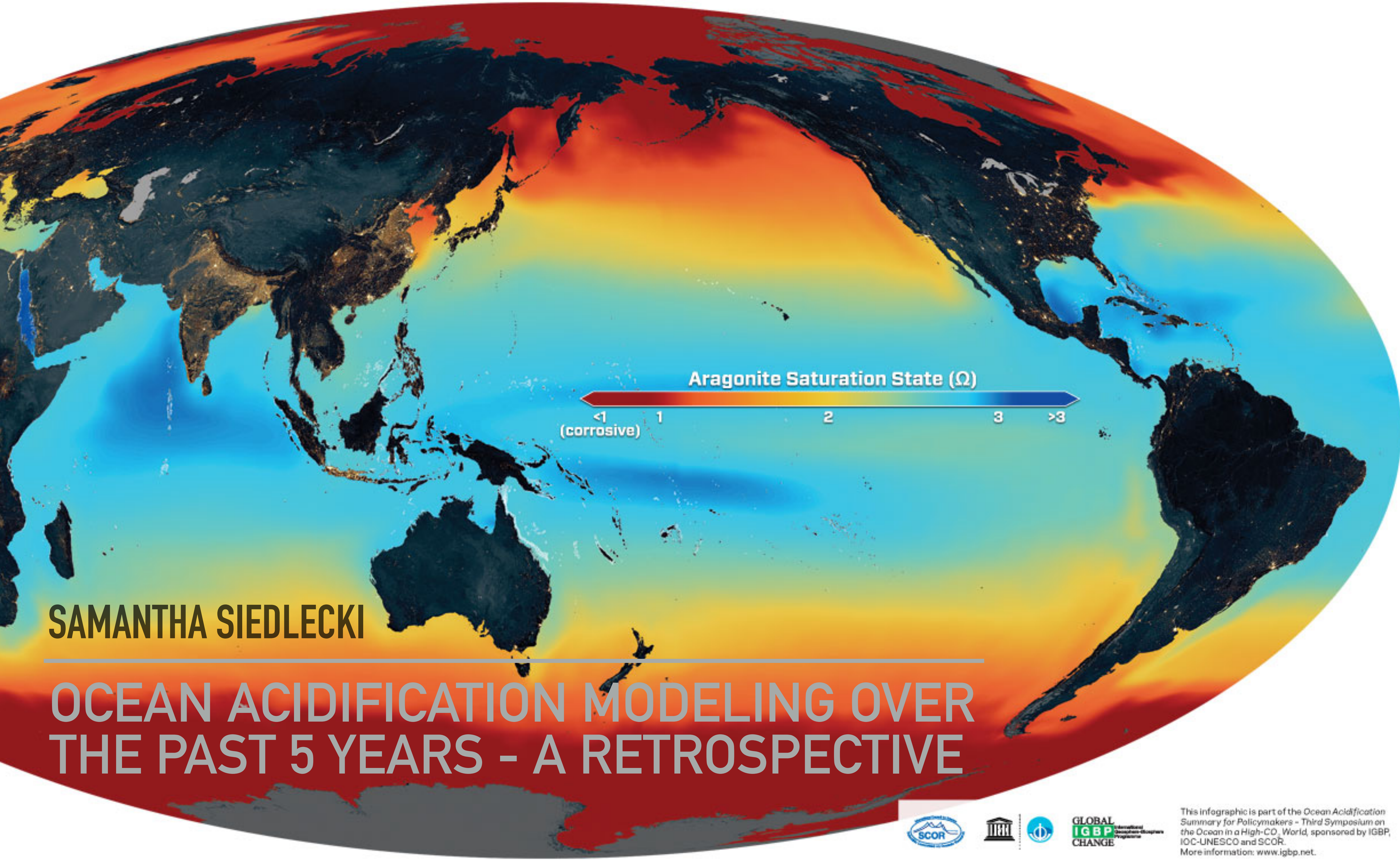


SAMANTHA SIEDLECKI

OCEAN ACIDIFICATION MODELING OVER THE PAST 5 YEARS - A RETROSPECTIVE

MODELS OF OCEAN ACIDIFICATION –WHAT HAVE MODELS BEEN UP TO?

- Forecasts and projections - (e.g. early warning systems, habitat changes, climate projections etc)
- Attribution experiments -
    - Time of emergence
    - Processes - e.g. role of local nutrients and runoff changes; freshwater; ENSO; subduction
    - Biological impacts

LONG-TERM CLIMATE SCALE

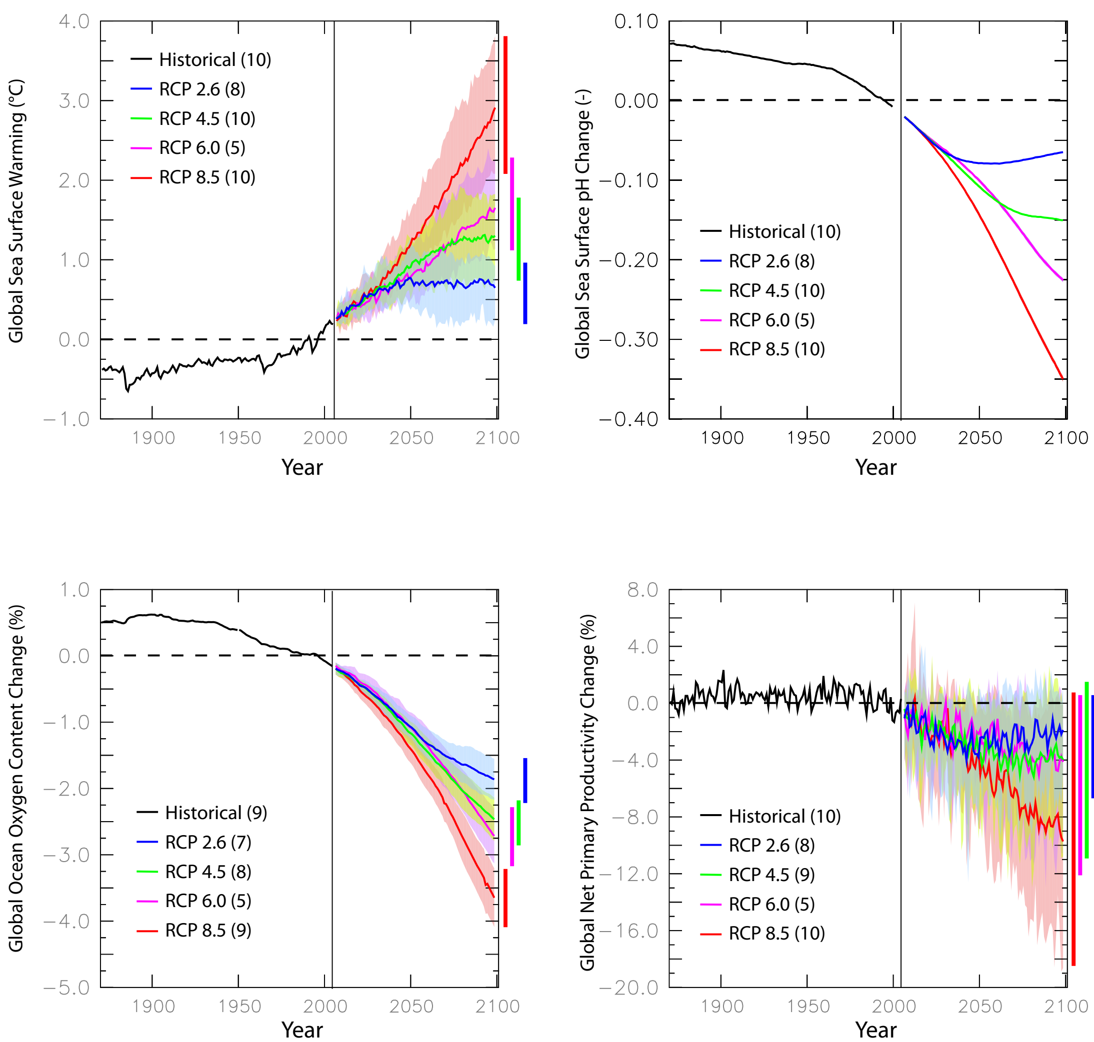
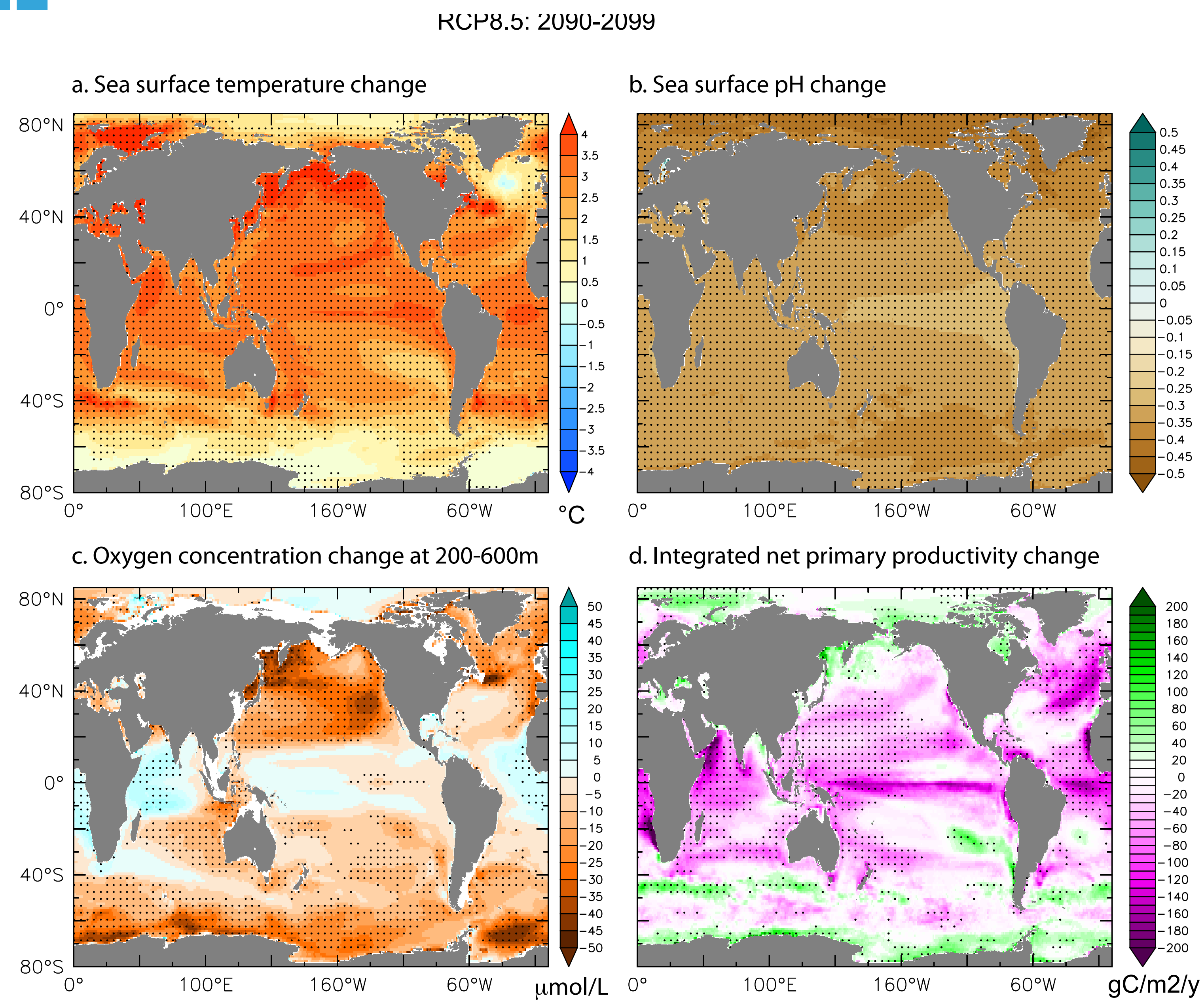


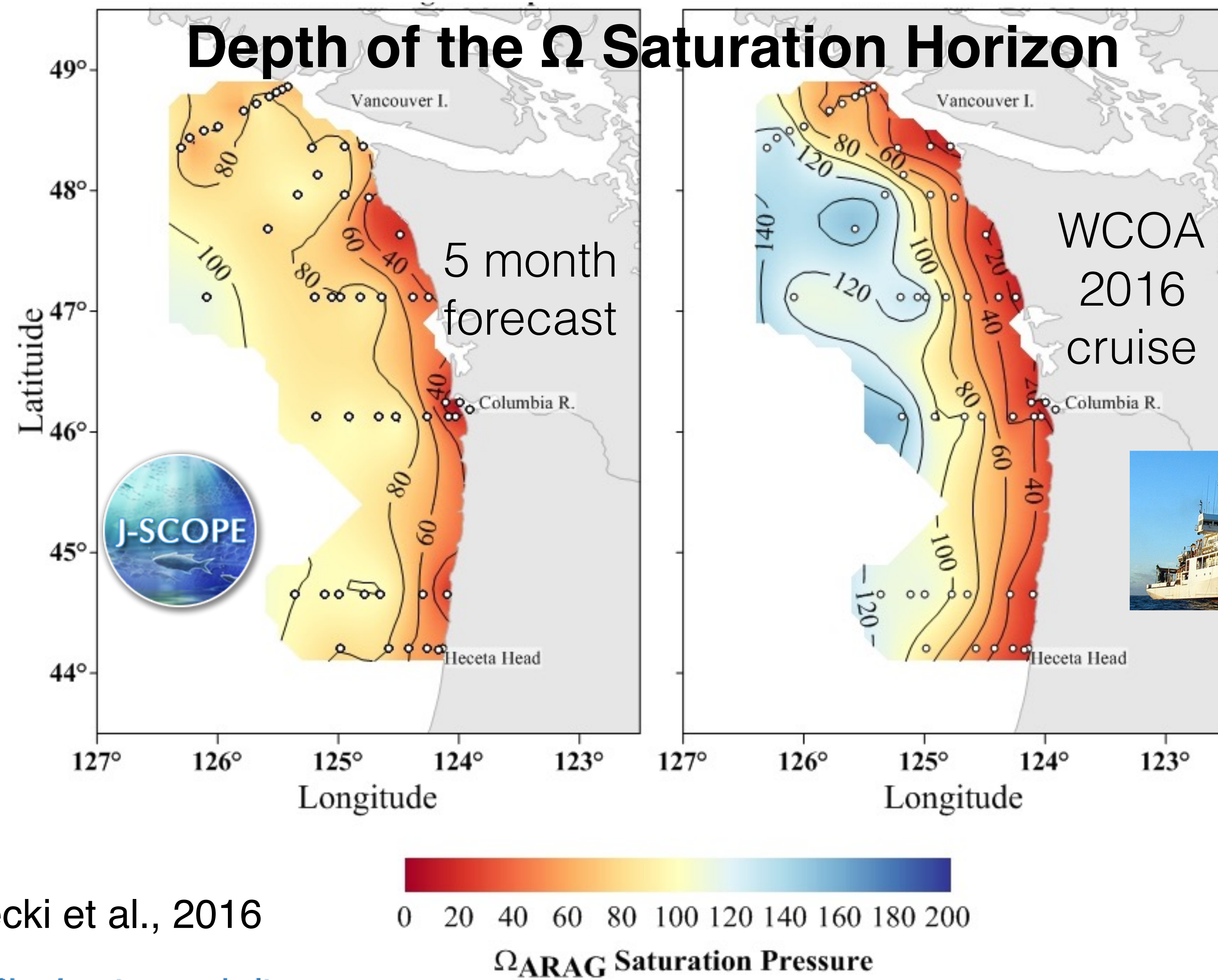
Fig. 3. Model-mean time series of global sea surface warming (°C), surface pH change (pH unit), ocean O_2 content change (%), and global NPP change (%) over 1870–2100 using historical simulations as well as all RCP simulations. Shading indicates one inter-model standard deviation. All variables are plotted relative to 1990–1999.



Bopp et al., 2013

Seasonal Forecasts - J-SCOPE

Depth of the Ω Saturation Horizon



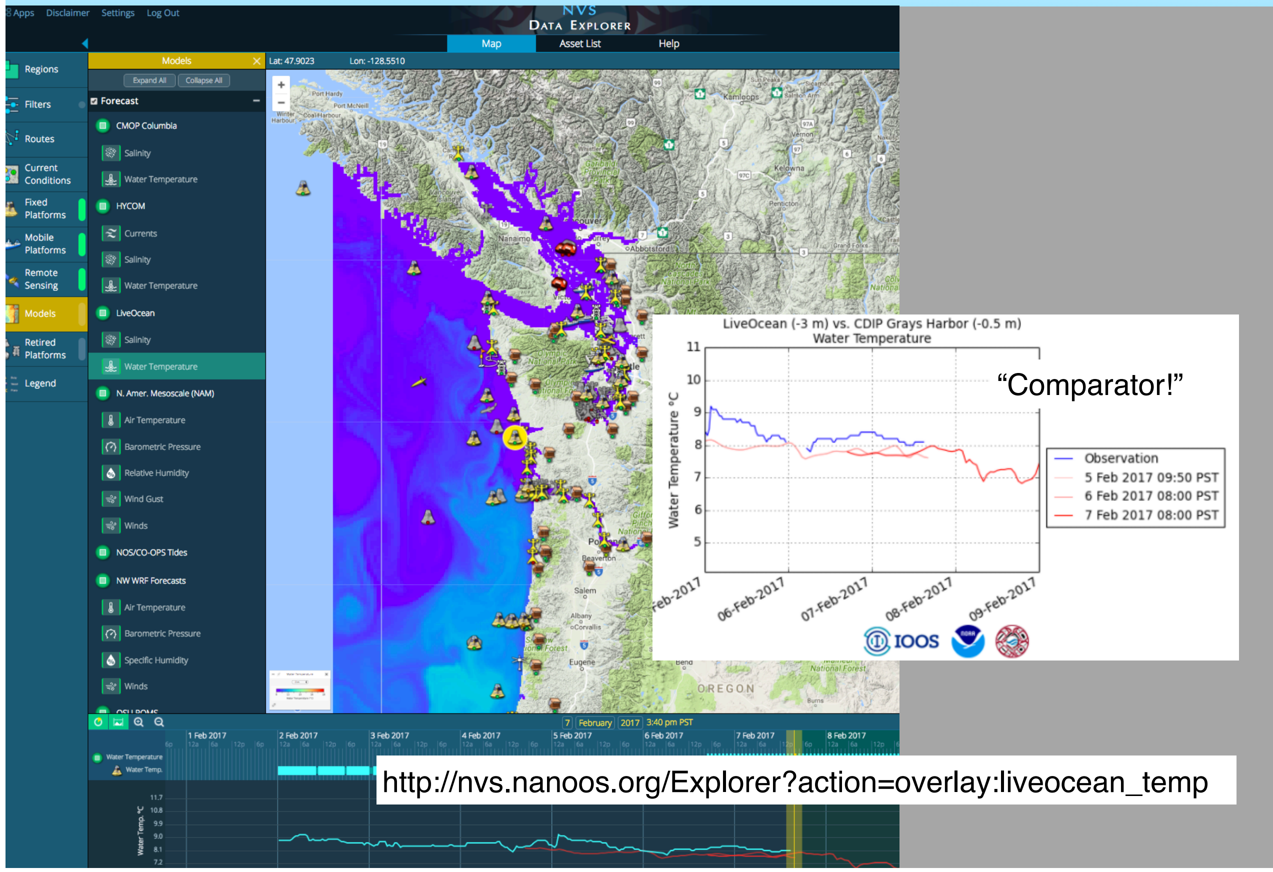
Siedlecki et al., 2016

Check out our website:
http://www.nanoos.org/products/j-scope/home.php

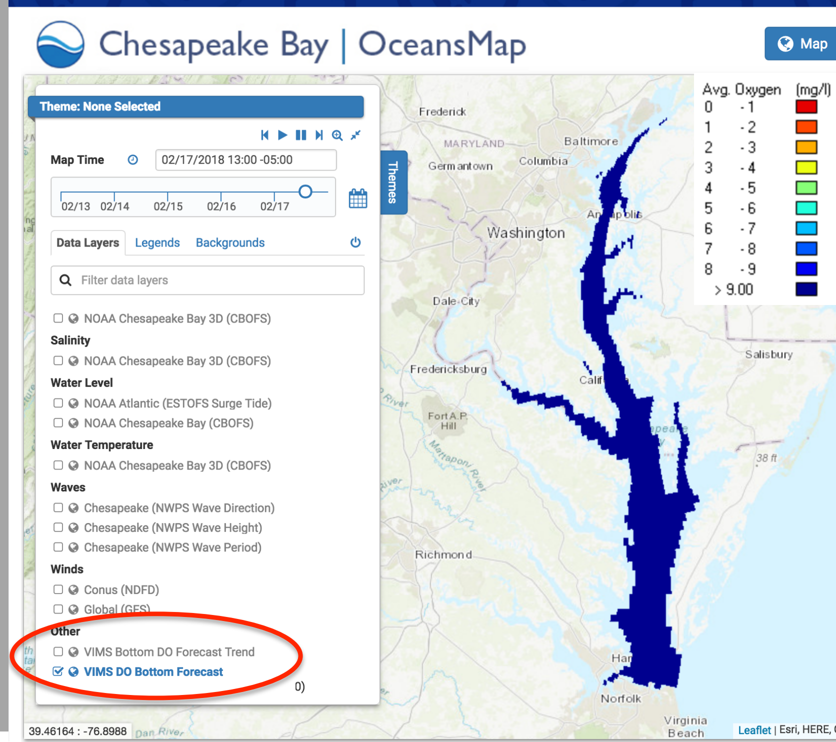
Data courtesy of NOAA-PMEL (Alin and Feely)

SHORT TERM FORECASTS (WEATHER)

LiveOcean on the NANOOS NVS



US IOOS/MARACOOS nowcast/forecasts

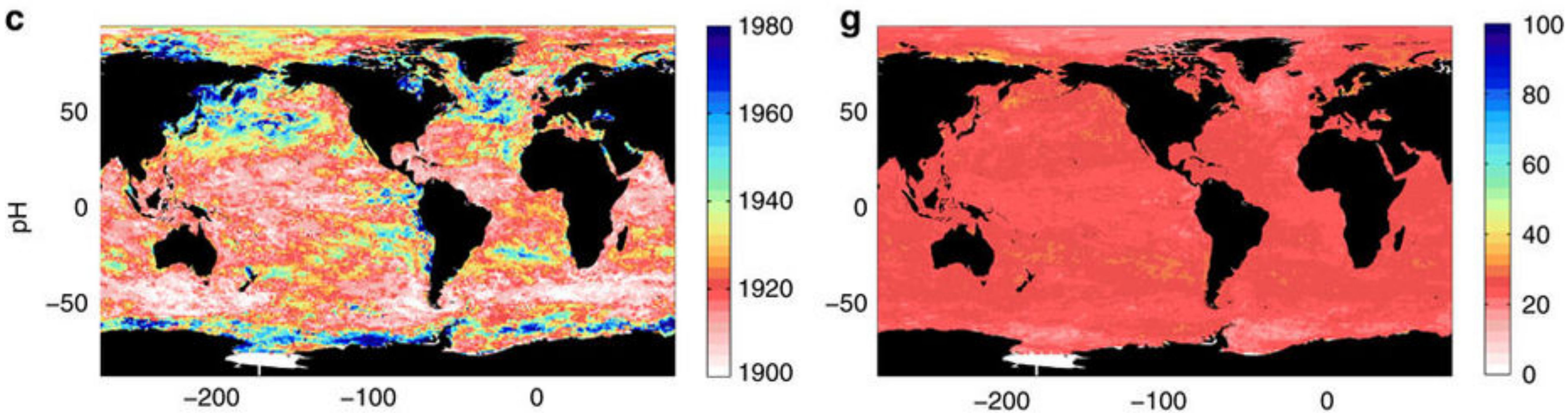


MARACOOS Developmental Operational Forecast:

- Mid-Atlantic Regional Assoc Coastal Coastal Ocean Observing System
- OceansMap platform
- Main site: http://oceansmap.maracoos.org.
- Developmental site: http://dev.oceansmap.com/ches-bay/
- VIMS SRM/ECB daily nowcasts/ forecasts posted since Jan. 2018

IOOS | EYES ON THE OCEAN™

TIME OF EMERGENCE



Multi-model median of the year when annual extrema exceed the climate change trend (see ‘Methods’ section) for (**a**) SST, (**b**) PP, (**c**) pH and (**d**) interior oxygen content in the ‘business-as-usual’ scenario (RCP8.5). Note the different colour scales for each variable. (**e**–**h**) The pace of climate change: the number of years between the start of climate change and the signal emerging (see ‘Methods’ section). White areas indicate where ecosystem stress does not emerge above the range of variability for that parameter by 2100.

HENSEN ET AL. (2017) [CARTER ET AL. (2016); MCKINLEY ET AL (2017)]

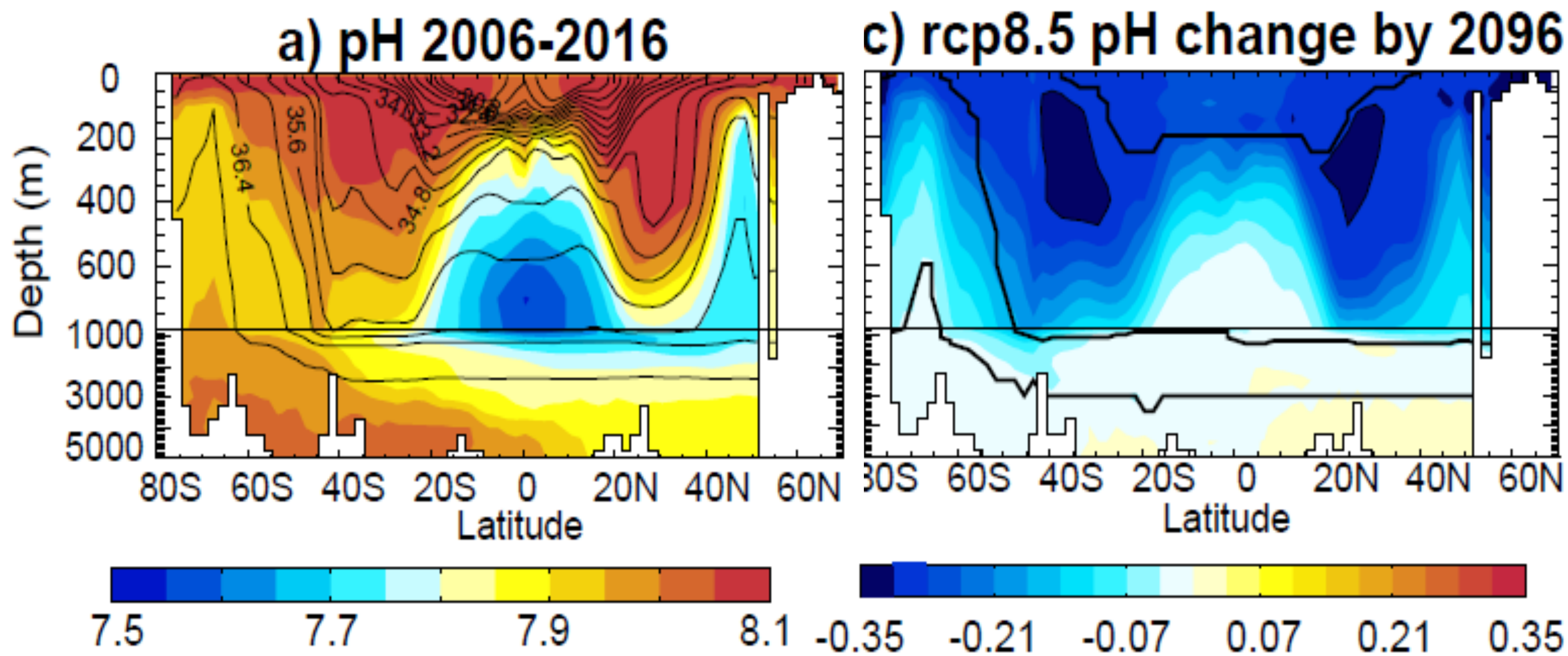
Talk about this at OSM this week…..

Emergence of Anthropogenic Signals in the Ocean (312401)
Sarah Schlunegger*1, Keith B Rodgers1, Jorge L Sarmiento2, John P Dunne3 and Thomas L Froelicher4, (1)Princeton University, Princeton, NJ, United States, (2)Princeton University, Atmosphere and Ocean Sciences, Princeton, NJ, United States, (3)Geophysical Fluid Dynamics Laboratory, Princeton, NJ, United States, (4)Universtity of Bern, Climate and Environmental Physics, Bern, Switzerland*

Mode Water – hot spots for physically amplified vulnerability

ESM2M Superior Mode Water pH Allows Identification of Largest Ocean Acidification in Tropical Subsurface Waters

ESM2M Pacific Section (190°E)



The achievement in GFDL's ESMs illustrates the importance of including dynamical, chemical and biogeochemical interactions

Resplandy, L. L. Bopp, J. Orr, and J. Dunne (2013)

Frenger, I., Bianchi, D., Stührenberg, C., Oschlies, A., Dunne, J., Deutsch, C., Galbraith, E. and Schütte, F., 2018. Biogeochemical role of subsurface coherent eddies in the ocean: Tracer cannonballs, hypoxic storms, and microbial stewpots. *Global Biogeochemical Cycles*.

LARGE SCALE CLIMATE – WINDS; PDO; ENSO

Climatic modulation of recent trends in ocean acidification in the California Current System

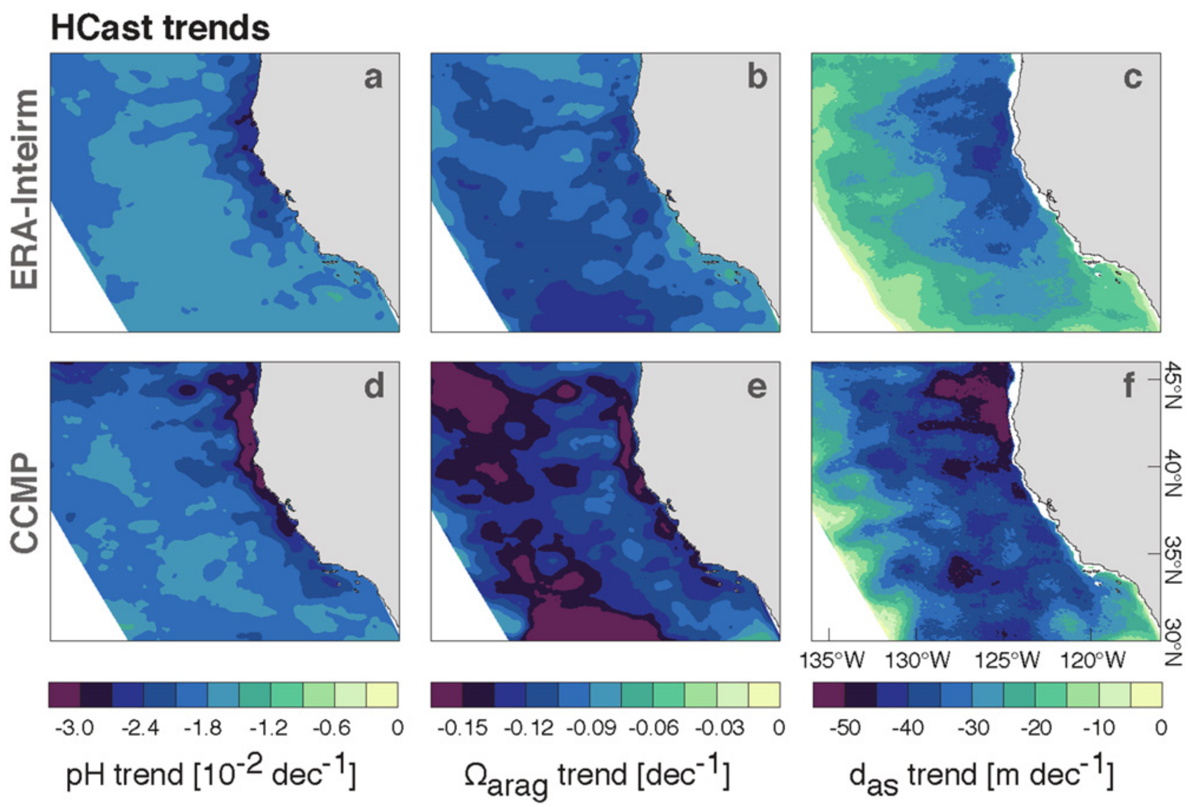
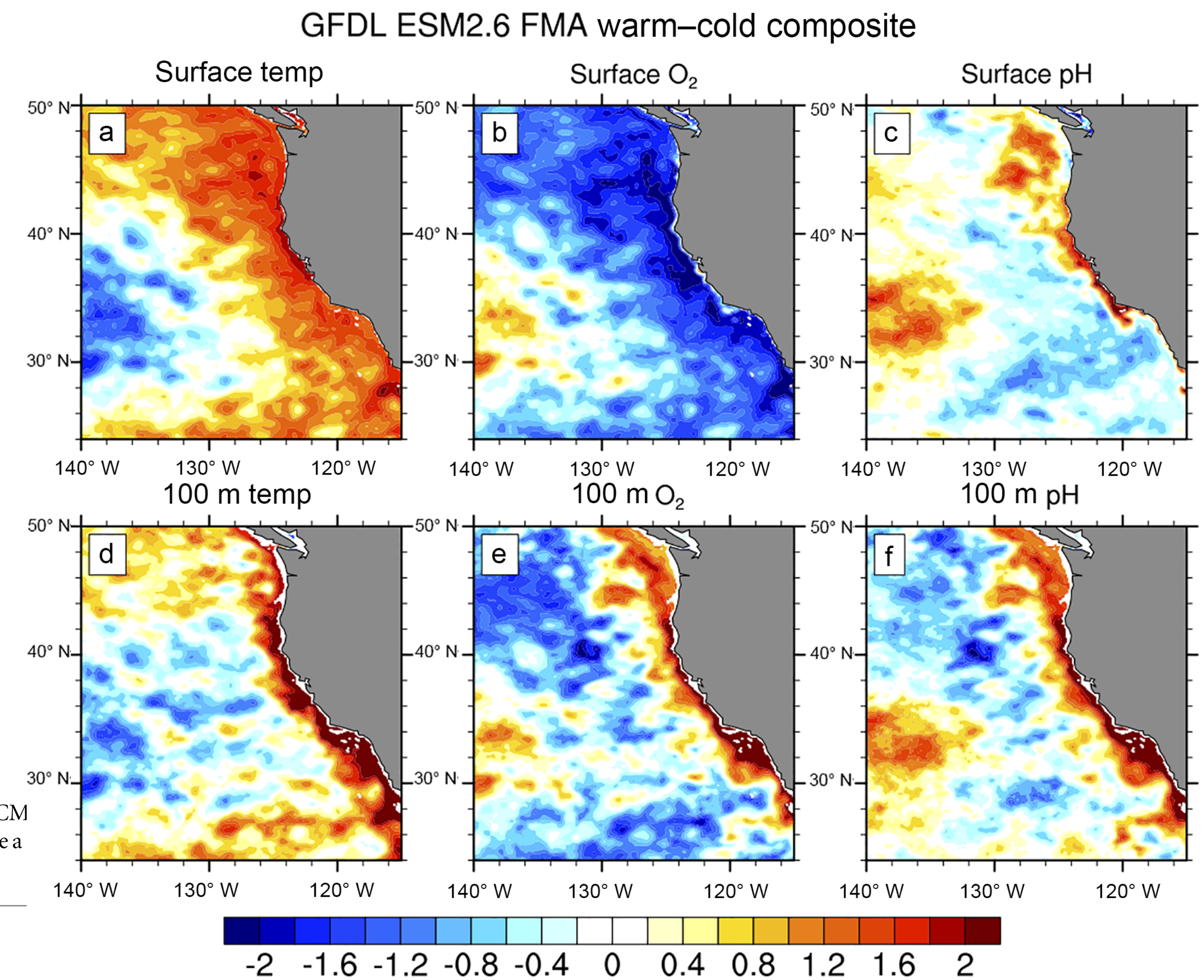


Figure 1. Trends per decade in pH, Ω_{arag} and d_{as} from (a)–(c) the HCast-ERAI simulation (1979–2012) and (d)–(f) the HCast-CCM simulation (1988–2011). pH and Ω_{arag} trends were averaged over the top 60 m of the water column. Negative trends in d_{as} denote a shoaling. All trends are significant at the 95% level.

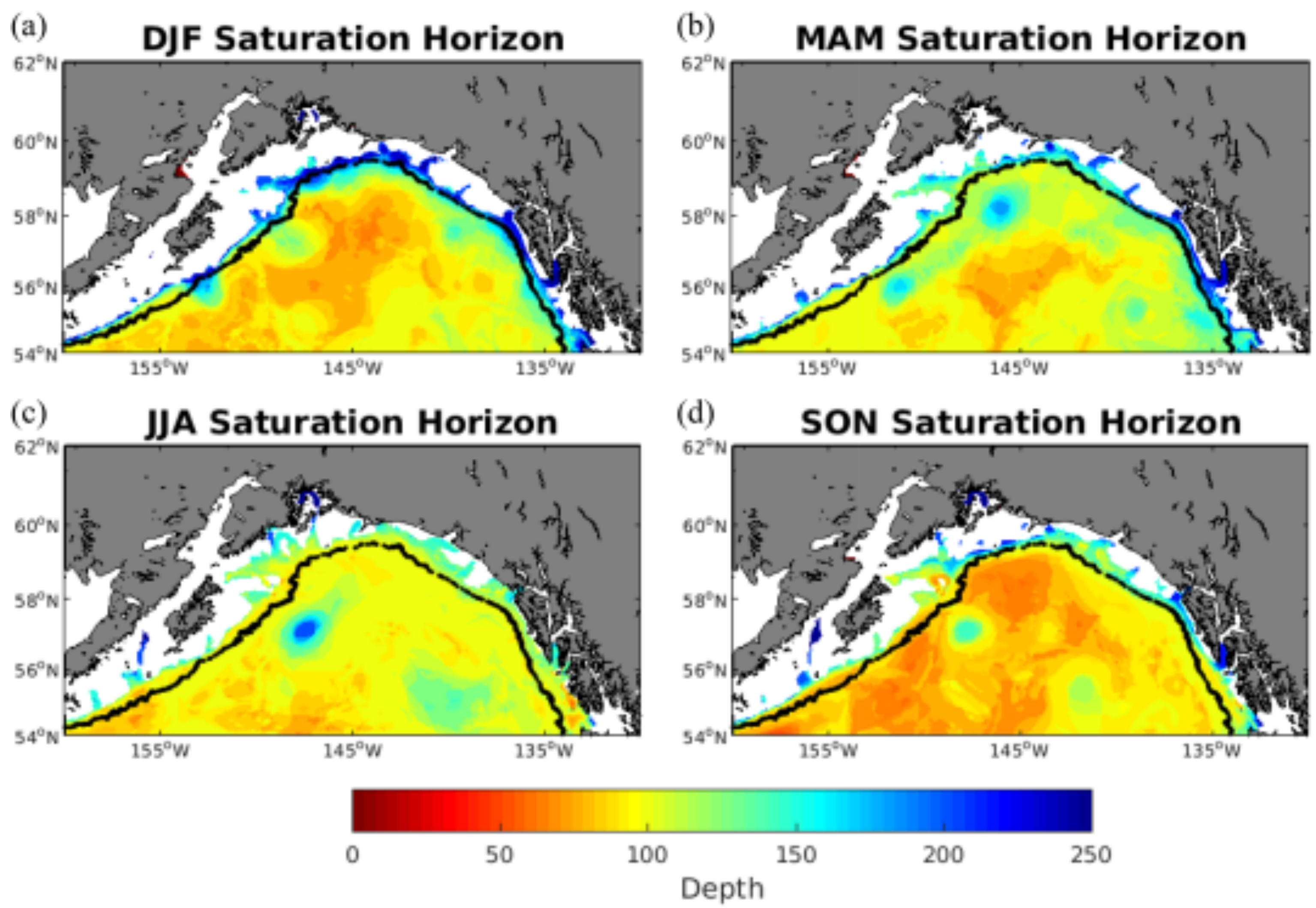
G. Turi et al.: Response of O_2 and pH to ENSO in the CalCS in a high-resolution climate model



Turi et al., 2016; 2018

GOA –THE ROLE OF FRESHWATER

The Importance of Freshwater to Spatial Variability of Aragonite Saturation State in the Gulf of Alaska



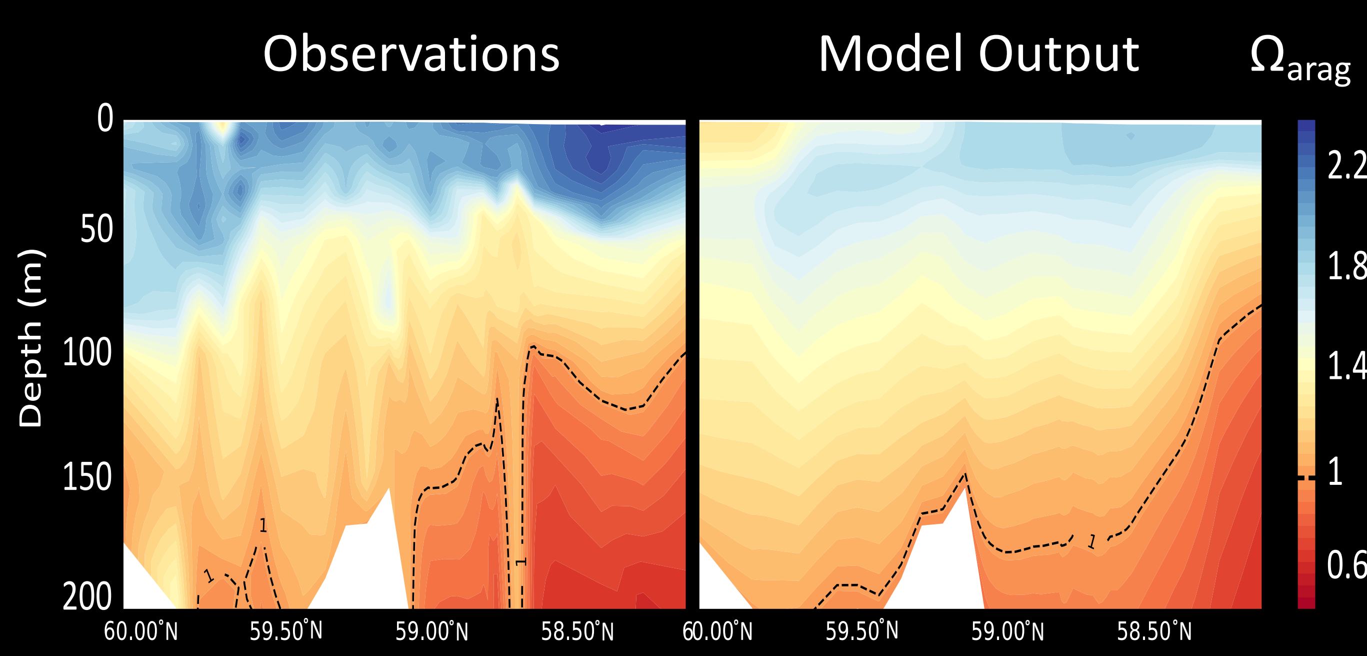
Journal of Geophysical Research: Oceans
Volume 122, Issue 11, pages 8482-8502, 7 NOV 2017 DOI: 10.1002/2017JC012791
http://onlinelibrary.wiley.com/doi/10.1002/2017JC012791/full#jgrc22511-fig-0011

Siedlecki et al., 2017; Pilcher et al. 2018

GOA –THE ROLE OF FRESHWATER

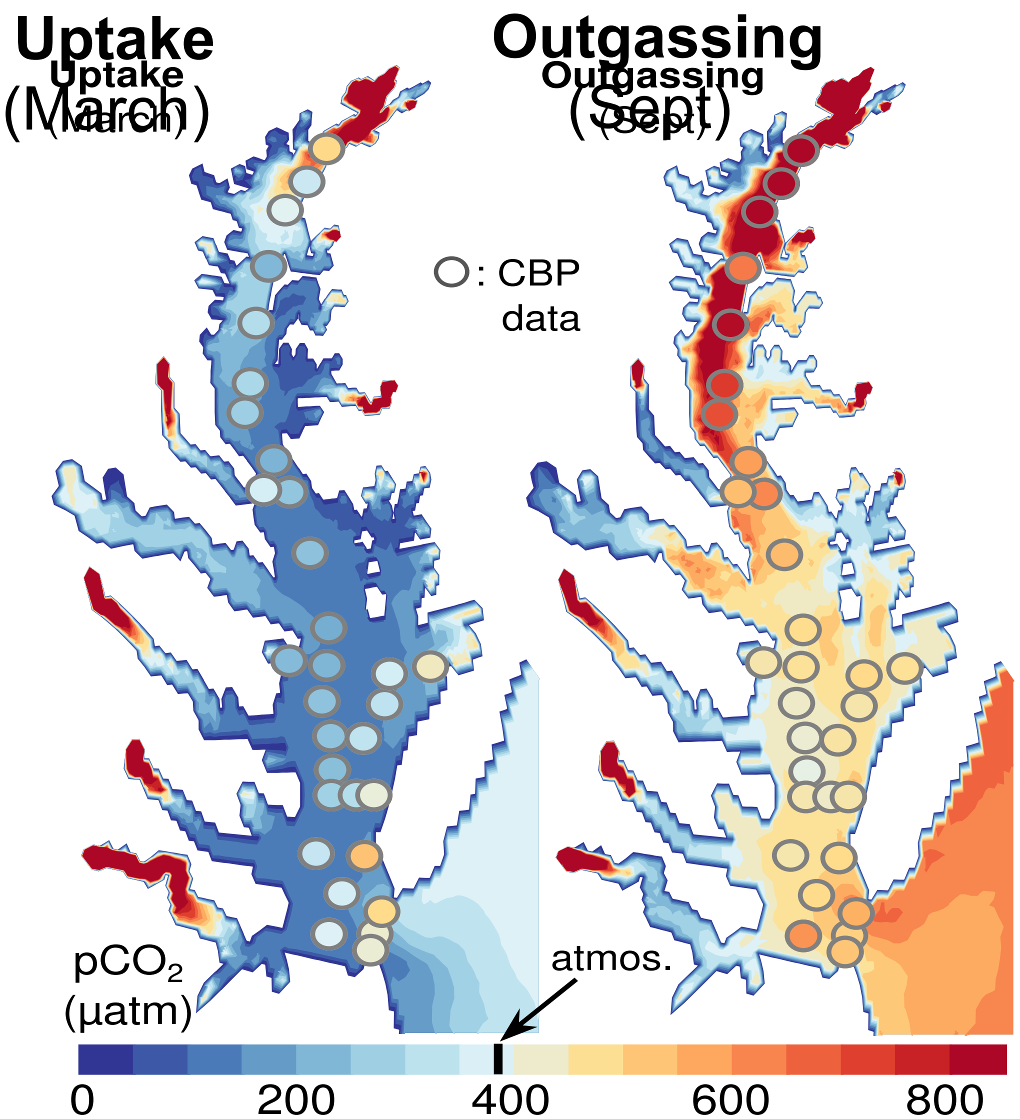
Highlight: Explicitly forced coastal freshwater discharges to model impact of OA and Climate Change on Biogeochemistry in Gulf of Alaska

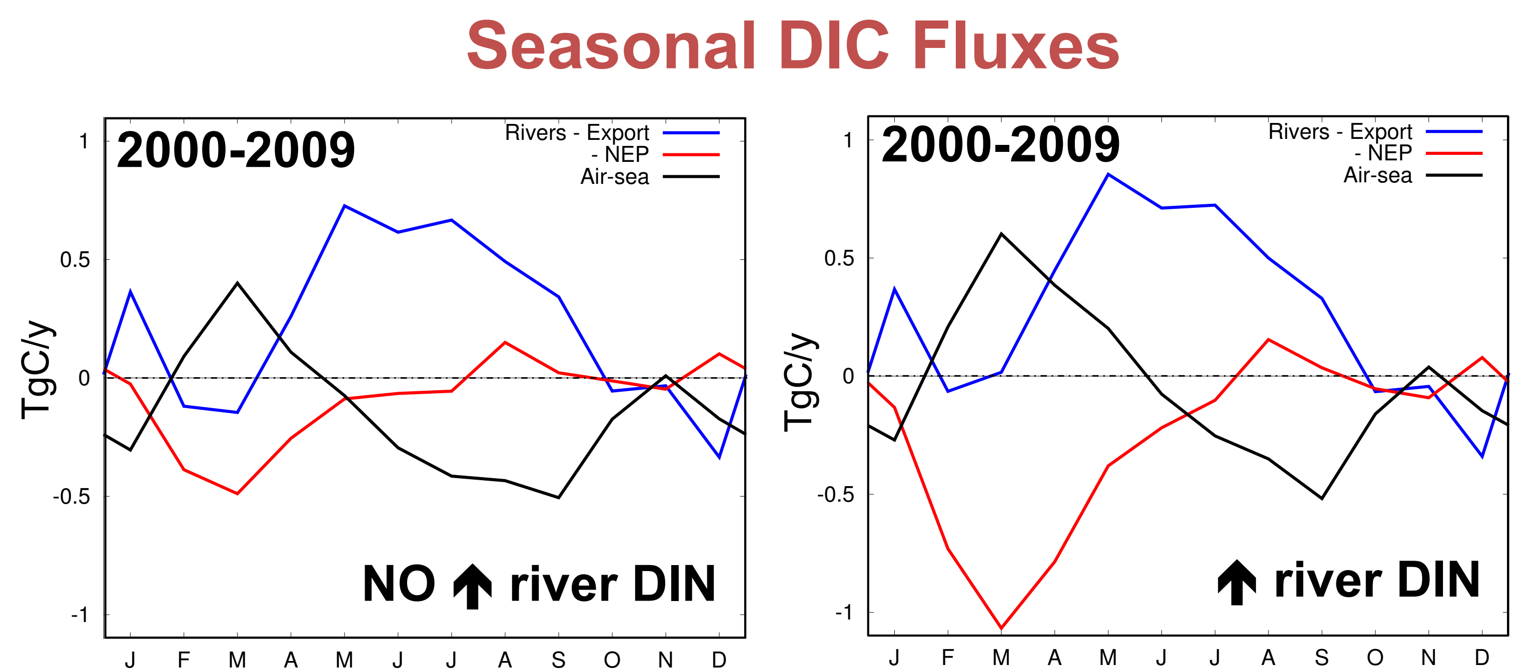
- Point-source river input through exchange of mass, momentum and tracers through the coastal wall at all depths
- TA, DIC, Fe, DOC, nutrients in freshwater are based on observations
- 35 year long hindcast simulation (1980 -2015) is still running



Hauri et al., in prep

CHESAPEAKE BAY





↑ Riverine DIN increases CO_2 uptake (spring) reduces outgassing (fall); increases NEP

*Ches*ROMS-ECB

Feng et al., 2015;
Irby et al., 2016, 2017
Friedrichs et al (in prep)

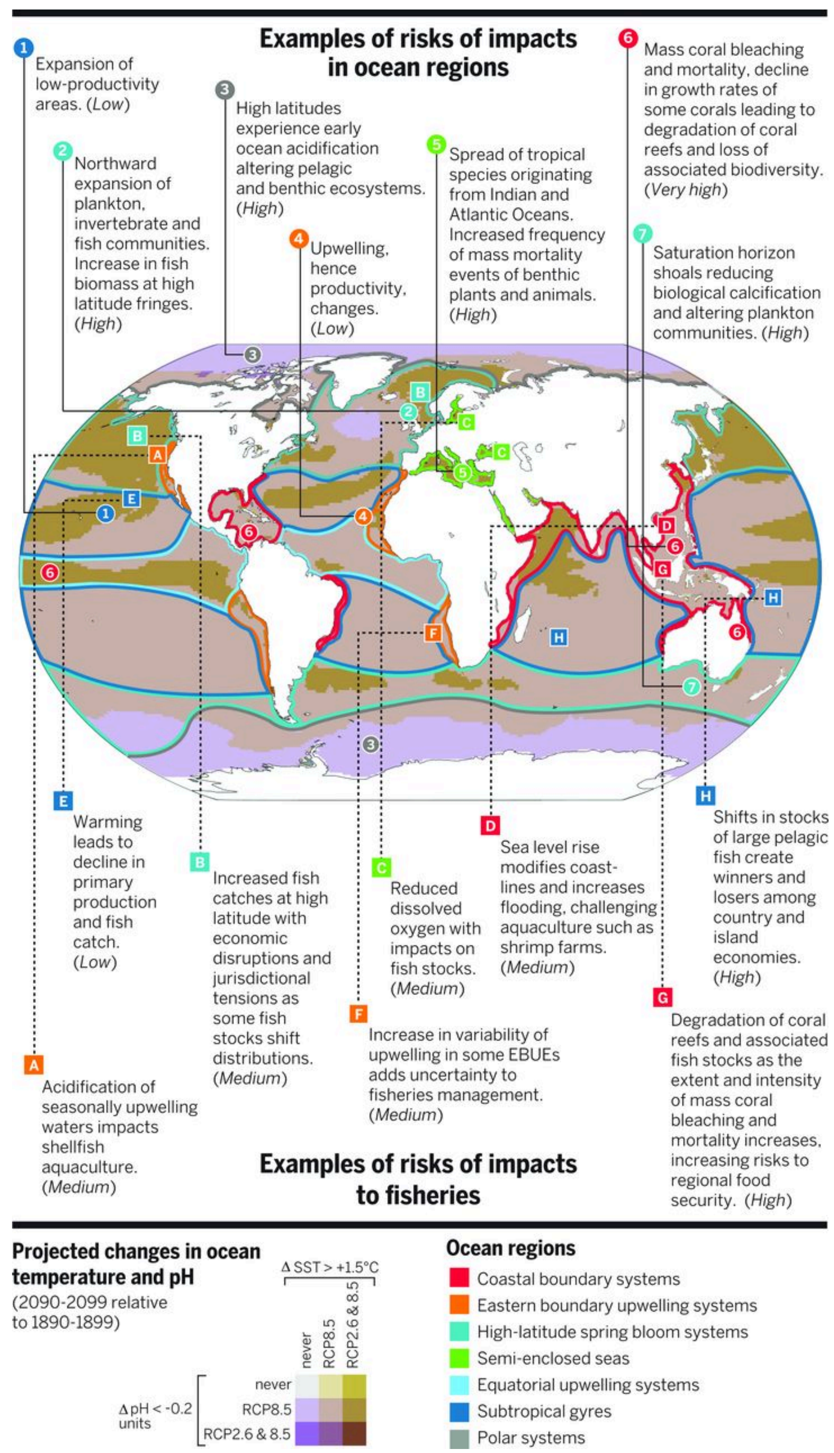
Talk about Gulf of Mexico at OSM this week…..

Projected Effects of Anthropogenic CO2 Emissions on Eutrophication-Induced Hypoxia and Acidification in the Northern Gulf of Mexico

__Arnaud Laurent__, Dalhousie University, Halifax, NS, Canada, Katja Fennel, Dalhousie University, Department of Oceanography, Halifax, NS, Canada, Dong Ko, US Naval Research Laboratory, Monterey, CA, United States and John C Lehrter, Dauphin Island Sea Lab, Dauphin Island, AL, United States

GLOBAL EXAMPLE

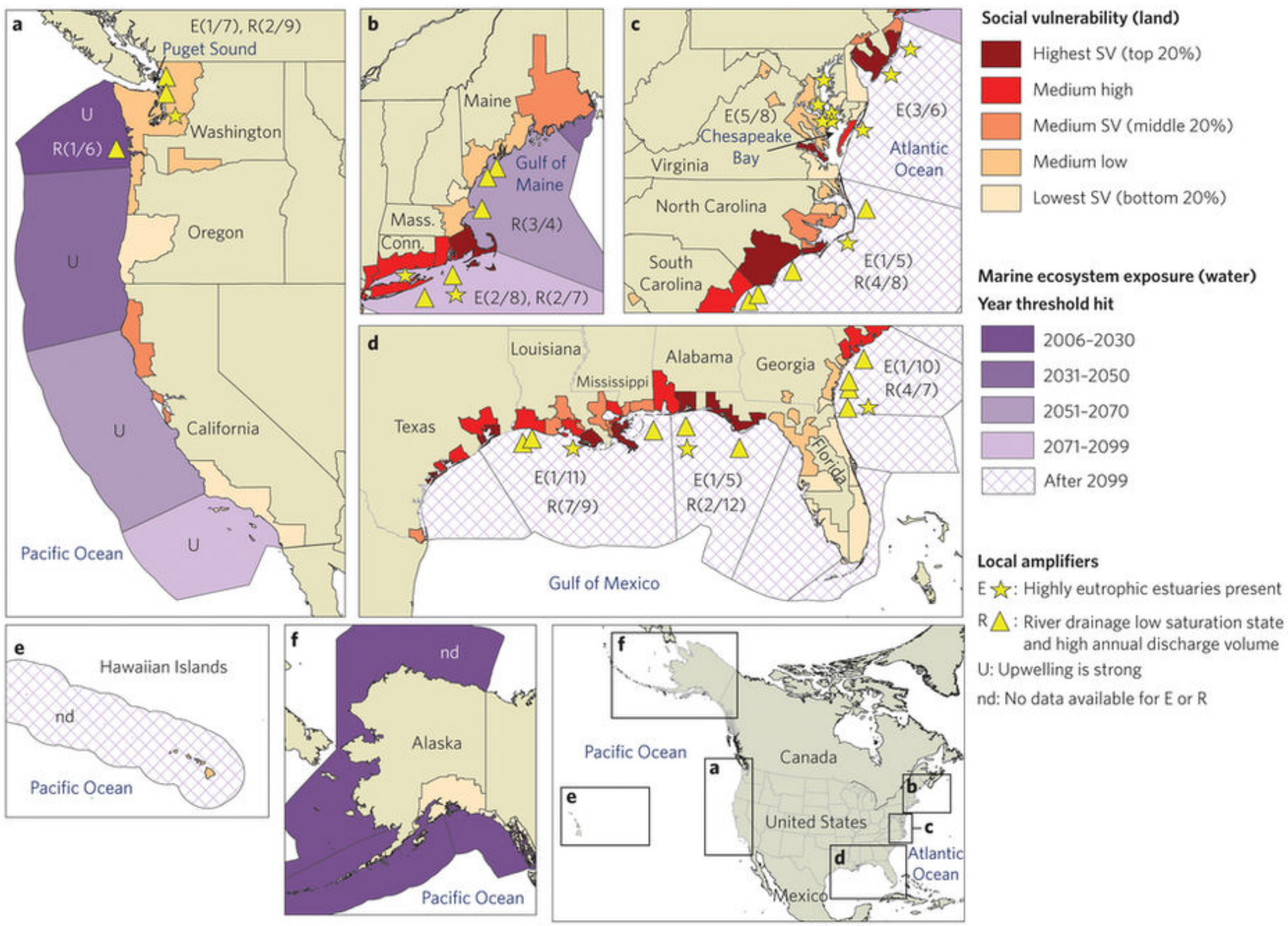
Fig. 3 Regional changes in the physical system and associated risks for natural and human-managed systems.



J.-P. Gattuso et al. Science 2015;349:aac4722

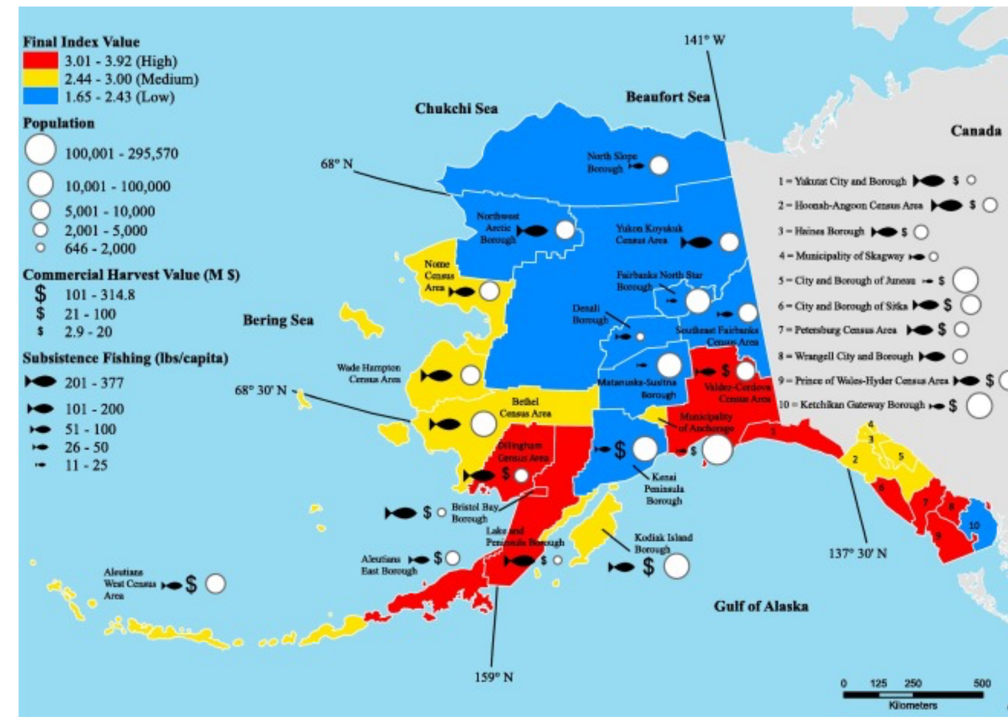
US AND GOA

Vulnerability and adaptation of US shellfisheries to ocean acidification



Ekstrom et al. 2015

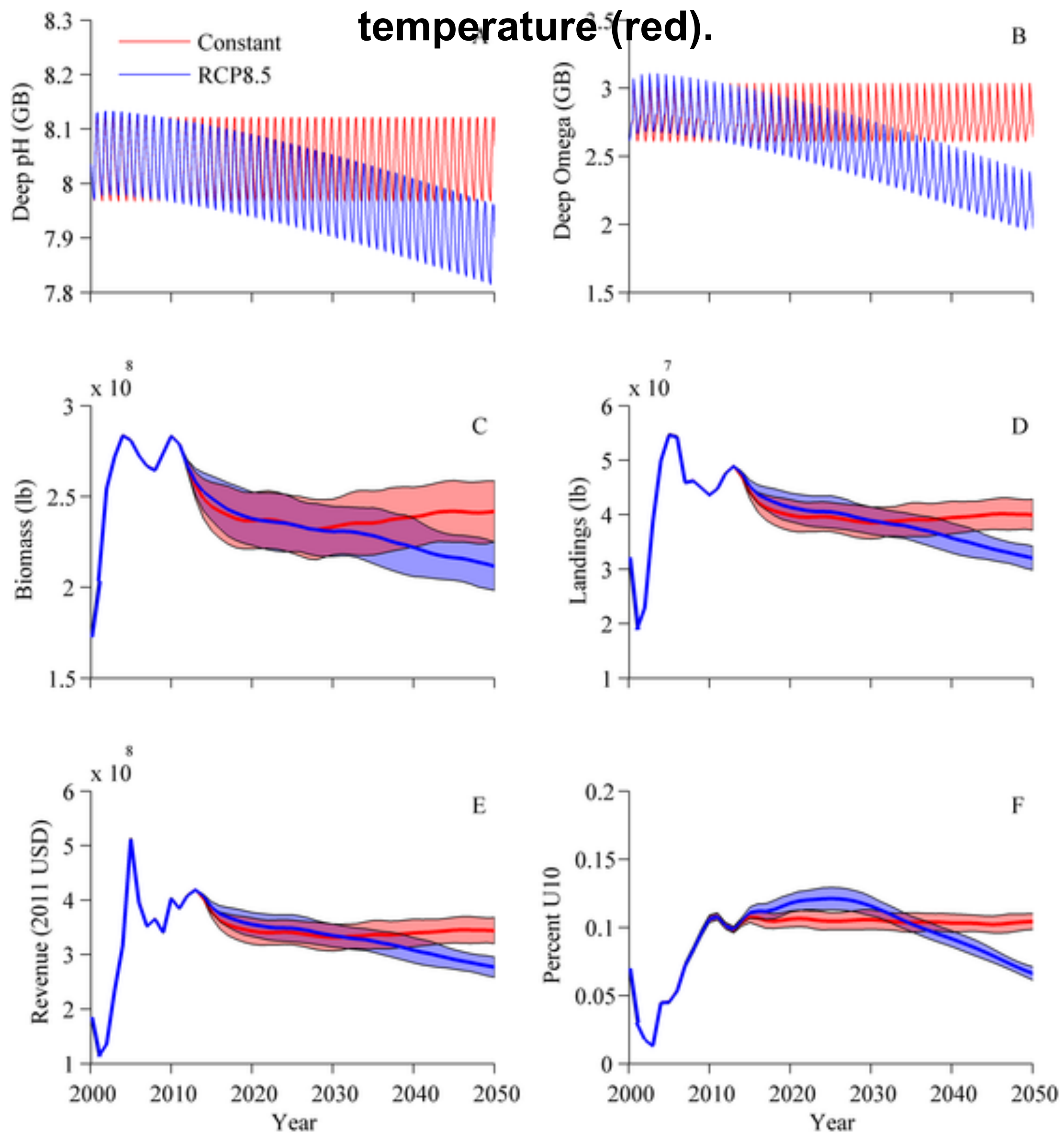
Ocean acidification risk assessment for Alaska's fishery sector



Mathis et al. 2015

GULF OF MAINE EXAMPLE

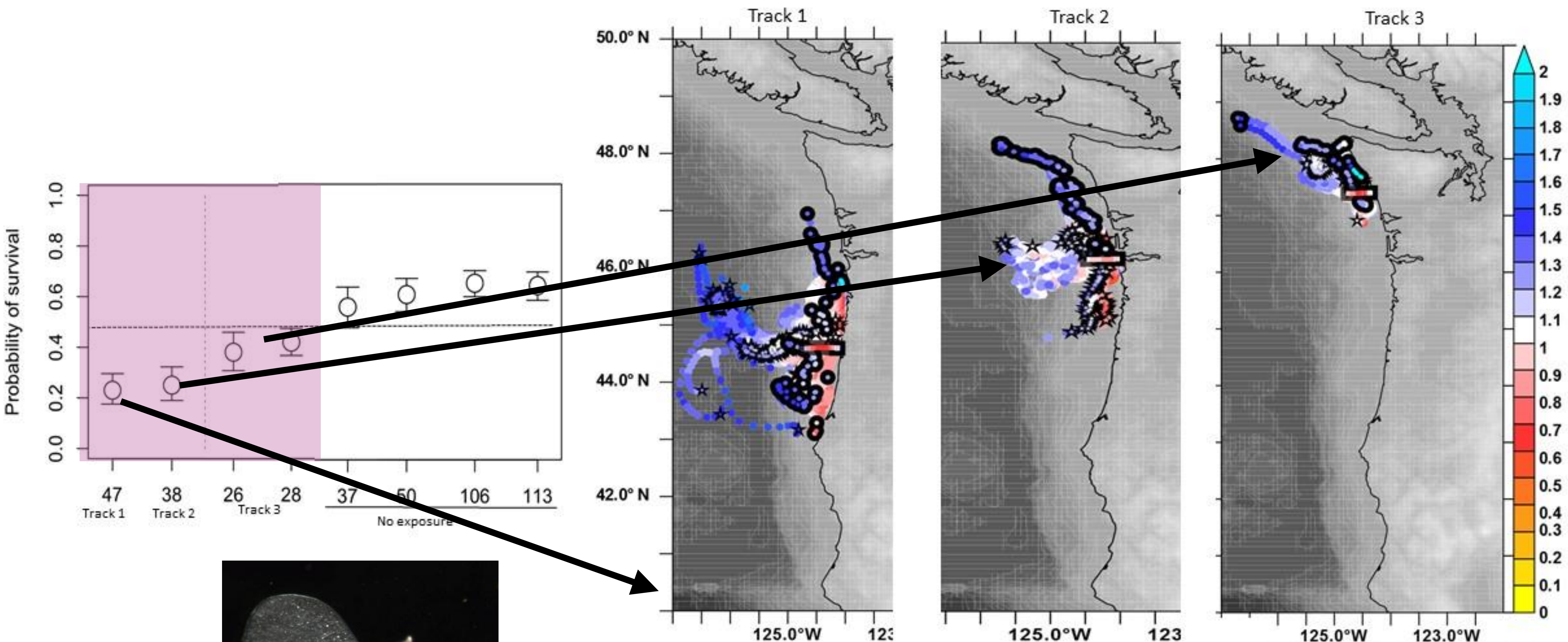
Fig 10. Mean ± SD (n = 100) model forecasts out to 2050 using CO2 forcing from RCP 8.5 and 1.4°C SST warming (blue) and forecasts with constant 2008 CO2 concentration and temperature (red).



Cooley SR, Rheuban JE, Hart DR, Luu V, Glover DM, et al. (2015) An Integrated Assessment Model for Helping the United States Sea Scallop (Placopecten magellanicus) Fishery Plan Ahead for Ocean Acidification and Warming. PLOS ONE 10(5): e0124145. https://doi.org/10.1371/journal.pone.0124145
http://journals.plos.org/plosone/article?id=10.1371/journal.pone.0124145

PLOS | ONE

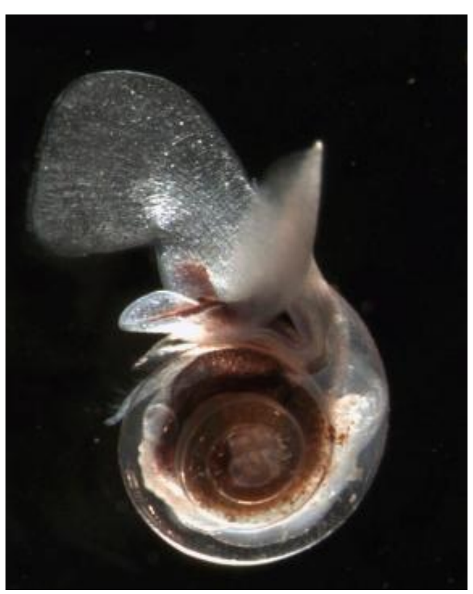
CCS EXAMPLE



Particles released along tracks where samples obtained

Particles vertically migrate

Particle tracks run forward and backward in time for 30 days to calculated undersaturation days experienced

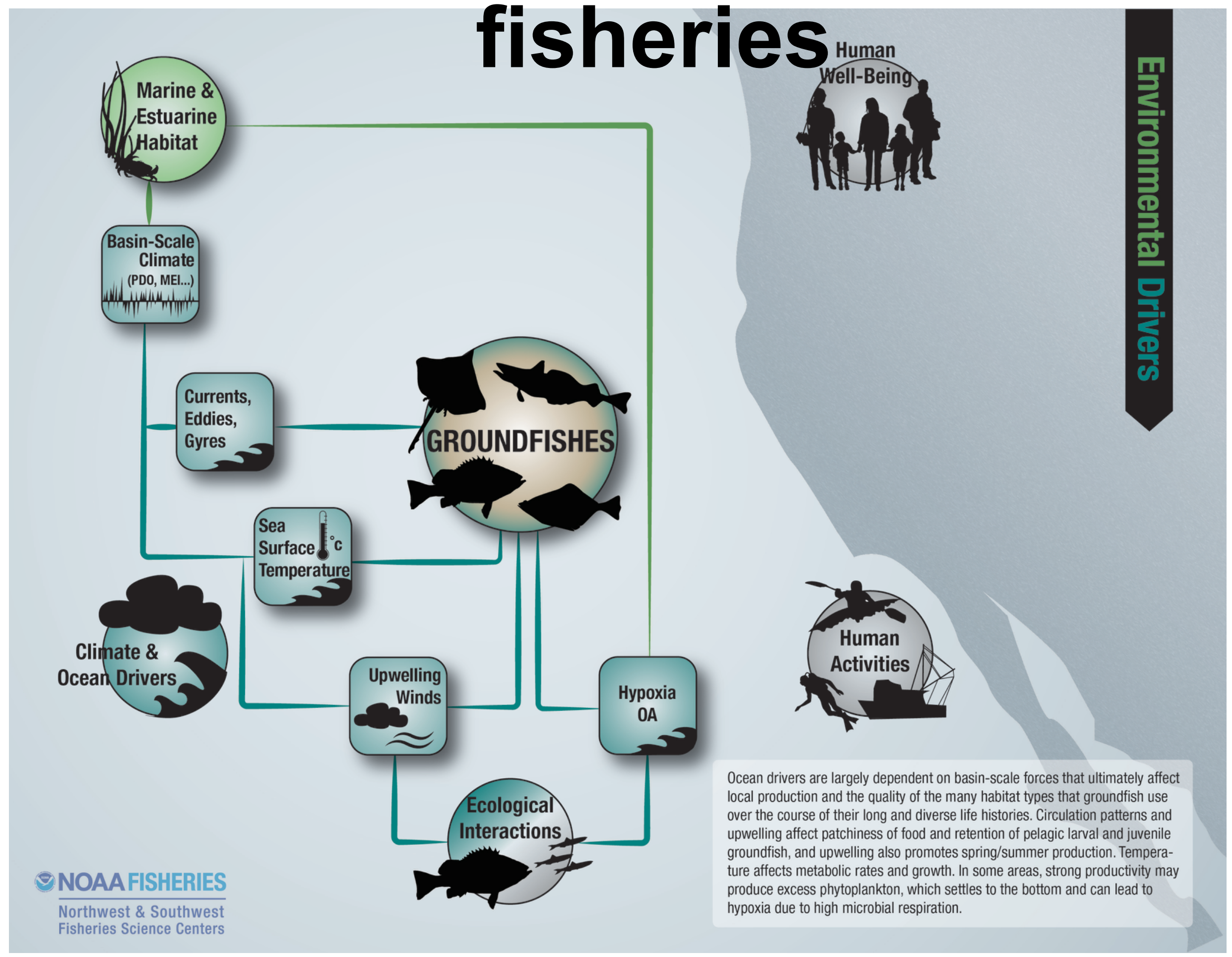


Pteropod
Photo: R. Hopcroft

Bednarsek et al., 2017

CCS EXAMPLE

Long-term forecasts: Potential effects of ocean acidification on the California Current food web and fisheries



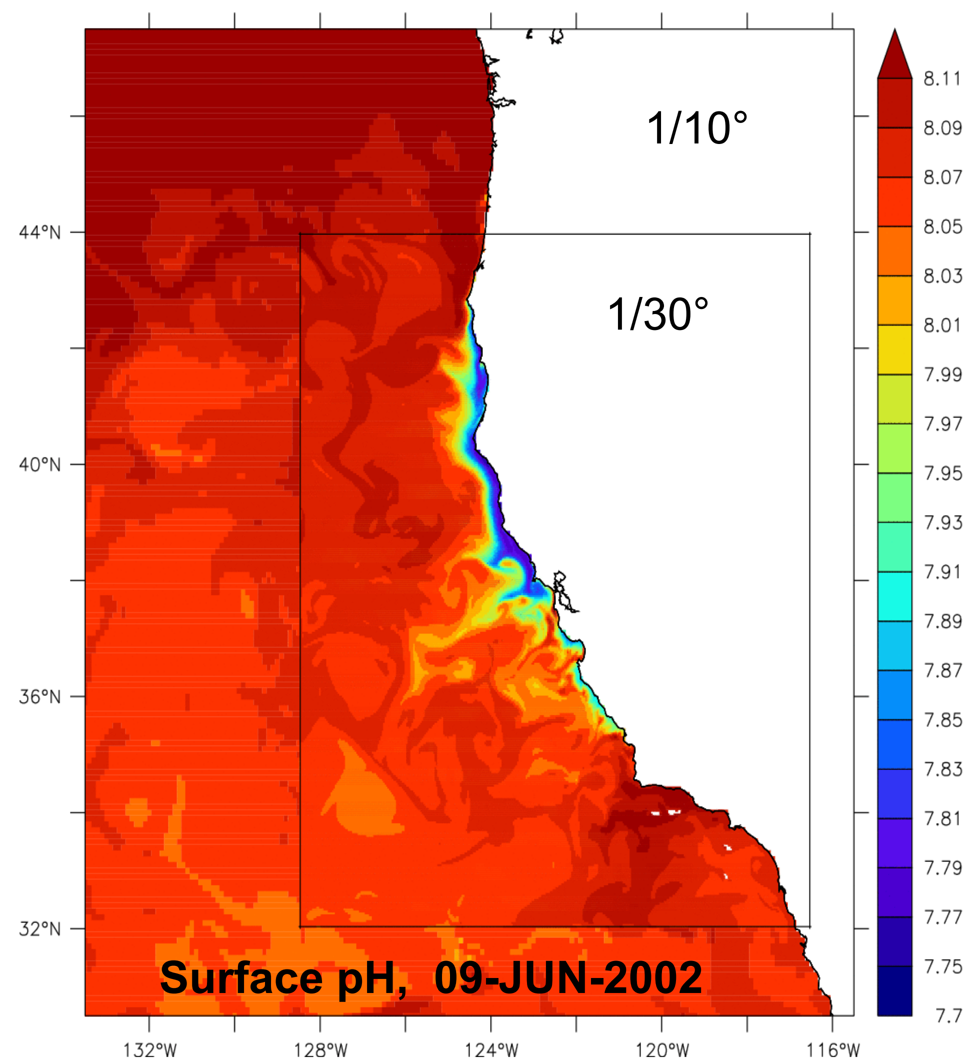
Marshall, K.N., Kaplan, I.C., Hodgson, E.E., Hermann, A., Busch, D.S., McElhany, P., Essington, T.E., Harvey, C.J. and Fulton, E.A., 2017. *Global change biology*, *23*(4), pp.1525-1539.

Hodgson, E. E., I. C. Kaplan, K. Marshall, J. L. Leonard, T. E. Essington, D. S. Busch, E. A. Fulton, C. J. Harvey, A. J. Hermann, P. McElhany. *In review*.

REGIONAL MODELS YOU ARE ABOUT TO HEAR MORE ABOUT

- K. Fennel's GOMex and GOM models
- Arctic - projections and hindcasts - see D. Pilcher

UCSC Hindcast Simulation for CCS at 1/30° (1988-2010)



Ocean Circulation:
ROMS
(1/30° nested domain)

Biogeochemistry:
NEMUCSC
(NEMURO+Carb+O_2)

Outer domain: offline NEMUCSC forced by data-assimilative reanalysis of CCS circulation at 1/10° for 1988-2010

Nested domain: coupled ROMS-NEMUCSC solution at 1/30° benefiting from physical data assimilation in outer domain

For more info:
fiechter@ucsc.edu

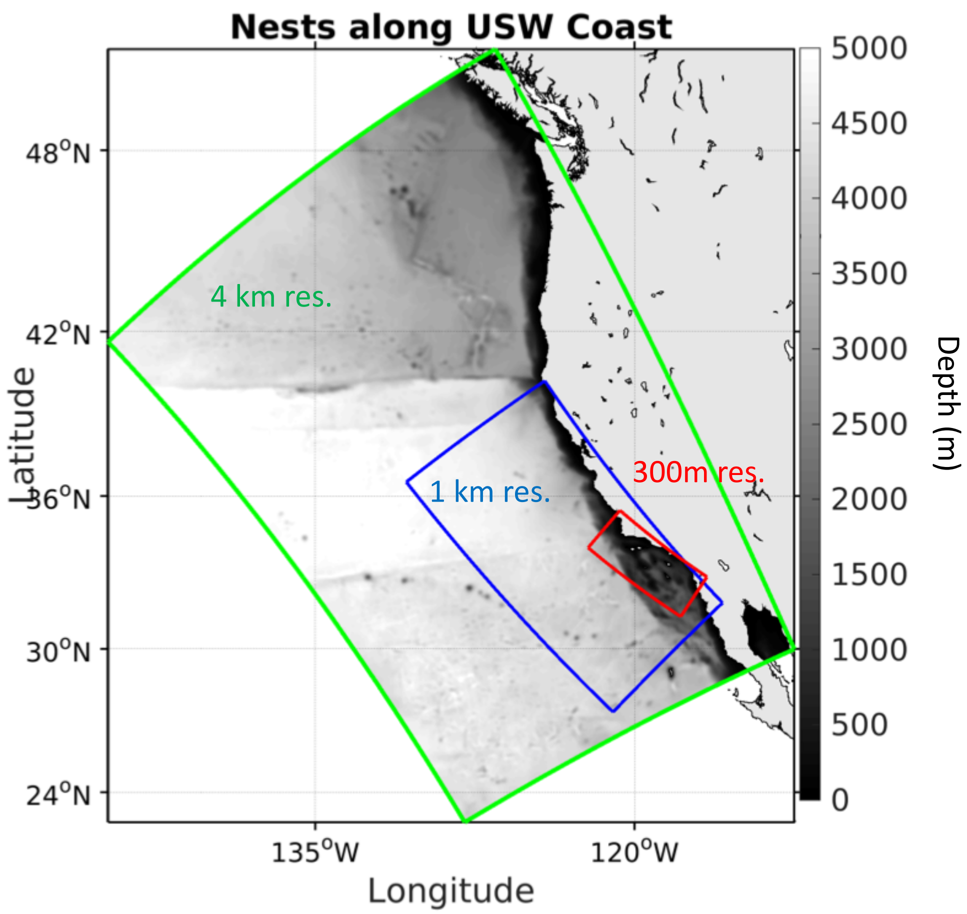
REGIONAL MODELS YOU ARE ABOUT TO HEAR MORE ABOUT

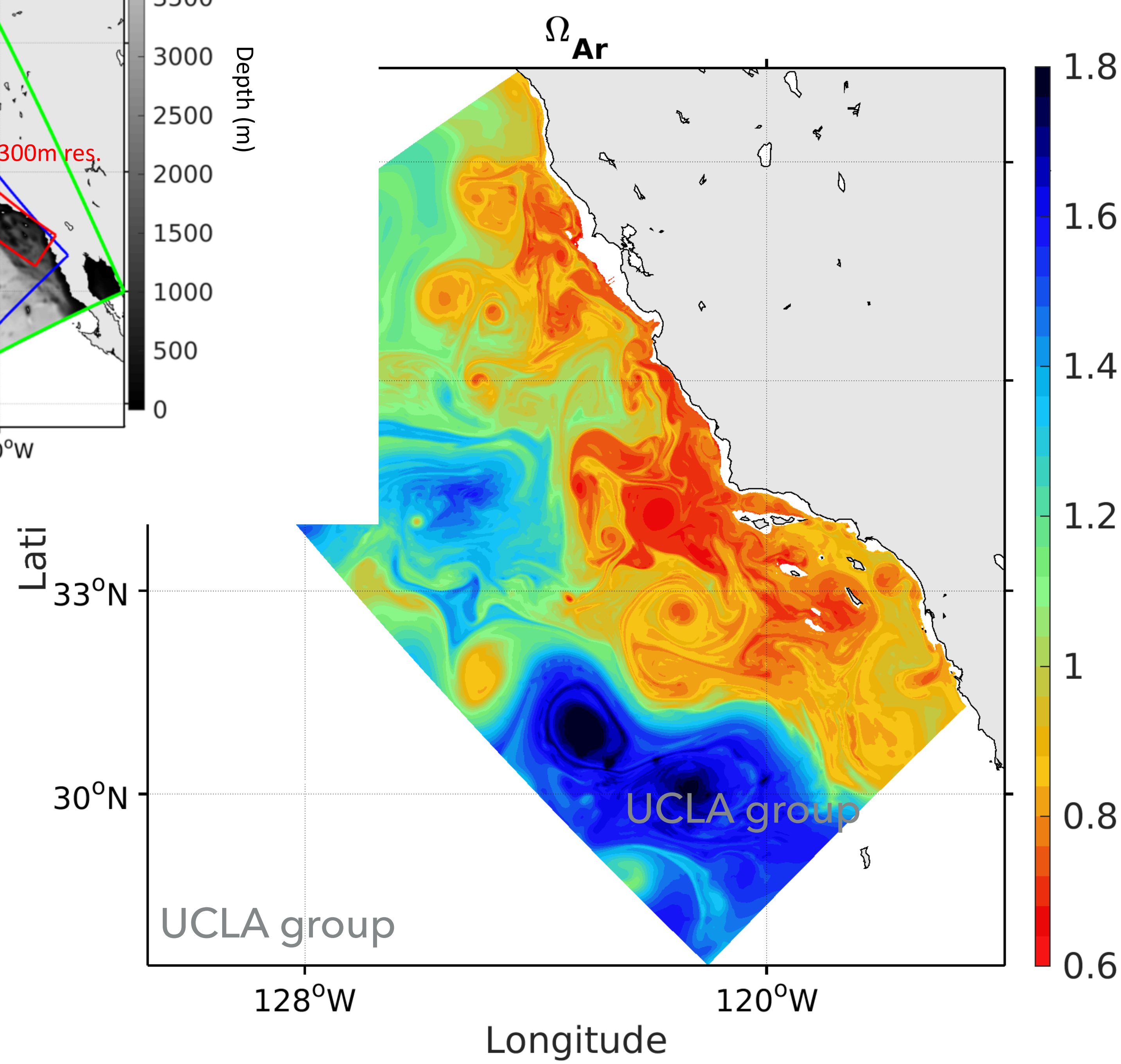
ROMS-BEC nests off California Current System

4km horizontal analysis for long term and habitat compression studies

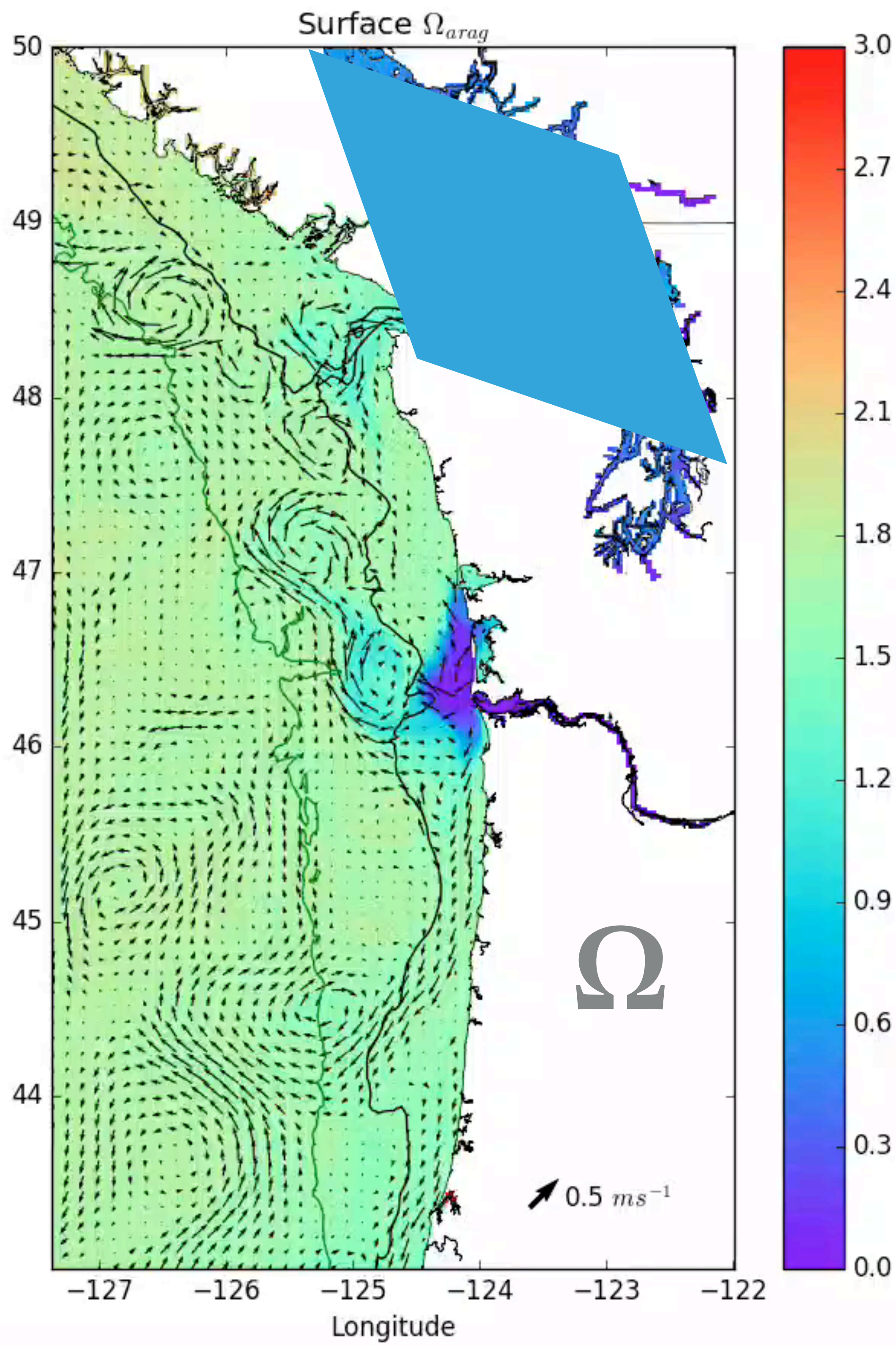
Submesoscale-resolving model at 1km horizontal resolution for state-wide analysis, including OA effects on coastal and offshore plankton communities

300m horizontal resolution solution to study local inputs' effects on the coastal ad benthic ecosystem





MODELS – WHERE DO WE GO FROM HERE?



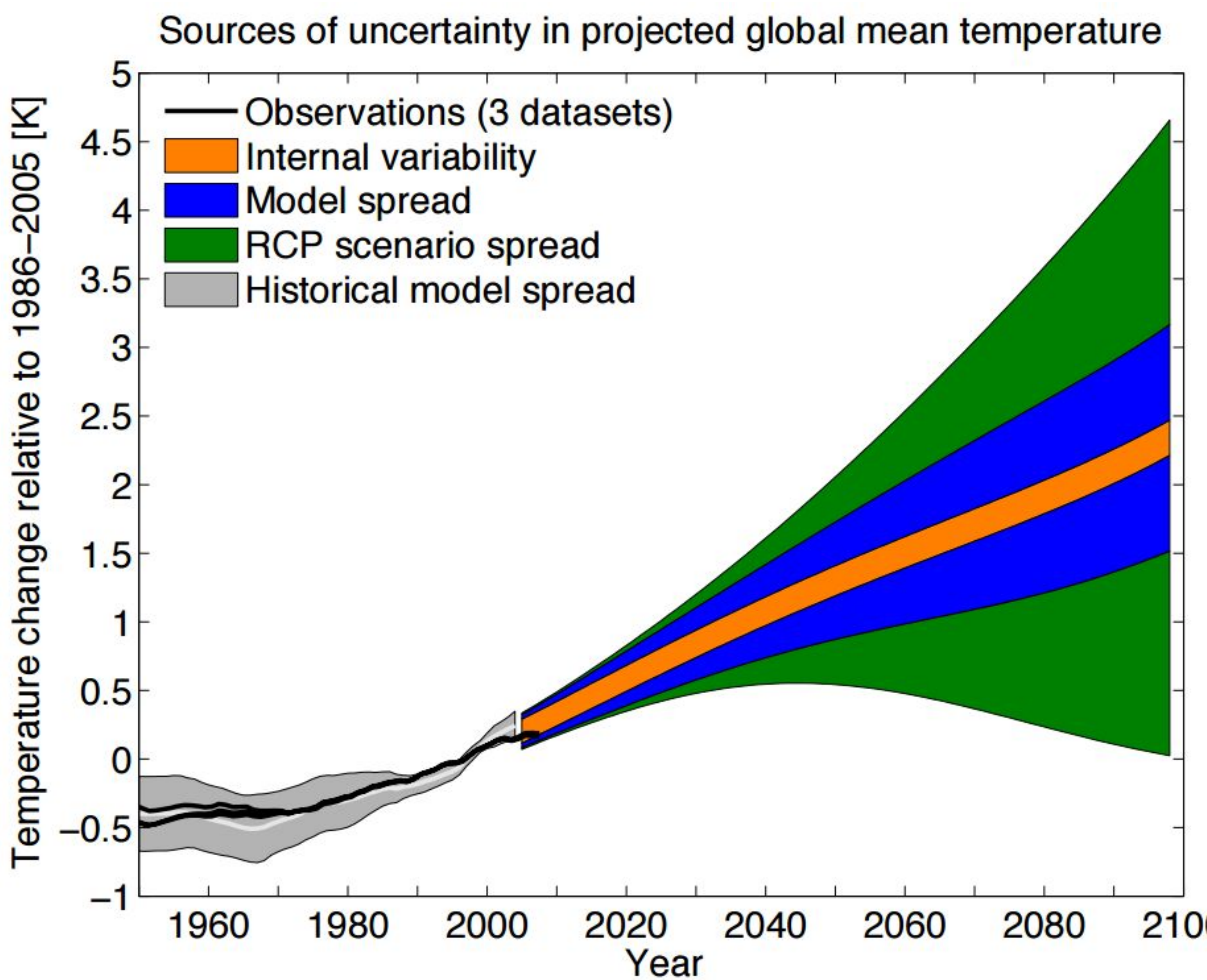
http://faculty.washington.edu/pmacc/LO/LiveOcean.html

Testbeds to explore mitigation and adaptation strategies (e.g. decision support, preparing for climate change)

Attribution - connection between global and local anthropogenic changes and the biological response

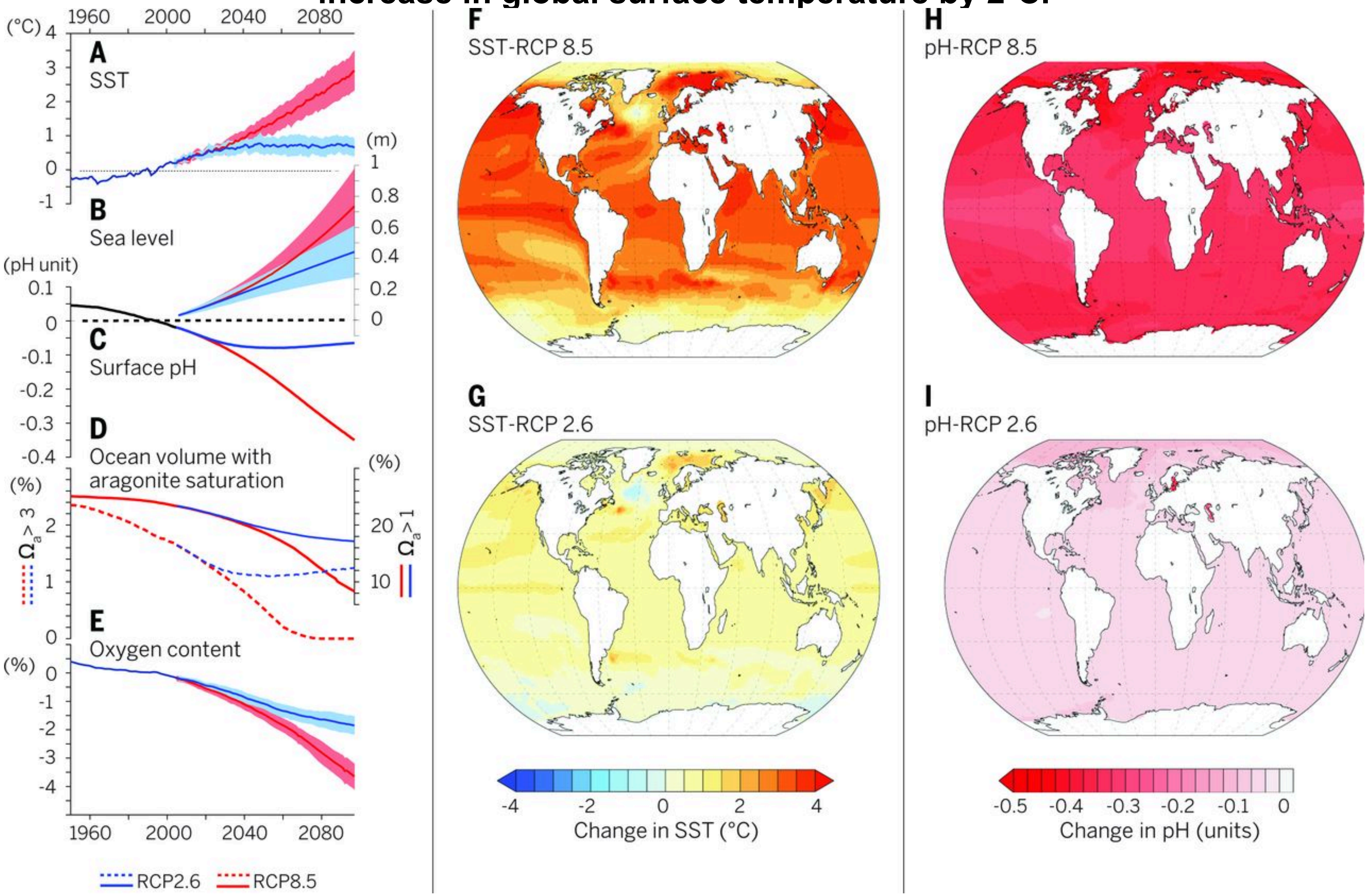
Sources of Uncertainty

EXTRA SLIDES



Sources of uncertainty in projected global mean temperature
Observations (3 datasets)
Internal variability
Model spread
RCP scenario spread
Historical model spread
Temperature change relative to 1986–2005 [K]
5
4.5
4
3.5
3
2.5
2
1.5
1
0.5
0
−0.5
−1
1960
1980
2000
2020
2040
2060
2080
Year

Fig. 1 Environmental changes over the industrial period and the 21st century for a business-as-usual scenario and a stringent emissions scenario consistent with the UNFCCC target of increase in global surface temperature by 2°C.



J.-P. Gattuso et al. Science 2015;349:aac4722

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TIME OF EMERGENCE