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A data science approach to understanding physical drivers of coastal primary productivity and effects on carbonate chemistry

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SalishSeaCast Carbonate Chemistry in the Context of Spatial Clustering of Primary Productivity

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Salish Sea Ecosystem Conference, April 6, 2018

PART 1: Our Biogeochemical Model

-Presenting SMELT:
the SalishSea Model Ecosystem (Lower Trophic)

-New developments: adding carbonate chemistry

-Preliminary carbonate chemistry results

PART 2: One Model Analysis Framework and Insights

-Cluster analysis: retrieving characteristic signals from a model dataset

-Preliminary carbonate chemistry

PART 1: Our Biogeochemical Model

Presenting SMELT:
the SalishSea Model Ecosystem (Lower Trophic)

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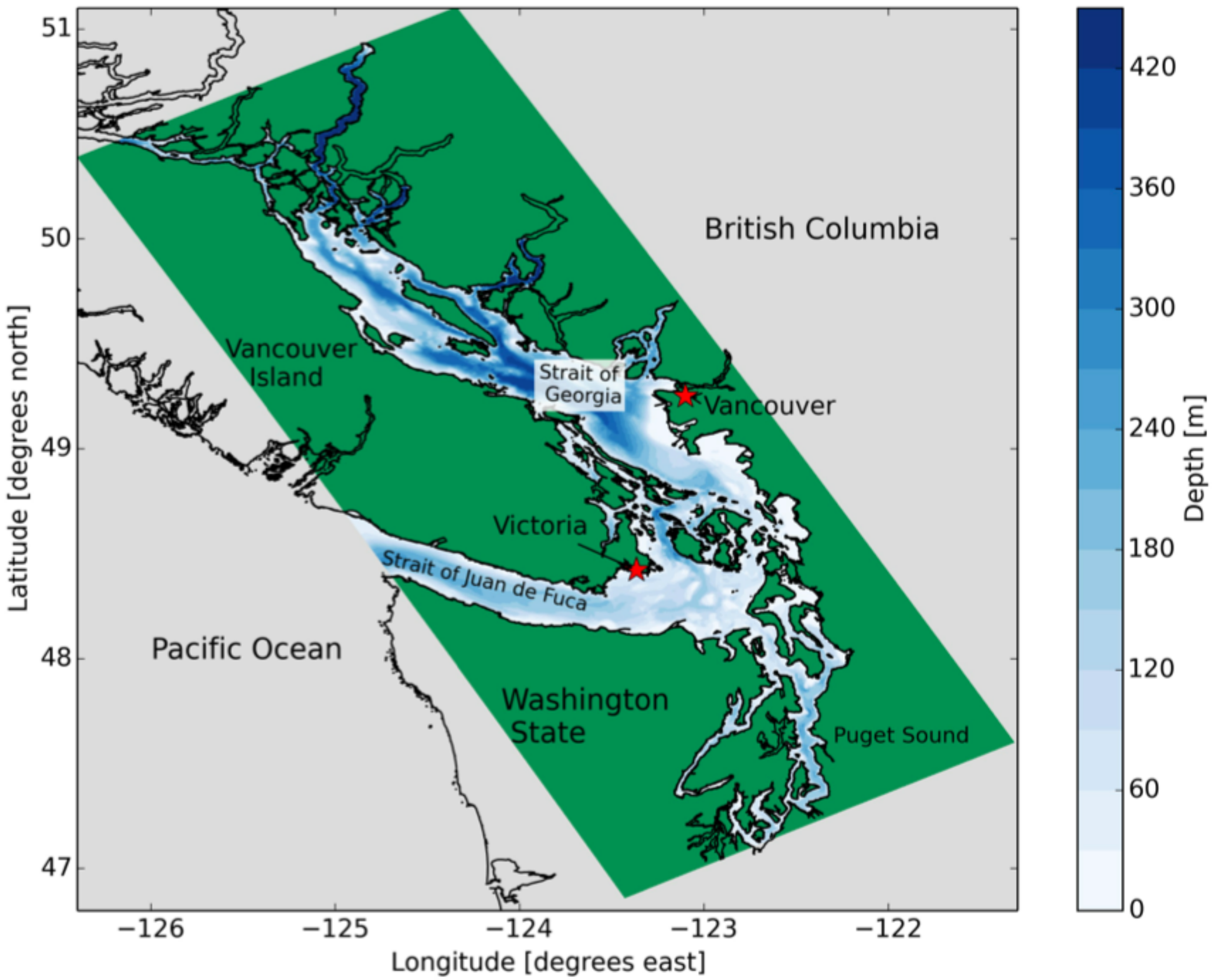
MODEL CONFIGURATION



Biological model component (NPDZ):

Nutrients (nitrate, phosphate)
3 Phytoplankton classes
Detritus
Zooplankton

SalishSeaCast

Full three-dimensional stratified model, based on NEMO 3.6 community model

Physical model operational since 2014

Horizontal grid spacing about 500 m

Vertical grid spacing 1 m (near surface) to 27 m

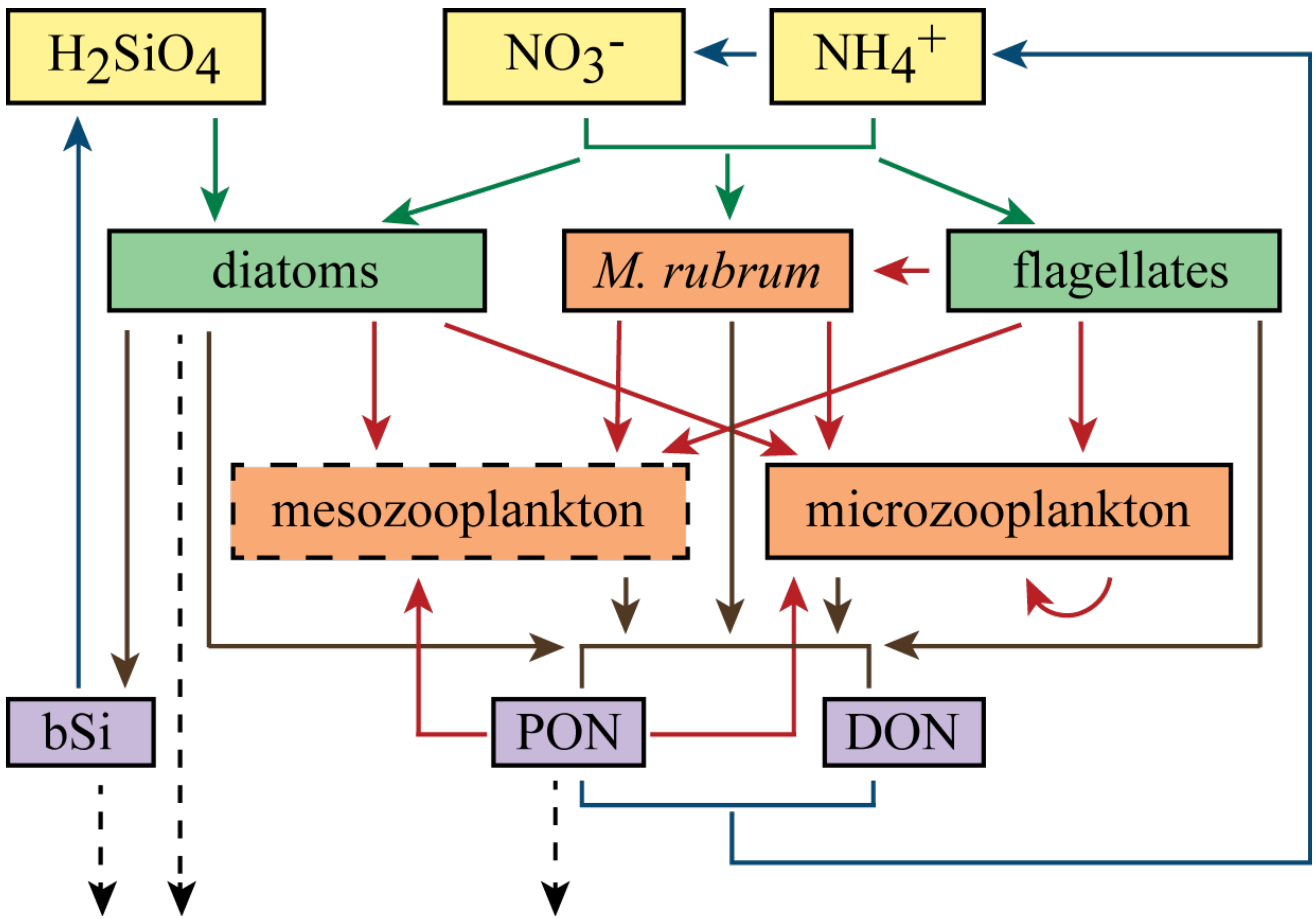
Tides: 8 tidal constituents at open boundaries

Freshwater: 150 rivers (149 monthly climatology and Fraser River daily)

Winds/ Meteorology: 2.5 km & hourly from Environment Canada

Biological Model

(Collins et al, 2009; Allen and Wolfe, 2013; Moore-Maley et al, 2016)



Carbonate Chemistry Model

(Moore-Maley et al, 2016)

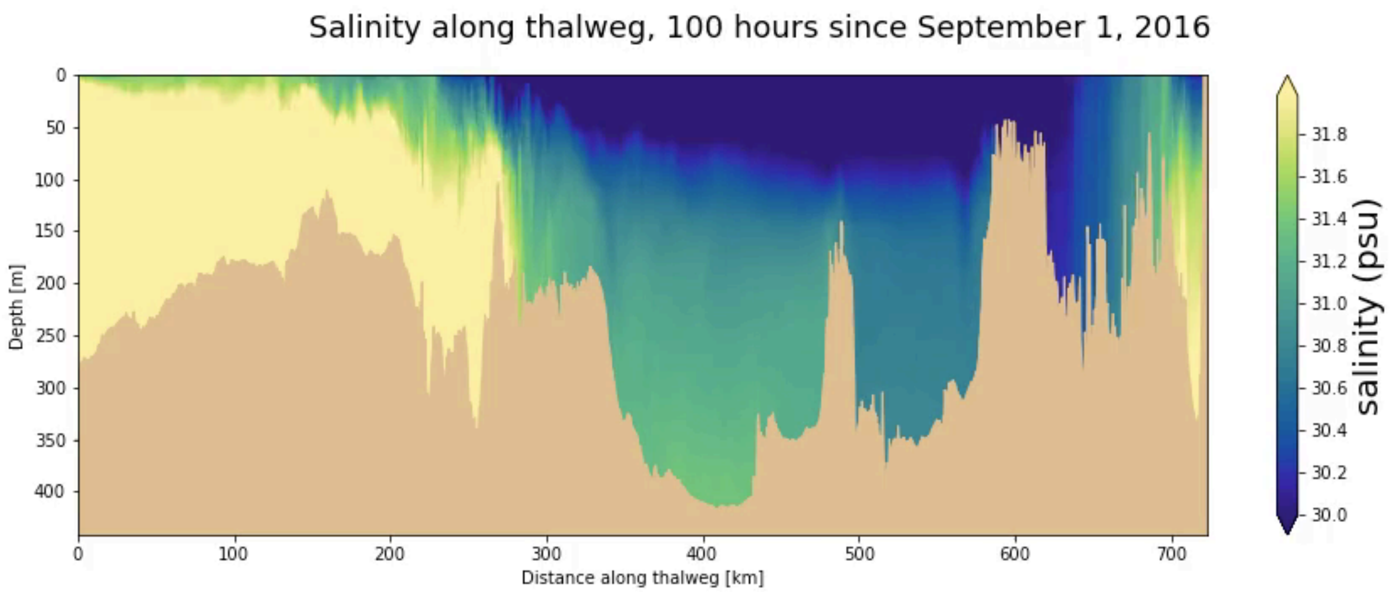
Schematic model equations:

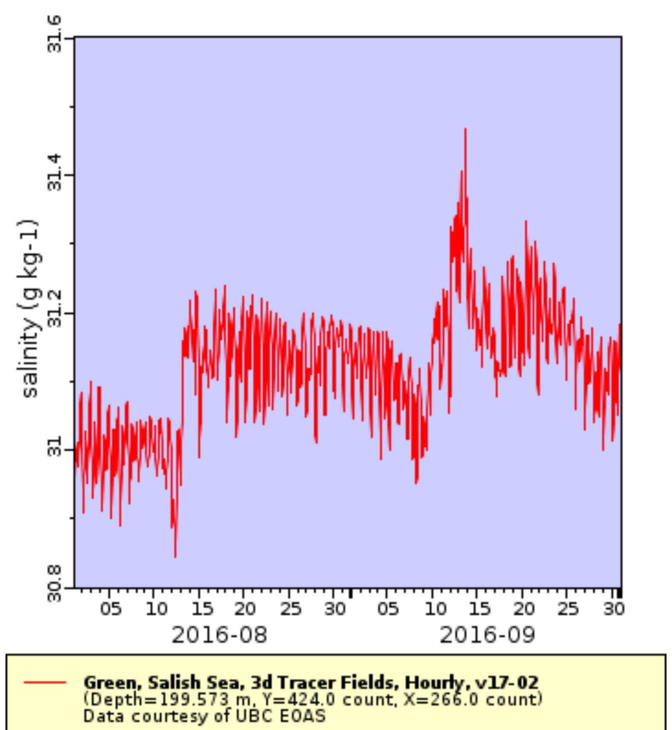
$$\frac{\partial \mathrm{DIC}}{\partial t} = -(U_{\mathrm{N}} + U_{\mathrm{PC}} - Rm_{\mathrm{N}})\mathcal{R}_{\mathrm{C:N}} + physical\ \ transport$$

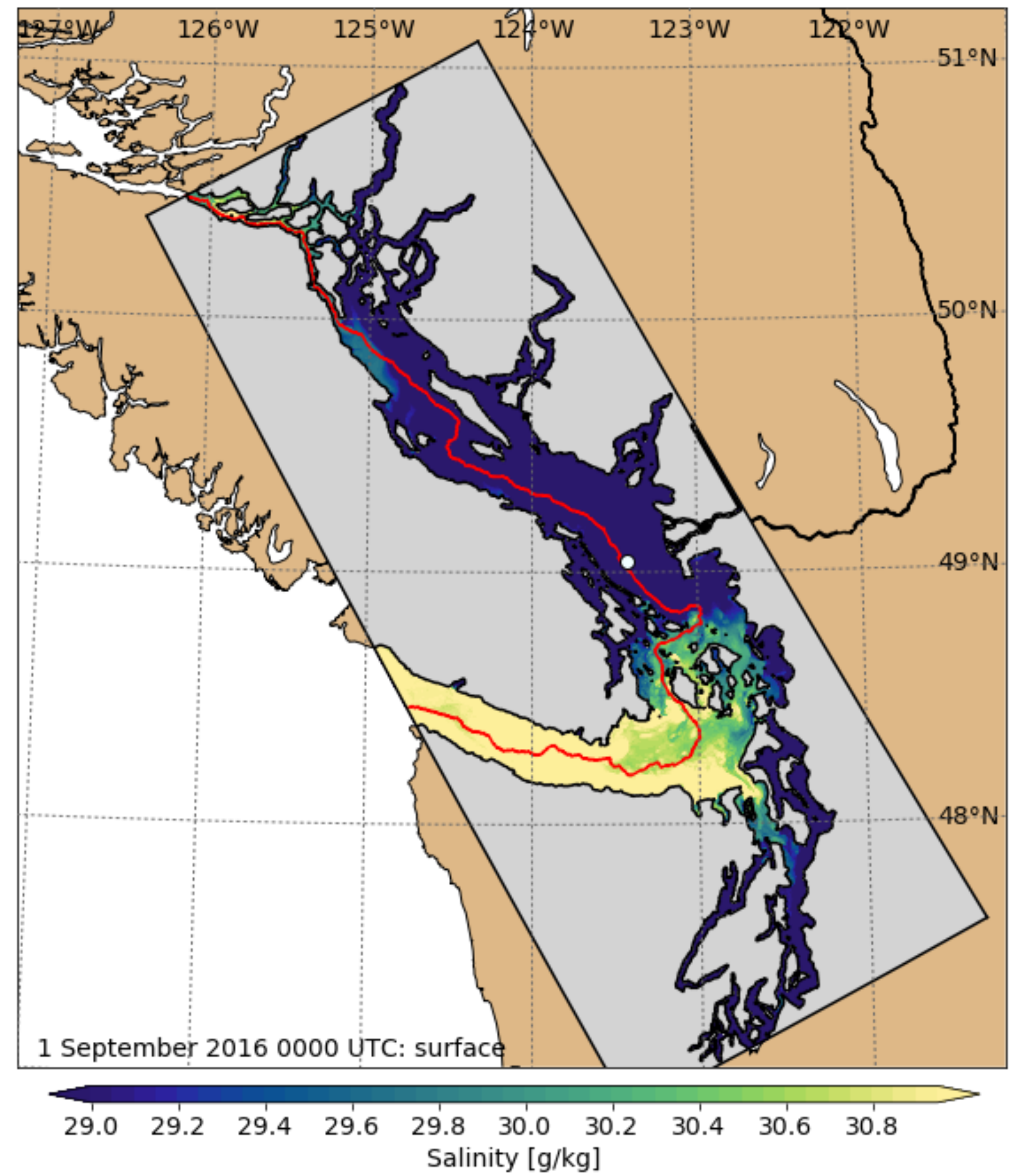
$$\frac{\partial \mathrm{TA}}{\partial t} = U_{\mathrm{NO_3^-}} - 2Rm_{\mathrm{NO_3^-}} - U_{\mathrm{NH_4^+}} + Rm_{\mathrm{NH_4^+}} + (U_{\mathrm{PO_4}} - Rm_{\mathrm{PO_4}})\mathcal{R}_{\mathrm{N:P}}$$
$$+ physical\ \ transport$$

Initialization:
-regional parameterization with salinity (comprehensive dataset, Ianson et al, 2016)
-initial model test: 30 day run, September 2016
-Caveat: no spinup, gas exchange not yet implemented (coming soon!)
very preliminary results

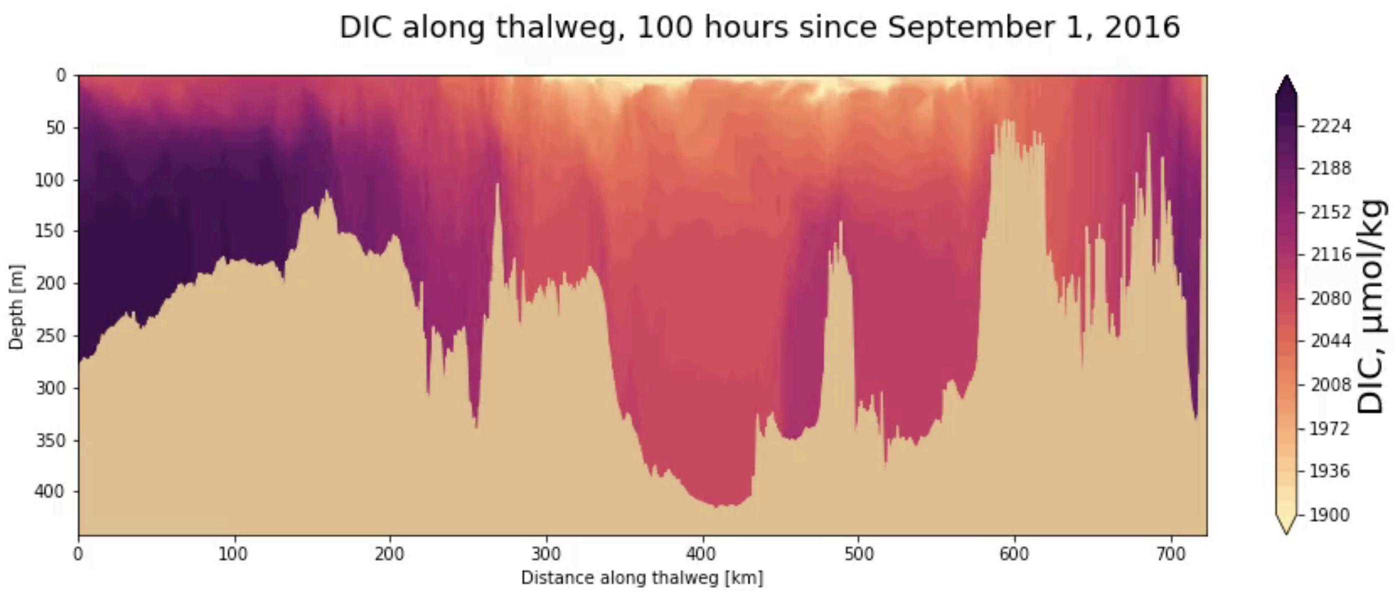
Carbonate Chemistry Model:
Observing a deep water renewal event, September 2016

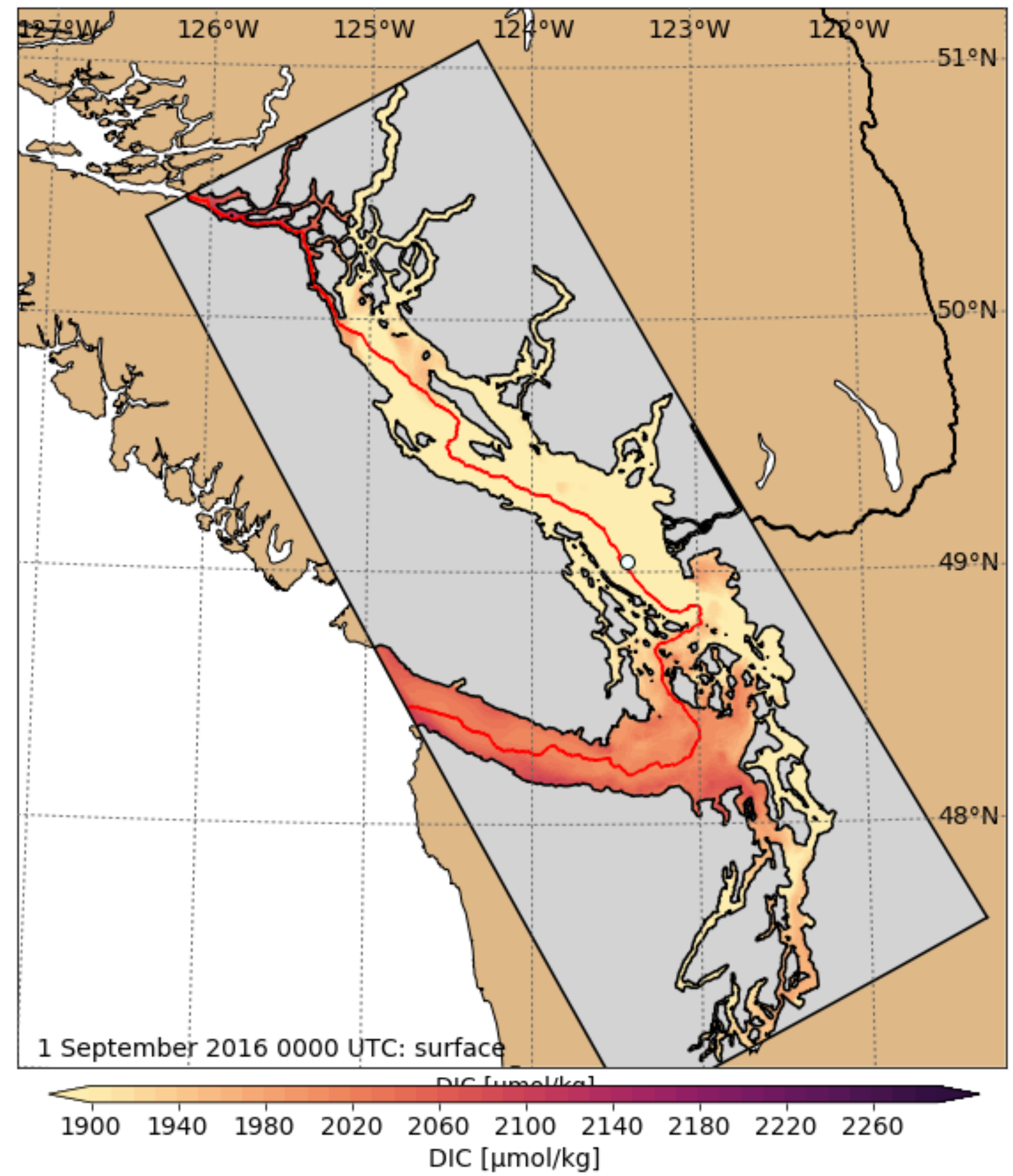






Carbonate Chemistry Model: Observing a deep water renewal event, September 2016





Preliminary result: A strong deep water renewal is accompanied by only a minor change in DIC

PART 2: One Model Analysis Framework and Insights

Cluster analysis: retrieving characteristic signals from a model dataset

Preliminary carbonate chemistry

CLUSTER ANALYSIS

Resolve yearly signals of 4 physical tracers and phytoplankton throughout the model domain:

Physics:

1) Wind Energy

2) Freshwater

Proxy: Difference between surface layer salinity and salinity at depth (50 m)

3) Tidal Mixing

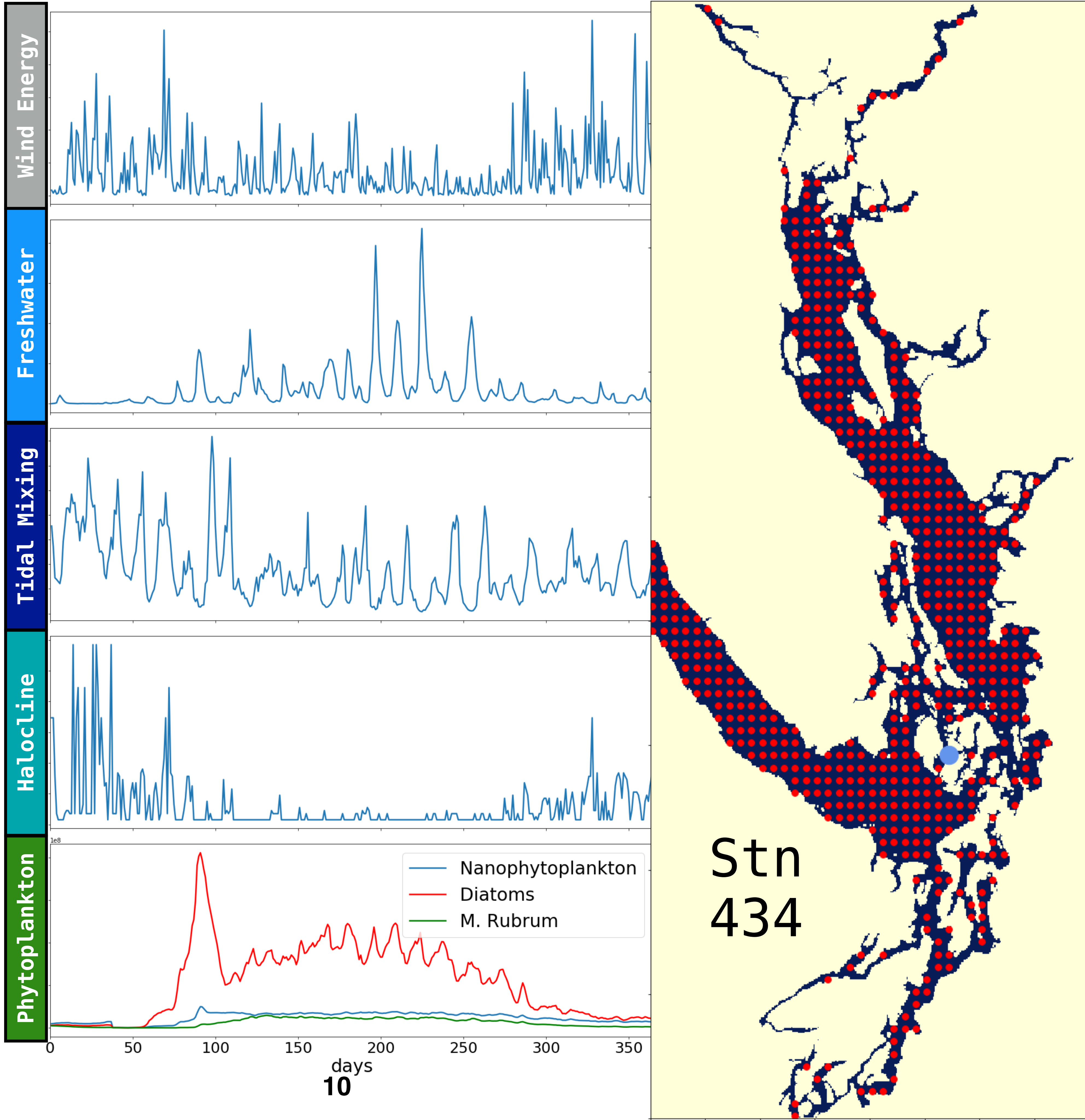
Proxy: Vertical eddy diffusivity

4) Halocline

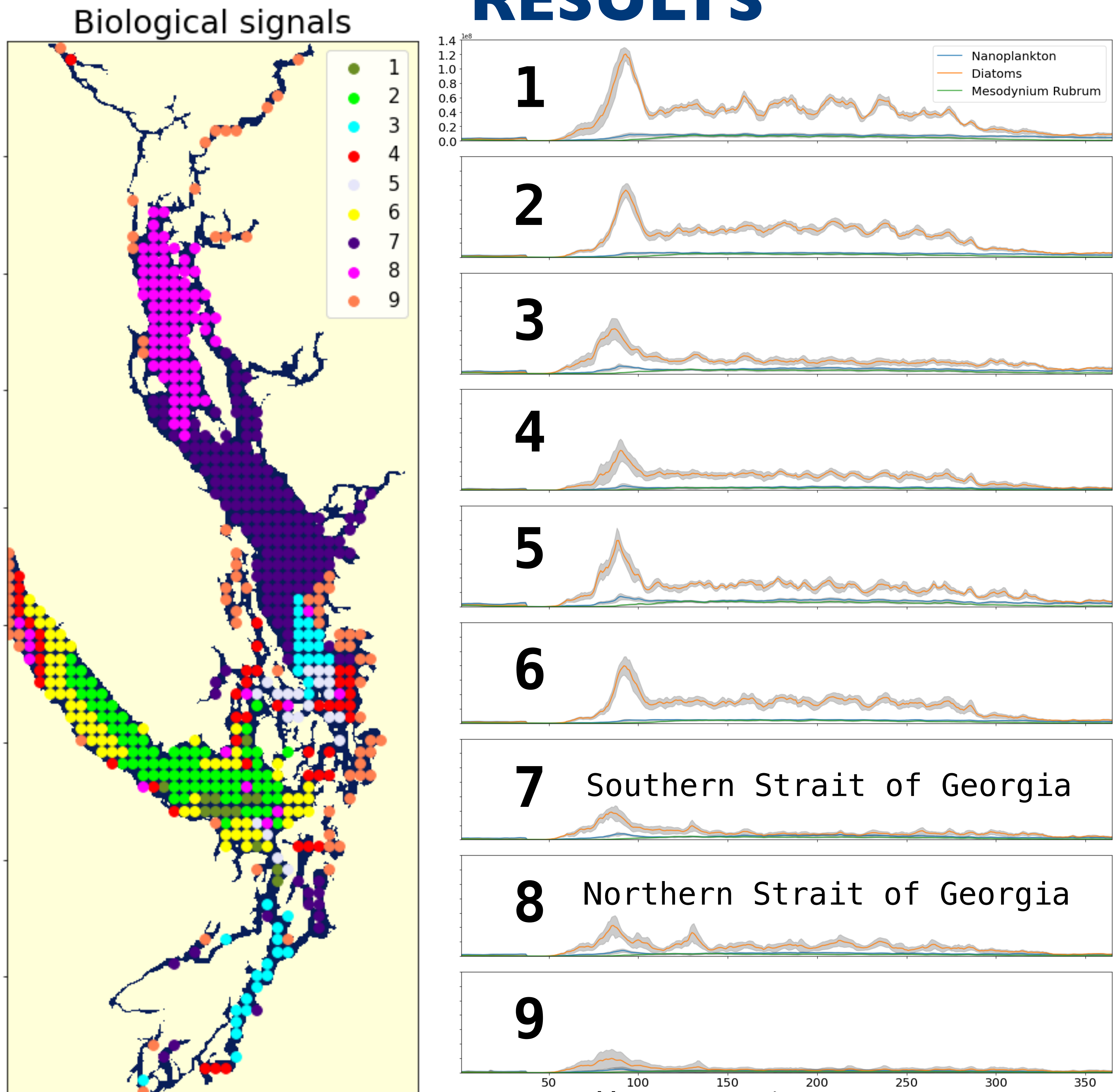
Proxy: Depth of maximum salinity gradient

Biology:

Phytoplankton biomass (chlorophyll)

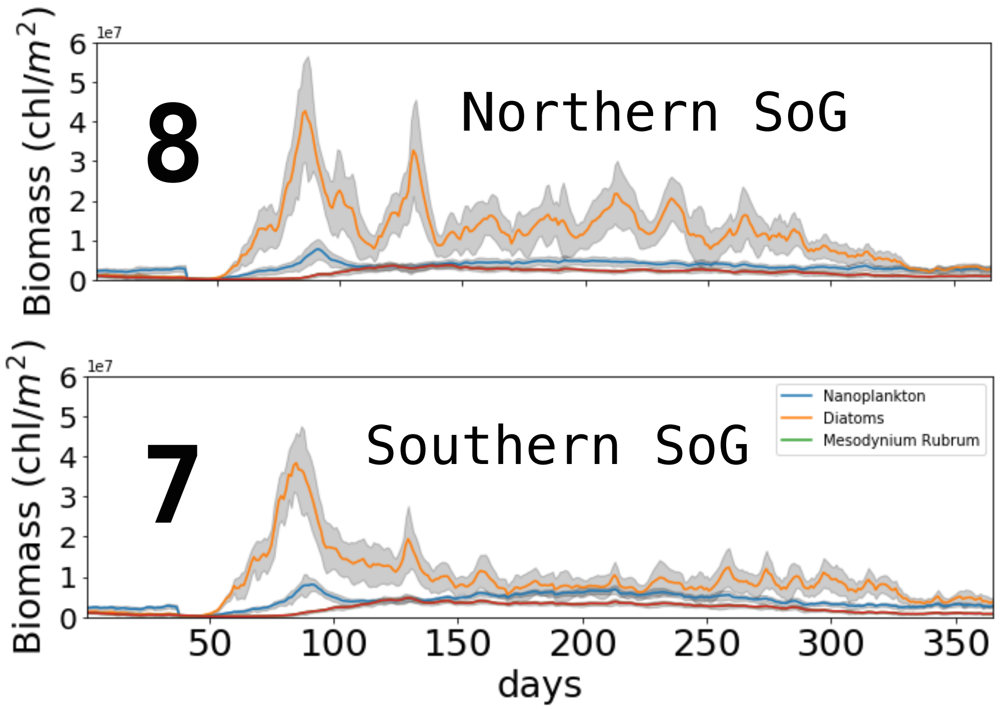


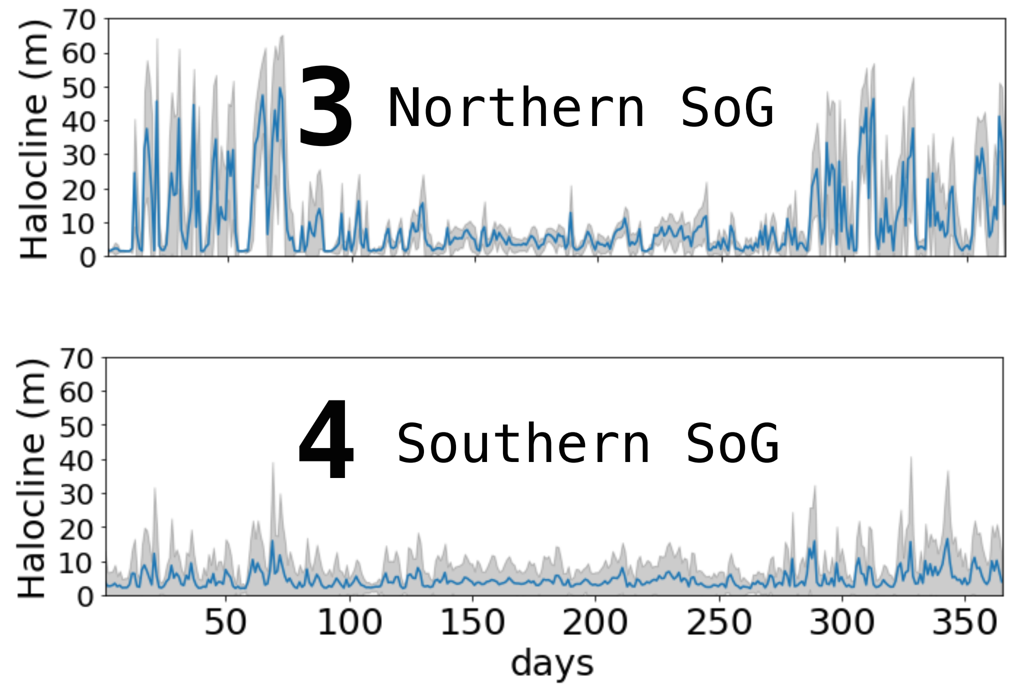
RESULTS

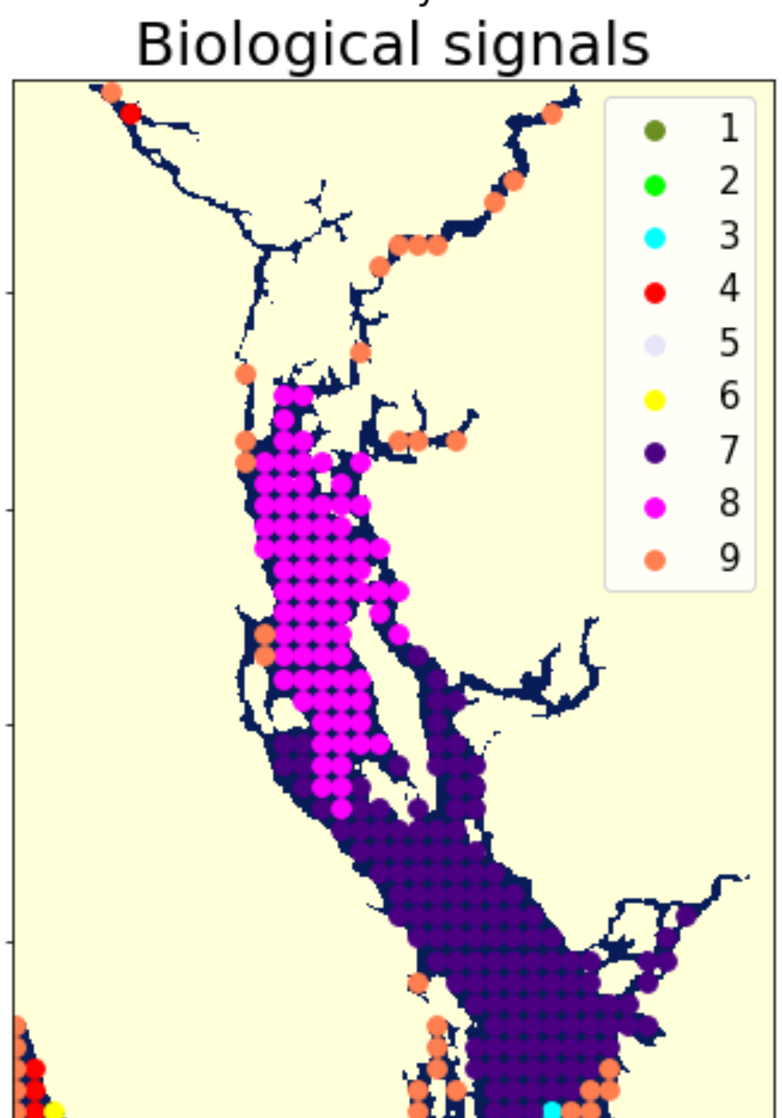


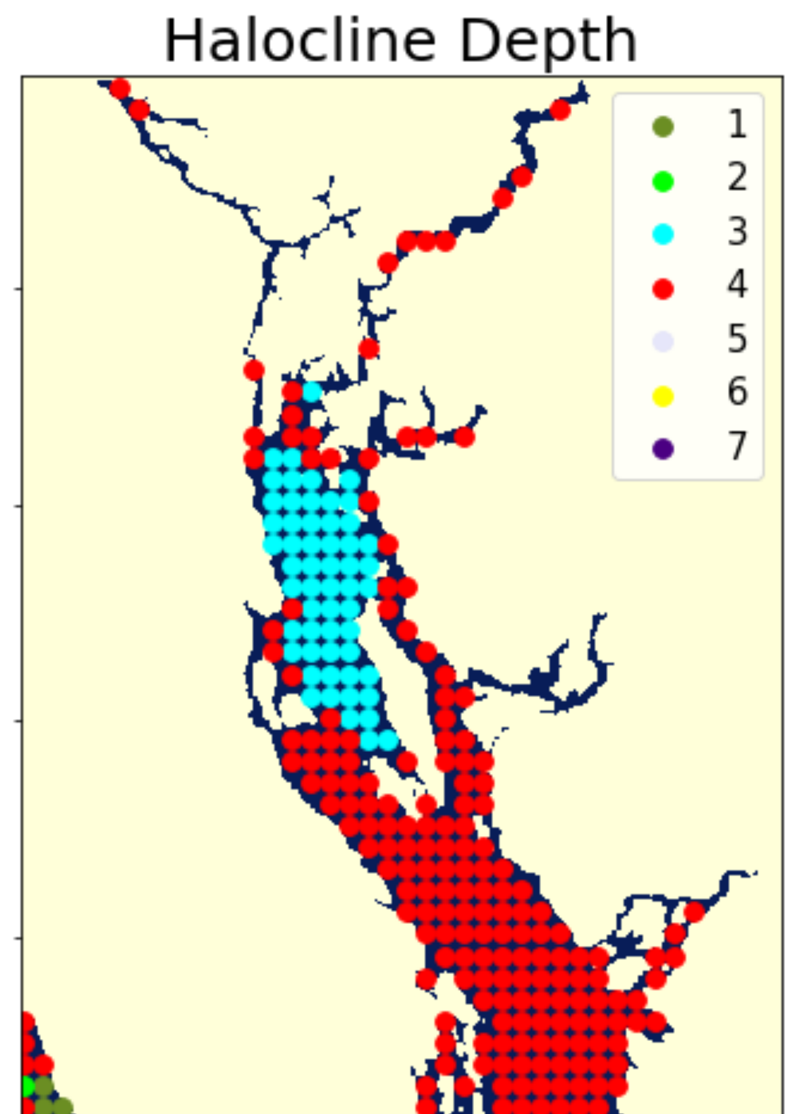
Biological signals
1
2
3
4
5
6
7
8
9
1e8
1.4
1.2
1.0
0.8
0.6
0.4
0.2
0.0
Nanoplankton
Diatoms
Mesodynium Rubrum
Southern Strait of Georgia
Northern Strait of Georgia
50
100
150
200
250
300
350
days

RESULT: Halocline differences between N. and S. Strait coincide with differences in biological activity

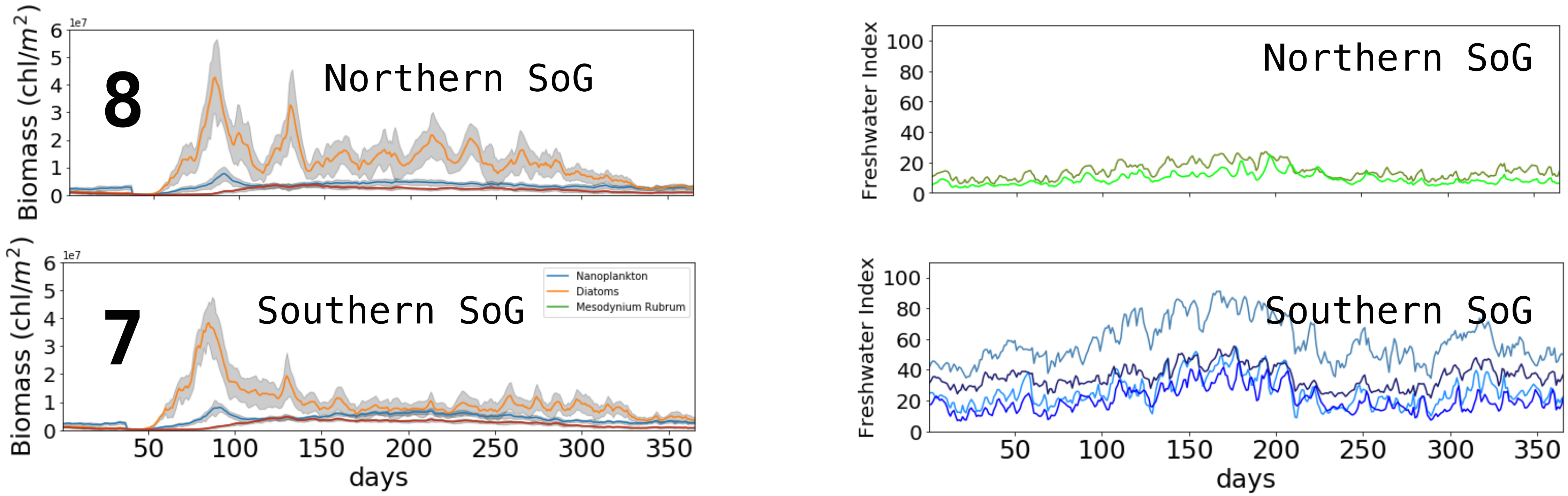


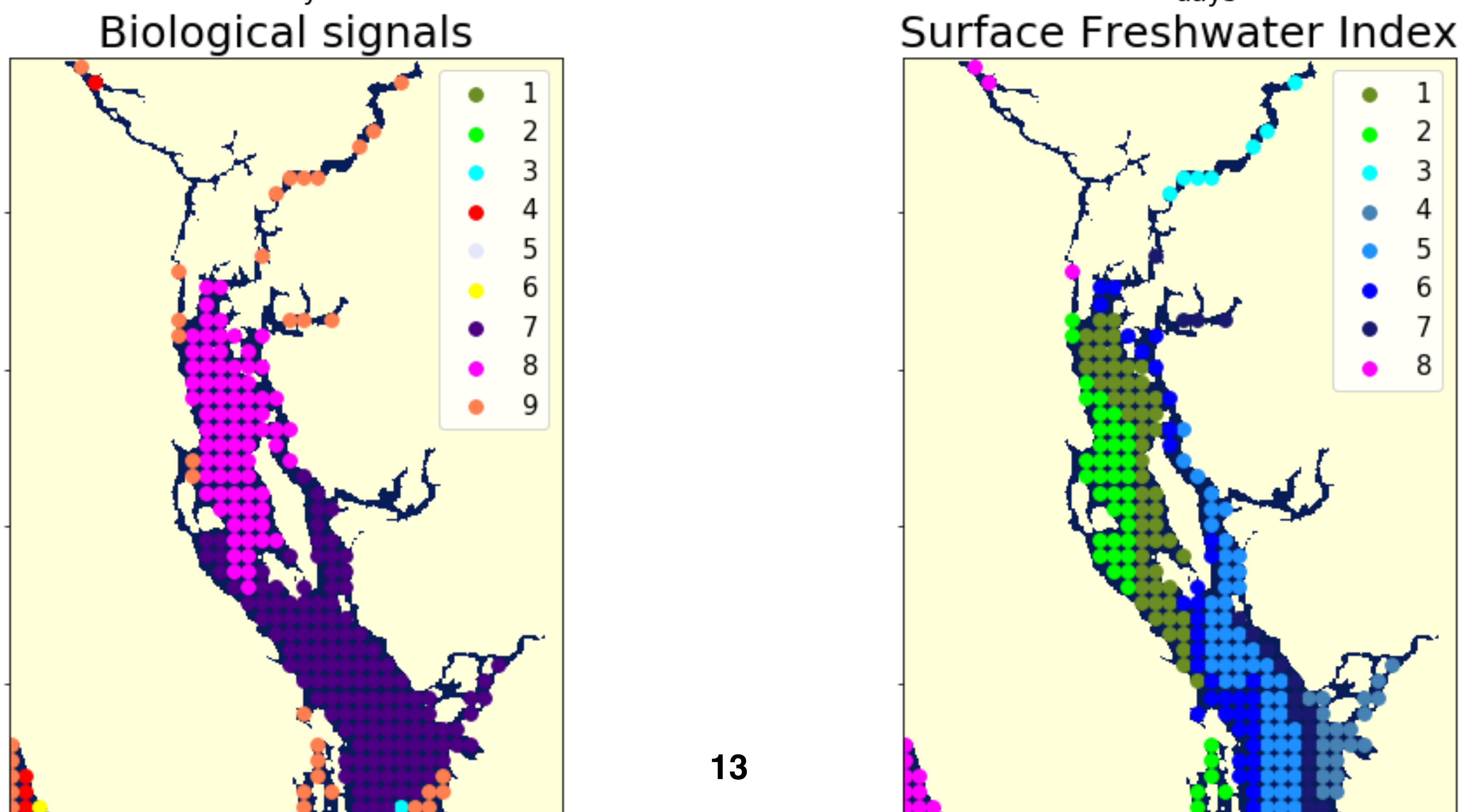




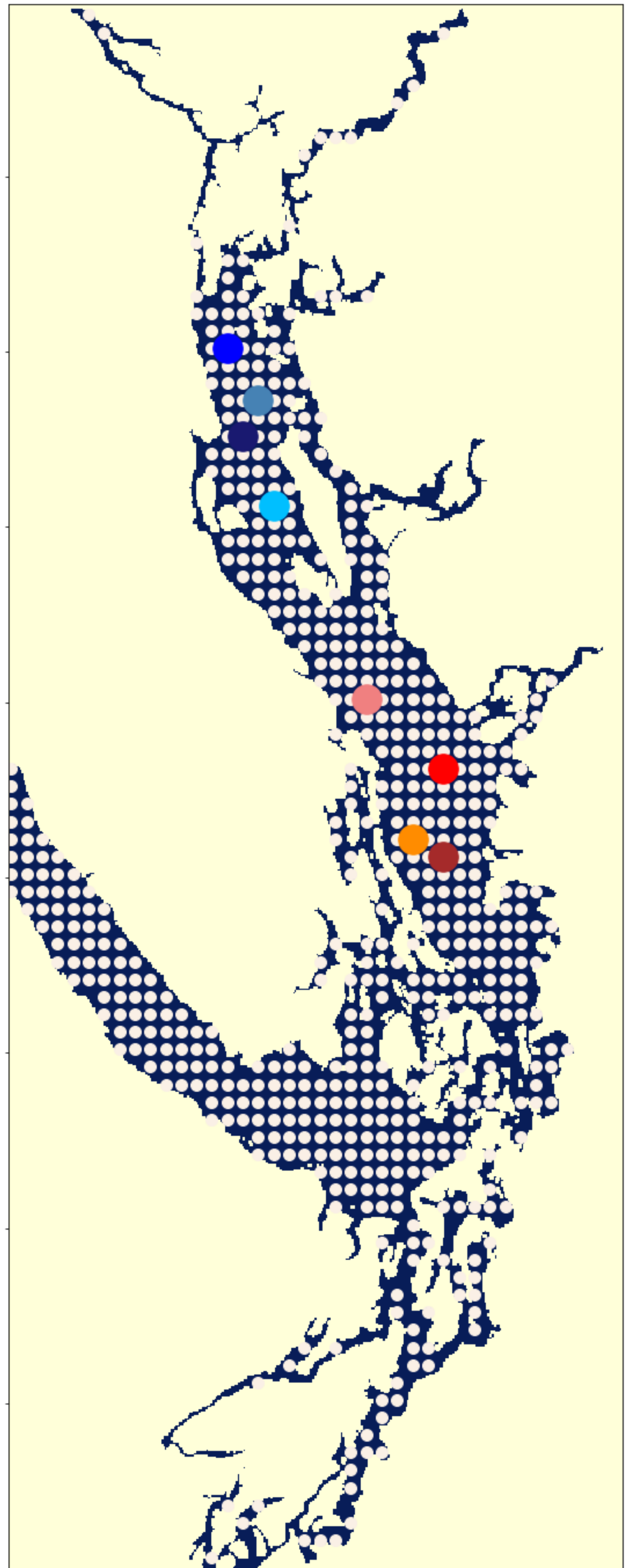


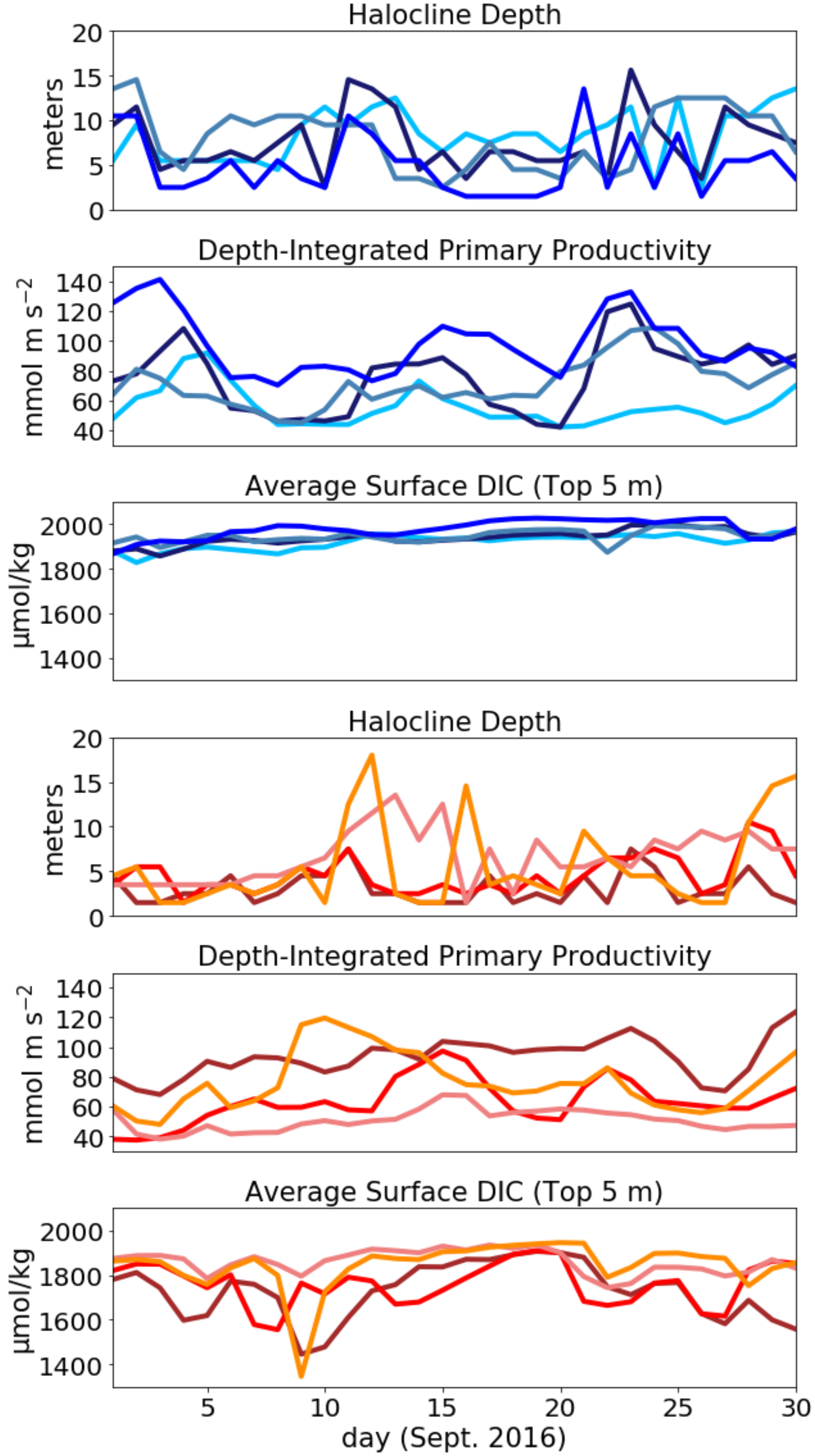
RESULT: Highly stratified, freshwater-driven systems are less productive





PRELIMINARY RESULT: What about the carbon?





Preliminary ideas:

-Deeper & more variable haloclines in north

-no clear differences in primary productivity over this short interval

-more stable DIC signal in north (stratification effects in the fresh south?)

Future work:
Long carbon model runs and cluster analysis

Final notes

1) Different regions of the Strait of Georgia have distinct, spatially cohesive biological signatures that coincide with changes in physical regimes

2) Higher productivity in northern Strait of Georgia may be explained by stronger mixing due to lower freshwater input

3) Data science approaches identify patterns in complex systems - help ask better questions!

4) Ongoing carbon modelling work shows regional differences; much more to do!

Thank you!