POC/SPM Concentration

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Introduction

Particulate mass has been measured routinely in the oceans for > 80yrs and using optical instruments for about 70yrs. Commercial instrumentation was introduced in the late 70's with significant strides in deriving proxy relationships in the 90's.

Why do we want to know the particle mass in the oceans?

1. Particles in the upper ocean covary with phytoplankton biomass, the energetic base of the oceanic foodweb.

2. Particles in the upper ocean transfer organic matter to depth and hence are a key component of the biological pump.

By quantifying the concentration of particles in the sea, we can constrain them in models and infer on their role of the oceans in the global carbon cycle.

Units reported are in mass or volume of solids per volume or mass of fluid, or mass of organic carbon per volume/mass of fluid. Turbidity units have also been used (a measure relative to a suspension of known material)

Introduction

Scattering measurements provide a constrained proxy for SPM and POC in the oceans.

Scattering is a *physical* measurement.

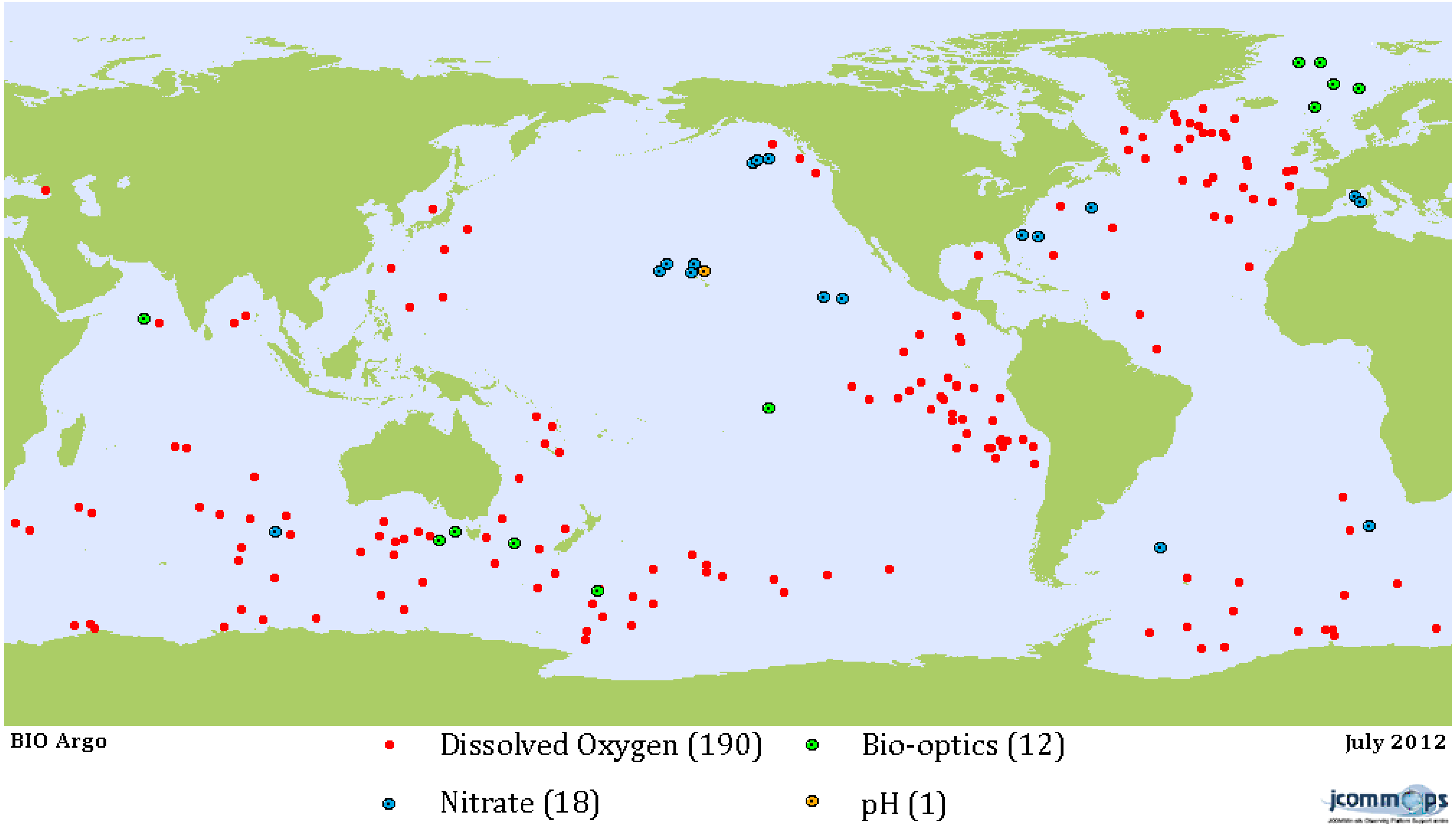
To predict the scattering from a given particle we need to know:

1. wavelength (and spectral range) of source and wavelength sensitivity of receiver.
2. Angle (and angular range) of light coming out of source.
3. Angle (and angular range) of light collected by receiver.
4. Know particle properties affecting light scattering (e.g. size, index of refraction, shape, internal structure).

Given the complexity of the above, empirical relationship are favoured (historical) and have been found to be constrained.

Introduction

A natural evolution/extension/enrichment/challenge of the Argo system, already on going



b_{bp}-POC: Example of empirical relationship. Some differences due to methods.

Table 2. Comparison of POC vs. b_{bp} slopes and methodologies. Literature POC vs. b_{bp} slopes are reported for original wavelength; the percentage increase in the slope is for b_{bp} recalculated to 700 nm, η=0.41. Units of slope are mg C m^{-2}.

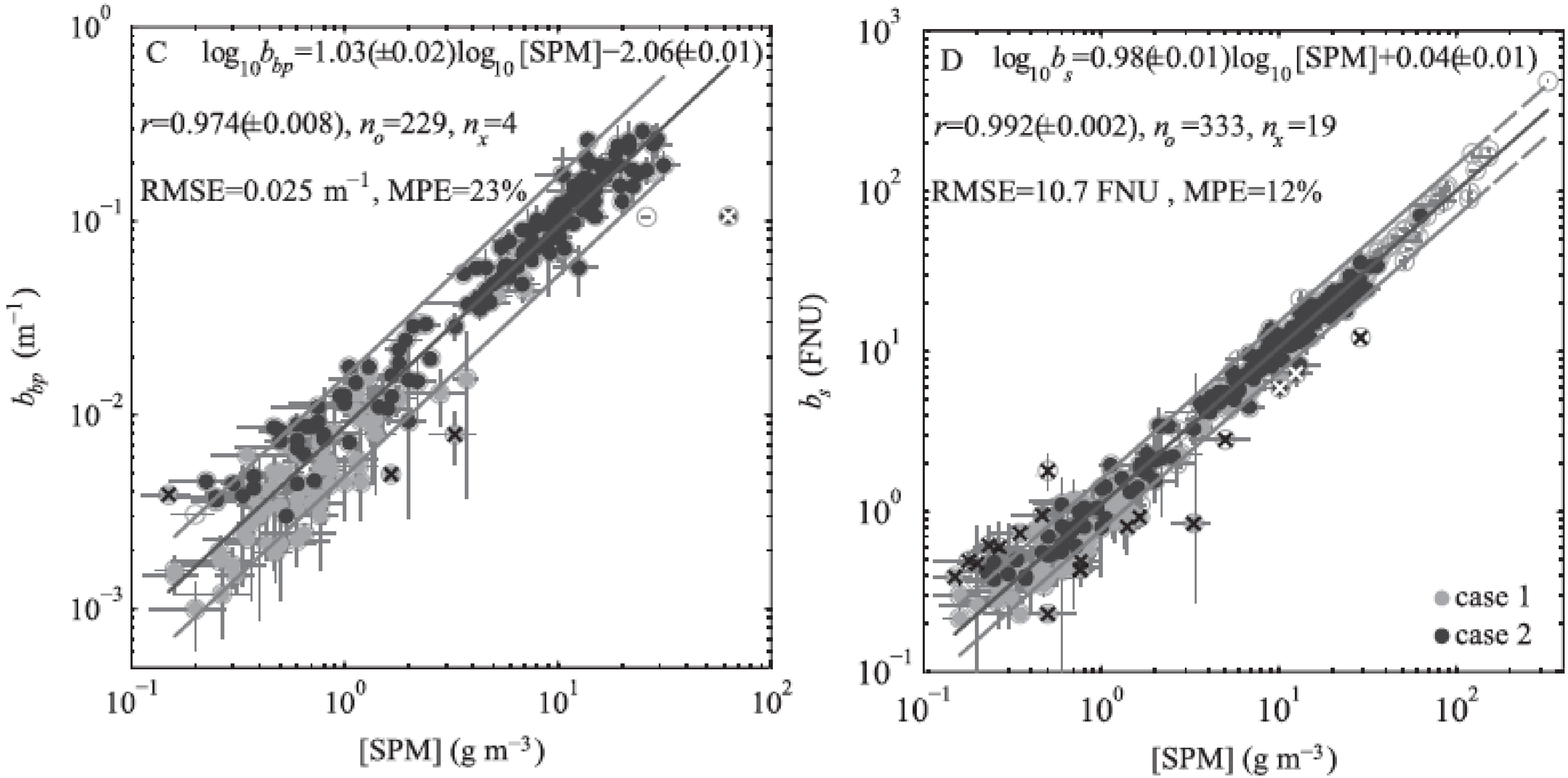
Author (sample size)	Area /Season	Depth (m)	POC vs. $b_{bp}(\lambda)$[a] (% increase for λ=700 nm)	DOC correction	Instrument / angle/ wavelength	b_{bp} sampling
Stramski et al., 2008 (n=54, 59[b])	Pacific, Atlantic / Oct-Nov	4–8	$53607.0\ b_{bp} + 2.5$ $7085.01\ b_{bp} - 9.1$[b] (10%)	No[c]	Hydroscat-6 /140°/ 555 nm	CTD rosette, averaged upcast and downcast
Stramski et al., 1999 (n=33)	APFZ / Summer-Fall	0-15	$17069.0 \pm 1.3 * b_{bp}^{0.859 \pm 0.046}$ (15%)	No	Hydroscat-6 /140°/ 510 nm	CTD rosette, cast direction ?
Stramski et al., 1999 (n=24)	Ross sea / Summer	0-15	$476935.8 \pm 1.5 * b_{bp}^{1.277 \pm 0.061}$ (15%)	No	Hydroscat-6 /140°/ 510 nm	CTD rosette, cast direction ?
Balch et al., 2010 (binned to n=18)	North and South Atlantic / all seasons	5	$841 * b_{bp}^{0.395}$ (12%)	No	EcoVSF□3 /110, 125, 150° / 532 nm	Ship flow-through, un-acidified b_{bp}
Loisel et al., 2001	Mediterranean / N/A	N/A	$37550.0\ b_{bp} + 1.3$ (10%)	No	merged from multiple sources/555 nm	N/A
NAB08, *this study* (n=321)	North Atlantic / Spring	0–600	$35422 \pm 1754\ b_{bp\_down}$ $- 14.4 \pm 5.8$[d] $43317 \pm 2092\ b_{bp\_up}$ $- 18.4 \pm 5.8$	Yes	FLNTU /140°/700	CTD rosette, downcast[d] or upcast

[a] POC vs. b_{bp} slope (mg C m^{-2}) with measured wavelength, as published.
[b] POC vs. b_{bp} slope developed using the entire dataset, including upwelling data; see Table 6 in *Stramski et al. (2008)*.
[c] Contribution of DOC adsorption was minimized with large filtration volume.
[d] The recommended NAB08 POC vs. b_{bp} relationship uses downcast data; upcast data is presented for comparison only.

Cetinic et al., 2012

b_{bp}-SPM: Example of empirical relationship.

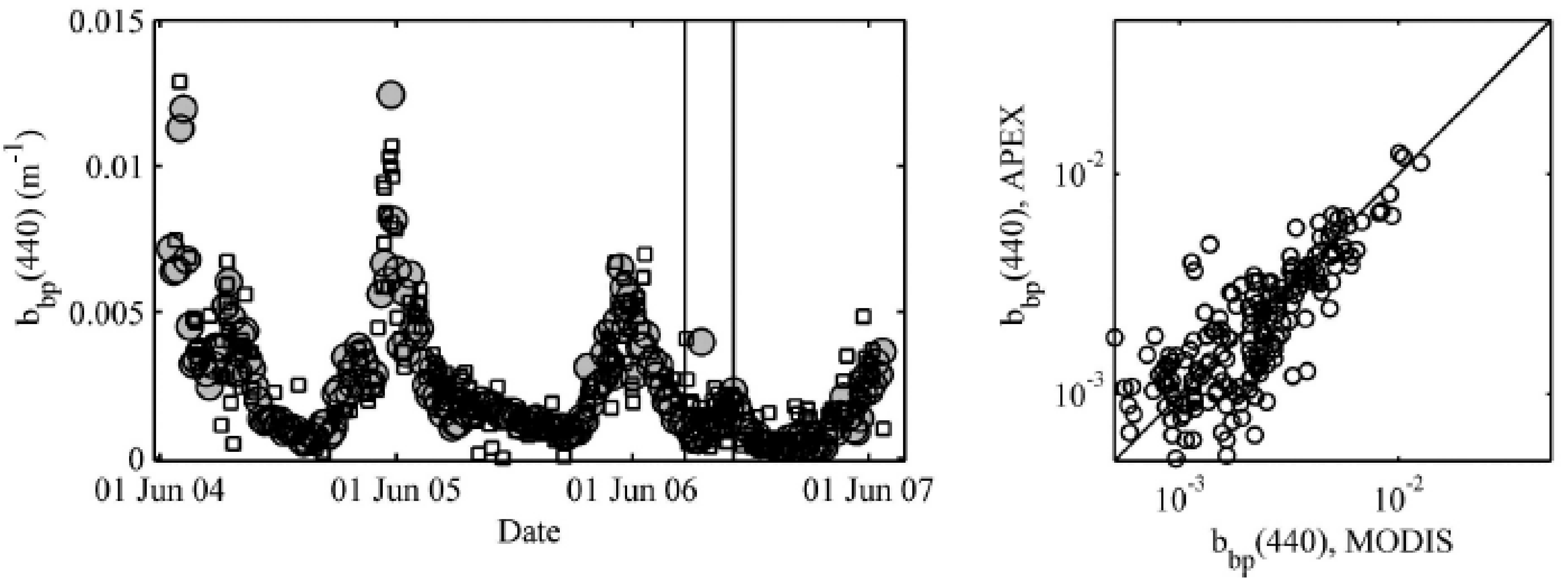
Nukermans et al., 2012:



Notice large dynamic range!

And we can relate measured back (side) scattering to Ocean Color:

Boss et al., 2008*:



*Actually measuring side-scattering at 880nm and using a transfer function to obtain $b_{bp}(440)$.

In short:

There are several technologies that can be put on float and measure scattering at different angular and spectral range.

No reason to limit Argo and users to one type (price do vary).

Experience will help choose the most robust/sensitive (much like the conductivity sensors in the early days of Argo.

Crucial to have sensor characteristics on file at data base (calibration coefficients as well as make, model, year, wavelength range, angular range).

Typical sensors used provide an output (analogue or digital *signal*) that is related to an optical property via a **linear equation**, *e.g.*:

$$b_{bp} = Slope(signal - dark)$$

Manufacturer provide *Slope* and *dark*.

It turns out that:

1. *dark* may be significantly different on float compared to the manufacturer's lab.

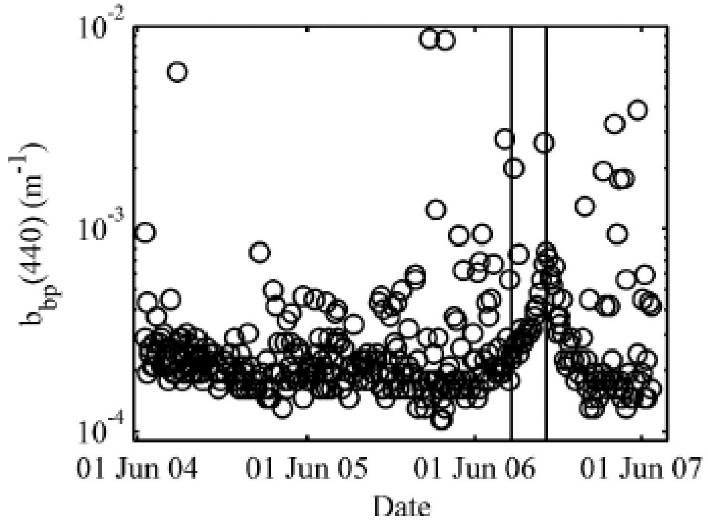
2. *Slope* may change in time (observed for WETLabs' Eco-bb in blue wavelengths, Dall'Olmo et al., 2012).

Calibration procedures change too…

It follows that:

1. Float could transmit *Signal* or *parameter*, but calibration parameters need to be available at data center.
2. Float manufacturer or user need to determine *dark* with instrument powered by float.
3. Data at depths should be monitored for drift as well as relationship to OCR at surface.

Data between 950-1000m over 3yrs:



Outline

In the next…..

- The characteristics of the Scatering parameter relevant for the RT QC
- For each characteristic:
  - a general overview
  - implication for the QC on profiling floats
  - description of existing methods to deal with (if any)
- Some scenarios for the RT QC
- Discussion topics

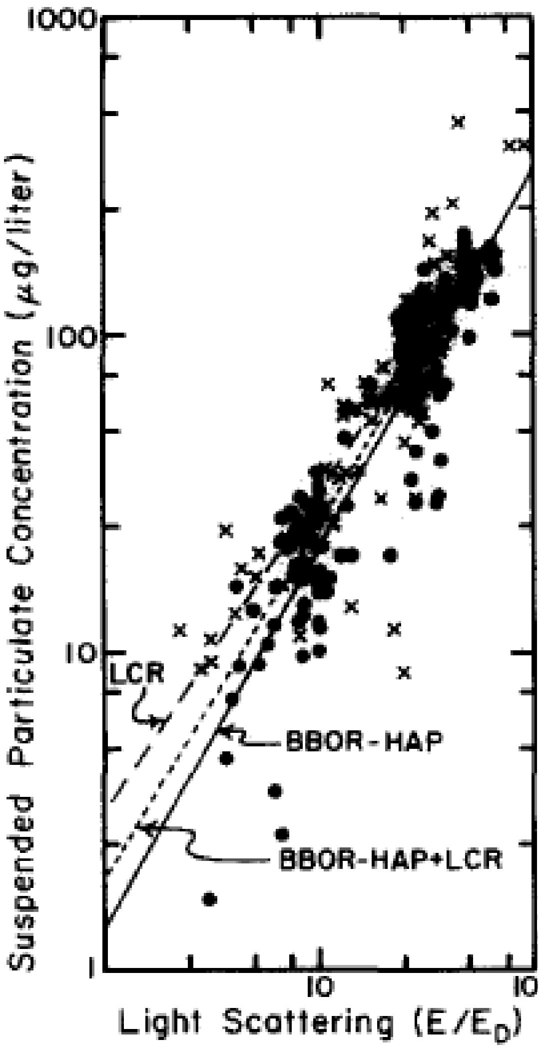
Characteristics of the scattering parameter

- Spatio-temporal variability of the scattering oceanic field
- Calibration
- Relation to other variables
- Spikes

SUSPENDED PARTICULATE LOADS AND TRANSPORTS IN THE NEPHELOID LAYER OF THE ABYSSAL ATLANTIC OCEAN*

PIERRE E. BISCAYE and STEPHEN L. EITTREIM

Marine Geology, 1977



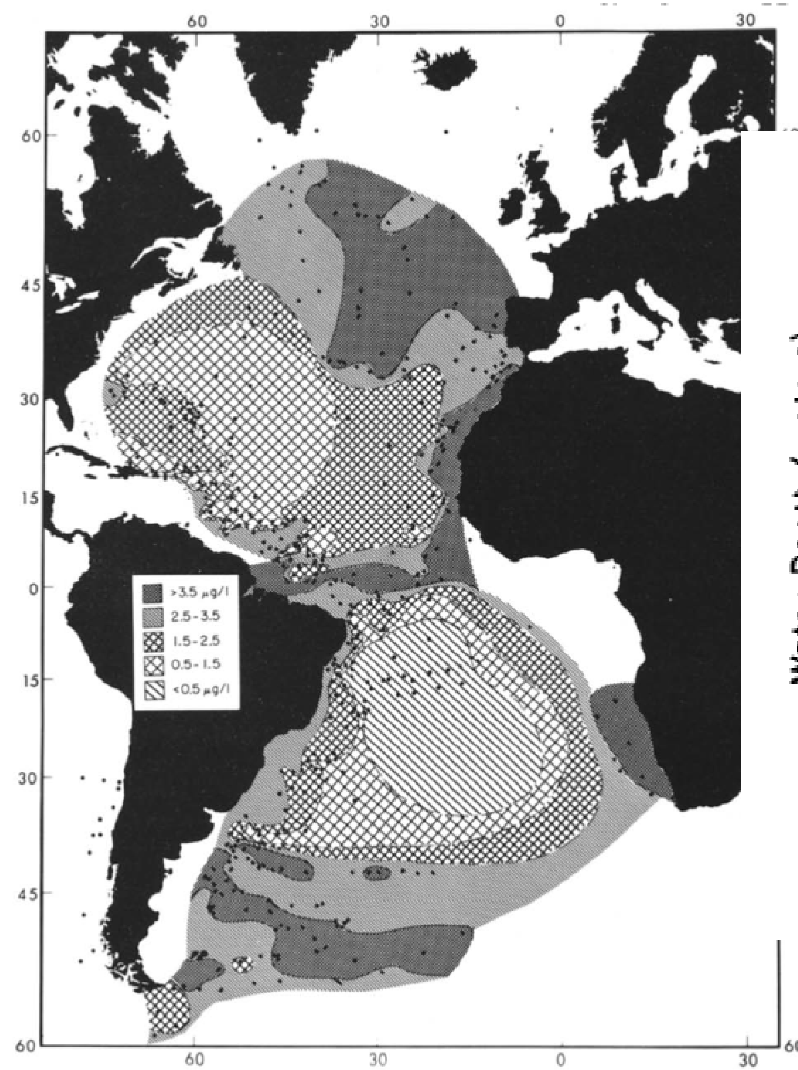
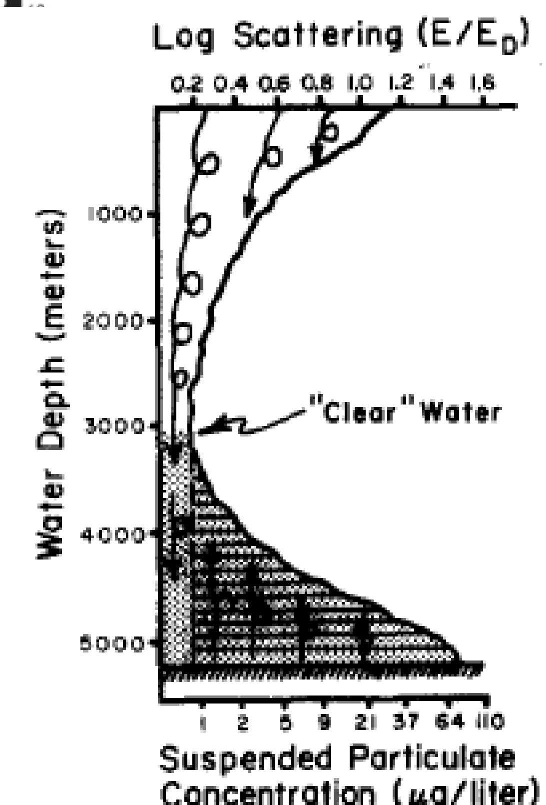
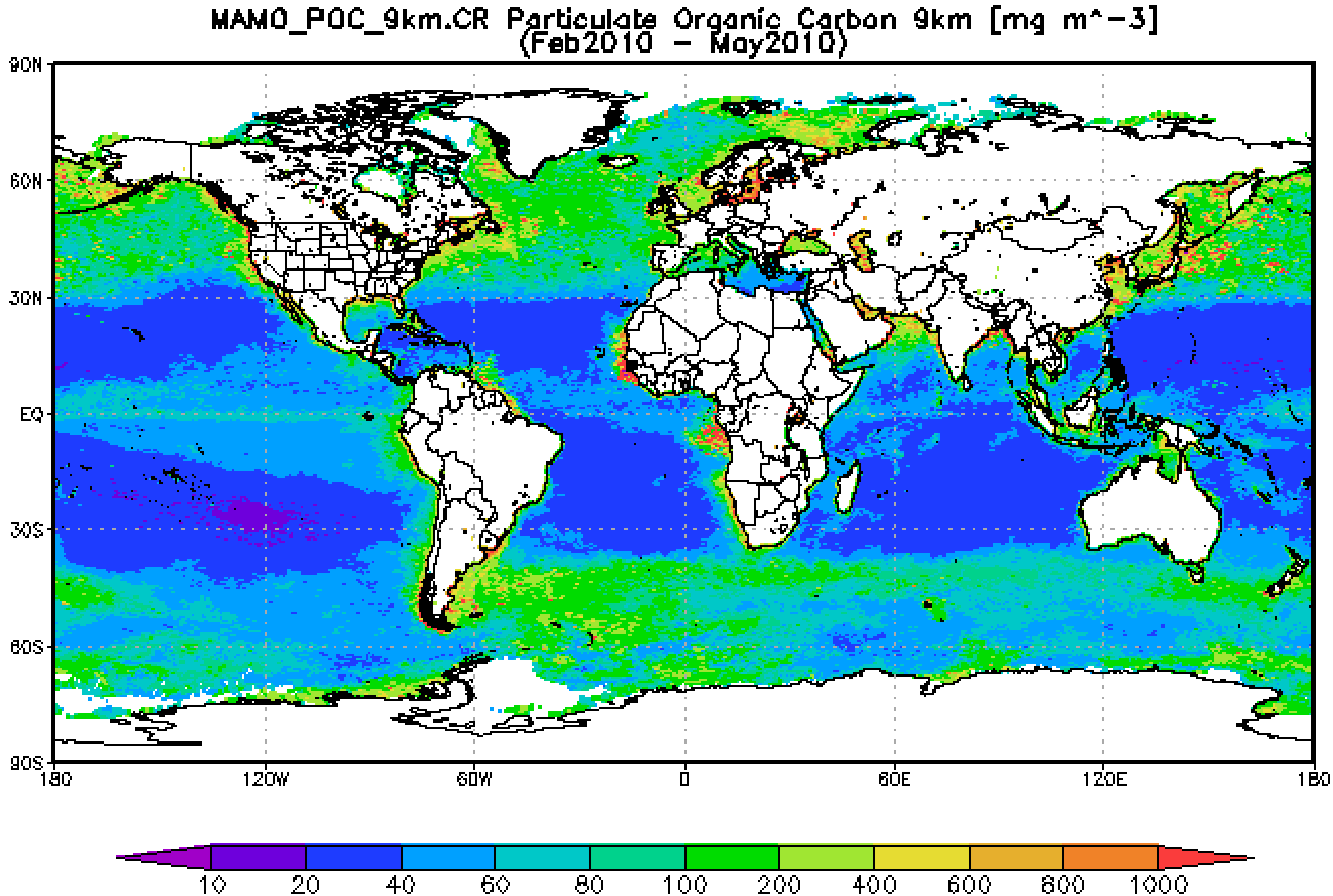


Fig. 3. Distribution of the concentration of suspended particulate matter at the clear water minimum in the Atlantic Ocean.



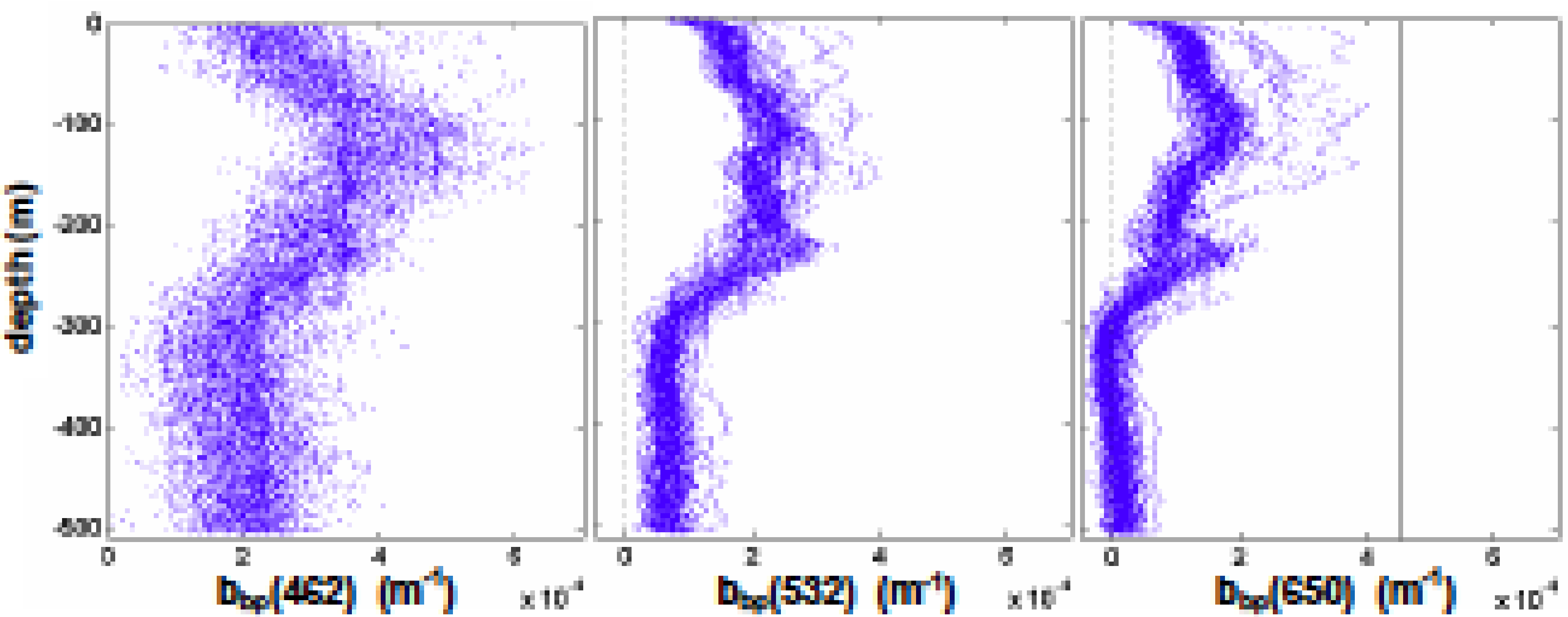
Spatio-temporal variability

General overview, large dynamic range in surface oceans:



Spatio-temporal variability

General overview, large dynamic range from surface to depth (depends on getting the 'background' right:

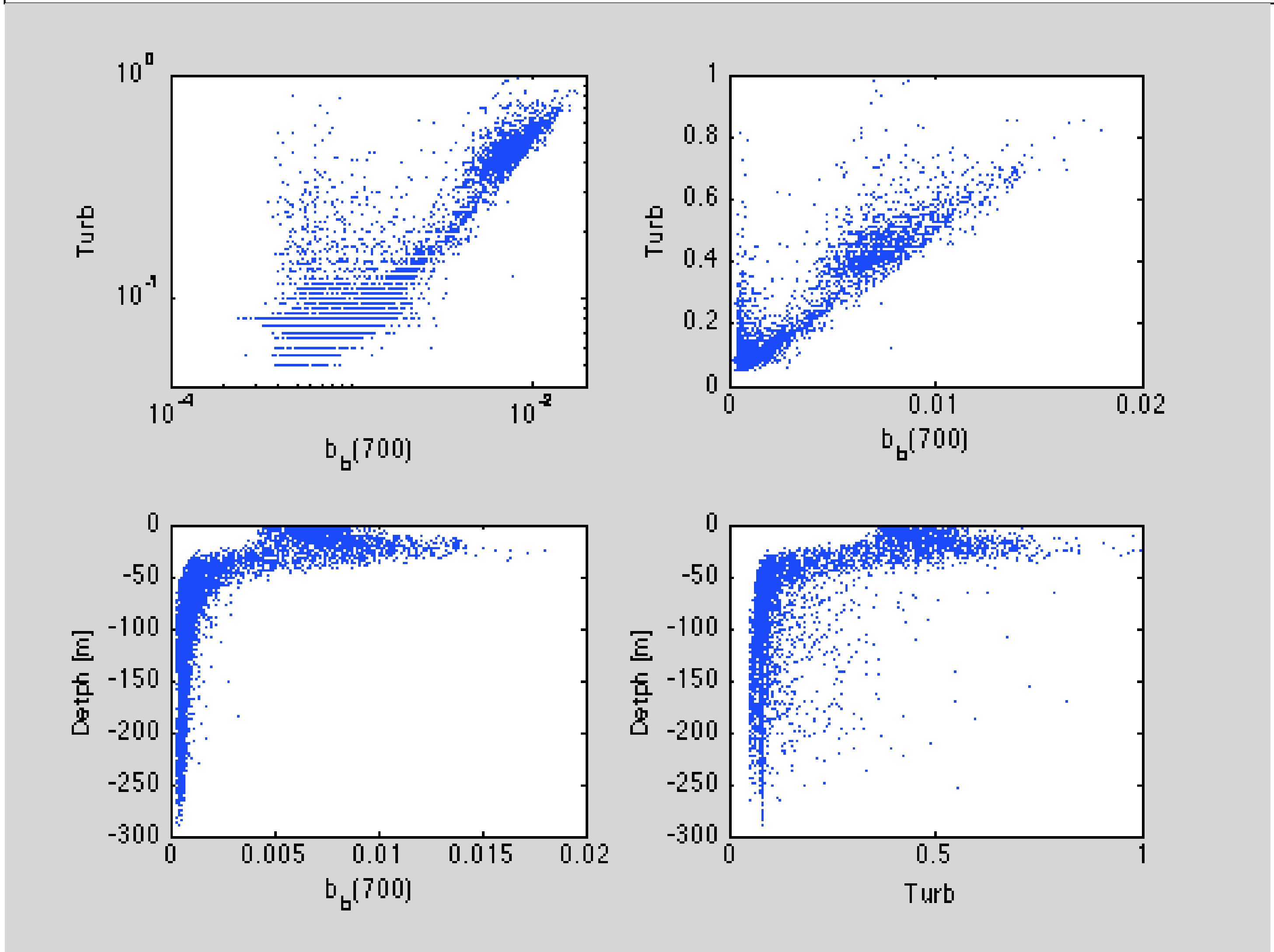


Clearest waters in the upper ocean

Twardowski et al., 2009

Spatio-temporal variability

'Turbidity' (Seapoint) and backscattering (WETLabs FLNTU) in the surface N. Atlantic (133 profiles, 132 shallow):



n~10,000pts

R~0.9 in both linear and log-space.

Noise could be due to non-optimal integration (A-D)

Particulate scattering

Characteristics of scattering data:

- Values should be positive.
- Values are bounded (unless spike) {values depend on parameter provided}.
- Deep values of scattering should be lowest in the water column (unless spike) and similar in trend to values before and after.
- Scattering should increase towards the surface, though sub-surface maxima are observed at time.
- Satellite Ocean Colour maps could provide reference at surface.
- Climatology could provide range at depth.
- Presence of other sensors (e.g. chlorophyll, radiometers, beam transmissometers) could provide constraints (through established relationships).
- Salinity (and to a lesser degree temperature) are needed to correct for signal from salts (significant in open ocean)
- Near surface values may be elevated due to bubbles.

Recommendation for scattering data RT:

- Report values in units of m^{-1} (backscattering) or NTUs (turbidity sensors). For a given sensor one can constrain the transition from one to the other.
- Users will transform to POC and SPM (we should provide example relationships).
- Use *slope* coefficient from manufacturer correcting *dark* current with those obtain from float manufacturer or deployment.

Flag data as suspect if:

1. Negative.
2. Spiky at all depths.
3. Out of range (particularly at depth).
4. Near surface data (>3m) that is >1.2 times data below (3-10m).

Recommendation for scattering data DM:

- Correct data for obvious drift at depth (possibly assume signal at depth=0 as is often done with transmissometers). If zero at depth name of variable could be called ‘Above background bbp’. This is akin of changing the *dark* value.

- Compare surface values with b_{bp}(440) from remote sensing for the whole deployment. If bias is not consistent (too large) consider deriving a new *slope* coefficient (a single one for the whole deployment or if drift is suspected, us a linear model for *slope* change with time).

Meta data and data format:

Crucial to have sensor characteristics on file at data base (calibration coefficients as well as make, model, year, wavelength range, angular range).

Data format: values are expected to be nearly log-normally distributed.

Hence it is important to have significant resolution at low value (which is insignificant, due to uncertainties, at large values).

Most digital sensors have discretized outputs in counts (~4096, 12 bits).

Analogue sensors give voltage with resolution of 0.001V up to about 5 volts (can be represented sufficiently with 12bits). If there is a need to compress, suggest a logarithmic transformation such that instrument output resolution is available at low values and is degraded for higher values.