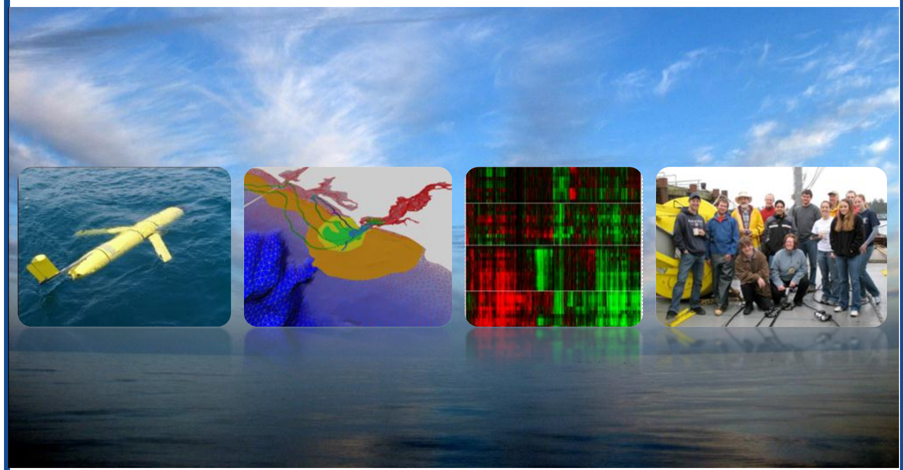
Oxygen in the Columbia River Estuary: Distribution and Dynamics

Observation ● Prediction ● Analysis ● Collaboration



CMOP
Center for Coastal Margin Observation & Prediction

www.stccmop.org

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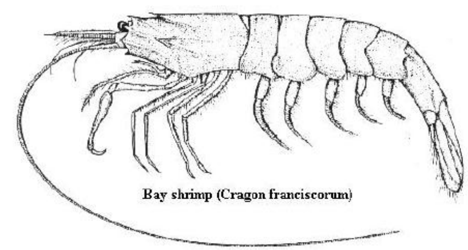
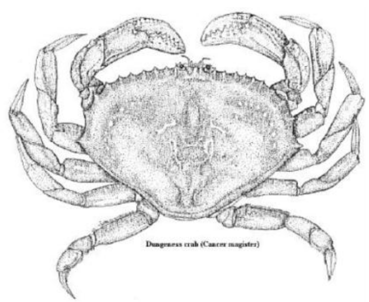
Outline

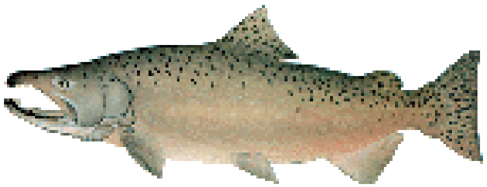
- Dissolved Oxygen (DO) in Columbia River estuary (CRE)
  - Freshwater source
  - Coastal source
- Observations
  - Upwelling forces
  - Biological forces
- Modeling
- Management Considerations

Dissolved Oxygen in the CRE

- Understanding DO is a key piece to understanding the physical and biogeochemical processes in the estuary
- Oxygen concentrations are critical to:
  - benthic species
  - migrating salmon

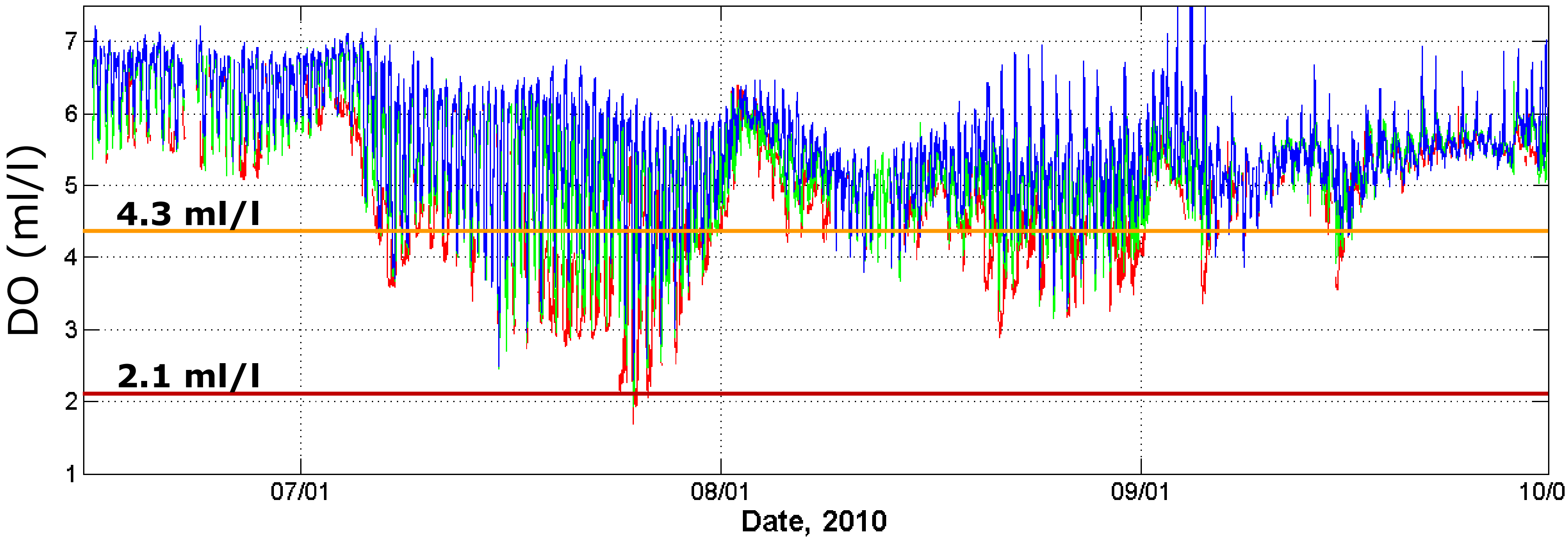




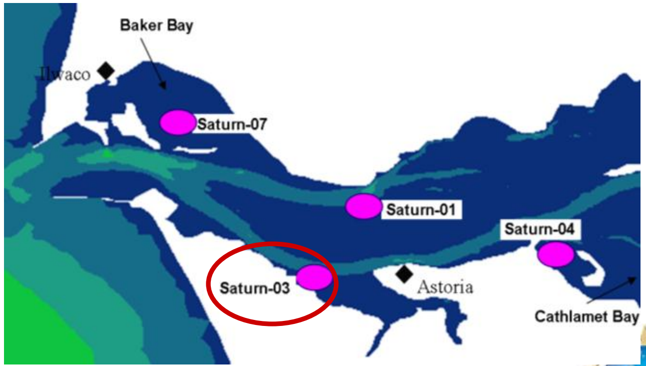


- Important to understanding net ecosystem metabolism

Dissolved Oxygen, SATURN-03, July – October 2010

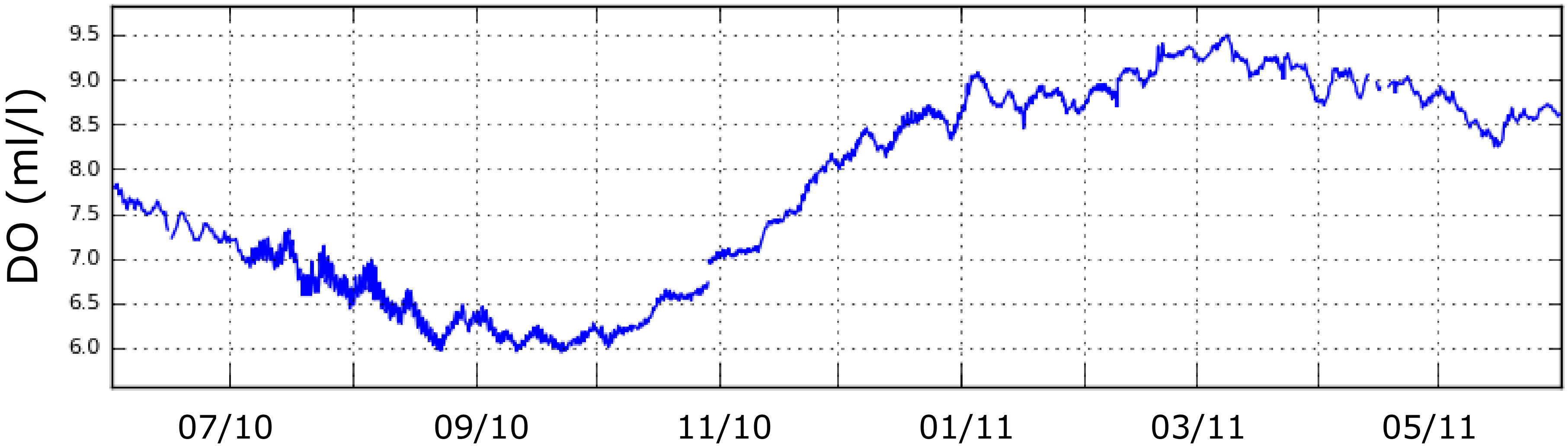


Surface	< 2.1 ml/l; hypoxic (EPA 1986)
Mid-Depth	
Bottom	< 4.3 ml/l; incipient response (Davis 1975)



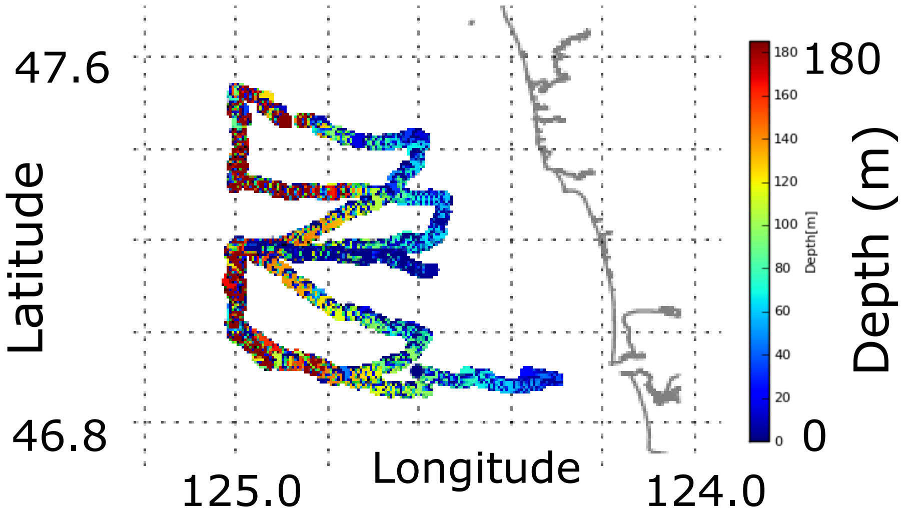
SATURN-05, June 2010 – May 2011

Seasonal freshwater signature



Incoming freshwater is consistently well oxygenated

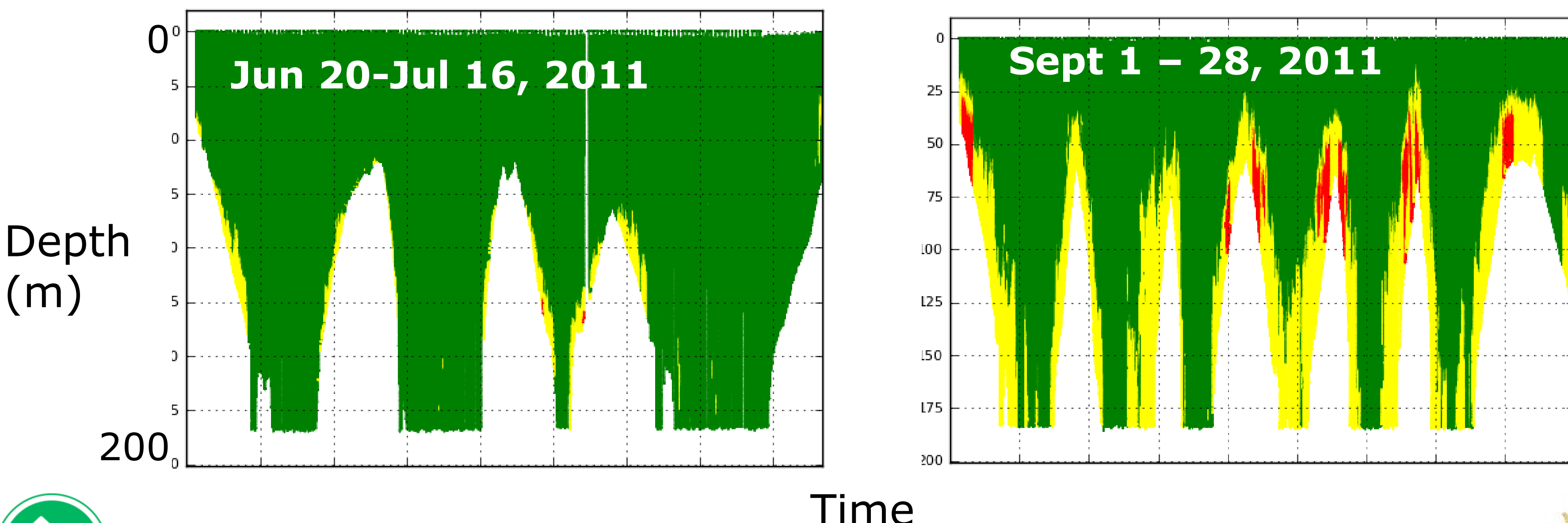
DO measured by Phoebe glider on the WA shelf, 2011



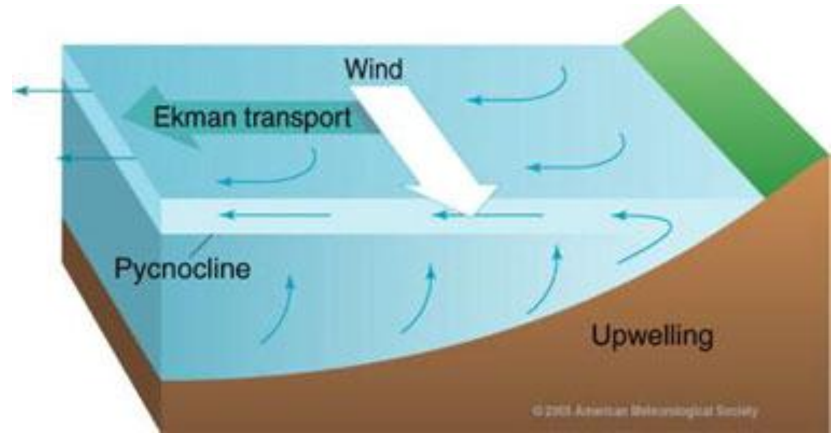
DO > 1.4 ml/l

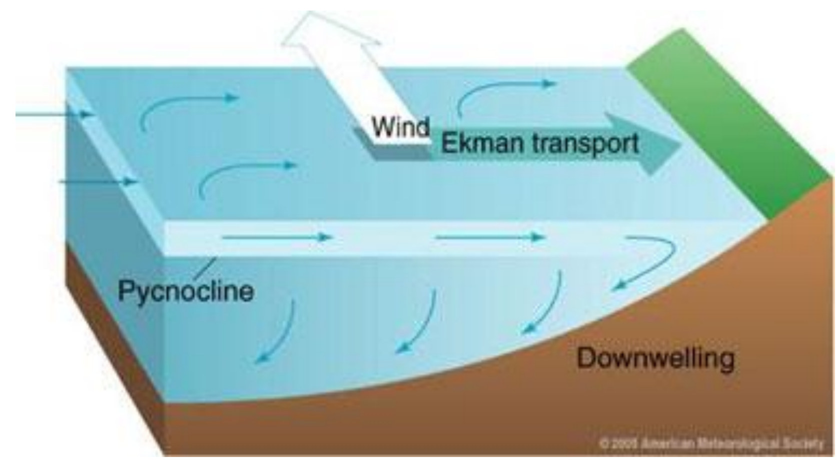
0.5 ml/l < DO < 1.4 ml/l (mild hypoxia)

DO < 0.5 ml/l (severe hypoxia)



- Increasing occurences of low DO off coast (Grantham et al 2004, Chan et al 2008)

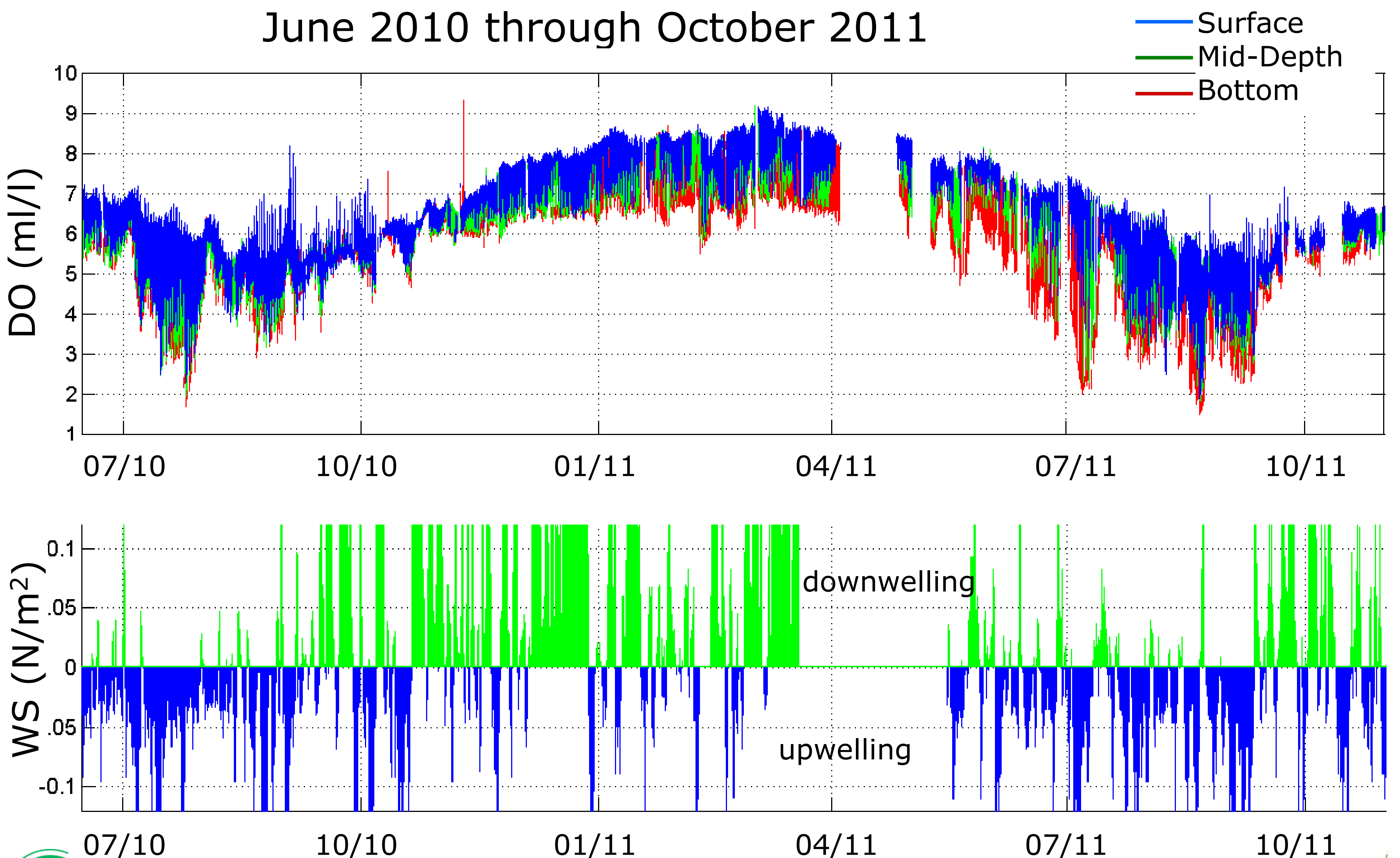




- Upwelling and downwelling are a response to shelf wind stress

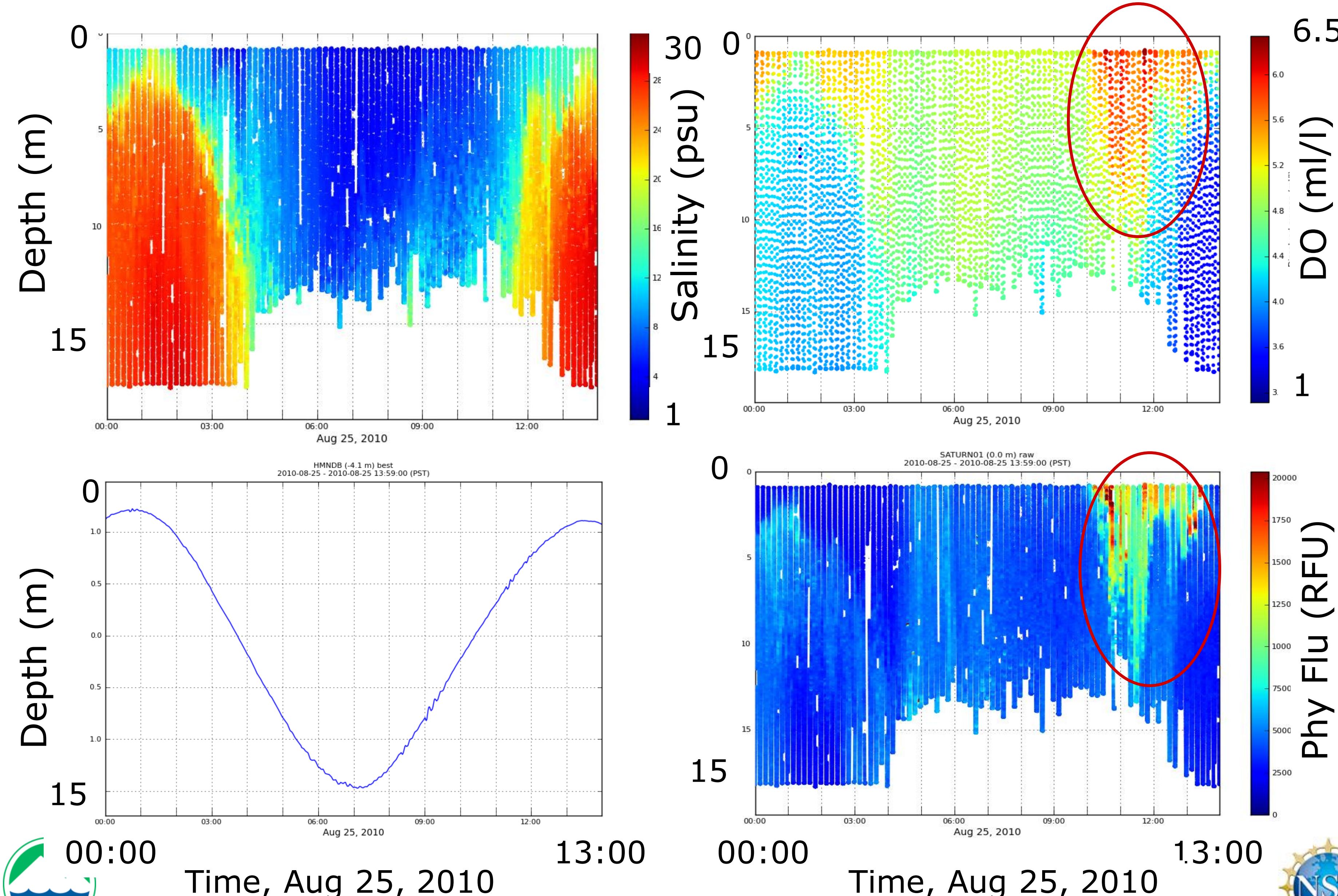
2001; American Meteorological Society

Wind Stress; SATURN-03, Seasonal DO Variability



WS = wind stress

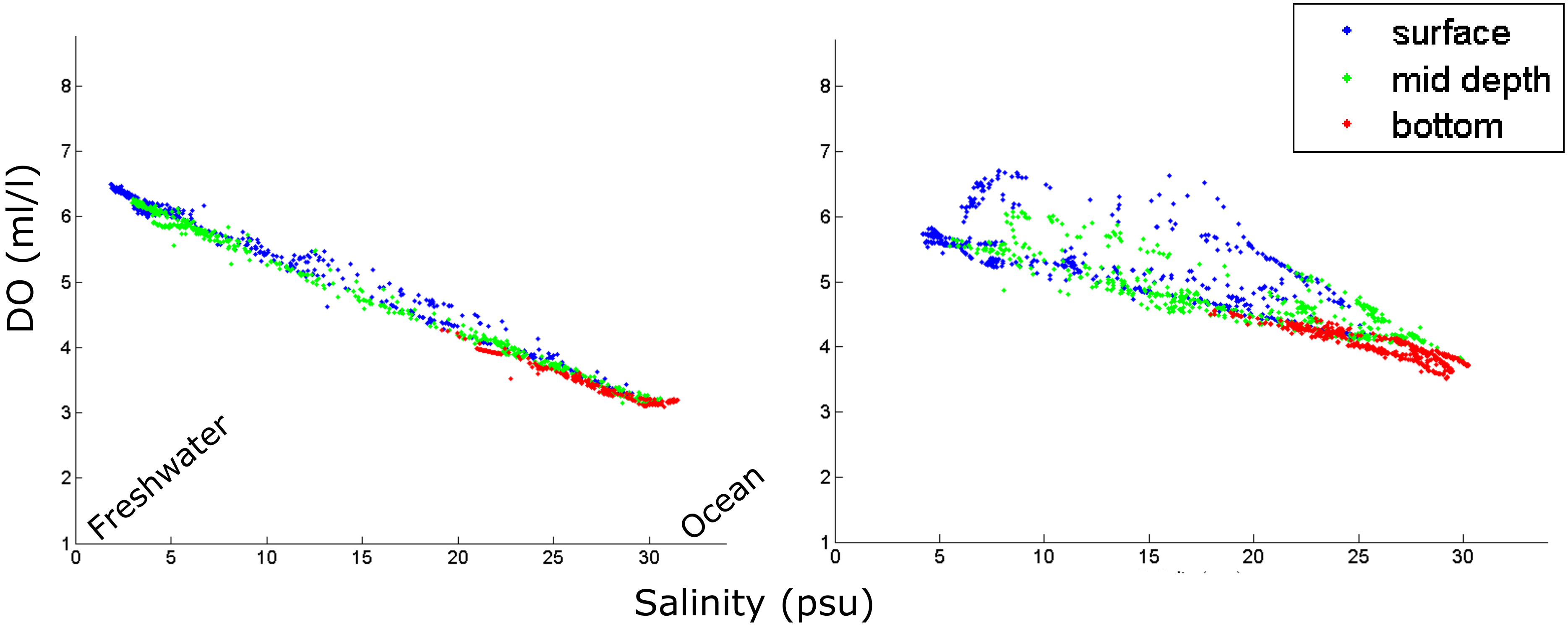
SATURN-01 – Salinity, DO, Phycoerythrin; tide-cycle



SATURN-03; Salinity-to-DO, Tidal Day

July 18, 2010

August 29, 2010



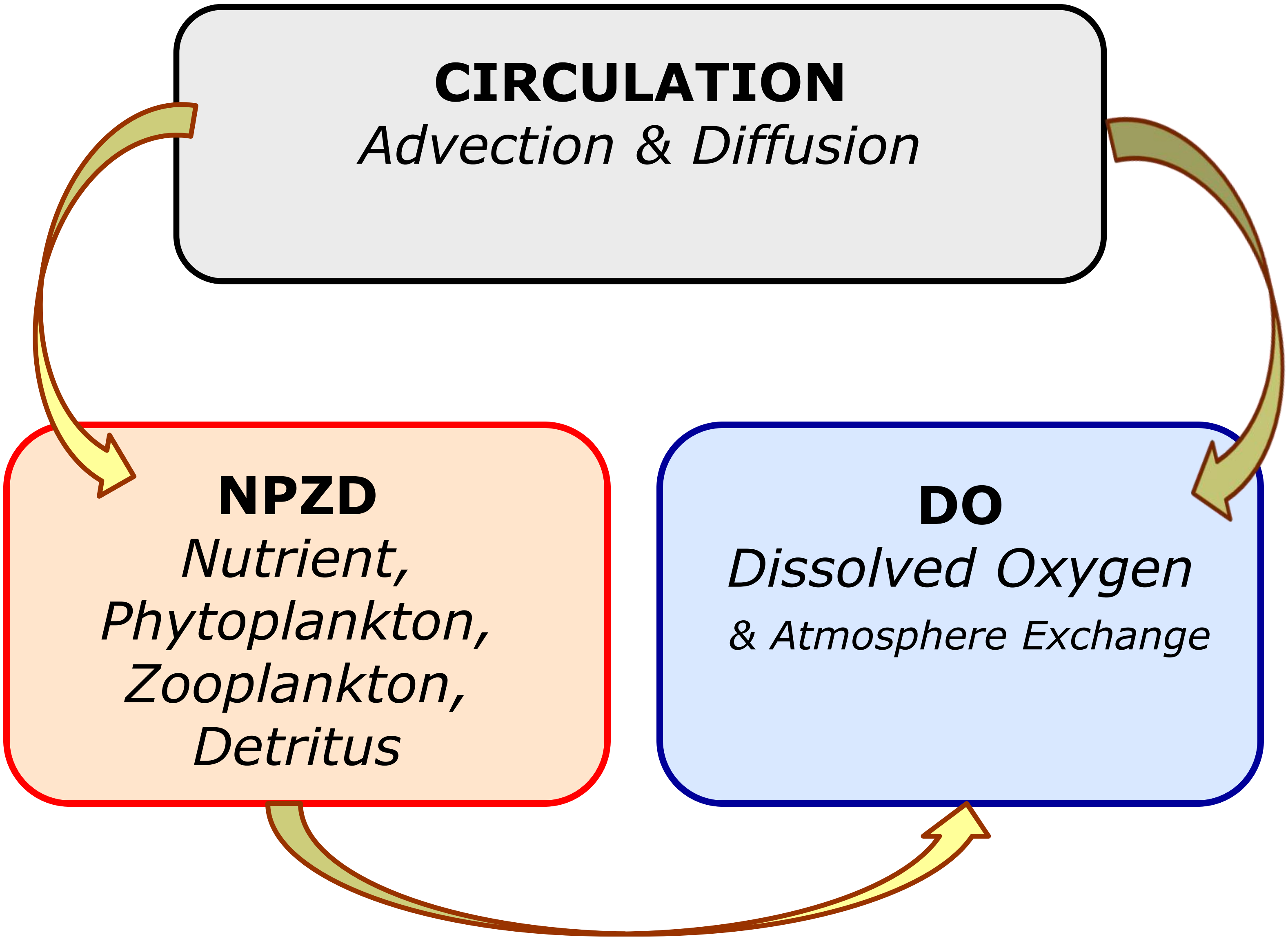
Low biology (chl max <5ug/l)
Upwelling
Neap tide
Moderate flow (4200m^{3}s^{-1})

Mod-high biology (chl max 15ug/l)
Upwelling
Neap tide
Mod-low flow (3000m^{3}s^{-1})

Model Concept

- Complicated biology
- An effective way to tease apart all the contributions to DO distribution is through data-supported modeling
- Our circulation models address
  - Elevation, velocity, salinity, temperature
- Adding DO and biology into the model moves toward representing the complex ecosystem functions
  - Model will rely heavily on empirical measurements for parameterization and validation

Model Components

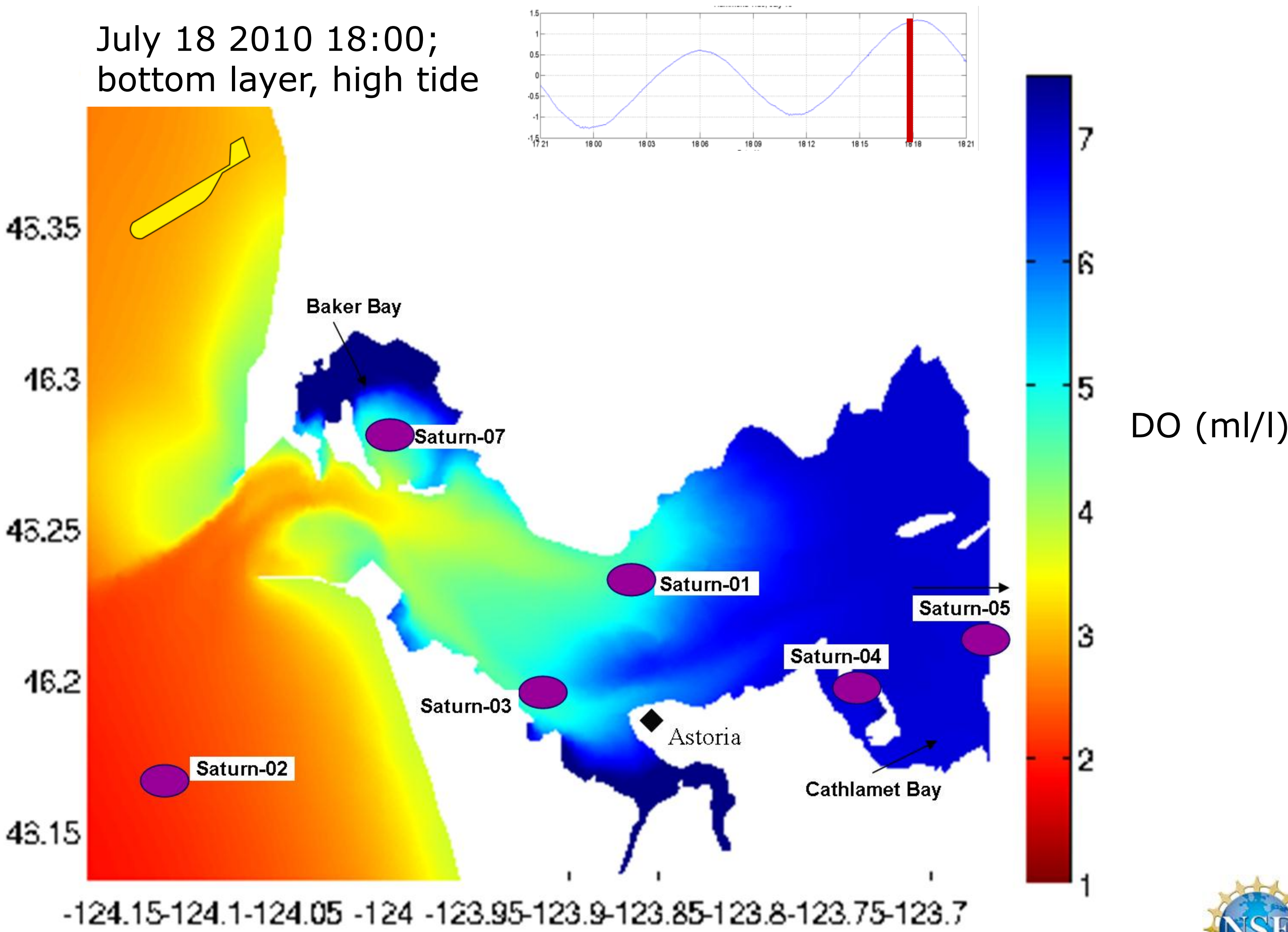


Model as Management Tool

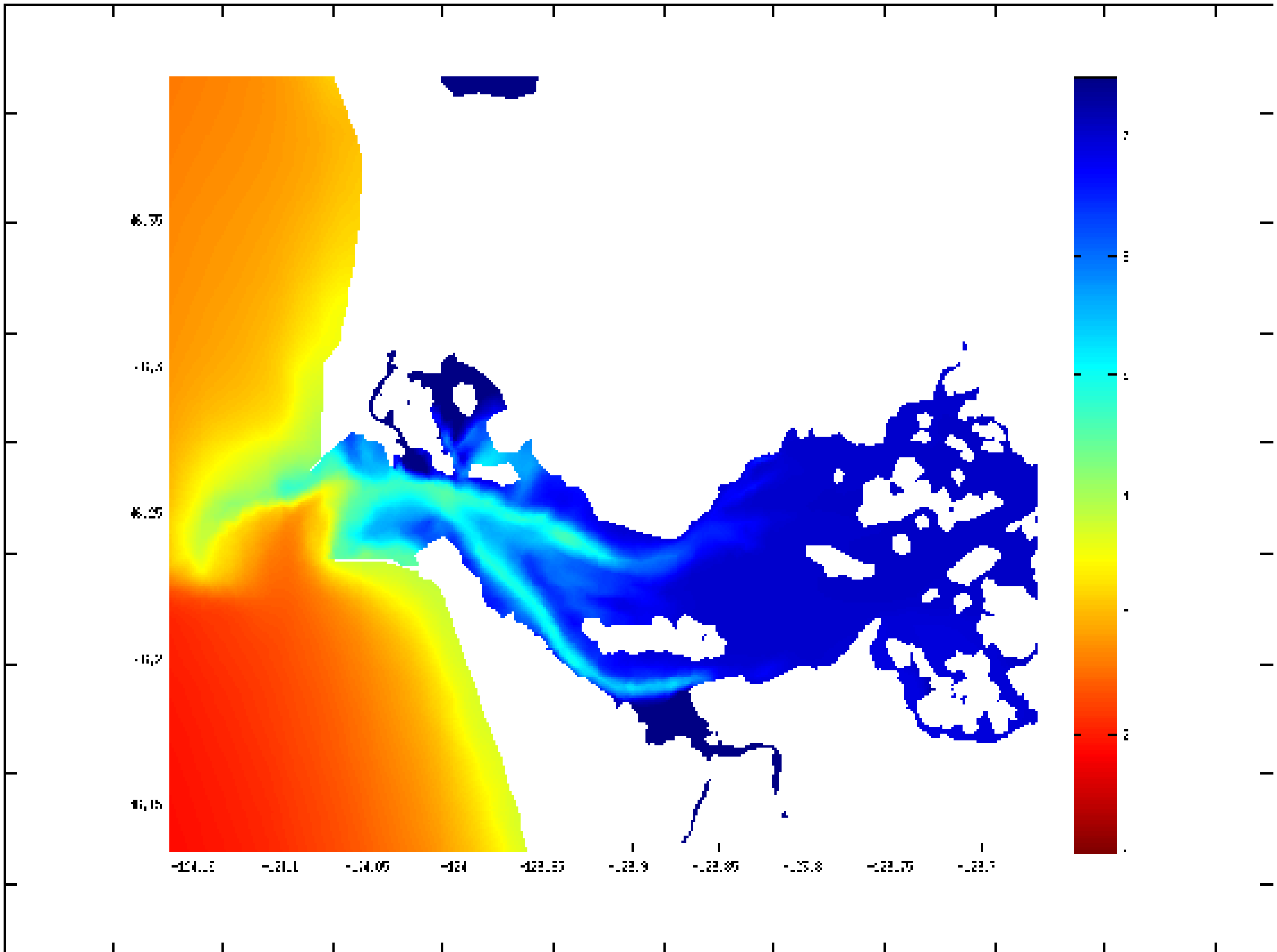
- Quantify and differentiate both the physical and biological forces influencing DO transformations over time and space in estuary
- Understand where, when, and under what forces low DO and hypoxic concentrations would be expected
- Leading to predictions of where and length of time at low DO within estuary
  - Look at how these may intersect with potential issues of concern for benthic and migrating species

Modeled Dissolved Oxygen, SATURN Stations

July 18 2010 18:00;
bottom layer, high tide



Modeled Dissolved Oxygen, July 18, 24-hour period



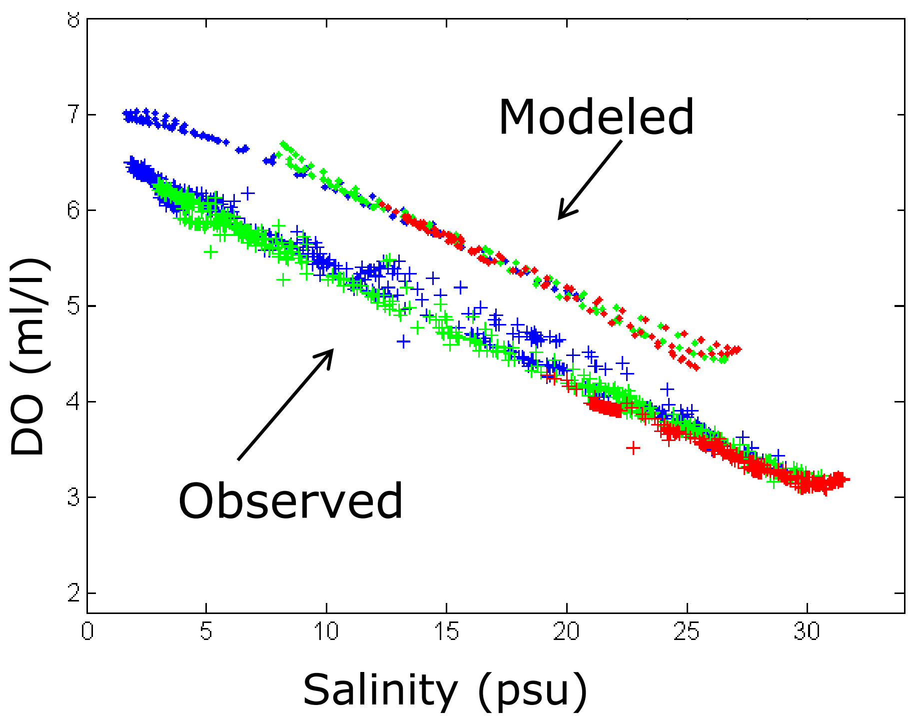
DO (ml/l)

Modeled data preliminary results, SATURN-03

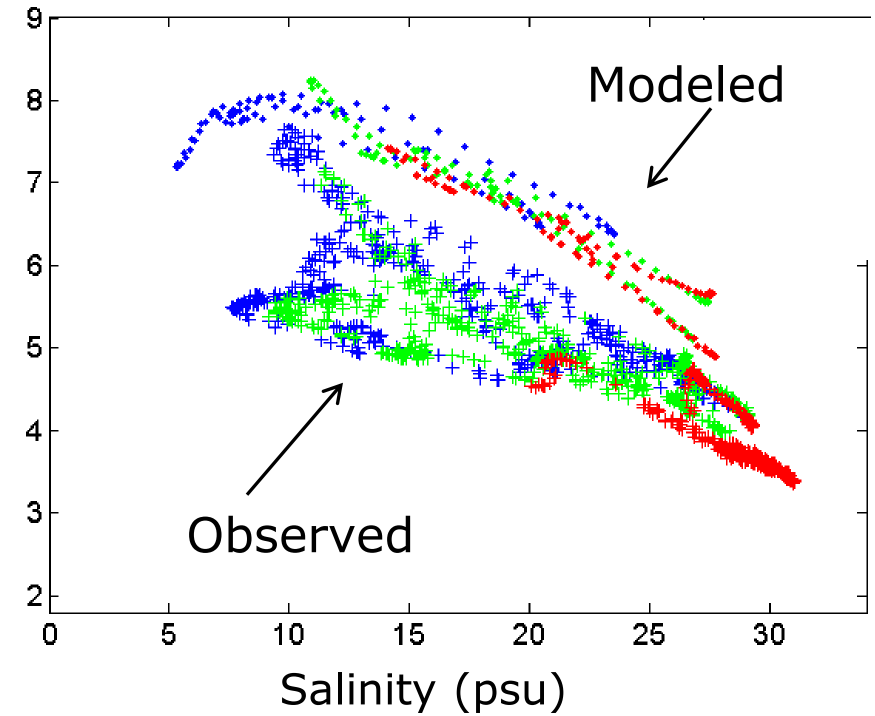
surface
mid depth
bottom

Salinity-to-DO, (tidal day); Model vs Observed

July 18, 2010



September 5, 2010



Low biology (chl max <5ug/l)
Upwelling

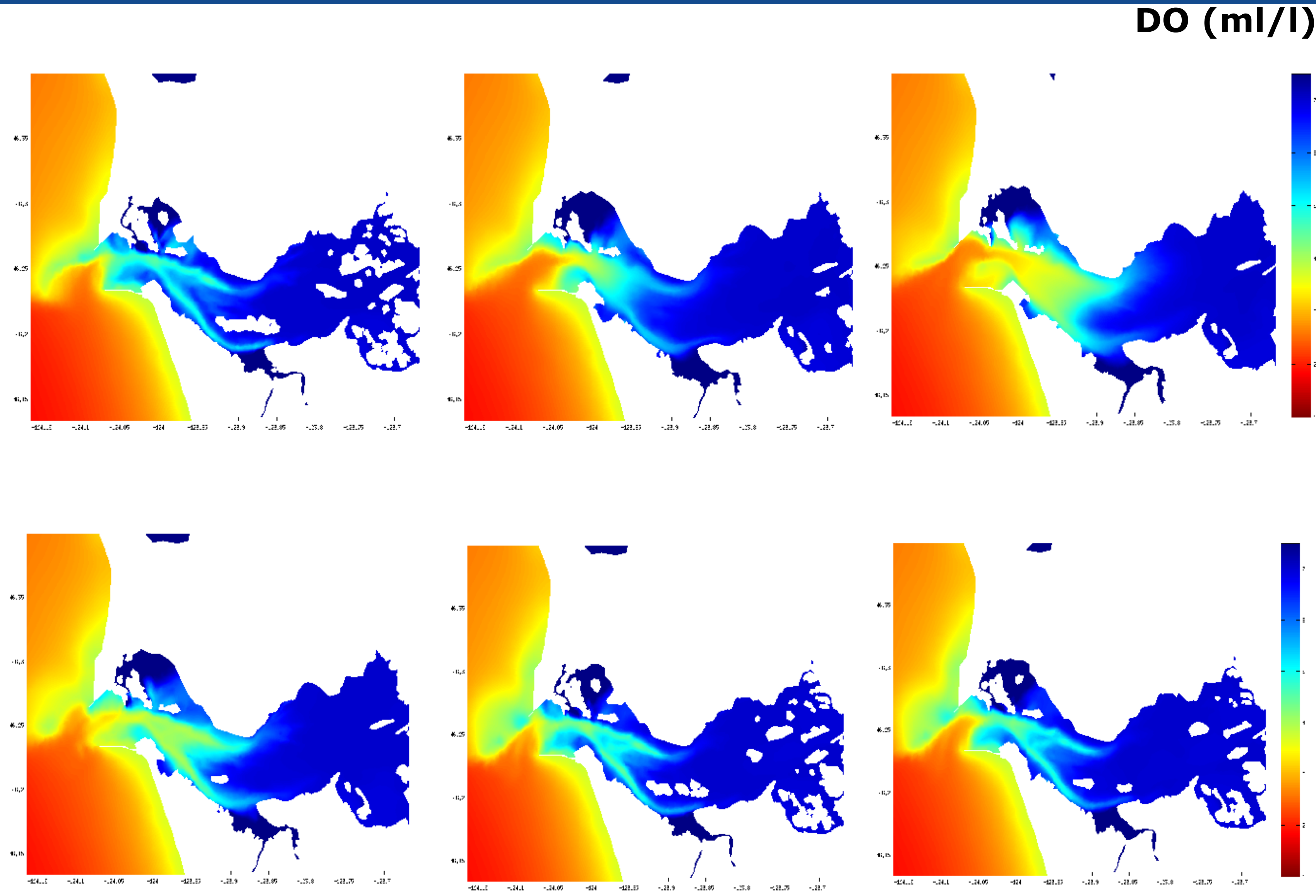
High biology (chl max 15ug/l)
Upwelling

Summary

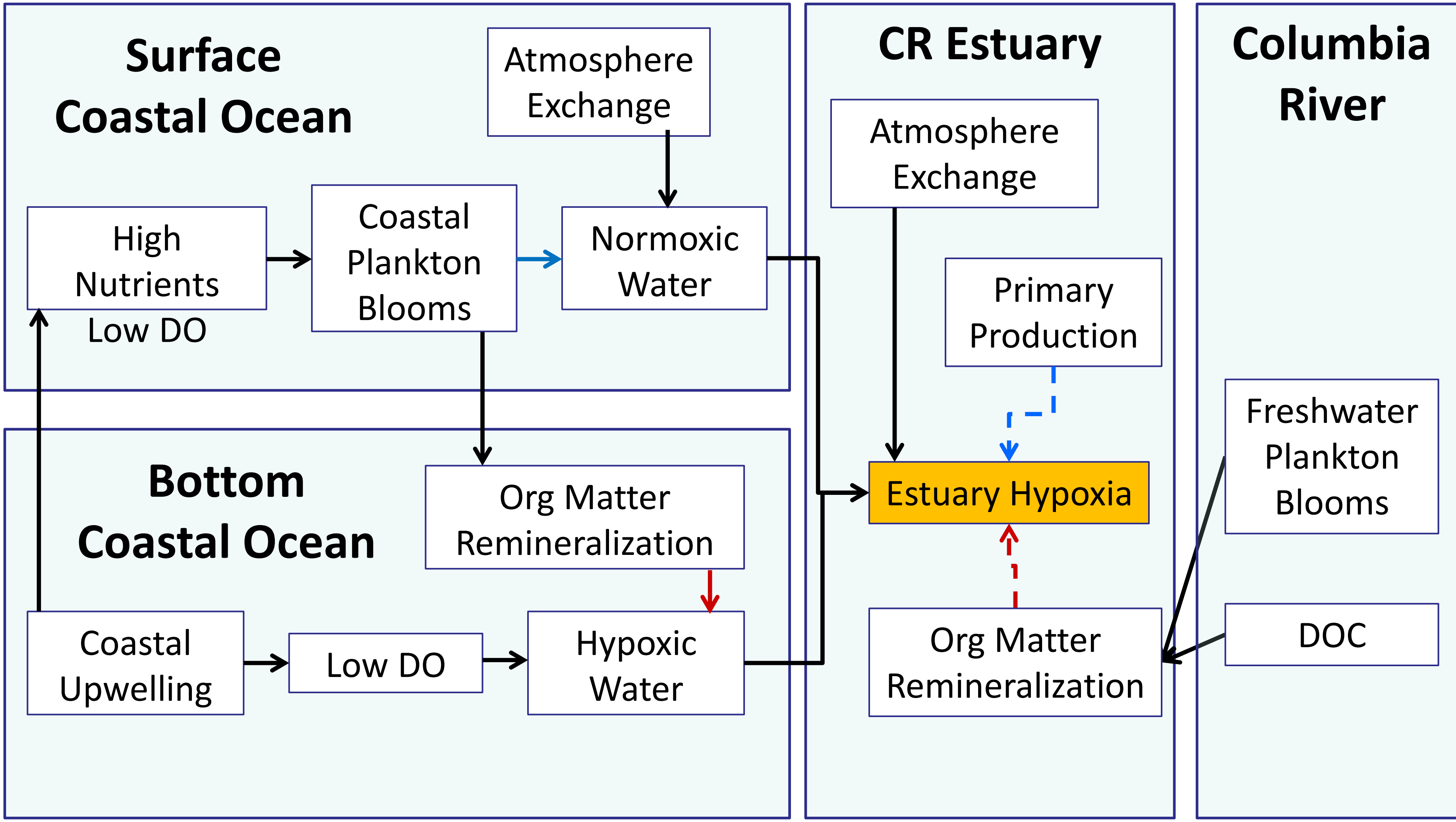
- Coastal upwelling brings low DO into the estuary, a potential water quality problem
- Sensors provide insight into DO distribution and controls
  - Have limited spatial resolution
  - No predictive ability for changes due to management or climate change
- Emerging DO model will allow us to better characterize and predict low DO and estuarine hypoxia; suggest mitigation strategies
- Continuing model development
  - Improve representation of physical processes of DO distribution
  - Refine parameterization, and validation of biological and DO models; sediment, light attenuation and nutrient cycling


Thank you

Modeled Dissolved Oxygen, July 18, 6-hour period



Estuarine Hypoxia: Mechanisms, Processes



Ecosystem Metabolism Stoichiometry:

$$106\ CO_2 + 16\ N + 1\ P \underset{\text{Respiration}}{\overset{1^\circ\ \text{Production}}{\rightleftharpoons}} \text{Organic Matter} + 150\ O_2$$

Modified from Needoba, 2011

Scale: 3km down to ~ 100m