Applications of in situ optical measurements to study open ocean plankton and particle communities

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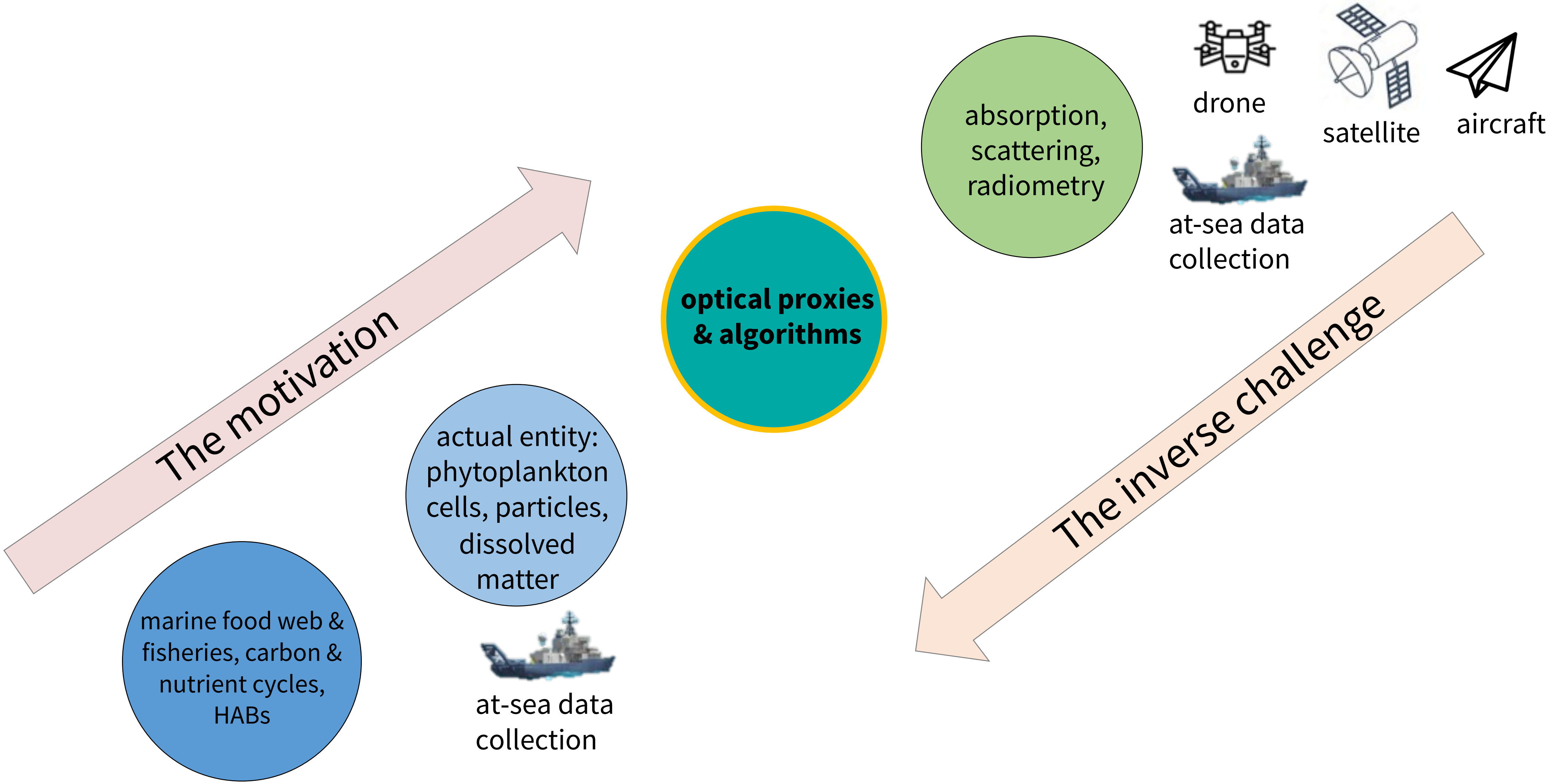
Who am I?

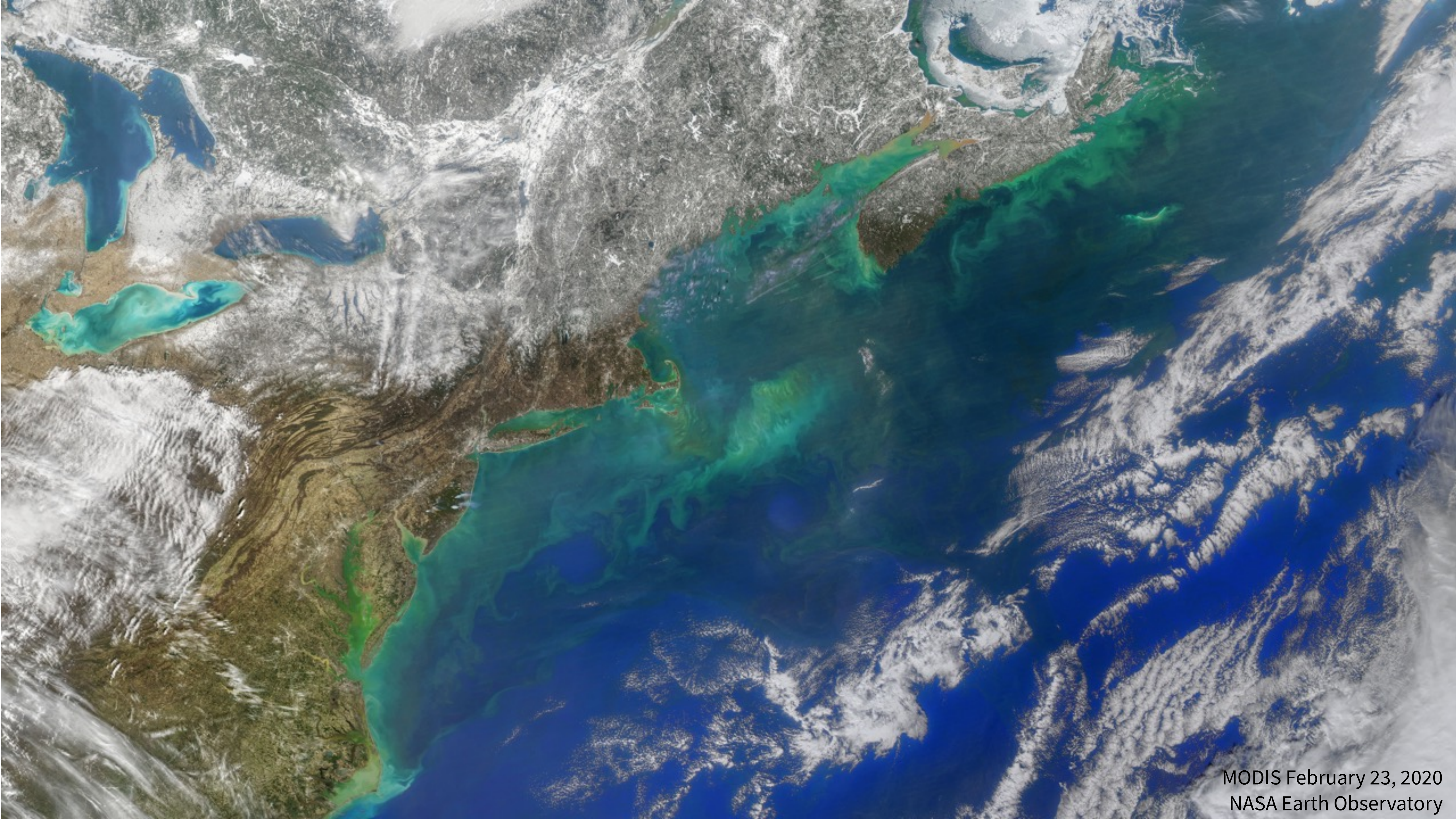
Overarching research goal: How are phytoplankton communities distributed in space and time? At various scales, what changes are occurring in these communities and their distributions?

→ use optical measurements to estimate parameters related to phytoplankton
→ application to remote sensing data for broad scale ocean ecosystem studies

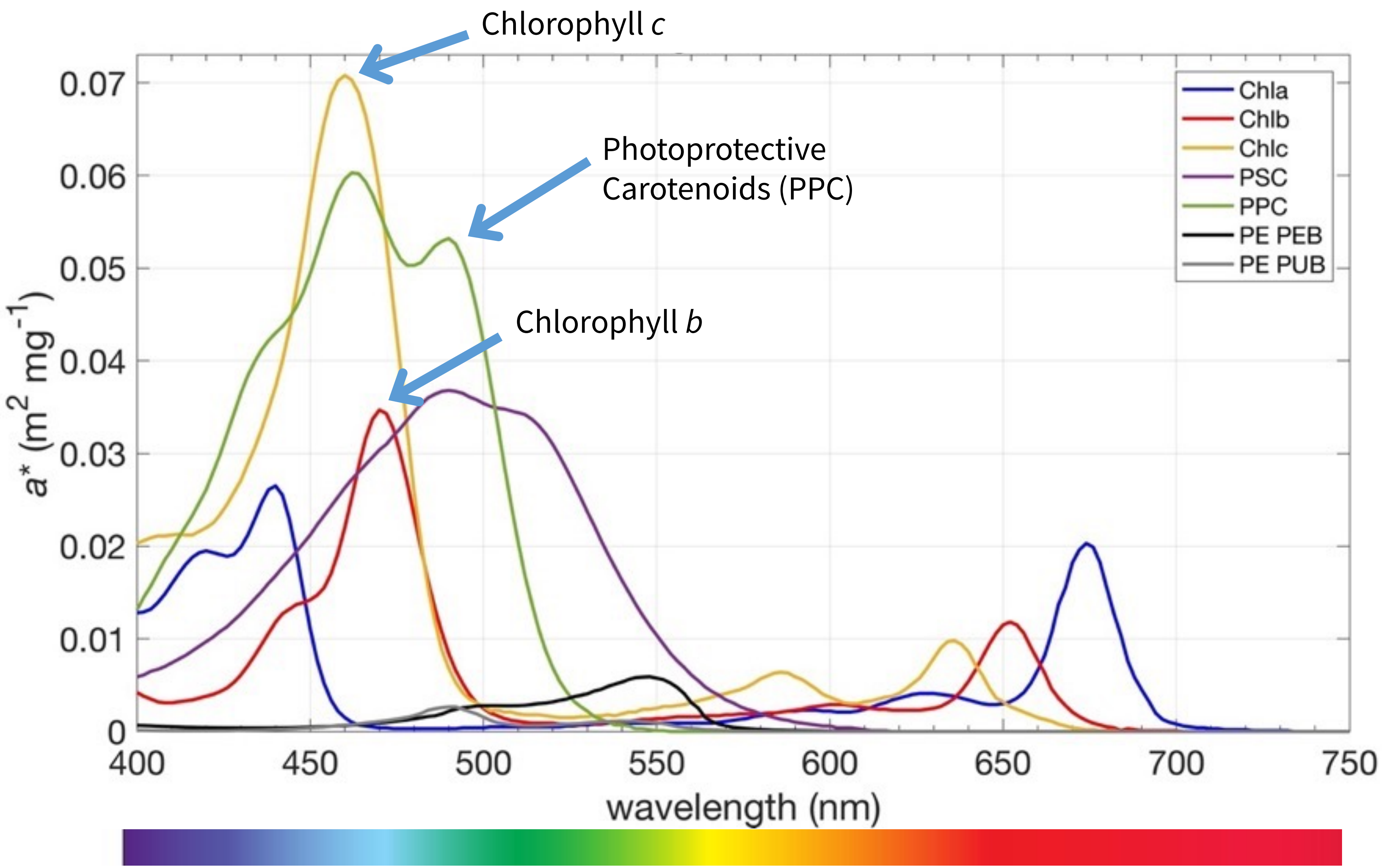
Optics: a tool to link what we can measure to what we want to know



Adapted from M. J. Perry


MODIS February 23, 2020
NASA Earth Observatory

Phytoplankton pigments drive spectral absorption features



data from Bidigare et al. 1990

Phytoplankton pigments estimated from ac-s absorption spectra

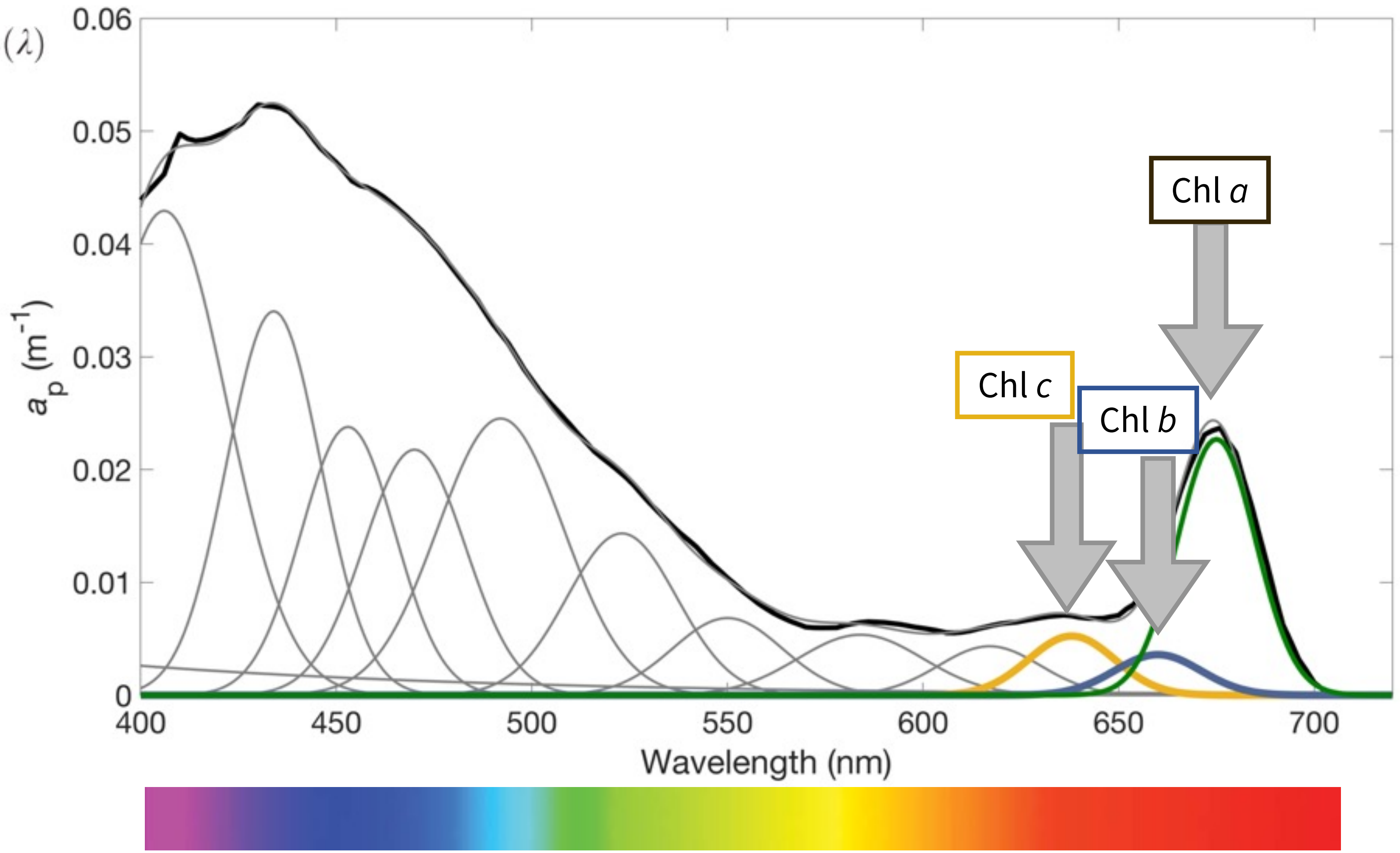
$a(\lambda)$ =

$a_{\varphi}(\lambda) + a_{CDOM}(\lambda) + a_{NAP}(\lambda) + a_{w}(\lambda)$

$$a_{\varphi}(\lambda) = \sum_{i=1}^{8} a_{gaus}(peak_i, \lambda) e^{\left(-0.5\left(\frac{\lambda - peak_i}{\sigma_i}\right)\right)^2},$$

$$a_{\mathrm{p}}(\lambda) = a_{\mathrm{tot}}(\lambda) - a_{0.2\ \mu\mathrm{m}}(\lambda)$$

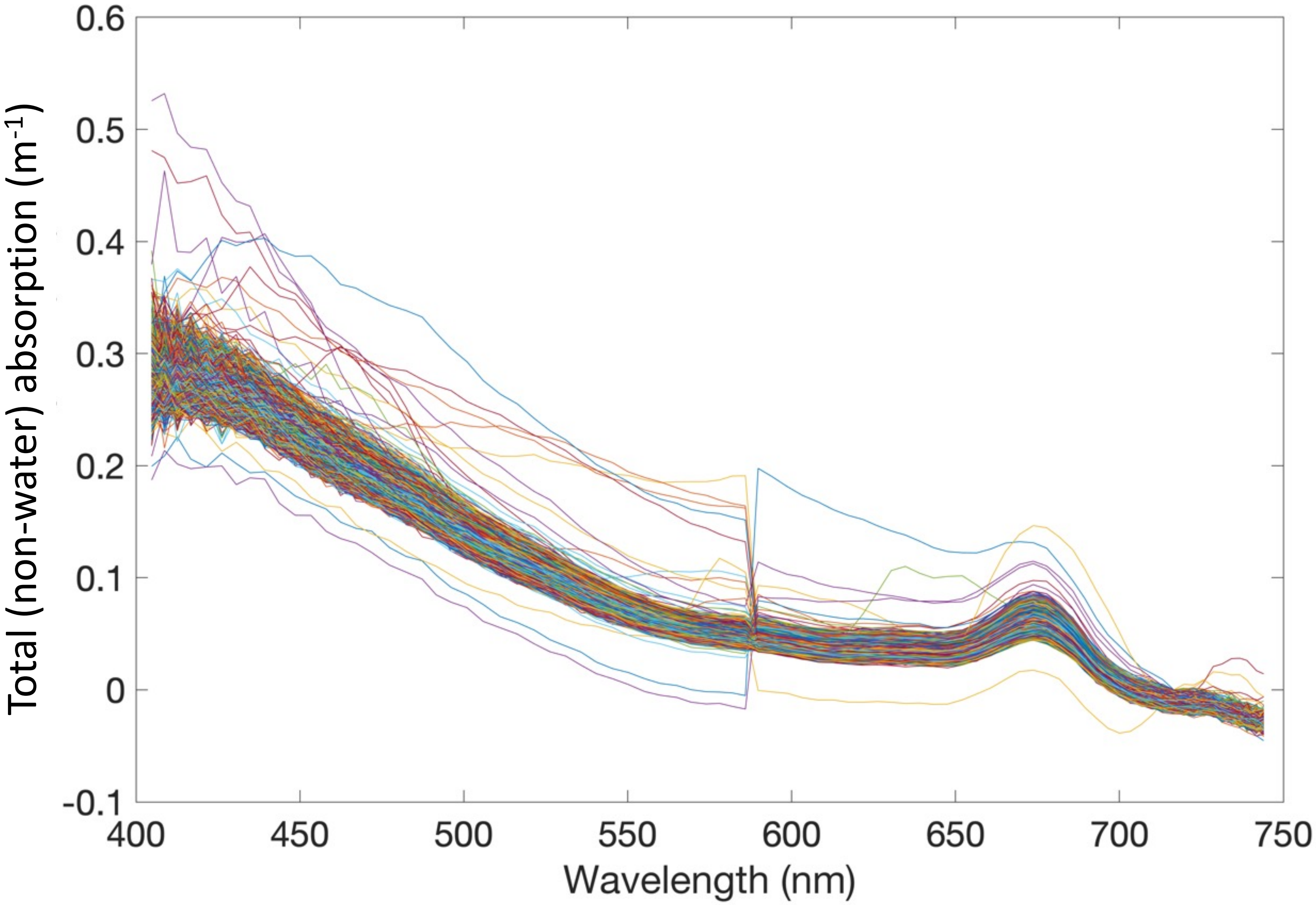
Where a_{tot} is total non-water absorption and $a_{0.2} = a_{CDOM}$



ac-s

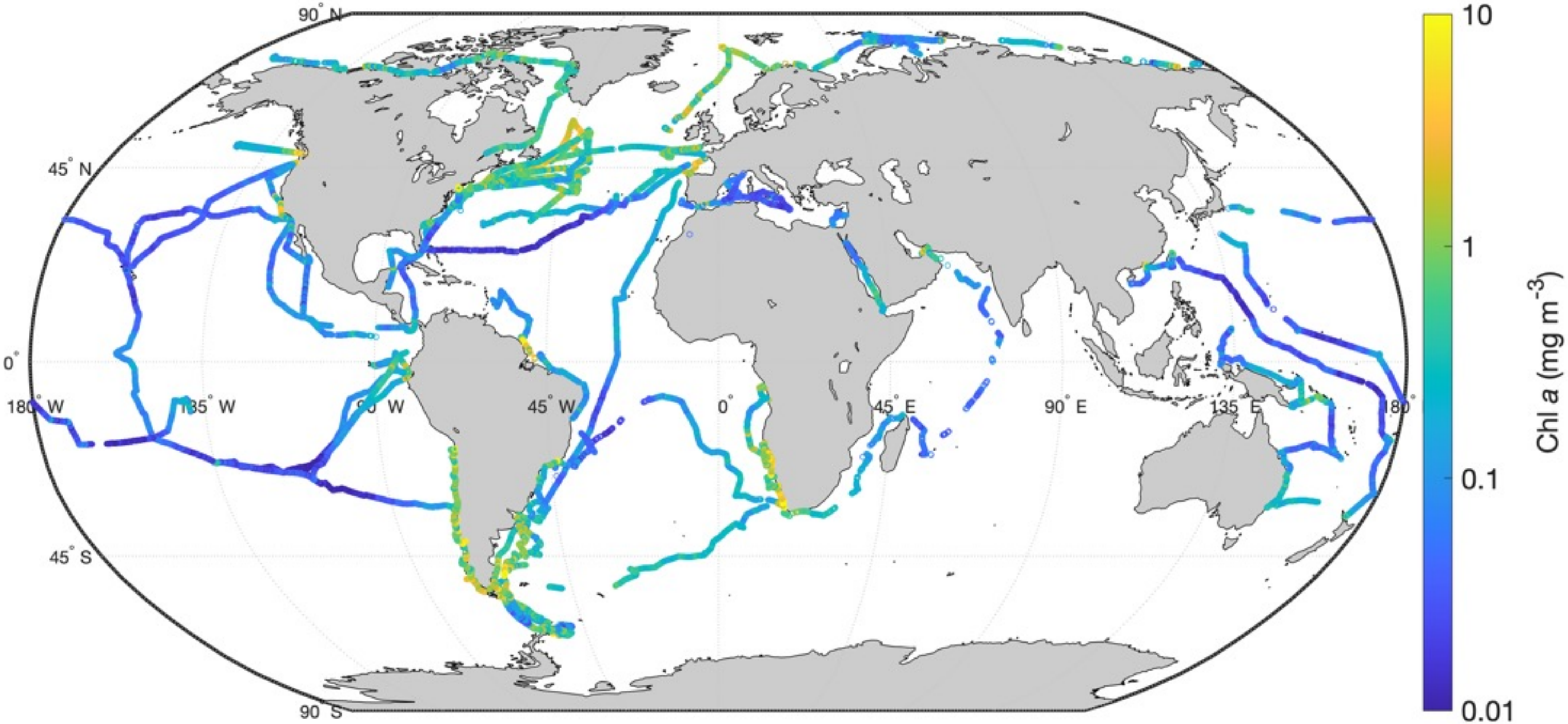
Chase et al., 2013

Reminder: OOI OPTAA data include CDOM absorption signal



OOI OPTAA datafile: deployment0013_CP01CNSM-RID27-01-OPTAAD000-recovered_host-optaa_dj_dcl_instrument_recovered_20210403T050332.487000-20210403T110332.489000.nc

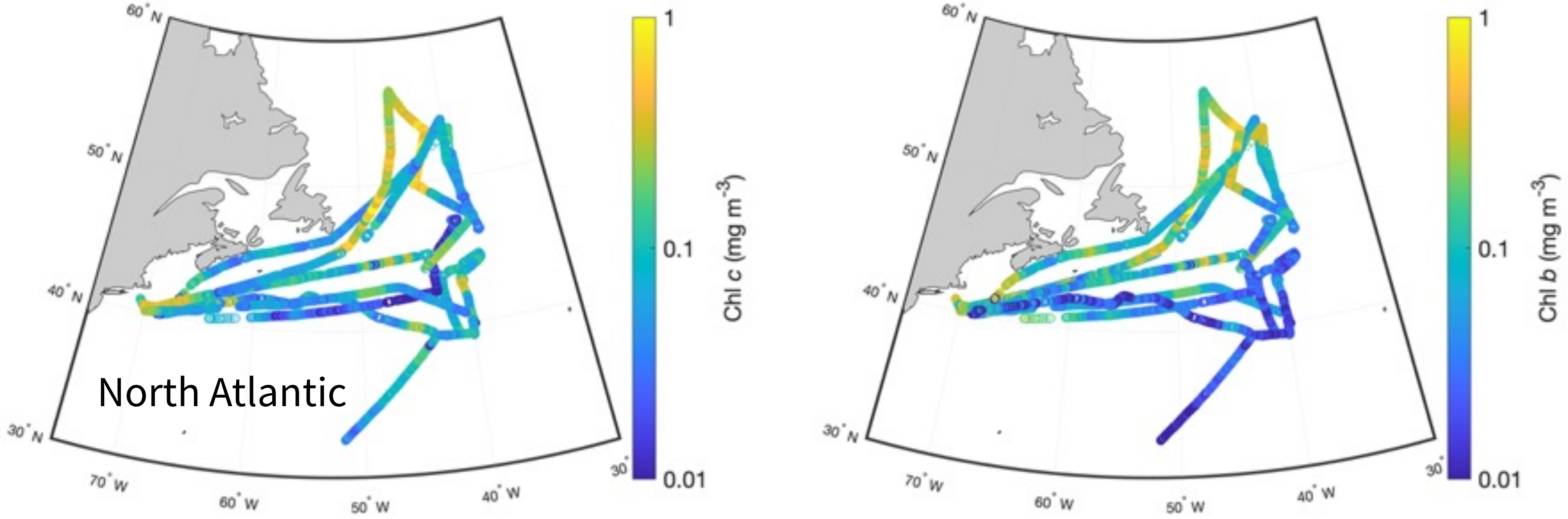
Chlorophyll *a* estimated from hyperspectral a_p measurements



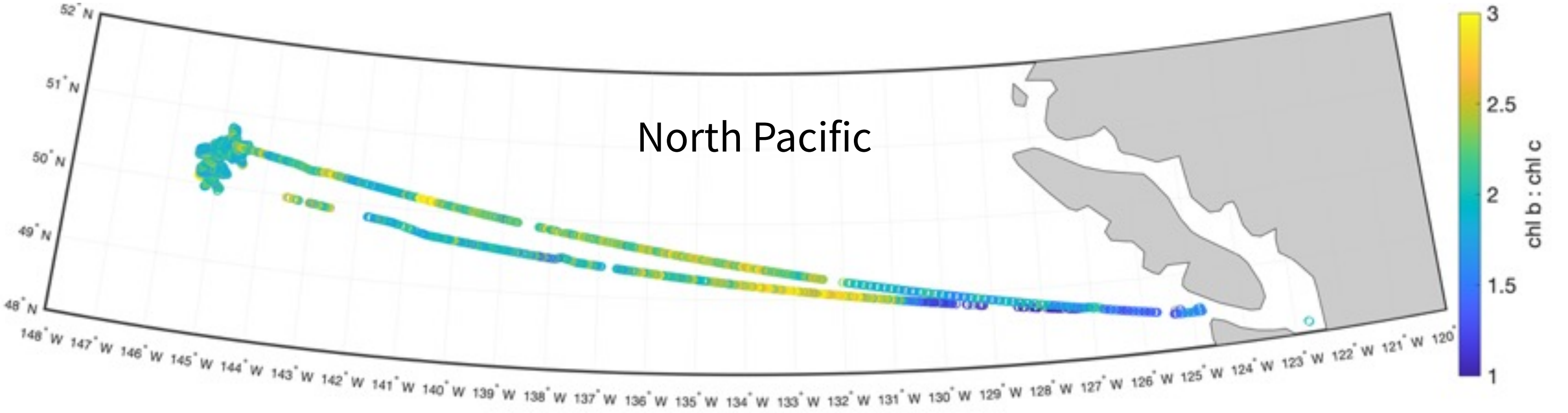
ac-s

Phytoplankton accessory pigments estimated from hyperspectral a_p

Accessory pigment absolute concentrations:

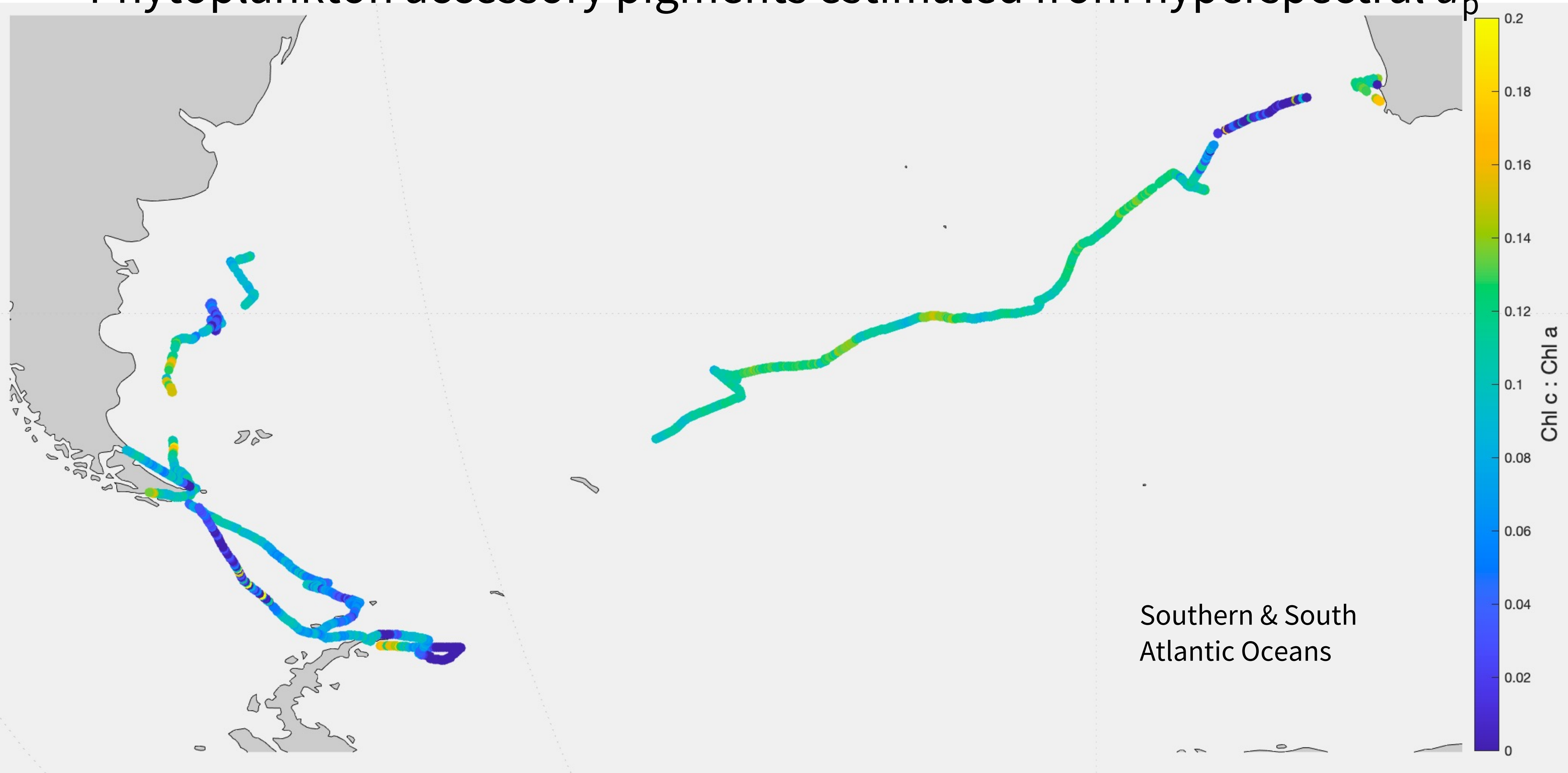


Accessory pigment ratios:



Data from NAAMES (2015-2018) and EXPORTS (2018) Expeditions

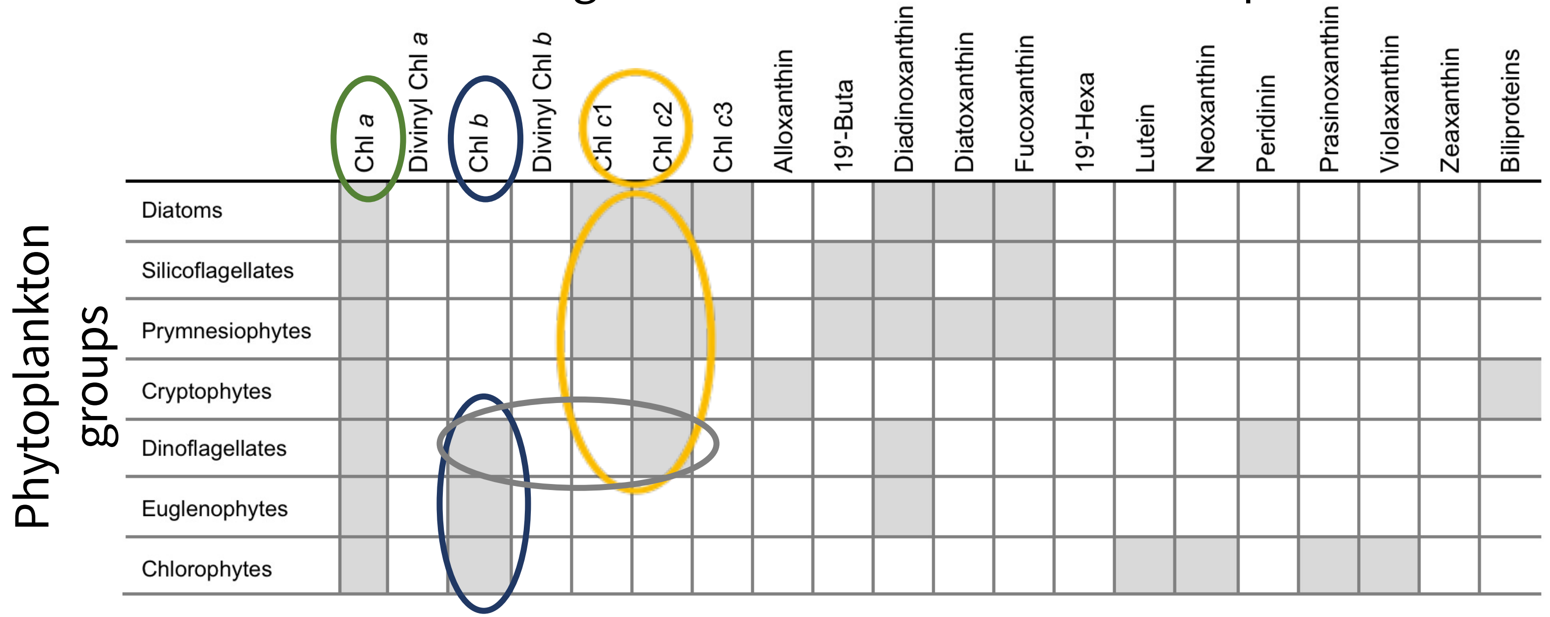
Phytoplankton accessory pigments estimated from hyperspectral a_p



Data from Tara Mission Microbiome Expedition, 2022

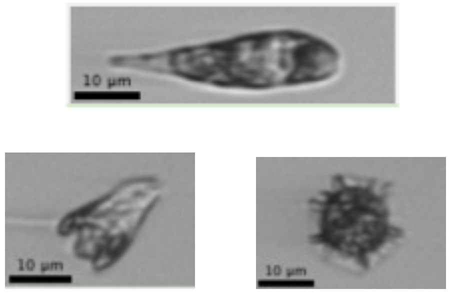
Phytoplankton pigments are attributed to different phytoplankton groups

Pigments from discrete water samples



Chlorophyll *b*

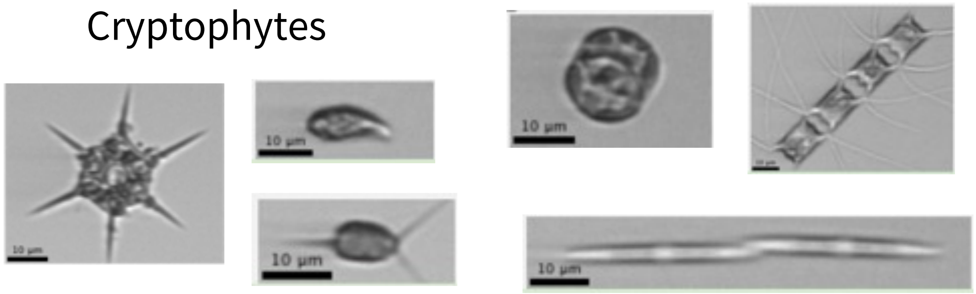
Chlorophytes, Euglenoids



Chlorophyll *c*

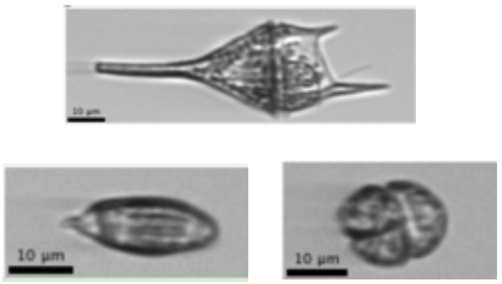
Silicoflagellates
Prymnesiophytes
Cryptophytes

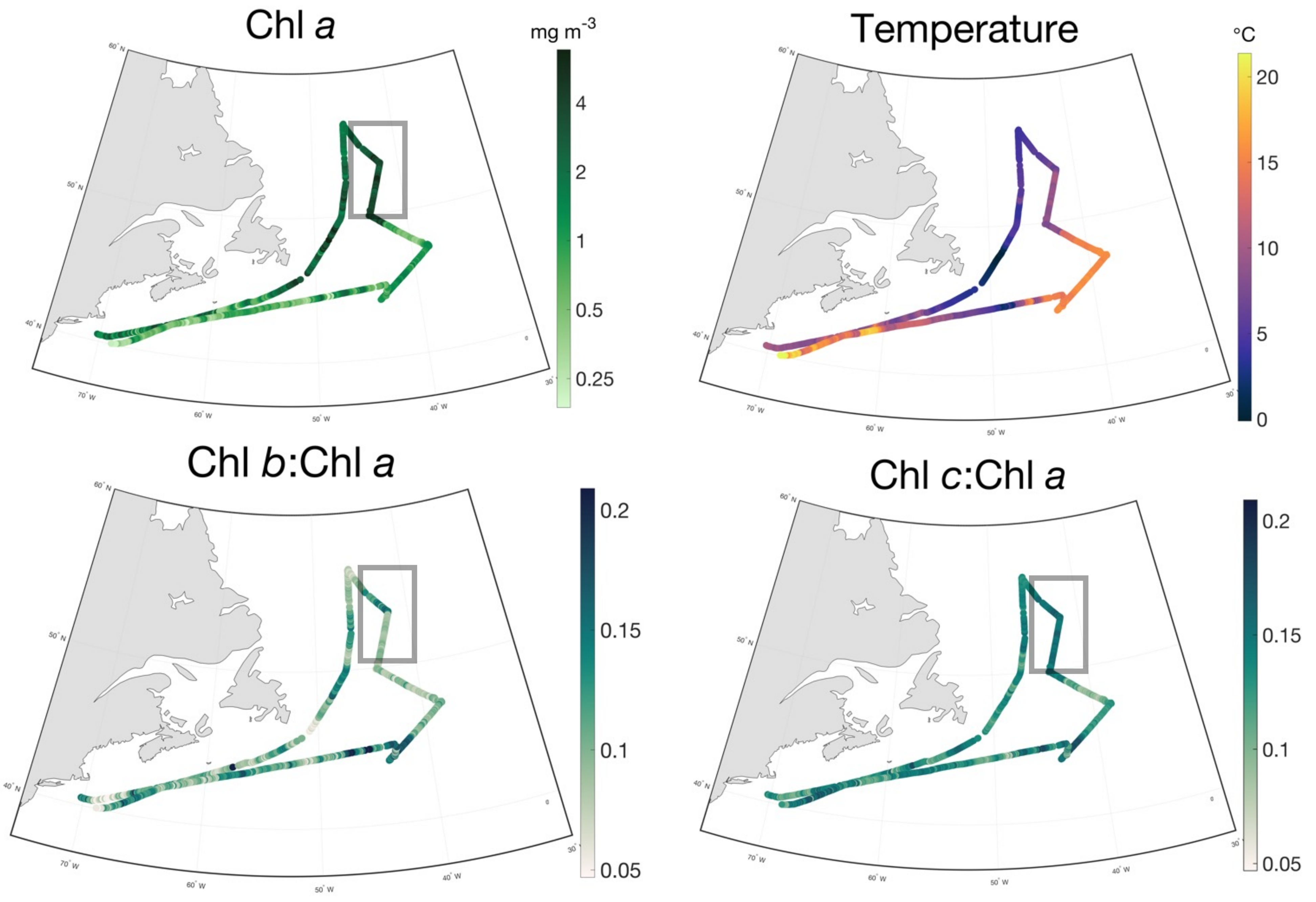
Diatoms



Chlorophylls *b* & *c*

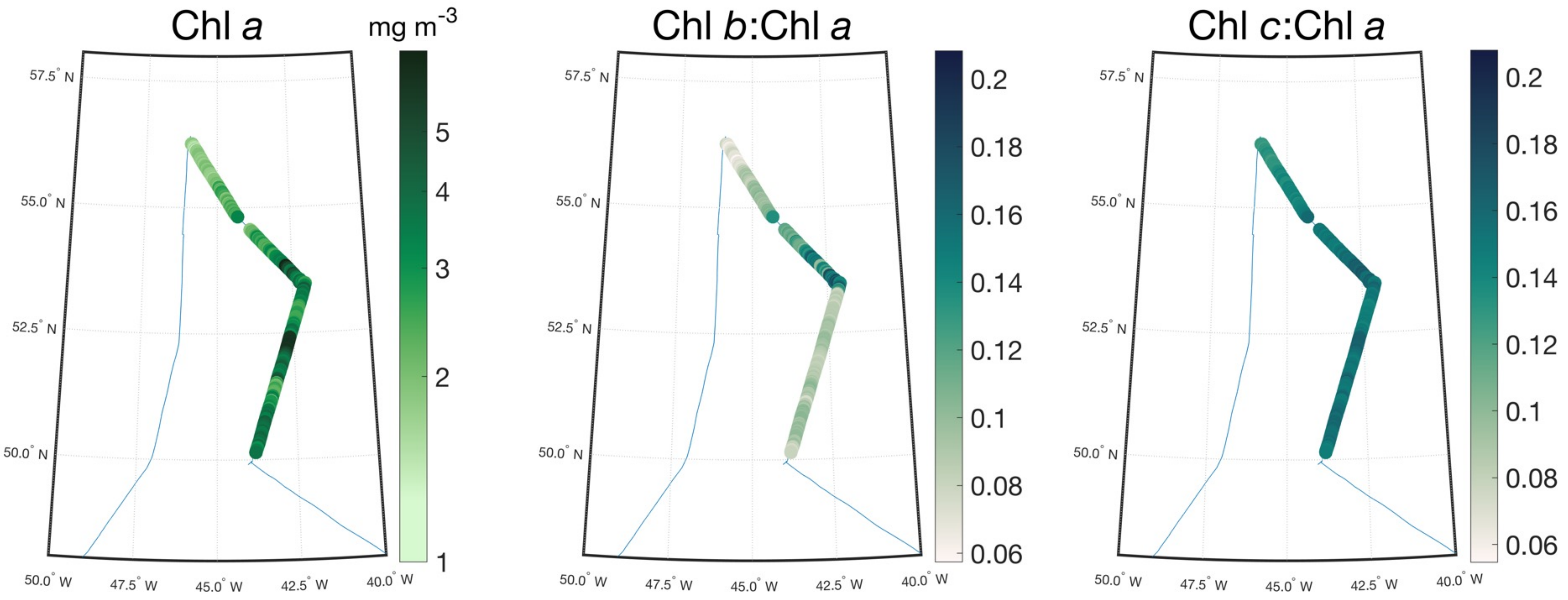
Dinoflagellates

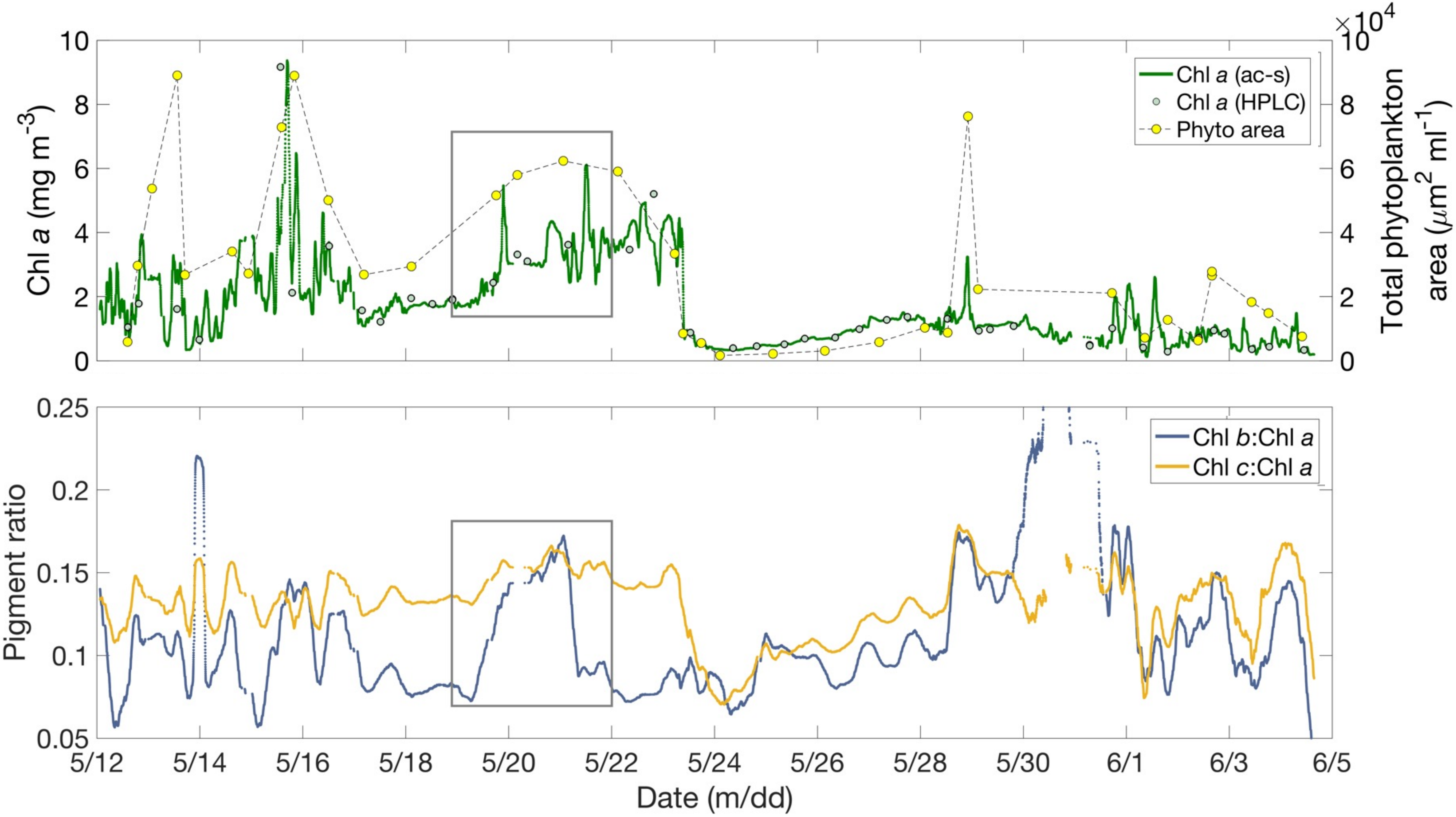




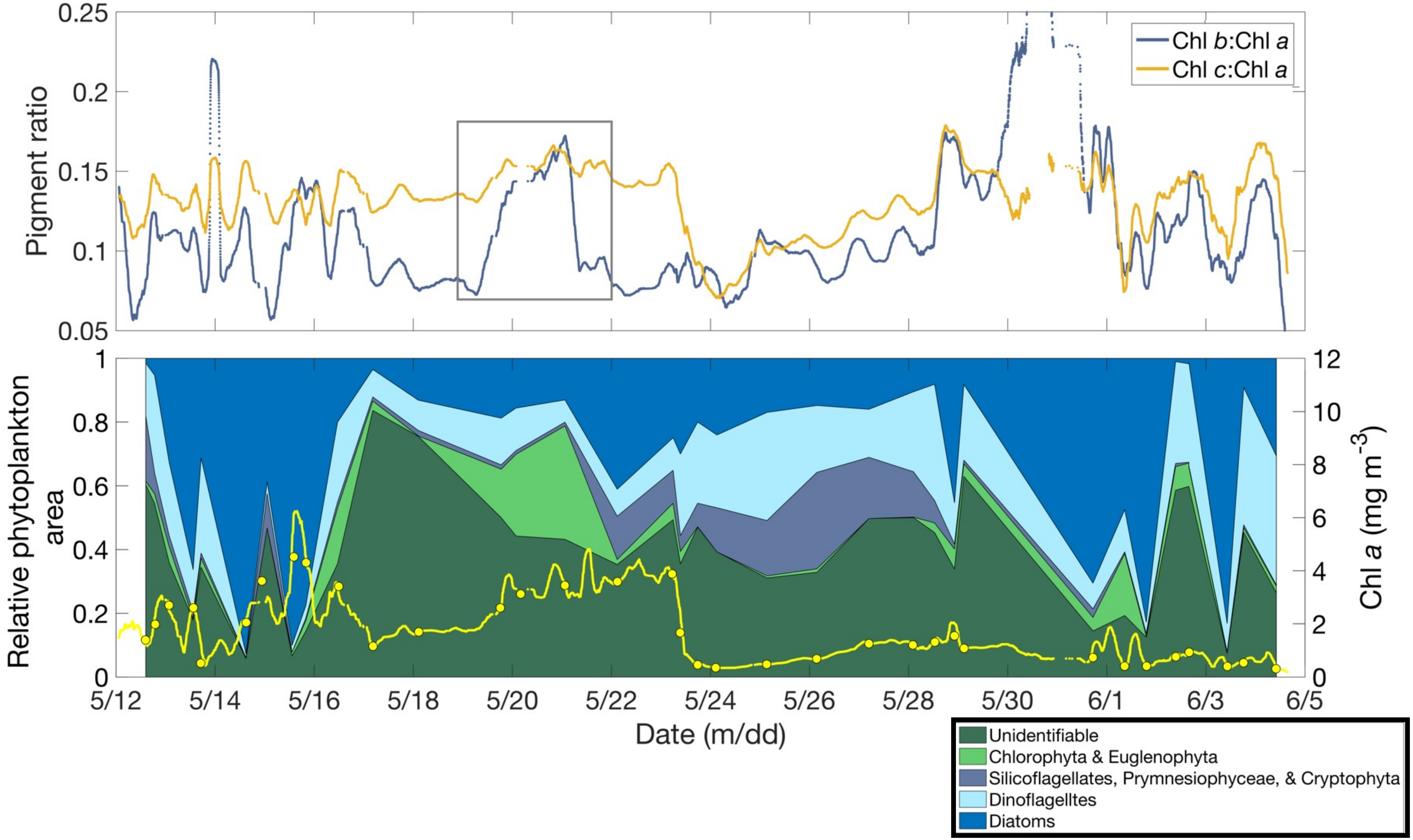
NAAMES 2
May 2016

May 19-21, 2016

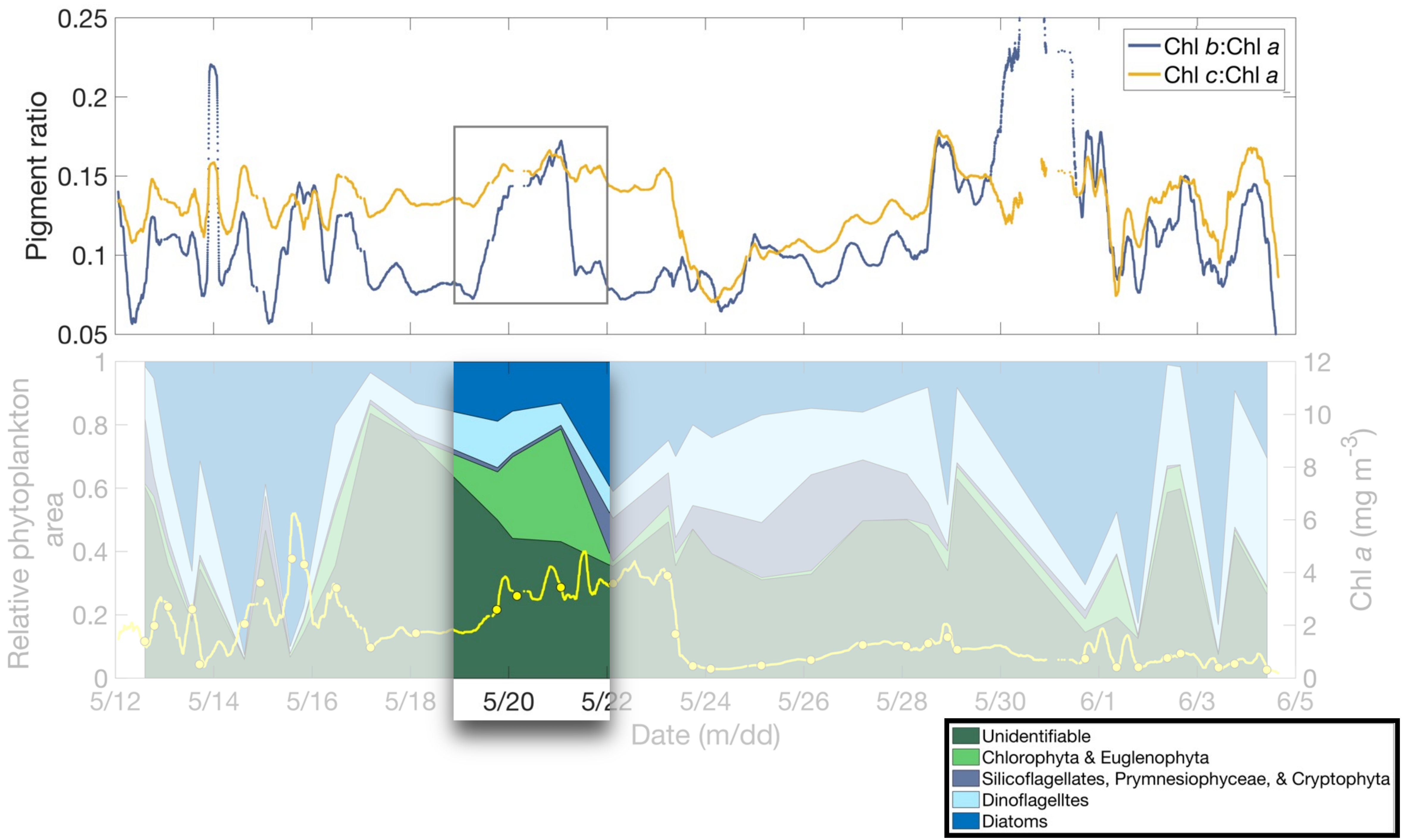




Chl a (mg m^{-3})
Total phytoplankton area (μm^2 ml^{-1})
×10^4
Chl a (ac-s)
Chl a (HPLC)
Phyto area
Pigment ratio
Chl b:Chl a
Chl c:Chl a
Date (m/dd)
5/12
5/14
5/16
5/18
5/20
5/22
5/24
5/26
5/28
5/30
6/1
6/3
6/5



Chl b:Chl a
Chl c:Chl a
Pigment ratio
0.25
0.2
0.15
0.1
0.05
Relative phytoplankton area
1
0.8
0.6
0.4
0.2
0
Chl a (mg m-3)
12
10
8
6
4
2
0
5/12
5/14
5/16
5/18
5/20
5/22
5/24
5/26
5/28
5/30
6/1
6/3
6/5
Date (m/dd)
Unidentifiable
Chlorophyta & Euglenophyta
Silicoflagellates, Prymnesiophyceae, & Cryptophyta
Dinoflagelltes
Diatoms



Chl b:Chl a
Chl c:Chl a
Pigment ratio
0.25
0.2
0.15
0.1
0.05
Relative phytoplankton area
Chl a (mg m-3)
1
0.8
0.6
0.4
0.2
0
12
10
8
6
4
2
0
5/12
5/14
5/16
5/18
5/20
5/22
5/24
5/26
5/28
5/30
6/1
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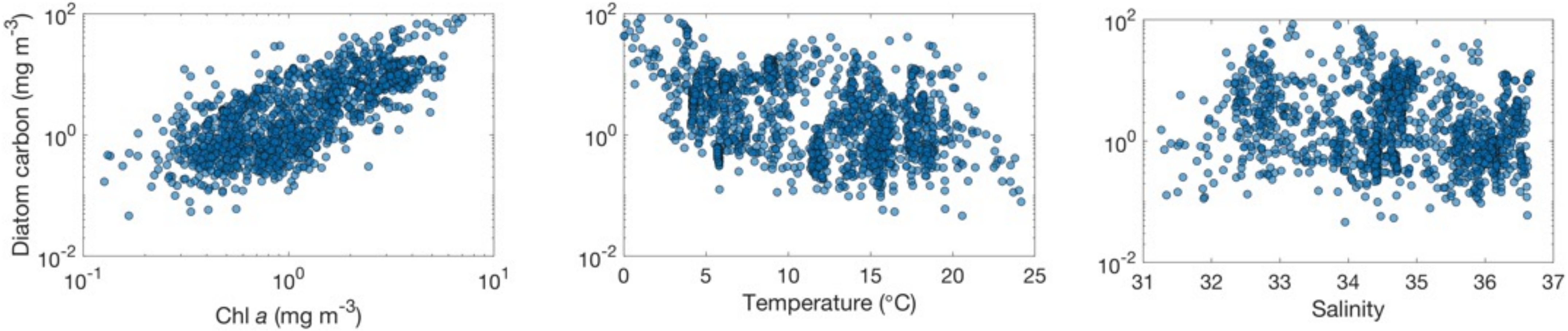
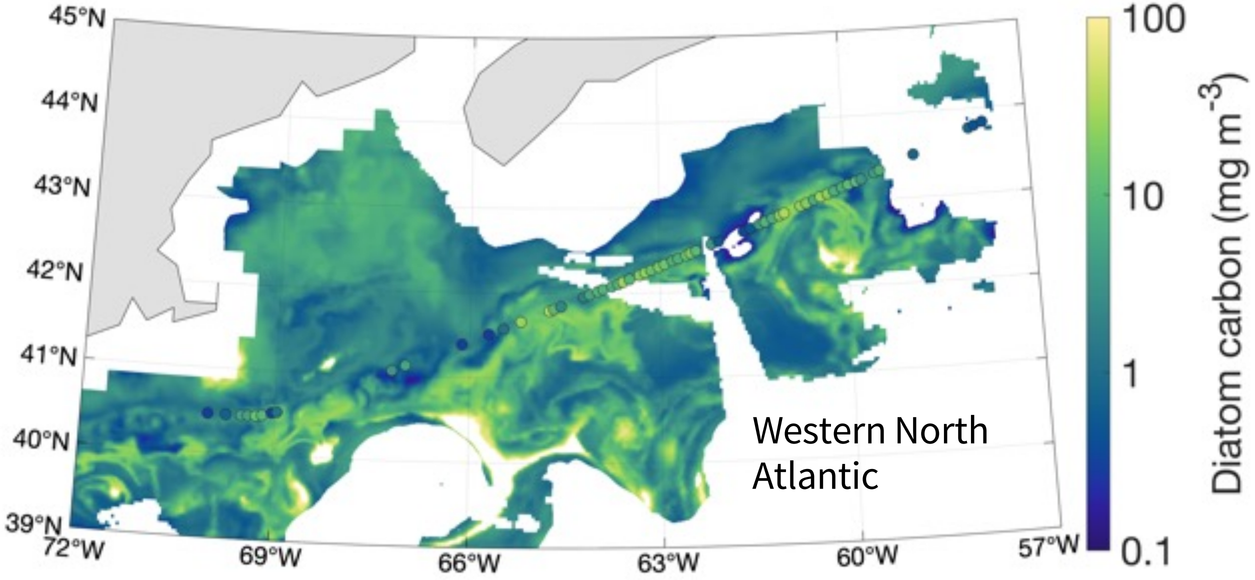
6/5
Date (m/dd)
Unidentifiable
Chlorophyta & Euglenophyta
Silicoflagellates, Prymnesiophyceae, & Cryptophyta
Dinoflagelltes
Diatoms

Pigments + environmental data + plankton imagery + machine learning = diatom carbon



Neural network-based method

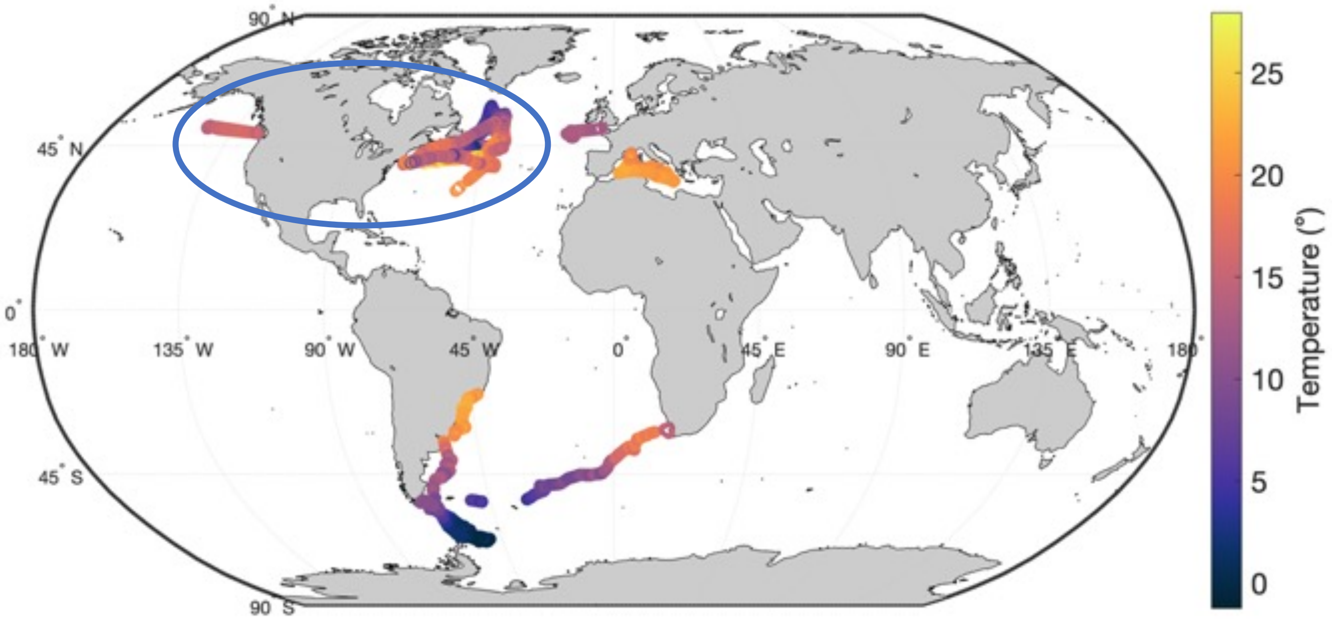


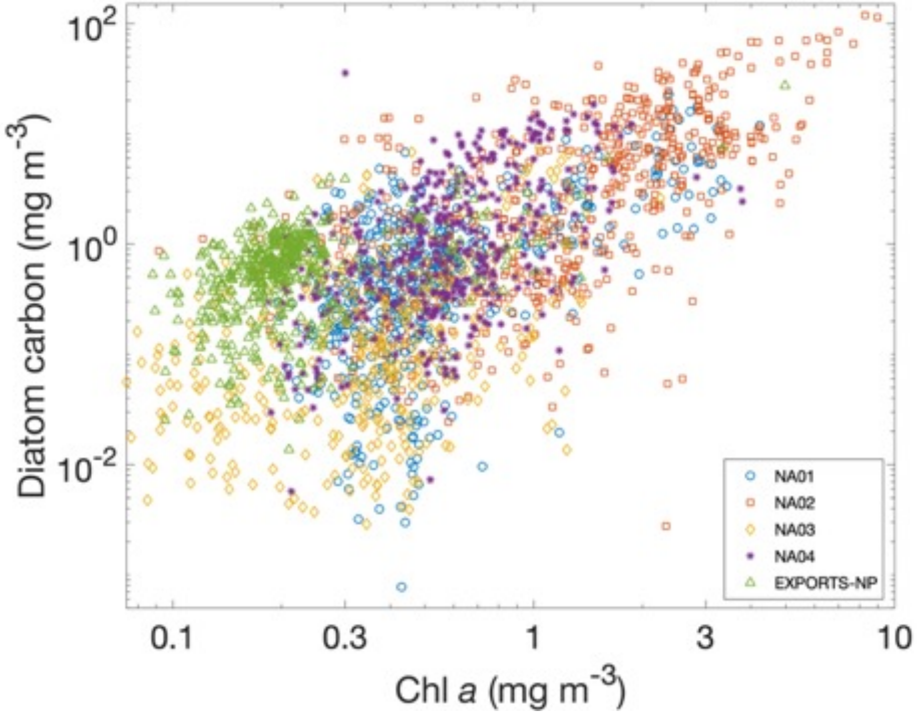
Model trained with Chl *a* derived from ac-s, and then applied to satellite measurements

Chase et al. 2022

A broadly applicable diatom biomass algorithm

Inputs for model training: environmental & optical datasets

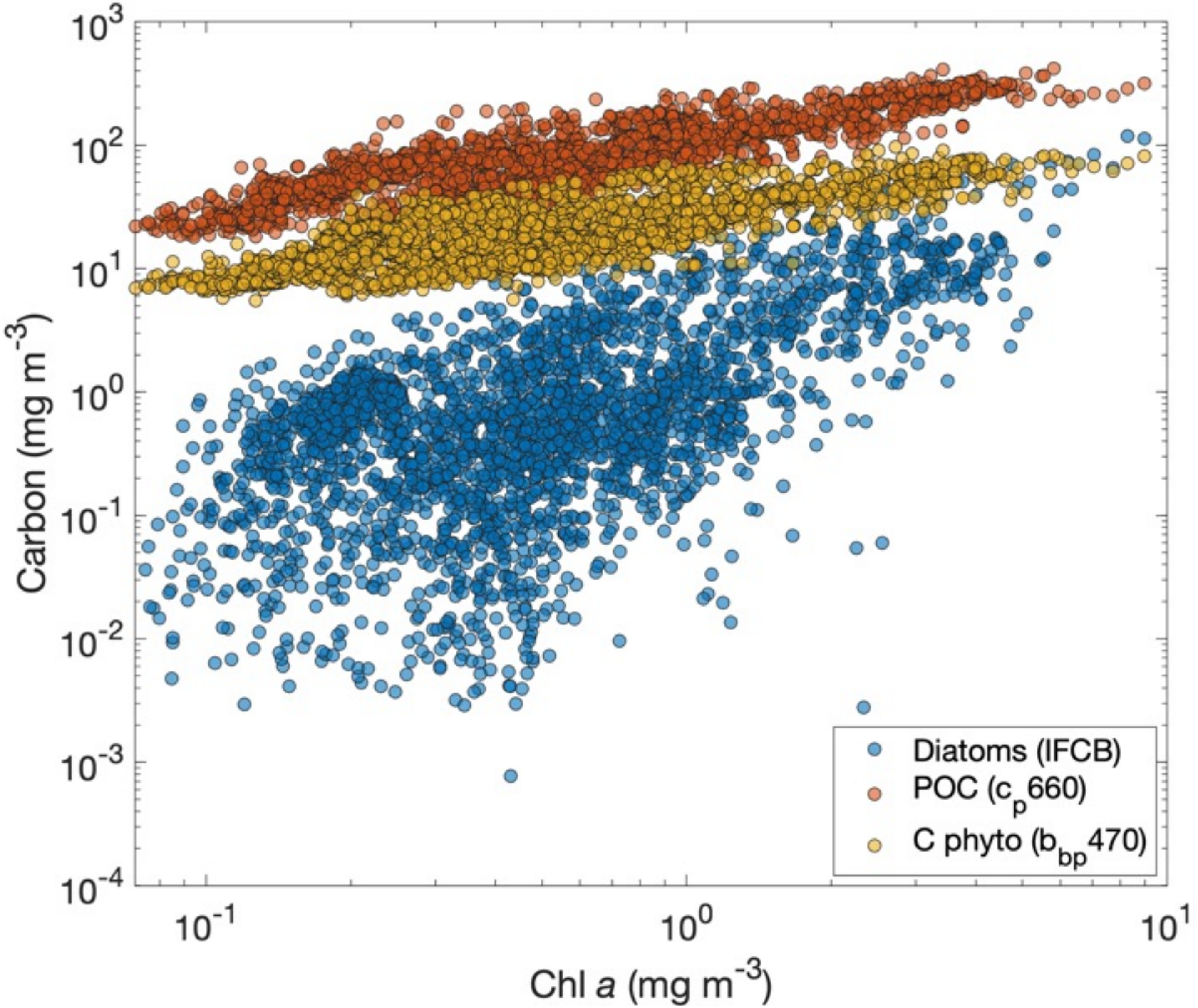




- Map shows locations with both input measurements and plankton imagery data
- Model inputs currently include: temperature, salinity, Chl *a*, Chl *b*, Chl *c*, carotenoids, b_{bp}

Chase et al. *in prep*

Variability in diatom carbon, phytoplankton carbon, and POC across chl *a*

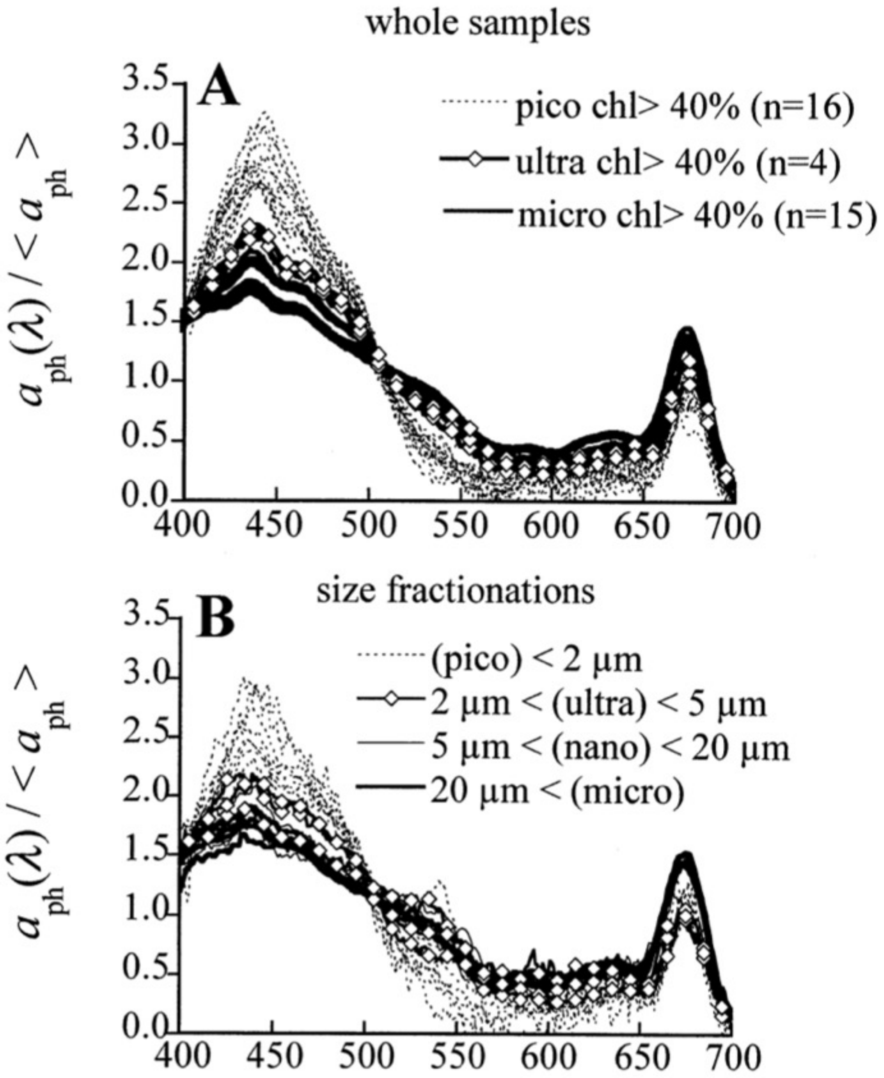


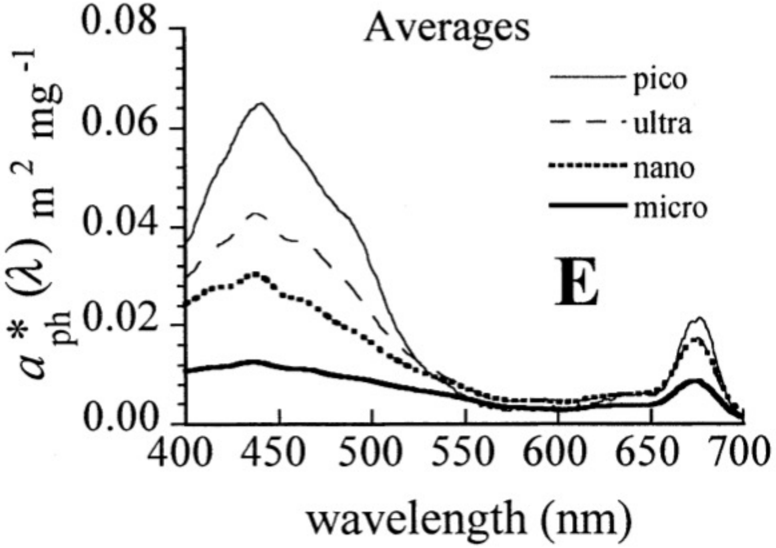
Diatom carbon from plankton imagery : Chase et al., 2022

POC from c_p : Gardner et al., 2006

C phyto from b_{bp} : Graff et al., 2015

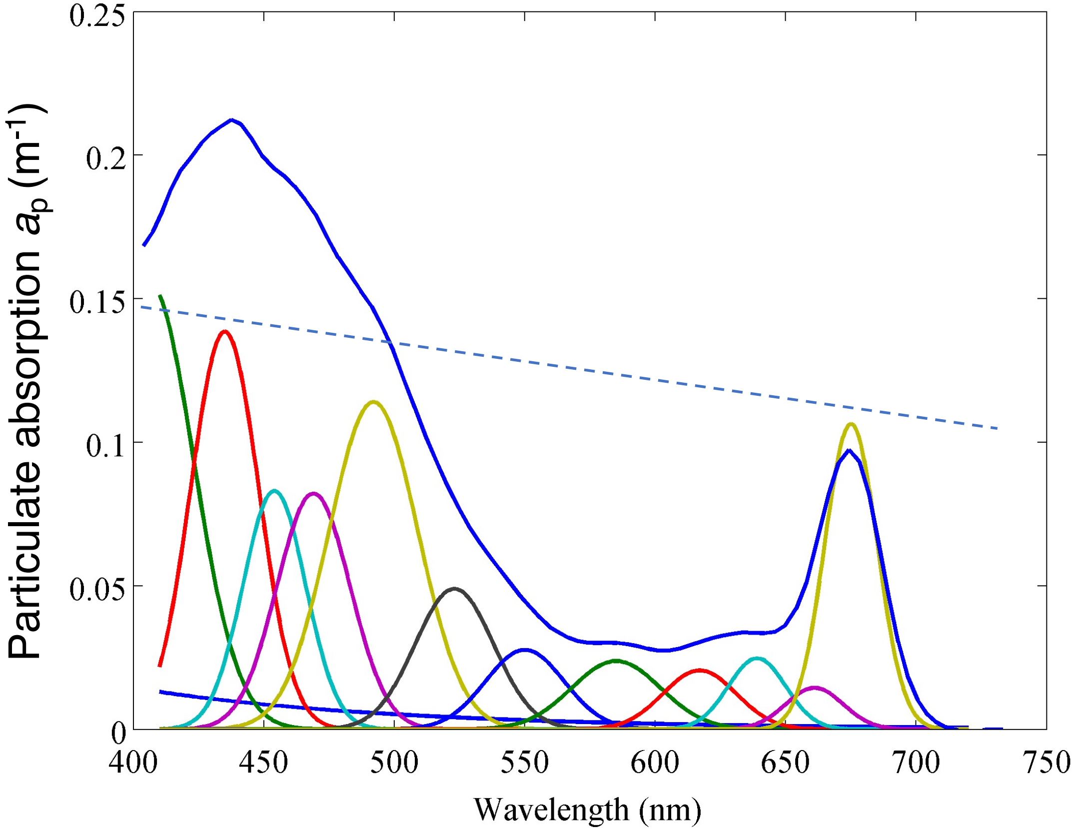
The use of spectral shape as a size metric



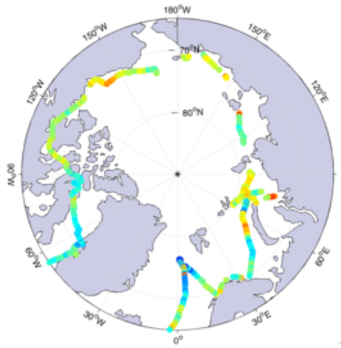


Ciotti et al., 2002

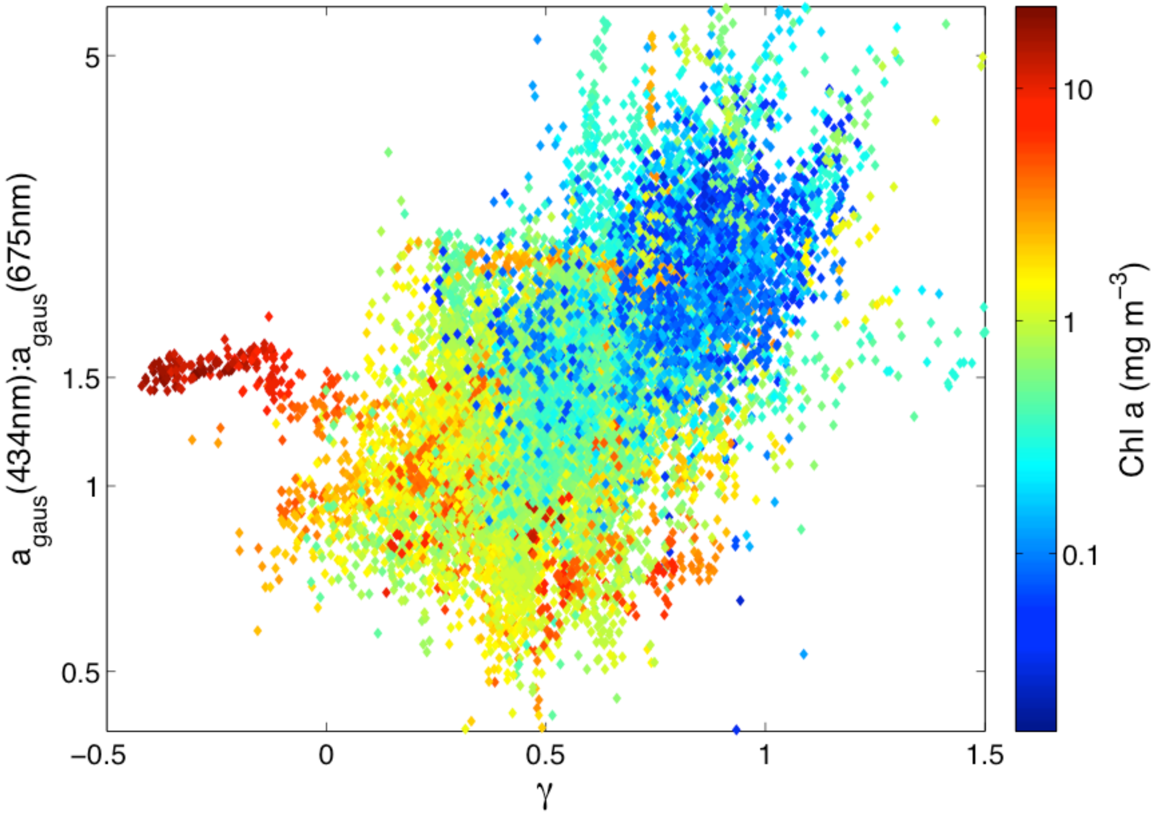
The use of blue:red absorption ratio derived from a_p as a size metric

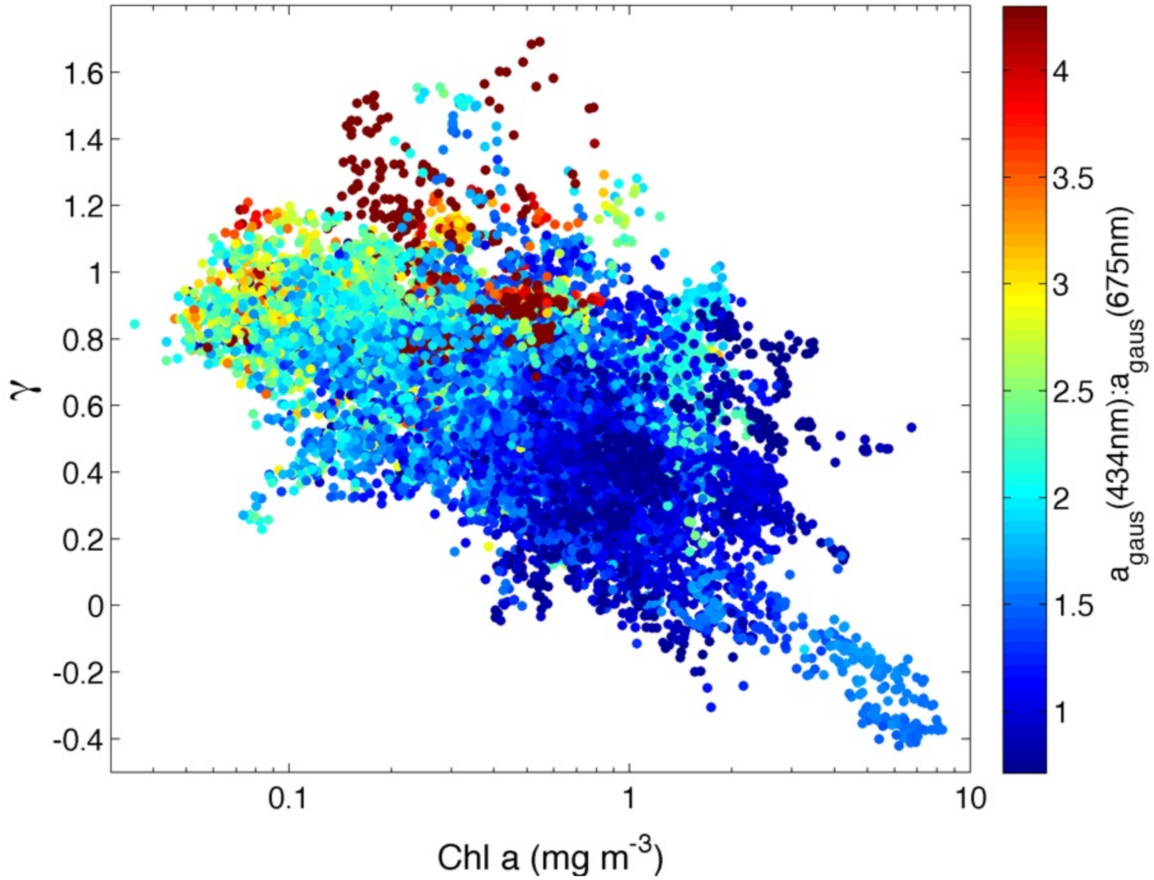


The use of the ratio between a_{gaus}(434nm) and a_{gaus}(675nm) rather than total phytoplankton absorption ($a_{\phi}(\lambda)$) at 434nm and 675nm improves the correlation between blue:red and γ, potentially due to removal of the effects of changing pigment composition on blue:red from $a_{\phi}(\lambda)$, since ideally a_{gaus}(434nm) represents absorption by Chl *a* and not other accessory pigments.



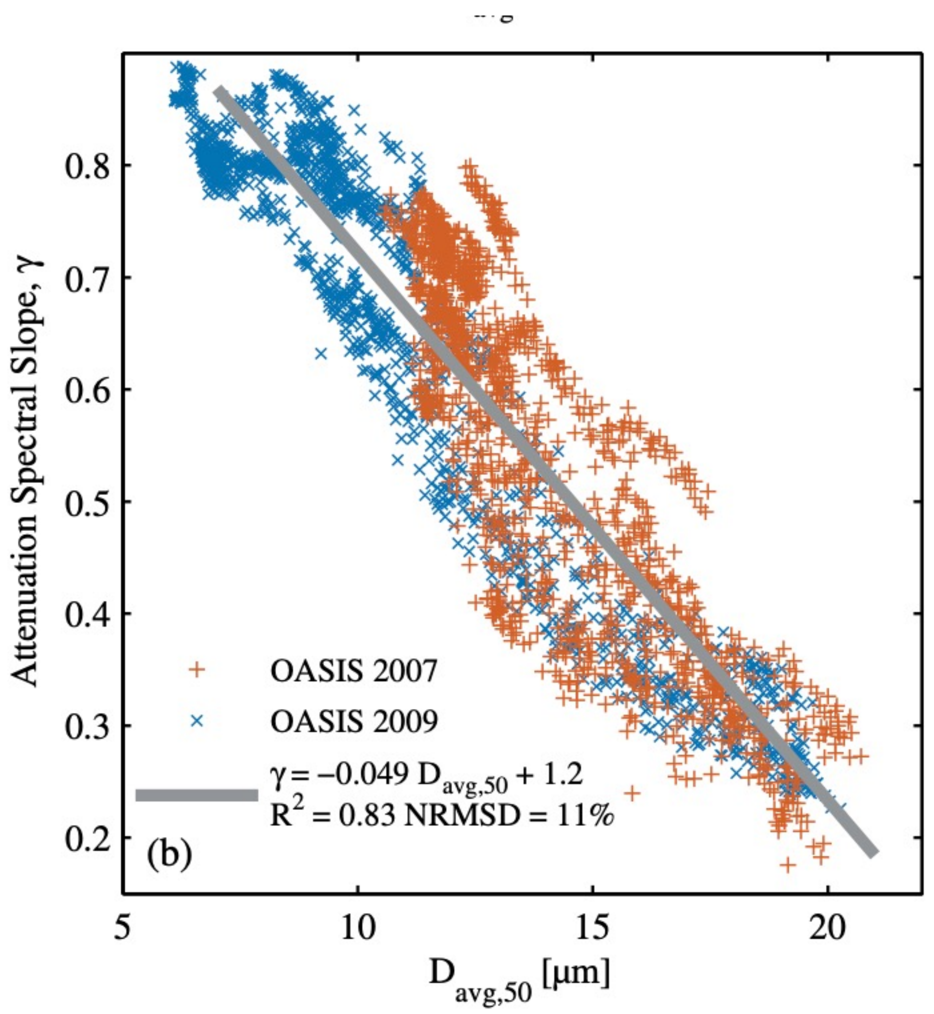
blue:red and γ in the Arctic Ocean





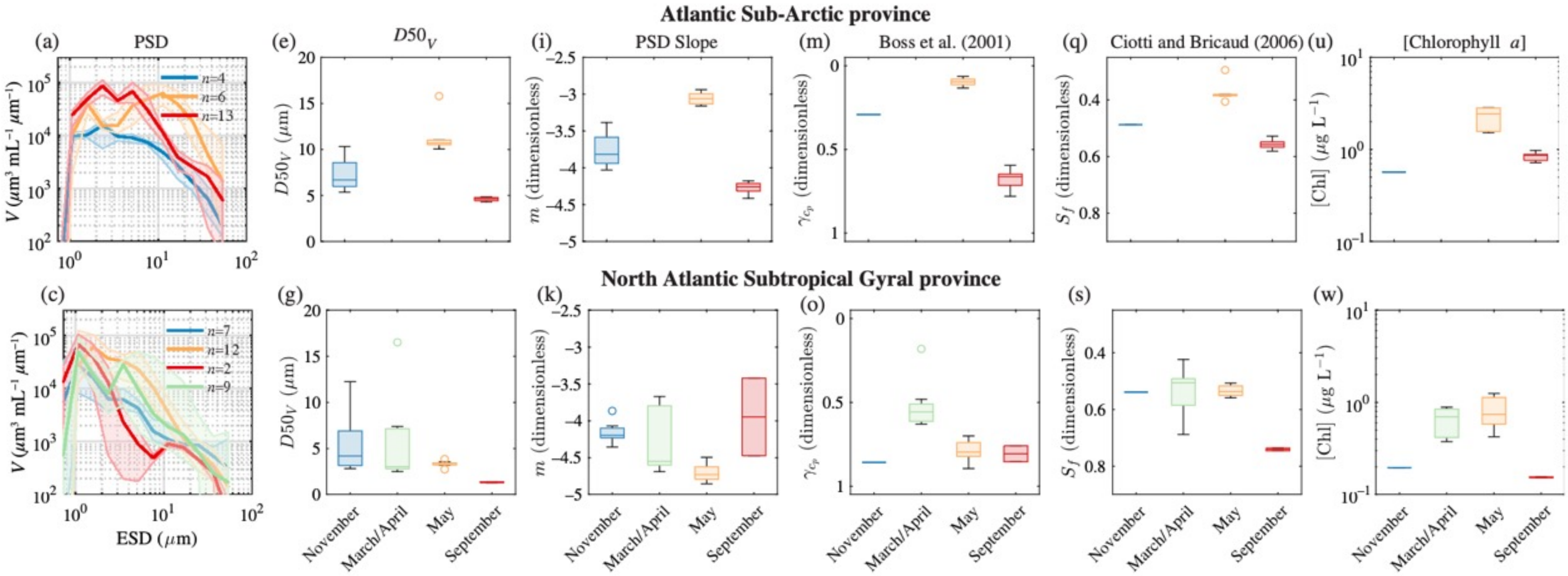
Data from Tara Oceans Polar Circle Expedition, 2013

The use of γ derived from c_p (spectral slope) as a size metric



Slade and Boss, 2015

PSDs and optical size proxies



Haëntjens et al., 2022

(near) real-time use of optics to locate features of interest

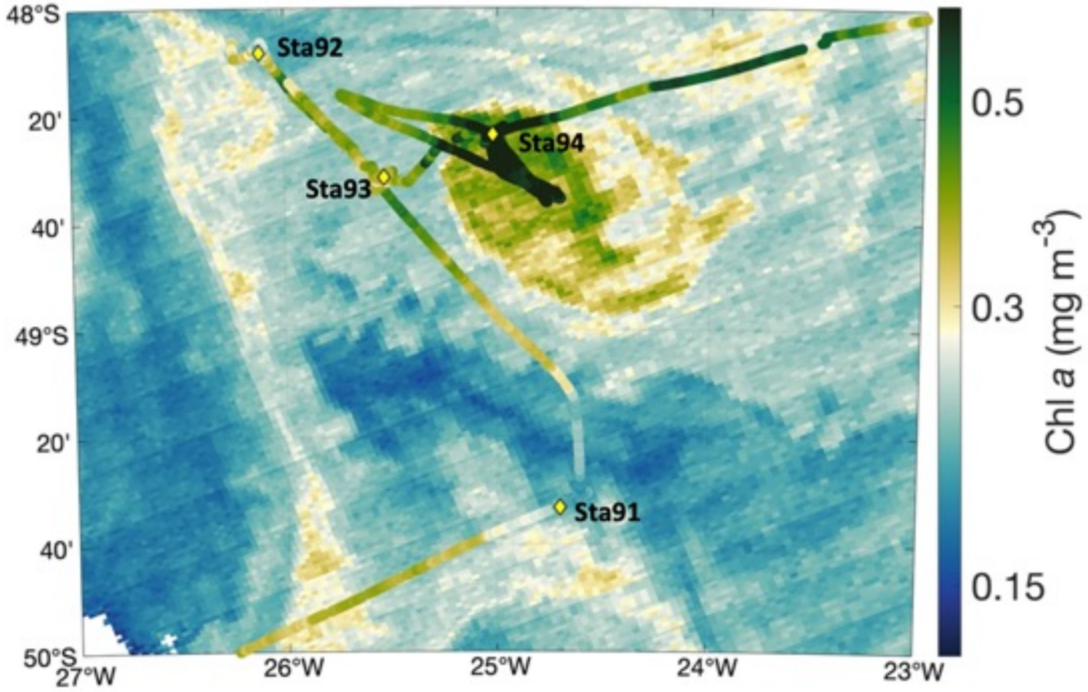
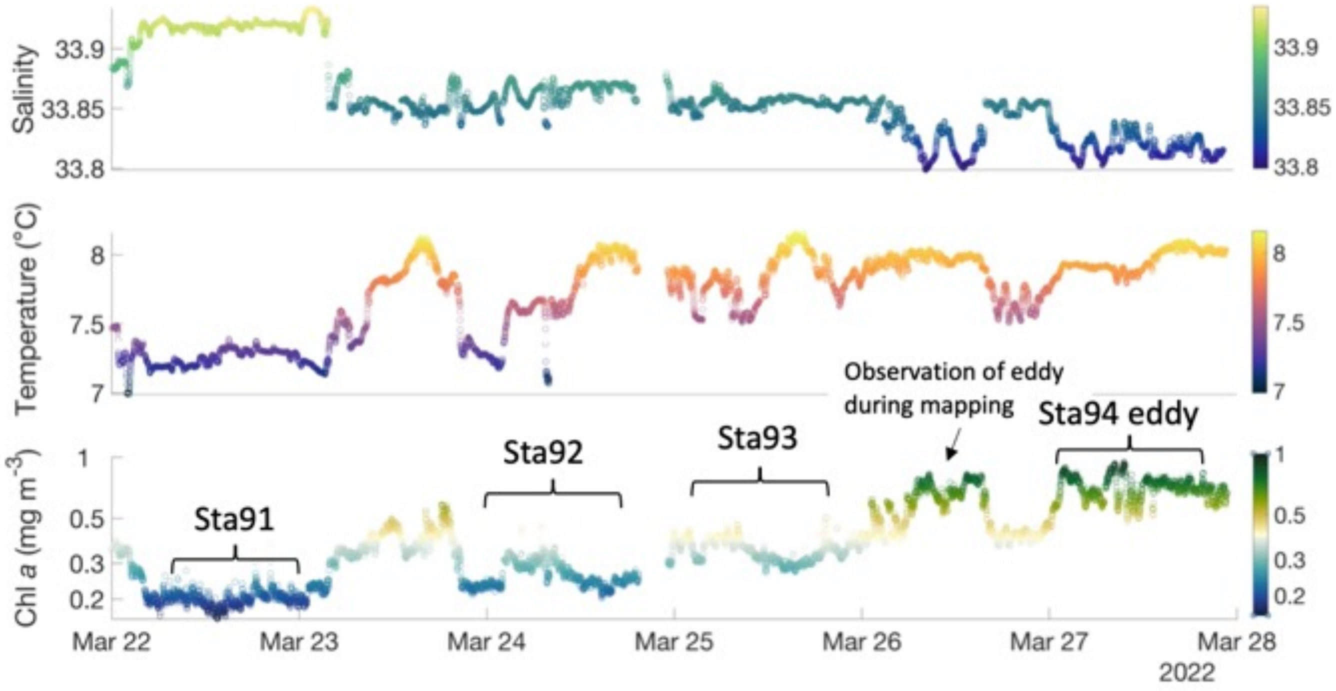


Figure 5. Satellite (MODIS AQUA) chlorophyll a (Chl a) from March 27. Ship-track from March 22-27 overlain with points colored by Chl a derived from absorption spectra, and with four stations labeled.



Data from Tara Mission Microbiome Expedition, 2022

Endorsed

Scan for a copy of the document:

OOI Biogeochemical Sensors Data: Best Practices & User Guide

Author(s): Hilary I. Palevsky, Sophie Clayton, Dariia Atamanchuk, Roman Battisti, Jennifer Batryn, Annie Bourbonnais, Ellen M. Briggs, Filipa Carvalho, Alison P. Chase, Rachel Eveleth, Rob Fatland, Kristen E. Fogaren, Jonathan Peter Fram, Susan E. Hartman, Isabela Le Bras, Cara C. M. Manning, Joseph A. Needoba, Merrie Beth Neely, Hilde Oliver, Andrew C. Reed, Jennie E. Rheuban, Christina Schallenberg, Michael F. Vardaro, Ian Walsh, Christopher Wingard

Essential Ocean, Climate, Biodiversity Variable(s): Oxygen, Nutrients, Inorganic Carbon, Particulate Matter, Ocean Colour
Supporting or other variables:
Network(s): US Ocean Observatories Initiative (OOI)
Sensors: oxygen optodes: SBE 43, SBE 43F, Aanderaa Optode 4330 and 4831: nitrate UV spectrometer sensors: SUNA V2 and ISUS; inorganic carbon Pro-Oceanus CO_2-Pro Atmosphere, Sunburst SAMI-pH, and Sunburst SAMI-CO_2; fluorometer and optical backscatter sensors: ECO-FLBBCD, ECO-FLbb, ECO-FLNTU, ECO-FL.
Endorsed by (GOOS PANEL, eg OCG, BIOECO): GOOS Biogeochemistry Panel
Endorsement date: May 2023
DOI Identifier: http://dx.doi.org/10.25607/OBP-1865

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Many relevant papers by Emmanuel Boss & colleagues: https://misclab.umeoce.maine.edu/publications/scientific_articles.php


Thank you!