

# Eyes on Puget Sound: What are we learning from ocean observing?



Allan Devol  
Jan Newton

University of Washington

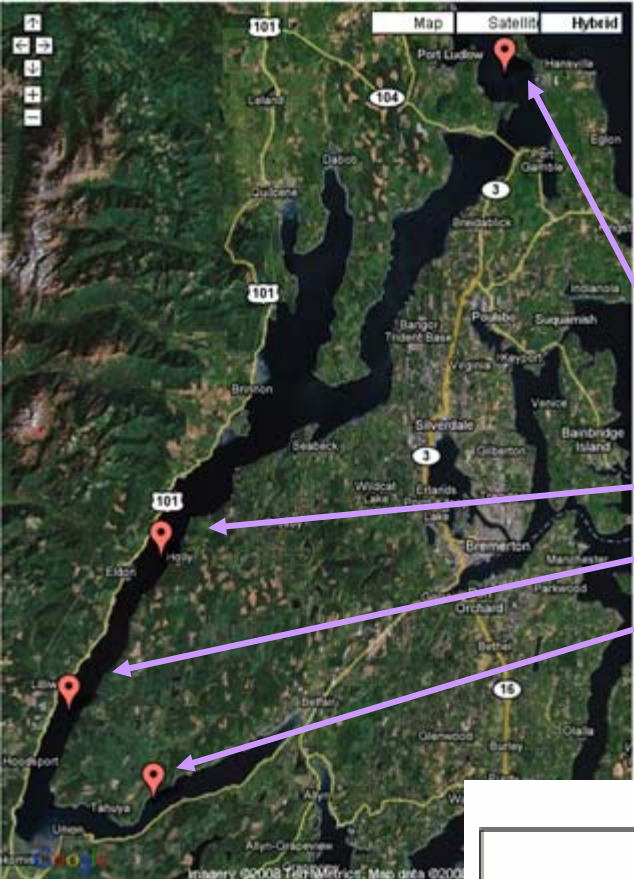


# How can we Observe Puget Sound ?

- Shortcomings of sampling with a bottle:
  - Usually only once a month or week
  - Usually only at one or a few depths
- Shortcomings of sampling with a ship:
  - Usually only daytime
  - Usually only fair weather

This has led to technology development...

# ORCA buoys



4 buoys, 4 locations...

- 1) North of HC Bridge
- 2) Hama Hama River
- 3) Hoodspout
- 4) Sister's Point

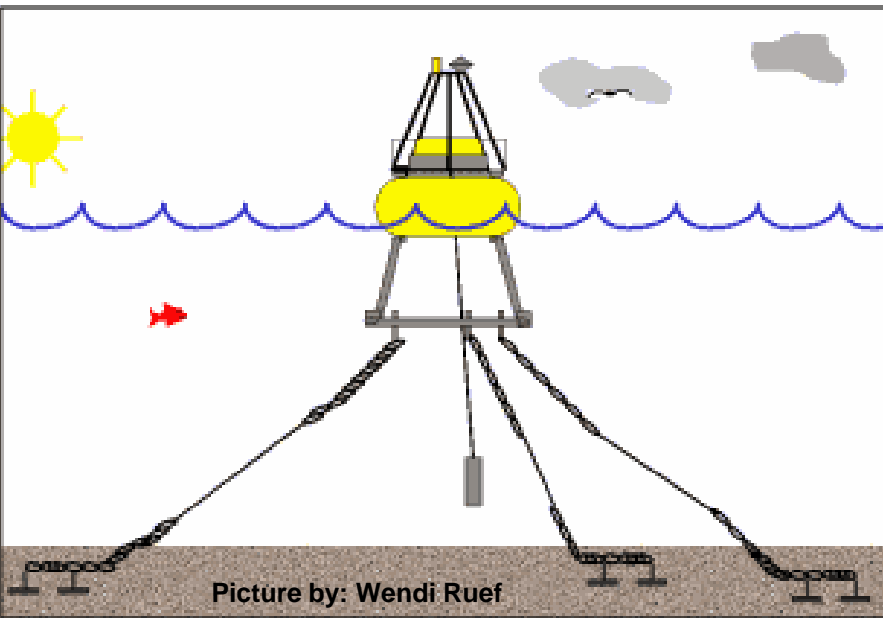
<http://orca.ocean.washington.edu>



“O.R.C.A.”

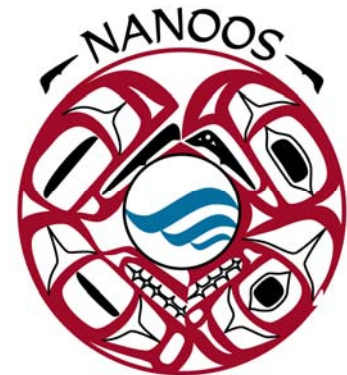


Oceanic  
Remote  
Chemical-optical  
Analyzer



Picture by: Wendi Ruef

Part of NANOOS  
Observing System



# Differences between Hood Canal and Puget Sound



*"ORCA" buoy data  
Devol, Ruef (UW)*

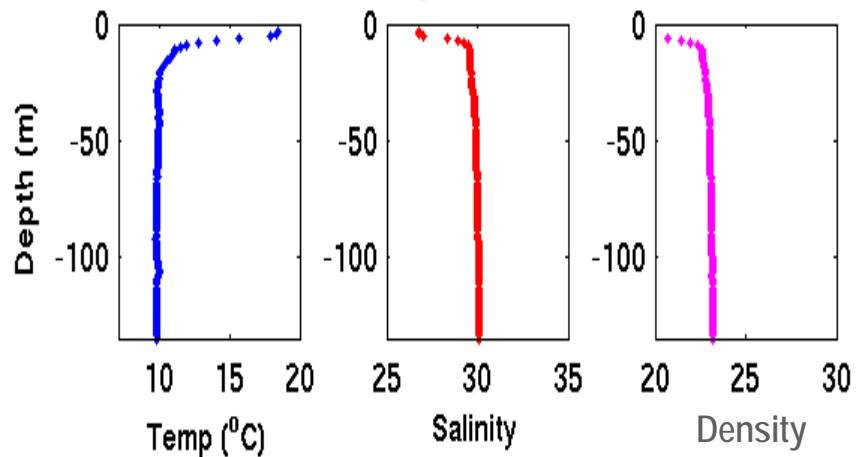
<http://orca.ocean.washington.edu>



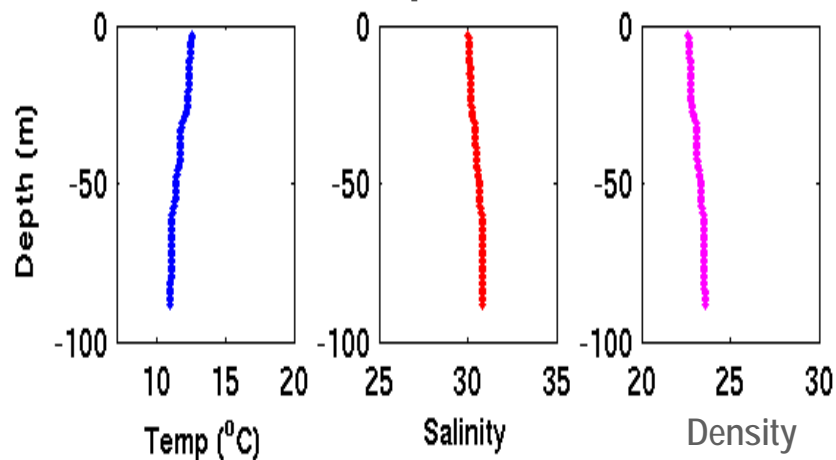
## Within Hood Canal

## Near Admiralty Inlet

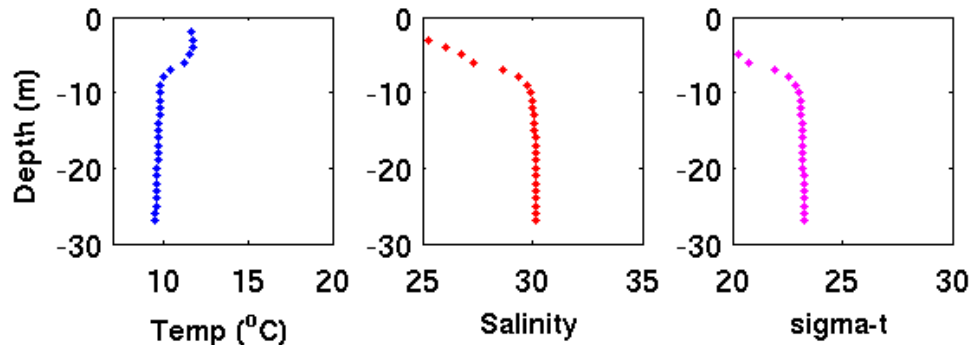
27-Aug-2007 12:18:00



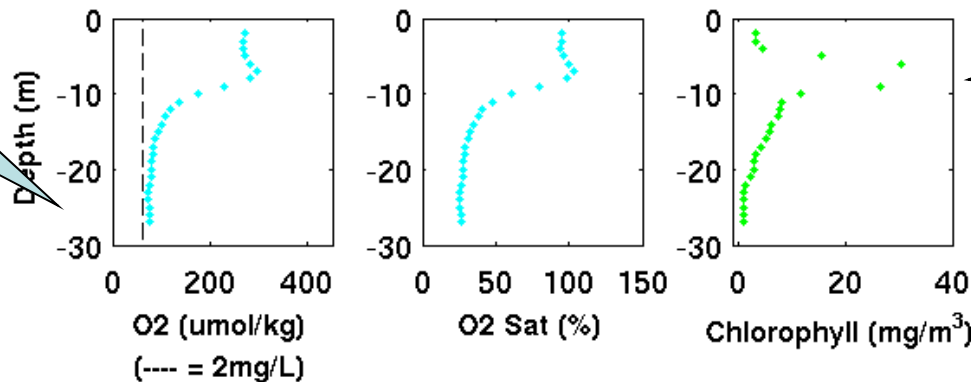
27-Aug-2007 14:10:05



02-May-2008 12:07:01

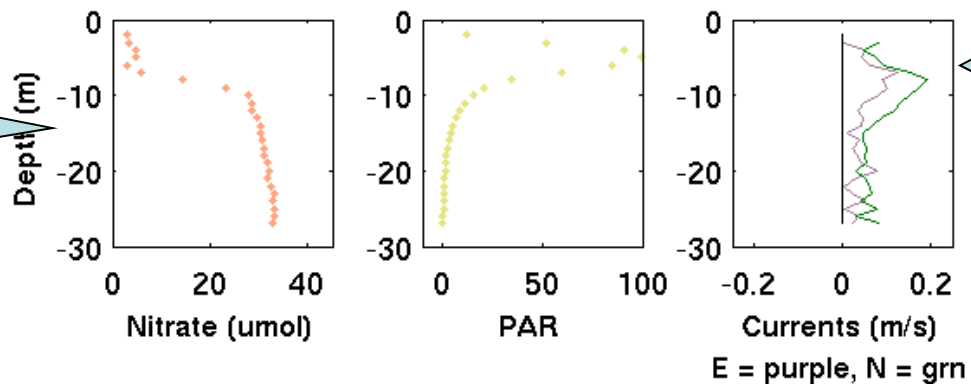


Strong stratification



Hypoxia at depth

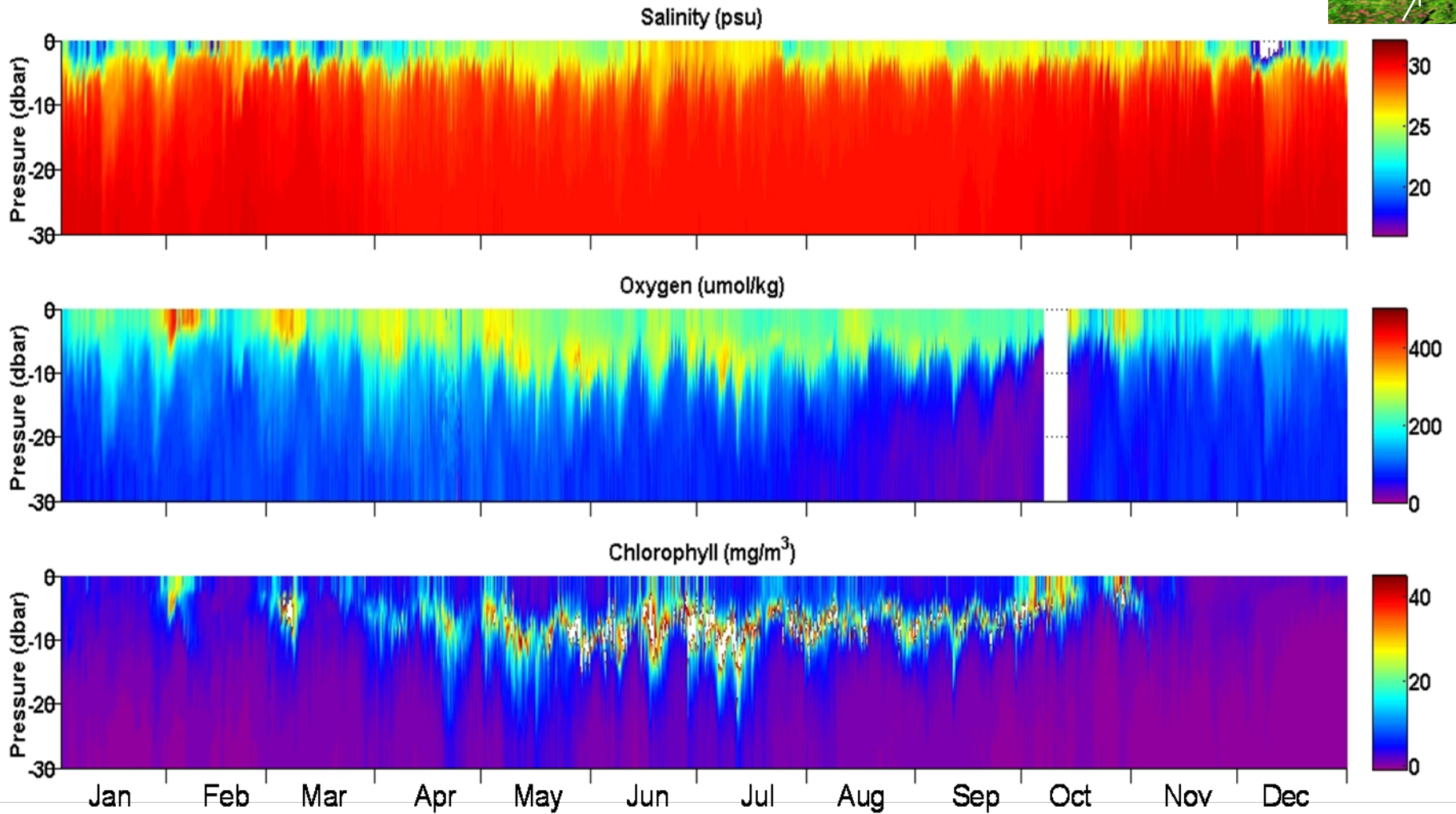
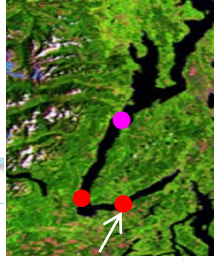
Deep chlorophyll max



Nitrate profile

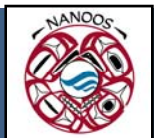
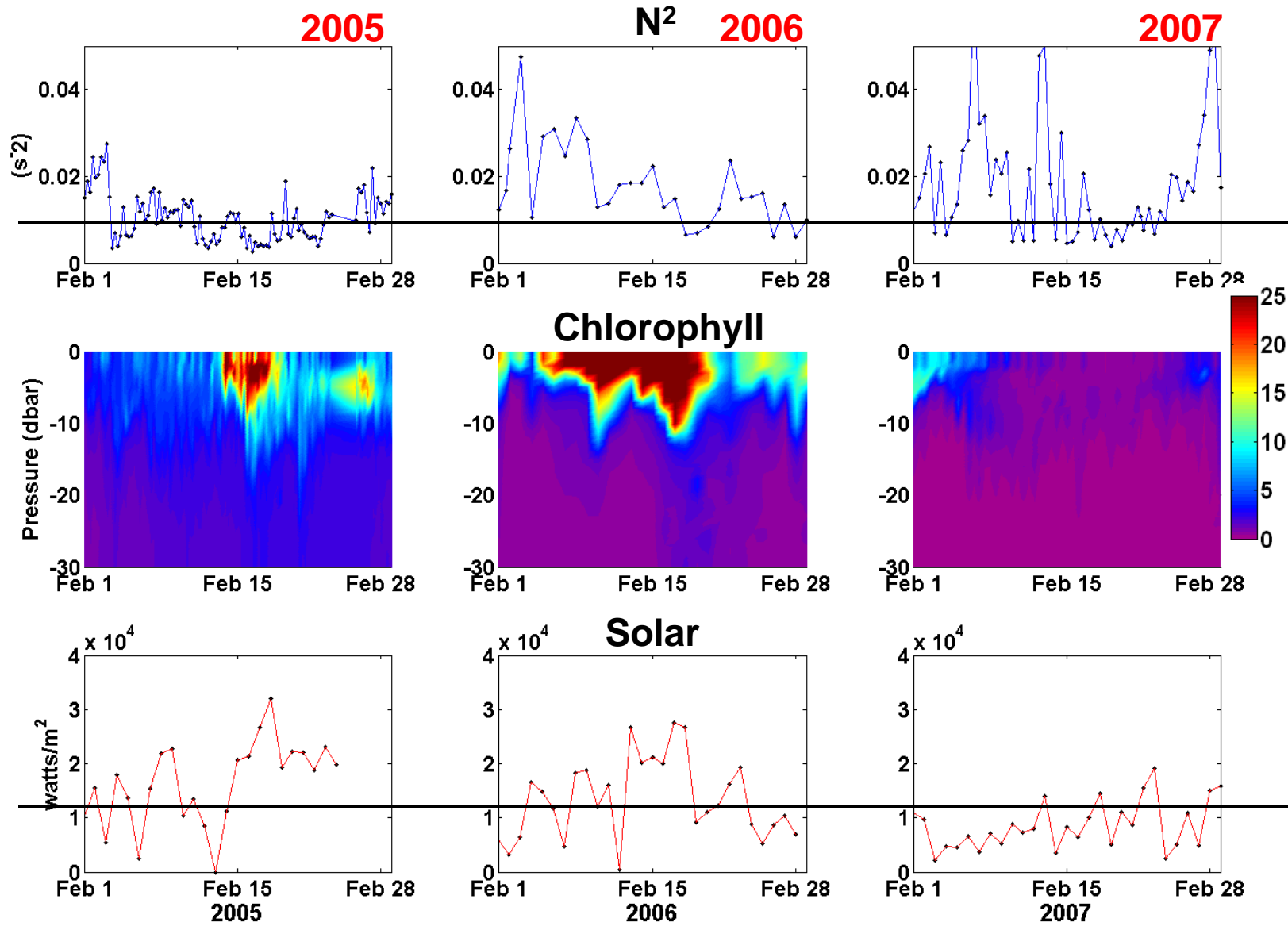
Water column current profile

# Information over the year



2006

# Info on processes: variation in spring bloom

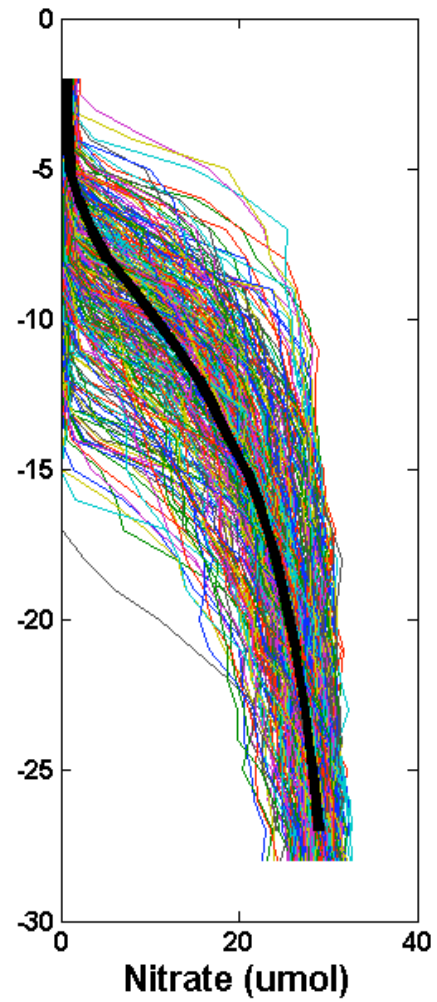
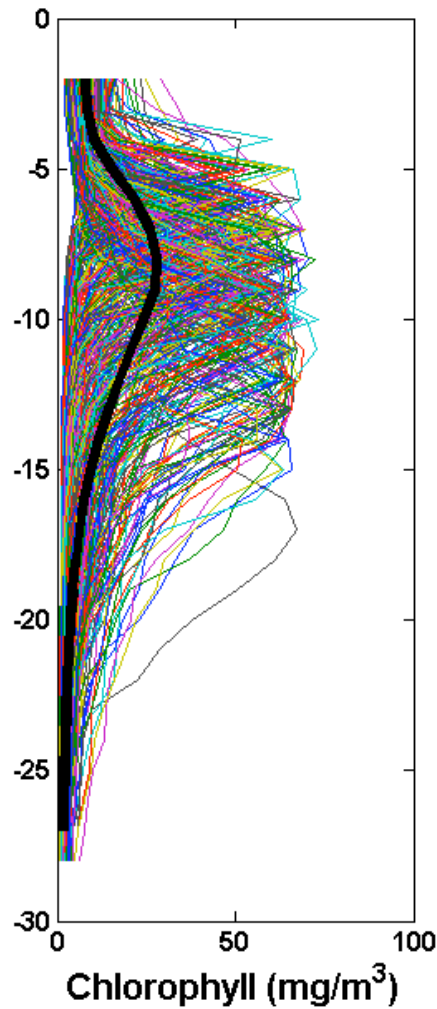
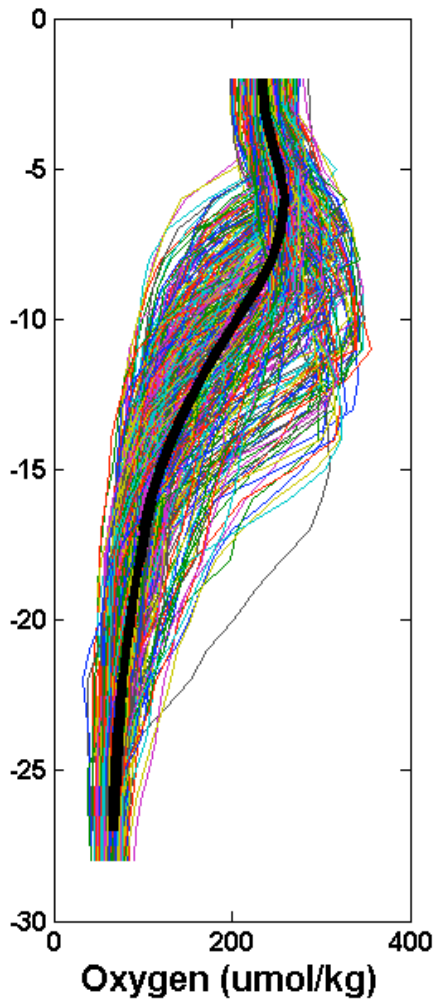
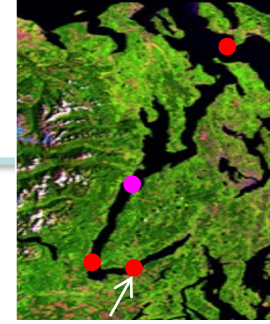


# What have we learned from ORCA in Puget Sound ?

*Some stories from Hood Canal...*



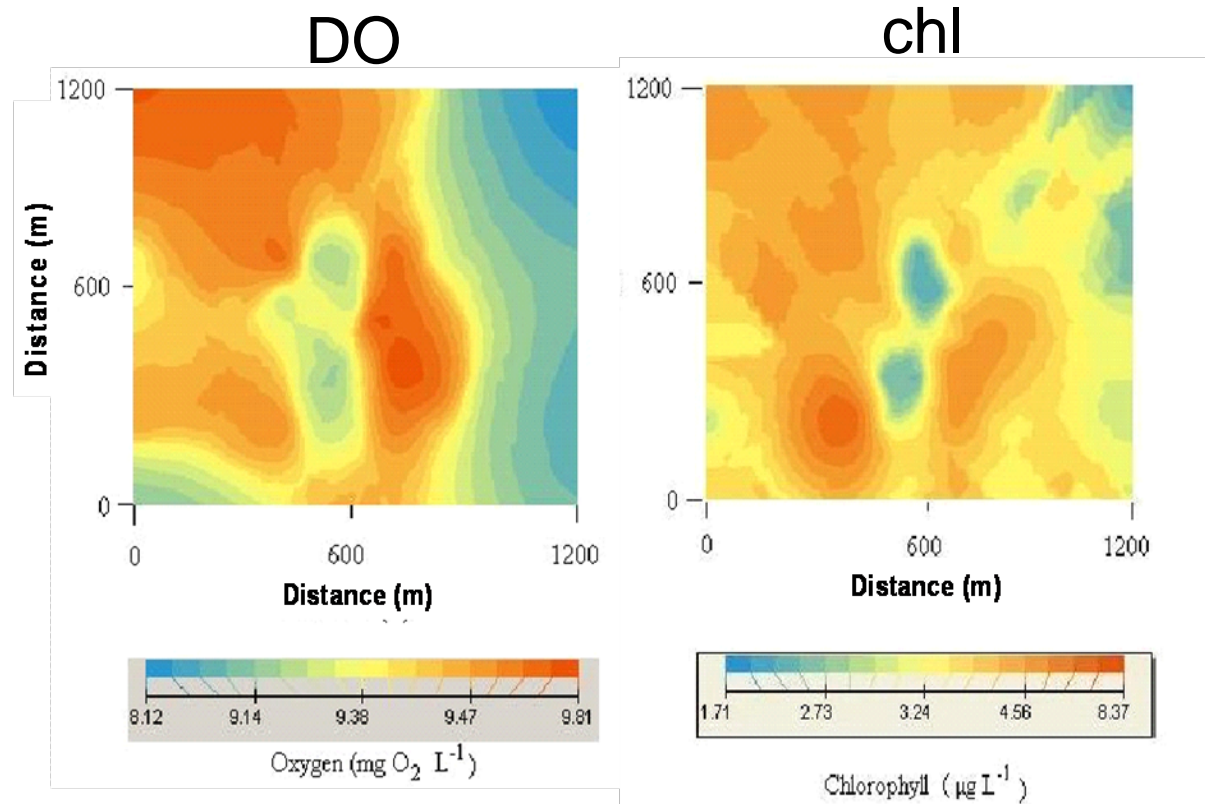
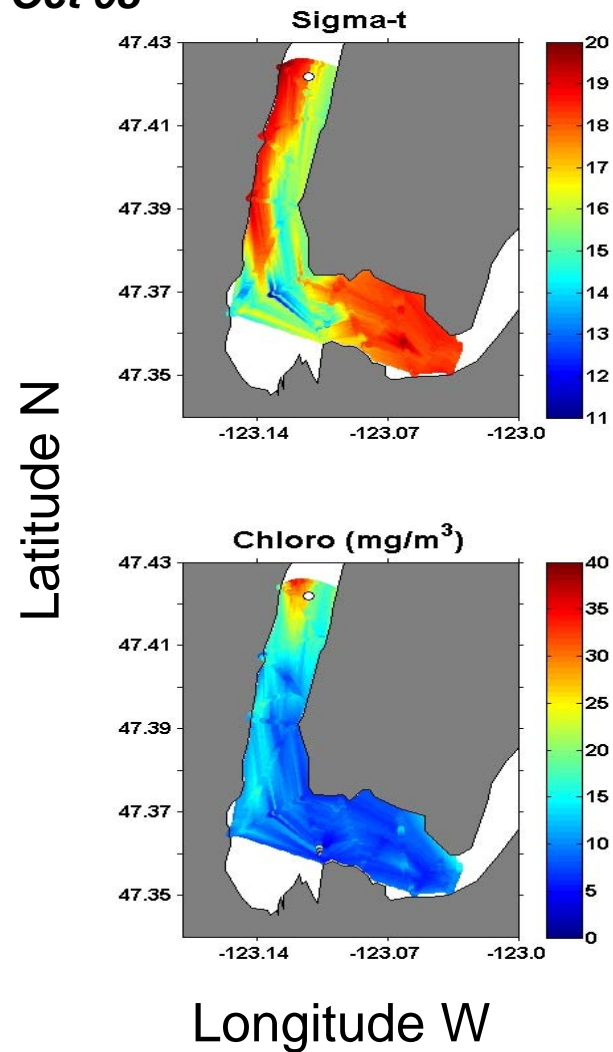
# High variability



July 08

# Strong spatial variation

Oct 08

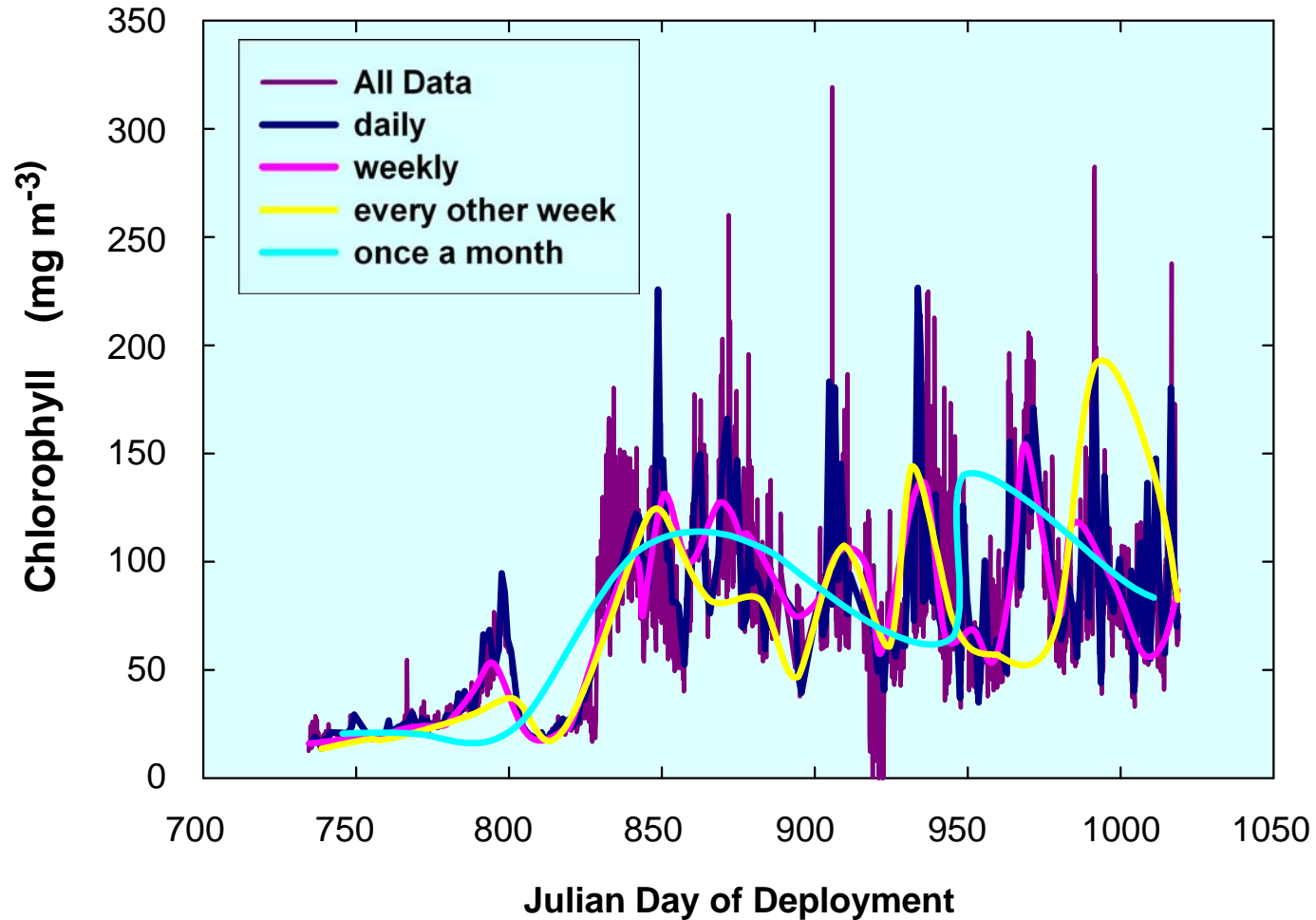


*Surface maps of dissolved oxygen and chlorophyll concentrations around the ORCA mooring in April 2007.*

*Note correlations of concentration fields.*

# What trends will you see ?

TwanoH (Jan – Oct '05)

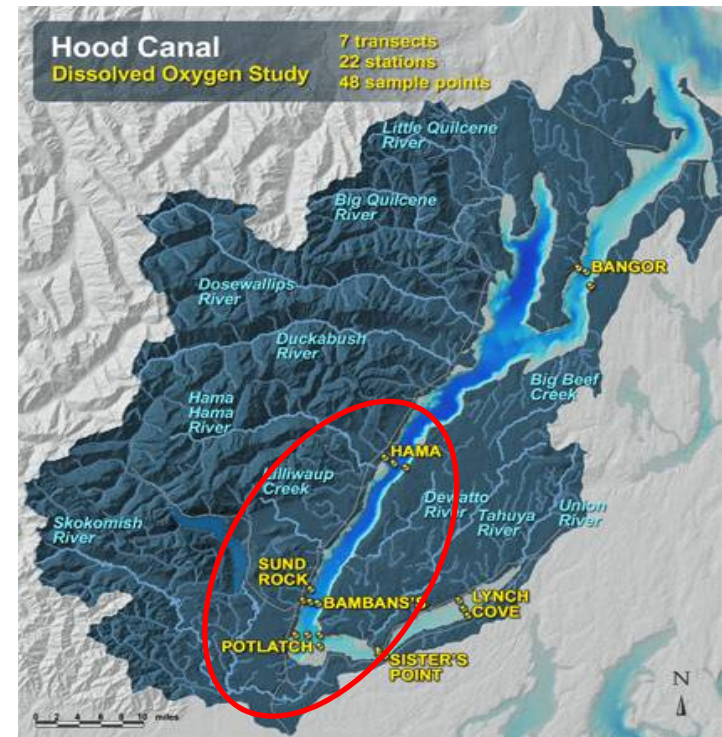


# Fish Kills:



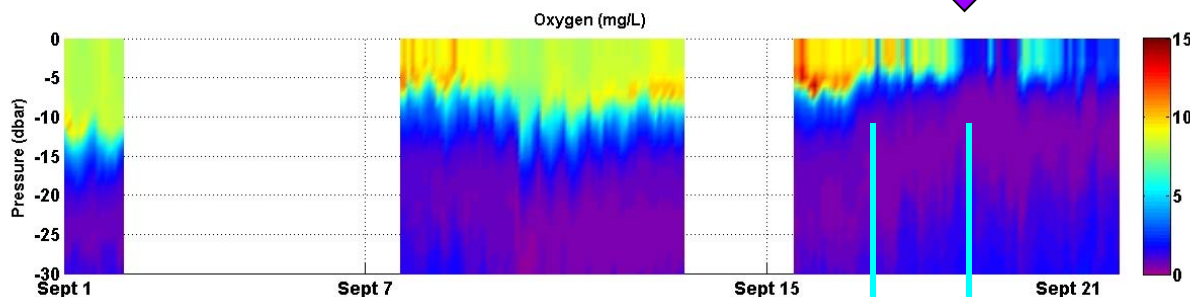
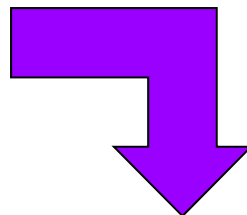
**19 Sept 2006**

“Several reports of dead fish, including flounder, sticklebacks, wolf eels and shrimp were observed from beaches including Tahuya, Lilliwaup, Hoodsport, Annas Bay, and North Beach off Highway 101.”

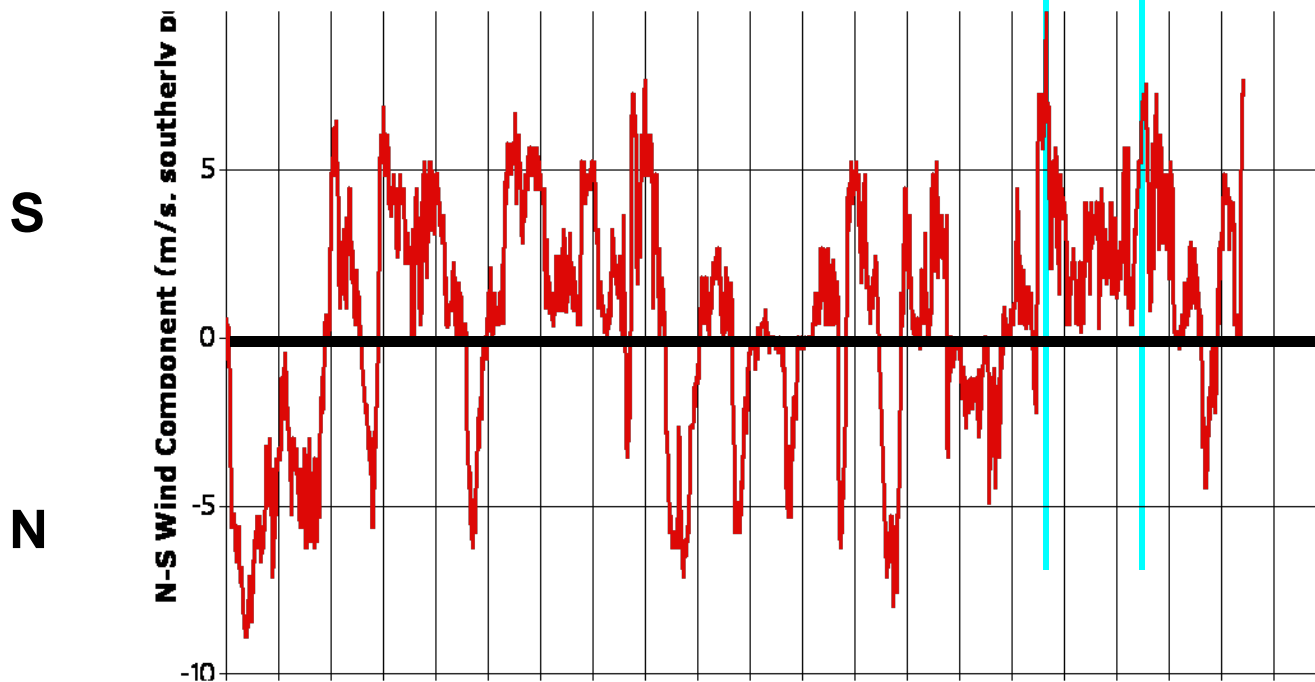




# September 19 2006 Fish Kill Event



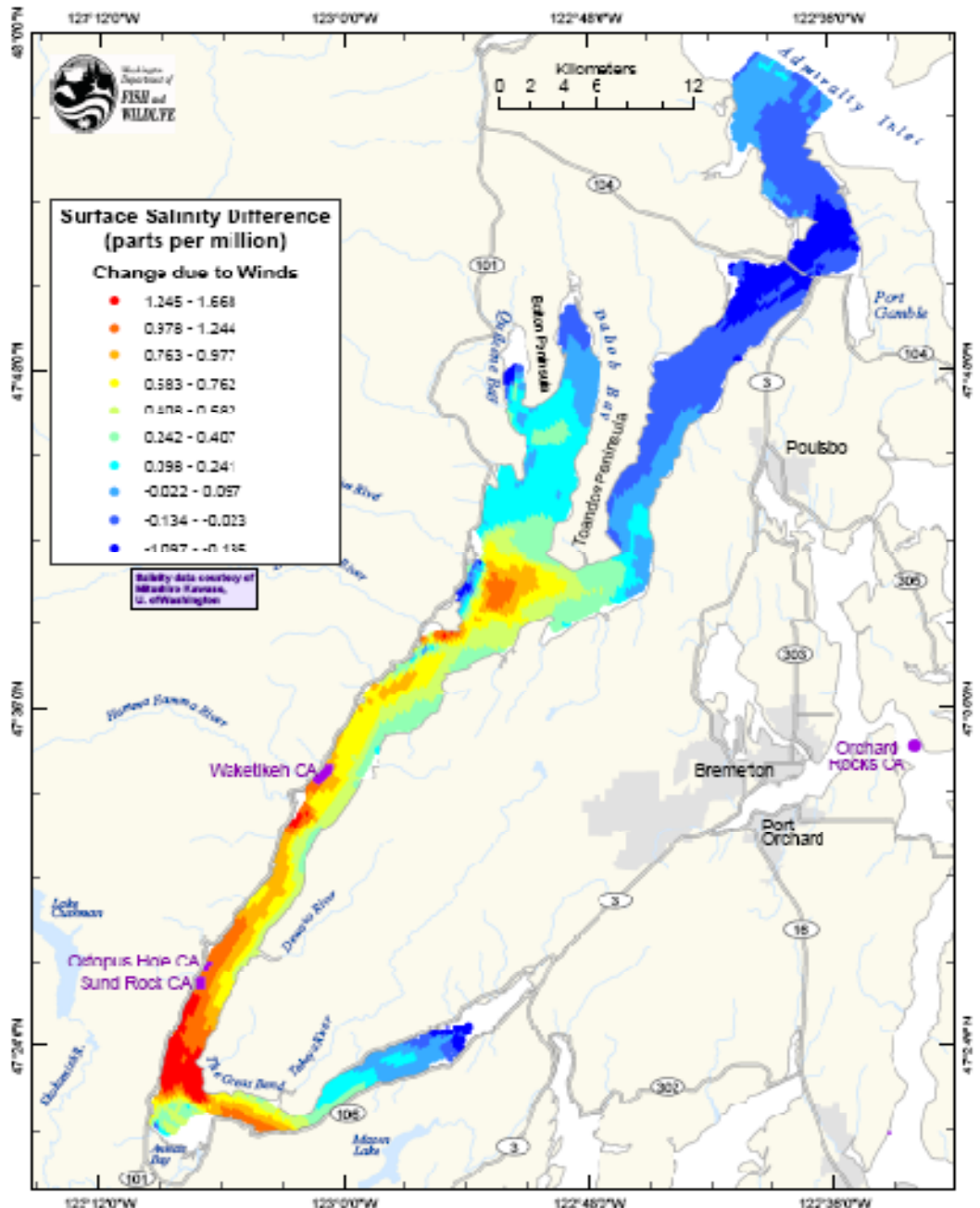
HOODSPORT  
ORCA buoy  
oxygen data



HOODSPORT  
ORCA buoy  
wind data



*Devol (UW) and  
HCDOP IAM Team*



## Episodic Oxygen Stress

- Areas where risk of exposure to episodic low oxygen conditions caused by wind-mediated upwelling is greatest.
- Intensity of red indicates where deep water rises to surface most effectively during southerly wind events.
- This indicates where highest risk of biota stress and mortality due to episodic wind-driven low oxygen events occurs.

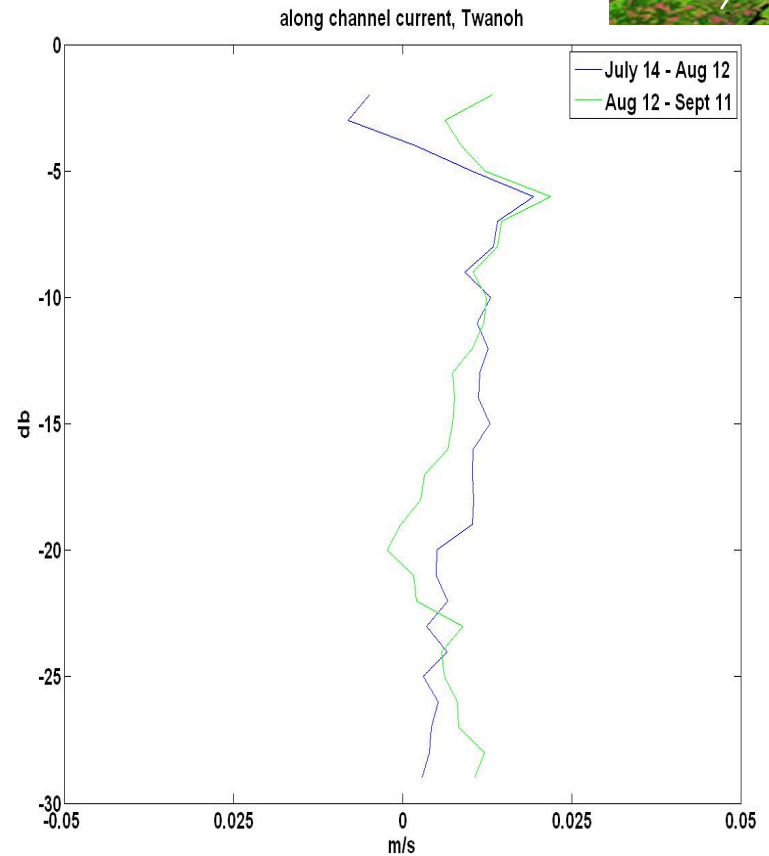
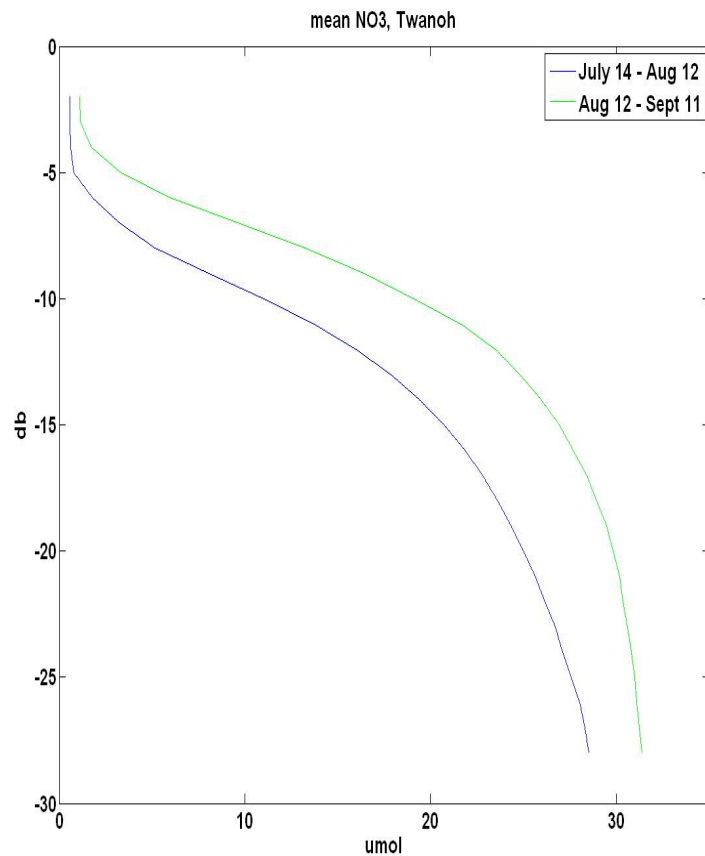
*Kawase (UW) model output, WDFW projection*

# Concentration x flow = flux !

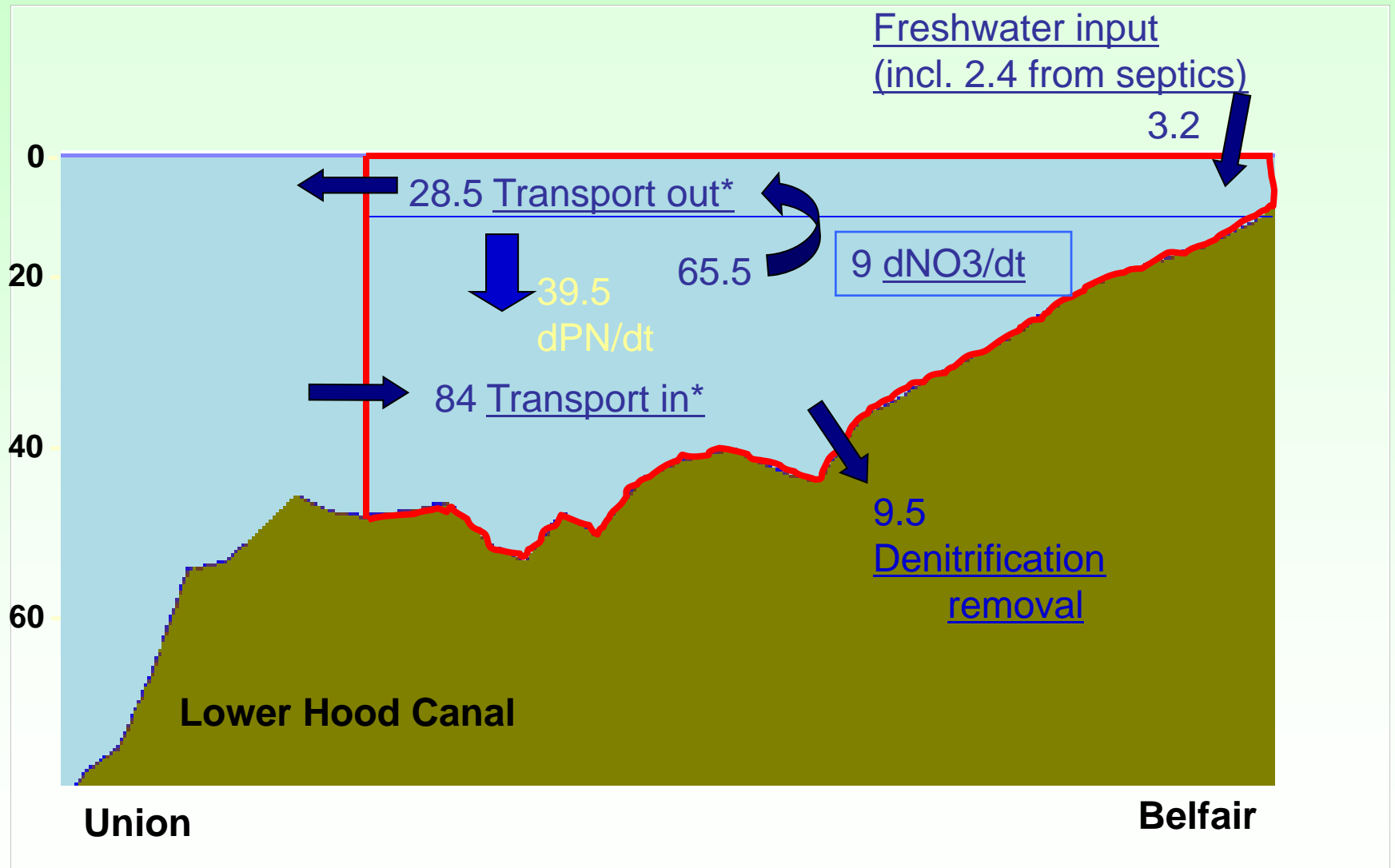


## Nitrate

## Currents

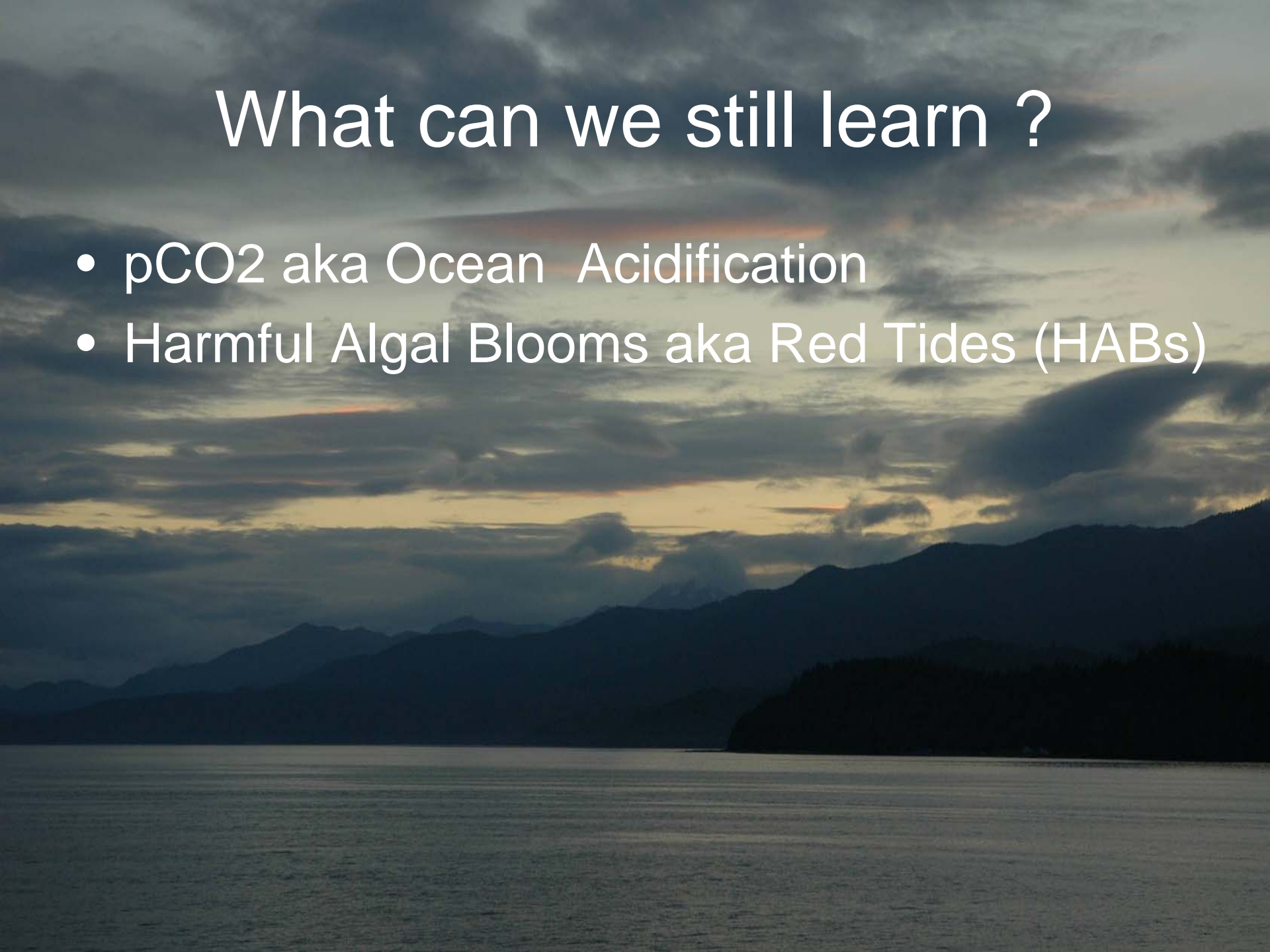


# Lower Hood Canal N-Budget (Mt/mo; JJAS):



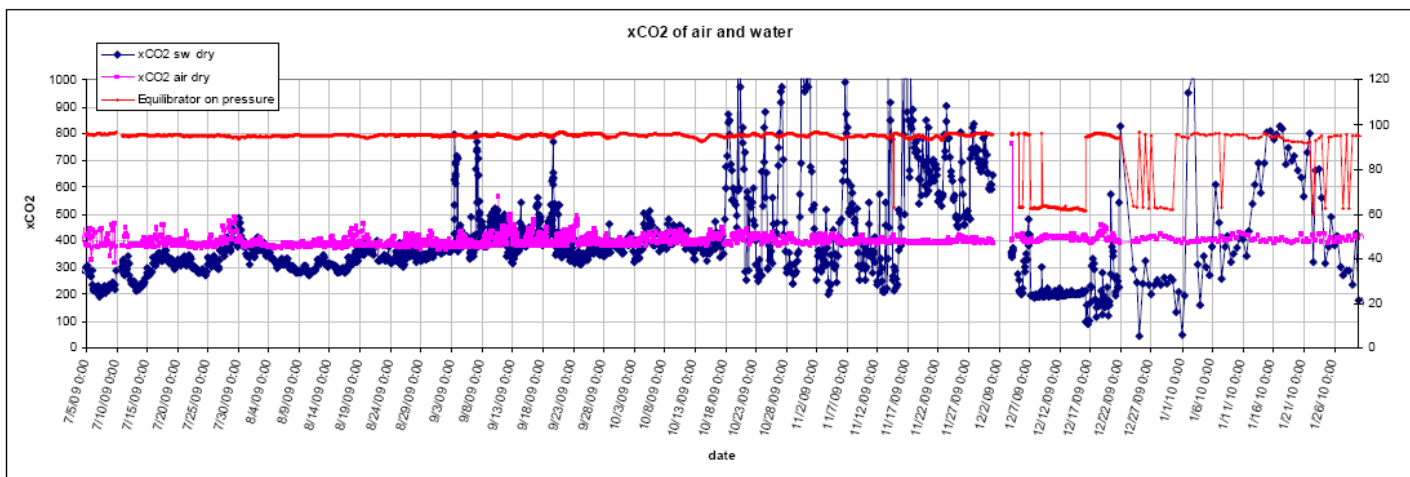
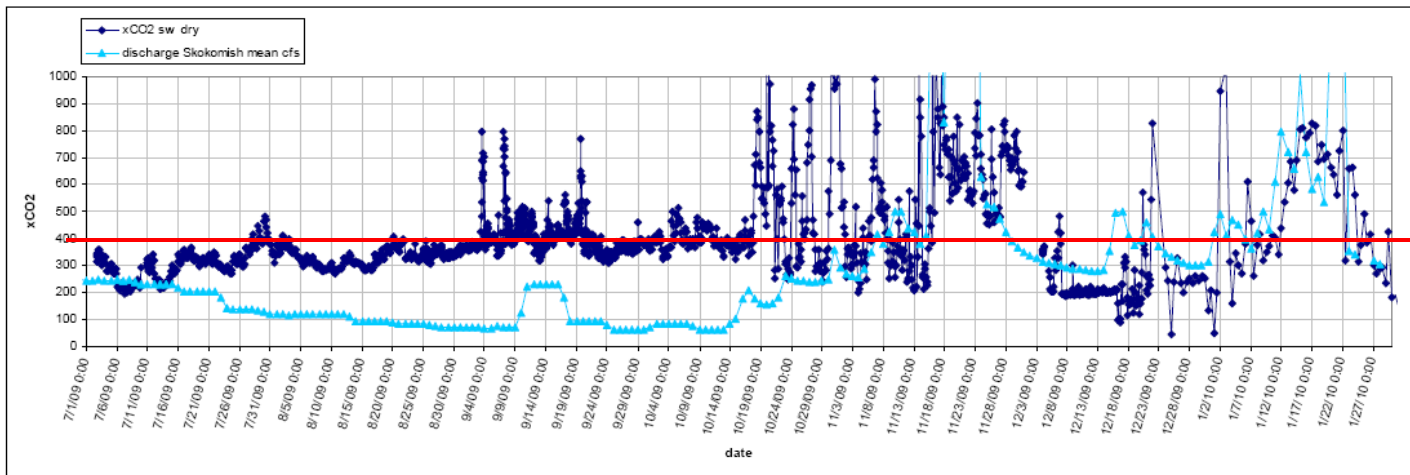
# What can we still learn ?

- pCO<sub>2</sub> aka Ocean Acidification
- Harmful Algal Blooms aka Red Tides (HABs)





NOAA  
pCO<sub>2</sub>  
atm  
sensor on  
NANOOS  
Hood  
Canal  
ORCA  
buoy



# Buoy network for Puget Sound

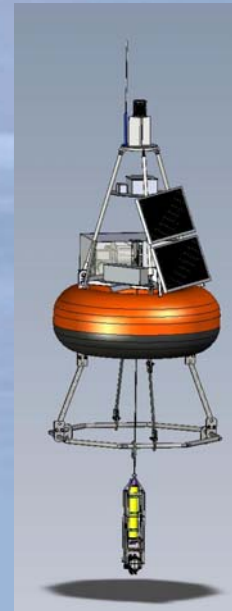
A private-public partnership  
between industry and UW

# Networked Buoy Project

“surface buoys”  
IC Mobilisa lead



“profiling buoys”  
APL-UW lead



## Surface:

potential for oil and  
other pollution

harbor security

## Profiling:

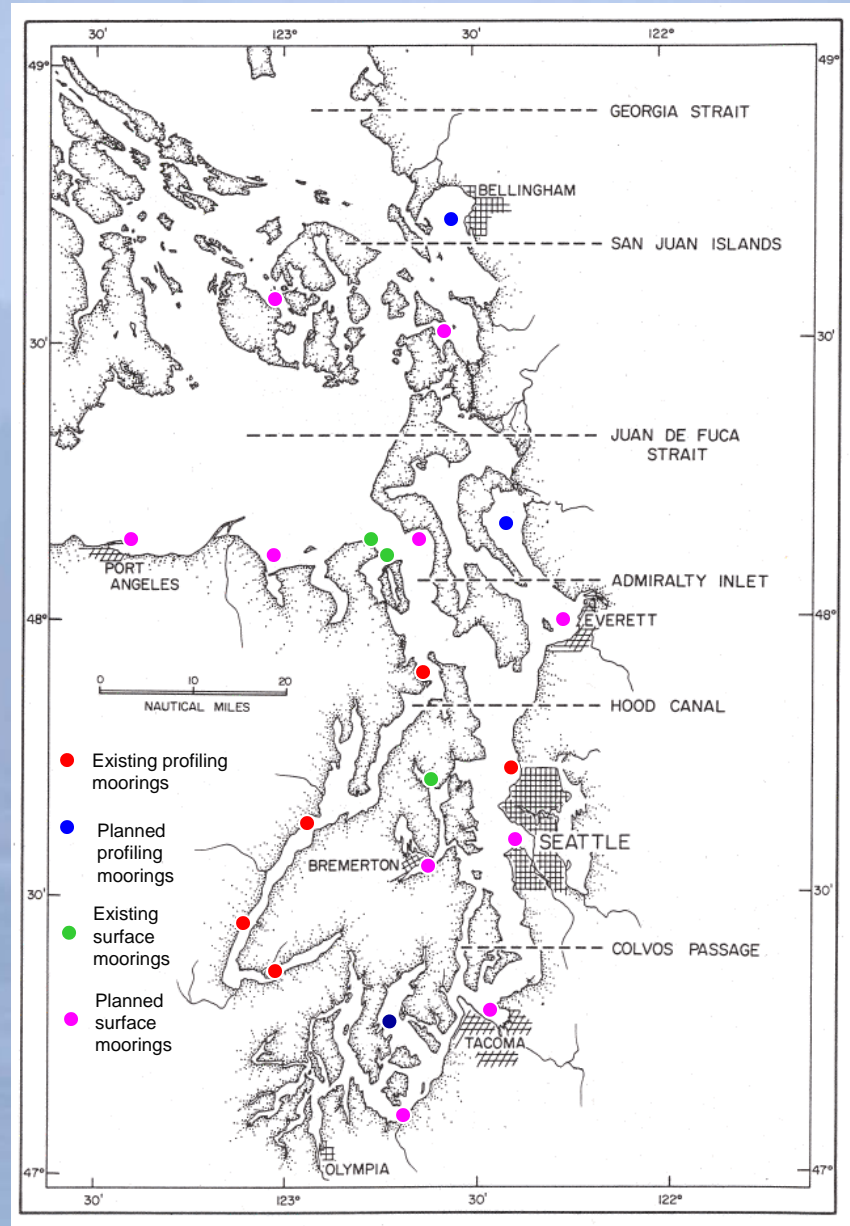
potential for low  
oxygen

climate change  
impacts

# Networked Buoy Project

“surface buoys”  
IC Mobilisa lead

“profiling buoys”  
APL-UW lead



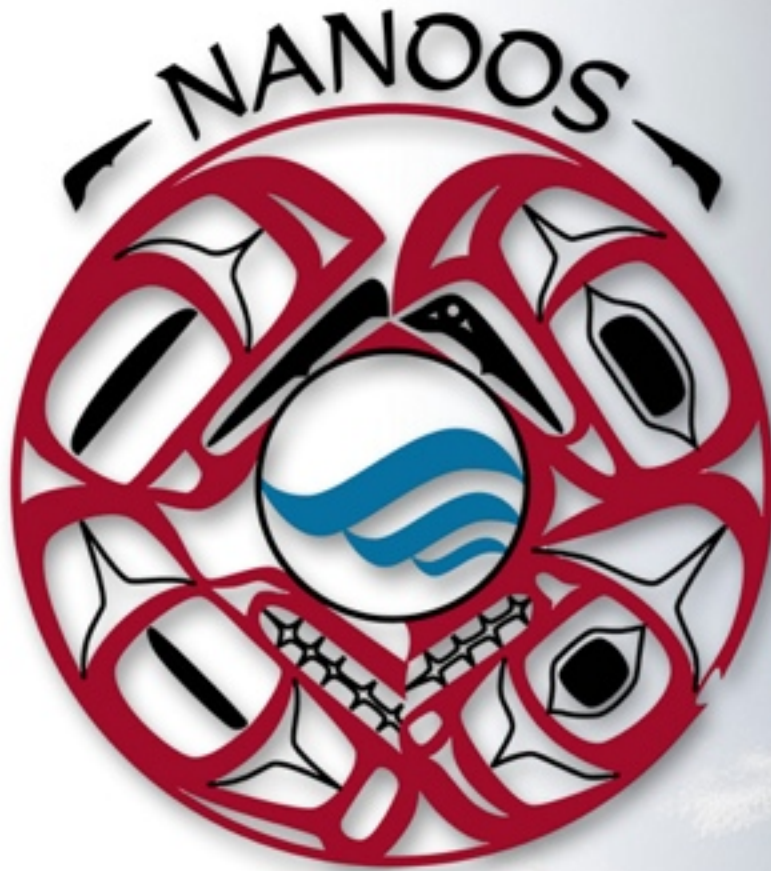
## Location logic

### Surface:

potential for oil and other pollution  
harbor security

### Profiling:

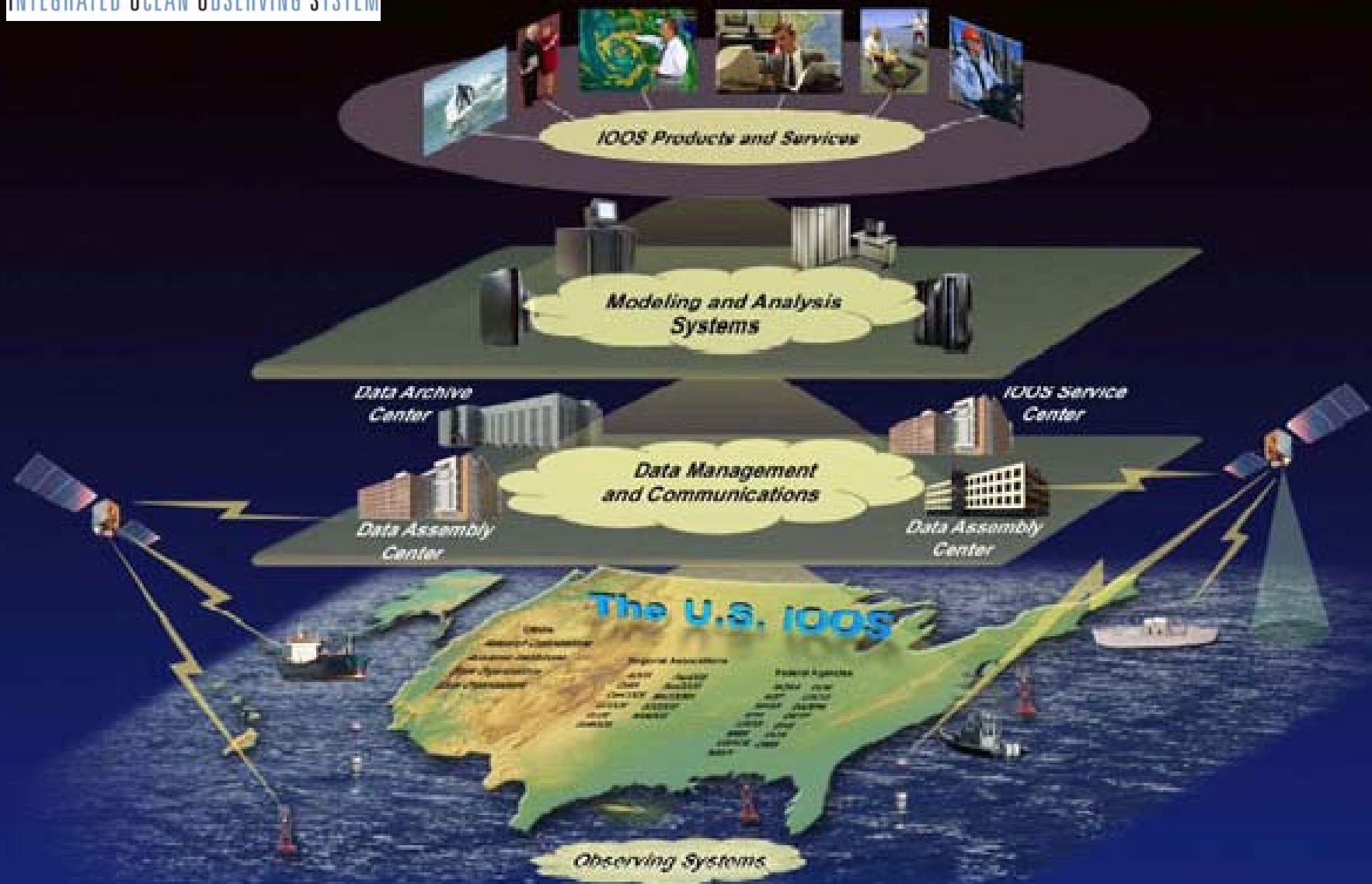
potential for low oxygen  
climate change impacts



Northwest Association of Networked Ocean Observing Systems  
The Integrated Ocean Observing System (IOOS)  
Regional Association for the Pacific NW



[www.nanoos.org](http://www.nanoos.org)



# The NANOOS Visualization System

The screenshot displays the NANOOS Visualization System interface. At the top, there is a navigation bar with "Log In | Register" on the left, the "NVS NANOOS VISUALIZATION SYSTEM" logo in the center, and a circular logo on the right. Below this is a "NVS > Assets" breadcrumb and a "Chart" tab. The main interface is divided into a left sidebar and a central map area.

**Filters Sidebar:**

- Filters** (expandable)
- In-Situ Assets (82)** (expandable)
- Platform Type:** (dropdown menu)
- Expand All** / **Collapse All** (buttons)
- Cruise** (checked)
- Buoy** (checked)
  - ORCA-UW** (checked)
    - ORCA Twanoh (radio button)
    - NDBC 46087 (green status)
    - NDBC 46015 (green status)
    - NDBC 46022 (green status)
    - NDBC 46027 (green status)
    - NDBC 46050 (green status)
    - NDBC 46089 (green status)
    - NDBC 46029 (green status)
    - NDBC 46041 (green status)
    - NDBC 46088 (green status)
    - NDBC 46002 (green status)
    - NDBC 46005 (grey status)
  - OSU** (checked)
    - OSU NH10 (radio button)
  - King County** (checked)
    - KC NSGE01 (radio button)
  - Env. Canada** (checked)
    - EC 46206 (green status)
    - EC 46132 (green status)
    - EC 46146 (green status)
    - EC 46131 (green status)
  - ICM-Mobilisa** (checked)
    - ICM Sent1 (radio button)
    - ICM Sent2 (radio button)
  - CDIP-Scripps** (checked)
    - CDIP 46230 (green status)

**Map Area:**

- Coordinates: Lat: 50.0642, Lon: -120.6519
- Map Style: Terrain (selected), Road, Satellite
- Map content: A topographic map of the Pacific Northwest coast of North America, showing numerous yellow buoy icons and city names like Vancouver, Seattle, Portland, and Eugene.
- Map controls: A vertical toolbar on the left with zoom in (+), zoom out (-), and other navigation icons.
- Scale: 100 mi / 200 km
- Map data: ©2009 Google, Tele Atlas - Terrain Mountain

At the bottom center of the interface, it says "NANOOS Home".

# ORCA buoy data

Log In | Register

NVS  
NANOOS VISUALIZATION SYSTEM

NVS ▸ Assets

Chart List Help

Lat: 46.0275, Lon: -115.5322

Terrain Road Satellite

**Profiling Buoy at Hoodspout - Hood Canal**

Location: Puget Sound, Washington Lat: 47.4218 Lon: -123.1126  
 Provider: ORCA-UW Data Source: NANOOS-APL

Data Updated: 8 Feb 2010 12:24 PST

ORCA Hoodspout - Dissolved Oxygen - 7 Days  
 08 Feb 2010 18:00 PST

Parameter	-3m	-20m
<b>Chlorophyll</b>		
-3m	4.1 ug/L	
-20m		0.4 ug/L
<b>Conductivity</b>		
-3m	2.7 S/m	
-20m		3.3 S/m
<b>Dissolved O2</b>		
-3m	6.7 mg/L	
-20m		5.2 mg/L
<b>Nitrate</b>		
-3m	8.4 umol/kg	

24 Hours 7 Days 30 Days

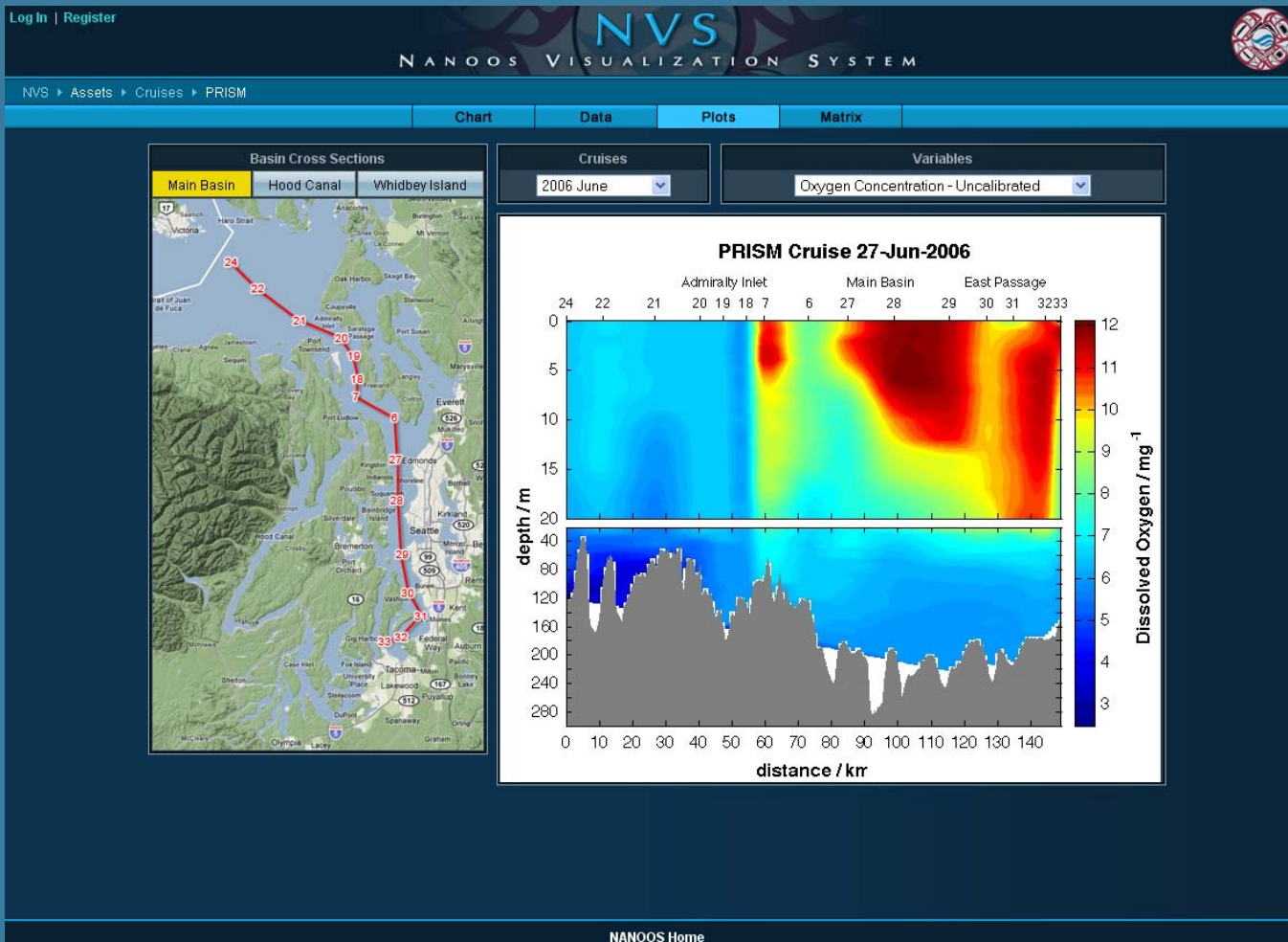
Link

POWERED BY Google

100 mi 100 km

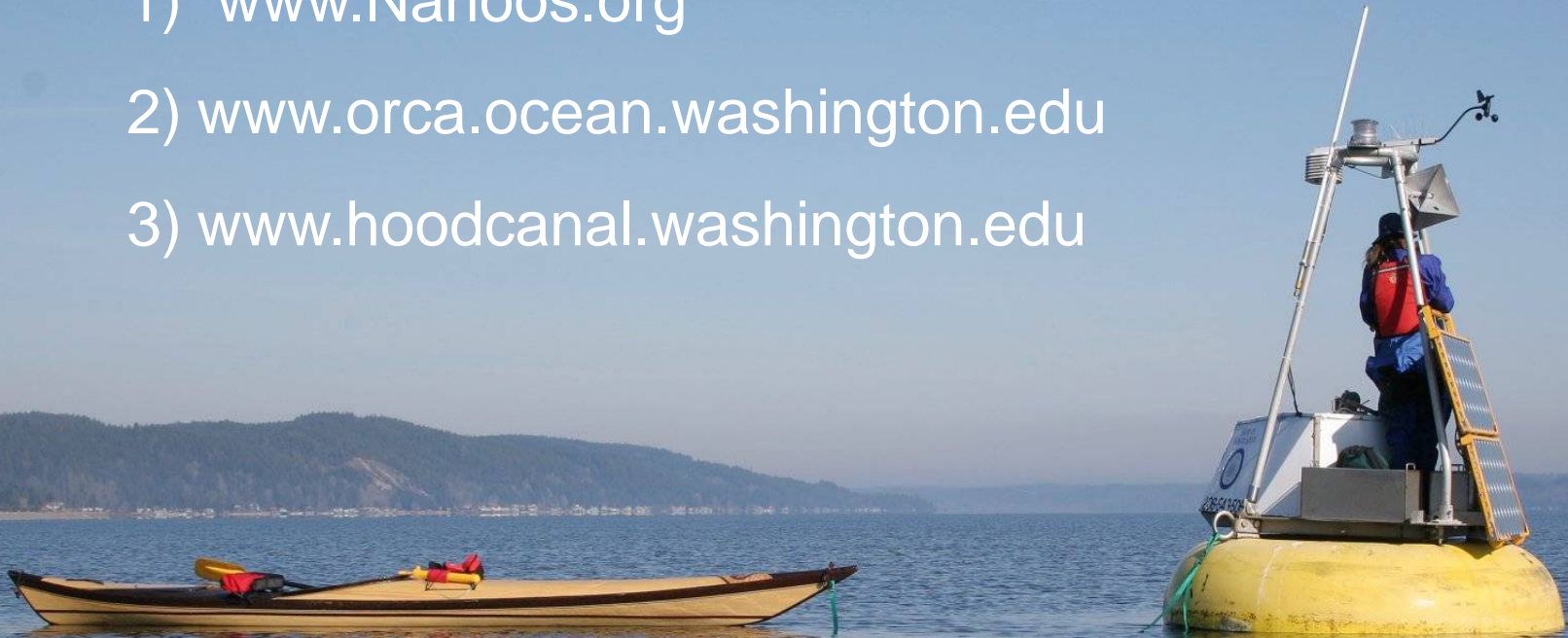
Map data ©2010 Google, Tele Atlas

# UW PRISM cruises



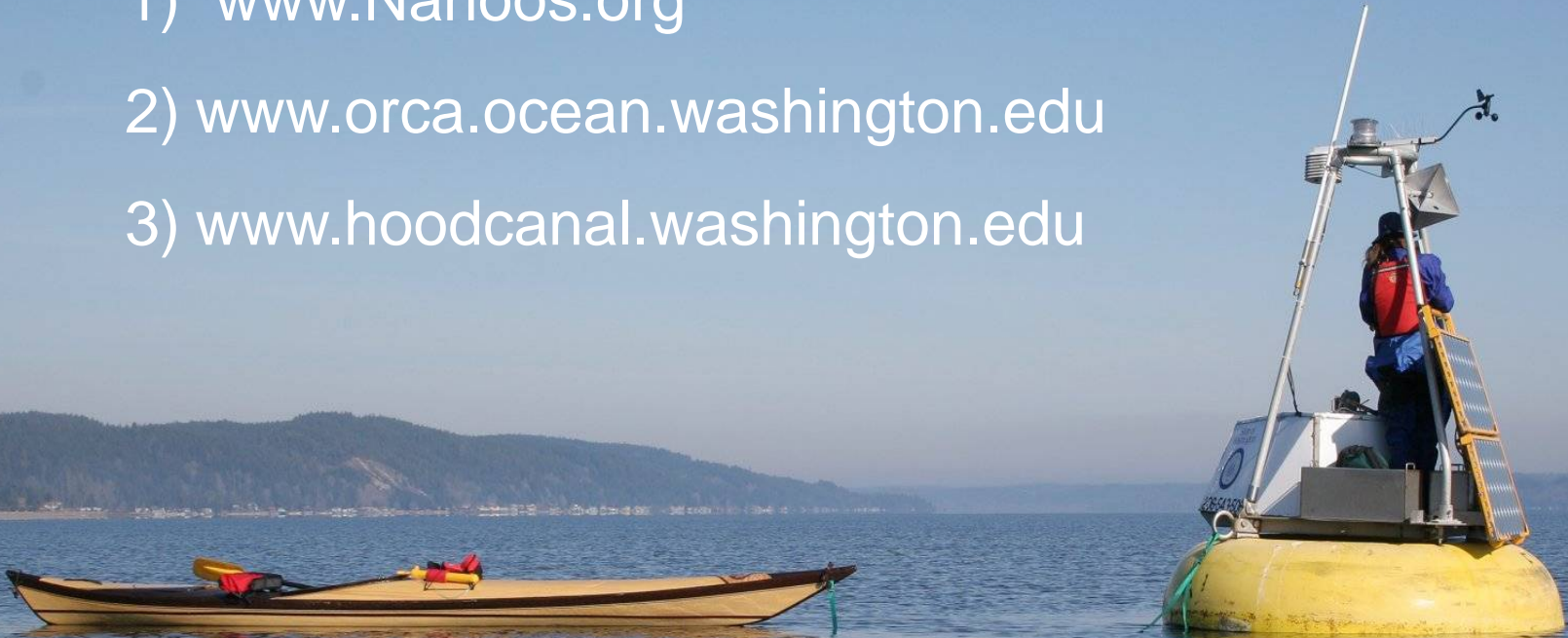
# Further Information

- 1) [www.Nanoos.org](http://www.Nanoos.org)
- 2) [www.orca.ocean.washington.edu](http://www.orca.ocean.washington.edu)
- 3) [www.hoodcanal.washington.edu](http://www.hoodcanal.washington.edu)



# Further Information

- 1) [www.Nanoos.org](http://www.Nanoos.org)
- 2) [www.orca.ocean.washington.edu](http://www.orca.ocean.washington.edu)
- 3) [www.hoodcanal.washington.edu](http://www.hoodcanal.washington.edu)



QUESTIONS ?

# Extras

# Recipe for a fish kill event

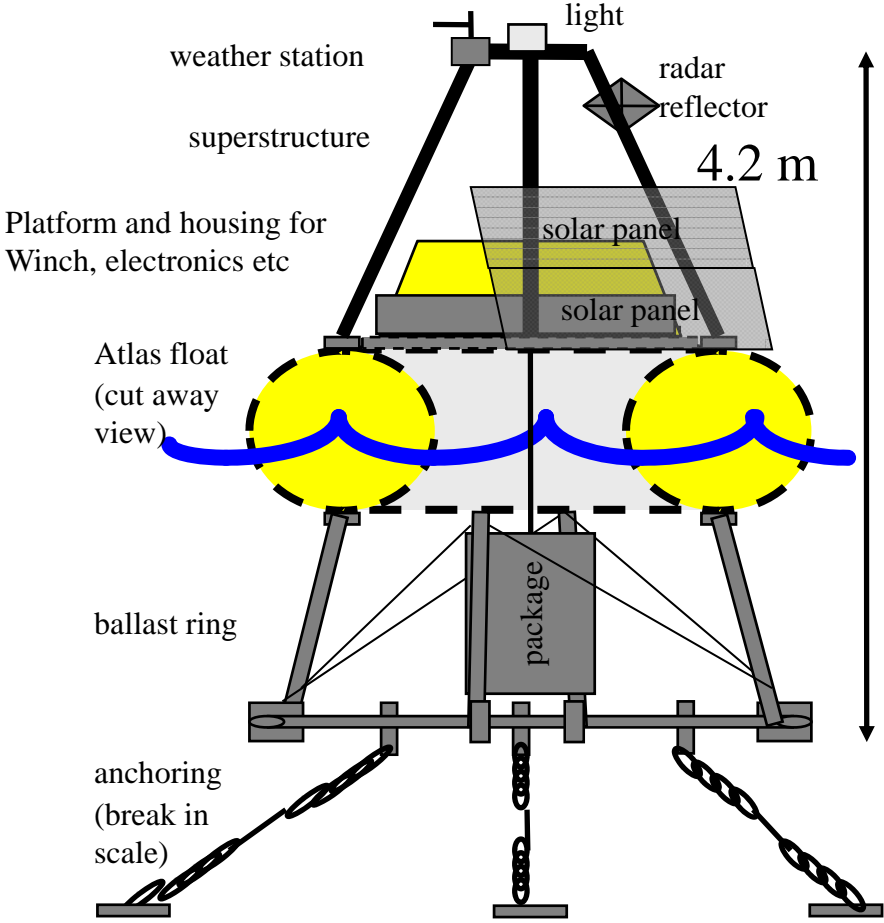
	2003	2004	2005	2006
	Fish kill	Odd behavior		Fish kill
S winds	X	X		X
Low DO	X	<b>X</b>	x	<b>X</b>
Shallow/ weak density gradient	X			X

# Conclusions

- 1) Many coastal and inshore waters have high frequency signals that are due to horizontal patchiness and tidal advection
- 2) Different variables/parameters require different measurement frequencies to discern seasonal or global change or anthropogenic influences, e.g gas exchange daily, chlorophyll concentration weekly
- 3) High frequency sampling reveals short term phenomenon

# Oceanic Remote Chemical Analyzer (ORCA) buoy

## ORCA Schematic View



*Developed at University of Washington*

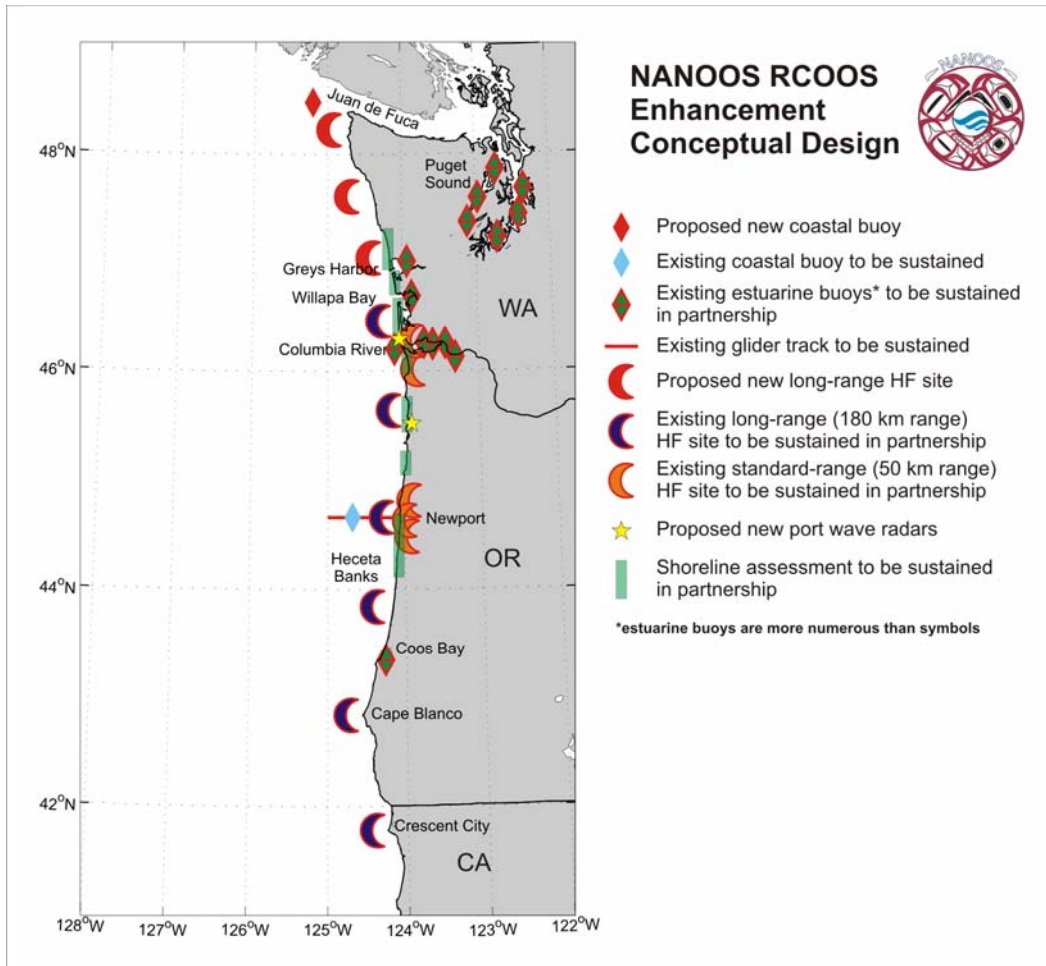


# NANOOS

NORTHWEST ASSOCIATION OF NETWORKED OCEAN OBSERVING SYSTEMS



WASHINGTON - OREGON - NORTHERN CALIFORNIA

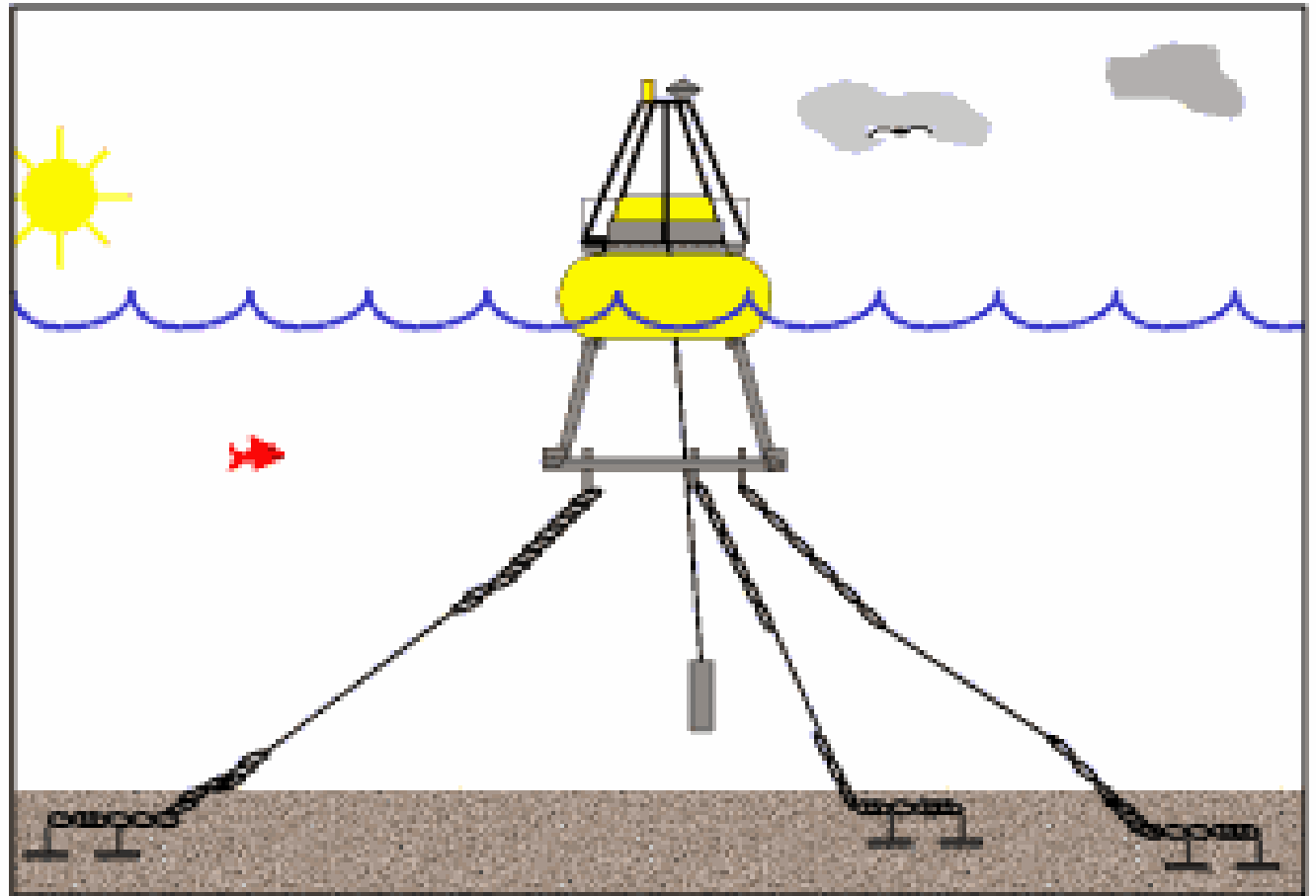


*Observing assets NANOOS supports are:*

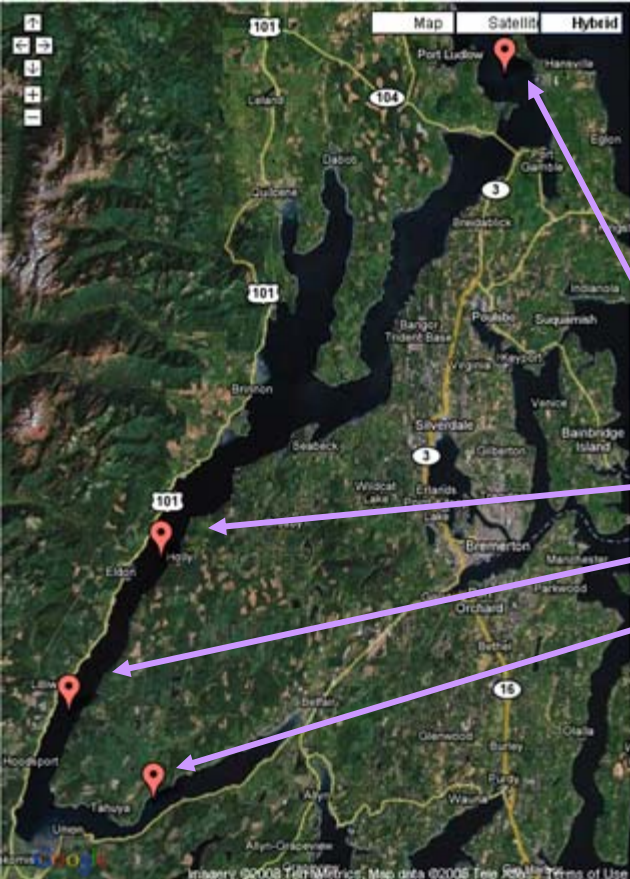
- OR coastal shelf buoy and glider (Newport Line)
- OR coastal shelf currents (HF)
- Puget Sound, Columbia River, Willapa and Coos Bays, and Grays Harbor moorings/buoys
- WA and OR shoreline profiles

*Grant from Murdock for WA buoy & glider*

# Profiling capability



# ORCA buoys



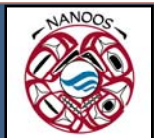
4 buoys, 4 locations

- 1) Hansville
- 2) Duckabush
- 3) Hoodsport
- 4) Twanoh



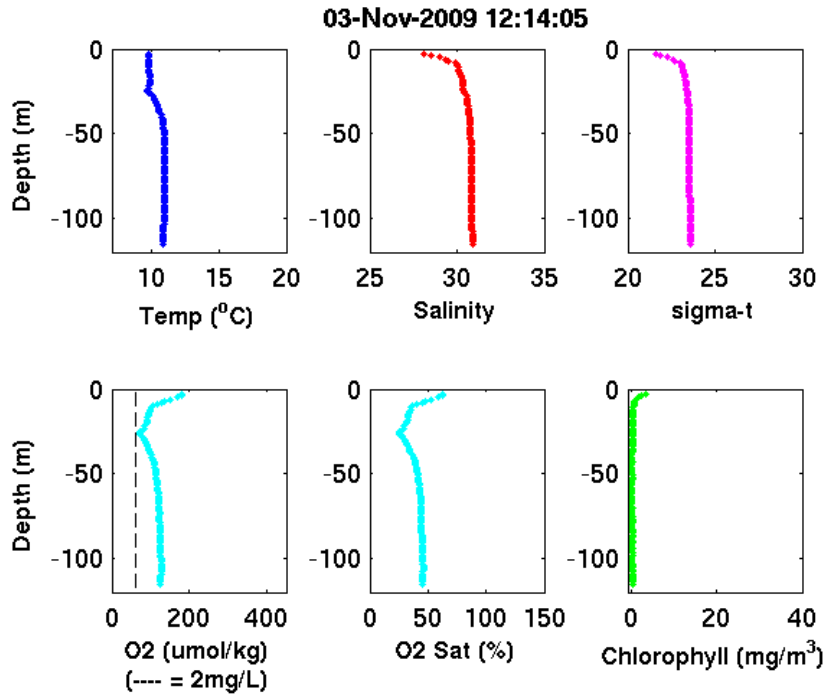
*Part of the NANOOS Observing System*

In southern Hood Canal, the buoy at Twanoh has recorded a total of 13071 profiles since January 2005.

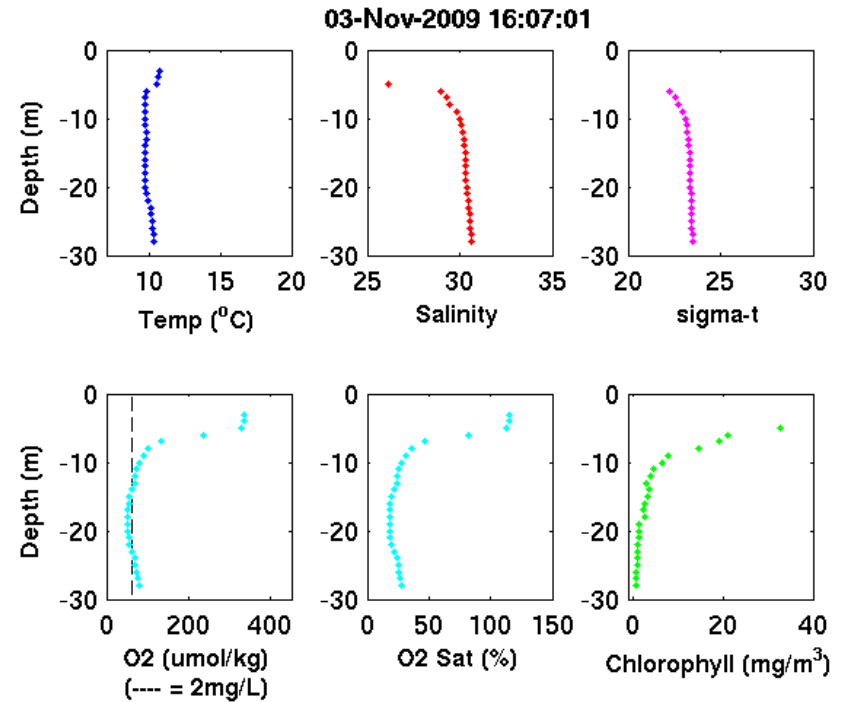


# ORCA gives information about now

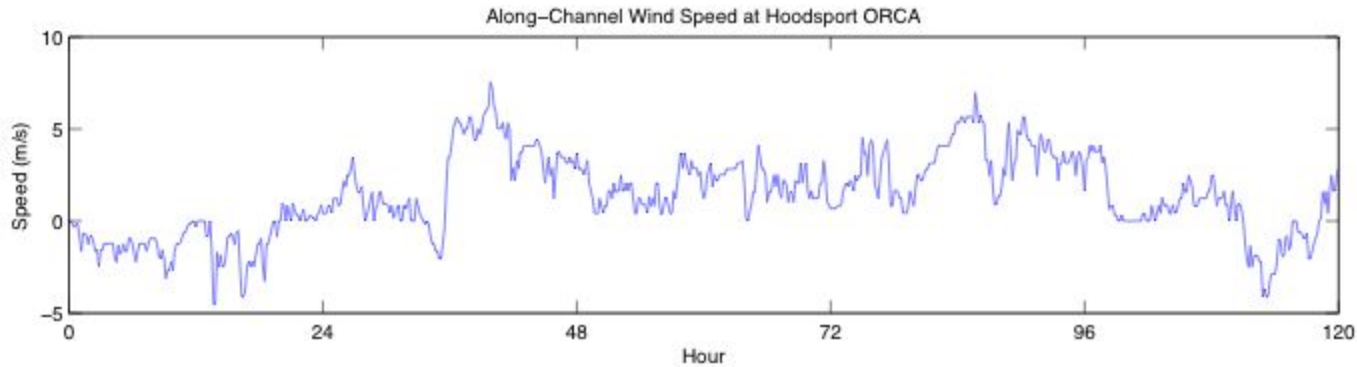
## Hoodspport



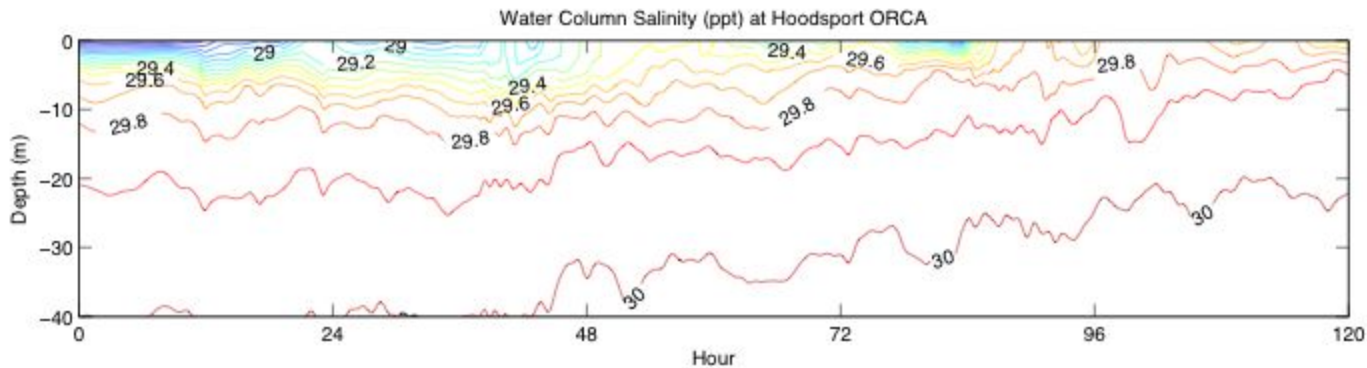
## Twanoh



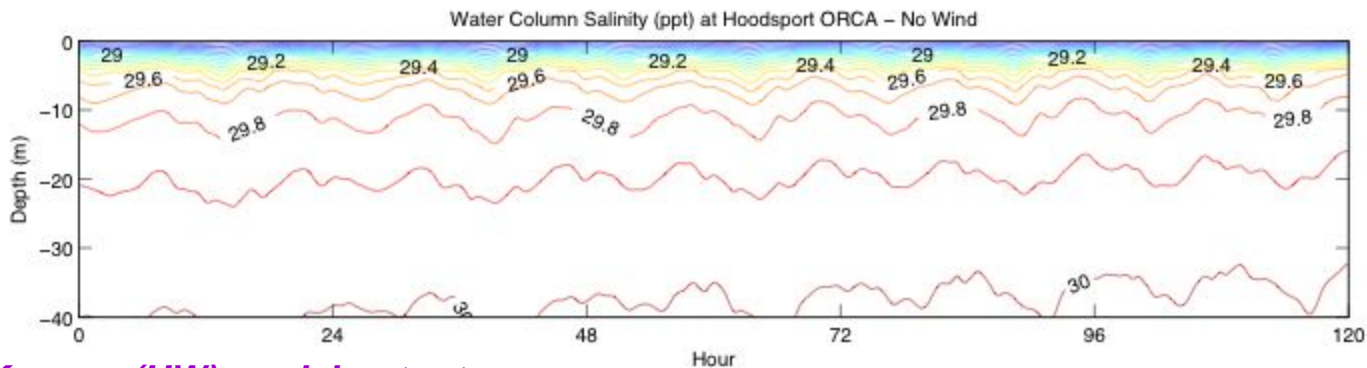
Marine model results show that winds do cause **outcropping** of deep waters to surface.



*Observed wind at Hoodspport*



*Modeled salinity at Hoodspport ORCA, with wind*



*Same, but without wind*





# UW PRISM cruises

Log In | Register

NANOOS VISUALIZATION SYSTEM

NVS ▸ Assets ▸ Cruises ▸ PRISM

Chart Data Plots Matrix

Lat: 49.9335, Lon: -121.1243

Terrain Road Satellite

**Cruises**

Show All Hide All  
Expand All Collapse All

- 2009
- 2008
- 2007
- 2006
  - June
- 2005
- 2004
- 2003
- 2002
- 2001
- 2000
- 1999
- 1998

PRISM Station P23, Off Sequim

Cruise: 2006 June 1

28 Jun 2006 - 14:20:33

Downcast

Chl Concentration	Uncalibrated
Light Transmissivity	Uncalibrated
<b>Oxygen Concentration</b>	<b>Calibrated</b>
Oxygen Concentration	Uncalibrated
Photosynthetically Active Radiation	Uncalibrated
Potential Density Sigmat	Uncalibrated
Water Pressure	Uncalibrated
Water Salinity	Uncalibrated
Water Temperature	Uncalibrated

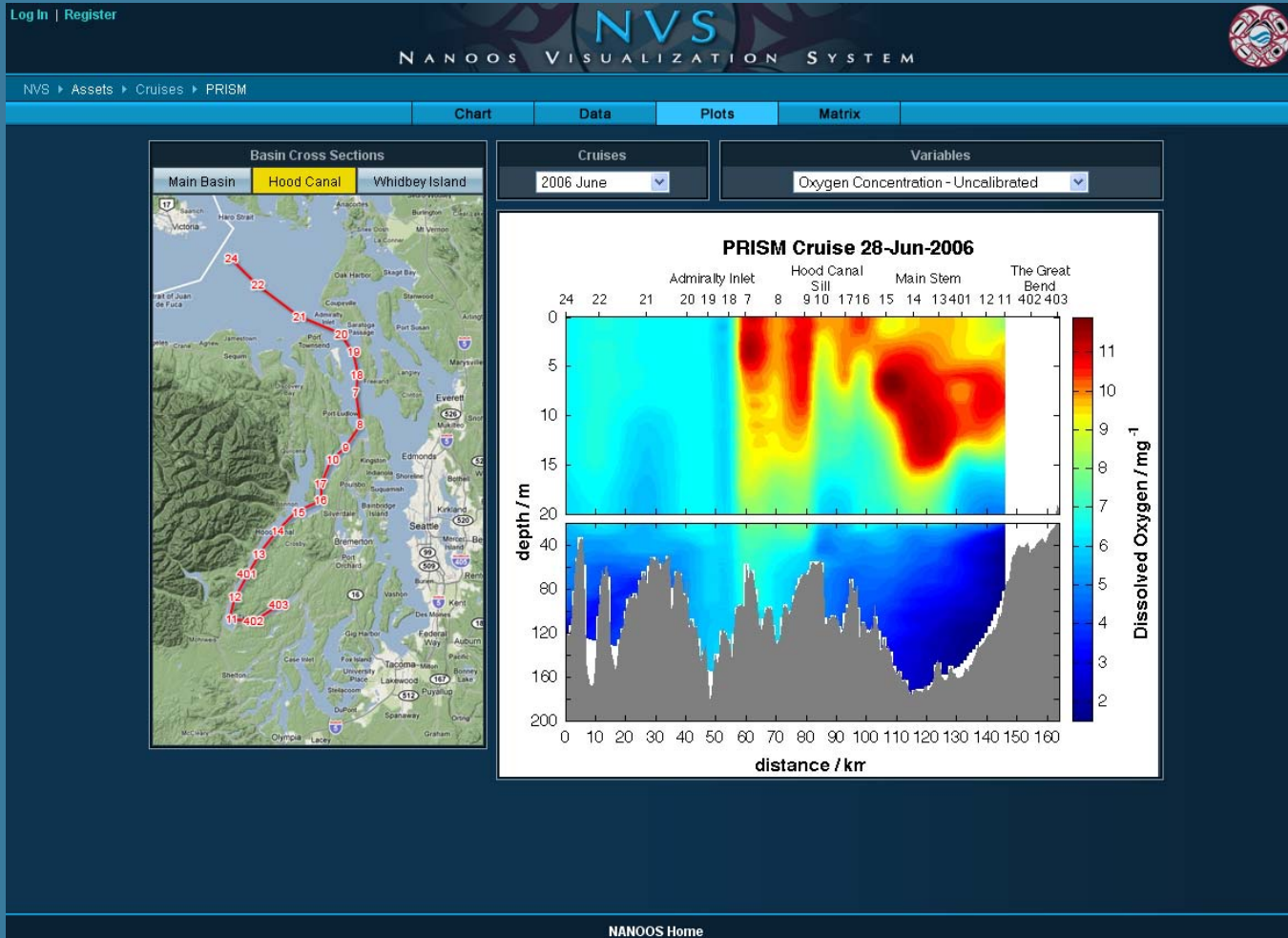
Map showing cruise locations (20-26) in the Sequim Bay area. Station 23 is highlighted.

POWERED BY Google

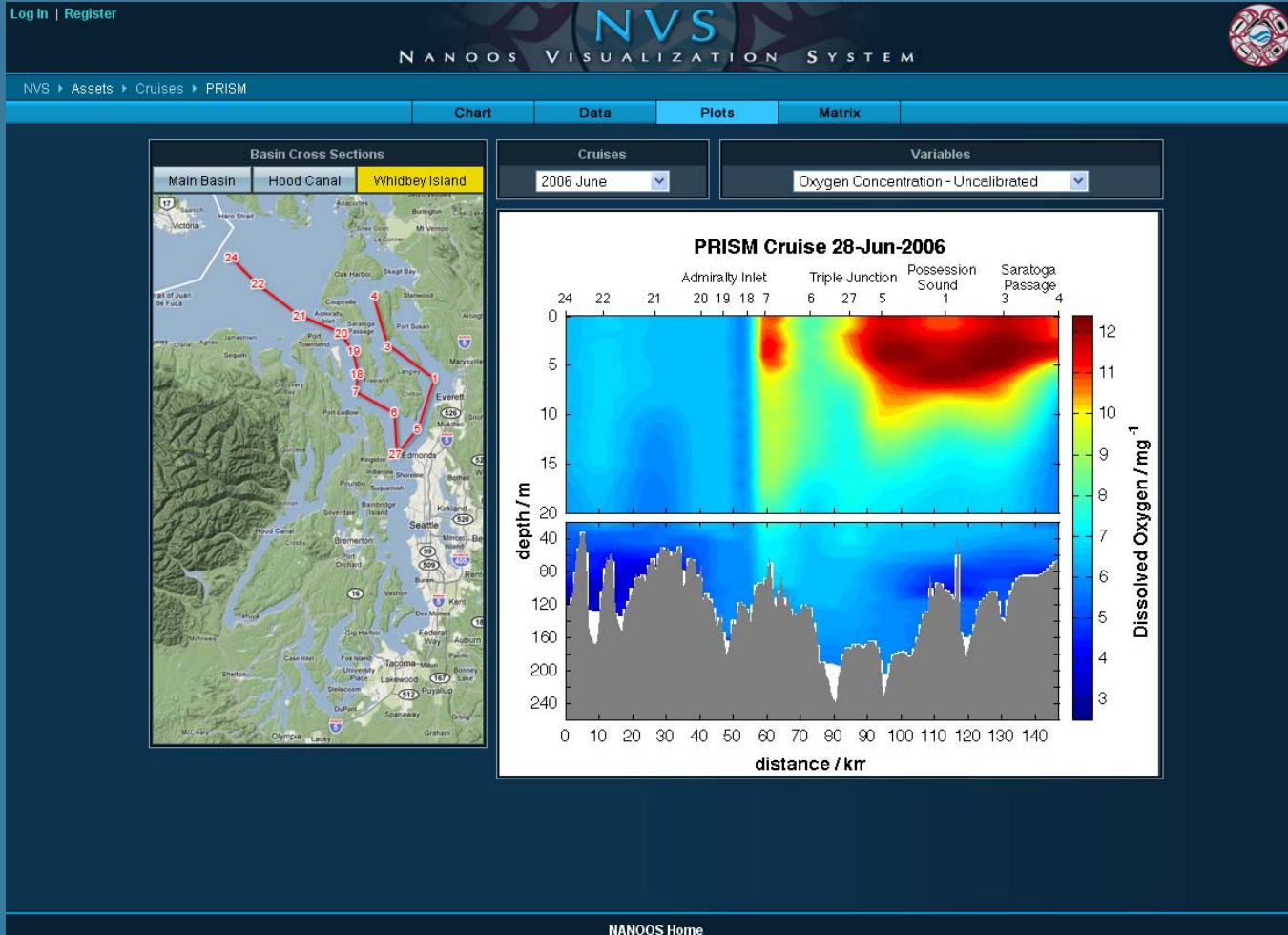
20 mi / 20 km

NANOOS Home

# UW PRISM cruises



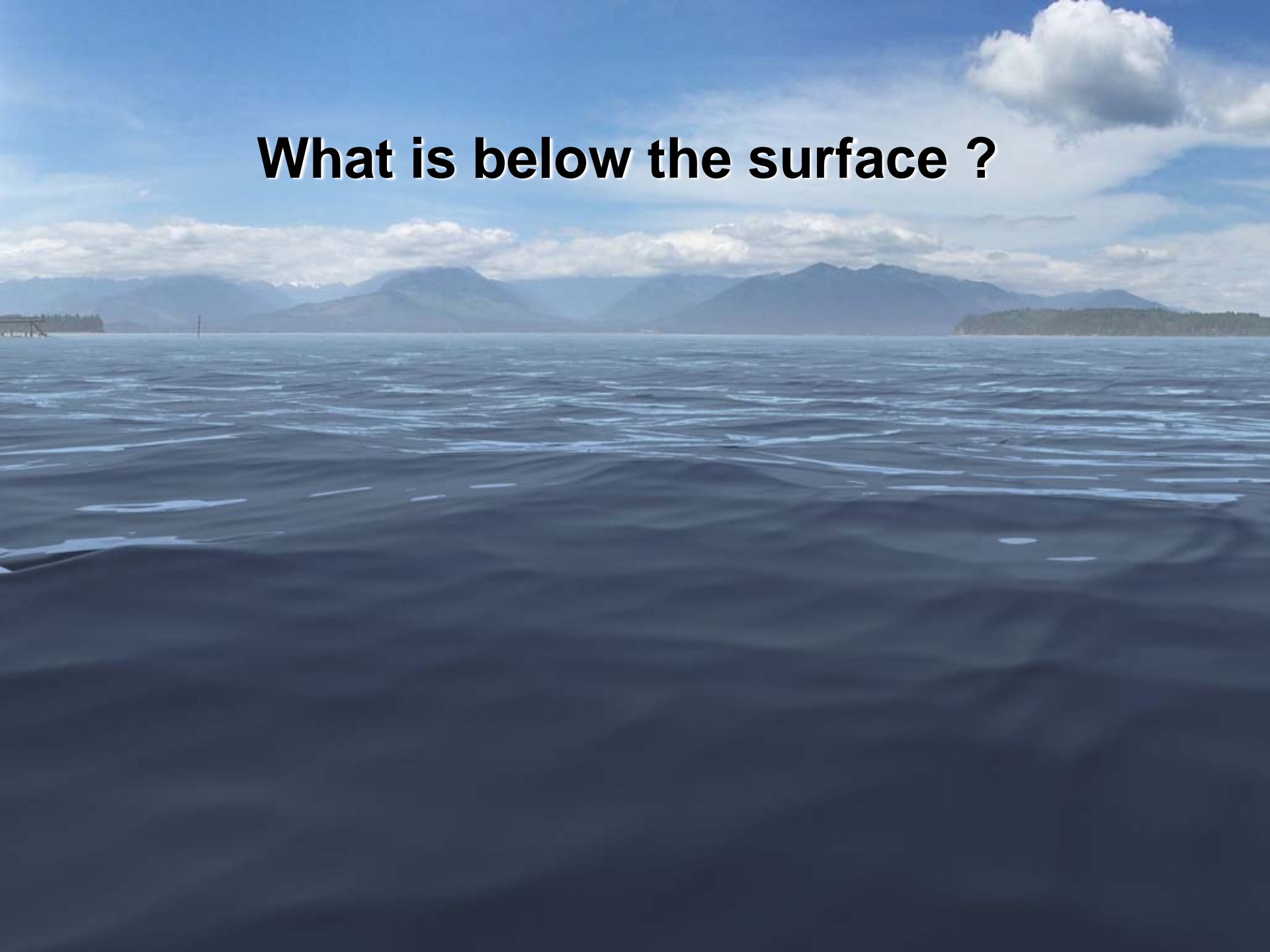
# UW PRISM cruises



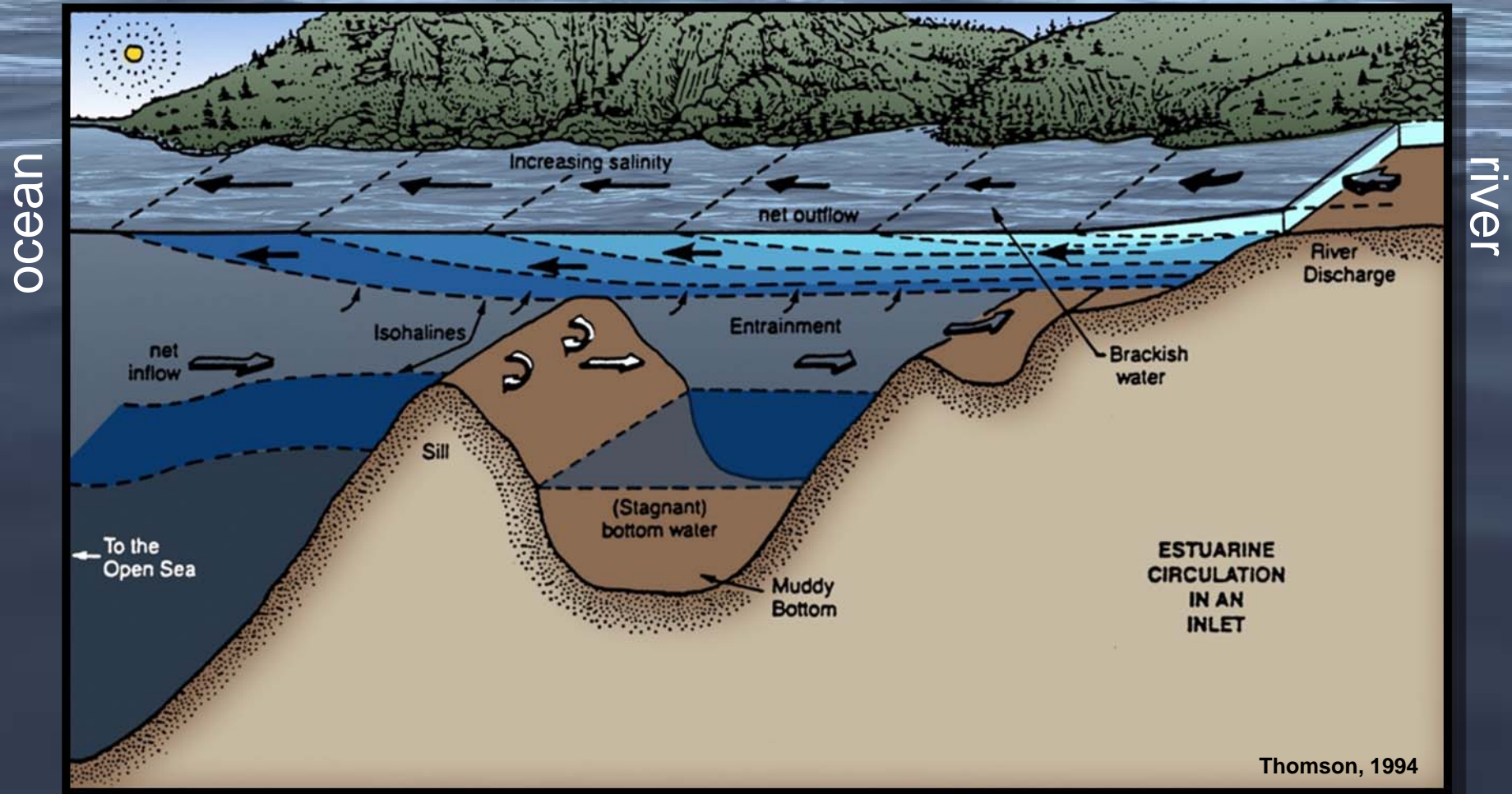
# Conclusions for Hood Canal hypoxia

- NANOOS ORCA buoy data for nitrate and currents enabled construction of a nitrogen budget for area most subject to anthropogenic effects.
- The budget shows that, although the largest input to the euphotic zone is from oceanic nutrients, the input of nitrogen from anthropogenic sources was ~5-10% of the oceanic input.
- If all of this N is used to create oxygen demand it is enough to lower the deep water oxygen content by 0.6-1.2 mg/l, which in certain years is enough to produce a fish kill.

**What is below the surface ?**



# What is below the surface ???



Buoyant river water flows out of an estuary on surface, dense ocean water flows in at depth, but there is mixing, and sills cause “reflux” of water back in to an estuary.