Constraining the full spatial and temporal scales of variability in the ocean's biological carbon pump

From episodic events to global patterns

2016 Biology of the Biological Pump Workshop

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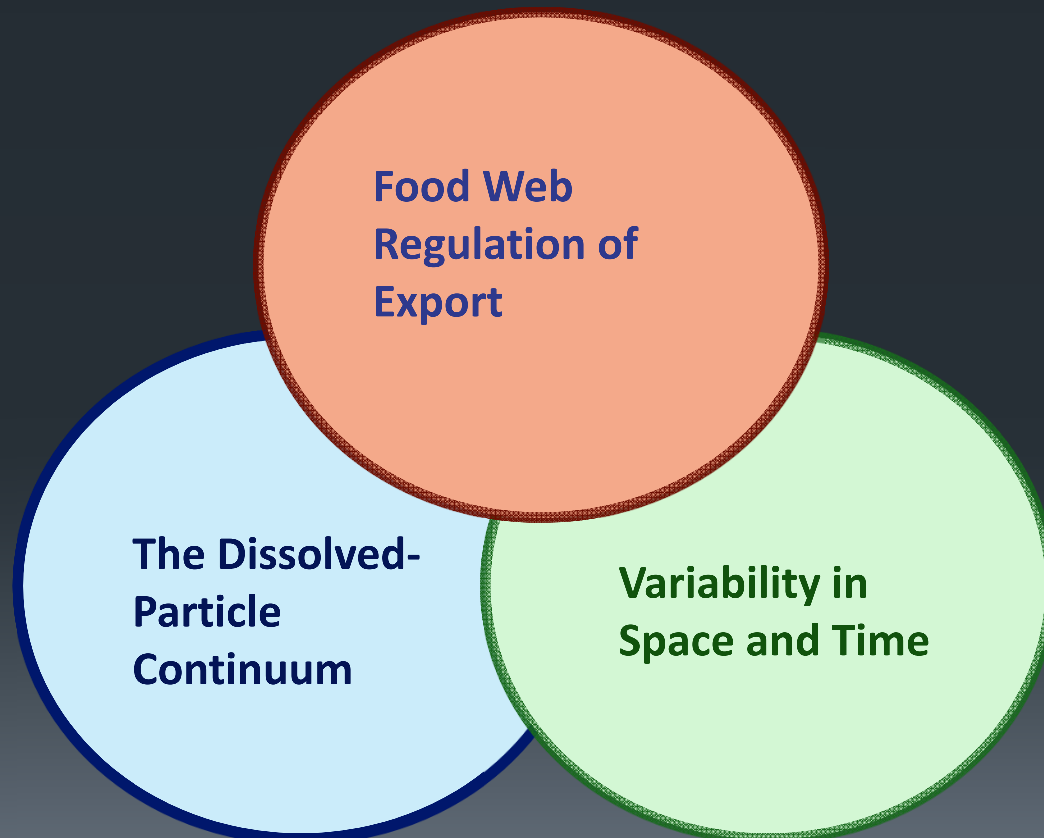
UNIVERSITY OF ALASKA FAIRBANKS

The Biological Pump: Priorities for future research

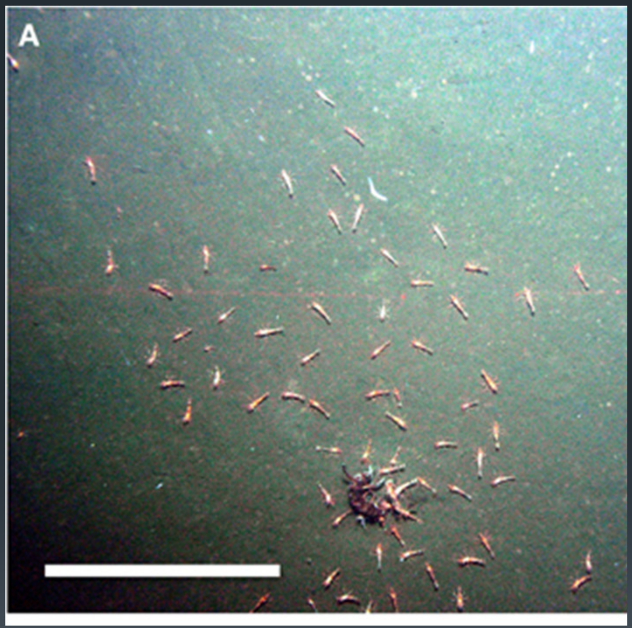


Variability in Space and Time

- Episodic Events
- Patterns and Scales of Temporal and Spatial Variability

Episodic Events

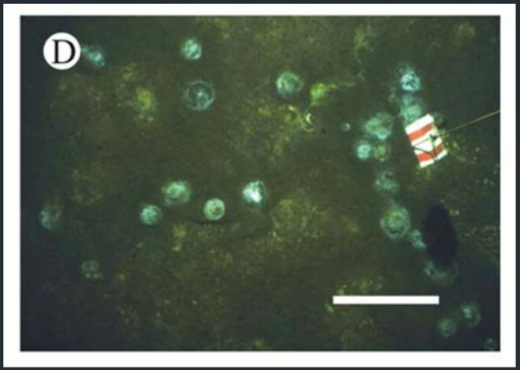
Jelly Falls



Sweetman and
Chapman, 2015

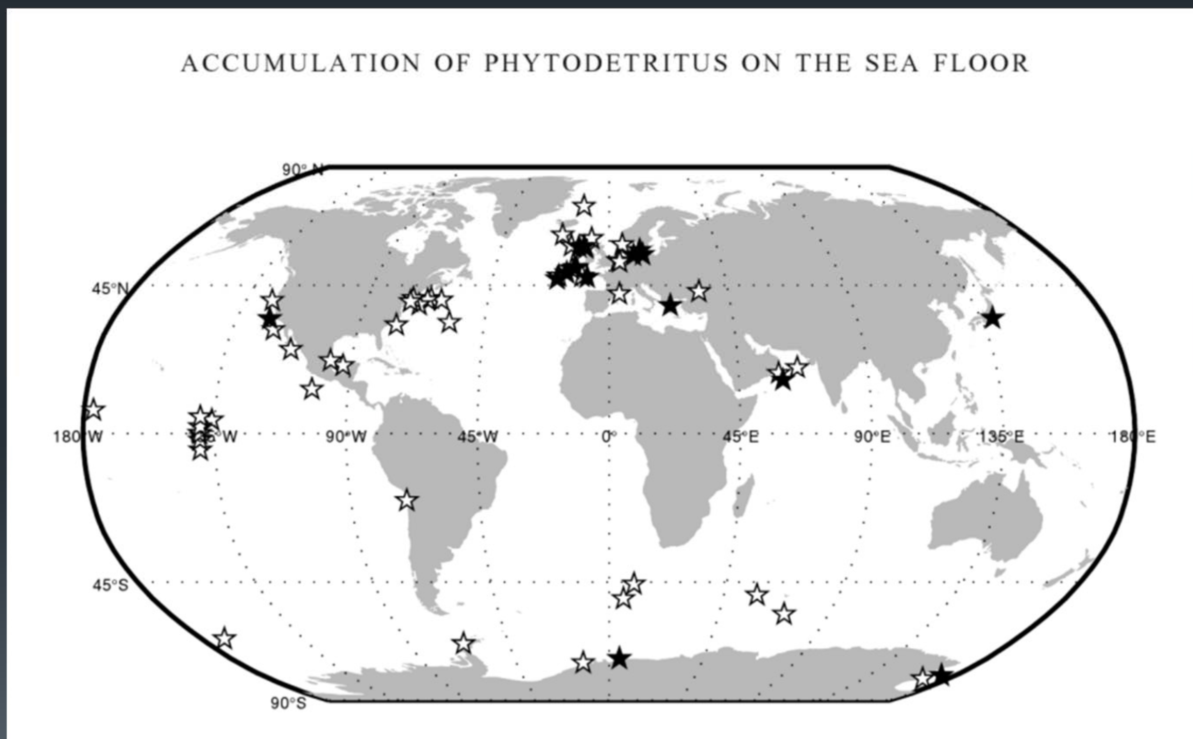
Salp Blooms

Phytodetritus



Billet et al., 2006

Phytodetritus found on sea floor



Beaulieu, 2002

Salp Biomass Variability at BATS

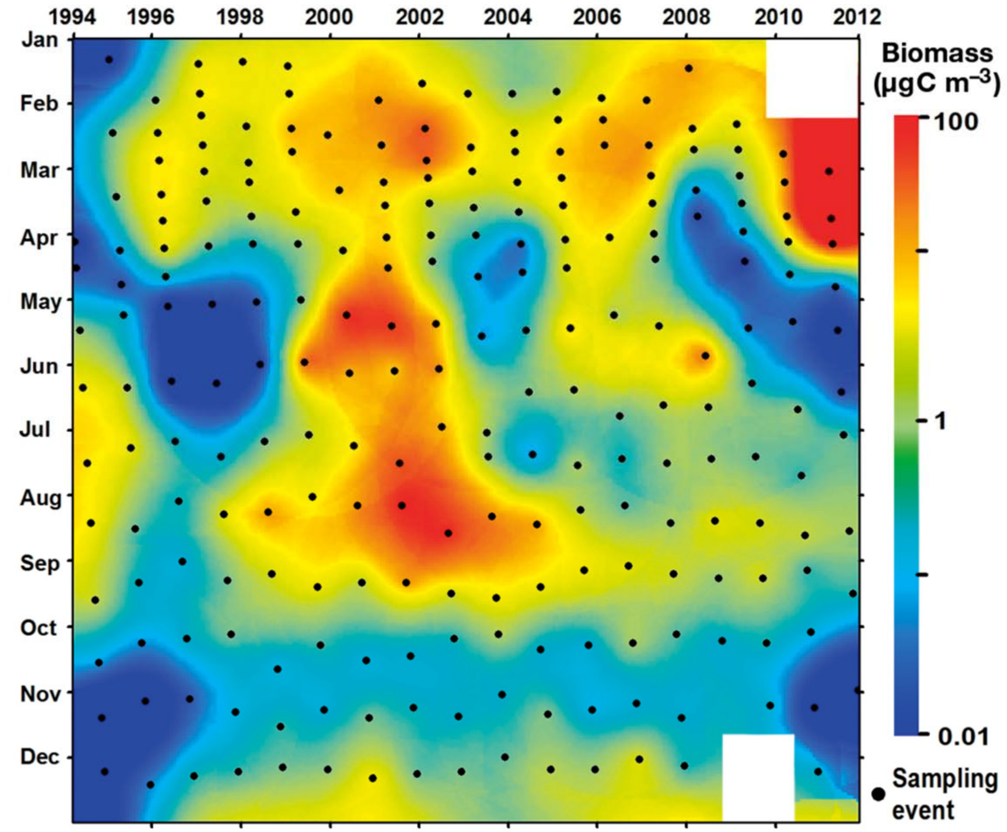
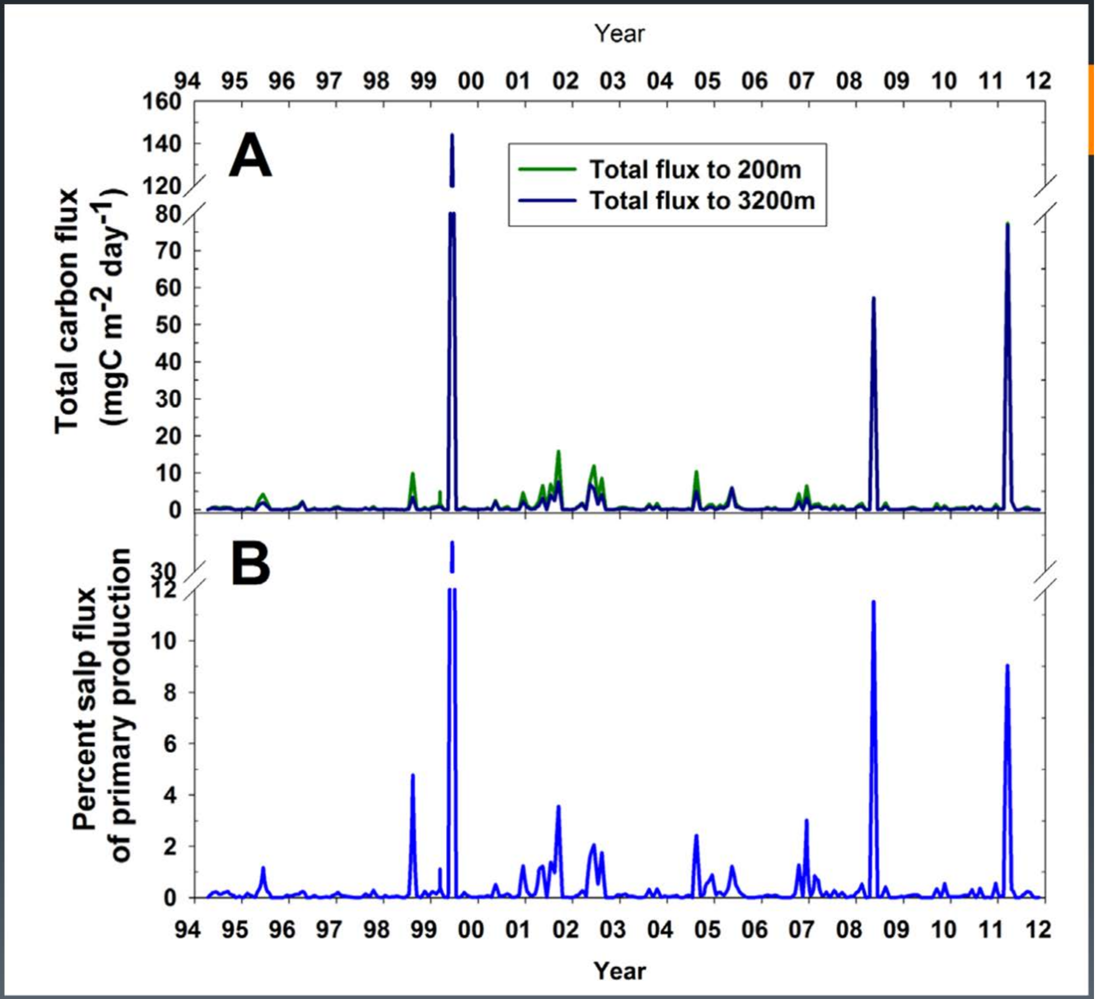


Fig. 2. Seasonal and interannual total salp biomass at the Bermuda Atlantic Time-series Study (BATS) site. Total combined (all species) salp biomass across the time series (April 1994–November 2011). Note that biomass is depicted on a log scale and areas with low temporal coverage have been whited-out

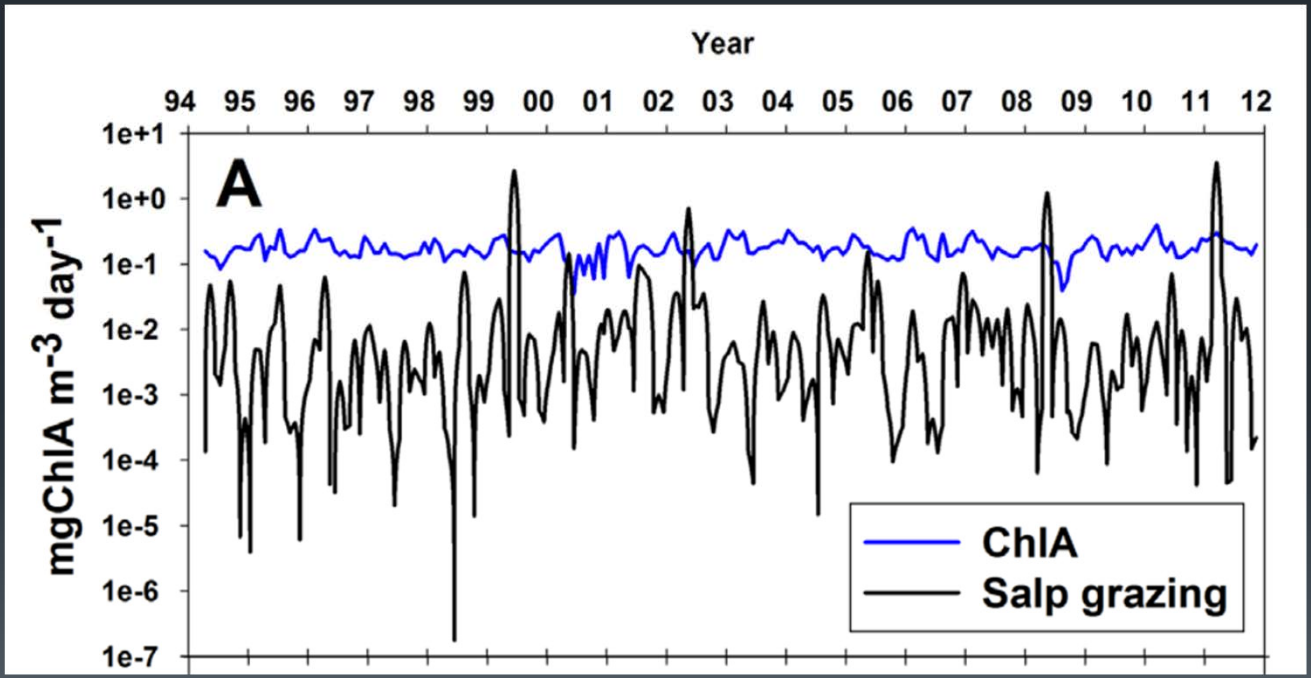
Stone and Steinberg, 2014

Salp Flux Model @ BATS



Stone and Steinberg, 2016

Salp Grazing Model @ BATS



Stone and Steinberg, 2016

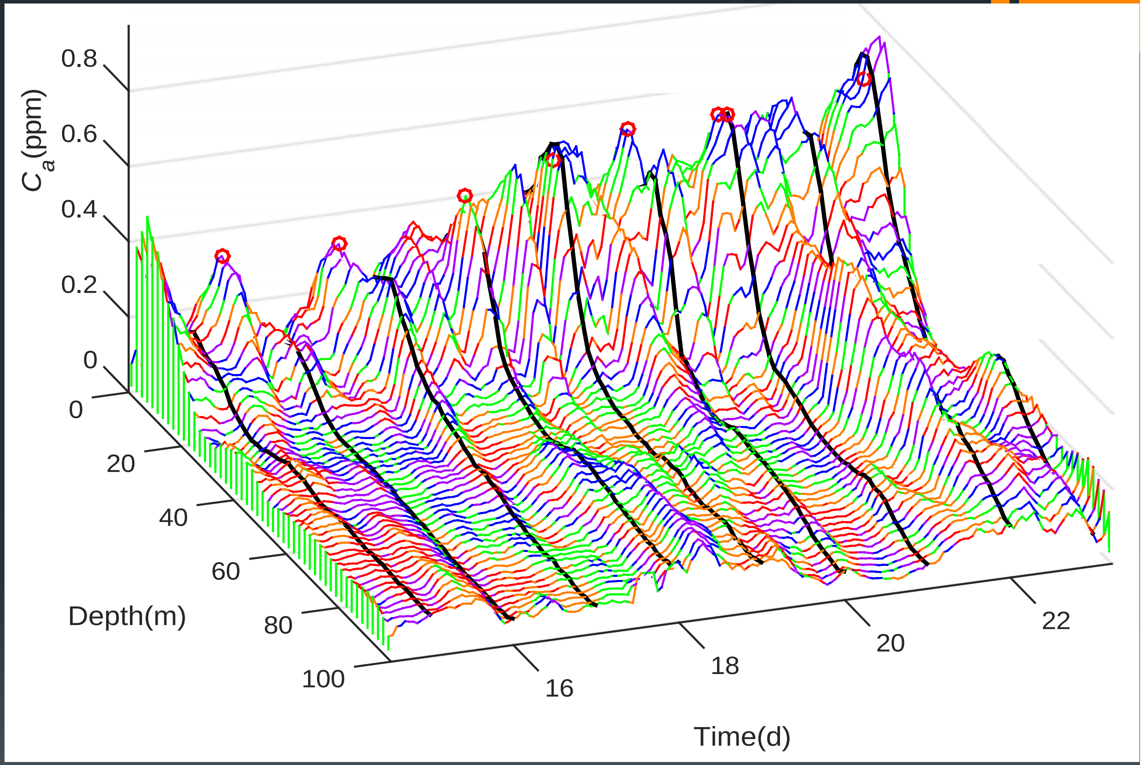
Episodic Events: Outstanding questions

- What is the frequency, intensity, and spatial scale of episodic export events across the globe?
- How might we better observe these events?
- What are the ecosystem traits and environmental conditions that lend themselves to episodic export events?
- What is the ultimate fate of this material and what controls it?
- How do episodic events structure ecosystems?

Patterns and Scales of Temporal and Spatial Variability

- What tools and approaches are needed to assess the variability in flux across all relevant scales?
- How do food-web processes structure the spatial and temporal variability in organic matter flux?
- How might these patterns be responsive to climate change?

Diurnal and multiday variability



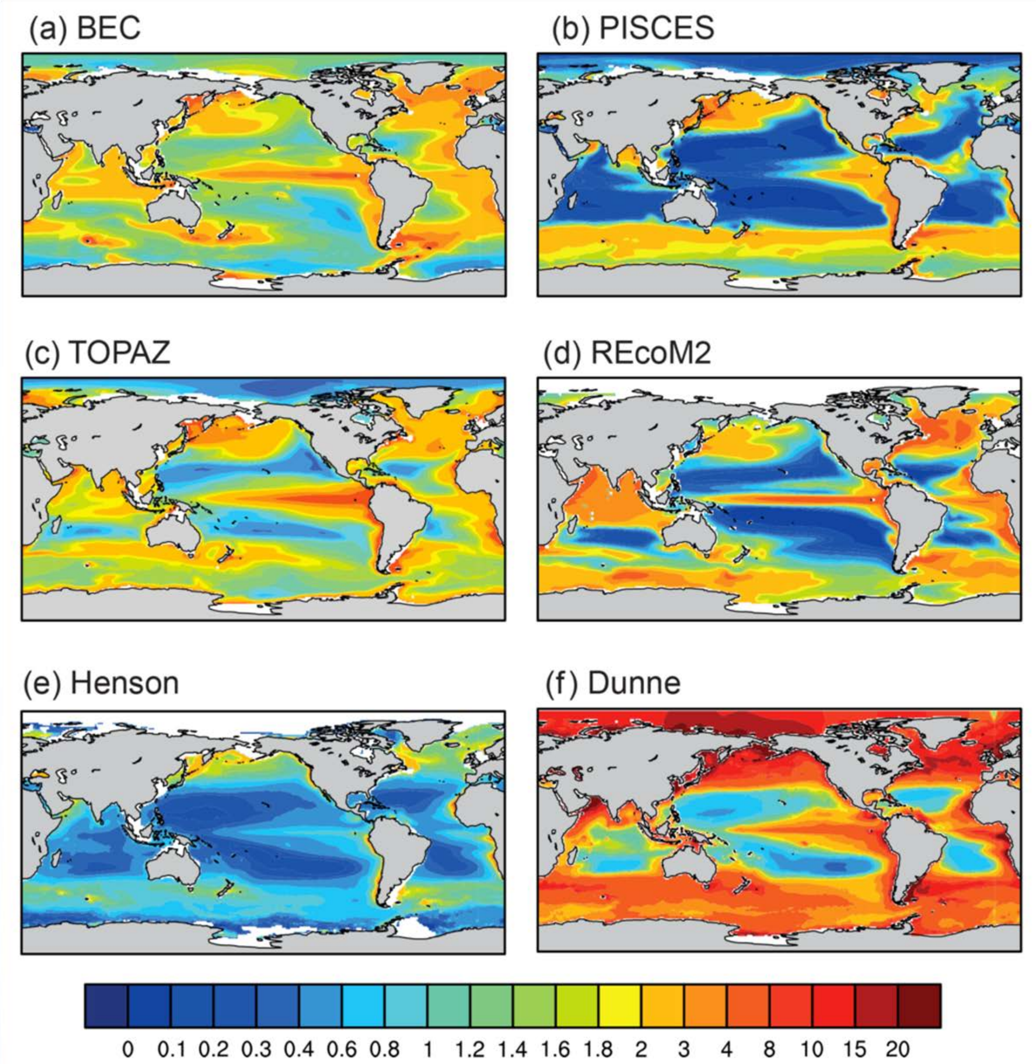
Jackson et al., 2015

- SOLOPC, Autonomous profiling float
- Measuring:
  - CTD
  - Optical backscatter
  - Chl/Fluor
  - LOPC (Laser Optical Plankton Counter): Particles and Zooplankton

Developed by Dave Checkley (SIO)

Large variability in model-based estimates of export production

Laufkötter et al., Biogeosci. Disc., 2016;
Henson et al., 2012;
Dunne et al., 2007



Sediment Trap and Thorium Data

HENSON ET AL.: EXPORT AND TRANSFER EFFICIENCY

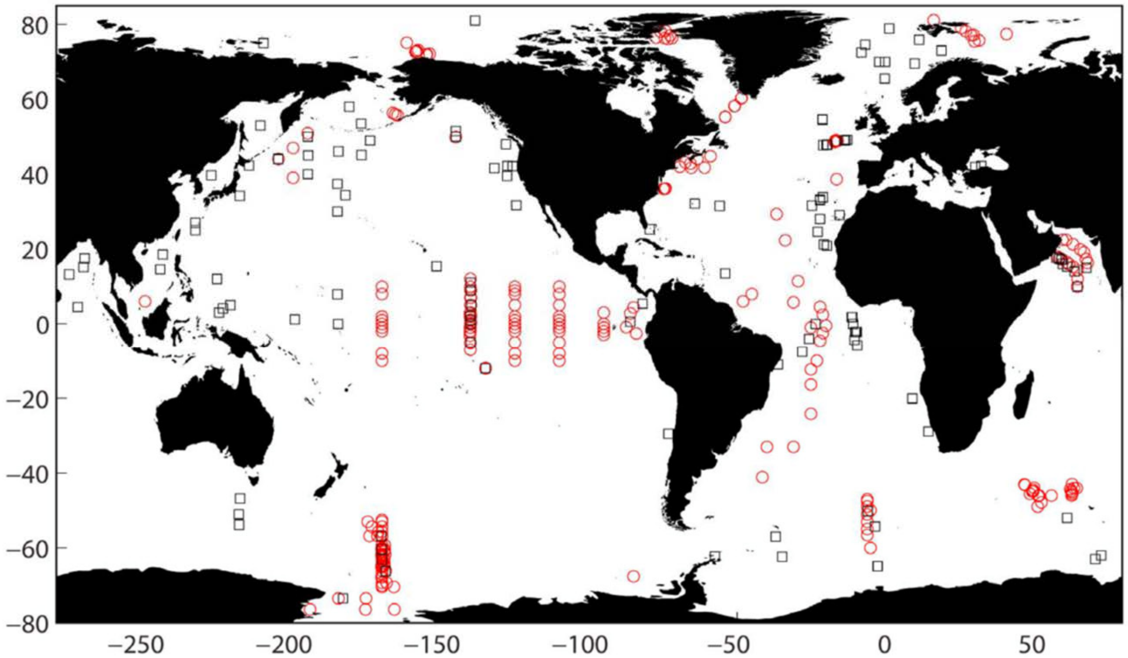
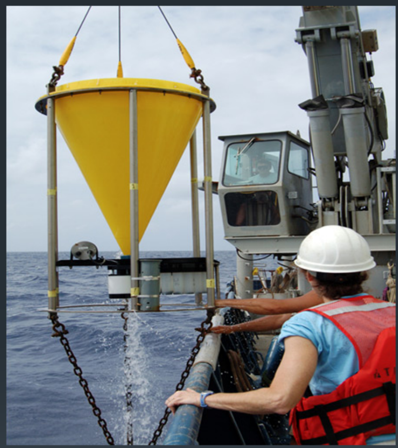


Figure 1. Location of data used in this study. Circles are locations of thorium-based particle export measurements (data in Table S1 in Text S1 in the auxiliary material); squares are locations of POC flux measured using sediment traps [from *Honjo et al.*, 2008].



Henson et al., 2012

if we're honest…

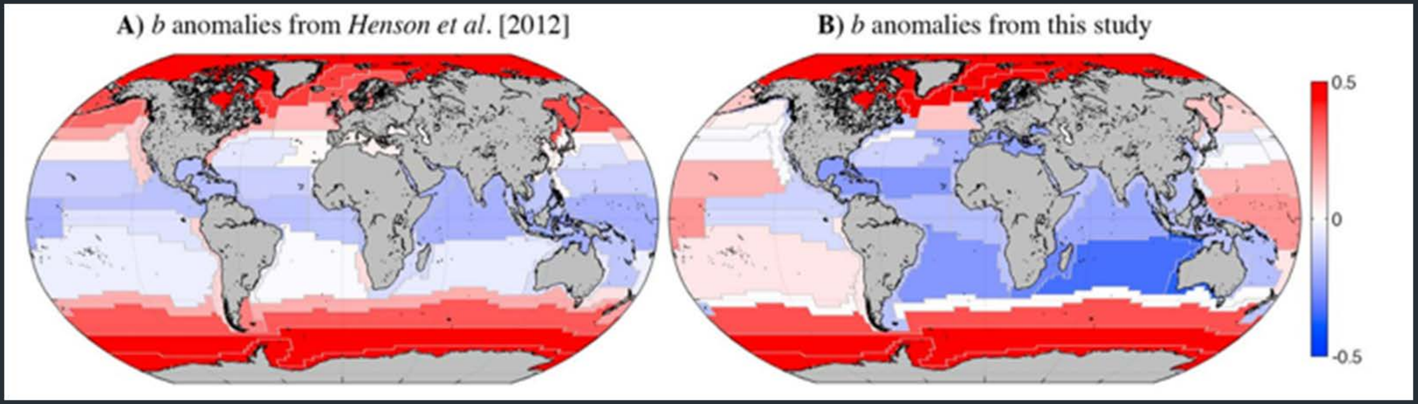
- "*definite interpretation is not straightforward because of heterogeneous data distribution and methodology*"

  - Kriest and Oschlies, 2013

- "*the sparseness and relatively large uncertainties of sediment trap data makes it difficult to accurately evaluate the skill of the model and other parameterizations*"

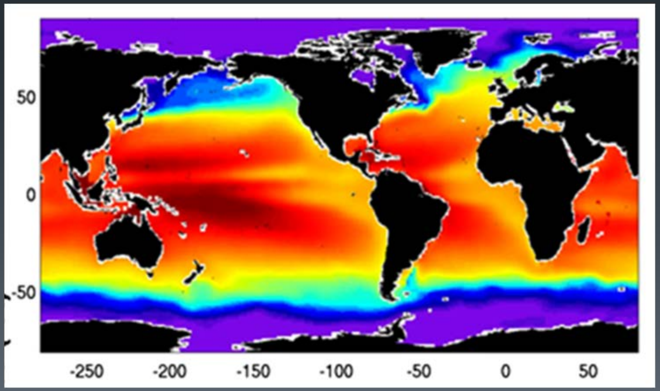
  - Lima et al., 2014

Global Variability in Flux Attenuation



Henson et al., 2012

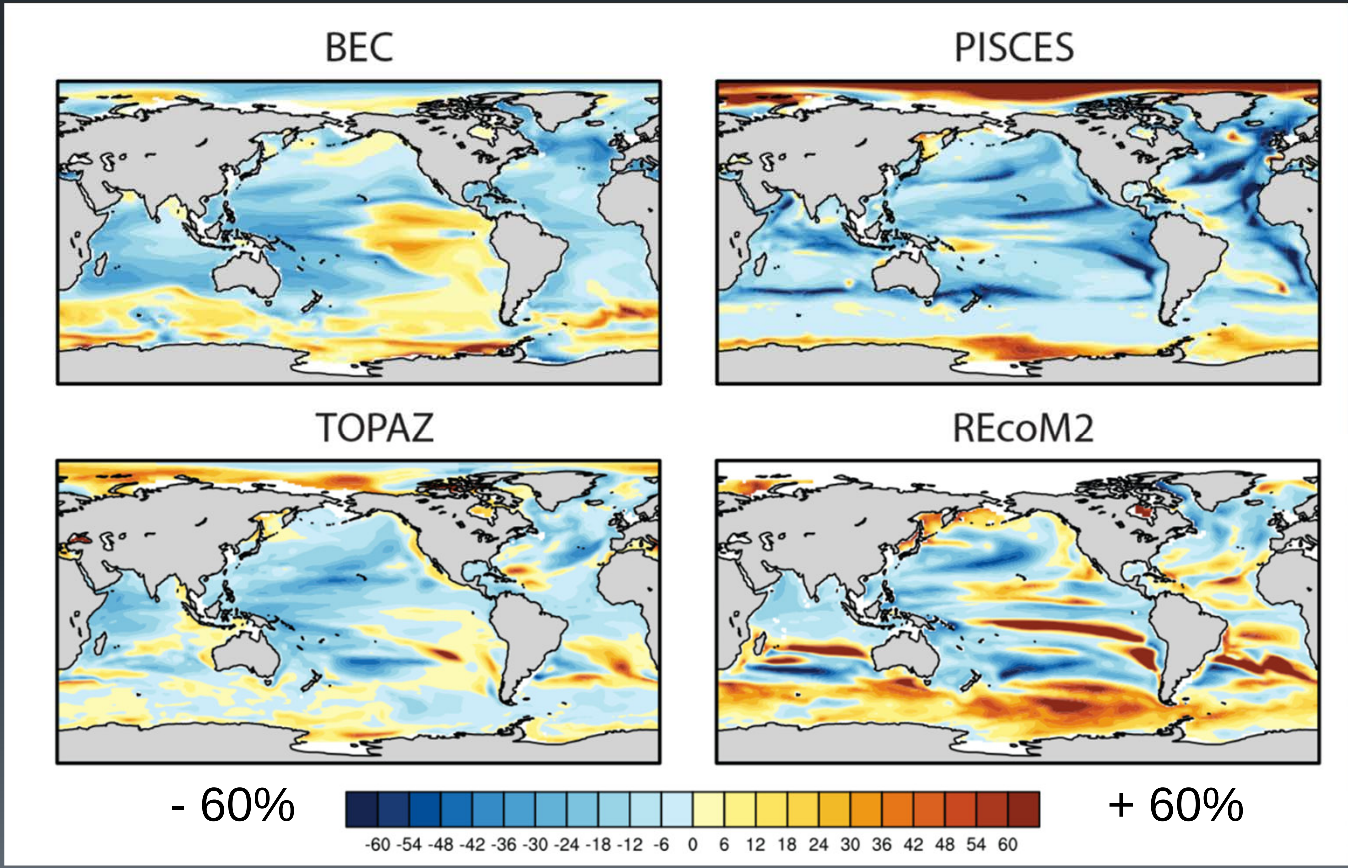
Guidi et al., 2015



Marsay et al., 2015

The need to detect changes in the biological pump

Modeled changes in export production by 2100 under RCP 8.5



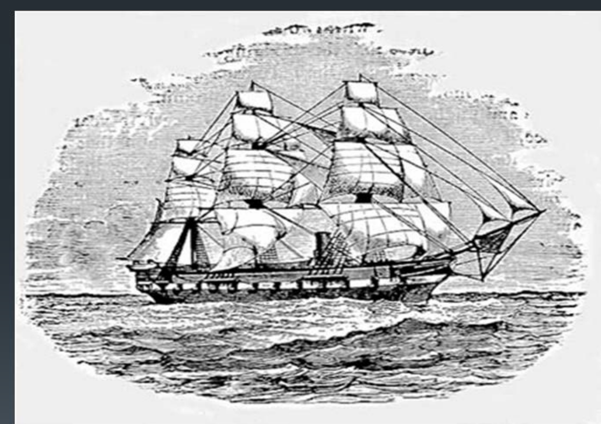
Laufkötter et al., Biogeosci. Disc., 2016

A Comparative History of Ocean Temperature Measurements

By the 1870's

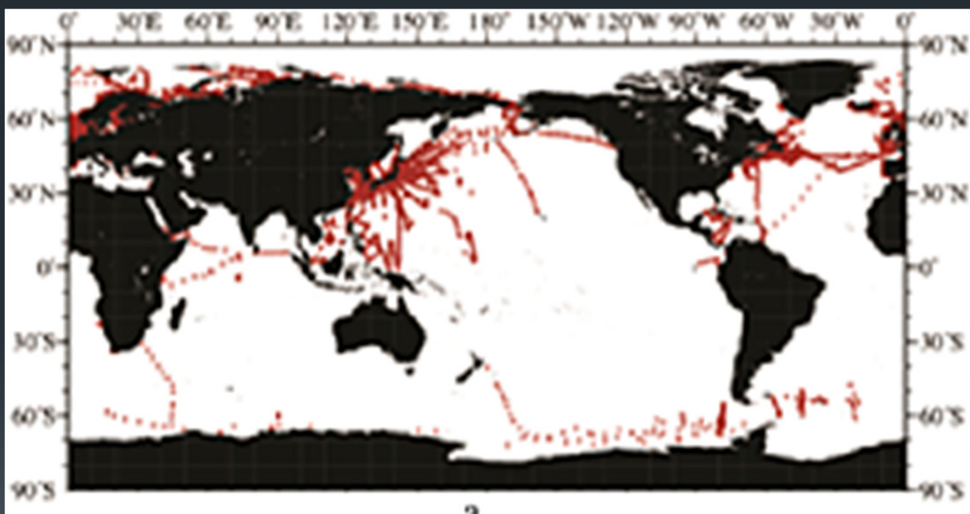
The Challenger Expedition

Pressure shielded thermometer



Measuring Ocean Temperature

By 1934:

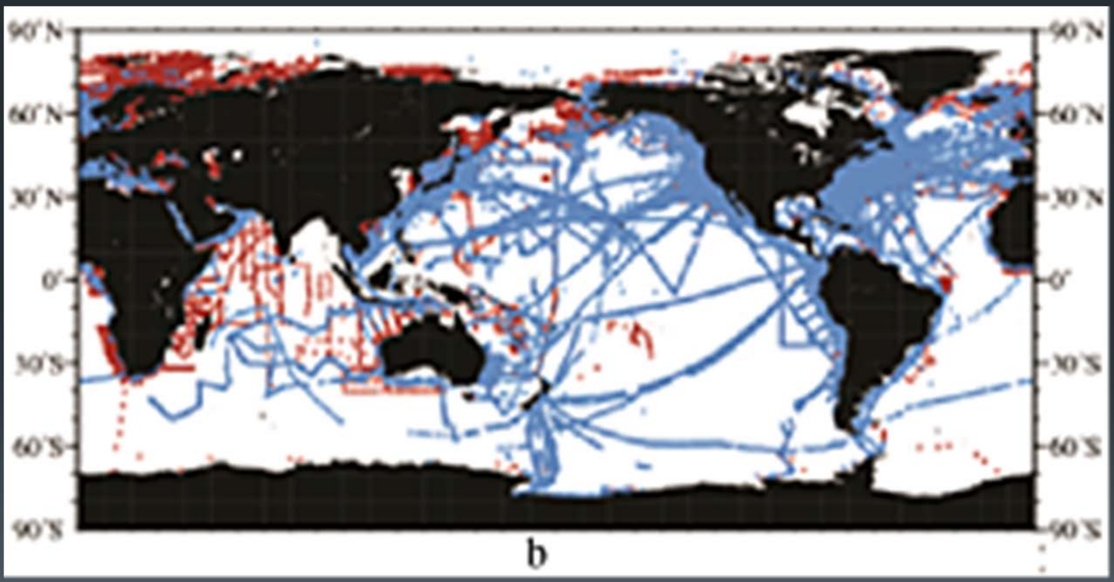


Abraham et al., 2013

The Reversing Thermometer/Nansen Bottle (1900-

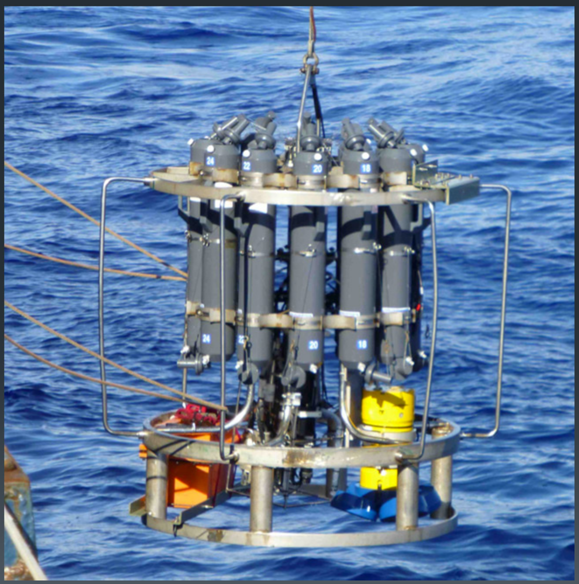
Measuring Ocean Temperature

By 1960



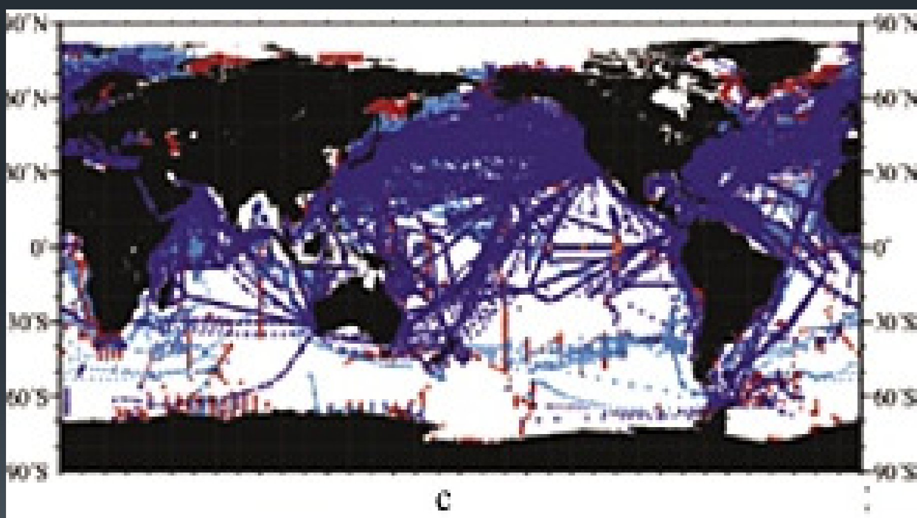
Abraham et al., 2013

Ship-based CTD measurements, 1955-present



Measuring Ocean Temperature

By 1985:

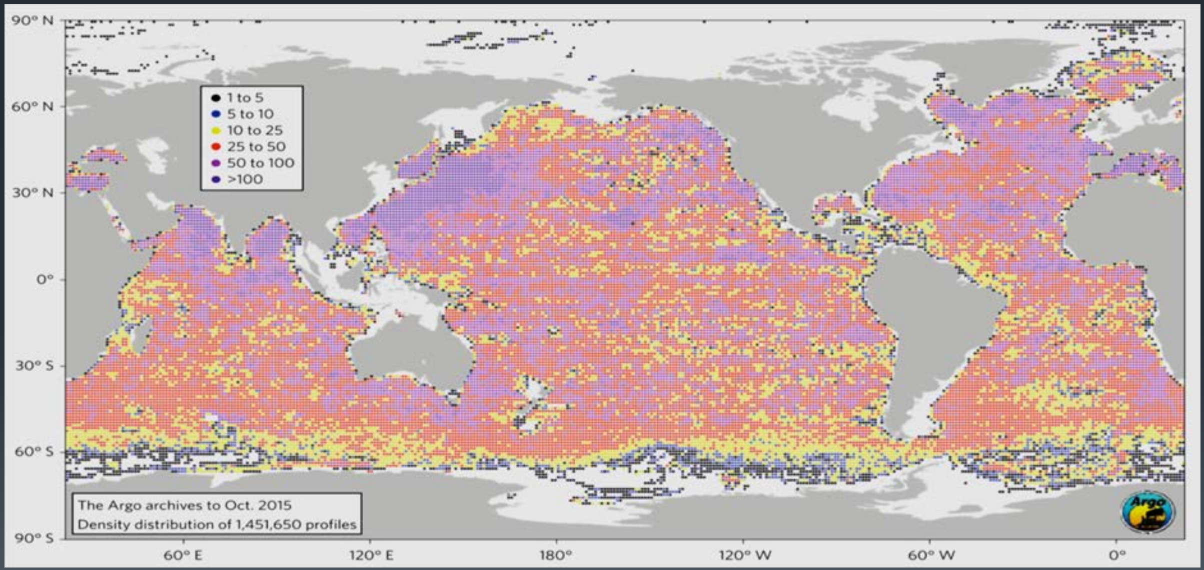


Abraham et al., 2013

Expendable Bathythermograph, 1967-present

Measuring Ocean Temperature

By 2015:
1.5 Million profiles and counting

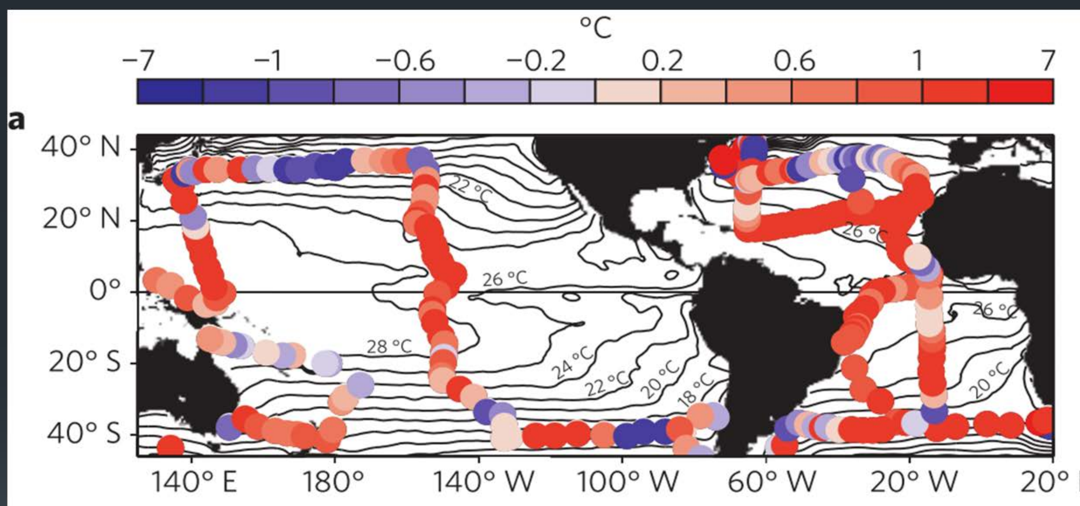


Argo profiling floats, 2001-present

MacDonald el., 2016

The power of observations

[Argo (2004-2010)] – Challenger



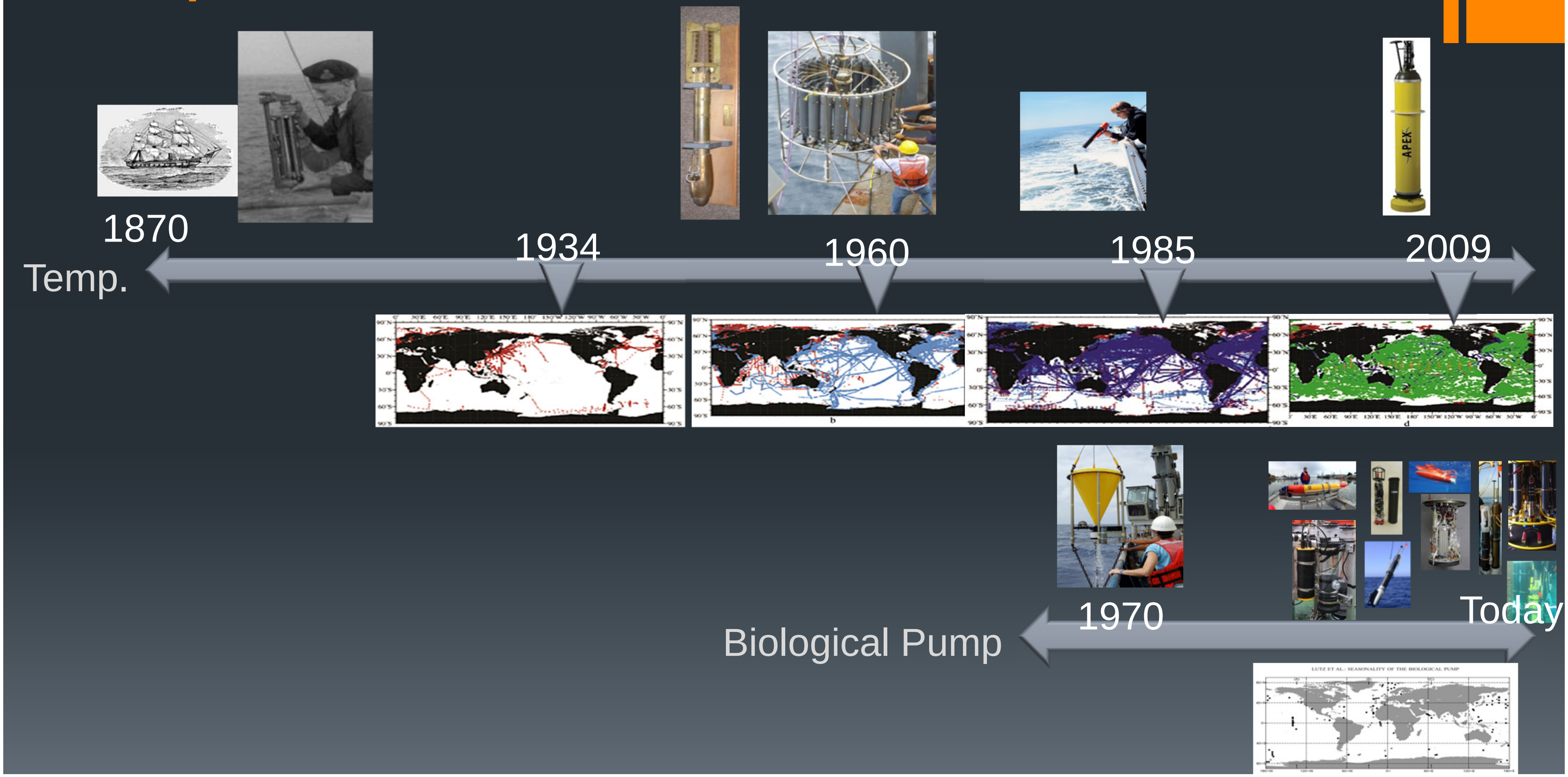
nature climate change

MacDonald el., 2016

- 90% of heat excess heat has ended up in the ocean
- Half of the increase in ocean heat content occurred since 1997

Glecker et al., 2016

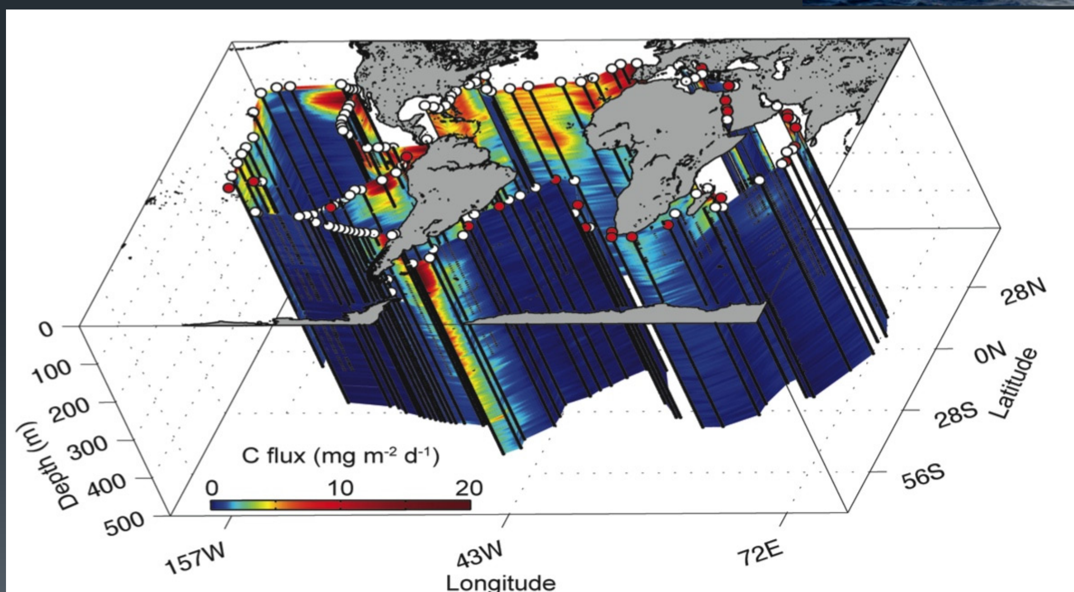
Comparative timelines

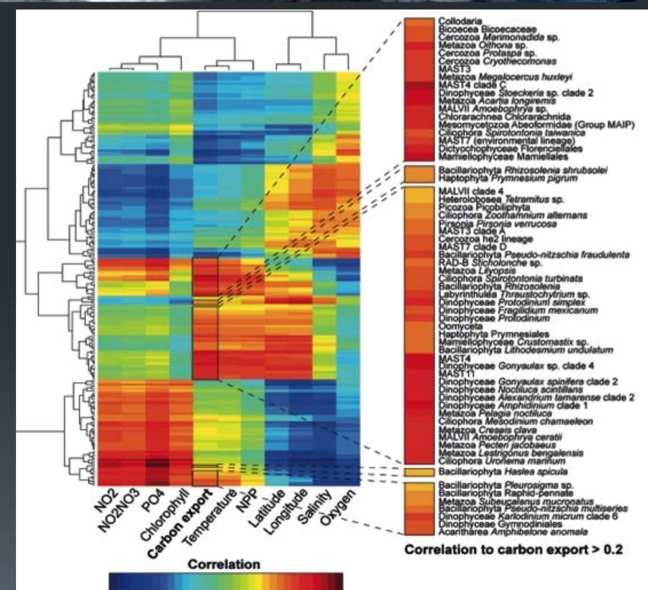


Tara Oceans Expedition

Tara Oceans

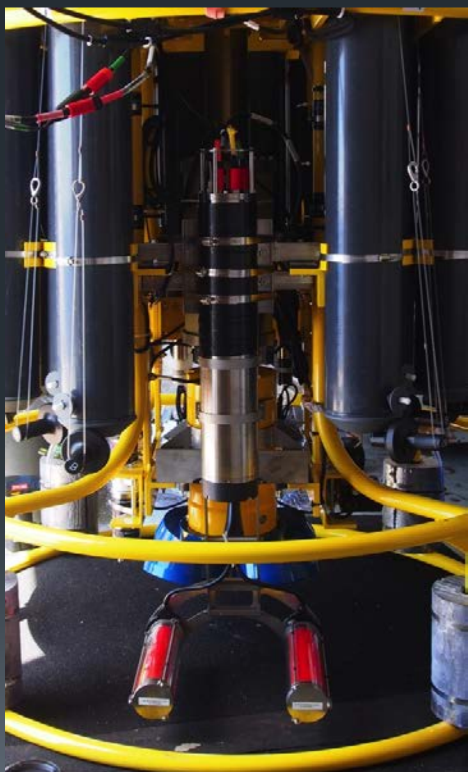
Plankton networks driving carbon export in the oligotrophic ocean

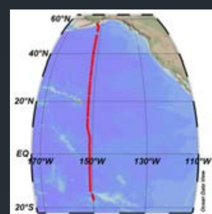


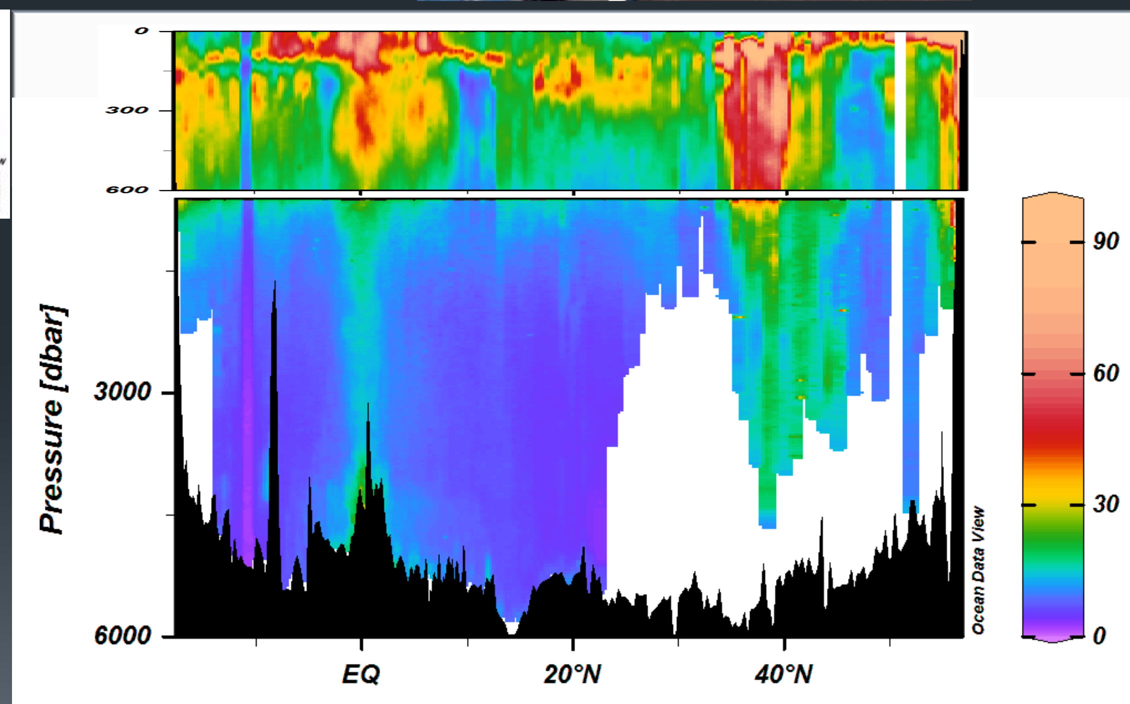


Guidi et al., *Nature*, 2016

Mapping Particles at Hydrographic Scales

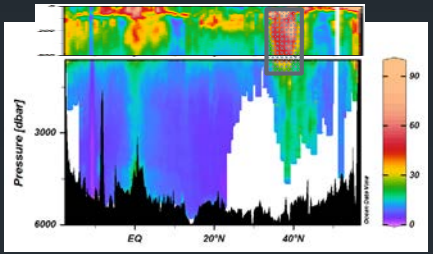




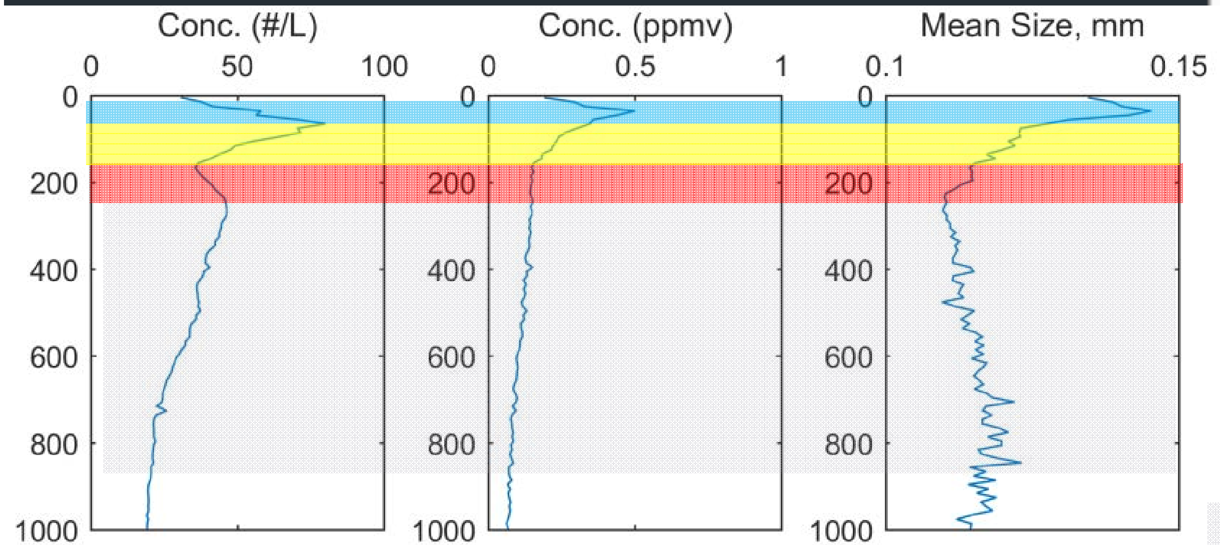


McDonnell et al., in prep

Particle distributions and processes from the UVP



Average across 32° N – 43° N



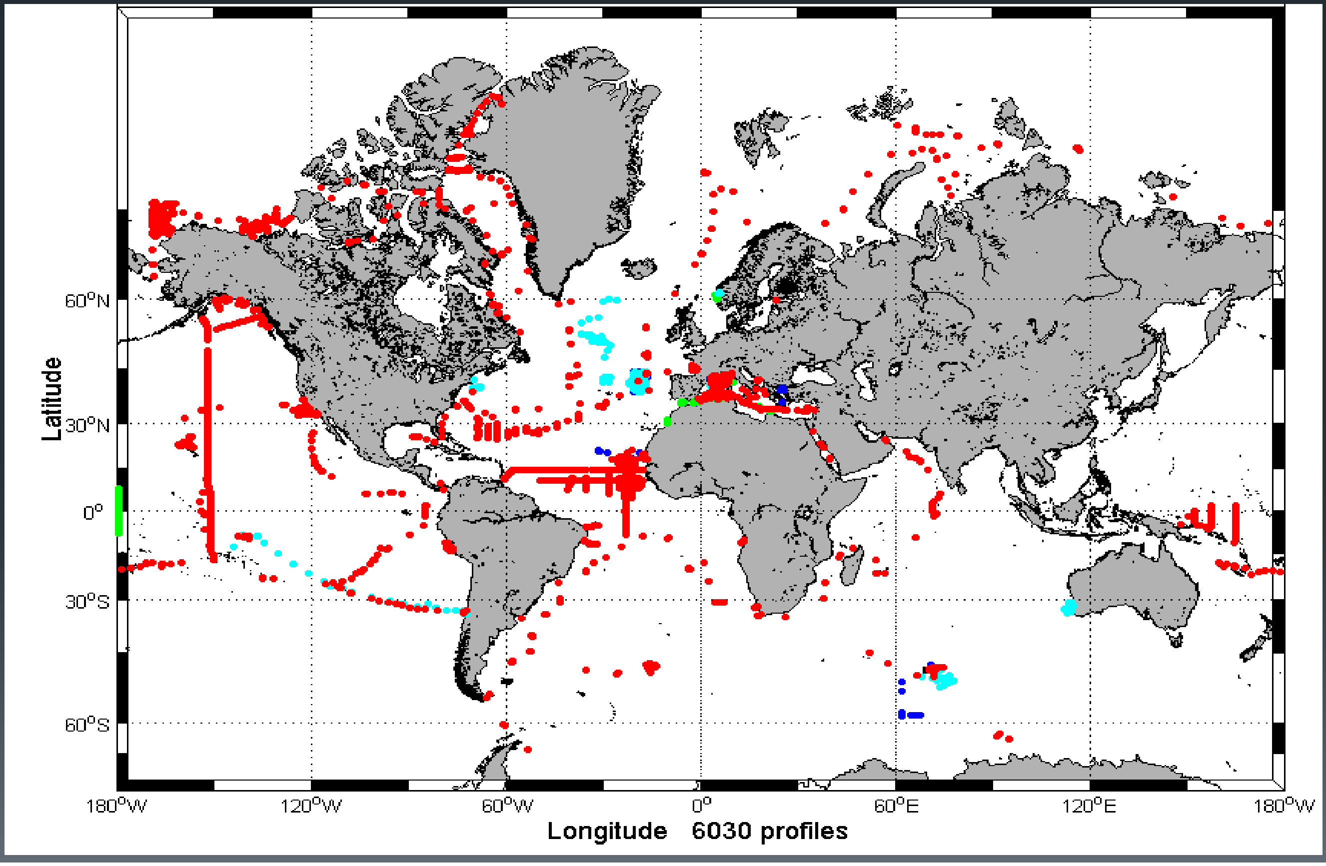
Large particle production & aggregation

Rapid destruction of all particles, especially large ones

Disaggregation/fragmentation large → small

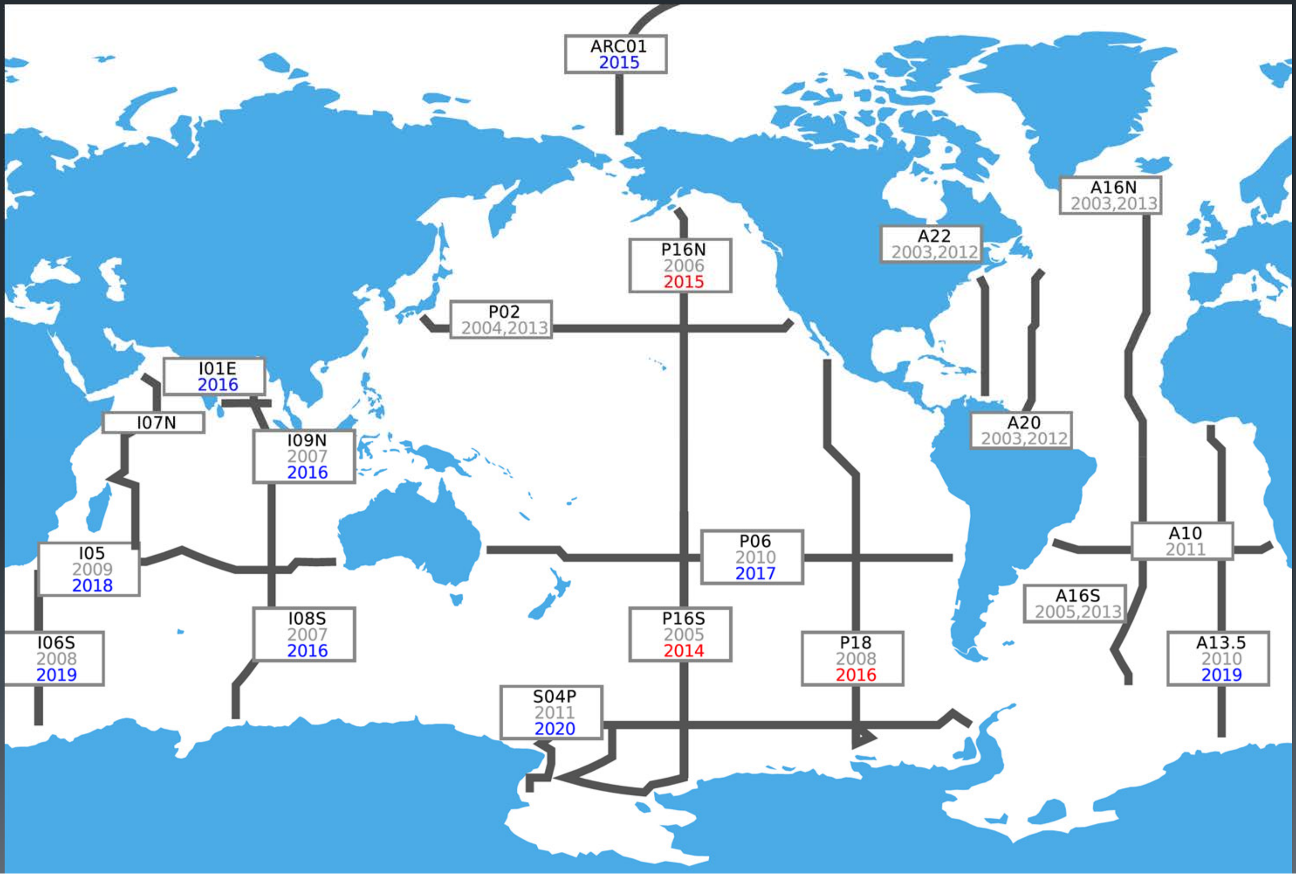
Small particles attenuate w.r.t. depth
Large particles penetrate deeply

Going Global: The UVP database



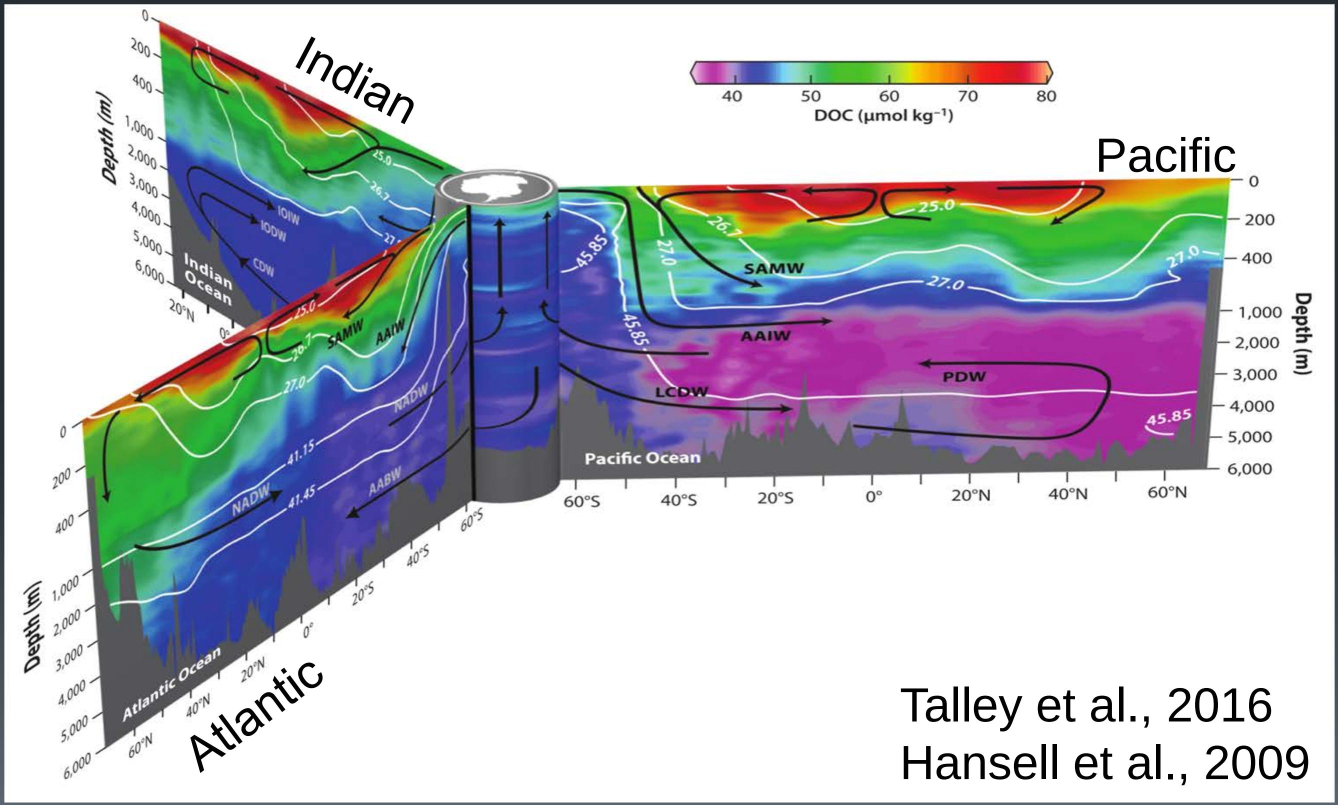
Map courtesy of
Marc Picheral

Going Global: The UVP database



US Hydro

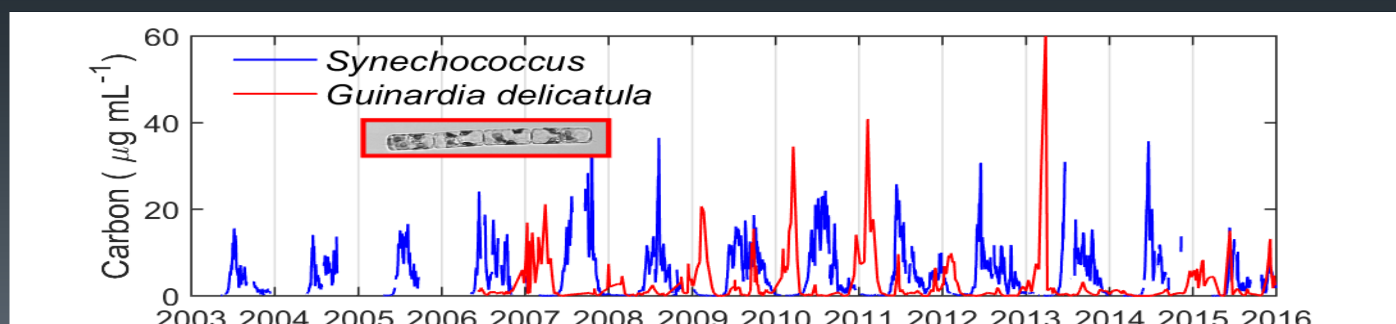
Our understanding of POM lags DOM



Imaging Flow Cytobot

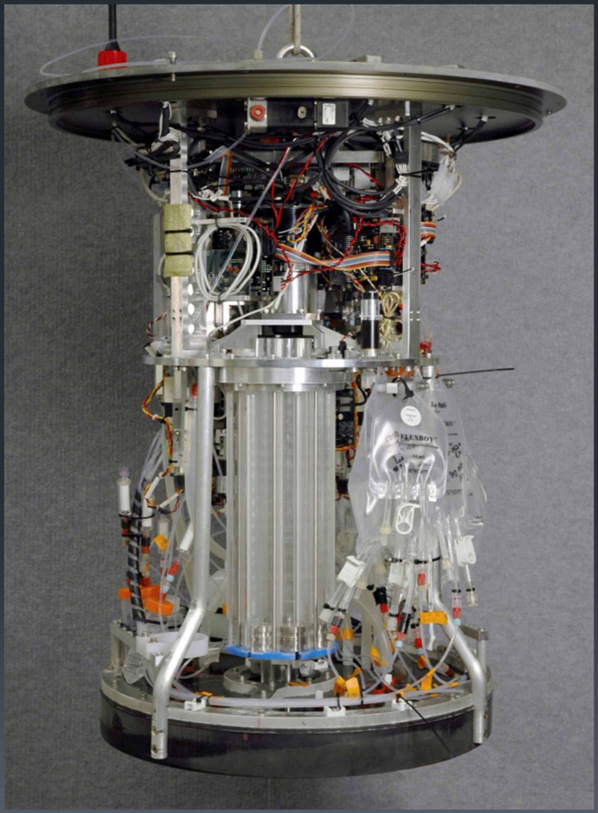
Biology: Caught on Camera!

Timeseries



Heidi Sosik

Environmental Sample Processor

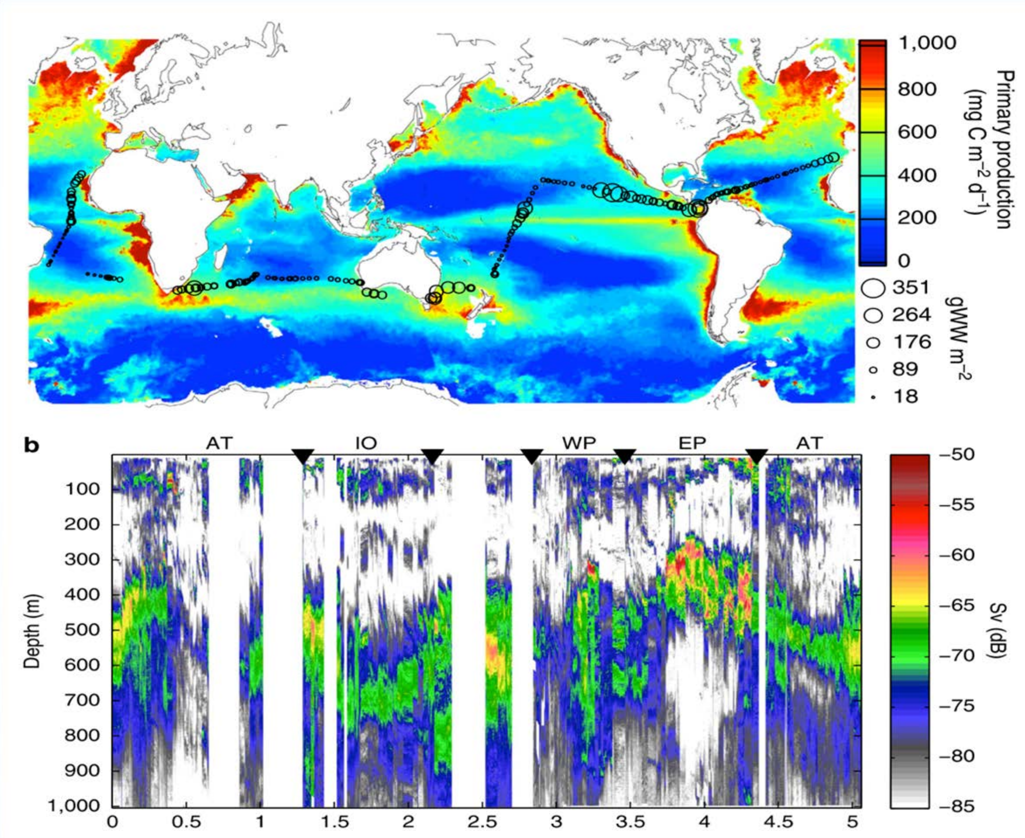


Scholin et al.,

- Designed @ MBARI
- Commercialized by McLane

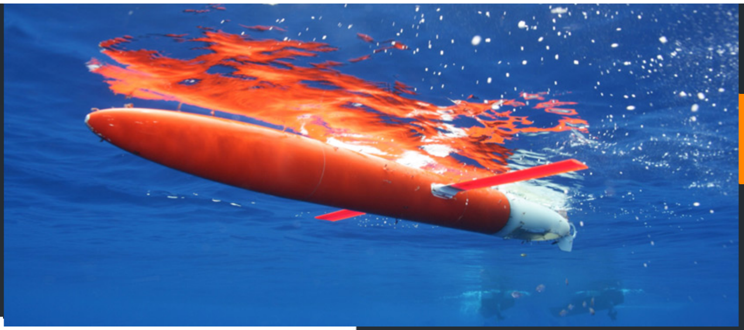
Acoustic assessments of mesopelagic fishes

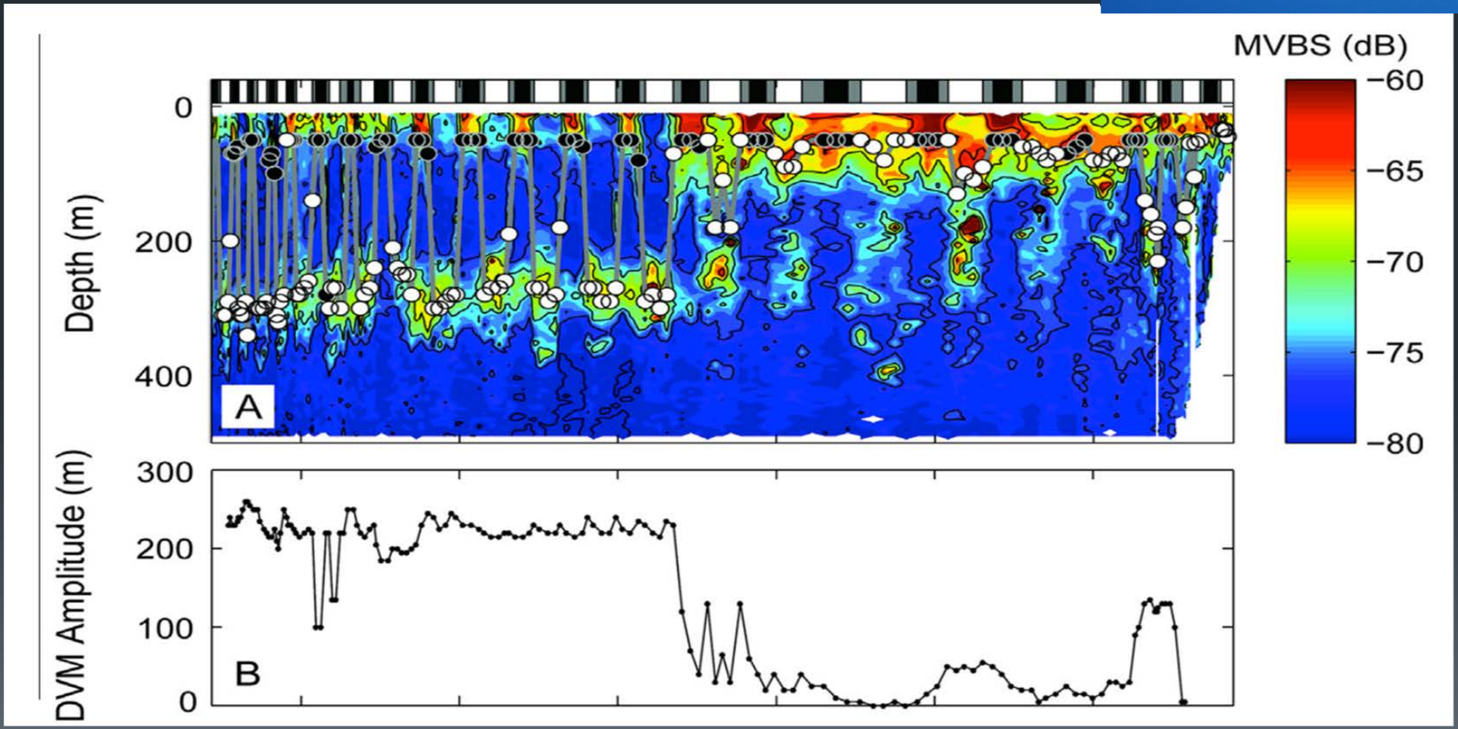
- Conventional estimates of fishes biomass are likely at least one order of magnitude low
- Close relationship between fishes and primary production
- Mesopelagic fishes may be respiring 10% of primary production!



Irigoien et al., 2014

Glider-mounted acoustics

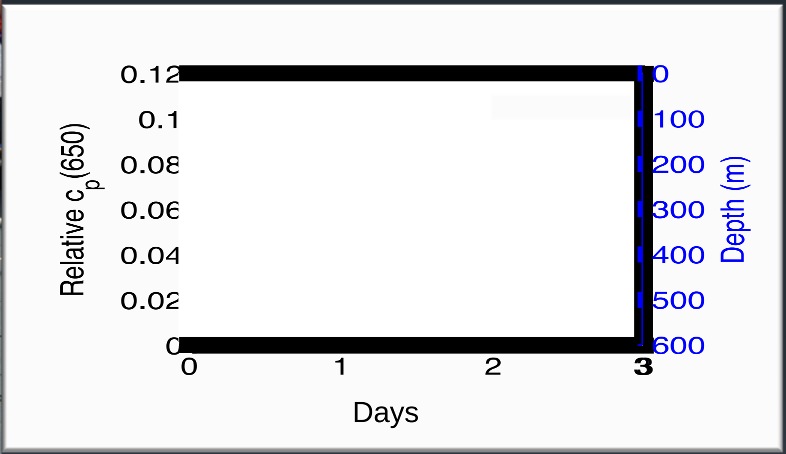


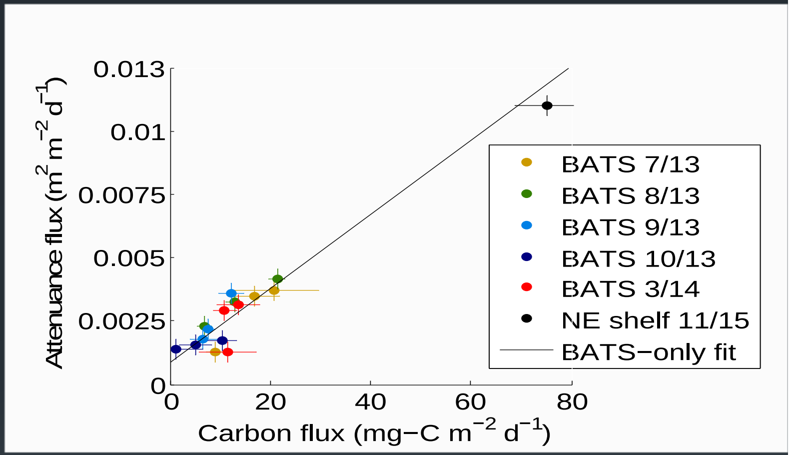


Powell and Ohman, 2015

Optical sediment traps

(Bishop et al. 2004; Bishop & Wood, 2009; Estapa et al., 2013; Estapa et al., *in revision*)





(BATS data: Estapa et al., *in revision;*
NE shelf data: Estapa OSM 2016 talk)

Other Platforms of Opportunity

Ocean Observatories Initiative

Open Questions

- Need for inter-comparison, calibration, and verification
- Are observational “proxies” for flux sufficient?
- Achieving new understanding through combining multiple approaches
- How can we use these tools to scale up to obtain global observational coverage?
- How are we going to track change in the biological carbon pump over long time scales?
  - Which parameters?
  - Which platforms?
  - Climate quality vs. weather quality data

Constraining the full spatial and temporal scales of variability in the ocean's biological carbon pump

From episodic events to global patterns

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