Revised Schedule

Day 4 (Thu) – July 11
Labs: Scattering by particulate material (b and b_b)
After dinner data lab: walk through ac-9 calculations

Day 5 (Fri) – July 12
Lab report: Temperature corrections ac-9, ac-s
Labs: Fluorescence of CDOM and chlorophyll

Day 6 (Sat) – July 13 (start at 0900)
Lab report: Scattering lab synthesis and summary **(moved from Friday)**
Synthesis of first week: critique process of learning, Q&A on any topic; tie up loose ends (staff)
Student U tube project (building on 2011 portfolio)
Chlorophyll fluorescence in-class exercise: without answers and with answers
Finish chlorophyll analyses from Friday lab

Day 1 (Mon) – July 15
Lab report: Fluorescence report

SMS 598: Calibration and Validation for Ocean Color Remote Sensing

Optical Proxies

(with emphasis on POC and other proxies-optical properties for phytoplankton and community composition)

July 11, 2013

Mary Jane Perry

What’s a proxy?

What’s a proxy?

prox·y

/ˈpräksē/

Noun

1. The authority to represent someone else, esp. in voting.
2. A person authorized to act on behalf of another.

Synonyms

deputy - representative - agent - substitute

surrogate

[1]sur·ro·gate transitive verb \ˈsər-ə-ˌgāt, ˈsə-rə-\

sur·ro·gat·ed | **sur·ro·gat·ing**

Definition of SURROGATE

g +1 Like

: to put in the place of another:

a : to appoint as successor, deputy, or substitute for oneself

b : SUBSTITUTE

Origin of SURROGATE

Latin *surrogatus,* past participle of *surrogare* to choose in place of another, substitute, from *sub-* + *rogare* to ask — more at RIGHT

First Known Use: 1533

Why we might want to develop optical proxies ?

One big advantage of *in situ* & remotely sensed optics is high resolution sampling – in space and time. To understand biogeochemisty & ecology, must **sample at same scales** as physics.

For example: measuring phytoplankton species by microscopy is very expensive (time and personnel), while ac-s profiles or underway sampling is relatively inexpensive.

A ‘proxy’, developed from analysis of absorption spectra, can be used to ‘project’ detailed information from microscopy and project to broader spatial /temporal scales.

What real entities, that can’t be measured at large spatial and temporal scales, might be candidates for optical proxies?

A few examples of optical proxies and real entities

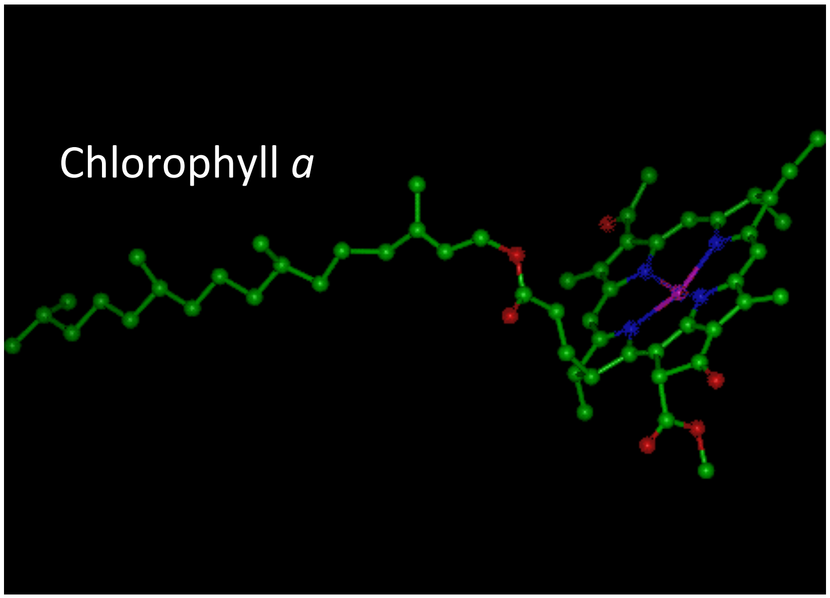
- Phytoplankton – Chl, HPLC pigments, Chl fluorescence,
  remote sensing reflectance, a(676)
- PFT – HPLC, a_phyt(λ), reflectance spectra, *a(676)
- Primary productivity – function ofphytoplankton, species or
  phytoplankton carbon; F_v/F_m
- Phytoplankton carbon – Chl, Chl fluorescence
- Particulate organic carbon (POC) – c_p and b_{bp}
- SPM – c_p and b_{bp}
- Phytoplankton vs. mineral particles – b_{bp}/b or b_{bp}/c_p
- Particle size or size distribution – c_p or b_{bp} slope
- CDOM – CDOM fluorescence
- Dissolved organic carbon – CDOM and slope, fluorescence

Kostadinov et al., 2012, Applied Optics
Optical assessment of particle size and composition

Particle Size/Composition Parameter or Proxy	Symbol	Calculated from	Notes
Slope of the particle size distribution	ξ	PSD data (LISST 100-X)	A fit of the actual PSD to a power law over a certain size range [Eq. (1)]. Can also be modeled from γ_{cp} and η (see below)
Number concentration at reference diameter	N_o	PSD data (LISST 100-X)	See [Eq. (1)]; here 2 μm is used as reference diameter. Can also be modeled from η and $b_{bp}(440)$ (see below)
Real index of refraction relative to seawater	n_p	N/A	Modeled from PSD slope ξ and particle backscattering probability $\tilde{b}_{bp}$ [30]
Slope of the particle beam attenuation spectrum, $c_p(\lambda)$	γ_{cp}	AC-9 beam attenuation data and CDOM absorption data, $c_p(\lambda) = c(\lambda) - a_g(\lambda)$.	Related to ξ via $\xi = \gamma_{cp} + 3$ [29]
Slope of the particle backscattering spectrum, $b_{bp}(\lambda)$	η	Hydroscat-6 data	Related to ξ and N_o [31]
Phytoplankton Functional Types	PFT's	Can be based on: • HPLC pigment data—% pico-, nano-, and microplankton [5] • $a^*_{ph}(\lambda)$ data—Ciotti *et al.* S_f parameter [62,63] • Measured or modeled ξ [7]	PFTs are related to size and can characterize the entire particle assemblage if it is of marine biogenic origin
Particulate backscattering probability	$\tilde{b}_{bp}$	Hydroscat-6 and AC-9 data	Function of the complex index of refraction (composition) and the PSD. Can be used to estimate the real index of refraction together with PSD slope data/estimates [30]
Ratio of phytoplankton absorption to total particulate absorption	$\%a_{ph}$	Discrete hyperspectral spectrophotometric data of component IOPs. Calculated as $a_{ph}(443)/a_p(443)$	Indicates particle composition, i.e., fraction of living phytoplankton cells in the total particle assemblage [38]

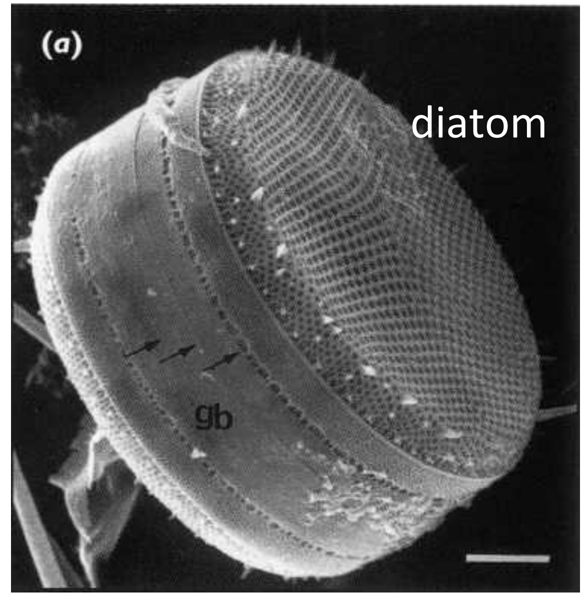
Lecture 4 – Phytoplankton

"Chlorophyll *a* is most common entity used to denote presence of phytoplankton and attempt to quantify concentration (mass)"



➔

How ???



Chlorophyll fluorescence (active, solar passive),
Pigment absorption (ac-s, QFT),
Chlorophyll extract (Friday's lab, HPLC),
Spectral reflectance (remote sensing, above water, in water),
etc.

Abstract. Probably because it is a readily available ocean color product, almost all models of primary productivity use chlorophyll as their index of phytoplankton biomass. As other variables become more readily available, both from remote sensing and in situ autonomous platforms, we should ask if other indices of biomass might be preferable. Herein, we compare the accuracy of different proxies of phytoplankton biomass for estimating the maximum photosynthetic rate (P_{max}) and the initial slope of the production versus irradiance (P vs. E) curve (α). The proxies compared are: the total chlorophyll *a* concentration (Tchl*a*, the sum of chlorophyll *a* and divinyl chlorophyll), the phytoplankton absorption coefficient, the phytoplankton photosynthetic absorption coefficient, the active fluorescence in situ, the particulate scattering coefficient at 650 nm (b_p (650)), and the particulate backscattering coefficient at 650 nm (b_{bp} (650)). All of the data (about 170 P vs. E curves) were collected in the South Pacific Ocean. We find that when only the phytoplanktonic biomass proxies are available, b_p (650) and Tchl*a* are respectively the best estimators of P_{max} and α. When additional variables are available, such as the depth of sampling, the irradiance at depth, or the temperature, Tc
timator of both P_{max} and α.

Chlorophyll is the basis of primary productivity models

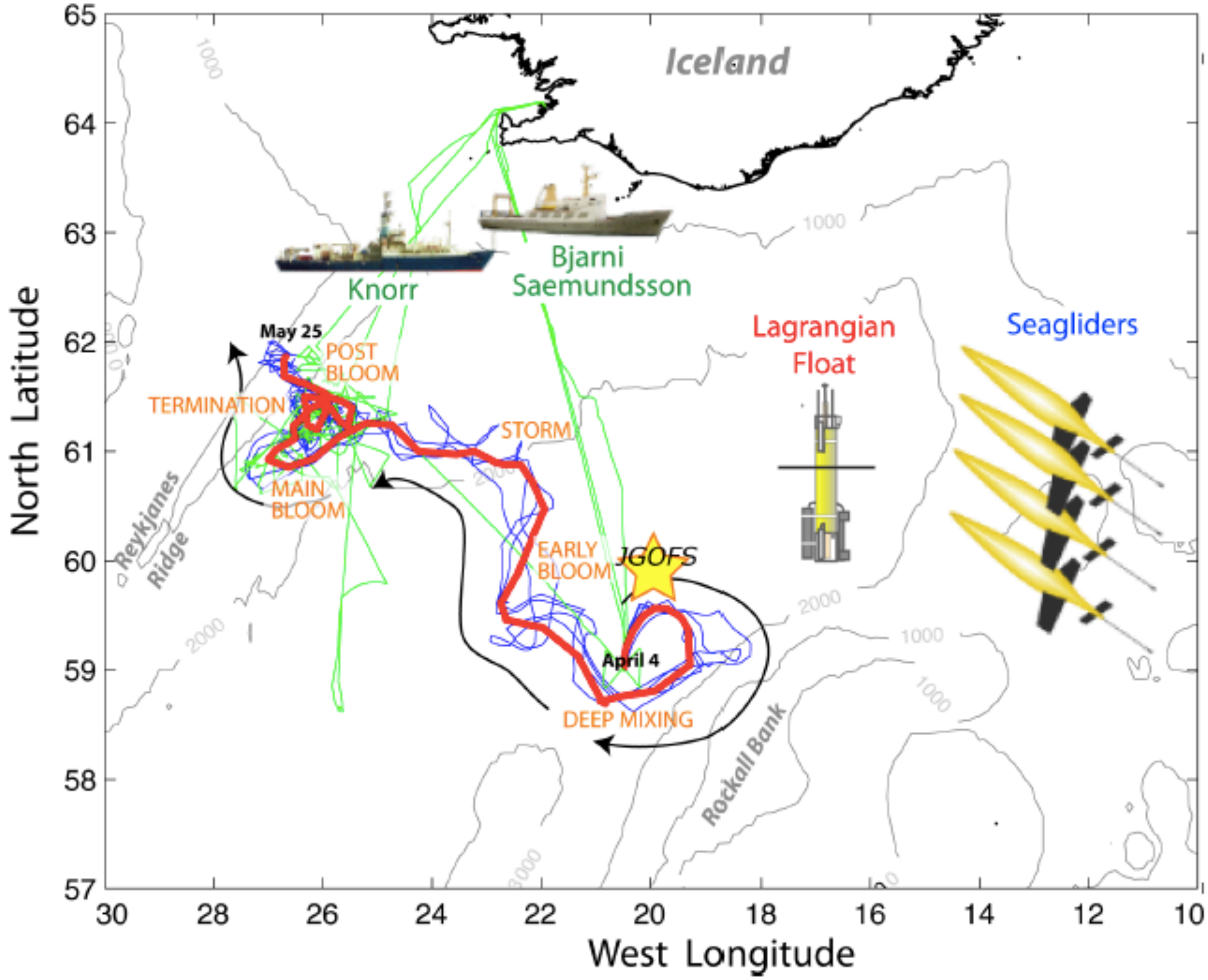
Relationship between photosynthetic parameters and different proxies of phytoplankton biomass in the subtropical ocean

Y. Huot[1], M. Babin[1], F. Bruyant[2], C. Grob[4], M. S. Twardowski[3], and H. Claustre[1]

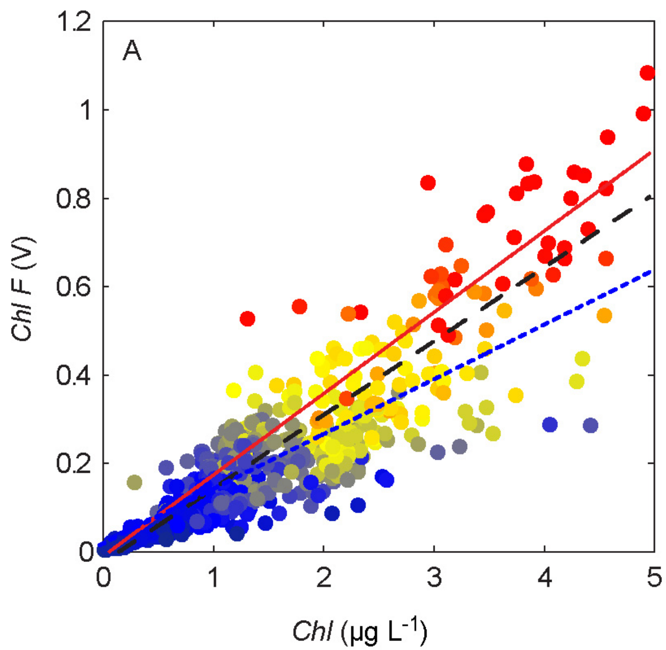
Biogeosciences, 4, 853–868, 2007

A few examples from North Atlantic spring bloom – NAB 2008

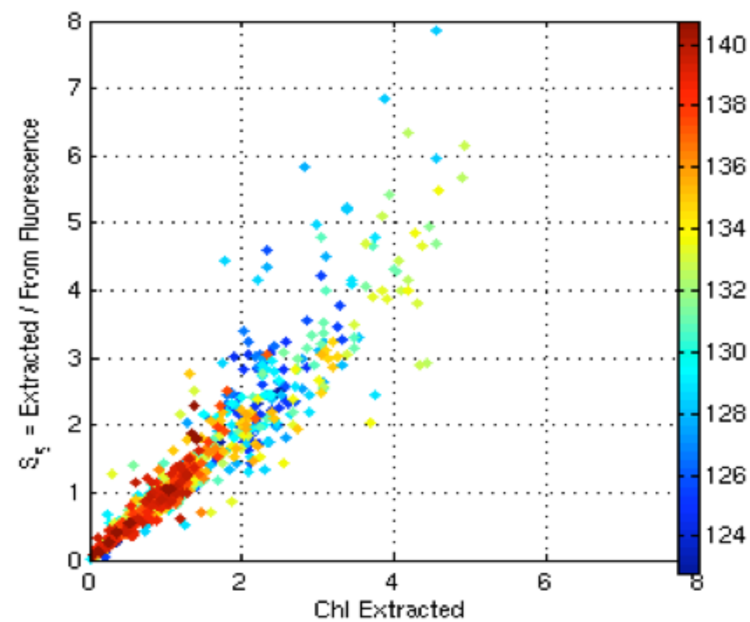
1) 4 Seagliders, 1 Lagrangian float, 1 set of ship sensors that were rigorously intercalibrated (chose ship sensors as the gold standard).
2) careful biogeochemical measurements on ship ➔ develop optical proxies (project expensive ship measurements to broader spatial/temporal scales.



Chlorophyll fluorescence to chlorophyll concentration (Friday's lab)

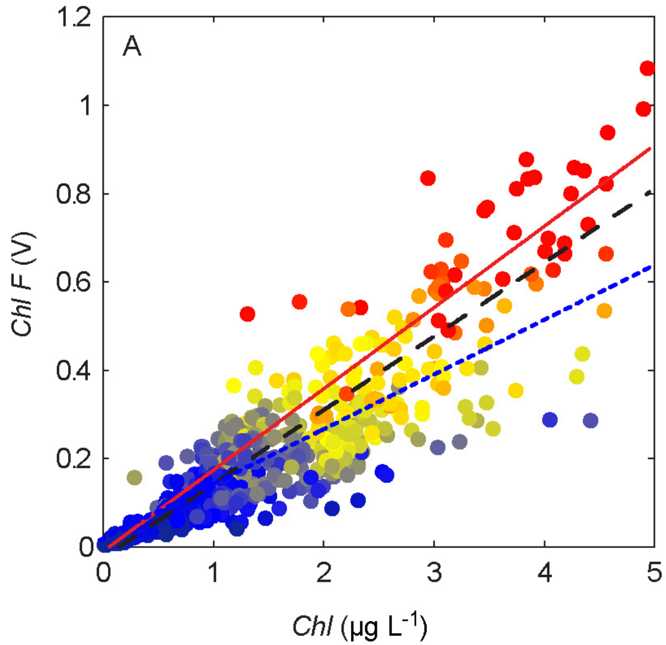


Raw data: fluorescence vs. extract

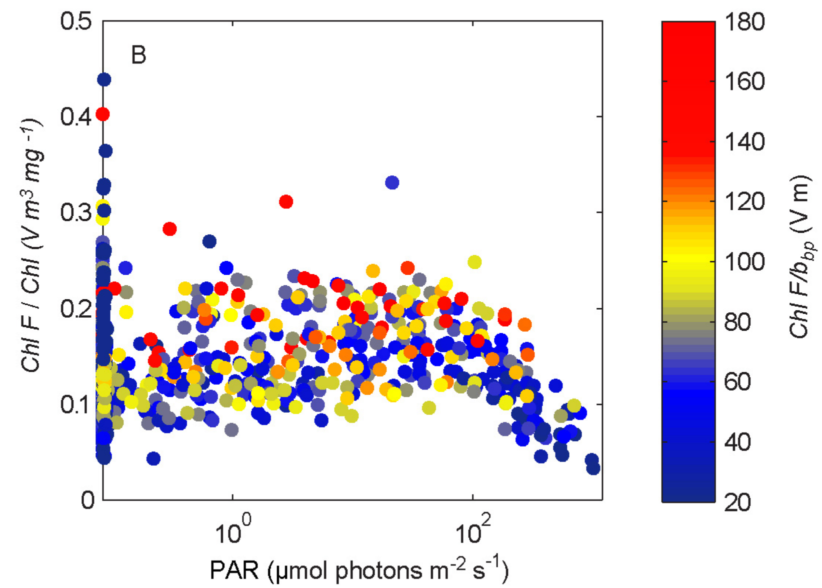


Linearized algorithm: function temperature, light,

Chlorophyll fluorescence to chlorophyll concentration (Friday's lab)

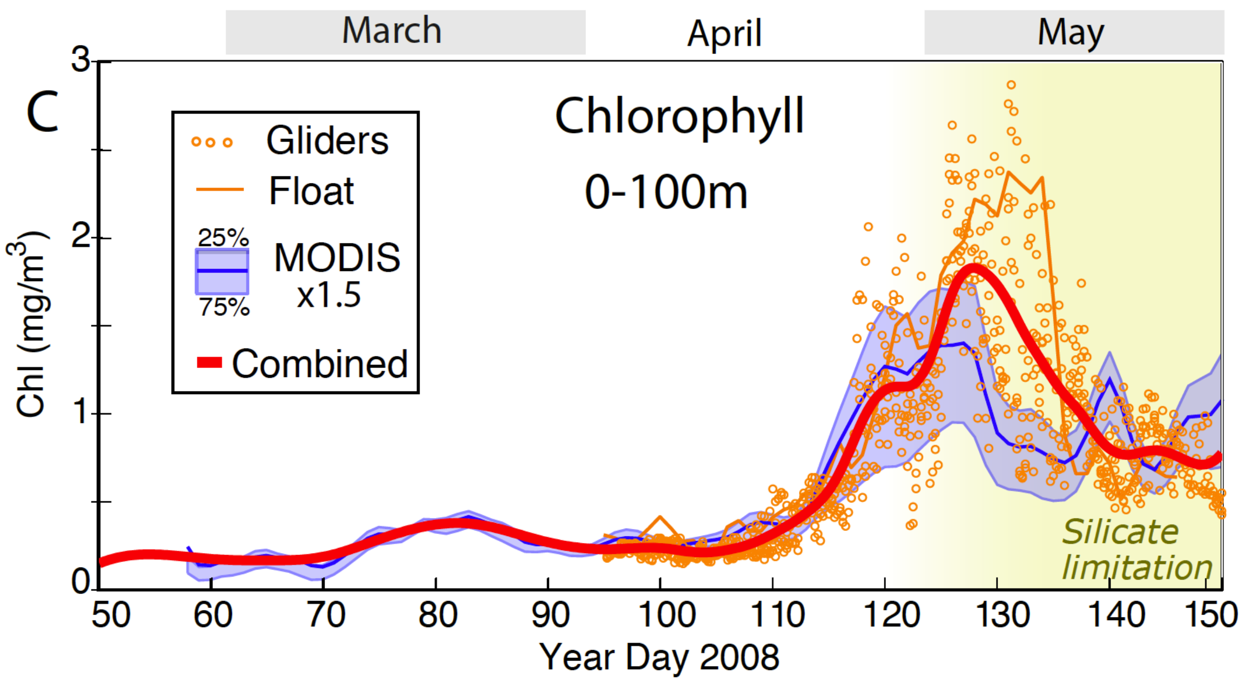


Raw data: fluorescence vs. extract

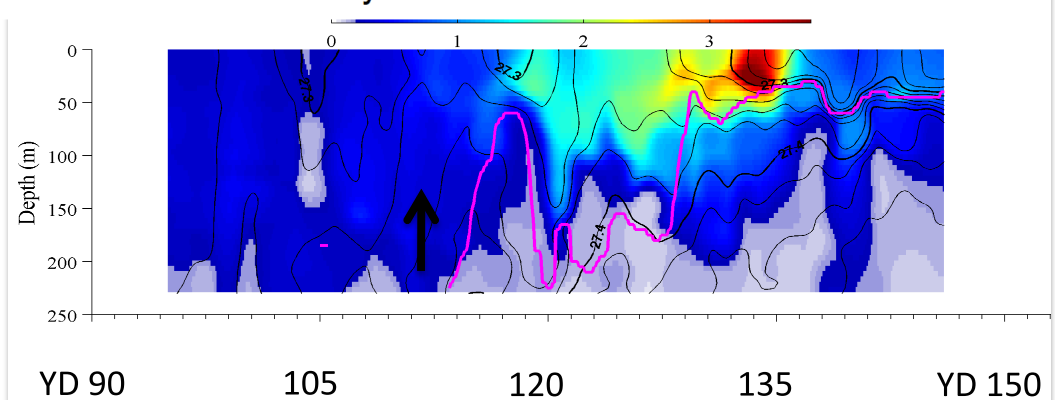


Part of variability in Chl fluorescence/ extracted chlorophyll is due to solar quenching

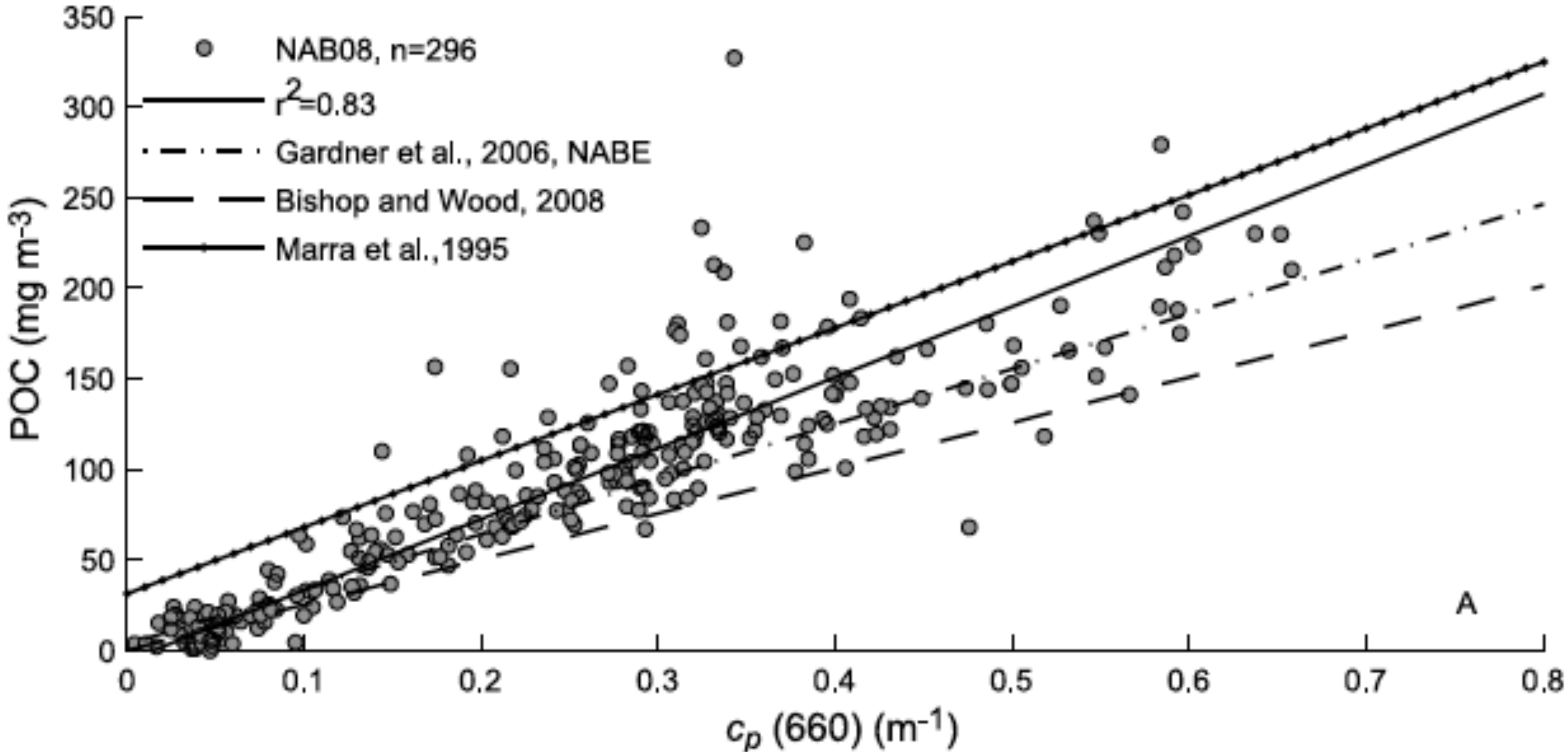
What do you get from a calibrated proxy of chlorophyll?
Validated multiplatform data shows patchy development of bloom.



0 – 250 m



Particulate attenuation (c_p) to POC (> 300 samples and >240 blanks)



Particulate organic carbon and inherent optical properties during 2008 North Atlantic Bloom Experiment

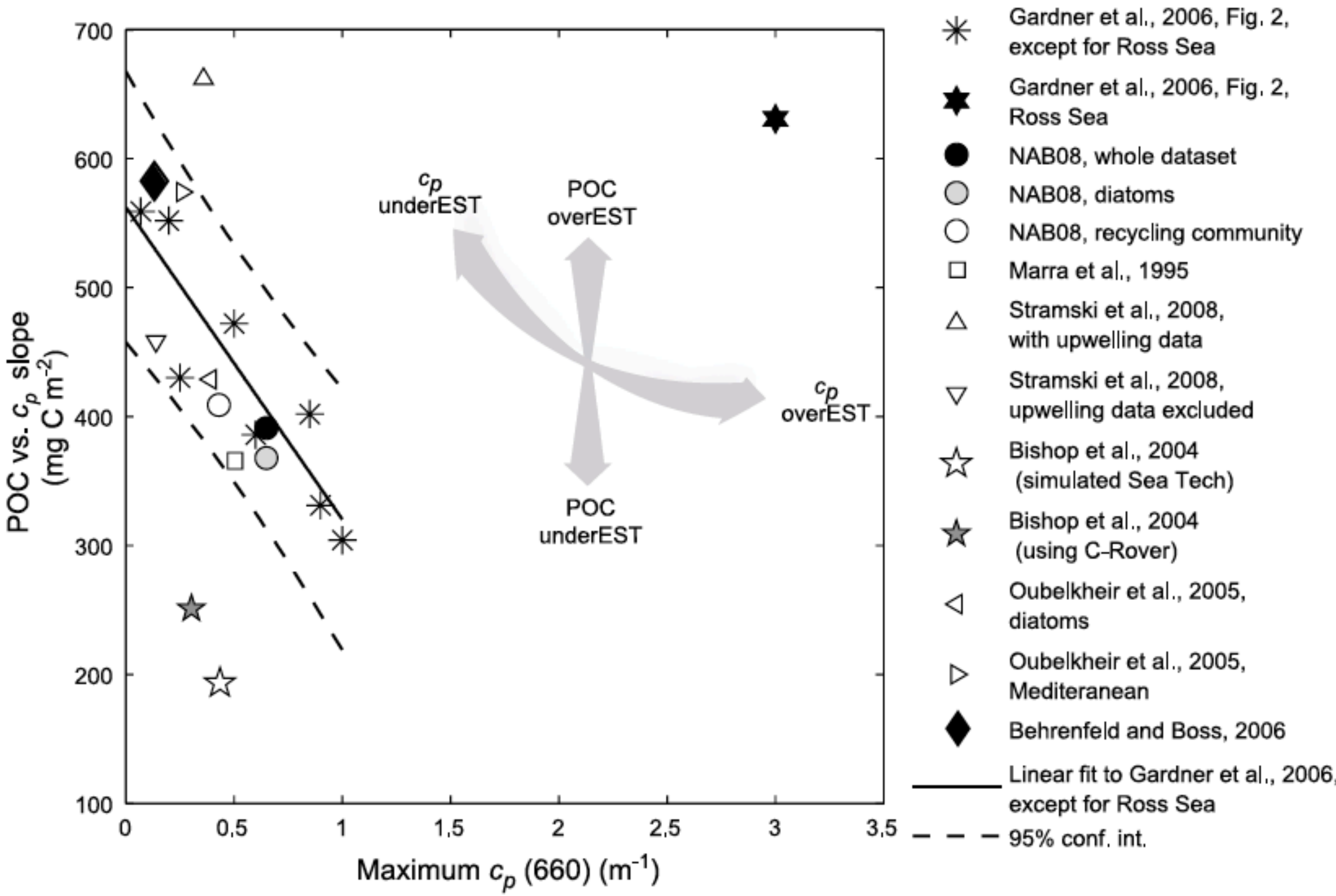
Ivona Cetinić,[1] Mary Jane Perry,[1] Nathan T. Briggs,[1] Emily Kallin,[1] Eric A. D'Asaro,[2] and Craig M. Lee[2]

JOURNAL OF GEOPHYSICAL RESEARCH, VOL. 117, C06028, doi:10.1029/2011JC007771, 2012

Table 1. Comparison of POC vs. c_p Slopes and Methodologies[a]

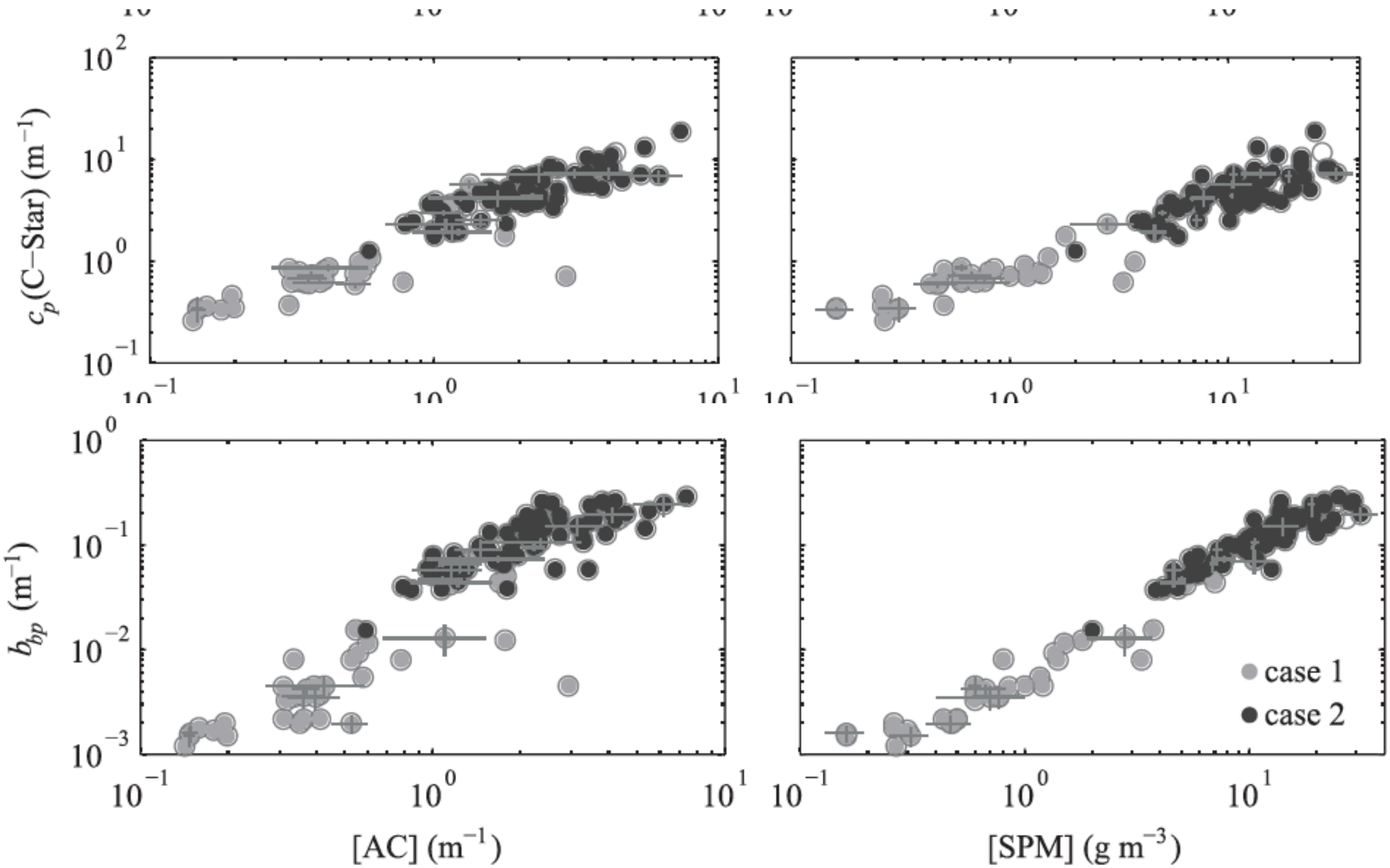
Author (Sample Size)	Area /Season	Depth (m)	POC vs. c_p Slope	Y-axis Intercept	DOC Correction	Instrument /Angle	c_p Sampling
Gardner et al. [2006] (n = 3462)	World /all seasons	0–6000	381 ± 3.3	9.4 ± 0.6	No	Sea Tech /1.03°	CTD rosette, upcast
Gardner et al. [2006] (n = 165)	NE Atlantic / Spring	0–2000	304 ± 7	3.3 ± 2.1	No	Sea Tech /1.03°	CTD rosette, upcast
Marra et al. [1995] (n = 15)	NE Atlantic / Summer	<200 m	367 ± 39.5	31.2 ± 13.8	No	Sea Tech /1.03°	CTD rosette, cast direction ?
Stramski et al. [2008] (n = 54, 59[b])	Pacific, Atlantic / Oct–Nov	0–10	458 (662)[b]	10.7 (−2.2)[b]	No[c]	C-Star /1.2°	CTD rosette, averaged upcast and downcast
Bishop et al. [2004] (n = 145)	SOFeX + Pacific / Spring-Summer	0–1000	251 (193)[d]	0 (0)[d]	No[c]	C-Rover /1.5° (Sea Tech /0.5°)[d]	CTD rosette, downcast
Oubelkheir et al. [2005] (n = 135, 5[e])	Mediterranean + Atlantic[e] / Fall	0–200	574 (429)[e]	−7.4[f] (−53.7)[e]	No	ac-9 /0.93°	CTD rosette, cast direction ?
Behrenfeld and Boss [2006] (n = 67)	Equatorial Pacific / Oct–Nov	surface	585	7.6	Yes	C-Star /1.2°	Flow-through
NAB08, this study (n = 296)	NE Atlantic / Spring	0–600	391 ± 19	−5.8 ± 5.5	Yes	C-Star /1.2°	CTD rosette, downcast

[a]All wavelengths are nominally 660 nm. Units of slope are mg C m^{-2}; ? for c_p sampling denotes lack of documentation about whether downcast or upcast data were used.
[b]POC vs. c_p slope (mg C m^{-2}) developed using the entire dataset, including upwelling data; see Table 6 in *Stramski et al.* [2008].
[c]Contribution of DOC adsorption was minimized with large filtration volume.
[d]c_p measured by C-Rover and converted to simulate 1-m pathlength Sea Tech measurement (described in text).
[e]POC vs. c_p slope and y-intercept for a small subset of the data (five samples) collected in waters in Moroccan upwelling region with relatively high concentrations of diatoms.
[f]*Oubelkheir et al.* [2005] report only the slope and not the y-intercept for their Mediterranean POC vs. c_p(660) regression; we report their intercept for POC vs. c_p(555) instead.



POC vs. c_p slope (mg C m^{-2})
Maximum c_p (660) (m^{-1})
c_p underEST
POC overEST
c_p overEST
POC underEST
Gardner et al., 2006, Fig. 2, except for Ross Sea
Gardner et al., 2006, Fig. 2, Ross Sea
NAB08, whole dataset
NAB08, diatoms
NAB08, recycling community
Marra et al., 1995
Stramski et al., 2008, with upwelling data
Stramski et al., 2008, upwelling data excluded
Bishop et al., 2004 (simulated Sea Tech)
Bishop et al., 2004 (using C-Rover)
Oubelkheir et al., 2005, diatoms
Oubelkheir et al., 2005, Mediteranean
Behrenfeld and Boss, 2006
Linear fit to Gardner et al., 2006, except for Ross Sea
95% conf. int.

area concentration, [AC] (left column) and mass concentration (SPM)

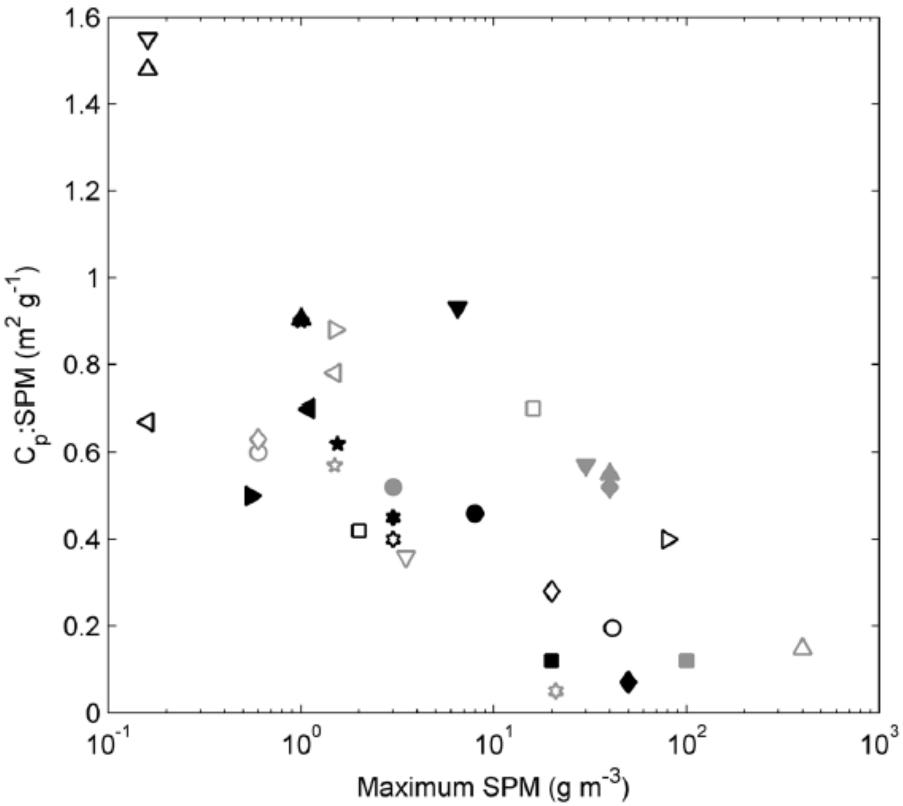


In situ variability of mass-specific beam attenuation and backscattering of marine particles with respect to particle size, density, and composition

Griet Neukermans,[a,b,c,d,*] Hubert Loisel,[b,c,d] Xavier Mériaux,[b,c,d] Rosa Astoreca,[e] and David McKee[f]

Limnol. Oceanogr., 57(1), 2012, 124–144

doi:10.4319/lo.2012.57.1.0124



JOURNAL OF GEOPHYSICAL RESEARCH, VOL. 116, C02023, doi:10.1029/2010JC006539, 2011

Observations of the sensitivity of beam attenuation to particle size in a coastal bottom boundary layer

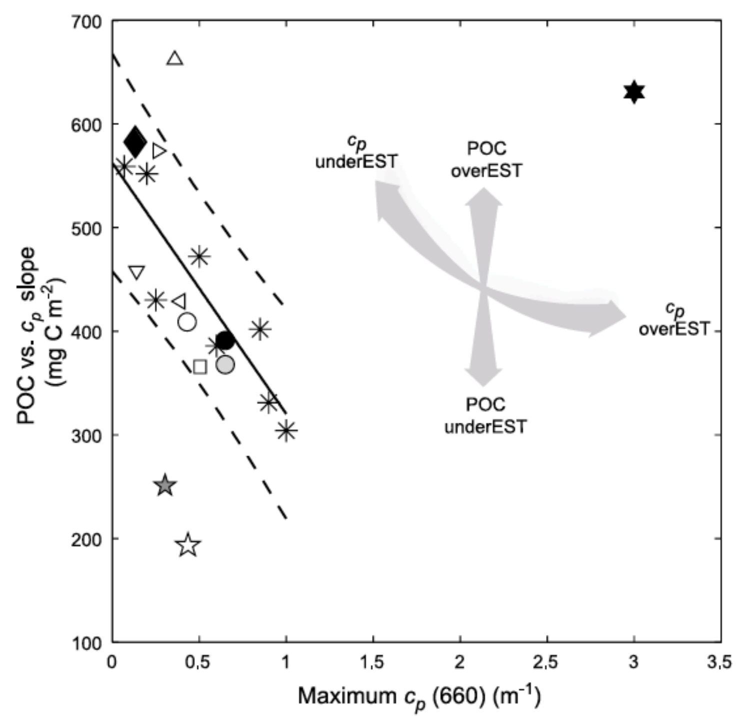
P. S. Hill,[1] E. Boss,[2] J. P. Newgard,[1] B. A. Law,[3] and T. G. Milligan[3]

c_p /SPM

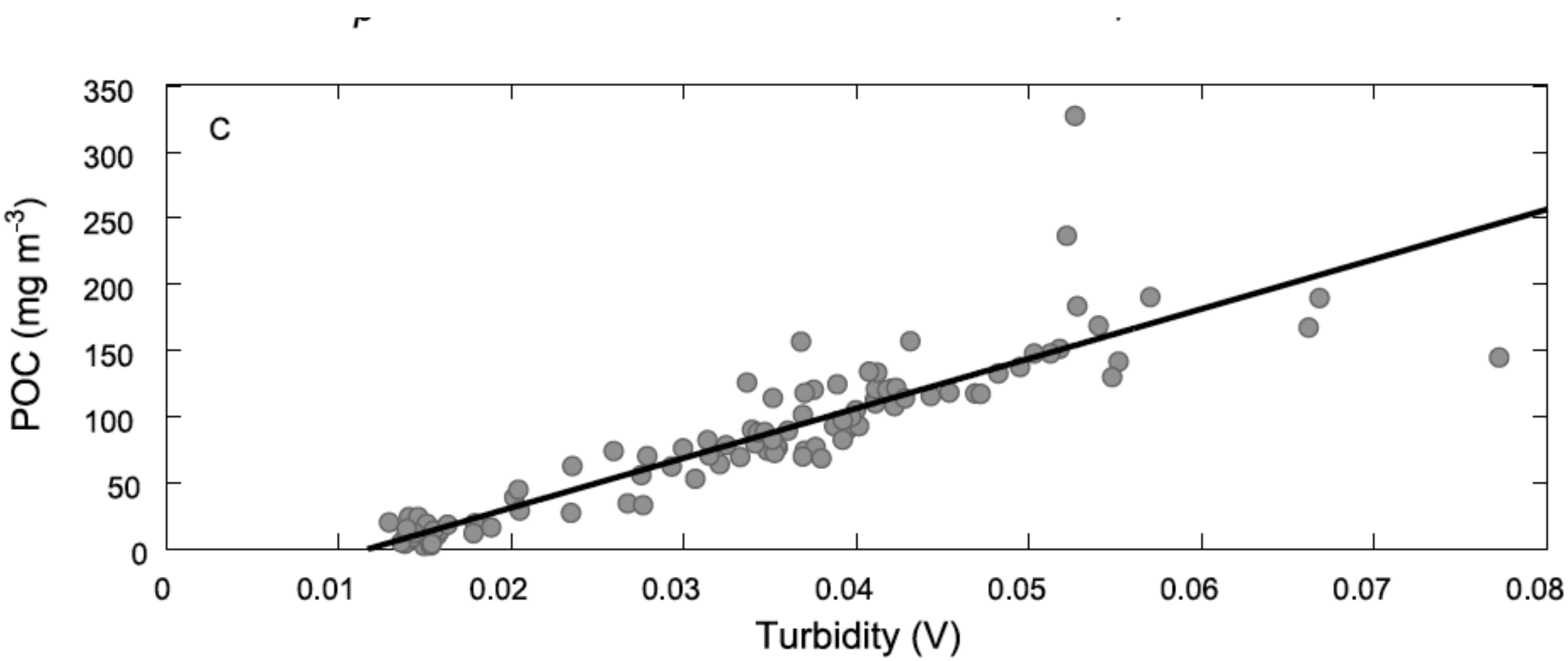
vs.

POC /p_c

????



POC vs. side scatter



Particulate backscattering (b_{bp}) to POC (> 300 samples and >240 blanks)

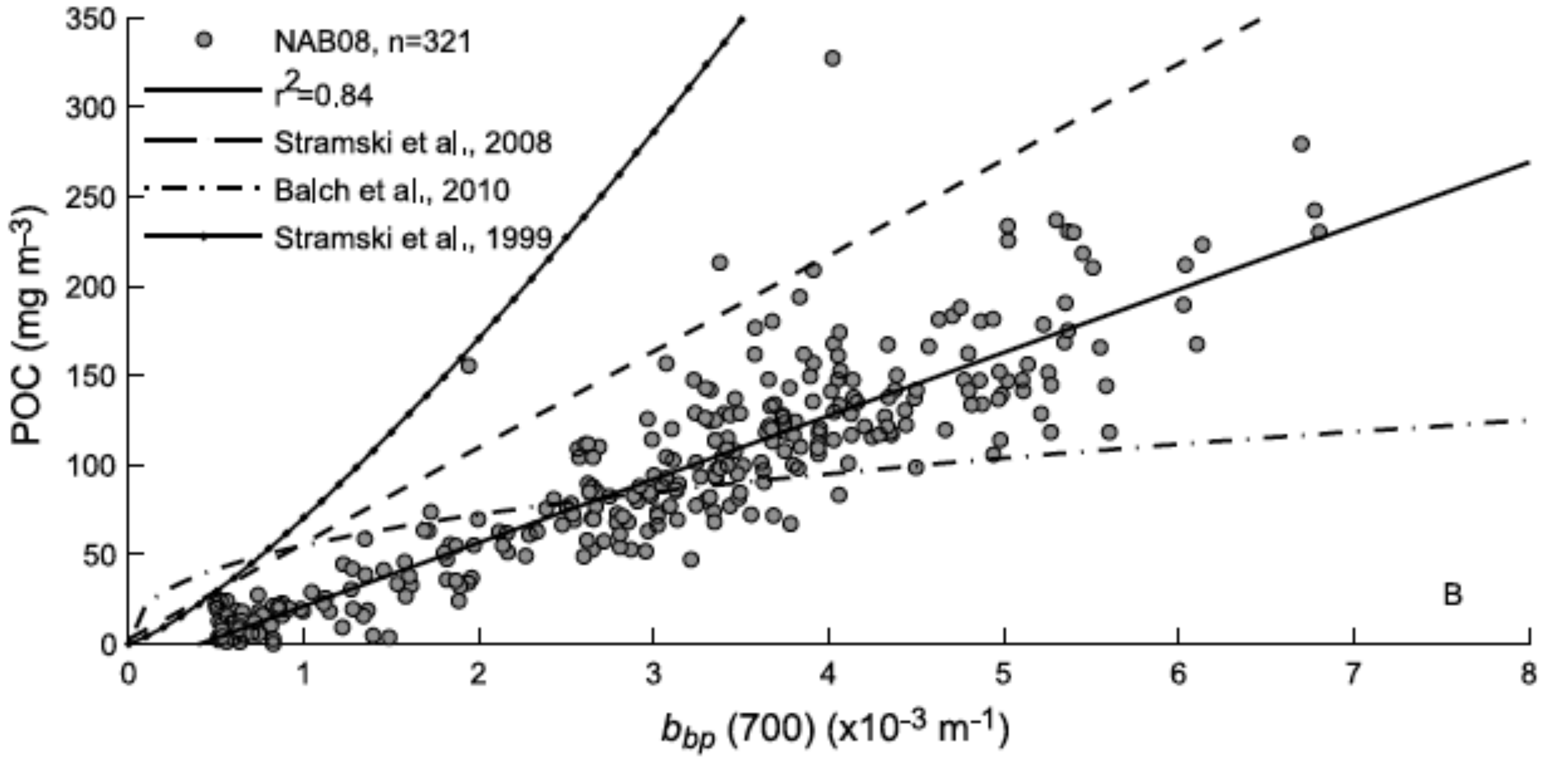


Table 2. Comparison of POC vs. b_{bp} Slopes and Methodologies[a]

Author (Sample Size)	Area /Season	Depth (m)	POC vs. $b_{bp}(\lambda)$[b] (% Increase for λ = 700 nm)	DOC Correction	Instrument / Angle/ Wavelength	b_{bp} Sampling
Stramski et al. [2008] (n = 54, 59[c])	Pacific, Atlantic / Oct–Nov	4–8	53607.0 b_{bp} + 2.5 7085.01 b_{bp} − 9.1[c] (10%)	No[d]	Hydroscat-6 /140°/ 555 nm	CTD rosette, averaged upcast and downcast
Stramski et al. [1999] (n = 33)	APFZ / Summer-Fall	0–15	17069.0 ±1.3*$b_{bp}^{0.859\pm0.046}$ (15%)	No	Hydroscat-6 /140°/ 510 nm	CTD rosette, cast direction ?
Stramski et al. [1999] (n = 24)	Ross sea / Summer	0–15	476935.8 ± 1.5* $b_{bp}^{1.277\pm0.061}$ (15%)	No	Hydroscat-6 /140°/ 510 nm	CTD rosette, cast direction ?
Balch et al. [2010] (binned to n = 18)	North and South Atlantic/ all seasons	5	841*$b_{bp}^{0.395}$ (12%)	No	EcoVSF 3 /110, 125, 150° / 532 nm	Ship flow- through, un-acidified b_{bp}
Loisel et al. [2001]	Mediterranean / N/A	N/A	37550.0 b_{bp} + 1.3 (10%)	No	merged from multiple sources/555 nm	N/A
NAB08, this study (n = 321)	North Atlantic / Spring	0–600	35422 ±1754 b_{bp_down}−14.4 ± 5.8[e] 43317 ± 2092 b_{bp_up} −18.4 ± 5.8	Yes	FLNTU /140°/700	CTD rosette, downcast[e] or upcast

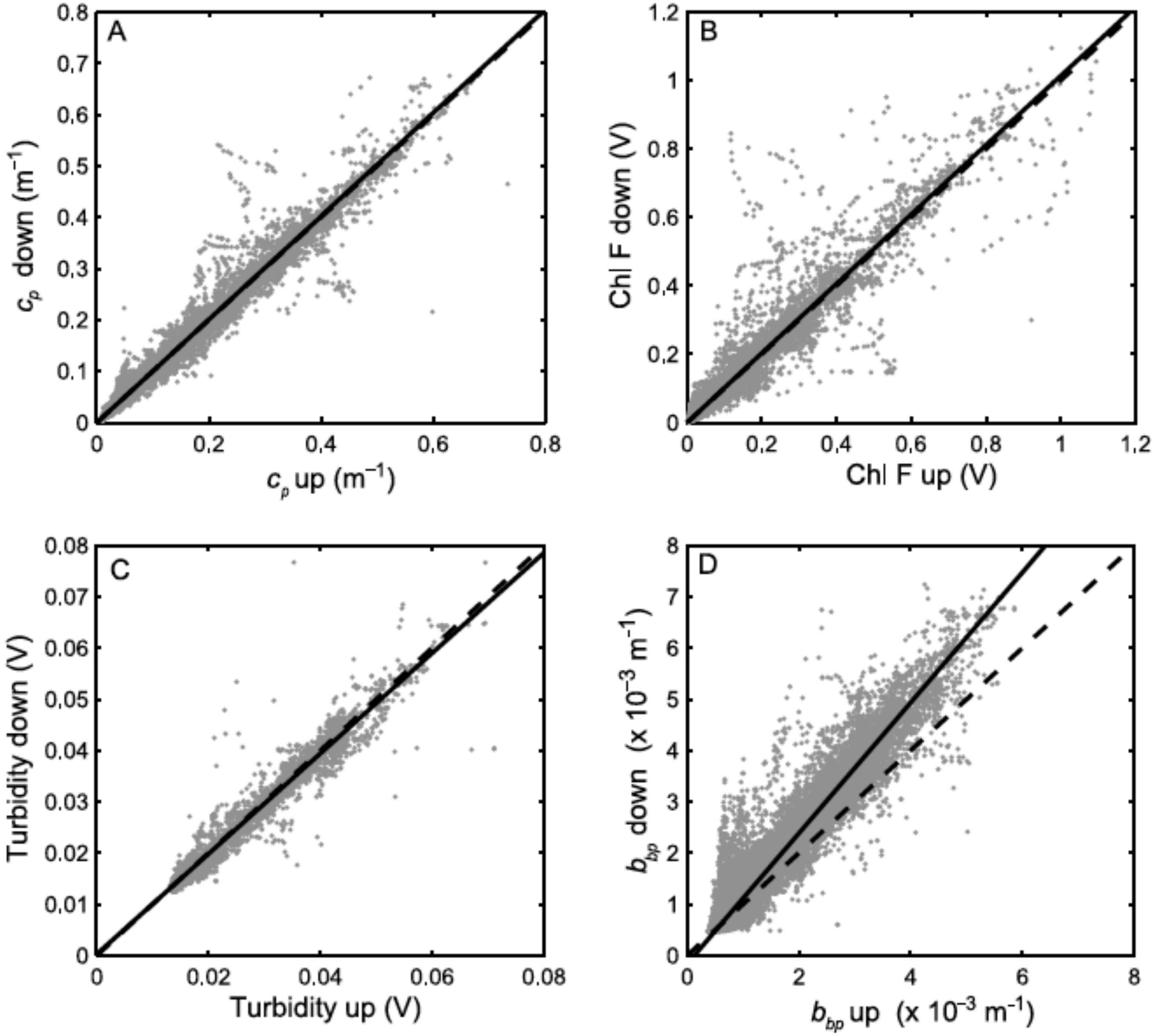
[a]Literature POC vs. b_{bp} slopes are reported for original wavelength; the percentage increase in the slope is for b_{bp} recalculated to 700 nm, η = 0.41. Units of slope are mg C m^{-2}.
[b]POC vs. b_{bp} slope (mg C m^{-2}) with measured wavelength, as published.
[c]POC vs. b_{bp} slope developed using the entire dataset, including upwelling data; see Table 6 in *Stramski et al.* [2008].
[d]Contribution of DOC adsorption was minimized with large filtration volume.
[e]The recommended NAB08 POC vs. b_{bp} relationship uses downcast data; upcast data is presented for comparison only.

b_{bp} is a real mess

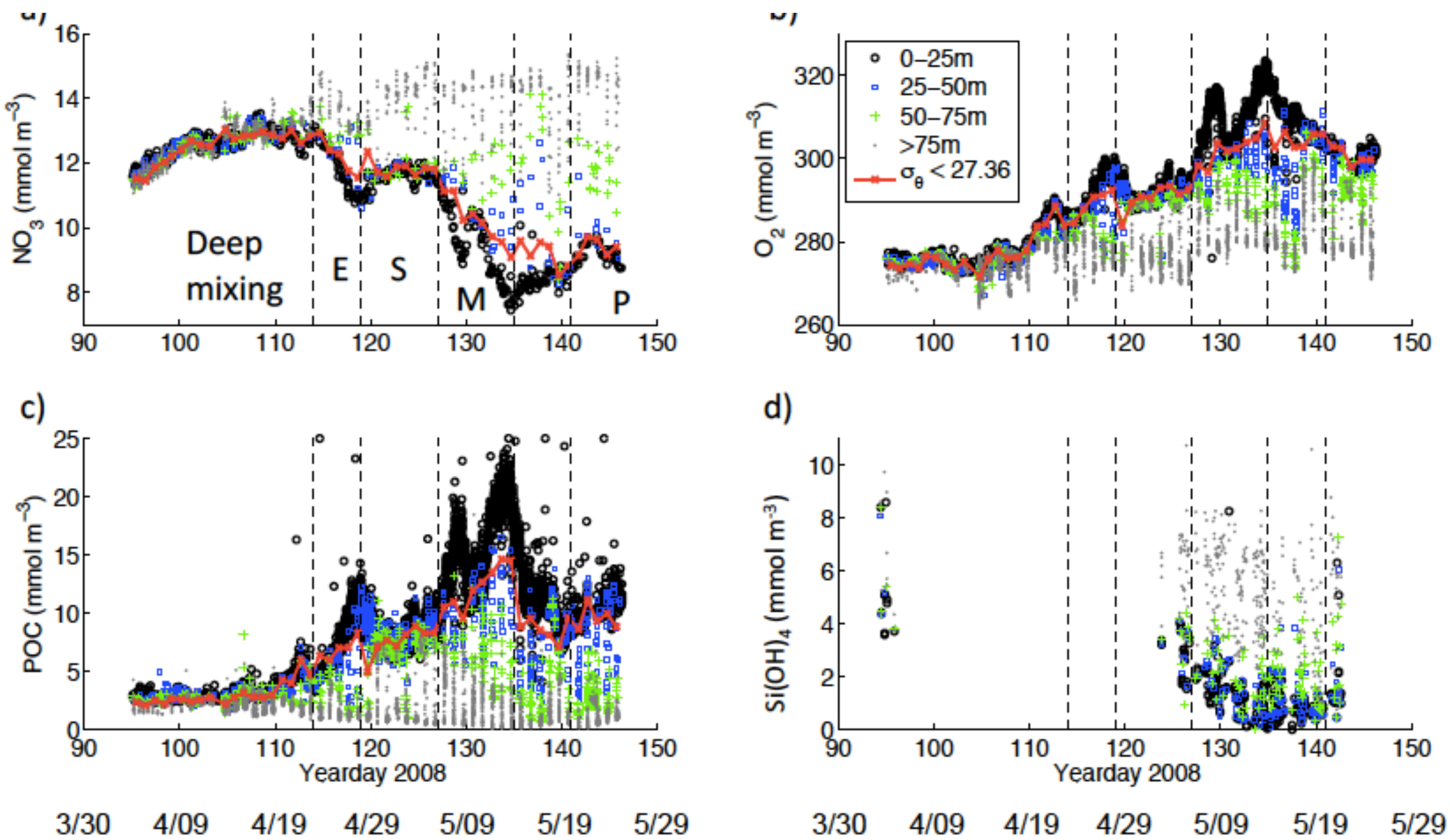
Changing calibration

Conversion of measurement at one λ to another (spectra of slope?)

b_{bp} downcast vs. b_{bp} upcast

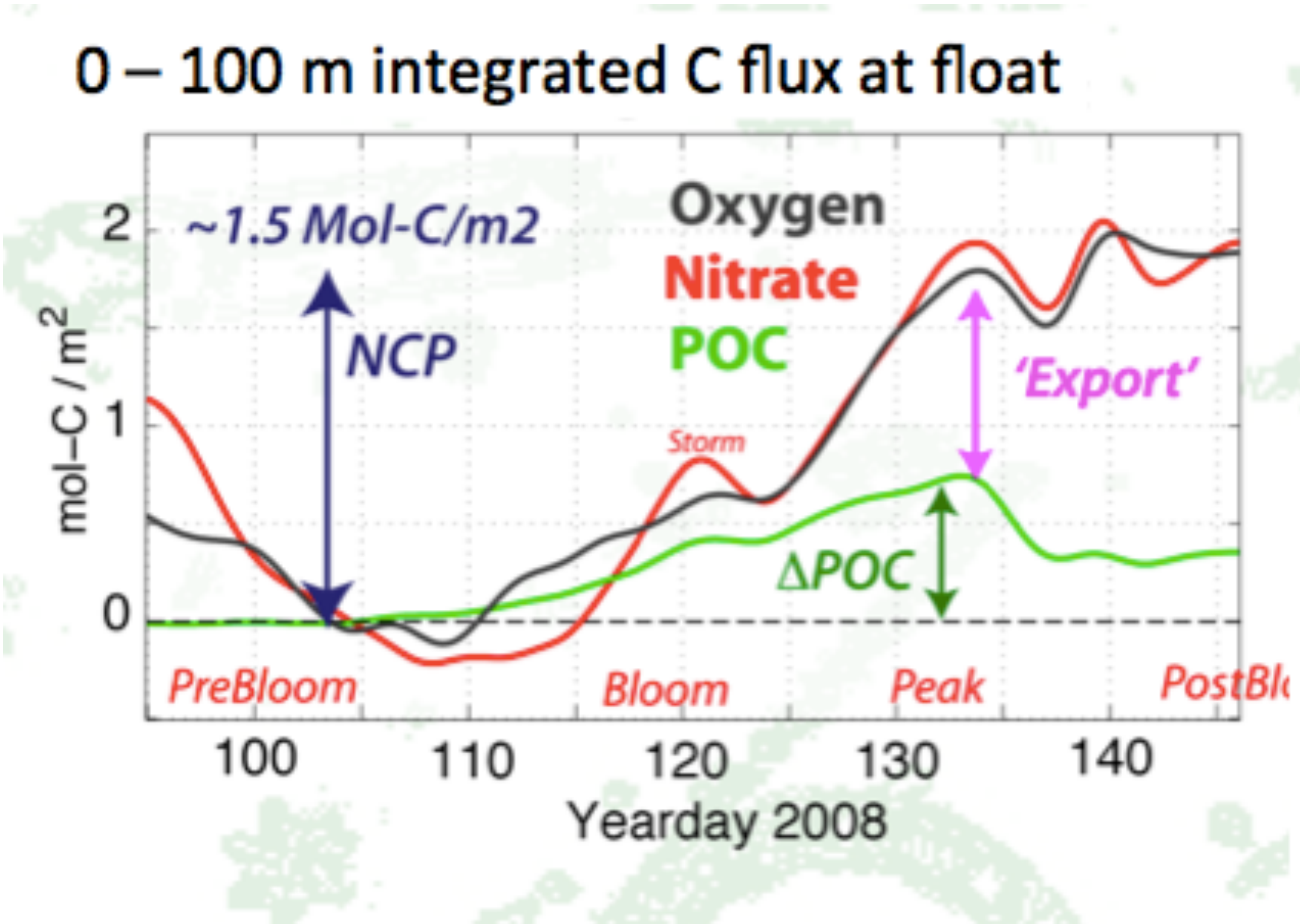

A
B
C
D
c_p down (m^{-1})
c_p up (m^{-1})
Chl F down (V)
Chl F up (V)
Turbidity down (V)
Turbidity up (V)
b_{bp} down (x 10^{-3} m^{-1})
b_{bp} up (x 10^{-3} m^{-1})

Net community productivity from float measurements of NO3 drawdown and O2 evolution, corrected for air/sea flux
(Advection minimized by Lagrangian water-following float)



Alkire et al., 2012, DSR-I

What do you get from a calibrated proxy of POC?
An estimate of export flux:
Net Community Productivity from NO3 & O2 – Net Community Productivity from POC.

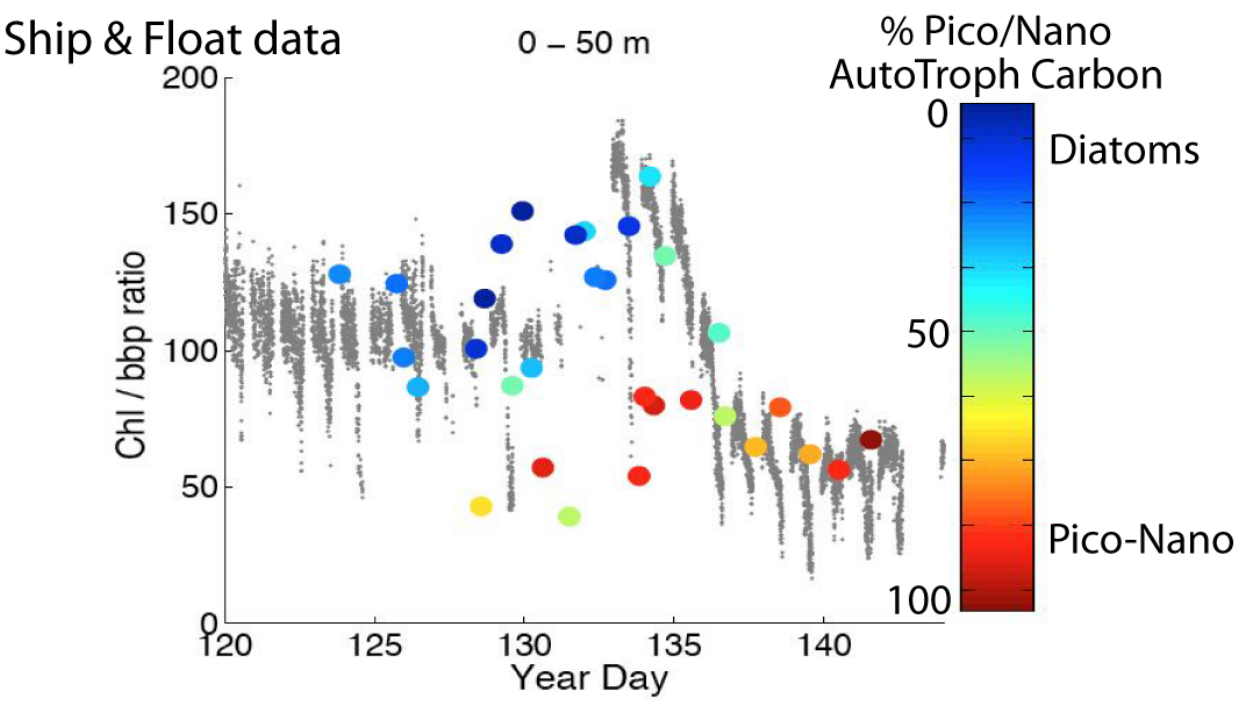


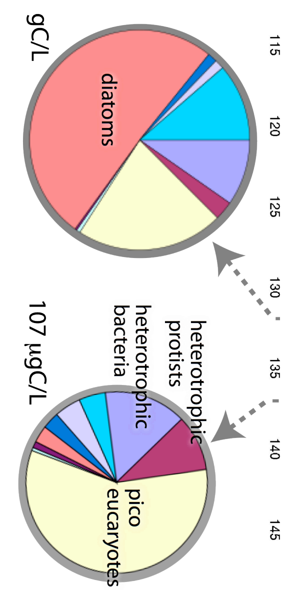
Optical Indices of Planktonic Community

Biology: Chlorophyll:Carbon ratio plankton varies with type of plankton (diatoms > picoplankton > heterotrophs) and with their physiological state

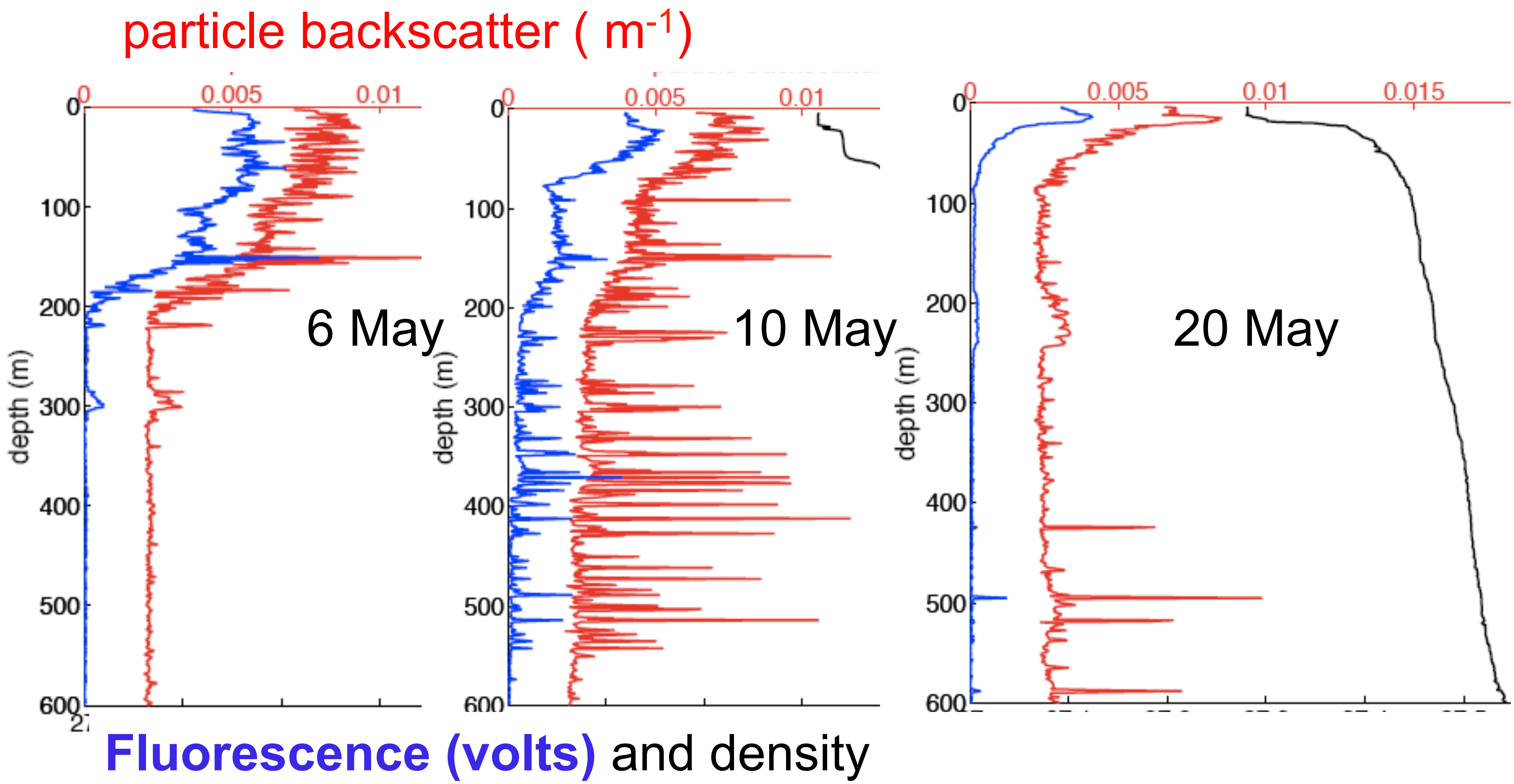
Optics: Fluorescence ~ Chl Backscatter ~ POC

Tool: Fluorescence : Backscatter ratio = Optical Index = **OI**





Novel use of optical spikes to develop proxy for sinking aggregates

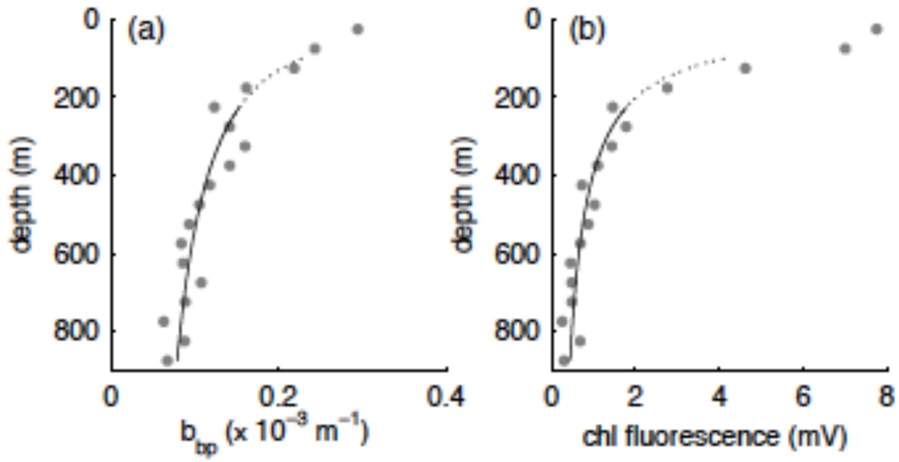


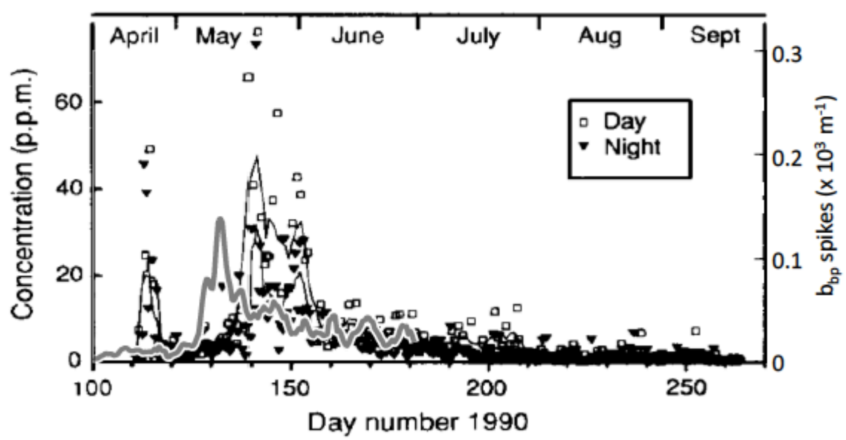
Briggs et al. 2011 DSR - I

What do you get from a calibrated proxy of spikes?

Flux attenuation of aggregates .

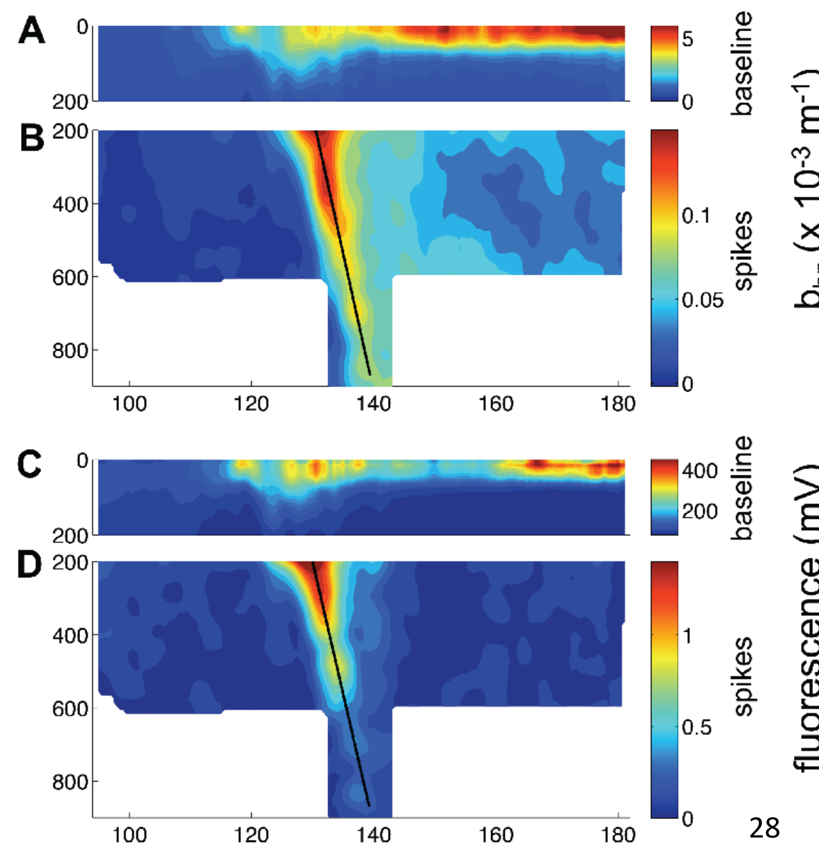
Briggs et al. 2011 DSR - I



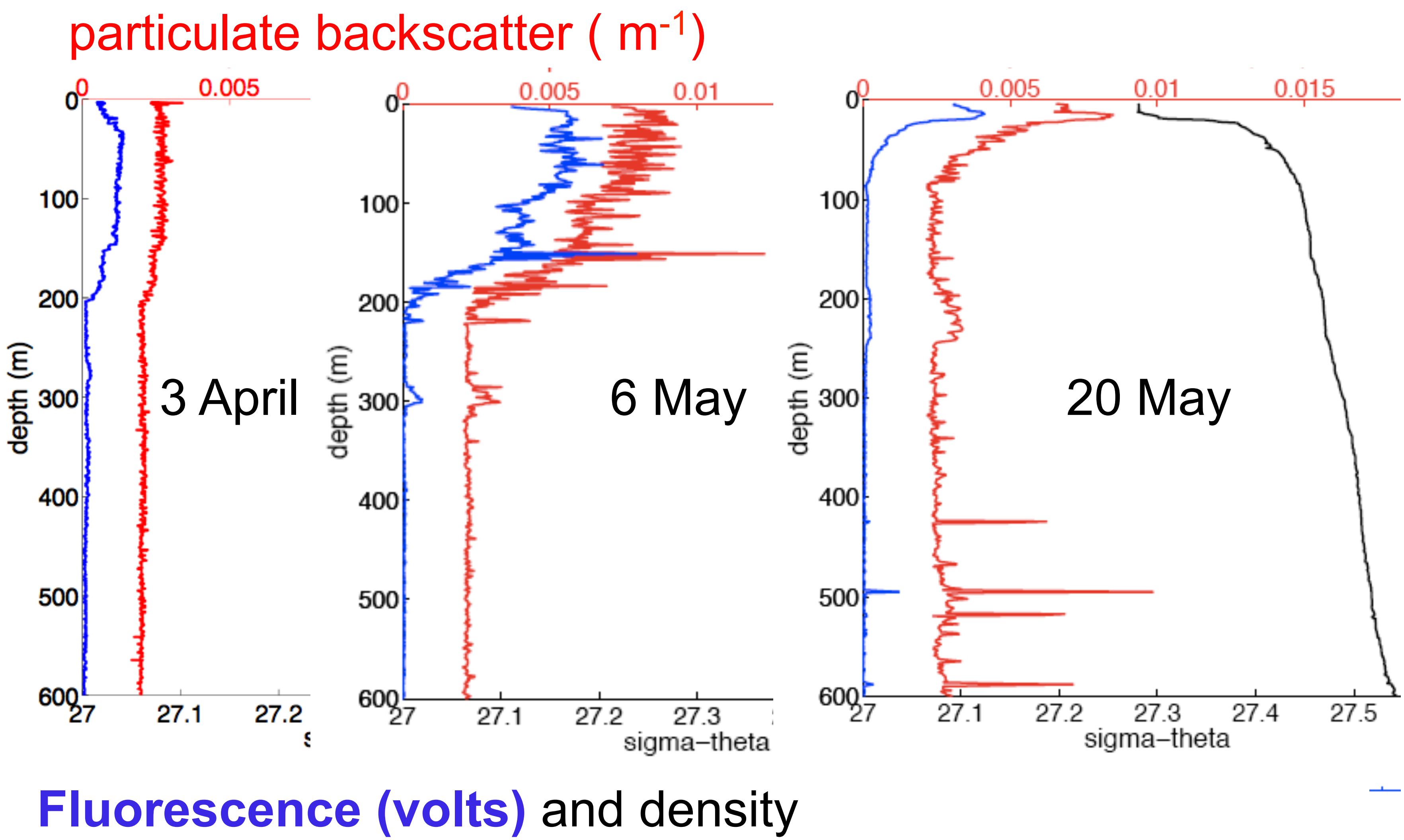


Lampitt 200 m camera at PAP, Briggs spikes superimposed

Briggs et al. 2011 DSR - I

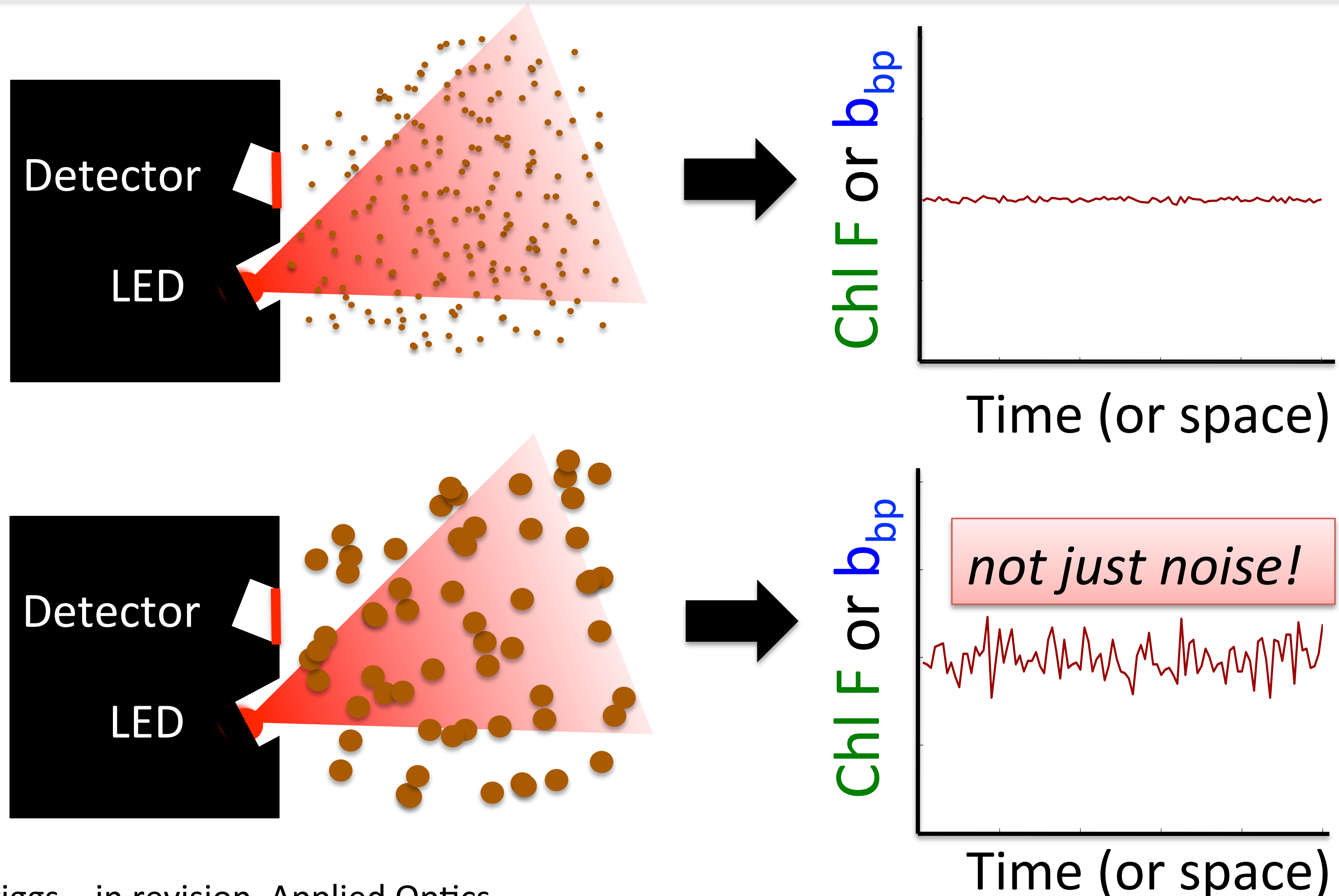


Novel use of optics to estimate mean particle size



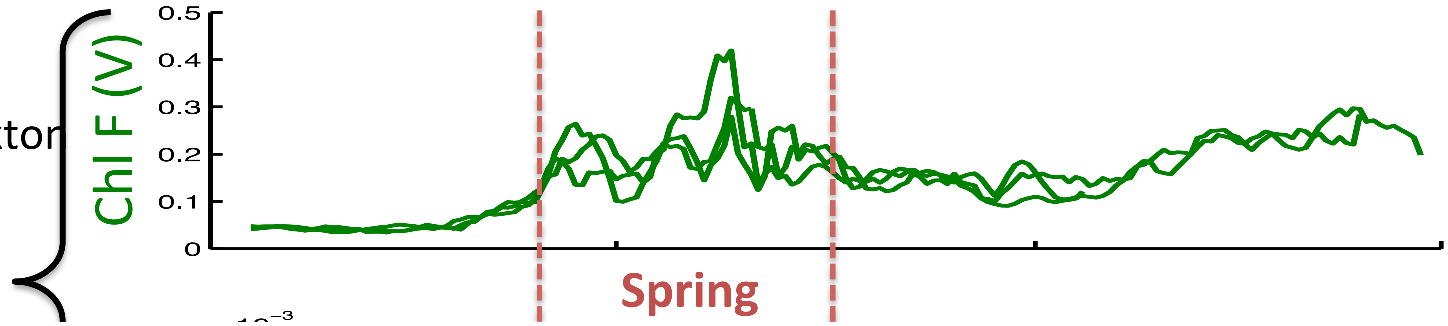
Briggs – unpublished

The mean contains information about *concentration*, but the variance to mean ratio contains *size* information



Briggs – in revision, Applied Optics

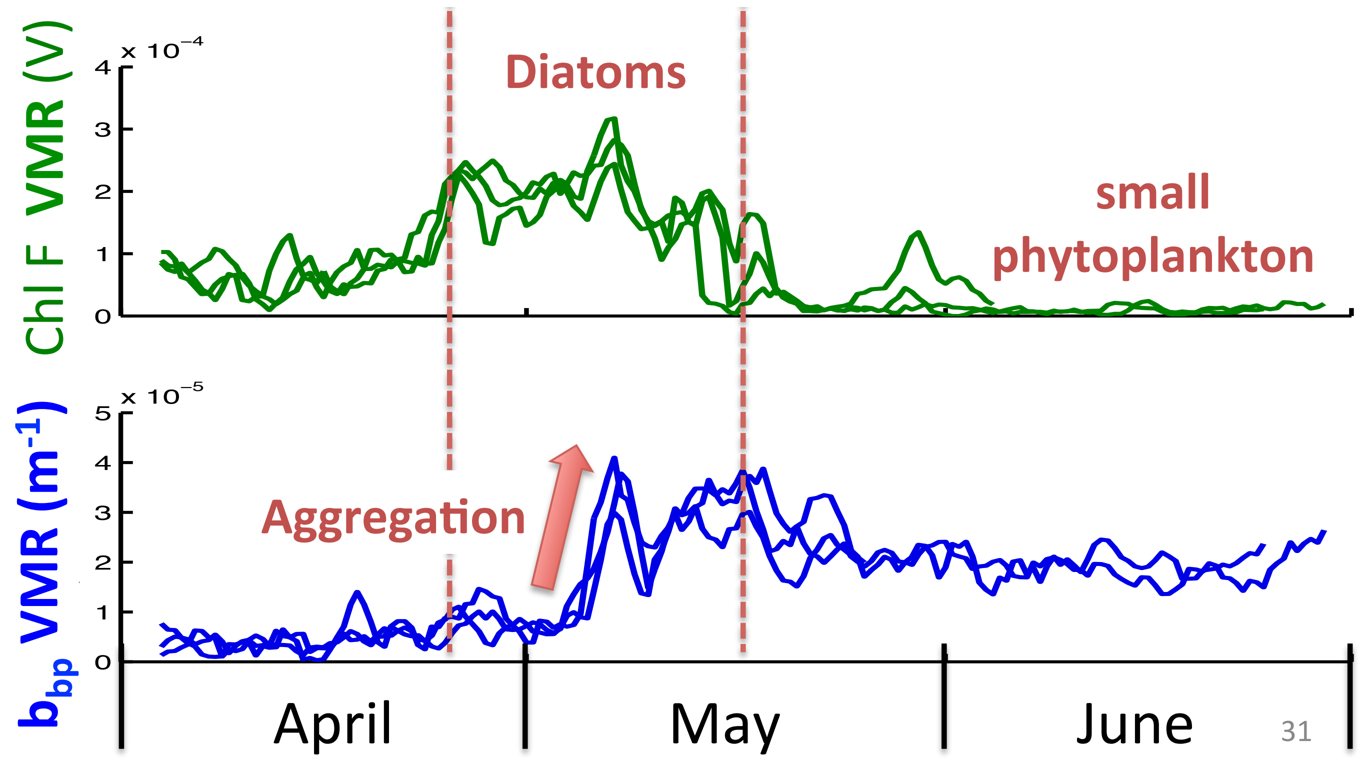
Concentration
proxy of phytoplankton



What do you get out of a validated estimate of size?
Changes in mean phytoplankton and particle size from pre- to post-bloom.

phytoplankton size proxy

particle size proxy



Nathan Briggs Ph.D worK

Optical-proxies of Particulate Iron Formation Kinetics in Hydrothermal Plumes: A Proof-of-concept Study for Future In-situ Measurements

SHARE THIS: TOOLS:

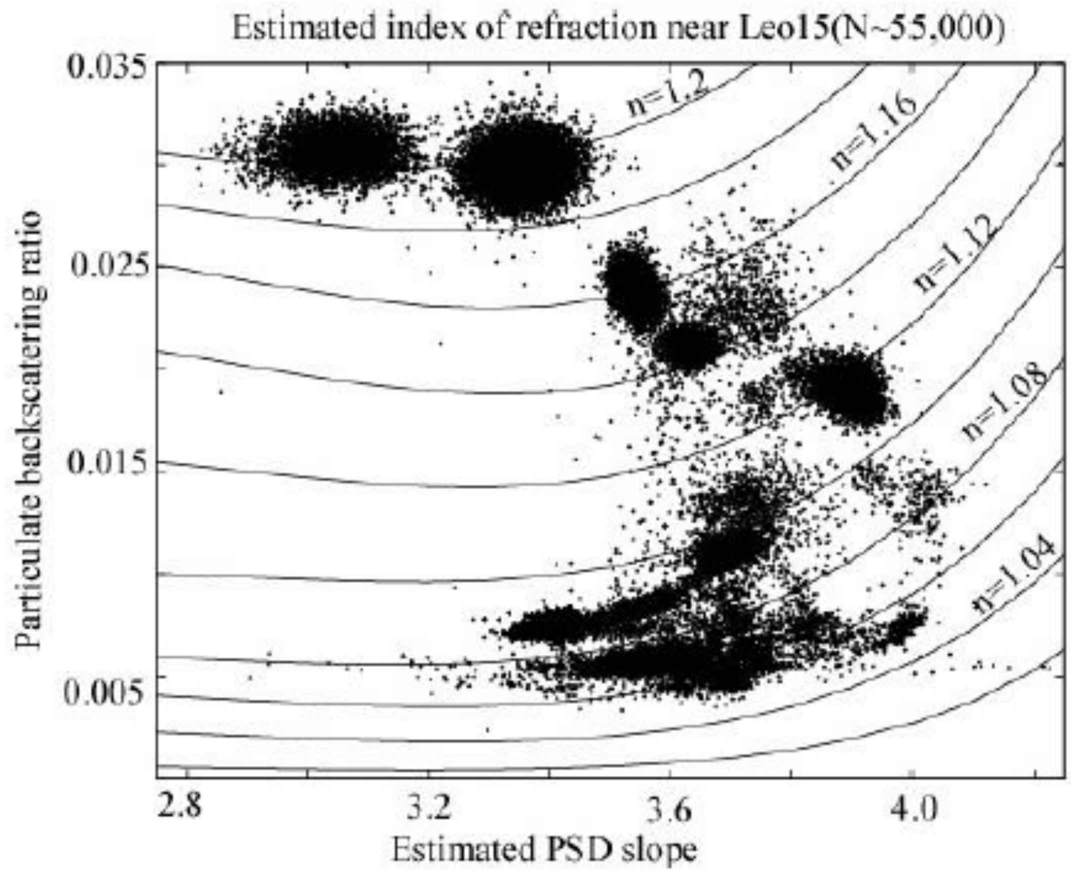
Margaret Estapa, Marine Chemistry and Geochemistry
John Breier, Marine Chemistry and Geochemistry

*Funded through the Ocean Ridge Initiative and the DOEI

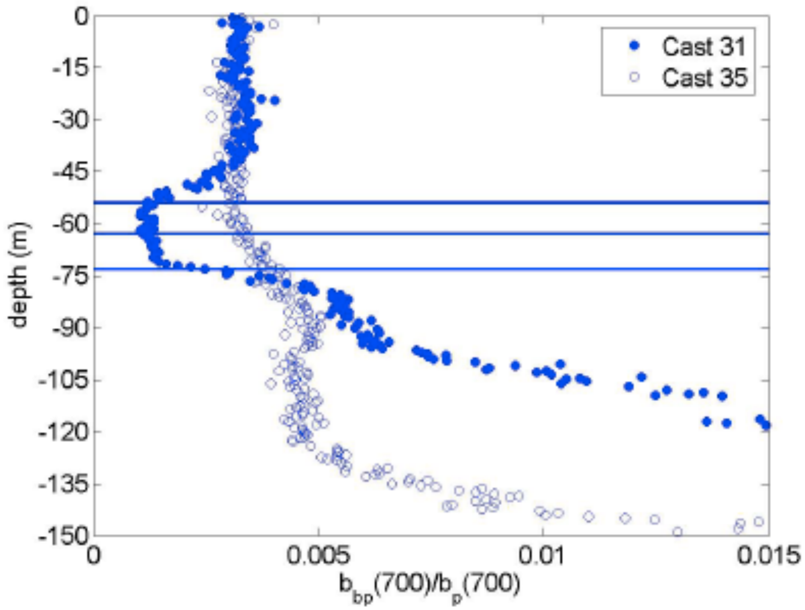
Abstract

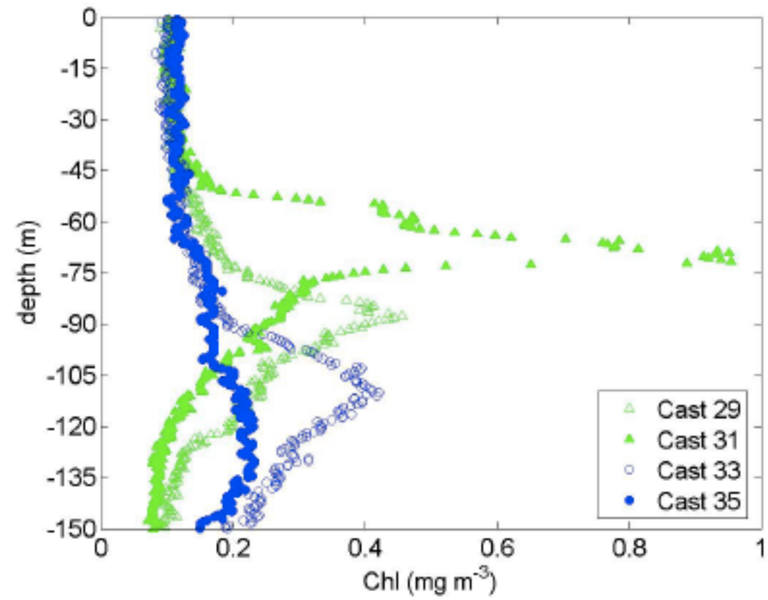
Iron fluxes to the ocean through hydrothermal vents may be similar in size to river inputs. The biogeochemical fate of this hydrothermal iron depends, in part, on how far currents transport it before particulate forms precipitate and grow to sizes where they settle out of the water column. Particle formation and evolution under rapidly changing conditions near plumes occur rapidly such that high spatiotemporal-resolution observations are required to determine the reaction timescales. Currently available discrete sampling technologies cannot achieve this resolution, although the samples returned can be analyzed in great detail to determine mineral particle composition. However, the light-absorption and -scattering properties of these particles can be measured rapidly and directly at depth using commercially available sensors. Such optical properties are used routinely as proxy measurements for particle concentration and composition in surface ocean environments. Here, we propose a series of shipboard laboratory experiments that will (I) measure the kinetics of hydrothermal particle formation and (II) test the utility of these sensors in plume environments. At a vent site characterized by high iron concentration, we will collect and return filtered plume water to the shipboard lab. Spectral beam attenuation, absorption and angular scattering, as well as particle composition and mineral phase, will be monitored simultaneously as the plume water oxidizes and particles form. Optical and compositional properties from the experimental timeseries will be analyzed to quantify characteristic optical properties of different forms of particulate iron. This study will provide new insight into hydrothermal plume chemistry and demonstrate the feasibility of rapid, in situ proxy measurements of particles as they form in vent plumes. Final results from this lab study will also include estimates of in situ detection limits, which can guide future field deployments, as well as modification of sensors for future hydrothermal plume applications, if necessary.

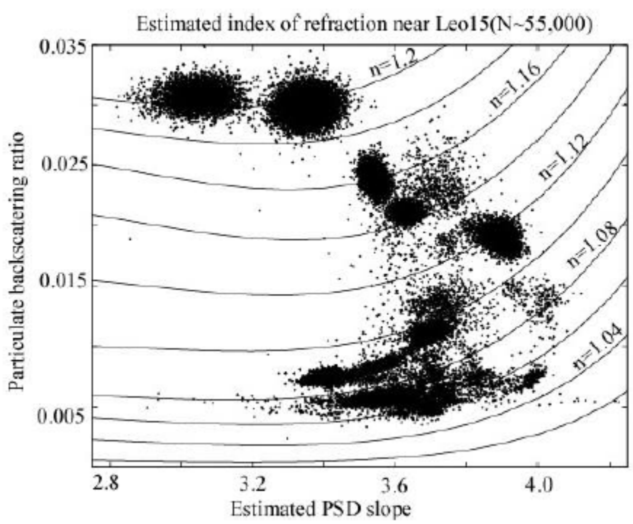
b_{bp}/b_p gives information on particle composition (Boss and Twardowski)



b_{bp}/c_p vs. depth is lowest at deep chlorophyll maximal layer





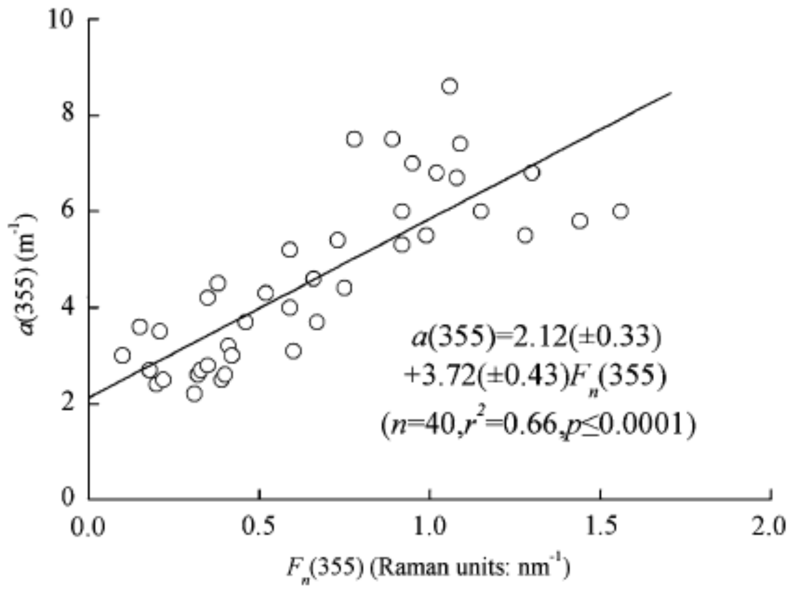


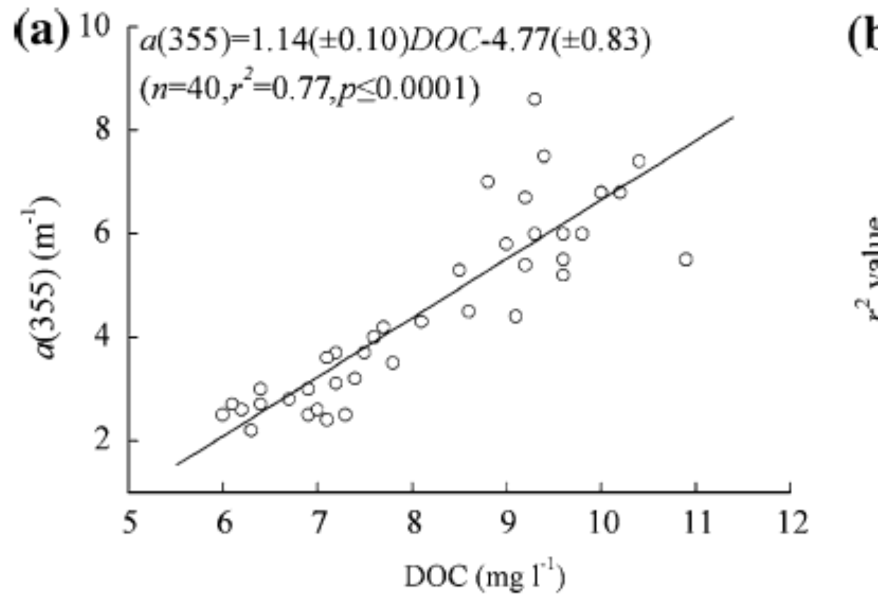
Optical Characterization of an Eddy-induced Diatom Bloom West of the Island of Hawaii

F. Nencioli[1], G. Chang[2], M. Twardowski[3], and T. D. Dickey[1]

Biogeosciences, 7, 151–162, 2010

CDOM and fluorescence; CDOM and dissolved organic carbon (DOC)





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EUTROPHICATION IN LAKES

Chromophoric dissolved organic matter (CDOM) absorption characteristics in relation to fluorescence in Lake Taihu, China, a large shallow subtropical lake

Yunlin Zhang · Boqiang Qin · Guangwei Zhu · Lu Zhang · Longyuan Yang

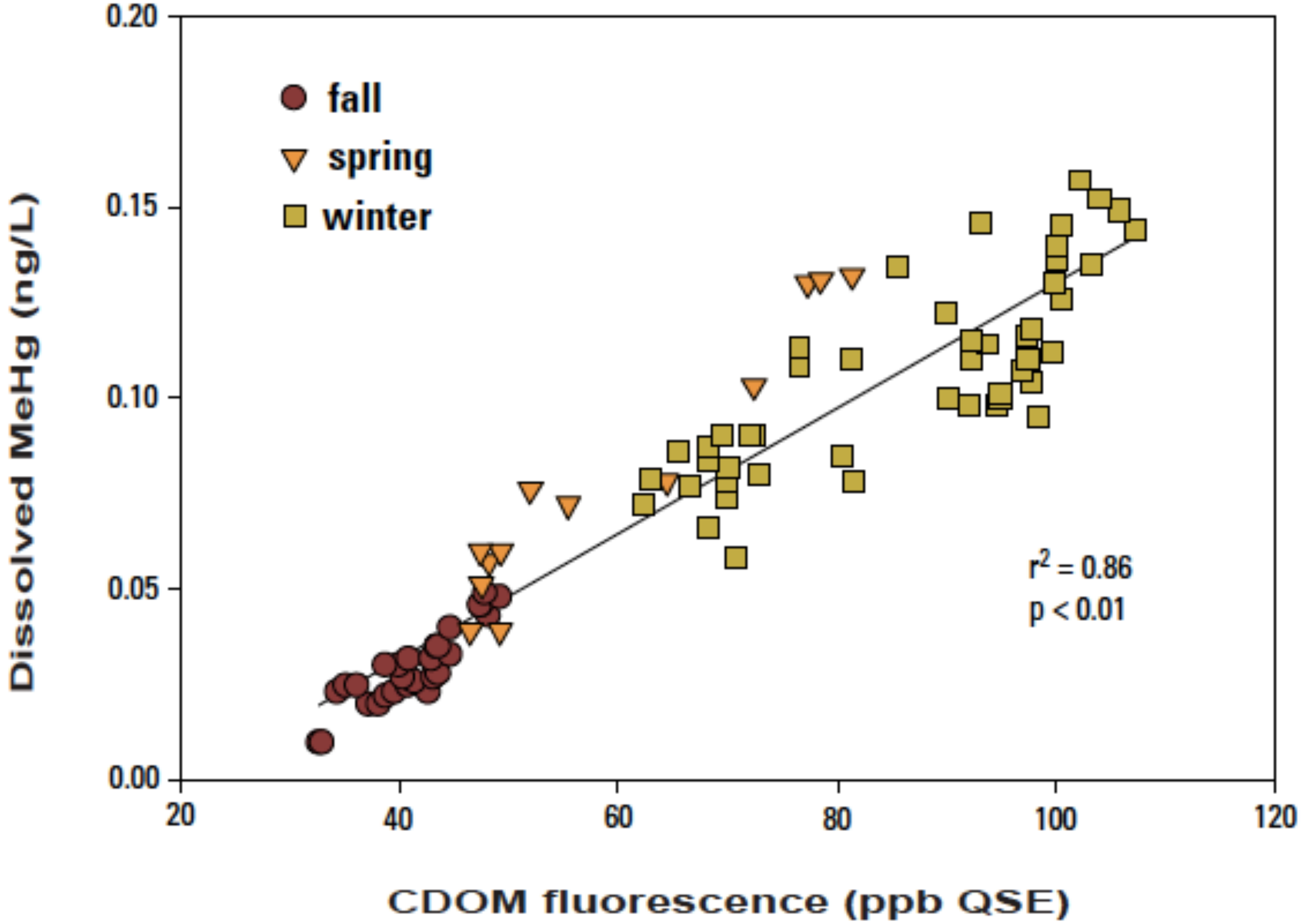

Figure 1. The relationship between in situ FDOM measurements and methylmercury concentrations in surface water of a tidal wetland across three seasons (Bergamaschi et al., in prep.)

A few examples of optical proxies and real entities

- Phytoplankton – Chl, HPLC pigments, Chl fluorescence,
  remote sensing reflectance, a(676)
- PFT – HPLC, a_phyt(λ), reflectance spectra, *a(676)
- Primary productivity – function ofphytoplankton, species or
  phytoplankton carbon; F_v/F_m
- Phytoplankton carbon – Chl, Chl fluorescence
- Particulate organic carbon (POC) – c_p and b_{bp}
- SPM – c_p and b_{bp}
- Phytoplankton vs. mineral particles – b_{bp}/b or b_{bp}/c_p
- Particle size or size distribution – c_p or b_{bp} slope
- CDOM – CDOM fluorescence
- Dissolved organic carbon – CDOM and slope, fluorescence

A few exampl… …ical proxies and real entities

Proxies work, until they don't.

- …ments, Chl fluorescence, …g reflectance, a(676)
- H… …ce spectra, *a(676)
- Pr… …ction ofphytoplankton, species o… phytoplankton carbon; F…/F…
- Phyt…kton carbon – Chl, Chl fluoresc…
- Particulate organic carbon (POC) –
- SPM – c_p and b_{bp}
- Phytoplankton vs. mineral particles – … b_{bp}/c_p
- Particle size or size distribution – c_p or b_{bp} slope
- CDOM – CDOM fluorescence
- Dissolved organic carbon – CDOM and slope, fluorescence

Proxies are empirical and require validation of relationship between optics and the entity.