Oxygen Content Decadal Variability in the Upper North Pacific

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PICES 13th [October, 2004]

S8: The impacts of climate change on the carbon cycle in the North Pacific

OUTLINE

- Methods
- Estimates of decadal O_2 variability
- Seasonal vs. decadal variability scales
- O_2/AOU/Heat decadal variability/trends
- Summary

METHODS

- Selected historical data from the *World Ocean Database 2001* (1955 to 1998; 70°S-70°N).

- Objective analysis on 5- and 10-year composite periods on a 1° grid, global (seasons removed).

- Estimate inventories & trends (0-100 m case)

$$OC = A \int_{z_1}^{z_2} \Delta O_2 \, dz$$

Estimates of variability in O_2 or AOU concentration in the World Ocean

Location	Time span (years)	Depth range (m)	ΔO_2 (µmol/kg)	ΔAOU (µmol/kg)
N. Atlantic (24.5°N section)	1981-1992	800-2200	**-3 to -7**	
N. Pacific (basin mean)	**1972s-1990s**	**1000-1750**		**-4**
N. Pacific (22°-44°N)	**1980-1997**	**100-600**	**-9 to -20**	
N. Pacific (48°-60°N)	**1950-2000**	**50-900**		**+5 to +25**
S. Pacific (28°S section)	1967-1995	800-1200	**-5 to -8**	
S. Indian (32°S section)	1962-1997	300-800 2500-4000	**-7 to -8** **+3**	
Southern Ocean (50°-60°S)	1965-1995	> 400	**-5 to -15**	

Updated from Keeling and Garcia (2002) . Other references: **1.** Garcia et al (1998); **2.** Keller et al (2002); 3. Emerson et al 2001; **4.** Andreev and Watanabe (2002) ; **5.** Shaffer et al. (2000); **6.** Bindoff and McDougal (2000); **7.** Matear et al. (2000)

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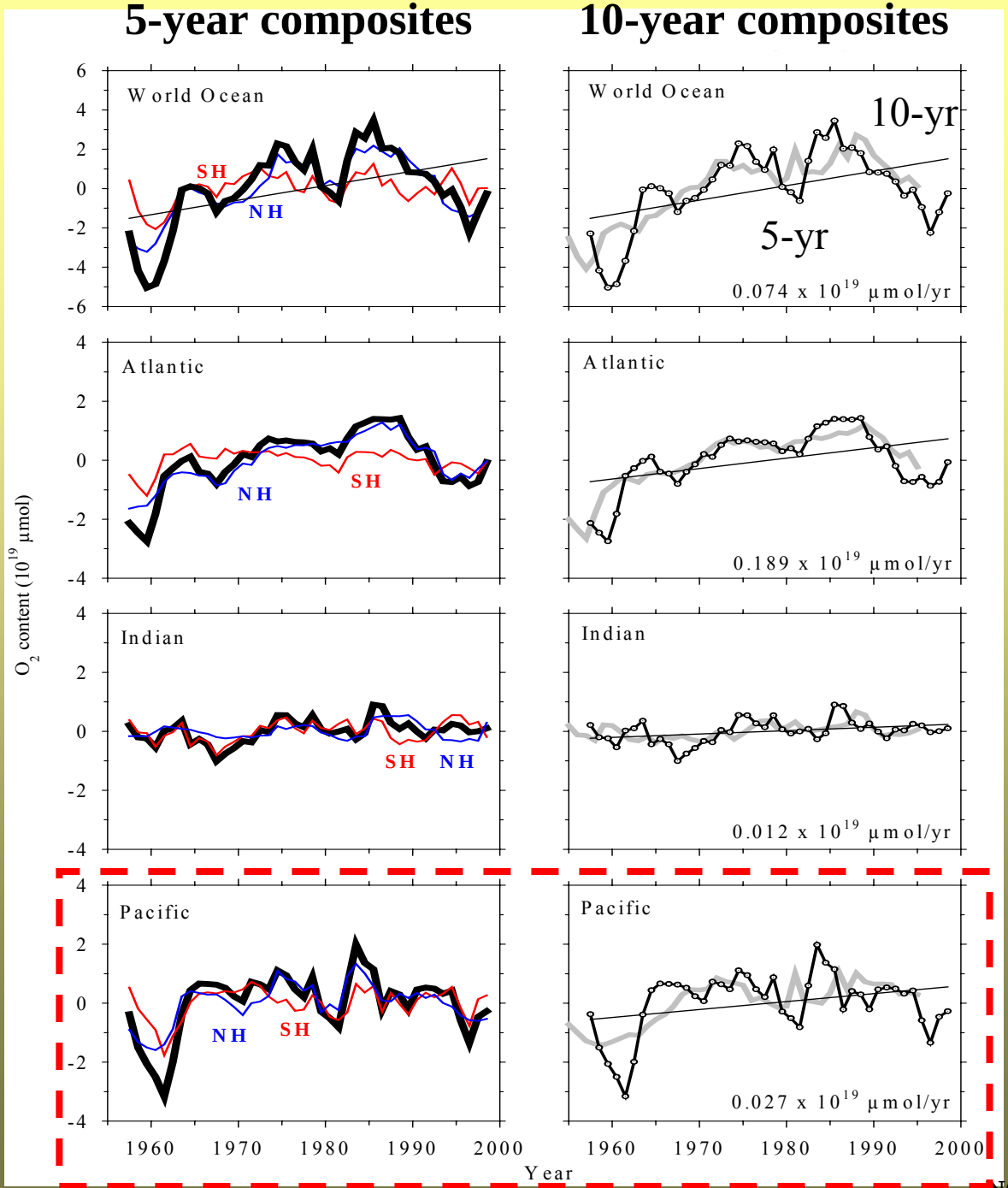

Oxygen content

10^{19} µmol

0-100 m layer

(70°S-70°N)

Pacific Basin Case

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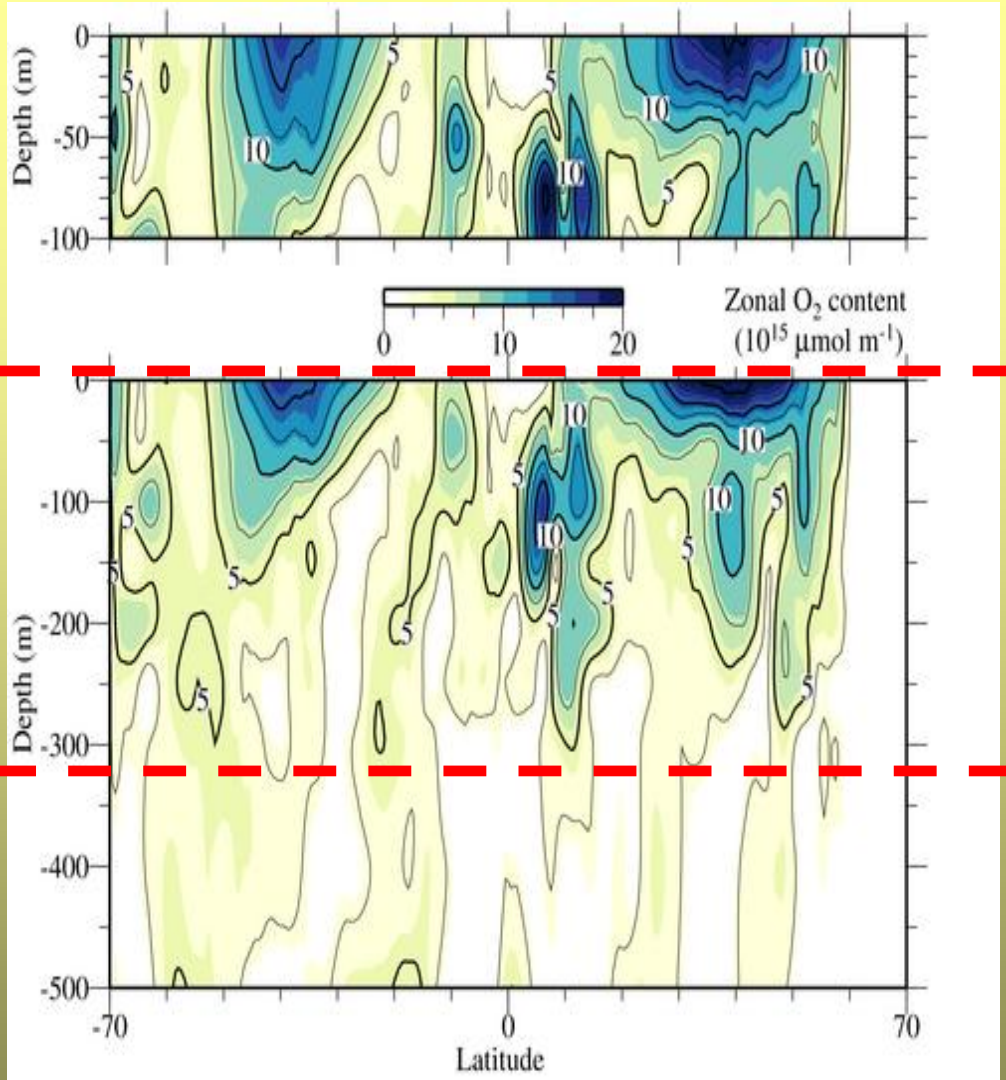
Seasonal vs. Decadal Variability Scales?



Amplitude of the annual harmonic of the zonally integrated monthly O_2 content per unit meter of depth for Pacific Basin 90-500 m depth). Zonal O_2 content values have been multiplied by the area of each zonal band. The nominal contour interval is 2.5 x 10^{15} µ mol m^{-1}.

Amplitude of annual harmonic zonally integrated monthly O_2 anomaly content (10^{15} µmol/m) in the Pacific Basin

Garcia *et al*. 2004, submitted

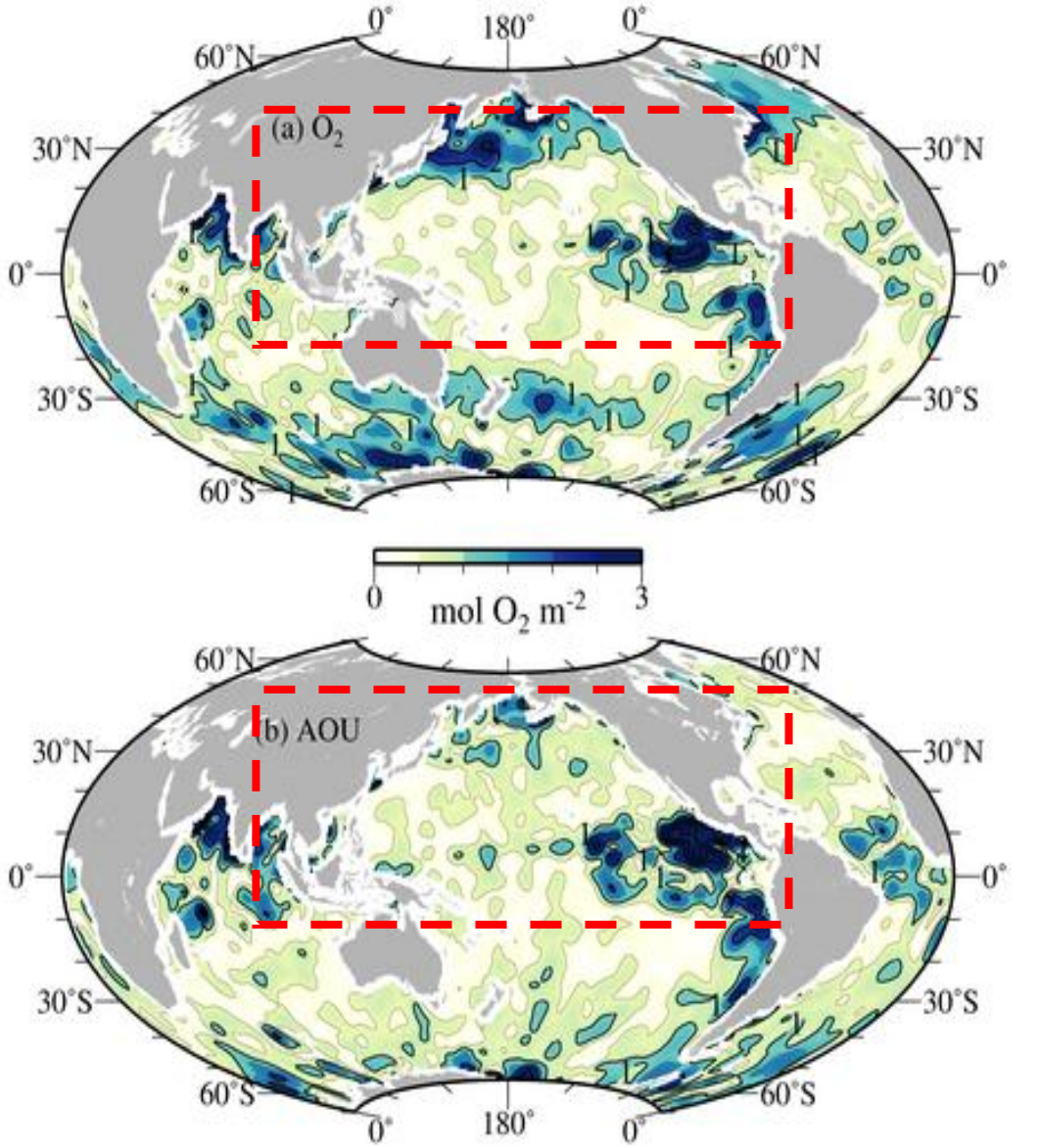


Figure 6. Amplitude per unit area of the annual harmonic for the 0-100 m depth of the montly content of (a) O_2 and (b) AOU. The nominal contour interval is 1 mol m^{-2}.

Amplitude of annual harmonic of monthly **O_2** anomaly content

Amplitude of annual harmonic of monthly **AOU** anomaly content

Garcia *et al*. 2004, submitted

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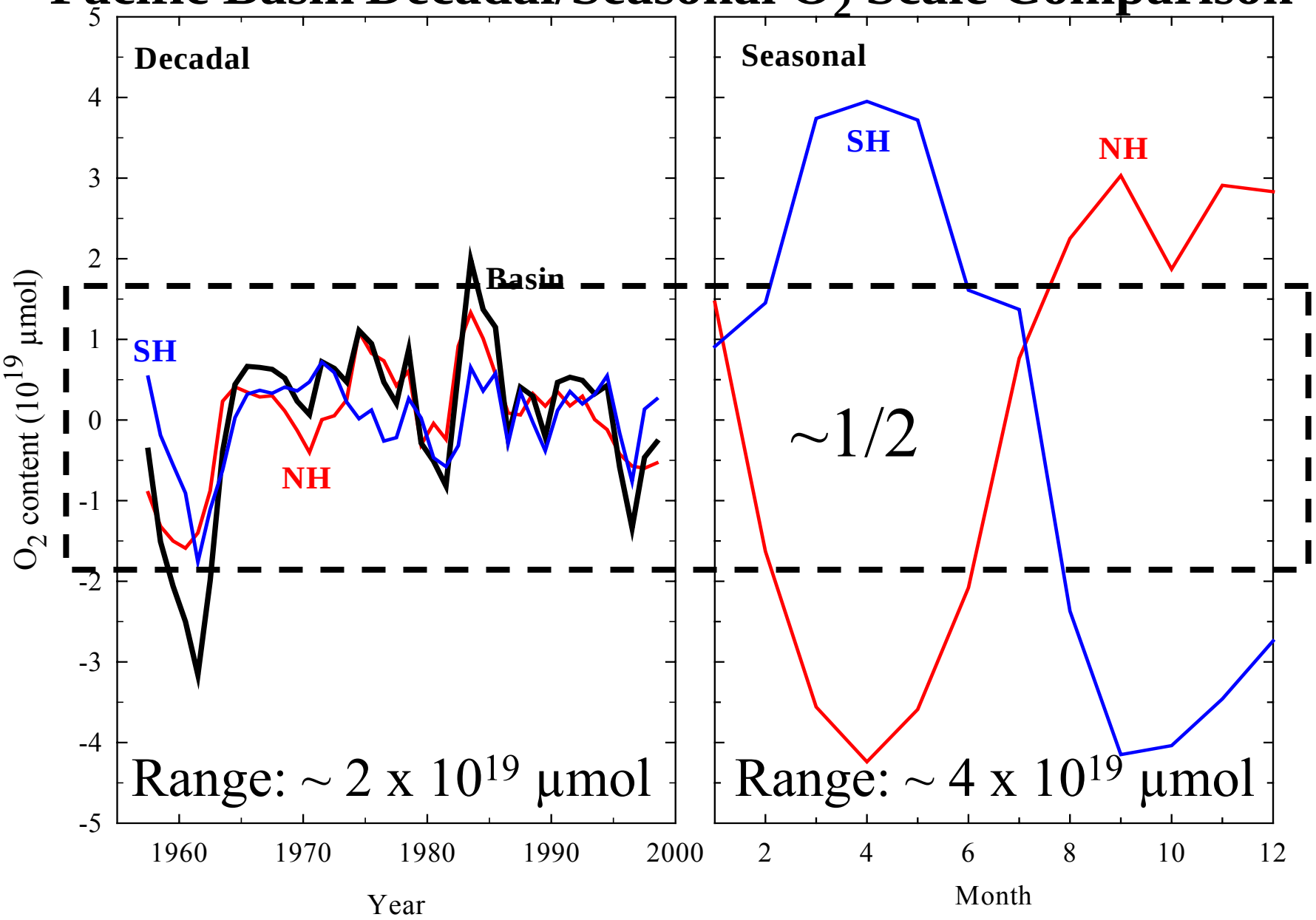
Pacific Basin Decadal/Seasonal O_2 Scale Comparison



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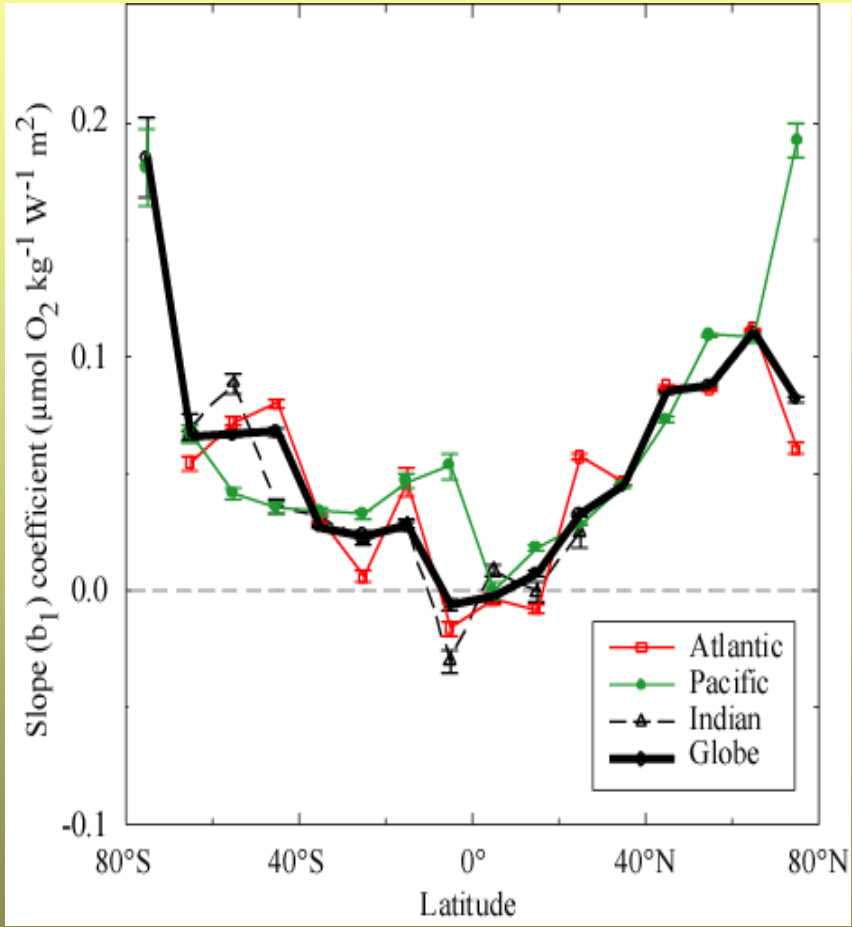
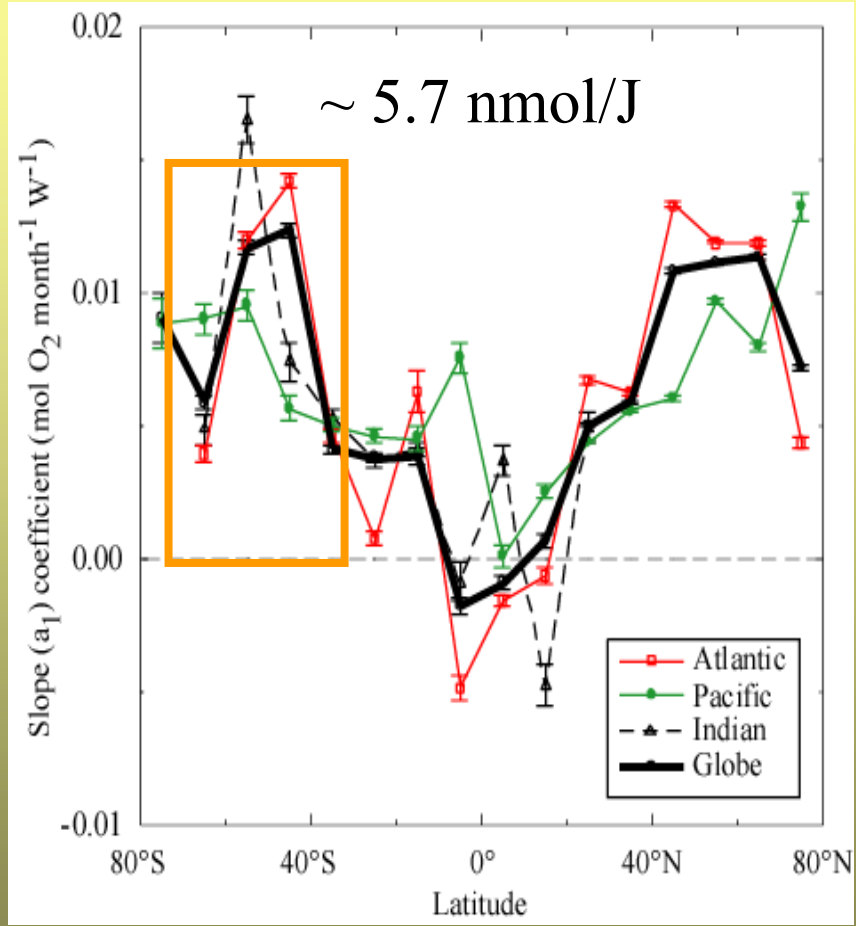
Surface ΔO_2/heat slope seasonal



Surface fO_2/heat slope seasonal



Garcia and Keeling [2001]

fO_2/H (1 mol $month^{-1}$ w^{-1} ~ 385.8 nmol J^{-1})

Corrections: O^S, skin-temperature, msl atmospheric pressure, sea-ice

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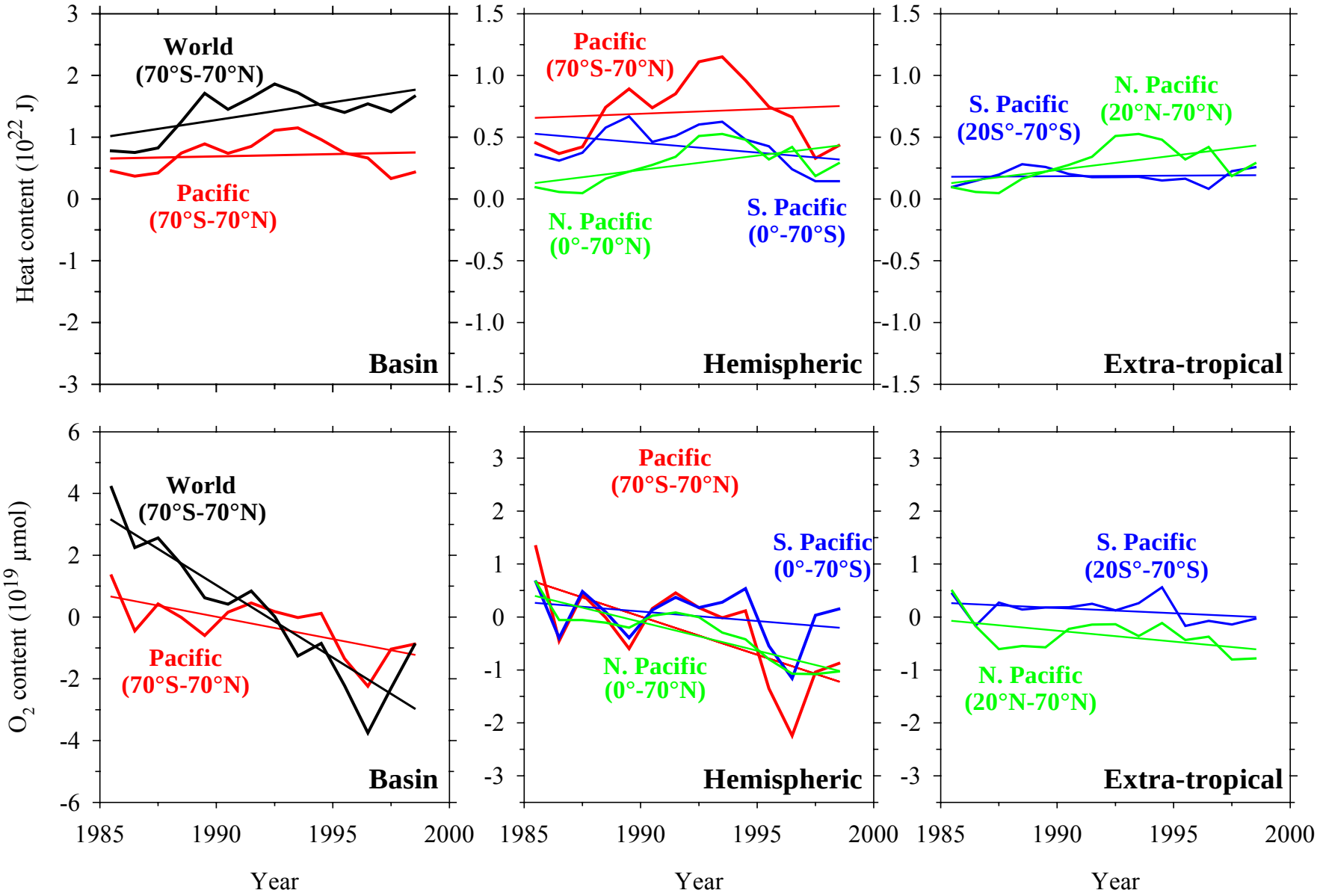
O_2 , AOU, Heat

decadal-scale

Variability

Are trends constant?

Pacific Basin: Heat and O_2 content [0-100 m; **1985-1998**]



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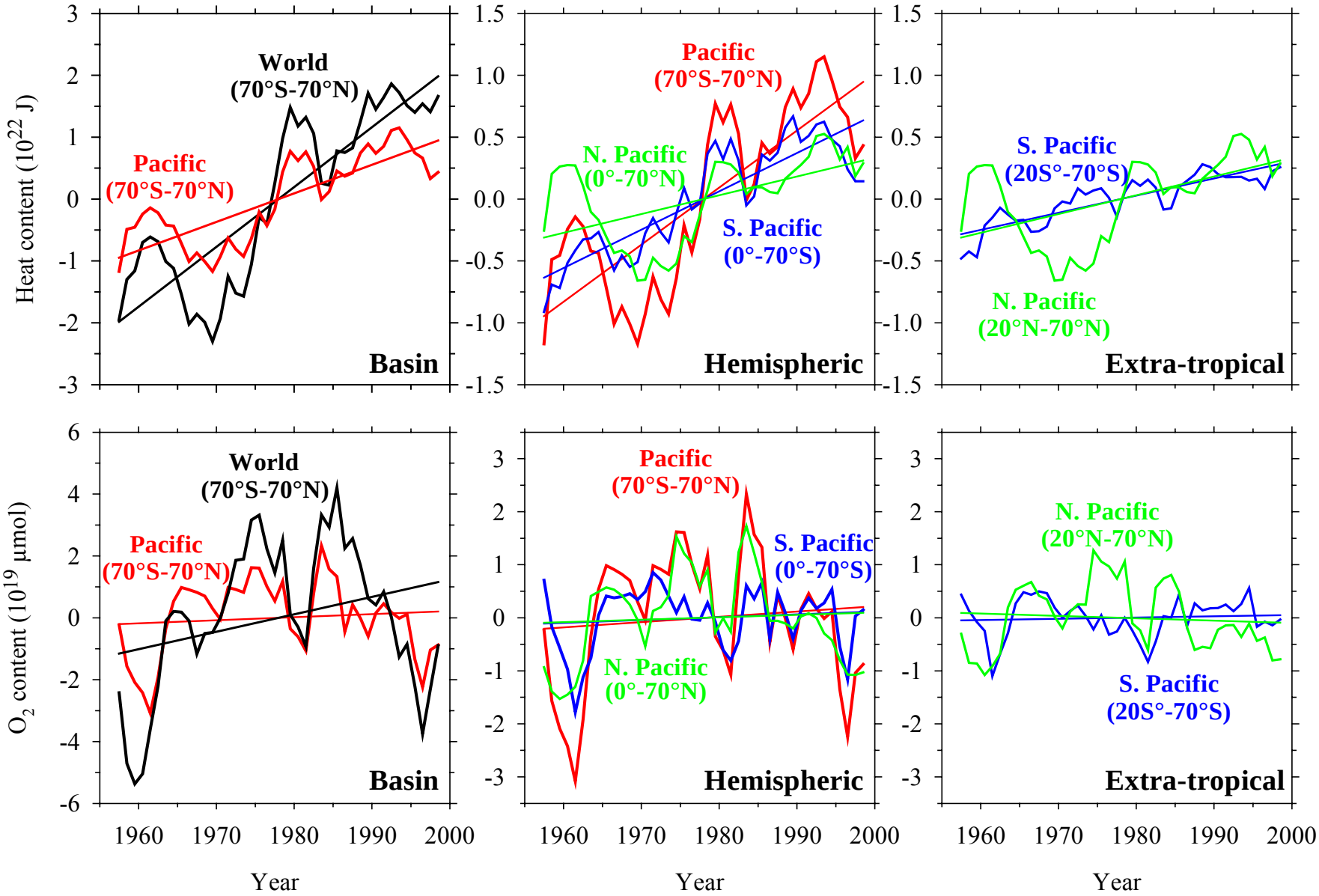
Pacific Basin: Heat and O_2 content [0-100 m; **1955-1998**]



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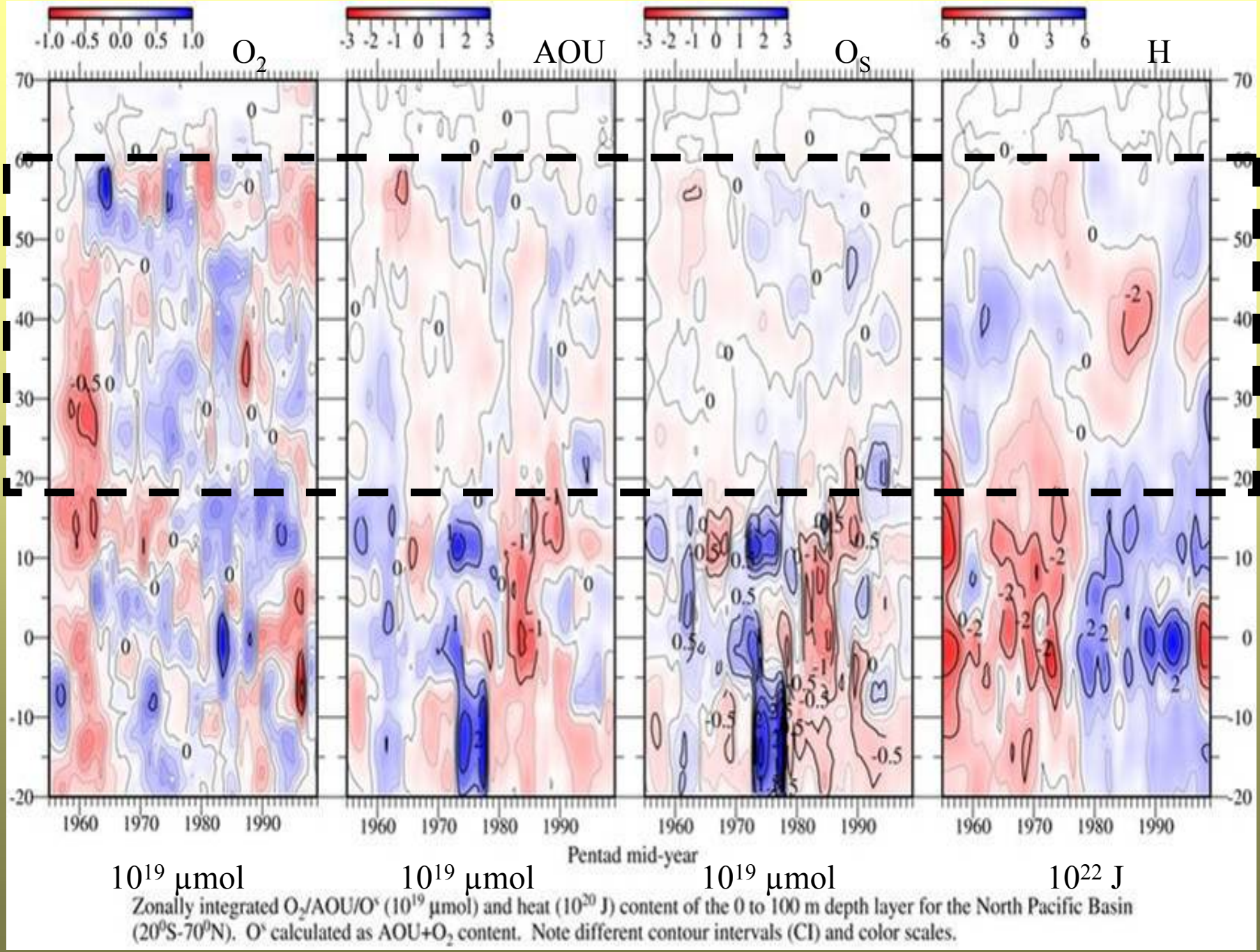
O_2-to-Heat ratios (nmol/J); [nmol=10^{-9} mol]

Basin (0-100m)	**1955-1998**	**1985-1998**
Pacific (70°S-70°N)	0.22	-19.7
North Pacific (0°-70°N)	**0.30**	**-4.7**
North Pacific (20°-70N)	**-0.32**	**-1.8**
South Pacific (0°-70°S)	0.17	2.3
South Pacific (20°-70S)	-0.17	-20.4



Zonally integrated O_2/AOU/O^s (10^{19} µmol) and heat (10^{20} J) content of the 0 to 100 m depth layer for the North Pacific Basin (20^0S-70^0N). O^s calculated as AOU+O_2 content. Note different contour intervals (CI) and color scales.

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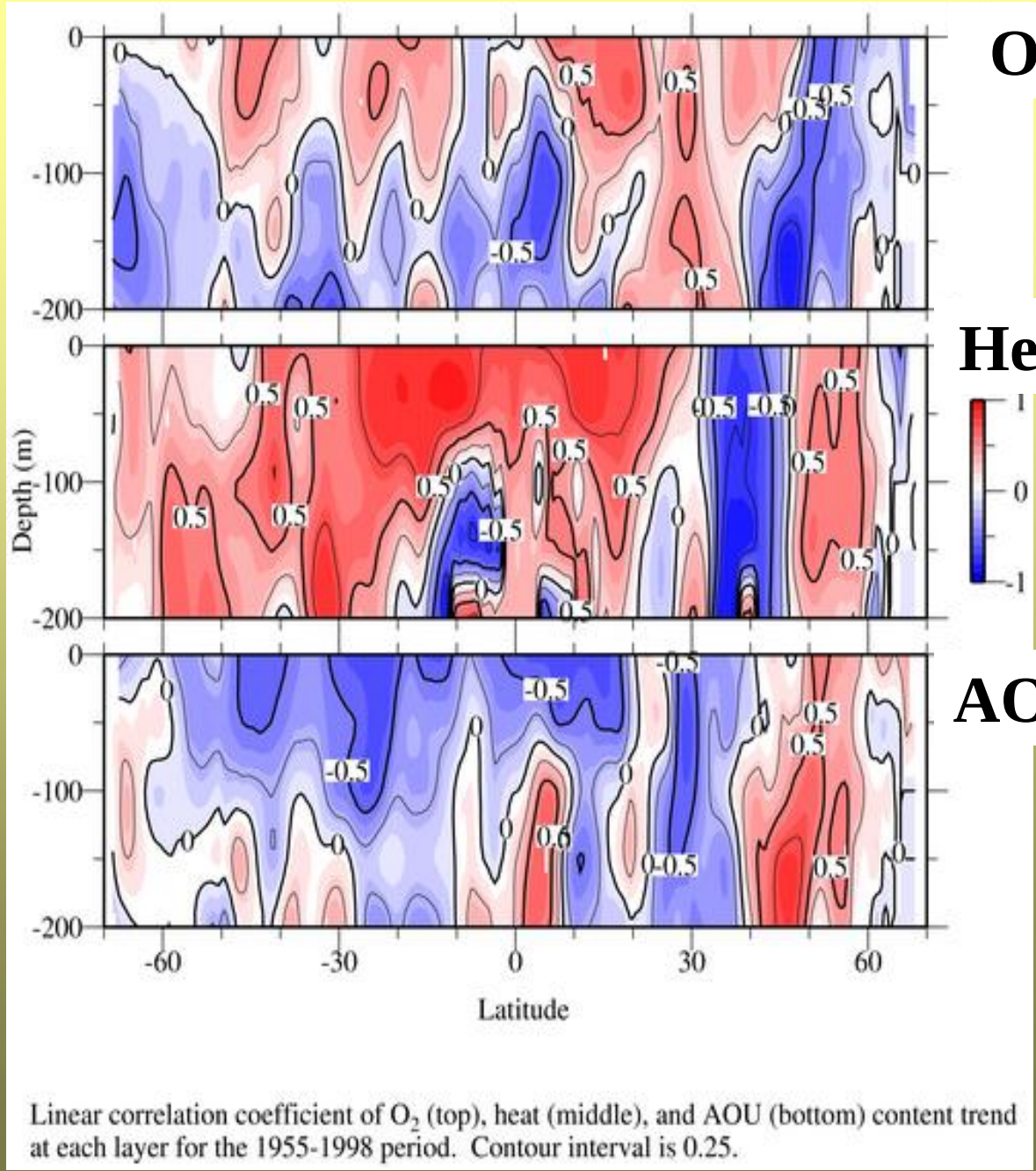


Linear correlation coefficient of O_2 (top), heat (middle), and AOU (bottom) content trend at each layer for the 1955-1998 period. Contour interval is 0.25.

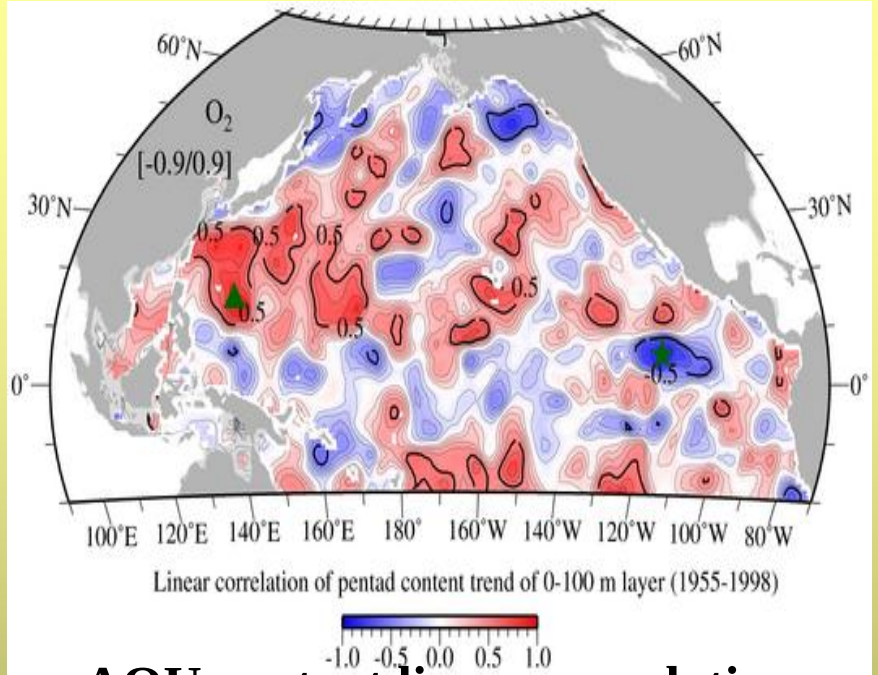
Linear correlation

zonally integrated

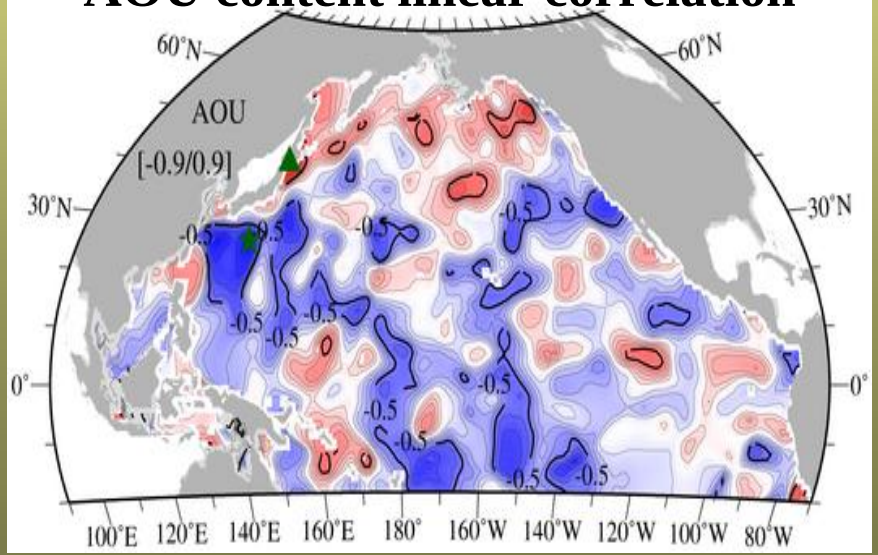
content

(1955-1998)

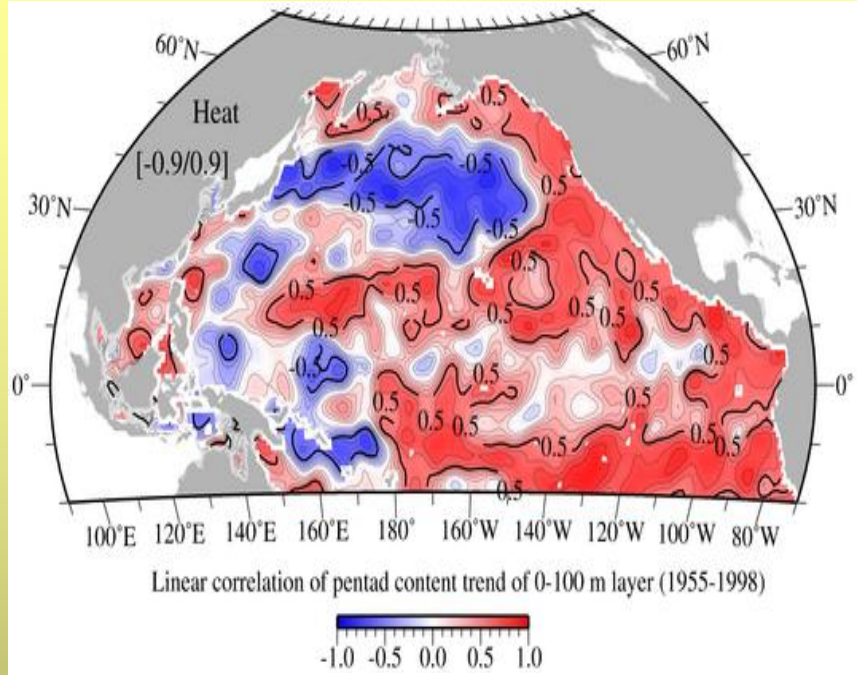
O_2 content linear correlation



AOU content linear correlation



Heat content linear correlation



Linear correlation Pentads (1955-1998)

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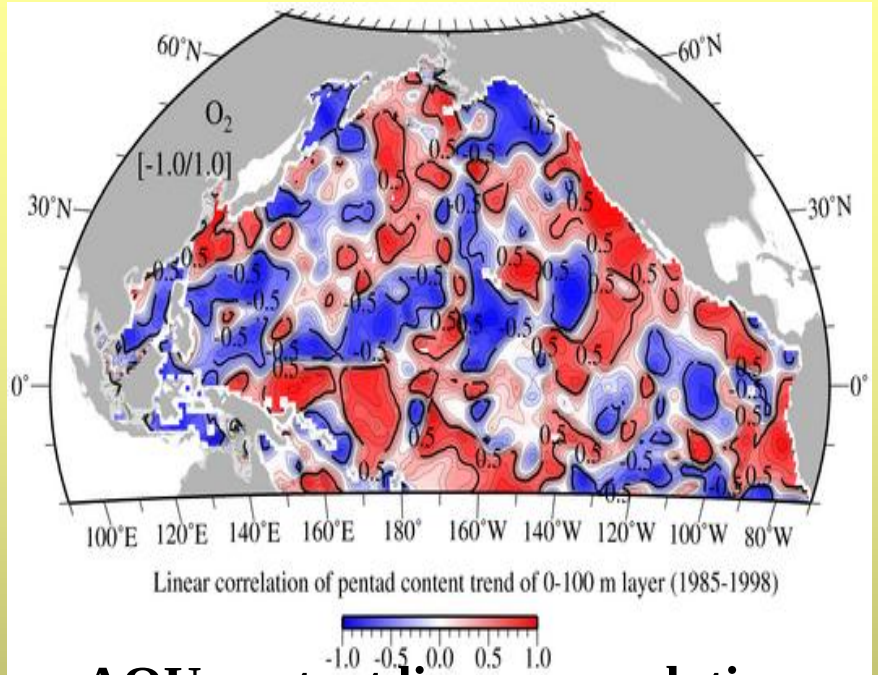
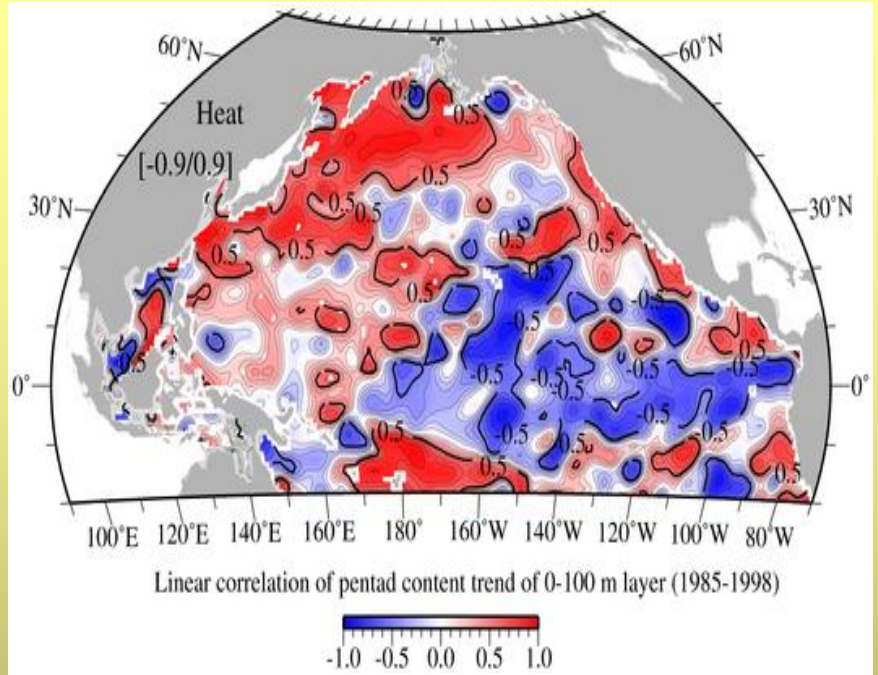
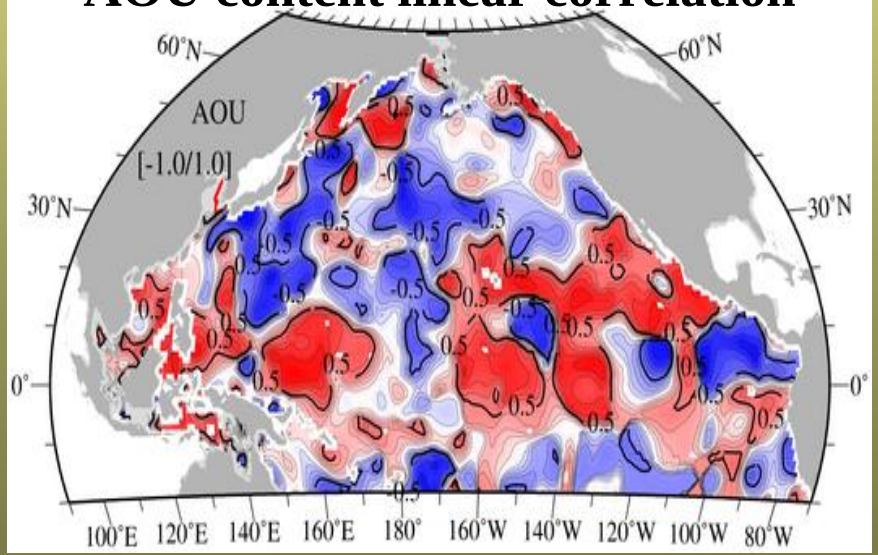
O_2 content linear correlation



Heat content linear correlation



AOU content linear correlation



Linear correlation Pentads (1985-1998)

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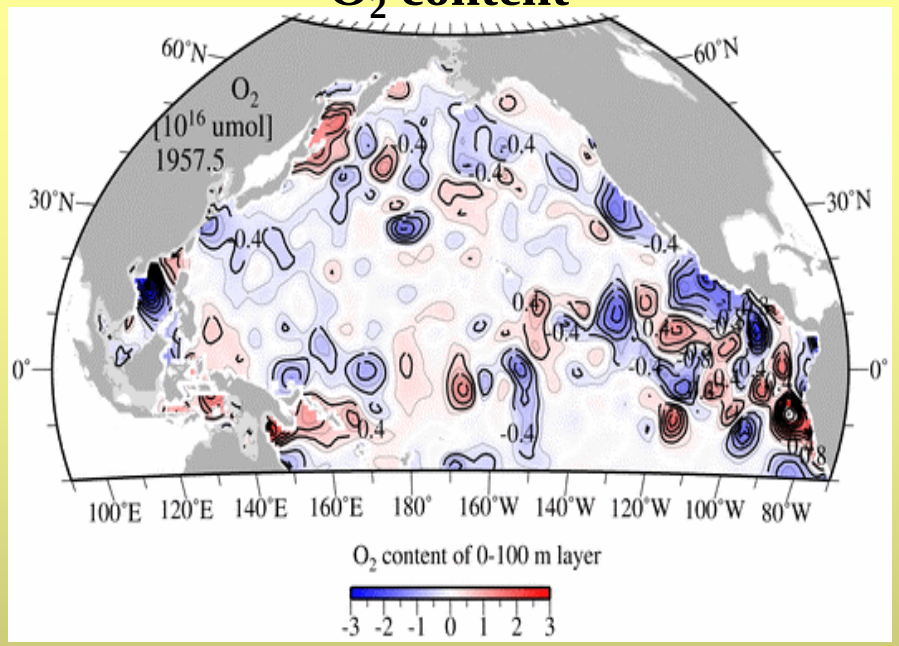
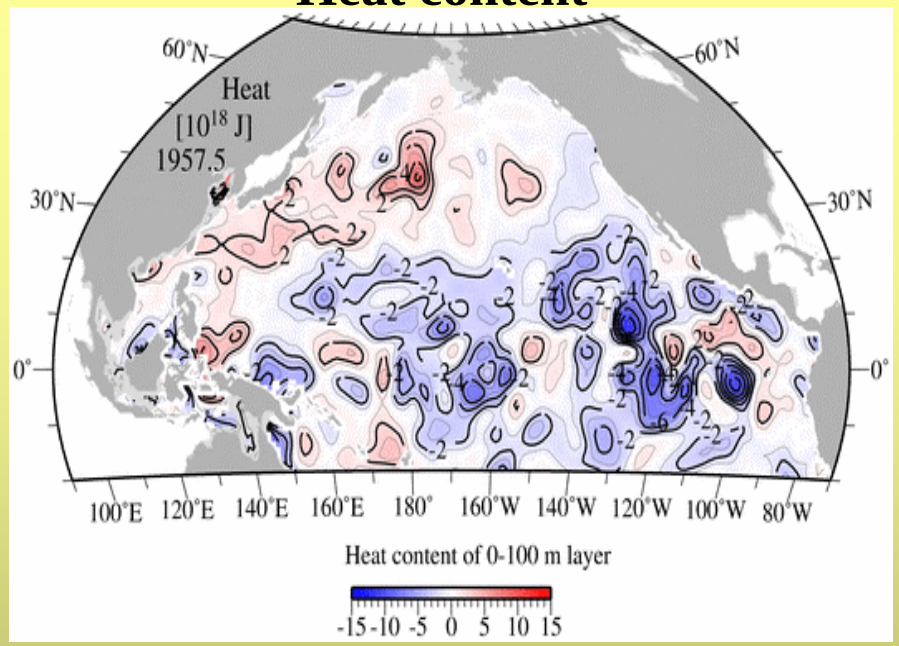
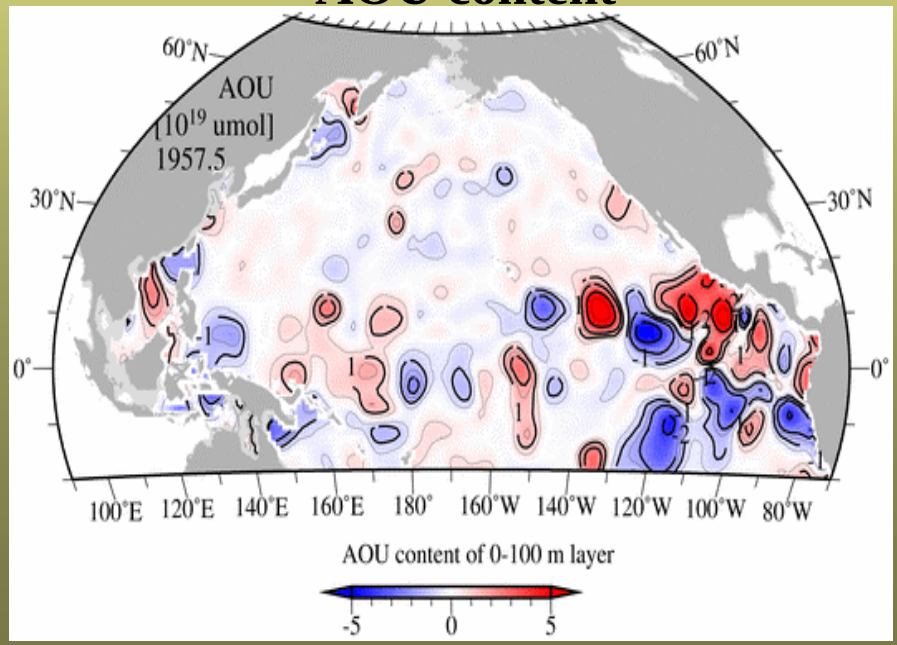
O_2 content



Heat content



AOU content



0-100 m layer

Pentads

1955/59

To

1996/1999

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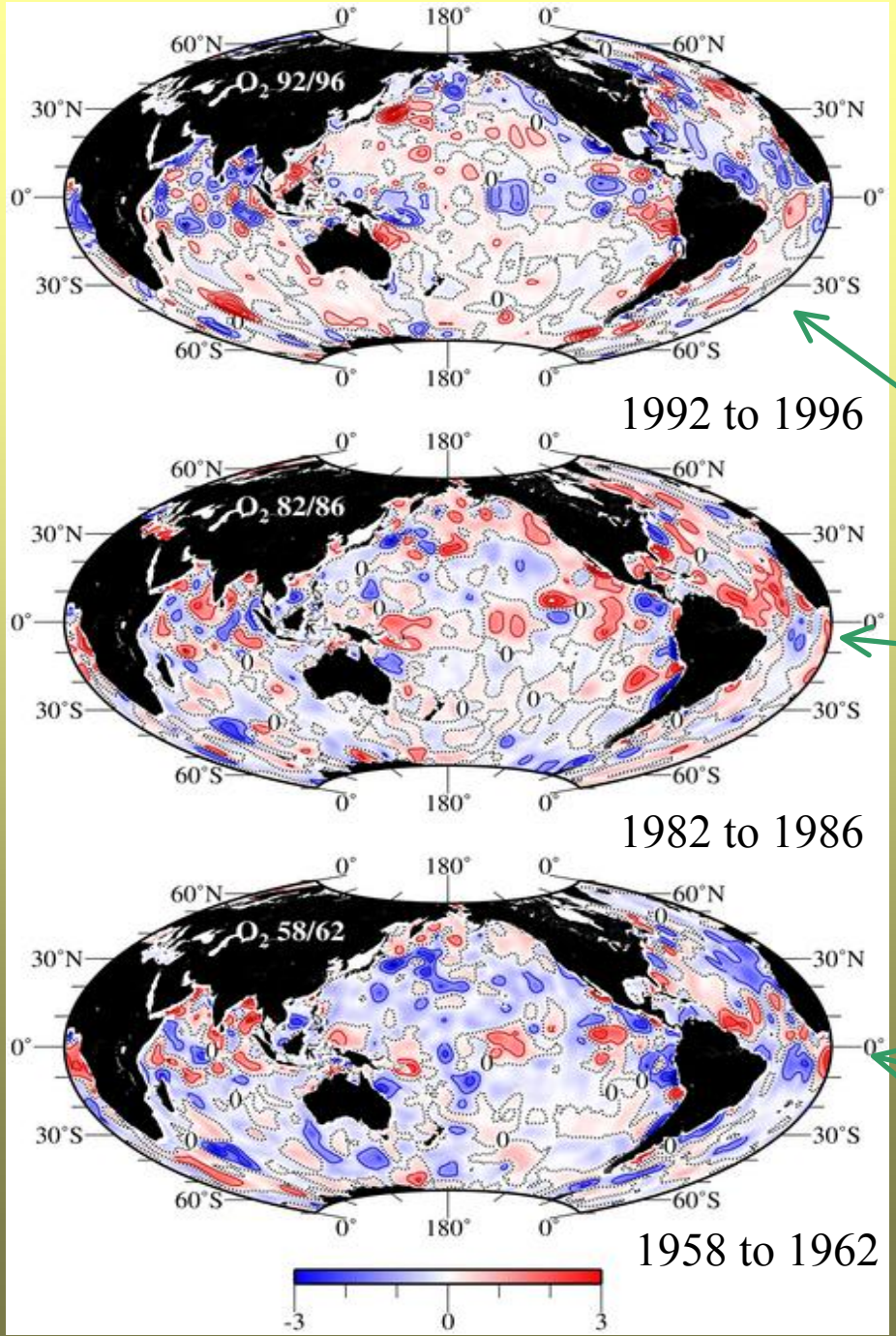
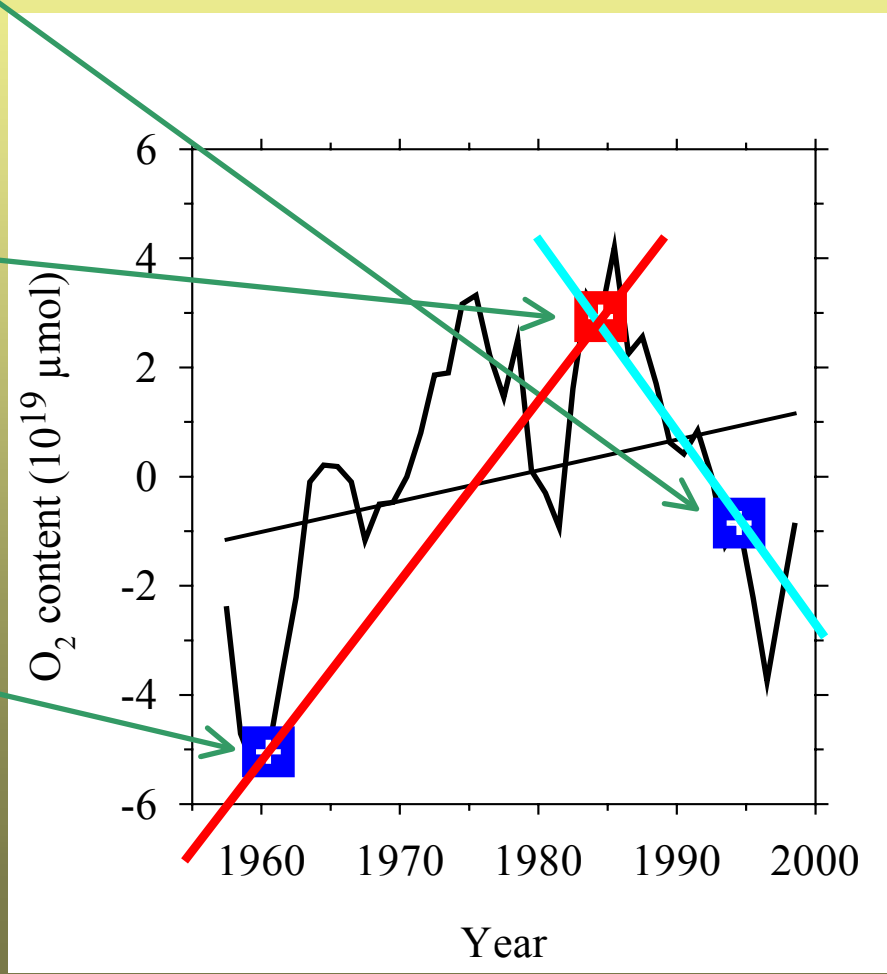
Global Ocean O_2 content anomaly

(0-100 m; 10^{19} µmol)

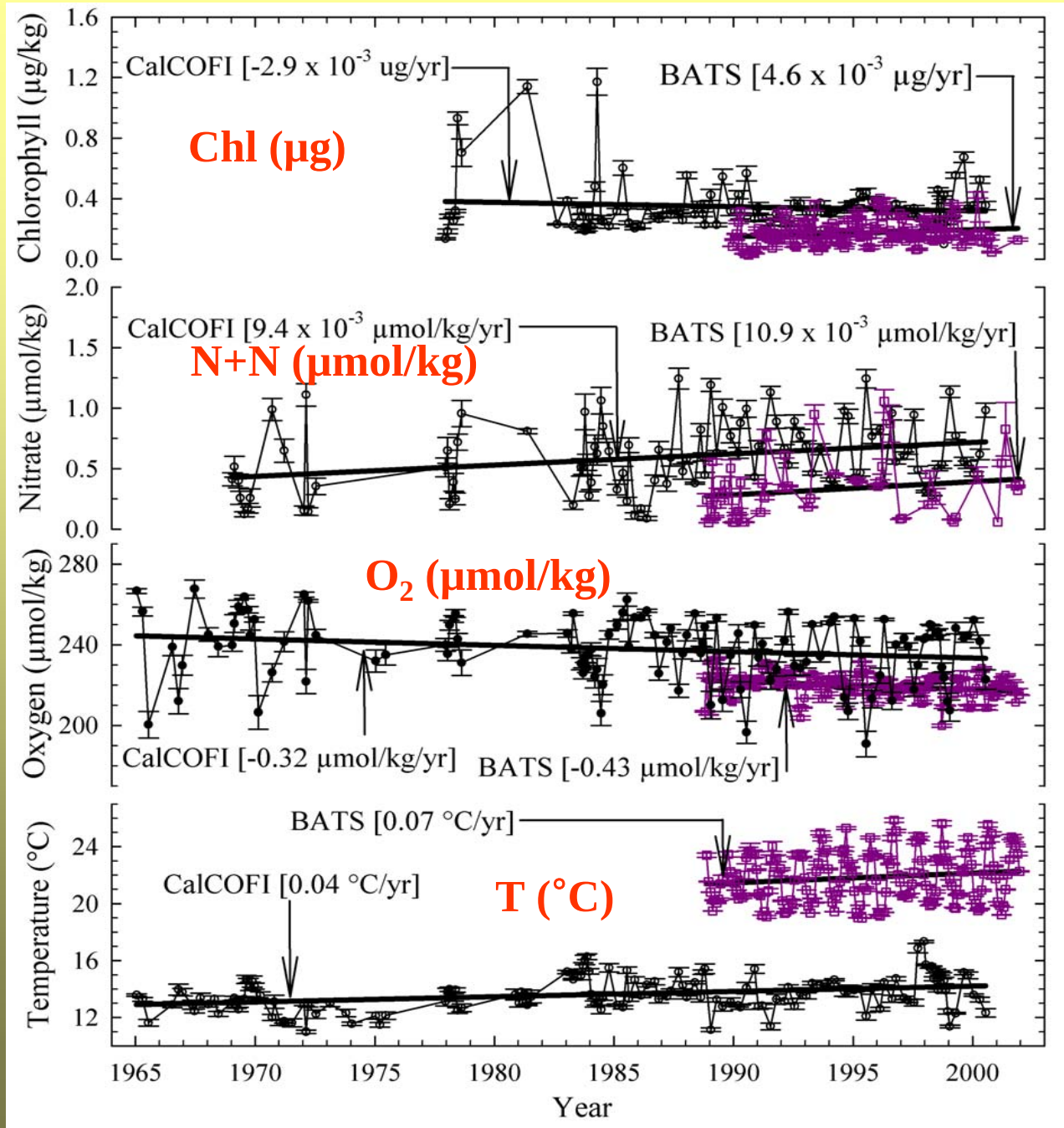




Summary

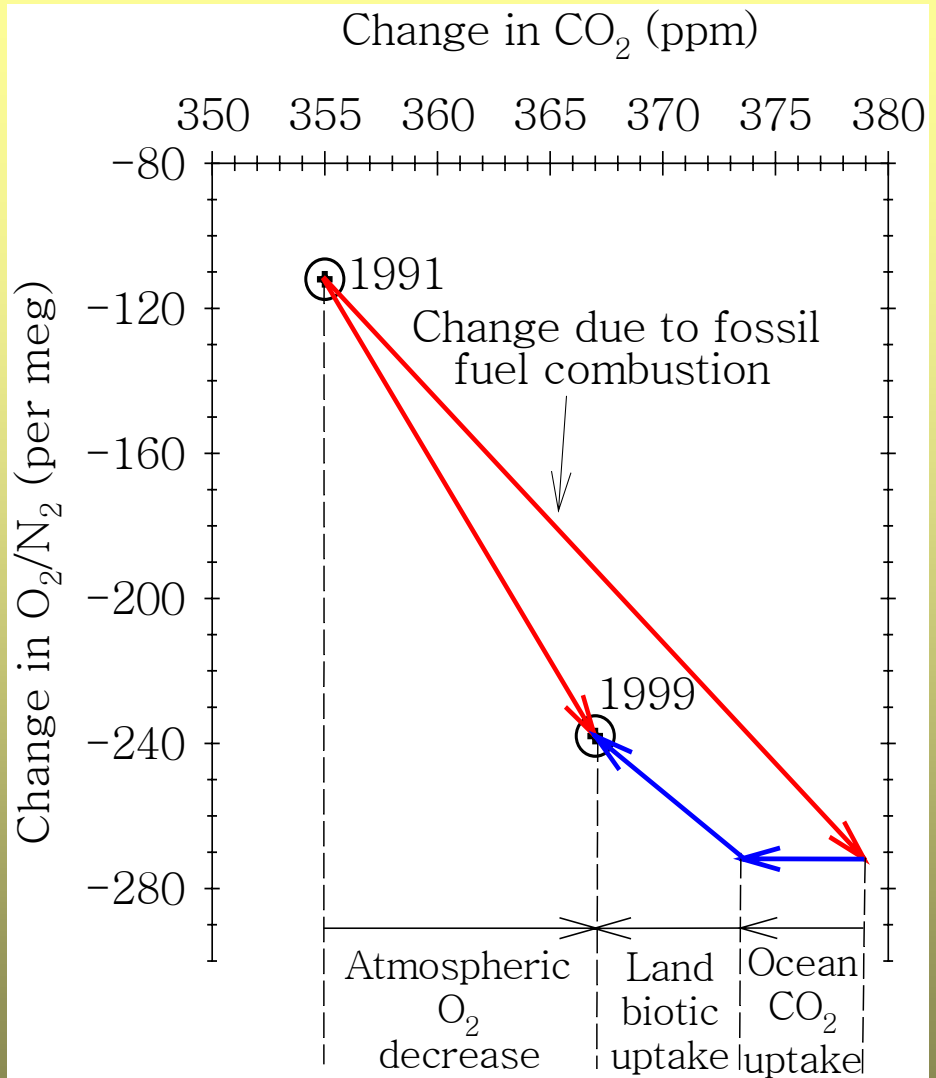
Decadal O_2 variability:

- Peak-to-peak ~1/2 of seasonal
- Measurable and spatially coherent
- Trends are dependent on time period
- Regionally complicated (e.g., tropical Pacific)
- Non-lag heat-to-O_2 trends are weak (timing?)
- Observation-validated decadal-resolving model is needed



Time series of N+N, chlorophyll, temperature and O_2 from **CalCOFI** (32°N, 120°W) and **BATS** (in purple). Data are averaged over the 10 to 80 m depth layer.

NO OCEAN O_2 SINK/SOURCE

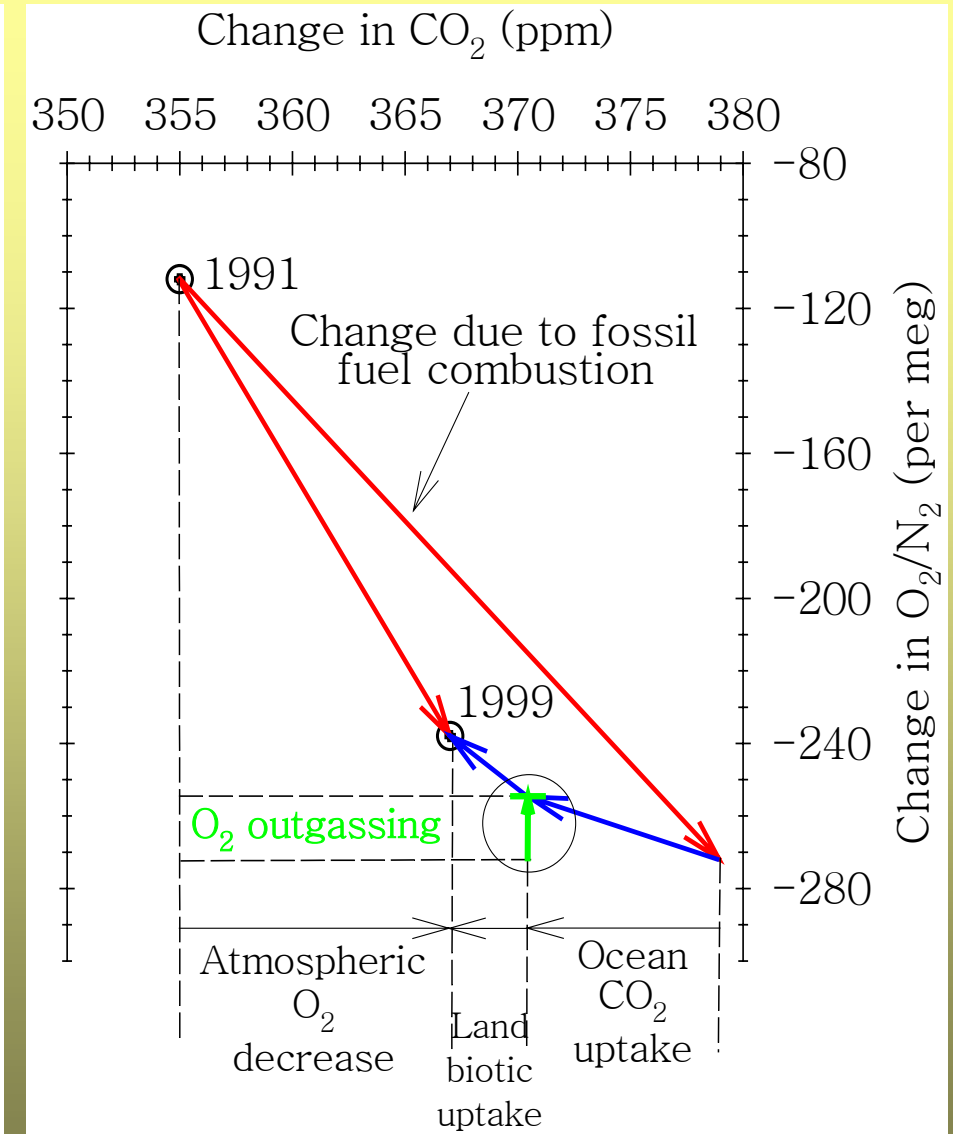


Land sink= 1.7 ± 0.6 Pg C/yr

Oceanic sink= 1.5 ± 0.4 Pg C/yr

After Keeling et al. [1996]

OCEAN O_2 SOURCE

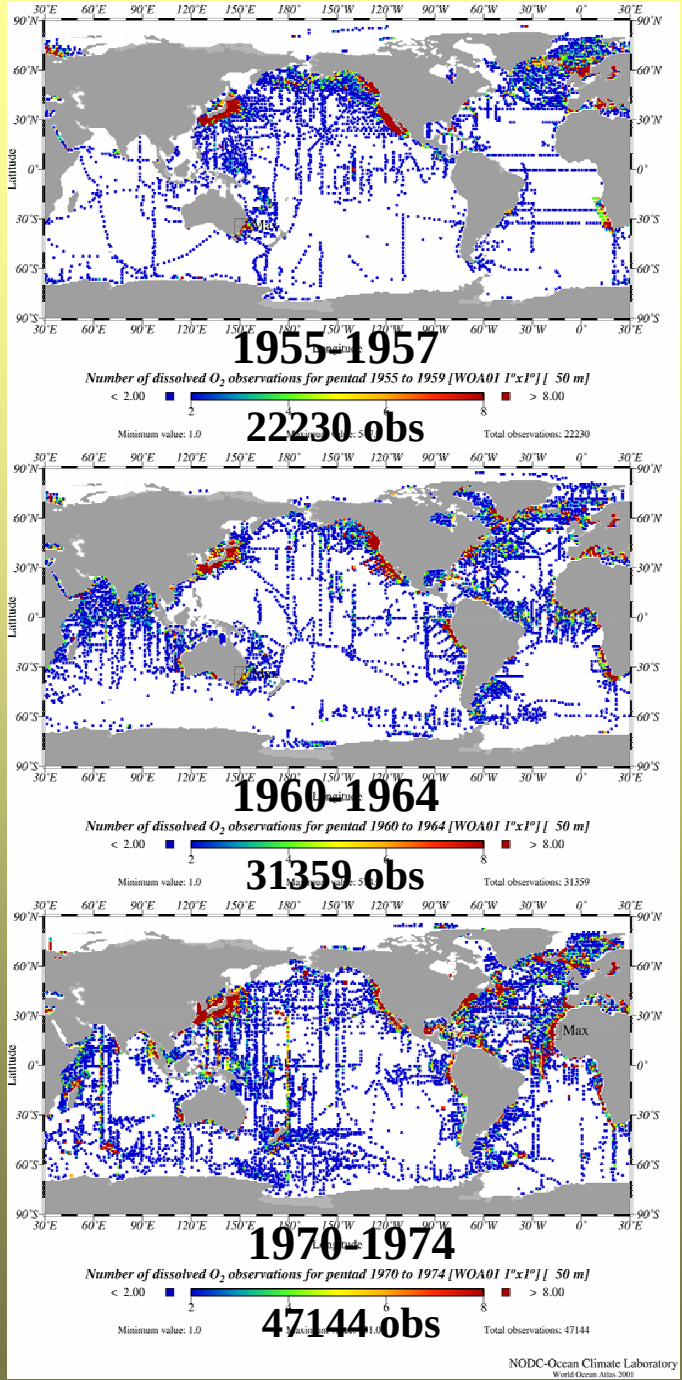


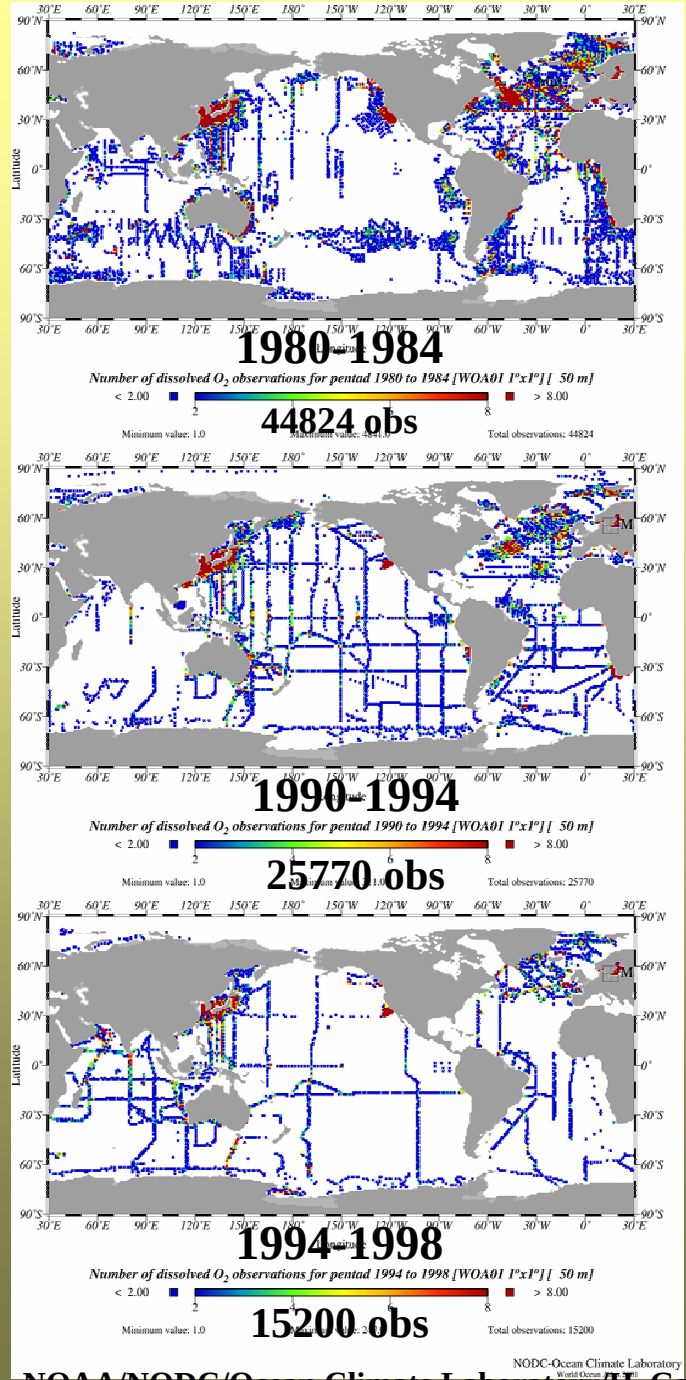
Land sink= 0.9 Pg C/yr

Oceanic sink= 2.3 Pg C/yr

After Manning [2000]

Examples of number of O_2 observations in each 1° grid square at 50 m depth [WOD01]





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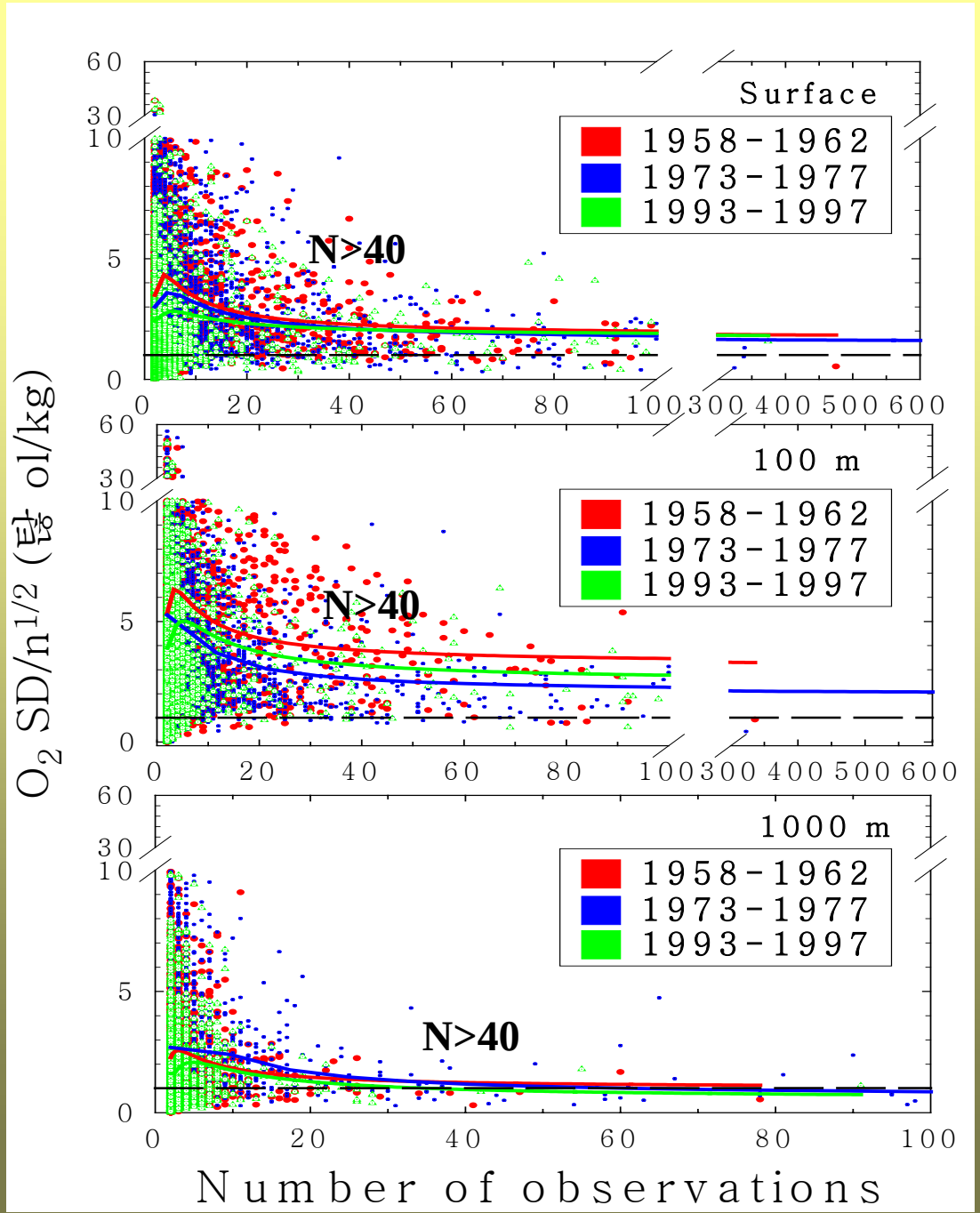

O_2 sampling errors for different pentads & depths

O_2 long-term precision (deep N. Pacific & N. Atlantic [1972-1996]):

± 1.0-2.2 µmol/kg

[e.g. Saunders, 1986; Gouretski and Jancke, 1996; WOCE, 1994; Garcia and Keeling, 2001; Garcia et al. 1998; Johnson et al 2000]

Std Error for N > 50; all basins

[1955-1962]: ± 2-4 µmol/kg

[1978-1977]: ± 1-3 µmol/kg

[1993-1997]: ± 1-2 µmol/kg

No systematic or proportional errors assumed