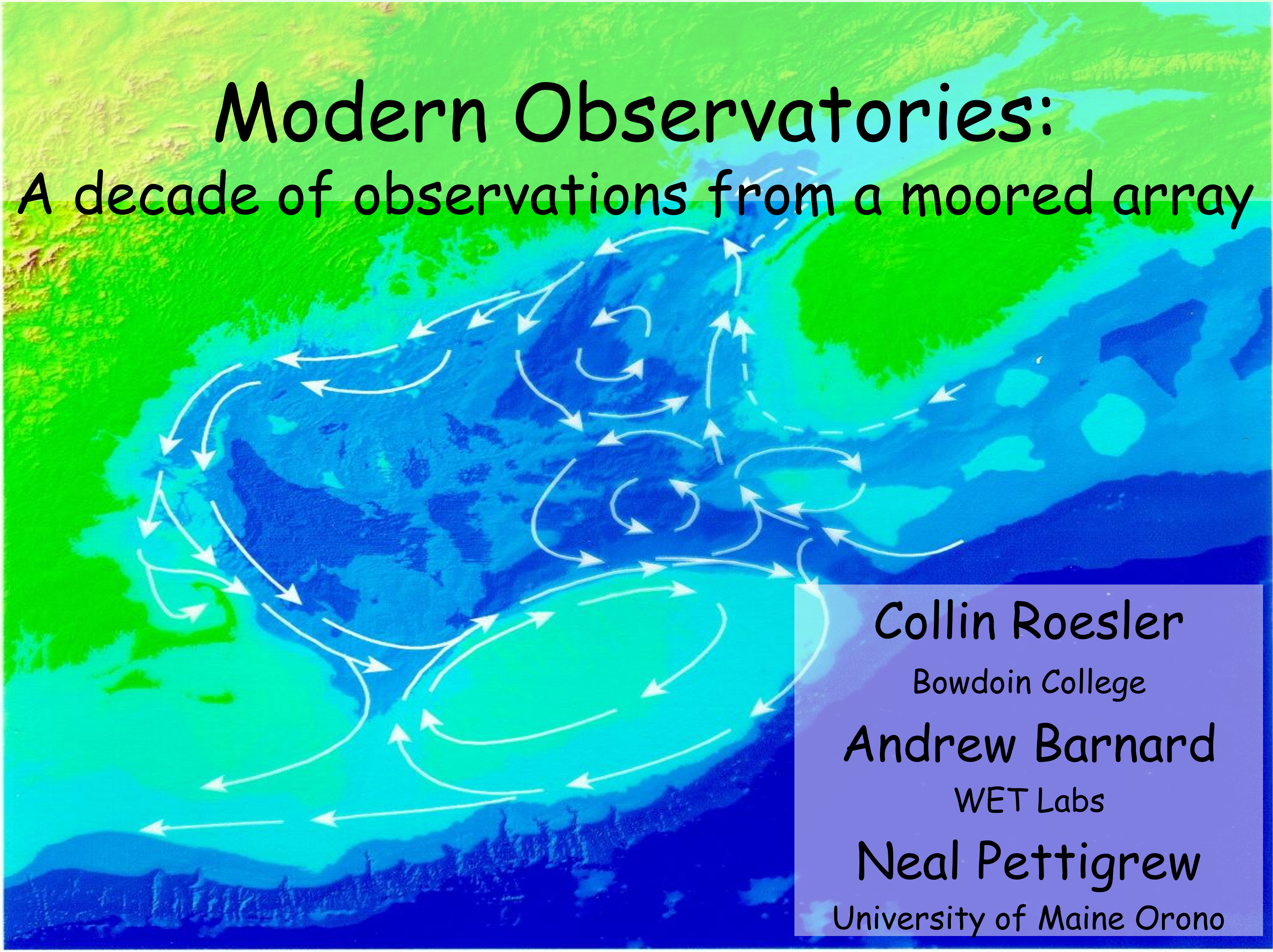
Modern Observatories:

A decade of observations from a moored array



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WET Labs

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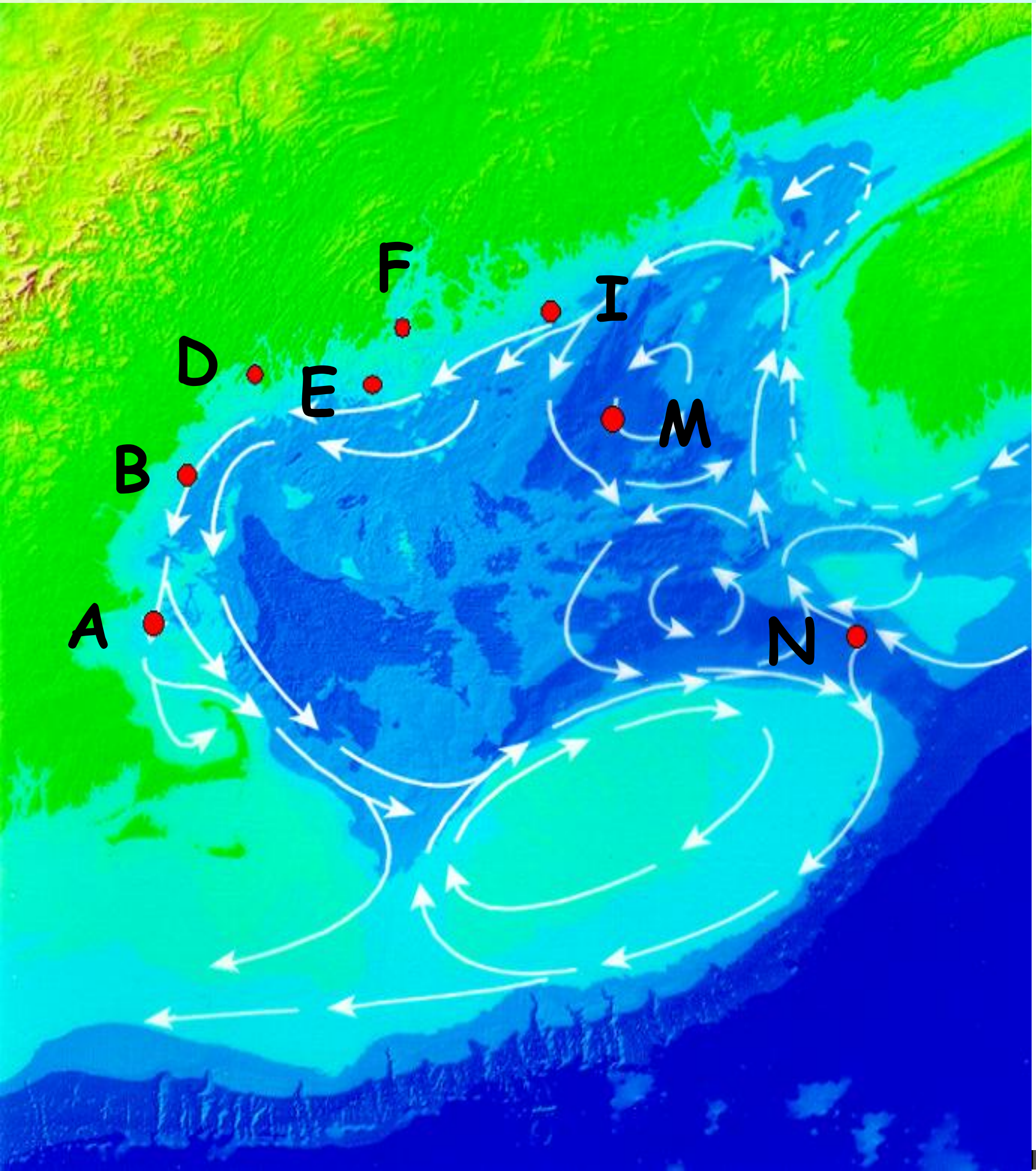
Questions we asked when designing the observing network:

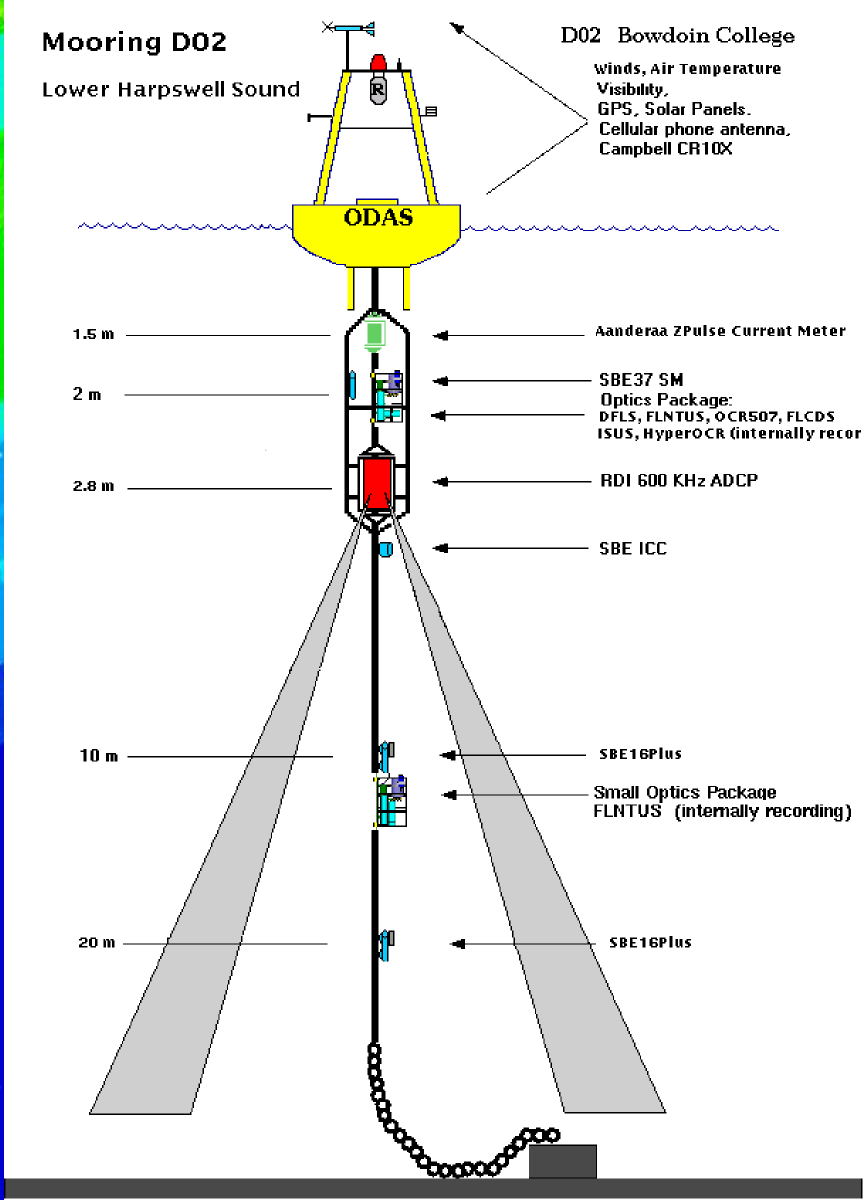
- Timing of Blooms
- Intensity of Blooms
- Duration
- Geographic patterns
- Interannual variability
- Coherence with stability

Sustained Ocean Observatories
"*It takes a village…*"

- Sustained Funding
  - ONR/ NOPP
  - ONR
  - NASA
  - MWRA
- Industry Support
  - WET Labs
  - Satlantic
- Dedicated Personnel
  - Environmental Optics Lab (A. Barnard, H. Franklin, B.Thompson, D. Abraham, M. Sauer, S. Drapeau)
  - PhOG (N. Pettigrew, J. Wallinga, L. Mangum, R. Stessel, R. Bell, R. Fleming, J. Evans, N. Fisher)

Buoy Array and Buoy Schematics





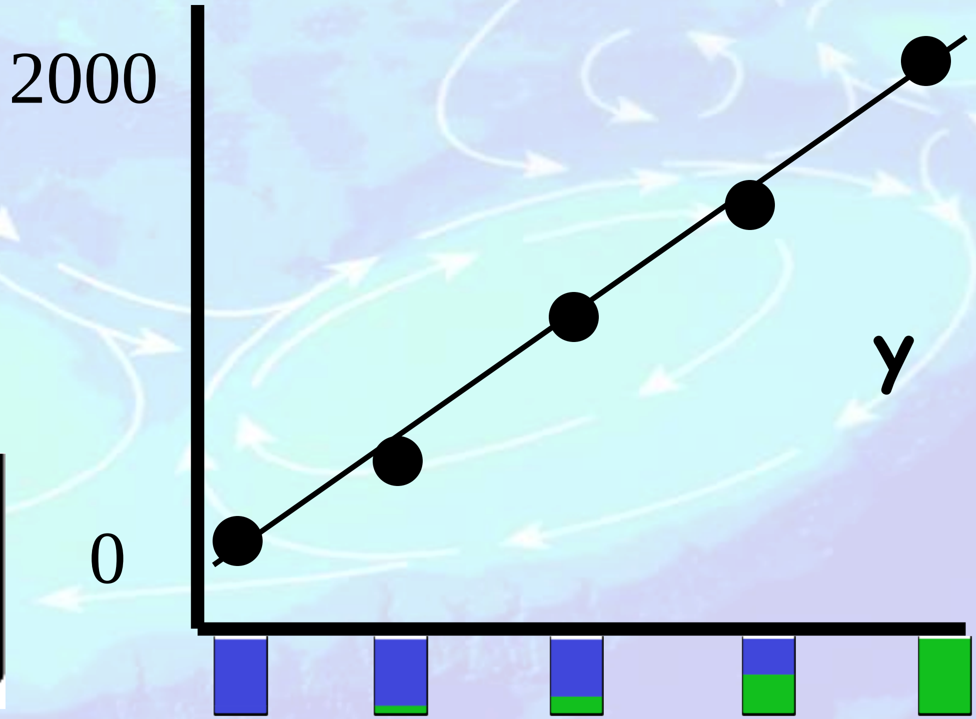
Observational necessities/solutions

- absolute calibration over observatory lifetime
  - pre- and post- calibration at factory
- relative calibrations between deployments
  - pre- and post-calibration in house, intersensor comparisons and tracking

In-lab calibration

- Calibration of Slope parameter, m (V → mg/m^3)
  - Sensor response to standard culture (controlled growth conditions)

live culture

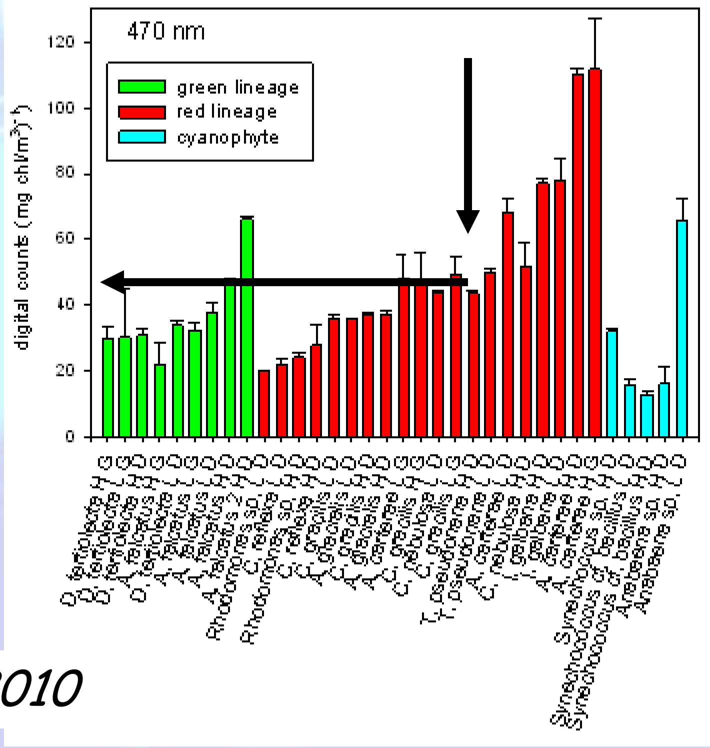


extracted culture

$$y = m * x + b$$

In-lab calibration

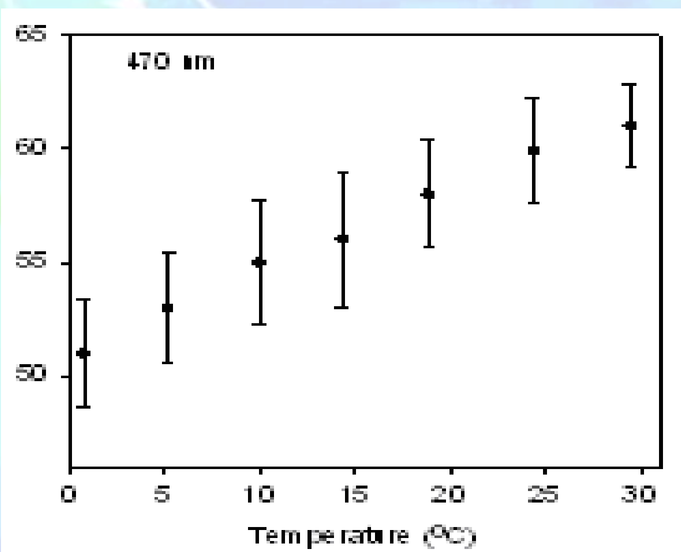
- Calibration of Slope parameter, m (V → mg/m^3)
  - Sensor response to standard culture (controlled growth conditions)
  - Quantify Natural Variations in F_{chl}/[Chl]
    - Species (pigment composition)
    - Light history (pigment packaging)
    - Cell size (pigment packaging)
    - Growth phase
    - Fluorescence quenching

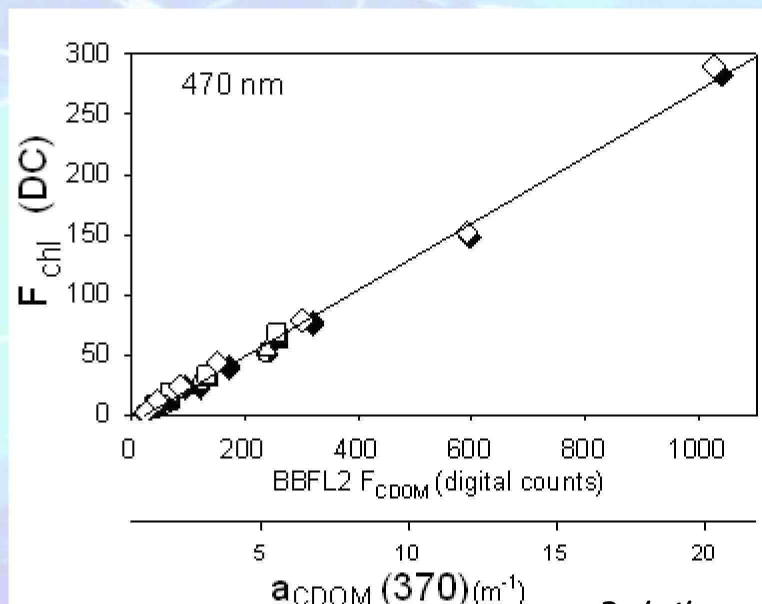


Proctor and Roesler 2010

Observational necessities/solutions

- absolute calibration over observatory lifetime
- relative calibrations between deployments
- environmental characterization
  - temperature responses
  - CDOM contamination





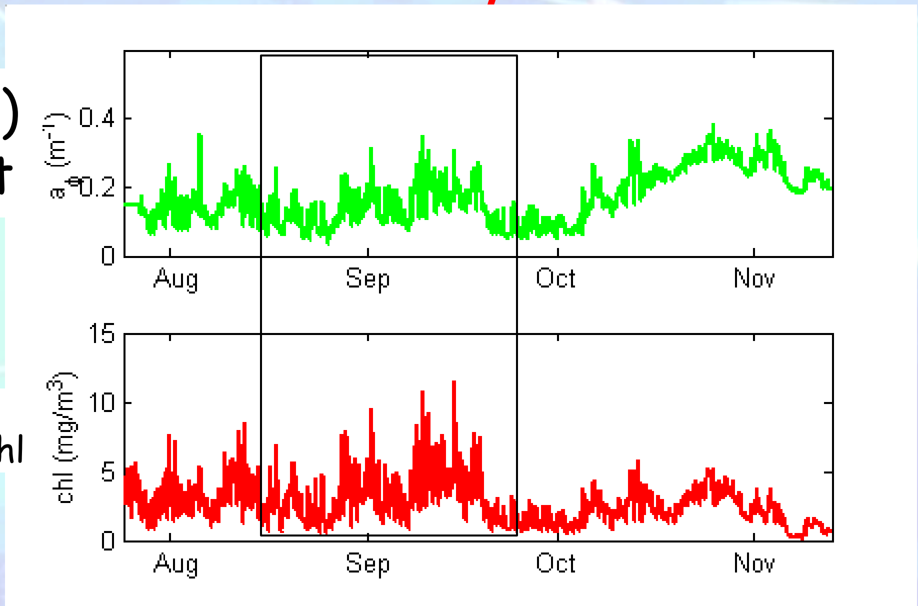
Belzile et al 2006, Proctor and Roesler 2010

Observational necessities/solutions

- absolute calibration over observatory lifetime
- relative calibrations between deployments
- environmental characterization
- drift and biofouling
  - in situ redundancy

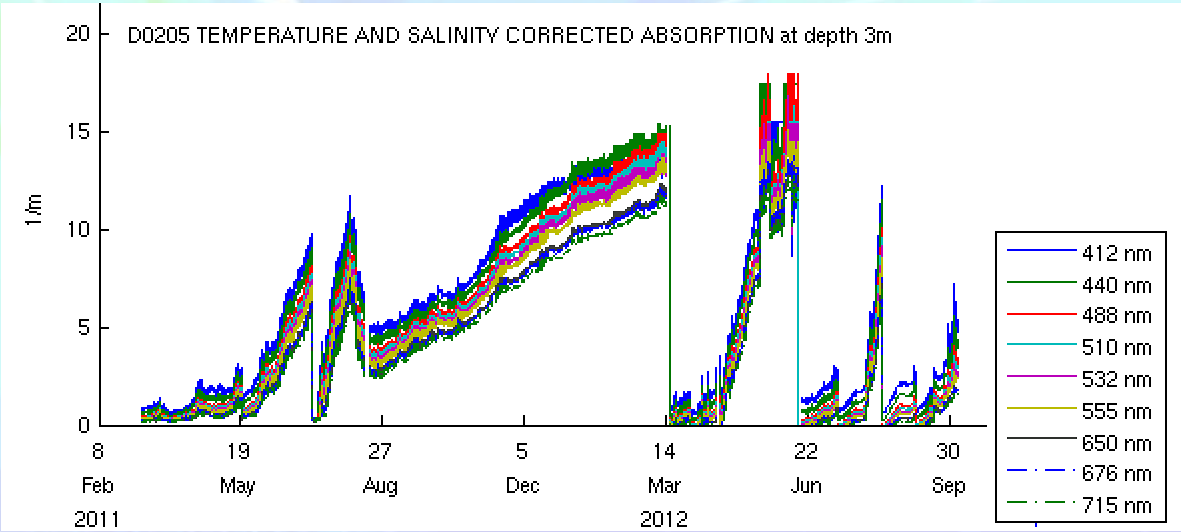
ac9 a(676)
line height

F_{chl}



Observational necessities/solutions

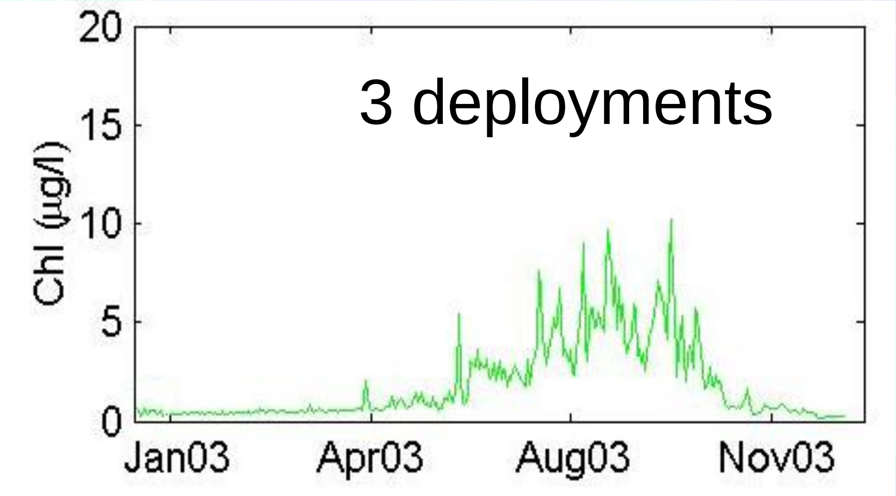
- absolute calibration over observatory lifetime
- relative calibrations between deployments
- environmental characterization
- drift and biofouling
  - in situ and recovery processing



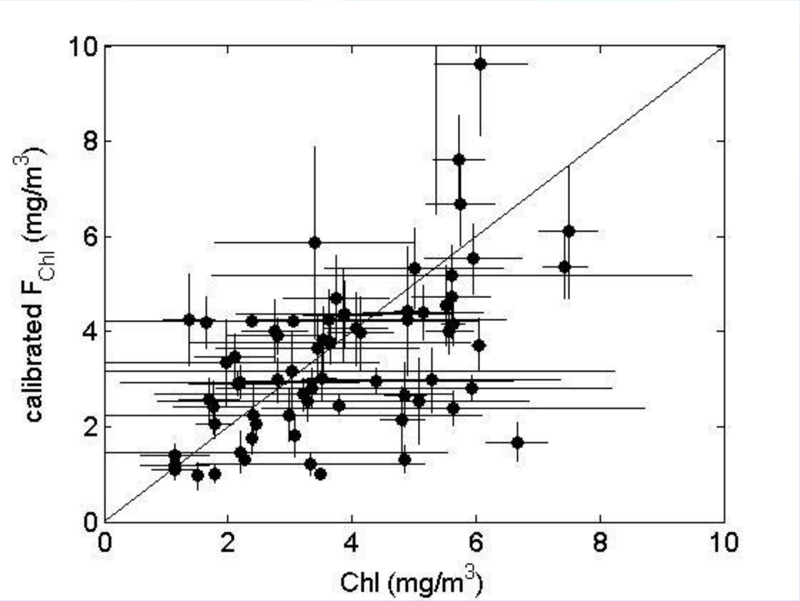
Roesler and Boss 2009

Calibration and Validation

Proctor, C.P., and C. S. Roesler. 2010
"New Insights on Obtaining Phytoplankton Concentration and Composition from in Situ Multispectral Chlorophyll Fluorescence."
Limnol. Oceanogr. Methods 8: 695-708.



- in situ samples, D02
- March-August, 2008 - 2011

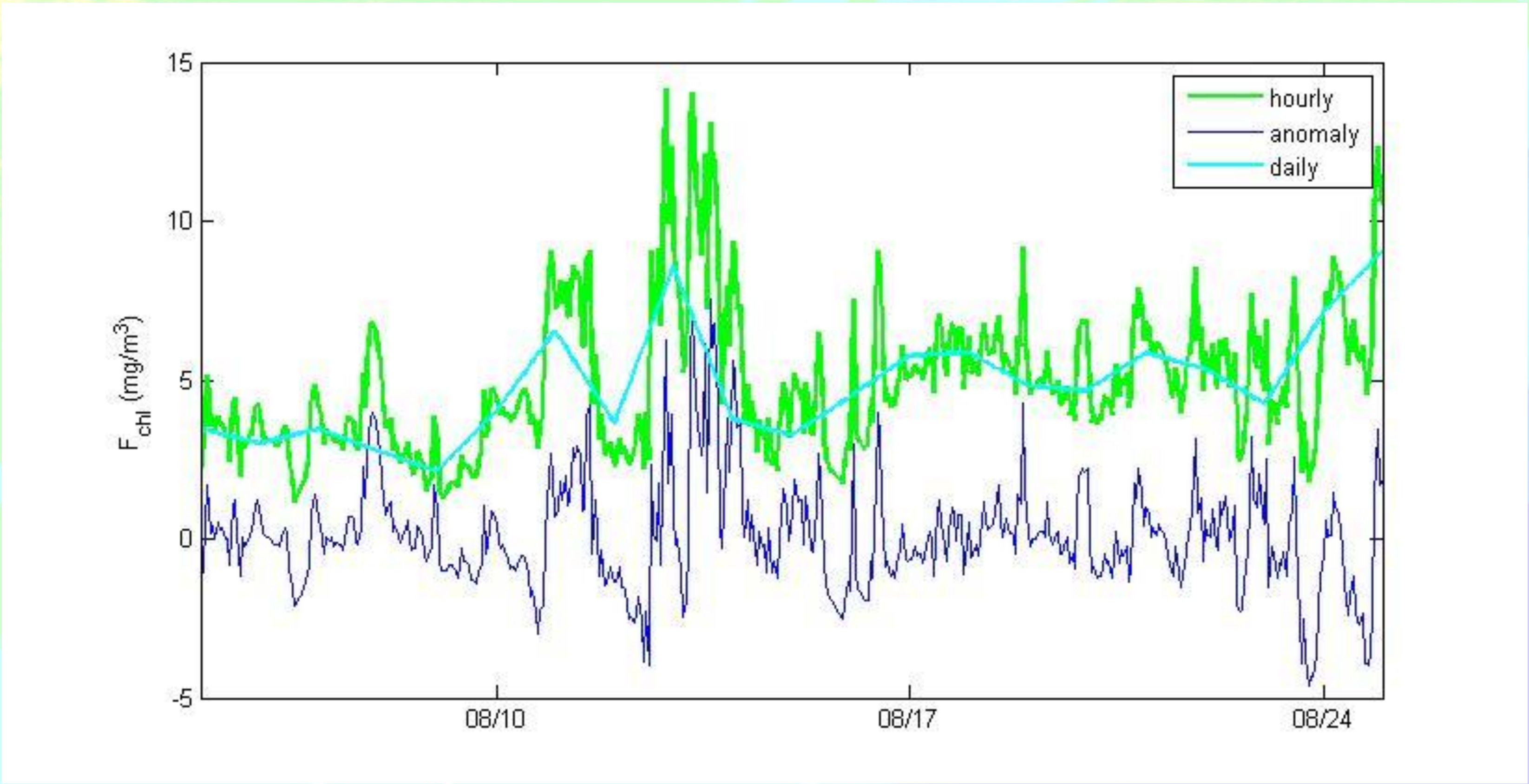


includes spatial-temporal sampling variations, species natural variability

Proxies for phytoplankton biomass

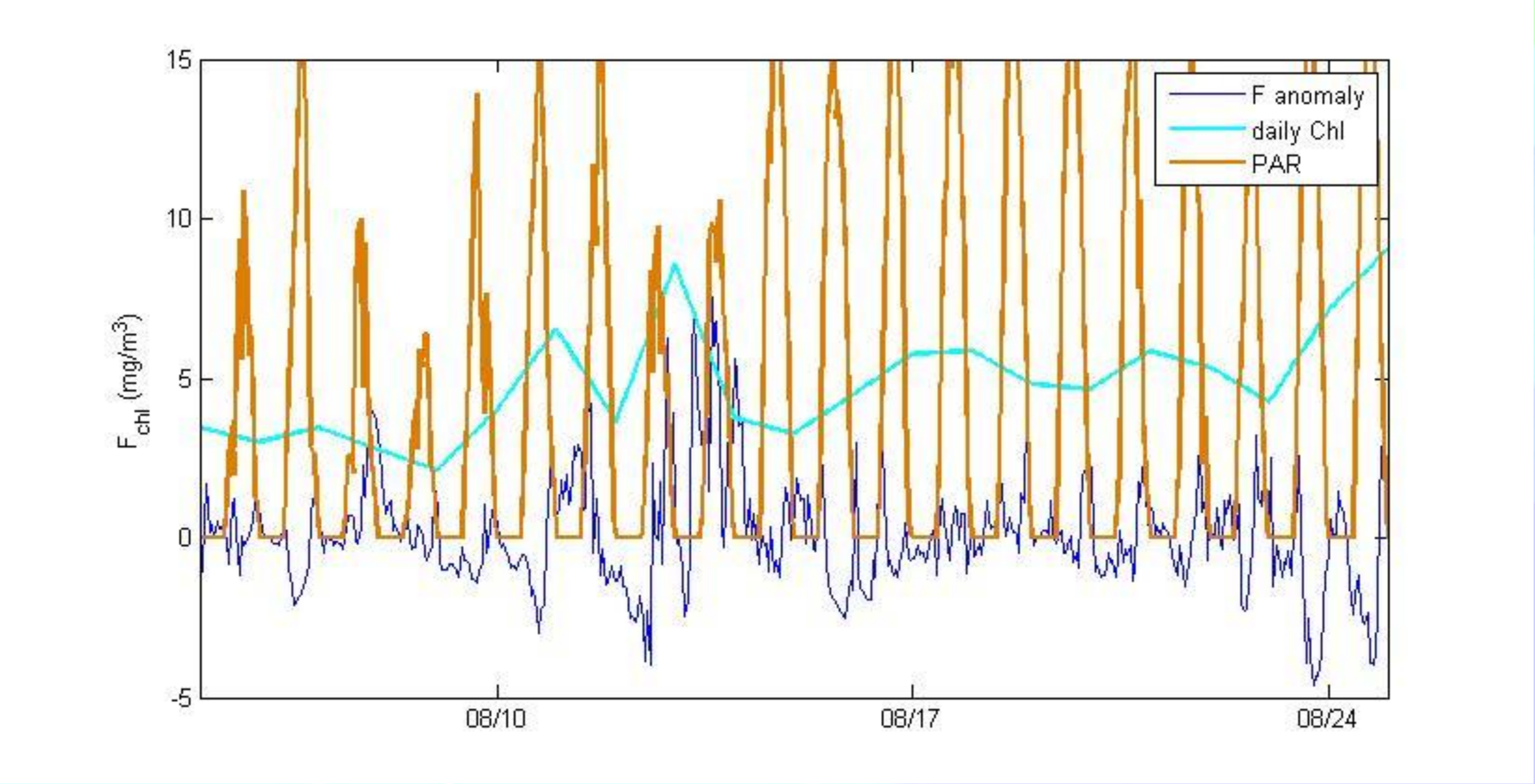
- Chlorophyll
- Chlorophyll Fluorescence

Hourly observations are biased by quenching



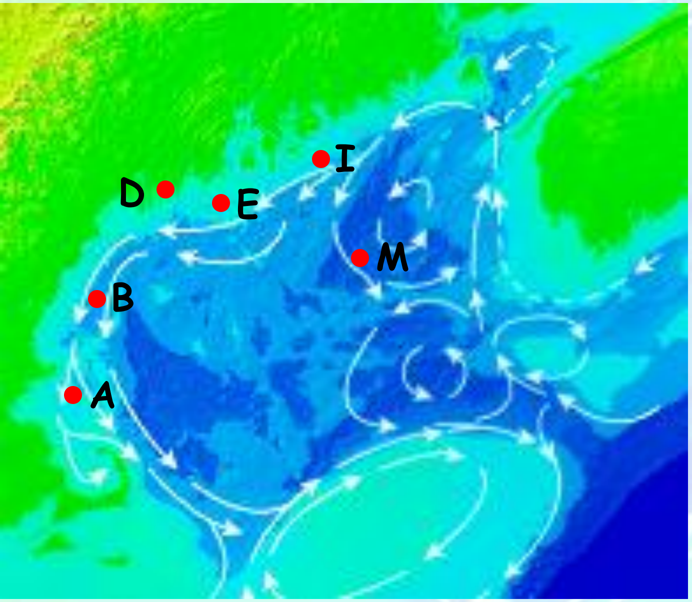
Anomaly = daily - hourly

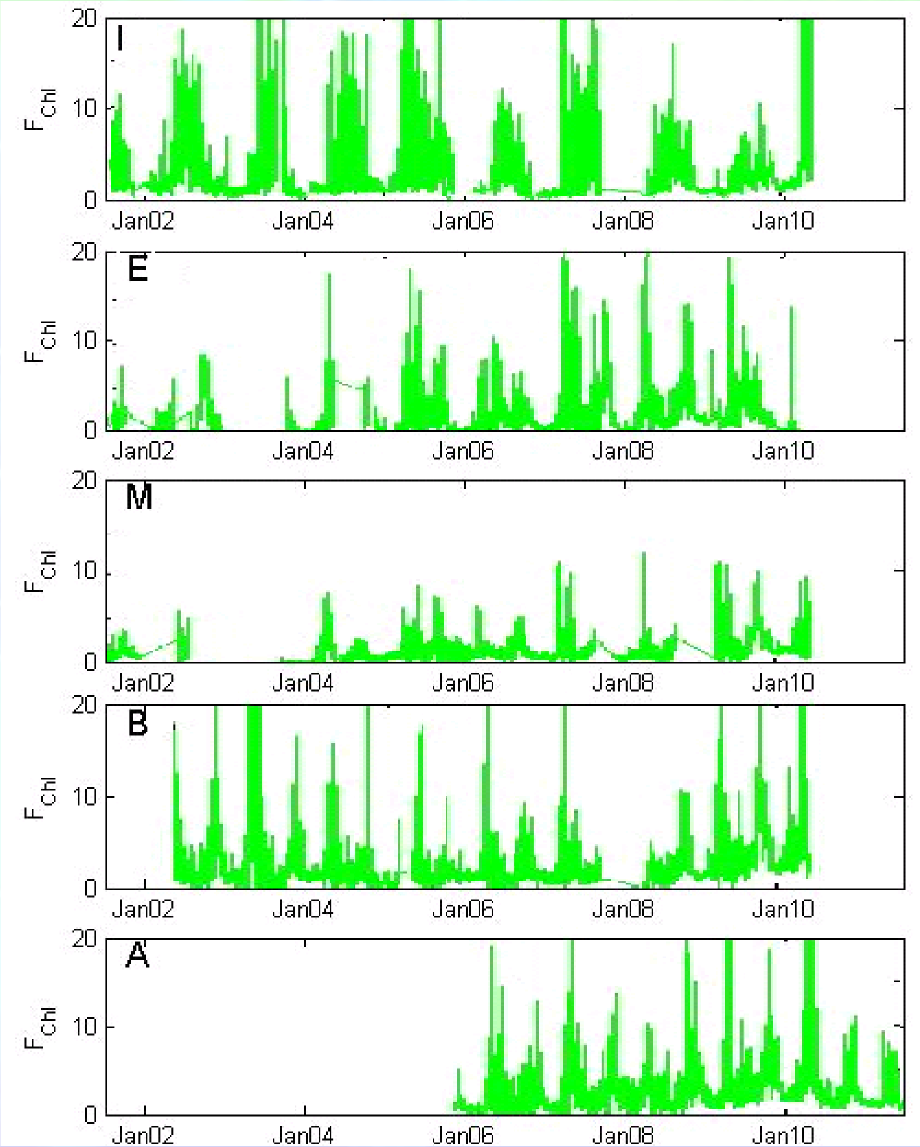
Hourly observations are biased by quenching



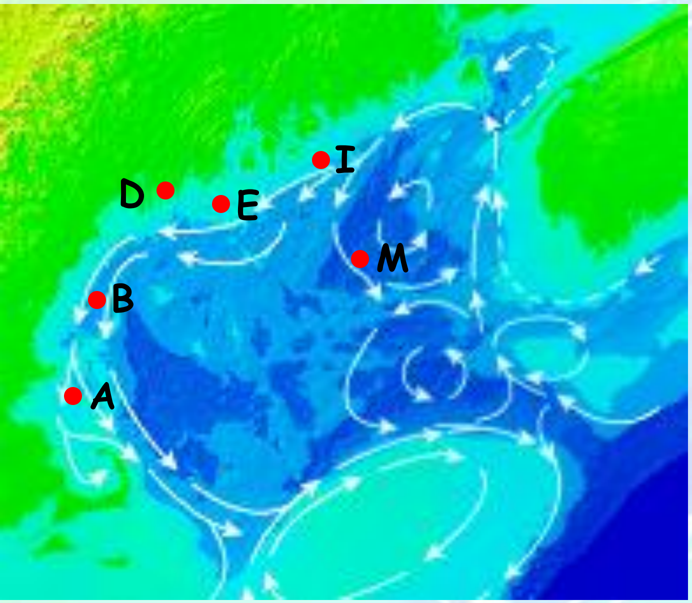
>60% hourly variations
Explained by NPQ in response to incident irradiance

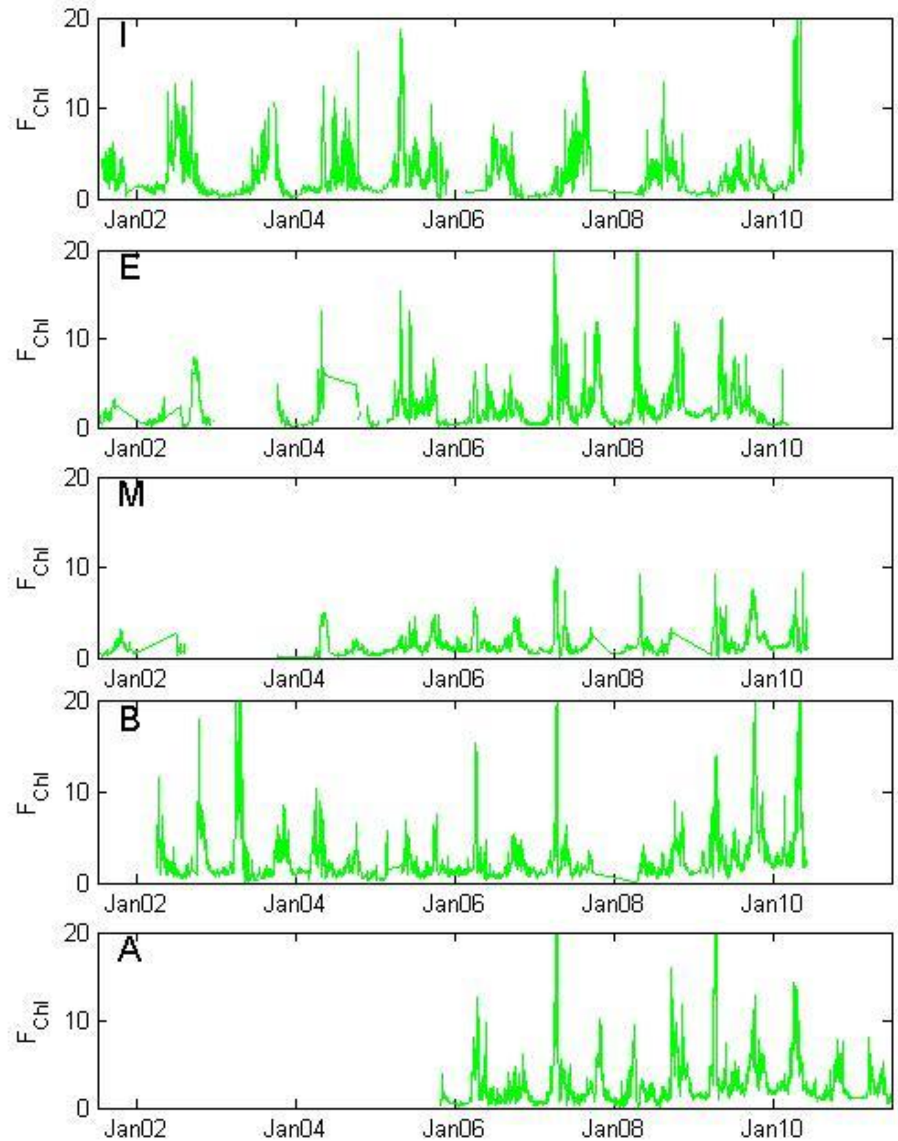
10 Years Hourly Chlorophyll Fluorescence





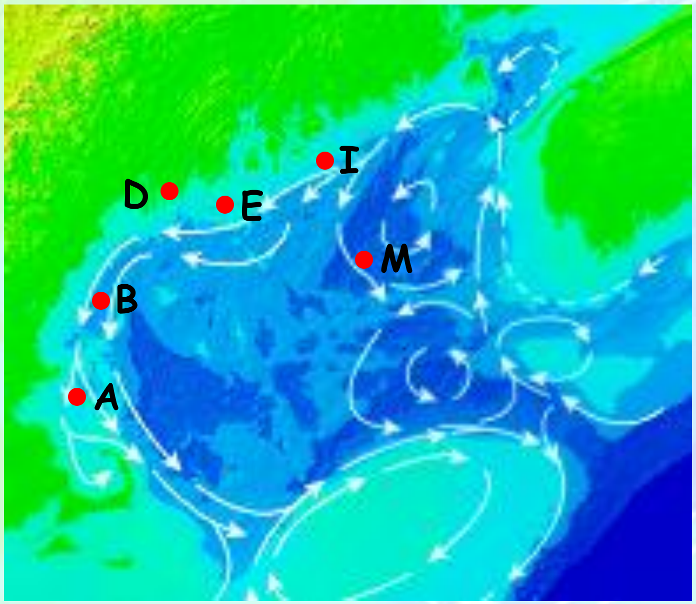
10 Years Daily Chlorophyll Fluorescence



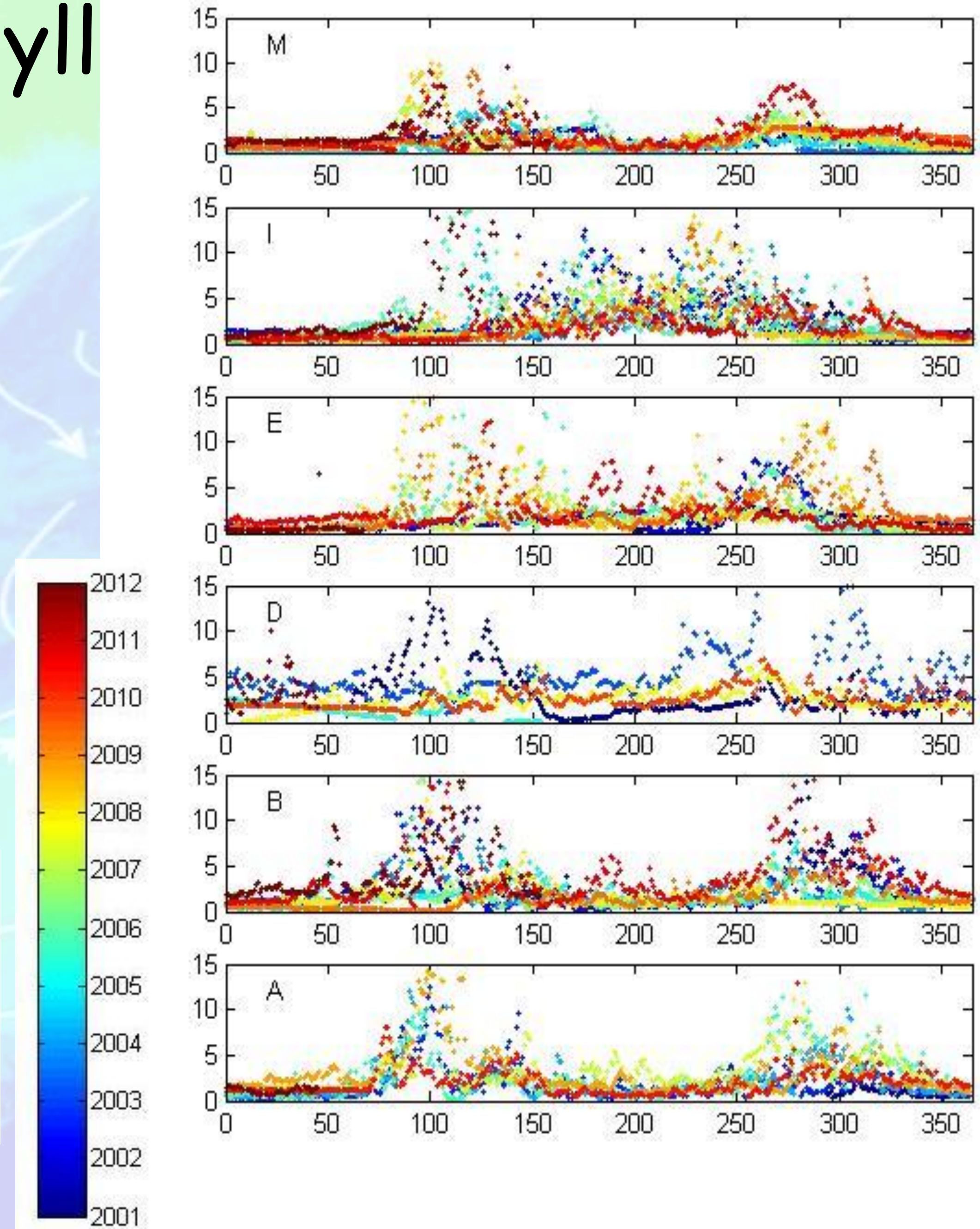


- bloom patterns
- variability

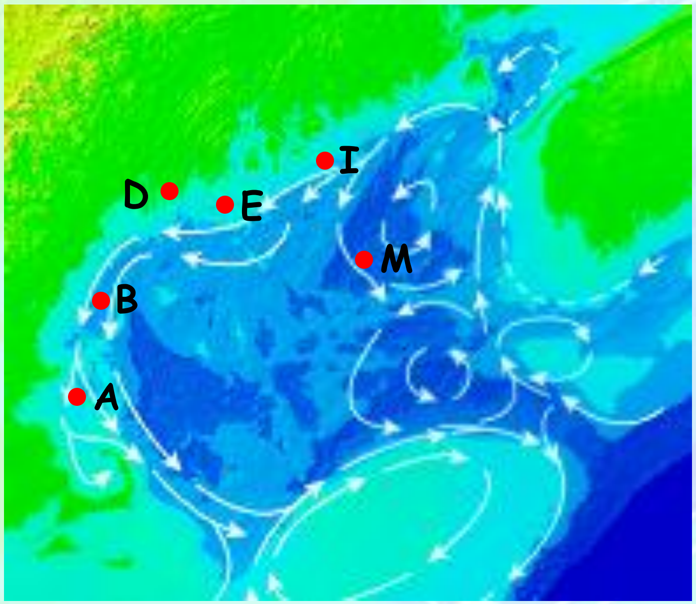
Annual Chlorophyll Fluorescence



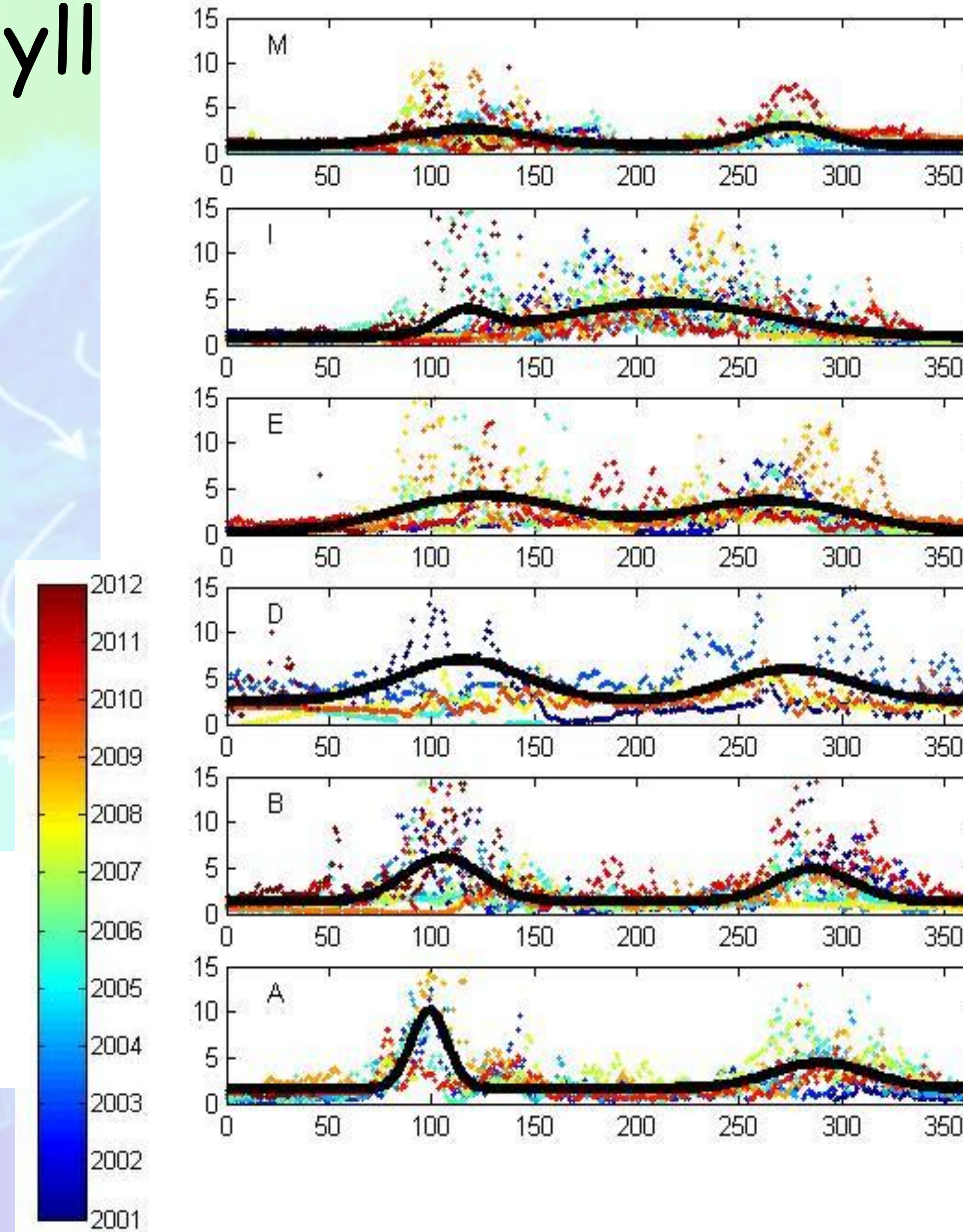
- variability
  - seasonal
  - interannual



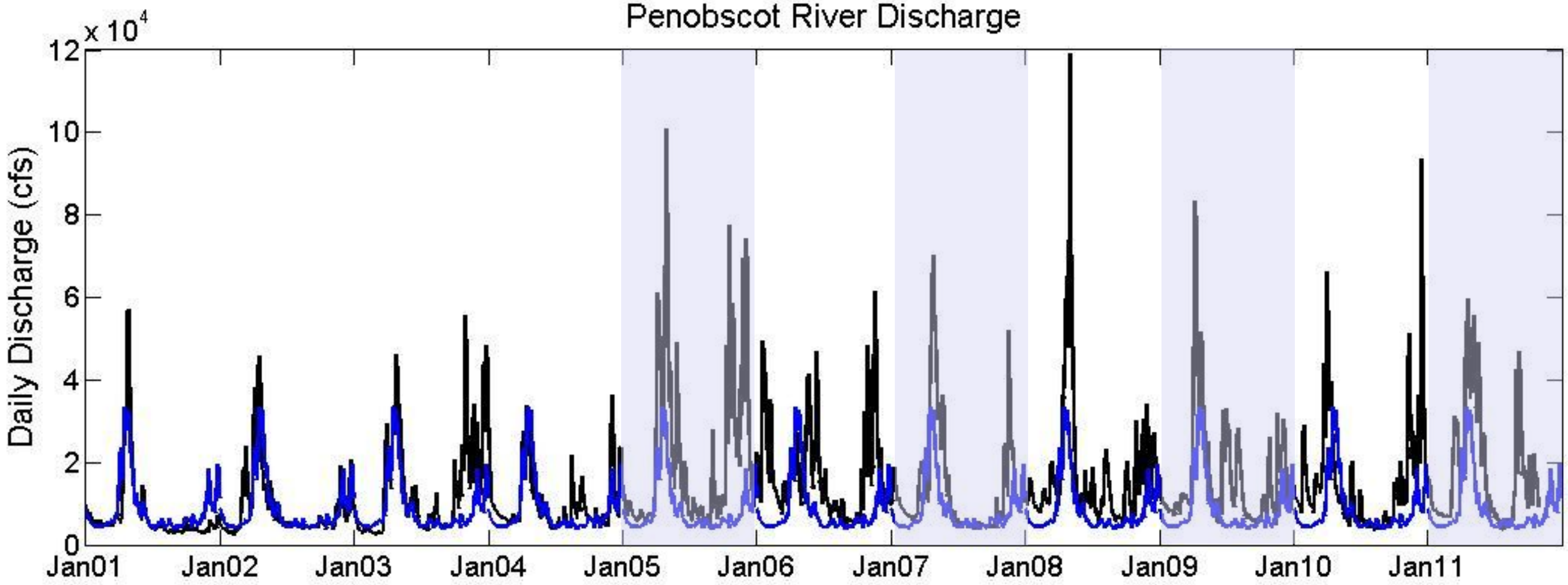
Annual Chlorophyll Fluorescence



- seasonal harmonics
- geographic trends

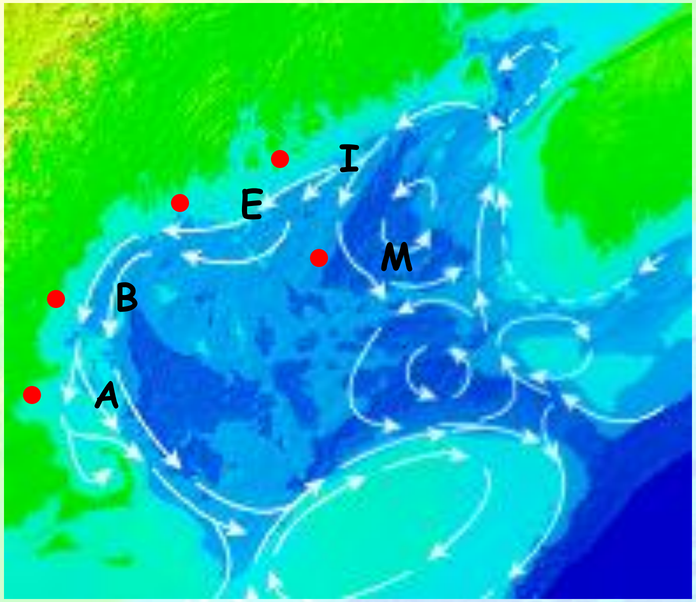


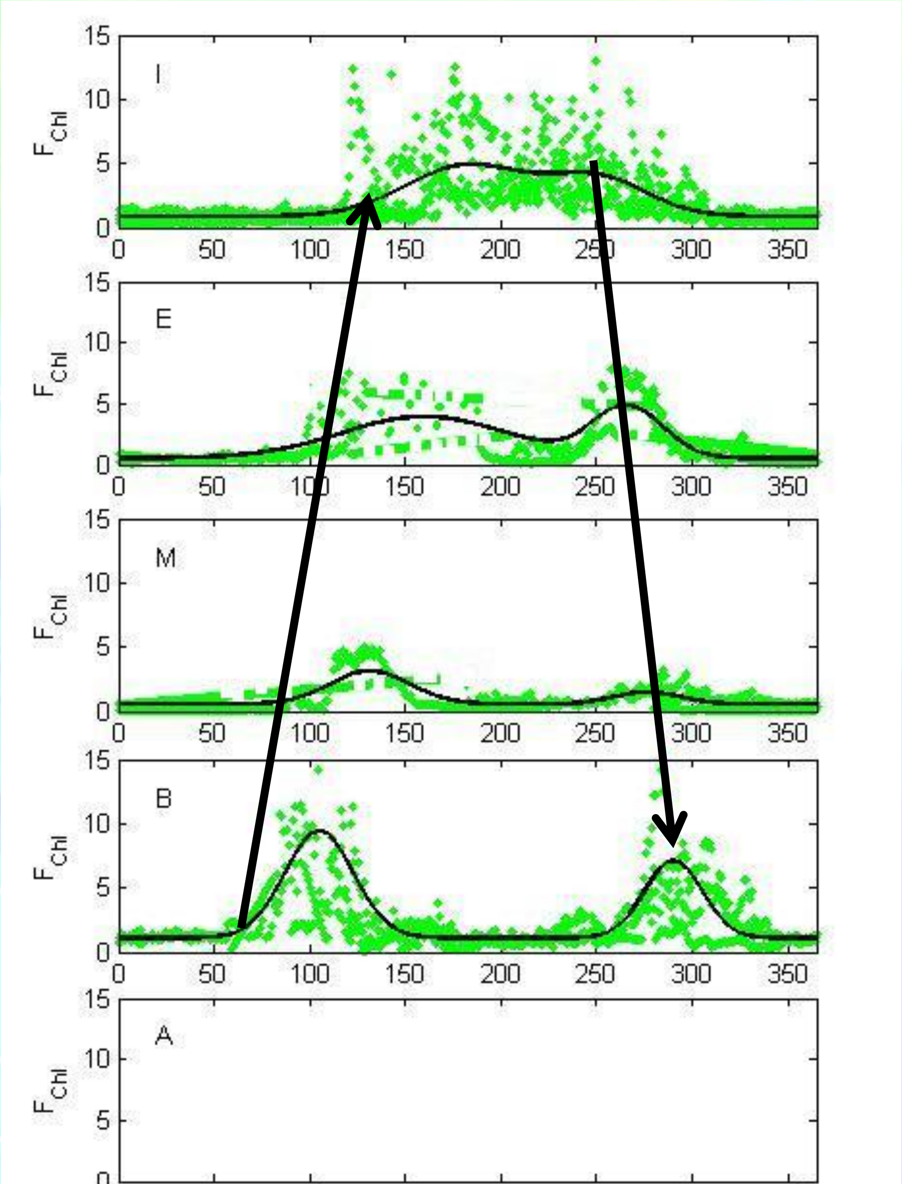
Living in Maine we notice



- 2004 last of a series of drought years
- 2005 Wettest year in a century
- 2006 Extremely wet summer
- 2007 topped 2006
- 2008 topped 2005 in maximal discharge
- …

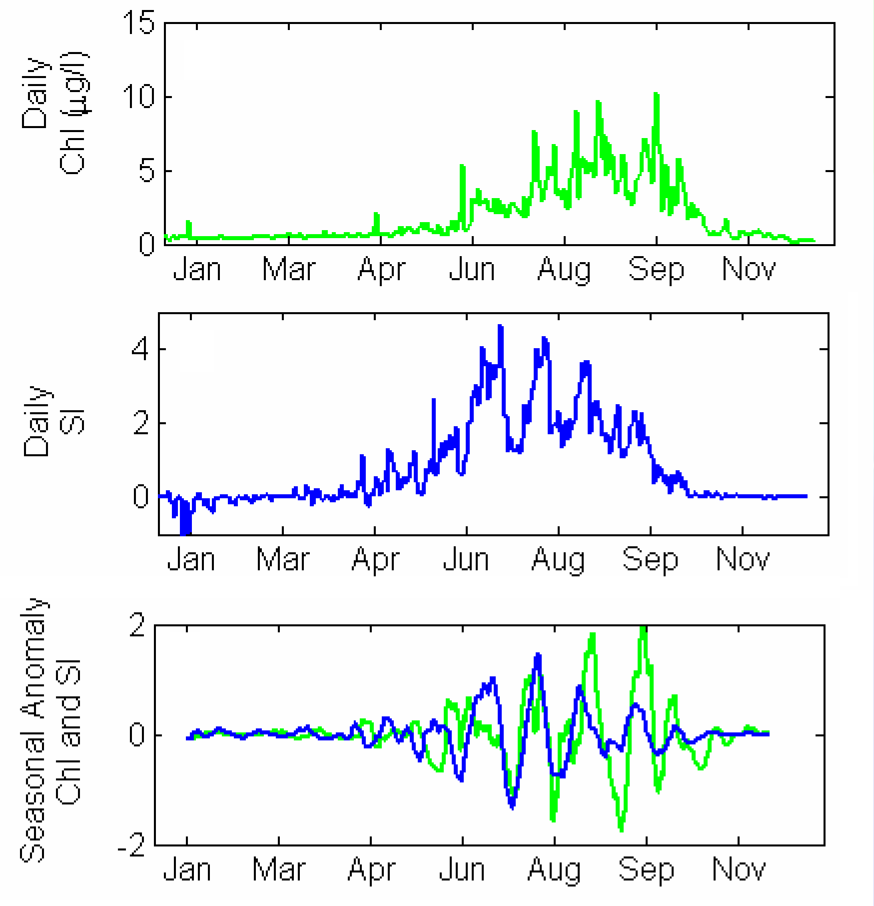
2001-2004 *seasonal cycle*





- Spring bloom SW→NE
- Fall bloom NE→SW
- M fits between B and E
- I spring merges with fall
- →Thermal stratification

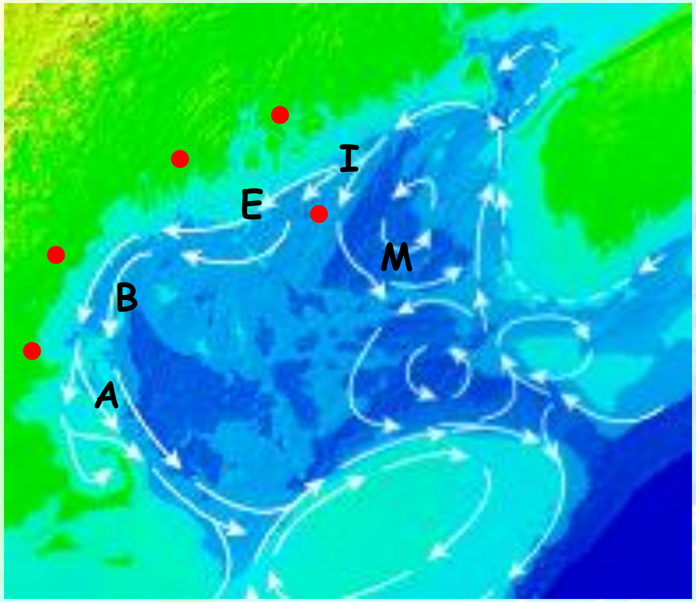
Shocking: a relationship between Stratification and phytoplankton blooms

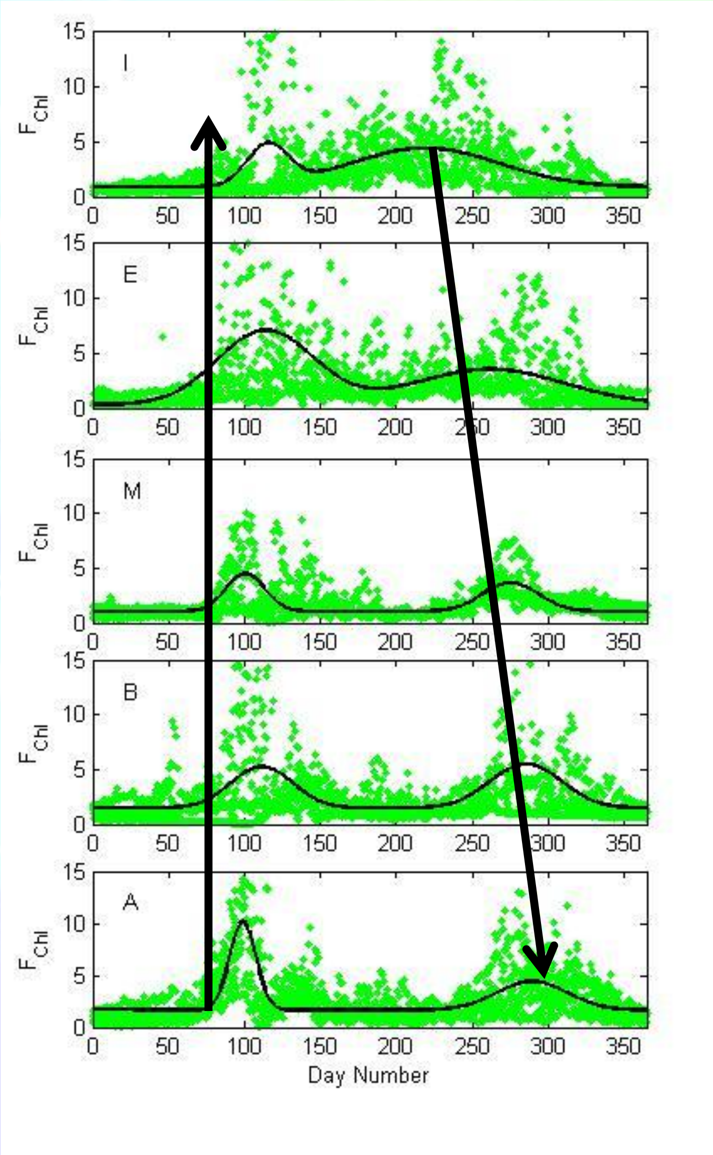


Intervals of mixing and stabilization produce blooms

2005-2012 *seasonal cycles*

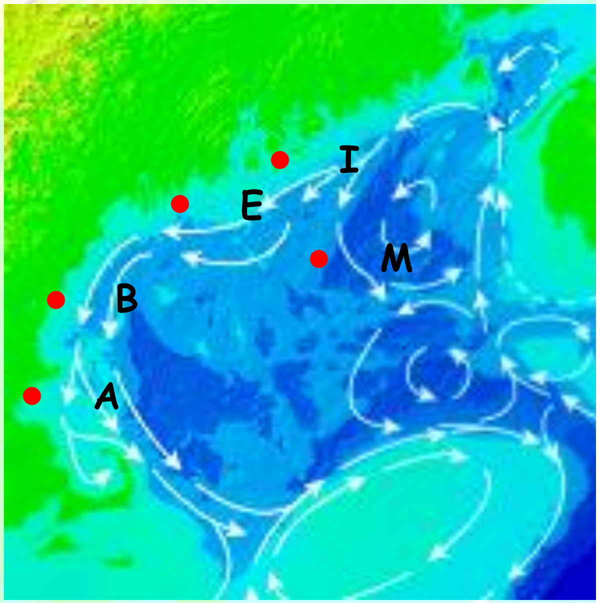
The impact of river discharge to surface waters in 2005-2012 fundamentally changed bloom patterns

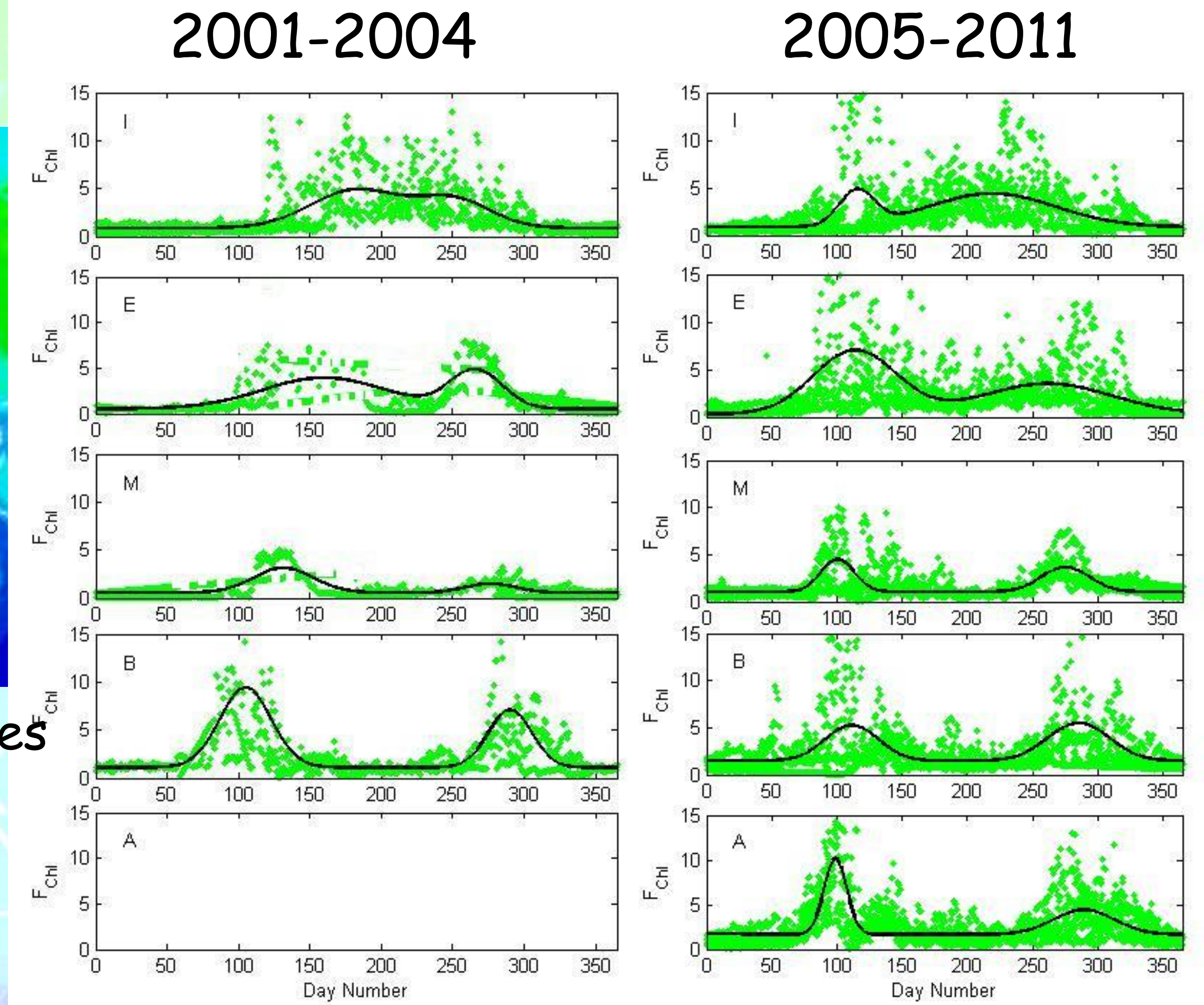




- Spring bloom simultaneous
- Fall blooms NE→SW
- locations A and D fit in
- M still fits between B and E
- →Salinity-induced stratification

Change in bloom patterns

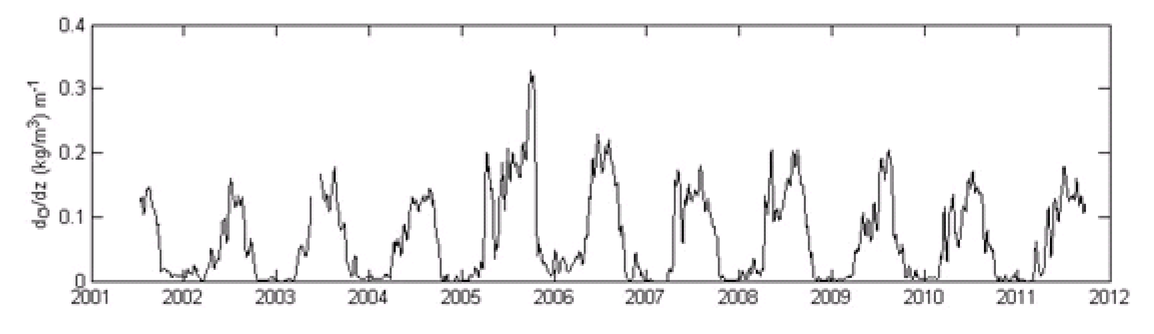




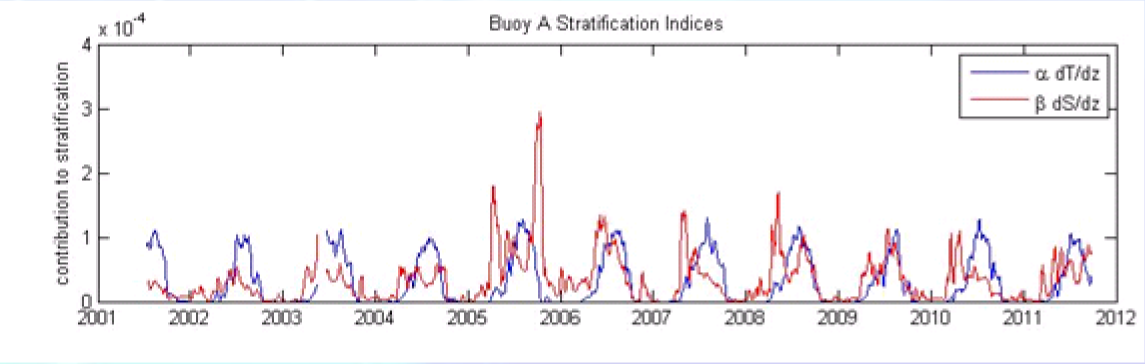
- E, I, M largest changes
- spring bloom
  - earlier 1-2 months
  - longer by 1-3 weeks
  - nearly simultaneous
- fall bloom

Fundamental change in seasonal development of stratification

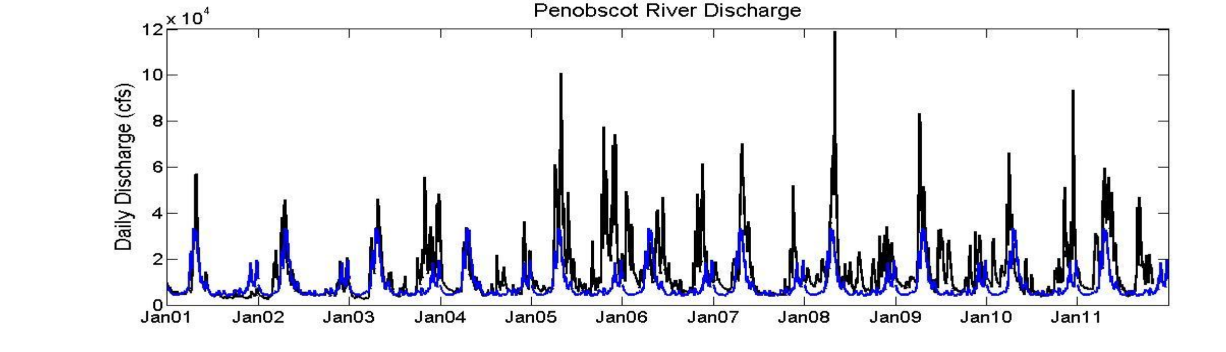
- stratification index



- contribution of temperature and salinity to stratification

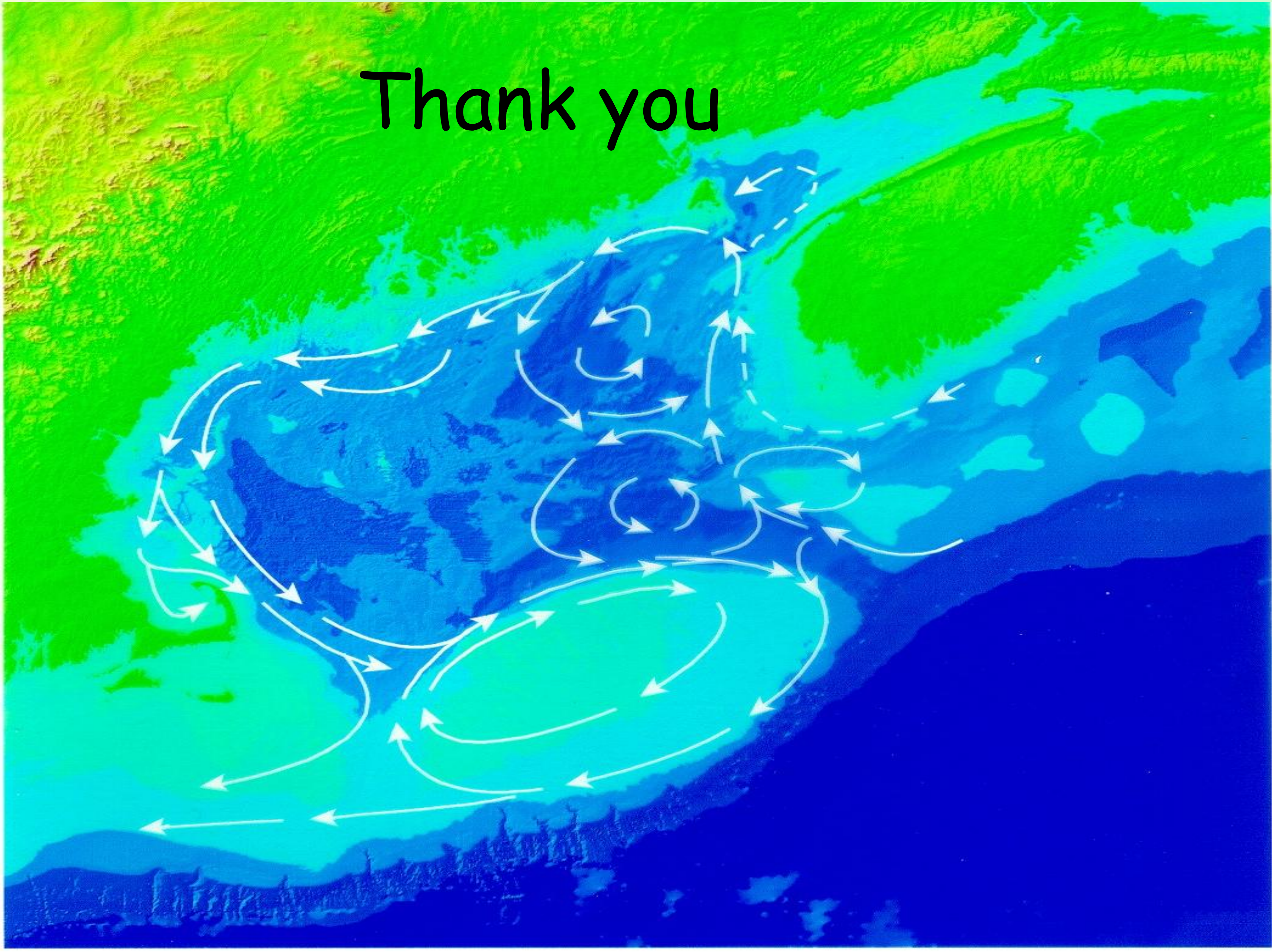


- river discharge



Conclusions

- paired hydrographic/bio-optics hourly observations over the Gulf of Maine has changed the picture of blooms in the Gulf of Maine even with >decade old technology
- Best to start simple, try one risky (transformative) technology; build slowly as data quality proves successful (rather than data quantity)
- invest in quality tested sensors;
- know your sensors; know what you are measuring
- calibrate, calibrate, calibrate
- validate, validate, validate
- redundancy and in situ assessment
- post processing; reprocessing


Thank you