Science Recommendations of the Washington Blue Ribbon Panel on Ocean Acidification:

Overview, Status, and Gaps

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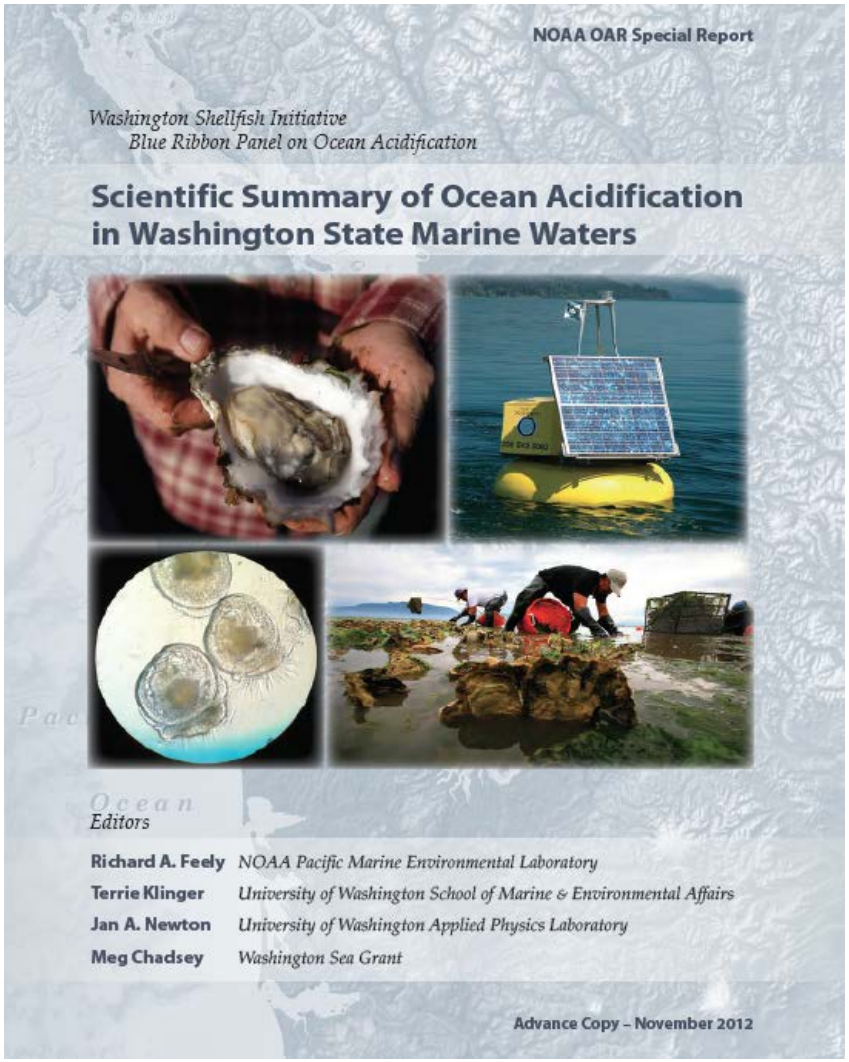
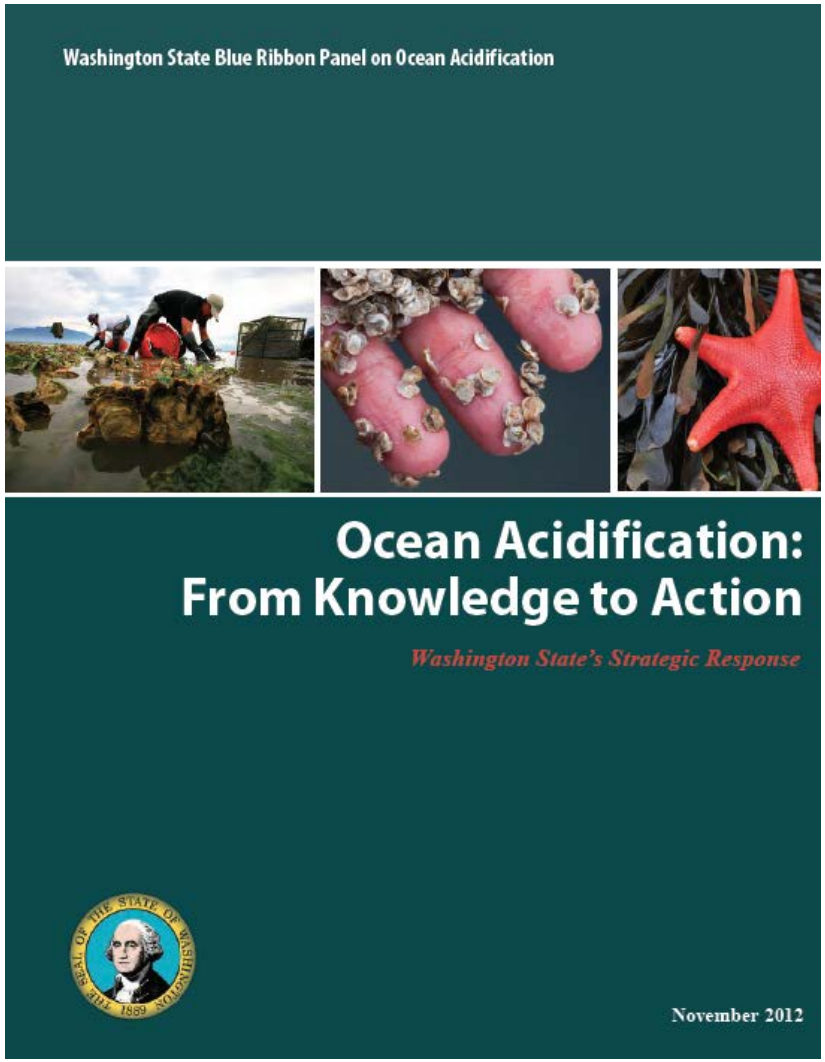
Washington State Panel Reports





http://www.ecy.wa.gov/water/marine/oceanacidification.html

Panel Recommendations

4. Address the root cause of acidification by reducing CO_2 emissions
5. Reduce local land-based pollutants that worsen acidification
6. Foster adaptation and remediation to protect the shellfish industry and marine ecosystems
7. Increase research and monitoring of acidification in state waters
8. Inform, educate, and engage the public, stakeholders, and decision makers in responding to ocean acidification
9. Maintain a sustainable and coordinated focus on ocean acidification

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Foster adaptation and remediation to protect the shellfish industry and marine ecosystems

Strategy 6.1 – Remediate seawater chemistry.

Strategy 6.2 – Increase the capacity of resource managers and the shellfish industry to adapt to ocean acidification.

Strategy 6.3 – Enhance resilience of native and cultivated shellfish populations and ecosystems on which they depend.

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Foster adaptation and remediation to protect the shellfish industry and marine ecosystems

Strategy 6.2 – Increase the capacity of resource managers and the shellfish industry to adapt to ocean acidification.

Action 6.2.1: Ensure continued water quality monitoring at the six existing shellfish hatcheries and rearing areas to enable real-time management of hatcheries under changing pH conditions**. [KEA] ****

Action 6.2.2: Expand the deployment of instruments and chemical monitoring to post-hatchery shellfish facilities and farms

Action 6.2.3: Investigate and develop commercial-scale water treatment methods or hatchery designs to protect larvae from corrosive seawater**. [KEA] ****

Action 6.2.4: Develop and incorporate acidification indicators and thresholds to guide adaptive action for species and places.

Panel Recommendations

4. Address the root cause of acidification by reducing CO_2 emissions;
5. Reduce local land-based pollutants that worsen acidification;
6. Foster adaptation and remediation to protect the shellfish industry and marine ecosystems;
7. Increase research and monitoring of acidification in state waters;
8. Inform, educate, and engage the public, stakeholders, and decision makers in responding to ocean acidification; and
9. Maintain a sustainable and coordinated focus on ocean acidification.

Increase research and monitoring of acidification in state waters

Strategy 7.1 – Understand the status and trends of ocean acidification in Washington's marine waters.

Strategy 7.2 - Identify factors that contribute to ocean acidification in Washington waters, and estimate the relative contribution of each.

Strategy 7.3 - Characterize biological responses of local species to ocean acidification and associated stressors.

Strategy 7.4 – Build capabilities for short-term forecasting and long-term prediction of ocean acidification.

Increase research and monitoring of acidification in state waters

Strategy 7.1 – Understand the status and trends of ocean acidification in Washington's marine waters.

<u>Action 7.1.1</u>: Establish an expanded and sustained ocean acidification monitoring network to measure trends in local ocean acidification conditions and related biological responses [KEA] **

Action 7.1.2: Develop predictive relationships for indicators of ocean acidification (pH and aragonite saturation state).

Action 7.1.3: Support development of new technologies for monitoring ocean acidification.

Increase research and monitoring of acidification in state waters

Strategy 7.2 - Identify factors that contribute to ocean acidification in Washington waters, and estimate the relative contribution of each.

Action 7.2.1: Quantify key natural and human-influenced processes that contribute to acidification based on estimates of sources, sinks, and transfer rates for carbon and nitrogen. [KEA]

Action 7.2.2: Develop new models or refine existing models to include biogeochemical processes of importance to ocean acidification.

Increase research and monitoring of acidification in state waters

Strategy 7.3 - Characterize biological responses of local species to ocean acidification and associated stressors.

Action 7.3.1: Determine the associations between water and sediment chemistry and shellfish production in hatcheries and in the natural environment. [KEA]

Action 7.3.2: Conduct laboratory studies to assess the direct effects of ocean acidification, alone and in combination with other stressors, on local species and ecosystems.[KEA] **

Action 7.3.3: Conduct field studies to characterize the effects of ocean acidification, alone and in combination with other stressors, on local species.

Increase research and monitoring of acidification in state waters

Strategy 7.4 – Build capabilities for short-term forecasting and long-term prediction of ocean acidification.

<u>Action 7.4.1</u>: Establish the ability to make short-term forecasts of corrosive conditions for application to shellfish hatcheries, growing areas, and other areas of concern. [KEA] **

Action 7.4.2: Enhance the ability to predict the long-term future status of carbon chemistry and pH in Washington waters and create models to project ecological responses to predicted ocean acidification conditions.

Action 7.4.3: Enhance the ability to model the response of organisms and populations to ocean acidification to improve our understanding of biological responses.

Washington OA Center
Progress on Implementation

Progress on Implementation:
Adaptation and Remediation

Action 6.2.1: Ensure continued water quality monitoring at the six existing shellfish hatcheries and rearing areas to enable real-time management of hatcheries under changing pH conditions. [KEA] **

Contract awarded to PCSGA:

- equipment and supplies to bolster existing effort
- technician salary and travel
- QA analyses
- local OA monitoring expert
- South Sound buoy enhancement (Y1 only)

A contribution to our Washington OA monitoring strategy

Progress on Implementation:
Adaptation and Remediation

<u>Action 6.2.3</u>: Investigate and develop commercial-scale water treatment methods or hatchery designs to protect larvae from corrosive seawater. [KEA] **

Contract to PCSGA:

- addition of tCO_2 monitoring capability at Taylor Shellfish
- ability to calculate water corrosivity in near-real time
- experimental water treatment work with oxygenation

Provide circumstantial knowledge on response of organisms under treatment methods

Progress on Implementation:
Monitoring Network

<u>Action 7.1.1</u>: Establish an expanded and sustained ocean acidification monitoring network to measure trends in local ocean acidification conditions and related biological responses [KEA] **

Partnership effort WA coast, Puget Sound, Northern Strait, Columbia River to include:

- Ship cruises
- High temporal resolution buoy observations
- Targeted time series and sensor upgrades

Integrated with shellfish monitoring sites
Data via existing NANOOS portal

Progress on Implementation:
Laboratory Studies

Action 7.3.2: Conduct laboratory studies to assess the direct effects of ocean acidification, alone and in combination with other stressors, on local species and ecosystems.[KEA] **

Competitive RFP, peer-reviewed, selection:

- Awarded to UW, WWU, and NOAA team
- Studies on krill, Dungeness crab, geoduck, copepods, and Olympia oysters
- Highly leveraged

Provides key information to future biological modeling

Progress on Implementation: Forecasting

Action 7.4.1: Establish the ability to make short-term forecasts of corrosive conditions for application to shellfish hatcheries, growing areas, and other areas of concern. [KEA] **

Competitive RFP, peer-reviewed, selection:

Awarded to UW Coastal Modeling Group
Coastal forecast due in Year 1
Puget Sound forecast due in Year 2

Allows for adaptation and natural resource management decisions.
Identifies spatial and temporal variation in OA signal

Summary

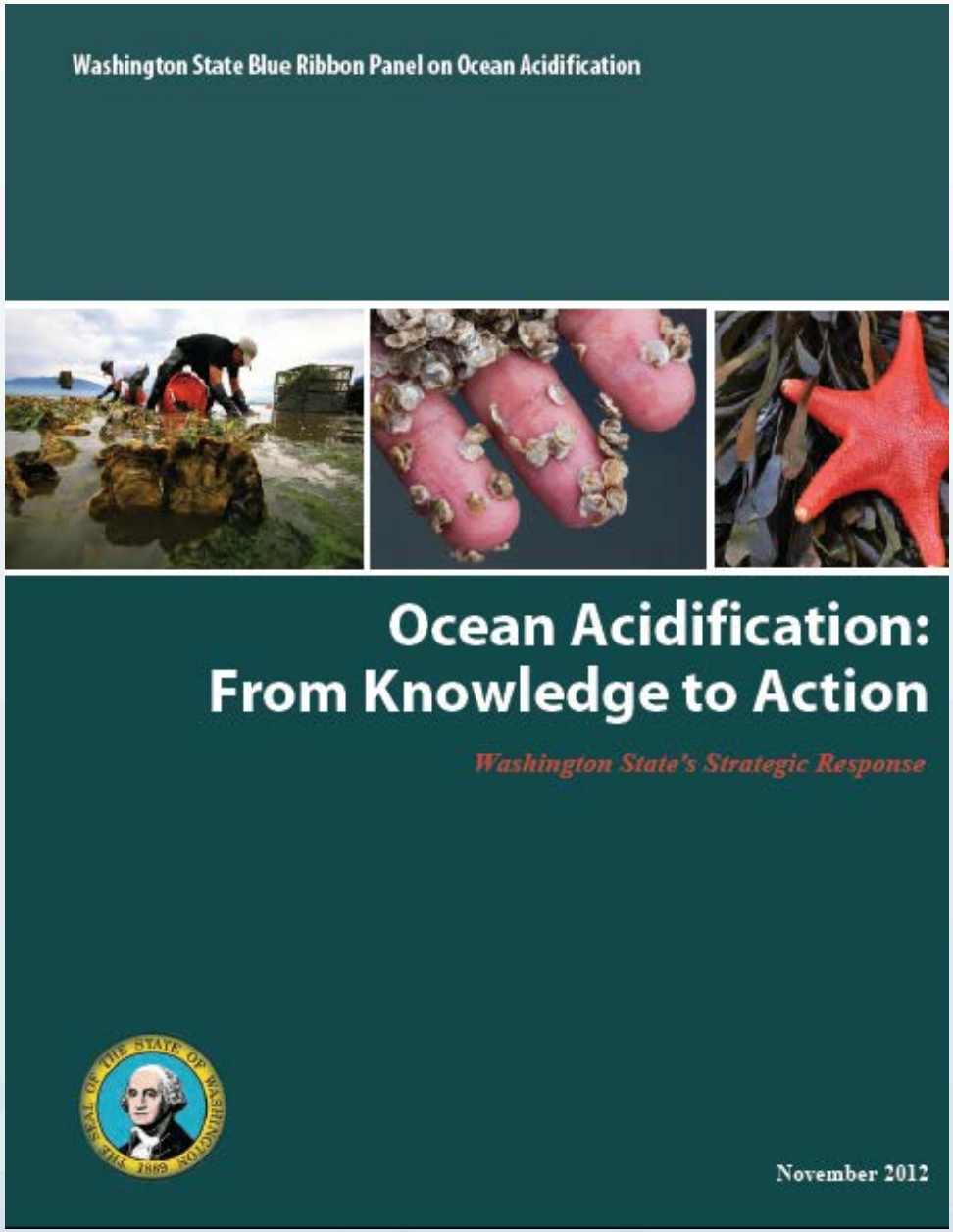
The Washington OA Center was funded to implement five science actions recommended by the BRP and selected by the Legislature during this biennium.

The Center has made awards for four of these and is actively engaged in planning full implementation of the fifth.

A number of recommendations of the Blue Ribbon Panel remain to be addressed; some of these may be best implemented in sequence and others may be priority gaps to address.

We will work with the MRAC sub-committee to assist their work to make recommendations on priority gaps, to be addressed by future action of the legislature or other entities.

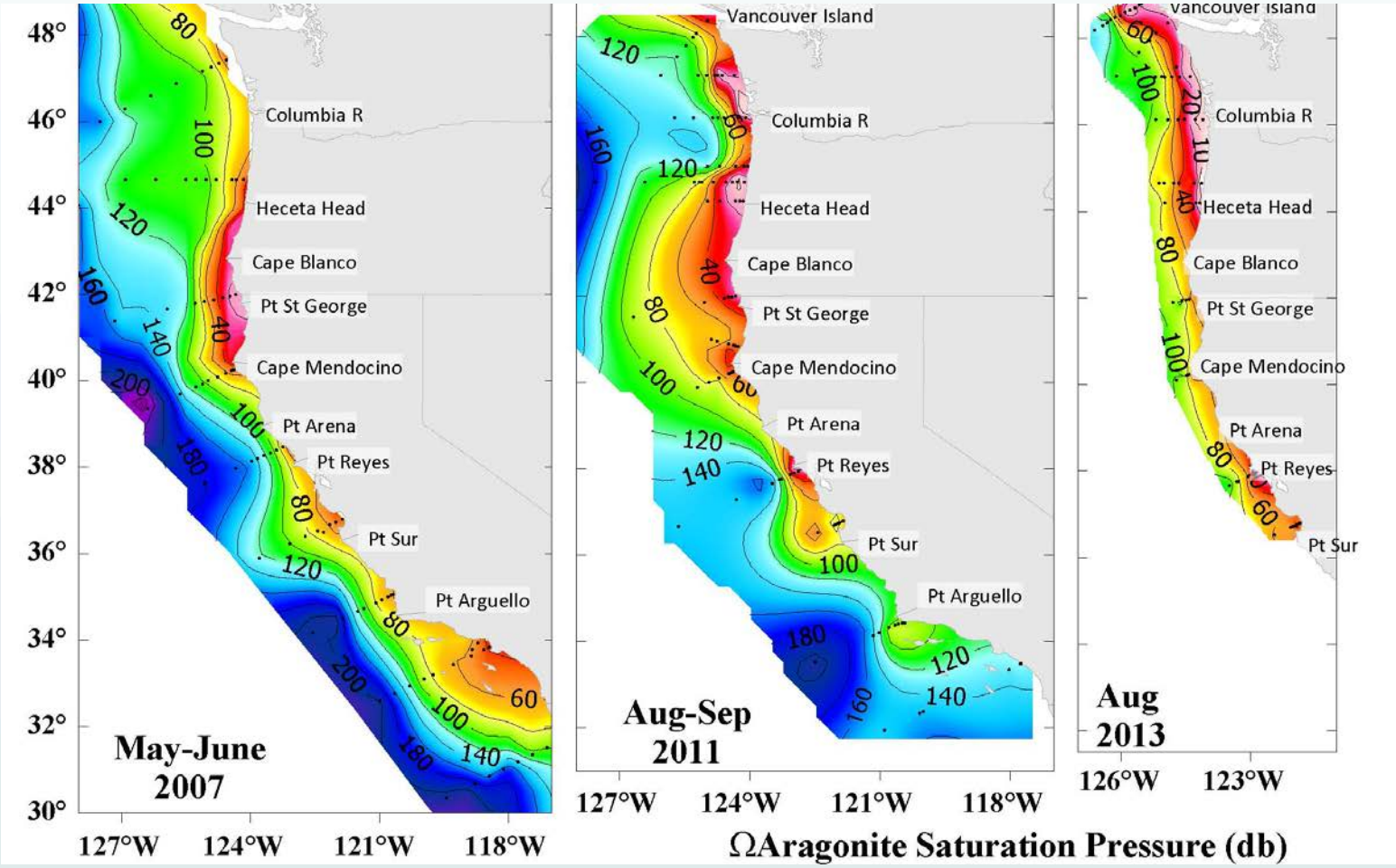
Washington Blue Ribbon Panel on OA



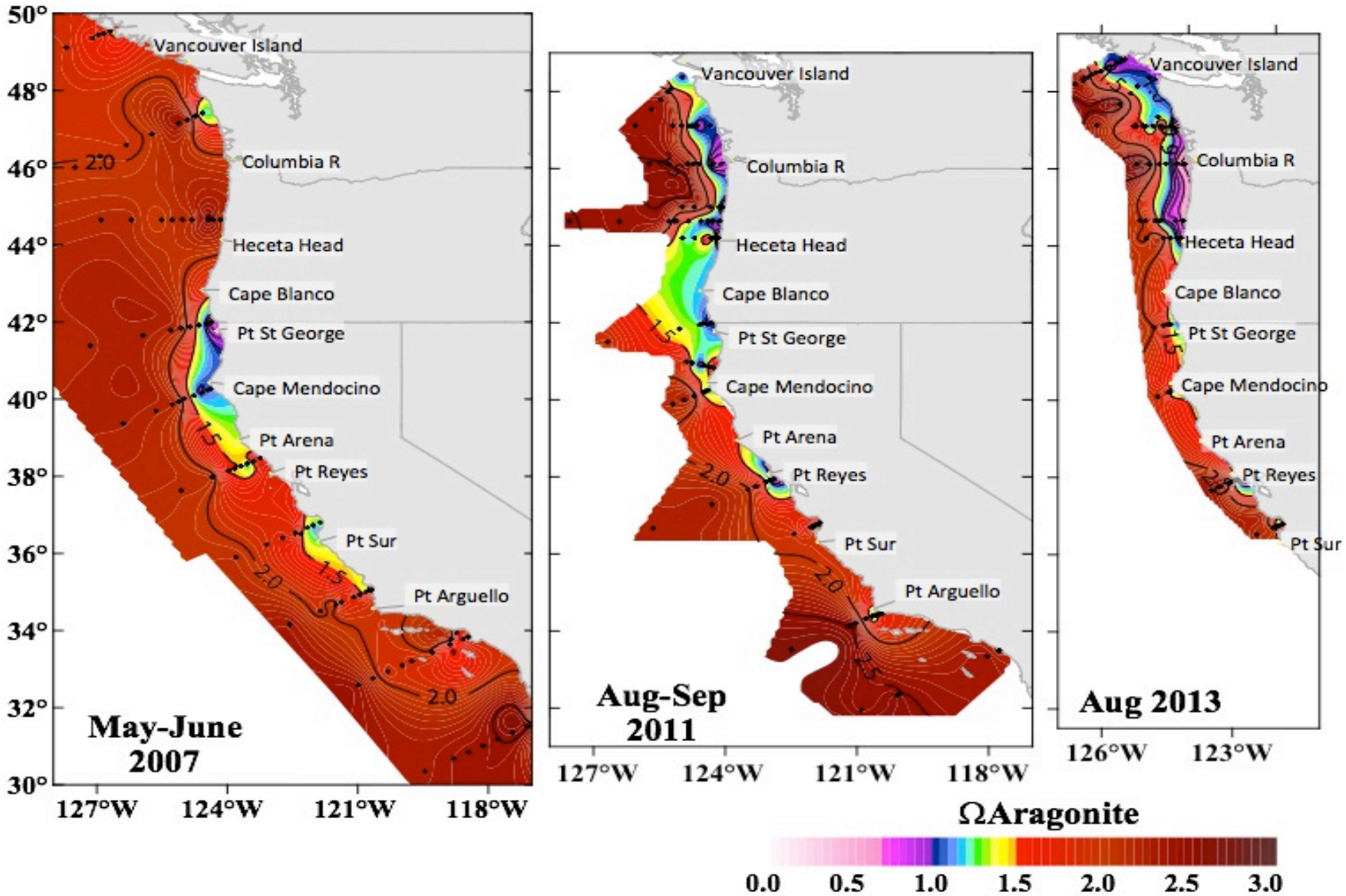
Recommended Key Early Action:

Quantify key natural and human-influenced processes that contribute to acidification based on estimates of sources, sinks, and transfer rates for carbon and nitrogen.

Location of the corrosive water from spring 2007 to summer 2013

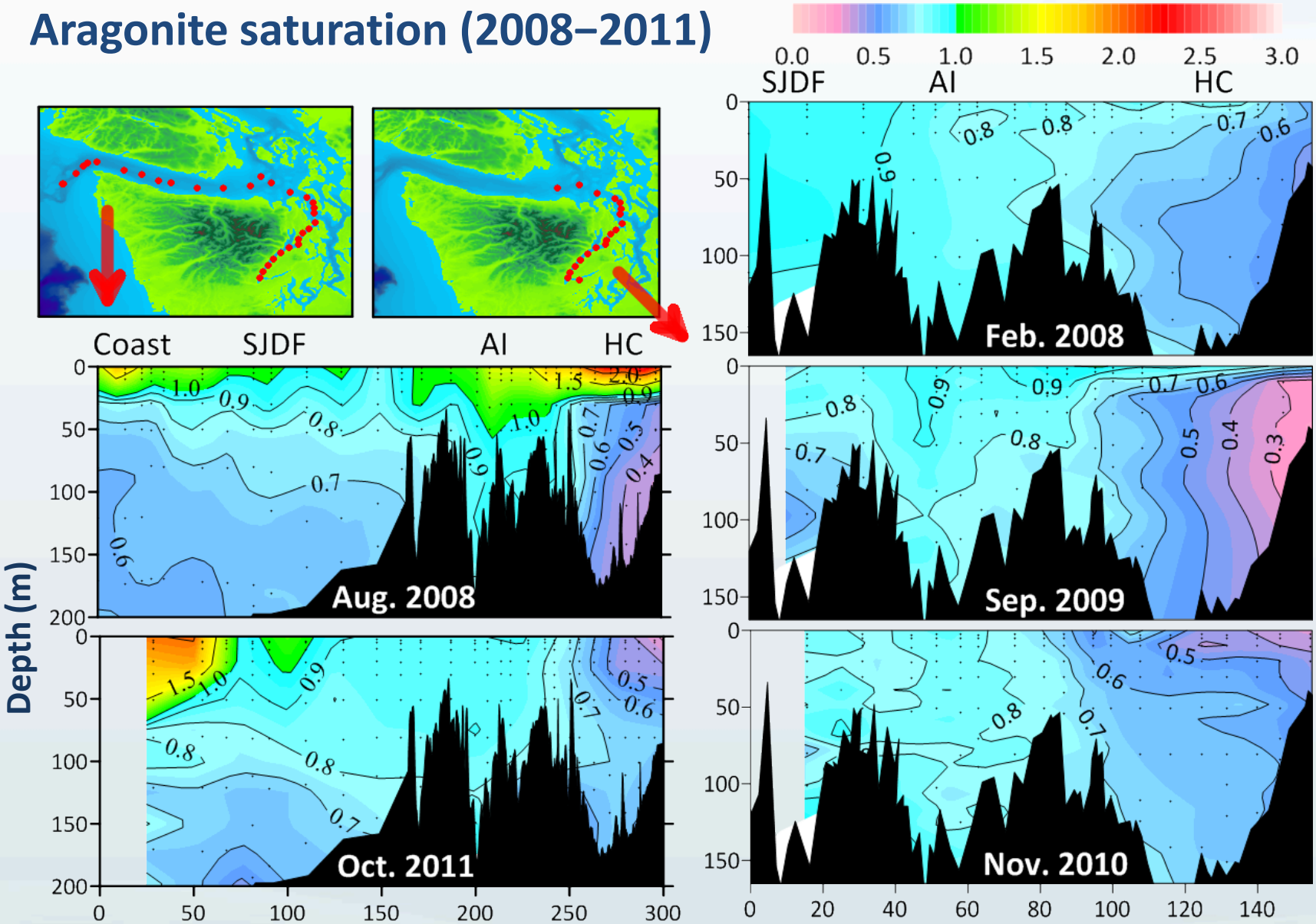


Aragonite Saturation at 20 m depth from spring 2007 to summer 2013



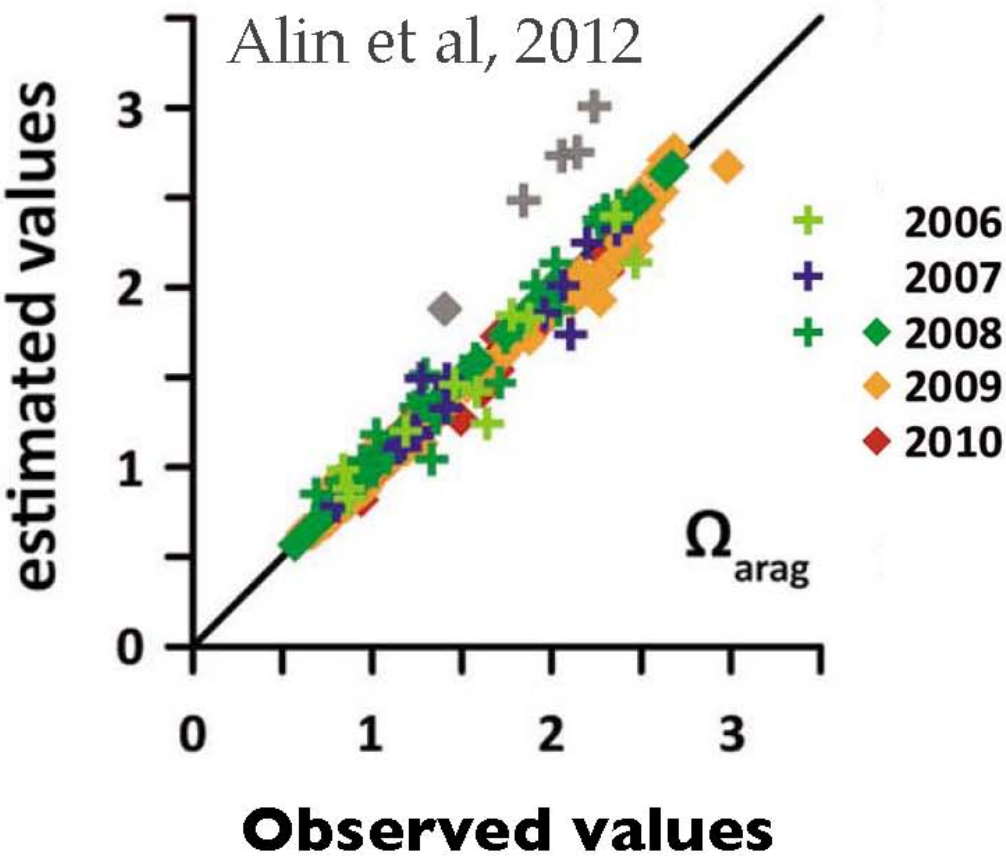
Corrosive conditions in Hood Canal

Aragonite saturation (2008–2011)



Alin et al. in prep,
Feely et al. 2010

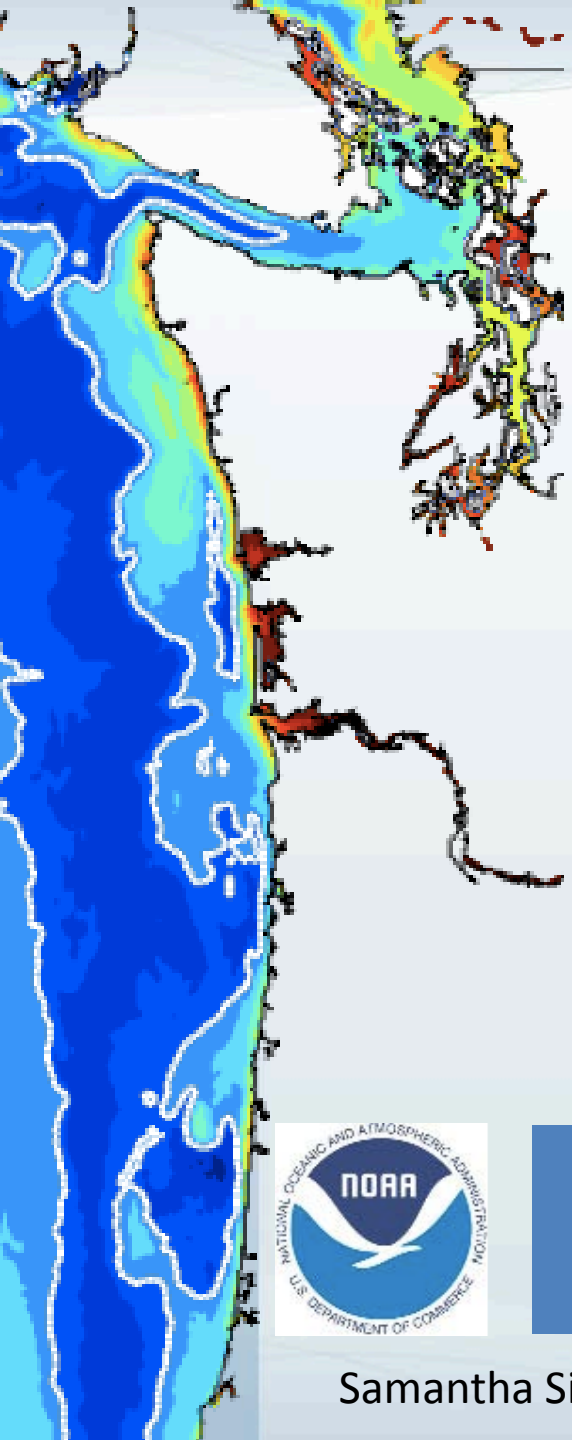
Predicting Aragonite Saturation state using Temperature and Oxygen



Good agreement between measured and calculated values through the use of Oxygen and Temperature to predict aragonite saturation and other carbonate parameters

Application limited in time and in freshwater

see also Juranek et al, 2009



JISAO's Seasonal Coastal Ocean Prediction of the Ecosystem (J-SCOPE)

UNIVERSITY of WASHINGTON

JISAO

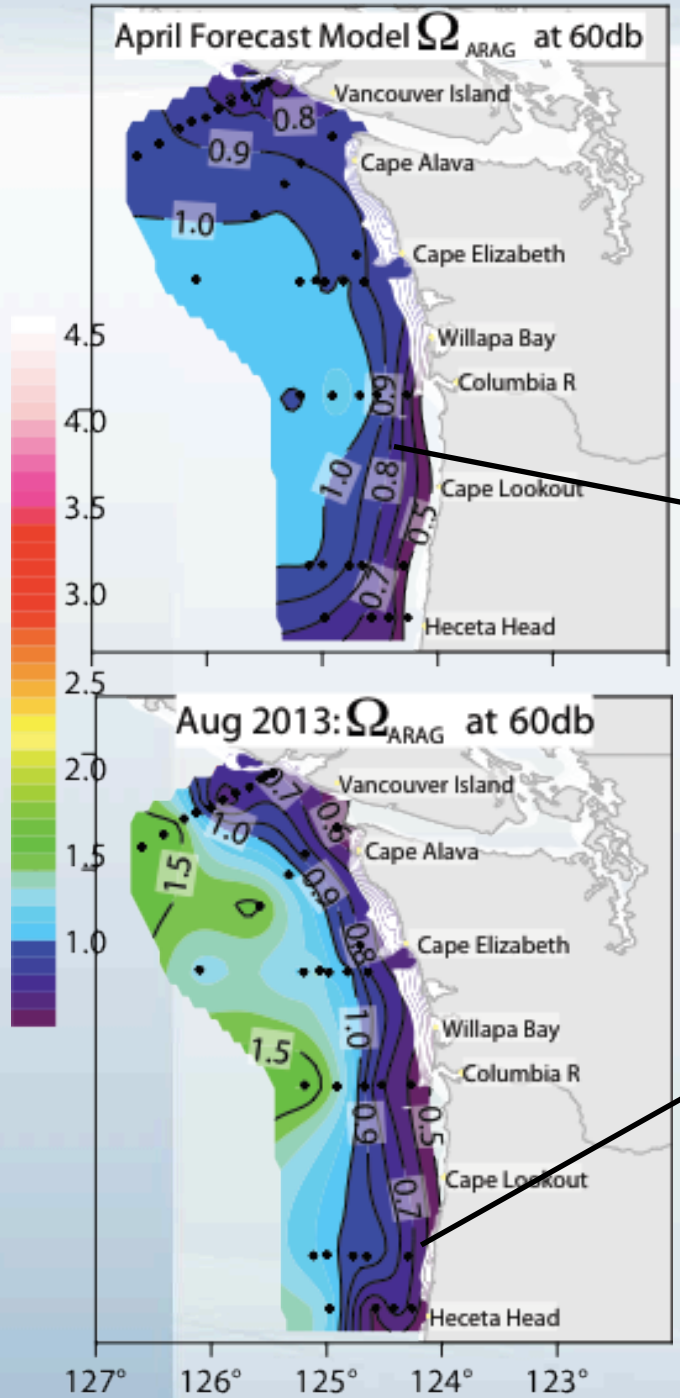
NOAA

CMG
UW Coastal Modeling Group

NWFSC
NORTHWEST FISHERIES SCIENCE CENTER

NANOOS

Samantha Siedlecki et al, in prep



Model

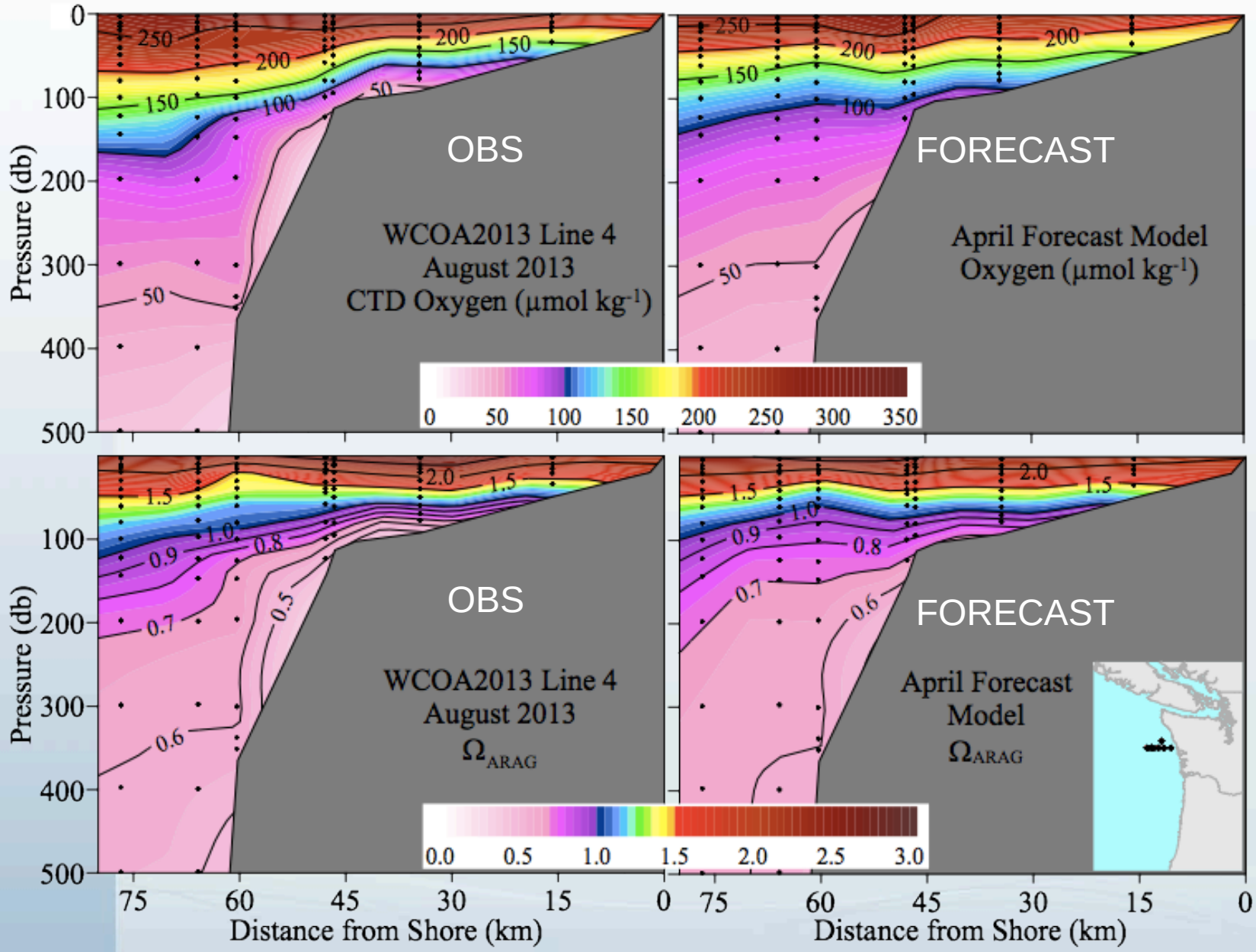
Observed

J-SCOPE forecast captures spatial variability (subsurface)

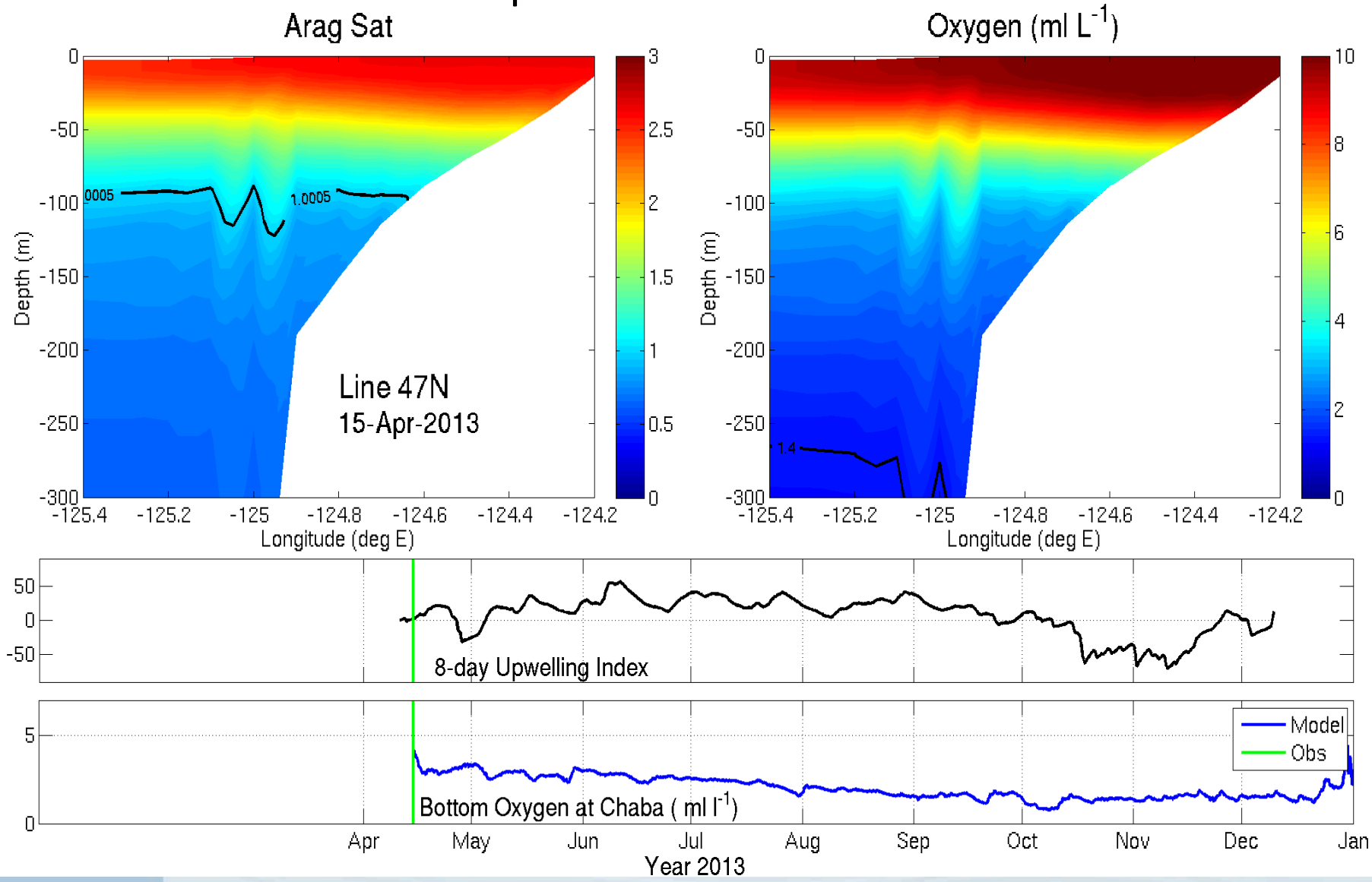
N-S trend along the coast, Oregon experiences more corrosive water shallower

Use T and O_2 to calculate Ω from local observed relationships determined by Alin et al, unpub; and Alin et al, 2012.

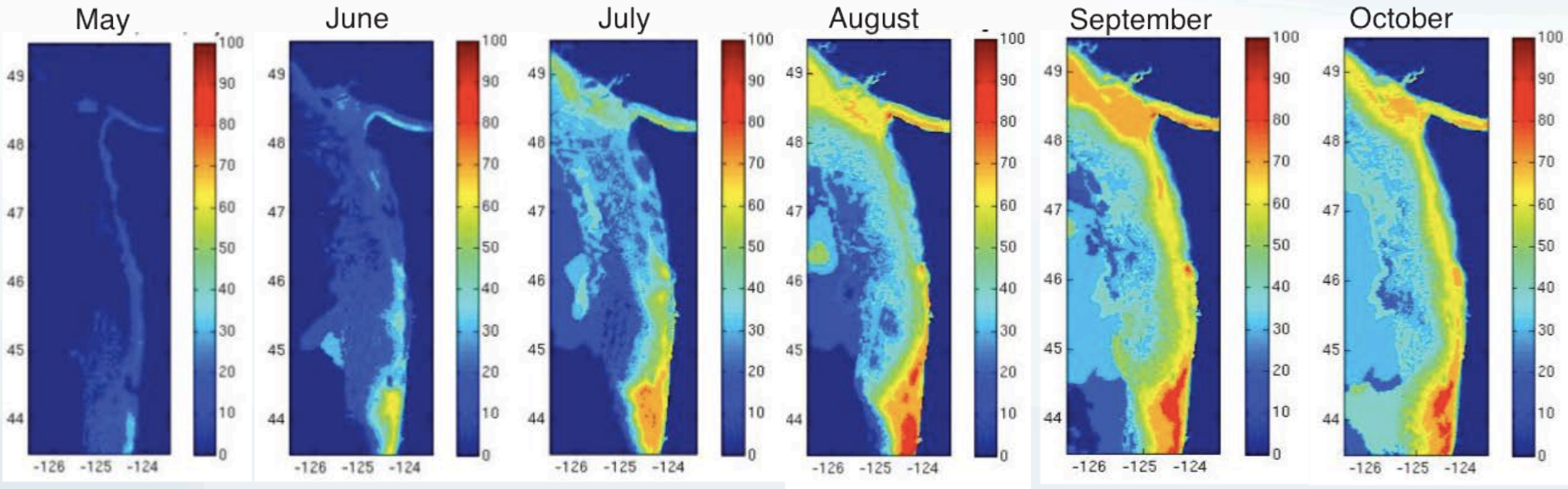
J-SCOPE forecast predicts outer shelf water properties



Temporal Changes in Aragonite Saturation and Oxygen Concentrations April to October 2013



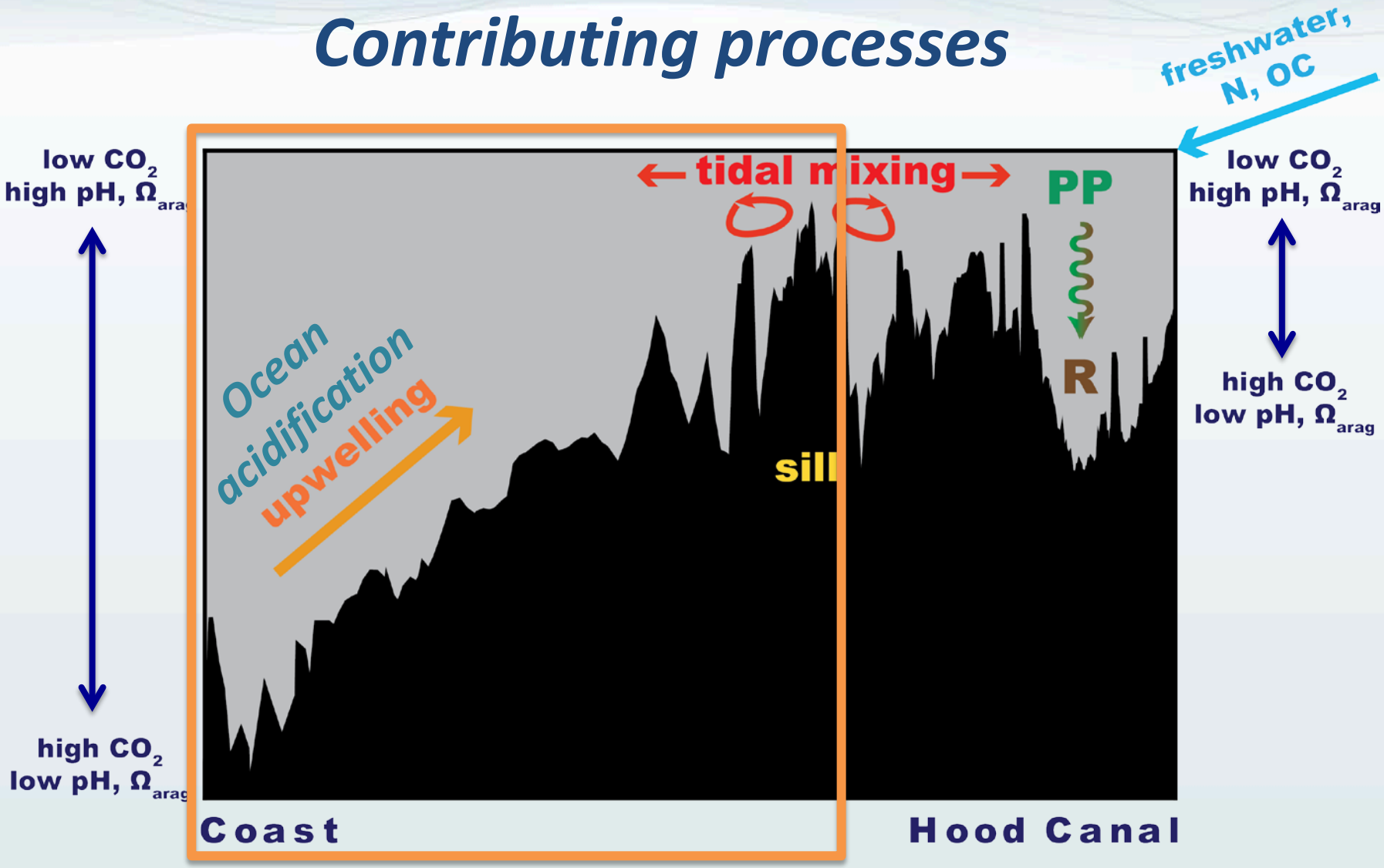
Seasonal Increase in Volume of Undersaturated water



Ω

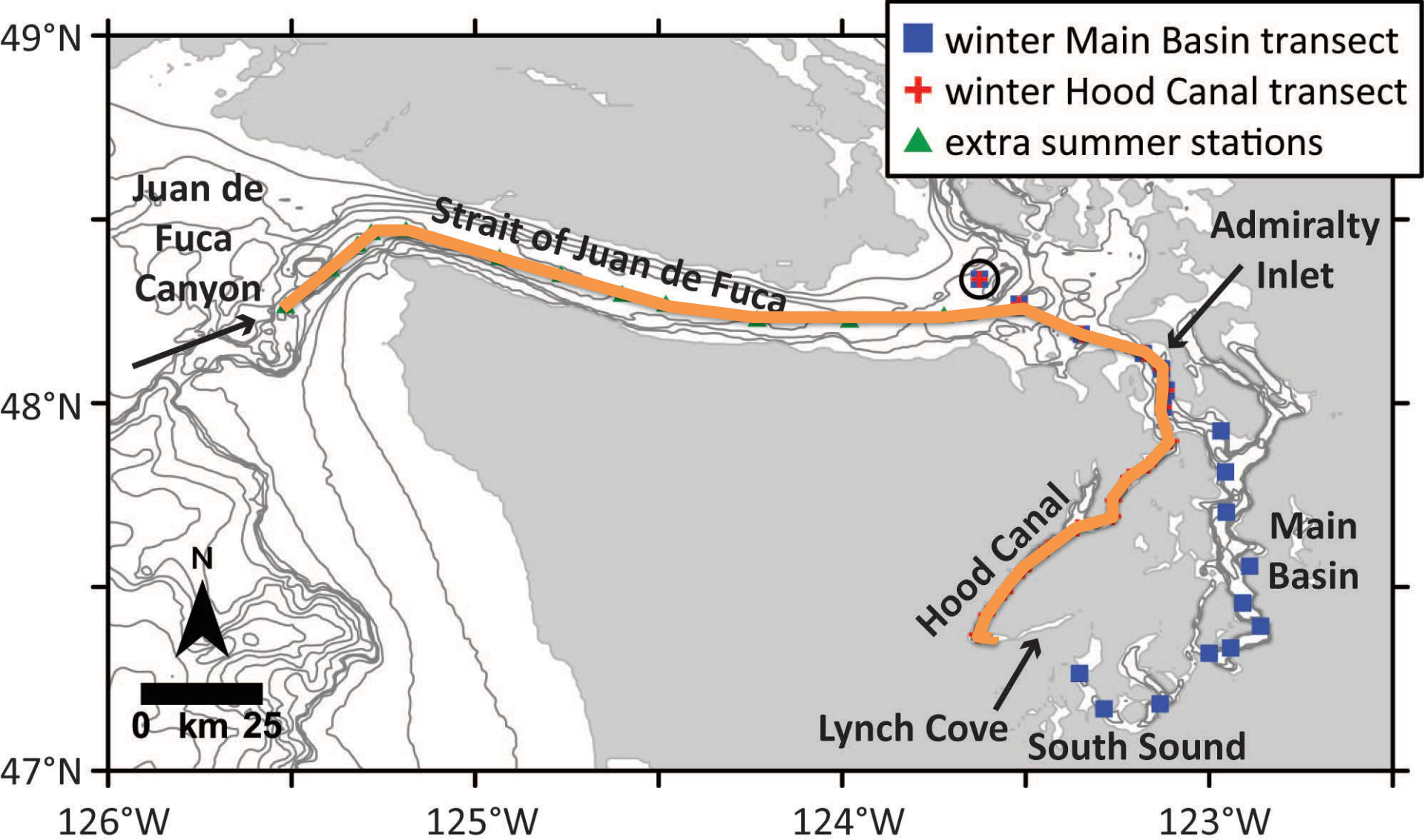
Maps of percent of the upper 100 m of the water column that is undersaturated with respect to aragonite

Contributing processes



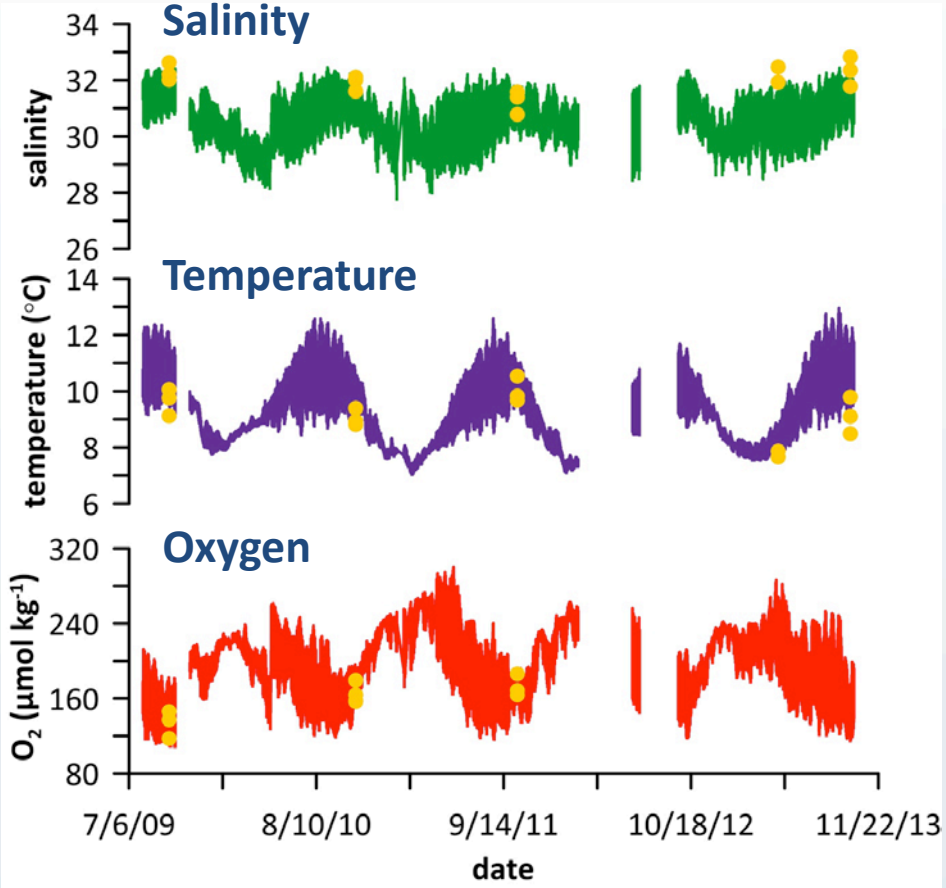
Natural factors: upwelling, tidal mixing, production-respiration

Human-influenced factors: Ocean acidification, nutrients



- Five cruises from Hood Canal into the Strait of Juan de Fuca or to the coast – snapshots from 2008-2011.
- Need more continuous time series.

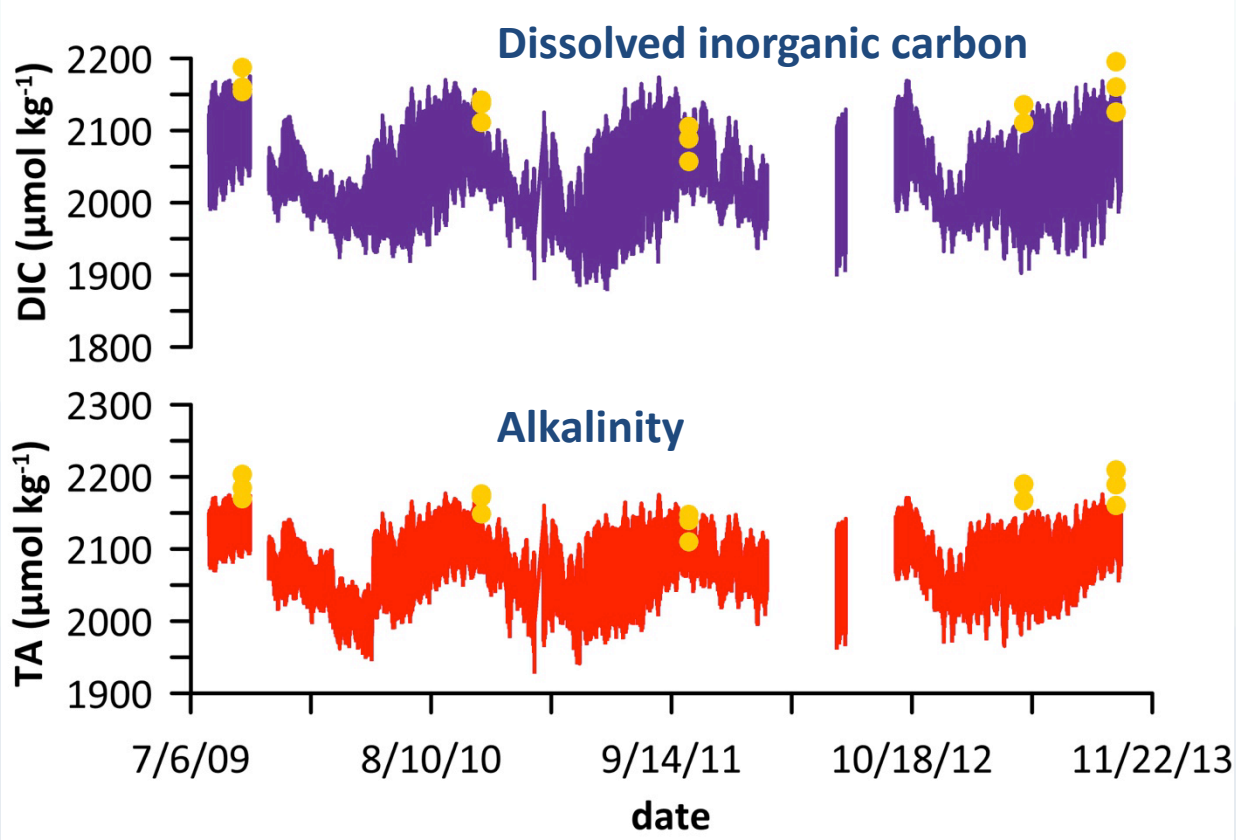
Estimating the role of ocean acidification



- **Bottom-mounted mooring at Admiralty Inlet** (UW-APL/WA Dept. Ecology)
- **Temperature, salinity, and O_2 used to estimate carbon system**
- **Yellow dots represent cruise data near mooring**

Alin et al. in prep

Carbon estimates agree well with observations



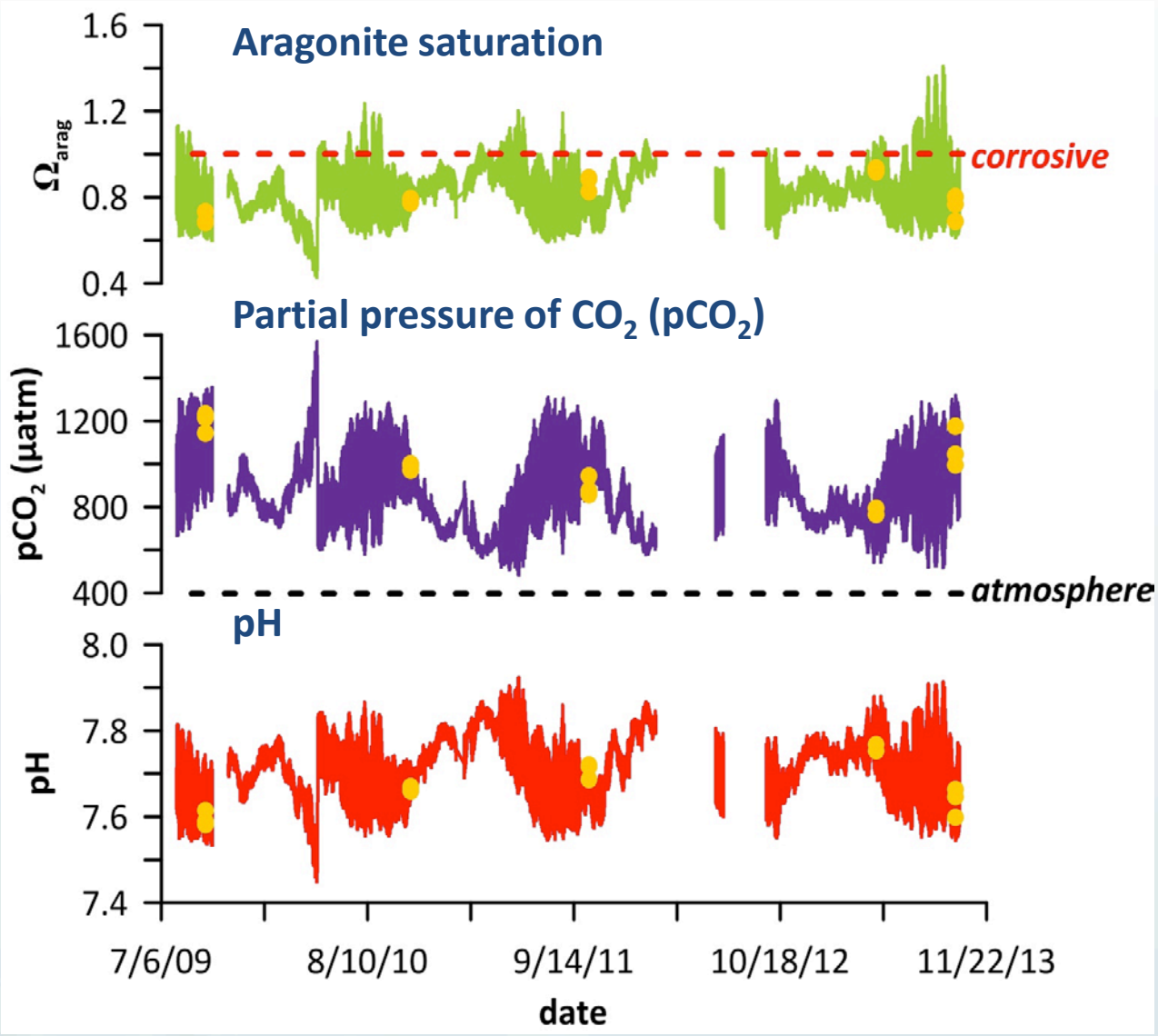
DIC = *f*(O_2, density)

TA = *f*(Temp, Salinity)

- **Used DIC and TA to calculate Ω_{arag}, pH, and pCO_2**
- **Good agreement. Sampling has been at times when higher DIC and TA conditions were present at the sill.**

Alin et al. in prep

Present-day water entering Puget Sound

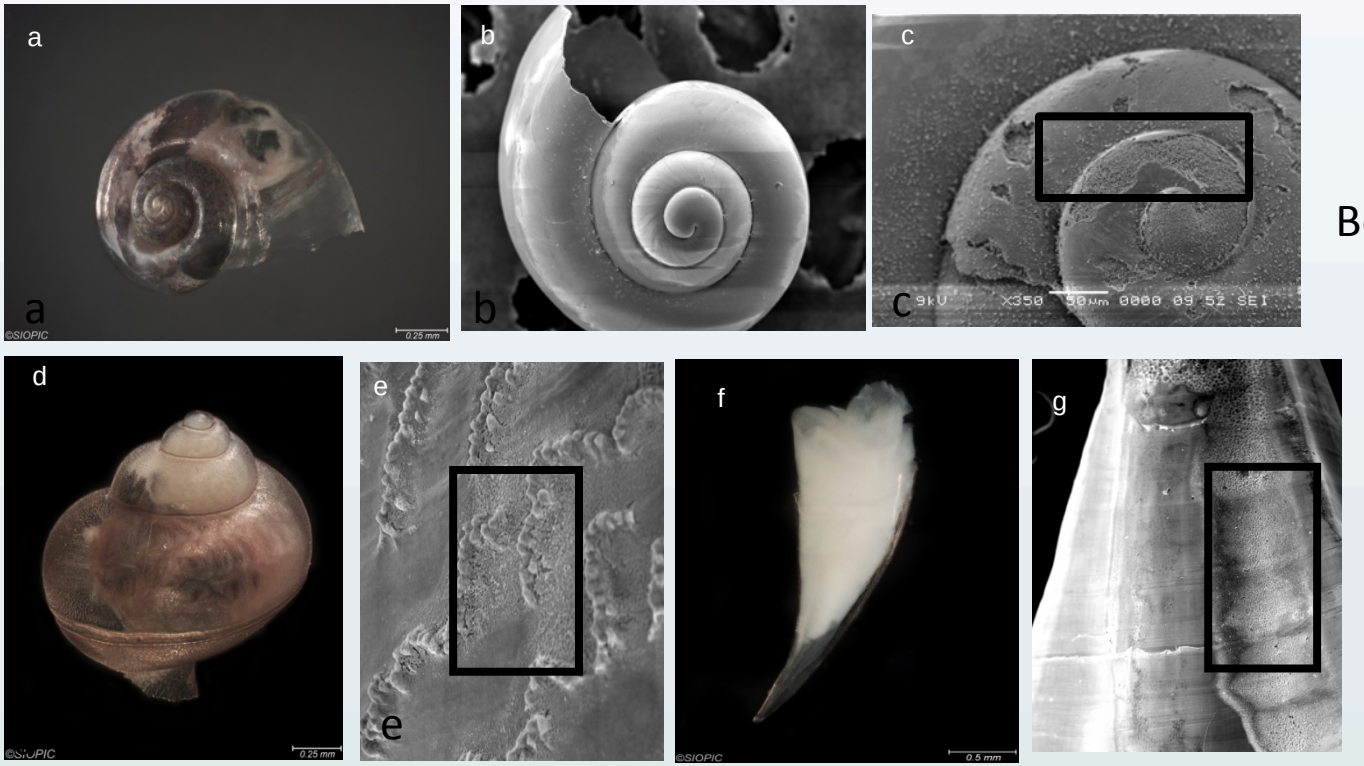


- Is often corrosive to aragonite (Ω_{arag}<1)
- Average pCO_2 is >2 x atmospheric values (880 µatm)
- pH is always <8, sometimes < 7.5
- Depth 50–70 m

Alin et al. in prep

Implication of ocean acidification on changes in a) shell dissolution, b) vertical distribution, and c) species richness reduction

<u>a) Surface shell dissolution is affecting different pteropod and heteropod species</u>

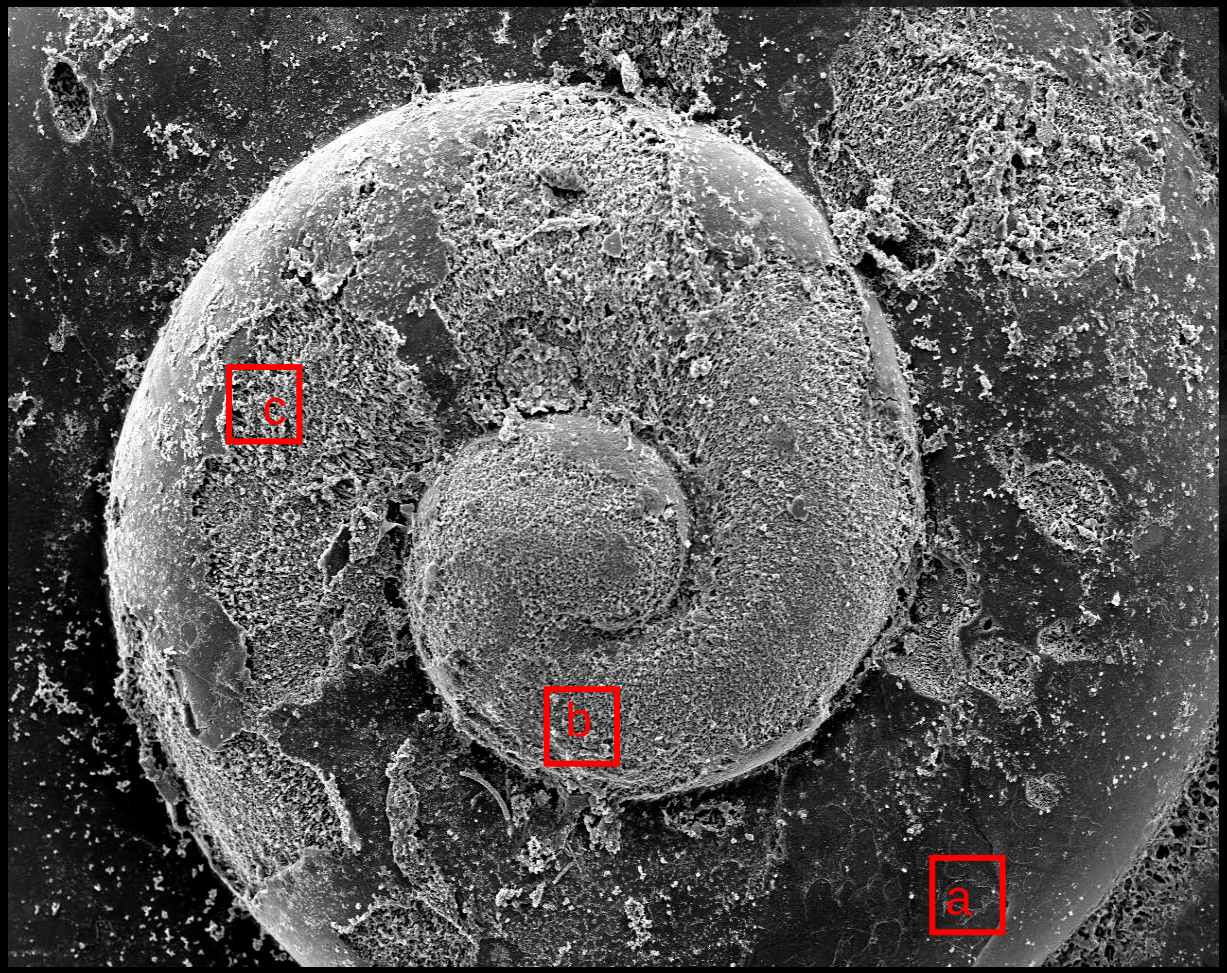


Bednarsek et al., in prep

Dissolution pattern: *Limacina helicina*: a) intact shell, b) SEM photo of intact shell, c) dissolved surface; *Peraclis bispinosa*: d) no dissolution; e) dissolution affecting shell structure; *Clio pyramidata*: f) no surface dissolution, g) surface shell dissolution along the vertical axis.

Pteropod Shell Dissolution

Pteropod shell dissolution is happening in the natural environment of the California Current System already…



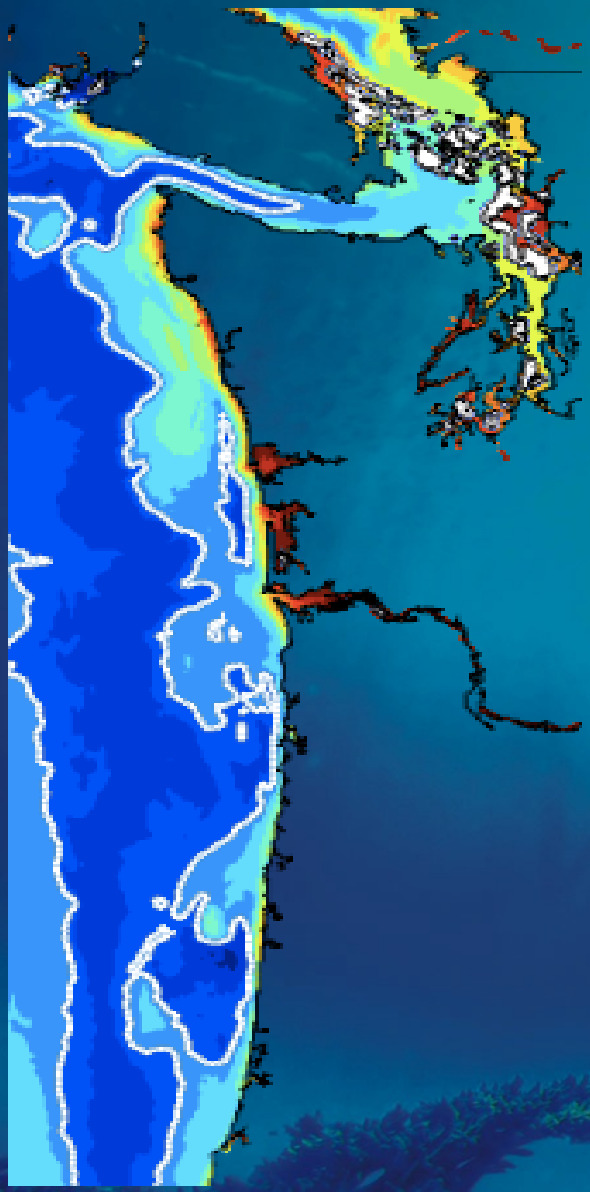
the most affected Northern and Central coastal regions, much less dissolution in the off-shore regions

→ Southern CCS not affected

→ considerable impact on pteropod community→ indicator of ocean heath-→ prediction

Bednarsek et al (in revision)

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