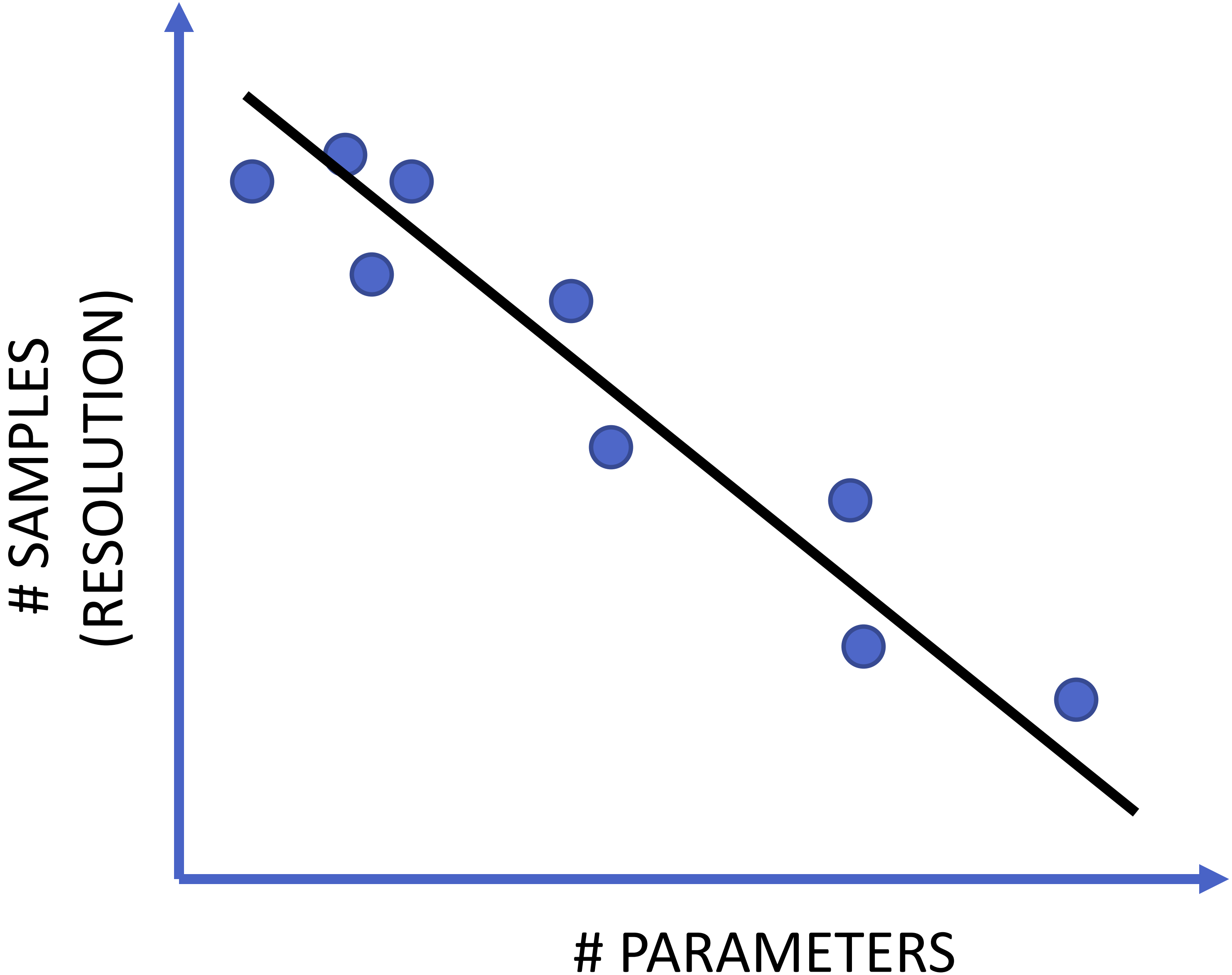
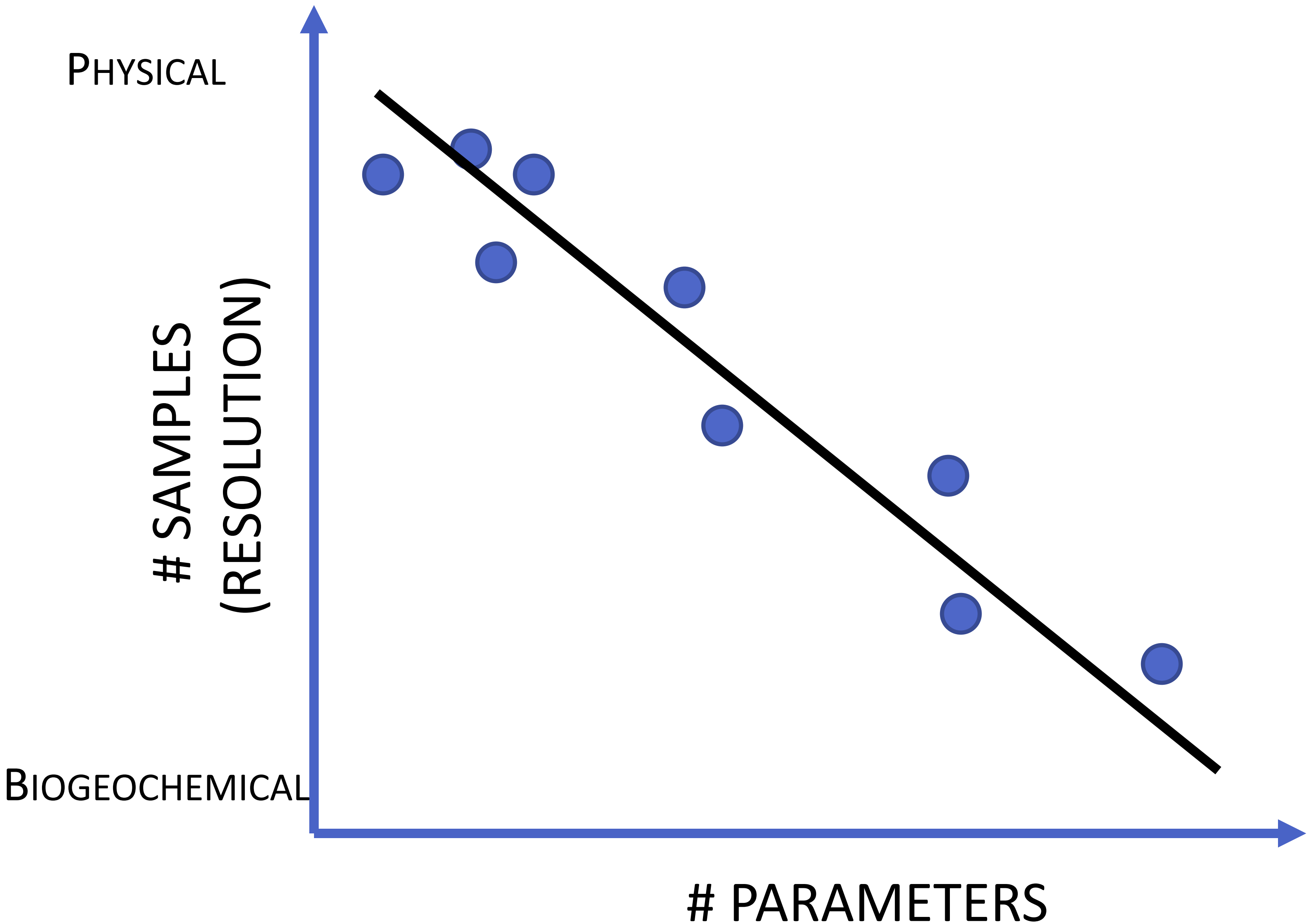
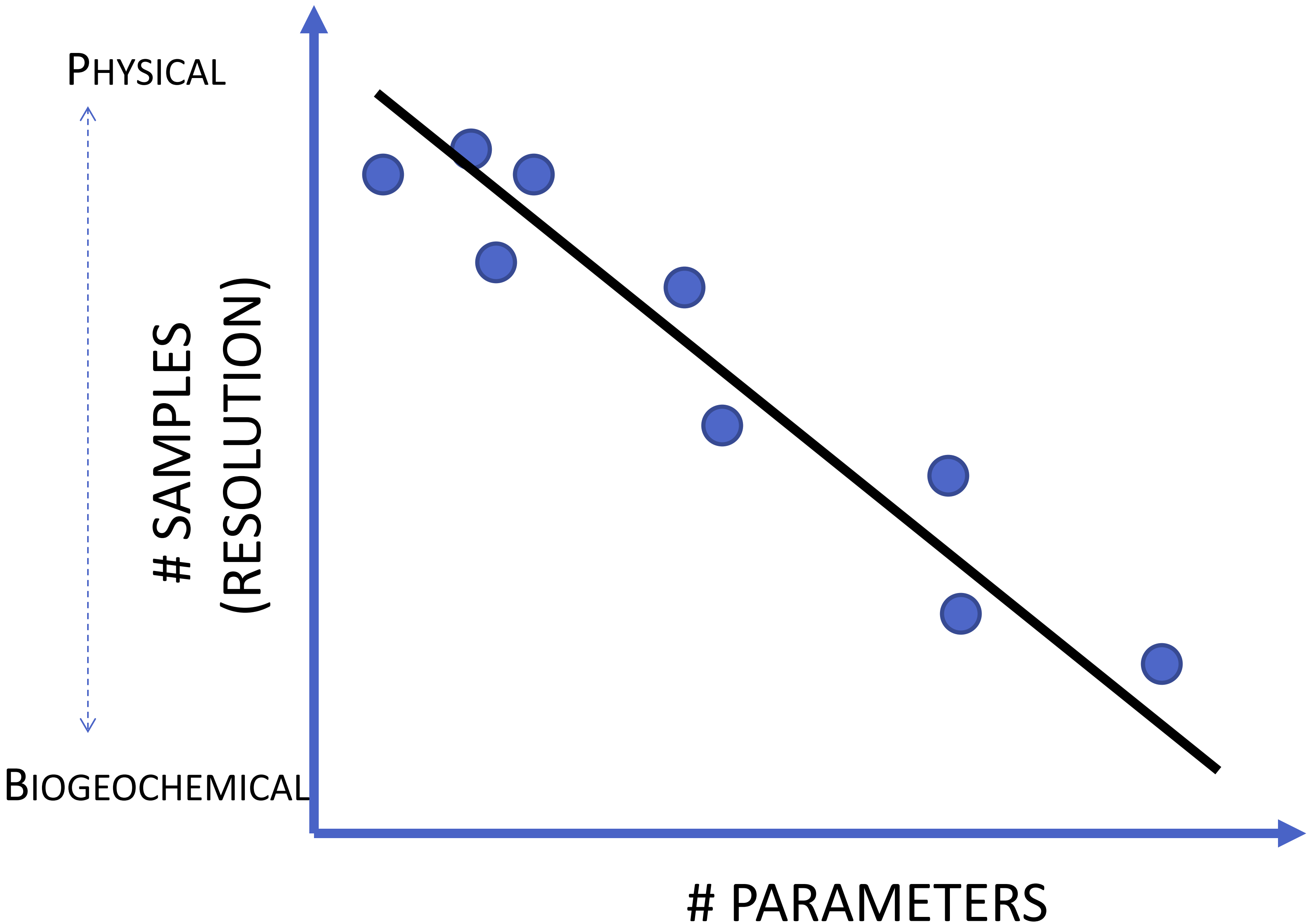
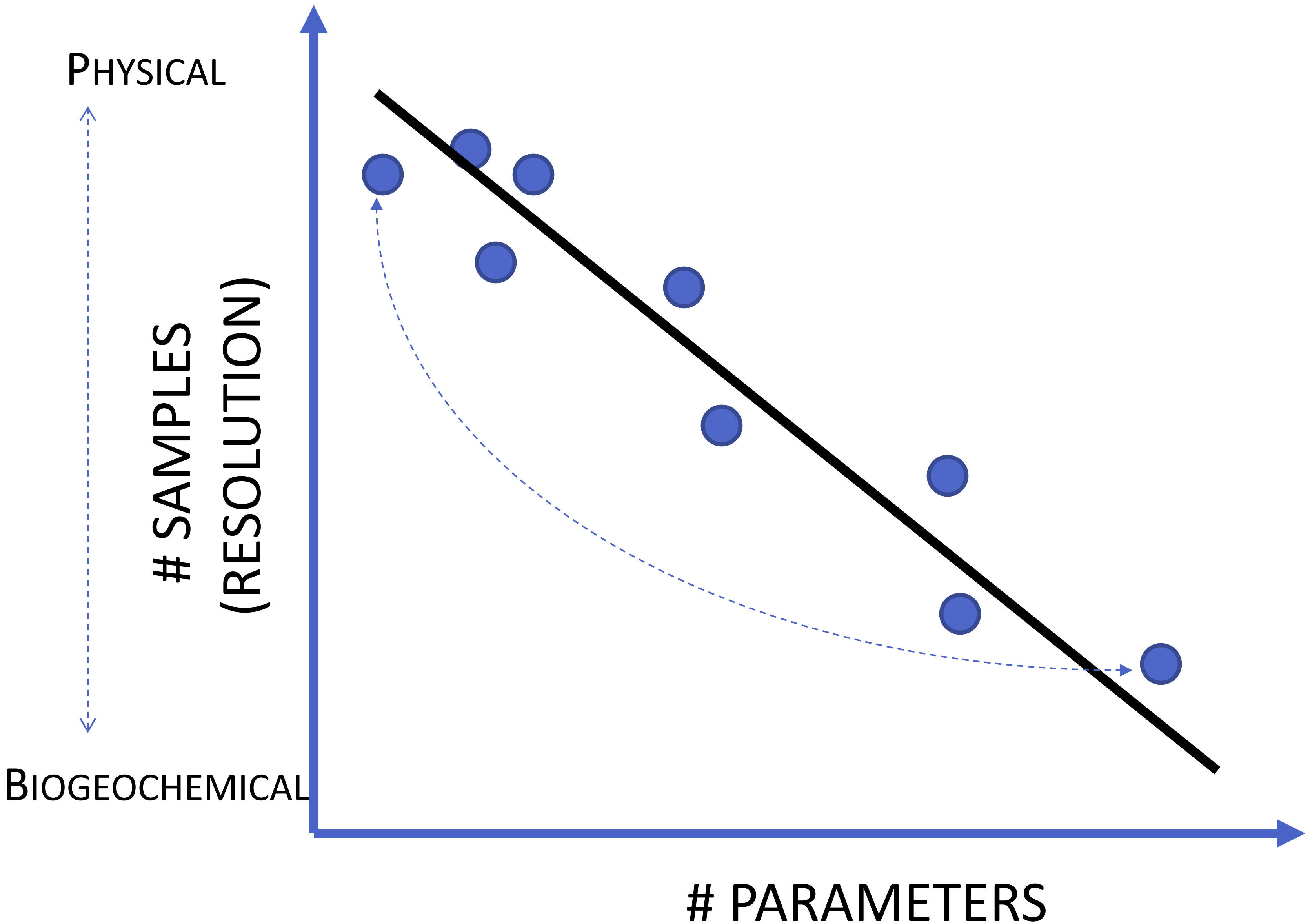

SAMPLES
(RESOLUTION)
PARAMETERS


PHYSICAL
BIOGEOCHEMICAL
SAMPLES (RESOLUTION)
PARAMETERS


PHYSICAL
SAMPLES
(RESOLUTION)
BIOGEOCHEMICAL
PARAMETERS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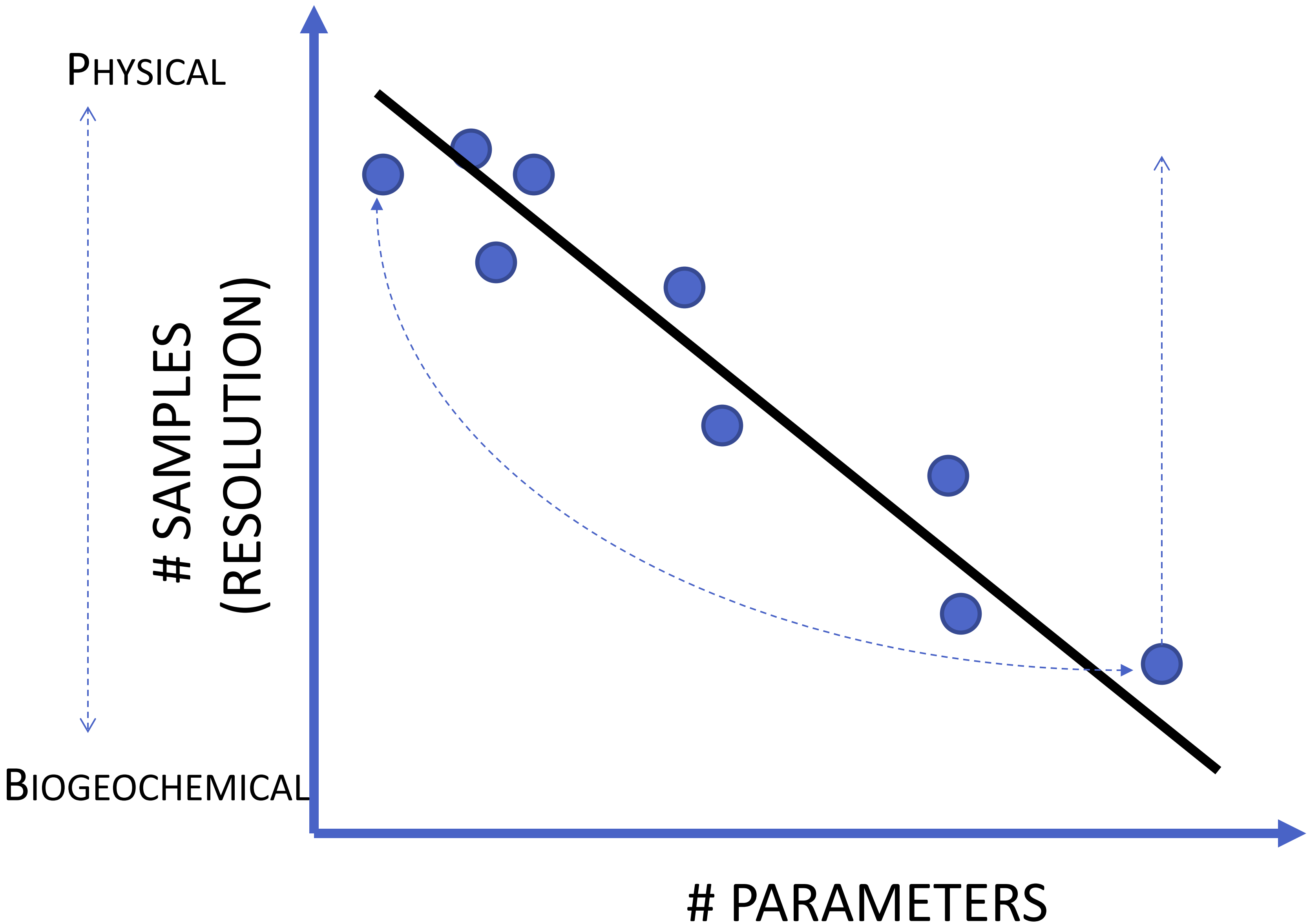
BIOGEOCHEMICAL
SAMPLES
(RESOLUTION)
PARAMETERS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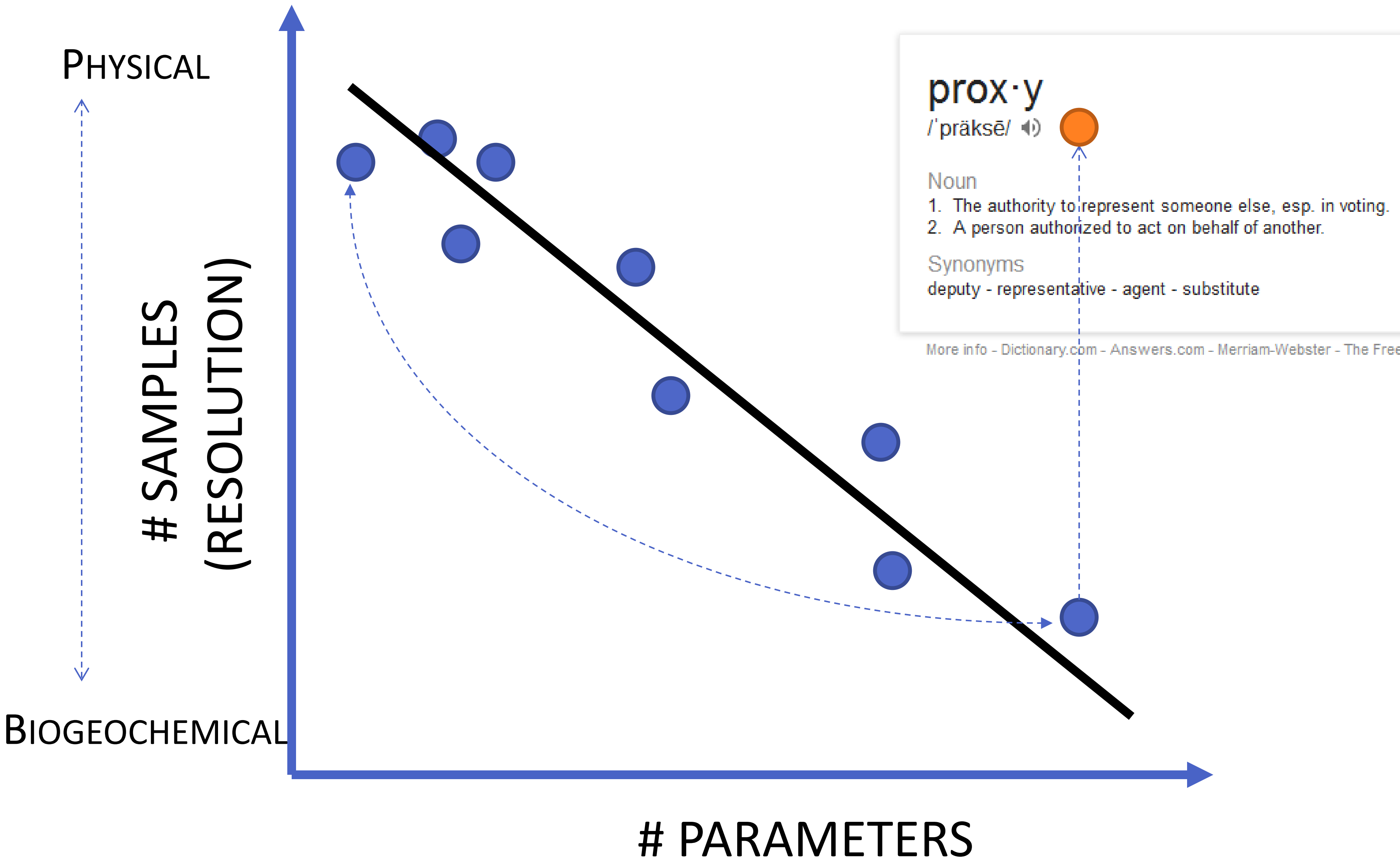
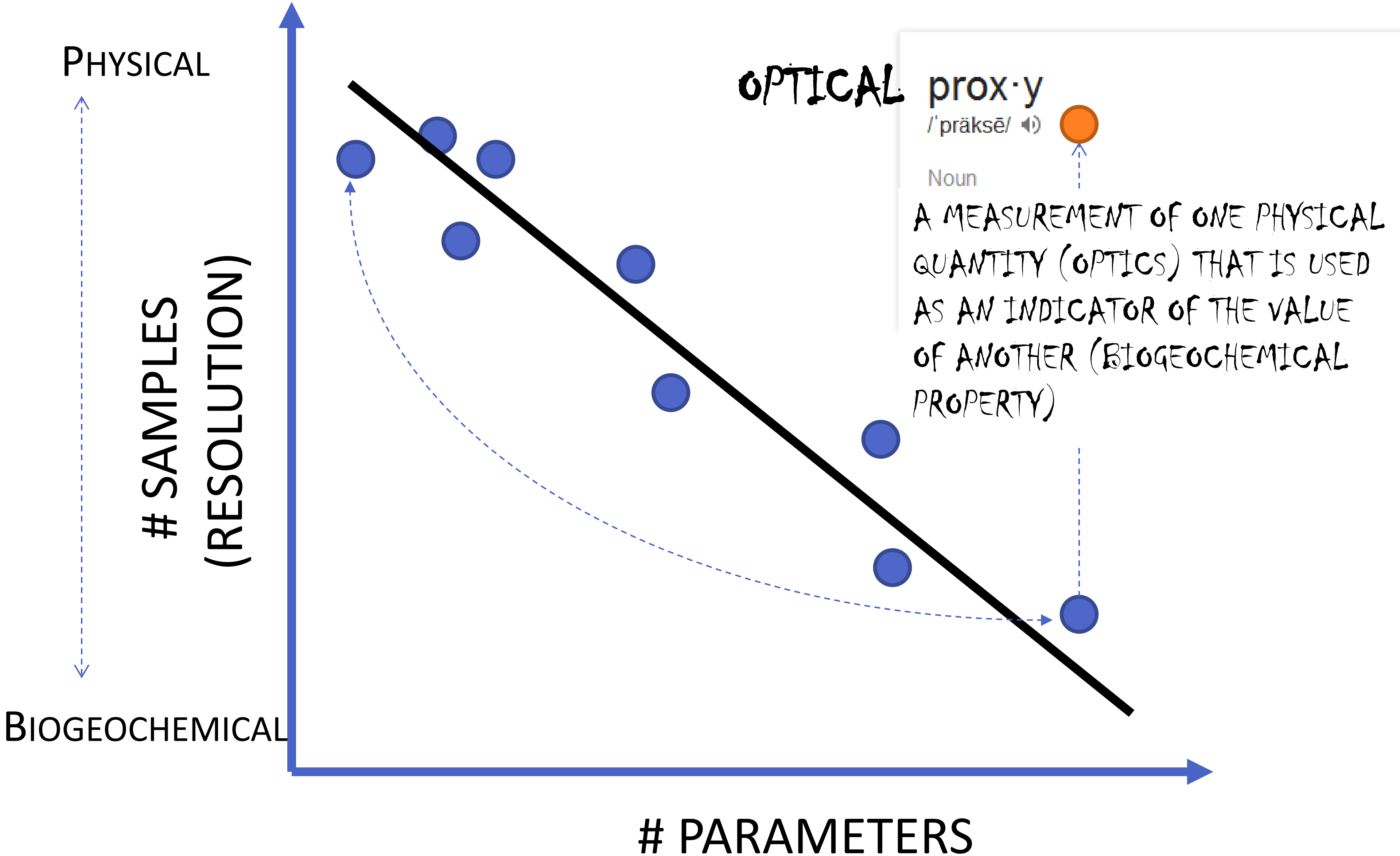
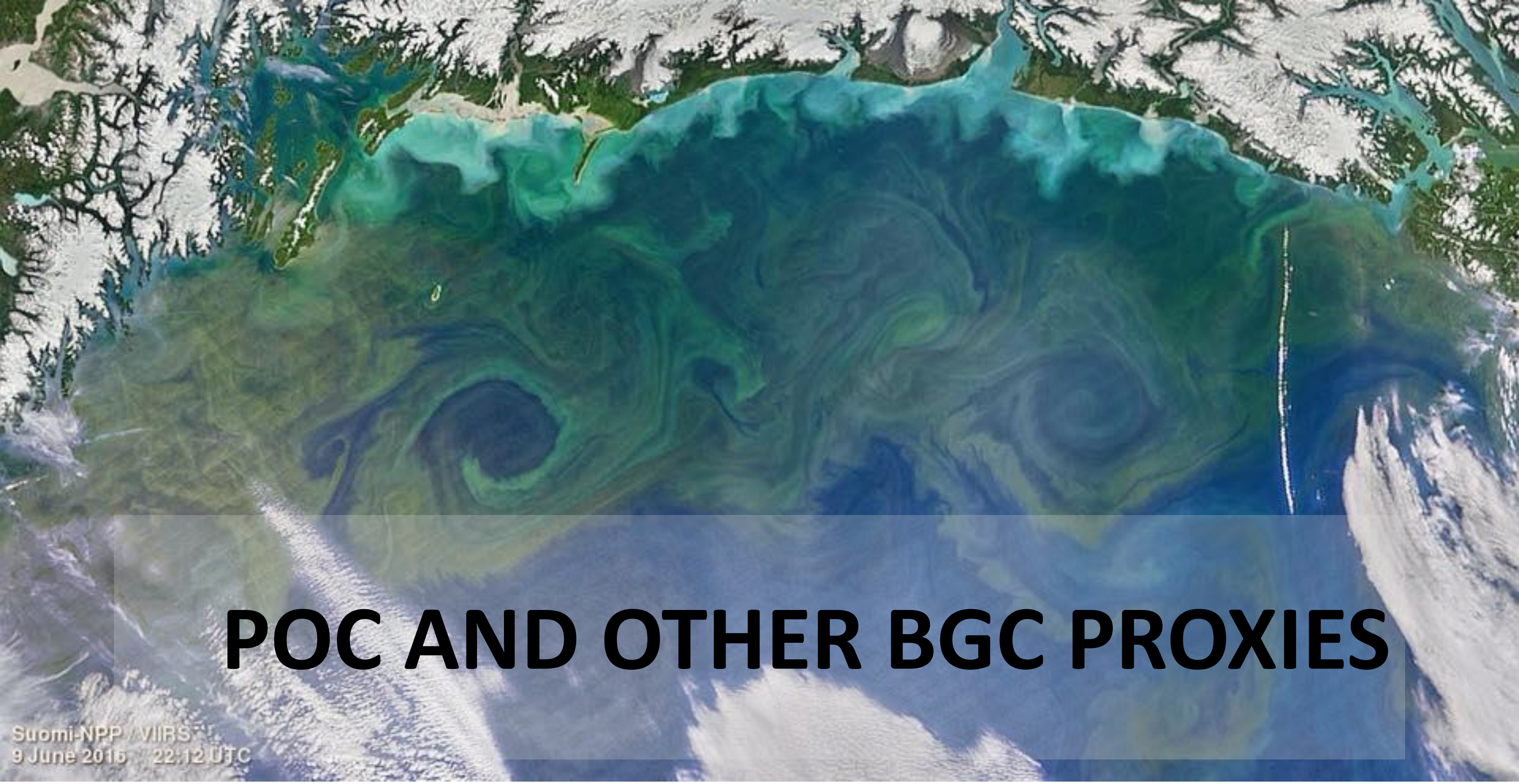
BIOGEOCHEMICAL
SAMPLES
(RESOLUTION)
PARAMETERS


PHYSICAL
BIOGEOCHEMICAL
SAMPLES
(RESOLUTION)
PARAMETERS
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
More info - Dictionary.com - Answers.com - Merriam-Webster - The Free


PHYSICAL
BIOGEOCHEMICAL
SAMPLES (RESOLUTION)
PARAMETERS
OPTICAL
prox·y
/ˈpräksē/
Noun
A MEASUREMENT OF ONE PHYSICAL QUANTITY (OPTICS) THAT IS USED AS AN INDICATOR OF THE VALUE OF ANOTHER (BIOGEOCHEMICAL PROPERTY)



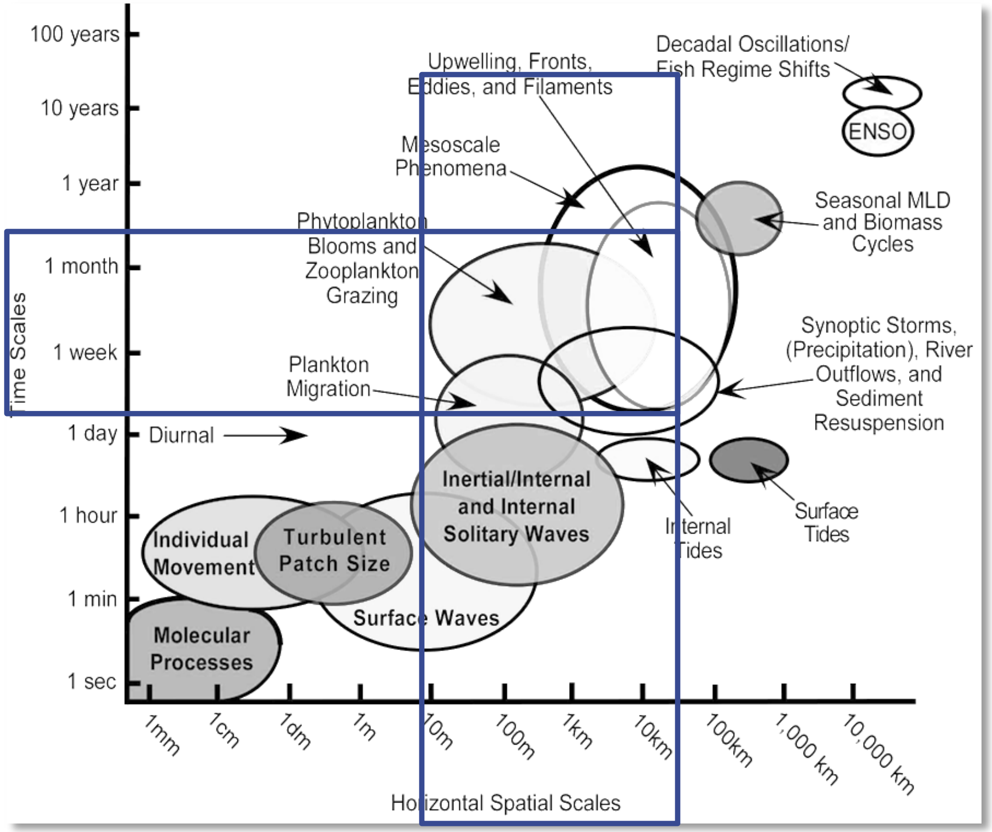
POC AND OTHER BGC PROXIES

IVONA CETINIĆ

NASA GODDARD SPACE FLIGHT CENTER / USRA

Why?

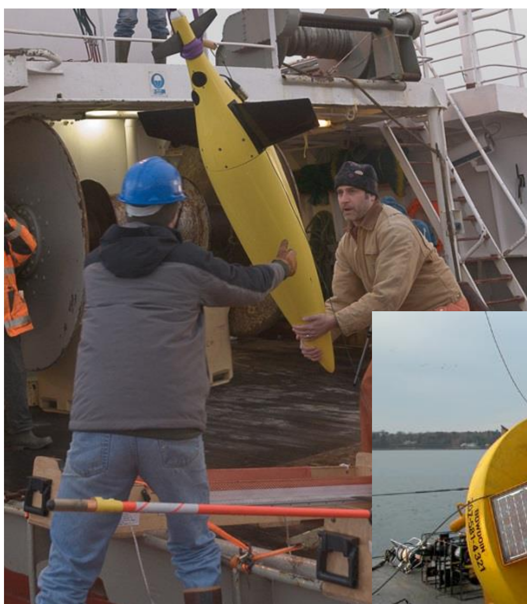
- Optics – in situ or remote sensed gives us higher resolution dataset
- Traditional methods (discrete) often expensive and time consuming
- Sampling the parameters on the scales of importance
- <u>Validation for remote sensing and hi-res biogeochemical models</u> (e.g. Haëntjens et al, 2017)

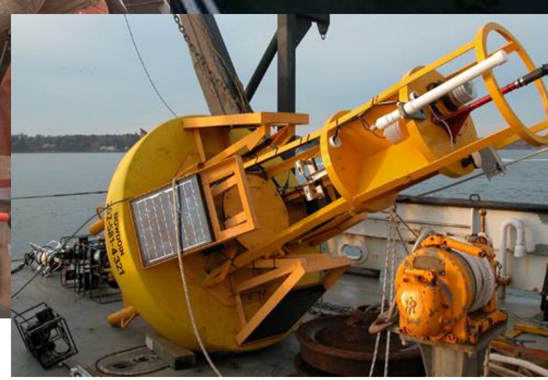


Chang, G. and T. Dickey (2008).

Why?

- Optical instruments are getting smaller, more robust and diverse
- They can be deployed over extended periods of time and in hard to reach areas





How?

COLLIN R., 2015:

ANYTHING THAT CAUSES VARIABILITY IN THE SAMPLE IS AN OPPORTUNITY TO EXTRACT ADDITIONAL INFORMATION FROM THAT SAMPLE.

Few examples of real entities and associated optical proxies (in situ)

- Quantity
  - Chlorophyll -> Chlorophyll fluorescence, a(676)
  - Particulate organic carbon – c_p, b_{bp}
  - Phytoplankton carbon – $b_{bp,}$ Chl
  - Suspended particulate matter - c_p, b_{bp}
  - Particulate Inorganic Carbon – acid labile b_{bp} (Balch – week 4), cross - polarized attenuation (Bishop's Carbon Exporer)
  - Dissolved organic carbon – CDOM absorption, fluorescence (next week more)
  - Nitrate, sulfates – UV absorption
  - Primary productivity – Fv/Fm , diel variability
- Quality (particulate composition)
  - Particulate composition – $b_{bp}/c_{p,}$ b_{bp}/b_p
  - Particle size - c_p, b_{bp} slopes and "fluctuation", multiple angle scattering, multiple angle c_p
  - Phytoplankton composition – Chl, a (λ), Chl/C, multiple channel fluorescence
  - DOC type – CDOM fluorescence and slope

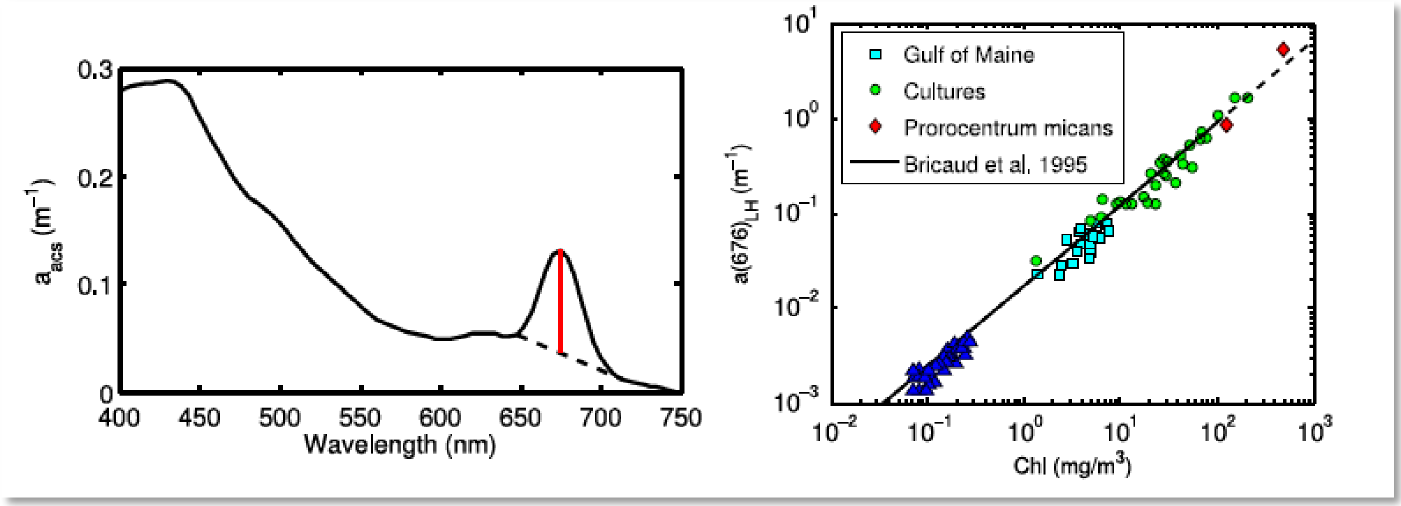
Check out - Boss et al (2014) and Babin, Roesler and Cullen (2008)

Few examples of real entities and associated optical proxies (in situ)

- Change in these quantities will tell us something about fluxes
  - Fluxes– movement of a quantity from one pool to another
    - Space - e.g. carbon export from mixed layer to deeper ocean
    - Time – productivity - e.g. primary production
    - Type – e.g. phytoplankton to detritus, POC to DOC

CHLOROPHYLL BIOMASS (ABSORPTION)

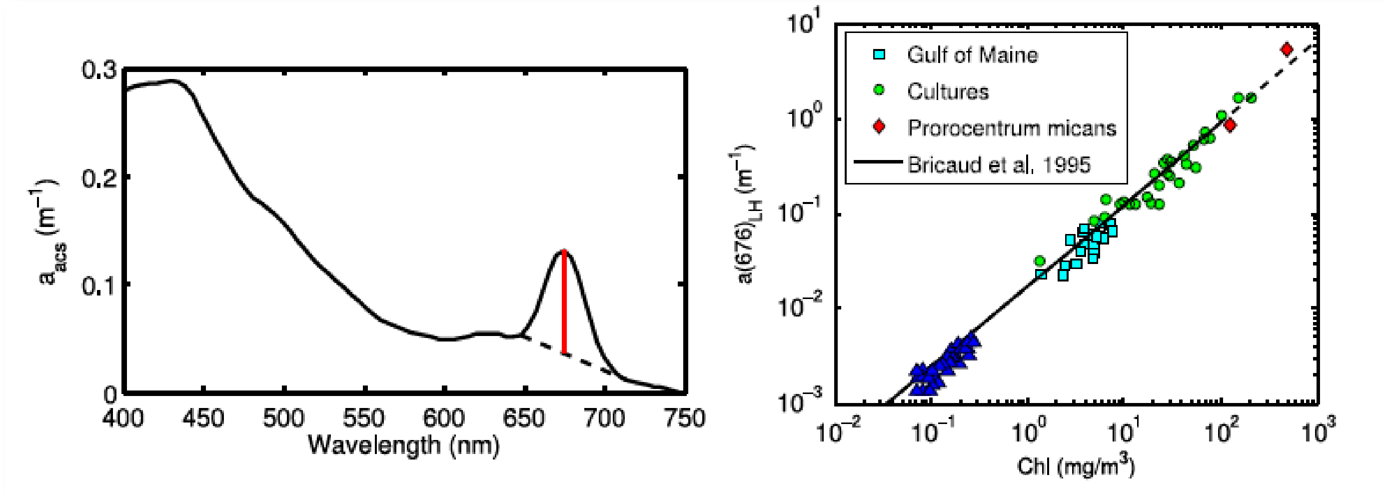
(CHLOROPHYLL IS NOT A CHLOROPHYLL IS NOT A CHLOROPHYLL)



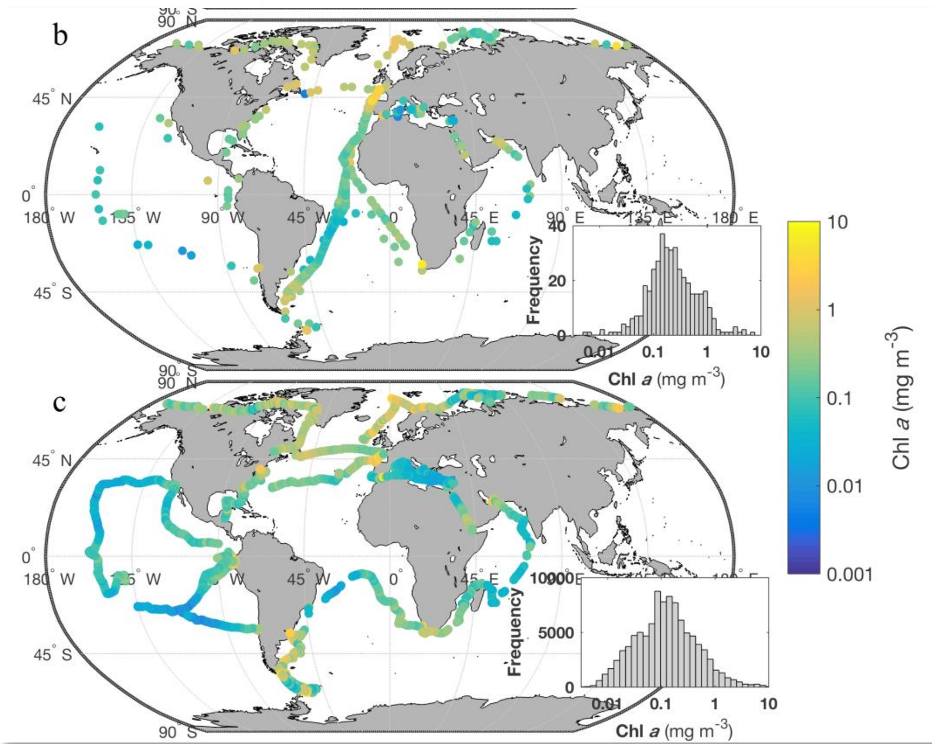
Roesler and Bernard, 2013

CHLOROPHYLL BIOMASS (ABSORPTION)

(CHLOROPHYLL IS NOT A CHLOROPHYLL IS NOT A CHLOROPHYLL)



Roesler and Bernard, 2013

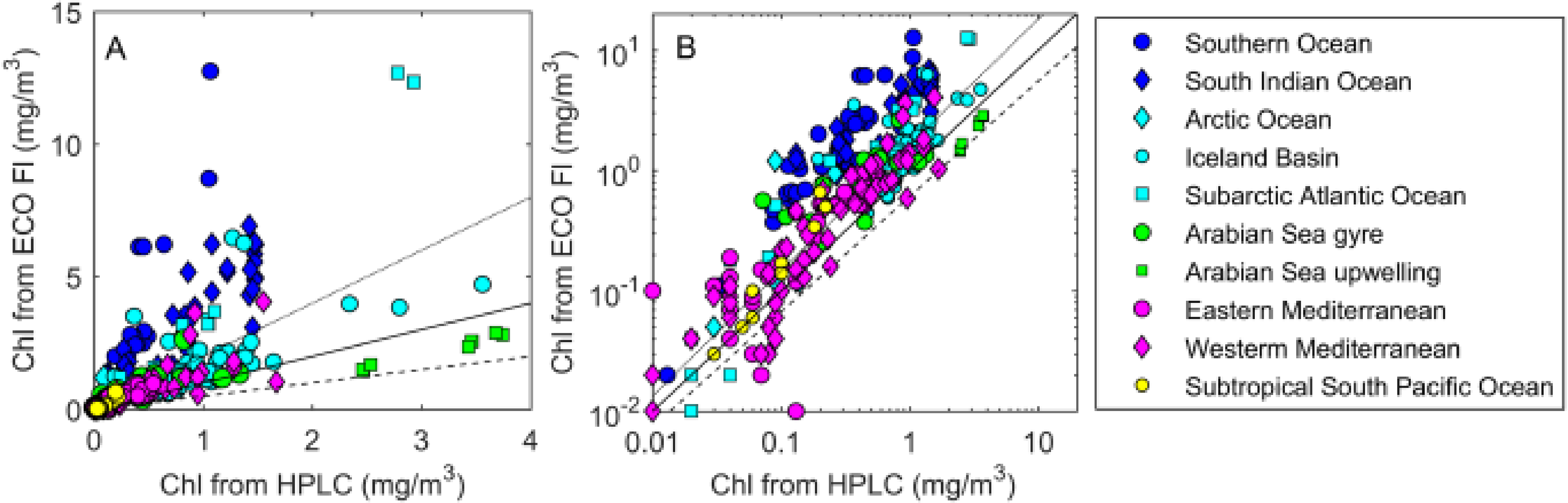


Chase et al, 2017 (in review)

Chl - HPLC n = 402
Chl – a_p n= 96,929

CHLOROPHYLL BIOMASS (FLUORESCENCE)

(CHLOROPHYLL IS NOT A CHLOROPHYLL IS NOT A CHLOROPHYLL)

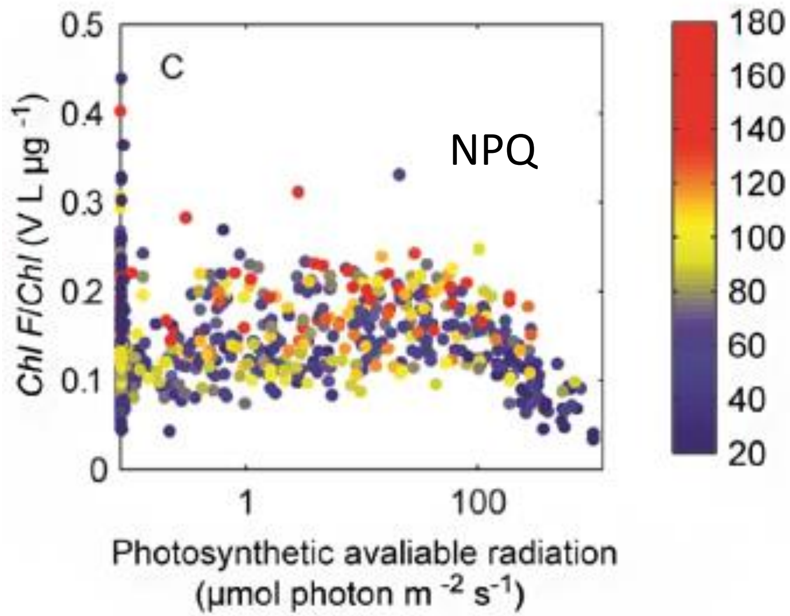


Roesler et al, 2017

CHLOROPHYLL BIOMASS (FLUORESCENCE)

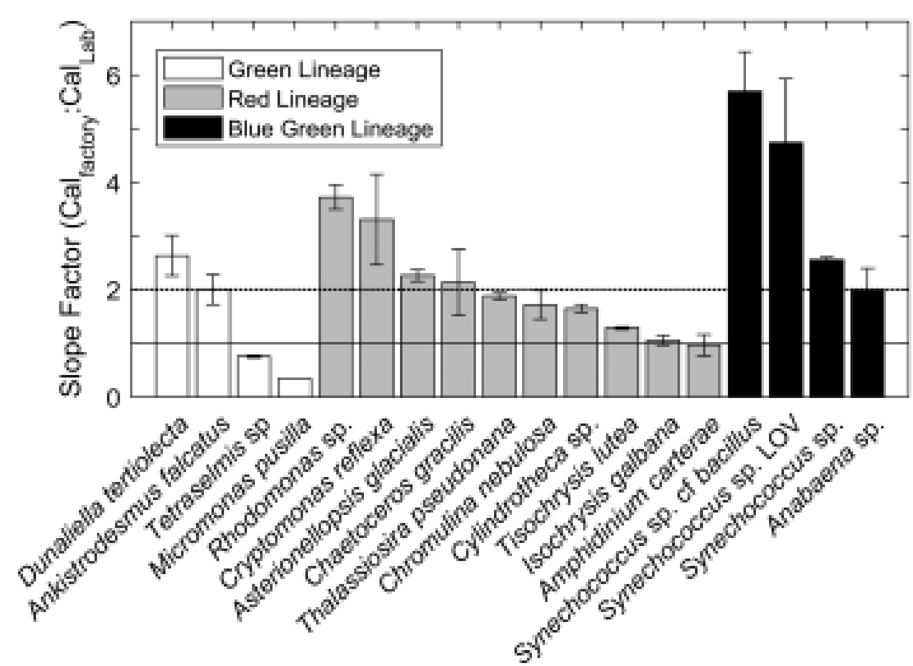
(CHLOROPHYLL IS NOT A CHLOROPHYLL IS NOT A CHLOROPHYLL)

1) Physiology - light, nutrients, life stages



Cetinić et al., 2015

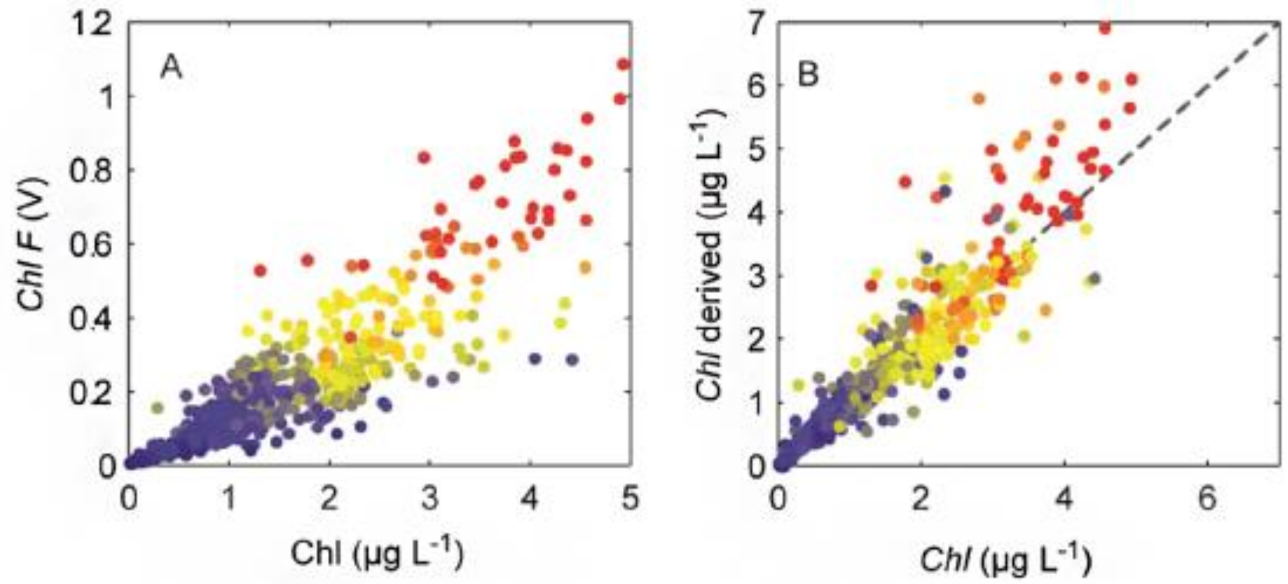
2) Species composition



Roesler et al, 2017

Chlorophyll biomass

(CHLOROPHYLL IS NOT A CHLOROPHYLL IS NOT A CHLOROPHYLL)



Non – linear function of PAR, temperature, depth and time (details in D'Asaro (2011))

- Not a simple correction, depended on multiple factors
- should be interpolated within the time/space of your experiment, not extrapolated

- See also Xing et al. 2016;

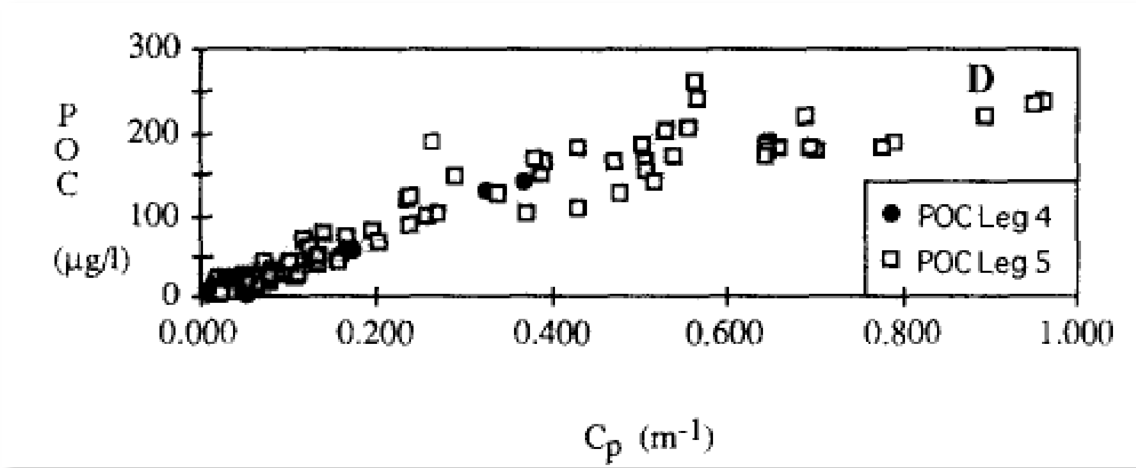
Particulate Organic Carbon & Suspended Particulate Material proxy

Backscattering and attenuation are associated with particle concentration / size.

However !!!

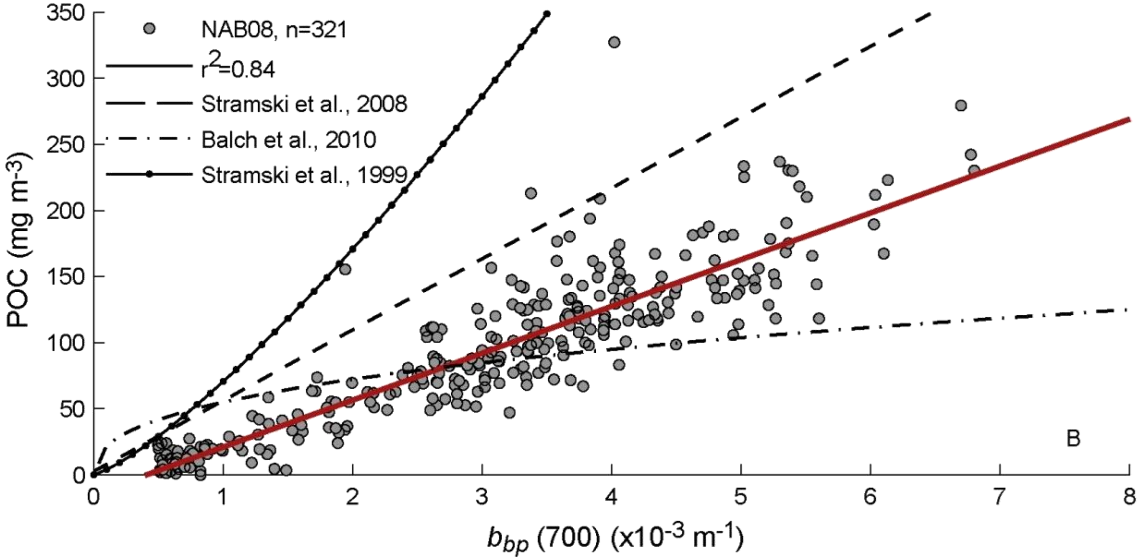
Backscattering is also highly dependent on morphology and type of the particle

Carbon density in all oceanic particles /phytoplankton is not the same.



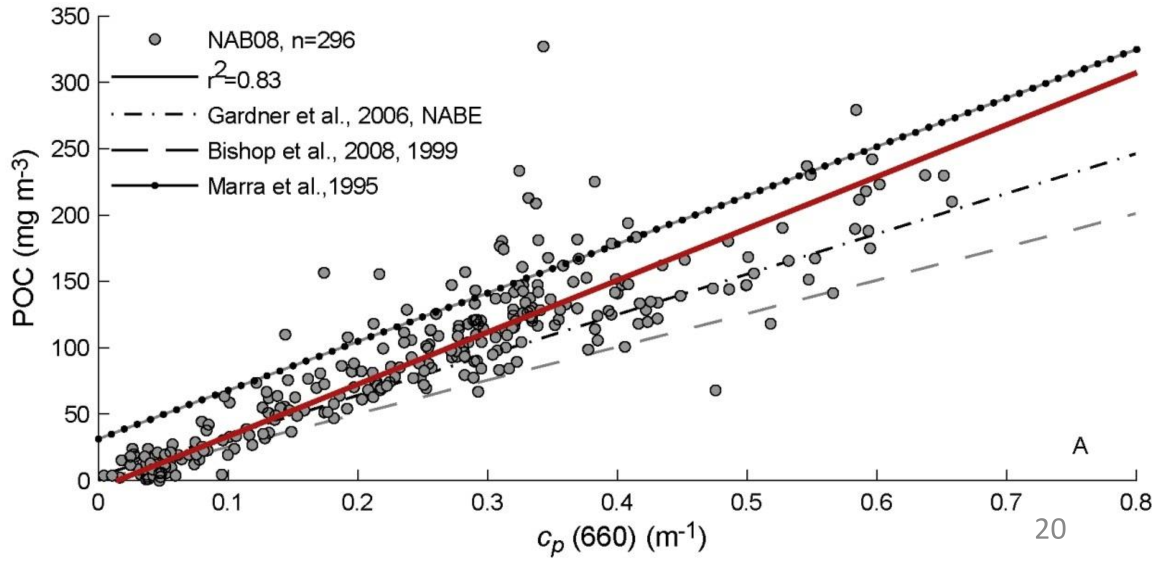
Gardner et al 1993

Particulate Organic Carbon



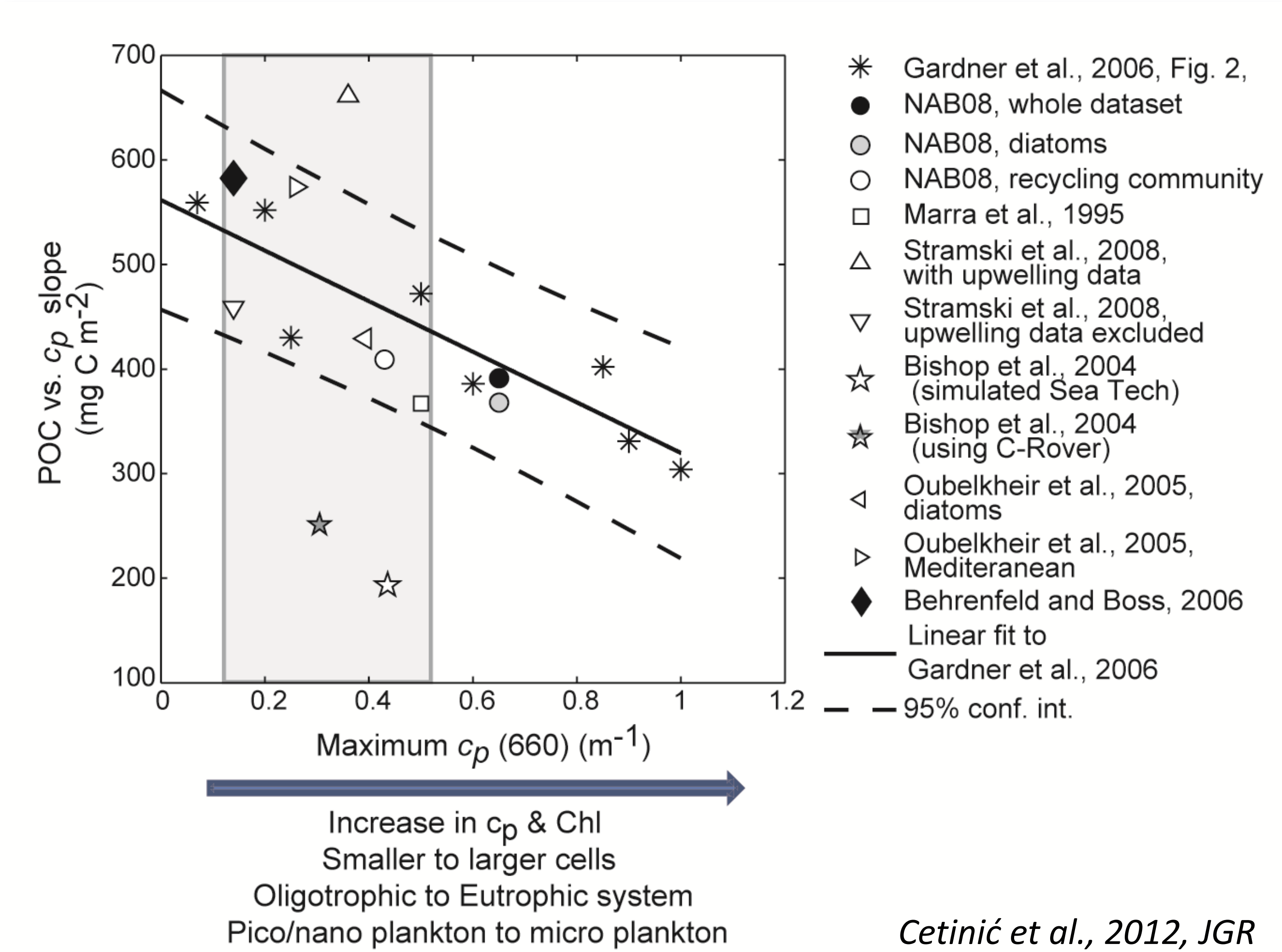
Particulate backscattering (b_{bp})

Beam attenuation (c_p)



Cetinić et al., 2012, JGR

POC/c_p slope comparison (mg C m^{-2})

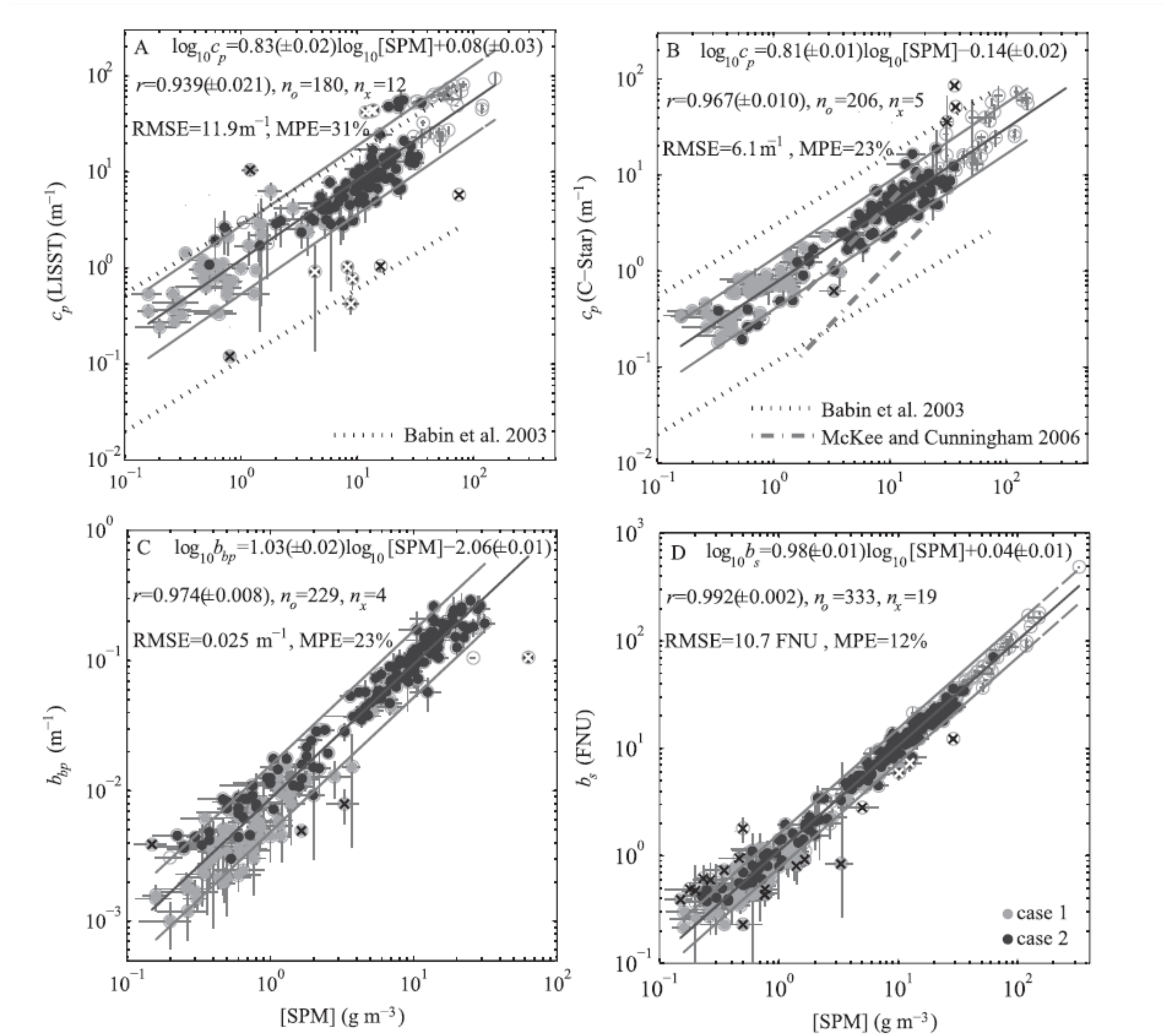


Cetinić et al., 2012, JGR

Suspended Particulate Matter

c_p

b_{bp}



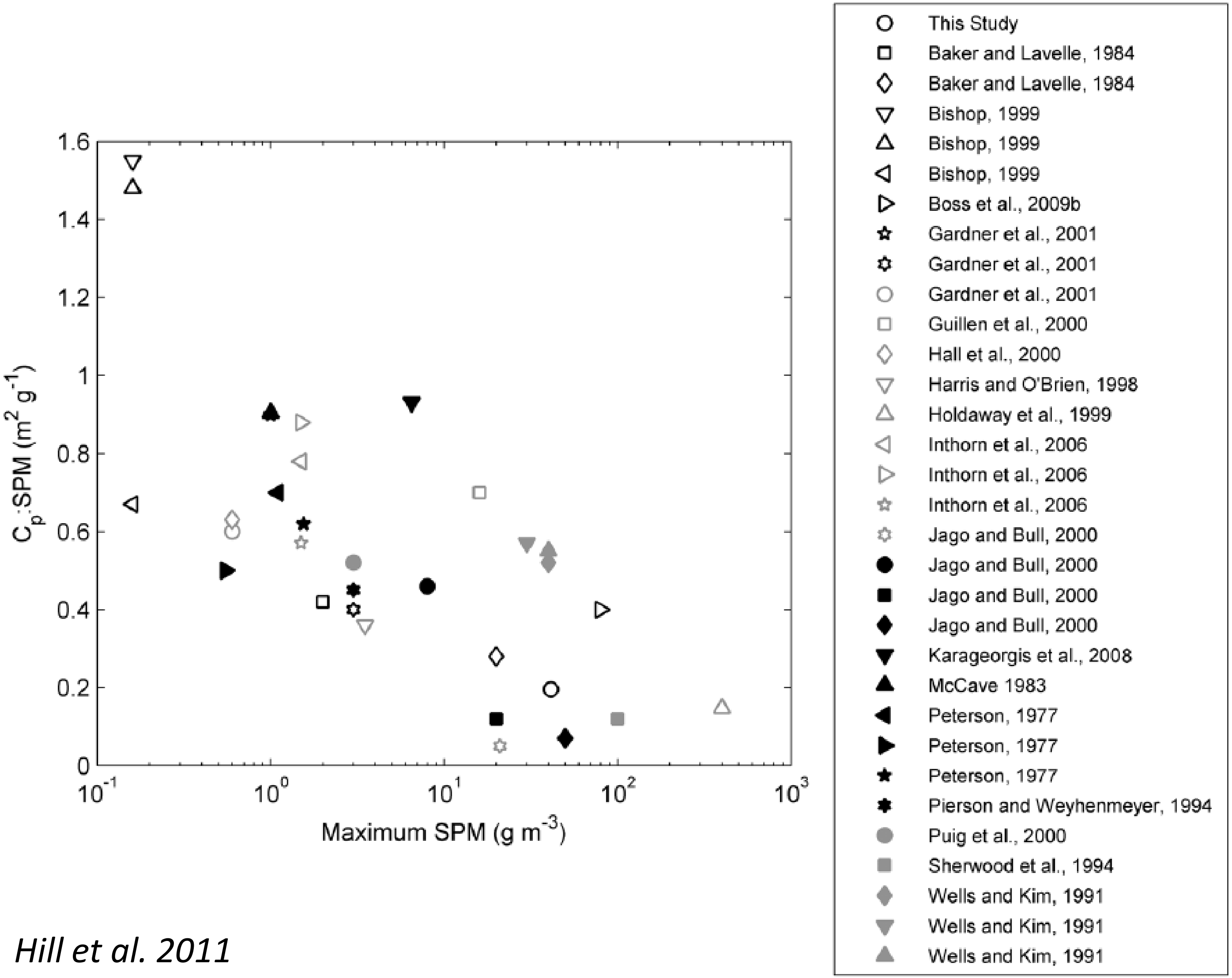
SPM

Particle apparent density

Particle composition

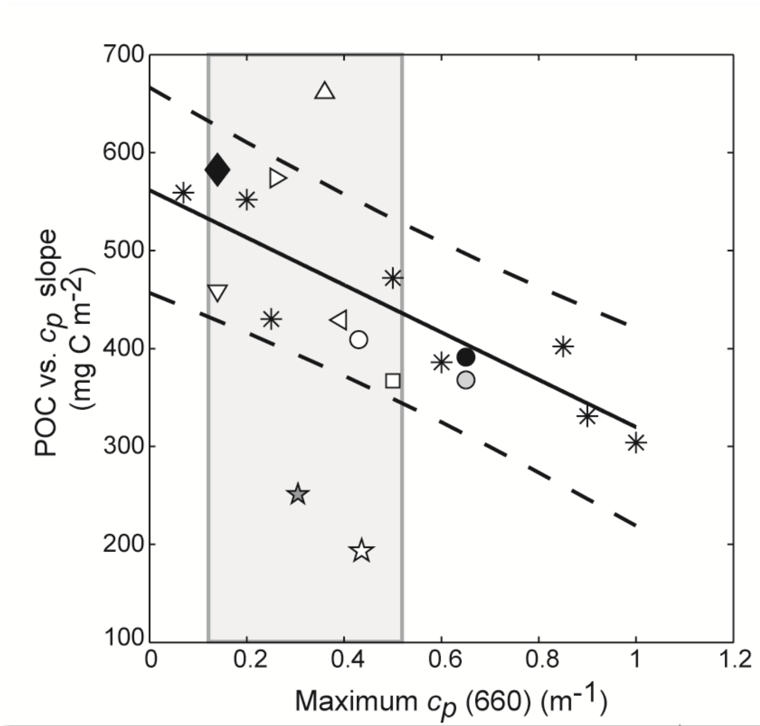
Nuekermans et al. 2012

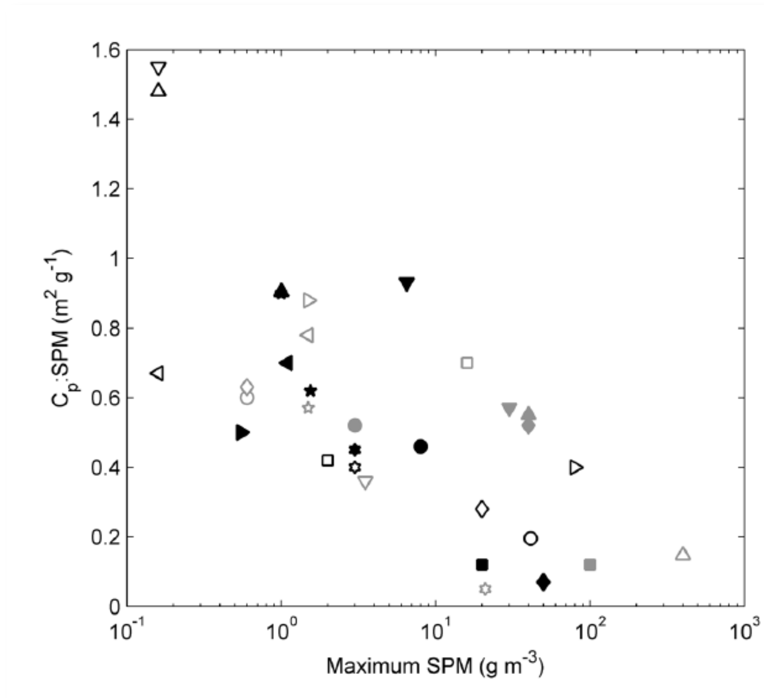
Suspended Particulate Matter



Hill et al. 2011

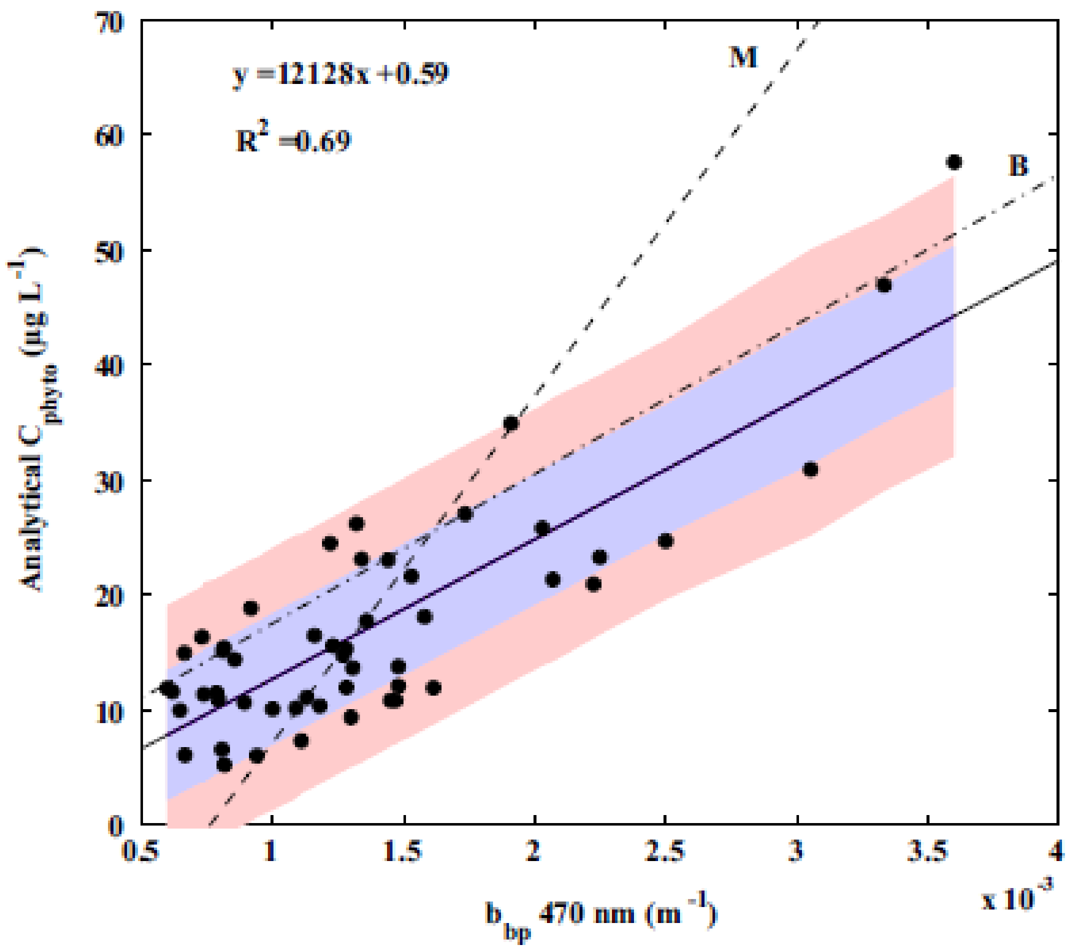
Why are we seeing opposite trends?





Phytoplankton carbon

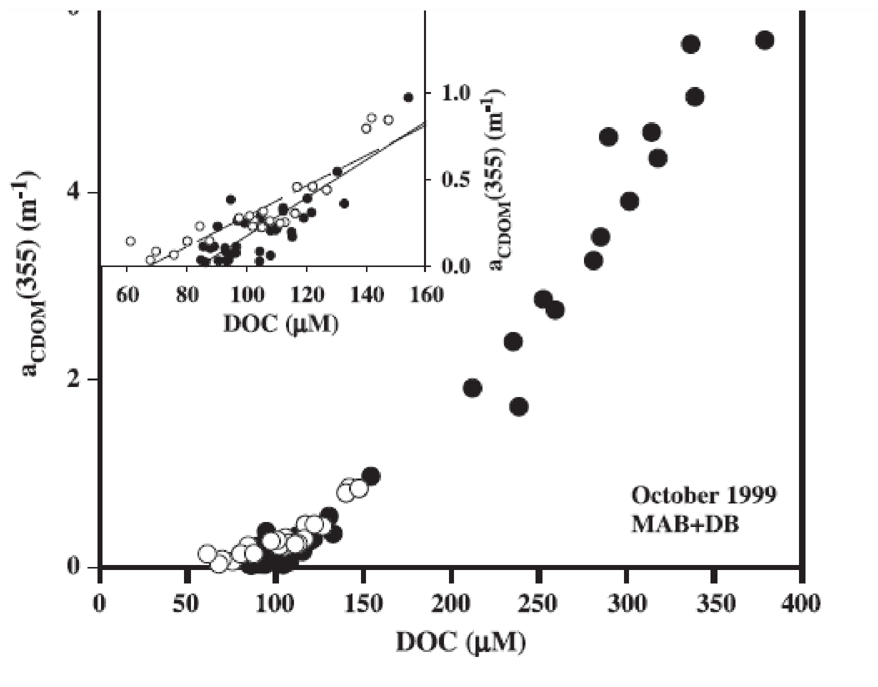
- Cell sorting technique in combination with optics
- Traditionally – calculation from of imaging/flow cytometry based biovolumes and cell/C values



Graff et al., 2015

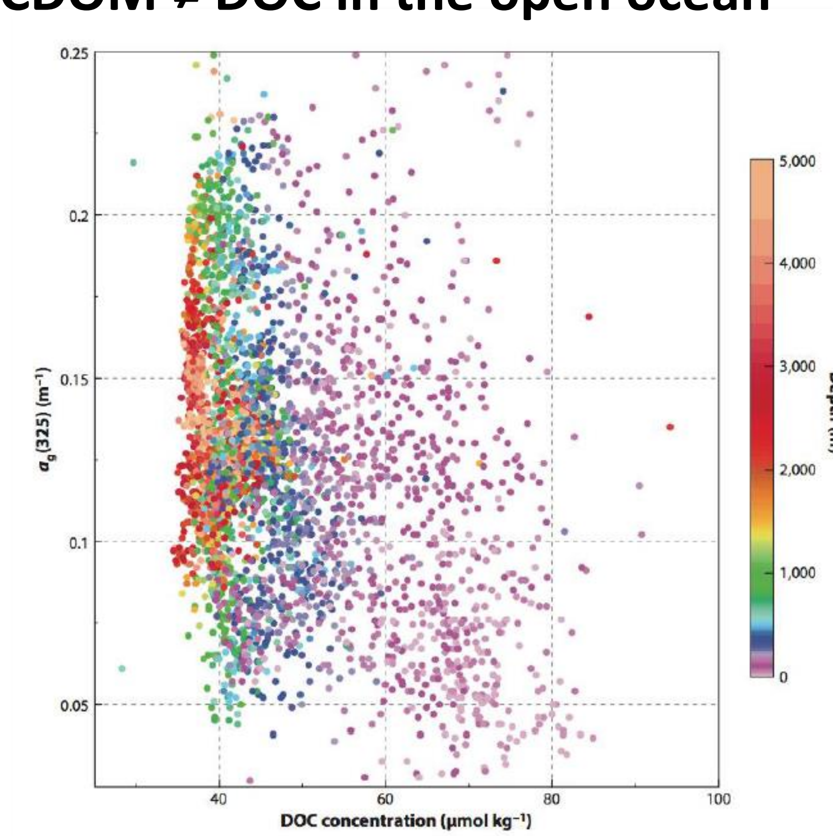
Dissolved Organic Carbon

CDOM = DOC in the coastal ocean



Vecchio and Blough, 2004

CDOM ≠ DOC in the open ocean

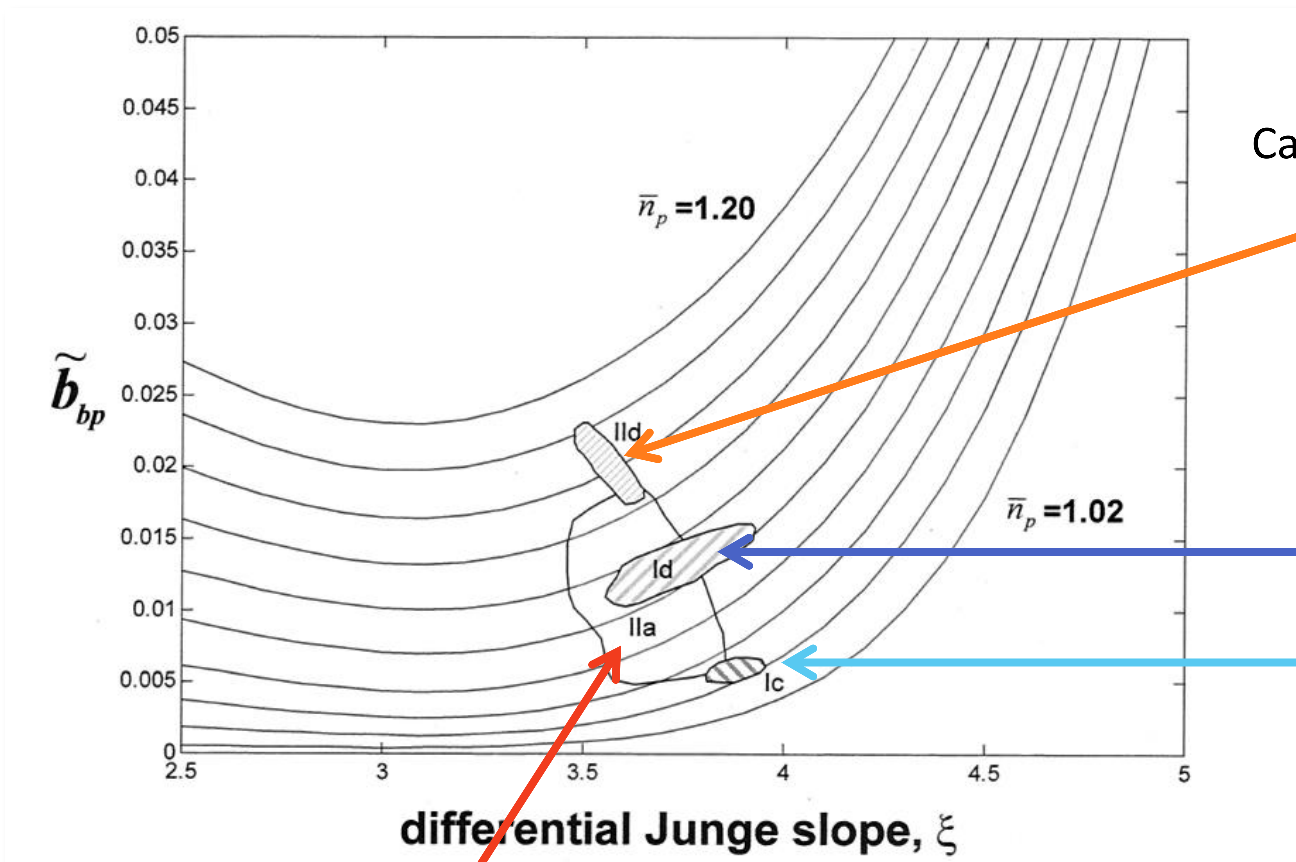


Nelson and Siegel 2013

As Rufus well knows, there's opportunity in chaos.

OPPORTUNITY IN CHAOS
QUALITY (COMPOSITION)

Particulate composition – b_{bp}/c_{p}, b_{bp}/b_{p}



Case II, bottom water

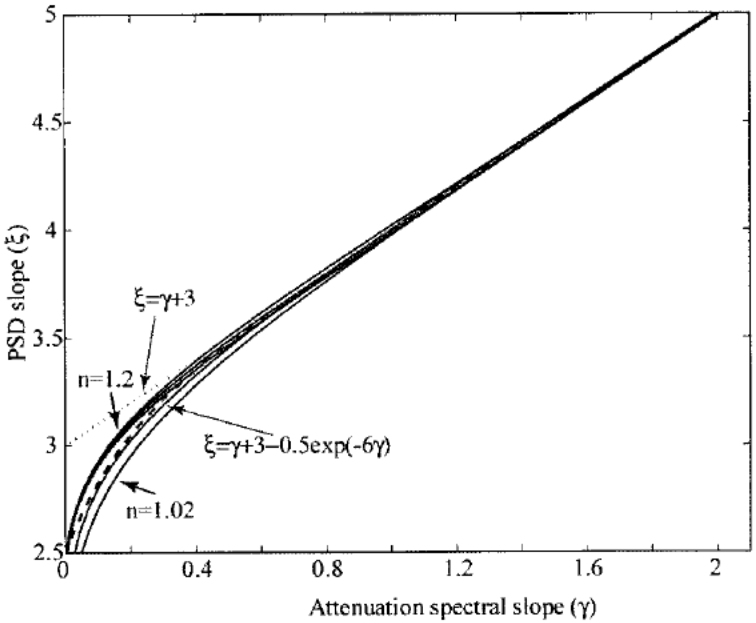
Case I, below 100 m

Case I, Chl maxima

Case II, coastal waters in complex enviroment

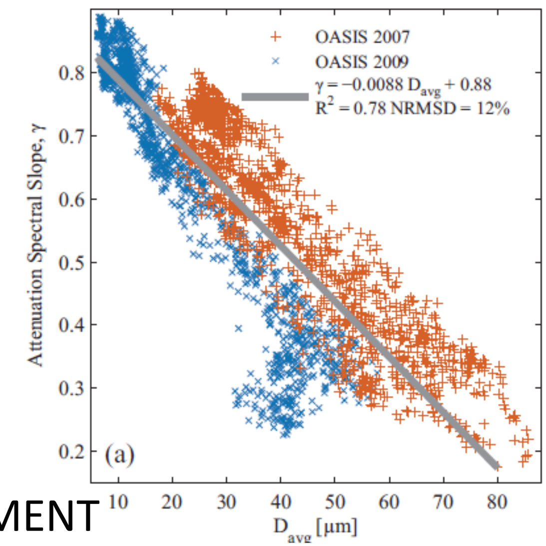
Twardowski et al, 2001

Particle size – slope based



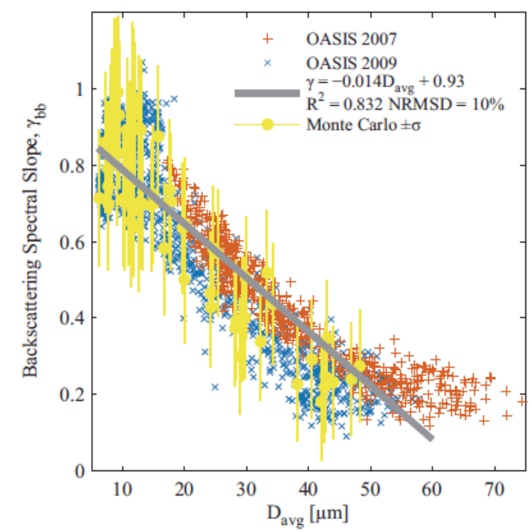
Boss et al, 2001

c_p



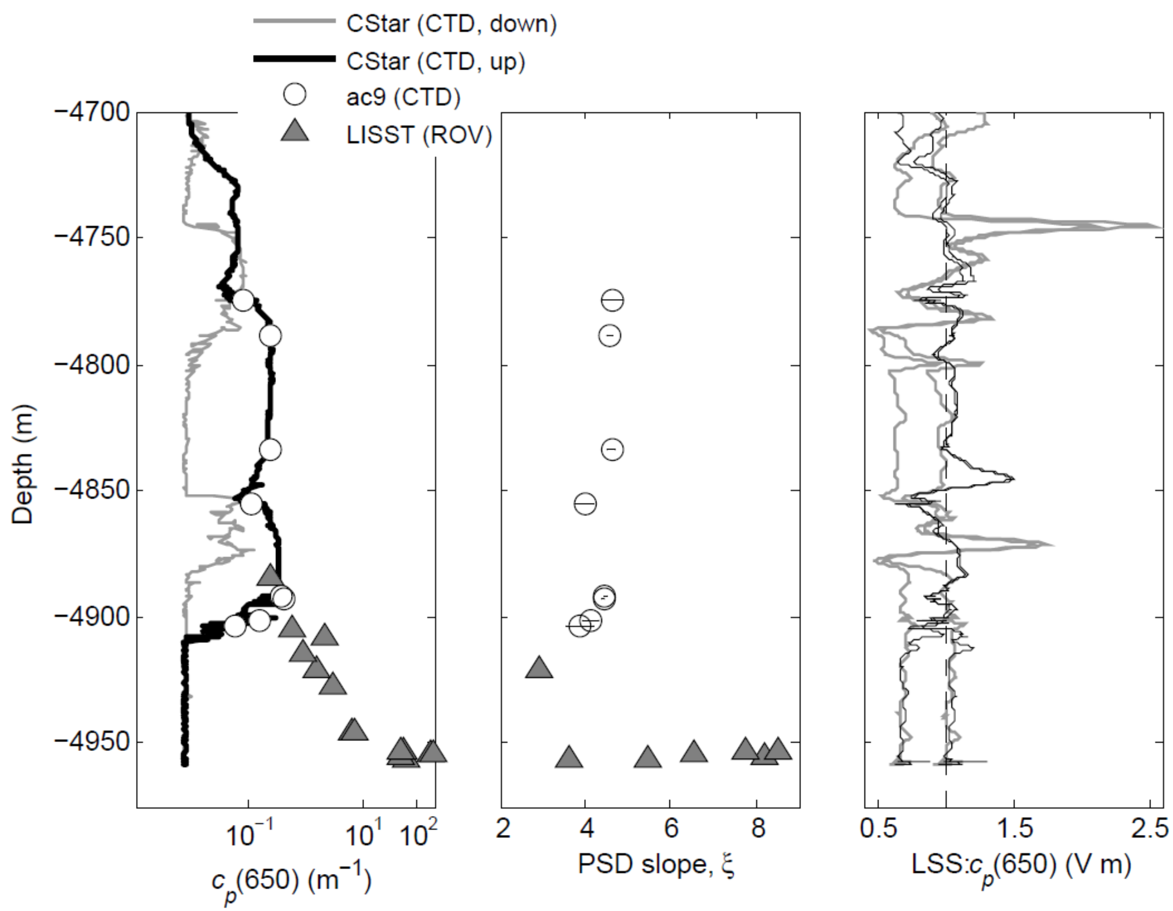
SEDIMENT

b_{bp}



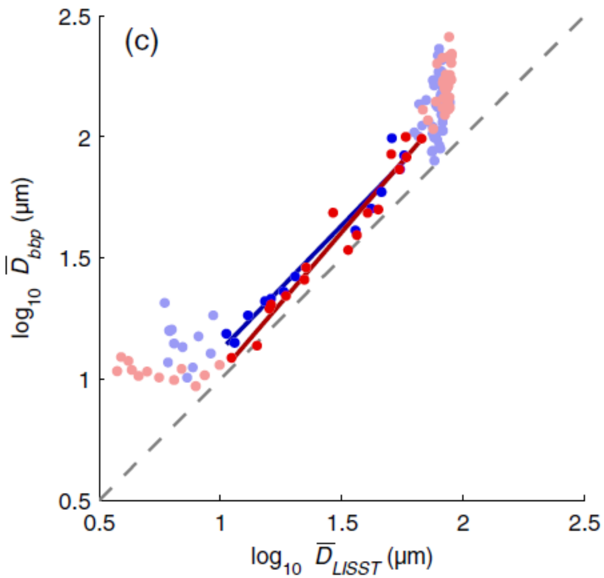
Slade & Boss, 2015

Application - Particle composition in a hydrothermal plume



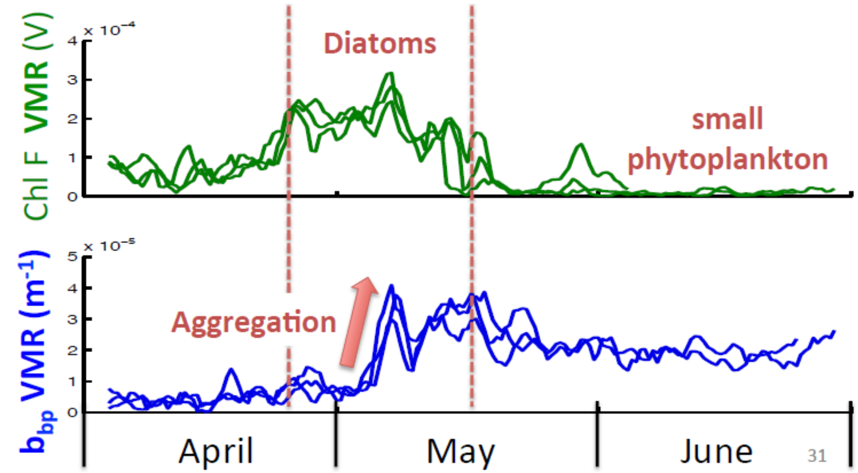
Estapa et al, 2015

Particle size – fluctuation based



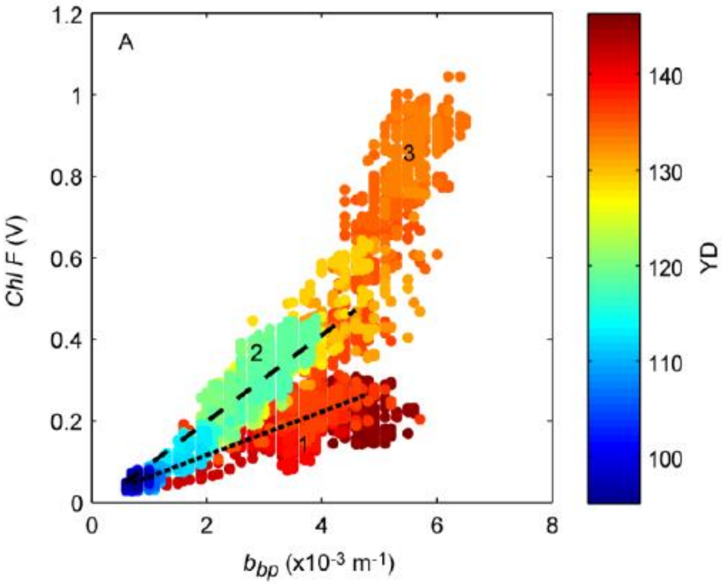
Briggs et al, 2013

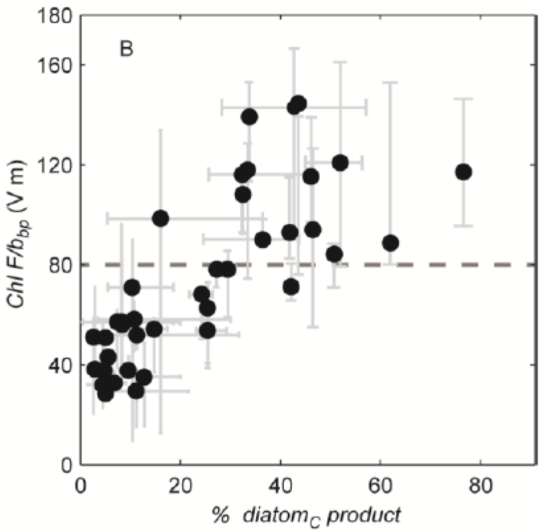
Application

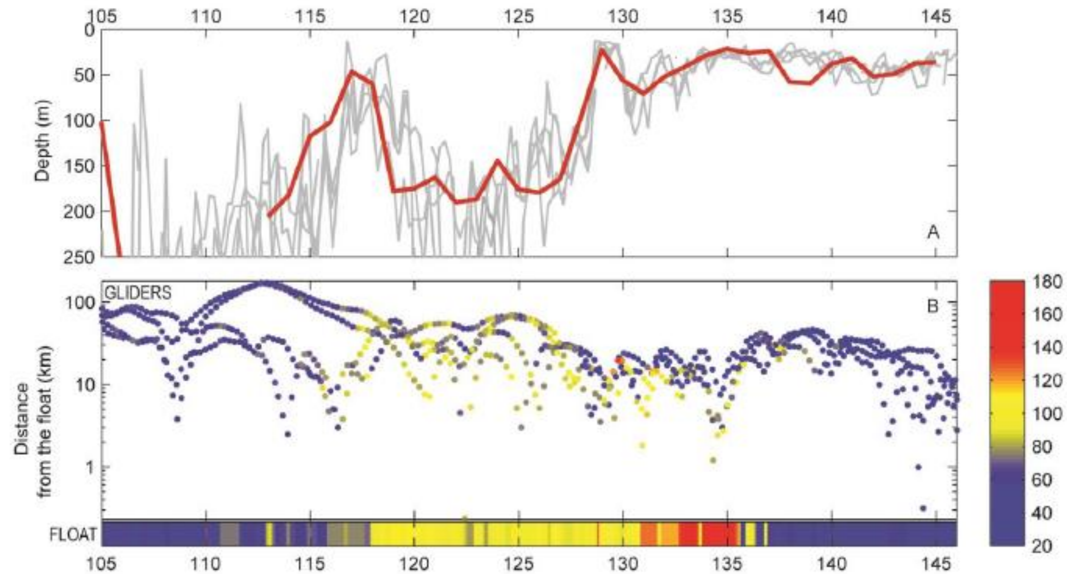


Briggs, PhD thesis

Phytoplankton Community composition

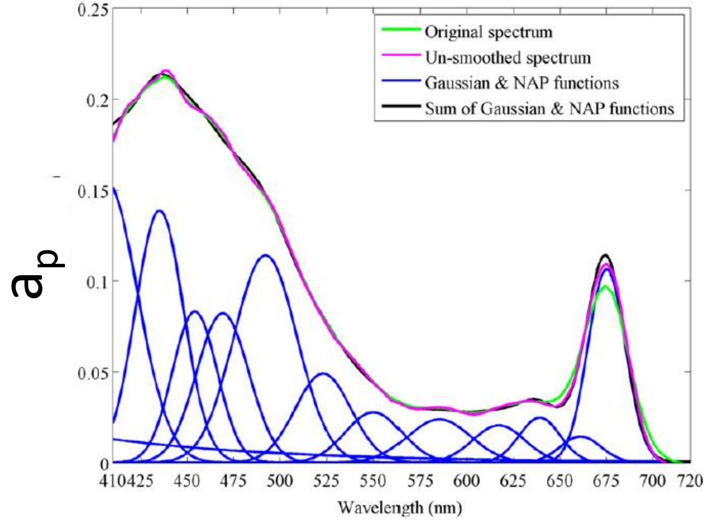






Cetinic et al, 2015

Phytoplakton community composition

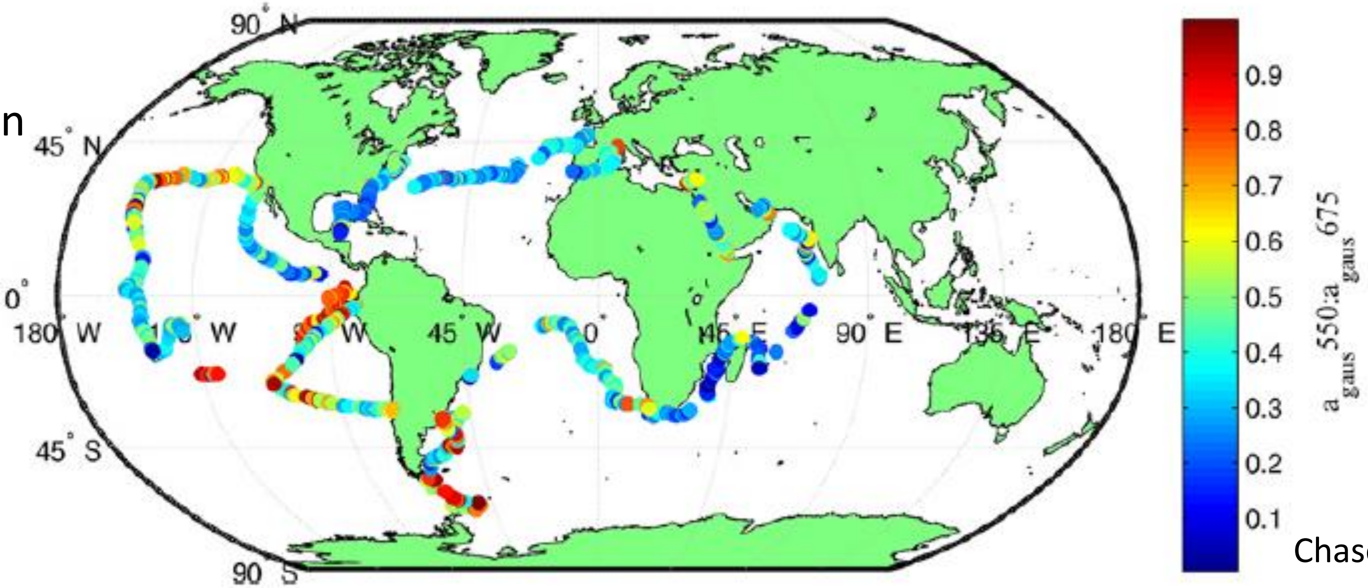


Wavelength (nm)

Table 2
Correlations between HPLC pigment concentrations and $a_{gaus}(\lambda_i)$ at ten different pigment absorption wavelengths. Correlation values are Spearman's rank correlation coefficient (non-parametric; denoted ρ). A and B are coefficients determined using Eq. (4) (Section 2.4).

Wavelength (nm)	Pigment(s)	ρ	A	B	e_{median} (%)
435	TChl *a*	0.868	0.031	0.578	35
617	TChl *a*	0.834	0.003	0.758	36
675	TChl *a*	0.899	0.014	0.798	30
454	0.03(TChl *b*) + 0.07(Chl *c*)	0.845	0.028	0.414	57
469	TChl *b*	0.783	0.066	0.533	52
661	TChl *b*	0.747	0.018	0.668	40
585	Chl *c*	0.846	0.014	0.582	53
639	Chl *c*	0.894	0.012	0.641	41
492	PPC	0.606	0.046	0.650	51
523	PSC	0.855	0.013	0.588	49

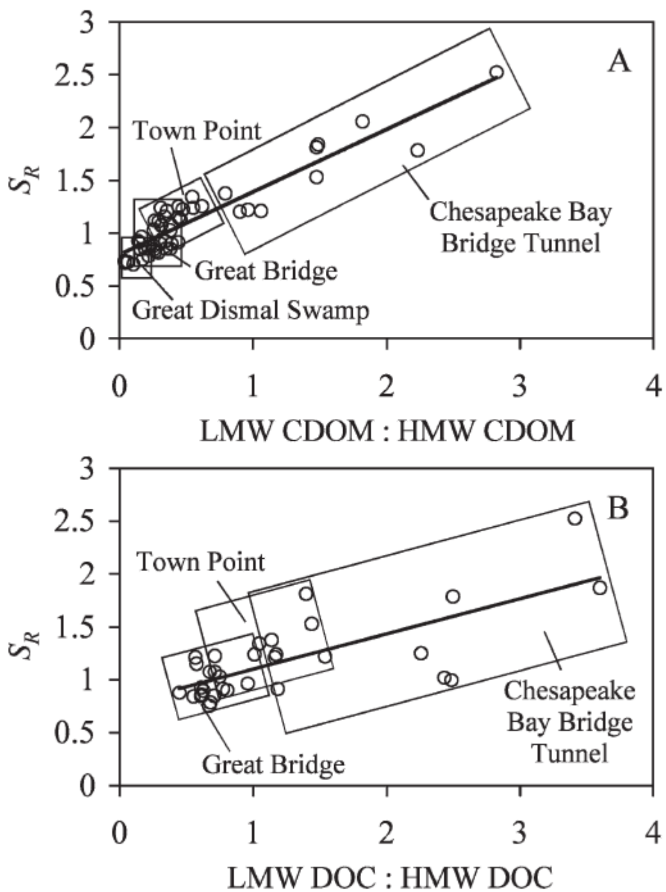
Phycoerithrin proxy distribution



Chase et al, 2013

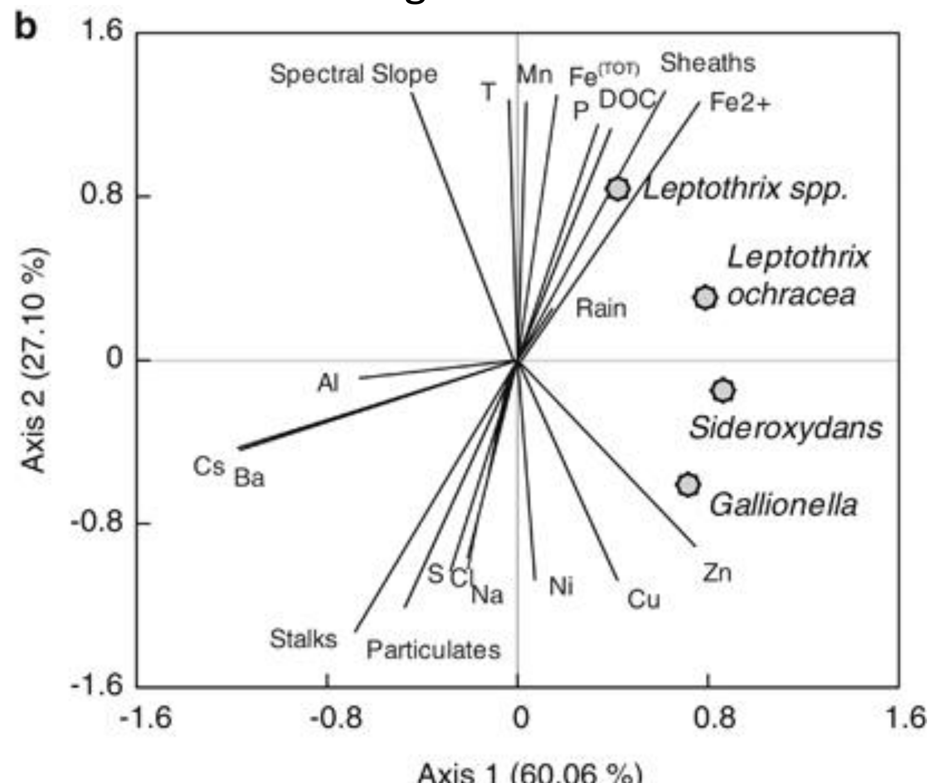
CDOM slope ~ DOC molecular mass

CDOM slope ratio



Helms et al., 2008

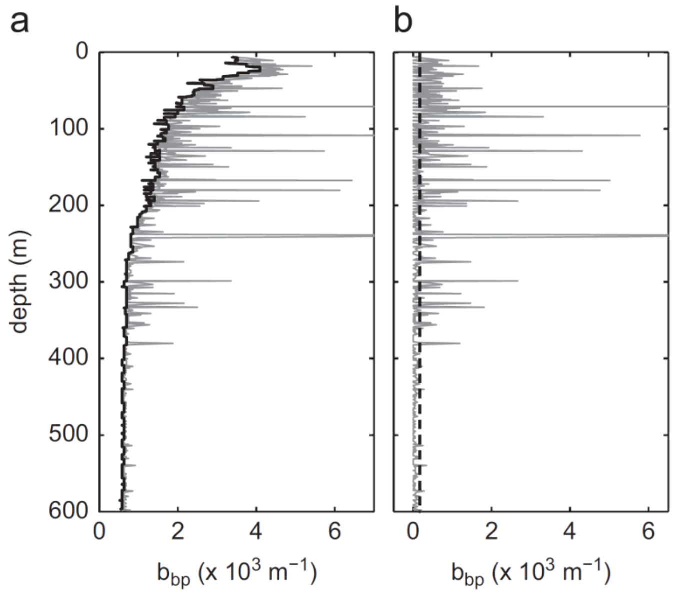
Ecological succession among iron-oxidizing bacteria
unexplored relationship between FeOB and organic carbon



Fleming et al. 2014

As Rufus well knows, there's opportunity in chaos.

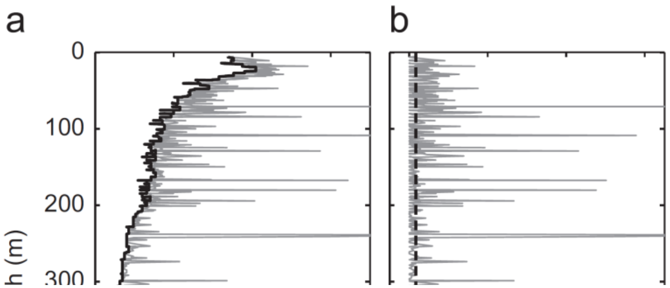
OPPORTUNITY IN CHAOS
FLUXES

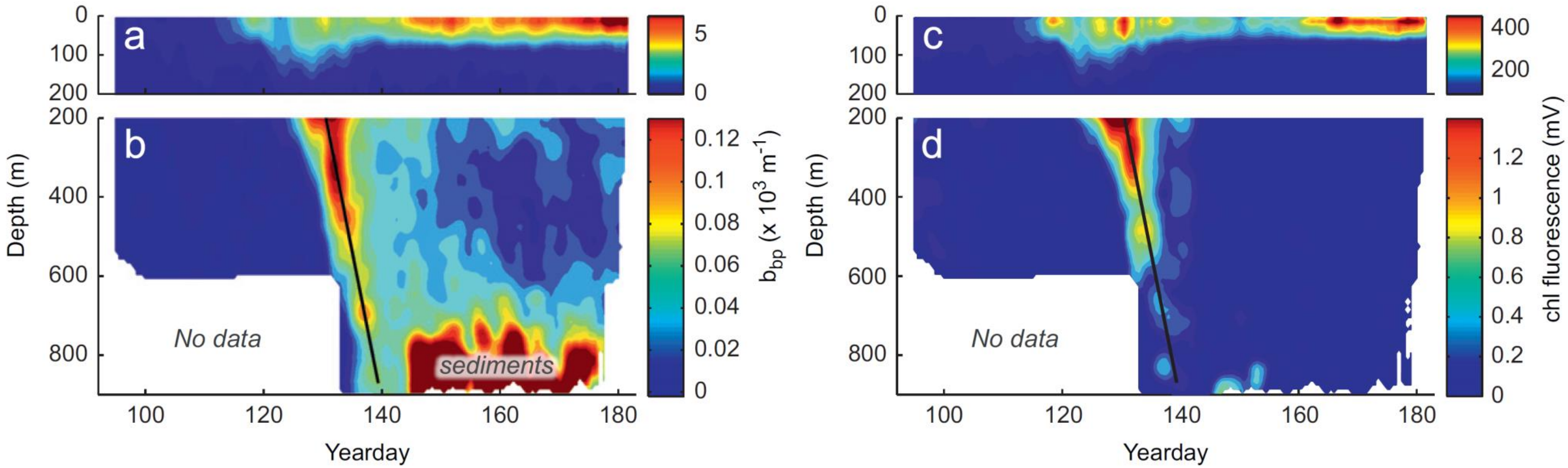


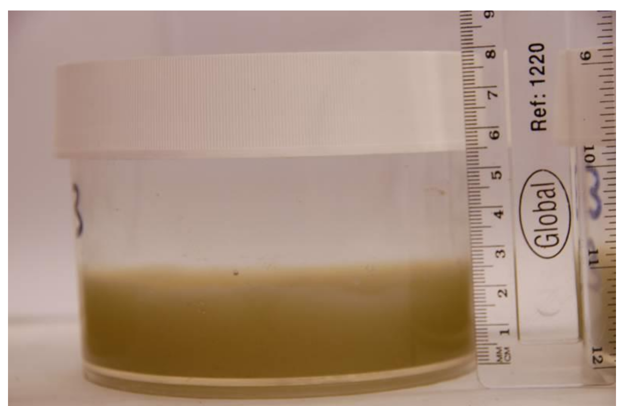
“noise” == aggregates

Briggs et al, 2011, DSR

“noise” == aggregates



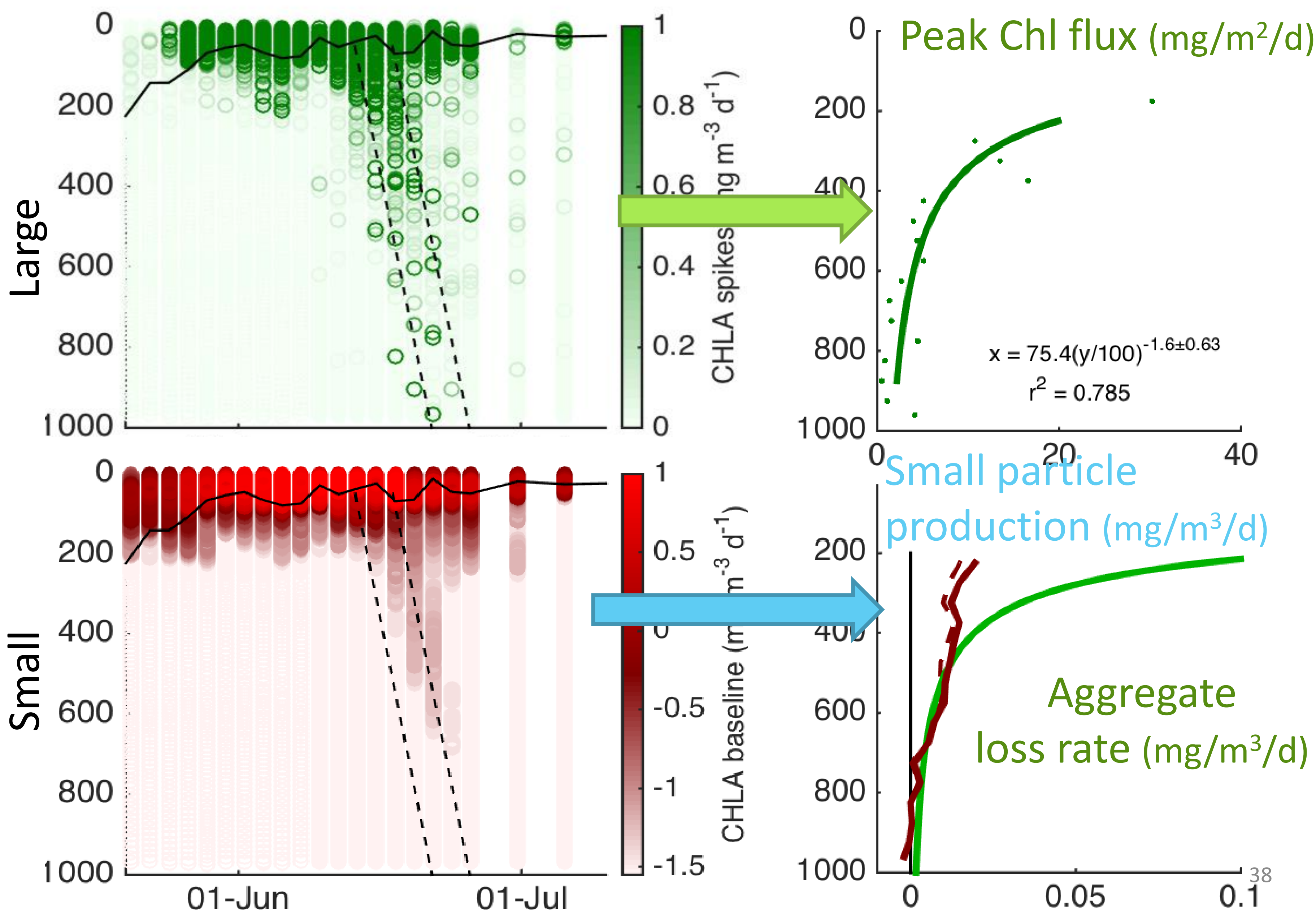




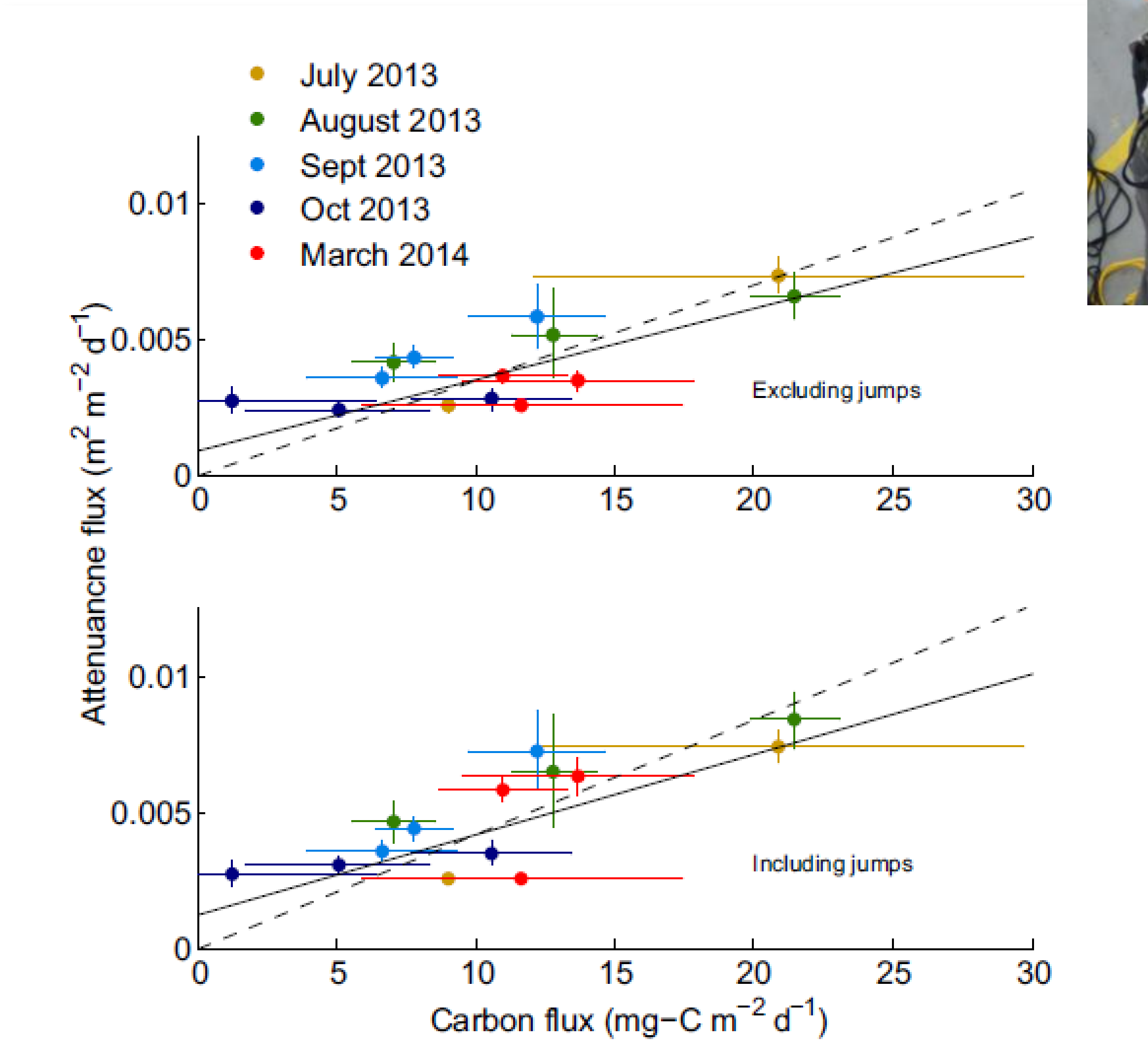
Briggs et al, 2011, DSR

DISSAGREGATION

Briggs et al, in prep.



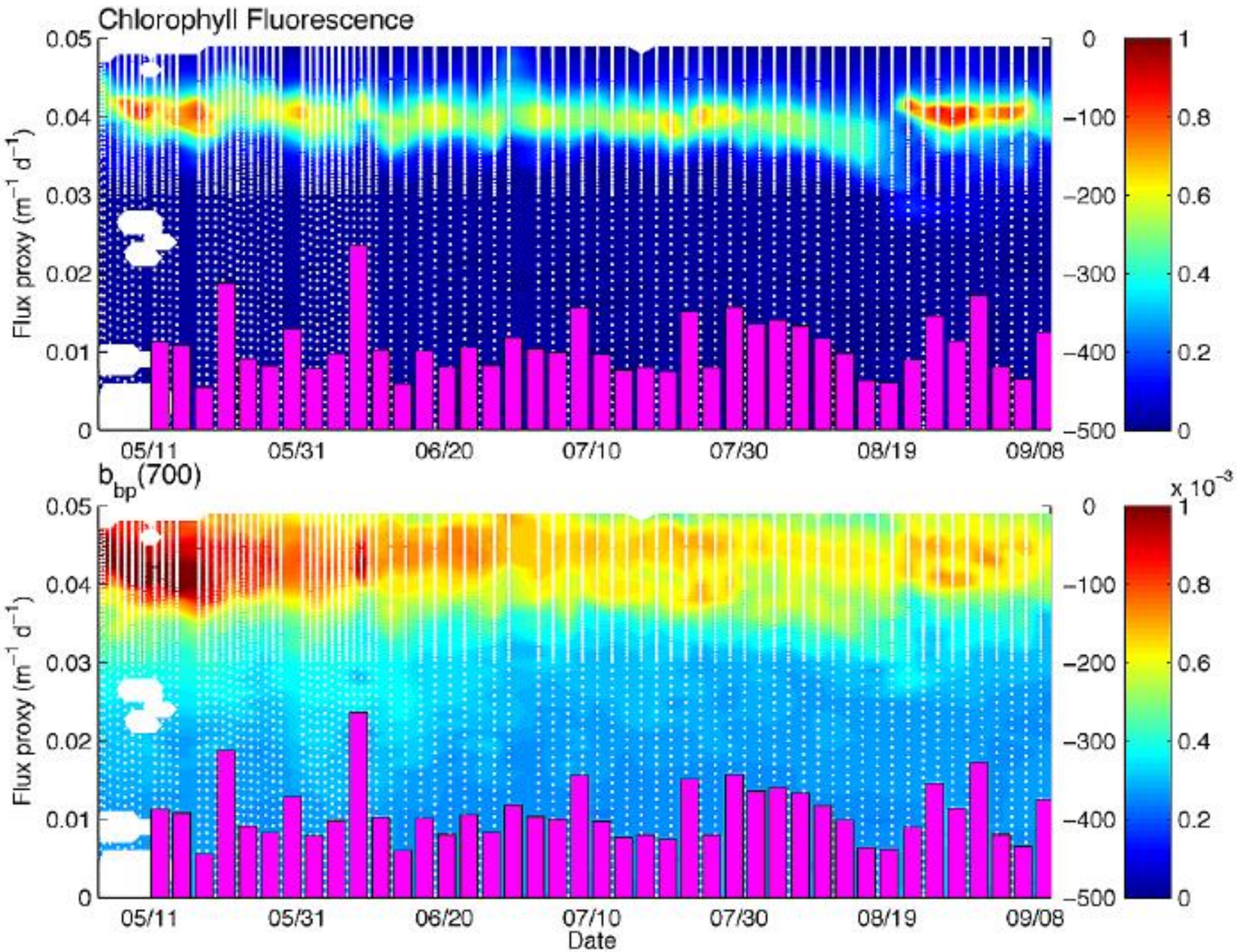
Optical sediment trap



Estapa et al 2013,

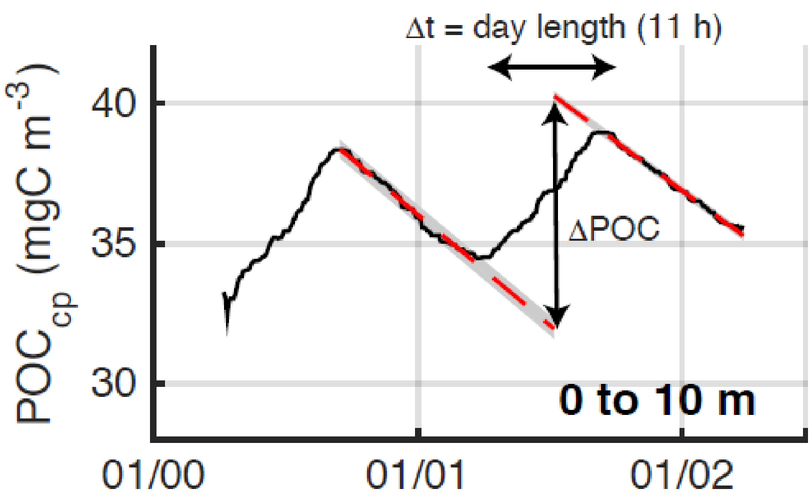
Estapa et al, 2017

Optical sediment trap



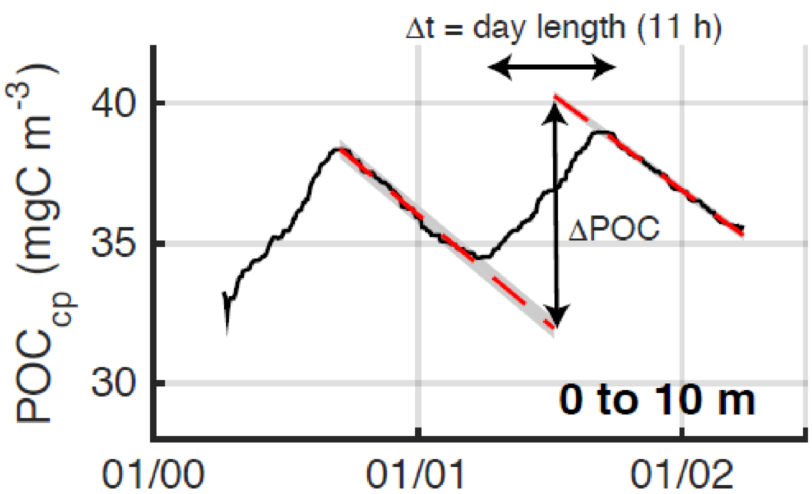
Estapa et al., 2013

PRODUCTIVITY/GROWTH

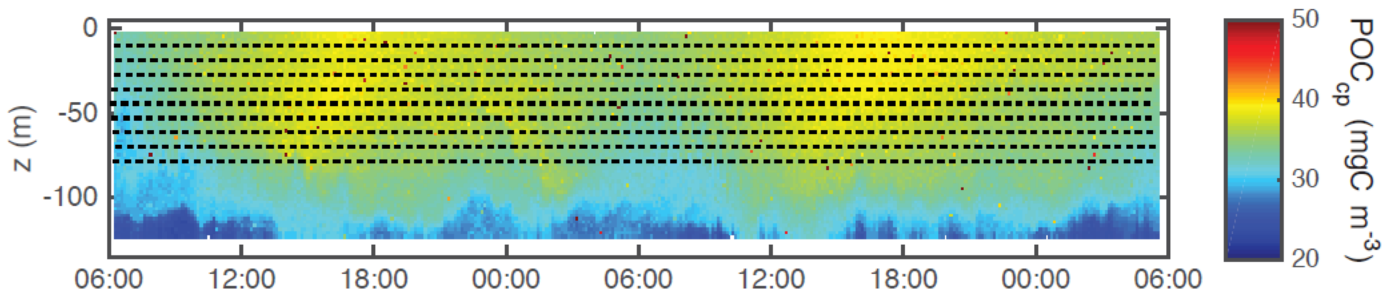


Omand et al, in prep,
(but see Claustre et al 1999, Dall'Olmo et al 2011)

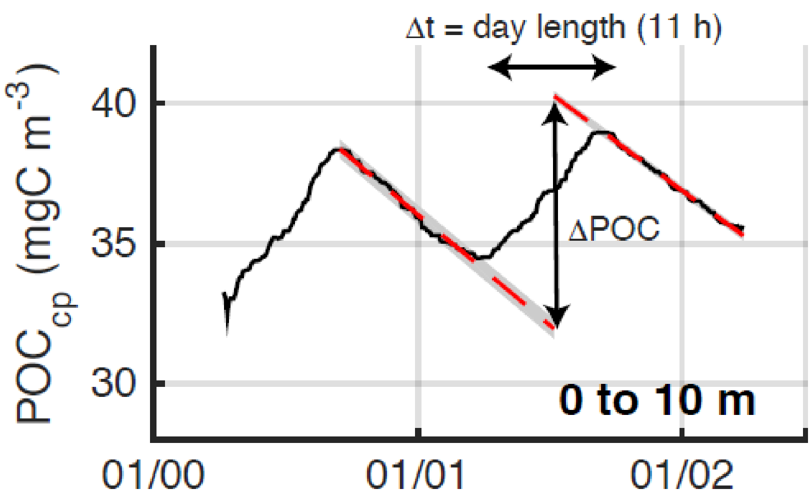
PRODUCTIVITY/GROWTH

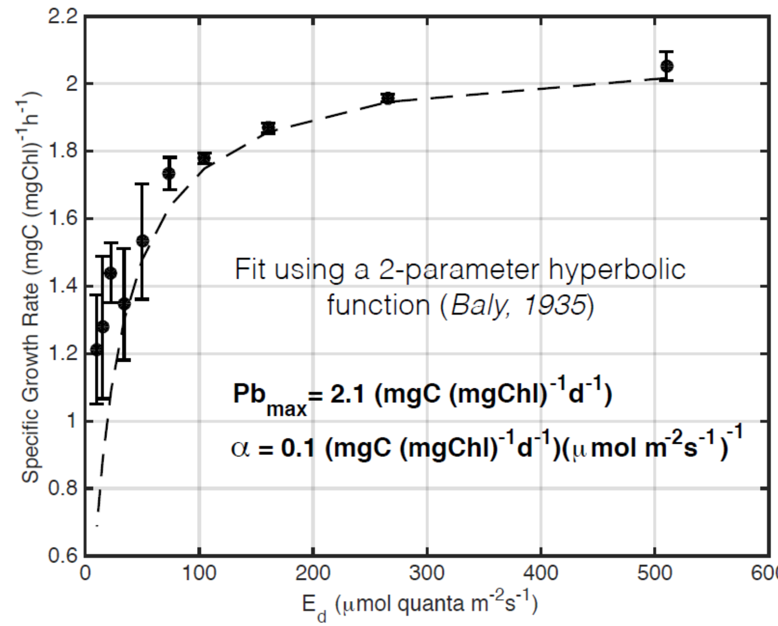


Omand et al, in prep,

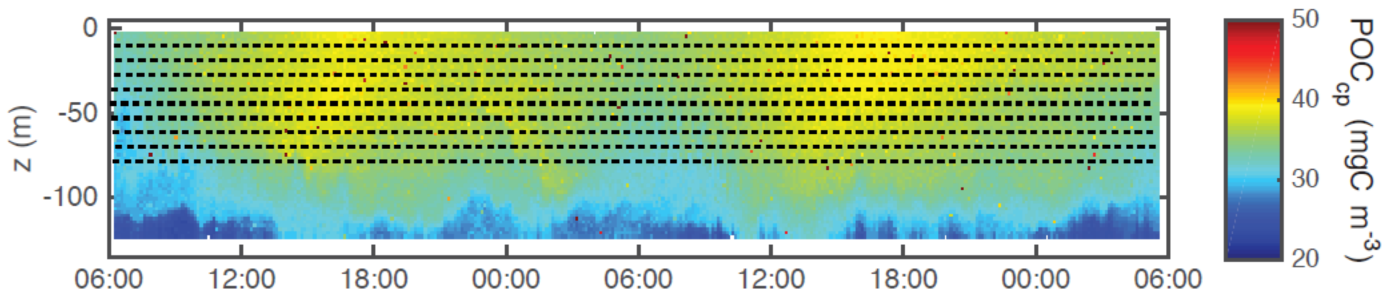


PRODUCTIVITY/GROWTH





Omand et al, in prep,



Few examples of real entities and associated optical proxies (in situ)

- Quantity
  - Chlorophyll - Chlorophyll fluorescence, a(676)
  - Particulate organic carbon – c_p, b_{bp}
  - Phytoplankton carbon – $b_{bp,}$ Chl
  - Suspended particulate matter - c_p, b_{bp}
  - Particulate Inorganic Carbon – acid labile b_{bp} (Balch – week 4), cross - polarized attenuation
  - Dissolved organic carbon – CDOM absorption, fluorescence
  - Nitrate, sulfates – UV absorption
  - Primary productivity – Fv/Fm
- Quality (particulate composition)
  - Particulate composition – $b_{bp}/c_{p,}$ b_{bp}/b_p
  - Particle size - c_p, b_{bp} slopes and "fluctuation", multiple angle scattering, multiple angle c_p
  - Phytoplankton composition – Chl, a (λ), Chl/C, multiple channel fluorescence
  - DOC type – CDOM fluorescence and slope

Few examples of real entities and associated optical proxies (in situ)

- Change in these quantities will tell us something about fluxes
  - Fluxes– movement of a quantity from one pool to another
    - Space - e.g. carbon export from mixed layer to deeper ocean
    - Time – productivity - e.g. primary production
    - Type – e.g. phytoplankton to detritus, POC to DOC

PROXIES WORK UNTIL THEY DON'T (MJP)

1. Validate – make sure your proxies are based on strong and meaningful relationship with biogeochemical parameters
2. Interpolate rather than extrapolate – know the limits of your method, spatial, temporal and logical
3. Same as Rufus the dog, seize the variability and chaos (but remember 1 and 2)