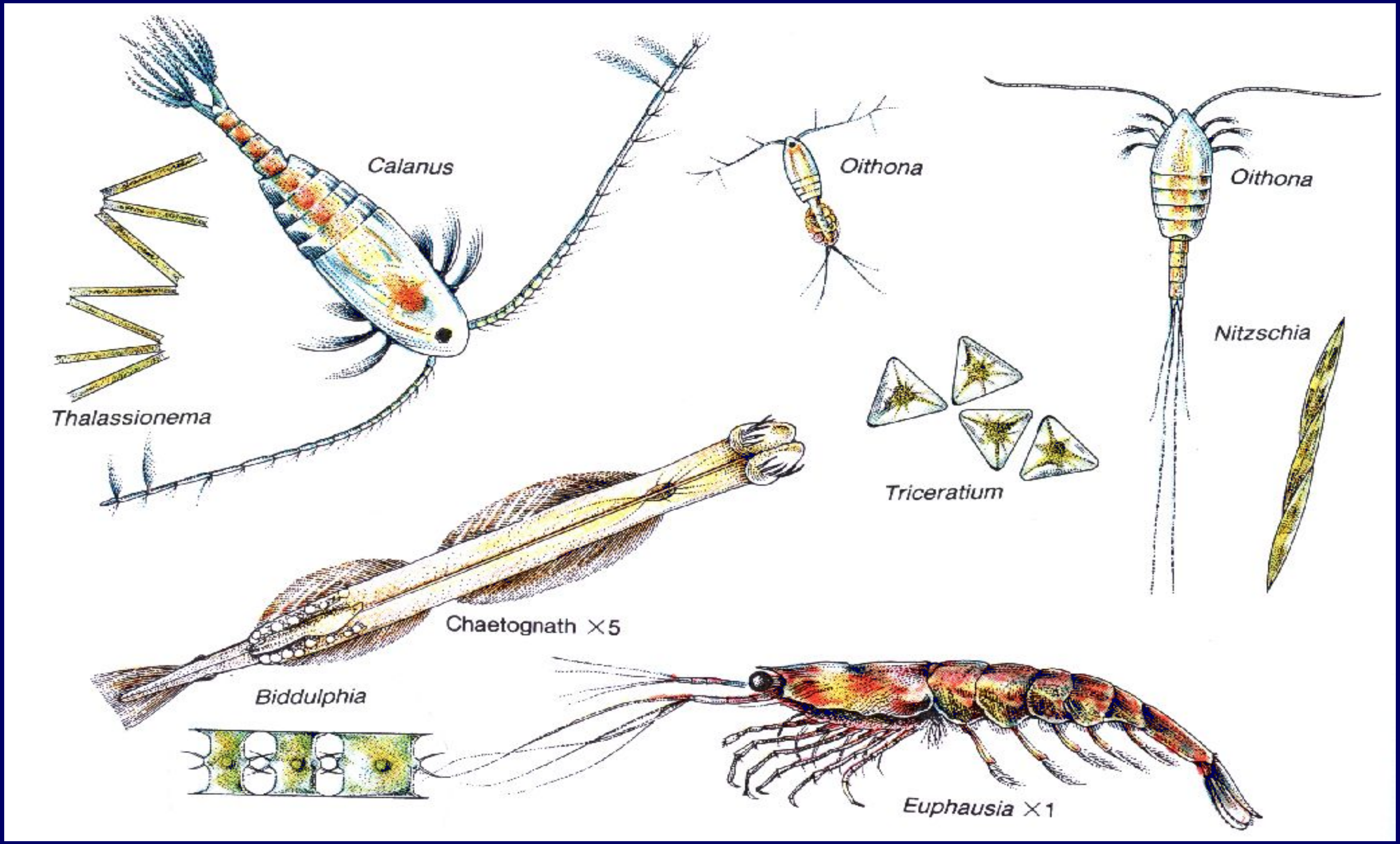
The importance of zooplankton in reducing levels of atmospheric CO_2 via the biological pump

Philip C. Reid



Hiroshima 4th IZPS May/June 2007

Acknowledgement

Gregory Beaugrand
Hjálmar Hátún
Martin Edwards
Wieslaw Maslowski
Anne Britt Sandø
Koji Shimada
Frank Beuchel

1. Accelerating temperature changes in the oceans
2. Plankton indicators of rapid change
3. The Ocean carbon cycle:
   Solubility, Biological, Carbonate pumps
4. Inadequate biological, biogeochemical ocean obs.
5. Conclusions

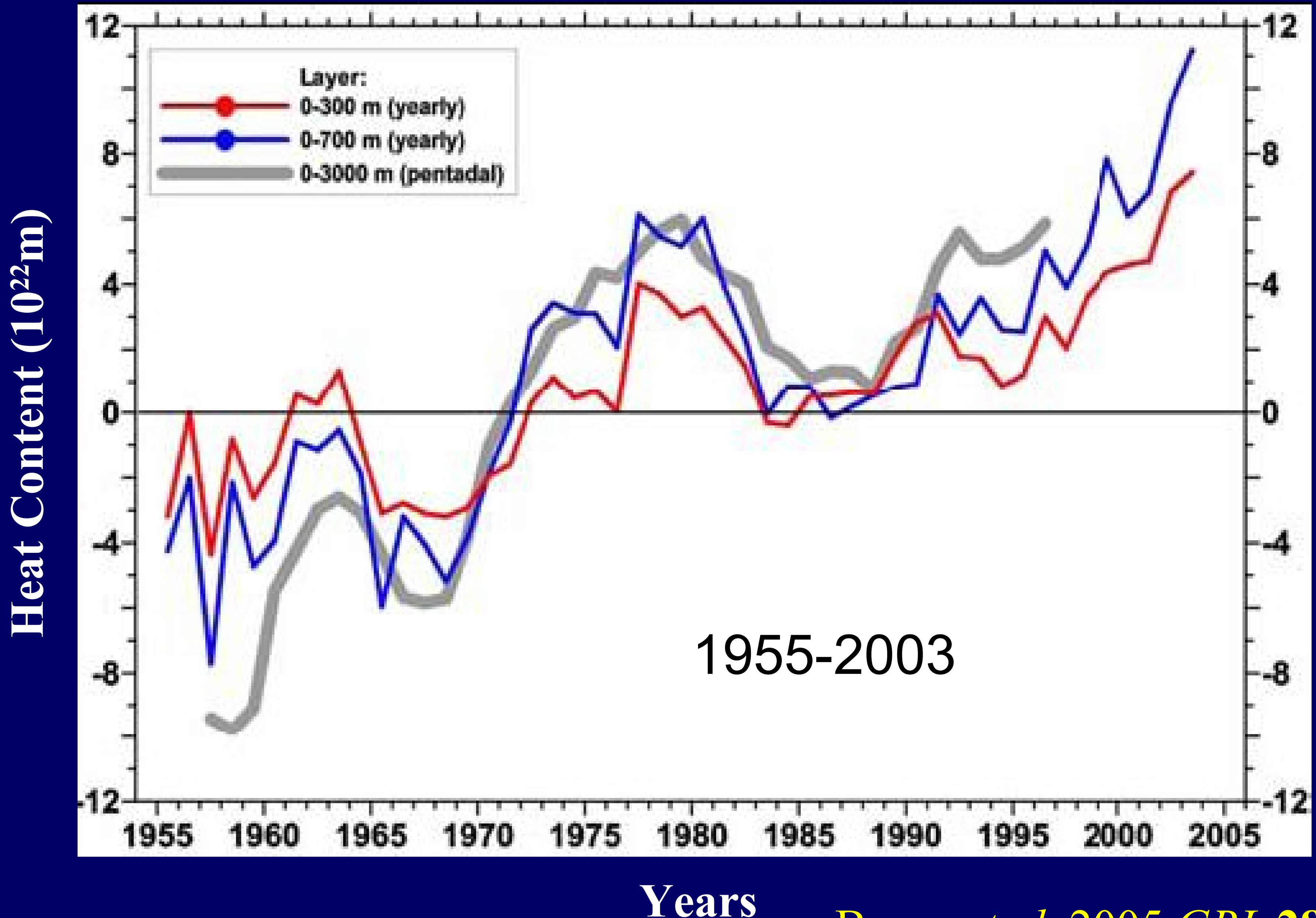
Zooplankton the ocean canary

A warning signal

New title for the symposium

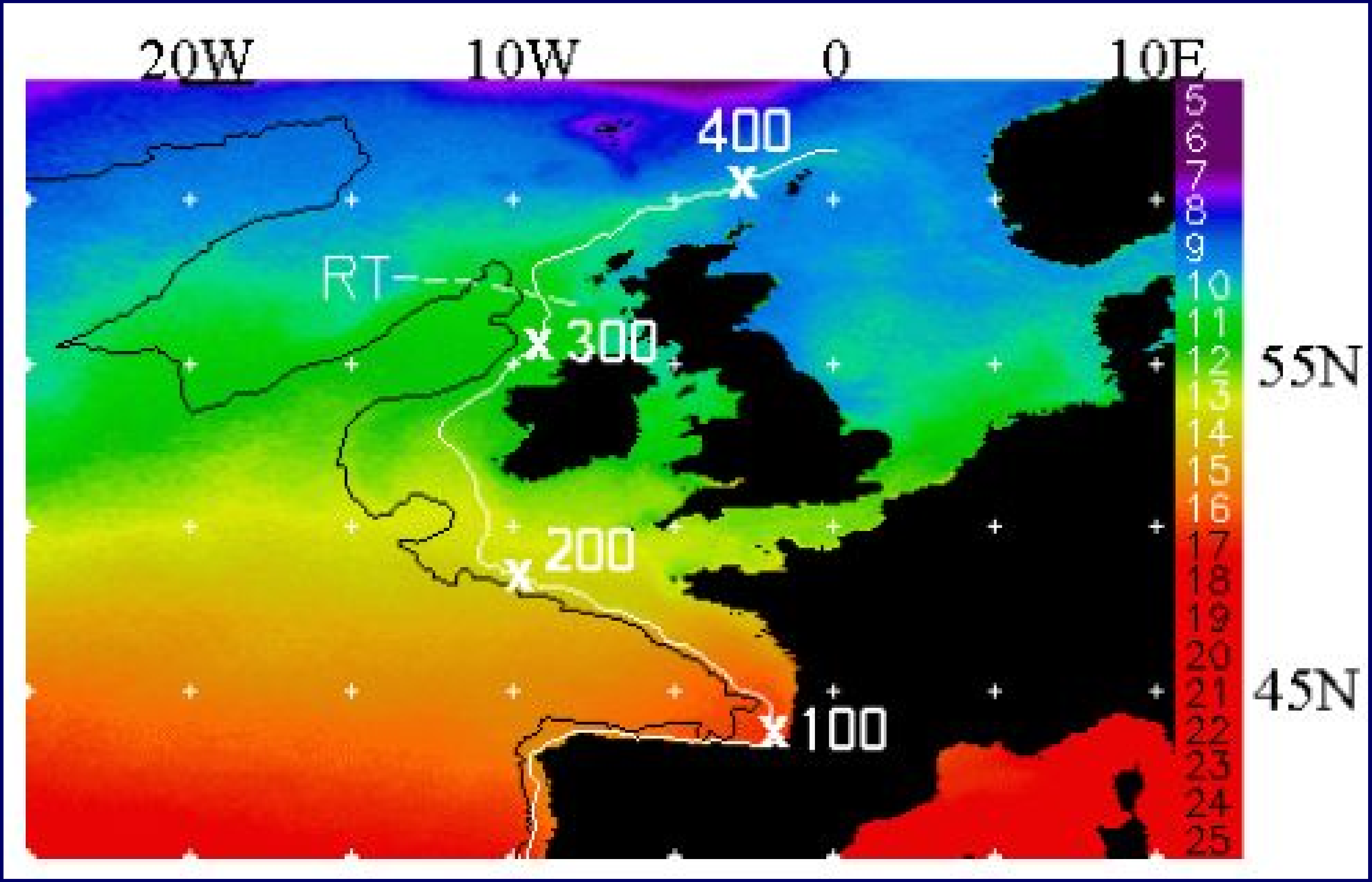
Human and zooplankton population forcing of climate

GLOBAL TRENDS IN OCEAN HEAT CONTENT



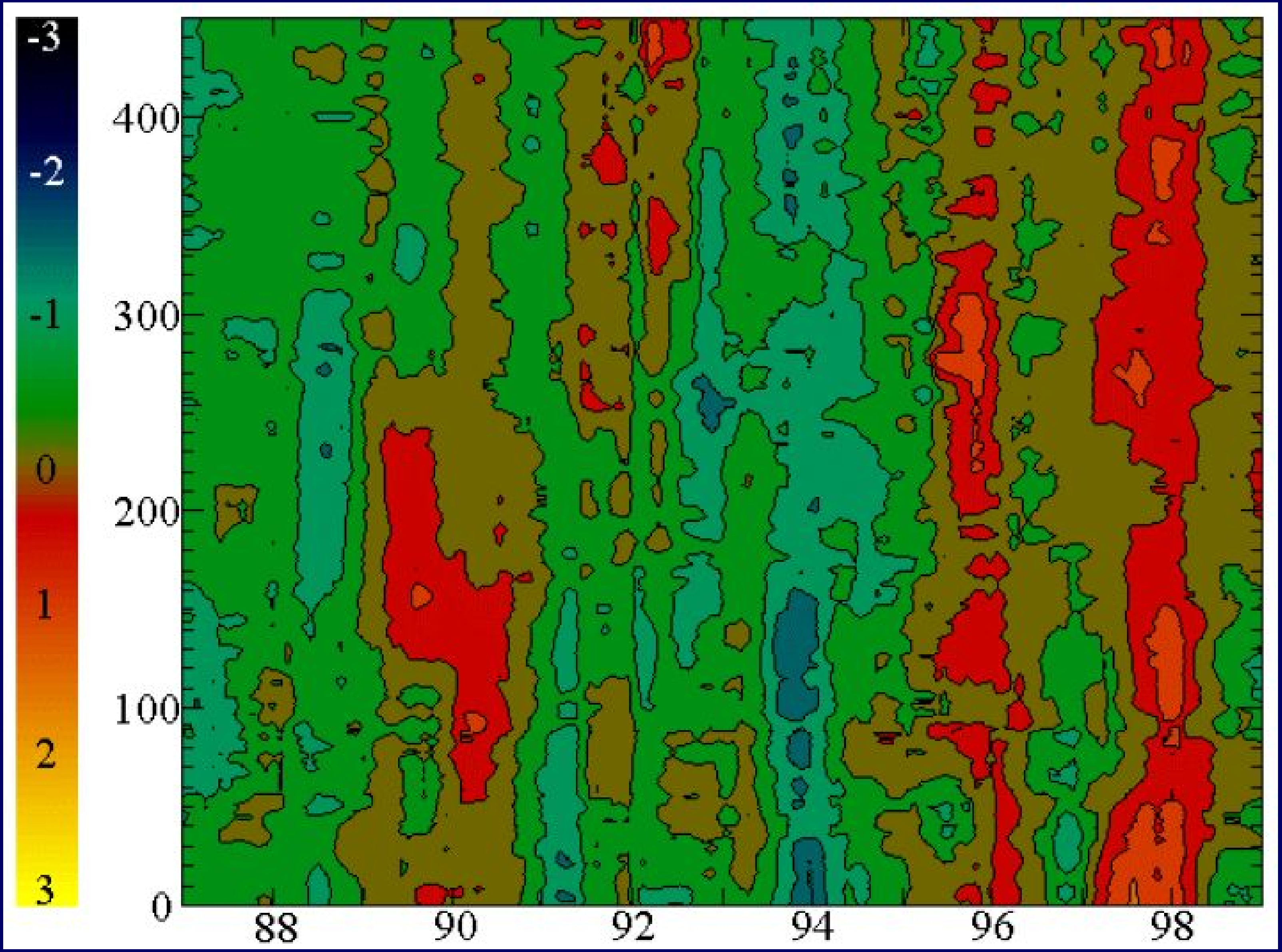
Boyer *et al*. 2005 *GRL* **287**

Sea surface temperatures averaged along the 200m contour



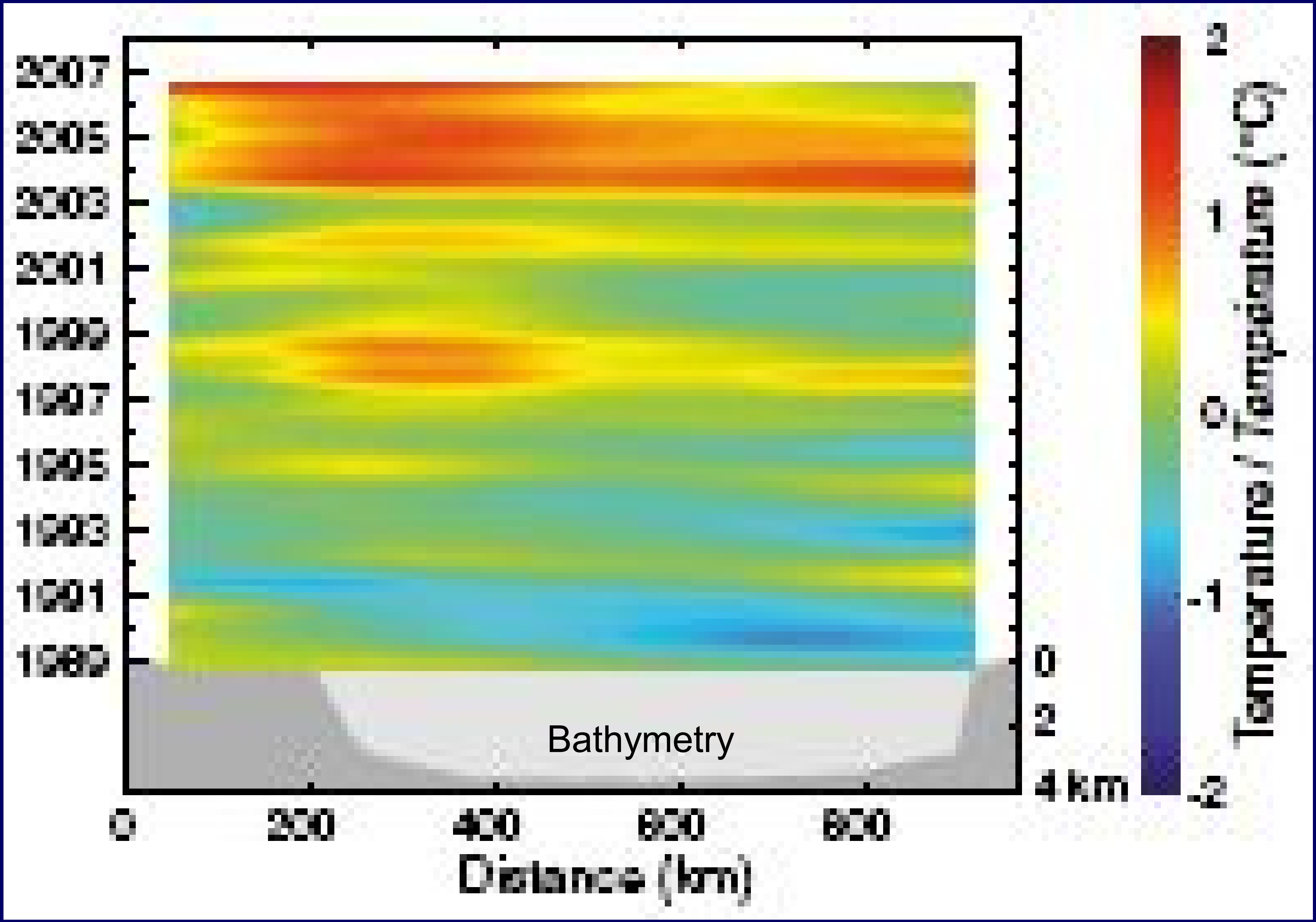
Reid, Holliday and Smythe 2001 MEPS 215

Contoured monthly sea surface temperature anomalies averaged along the 200m contour to the west of North-west Europe Note continuity of anomalies south to north.



Reid, Holliday and Smythe 2001 MEPS 215

SST Anomalies1989-2006 (1971-2000) between Greenland and Labrador



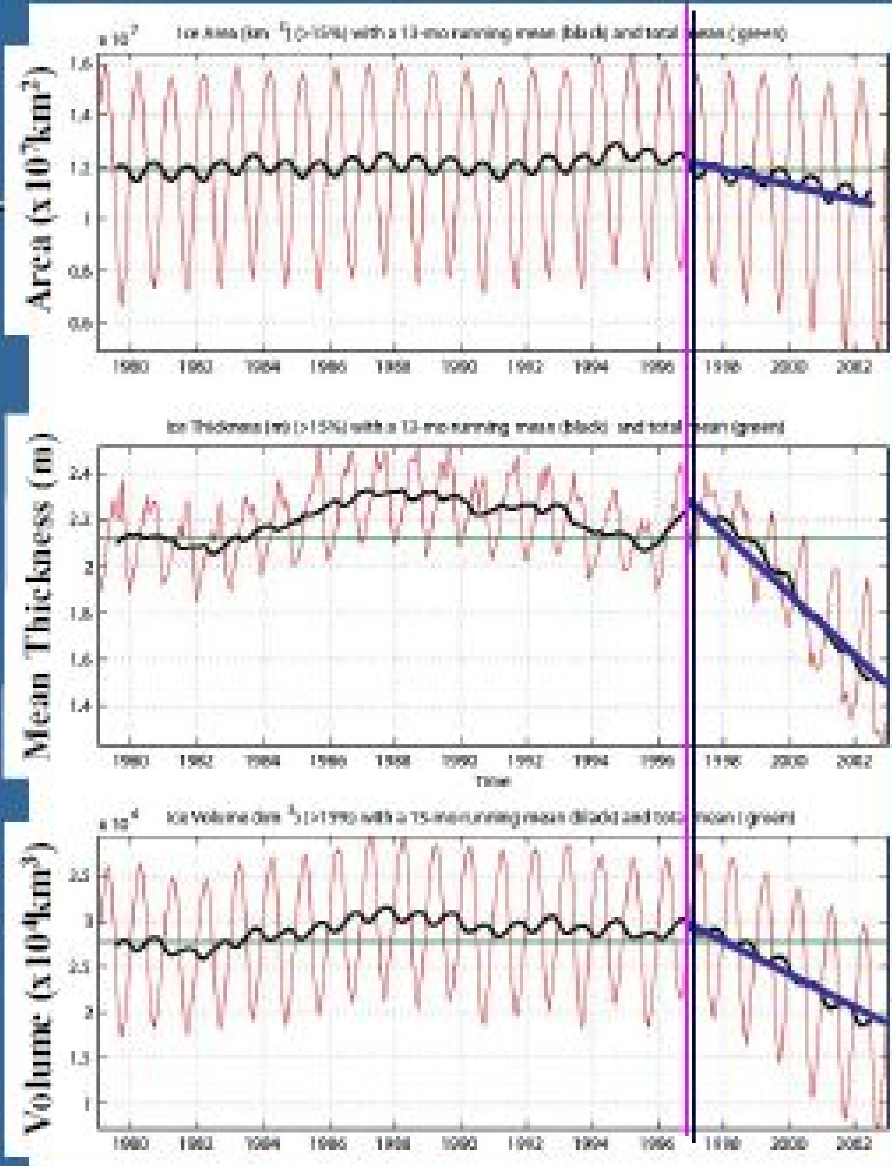
HadISST data

AZMP Bulletin 2007 No 6 p. 13.

Northern Bering Sea, Canada Basin Change 1998

Grebmeier *et al*. 2006 Science 311

Shimada *et al*. GRL 2006 33



Modeled Sea Ice Area, Thickness, and Volume

Decrease from 1997 to 2002:

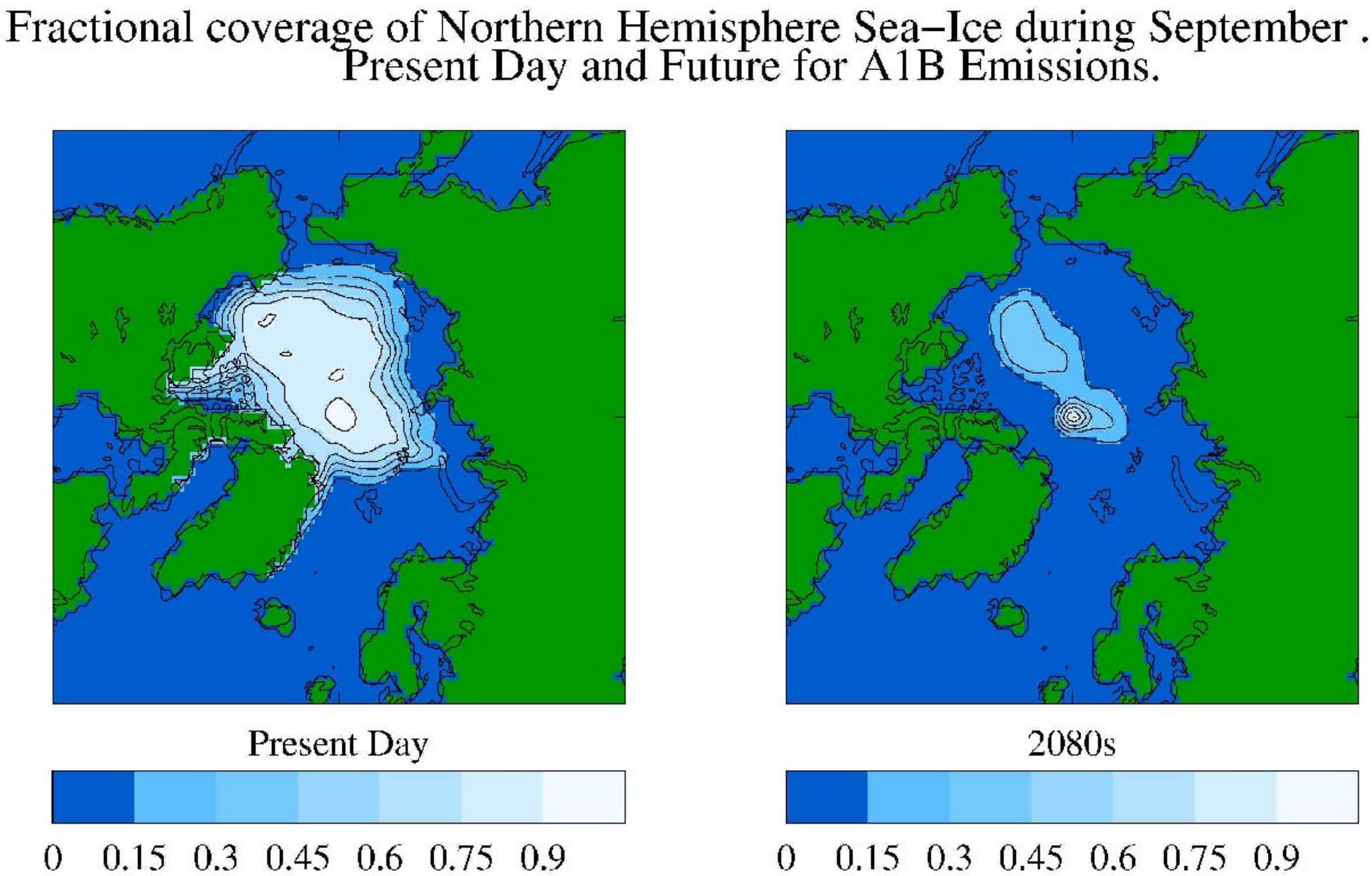
- Ice area by 15-18%, in agreement with observations

- Ice thickness by ~35% (or 80 cm from 2.3 m to 1.5 m)

- Ice volume by ~33% (from $30x10^3$ km^3 to $20x10^3$ km^3), which is twice the ice area

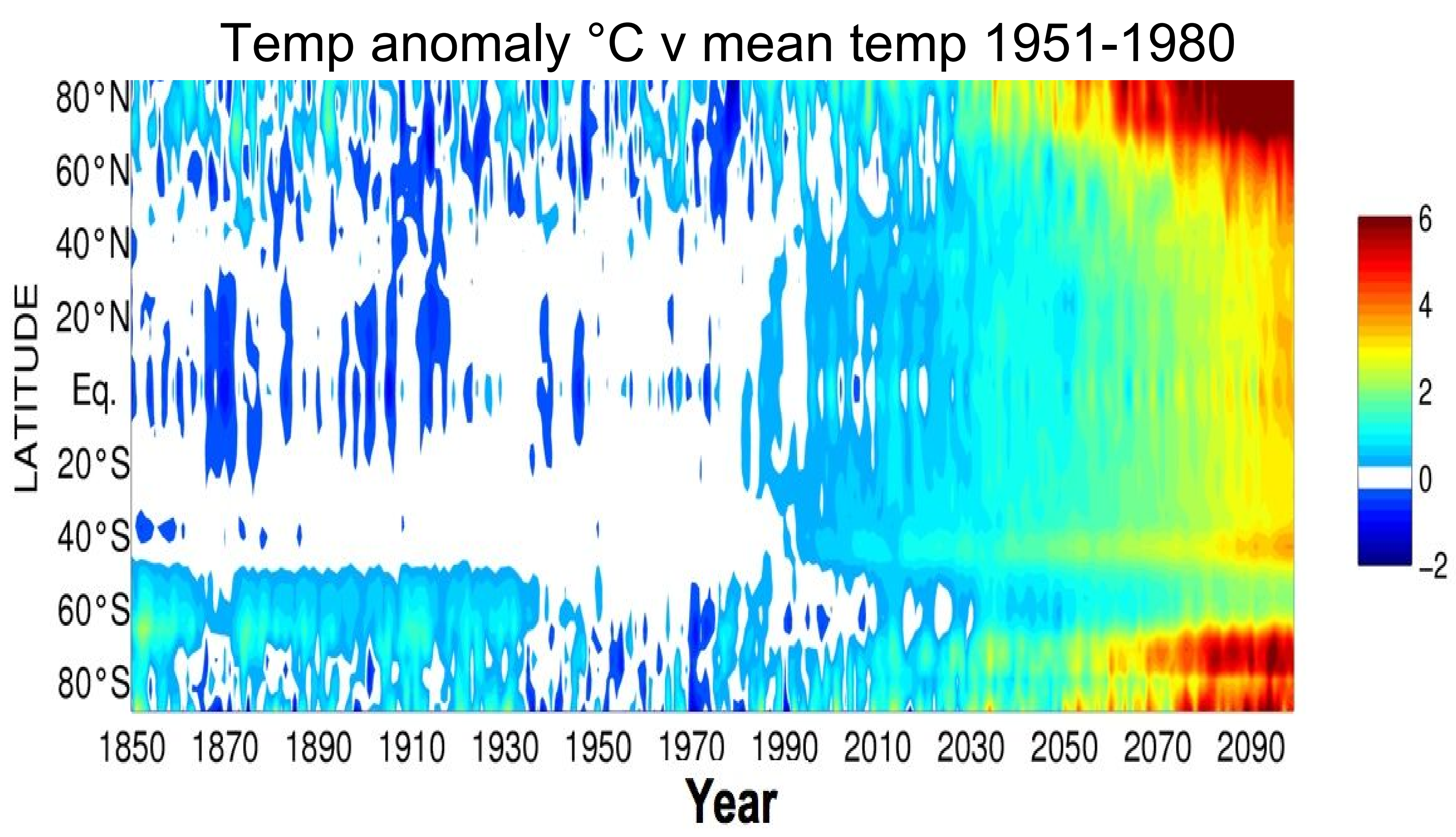
<u>If this trend persists for another 10 years (and it has through 2005) the Arctic Ocean could be ice-free in summer!</u>

Wieslaw Maslowski, NPS Monterey



Courtesy Chris Wood Hadley Centre UK

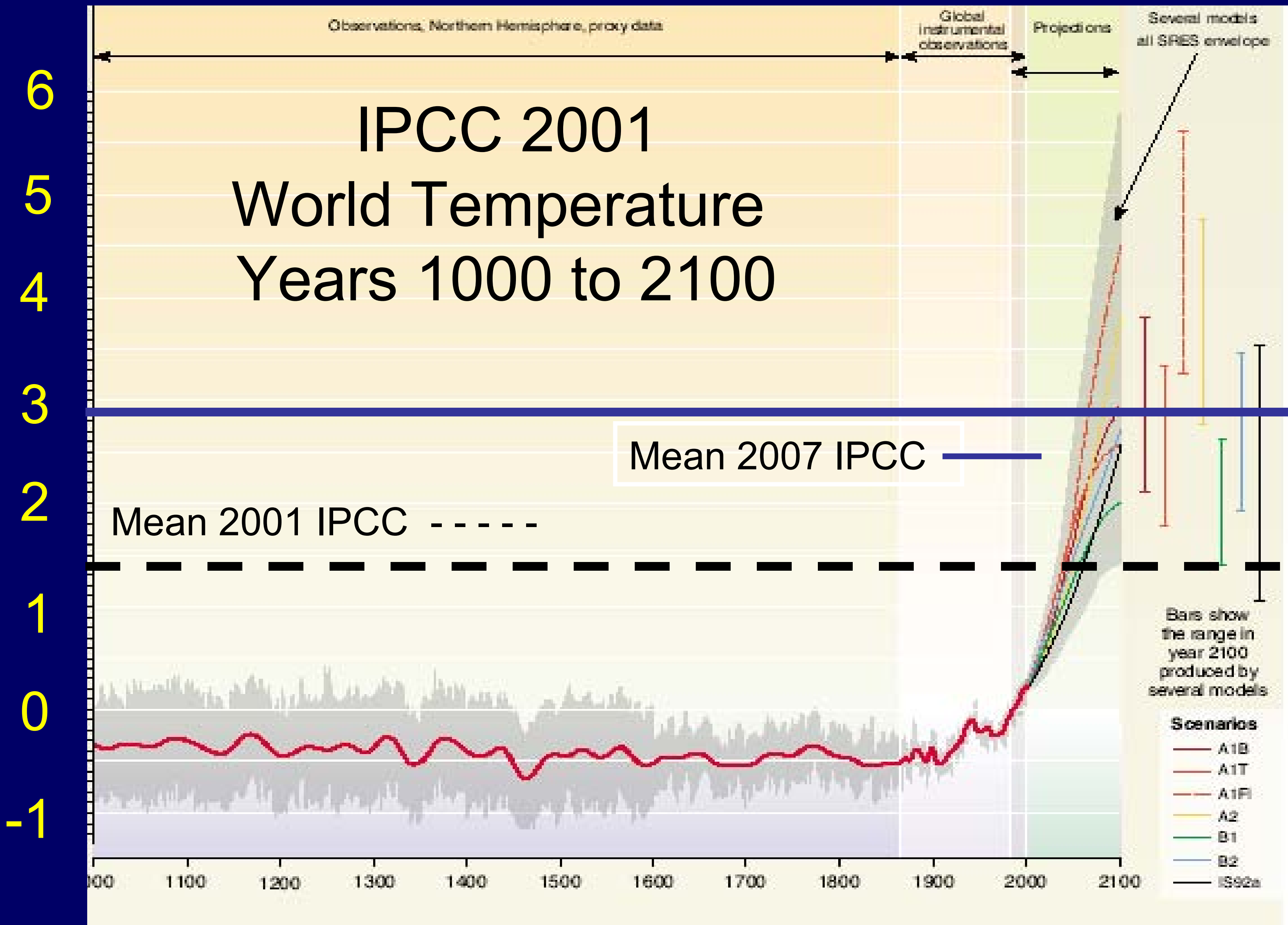
Simulated surface air temperature in Bergen model



Helge Drange, Bergen

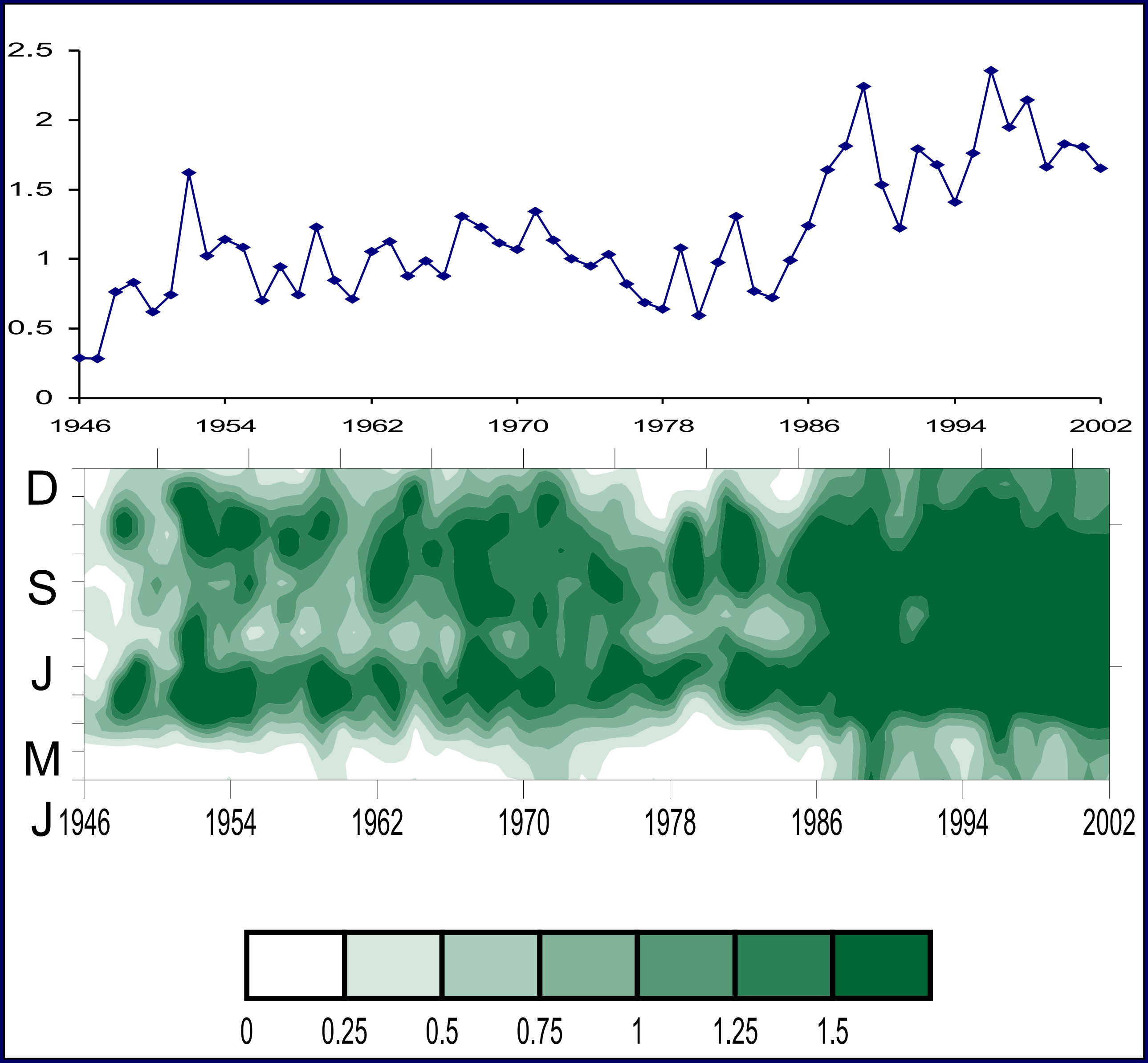
Projected enormous change within 100 years

Temperature departures °C from 1990 value



North Sea Phytoplankton Colour

1946

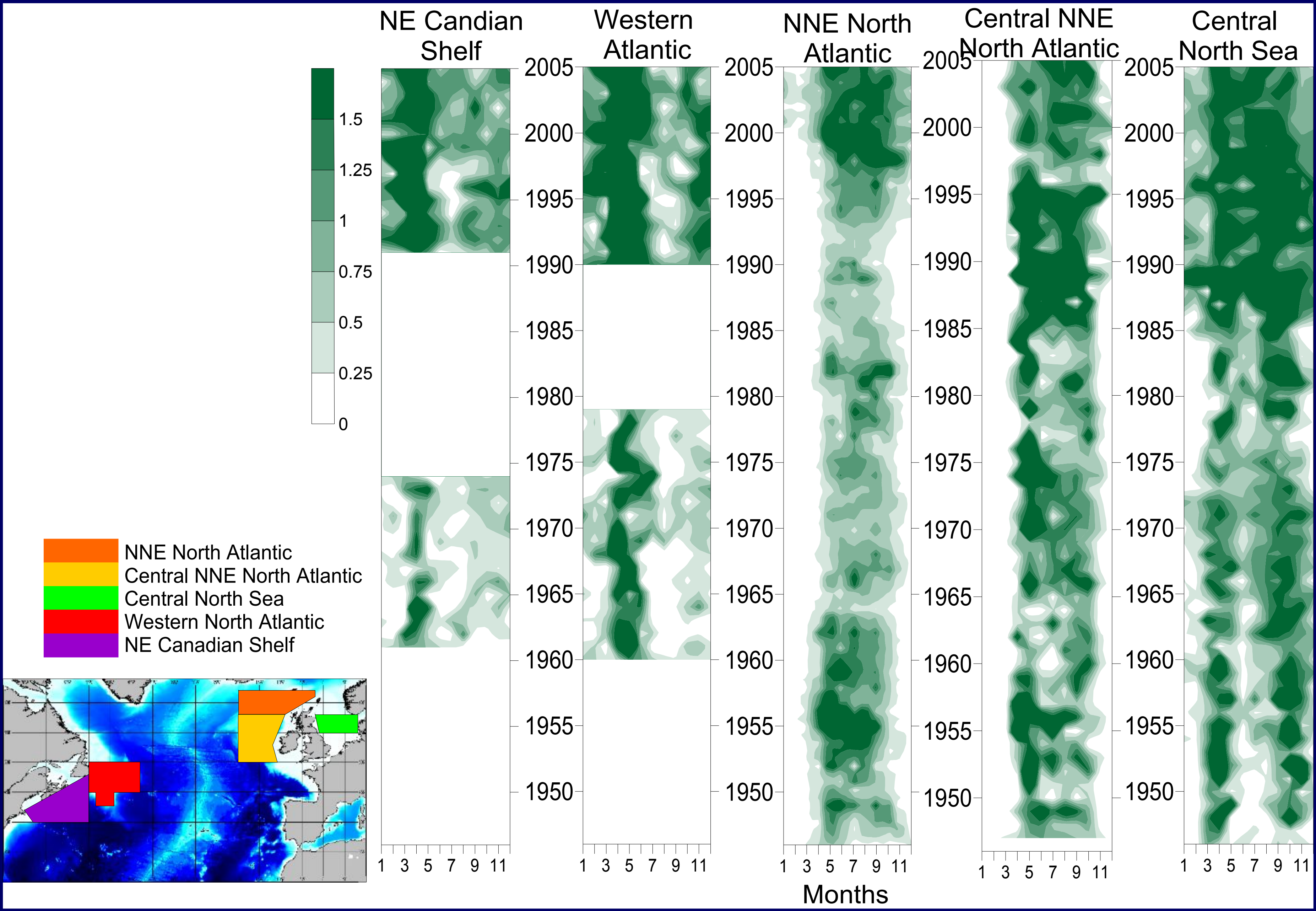


2002

Reid *et al*. 1998, Nature 391, 546 (updated)

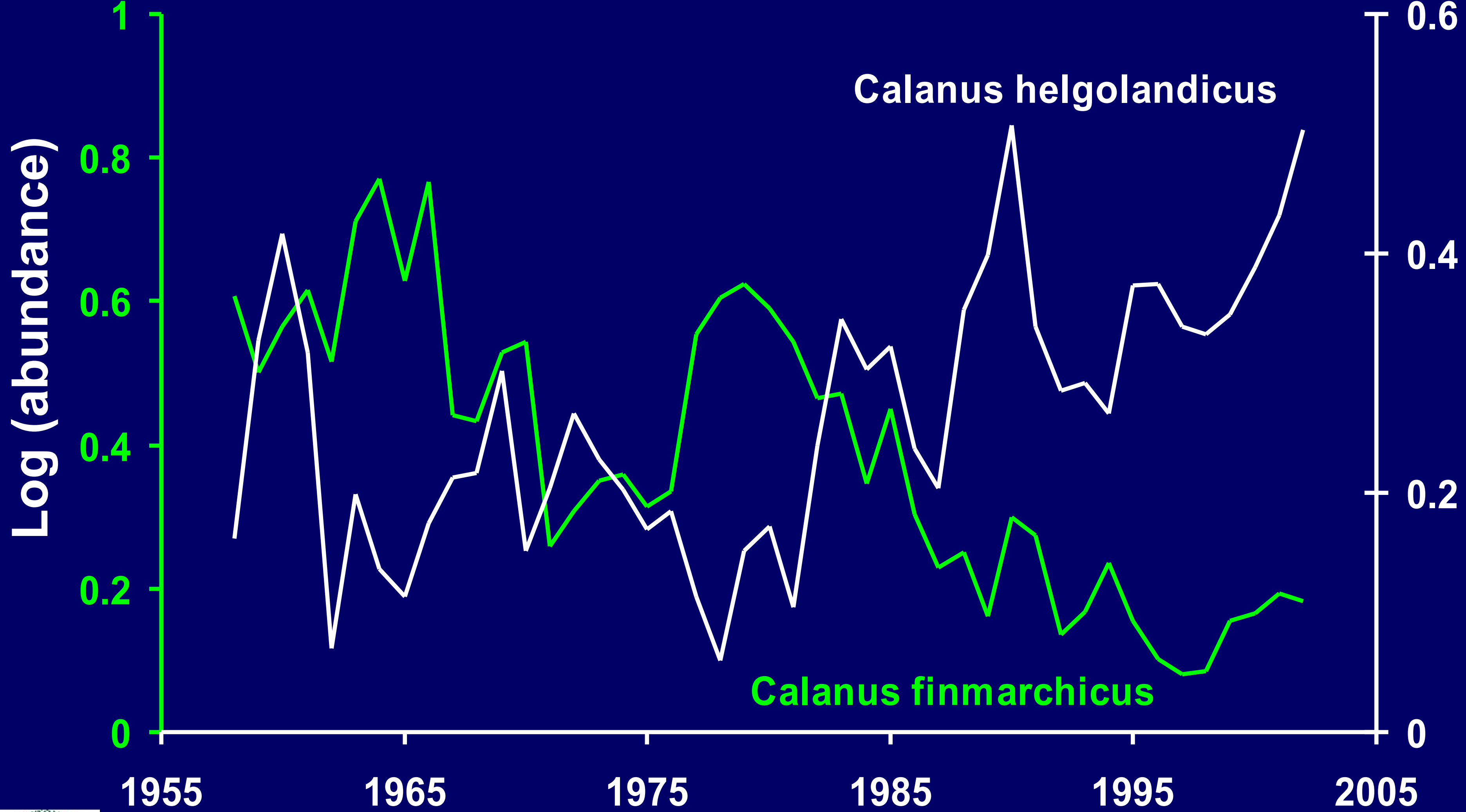
Step changes regional sea systems: Regime shift

Time series of Phytoplankton Colour 1946-2005



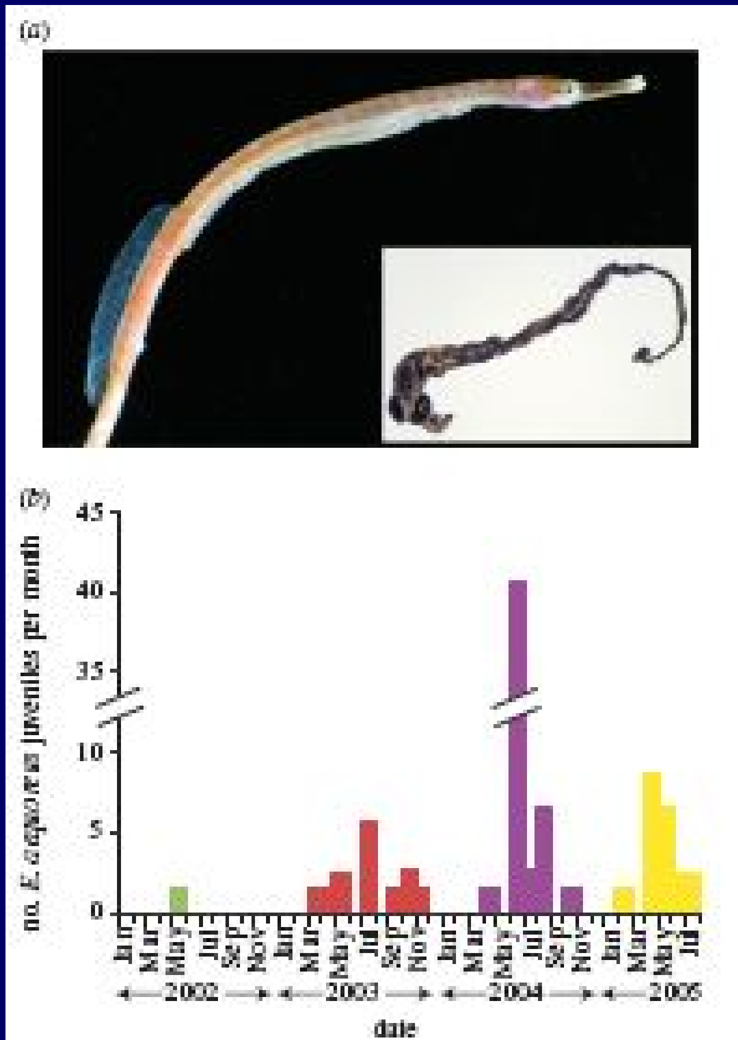
Reid 2005 GLOBEC Newsletter

Calanus North Sea 1958-2002



Reid et al. 2003, Fisheries Oceanography 12, 260-269

CPR pipefish records

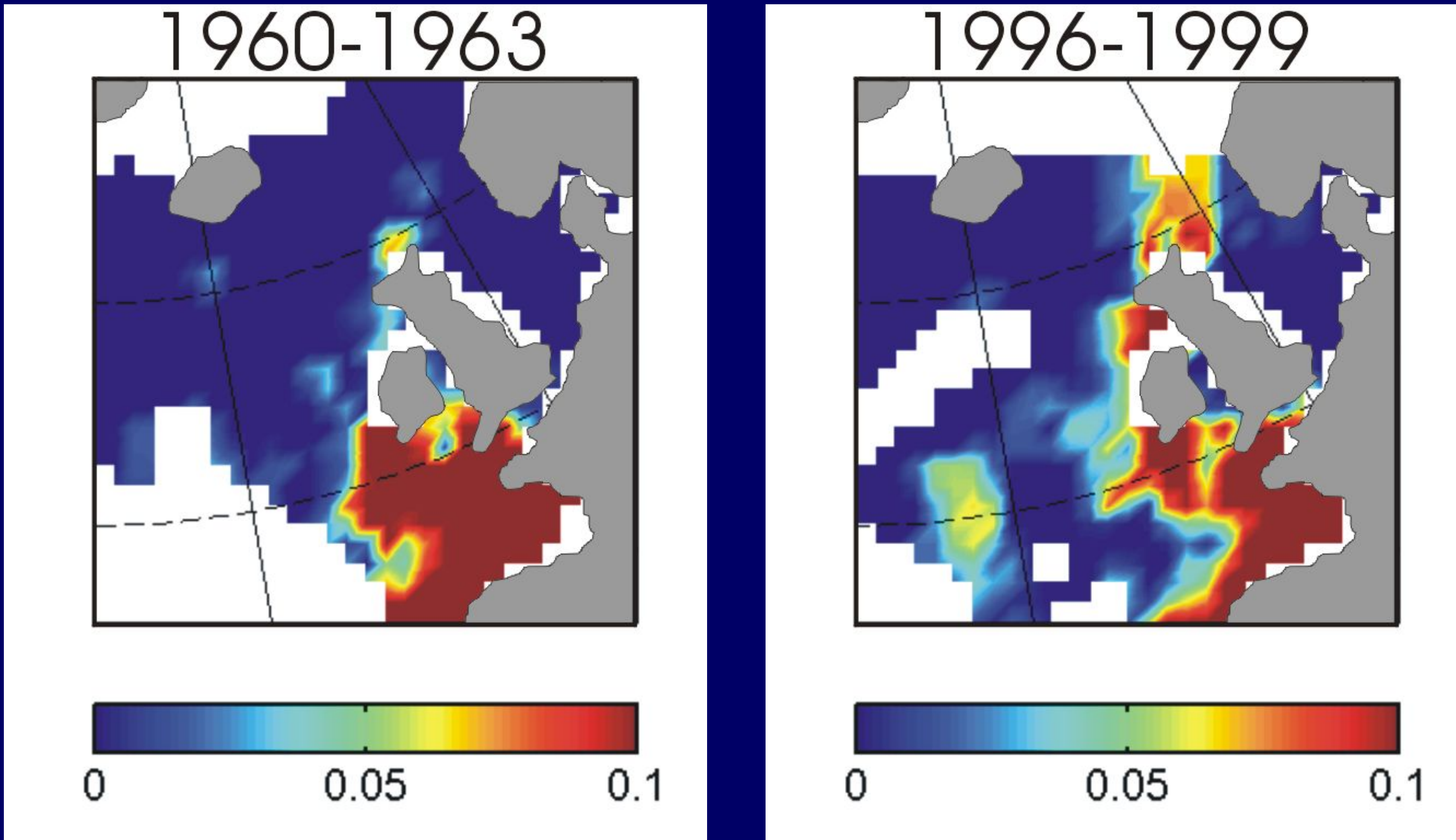


Common tern chick eating pipefish 2004

http://www.birdlife.org/news/features/2005/01/north_sea_seabirds.html

Kirby *et al*. 2006 Biology Letters 2

Northerly movement of plankton and fish



Warm temperate slope species

2005 *Euchaeta hebes, Clausocalanus, Ceratium hexacanthum*

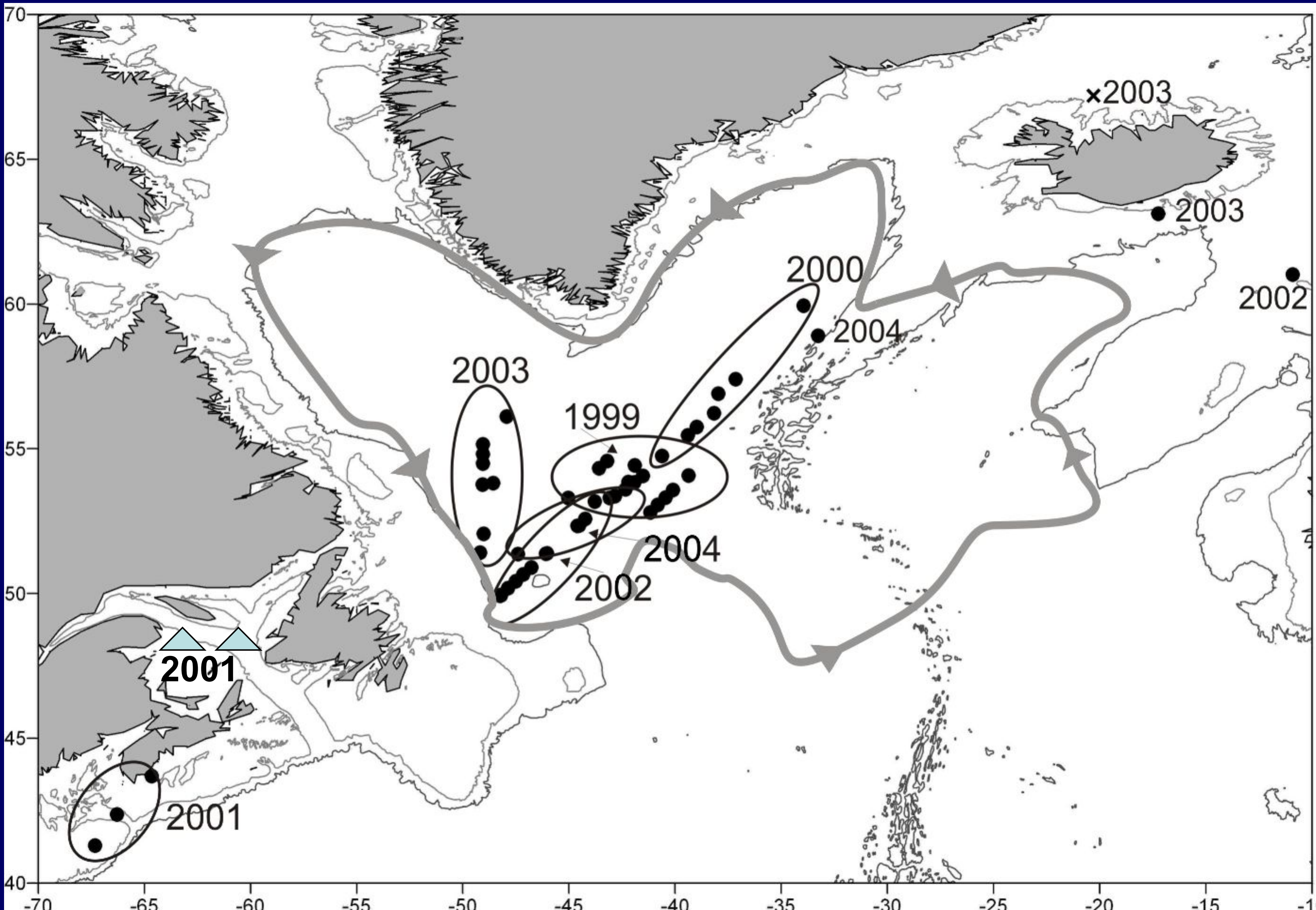
Beaugrand *et al*. 2003. Science **296**, 1692-1694

SAHFOS

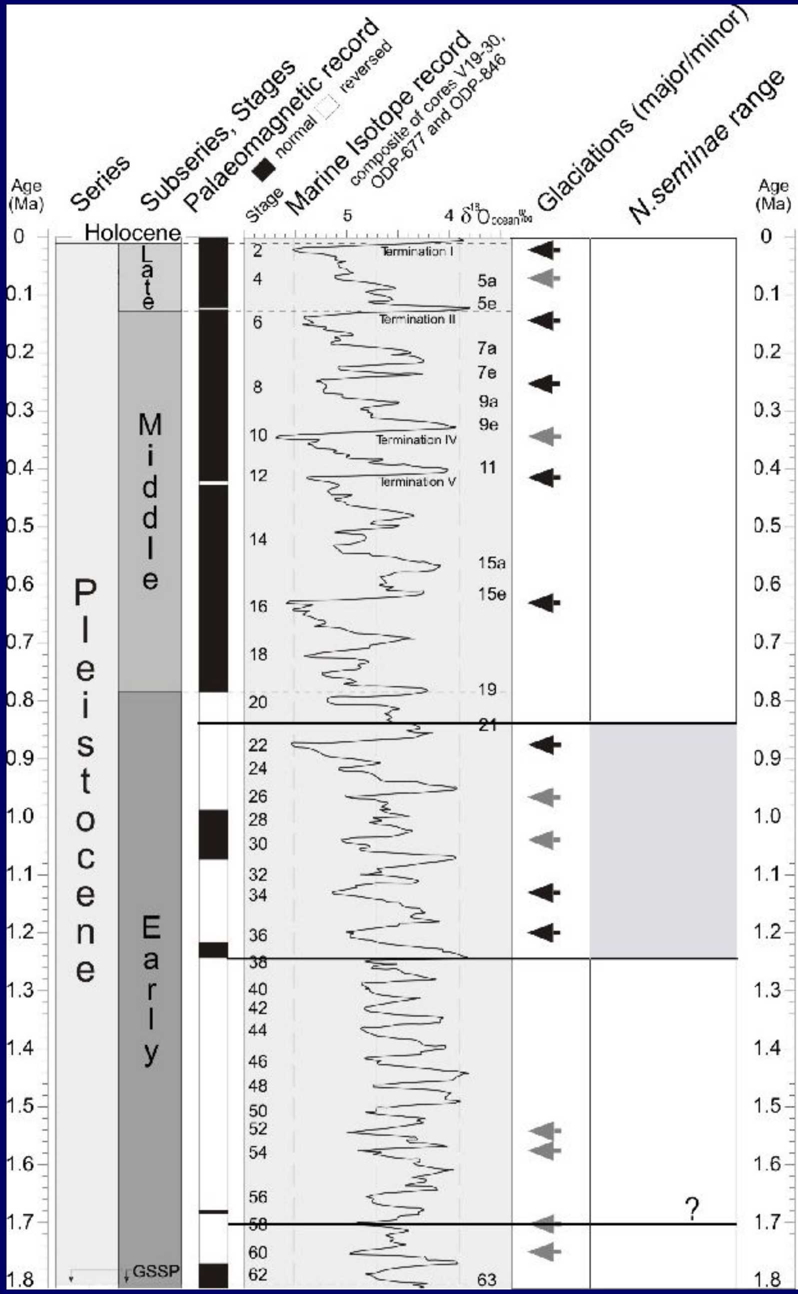
Time series of summed calcareous plankton from the CPR survey 1946-2005

Pteropods
Bivalve larvae
Echinoderm lar.
Brachiopod lar.

Long-term changes (1946-2005) in calcareous plankton in relation to Ocean acidification. Slide removed.



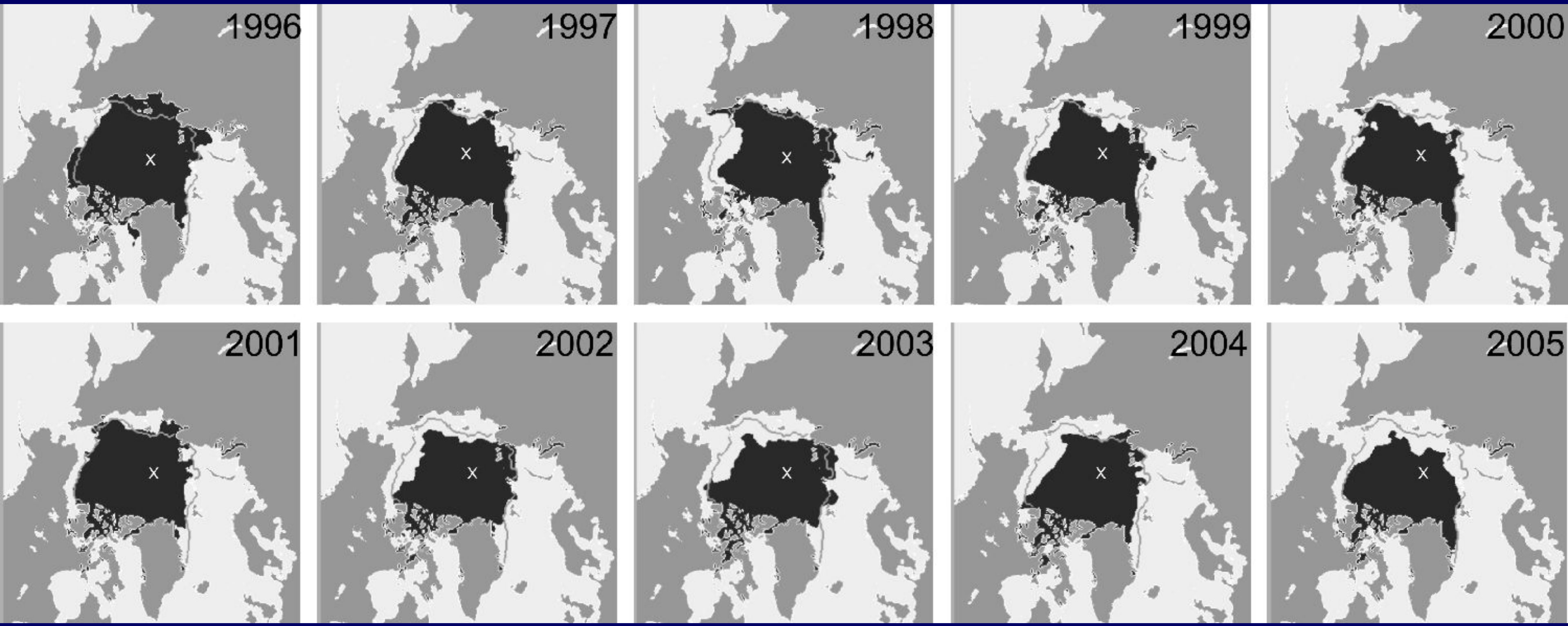
Reid *et al*. in press Global Change Biology



Mid-Pleistocene Transition

Reid et al. in press Global Change Biology

Polar ice extent in September 1996-2005

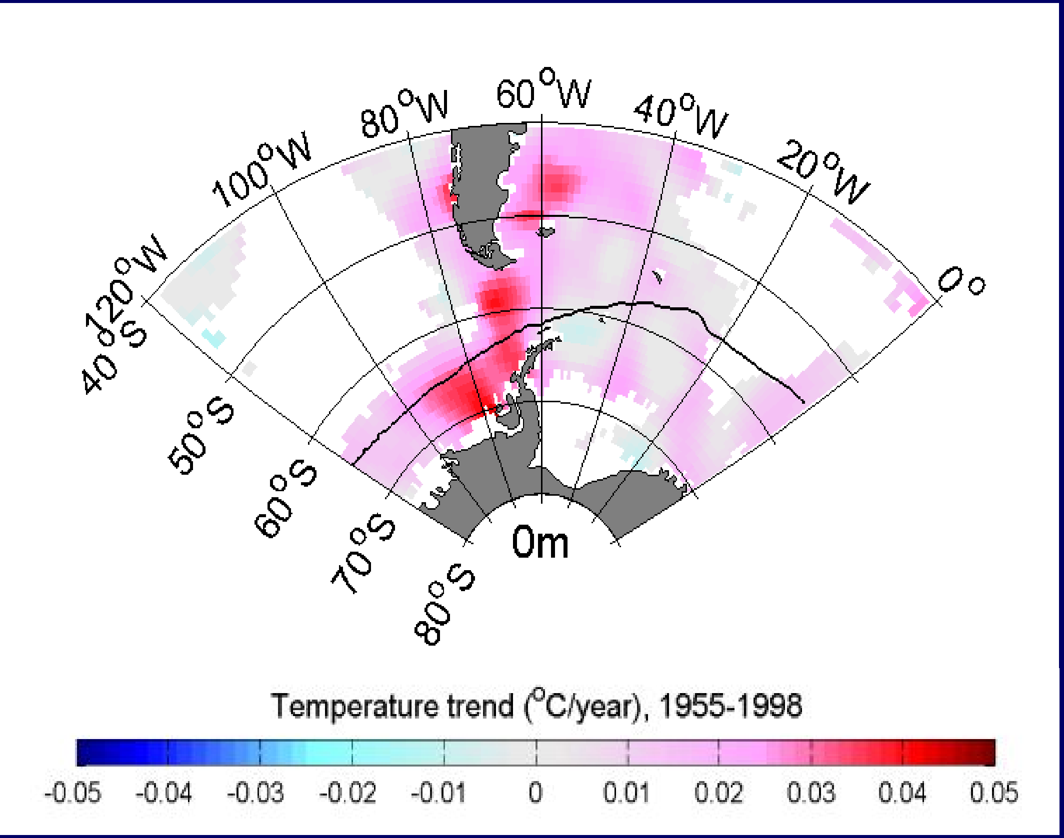


x Marks the North Pole

Reid et al. in press Global Change Biology

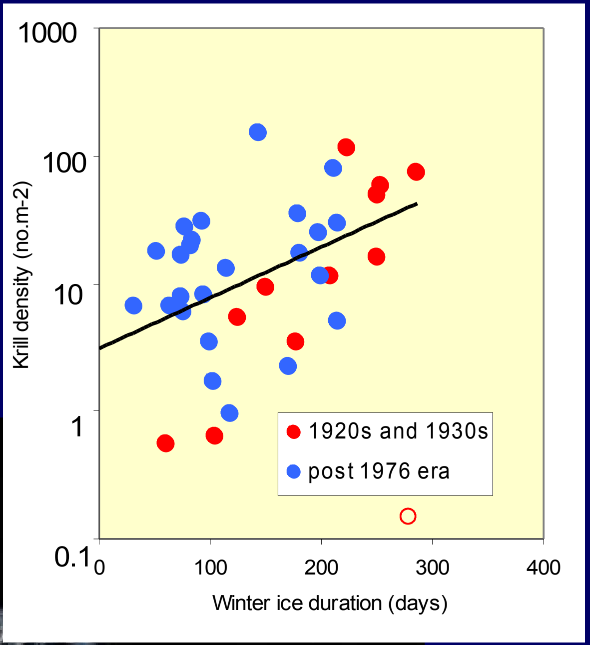
Ocean temperature trends, 1955-1998, based on *in situ* data (of which there isn't much!)

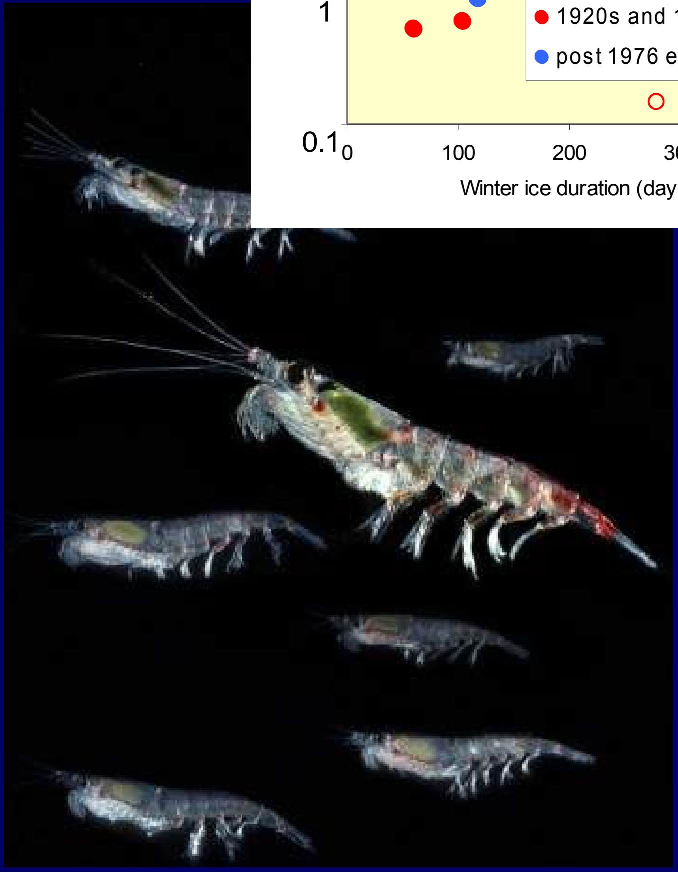
- Air temperatures rising more rapidly than anywhere else in the world… > 5˚C in winter since 1955
- Much greater than rate of warming of circumpolar Southern Ocean
- Strongly surface-intensified

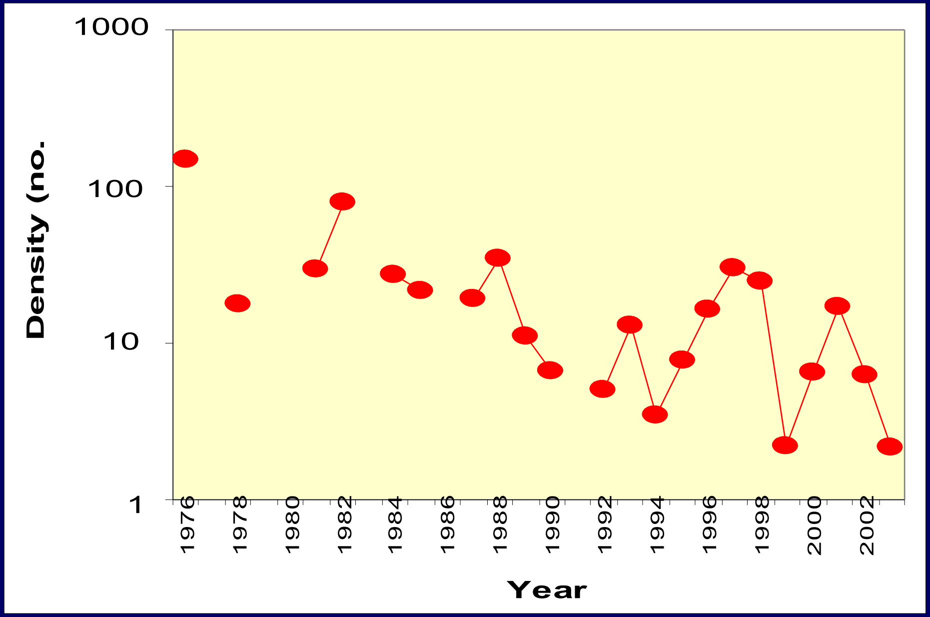


Meredith and King, 2005

- Krill stocks in SW Atlantic (which are sourced, at least partially, from the Antarctic Peninsula) are in steep decline
- This could be due to decrease in sea ice (and hence algae)
- But krill are known to favour cold water also …

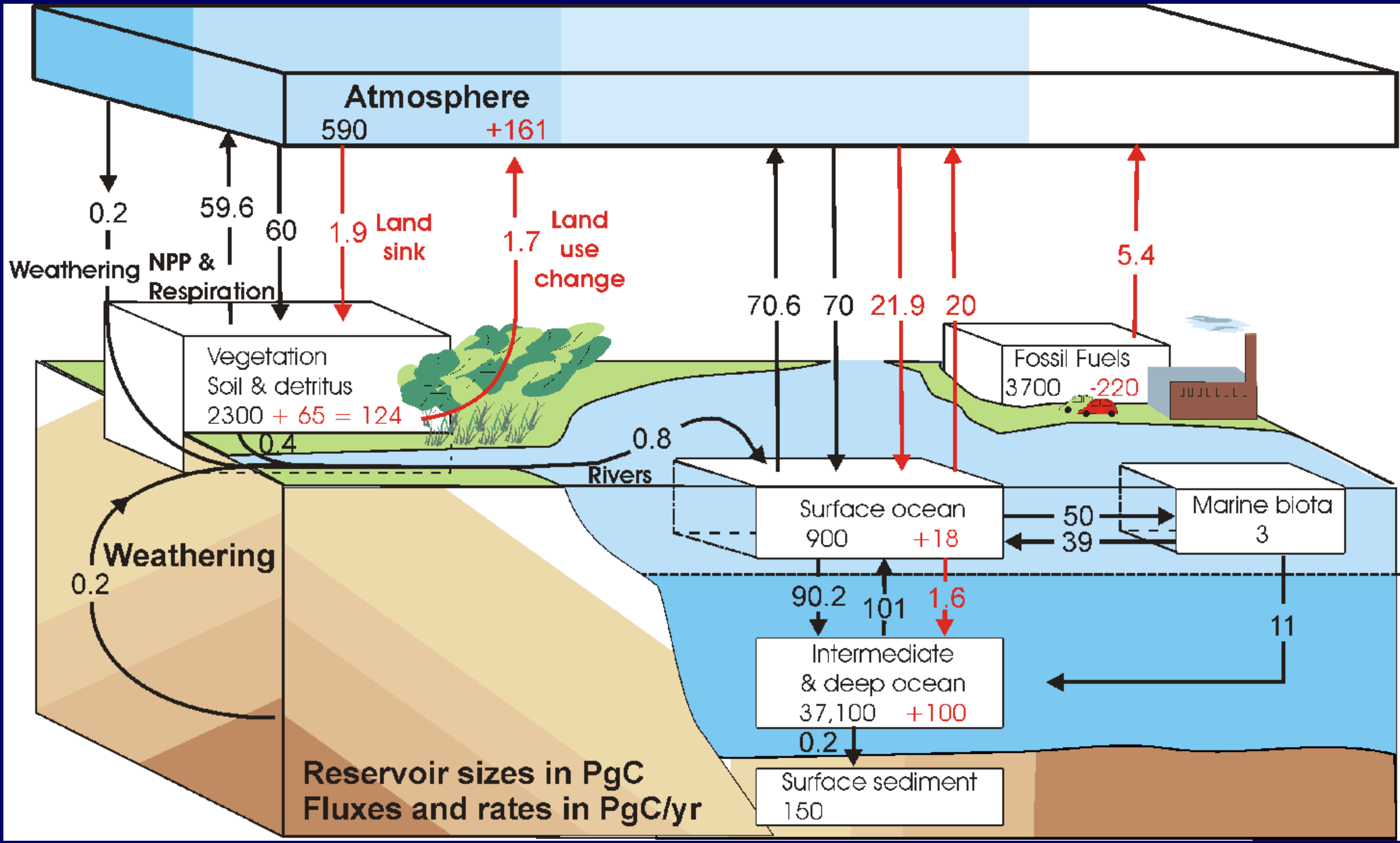






Atkinson et al. 2004 Nature

Carbon Cycle/ Biological Pump – CO_2, sensitivities



Sarmiento & Gruber, 2002 *Physics Today* 55

Net Atmosphere to Ocean flux
Natural and anthropogenic

0.6 Pg ↑ 1.9 Pg ↓

Total net Atmosphere to Ocean flux

1.3 Pg ↓

Ocean/deep Ocean fluxes

10.8 Pg ↑

11 Pg ↓

Ocean to bottom sediment flux

0.2 Pg ↓

1 Petagram (Pg) = 1 x 10^{15} g = 1 Gigatonne

	Oceans	Margins
Net primary production ~50 – >60 Pg C	81%	19%
Flux to thermocline	40%	60%
Flux to bottom	60%	40%

Frank Muller-Karger http//imars.usf.edu

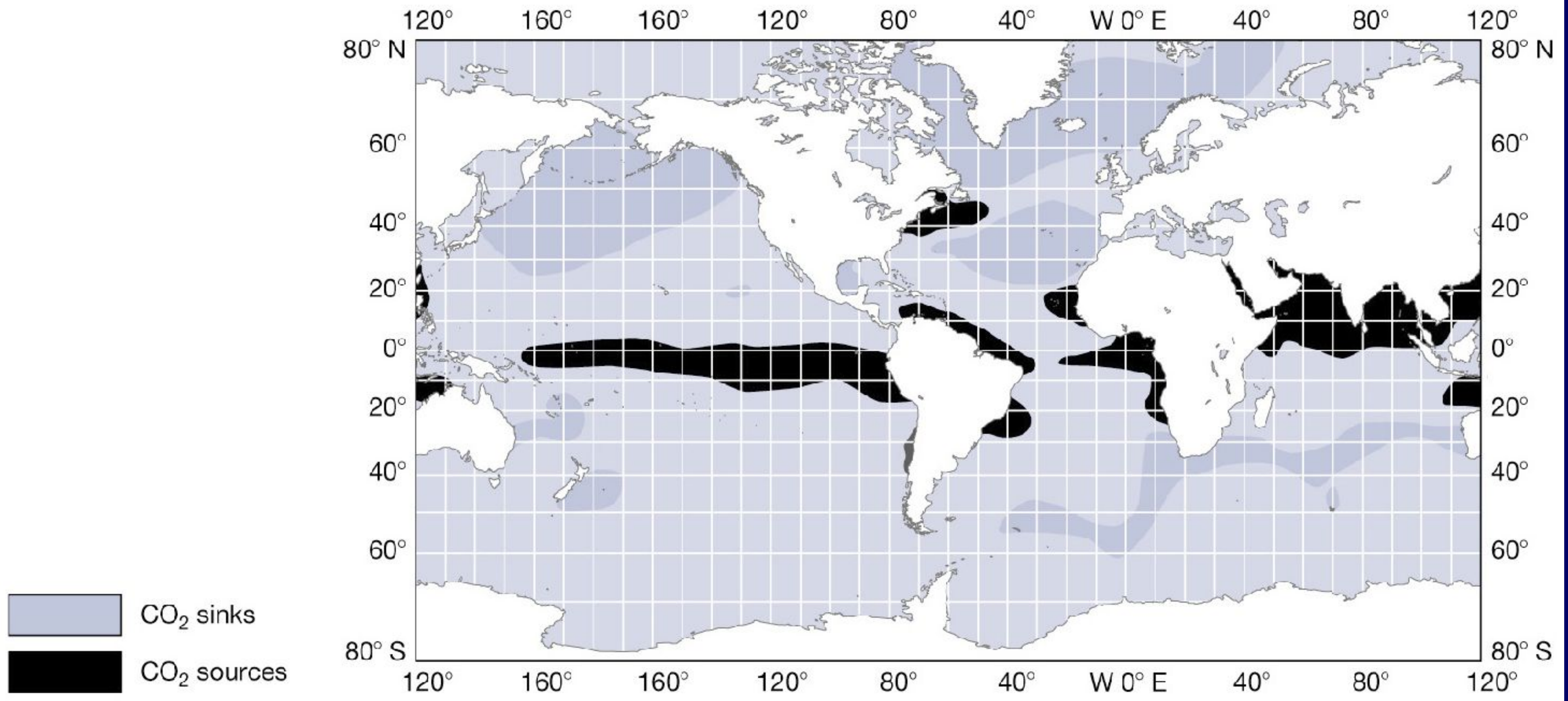
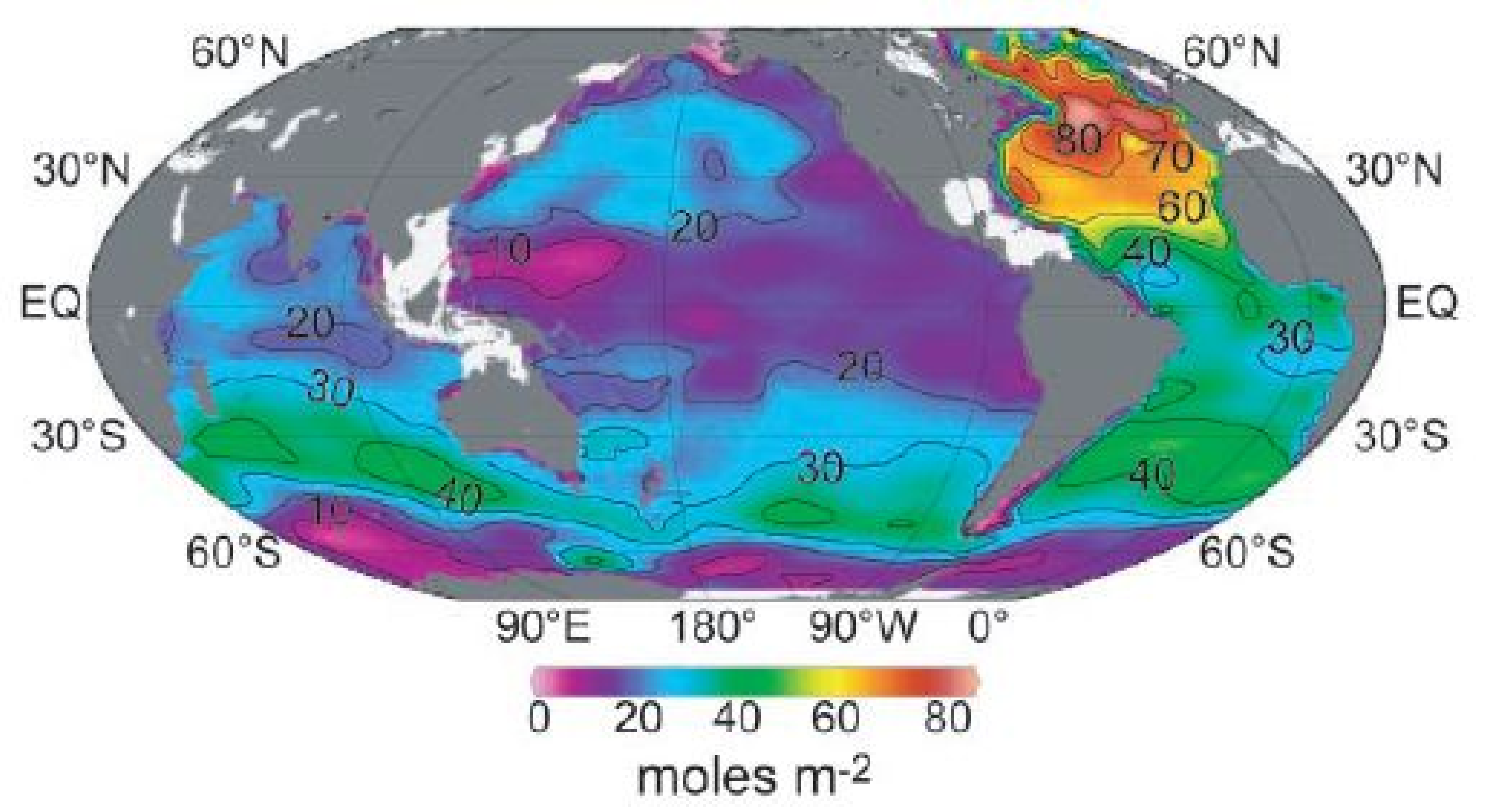


Fig. 8-13 Oceanic sources (darker shading) and sinks (lighter shading) of atmospheric CO_2. Sources have CO_2 concentrations larger than those in equilibrium with the atmosphere, whereas sinks have lower-than-equilibrium CO_2 concentrations. (After T. Takahashi. 1989. *Oceanus*, 32, pp. 22–29.)

The solubility pump

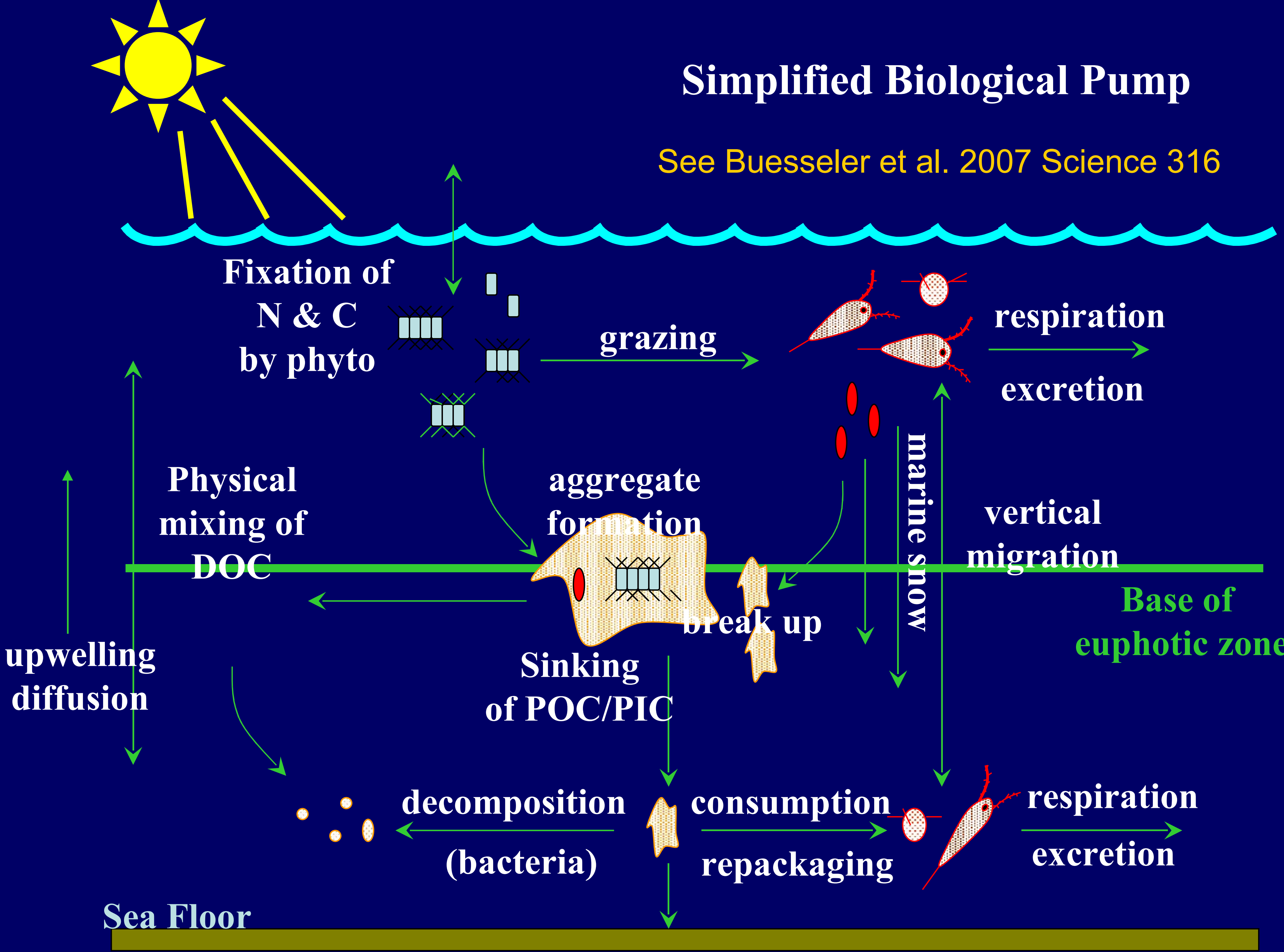
Inventory of anthropogenic CO_2 in the ocean water column



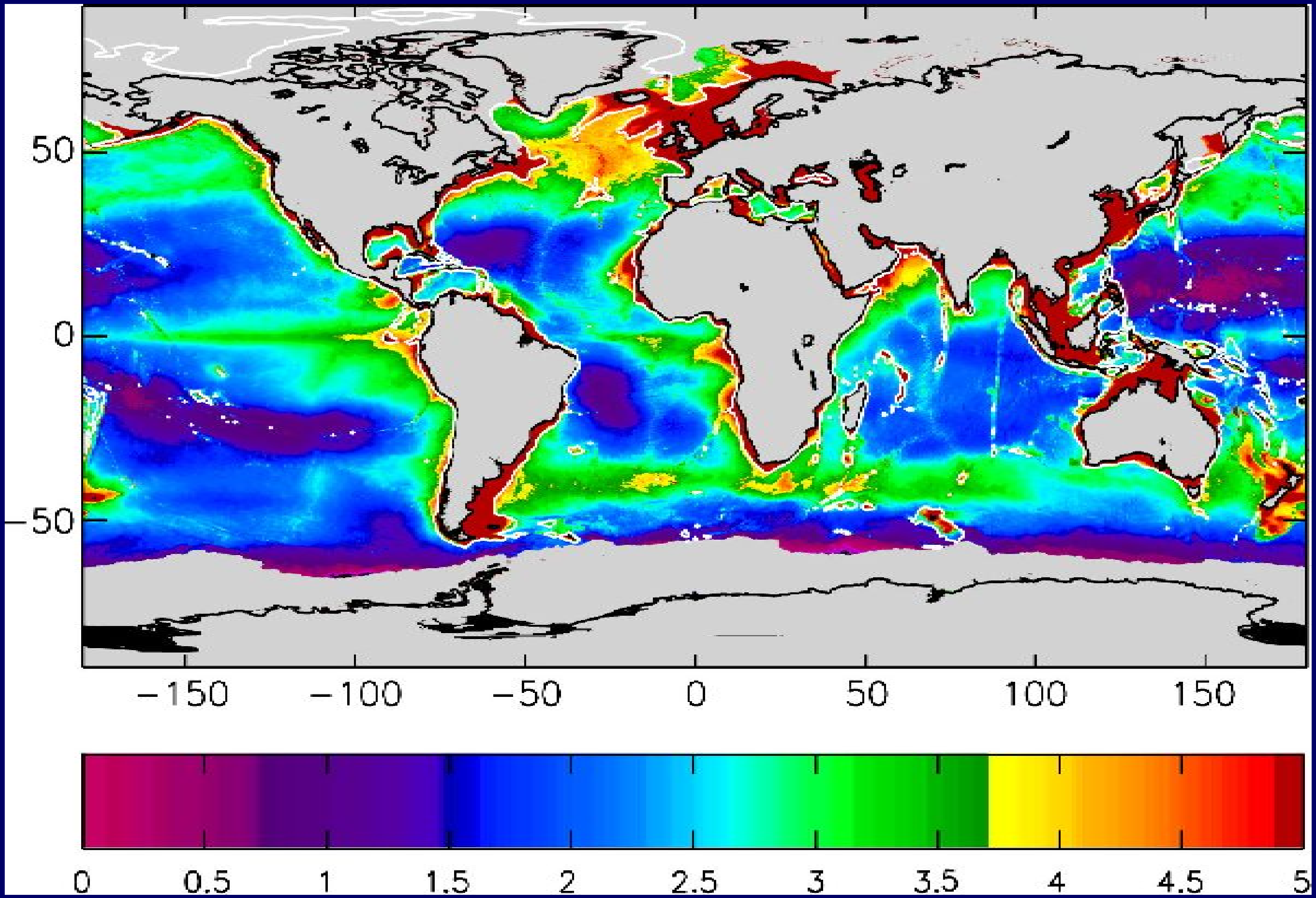
Sabine *et al*. 2004 Science 305

Simplified Biological Pump

See Buesseler et al. 2007 Science 316

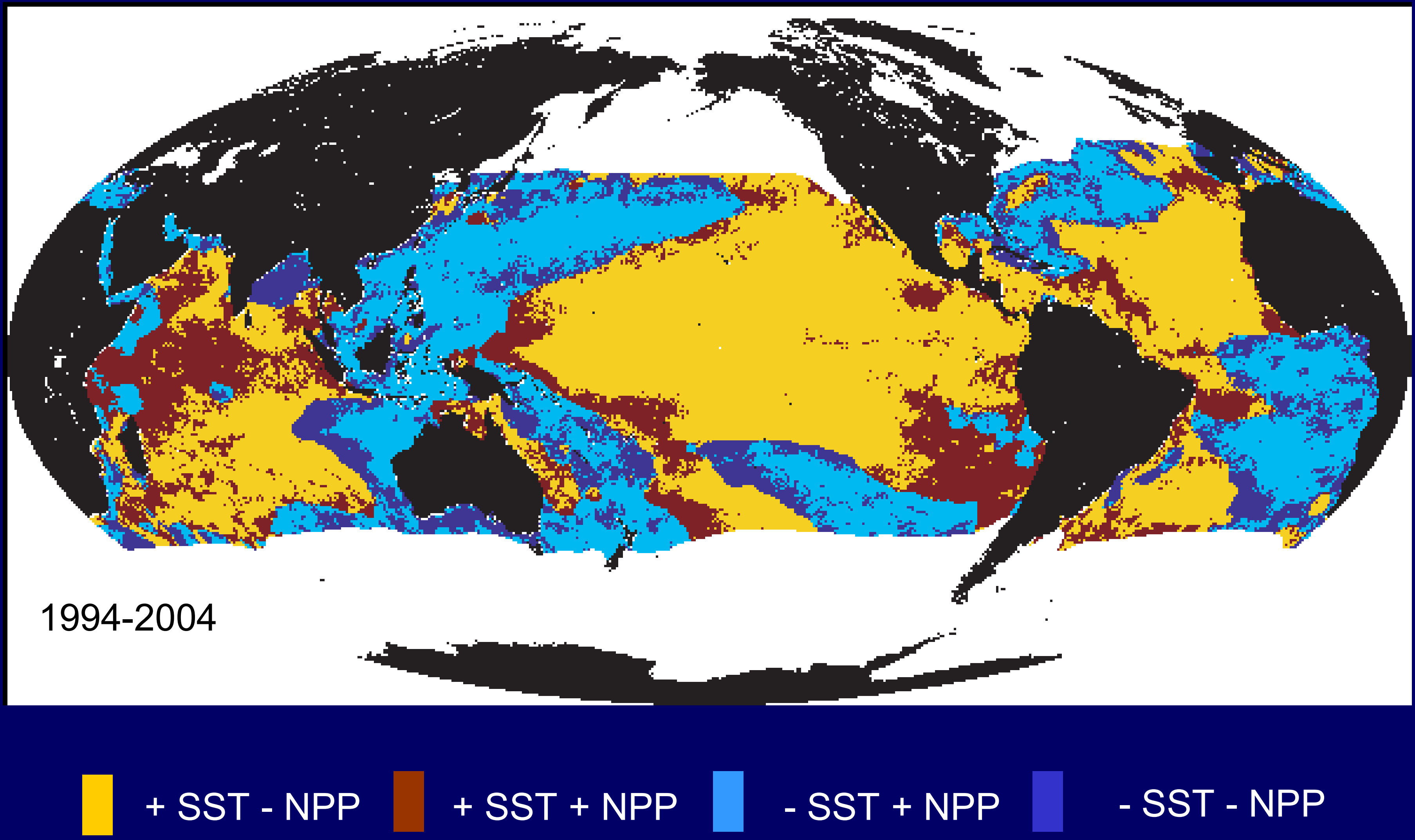


Average annual bottom POC flux (g m-2 y-1) (1998-2001)



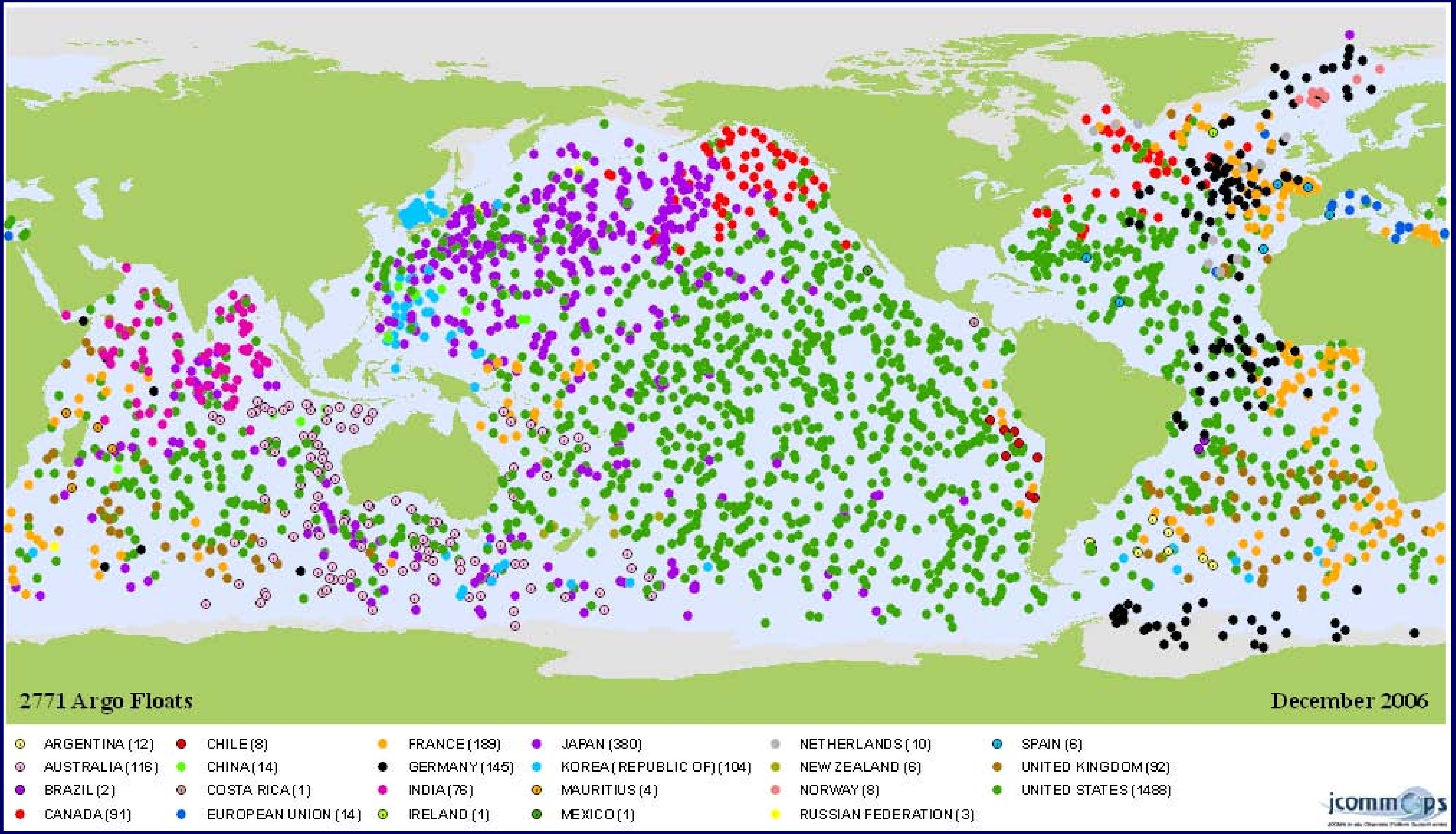
Frank Muller-Karger http//imars.usf.edu

Inverse relationship between NPP and SST



Behrenfeld et al. 2006 Nature 444

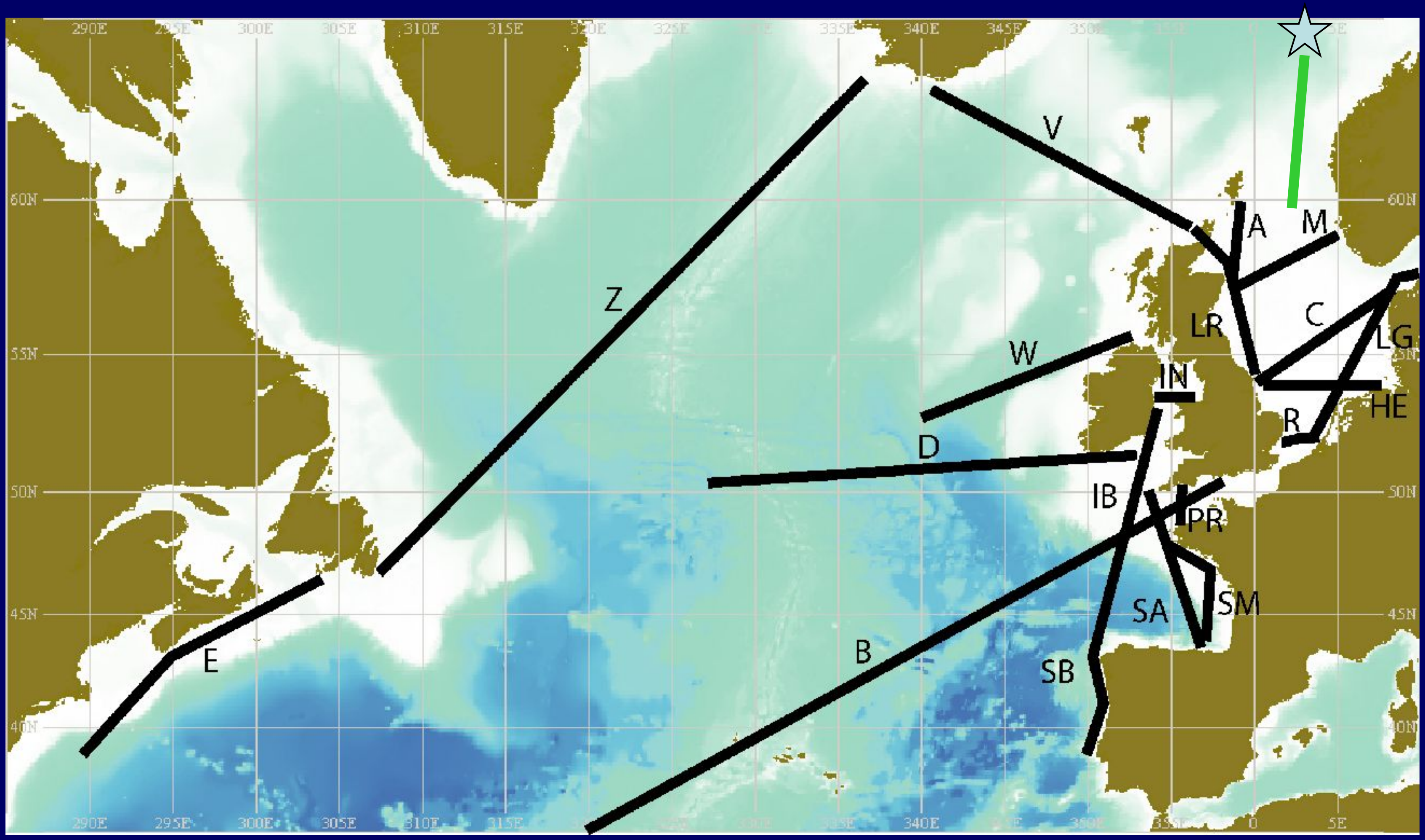
Argo Operational and funding gaps



http://www.ocean-partners.org/

Parnership for Observation of the Global Oceans (POGO)

Standard monthly Continuous Plankton Recorder routes in the North Atlantic



Conclusions / Recommendations

Key role of the Oceans in the carbon cycle not recognised
Crucial importance of the plankton (zooplankton) not appreciated
Very rapid observation and predictive change, apparently accelerating
Decadal to 100 year plus prognosis worrying
Poor understanding of processes and techniques still at development level
Additional complication of effect on carbon cycle of acidification (pH)

NOT TACKLING ISSUES WITH URGENCY AND RESOURCES REQUIRED

Need an integrated global ocean biological/biogeochemical observing programme NOW
Establish a global monthly CPR survey for regional variability of plankton
Increase coverage of OceanSITES to represent ocean variability
Standardise methods globally
Incorporate new techniques instruments for finer scale variability and process studies
Actively collaborate with modellers to find out what they need and vice versa

PASS ON THE MESSAGE OF THE IMPORTANCE OF PELAGIC BIOLOGY
TO POLICY MAKERS, THE PUBLIC AND MEDIA
BY IMPROVED COMMUNICATION AND KT

SAHFOS pogo

PREPARE FOR THE FUTURE BY ADAPTING!