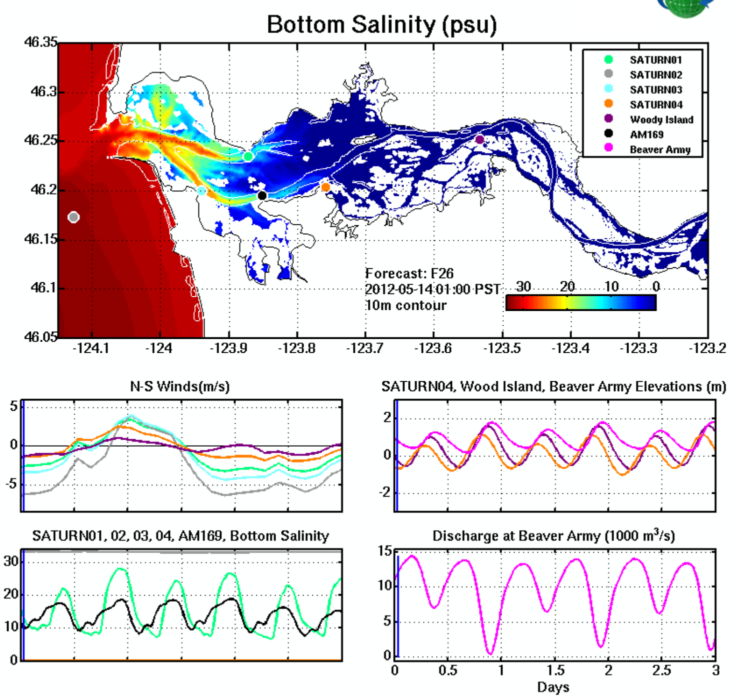
Columbia River Estuary Conference

May 2012, Astoria, OR

The SATURN collaboratory for the Columbia River coastal margin: capabilities and applications



CMOP
Center for Coastal Margin Observation & Prediction

António M. Baptista
Joseph Needoba

On behalf of the multi-institutional
NSF Science and Technology Center for Coastal Margin Observation & Prediction (CMOP)

OHSU OSU Oregon State University ...

Acknowledgments:

National Science Foundation
WHERE DISCOVERIES BEGIN

BONNEVILLE POWER ADMINISTRATION NOAA NANOOS ...

USGS science for a changing world

Order of slides

These slides are organized to support a non-sequential presentation of materials, adjustable to time elapsed and/or the perceived response/interest of the audience.

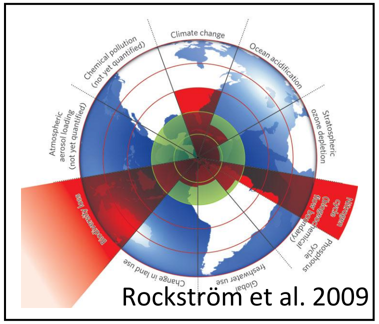
If you are view the slides on your own, consider using the following sequence:

- Slide 1 Slide 3 Slide 6
- Slide 7 Slides 8-12 Slides 13-15(16)
- Slide 17 Slides 18,19,13 Slides 20-23
- Slides 24-26 (plus browse Additional Slides, 28 and beyond)

You can achieve this sequence (or close to it) by clicking on icons (mostly blue buttons) in slide 3, each of which starts a particular slide sequence. After you are done with that sequence, click on the CMOP logo (bottom left of each slide) to return to slide 3

The SATURN collaboratory in context

Challenge: Track and manage the *Safe Operating Space* for the Columbia River estuary



Rockström et al. 2009

Photo: Barchowski

CRCM

Variability | Change

Variability or Change?

SATURN

Modeling framework

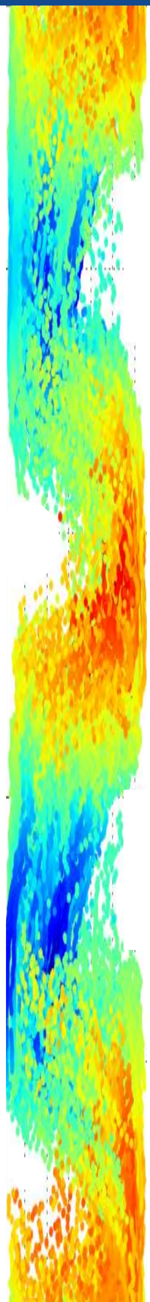
Observation network

- Flow through the Federal **C**olumbia **R**iver Power System affects a broad, river-to-ocean geography (referred here as the '**c**oastal **m**argin' or CRCM for short)
- Highly variable, the CRCM is also changing in response to climate and humans
- Distinguishing between **natural variability** and **change** is complex, requires solid understanding of processes and "baselines"
- The **SATURN collaboratory** is designed to meet these challenging requirements, with a view towards both foundational science and science applications
- **Coupled biogeochemical, habitat and circulation modeling** offers powerful opportunities to characterize and distinguish between **variability and change**
- Modeling requires science context and **high-resolution, long-term observations**

Final considerations

- SATURN is a powerful and unique regional asset – **your** asset.
- SATURN extends and replaced CORIE (1996-2007), and is an anchoring sub-system of the PNW-wide NANOOS, and of the national IOOS.
- Our standing invitation to the CR stakeholders: use SATURN, challenge its capabilities, help us improve and sustain it
- A major strength of SATURN is the circulation and PHO modeling of the Virtual Columbia River. 'Coming soon' capabilities include modeling of sediments and of the lower trophic chain
- The Virtual Columbia River is only feasible because of the very strong and interdisciplinary SATURN observation network, a major regional asset in itself
- Data explorer (see Seaton talk) is a powerful, flexible tool for accessing SATURN (and other regional) observations.

CMOP Posters and Talks



Salinity or Art? ☺

CMOP Posters

Jesse Lopez, PhD student

- Sediment modeling

Mojgan Rostaminia, MS student

- Habitat opportunity modeling

→ Directly or indirectly integral to several non-CMOP talks at this conference

CMOP Talks

Tawnya Peterson

- River and estuarine food webs

Charles Seaton

- Data Explorer (today!)

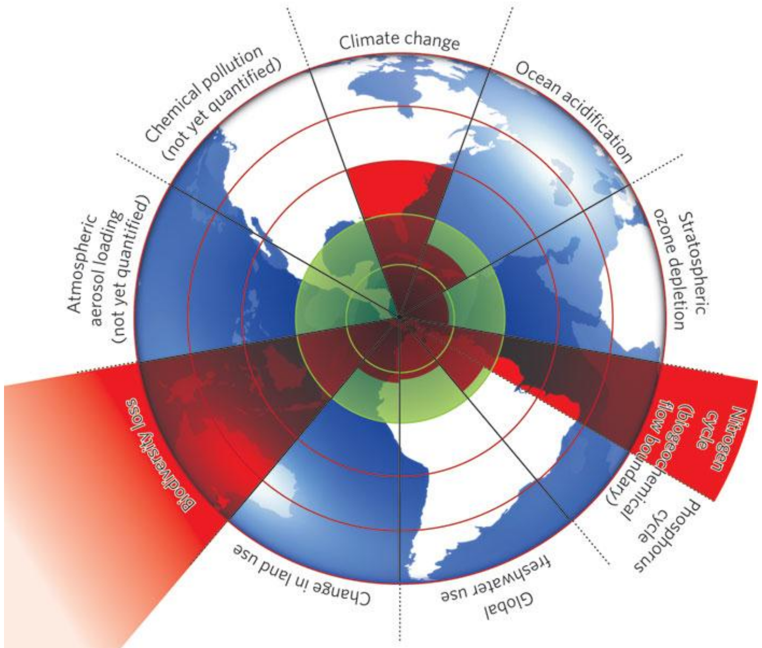
Pat Welle, PhD student

- Modeling estuarine hypoxia (today!)

→ Extending the modeling scope of the Virtual Columbia River

The 'Safe Operating Space' for the Columbia River

Johan Rockström et al. 2009, *Nature* 461, 472-475



Candidate 'metrics'

- Estuarine habitat opportunity
- 'Estuarine bioreactor' function
- Plume function
- …

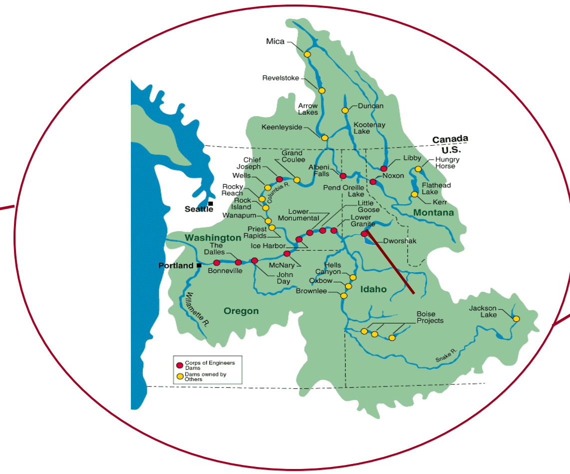
An adaptation of the concept might offer a much needed framework to organize thinking and to advance ESA-influenced management of the Columbia River

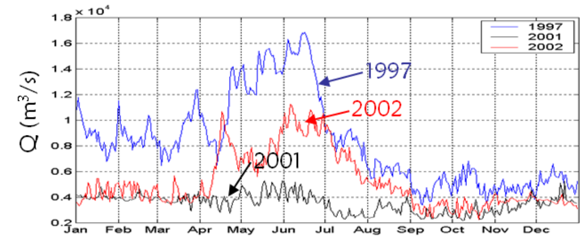
Candidate 'issues'

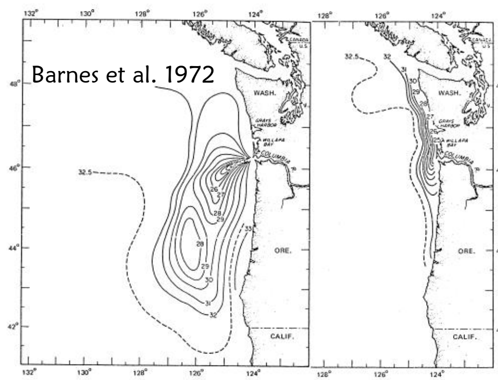
- Columbia River Treaty
  - Changes in flow regulation
  - Changes in sediment budget
  - Changes in nitrogen loads
- Climate change
  - Sea level rise
  - Changes in water temperature
  - Changes in coastal upwelling
  - Increased ocean acidification and hypoxia
- Navigation improvements
  - Channel deepening
- Changes in land use
  - Irrigation
  - Restoration projects

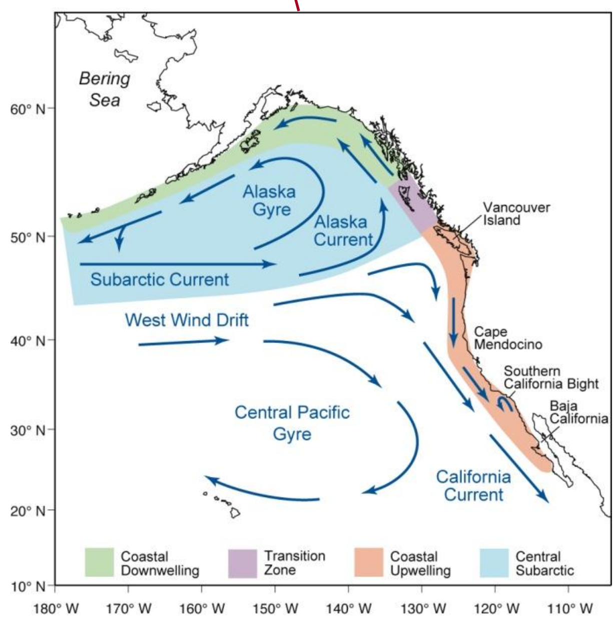
…

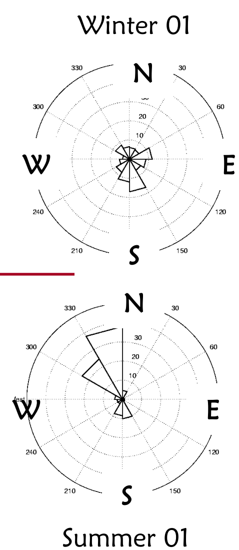
The Columbia River coastal margin

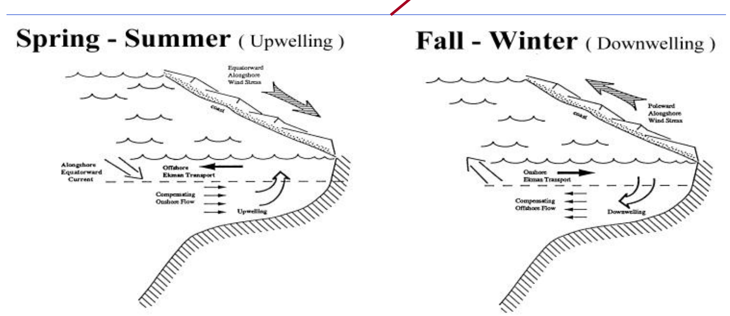






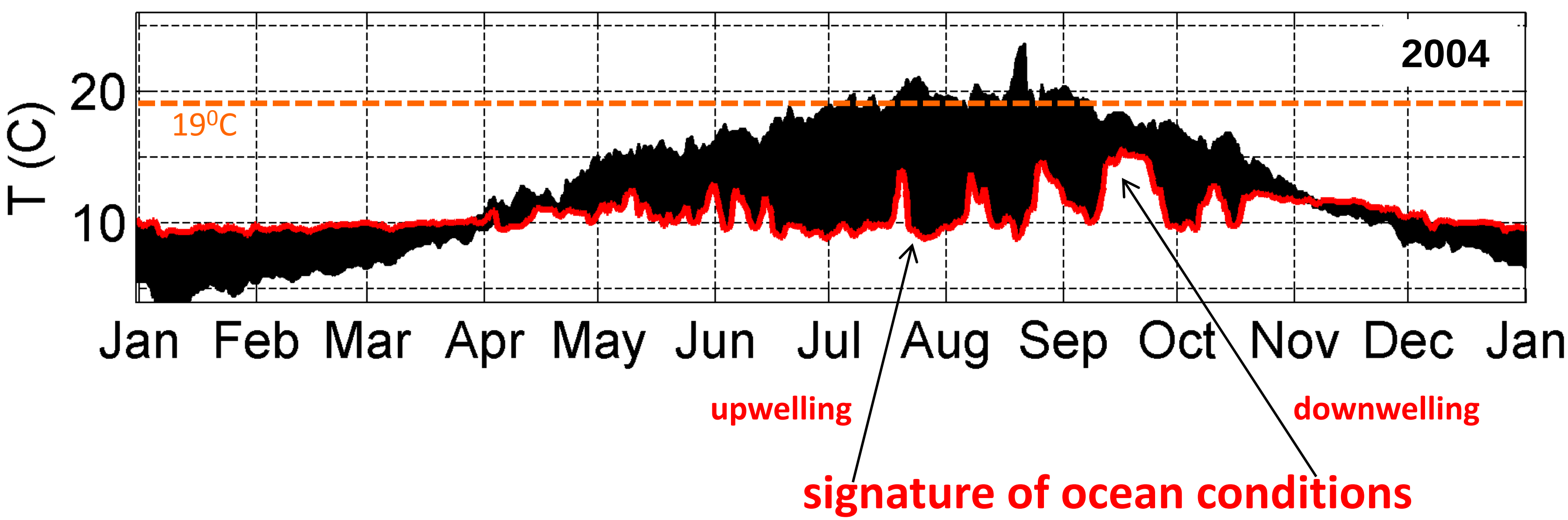






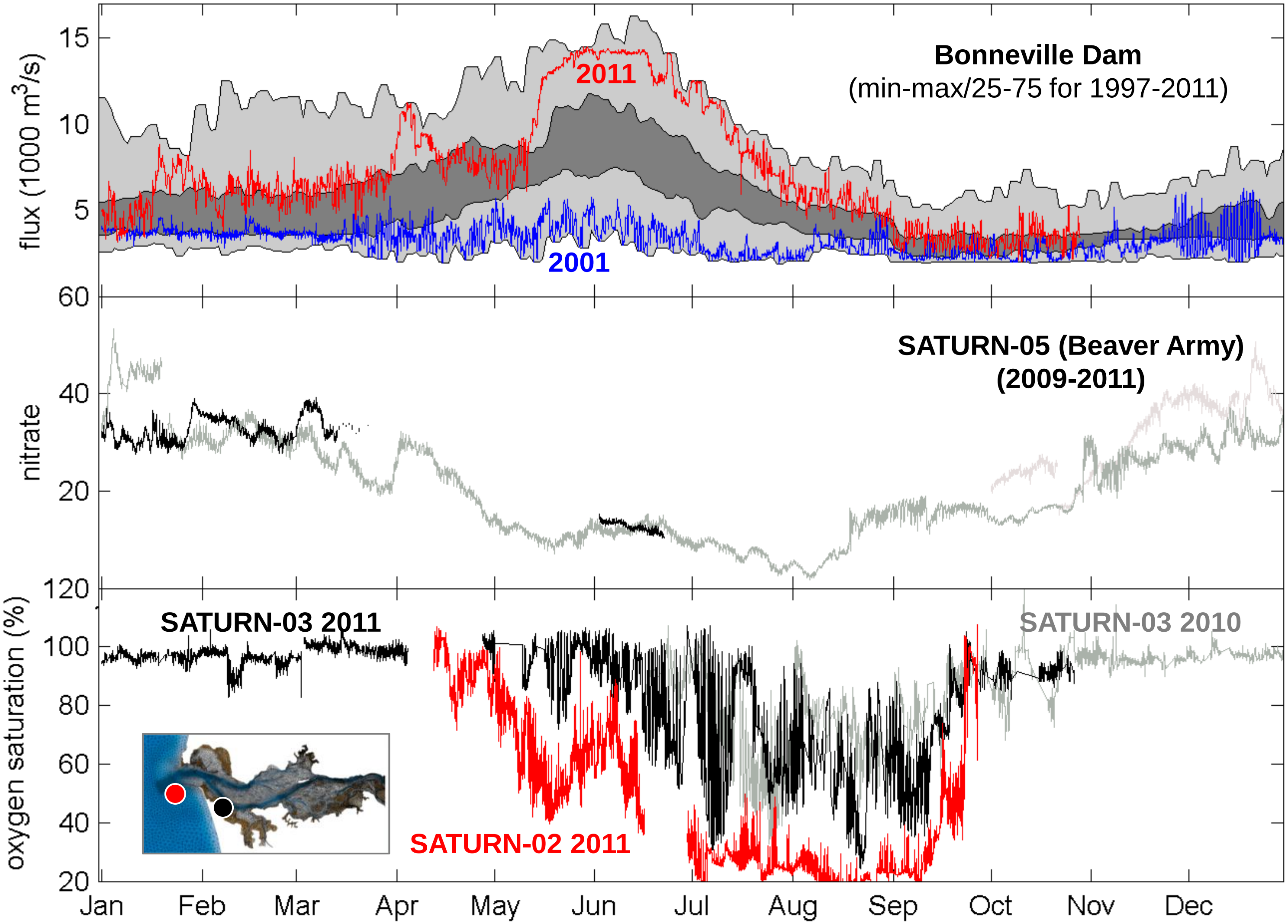
Multi-scale variability: seasonal

- The estuary is (at first-order thinking) a two-end member system, with multi-scale variability controlled by tides and by the river and ocean end members.
- Temperature in the estuary, shown as aggregate of multiple stations, illustrates (a) seasonal variability; (b) the end-member concept, and some of its fine details; and (c) performance outside a safe operating space.

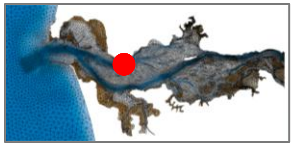


Multi-scale variability: inter-annual (end members)

Both end members have strong inter-annual variability. Some aspects of their variability are well known, others are only now being uncovered

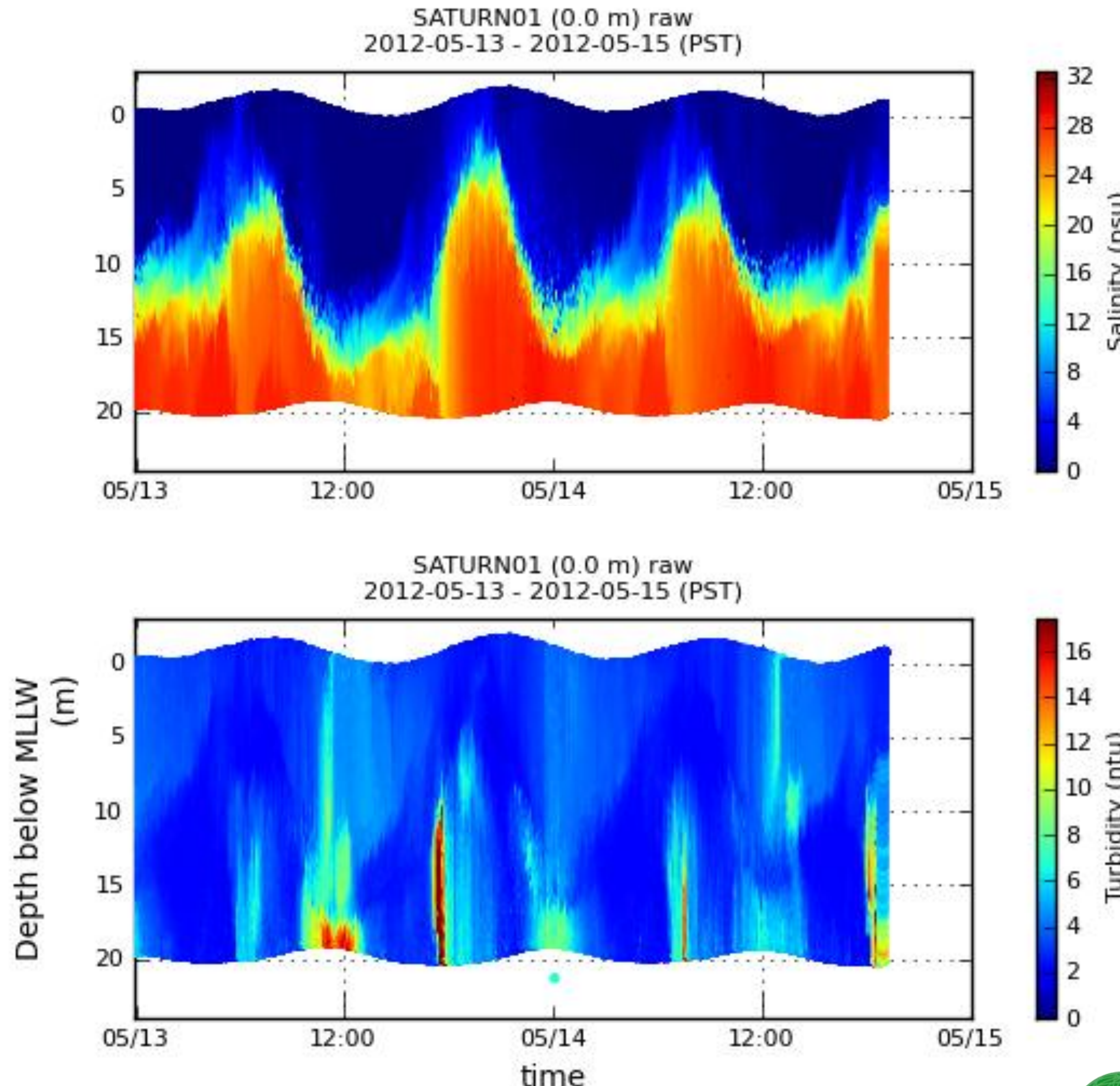


Multi-scale variability: tidal

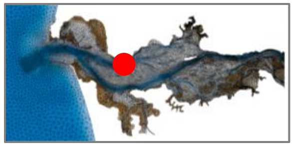


SATURN-01

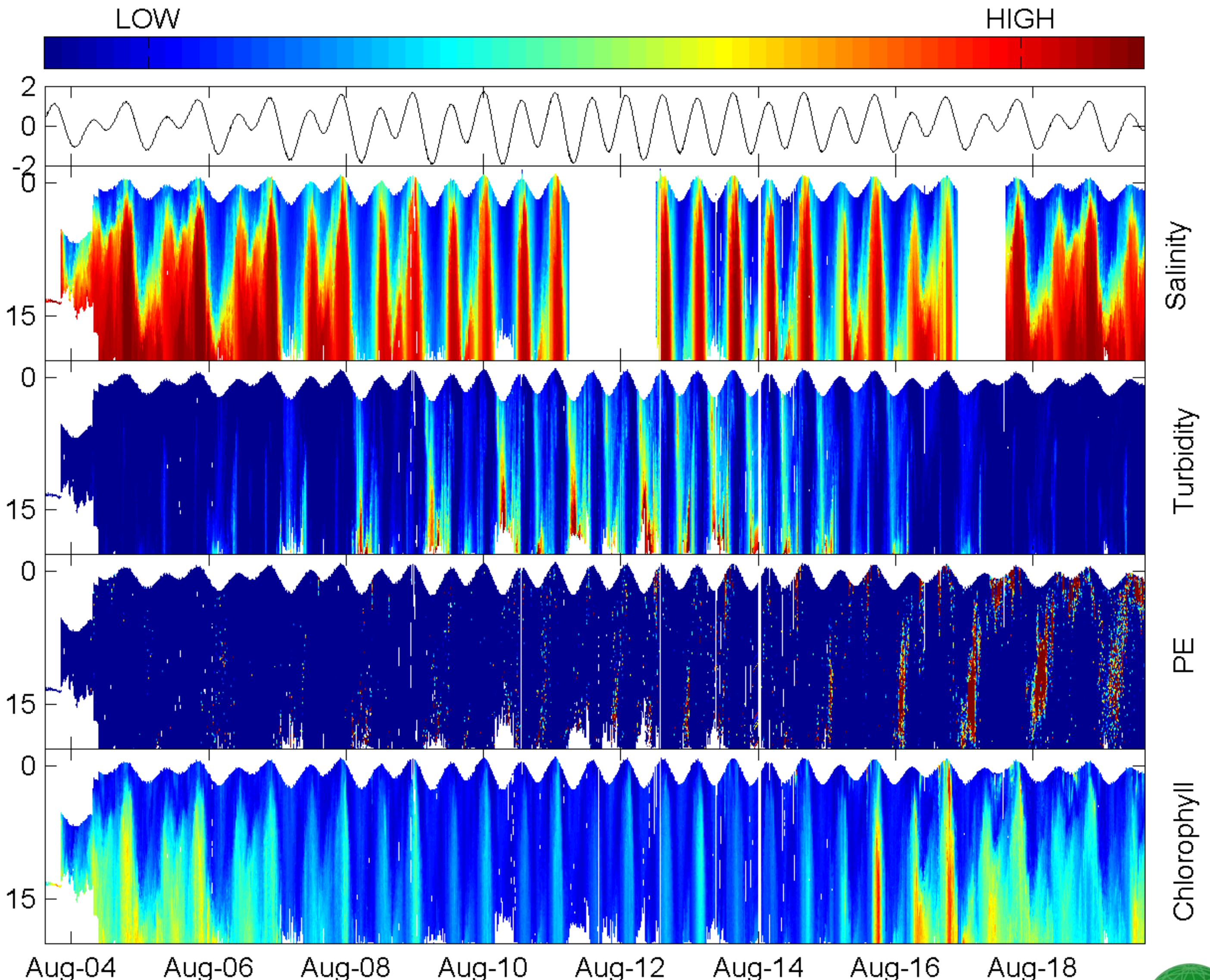
- Tidal variability and vertical structure are complex
- Correlation across variables reflects “two end members” behavior for nearly conservative tracers; is complex otherwise
- Many ecologically important fine details are only now being understood and/or becoming predictable



Multi-scale variability: spring-neap cycle



SATURN-01



- Tides are NOT all the same!
- There is strong spring-neap variability
- There are strong diurnal assymetries

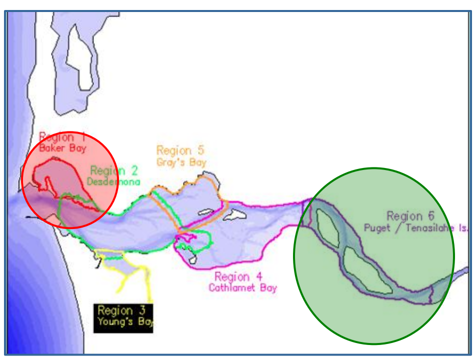
Multi-scale variability: seasonal with spatial effects

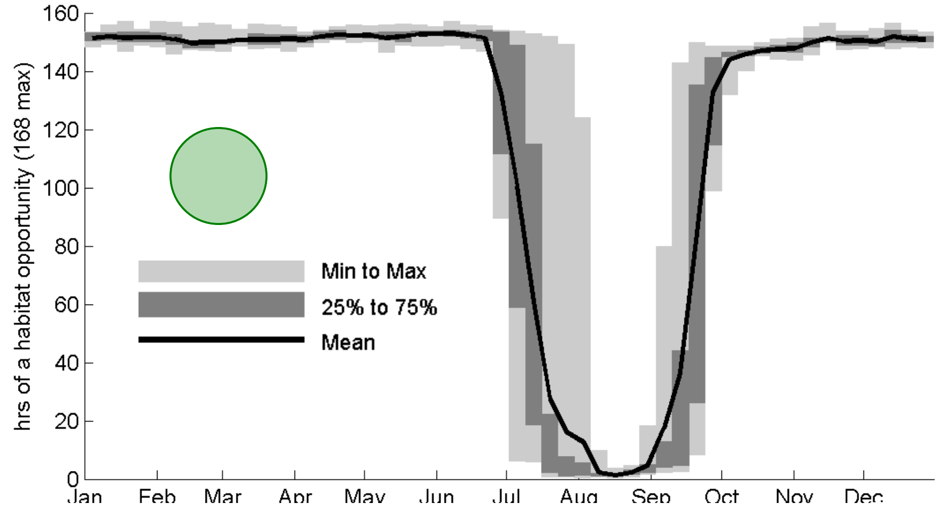
Virtual CR
simulation DB22
(1997-2010)

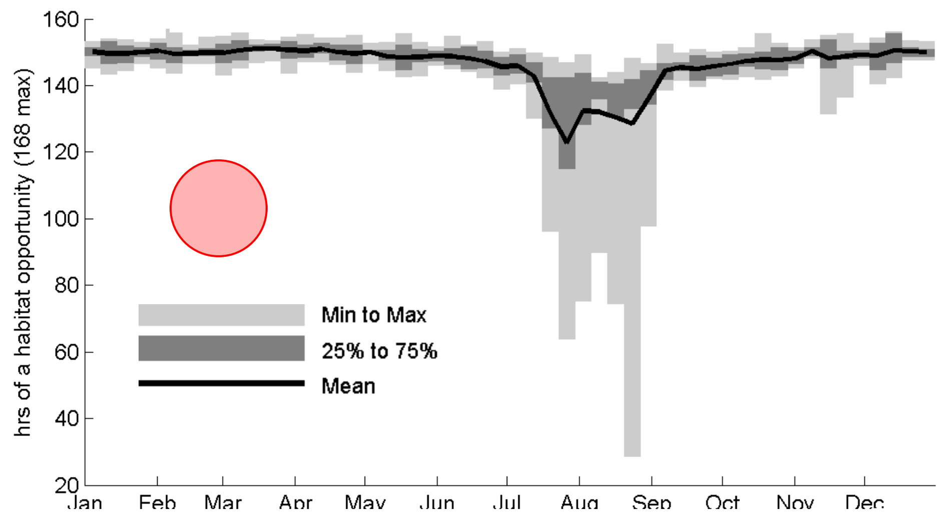
↓

Physical Habitat Opportunity (PHO)

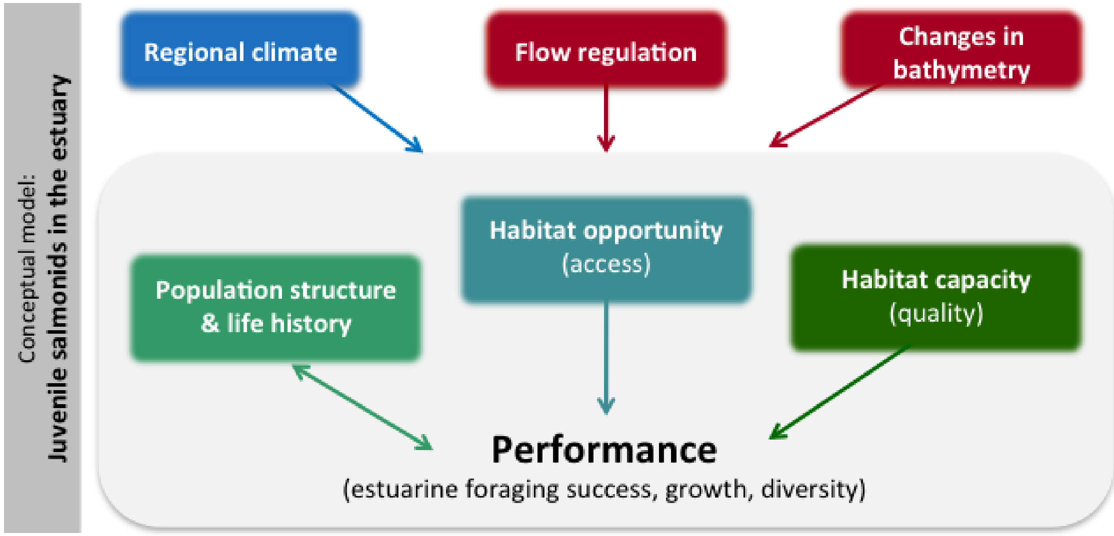
- T < 19 °C

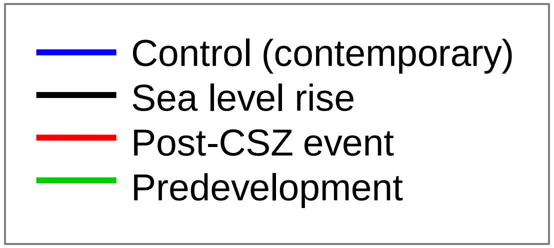


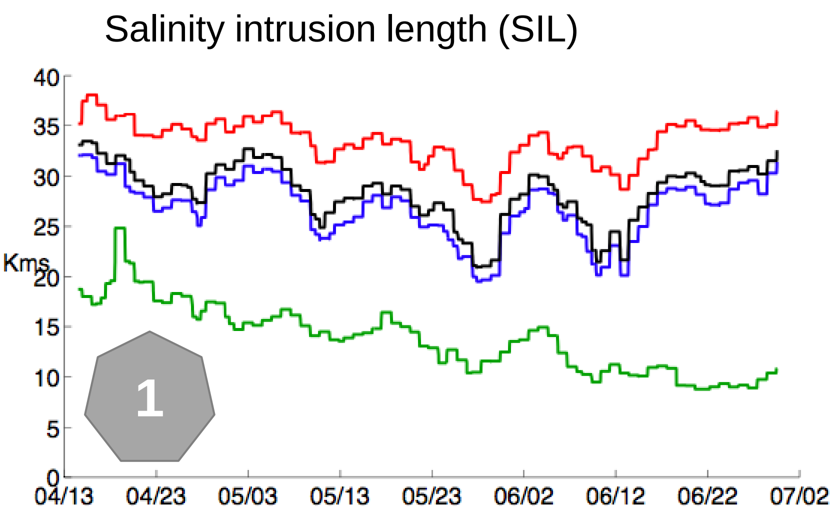


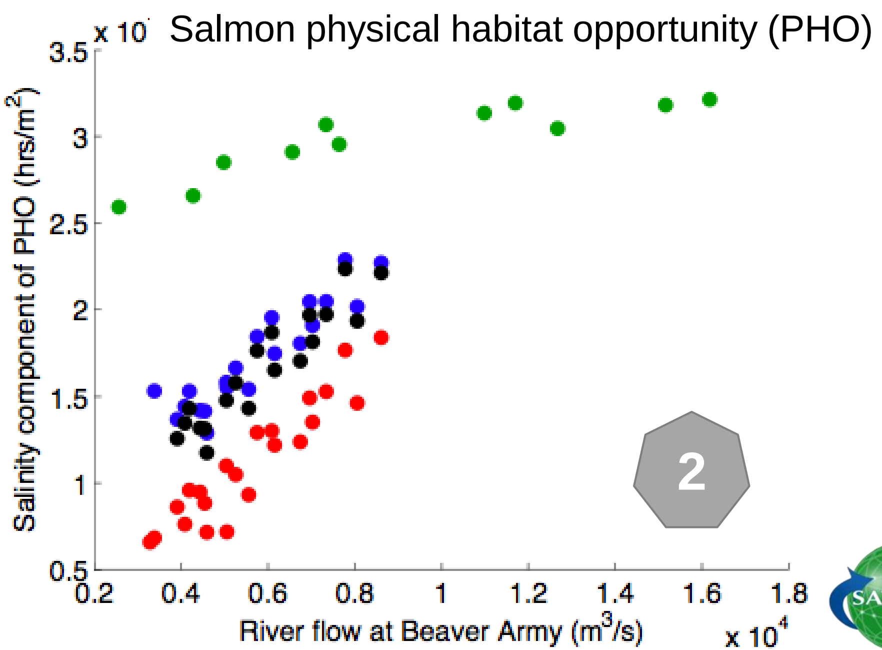


Change


Conceptual model:
Juvenile salmonids in the estuary
Regional climate
Flow regulation
Changes in bathymetry
Habitat opportunity (access)
Population structure & life history
Habitat capacity (quality)
Performance
(estuarine foraging success, growth, diversity)

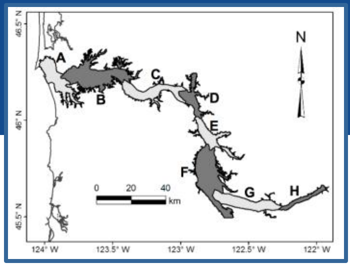

Control (contemporary)
Sea level rise
Post-CSZ event
Predevelopment

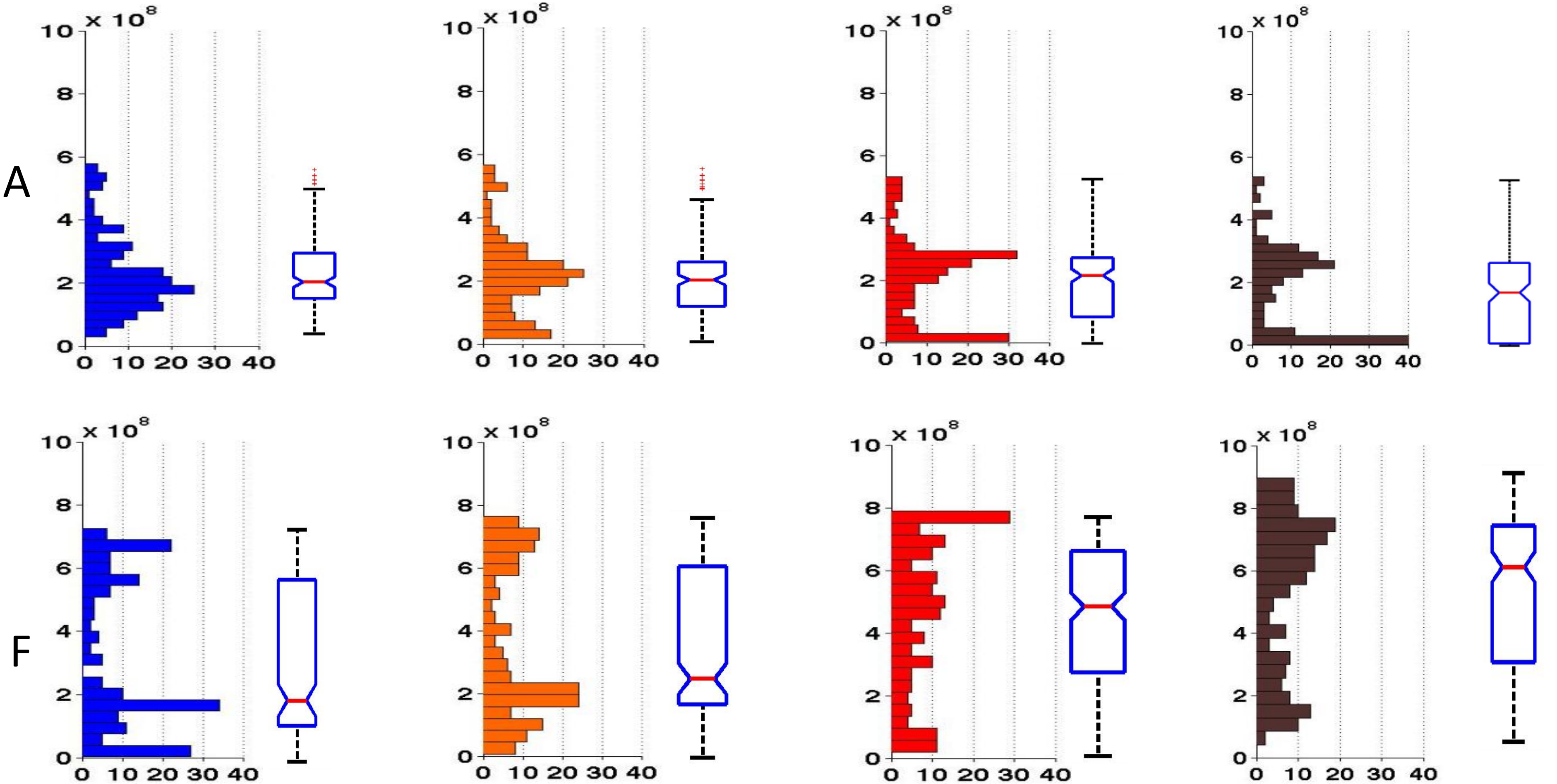

Salinity intrusion length (SIL)
Kms
1
04/13
04/23
05/03
05/13
05/23
06/02
06/12
06/22
07/02


Salmon physical habitat opportunity (PHO)
Salinity component of PHO (hrs/m²)
River flow at Beaver Army (m³/s)
x 10⁴
2

Change in PHO with sea level rise

?

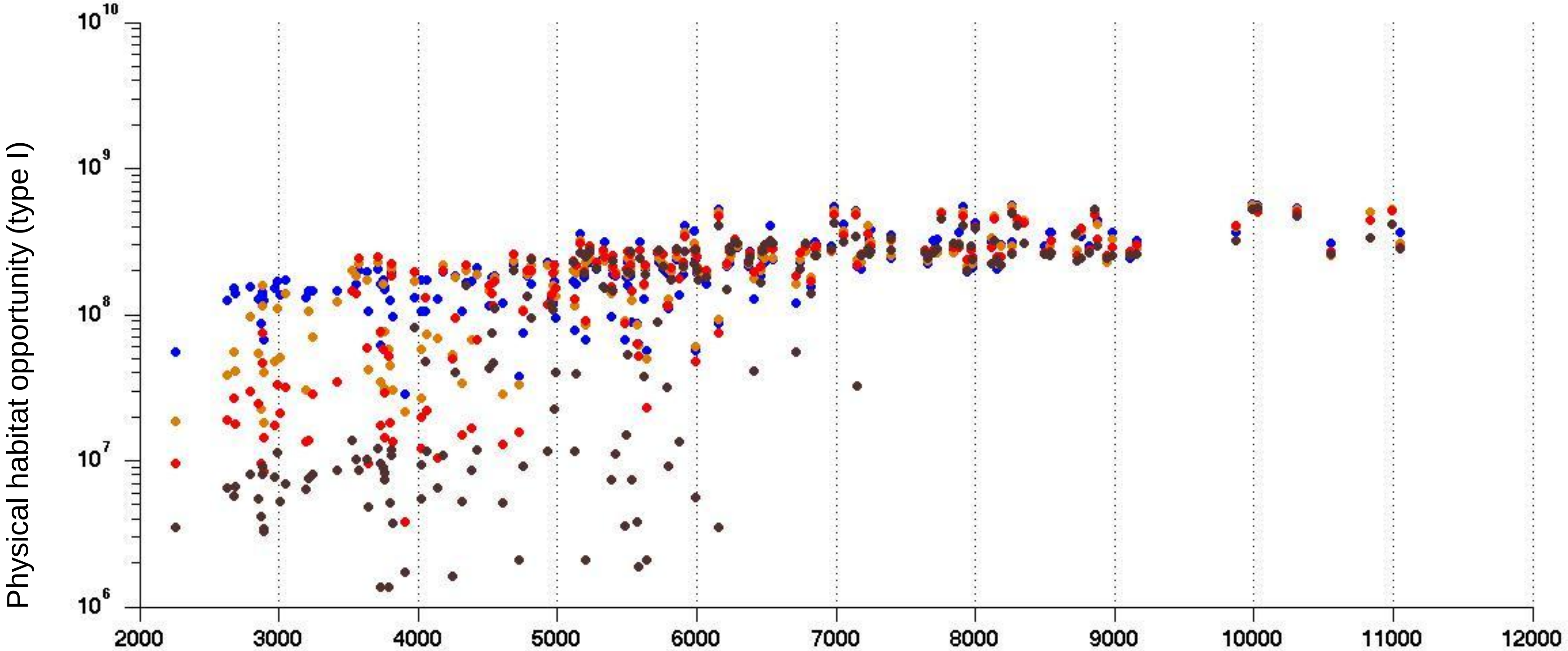




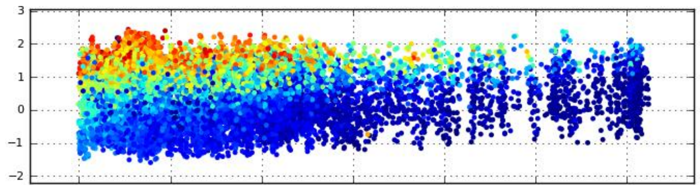
Contemporary SLR:30cm SLR:70cm SLR:130cm

CMOP SATURN

The ‘Q_{crit}‘ effect: will it change?



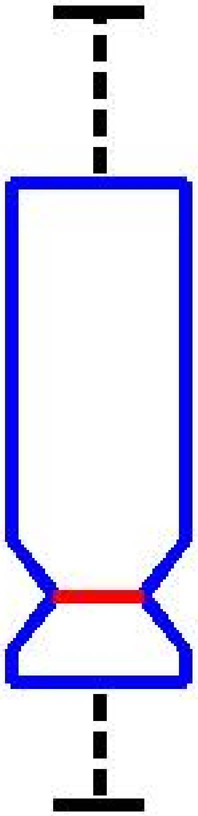
Contemporary **SLR:30cm** **SLR:70cm** **SLR:130cm**



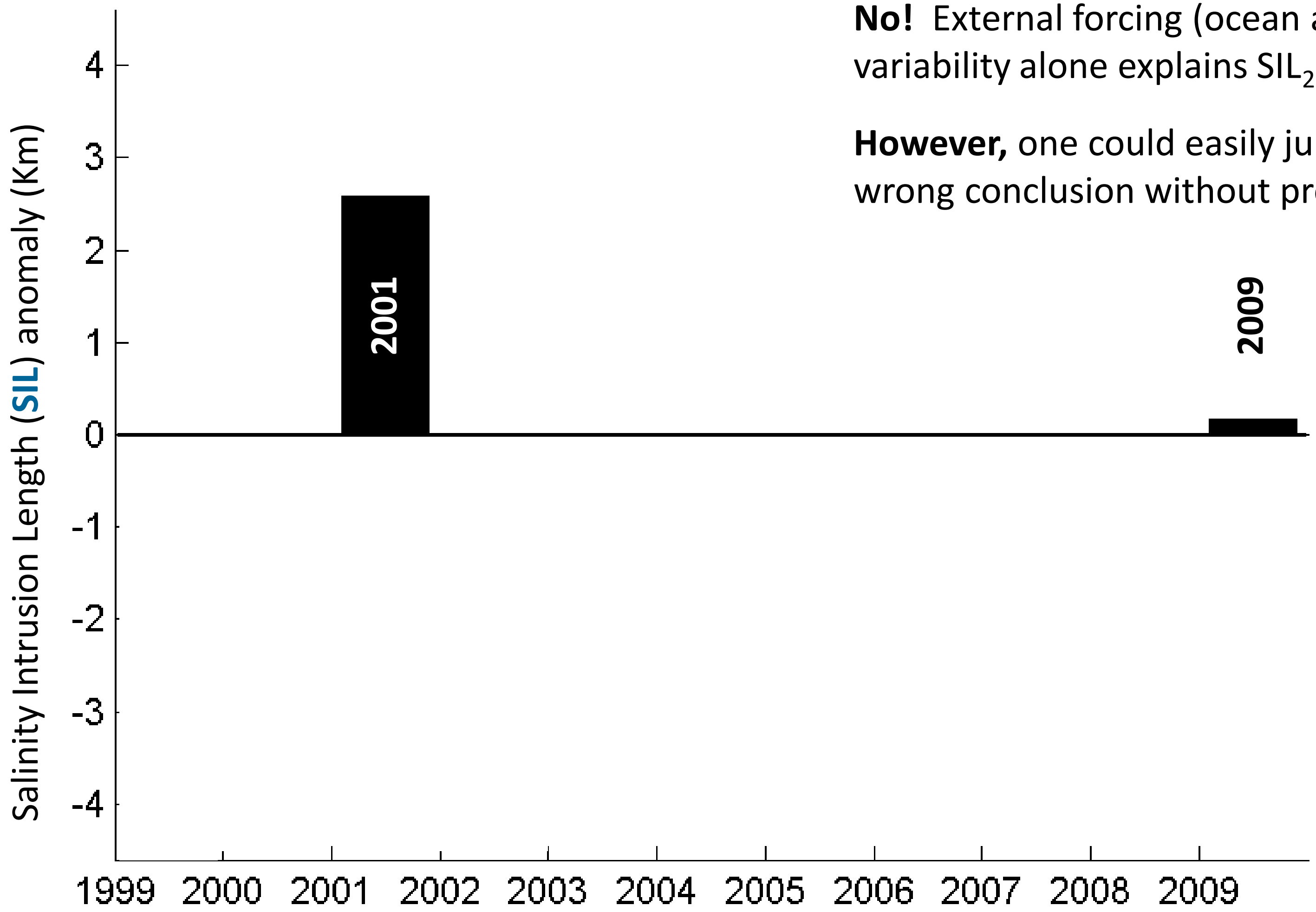
For another manifestation of the Q_{crit} effect, see Seaton talk

Explanation

- The top of the blue boxes show the 75th percentile and the bottom of the blue boxes show 25th percentile.
- The notch marks the 95% confidence interval for median.
- The height of each box represent the inter quartile range (75th minus 25th percentile).
- The black dash line shows the highest and lowest values that are within 1.5 times of the inter quartile range of box edges.



SIL_{2001} » SIL_{2009} ! **Did deepening the channel (2005-2010) reduce salinity intrusion into the estuary?**



No! External forcing (ocean and river) variability alone explains SIL_{2001} » SIL_{2009}

However, one could easily jump to the wrong conclusion without proper context.

Based on **Virtual Columbia River** simulation DB22

Strengthening modeling through a ‘collaboratory’

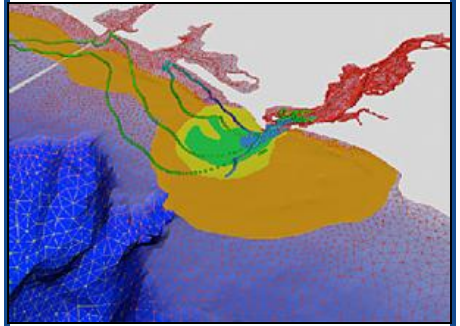
“Grand Challenge” science

K-gray education

Uses and users

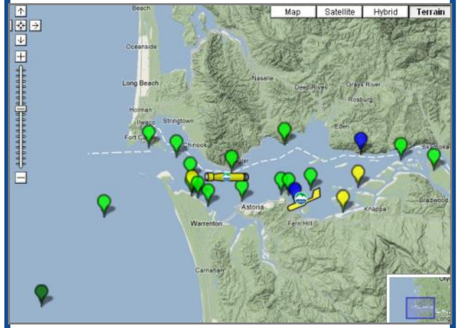
Regional management & Sustainability

Virtual Columbia River



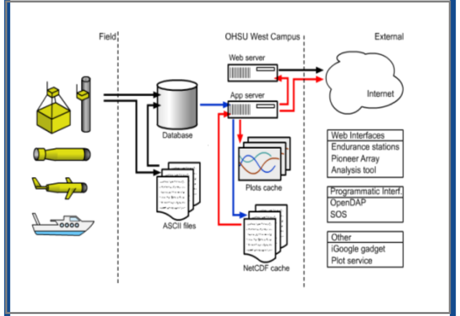
Simulation & prediction

Observation network



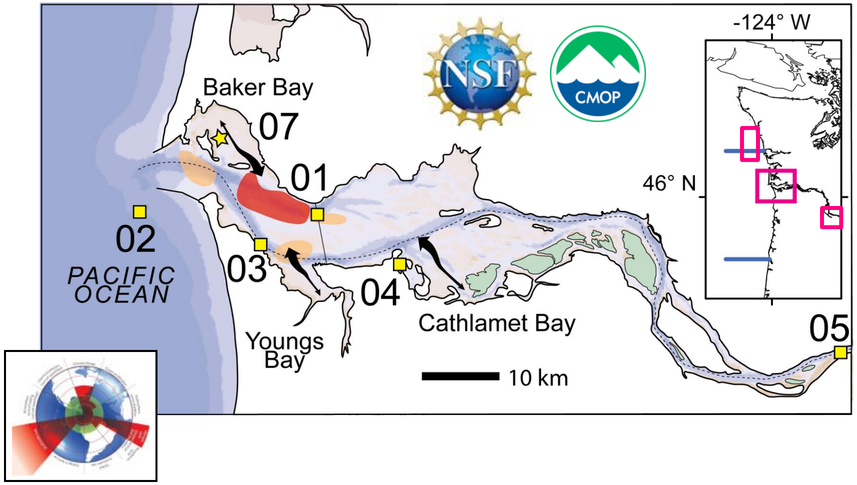
Endurance stations & pioneer array

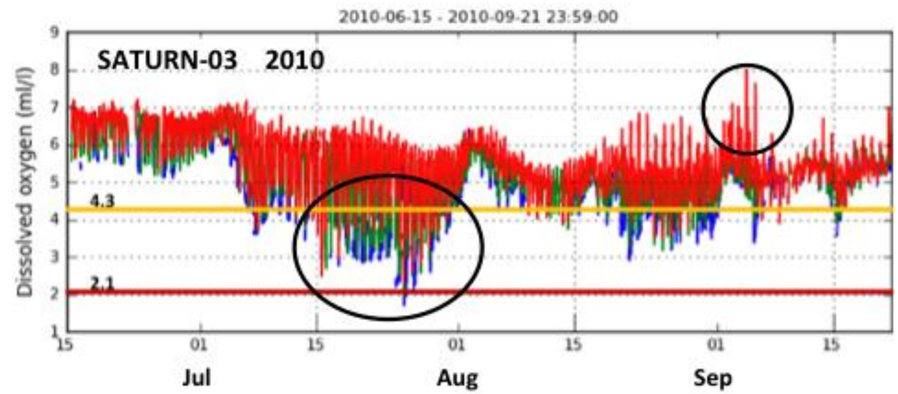
Cyber infrastructure



Information flow & integration

The estuary viewed through key biological "hotspots"





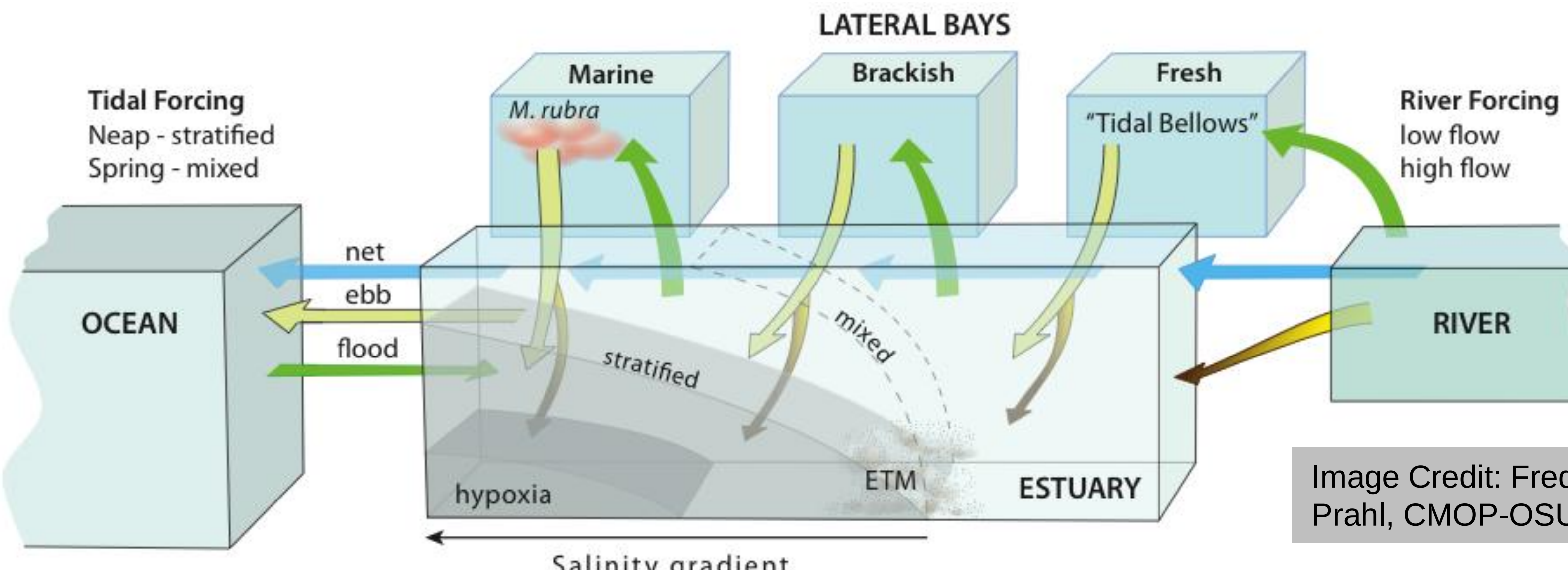
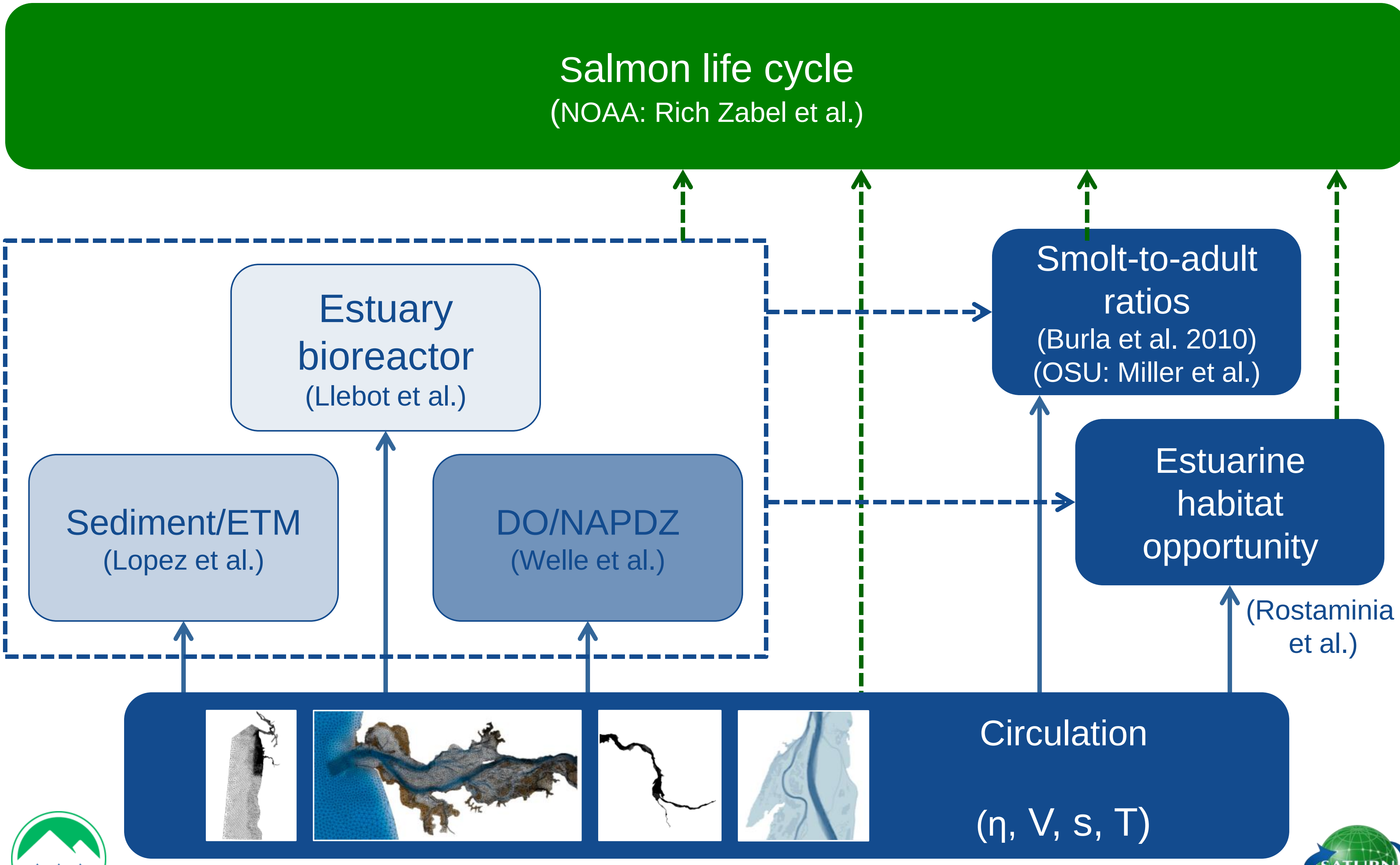


Image Credit: Fred Prahl, CMOP-OSU

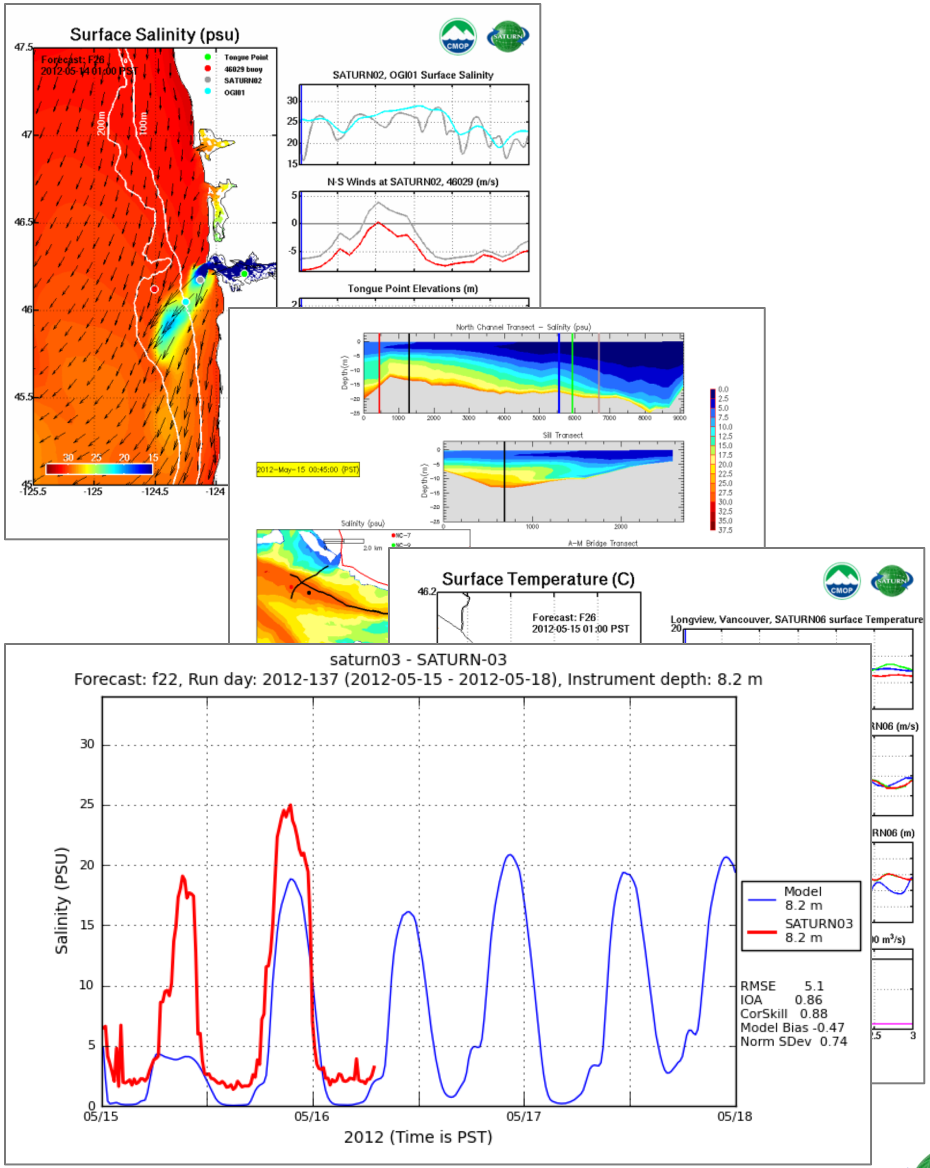
SATURN modeling system: the Virtual Columbia River



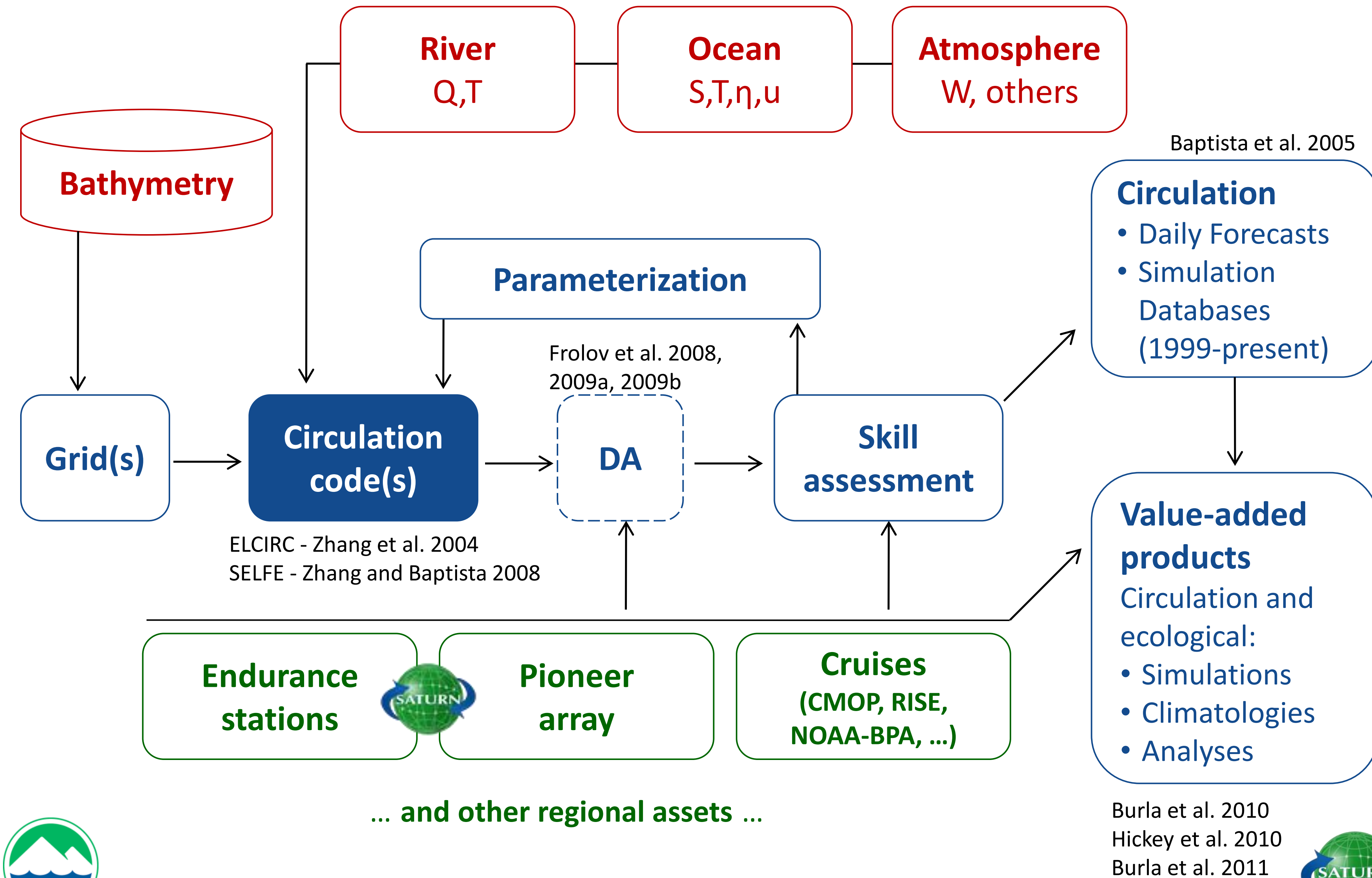
Circulation modeling as foundation

The **Virtual Columbia River** offers systemic "in simulation" representations of the circulation in the CR coastal margin.

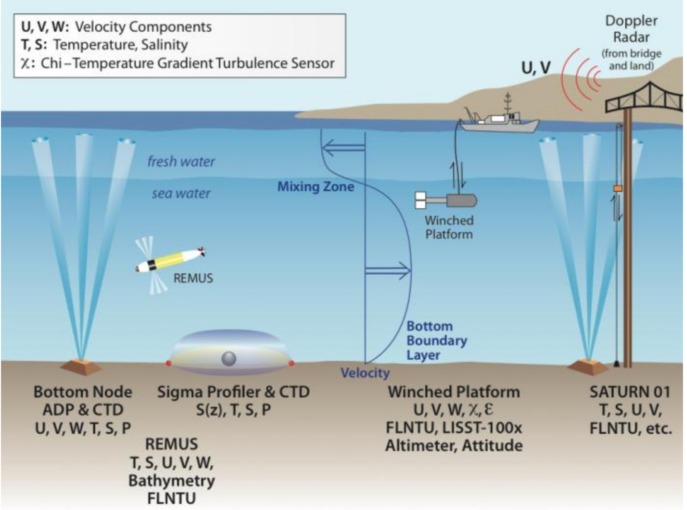
- Forecasts, simulation databases, analysis of scenarios
- River-to-ocean 4D (space-time) representation. Domain extends upstream to Bonneville Dam and Willamette Falls
- Realistic bathymetry and forcing (river, ocean, atmosphere)
- Extensive automation, diverse products, and continued skill assessment

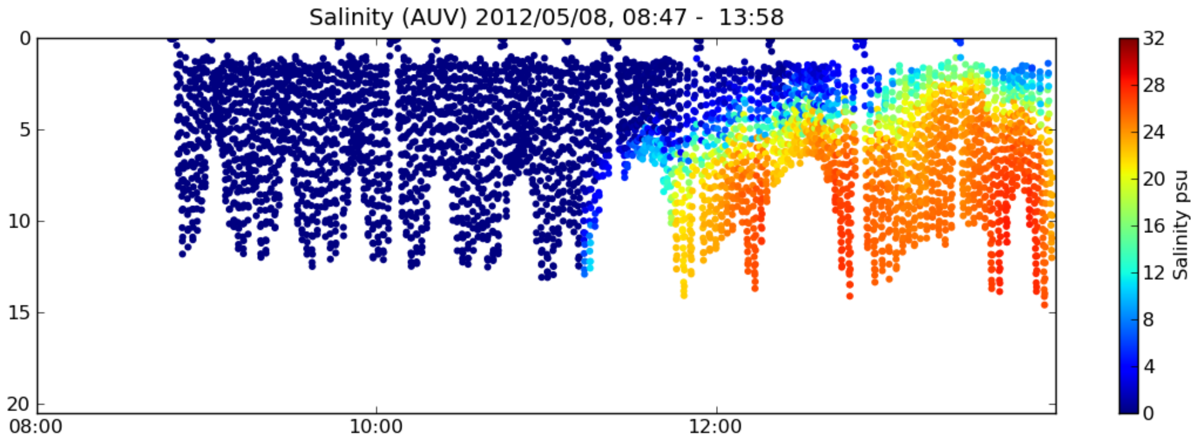


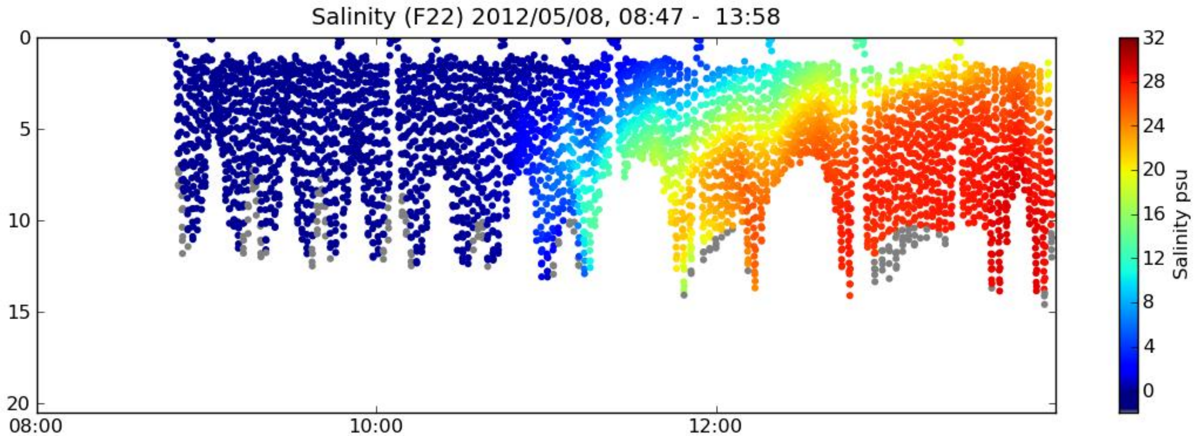
Organizing structure



A recent, stringent model benchmark





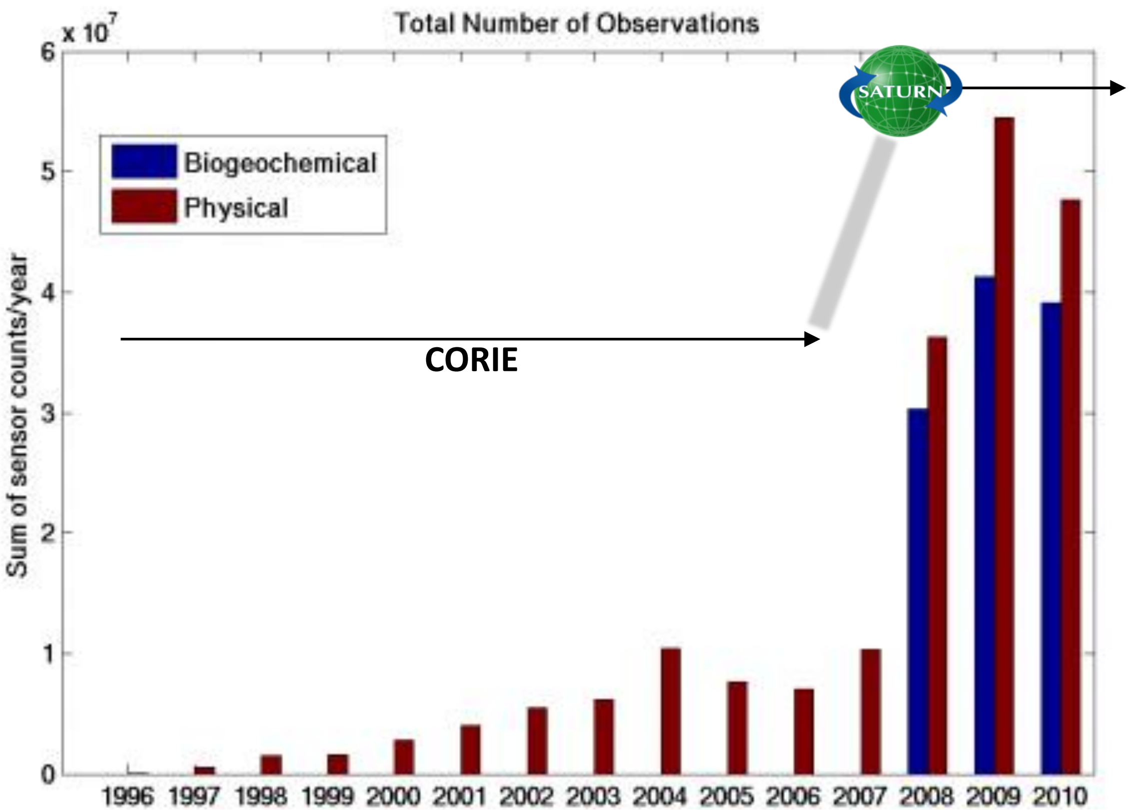


- Multi-platform campaign, April 30-May 10
- Multiple "2 days ahead" forecasts (F22, F26 and F28)
- Post-campaign skill analysis in progress.
- Forecast results shown as used to guide AUV missions

Observation network

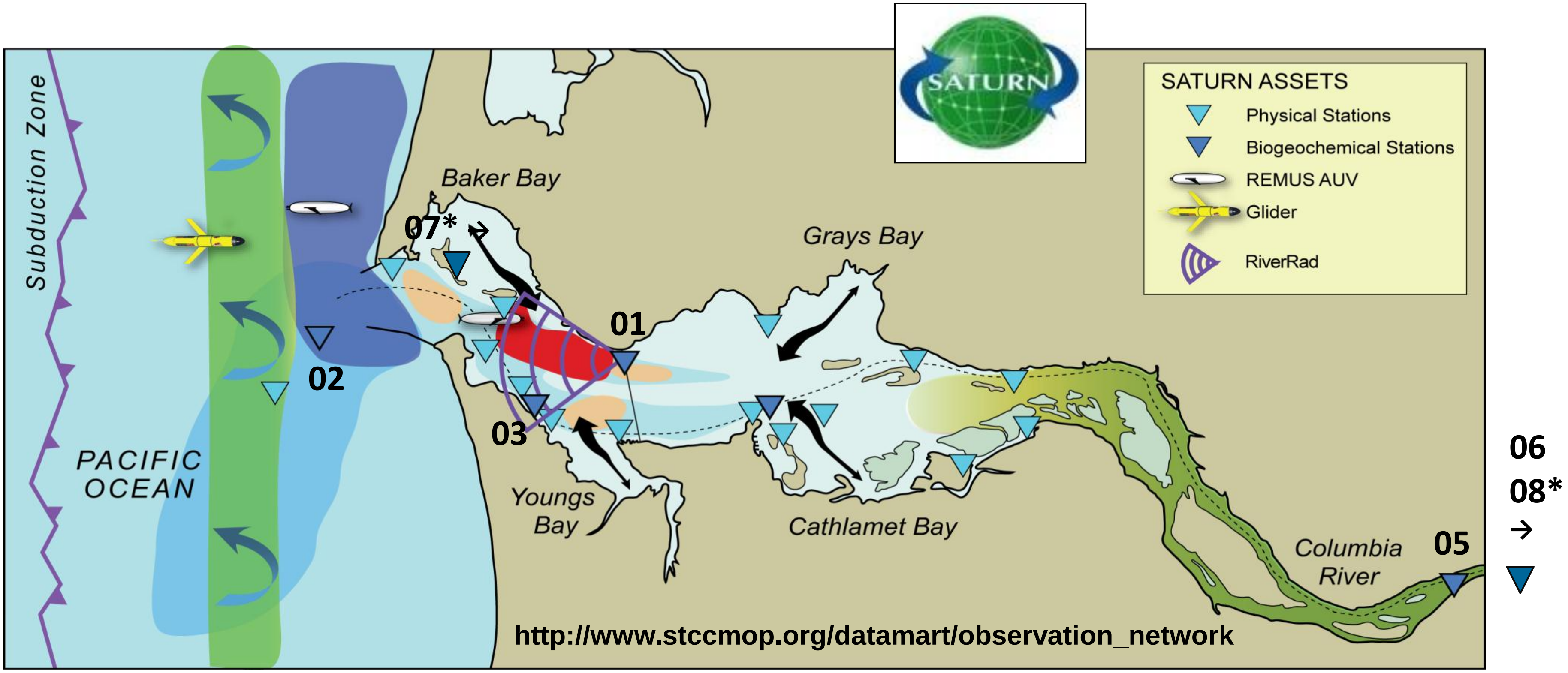
Constituted by endurance stations and a pioneer array, SATURN is built on top of an historical **physical observation network** for the estuary (CORIE, s. 1996), by adding:

- Collaborative implementation
- River-to-shelf coverage
- Extensive biogeochemistry, with microbiology coming soon
- Land access at selected stations
- Vertical resolution at selected stations
- Mobility (AUVs, glider)



http://www.stccmop.org/datamart/observation_network

Observation network



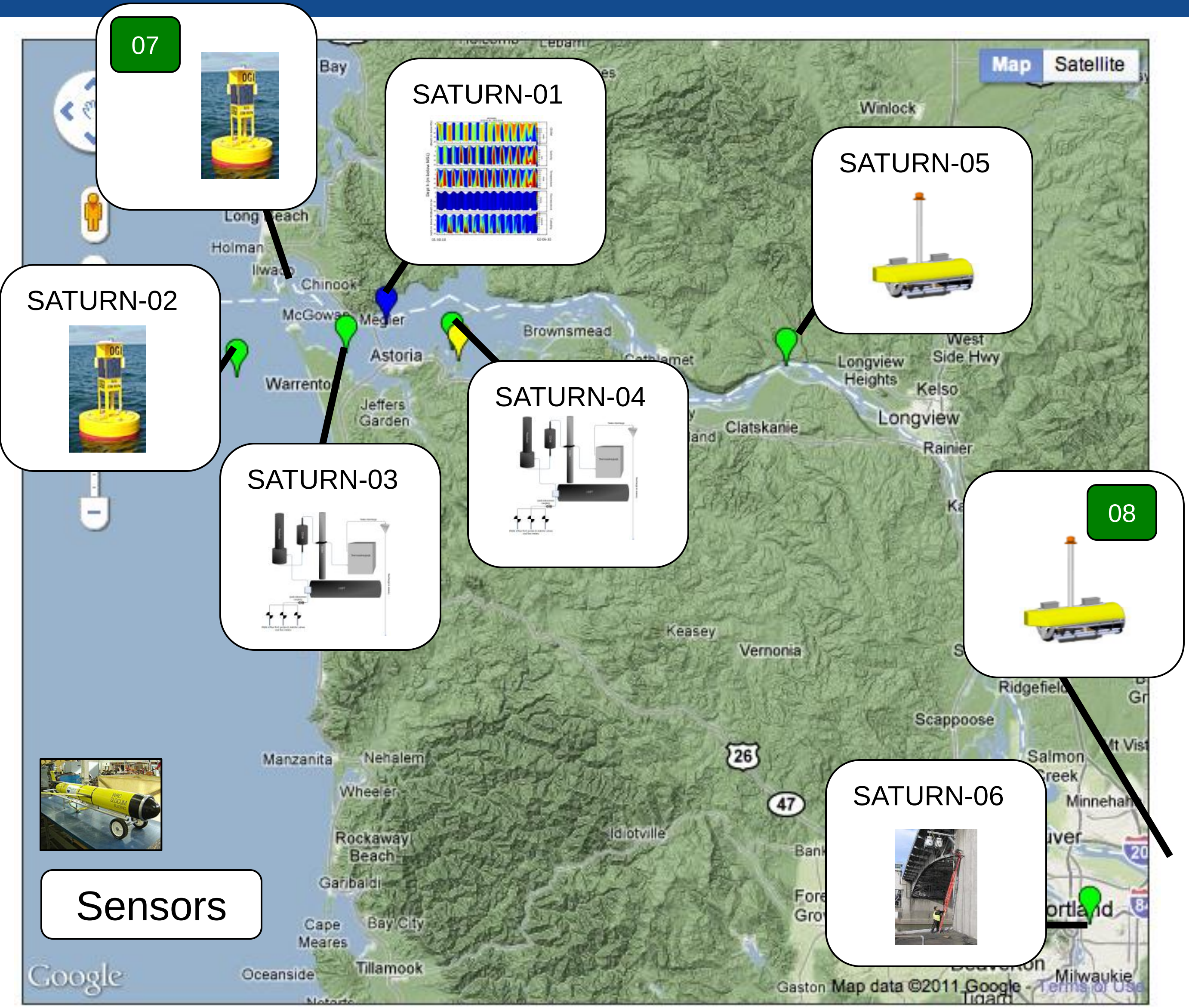
Endurance stations

- Physical stations
- Biogeochemical stations (numbered)
- RiverRad (temporary)

Pioneer array

- 2 AUVs
- 2 gliders
- bottom nodes, sigma profilers

Biogeochemical endurance stations



Deployed/Planned for 2012

SATURN-01
- Vertical Profiler
- Shore power

SATURN-02
- Multi-level buoy

SATURN-03
- Land access (dock and hut)
- Shore power
- Pumping ports at three levels

SATURN-04
- Land access (dock and hut)
- Will have shore power (anticipated late 2011)
- Pumping ports at three levels

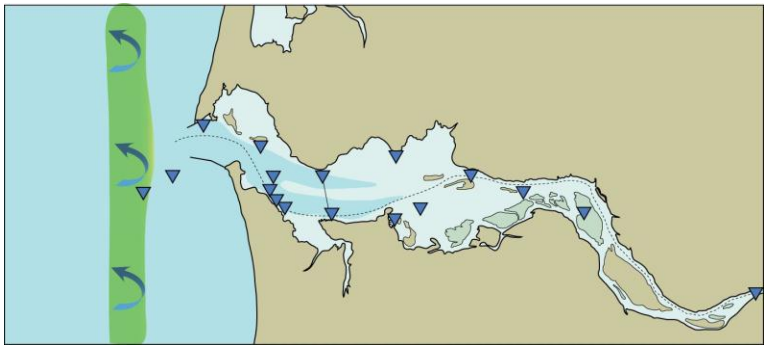
SATURN-05 and 08
- Surface LOBO buoy

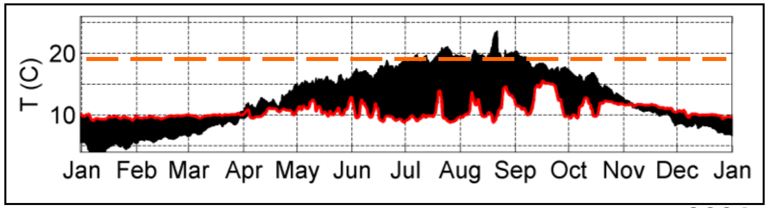
SATURN-06
- Single level pile mount

SATURN-07
- Surface buoy

Additional slides

Physical endurance stations

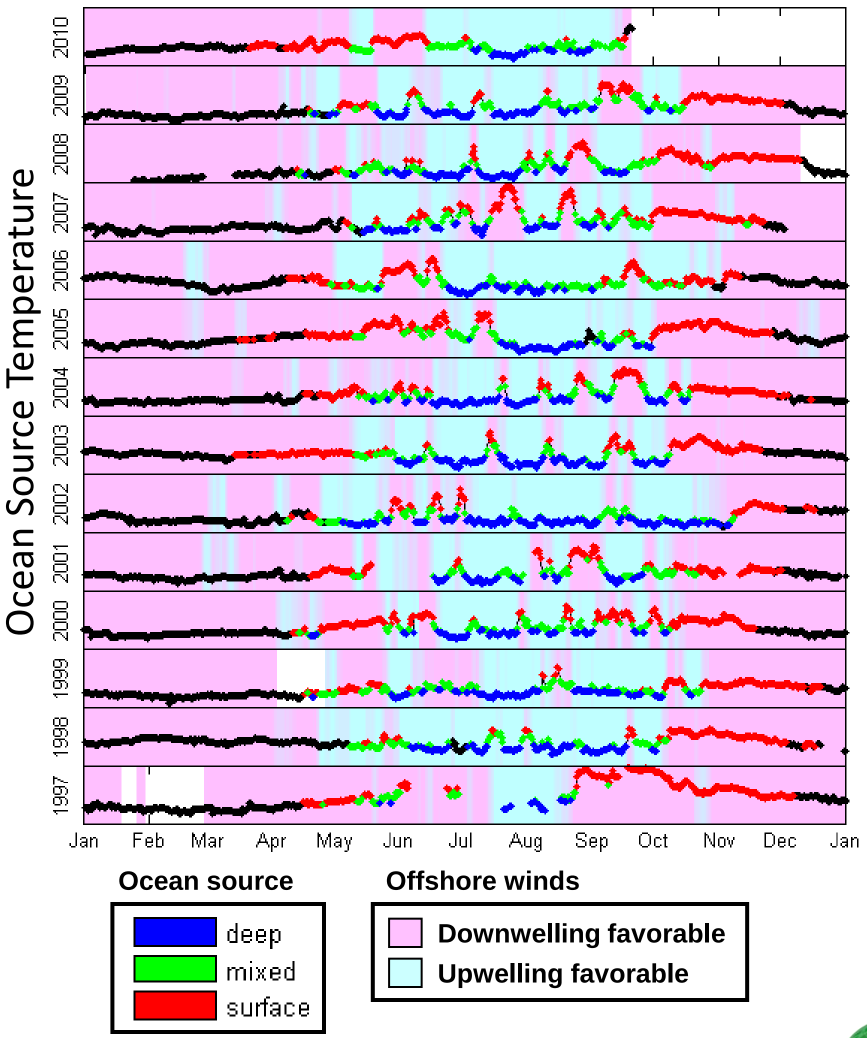




2004

- First station deployed in 1996
- Abundant near-bottom S (via conductivity) and T in the estuary
- One tide gauge and multiple pressure gauges in the estuary
  Note: Complement NOAA tide stations
- Various ADPs: one in the plume; new in 2012 four in the estuary: 3 re-occupying historical stations, 1 supporting new research needs

Ocean source classification overlaid on offshore wind



Sensors at biogeochemical endurance stations

Baseline sensors ("all" stations)

- Conductivity
- Temperature
- Fluorescence
- CDOM
- Turbidity
- DO
- Nitrate (optical)

Additional sensors (selected stations)

- ADP/ADCP
- LISST-100
- Phycoerythrin fluorescence
- Phytoflash
- In-situ spectrofluorometer ('Multi-exciter')
- pCO2

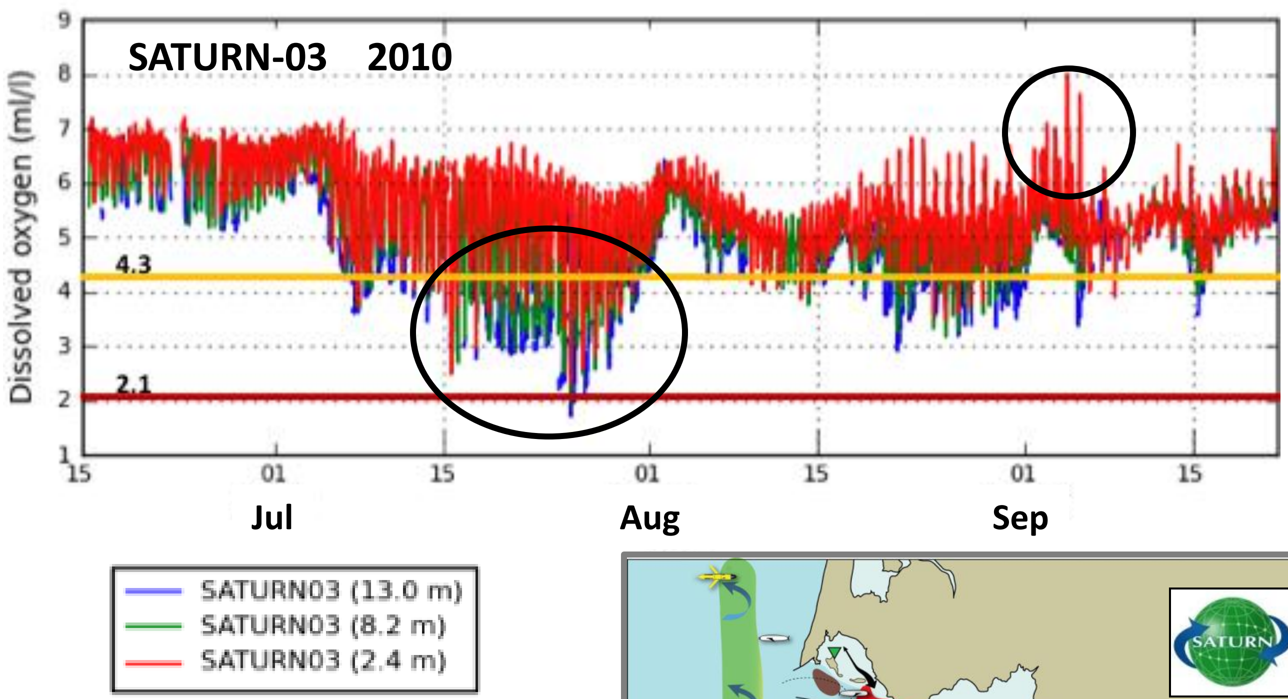
"Campaign sensors" (SATURN-03 & 04)

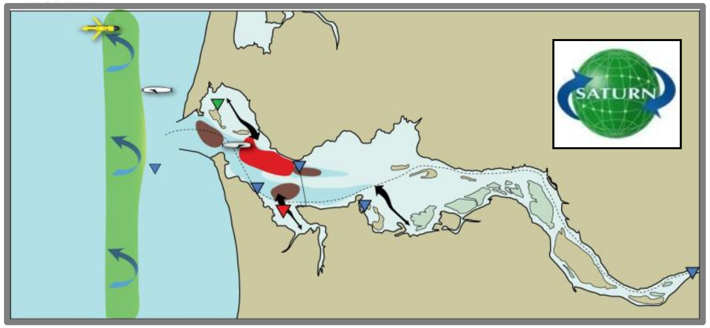
- APNA (multiple nutrients; wet chemistry)
- Cycle P (phosphate; wet chemistry)
- FlowCAM (images of micro-organisms)
- Environmental sampling processor (ESP) – to be deployed 2012

SATURN-01 instrument package undergoing final checks at the CMOP field station at MERTS, before redeployment

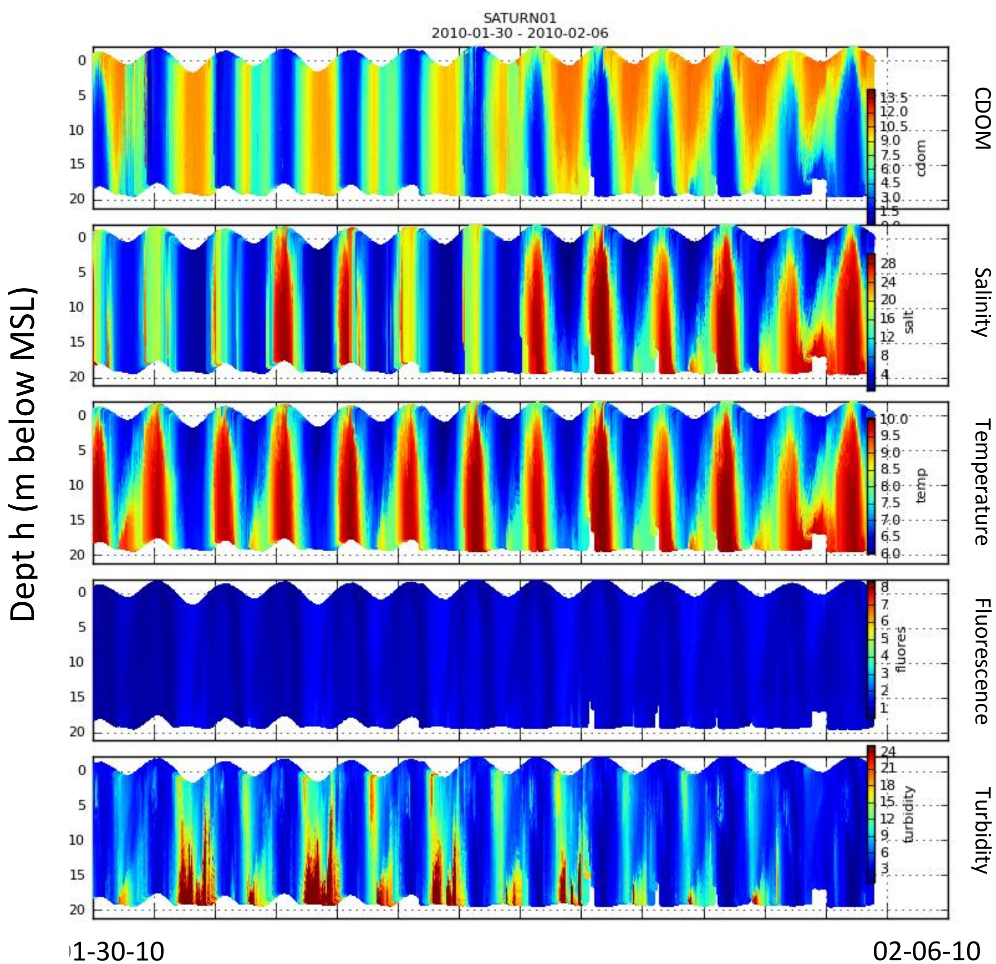
New sensors → New insights

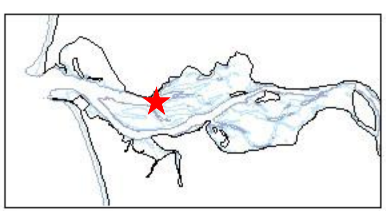
E.g., estuarine hypoxia (see Welle talk)





SATURN-01





North Channel, in ~20m waters

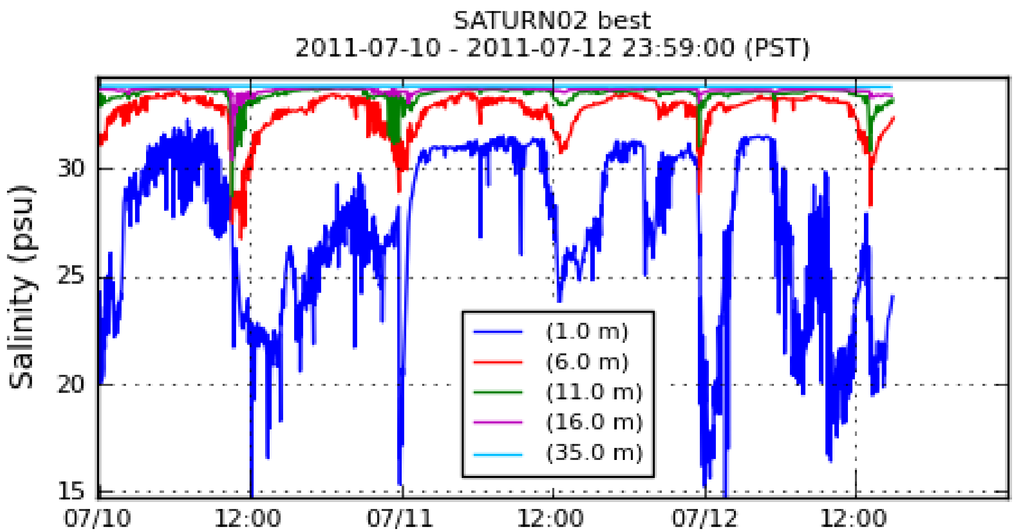
- Bridge power
- Winch-activated profiler
- High-maintenance

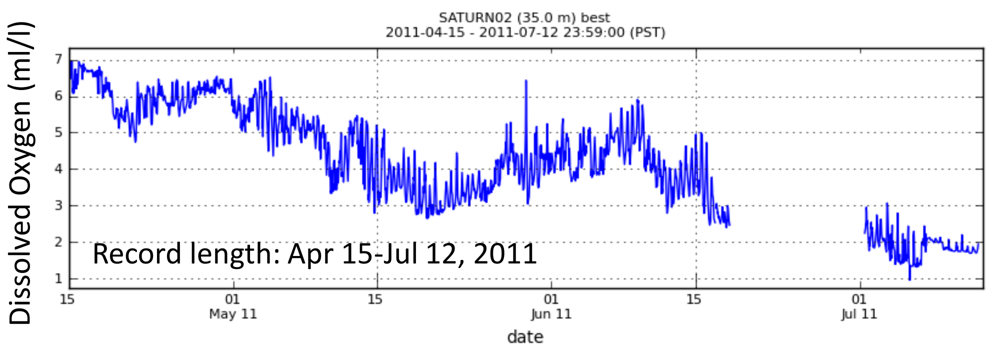
Sensors:

- All baseline sensors
- Specialty sensors:
  - PhytoFlash
  - Phycoerythrin fluorometer
  - LISST-100 (on occasion)
  - ADP

Link: http://www.stccmop.org/datamart/observation_network/fixedstation?id=saturn01

SATURN-02



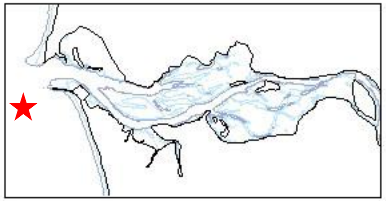


Near-field plume, in ~40m waters

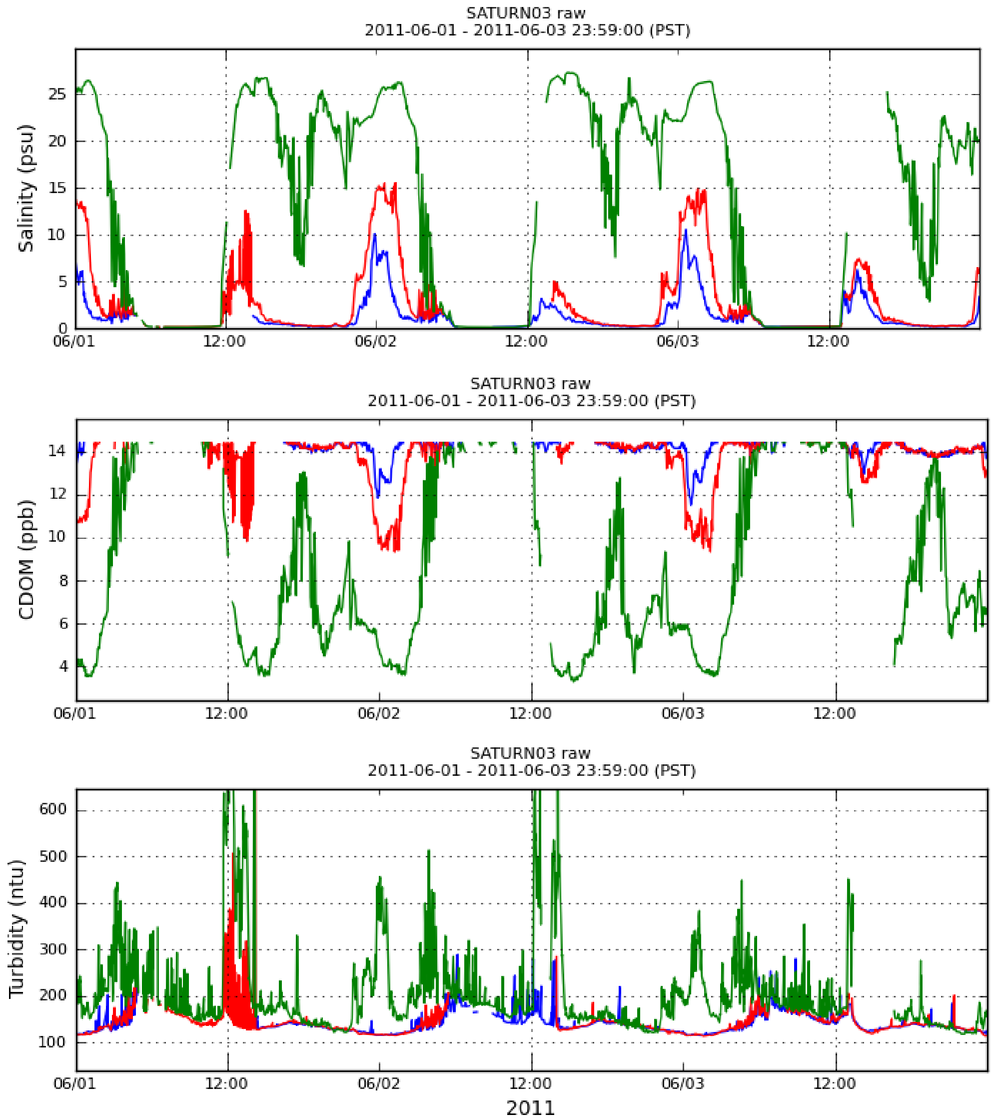
- Surface buoy
- Seasonal (Apr-Oct)
- Substantially upgraded in 2011
- 5 sensing levels

Sensors:

- Surface: all baseline variables and bottom-looking ADP
- Intermediate levels: C, T
- Near-bottom (~35m): C, T, DO
- Specialty sensors: Multi-exciter



Link: http://www.stccmop.org/datamart/observation_network/fixedstation?id=saturn02

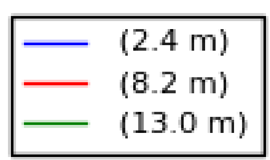


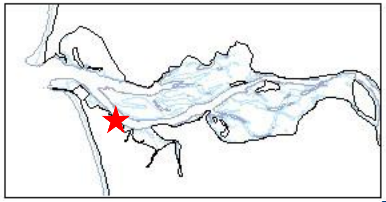
South Channel, in ~15m waters

- Land access (dock and hut)
- Pumping system, ports at 3 depths
- Shore power
- Simple but frequent maintenance required (short-term data loss)

Sensors:

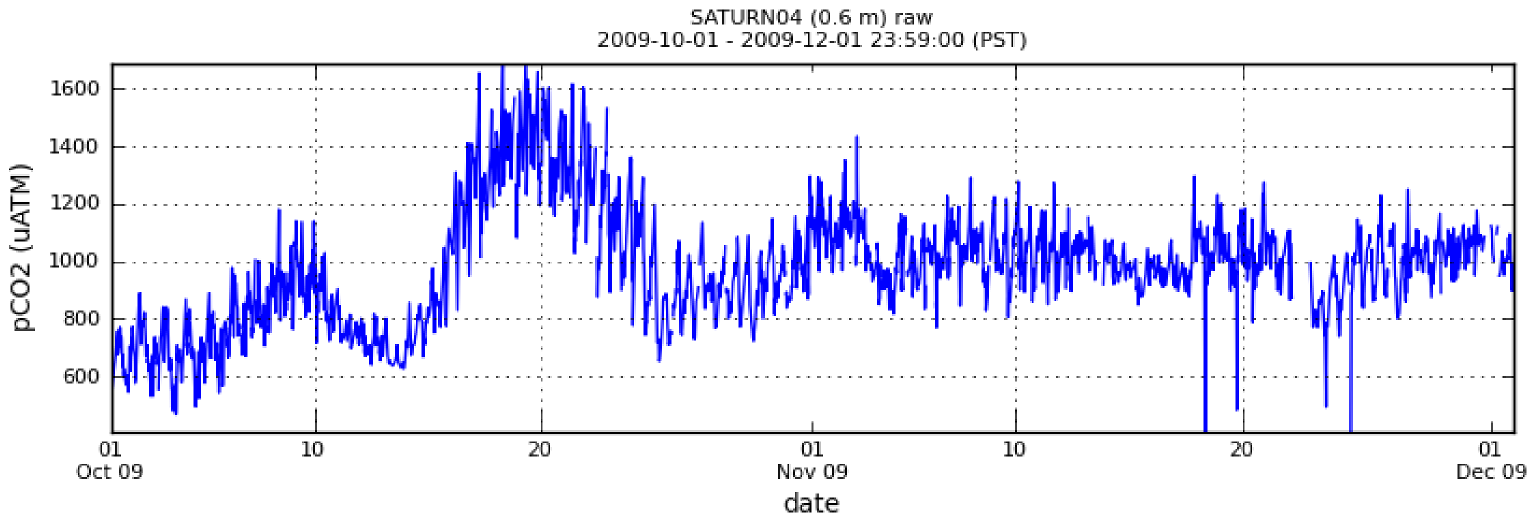
- All baseline sensors
- Specialty sensors: PhytoFlash, Phycoerythrin, APNA (on occasion), CyclePO4 (on occasion)
- Coming soon: ADP, ESP (on occasion), FlowCAM (on occasion)
-





Link: http://www.stccmop.org/datamart/observation_network/fixedstation?id=saturn03

SATURN-04

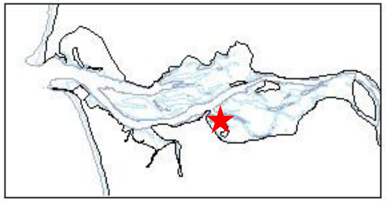


Cathlamet Bay, in ~15m waters

- Land access (dock and hut)
- Pumping system, ports at 2 depths
- Surface port is in a float
- Shore power will be installed in 2011/2012
- Maintenance: similar to SATURN-03, but less frequently needed

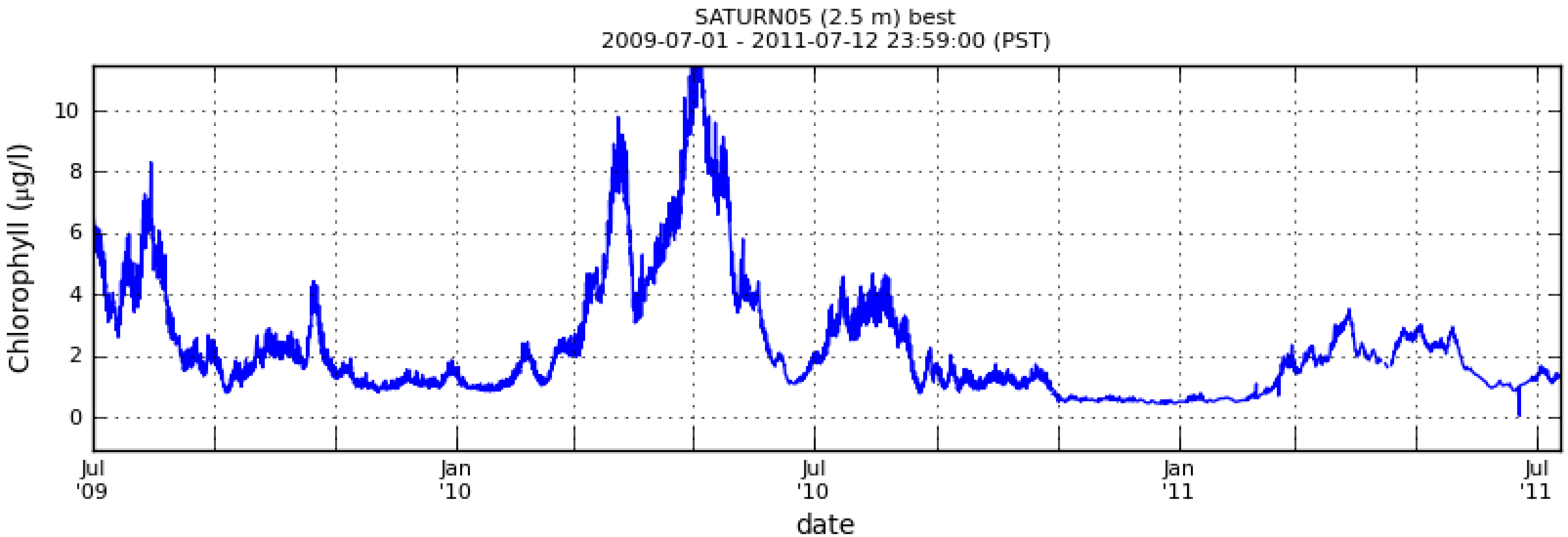
Sensors:

- All baseline sensors
- Specialty sensors:
  - PhytoFlash
  - pCO2
- Coming soon:
  - ADP
  - pH
  - ESP (on occasion)
  - FlowCam (on occasion)



Link: http://www.stccmop.org/datamart/observation_network/fixedstation?id=saturn04

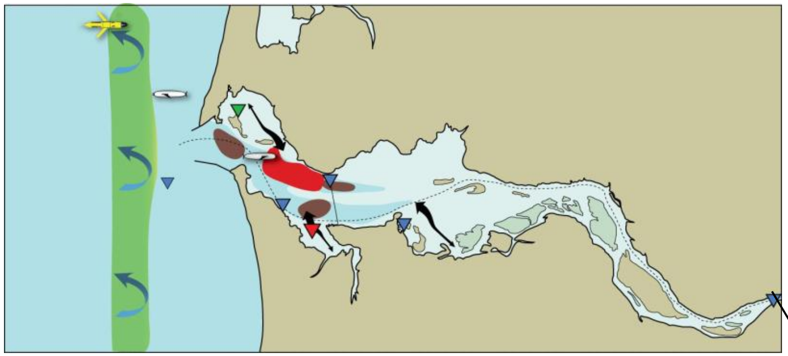
SATURN-05



Beaver Army, in freshwater

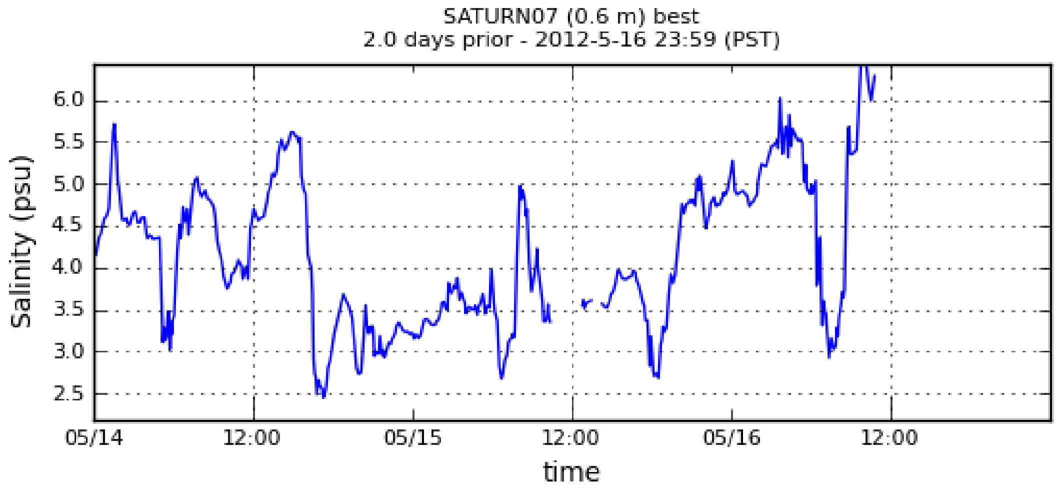
- Integrated LOBO system
- Surface, freshwater measurements
- Characterizes river source
- Sensors: all baseline sensors
- Multi-year time series with limited gaps
- Maintenance: less challenging, yet requiring regular visits

- A collaboration with WetLabs and USGS



Link: http://www.stccmop.org/datamart/observation_network/fixedstation?id=saturn05

SATURN-07



Baker Bay, in ~2m waters

- Surface buoy
- Single level of measurements
- Battery powered
- Telemetry
- Test installation on May 2012

Sensors:

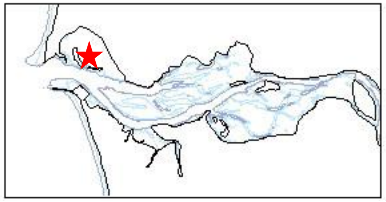
- CT

Coming soon

- Most baseline sensors

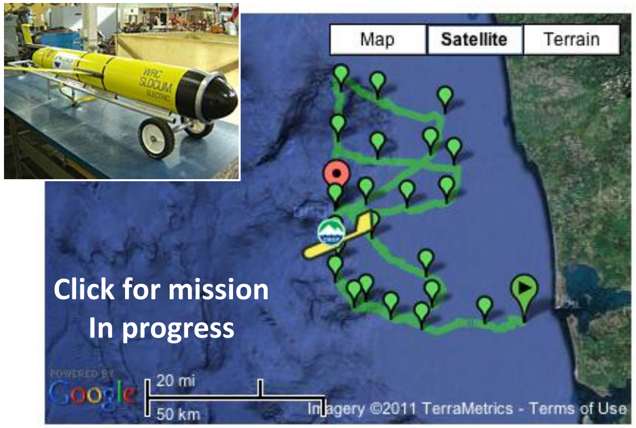
Specialty sensors:

- Multi-exciter

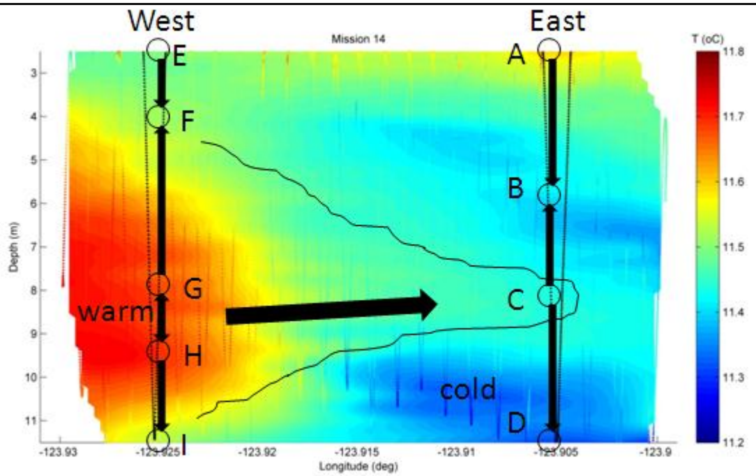


Link: http://www.stccmop.org/datamart/observation_network/fixedstation?id=saturn07

Mobile platforms



Glider (shelf, large sweeps, since 2009)



AUV (estuary and plume, small scales)

Glider sensors

- Conductivity
- Temperature
- Fluorescence
- CDOM
- Turbidity
- DO
- (no nitrate)

AUV sensors

- Conductivity
- Temperature
- DO
- ADCP

Ordered:

- ECOpuck #1: Chlorophyll, CDOM, 700 nm backscattering/turbidity
- ECOpuck #2: Phycoerythrin, Phycocyanin , 880 nm backscattering/turbidity

The Columbia River estuary

Approximate maximum extent of penetration of salt