A Far-field View of Ocean Acidification in the South Atlantic Bight

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SOCAN Webinar March 10, 2015

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Hypothesis:

Trends and variability in physics and chemistry have a larger impact on OA in the SAB than current models suggest

Outline:

Ocean Acidification: What, How, Why, ?

- What is OA?
- How is impacting ocean chemistry ?
- How are the variations in inorganic carbon chemistry related?
- Connection to the global carbon problem

OA in the SECAN region and beyond

- Ocean OA forcing monitoring assets in the SAB
- Patterns of OA in the SAB as expressed in aragonite saturation state
    - Spatial Patterns
    - Temporal patterns
    - Changes in context of large-scale oceanographic features

Using data and insights from the local experts: W.-J. Cai, A. Sutton, S. Noakes, L.Q. Jiang, W.-J. Huang, A. Wang

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Prelude:

Acidity is an often [mis]used concept in a variety of situations which can lead to misconceptions about ocean acidification

e.g. http://www.thebestofrawfood.com/ph-scale.html

"Very simply put, the pH scale measures the amount of oxygen in your blood."

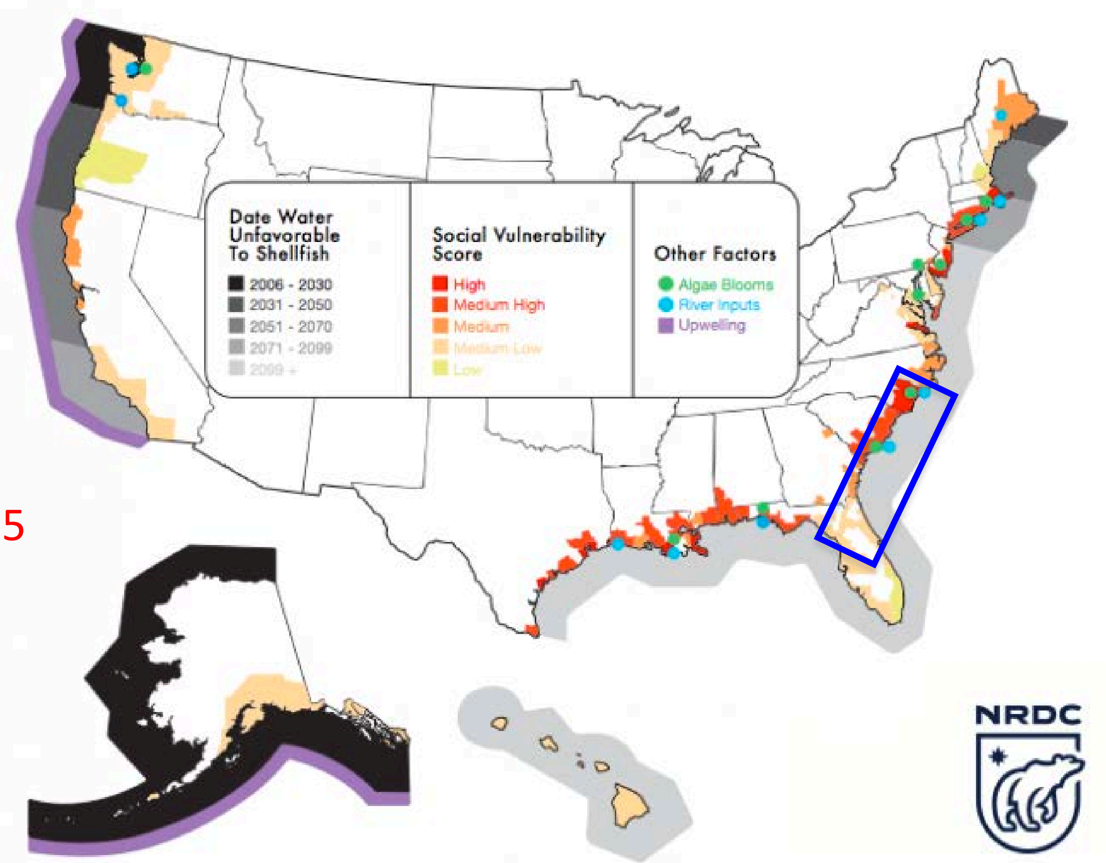
"Symptoms of a Person with Low pH:
Typical characteristics of <u>an acid person</u> are: low energy, no enthusiasm, tires quickly, irritable or poor sleep."

Context:

Linking OA to Socio-Economics

Vulnerability and adaptation of US shellfisheries to ocean acidification

Tipping point $\Omega_{Ar} = 1.5$



Ocean acidification rates and social vulnerability around the U.S.
Source: NRDC

- SAB : relatively favorable for shellfish- but high social vulnerability
- There is little correlation between social vulnerability and degree of severity of OA

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Ekstrom et al. 2015

Ocean Acidification

The decrease in pH of the Earth's oceans and changes in ocean chemistry *caused by chemical inputs from the atmosphere,* including carbon dioxide.

Legislative driver for OA research in the USA.

Federal Ocean Acidification Research And Monitoring Act of 2009 or the ''**FOARAM Act**''

To monitor and conduct research on the processes and consequences of ocean acidification on marine organisms and ecosystems

Physical-chemical driver is atmospheric CO_2 increases, a portion (≈ 25 %) of which enters the ocean.

Mankind is perturbing the chemical [inorganic carbon] balance of the ocean

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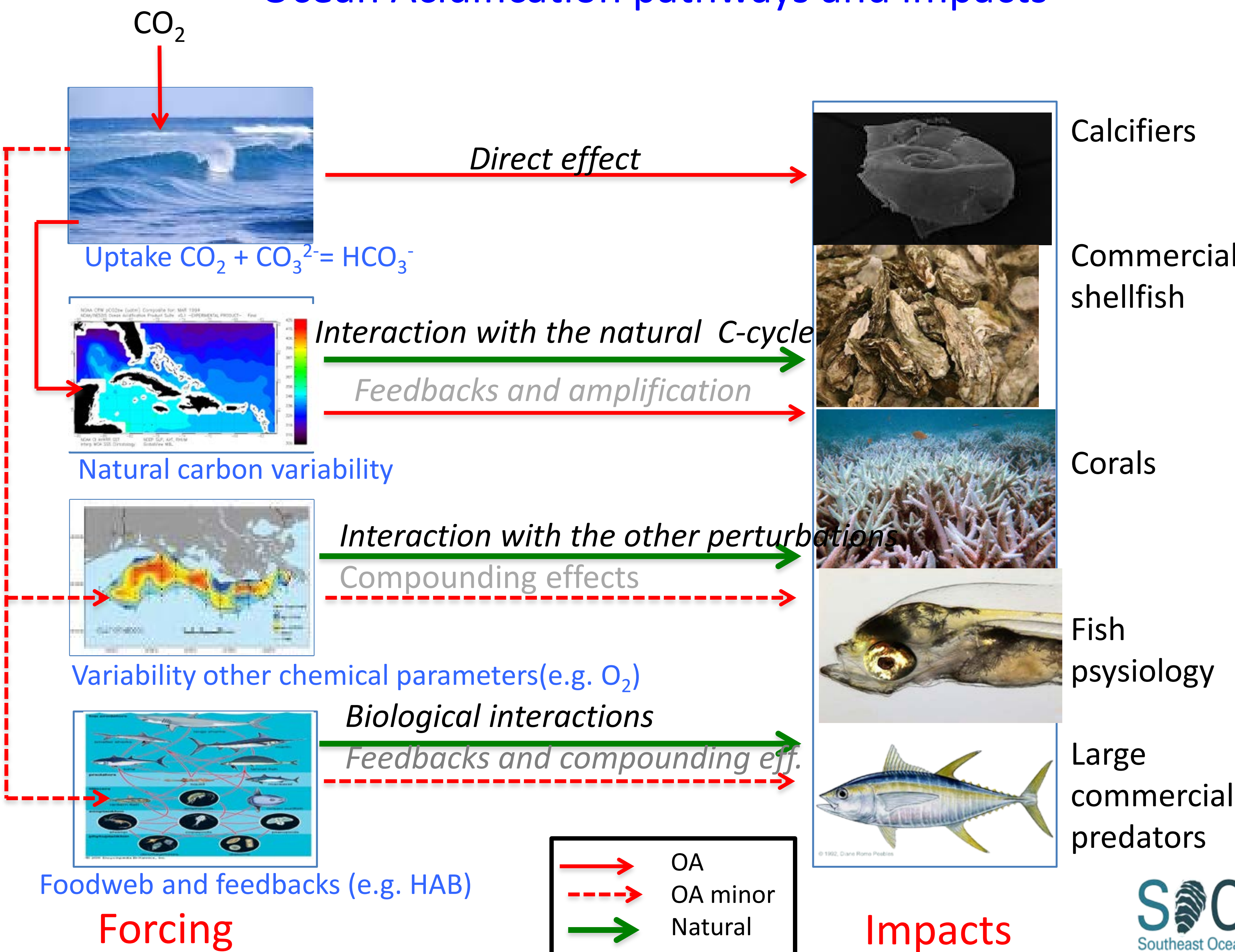
Ocean Acidification pathways and impacts



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The chemistry of OA in words, graphs and equations

- There are three species of interest that are connected through basic chemistry
- They are minor species of the inorganic C system in surface seawater

pCO_2: the partial pressure of CO_2 (<≈ 1 %)
pH: the negative log of the hydrogen concentration $-\log [H^+]$ (<≈0.005 %)
CO_3^{2-}: the carbonate ion concentration (<≈ 10 %) (calculated)

$$pCO_2 \xrightarrow{K_0} [CO_2]$$

$$[CO_2] \xrightarrow{K'_1} [HCO_3^-] + [H^+]$$

$$[CO_3^{2-}] + [H^+] \xrightarrow{K'_2} [HCO_3^-]$$

$$\mathbf{[CO_2] + [CO_3^{2-}] \longrightarrow [HCO_3^-]}$$

For many OA related responses it's the saturation state of the mineral phase of the shell/skeleton that is of critical importance. It is a keystone variable for OA

$$\Omega_{Ar} = \mathbf{[CO_3^{2-}]}\ [Ca^{2+}]\ K'^{-1}_{sp}$$

Chemist's view: $\Omega_{Ar} < 1$ mineral phase dissolves
Biologist's view: Any Ω_{Ar} decreases causes calcifying organism to be stressed

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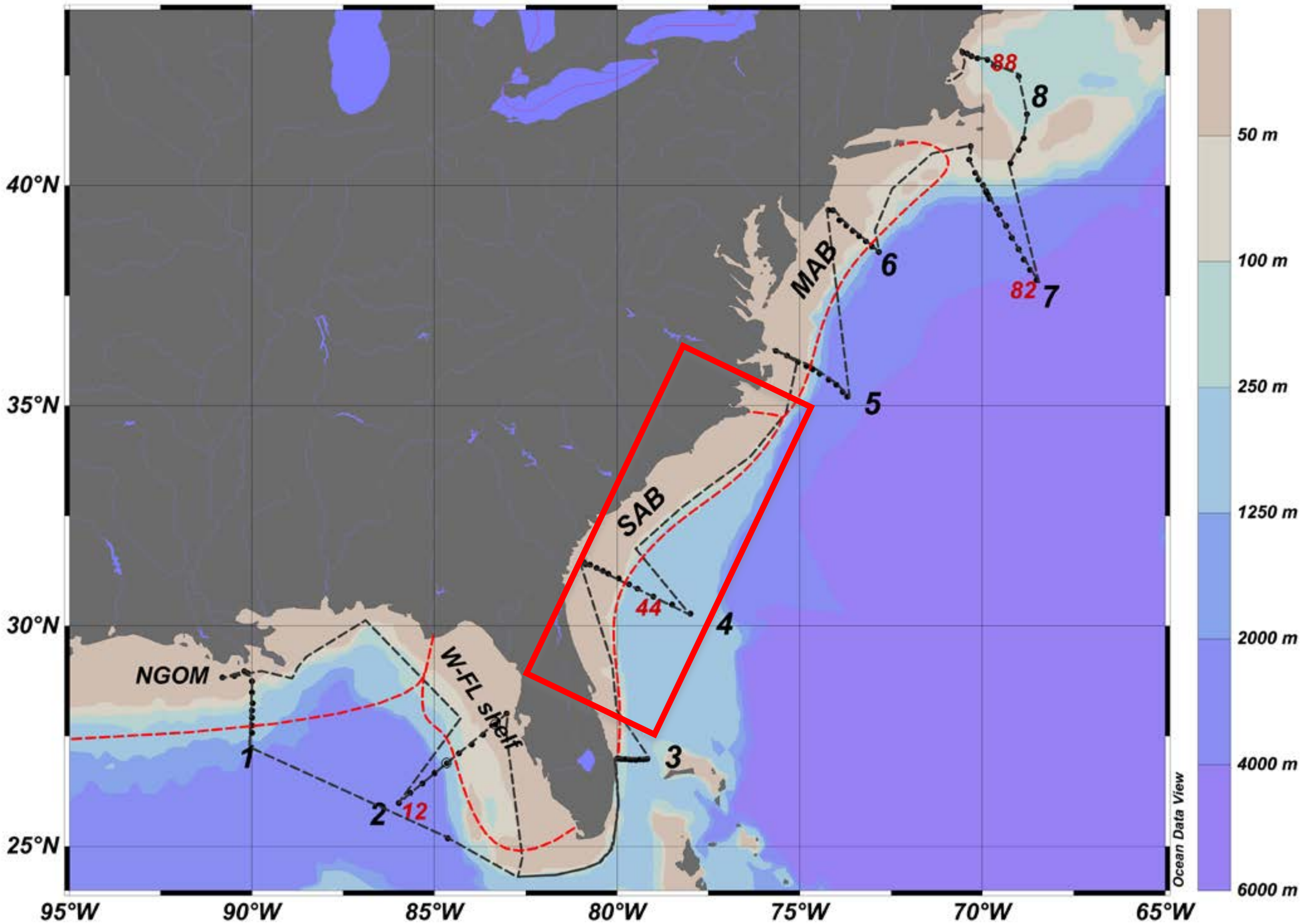
The area of interest

South Atlantic Bight (SAB)

The study area as part of a larger region



Cruise track of GOMECC-2

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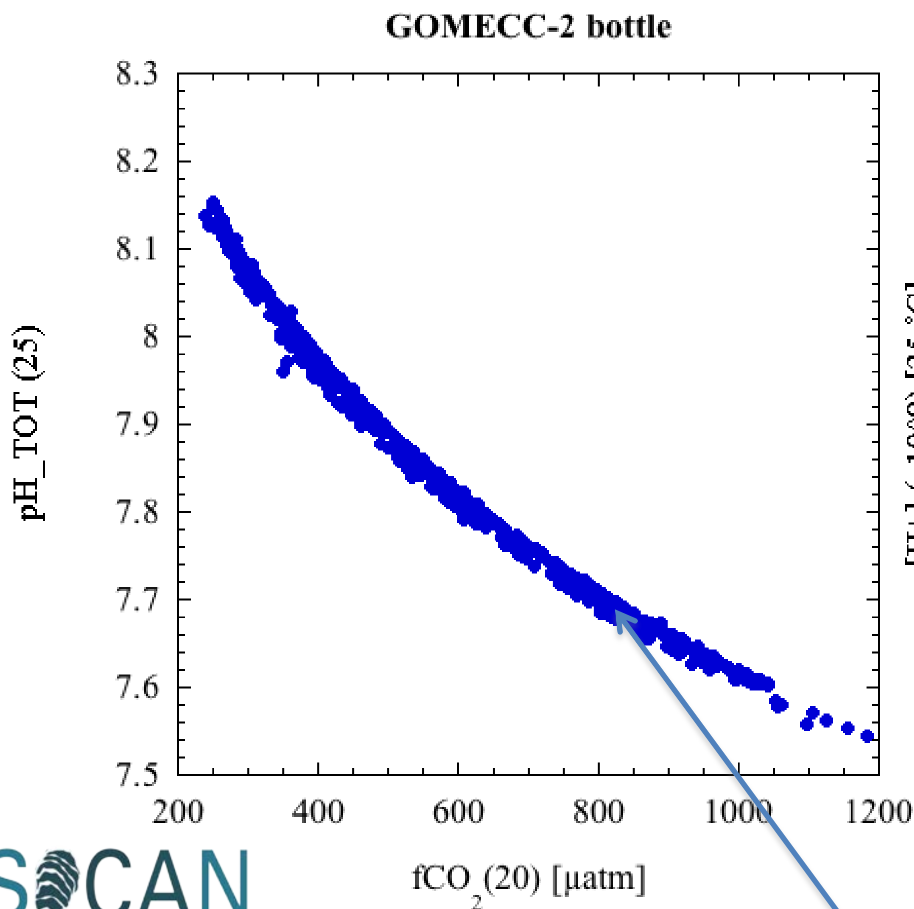
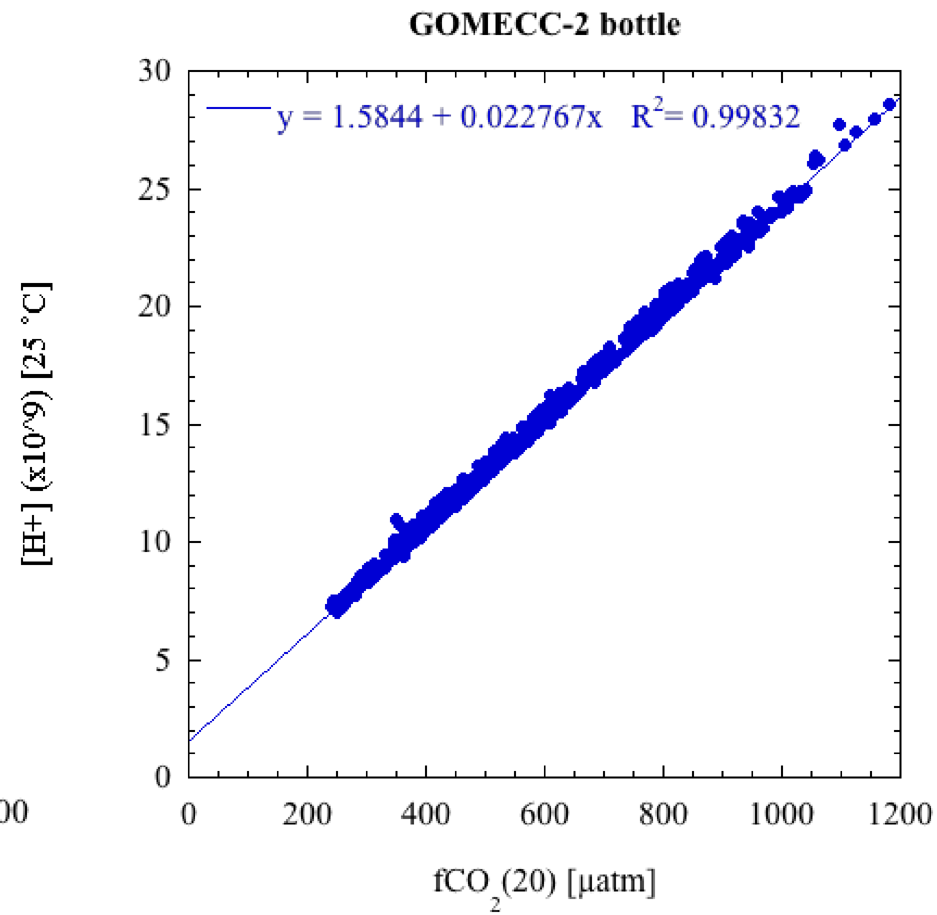
Data of GOMECC-2

pCO_2 vs pH

Connectivity of inorganic carbon parameters: Chemistry works!





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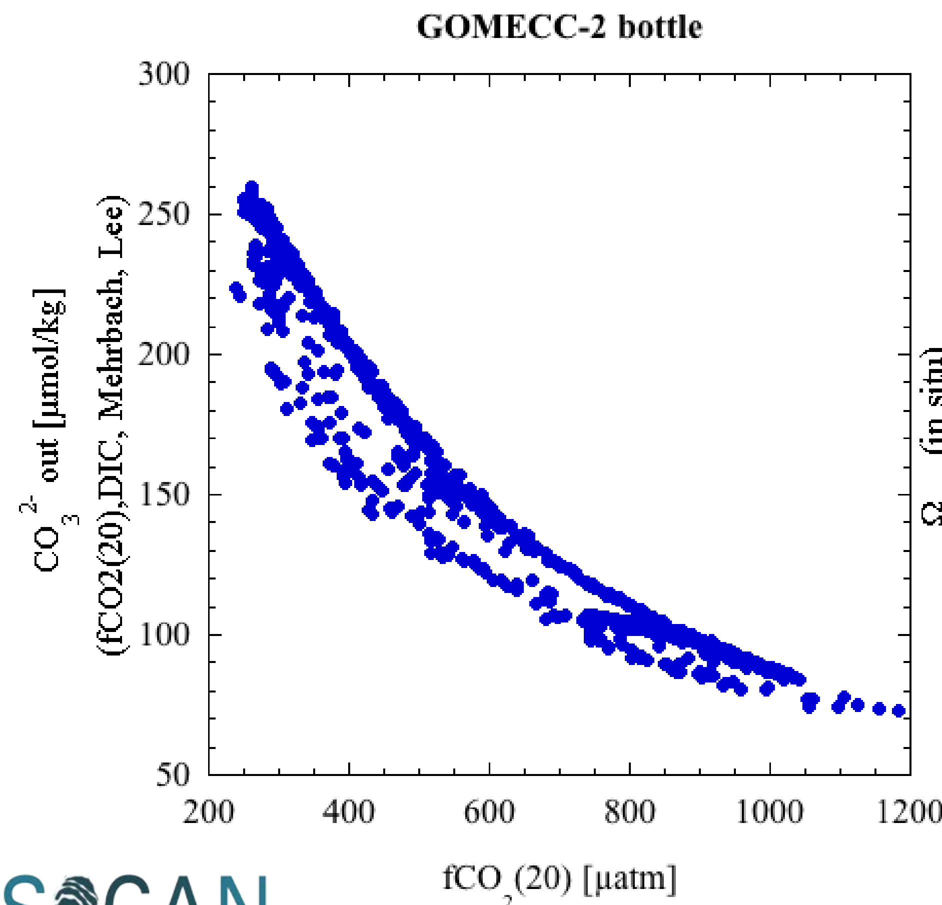
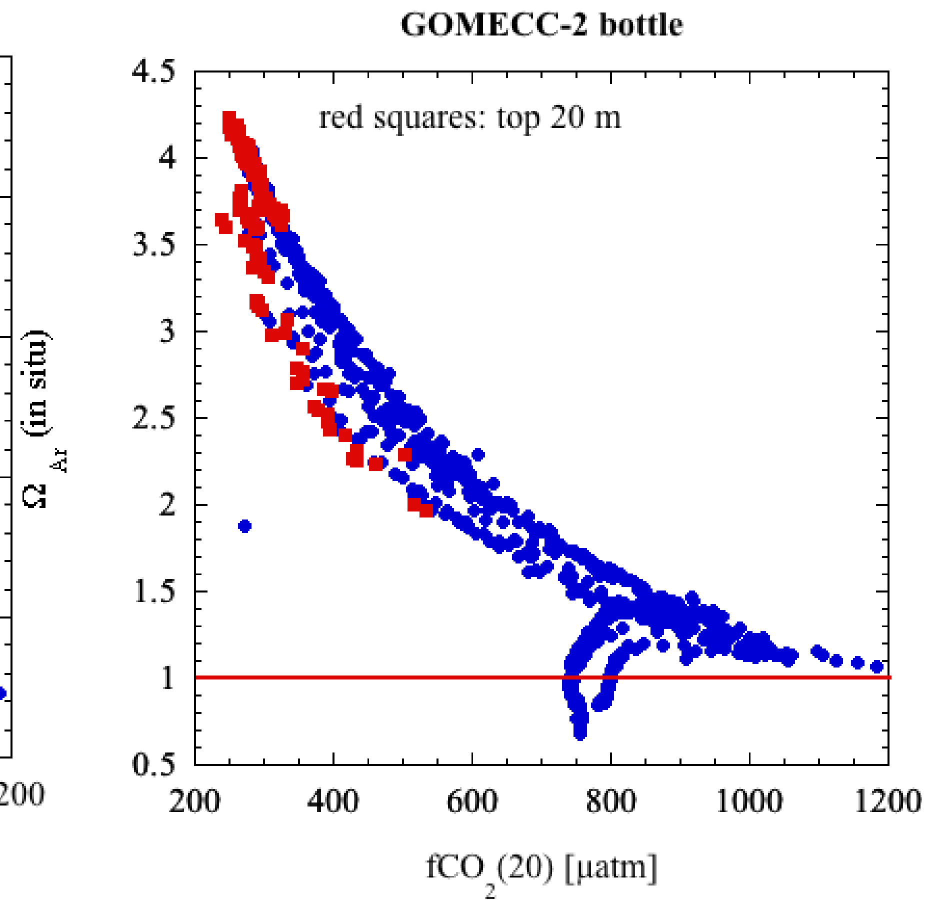
Much of the OA story is in the width of this line

Data of GOMECC-2

pCO_2 vs Ω_{Ar}

Estimates of OA can be obtained from pCO_2 (or pH) by itself but
to fully understand chemical forcing we need and additional carbon parameter
(DIC or TAlk)





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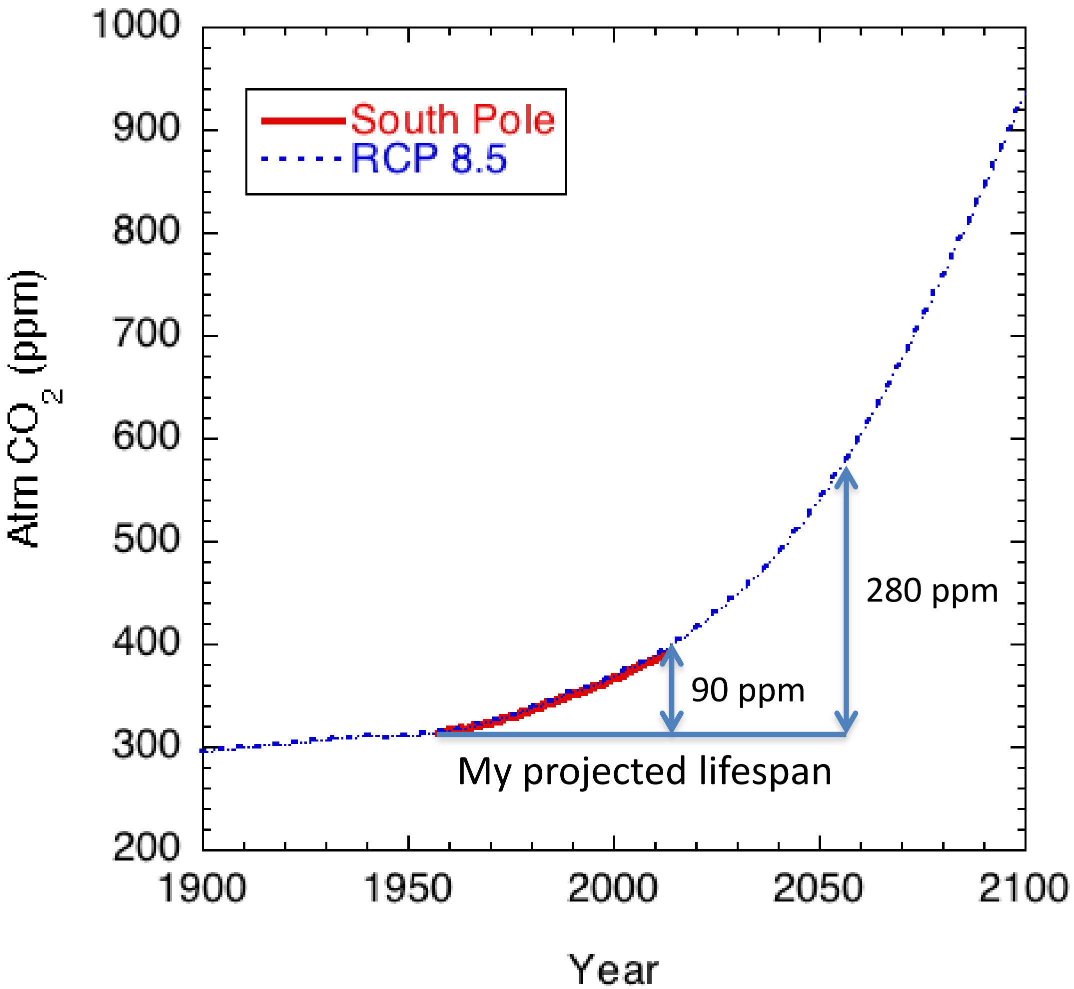
Trends CO_3^{2-} and Ω_{Ar} are very similar

OA forcing: What will the future hold?



We are at the start of a meteoric atmospheric CO_2 rise

"We ain't seen nothing yet"

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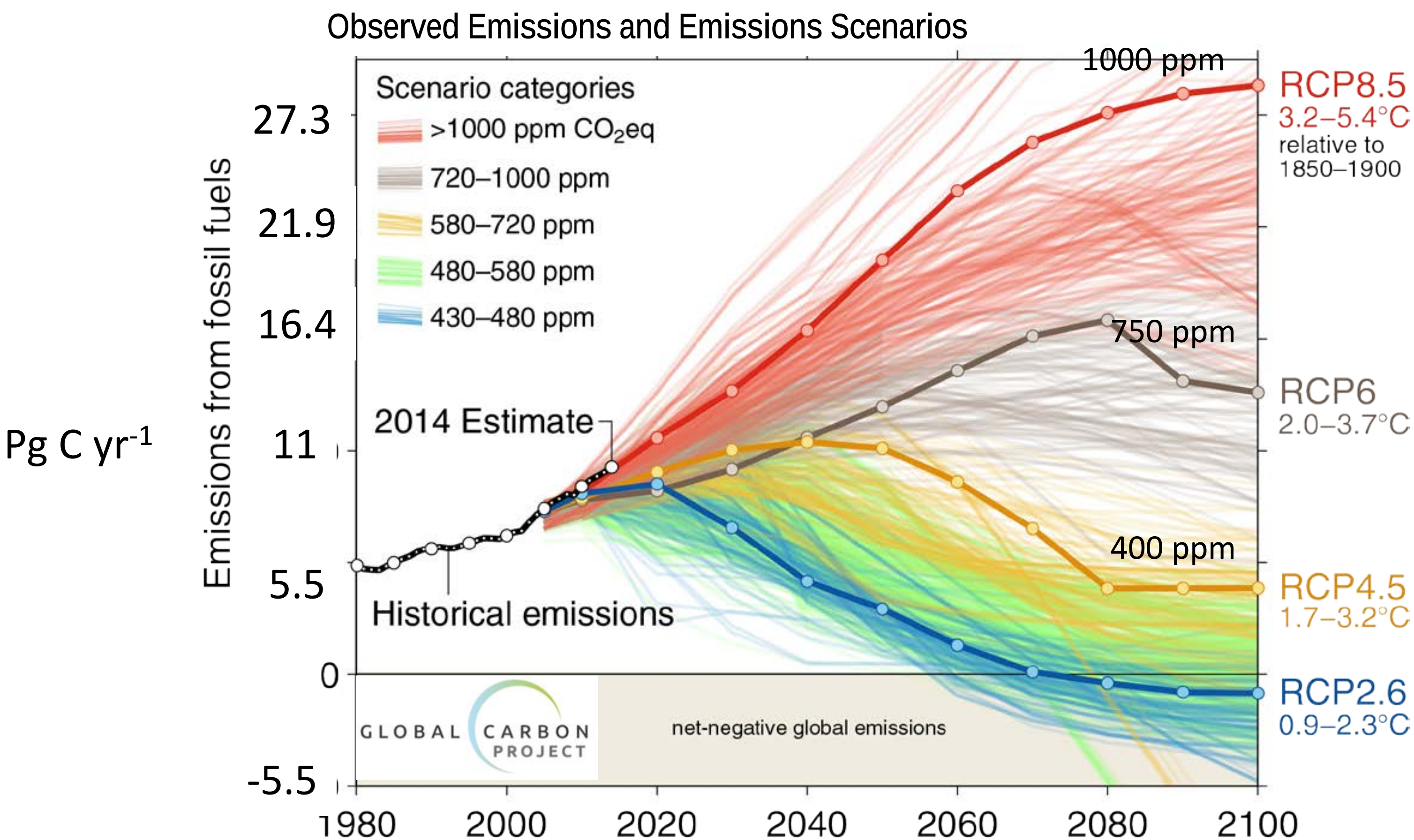
The Global Carbon Cycle: Uncertainties in modeling the future

Inherent uncertainties in connection between radiative forcing and CO_2



- Emissions are on track for 3.2–5.4ºC "likely" increase in temperature above pre-industrial
- Large and sustained mitigation is required to keep below 2ºC

Over 1000 scenarios from the IPCC Fifth Assessment Report are shown

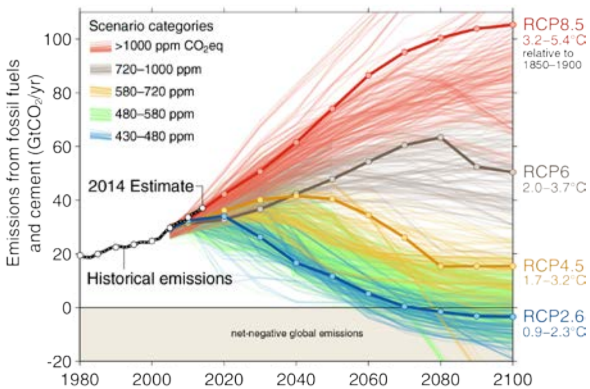
Source: Fuss et al 2014; CDIAC; Global Carbon Budget 2014

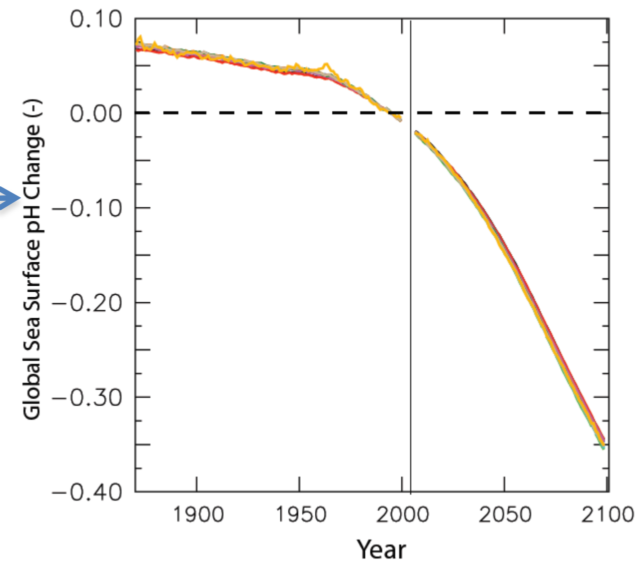
Uncertainty in future OA **projections**

For a given atm. CO_2 level we know the surface pH (an optimistic assessment)

Based on models

- we know the future surface water pH scenario perfectly
- we know the future better than we can reconstruct the past





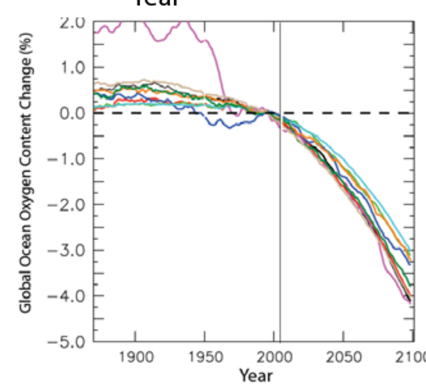
Ocean Acidification

Change in pCO_2: 25 µatm decade^{-1} [Δ DIC = 16]

Change in pH(25):- 0.026

Change in CO_3^{2-} : -10 [Δ HCO_3^- = 26]

Change in Ω_{Ar} : -0.16



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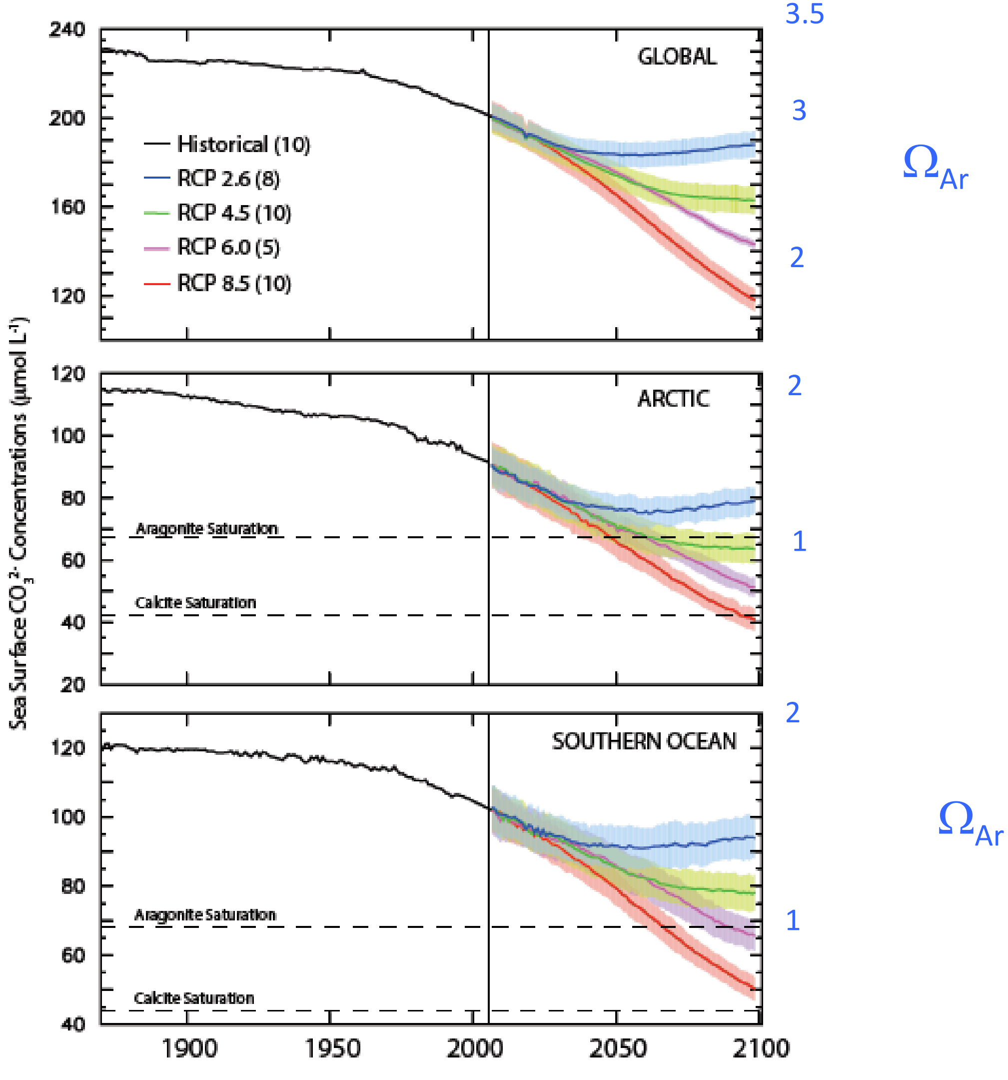
Coupled Model Intercomparison Project 5:Individual model time series of global sea surface warming surface pH change (pH unit), ocean O_2 content change (%), over 1870–2100 using historical simulations as well as all RCP8.5 simulations.

Bopp et al. 2013

Uncertainty in future OA **projections**

Regional differences: Higher latitudes-lower Ω_{Ar}



Model-mean time series of mean surface carbonate ion concentrations (µmol L^{-1}) for the global ocean, the Arctic Ocean(north of 70 N), and the Southern Ocean (south of 60 S) over1870–2100 using historical simulations as well as all RCP simulations.Also indicated are estimates of aragonite and calcite saturationlevels for the Arctic and the Southern oceans (dashed lines). (Bopp et al. 2013)

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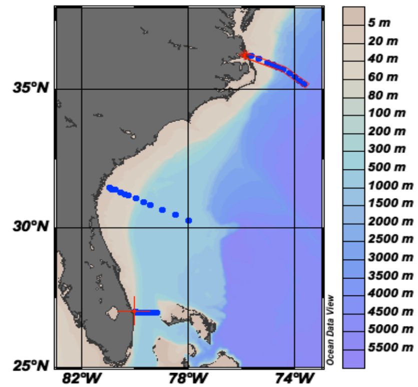
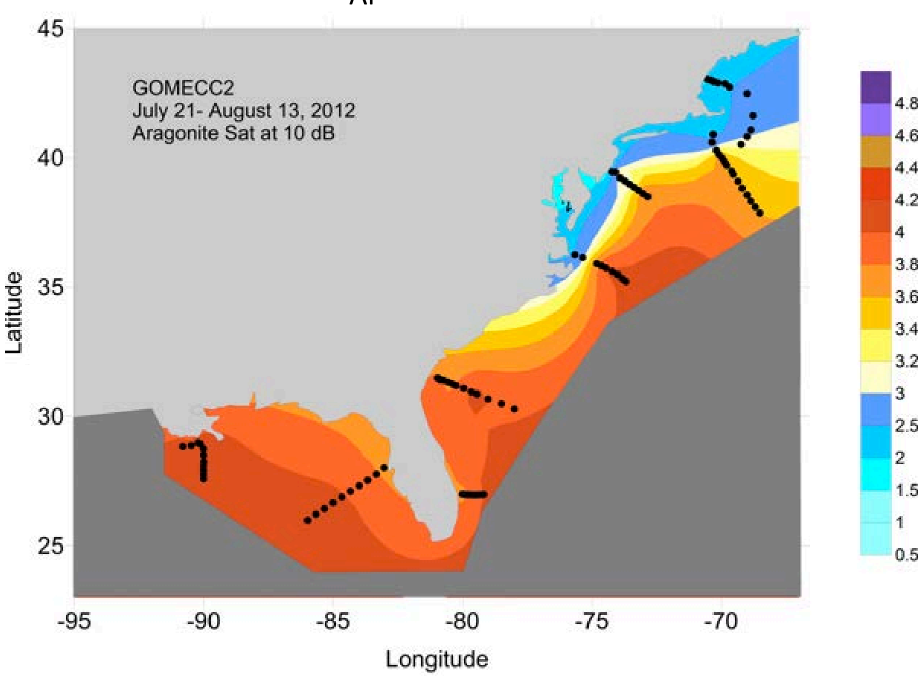
Spatial (summertime) patterns of Ω_{Ar} in the GOMECC region

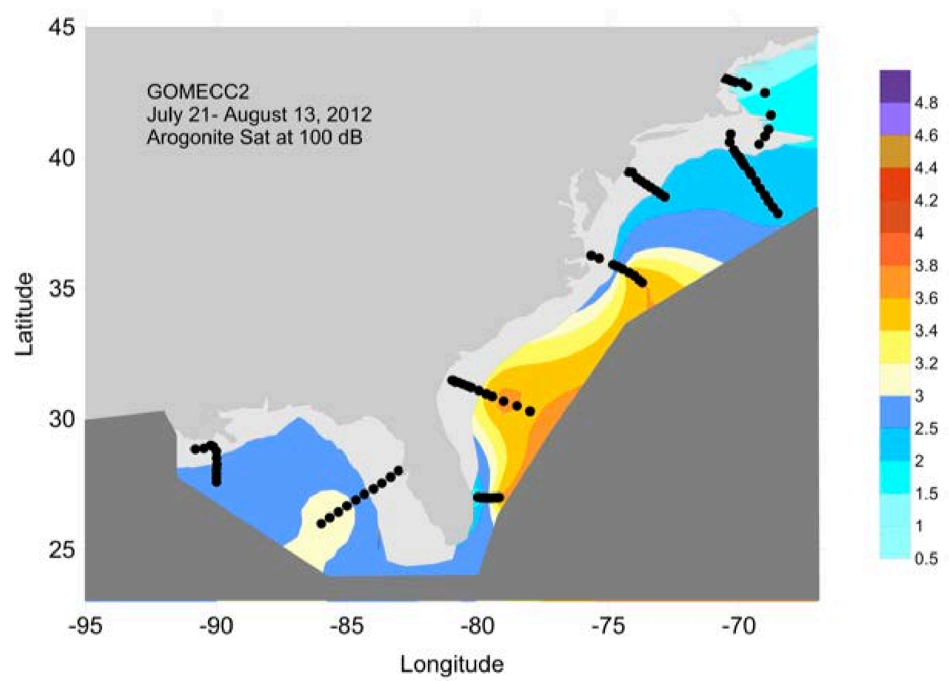
Ranges of Ω_{Ar} in from 2 to 4.5 in surface and 1.5 -3 at 100-m depth



Ω_{Ar} 10-m



Ω_{Ar} 100-m



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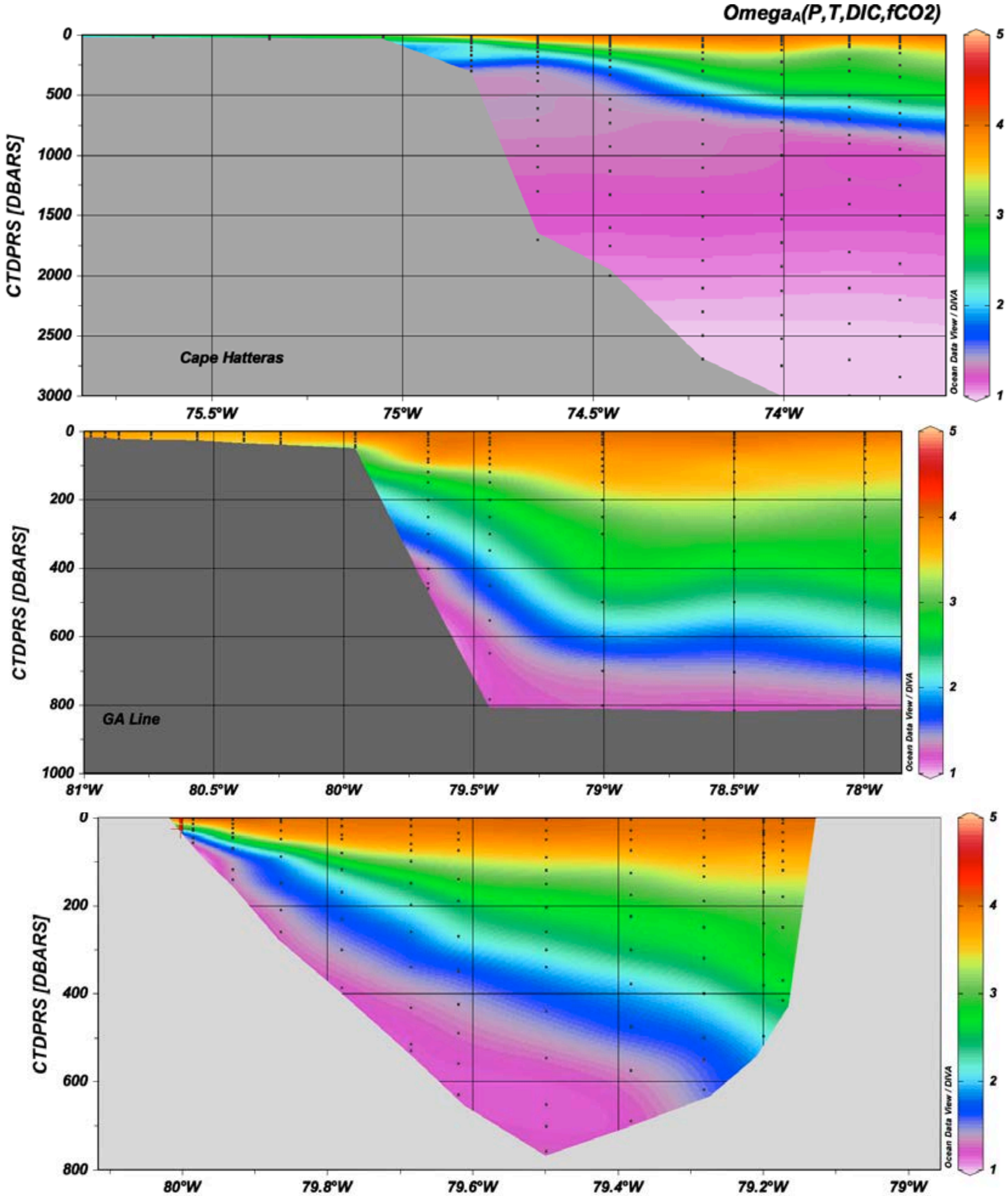
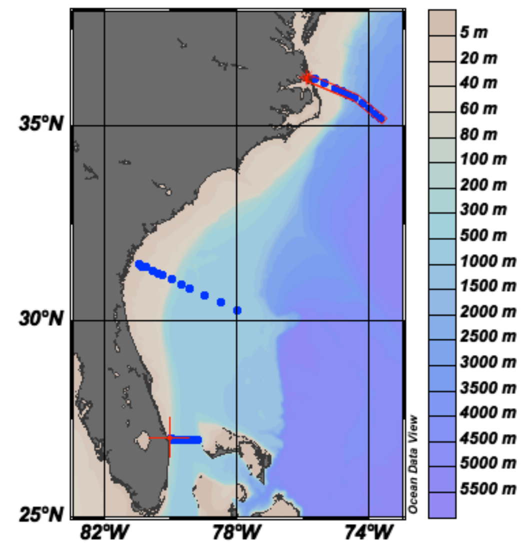
Lower Ω_{ar} near the coast, to the North and at depth,

Wanninkhof et al. 2015

Depth patterns of Ω_{Ar} in the SAB region

Ranges of Ω_{ar} from 1 - 4.5 in the top 3000 m (1.5 to 4.5 along GA line)





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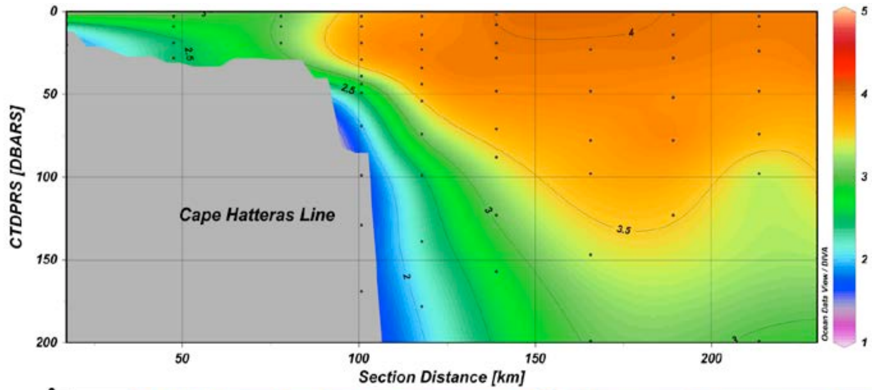
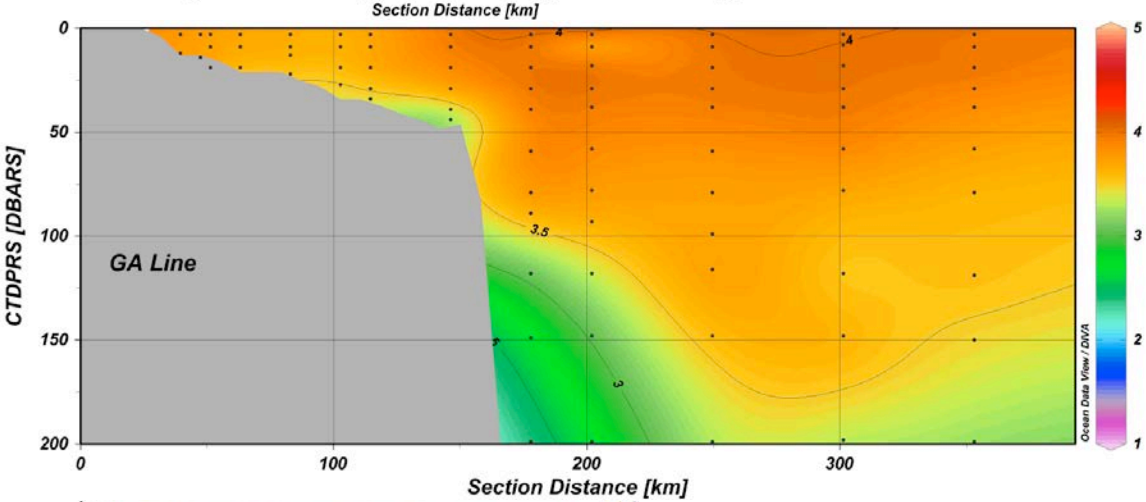
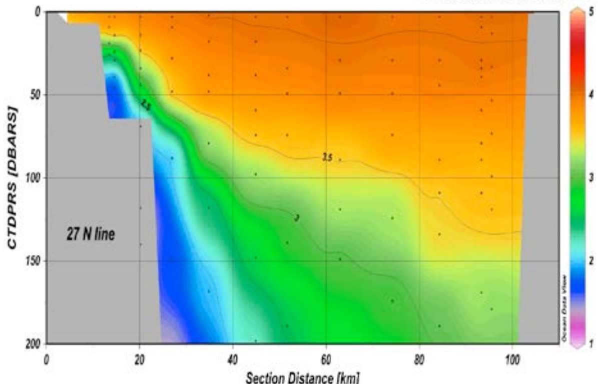
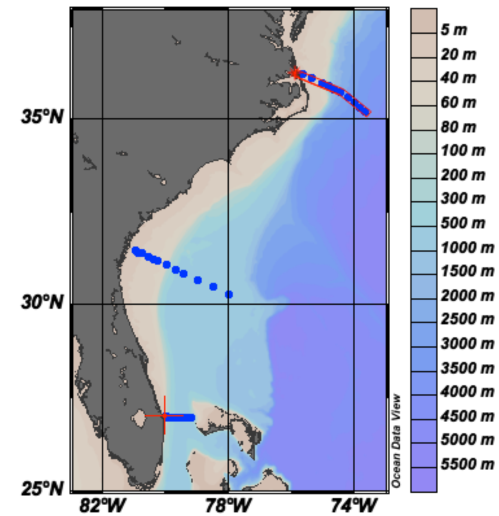
Depth patterns of Ω_{Ar} in the SAB region

SAB- Influence of large current structure









Ranges of Ω_{Ar} from 2-4.5 in the top 200 m (3 to 4.5 along GA line)

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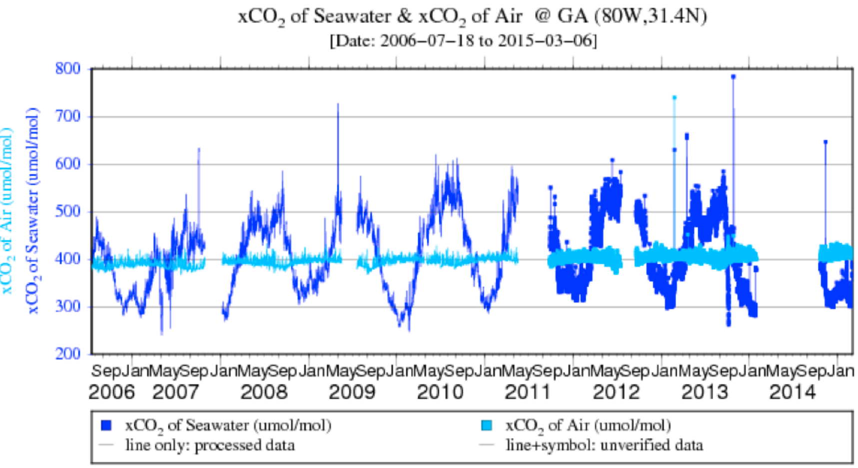
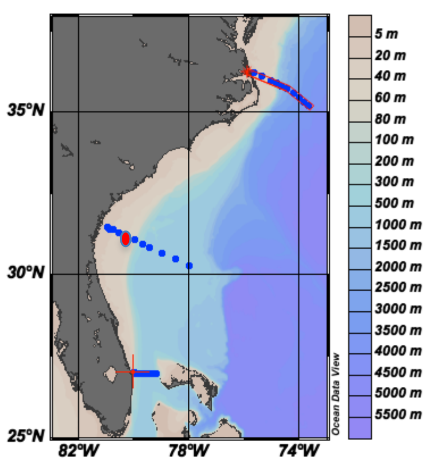
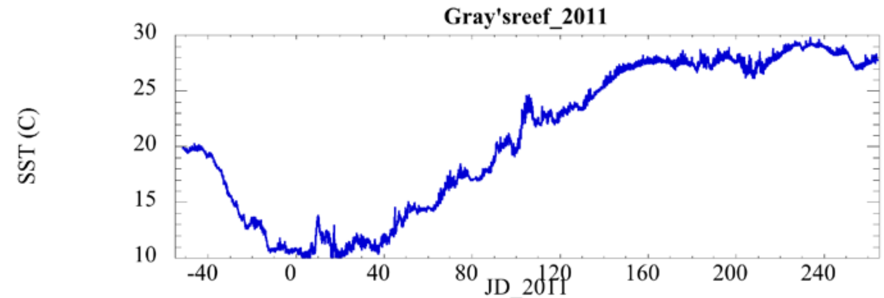
Temporal trends of Ω_{Ar} in the SAB region (Gray's Reef)

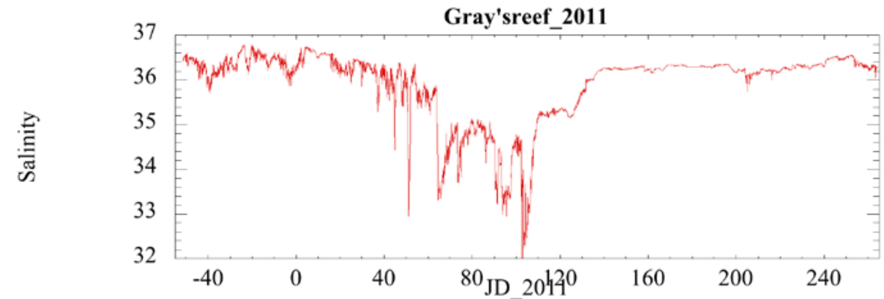
Grays Reef

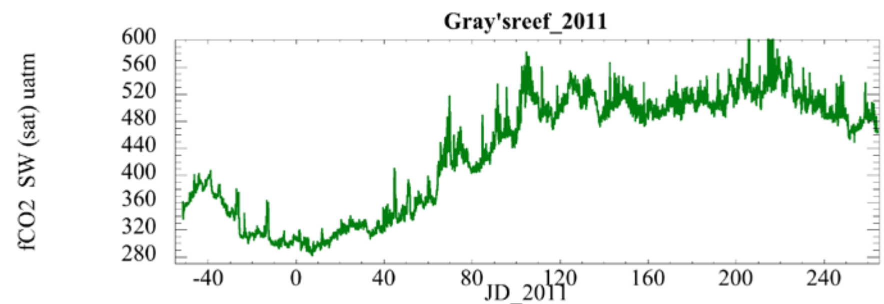


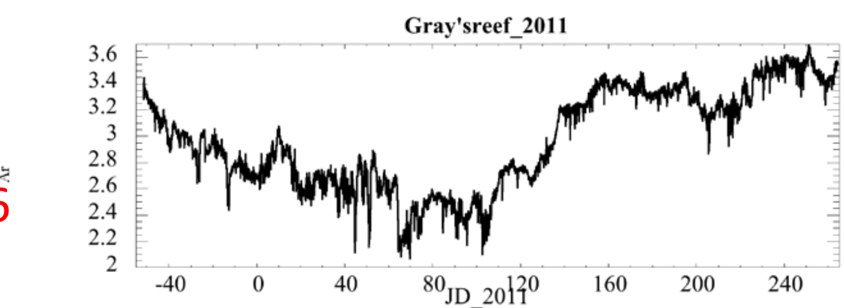
Sutton et al. 2011











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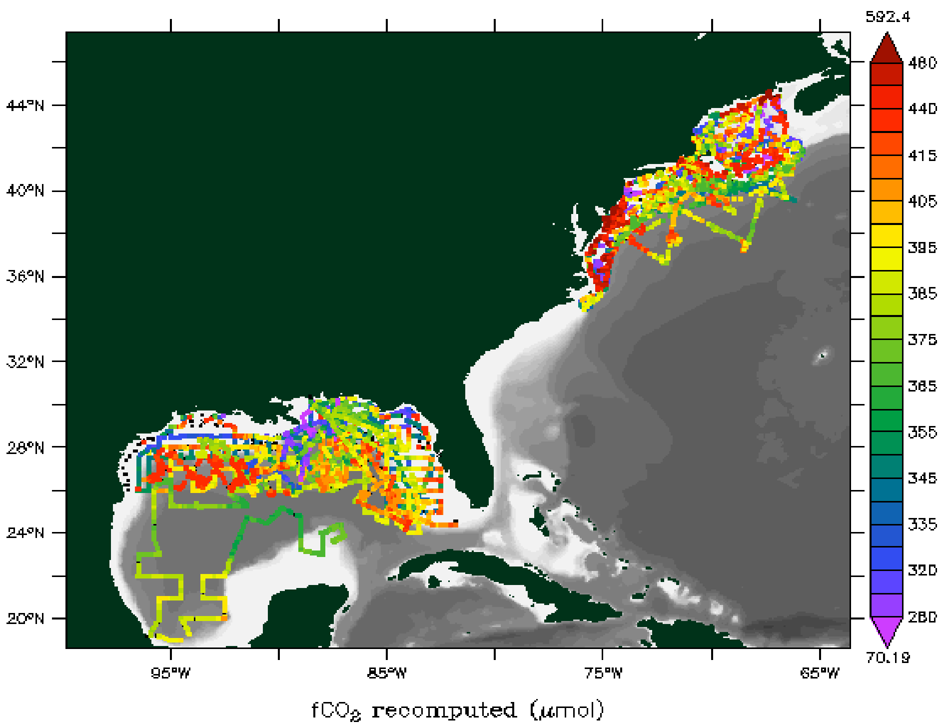
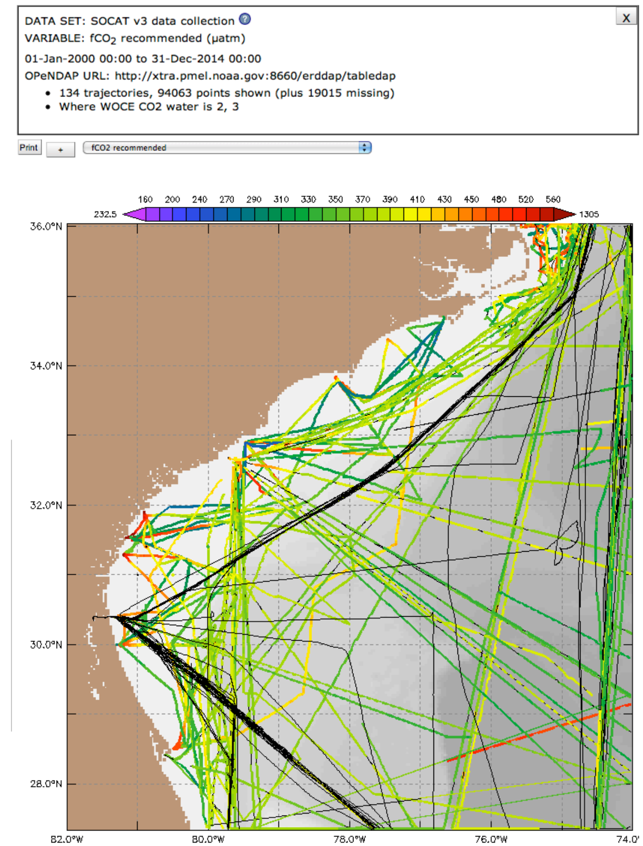
Ranges of Ω_{Ar} from 2.4 to 3.6

Spatio Temporal trends of Ω_{Ar} in surface waters the SAB region

Using ships of opportunity and community data assembly (SOCAT, NODC_OA)



SOOP-OA does not cover SAB



Despite major ports and NOAA homeport little SOOP data in the SAB

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Spatio-Temporal trends of Ω_{Ar} in surface waters the SAB region

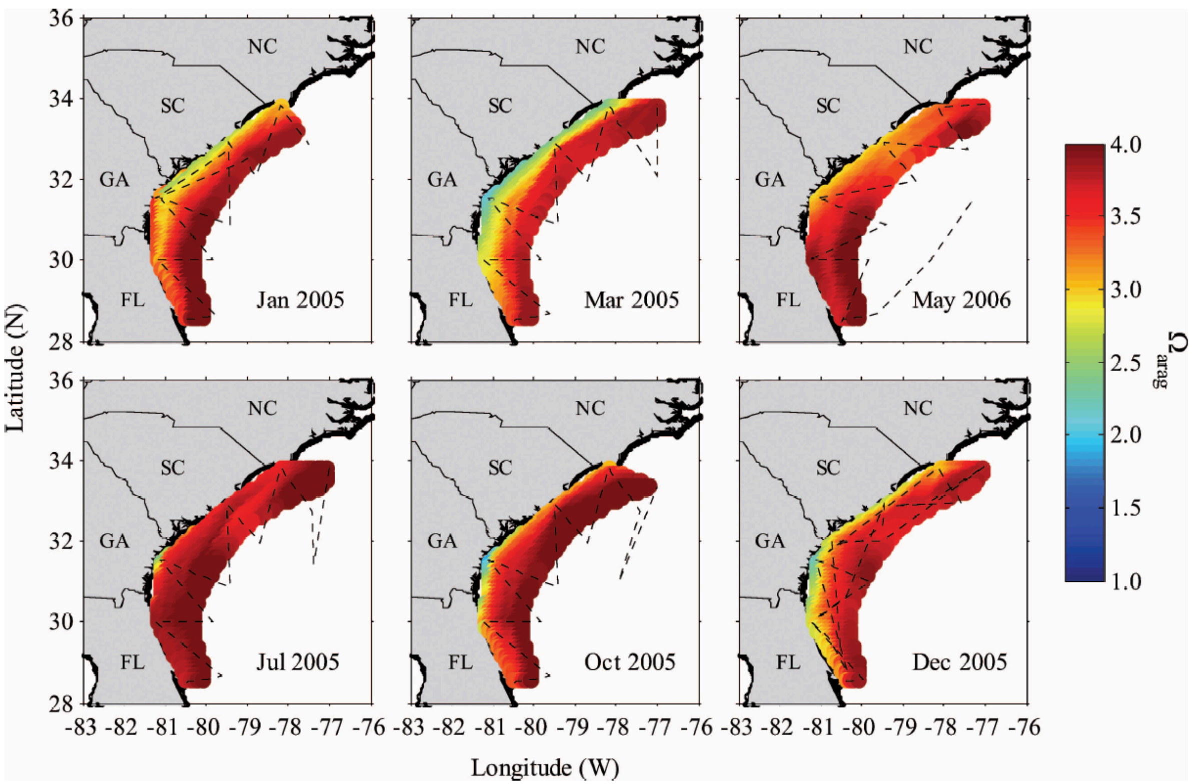
Large changes Ω_{Ar} in surface waters in the SAB region nearshore (≈2); smaller changes offshore

Limnol. Oceanogr., 55(6), 2010, 2424–2432

doi:10.4319/lo.2010.55.6.2424

Carbonate mineral saturation states along the U.S. East Coast

Li-Qing Jiang,[a,*,1] Wei-Jun Cai,[a] Richard A. Feely,[b] Yongchen Wang,[a] Xianghui Guo,[a,2] Dwight K. Gledhill,[c] Xinping Hu,[a] Felipe Arzayus,[d] Feizhou Chen,[a,3] Justin Hartmann,[a] and Longjun Zhang[e]



Jiang et al. 2010

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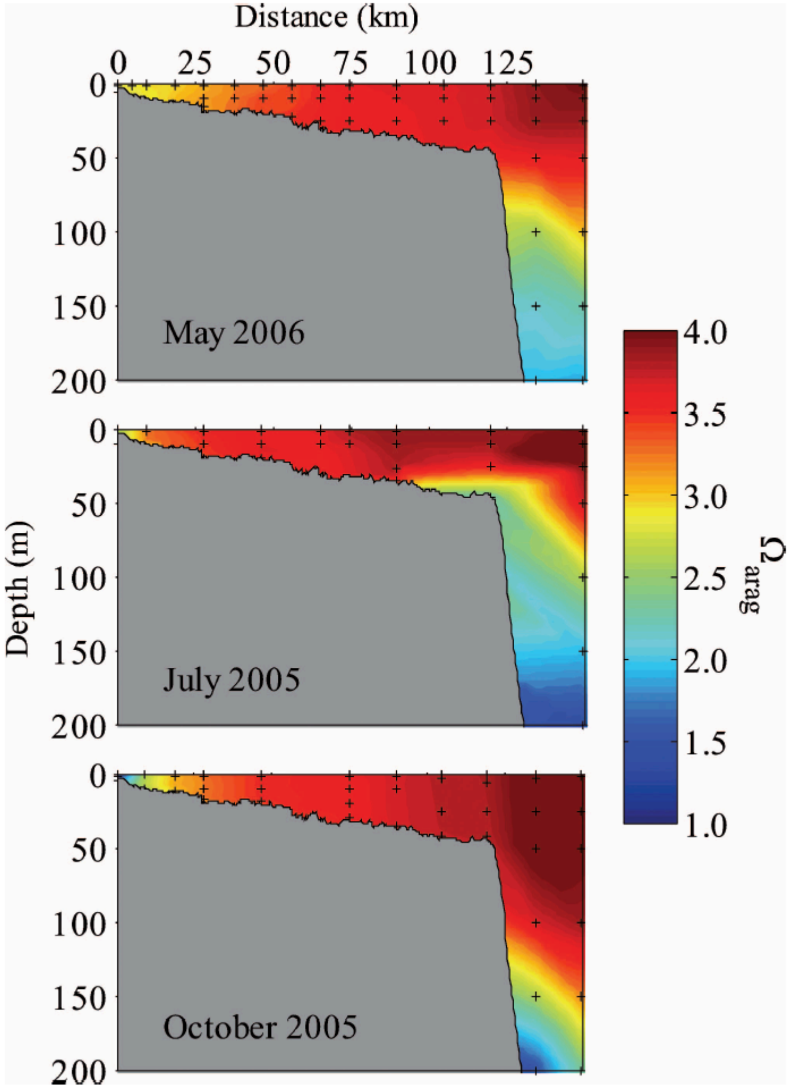
Spatio Temporal trends of Ω_{Ar} in surface waters the SAB region

Effect of offshore currents



Jiang et al. 2010

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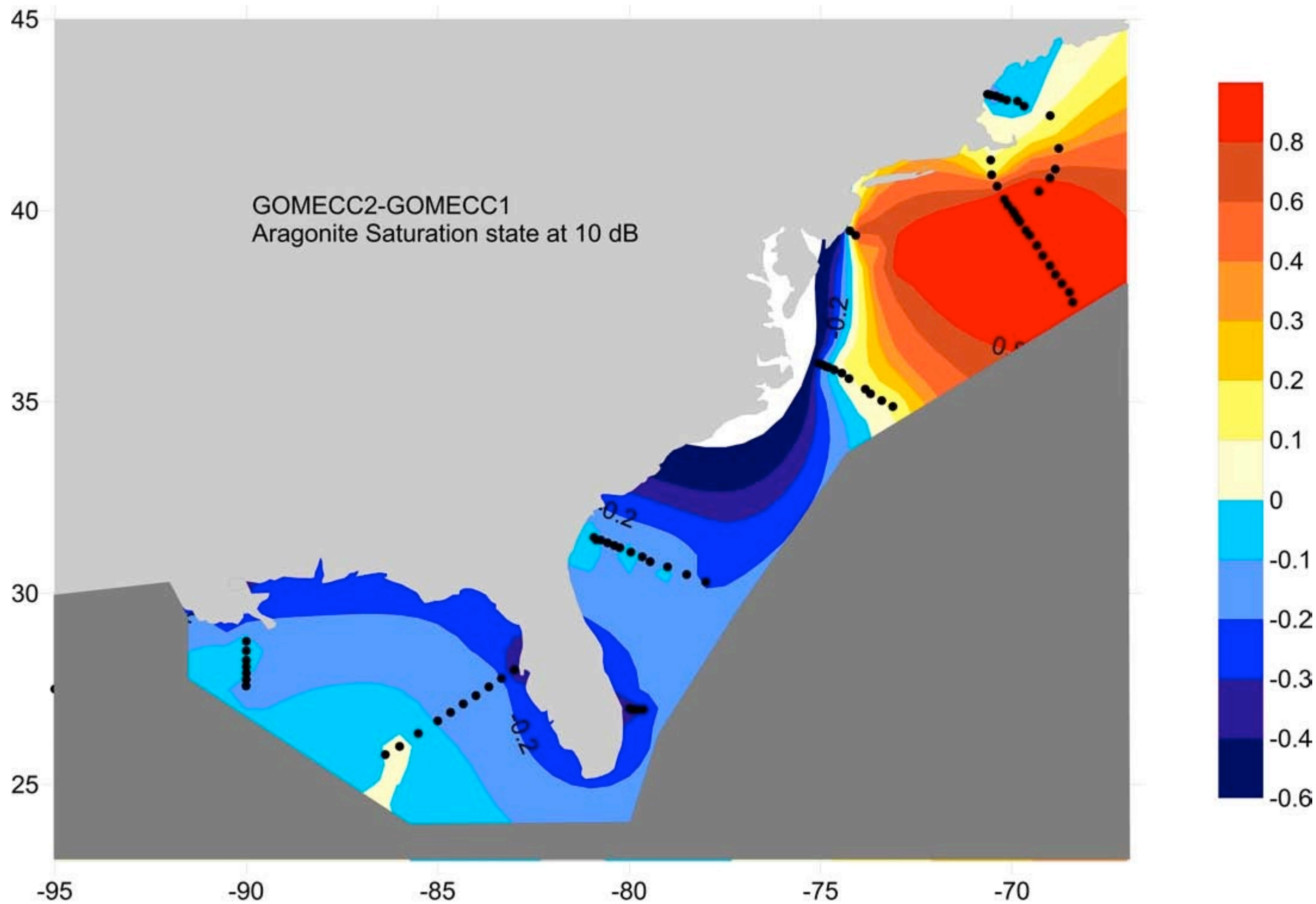
Changes in Ω_{Ar} in surface waters GOMECC region from 2007 to 2012

Expected OA change ≈- 0.08 from 2007 to 2012 but much larger changes observed



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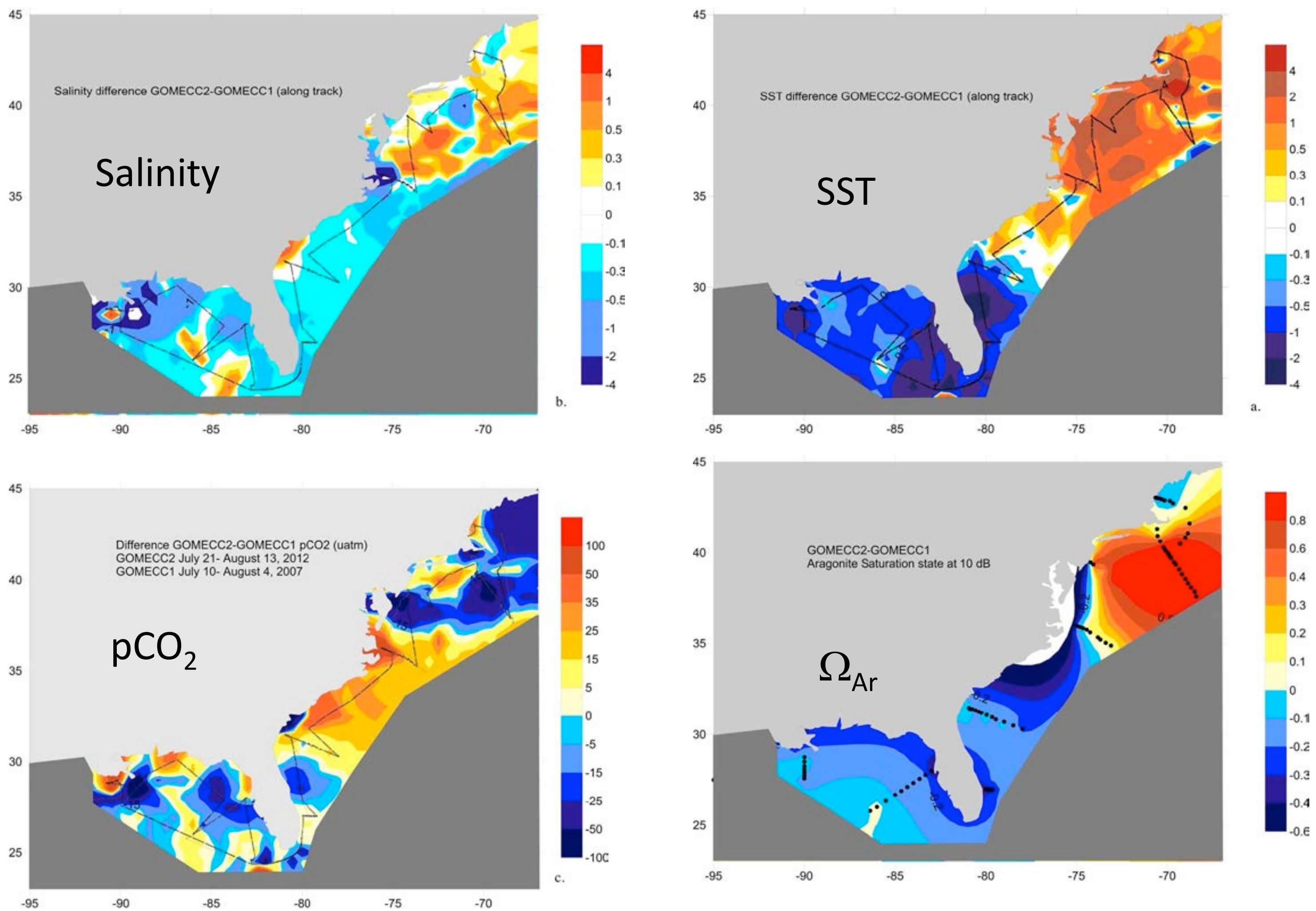
Changes in surface waters GOMECC region from 2007 to 2012

Changes in pCO_2, SST and SSS in surface waters GOMECC region



GOMECC-2 –GOMECC1 : Blue-GOMECC1 higher

Red :GOMECC2 higher

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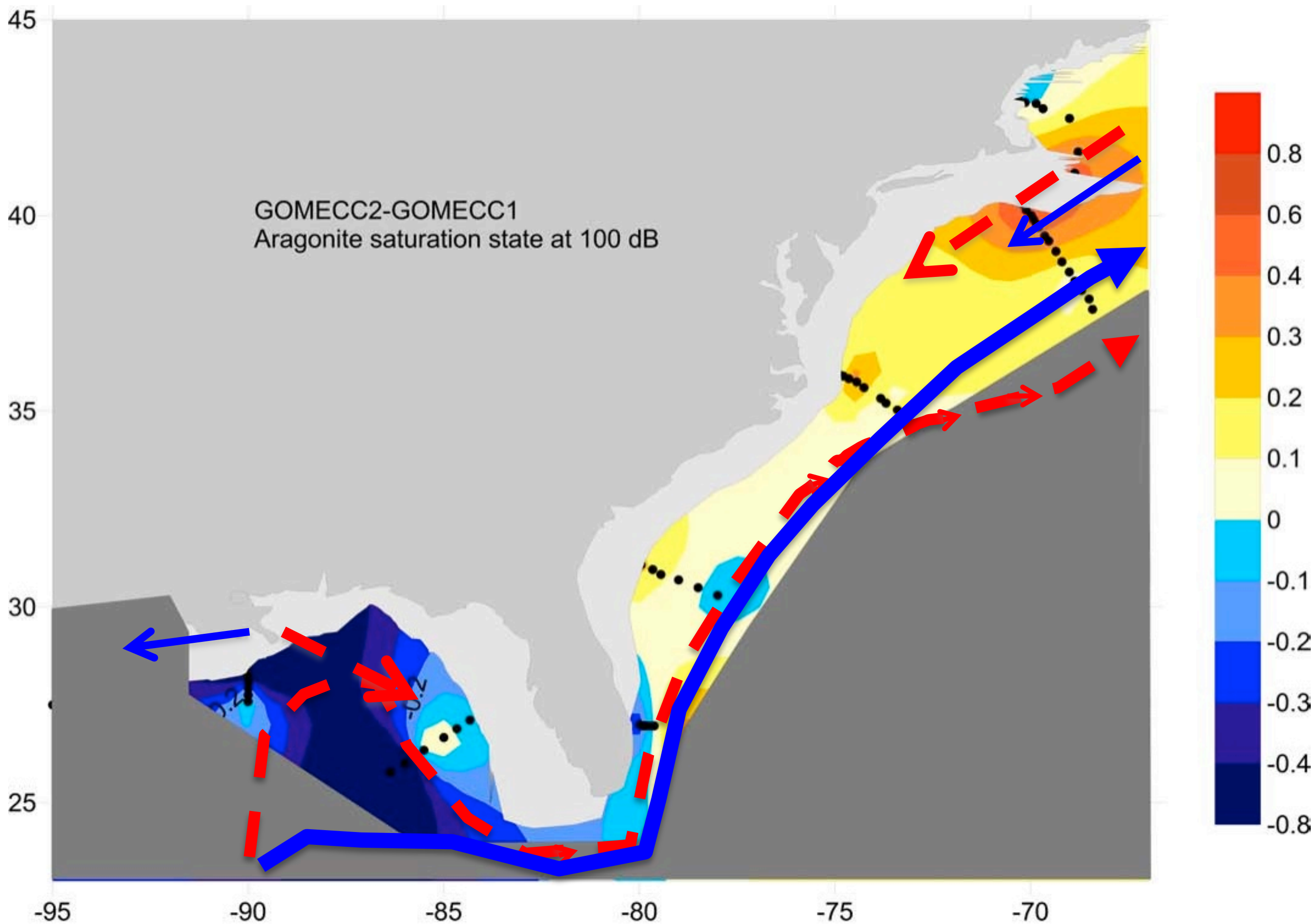
Changes in Ω_{Ar} (100-m) GOMECC region from 2007 to 2012

Changing currents cause large changes in Ω_{Ar}



Summer 2007 (GOMECC-1: Strong Loop Current;MARS along WFl shelf; Strong Labrador Coastal current

Summer 2012 (GOMECC-2: Weak Loop Current;MARS Westward; Weak Labrador Coastal current

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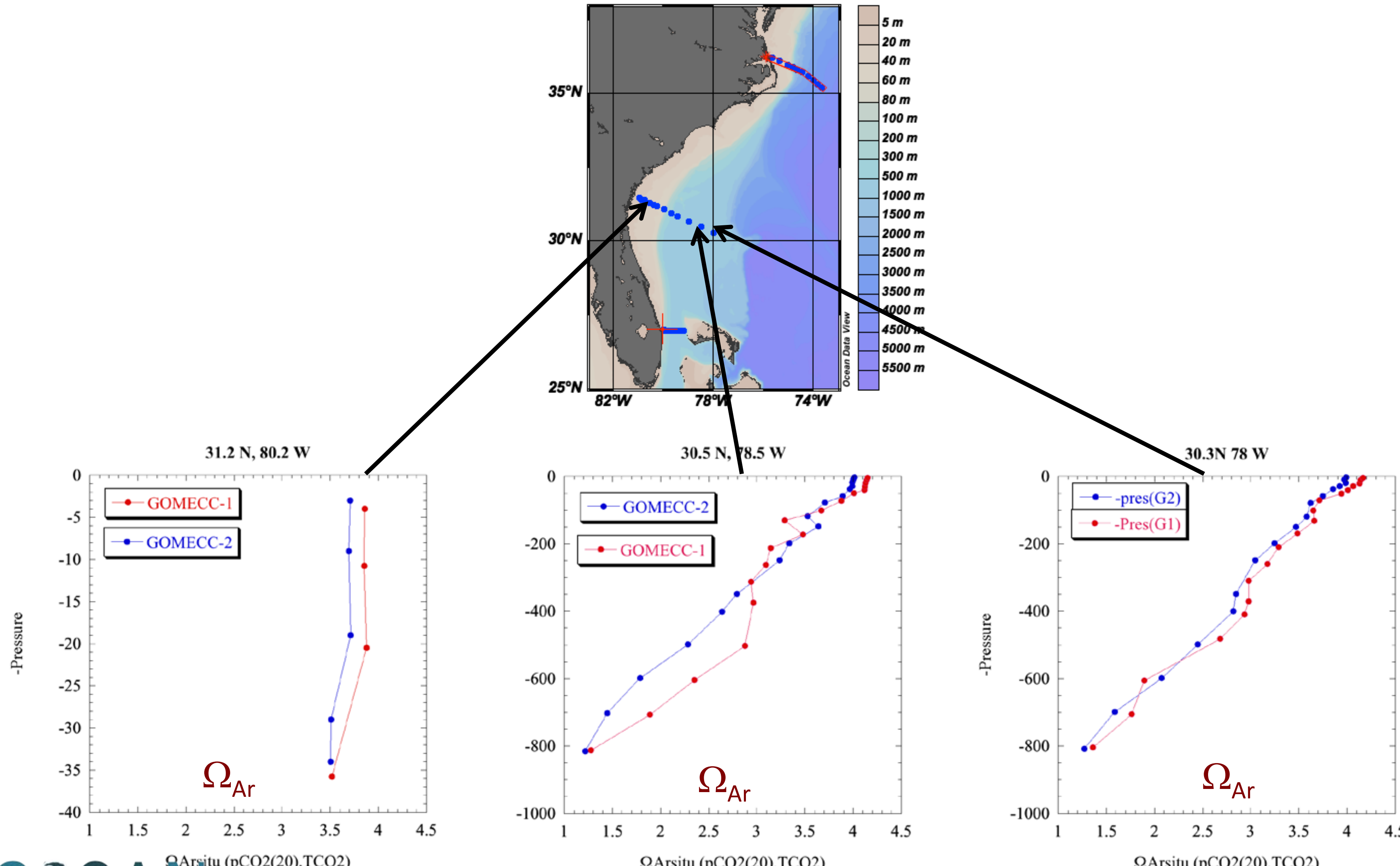
Changes in Ω_{Ar} (100-m) SAB region from 2007 to 2012 (GA line)

Surface- largely OA, subsurface water mass influences



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Expected changes and ranges of OA in the SAB in the next decade

It can be measured and separated from other changes

Ocean Acidification

[S = 36.1, TA = 2368, DIC = 2044]

Change in pCO_2: 25 µatm decade^{-1} [Δ DIC = 16]

Change in pH(25):- 0.026

Change in CO_3^{2-} : -10 [Δ HCO_3^- = 26]

Change in Ω_{Ar} : -0.16

Regional

Changes between GOMECC-2 and GOMECC -1

Change in pCO_2: 100 µatm [Δ DIC = 200]

Change in pH(25):- 0.1

Change in CO_3^{2-} : -40

Change in Ω_{Ar} : -0.6

Temporal

Ranges: (Gray's Reef 2011) (natural changes 10 X decadal changes)

Range in pCO_2: 300 µatm [Δ DIC = 200]

Change in pH(25):- 0.2

Change in CO_3^{2-} : -100

Change in Ω_{Ar} : -1.5

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Expected changes of OA in the SAB in the next century

Wintertime nearshore Ω_{Ar} below threshold of 1.5

Jiang et al.

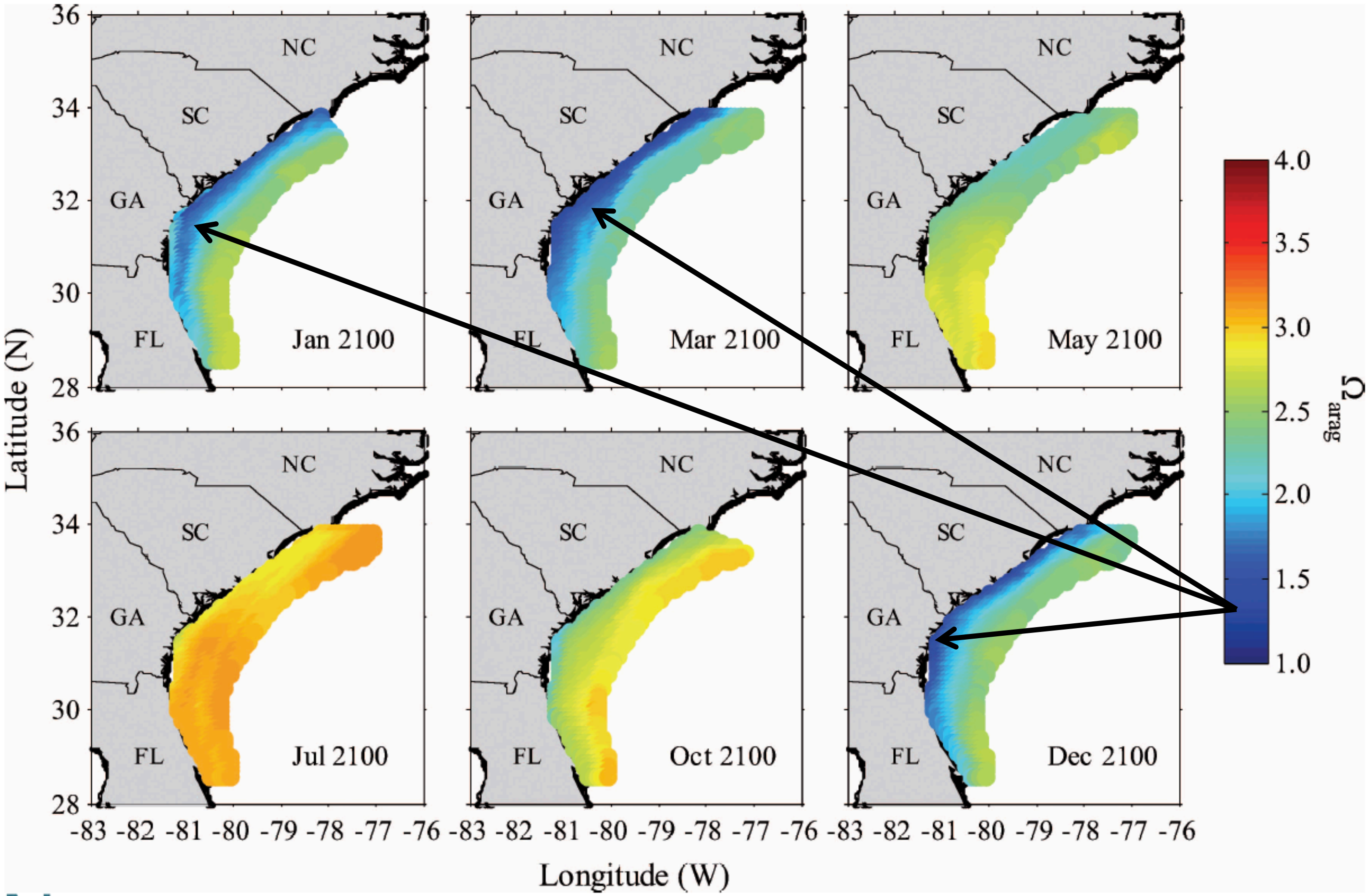

Fig. 7. Predicted surface water aragonite saturation state in the SAB coast by the year 2100.

Jiang et al. 2010

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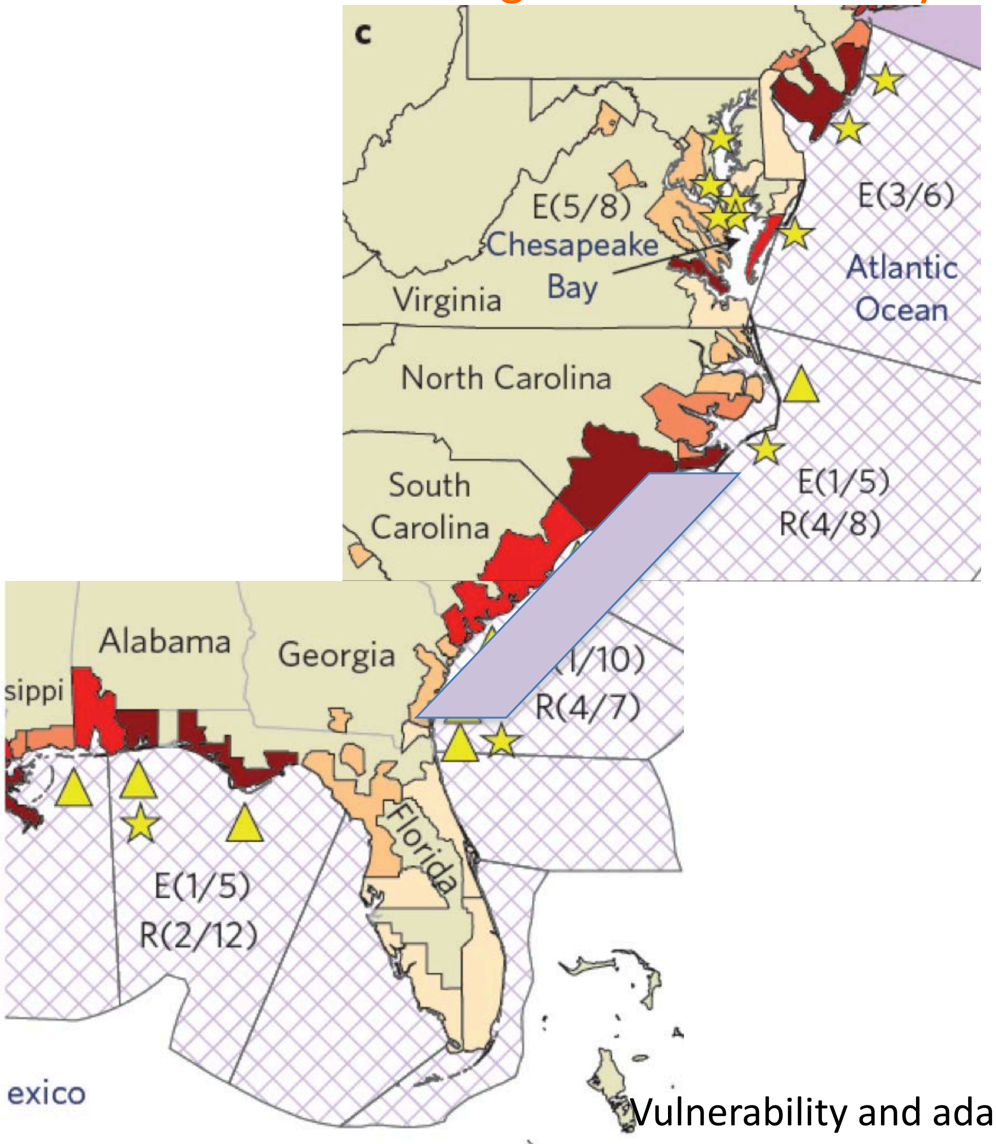
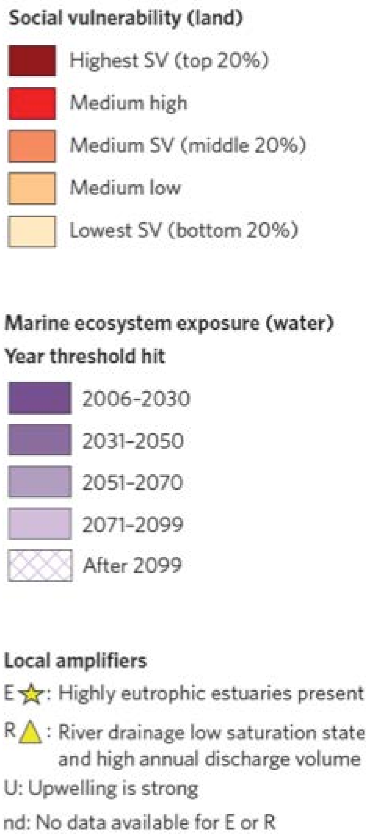
Impact on social vulnerability

Greater OA effect-greater vulnerability





Vulnerability and adaptation of US shellfisheries to ocean acidification

Julia A. Ekstrom et al. Nature Climate change (2015)

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Summary

- Ocean Acidification is real and here to stay
- Trends in Ocean Acidification can be determined on 5-10 year timescales
- The challenge [in the SAB] is to separate OA from other effects
- For the SAB, the farfield influences and feed backs on saturation state need to be considered
- Changing ocean currents have a first order effect on saturation state

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Closing Remark

From:http://www.thebestofrawfood.com/ph-scale.html

"Step 7 - Get Healthy - Get Alkaline!

Eat more seaweed and super foods"

[this is not a NOAA endorsement]

Thank you for your attention !

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