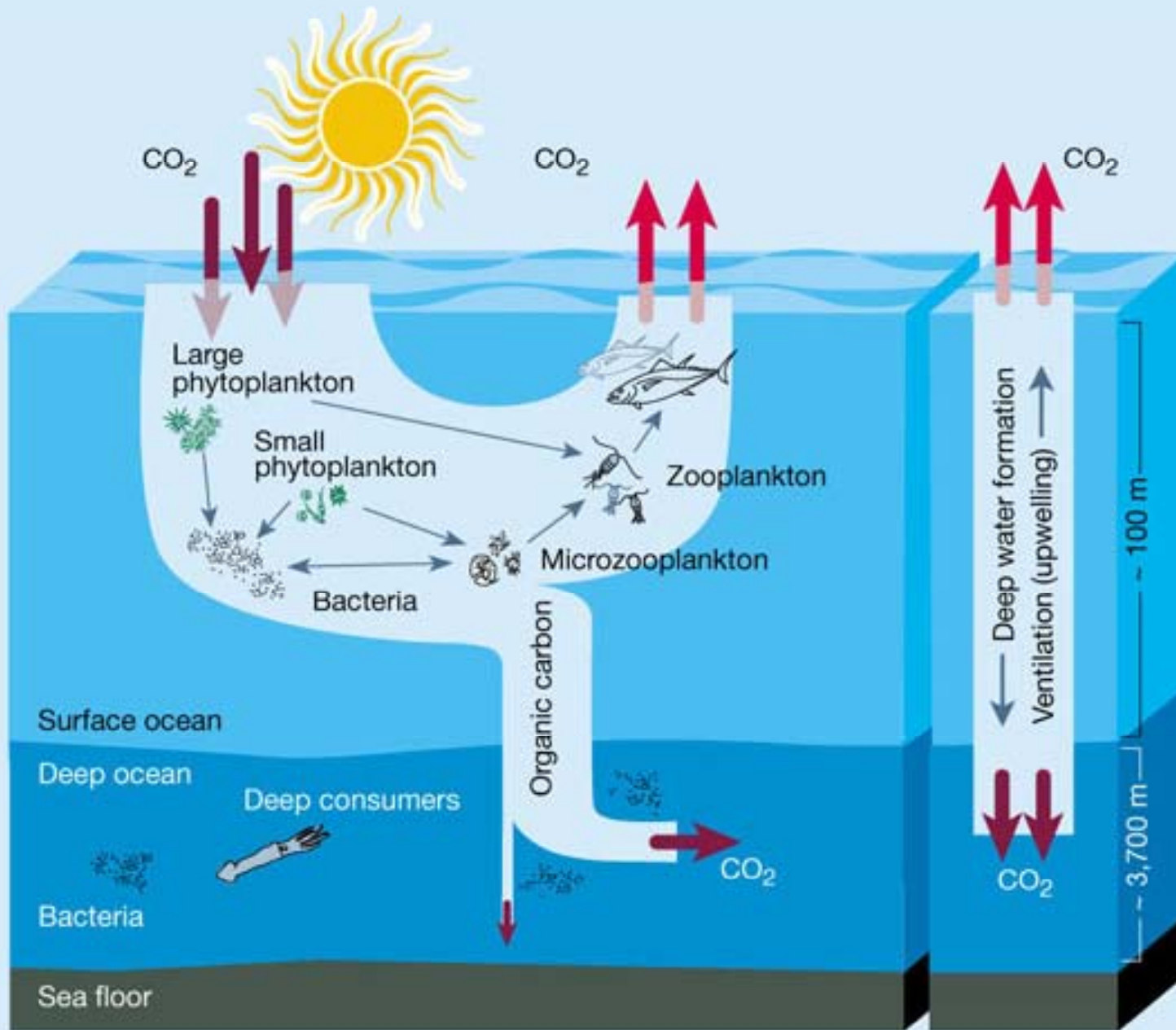
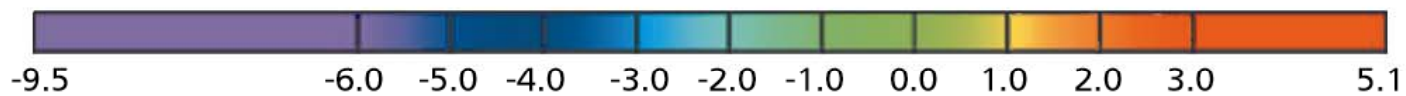
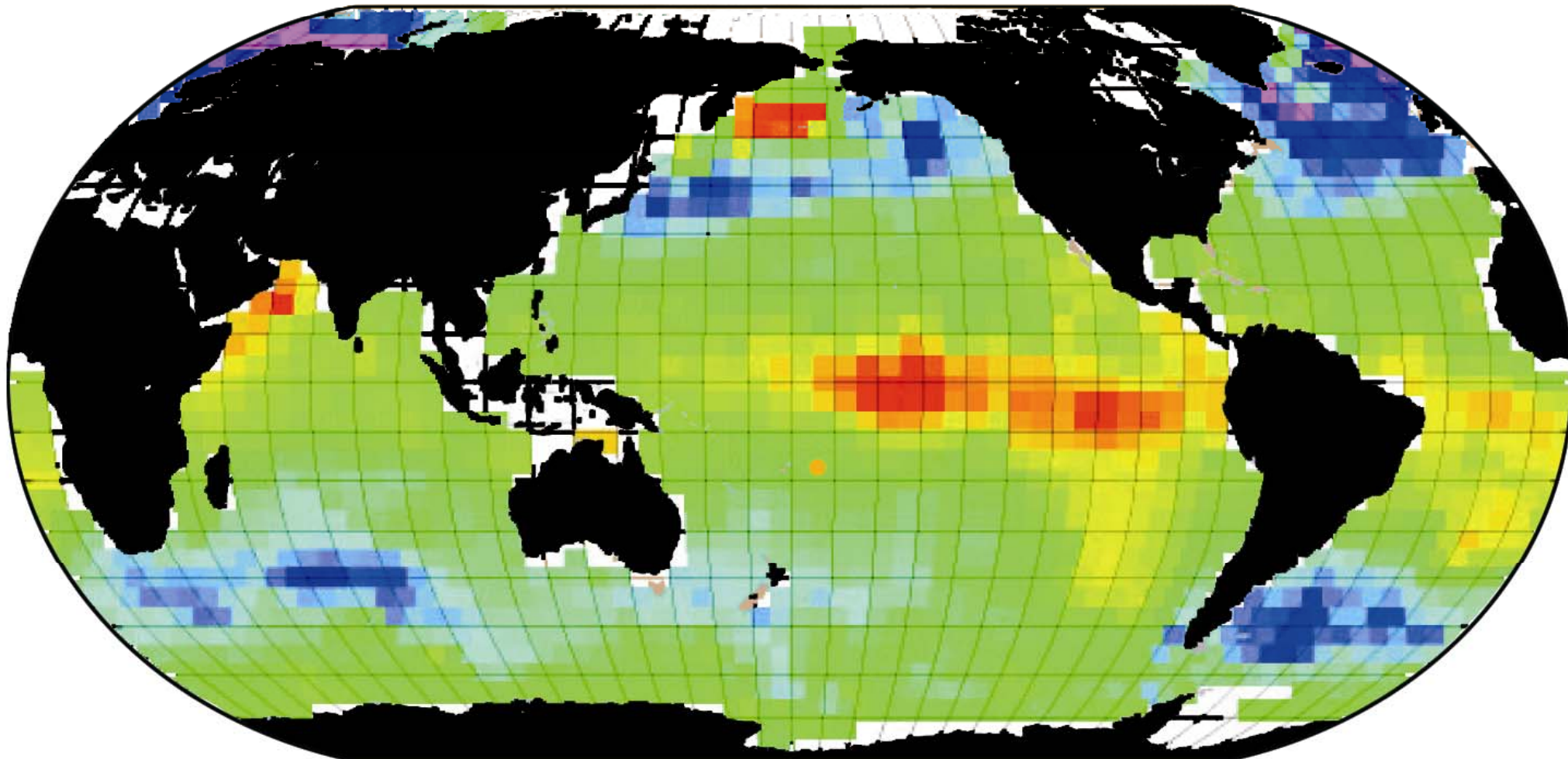


NASA MODIS



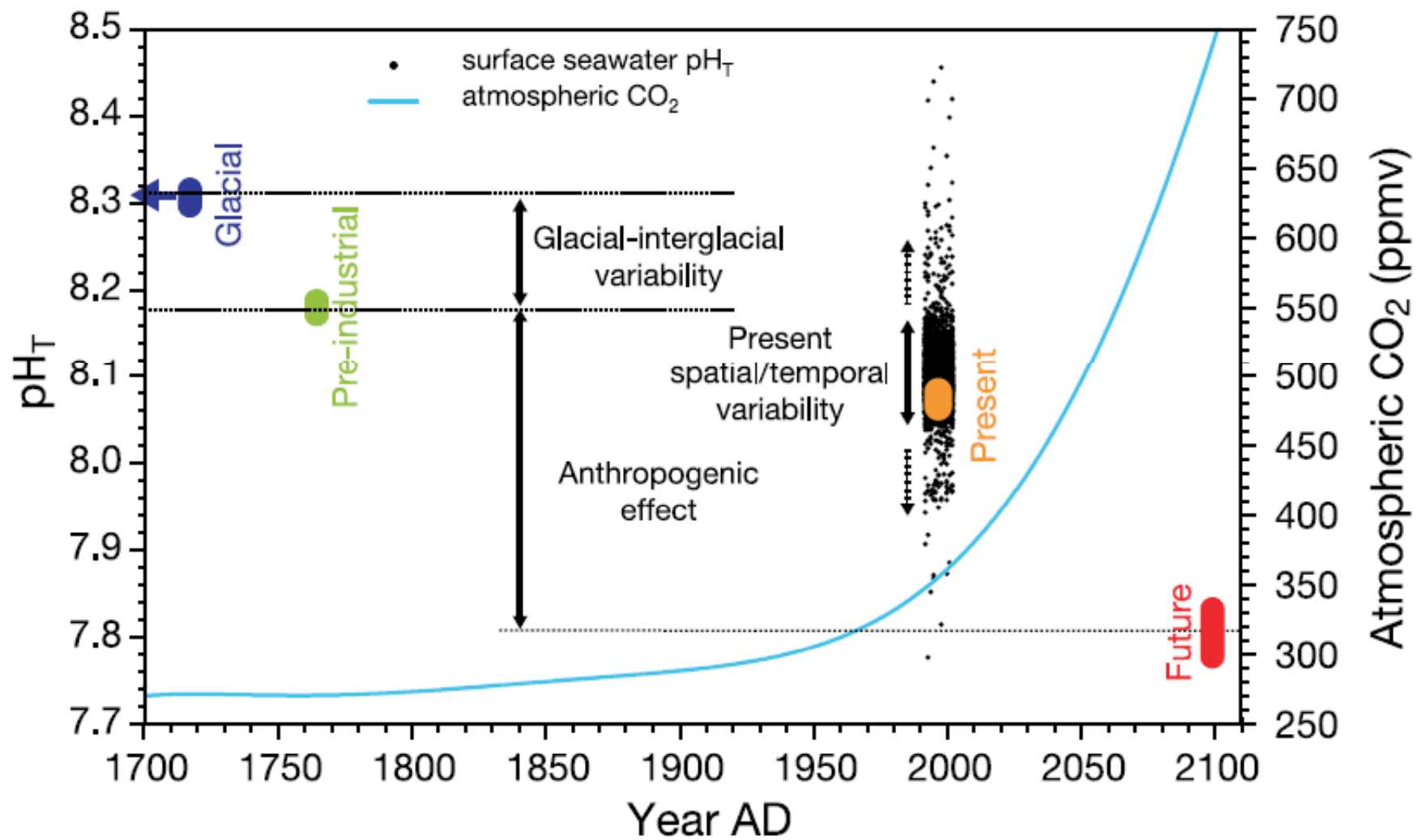
Chisholm 2000



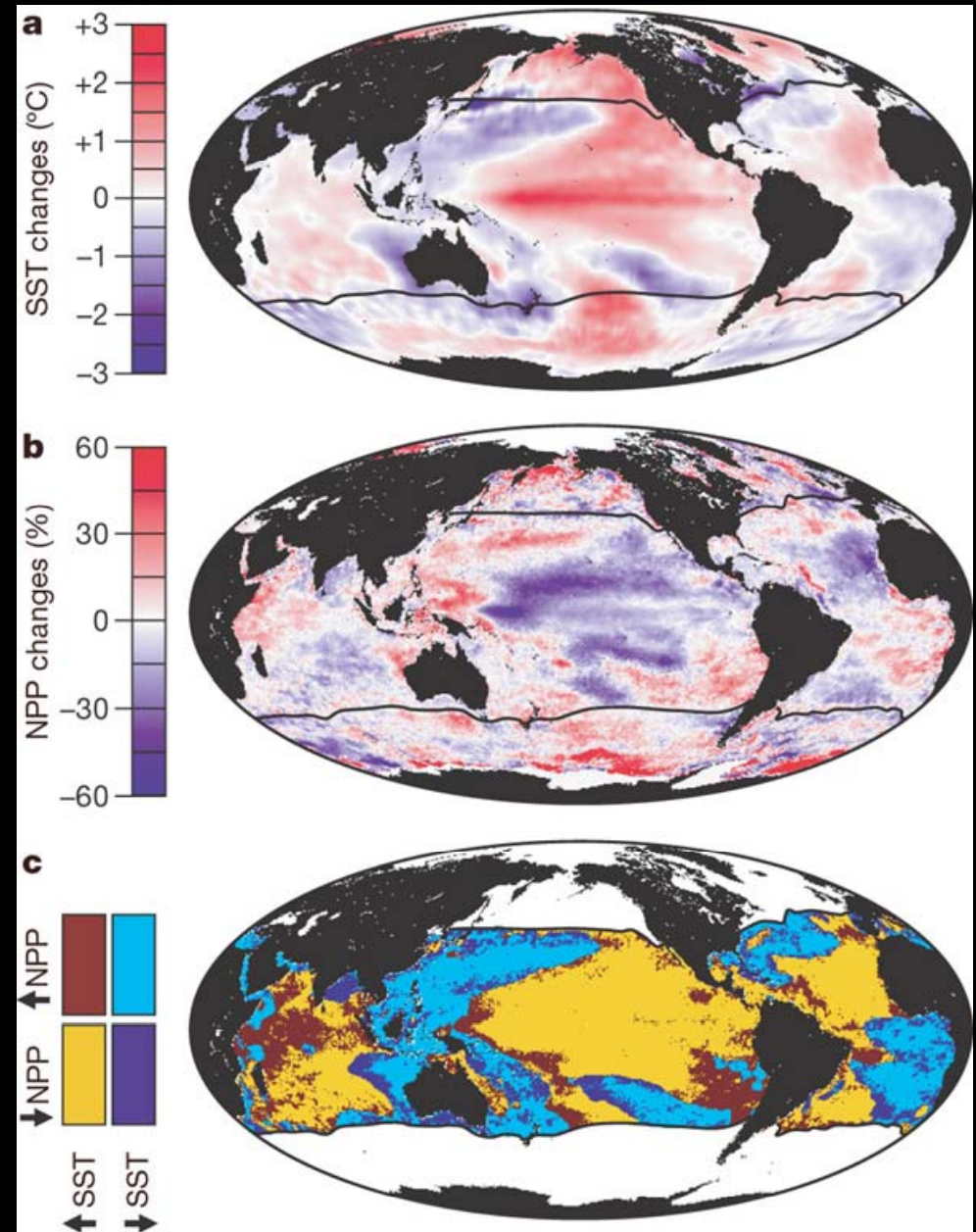
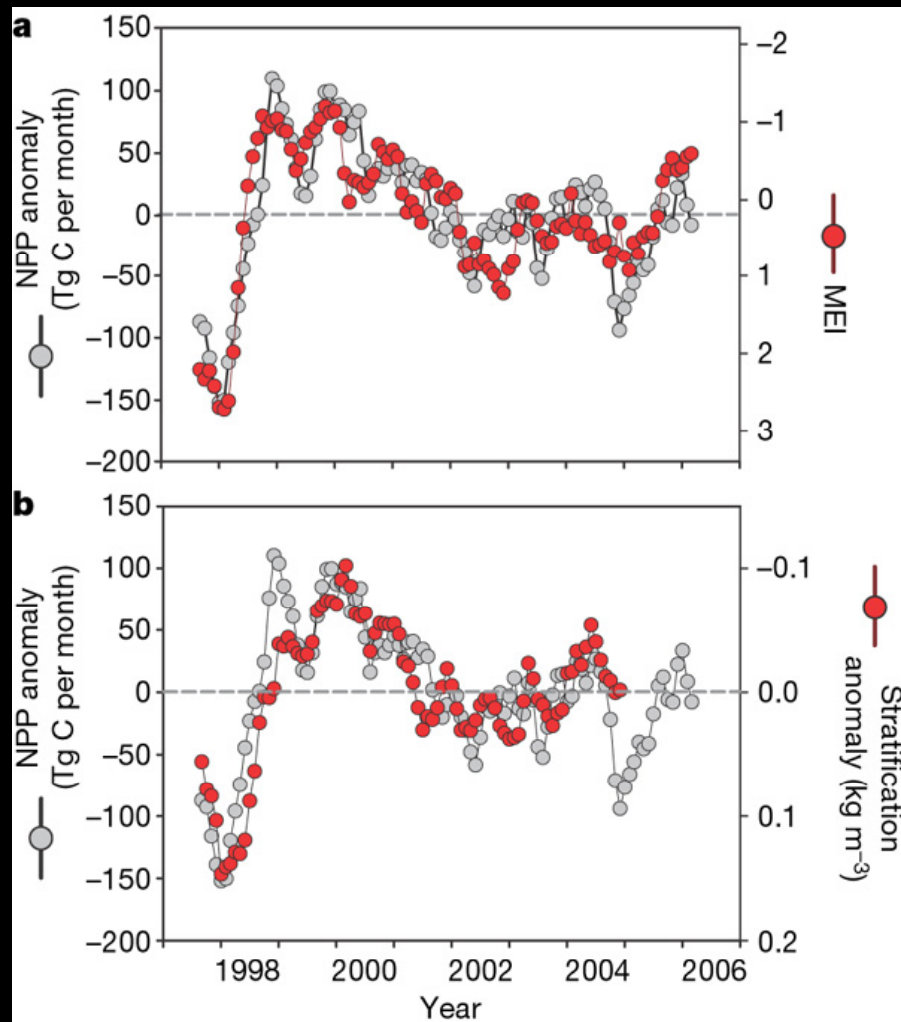
*CO<sub>2</sub> Flux (moles carbon dioxide per square meter per year)*

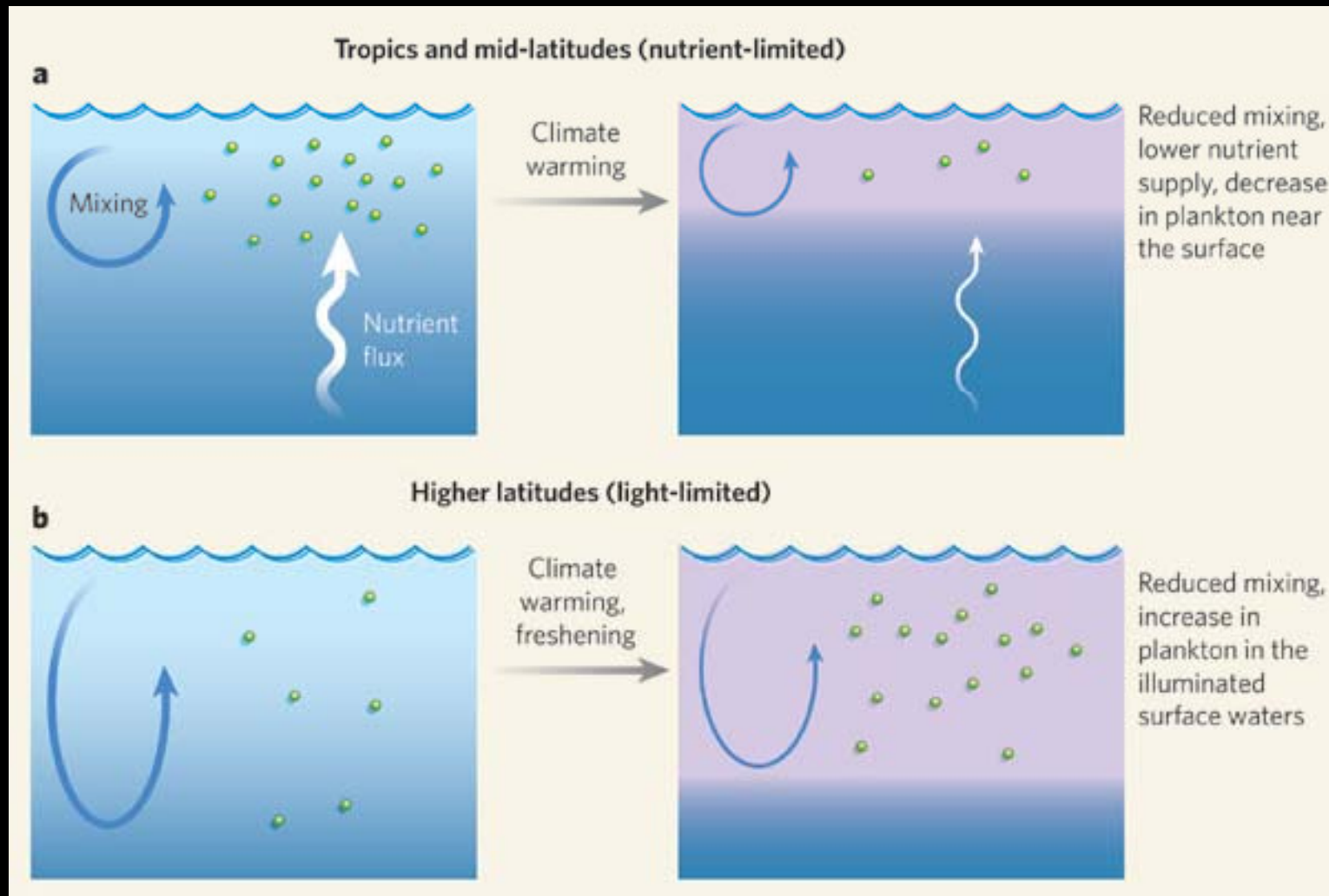
**U.S. JGOFS**

*Feely et al 2001*



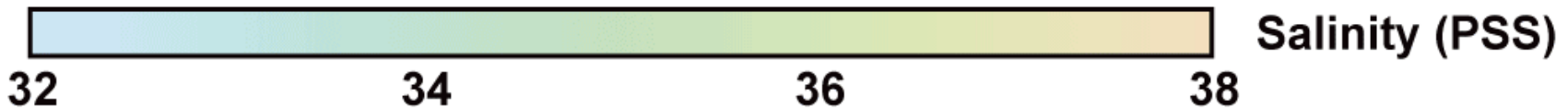
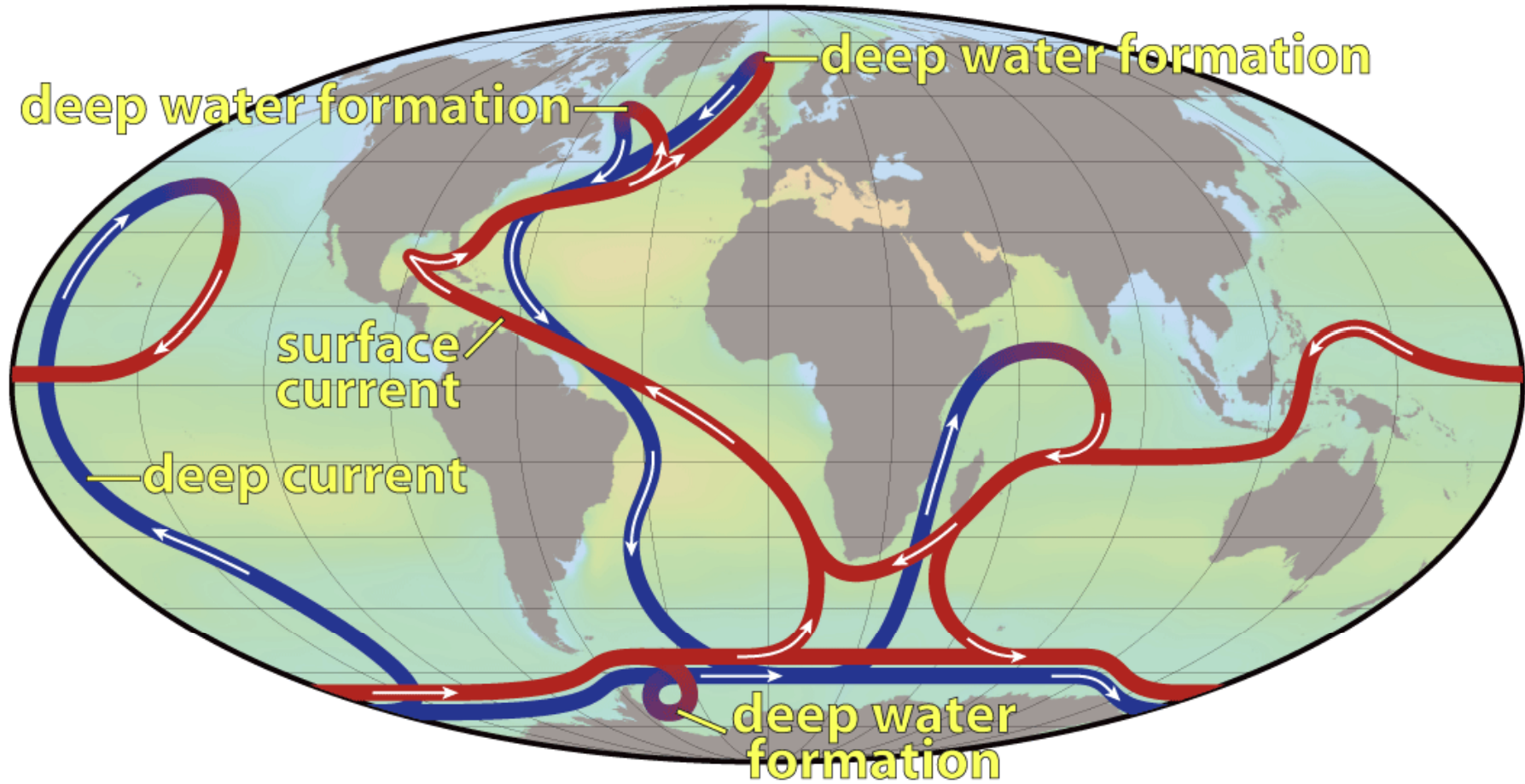
*IMBER Science Plan, 2005*

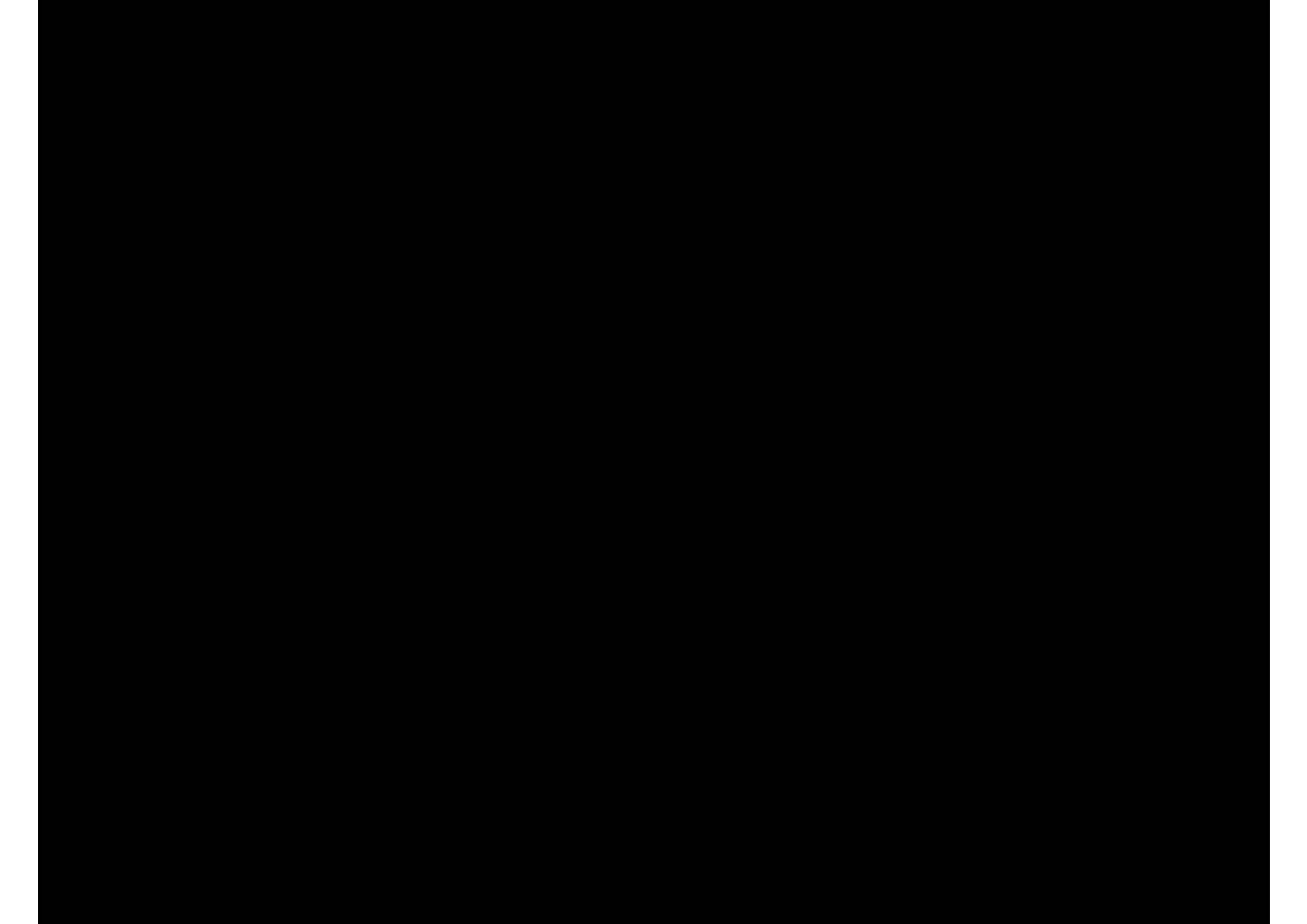




*Doney et al 2006*

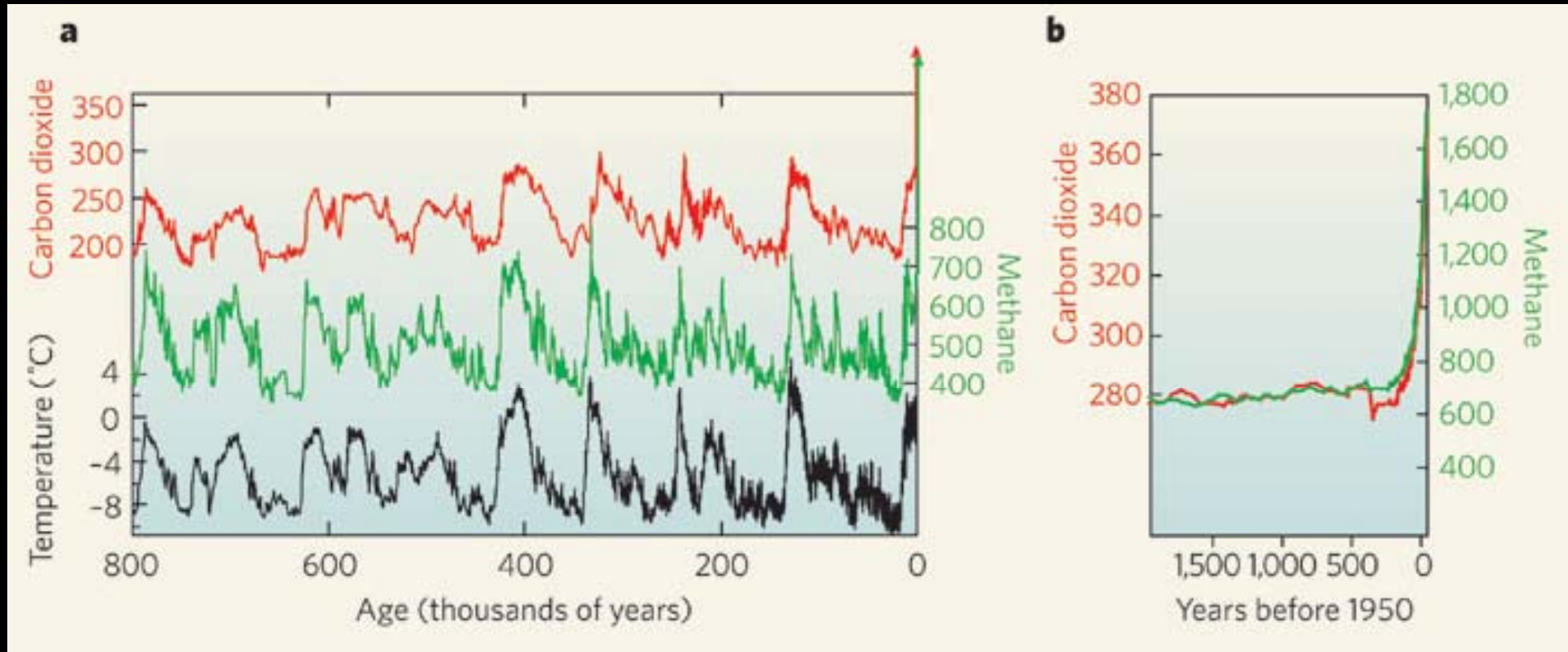
# Thermohaline Circulation





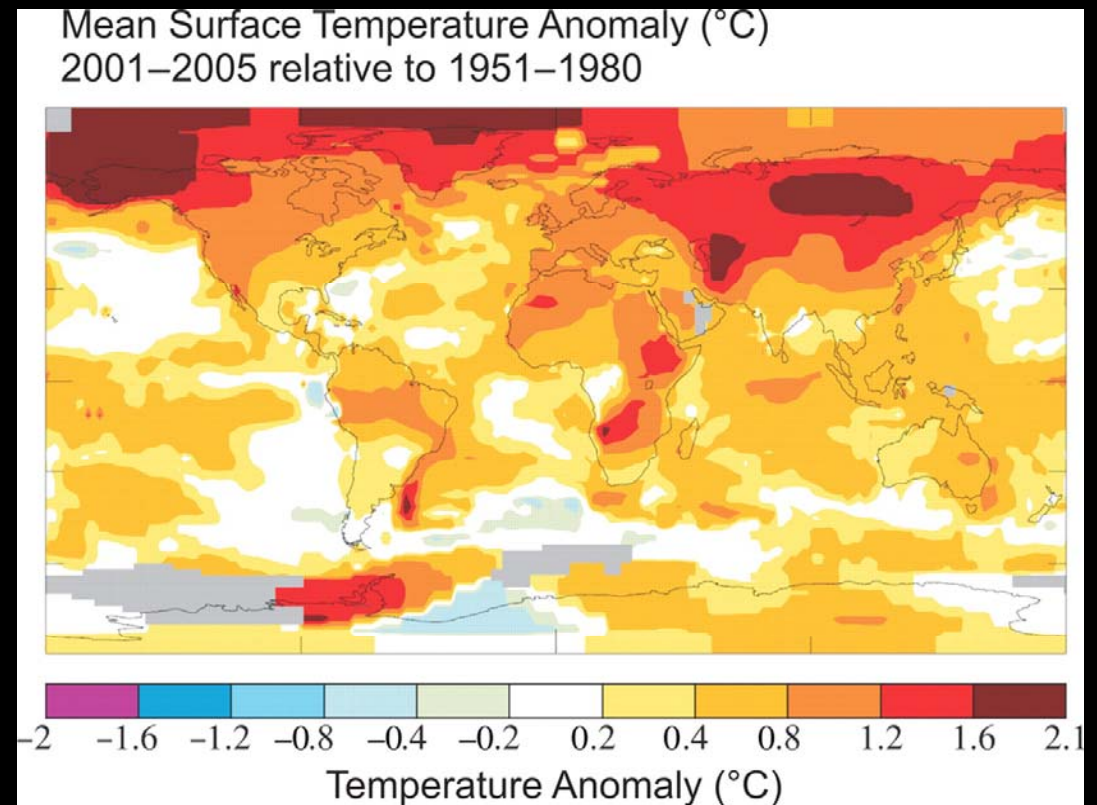
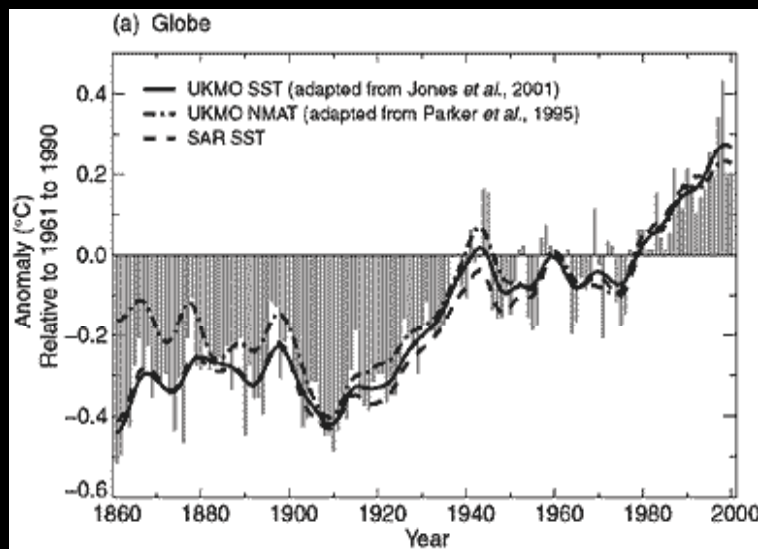
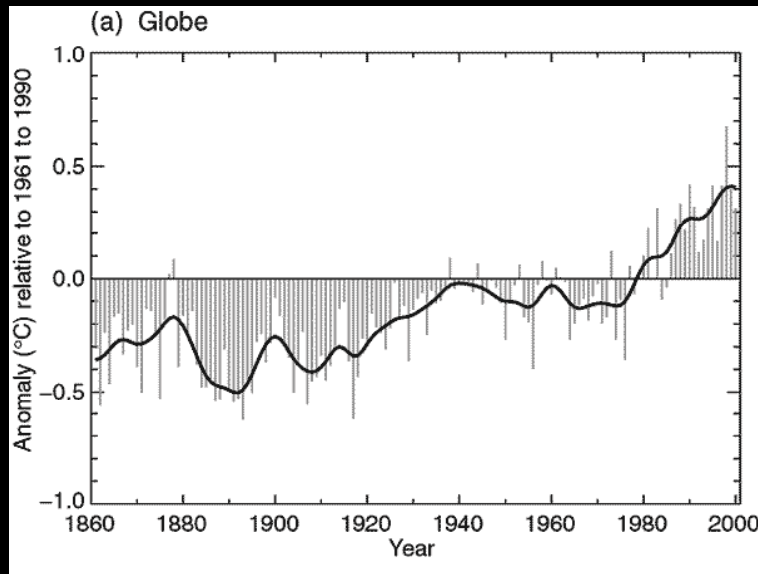


# Current increase in atmospheric CO<sub>2</sub> is unprecedented in the last 800,000 yrs



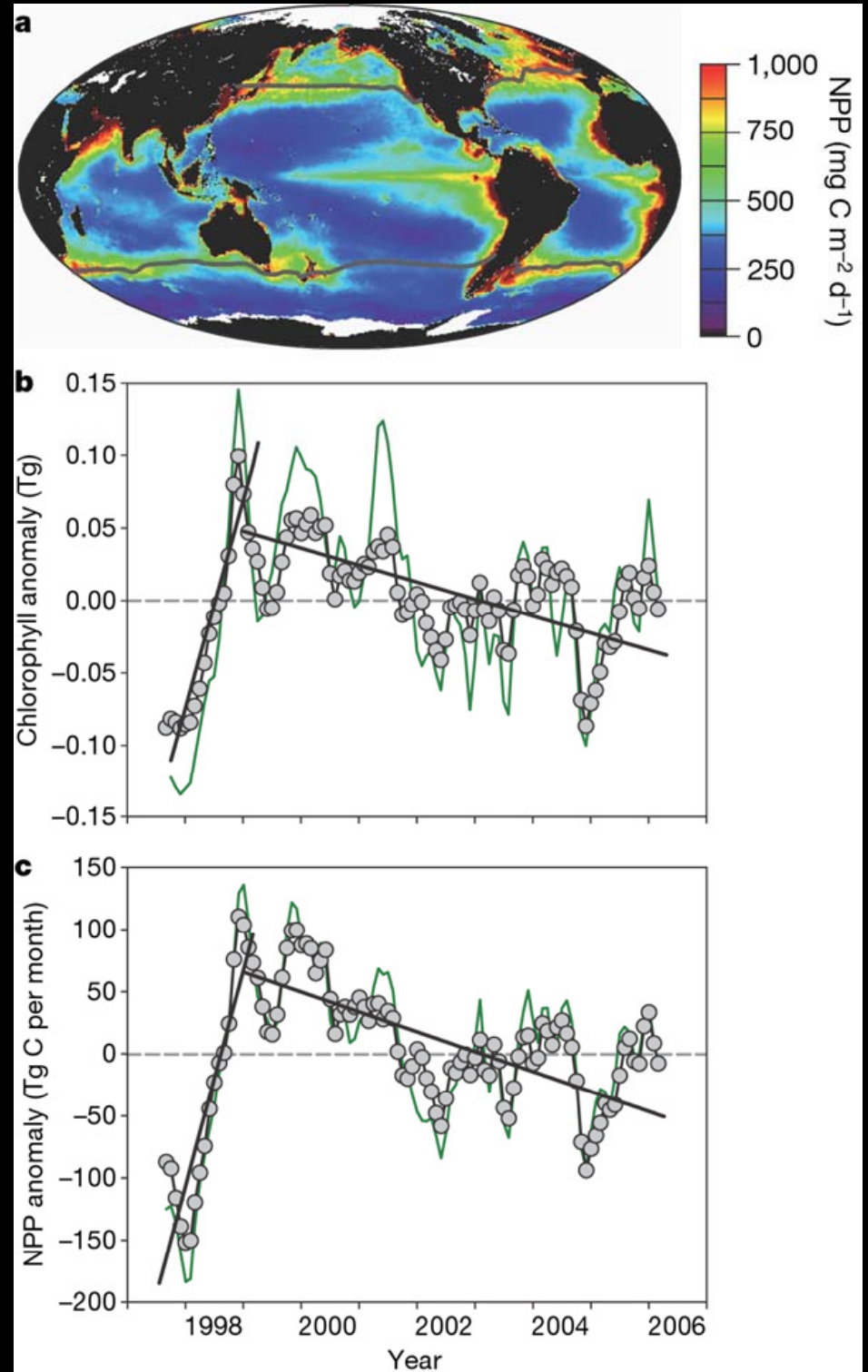
*The EPICA team 2004*

# 20th century warming of land and ocean

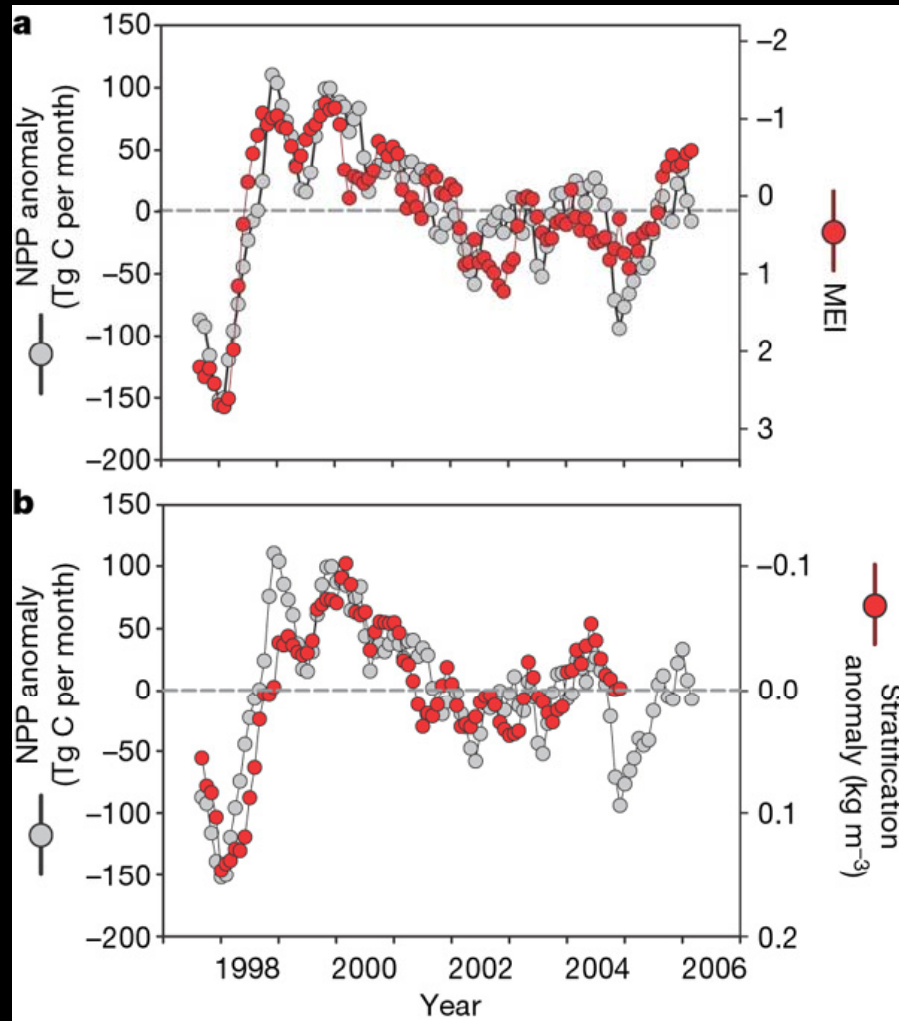


IPCC 2004

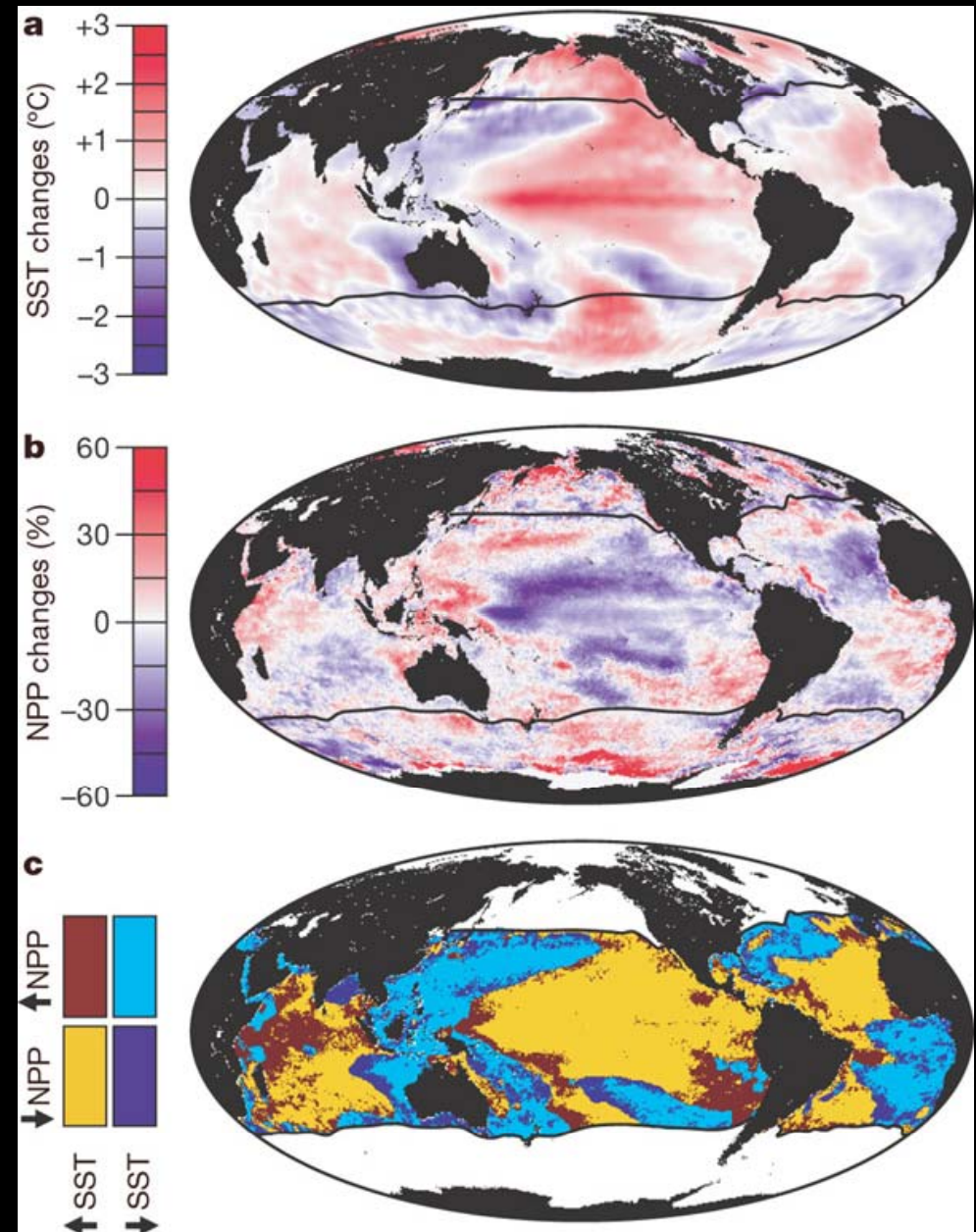
## Interannual variability in global marine productivity



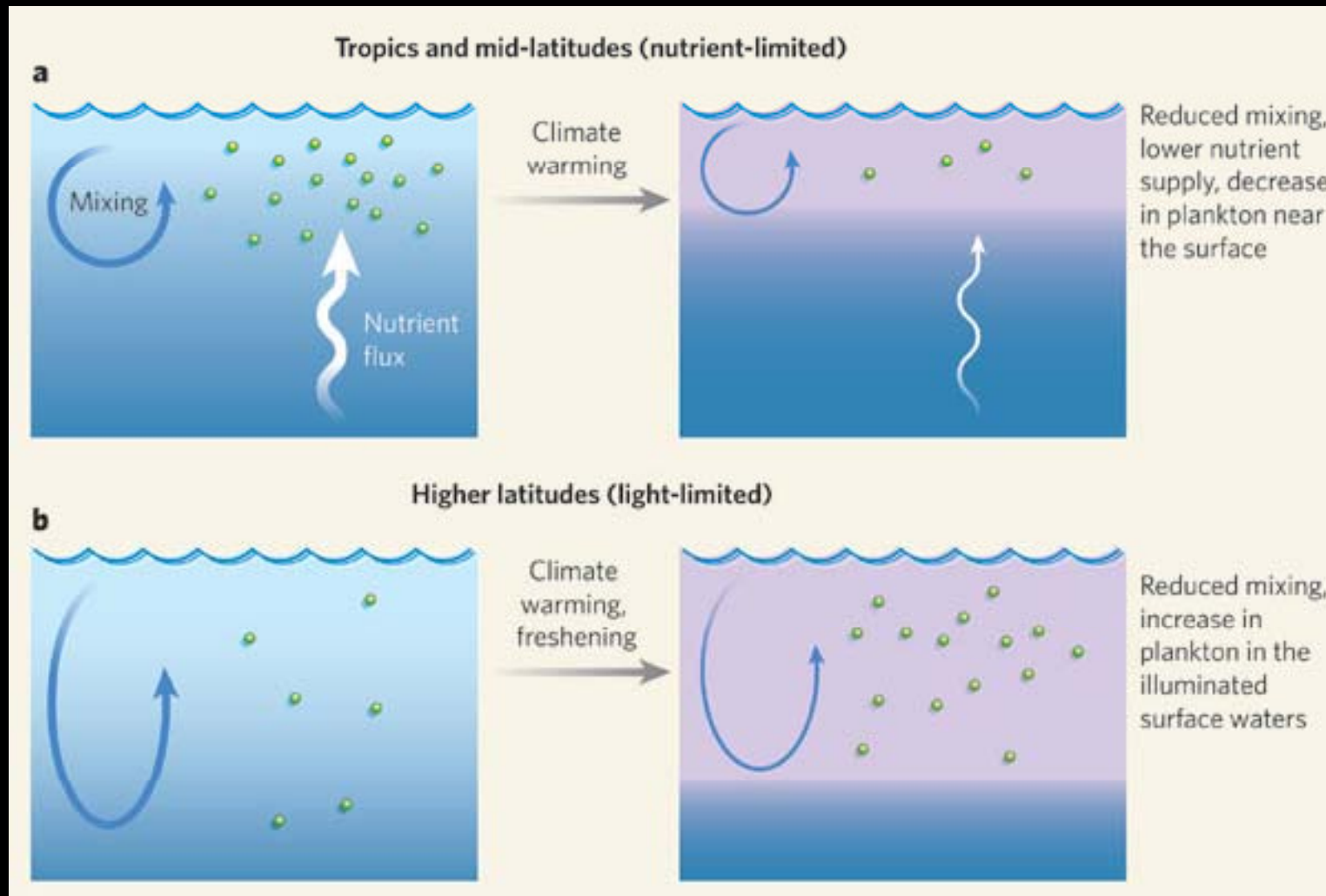
# Correlation between stratification and productivity in mid- and low-latitudes



*Behrenfeld et al 2006*



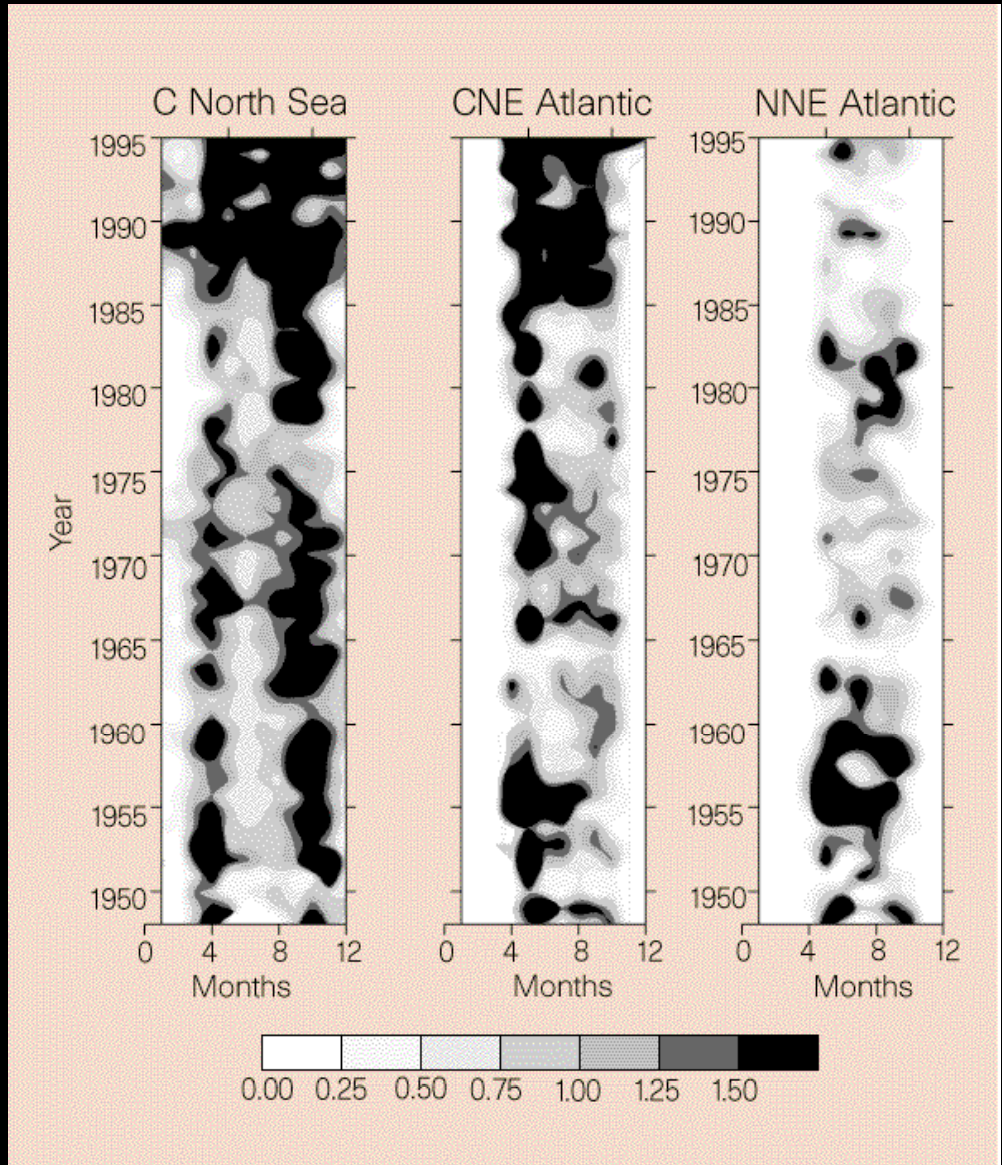
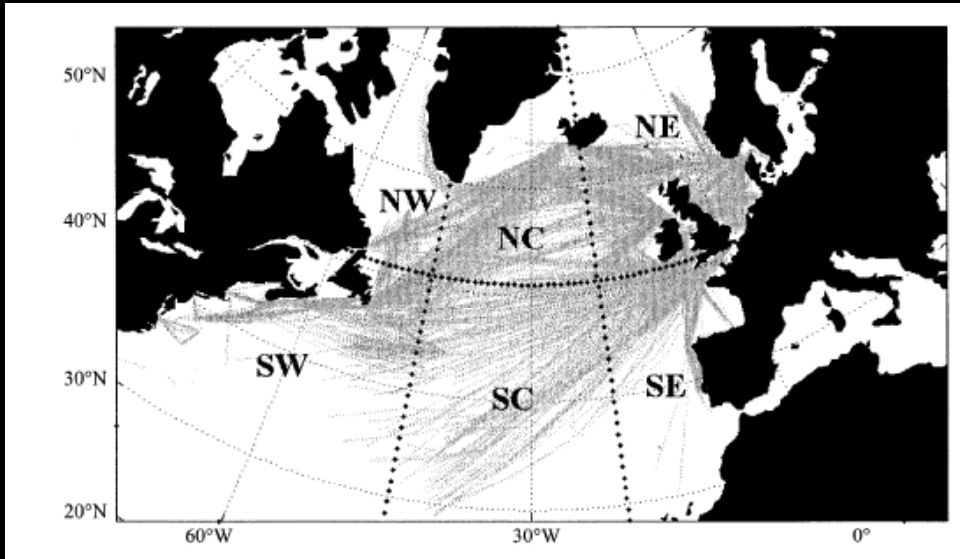
# Contrasting effects of warming in mid- and low-latitudes versus higher latitudes



*Doney et al 2006*

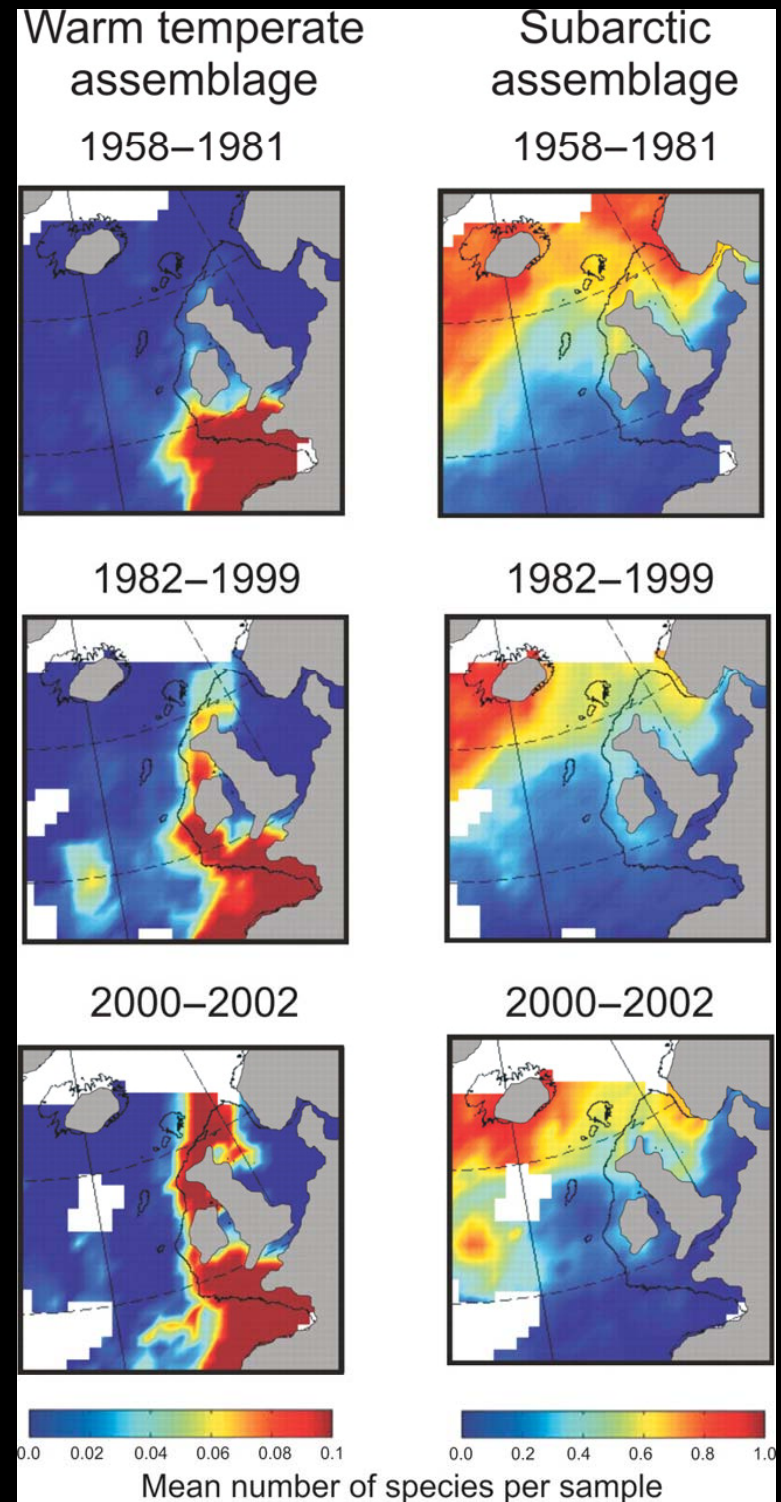
# Long-term variability in phytoplankton abundance in the North Atlantic is probably linked to climate

## The Continuous Plankton Recorder survey



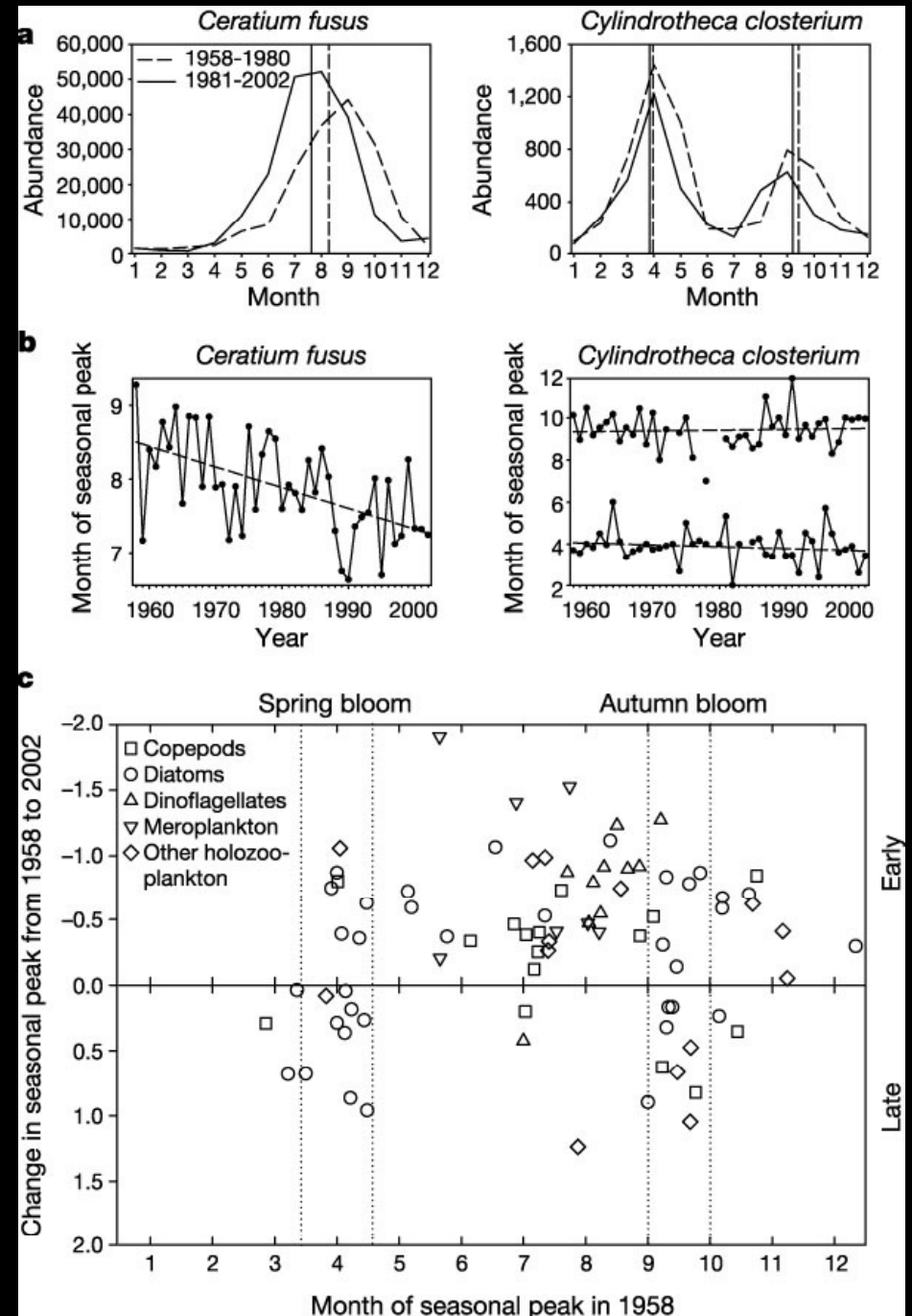
Reid et al 1998

# Changes in zooplankton distribution as a result of warming



Richardson 2008

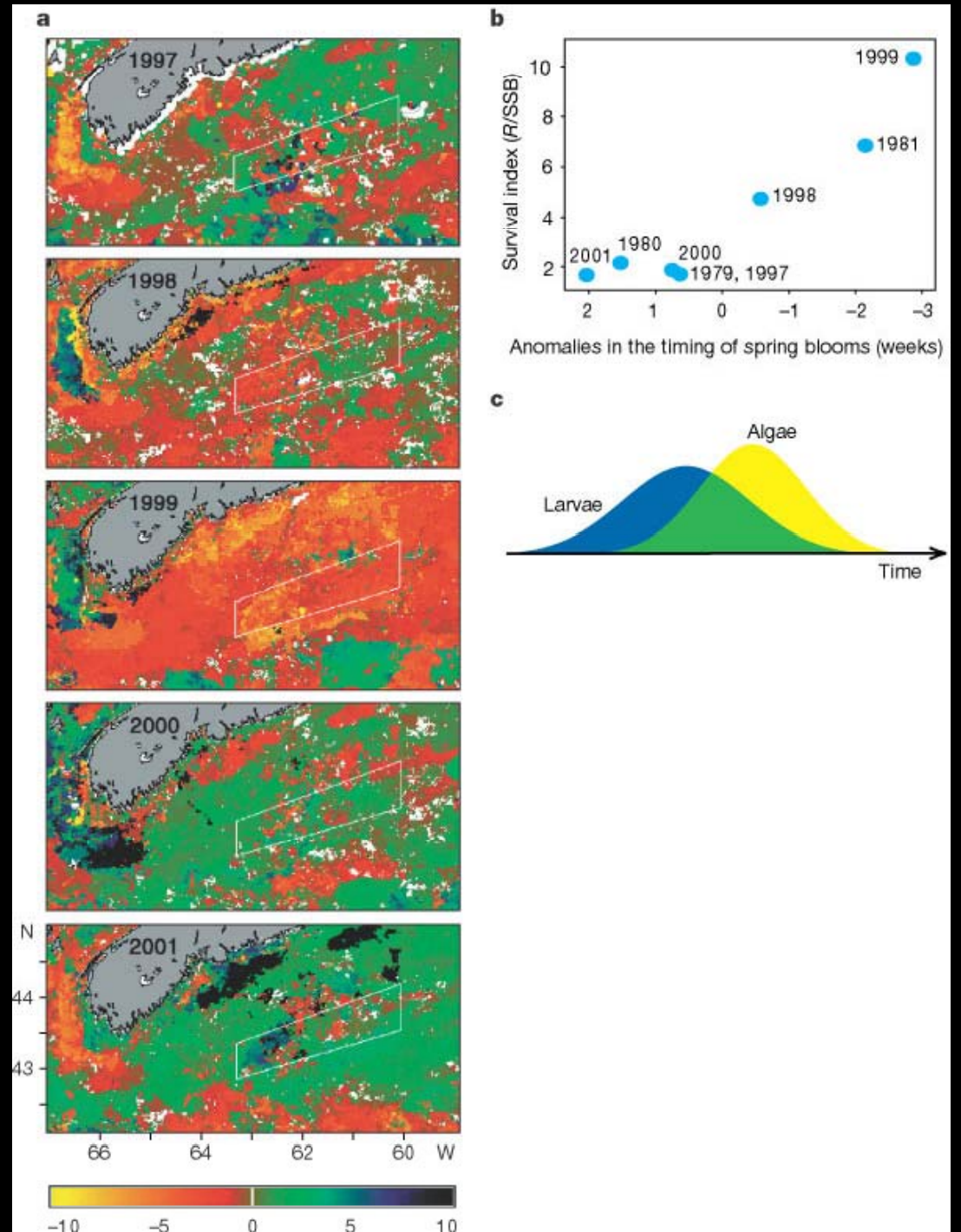
# Changes in timing of seasonal peaks (phenology) vary among taxa



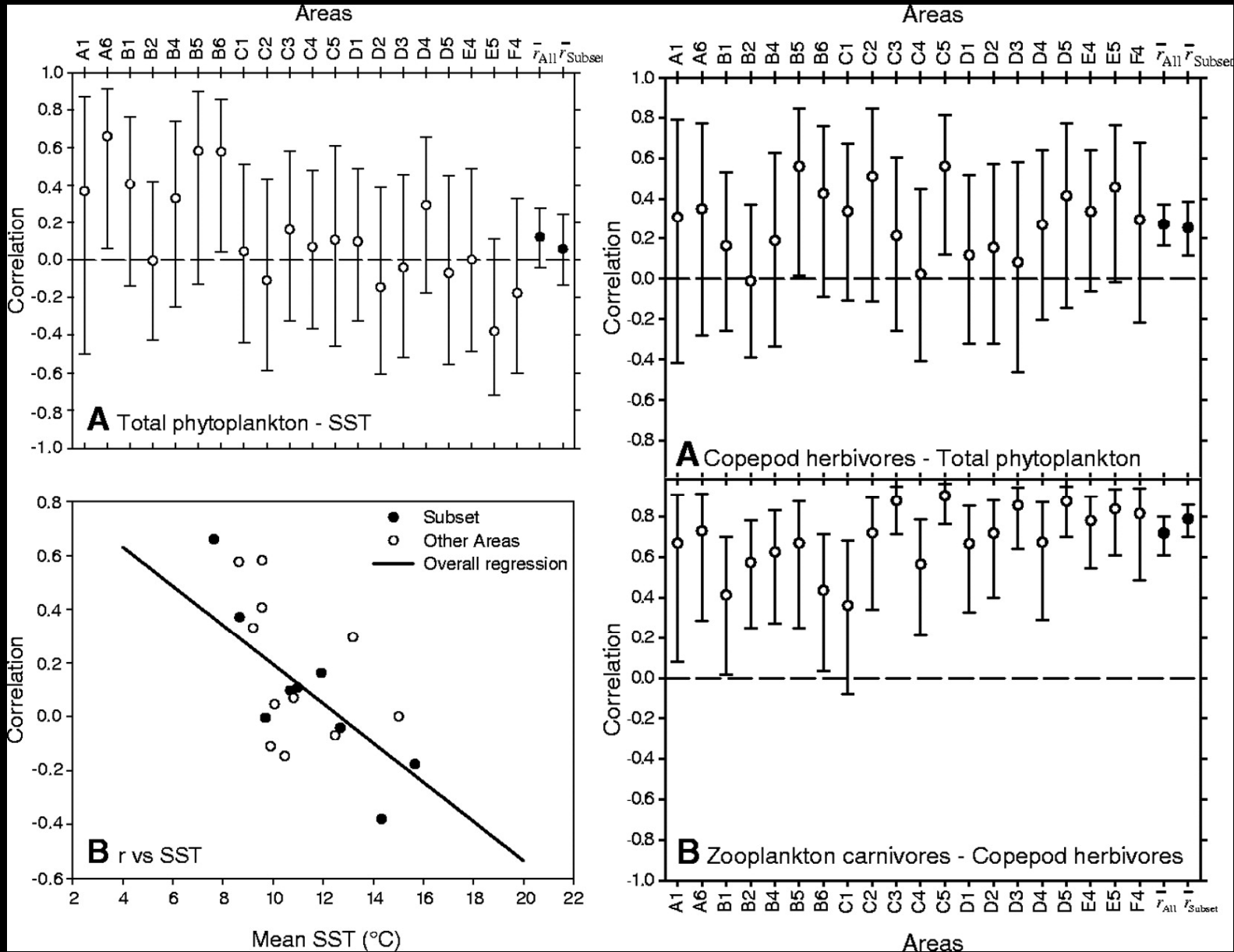
Edwards & Richardson 2004



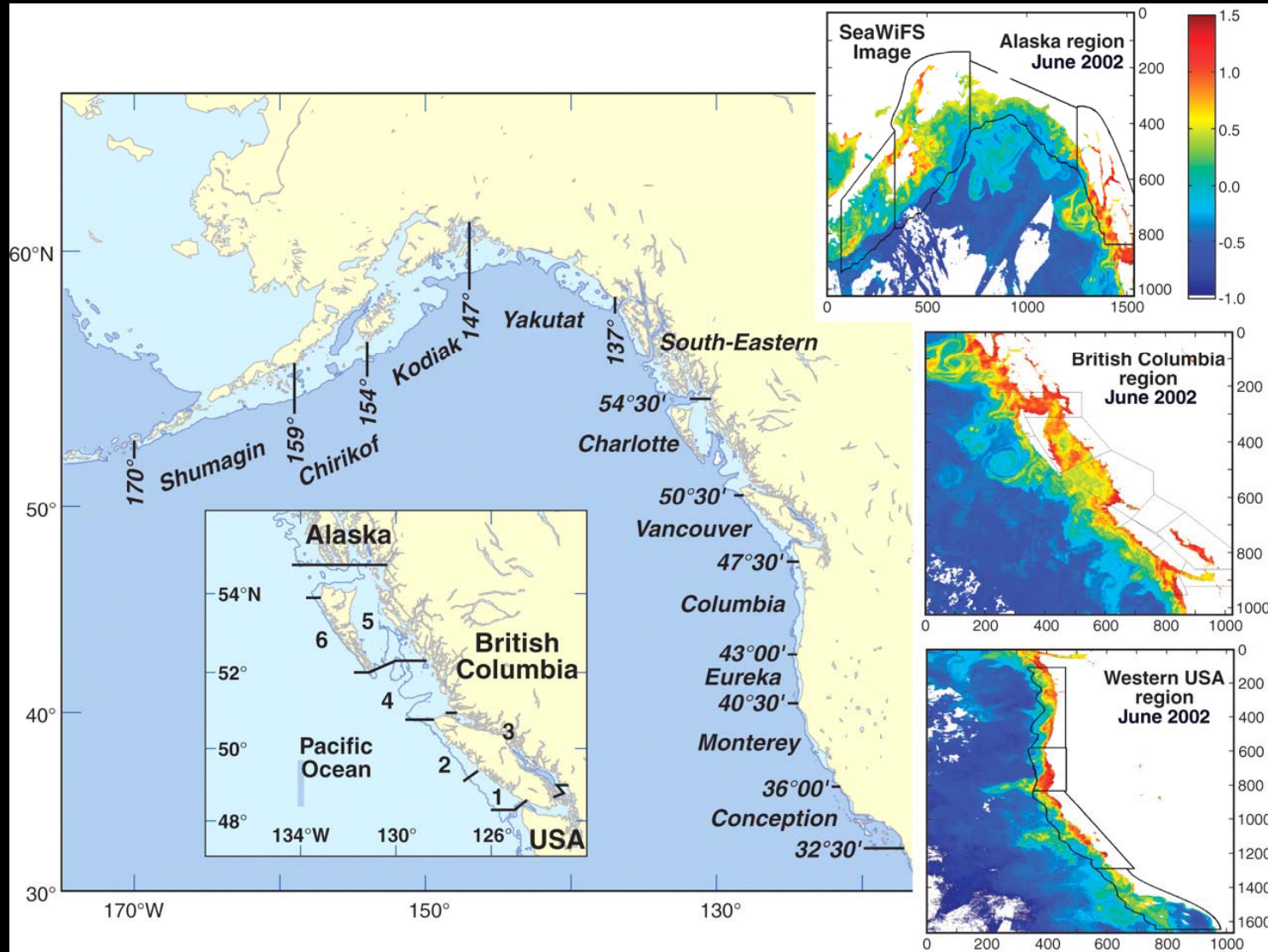
# Importance of coupling between trophic levels: the match-mismatch hypothesis



# Climate impact on plankton ecosystems in the NE Atlantic



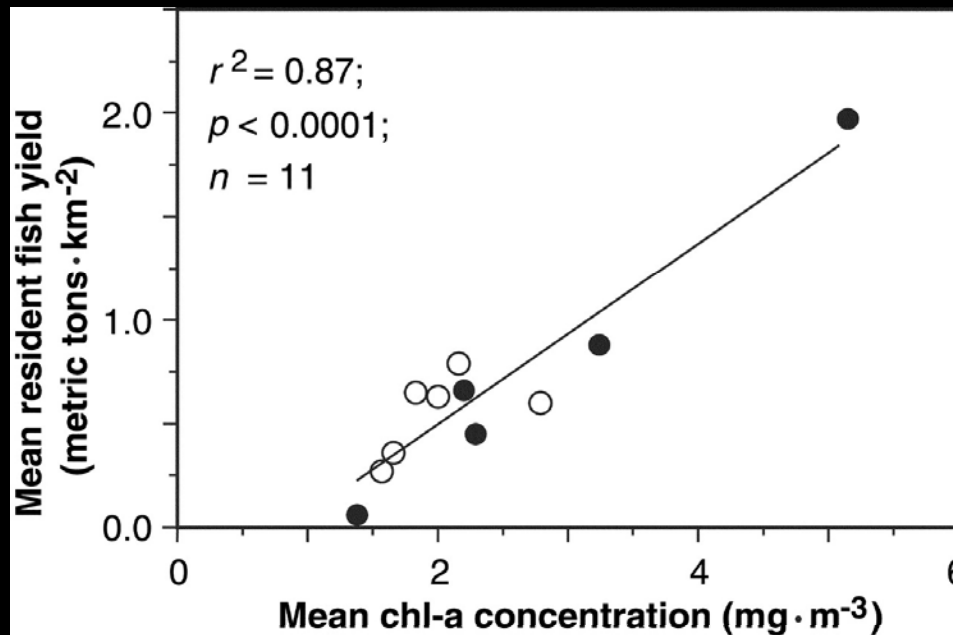
# Bottom-up control of fish production in the NE Pacific



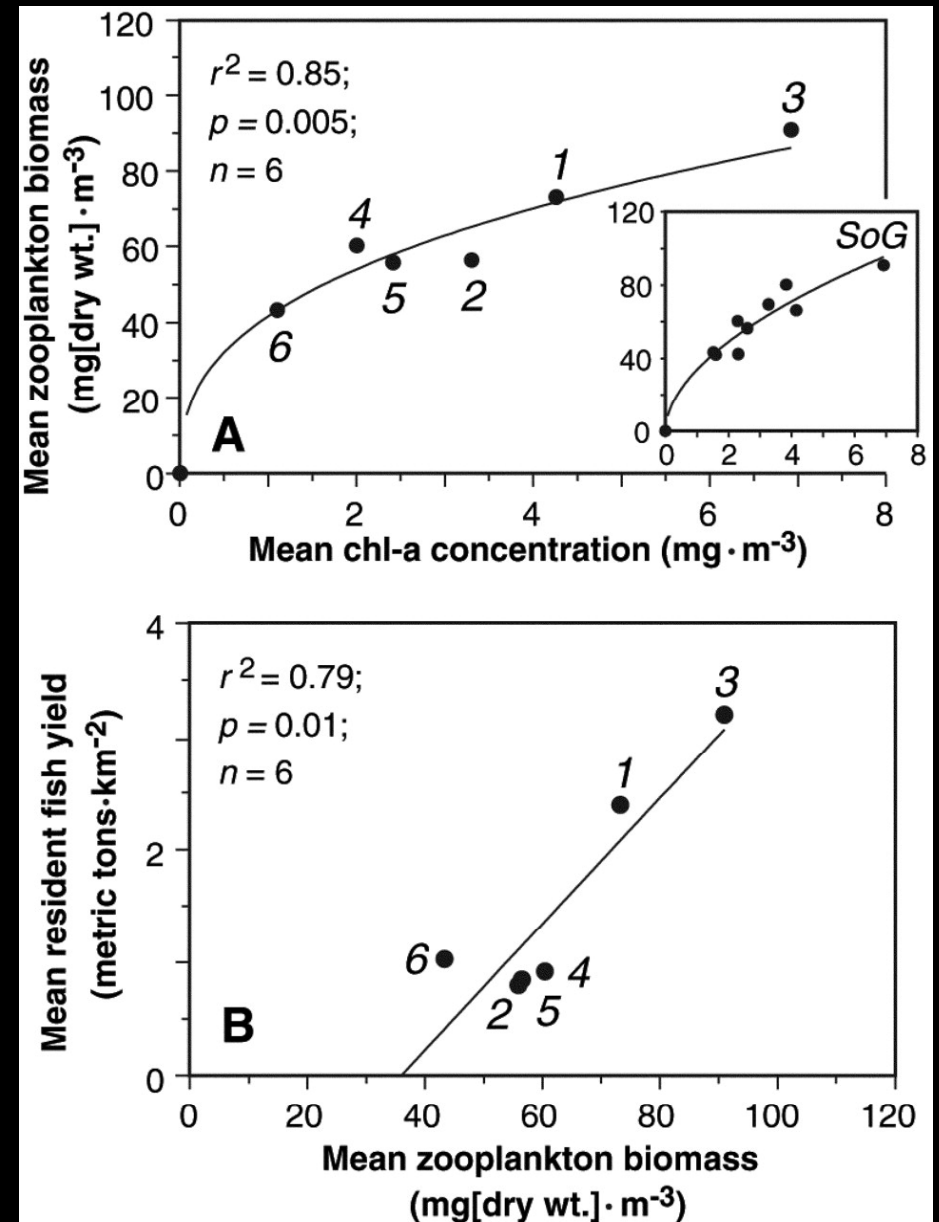
Ware & Thomson 2005

# Bottom-up control of fish production in the NE Pacific

## Large-scale

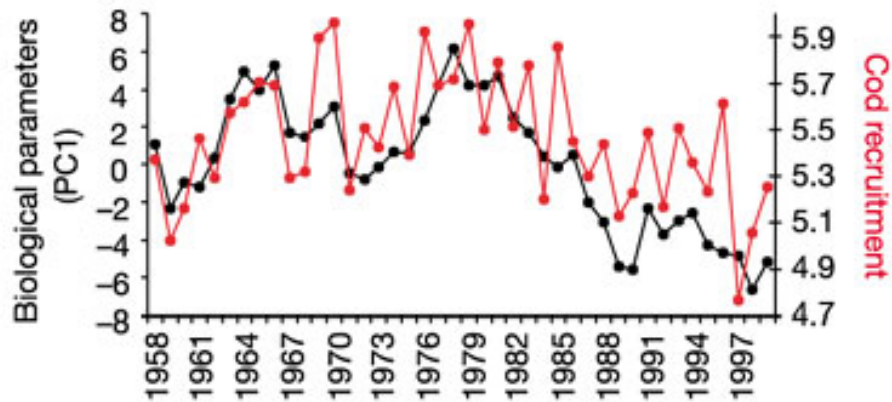


## Small-scale

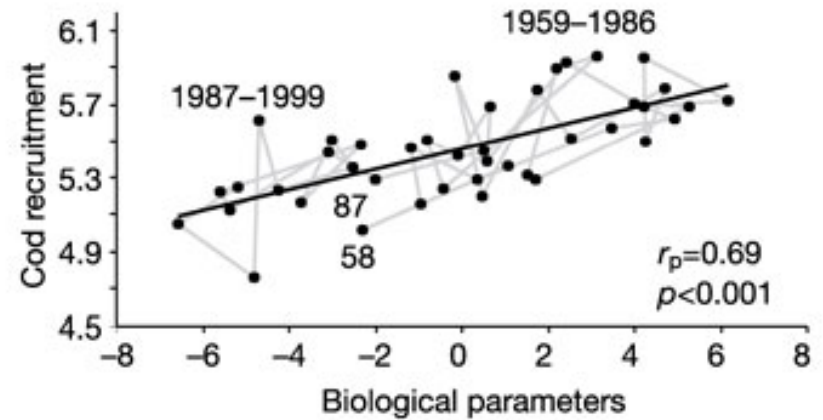


# Changes in plankton affect cod recruitment in the North Sea

**a** Cod recruitment (one-year-olds) and biological parameters (original)

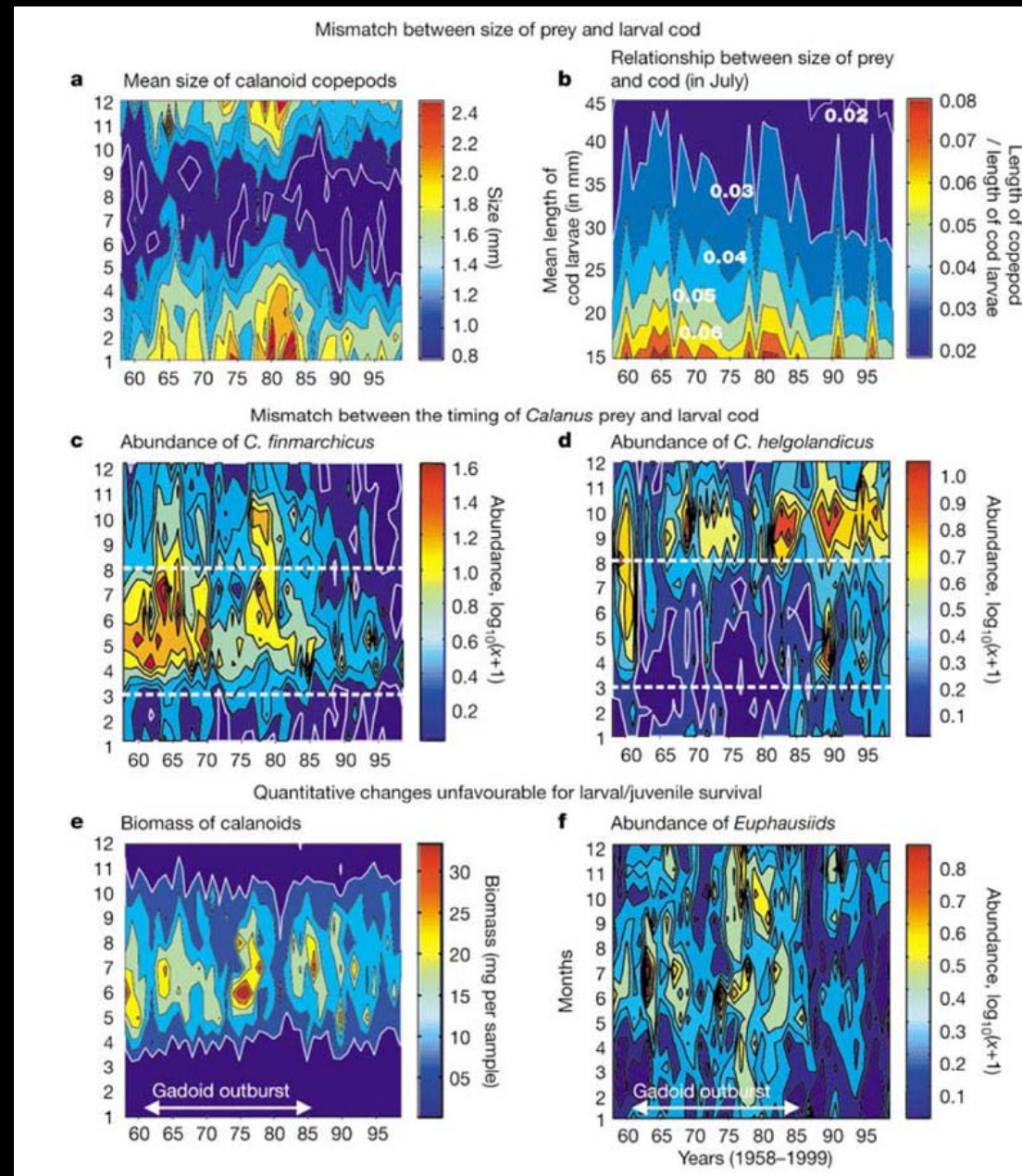


**b** Scatter plot of cod recruitment (one-year-olds) and biological parameters (original)



*Beaugrand et al 2003*

# Changes in plankton affect cod recruitment in the North Sea



## Summary

- The effects of global warming are already detectable in the abundance, distribution and phenology of different plankton groups
- Warming impacts different ocean regions in different ways
- The level of response also differs through the community: possibility of trophic mismatch
- Climate-driven variability in plankton ecology propagates through the trophic web, therefore affecting fisheries (bottom-up control)