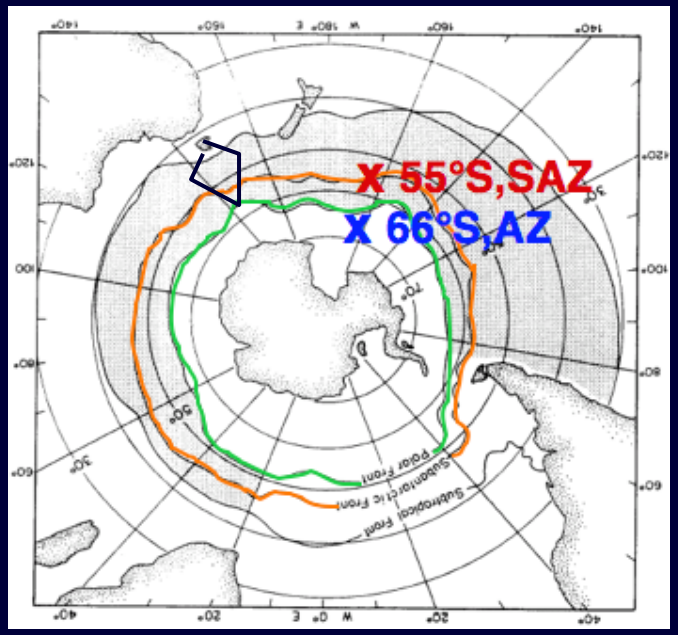
e-folding length scale

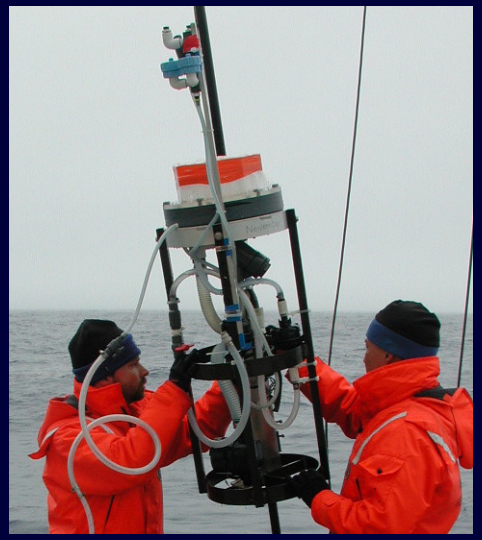
If assume $w_s = w_{80} z$ or $r = r_{80}/z$ then solution is a power law function:

$$C(z) = C_{80}\left(\frac{z}{z_{80}}\right)^{-\left[\frac{z_{80}}{(w_{80}/r_{80})}\right]}$$

length scale

Southern Ocean Iron Enrichment Experiment (SOFeX)

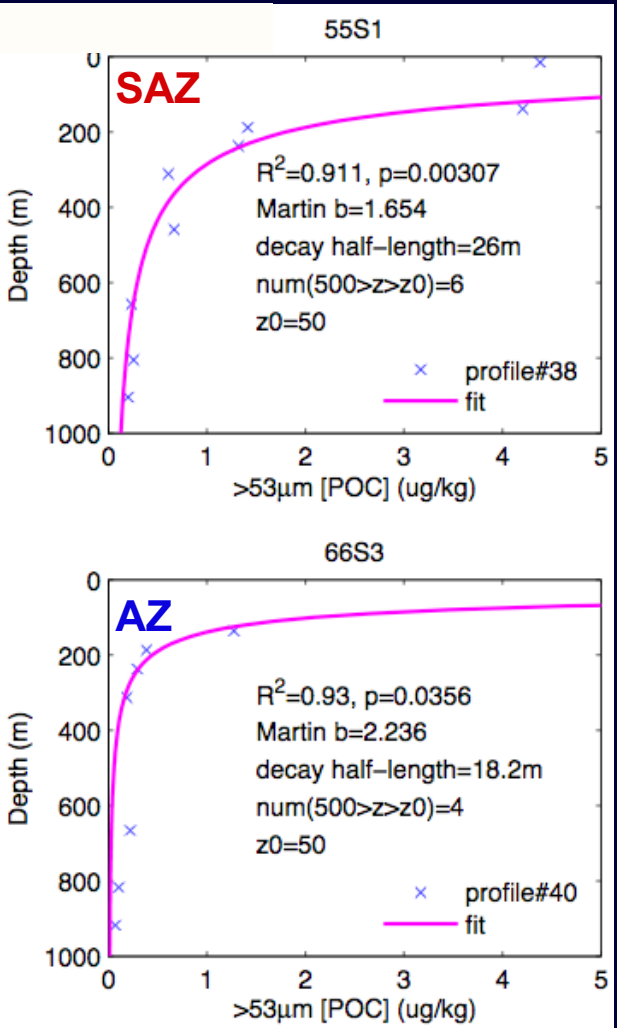




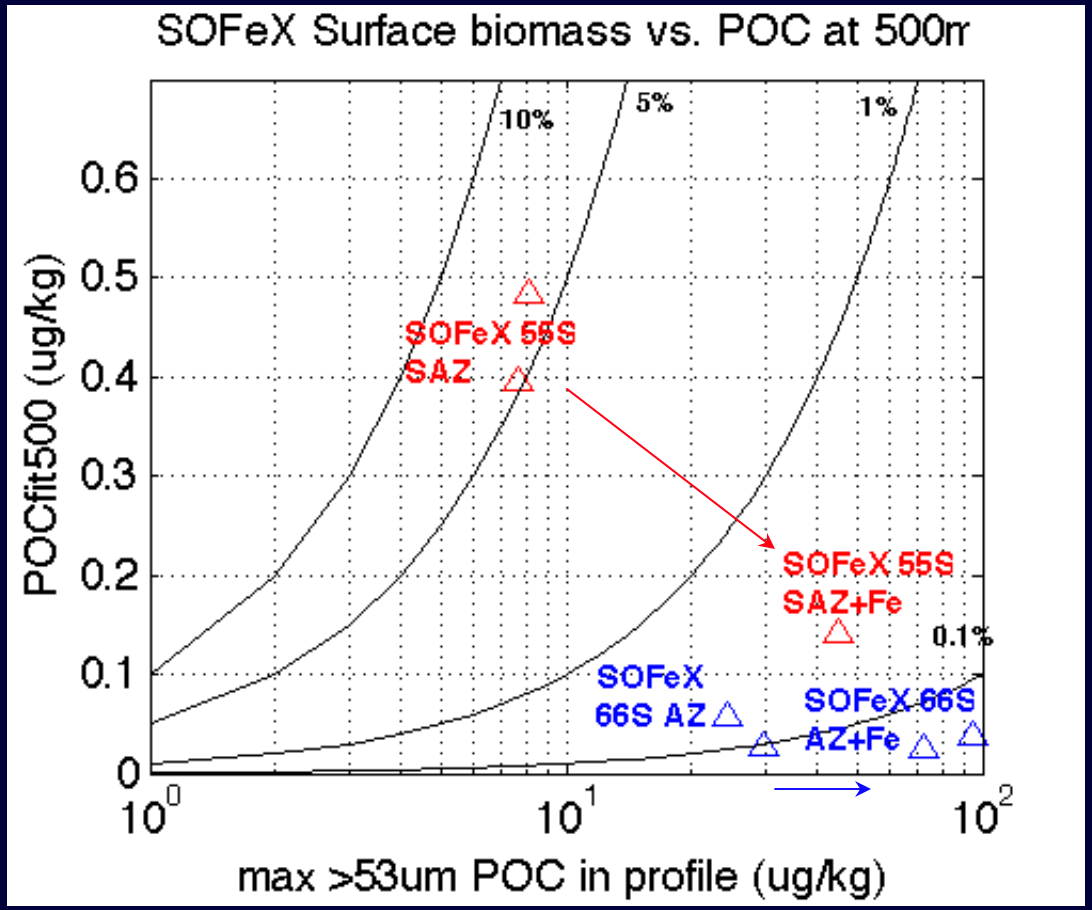
Size-fractionated particle profiles collected by Multiple Unit Large Volume in-situ Filtration (MULVFS) during SOFeX in SubAntarctic Zone (SAZ, N=3) and Antarctic Zone (AZ, N=5), in and out of Fe patch

>51um (sinking) size fraction POC presented here

SOFeX: 66°S AZ has higher surface POC but lower POC at depth compared to 55°S SAZ



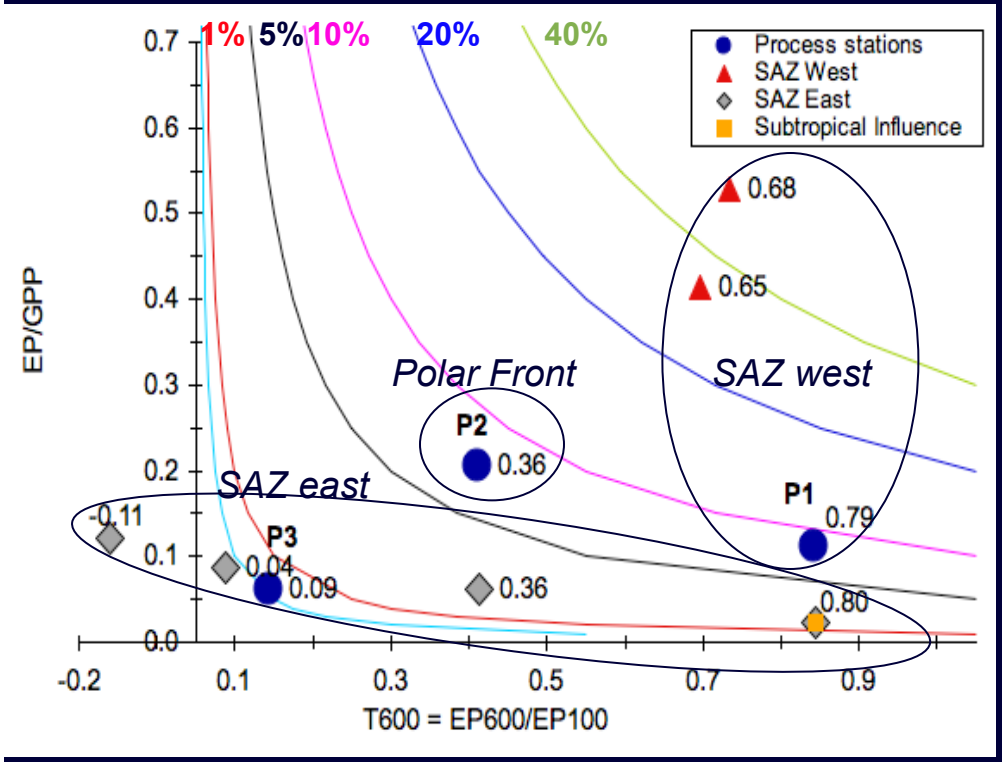
Lam and Bishop, DSR2 2007



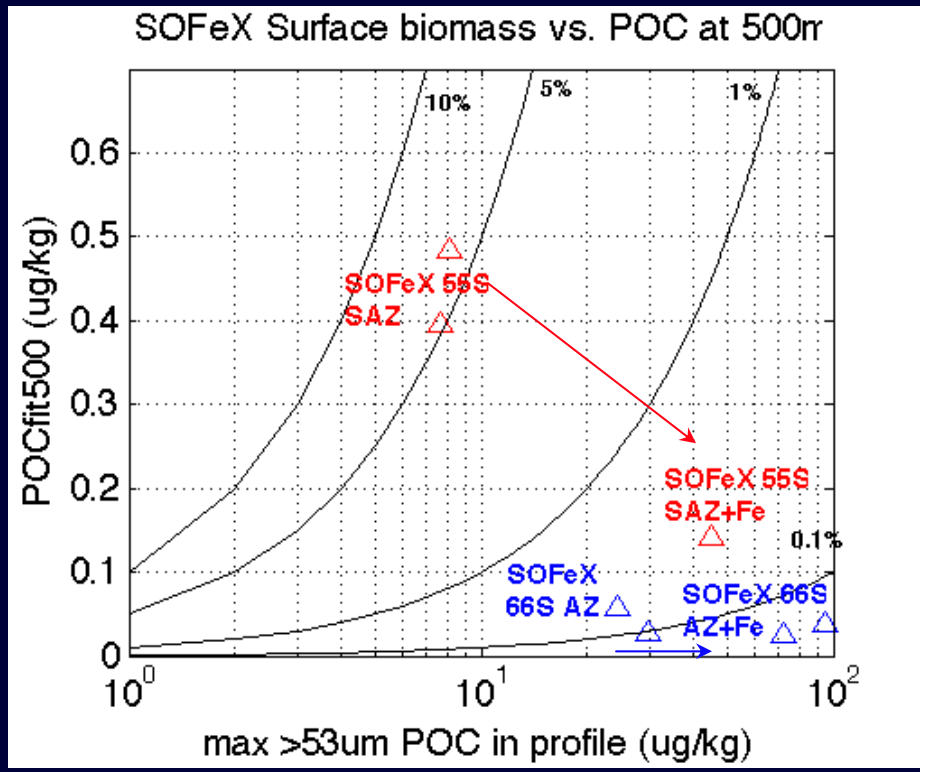
Contours are constant POC500/maxPOC = efficiency of transfer of surface biomass to 500m

How do SAZ SENSE and SOFeX compare?

SAZ Sense



SOFeX

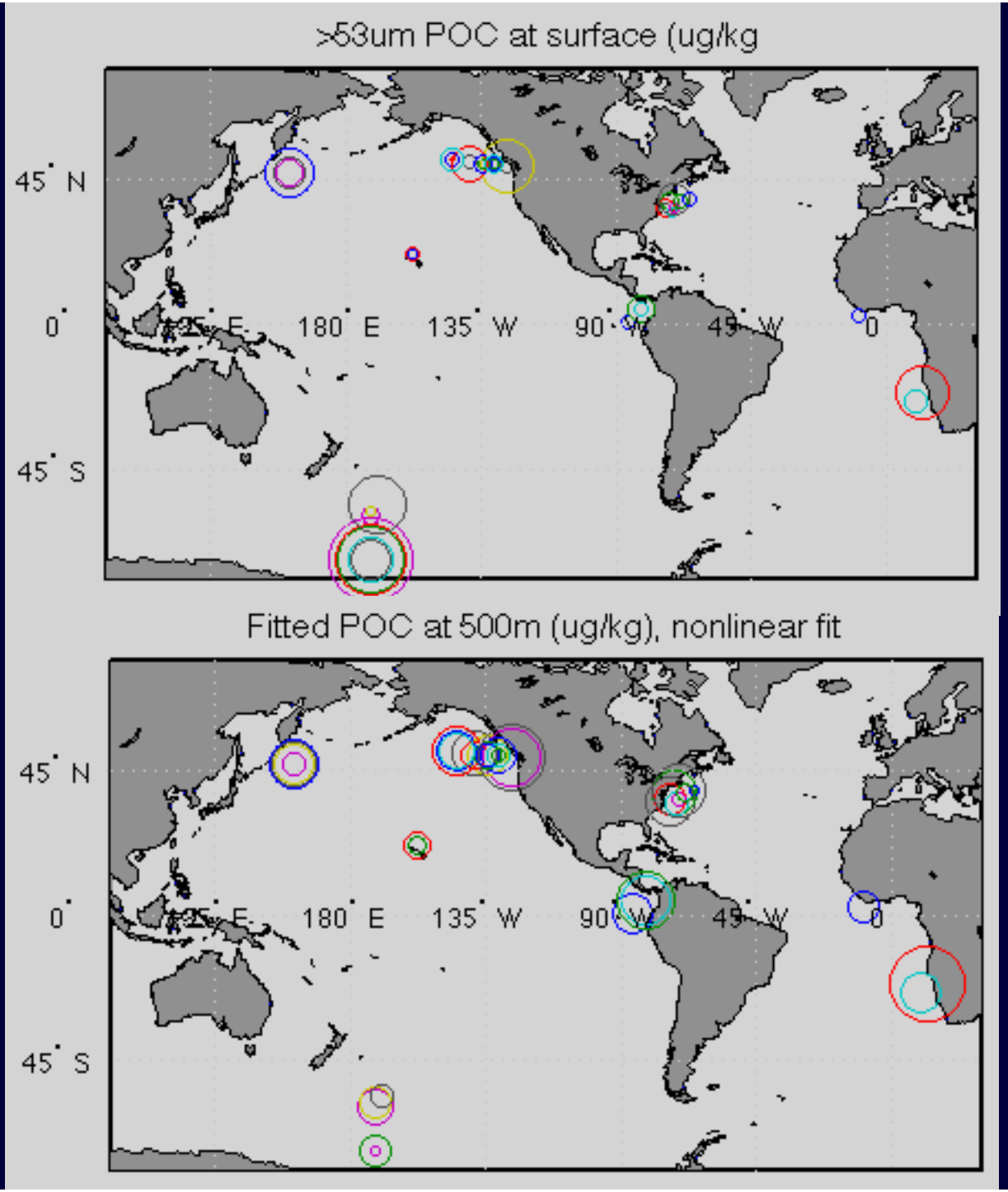


Jacquet, Lam, Trull, Dehairs, DSR2
Jacquet, Dehairs, et al. DSR2

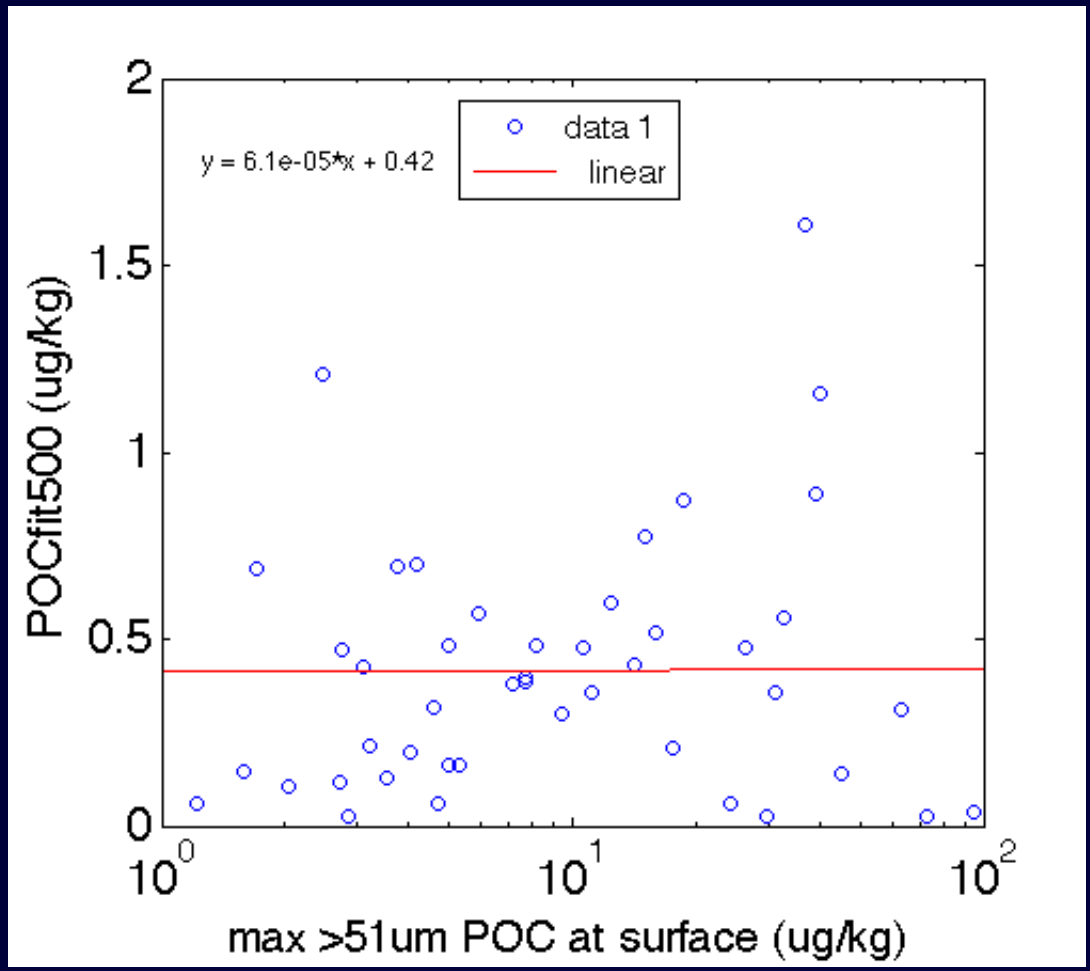
In both projects, the low Fe SAZ regions have longer remineralization length scales than Polar or SAZ+Fe regions

The Global (MU)LVFS dataset

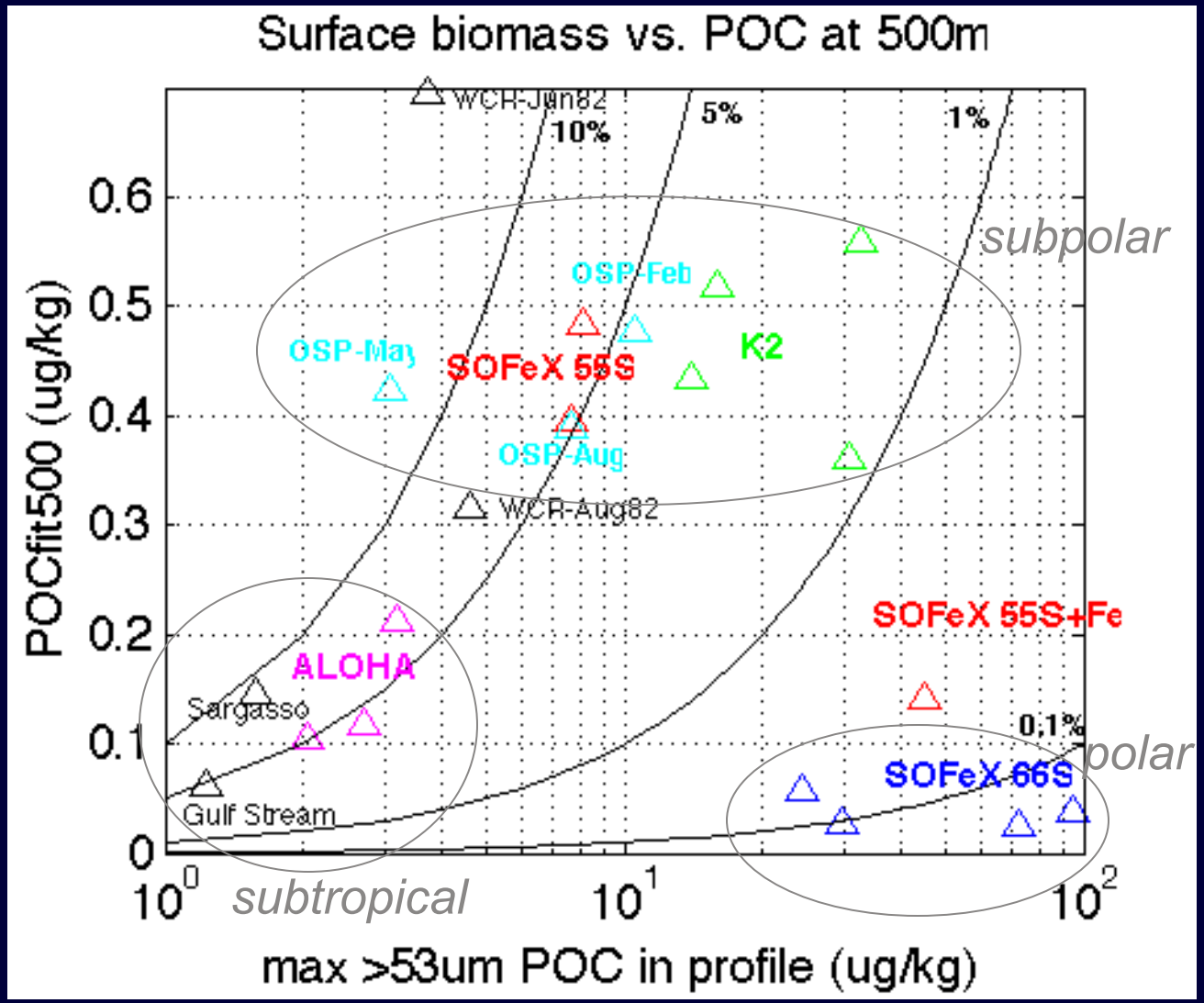
Top: Bubble area indicate >53um [POC] at surface
Bottom: Bubble area indicates >53um [POC] at 500m



Globally, no relation between >53um POC at surface and POC at 500m



Geographical clustering of lengthscales



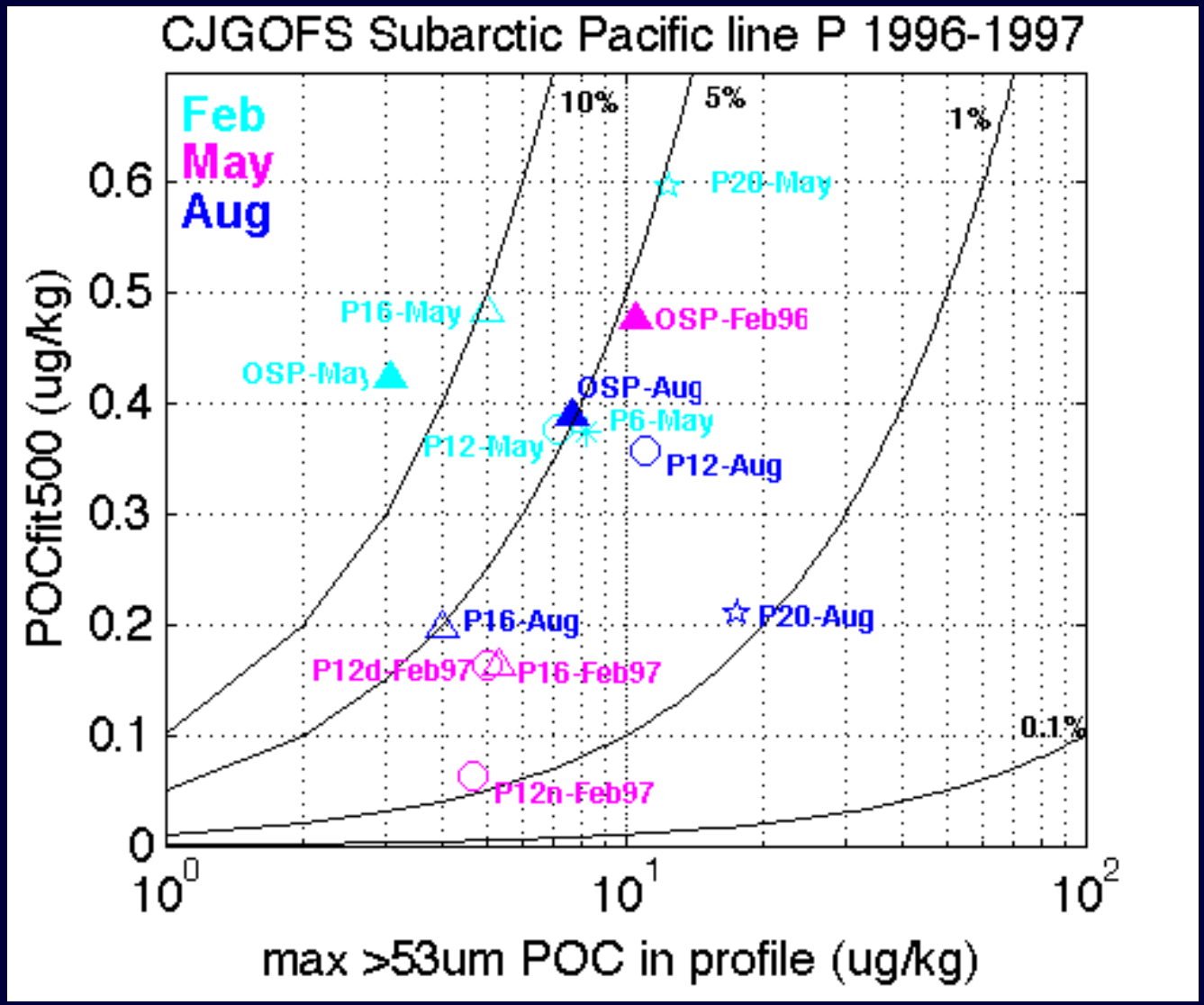
Lam, in prep

Long remin. lengthscale

Short remin. lengthscale

Subpolar regions tend to have higher POC at 500m

Though variability within one subpolar region is high

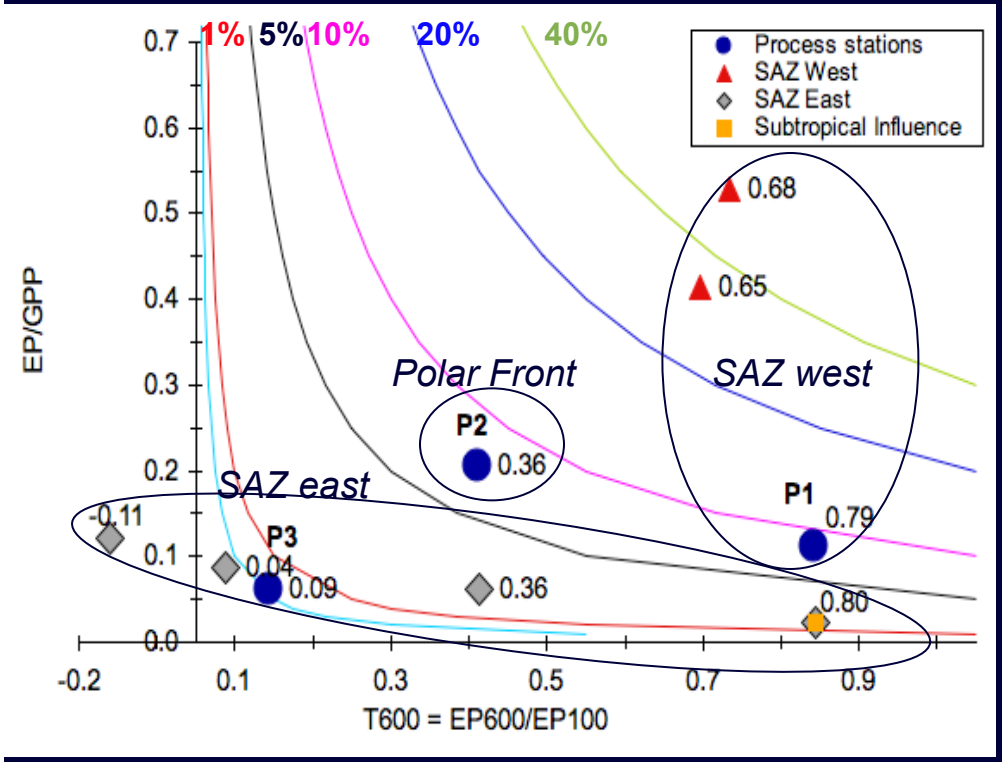


Long remin. lengthscale

Short remin. lengthscale

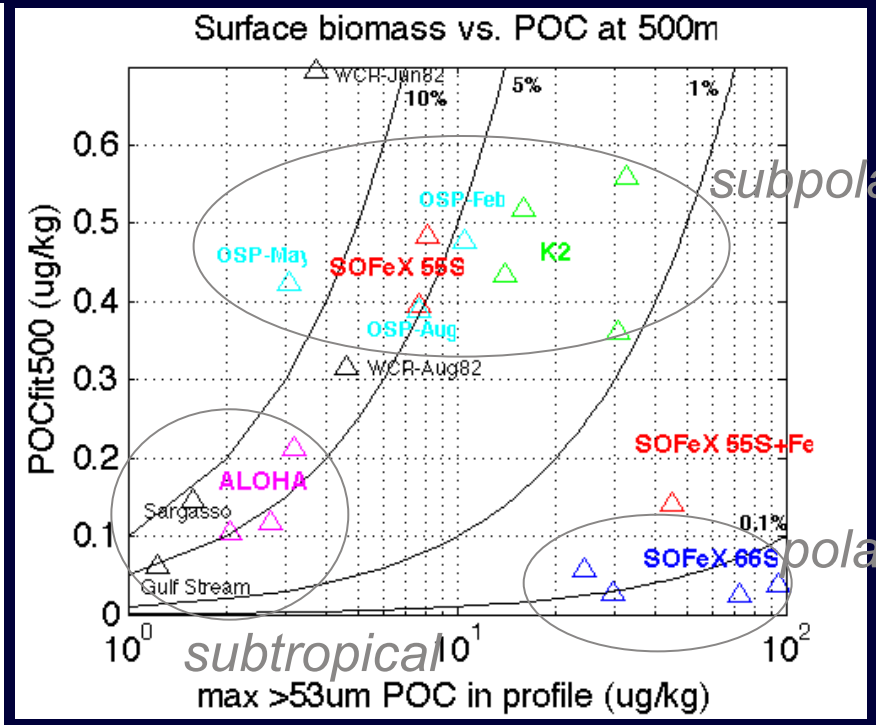
How does SAZ SENSE compare to the global compilation?

SAZ Sense



Jacquet, Lam, Trull, Dehairs, DSR2
Jacquet, Dehairs, et al. DSR2

SOFeX



Lam, in prep

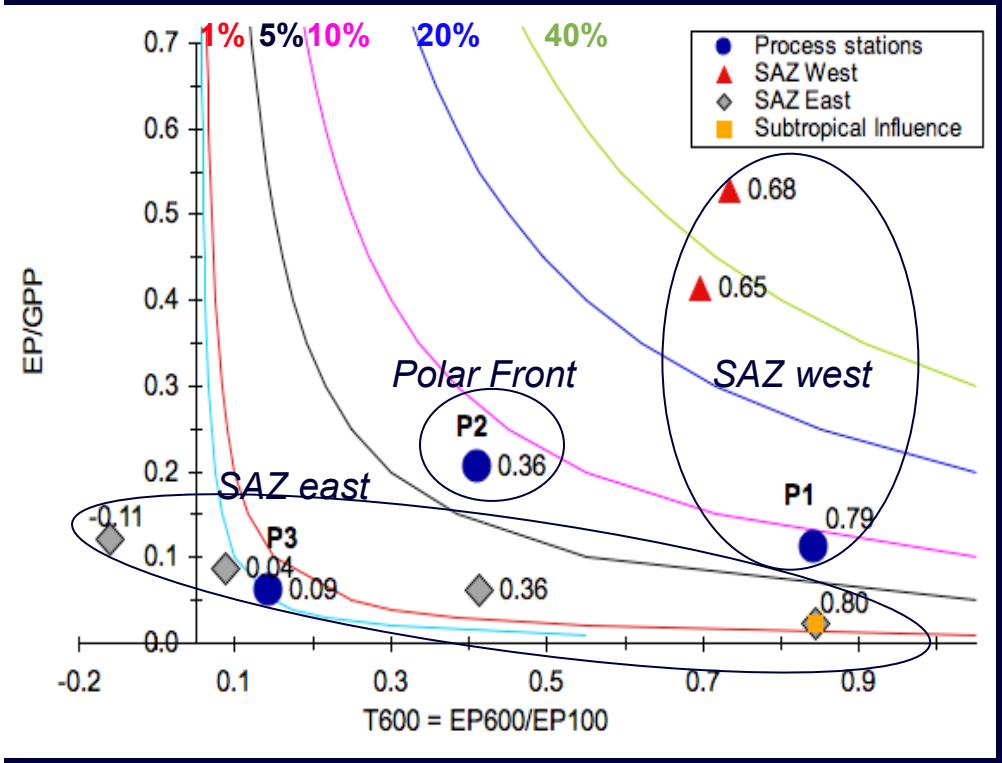
Fe-limited sub-polar regions seem efficient at transferring POC to depth

Conclusions

- Subantarctic regions are better at transferring POC to depth (mesopelagic) than Antarctic regions
- Stimulating surface production in Subantarctic regions (eg. +Fe) is not associated with higher POC at depth
- Subpolar regions should be targeted for more study of the biological carbon pump

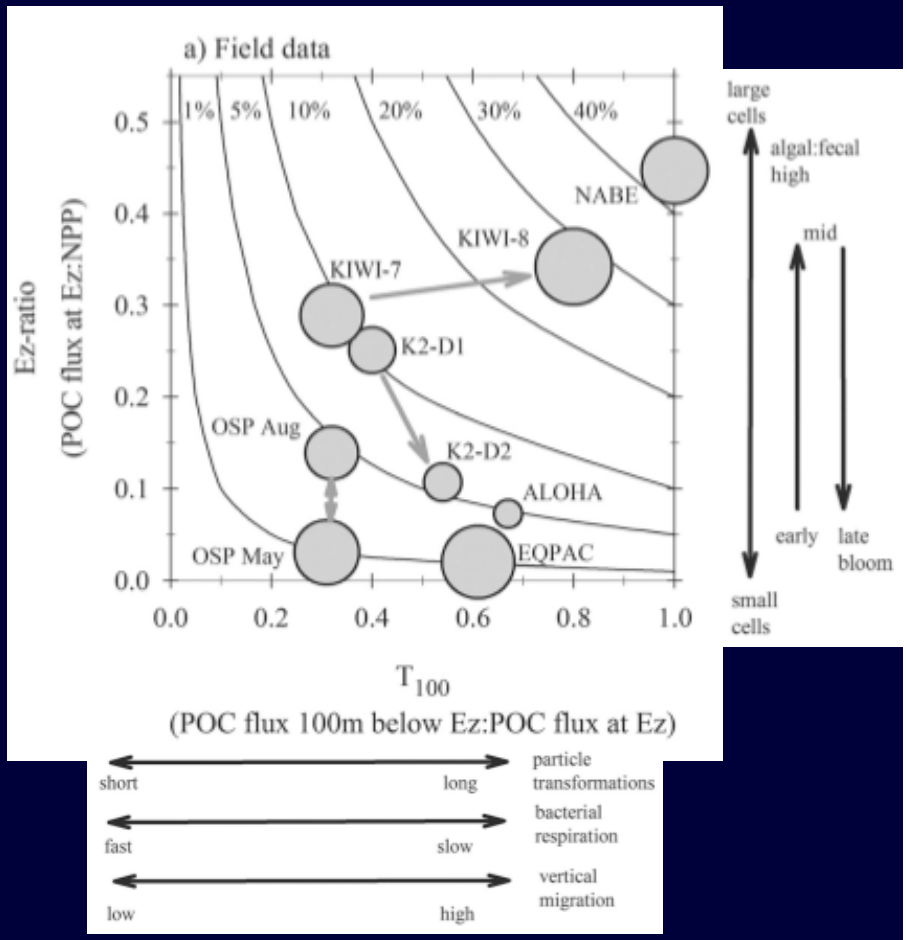
Comparing SAZ Sense to B&B compilation

SAZ Sense



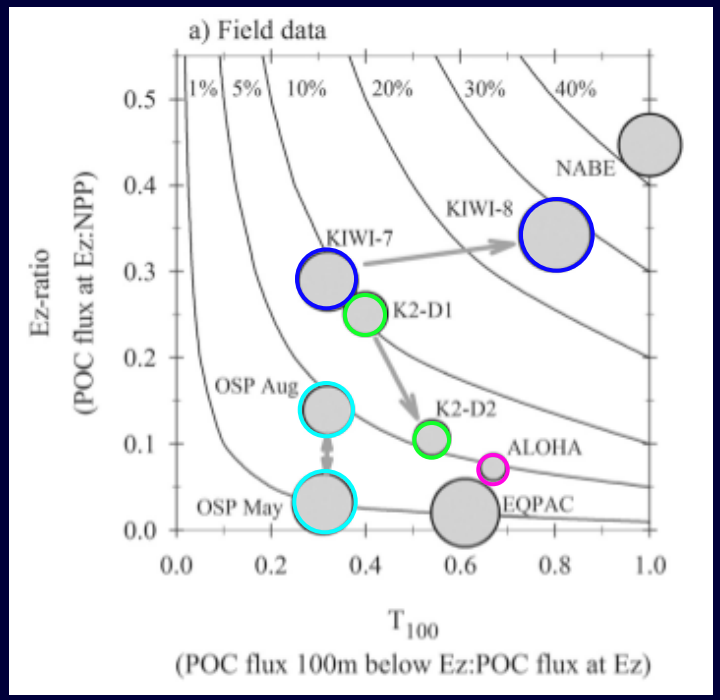
Jacquet, Lam, Trull, Dehairs, DSR2
Jacquet, Dehairs, et al. DSR2

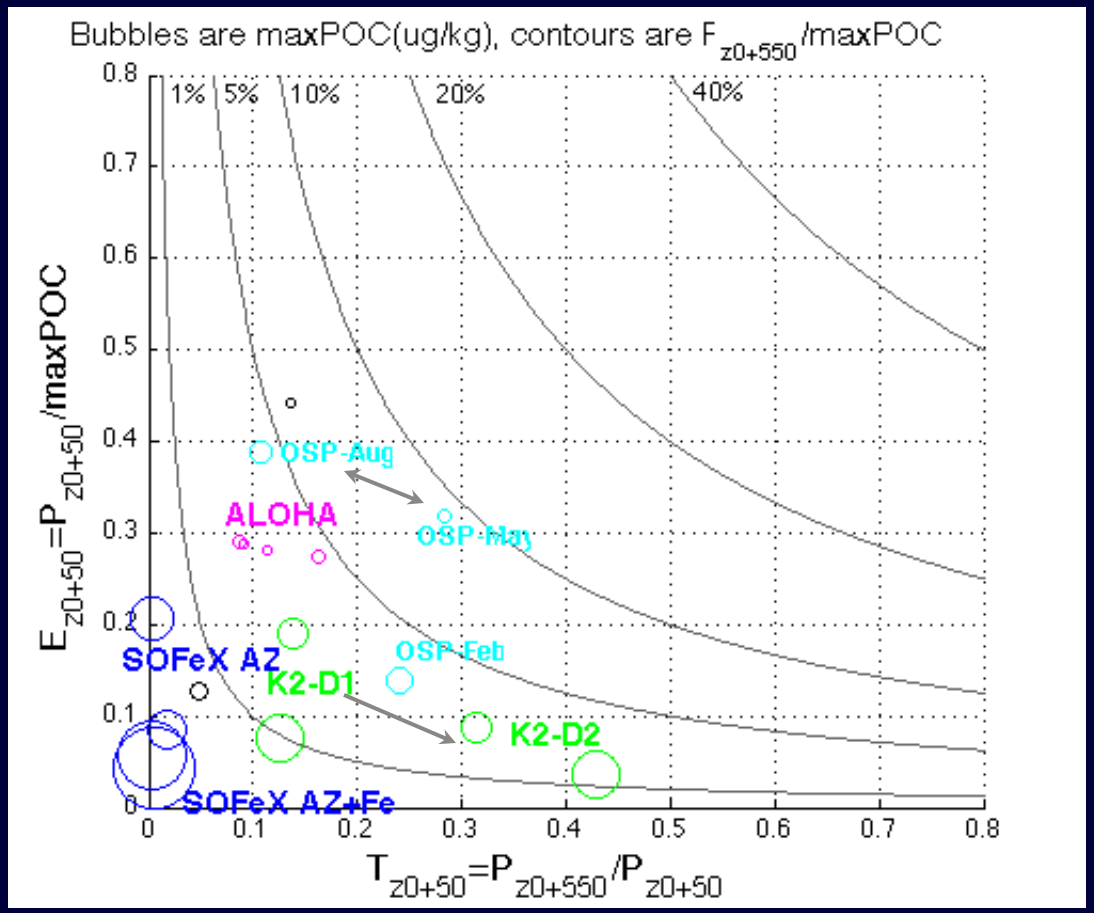
Global Compilation



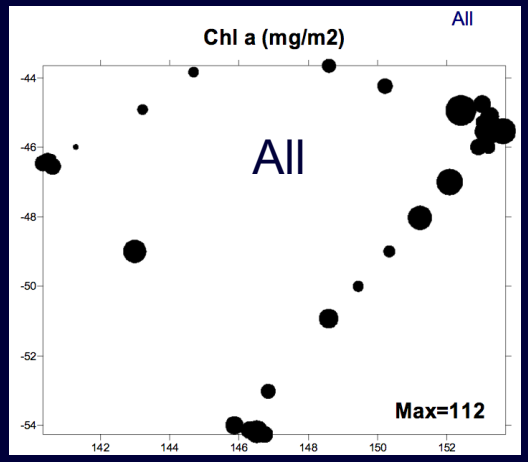
Buesseler and Boyd, L&O 2009

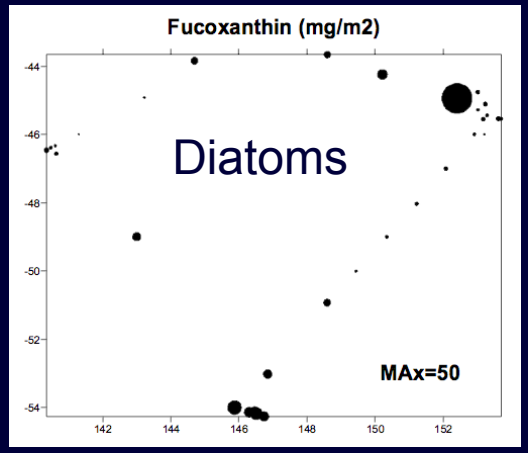
Comparing Flux to Concentration

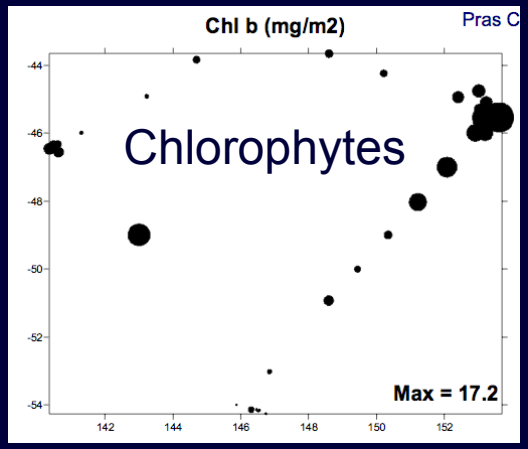


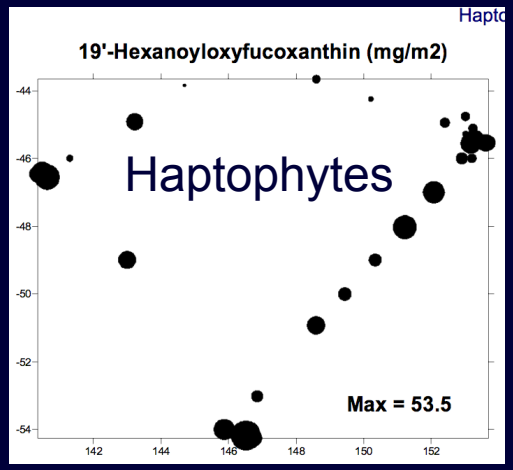


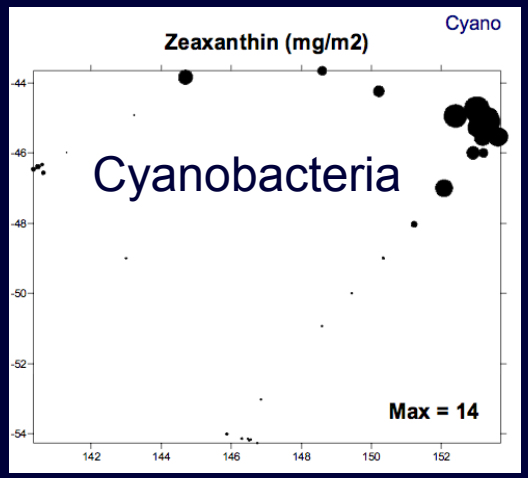
Lower export efficiency from SAZ east: Phytoplankton community structure?

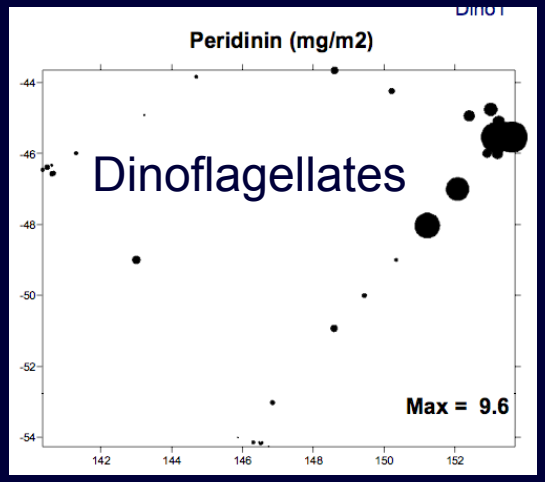












Pigment data from Simon Wright

Low diatoms throughout SAZ; some in PFZ (deep). Flagellates and cyanobacteria higher in SAZ east.