Science Update

Jan Newton, WOAC
Andy Suhrbier, PSI
Nina Bednarsek, NOAA PMEL
Richard Feely, NOAA PMEL

Aragonite Saturation State

- What is it?
- Why is it relevant to shellfish growers?
- Why is it relevant to the food web?
- What do we know about its future status?

Aragonite Saturation State

What is it?

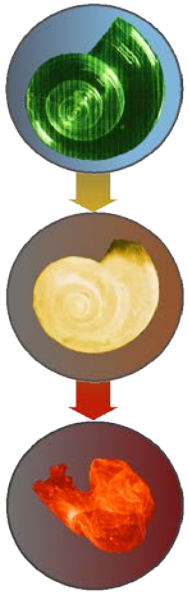
$$Ca^{2+} + CO_3^{2-} \rightarrow CaCO_3$$

calcium carbonate calcium carbonate

- Calcium carbonate exists as two common "bio-minerals" used by organisms: calcite and aragonite
- With ocean acidification, carbonate ions are fewer
- With ocean acidification, calcium carbonate is more likely to dissolve
- Saturation state (Ω) tells us whether formation or dissolution is favored

Aragonite Saturation State (Ω)

How easy is it to build shells?



$\Omega > 1$ shell-building relatively easy

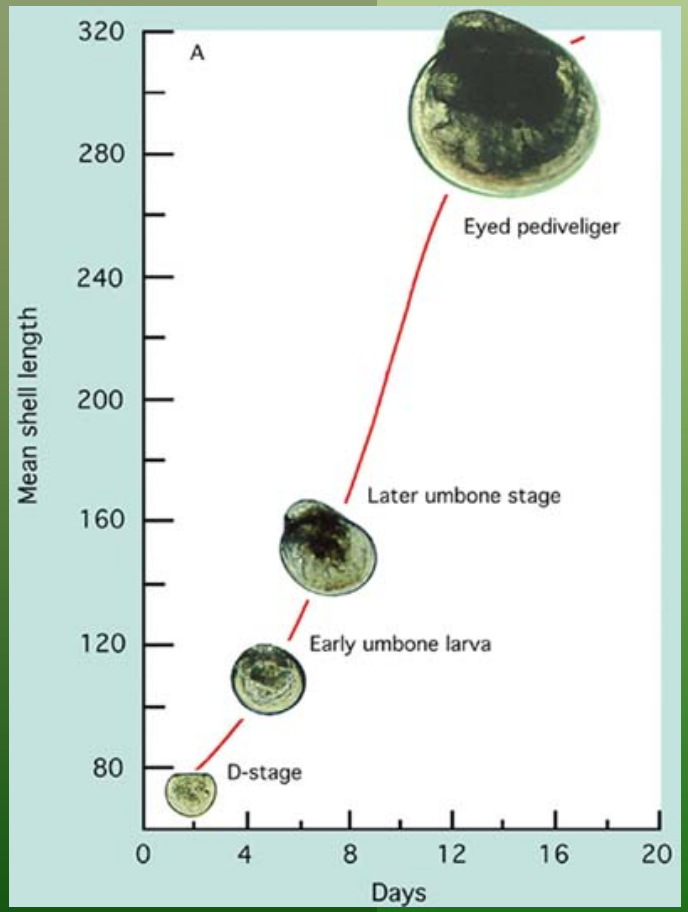
$\Omega = 1$ equilibrium or threshold

$\Omega < 1$ corrosive conditions

pH doesn't vary linearly with Ω_{arag} but is ~1 when pH is ~7.7

PSI & PCSGA & Water Quality

- Hatchery and wild production demand good water quality
  - Temperature and Salinity
  - DO
  - pH (as a proxy)
  - p & TCO2
  - Ω aragonite
    - (Calcium Carbonate)



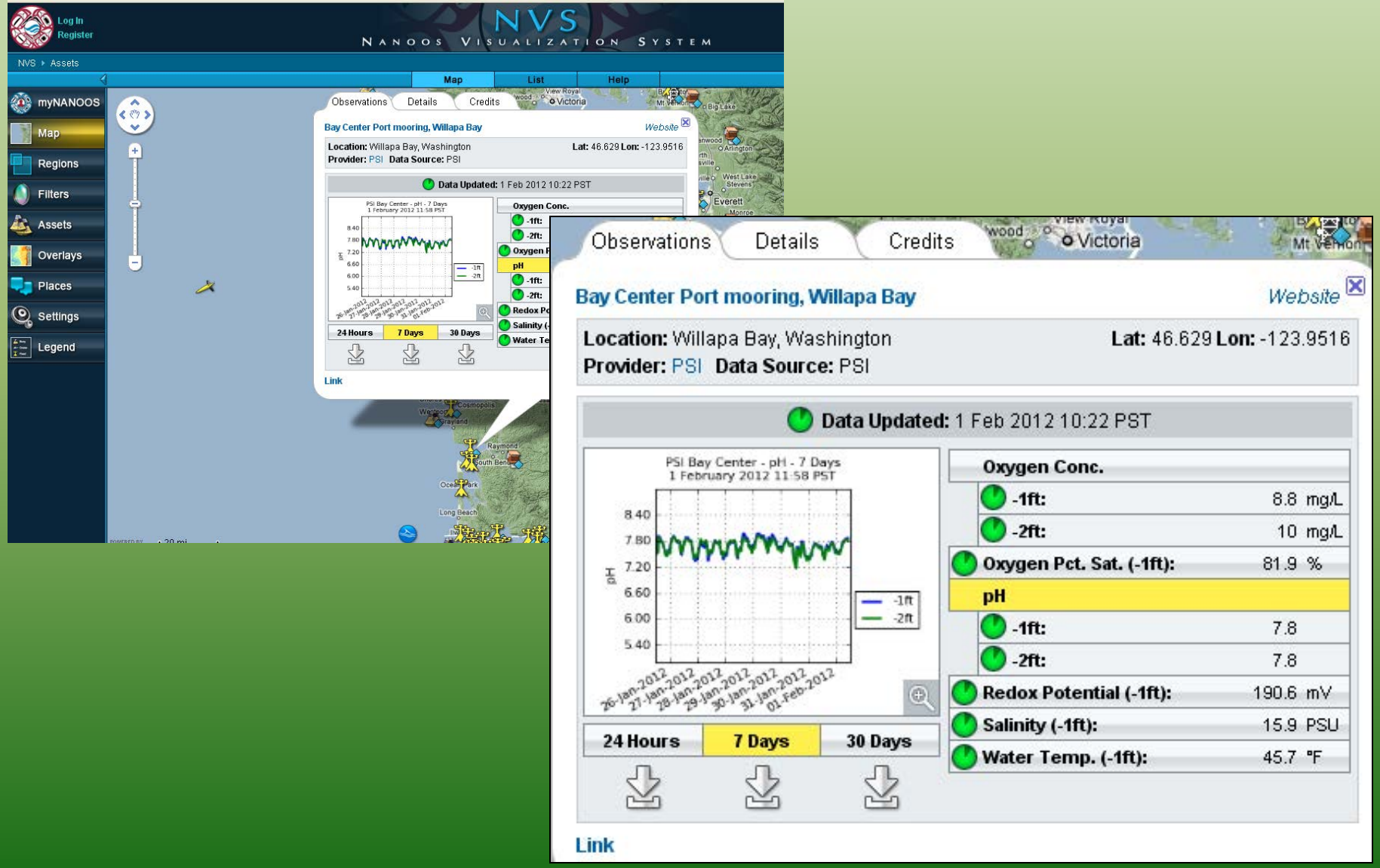
- Washington Ocean Acidification Center
  - Continuation of monitoring
  - Hatchery modifications
  - Fine tune systems/data

Washington Field Sites

- **Bay Center Port - Remote Setting & Hatchery**
  - **Real Time data online (pCO_2, Ω aragonite soon)**
- **Nahcotta Port – Remote Setting & Hatchery**
  - **Real Time data online**
- **Tokeland Port – Oceanic Influences**
  - **Data downloaded monthly**
- **Lummi Hatchery - Intake water**
  - **On the wall data**

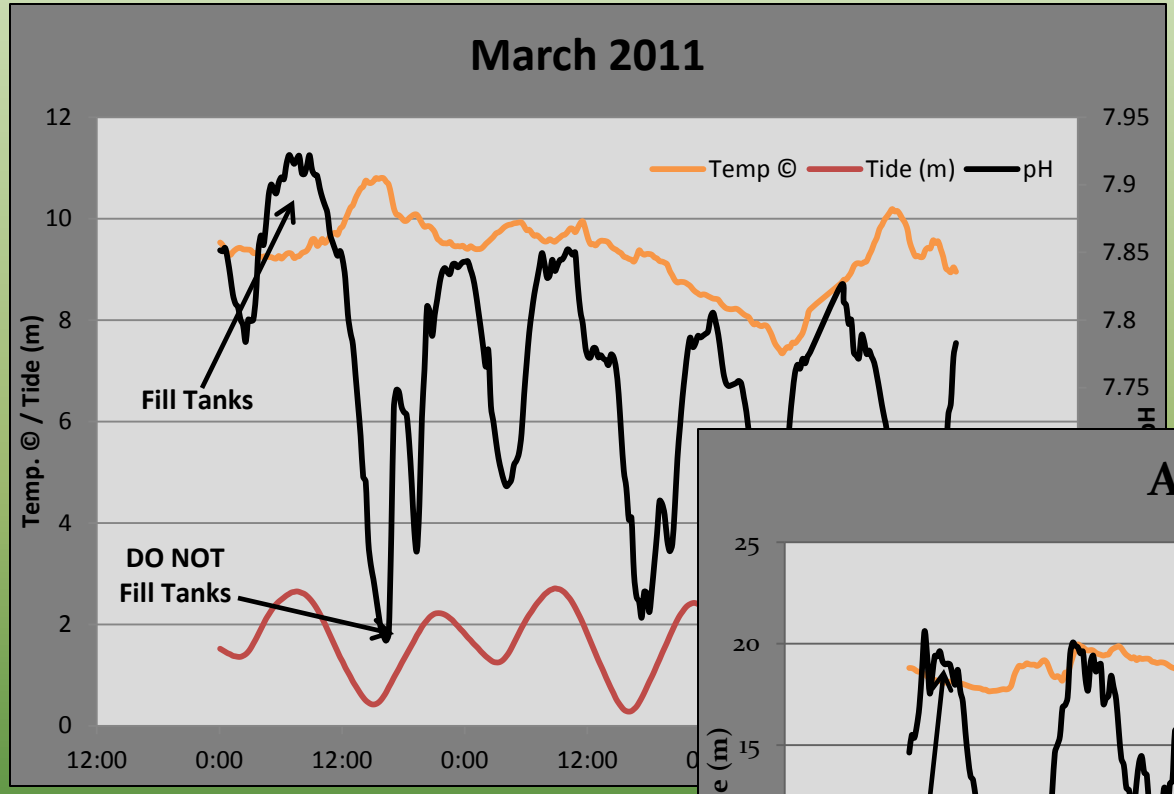
NANOOS @ Bay Center

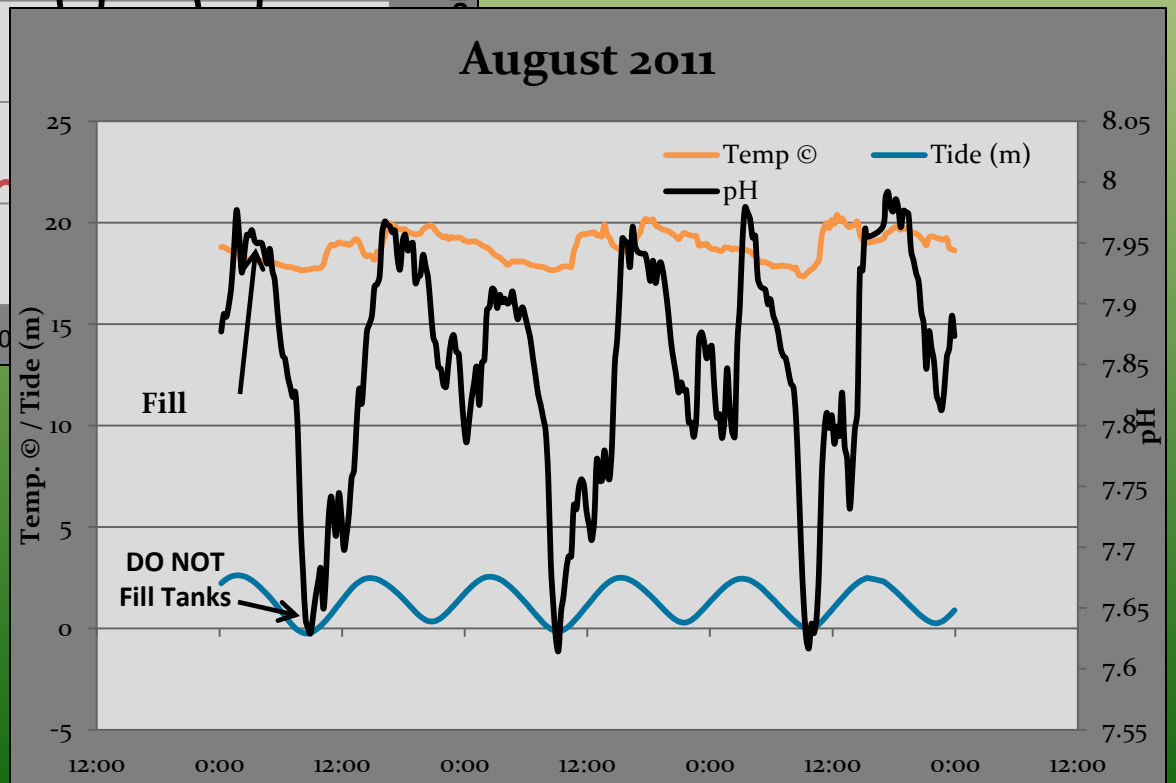
http://nvs.nanoos.org/Explorer & Phone Apps

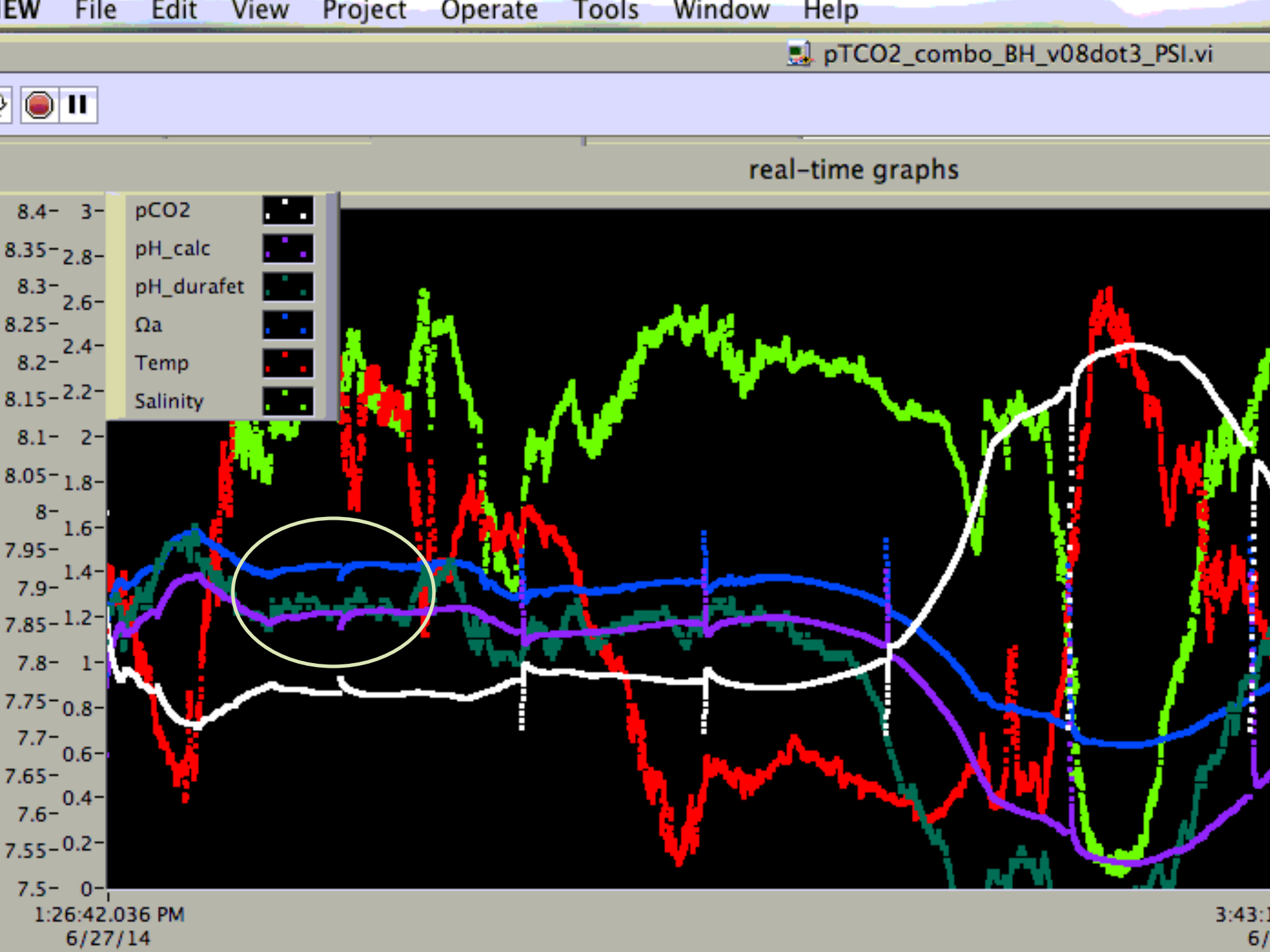


Bay Center Port

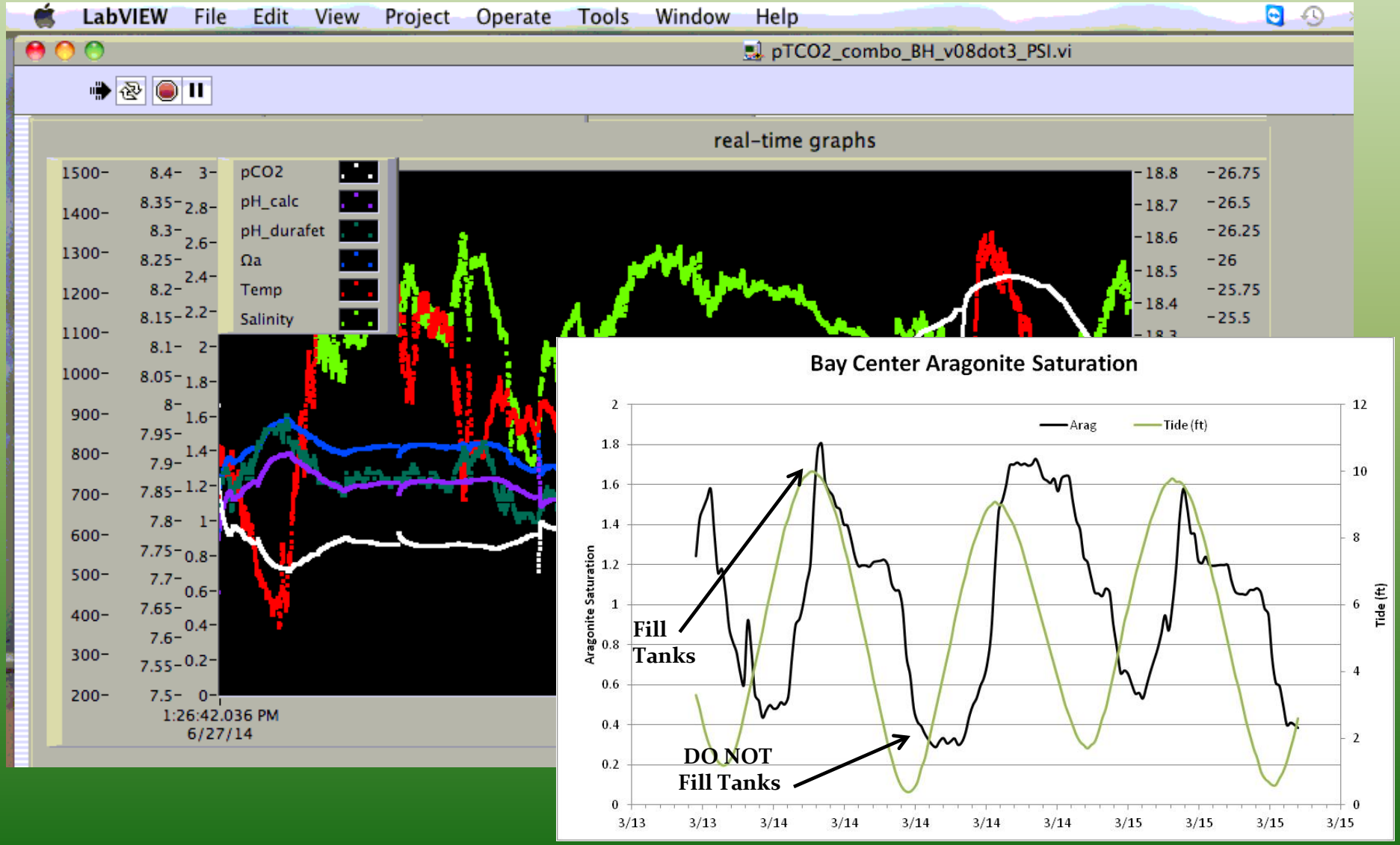
Bay Center Port pH






File Edit View Project Operate Tools Window Help
pTCO2_combo_BH_v08dot3_PSI.vi
real-time graphs
pCO2
pH_calc
pH_durafet
Ωa
Temp
Salinity
8.4
8.35
8.3
8.25
8.2
8.15
8.1
8.05
8
7.95
7.9
7.85
7.8
7.75
7.7
7.65
7.6
7.55
7.5
3
2.8
2.6
2.4
2.2
2
1.8
1.6
1.4
1.2
1
0.8
0.6
0.4
0.2
0
1:26:42.036 PM
6/27/14

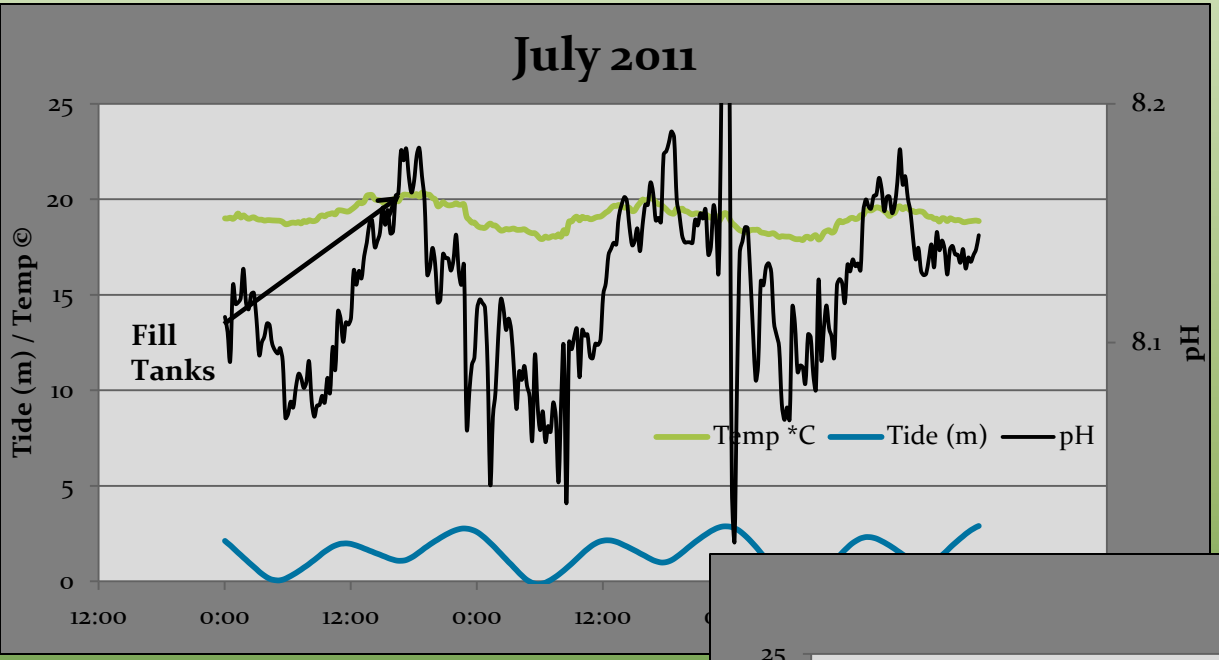
Bay Center pCO2 Unit

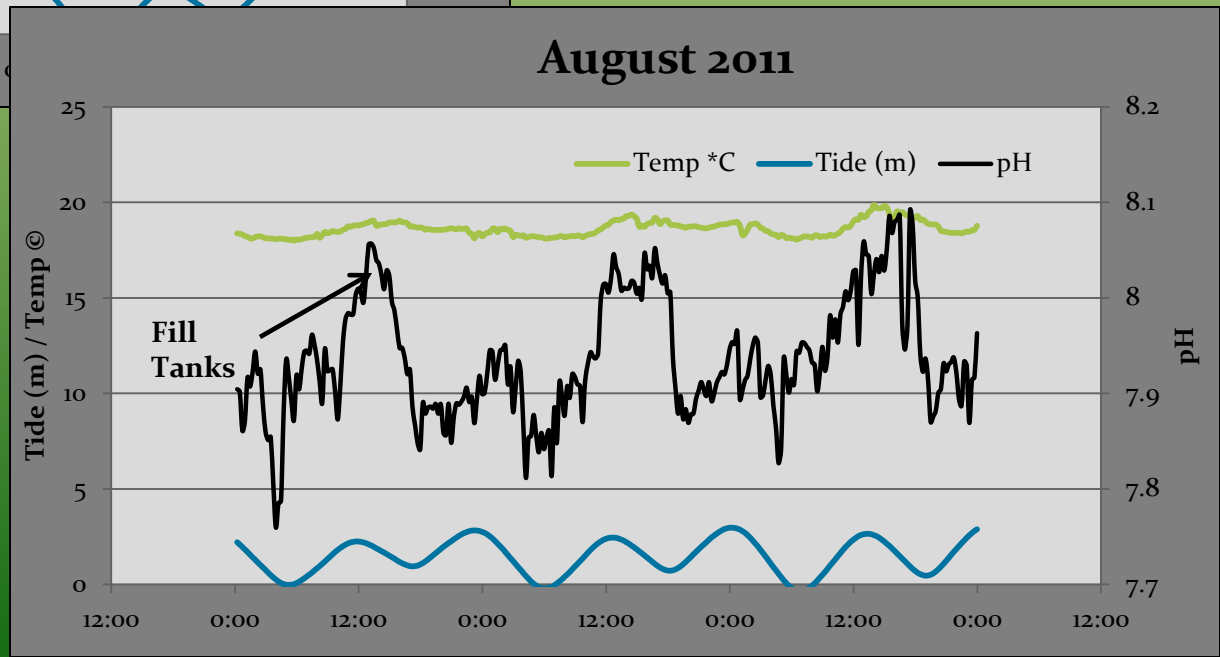


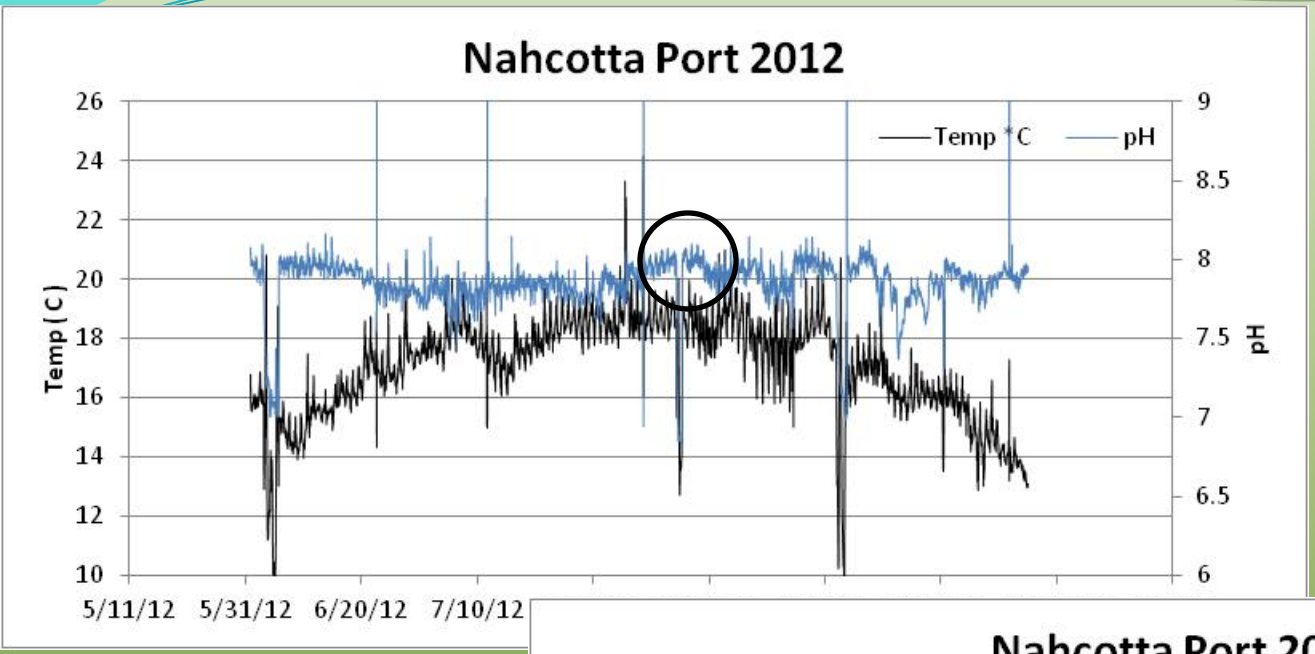
Nahcotta Port

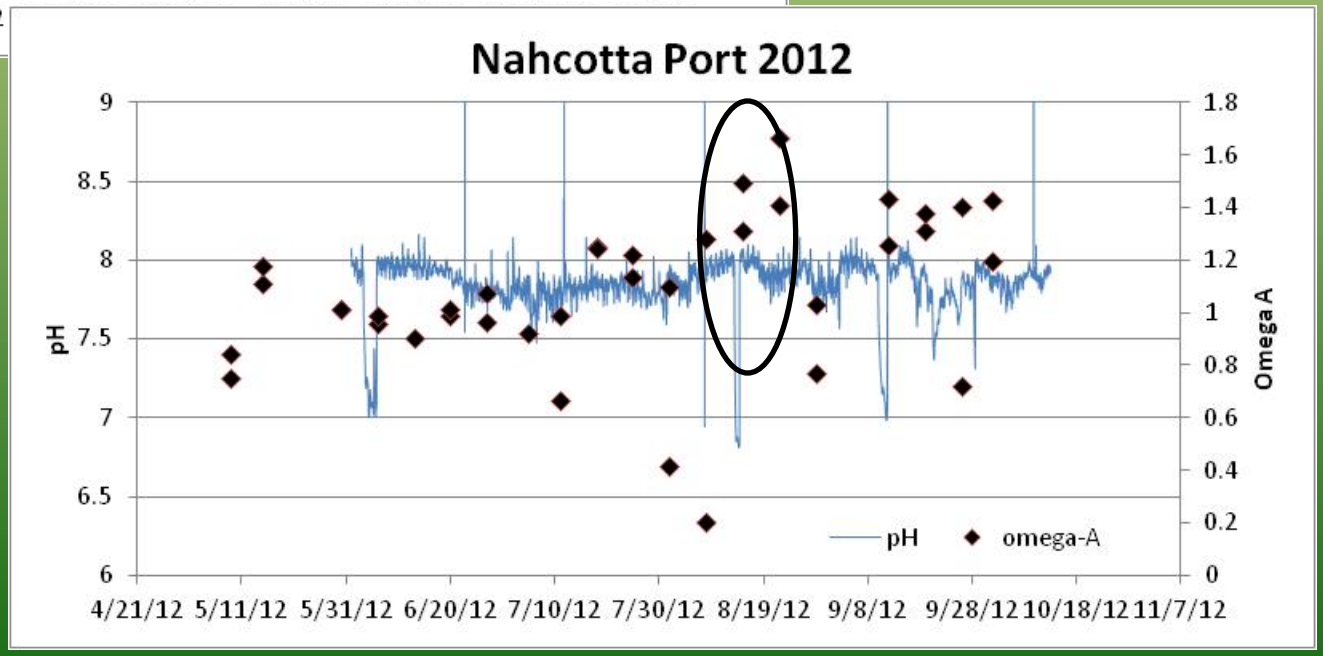
Nahcotta Site

Nahcotta Port






Nahcotta Port 2012
Temp °C
pH
Temp (C)
pH
26
24
22
20
18
16
14
12
10
9
8.5
8
7.5
7
6.5
6
5/11/12
5/31/12
6/20/12
7/10/12


Nahcotta Port 2012
pH
omega-A
pH
Omega A
9
8.5
8
7.5
7
6.5
6
1.8
1.6
1.4
1.2
1
0.8
0.6
0.4
0.2
0
4/21/12
5/11/12
5/31/12
6/20/12
7/10/12
7/30/12
8/19/12
9/8/12
9/28/12
10/18/12
11/7/12

Take Home Messages:

-Bay Center best water: End of incoming tide/high tide events.

-Nahcotta best water: End of incoming tide/high tide & afternoons.

Lummi best water: In the afternoon.

-Estuaries demand localized sampling.

-Control DO, S, T, pH variables in the hatchery/remote setting sites.

Many thanks to:

- Ekone Oyster
- Wiegardt Brothers/Jolly Roger
- WDFW
- Lummi hatchery
- Whiskey Creek hatchery
- NANOOS
- Alan Barton
- Jennifer Ruesink

Andy Suhrbier f: 360-754-2741 c: 360-280-1517 suhrbier@pacshell.org

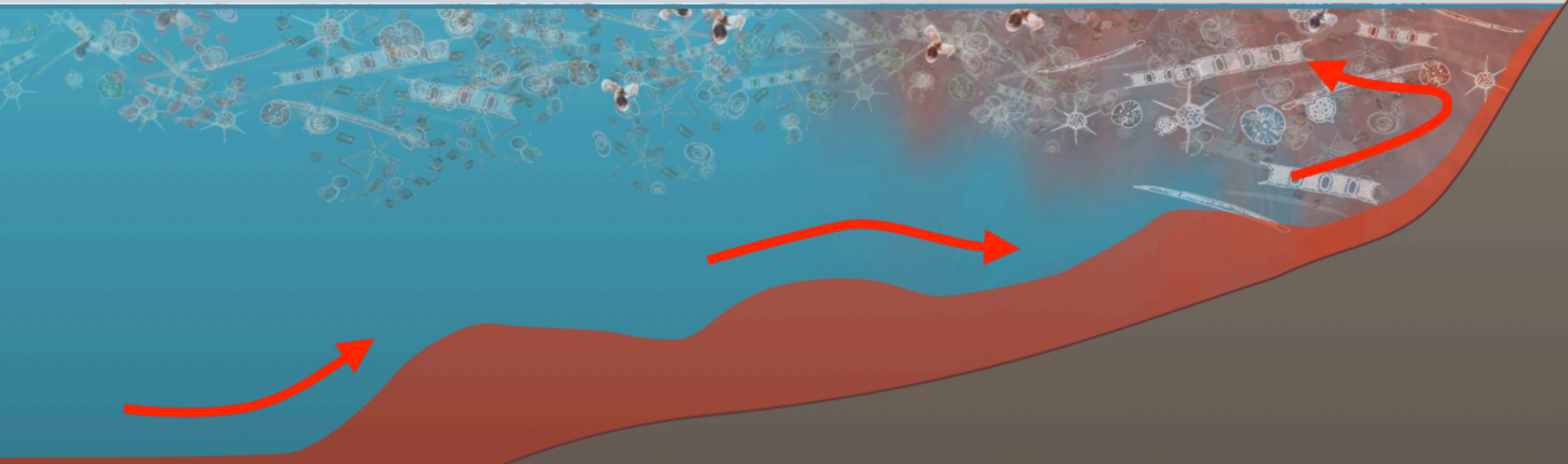
Pteropods as indicators of OA: Beyond experimental work

Bednarsek et al.

(Feely, R., Hales, B., Reum, J., Peterson, B., Alin, S., Caplan, I., Hermann, A., Ohman, M., Thuesen, E.)

Marine Resources Advisory Committee, July 8, 2014

Seasonal invasion of corrosive upwelled water on the west coast of North America



- Upwelling of CO_2-rich intermediate waters, undersaturated with aragonite (Ω_{arag}), onto continental shelf from a depth of 150 – 200m
- Exposure of productive coastal ecosystems to corrosive upwelled water

From Concerns to filling data gaps in knowledge… for pteropods

- Increased dissolution occuring in the natural environment
- Reduced calcification rates
- Changes to behavior responses
- Physiological changes
- Changes to fitness and survival

Onboard experiments

In situ observations

Historical samples

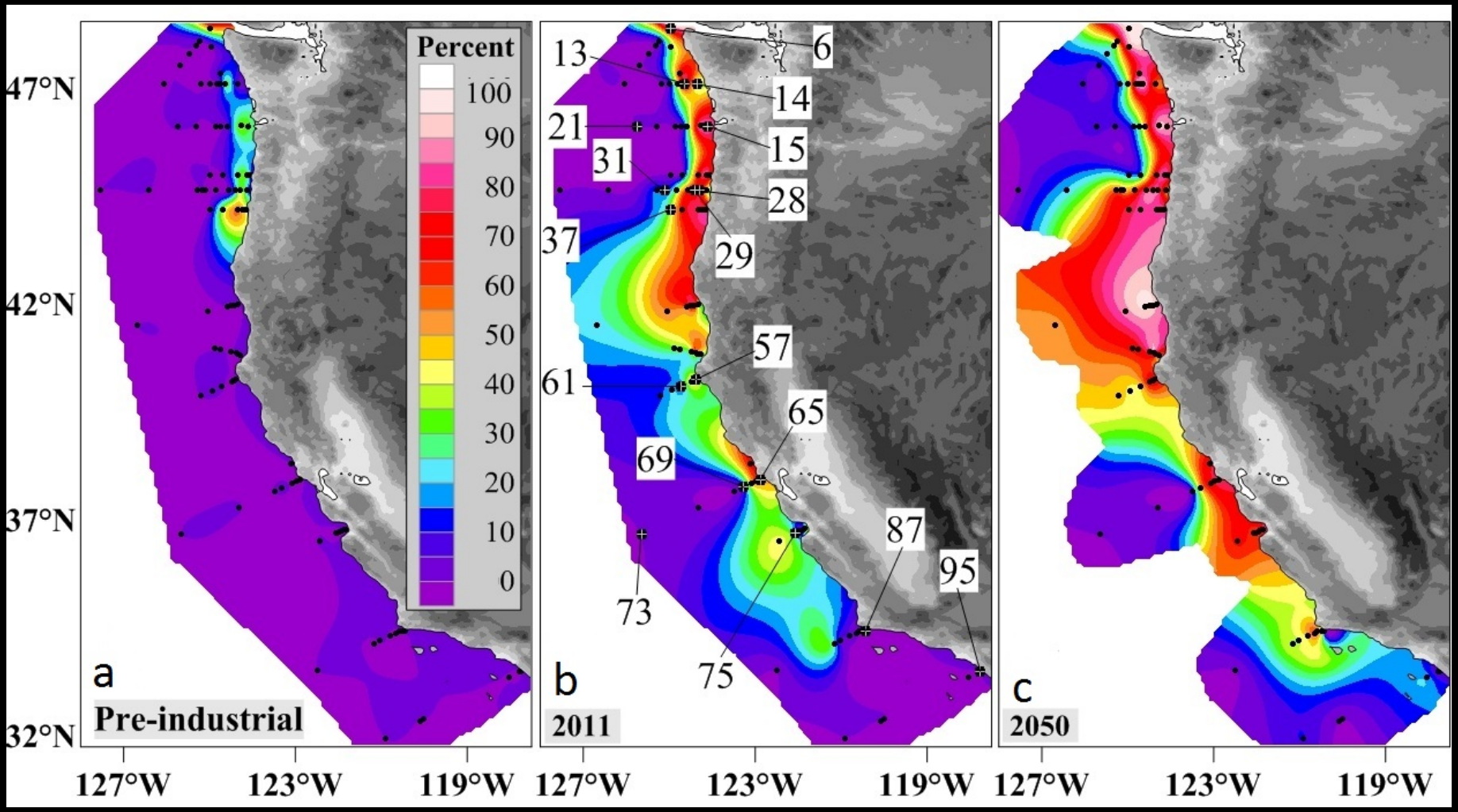
(completed)

- Change to biogeography/transportation
- Changes to food webs
- Changes to key biogeochemical cycles

Modelling work (in progress)

Q1: What is driving pteropod shell dissolution

integration of chemistry for understanding in situ observations



Percent of upper 100 m in CCE water column estimated to be undersaturated during the (a) pre-industrial; (a) 2011; and (a) future (2050) time periods.

Bednaršek et al., 2014

Q3: Dissolution in the upwelling regions? Past? Future?

Pre-industrial times: naturally occurring dissolution (20%)

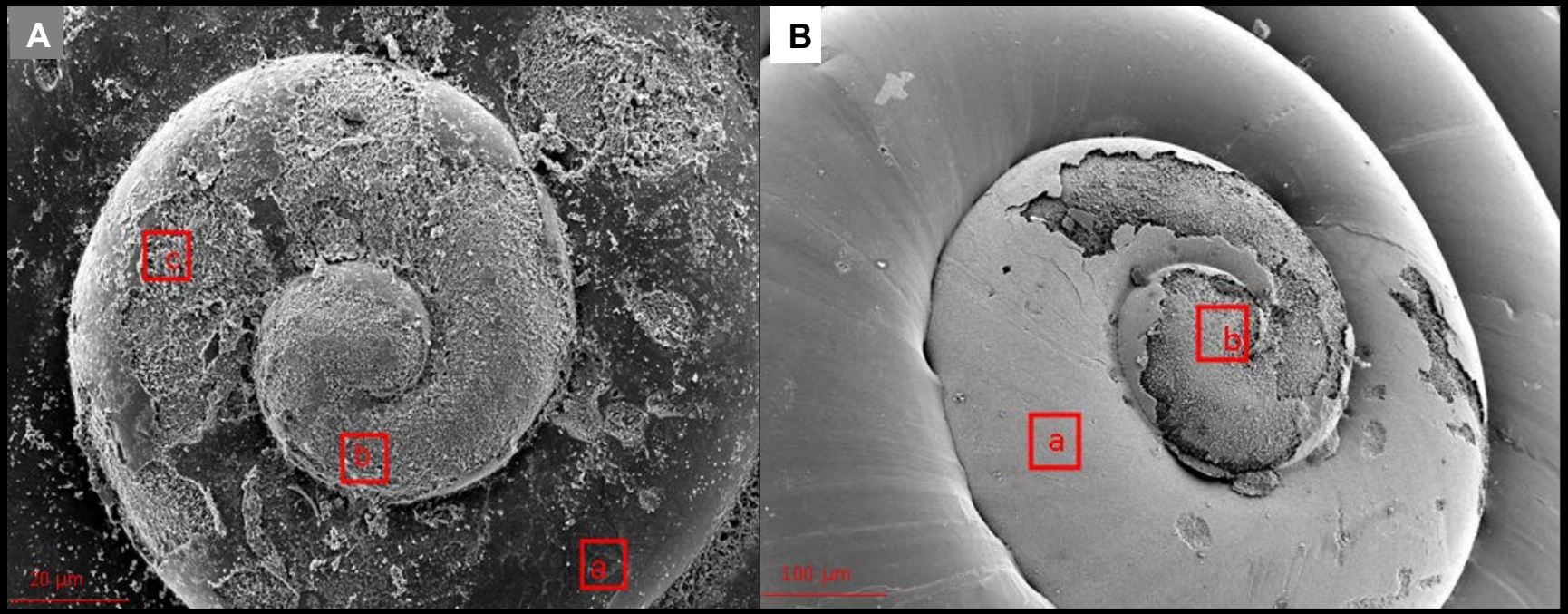
Significant increase in the current level of dissolution → 53% in the coastal regions

By 2050: ~70% of water column will be undersaturated →70% of pteropods affected by severe dissolution in the coastal regions

Bednarsek et al 2014

Q2: Are pteropods being affected right now?

Pteropod shell dissolution is not the case of future scenarios (82% stations showed dissolution, North, Coastal)



- Discerning anthropogenic carbon contribution (A vs. B picture)
- Much more spatially extensive than in the Southern Ocean with more individuals affected

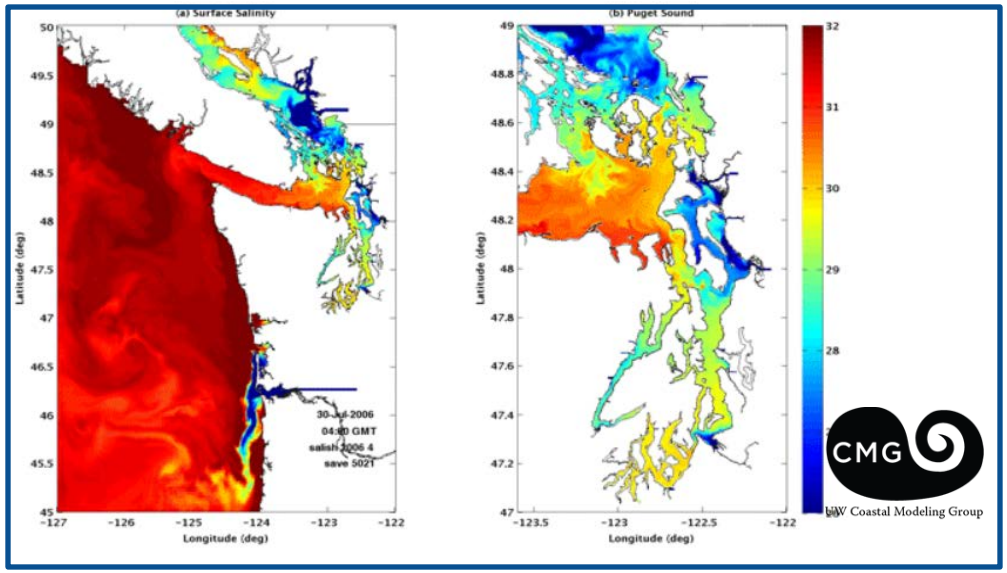
after Bednarsek et al 2014

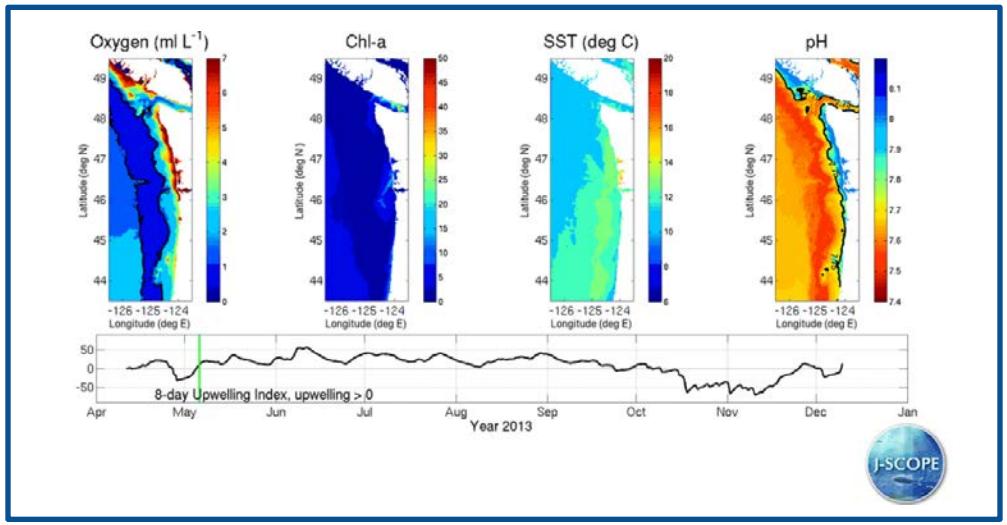
Pteropods as a sensitive indicators of OA in the natural environment

- **Several responses that can be measured *in situ*; some of them as rapid screening processes; fast response.**
- **Indicator for OA effects, discerning the effects of OA from other stressors (not possible in the other species).**
- **Extent of OA affects in the CCS, current dataset used as a new baseline, predicting pteropod thresholds.**
  - **NO shortage of data anymore (vulnerability, acclimatization, shift ranges)**
  - **OA [CO_3^{2-}] and hypoxia [O_2] forcing**

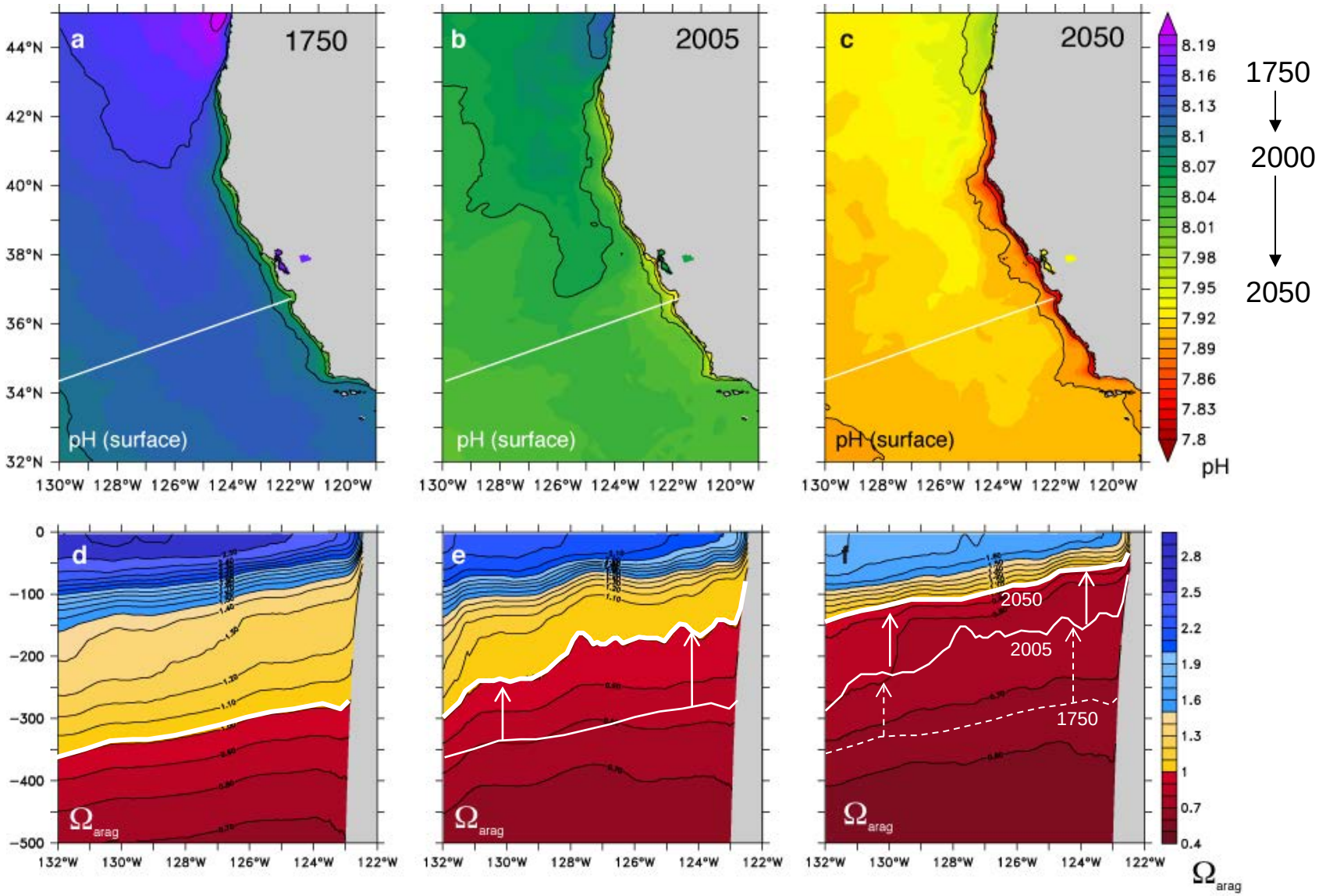
Modeling/predicting aragonite saturation state

- Two time scales:
  - Days to weeks; funded by WOAC
  - 3-6 months; J-SCOPE funded by NOAA FATE
- WOAC and NOAA observing data provide validation for both efforts





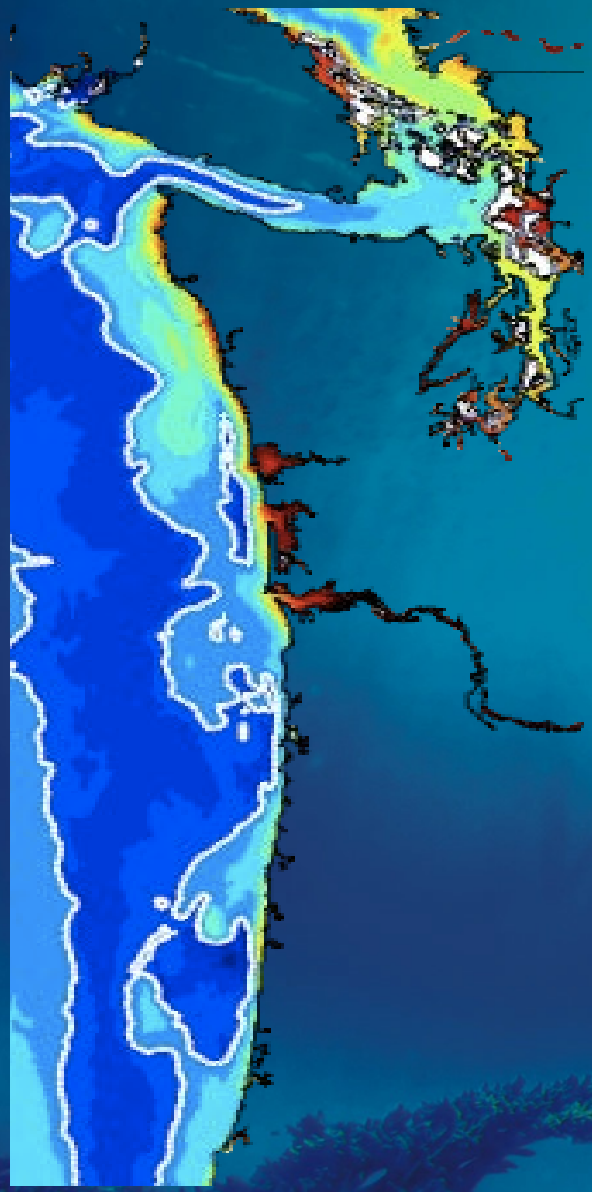
Evolution since 1750 and projection until 2050



Strong shoaling of the saturation horizon

Gruber et al. (2012)

Conclusions



- There is a seasonal progression in the acidification of coastal waters of Washington and Oregon
- Higher volume of the water column is undersaturated by the end of the upwelling season
- Local retention creates hot-spots of acidification
- Some species are impacted by acidification now