Bigelow | Laboratory for Ocean Sciences

Copepods from Space?

Remote sensing of Calanus finmarchicus

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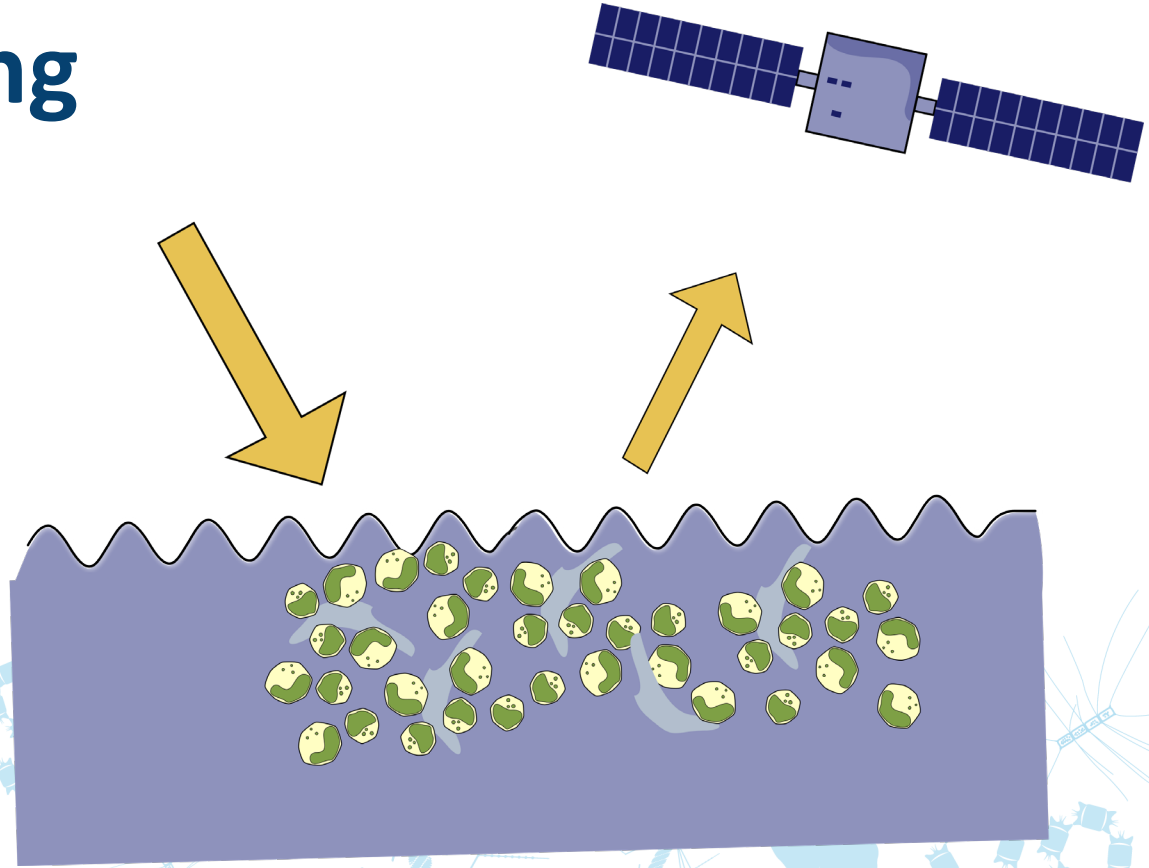
Ocean color remote sensing



What materials contribute to ocean color?

sediments (sands, silts, clays)
inorganic

phytoplankton

CDOM (colored dissolved organic matter)

water

What is the size range of these materials?

Stemmann & Boss (2012)

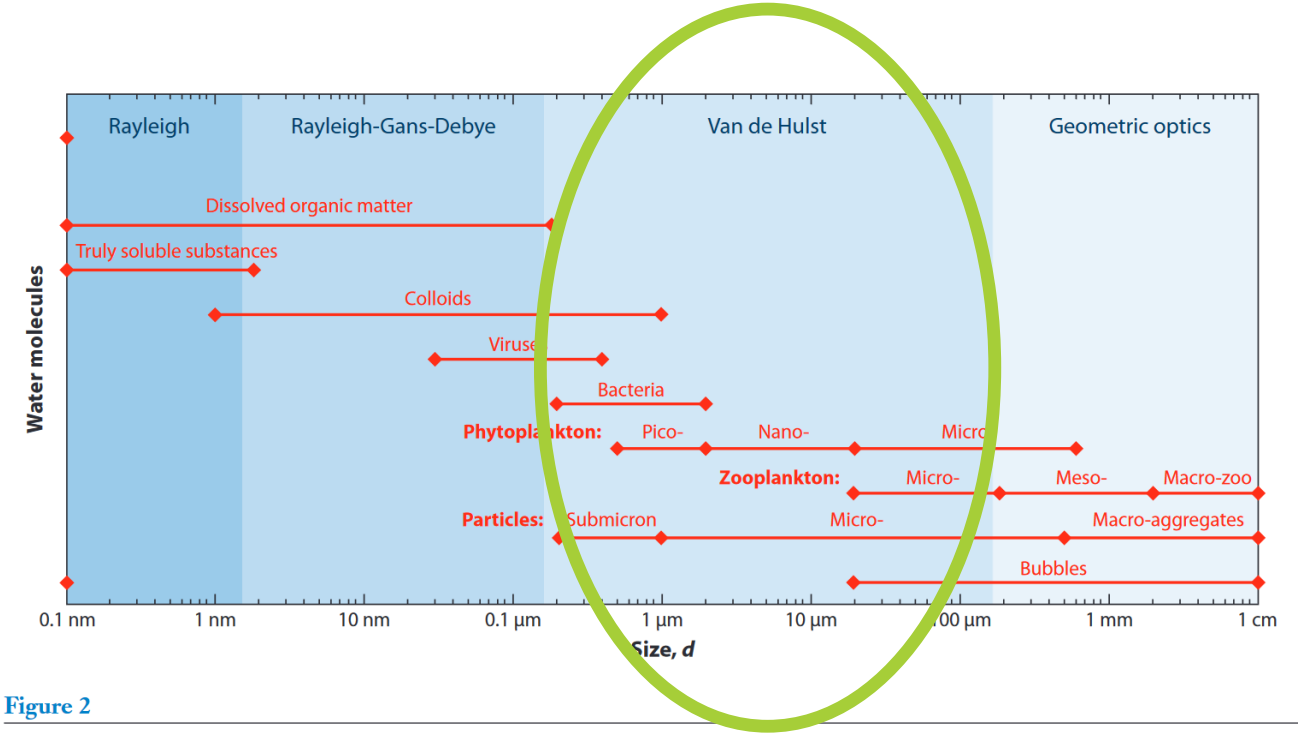
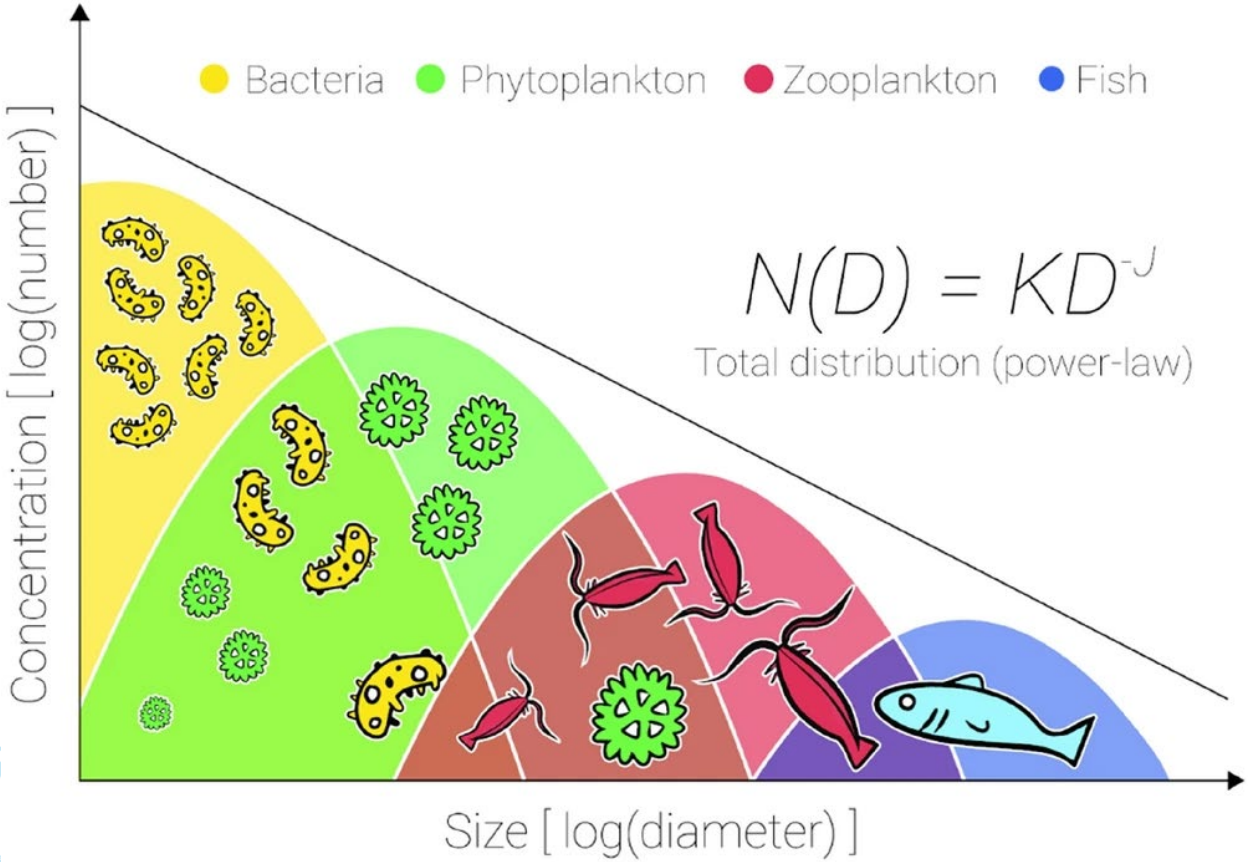


Figure 2

What is the size range of these materials?

Davies et al (2021)



Stemmann & Boss (2012)

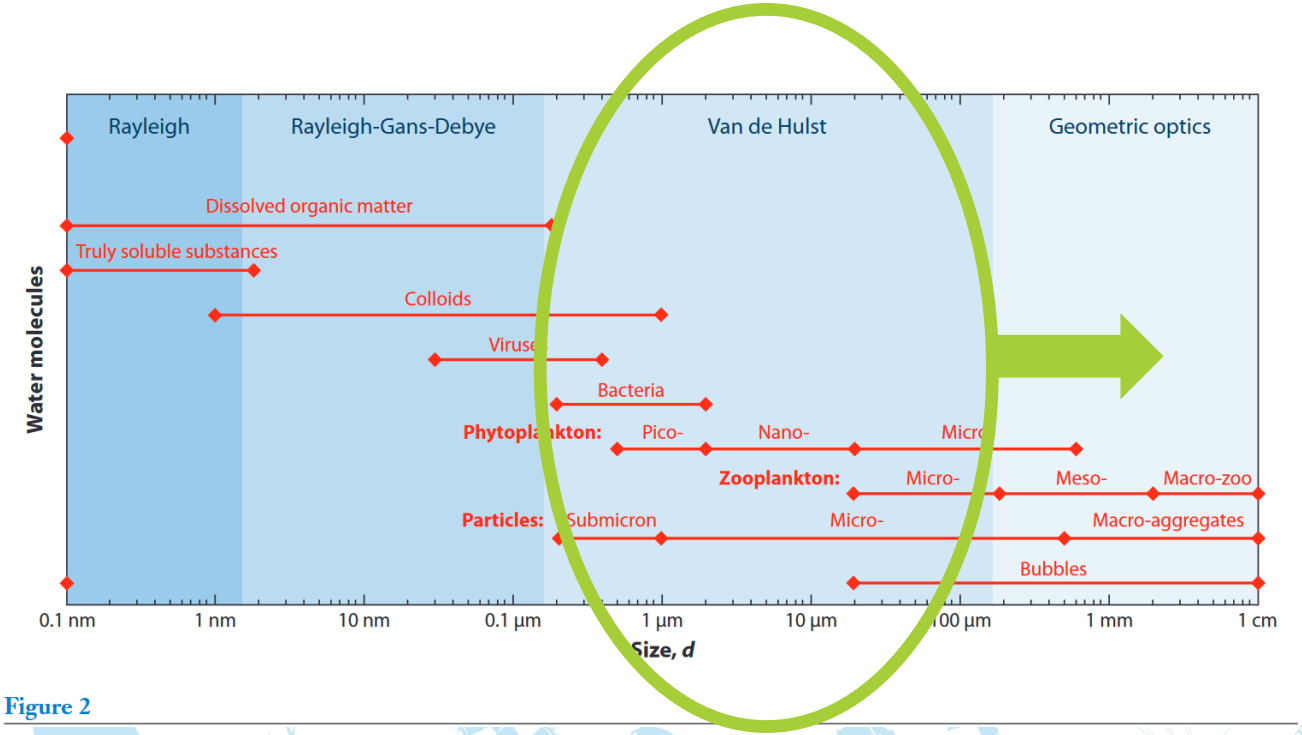
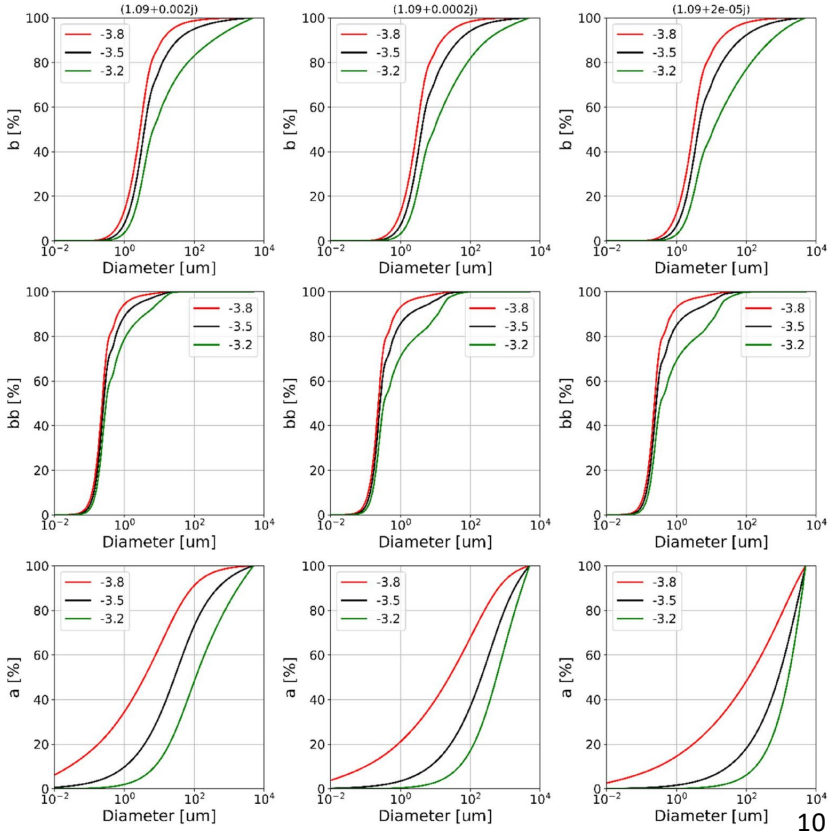


Figure 2

Influence of “large” particles on optical properties



10 mm

Figure 4. Changing imaginary refractive index (columns) on cumulative contributions to (top row) scattering, (middle row) backscattering, and (bottom row) absorption. Red, black and green lines represent PSD slopes of 3.8, 3.5 and 3.2 respectively. Failure to reach a horizontal asymptote implies that the range of significant particle sizes extends beyond the range of sizes simulated here (0.001–5000 μm).

Mie theory modeling

→ homogeneous spheres

Inputs:

Particle diameter

Refractive index, m

$m = n_r + in_i$

where

n_r represents the phase velocity of light

n_i represents the extinction of light due to absorption

Article | Open Access | Published: 17 February 2021

The hidden influence of large particles on ocean colour

Emlyn J. Davies, Sünnje L. Basedow & David McKee

Scientific Reports **11**, Article number: 3999 (2021) | Cite this article

What are these large particles?

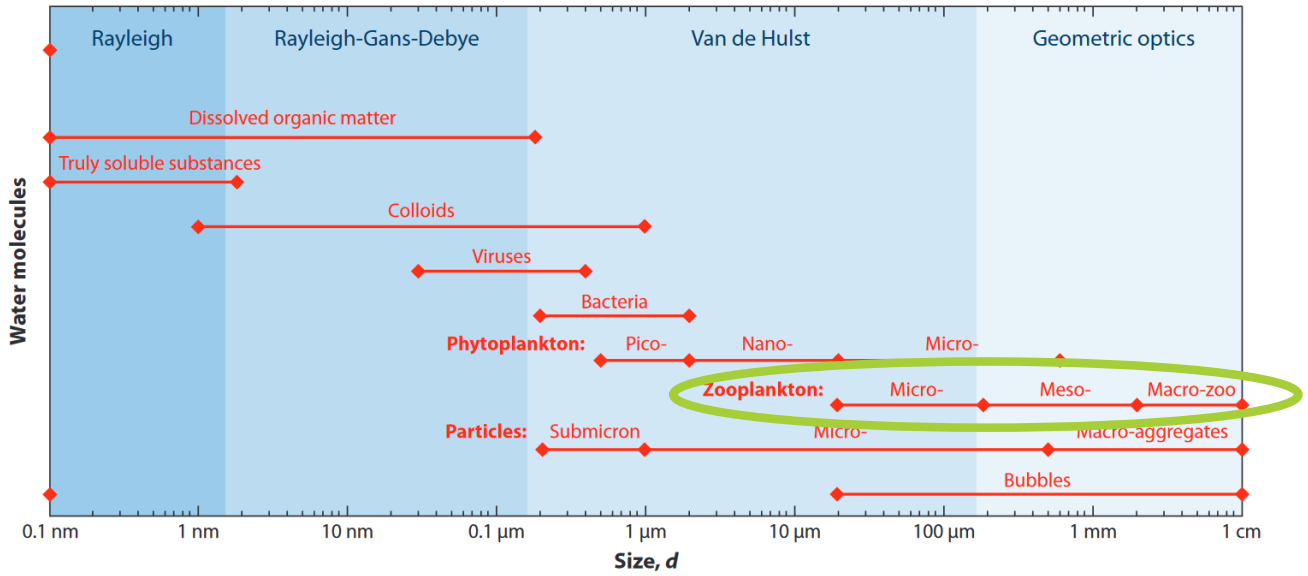


Figure 2

Article | Open Access | Published: 24 January 2019

Remote sensing of zooplankton swarms

Sünnje L. Basedow, David McKee, Ina Lefering, Astthor Gislason, Malin Daase, Emilia Trudnowska, Einar Skarstad Egeland, Marvin Choquet & Stig Falk-Petersen

Scientific Reports **9**, Article number: 686 (2019) | Cite this article

Passive ocean color remote sensing

Active ocean color remote sensing

Article | Published: 27 November 2019

Global satellite-observed daily vertical migrations of ocean animals

Michael J. Behrenfeld, Peter Gaube, Alice Della Penna, Robert T. O'Malley, William J. Burt, Yongxiang Hu, Paula S. Bontempi, Deborah K. Steinberg, Emmanuel S. Boss, David A. Siegel, Chris A. Hostetler, Philippe D. Tortell & Scott C. Doney

Nature **576**, 257–261 (2019) | Cite this article

Article | Open Access | Published: 24 January 2019

Remote sensing of zooplankton swarms

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Skarstad

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Estimating Surface Concentrations of *Calanus finmarchicus* Using Standardised Satellite-Derived Enhanced RGB Imagery

by Cait L. McCarry [1,*], Sünnje L. Basedow [2], Emlyn J. Davies [3] and David McKee [1,2]

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[2] Department of Arctic and Marine Biology, UiT The Arctic University of Norway, 9019 Tromsø, Norway
[3] SINTEF Ocean, 7010 Trondheim, Norway
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Remote Sens. **2023**, *15*(12), 2987; https://doi.org/10.3390/rs15122987

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Why the Gulf of Maine ?

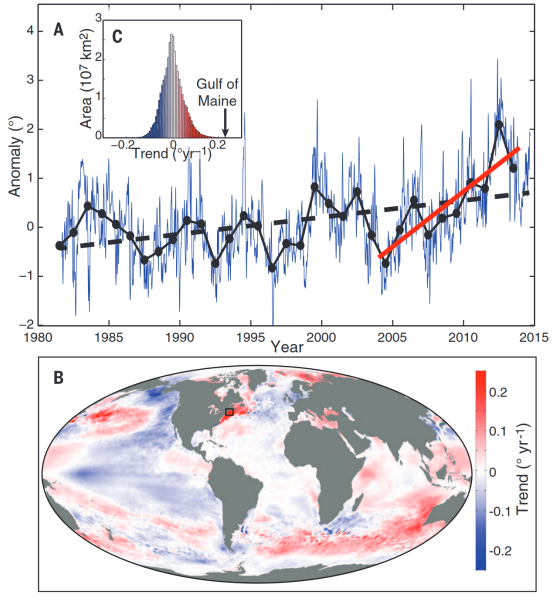
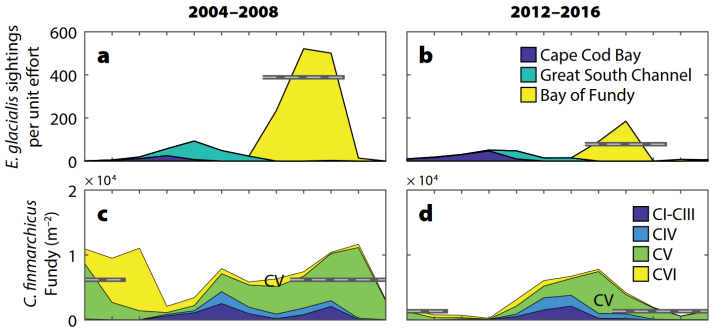
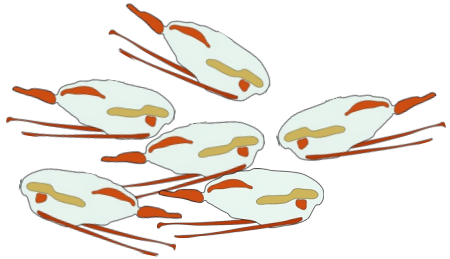


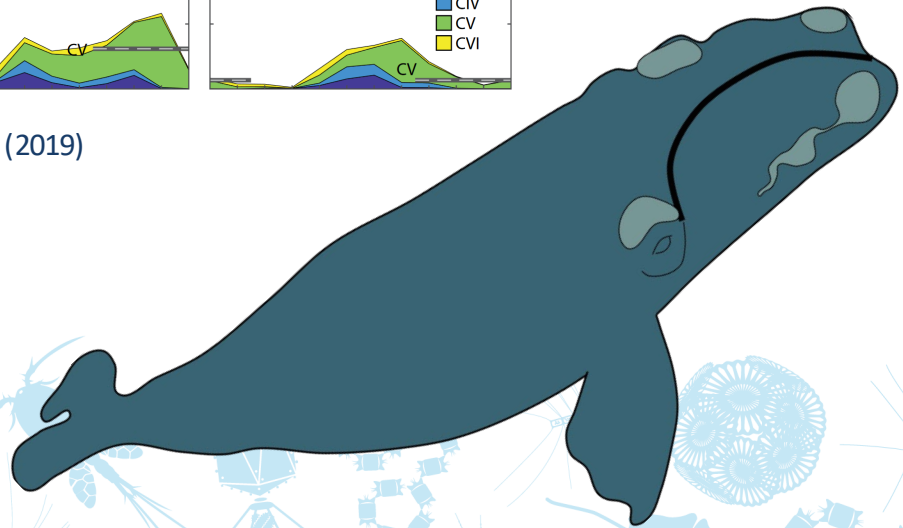
Fig. 1. Sea surface temperature trends from the Gulf of Maine and the global ocean. (**A**) Daily (blue, 15-day smoothed) and annual (black dots) SST anomalies from 1982 to 2013, showing the long-term trend (black dashed line) and trend over the decade 2004–2013 (red solid line). (**B**) Global SST trends, 2004–2013. The Gulf of Maine is outlined in black. (**C**) Histogram of global 2004–2013 SST trends, with the trend from the Gulf of Maine indicated at the right extreme of the distribution.

Pershing et al (2015)



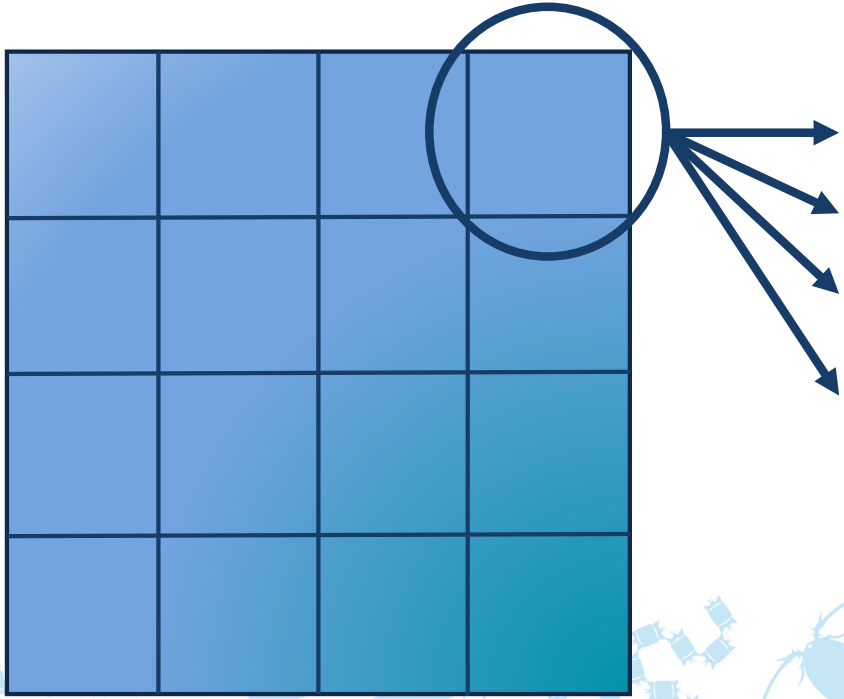
Record et al (2019)





Optically significant material (OSM)

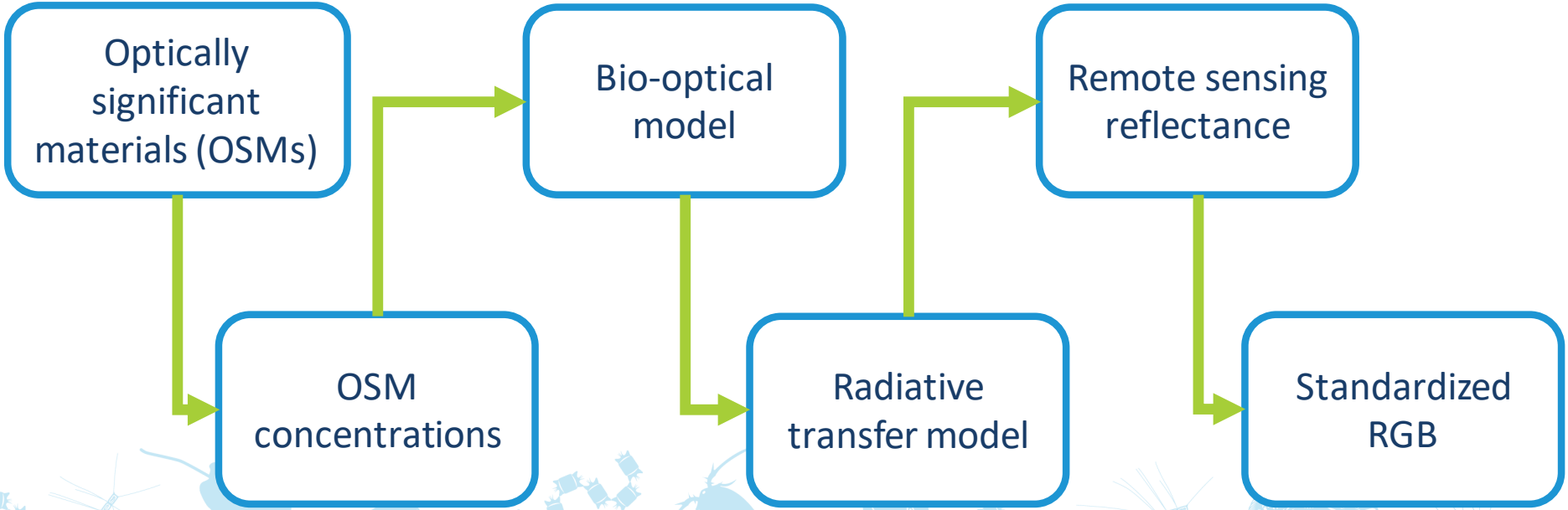
What are we doing?



Look-up-table (LUT)

RED	GREEN	BLUE	OSM 1	OSM 2	OSM 3

Building the LUT



Bio-optical model

Mass-specific inherent optical property (SIOP)

$$a = a_w + a_{ph} + a_{CDOM} + a_{MSS}$$

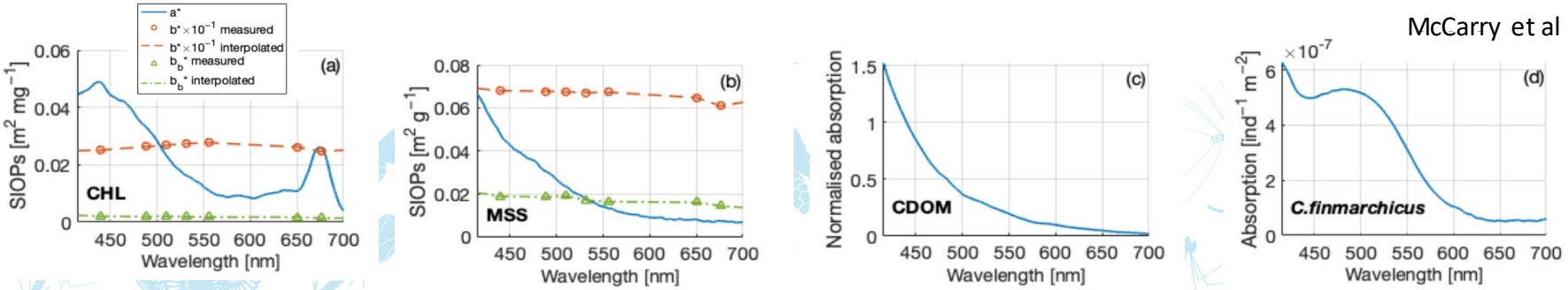
$$a = a_w + a^*_{ph}[CHL] + a^*_{CDOM}[CDOM] + a^*_{MSS}[MSS] + a^*_{cal}[CAL]$$

OSM concentration

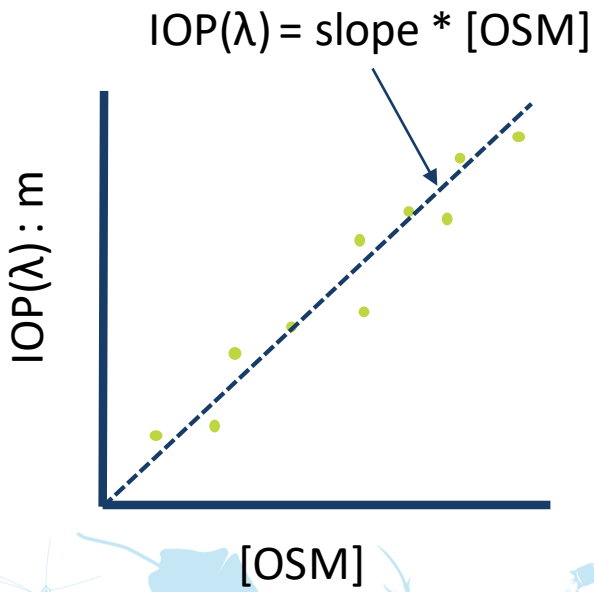
$$b = b_w + b^*_{ph}[CHL] + b^*_{MSS}[MSS]$$

$$b_b = b_{bw} + b^*_{b\ ph}[CHL] + b^*_{b\ MSS}[MSS]$$

McCarry et al (2023)



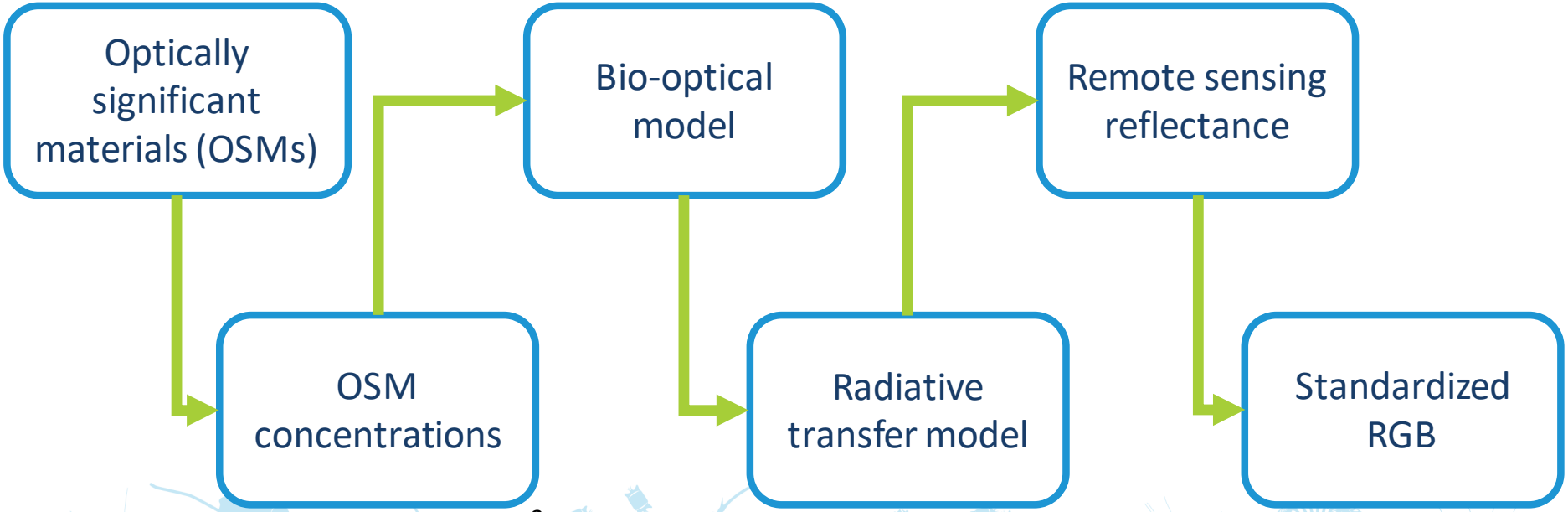
Where do the SIOPs come from?



How do we measure the IOPs?

- ac-9 (or ac-s) gives absorption, attenuation and scattering
- bb-9 (or bb-3 or Hyper-bb) gives backscattering
- PSICAM (point source integrating cavity absorption meter) give absorption
  - Particulate & dissolved absorption (CDOM)
- Filter pad absorption
  - Total particulate, non-algal pigments, phytoplankton absorption
- Offshore stations used to derive CHL-specific IOPs
- Onshore stations partitioned using CHL SIOPs

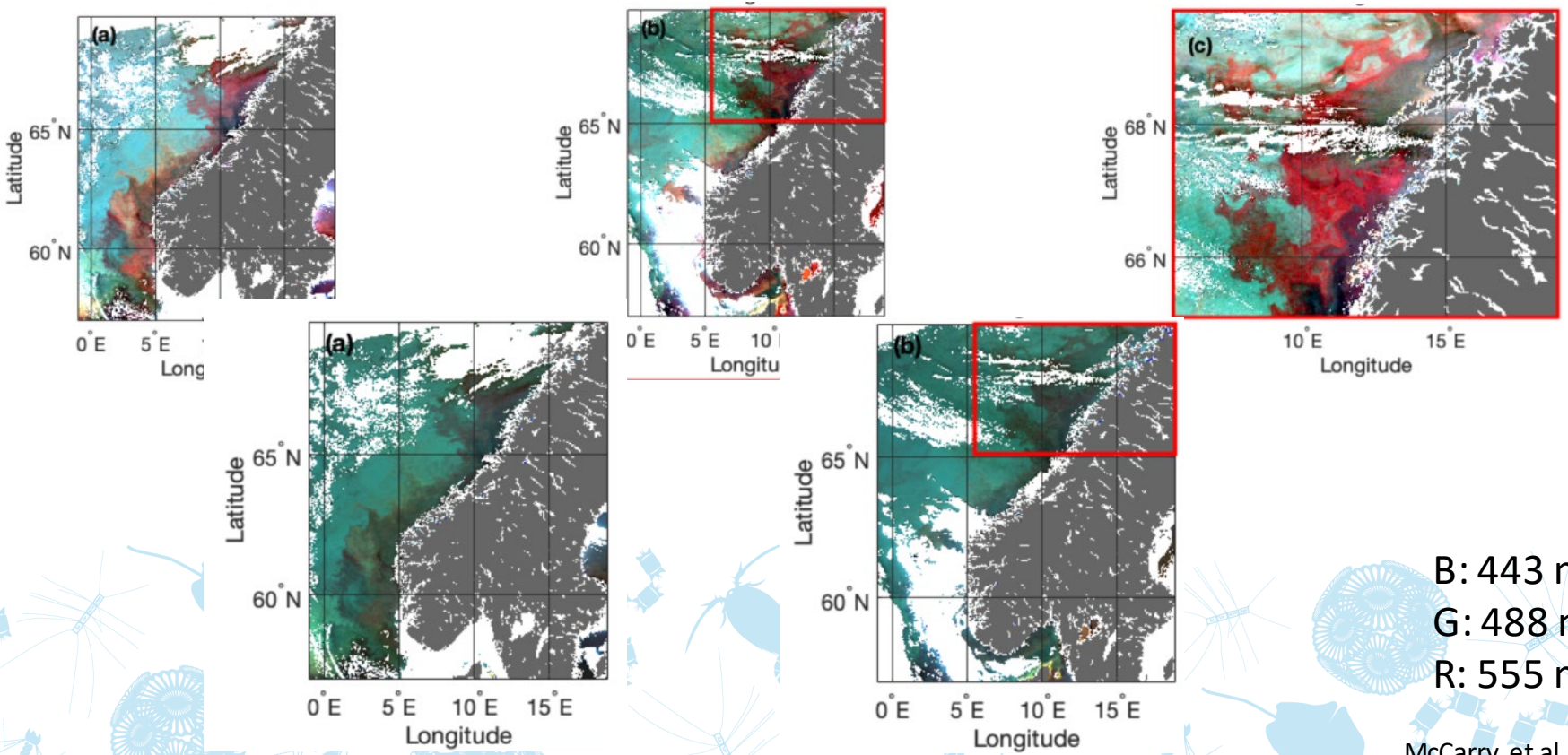
Building the LUT



CHL: 0.01 – 50 mg m^{-3}
MSS: 0.01 – 25 g m^{-3}
CDOM: 0.01 – 0.5 m^{-1}
Calanus: 0 – 200,000 ind m^{-3}

HydroLight
"MEASURED IOPS"

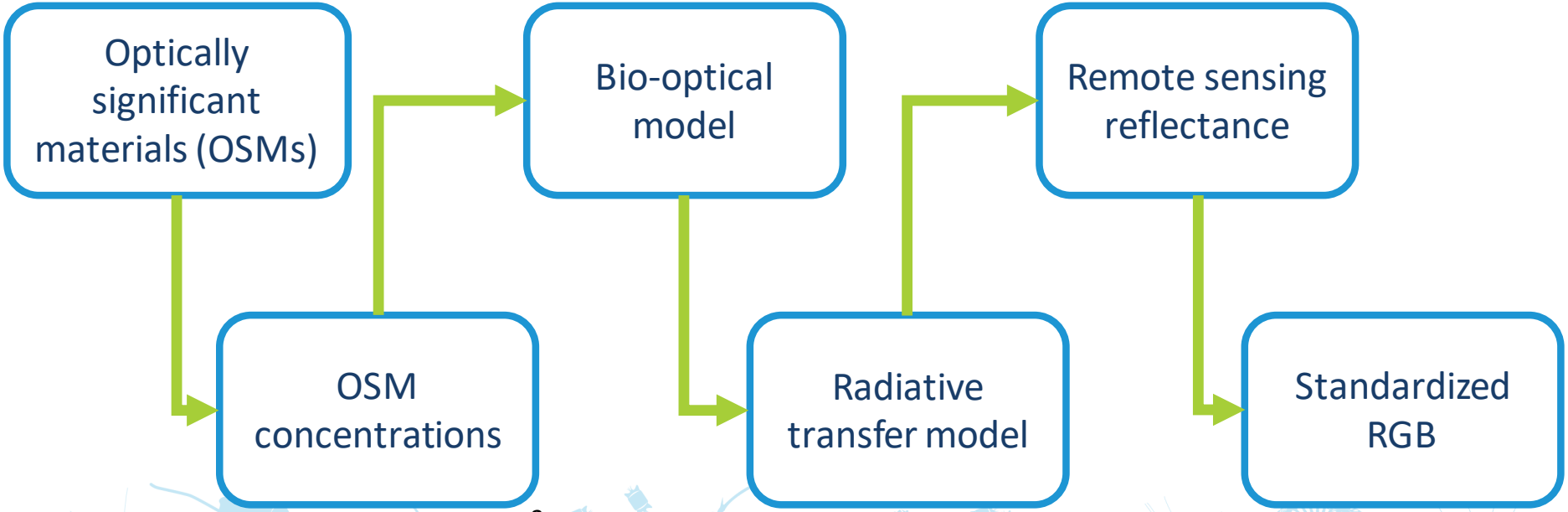
Enhanced RGB imagery (eRGB)



B: 443 nm
G: 488 nm
R: 555 nm

McCarry et al (2023)

Building the LUT



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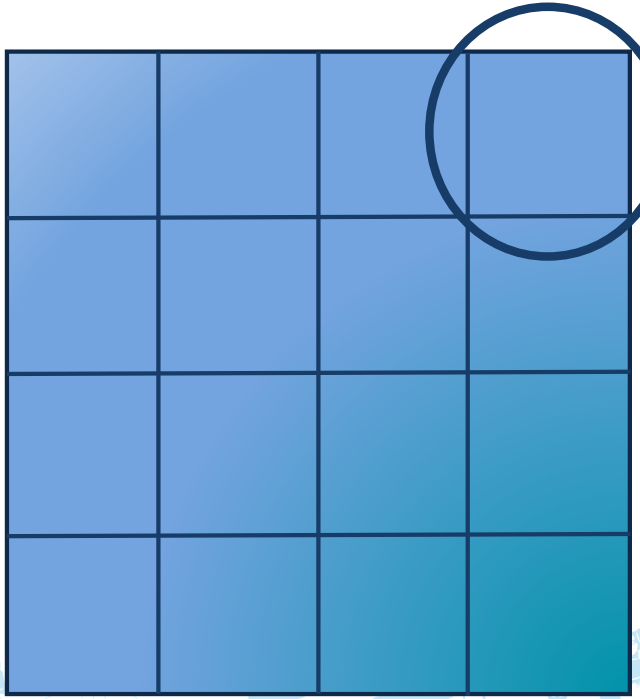
HydroLight
"MEASURED IOPS"

What are we doing?



?

Look-up-table (LUT)

RED	GREEN	BLUE	CHL	MSS	CDOM	CAL

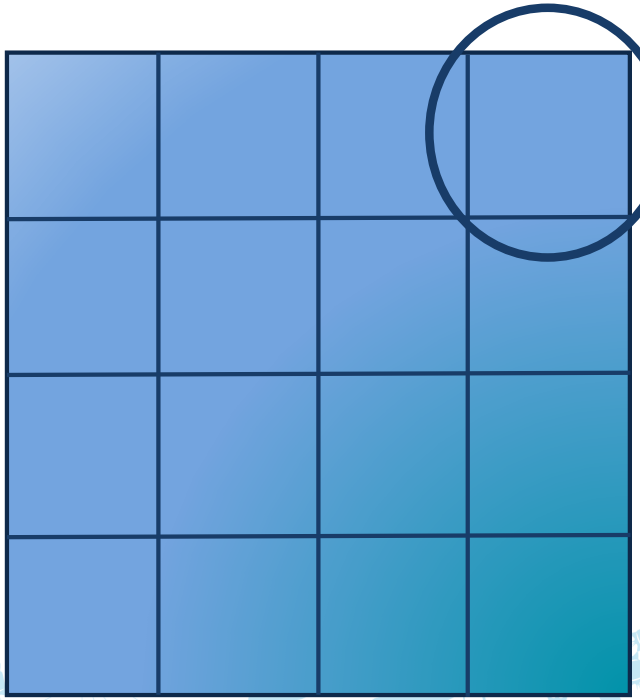
DeltaE: Color Difference

The difference between the visual perception of two colors

Delta E	Perception
<= 1.0	Not perceptible by human eyes.
1 - 2	Perceptible through close observation.
2 - 10	Perceptible at a glance.
11 - 49	Colors are more similar than opposite
100	Colors are exact opposite

Defined by the International Commission on Illumination (*CIE*) & a standard quantity in colorimetry

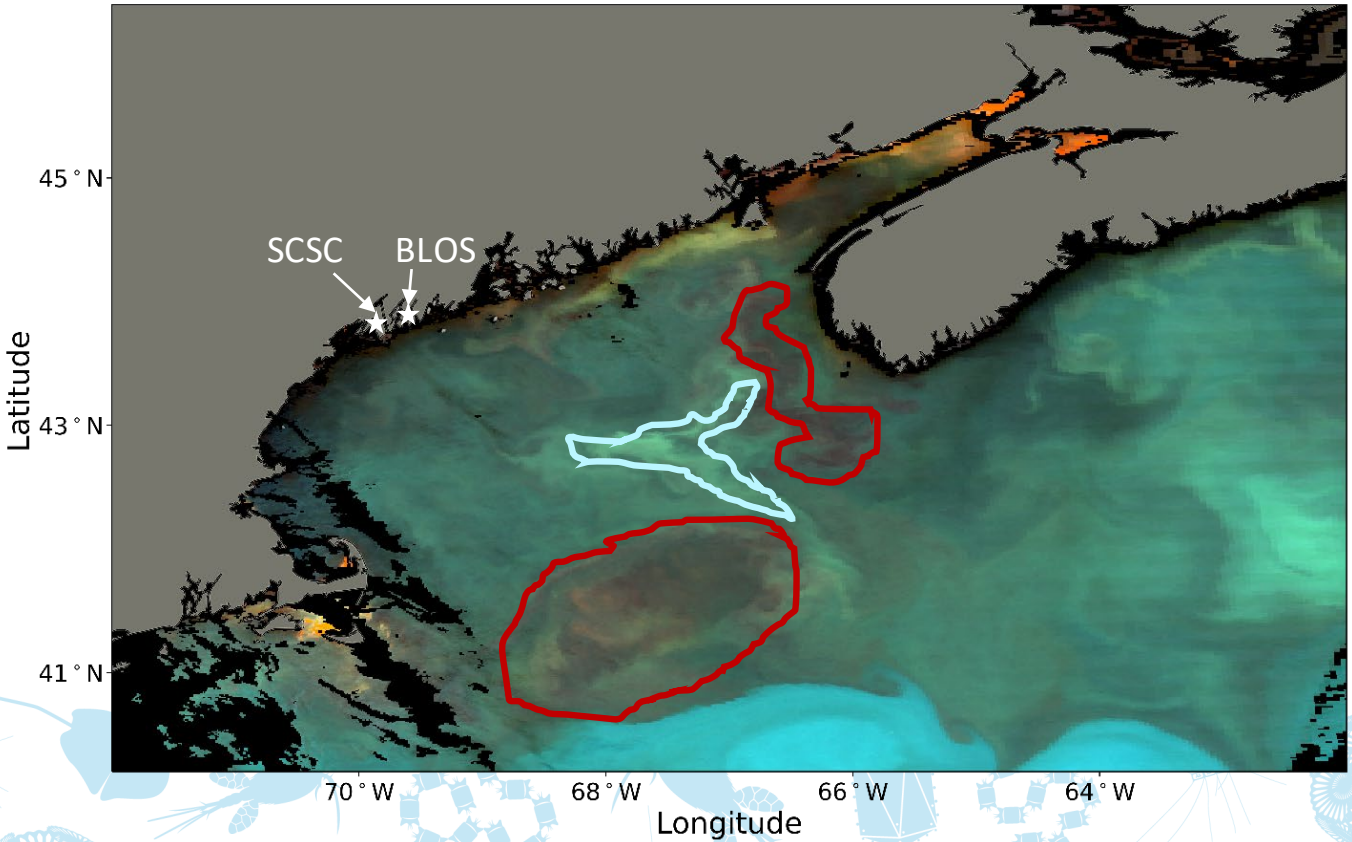
What are we doing?



DeltaE

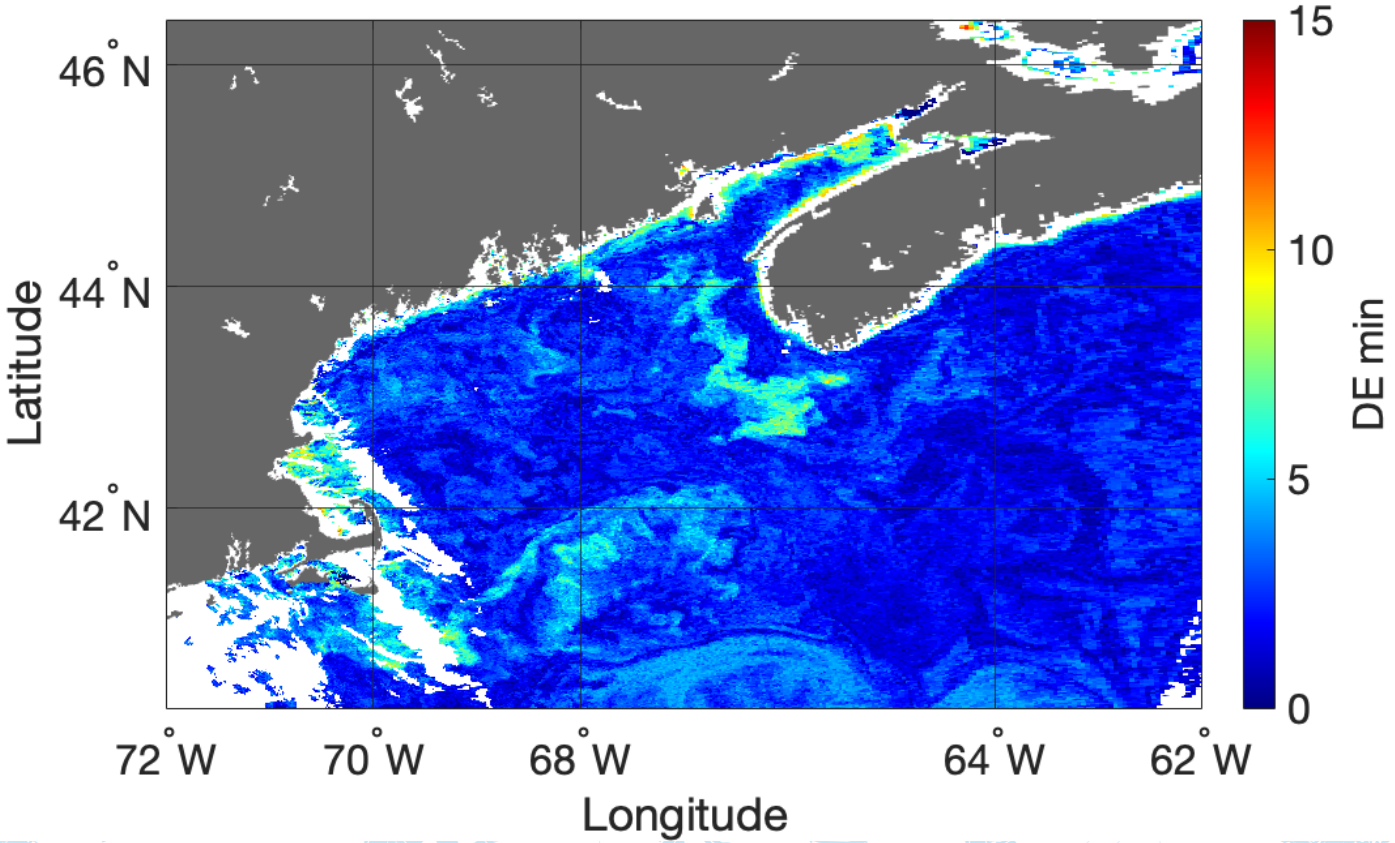
Look-up-table (LUT)

RED	GREEN	BLUE	CHL	MSS	CDOM	CAL



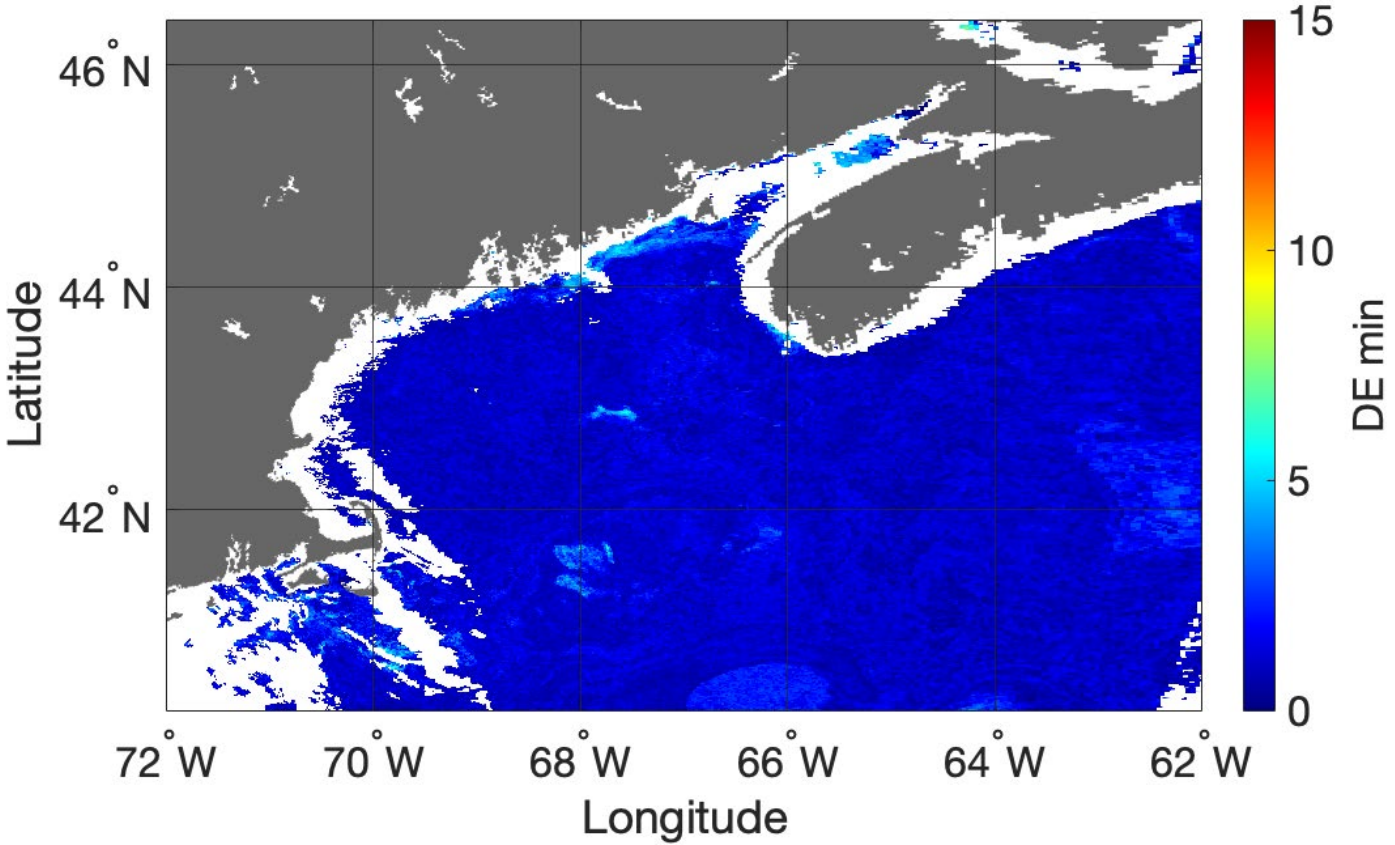
MODIS June 17th 2009

DeltaE anomaly map: CHL, MSS, CDOM



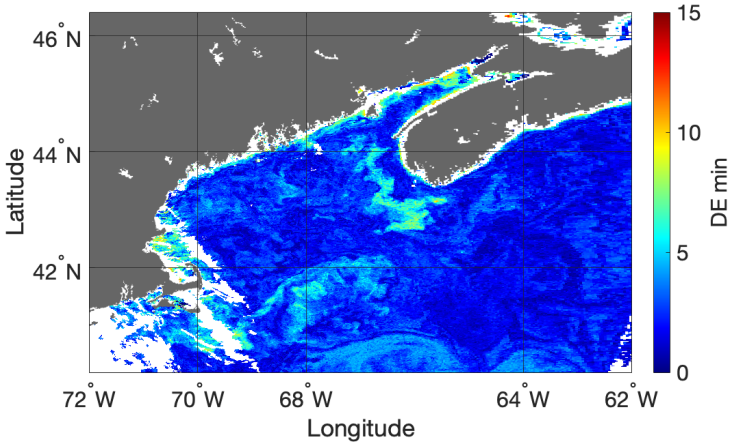
MODIS June 17th 2009

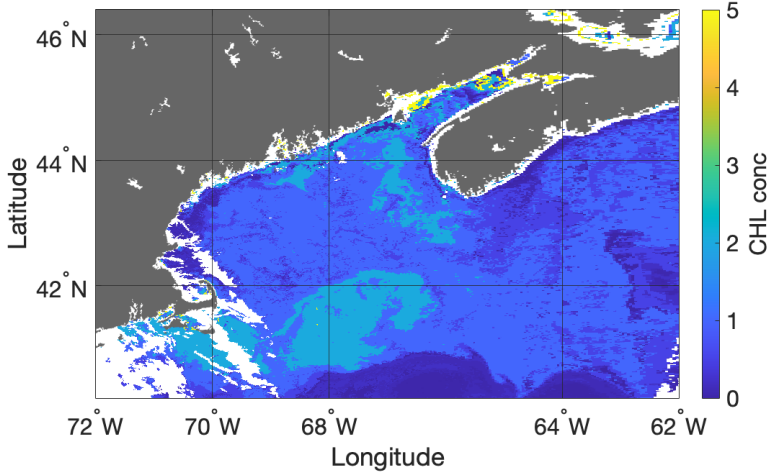
DeltaE anomaly map: CHL, MSS, CDOM, Cal



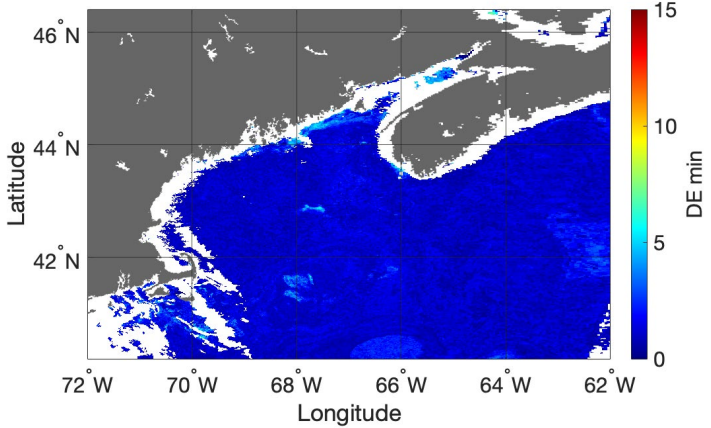
MODIS June 17th 2009

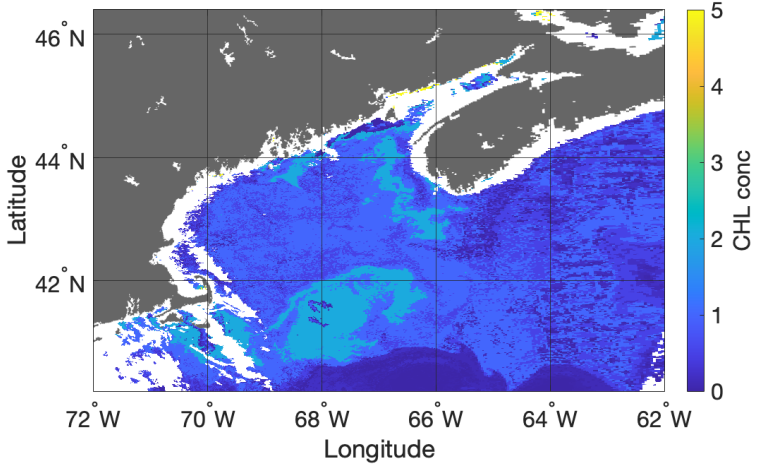
No Calanus



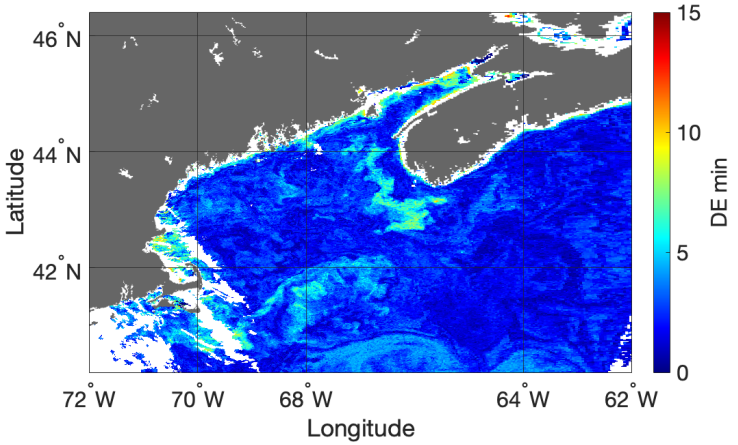


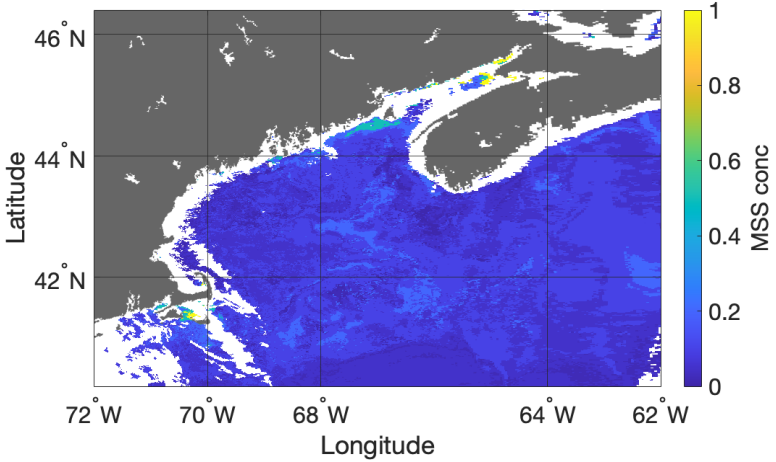
Includes Calanus





No Calanus





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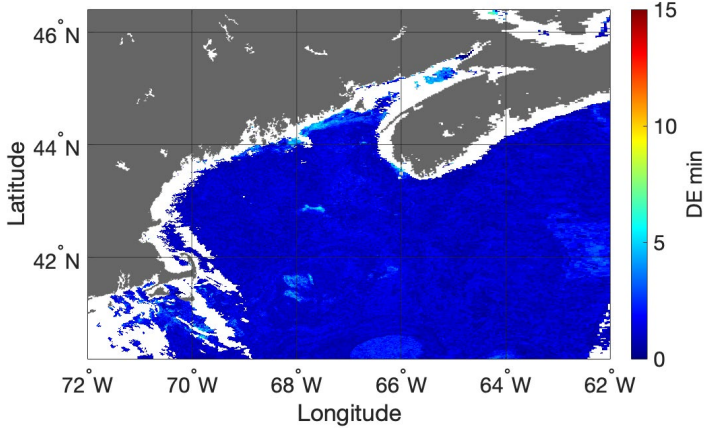
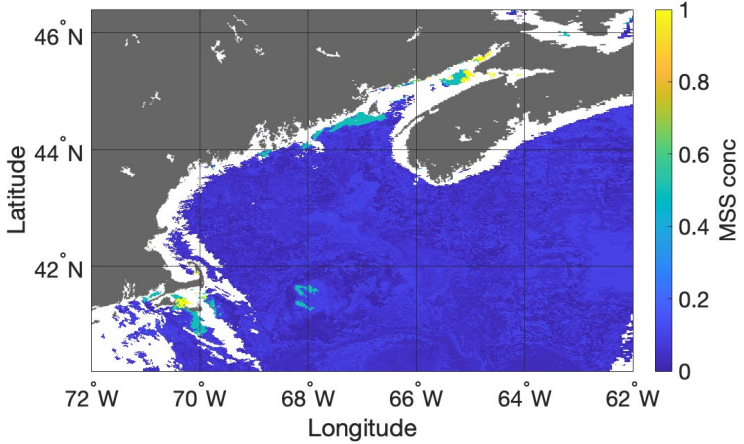
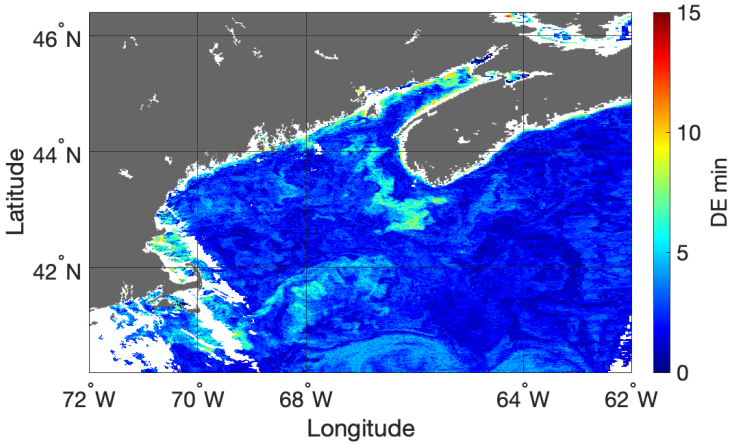
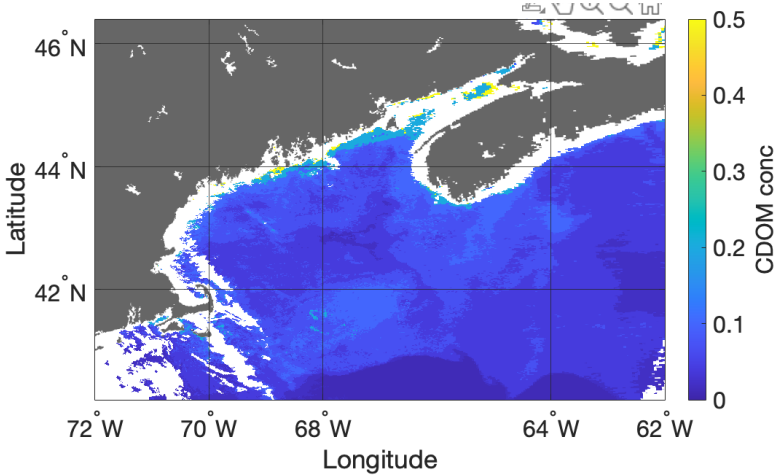


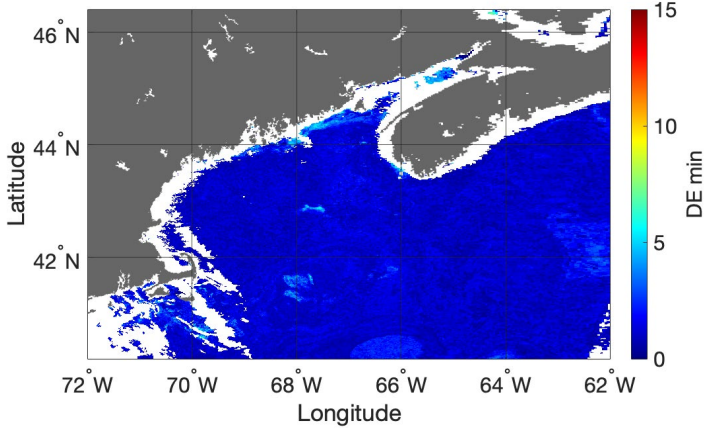


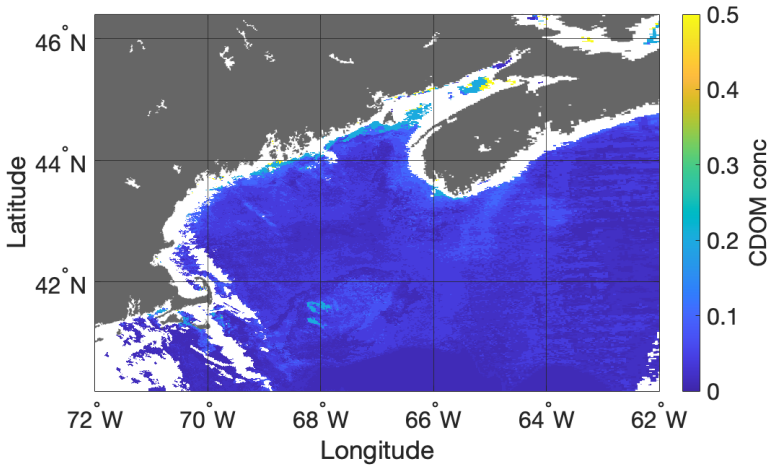
No Calanus

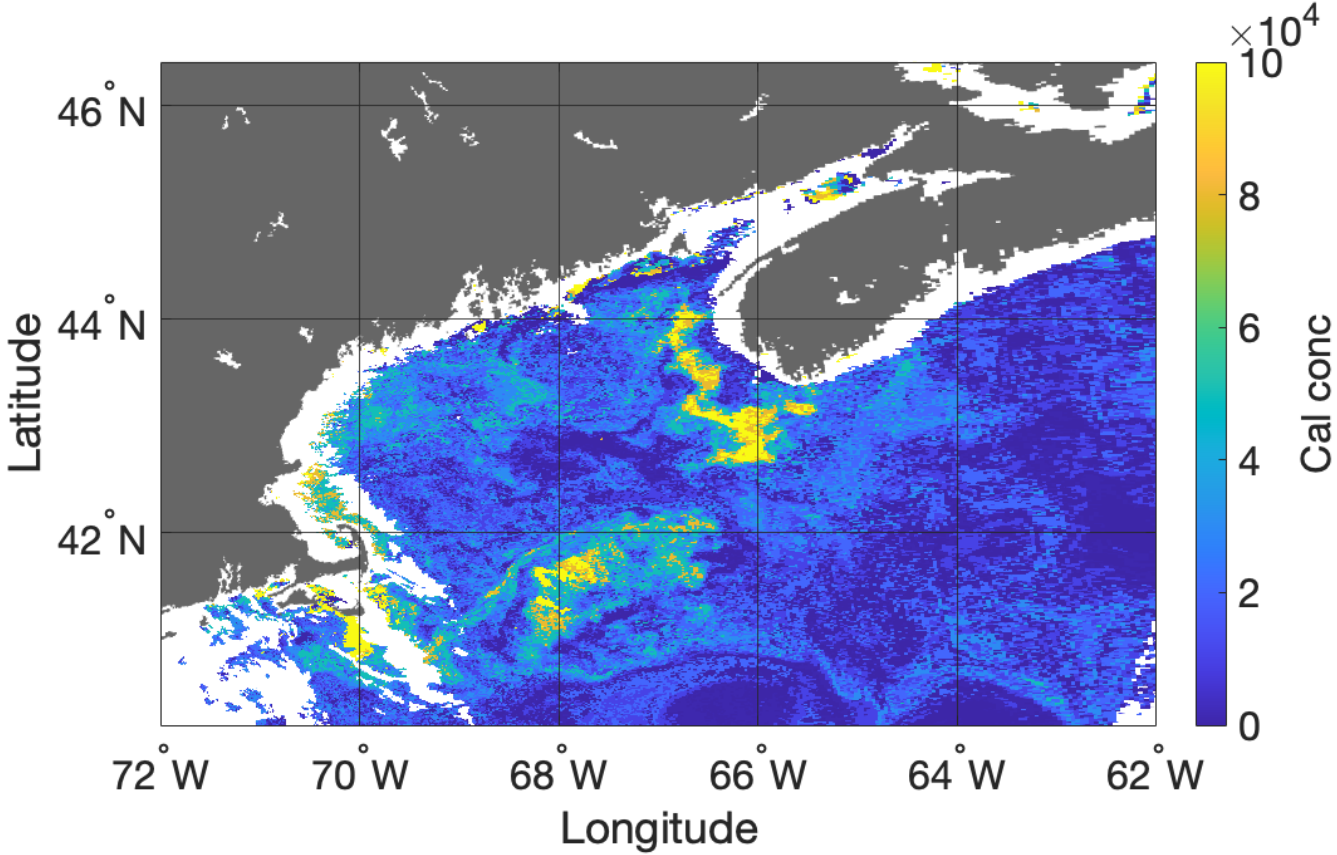


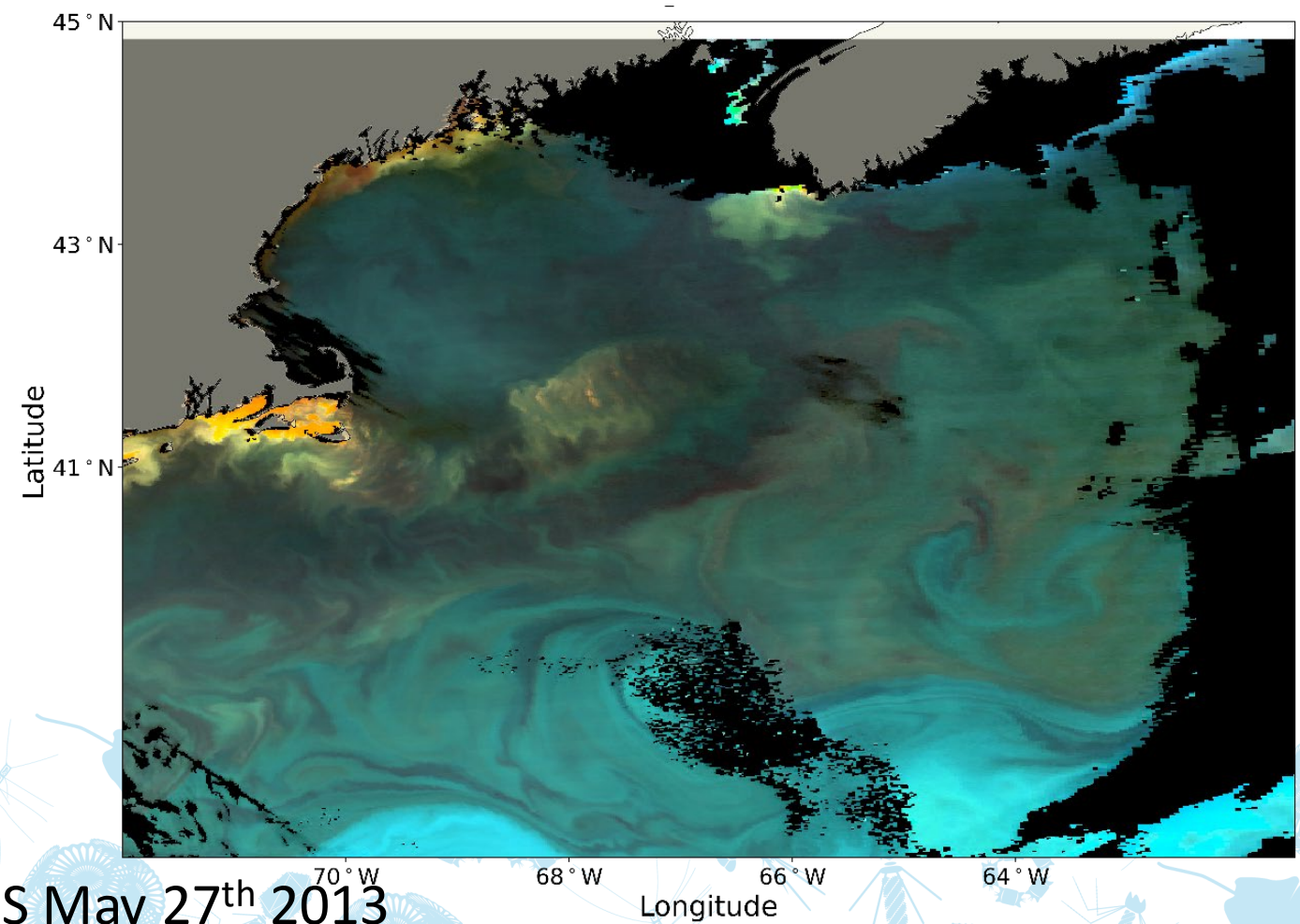


Includes Calanus



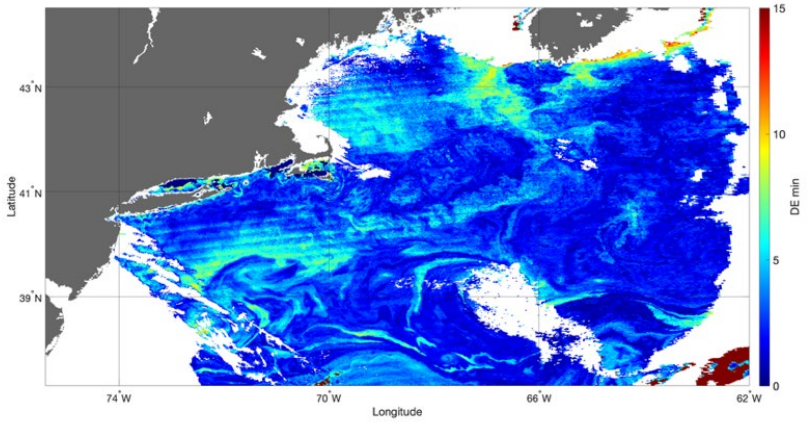



46°N
44°N
42°N
Latitude
72°W
70°W
68°W
66°W
64°W
62°W
Longitude
×10^4
10
8
6
4
2
0
Cal conc

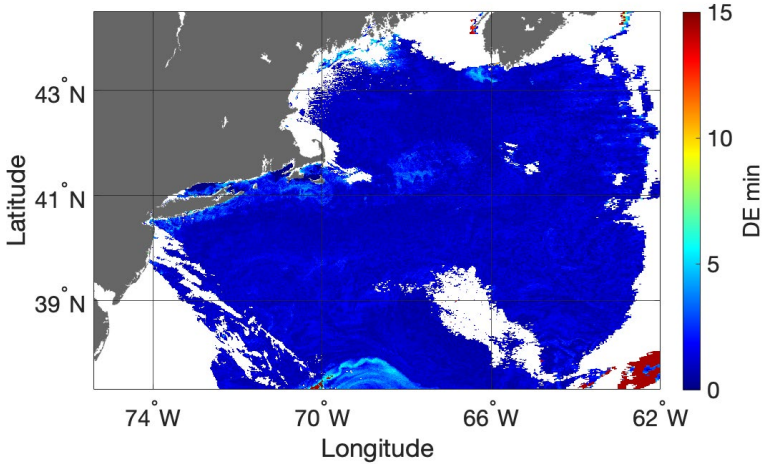


MODIS May 27th 2013

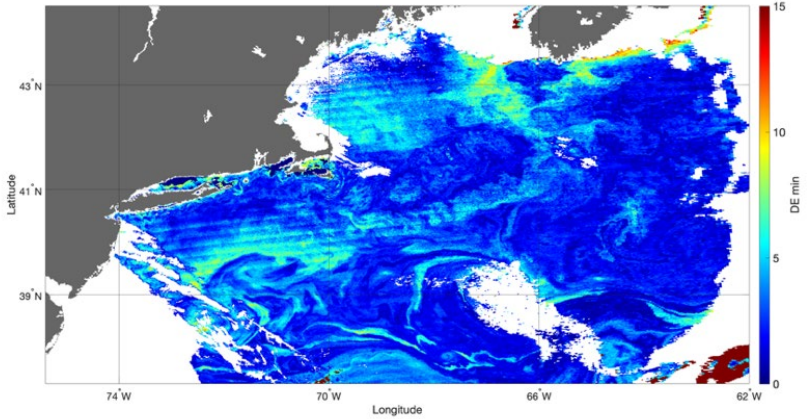
No Calanus

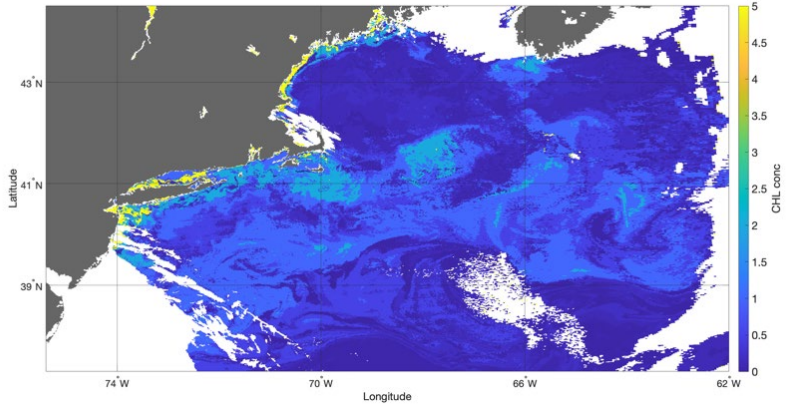


Includes Calanus

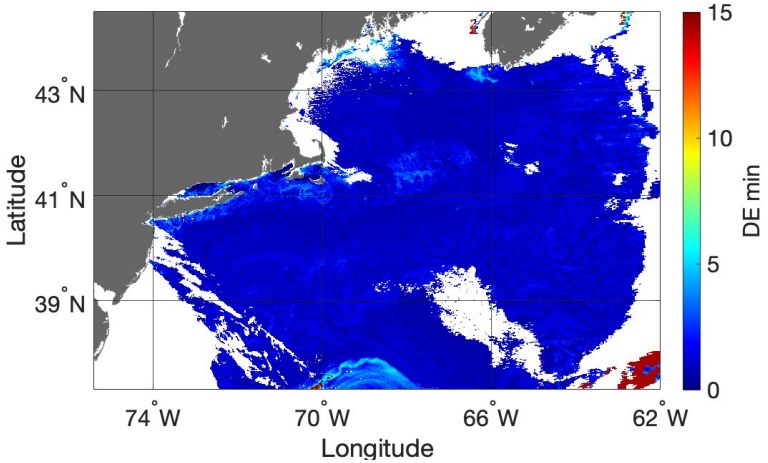


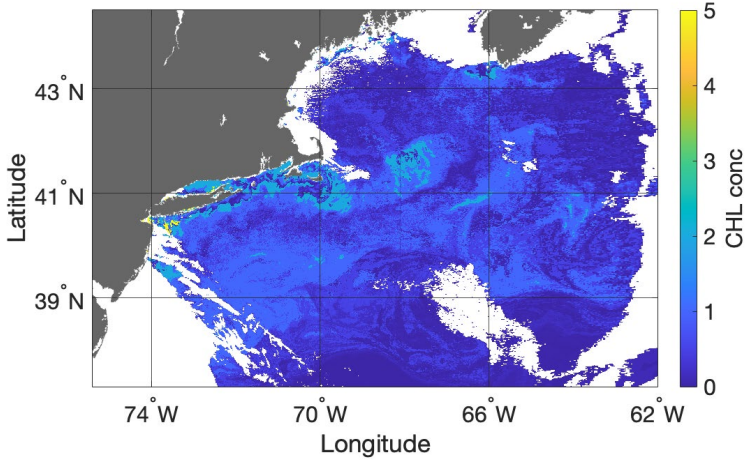
No Calanus



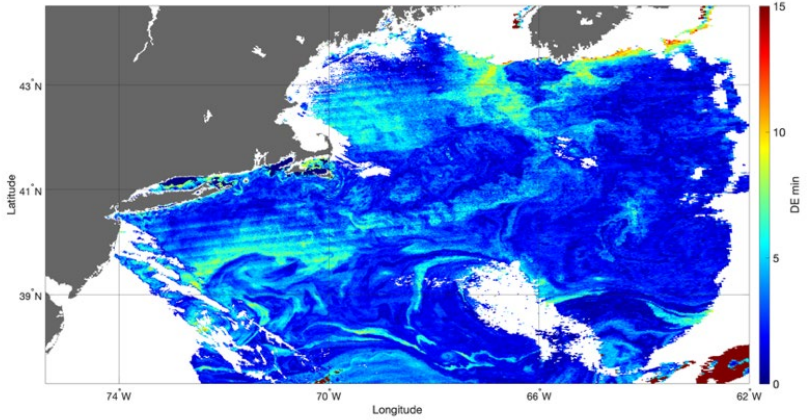


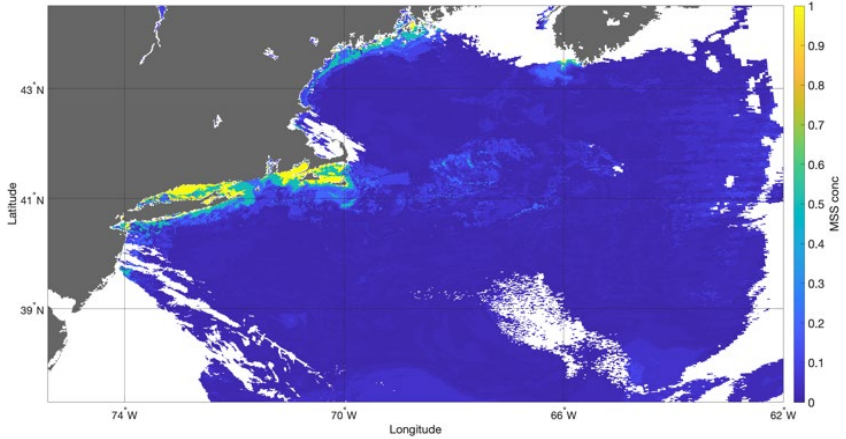
Includes Calanus



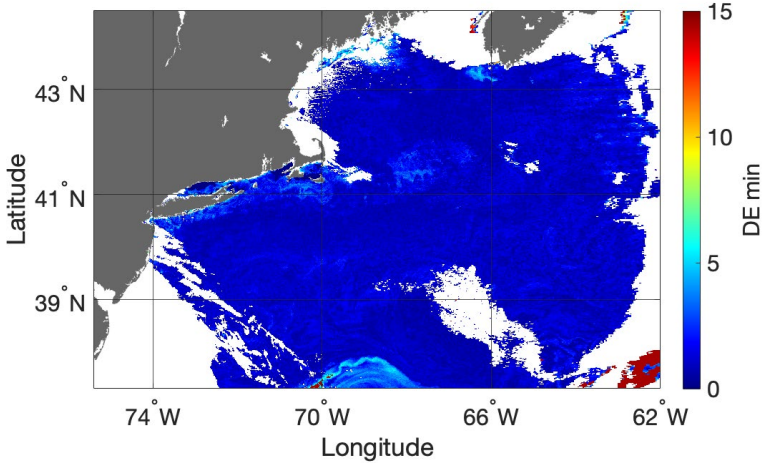


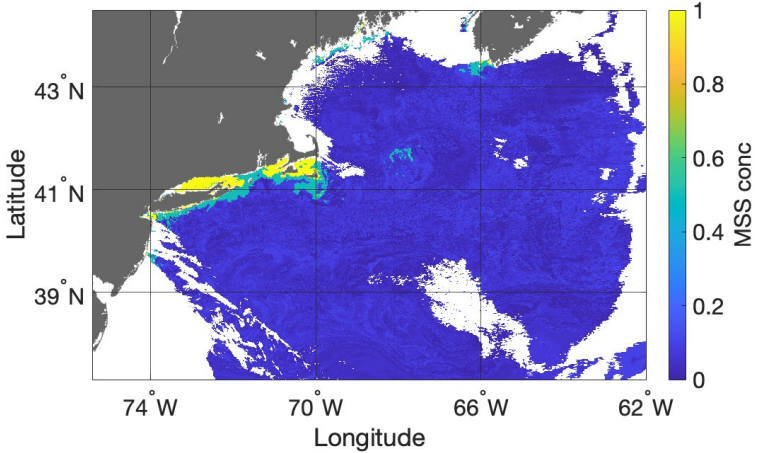
No Calanus



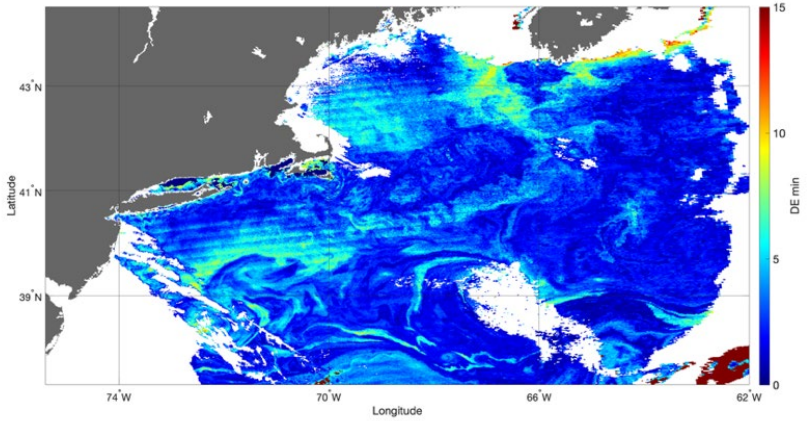


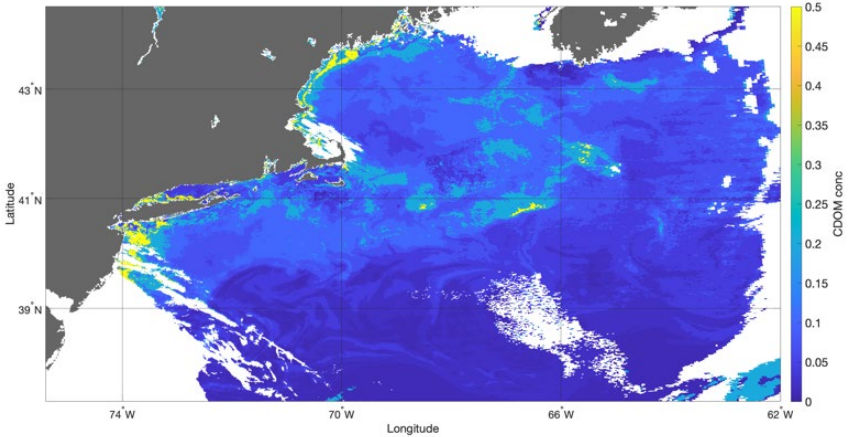
Includes Calanus



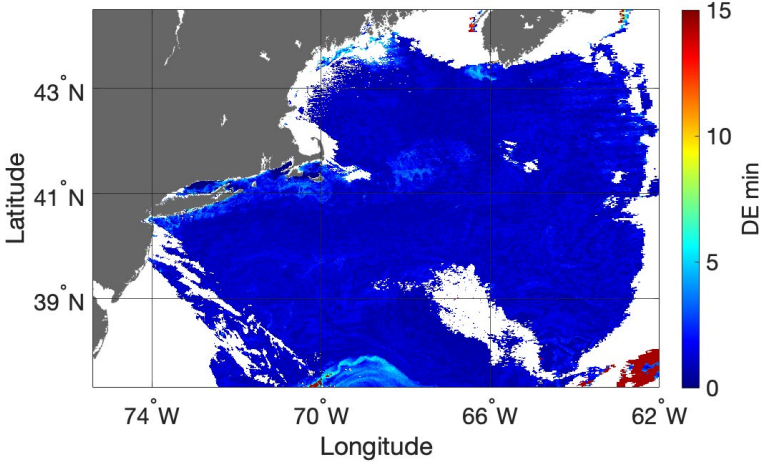


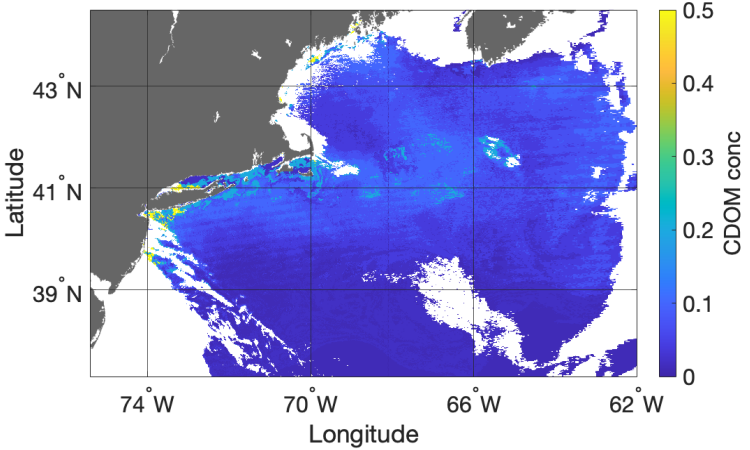
No Calanus

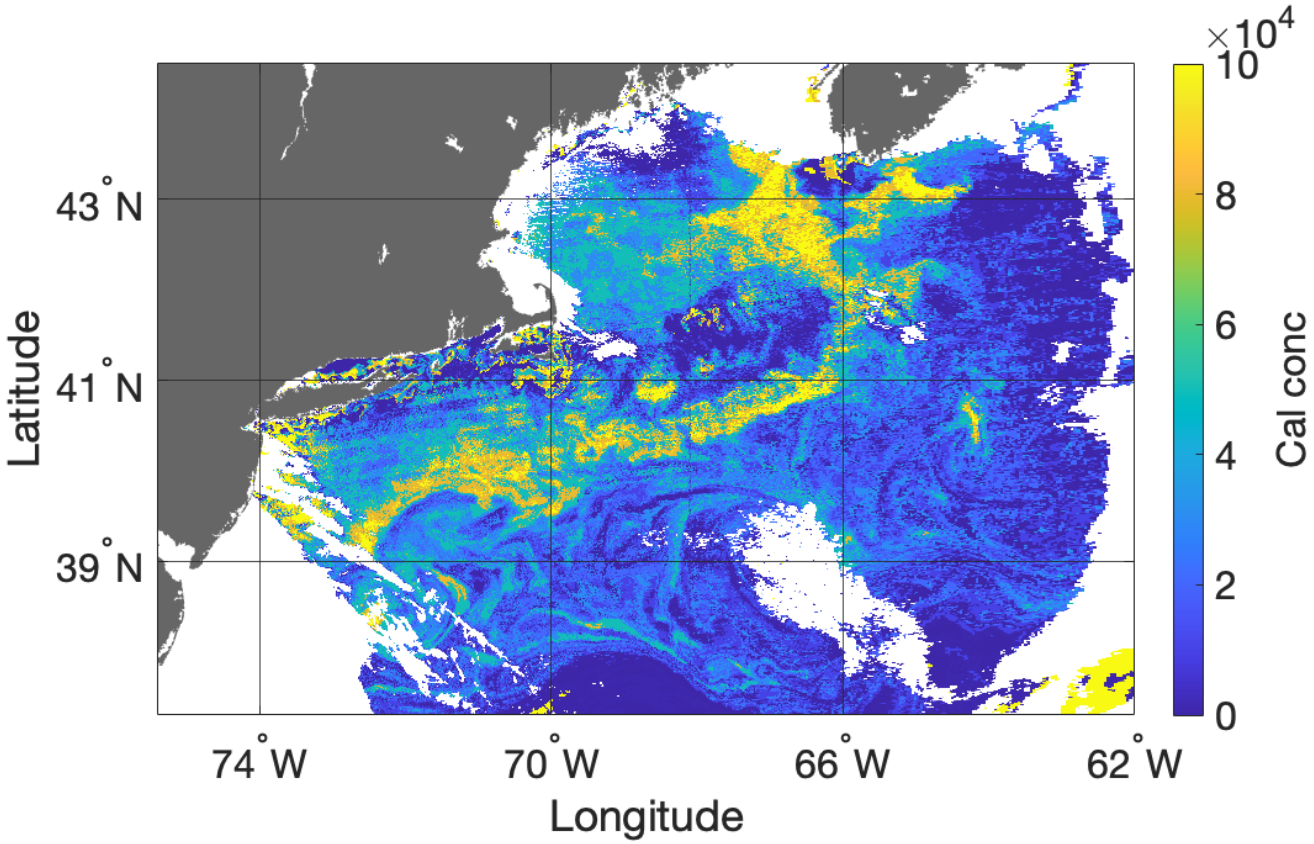


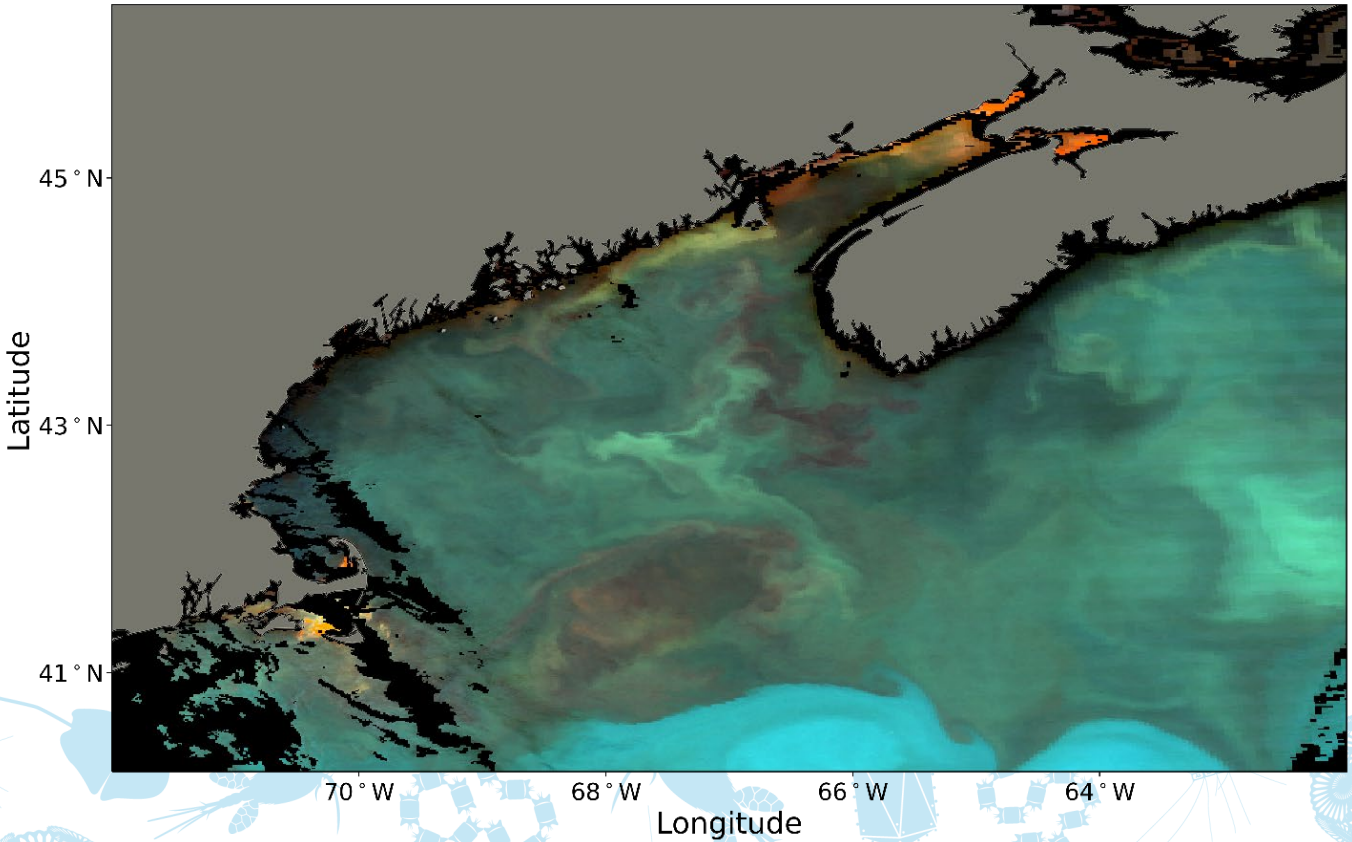


Includes Calanus



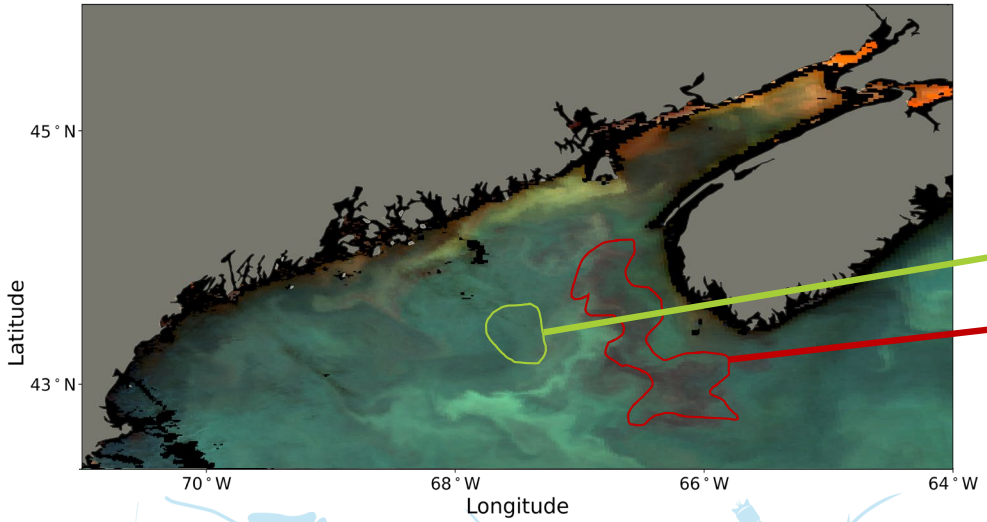


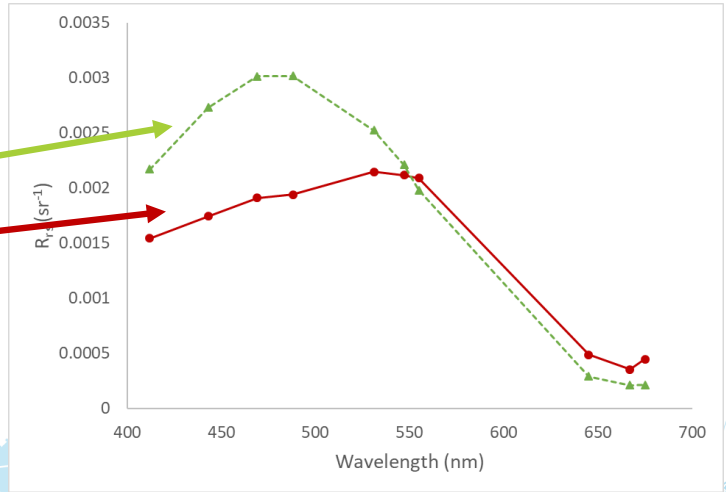

43°N
41°N
39°N
Latitude
74°W
70°W
66°W
62°W
Longitude
×10^4
10
8
6
4
2
0
Cal conc



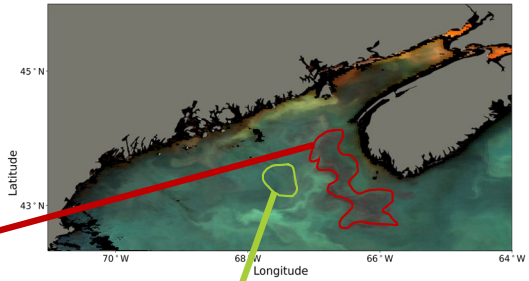
MODIS June 17th 2009

Remote sensing reflectance

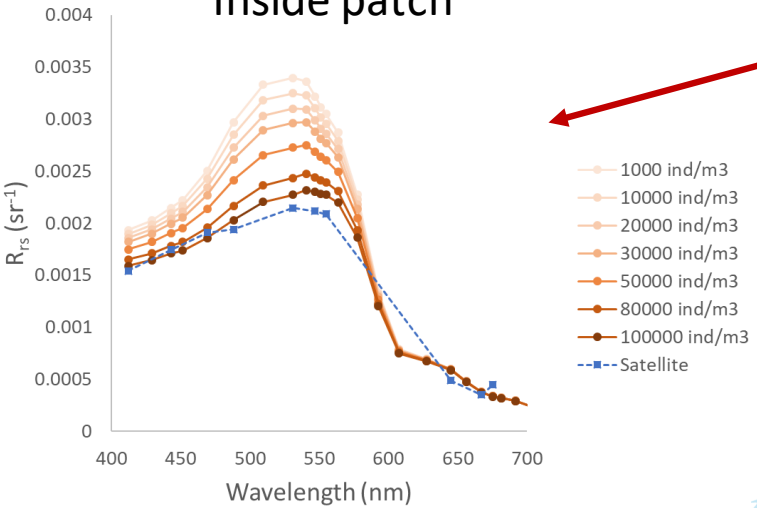




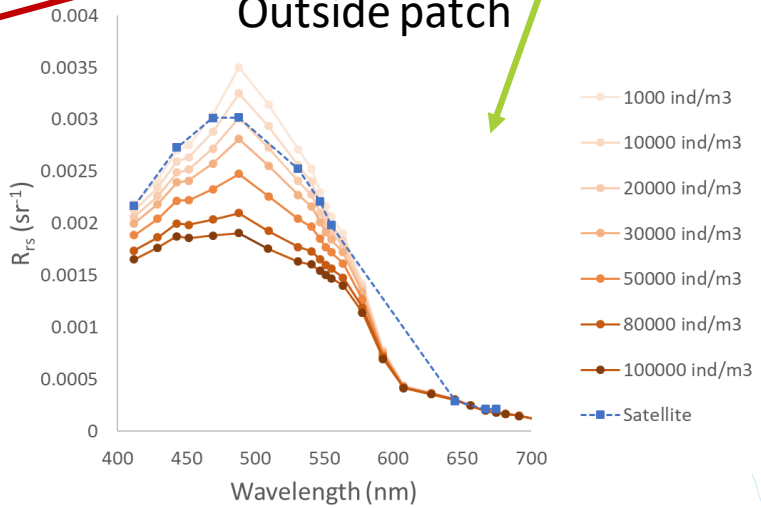
Remote sensing reflectance



Inside patch



Outside patch



Where we are now?

- Compare satellite data record with in situ datasets
- What about a full spectral approach, rather than eRGB?