Impact of local biogeochemical processes and climate variability on ocean acidification in the Bering Sea

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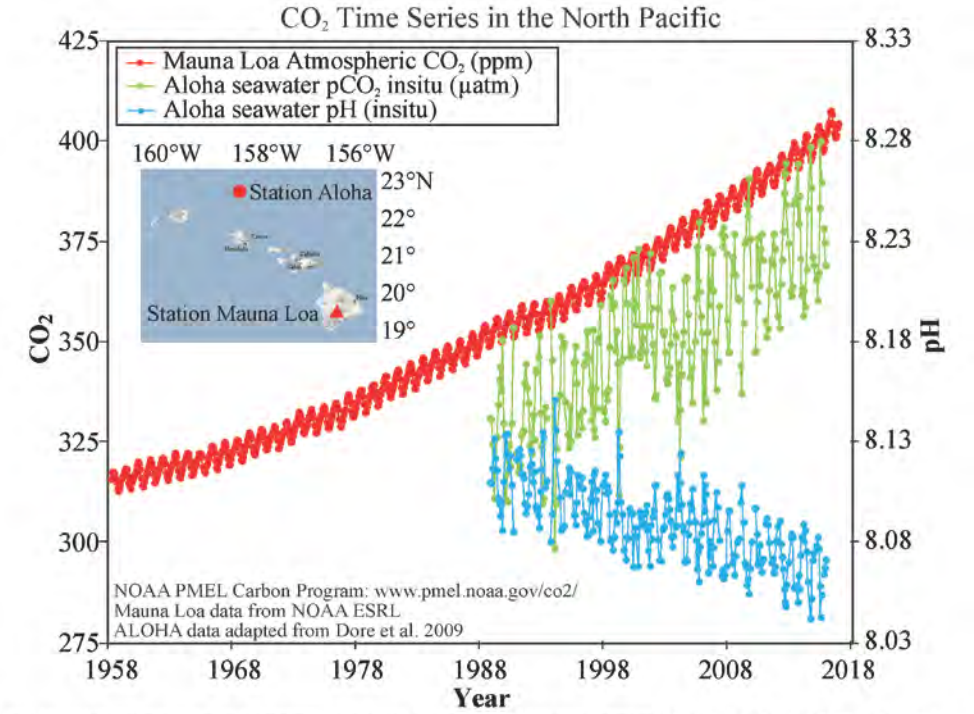
Ocean Acidification (OA)



Data: Mauna Loa (ftp://aftp.cmdl.noaa.gov/products/trends/co2/co2_mm_mlo.txt) ALOHA (http://hahana.soest.hawaii.edu/hot/products/HOT_surface_CO2.txt)
Ref: J.E. Dore et al, 2009. Physical and biogeochemical modulation of ocean acidification in the central North Pacific. *Proc Natl Acad Sci USA* **106**:12235-12240.

Ocean carbon uptake

⬇

Shift in marine carbonate system

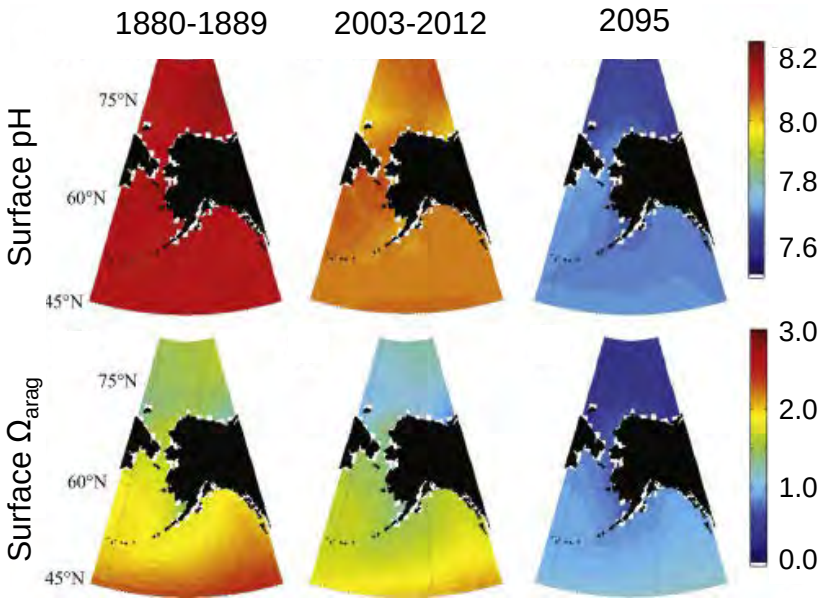
⬇

Reduced pH

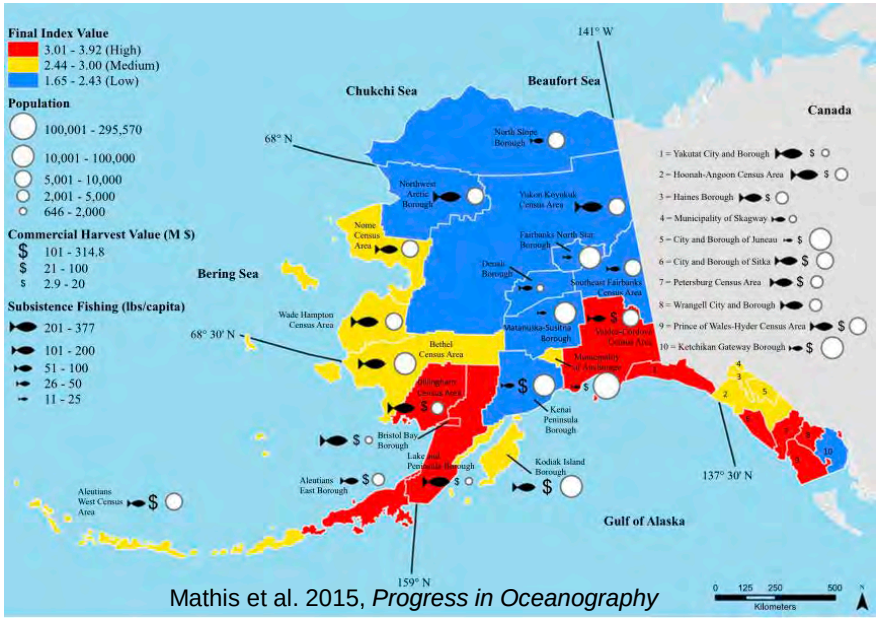
⬇

Reduced $[CO_3]^{2-}$ and difficulties for biogenic shell building

Alaska's Fisheries are at Risk

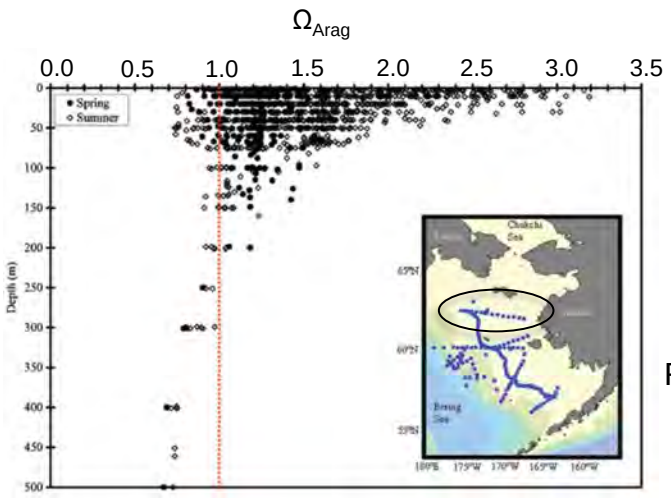


Mathis et al. 2015, *Progress in Oceanography*

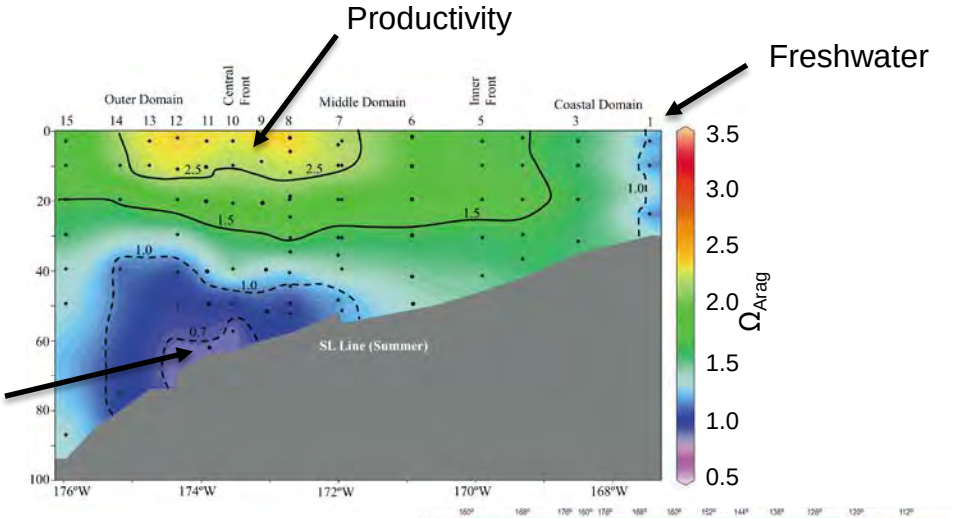


Mathis et al. 2015, *Progress in Oceanography*

Spatial Variability



Fabry et al. 2009, *Oceanography*

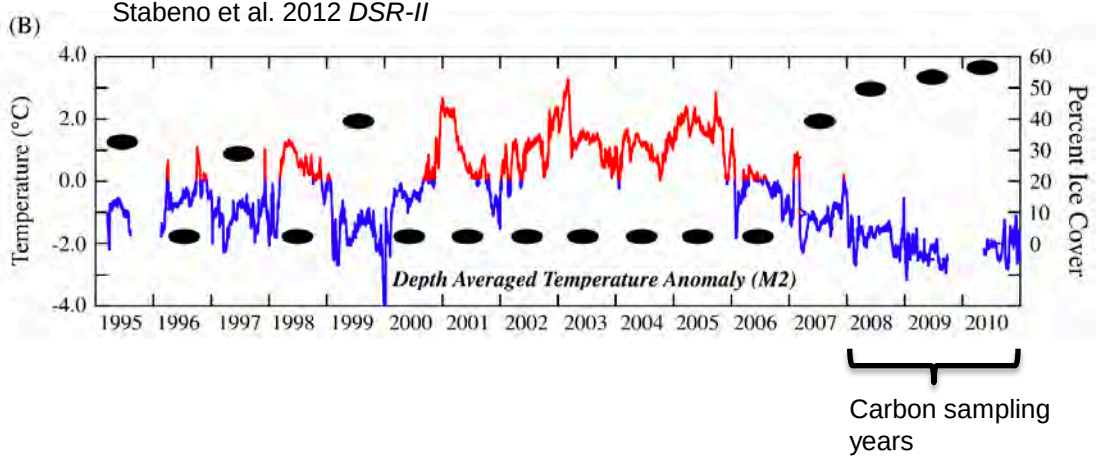


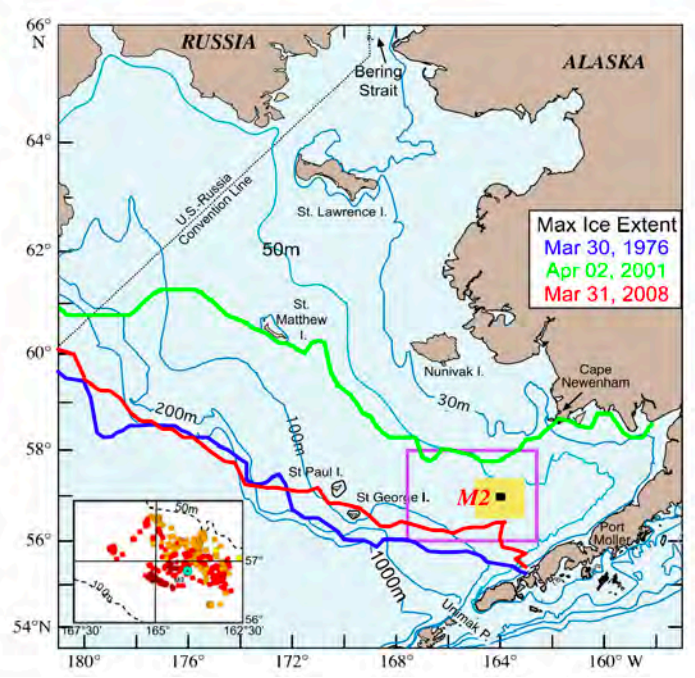
Mathis et al. 2011, *JGR*

Ω_{arag} undersaturation observed near regions of river runoff (e.g. Yukon River) and at depth in summer

Temporal Variability

Stabeno et al. 2012 *DSR-II*



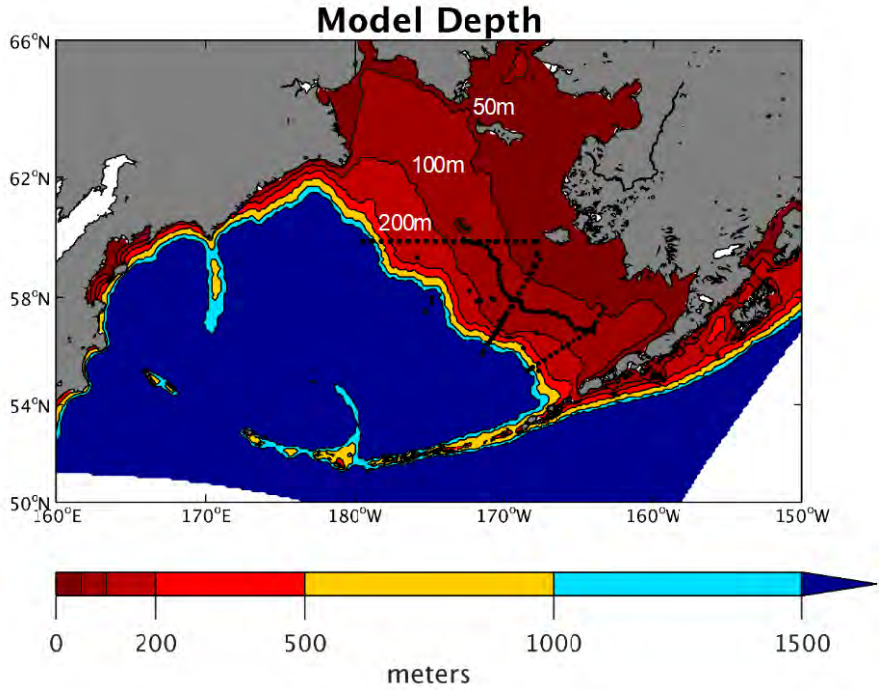


Multi-year periods of temperature variability

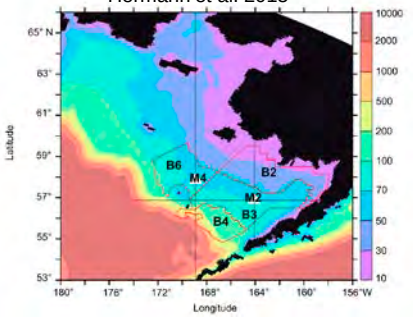
Lots of work on impact to ecosystem, but unknown effects to carbon chemistry

Research Questions

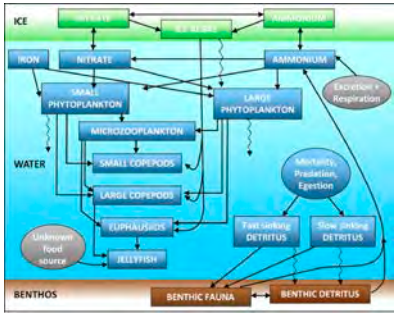
1. What are the mechanisms behind the observed spatial variability in Ω_{arag}?
2. What is the impact of climate variability on the ocean carbon cycle?
3. How does this climate variability impact the rate of ocean acidification?



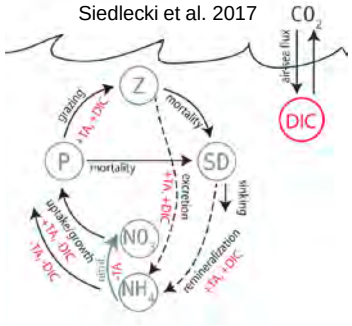
Hermann et al. 2015



Gibson and Spitz 2011



Siedlecki et al. 2017



Physics

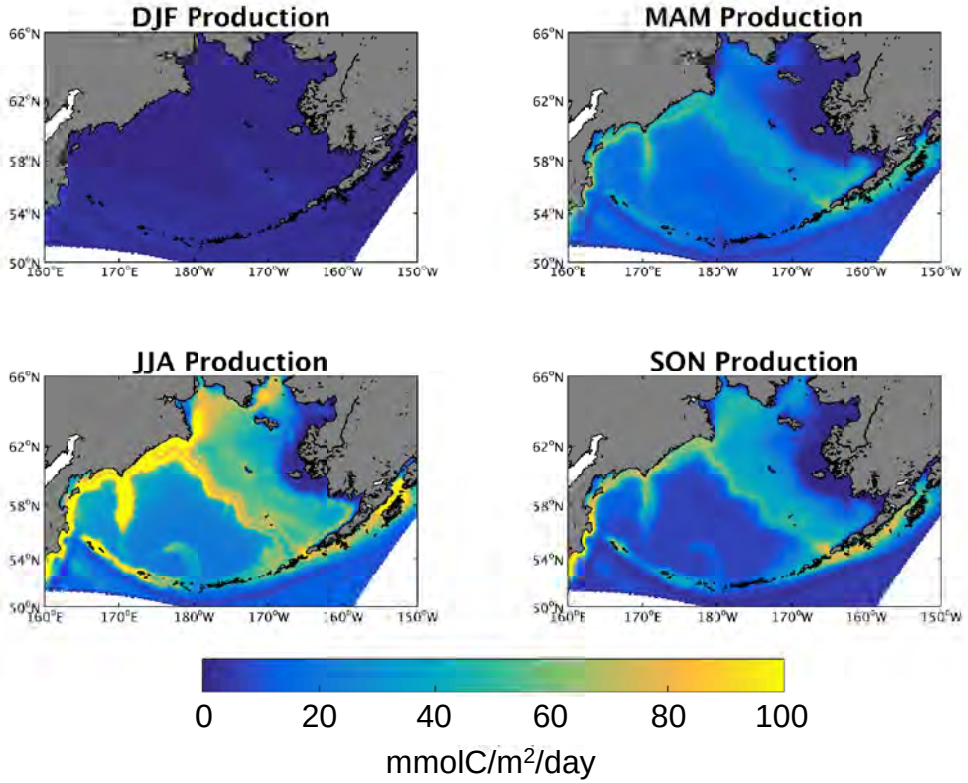
Biology

Chemistry

Bering Sea OA Model

Hindcast simulation of 2003-2012

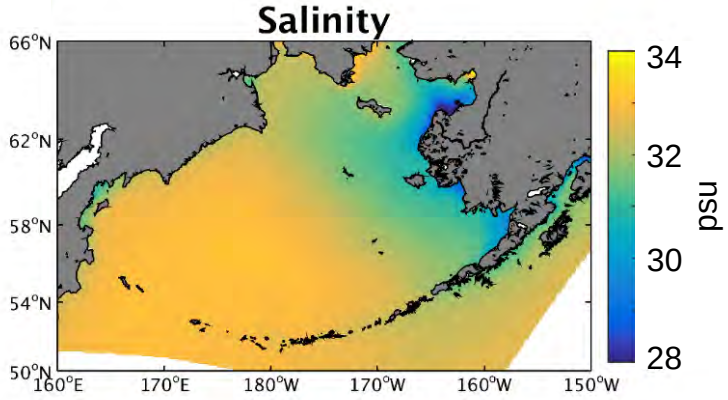
Biological Productivity

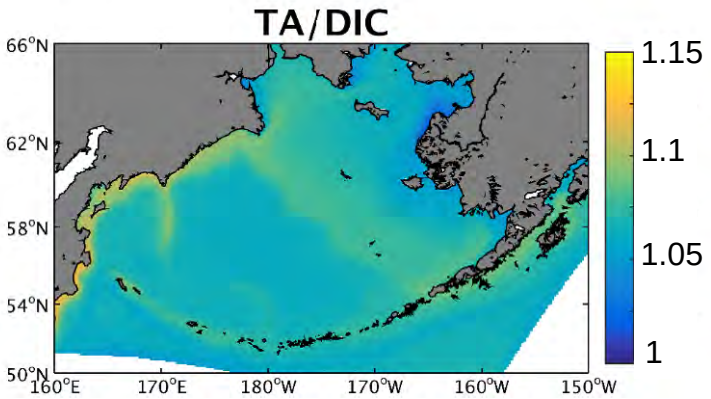


Phytoplankton productivity drives seasonal cycle, elevated shelf Ω_{Arag}

Minimal production in nearshore regions, but doesn't explain corrosive conditions

Freshwater Runoff





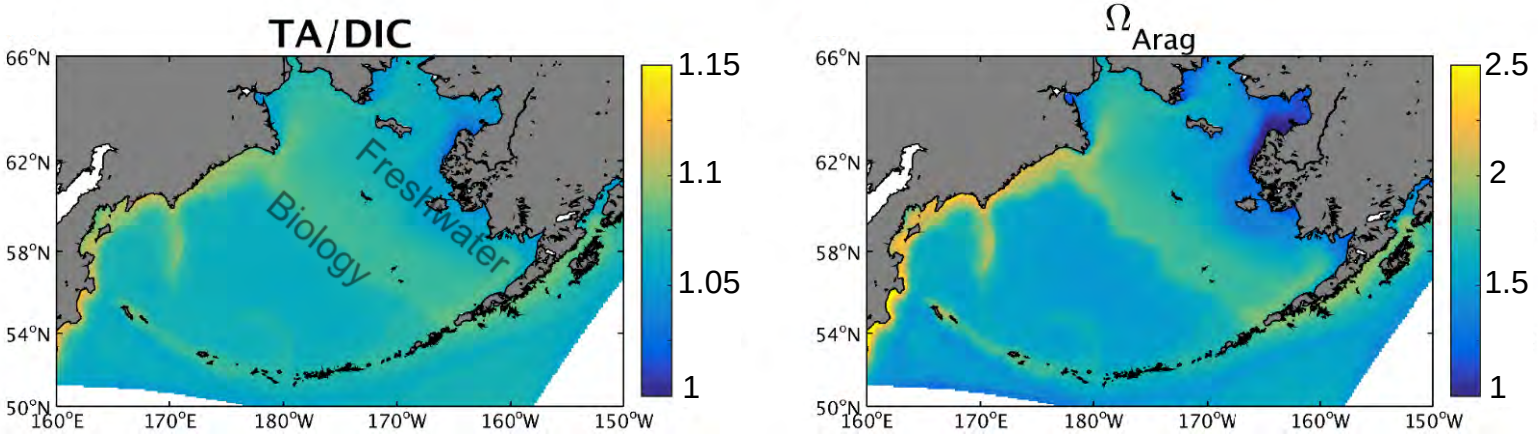
Season	TA[1]	DIC[2]	TA/DIC
Spring (May-Jun)	1238	1480	0.84
Summer-Autumn (Jul-Oct)	1518	1890	0.80
Winter (Nov-Apr)	2743	4100	0.67

[1] Mathis et al. 2011; PARTNERS 2010
[2] Striegl et al. 2007

TA/DIC Ratio:
Low values = lower buffer capacity
High values = higher buffer capacity

Low salinity regions correspond to regions of reduced buffering capacity

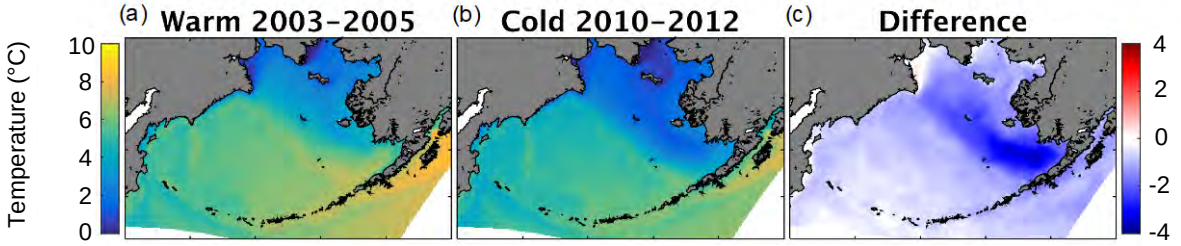
Combined Effect



Productivity increase TA/DIC and Ω_{Arag} in middle and outer shelf

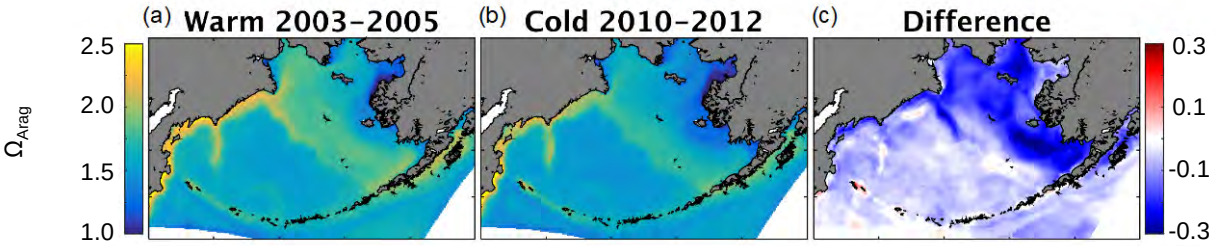
Freshwater runoff decrease TA/DIC and Ω_{Arag} in inner shelf

Climate Variability



Colder temperatures

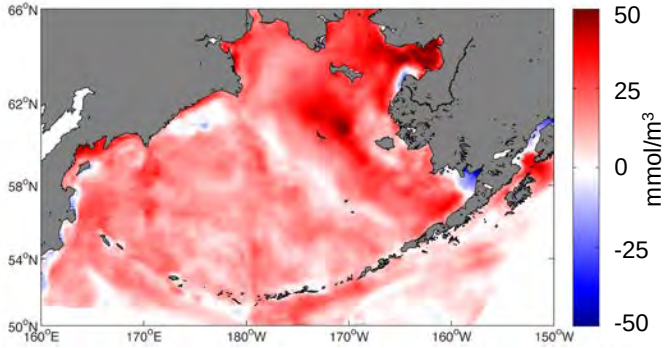
Climate Variability



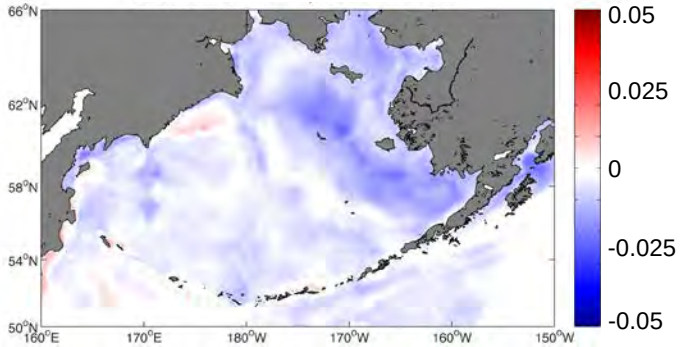
Reduced omega

TA/DIC drives change in Ω_{Arag}

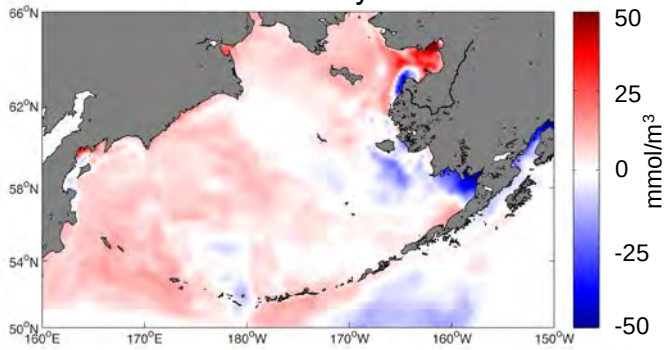
ΔDIC



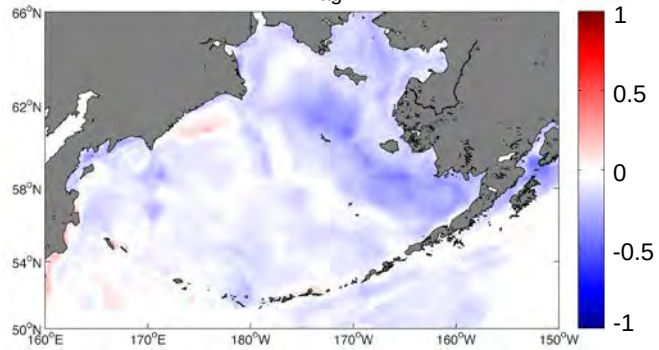
ΔTA/DIC



ΔAlkalinity

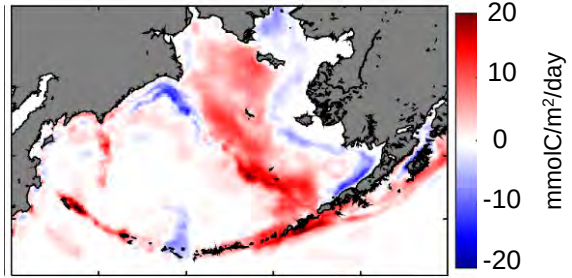


Δ Ω_{Arag}



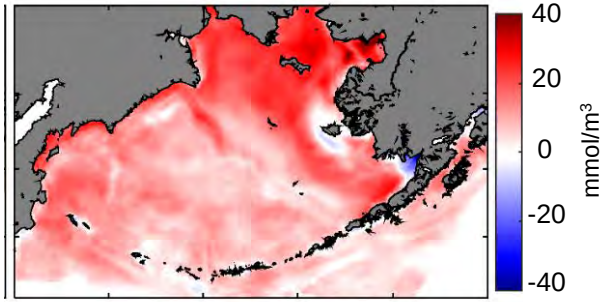
DIC Increases Despite Increase in Productivity

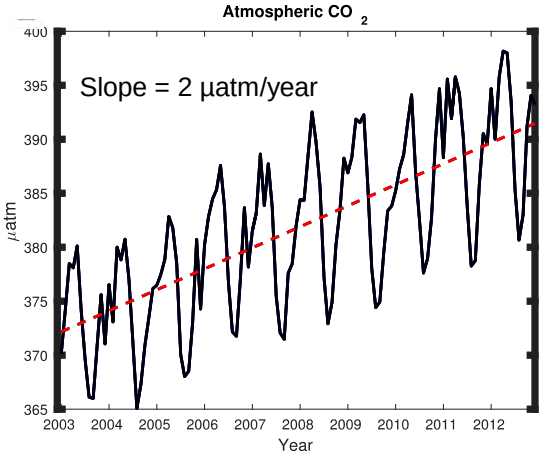
ΔProduction



Primary production alone does not account for change in DIC

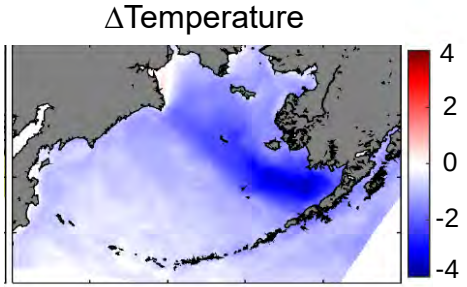
ΔDIC





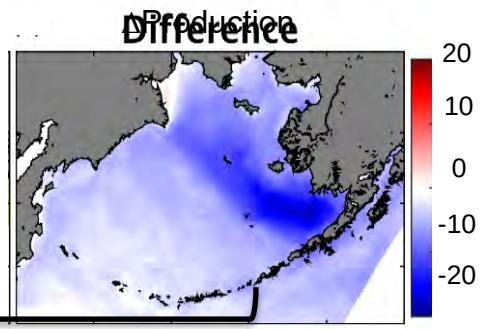
Increasing atmospheric CO_2, i.e. ocean acidification!

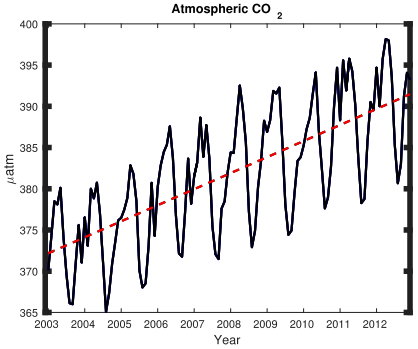
OA Amidst Natural Variability

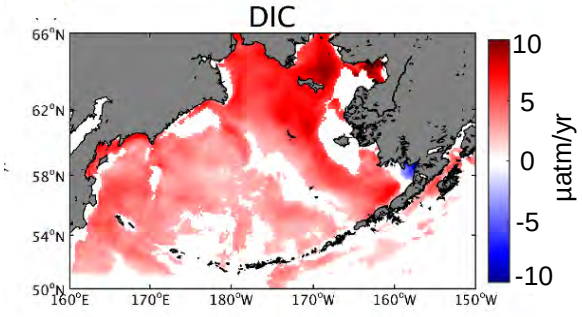


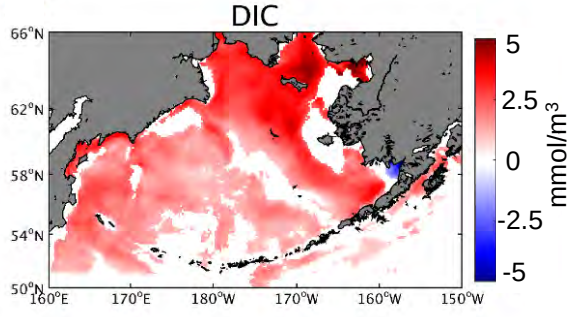
Climate variability pushing towards *decrease* in pCO_2

OA pushing towards *increase* in pCO_2

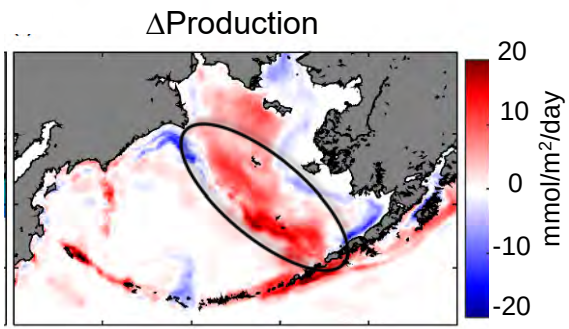


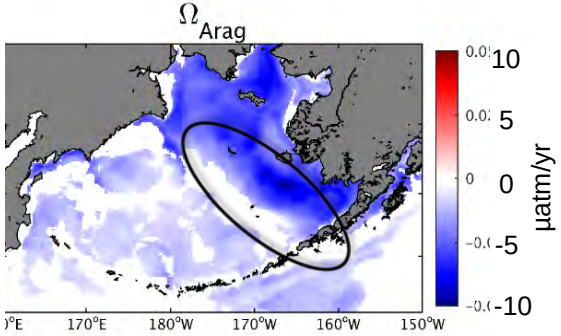


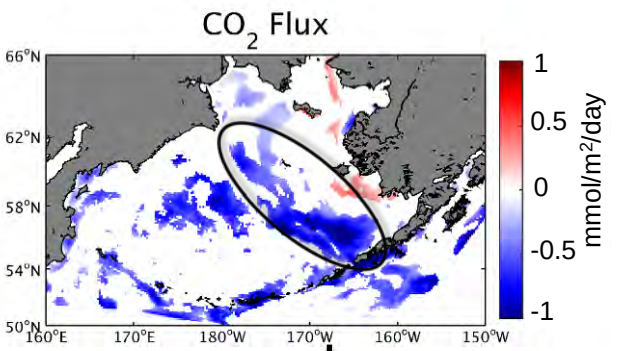


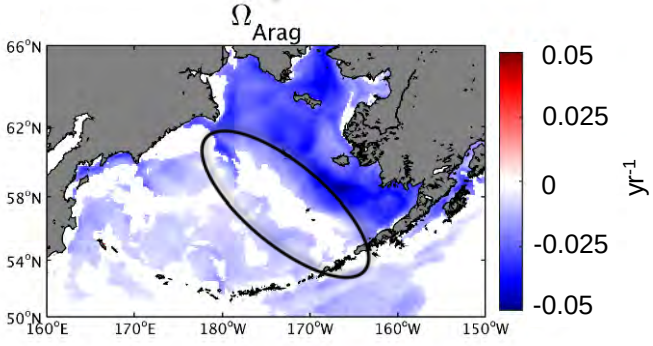


Masking Effect





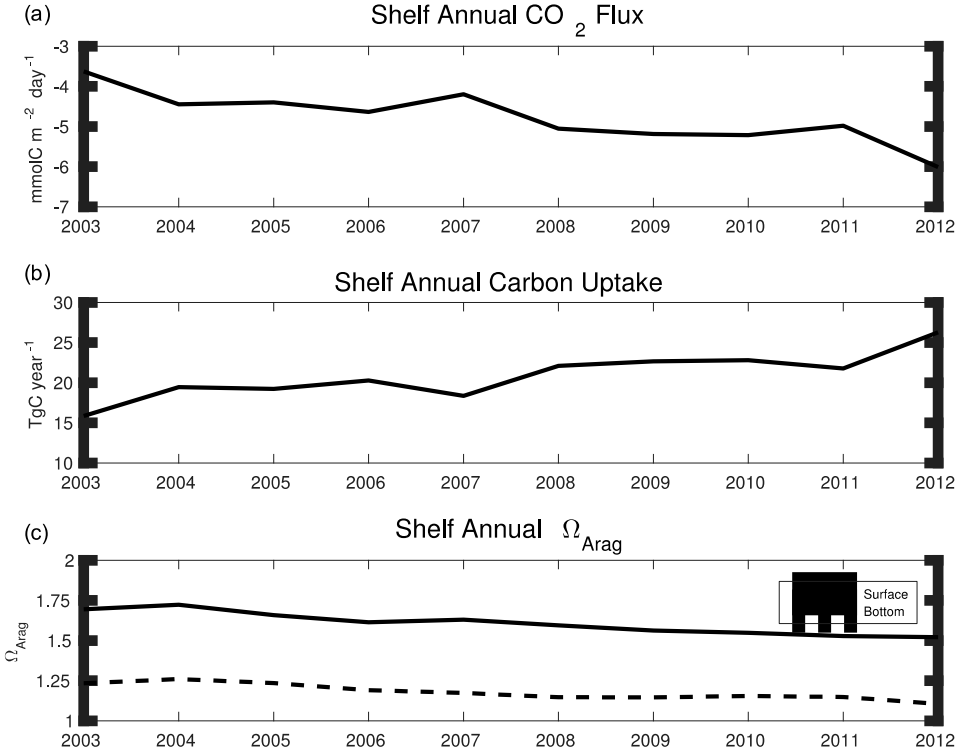




No change in Ω_{Arag} due to enhanced productivity

However, carbon uptake continues and increases

Increasing Carbon Uptake on Shelf



Substantial increase in shelf carbon uptake driven by increase in fall phytoplankton productivity

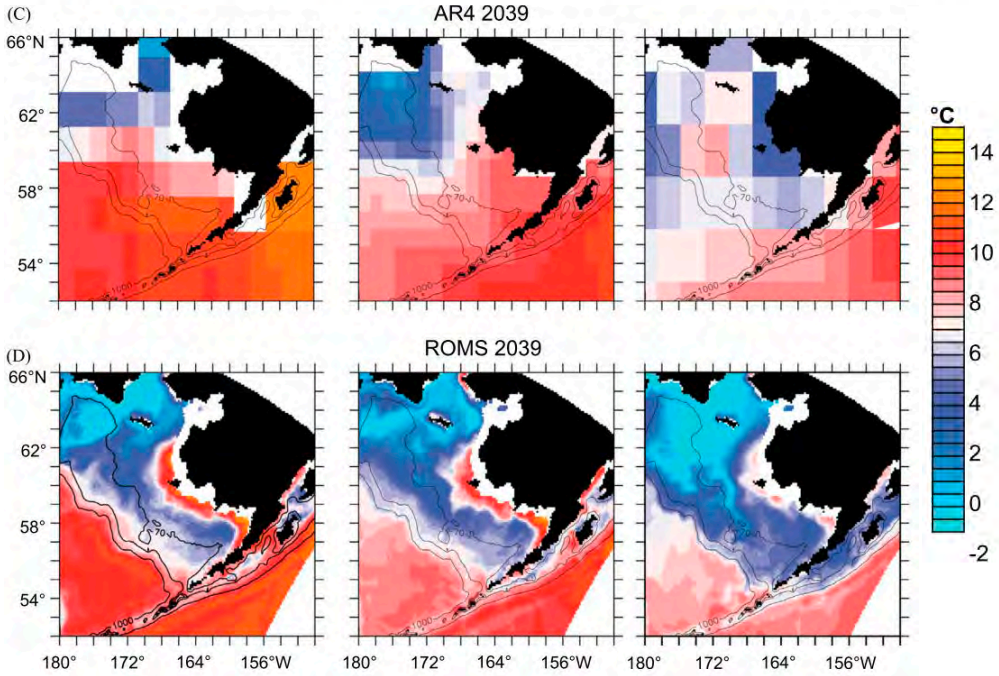
Observational estimates vary considerably (2-67 PgC/year)

Extrapolating suggests shelf annual $\Omega_{Arag} < 1$ by 2040

But we can do better!

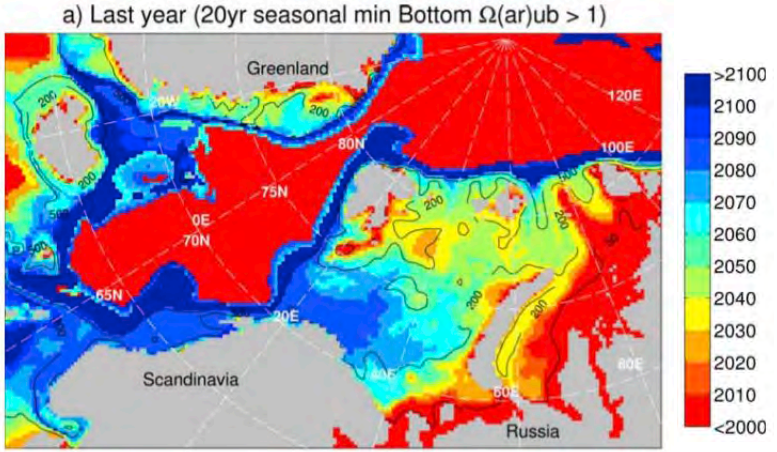
Projected future biophysical states of the Bering Sea

Albert J. Hermann [a,e,*], Georgina A. Gibson [b], Nicholas A. Bond [a,e], Enrique N. Curchitser [c], Kate Hedstrom [d], Wei Cheng [a,e], Muyin Wang [a,e], Edward D. Cokelet [e], Phyllis J. Stabeno [e], Kerim Aydin [f]



Bottom Water Acidification and Warming on the Western Eurasian Arctic Shelves: Dynamical Downscaling Projections

P. J. Wallhead[1], R. G. J. Bellerby[1,2], A. Silyakova[3], D. Slagstad[4], and A. A. Polukhin[5]



Conclusions

- Productivity, freshwater runoff drive spatial heterogeneity in Ω_{Arag}
- Observed climate variability modifies rate of Ω_{arag} decrease, masks in outer shelf region
- Increase in atmospheric CO_2 still dominant mechanism, Ω_{arag} decreases by 0.2 over 10-year timeframe

Team: Jeremy Mathis (NOAA Arctic Research Program), Samantha Siedlecki (UConn), Al Hermann (PMEL/JISAO), Danielle Naiman (UCSD), Jessica Cross (NOAA PMEL), Ken Coyle (UAF), Wiley Evans (Hakai Institute)

Funding: NOAA Arctic Research Program, National Research Council, Integrated Ocean Observing System, Alaska Ocean Observing System

Questions?

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