Modeling the San Francisco Bay Ecosystem dynamics

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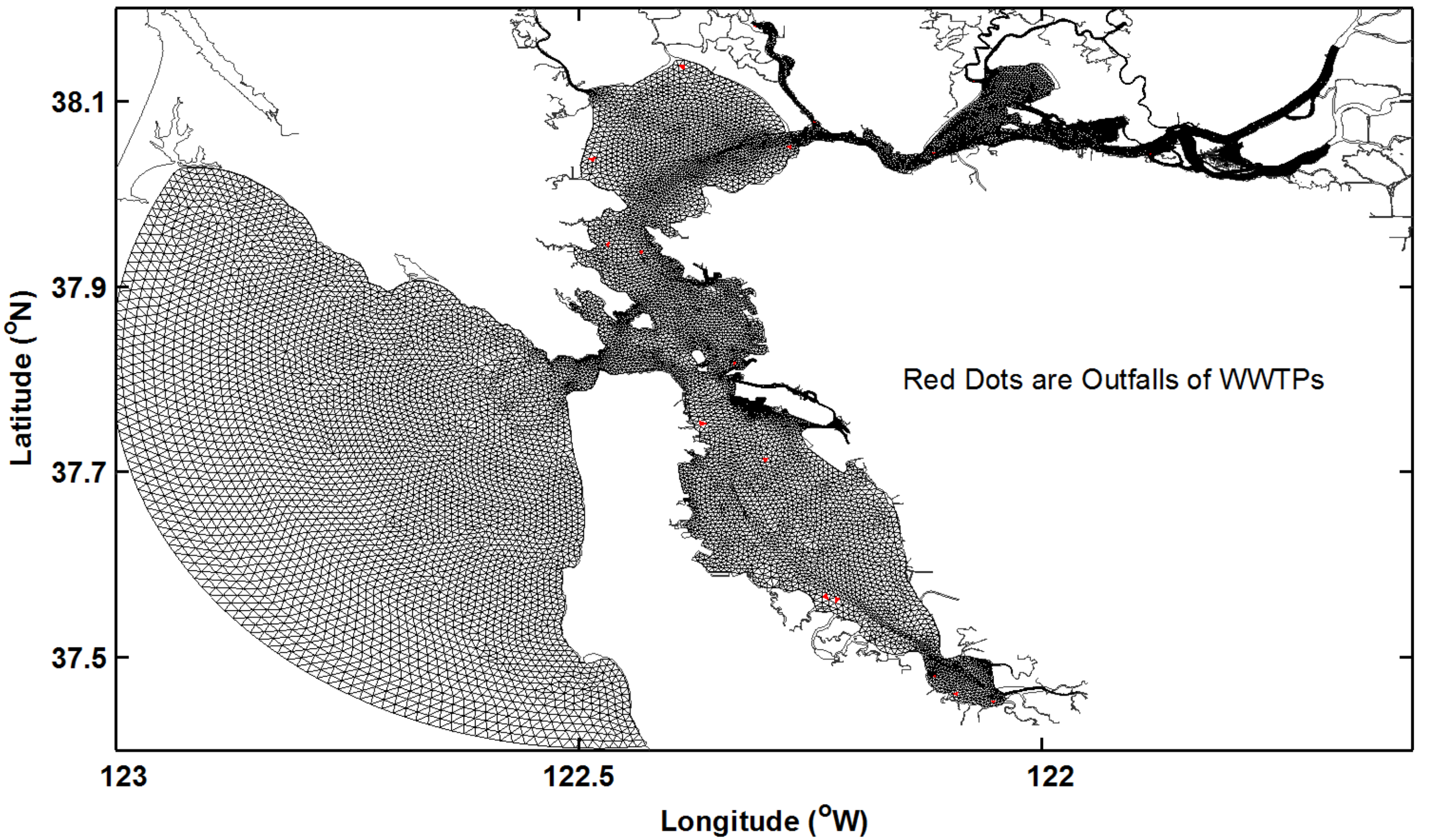
Outline

- Method: Coupled SCHISM-CoSINE model
- Ecological Model Results and Assessment
- Ecological Response to
  - Hydrological Conditions
  - NH_4 Concentration
  - NH_4 Inhibition Parameter
  - Bottom Grazing
- Summary
- Future Plan

Method: Coupled Schism-CoSiNE Model

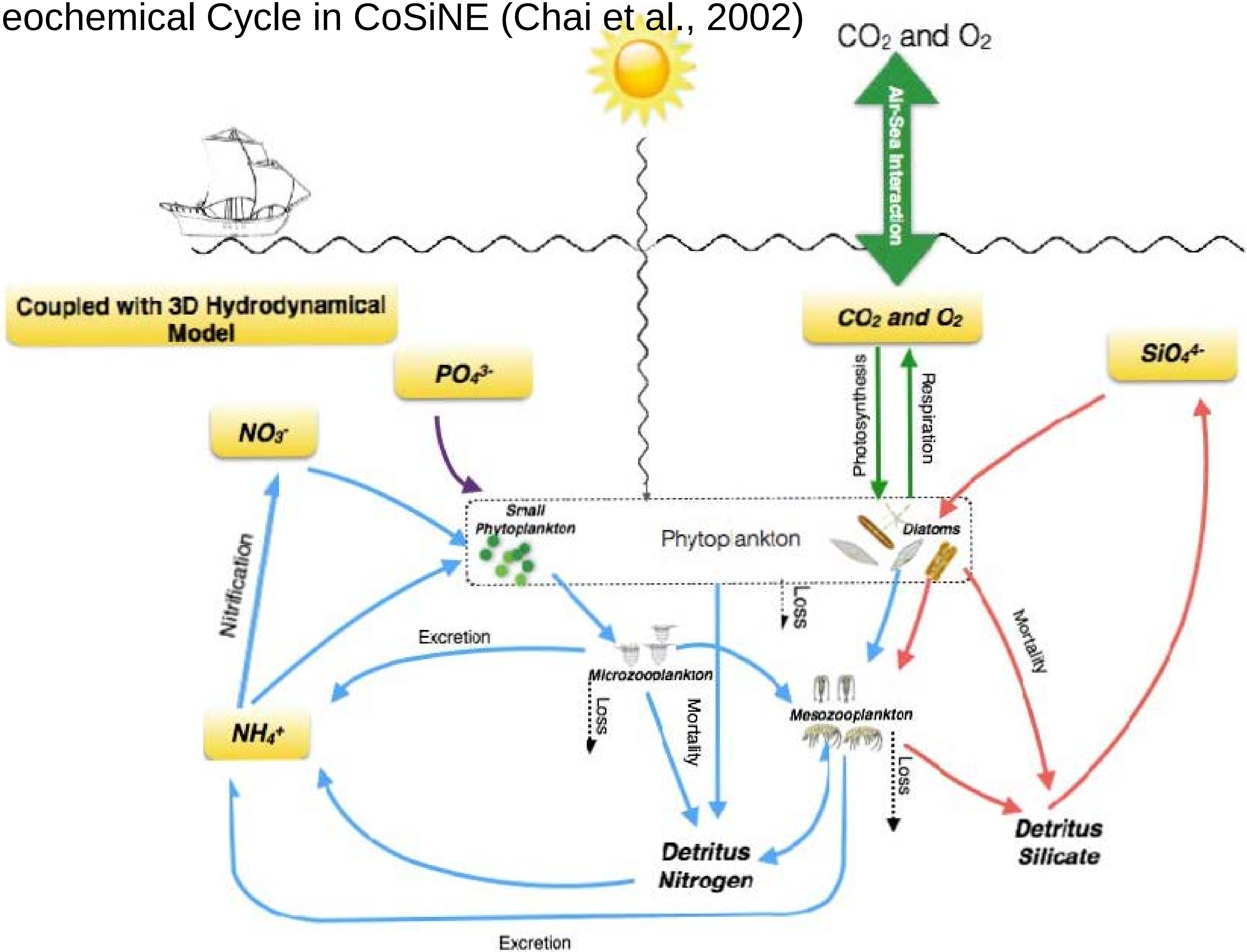
SCHISM (Semi-Implicit Cross-scale Hydroscience Integrated System Model):

CoSiNE (Carbon, $Si(OH)_4$, Nitrogen Ecosystem Model; Fei Chai et al. at UMaine)



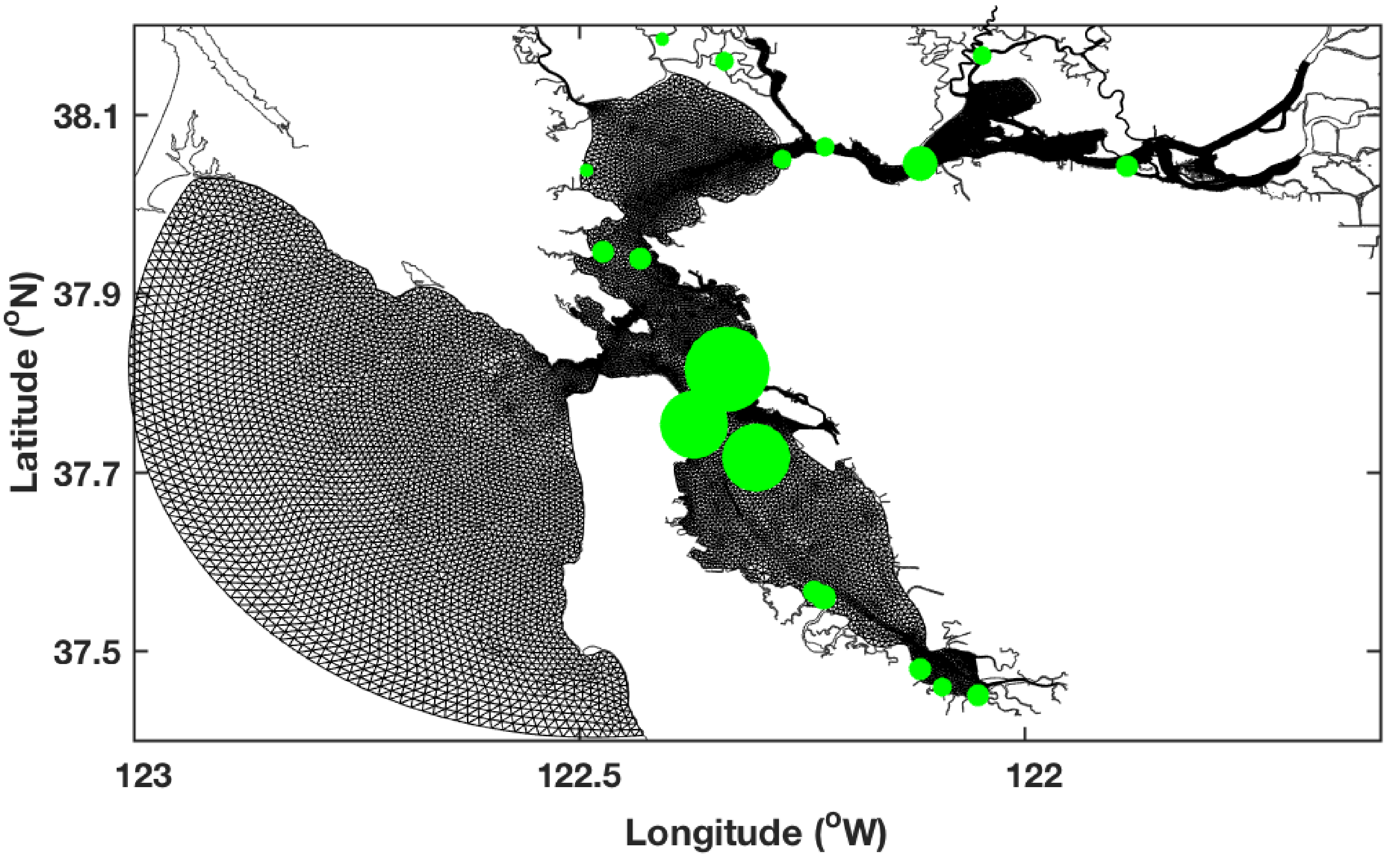
Model Configuration (Courtesy of Yinglong Zhang, Virginia Institute of Marine Science)

Method: Coupled Schism-CoSiNE Model:
Biogeochemical Cycle in CoSiNE (Chai et al., 2002)



Method: Coupled Schism-CoSiNE Model

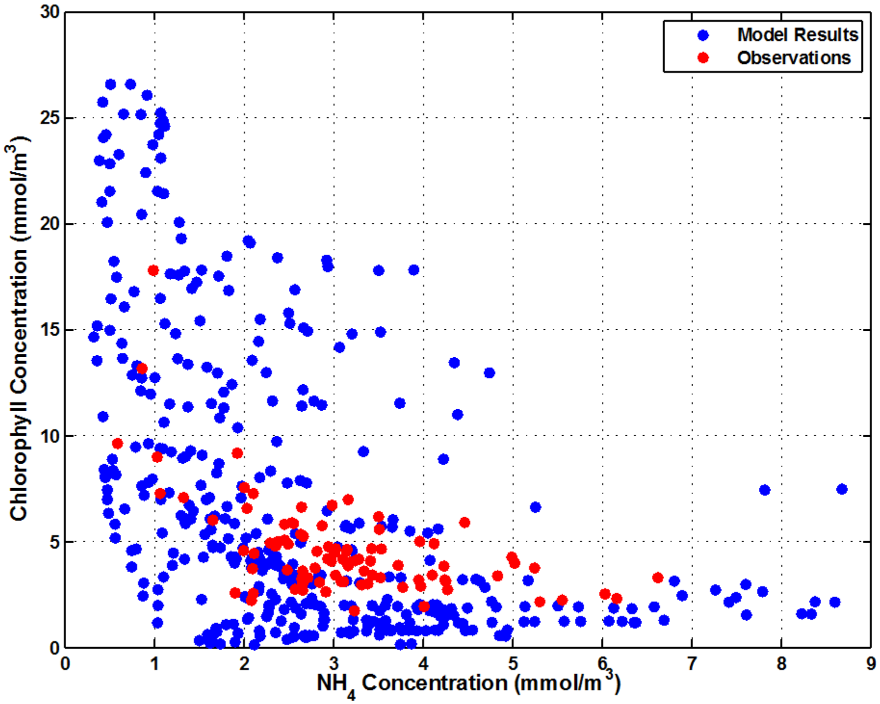
- **Boundary Conditions:** 3-km ROMS-CoSiNE; Rivers with discharge, dissolved inorganic nutrients;
- **Sources:** Nutrients from 18 WWTPS

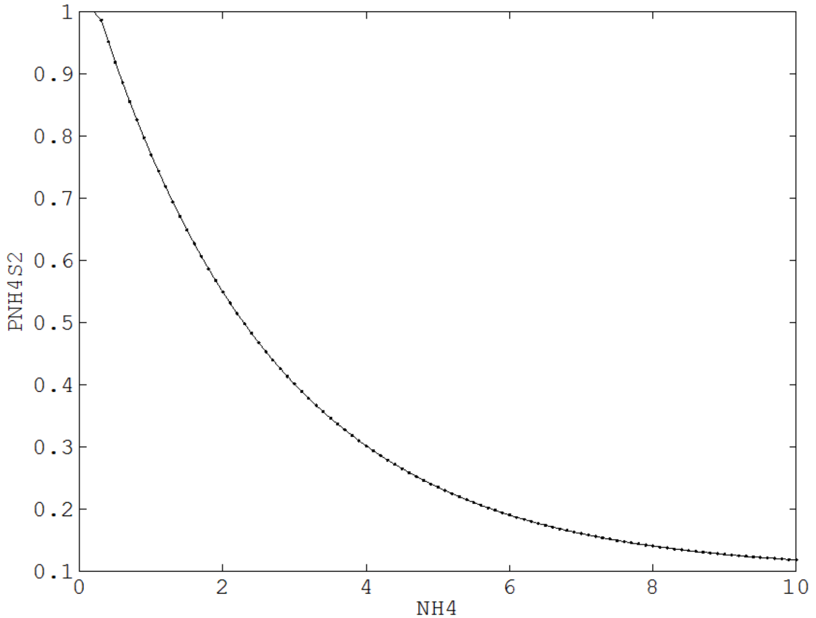


Model Configuration (Courtesy of Yinglong Zhang, Virginia Institute of Marine Science)

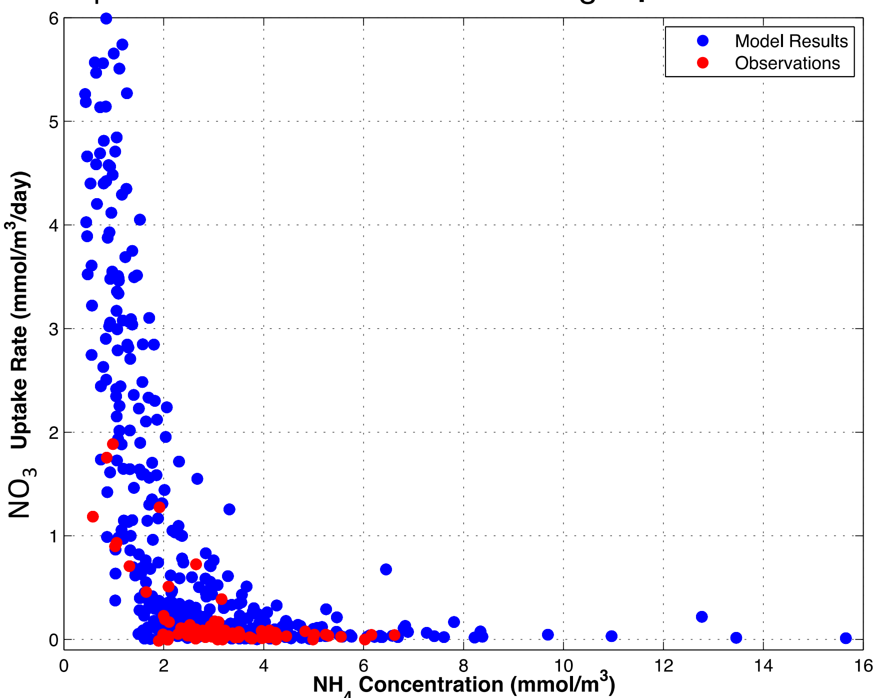
Model Functioning

NH$_4$ Conc. **v.s.** Chlorophyll Conc.

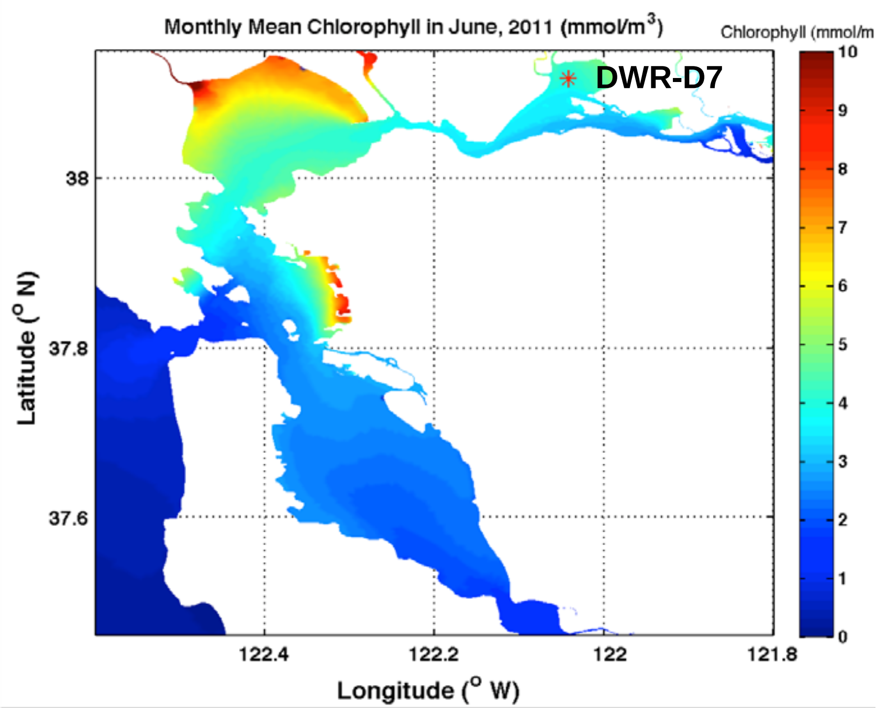




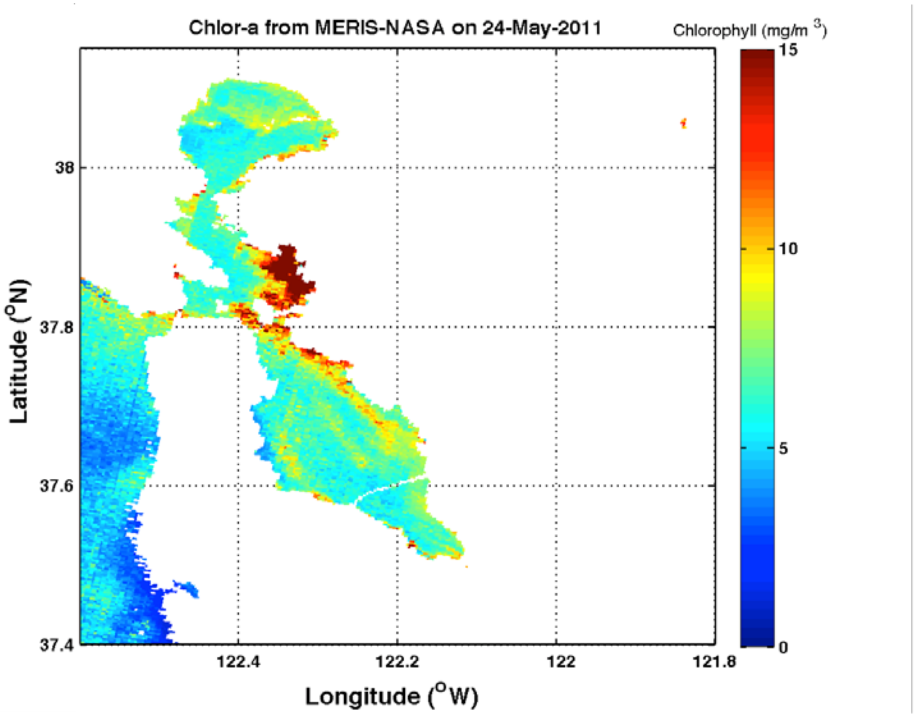
NH$_4$ concentration **v.s.** NO$_3$ uptake Rate



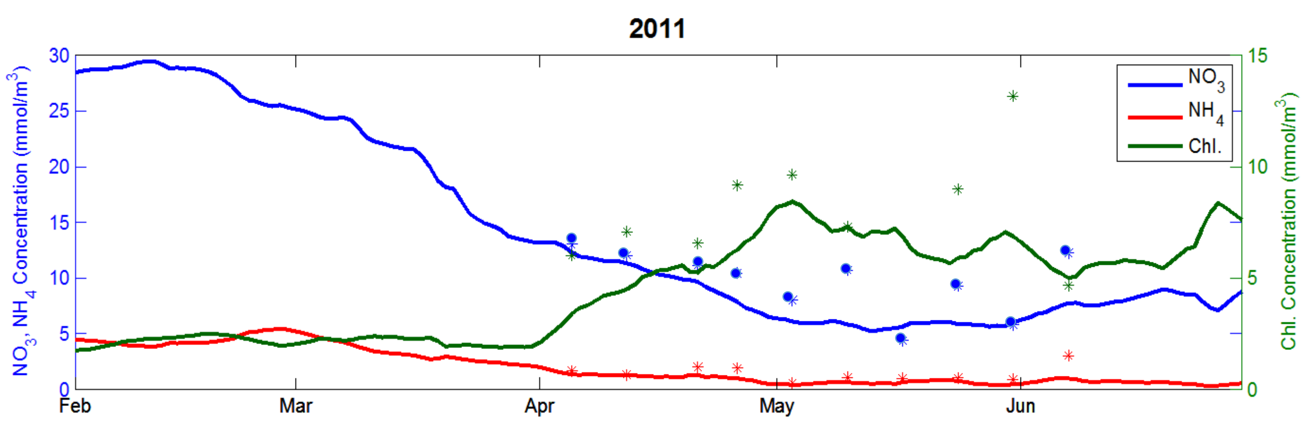
SCHISM-CoSiNE Depth-averaged Nutrients and Chlorophyll in Control Experiment (R1)



Modelled monthly mean Chlorophyll in June, 2011

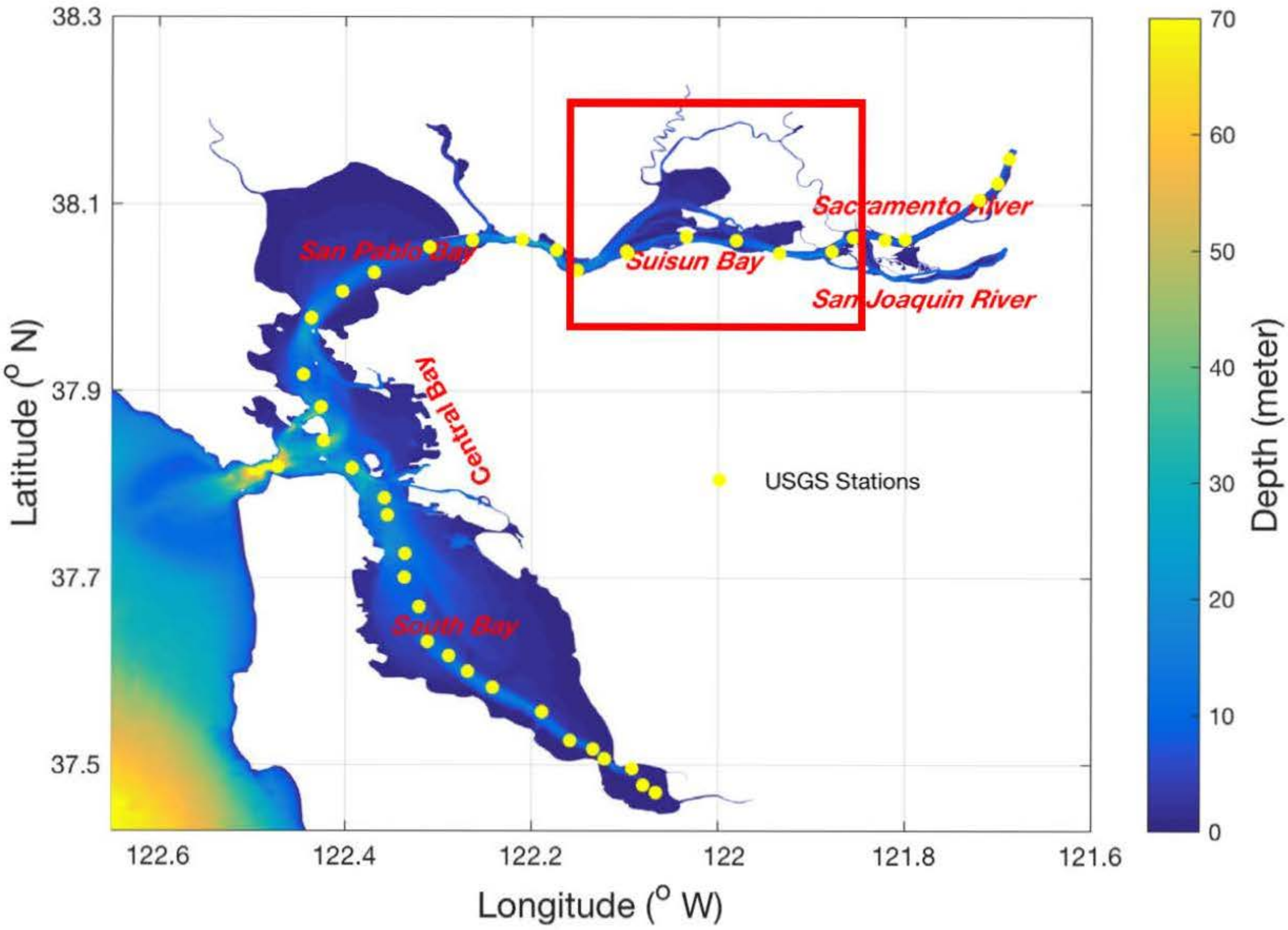


Chl-a from MERIS-NASA on 24th May, 2011

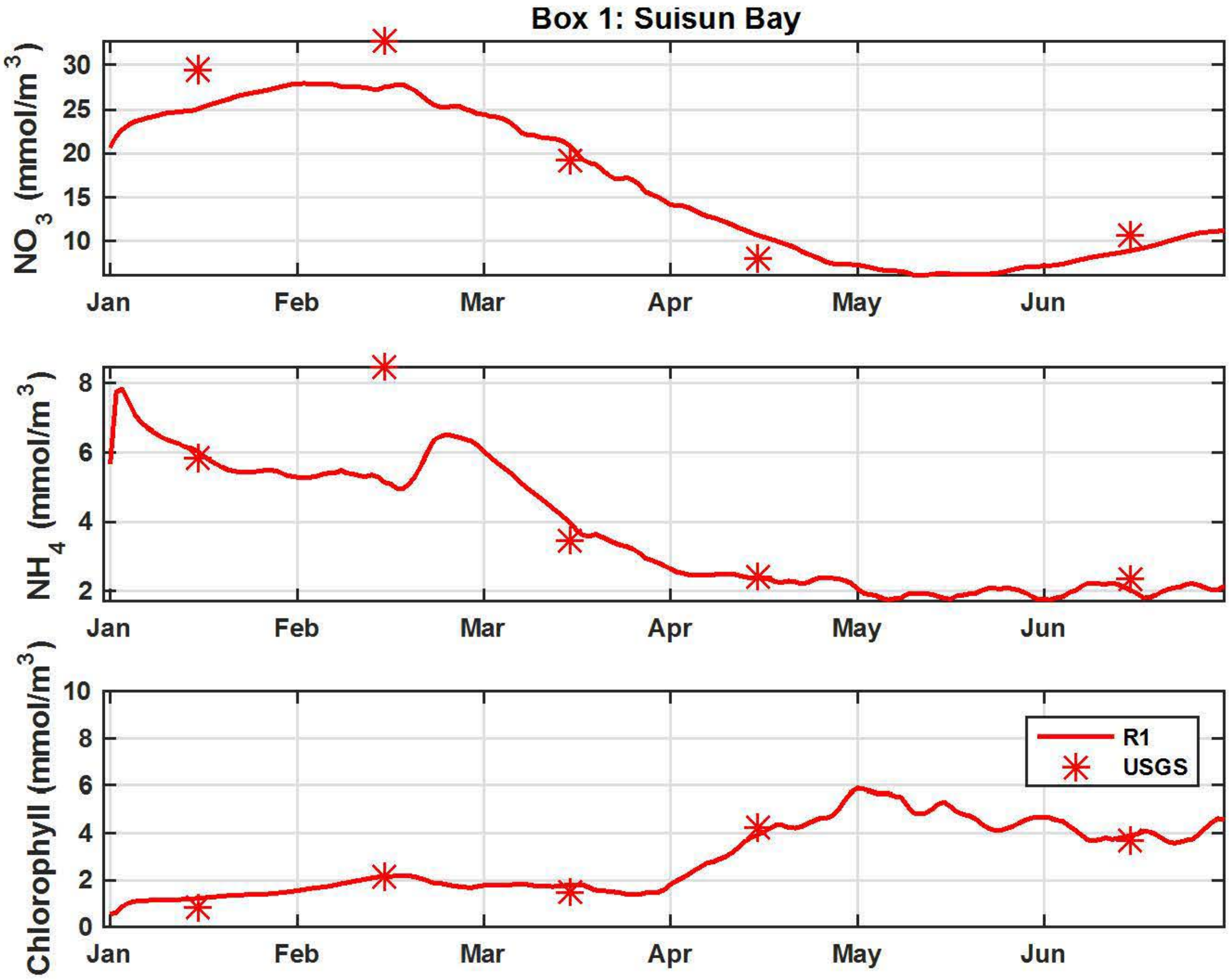


Comparisons of NO_3, NH_4 and **Chlorophyll** concentrations at the station of DWRD7. Lines for model results; Stars for observations (Dugdale et al., 2015).

SCHISM-CoSiNE Depth-averaged Nutrients and Chlorophyll in Control Experiment (R1)

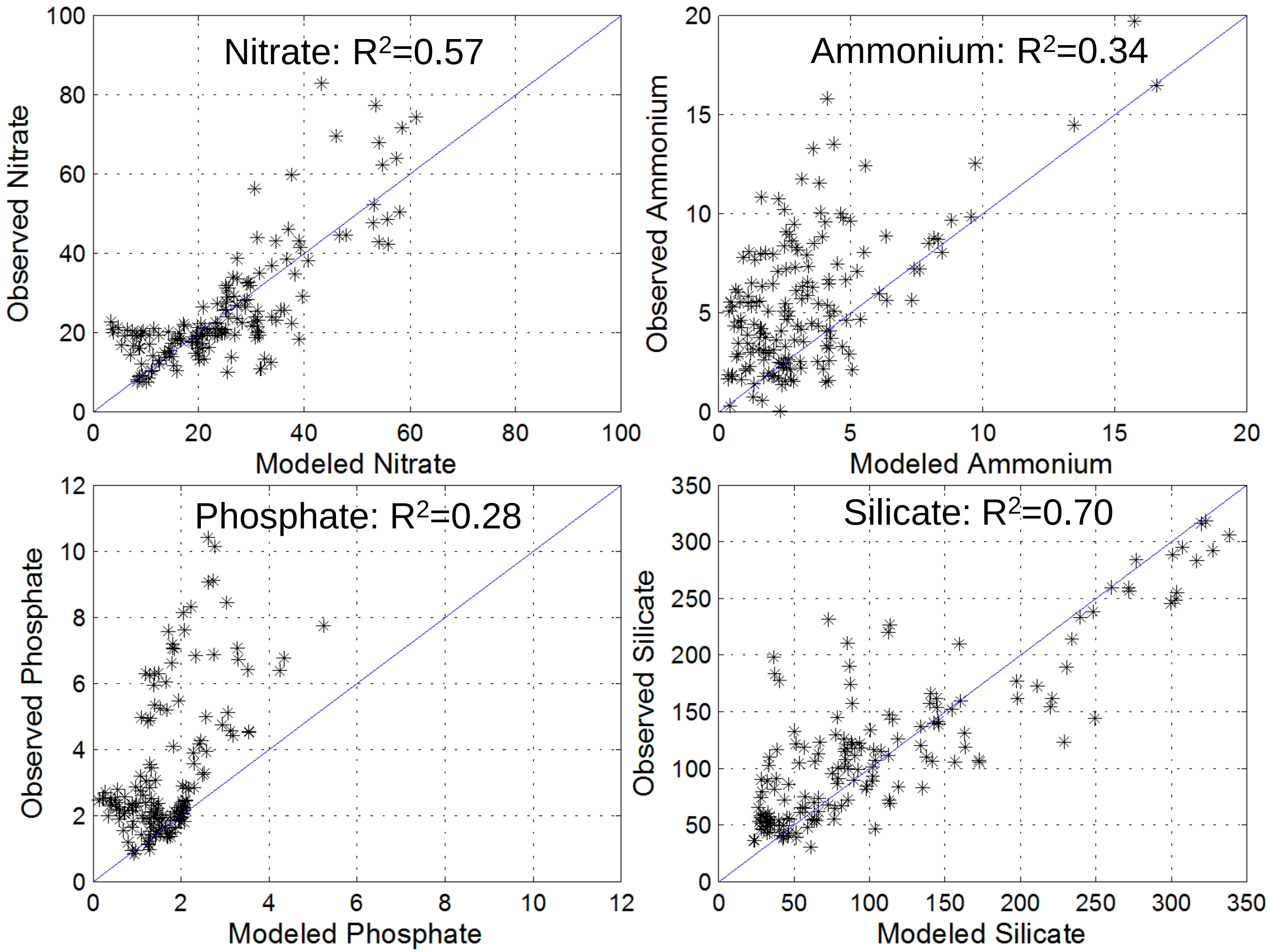


SCHISM-CoSiNE Depth-averaged Nutrients and Chlorophyll in Control Experiment (R1)



Comparisons of $\mathbf{NO_3}$, $\mathbf{NH_4}$ and **Chlorophyll** concentrations over the USGS stations in Suisun Bay. Lines for model results; Stars for observations.

Model Evaluation: Scattered Plots of Nutrients



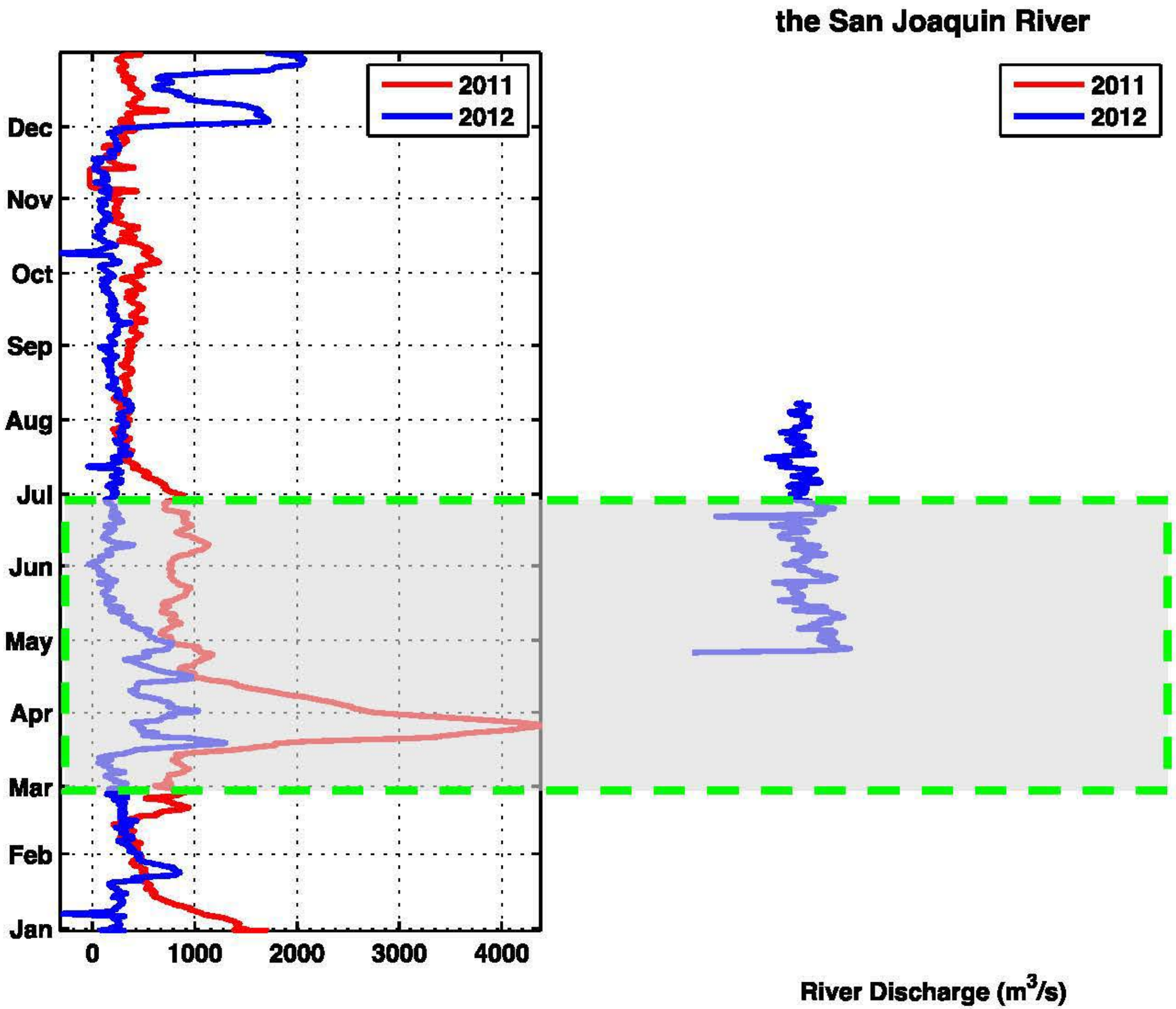
Scattered Plot of Nutrients

SCHISM-CoSiNE Sensitivity Experiments

Name	Design	River	Nutrient Source from Rivers	WWTPs	Bottom Grazing
R1	The Base, Control Case	2011	USGS for 2011	Constant	No
R2	Weaker River Discharge in 2012	2012	USGS for 2012	Constant	No
R3	Double NH4 from Rivers	2011	Double NH4 from Rivers in 2011	Constant	No
R10	Triple NH4 from WWTPs	2011	USGS for 2011	Double NH4	No
R12	No WWTPs	2011	USGS for 2011	No WWTPs	No
R5	Increase Bottom Grazing	2011	USGS for 2011	Constant	Yes
R6	Inhibition parameter 6.6	2011	USGS for 2011	Constant	No
R7	Inhibition parameter 0.5	2011	USGS for 2011	Constant	No
R8	Constant SPM of 100 mg/m^3 in Suisun and San Pablo Bays from Apr. to Sep.	2011	USGS for 2011	Constant	No

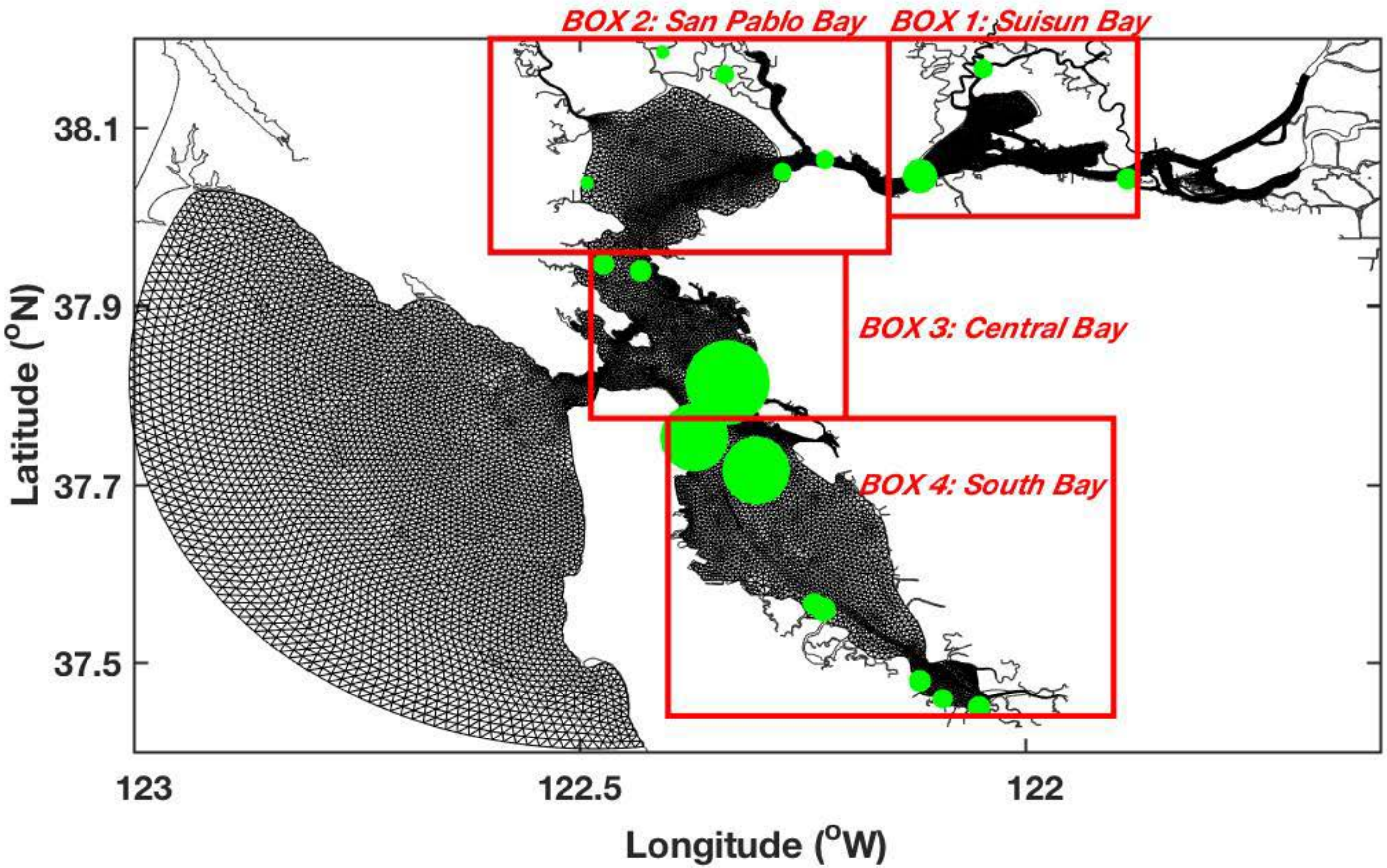
Sensitivity Experiments: Response to Different Hydrological Conditions in 2011 (R1) and 2012 (R2) for Box 1

Hydrological Conditions in 2011 and 2012



River flux at the mouth of the Sacramento and San Joaquin Rivers in 2011 and 2012 (Courtesy of USGS)

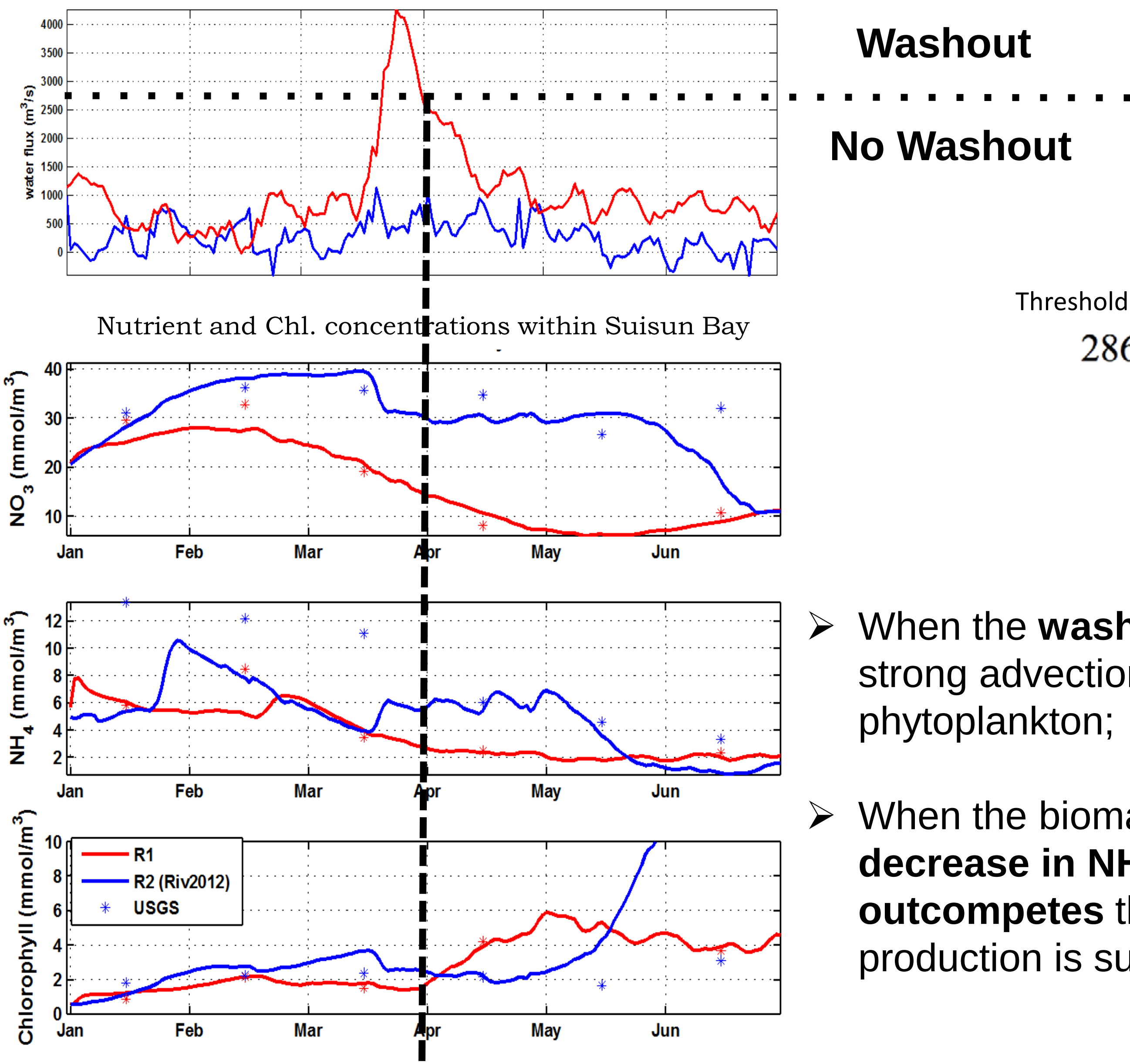
SCHISM-CoSiNE Simulated Nutrients Transport over the Box Regions for the Control Experiment (R1)



The red boxes partition SFB into four box regions

Sensitivity Experiments: Response to Different Hydrological Conditions in 2011 (R1) and 2012 (R2) for Box 1

Volume flux at the mouth of the Sac. River in 2011 and 2012



$9.9\times10^{8}\ \mathrm{m}^3$

Volume of Suisun Bay

$$F_{max} = \nu NH_4 * V$$

Threshold volume flux

$2860\ \mathrm{m}^3/\mathrm{s}$

Specific NH_4 uptake rate

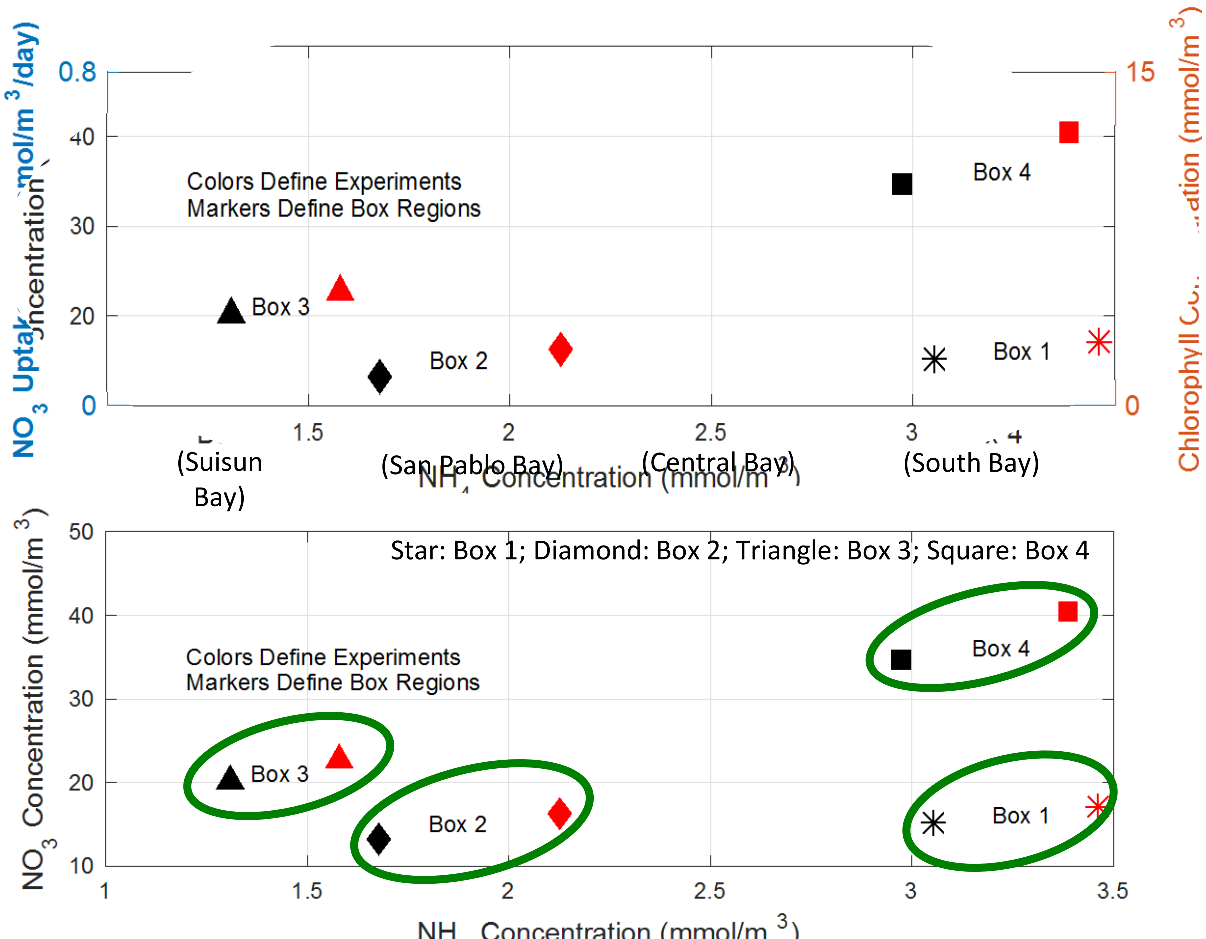
0.25 mol/day

Dugdale (2012)

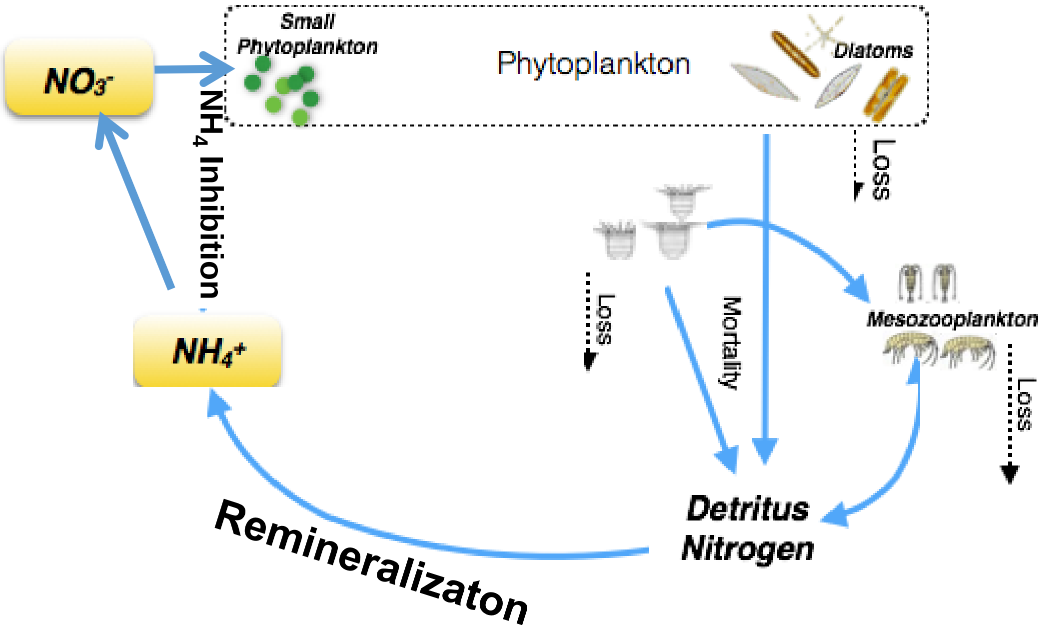
- When the **washout effect** is significant, the strong advection **suppresses** the growth of phytoplankton;
- When the biomass growth caused by **the decrease in NH_4** concentration **outcompetes** the washout effect, the primary production is sustained.

Sensitivity Experiments: with 10 times mortality of phytoplankton and zooplankton at the bottom 2 layers (R5)

Comparisons of Biomass Response

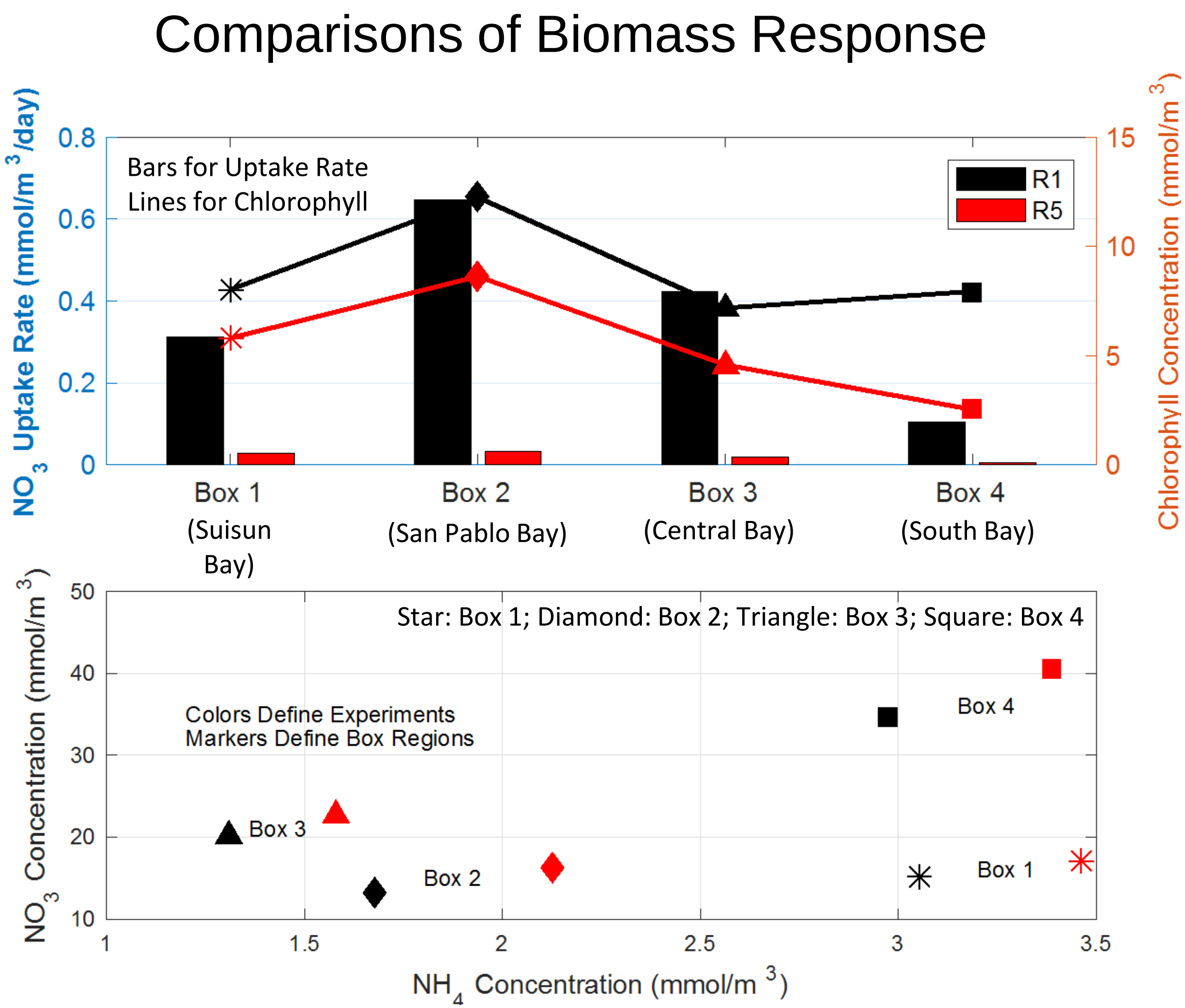


Annual Mean NO_3 uptake rate, Chl. NO_3 and NH_4 concentrations in the Box Regions in **R1 and R5**



Agree with the study by Dugdale et al. (2016) who found the invasive clams could modulate NH_4 concentrations and affect the biomass by NH_4 inhibition.

Sensitivity Experiments: with 10 times mortality of phytoplankton and zooplankton at the bottom 2 layers (R5)

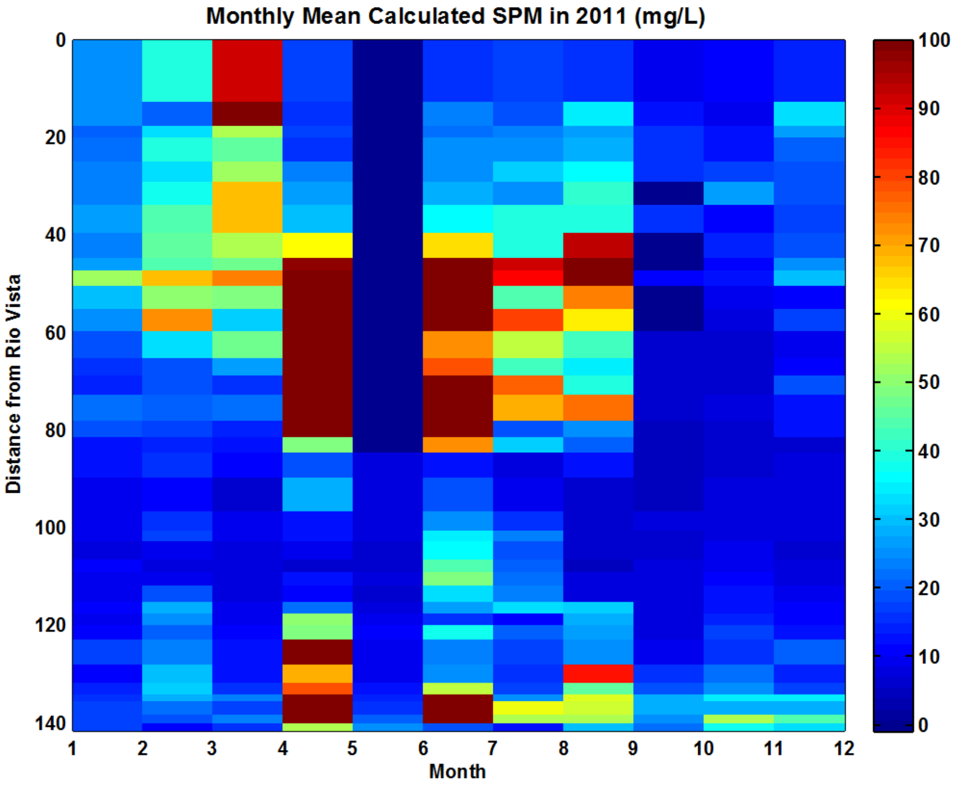


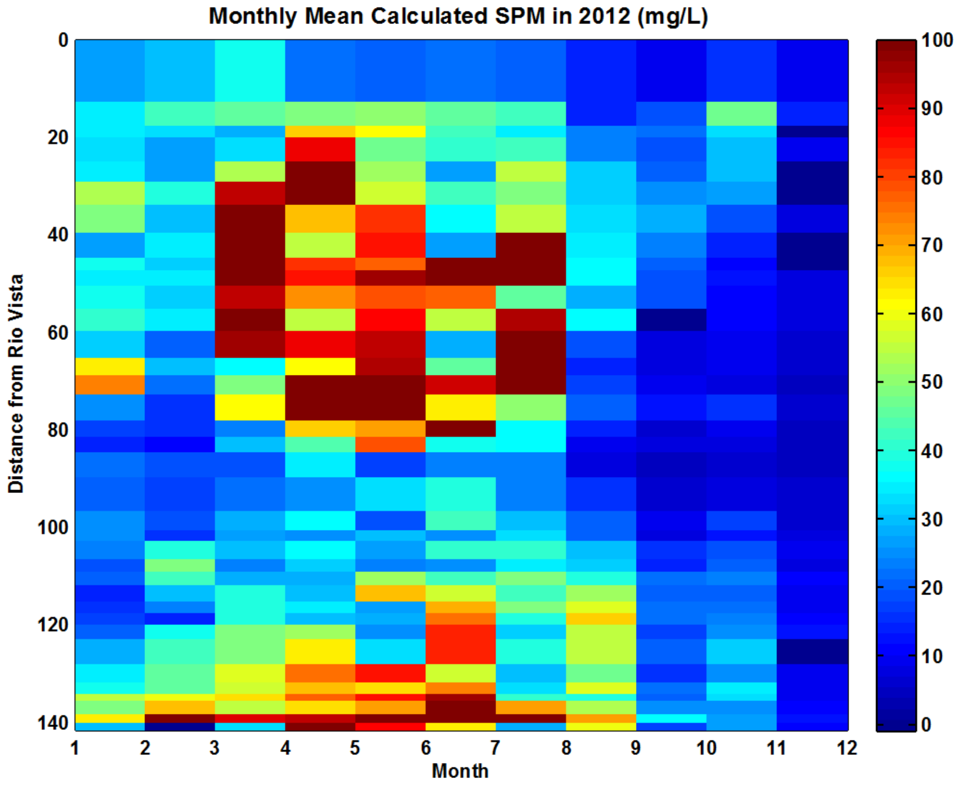
Annual Mean NO_3 uptake rate, Chl. NO_3 and NH_4 concentrations in the Box Regions in **R1 and R5**

Summary

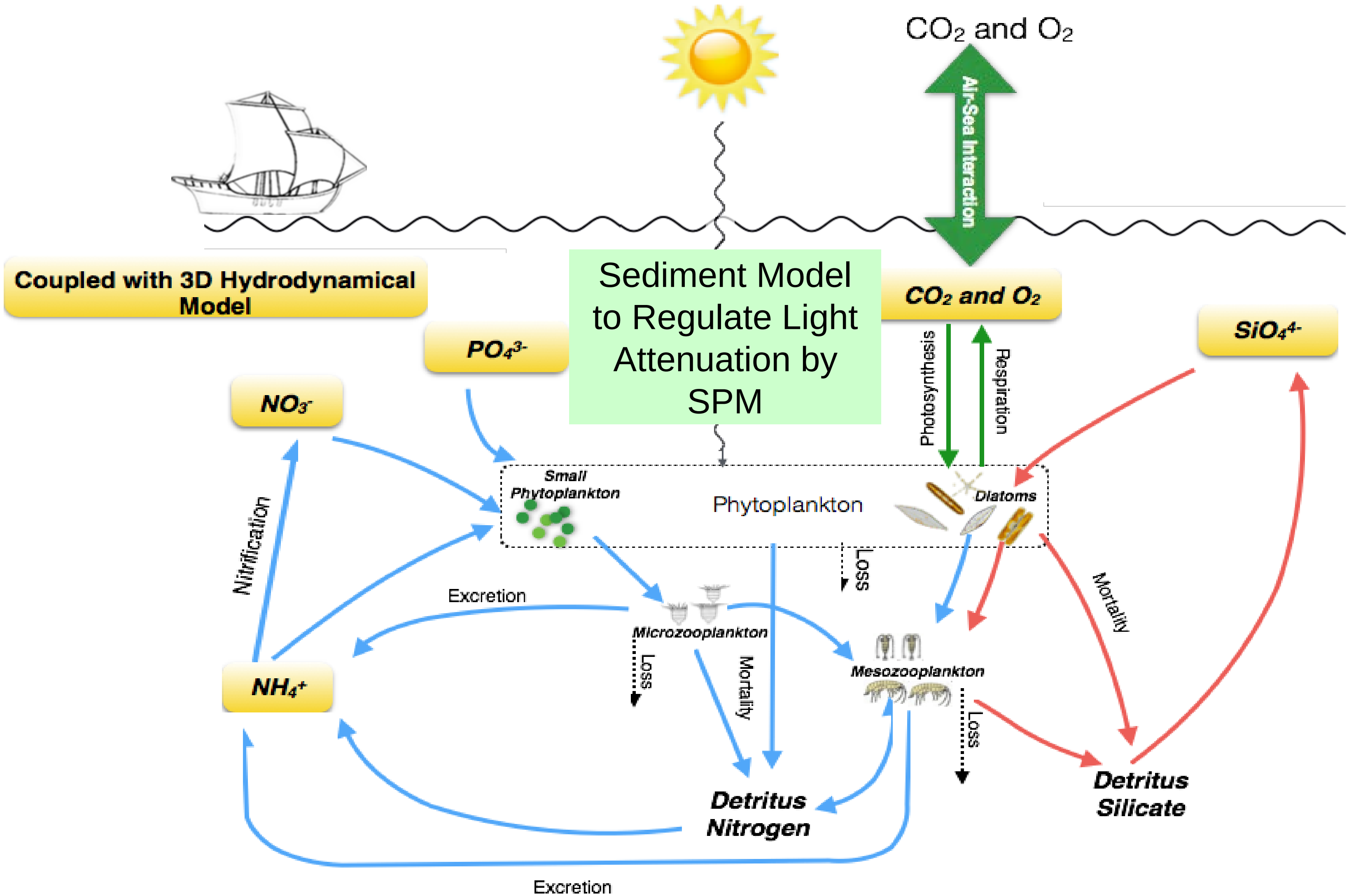
- Model successfully captures the spring blooms in 2011;
- In spring, river discharge regulates the nutrients uptake rate by modulating the NH_4 concentration, while the washout effect can limit the biomass. There is a competition between washout effect and the dilution of NH_4;
- NH_4 inhibition is an important factor in regulating ecosystem response;
- At the same time, bottom grazing is important in suppressing biomass bloom.

Monthly mean Suspended Particulate Matter (SPM) concentration in 2011 and 2012 as obtained from USGS





Future Work


CO2 and O2
Air-Sea Interaction
Coupled with 3D Hydrodynamical Model
Sediment Model to Regulate Light Attenuation by SPM
CO2 and O2
PO4 3-
NO3-
SiO4 4-
Photosynthesis
Respiration
Small Phytoplankton
Phytoplankton
Diatoms
Nitrification
Excretion
Loss
Mortality
Microzooplankton
Mesozooplankton
NH4+
Detritus Nitrogen
Detritus Silicate
Excretion

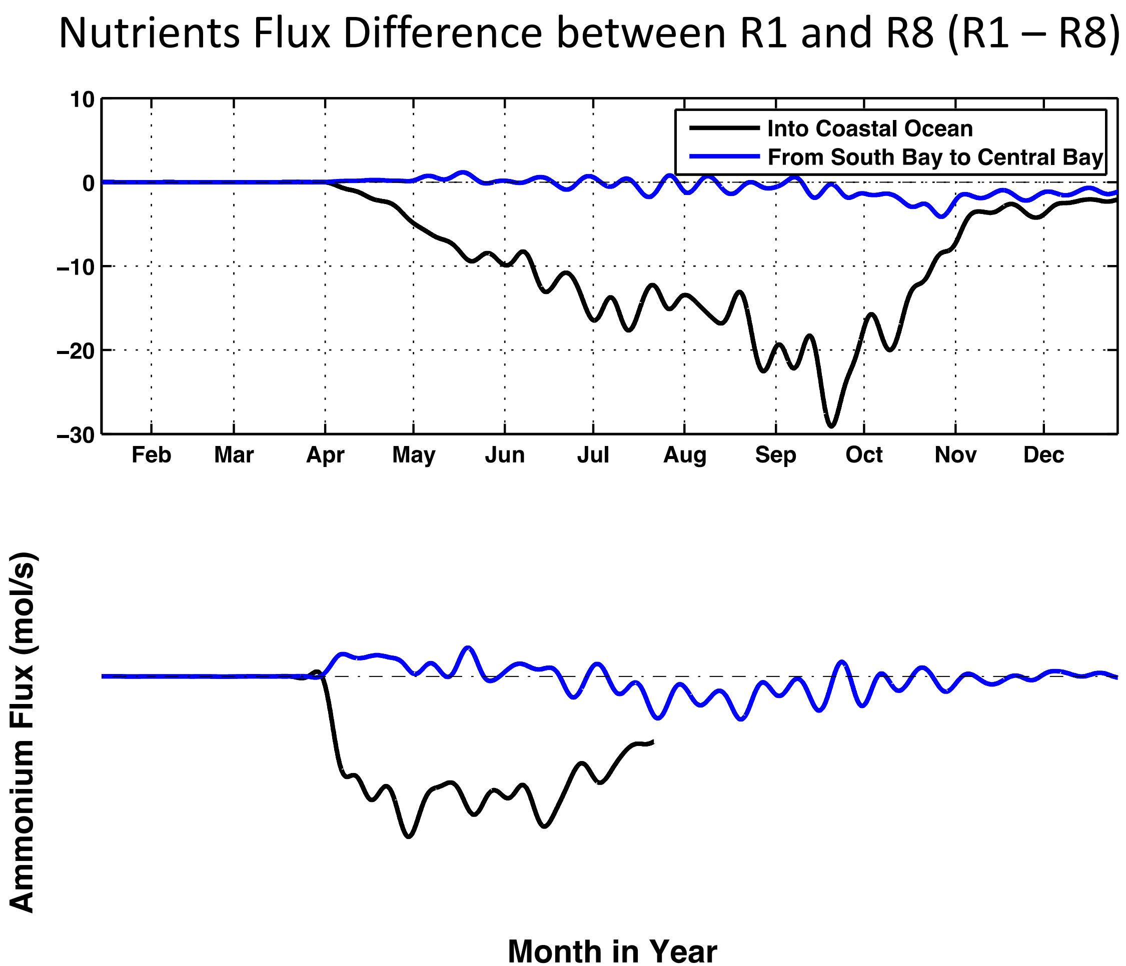
Acknowledgments

- This work is supported by the NASA Grant: NNX14AD79G: impacts of population growth on the San Francisco Bay and Delta ecosystem (RIO-SFE).

Thank you!

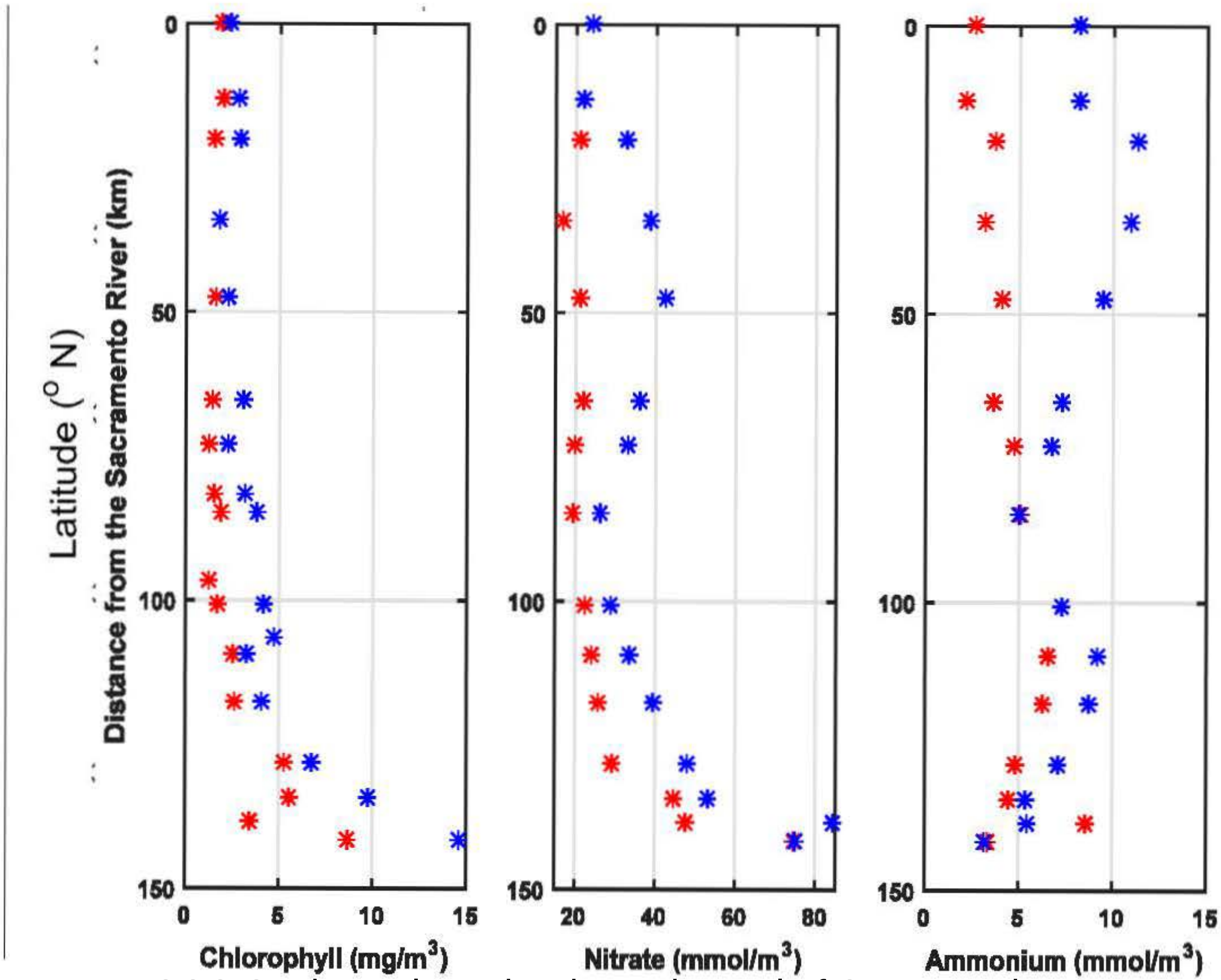
Questions?

R8: Experiment with a constant SPM of 100 mg/m³ for Suisun Bay and San Pablo Bay between April and September.



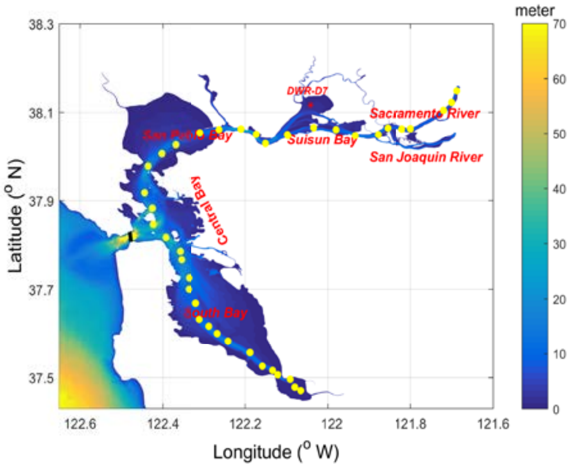
Differences of nutrient flux across the Golden Gate and across the section between South Bay and Central Bay between the experiment R8 and the experiment R1 (R1-R8).

Background: Nutrient and Biomass in spring of 2011 and 2012



USGS Stations along the deep channel of San Francisco Bay

Biomass and nutrient concentrations along the USGS stations in 2011 and 2012 spring

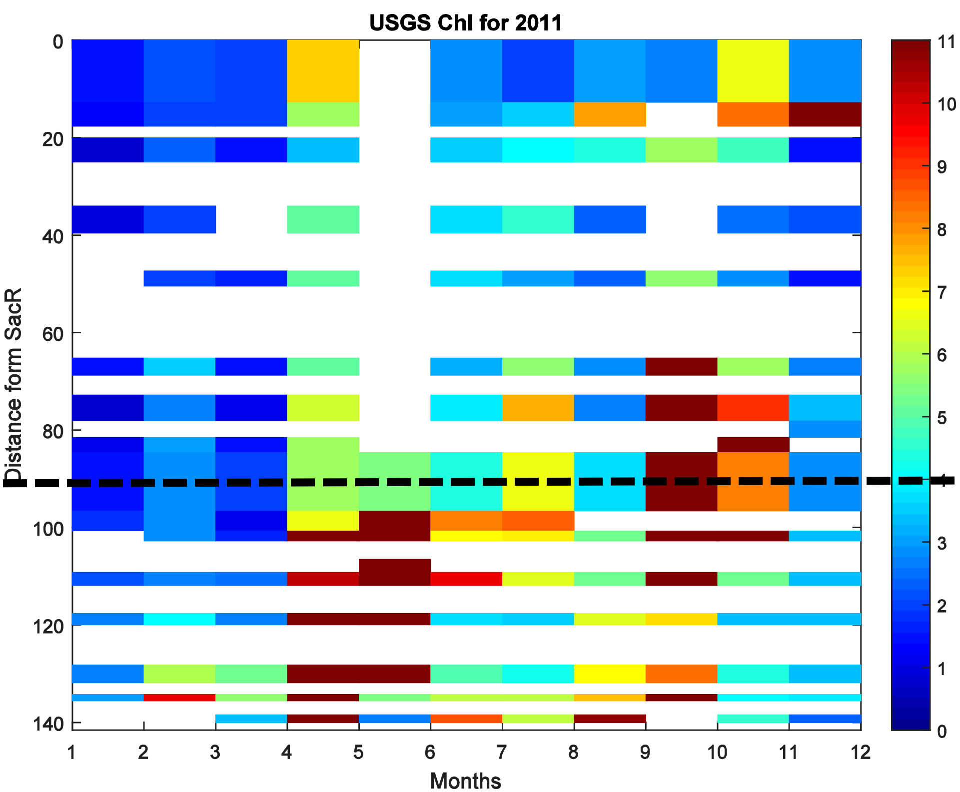


Ecological Model Assessment:

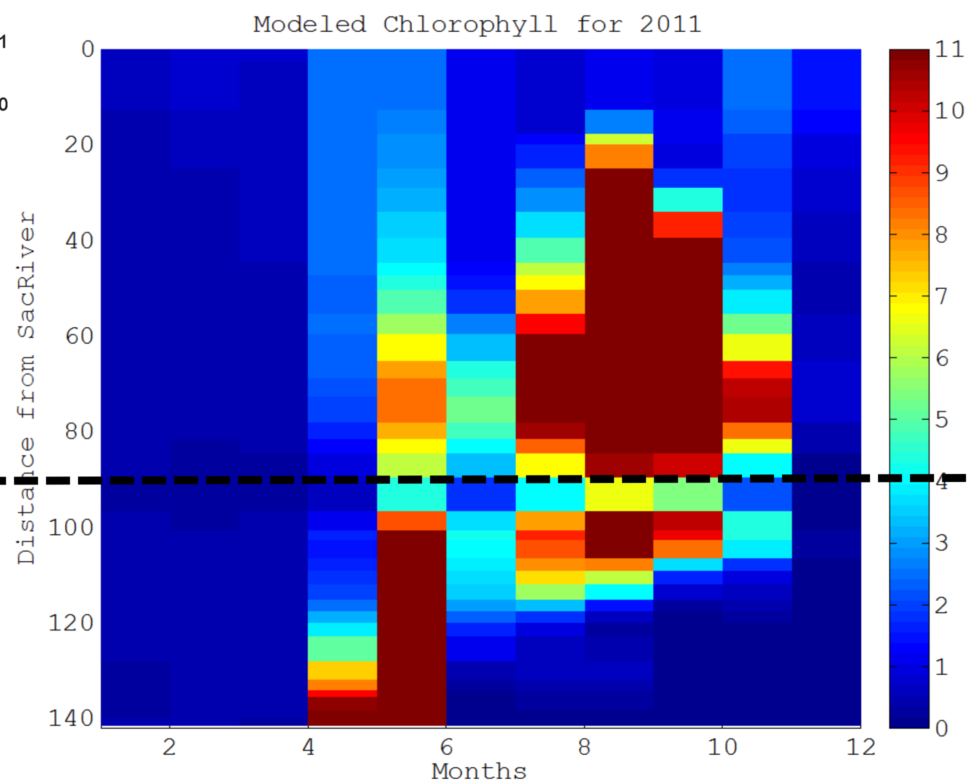
Chlorophyll along the USGS Stations

North Bay: 0-90 km Weak spring bloom; Stronger fall bloom

South Bay: 90-140 km: Strong spring bloom throughout the Bay Fall bloom stronger close to Central Bay

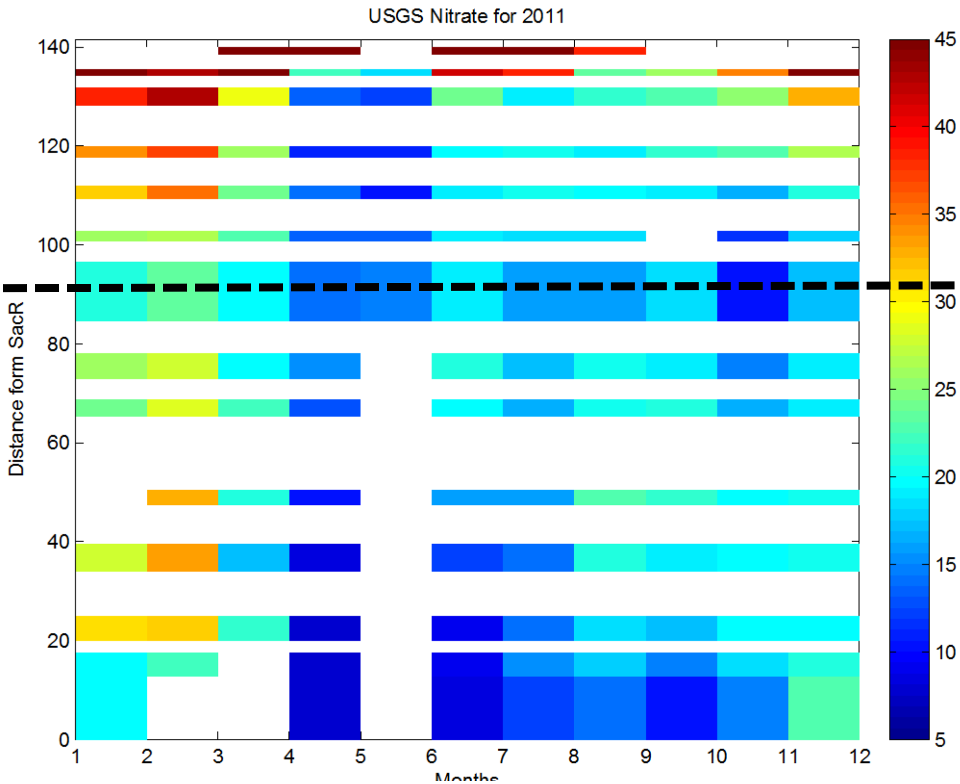


Observed Chlorophyll along the USGS Stations

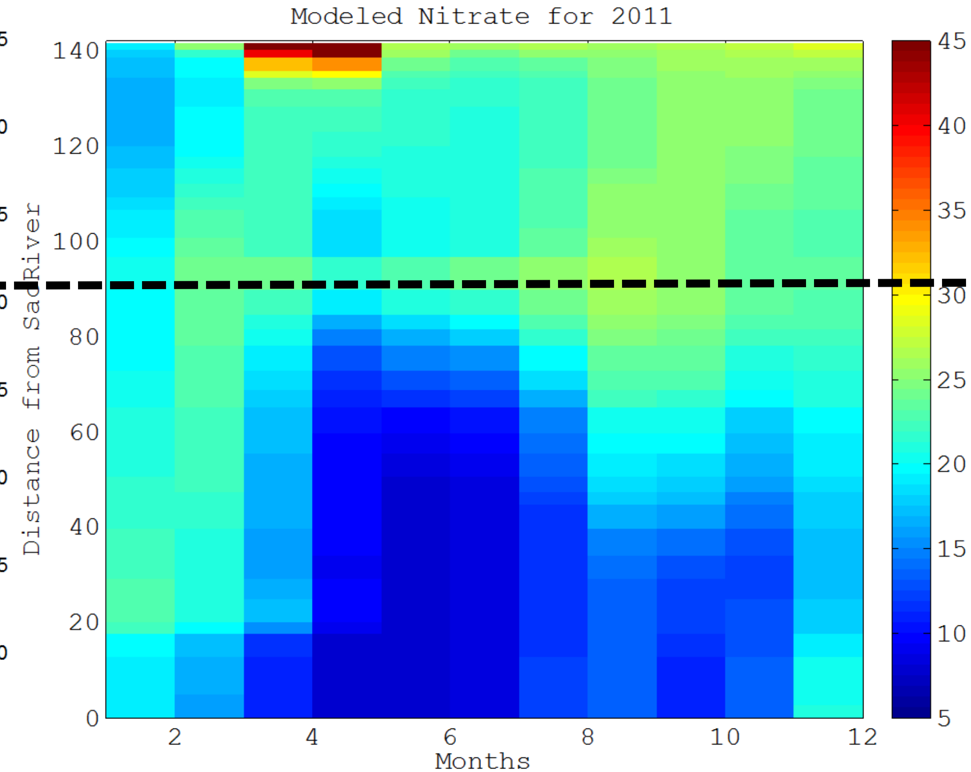


Modeled Chlorophyll along the USGS Stations

Model-Observation Comparisons: Nitrate 2011



Observed Nitrate along the USGS Stations

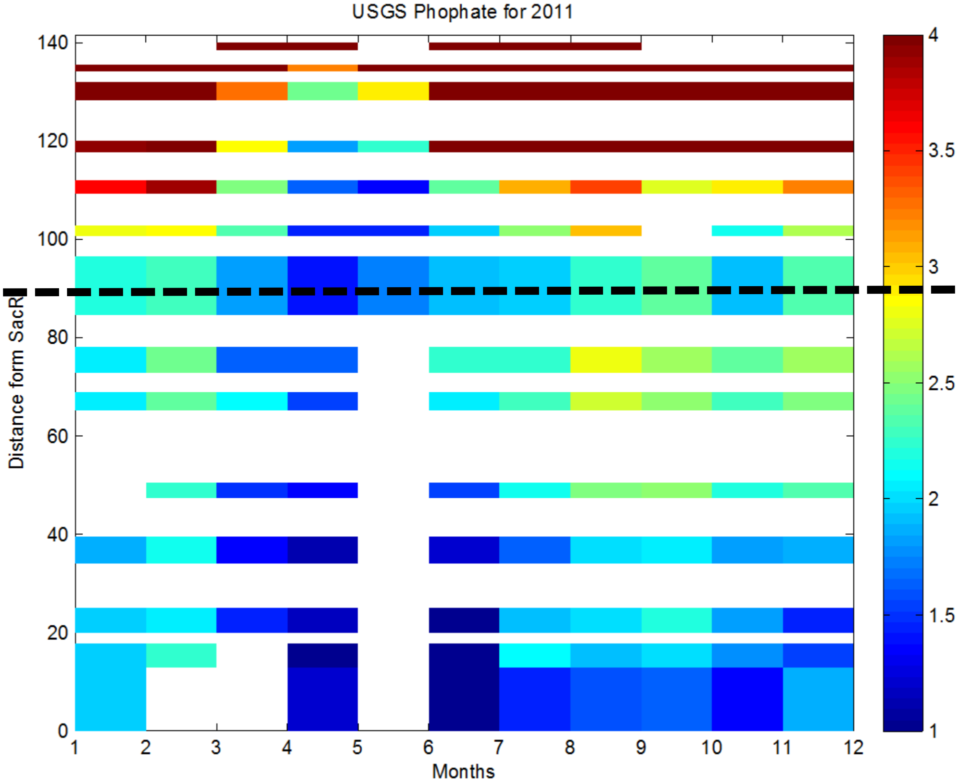


Modeled Nitrate along the USGS Stations

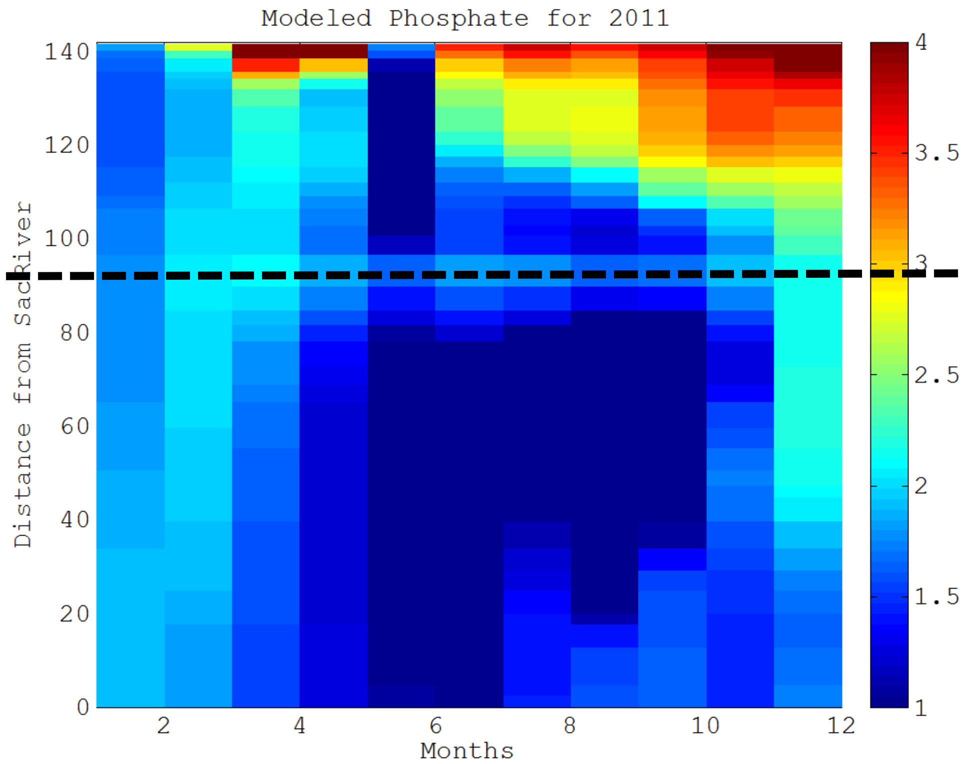
North Bay: 0-90 km
Low Nitrate in spring
During fall, Nitrate increases toward Central Bay

South Bay: 90-140 km
Low Nitrate in spring
High concentration close to the southern end
Stronger Nitrate in Fall

Model-Observation Comparisons: Phosphate 2011



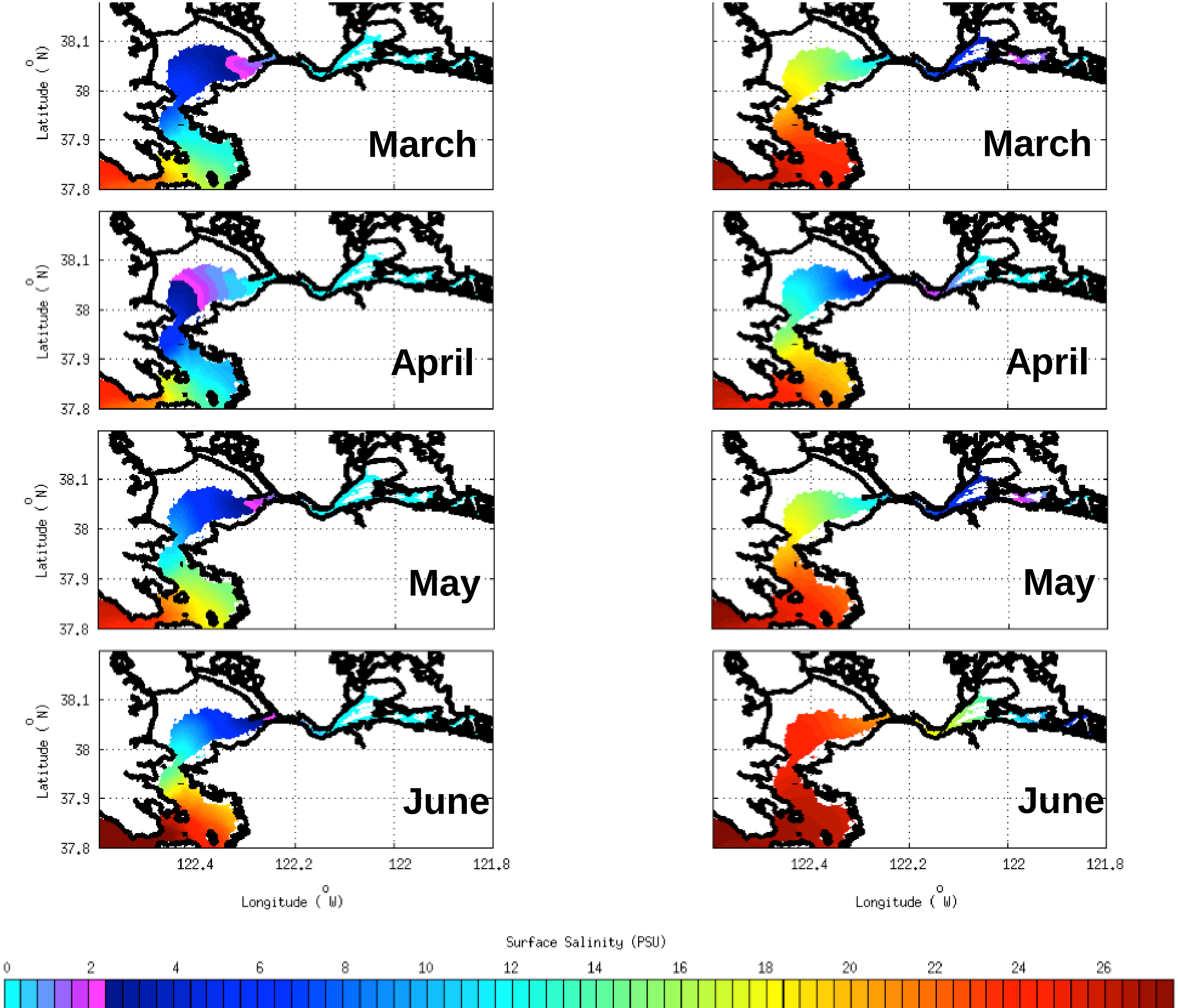
Observed Phosphate along the USGS Stations



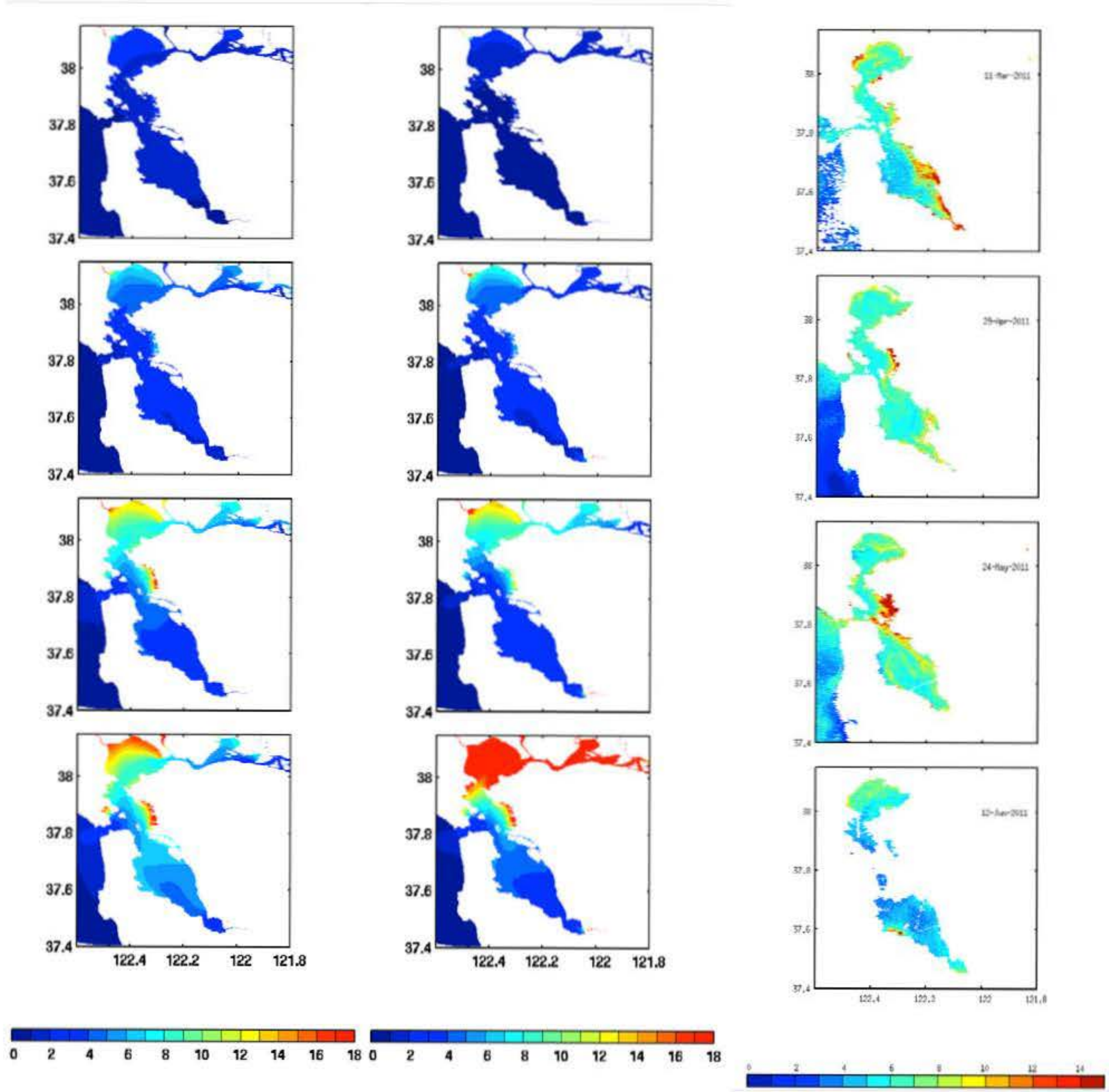
Modeled Phosphate along the USGS Stations

- Generally, low concentration in North Bay
- Higher in South Bay with relatively lower values in May

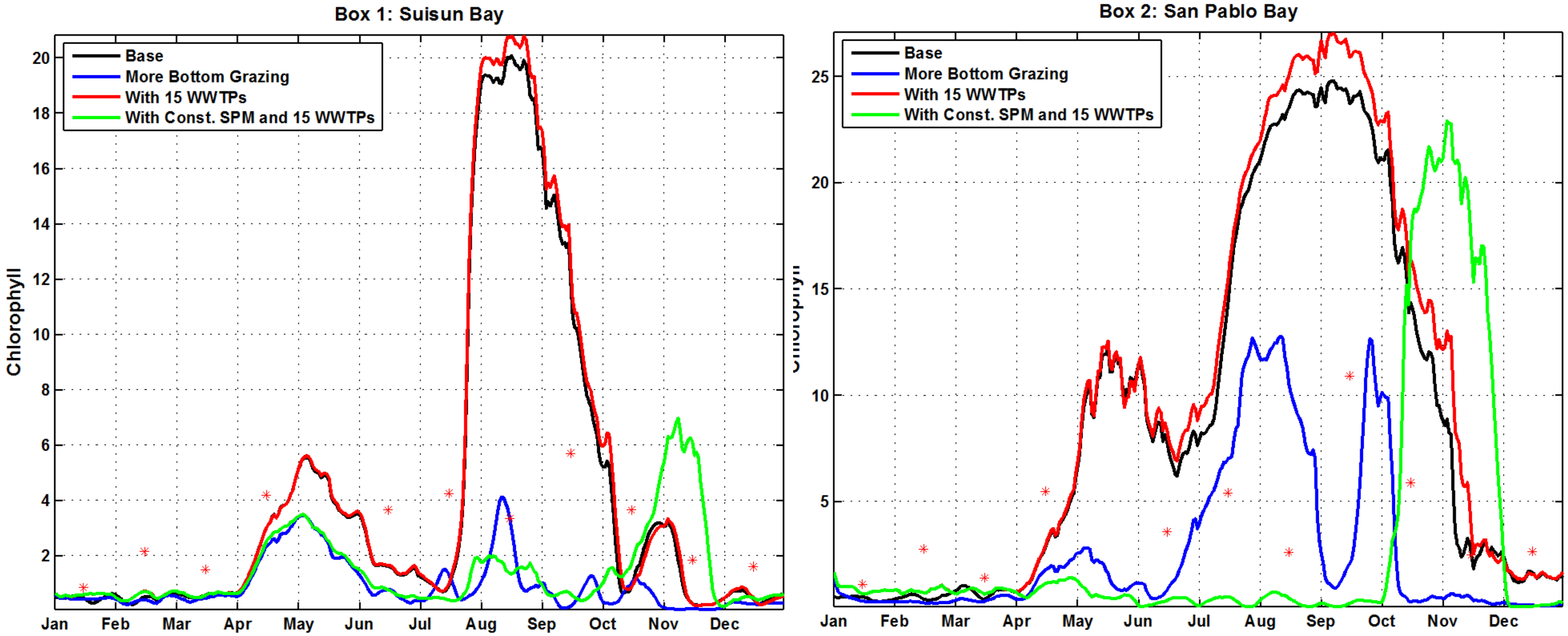
Monthly mean surface salinity for the experiments R1 (left) and R2 (right) from March to June



Monthly mean surface Chl. for R1 and R2 from March to June, and the surface Chl. from satellite MERIS on a day with good coverage from March to June

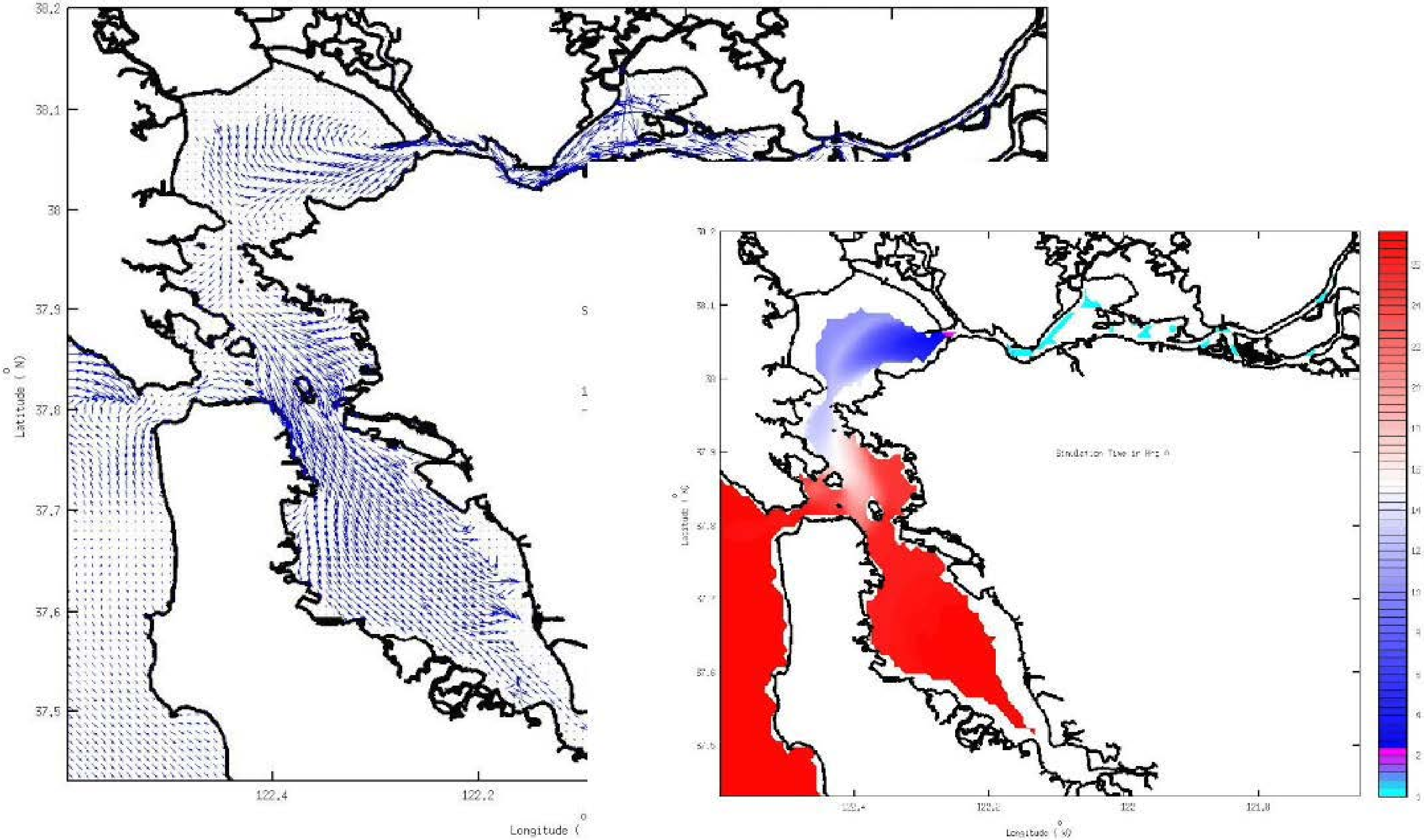


Biomass in Suisun and San Pablo Bays for the Base experiment (old one without WWTPs), and the experiments with more bottom grazing, 15 WWTPs, and constant SPM.



Model Results: Physical Part

Shorter Residence Time in North Bay than in South Bay

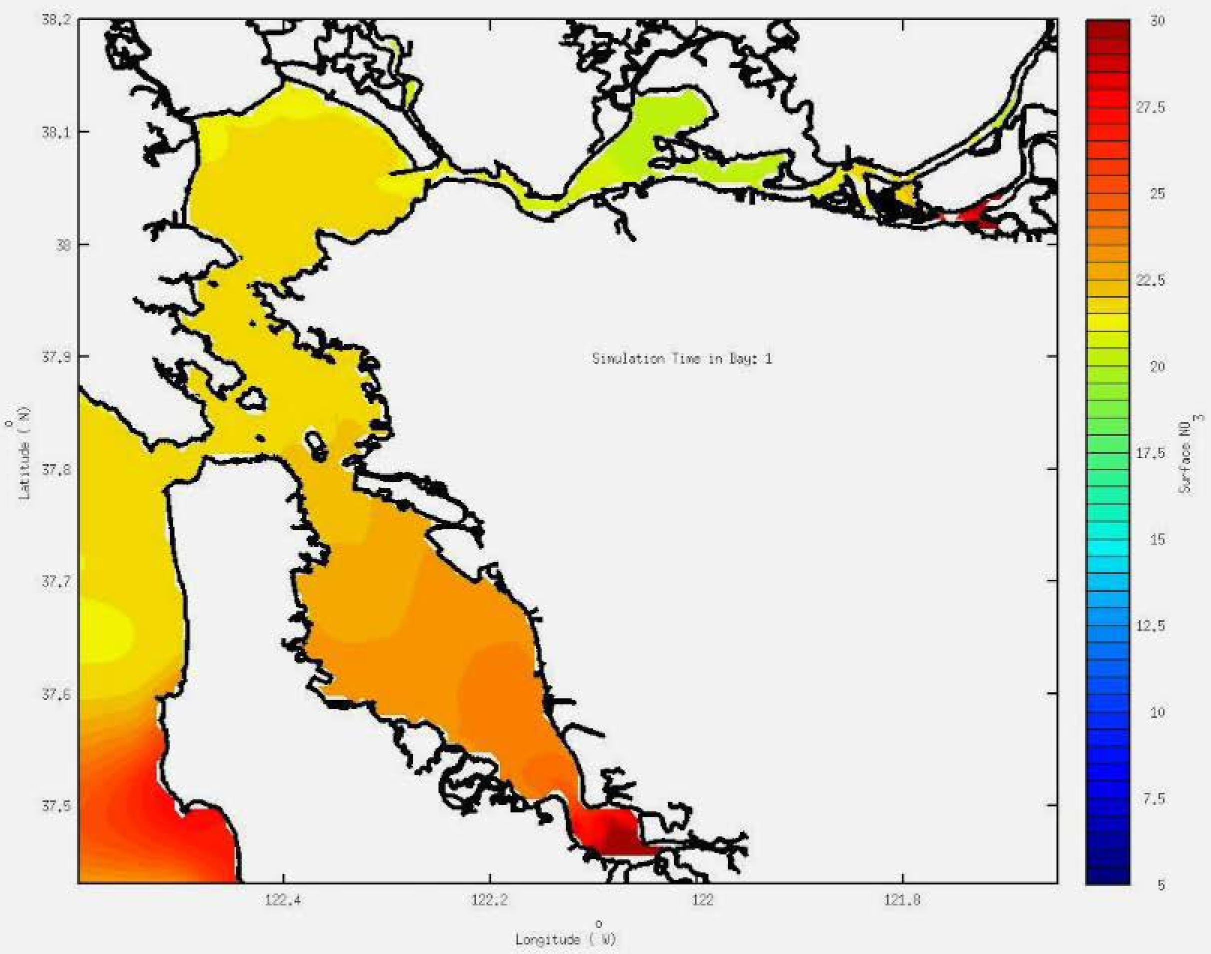


Simulated Surface Currents and Salinity in Every 30 Minutes

	NO_3	NH_4
From WWTPs	2.42 mol/s	21.3 mol/s
From Rivers	13.87 mol/s	5.73 mol/s

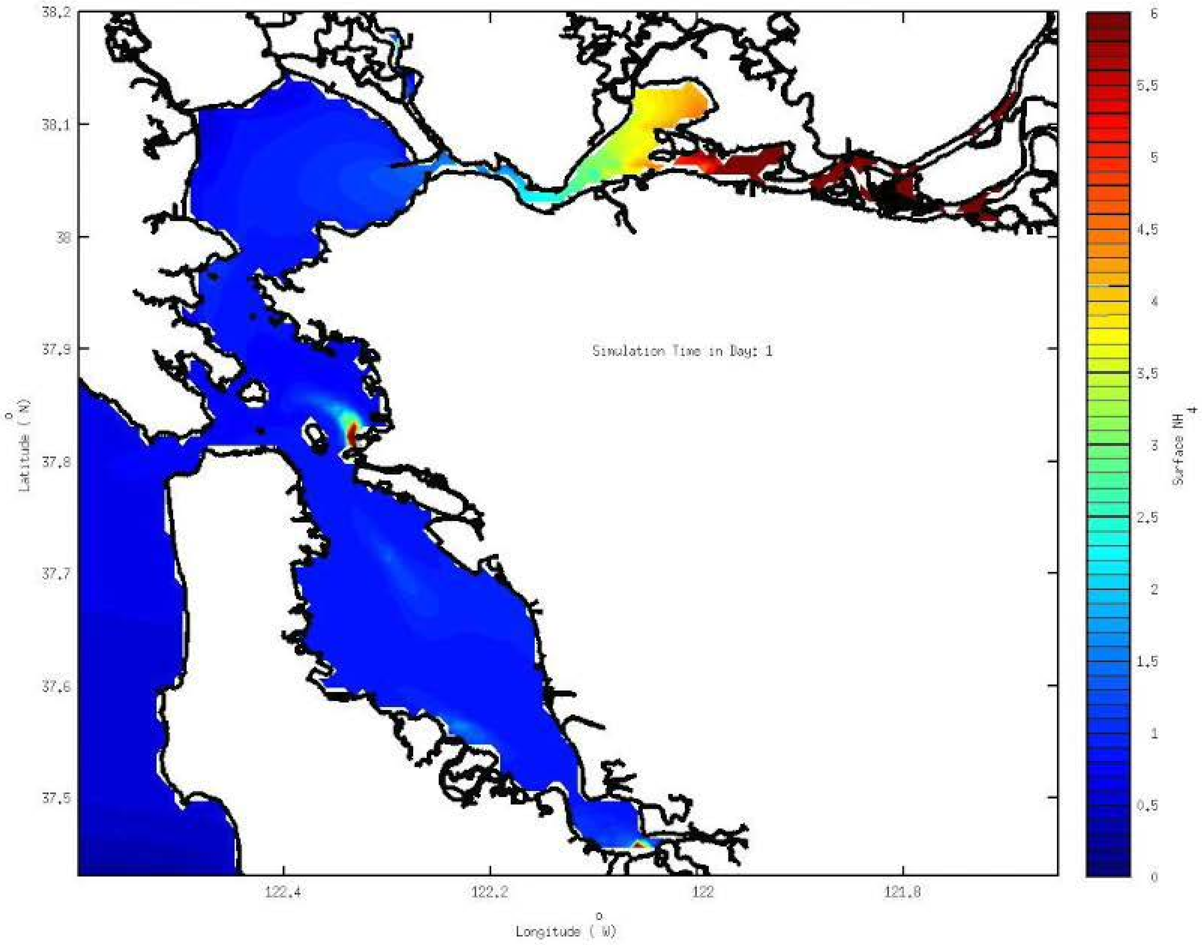
Model Results: Ecological Part

Daily averaged NO_3 Concentration



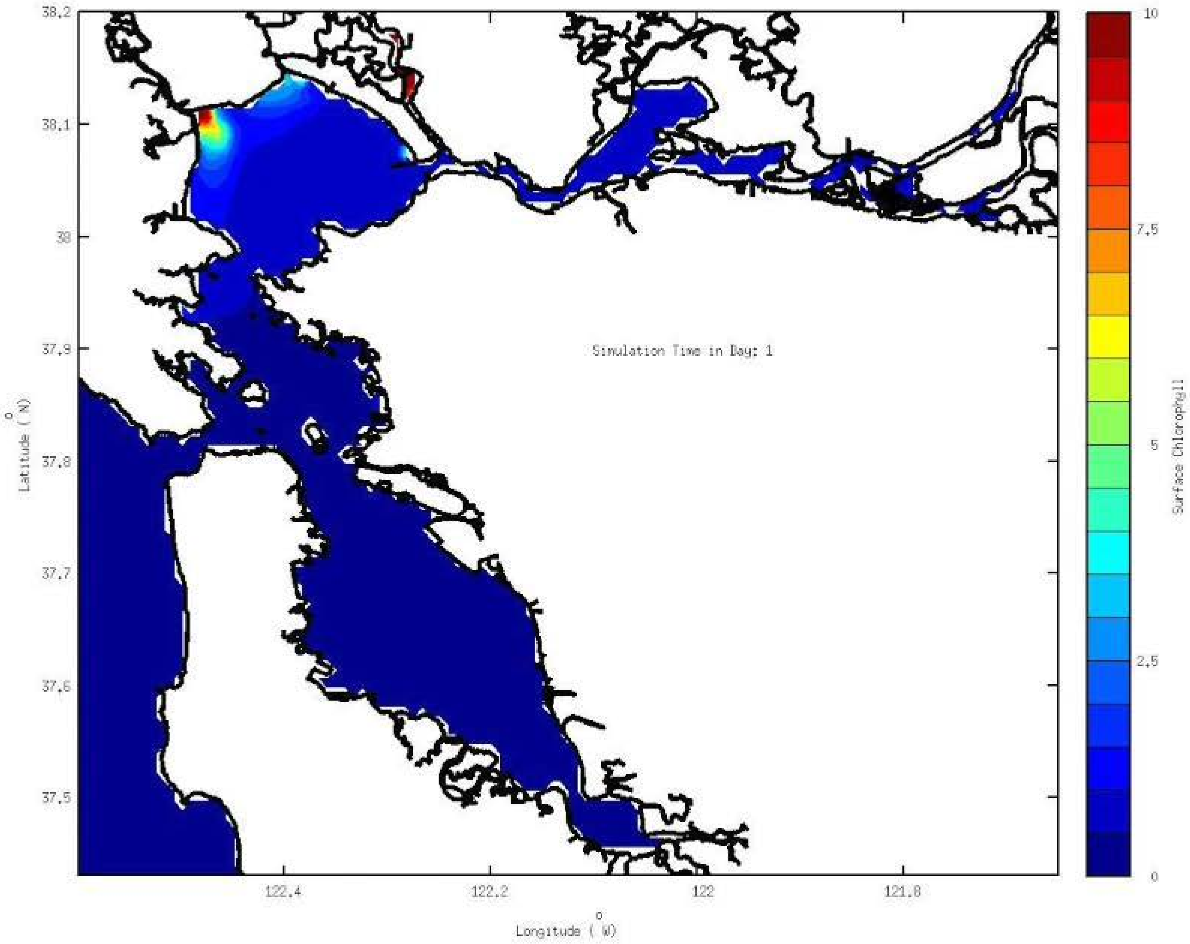
Model Results: Ecological Part

Daily averaged NH_4 Concentration

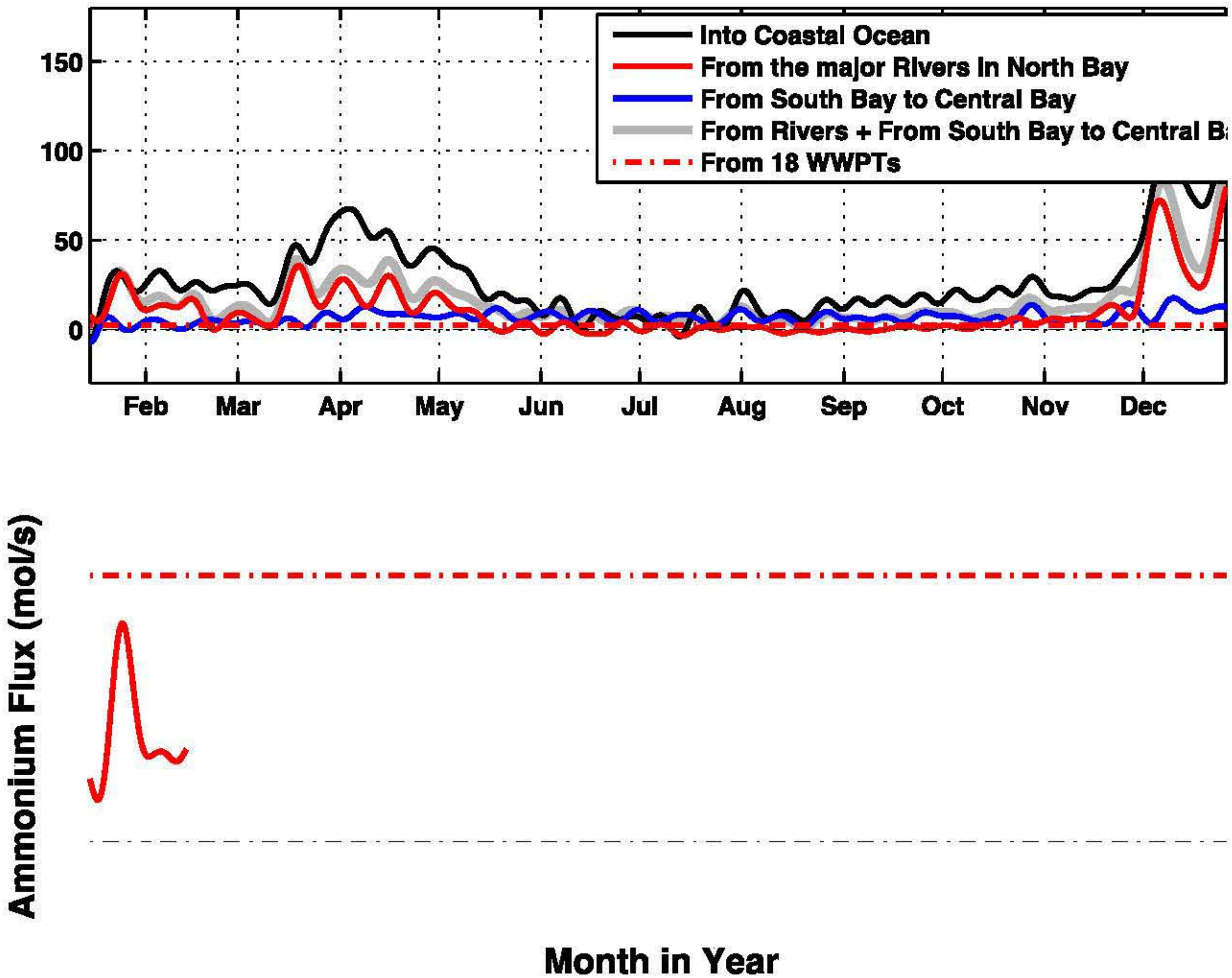


Model Results: Ecological Part

Daily averaged Phytoplankton Concentration

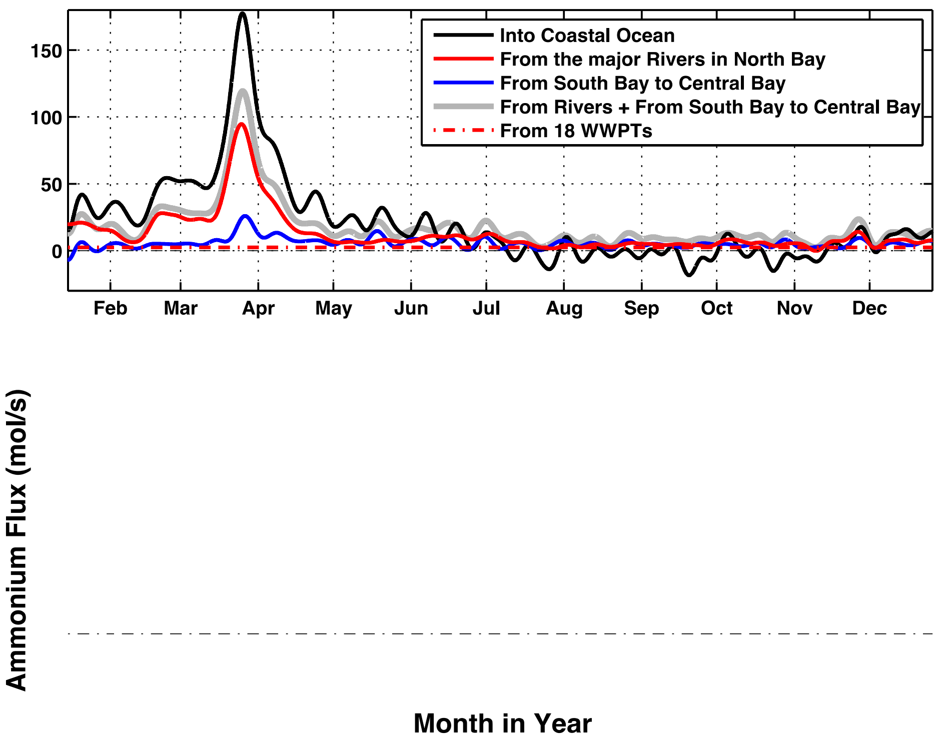


Nutrients Flux for the Experiment R2: With Rivers as Obtained in 2012

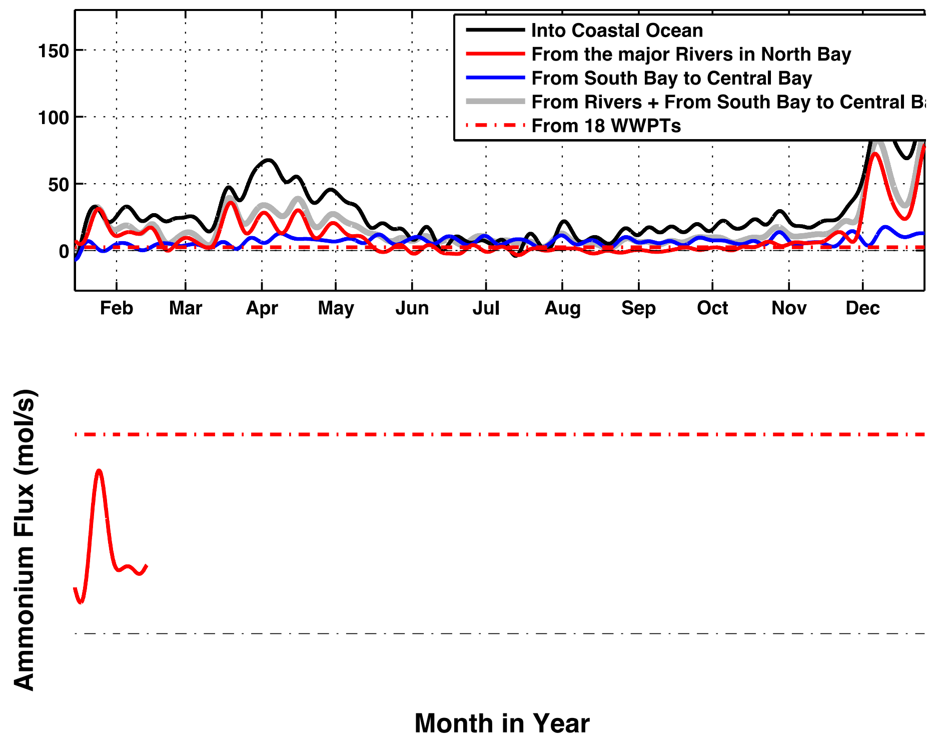


Nitrate and Ammonium flux for the experiment R2

Nutrients Flux Comparisons between R1 and R2

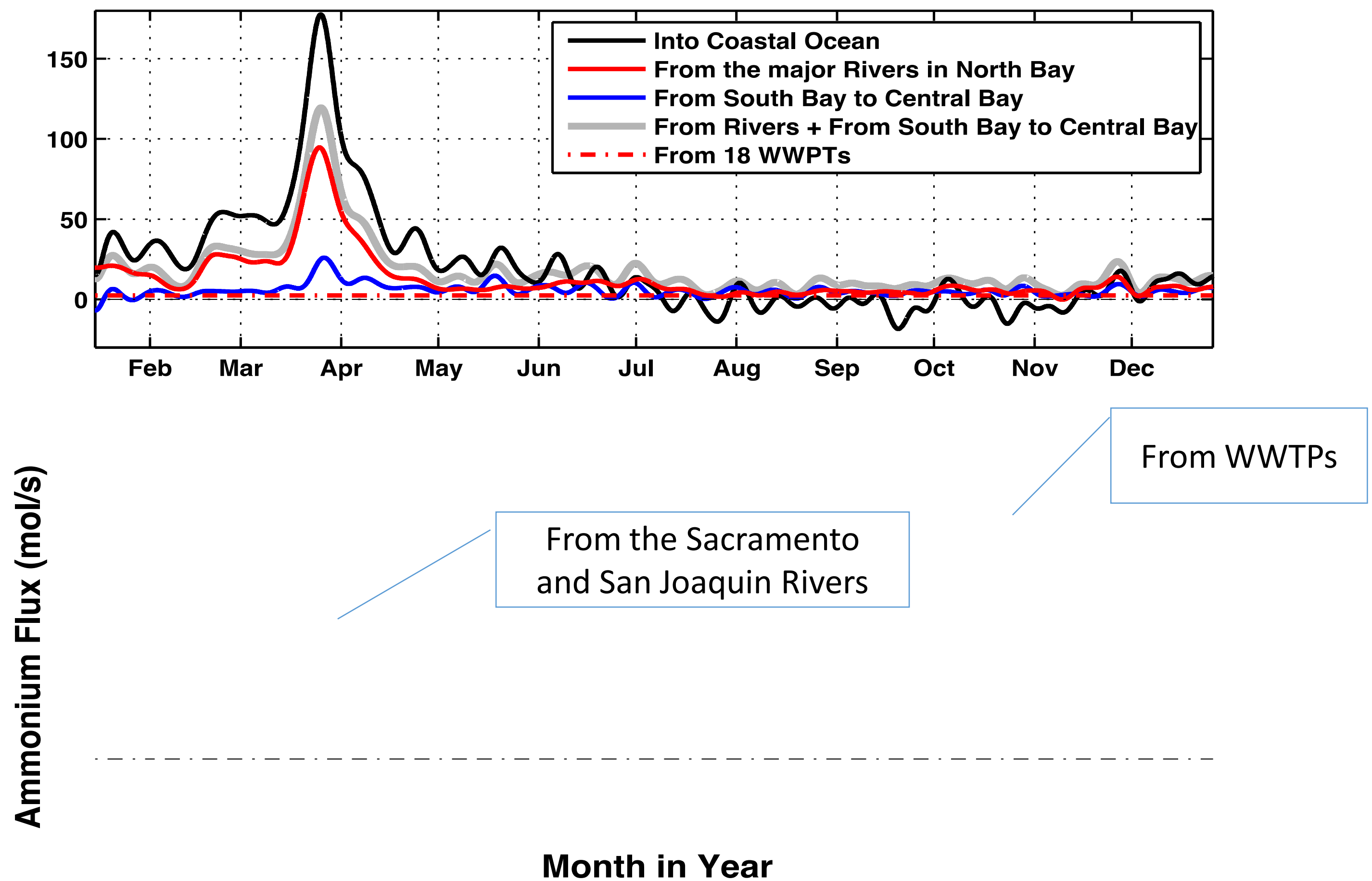


Nitrate and Ammonium flux for the experiment **R1**



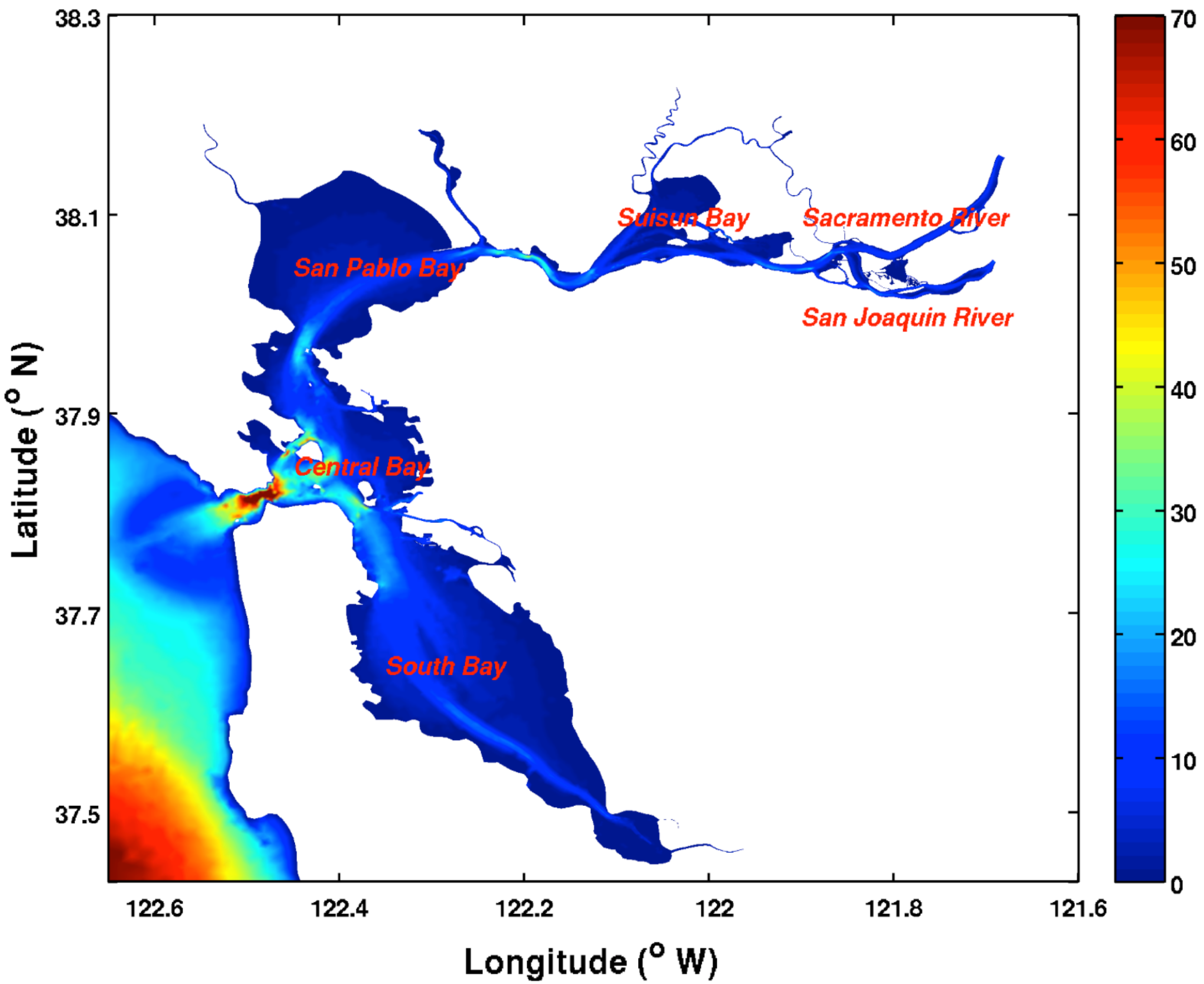
Nitrate and Ammonium flux for the experiment **R2**

SCHISM-CoSiNE Simulated Nutrients Transport over the Box Regions for the Control Experiment (R1)



Nitrate and Ammonium flux for the experiment R1

Background



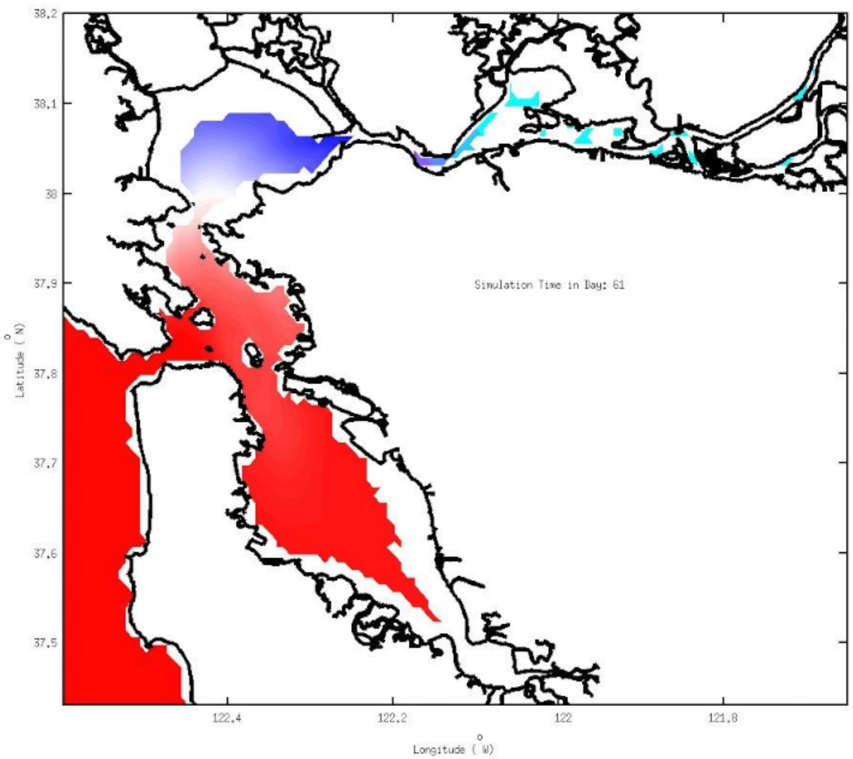
Bathymetry of the San Francisco Bay Coastal System

- Populous region;
- High Nutrients Inputs by Sewage Effluents;
- HNLG (High Nutrient Low Growth)

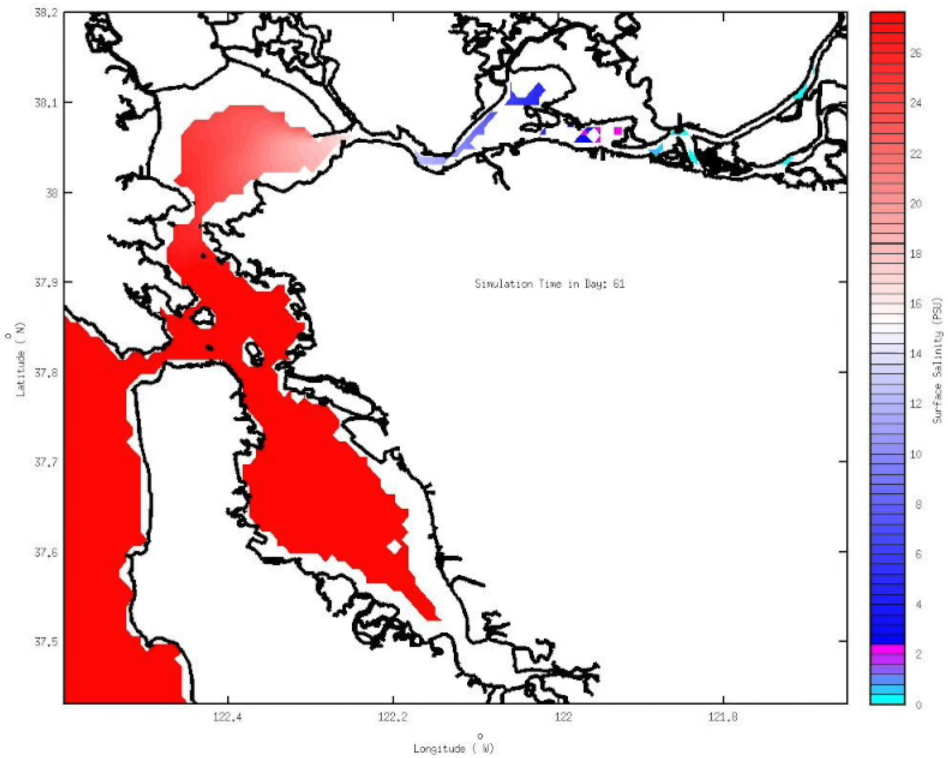
Model Results: Physical Part

- **In 2011, freshwater pushes salty water further into the middle bay;**
- **In 2012, salty water moves further up into the Delta.**

2011

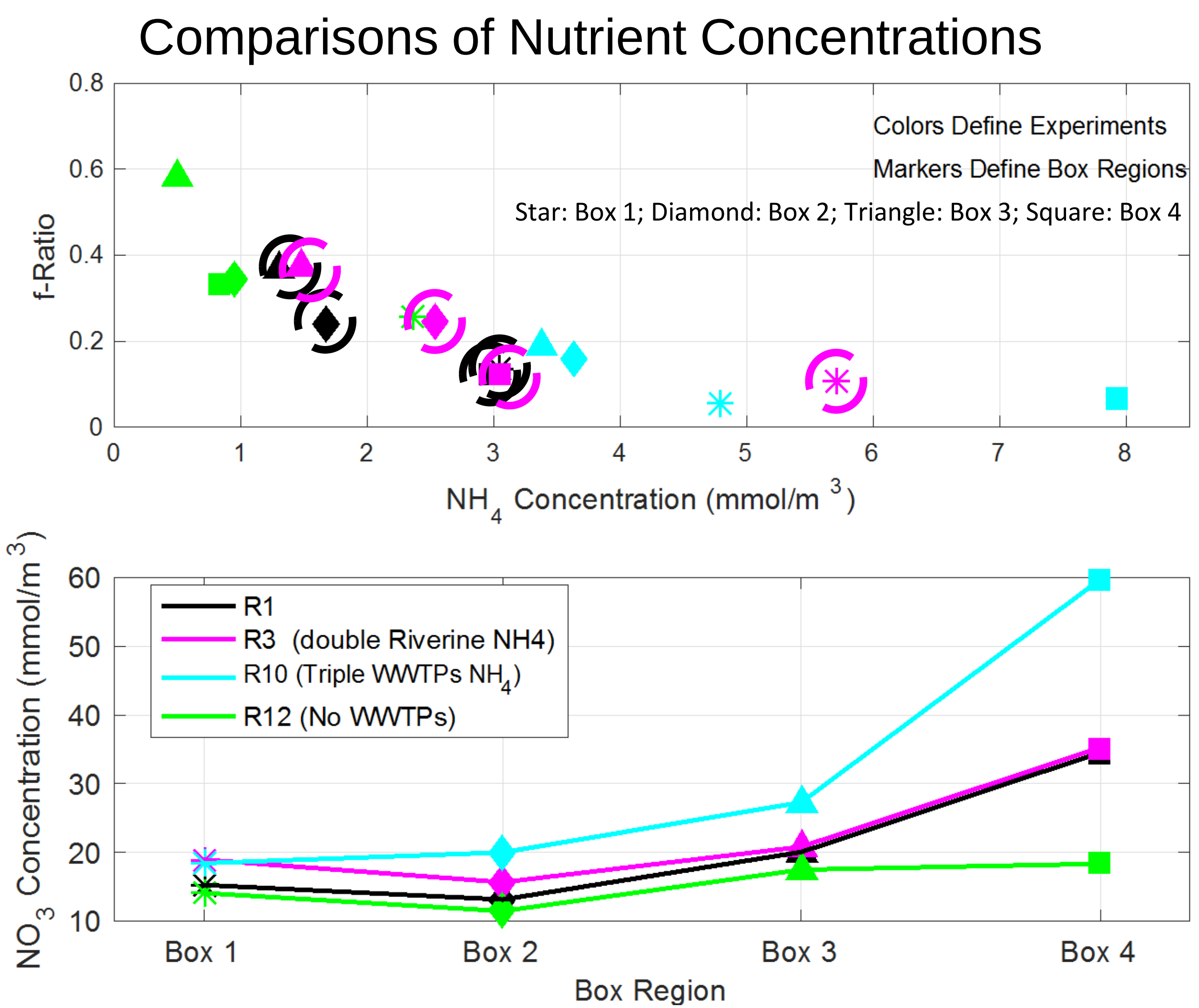


2012



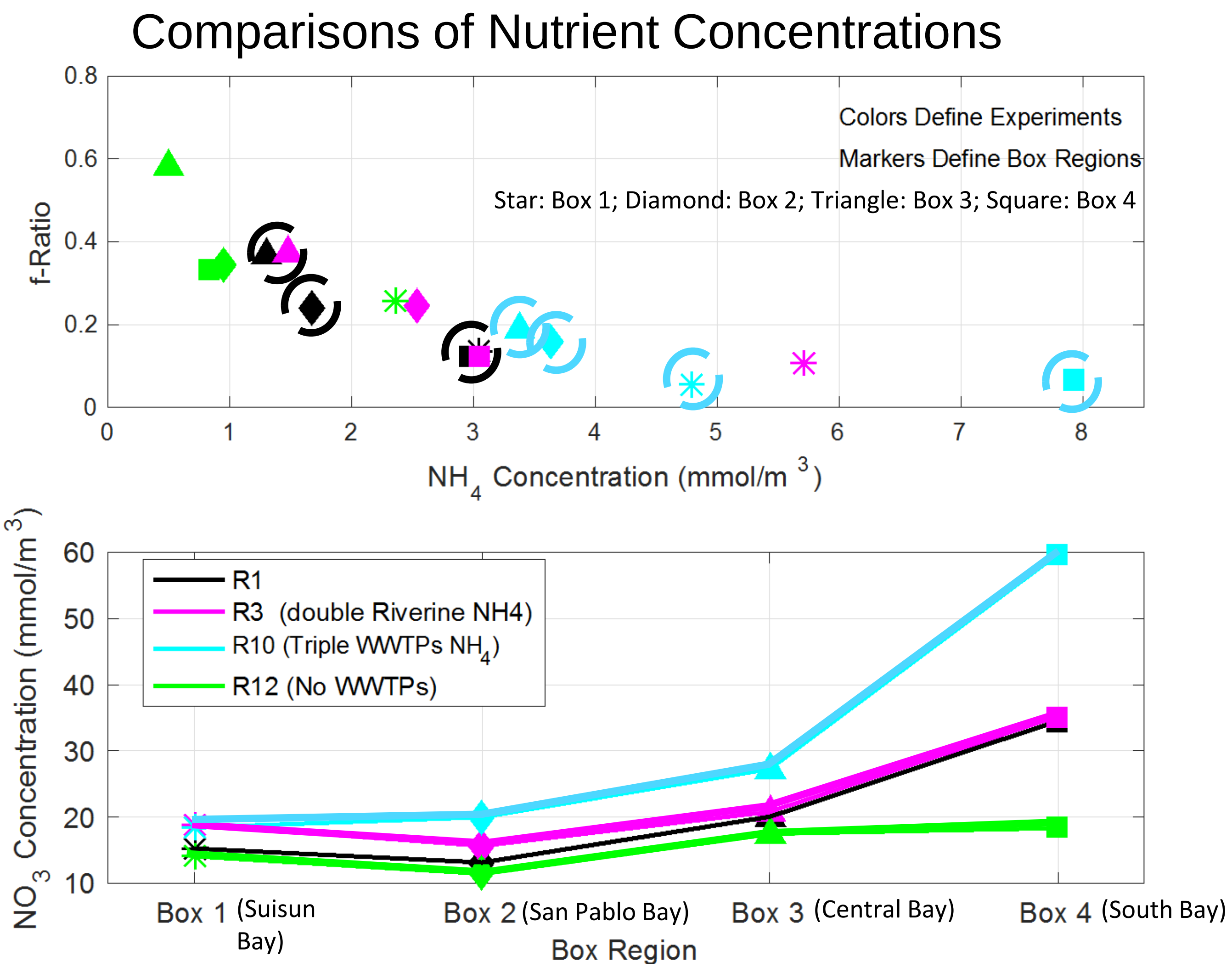
Daily Averaged Surface Salinity from March to June in 2011 and 2012

Sensitivity Experiments: Double NH4 from Rivers (R3), Triple WWTPs (R10) and Remove WWTPs (R12)

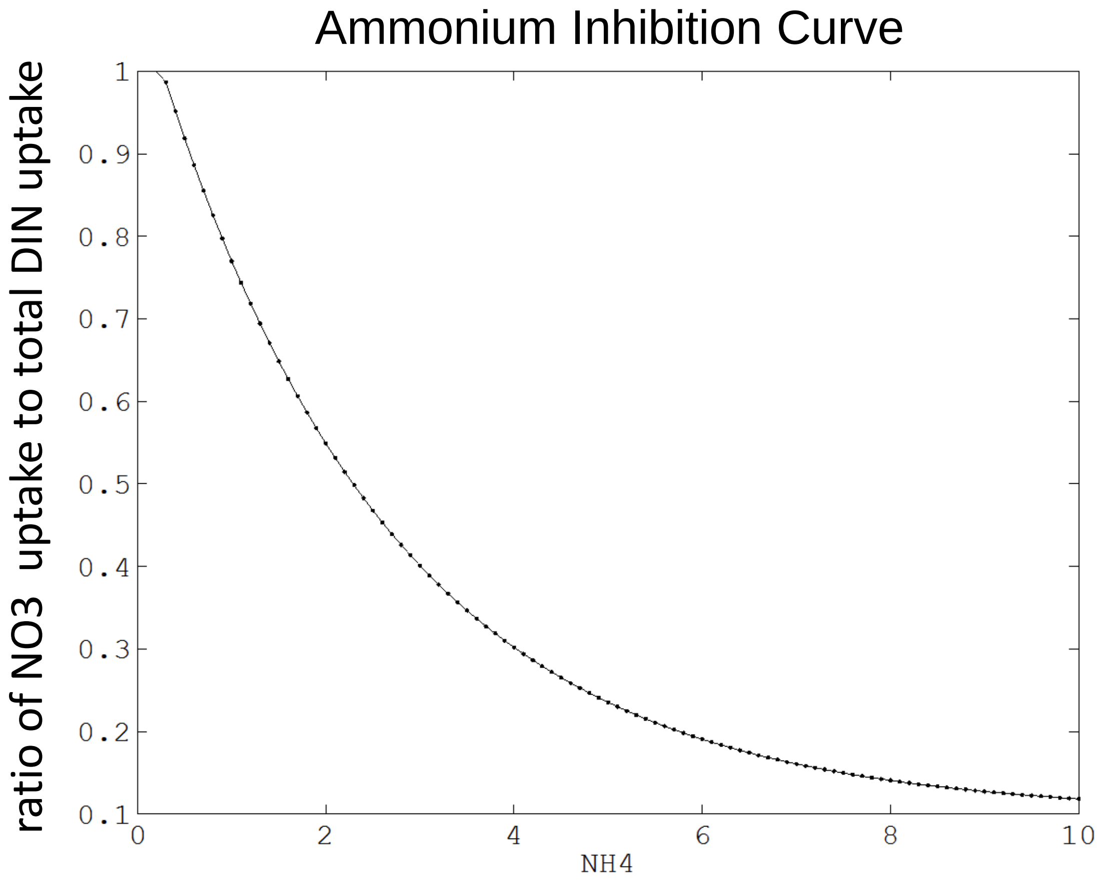


NH_4, NO_3 Concentrations and f-Ratio for the Box Regions in **R1, R3, R10 and R12**

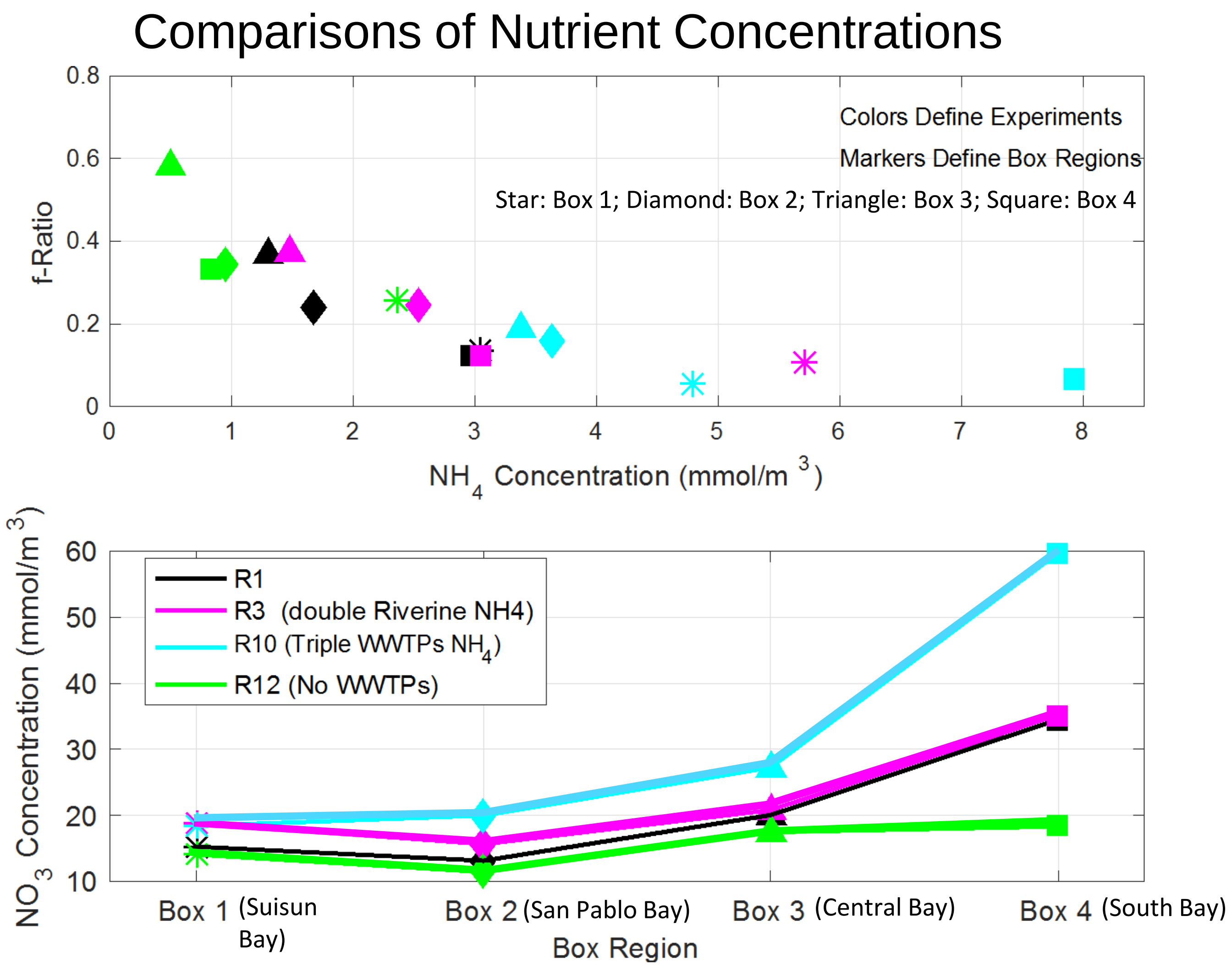
Sensitivity Experiments: Double NH4 from Rivers (R3), Triple WWTPs (R10) and Remove WWTPs (R12)



NH_4, NO_3 Concentrations and f-Ratio for the Box Regions in **R1, R3, R10 and R12**


Ammonium Inhibition Curve
ratio of NO3 uptake to total DIN uptake
NH4
1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
2
4
6
8
10

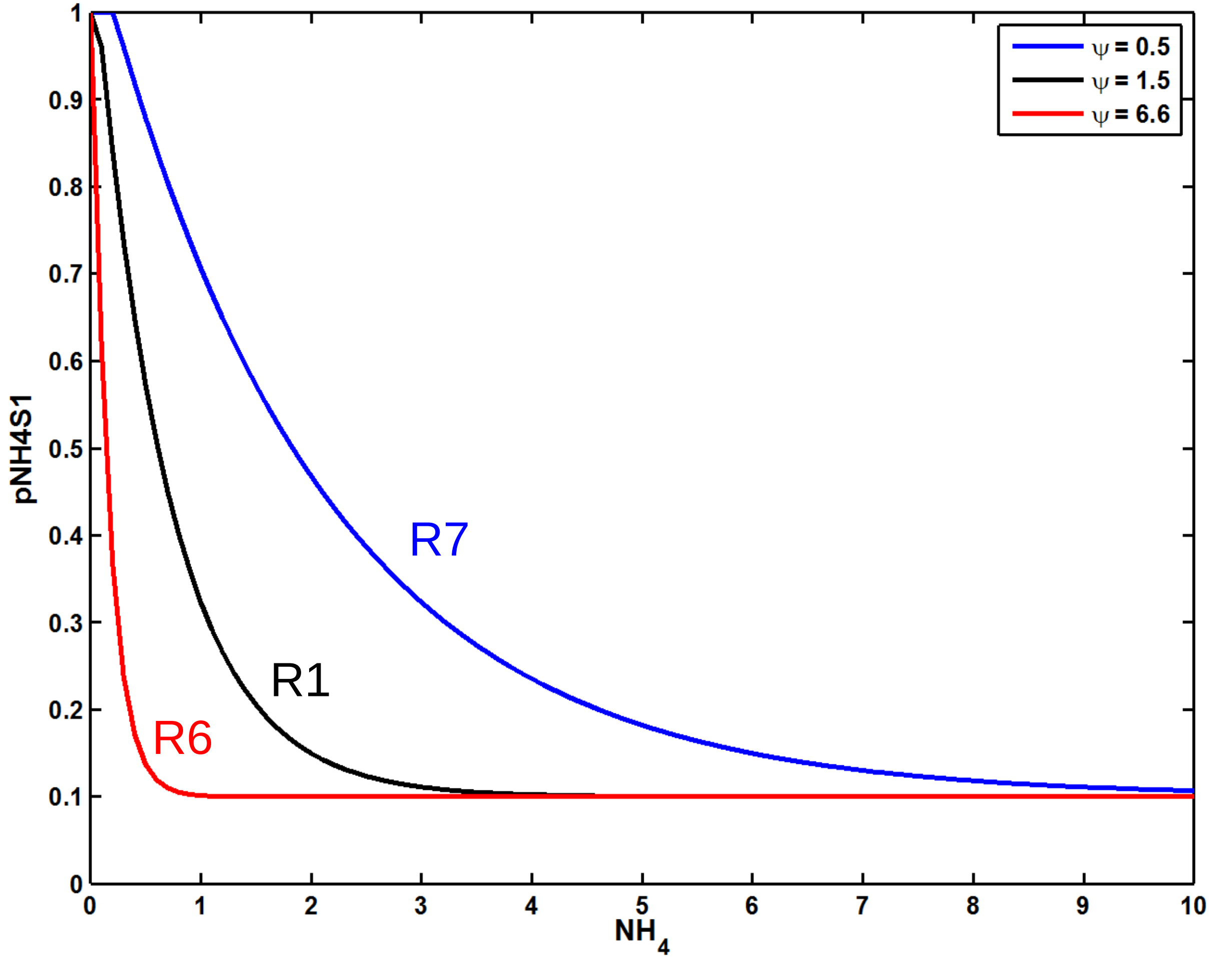
Sensitivity Experiments: Double NH4 from Rivers (R3), Triple WWTPs (R10) and Remove WWTPs (R12)



NH_4, NO_3 Concentrations and f-Ratio for the Box Regions in **R1, R3, R10 and R12**

Sensitivity Experiments: Inhibition Parameter 1.5 (R1), Stronger Inhibition Parameter 6.6 (R6), Weaker Inhibition Parameter 0.5 (R7)

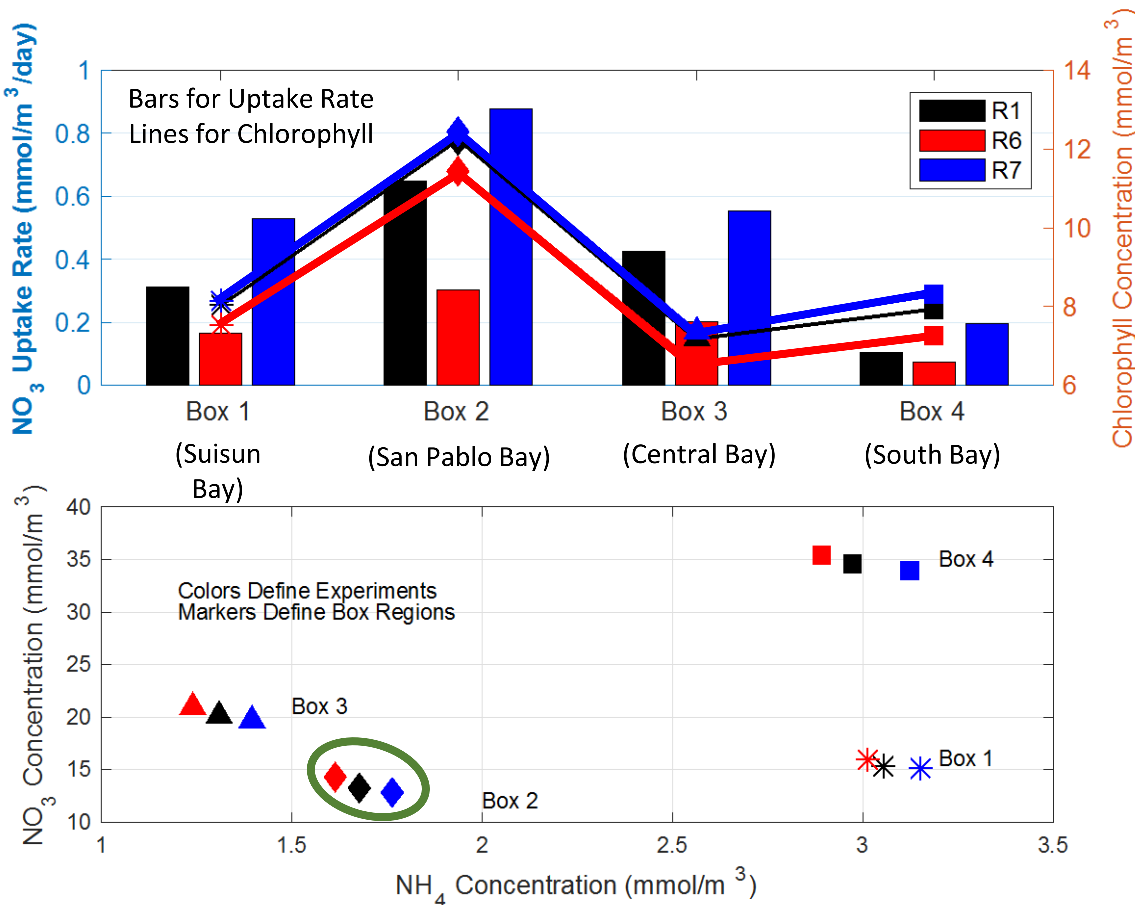
NH4 Inhibition Curve (Low NH_4 Corresponds to High NO_3 Uptake)



NH_4 Inhibition for S1 (The Same For S2)

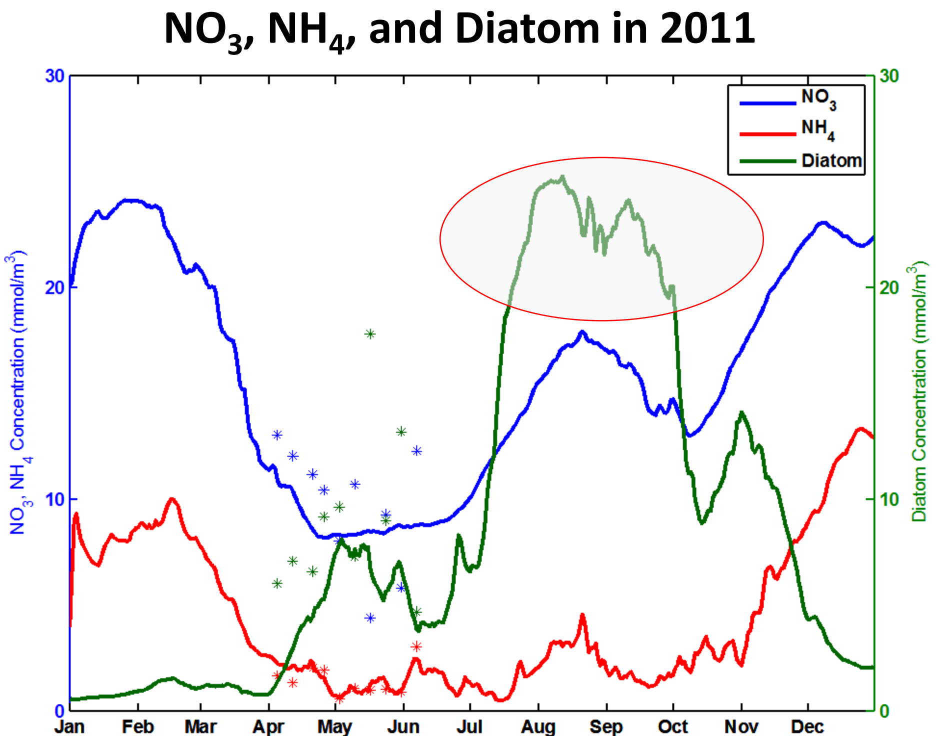
Sensitivity Experiments: Inhibition Parameter 1.5 (R1), Stronger Inhibition Parameter 6.6 (R6), Weaker Inhibition Parameter 0.5 (R7)

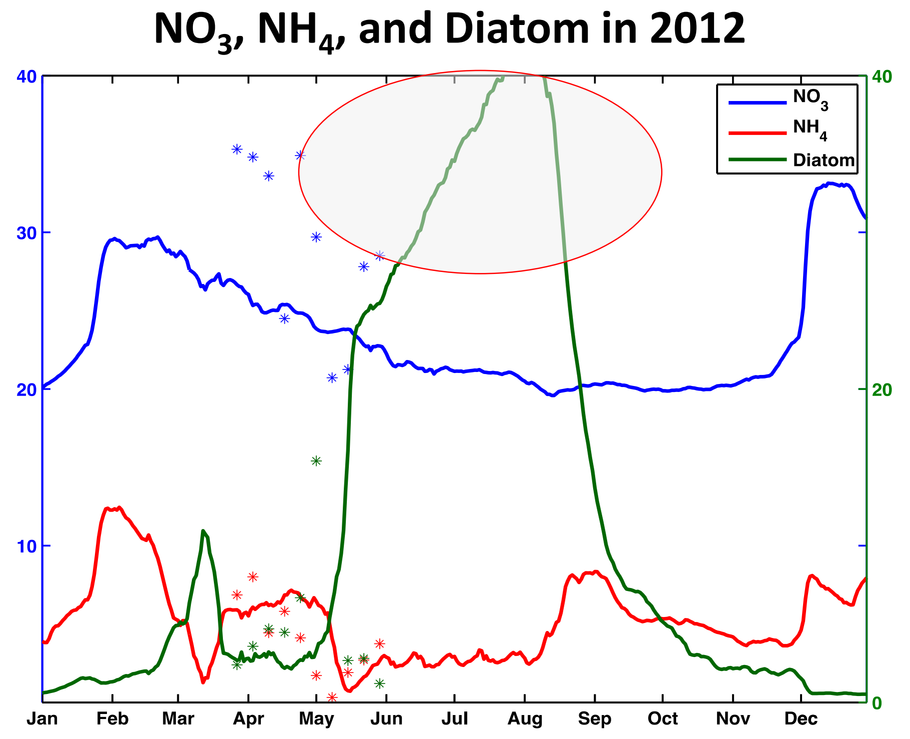
Comparisons of NO_3 Uptake Rate



Annual Mean NO_3 Uptake Rate, Chlorophyll and NO_3 and NH_4 concentrations the Box Regions in **R1, R6, and R7**

Too High Summer Bloom





Diatom and nutrients (NO_3 and NH_4) concentrations at the station of DWR-D7 in 2011 and 2012