Optical proxies of biogeochemical variables in the ocean: how well they work and link to processes.

Emmanuel Boss, University of Maine

Proxy (wiktionary): (*science*) A measurement of one physical quantity that is used as an indicator of the value of another.

Why proxies?

We use proxies to increase data density in space and time.

Focus here:

1. What optical properties are used as proxies for bio-geo-chemical properties? (+ Demos)
2. Sources of variability in property-proxy relation.

Reality vs. proxy;
sensors are a filters through which we see the world.

Picasso museum has a whole room devoted to it…

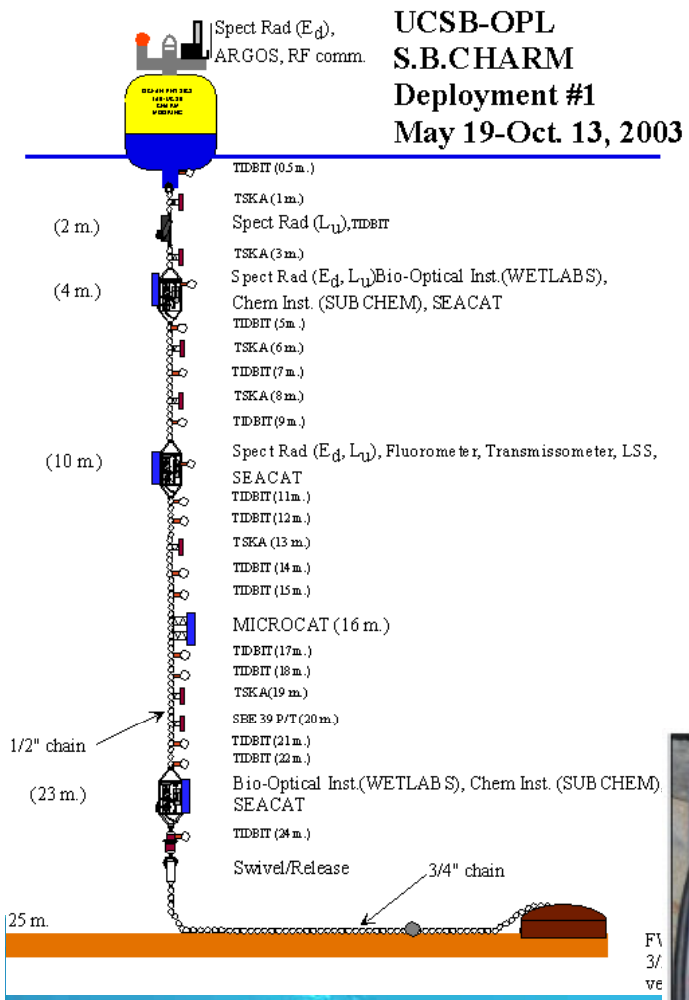
Optical proxies of particulate properties (concentration, size, composition):

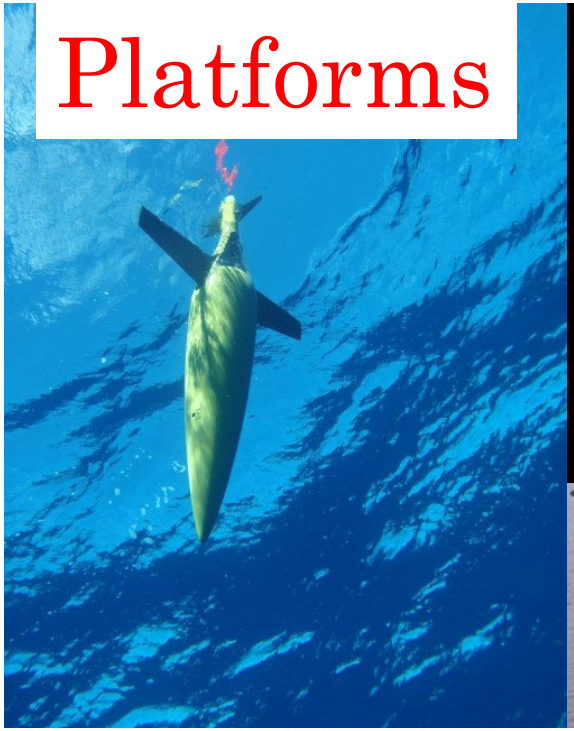
- bulk properties.
- single particle properties.

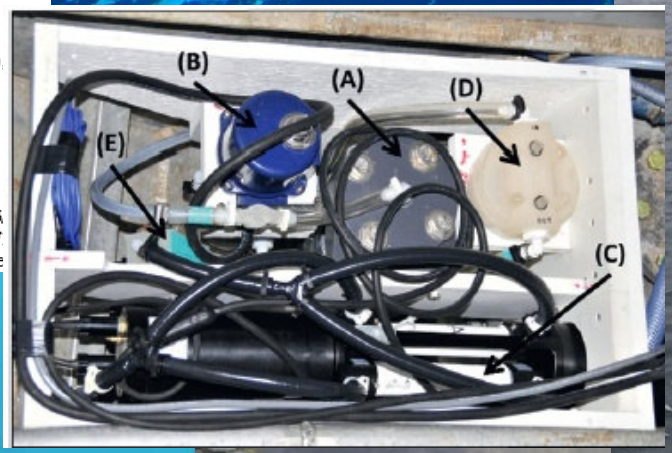
Here I focus on the bulk properties
(M. Sieracki's uncertainty principle: with finite resources, we can either know a lot about a few particles or a little about many particles).

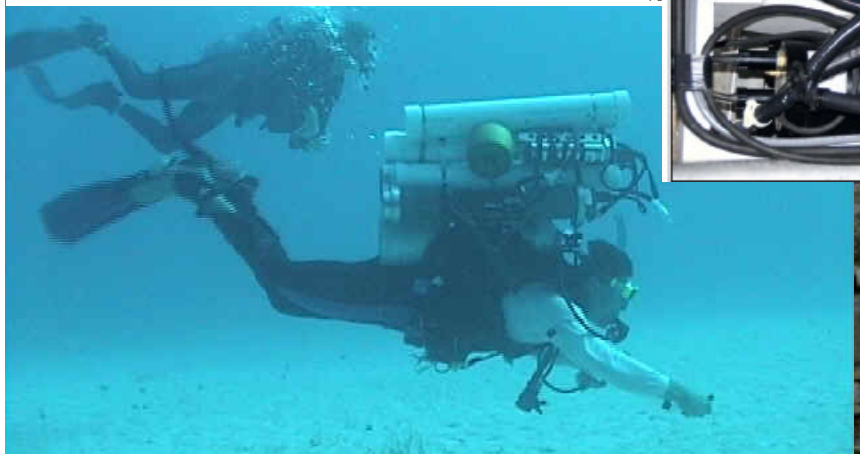
Demo: attenuation, scattering , fluorescence

Platforms


Spect Rad (E_d), ARGOS, RF comm.
UCSB-OPL
S.B.CHARM
Deployment #1
May 19-Oct. 13, 2003
TIDBIT (0.5 m.)
TSKA (1 m.)
(2 m.)
Spect Rad (L_u),TIDBIT
TSKA (3 m.)
(4 m.)
Spect Rad (E_d, L_u)Bio-Optical Inst.(WETLABS), Chem Inst. (SUB CHEM), SEACAT
TIDBIT (5 m.)
TSKA (6 m.)
TIDBIT (7 m.)
TSKA (8 m.)
TIDBIT (9 m.)
(10 m.)
Spect Rad (E_d, L_u), Fluorometer, Transmissometer, LSS, SEACAT
TIDBIT (11 m.)
TIDBIT (12 m.)
TSKA (13 m.)
TIDBIT (14 m.)
TIDBIT (15 m.)
MICROCAT (16 m.)
TIDBIT (17 m.)
TIDBIT (18 m.)
TSKA (19 m.)
SBE 39 P/T (20 m.)
1/2" chain
TIDBIT (21 m.)
TIDBIT (22 m.)
(23 m.)
Bio-Optical Inst.(WETLABS), Chem Inst. (SUB CHEM), SEACAT
TIDBIT (24 m.)
Swivel/Release
3/4" chain
25 m.




(B)
(A)
(D)
(E)
(C)



Laundry list of optical proxies of bulk biogeochemical properties

Nitrate, Sulphides– UV absorption.

DOM, Hydrocarbons – fluorescence (UV-ex, VIS-em), absorption, diffuse attenuation, ocean color.

PM, POC – attenuation, scattering, ocean color.

Phytoplankton pigments – fluorescence, absorption, , diffuse attenuation, ocean color.

Phytoplankton functional types – ocean color

Particulate size distribution – spectrum of attenuation, near forward scattering, spikes in optical properties, ocean color.

Particulate composition (index of refraction) – back-scattering to scattering ratio, degree of polarization.

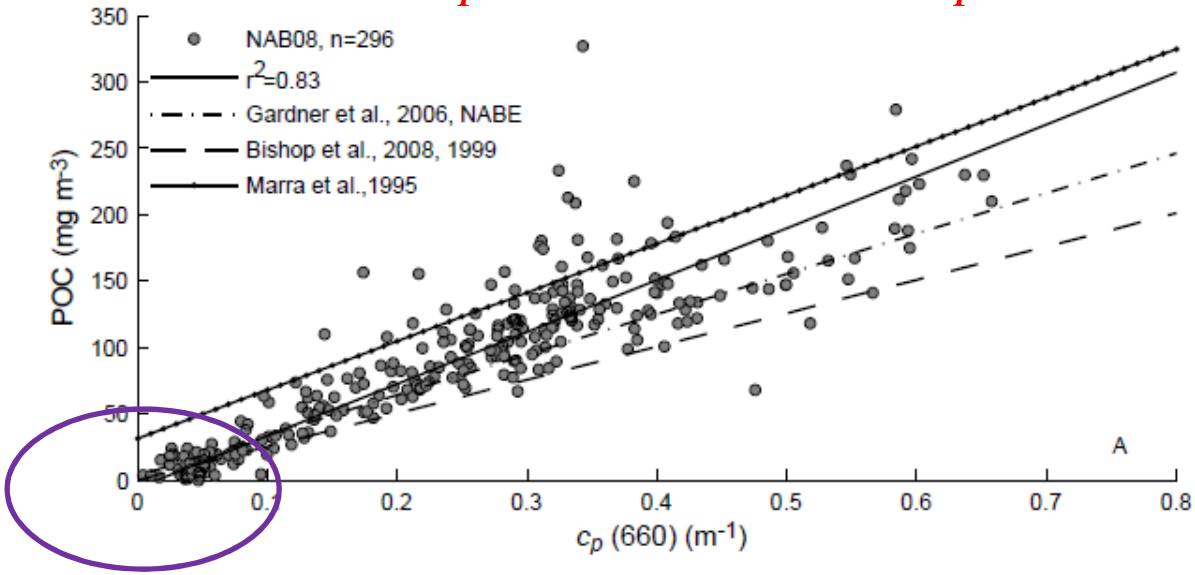
Proxy relationships

Issues with biogeochemical parameter:
Methodology: Filter type & size,volumefiltered, blank (DOC on filter for POC analysis), contamination (from air, etc.).

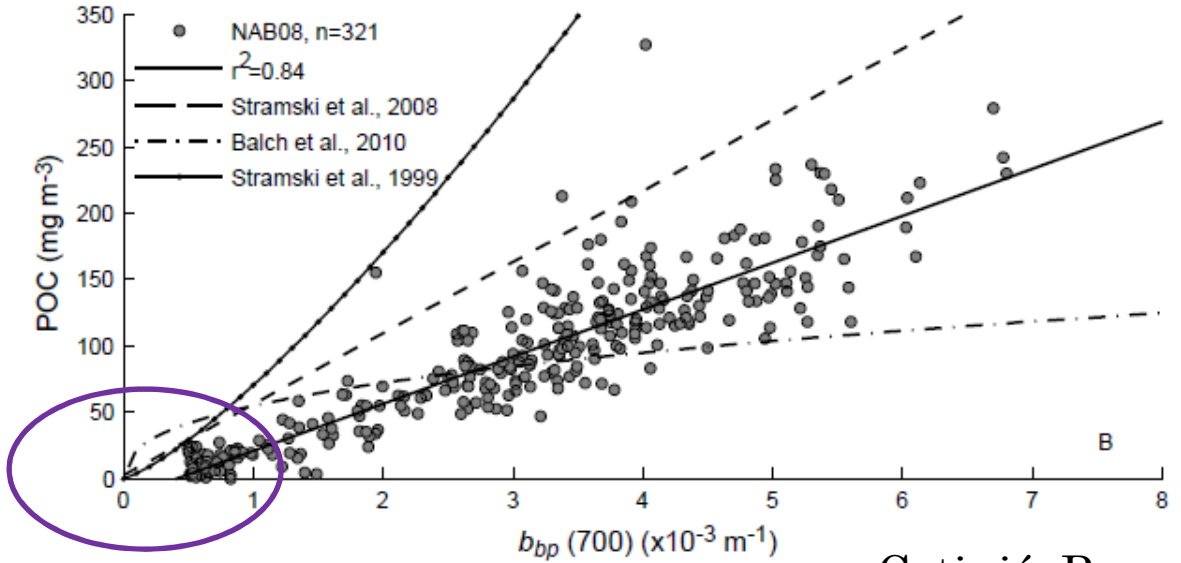
Issues with optical measurement:
Variability in instrument characteristics (wavelength, acceptance angle), calibration/blank, drift.

Underlying relationship:
Is it causal or correlation-based?
Most often it is *mixed*, e.g. relation to size is causal but then requires empirical conversion using BGCtransfer function.

Examples: c_p - POC and b_{bp}- POC



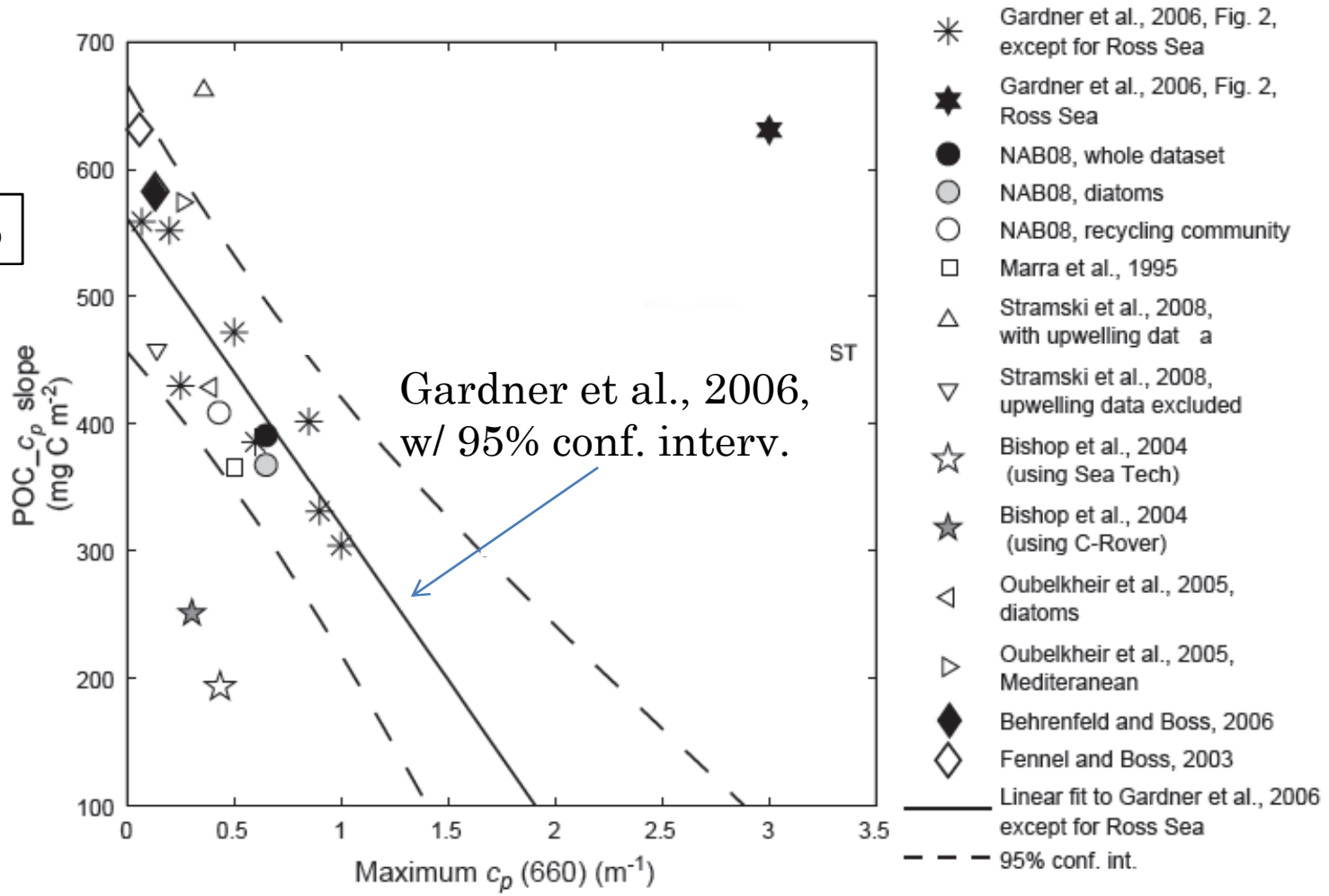
Dynamic range is our saving grace



Cetinić, Perry et al., submitted

Example: c_p - POC

< ±50%

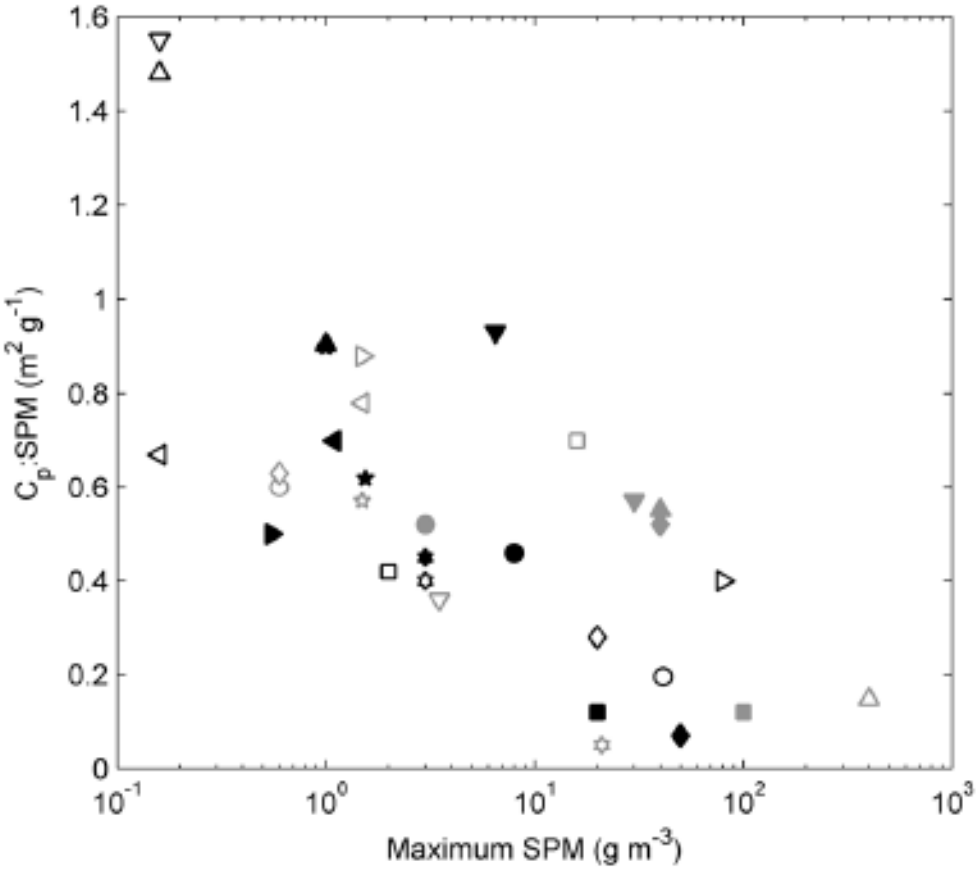


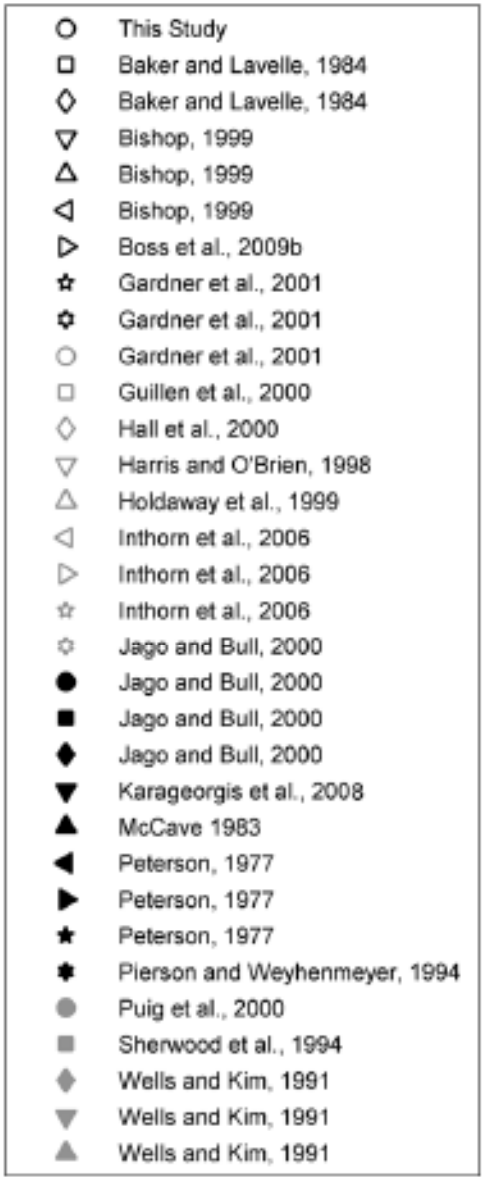
Cetinić, Perry et al., submitted

Variability likely due to combined effects of :
1. methodology.
2. change in underlying particles.

Example: c_p – SPM
Opposite trend

±50%

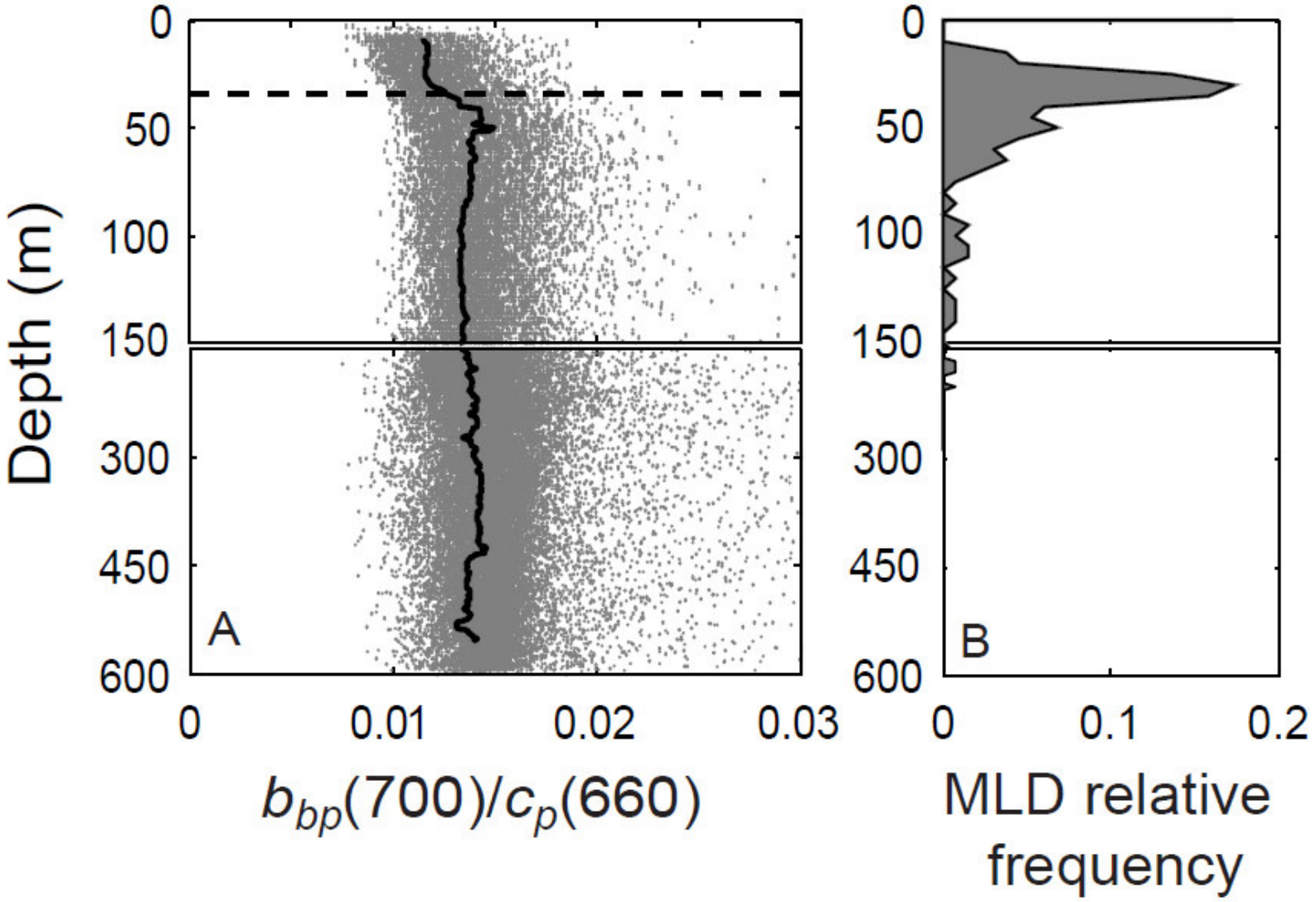




Hill et al., 2011, JGR

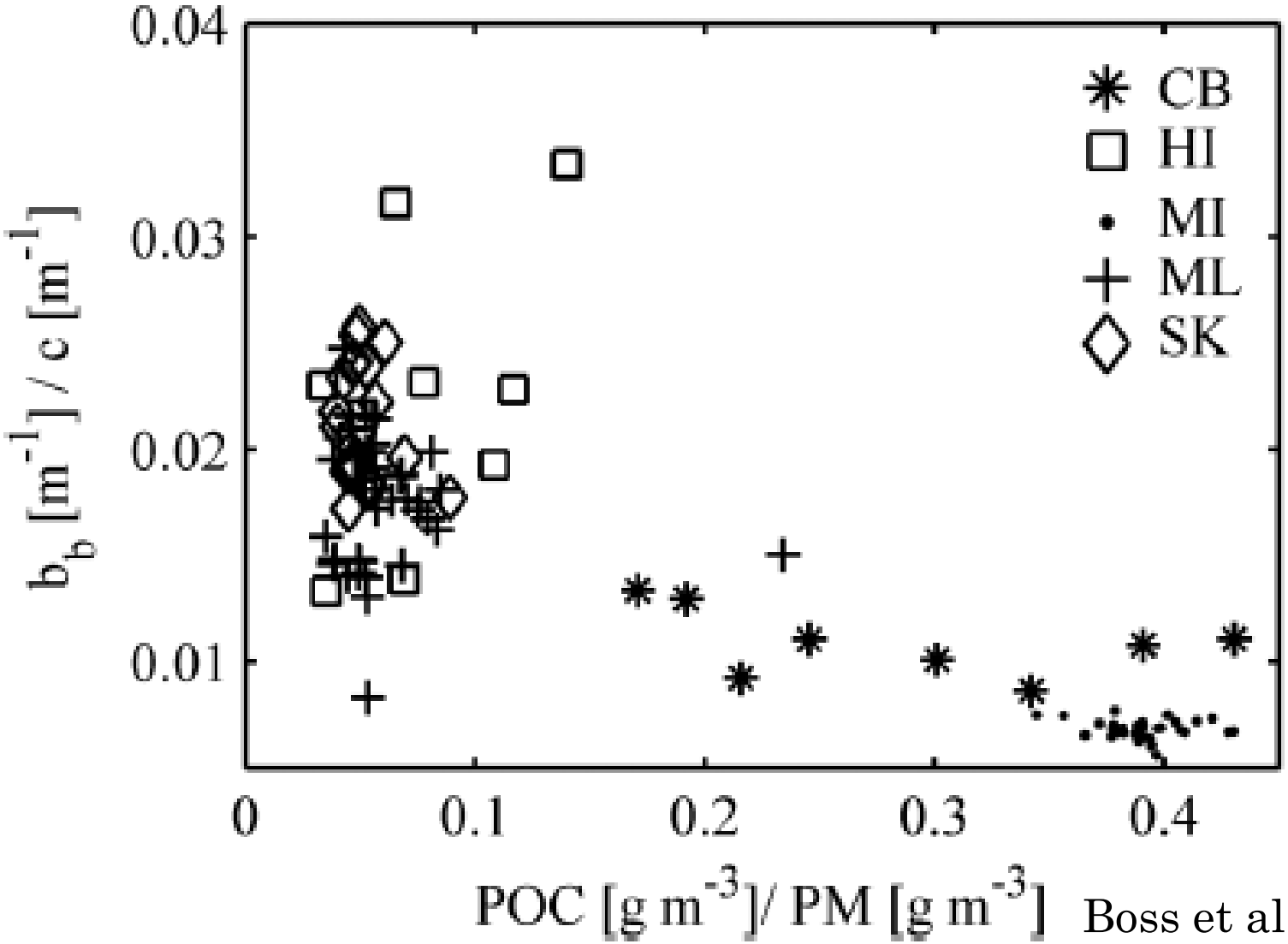
Variability likely due to combined effects of :
1. methodology.
2. change in underlying particles.

How about b_{bp}- POC ? ($b_{bp}$is a simpler measurement)



Cetinić, Perry et al., submitted

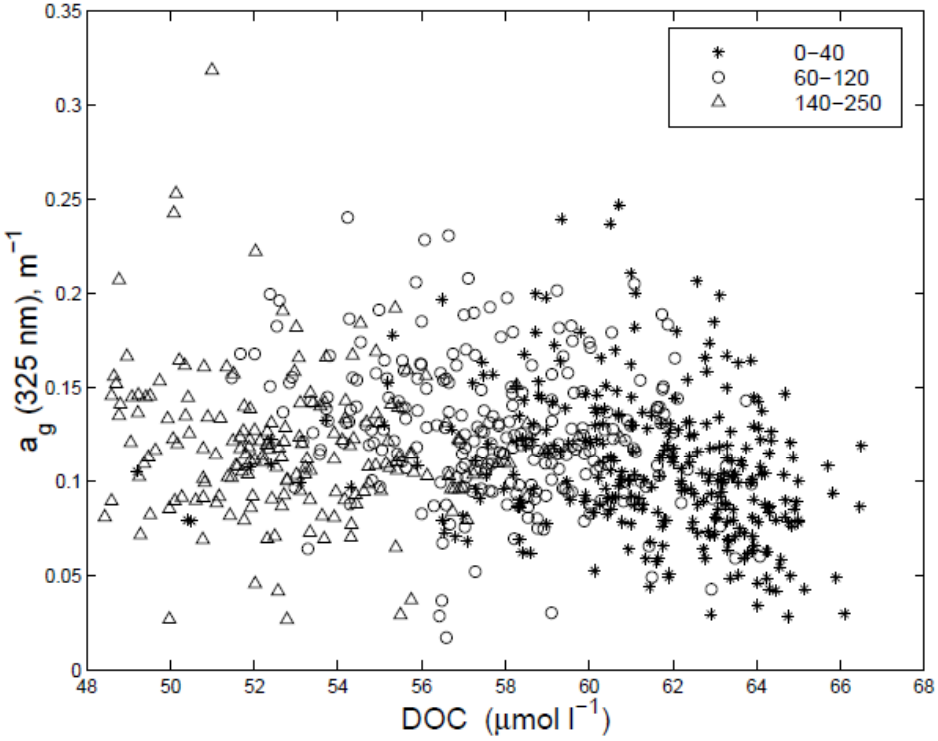
If both b_{bp} and c_p are available, we can get compositional information:



Boss et al., 2009

Example: DOC

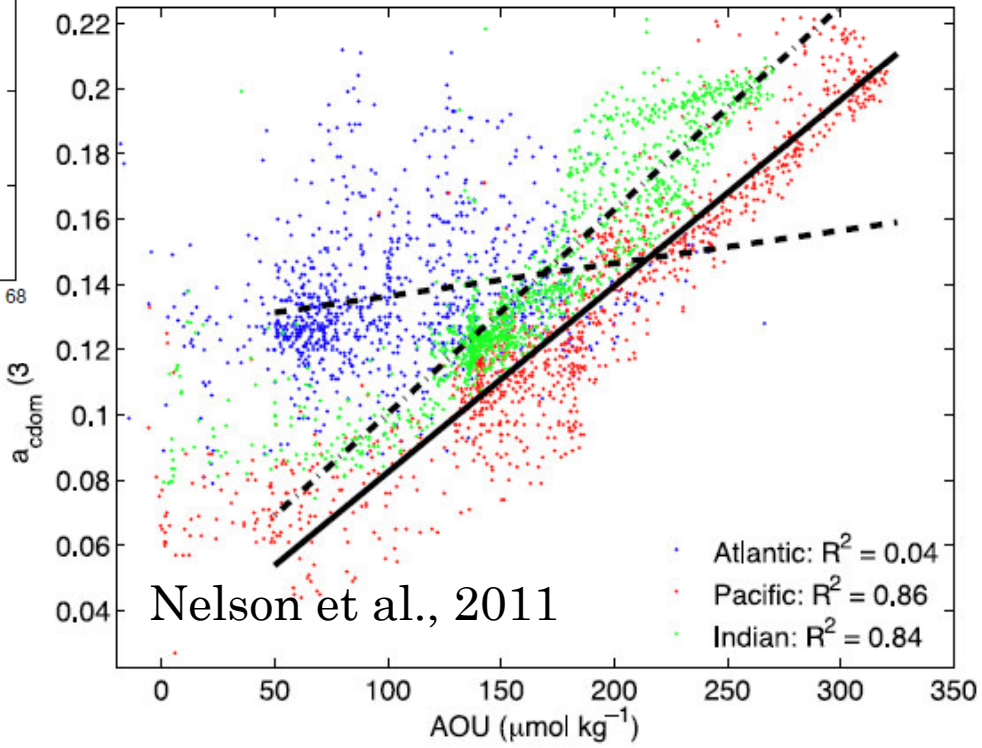
CDOM vs DOC:



Nelson & Siegel., 2002

Open ocean concentrations are still a challenge for in-situ instrumentation for both CDOM and FDOM

CDOM vs AOU:



Nelson et al., 2011

What properties do we obtain from ocean color?

Optical Properties – absorption & backscattering. Absorption can be subdivided to phytoplankton and CDM. Semi-analytical or empirical band-ratios.

Chlorophyll – from absorption, fluorescence (semi-analytical) or band-ratios.

Phytoplankton functional types – semi-analytical.

Size index – semi-analytical.

POC – from b_{bp} or empirical band ratios.

Uncertainties?

Uncertainties in remotely sensed products:

- Hard to come by.
- Training data is limited regionally.
- Hard to find independent data sets (i.e., not used in algorithm development).

Very active present area of research – stay tuned !

A class-based approach to characterizing and mapping the uncertainty of the MODIS ocean chlorophyll product 2009

Timothy S. Moore [a,*], Janet W. Campbell [a], Mark D. Dowell [b]

Assessment of apparent and inherent optical properties derived from SeaWiFS with field data 2005

Frédéric Mélin *, Jean-François Berthon, Giuseppe Zibordi

Uncertainties of inherent optical properties obtained from semianalytical inversions of ocean color 2005

Peng Wang, Emmanuel S. Boss, and Collin Roesler

Ensemble uncertainty of inherent optical properties 2011

Mhd. Suhyb Salama,[1,*] Frederic Mélin,[2] and Rogier Van der Velde[1]

Uncertainties in the Products of Ocean-Colour Remote Sensing 2005

Emmanuel Boss and Stephane Maritorena

Some processes that have been studied/observed using optical proxies (if not covered by J. Bishop)

1. Accumulation of CDOMthrough the growth season.

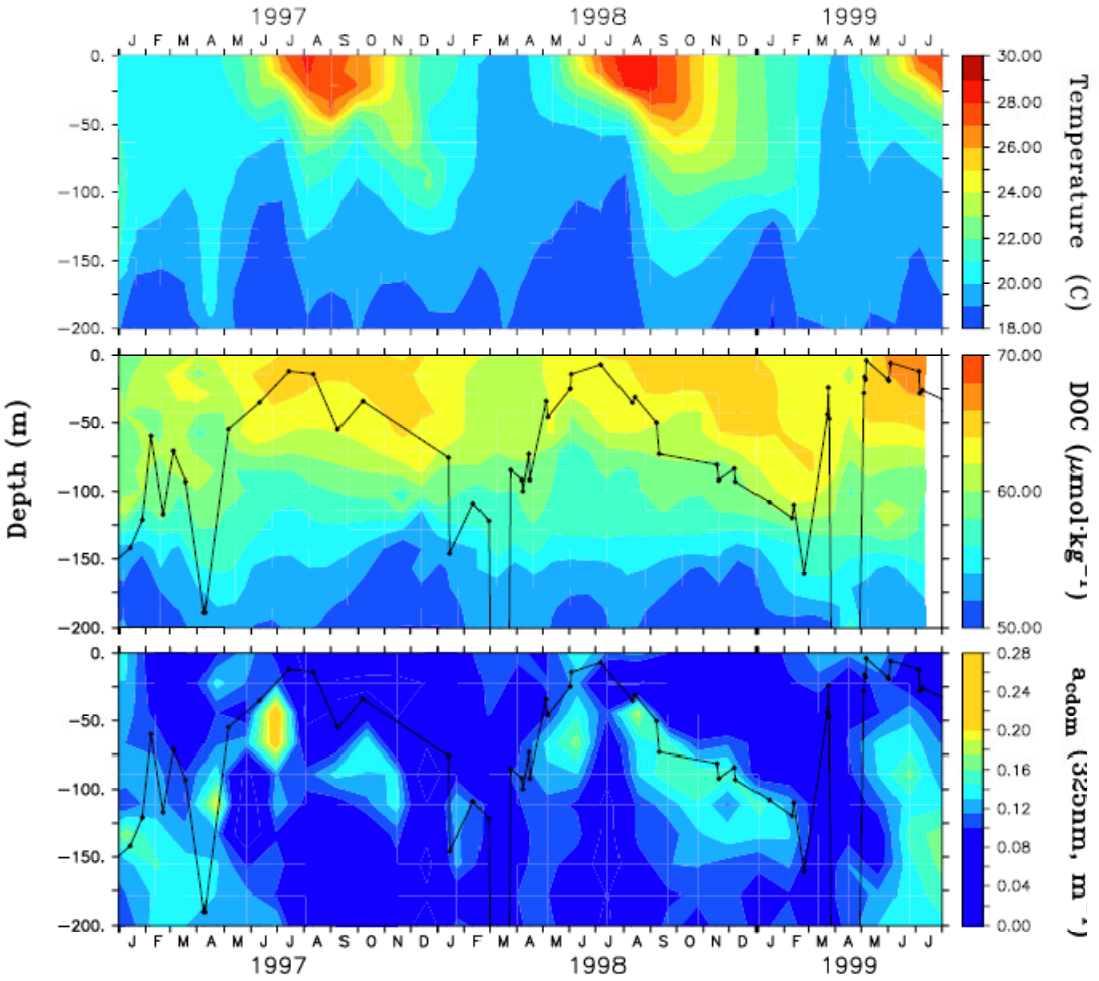
2. Use of autonomous platforms to measure particle distributions.

3. Spikes – expression of large rare particles

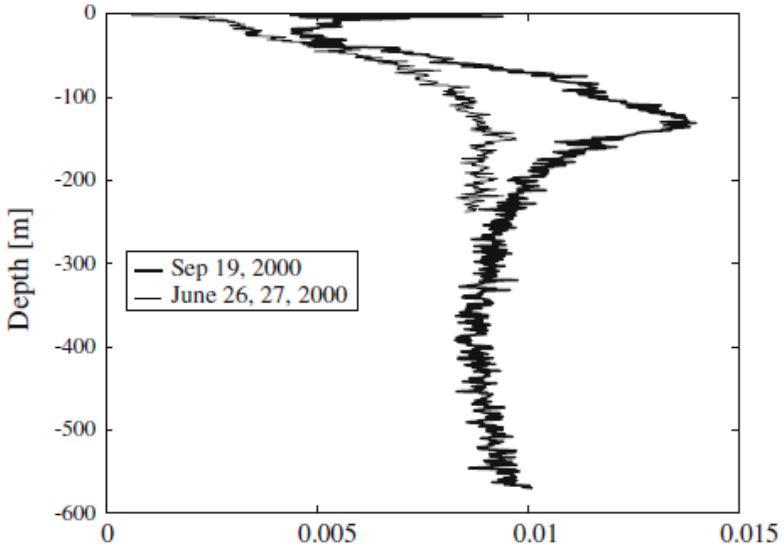
4. Community production during the NA spring bloom.

Accumulation of CDOM through the growth season

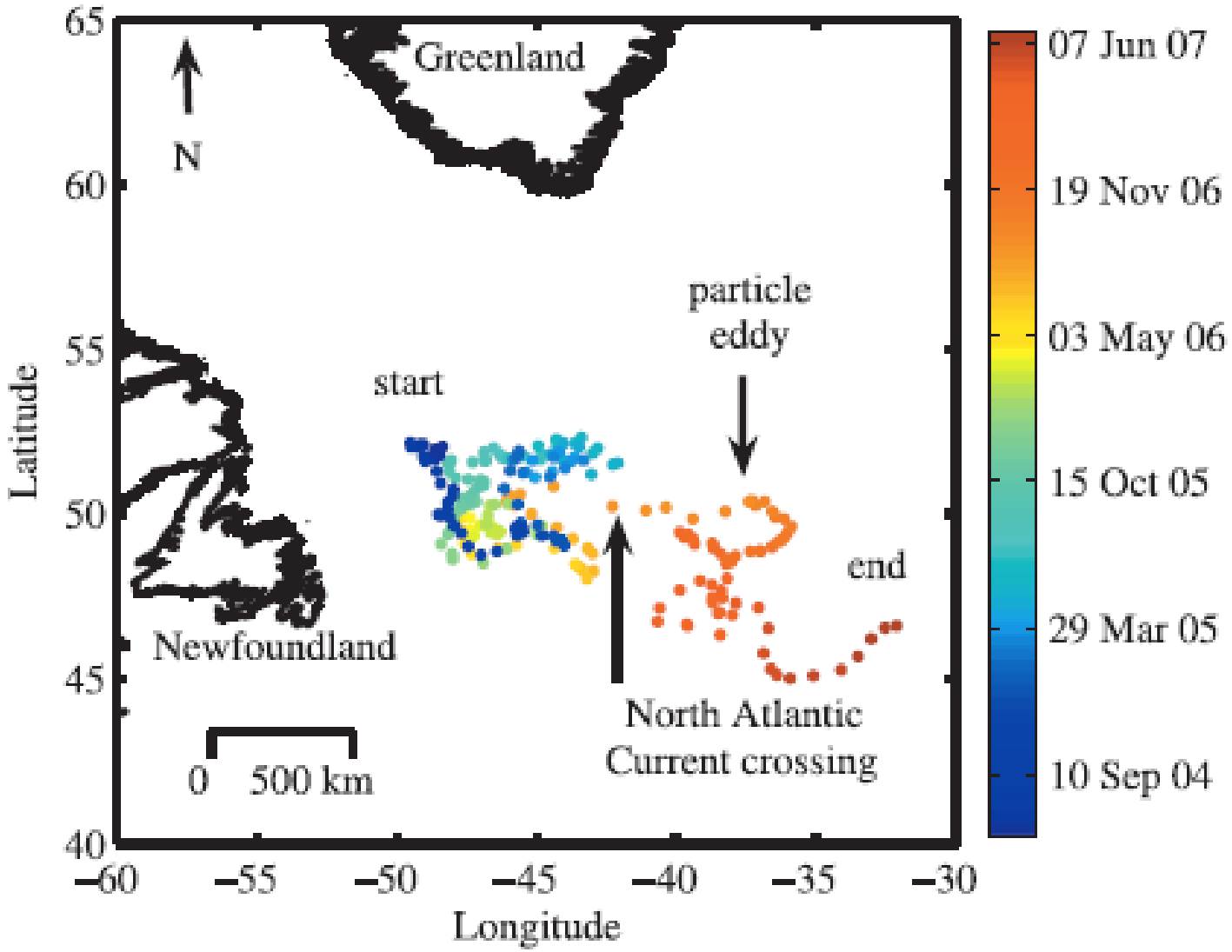
Nelson and Siegel, 2002, BATS (discrete):



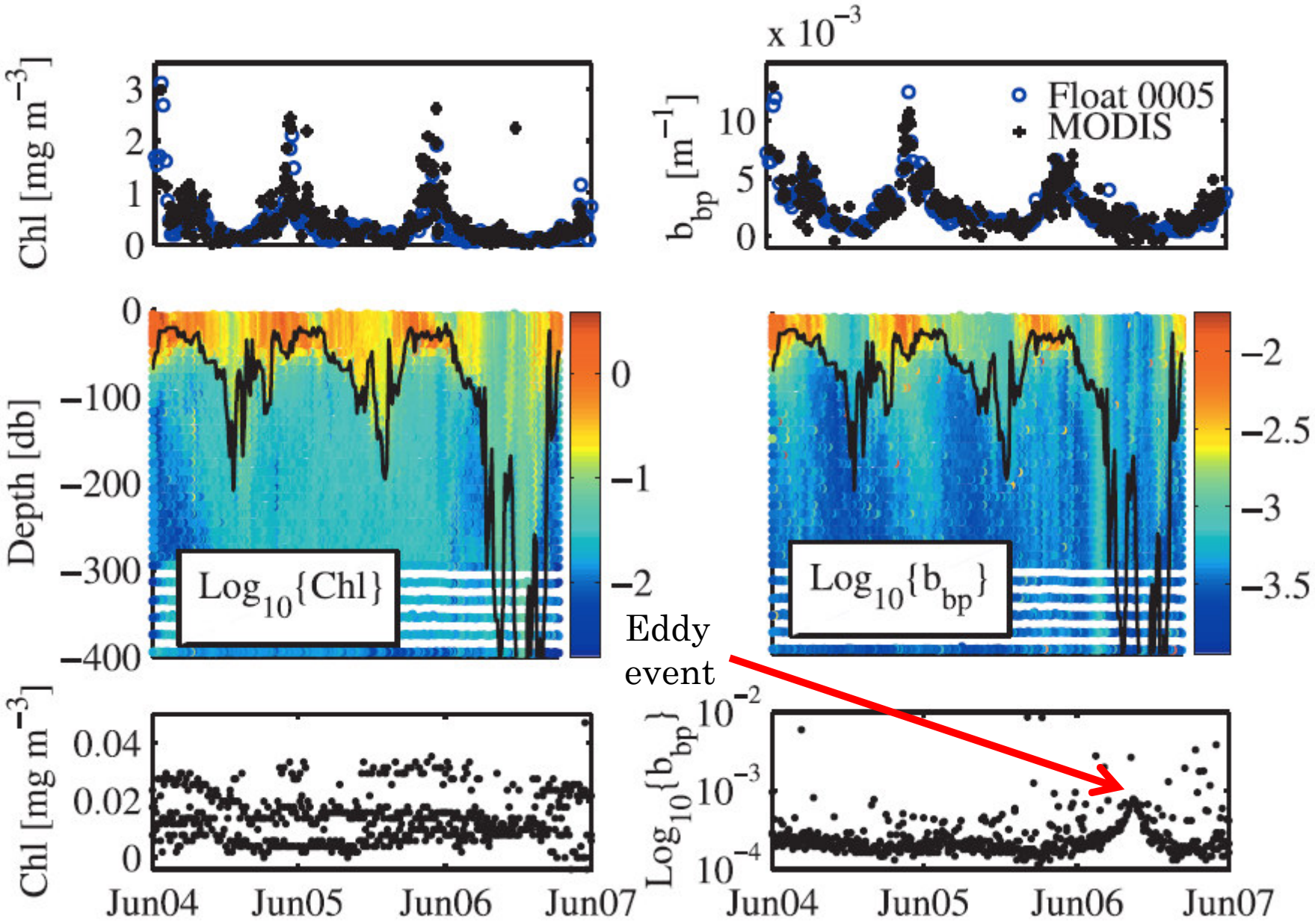
Boss et al., 2007, Crater Lake ('continuous'):



Float's trajectory (221 profiles, 3 yrs):

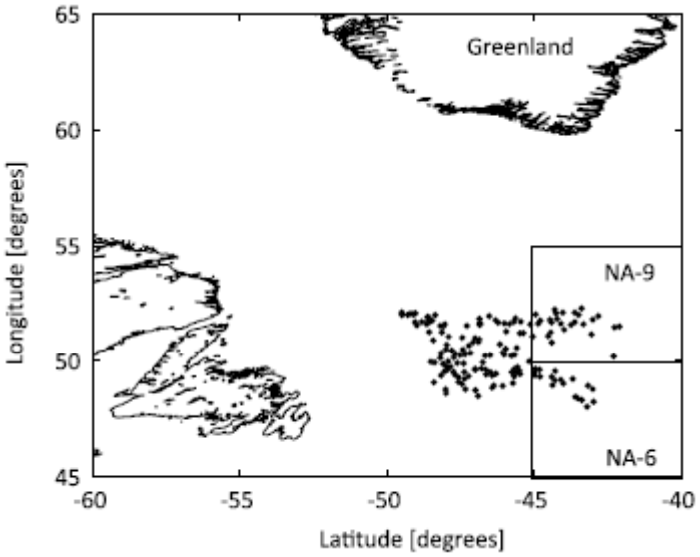


Focus: Surface vs. satellite, stability at depth

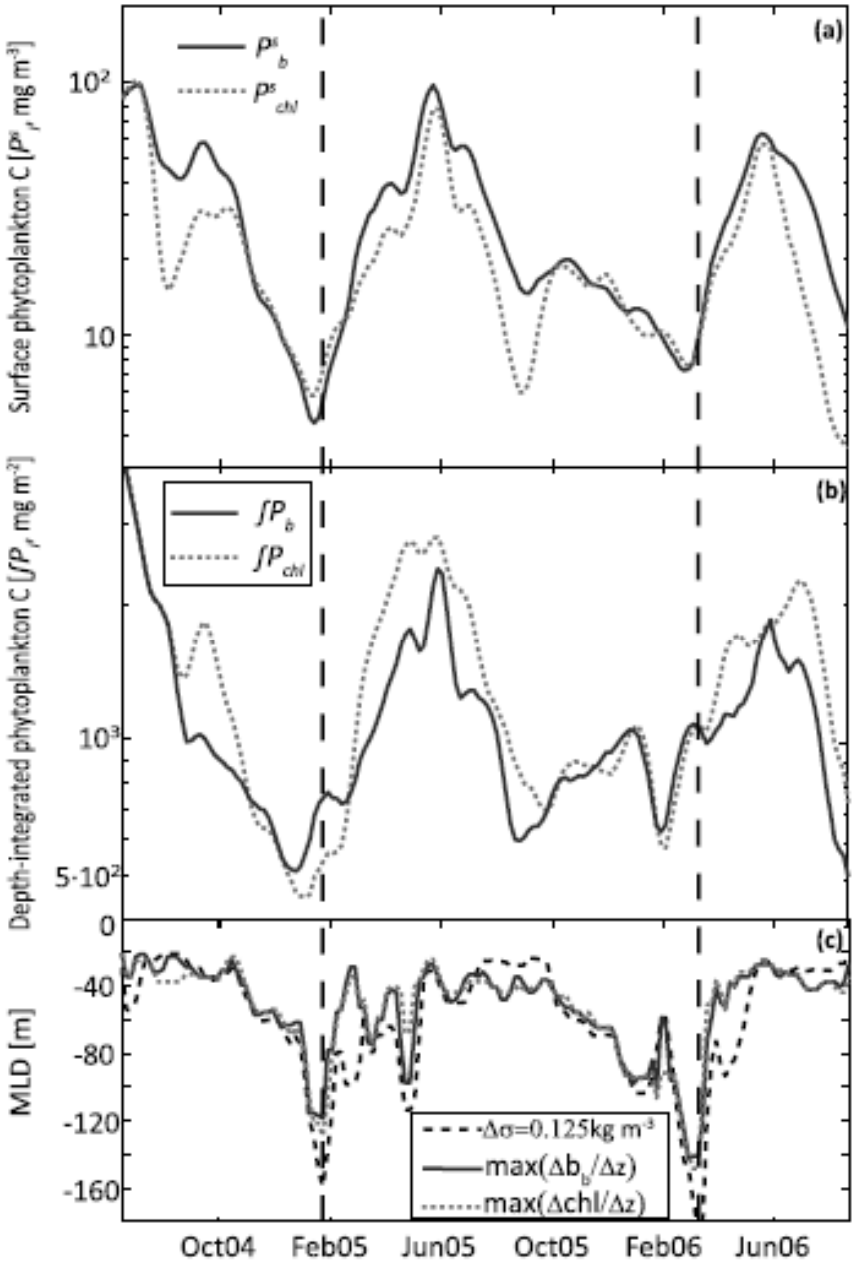


Boss et al., 2008

Initiation of the spring bloom starts prior to re-stratification

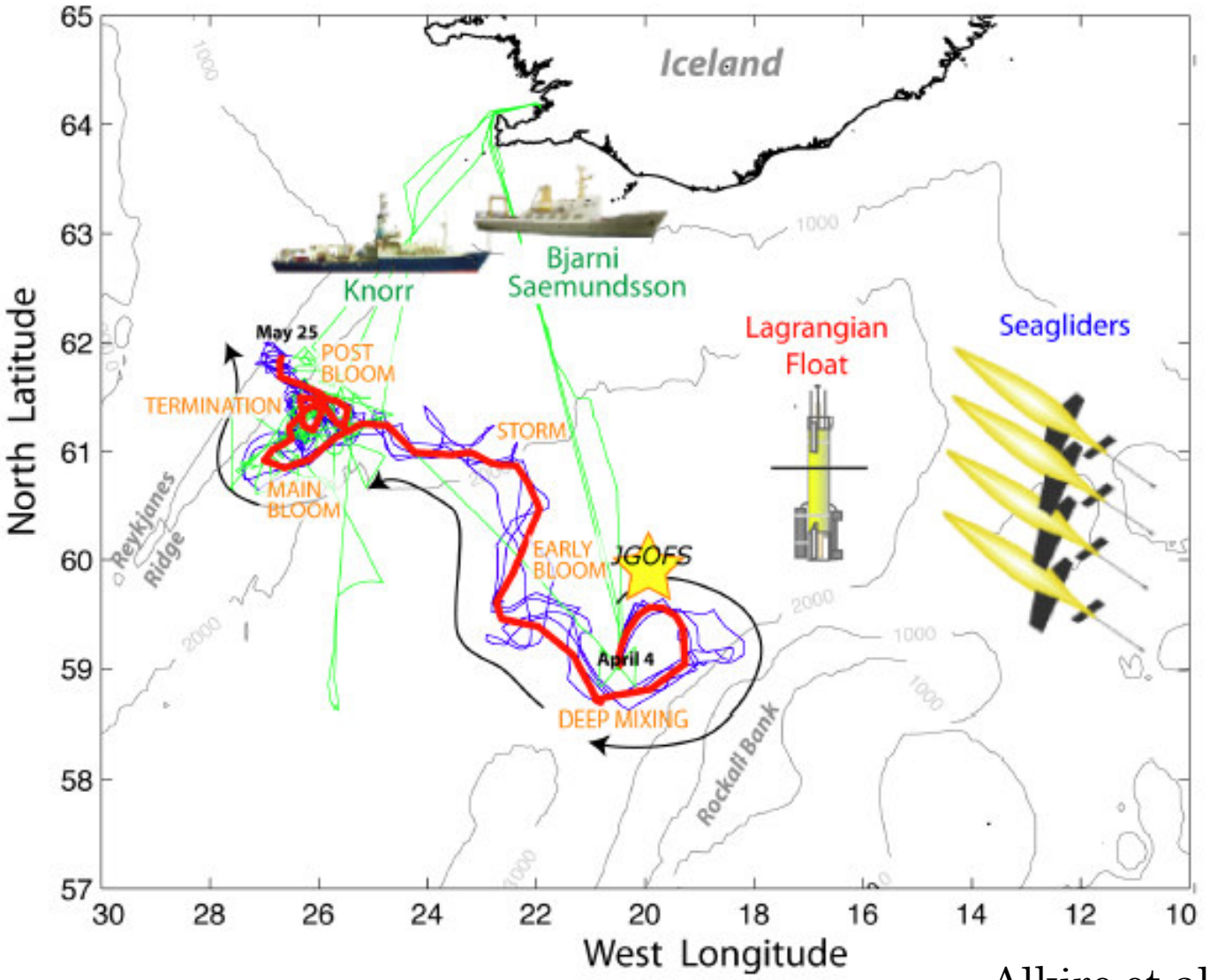


Surface and depth integrated biomass do not necessarily track each other



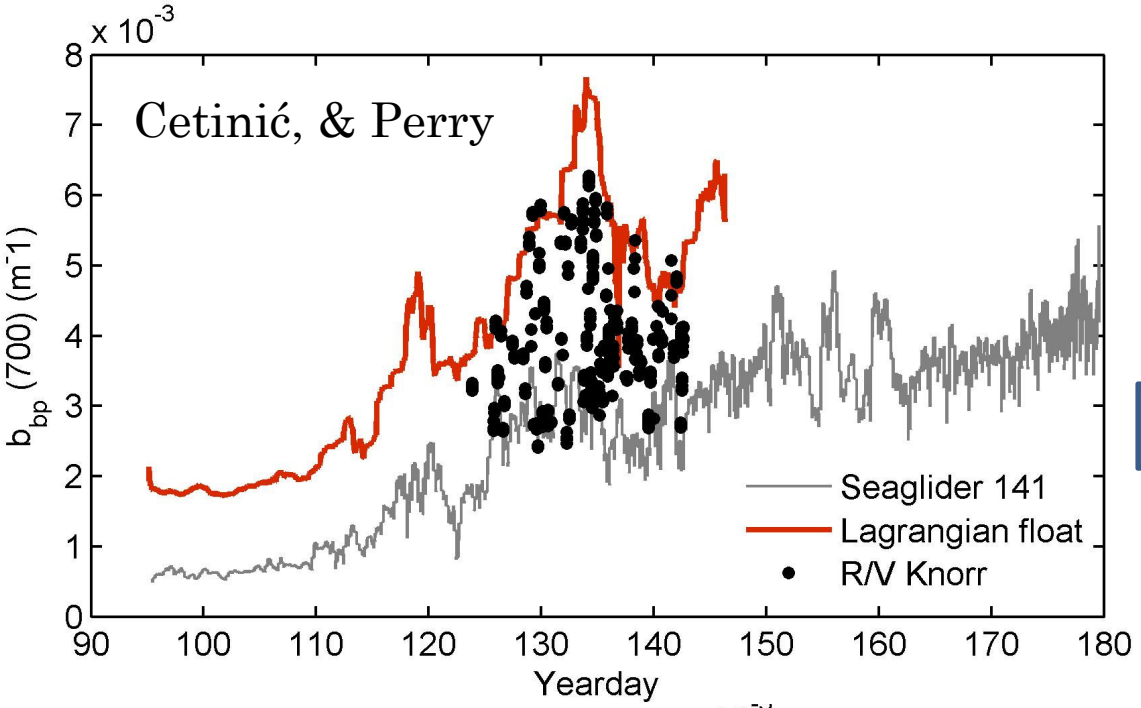
Boss &Behrenfeld, 2010

Case study: NAB 2008



Alkire et al., submitted

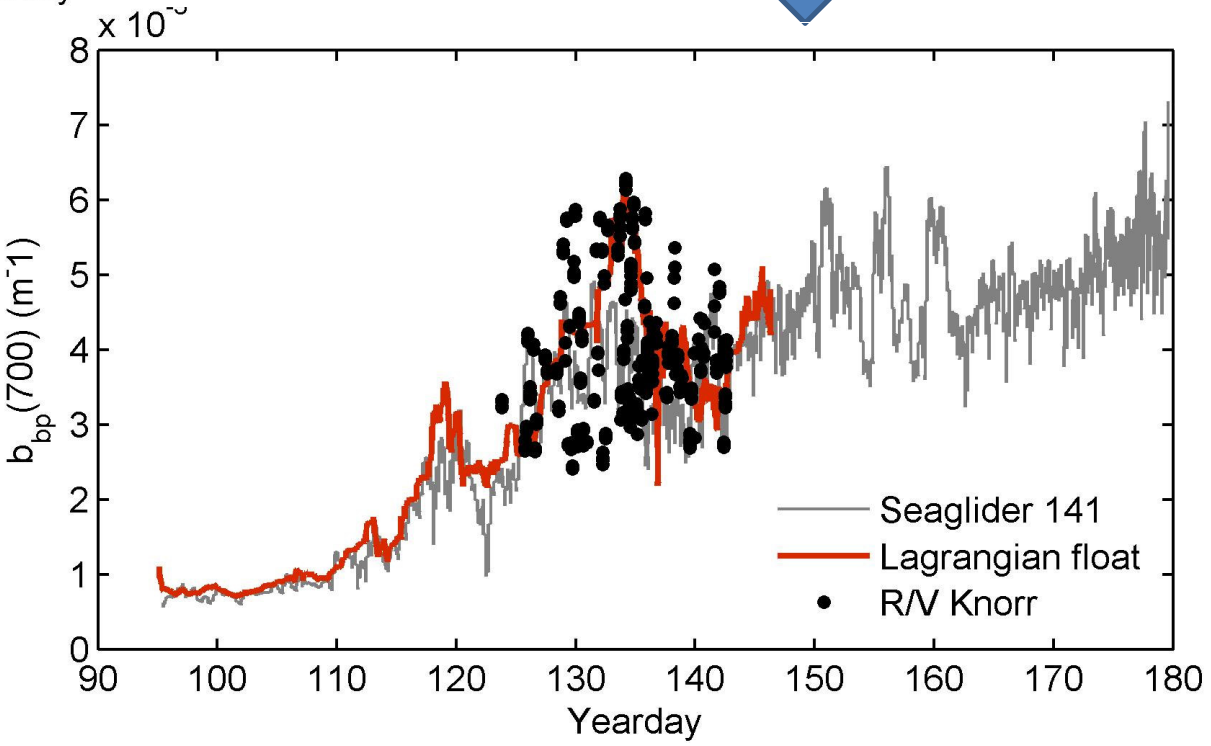
Optical proxies link measurements done from different platforms



Variability in sensors (even with factory calibration) is challenging.

Vicarious calibration of sensors on different platforms is key.

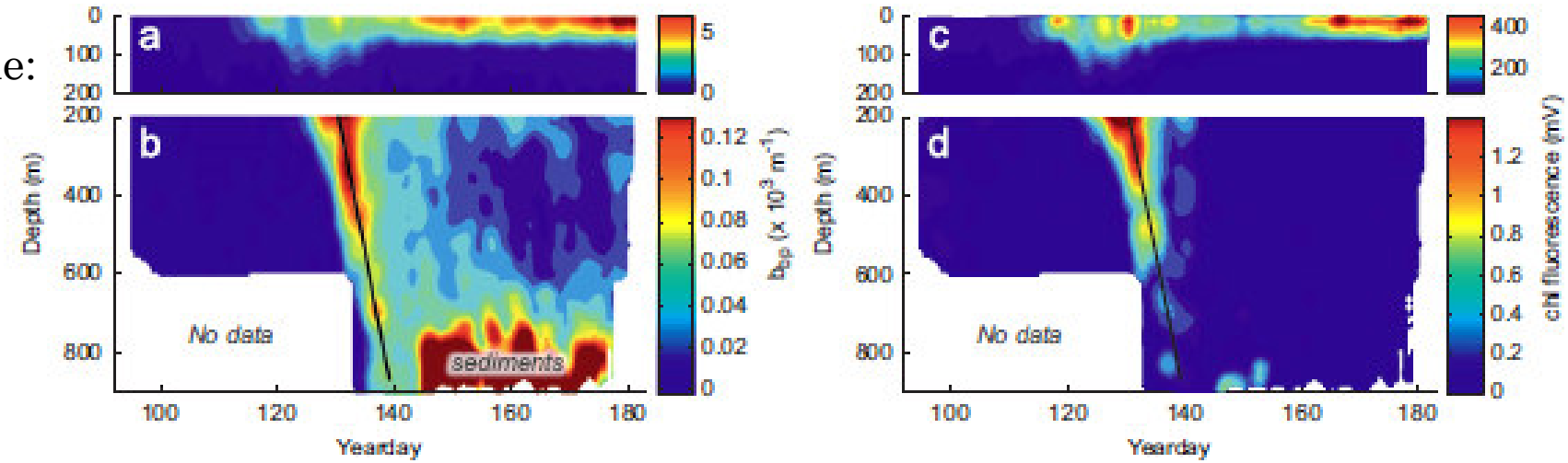
Great role for gliders (C. Lee).



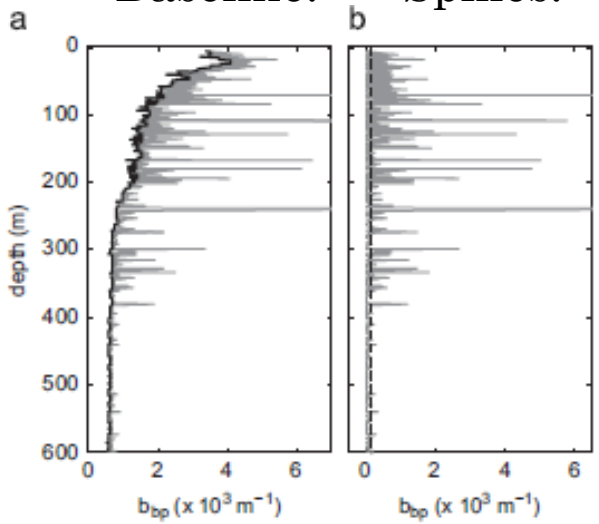
Case study: spike analysis during spring bloom (Briggs et al., 2011)

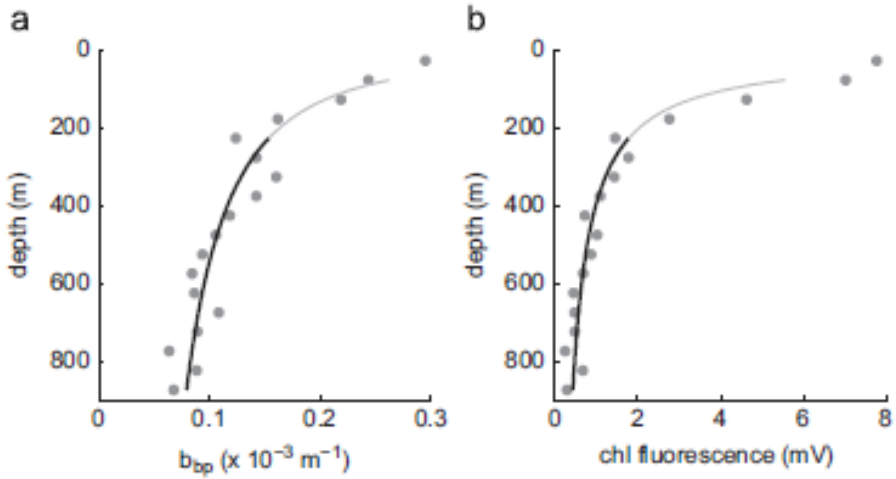
Baseline:

Spikes:



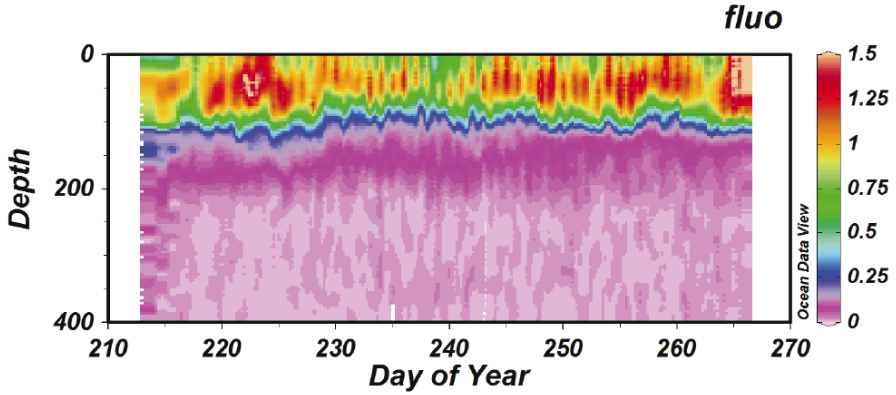
Baseline: Spikes: Martin curves based on spikes (b_{bp}&Chl F)

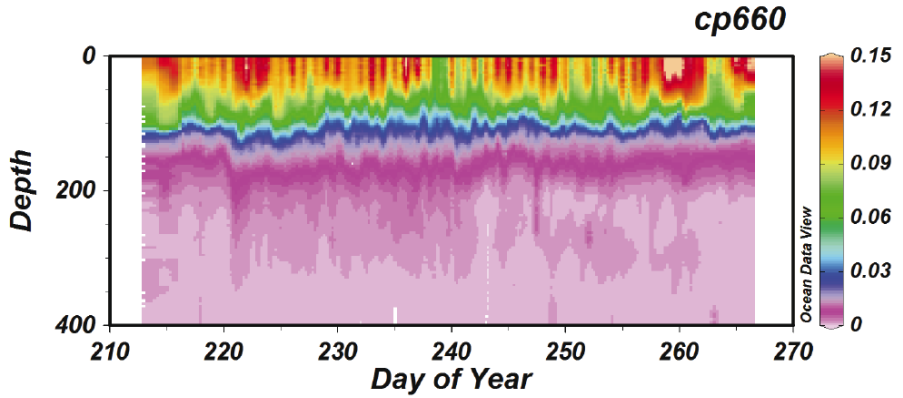


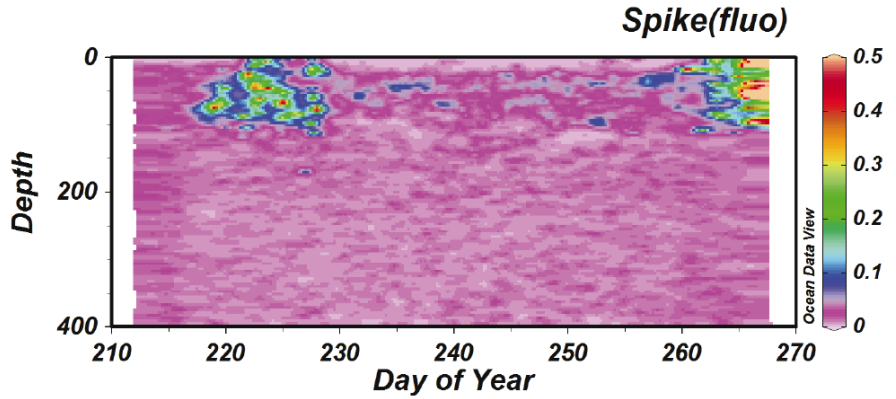


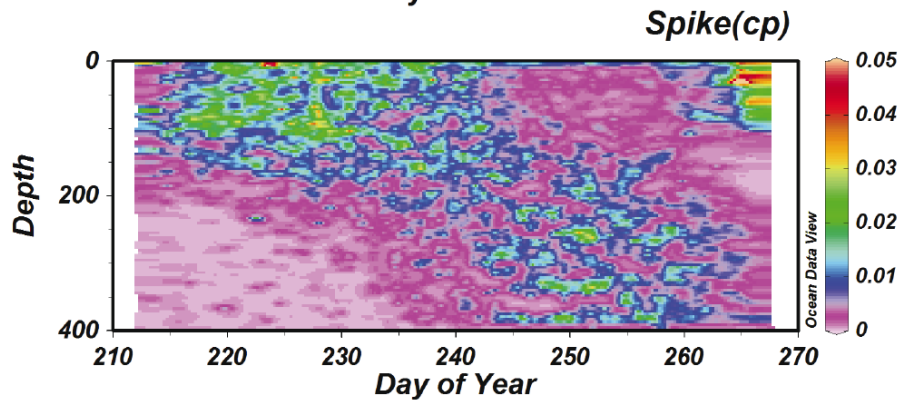
Separation of rare, large (fast sinking) particles (aggregates) from background.

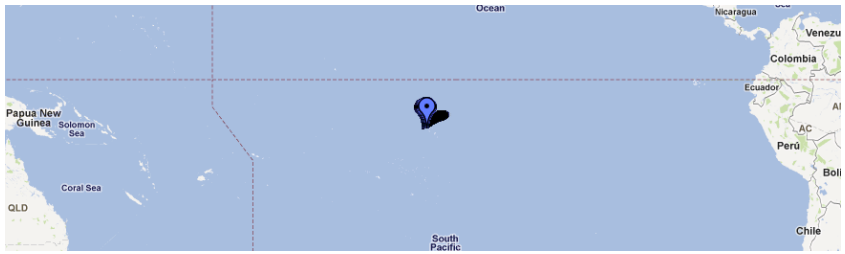
High resolution time series of Chl a (fluo) and POC (c_p_660) in plume of Marquesas Island – total biomass and spikes

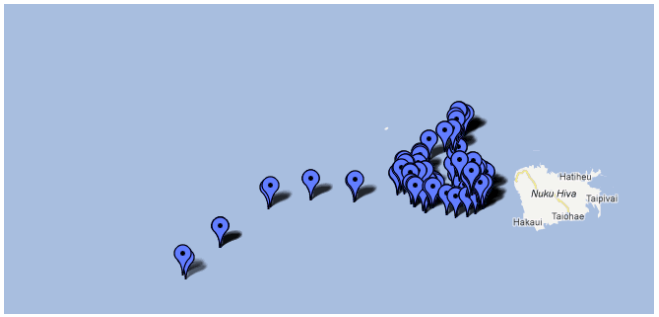






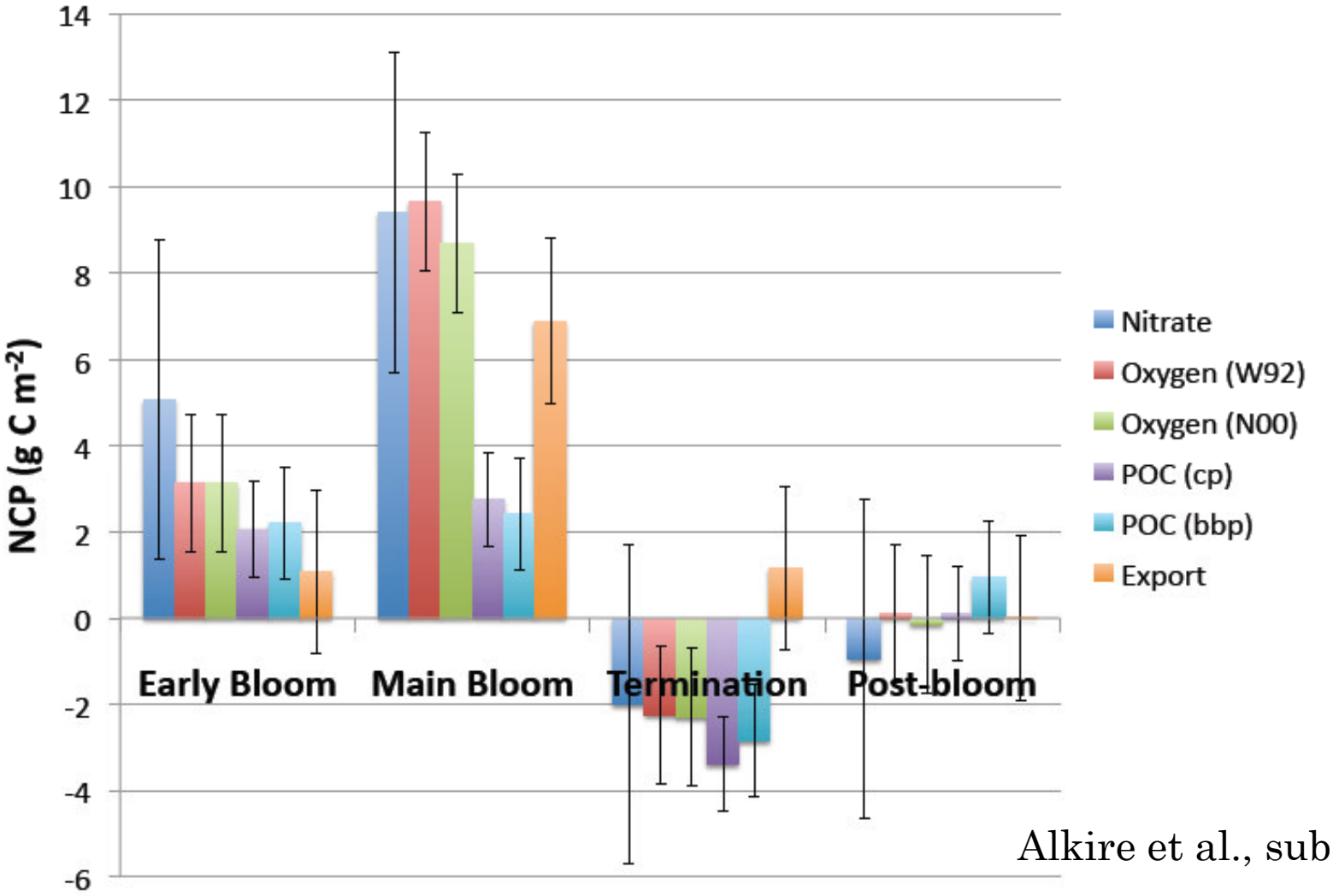






H. Claustre, 2011, personal communication

Net community production based on different in-situ measurements



Alkire et al., submitted

Multiple approaches better constrain a process.

Summary

- Proxies are continuously being created and refined.

- Understanding the issues associated with conversion between proxies and biogeochemical variables can further improve conversions.

- Using multiple proxies, and coupling proxies with velocity measurements, could further constrain standing stocks and fluxes.

- Standard protocols and inter-comparisons are essential for quality distributed data (in time and space).