Ocean Acidification in Pacific Northwest Waters

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Outline

- Why coastal oceans are especially vulnerable
- Recent OA results for the U.S. West Coast
- OA in an estuarine environment: Hood Canal

With Simone Alin (PMEL), Chris Sabine (PMEL), and Jan Newton (UW)

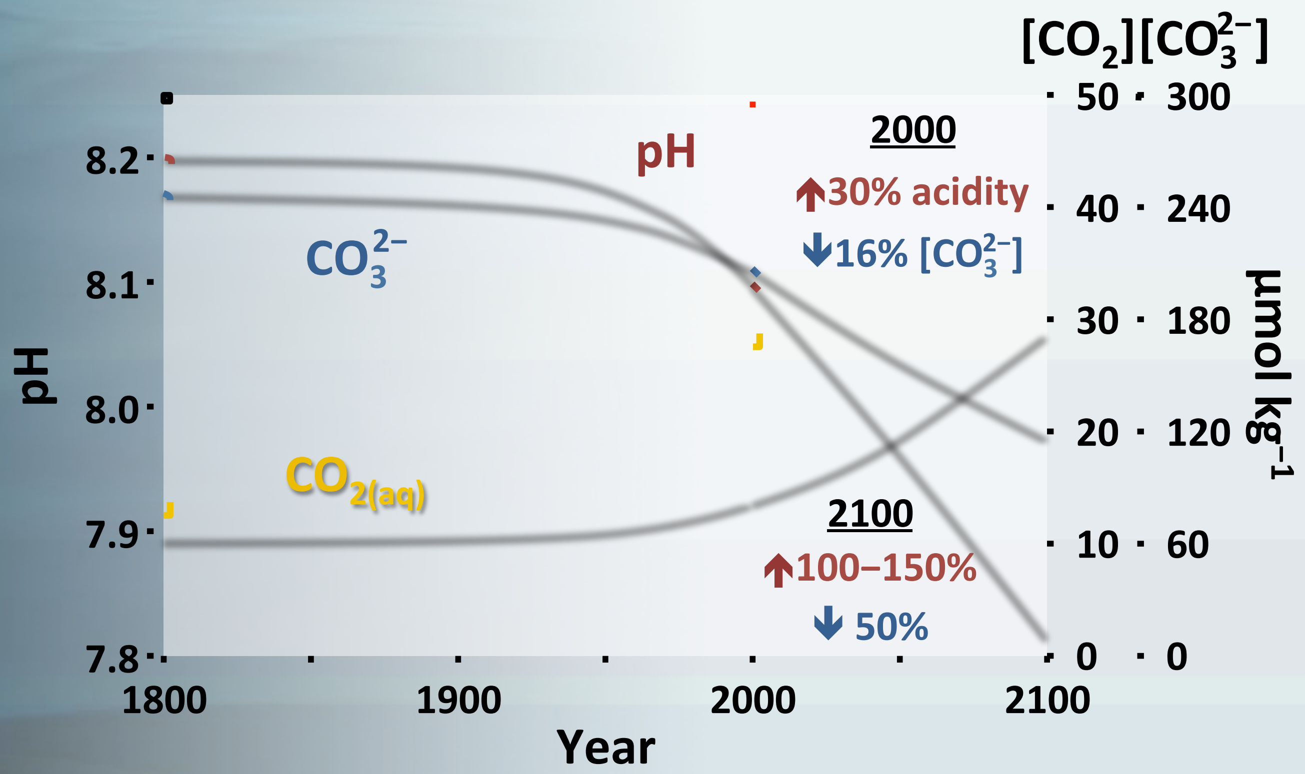
Sea Grant Washington

Ocean Acidification

$$CO_2 + H_2O \rightarrow H_2CO_3 \rightarrow H^+ + HCO_3^-$$

$$CO_2 + CO_3^{2-} + H_2O \Leftrightarrow 2HCO_3^-$$

$$H^+ + CO_3^{2-} \rightarrow HCO_3^-$$



Wolf-Gladrow et al. (1999)

Saturation State

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

calcium carbonate calcium carbonate

Saturation State

$$\Omega_{phase} = \frac{[Ca^{2+}][CO_3^{2-}]}{K^{*}_{sp,phase}}$$

$\Omega > 1$ $CaCO_3$ precipitates

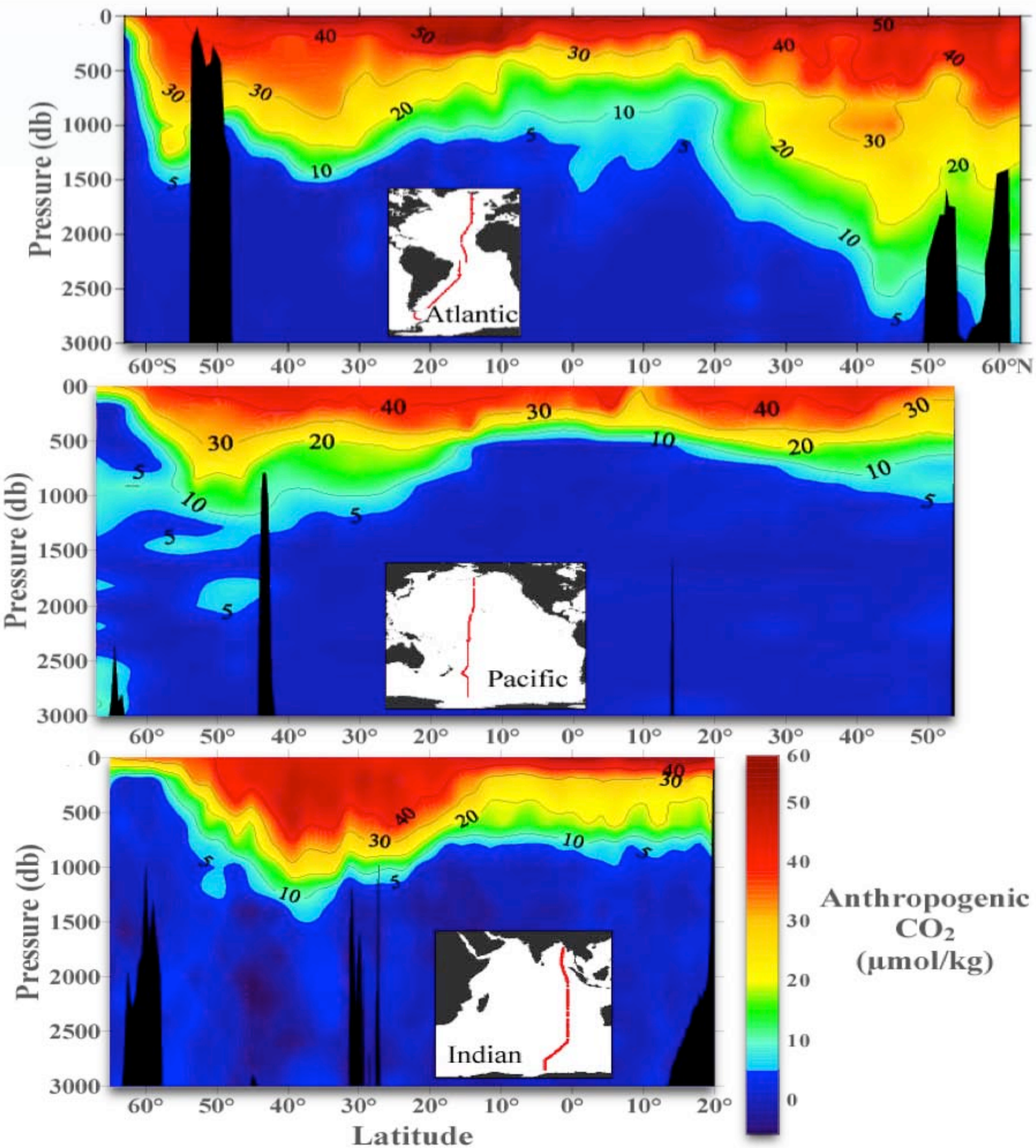
$\Omega = 1$ equilibrium

$\Omega < 1$ $CaCO_3$ dissolves

Common carbonate minerals:

aragonite (more soluble) and calcite (less soluble)

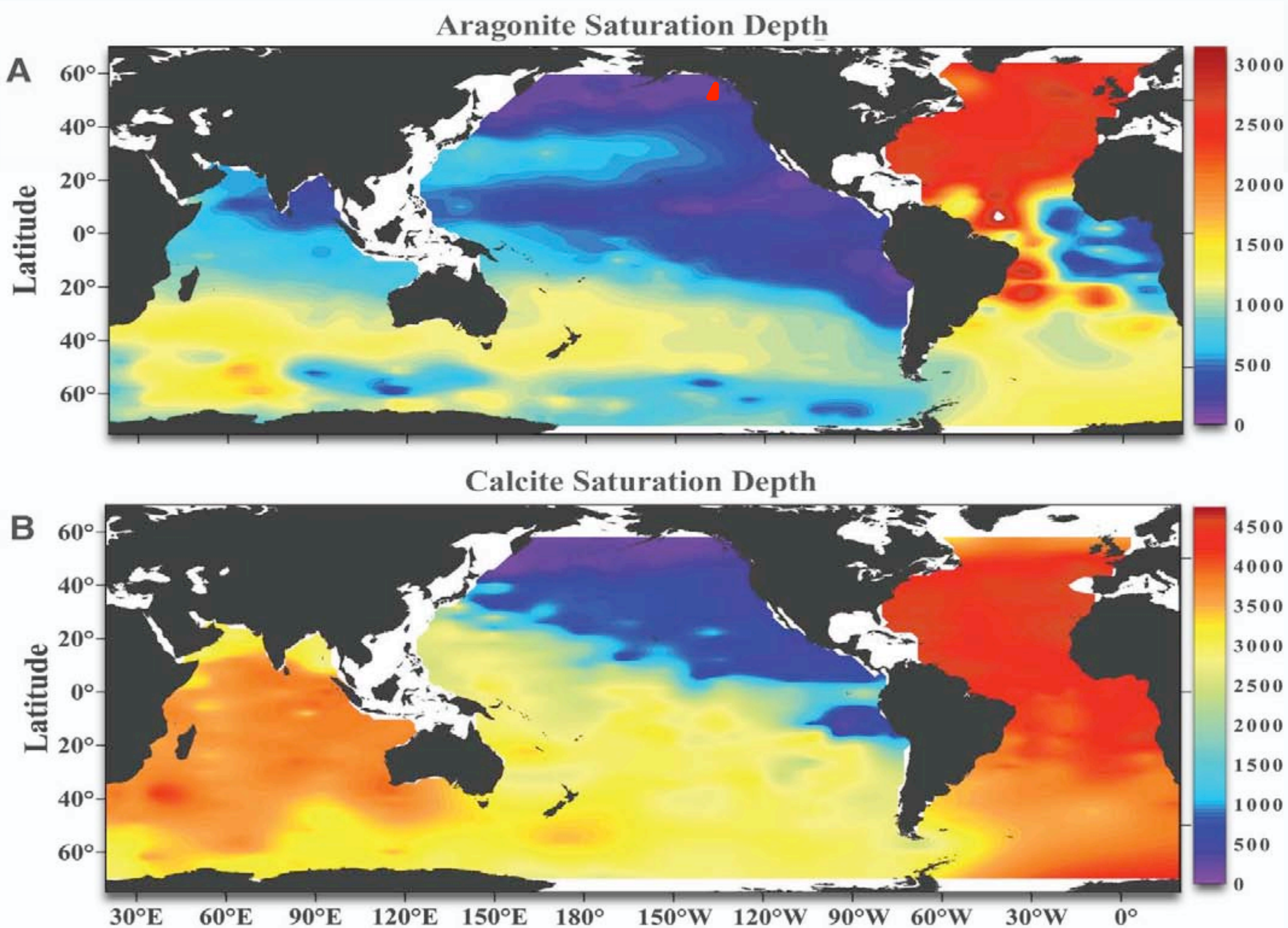
Penetration of Anthropogenic CO_2 into Ocean



- Difference of present-day levels minus pre-industrial (year 1800)
- Half trapped in upper 400 m
- Equivalent to about a third of all historical carbon emissions
- 148 Pg C since the beginning of the industrial era have accumulated in the oceans

Sabine et al. Science 2004

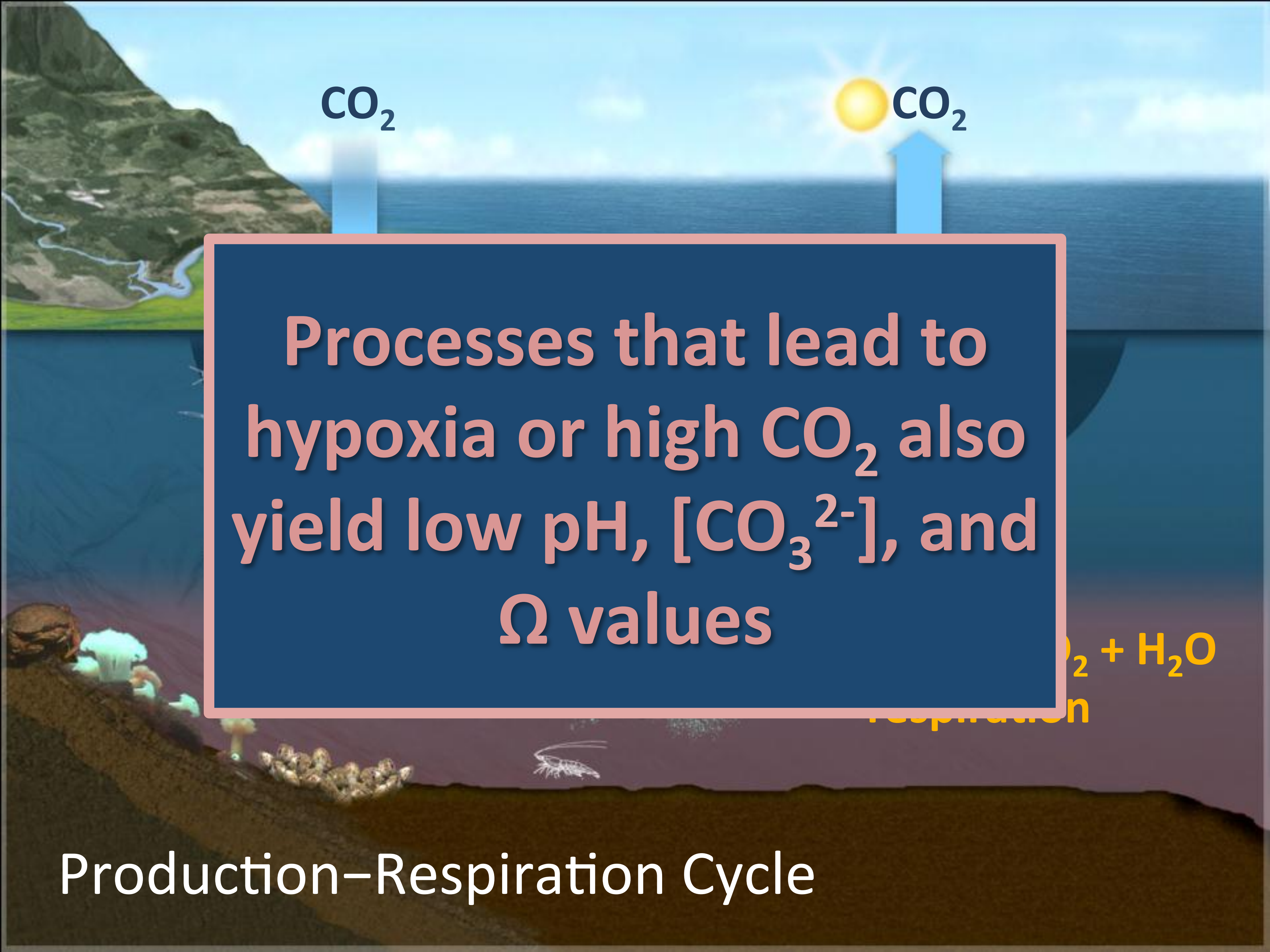
Observed aragonite & calcite saturation depths



Feely *et al.* (2004)

The **aragonite saturation horizon (Ω = 1)** migrates towards the surface at the rate of 1-2 m yr^{-1}, depending on location.

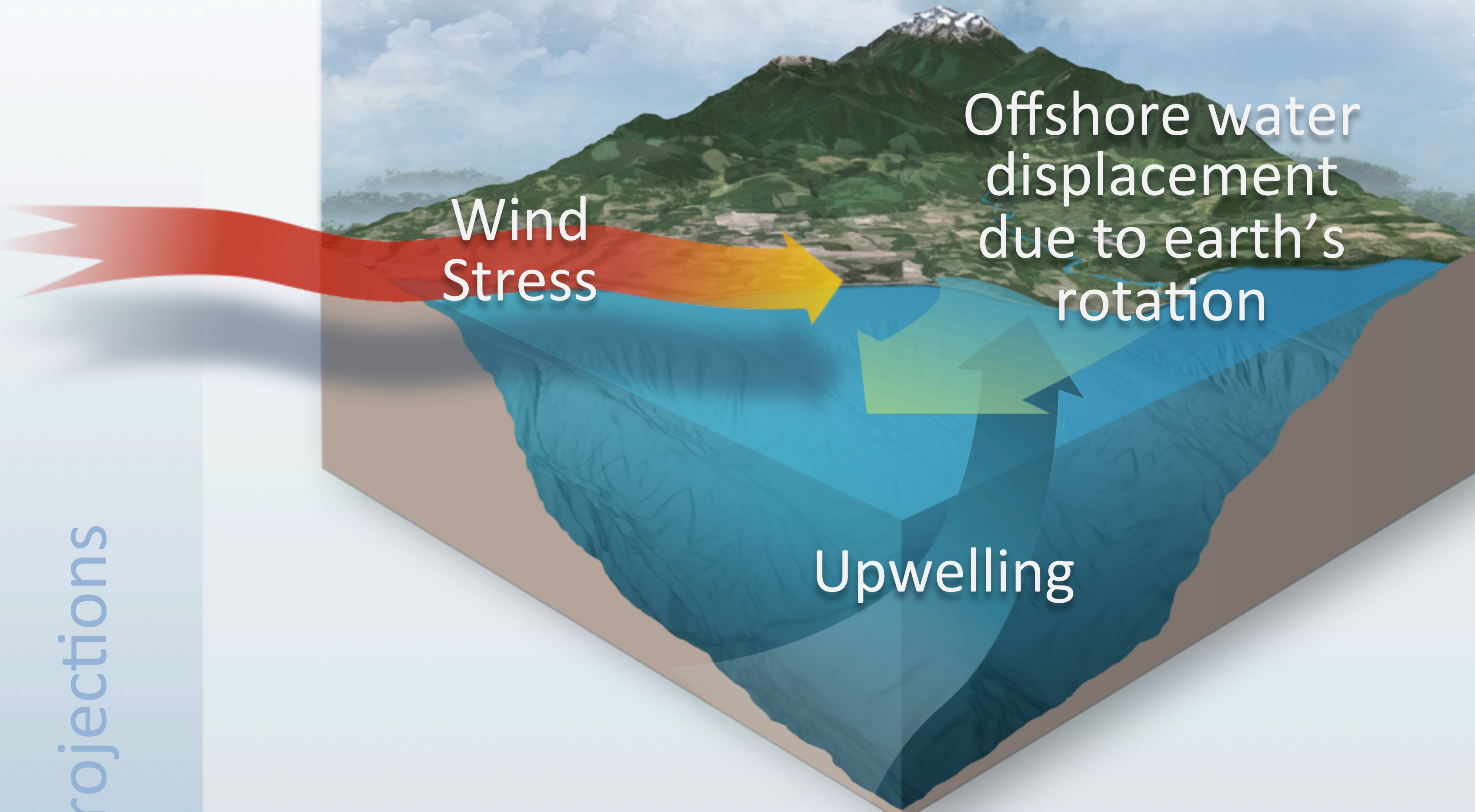
Why are coastal oceans particularly vulnerable to acidification?



Processes that lead to hypoxia or high CO_2 also yield low pH, [CO_3^{2-}], and Ω values

Production–Respiration Cycle

Natural processes that could accelerate ocean acidification in coastal waters

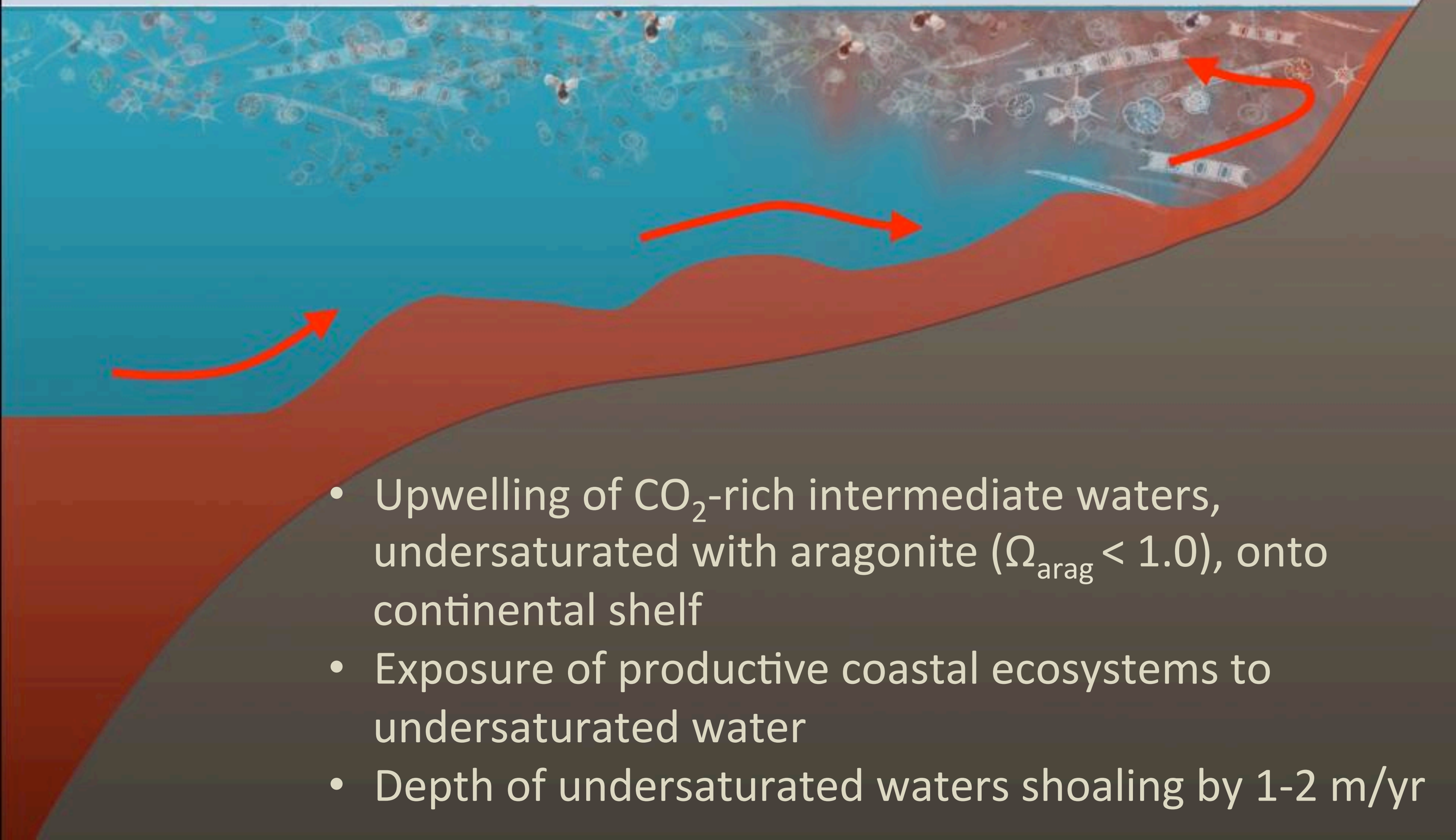


brings high CO_2, low pH, low Ω, low O_2 water to surface

Coastal Upwelling

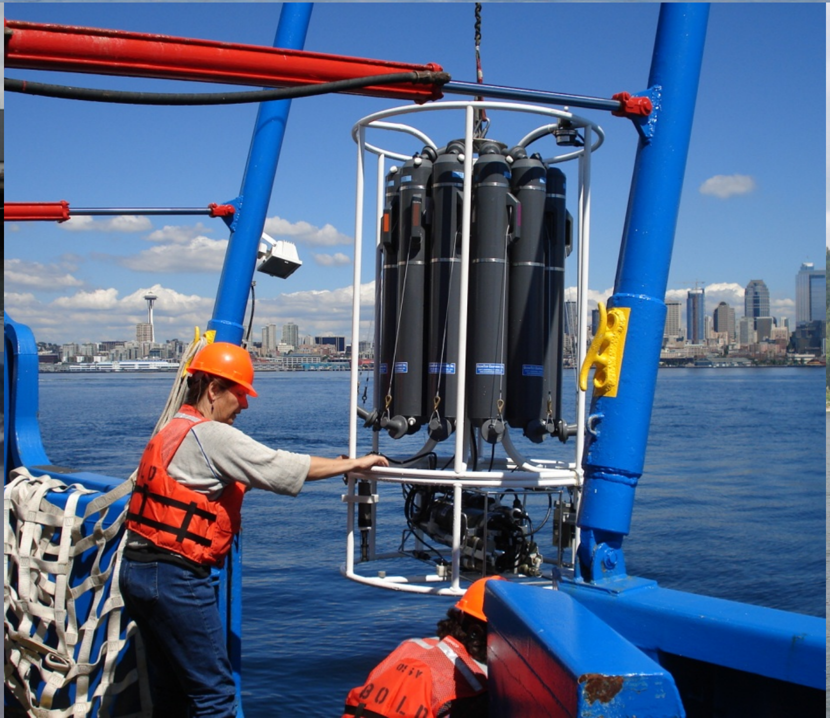
Projections

Seasonal invasion of corrosive waters on the west coast of North America

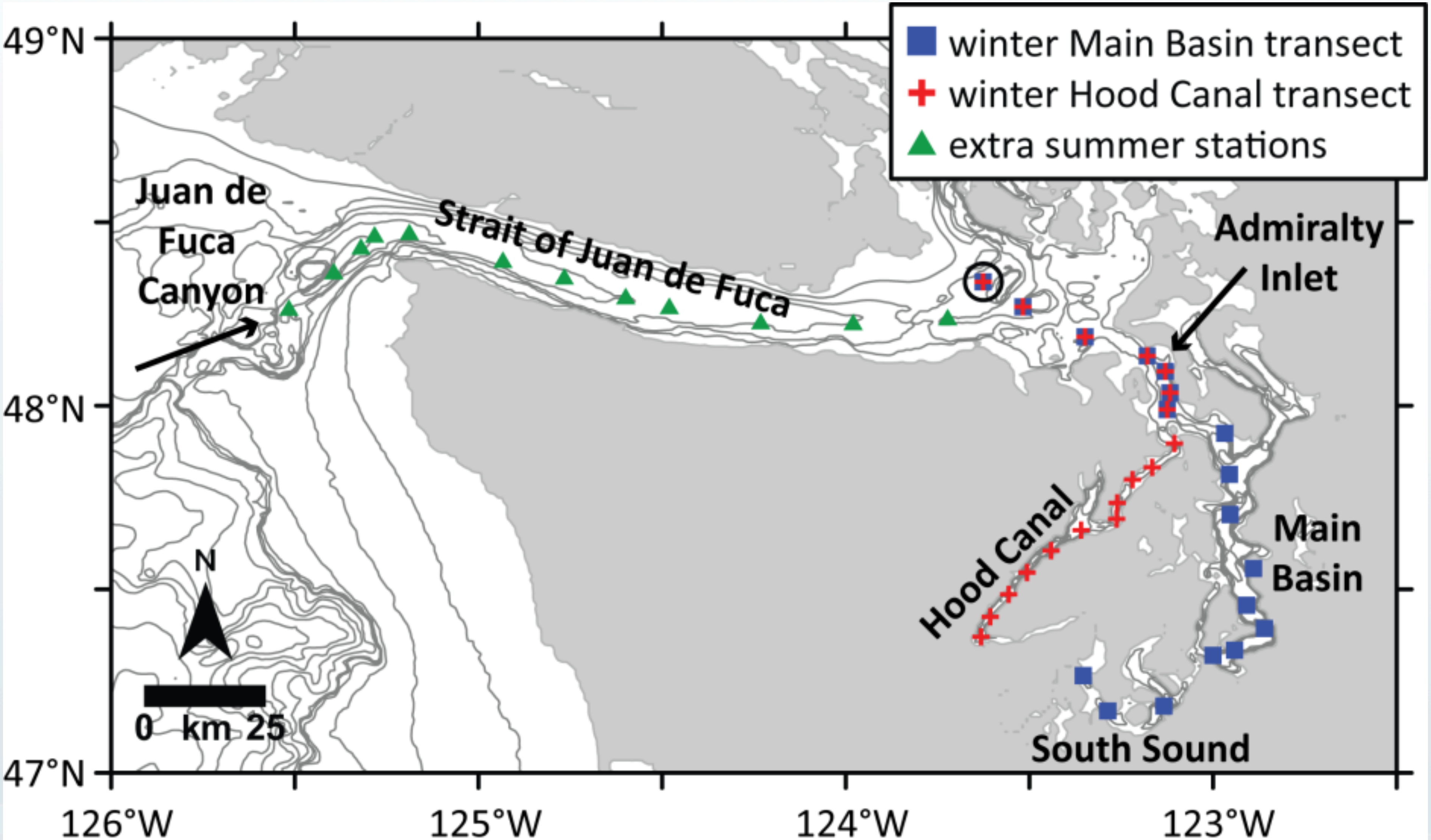


- Upwelling of CO_2-rich intermediate waters, undersaturated with aragonite ($\Omega_{arag} < 1.0$), onto continental shelf
- Exposure of productive coastal ecosystems to undersaturated water
- Depth of undersaturated waters shoaling by 1-2 m/yr

Monitoring Ocean Acidification in Puget Sound

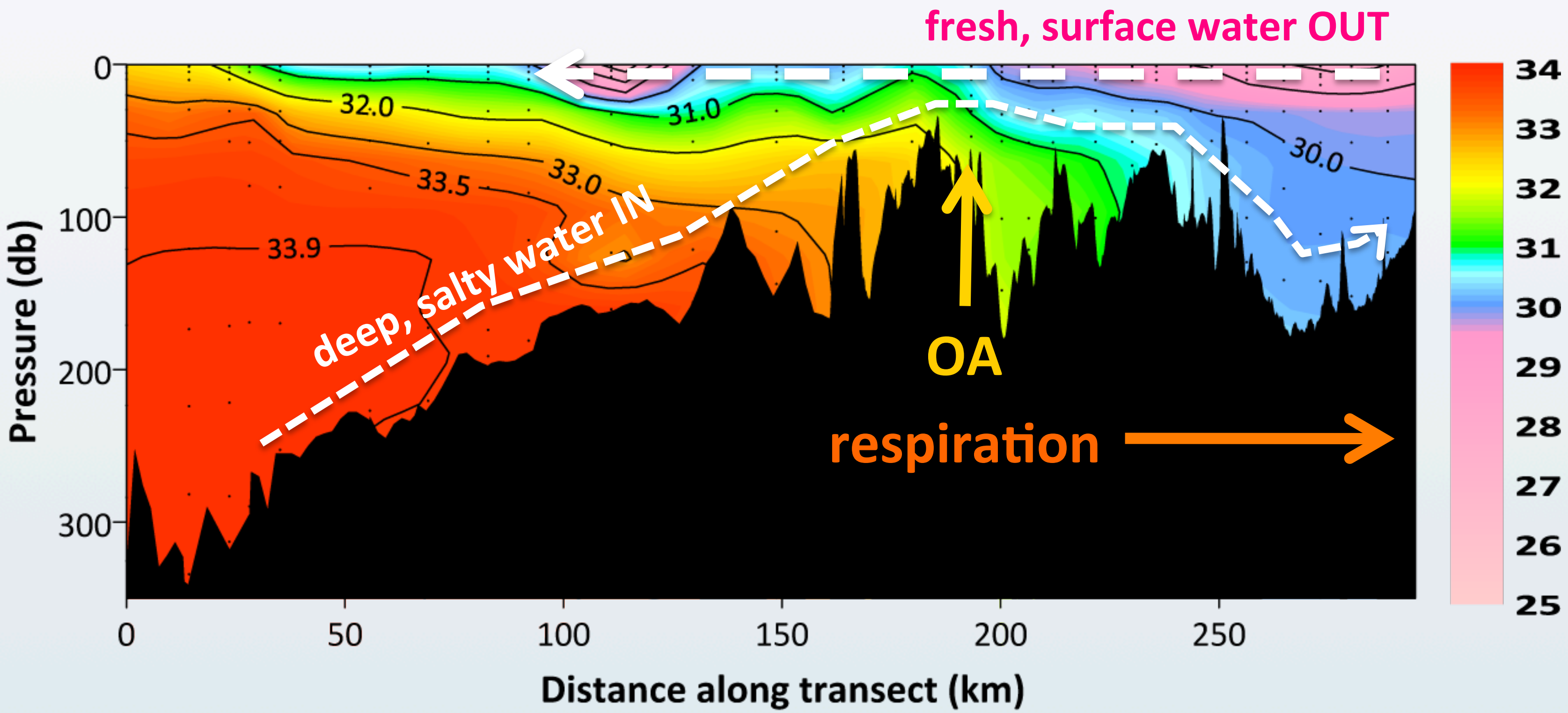


Interaction between ocean acidification and hypoxia: *A case study from Puget Sound, Washington*

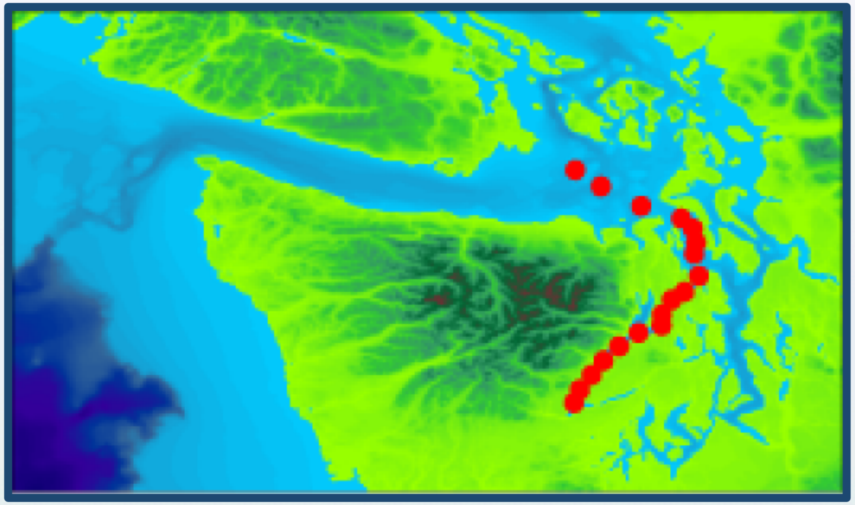


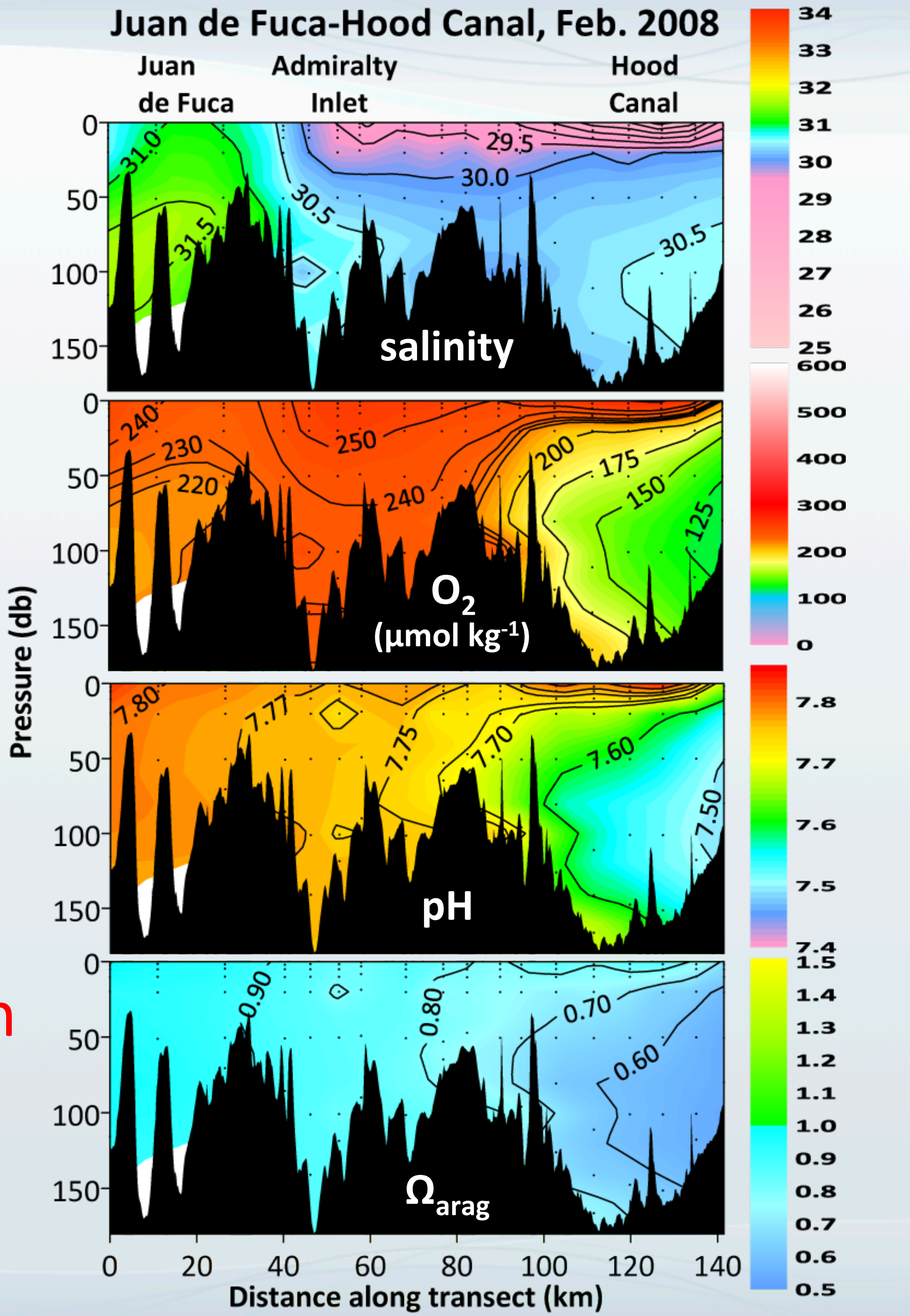
Feely et al. (2010)

Question: How much of the corrosive conditions in Hood Canal result from ocean acidification?



Winter 2008 transect: Juan de Fuca Strait to Hood Canal





Corrosive undersaturated (Ω<0.9) water occurs throughout the water column in Winter with pH as low as 7.5

Feely et al. (2010)

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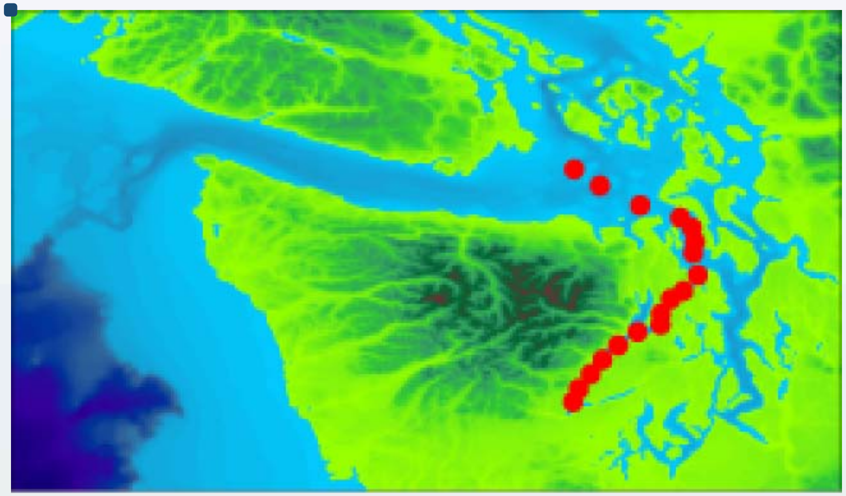

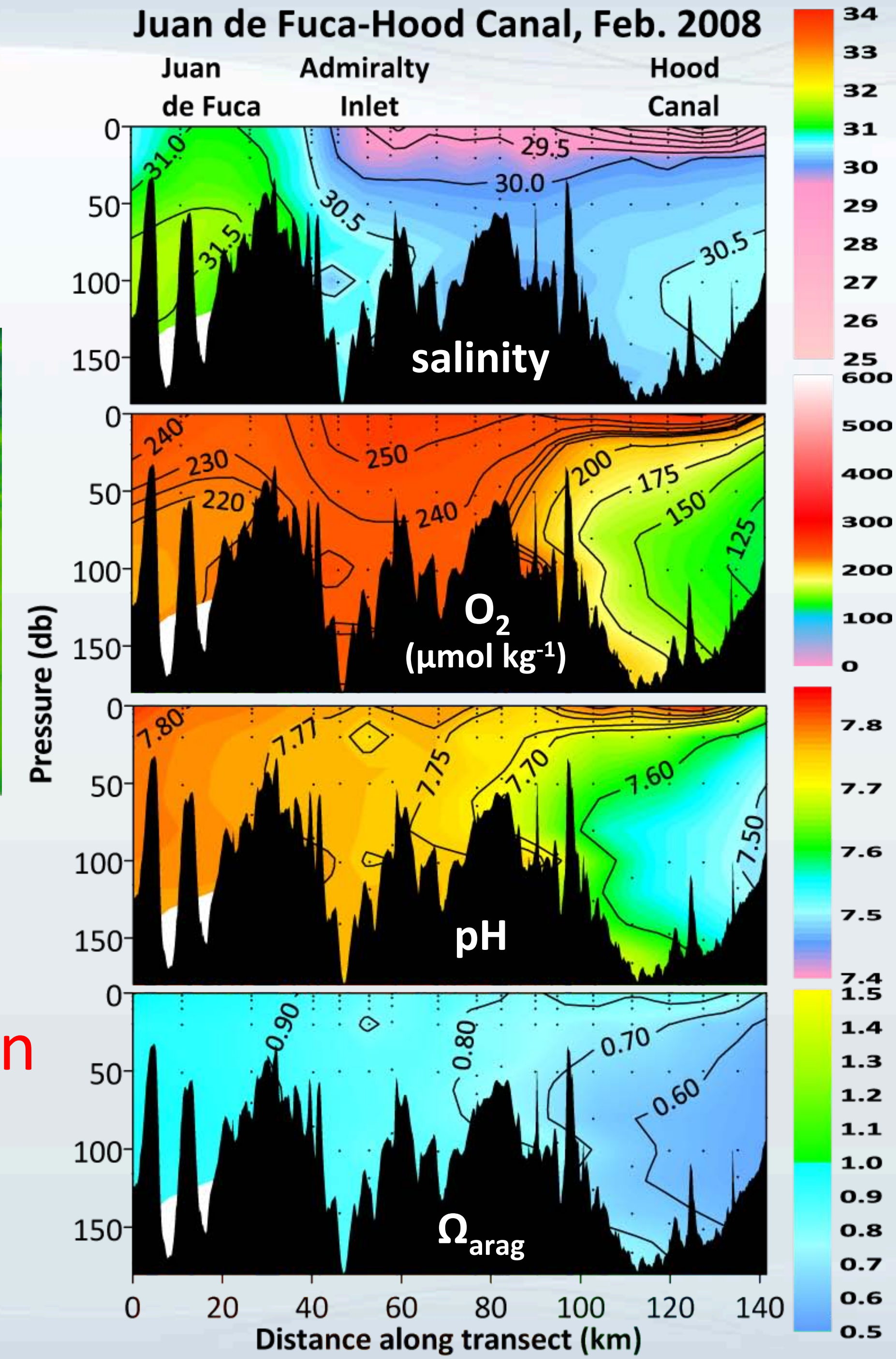

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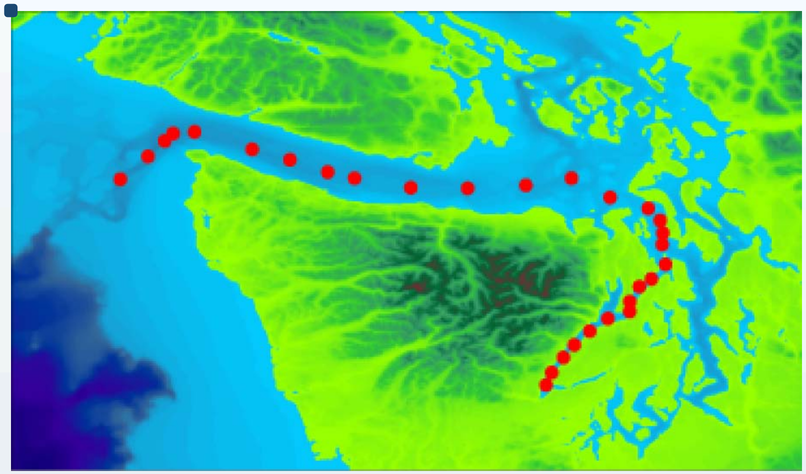
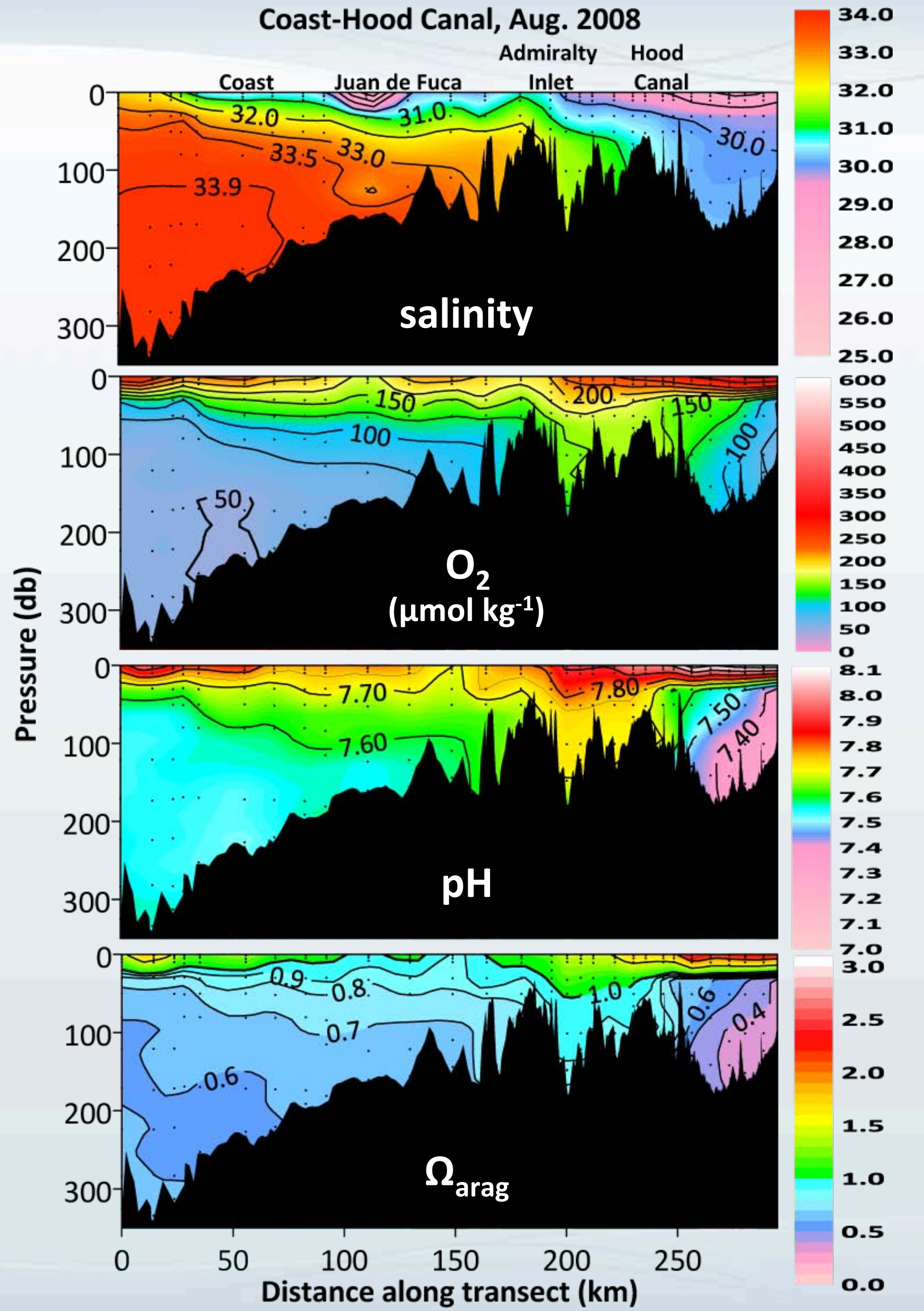
Feely et al. (2010)

Summer 2008 transect: Coast to Hood Canal



Corrosive undersaturated water (Ω<1.0) occurs in the lower 180 m of the water column, but is sometimes mixed upward into the surface layer during high-wind conditions.

Feely et al. (2010)



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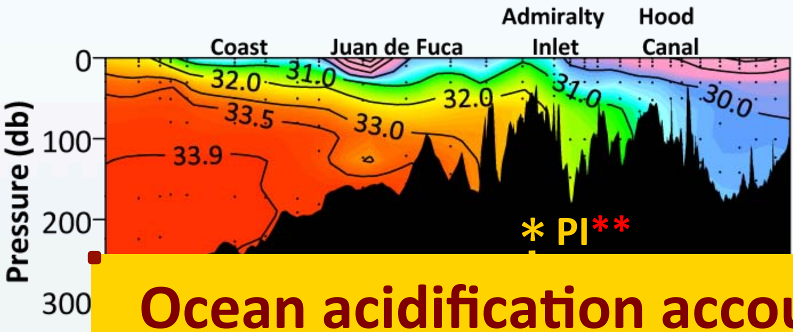
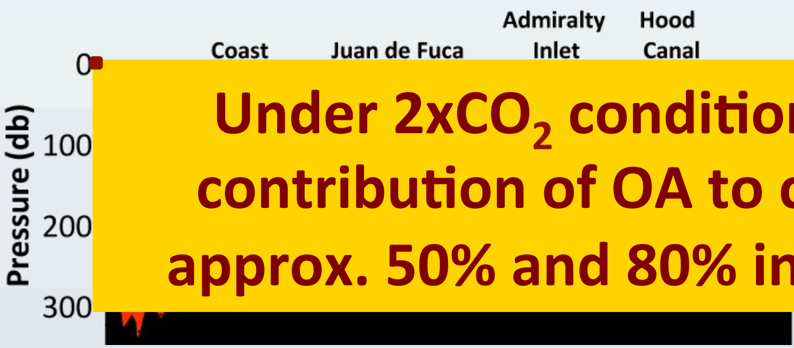


Ocean acidification ($DIC_{\Delta OA}$) = $DIC_{AI(avg\ 2008)}$ – $DIC_{AI(avg\ PI)}$

Ocean acidification accounts for 24% and 49% of corrosive conditions in summer and winter, respectively.

- OA accounts for 17 µmol kg^{-1} higher average CO_2 at Admiralty Inlet in 2008 relative to pre-industrial times.



Under $2xCO_2$ conditions (atmo. CO_2 = 560 ppmv), the contribution of OA to corrosive conditions would rise to approx. 50% and 80% in summer and winter, respectively.

- Respiration accounts for 54 and 18 µmol kg^{-1} CO_2 in summer and winter, respectively.

Feely et al. (2010)

Pacific Northwest Ocean Acidification Conclusions

- **Both on the continental shelf and in some estuarine environments, undersaturated (Ω<1) low pH (<7.7) conditions can be present during some parts of the year, most often in near-bottom waters.**

- **Upwelling and respiration processes are major contributors to the high pCO_2 and low pH, undersaturated bottom waters that are highly vulnerable to further acidification in the future, *therefore there is a need for linkages with chemical and biological time-series measurements as well as laboratory observations.***

Pacific Northwest Ocean Acidification Summary

- OA research in the Pacific Northwest Coastal Waters is growing and will benefit from better coordination and integration.
- Comparative field measurements and laboratory experiments are required for determining spatial and temporal dynamics.
- Societal impacts and economic assessments must be addressed directly.
- Education/outreach of research and policy results must be delivered to the public in a timely manner.

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