Tracer relationships in surface waters of coastal waters from the ~~Gulf of Alaska,~~ Bering and Chukchi Seas

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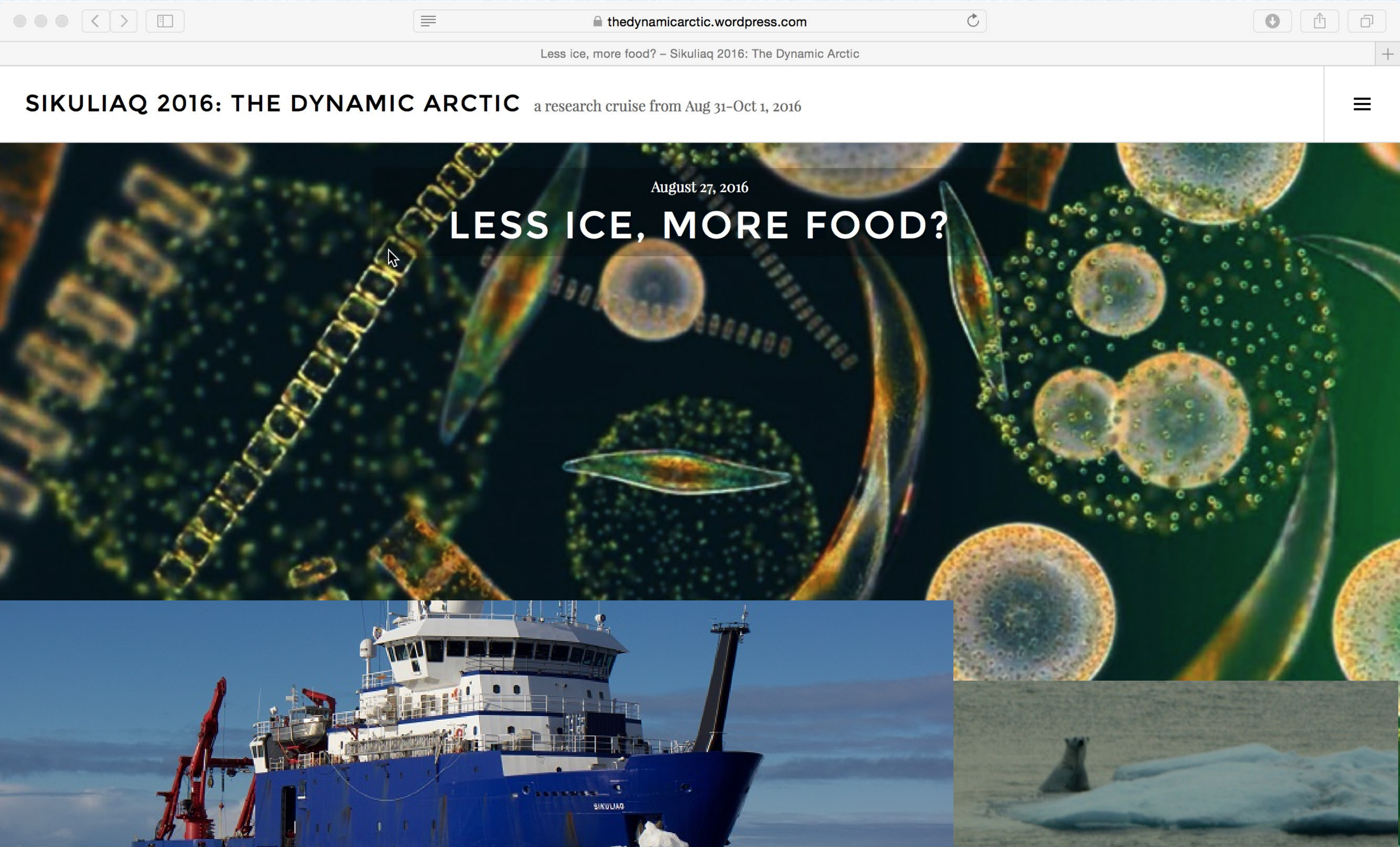
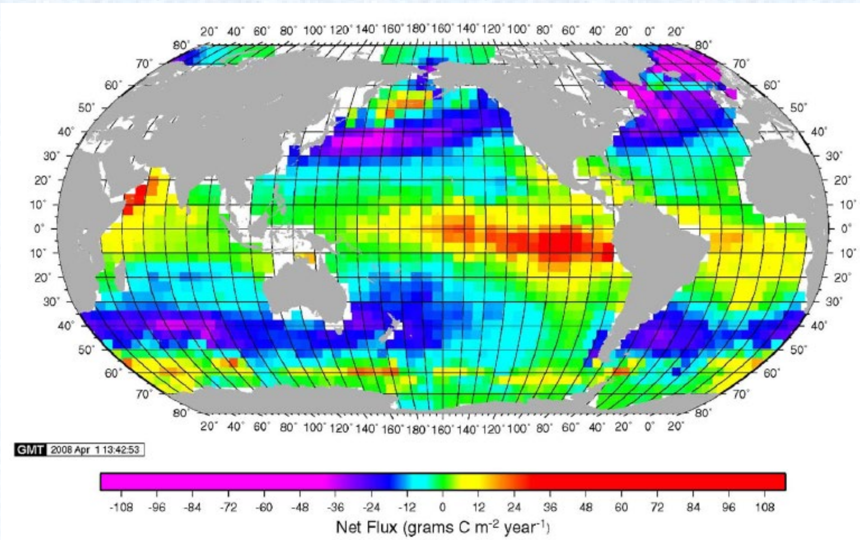
A Stirred Up Arctic

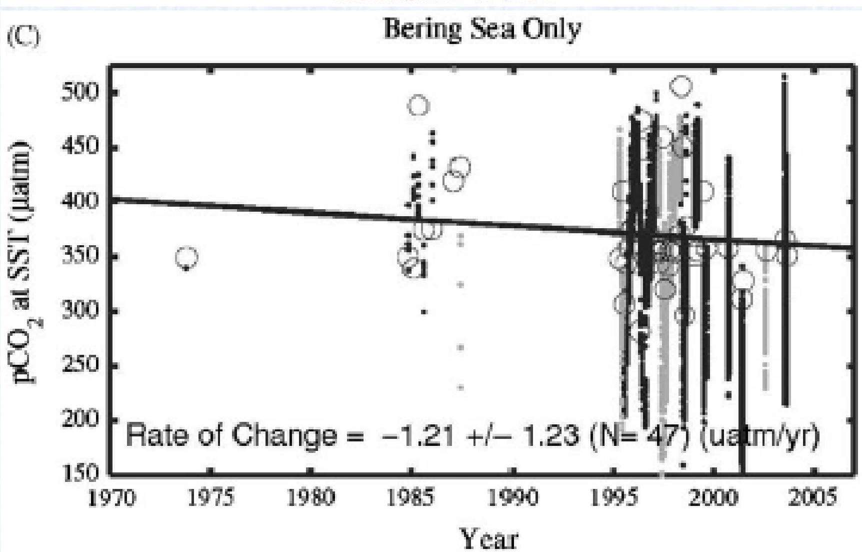
Does reduced ice cover in late-summer coastal Arctic waters allow a second burst of productivity as katabatic winds mix exposed waters and re-supply nutrients to the surface?



Relevance of high-latitude carbonate chemistry?

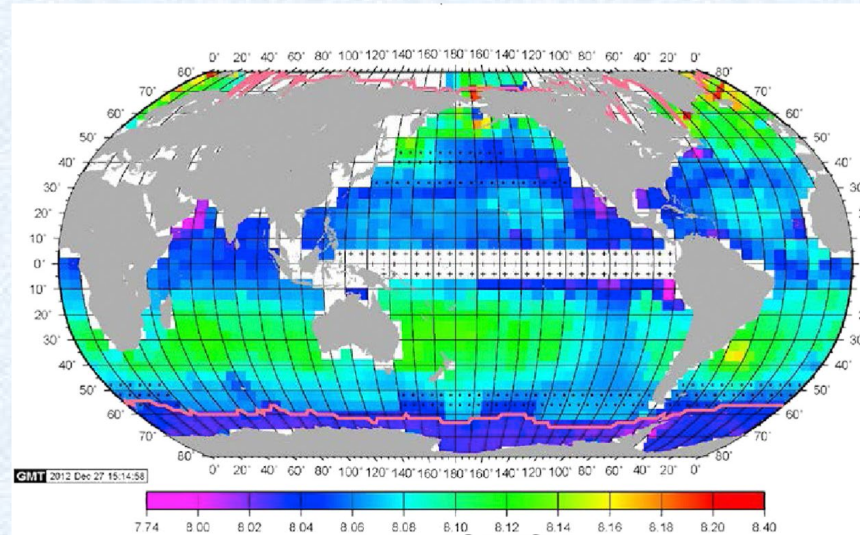
Air-sea CO_2 exchange. High-lat areally-disproportionate sink, may be intensifying

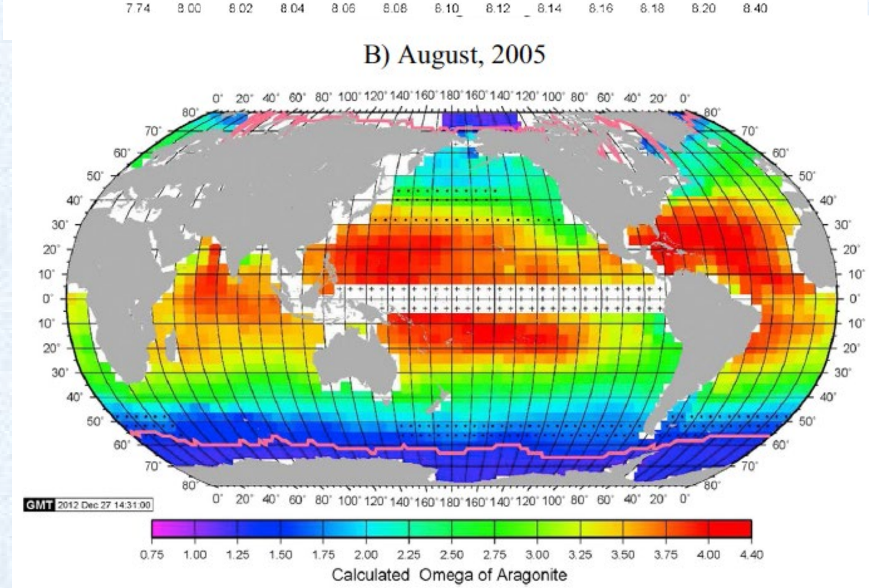




Takahashi et al., 2009

Ocean acidification. Arctic has seemingly benign pH, but low shell-mineral stability





Takahashi et al., 2014

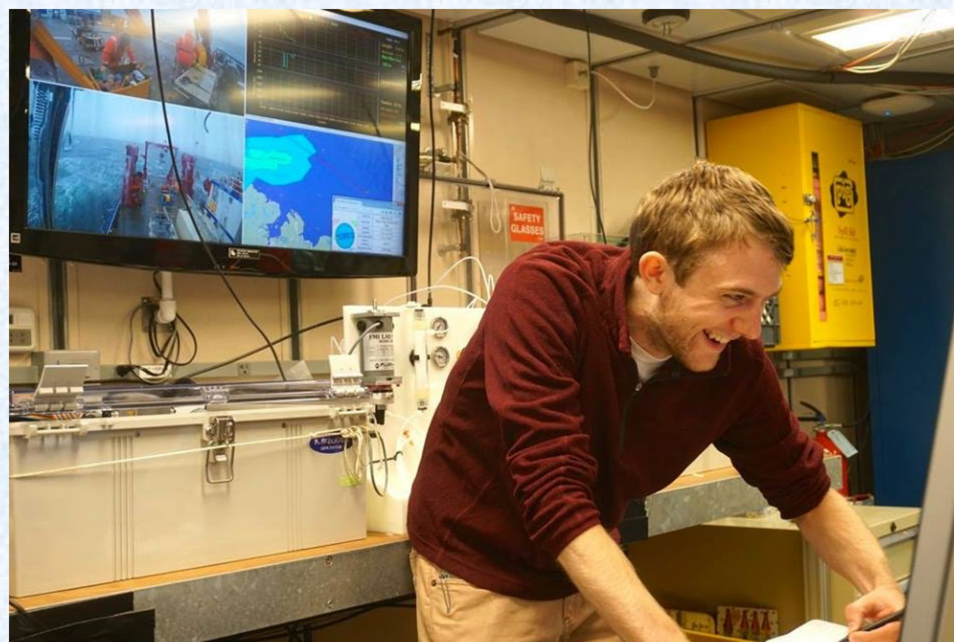
New monitoring approaches

Full constraint of carbonate system requires determination of two independent parameters; ‘safest’ two are CO_2 partial pressure (pCO_2) and total dissolved carbonic acid (TCO_2)

Combined pCO_2/TCO_2 measurement on continuous flow and/or discrete samples (aka ‘Burke-o-Lator’).

State of the art accuracy and precision (0.2% in TCO_2, and < 1% in pCO_2).

Two parallel systems aboard RV Sikuliaq, one in continuous TCO_2 mode, one in continuous pCO_2



Cruise description

Two cruises, Nome-Nome:

<u>3-24 September 2016</u>

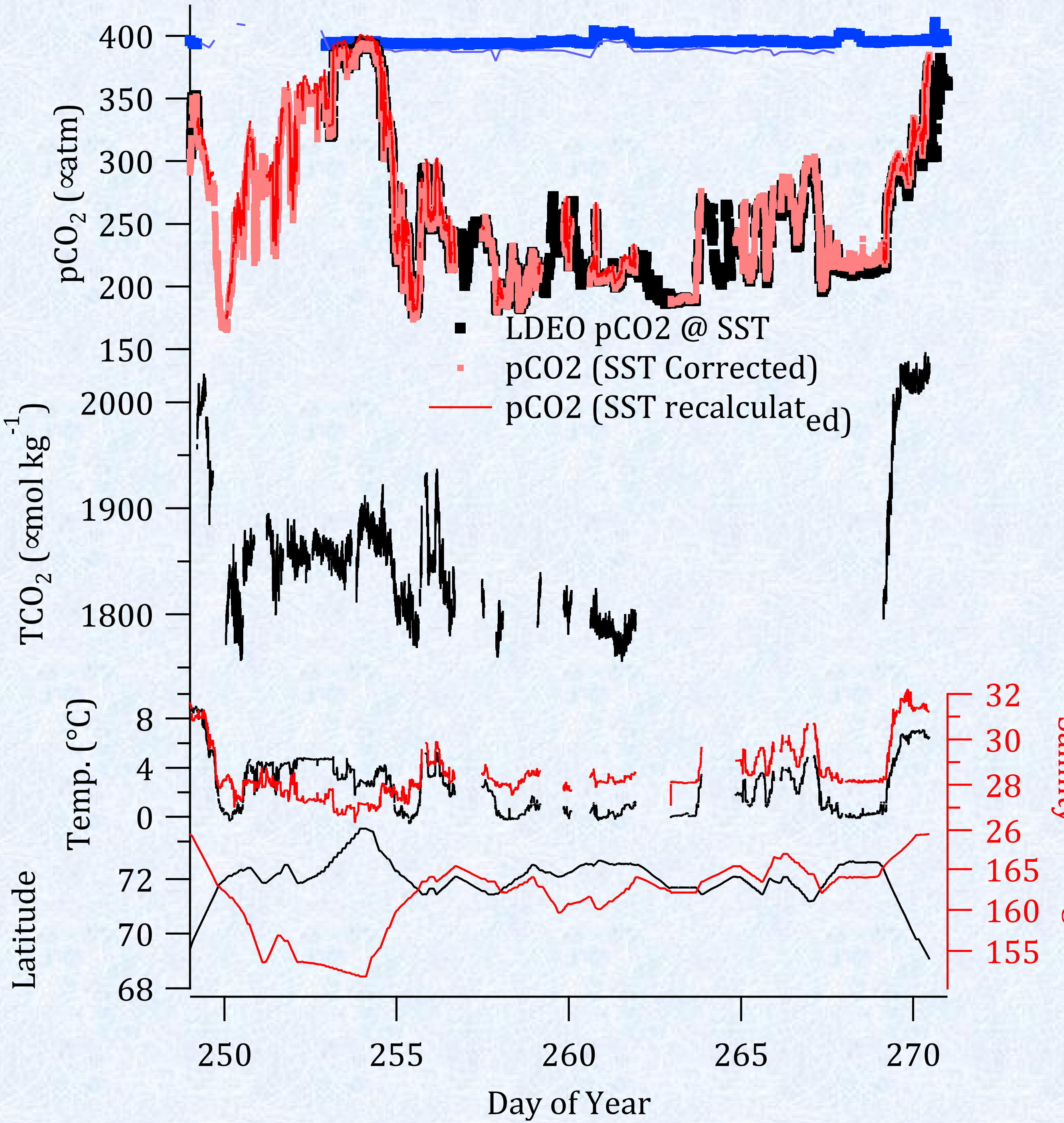
-Focus on Chukchi Sea waters > 20 nm offshore, but with excursion to Beaufort Sea and Arctic Basin.

-Significant wind-transport of ice into study area

<u>8-22 August 2017</u>

Focus on Chukchi Sea waters closer to shore.

No sea ice in study area.



Basic Observations:

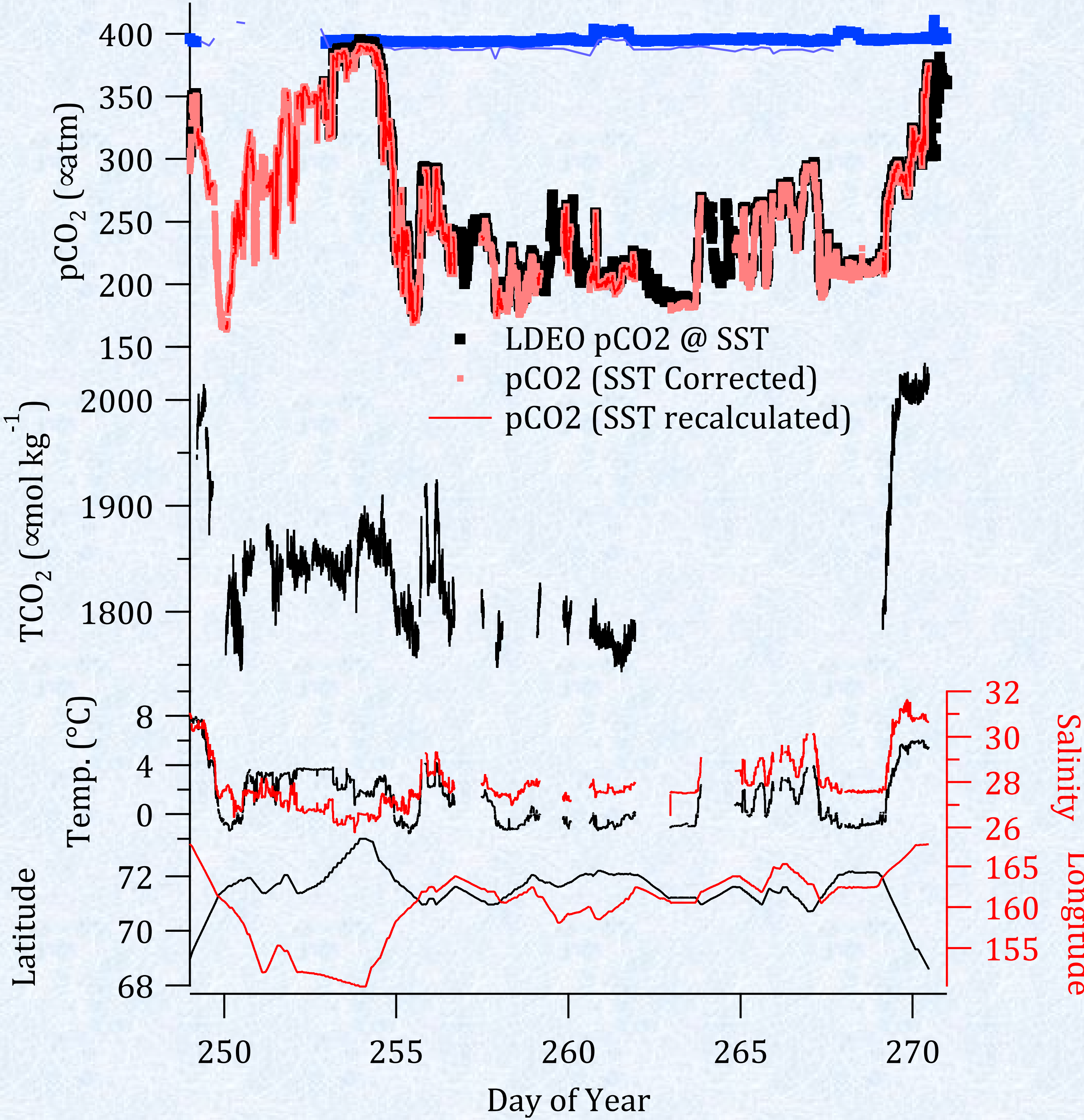
Continuous 1-Hz surface underway pCO_2 and TCO_2 measurements.

Reduced to 30-second intervals using running polynomial fit

pCO_2 measurements within 2 µatm of LDEO system

TCO_2 'native inaccuracy' is +2%, based on SIO CRM analysis; accuracy correction reduces combined uncertainty to <0.2%

Basic Observations, 2016:

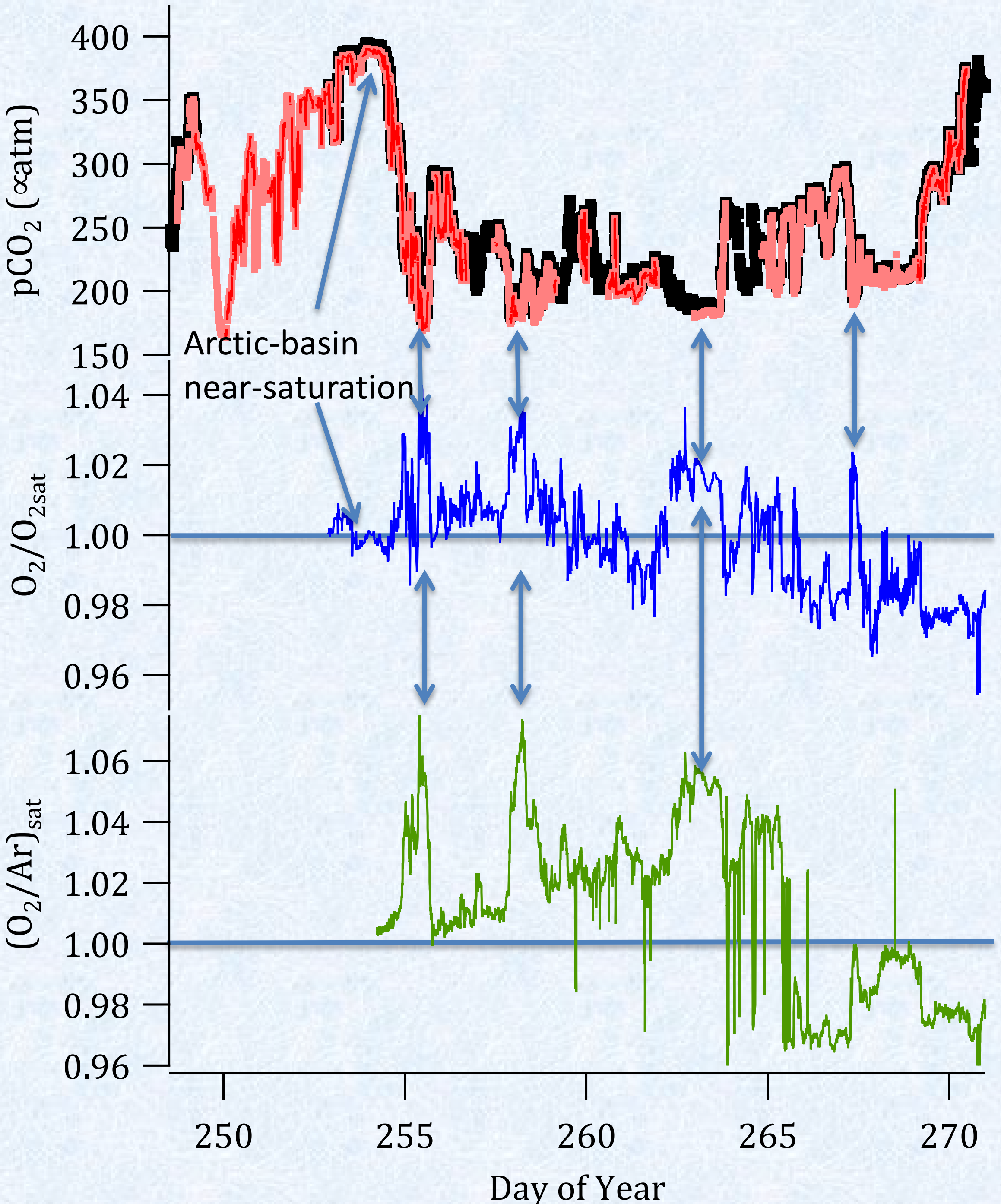


pCO_2 is low (below atmospheric saturation) for entire transect, particularly in Chukchi Sea coastal waters.

TCO_2 exhibits local, but not global, coherence with pCO_2, suggesting variable Alkalinity:TCO_2 relationships.

T-S dynamics mostly driven by

Biological and physical drivers



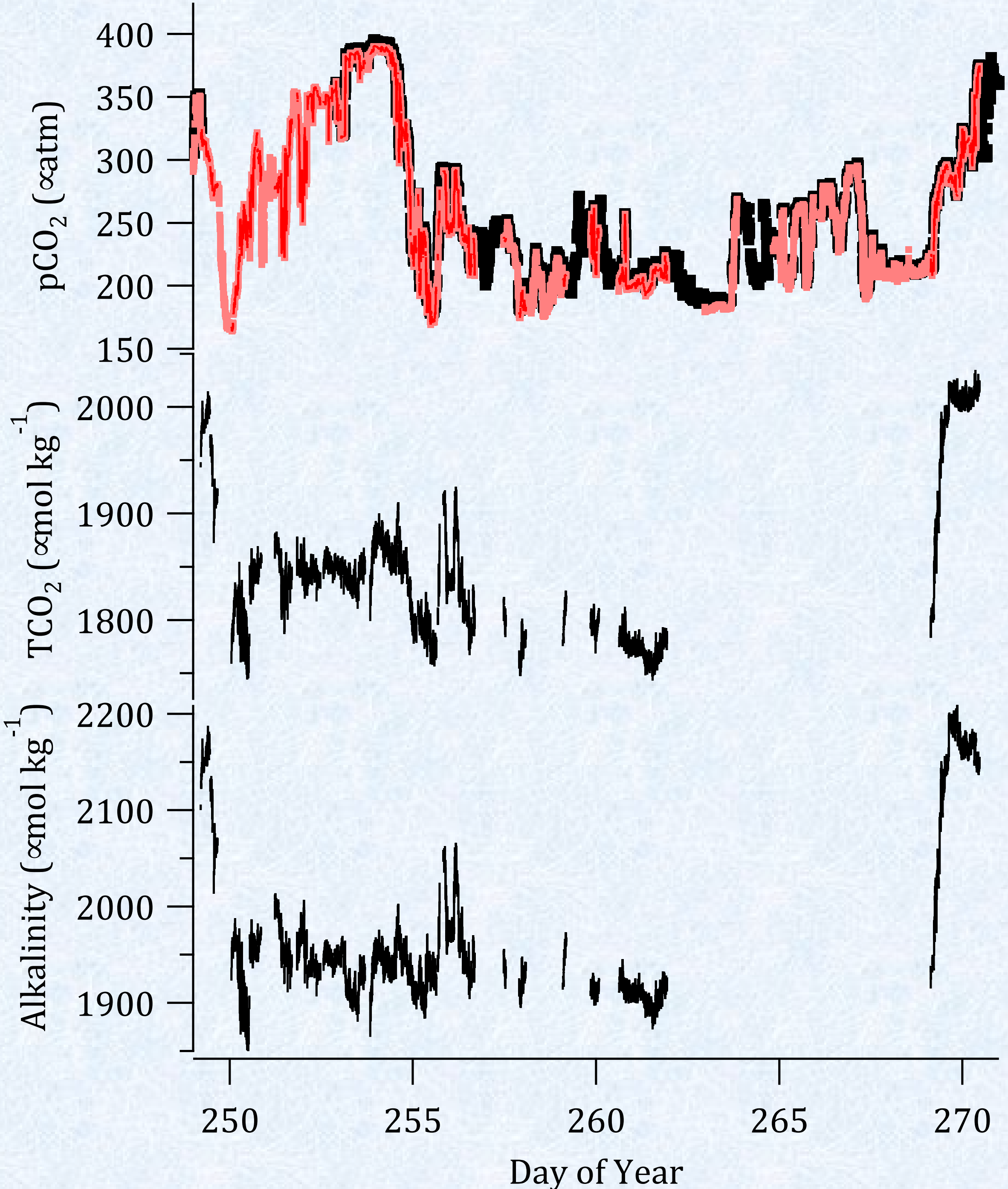
Low pCO_2 is the result of remnant net productivity and slow gas-exchange time-scales for CO_2.

Local features show strong coherence.

Normalization of O_2 to the inert Ar highlights the role of biological processes

Differential gas exchange timescale explains the loss of O_2 supersaturation while pCO_2 remains low.

Late O_2/Ar undersaturation implies development of respiration signal

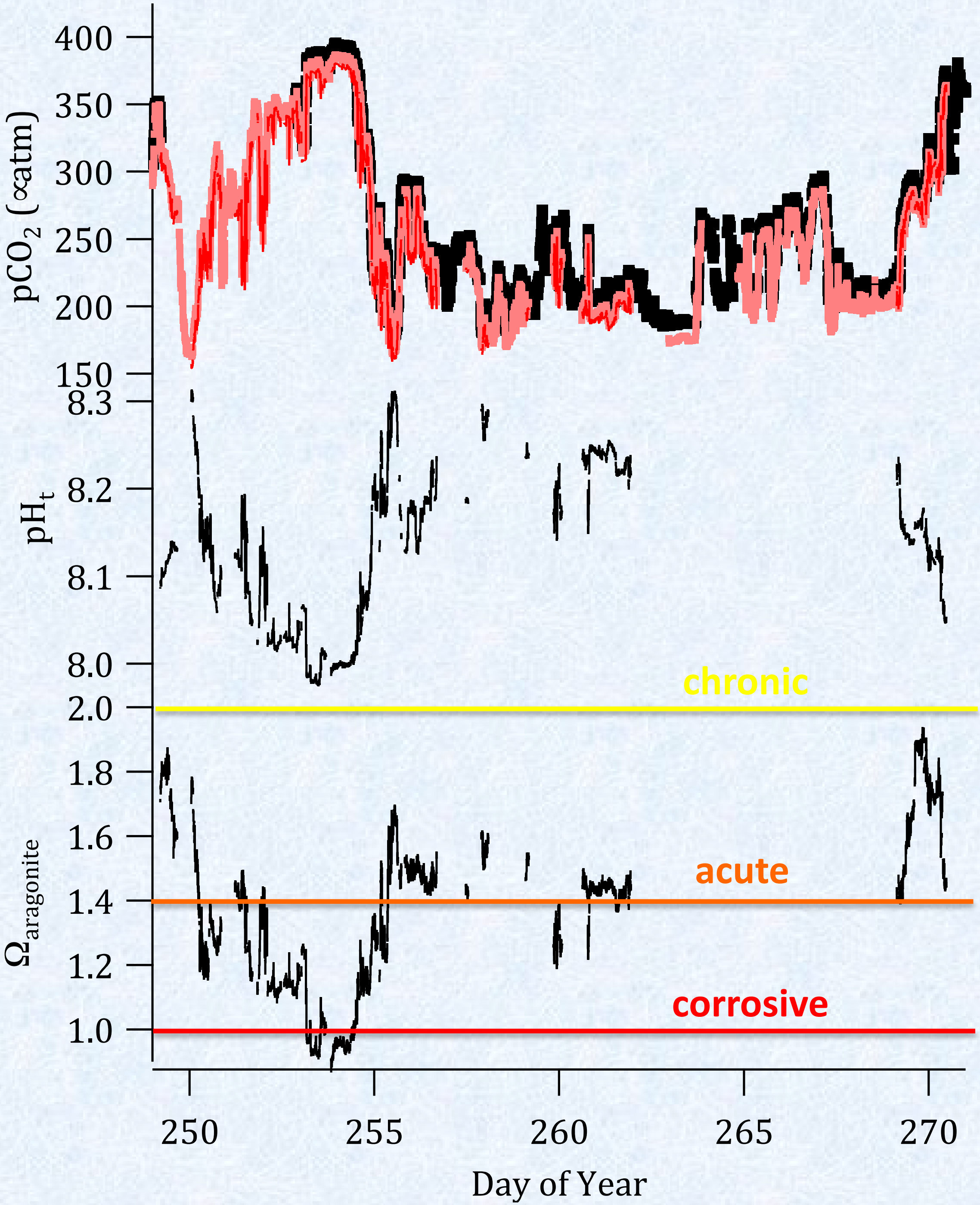


Calculated parameters

With coincident TCO_2 and pCO_2 (and T and S) we can recalculate other parameters of the carbonate system.

Alkalinity is the most basic of these parameters, as it is Temperature-independent, and displays quasi-conservative behavior with respect to Salinity.

Its determination allows recalculation of pCO_2 @ in situ temperatures, and local determination of the T-correction coefficient.



Calculated parameters

Other parameters of interest can be calculated as well.

The overall low pCO_2 corresponds with an overall high pH. Good news for OA, right?

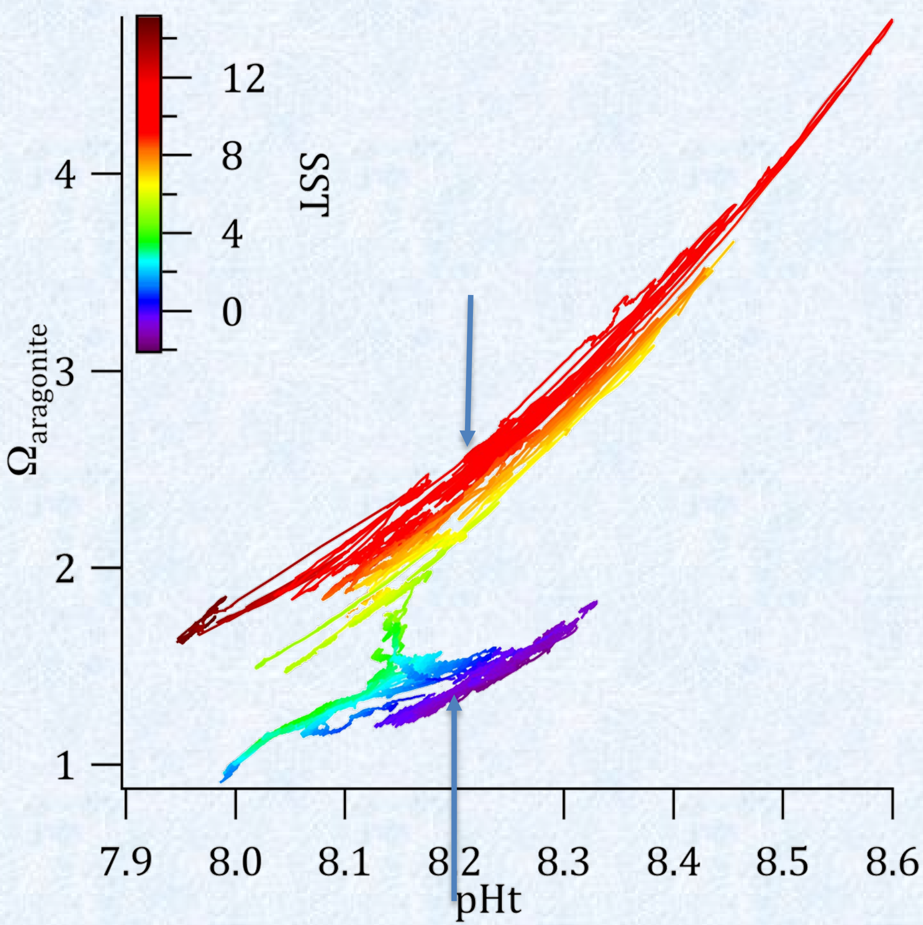
Wrong. The most proximally important parameter, shell-mineral stability (aka Ω), is low.

Always below chronic-effect threshold in 2016.

~50% of time below acute threshold

Sometimes even corrosive!

Failure of single-proxy assessment of Ocean Acidification status



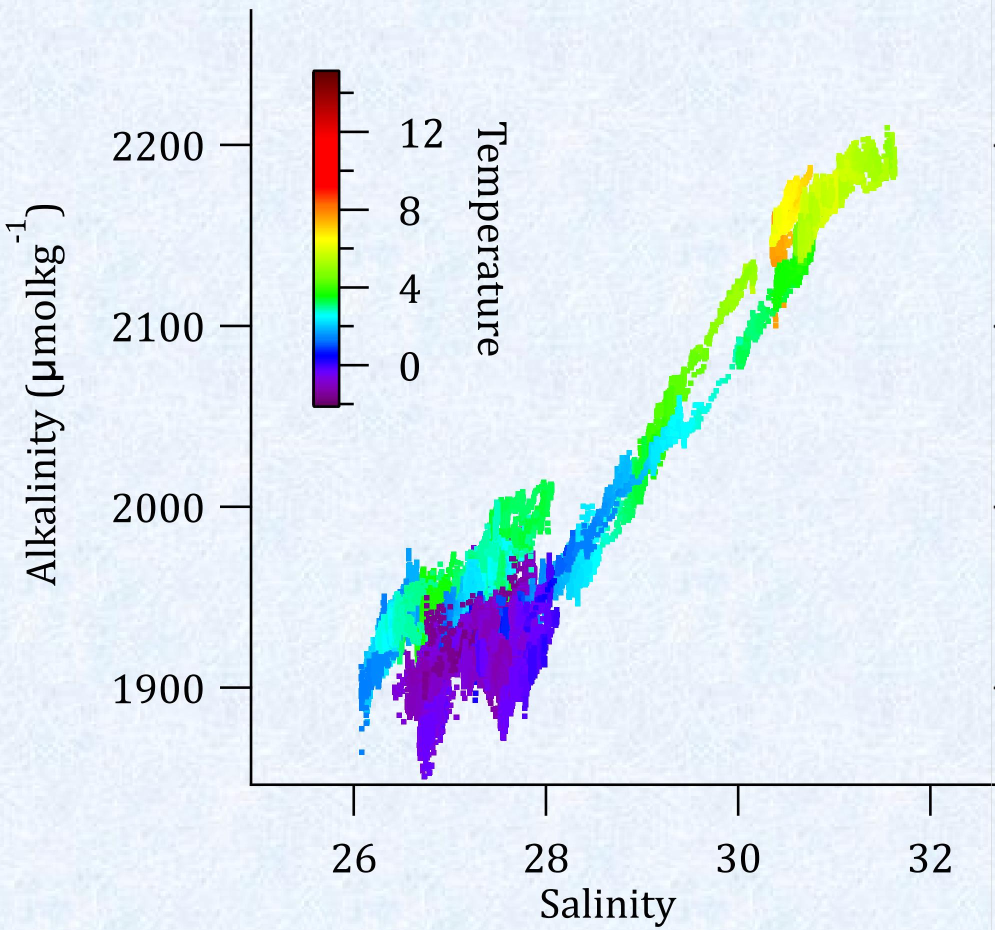
One last reminder of the need for full CO_2-system constraint.

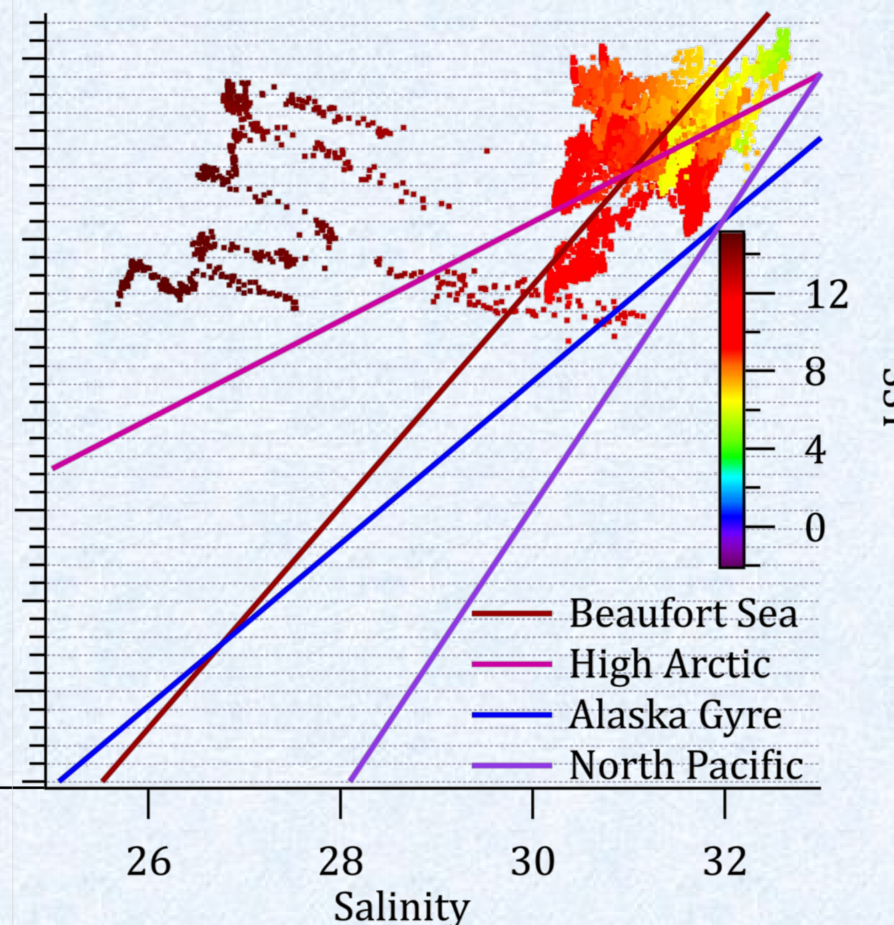
Different Ω for same pH among different water masses (>100% difference in Ω for common pH).

Different Ω-pH relationships across water masses, between years.

Alkalinity - Salinity

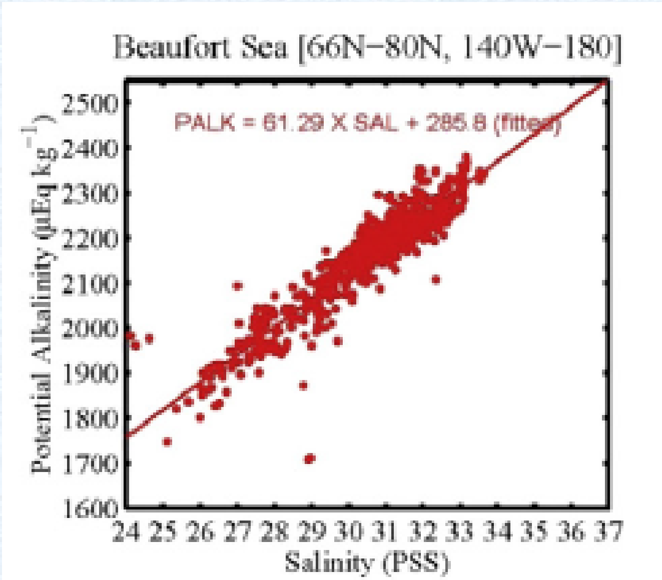
Alkalinity is semi-conservative, and can be estimated from empirical dependences on salinity

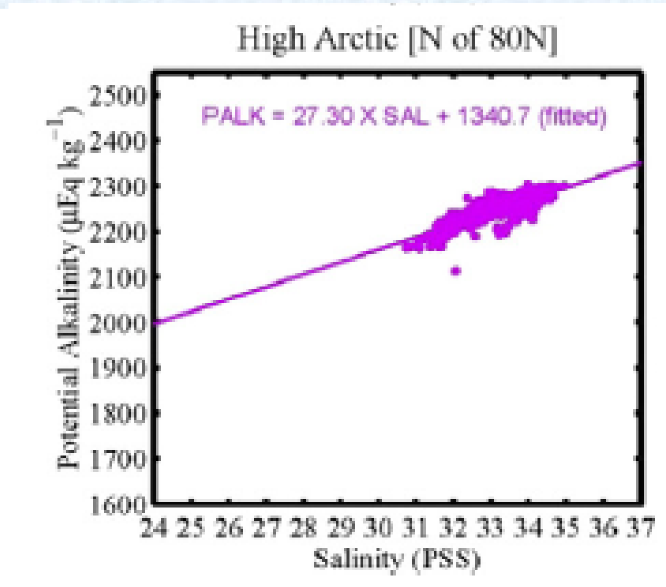


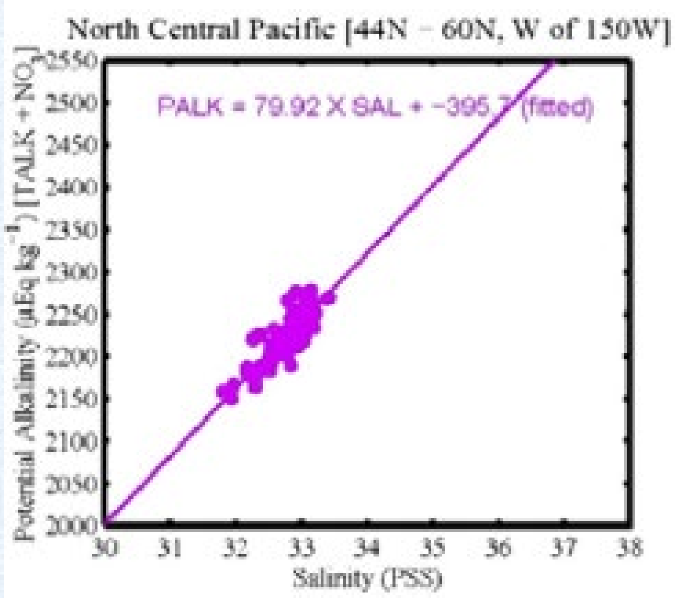


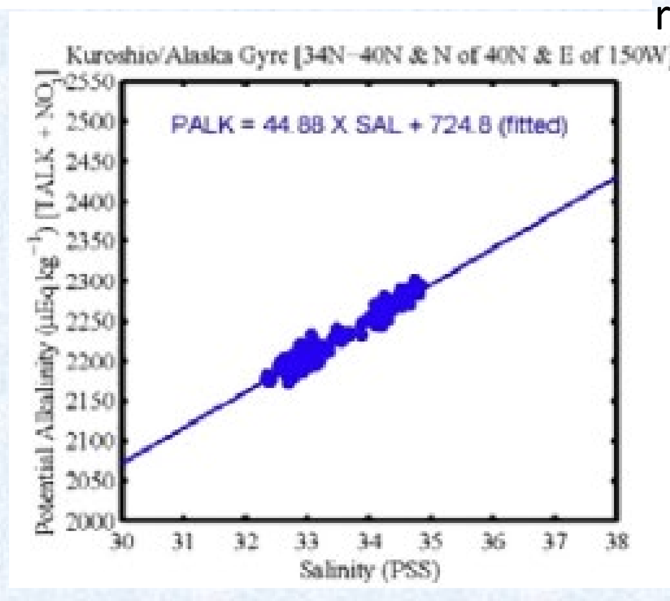
Recent results show several distinct Alk-S characteristics

Sources of variability in the alk-S relationship





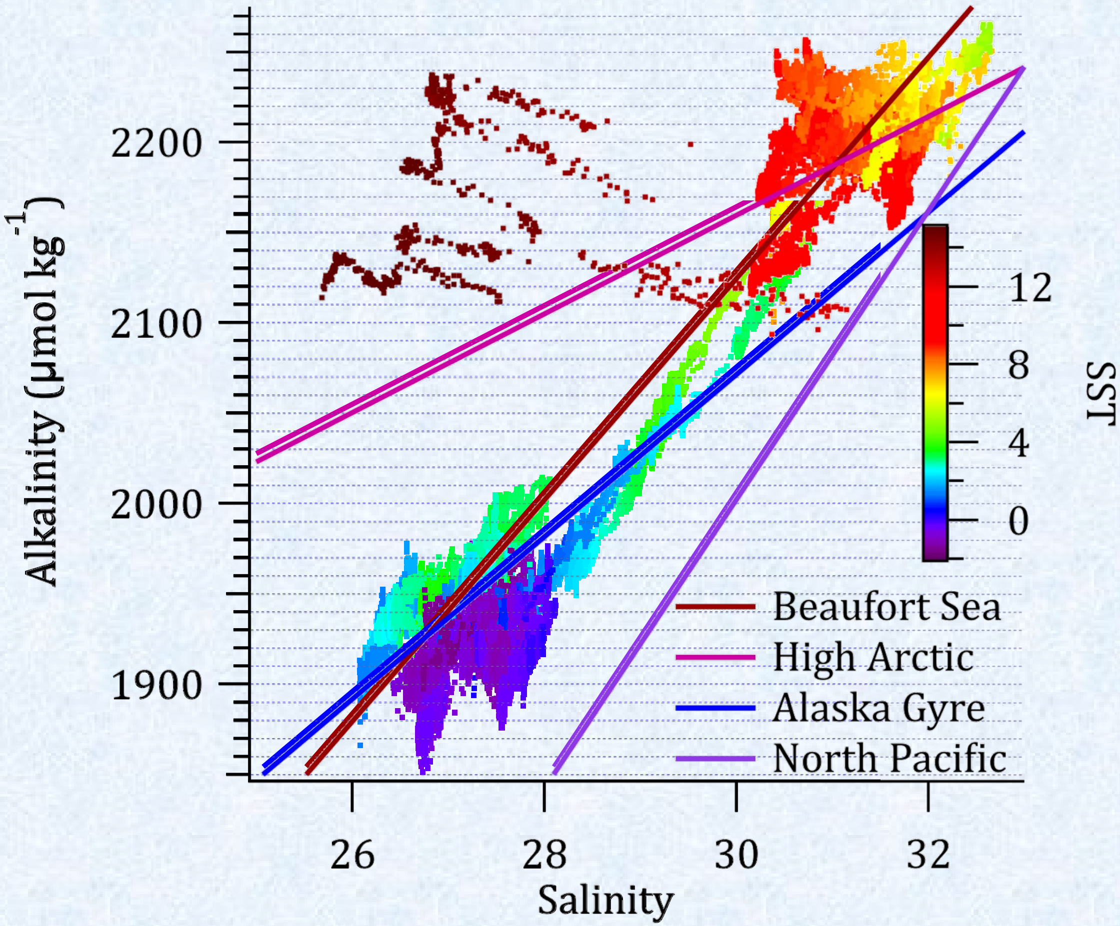




Takahashi et al. 2014 identified several proximally-relevant sub-regimes.

These have distinct Alk-S relationships

Our data within this context



Best overall agreement Takahashi's historical data is with the 'Beaufort Sea'

Significant areas of departure from published relationships, mostly negative in 2016: As much as 80 µmol kg^{-1} (0.15 error in Ω)

Positive deviations in 2017, both at high and low-S

What are these? Calcification? De-nitrification? Multiple end-member mixing? High-Alk terrestrial freshwaters?

Conclusions

- First-ever high-resolution continuous combined pCO_2 and TCO_2 measurements in Arctic surface waters show low pCO_2, persistently below atmospheric saturation.

- pCO_2 is low because of recent net community photosynthesis; persists because of long gas-exchange times for CO_2.

- Combination of pCO_2 and TCO_2 allows most robust calculation of other carbonate-system parameters like alkalinity, pH, and Ω.

- Low pCO_2 and high pH belie low Ω, frequently below thresholds identified for harmful impacts on planktonic larval bivalves, and illustrating the need for full carbonate-system constraint.

- Alk-S relationships show significant departures from historical data; causes uncertain.

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