Outline

◆ Anthropogenic CO₂ Increases
◆ Effect of Increasing Revelle Factor
Accomplishments: Repeat hydrography (left) continues to demonstrate the growing global ocean CO$_2$ sink while fixed time series stations (top) illuminate how interannual events, such as “the blob,” impact CO$_2$ flux (from Carter et al. 2017; Carter et al. in prep; Feely et al. 2018; Sutton et al. 2017)
Increasing CO$_2$ levels in the ocean increases its acidity (lowers its pH). These processes are faster in California coastal waters due to the combined effects of acidification, upwelling, and local carbon and nutrient sources.

Observations and modeling studies indicate that local anthropogenic carbon and nutrient sources provide significant contributions to local acidification but vary widely depending on location.
Aragonite saturation depth indicates strong upwelling near the coast from northern California to Vancouver Island.

NOAA West Coast Cruise 8 May – 6 June 2016 compared with May-June 2007.
Anthropogenic CO$_2$ vs potential density in the California Current System

Anthropogenic CO$_2$ is calculated from PO2 Repeat Hydrography cruises in 2004 and 2013 and then interpolated onto California Current System potential density surfaces.

$$C_{Anth} = \min \left( \frac{C_{ML}}{S_{\sigma_{e}}}, A \left( \frac{(\sigma_{\theta} - \overline{\sigma_{\theta}})}{S_{\sigma_{e}}} \right)^{2} + B \left( \frac{(\sigma_{\theta} - \overline{\sigma_{\theta}})}{S_{\sigma_{e}}} \right) + C \right)$$
Anthropogenic Carbon Distributions in 2016

May-June 2016 $C_{\text{anth}}$ µmol kg$^{-1}$

- High $C_{\text{anth}}$ surface values (55-66 µmol kg$^{-1}$) offshore and to the south

- Low $C_{\text{anth}}$ subsurface values (40-54 µmol kg$^{-1}$) in onshore waters from Heceta Head to Point Reyes

- Low $C_{\text{anth}}$ waters everywhere below 100m

Feely et al., in prep
Evolution of chemical conditions in the California Current Ecosystem

Decadal trend in anthropogenic carbon concentration and aragonite saturation changes from the preindustrial to present

Anthropogenic CO₂ (µmol/kg)  
Change in aragonite saturation state
Evolution of chemical conditions in the California Current Ecosystem

Decadal trend in anthropogenic carbon rate of change in the water column
Surface water changes over time

pH: lower in West Coast surface waters
similar decreases from present-day

$\Omega_{\text{arag}}$: lower in West Coast surface waters
larger decreases in GOM from present

$RF = (\Delta pCO_2/pCO_2)/(\Delta DIC/DIC)$ changes more rapidly in the cooler West Coast waters

Feely et al (2018)
In coastal environments like the Salish Sea, the increasing anthropogenic carbon reduces the ability of the system to buffer natural variations in CO₂. This reduced buffering capacity leads to preferential amplification of naturally extreme low pH and high pCO₂(s.w.) events above changes in average conditions, which outpace rates published for atmospheric and open-ocean CO₂ change. - Pacella et al., PNAS 2018
Conclusions

- Our major challenge is to determine anthropogenic ocean acidification changes and biological responses against a backdrop of large natural variability. **Approach to Solve: Collaborative Monitoring and Modeling**

- Co-located chemical/biological field observations provide unique opportunities to observe and understand long-term changes as impacted by ocean acidification and hypoxia. **Approach to Solve: Collaborative Monitoring and Modeling**

- Oyster larvae, Pteropods and Crab larvae exhibit physiological responses that appear to be impacted by ocean acidification now. **Approach to Solve: Continued Collaborative Field and Laboratory Studies**