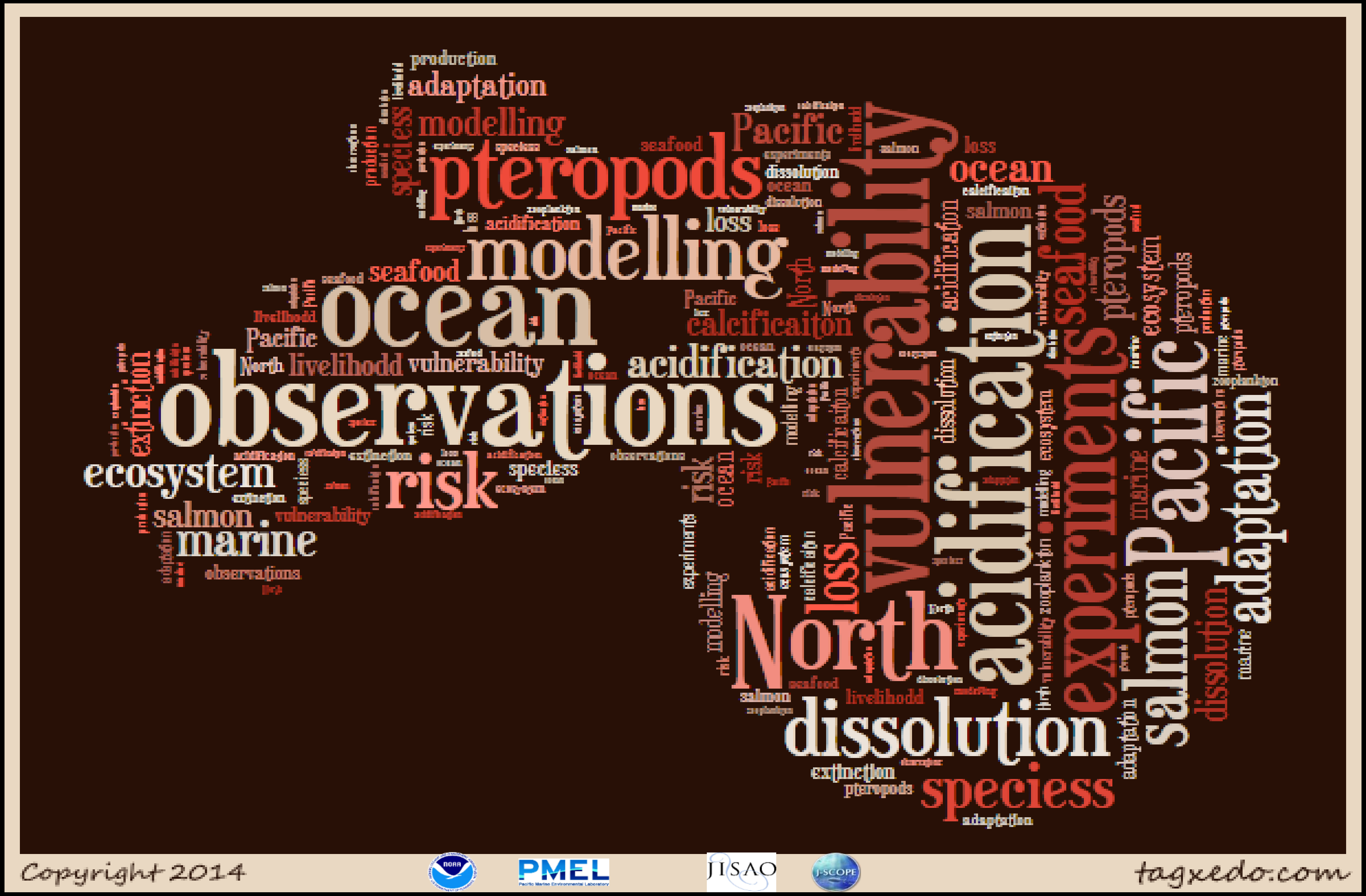
Pteropods and Ocean Acidification:
Combining Observation, Experiments and Modelling

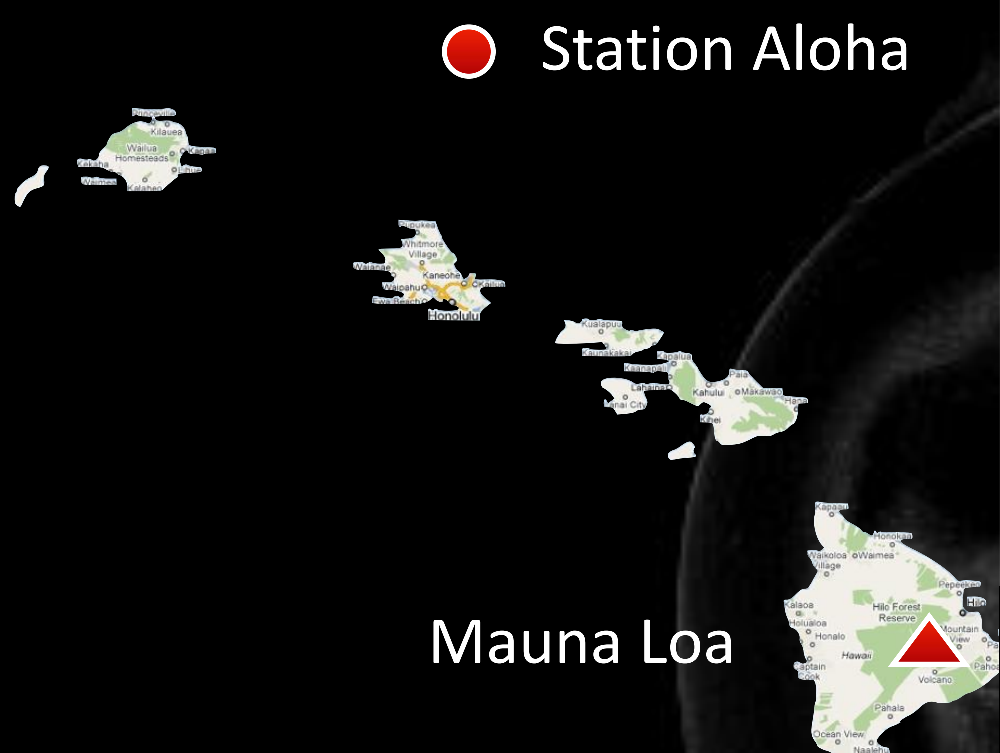


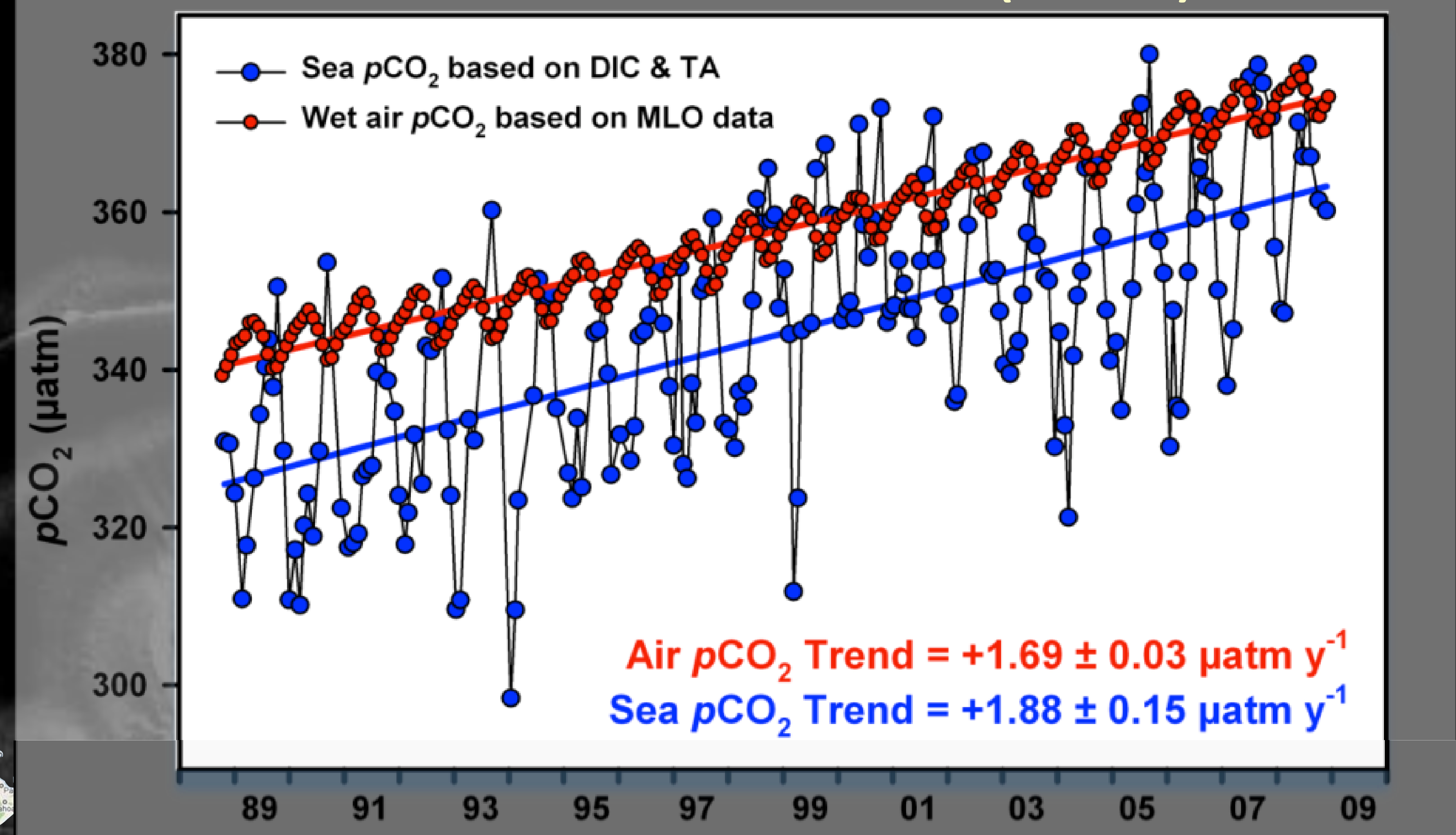
Nina Bednarsek

PICES, Korea, 2014

R Feely, S Aline, A Hermann, J Menkel, B Peterson, J Reum, S Siedlecki, N Tolimieri

Carbon Changes at the Hawaii Ocean Time-series (HOT) site



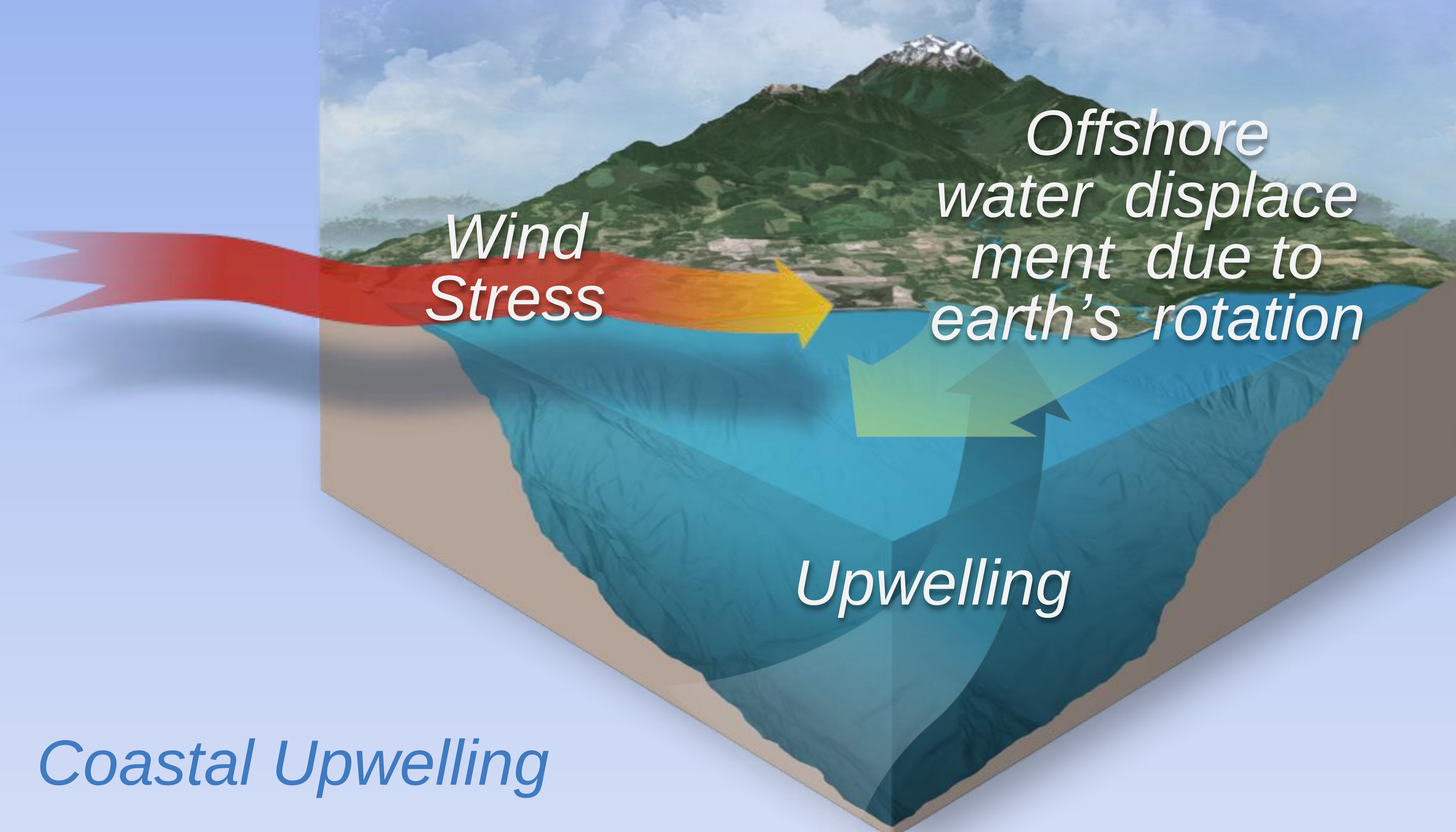


Surface water pCO_2 is increasing at about the same rate as atmosphere CO_2 emissions.

We see a commensurate decrease in pH with the rise in surface water pCO_2

Doney, Science 2010
Dore et al., PNAS 2009

Natural processes that could accelerate ocean acidification in coastal waters



Coastal Upwelling

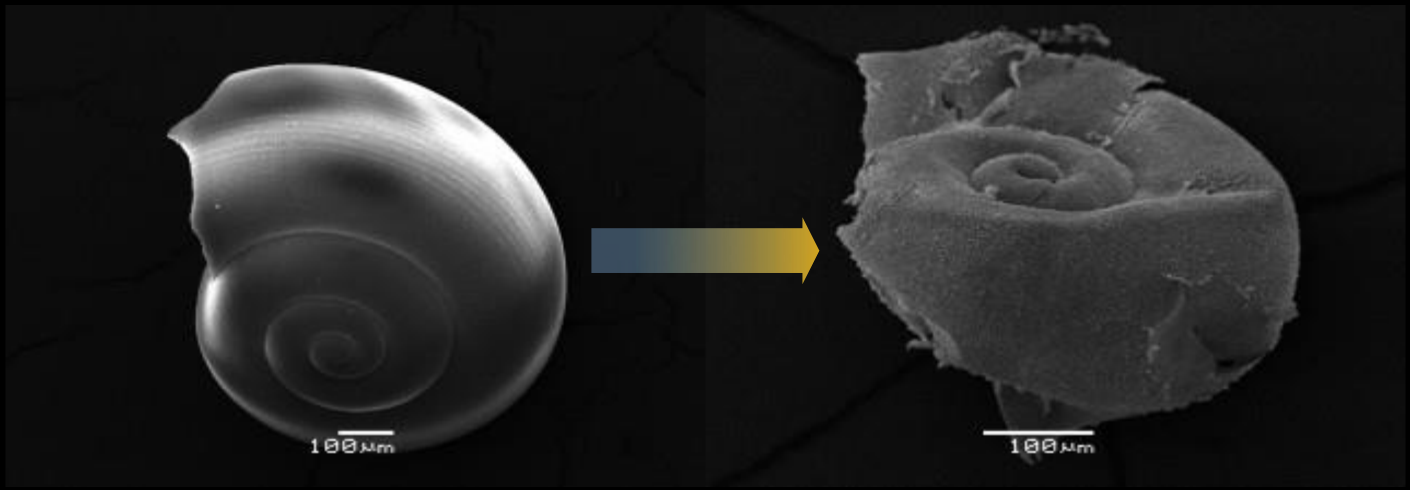
brings high CO_2, low pH, low O_2, low Ω, water to surface

Exposure of coastal ecosystems to corrosive upwelled water

Saturation State

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

calcium carbonate calcium carbonate



Saturation State

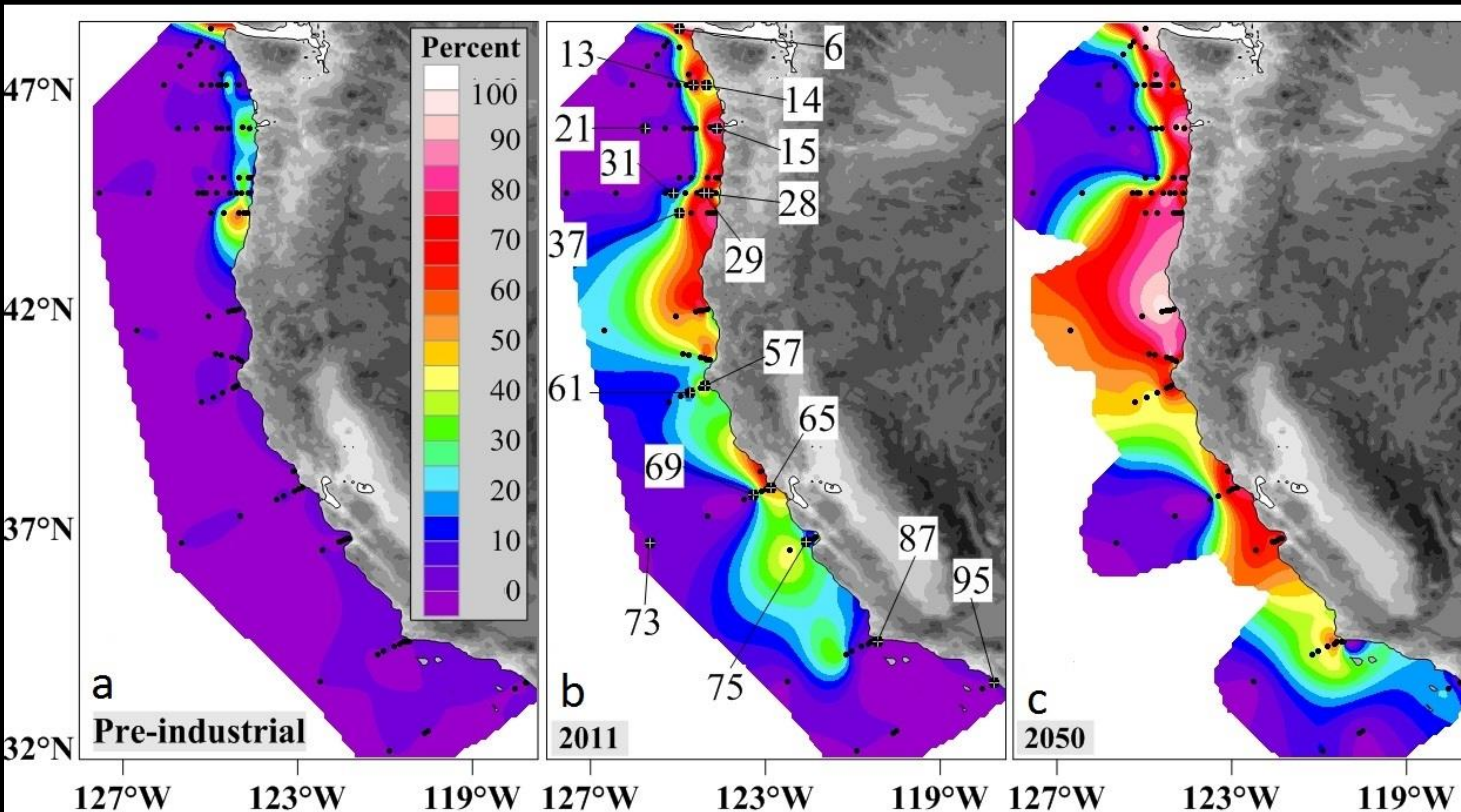
$$W_{phase} = \frac{[Ca^{2+}][CO_3^{2-}]}{K^*_{sp,phase}}$$

$\Omega > 1$ $CaCO_3$ precipitates

$\Omega = 1$ equilibrium

$\Omega < 1$ $CaCO_3$ dissolves

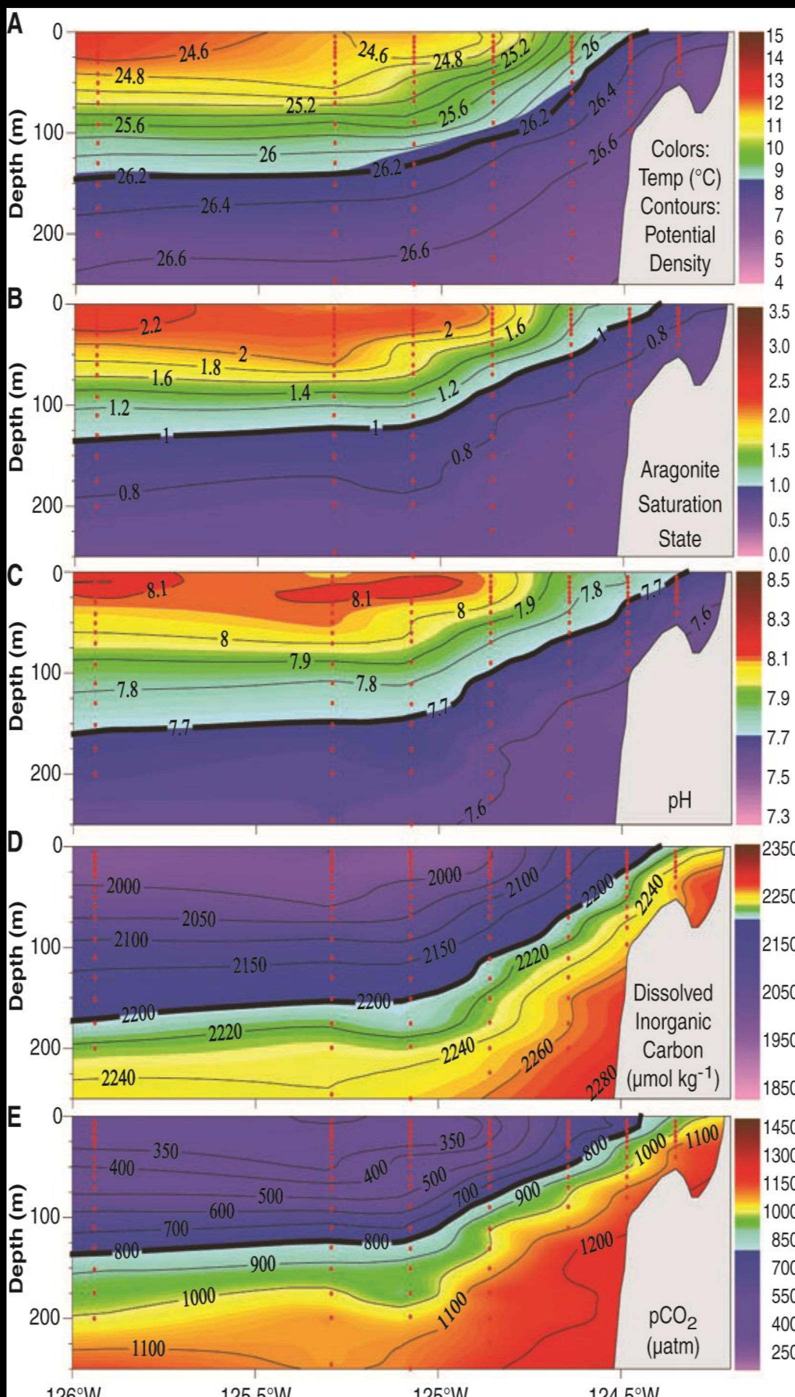
Ocean Acidification in California Current System



Percent of upper 100 m in CCE water column estimated to be undersaturated during the (a) pre-industrial, (b) 2011 and (c) predicted for 2050.

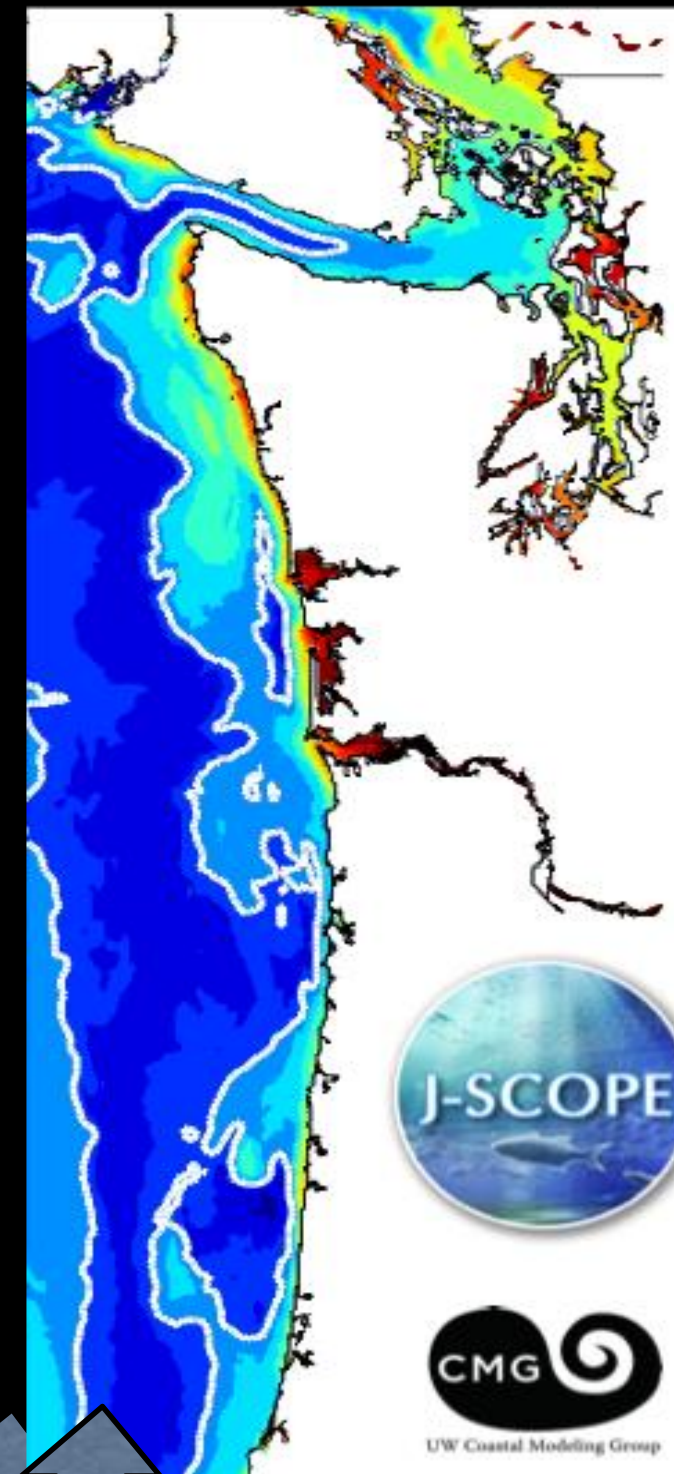
Ocean Acidification from a perspective of:

a) carbonate chemist b) bio experimentalist c) modeler



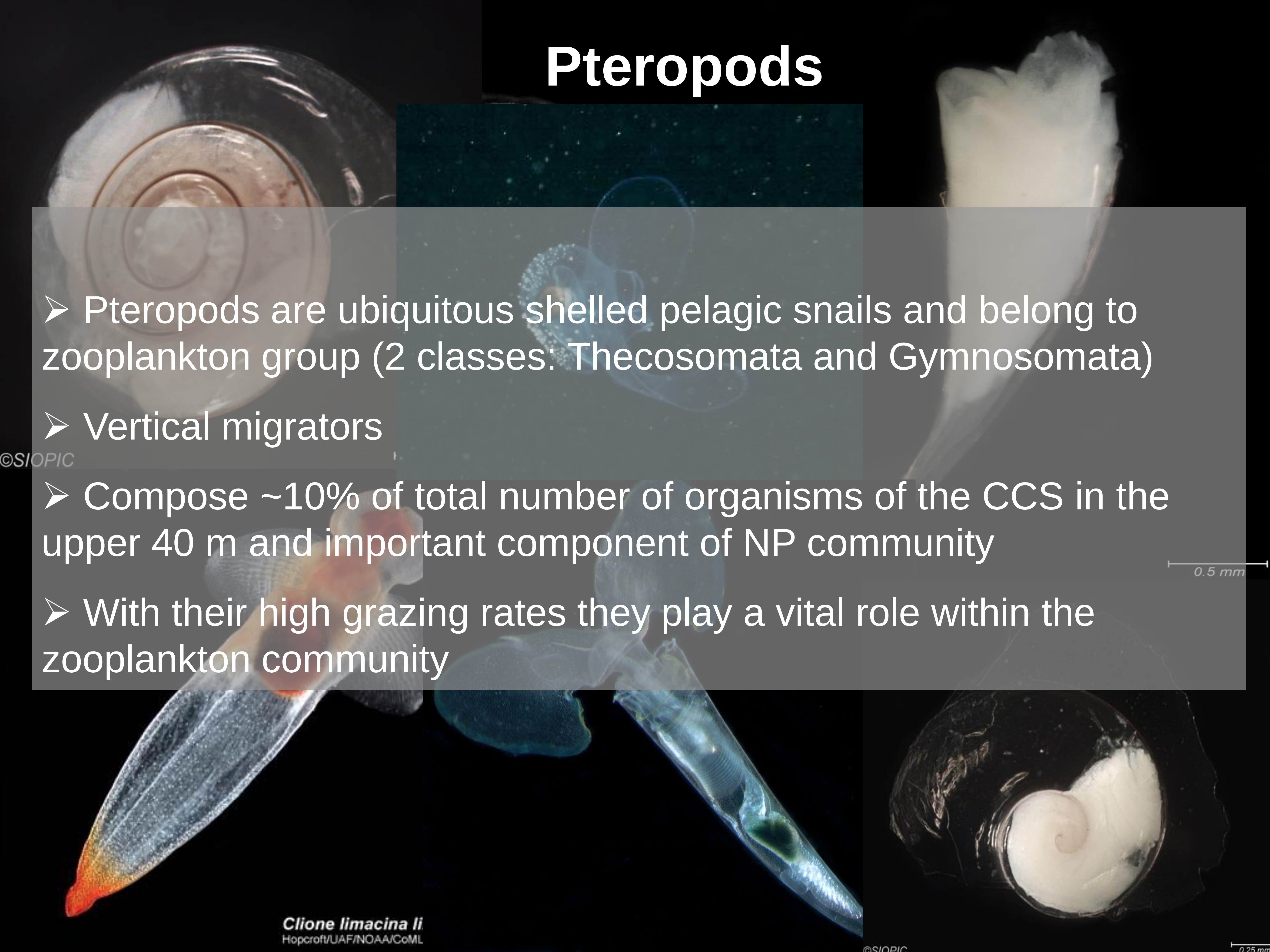
Seasonal/interannual variability
Processes

- **Basic biological processes (calcification, growth, survival, biogeography)→ changes in food webs, ecosystem goods & services**
- **Understanding impacts → correlation to carbonate chemistry and interactive effect of multiple stressors**
- **Experimental design**
- **Biologically relevant index (Magnitude/Duration/Severity Index)**
- **Pteropods as a case study**



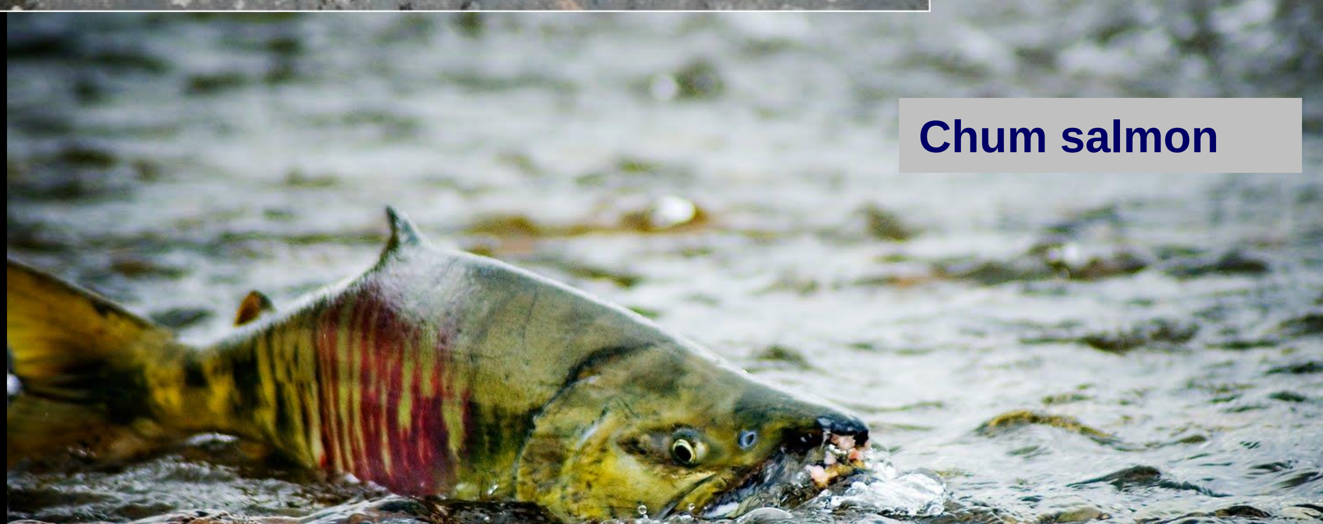
Teasing out each process at space/time scale, observations to validate models

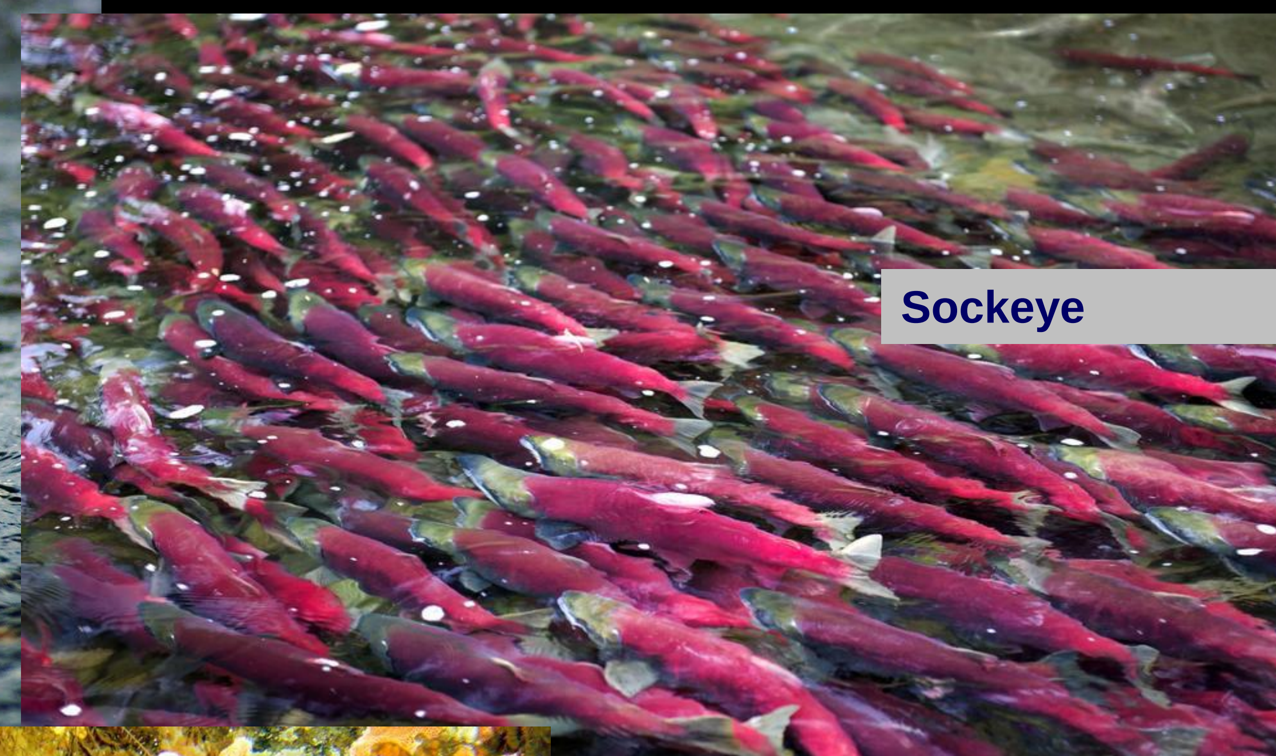
Pteropods

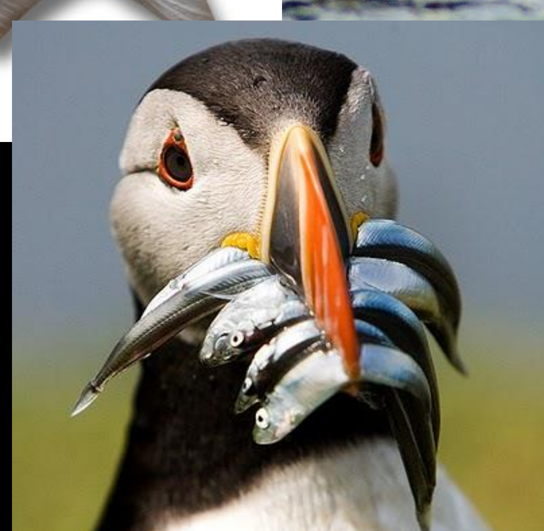


- Pteropods are ubiquitous shelled pelagic snails and belong to zooplankton group (2 classes: Thecosomata and Gymnosomata)
- Vertical migrators
- Compose ~10% of total number of organisms of the CCS in the upper 40 m and important component of NP community
- With their high grazing rates they play a vital role within the zooplankton community

Pteropods as food source for …



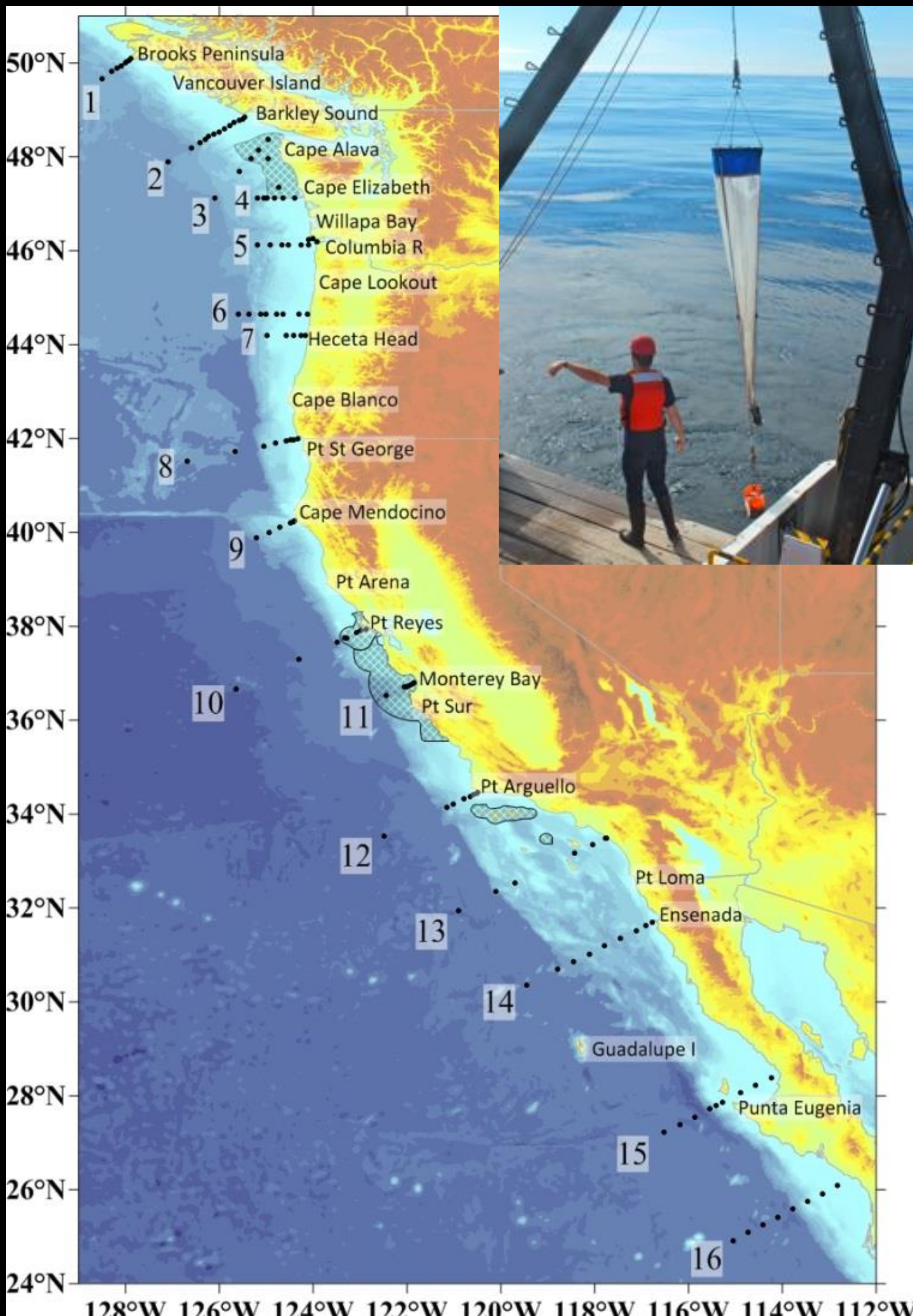




Pteropods – biogeochemical implications

- As a microphagous zooplankton important producer of faecal pellets → biogenic matter export
- The only pelagic aragonite producers → maintaining alkalinity flux
- 20-42% to the global carbon export production → fuelling long-lived carbon pool and carbon sequestration

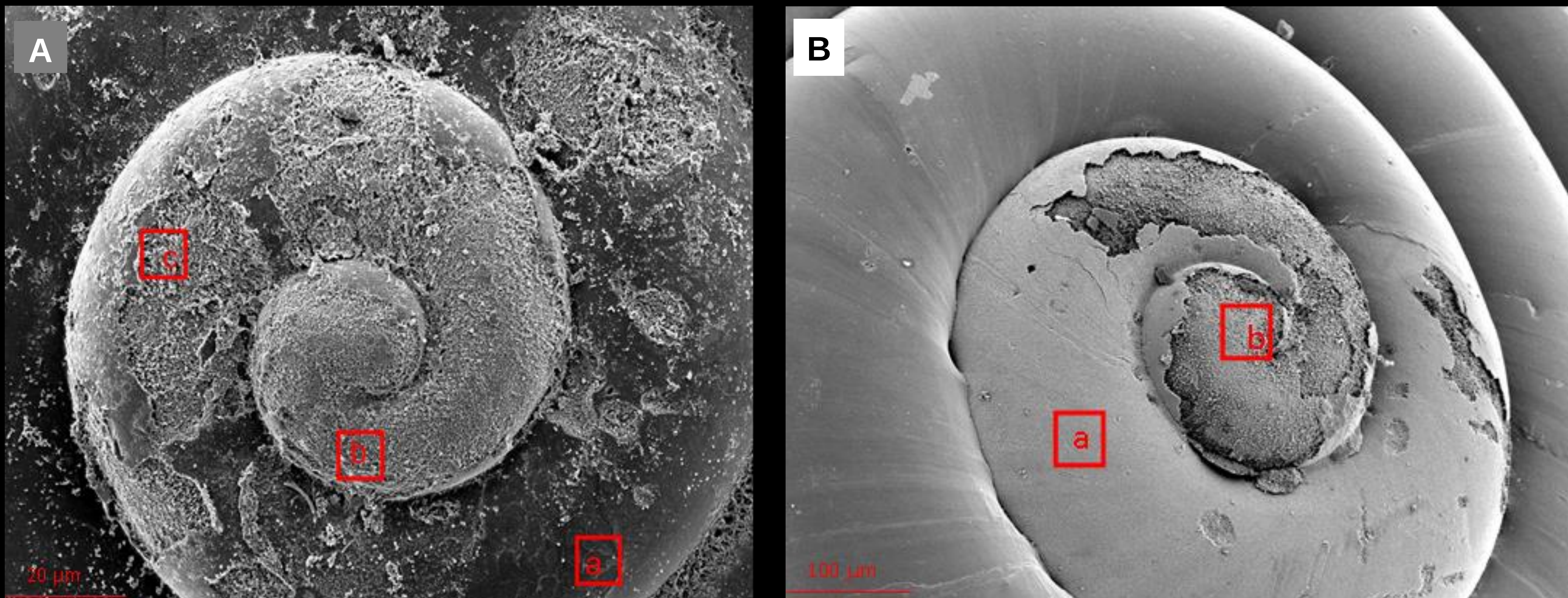
WCOA NOAA 2013 cruise



→Space-for-time approach→ pteropod response at various carbonate gradients in the natural environment

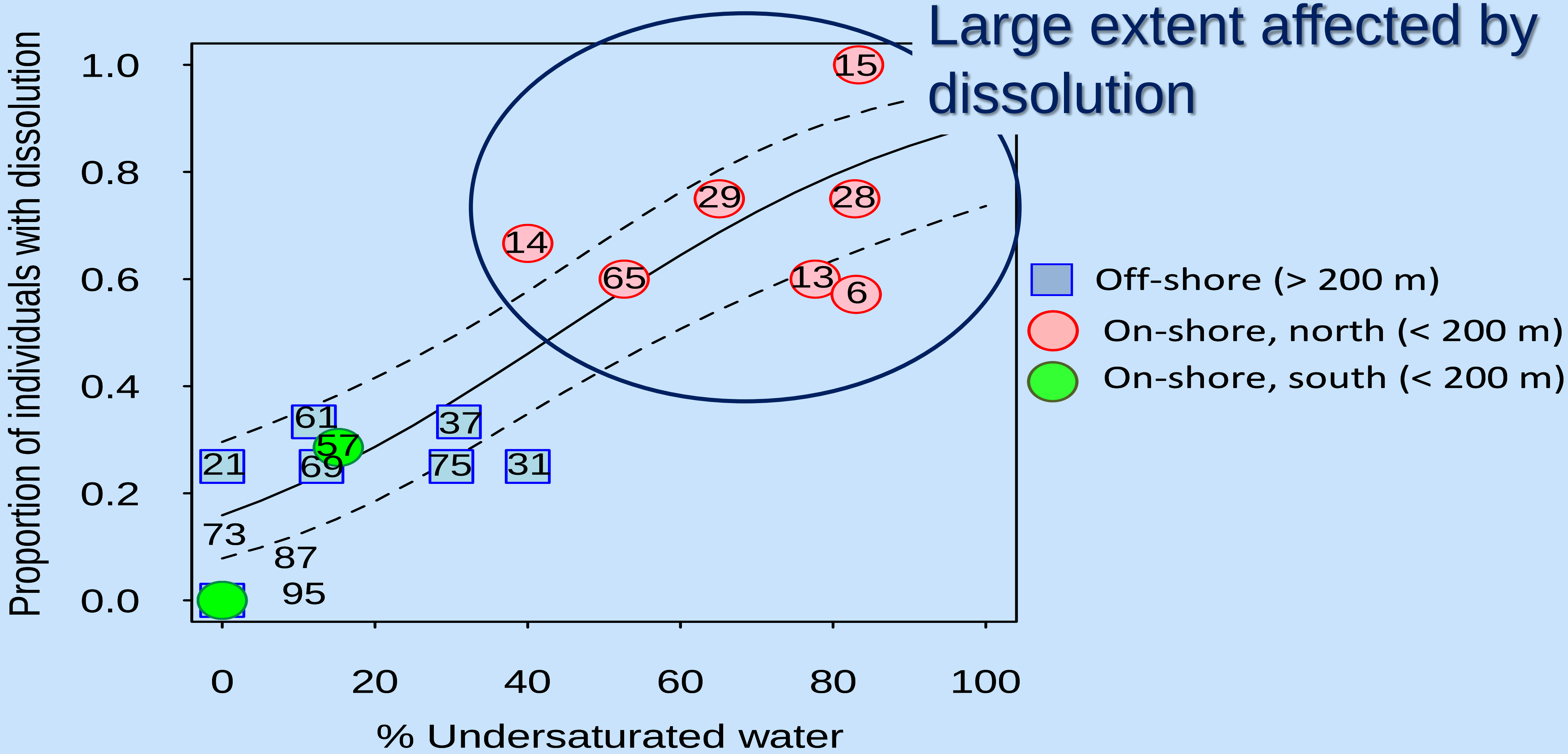
→**What 'stress' are pteropods exposed to due to OA? What is the status of 'healthy' pteropod?**

Pteropod shell dissolution in the California Current Ecosystem



Shell dissolution not the case of future scenarios (North, Coastal regions of CCS)
Onshore vs offshore shell as observed under the scanning electron microscope

Pteropod Shell Dissolution in the Natural Environment



- Strong positive relationship between % of undersaturated waters and proportion of dissolved individuals
- ↑ % of undersaturation → reduction in suitable habitat availability

Bednaršek et al., Proceedings to the Royal Society, 2014

Dissolution of indicator of past, present and future

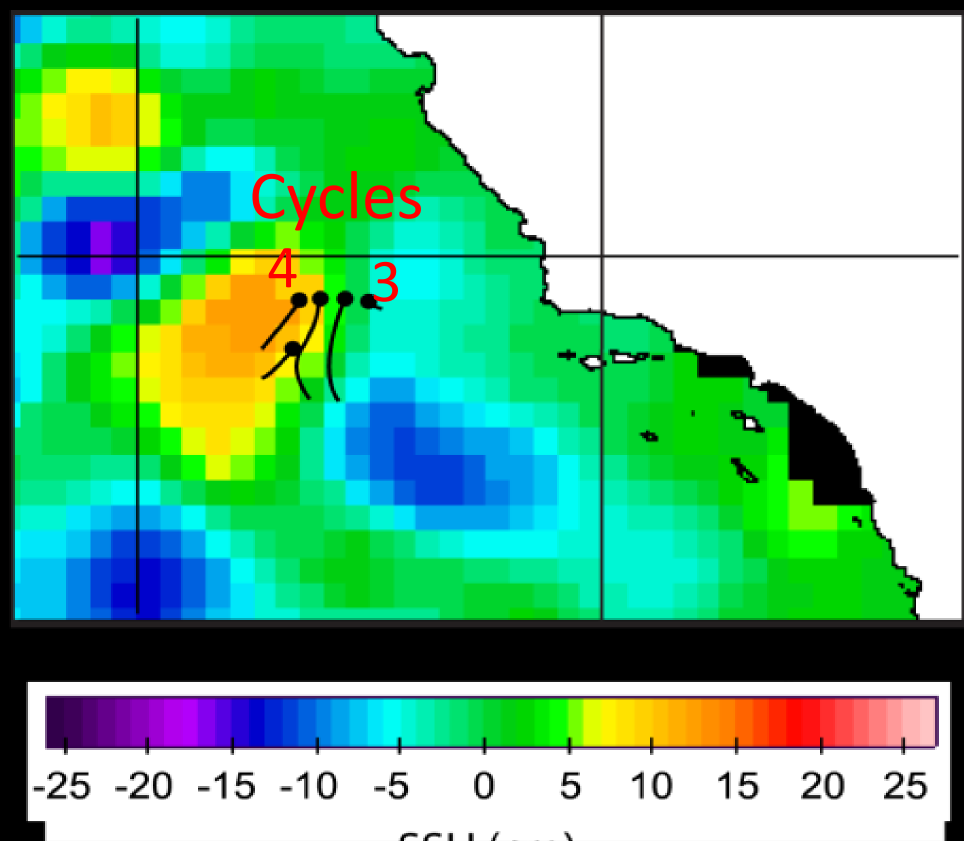
Pre-industrial level of dissolution only due to upwelling: naturally occurring dissolution (18%)

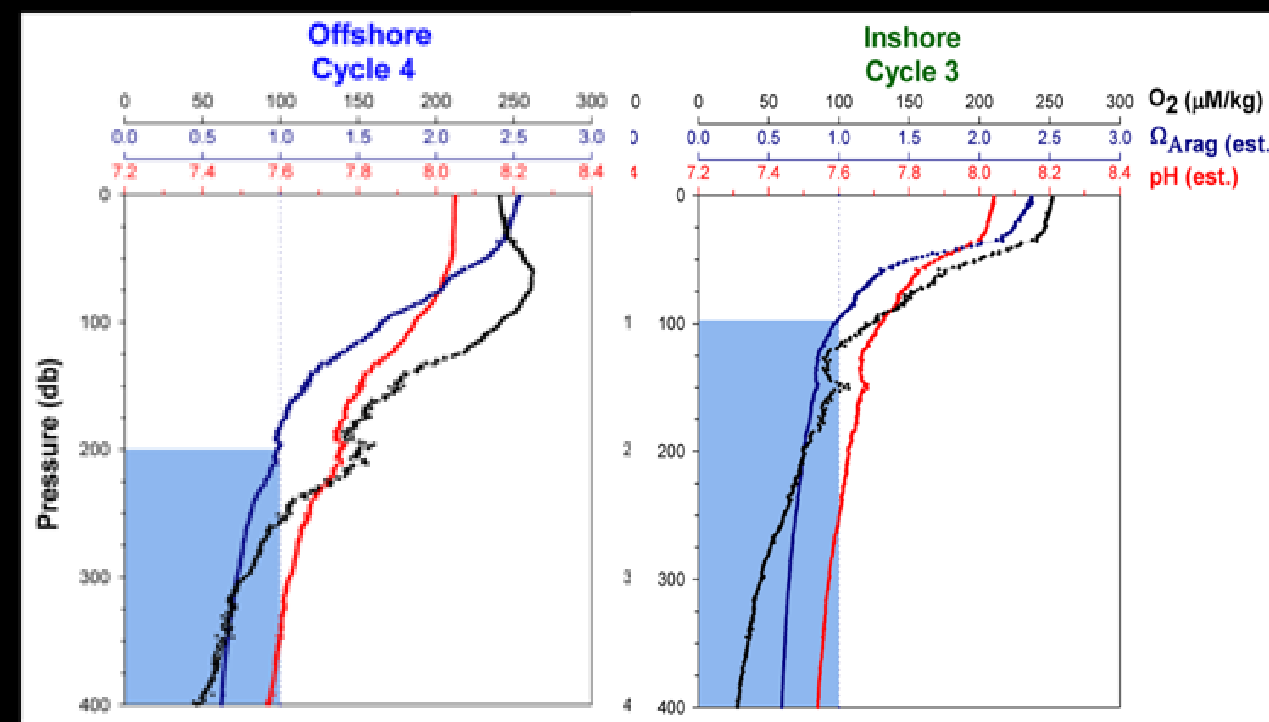
Currently, significant increase in dissolution → 53% in the coastal regions.

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

Vertical migration responses

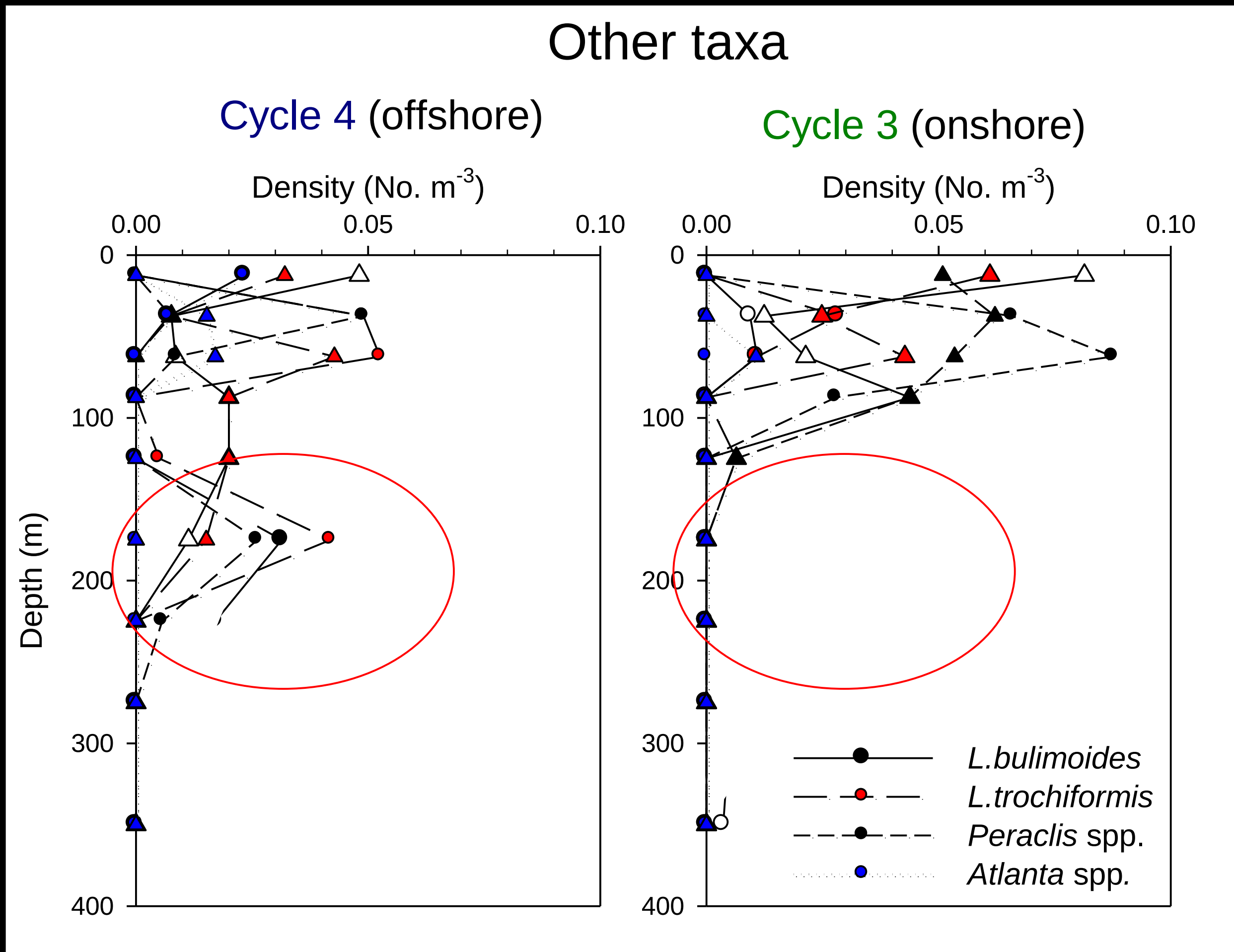
- Eddy-associated front (off- and on-shore of the front)
- Difference in the aragonite saturation depth: Cycle 4 vs Cycle 3

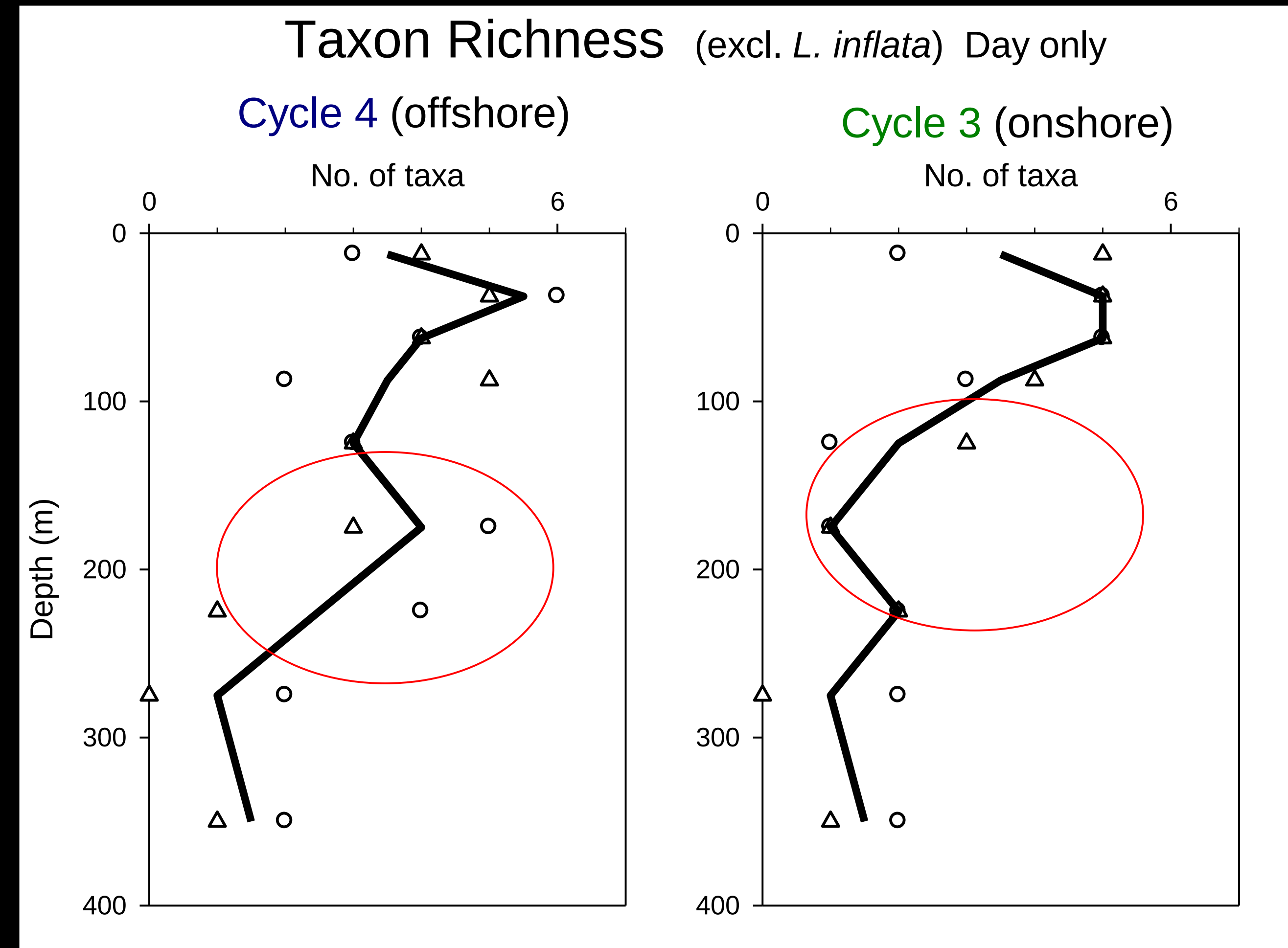




- Space-for-time exchange approach to examine pteropod vertical distribution and species richness

Changes in **vertical migration** and **species richness**



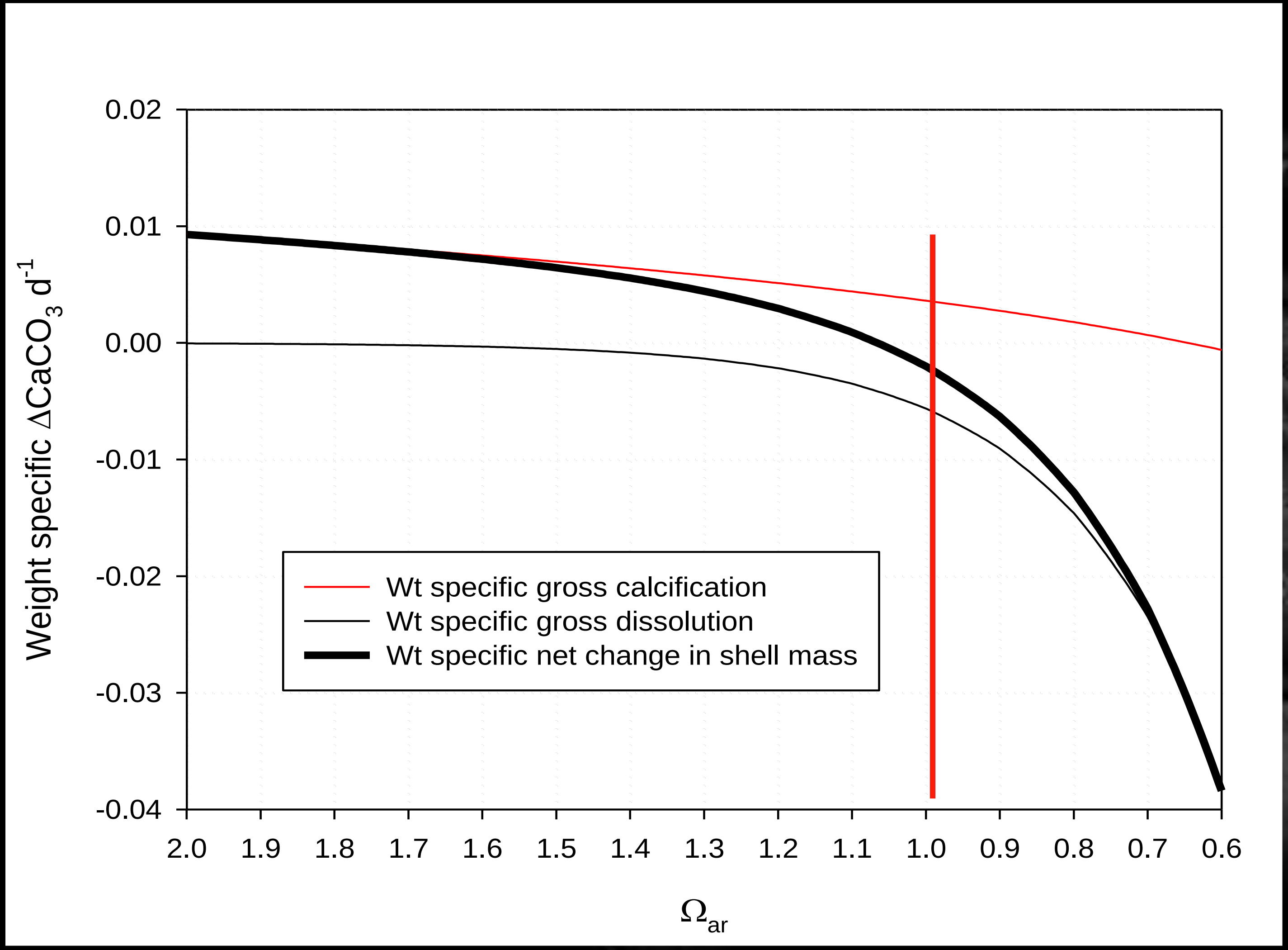


→ Changes in biodiversity with reduced habitat

→ Potential food web implications

Bednarsek and Ohman, in review, MEPS

Dissolution vs Calcification?



→Dissolution becomes the dominating process even at Ω_{ar}~1

→ Calcification cannot offset dissolution Ω_{ar}< 1

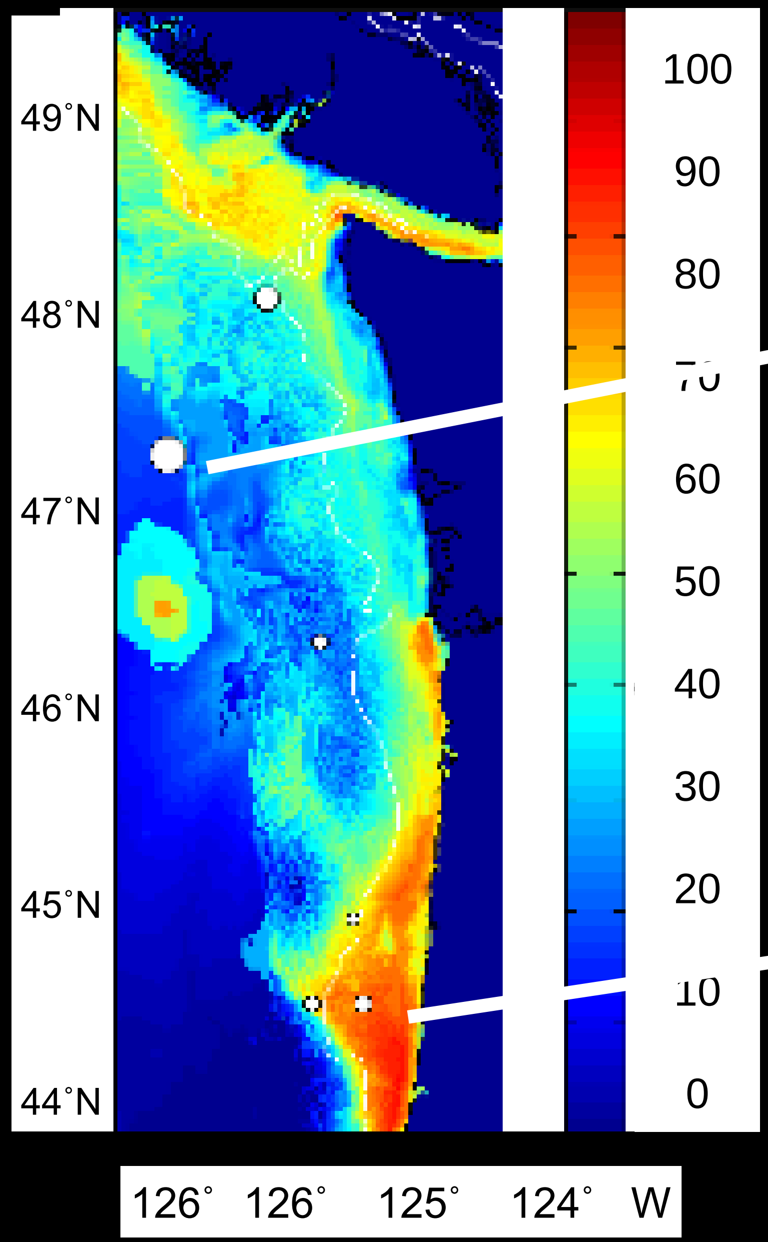
→ 1.4% of shell mass per day (Ω_{ar}=0.8) and slower sinking velocities (2X) and decreased carbonate fluxes to the deep

Bednarsek et al., PLOS One, 2014

Model predictability

J-SCOPE:
Combination of NOAA's Climate Forecast System and Regional Ocean Modeling System

Model Output, forecasting average undersaturation
July 2013



19%
undersaturation

76%
undersaturation

Model largely agrees with chemical observations → forecasting of biological responses → Magnitude index

Next steps

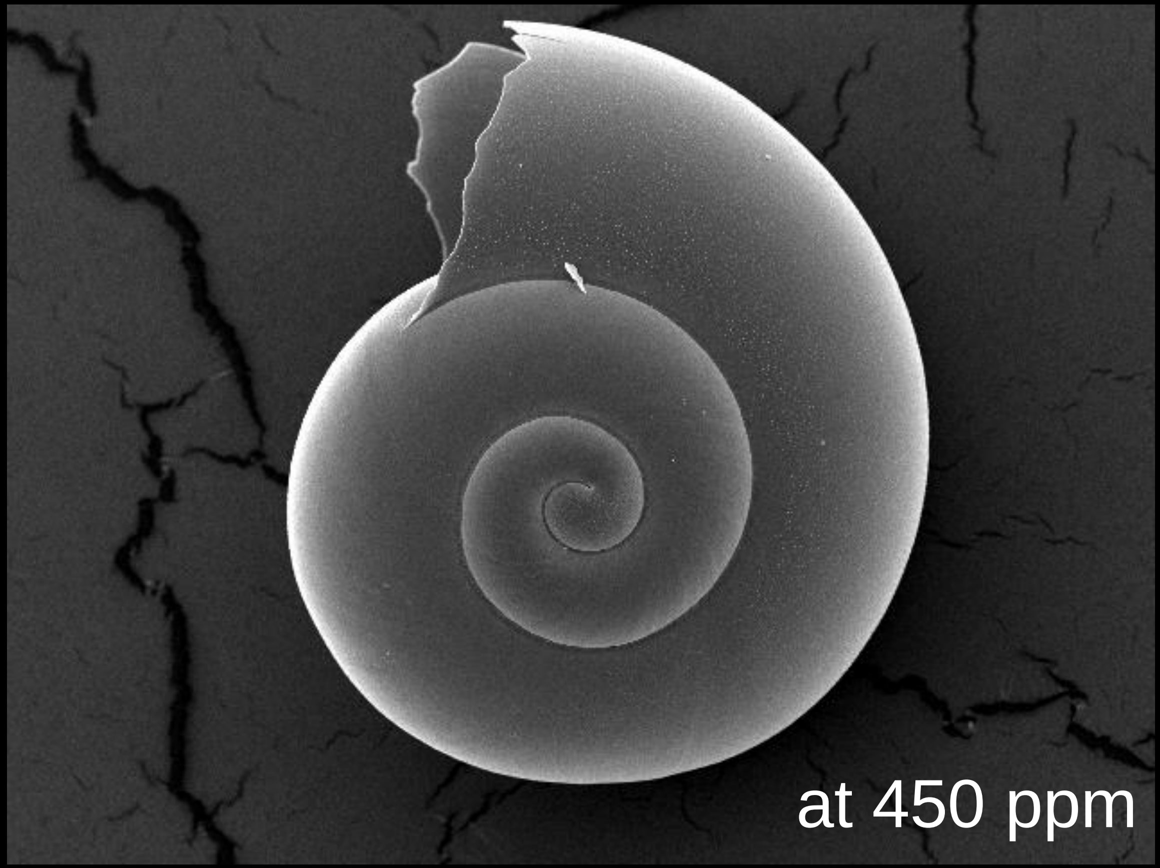
- Various pteropod responses strongly correlated with Ω_{ar}, OA monitoring: hypoxia next→ multicolinearity!
- First steps towards the development of an index for forecasting OA for pteropods (other calcifiers?)
- Determination of exposure regimes for bioassays
- Pteropods as ecosystem indicators in the integrated ecosystem assessment
- Translation into policy (communication and information sharing) for stakeholders along the West Coast → Mitigation/Adaptation Strategies

Future of Pteropods?

Will pteropods survive ocean acidification?

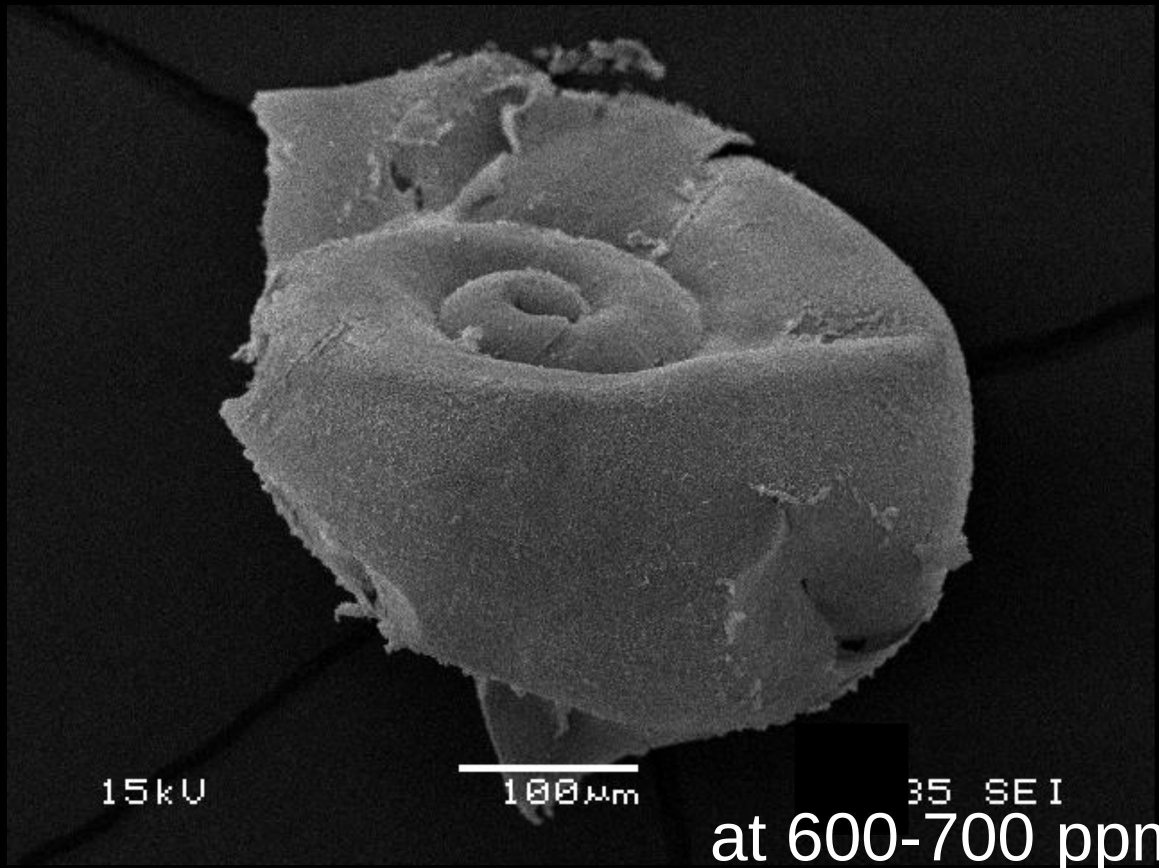
At 600-700 ppm stabilization scenario, dissolution and mortality increased, calcification decreased.

Important to keep pCO_2 as low as possible.



at 450 ppm

OR



at 600-700 ppm **?**