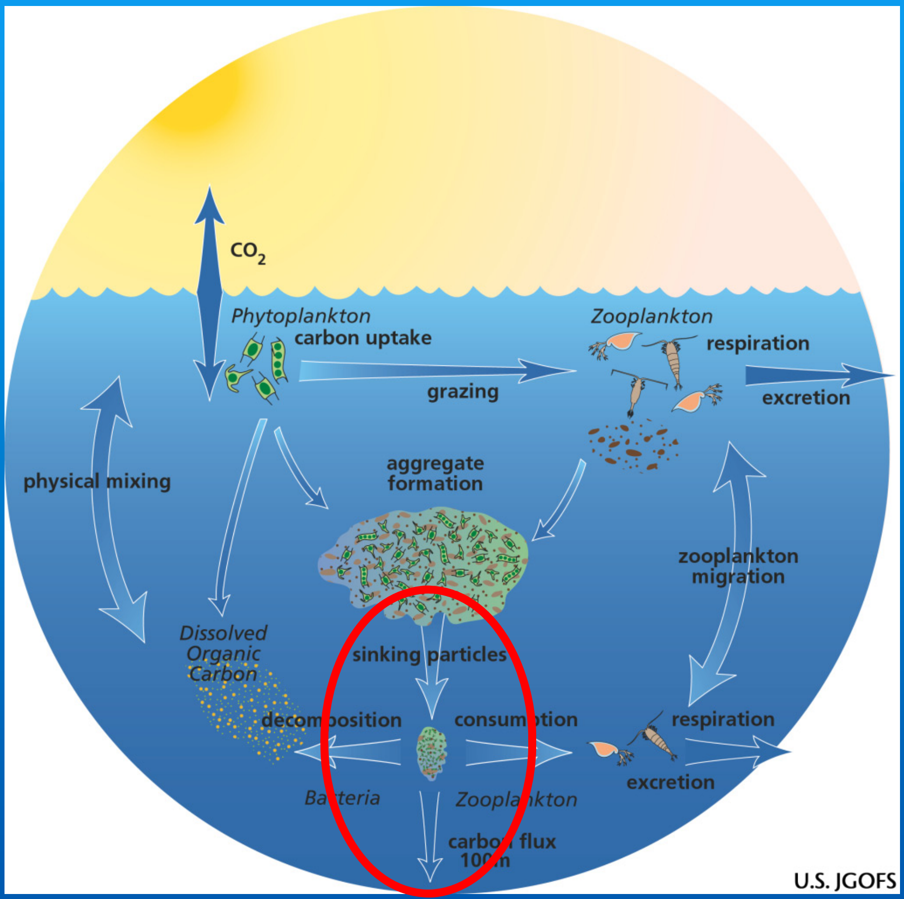
The biological pump- passive particle flux
What have we learned post JGOFS?

Ken Buesseler

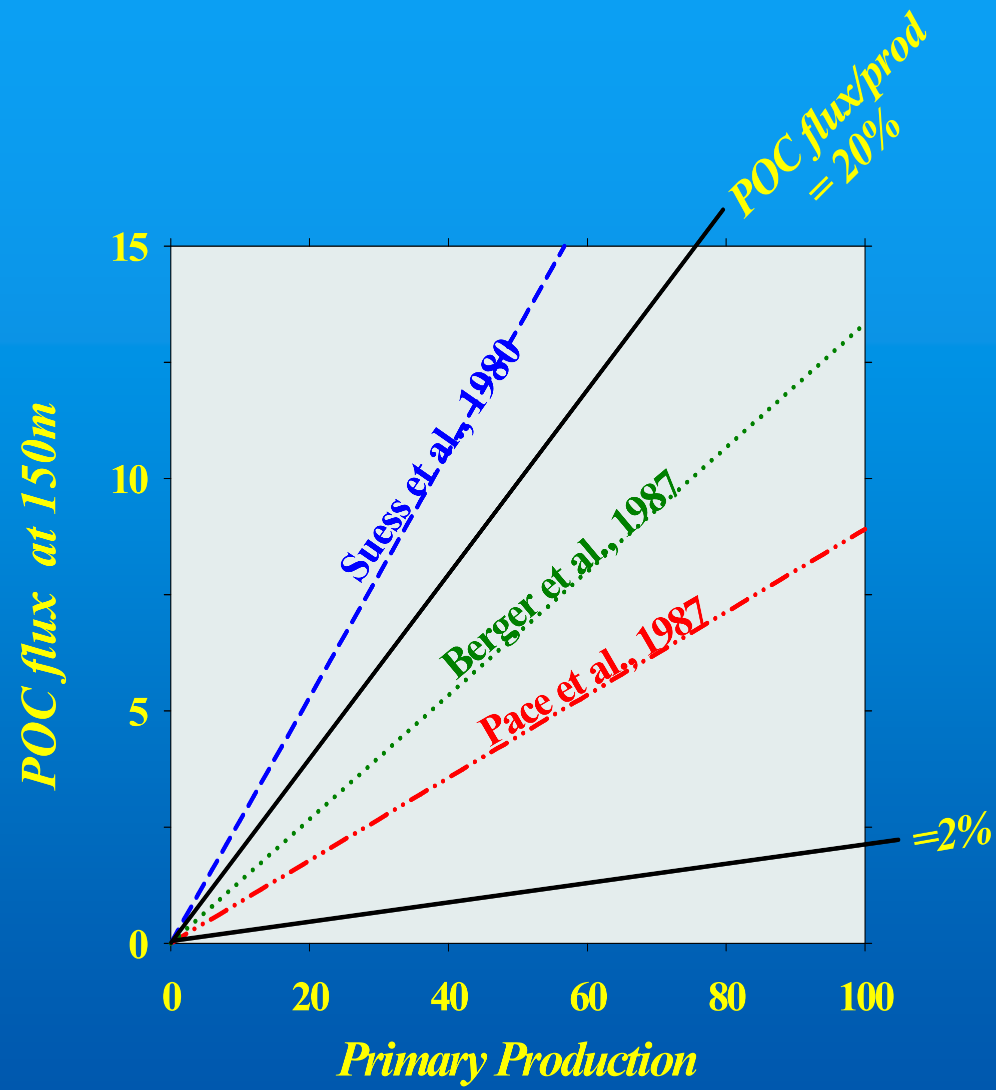


JGOFS Brochure, 2001

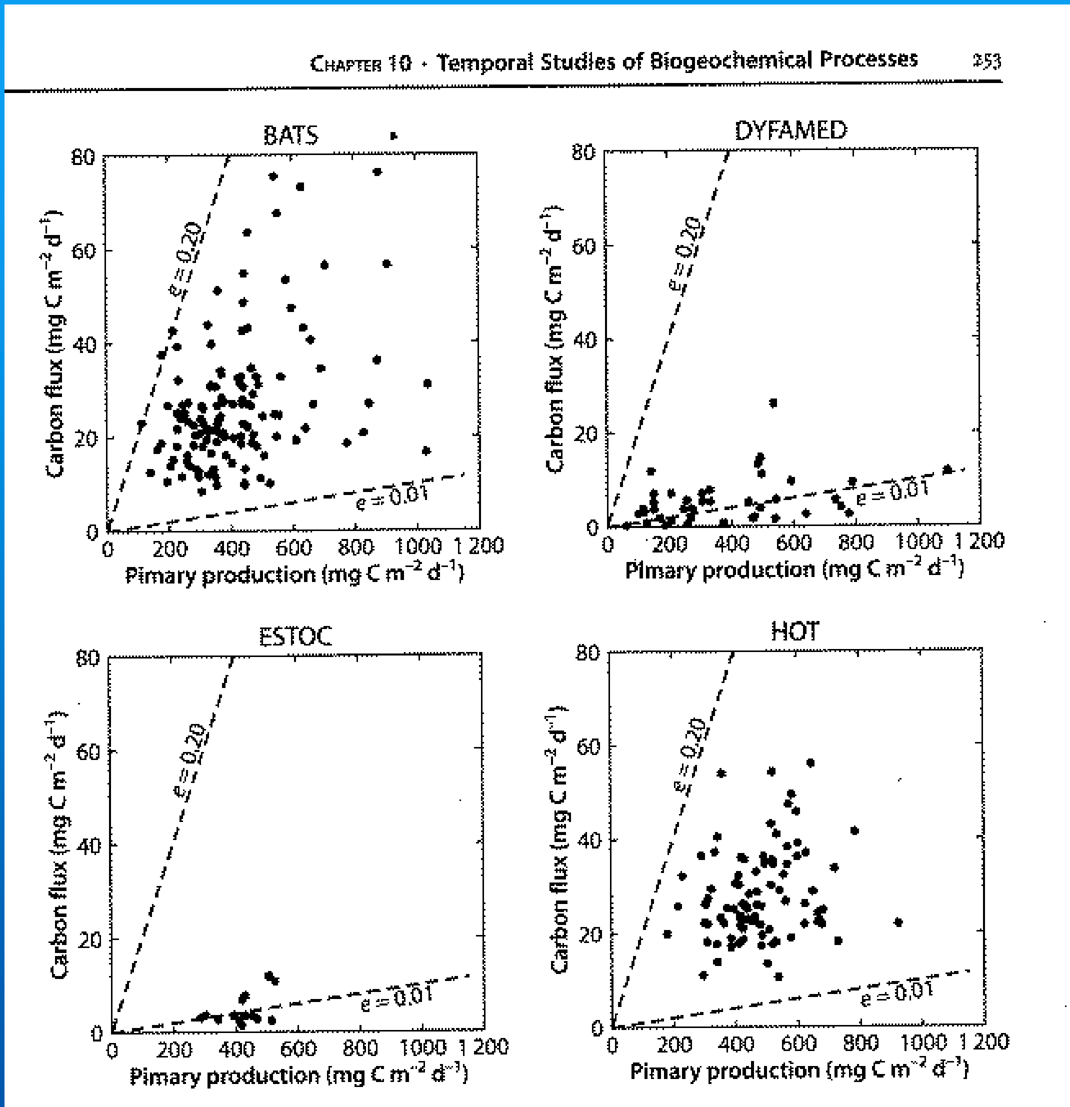
Outline

1. JGOFS lessons
2. Advances in methods
3. Scales of variability

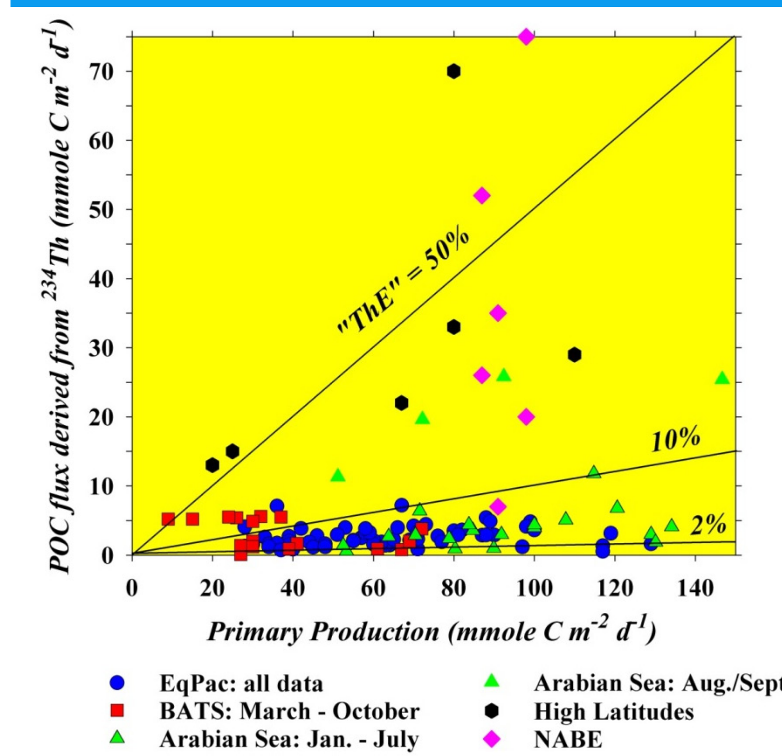
pre-JGOFS: POC flux ≈ β z * Primary Production



JGOFS results: POC flux vs. *Primary Production*



Karl et al., 2003

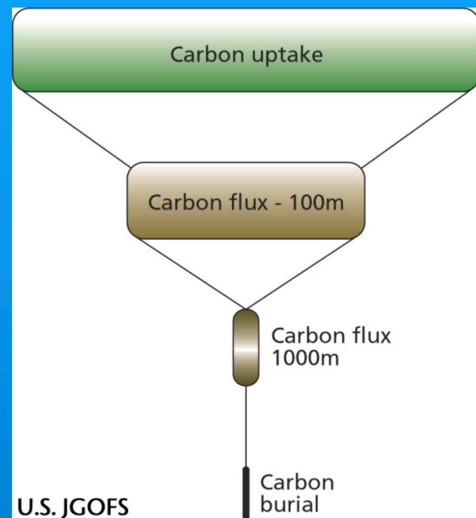


Buesseler, 1998

What about POC flux below the upper 100m?

Euphotic zone

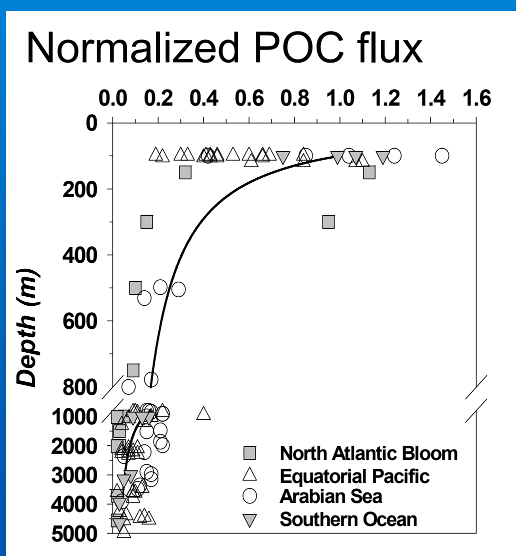
Twilight zone



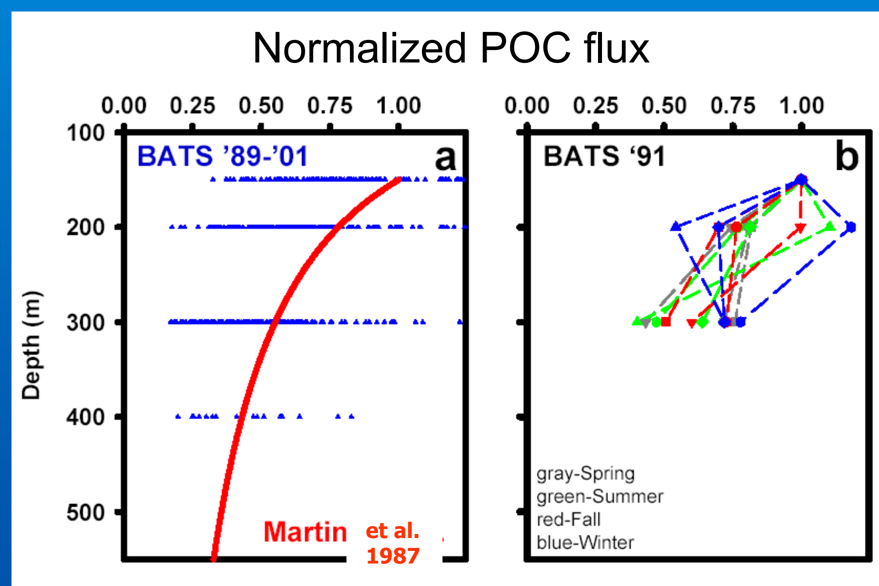
~50 Pg C/yr

~5-10 Pg C/yr

<1 Pg C/yr



But least amount of data from TZ



Variability is large

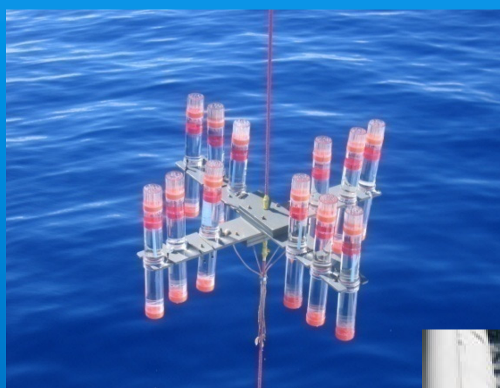
Controls poorly understood

How we measure particle export matters

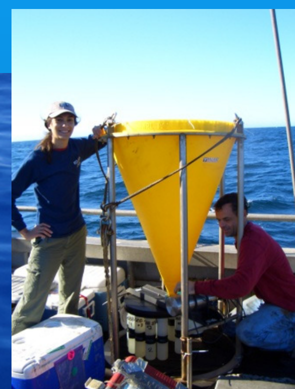
Directly:

Sediment Traps

PITs



Conical



SVT: Particle velocity

Neutrally Buoyant

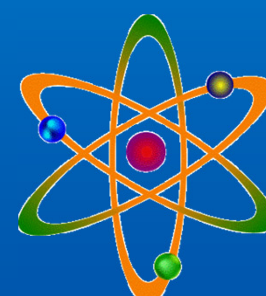
Indirectly:

Cameras

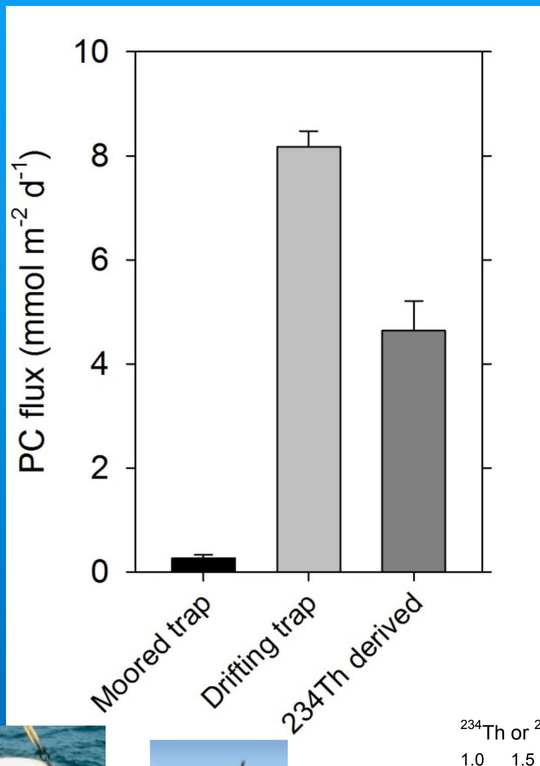
~~Geochemical Mass Balance~~

~~O_2, DIC, etc.~~

Radioactive Disequilibria



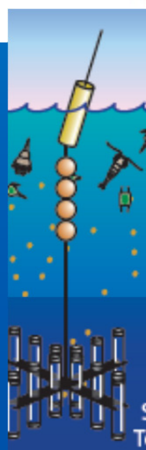
Long standing issue- methods differences

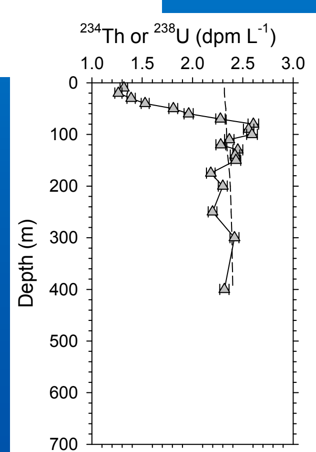


Recent example- W. Antarctic Peninsula

Buesseler, McDonnell, Steinberg, Schofield, Ducklow, 2010

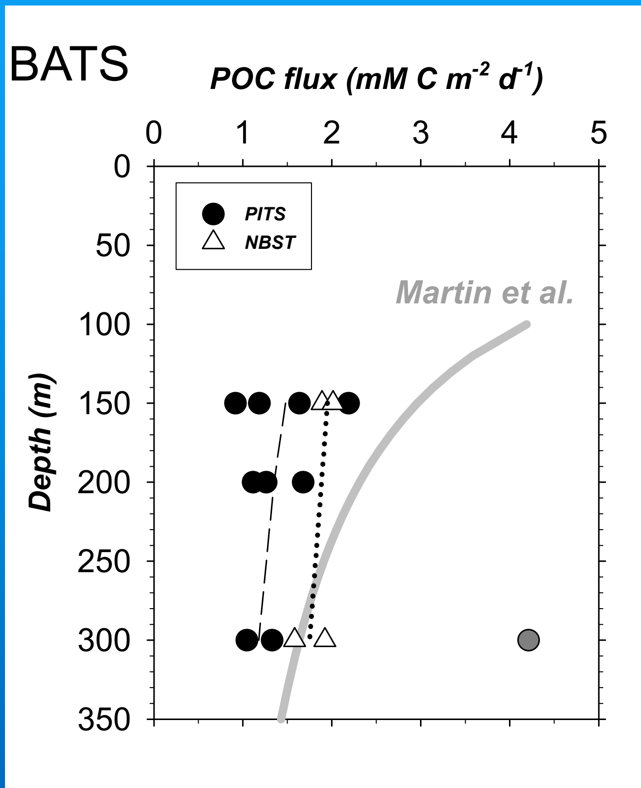
170m

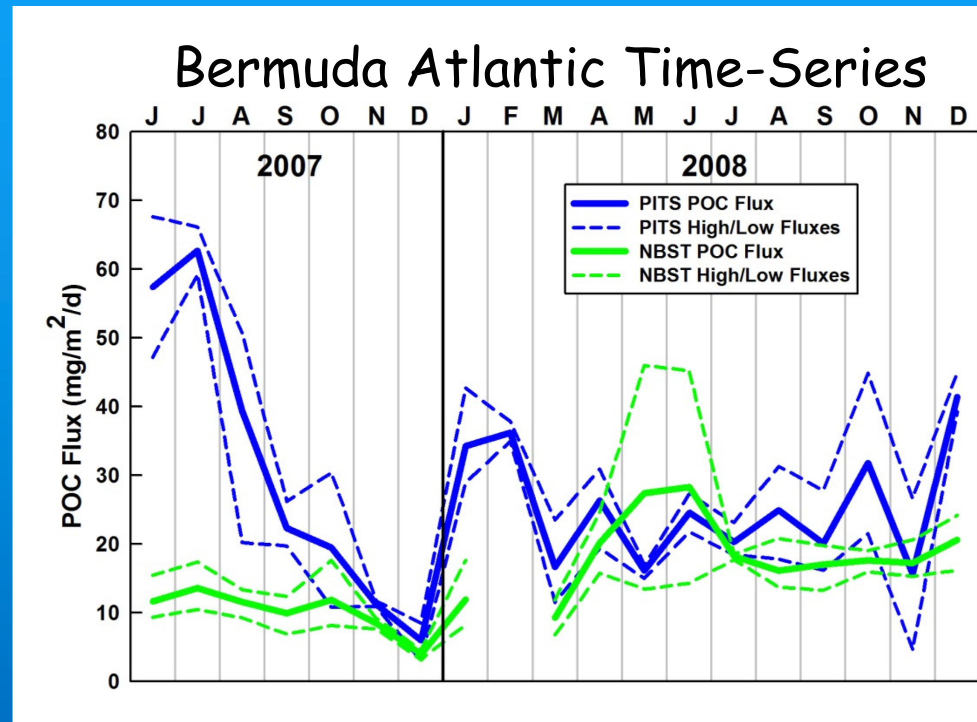




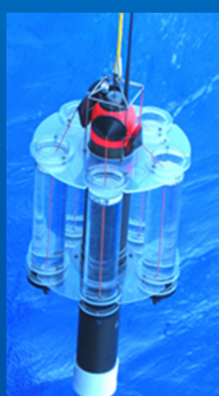
See also-
JGOFS report #10
Knauer & Asper 1989
JGOFS mid-term synthesis
Gardner, 2000
SCOR WG# 116
Buesseler et al. 2007

Neutrally Buoyant Sediment Trap (NBST)

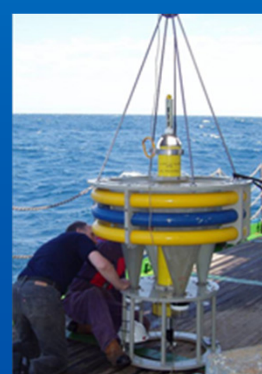




Owens et al., 2013



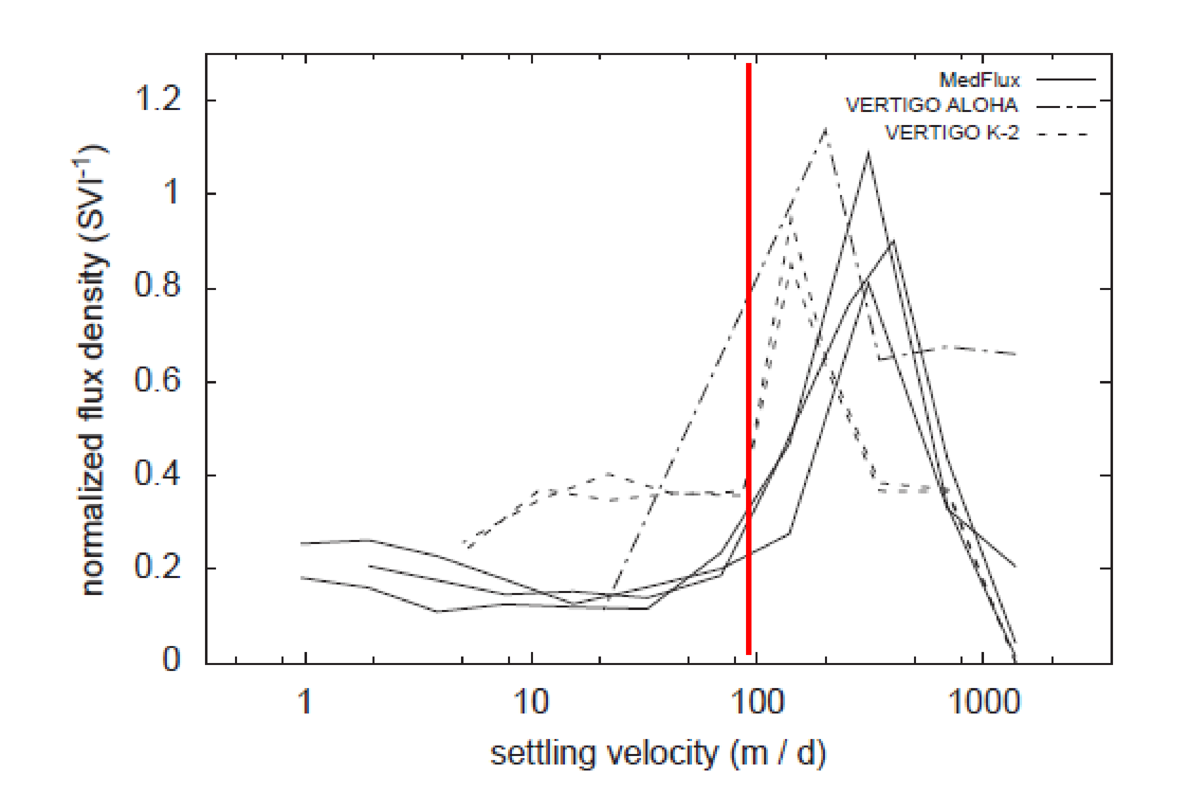
Valdes and Price 2000

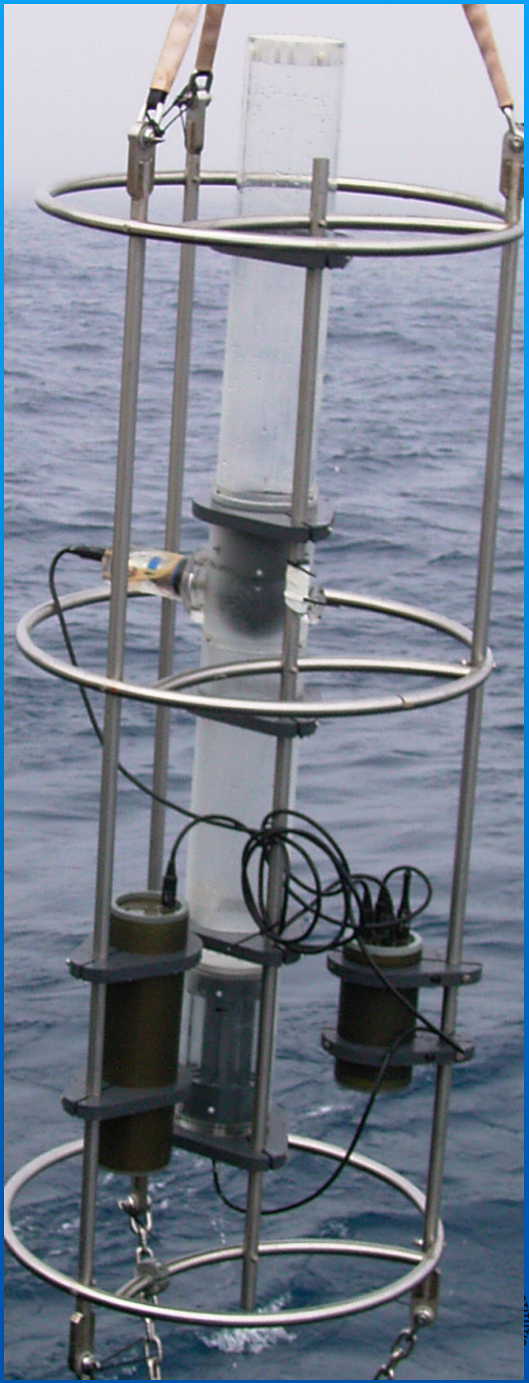


Lampitt et al. 2007

See also
Asper, 1996
Smith et al ,2011

Sinking velocity trap



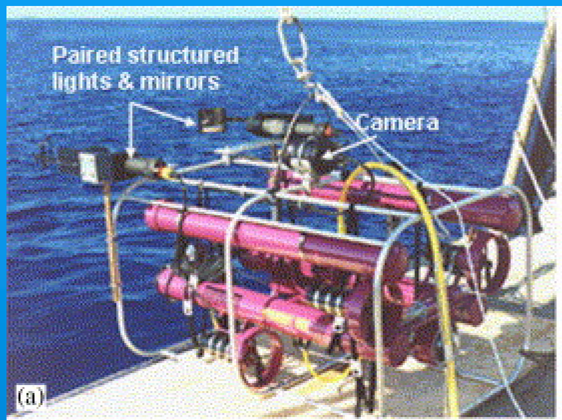


50% of flux > 100 m/d
Med, HOT, NW Pacific

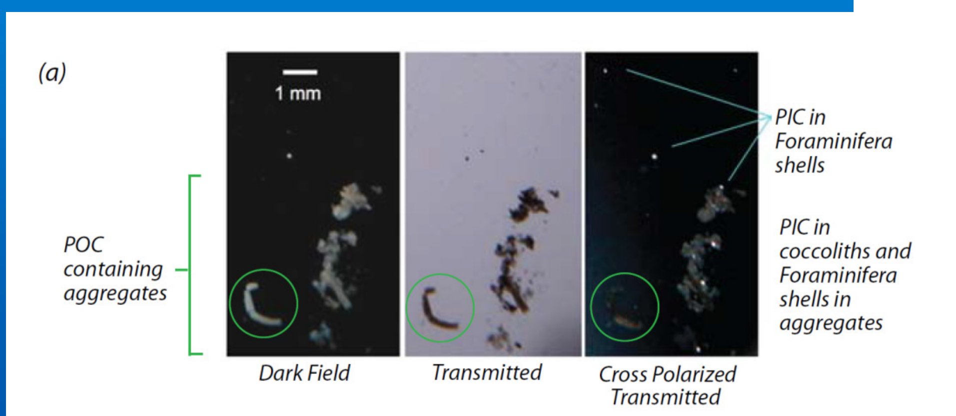
MedFlux- Armstrong et al. 2009

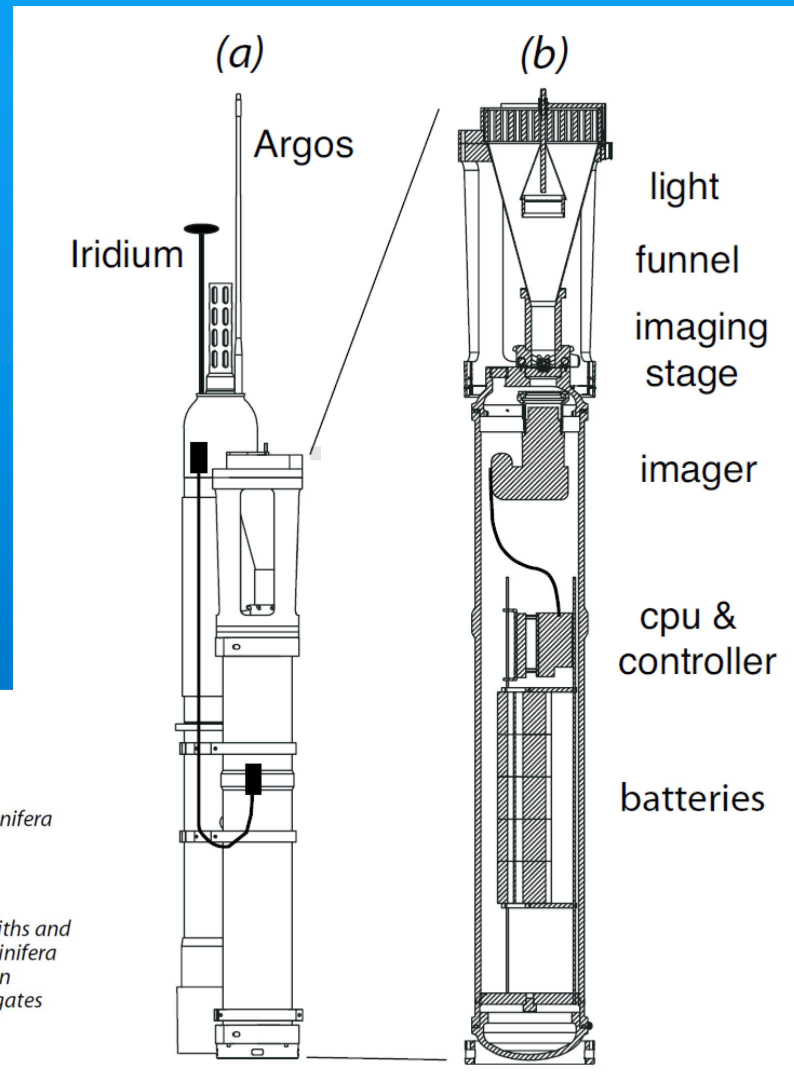
VERTIGO- Trull et al. 2008

Optical methods for particles advancing quickly



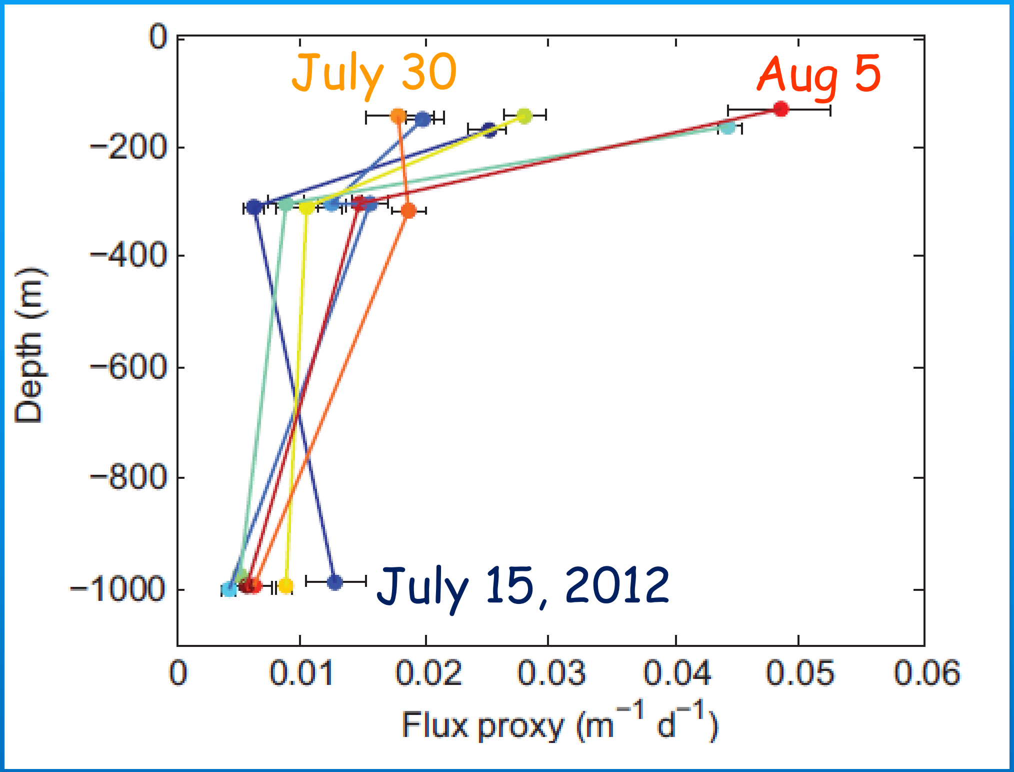
Pilskaln et al. 2005





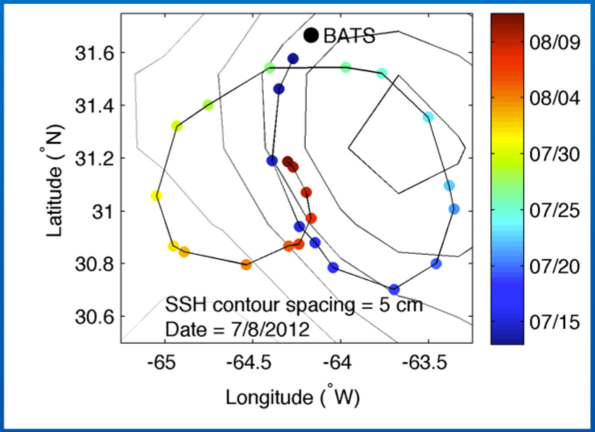
Ocean Carbon Flux Explorer
Bishop 2009

Optical flux index shows short term variability



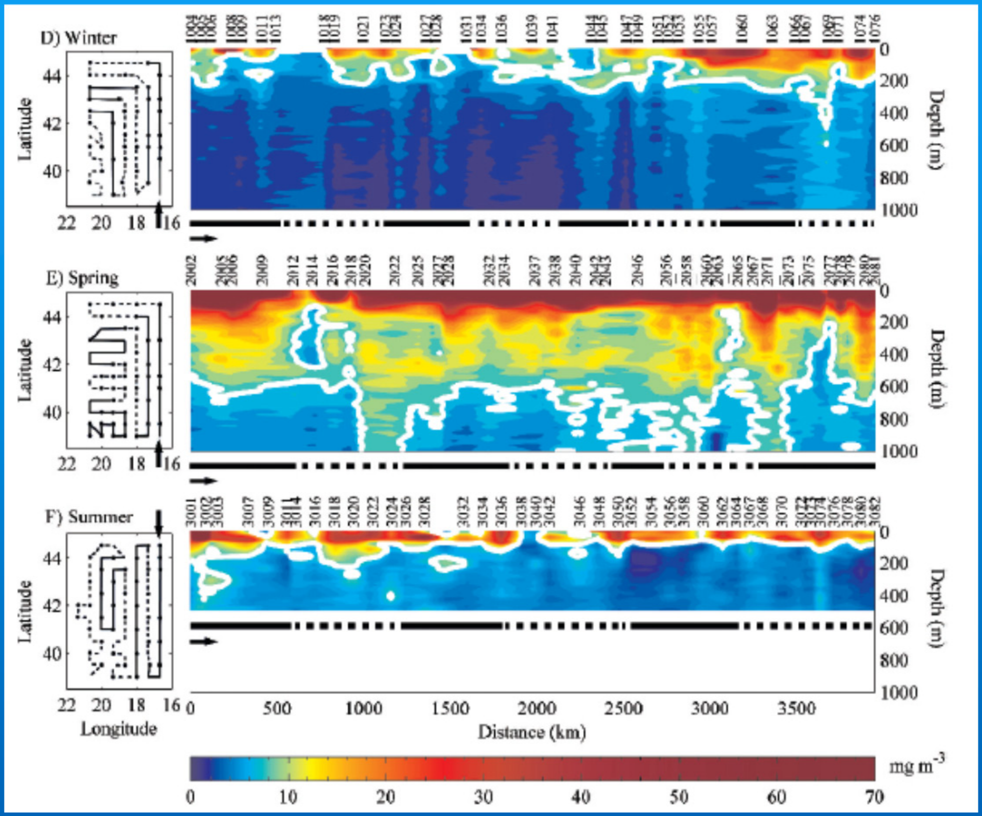
Can calibrate for C flux

Estapa et al. 2013



Improved cameras show variable particle stocks

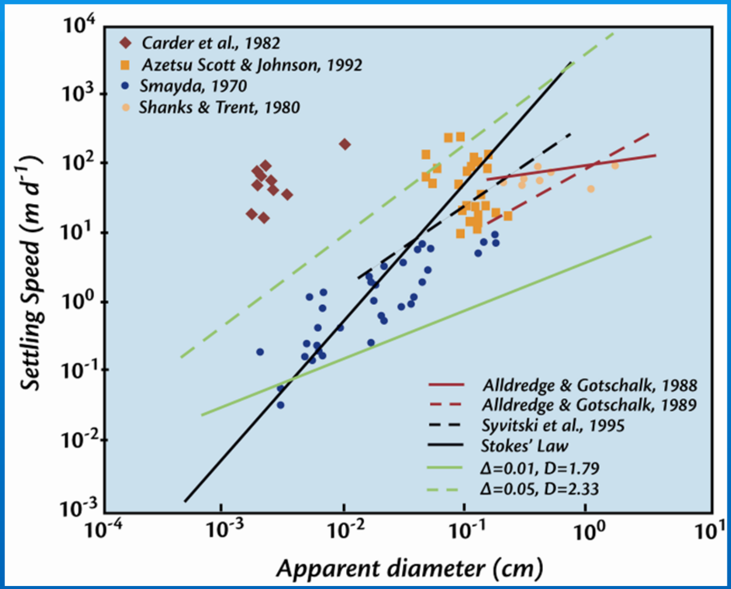
But what about Flux = Concentration x sinking velocity?



Particle distributions with cameras UVP

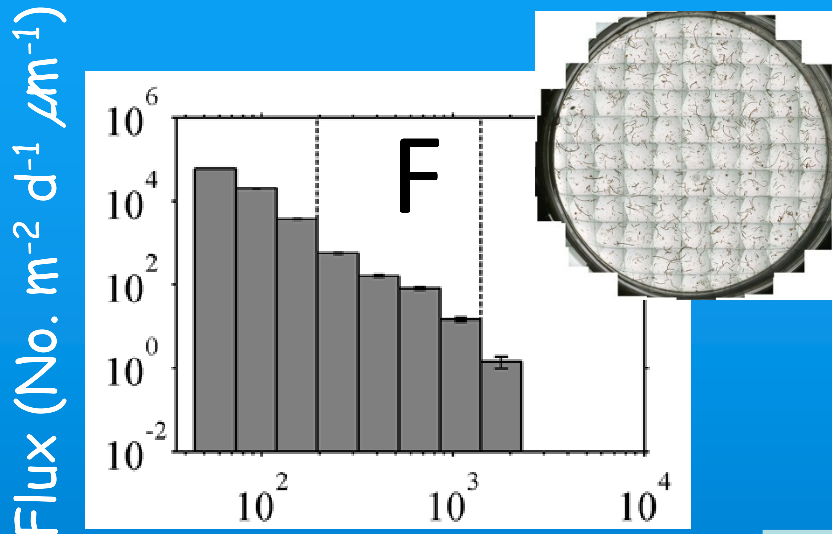
Guidi et al., 2007
POMME expt.

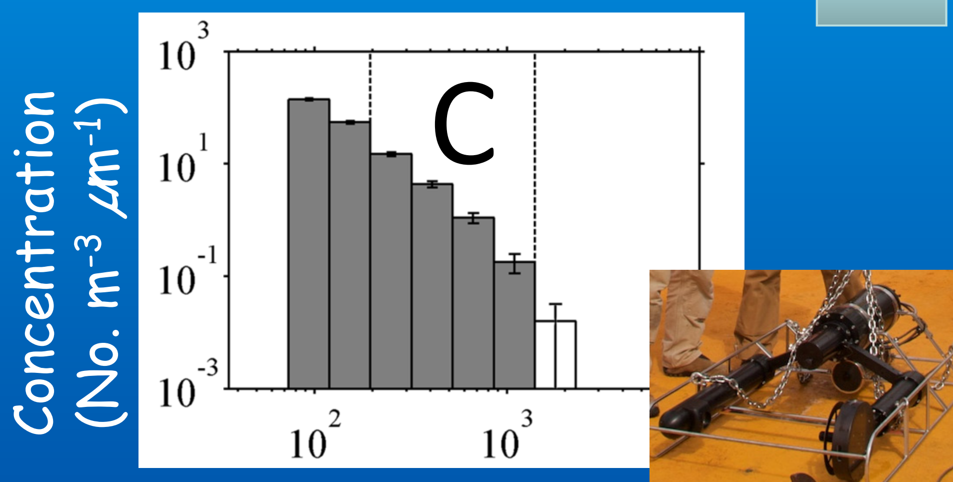
But also sinking rate variability



Stemmann et al. 2004

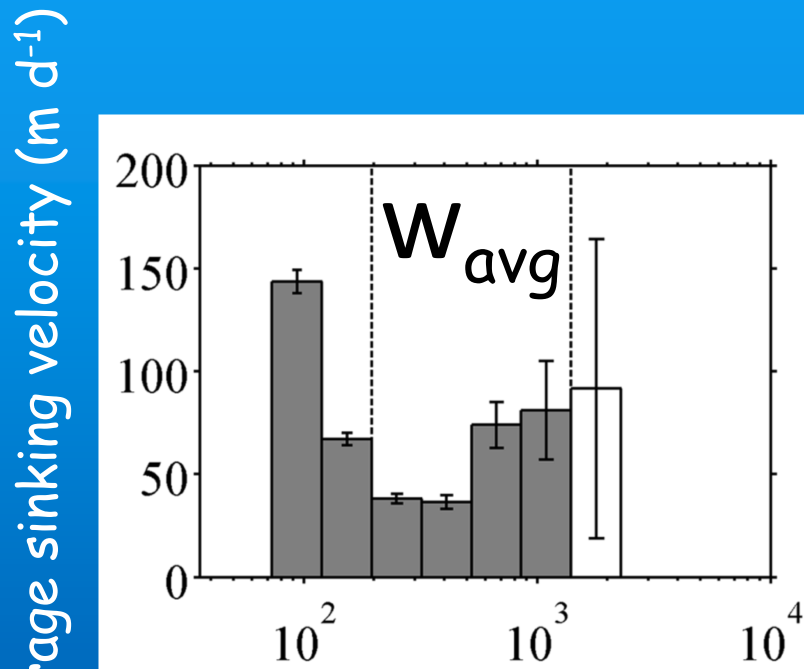
How to determine sinking rates using "gel" traps





Equivalent Spherical Diameter (µm)

=



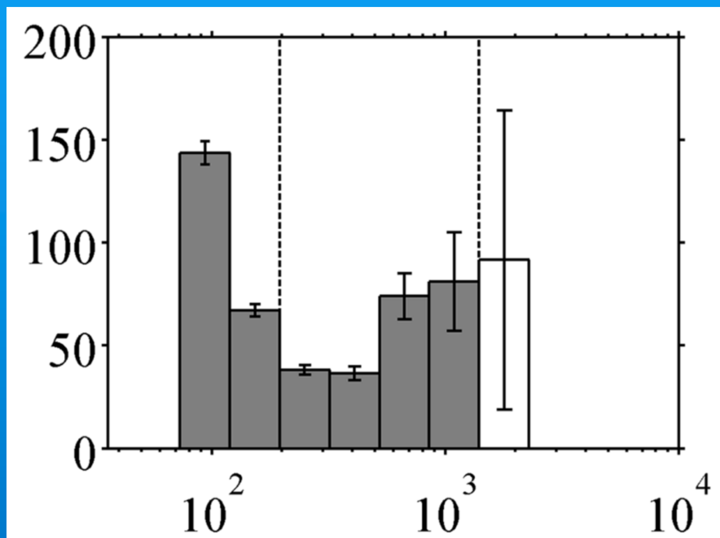
Equivalent Spherical Diameter (µm)

McDonnell and Buesseler 2010

Variability seen in regional sinking velocities

Antarctica

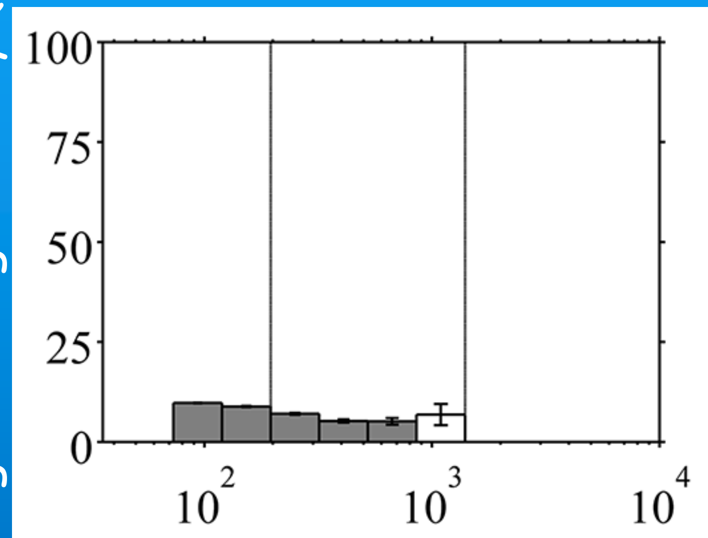
Average sinking velocity (m d-1)



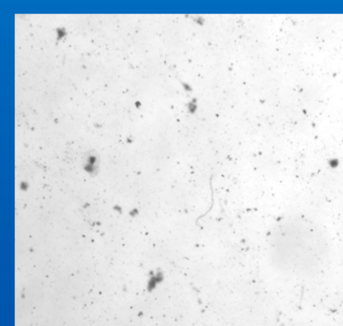
Equivalent Spherical Diameter (µm)

Bermuda

Average sinking velocity (m d-1)



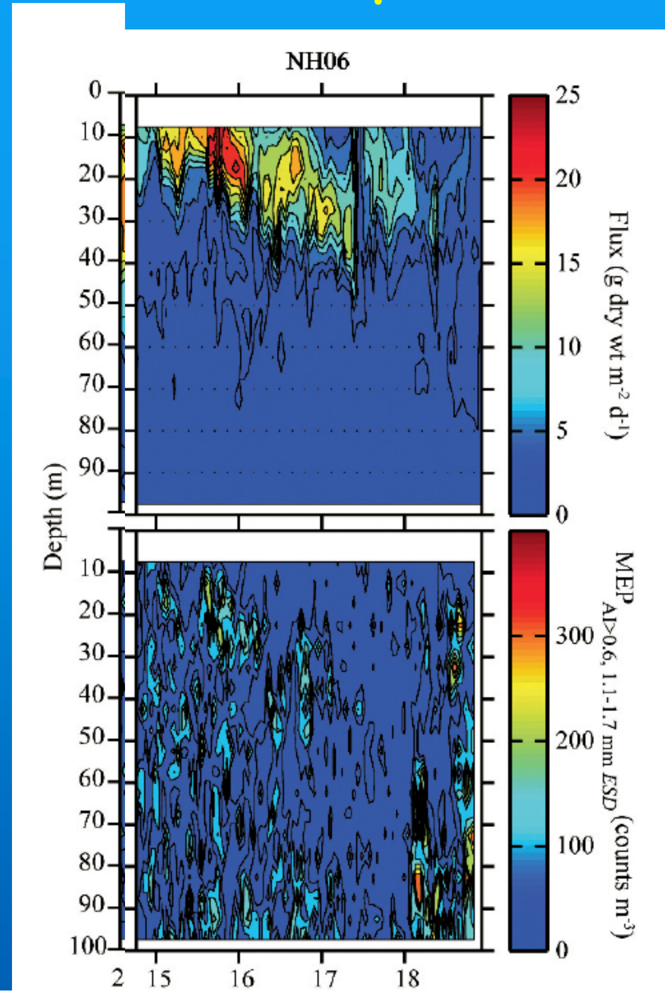
Equivalent Spherical Diameter (µm)



ID work too- Waite and Nodder, 2001, Durkin et al, 2014

Measuring diel particle size spectra changes

SOLOPC
Checkley et al., 2008



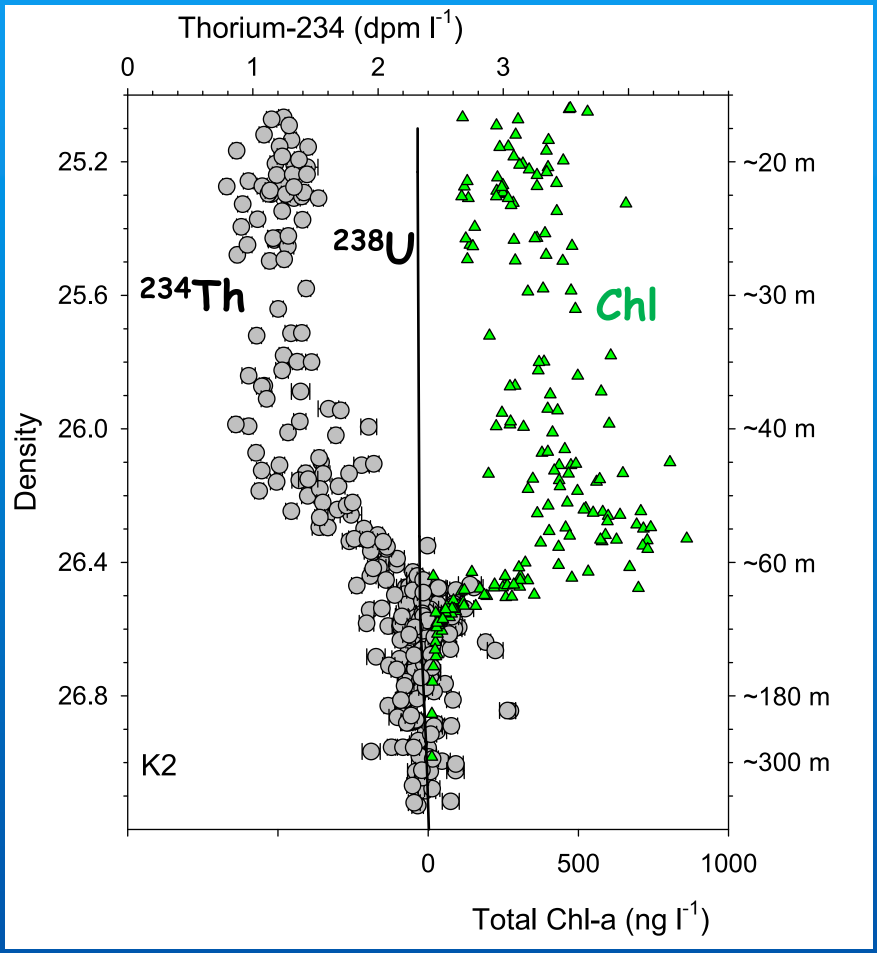
Flux

Grazers

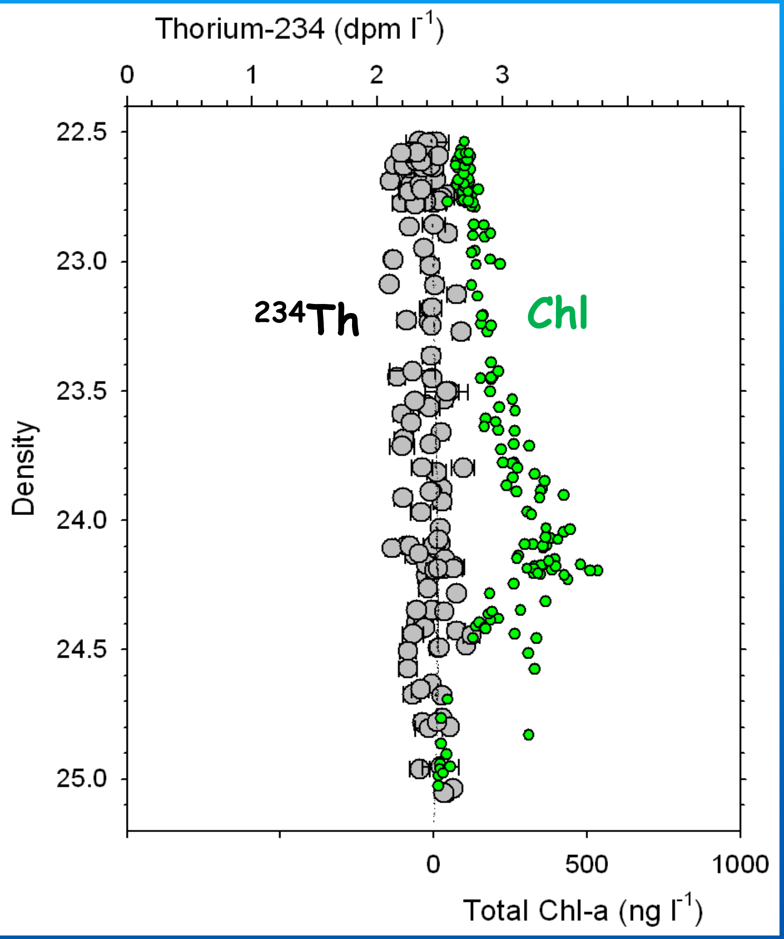
Fig. 9. Estimated particle flux (upper panels) and abundance of MEPs the size (*ESD* 1.1–1.7 mm) and transparency (*AI* > 0.6) of large copepods (lower panels) for SP05 (2005) and NH06 (2006).

Radionuclides capture large scale flux differences

NW Pacific $^{234}Th/^{238}U$ <1
Flux high



Hawaii $^{234}Th/^{238}U$ ~1
Flux low



Buesseler et al., 2008, DSRI

Many now use ^{234}Th for spatial mapping of C flux

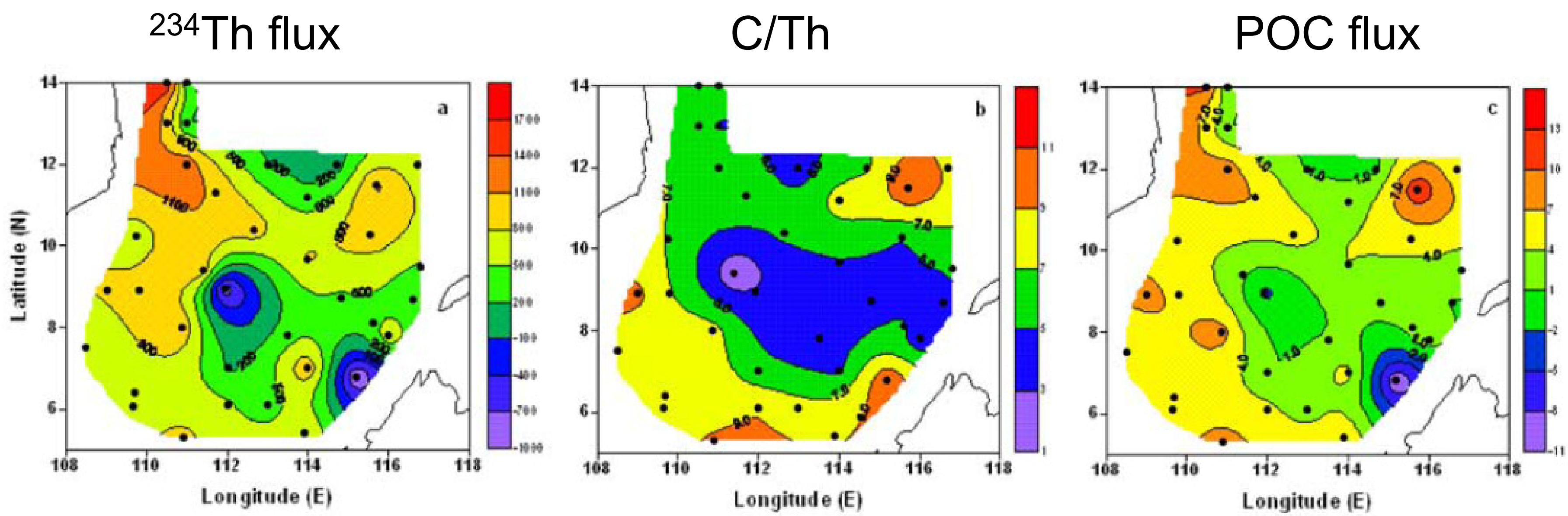
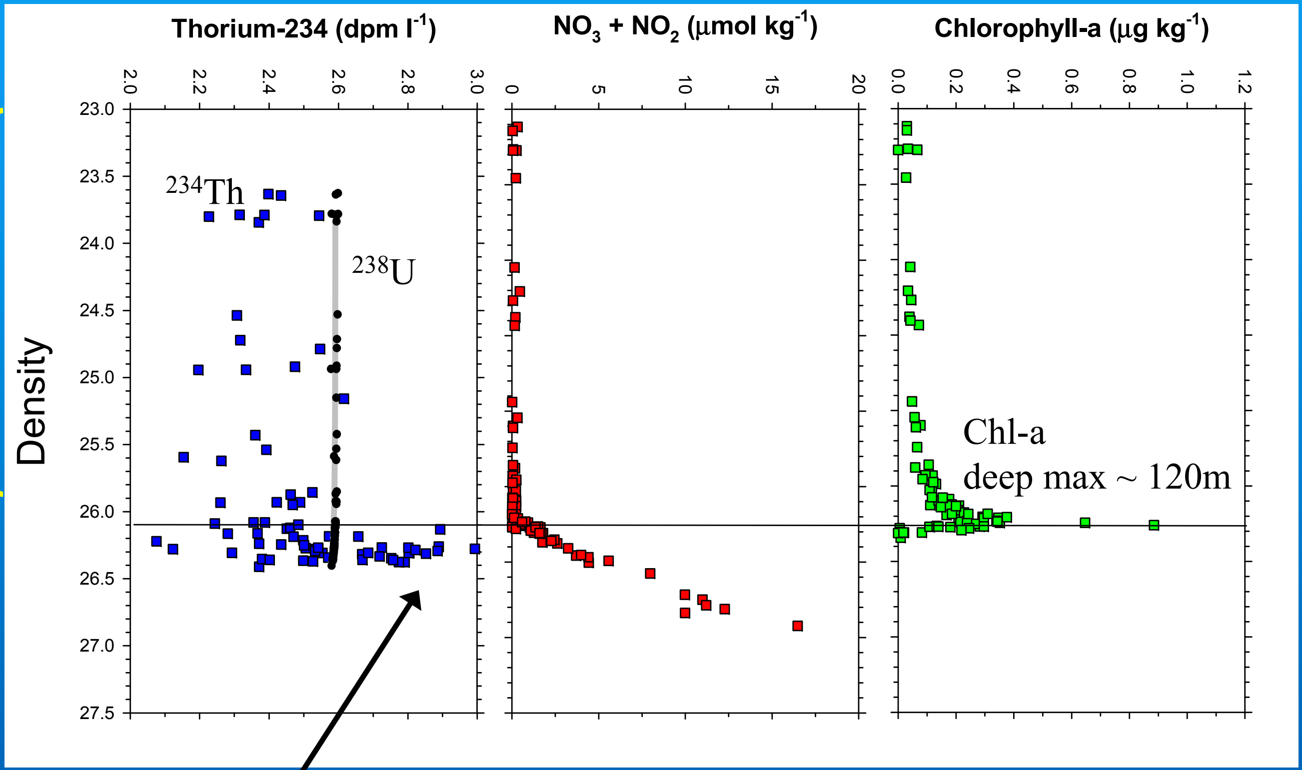


Figure 6. Contour plots of (a) particulate ^{234}Th flux (dpm m^{-2} d^{-1}), (b) POC/^{234}Th ratio (μmol dpm^{-1}), and (c) POC export flux (mmolC m^{-2} d^{-1}) at the export horizon. Station locations are shown as filled dots.

South China Sea- Cai et al., 2008
& many other examples

Radionuclides show small scale vertical layering of export and remineralization



Th<U
particle
loss

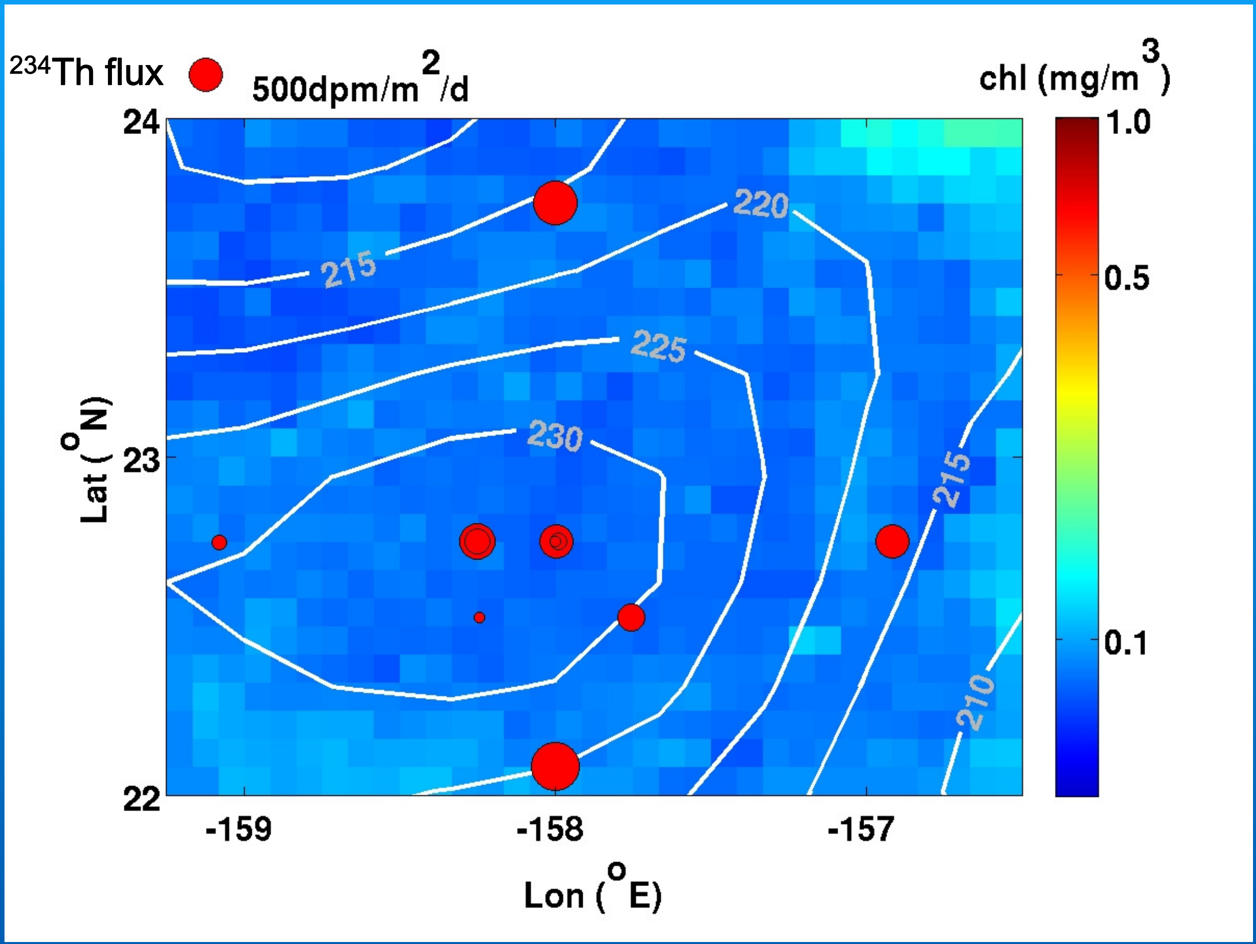
Euphotic
zone

Th>U
particle
remineralization

Buesseler et al., 2008
see also
Maiti et al., 2010

What are scales of spatial variability in export?

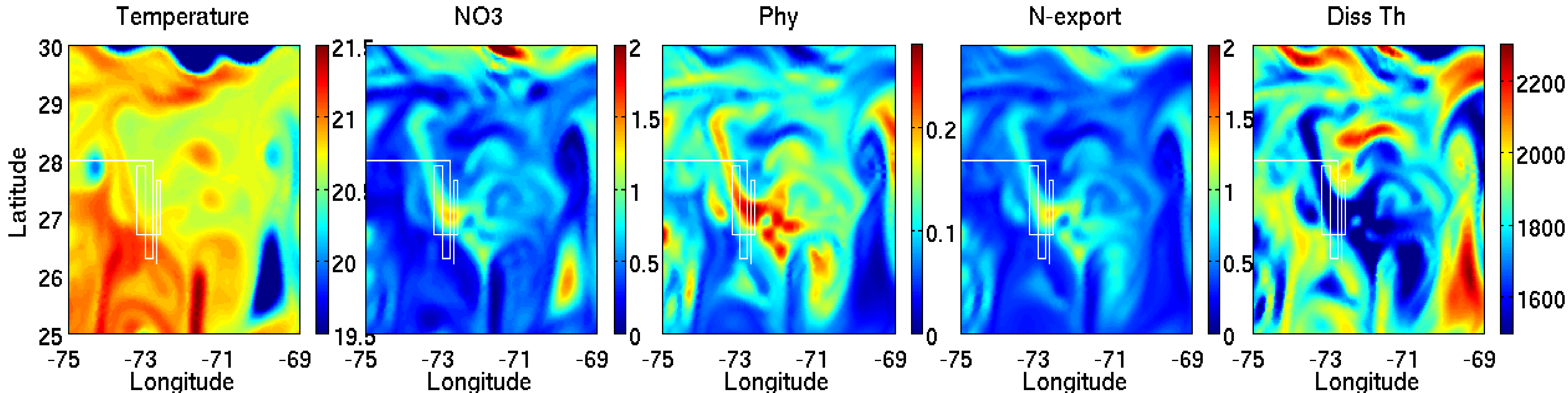
- in subtropical N Pacific, export/PP varies from 0-32%



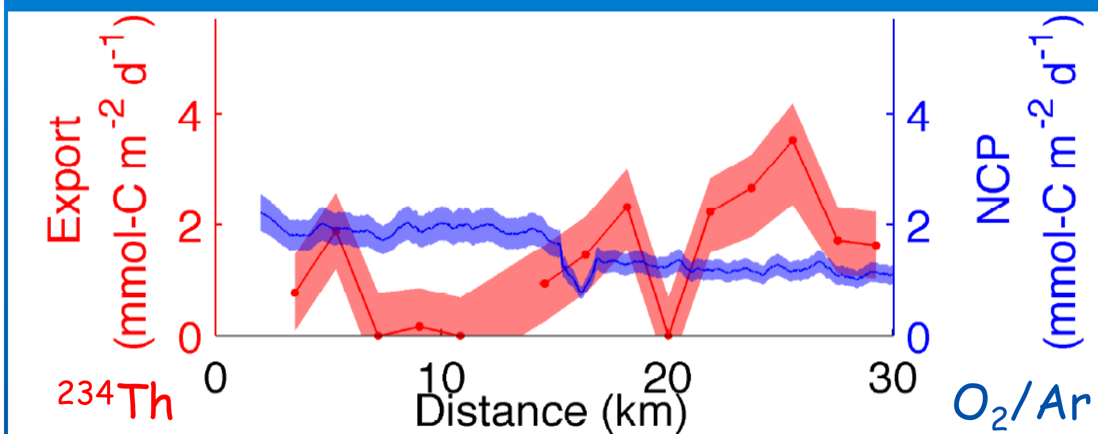
Why?
- food web
  - phyto type
  - bacteria
  - zooplankton
- physical processes
  - aggregation
- phys/bio
  - TEP
  - ballast

adapted from Buesseler et al., 2009, DSRI

Models suggest export variability at submesoscales



Levy et al., Resplendy et al. 2012



Field evidence emerging that confirms SMS variability in NCP and EP

Estapa et al., 2014, in review

Post JGOFS POC fluxes- lessons & needs

Many NEW tools to measure particle flux and size spectra

- each method sees different part of bio pump

VARIABILITY- sinking rates, size, stocks, flux & attenuation

Rapid remineralization just below EZ- depth matters

Few studies use MULTIPLE tools & measure bio/phys rates

Recognize VARIABILITY exists on all space & time scales

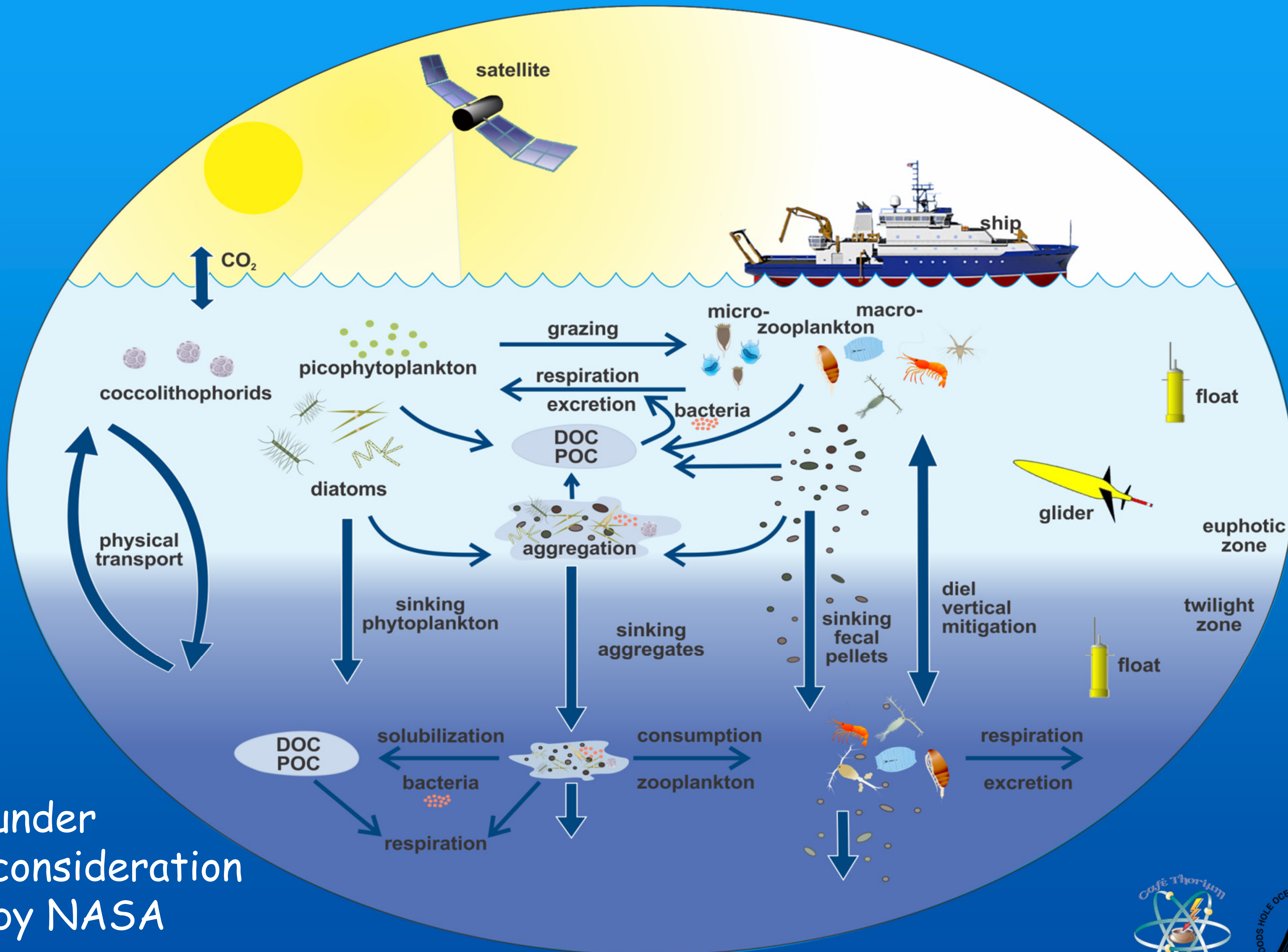
- remote sensing, profilers, gliders can help resolve
- need 3D Lagrangian studies of different pump “states”

PROCESS studies to link biogeochemistry and food webs

MODELS are needed that include mechanistic understanding

- extrapolate to times and scales we can’t observe
- allow future predictions of C flux

go EXPORTS!



under consideration by NASA