

# Biological Ramifications of Climate-Change Mediated Oceanic Multi-Stressors

**Scott Doney**

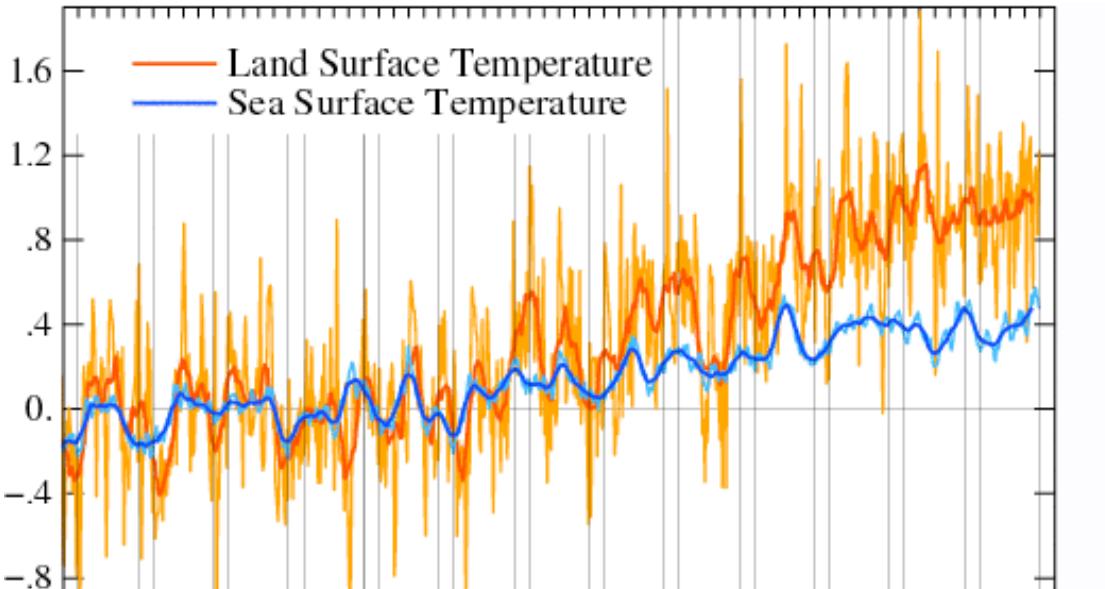
Woods Hole Oceanographic Institution

Phil Boyd (U. Tasmania), Sinikka Lennartz  
(GEOMAR), & David Glover (WHOI)

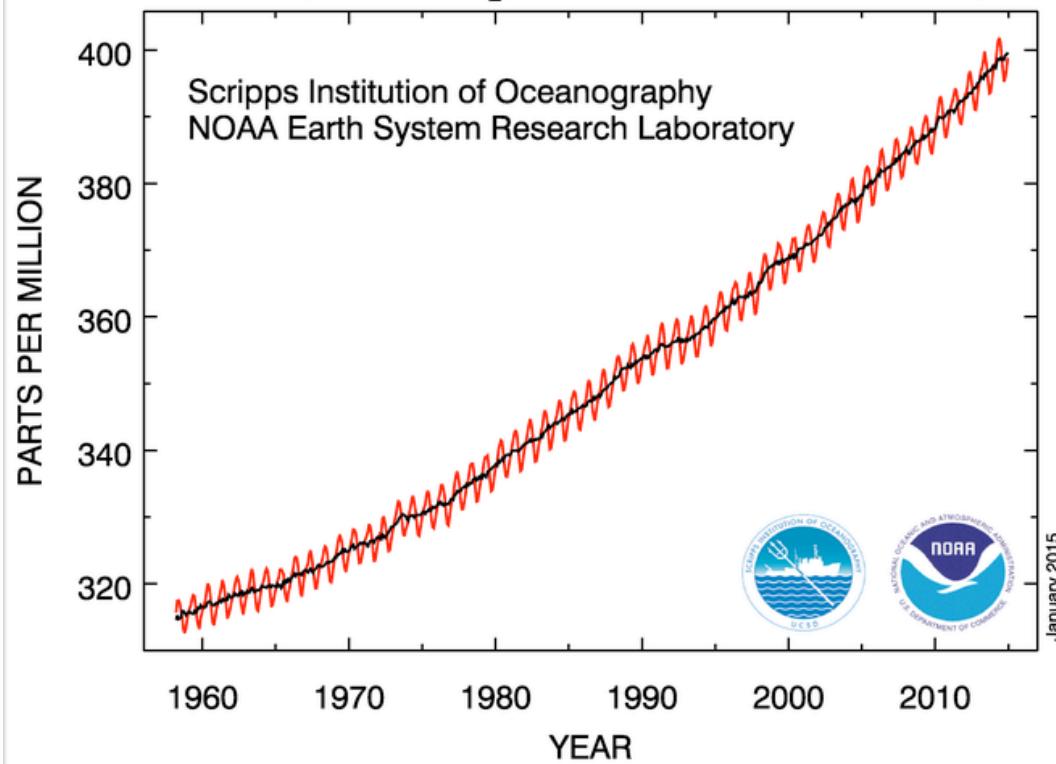
Southern Ocean Dynamics  
& Biogeochemistry  
Workshop  
Caltech, Feb. 2015

Supported by:





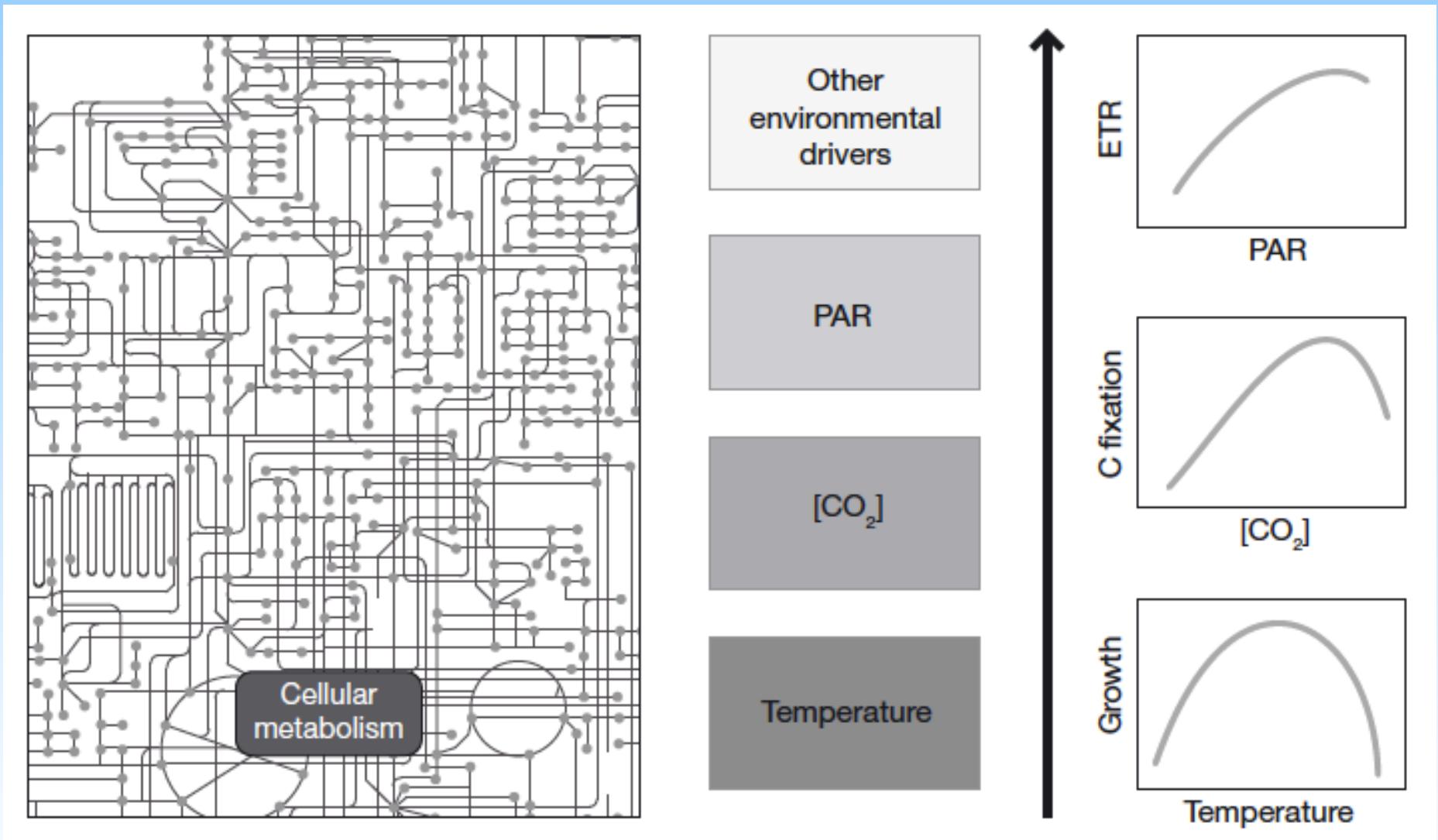
Atmospheric CO<sub>2</sub> at Mauna Loa Observatory



# Climate Change Drivers



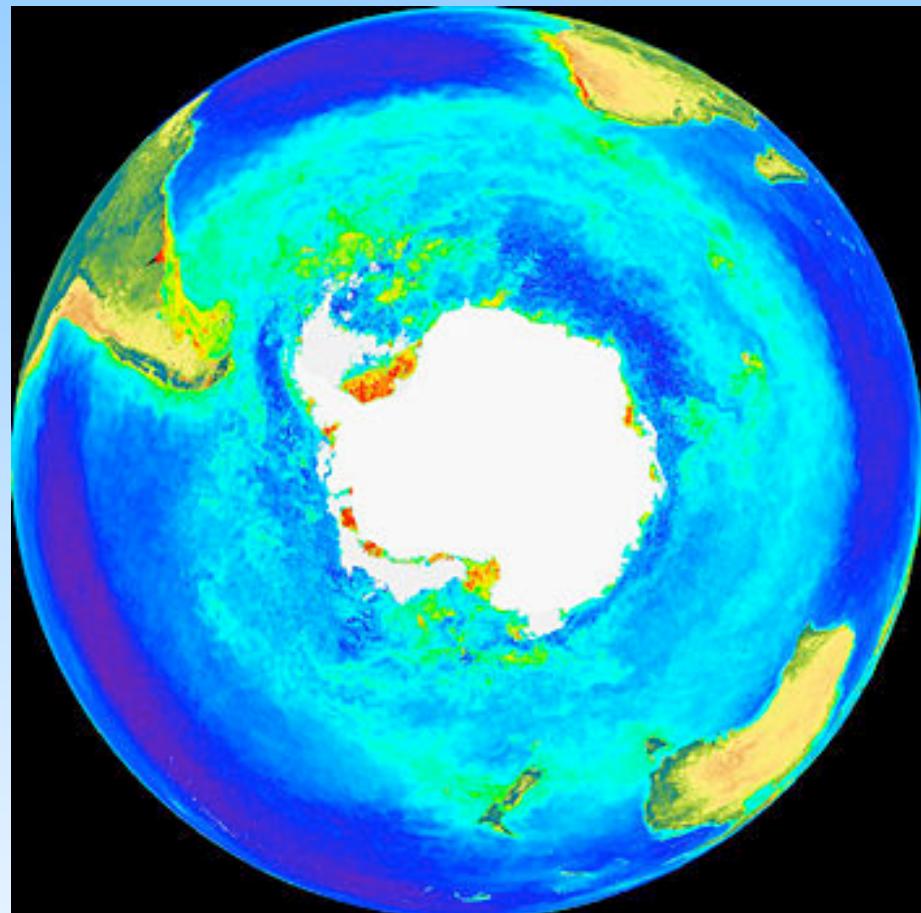
# Plankton Response to Multiple Environmental Drivers



Boyd & Hutchins, Mar. Ecol. Prog. Series, 2012



# Talk Outline



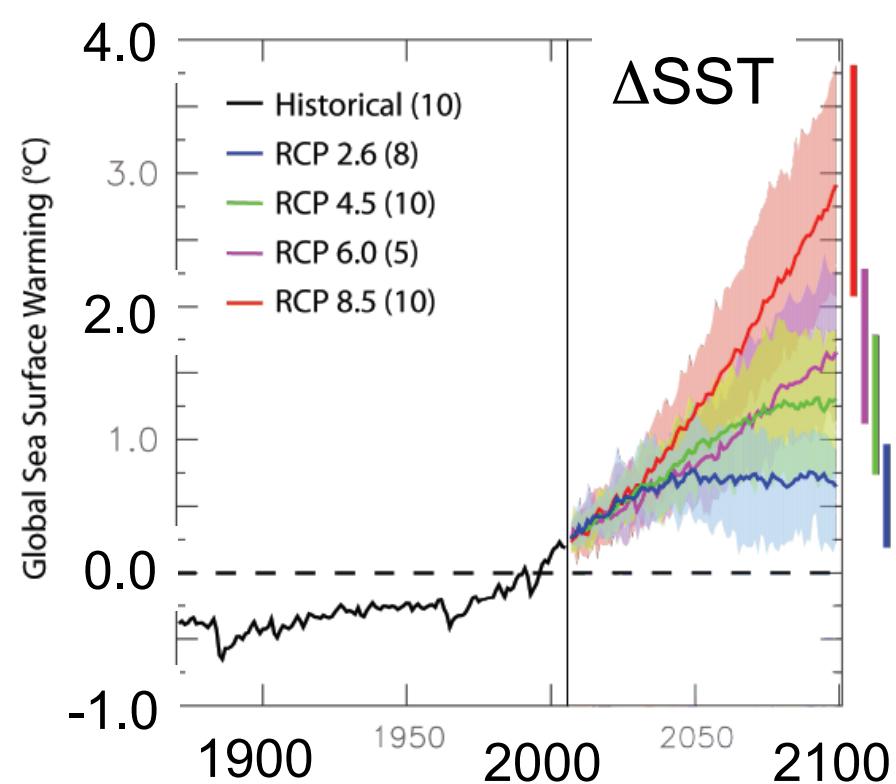
Earth System Model Projections:

- multiple stressor trends
- regional variability

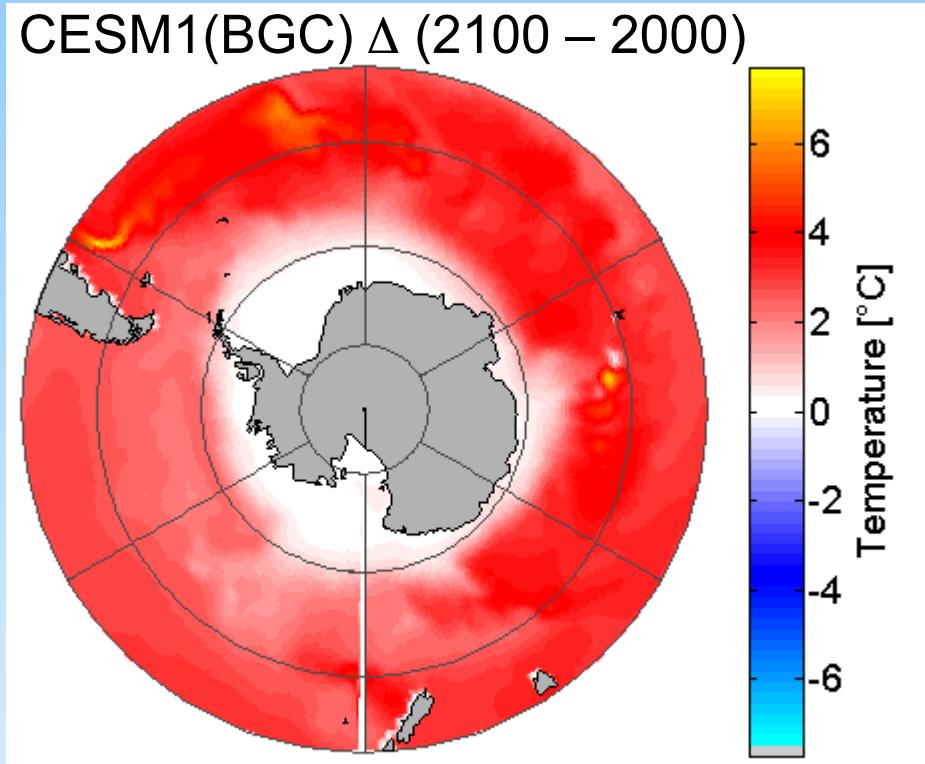
Guide design & interpretation of  
field/lab manipulation studies



# Surface Warming



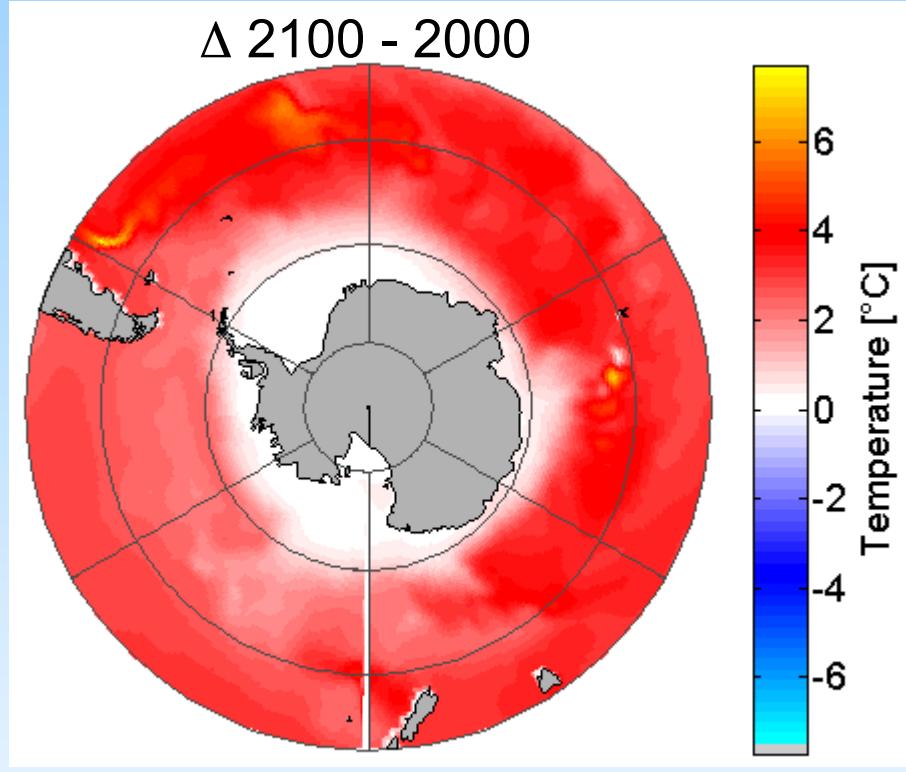
Ensemble of CMIP5 Coupled  
Climate-Carbon Models  
Bopp et al. Biogeosciences  
2013



Moore et al., J. Climate 2013  
Boyd et al., Nature Climate  
Change 2015

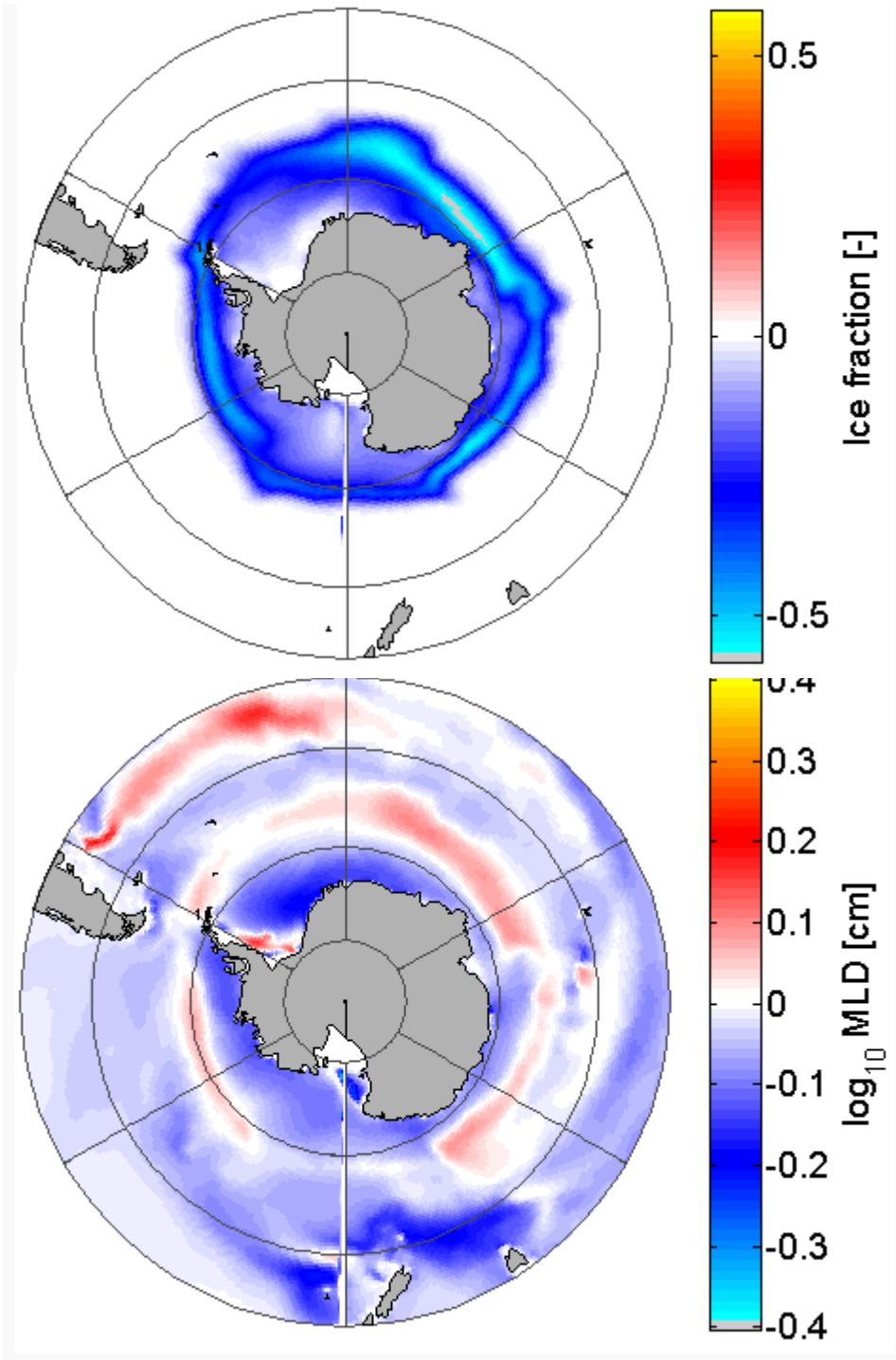


# Physical Drivers

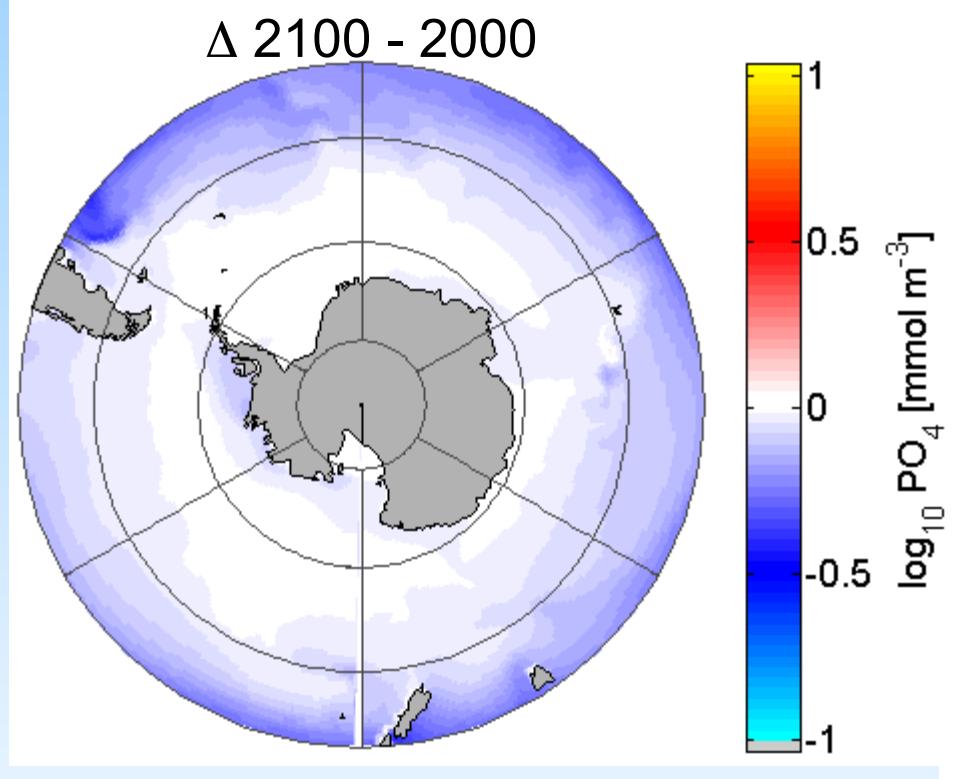


CESM1(BGC)

Moore et al., J. Climate 2013  
Boyd et al., Nature Climate Change 2015

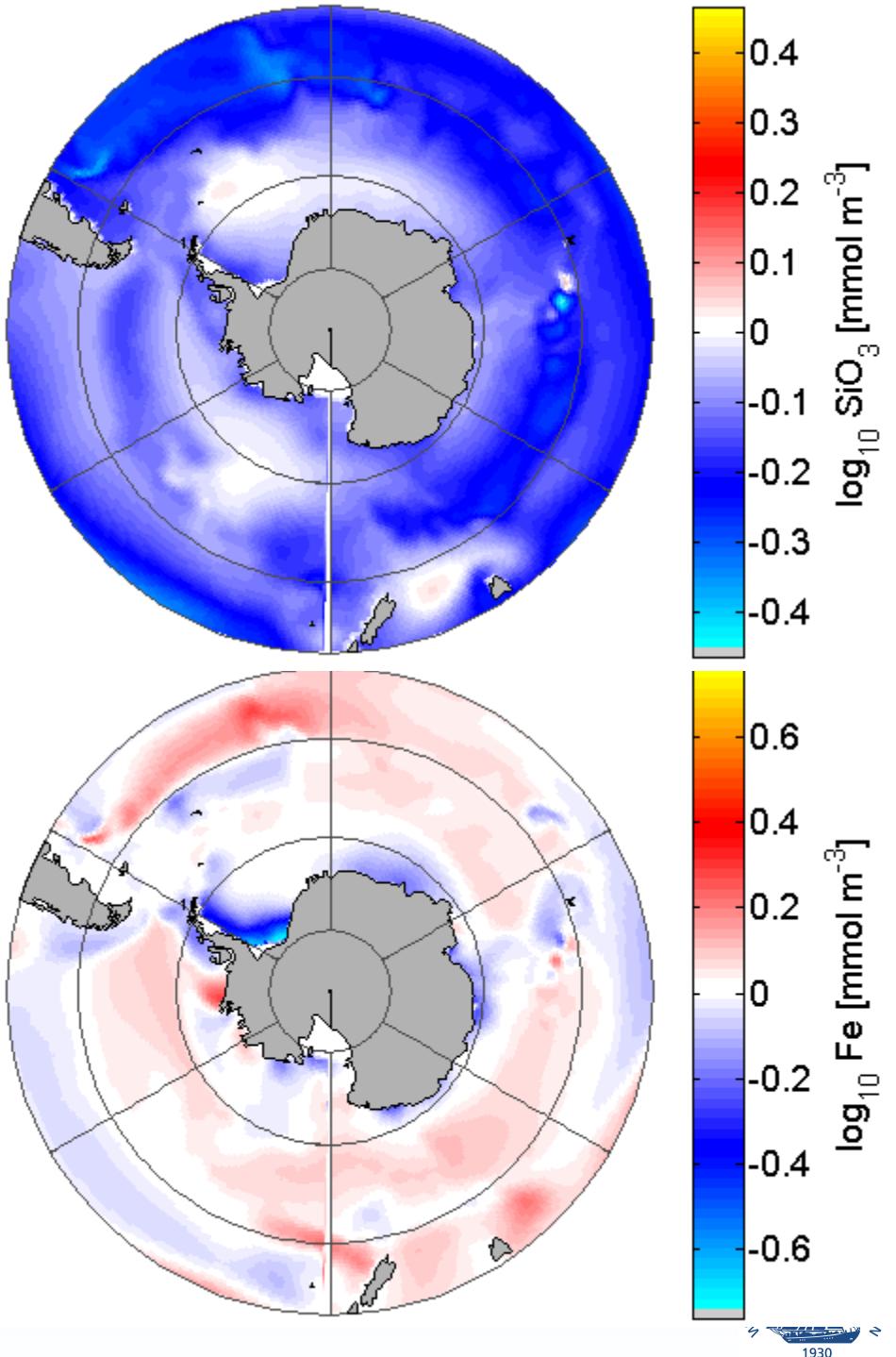


# Biogeochemical Drivers

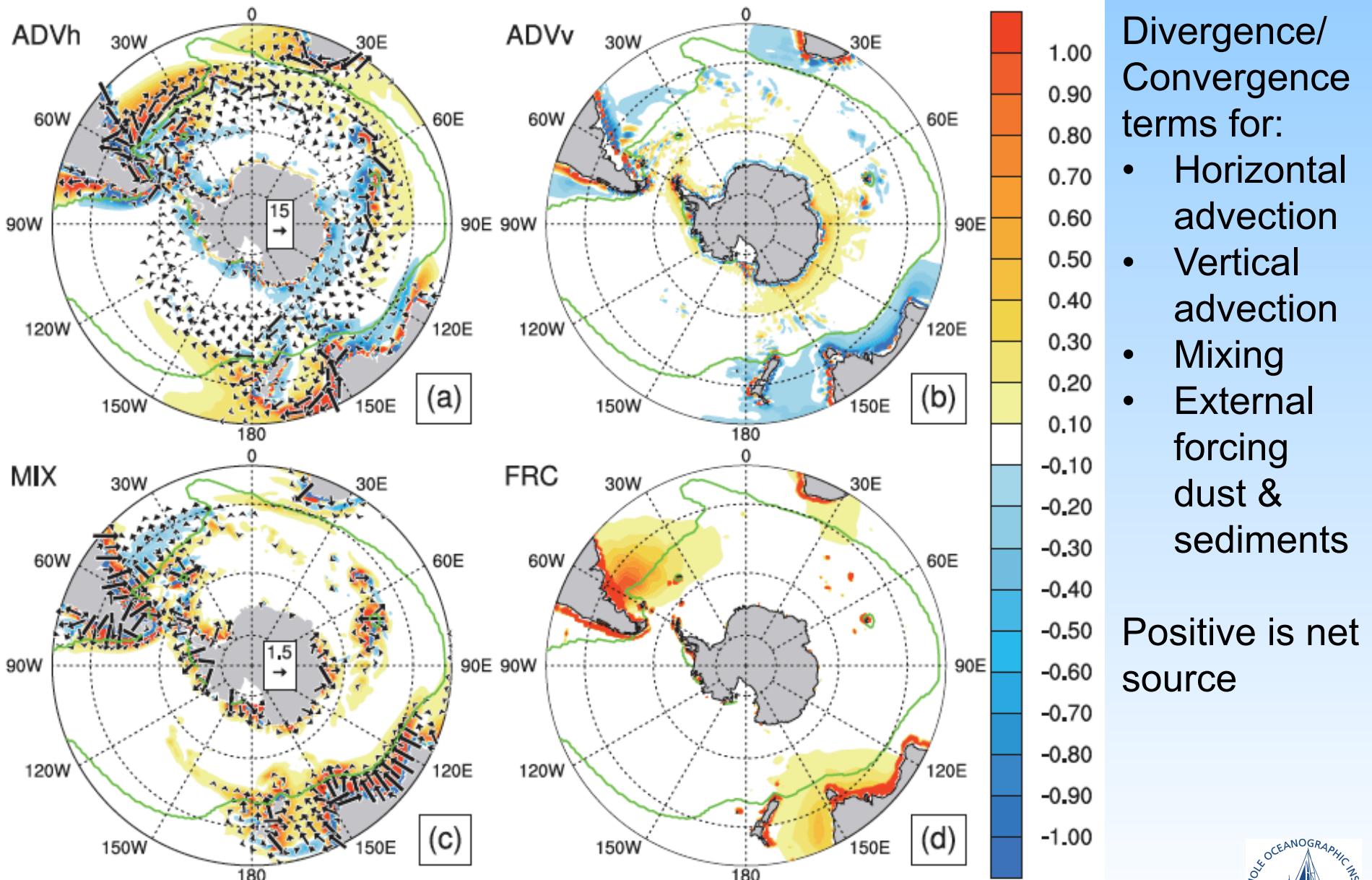


CESM1(BGC)

Moore et al., J. Climate 2013  
Boyd et al., Nature Climate Change 2015



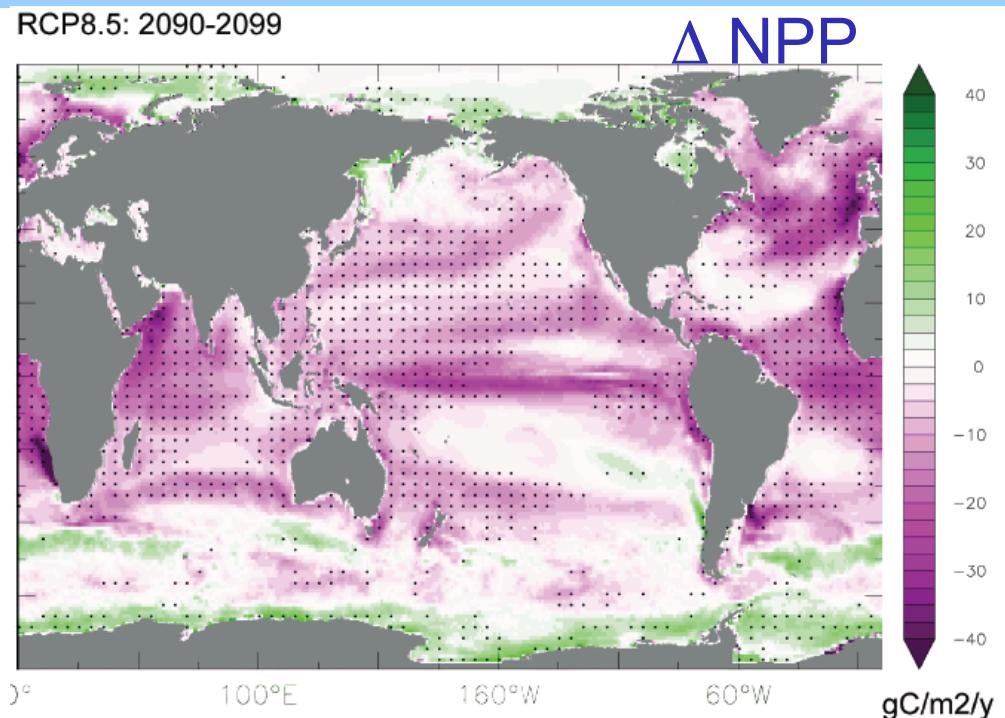
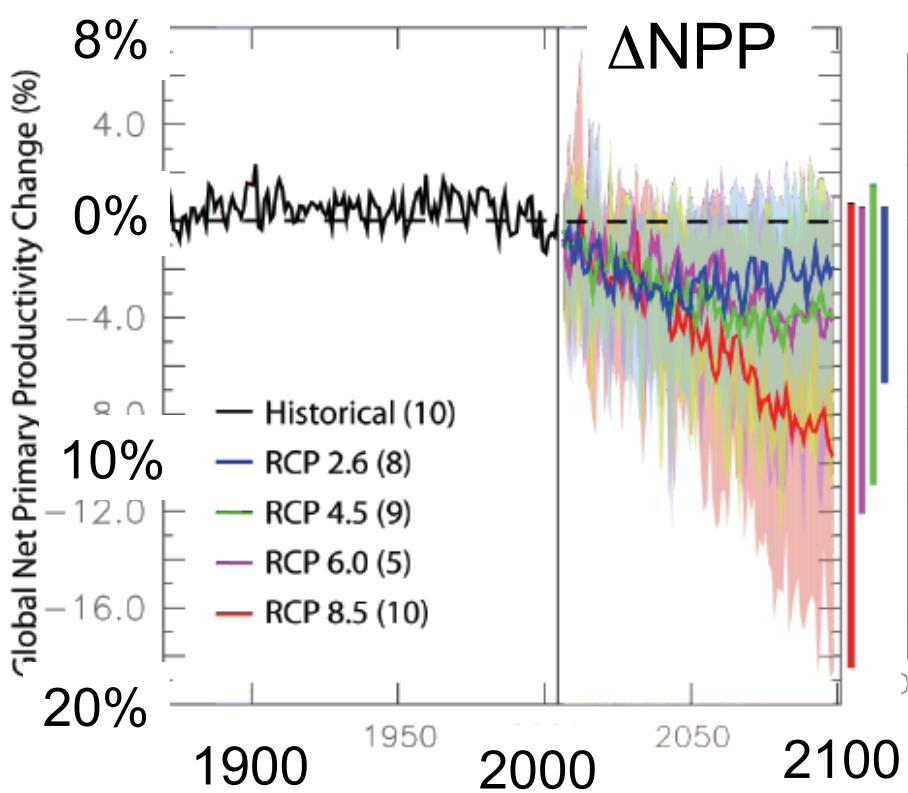
# Present-Day Southern Ocean Iron Budget Terms



Misumi et al. Biogeosciences 2014



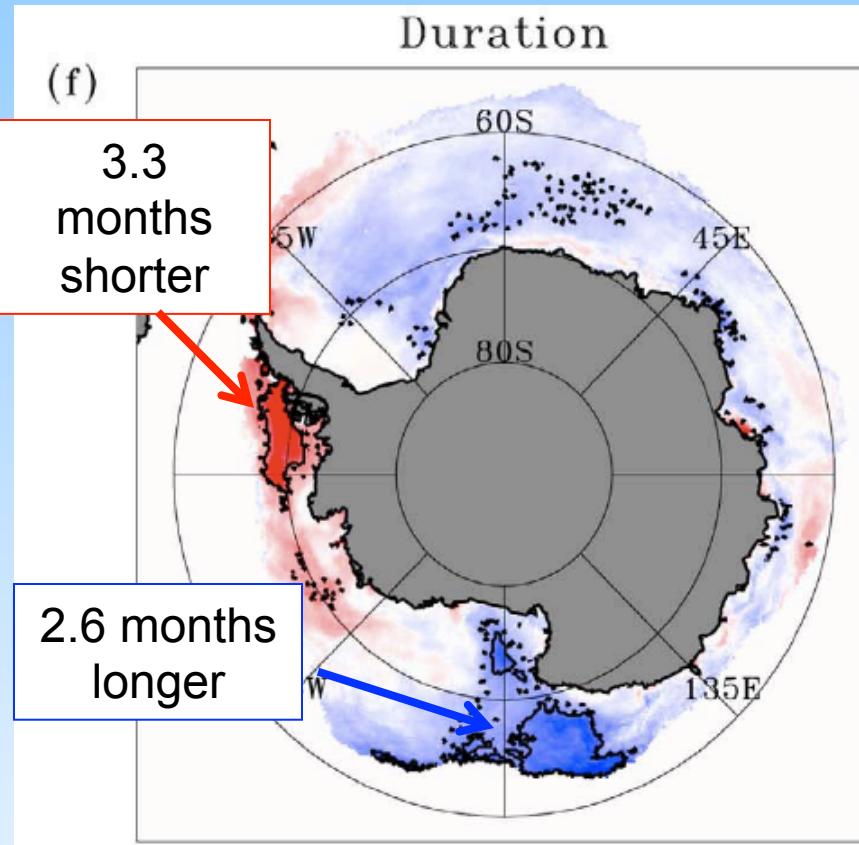
# Net Primary Productivity



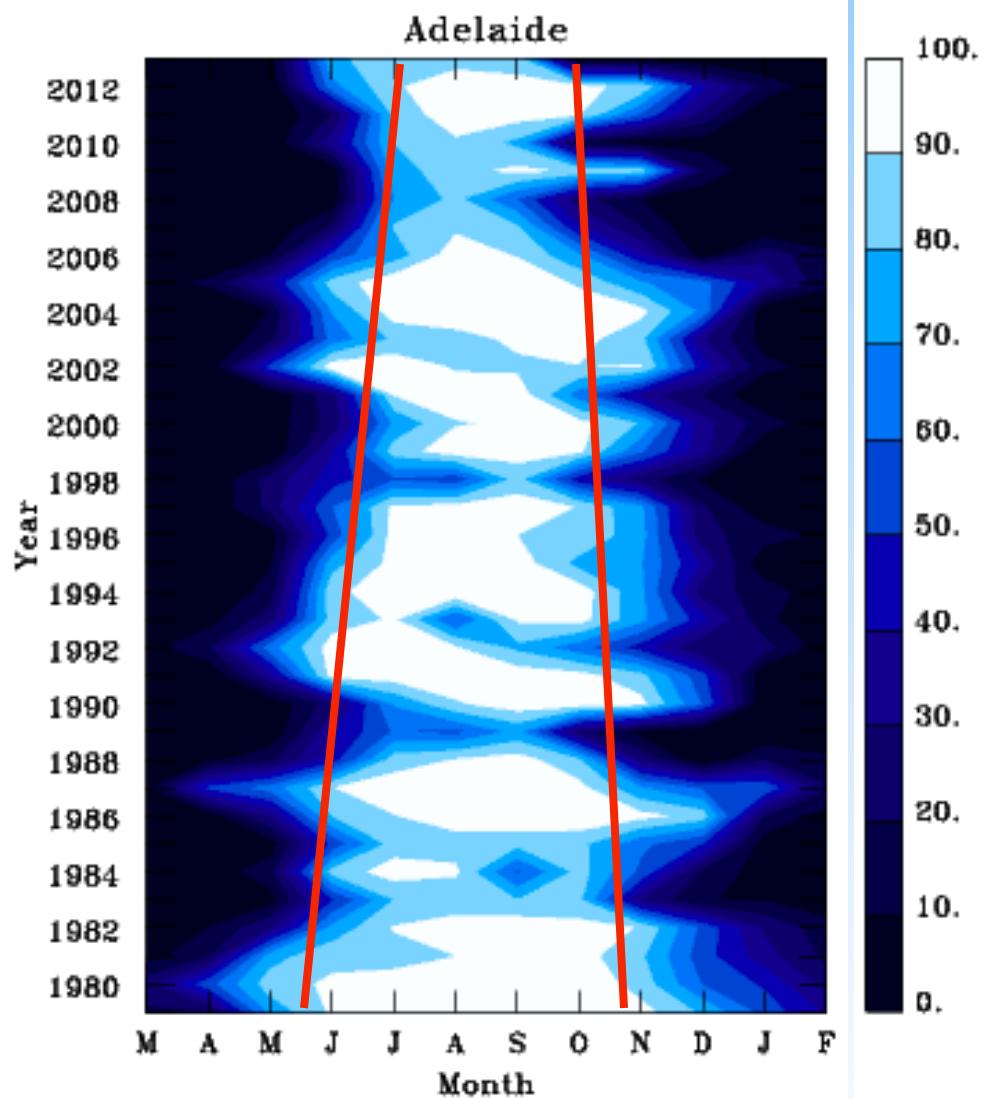
Bopp et al. Biogeosciences 2013



# Declining Seasonal Sea-ice along Peninsula

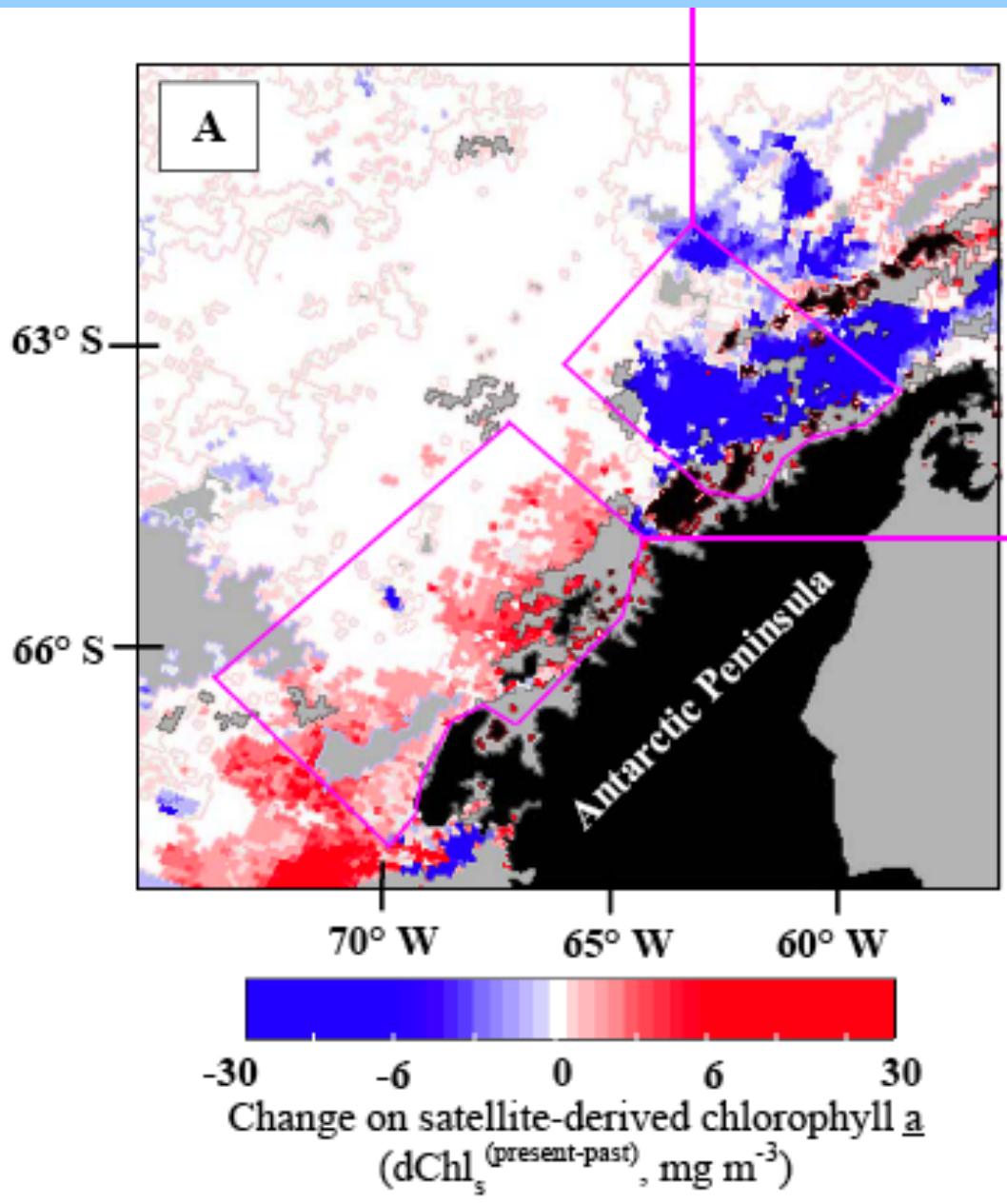


Stammerjohn et al.  
Geophysical Research Letters  
2012



Sharon Stammerjohn U Colorado Boulder

# Ecological Changes to Retreating Sea-Ice



Decadal Change in Surface Chlorophyll

Montes et al.  
Science (2009)



Region of Antarctic Peninsula

1978-'86

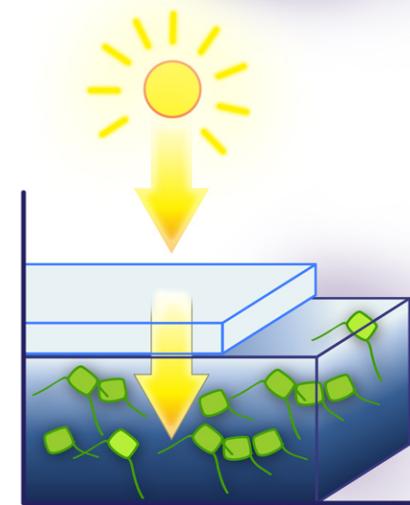
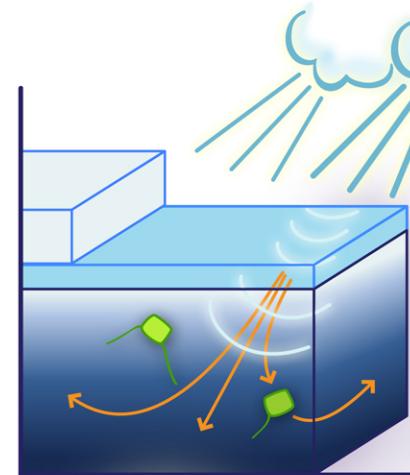
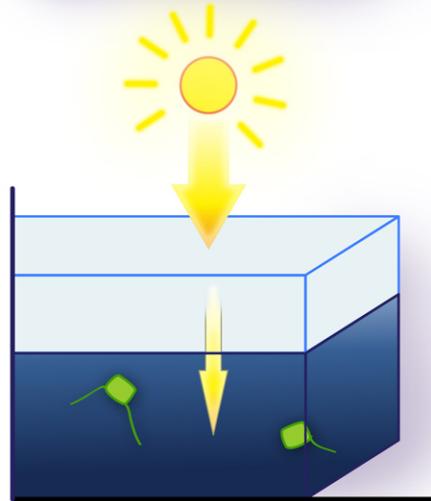
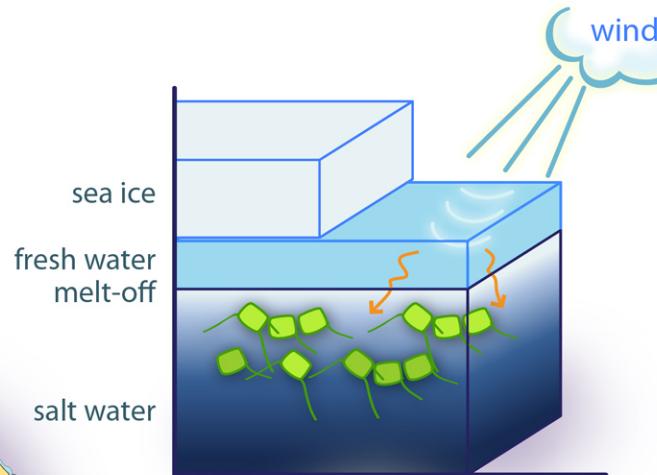
'98-2006

Phytoplankton

Northern



Southern



- Sea ice melt stabilizes upper ocean and fosters phytoplankton growth
- Long sea ice duration acts as a barrier to light penetration and prevents growth

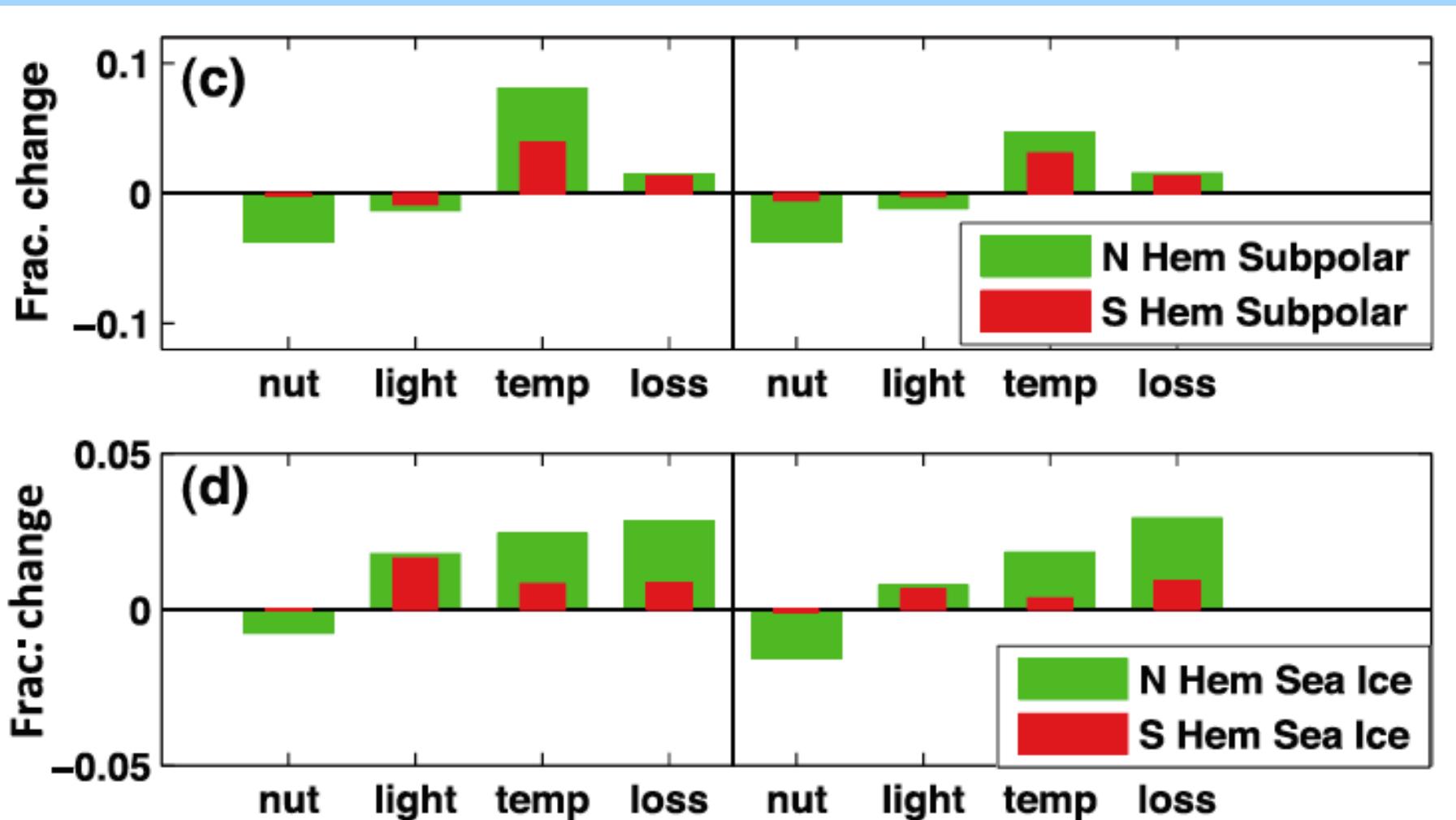
Courtesy Zina Deretsky, NSF



# Effects on Growth & Community Structure

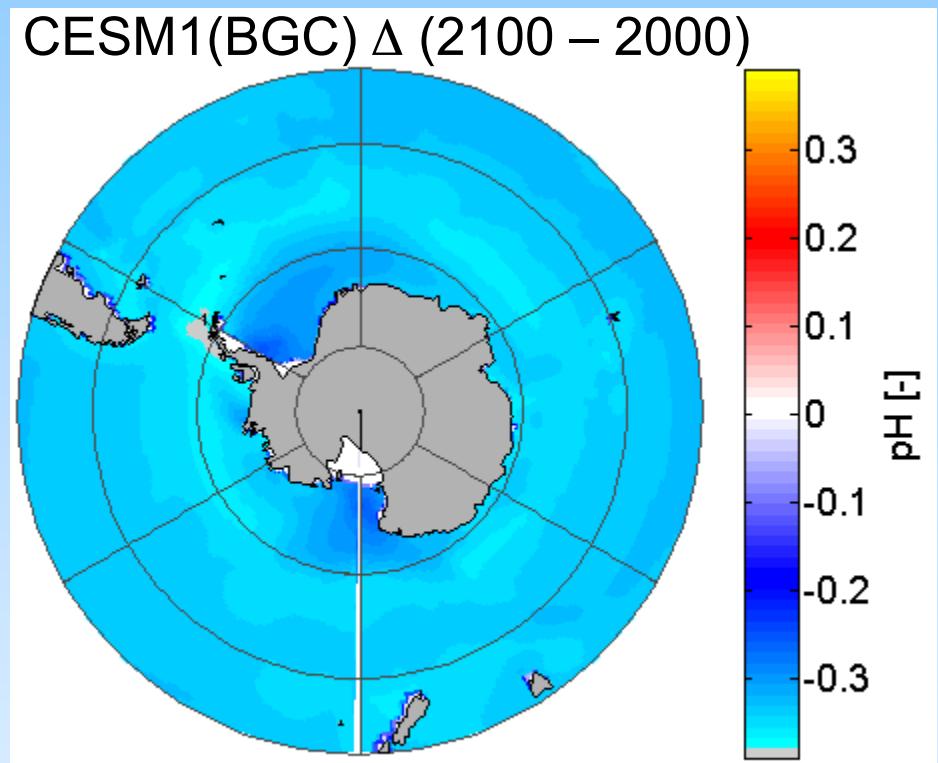
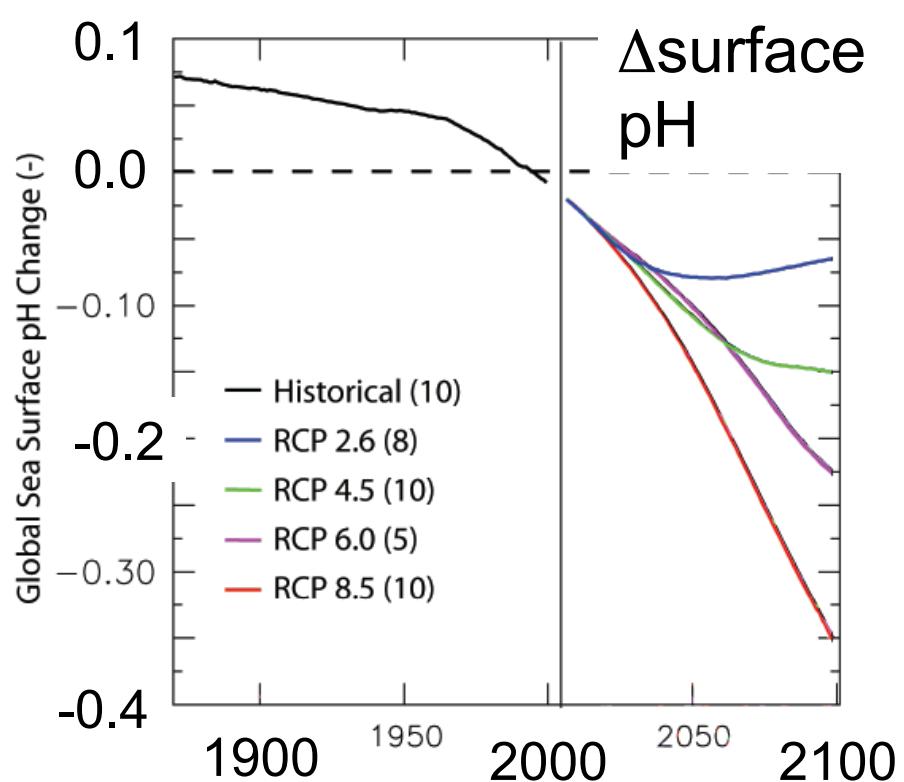
Small Phytoplankton  
Growth Rate

Diatom  
Growth Rate



Marinov et al. Global Biogeochemical Cycles 2013

# Ocean Acidification

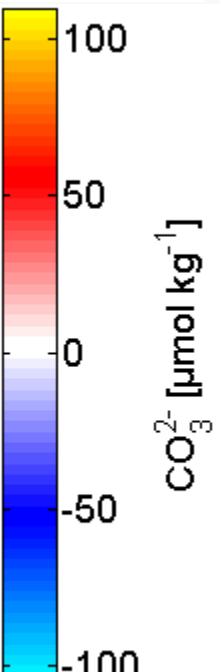
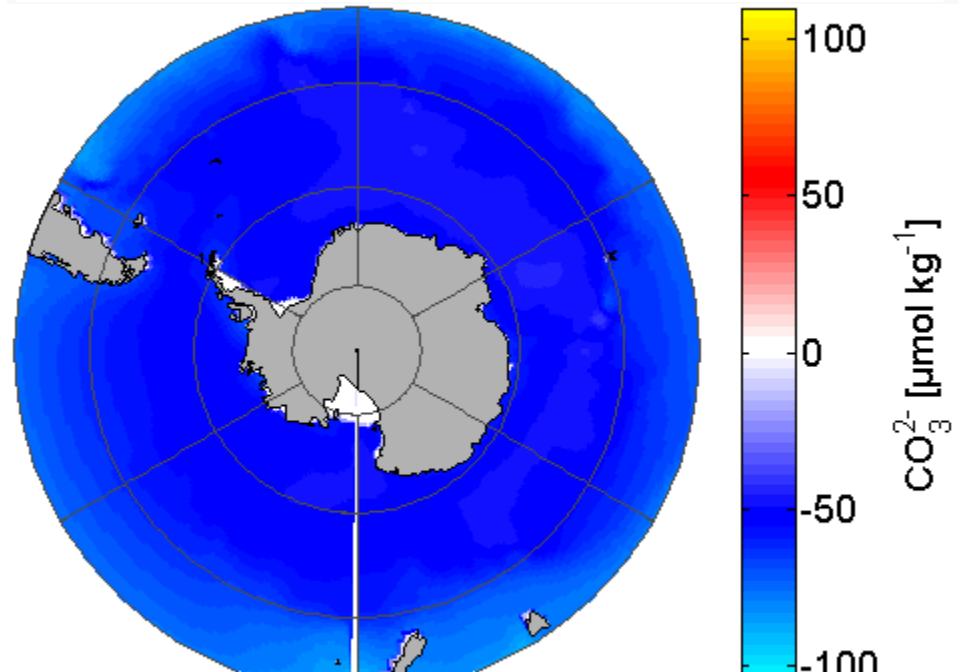
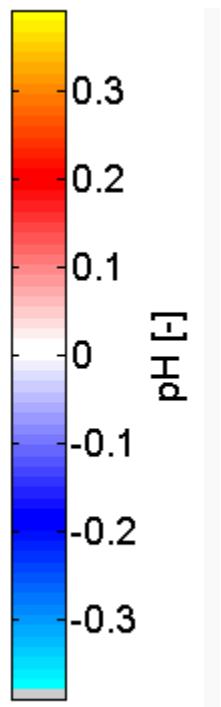
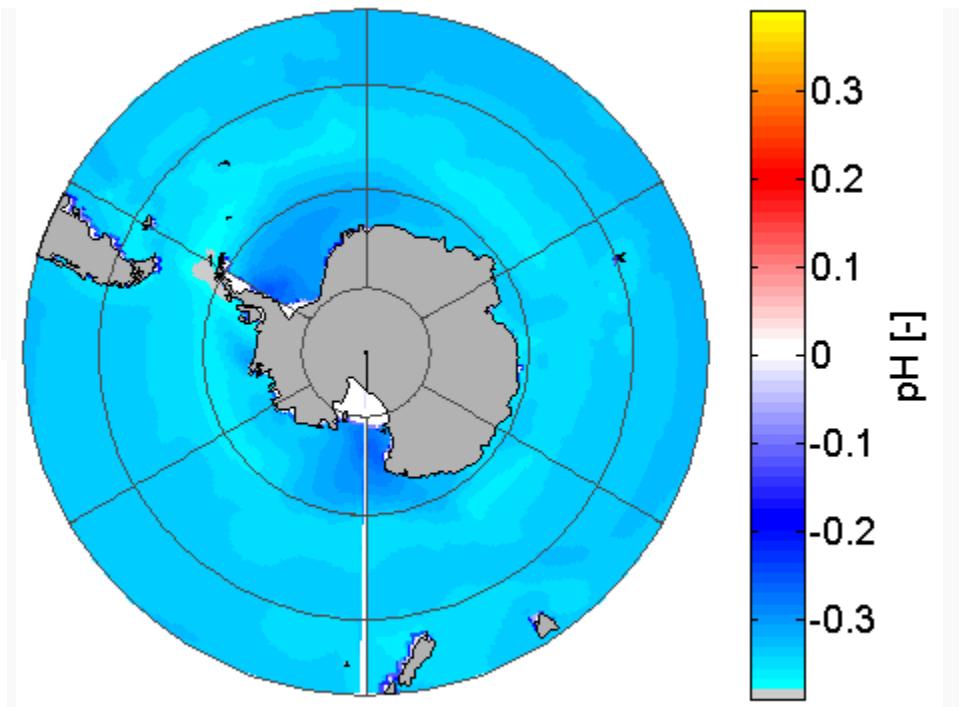
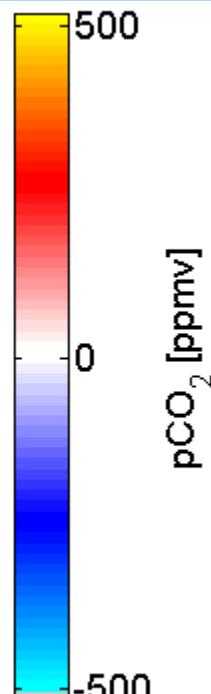
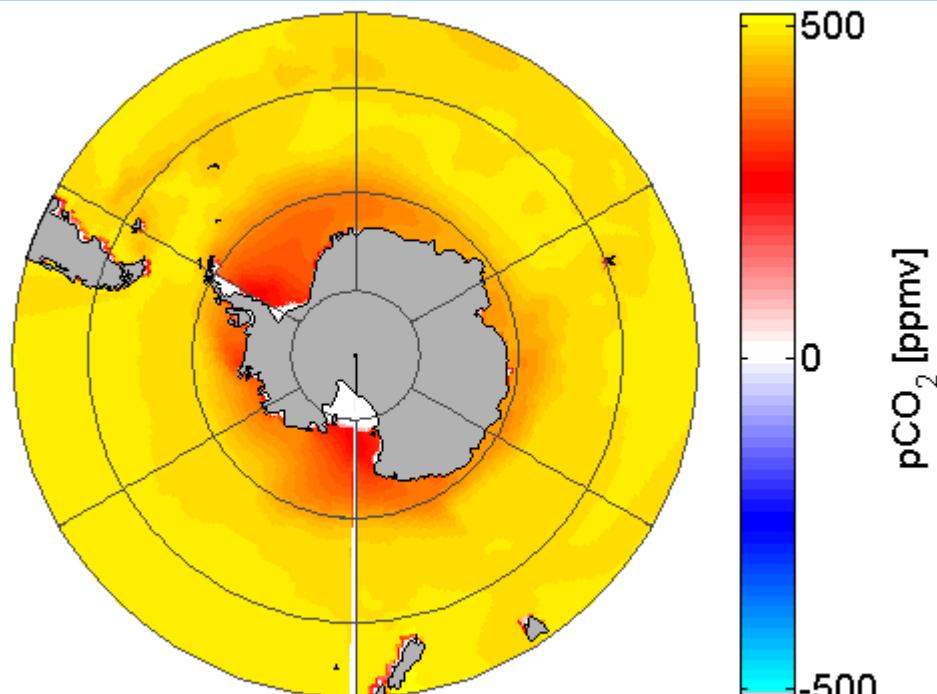


Bopp et al. Biogeosciences 2013

Moore et al., J. Climate 2013  
Boyd et al., Nature Climate Change 2015



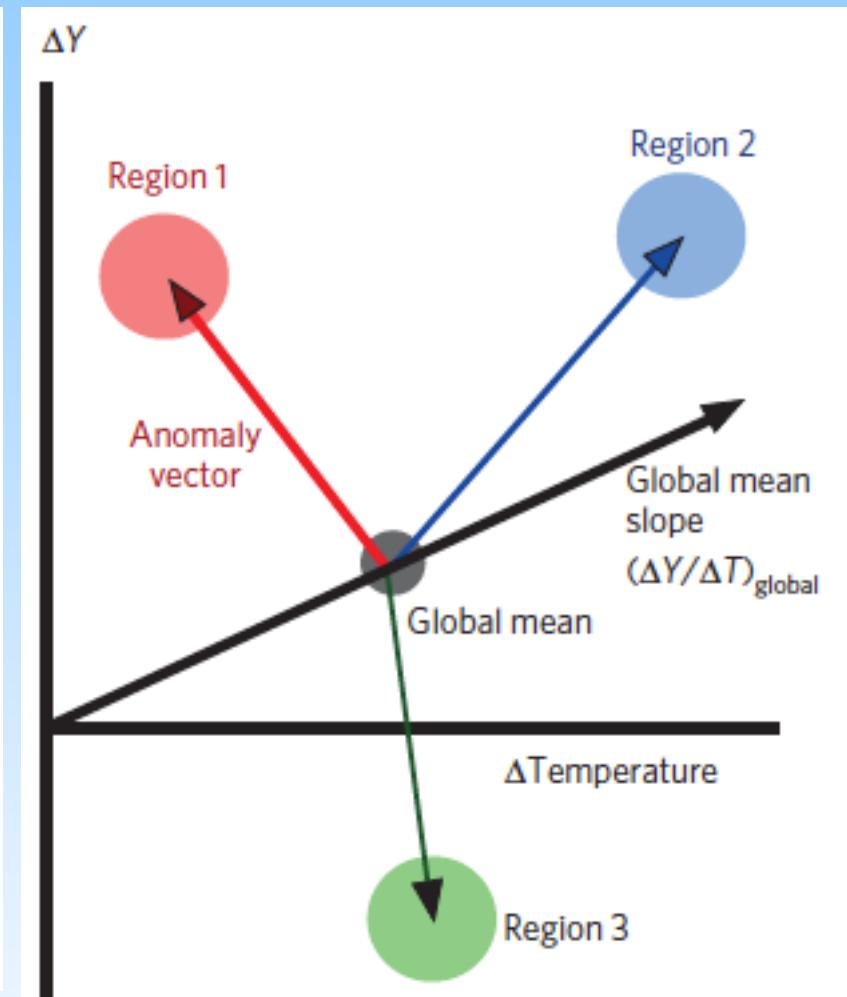
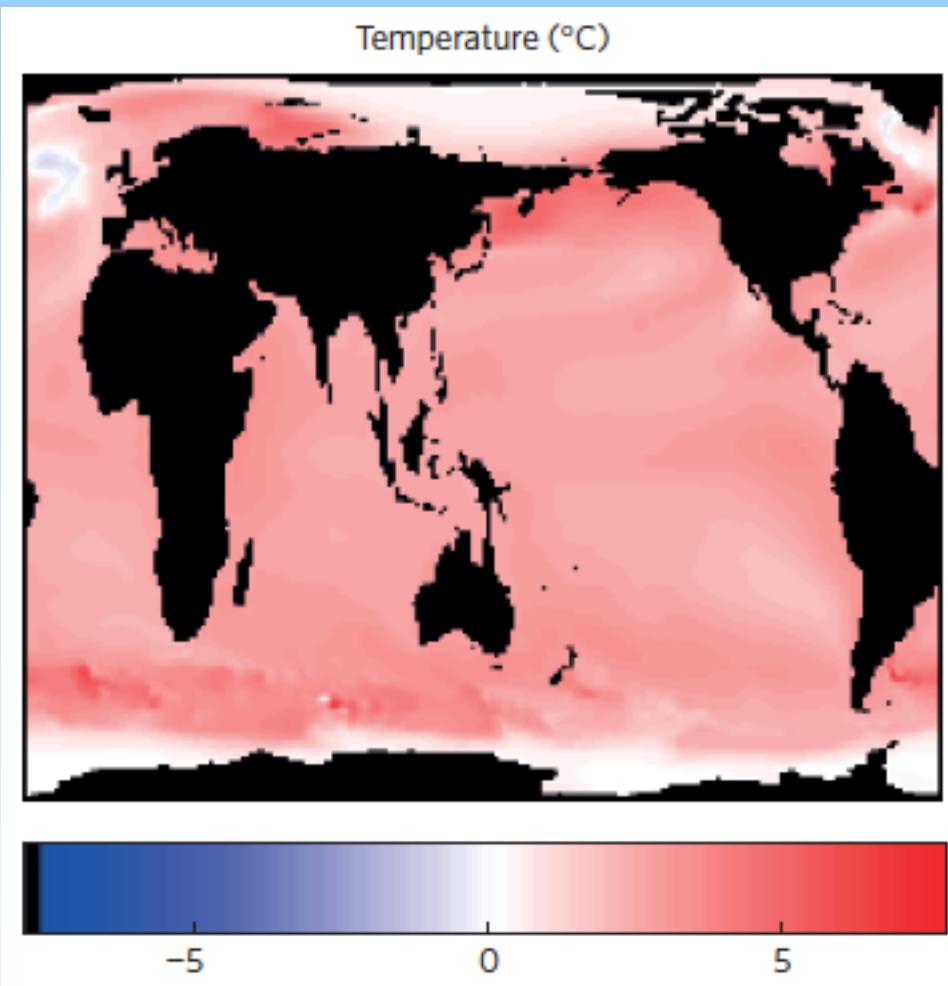
# Ocean Acidification



CESM1(BGC)

Moore et al., J. Climate 2013  
Boyd et al., Nature Climate Change 2015

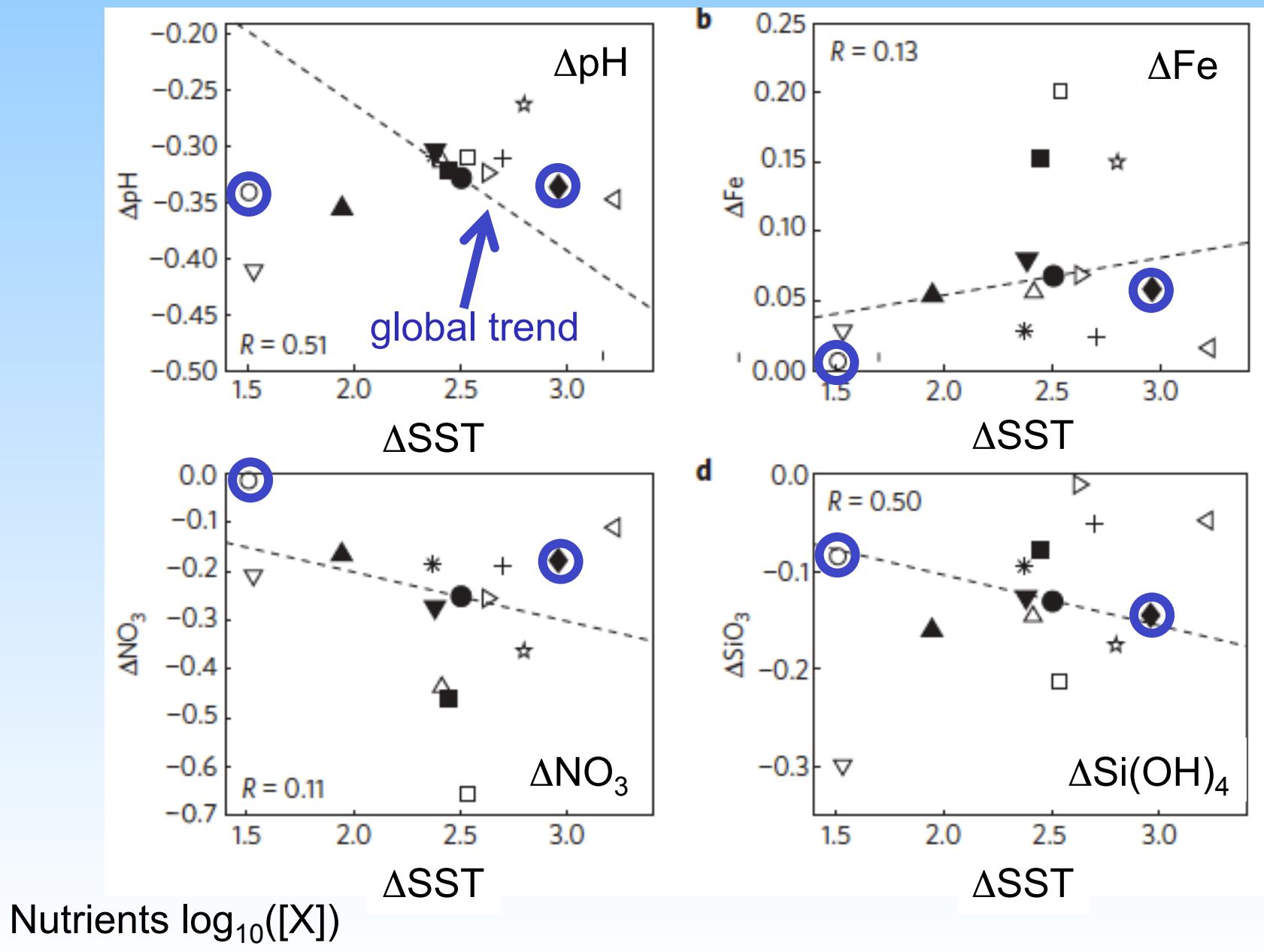
# Regional Climate Signals: “Climate Clusters”



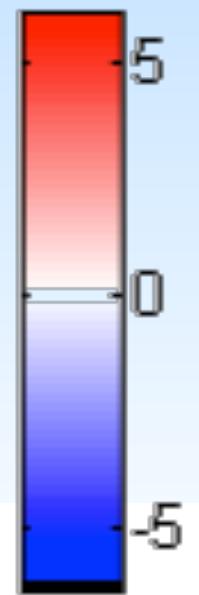
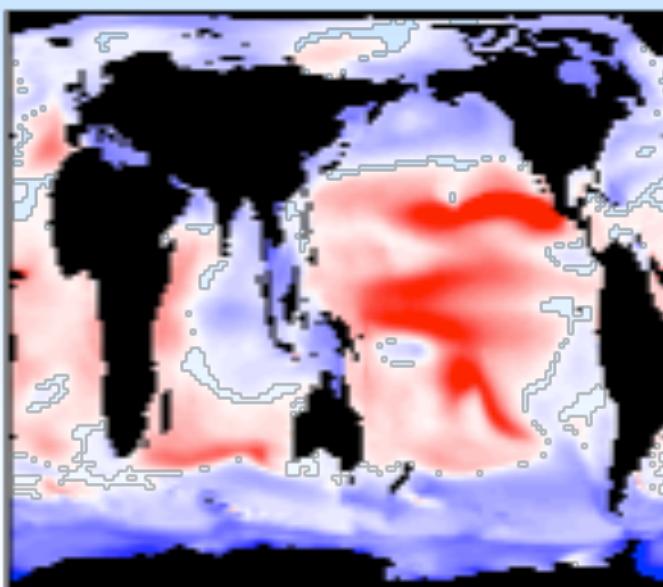
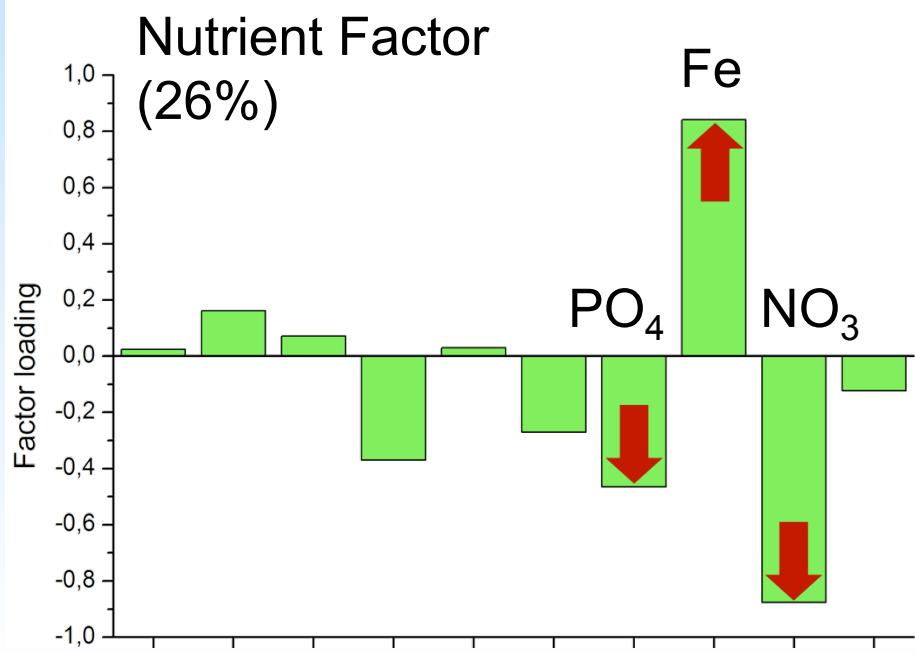
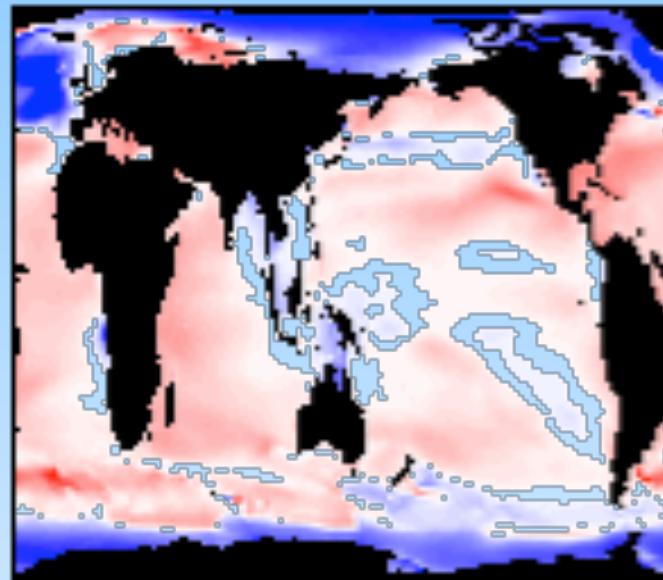
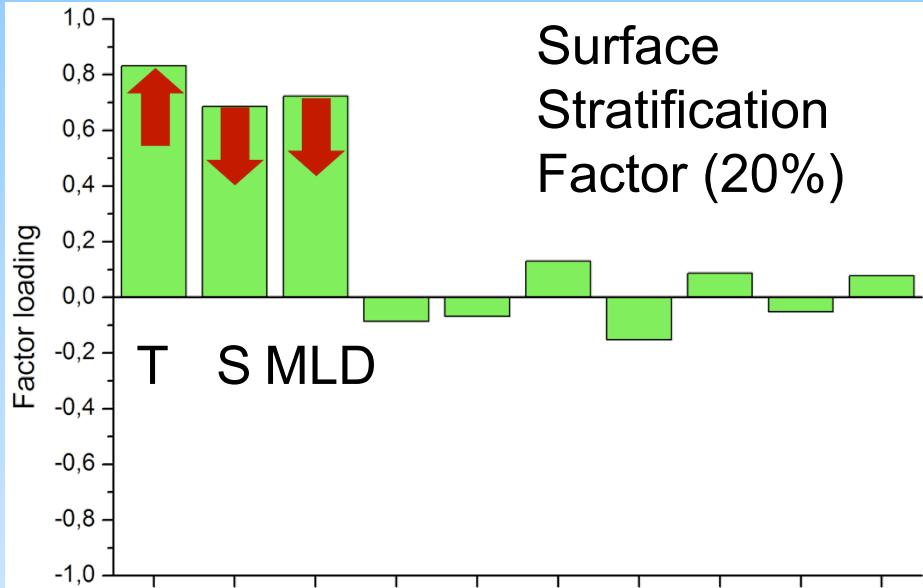
Boyd, Lennartz, Glover & Doney  
Nature Climate Change 2015



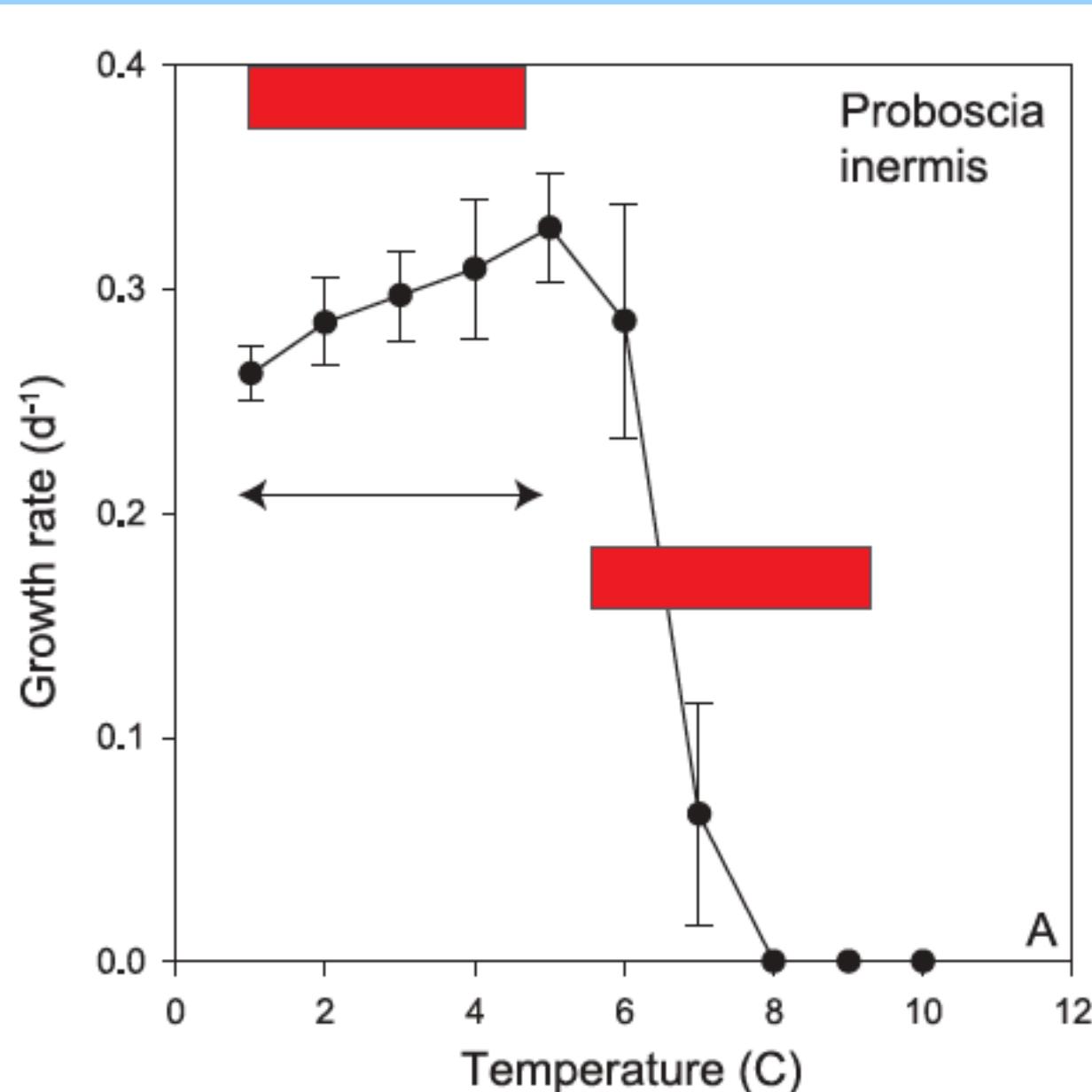
# Global Trends vs. Regional Variation



# Principal Component Analysis (PCA)



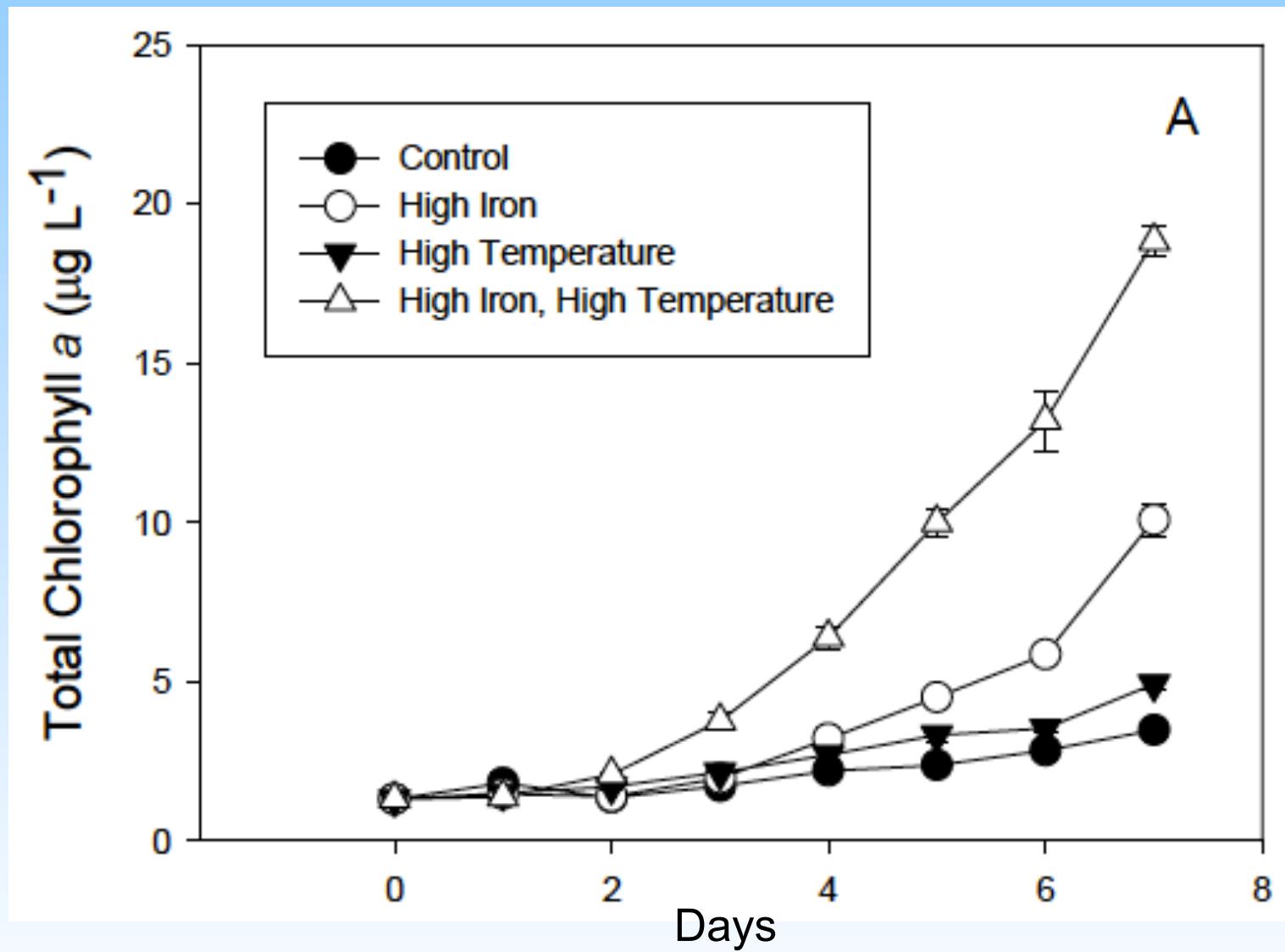
# Temperature-Growth Curves



Boyd et al.  
PLoS One  
2013



# Interactive Effects of Multiple Environmental Drivers



Rose et al. Biogeosciences 2009



High-latitude provinces (NSO; NAO)	Temp. (2.96 °C; 1.94 °C)	CO <sub>2</sub> (143%; 151%)	Silicate (32%; 29%)
	↑	↑	↓
<b>Coccolithophores</b>			
Effects of individual stressors	Warming enhances growth rates by ~25% (NAO; ref. 44)	Alters calcification (0–20% decrease, NSO; ref. 45)	–
Effects of interactive stressors	Warming and high CO <sub>2</sub> cause a 40% decrease in calcification, but increase coccolithophore stocks (NAO; ref. 22)	Interactions with warming <sup>22</sup> (see left), and high PAR (ref. 31; see right)	–
<b>Diatoms</b>			
Effects of individual stressors	Warming enhances growth by 35% (20); warming decreases cellular P requirements <sup>46</sup>	High CO <sub>2</sub> favours some diatom species and enhances NPP (ref. 32)	Decreases silicification <sup>48</sup>
Effects of interactive stressors	Warming and iron supply cause 400% enhancement of growth rates <sup>14</sup>	–	Iron, PAR and silicate interact to control summer diatom growth rates <sup>47</sup> (NSO)

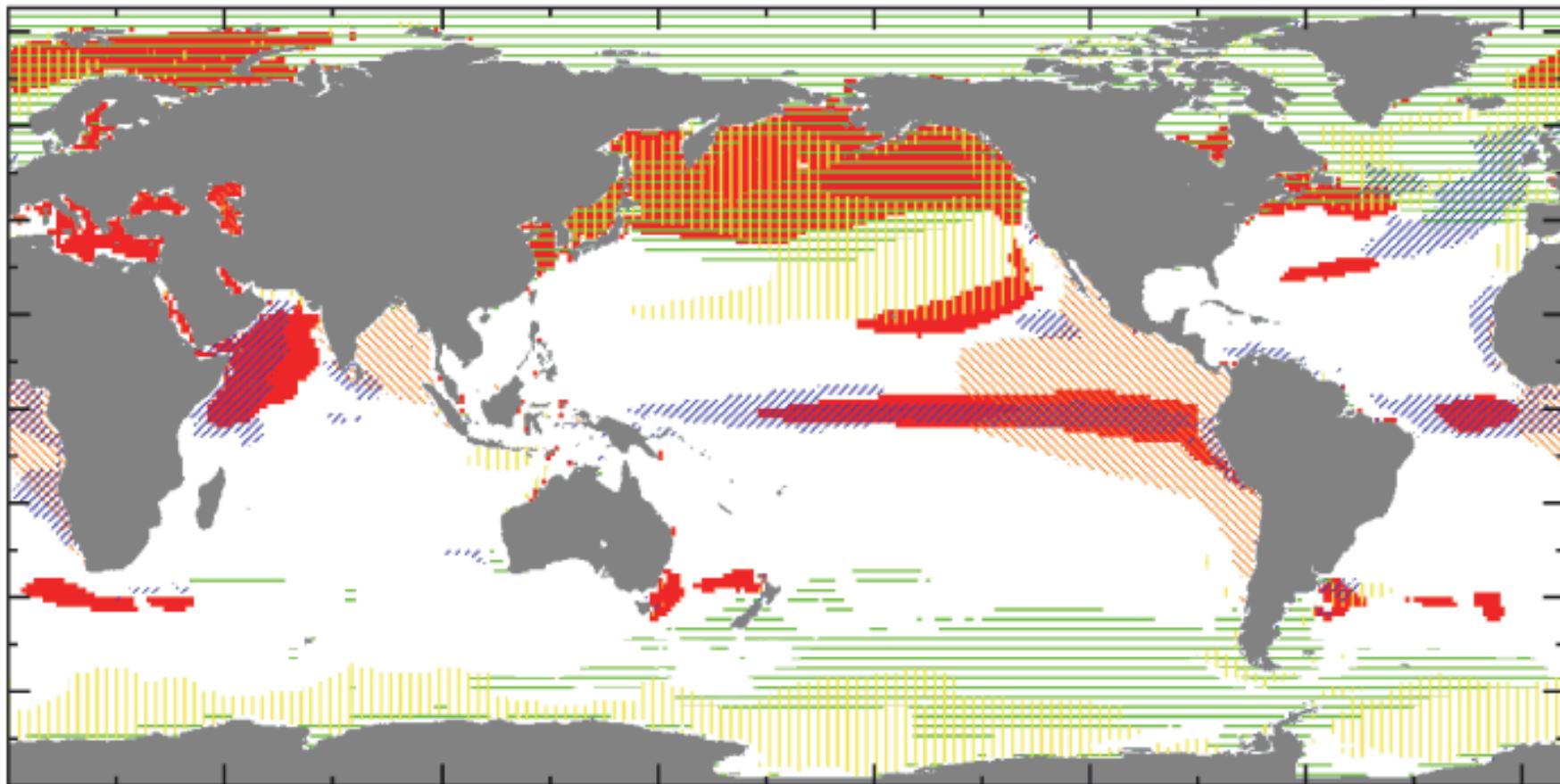
Boyd, Lennartz, Glover & Doney  
Nature Climate Change 2015



# Regional Variation in Multiple Stressors

RCP8.5 - 2090s, changed from 1990s

Bopp et al. Biogeosciences 2013



$\Delta\text{SST} > 3.5 \text{ K}$

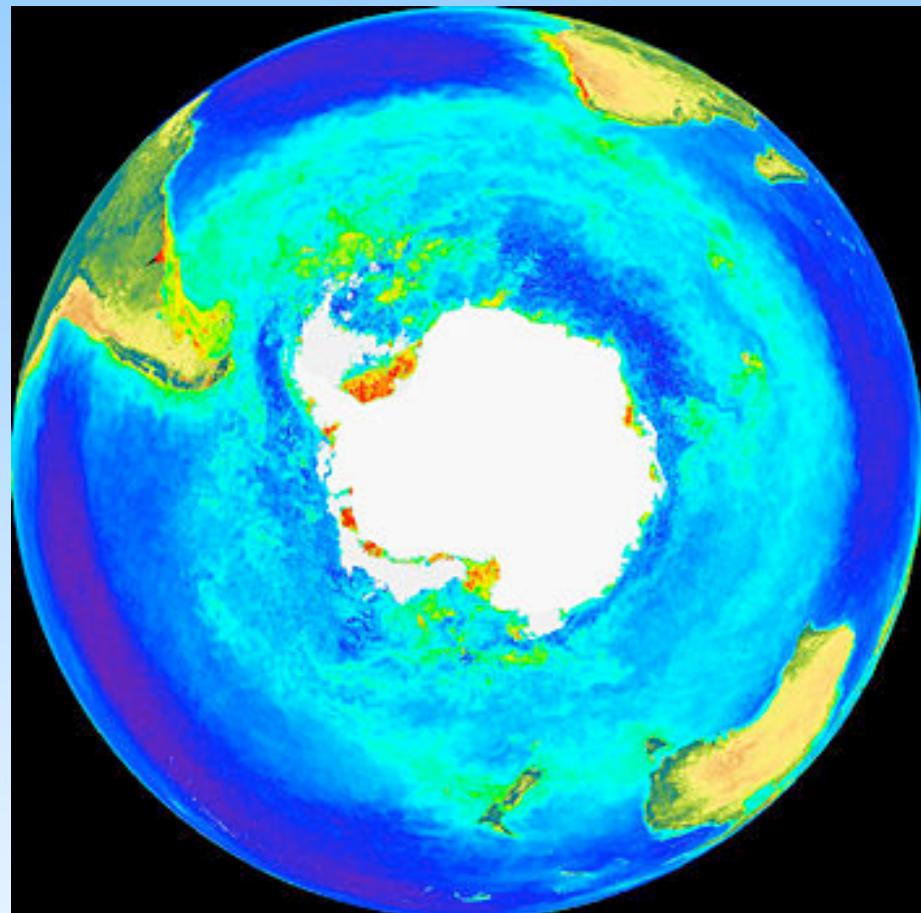
$\Delta\text{pH} < -0.35$

$\Delta\text{NPP} < -100 \text{ mgC m}^{-2} \text{ y}^{-1}$

$\Delta\text{O}_2 < -20 \text{ mmol m}^{-3}$

$\text{O}_2 < 50 \text{ mmol m}^{-3}$

# Talk Outline



Earth System Model Projections:

- multiple stressor trends
- regional variability

Guide design & interpretation of  
field/lab manipulation studies



