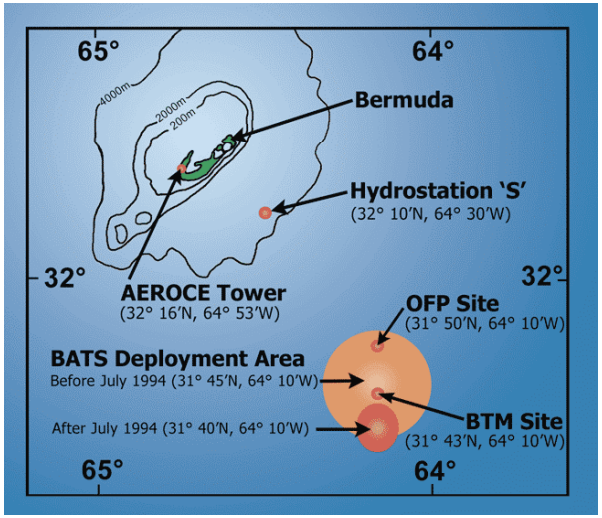
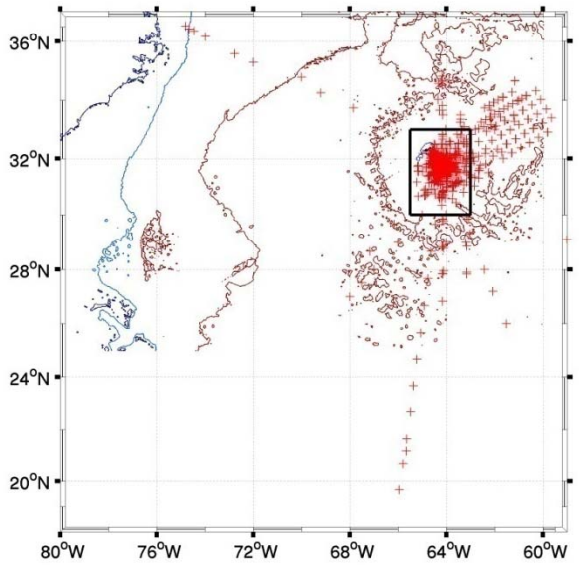
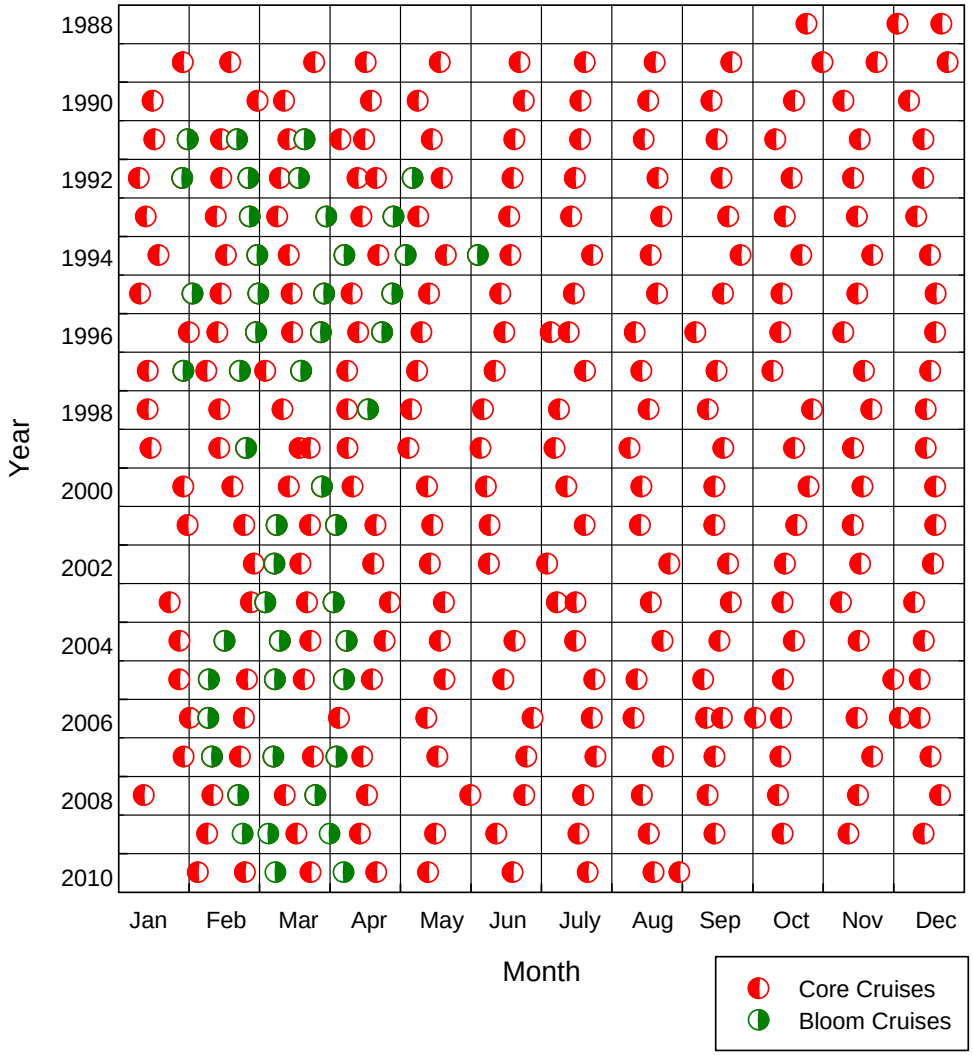
The Bermuda Atlantic Time-series Study: A Research Platform to Study Change in the subtropical North Atlantic

Michael W. Lomas, Nicholas R. Bates, Rodney J. Johnson, and Anthony H. Knap
CINTOO: Center for Integrated Ocean Observations
Bermuda Institute of Ocean Sciences

BATS/ location& sampling frequency/







http://bats.bios.edu

BATS/ Original Motivation and Objectives/

The Bermuda Atlantic Time-series Study (BATS) was initiated under the JGOFS umbrella with the overall motivation…

> *" To determine and understand the time-varying fluxes of carbon and associated biogenic elements in the ocean and to evaluate the related exchanges with the atmosphere, sea floor and continental boundaries ."* (SCOR, 1987)

Original Objectives:

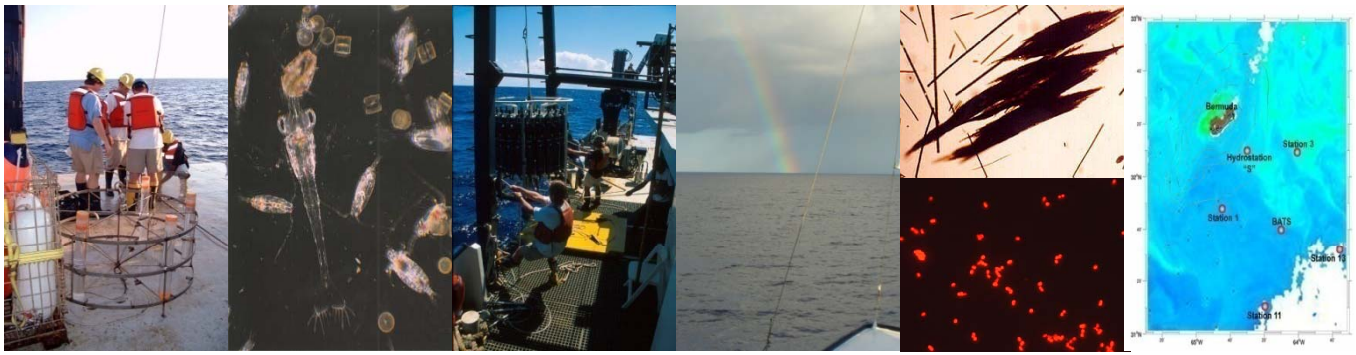
- **To understand the seasonal and interannual variations in ocean physics, chemistry and biology**
- **To understand the processes that control surface pCO_2**
- **To understand the physical controls on biological rate processes**
- **To provide a test-bed for the validation of new methods and technologies**

OBJECTIVES OF THIS TALK…

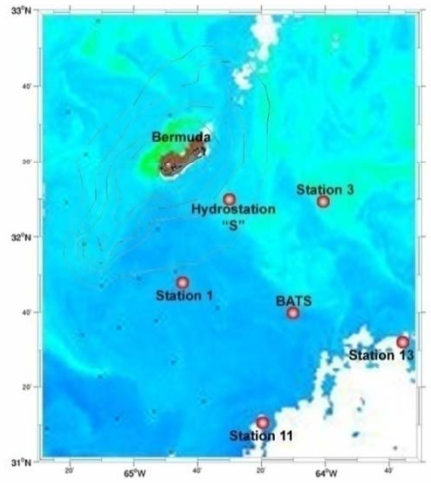
1. Present patterns in the 22-year data records.

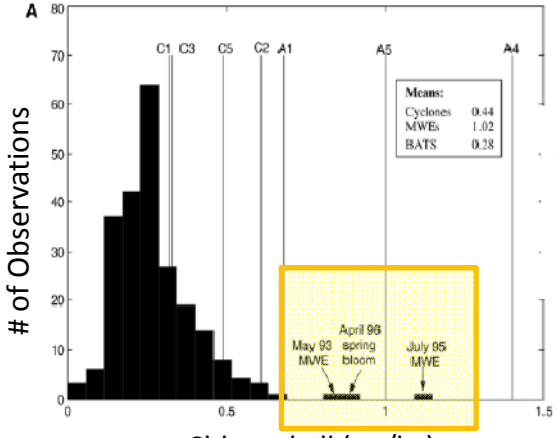
2. Identify what we now think we are missing (e.g., eddies, mesopelagic ecosystem) to understand the original objectives.

3. Present brief overview of a future “integrated time-series platform”

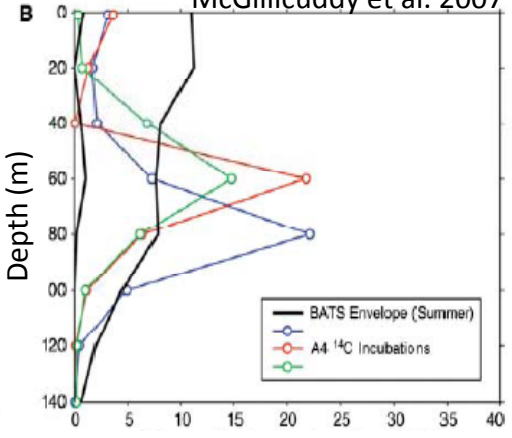


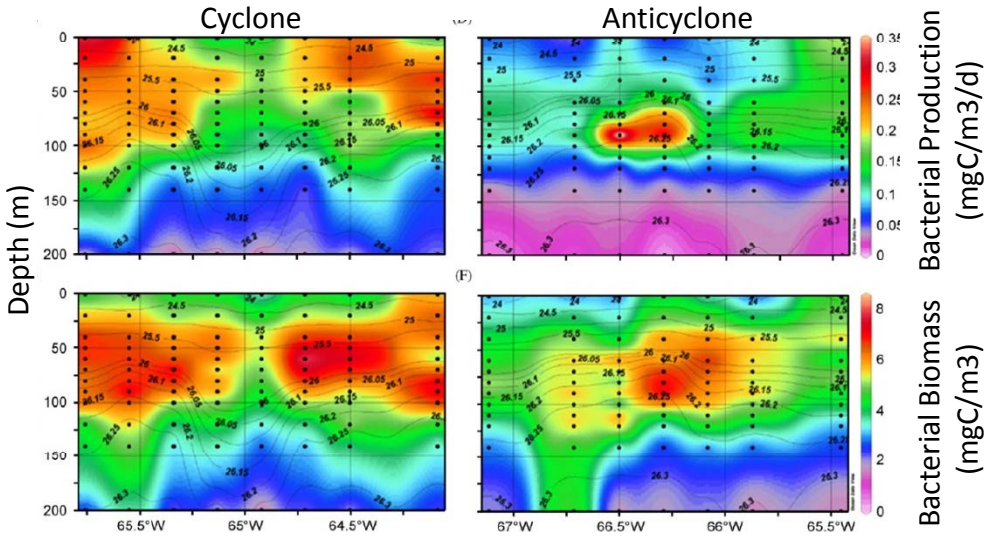
BATS/ Mesoscale variability/ Eddies



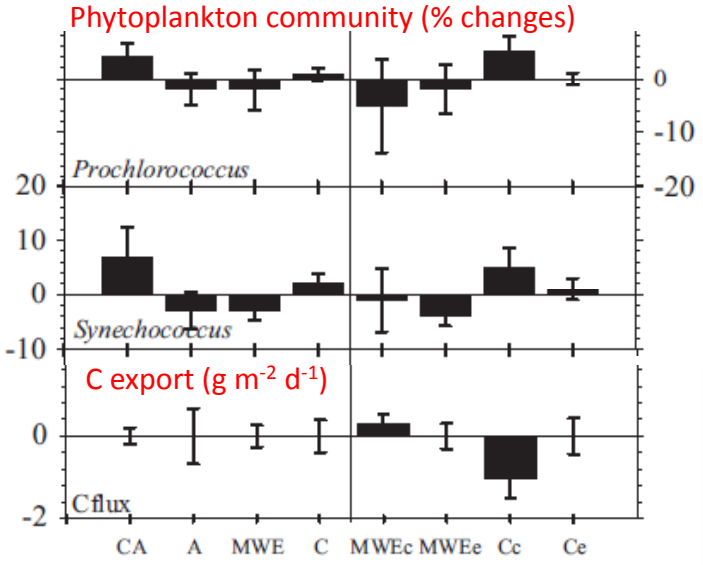


McGillicuddy et al. 2007





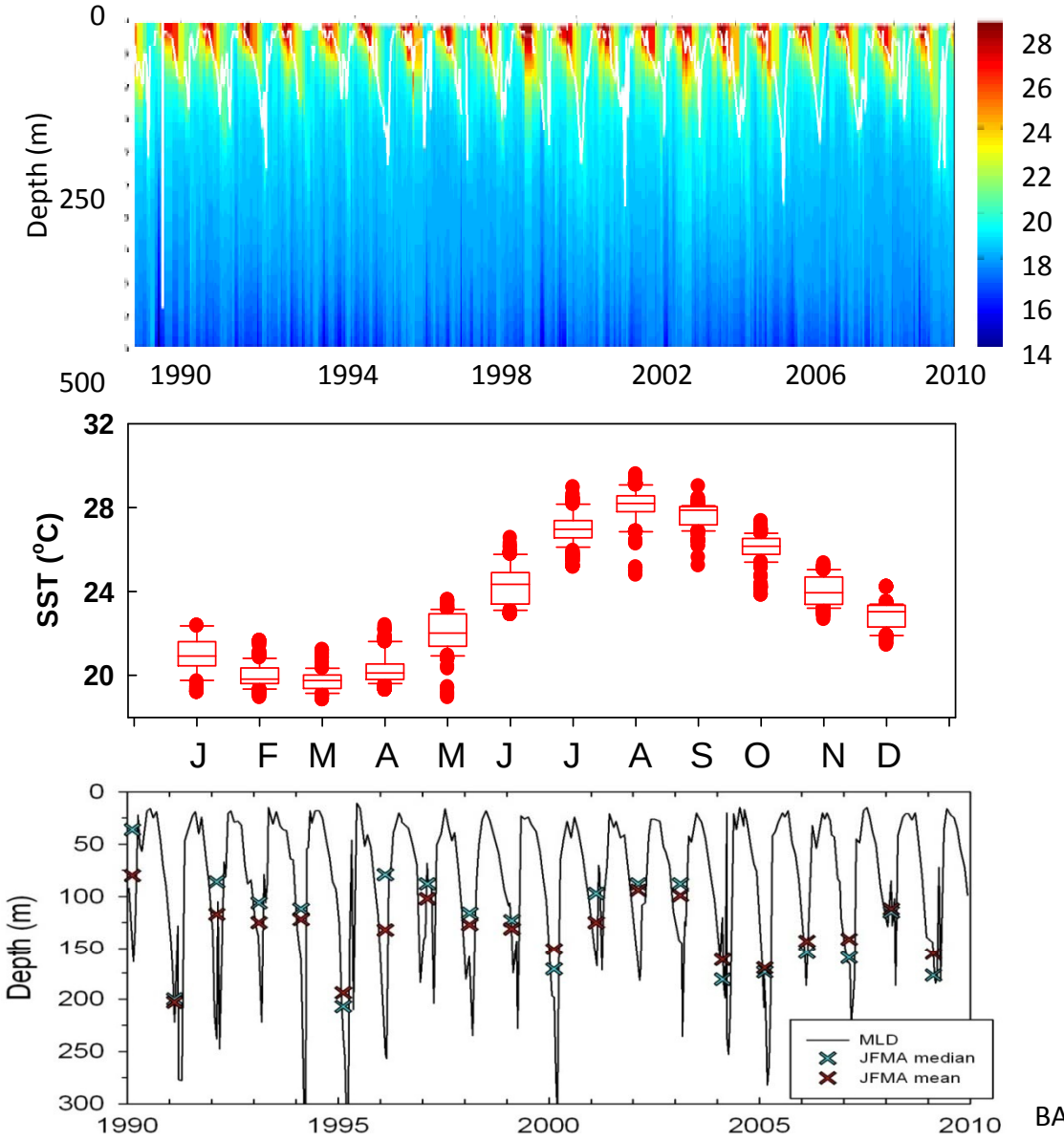
Ewart et al. 2008



Mourino-Carballido 2009

On an annual scale, eddies appear to 'average out' their impact on biogeochemistry.

BATS/ Multi-year Variability/ Hydrography/



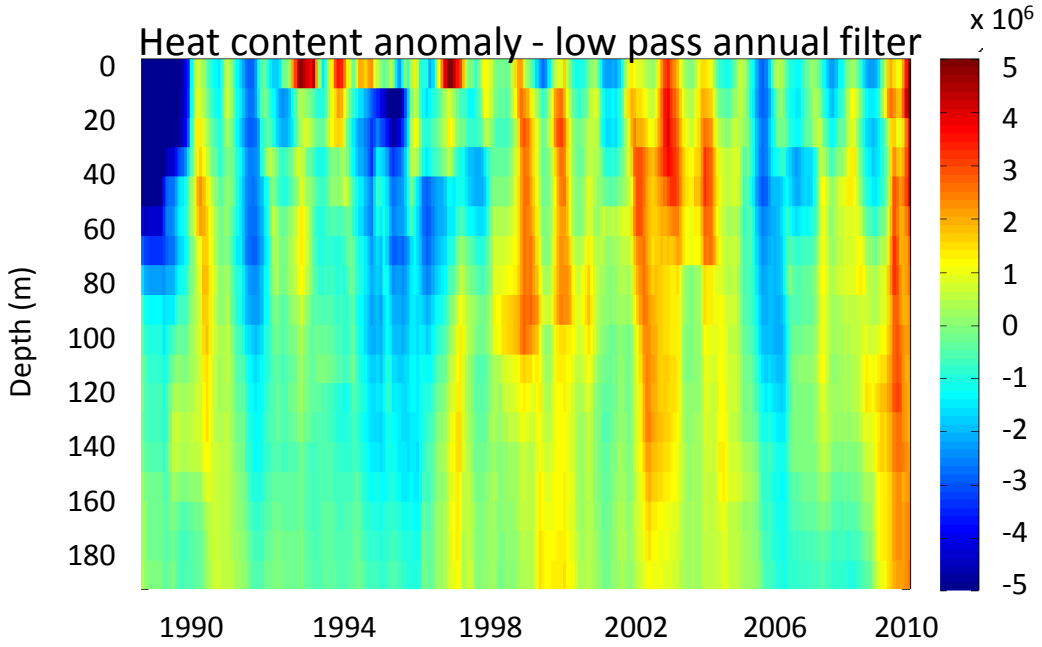
Repeatable annual pattern, with a seasonal cycle of ~9°C

MLD driven by temperature ranging from 150-300m.

No clear long-term pattern, although deep MLD in 1991 and 1995 are the cause. Interactive effects of eddies and convection?

BATS, unpubl.

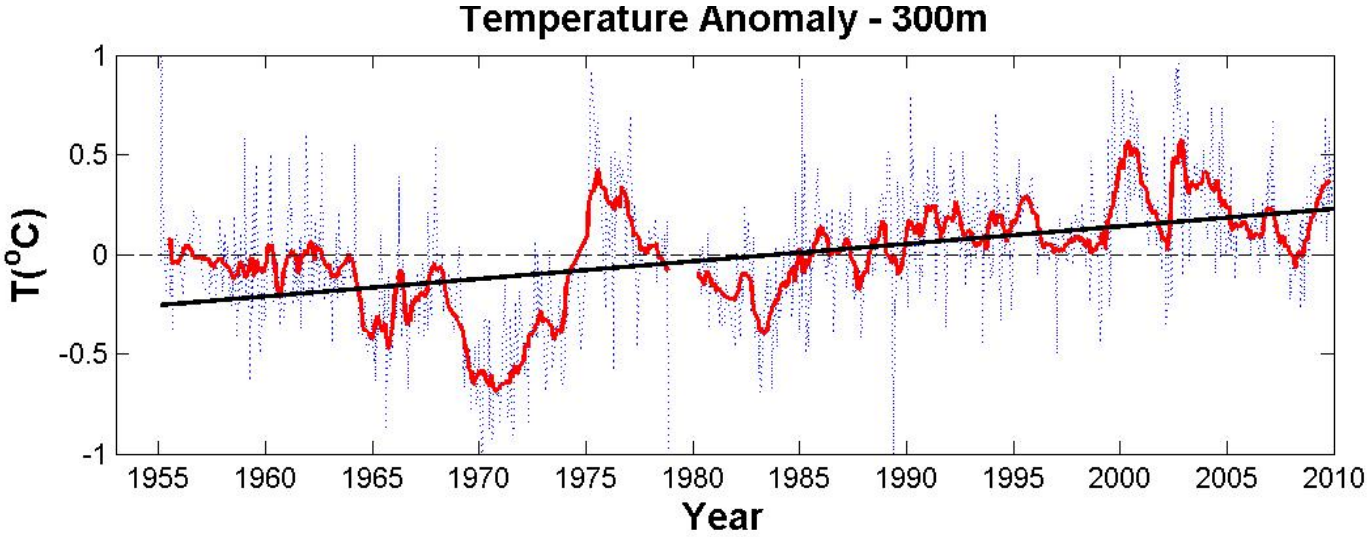
BATS/ Multi-year Variability/ Hydrography/



Long-term changes in heat content -

Seasonal cycle but apparent increase in surface waters at BATS

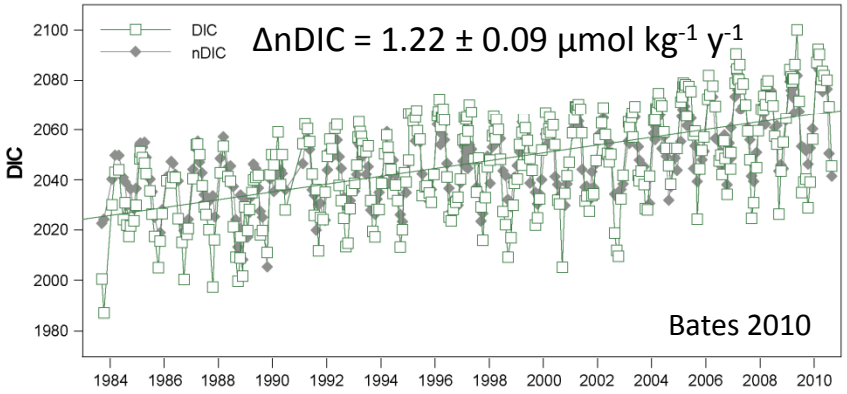
Longer HS record suggests warming subsurface waters within the gyre.

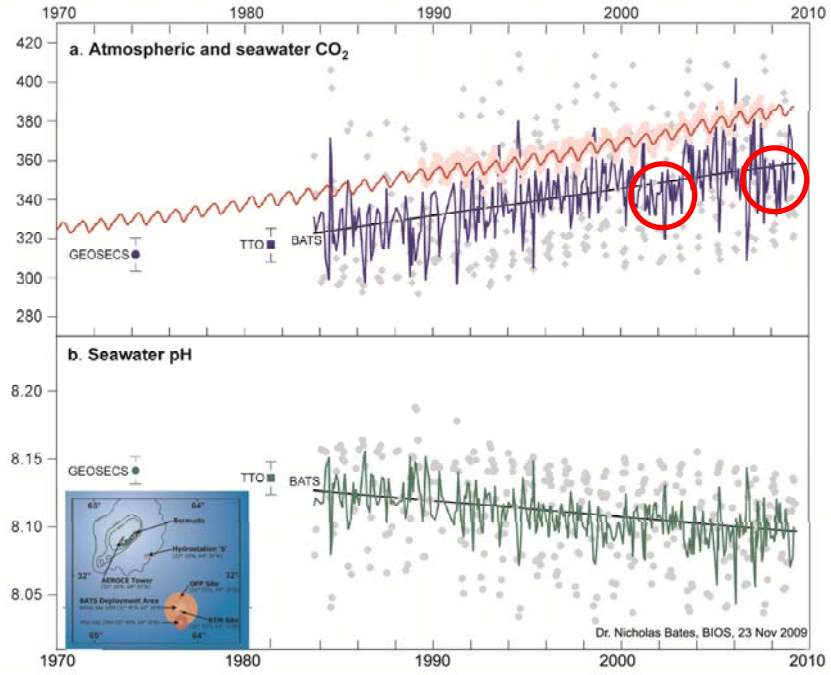


BATS, unpubl.

BATS/ Multi-year Variability/ Dissolved inorganic carbon/

BATS-Hydrostation S Surface Trends (Sept. 1983-July 2010)



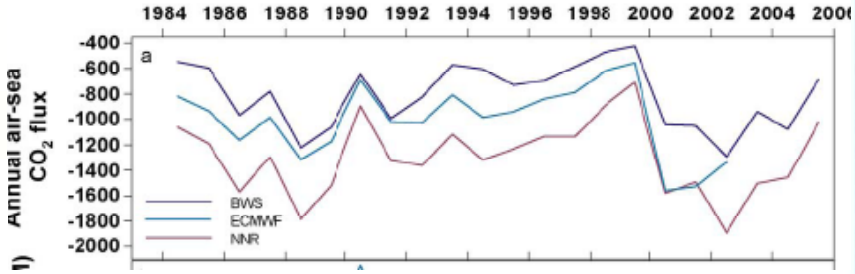


Inorganic carbon content has increased to a level exceeding annual variability.

Surface ocean pCO_2 increasing at the same rate as atmosphere, but notice 'stutters'

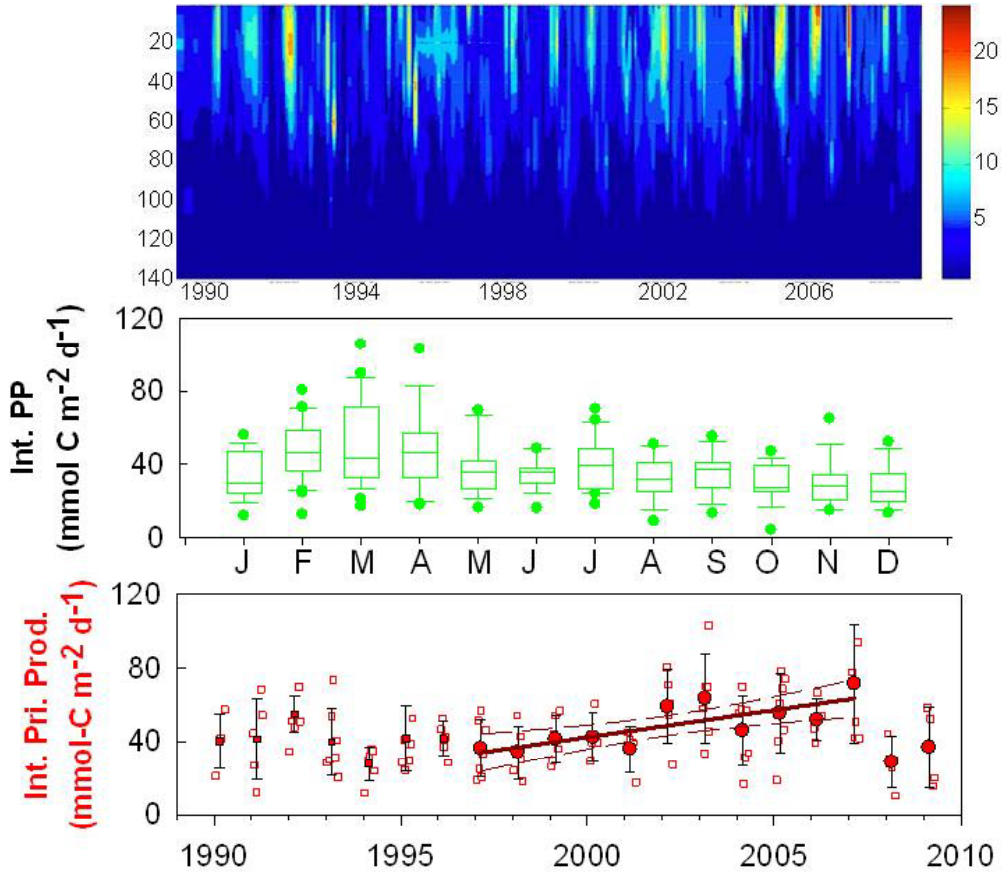
Surface ocean is acidifying.

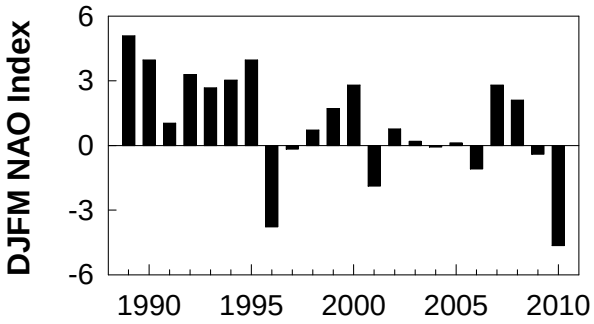
Annual sink increasing overall due to increasing winter flux which offsets summer.

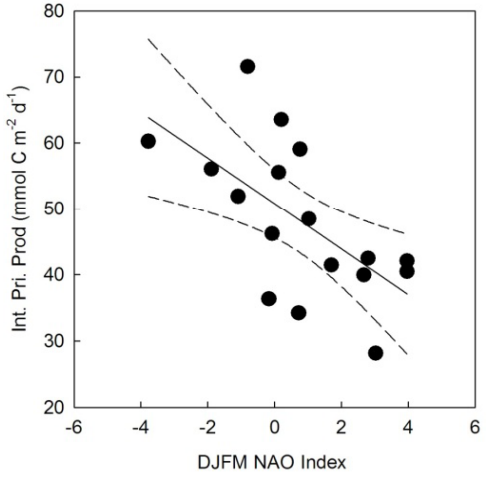


Bates et al. 2007

BATS/ Multi-year Variability/ Particulate Matter Production/





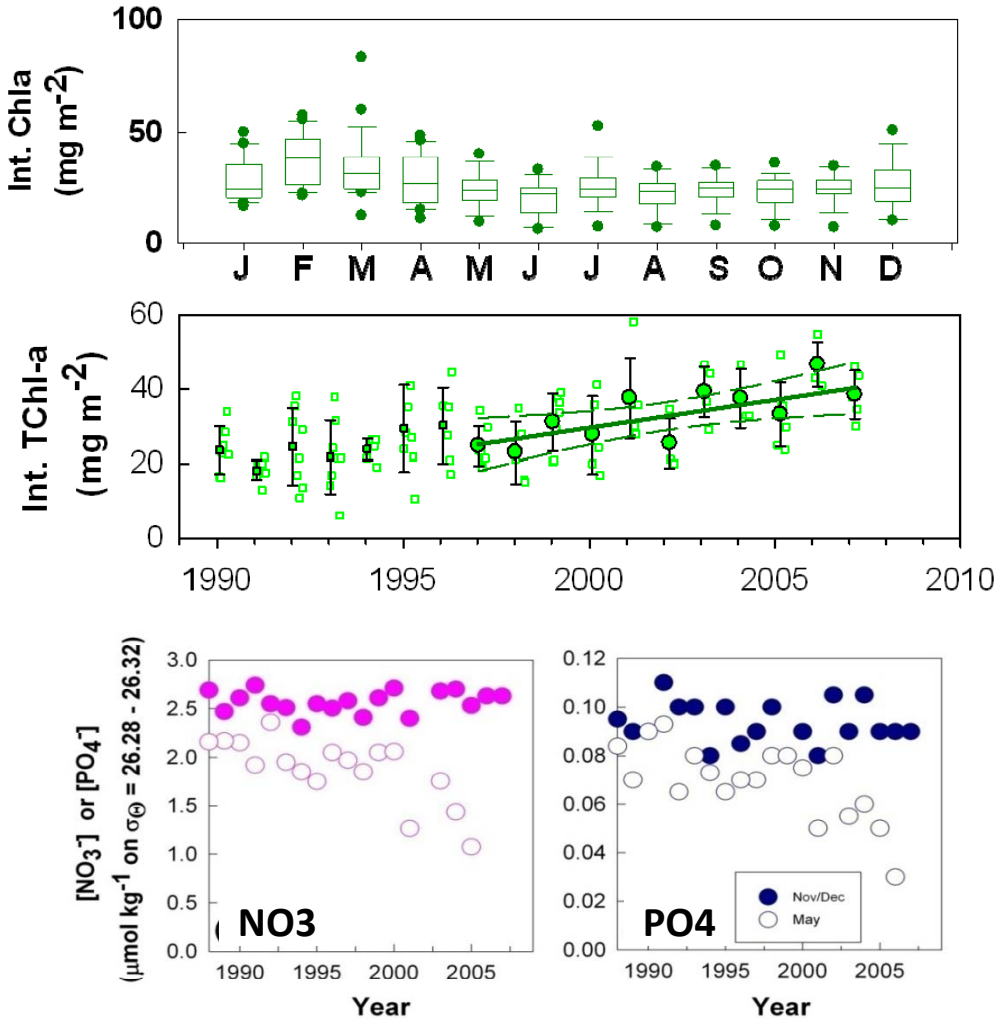


Lomas et al. 2010

Summer net primary production (NPP) doesn't change significantly.

Winter NPP inversely related to NAO via mechanism of convective nutrient inputs.

BATS/ Multi-year Variability/ Particulate Matter Composition/



NPP increase due to biomass accumulation during the winter/spring bloom.

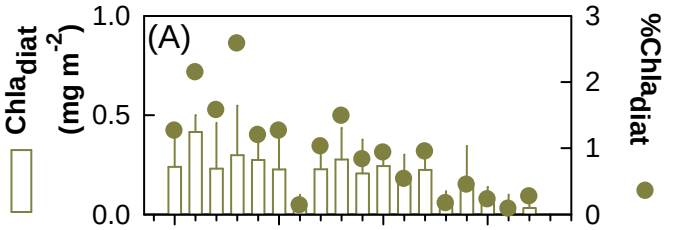
<u>Increased nutrient drawdown</u>

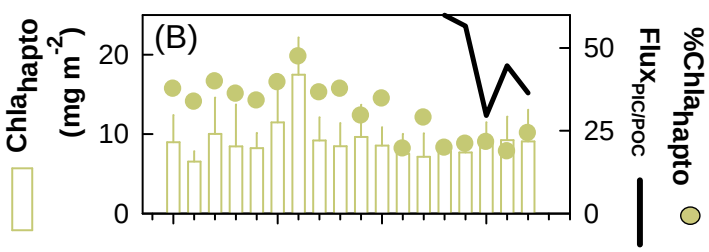
i. Autotrohic biomass has become more efficient.

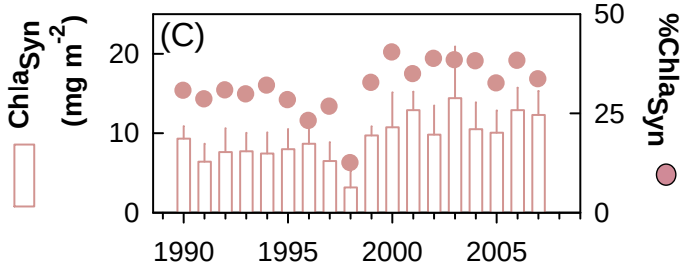
ii. Increase in supply – frequency of mixing?

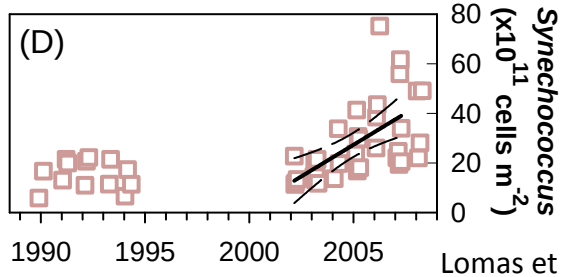
Lomas et al. 2010

BATS/ Multi-year Variability/ Particulate Matter Composition/

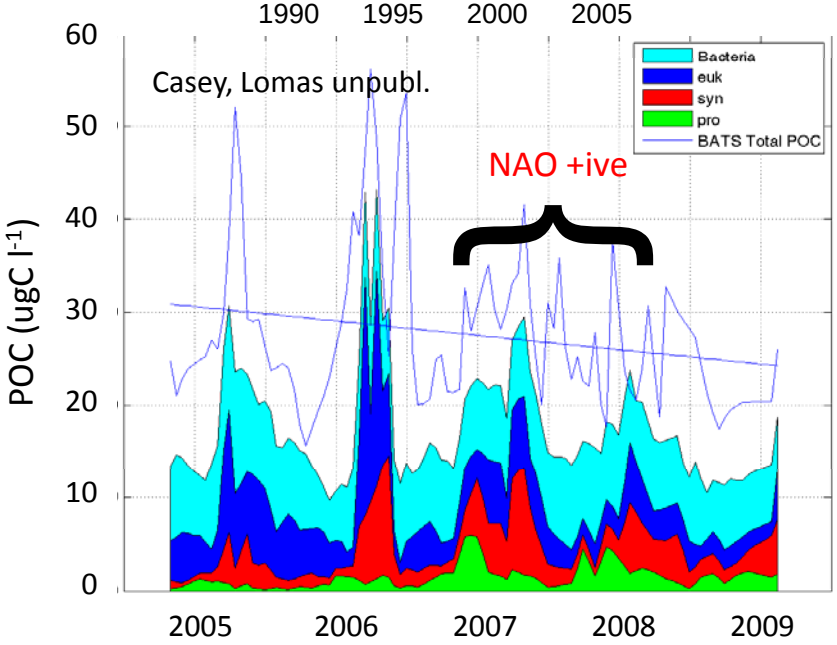


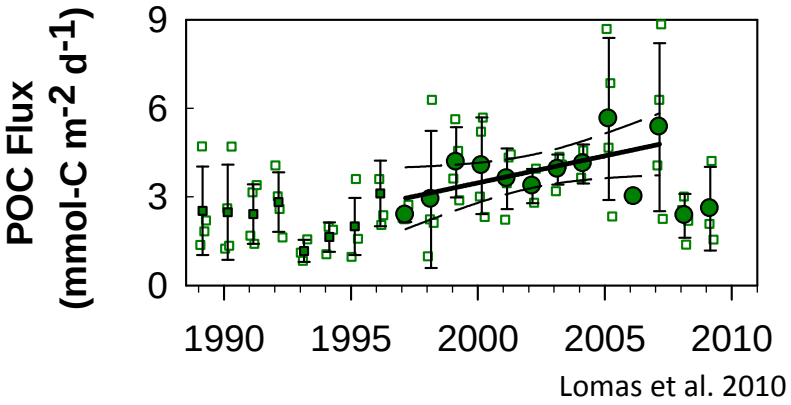






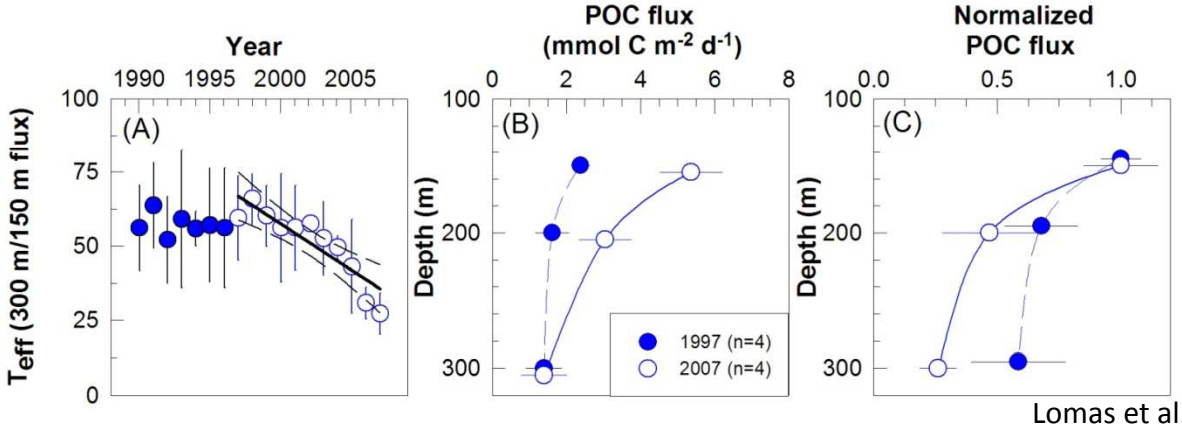
Lomas et al. 2010





Lomas et al. 2010

BATS/ Multi-year Variability/ Particulate Matter Remineralization/



Lomas et al. 2010

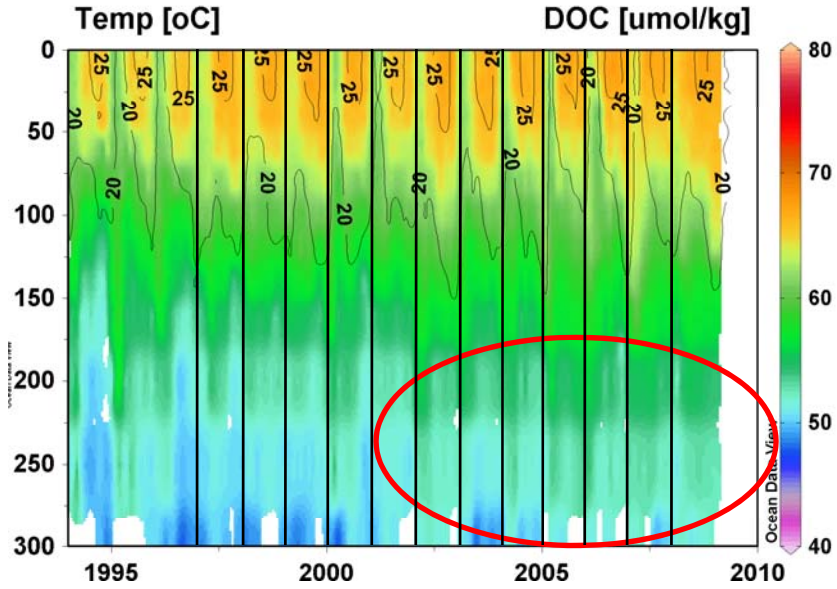
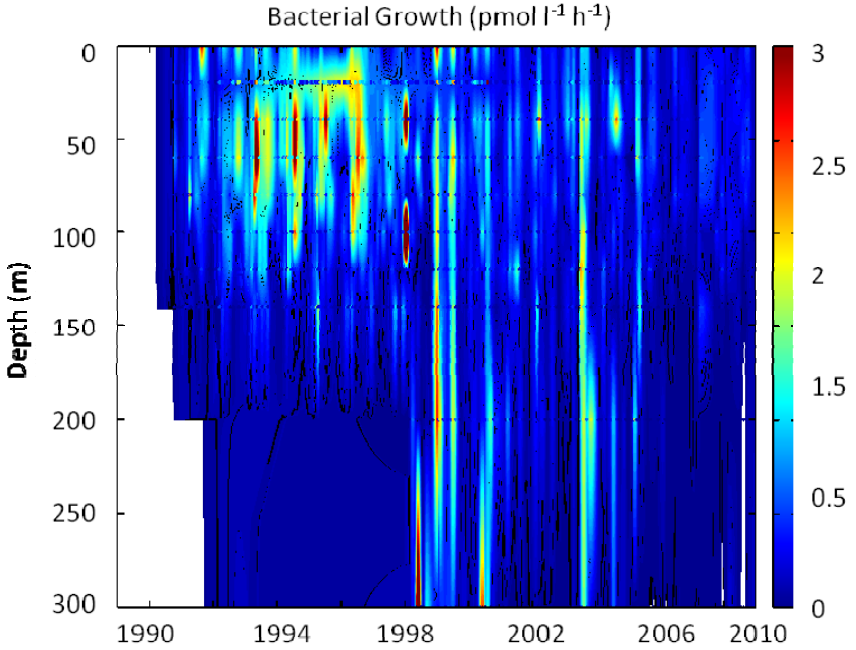


Figure courtesy of Dennis Hansell, modified.

POC more extensively remineralized,

[DOC] higher, deeper and not being consumed as completely through the year.

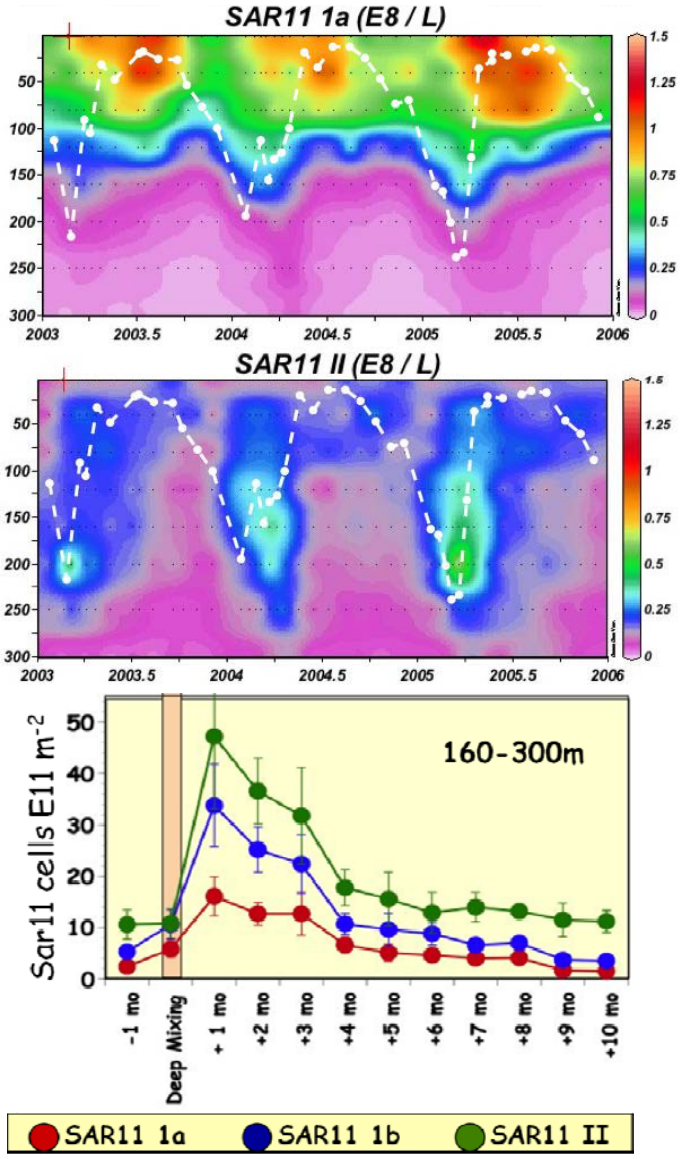
BATS/ Multi-year Variability/ Particulate Matter Remineralization/



BATS unpubl.

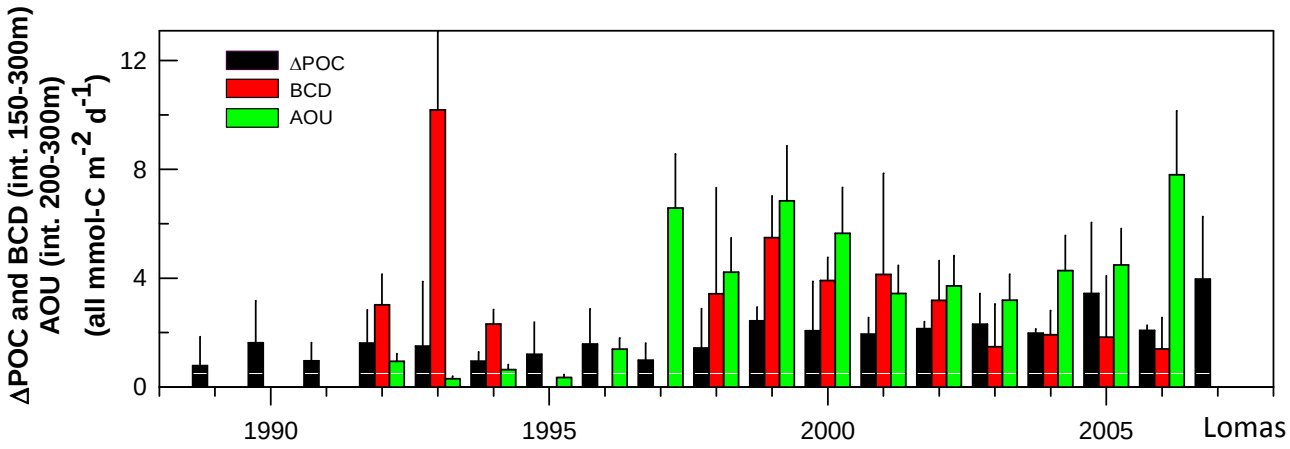
Changes in bacteria in response to dissolved organic matter inputs via convection.

What about in response to enhanced availability due to POC remineralization?

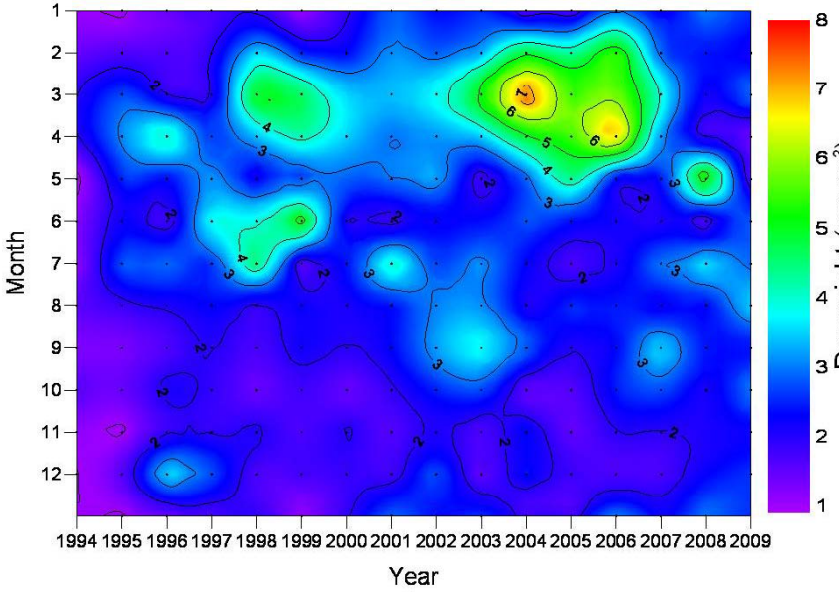


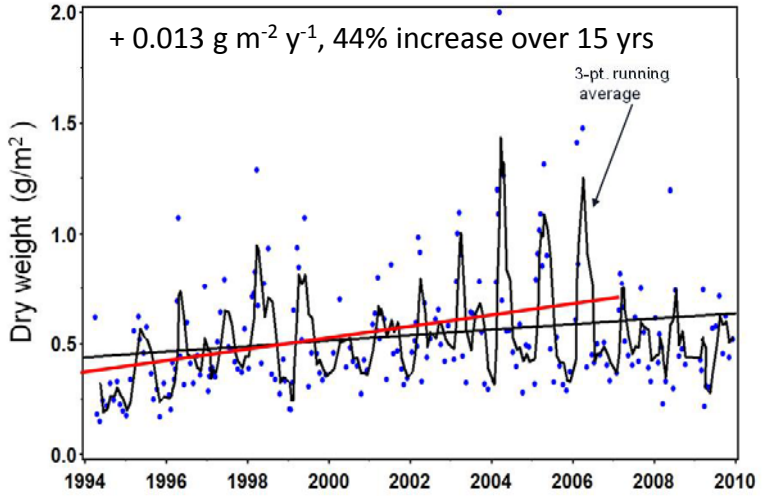
Carlson et al. 2009

BATS/ Multi-year Variability/ Particulate Matter Remineralization/



Lomas et al. 2010

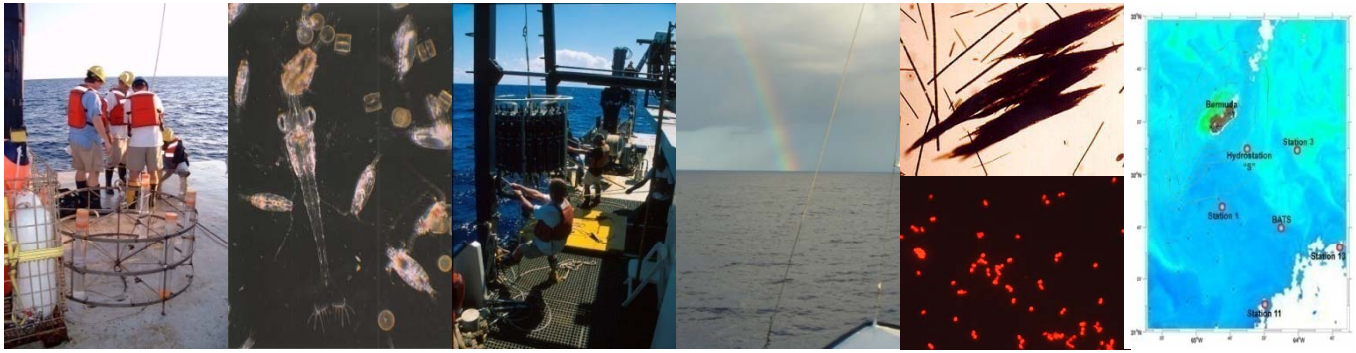




Steinberg et al. in prep.

OBJECTIVES OF THIS TALK…

1. Present patterns in the 22-year data records.
2. Identify what we now think we are missing (e.g., eddies, mesopelagic ecosystem) to understand the original objectives.
3. Present brief overview of a future “integrated time-series platform”



Future research topics to understand original objectives:

1. What are drivers of episodic/patchy biogeochemical events – atmospheric inputs, eddies, convergent zones?

2. Eddies: mesoscale variability of the Sargasso Sea potentially masks the impact of atmospheric forcing over annual or shorter timescales, but what about year-over-year predictions of climate forcing?

3. How does plankton community structure change in response to short-term and long-term forcing and how does this affect C flux (events vs. trends)?

4. The mesopelagic: What are the regeneration length scales of individual elements? Role of chemoautotrophy?

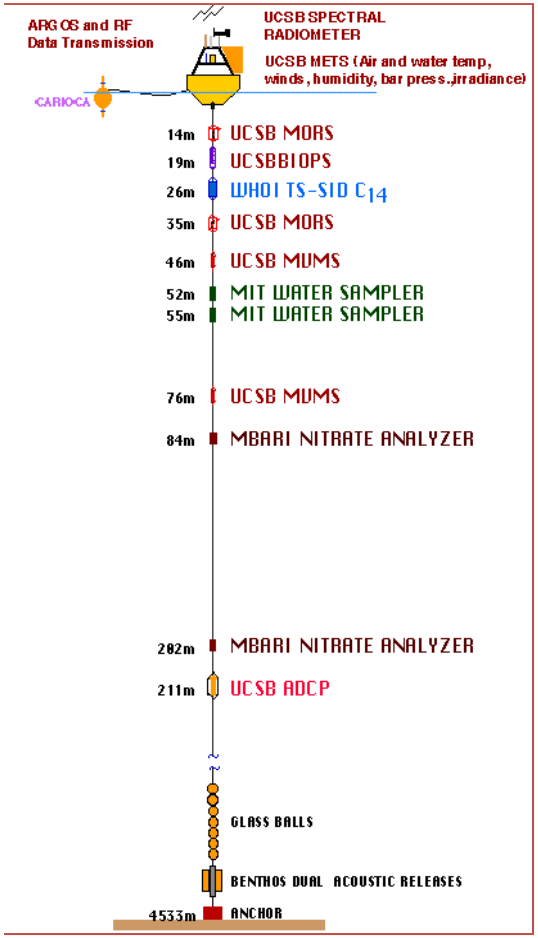
5. How do we define the right timescales to assess the natural versus anthropogenic signal?

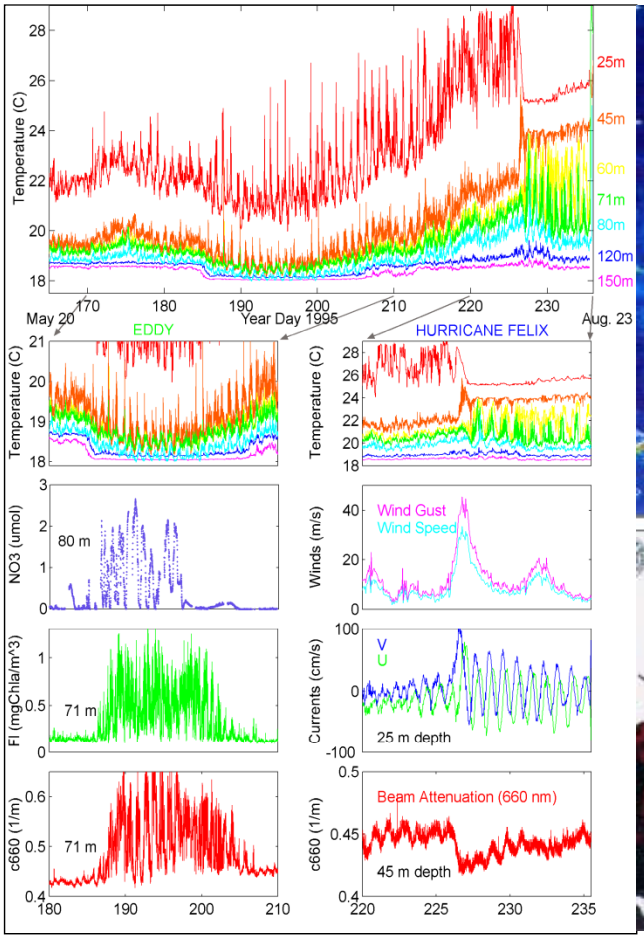
6. Have we defined all the ecosystem processes?

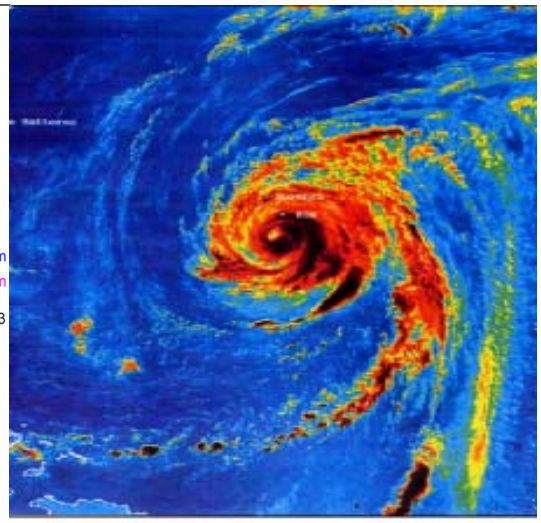
Integrated Time-series Platform: coordinated integration of ship-based underway sensors, **moorings** and floats.

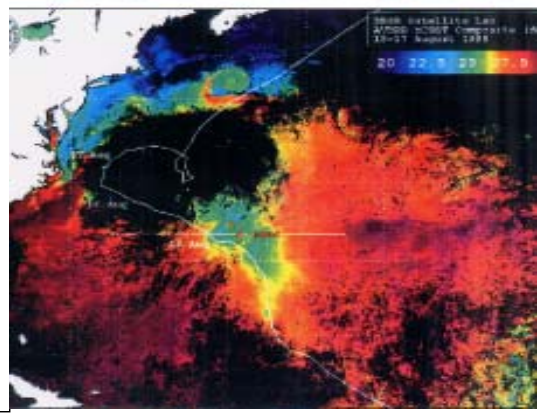
Topic 1 & 2, episodic events over time

Bermuda Testbed Mooring (e.g., Dickey et al. 2001)





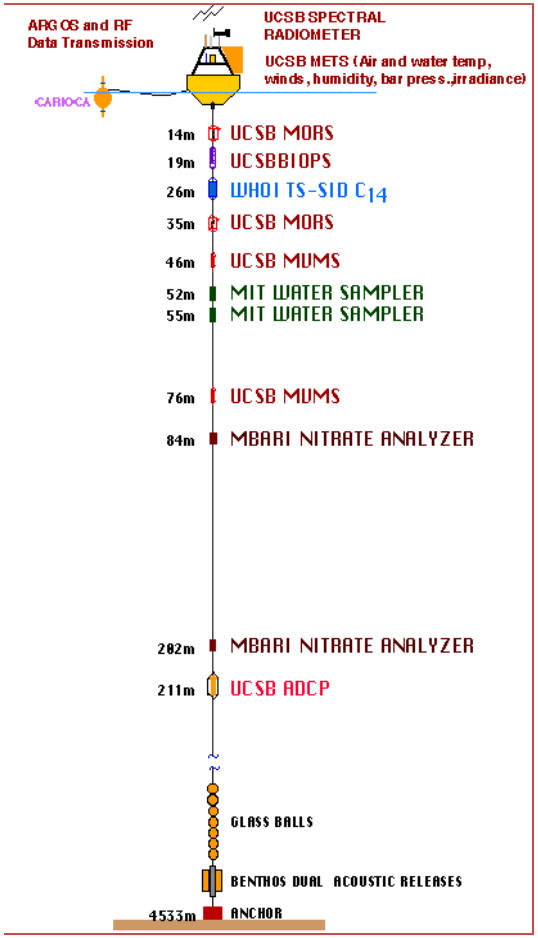




Integrated Time-series Platform: coordinated integration of ship-based underway sensors, **moorings** and floats.

Topic 1 & 2, episodic events over time

"Future" Bermuda Mooring



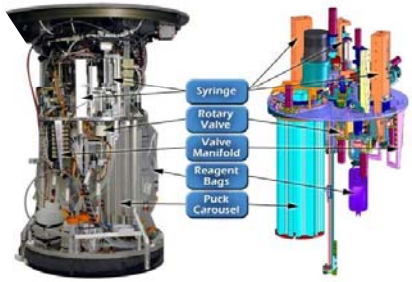
Particulate matter sampler (McLane)

UV nitrate analyzer (Satlantic)

Submersible incubation devic (Craig Taylor, WHC

Submersible flow cytometer (Cytobuoy, Inc)

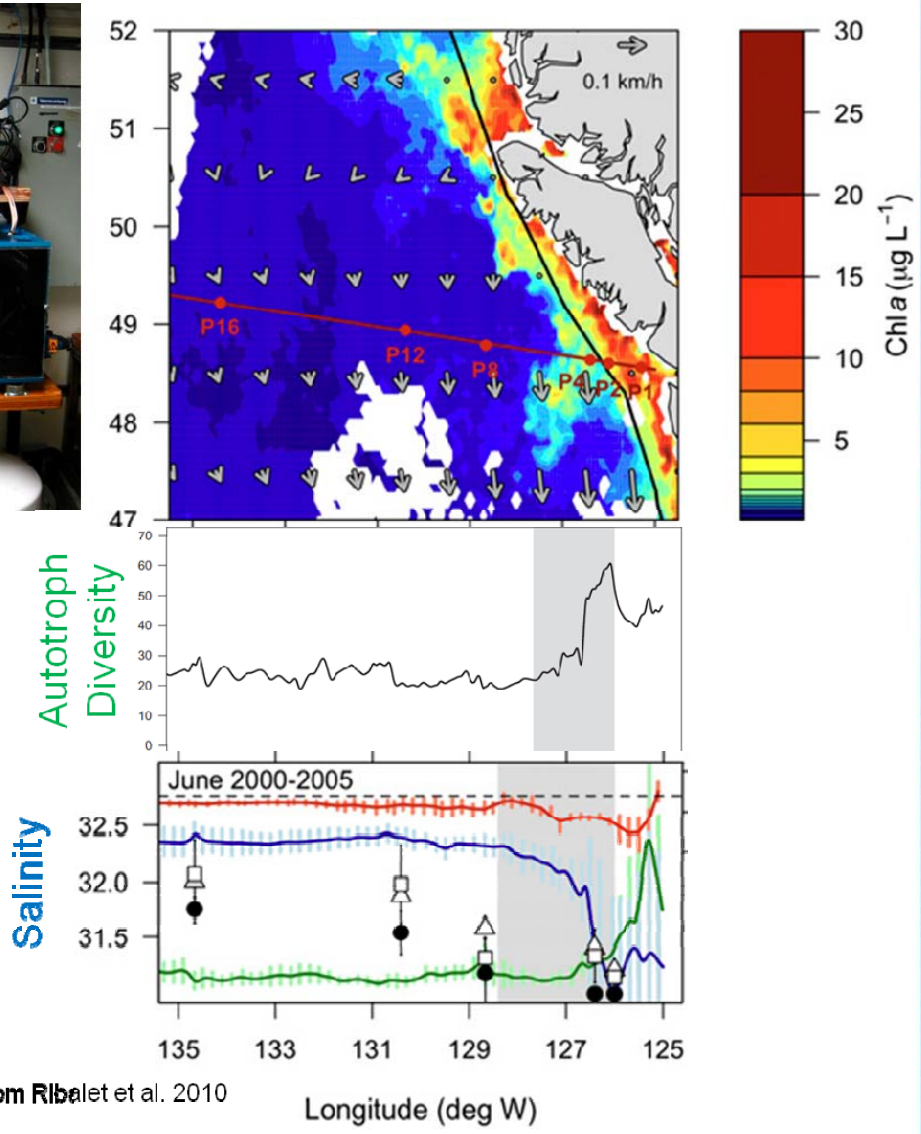
Environmental sample processor



Integrated Time-series Platform: coordinated integration of **ship-based underway sensors**, moorings and floats.

Topic 3 (parts of)

SeaFLOW – position sensitive underway flow cytometer. Highlights small scale spatial variability (great for coordinating with satellite data products.

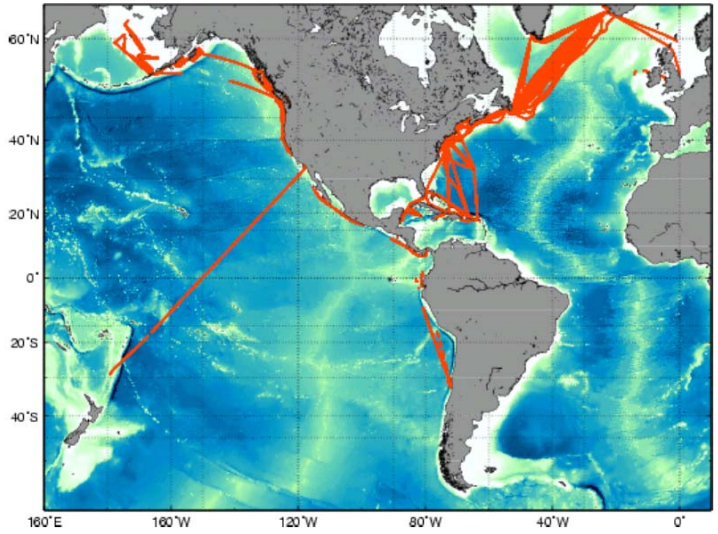


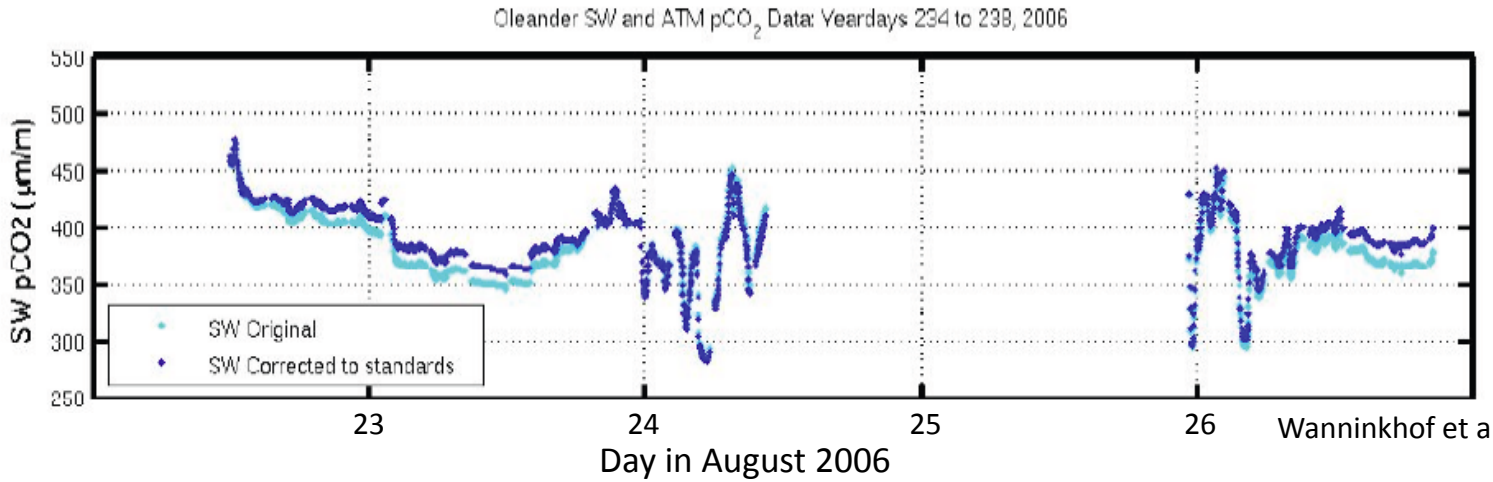
Modified from Ribalet et al. 2010

Integrated Time-series Platform: coordinated integration of **ship-based underway sensors**, moorings and floats.

NOAA underway pCO_2 VOS program

Topics 1 & 3





Wanninkhof et al. 2007

Integrated Time-series Platform: coordinated integration of ship-based underway sensors, moorings and **floats**.

APEX Float program (Johnson et al.)

Topics 1, 2 & 4 (parts of)

Floats provide a combination of temporal data and 'drifting' spatial data

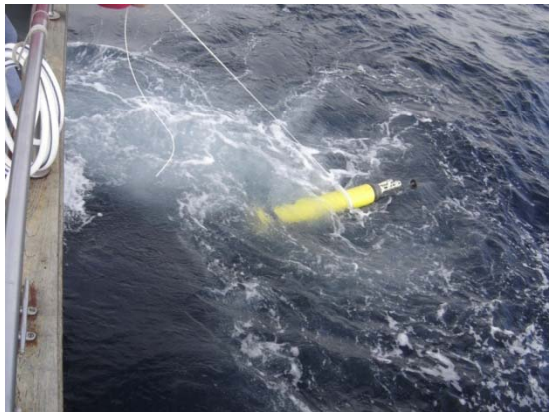
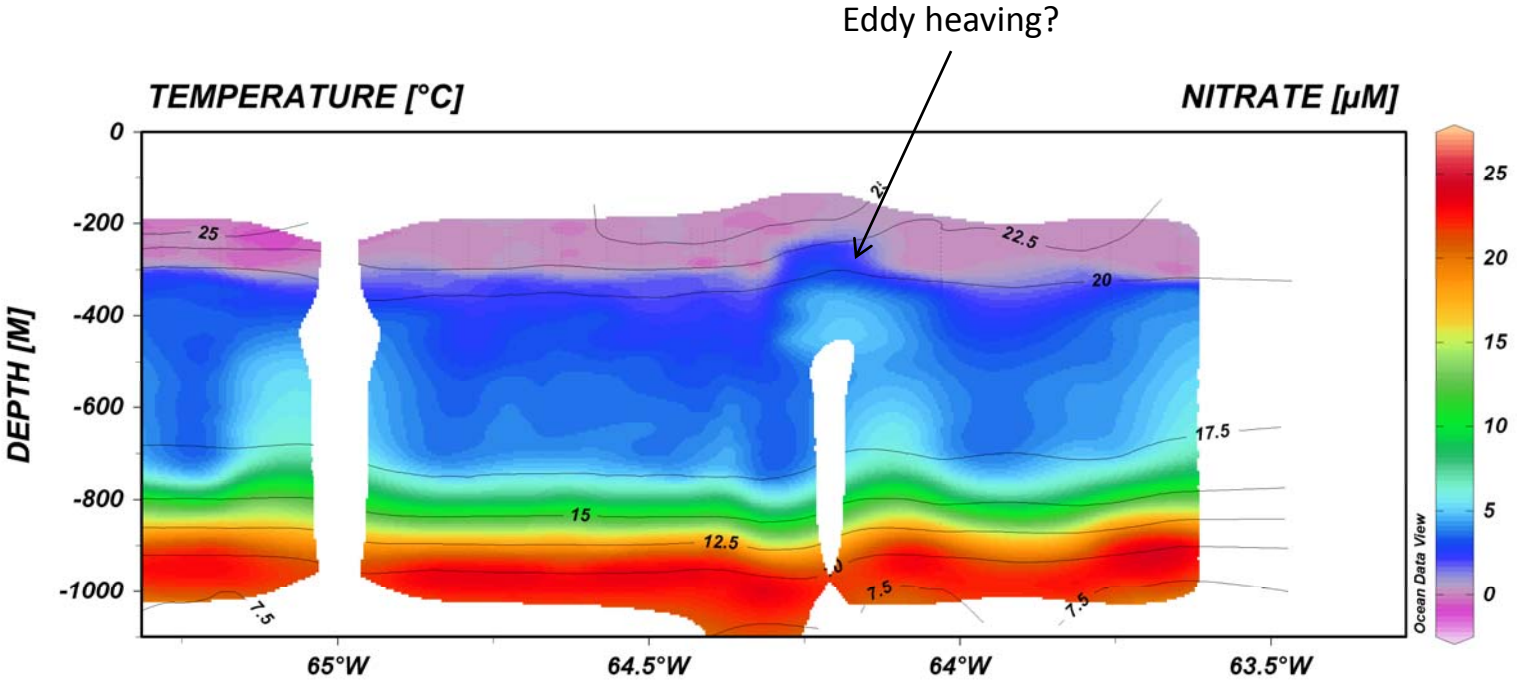


Photo credit: Ken Johnson

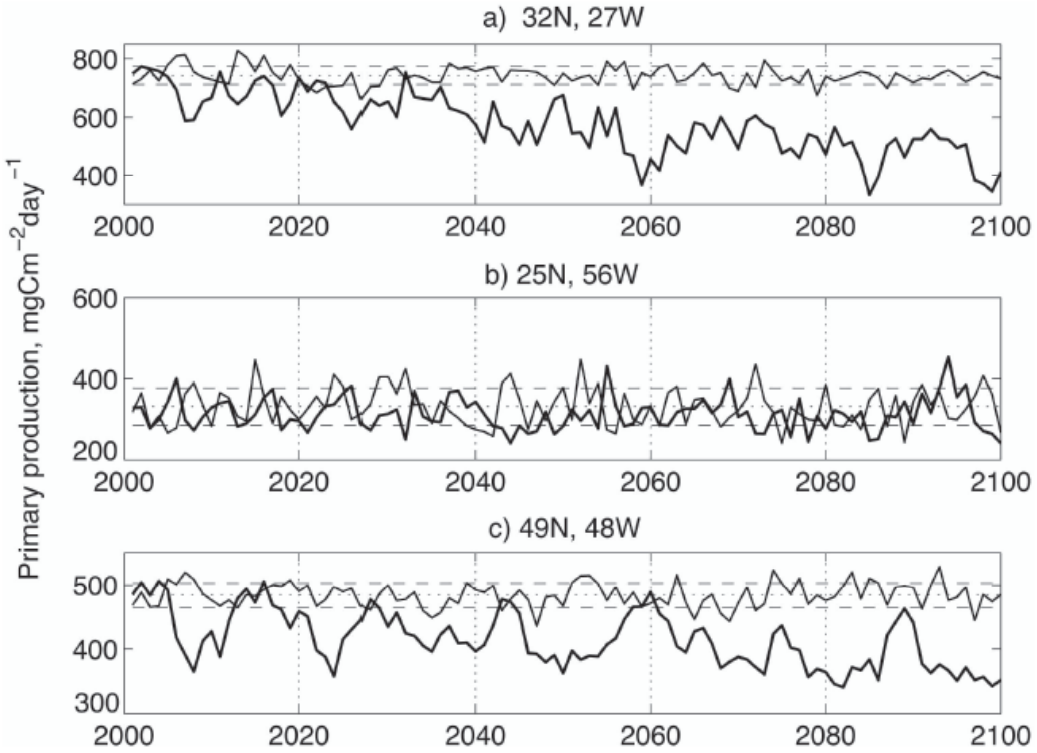


Future research topics to understand original objectives:

5. How do we define the right timescales to assess the natural versus anthropogenic signal?

6. Have we defined all the ecosystem processes?

Year when 'global warming' signal can be detected.



Henson et al. 2010

Thanks to:

All the BATS technicians and project scientists, past and present, whose diligence and dedication have assisted in the collection of the data and publication of the results presented in this talk.

Members of the international oceanographic community who have supported BATS both in the peer-review process and through ancillary projects.

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National Science Foundation
WHERE DISCOVERIES BEGIN
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