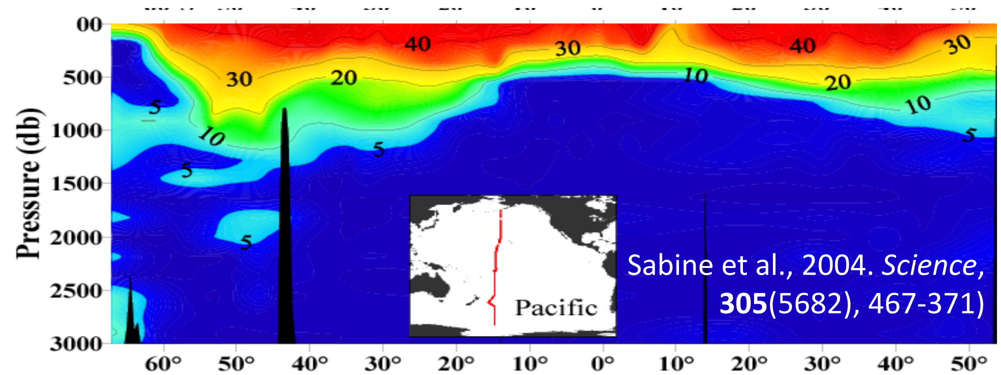
Controls on Carbonate Mineral Saturation States and Ocean Acidification on the Southeastern Bering Sea Shelf

Jessica N. Cross[1]*
Jeremy T. Mathis[1]
Nicholas R. Bates[2]

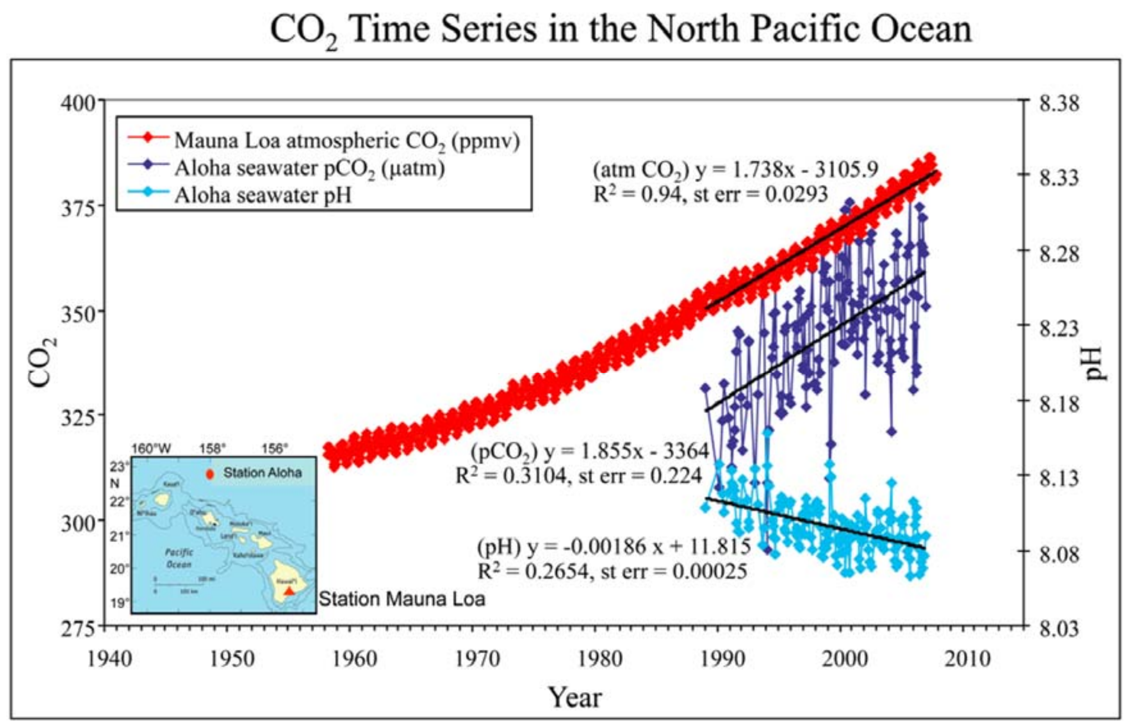
[1]Ocean Acidification Research Center, School of Fisheries and Ocean Sciences, University of Alaska, Fairbanks
[2]Bermuda Institute of Ocean Sciences

Rising CO_2 levels

- The oceans have absorbed ⅓ to ½ of all anthropogenic CO_2 emissions.
- As CO_2 in seawater increases:
  - pH decreases
  - Concentrations of CO_3^{2-} decrease
  - Saturation States (Ω) decrease

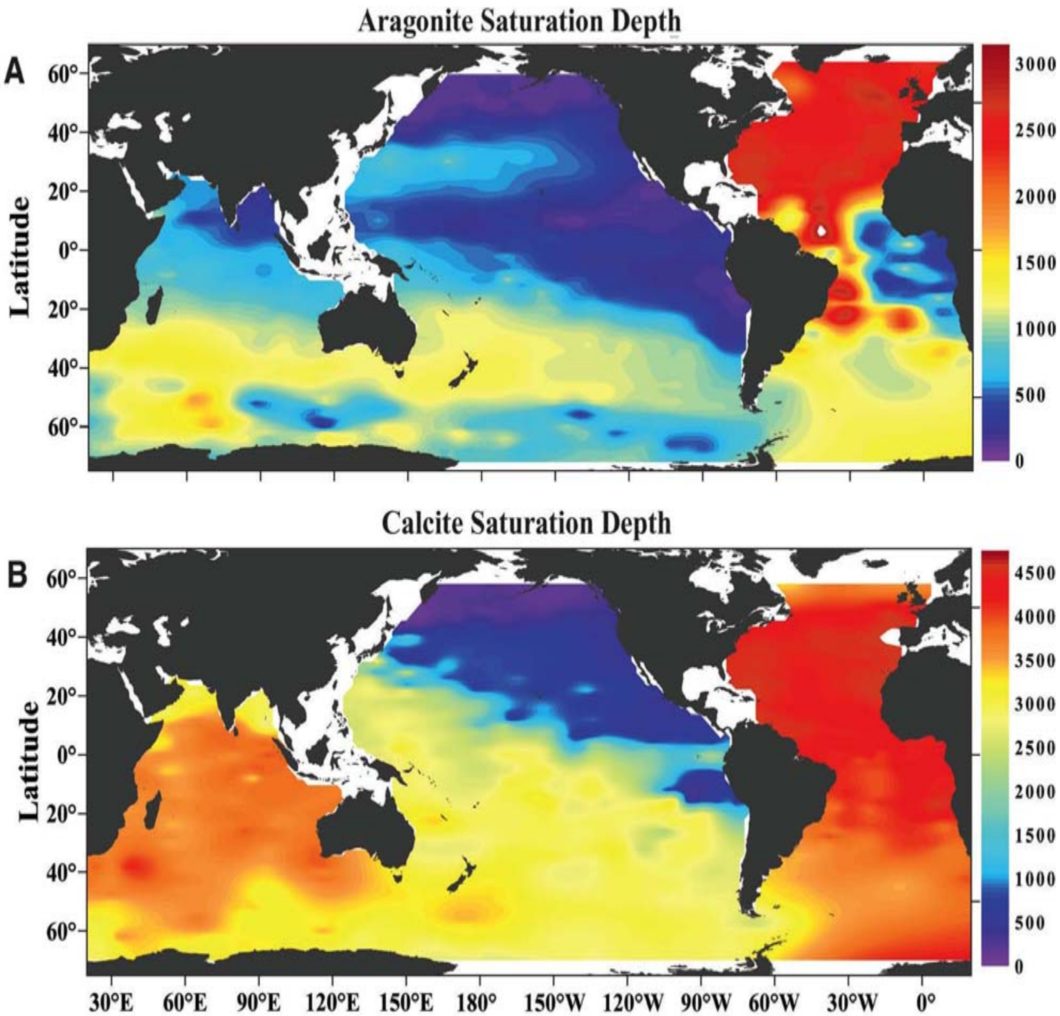


Sabine et al., 2004. *Science*, **305**(5682), 467-371)



Doney et al., 2009. *ARMS*, **1**, 169-192

Preconditioning at high latitudes



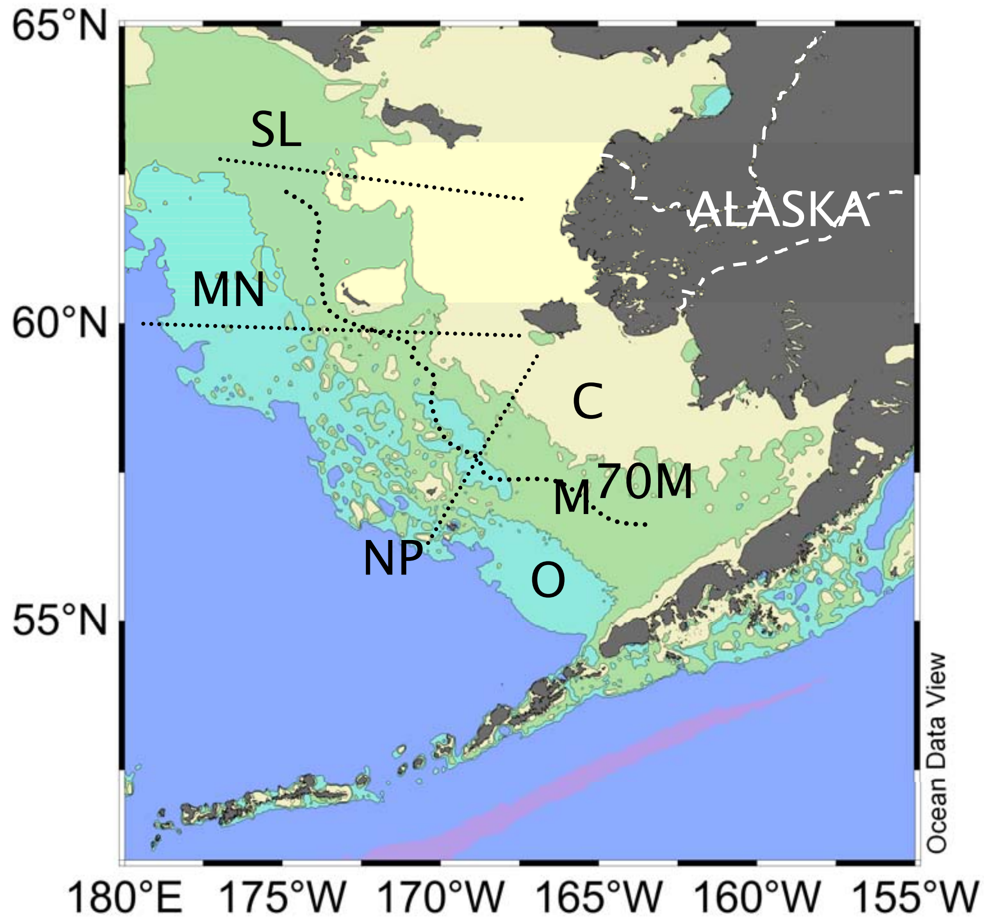
Feely et al., 2004. *Science*, **305**(5682), 362-366

- Cold, highly productive waters can hold more CO_2.
- This results in a high potential for undersaturation.
  - $\Omega = 1$: Horizon
  - $\Omega \leq 1$: Undersaturation.

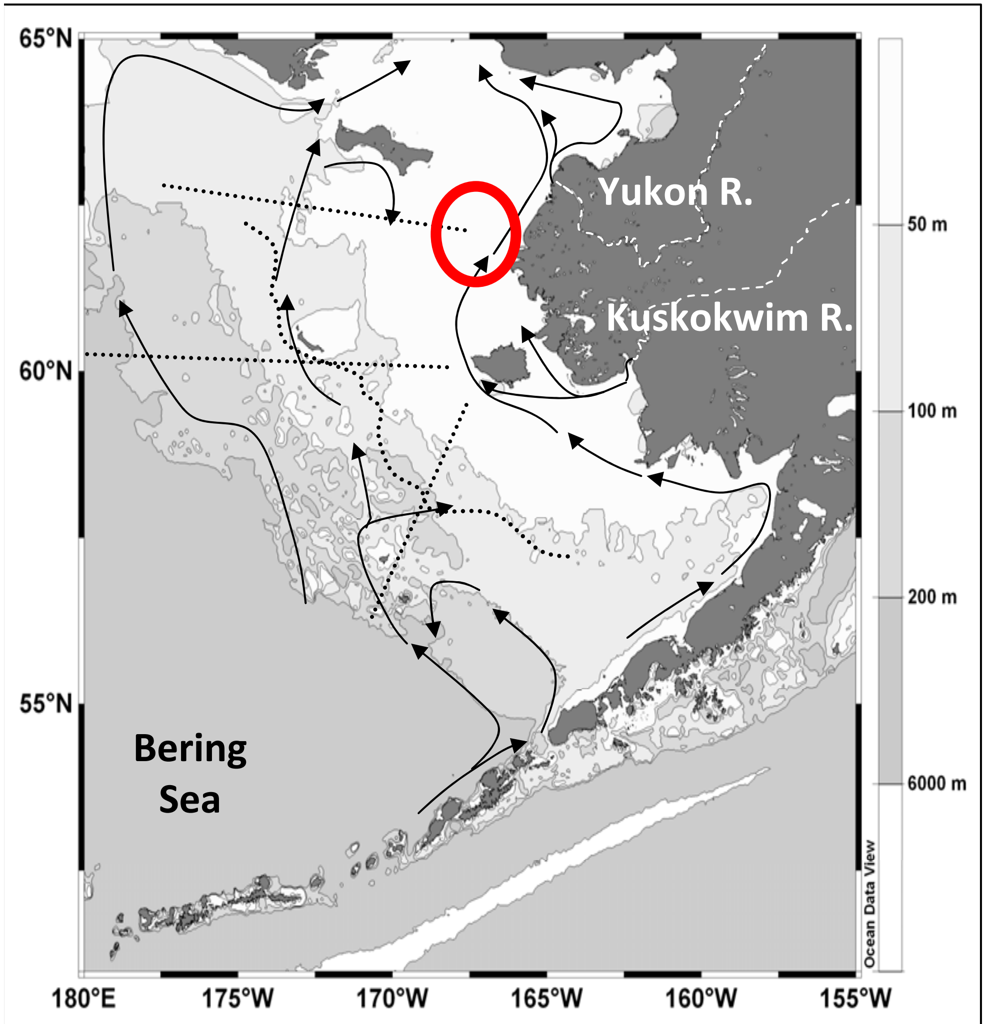
Southeastern Bering Sea Shelf

Some natural processes seasonally affect Ω and pH in the Bering Sea.

- [DIC], pCO_2 ↑ and/or [Alk] ↓ = Ω ↓
  - DIC = Dissolved Inorganic Carbon
  - Alk = Alkalinity
- Freshwater Inputs
  - Terrestrial Preconditioning
  - Ice Melt
- Primary Production
  - Areas of high production rates
  - Specific species assemblages

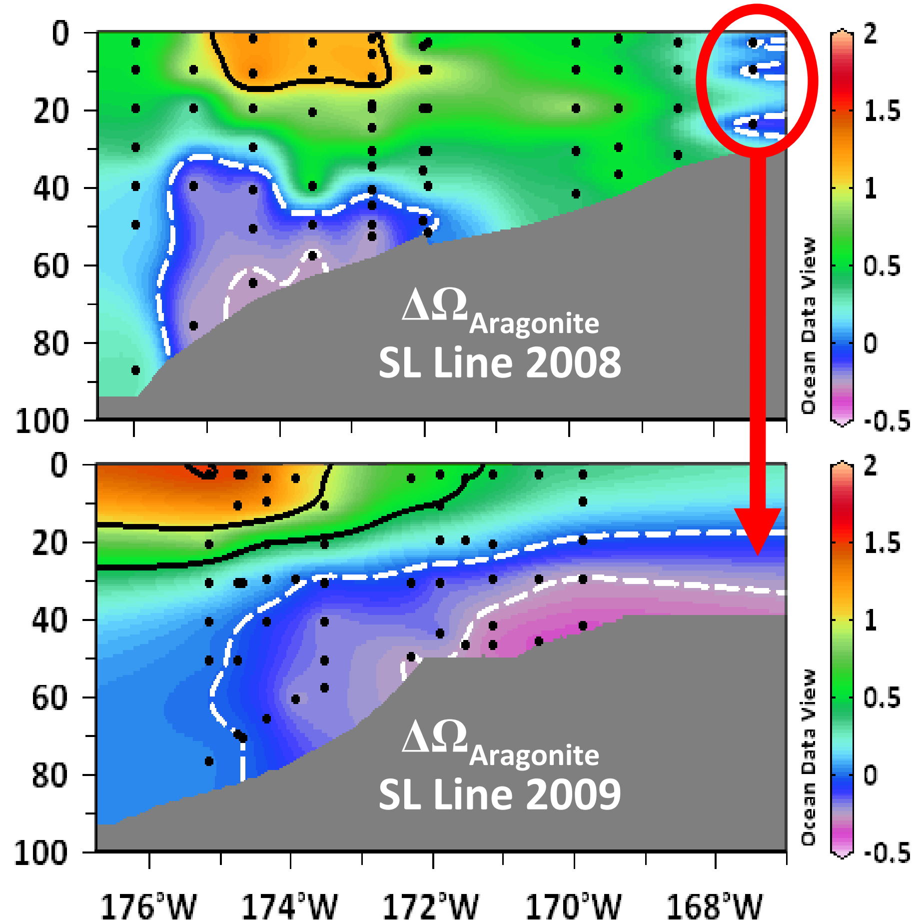


Nearshore Waters



Mathis et al., 2011. *JGR*, **116**, C02030

- **Decrease in Ω between spring and summer at innermost stations**



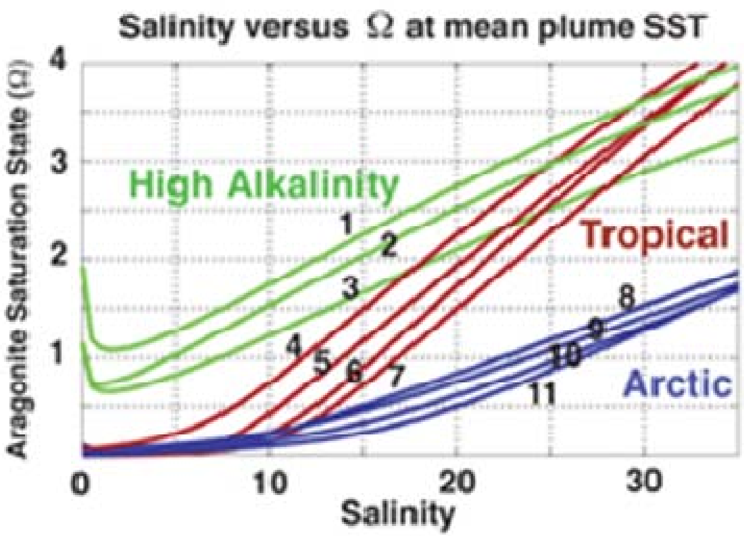
Terrestrial Preconditioning

Alaskan River Discharge

- Low pH, high pCO_2 relative to Bering Sea
- Carbonate-poor drainage basins: low relative alkalinity

	Spring	Summer	Winter
pCO_2 (μatm)	1530	1650	8280
pH	7.8	7.9	7.0
TA (μmol kg^{-1})	619	898	1300
Discharge (ft^{3}s^{-1})	400	375	40

from Striegl et al., 2007; PARTNERS Data; USGS
In Mathis et al., 2011. *JGR,* **116**, C02030



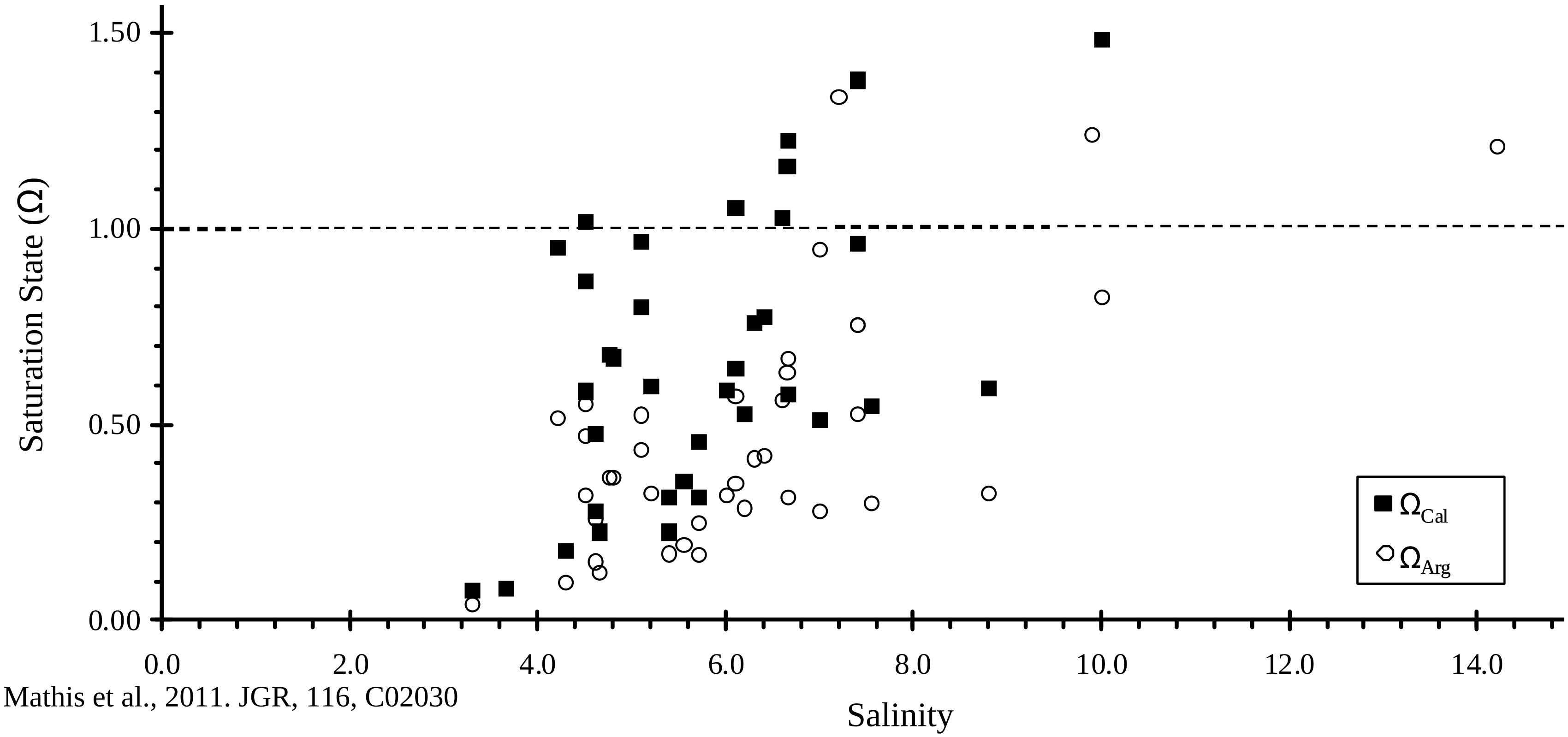
Salisbury et al., 2008. *Eos Trans. AGU*, **89** (50), 513

Seasonal cycle suppresses saturation states in two ways:

- Low discharge = highest pCO_2 concentrations
- High discharge = lowest alkalinity concentrations

Sea Ice

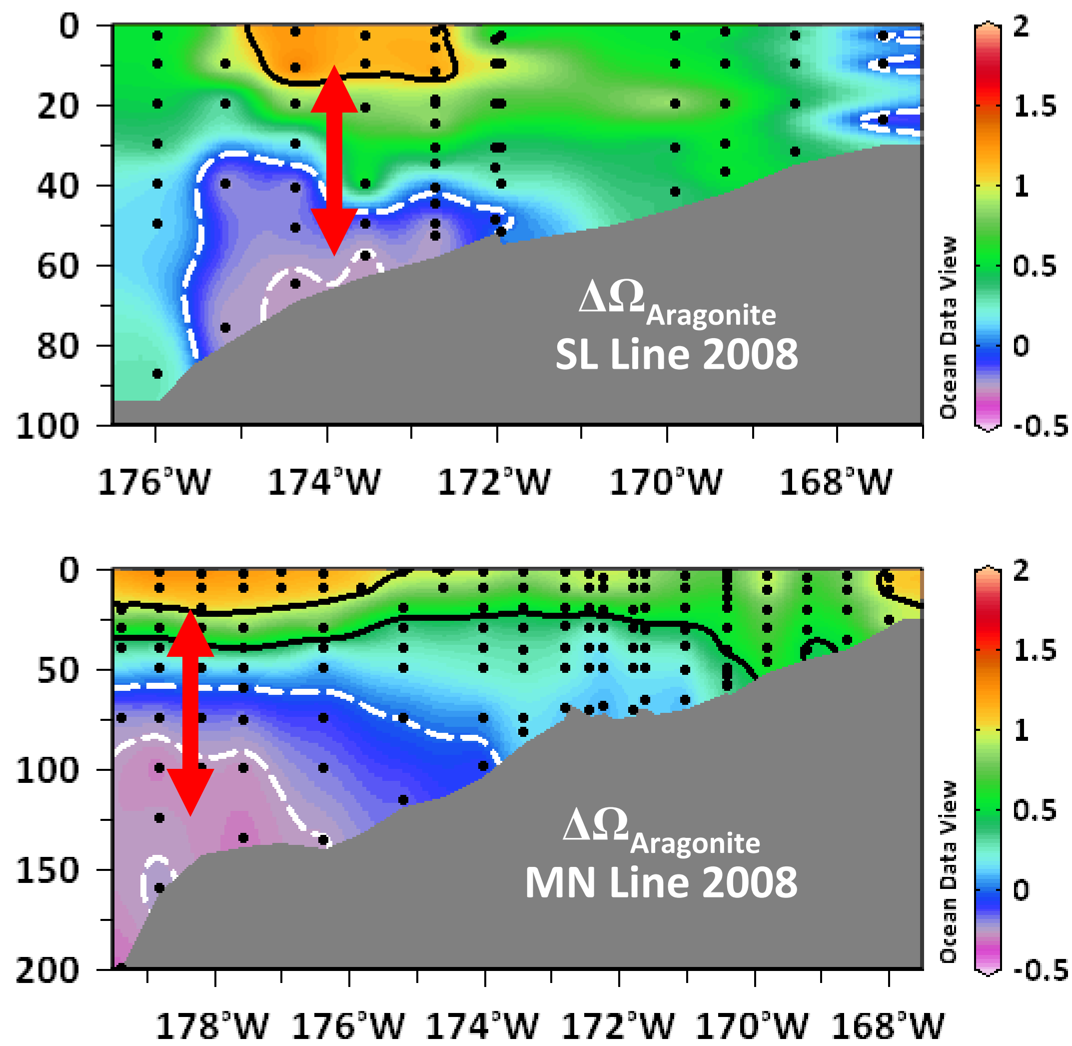
- Ice core samples from 2008 were mostly undersaturated with respect to carbonate minerals.
- Melt waters will suppress Ω and pH at the surface.



Mathis et al., 2011. JGR, 116, C02030

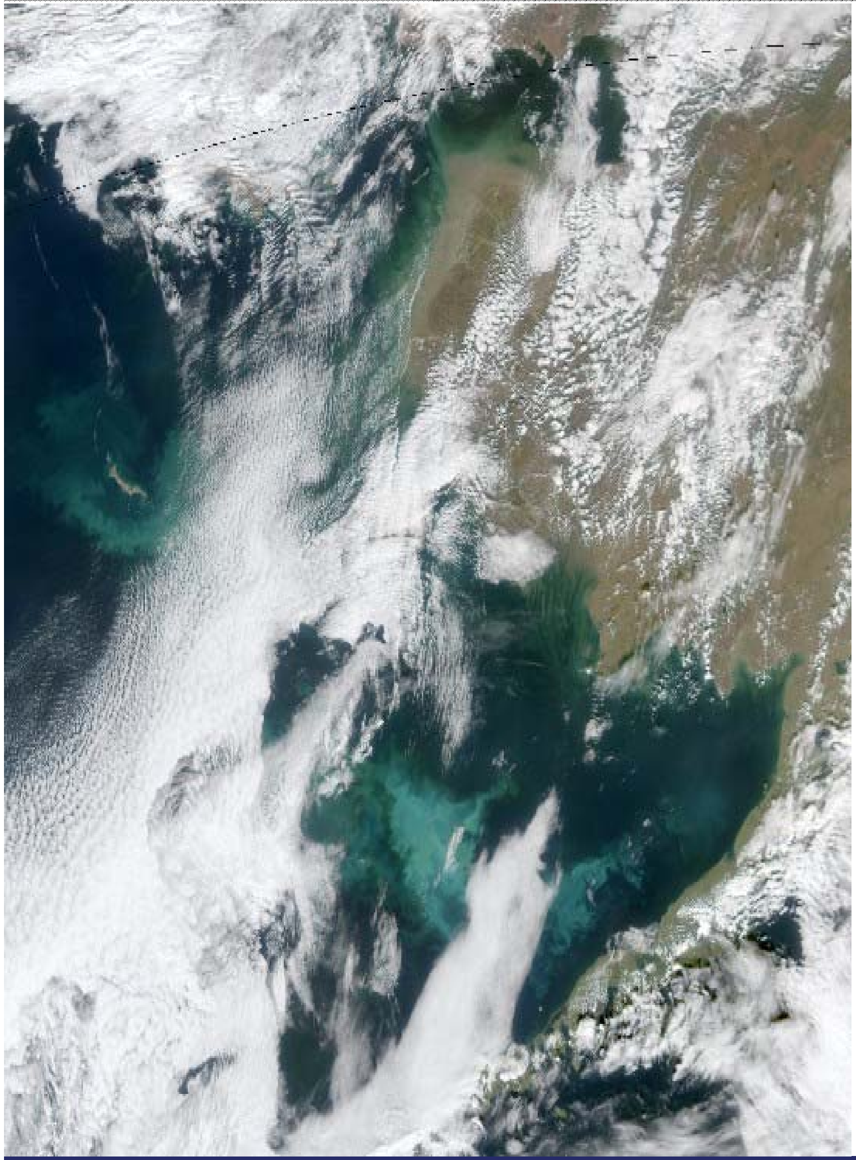
Primary Production: 2008

- PhyCaSS: High levels of productivity cause divergent trajectories of Saturation States
  - Biotic consumption of CO_2 increases pH, Ω at surface
  - Remineralization of organic matter in bottom waters lowers pH and Ω
- Stronger in cold years, when export production is heaviest



Mathis et al., 2011. *JGR*, **116**, C02030

Primary Production: 2009



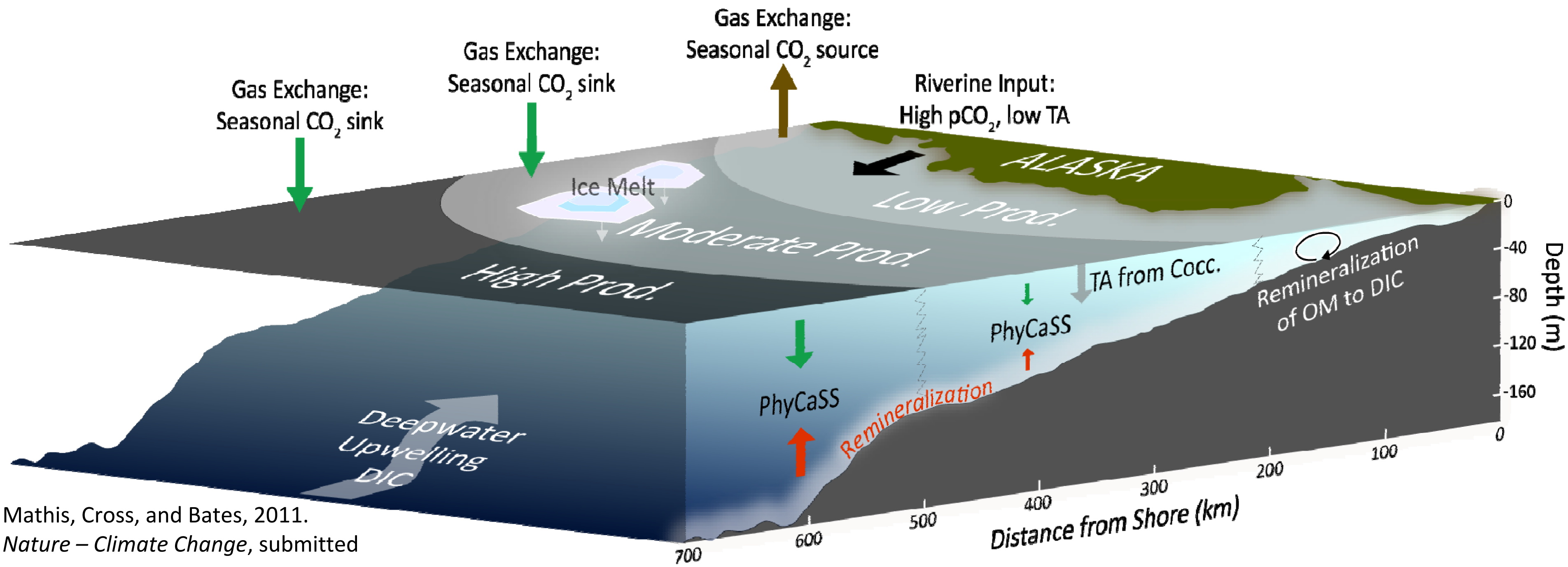
- PhyCaSS is also dependent on alkalinity.
  - Primary productivity causes an increase in alkalinity.
    - PhyCaSS dampened in bottom water, increased in surface waters
  - Drawdown of alkalinity in 2009
    - PhyCaSS dampened in surface waters, increased in bottom waters
    - Undersaturation of aragonite **and calcite** observed in 2009 bottom waters
    - Not correlated with Salinity…

Coccolithophore Production

Feldman and McClain, Ocean Color Web, SeaWiFS
Reprocessing 2009_26400_250

Natural controls on Ω and pH

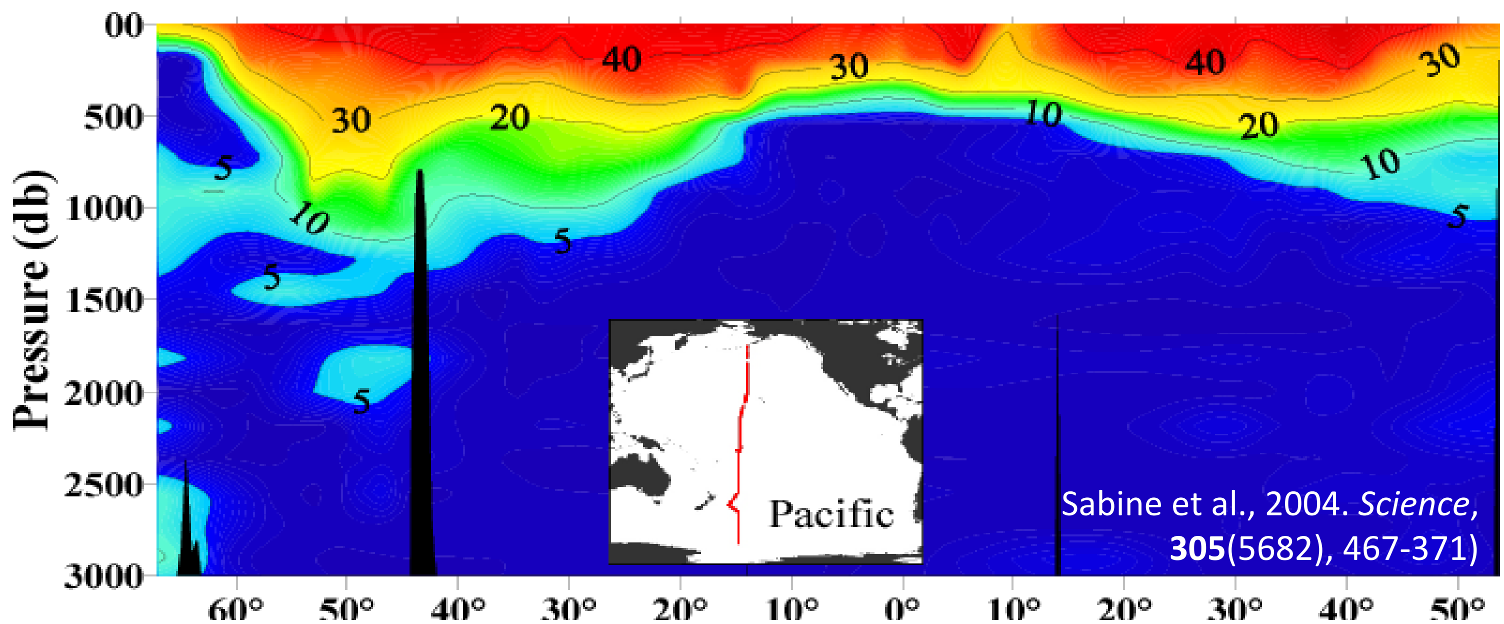
- River discharge suppresses Ω, pH at the nearshore
- Ice melt suppresses Ω, pH in surface waters; signal overwhelmed by PP
- PhyCaSS Interaction raises surface layer Ω, pH and suppresses bottom water Ω, pH; strength controlled by timing of sea-ice retreat
- Coccolithophore production suppresses Ω, pH via alkalinity removal



Mathis, Cross, and Bates, 2011.
Nature – Climate Change, submitted

Ocean Acidification

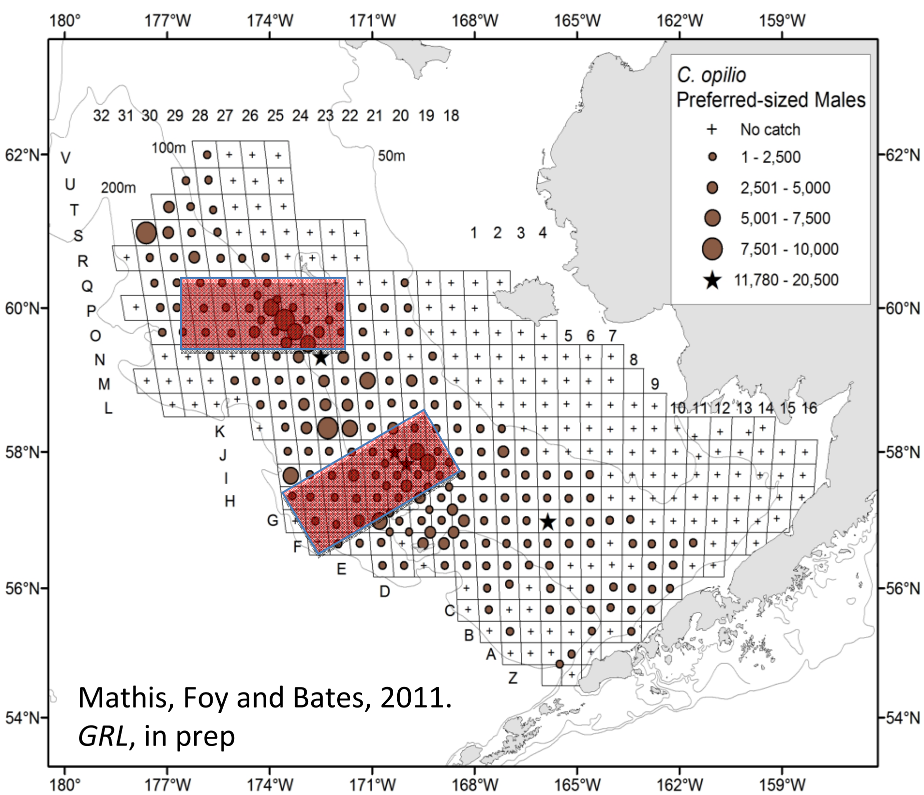
- These natural mechanisms for suppressing Ω and pH, combined with the anthropogenic load of CO_2 absorbed by the oceans, result in seasonal undersaturations in the Bering Sea.
- Without anthropogenic CO_2, no undersaturations would be present



Implications

Bering Sea Ecosystem

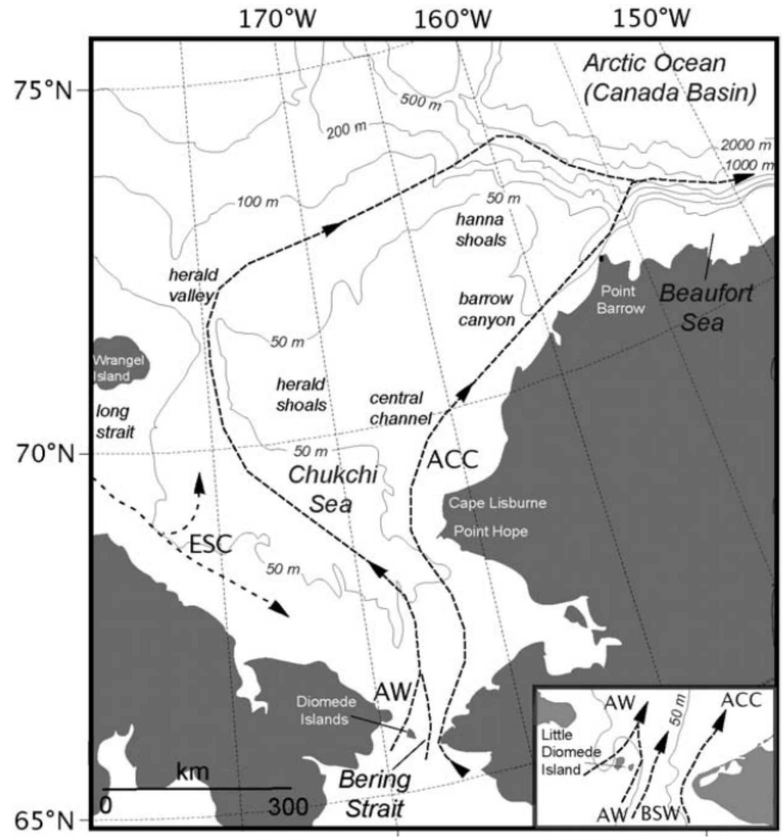
PhyCaSS provides organic matter to benthic communities, but also causes seasonal undersaturations



Mathis, Foy and Bates, 2011. *GRL*, in prep

Downstream conditions

Bering Sea waters condition the halocline of the Canadian Basin



Bates et al., 2009. *JGR*, **114**, C11007

Acknowledgements

USCGC Healy, R/V Knorr, NOAA ship *Miller Freeman*

PMEL

BEST-BSIERP: NSF and NPRB

Alaska MMS-CMI

NMFS-NOAA

UNIVERSITY OF ALASKA FAIRBANKS

BIOS BERMUDA INSTITUTE OF OCEAN SCIENCES