Are the observed pattern changes of ocean heat, salinity, oxygen man made?

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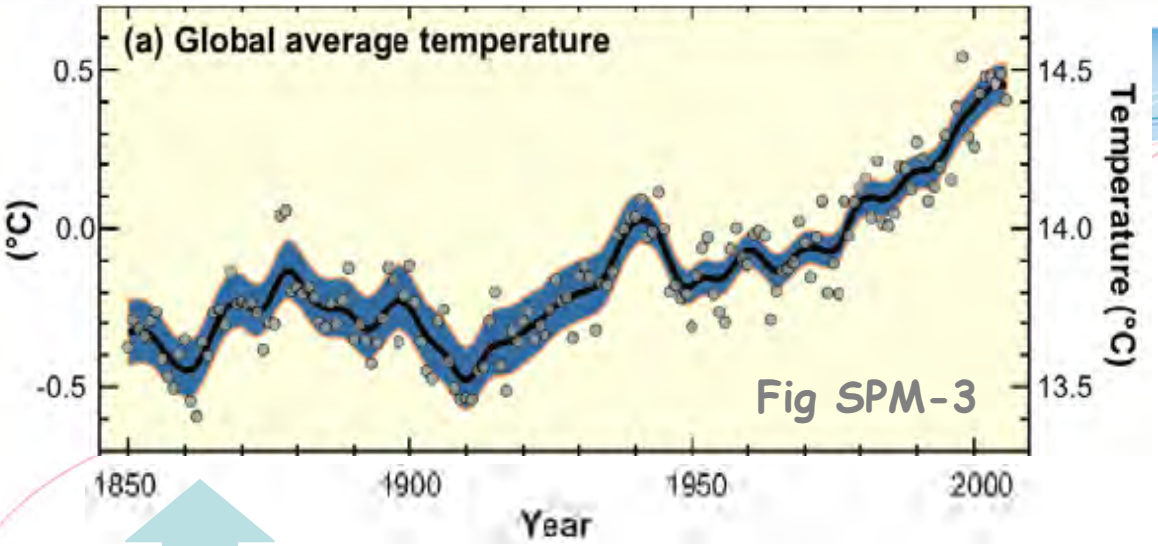
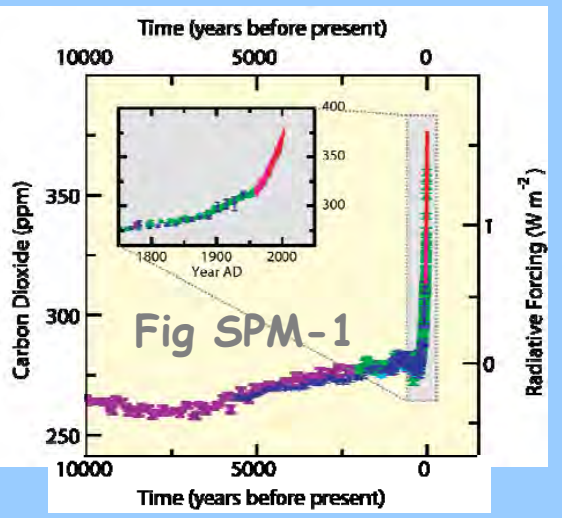
Outline

- Introduction
- Background (detection and attribution)
- The patterns of change (indices)
- Attribution to GHG emissions
- Conclusions about ocean and application to marine ecosystems

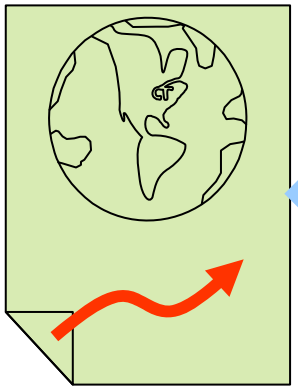
Attribution Process

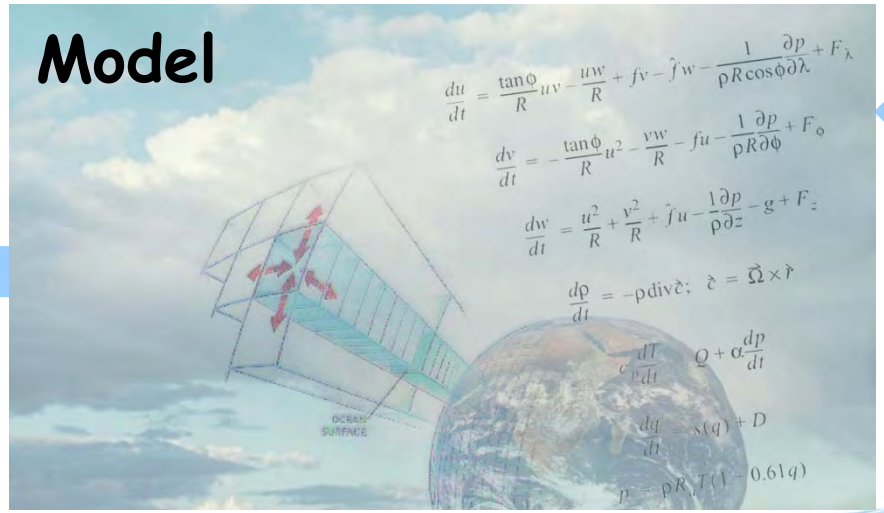


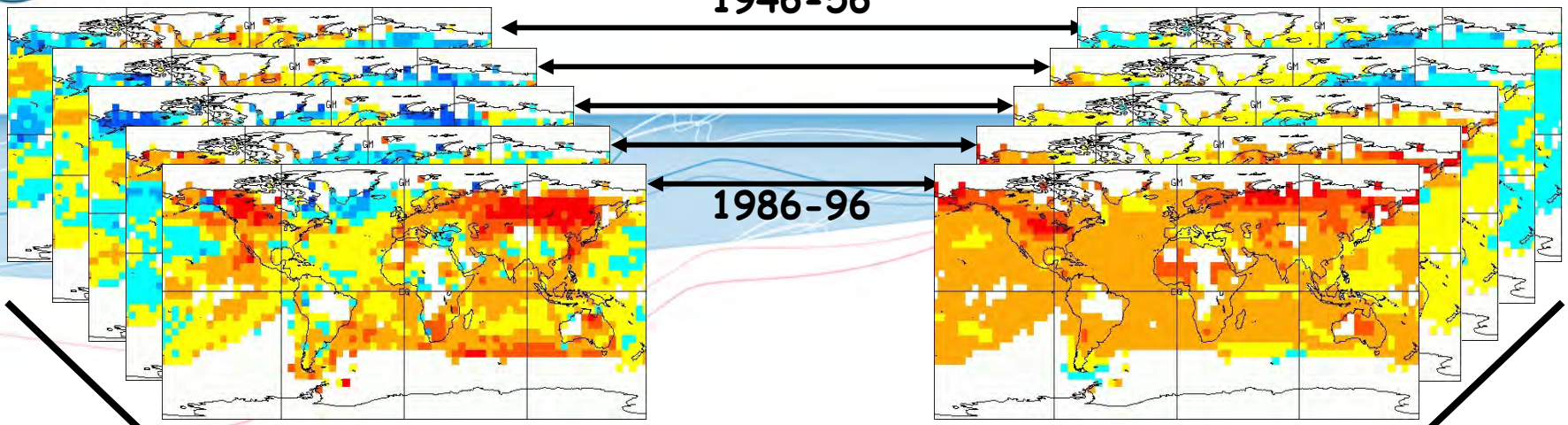


- other GHGs
- aerosols
- volcanic
- solar
- natural internal

?







Filtering and projection onto reduced dimension space

$\mathbf{Y}$

$\mathbf{X}$

$$\mathbf{Y} = \beta\mathbf{X} + \varepsilon$$

Total least squares regression in reduced dimension space

Evaluate amplitude estimates

$\hat{\beta}$

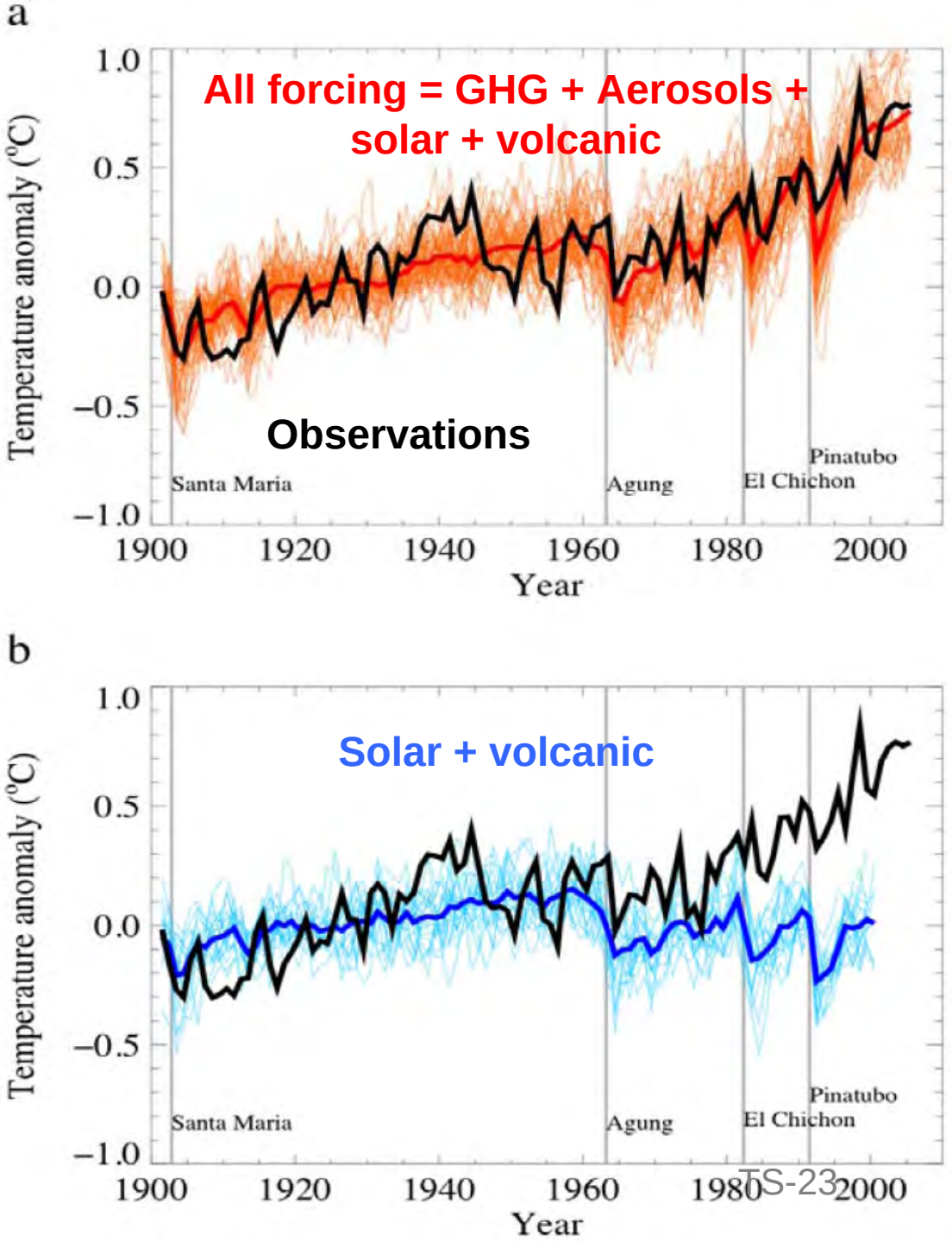
$\hat{\varepsilon}$

Evaluate goodness of fit, internal variability

Weaver and Zwiers, 2000

Attribution to man

- Anthropogenic greenhouse gas increases *very likely* caused most of the observed warming since mid-20th century
- *extremely unlikely* due to natural variation



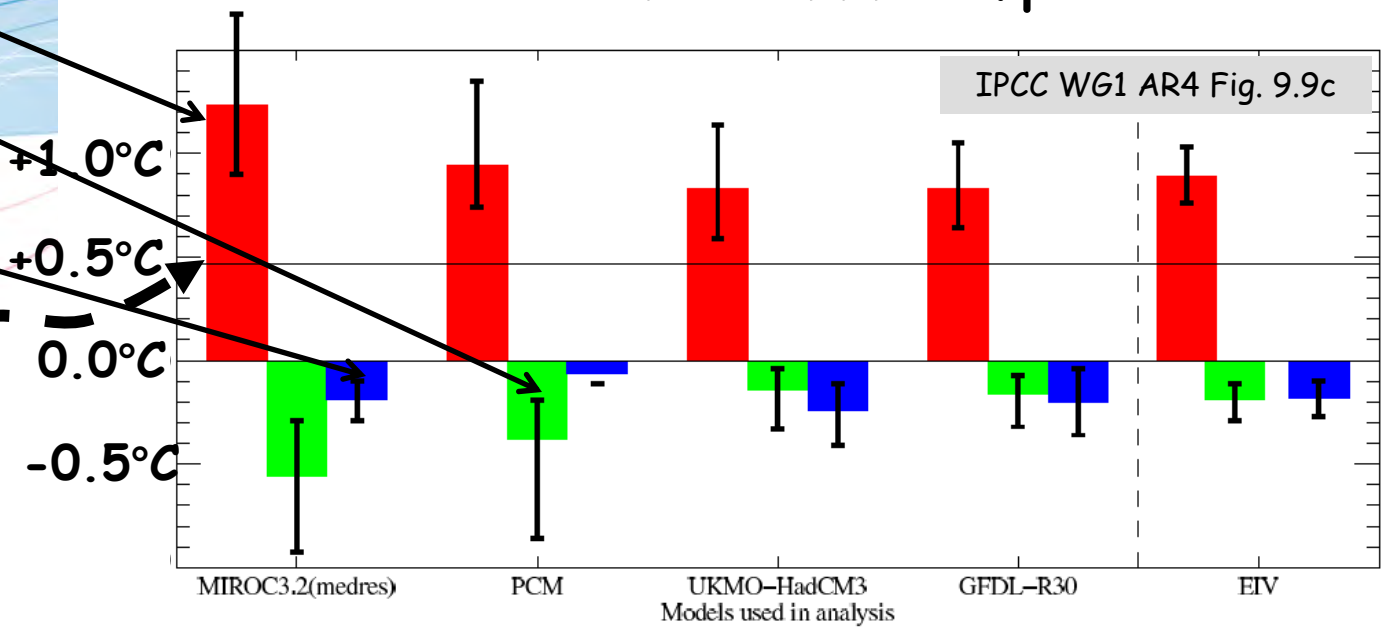
Attribution results – SST

GHG

Aerosols

Natural

Observed



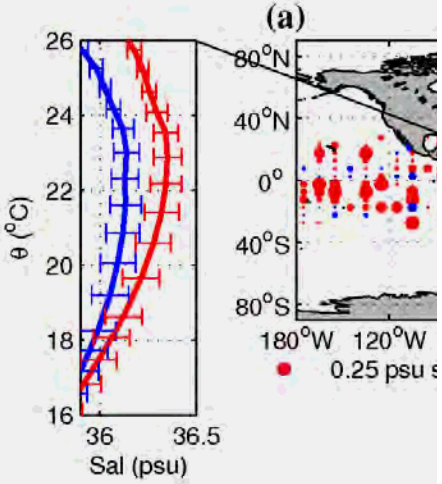
TAR – "most of the observed warming over the last 50 years is likely to have been due to the increase in greenhouse gas concentrations"

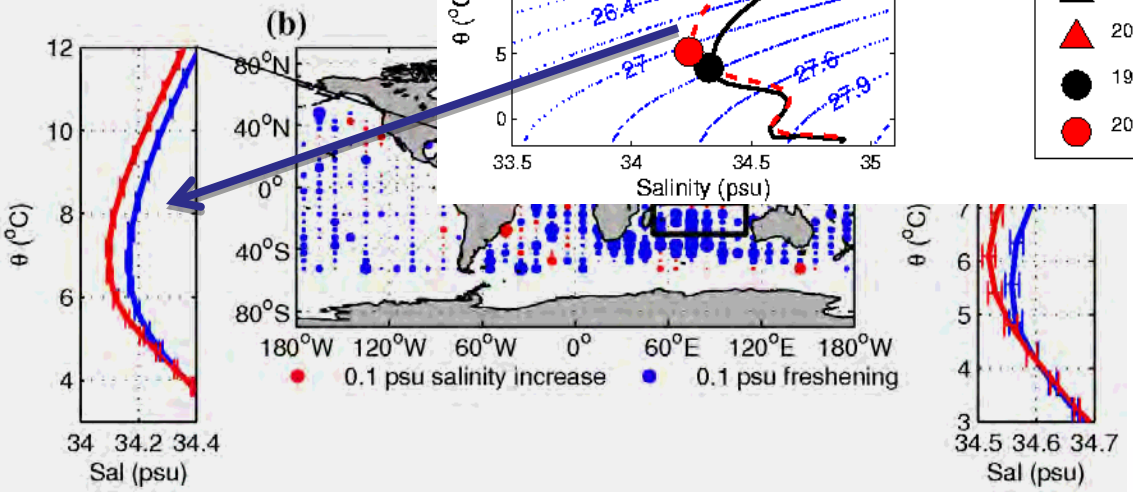
- likely replaced with very likely
- GHGs likely would have caused more than observed

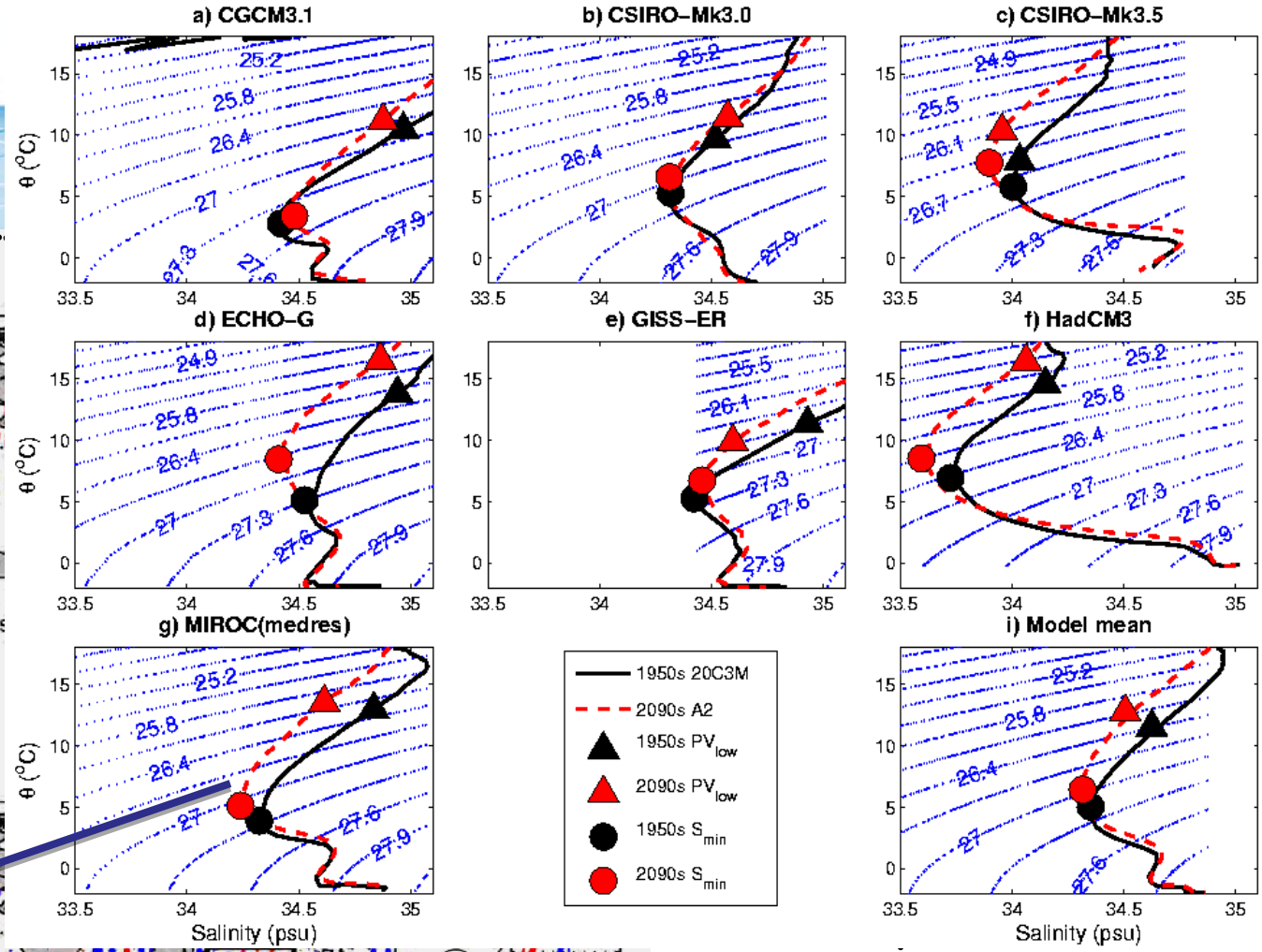
The Changing Oceans

Water Mass change

Shallow salinit







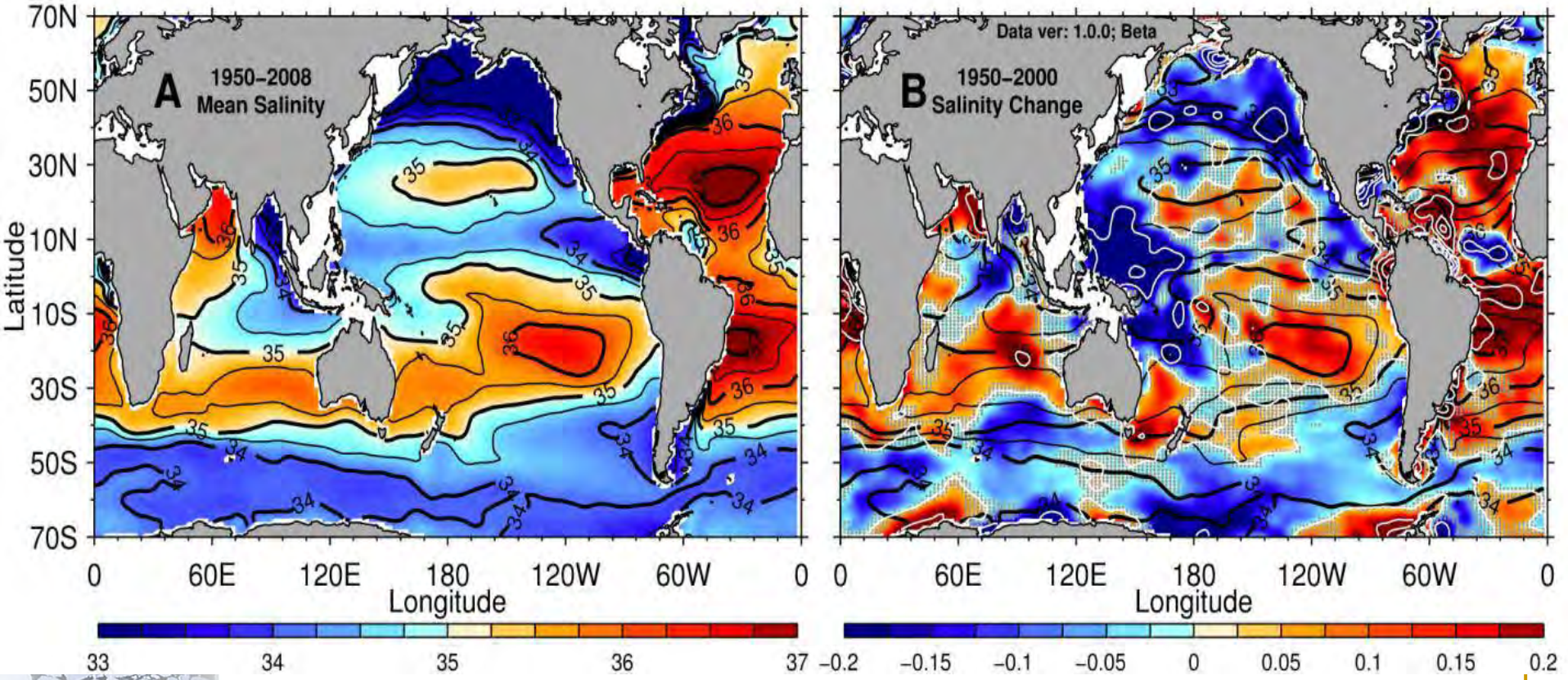
Helm et al 2010

Downes et al, 2011

Surface salinity changes

Mean Salinity

Change salinity, 50 years



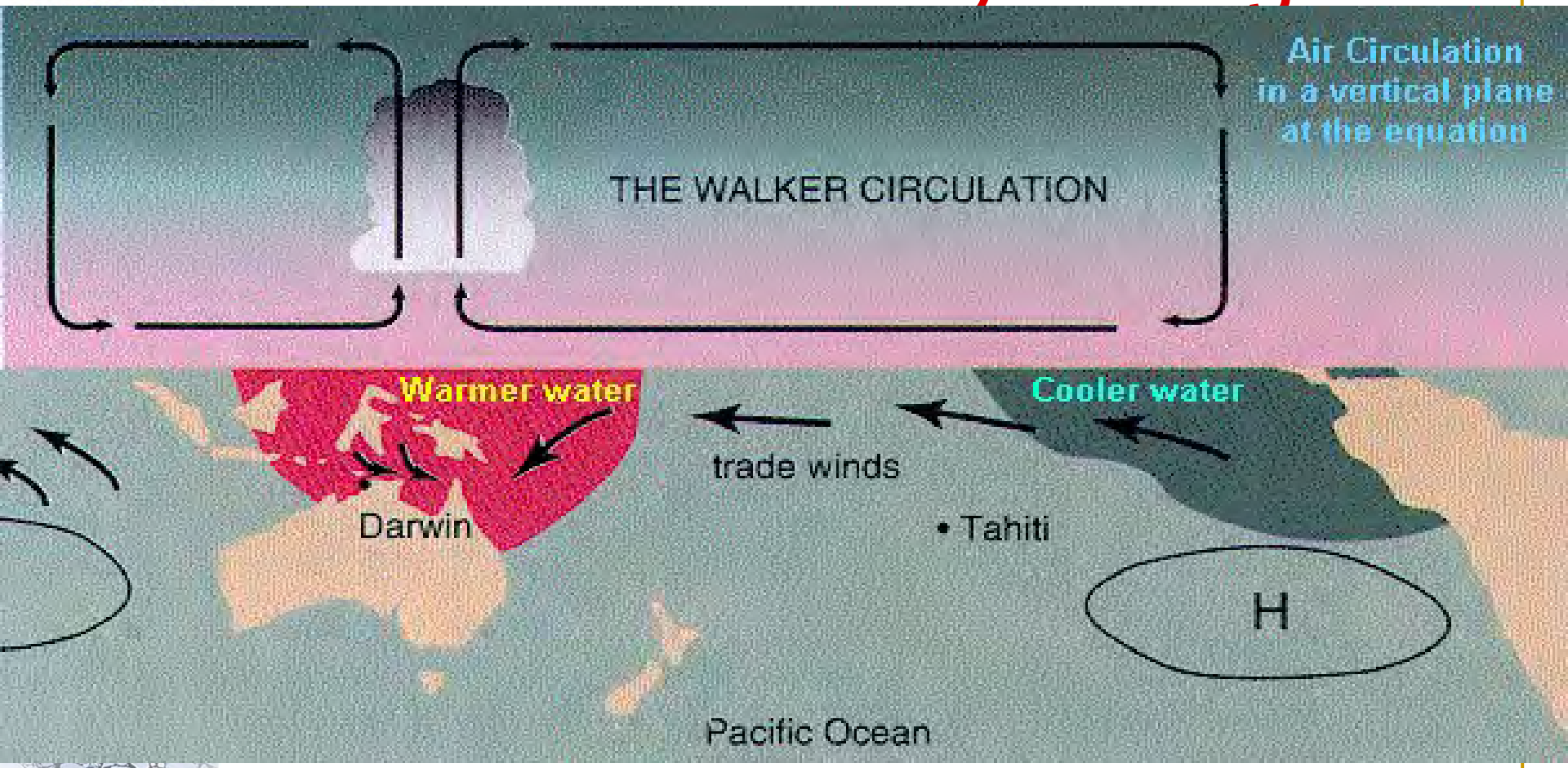
The salty region are saltier

The Fresher regional are fresher

Durack et al. 2010

Durack et al. 2012

Surface salinity changes



The changed salinity in the equatorial region implies strengthened "walker" circulation

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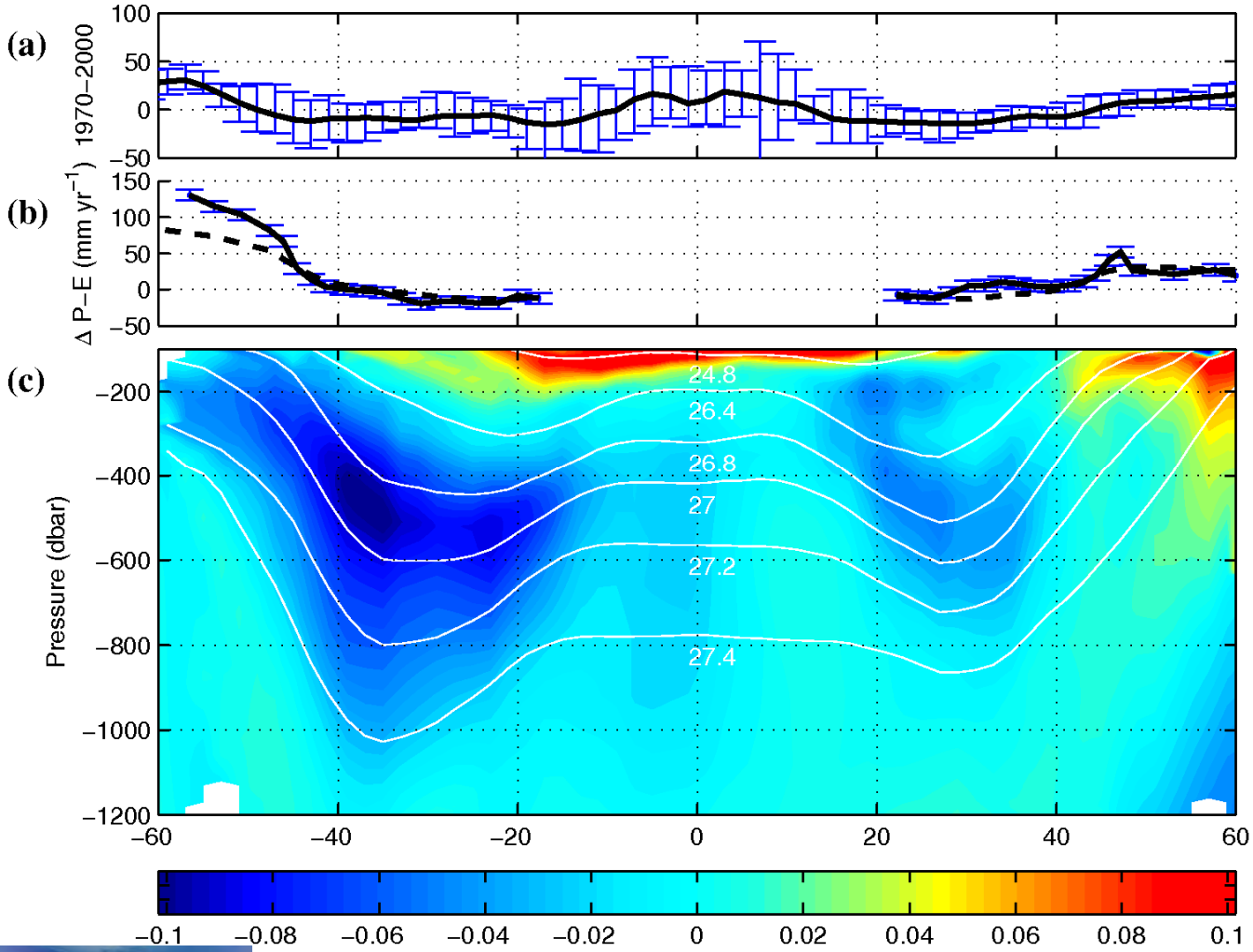
Comparison with models



10 IPCC models 1970-2000

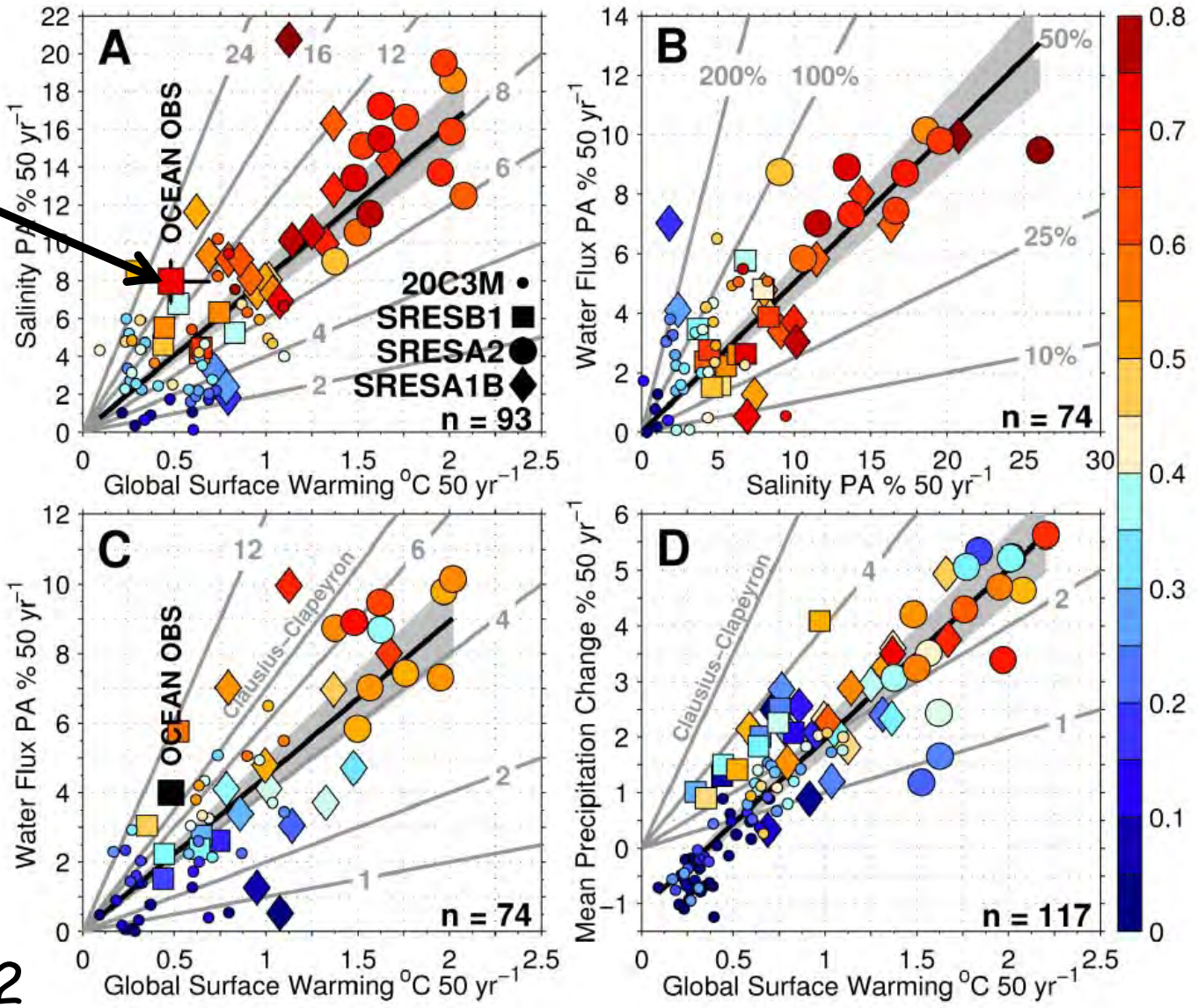
Estimated P-E

+16±6% in S. Ocean
+ 7±4% in N.H
- 3±2% in S.T. gyres

Helm et al 2010

Surface salinity changes

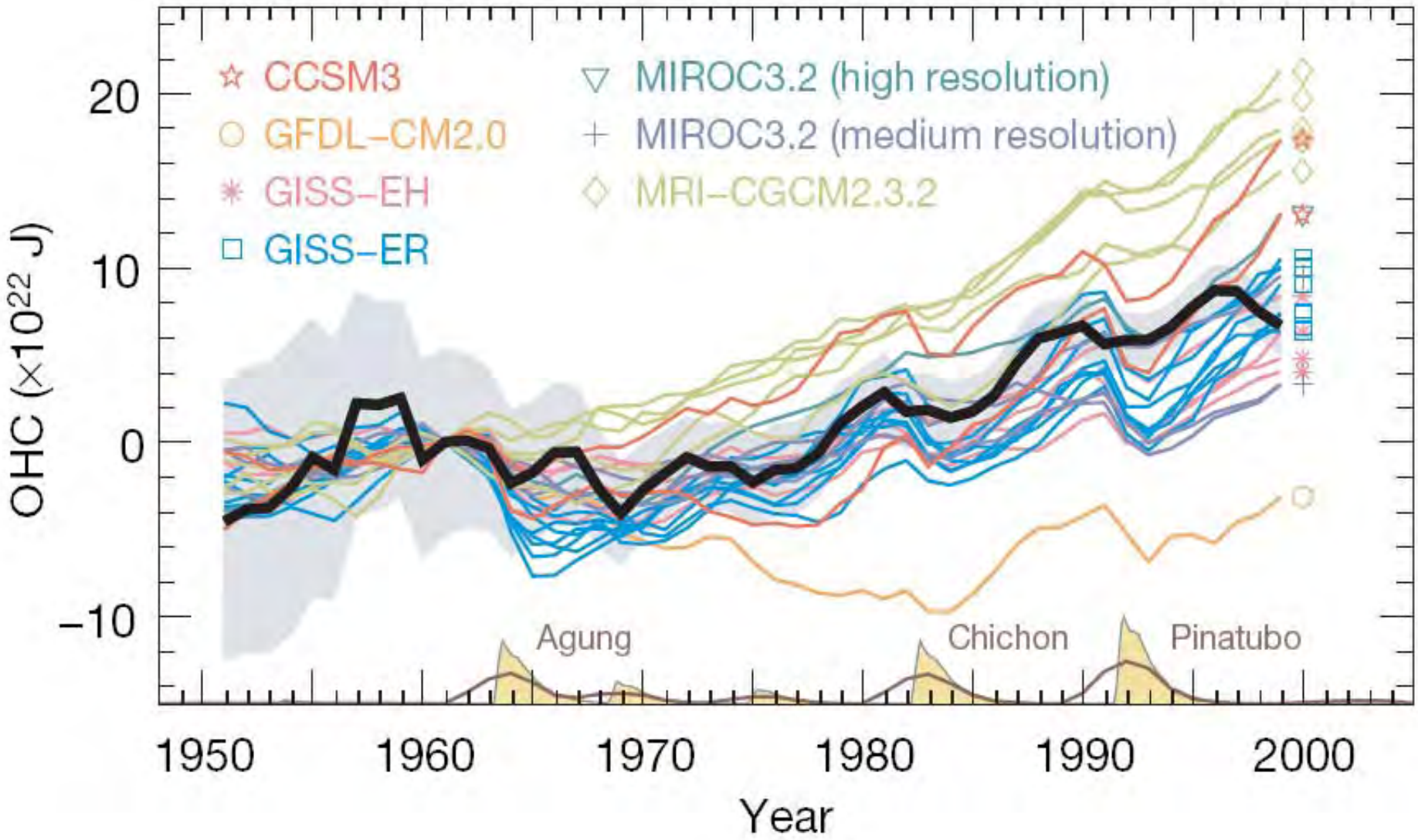
Observed Amplification



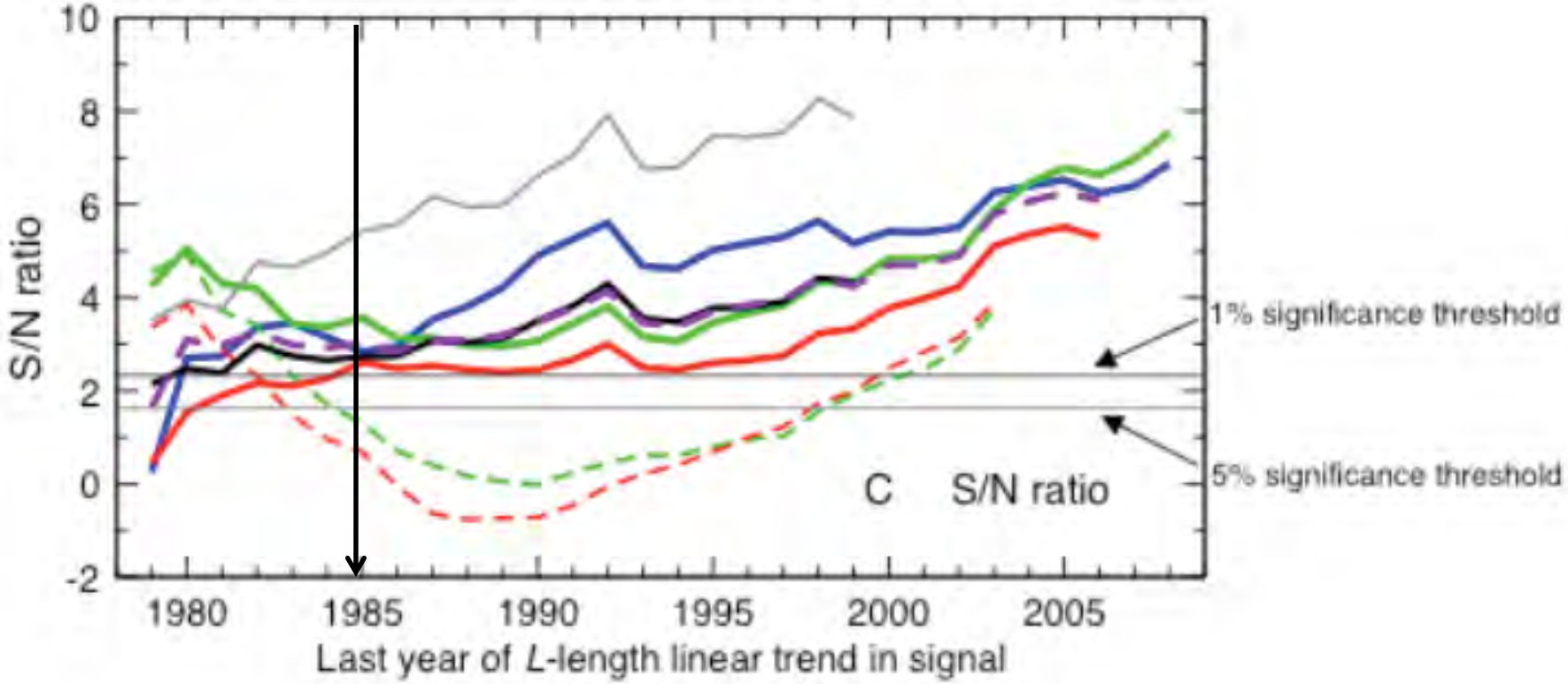
Observations show a stronger amplification than models

Durack et al. 2012

Ocean temperatures and human influence



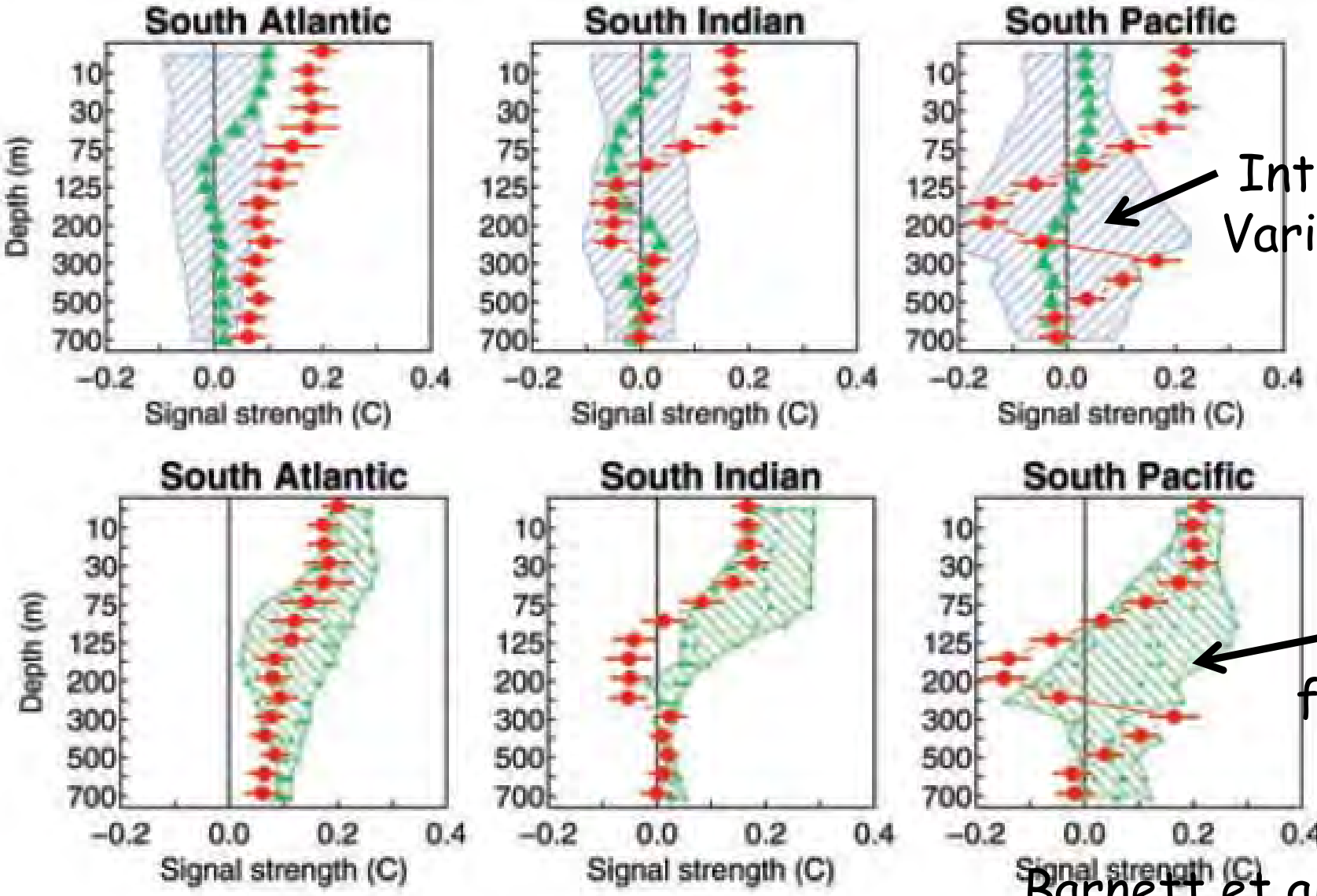
Time of emergence of human influence



Significant improvements in knowledge of data errors

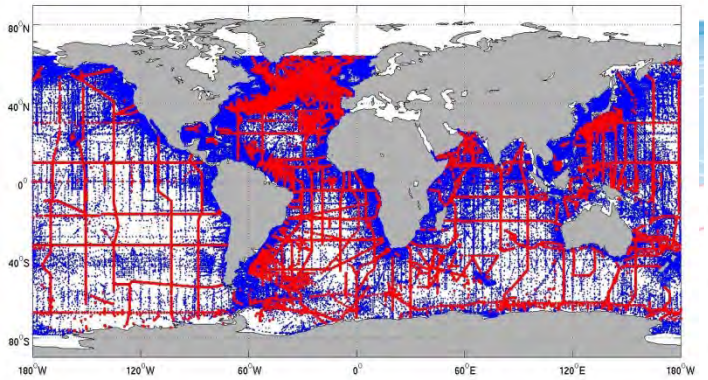
Hindsight view, says fingerprint of change virtually certain of detection in 1985

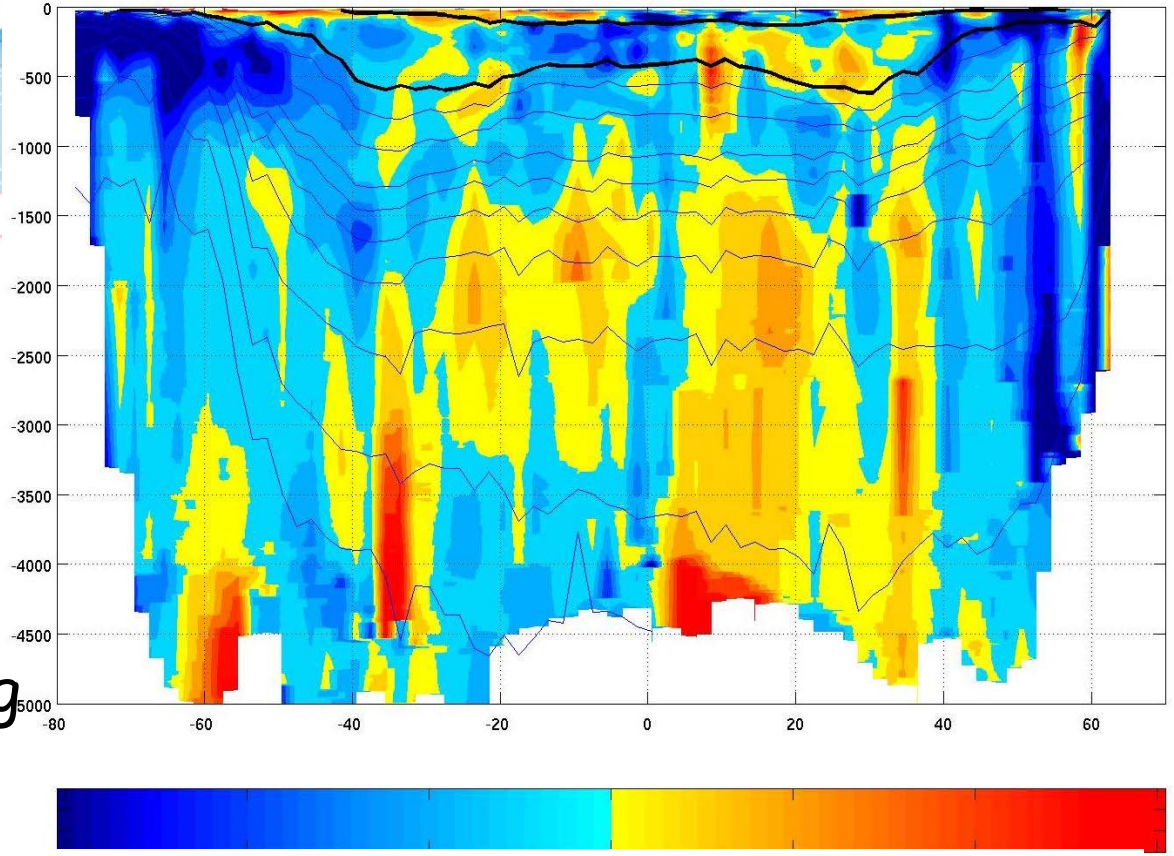
Ocean temperatures and human influence



Barnett et al 2005

Ocean renewal - global oxygen decreases



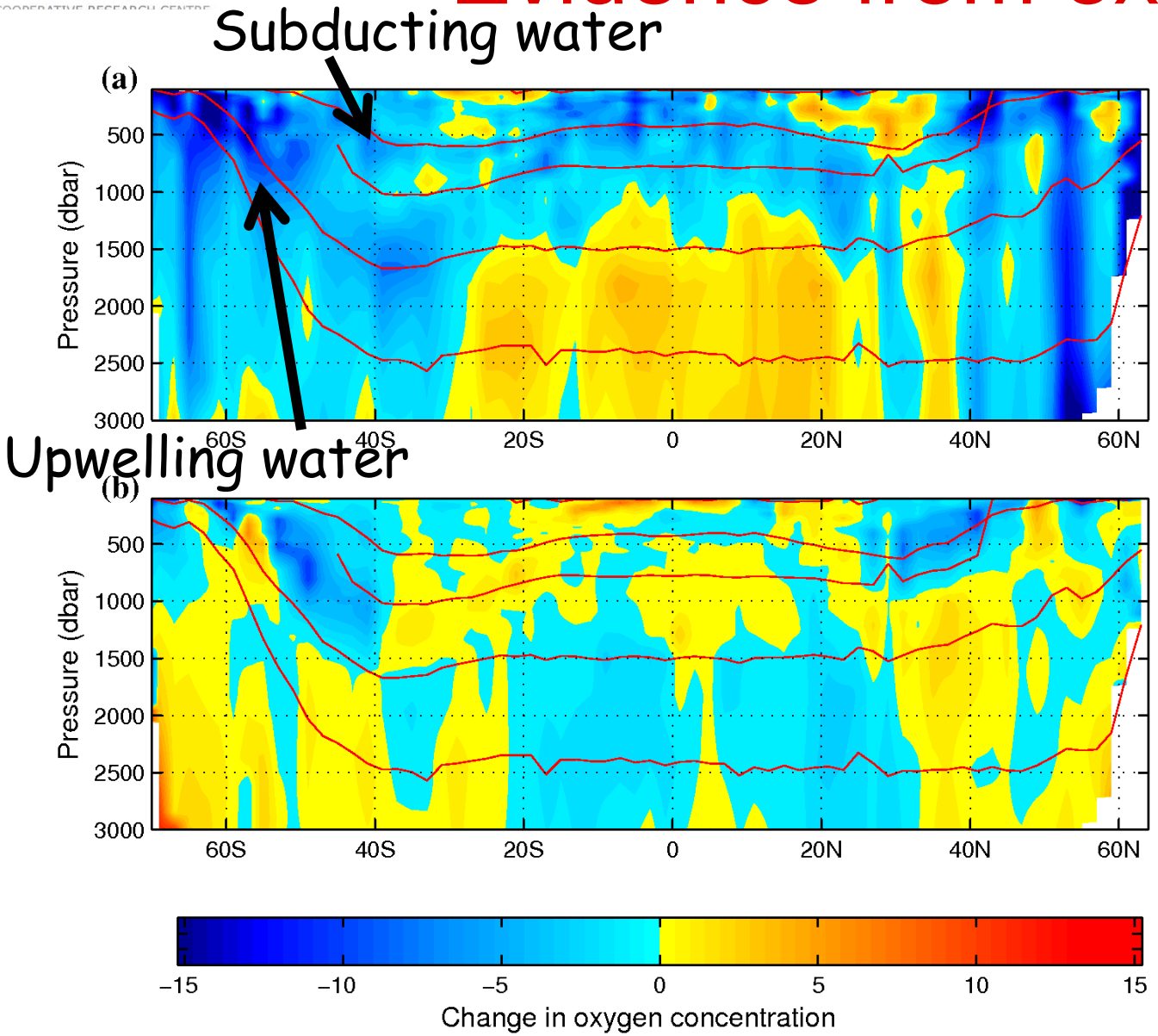


- Decreased ventilation
- Weaker over-turning

Table 5.1. Fraction of CO_2 emissions taken up by the ocean for different time periods.

Time Period	Oceanic Increase (GtC)	Net CO_2 Emissions[a] (GtC)	Uptake Fraction	Reference
1750–1994	118 ± 19	283 ± 19	0.42 ± 0.07	Sabine et al., 2004a
1980–2005[b]	53 ± 9	143± 10	0.37 ± 0.07	Chapter 7[c]

Is Ocean renewal changing? Evidence from oxygen

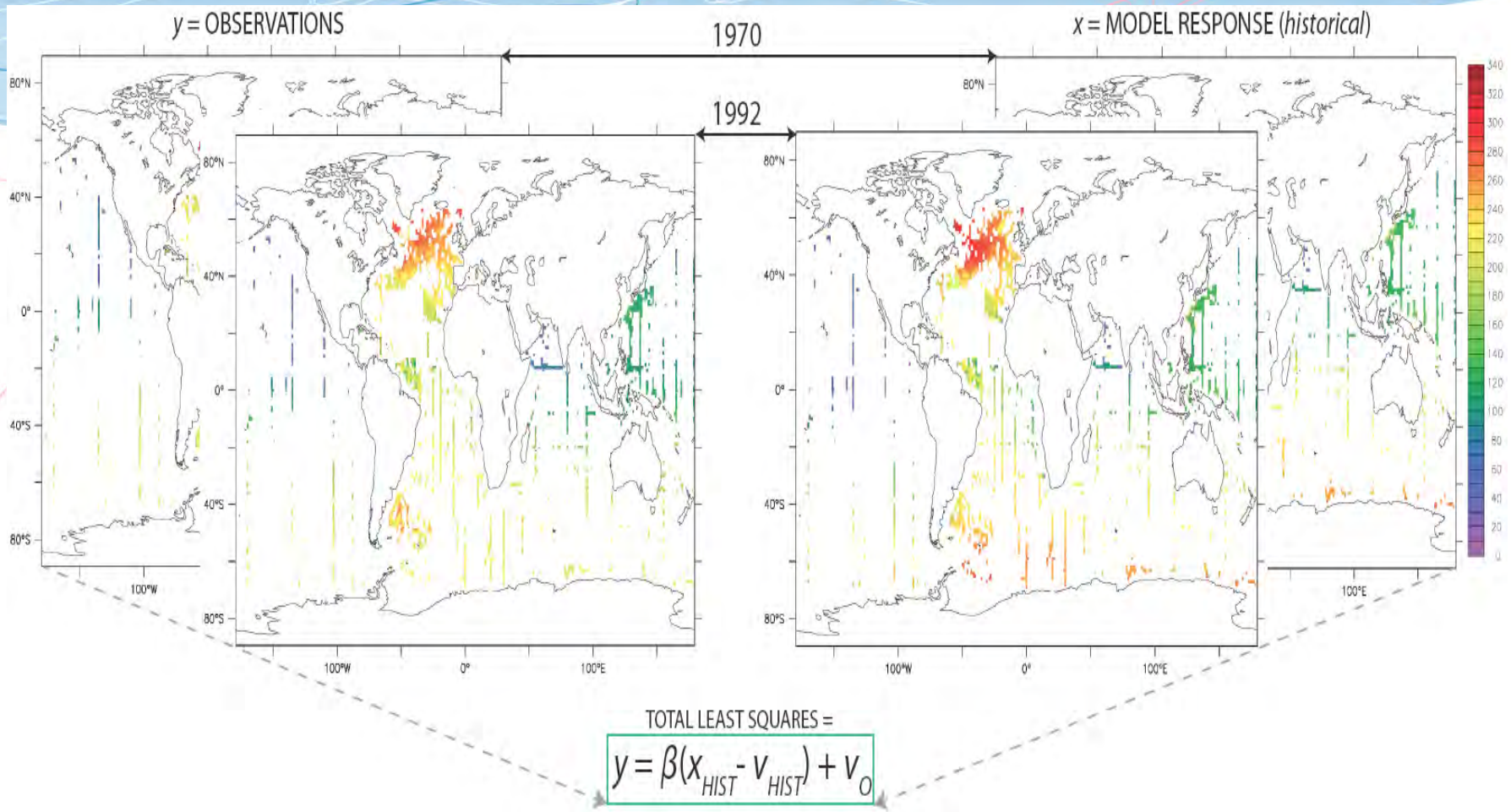


Oxygen change on density surface

Oxygen change from displacement of density surface

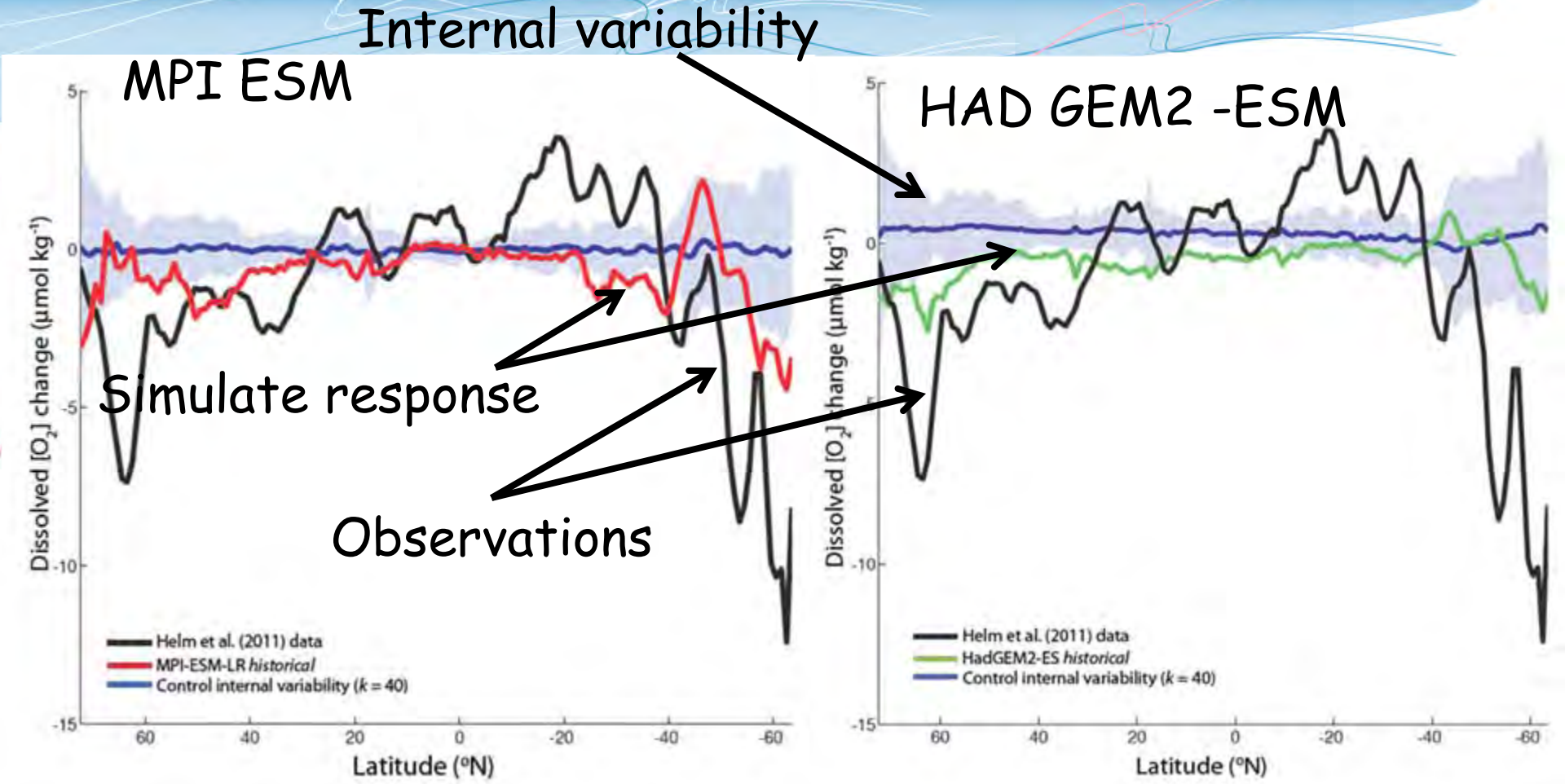
- Global Scale
- Not heave
- 1970 to 1990's

Are oxygen changes anthropogenic in origin?



Andrews et al, 2012

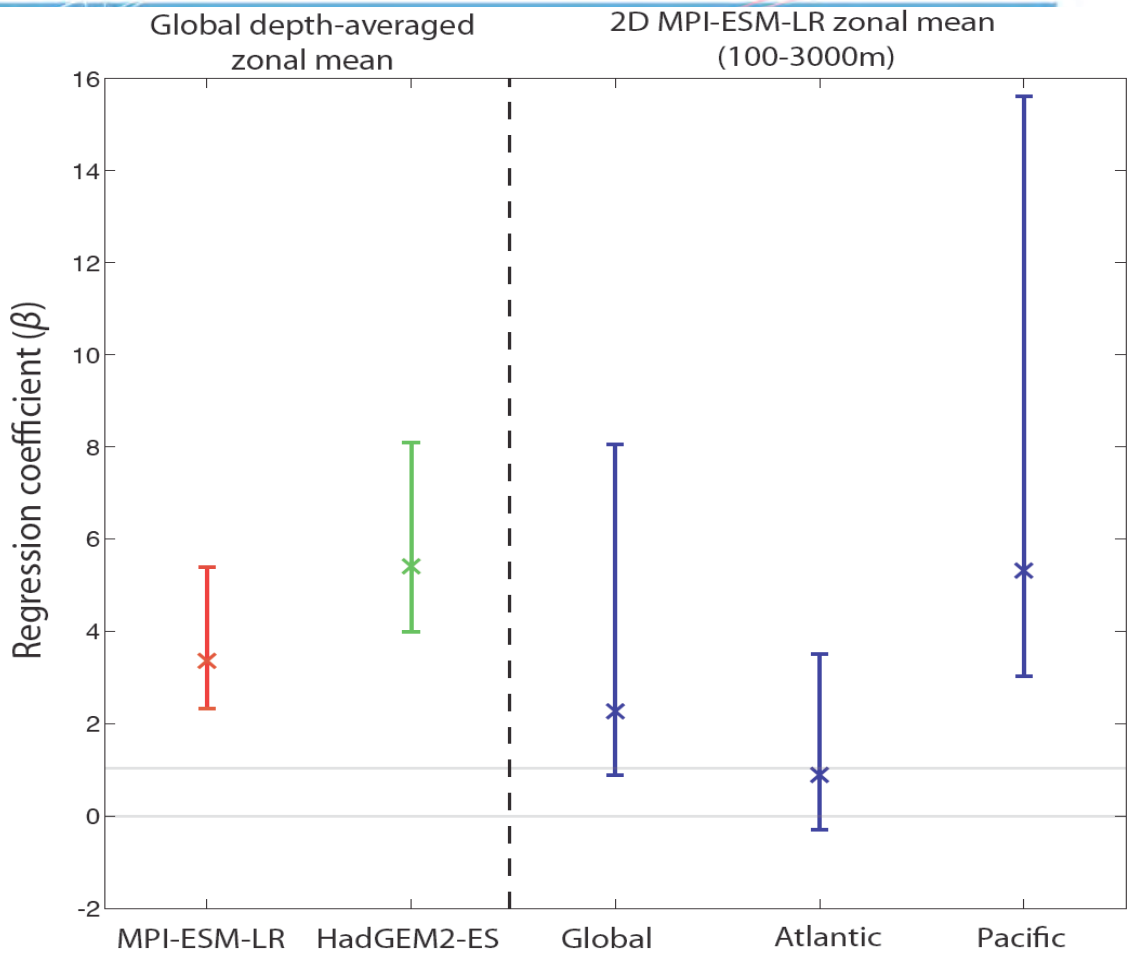
Are oxygen changes anthropogenic in origin?



Are oxygen changes anthropogenic in origin?

95% confidence interval

- Regression coefficients > 1
- Under-estimation of oxygen changes by models



Very likely that oxygen decreases are anthropogenic
Evidence is mainly driven by physics (except at depth)

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Conclusions: Global Ocean

- Ocean is Changing
  - Surface waters are lighter
  - Strong evidence for reduced ocean exchanges (SAMW lower in oxygen, upwelling CDW lower in oxygen)
  - Surface salinity show acceleration of water cycle (meridional and equatorial)
  - Attributions imply reduces overturning circulation
  - Significant evidence of ocean responses that attributable rising GHG

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Prospects: marine ecosystems

- Best applications
  - Detection works for global distributions
  - Longish time series
  - Numerical, quantitative models of ecosystems responses ("coupled") to physical models
  - Internal variability (control simulations) represent the "null" hypothesis
- IPCC
  - Detection and Attribution guidance paper
    - Qualitative and quantitative approaches