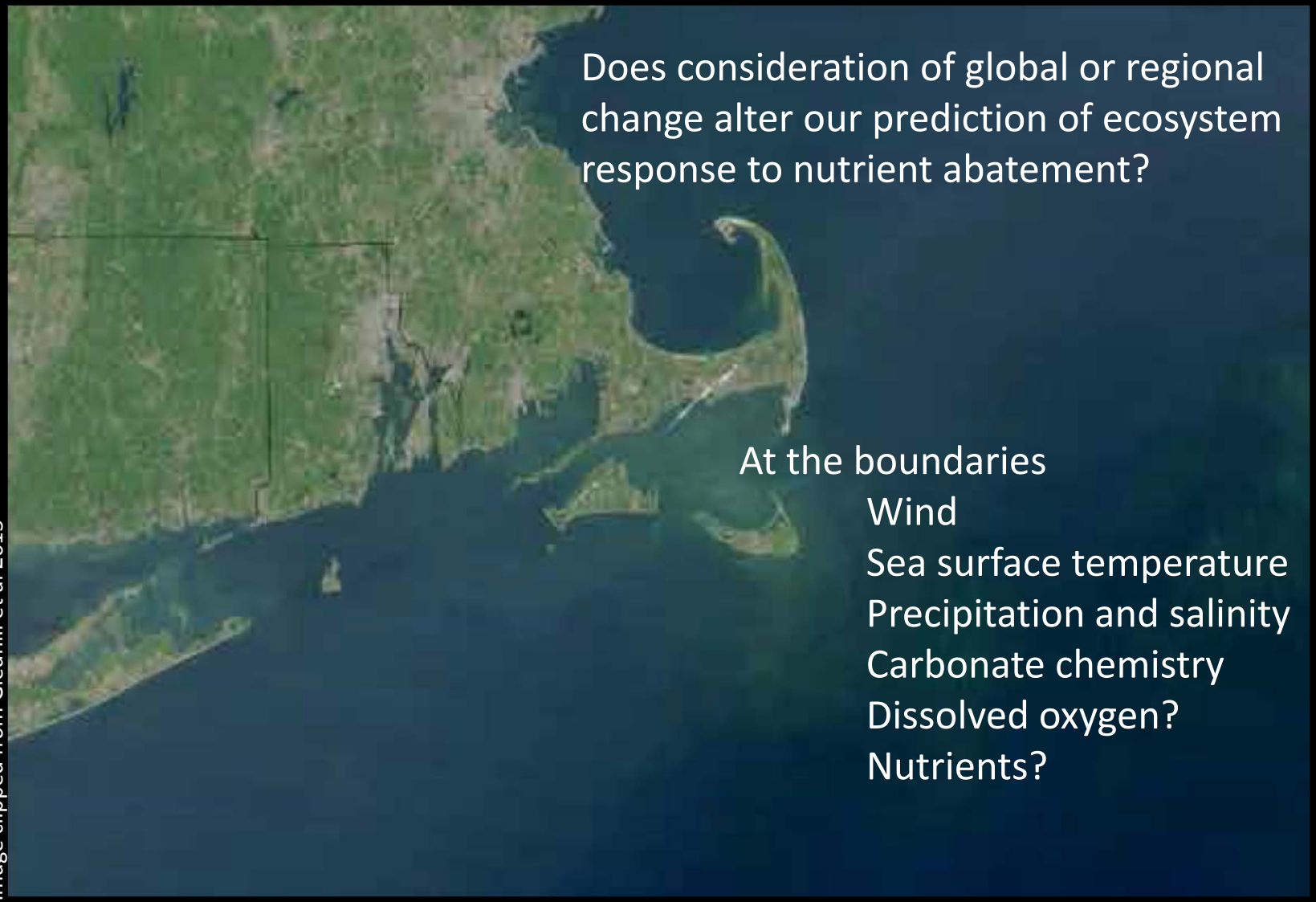


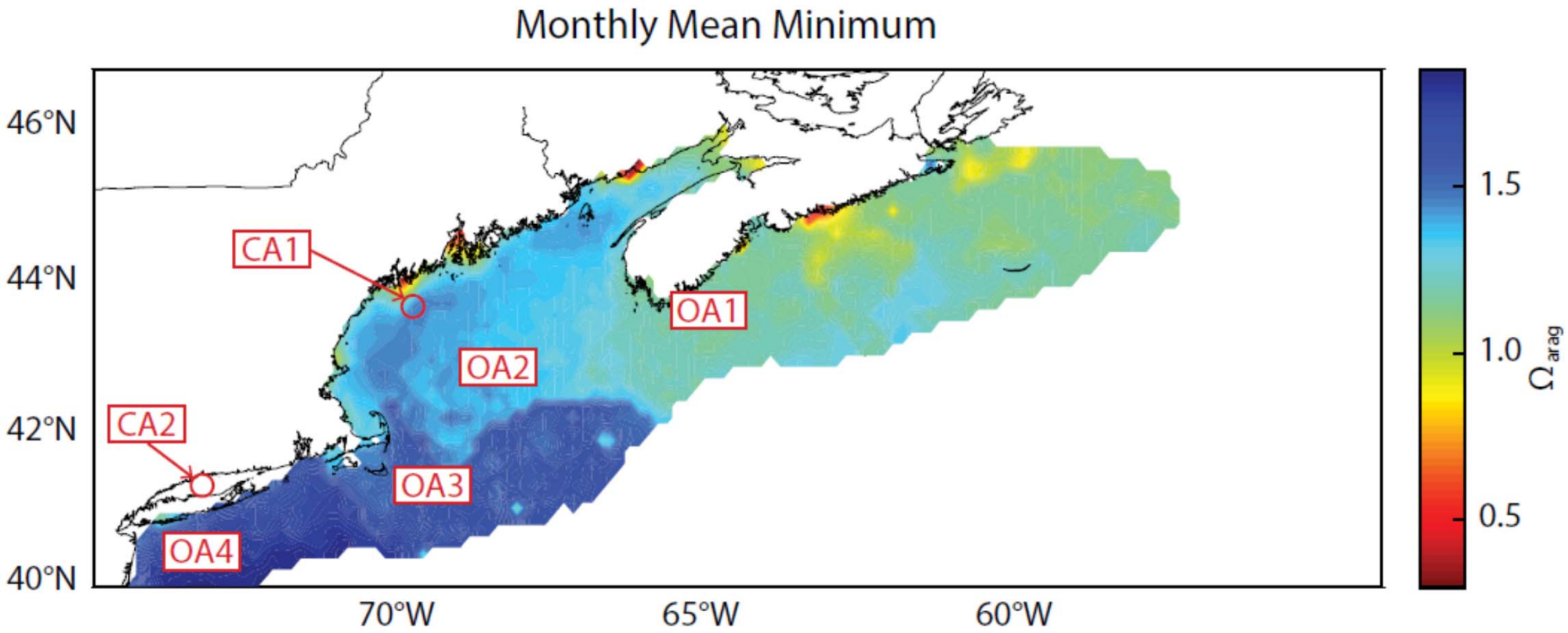
Image clipped from Gledhill et al 2015

Should we treat regional trends simply as boundary changes?

Working backwards from field data, can formal inverse modeling sort out changes in the biology of the system

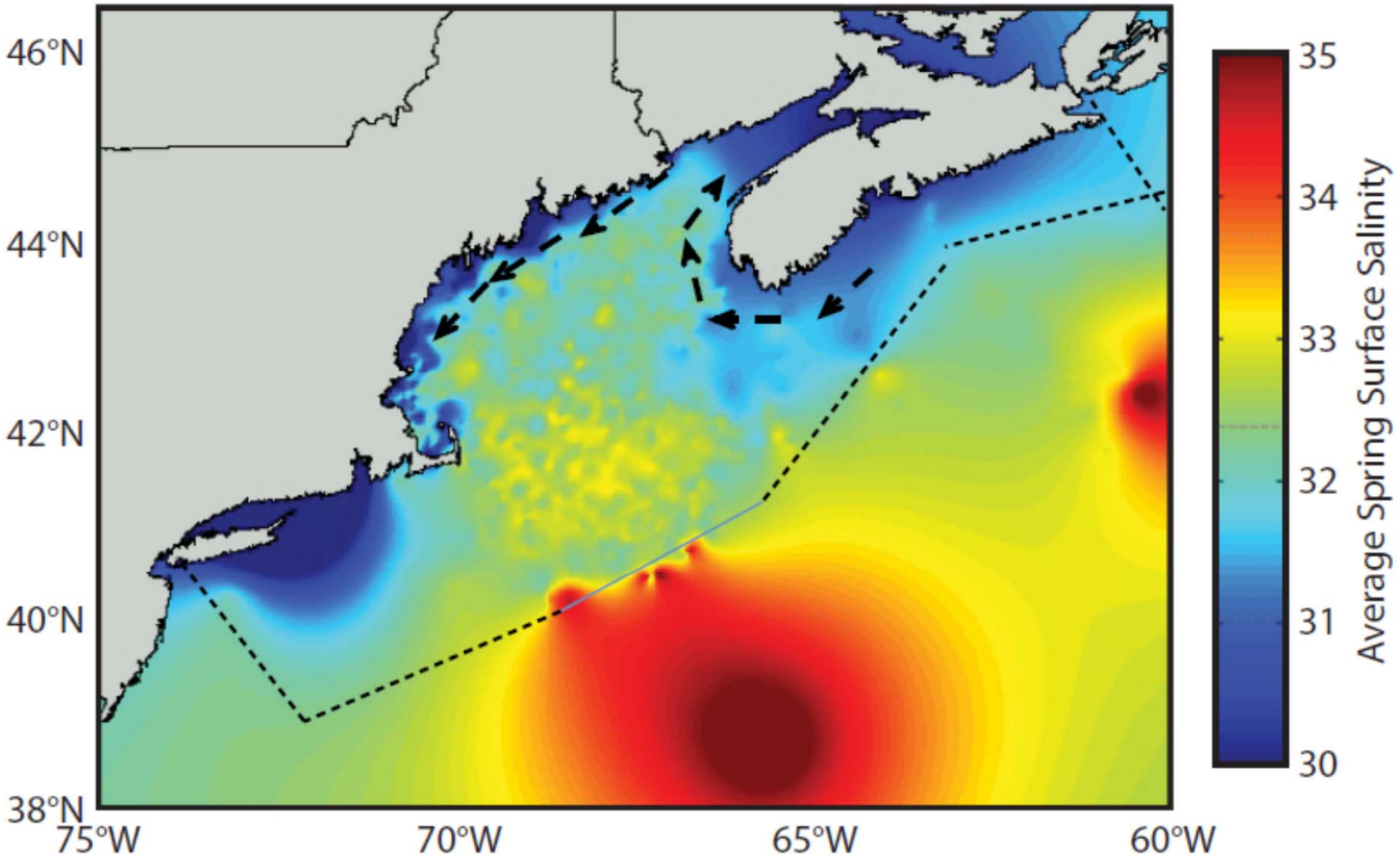
How do we address the inevitable need to compare models or evaluate the benefit of a new state variable (e.g., grazers)?

ARAGONITE SATURATION STATE



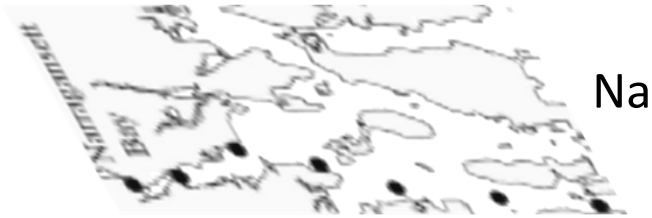
Gledhill et al 2015

SALINITY

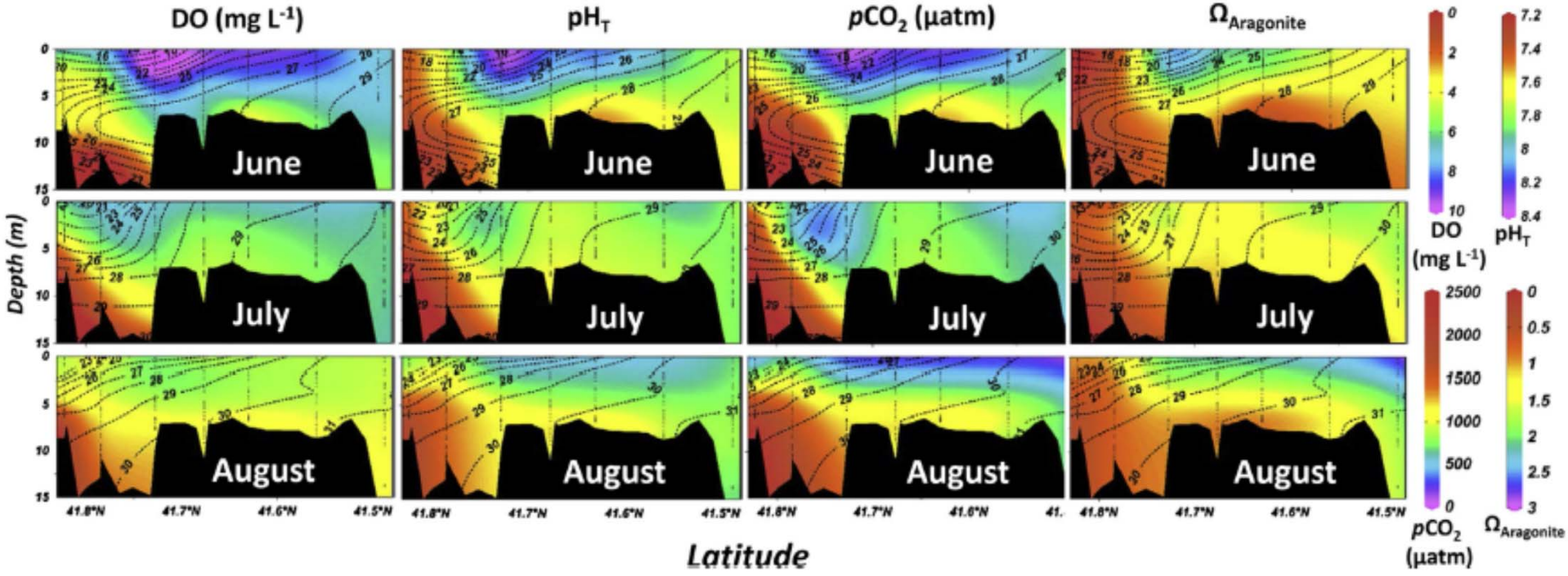


Gledhill et al 2015 and NOAA NFSC

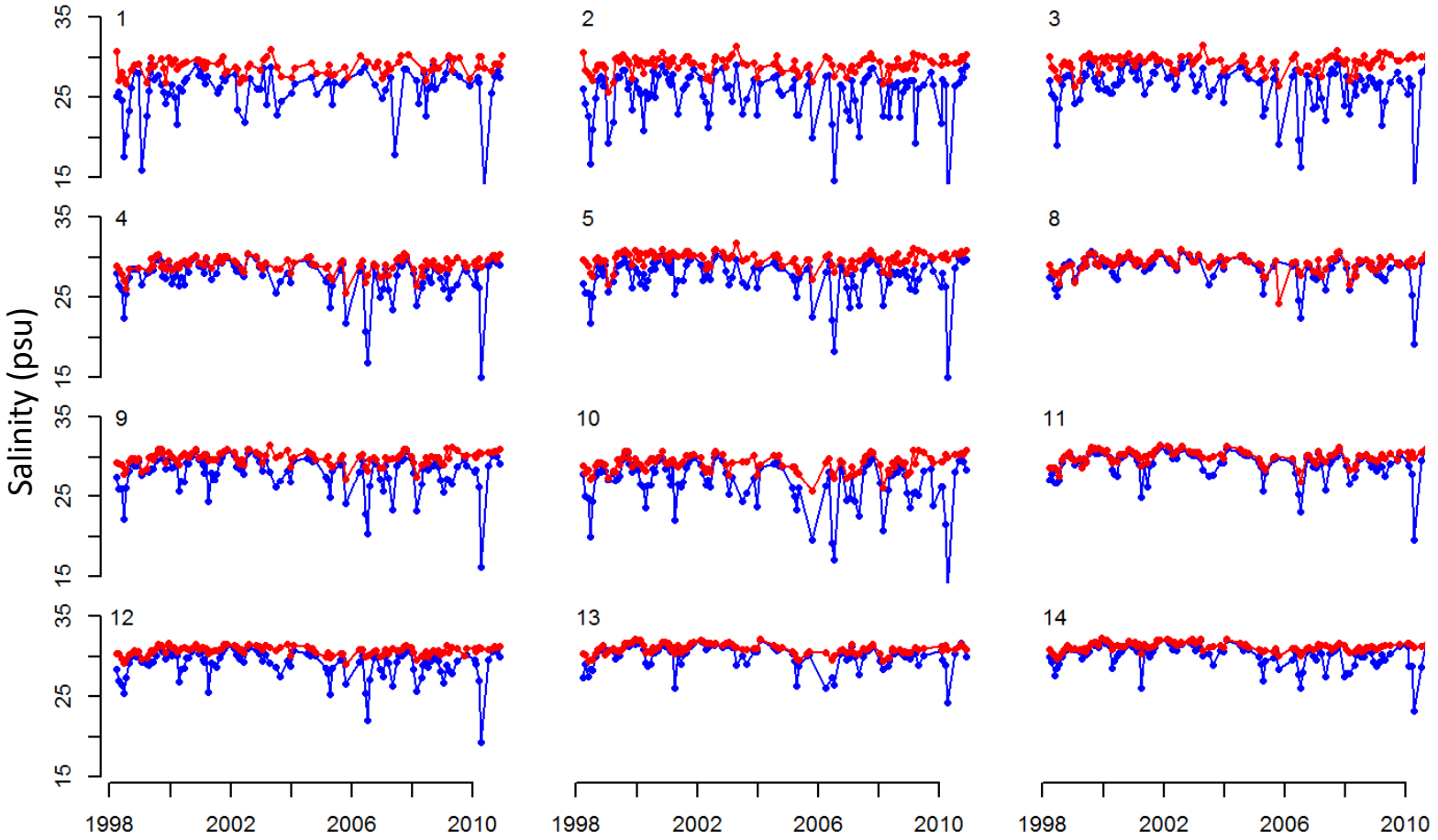
Metabolic CO_2 (and Reduced Buffering ?)

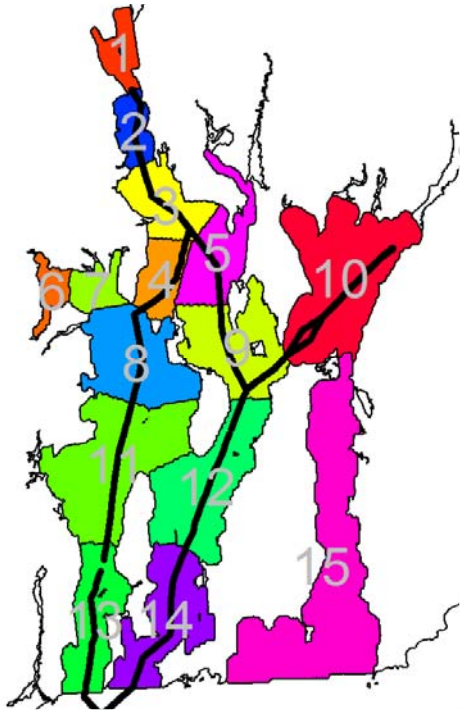


Narragansett Bay, 2013



Wallace et al. 2014


Salinity (psu)
1
2
3
4
5
8
9
10
11
12
13
14
35
25
15
1998
2002
2006
2010
---- Lower
---- Upper


1
2
3
4
5
6
7
8
9
10
11
12
13
14
15

NuShuttle

Does any of this matter for predicting ecosystem response?

Consider carbon to chlorophyll ratios

Key parameter in water quality models

Current best estimate is based on algal monocultures

C:Chl is determined by….

phytoplankton community structure (not predictable from monocultures)

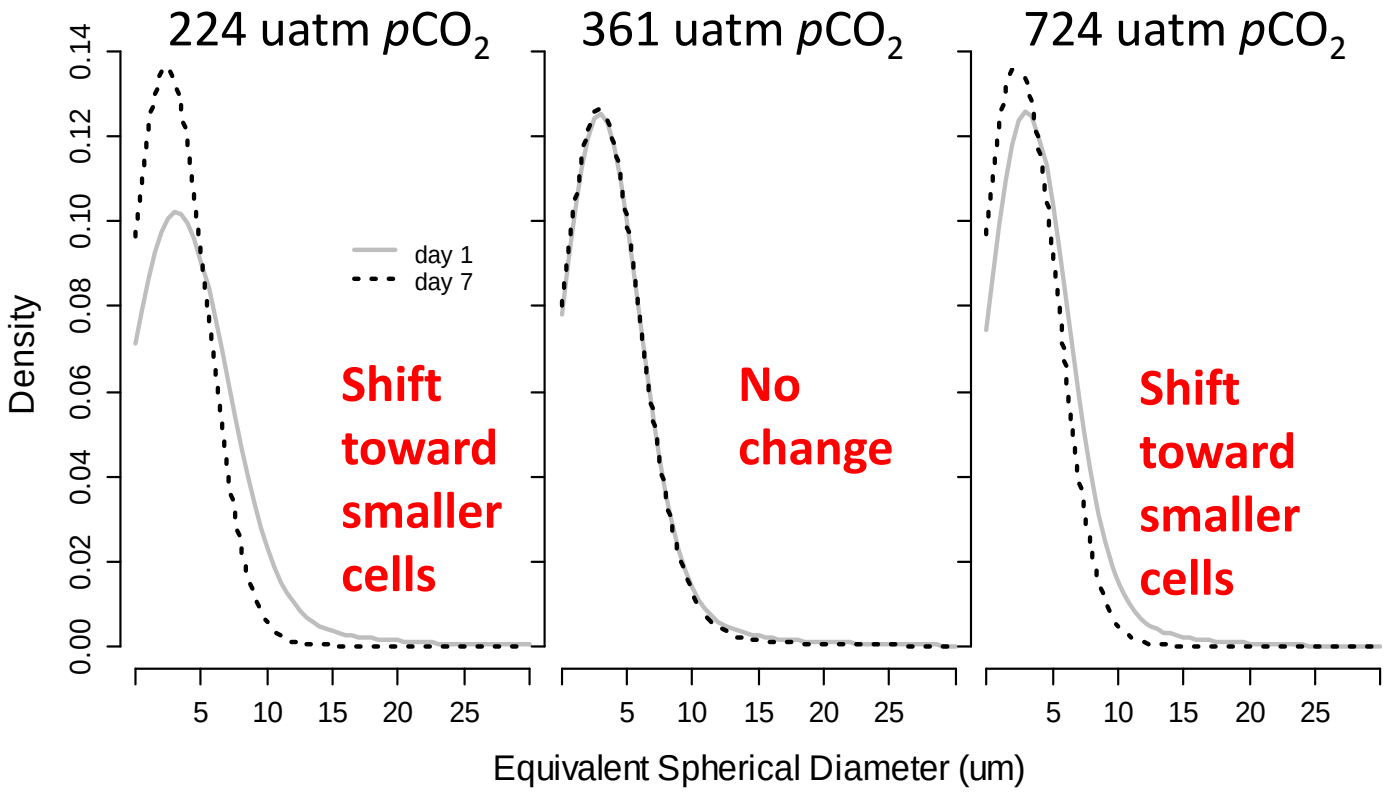
e.g., cell size-abundance, species abundance

And is therefore sensitive to…

Things that alter community structure

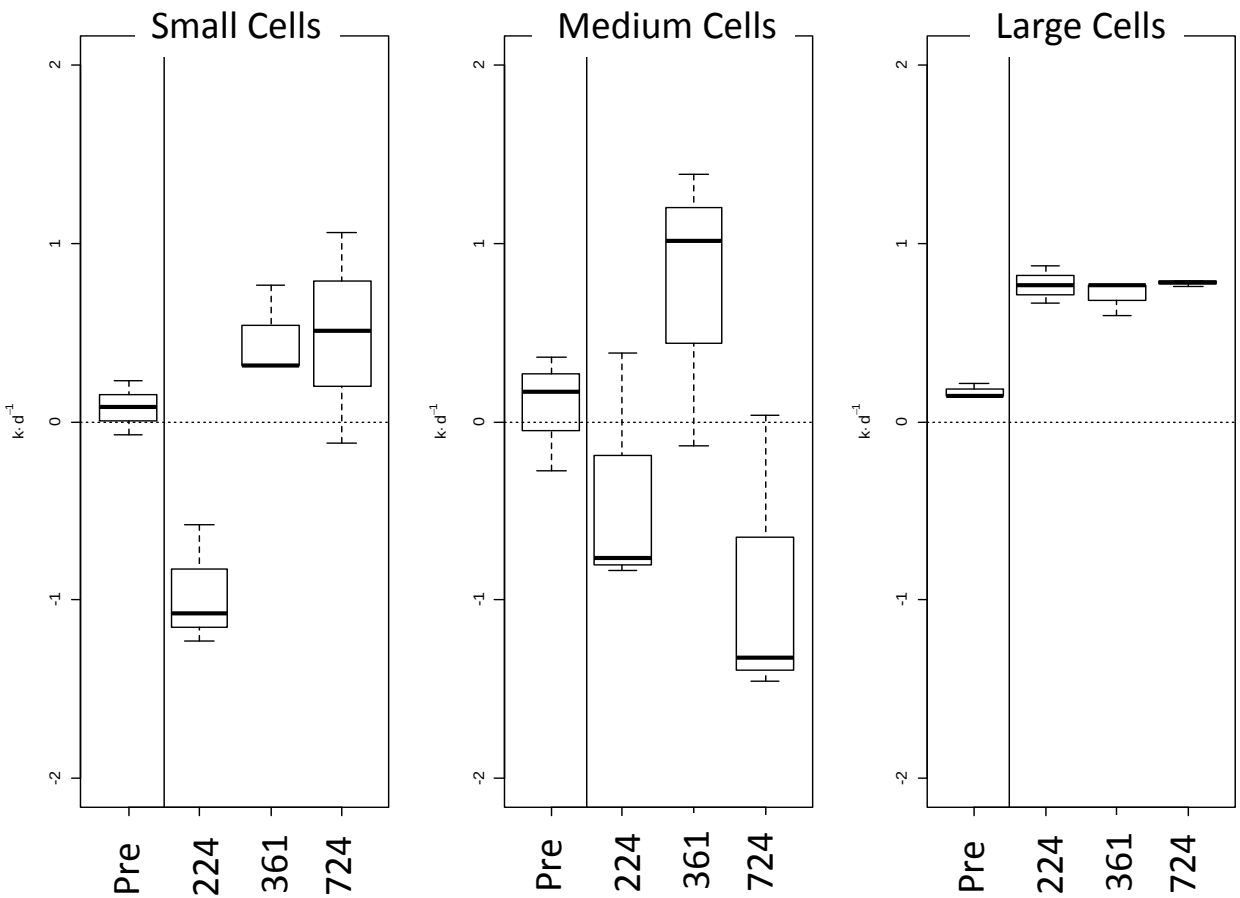
e.g., salinity, temperature, grazing, nutrients, light, carbonate chemistry

Size-abundance spectra of incubated whole plankton communities from Narragansett Bay



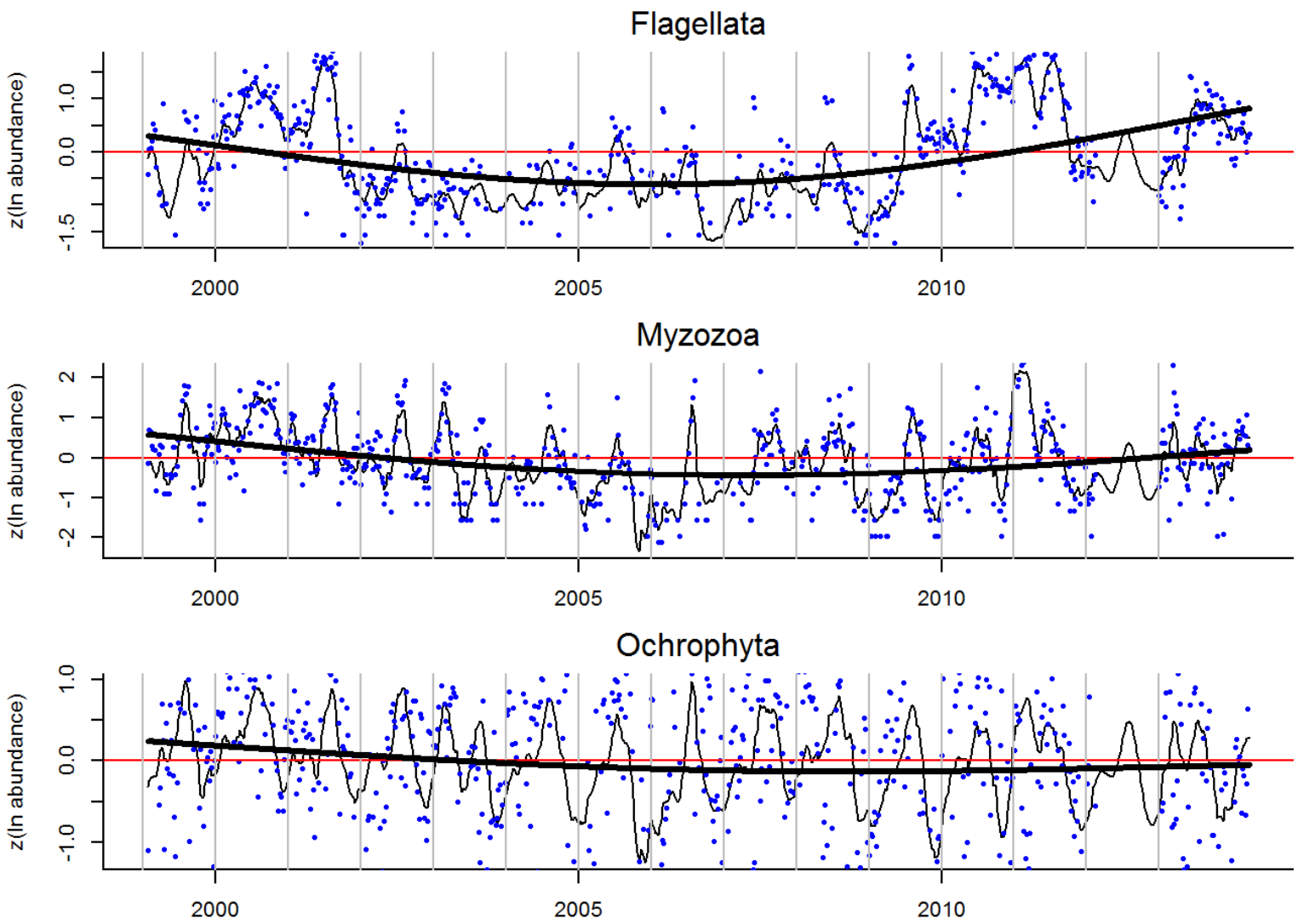
Grear, Rynearson, Montalbano, Govenar and Menden-Deuer, *submitted*

RI STAC



Each size class affected differently by pCO_2

Grear, Rynearson, Montalbano, Govenar and Menden-Deuer, *submitted*


Flagellata
z(ln abundance)
-1.5
0.0
1.0
2000
2005
2010
Myzozoa
z(ln abundance)
-2
-1
0
1
2
2000
2005
2010
Ochrophyta
z(ln abundance)
-1.0
0.0
1.0
2000
2005
2010

WHAT ABOUT THE MODELS?

Fixed water quality model parameters that may change annually or decadally:

CtoChl	Carbon to chlorophyll ratio
K0	light attenuation due to phytoplankton
BR	Benthic remineralization
Rphyt	River phytoplankton load

Others?

Fixed water quality model parameters that may change annually or decadally:

$\theta = \{CtoChl, K0, BR, Rphyt\}$

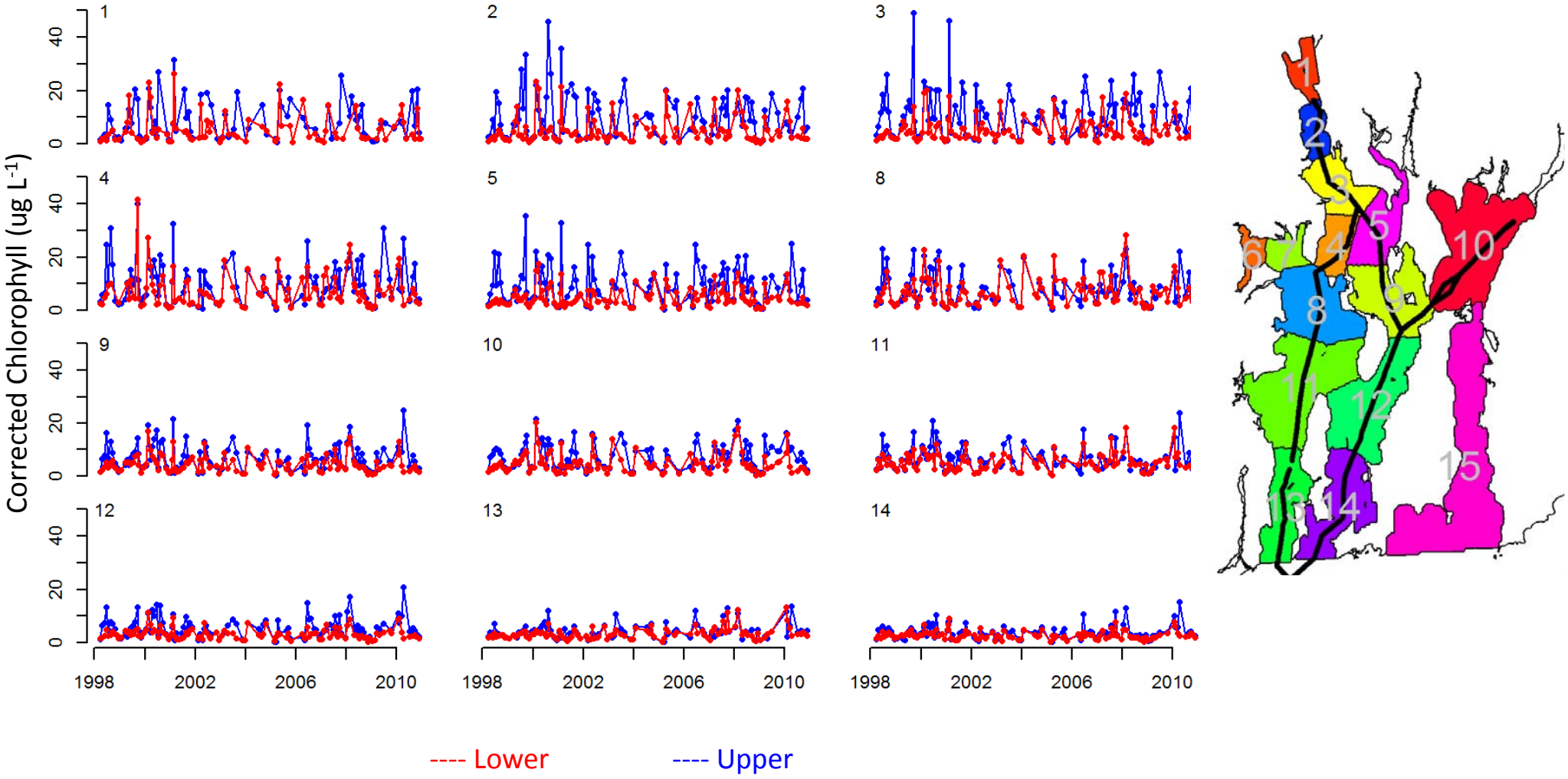
What value of θ maximizes the likelihood,

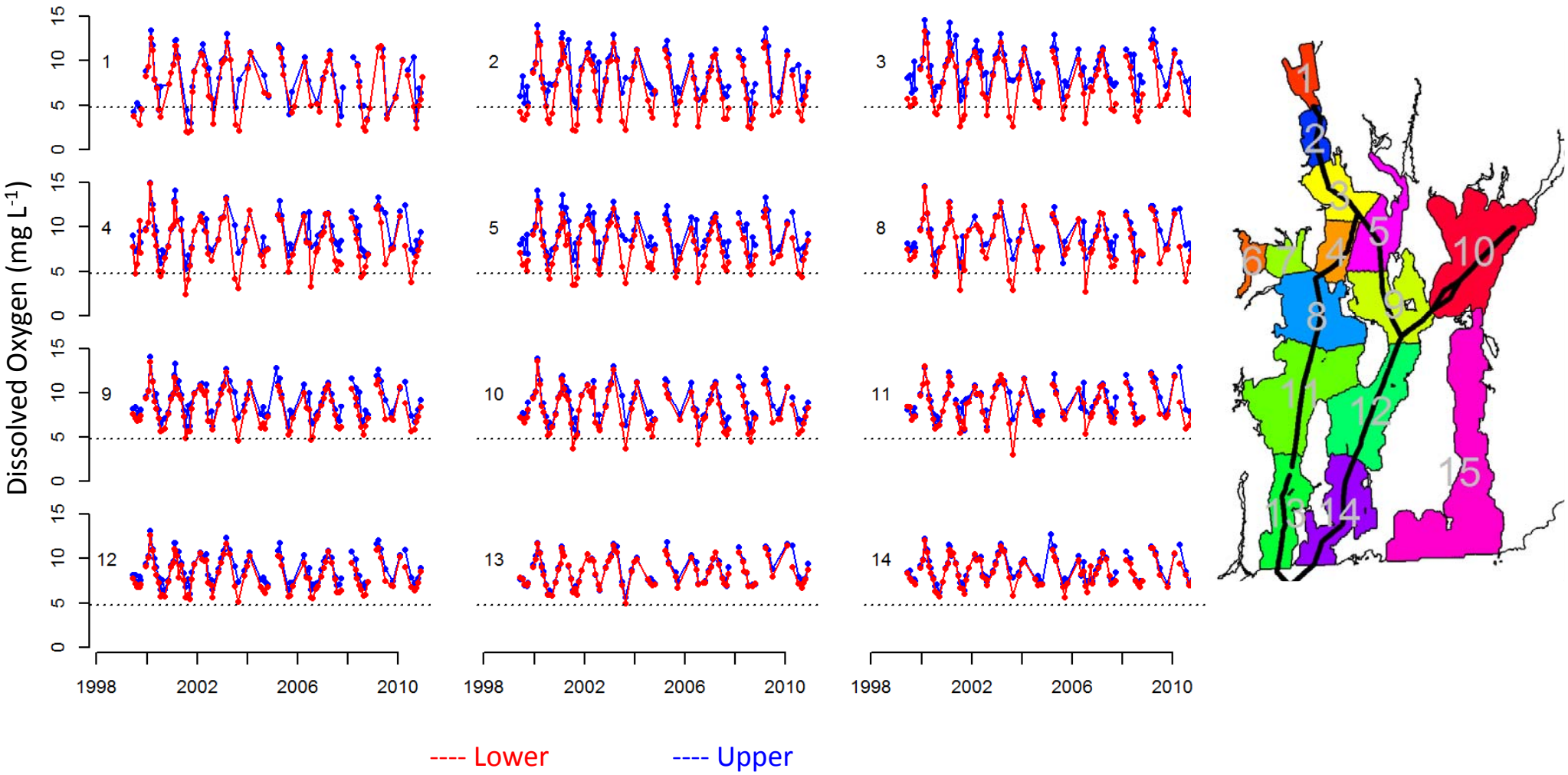
given the 2006 nushuttle data, the 2006 physics, and the rest of the WQ model ?

Does this model:

$\theta = \{CtoChl_A, CtoChl_B, K0, BR, Rphyt\}$,

improve fit (likelihood) without adding variance?

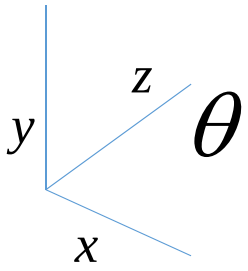

Corrected Chlorophyll (ug L-1)
1
2
3
4
5
8
9
10
11
12
13
14
0
20
40
1998
2002
2006
2010
---- Lower
---- Upper


Dissolved Oxygen (mg L-1)
1
2
3
4
5
8
9
10
11
12
13
14
0
5
10
15
1998
2002
2006
2010
---- Lower
---- Upper

θ = {CtoChl, K0, BR, Rphyt}
Use of likelihood methods requires joint probability model.

Bayes methods provide a workaround, by sampling the joint posterior probability.

Markov Chain Monte Carlo methods "randomly walk" through the joint space and "sniff out" the peak in the likelihood.



Parameter hyperspace

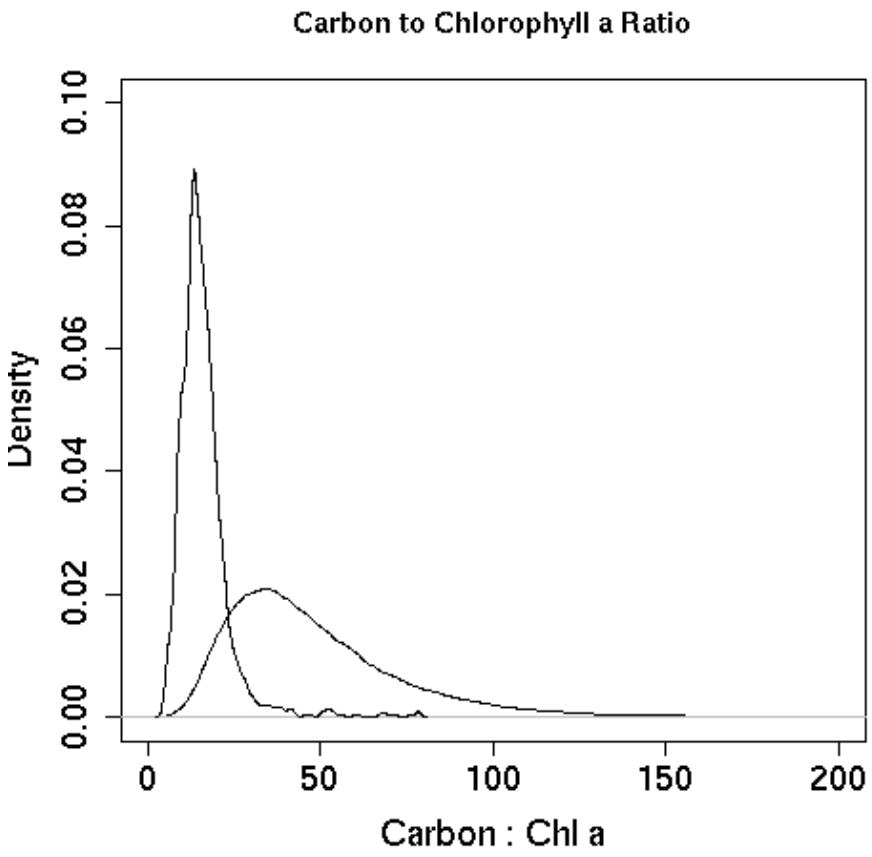
Observations: $y_{i,j,\cdot} = y_{i,j,1}, y_{i,j,2} \cdots y_{i,j,365}$

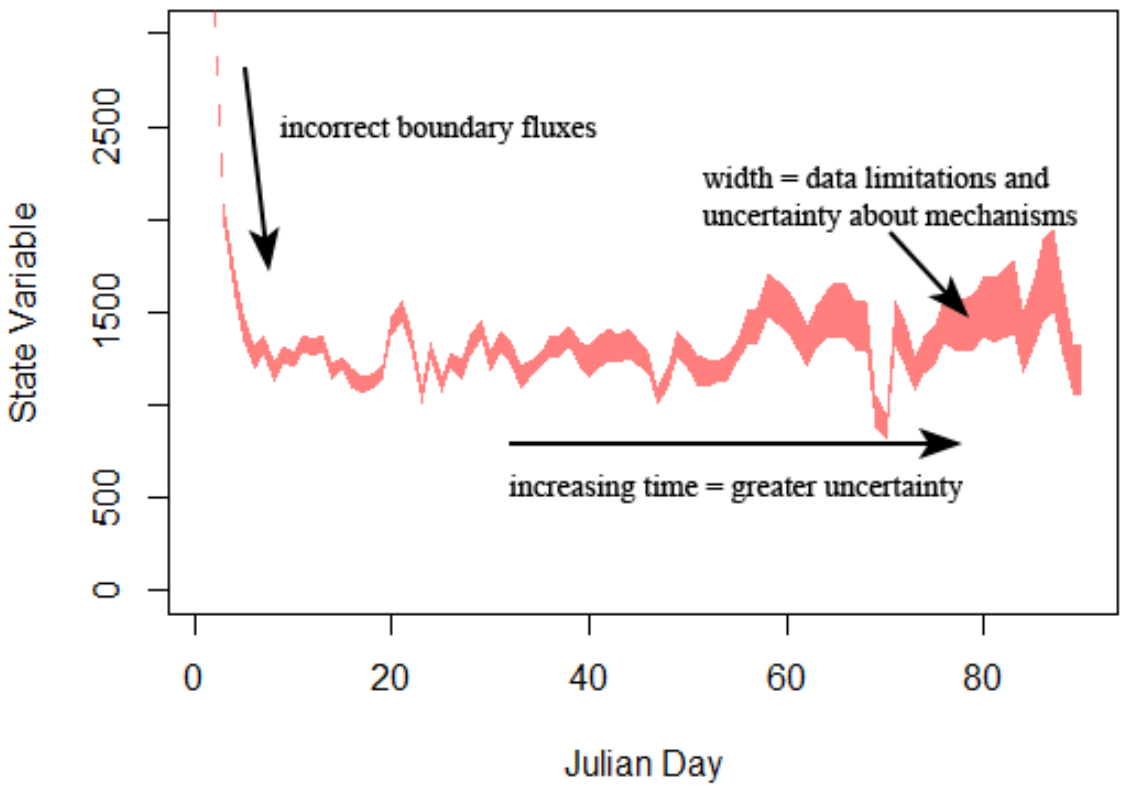
i.e., state variable *i* (DO, Chl a) in segment *j* on day *t*

$$L(\theta, \Sigma \mid y) = \prod \Pr(y_{\ldots} \mid w_{\ldots}, \theta, \Sigma)$$

$$w_t = \text{AnyEcoModel}(y_0, \theta) + e$$

$$e \sim \text{mvNormal}(0, \Sigma)$$


Carbon to Chlorophyll a Ratio
Density
0.00
0.02
0.04
0.06
0.08
0.10
0
50
100
150
200
Carbon : Chl a


State Variable
0
500
1500
2500
incorrect boundary fluxes
width = data limitations and
uncertainty about mechanisms
increasing time = greater uncertainty
0
20
40
60
80
Julian Day

Each stop (> 10^4) in the random walk requires a full annual simulation

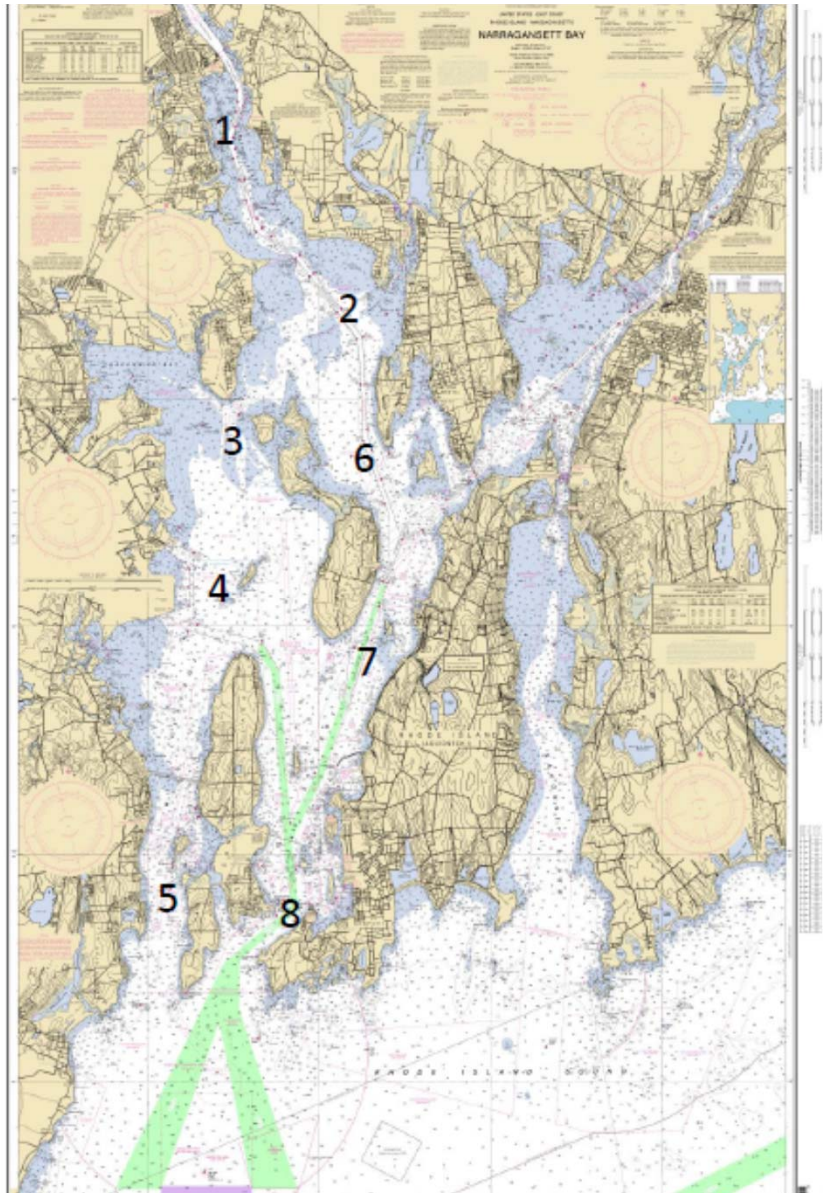
Coded ODE in C

8 days on a Linux with parallel processors (very tricky with MCMC)

FUTURE DIRECTIONS:

I would like to use correct initial conditions, boundary fluxes, and both GEM and OBM-based exchanges

Need a geospatial model of observations for better linkage to WQ model (parse out observation and process error).



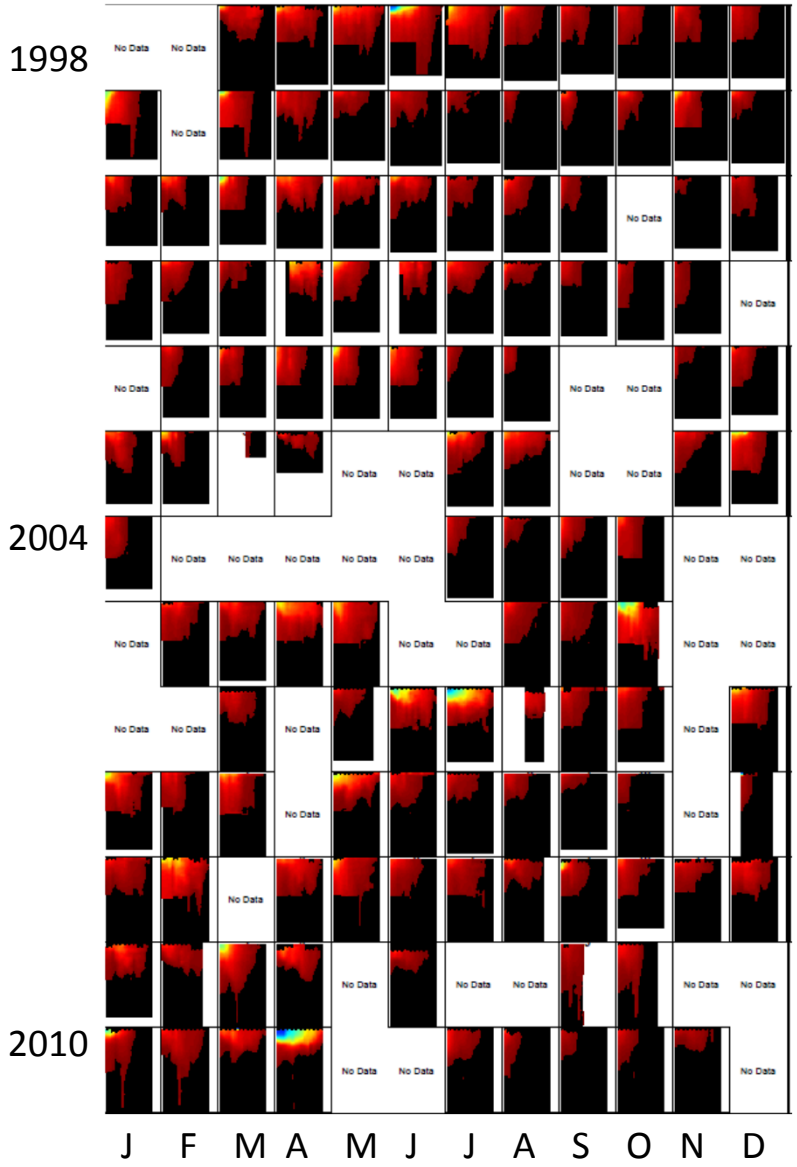
EPA ATLANTIC ECOLOGY DIVISION

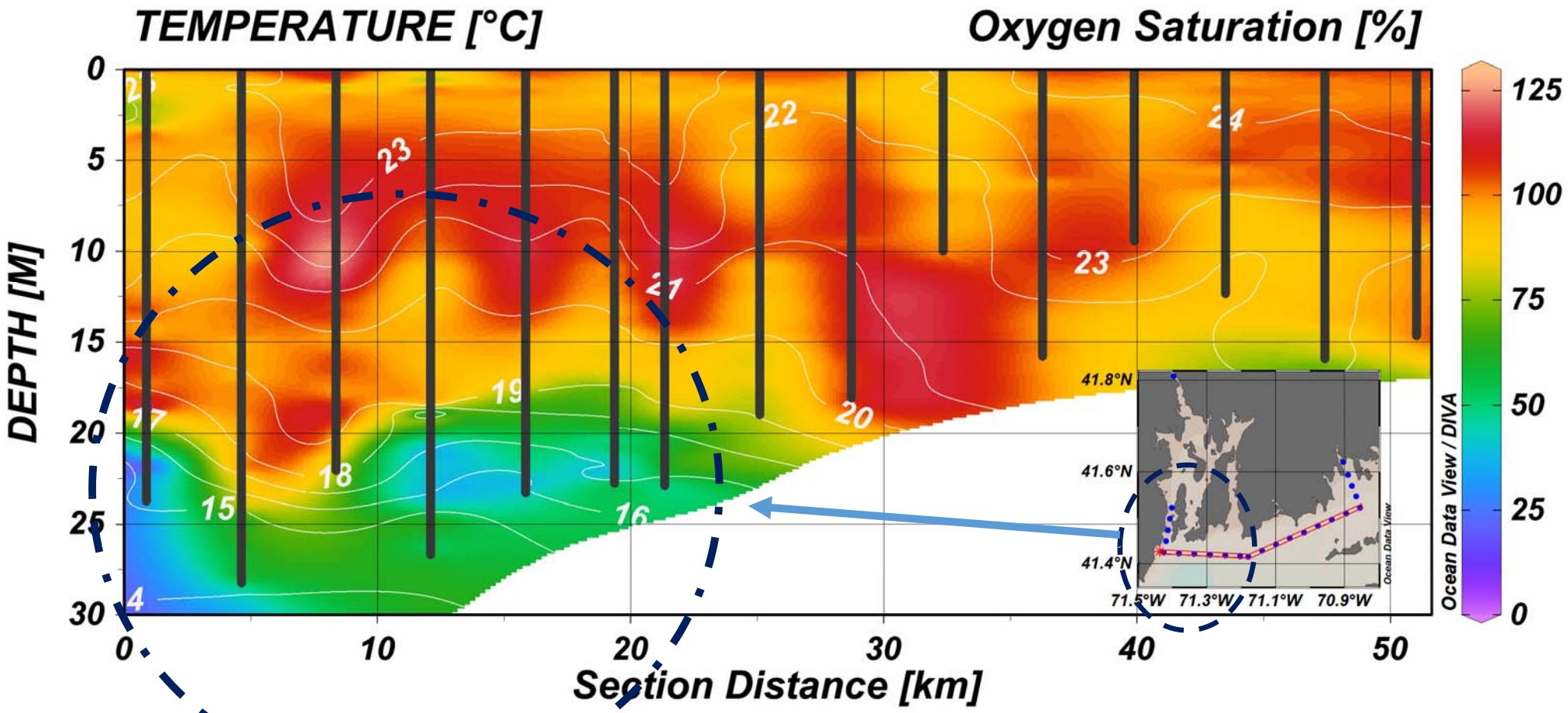
Bay Ecosystem Time Series (BETS)

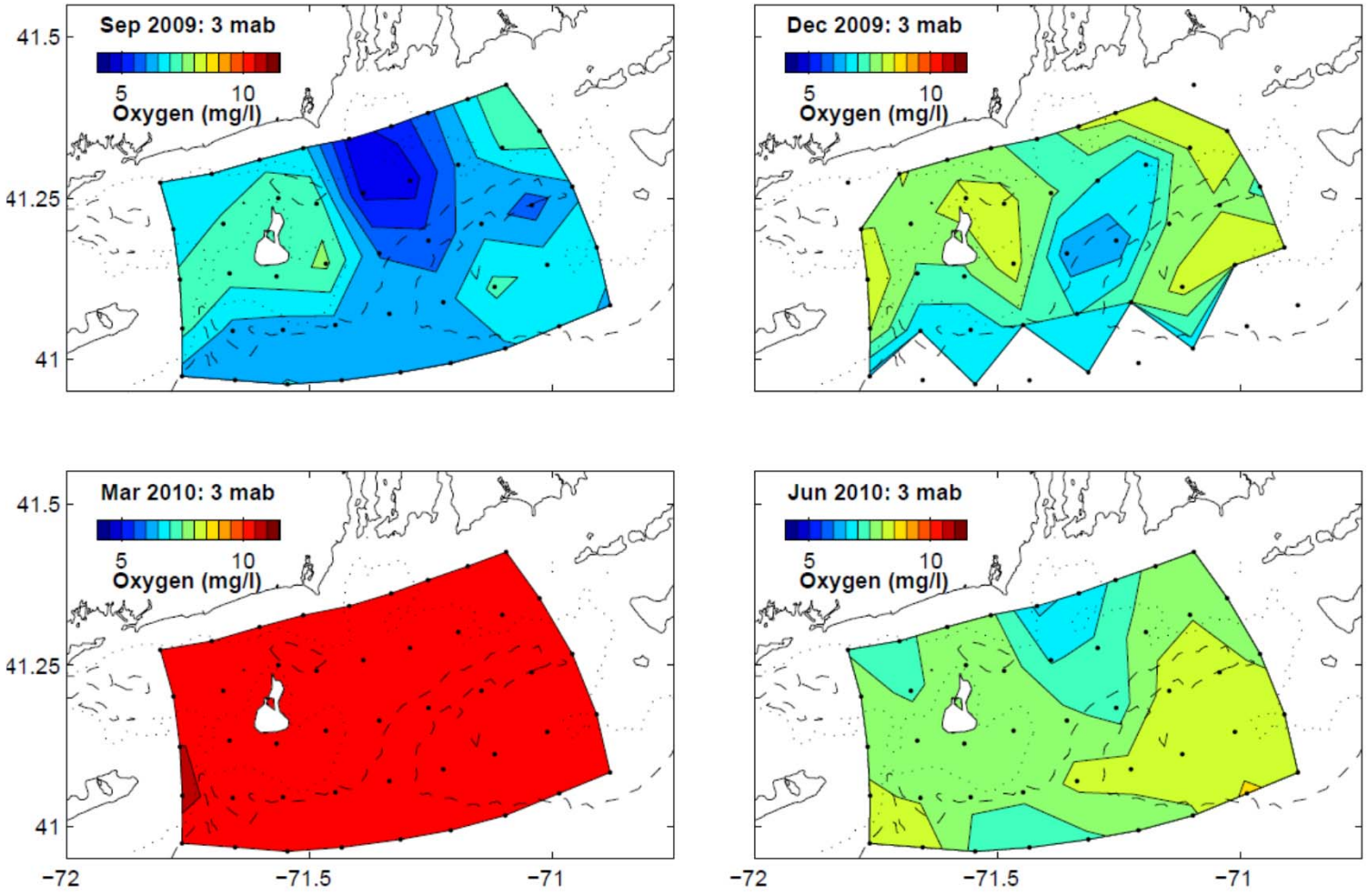
Monthly
Temperature
Salinity
Dissolved oxygen
Nutrients
Chlorophyll
Total suspended solids
Carbonate chemistry
Stable isotopes

Contact: Autumn Oczkowski

NuShuttle
Salinity




TEMPERATURE [°C]
Oxygen Saturation [%]
DEPTH [M]
Section Distance [km]
0
5
10
15
20
25
30
0
10
20
30
40
50
22
24
23
21
19
17
18
15
16
20
23
41.8°N
41.6°N
41.4°N
71.5°W
71.3°W
71.1°W
70.9°W
Ocean Data View
Ocean Data View / DIVA
125
100
75
50
25
0



Ullman, D. S., and D. L. Codiga http://www.crmc.ri.gov/samp