Title Version 1:
Requirement for quality data: OMZ as an example

Title Version 2: Data quality requirements: OMZ example

Title Version 3: Requirement for quality data: OMZ & Southern Ocean examples

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OMZ: D. Bianchi, E. Galbraith, I. Kriest, E. Kwon, A. Oschlies, and Allison Smith

Southern Ocean: J. Russell, L. Talley, et al.

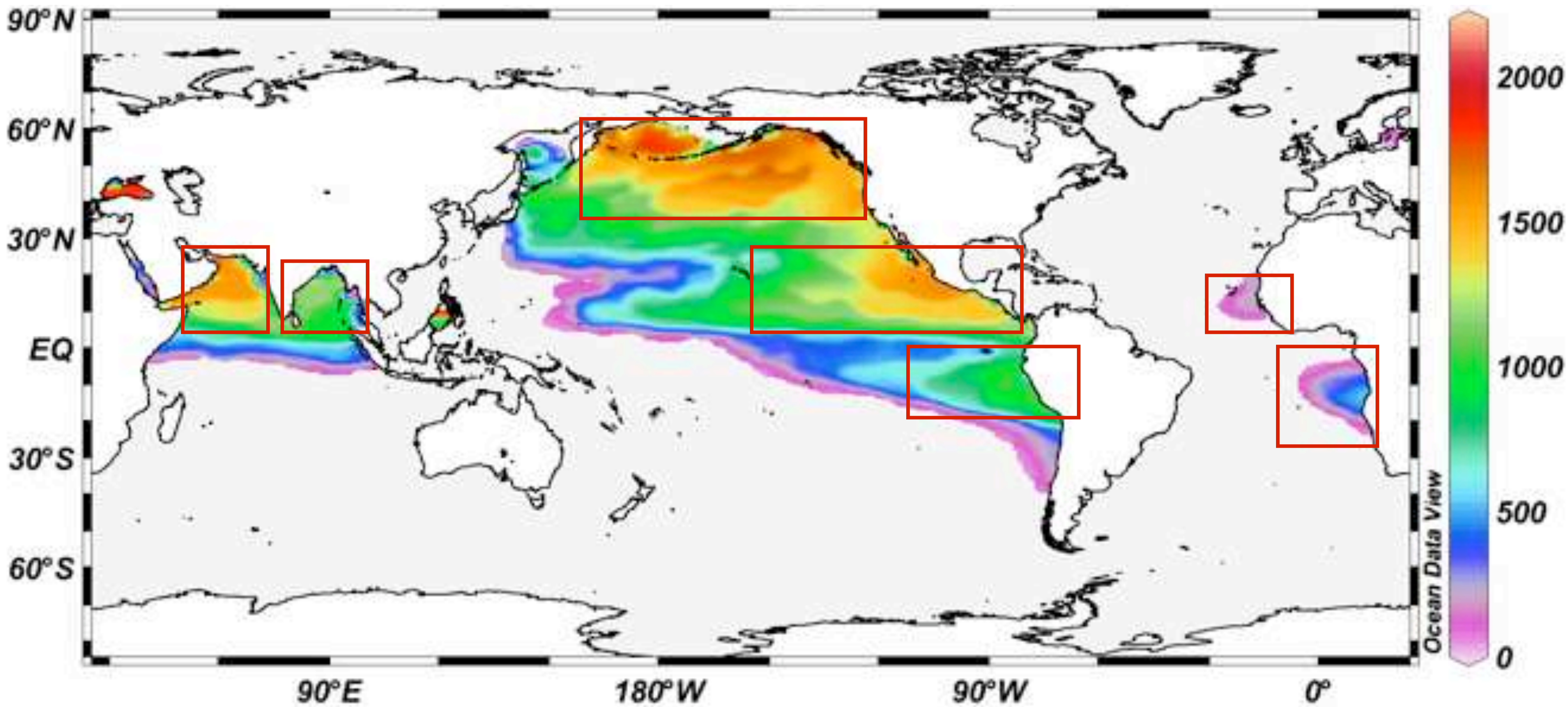
Requirement for quality data

I. The oxygen minimum zone (OMZ) grand challenge
   A. The present
   B. The future
II. The Southern Ocean grand challenge
   A. The challenge
      1. The present
      2. The future
   B. The opportunity
      1. Floats
      2. Modeling

I. The OMZ

I. A. The present

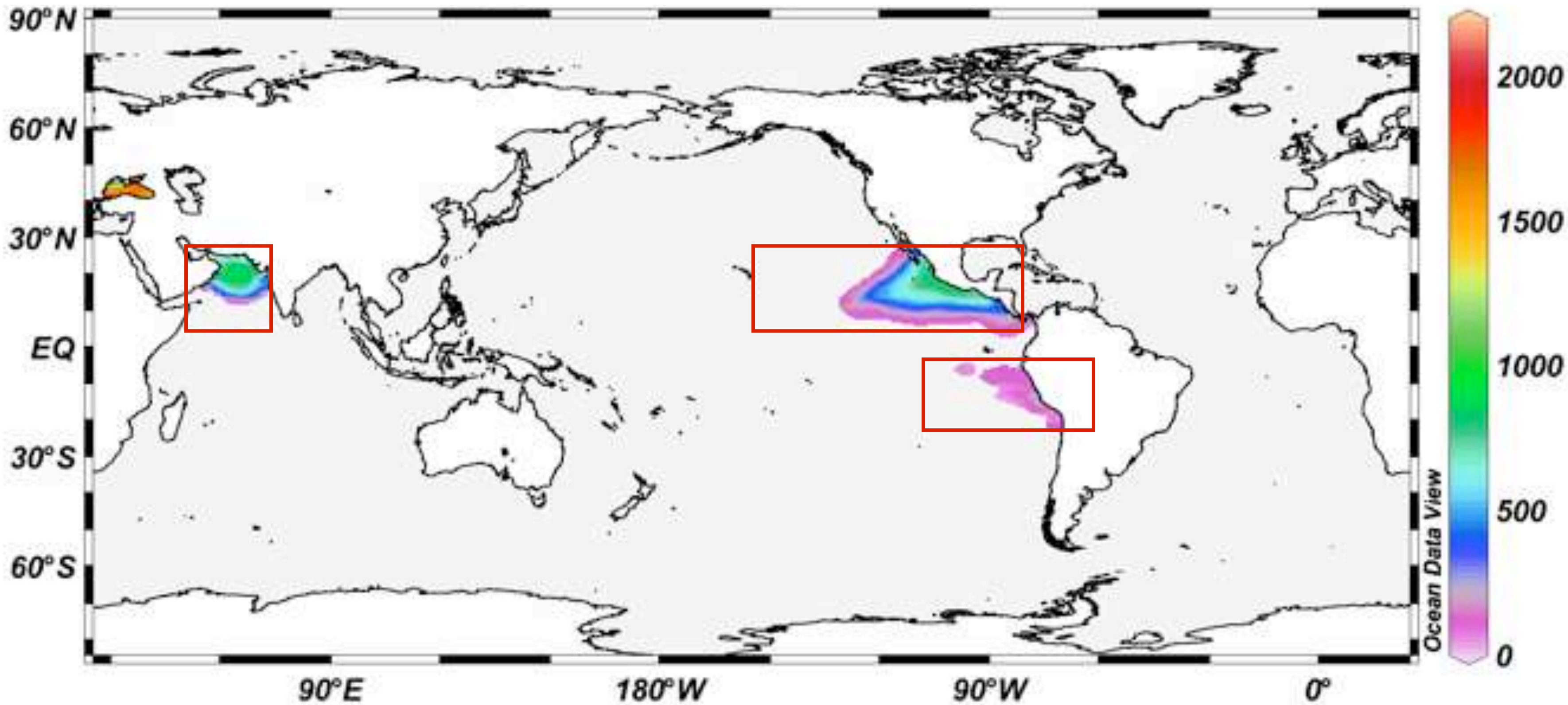
Water column thickness with O_2 < 63 υμολ/Λ



7 major OMZs

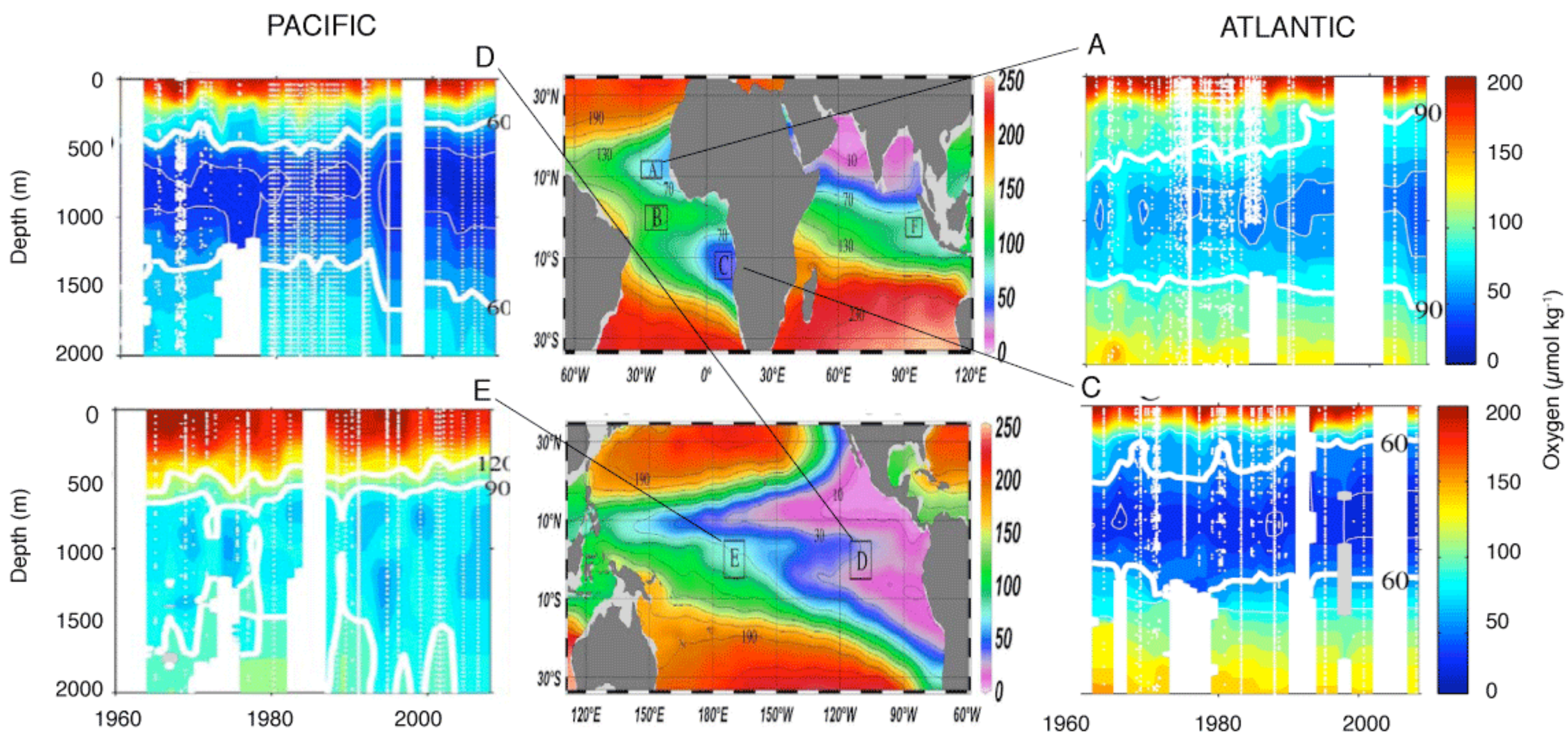
from WOA01

Water column thickness with O_2 < 10 υμολ/Λ



Only 3 OMZs show very low O_2

Evolution of oxygen content in O_2-minimum regions



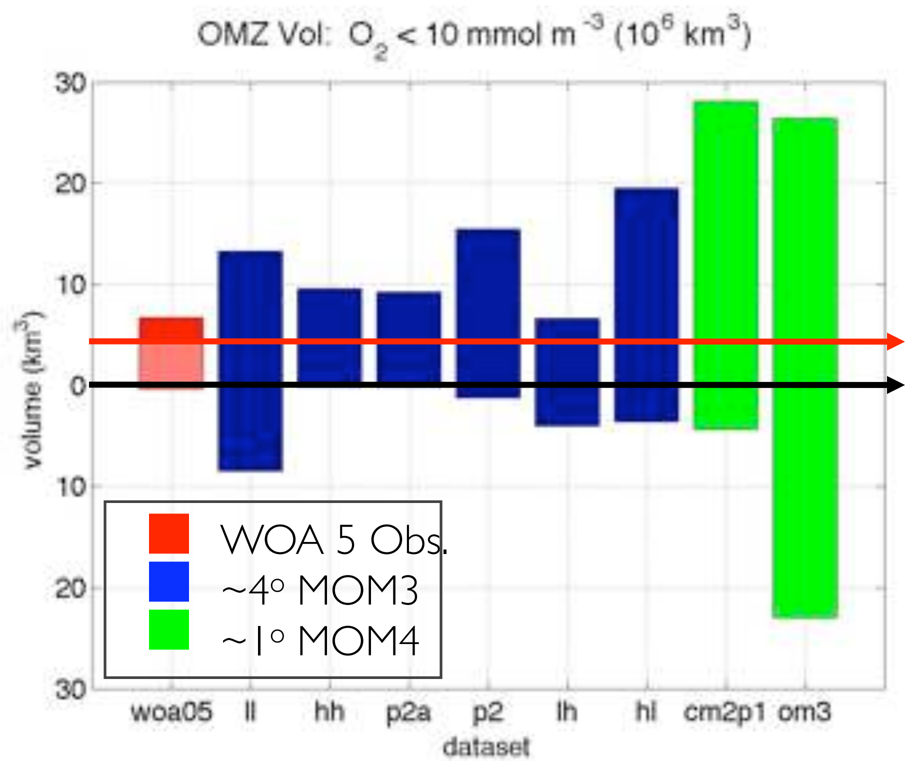
Stramma et al. (2008)

Several O_2-minimum zones have lost O_2 in the recent decades, resulting in a expansion of the regions with hypoxia

ARGO O_2

Effect of physics on OMZ volume in Princeton biogeochemistry models

volume of suboxic water

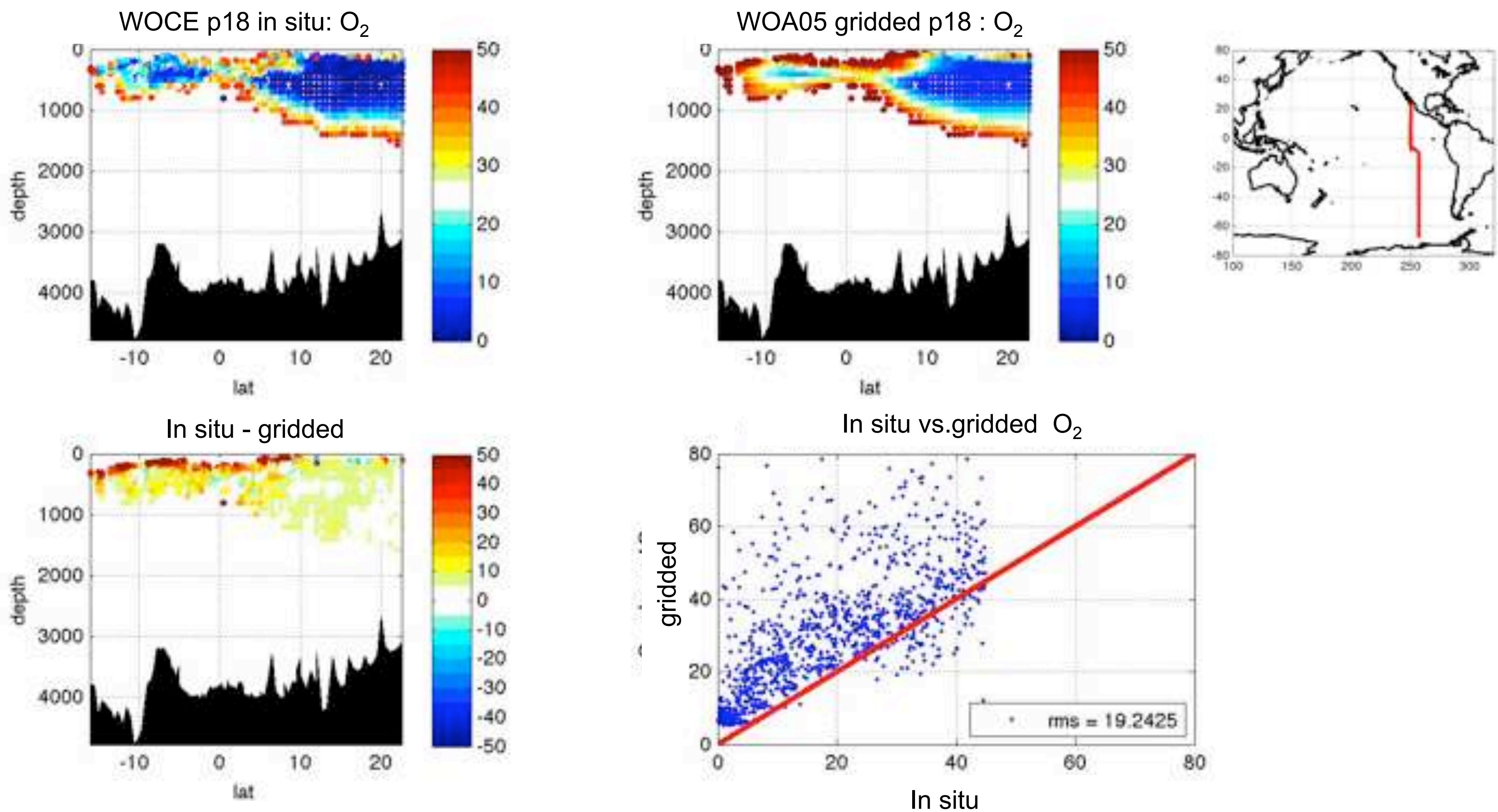


Upper
1000 m

Below
1000 m

Bianchi (pers. comm.)

Bias in existing gridded O_2 datasets - 1



Gridded datasets show O_2 biases around 5 mmol m^{-3} inside OMZs
Can mask large volumes of suboxic waters!

Bianchi (pers. comm.)

Datasets: Oxygen distribution

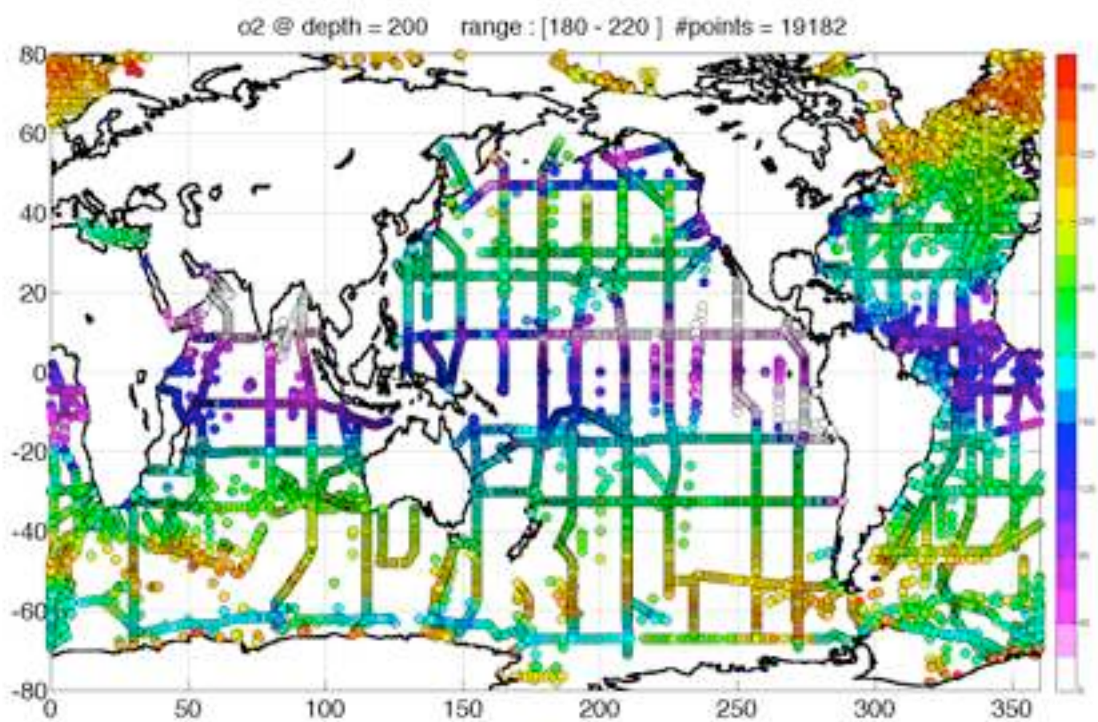
Three oxygen datasets:

1,2 : objective mapping of GLODAP

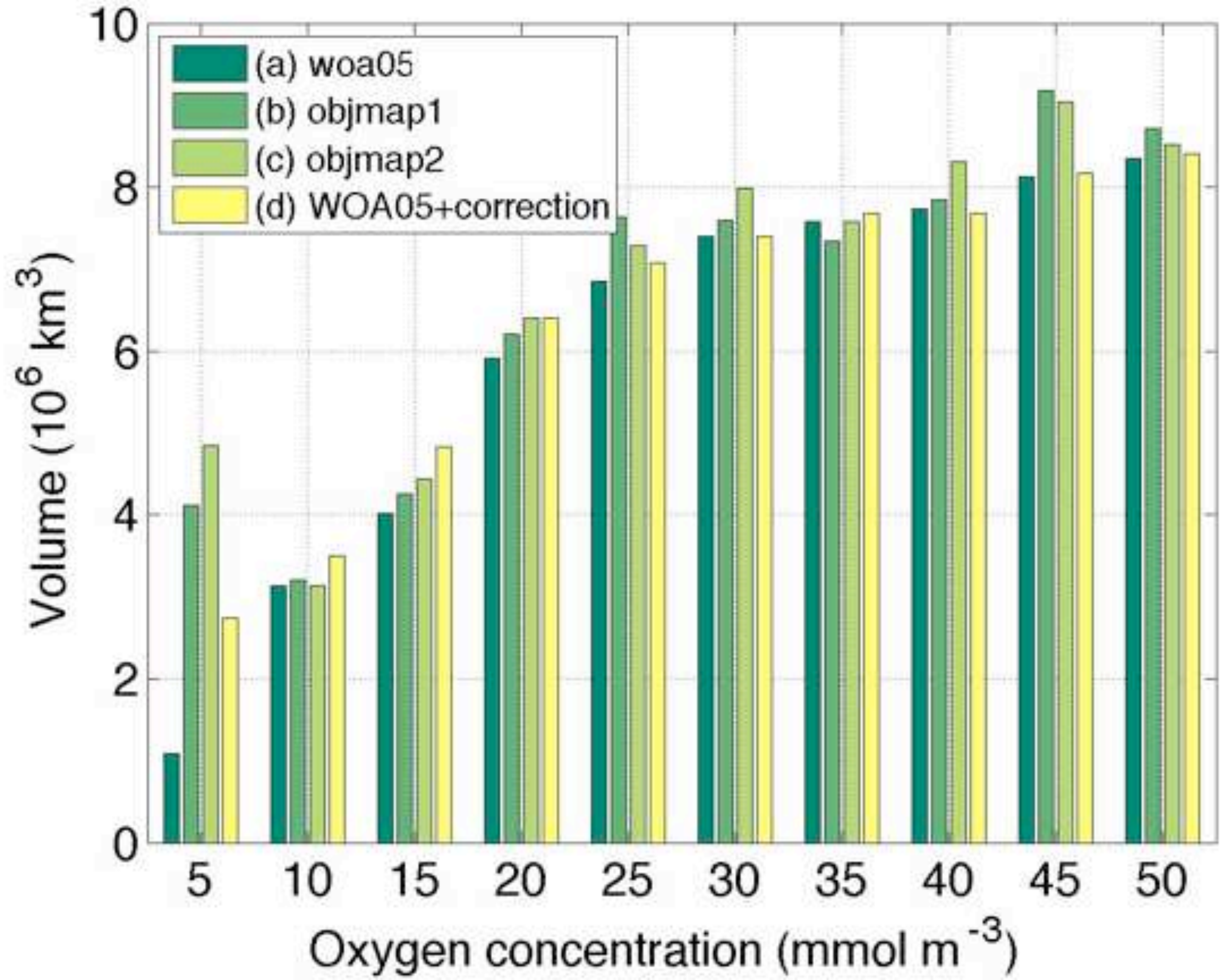
3: WOA05 corrected using in situ GLODAP

GLODAP + CARINA:

High quality measurements from WOCE, JGOFS, CLIVAR, mostly after the 1990's (compare to WOA starting from the 1950's)



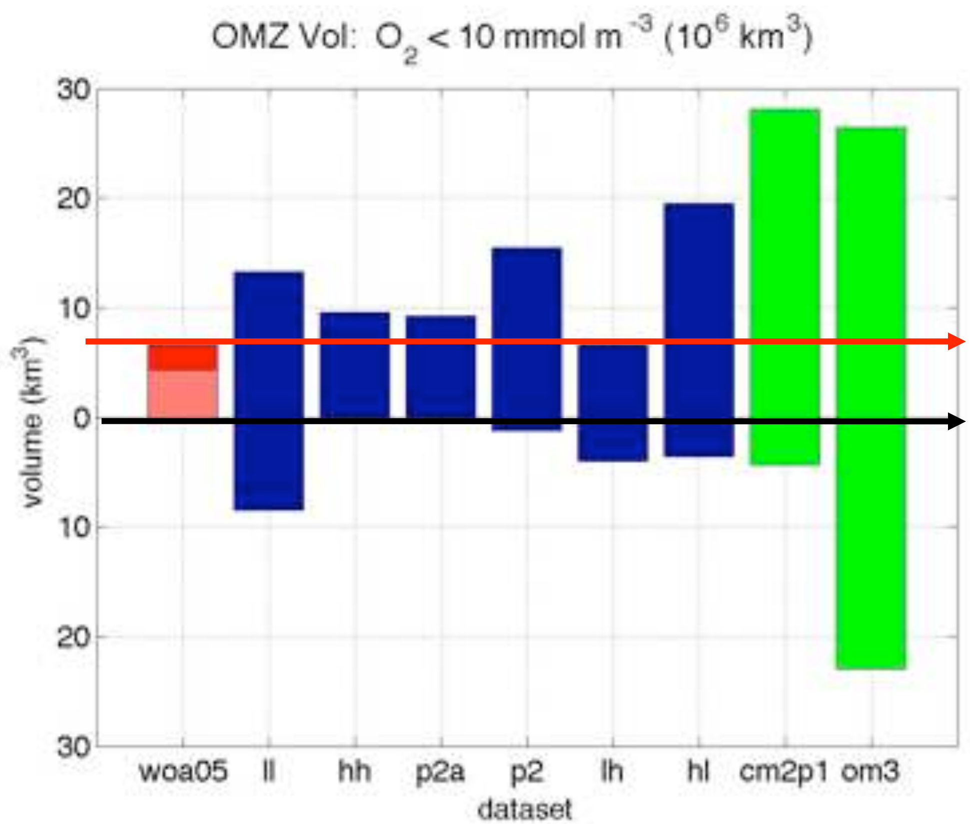
Oxygen dataset results - 3



Effect of physics on OMZ volume in Princeton biogeochemistry models

Volume of suboxic water (<10 umol/L)

- WOA 5 Obs.
- ~4° MOM3
- ~1° MOM4



Upper 1000 m

Below 1000 m

- Large model variability in deep (>1000 m). OMZ volumes are determined by preformed nutrients.
- Relatively uniform thermocline (<1000 m) OMZ volumes

Bianchi (pers. comm.)

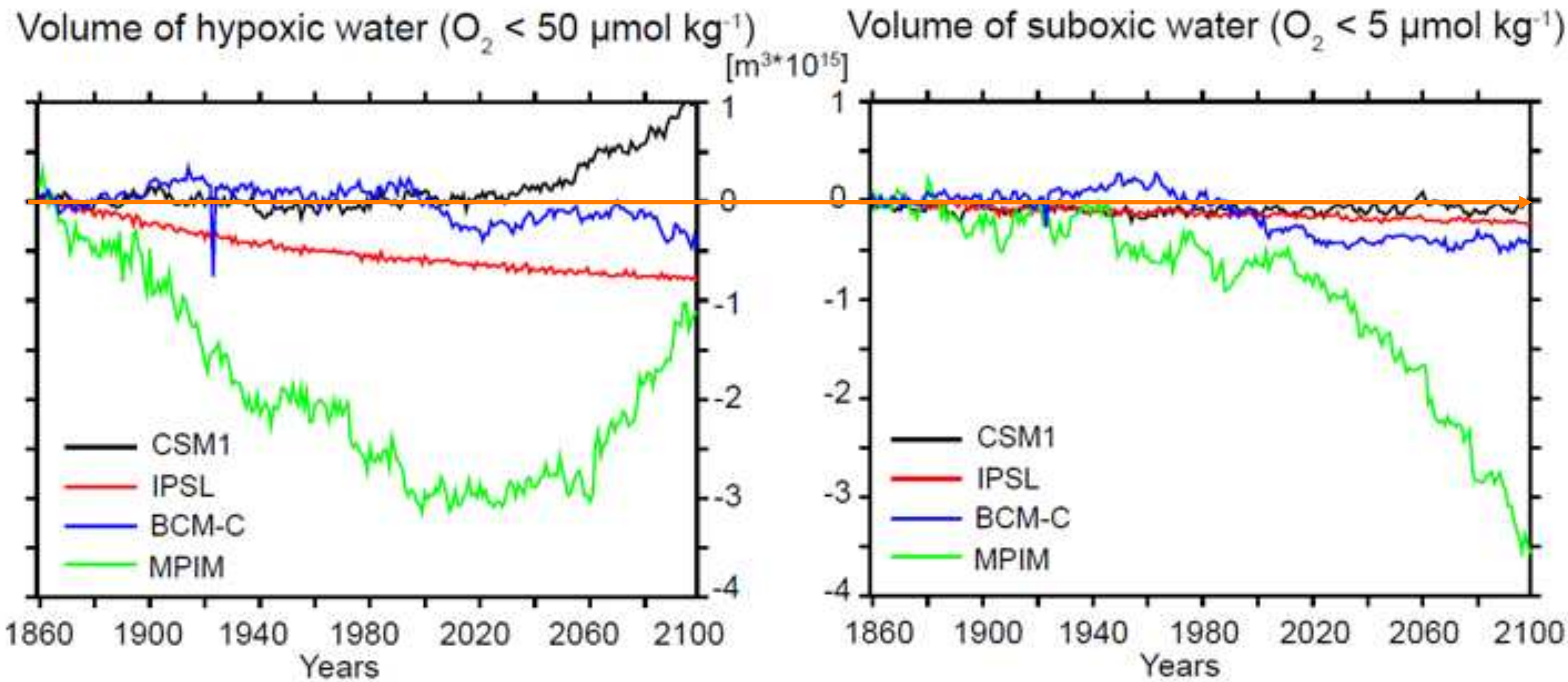
I. B. The future

Model predictions of average O_2 decrease by 2100

Study	Forcing	O_2 decrease (umol/L)	Solubility contribution (%)
Sarmiento et al. (1998)		7	
Matear et a. (2000)	IS92A	7	18
Plattner et al.	SRES A1	12	35
Bopp et al.. (2002)	SRES A2 CO_2 only	4	25
Matear & Hirst (2003		9	26
Schmittner (2008)	SRES A2	9	
Oschlies et al. (2008)	SRES A2	9	
Frölicher et al. (2009)	SRES A2	4	50

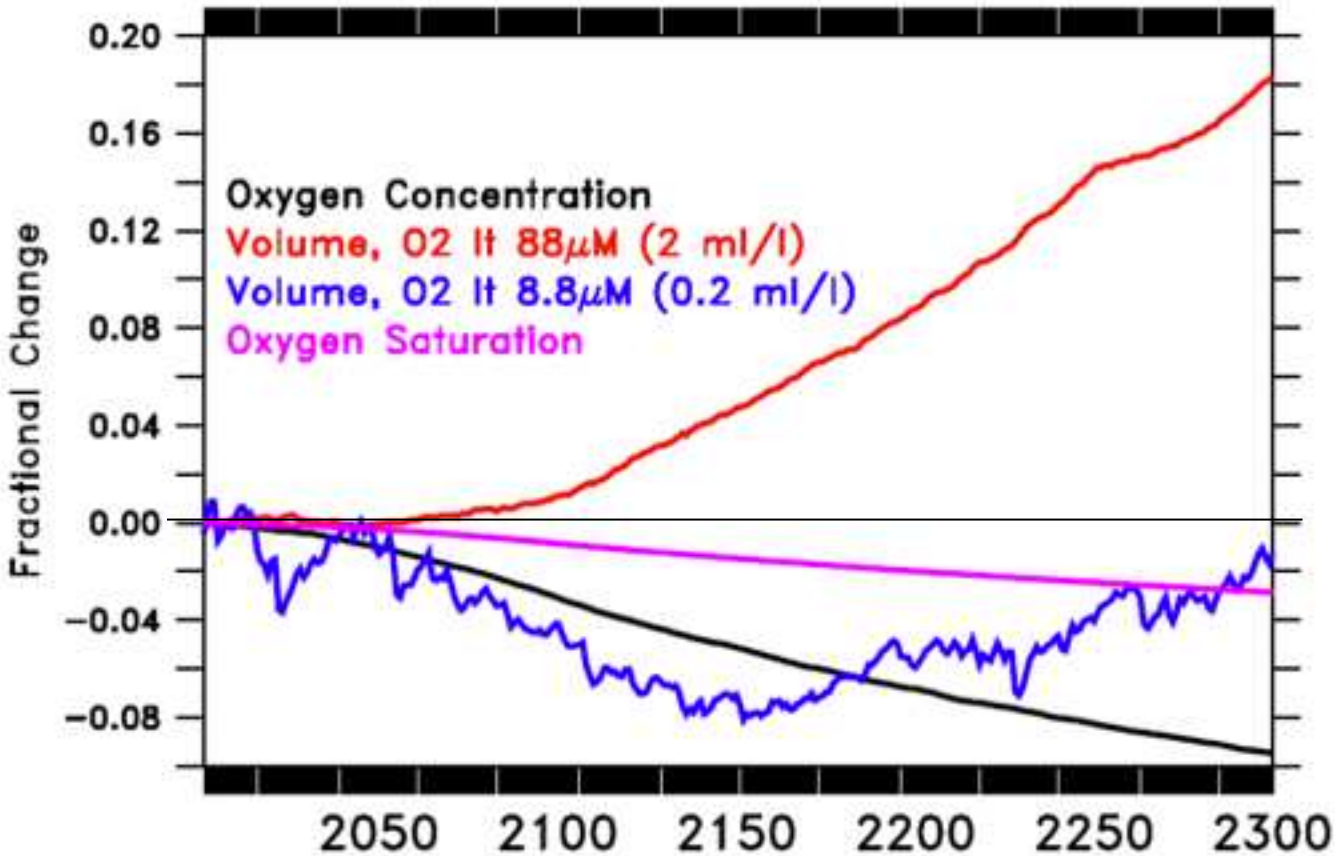
Keeling et al. (2010)

Changes in global volume of hypoxic and anoxic water from 1860 to 2100 in CARBO-OCEAN model study



Frölicher et al. (2009)

Fractional O_2 change in GFDL ESM2.1 SRES A2 simulation

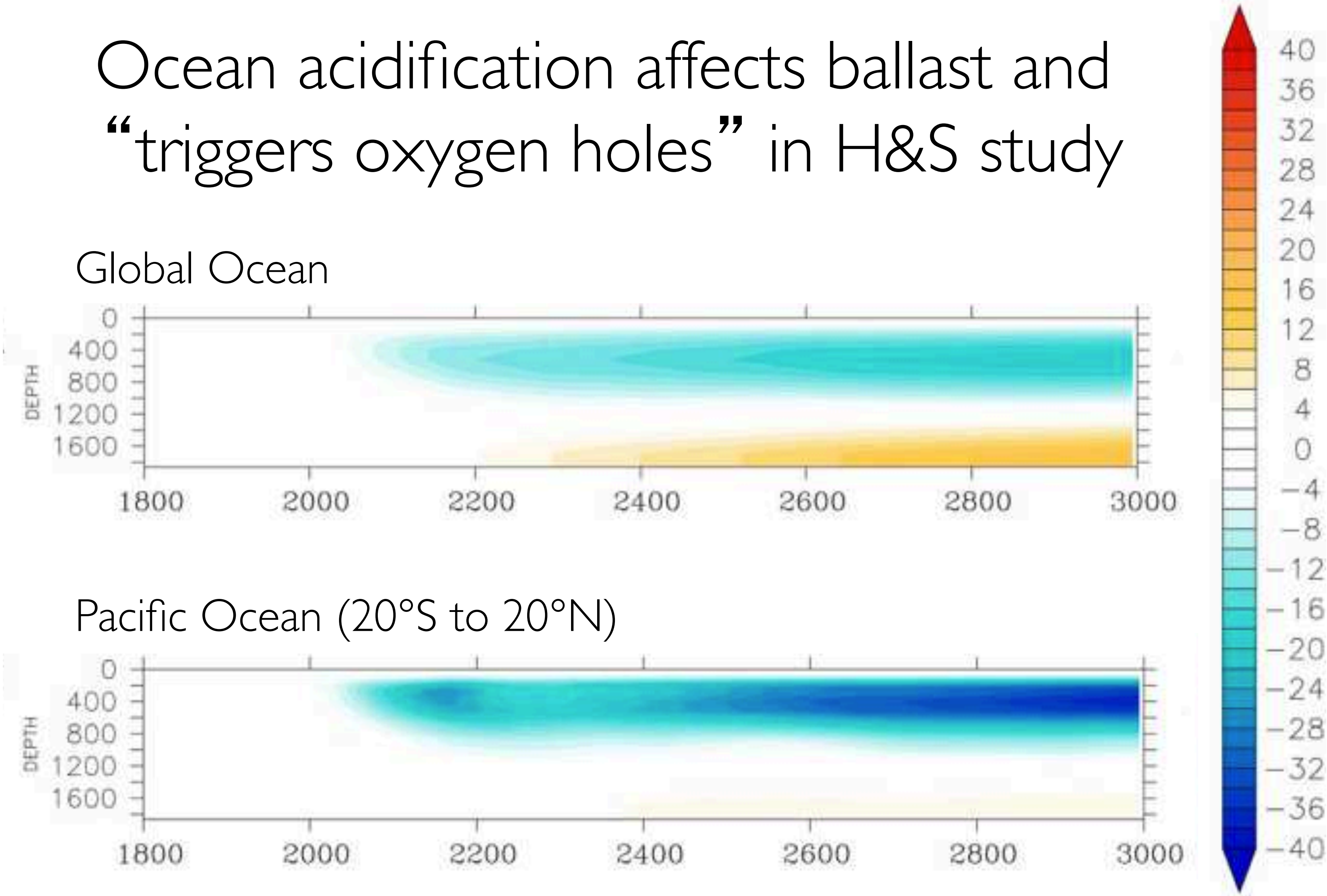


Analysis shows an increased supply of oxygen due to lateral diffusion compensating an increase in remineralization within the hypoxic waters. The lateral diffusive flux is the result of an increase of ventilation along the Chilean coast, as a drying of the region opens up a region of wintertime convection.

Ocean acidification affects ballast and "triggers oxygen holes" in H&S study

Global Ocean

Pacific Ocean (20°S to 20°N)

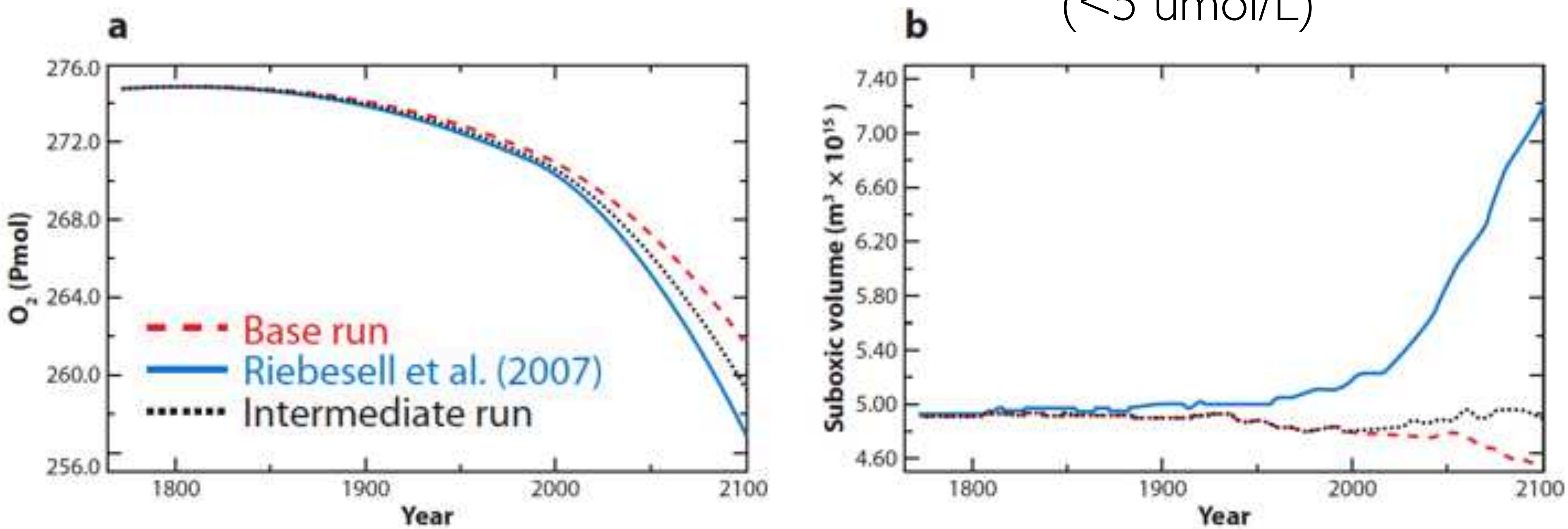


Hofmann & Schullnhuber (2009)

Increase in C:N ratio with increasing CO_2 leads to greater O_2 loss & more suboxia

Oxygen inventory

Suboxic volume (<5 umol/L)



Keeling et al. (2010), adapted from Oschlies et al. (2008).

Goals for an OMZ observational program

(1) To capture interannual variability and trends of the distribution of:
  - -- temperature
  - -- salinity
  - -- nitrate, oxygen, , chlorophyll & POC, and pH (and C system using mapped alkalinity from hydrographic sections)

(2) To capture interannual variability and trends of the atmosphere-ocean flux of:
  - -- heat
  - -- water
  - -- CO_2
  - – oxygen

(3) To provide data for estimation of physical rates and processes of OMZ ventilation

(4) To provide data for estimation of biogeo-chemical rates such as
  - -- primary production
  - -- export production & remineralization
  - -- nitrogen fixation and denitrification

II. The Southern Ocean

II. A. The challenge

II. A. 1. The present

Spatial distribution of CO_2 uptake in ocean inverse (Gruber et al., 2009)

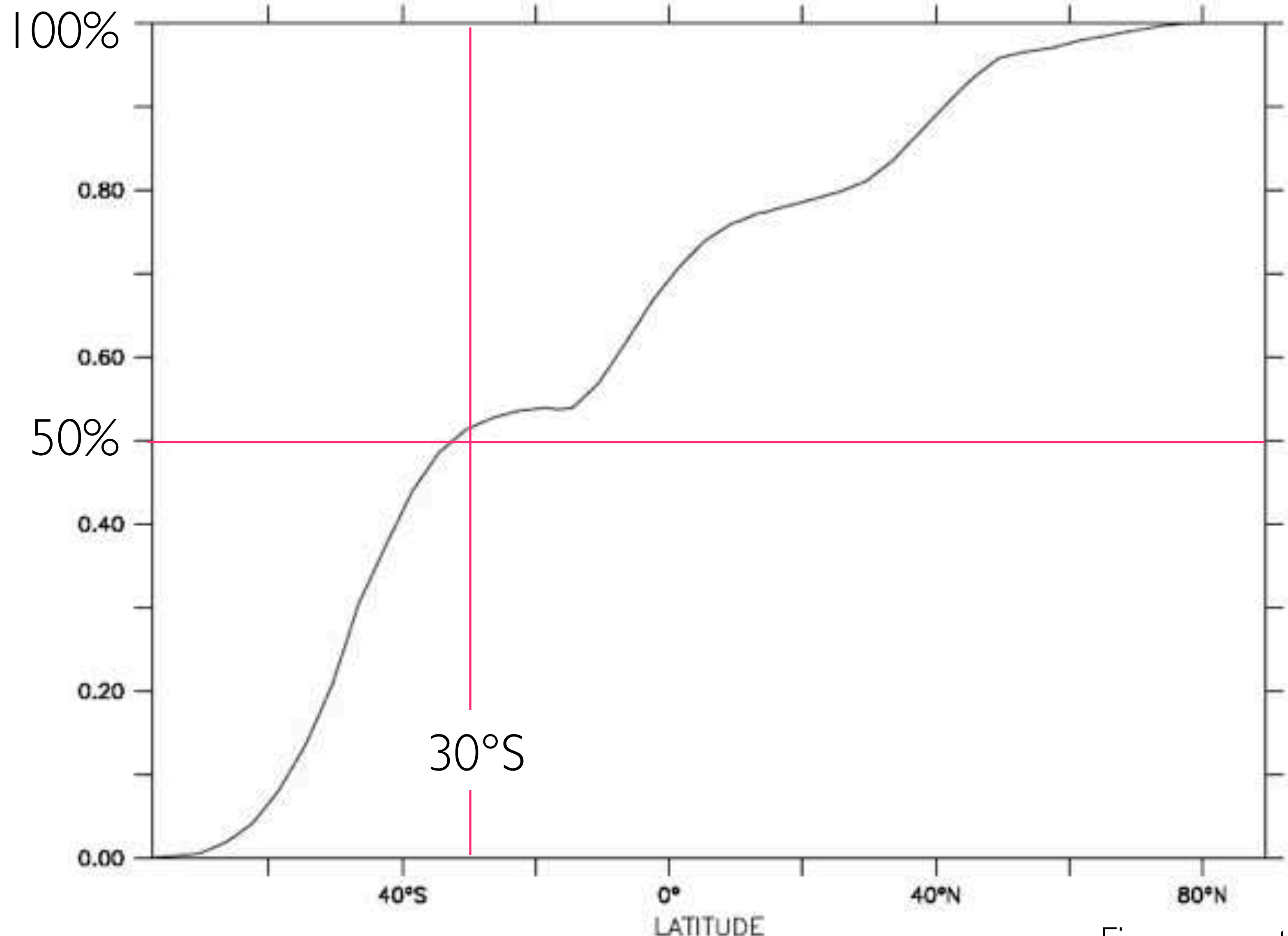


Figure courtesy R. Slater

Cumulative Heat flux/Total Heat flux: HIST – CTRL: 1990-1999

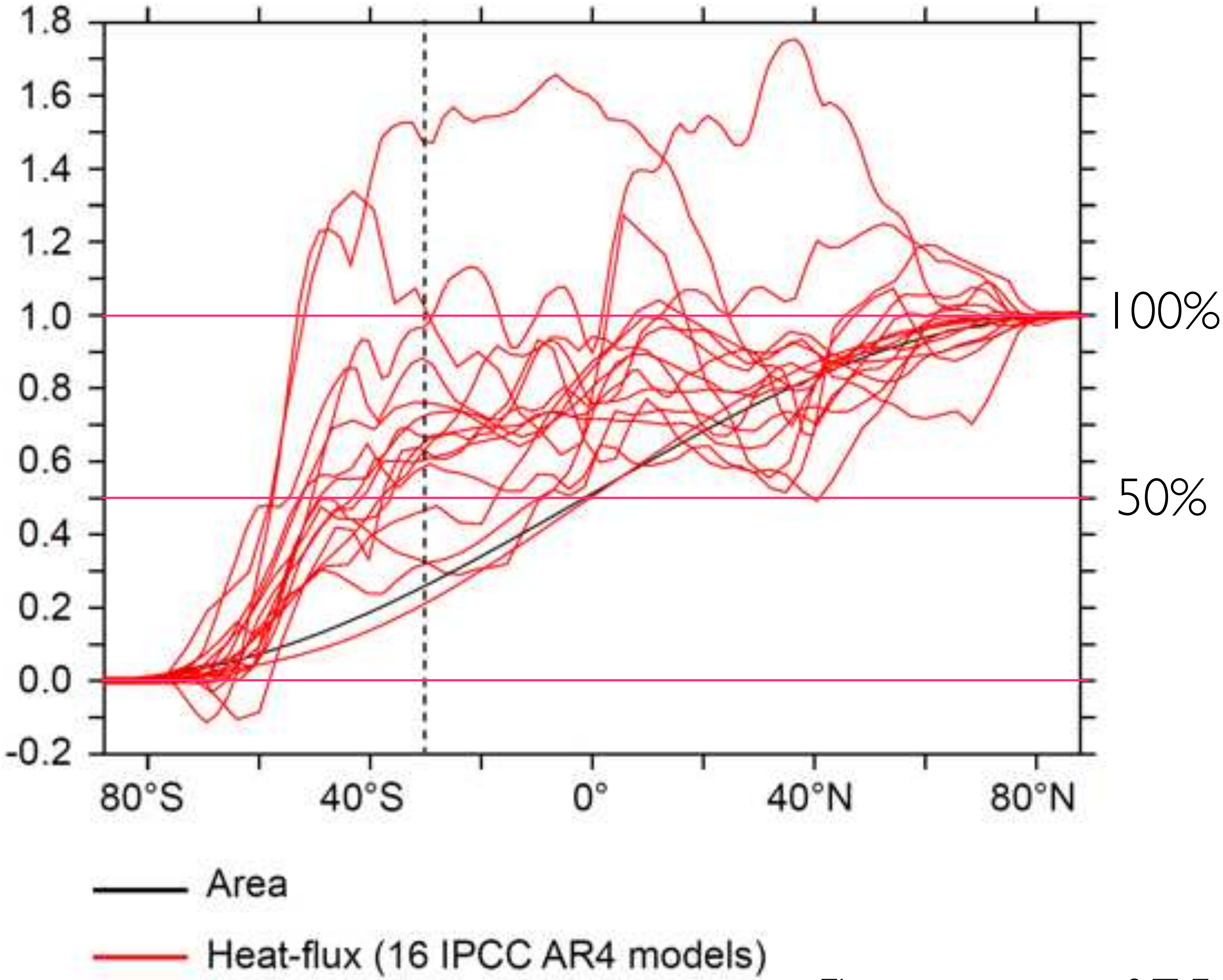


Figure courtesy of T. Frölicher

Zonal Heat content changes:
HIST – CTRL: 1990-1999
Units: TJ/m^2

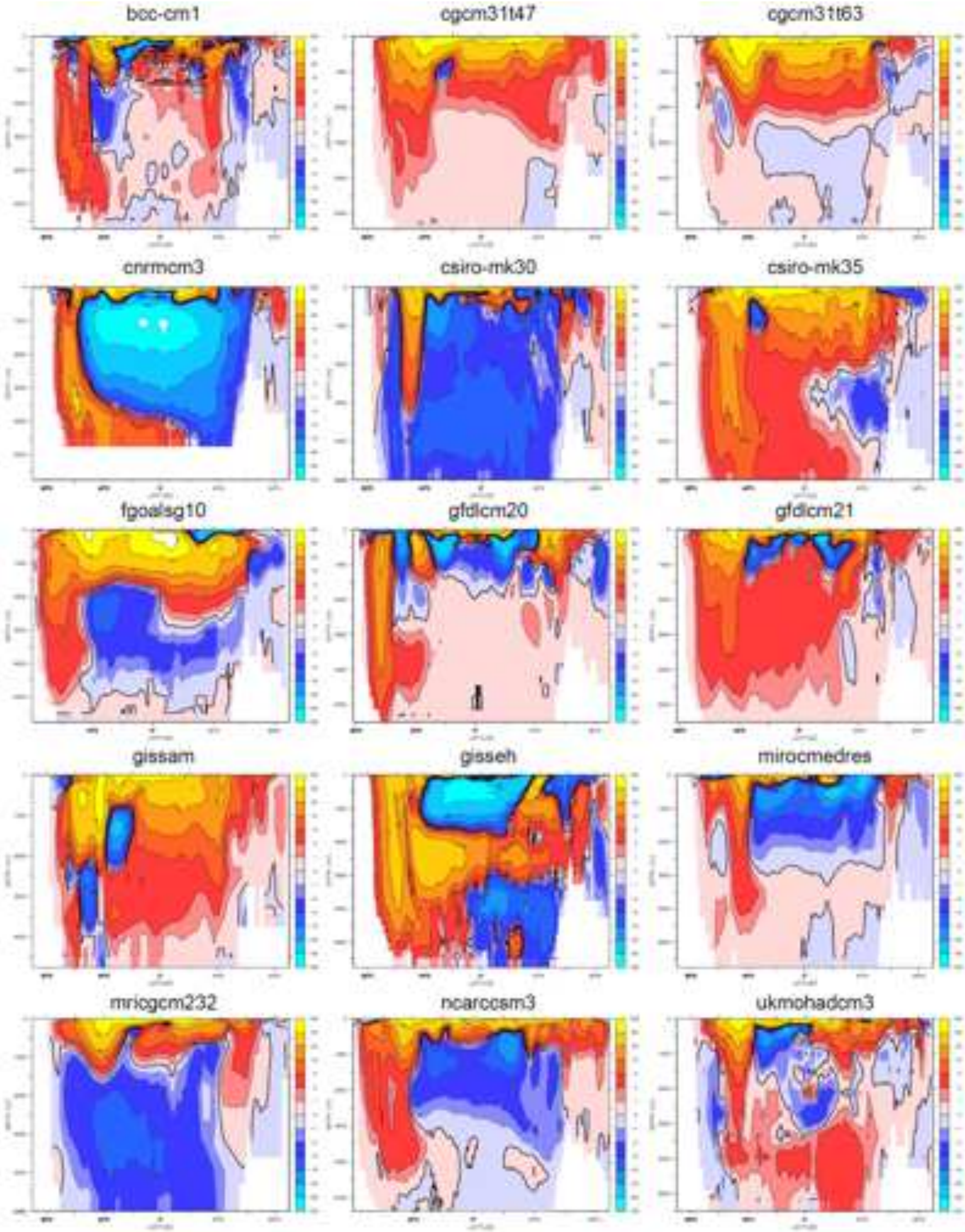


Figure courtesy of T. Frölicher

6-member ensemble (NCAR CSM1.4-carbon)

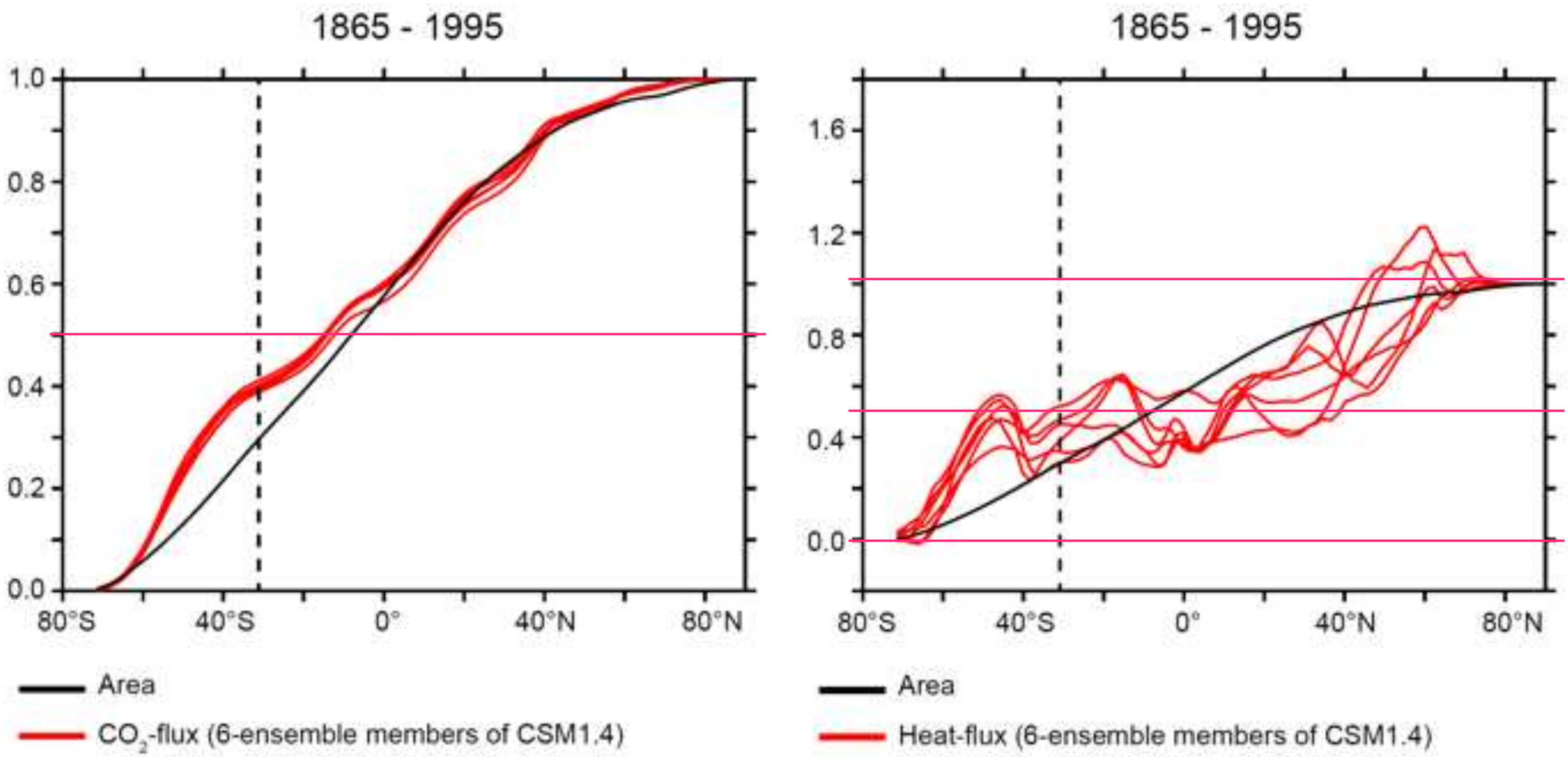
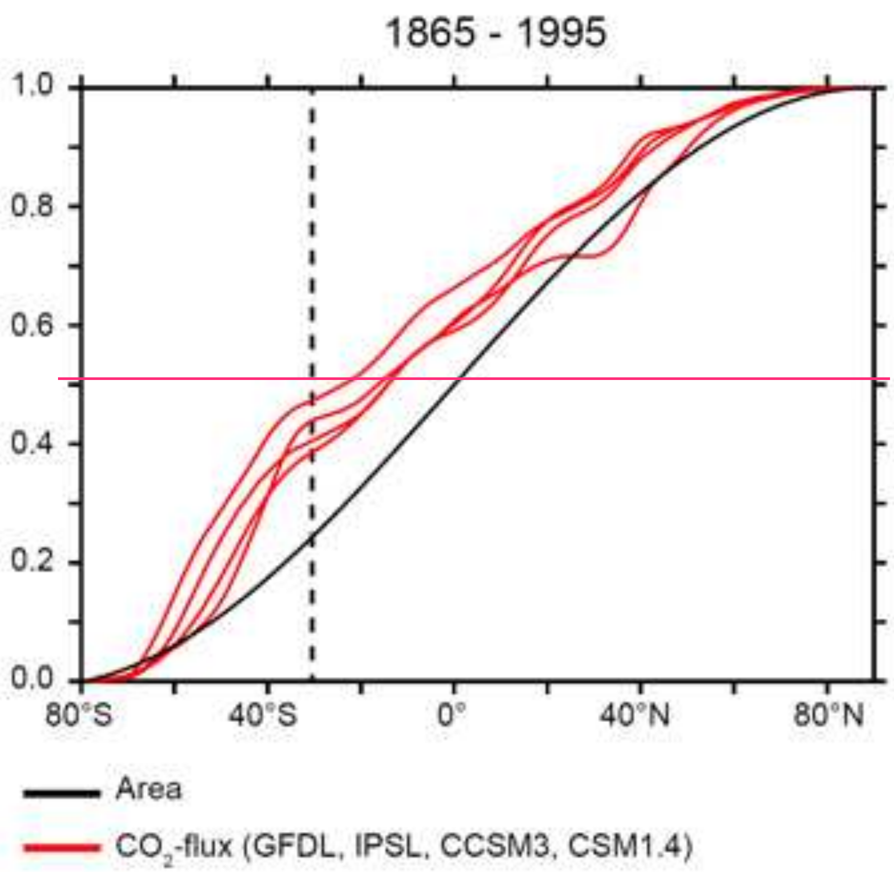


Figure courtesy of T. Frölicher

4 different ESMs



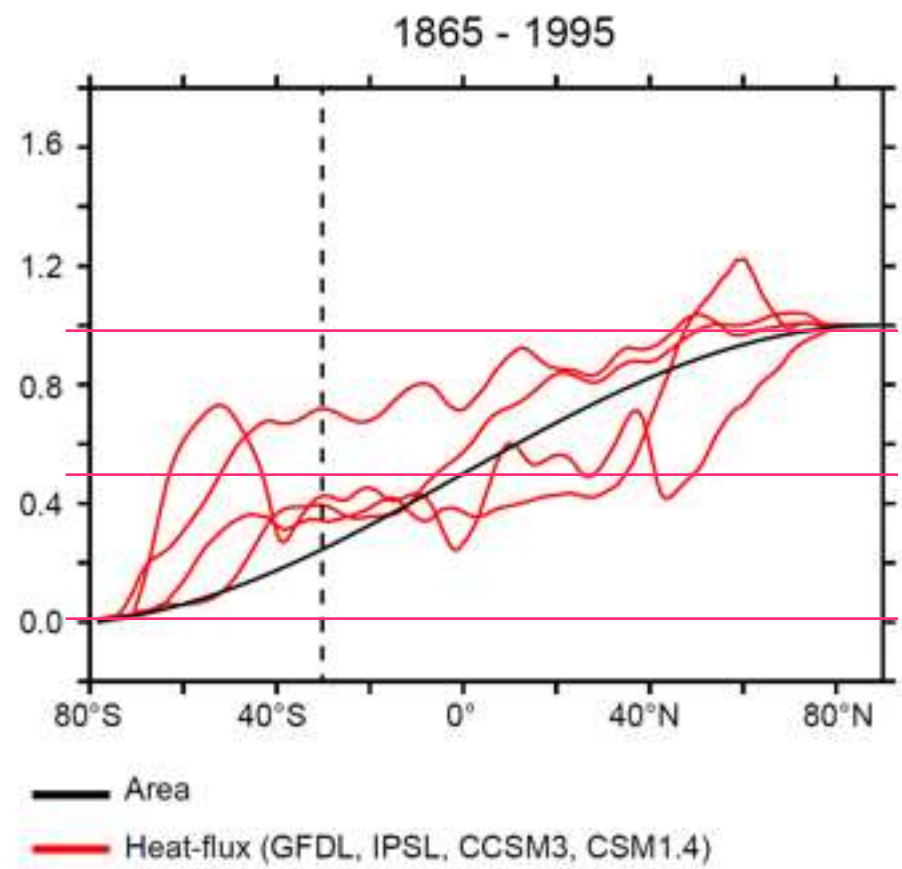


Figure courtesy of T. Frölicher

Vertical distribution of CO_2 and heat uptake in CM2.1 and CORE

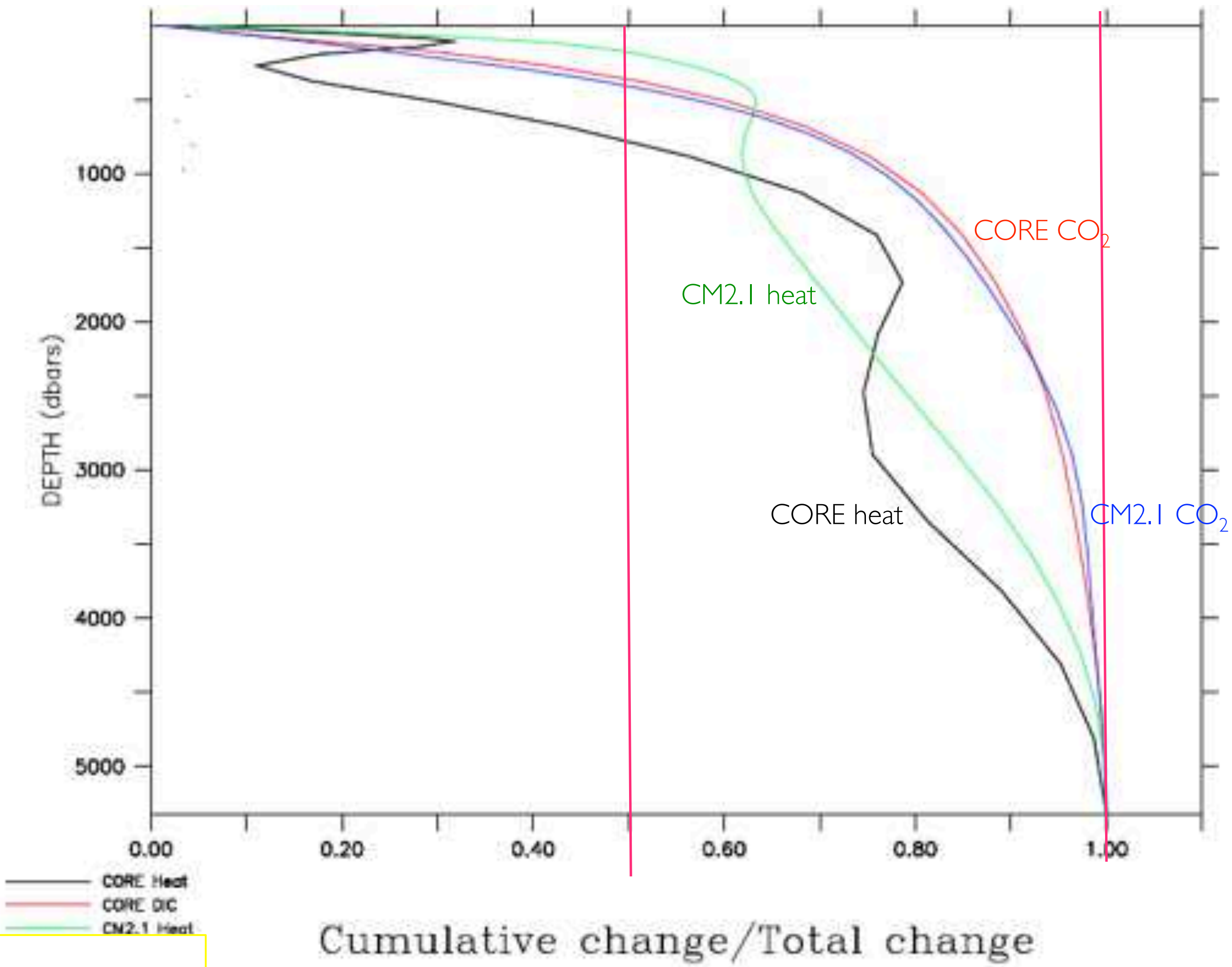
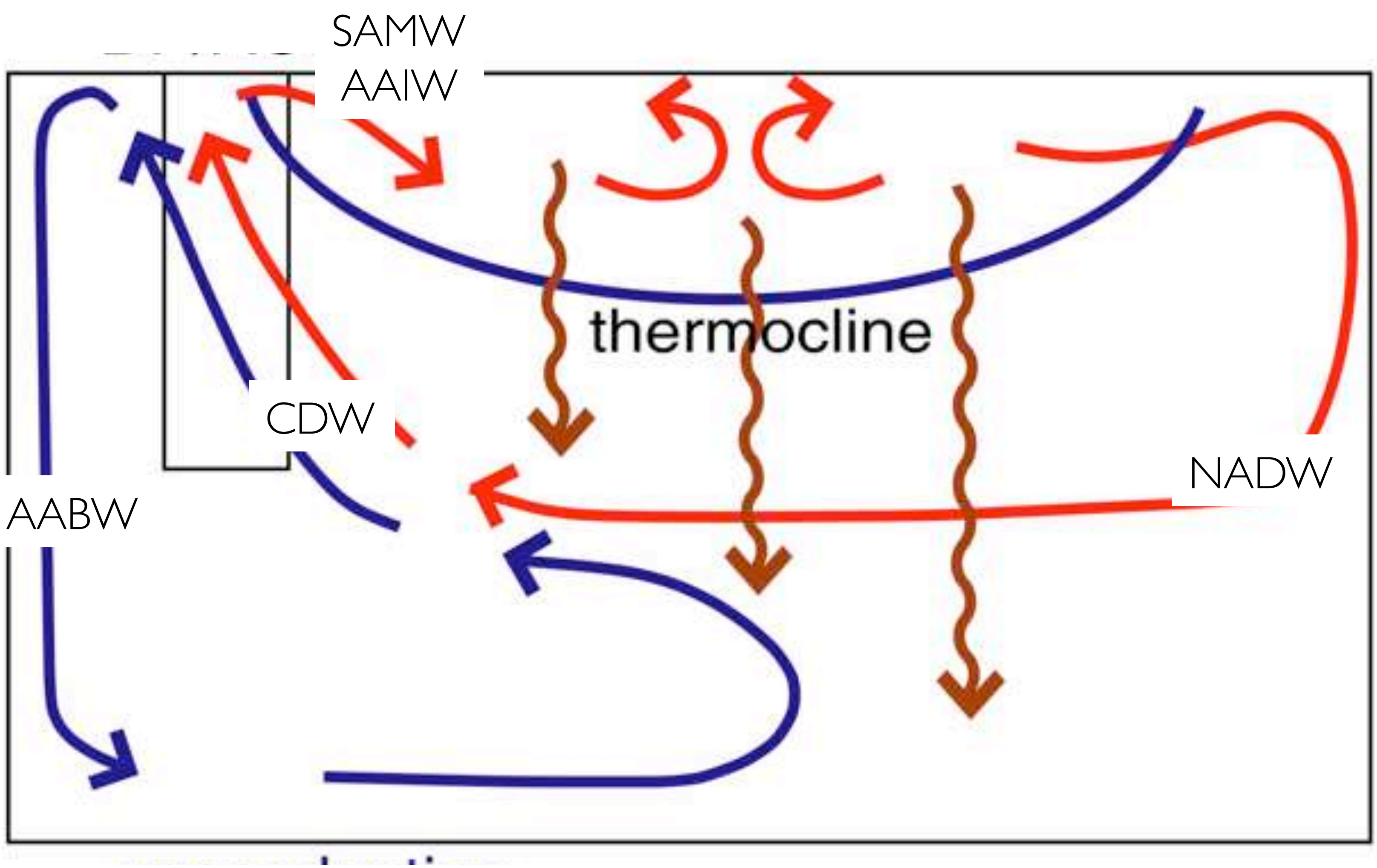


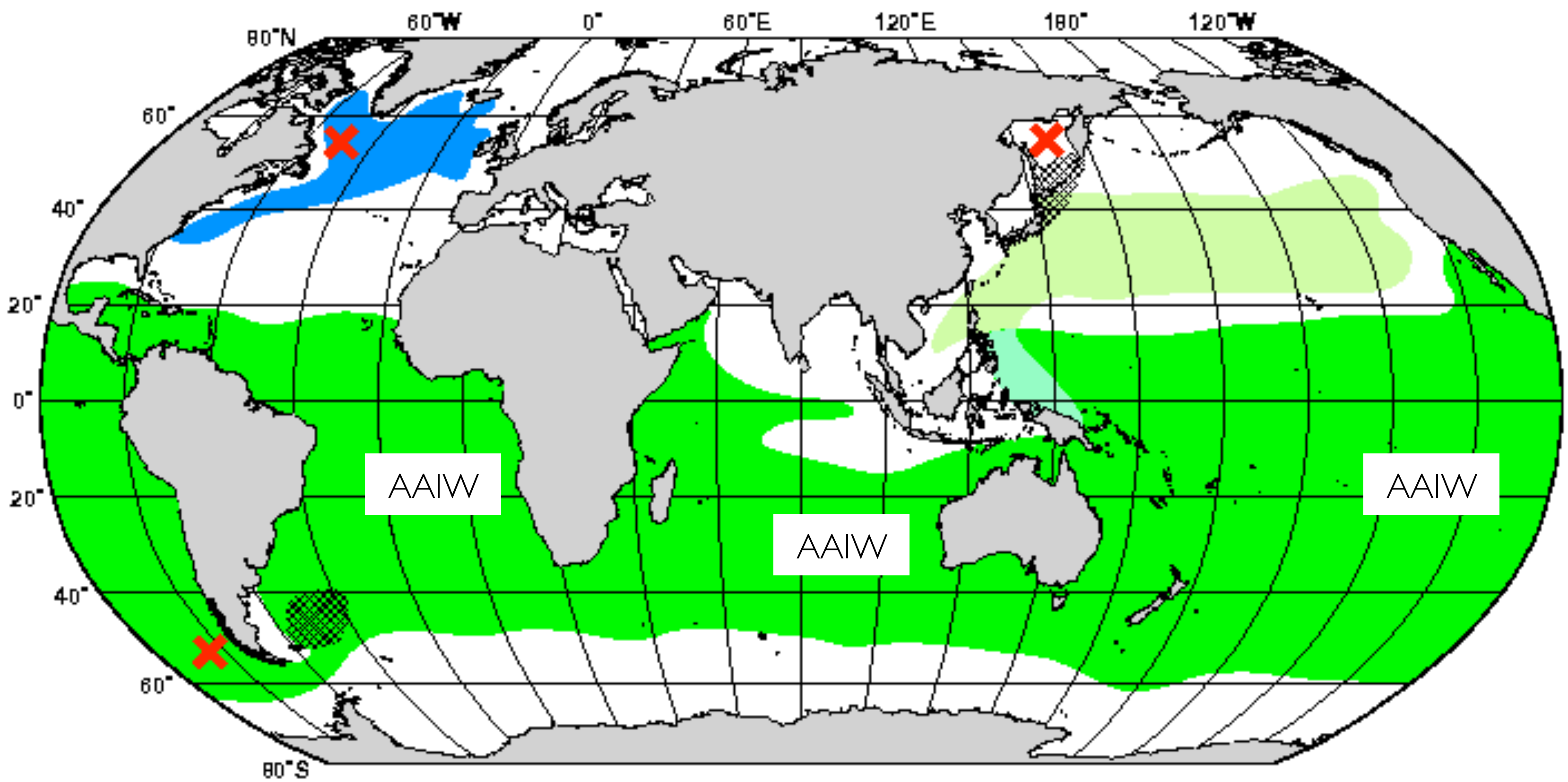
Figure courtesy of R. Slater

A schematic of the global meridional overturning circulation.



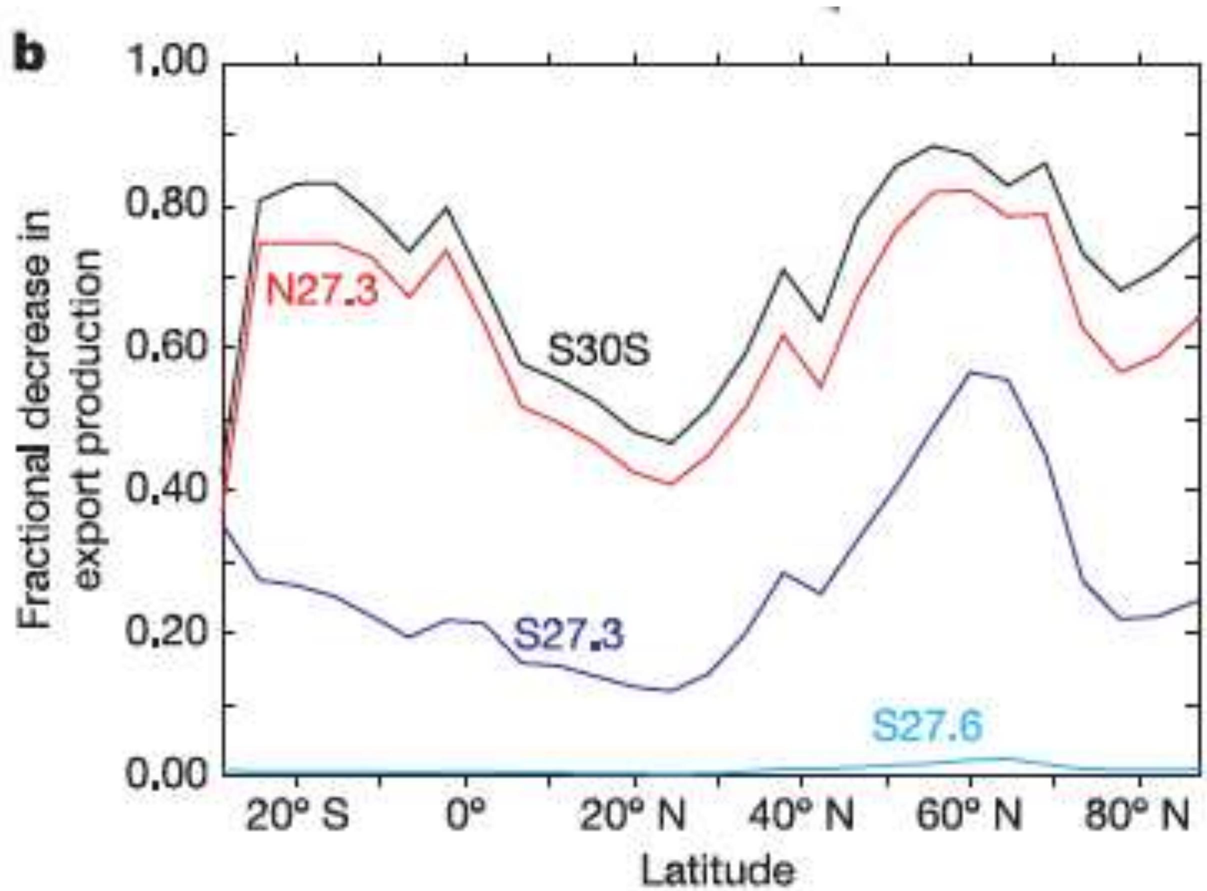
Marinov et al. (2006)

Spatial distribution of Intermediate Waters



L. Talley (pers. comm.)

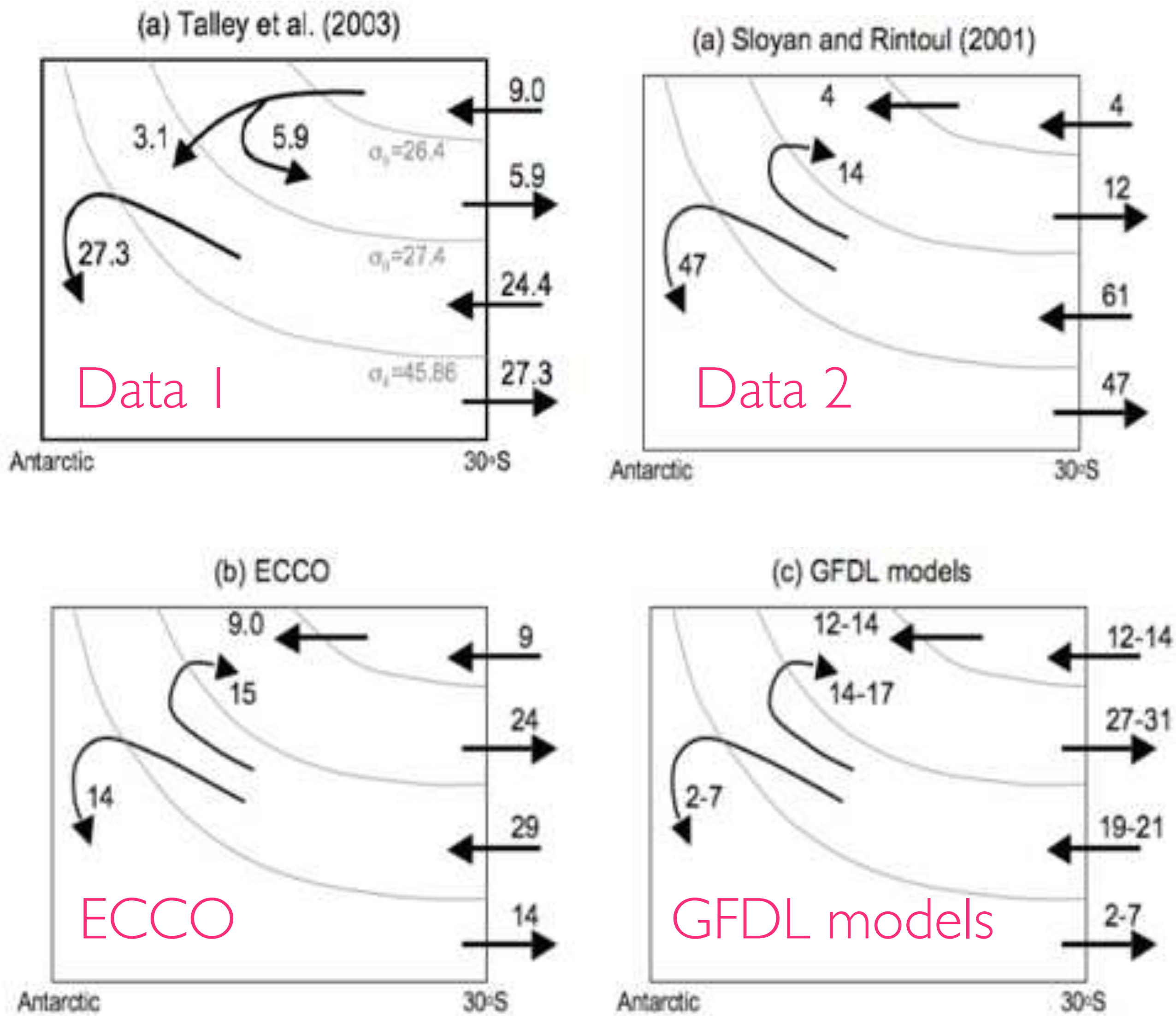
Fractional reduction in biological productivity resulting from nutrient depletion in Southern Ocean



Southern Ocean surface nutrient depletion blocks the Southern Ocean nutrient resupply pathway & reduces low latitude biological productivity by ~75%

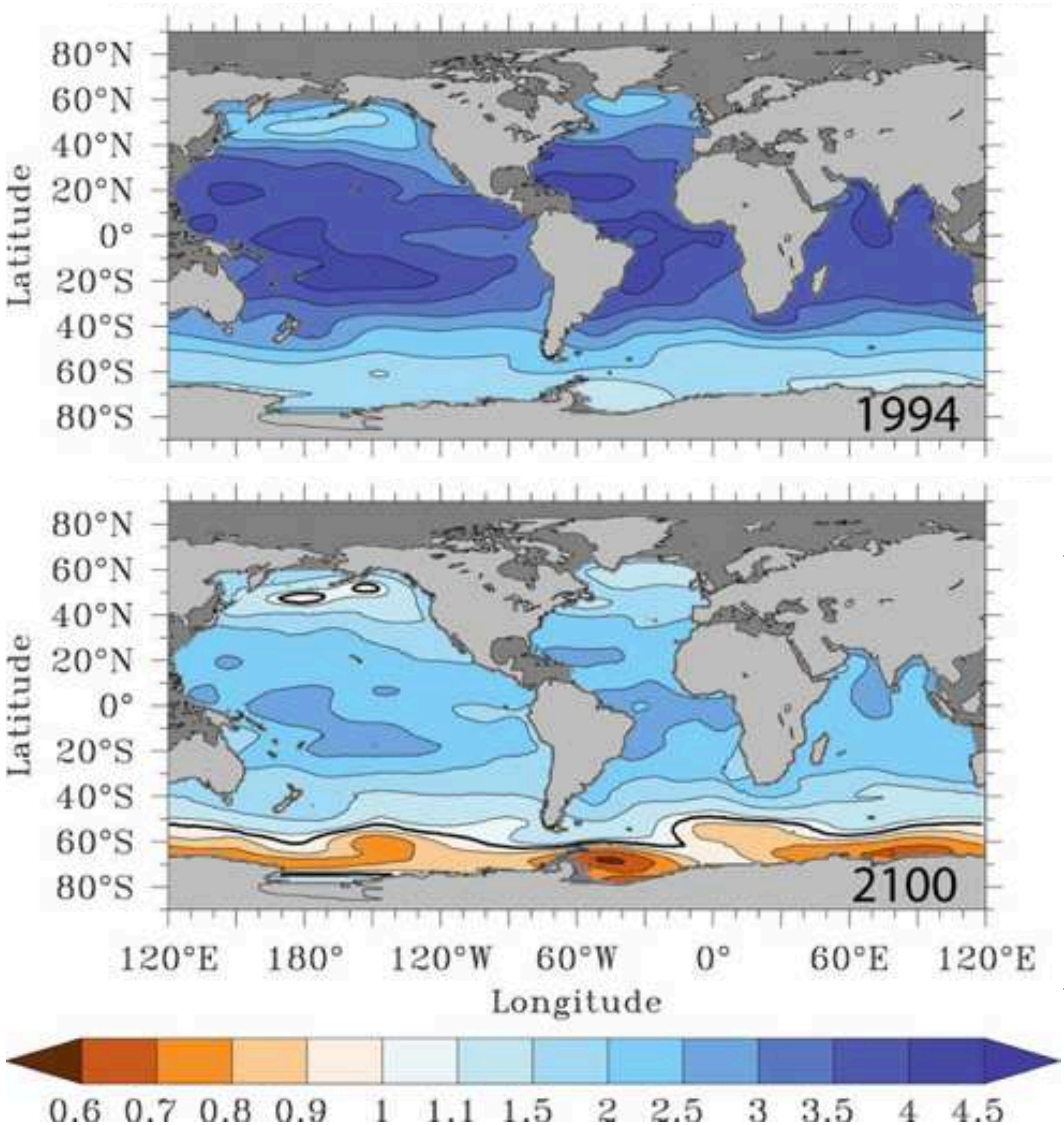
Marinov et al. (2006)

Meridional overturning in the Southern Ocean (Downes et al., in press)



II. A. 2. The future

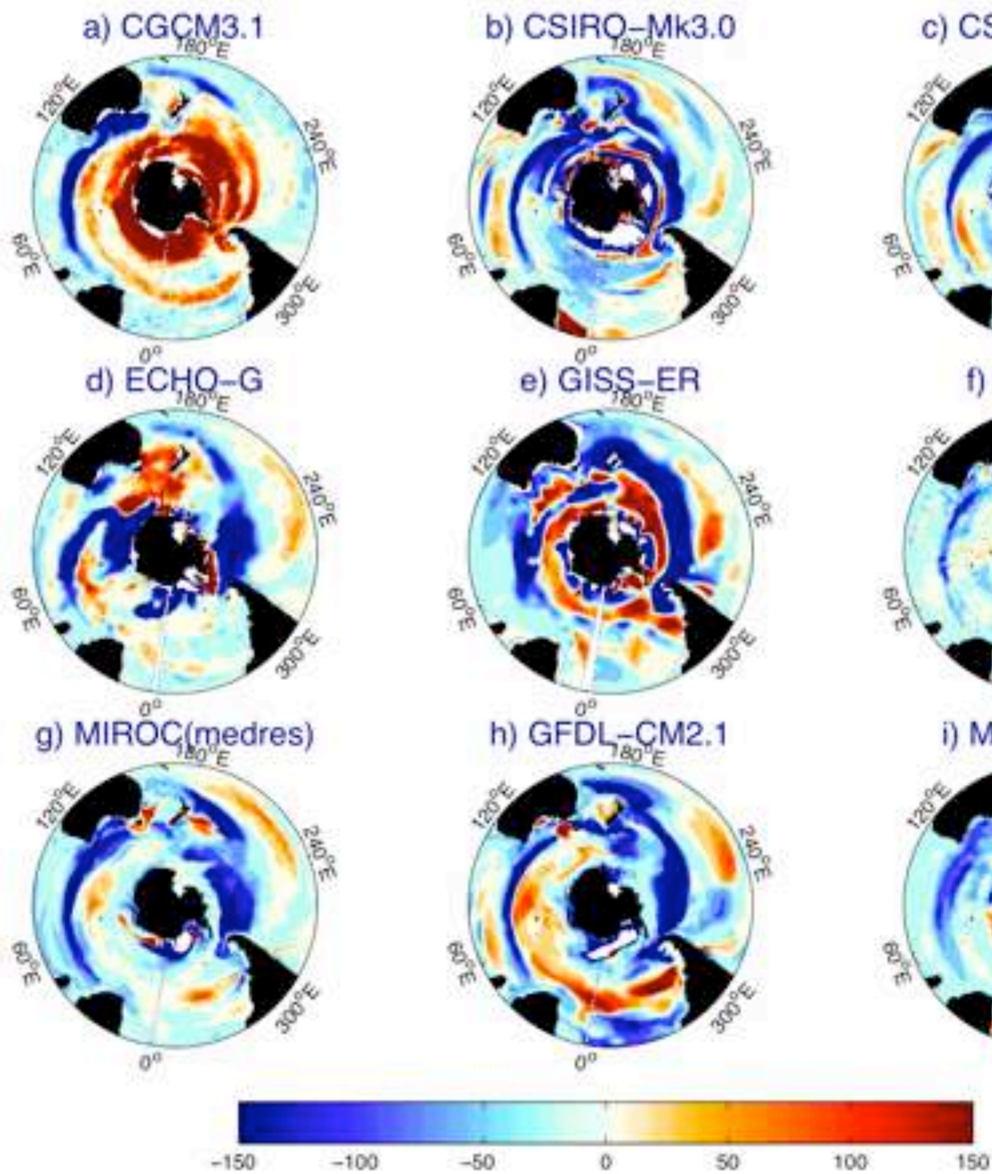
Impact of ocean acidification



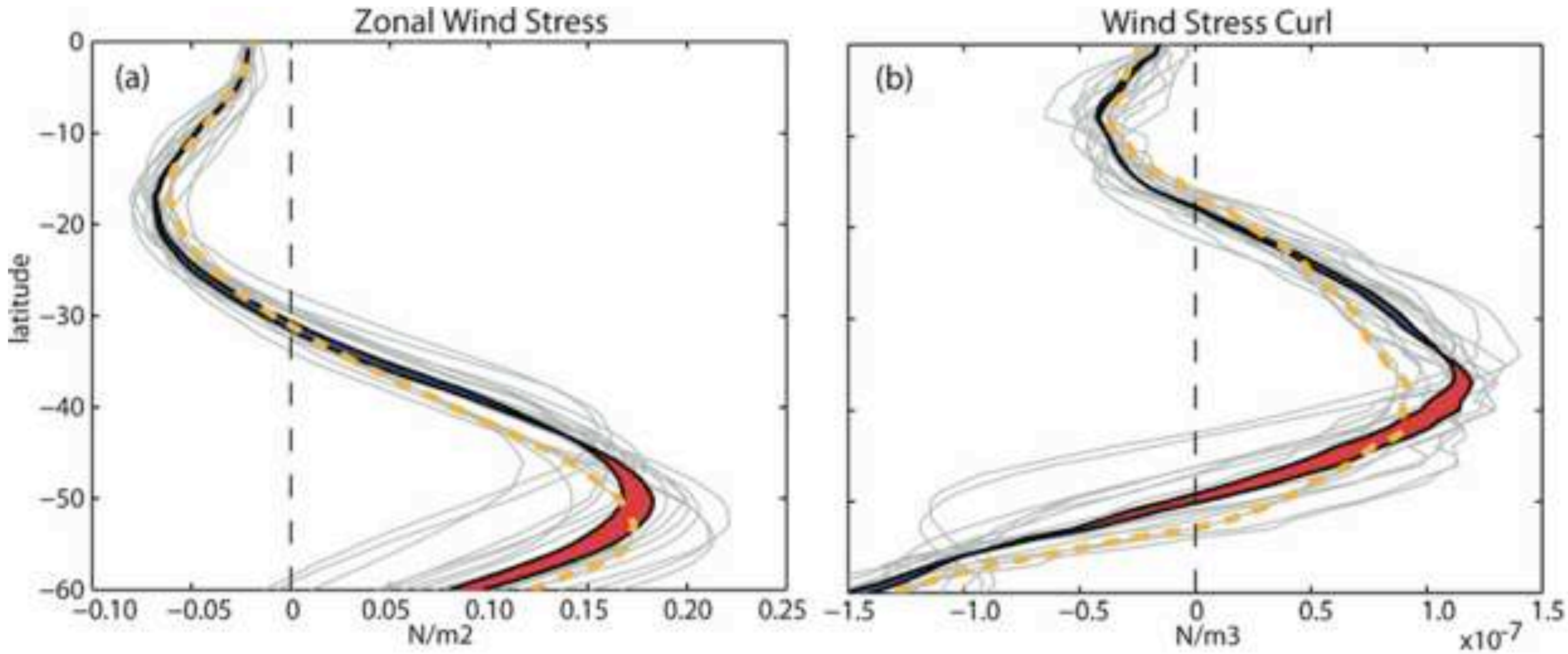
Surface water aragonite saturation state (Ω_{arag}). Values for 1994 were computed from GLODAP (Key et al., 2004), whereas 2100 is the median of 13 ocean general circulation models forced under the IPCC's IS92a "business-as-usual" CO_2 emission

Fabry et al (2008)

Winter mixed layer depth change: SRES A2 minus 20th century



Sen Gupta et al. (2009)



From: SEN GUPTA et al., 2009, J. CLIMATE

(a) Zonally averaged wind stress (N m^{-2}) and (b) wind stress curl (N m^{-3}), from the multi-model ensemble for 20th century and SRES A1B. Strengthening (red) and weakening (blue) of the variable from 20th century to SRES A1B. ERA-40 results (yellow line). 20th century zonal averages for the individual models (gray lines).

Sen Gupta et al. (2009)

Goals for a Southern Ocean research program

(1) To capture interannual variability and trends of the distribution of:
  -- temperature
  -- salinity
  -- nitrate, oxygen, , chlorophyll & POC, and pH (and C system using mapped alkalinity from hydrographic sections)

(2) To capture interannual variability and trends of the atmosphere-ocean flux of:
  -- heat
  -- water
  -- CO_2
  – oxygen

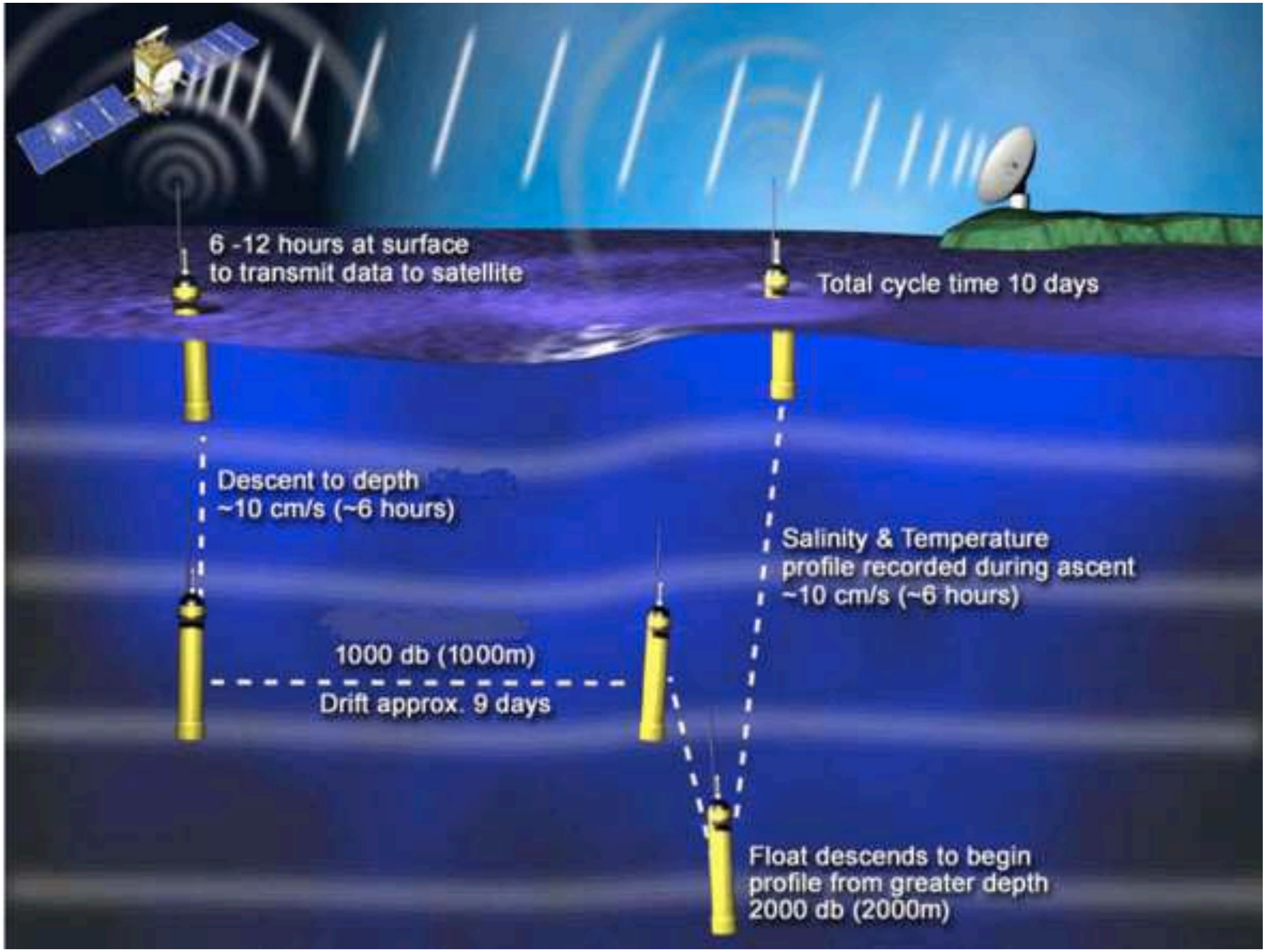
(3) To capture formation rates of
  -- SAMW
  -- AAIW
  -- UCDW
  -- LCDW
  -- AABW

(4) To provide data for estimation of biogeochemical rates, e.g.,
  -- primary production
  -- export production & remineralization
  -- nitrogen fixation and denitrification

II. B. The opportunity

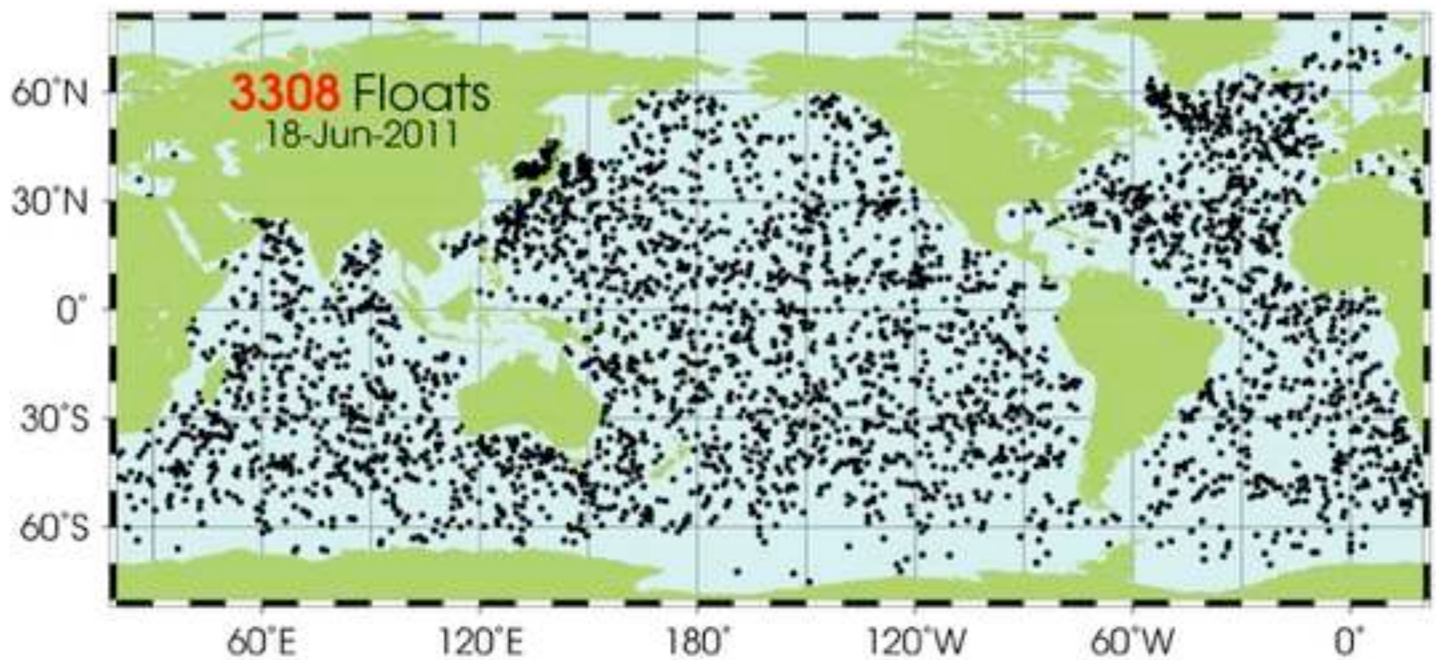
II. B. 1. Floats

A typical Argo mission (200-250 profiles)



Courtesy of S. Riser

The present status of the Argo profiling float array



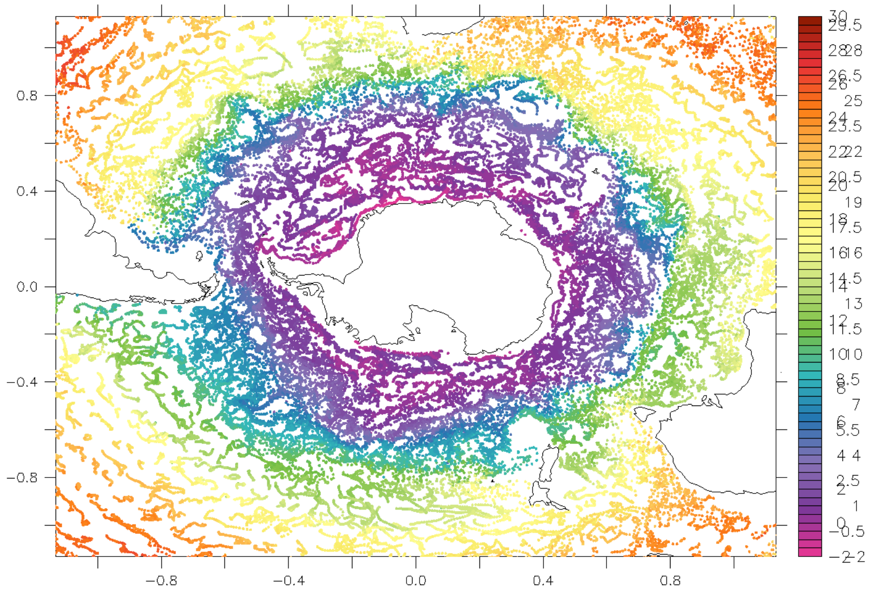
<u>Canonical Argo mission:</u>

- 0-2000 m; *T*, *S*, *p* (0.005 °C; 0.01 PSU ; 2.5 dbar)
- Δt= 10 days
- 4-5 years/200-250 profiles
- 27 countries; 800 floats per year
- UW: ~120 floats per year

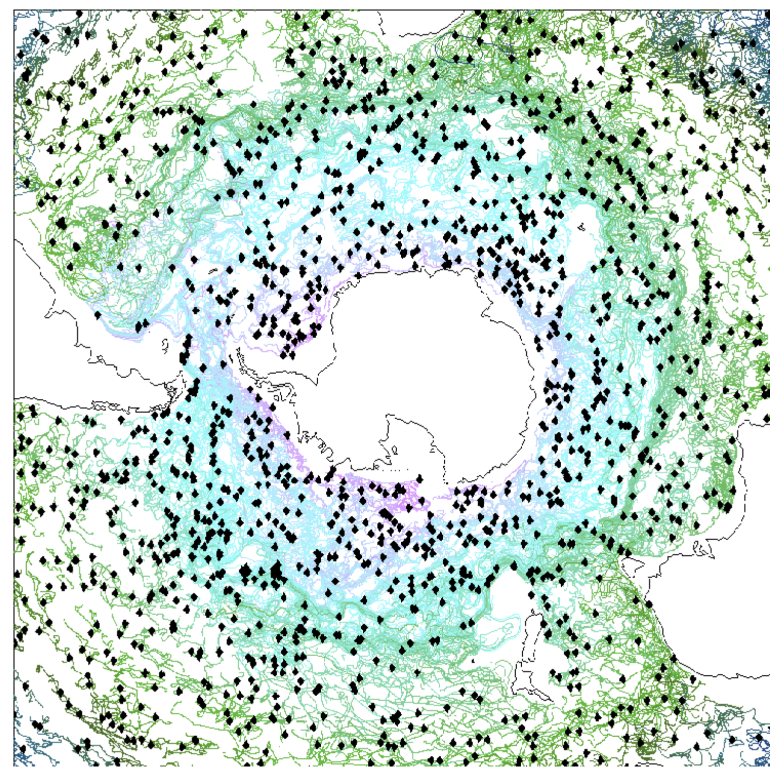
Note: all new floats being deployed south of 45°S (?) have ice avoidance software

Courtesy of S. Riser

Simulated Argo in offline MESO (Hallberg and Gnanadesikan 2005) model



100 m temperature measurements
From 1 year of simulation



Profiler locations and trajectories
after 3 years. Colored by initial latitude.

Images courtesy of Vecchi and Hallberg

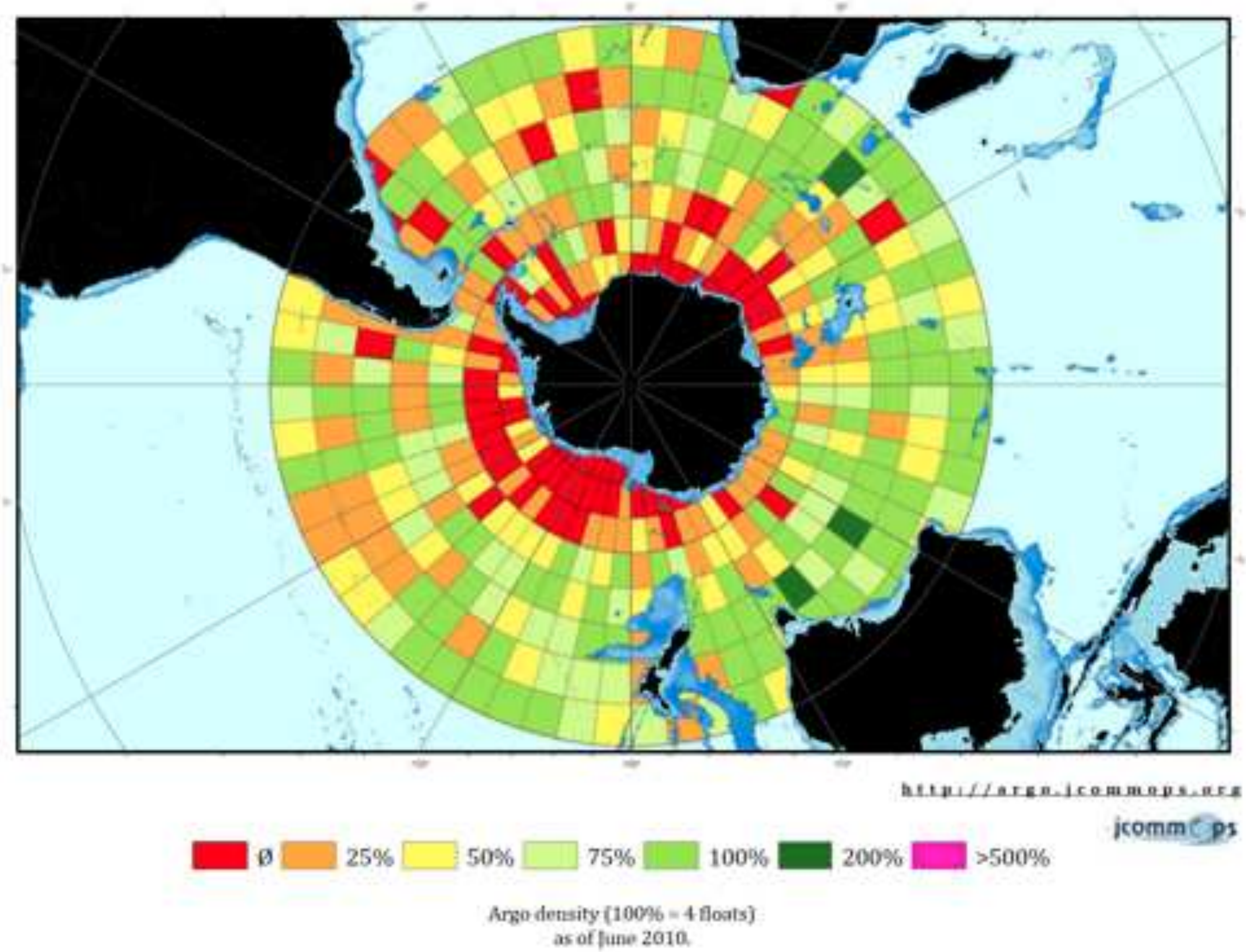
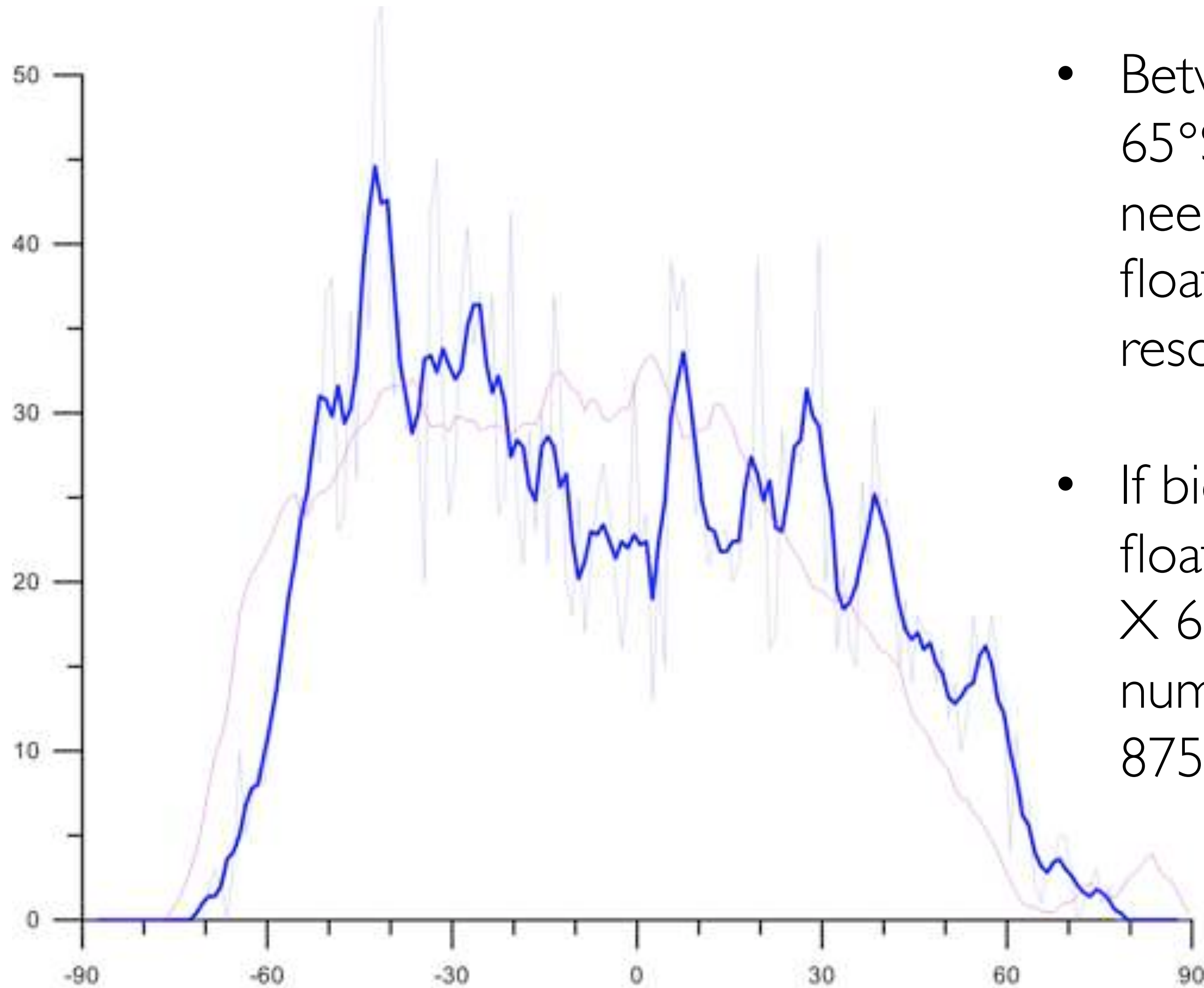


Figure 21: The status of the Argo array in the Southern Ocean, as of July 2010. Blue colour indicates 0-2000 depth contour. Despite the progress in recent years, large regions of the high-latitude Southern Ocean remain poorly observed, especially close to the Antarctic continent. Courtesy of Mathieu Belbeoch, JCOMMOPS.

Number of floats per degree of latitude required for 300 km by 300 km Argo coverage



- Between 30°S and 65°S one would need about 875 floats at 300 X 300 resolution.

- If biogeochemical float coverage is 600 X 600. then the number required is 875/4 ~ 220.

Courtesy of S. Riser

Cost of 2000 m floats

	Item: Configuration 1	$
1	Basic Iridium profiling float, 0-2000 meters	18,000
2	Dissolved O_2 sensor (Aanderaa or SBE)	5,000
3	WebLabs FLBB sensor	8,000
4	pH sensor	5,000
5	ISUS nitrate sensor	11,000
6	Lithium batteries	3,000
	TOTAL	50,000

	Item: Configuration 2	$
1	Basic Iridium profiling float, 0-2000 meters	18,000
2	Dissolved O_2 sensor (Aanderaa or SBE)	5,000
3	WebLabs FLBB sensor	8,000
4	pH sensor	5,000
5	Lithium batteries	3,000
	TOTAL	39,000

Courtesy of S. Riser

II. B. 2. Models

A Science and Technology Center for Southern Ocean biogeochemical observations & modeling

Theme 1: Observations, L. Talley (SIO/UCSD)

Theme 2: Modeling, J. E. Russell (University of Arizona)

Theme 3: Outreach, Heidi Cullen (Climate Central)