A) Science Data Analysis for the MODIS Ocean Product for Particulate Inorganic Carbon (PIC)

B) Generating environmental data records of ocean particulate inorganic carbon with NPP/NPOES

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Outline

- Primer about merged 2-band/3-band MODIS calcite algorithm
- MODIS Project-Recent results, plans
- VIIRS Project
- Great Belt Recent results
- Other related programs
- Summary Future work

Two PIC algorithms are used by MODIS

- Two band algorithm (based on nLw440 and nLw550); Balch et al. (2005 Calcium Carbonate Measurements in the Surface Global Ocean based on MODIS Data. *JGR-Oceans **110**, C07001 doi:10.1029/2004JC002560*)
- Algorithm separates the contribution of PIC from POC backscattering
- Based on absorption and scattering properties of chlorophyll and PIC, iteratively solve for Chl and PIC as function of absolute nLw440 and nLw550 (as look-up table).

- Three-band algorithm (based on 670, 765, and 865nm bands; Gordon et al. (2001. Retrieval of coccolithophore calcite concentration from SeaWiFS imagery, *Geochemical Research Letters*, *28* (8), 1587-1590.)
- For turbid blooms, switch to the 3-Band Algorithm
- At 670nm, 765, and 865nm, we assume absorption is mainly due to water (a_w):

$$R=\sim b_b/[3(b_b+a_w)]$$

Measure $R(\lambda)$, use published $a_w(\lambda)$, estimate $b_b(\lambda)$.

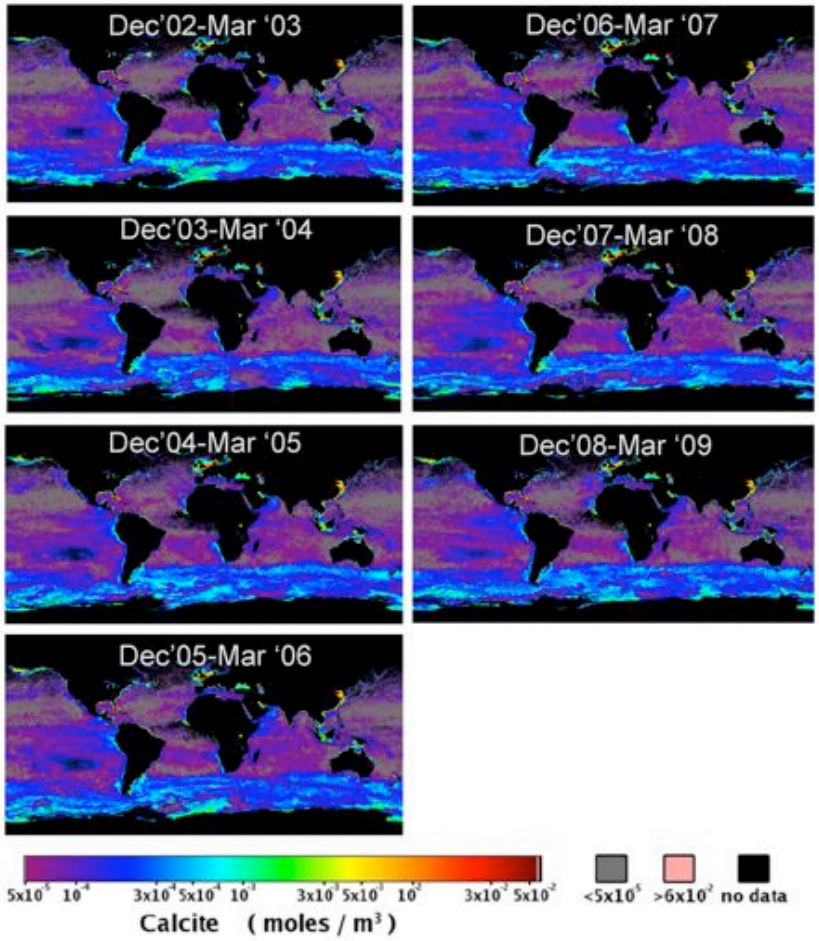
- Also assume that: $b_b(\lambda)=b_b(550)*(550/\lambda)^n$

where n~1.35 based on empirical results with PIC particles

- These assumptions allow estimation of b_b at other wavelengths

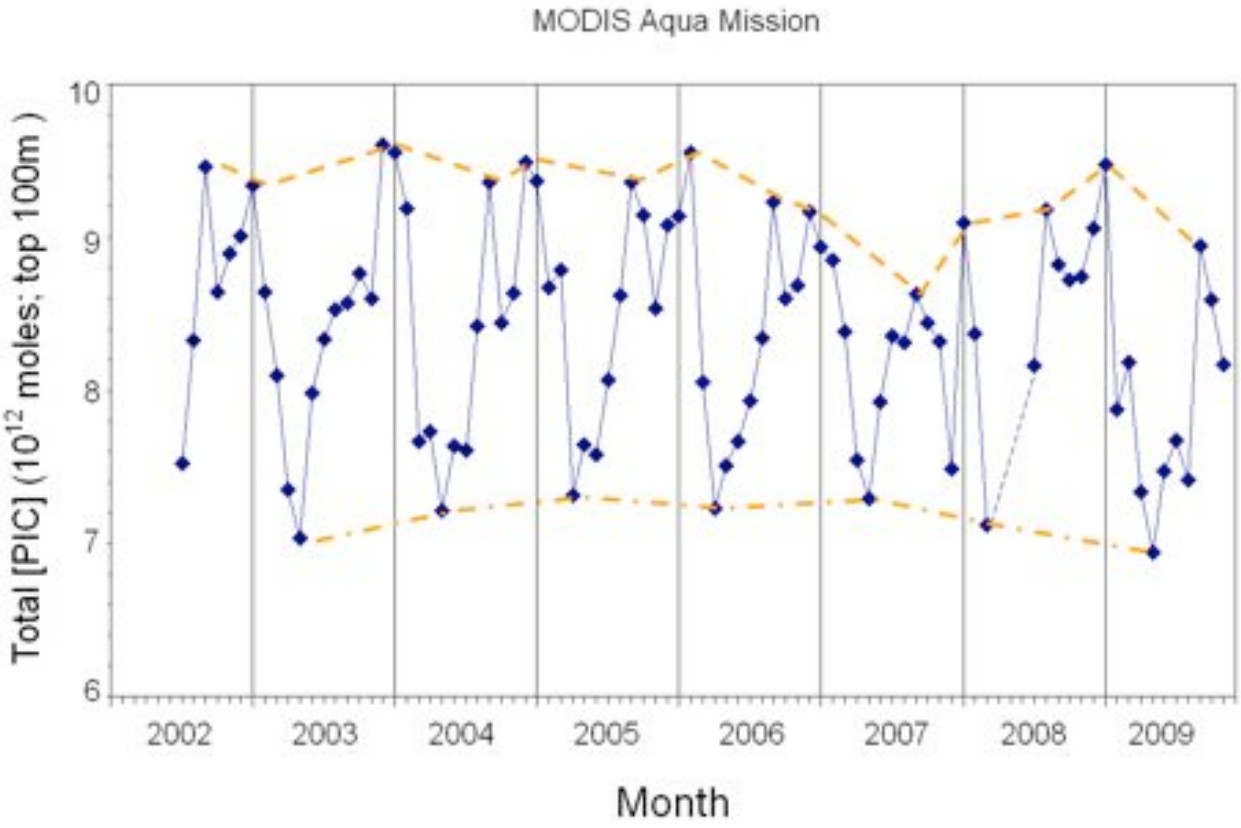
The NASA PIC algorithm has broadened our *spatial* view of truly global PIC phenomena…

- The “Great Calcite Belt”



The NASA PIC algorithm has broadened our *temporal* view of global PIC …

- Global patterns of PIC standing stock



Recent publication in GRL…

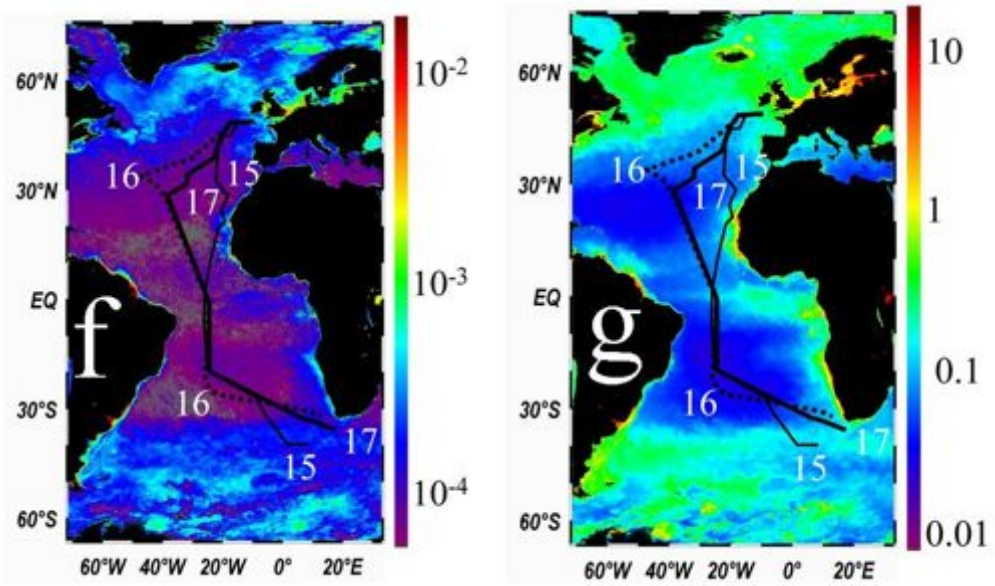
GEOPHYSICAL RESEARCH LETTERS, VOL. 37, L22605, doi:10.1029/2010GL044640, 2010

Biominerals and the vertical flux of particulate organic carbon from the surface ocean

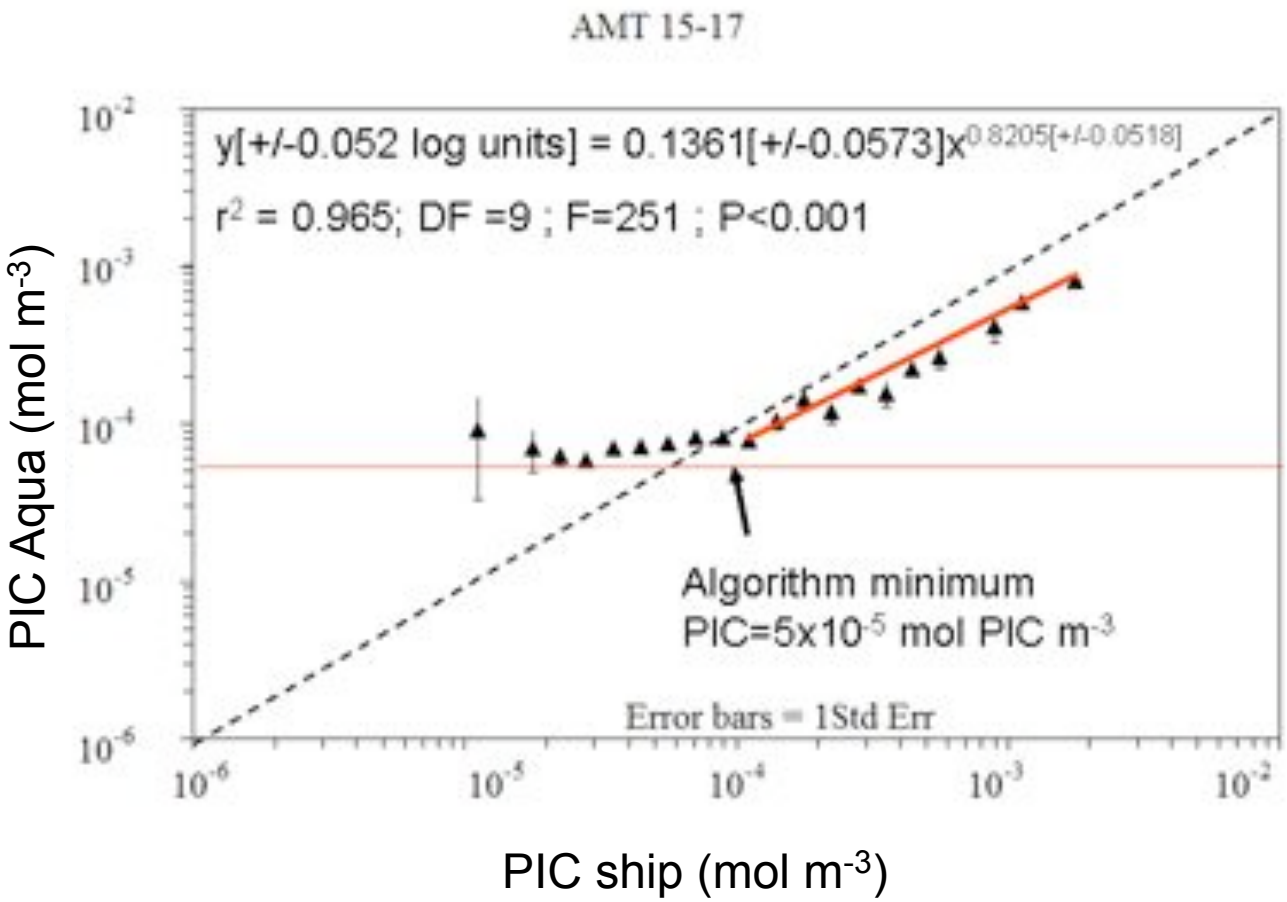
W. M. Balch,[1] B. C. Bowler,[1] D. T. Drapeau,[1] A. J. Poulton,[2] and P. M. Holligan[2]

Received 9 July 2010; revised 17 September 2010; accepted 27 September 2010; published 20 November 2010.

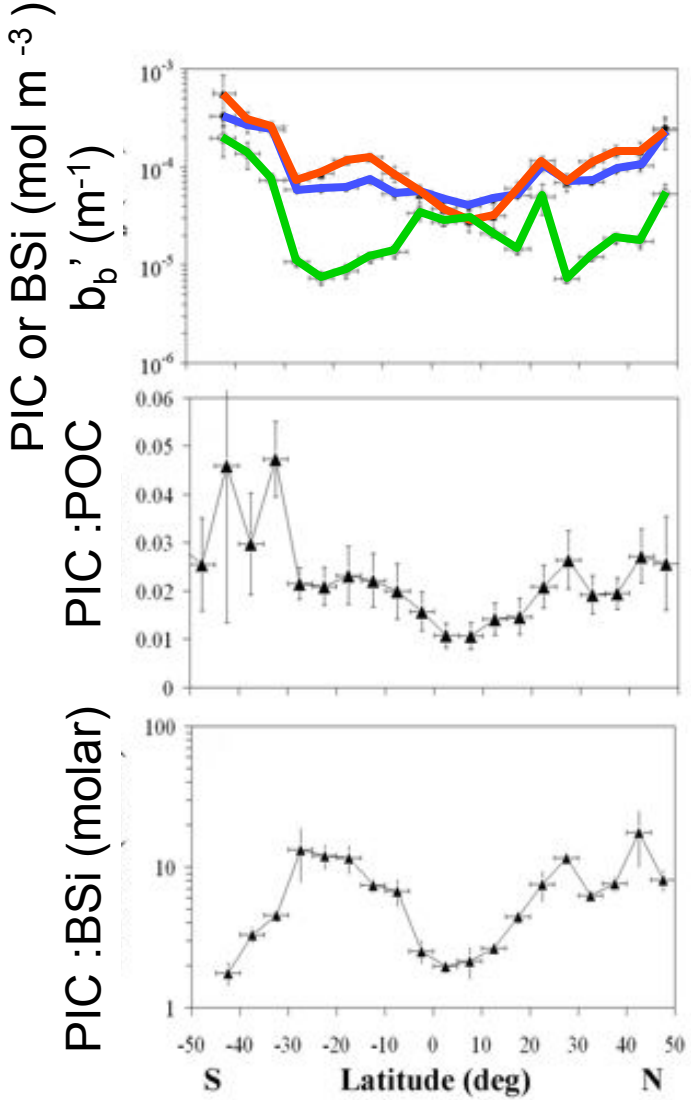
[1] Particulate inorganic carbon (PIC; calcium carbonate) is thought to be a significant source of light scattering in the sea. It also provides ballast for particulate matter, driving the ocean's biological carbon pump. During three trans-Atlantic cruises, we measured particle optical properties plus concentrations of the three major components of sinking aggregates [particulate organic carbon (POC), PIC and biogenic silica (BSi)]. PIC contributed 15–23% of particle backscattering in oligotrophic subtropical gyres and temperate waters. Light scattering properties allowed quantification of the surface PIC:POC ratio. The ratio of the two ballast minerals (PIC:BSi) was significantly, *inversely*, correlated to POC concentration, allowing robust modeling of the density of sinking aggregates. Results showed greater PIC:POC ratios and sinking rates in oligotrophic regions due to greater relative abundance of PIC. **Citation:** Balch, W. M., B. C. Bowler, D. T. Drapeau, A. J. Poulton, and P. M. Holligan (2010), Biominerals and the vertical flux of particulate organic carbon from the surface ocean, *Geophys. Res. Lett.*, *37*, L22605, doi:10.1029/2010GL044640.



Point #1-For AMT 15-17, the algorithm performs well down to $5x10^{-5}$ mol PIC m^{-3}

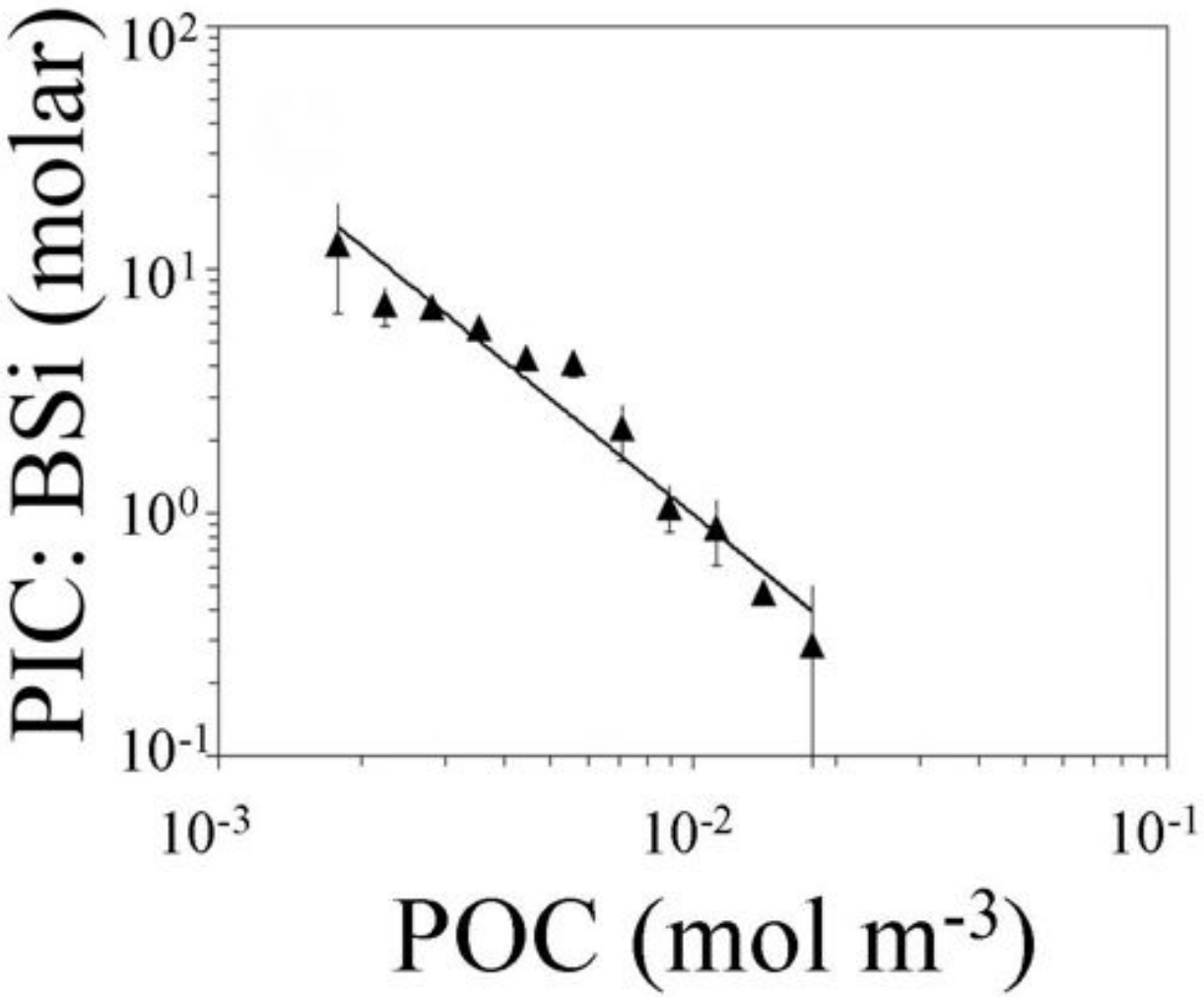


Point #2-Ballasting minerals in the subtropical gyres (PIC and BSi) behave in a predictable inverse way…

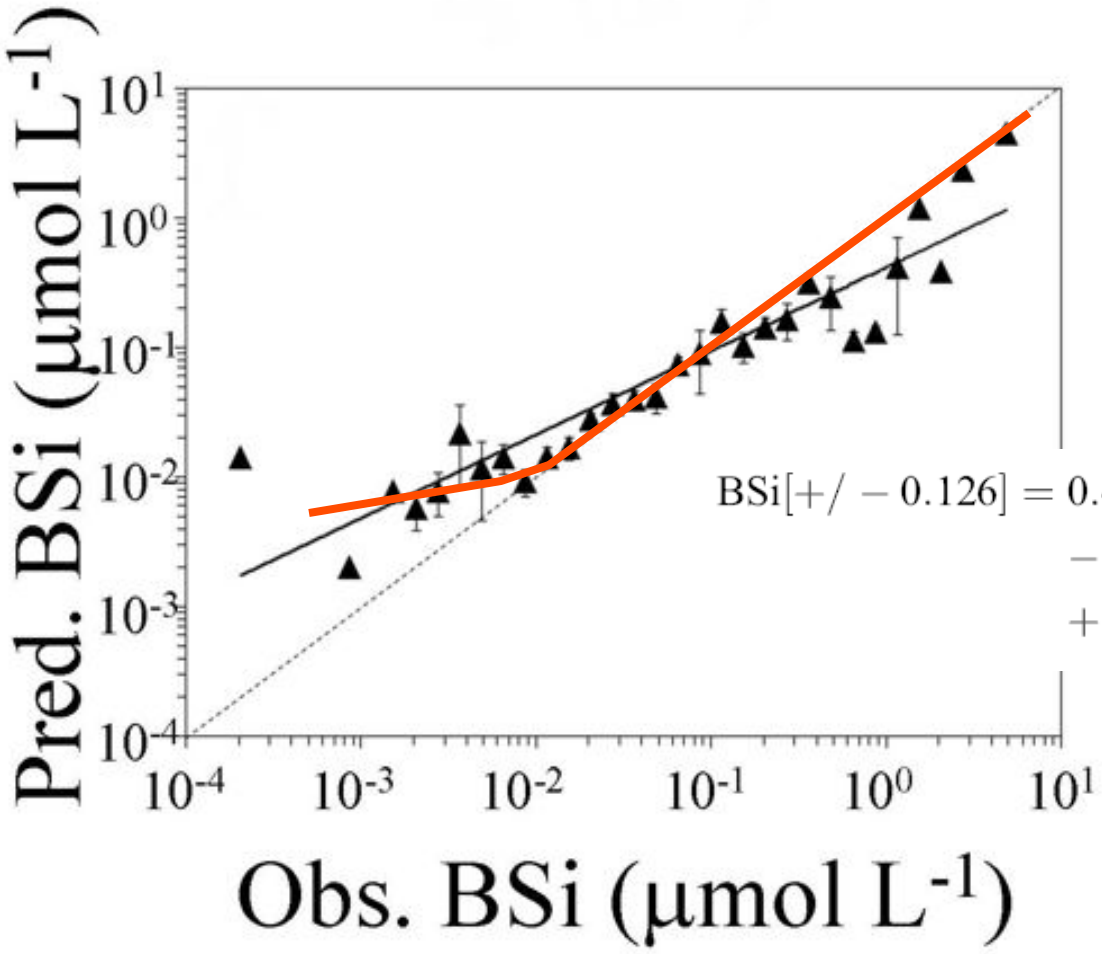


BSi = O ▲= b_b'; ◆=PIC

Predicting the “ballast ratio” based on POC…

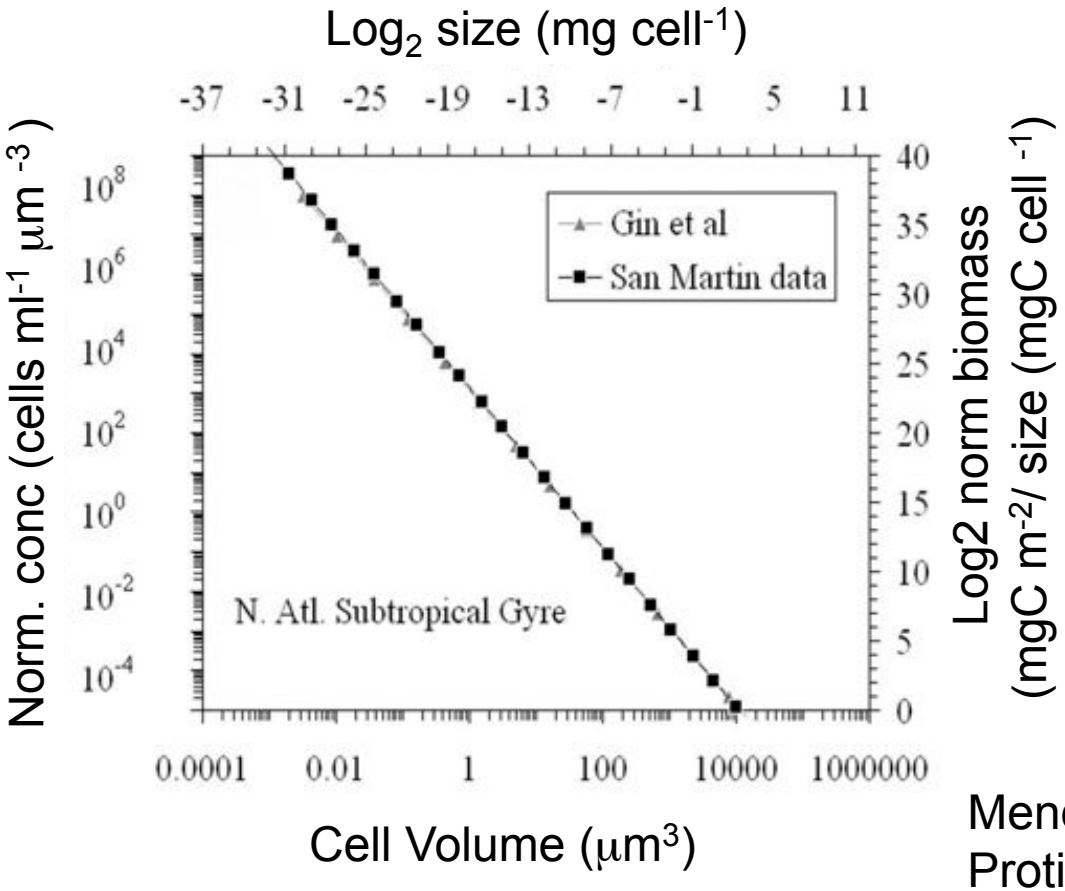


Point #3-A simple algorithm to estimate biogenic silica…



$$\mathrm{BSi}[+/-0.126] = 0.415[+/-0.00628]\mathrm{Chl} - 0.0052[+/-0.0015]\mathrm{SST} + 0.1073[+/-0.0360]$$

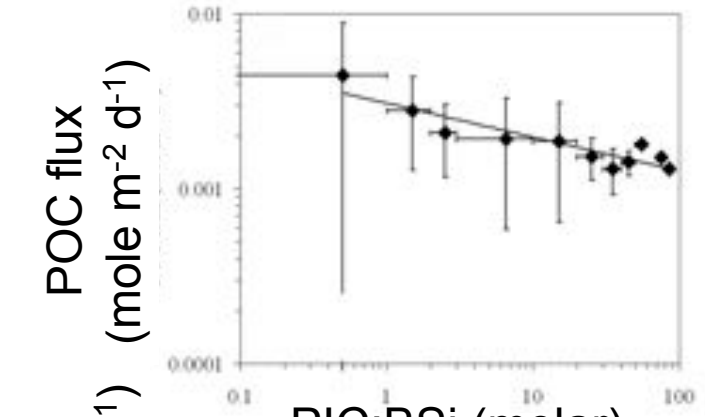
Point #4- Internal consistency for interrelating particle size distribution functions whether cell- or biomass-normalized …critical for estimating sinking rates, carbon export, etc.

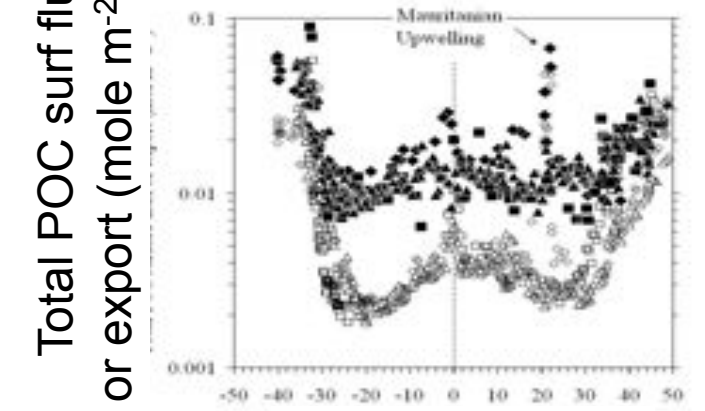


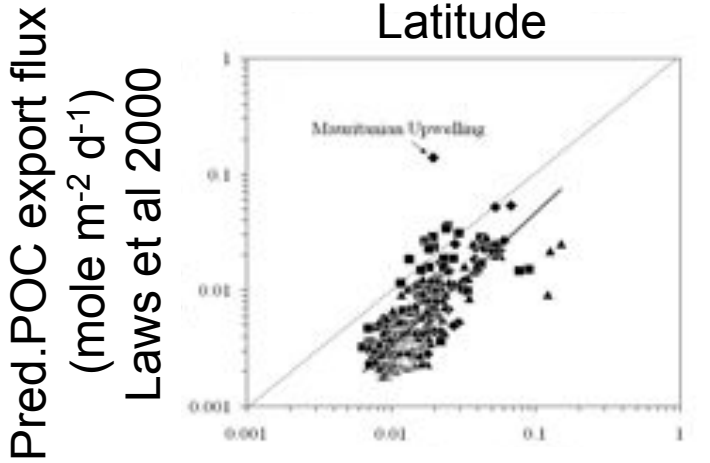
Menden Deuer & Lessard, 2000
Protistan Plankton (excluding diatoms)
Log pgC cell^{-1} = -0.665 + 0.939 x Log Vol.
Where cell Volume is in units of μm^3

Point #5-Predicting C flux from space…

- With knowledge of POC, PIC, BSi and PSDF (all can be determined remotely), can estimate sinking rates for POC aggregates of different size classes containing BSi and PIC ballast
- Flux estimates are highly coherent with flux predictions of Laws et al., 2004







MODIS Project

- Science Data Analysis for the MODIS Ocean Product for Particulate Inorganic Carbon (PIC) Algorithm Maintainance: *PIC algorithm field support and validation for 3 cruises into the "Great Calcite Belt":*
  - 1) Great Belt 1(*R/V Melville*; Atlantic sector of S. Ocean; Chile to S. Africa; Jan-Feb 2011),
  - 2) GeoTraces *R/V Tangaroa*, SW Pacific (June-July 2011)
  - 3) Great Belt 2 (*R/V Melville*; Indian sector S. Ocean, S. Africa to Freemantle, Australia; Feb-March 2012)

MODIS Algorithm Maintenance continued…

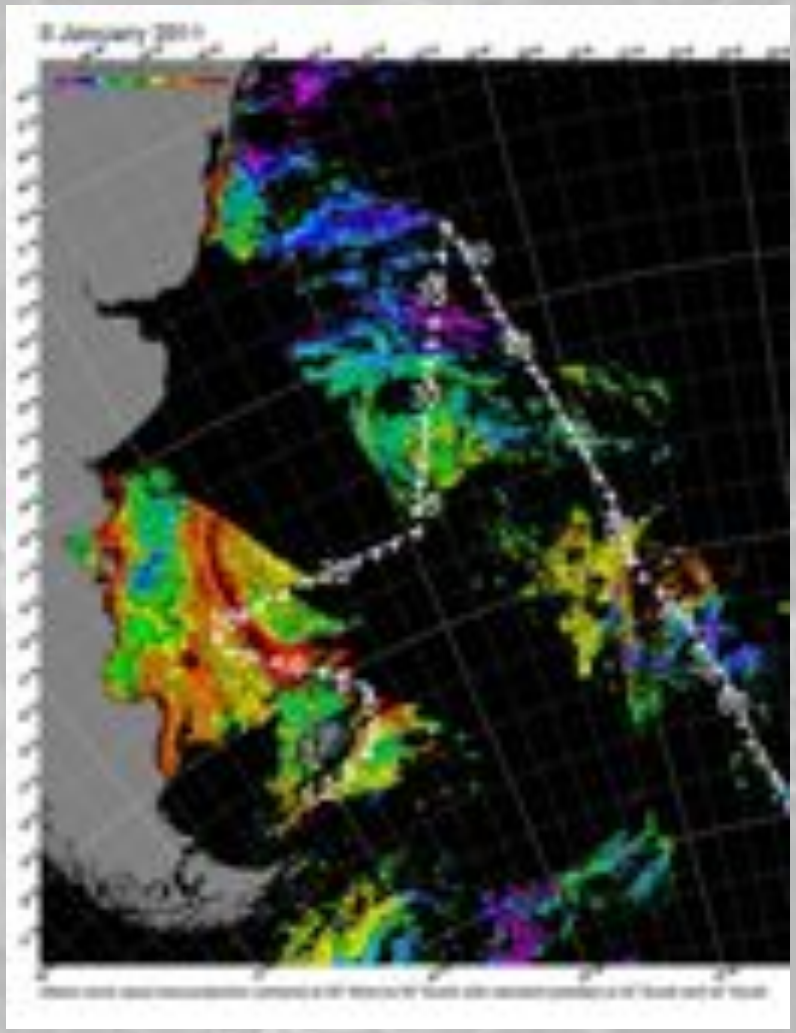
- Statistical analyses to better understand vertical profiles of PIC, for better construction of integrated PIC budgets.
- Perform new evaluations of algorithm accuracy, refinements to $b_{b\ PIC}^{*}$.

Science Data Analysis

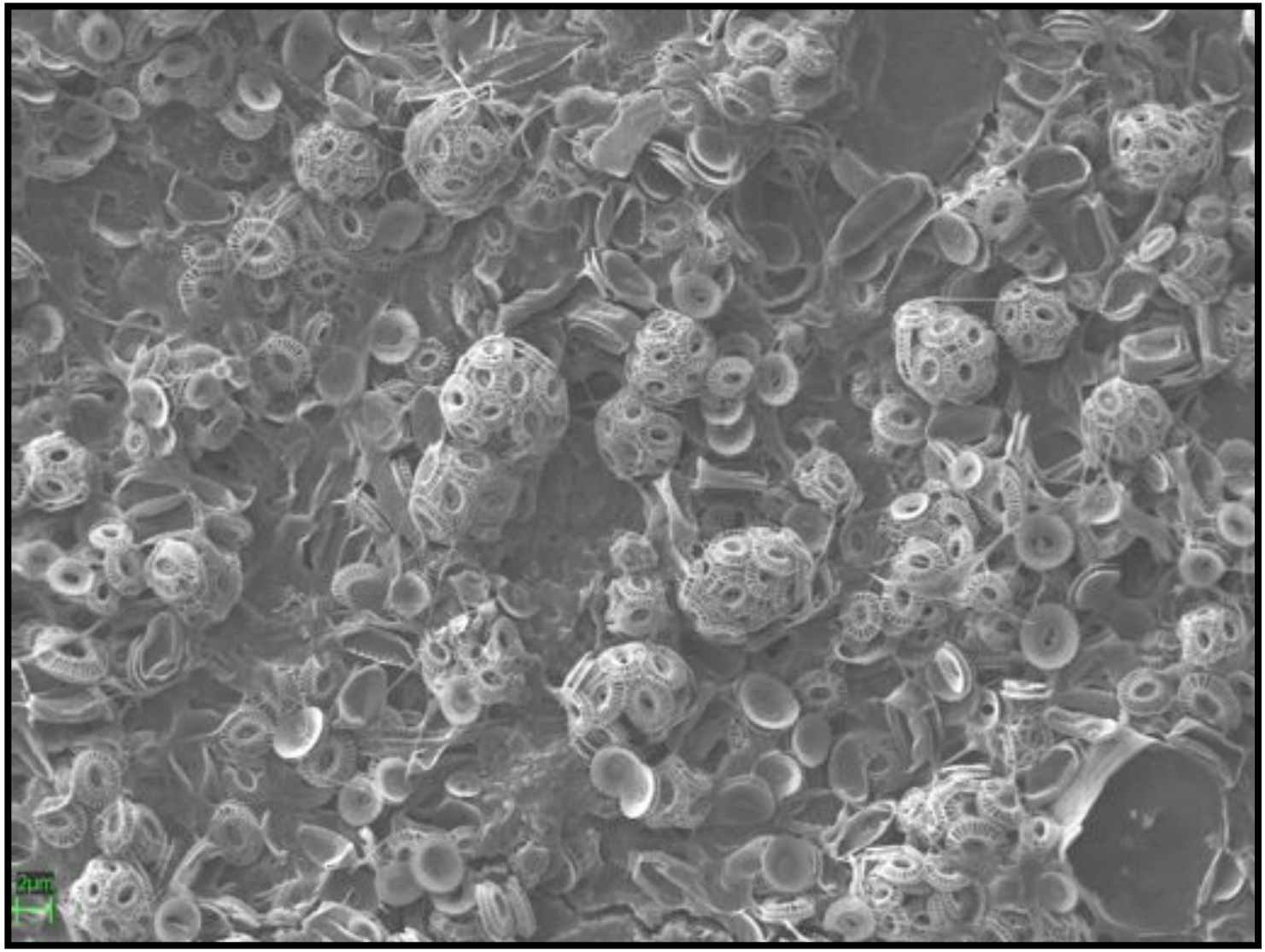
- Use MISR bi-directional reflectance in conjunction with MODIS data to improve identification of coccolithophore features
- Re-analyze the global time series of PIC using latest MODIS reprocessings and updated algorithms for global, hemispherical and meridional trends

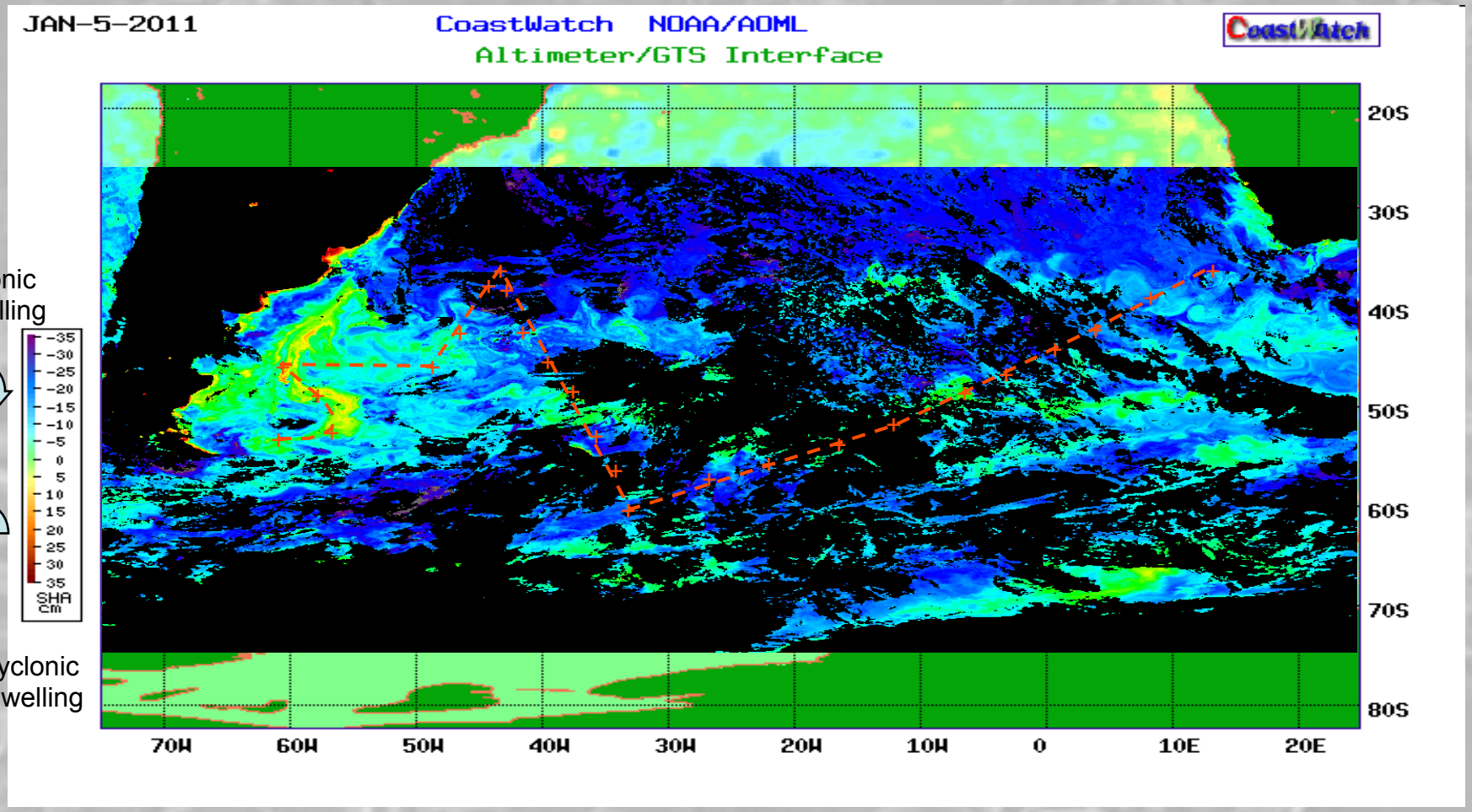
Great Belt I Cruise- R/V Melville; Jan 11-16 Feb 2011

- Ran within feature around the Falkland/Malvinas Islands
- We first sampled the coccolithophore bloom on the Patagonian Shelf
- Extraordinary feature 40 miles wide, 800 miles long
- Then proceeded to subtropical water to find northern boundary of Great Belt



The greenist coccolithophore bloom we've ever seen…




JAN-5-2011
CoastWatch NOAA/AOML
Altimeter/GTS Interface
CoastWatch
Cyclonic upwelling
Anticyclonic downwelling
-35
-30
-25
-20
-15
-10
-5
0
5
10
15
20
25
30
35
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20S
30S
40S
50S
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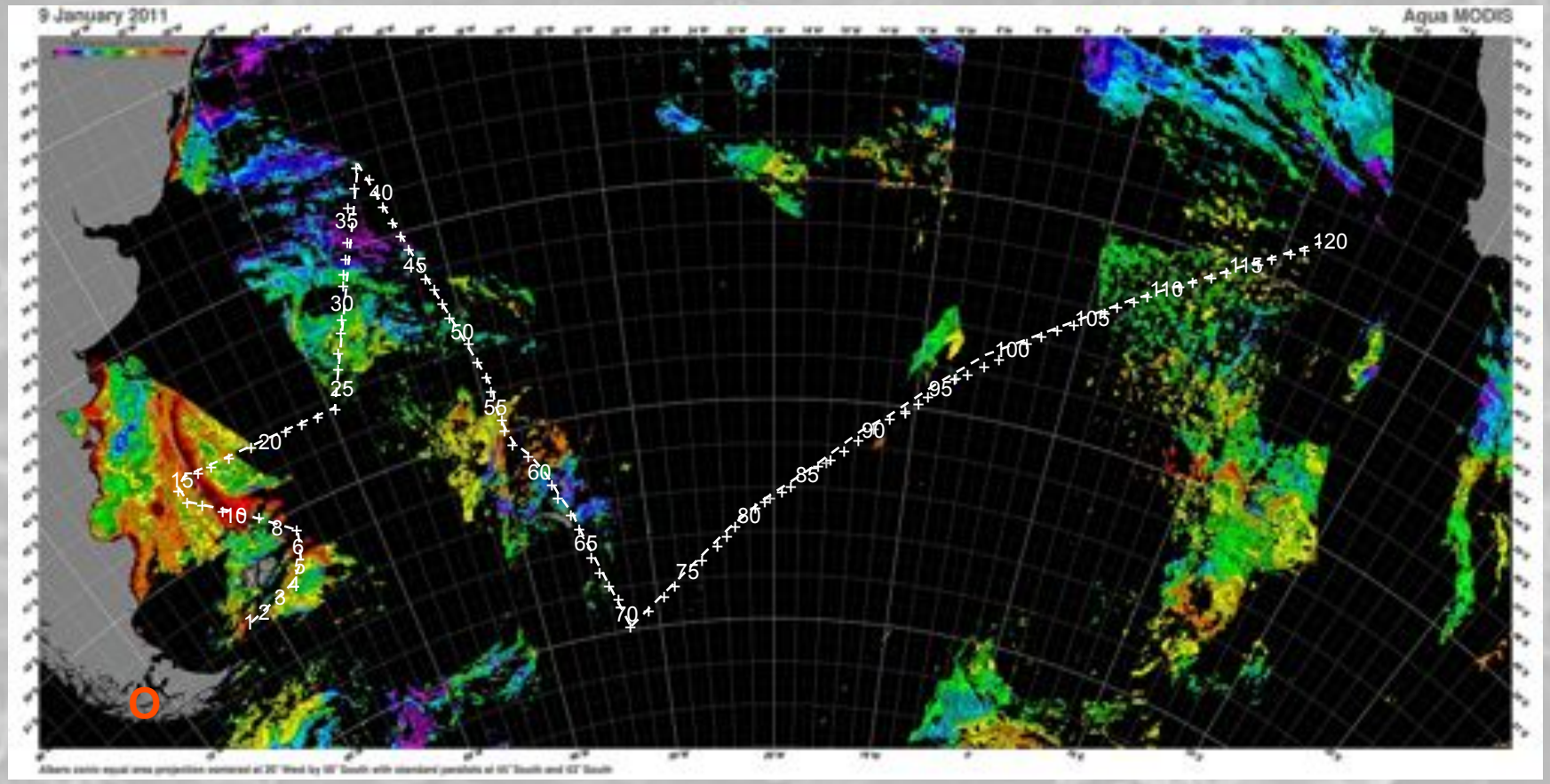
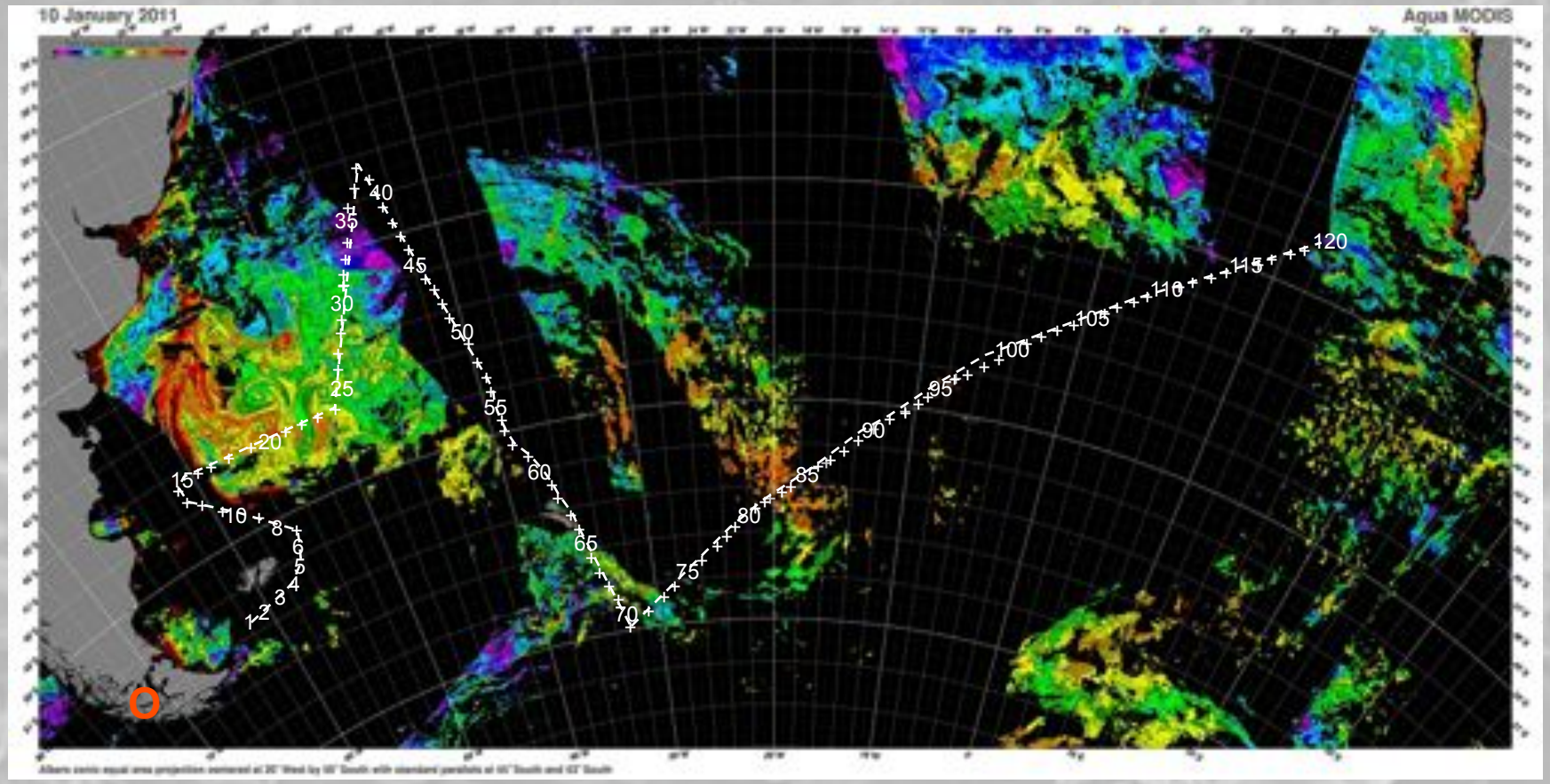
80S
70W
60W
50W
40W
30W
20W
10W
0
10E
20E

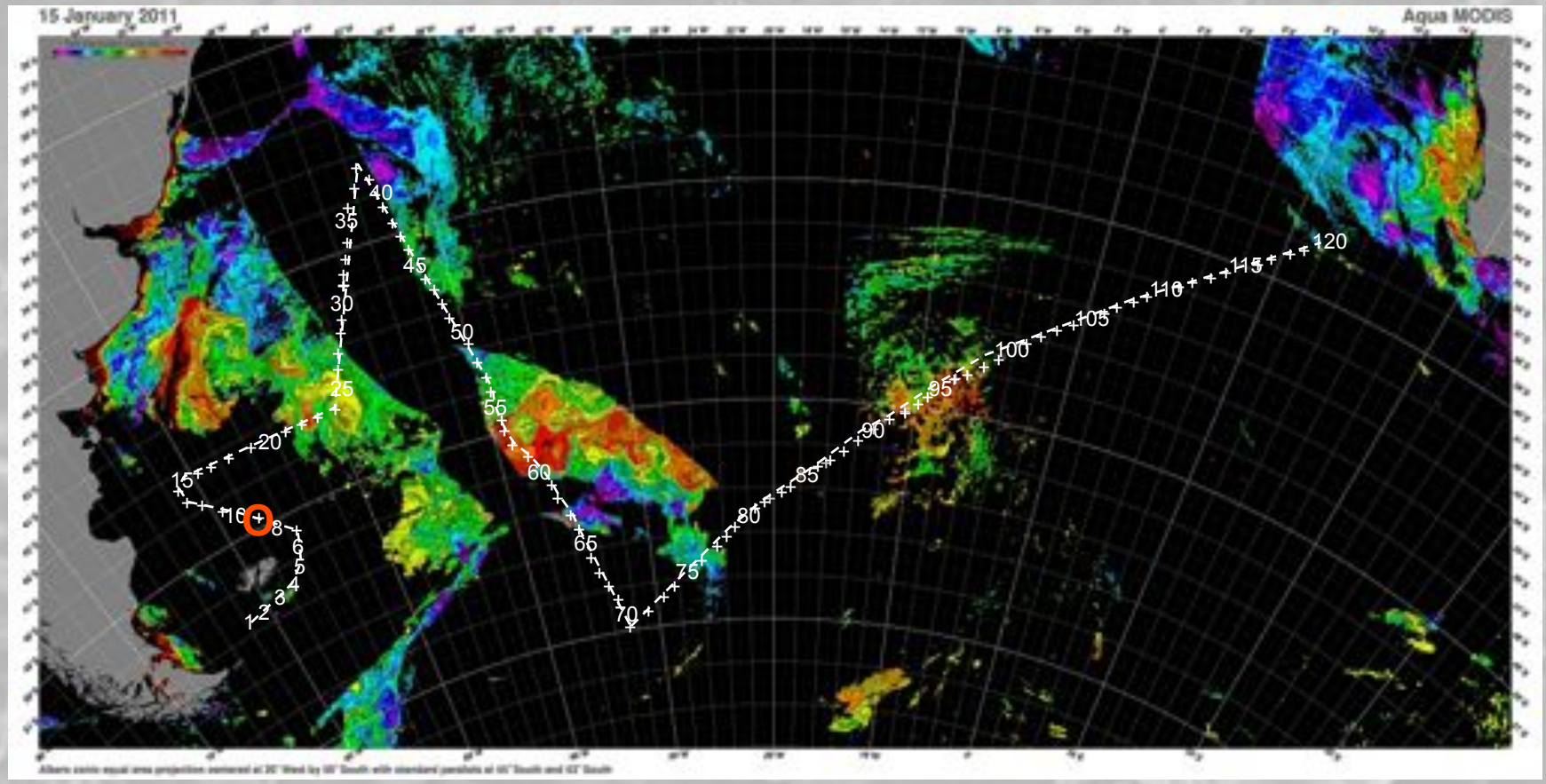
9 January PIC image



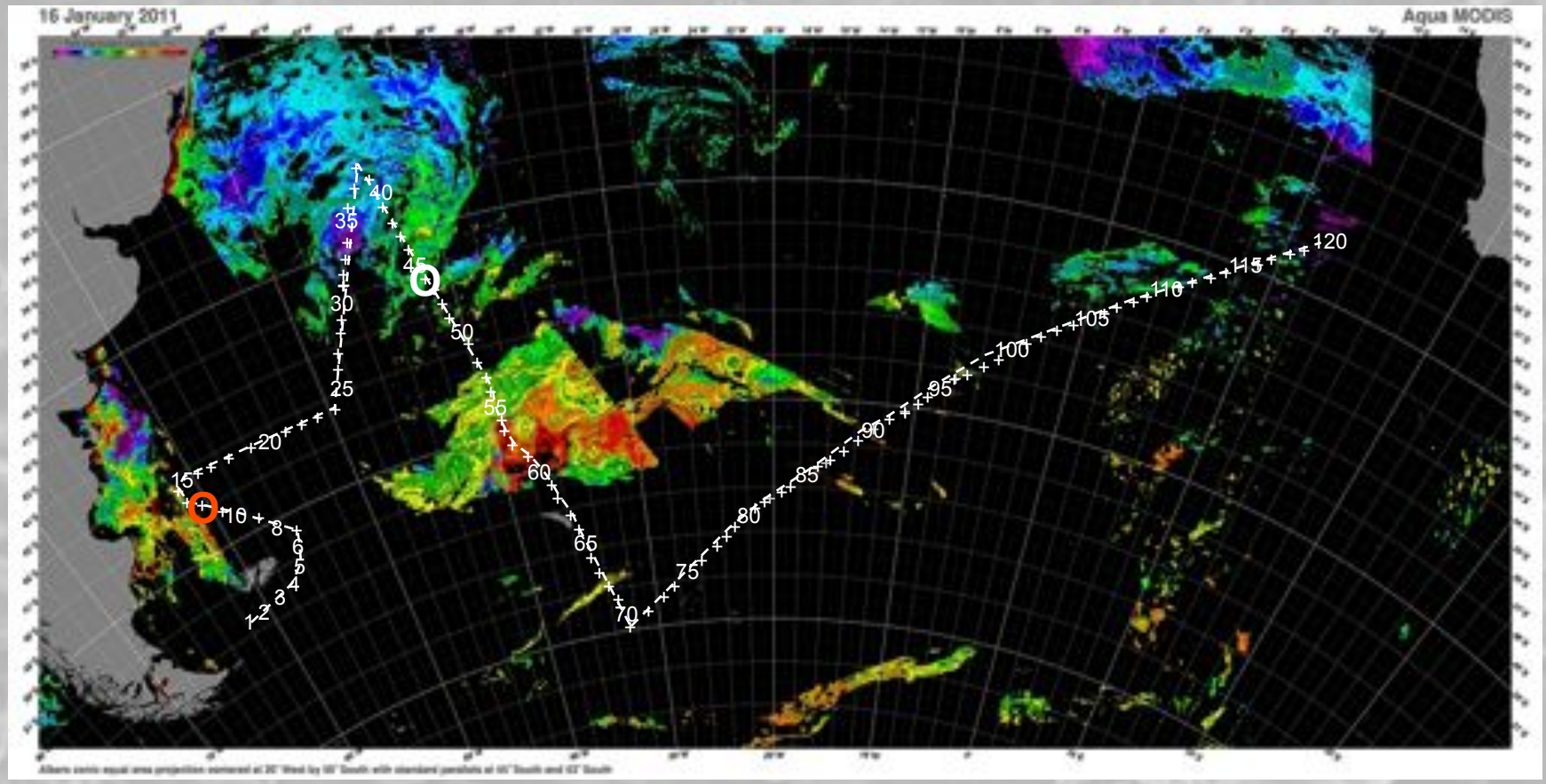
10 January PIC image



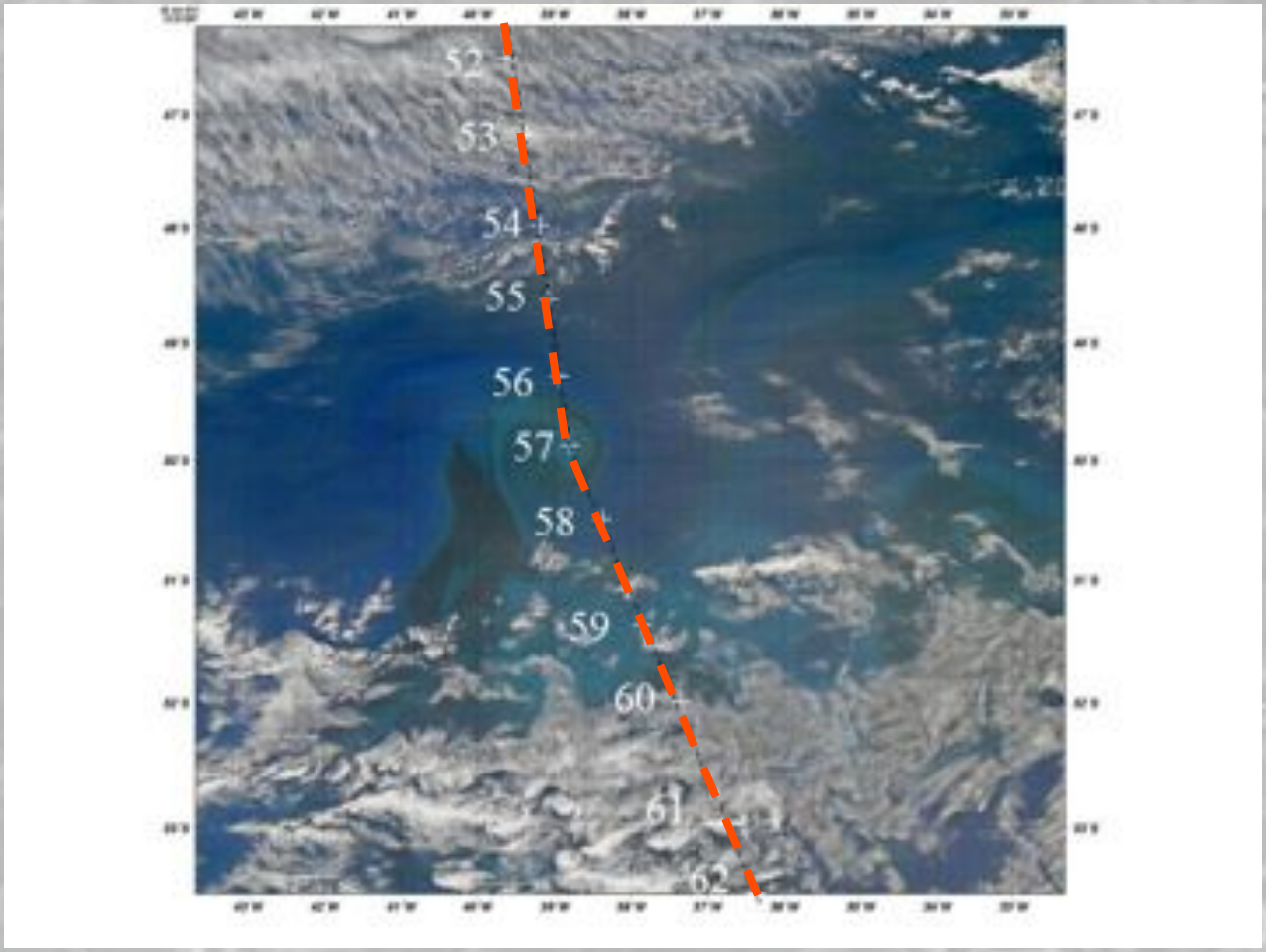
15 January PIC image



16 January PIC image

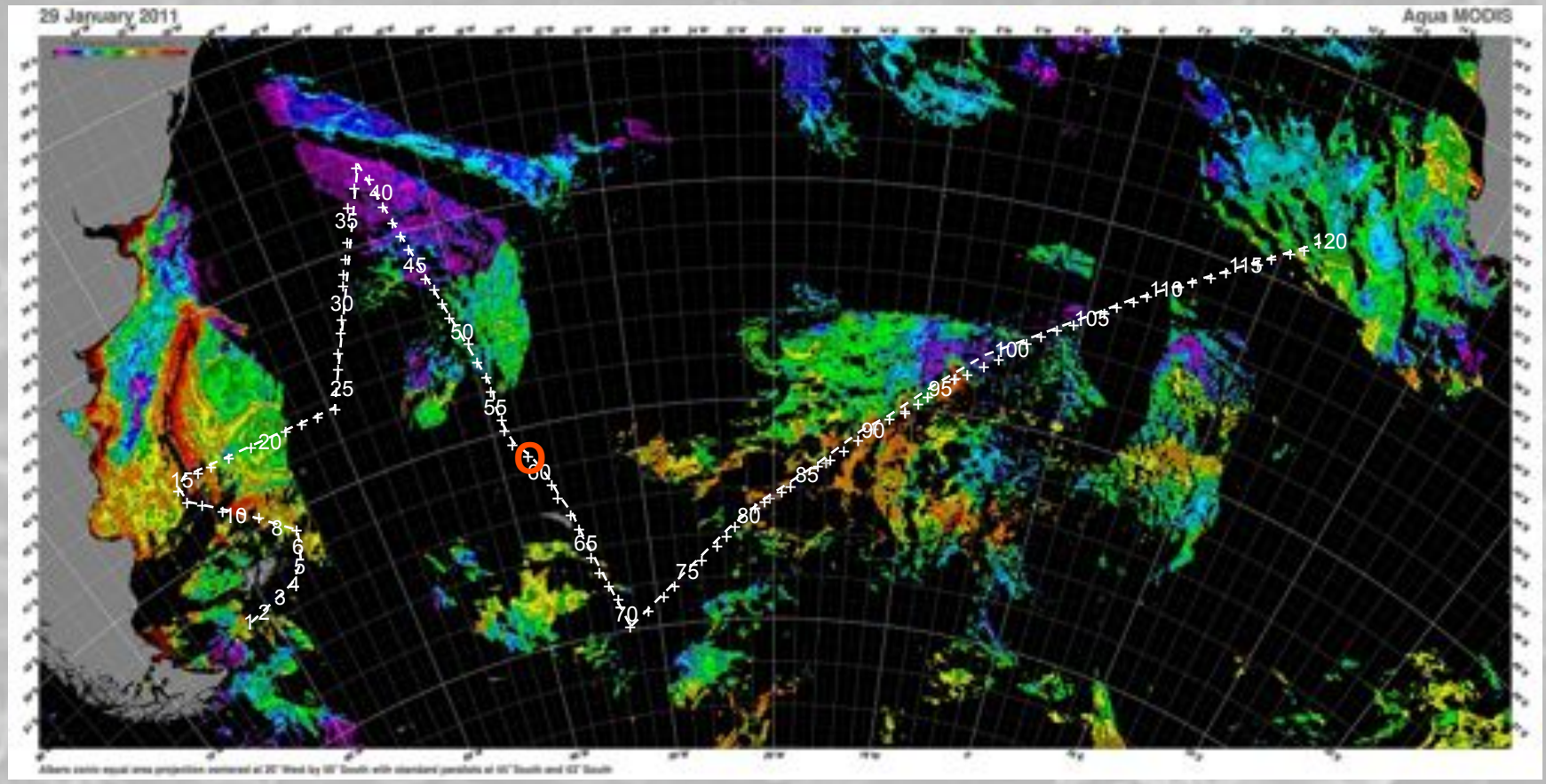


Threaded the needle through the eddy…

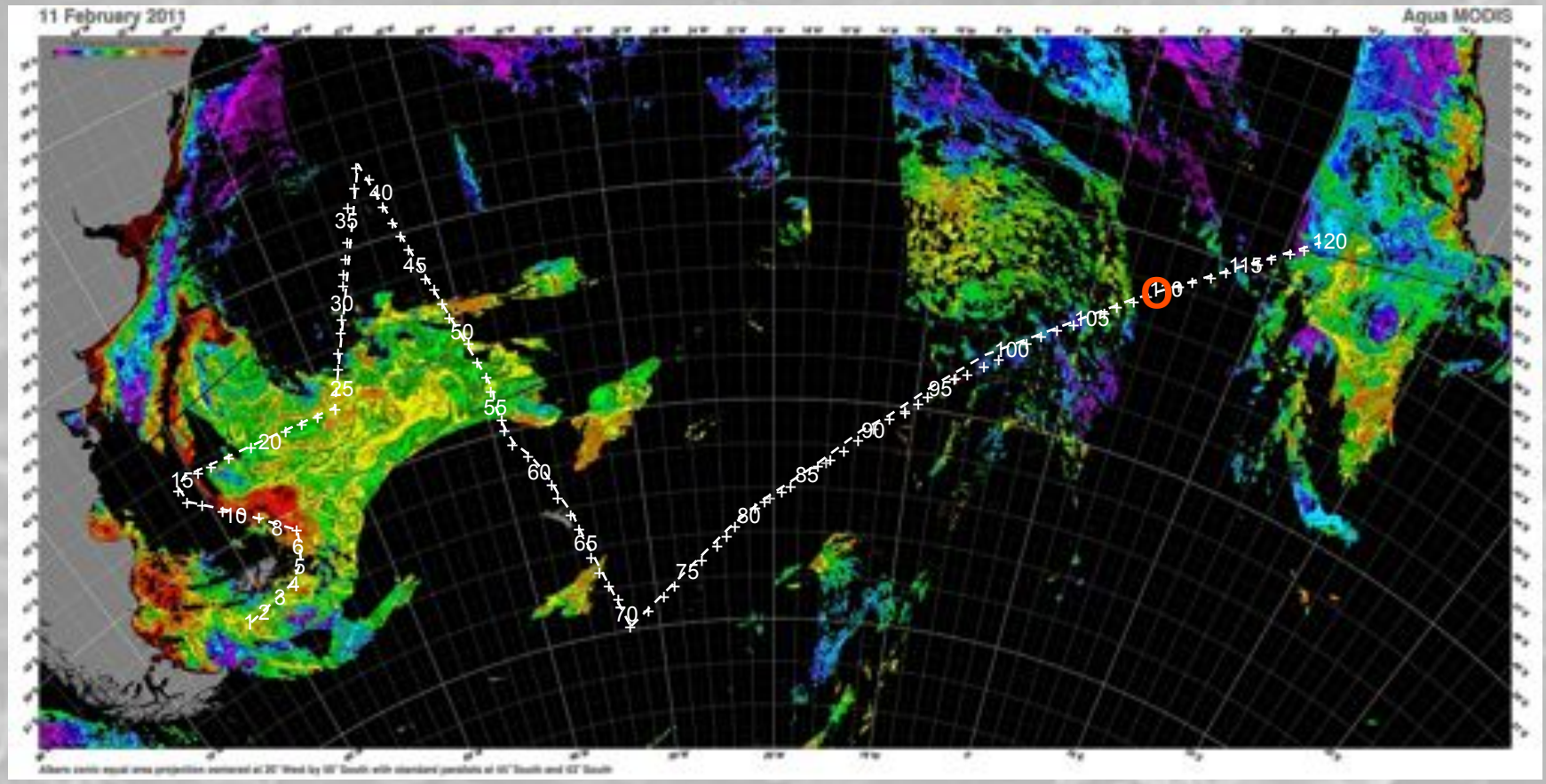


25 January'11 image

29 January PIC image



11 February PIC image

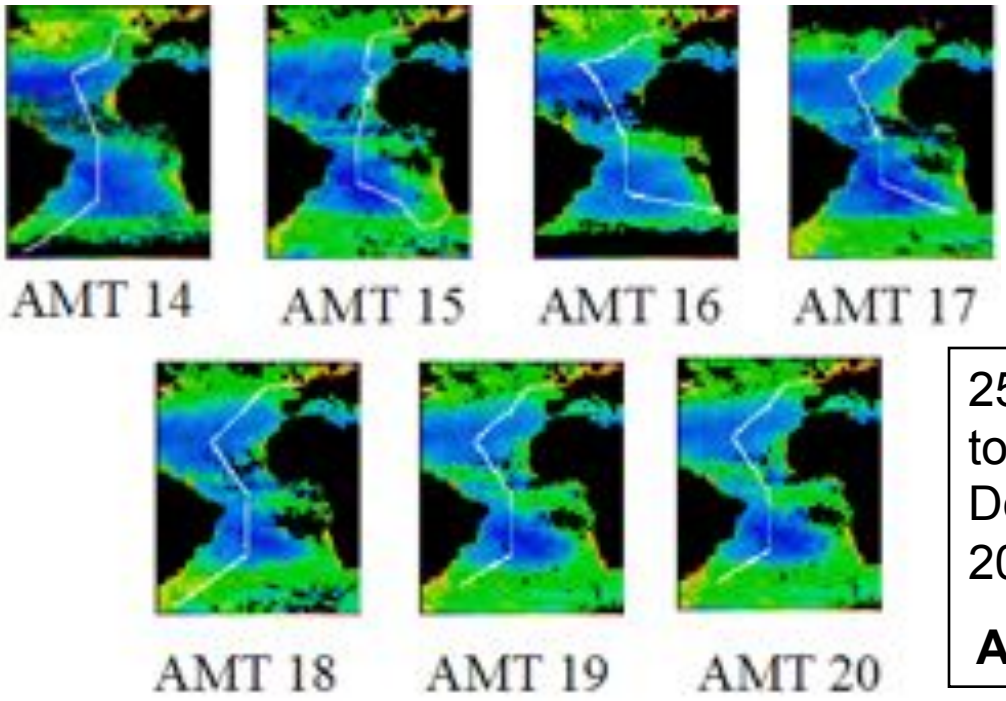


NPP/NPOES project: Generating environmental data records of ocean particulate inorganic carbon with NPP/ NPOES (JPSS)

- VIIRS has close bands necessary to run the merged 2-band/3-band PIC algorithm.
- Requirement for validated ship data for chlorophyll plus no idea for utility of other algorithms
- Focus on PIC, coccolith counts, POC, biogenic silica, chlorophyll *a* plus along-track bio-optical measurements of $b_{bp}(531)$, $b_b'(531)$, absorption(λ) and bow-mounted measurements of Ed(λ), $L_{sky}(\lambda)$ and $L_u(\lambda)$ (for derivation of $nL_w(\lambda)$

- Algorithm maintenance
  - Two AMT cruises planned (Fall 2011 and 2012) between UK and Chile. (will be 7th and 8th AMT).
  - Accuracy Assessment for PIC, POC, coccolith concentrations, Chl plus BSi
  - Will be making bow-mounted radiometer measurements
  - Sampling over depth to better understand vertical variability of PIC (coccolith concentrations, BSi, chlorophyll)

Past involvement with Atlantic Meridional Transect Program



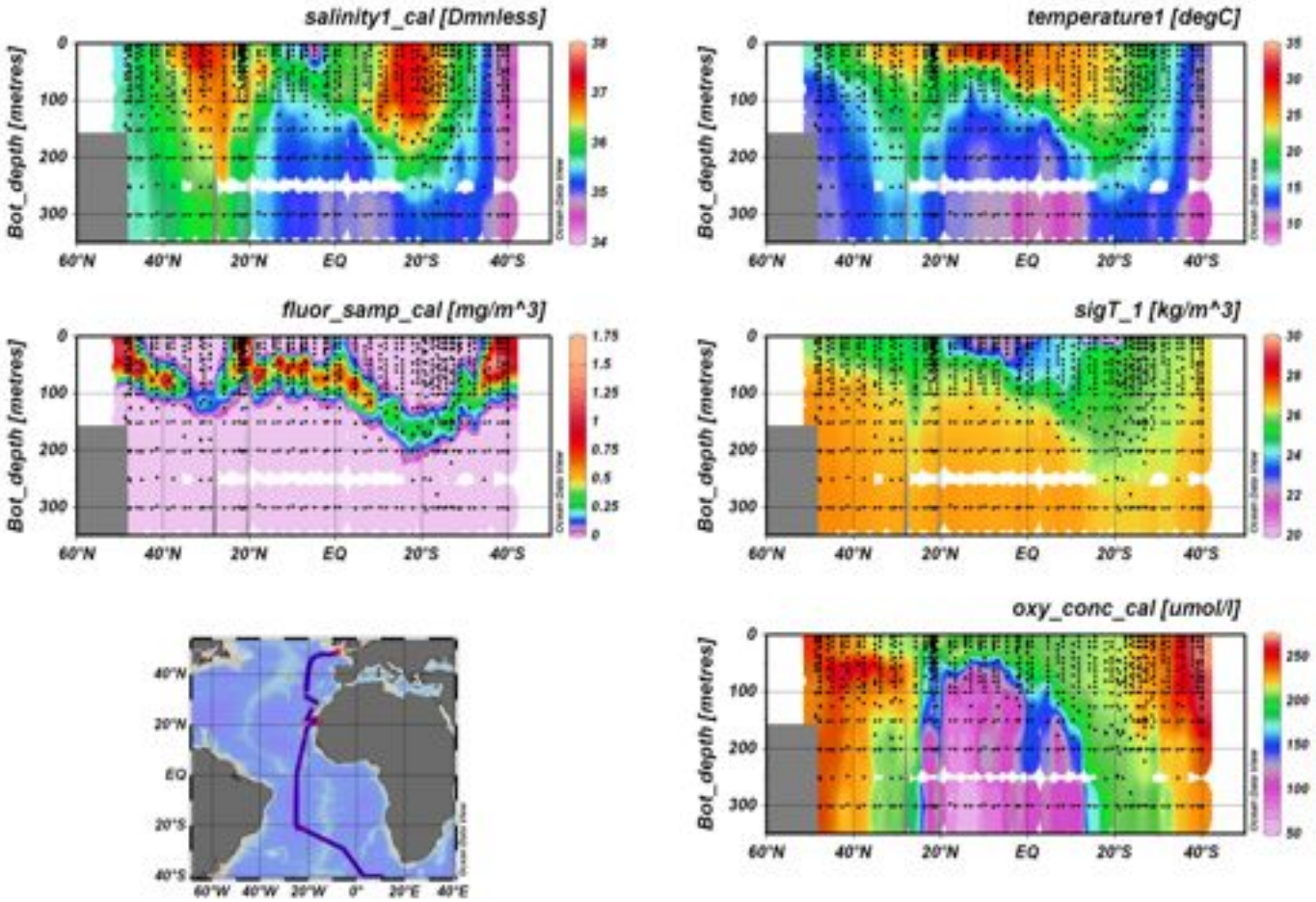
25 Sept to 12 Dec, 2011

AMT 21

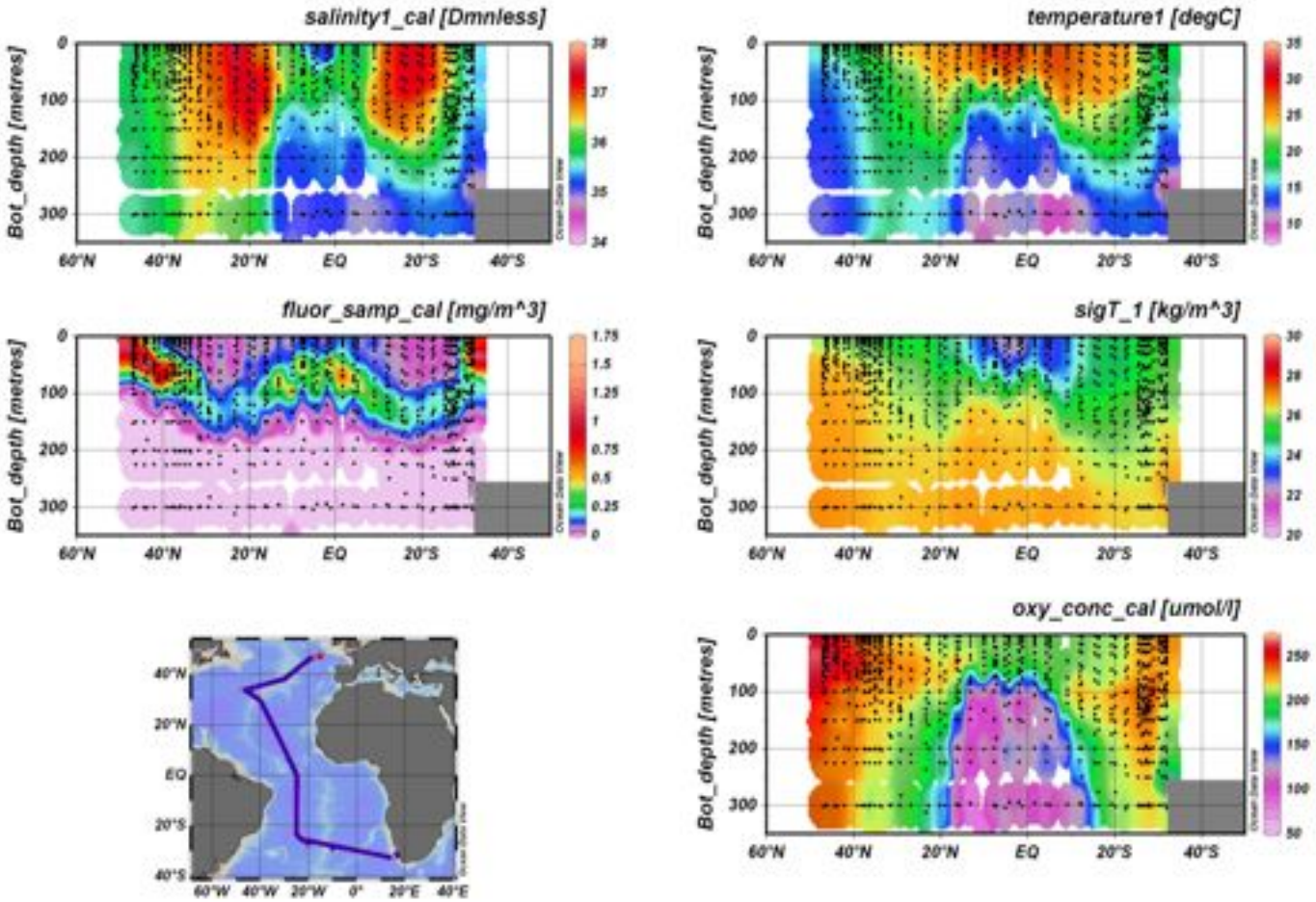
Sept to Dec, 2012

AMT 22

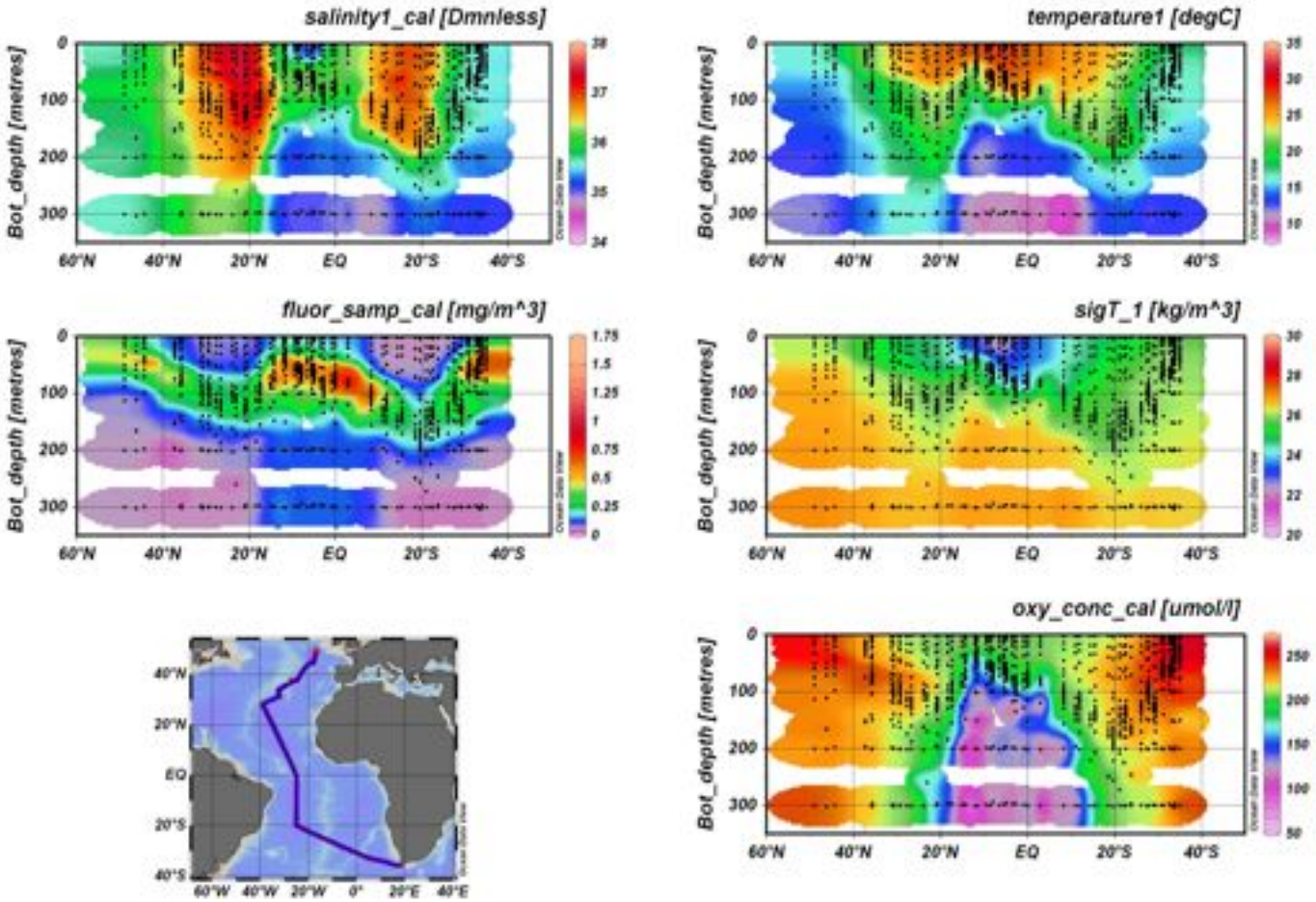
AMT 15: Hydrography, O2



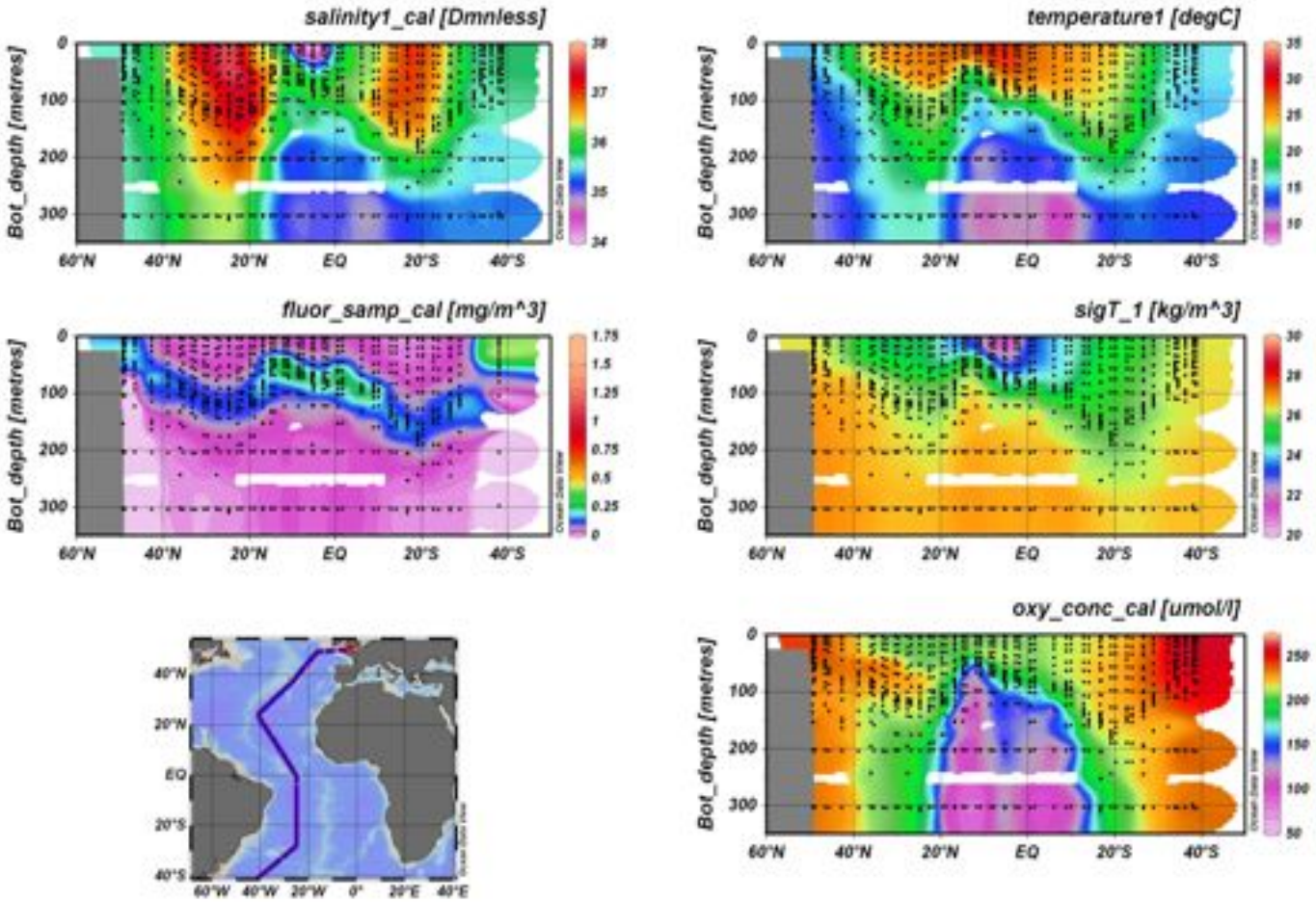
AMT 16: Hydrography, O2



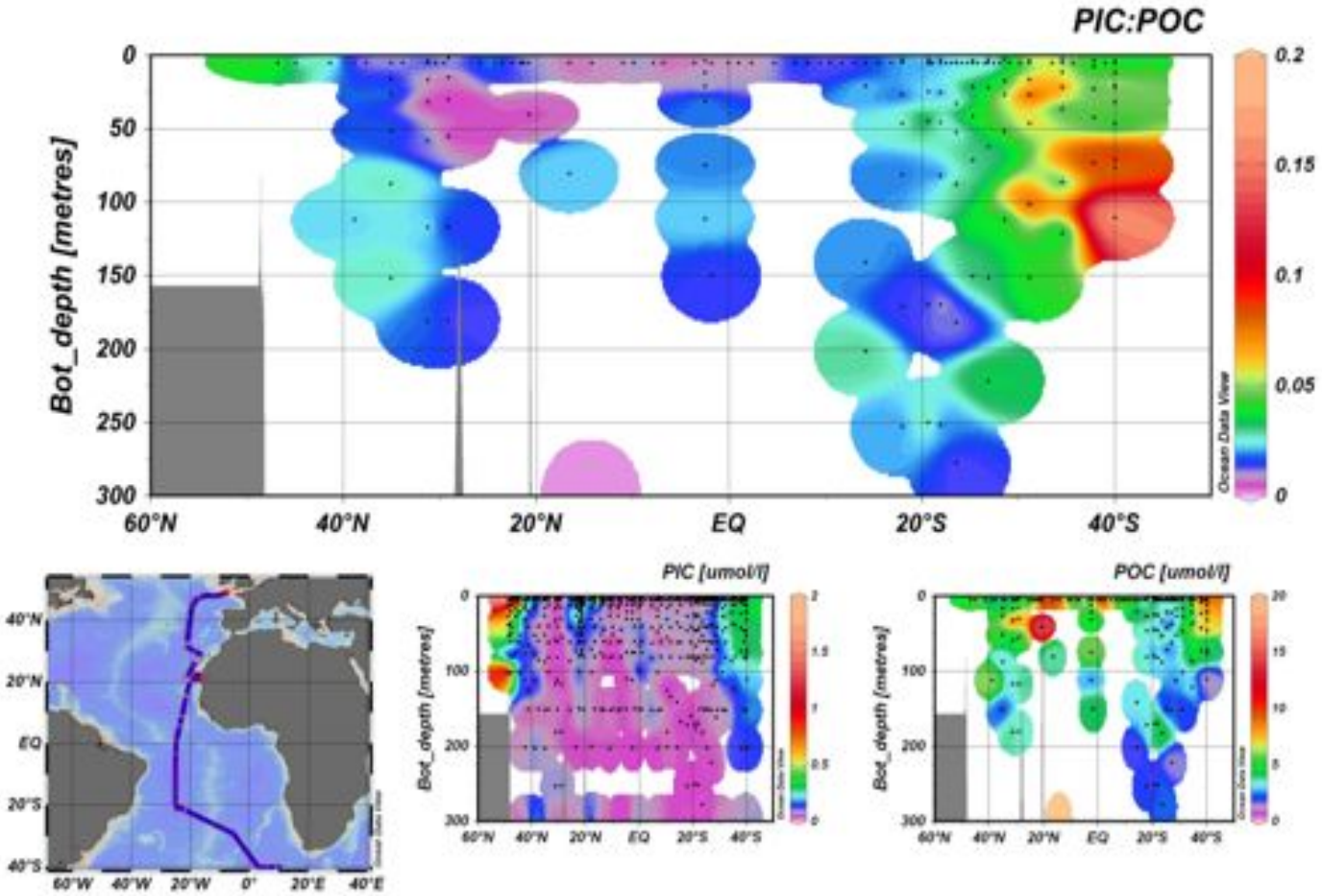
AMT 17: Hydrography, O2



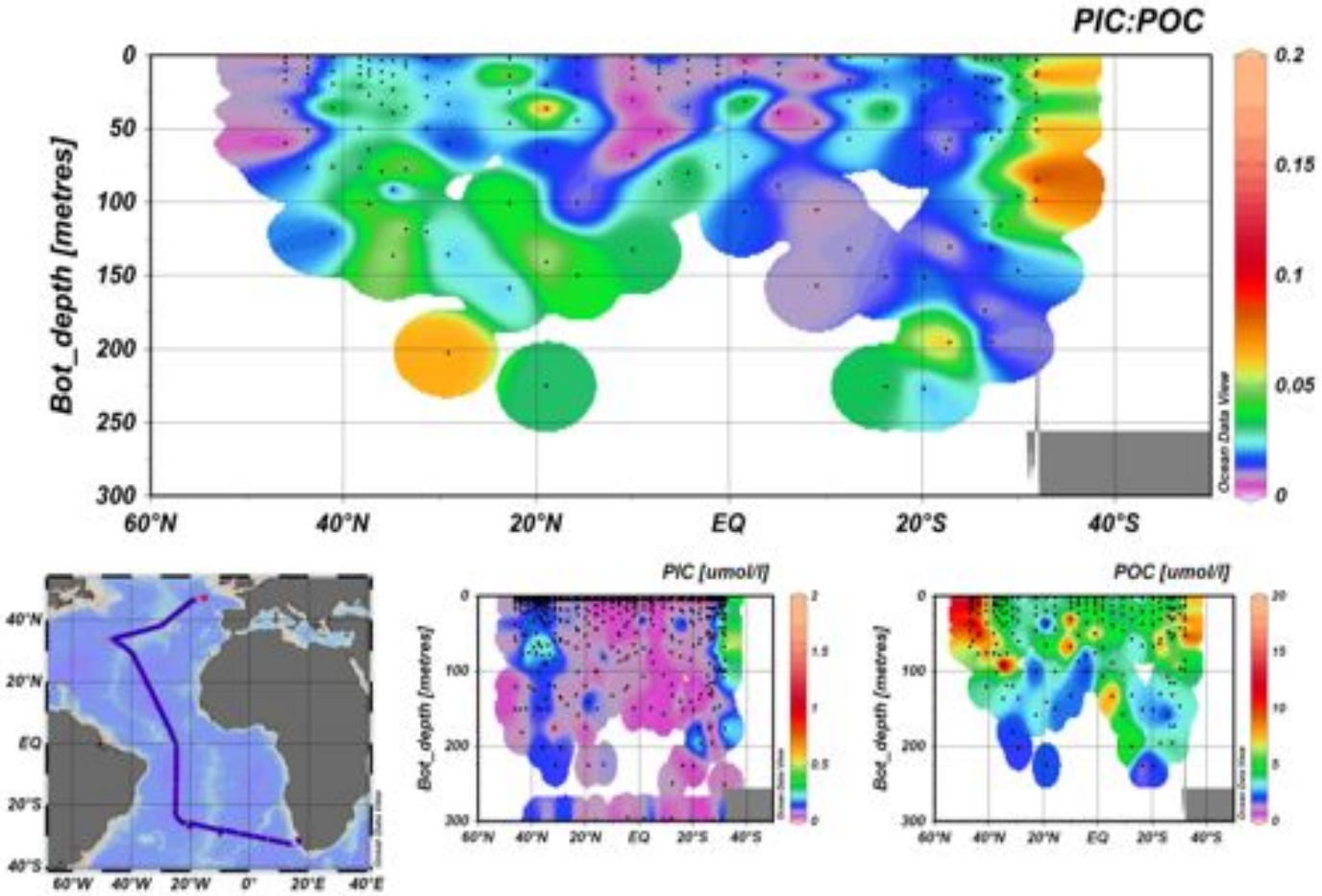
AMT 18: Hydrography, O2



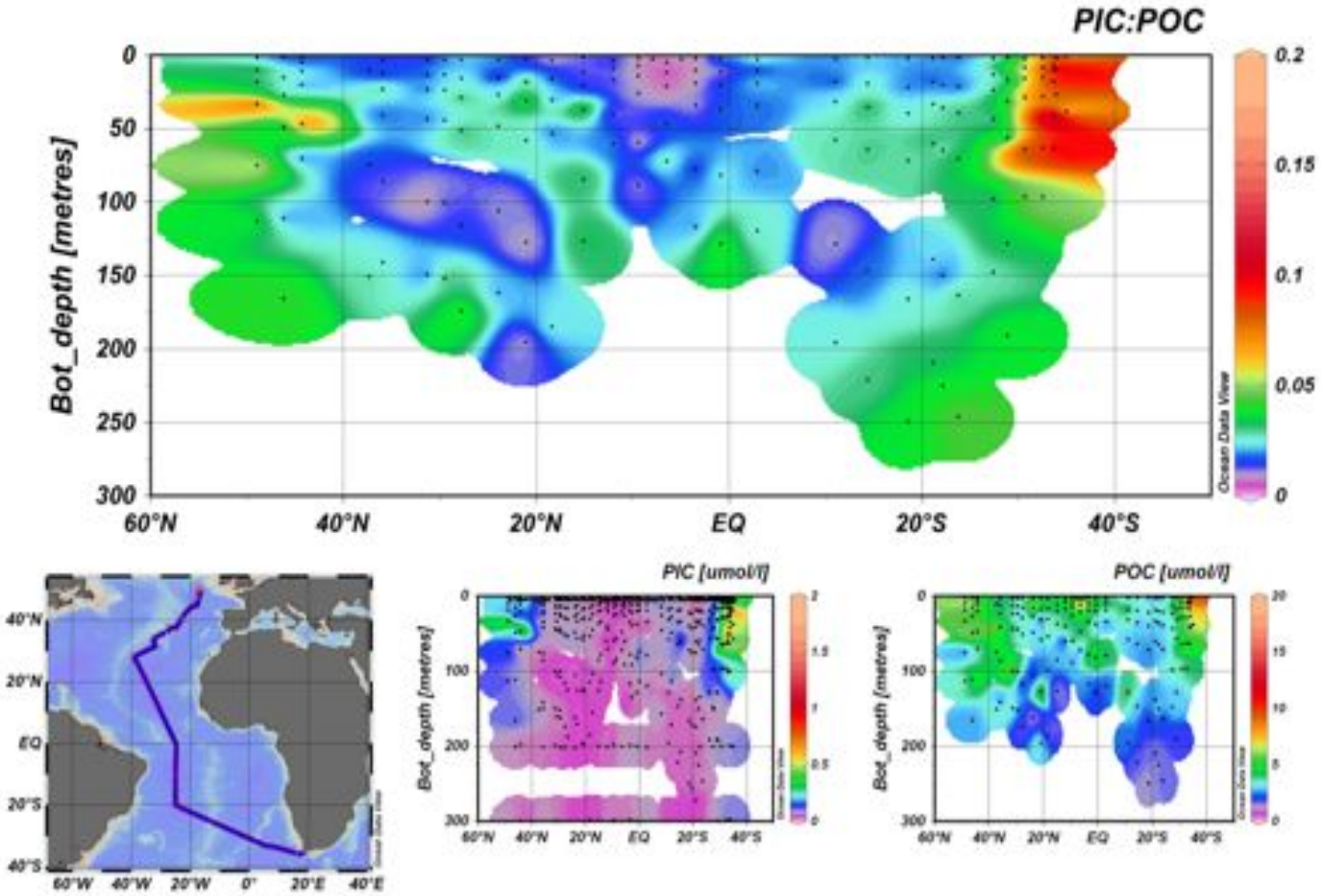
AMT 15: PIC & POC



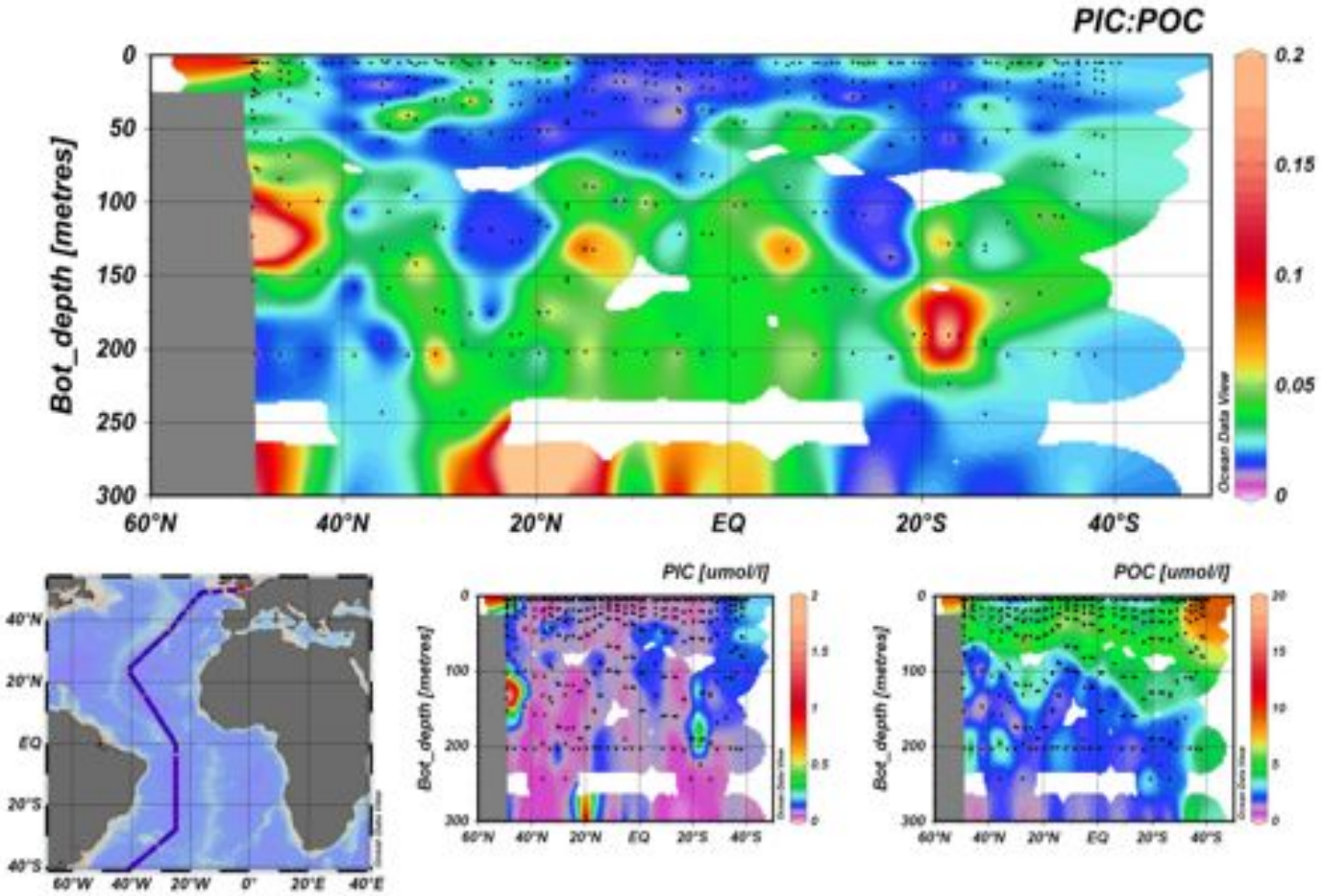
AMT 16: PIC & POC



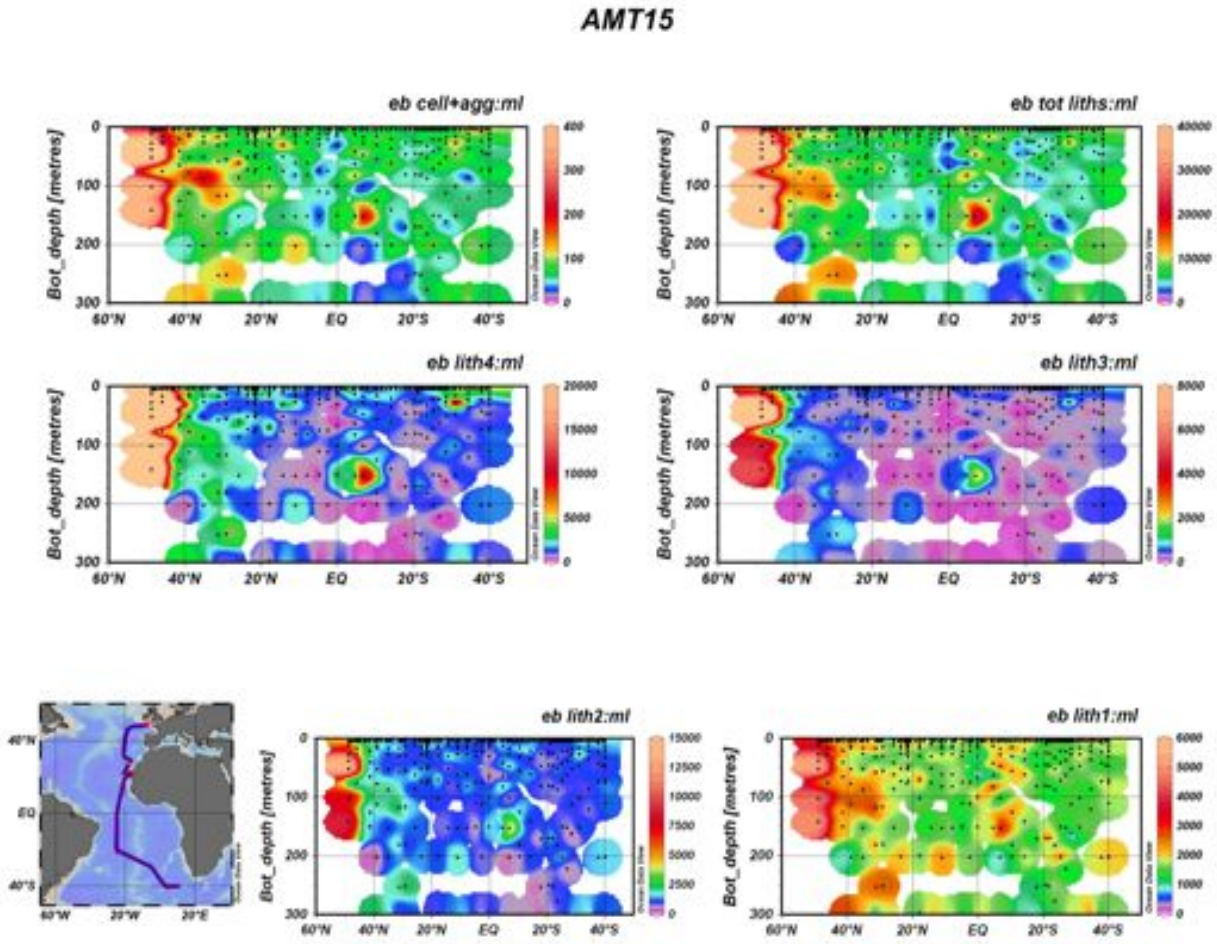
AMT 17: PIC & POC



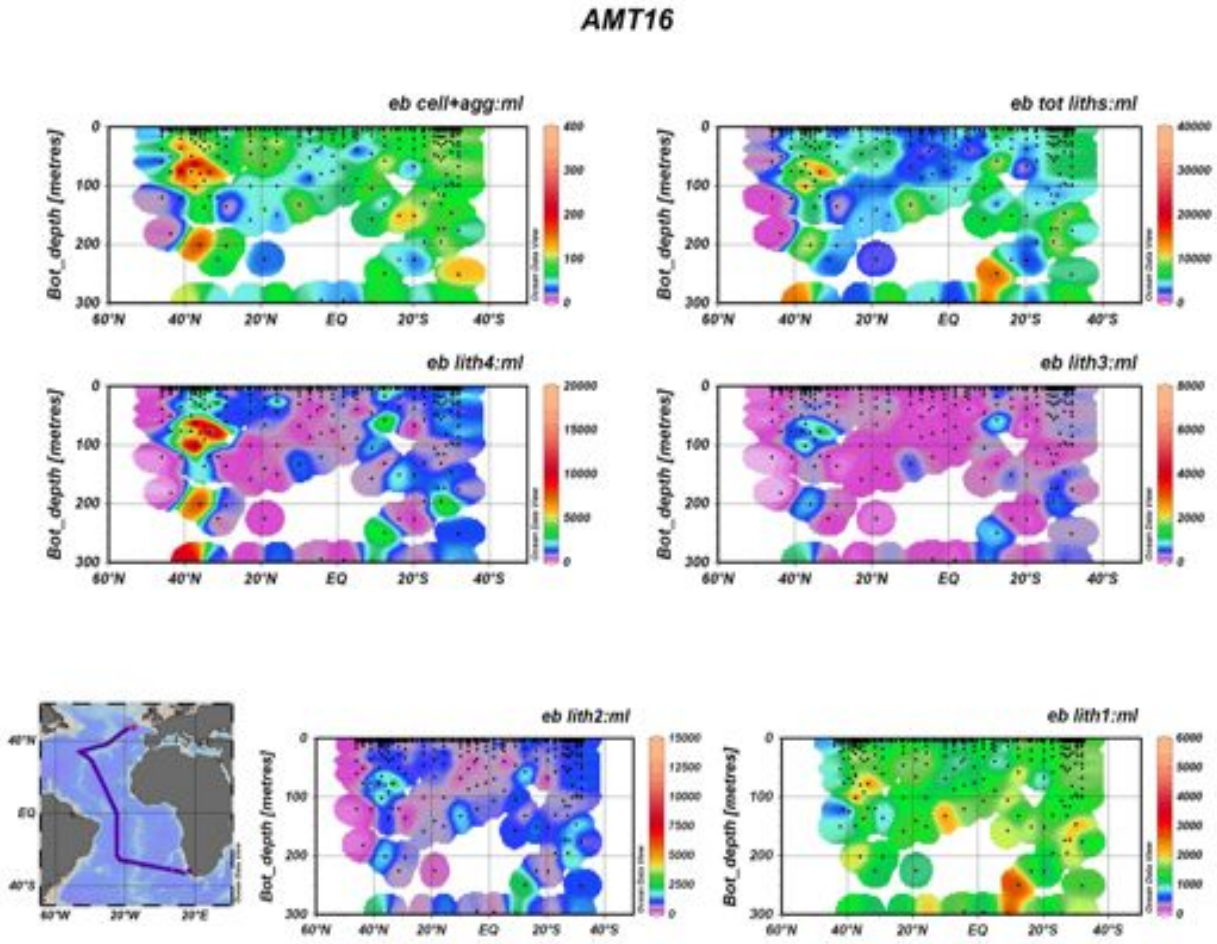
AMT 18: PIC & POC



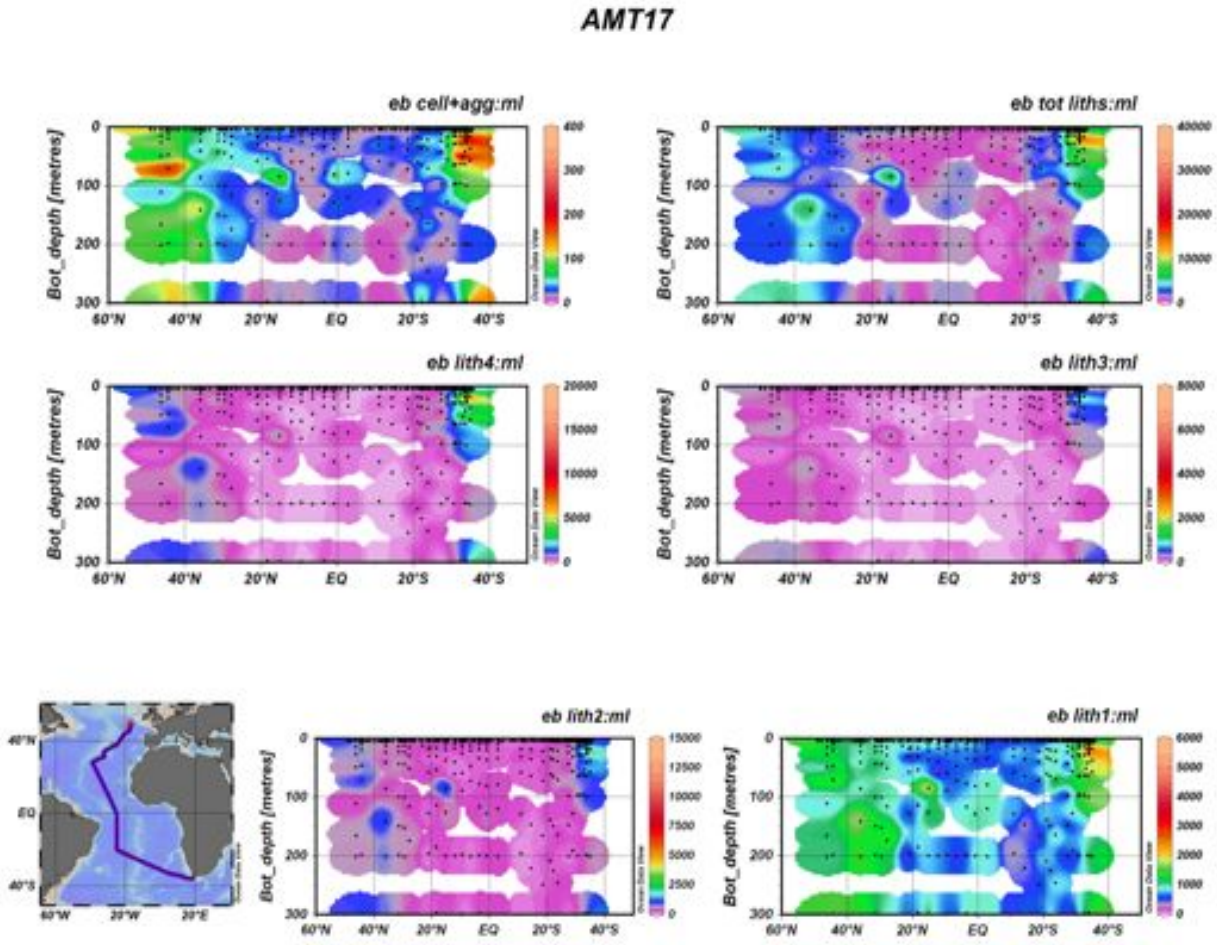
AMT 15: Coccolith counts



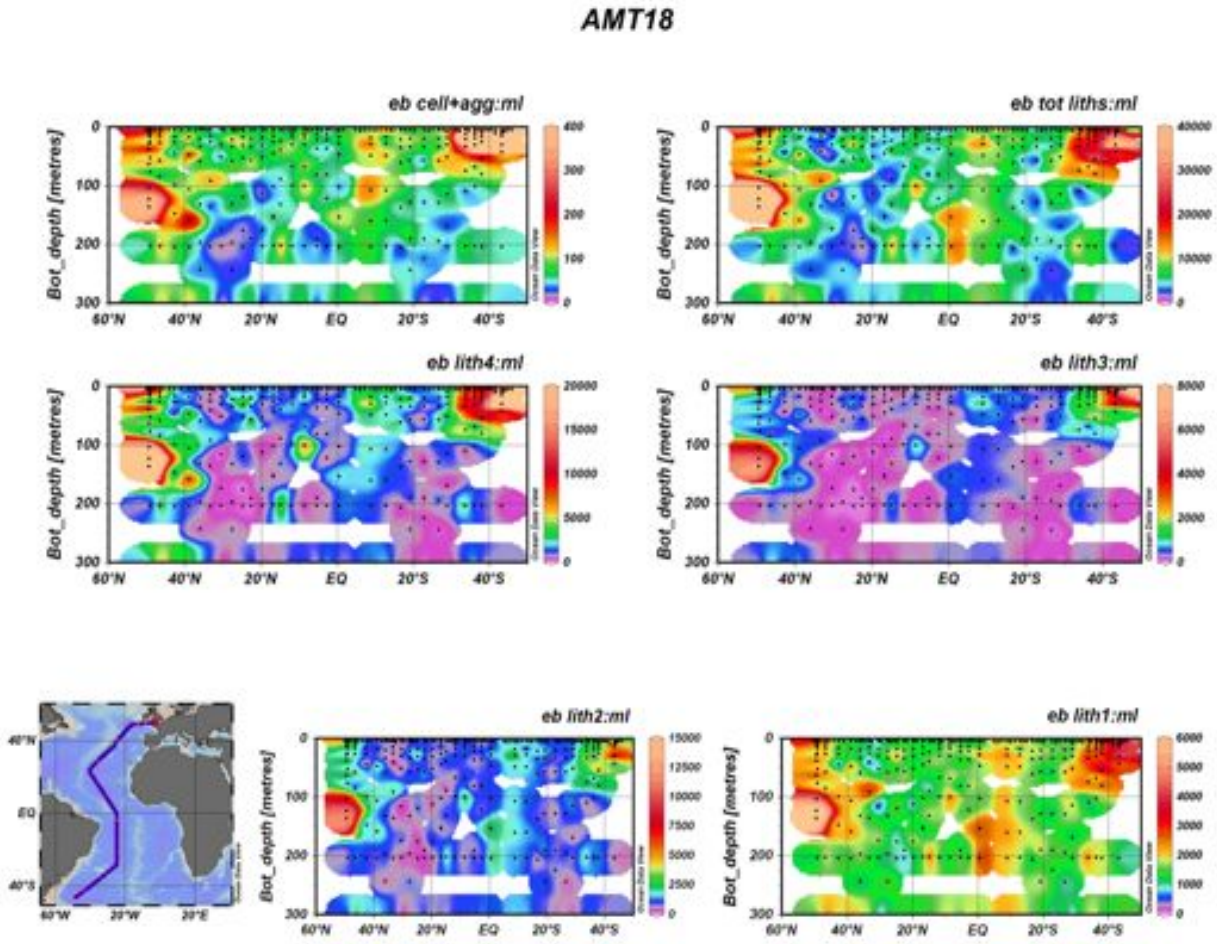
AMT 16: Coccolith counts



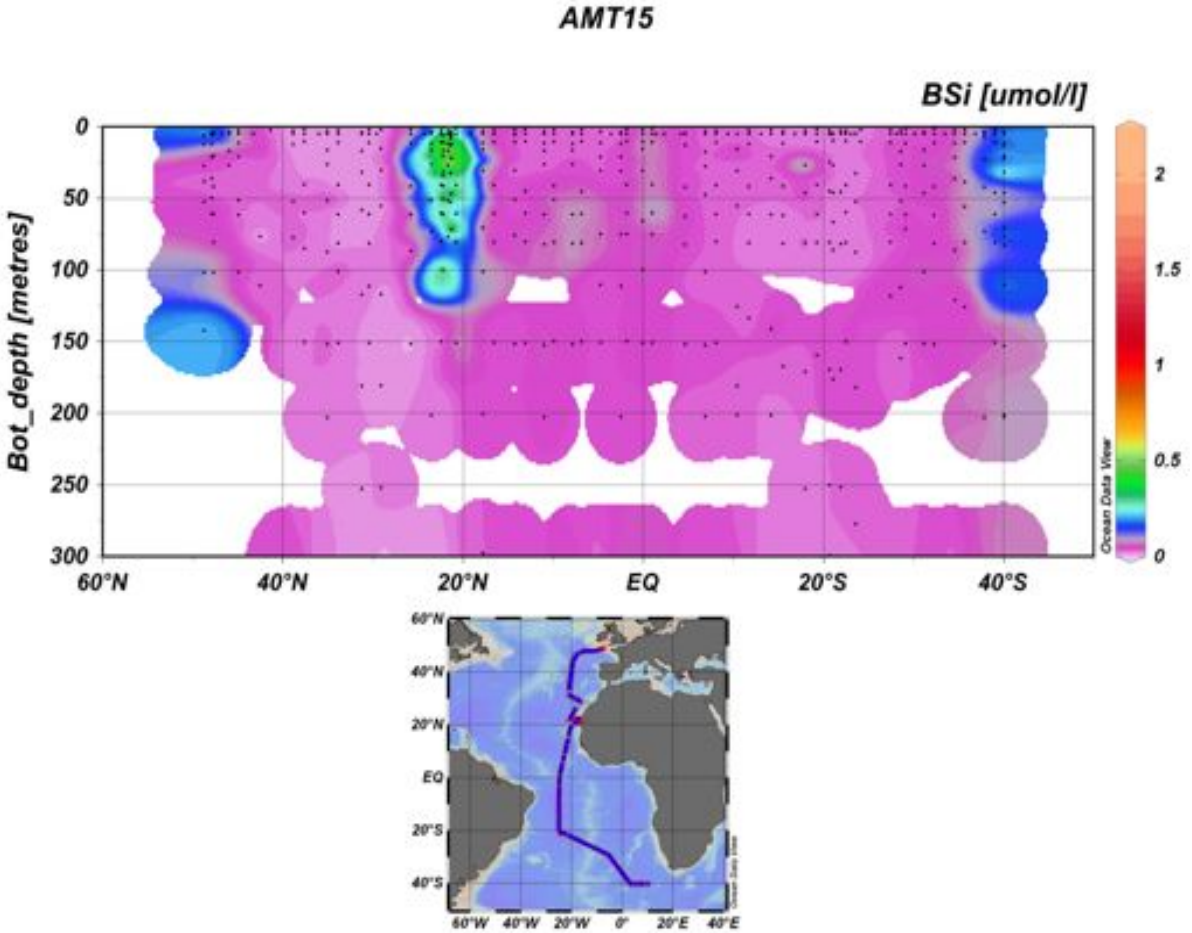
AMT 17: Coccolith counts



AMT 18: Coccolith counts



AMT 15: BSi


AMT15
BSi [umol/l]
Bot_depth [metres]
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100
150
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40°S
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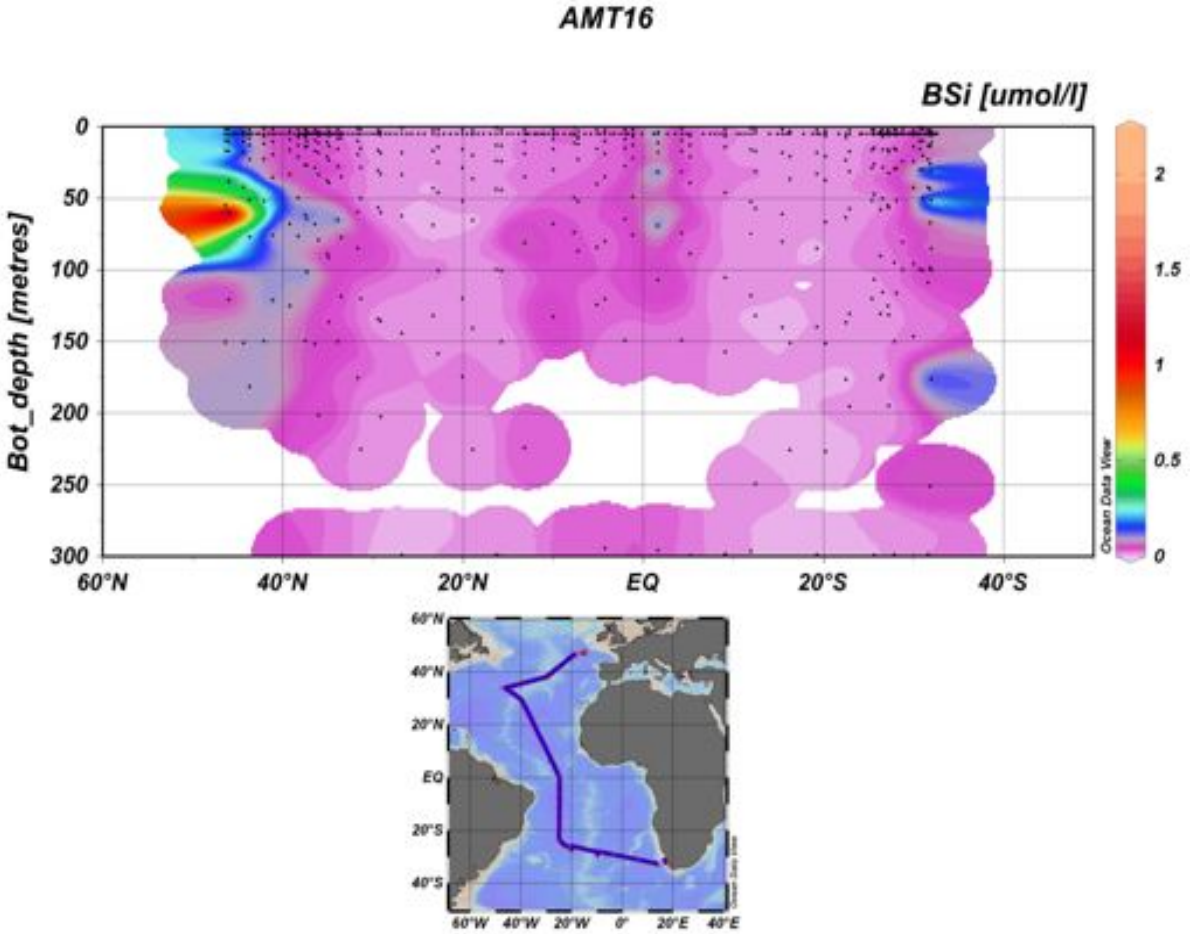
40°E

AMT 16: BSi


AMT16
BSi [umol/l]
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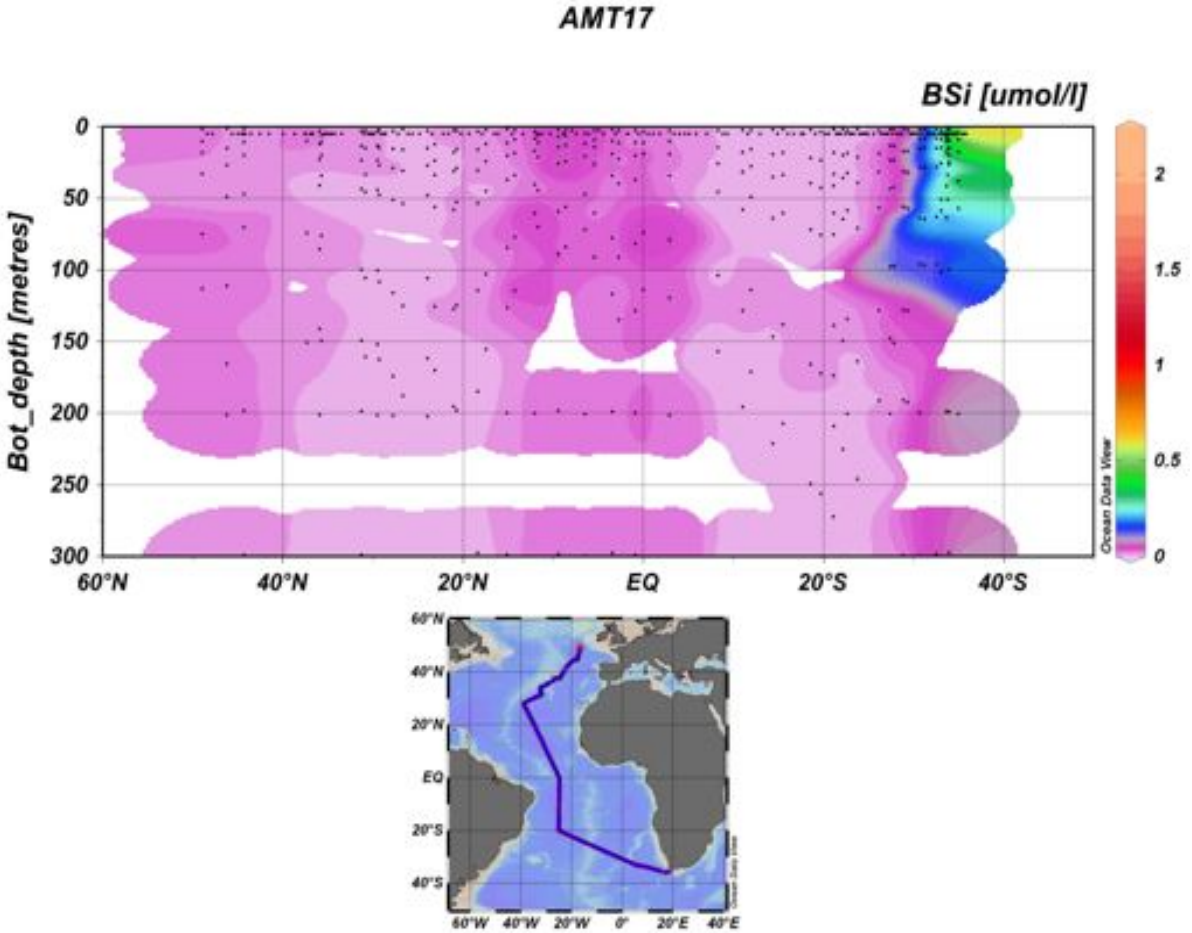
AMT 17: BSi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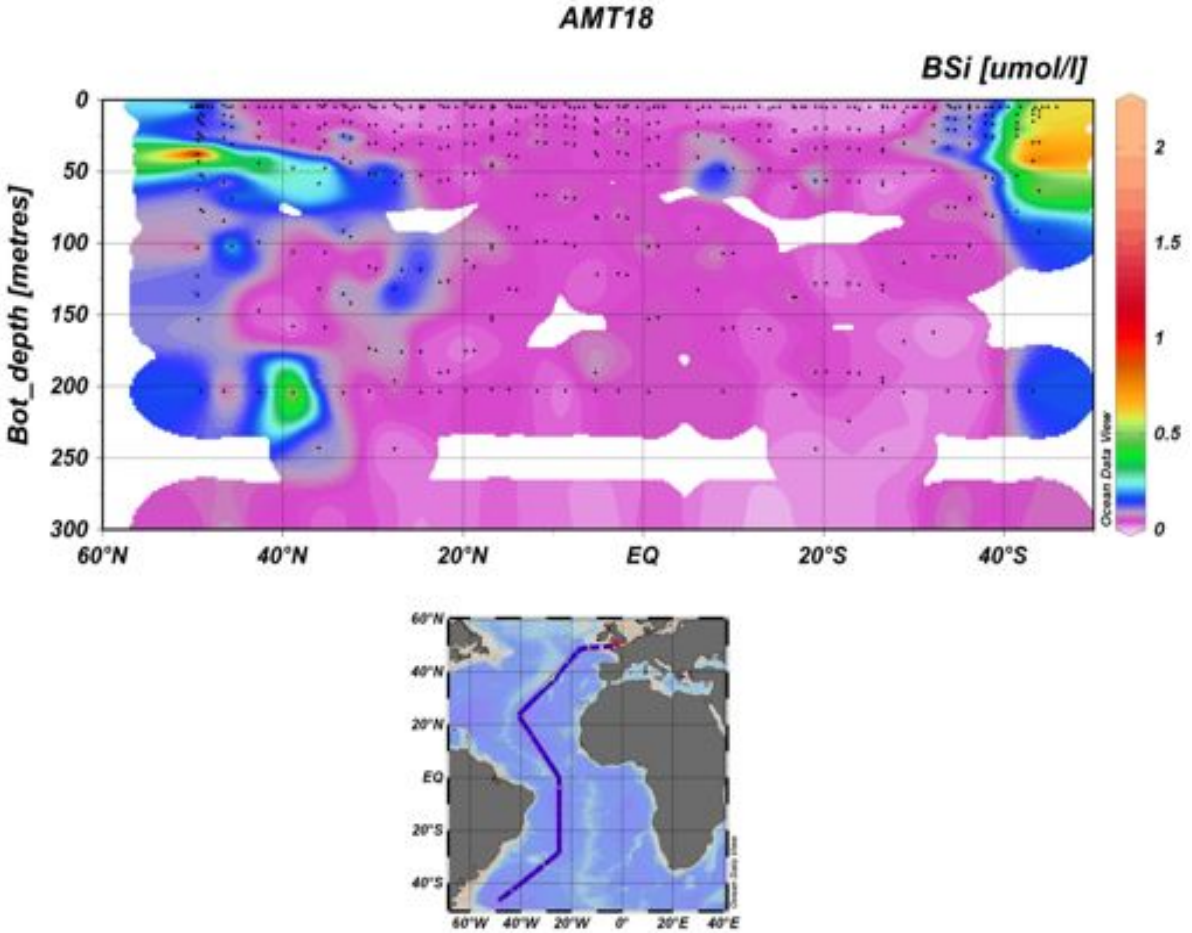
AMT 18: BSi


AMT18
BSi [umol/l]
Bot_depth [metres]
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40°N
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20°S
40°S
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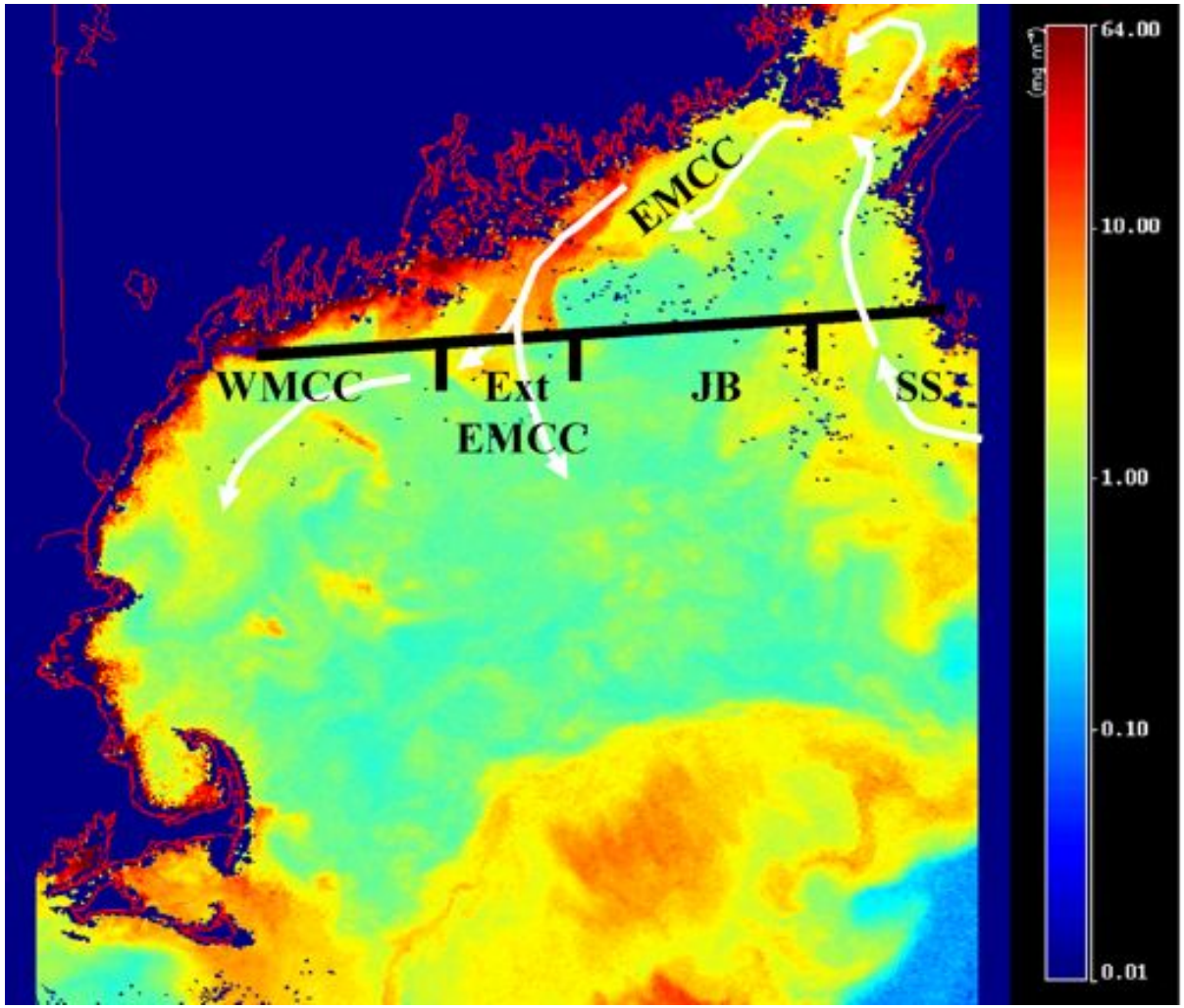
1.5
1
0.5
0
Ocean Data View
60°W
40°W
20°W
0°
20°E
40°E

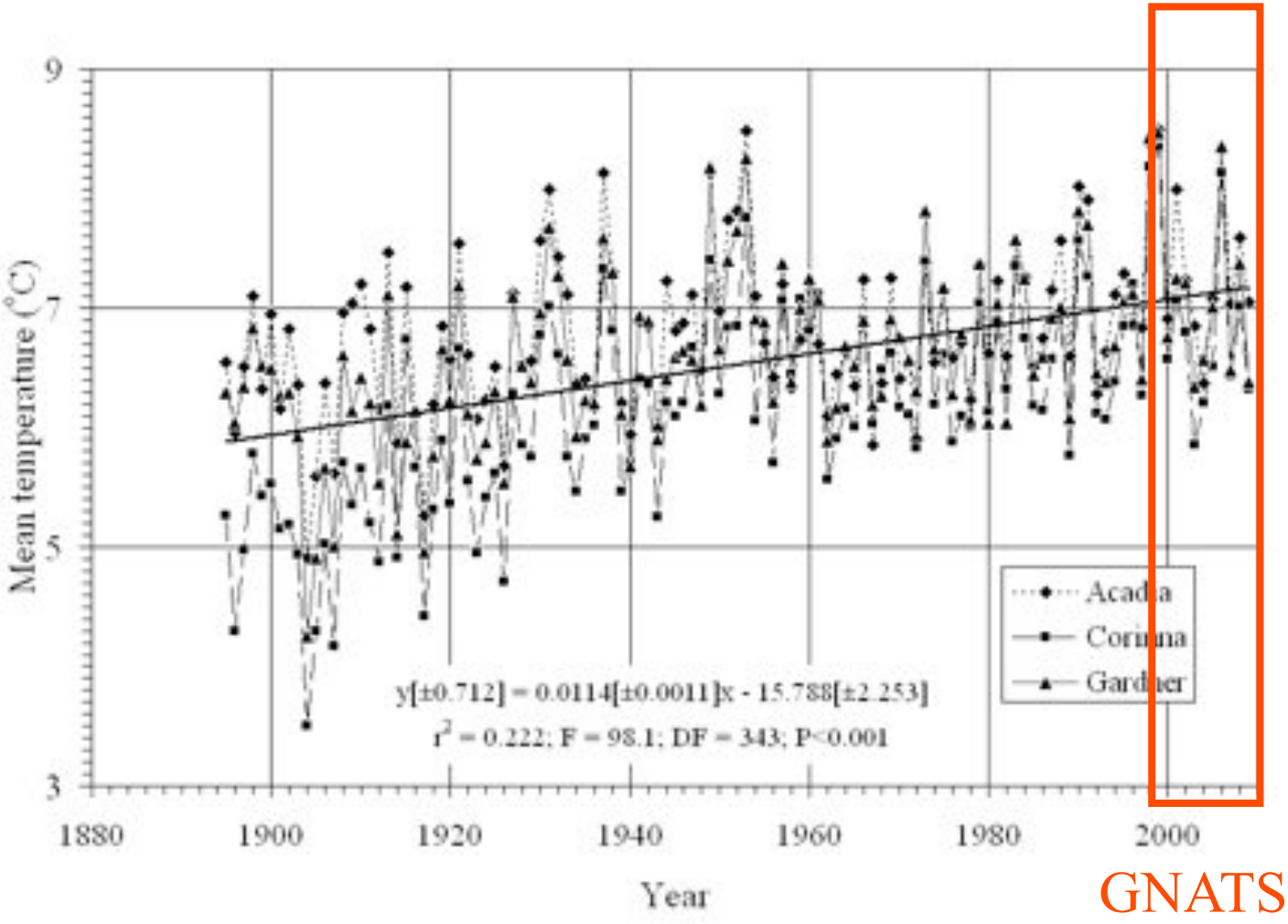
Other related activities

- Arctic ICESCAPES Cruise on Healy in a month
  - Coccolithophores appear to be increasing in Arctic but no systematic studies
  - First region to suffer major impact of ocean acidification
  - Measuring underway IOPS
  - Measuring coccolithophore calcification
- GNATS-**Gulf of Maine North Atlantic Time Series**
  - Completed 12+ years of data across Gulf of Maine (35 years if you include historical data on same line)
  - Supported 20% of chlorophyll matchups & 13% of radiance match-ups in SeaBASS
  - 3 new manuscripts in preparation

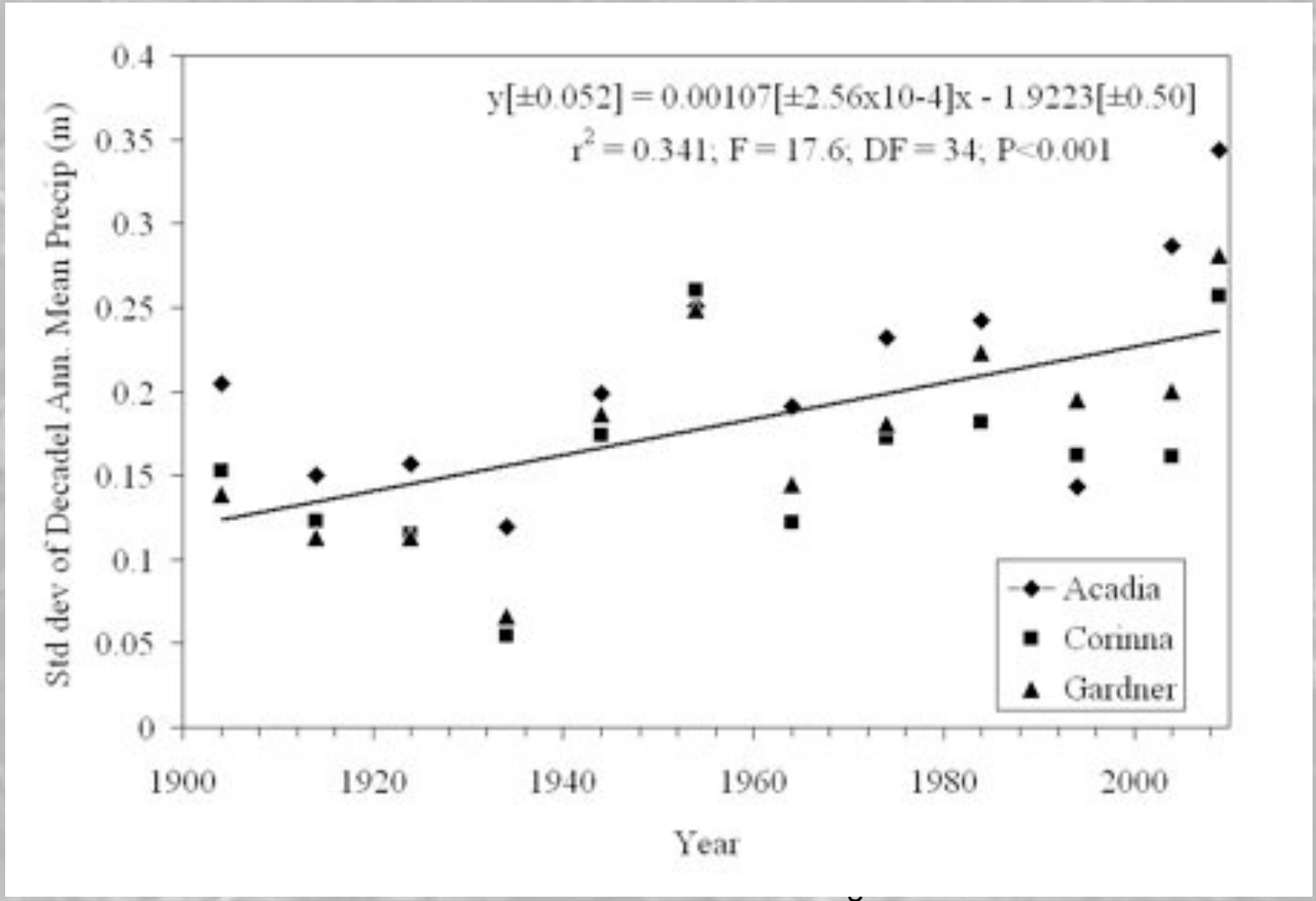
What is GNATS?



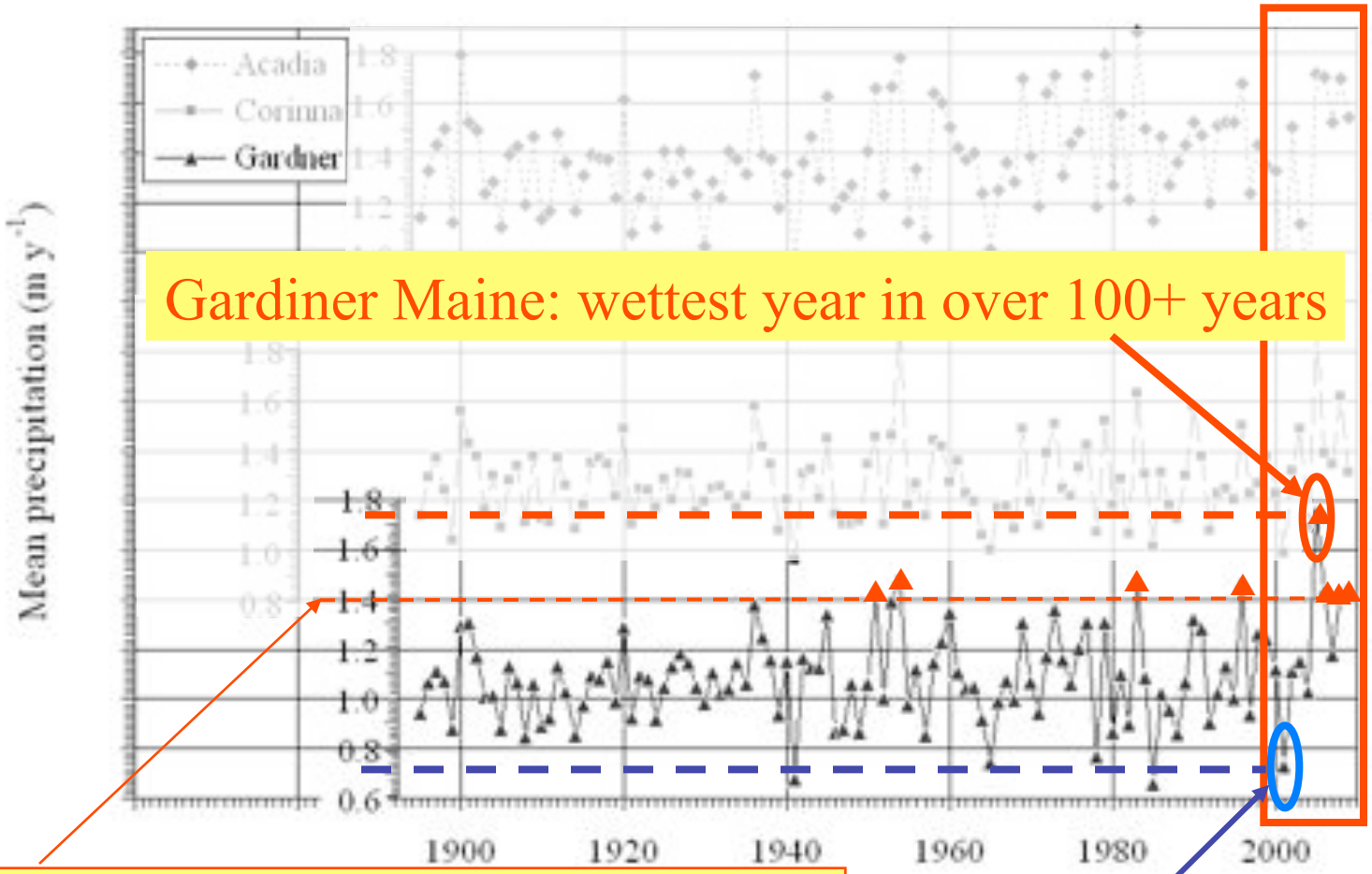
The climate of New England is changing…



Variance in precipitation has increased…



GNATS has seen some of the century's most extreme precipitation events…



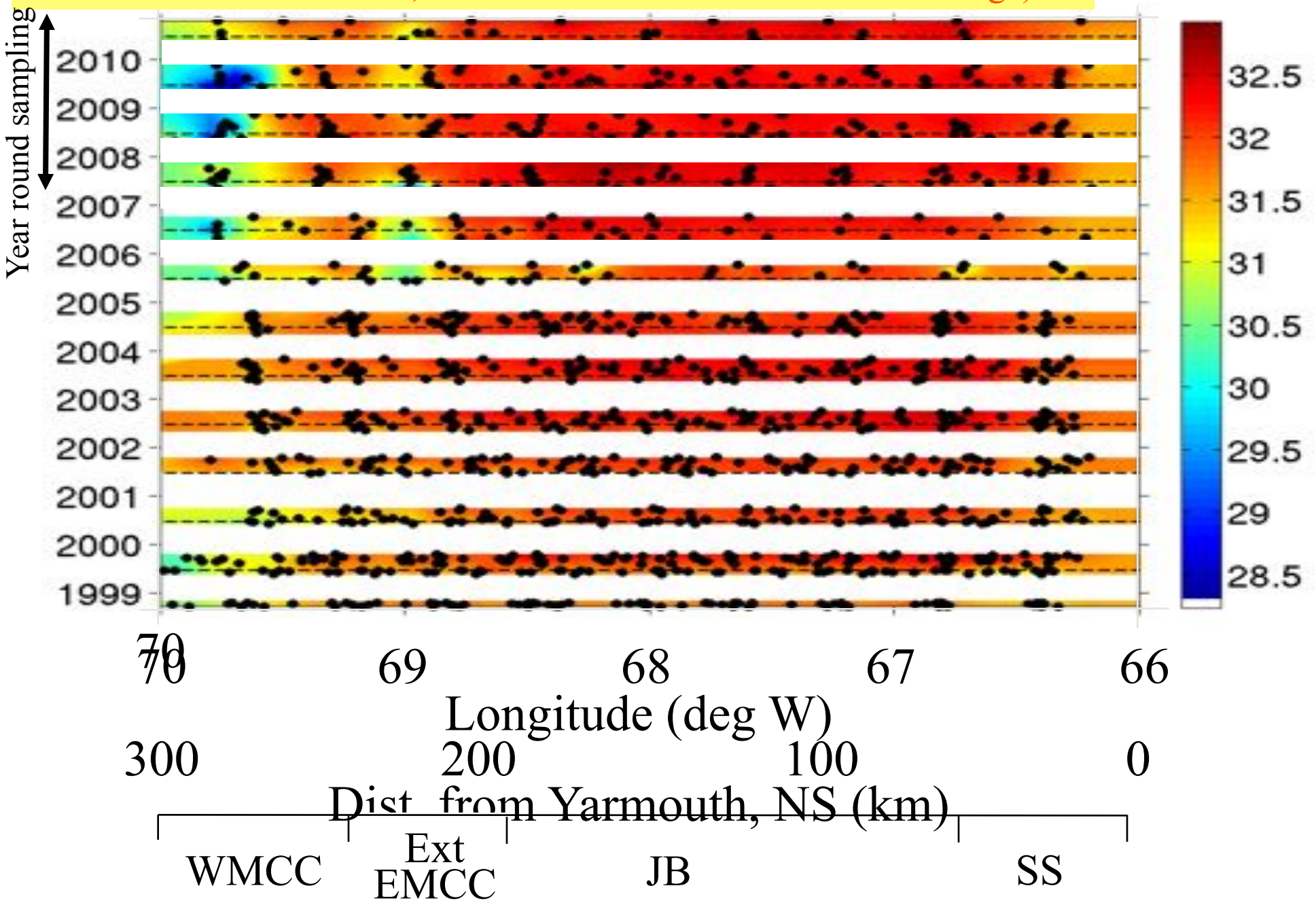
Gardiner Maine: wettest year in over 100+ years

Of 8 years >1.4m y^{-1}, half during GNATS

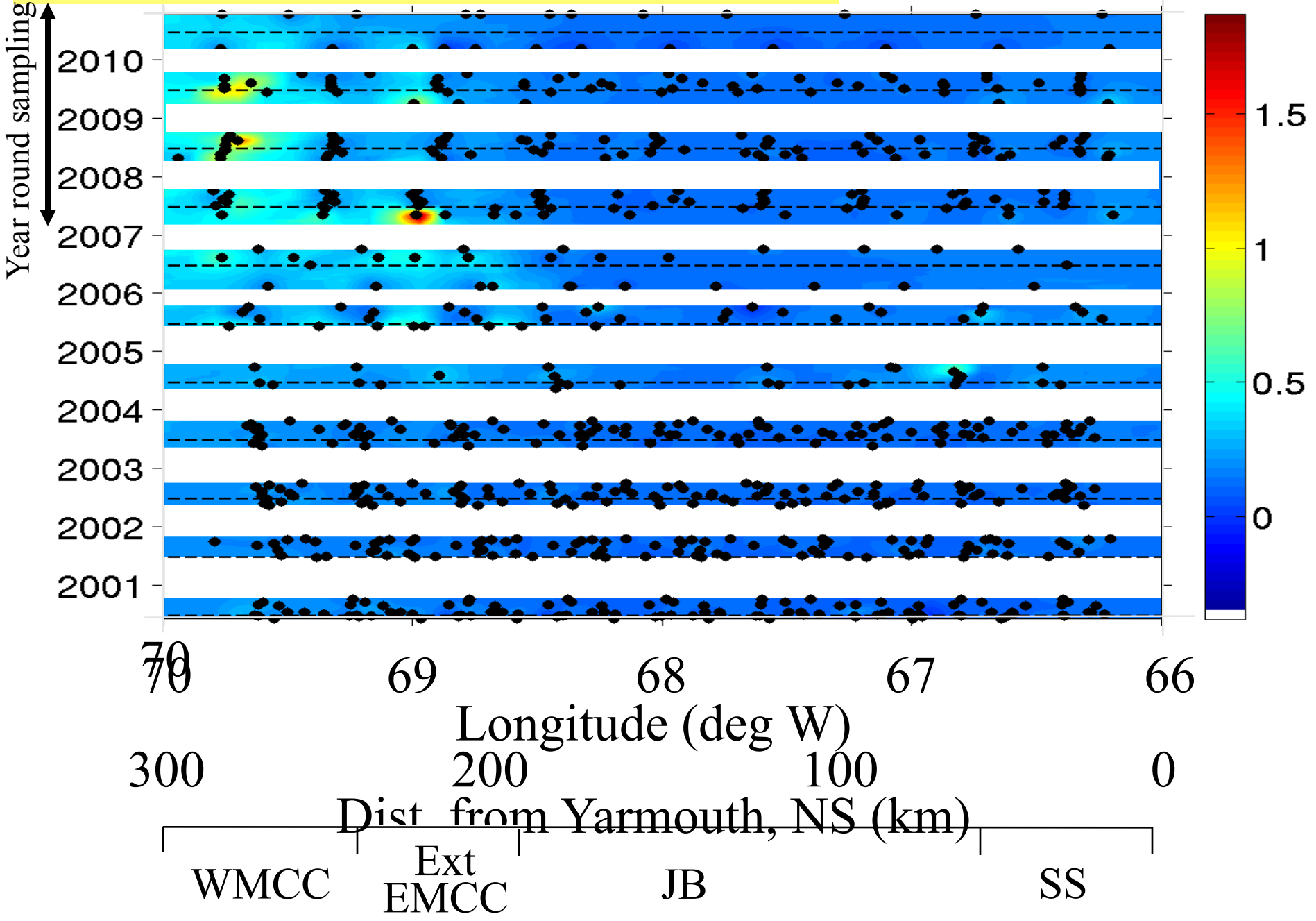
GNATS

Gardner Maine: 3rd driest year in 100+ years

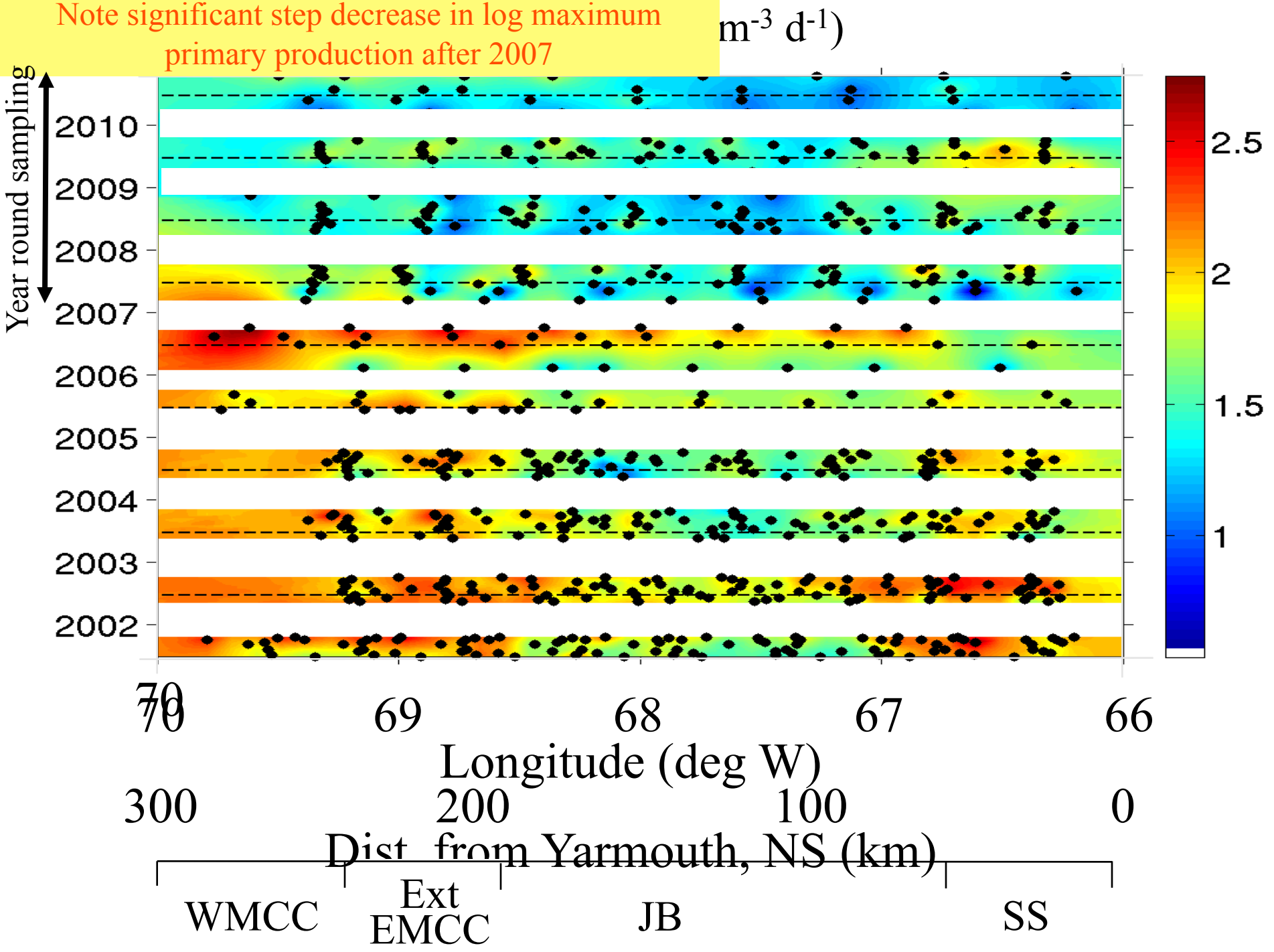
Note decrease in salinity on west side of Gulf during wet years (in WMCC and Ext EMCC, associated with increased river discharge).



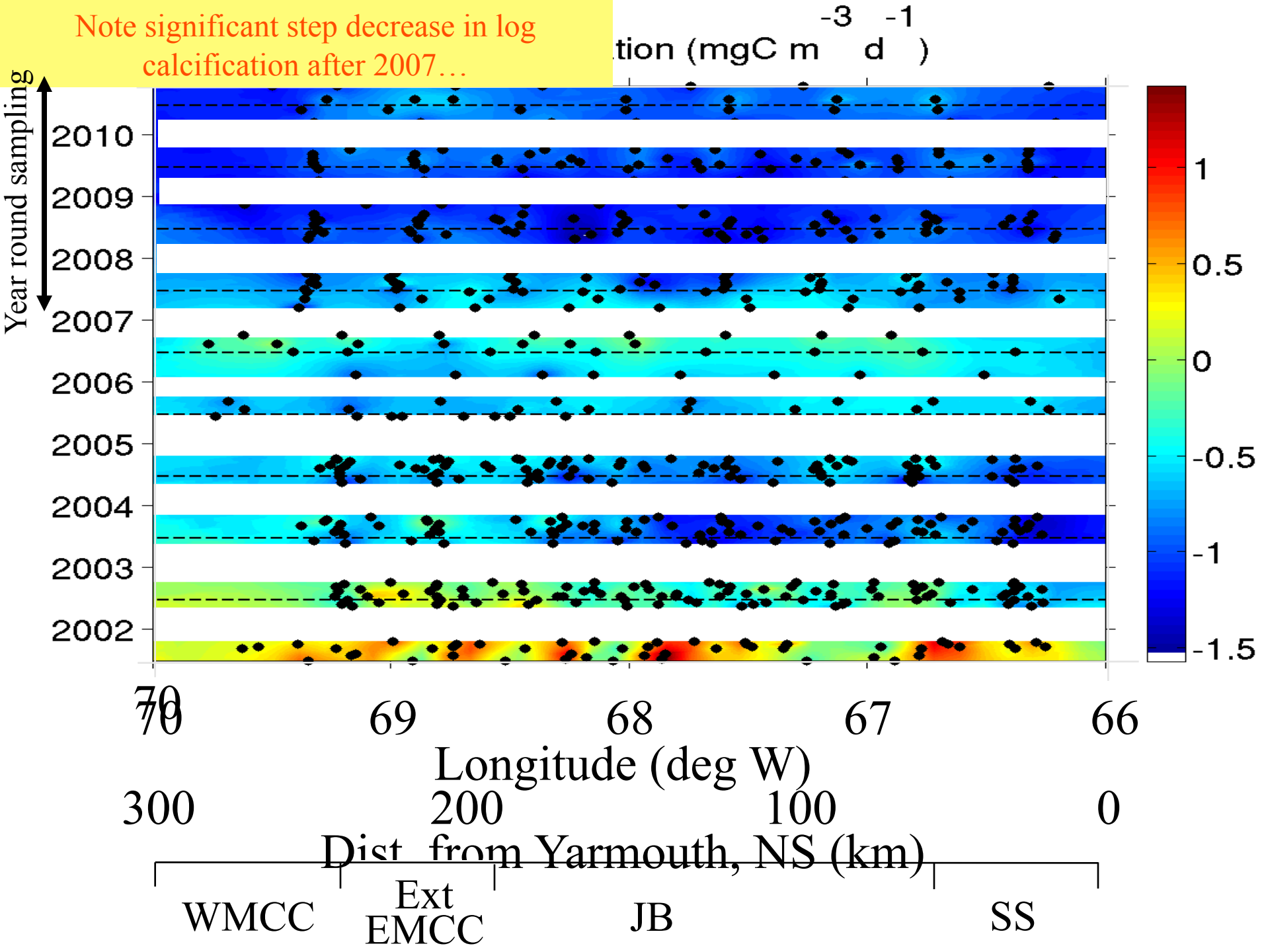
Note increase in CDOM on west side of Gulf (likely associated with increased river discharge…)



Note significant step decrease in log maximum primary production after 2007



Note significant step decrease in log calcification after 2007…



Summary-Future Activities

- New results published relevant to PIC algorithm
- Validation for MODIS & VIIRS (chlorophyll plus PIC, POC, BSi, coccolith enumeration)
  - ICESCAPES
  - GEOTRACES New Zealand
  - AMT
  - Great Belt II
- Science data analysis also involved in projects
- GNATS funding technically ran out in December 2010 but we are trying to re-establish funding, especially important as related to a) ongoing changes plus b) calibration/validation of MODIS and VIIRS

Thank you!