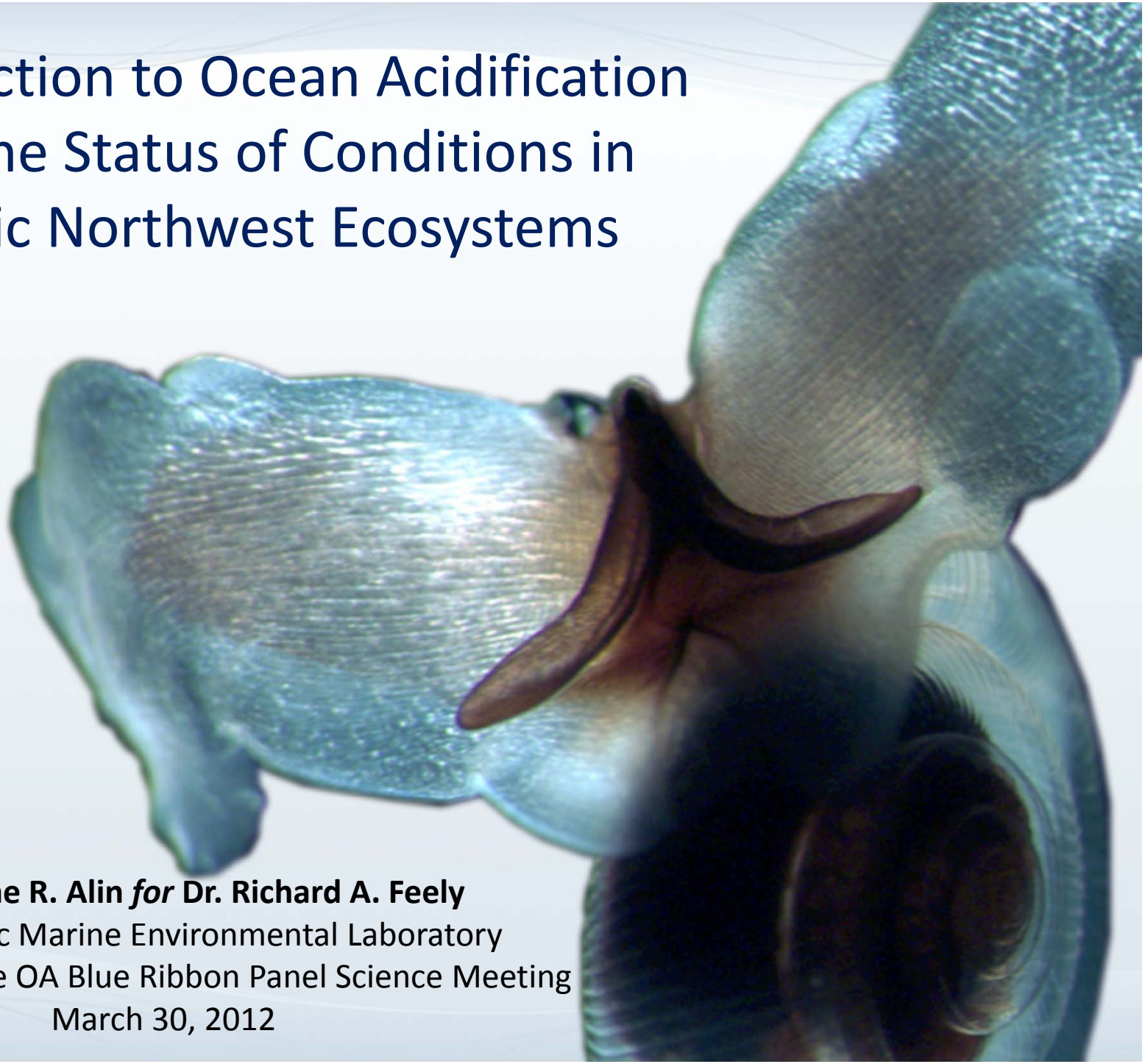
Introduction to Ocean Acidification and the Status of Conditions in Pacific Northwest Ecosystems



Dr. Simone R. Alin *for* Dr. Richard A. Feely
NOAA Pacific Marine Environmental Laboratory
Washington State OA Blue Ribbon Panel Science Meeting
March 30, 2012

Outline

- Introduction to the chemistry of ocean acidification (OA).
- Description of current conditions along the West Coast and in Puget Sound.
- Discussion of natural and other human factors that contribute to acidification of coastal waters.

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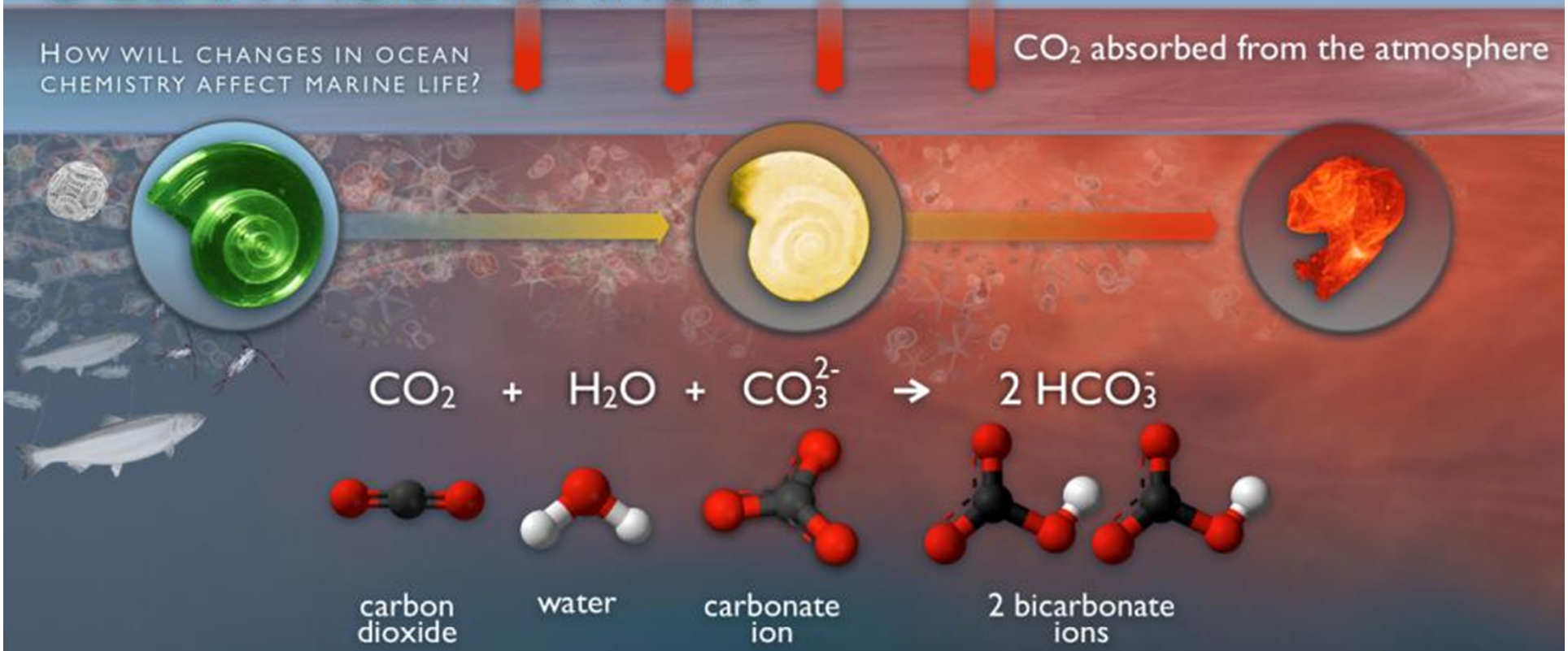
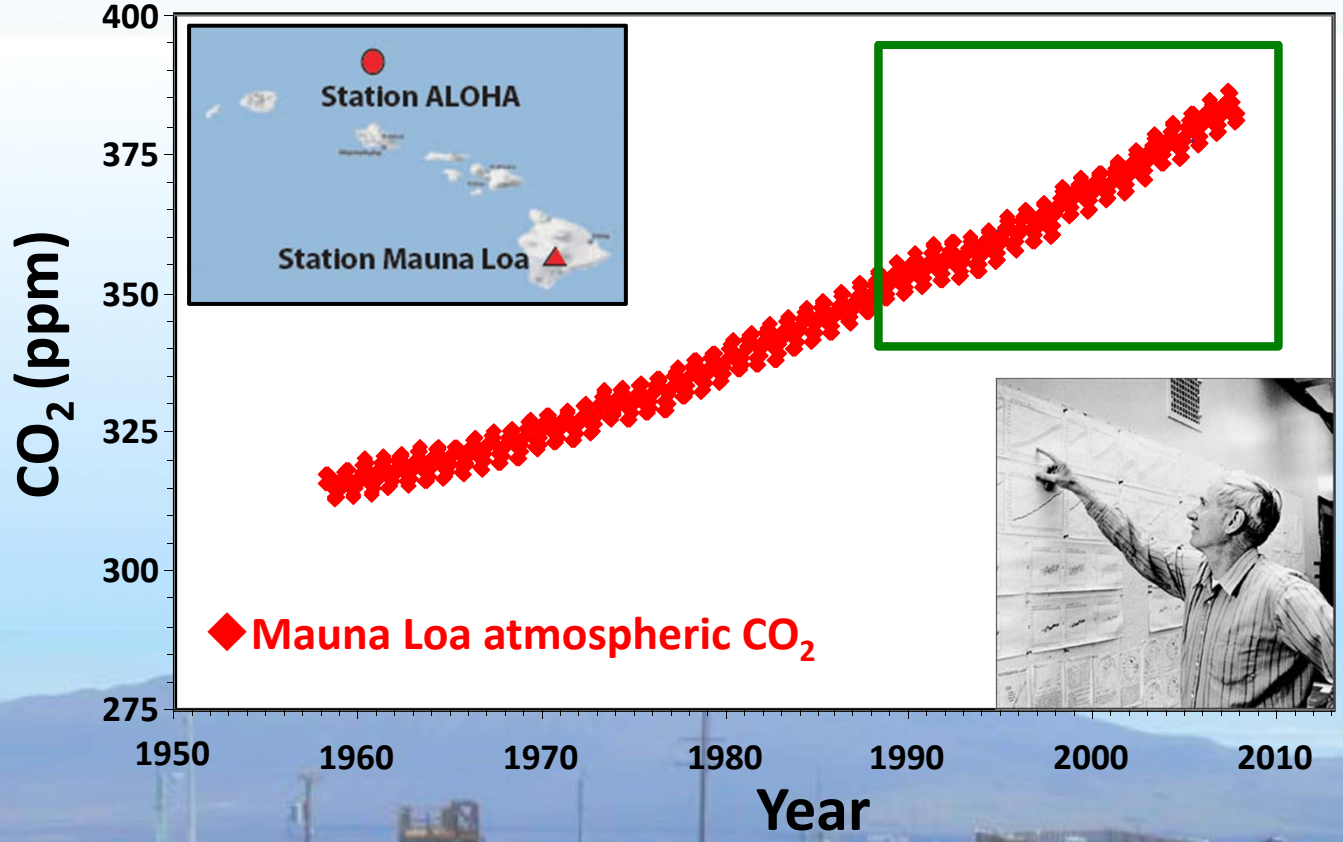
Ocean Acidification

How will changes in ocean chemistry affect marine life?



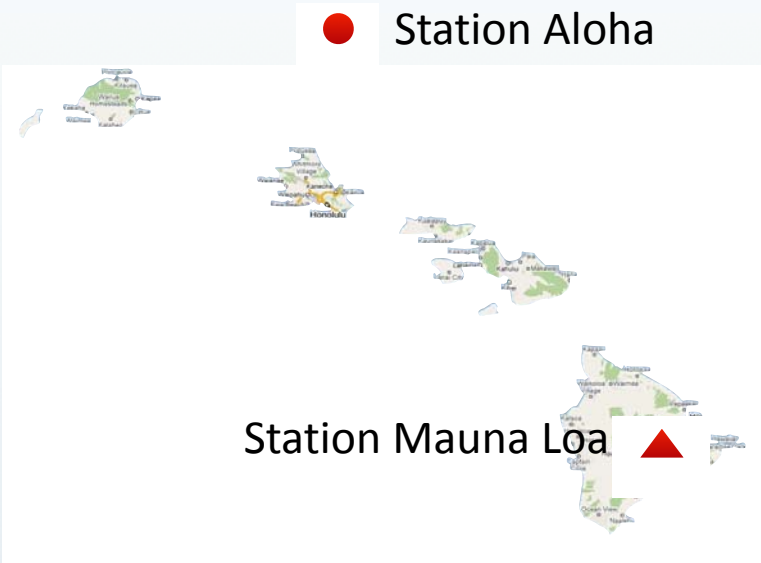
consumption of carbonate ions impedes calcification

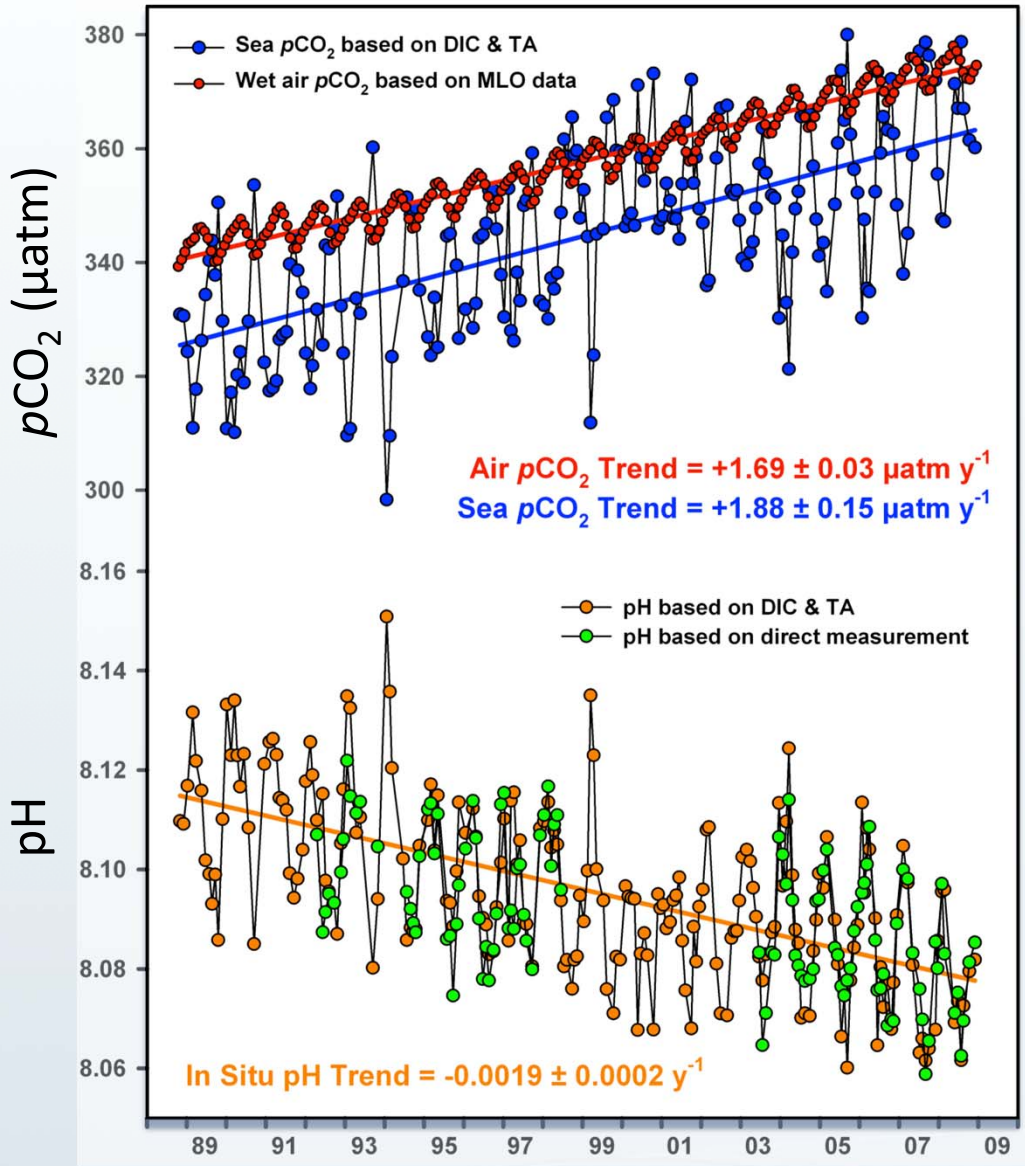
Increasing CO_2 in the atmosphere



Station Mauna Loa

CO_2 absorbed by the ocean

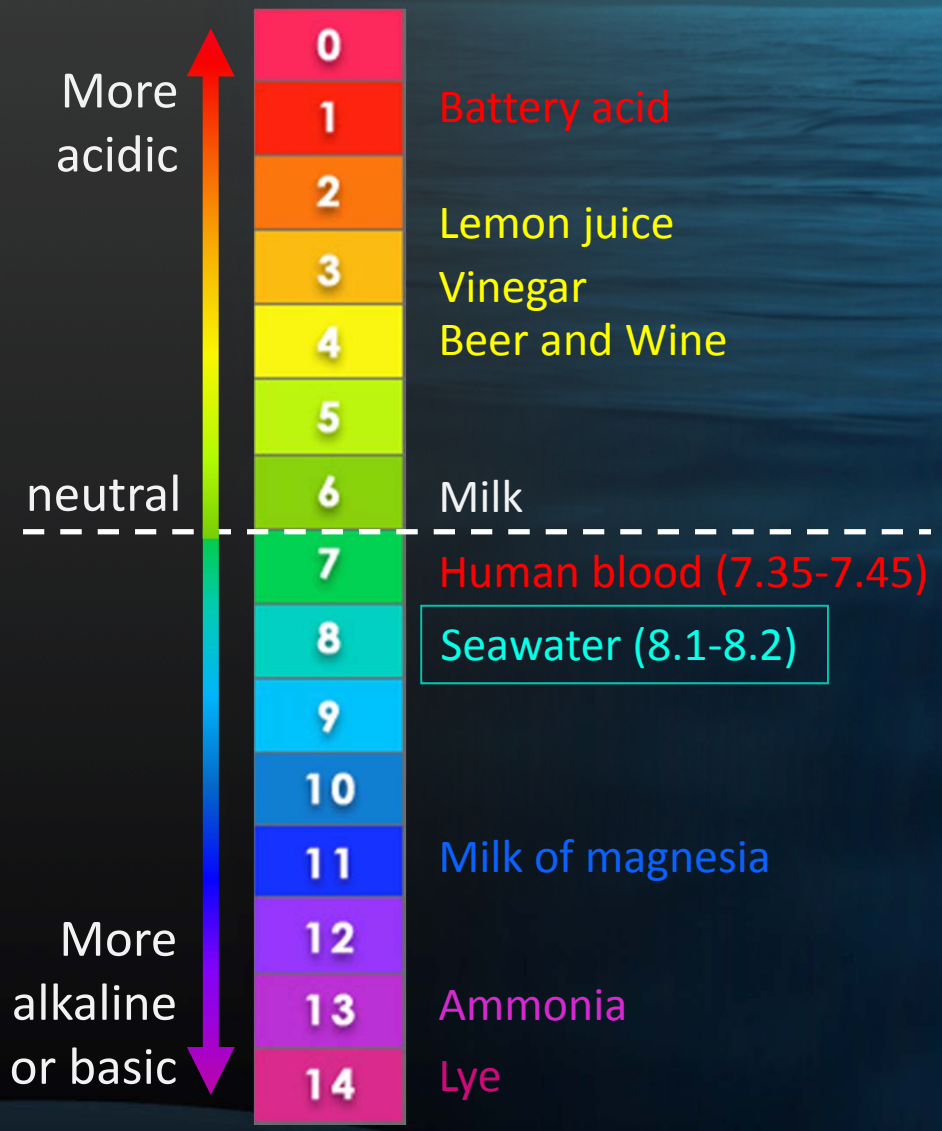




pCO_2 is the CO_2 gas content of the air or water

Doney, Science, 2010
Dore et al., PNAS 2009

The pH scale: How we measure acidity



pH is a logarithmic scale so that a pH change of 1 unit means a 10-fold change in acidity

In other words, small changes in pH units mean much larger changes in acidity!

acidification

Ocean Acidification Chemistry 101

CO_2

$$CO_2 + H_2O \rightarrow H_2CO_3$$

carbonic acid

$$\downarrow$$

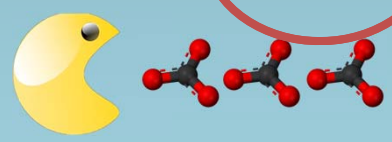
pH →

$$H^+ + HCO_3^-$$

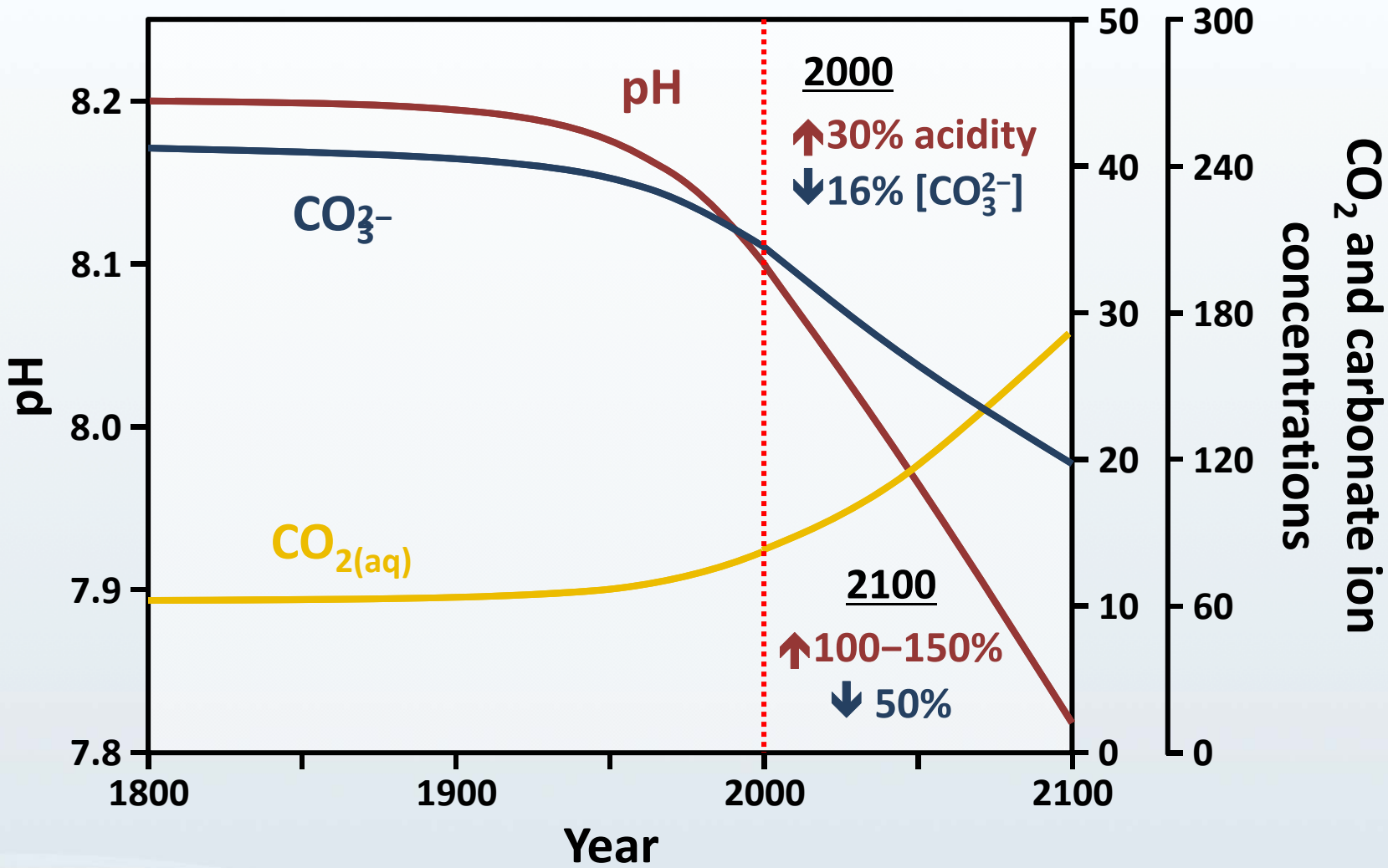
$$\downarrow$$

$$H^+ + CO_3^{2-}$$

carbonate ion



History and future of OA at the ocean surface



Wolf-Gladrow et al. (1999)

Rate of change is important

The New York Times

Green

A Blog About Energy and the Environment

March 2, 2012, 6:11 PM

Pace of Ocean Acidification Has No Parallel in 300 Million Years, Paper Says

By JUSTIN GILLIS

Ko Sasaki for The New York Times

Corals threatened by acidification near Ishigaki island in Okinawa, Japan.

Science

A new scientific paper suggests that the ocean is acidifying at a rate that is many times faster than at any time in the last 300 million years. The change is occurring so rapidly that it raises "the possibility that we are entering an unknown territory of marine ecosystem change," said the paper, published this week in the journal Science.

Hönisch et al., Science, 2012

Aragonite Saturation State (Ω)

How easy is it to build shells?

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

calcium carbonate calcium carbonate

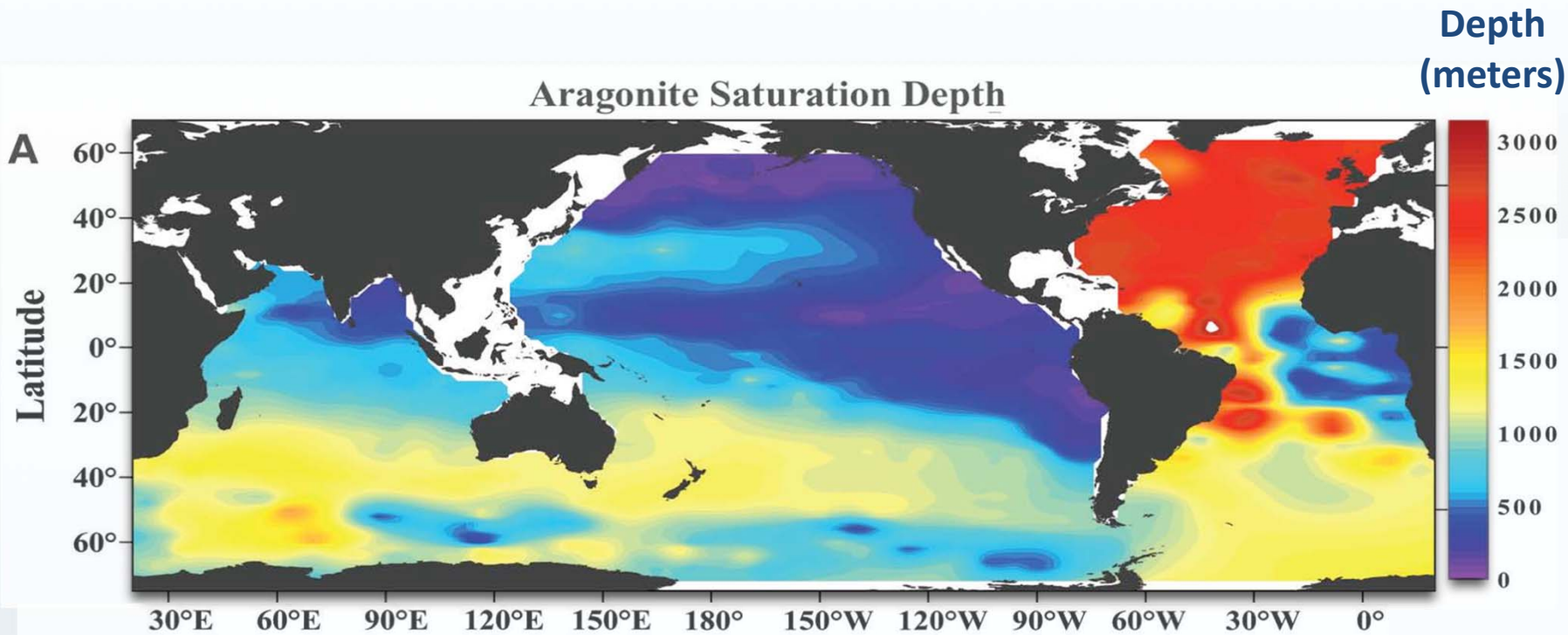
$\Omega > 1$ shell-building relatively easy

$\Omega = 1$ threshhold

$\Omega < 1$ corrosive conditions

pH is 7.7 when $\Omega_{arag} = 1$

Observed aragonite saturation depths



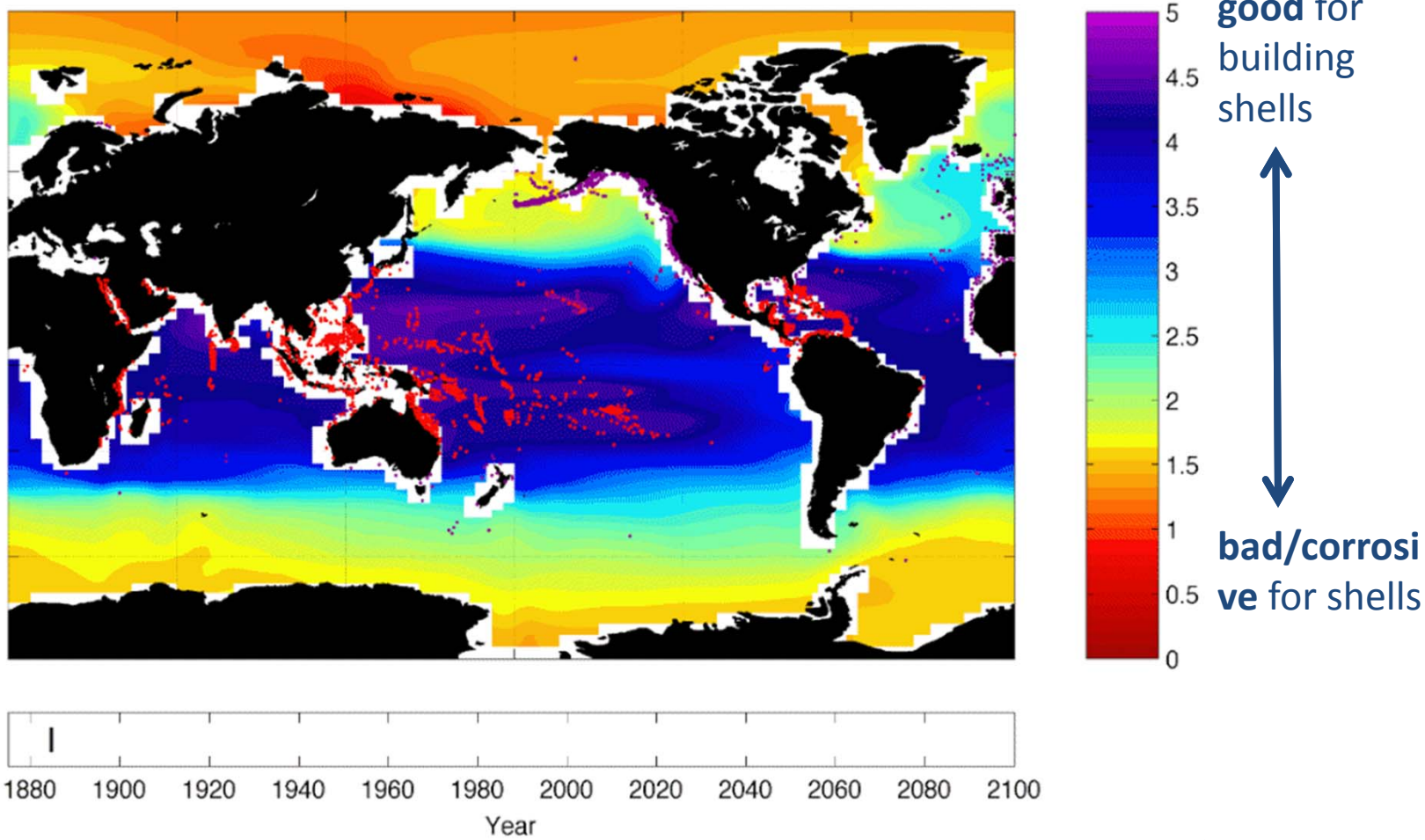
Natural processes make North Pacific water very rich in CO_2, so we are already closer to the aragonite threshold.

The aragonite saturation depth is getting shallower by 3–6 feet per year.

Feely et al. (2004)

Historical and Future Trajectory of Aragonite Saturation

Click on title to watch movie



Projections

tropical corals

deep-water corals

after **Feely et al (2009)** with Modeled Saturation Levels using NCAR CCSM3 model

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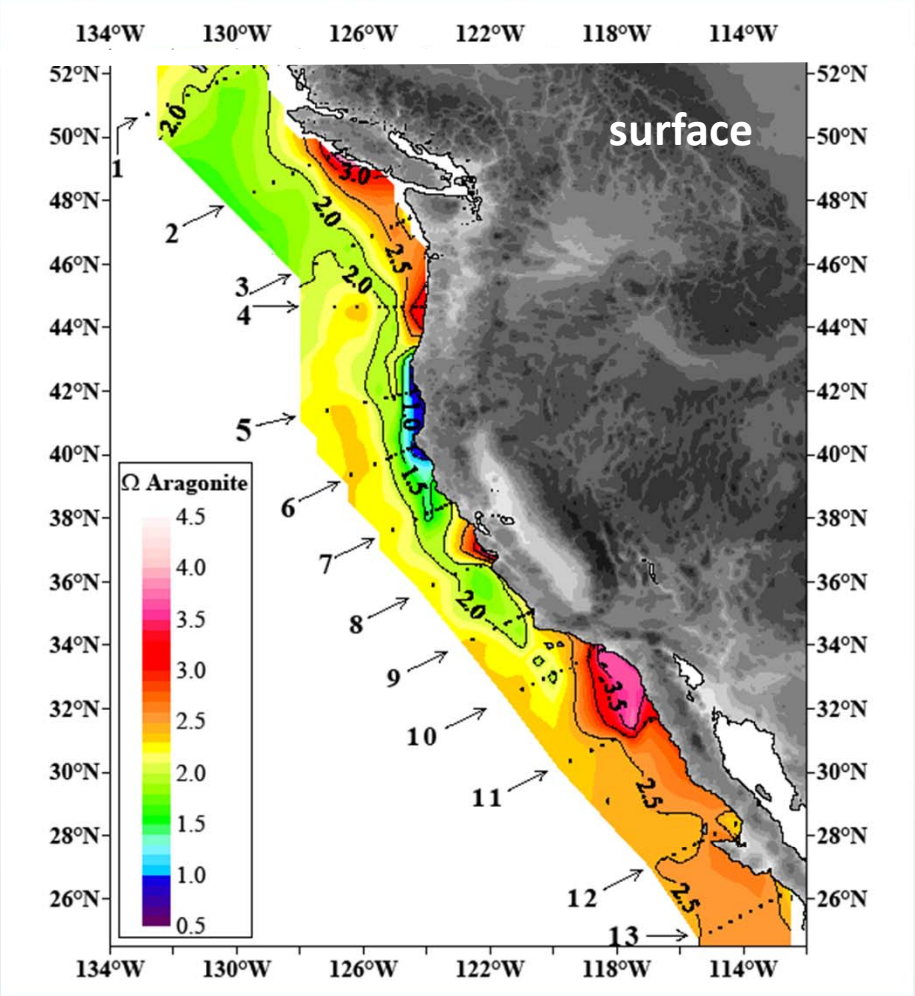
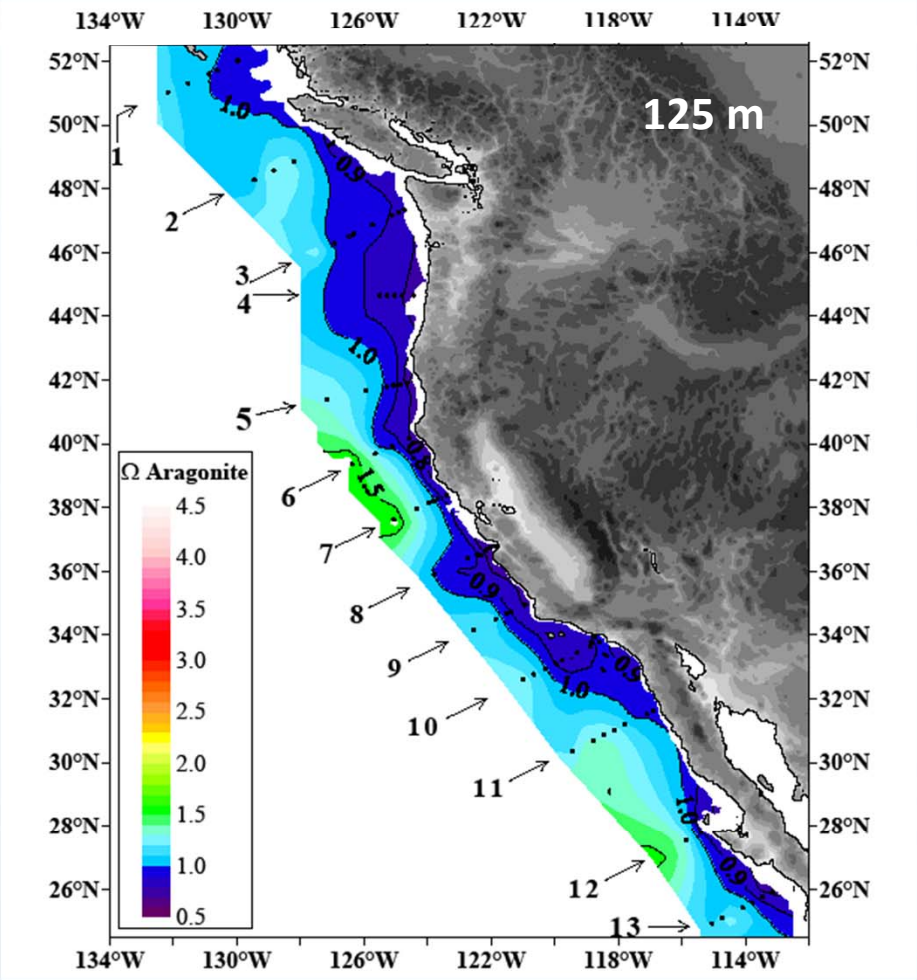
Discovery of acidified water on the West Coast

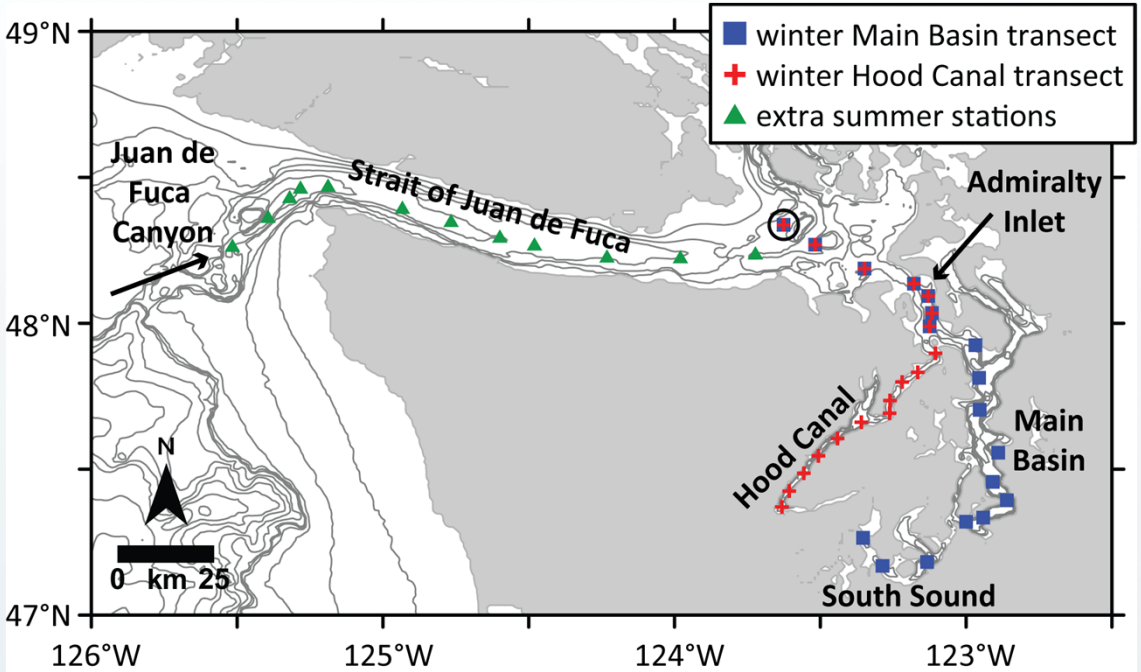
May–June 2007 – A first look at ocean acidification on our coast





- Acidified water at ocean surface (N. California)
- Acidified water everywhere on continental shelf

The situation in Washington waters



- Lower pH and saturation states seen on the Washington coast.
- Still lower values seen in the southern end of Hood canal.
- Corrosive conditions everywhere in Puget Sound in winter.
- Nearshore conditions (near shellfish beds) are very diverse and have diverse drivers throughout Puget Sound.

Feely et al. (2010)

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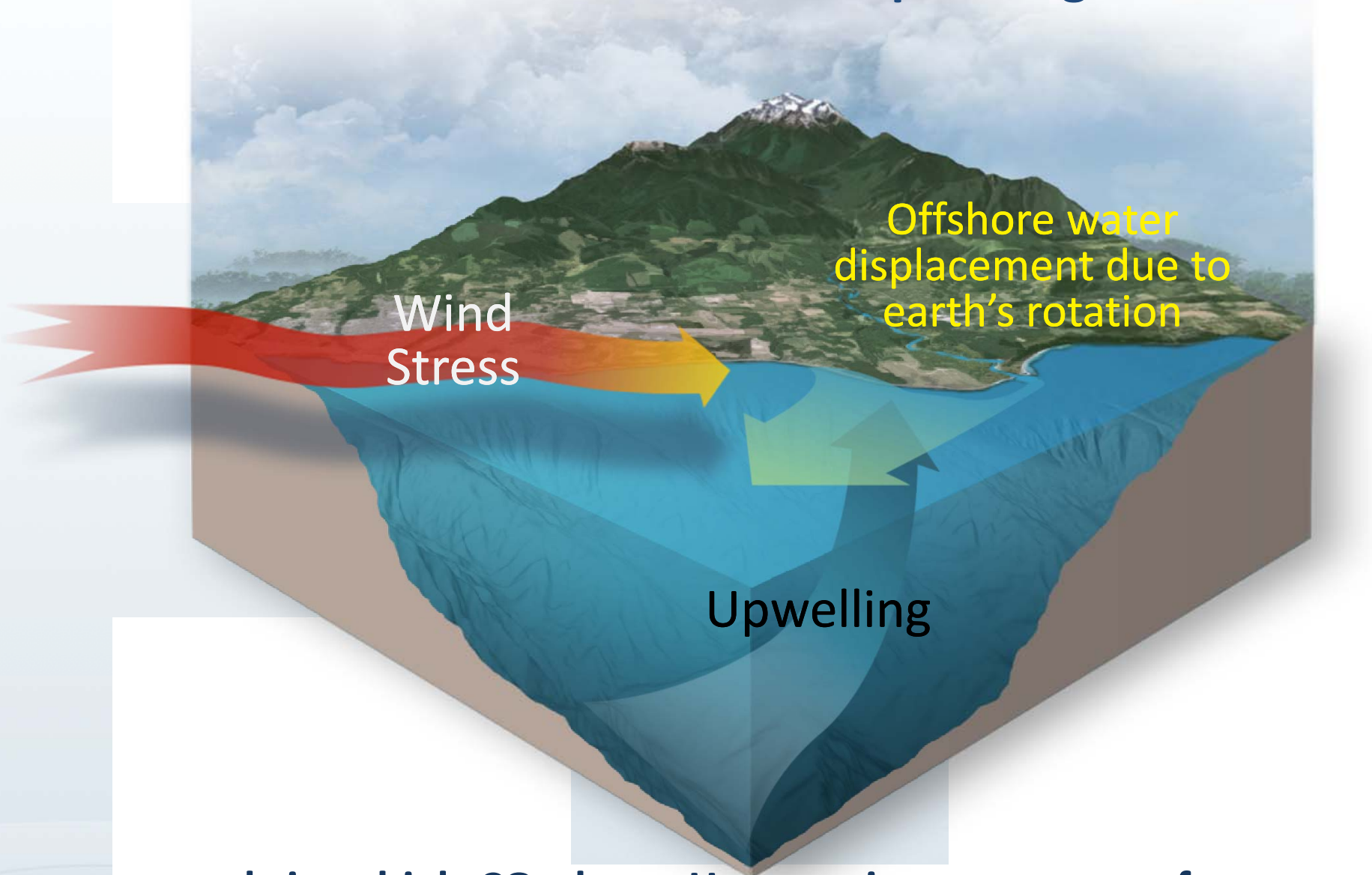
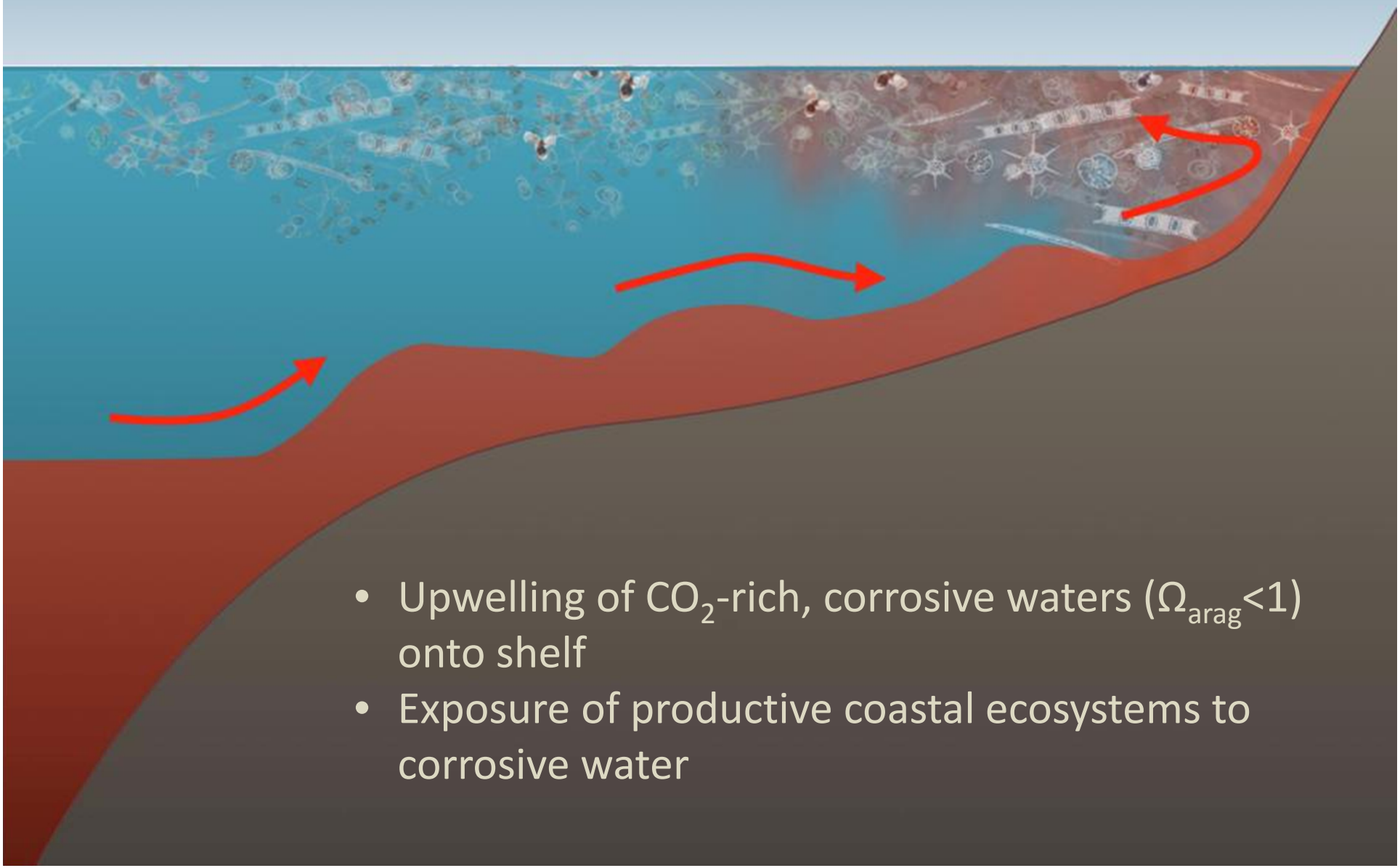
Natural processes can accelerate acidification in coastal waters: coastal upwelling

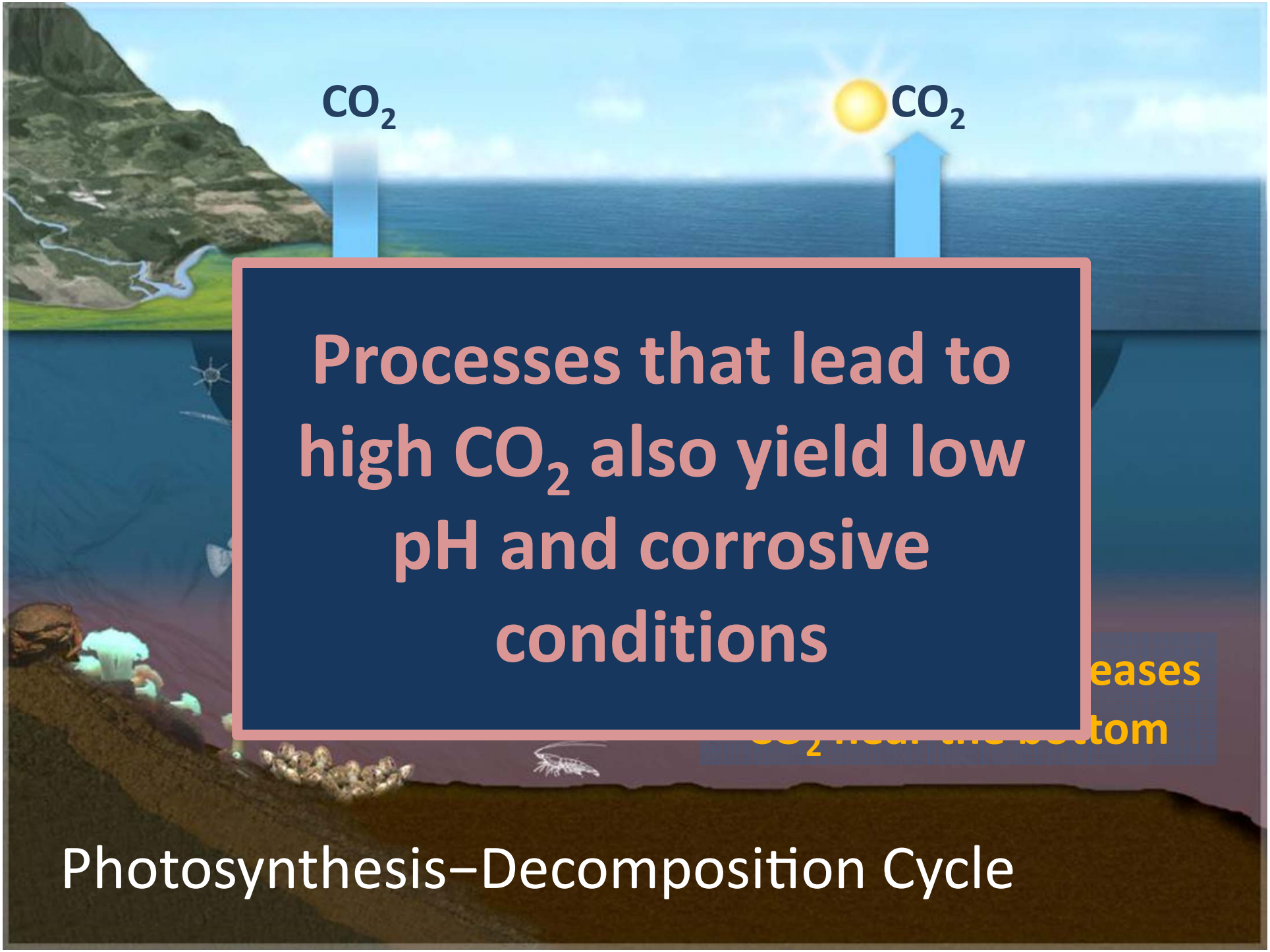


brings high-CO_2, low-pH, corrosive water to surface

Seasonal invasion of corrosive waters on West Coast



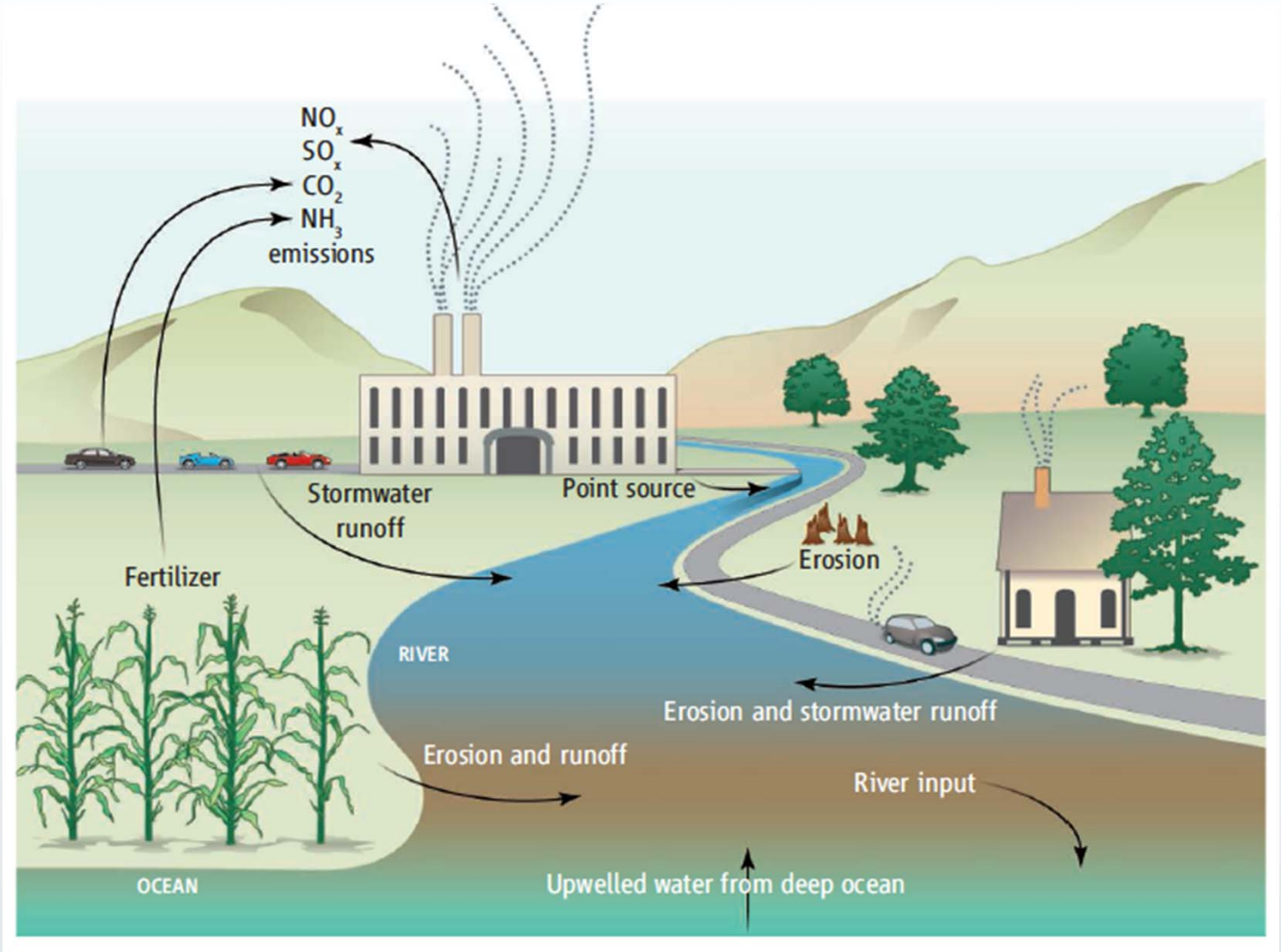
- Upwelling of CO_2-rich, corrosive waters ($\Omega_{arag}<1$) onto shelf
- Exposure of productive coastal ecosystems to corrosive water



Processes that lead to high CO_2 also yield low pH and corrosive conditions

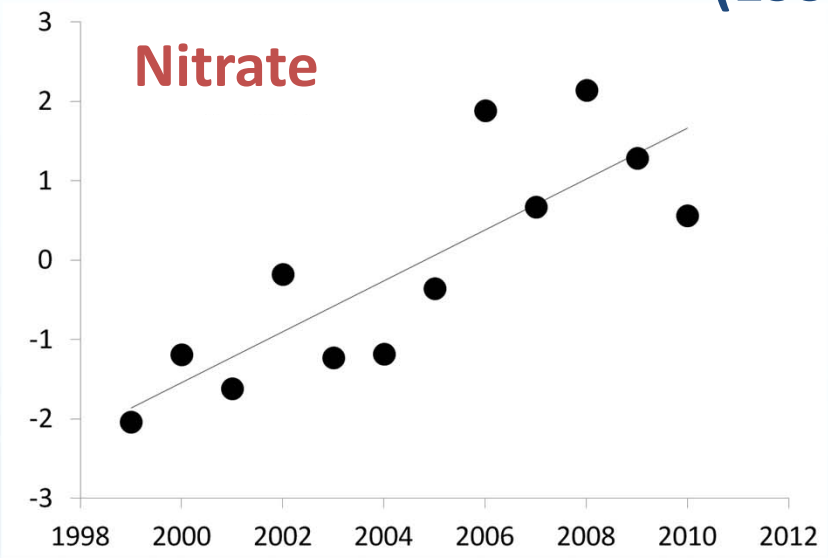
Photosynthesis–Decomposition Cycle

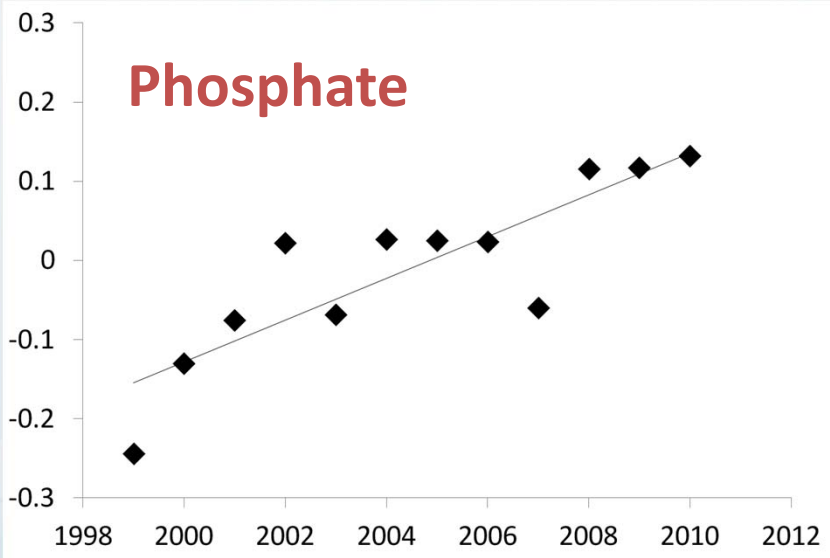
Terrestrial factors that contribute to acidification



Kelly et al., Science (2011)

Increasing nutrient concentrations in Puget Sound (1998-2012)





- Land-based sources are the apparent cause of this increase.
- No apparent change in river and waste-water treatment sources.
- Septic systems may be important in local areas.
- Non-point source runoff – urban and agricultural – ??

Courtesy: Christopher Krembs (WDoE)

How much acidification is due to rising CO_2 emissions?

Coastline	Upwelling	Decomposition	CO_2 emissions
Puget Sound	66%	17-26%	8-17%
Washington	66%	20%	14%
Oregon	74%	12%	14%
Northern California	67%	9%	24%
Central California	59%	16%	25%
Southern California	60%	13%	28%

Conclusions

- In the Pacific Northwest, we are particularly vulnerable to ocean acidification due to our location.
- Rising greenhouse gas emissions suggest there will be rapid change in ocean chemistry in the 21st century.
- By 2100, we expect to see a 100–150% increase in acidity – a rate of change that is unprecedented in the last 300 million years.
- Natural and other human factors besides greenhouse gas emissions can contribute to acidification of coastal waters.