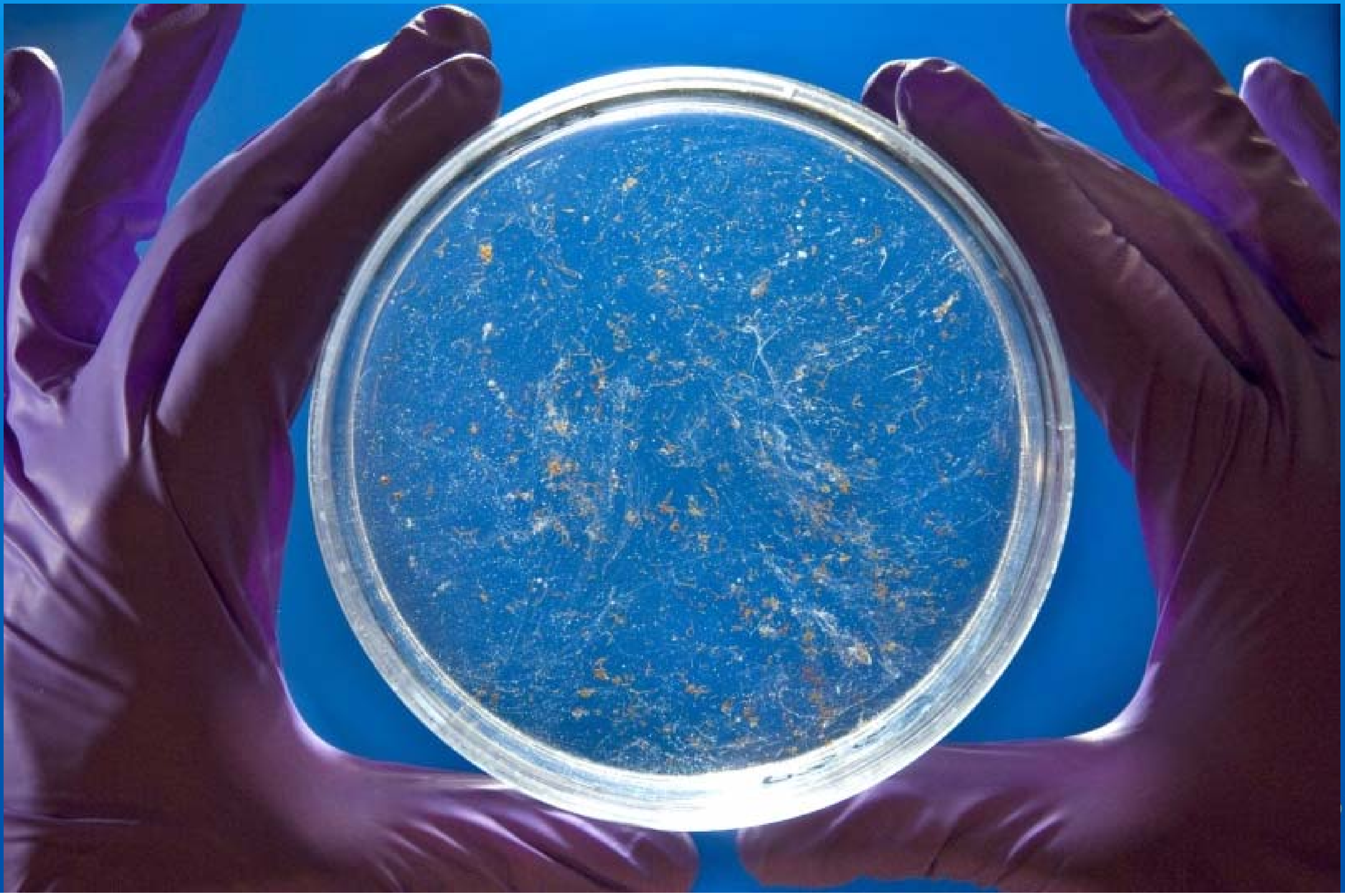
Measuring particle fluxes and sinking rates- how can polyacrylamide gel sediment traps help?

Ken Buesseler
*& Andrew McDonnell**
*Woods Hole Oceanographic Institution (& *ETH)*



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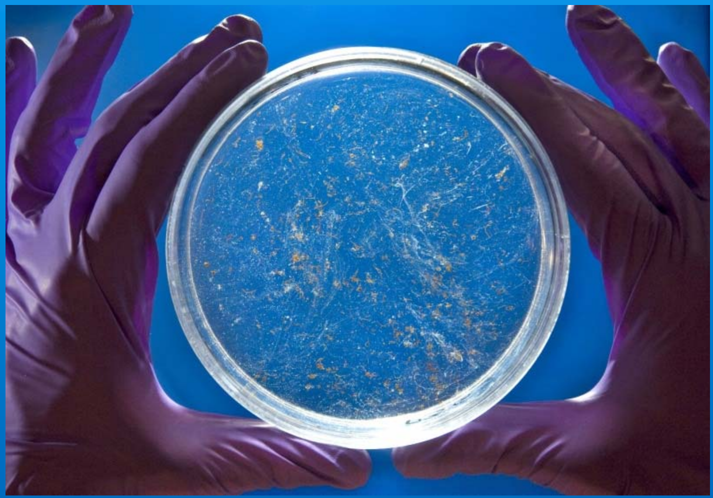


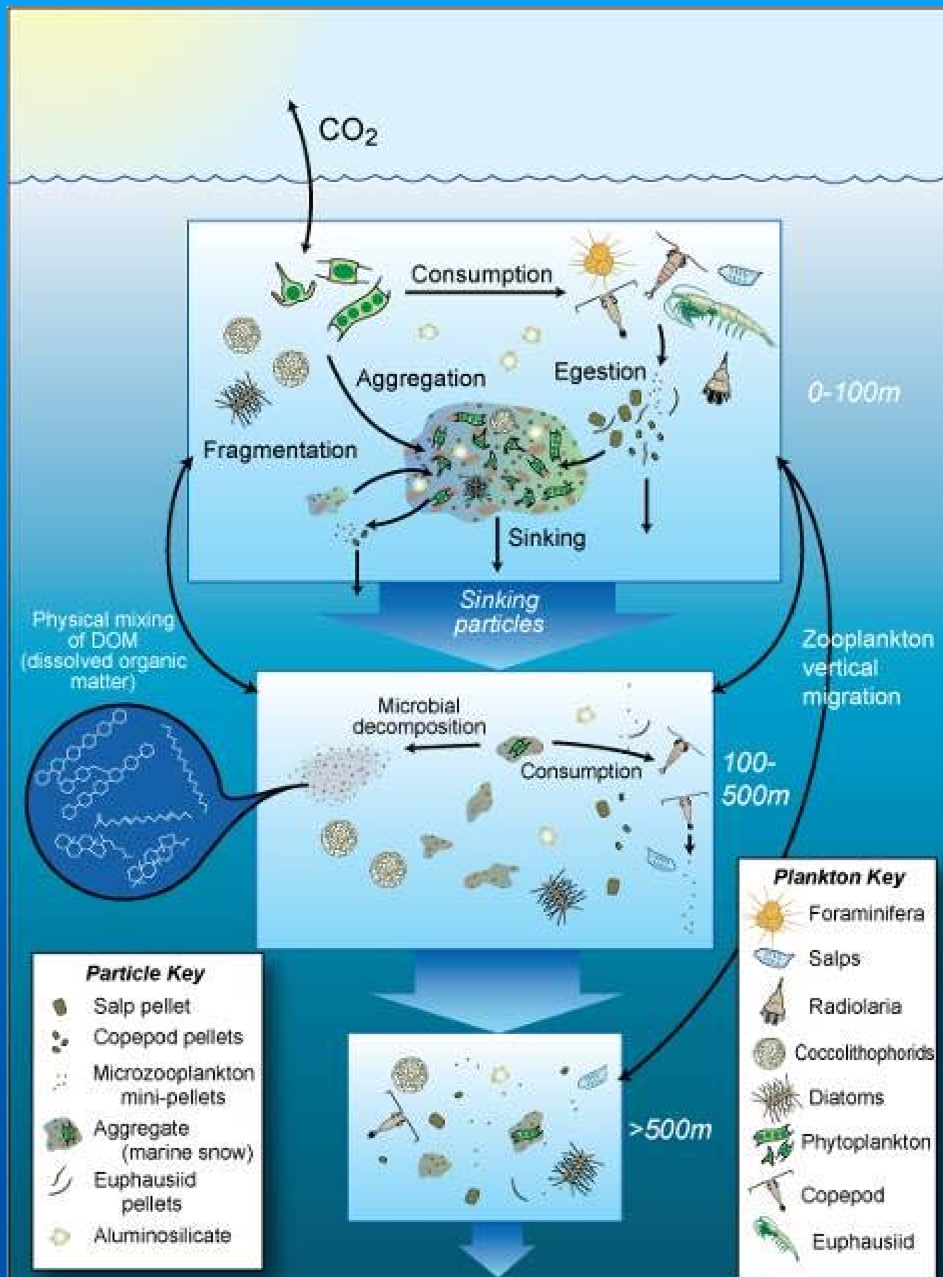
Outline

1. *Biological pump- Motivation and current understanding*
2. *Particle sinking velocities- How do we determine?*
3. *Gel traps & water column particle studies*
4. *Future research directions*

The Biological Pump & Twilight Zone

Euphotic zone

Twilight zone



Combined processes which transfer organic matter and associated elements to depth

EZ = source of fresh sinking particles

TZ = layer of net loss of sinking POC

DEPTH MATTERS!

Buesseler & Boyd 2009

Motivation behind biological pump & particle studies

Biological pump impacts surface to deep ocean DIC gradients and hence global C cycle and climate *Sarmiento and LeQuere, 1996*

Increase in remineralization depth by 25m will decrease atmos. CO_2 by ~20 ppm *Kwon et al. 2009*

>1 °C temp increase in twilight zone with climate change
Levitus et al., 2009

Many elements (nutrients, TEI's) "hitch a ride on the bus"
Gieskes, 1980 lecture SIO; Scavenging concept- Goldberg, 1954

The biological pump "feeds" the interior ocean and seafloor
Alexander Agassiz, 1888

The twilight zone carbon budget is unbalanced
Steinberg et al., 2008, Burd et al., 2010

Current understanding of biological pump & particle cycle

Global models do not adequately represent observed biogenic particle fluxes to the deep ocean
Gehlen et al., 2006

No models have yet incorporated sufficient complexity to capture the observed variability of export fluxes
Boyd and Trull 2007

The reason for this is we have not yet quantified the processes producing or transforming the particle flux
Stemmann and Boss, 2011

The most critical parameter for particle flux is the particle settling speed
in Stemmann and Boss, 2011 & attributed to Fasham et al., 1990

Given that it is so critical,
how do we determine particle sinking speeds?

1. Settling columns

2. In-situ observations

3. Sediment trap peak matching

4. Settling velocity traps

5. Gel traps and particle imaging in water and flux

1. Settling columns

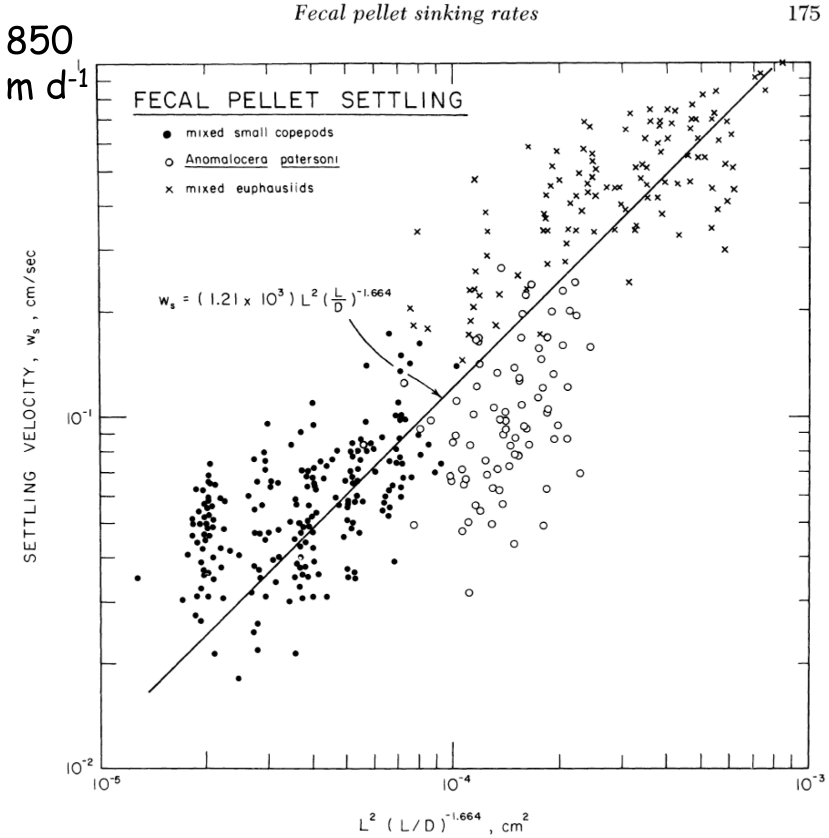


Fig. 1. Comparison of copepod data of Small et al. (1979) and the euphausiid data of Fowler and Small (1972) to relationship suggested by Eq. 3. Straight line shown yields Eq. 6.

Limnol. Oceanogr., 26(1), 1981, 172–180

An analysis of sinking rates of natural copepod and euphausiid fecal pellets[1]

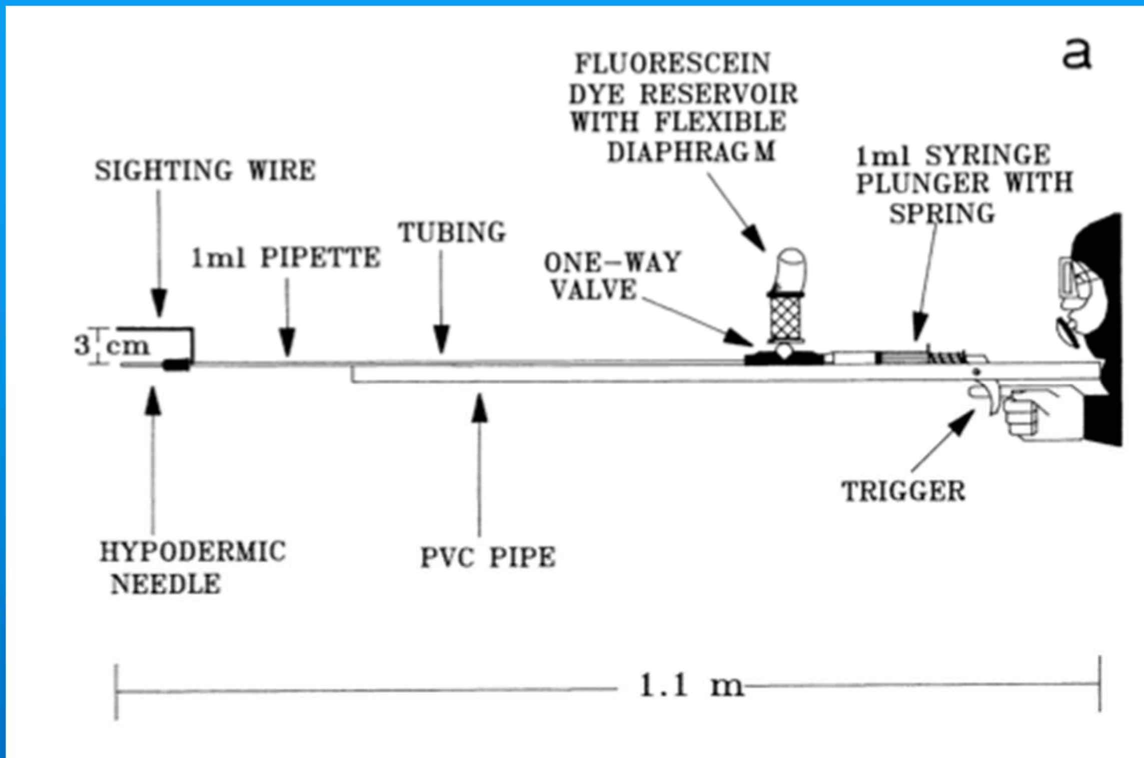
Paul D. Komar, Alan P. Morse, and Lawrence F. Small
School of Oceanography, Oregon State University, Corvallis 97331

Scott W. Fowler
International Laboratory of Marine Radioactivity,[2] Musée Océanographique, Prin

$$w_s = 0.0790\frac{1}{\mu}(\rho_s - \rho)gL^2\left(\frac{L}{D}\right)^{-1.664}$$

- lab vs. field vs. in situ?
- works best for large/fast intact particles
  pellets 100's-1000 m/d

2. In situ observations



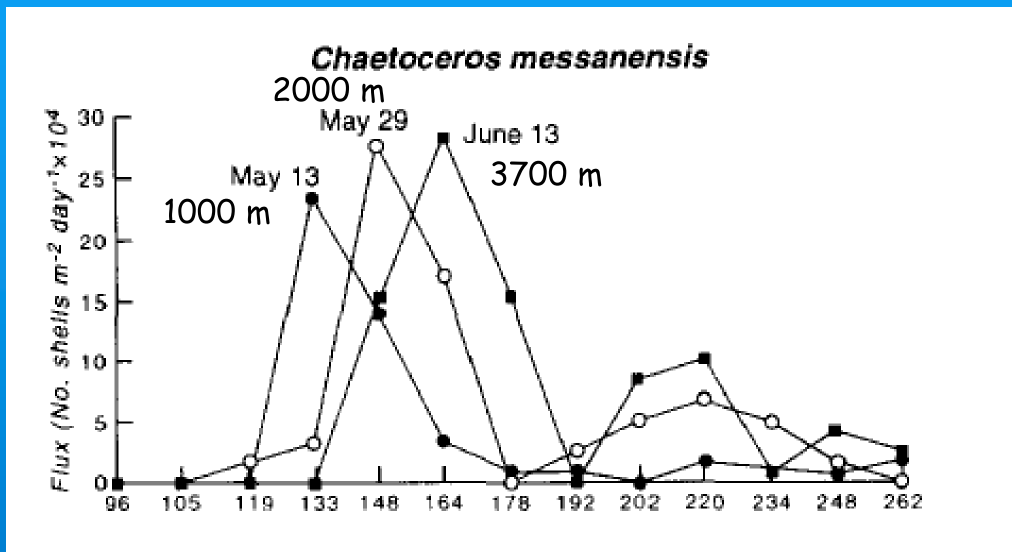
Alldredge and Gotschalk 1988

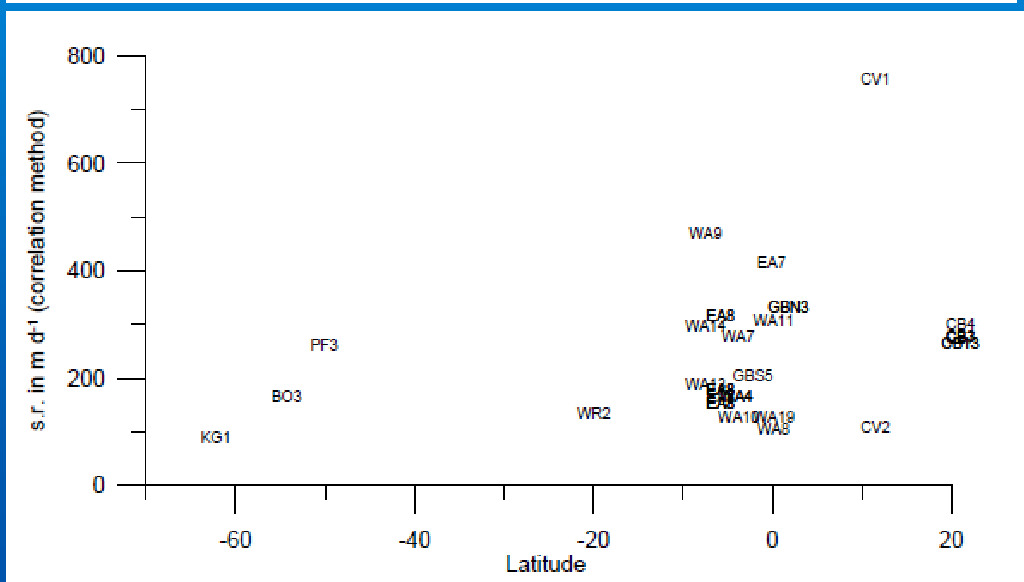
The human approach
- limited to large, slow sinking marine snow
- variable human limits

Progressed to in-situ work with cameras

in trap tubes- Asper, Honjo et al.
on ROVs- Silver, Pilskaln et al.
on AUV's?

3. Sediment trap peak matching





NABE w = 200-250 m/d

Honjo and Manganini, 1993

N. Atlantic- sinking rate & ballast, packaging relationships

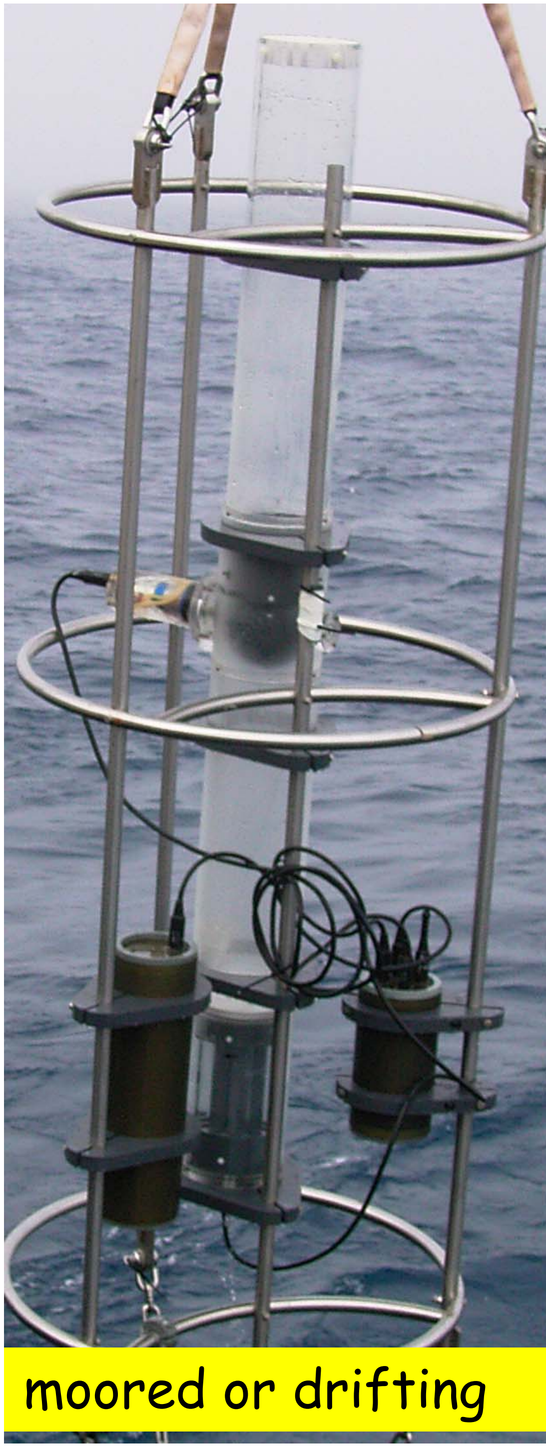
Fisher and Karakas, 2009

Sinking rate increases with depth

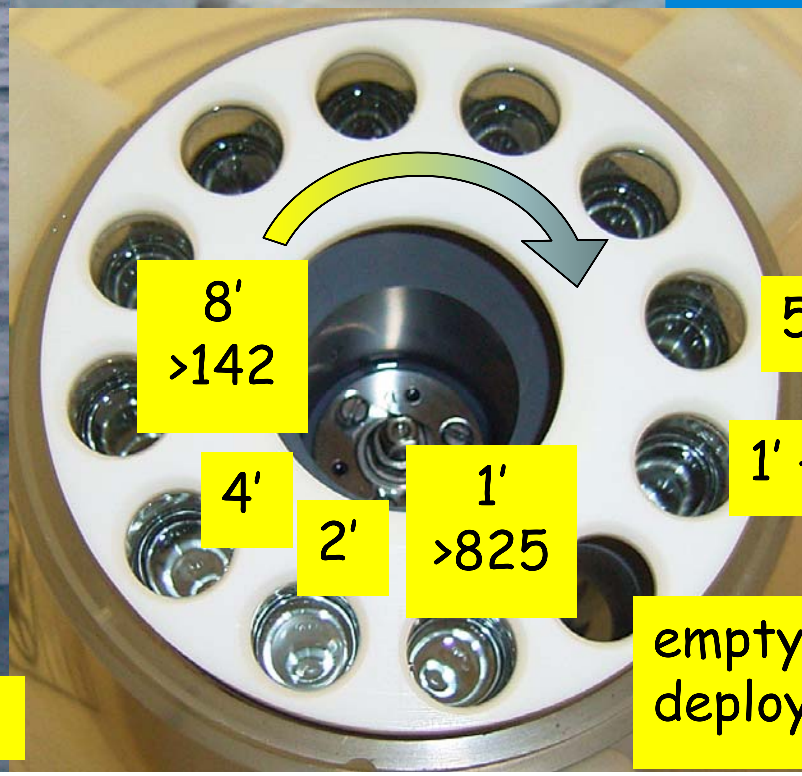
see also Berelson 2002

4. In-situ sinking-velocity trap

Peterson et al., 2003



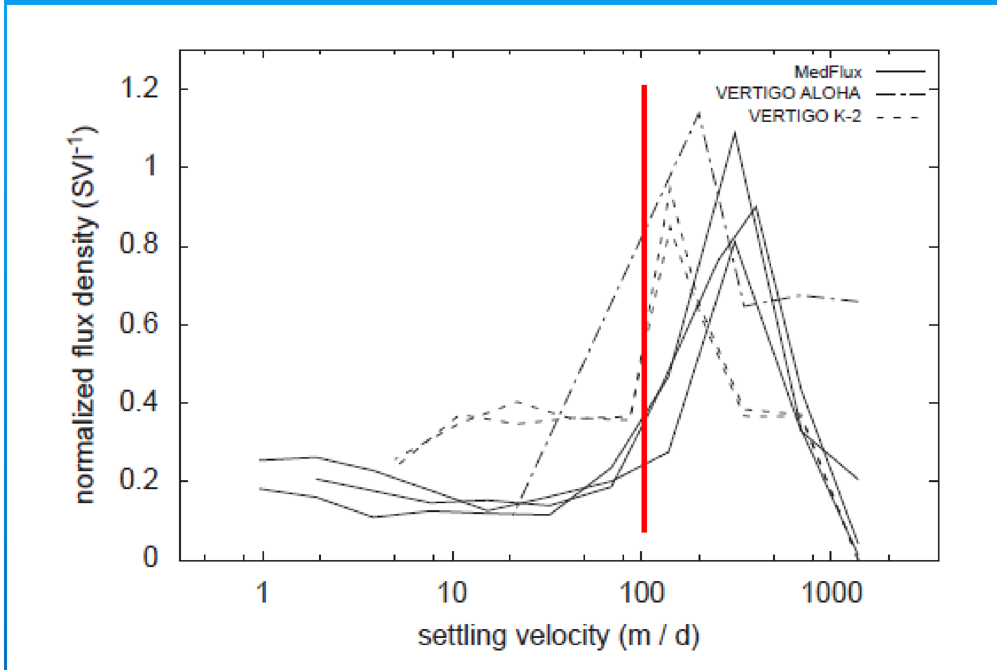
IRS collects for 6 hours, dumps to carousel below and repeats cycle for 7 days.



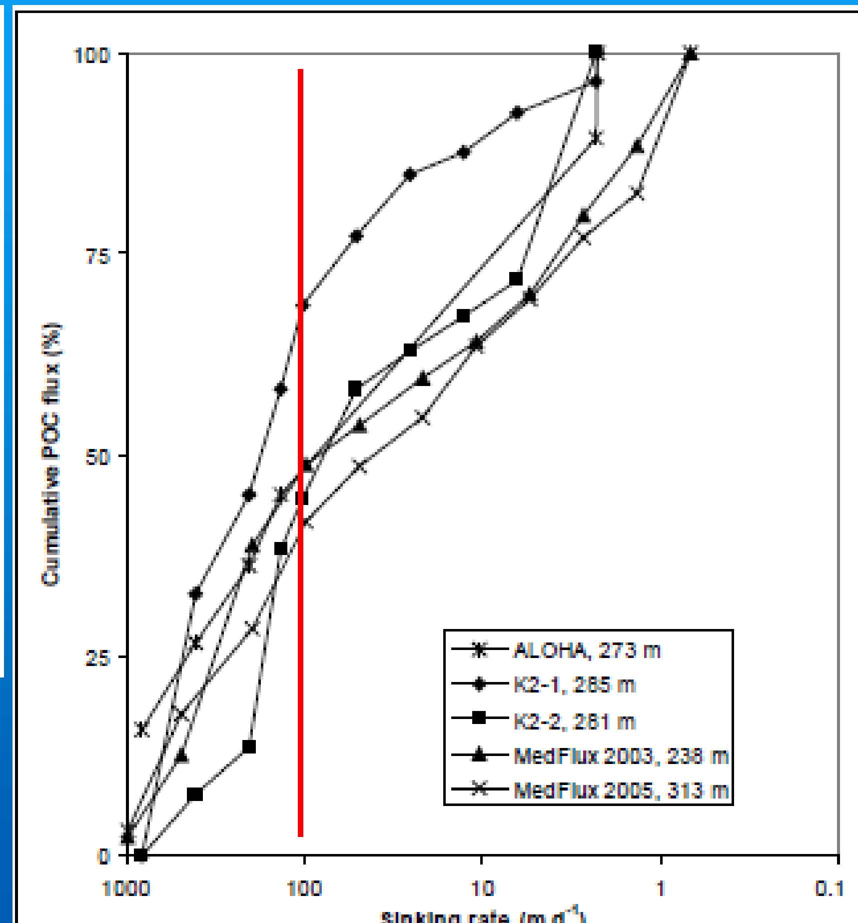
Carousel separates particles into 11 cups/sinking rates

Sinking velocity trap- 2 examples

50% of flux > 100 m/d



MedFlux- Armstrong et al. 2009



VERTIGO- Trull et al. 2008

Concerns

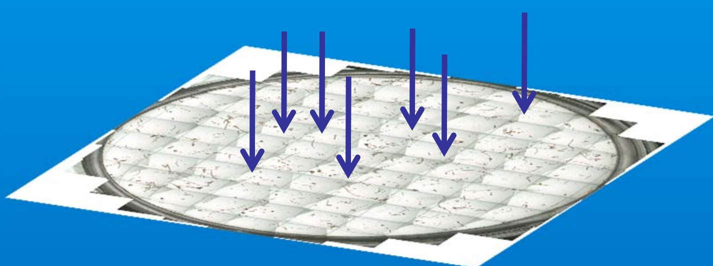
- it is still a trap
- changes in situ on rotating ball
- carry over between cups

5. Particle settling velocity from gel traps

$$F_i = C_i \times W_{i,avg}$$

Flux = Concentration × Avg. Sinking Velocity

$\# \ m^{-2} \ d^{-1}$



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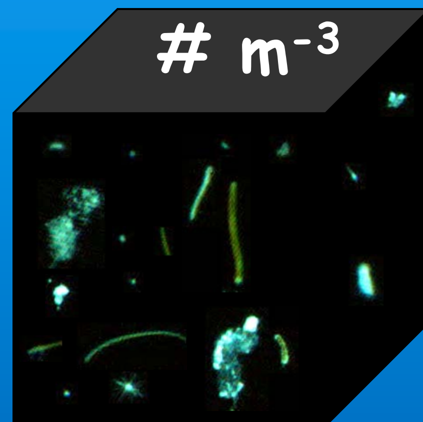
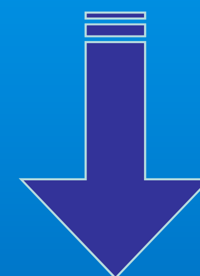


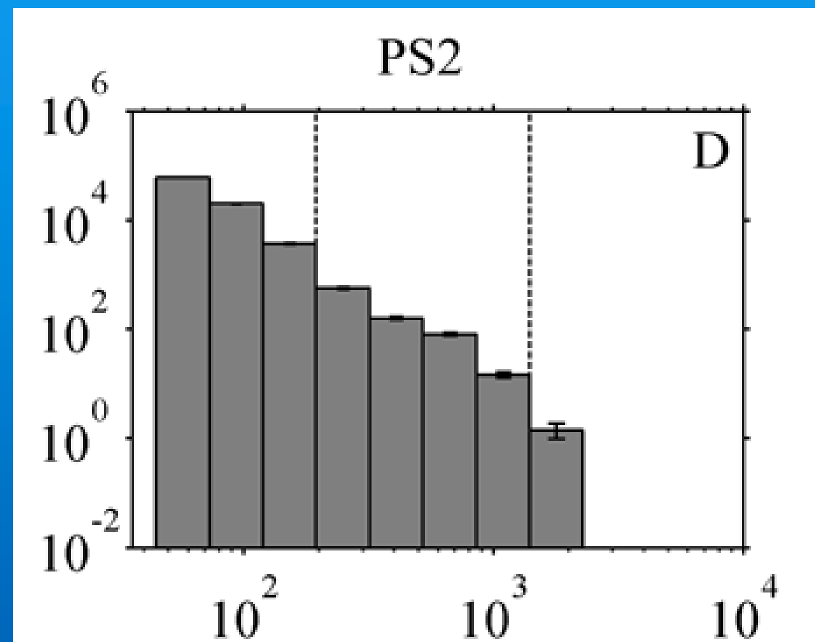
×

$m \ d^{-1}$



first used in McDonnell and Buesseler 2010

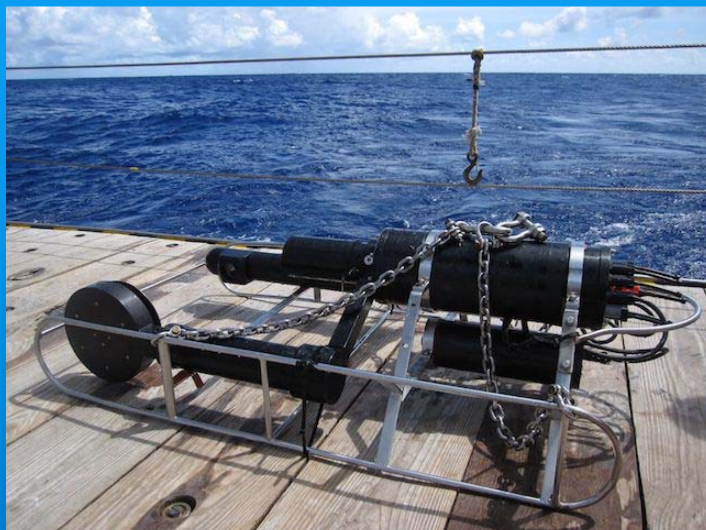
Measuring the flux size distribution

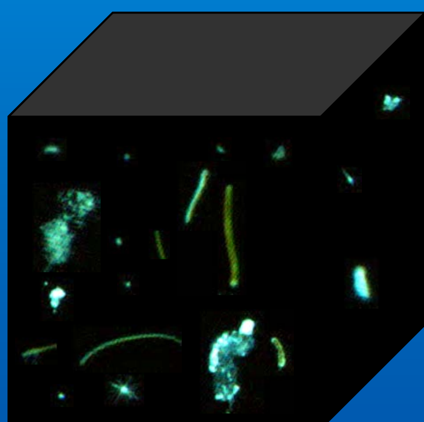


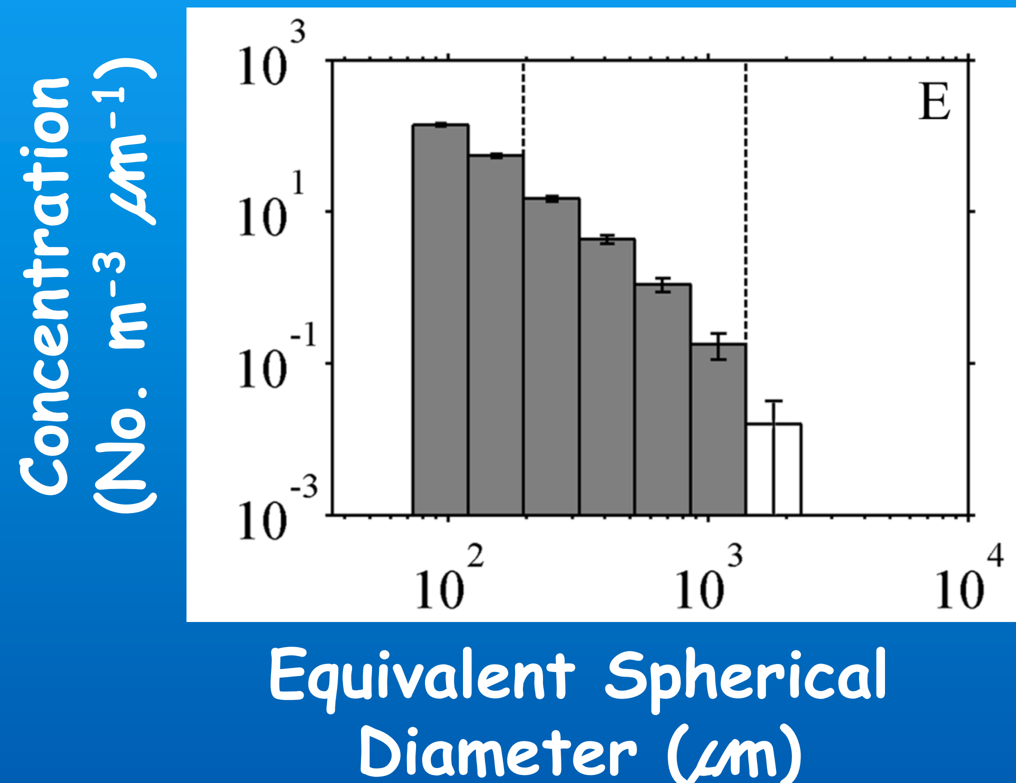
Flux (Nao. m^{-2} d^{-1} μm^{-1})

Equivalent Spherical Diameter (μm)

Measuring the concentration size distribution

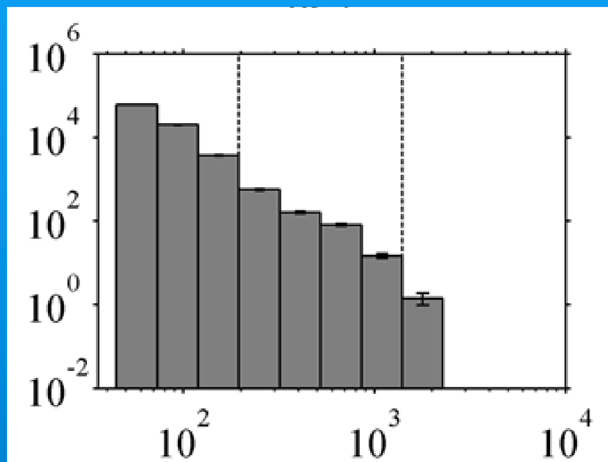




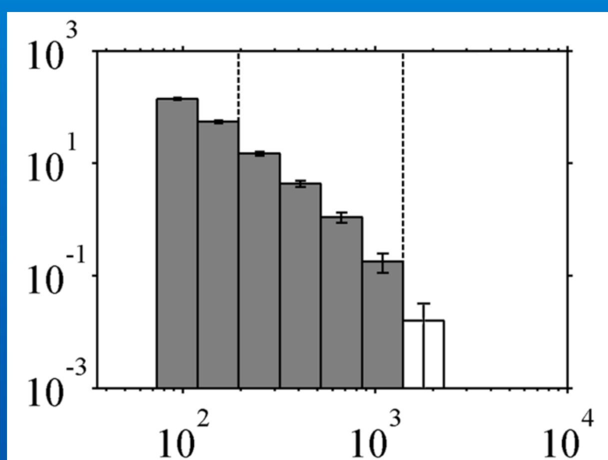


Calculating the average sinking velocity size distribution

Flux (No. m^{-2} d^{-1} μm^{-1})



Concentration (No. m^{-3} μm^{-1})

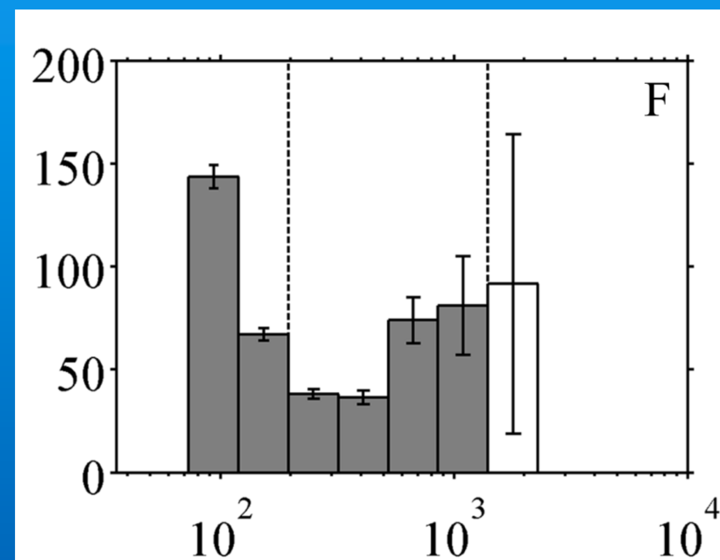


Equivalent Spherical Diameter (μm)

=

$F_i / C_i = W_{i,avg}$

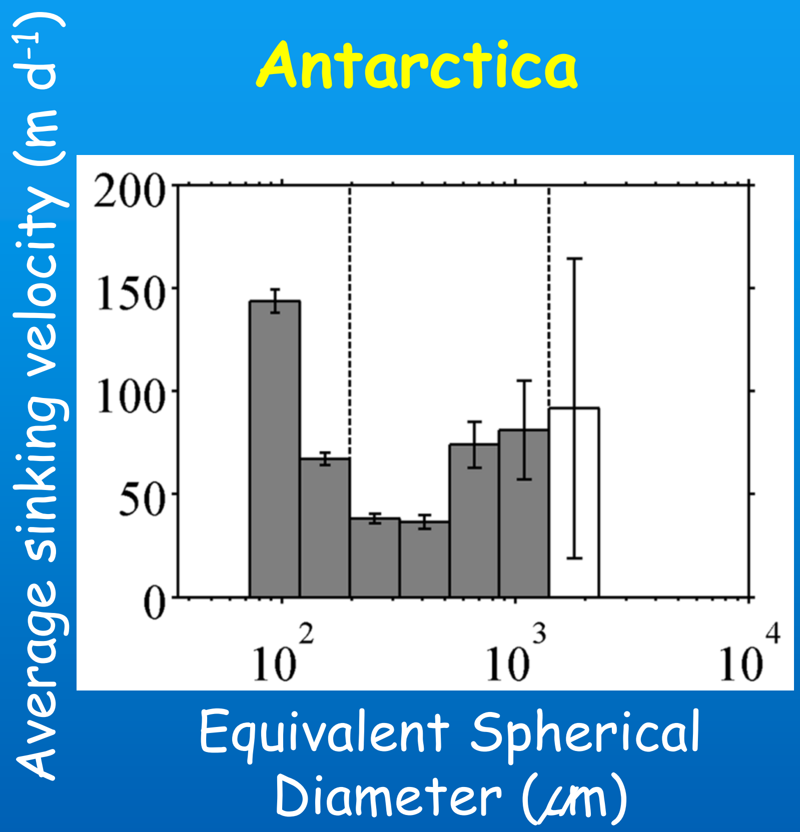
Average sinking velocity (m d^{-1})

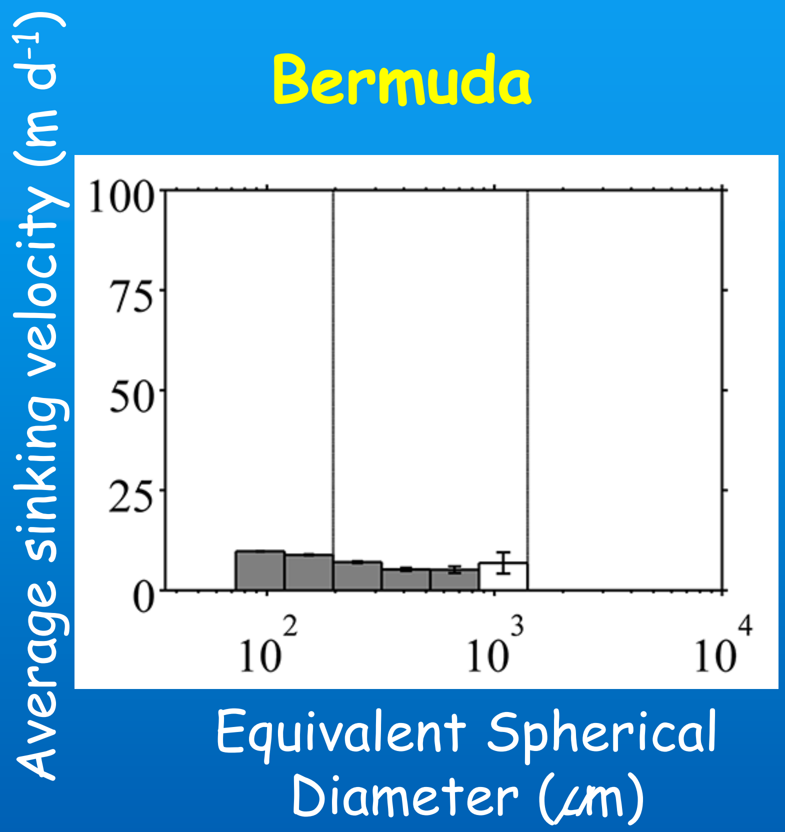


Equivalent Spherical Diameter (μm)

McDonnell and Buesseler 2010

Variability in regional average sinking velocities

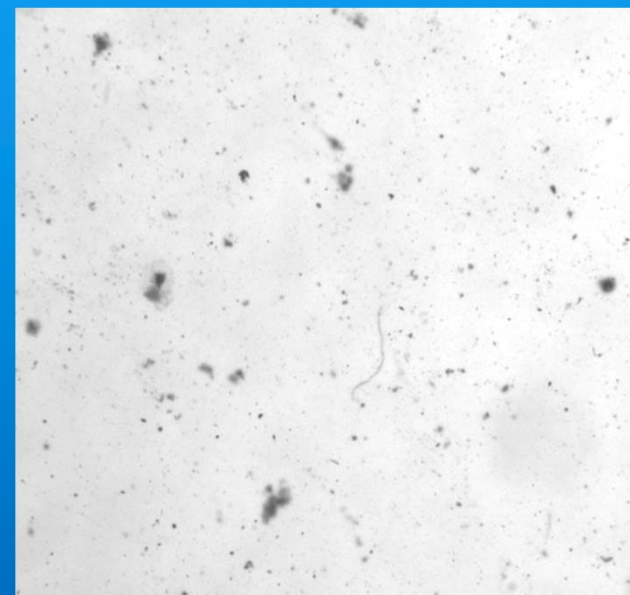




Sinking speed variability linked to differences in the particulate material

Antarctica

Bermuda

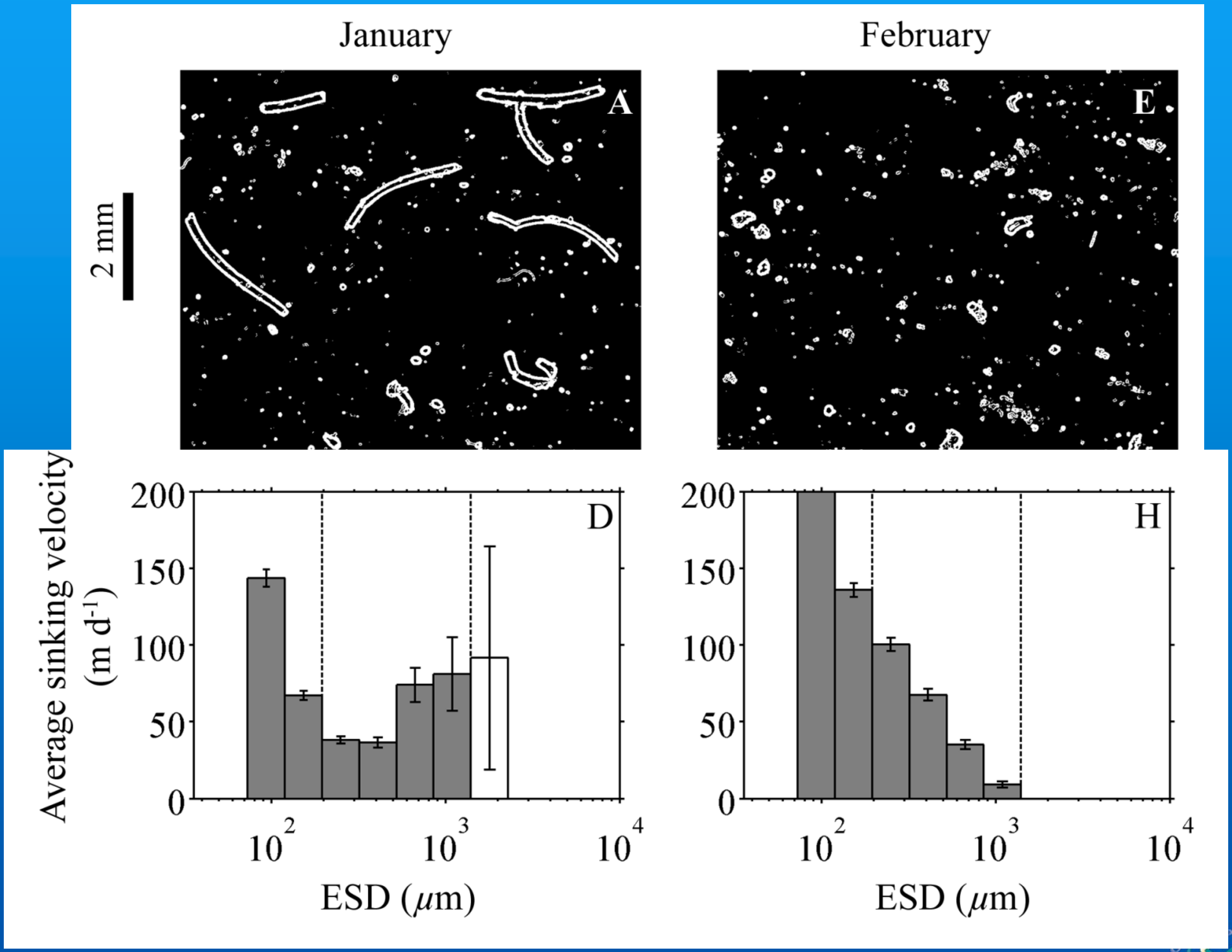


2 mm

*** Gel traps quite useful for particle ID work**

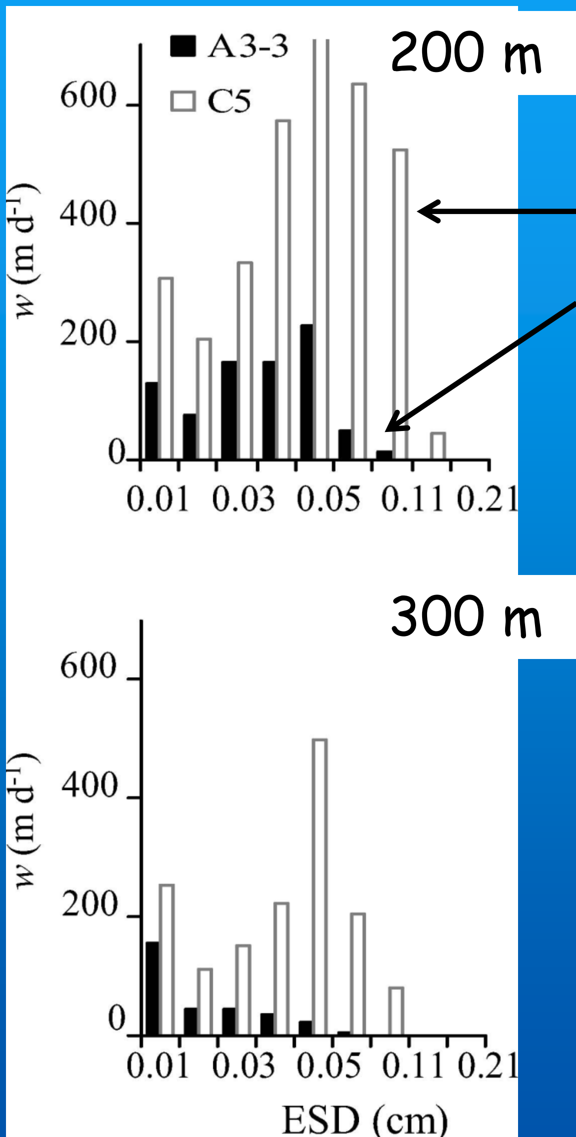
see Waite and Nodder, 2001
Ebserbach et al, 2011

Temporal variability in average sinking velocity



McDonnell and Buesseler 2010

Depth and spatial variability in sinking velocities



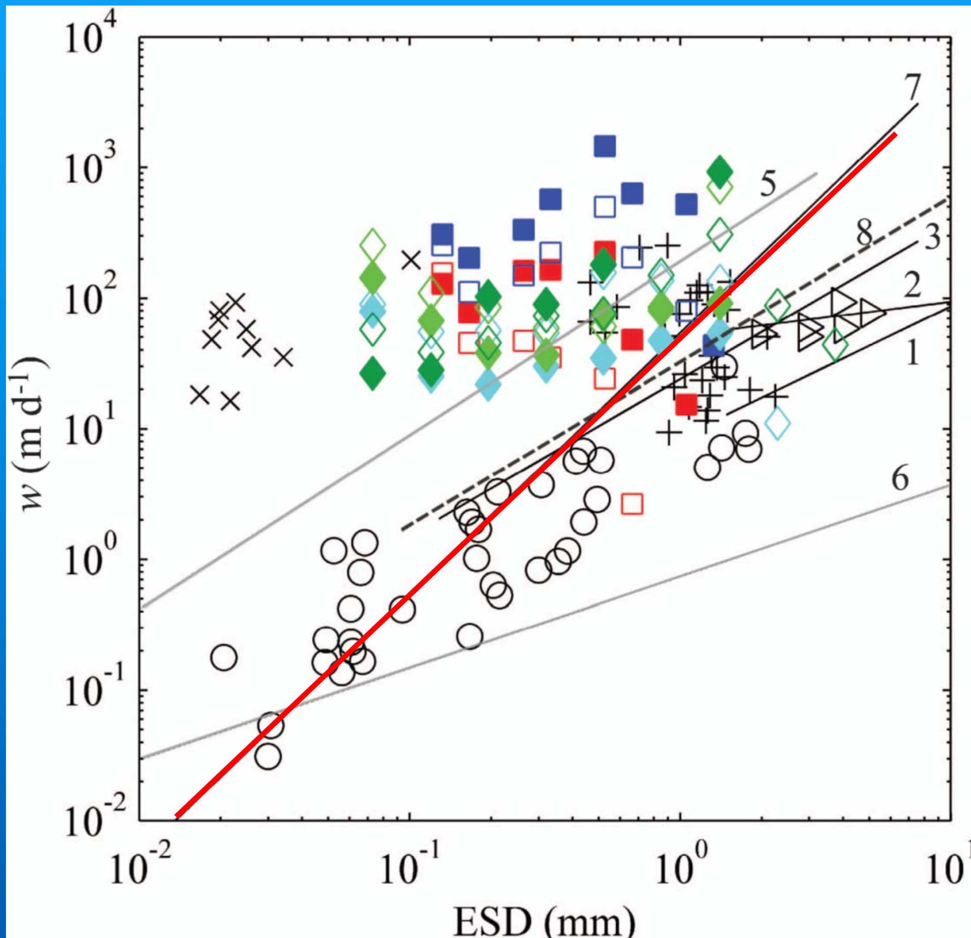
open bar = HNLC
filled bar = Fe replete

- faster in HNLC areas (ballast?)
- slower at depth in this study
- faster at depth in W. Antarctic

Gel traps and water column imaging study in KEOPS
Jouandet et al., 2011

Can we put it all together?

Not very well…..



Gel traps (color)
other methods (B&W)
#7 Stokes ≠ data
No single relationship

Are we even measuring the same parameter?

$w_{individual}$ vs $w_{average}$

What are limitations & biases of each method?

Expect variability!

Jouandet et al., 2011
from Stemmann et al. 2004, Guidi et al. 2008 & many more

Grand challenges & future research directions

Need observations!

- multiple methods for flux, particle conc., sources, decomposition and sinking rates
  - ✓ gel traps images provide source info
  - ✓ gel traps and particle images provide sinking rates

Recognize variability exists on all space & time scales

- moored inst., profilers, gliders can help resolve

BUT also include BIO in biopump PROCESS studies

- need to separate roles of zooplankton & bacteria
- physical controls on aggregation & biota linked
- need to know processes to understand variability & predict changes in biopump due to climate

ASSUMING most critical parameter is sinking speed

why does it vary?