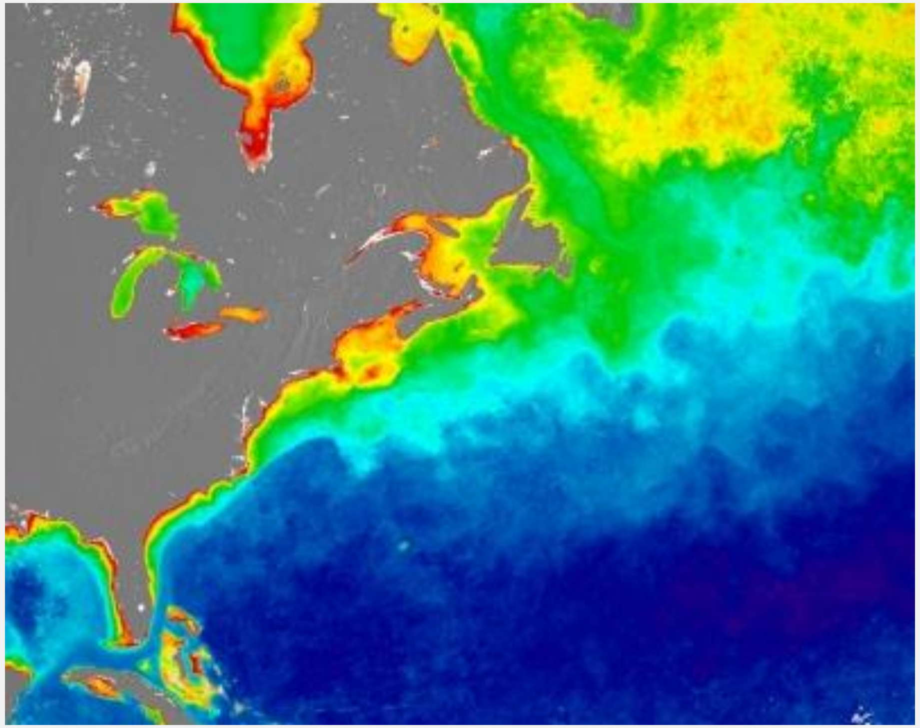
An overview of oceanographic drivers of change along the U.S. east coast



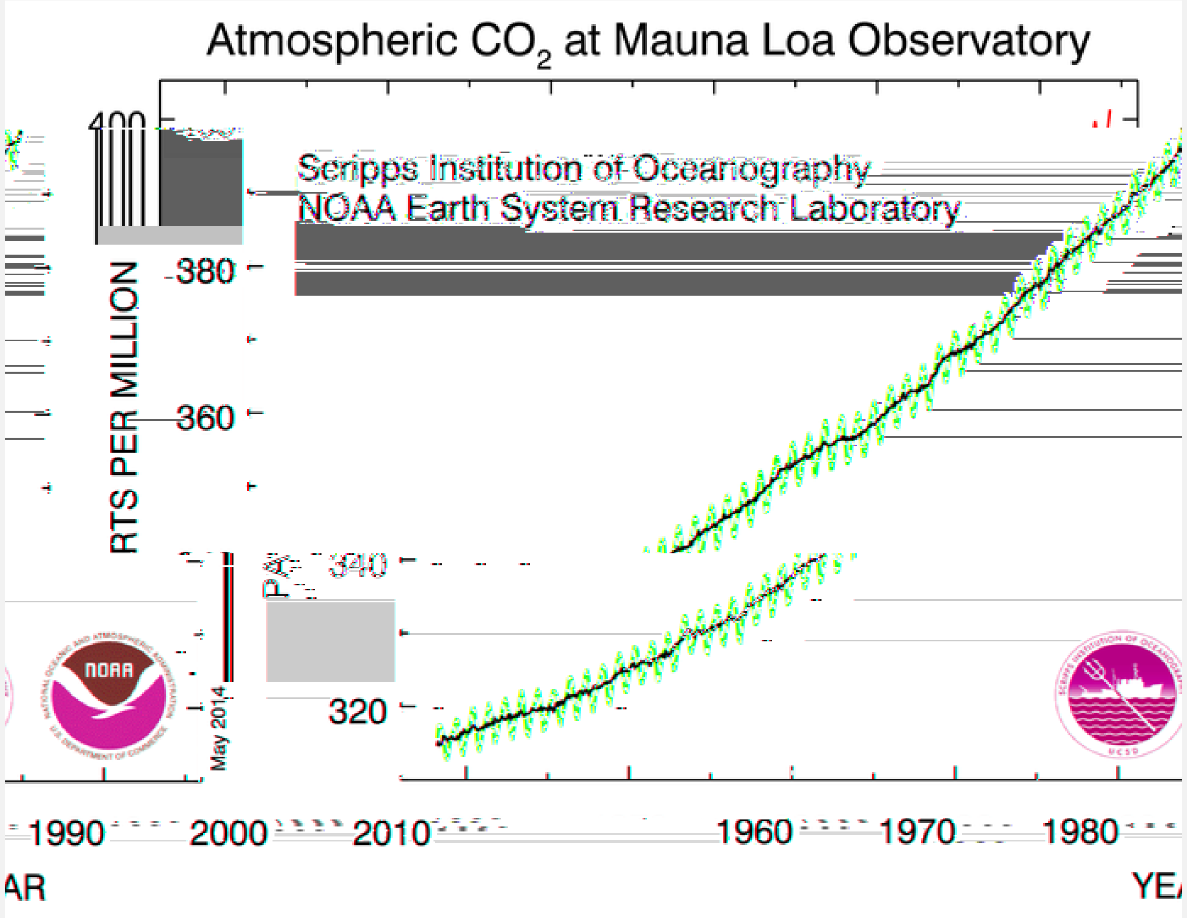
East Coast Climate Change Scenario Planning Exploration Webinar

Presented by Charles Stock (NOAA/GFDL)

(drawing on the work of many others)

February 14, 2022

Greenhouse gases and climate change

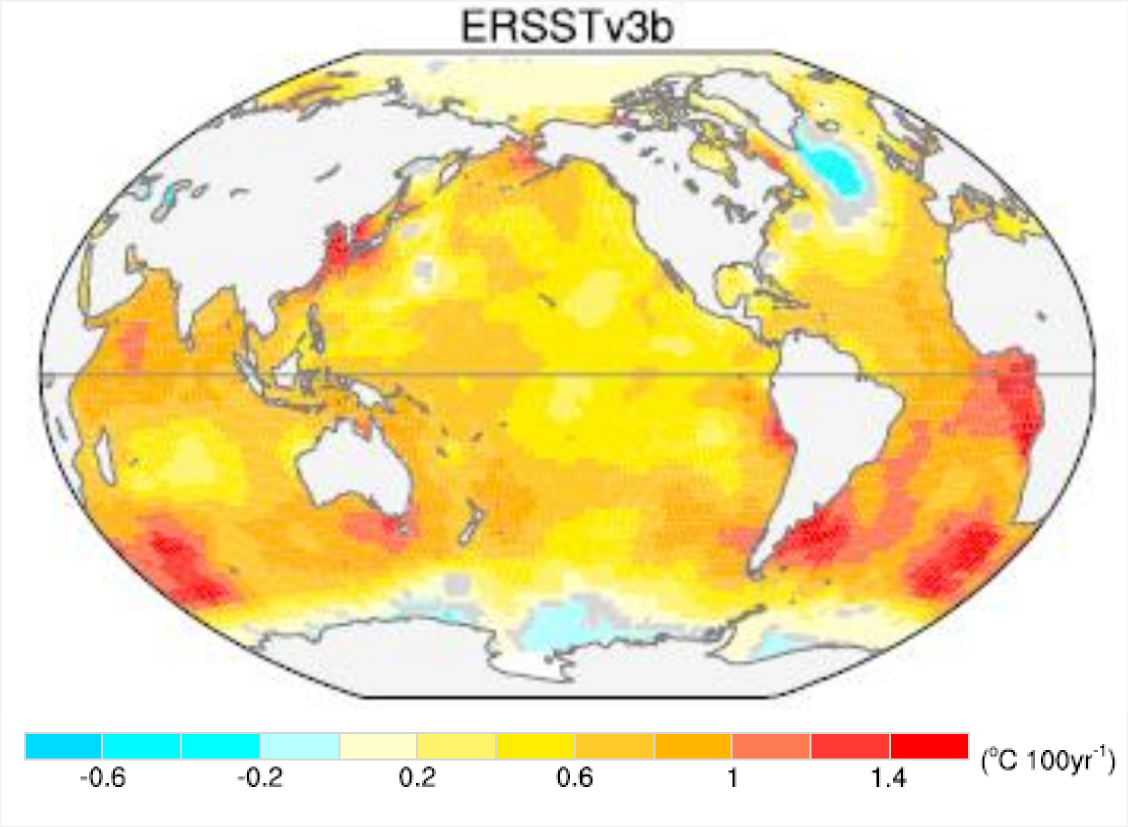


- Sun warms the earth, the earth radiates heat back.
- Greenhouse Gases (GHGs) absorb energy radiating from the earth and return some back to the earth's surface.
- This "blanket" is critical to making earth habitable.
- The "heavier blanket" resulting from increasing CO_2 and other greenhouse gases warms the earth surface and drives other changes in earth's climate.

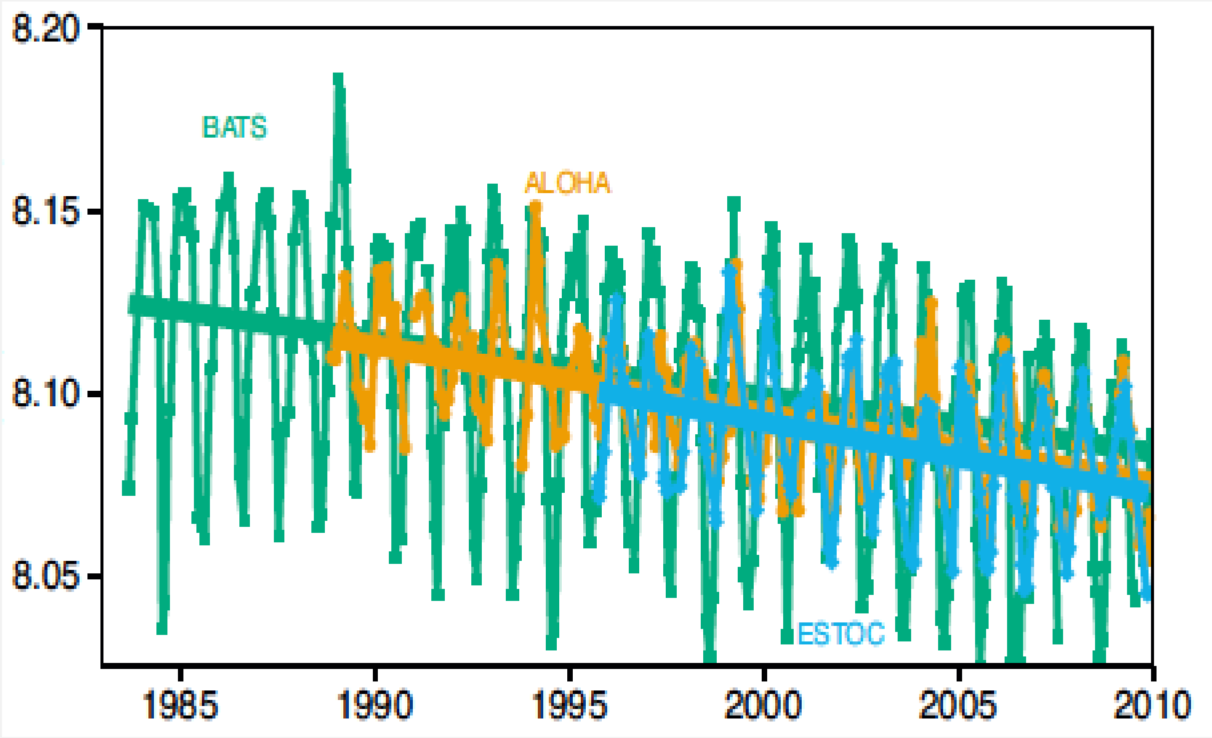
Global warming would be far worse were it not for the ocean

- The ocean has absorbed about 30% of emitted CO_2 and over 90% of excess heat
- This service, however, has come with a price: warming and acidification

Warming rate for past century (through 2010!)

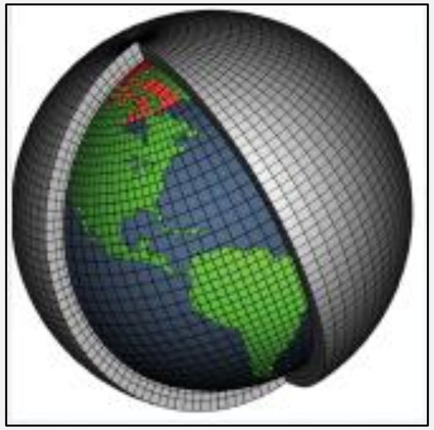


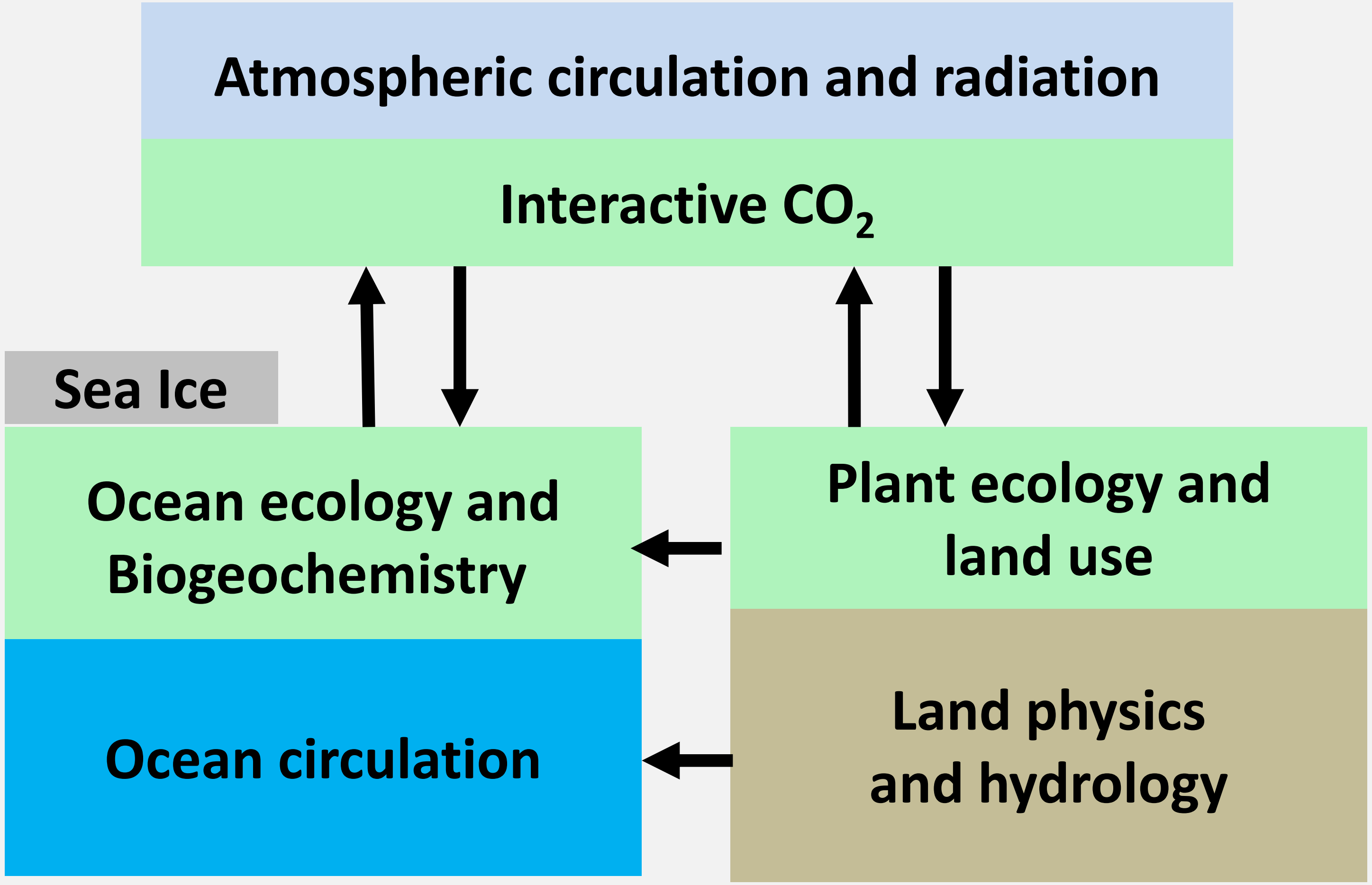
Declining pH at long-term observation sites



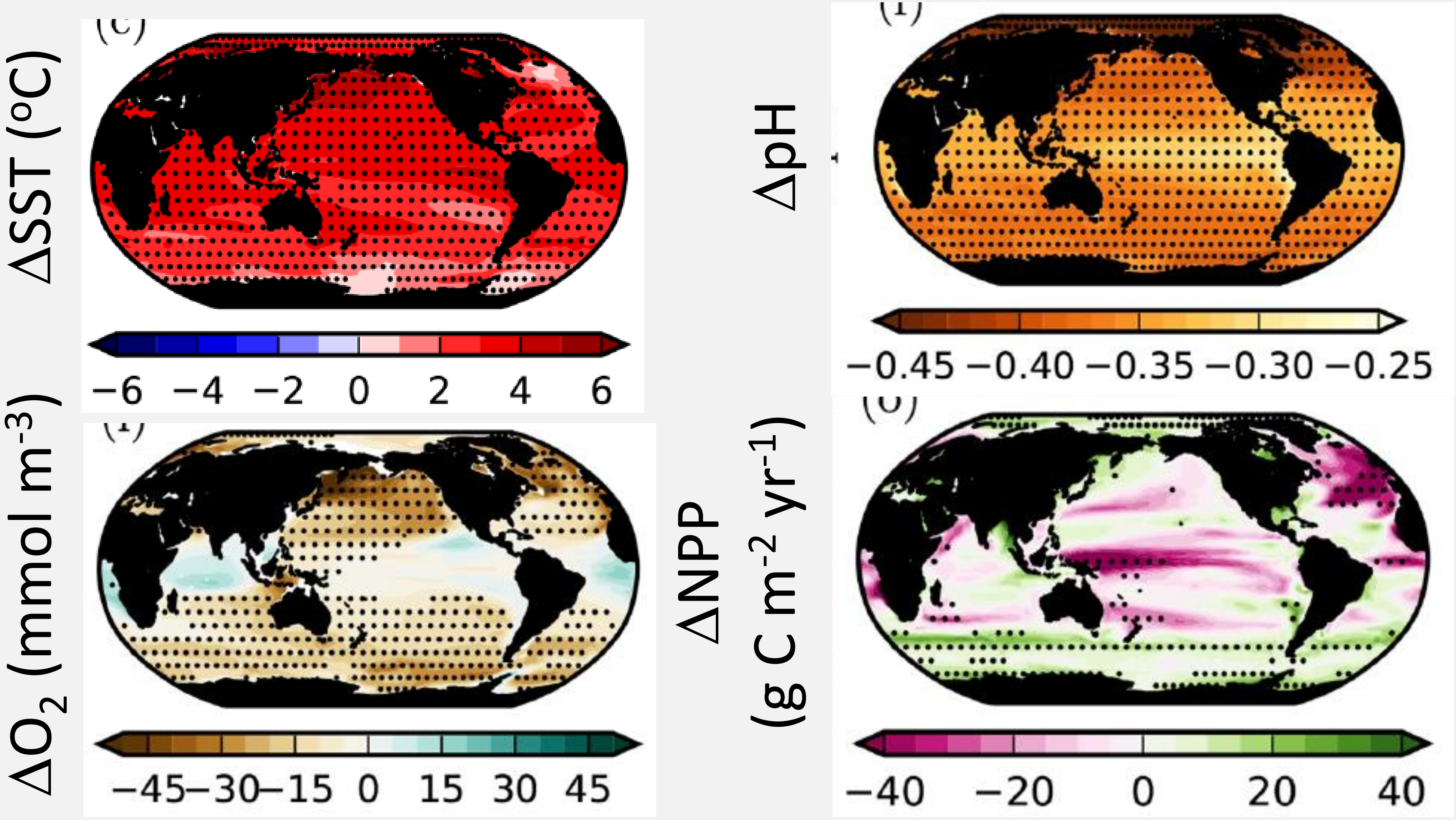
Source: Deser et al., 2010, GRL; IPCC 5th Assessment Report

What is a global earth system model?





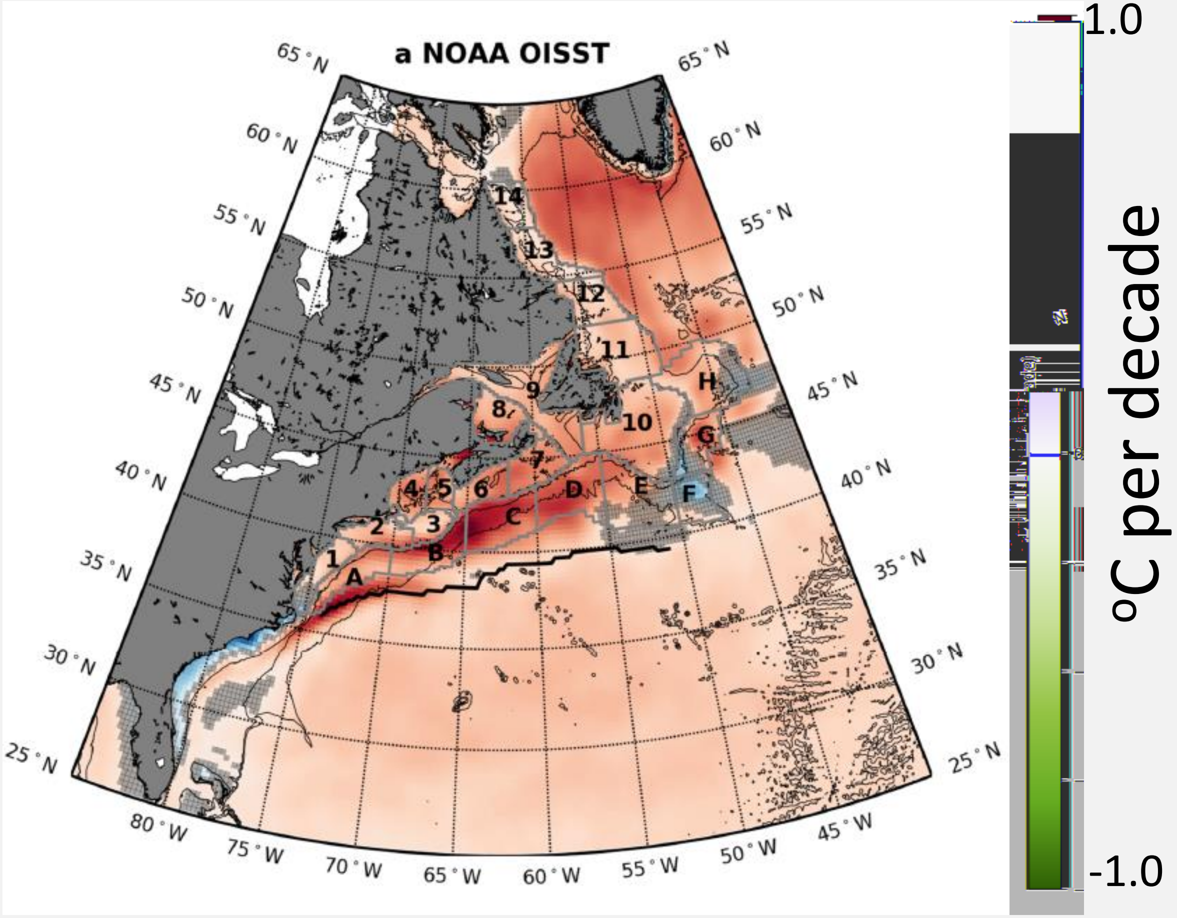
Warming and acidification is projected to continue, and be accompanied by other physical and biogeochemical changes



Oceans are "warming up, turning sour and losing breath" by the end of the century under high CO_2 emissions

(Gruber, Royal Society A; 2011; Kwiatkowski et al., Biogeosciences, 2020)

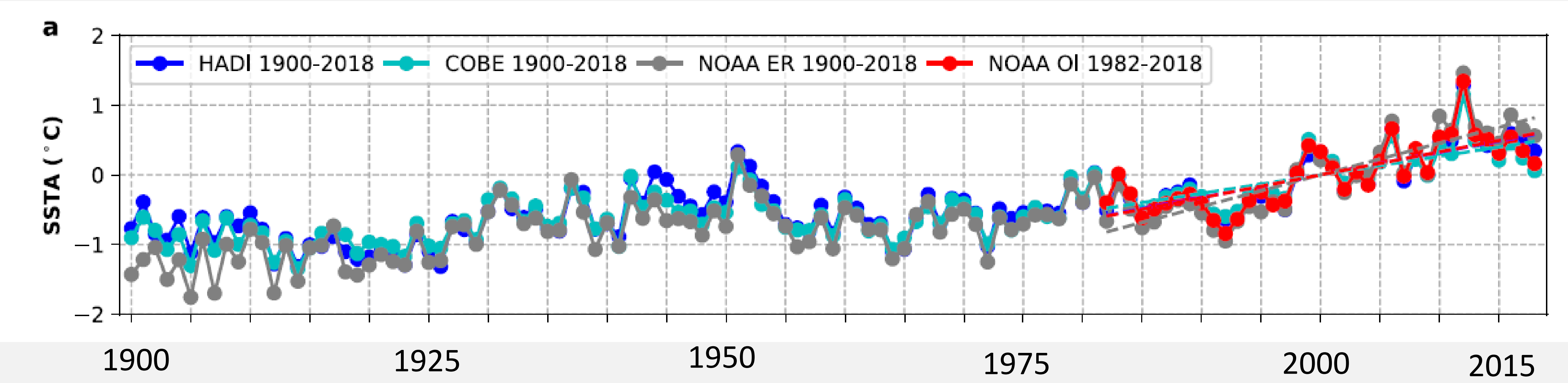
Much, but not all, of the east coast has been warming rapidly



Chen et al., (2020). Long-term SST variability on the northwest Atlantic continental shelf and slope. *GRL*, *47*, e2019GL085455. https://doi.org/10.1029/2019GL085455

Source: NOAA Northeast Integrated Ecosystem Assessment

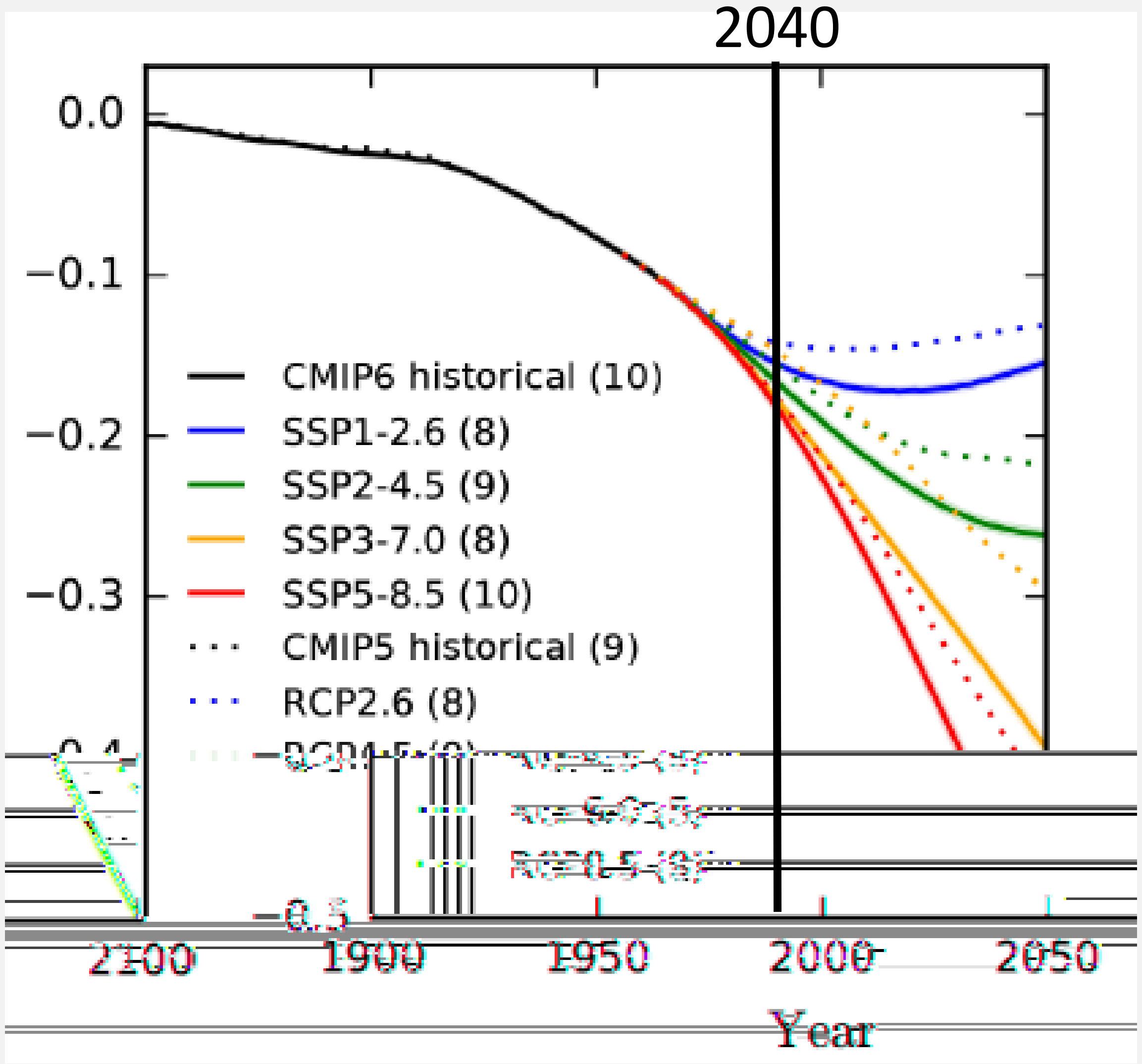
Temperature changes reflect a combination of climate change and climate variability

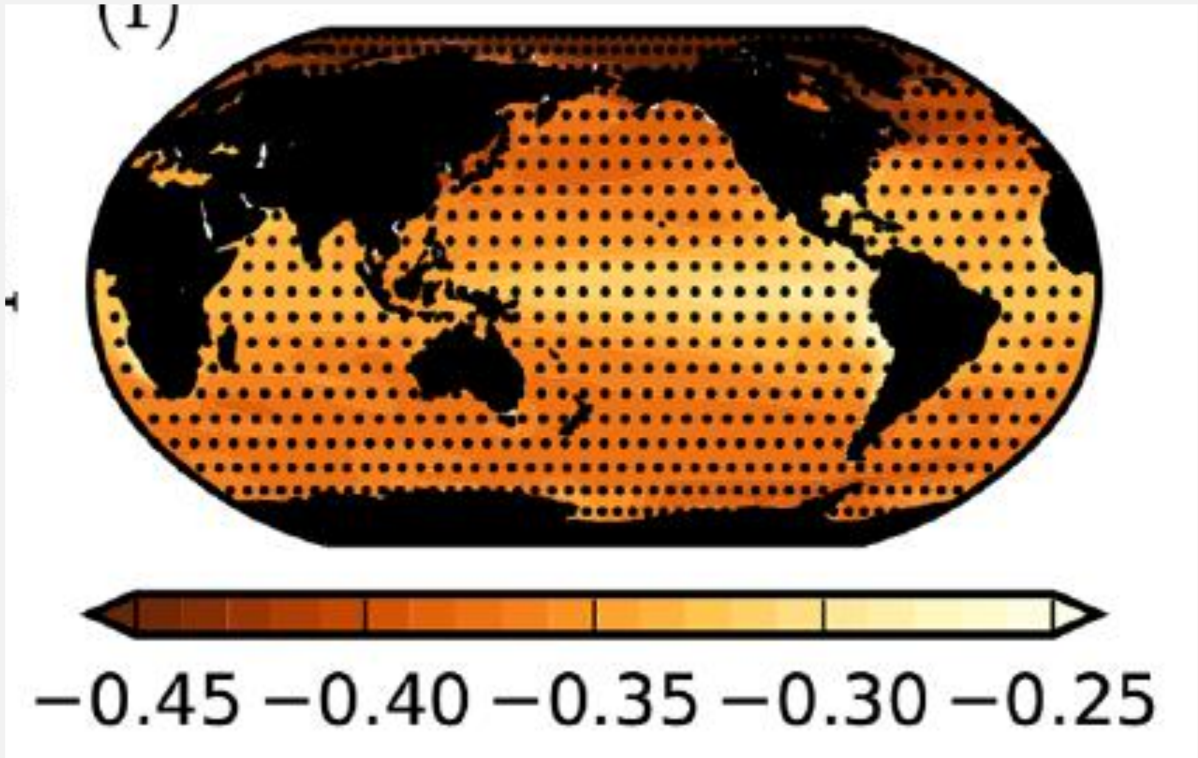


Chen et al., (2020). Long-term SST variability on the northwest Atlantic continental shelf and slope. *GRL*, *47*, e2019GL085455. https://doi.org/10.1029/2019GL085455

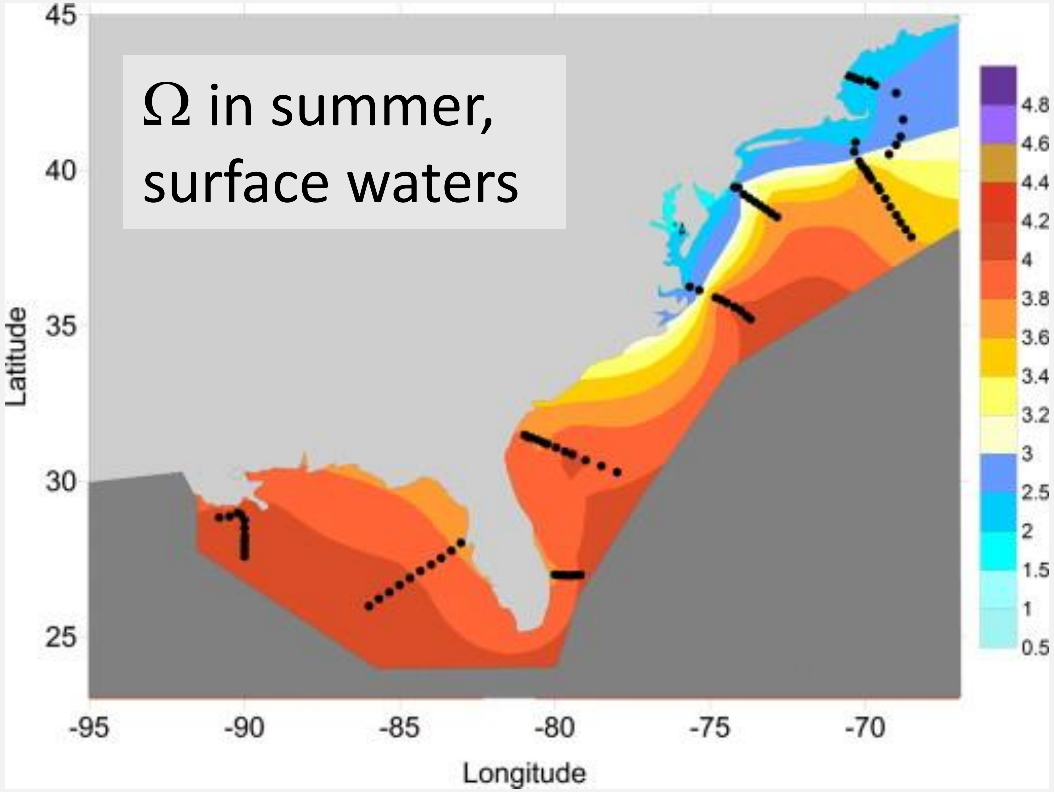
- Will the Atlantic Multidecadal Oscillation (AMO) and other modes of natural climate variability swing toward a "cooler" state, counteracting GHG warming and temporarily stalling warming trend?
- Will AMO and other variability modes remain "warm", allowing GHGs to continue warming, though likely at a reduced rate relative to when variability was shifting from "cold" to "warm".
- Will climate change-induced circulation changes continue to favor increasingly prominent Gulf Stream impacts on Northwest Atlantic slope and shelf water, maintaining rapid warming in the Northwest Atlantic?

Ubiquitous acidification (ΔpH) in upper ocean determined by CO_2 emissions





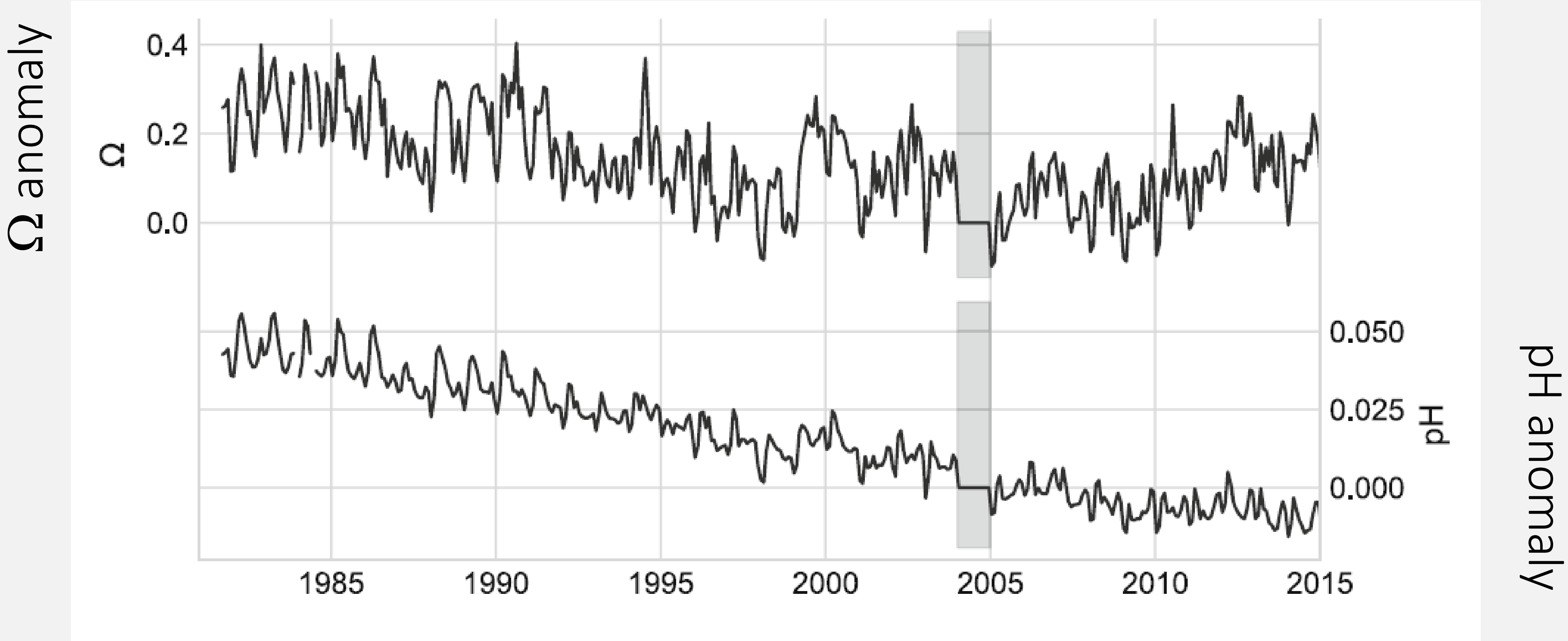
But impact on shell formers more connected to water saturation with respect to calcium carbonate



Wanninkhof et al., (2015). Ocean acidification along the Gulf Coast and East Coast of the USA. Continental Shelf Research. 98, 54-71.

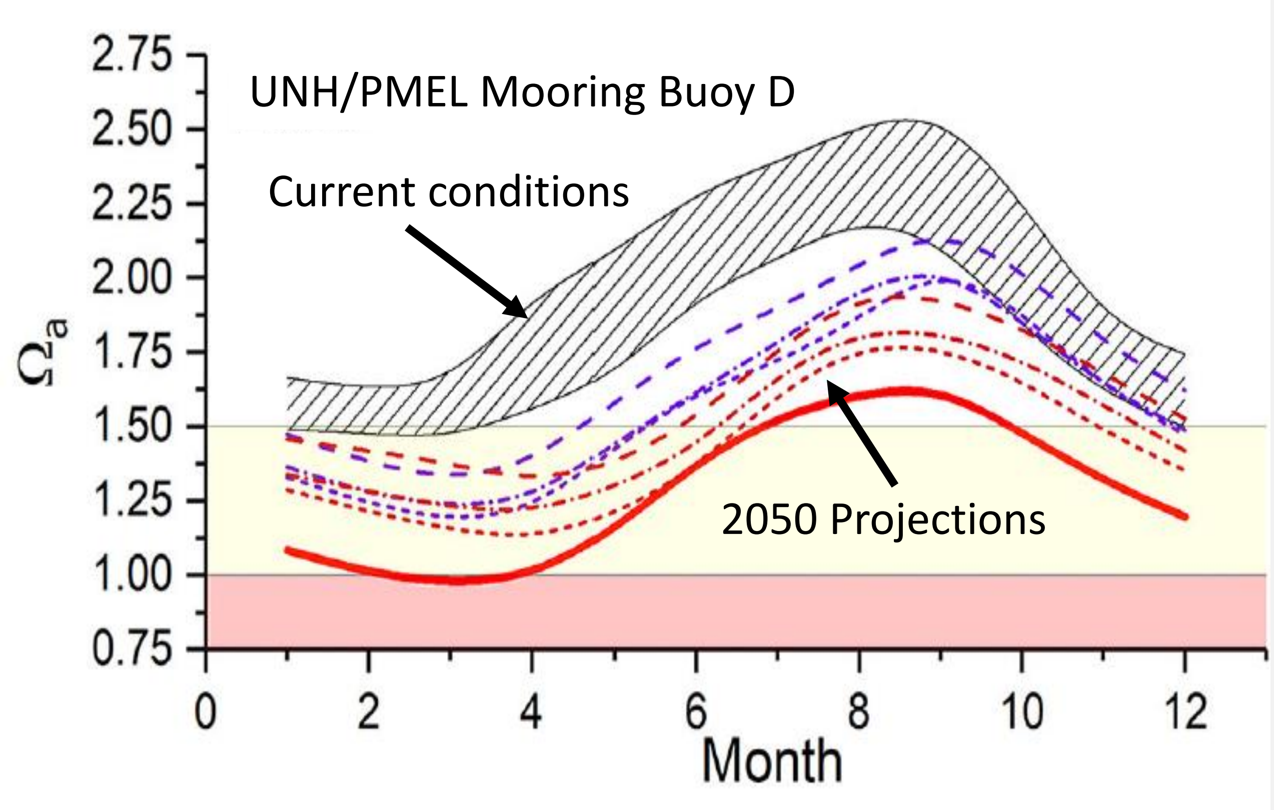
- Low Ω = under-saturated water = hard to form shells
- Ω is lower in the MAB and NEUS then in the SAB and Gulf of Mexico
- Thresholds for the biological impacts vary, but negative impacts tend to pick up around Ω_{arag}=1.5.
- Acidification tends to decrease Ω, but Ω is also affected by circulation and warming.
- Coastal processes that are not well resolved by global models can also generate regional pH and Ω trends.

Estimates suggest recent warm, salty conditions in the Gulf of Maine have stabilized Ω_{arag} despite pH declines



Salisbury and Jönsson, (2018) Rapid warming and salinity changes in the Gulf of Maine alter surface carbonate parameters and hide ocean acidification. Biogeochemistry, 141. pp. 401-418

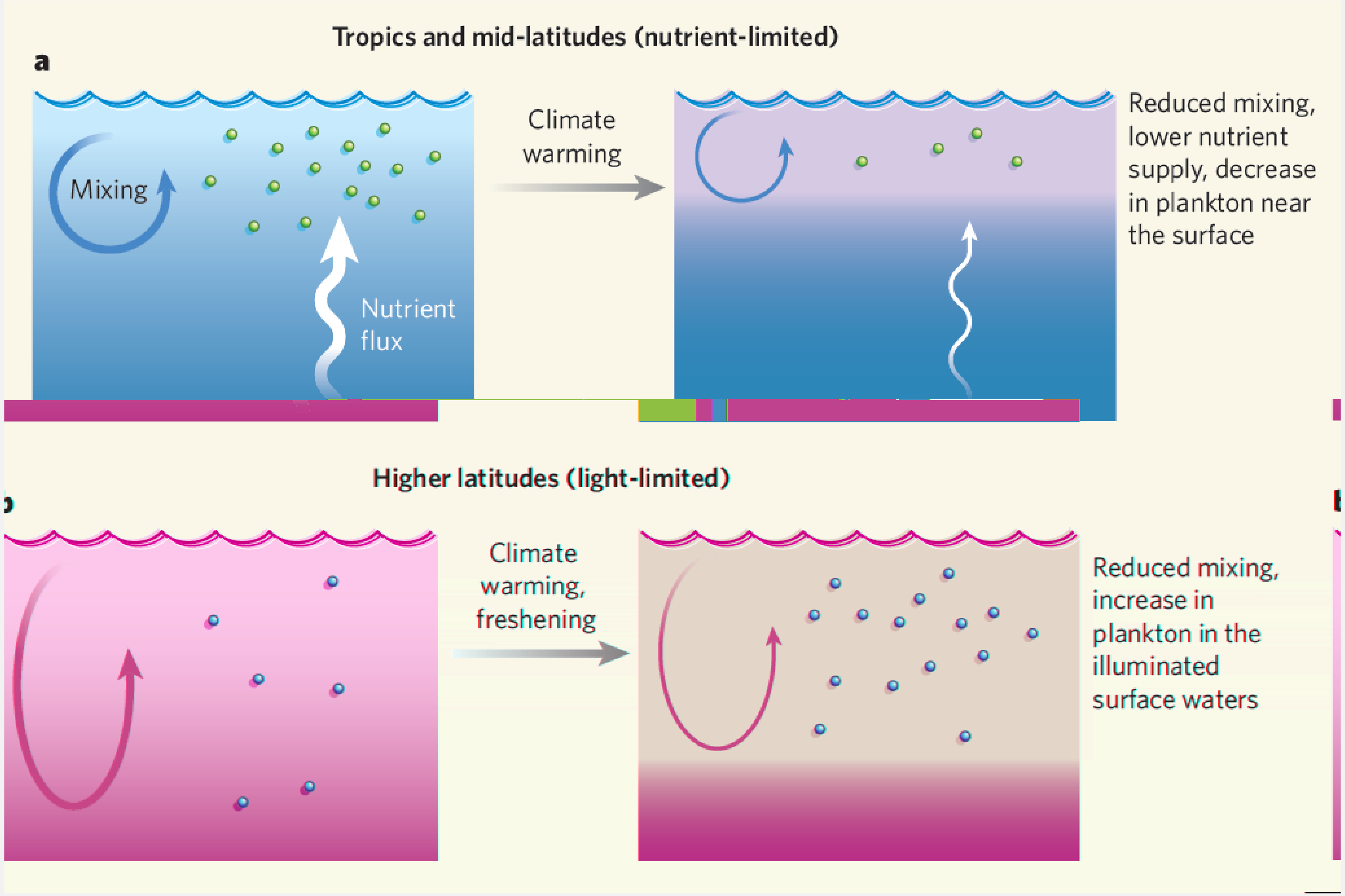
Projections suggest marked increase in Ω_{arag} < 1.5 conditions in the Gulf of Maine by 2050



- 6 projections from to 2050 (dashed lines) all suggest more time under Ω_{arag} < 1.5.
- Differences in severity reflect different circulation and warming-driven effects that moderate the impact of CO_2 uptake (thick red line).
- Scenarios could consider a similar range of impacts, but acidity and temperature scenarios must be self-consistent

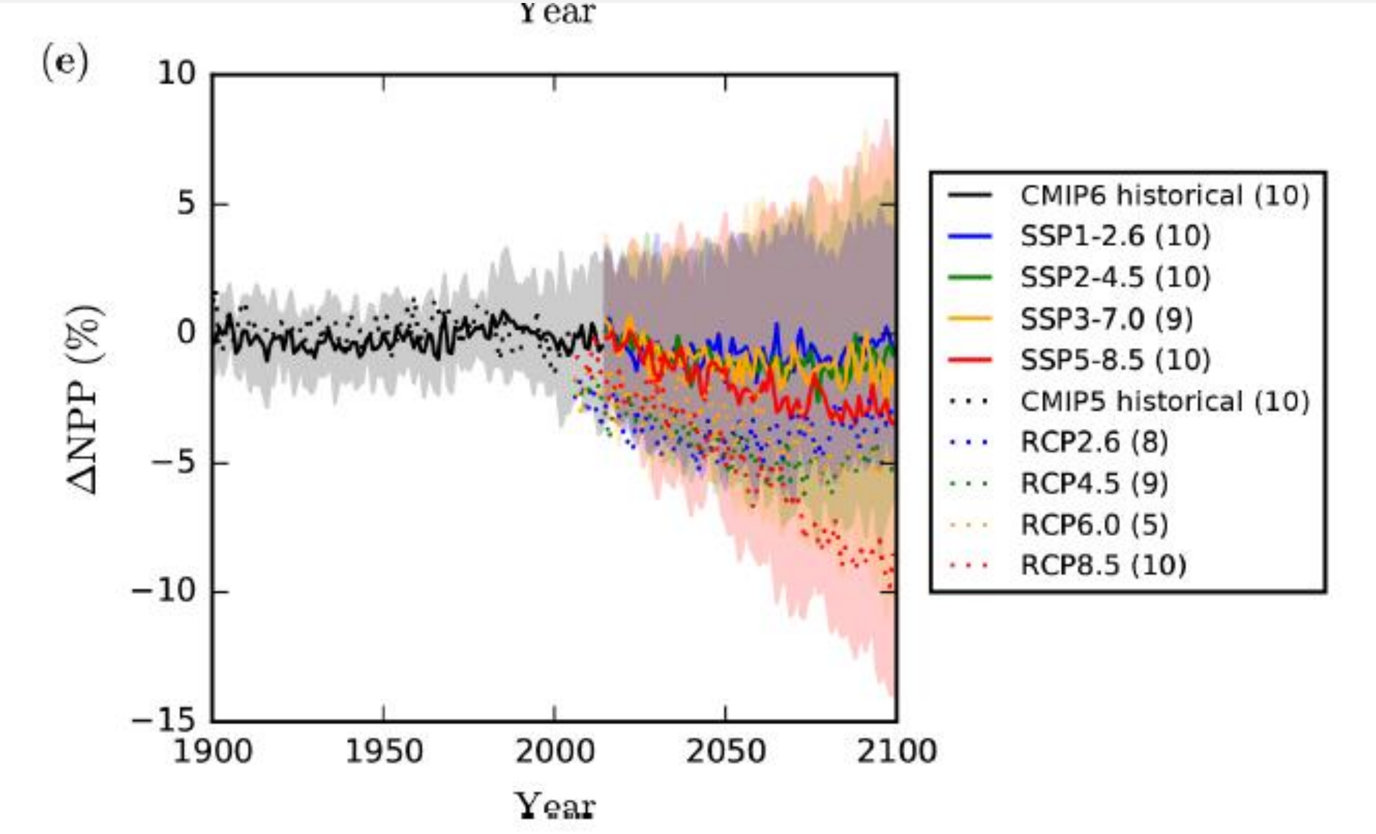
Siedlecki et al., 2021. Projecting ocean acidification impacts for the Gulf of Maine to 2050. *Elementa: Science of the Anthropocene* 9 (1): 00062. https://doi.org/10.1525/elementa.2020.00062.

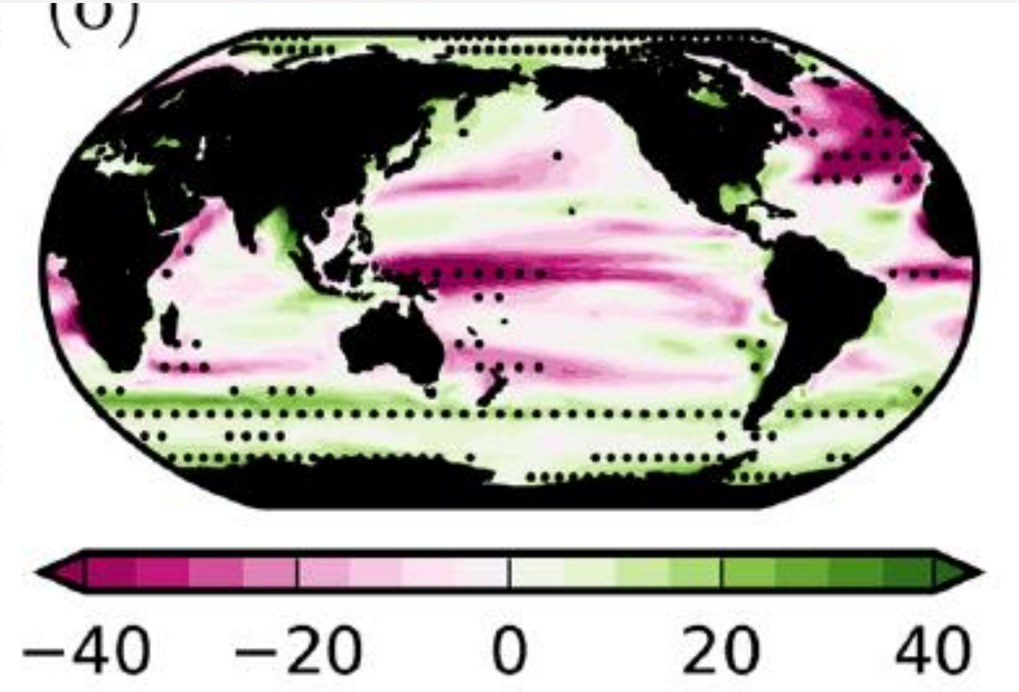
The impact of climate change on net primary production (NPP) is hypothesized to vary with latitude



Doney, S.C., 2006. Plankton in a Warmer World. Nature. 444. 695-696.

Current global NPP projections show limited agreement on global or regional scales



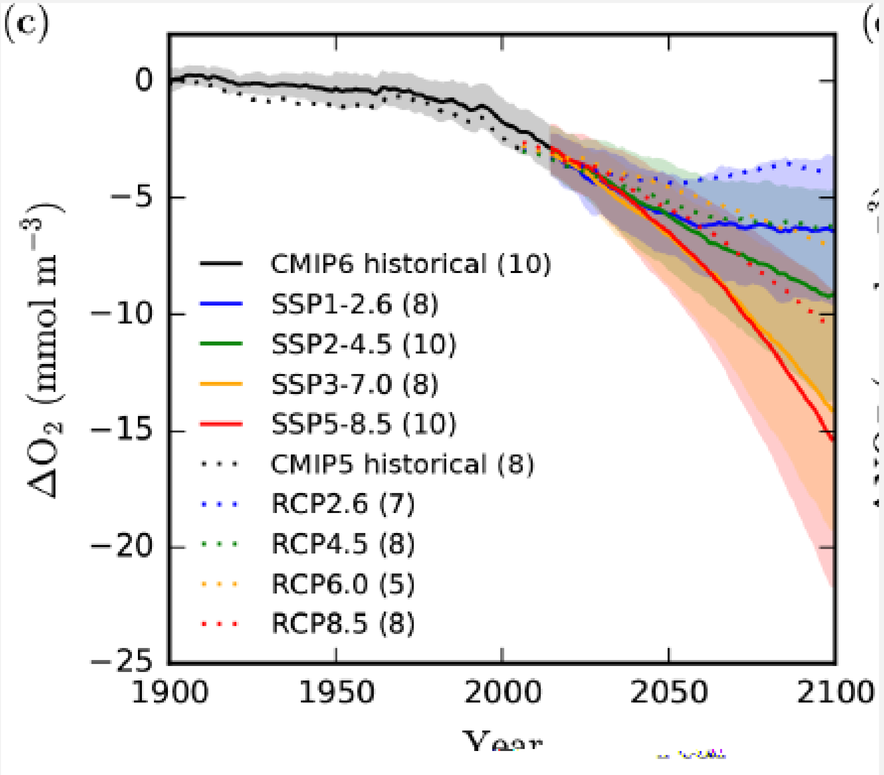


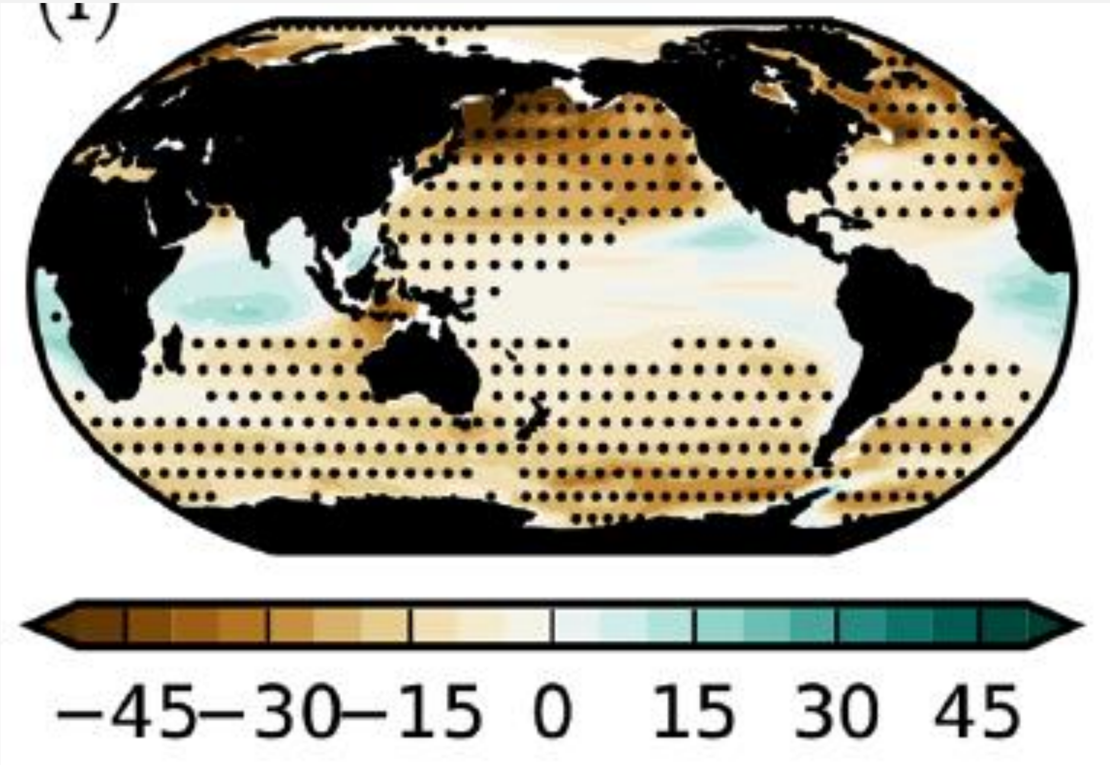
There are consistent features in ocean productivity projections that could help inform change scenarios

- Projected regional NPP trends can be substantial, with 10-20% changes over the century not uncommon.
- Earlier spring blooms and suppression of large phytoplankton are robust outcome of enhanced stratification.
- Projected phytoplankton trends are nearly always amplified at higher trophic levels (e.g., a 10% NPP decrease may yield a 20% decrease in zooplankton production and a 30% change in fish production).

Considering potential shifts in primary production is advisable, but they are uncertain. One could rely on estimates of NPP variation and trends from the satellites to bound scenarios. The relatively short time horizon (20 years) reduces risks associated with this approach.

Warming and enhanced stratification (decreased ocean ventilation) lead to widespread oxygen declines





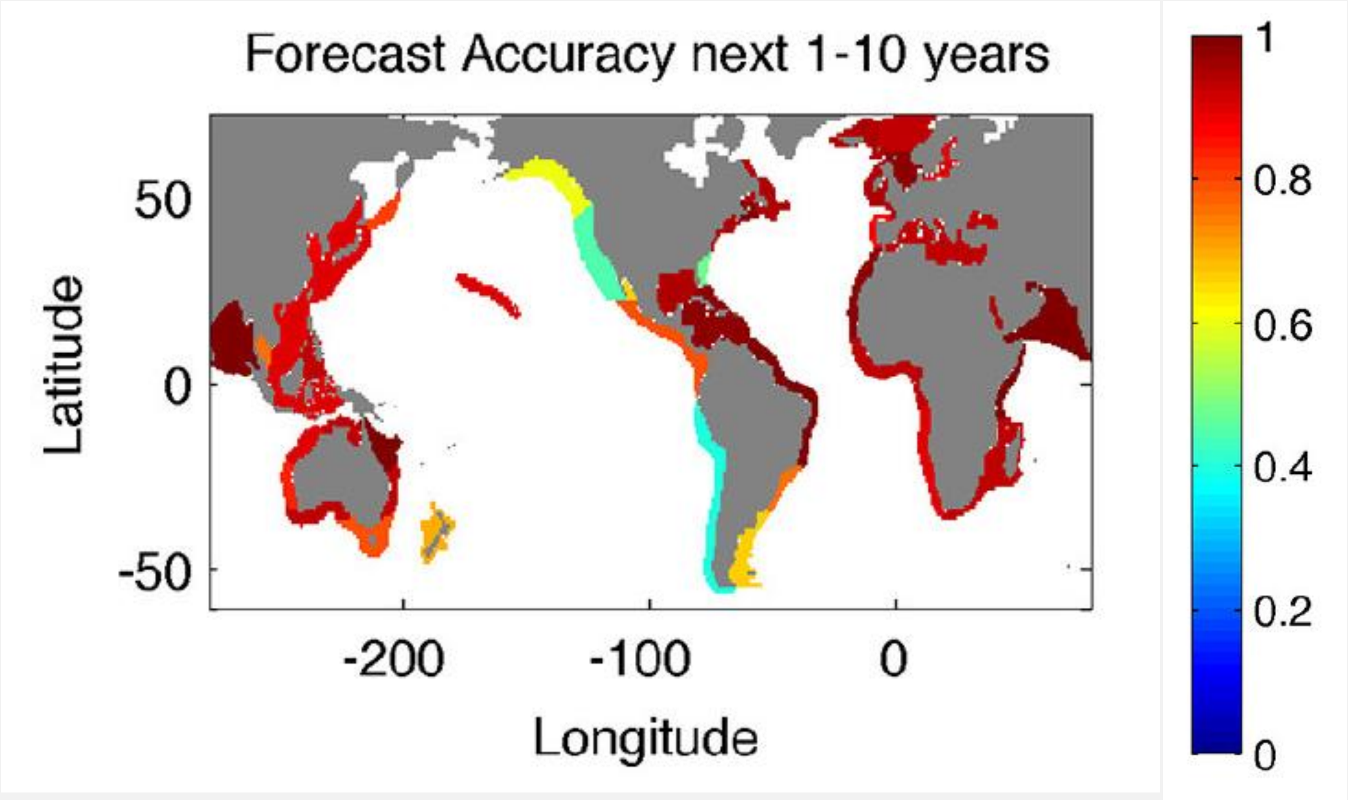
Declining O_2 trends due to similar mechanisms projected to extend to some estuaries (e.g., Chesapeake Bay; Irby et al., 2018; Ni et al., 2019), though local choices also impact trends!

Closing thoughts on scenarios for physical drivers of stock availability and distribution over the next 20 years

- Will rapid warming continue? Will it continue at a reduced rate? Or will climate variability temporarily halt warming?
- Will circulation, warming and other coastal processes moderate acidification signals associated with atmospheric CO_2 increases?
- Based on the historical observations, what changes in primary productivity and bloom characteristics may be associated with each scenario? Consider phytoplankton size!
- Known solubility and water mass characteristics provide a means to estimate oxygen effects associated with each physical scenario
- Relationships between ocean drivers will help limit the number of scenarios that must be considered

Wild Cards: Harmful Algal Blooms, regime shift resulting in loss of critical food resource

Would a capacity to anticipate ocean driver scenarios yield better conservation and economic outcomes?

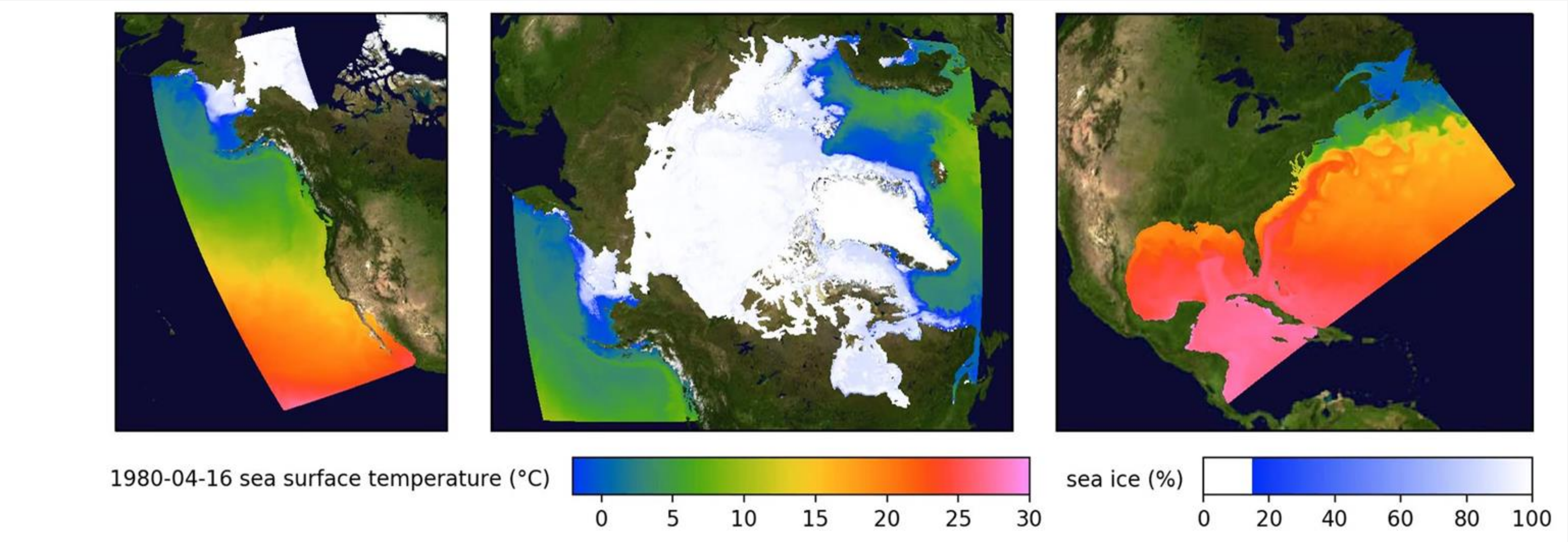


Will the next 10 years be within the warm tercile of the last 50?

$$Accuracy = \frac{Hits + Correct\ Negatives}{Total\ Forecasts}$$

Tommasi et al., (2017), Multi-annual climate prediction for Fisheries. Frontiers in Marine Science.
https://doi.org/10.3389/fmars.2017.00201

Toward high-resolution ocean driver predictions spanning the range of ocean futures across management time scales



Visualizations by Andrew Ross