Particulate absorption and attenuation of the Arctic Ocean; Contribution of the Tara polar-circle expedition

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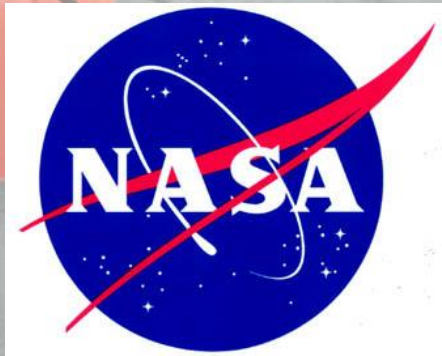
LOV: Marc Picheral, Annick Bricaud, Herve Claustre, Josephine Ras

Laval: Marcel Babin, Atsushi Matsuoka

+ the Tara Consortium



Introduction:

The Arctic ocean

The Tara polar circle expedition

Methodology of data acquisition and binning

Results:

distributions and frequency diagrams of $a_p(\lambda)$ and $c_p(\lambda)$

Biogeochemical parameters

Comparison with Tara Oceans

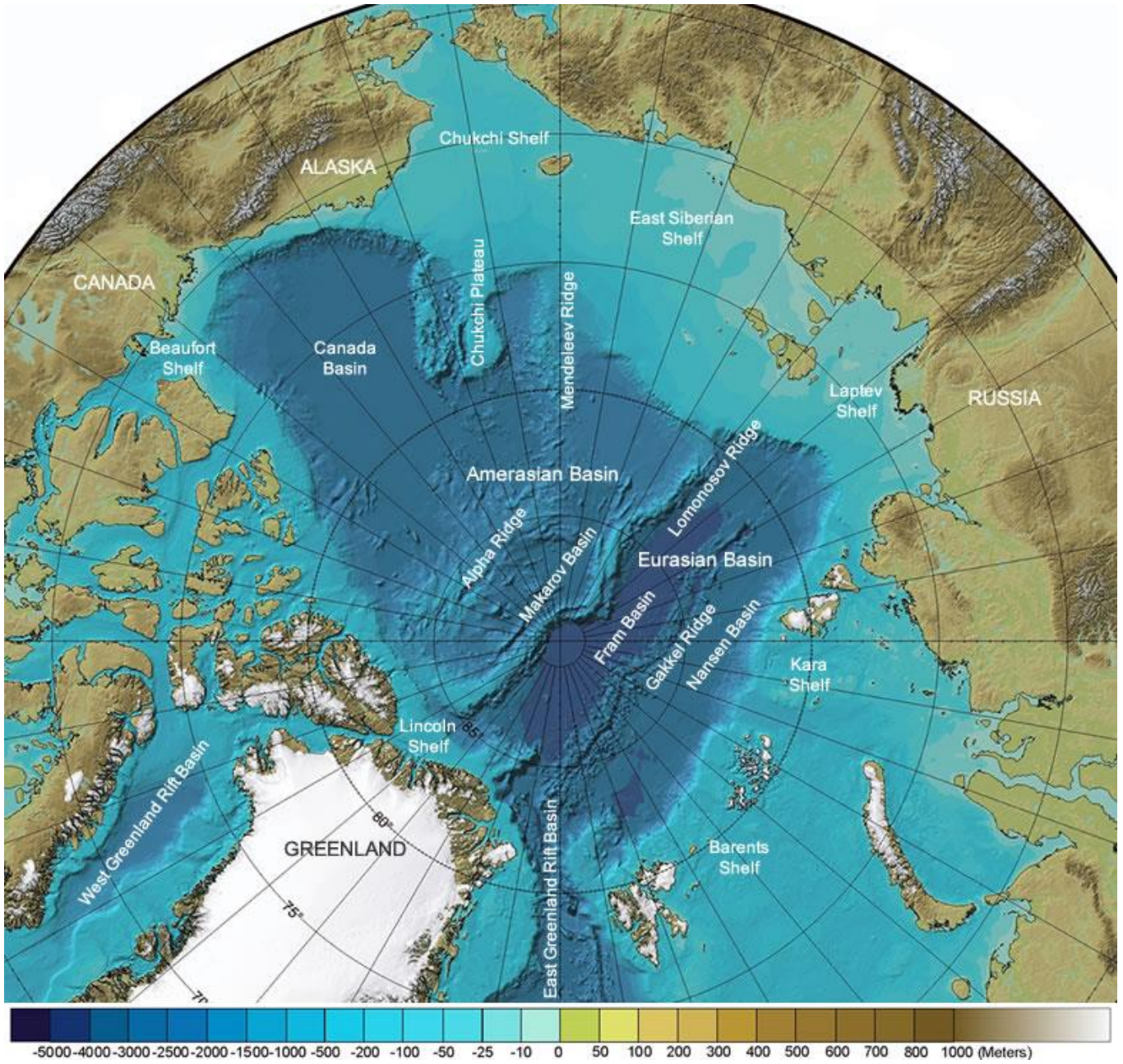
Science: linking size – chlorophyll – temperature

Future work:

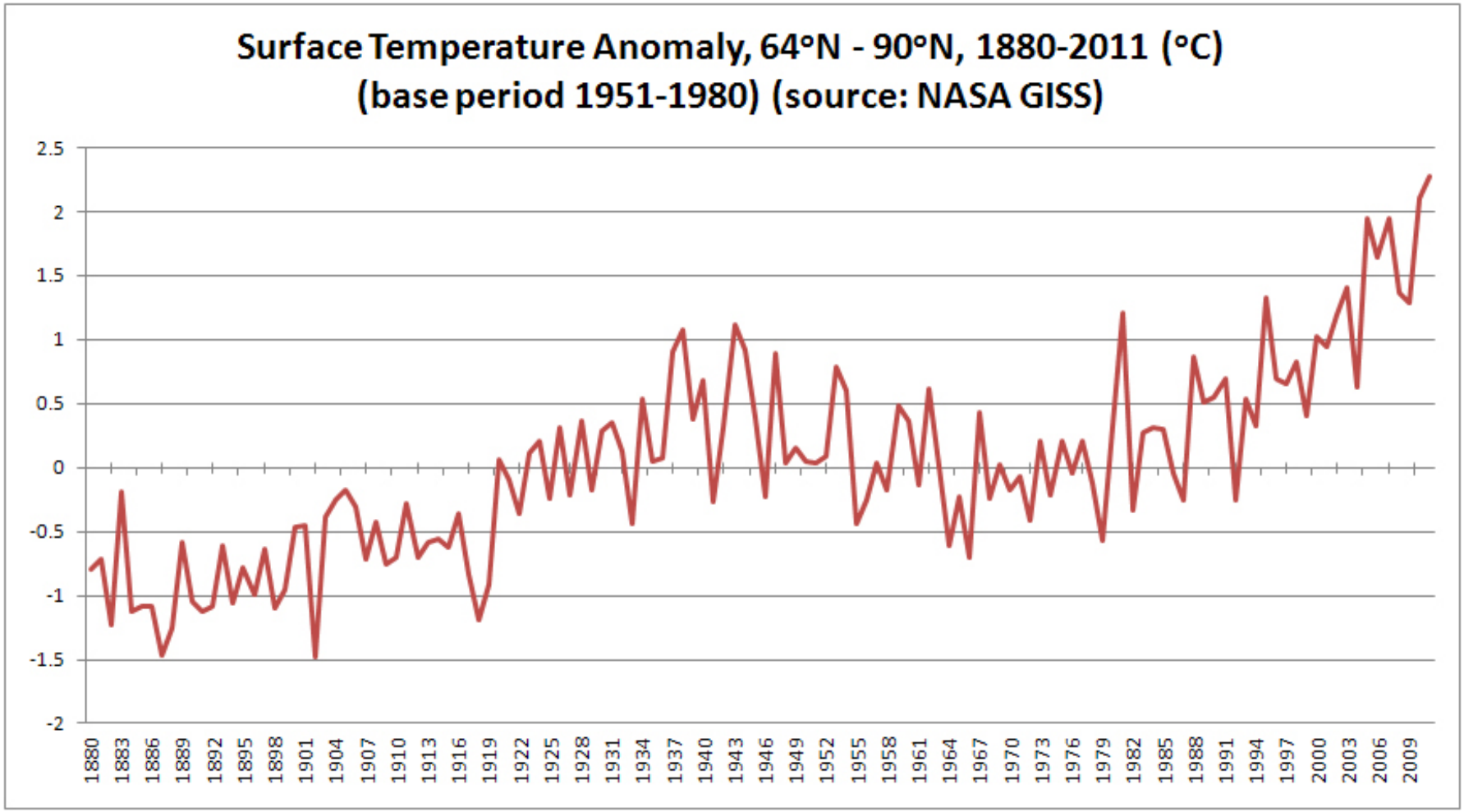
CDOM, $b_{bp}(\lambda)$, vertical profiles of $c_p(660)$, $b_{bp}(650)$, reflectance.

Link to: flowcytometry, imaging-cytometry, genetics, higher trophic levels

The Arctic ocean

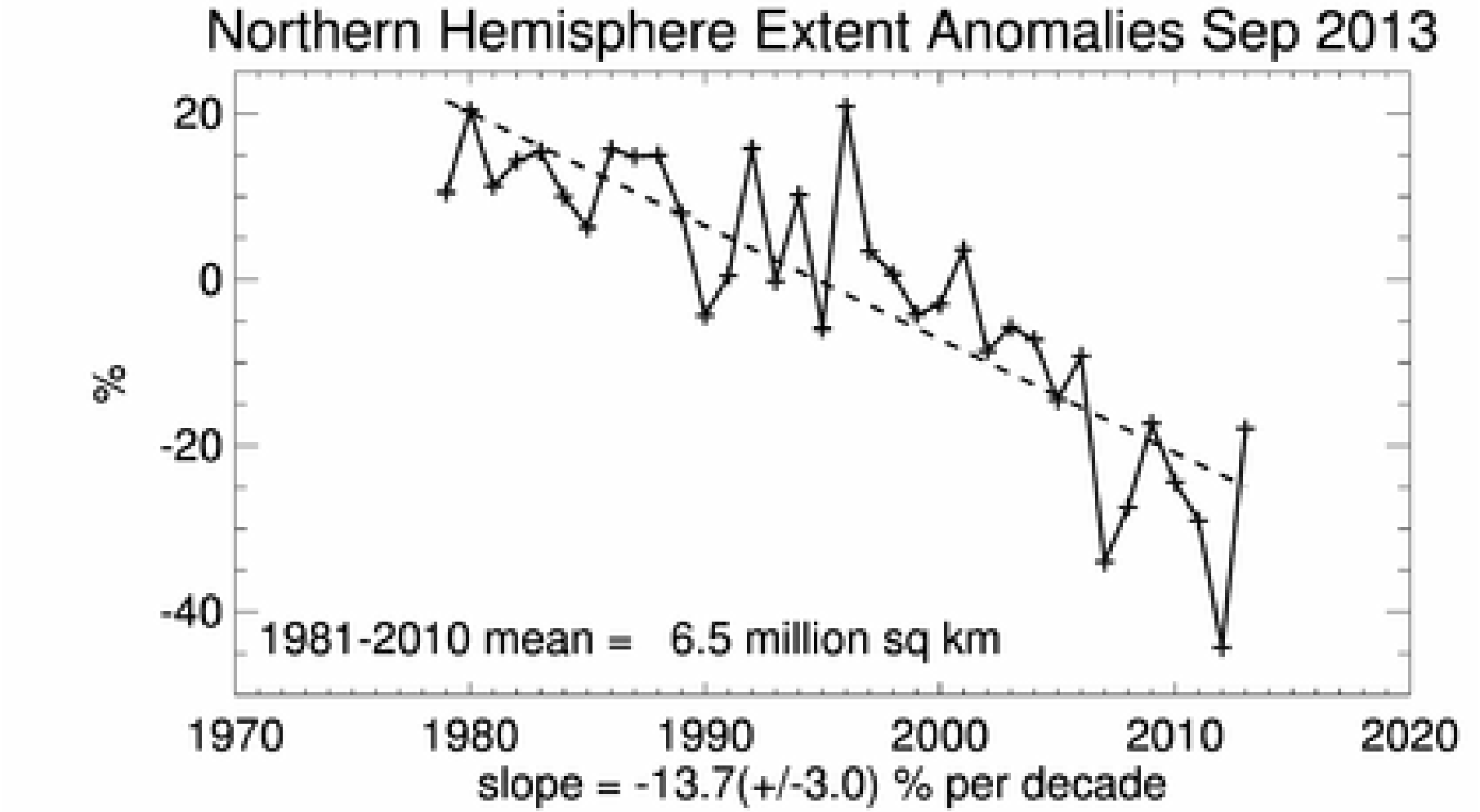


Why study the Arctic?



Large changes in mean temperature

Large changes in mean ice cover



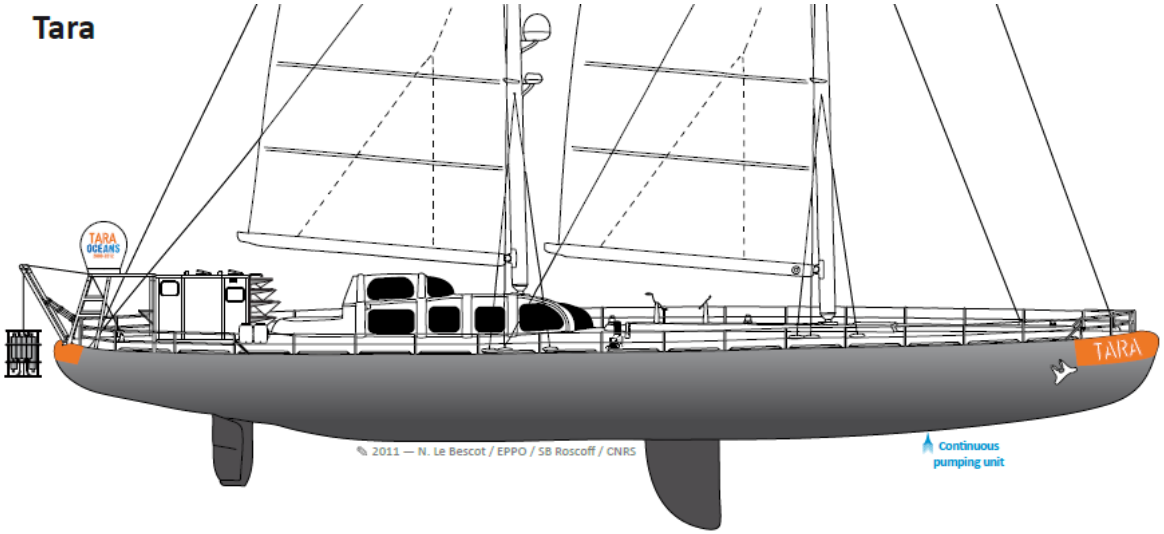
Source: NOAA

Some facts about Tara

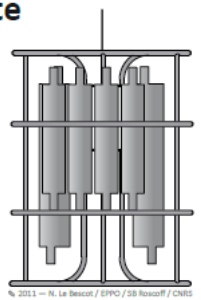
- Aluminum hull – ice strengthen
- 36m long x 10m wide
- Draught: 1.50 – 3.50m
- Weight: 120 tons
- Sail area: 400m^2
- Propulsion: 2 x 350 HP
- Watermaker: 300 litres/hour
- Fuel tanks: 40,000 litres
- Water tank: 6,000 litres
- 3 kW wind generator power system
- Communication: Satellite/radio
- Oceanography: 3,000 m winch
- Autonomy: 5,000 nautical miles
- Number of berths: 14

The R/V Tara

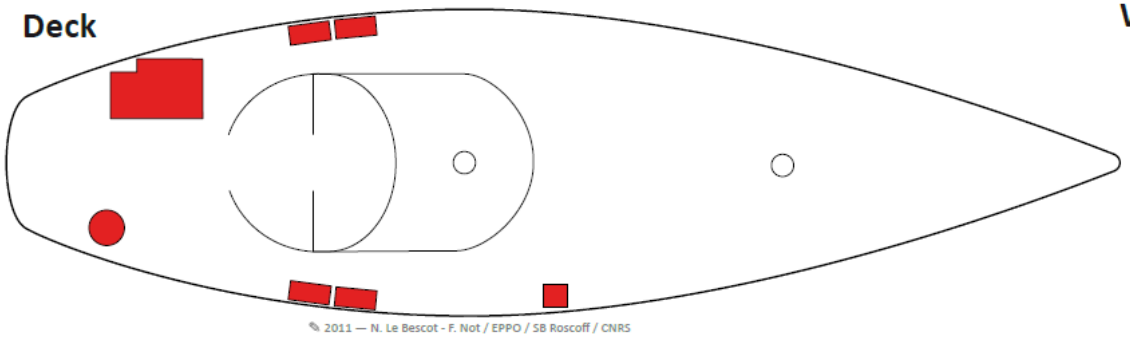
Tara



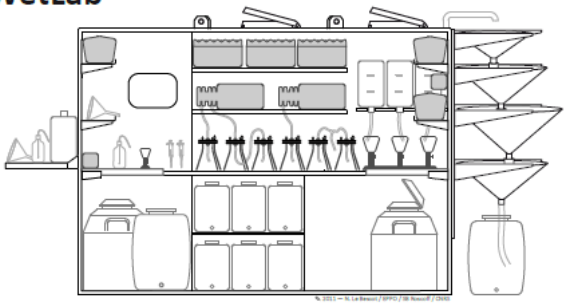
Rosette



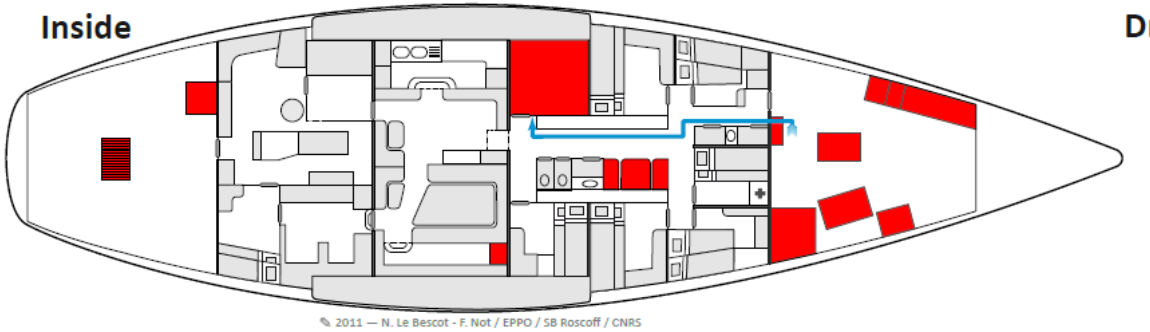
Deck



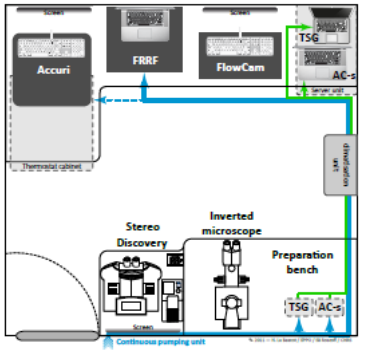
WetLab



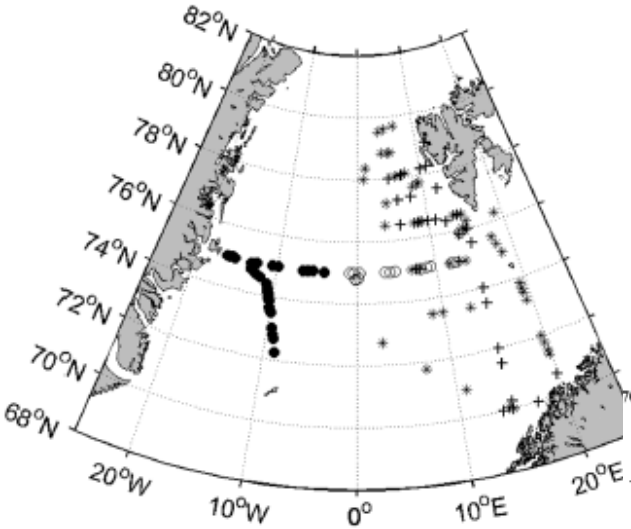
Inside



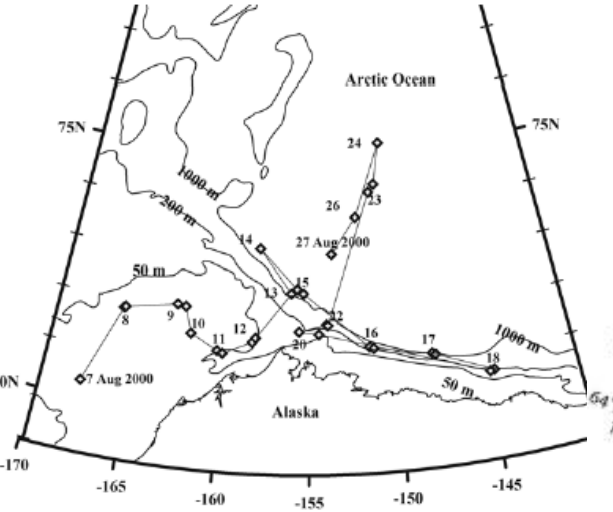
DryLab



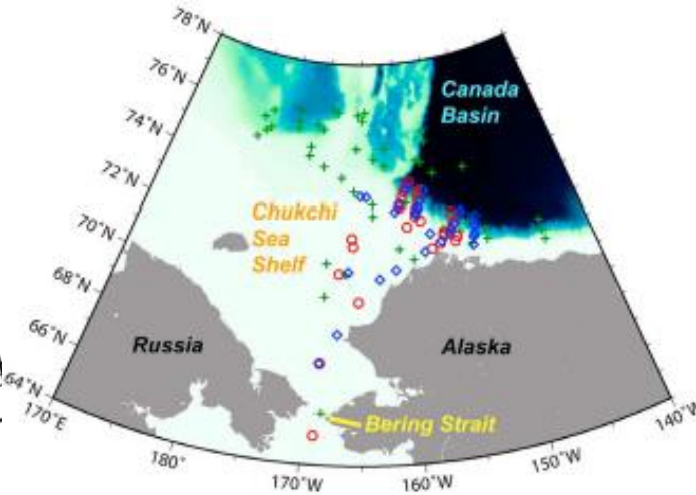
Where have measurements of IOPs been taken?



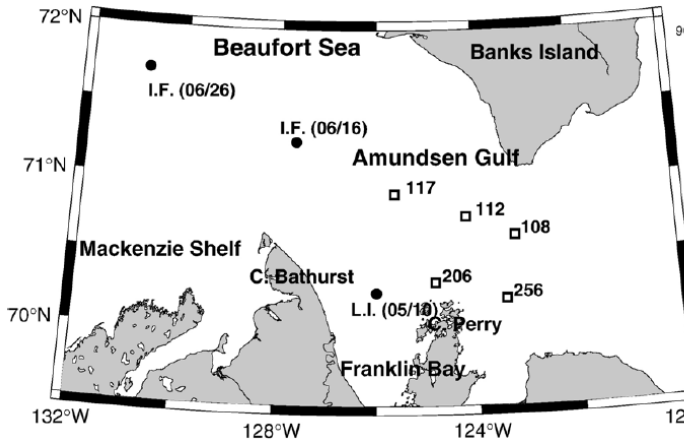
Stramska et al., 2006



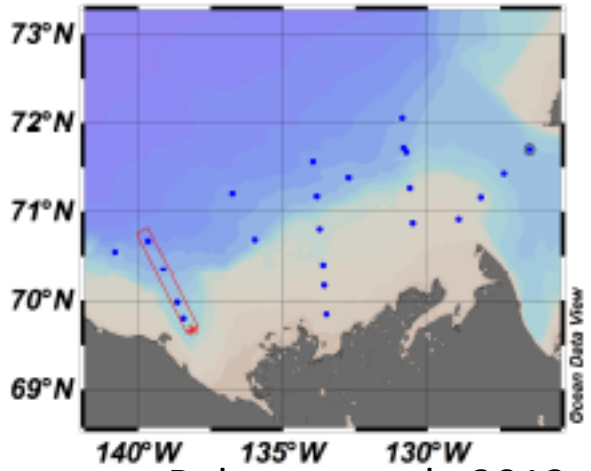
Wang et al., 2005



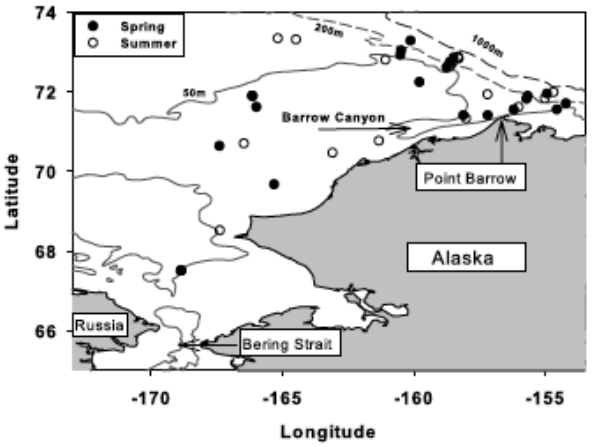
Matsuoka et al., 2007,2011



Belanger et al., 2007



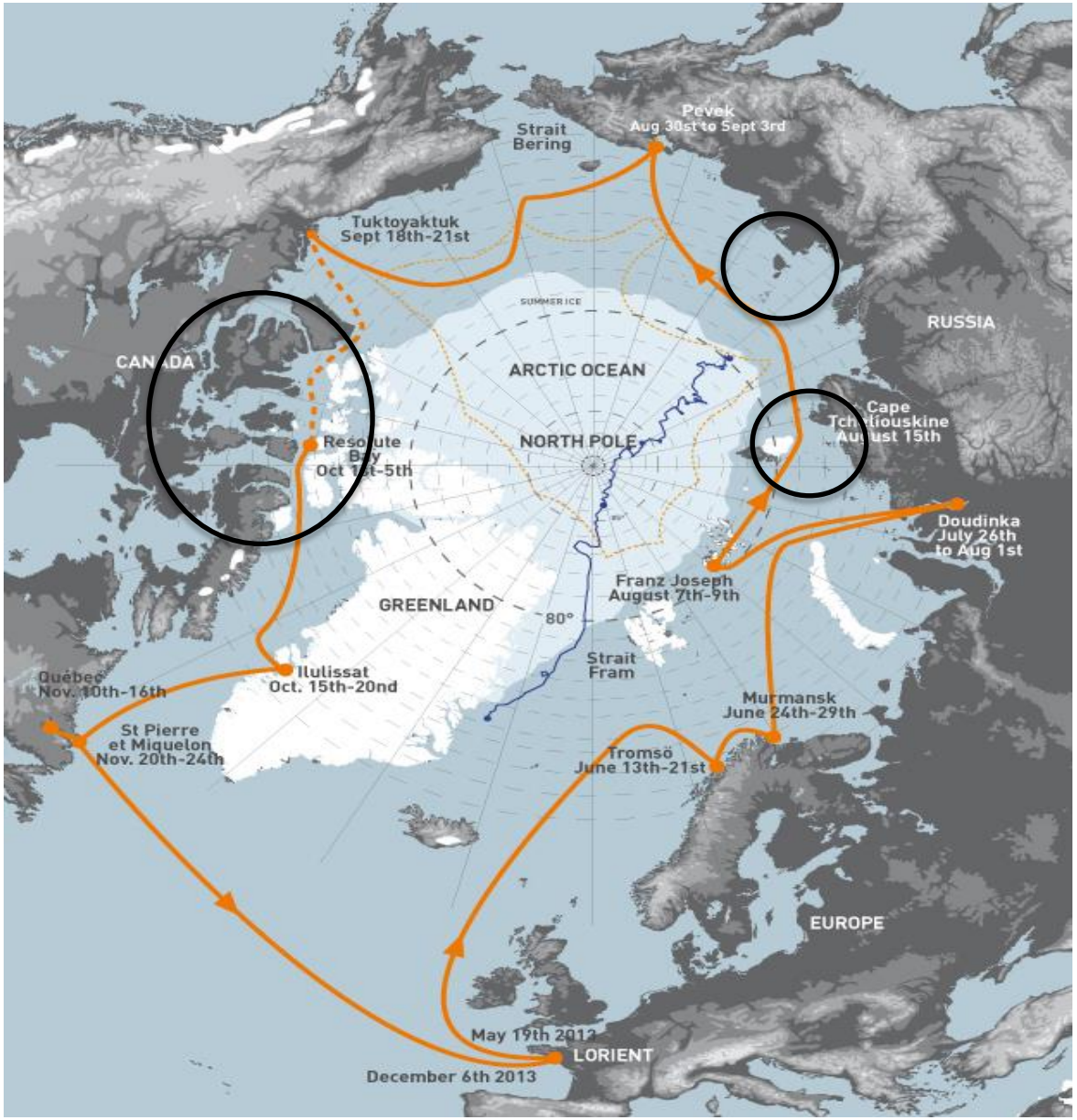
Belanger et al., 2013

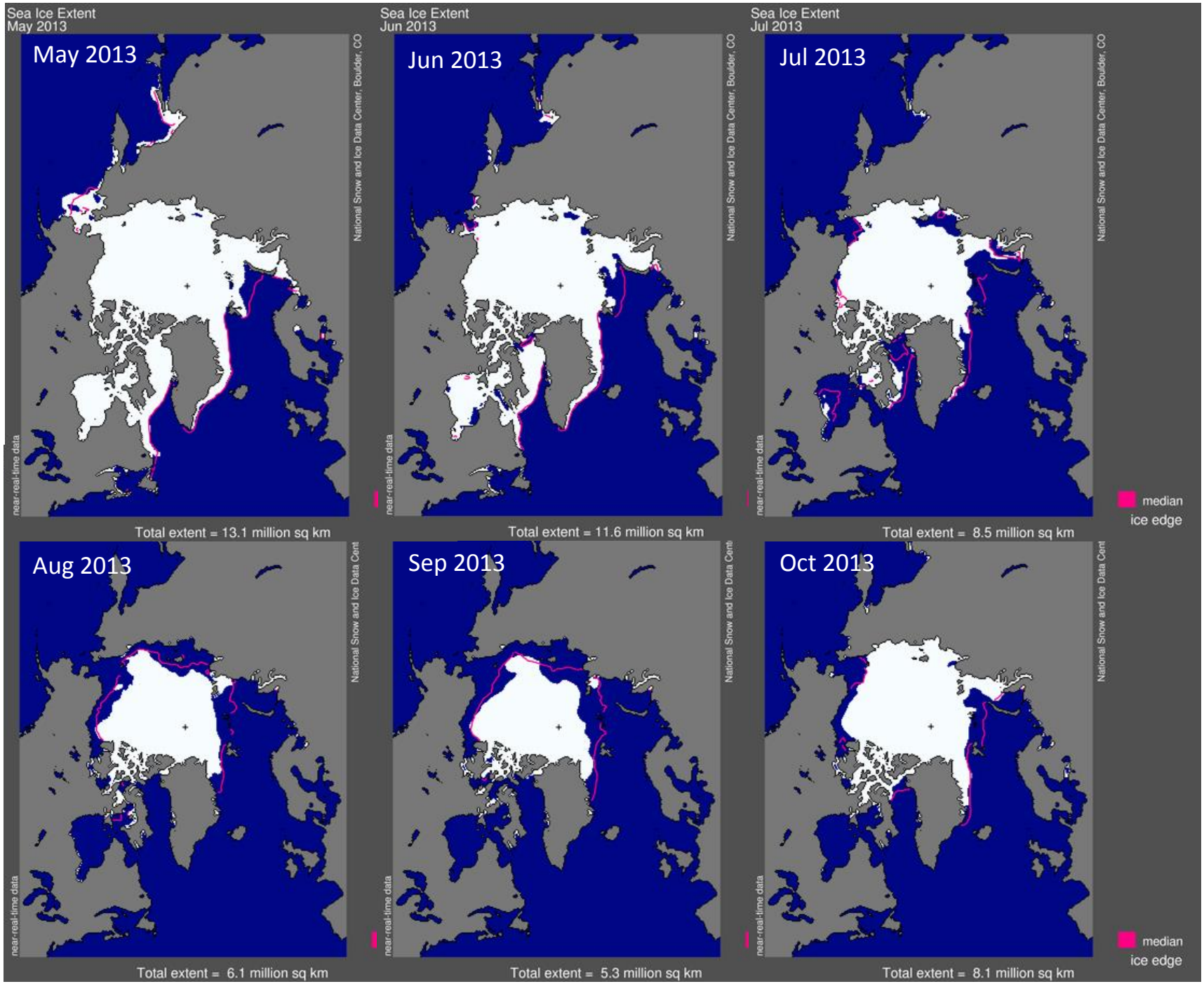


Hill, 2008

Polar circle plan

Mandatory passages:





Source: National Snow & Ice Data Center

The Tara polar-circle expedition

Comprehensive and homogeneous data comparable)

Unique! Covers all the Arctic sectors

Not synoptic

Sampling: in-line continuous (1.5m) + discrete stations (up to 1000m)

Dry Lab – continuous sampling + analysis of discrete samples

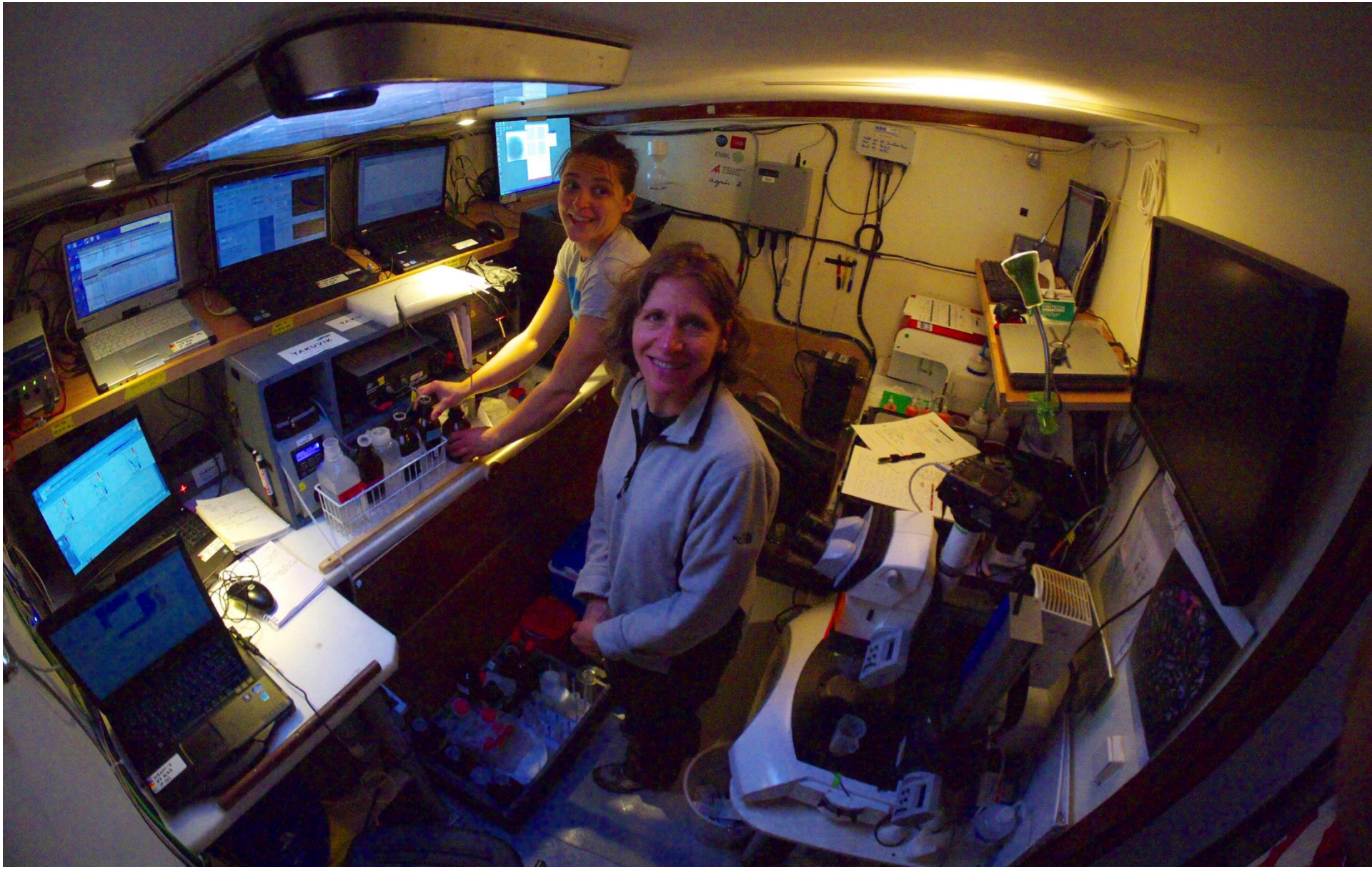


Photo: Marc Picheral

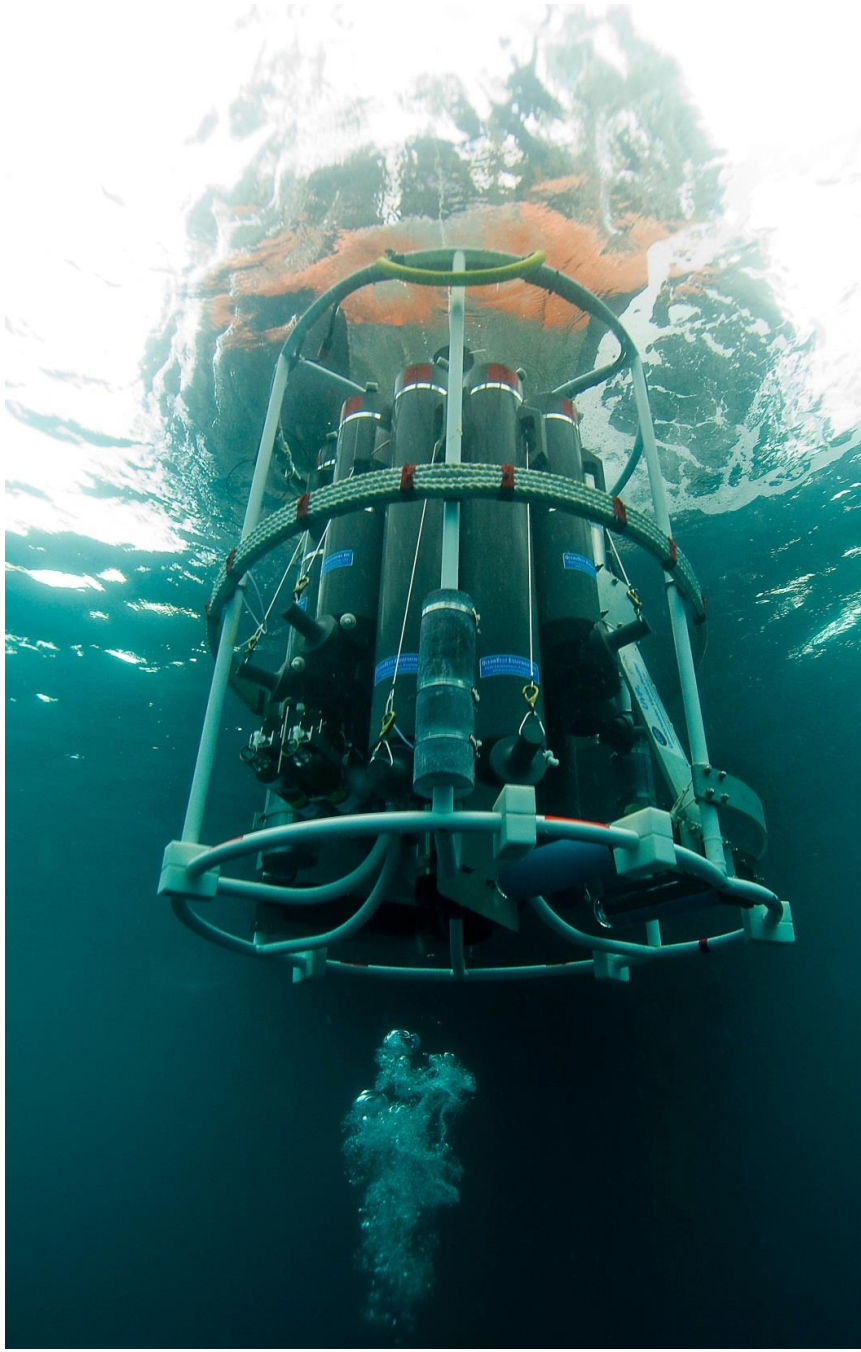
At stations:

I. Rosette:
Physical variables: temperature, salinity, pressure, light level.
Optical variables: scattering, attenuation.
Biological variables: imaging camera, chlorophyll.
Chemical variables: nitrate, oxygen, DOM.

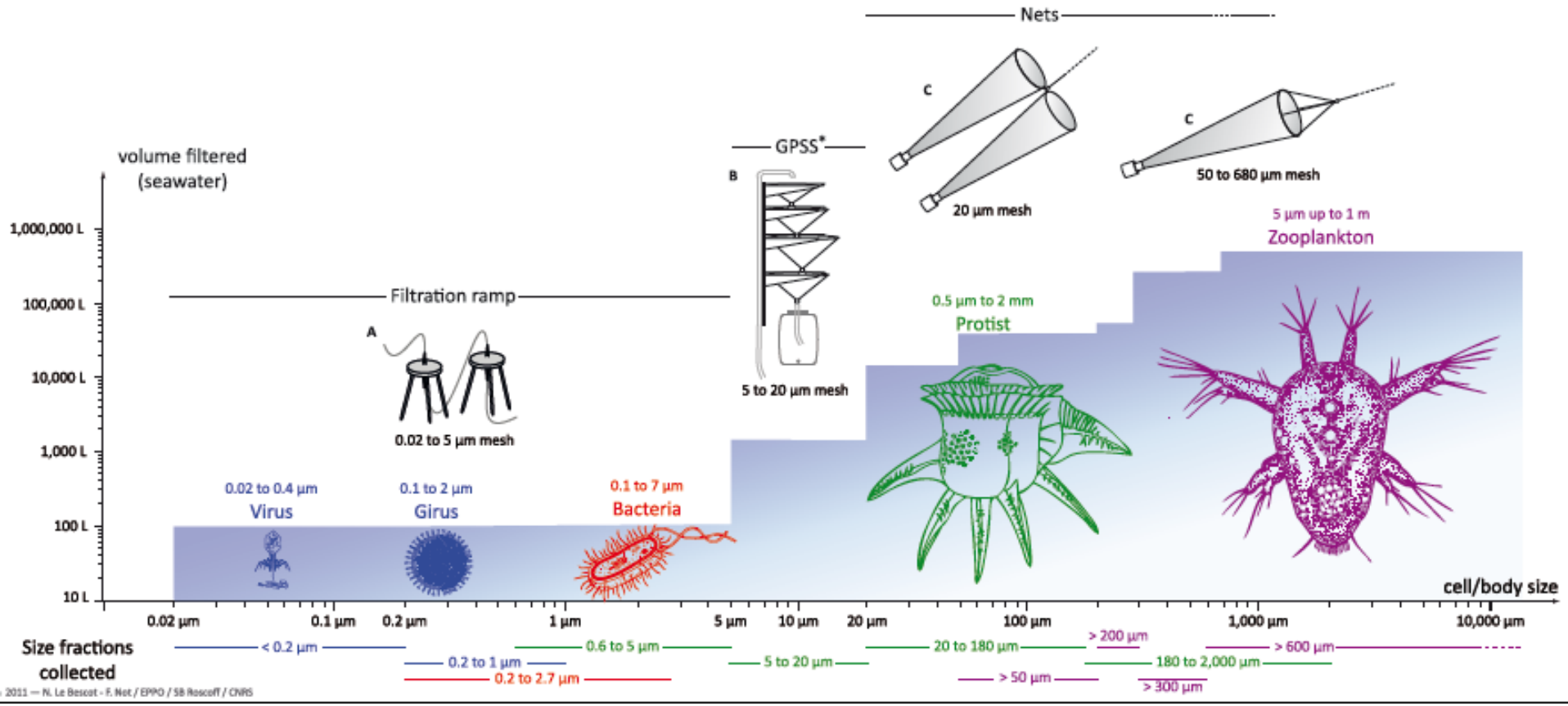
Bottles to collect water ->
Biological variables: Virus, bacteria, pigments
Chemical variables: Carbonates, nutrients, O^{18}, DOC

II. Nets (of variables mesh size):
Biological variables: phytoplankton, other protists and zooplankton (for '-omics' and imaging)

Spatial scales: $1km^2$
Temporal scales: days/weeks
Vertical scales: surface to 1000m at O(1m)

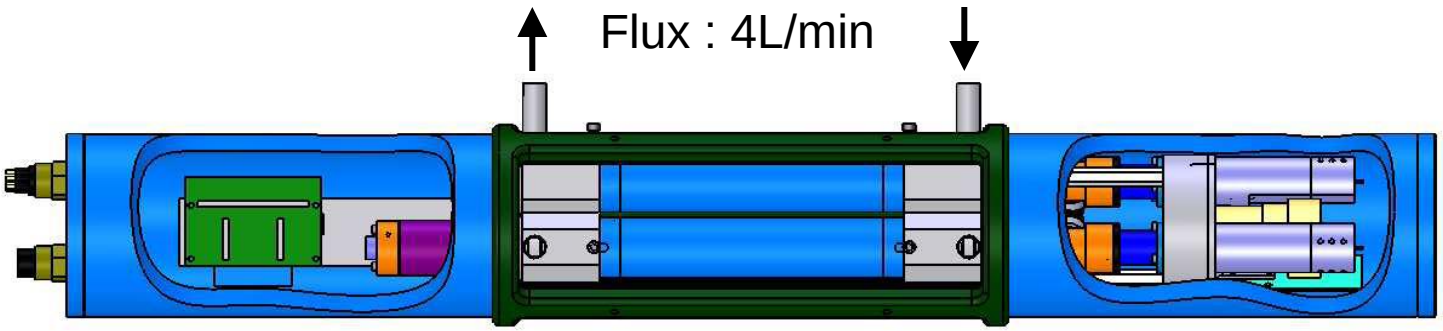


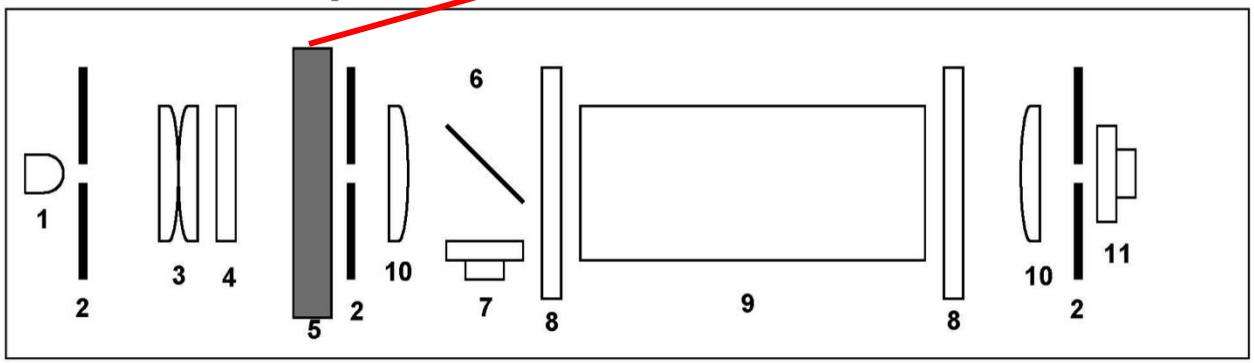
Tara Oceans sampling overview



+ flow cytometer (Accuri), Flow-cam, Imaging flowcytobot, & UVP

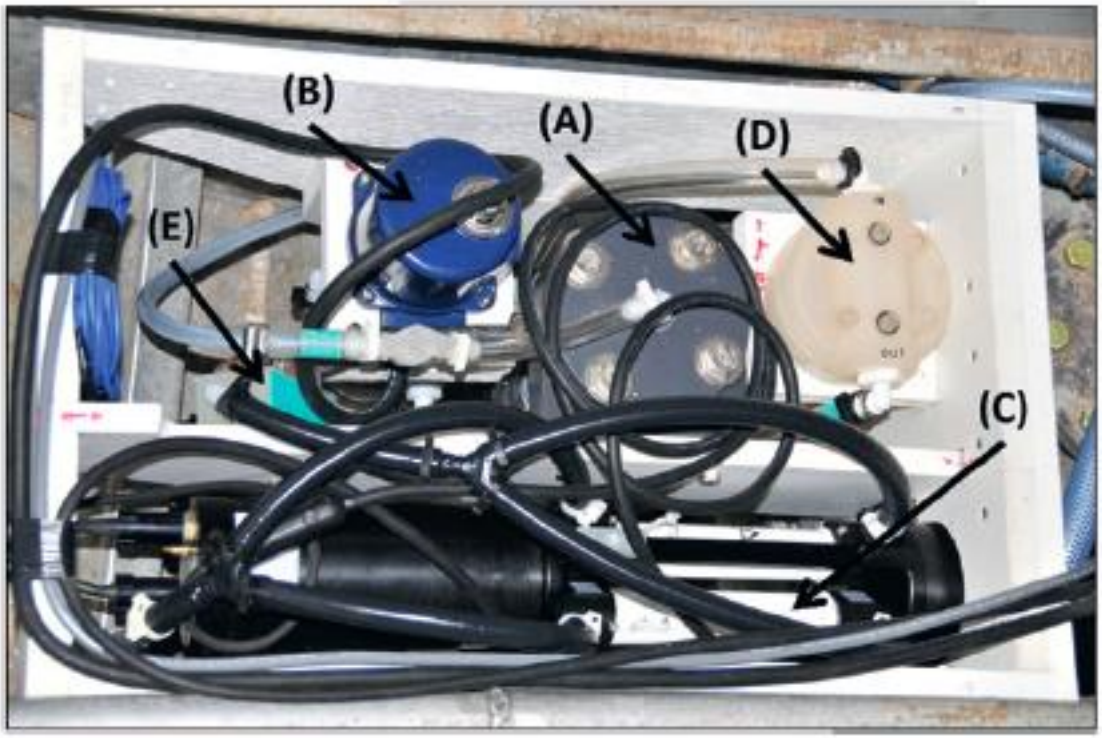
Spectral Absorption and Attenuation Meter (ACS)



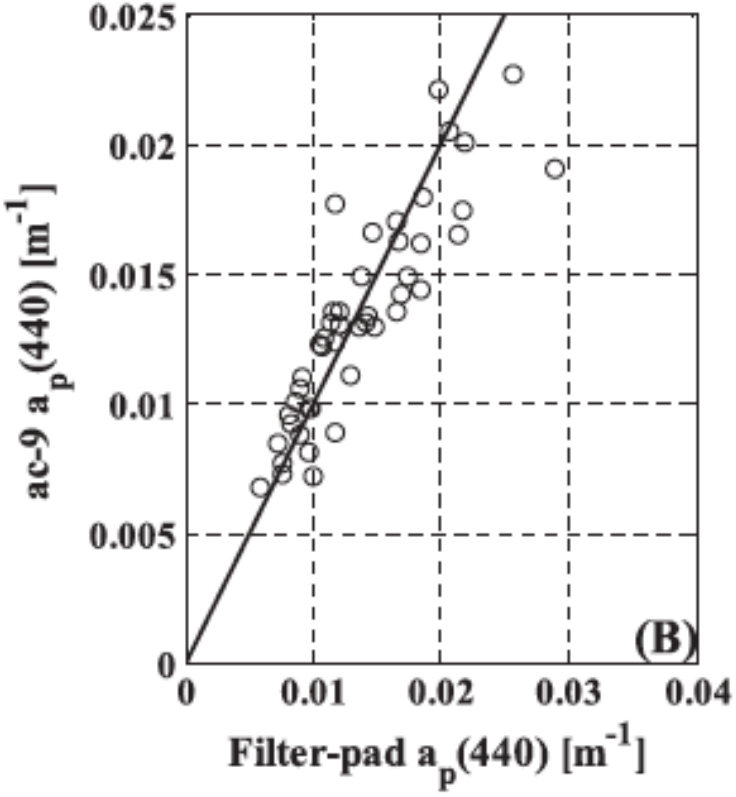


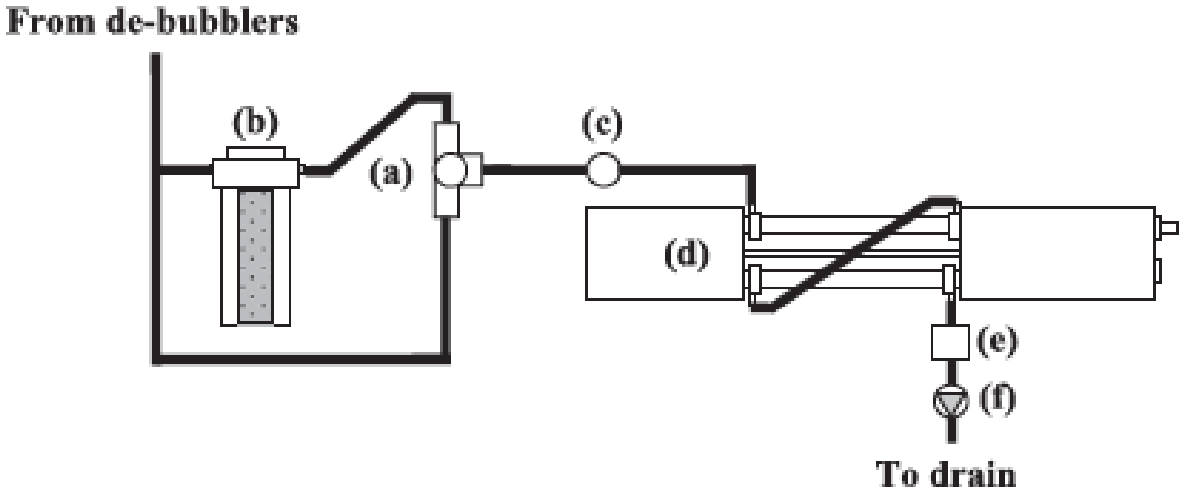
1	Lamp	**7**	Reference detector
2	1 mm aperture	**8**	6 mm quartz pressure window
3	Lenses	**9**	Flow tube
4	IR Filter	**10**	Singlet lens
5	Filter wheel	**11**	Signal detector
6	Beam splitter		

System for acquisition of particulate absorption/attenuation data



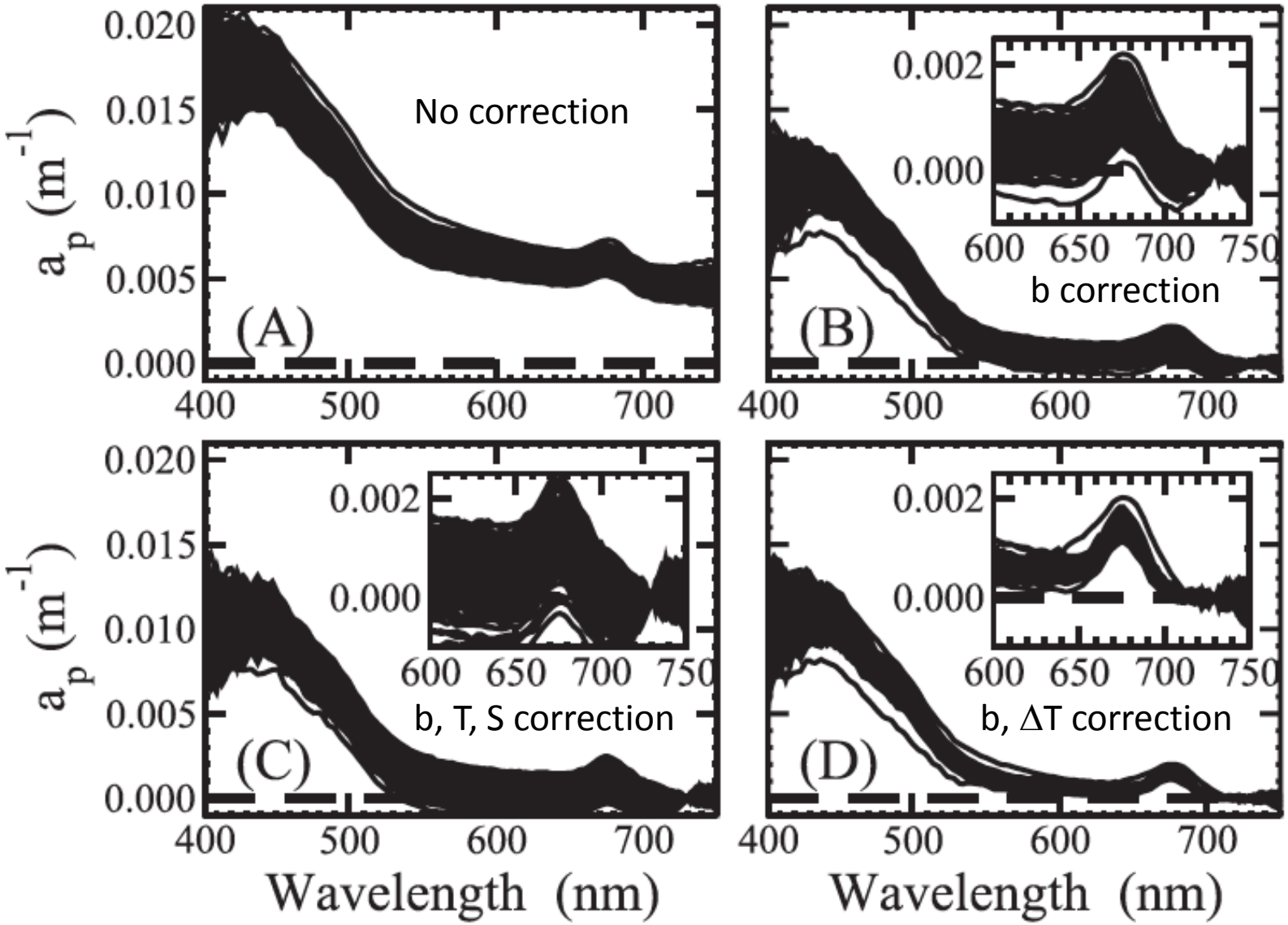
Validation against filter-pad



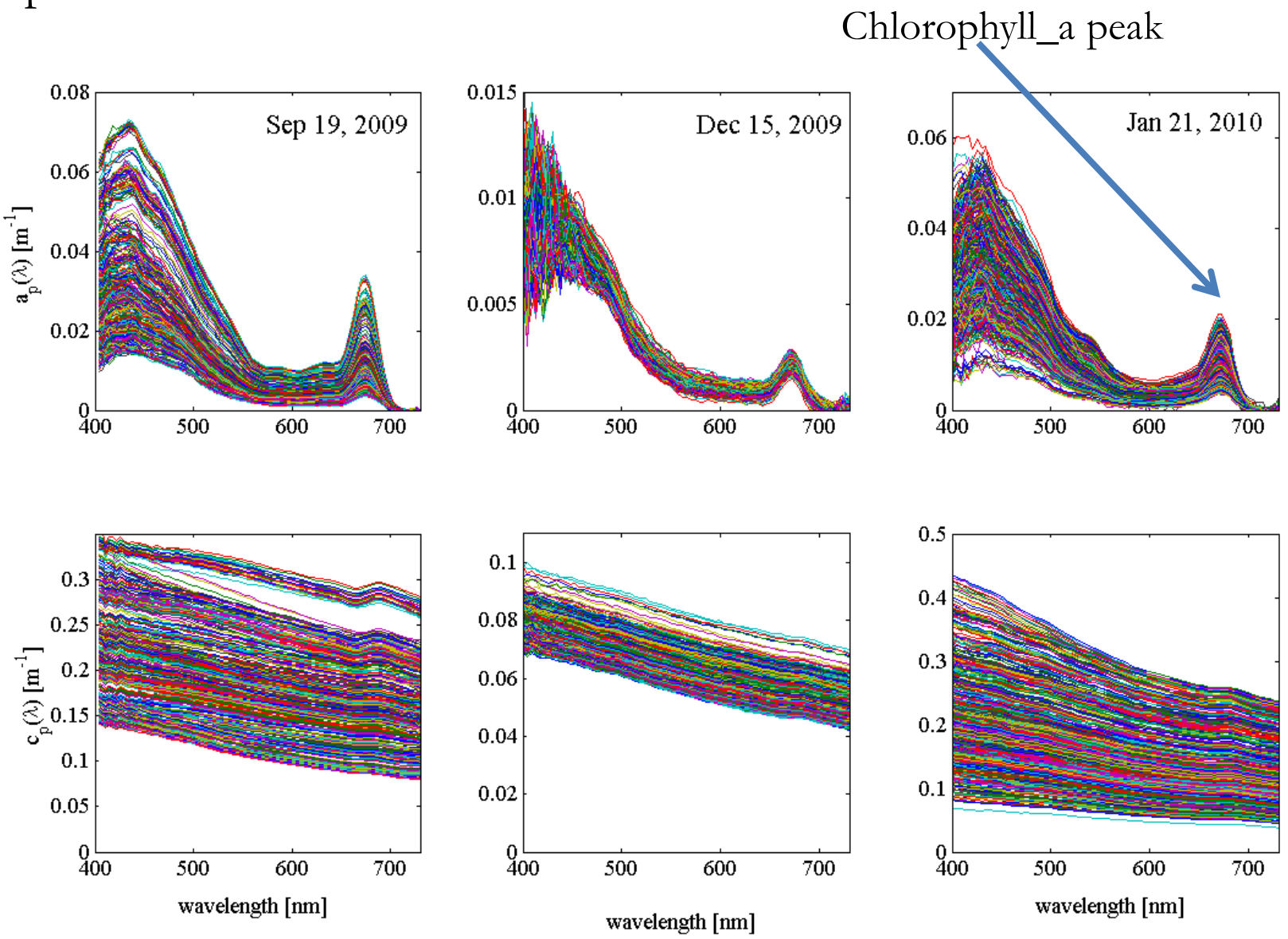


Slade et al., 2010, JTECH

Scattering and residual temperature correction

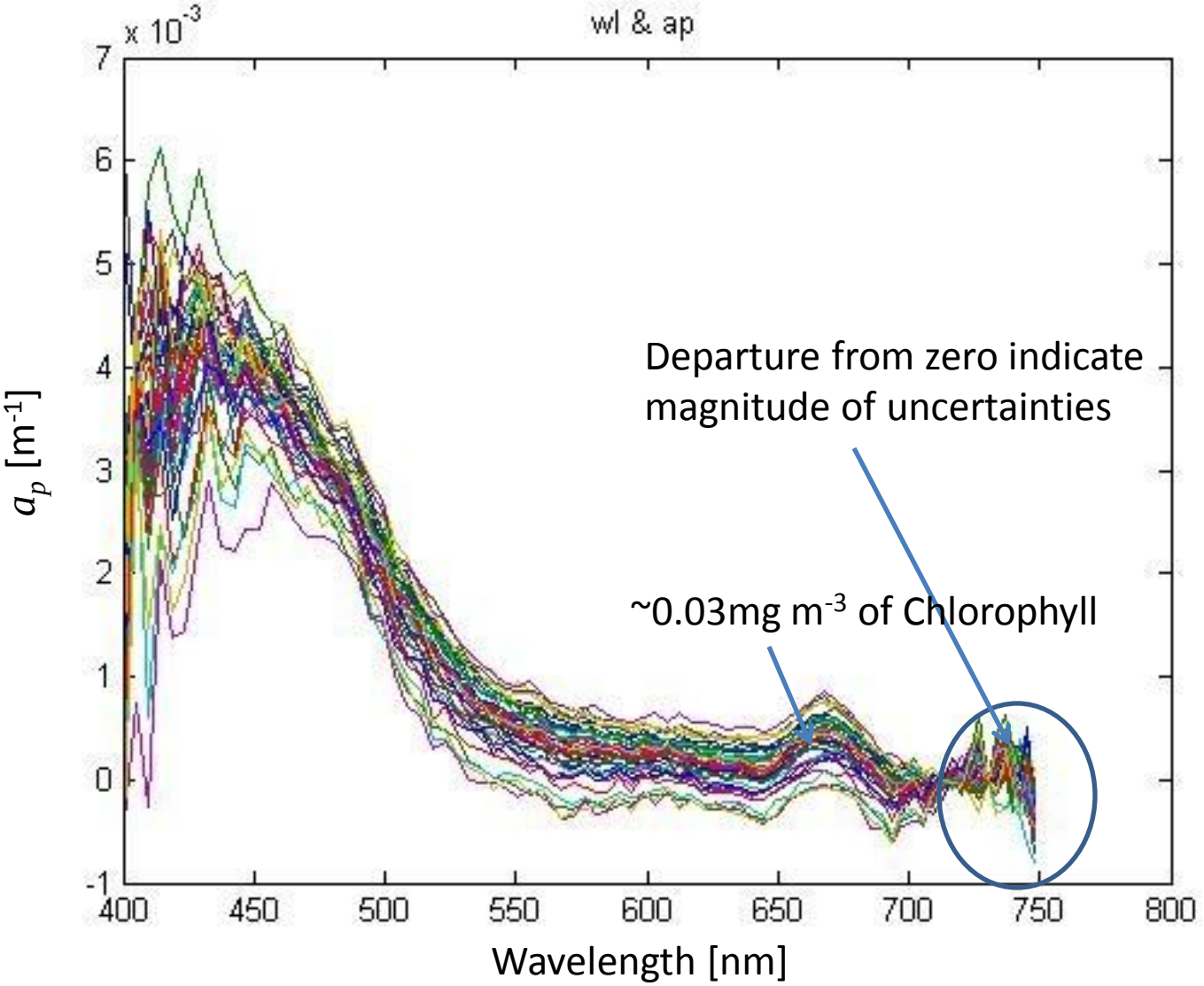


Example 1min binned data:



Steeper beam-c spectra -> steeper size distribution

Example data in the clearest waters

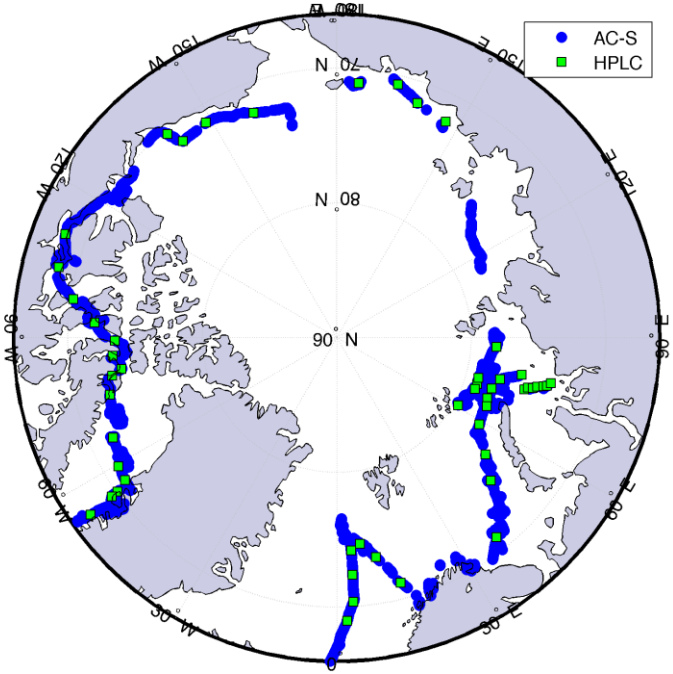


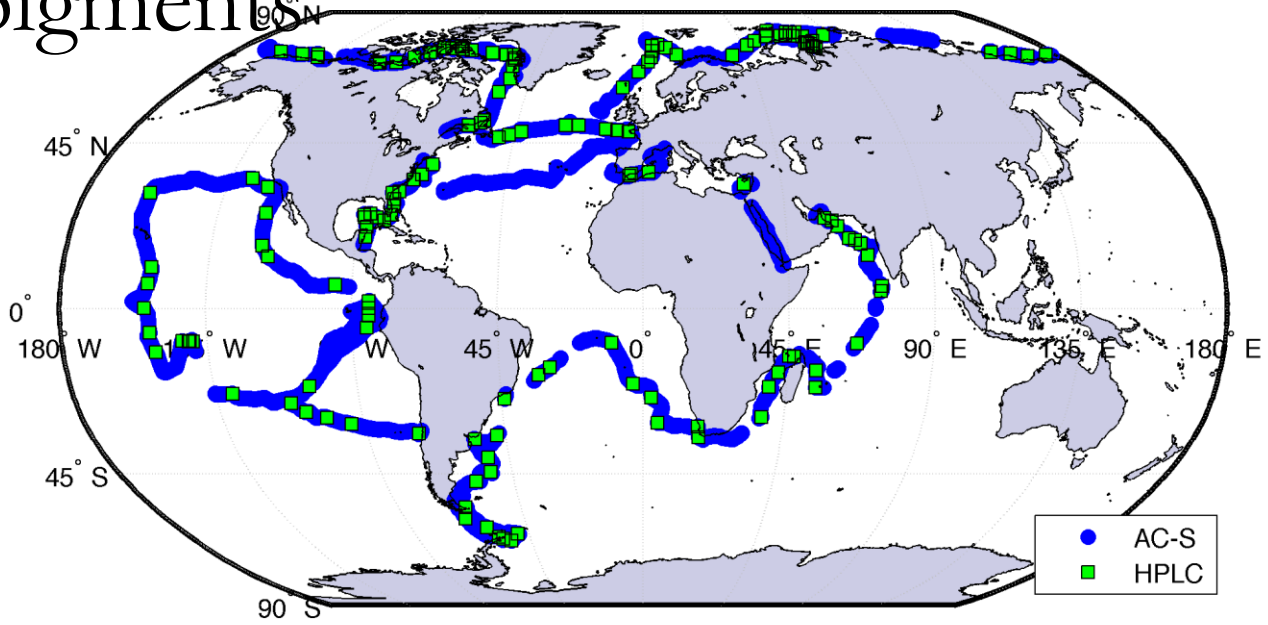
Manufacturer stated accuracy possible: 0.01m^{-1}

We are resolving absorption peaks on the order of: 0.001m^{-1}

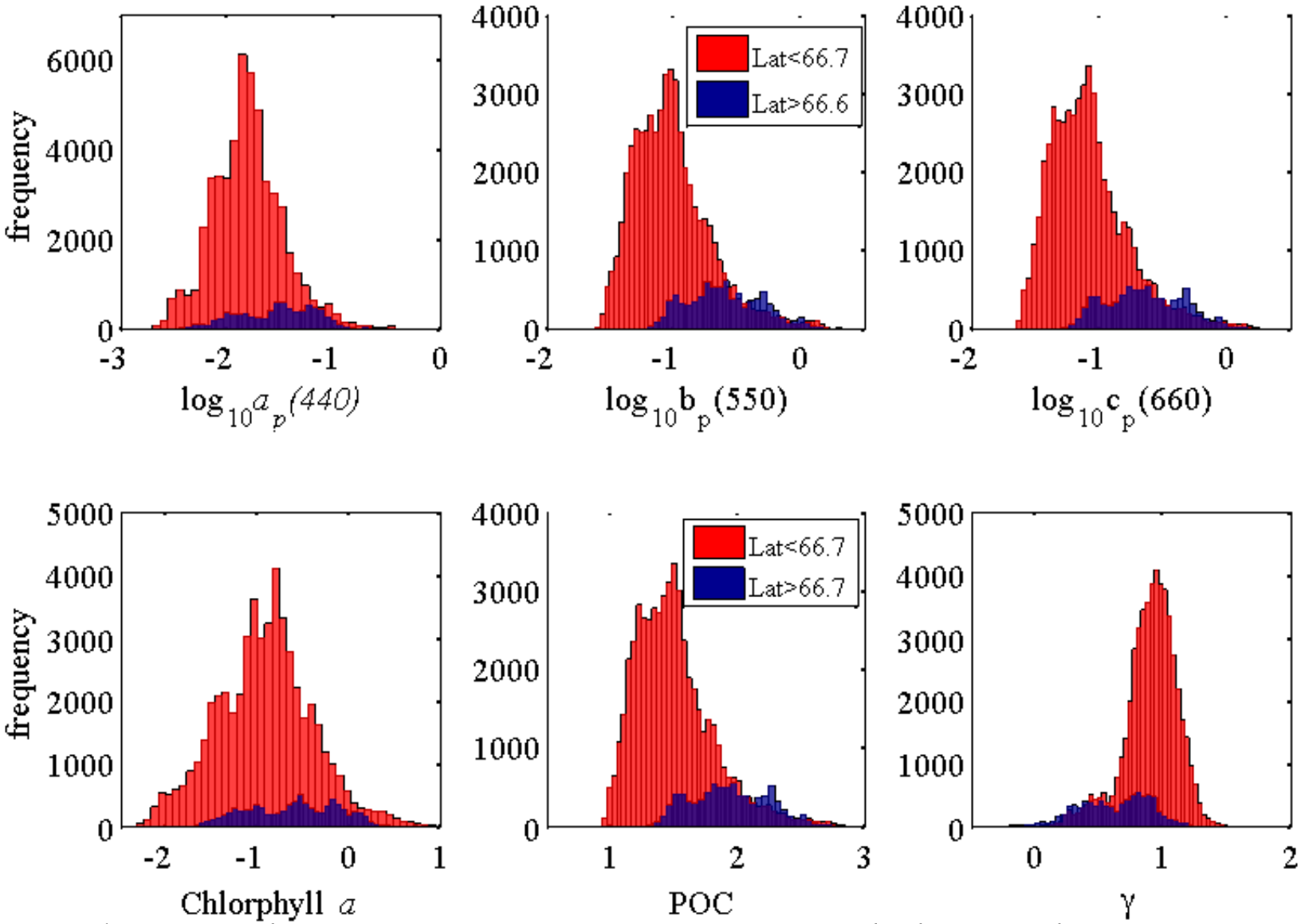
DATA

Locations where we have particulate absorption (95,000) and attenuation (72,000) 1km^2-averaged spectra and HPLC pigments



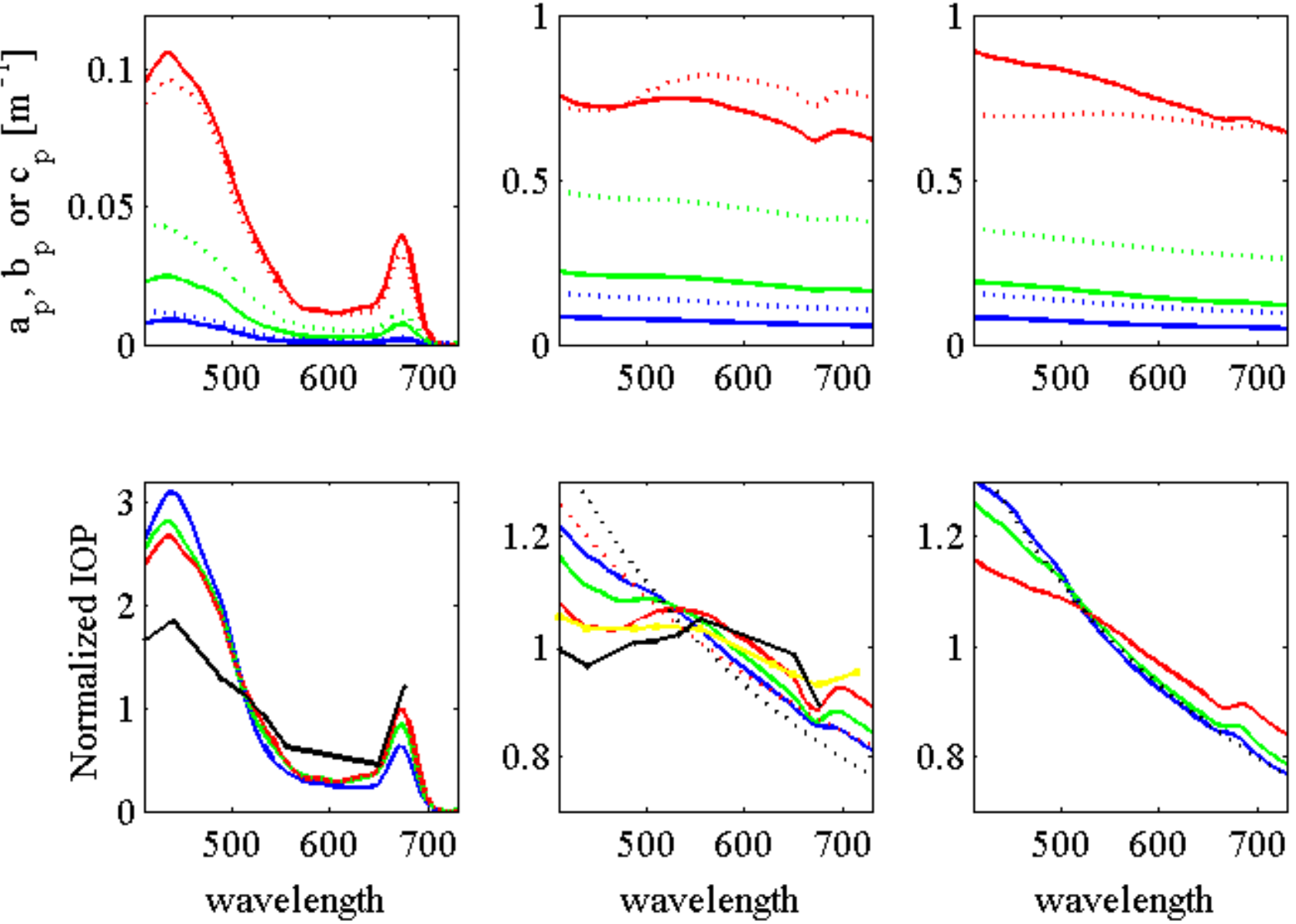


Results



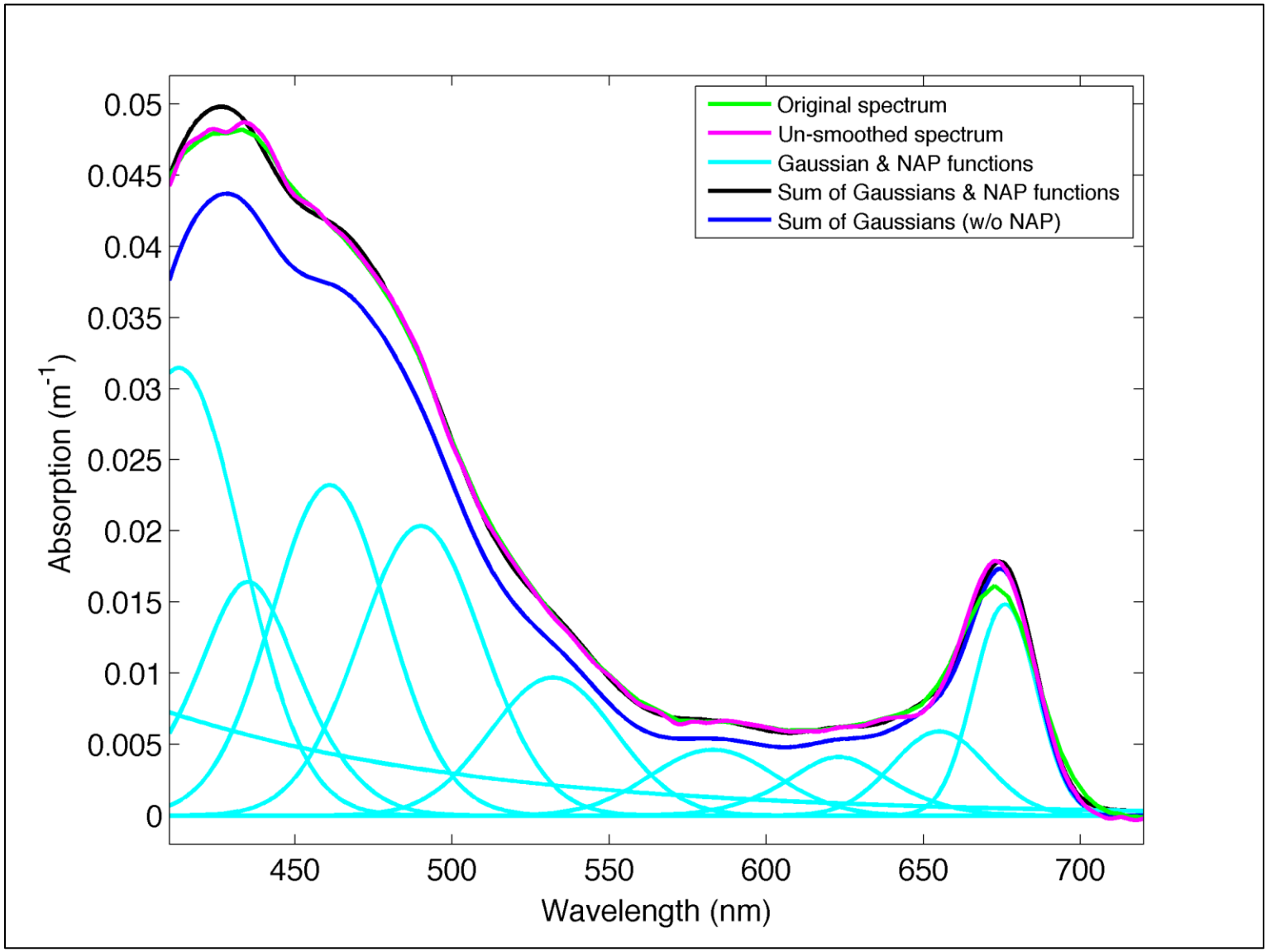
Observed particulate properties and derived properties.

Results

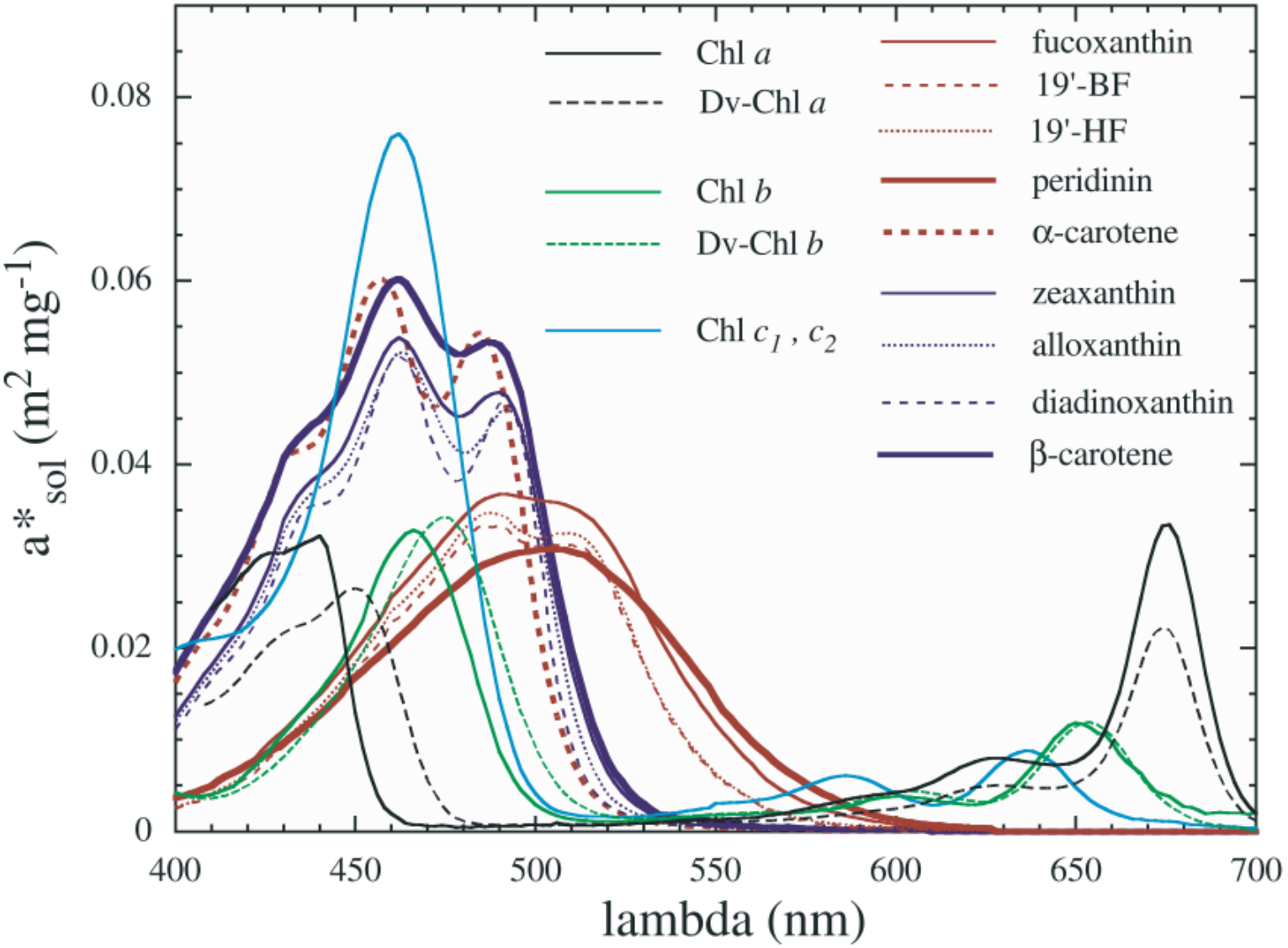


Observed particulate properties (100km off coast).

Decomposition of particulate absorption



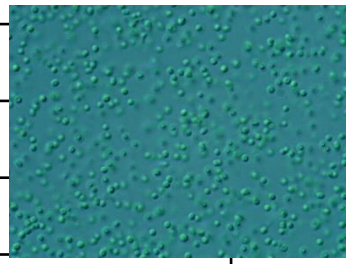
Example of decomposition for a measured a_p spectrum from the Equatorial Pacific, near the Marquesas (Chase et al., 2014).

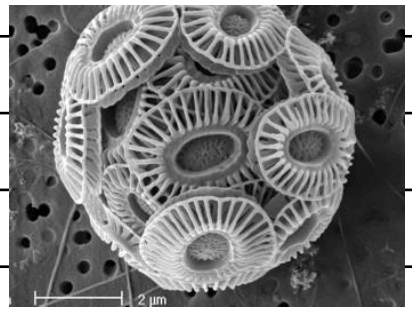


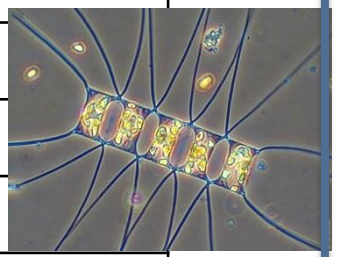
from Bricaud et al., 2004

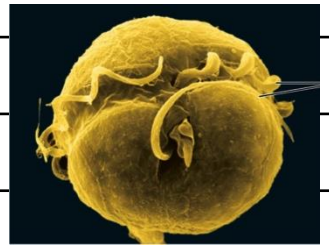
Phytoplankton pigments measured by HPLC and used in this study

TChl a	Chlorophyll a	All except prochlorophytes
	Divinyl chl a	Prochlorophytes
	Chlorophyllide a	Senescent diatoms
TChl b	Chlorophyll b	Green algae
	Divinyl chl b	Prochlorophytes
Chl c	Chlorophyll c1	Chromophytes
	Chlorophyll c2	Chromophytes
PSC	19'-hexanoyloxyfucoxanthin	Prymnesiophytes
	19'-butanoyloxyfucoxanthin	Prymnesiophytes
	fucoxanthin	Diatoms
	peridinin	Dinoflagellates
PPC	α-carotene* + β-carotene	Various
	alloxanthin	Cryptophytes
	zeaxanthin	Cyanobacteria and prochlorophytes
	diadinoxanthin	Various



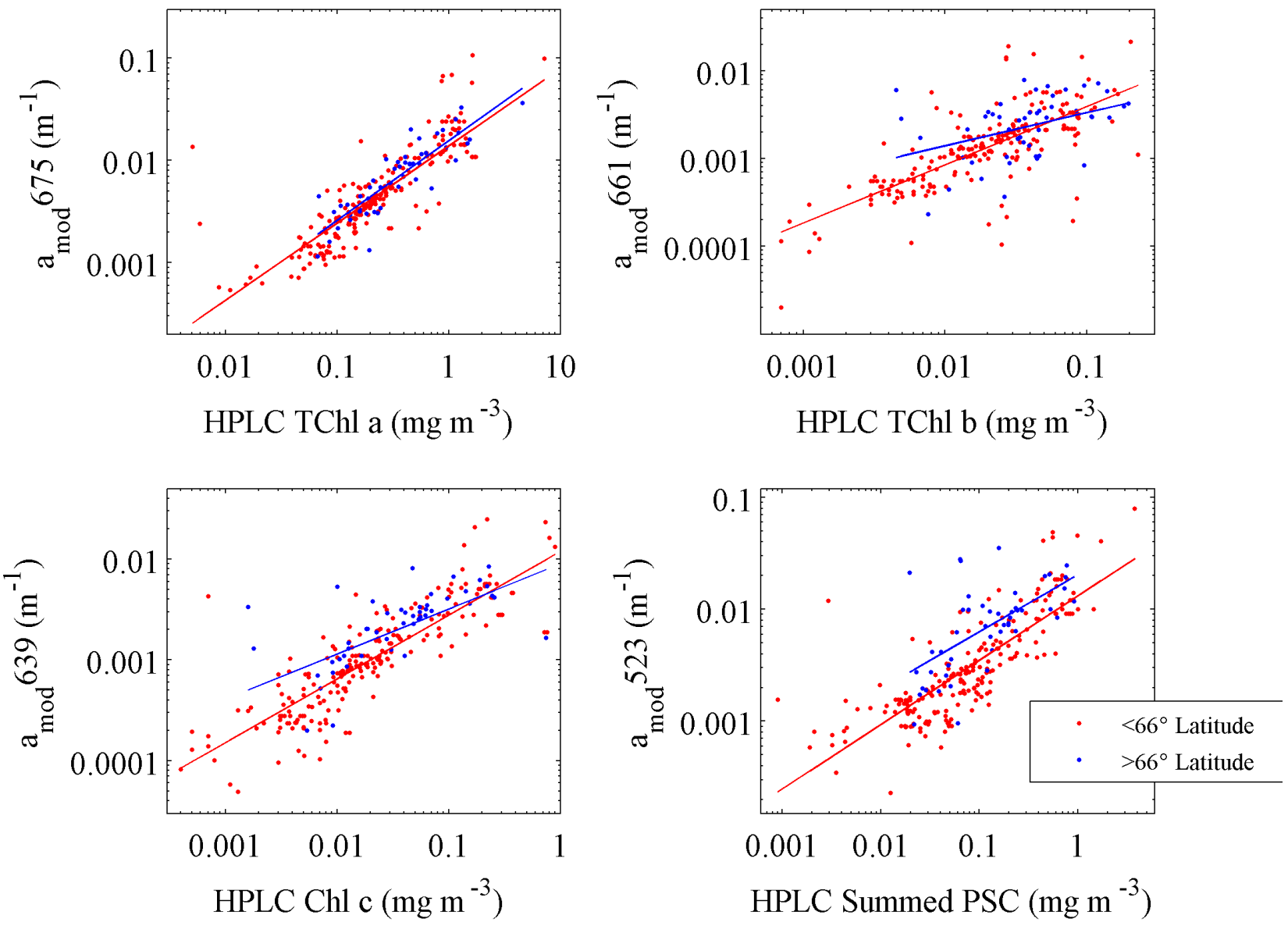




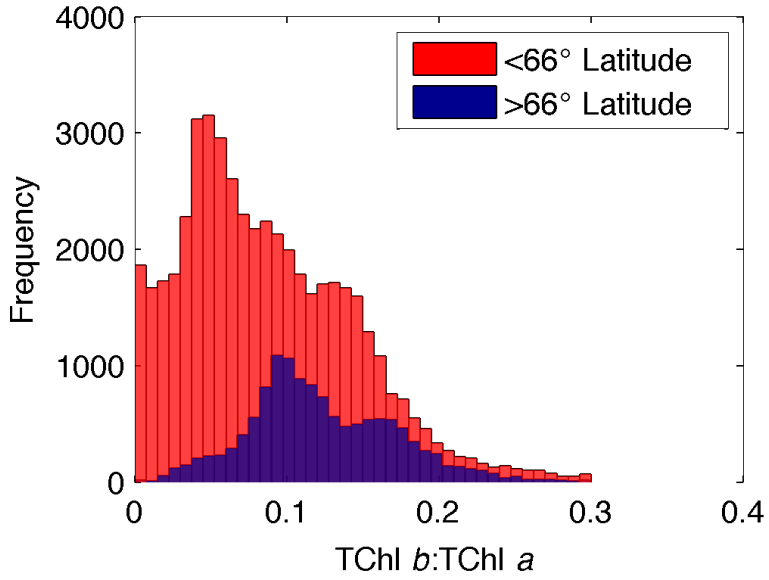


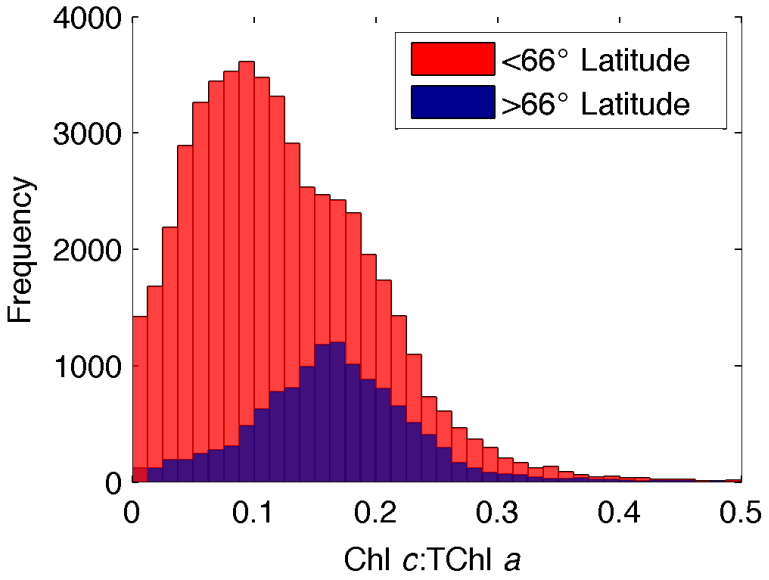
*α-carotene is photosynthetic (a PSC), but is grouped with β-carotene in the reported HPLC pigment data

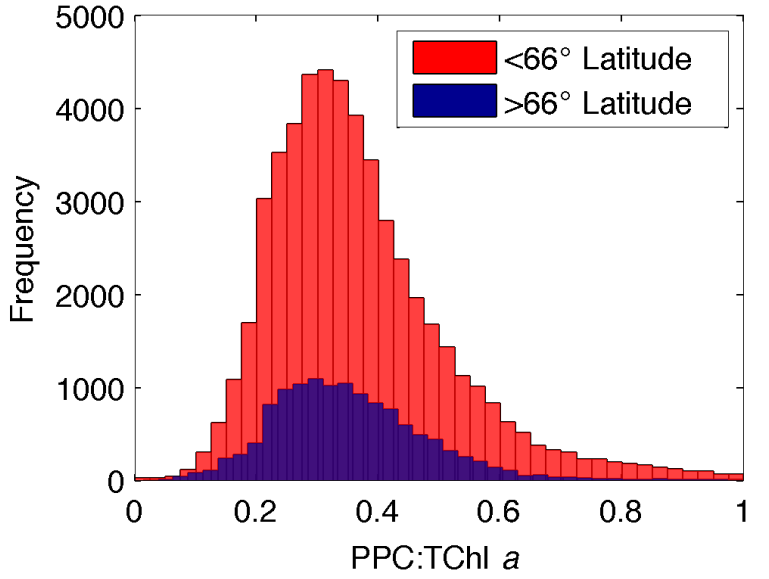
Pigments and pigments distributions

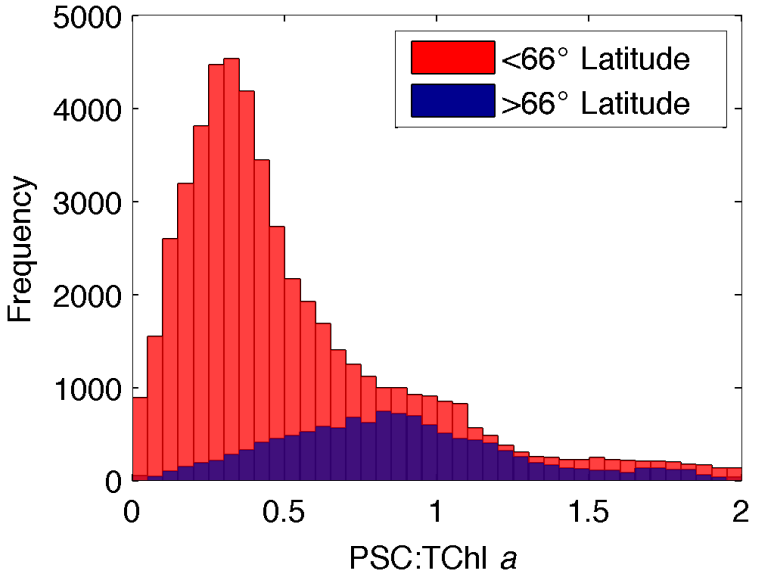


Pigments and pigments distributions

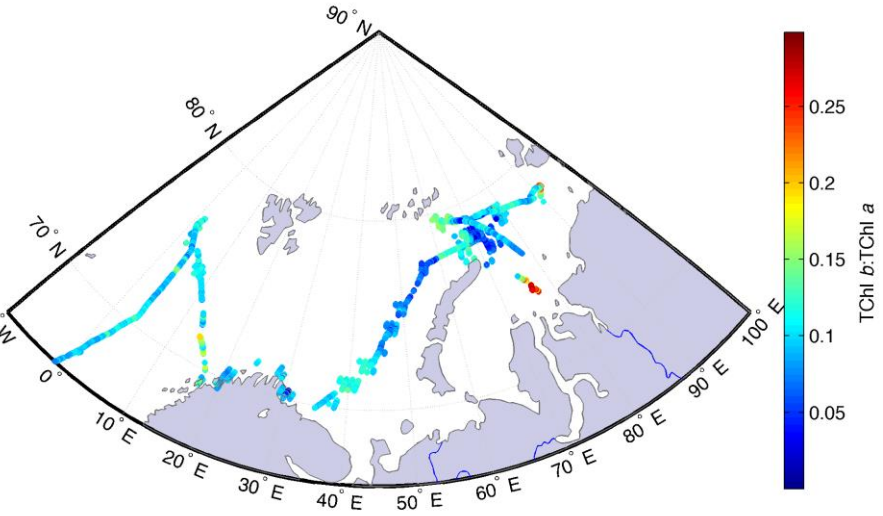


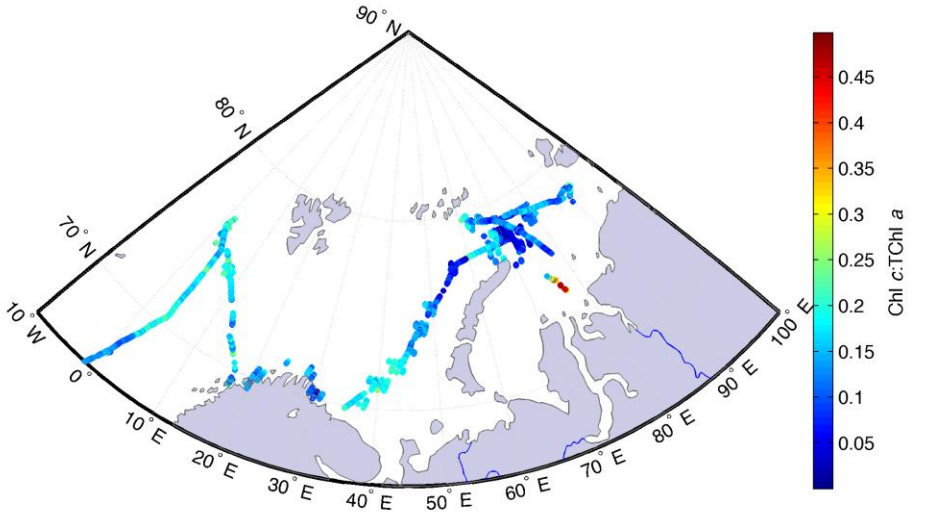


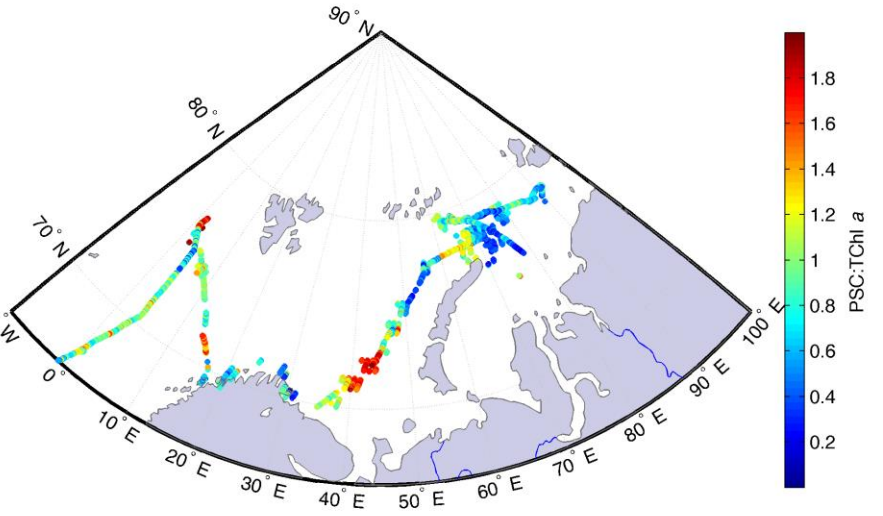


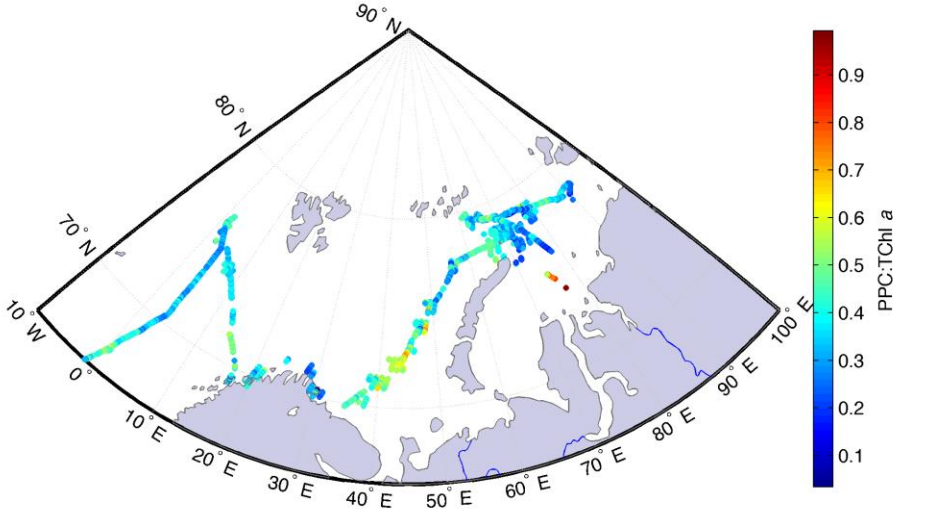


Example distributions of pigments relative to chlorophyll *a*

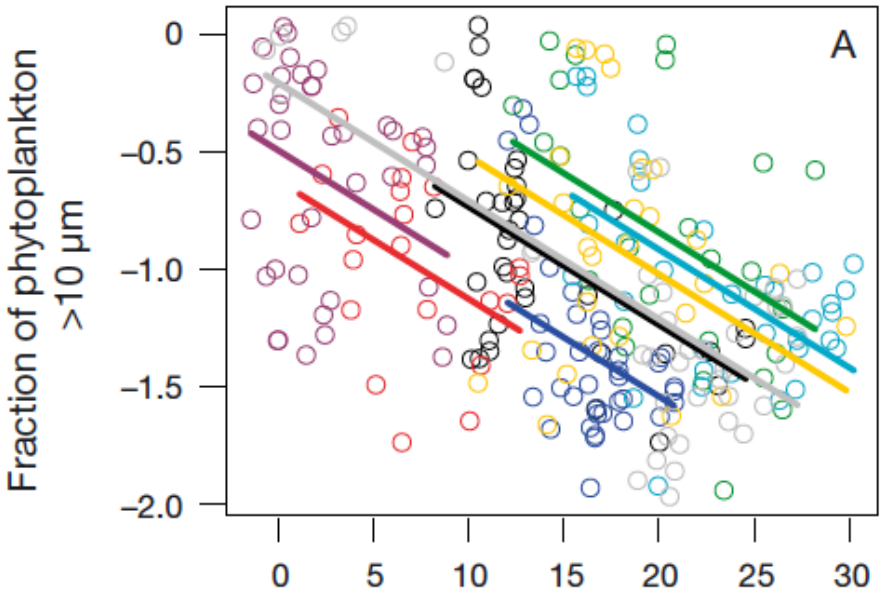




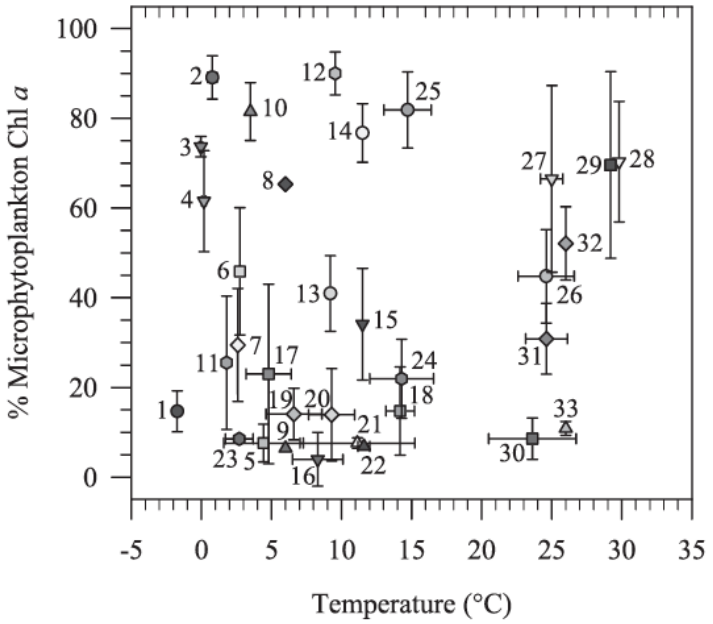




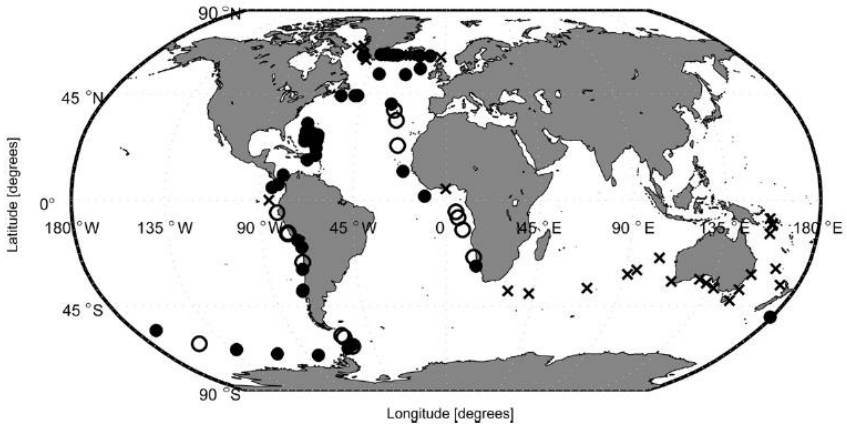
Chlorophyll, particles size and temperature

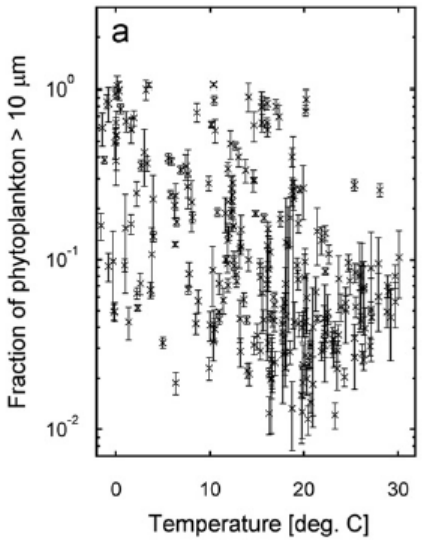


Mousing et al., 2014, MEPS



Maranon et al., 2012, L&O

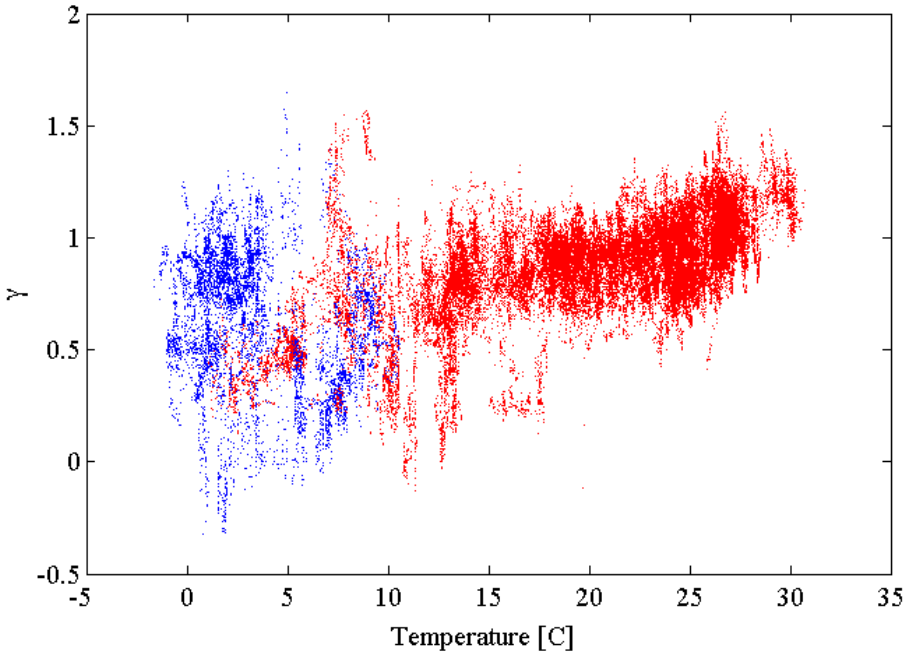


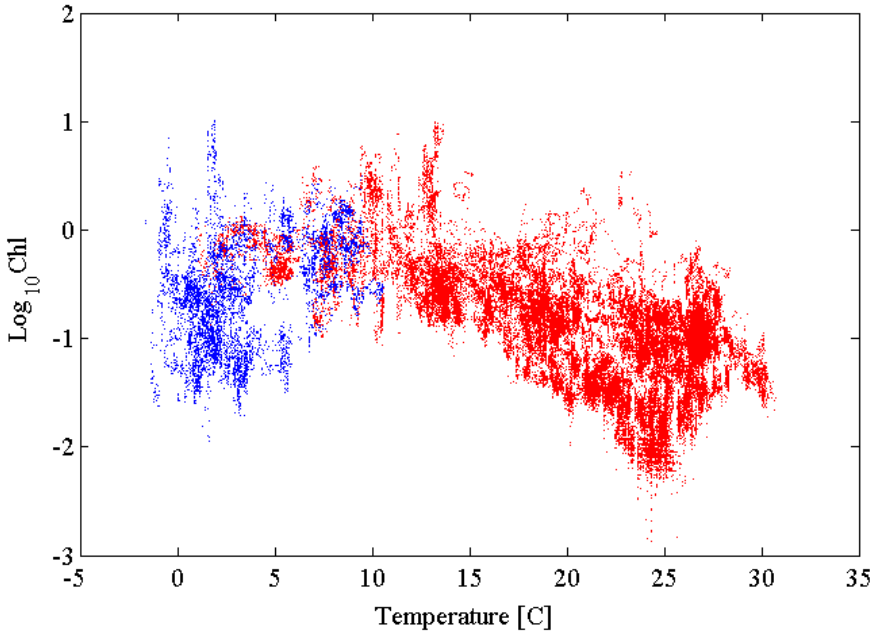


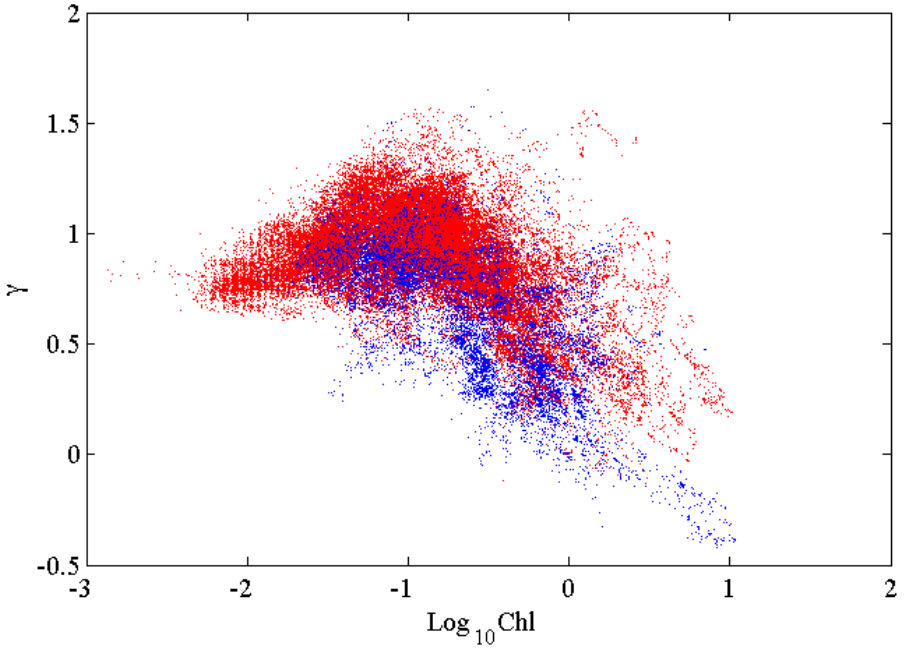
Hilligsoe et al., 2011, DSR

Results:

Link between size parameter, temperature and chlorophyll

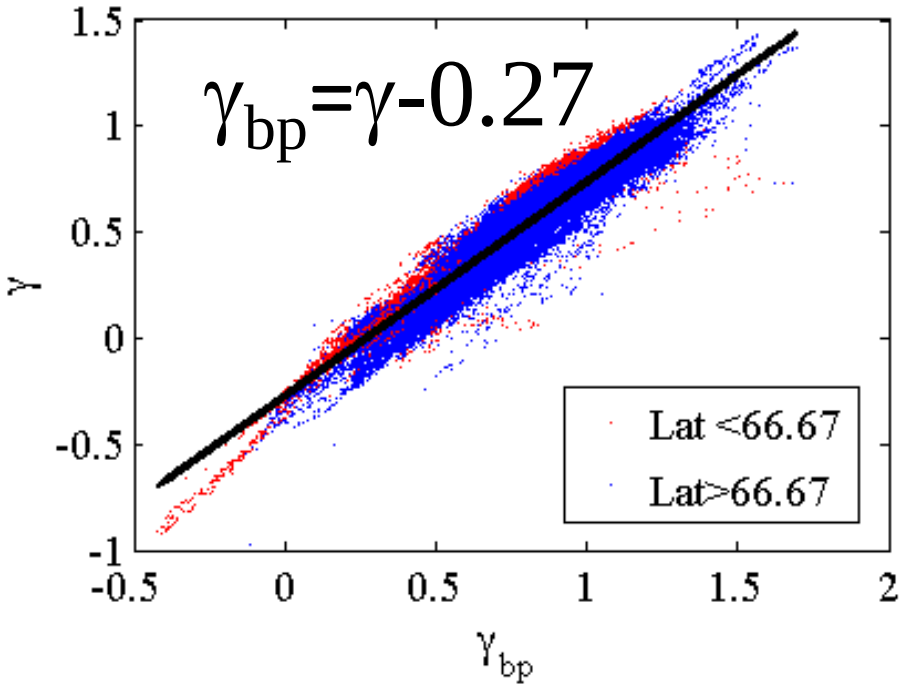


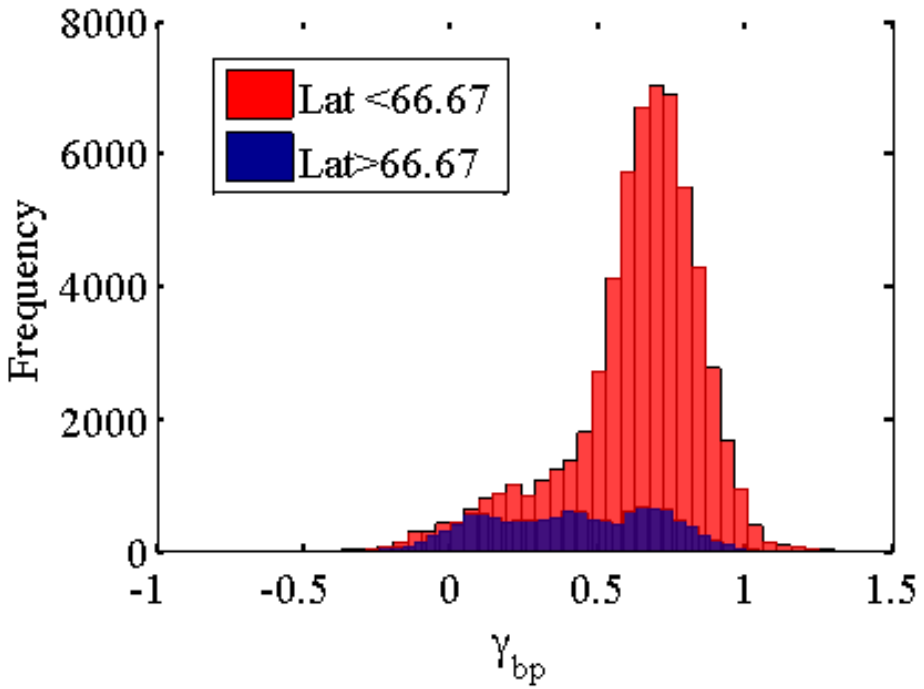




Spectra of b_p and c_p are well correlated (ρ=0.96)

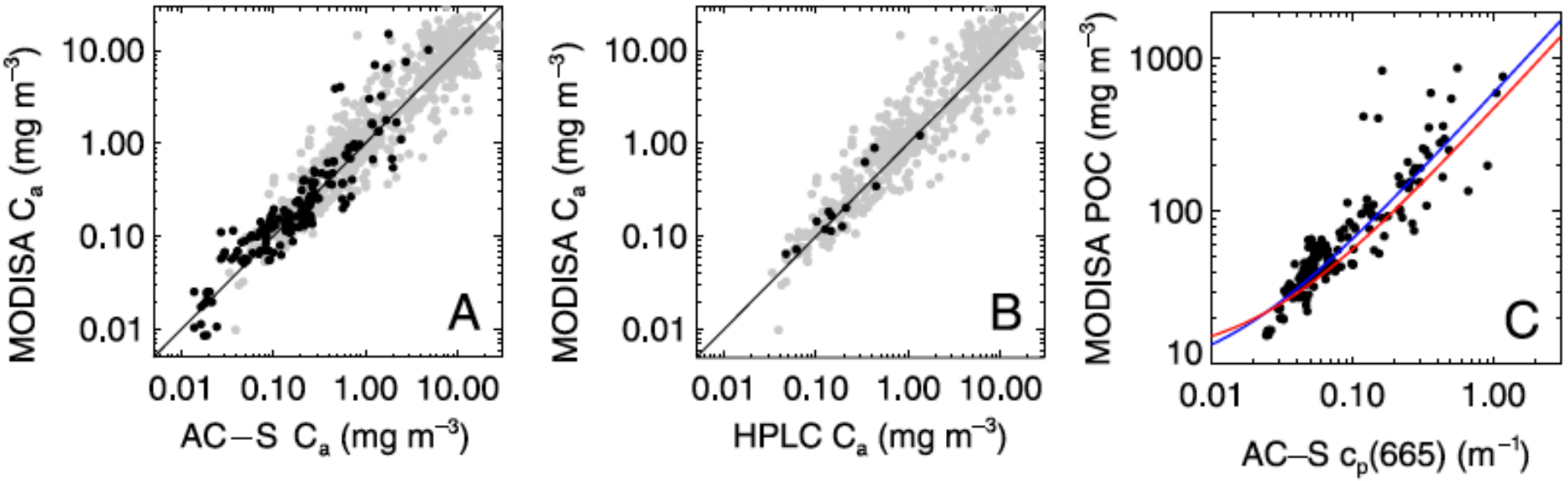
But, Spectral exponents of b_p vs c_p are *different*



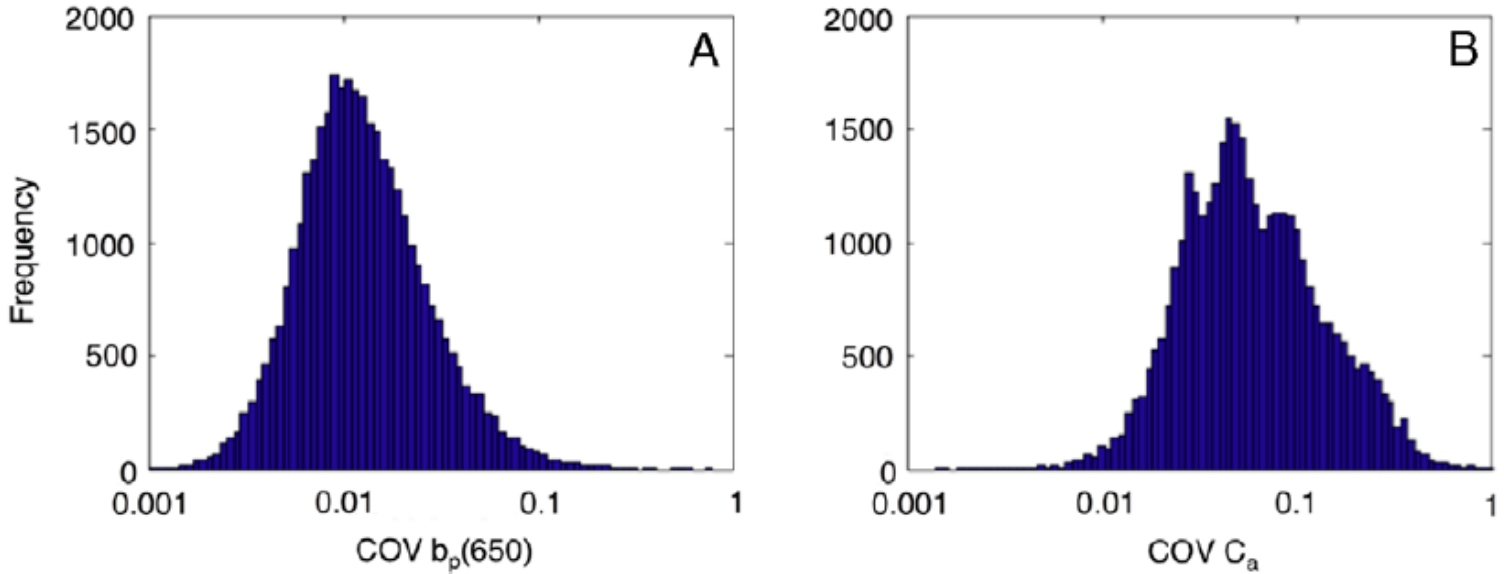


Important for algorithms such as GIOP

Comparison with remote sensing



IOP variance – within satellite pixel variability



Data dissemination

What is already on SeaBASS from Polar Circle (or in the mail box)?

AC-S particulate absorption and attenuation (1min & 1km^2 bins).

What will be submitted next?

Processed:
CDOM (U-Path, AC-S), Radiometry, Pigment, ALFA, profiles with $b_{bp}(650)$ and c(660);

Being processed:
bb3, Flow-cytometer, Imaging-cytometers.

Summary

High quality data has been collected and is available.

Absorption/Pigment relationship in Arctic are similar to those observed in other oceans.

In general, surface arctic particles are larger than those in the global ocean consistent with trends observed in the literature.

In-line systems provide high spatial coverage hence more opportunities for match-up with satellites overpass (Werdell et al., 2014).

Proposed a PACE IOP activity to form a coherent database using community data collected in-line.

The characteristics of particulate absorption, scattering and attenuation coefficients in the surface ocean; Contribution of the Tara Oceans expedition☆

Emmanuel Boss[a,*], Marc Picheral[b,e], Thomas Leeuw[a], Alison Chase[a], Eric Karsenti[c], Gabriel Gorsky[b,e], Lisa Taylor[a], Wayne Slade[d], Josephine Ras[b,e], Herve Claustre[b,e]

Manuscripts in MiO special issue in honor of R. Zaneveld. All open access.

Decomposition of in situ particulate absorption spectra

Alison Chase[a,*], Emmanuel Boss[a], Ronald Zaneveld[b], Annick Bricaud[c], Herve Claustre[c], Josephine Ras[c], Giorgio Dall'Olmo[d], Toby K. Westberry[e]

Underway sampling of marine inherent optical properties on the Tara Oceans expedition as a novel resource for ocean color satellite data product validation☆

P. Jeremy Werdell[a,*], Christopher W. Proctor[a,b], Emmanuel Boss[c], Thomas Leeuw[c], Mustapha Ouhssain[d,e]



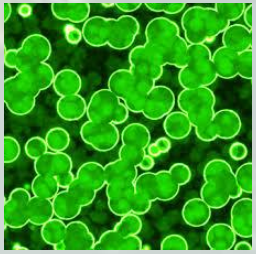


Public outreach



Tara data: where does it fit?

Ecology

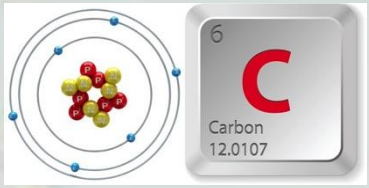


Presence/absence Prey/Predator/symbiosis

Ecosystem models

Environment
Physics/chemistry

Biogeochemistry



Biomass

Rates

Biogeochemical models