Tour of particles in the ocean

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Ocean Optics class 2023

Outline

- High-level overview of the composition of matter in the ocean
- The variety of particle types that may contribute to bulk IOP measurements
- Combining the advantages of optical methods with other particle characterization techniques

Discuss: What are the important constituents of seawater? (inclusive of all scientific perspectives)

Phytoplankton
Suspended Particulate Matter (SPM)
Salt
Dissolved gases
CDOM
Contaminants
- Organics, Oil, Plastic
Nutrients
Macro algae

Dissolved Inorganic Carbon (DIC)

Bubbles
Scum/foam/surface films
Trace metals
Bacteria
Viruses
Detritus - of all sizes
Zooplankton

Ice
DOM

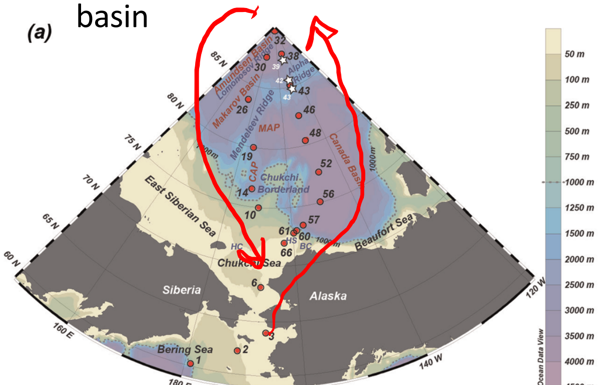
What fraction of particles are "organic"?

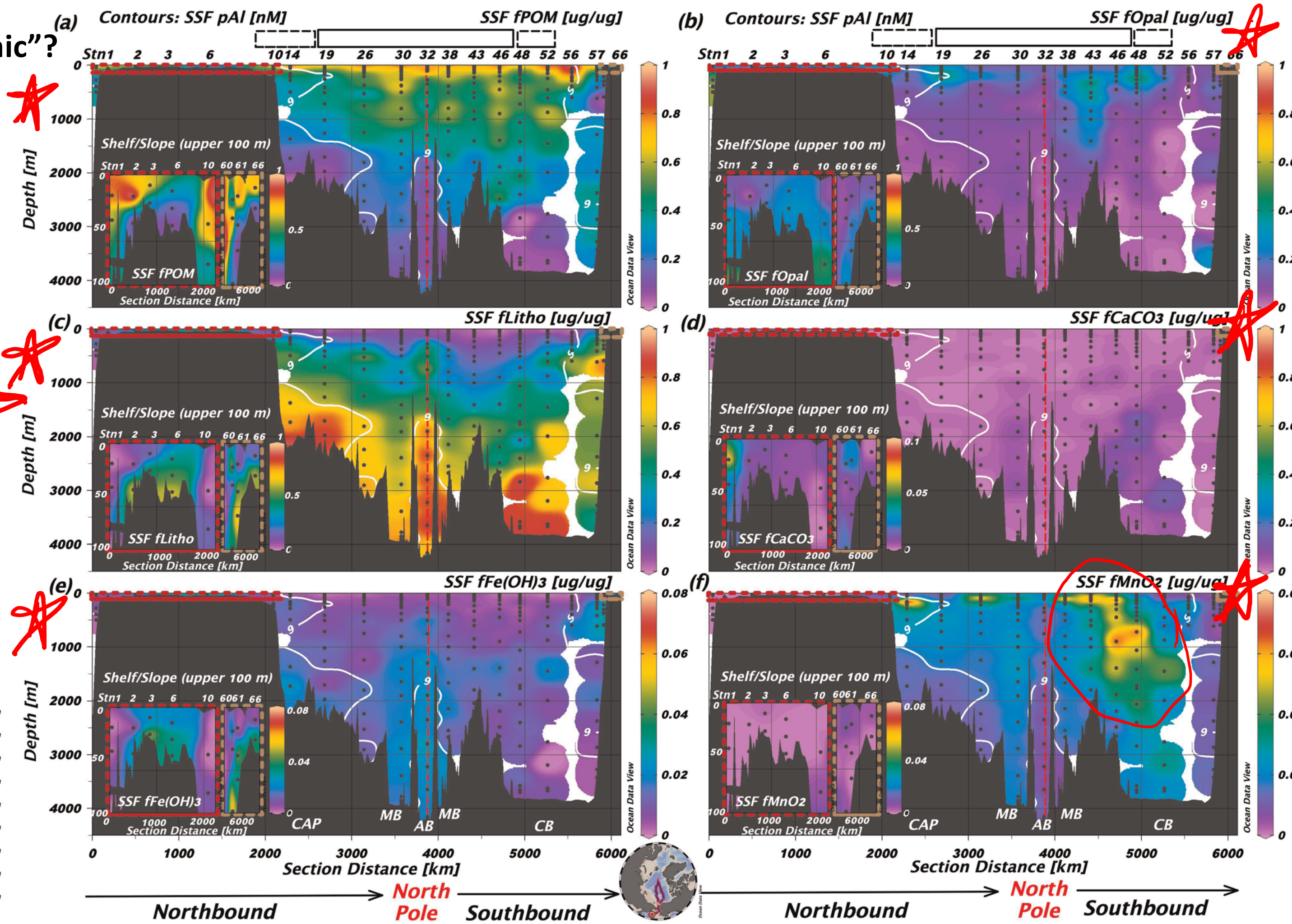
Particle composition during Arctic GEOTRACES cruise, 2015.

- August-October
- 1-51 μm particles collected with in situ pumps
- Composition estimated from major and trace element concentrations

Arctic Ocean

- Strong halocline ~100-300 m
- Red dashed line @~4000 km→brief crossing from Canadian to Eurasian basin





Figures: Xiang and Lam 2020. 10.1029/2020JC016144

How much of particulate organic matter is "alive"?

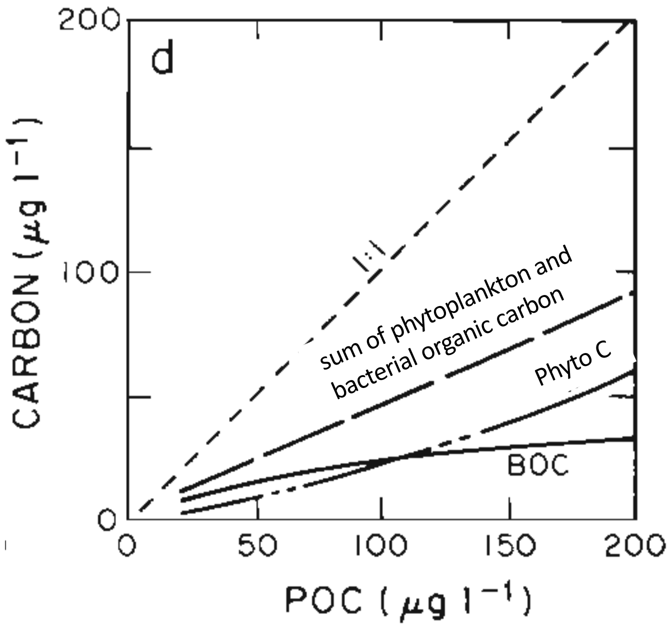


Figure: Cho and Azam, 1990. 10.3354/meps063253

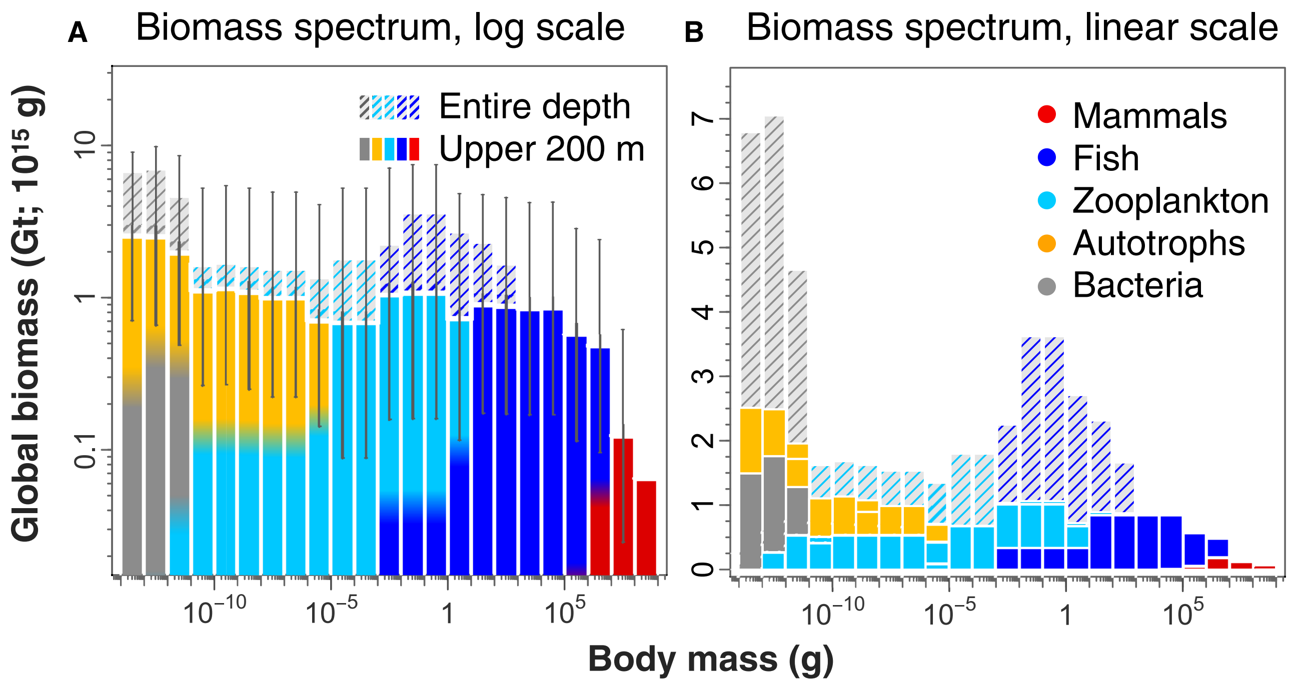
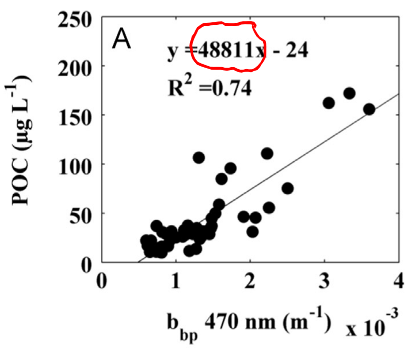
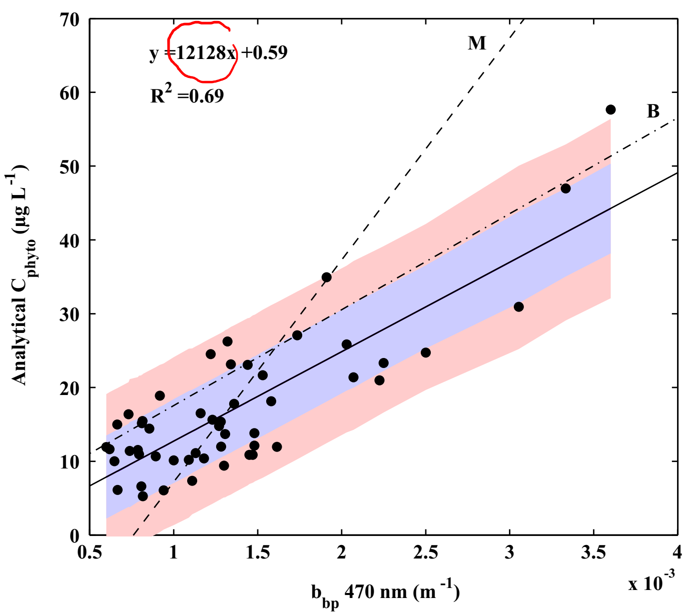


Figure: Hatton et al., 2020. 10.1126/sciadv.abh3732

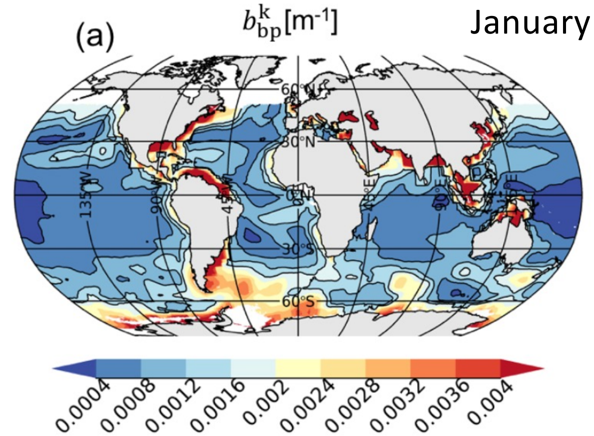
- Sheldon et al., 1972 was not too far off!
- Rest of Hatton paper projects future human impacts on the biomass PSD... an interesting read.

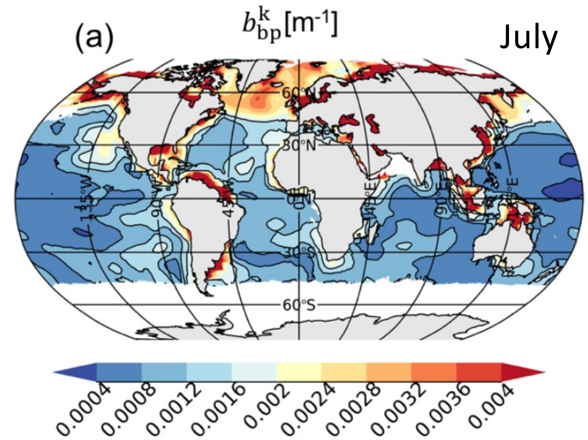
How much of particulate backscattering is due to phytoplankton?
Is this fraction constant everywhere?





Figures: Graff et al. 2015. 10.1016/j.dsr.2015.04.006





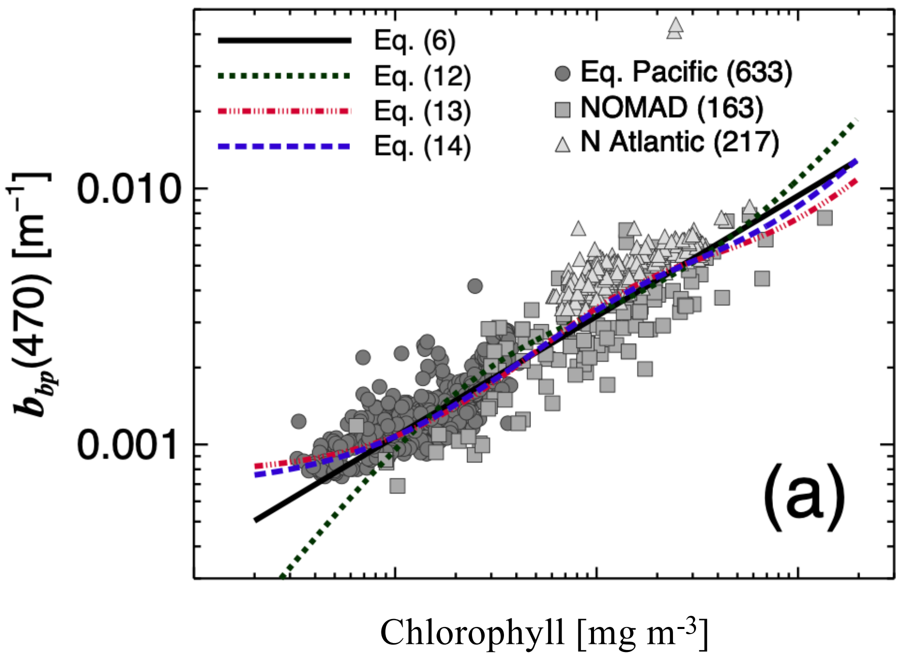
Map figures: Supplement to Bellacicco et al., 2020.
10.3390/rs12213640

- b_{bp}^k is the intercept of the regression of b_{bp} against Chl
- Map figures show January and July means of monthly determinations from merged satellite data

Photoacclimate
Size

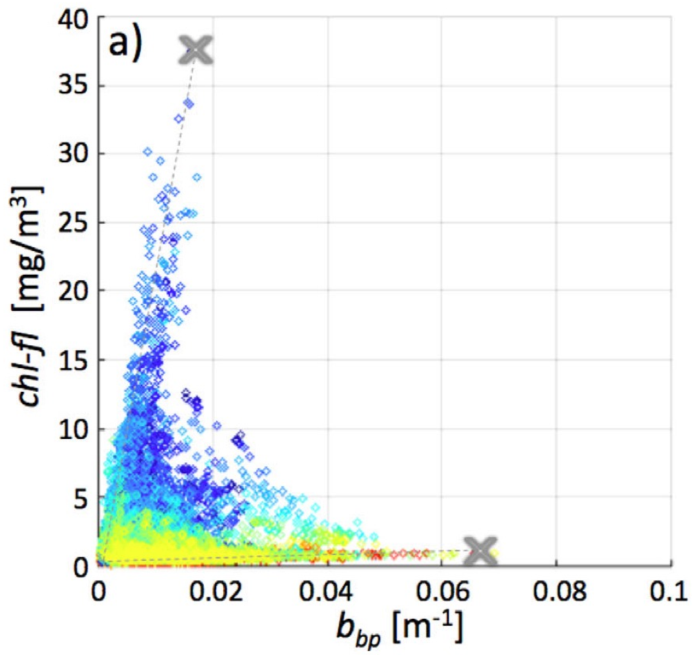
Balance of phytoplankton and detritus contributions to b_{bp} can vary with scale (regional/local vs. global, coastal vs. open ocean)

Open ocean



Brewin et al., 2012

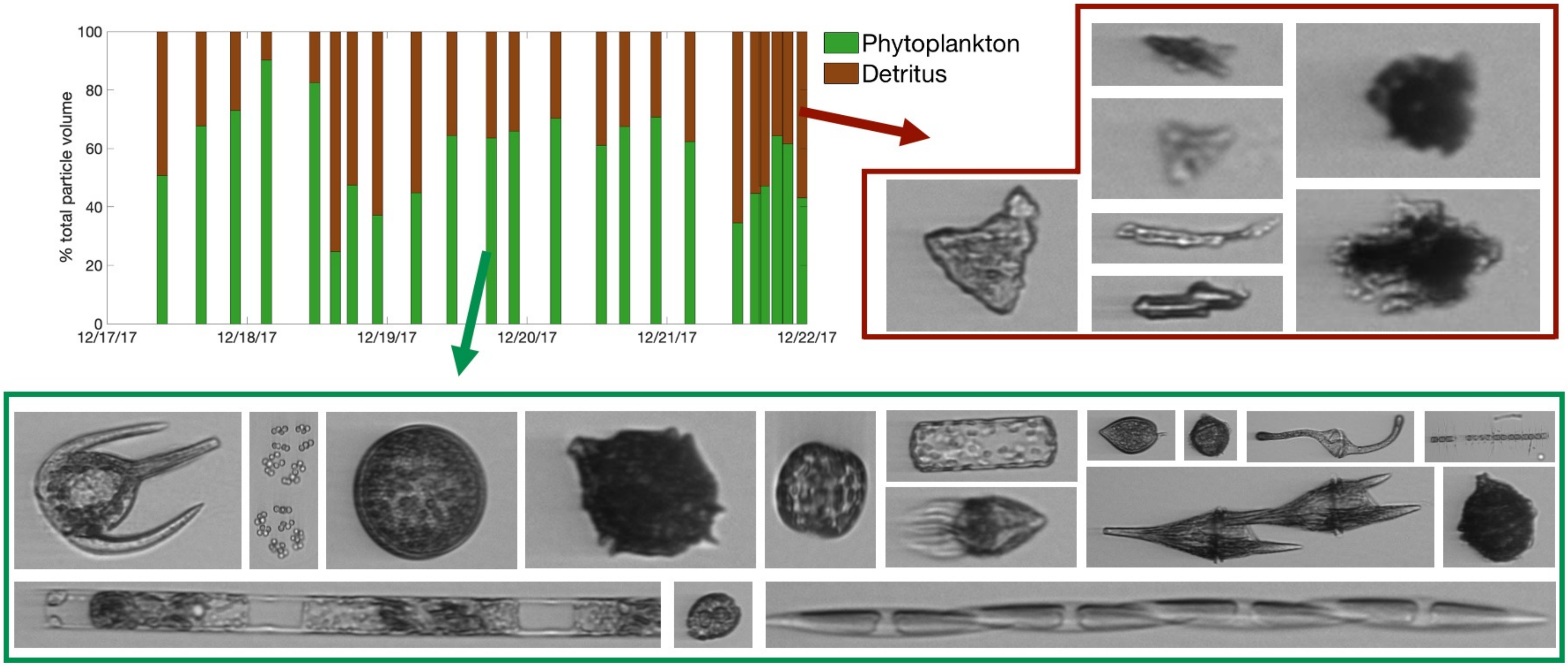
Coastal



Henderikx Freitas et al., 2016

Observing phytoplankton and detritus under dynamic conditions

Example IFCB images collected using the scattering trigger during the Thomas Fire in the Santa Barbara Channel. Ash particles vary in composition, shape, and color but are in the same size range as phytoplankton! Ash ranged from 10-65% of the total particle volume.

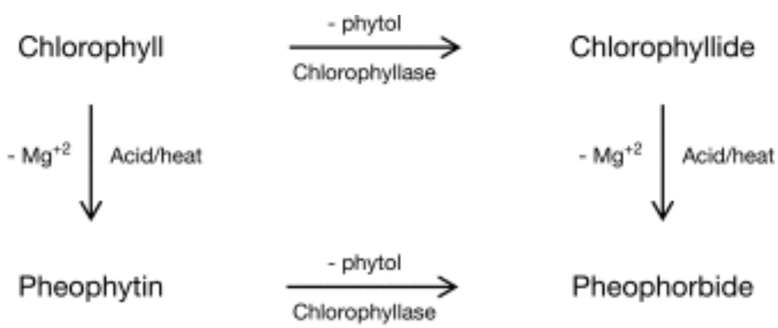


Kramer et al., 2020

What happens to phytoplankton as they turn into detritus?

In a sediment trap gel: sinking phytoplankton cells, fecal pellets, zooplankton

Chlorophyll is converted into degradation pigments (phaeophytin, pheophorbide, chlorophyllide)



Yilmaz & Golkim, 2016

What constitutes the boundary between a particle and the surrounding fluid?

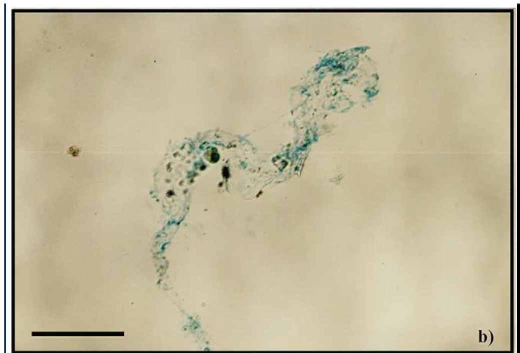
Change in refractive index ←

Cell membrane

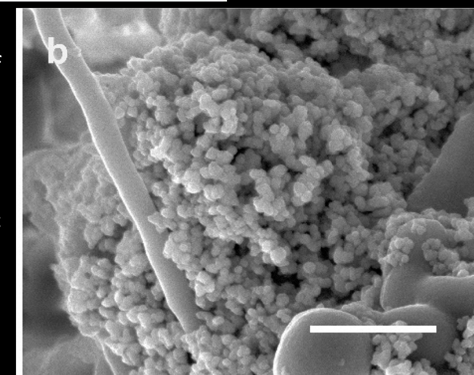
Fluid boundary layer

Compositional change

Change in density



TEP aggregate stained with Alcian Blue, scale = 0.1 mm. Passow and Alldredge 2002. doi: 10.1016/S0079-6611(02)00138-6



SEM photomicrograph of hydrothermal plume particle at EPR axis, scale = 1 µm. Hoffman et al., 2020. 10.1021/acsearthspacechem.0c00067

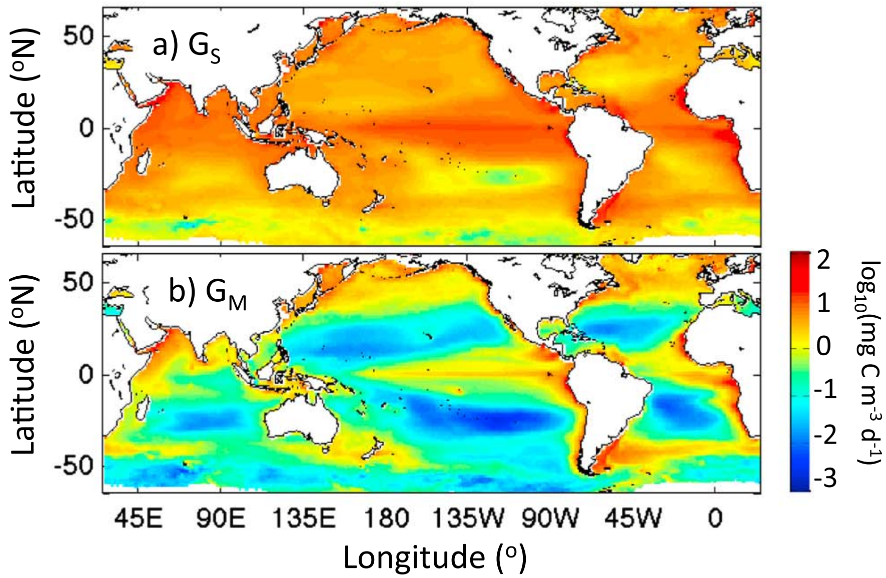
Pseudonitzchia australis, Phyto'pedia. Scale 50 µm. https://phytoplankton.eoas.ubc.ca/research/phytoplankton/diatoms/pennate/pseudonitzschia/p_pungens_australis.html

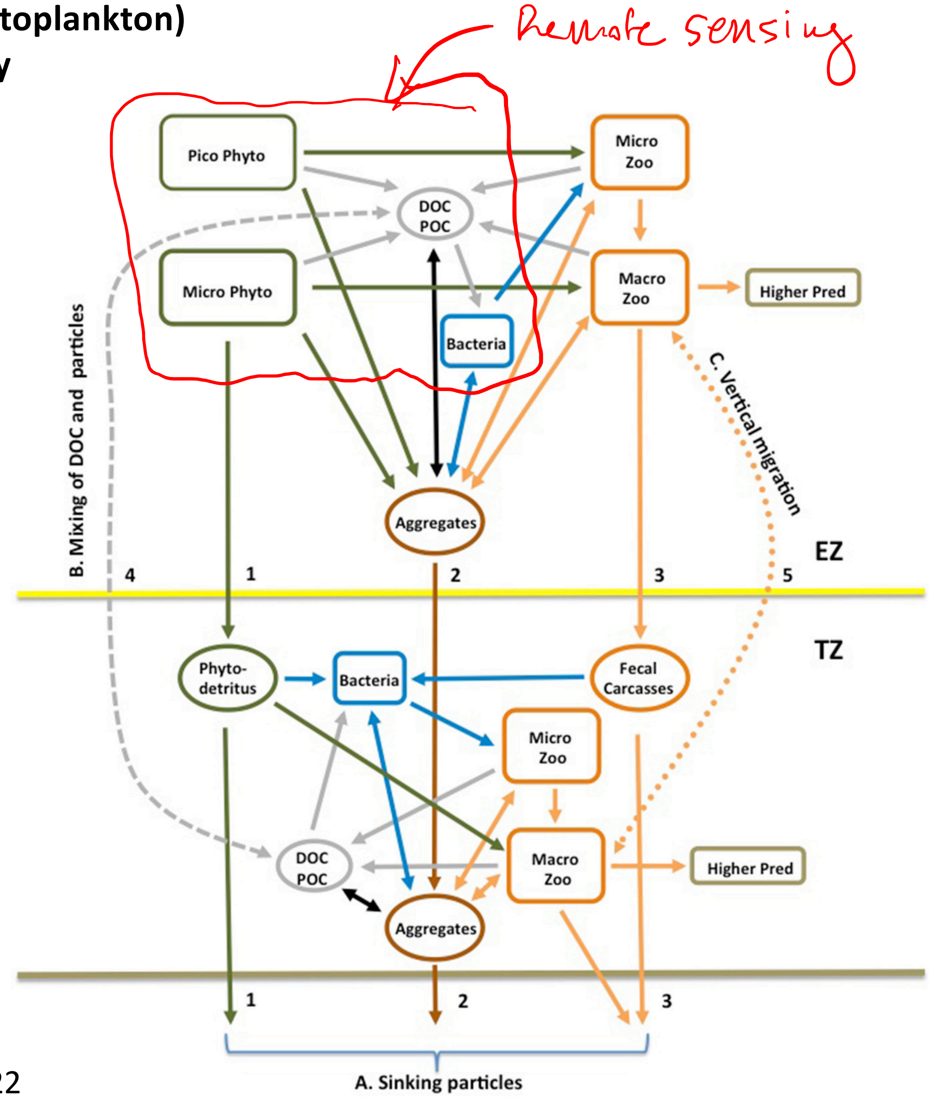
What are the advantages of optics/remote sensing methods?

- Synoptic ("see it all at once"), large scale sampling
- High depth resolution
- Ability to directly or synthetically sample large volumes and rare particles/events
- Combine the extent and resolution of optical methods with the less ambiguous/more detailed analyses available for discrete samples.

Use changes in things you *can* sense with optical methods (phytoplankton) to estimate the magnitude of processes you *can't* sense directly

Zooplankton grazing mortality of small (top) and large (bottom) phytoplankton
Figure: Siegel et al. (2014). 10.1002/2013GB004743

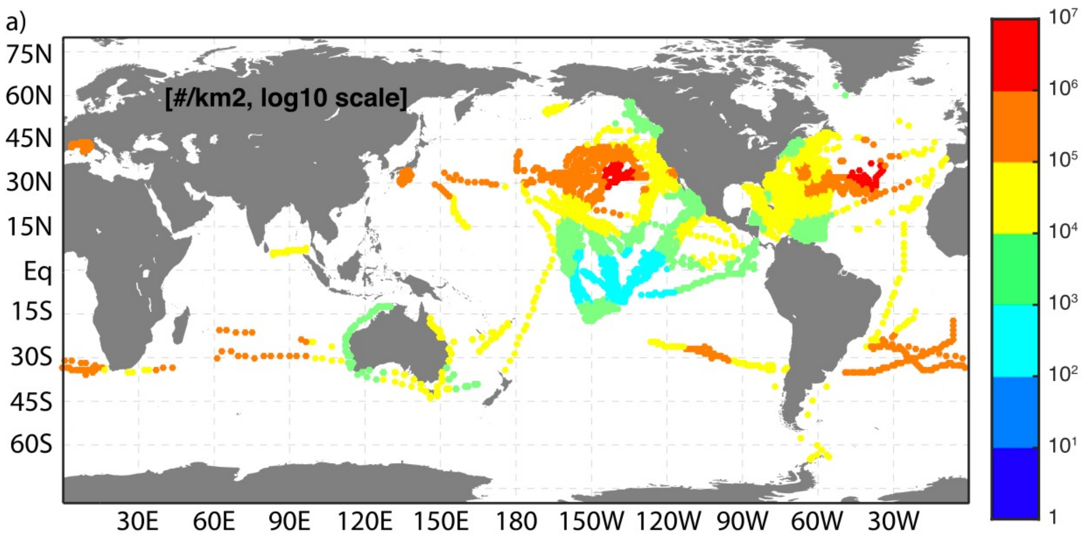




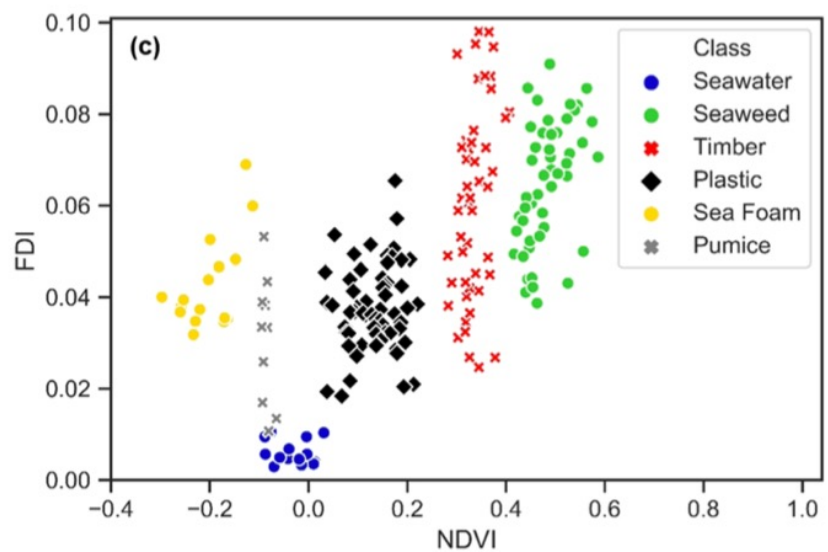
Schematic diagram of food web and biological carbon export from EXPORTS Science Plan
Figure: Siegel et al. (2016). 10.3389/fmars.2016.00022

Remote sensing of larger, rare non-living things

Anthropogenic marine debris is widespread...can we develop an optical index to separate plastic from other surface ocean constituents?

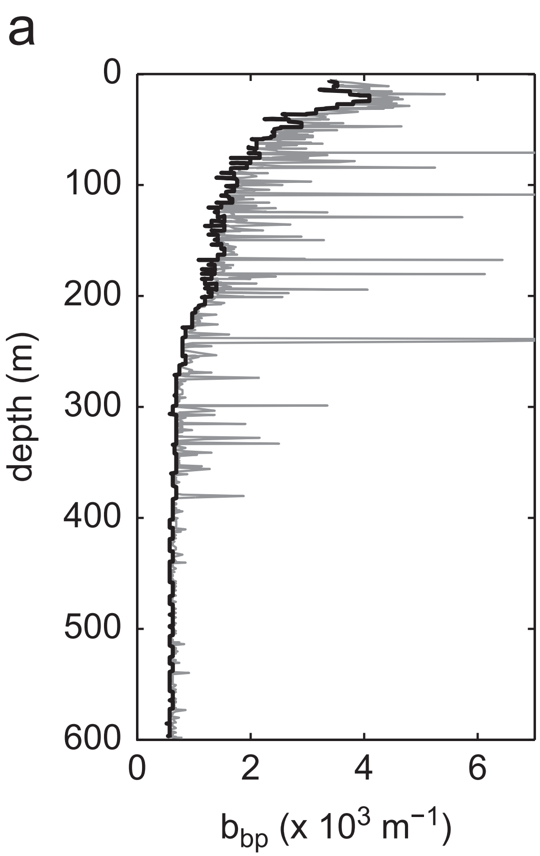


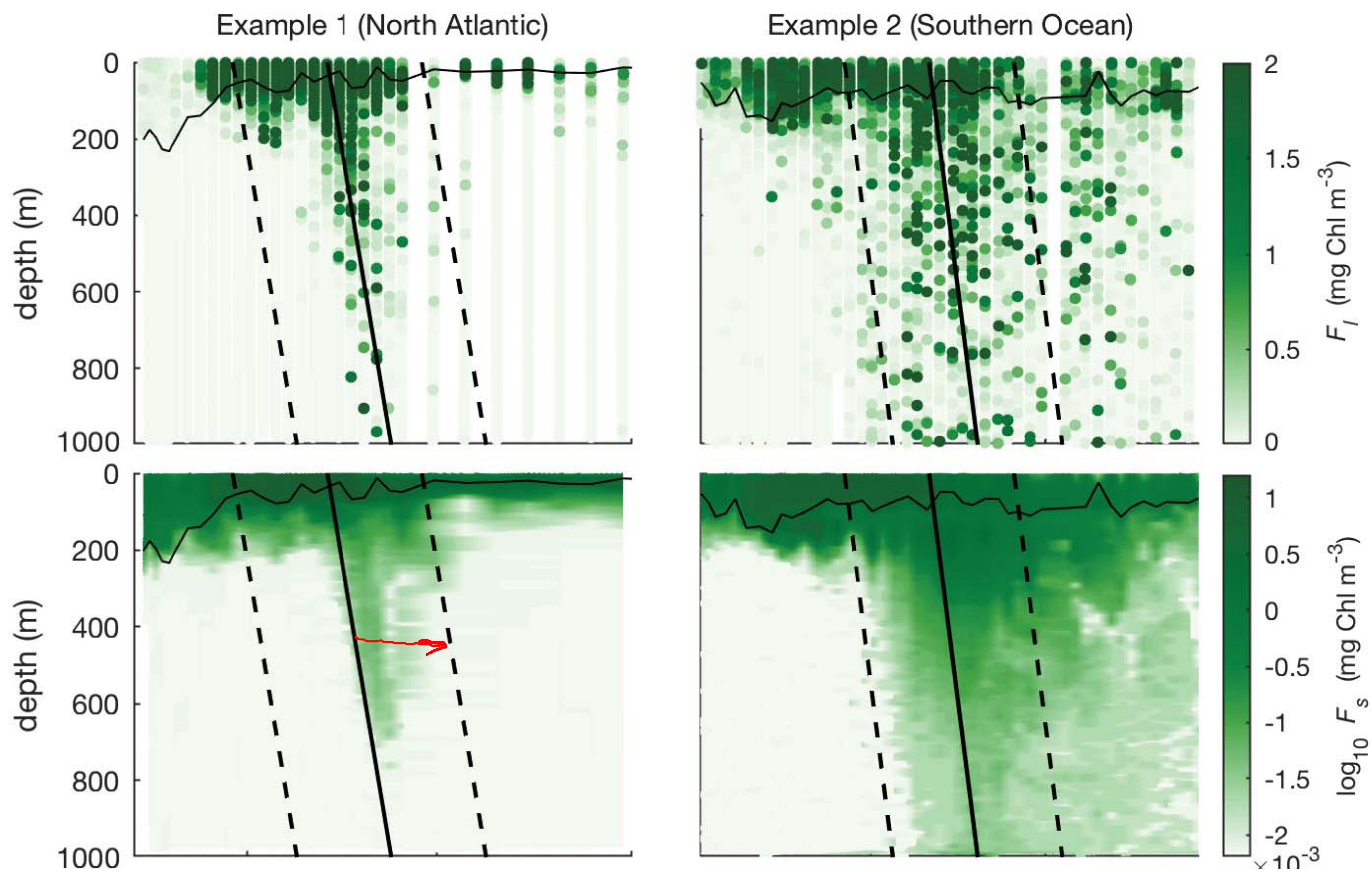
van Sebille et al., 2015



Biermann et al., 2020

Use of high frequency fluctuations in optical signals to quantify large particle stocks and observe their fragmentation rates





Figures: left, Briggs et al. 2011. 10.1016/j.dsr.2011.07.007. Right, Briggs et al. 2020. 10.1126/science.aay1790

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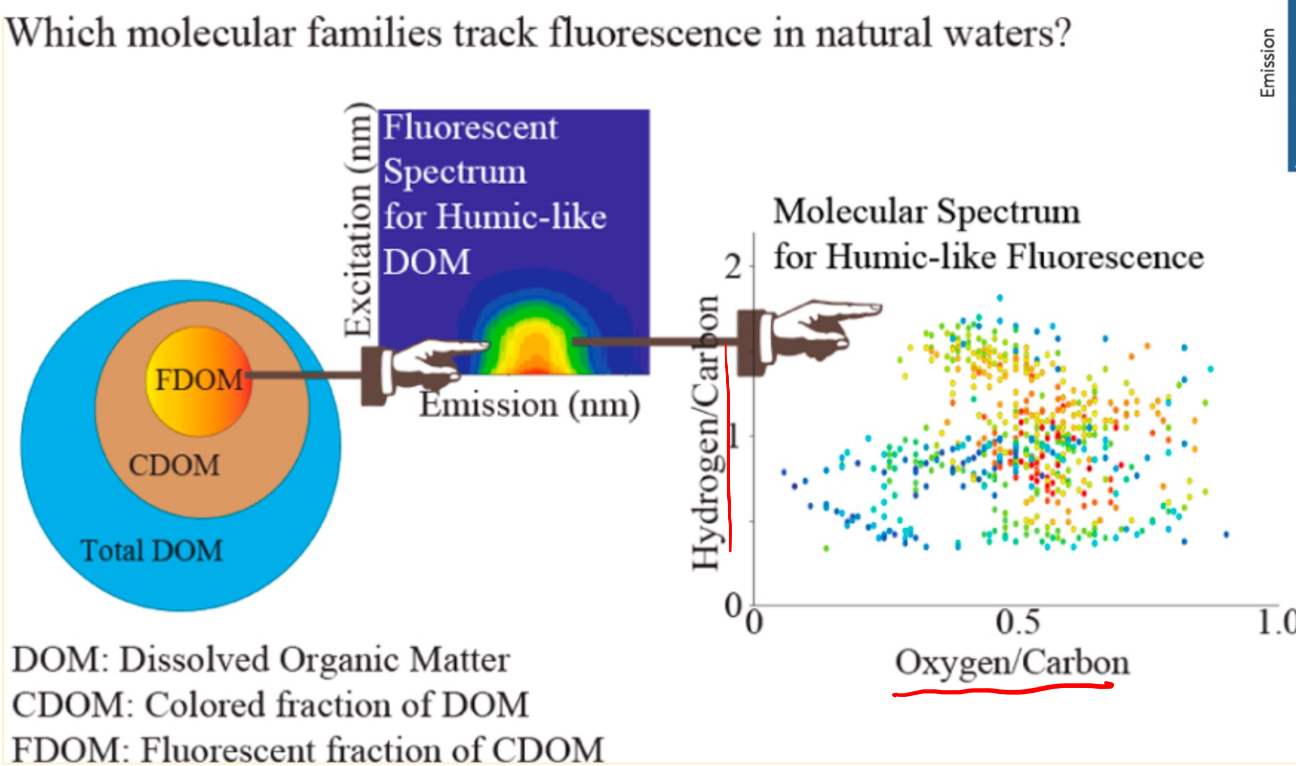
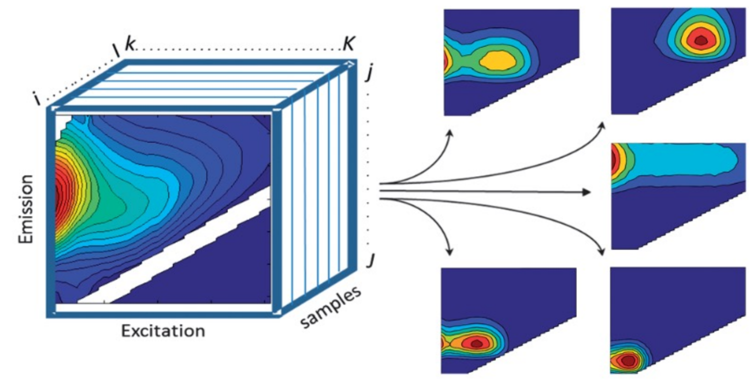
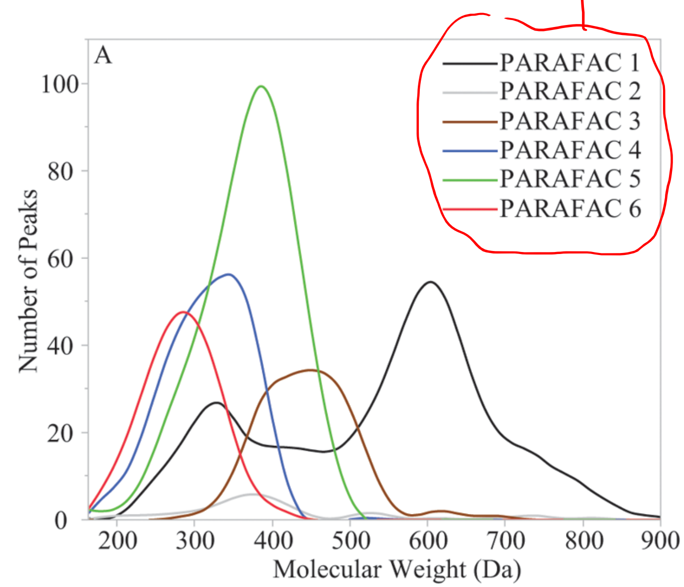
  - Examples here are distinct from “proxy building” – to which we will return later this afternoon
  - They represent what could be thought of as the earliest stage of proxy development

Example: linking DOM fluorescence with high-resolution molecular spectroscopy

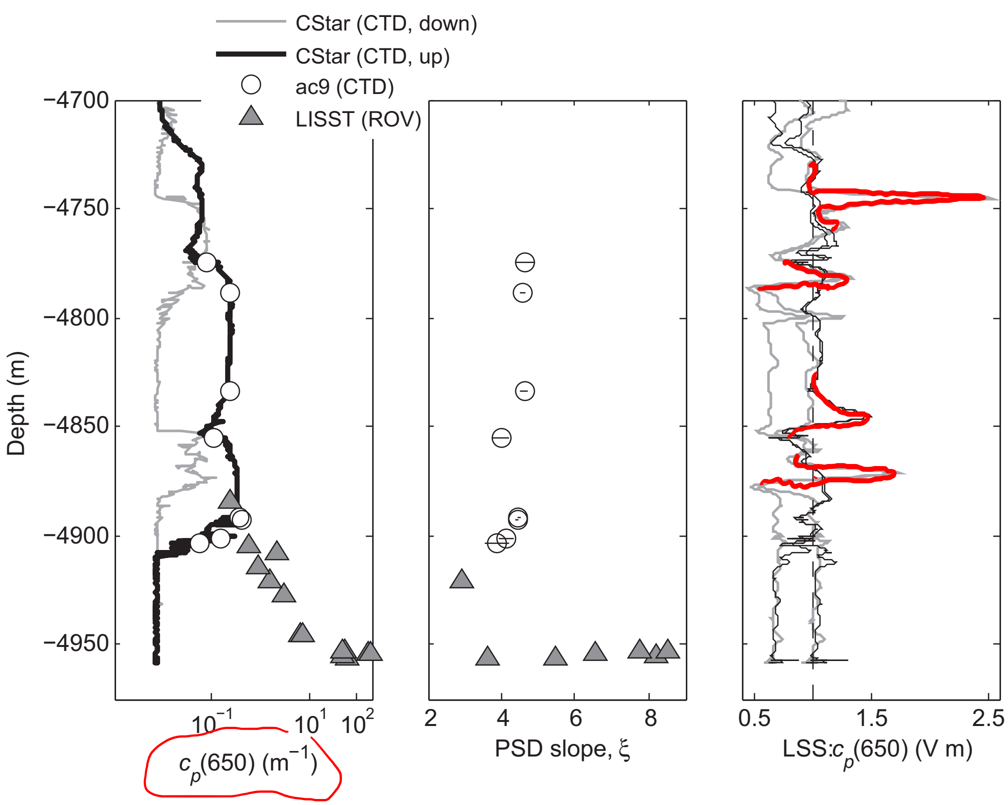


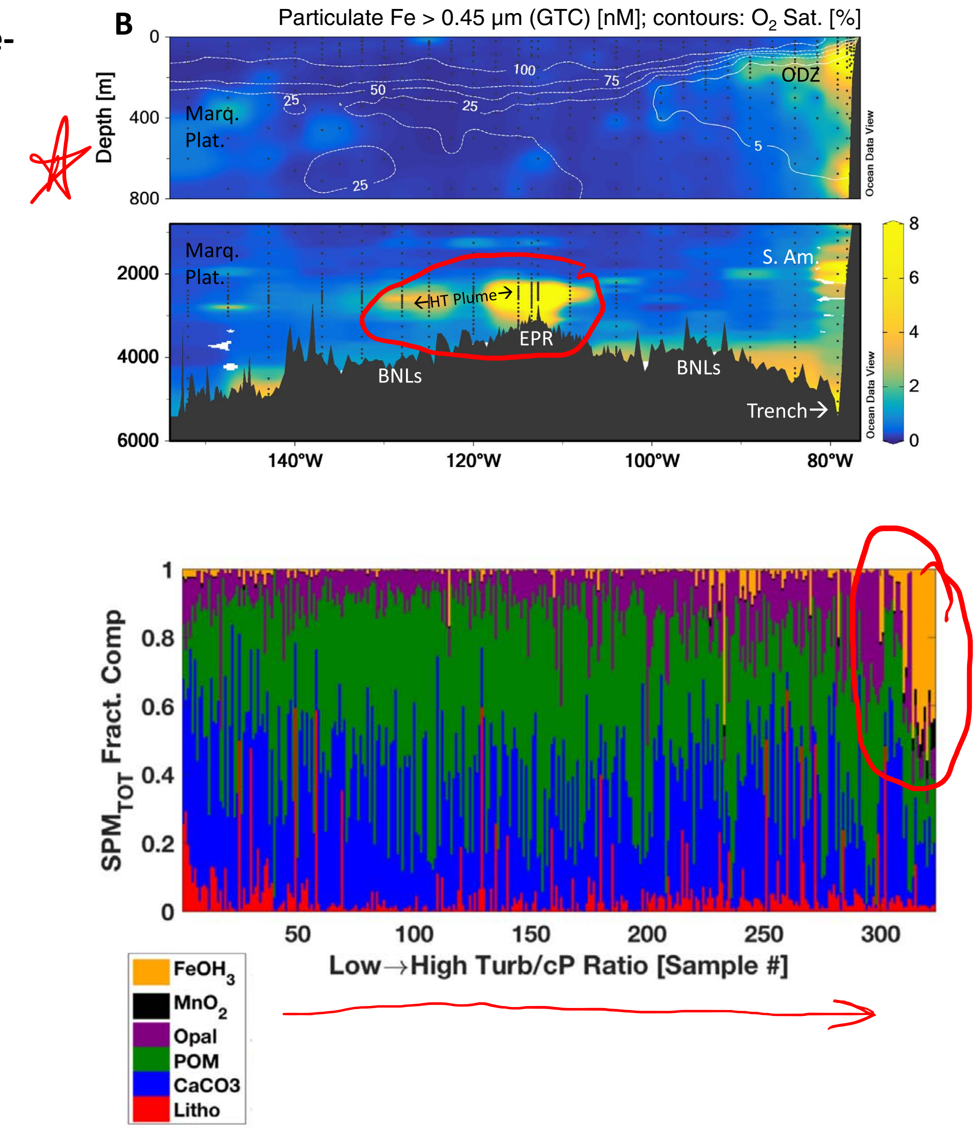




Graphical abstract and lower left figure are from Stubbins et al., 2014. 10.1021/es502086e
Upper left method figure is from Murphy et al., 2013. 10.1039/c3ay41160e

Using in situ optical sensors (beam attenuation and turbidity/side-scattering) to detect tiny iron hydroxide particles from hydrothermal vent plumes

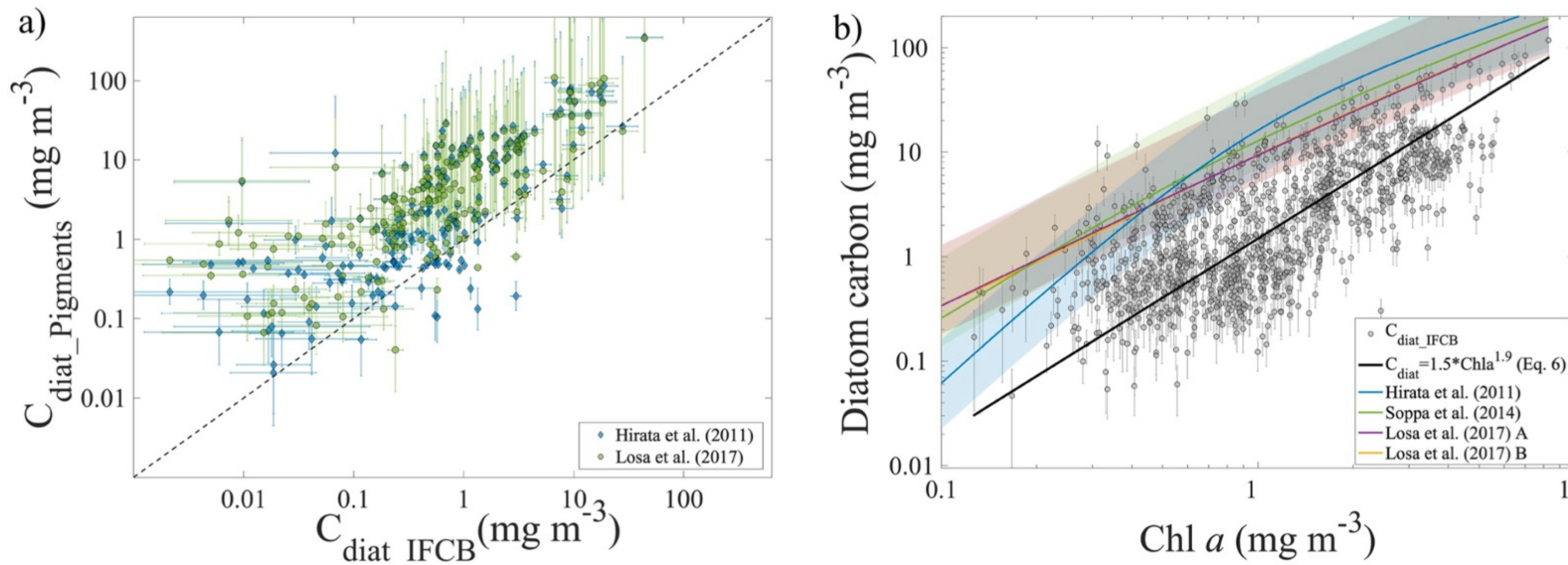




Figures: above: Estapa et al. (2015) 10.1002/2015GC005831
right: Ohnemus et al. (2016) 10.1016/j.marchem.2017.09.004

Using IFCB imagery to confirm the results of pigment-based phytoplankton characterization

Comparing carbon from diatoms measured with the IFCB to carbon from diatom pigments, then comparing the performance of chlorophyll-based remote sensing models for retrieving diatom carbon.



Chase et al., 2022

Outline

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- The variety of particle types that may contribute to bulk IOP measurements
- Combining the advantages of optical methods with other particle characterization techniques

From particles to IOPs and back