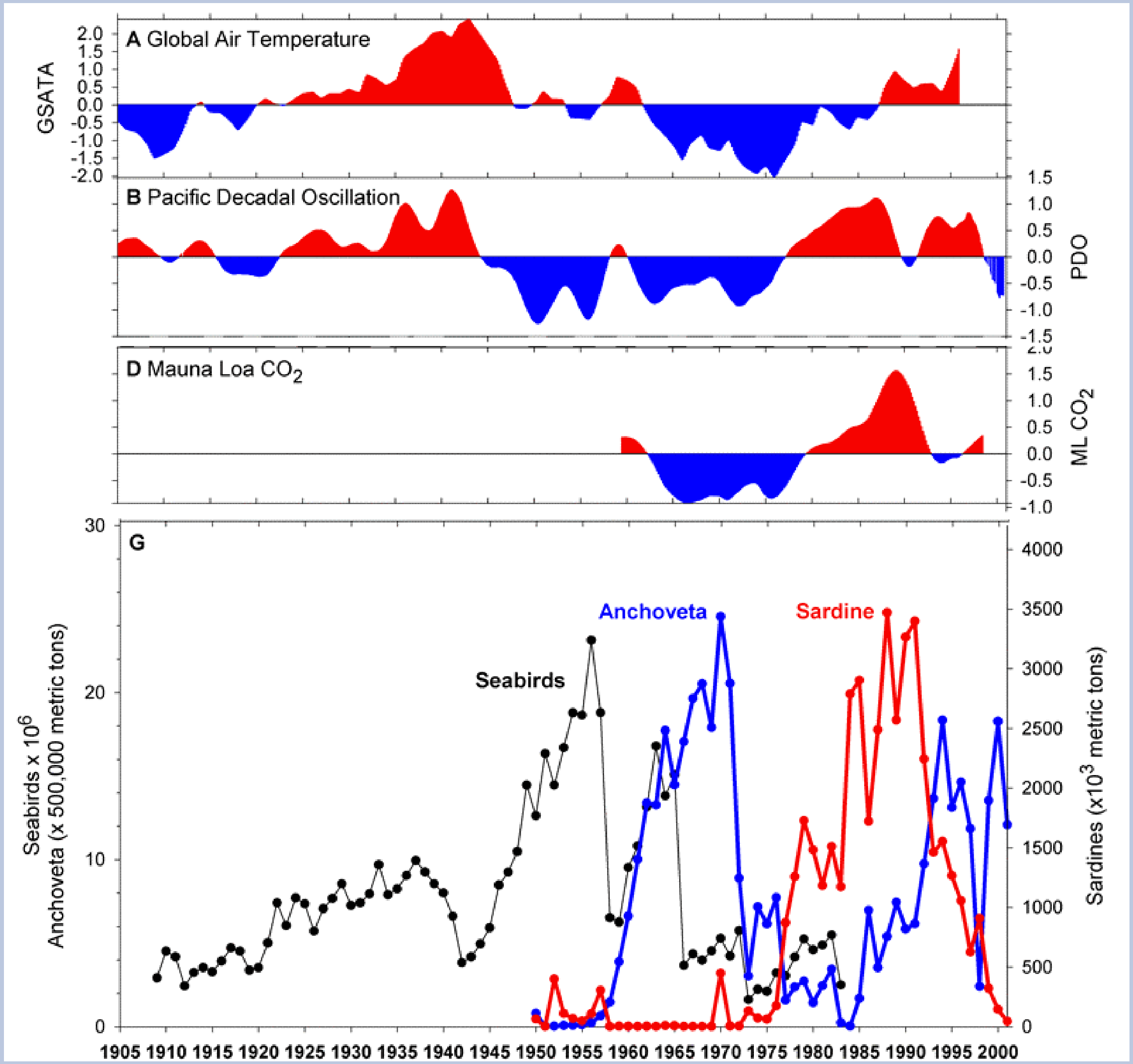
GLOBAL CLIMATE AND PACIFIC FISHERIES



Air-temperature (global)

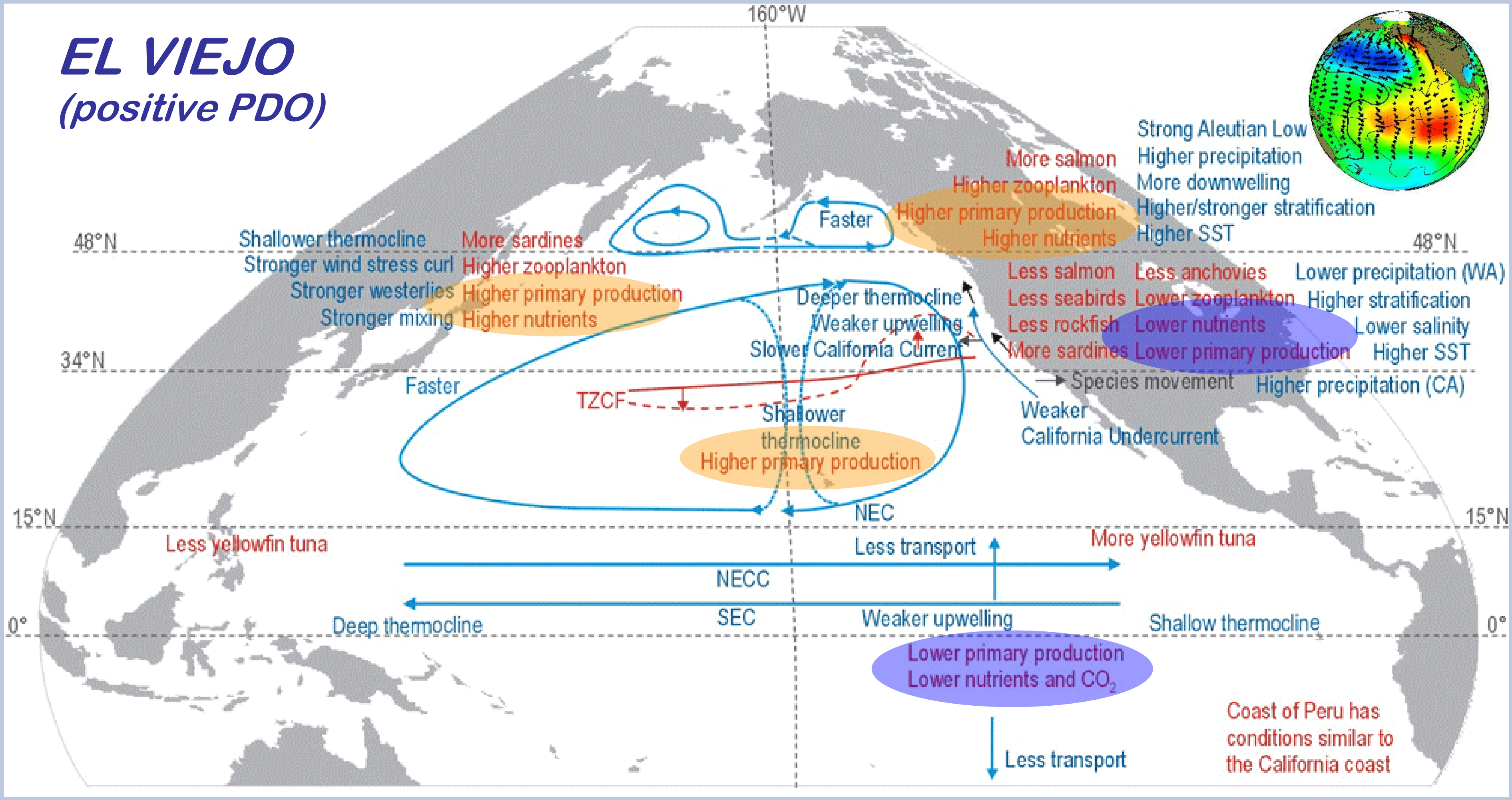
PDO

Atmospheric CO_2 anomalies

Fisheries landing in Peru

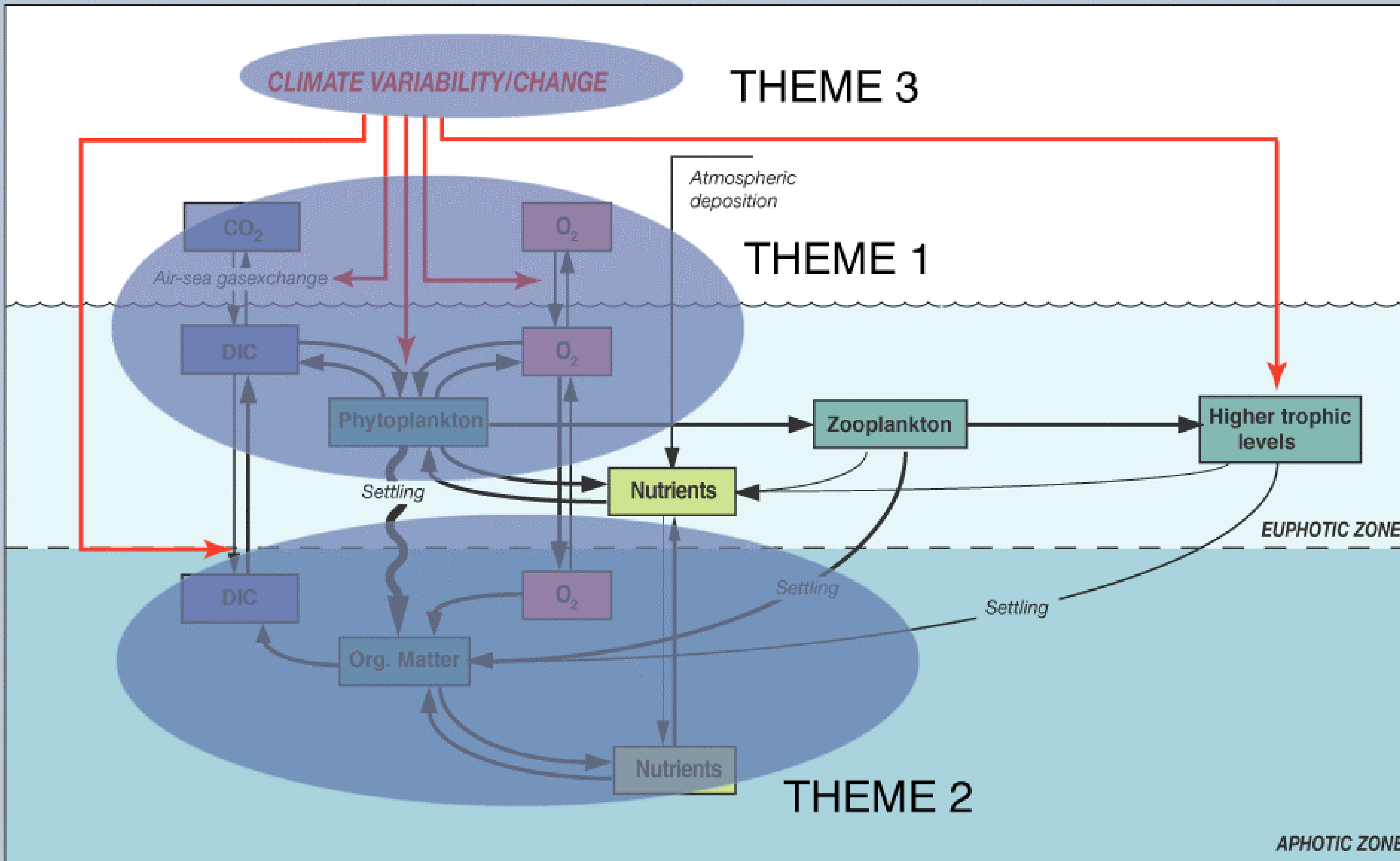
Chavez et al. (2003)

DECADAL CHANGES IN THE NORTH PACIFIC



Chavez et al. (2003)

IMPACT OF CLIMATE VARIABILITY/CHANGE ON BGC/ECOLOGY



UNDERSTANDING NORTH PACIFIC CARBON CYCLE CHANGES

Decadal variability in the carbon cycle and biogeochemistry of the North Pacific

Highlights from the NOAA/GCP/PICES synthesis and modeling workshop

Nicolas Gruber
Department of Atmospheric and Oceanic Sciences & IGPP, UCLA

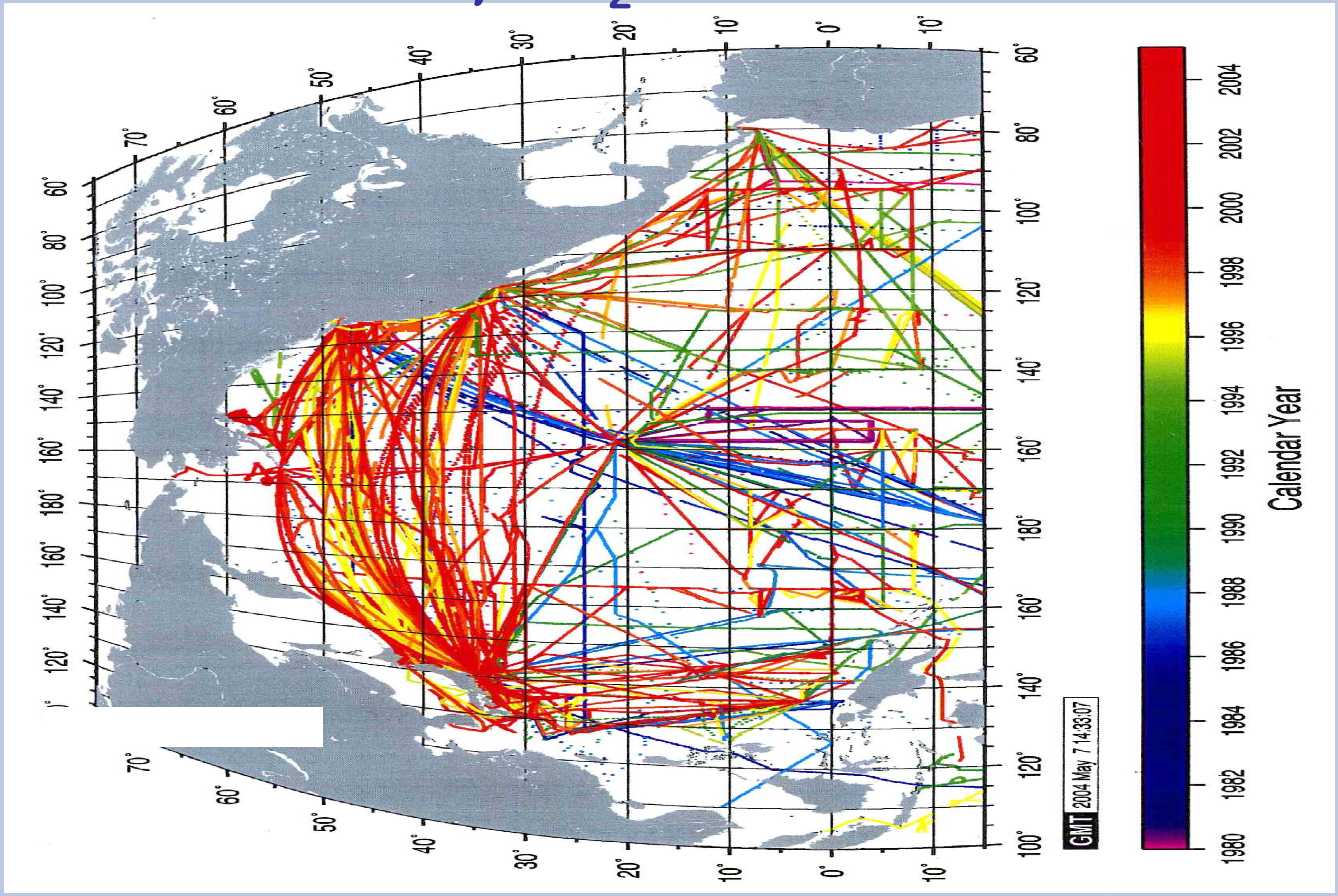
Acknowledgements:

C. L. Sabine, R. A. Feely, S. C. Doney, R. M. Key, J. L. Sarmiento, A. Kozyr and all workshop participants
NOAA, Global Carbon Project and PICES for funding

Outline

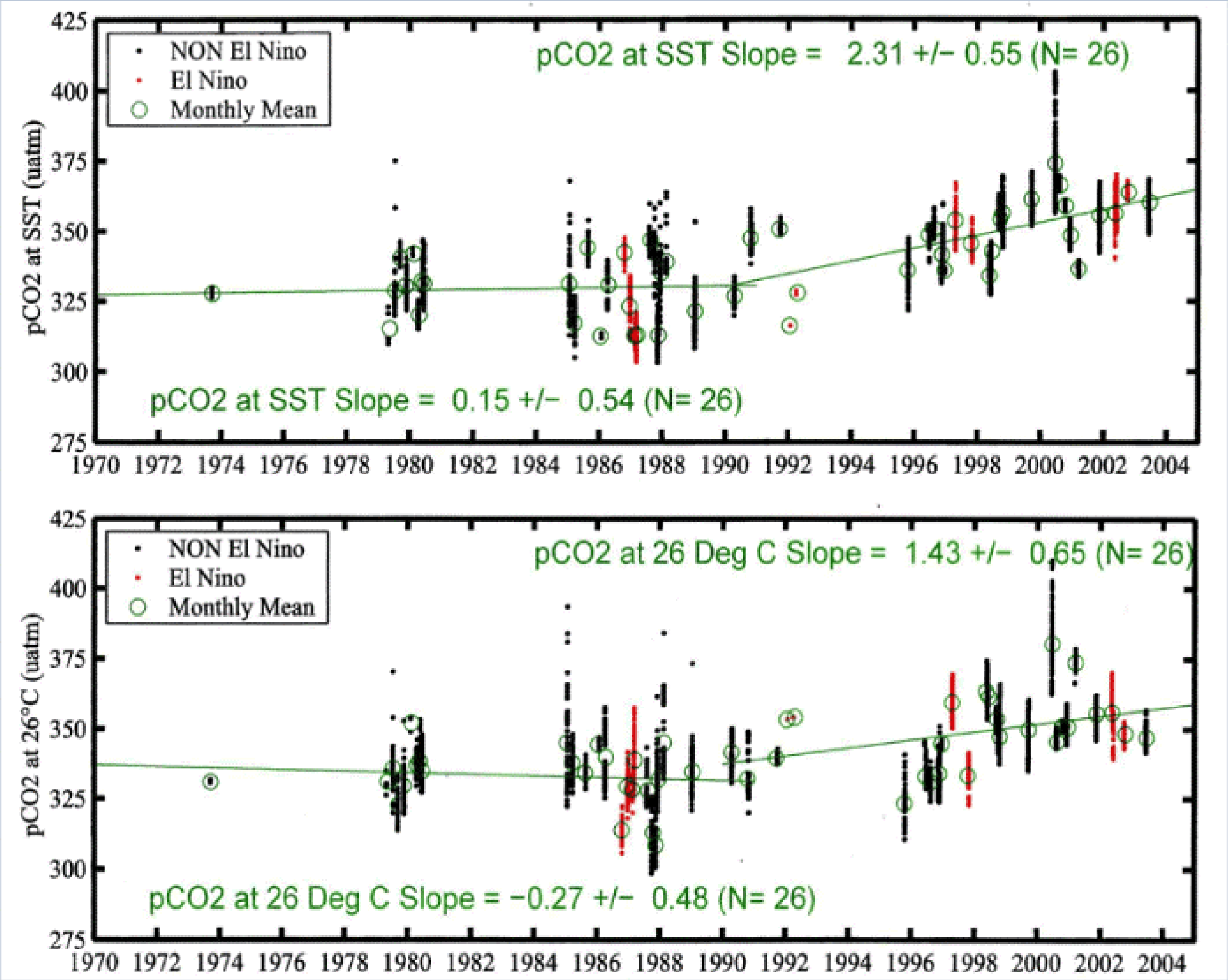
- Introduction: *Why studying North Pacific carbon cycle changes?*
- Decadal changes in surface pCO_2: *observations and mechanisms*
- Decadal changes in ocean interior properties
- Anthropogenic climate change: *Detection and Attribution*

Surface ocean pCO_2 observations



Takahashi et al.

TRENDS IN SURFACE OCEAN pCO_2 NEAR HAWAII



pCO_2 at in situ temperature

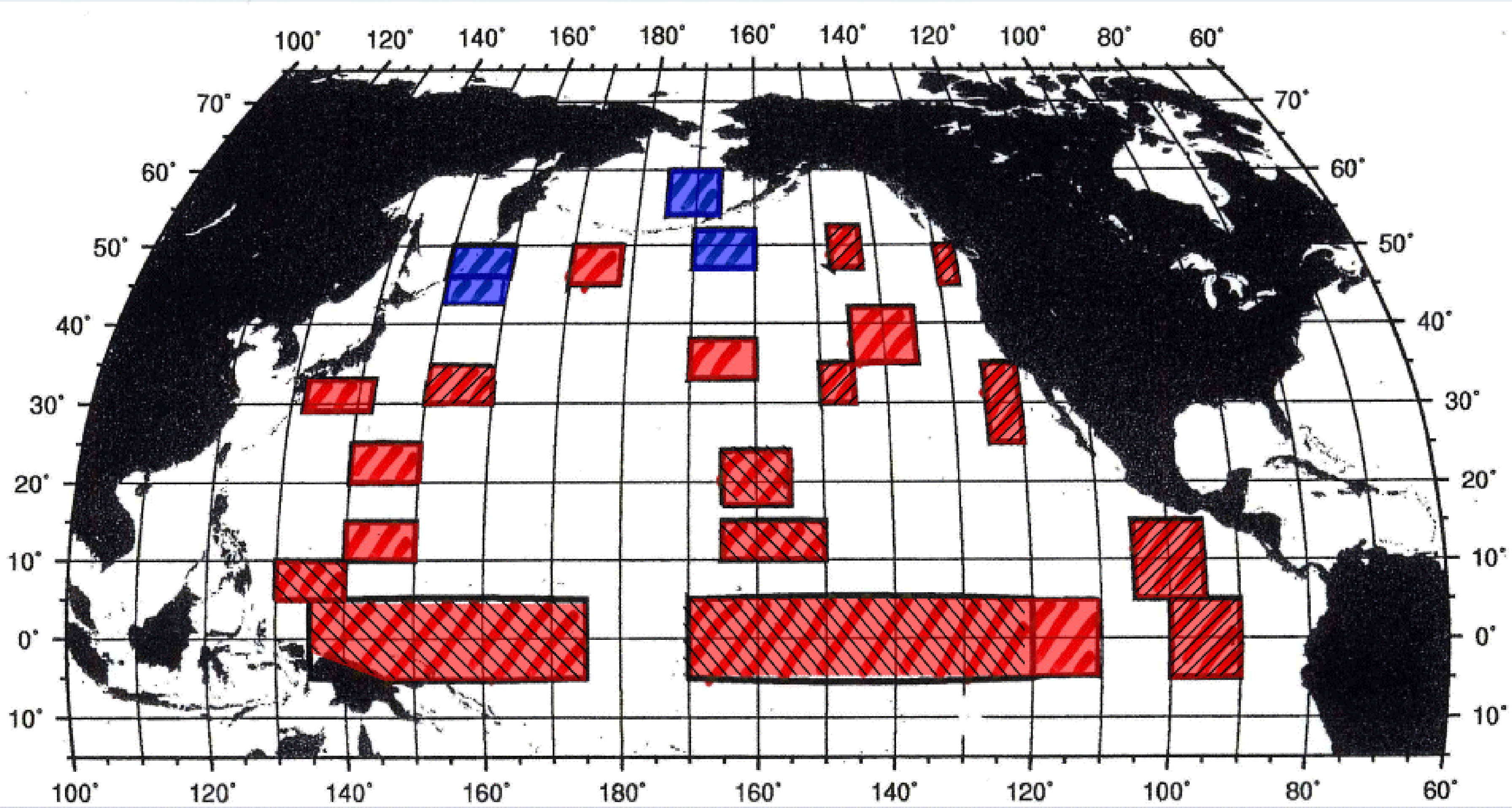
trend after 1990: 2.3±0.55 ppm/yr

pCO_2 at constant temperature (DIC and/or Alk driven)

(17°N-24°N; 155°W-165°W)

Takahashi et al.

TRENDS IN SURFACE OCEAN pCO_2



positive trend in 1990s

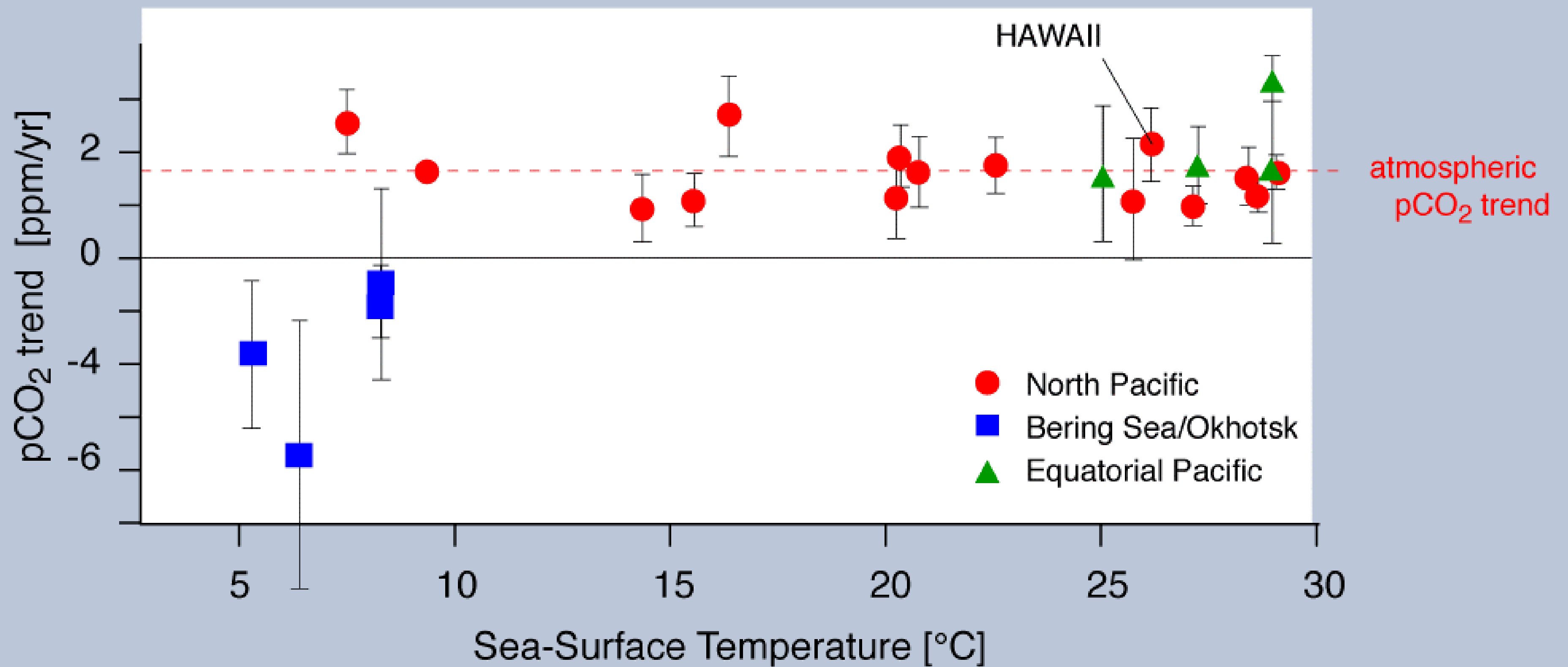
negative trend in 1990s

no trend change 1990±5

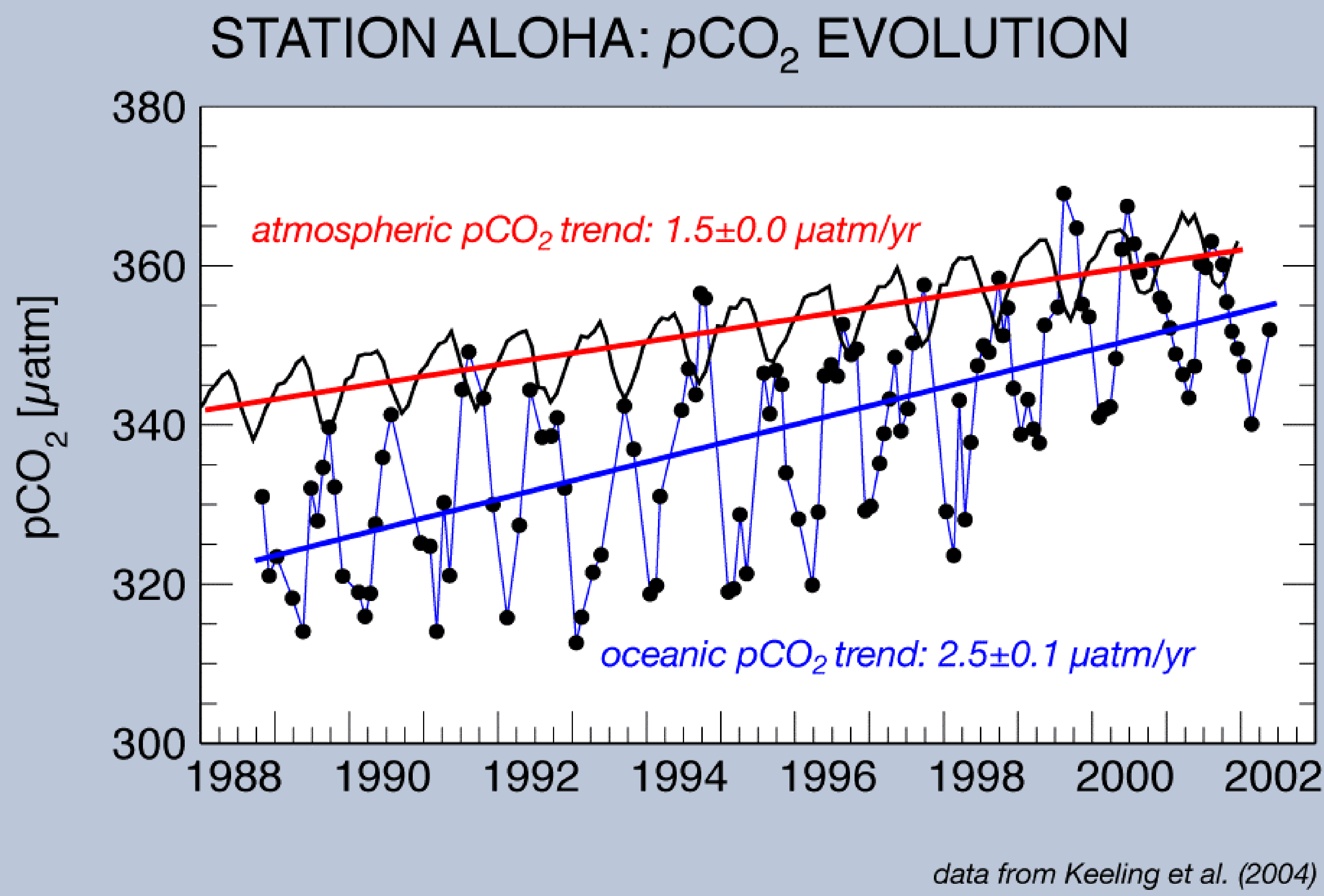
trend change 1990±5

Takahashi et al.

TRENDS IN SURFACE OCEAN pCO_2 (post 1990)



Takahashi et al.


STATION ALOHA: pCO2 EVOLUTION
atmospheric pCO2 trend: 1.5±0.0 µatm/yr
oceanic pCO2 trend: 2.5±0.1 µatm/yr
pCO2 [µatm]
380
360
340
320
300
1988
1990
1992
1994
1996
1998
2000
2002
data from Keeling et al. (2004)

Mechanisms for pCO_2 change:

$$pCO_2 = f(T, S, DIC, Alk)$$

$$\Delta pCO_2 = \underbrace{\frac{\partial pCO_2}{\partial T}\Delta T}_{\text{Temperature}} + \underbrace{\left(\frac{\partial pCO_2}{\partial S} + \frac{\partial pCO_2}{\partial DIC}\frac{\partial DIC}{\partial S} + \frac{\partial pCO_2}{\partial Alk}\frac{\partial Alk}{\partial S}\right)\Delta S}_{\text{Salinity}} + \underbrace{\frac{\partial pCO_2}{\partial DIC}\Delta sDIC}_{\text{DIC}} + \underbrace{\frac{\partial pCO_2}{\partial Alk}\Delta sAlk}_{\text{Alk}}$$

At Station ALOHA (Hawaii)

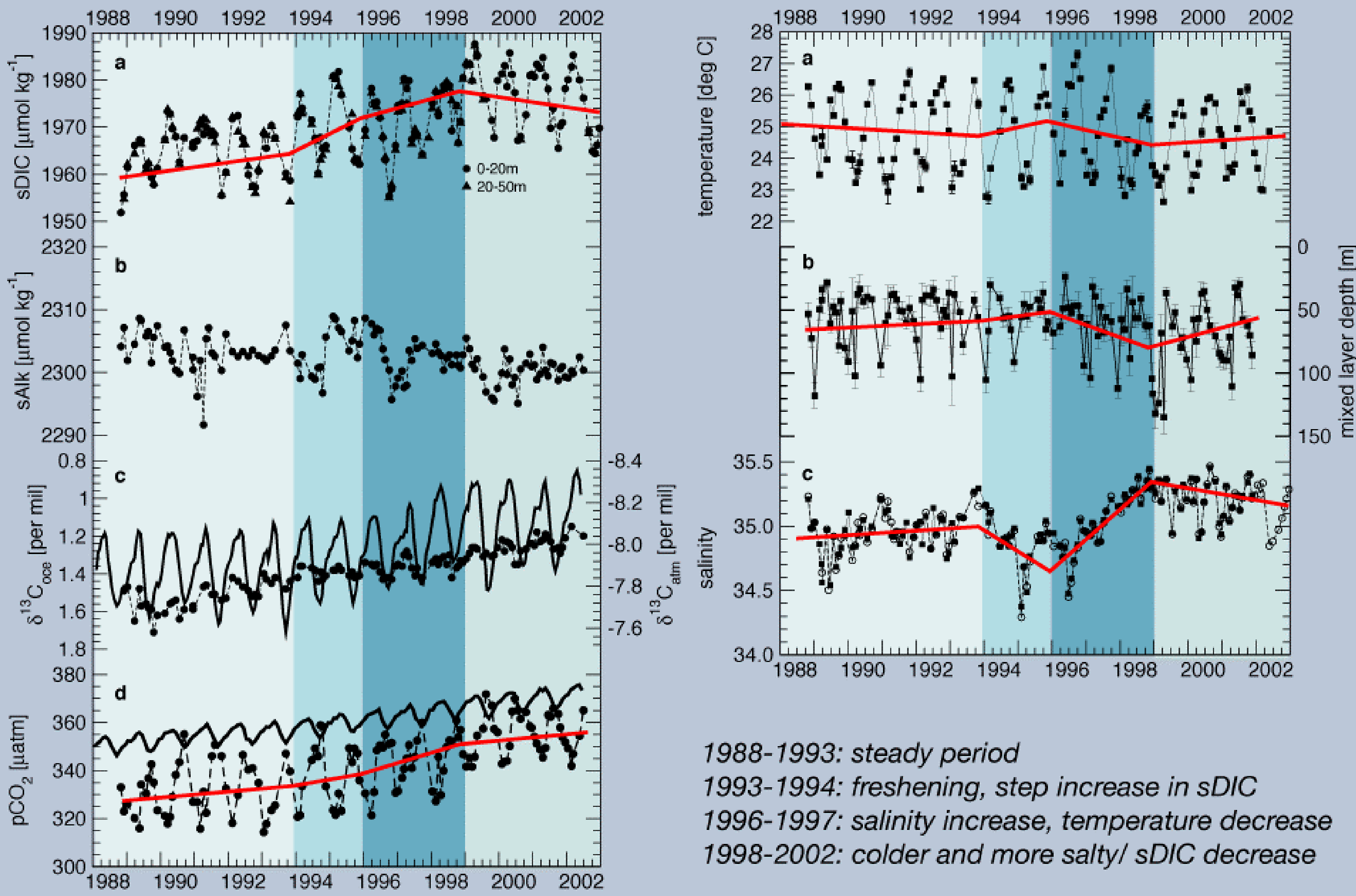
Process:	pCO_2 Trend (1988-2002) [ppm/yr]
콰 emperature	-0.3
² Salinity	0.4
콼DIC	2.1
콼Alk	0.4
Observed trend	2.5? .1

mostly driven by C_{ant}

also by ΔSalinity

Data from Keeling et al. (2004)

HAWAII OCEAN TIME-SERIES



1988-1993: steady period

1993-1994: freshening, step increase in sDIC

1996-1997: salinity increase, temperature decrease

1998-2002: colder and more salty/ sDIC decrease

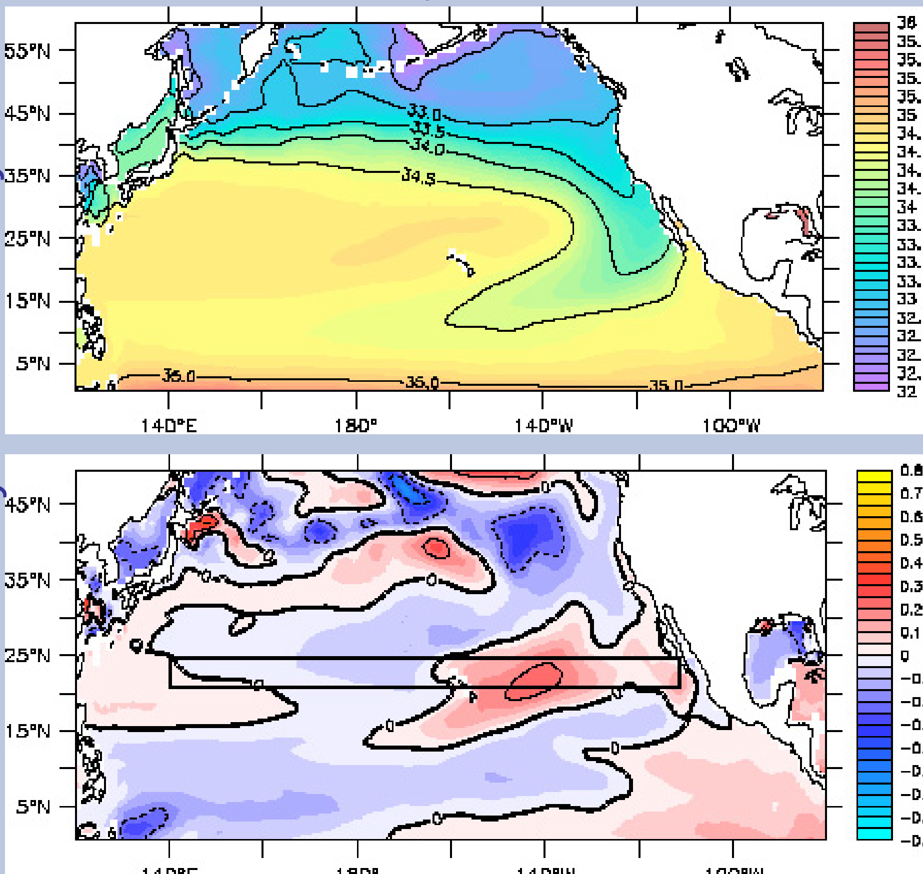
Keeling et al. (2004)

Mechanisms for salinity changes:

LARGE-SCALE (σ_θ=25.5 from ECCO)

Mean salinity

Pentadal anomaly



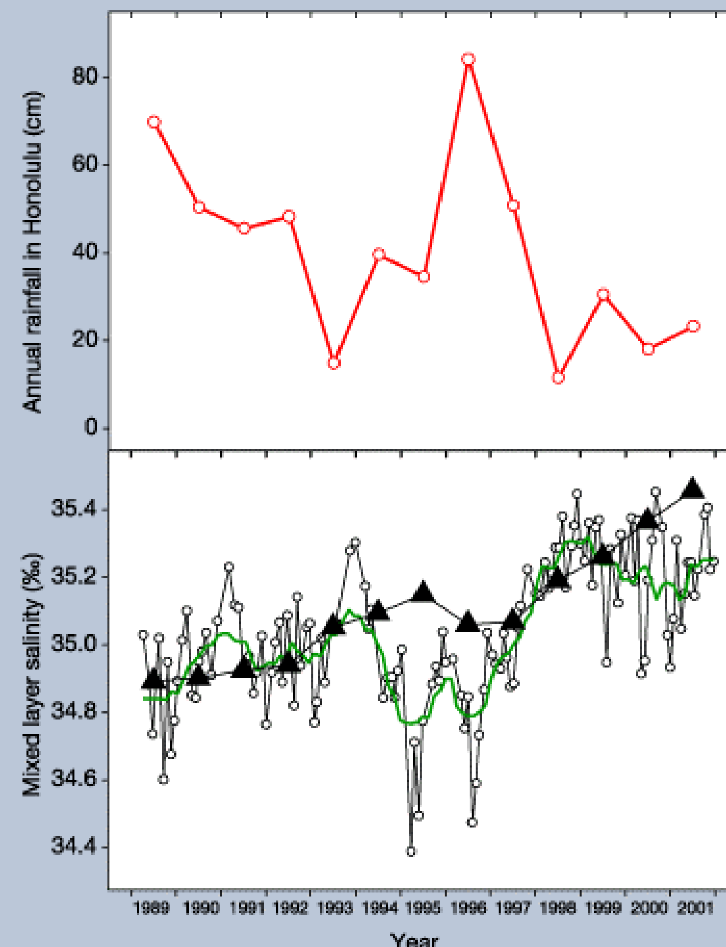
(1997-2001) minus (1992-1996)

Brix (unpublsihed)

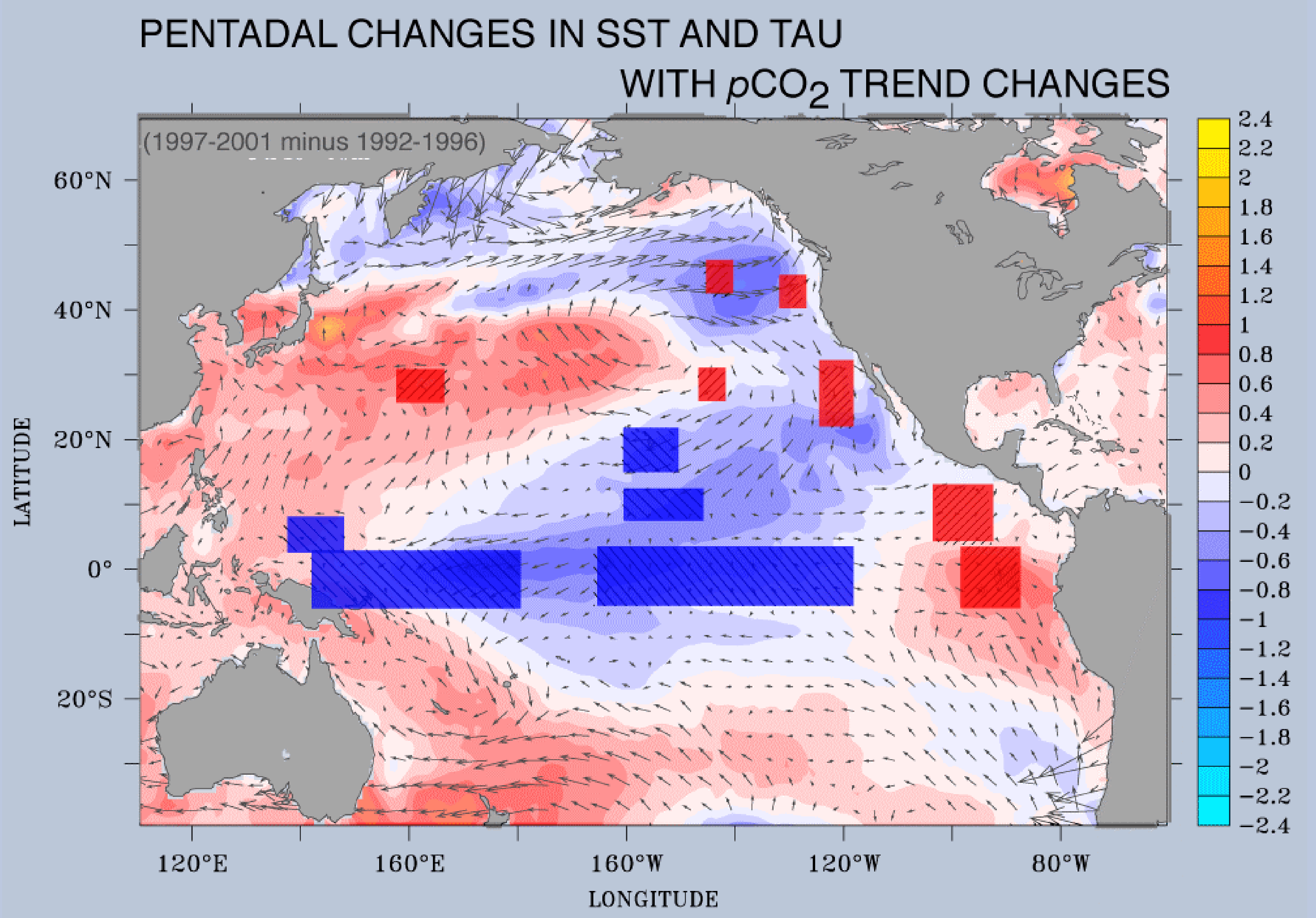
LOCAL-SCALE

Rainfall

Surface salinity



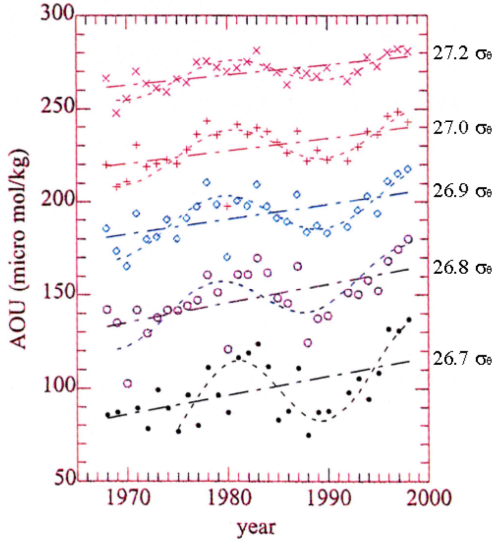
Dore et al. (2003)

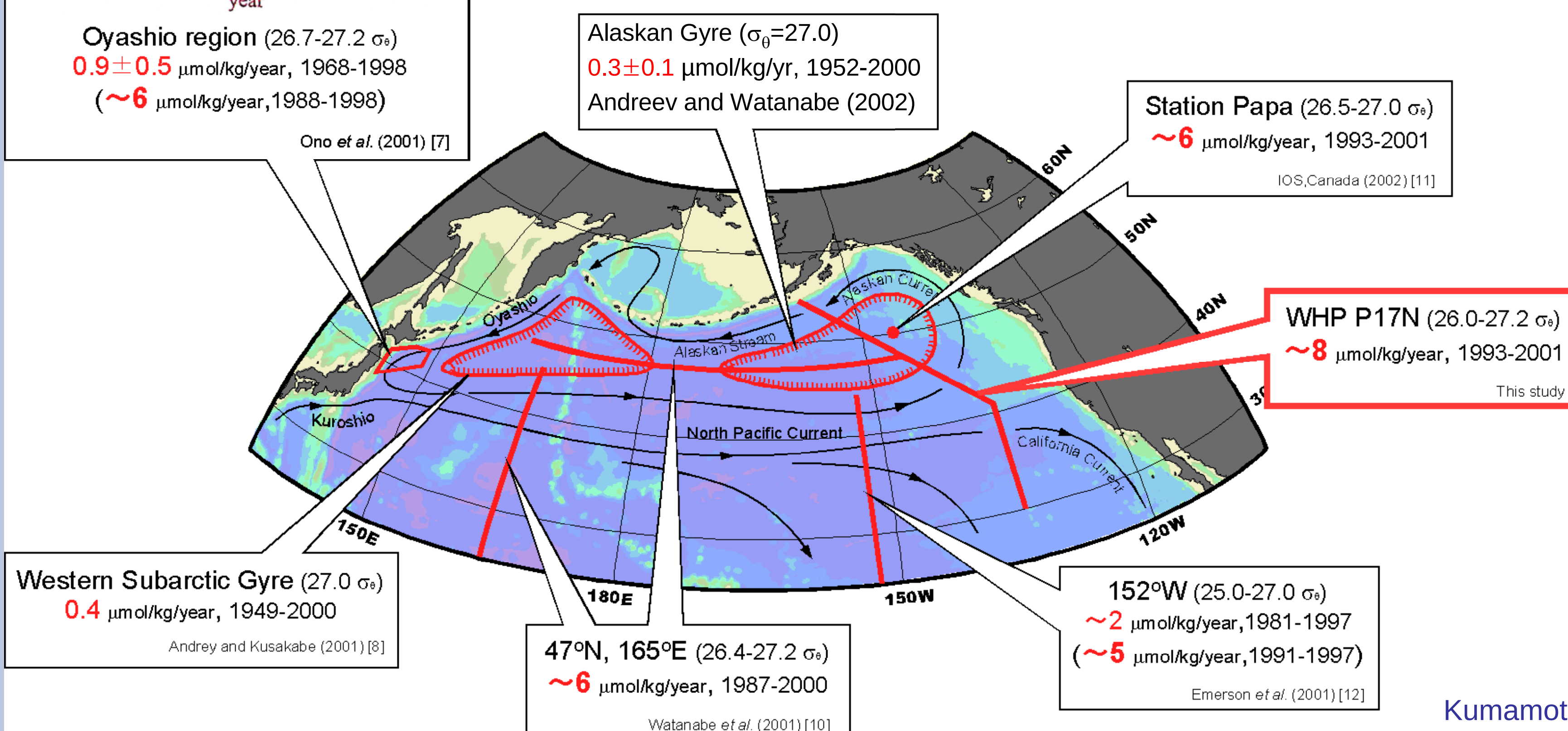

PENTADAL CHANGES IN SST AND TAU
WITH pCO_2 TREND CHANGES
(1997-2001 minus 1992-1996)
60°N
40°N
20°N
0°
20°S
LATITUDE
120°E
160°E
160°W
120°W
80°W
LONGITUDE
2.4
2.2
2
1.8
1.6
1.4
1.2
1
0.8
0.6
0.4
0.2
0
−0.2
−0.4
−0.6
−0.8
−1
−1.2
−1.4
−1.6
−1.8
−2
−2.2
−2.4

Outline

- Introduction: *Why studying North Pacific carbon cycle changes?*
- Decadal changes in surface pCO_2: *observations and mechanisms*
- Decadal changes in ocean interior properties
- Anthropogenic climate change: *Detection and Attribution*

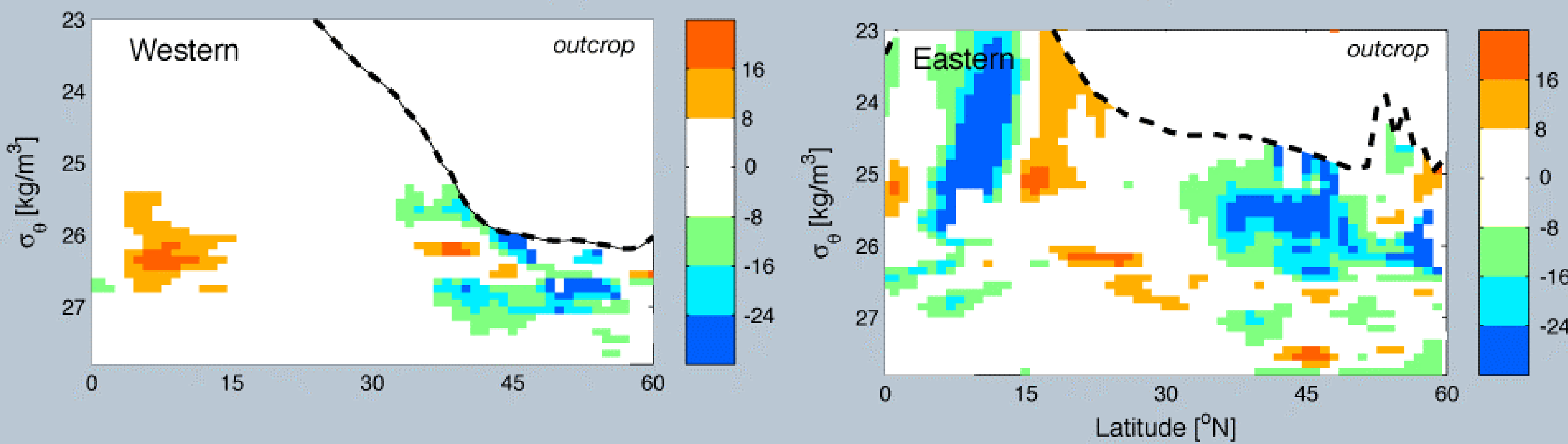
SUMMARY OF NORTH PACIFIC AOU CHANGES

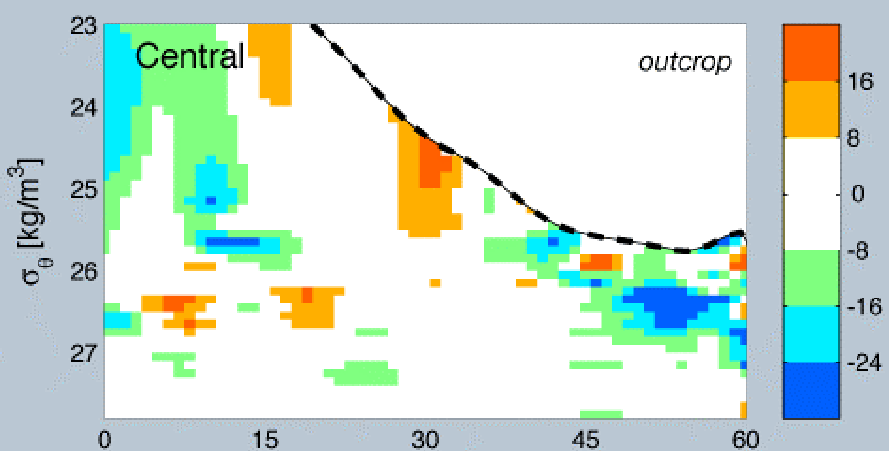




Kumamoto

DECADAL OXYGEN CHANGES IN THE NORTH PACIFIC (1990s-1970s)





from trends to variability spectrum

- distinct spatial heterogeneity
- variations occur on all time-scales
- linear trend models inadequate!

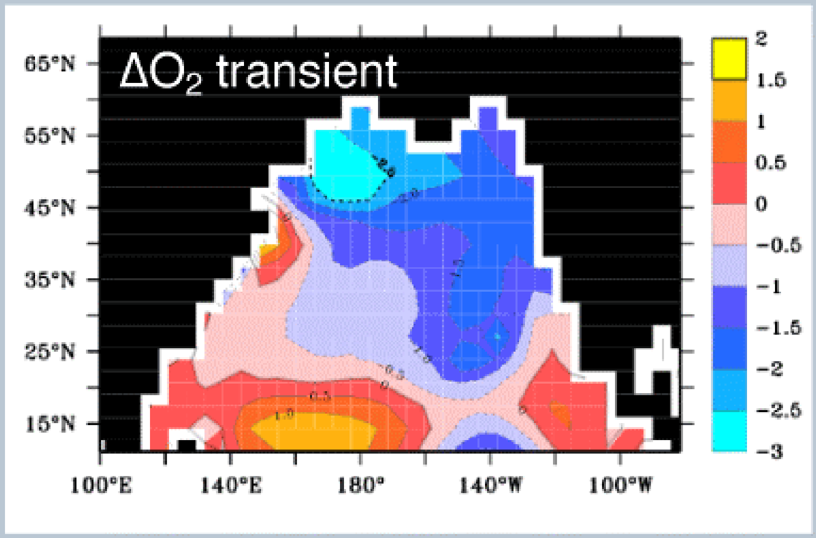
Min and Keller (pers. comm)

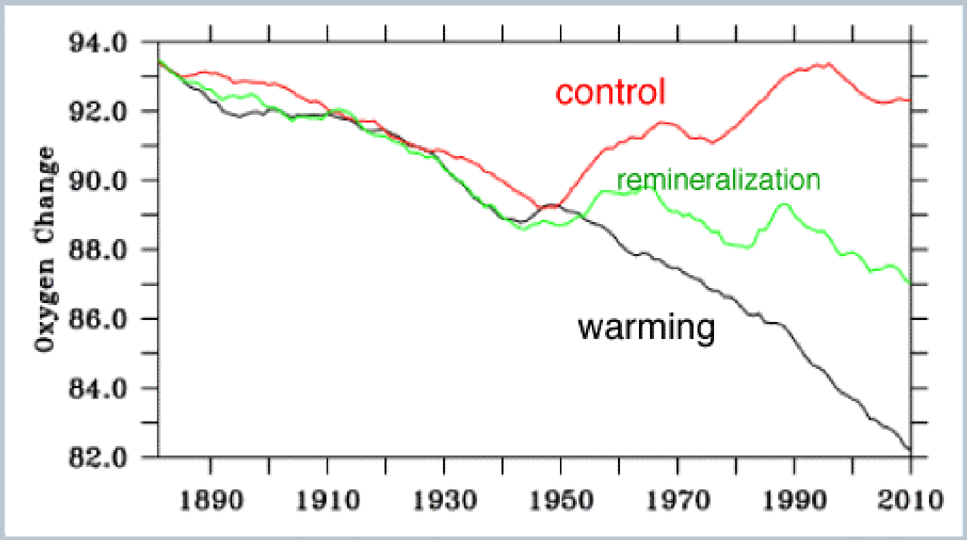
Outline

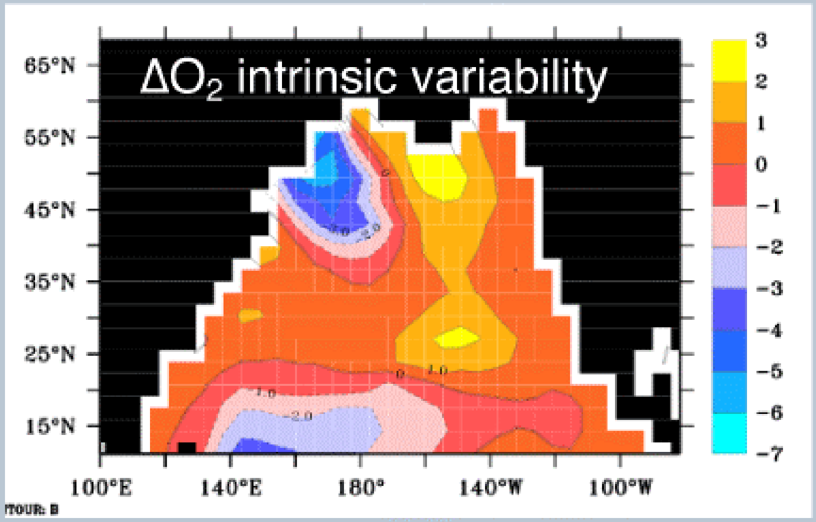
- Introduction: *Why studying North Pacific carbon cycle changes?*
- Decadal changes in surface pCO_2: *observations and mechanisms*
- Decadal changes in ocean interior properties
- Anthropogenic climate change: *Detection and Attribution*

THE CLIMATE CHANGE DETECTION CHALLENGE

sigma-theta 27.00







Part of the oxygen changes are likely due to global warming

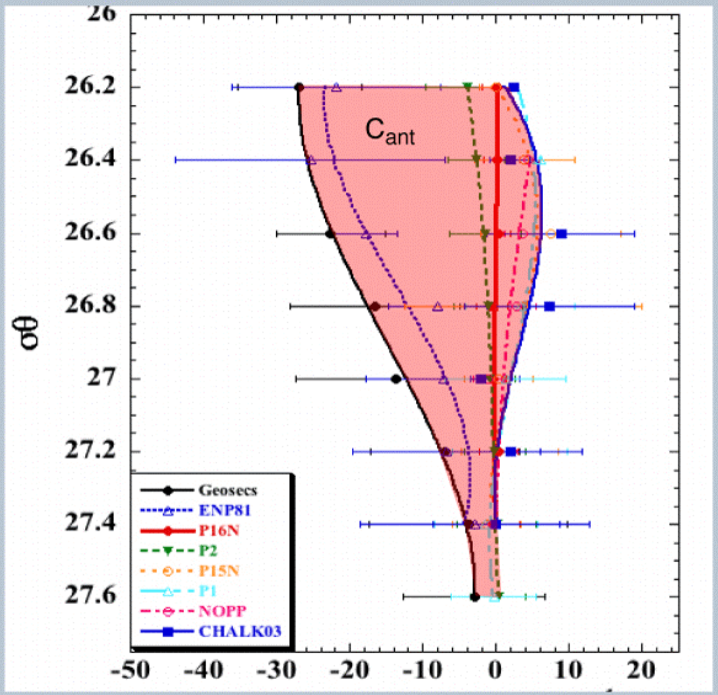
BUT

Magnitude not yet large enough relative to natural variability to detect signal

results from Matear (pers. comm)

Implications for anthropogenic DIC

$$\Delta DIC = \Delta DIC_{ant} + \Delta DIC_{nat}^{\text{climate change}} + \Delta DIC_{nat}^{\text{intrinsic}}$$
$$\Delta O_2 = + \Delta O_{2nat}^{\text{climate change}} + \Delta O_{2nat}^{\text{intrinsic}}$$



RESIDUALS OF MLR FIT = "C_{ant}"

Feely et al. (pers. comm.)

We need to separate the DIC changes in the natural carbon pool into into an intrinsic component, $\Delta DIC^{intrinsic}$, and a climate change component, $\Delta DIC^{climate\ change}$, in order to determine the anthropogenic CO_2 balance of the ocean!

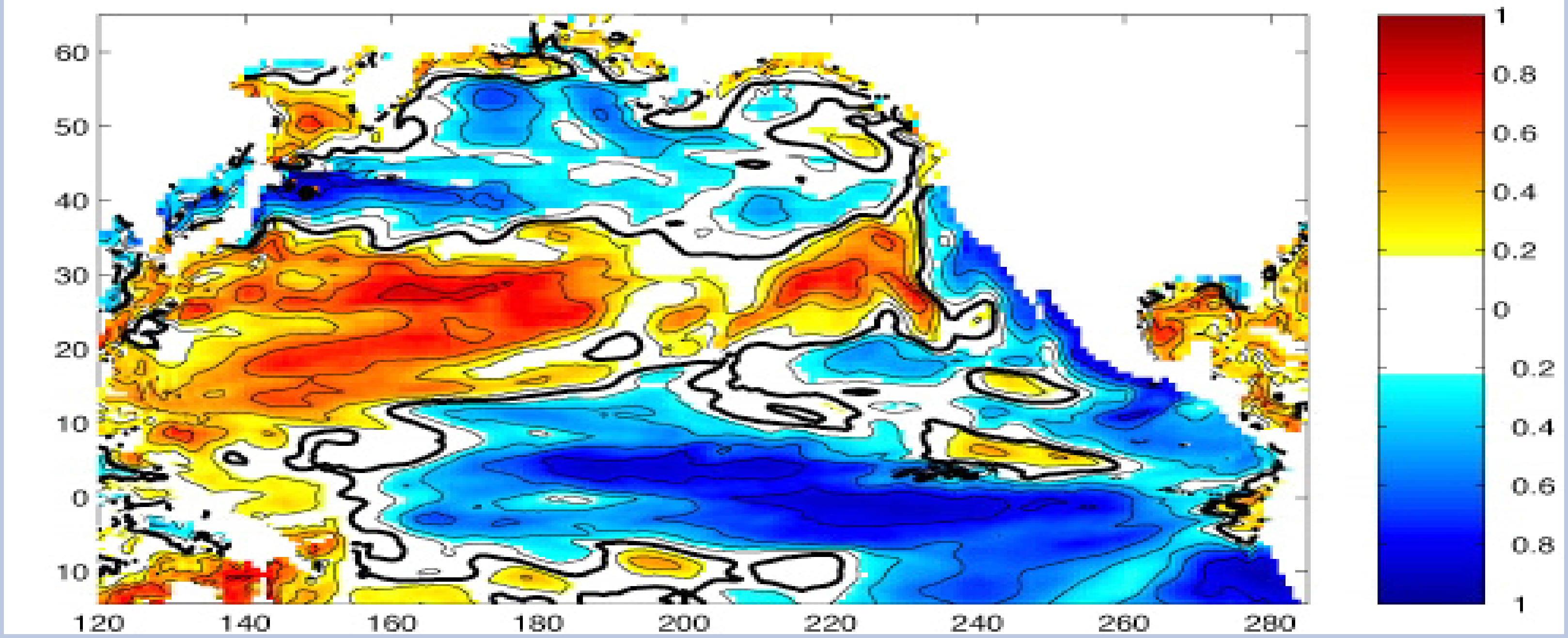
Oxygen can be of very helpful for this!

Conclusions

- First initial steps: Many challenges, few answers yet (*much more to come, >15 publications planned*)
- Good progress toward the integration of observations and models.
- Data synthesis and modeling activities need to be continued… (annual workshops, etc)

The End.

Role of SST variations on $p CO_2$ variability

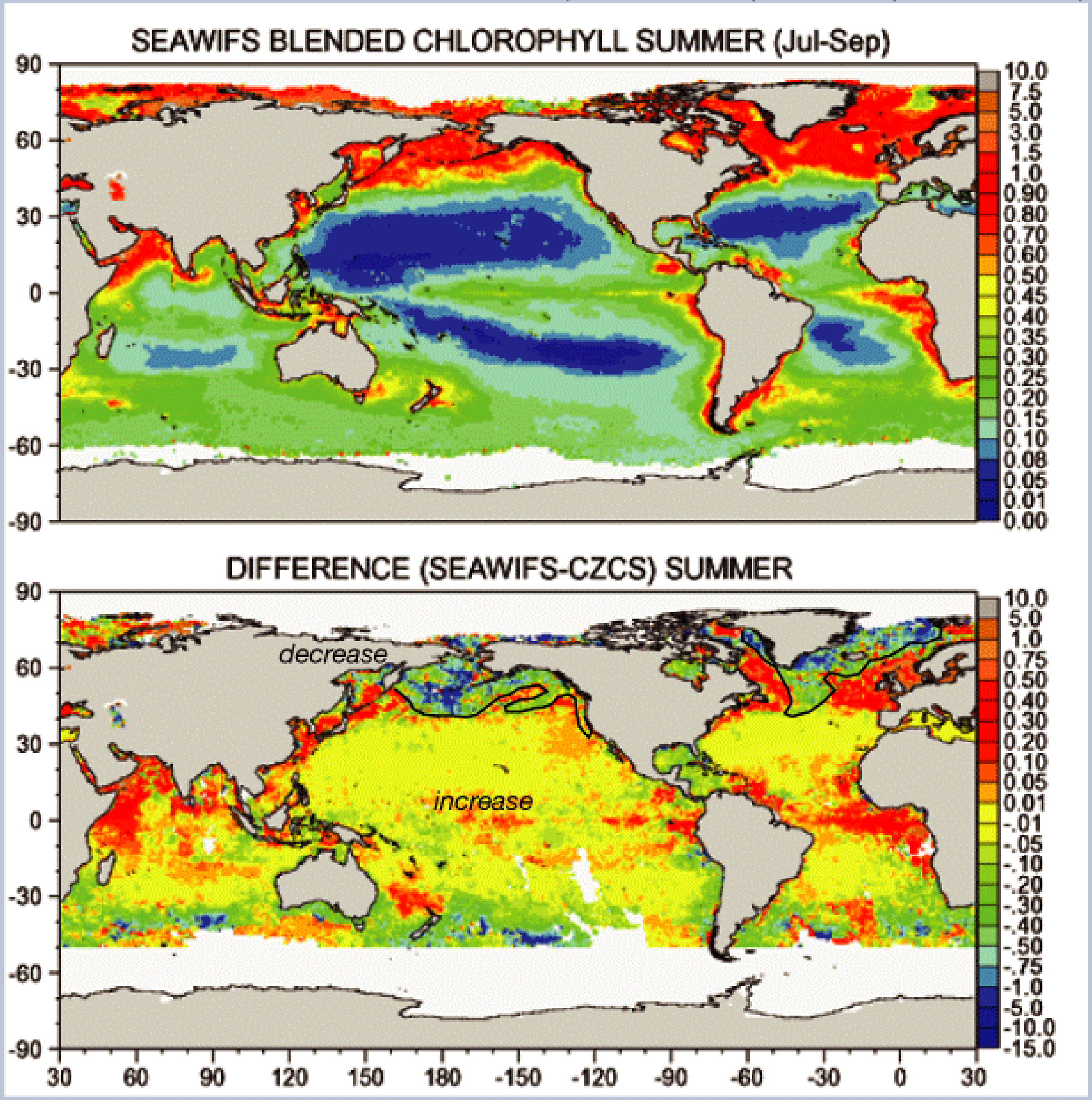


McKinley (pers. comm.)

Tropics: $p CO_2$ anomalies are DIC controlled
Sub-tropics: $p CO_2$ anomalies are SST controlled
Sub-polar gyres: $p CO_2$ anomalies are DIC controlled

DECADAL CHLOROPHYLL CHANGES

(1997-2002) minus (1979-1986)



Gregg and Conkright (2002)

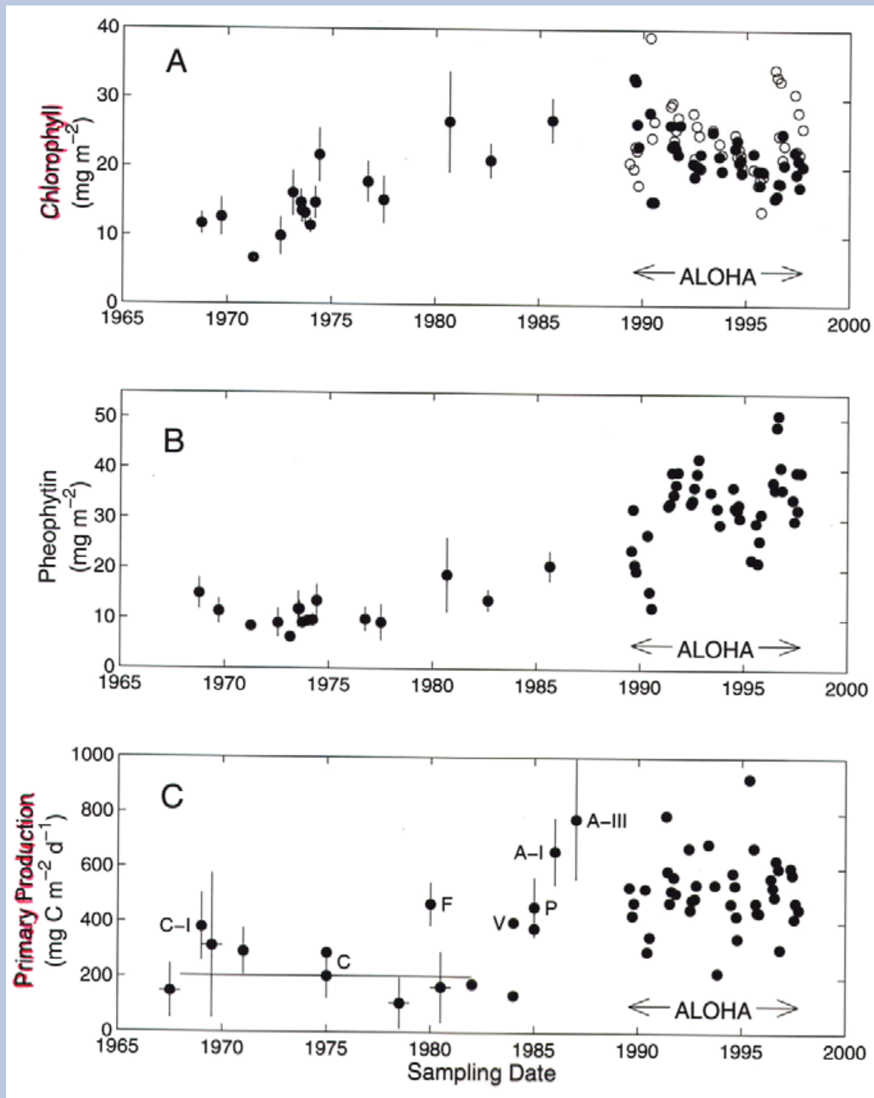
Decrease in sub-arctic Pacific

Small decrease in subtropical Pacific

Increase in marginal Seas and Tropical Pacific

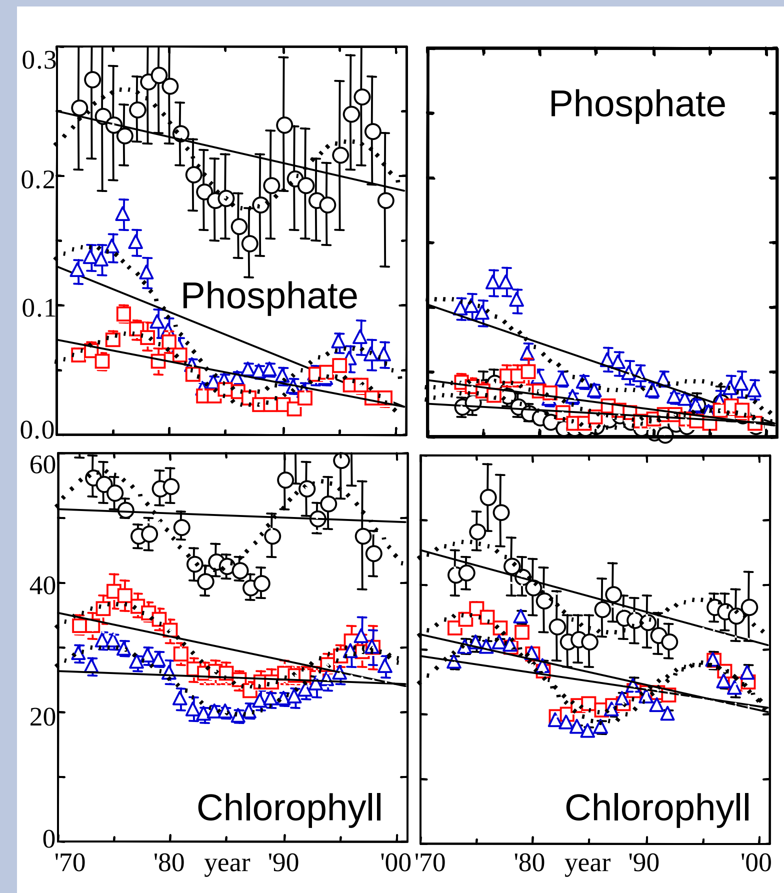
Productivity changes?

NPAC CENTRAL GYRE



Karl et al. (2000)

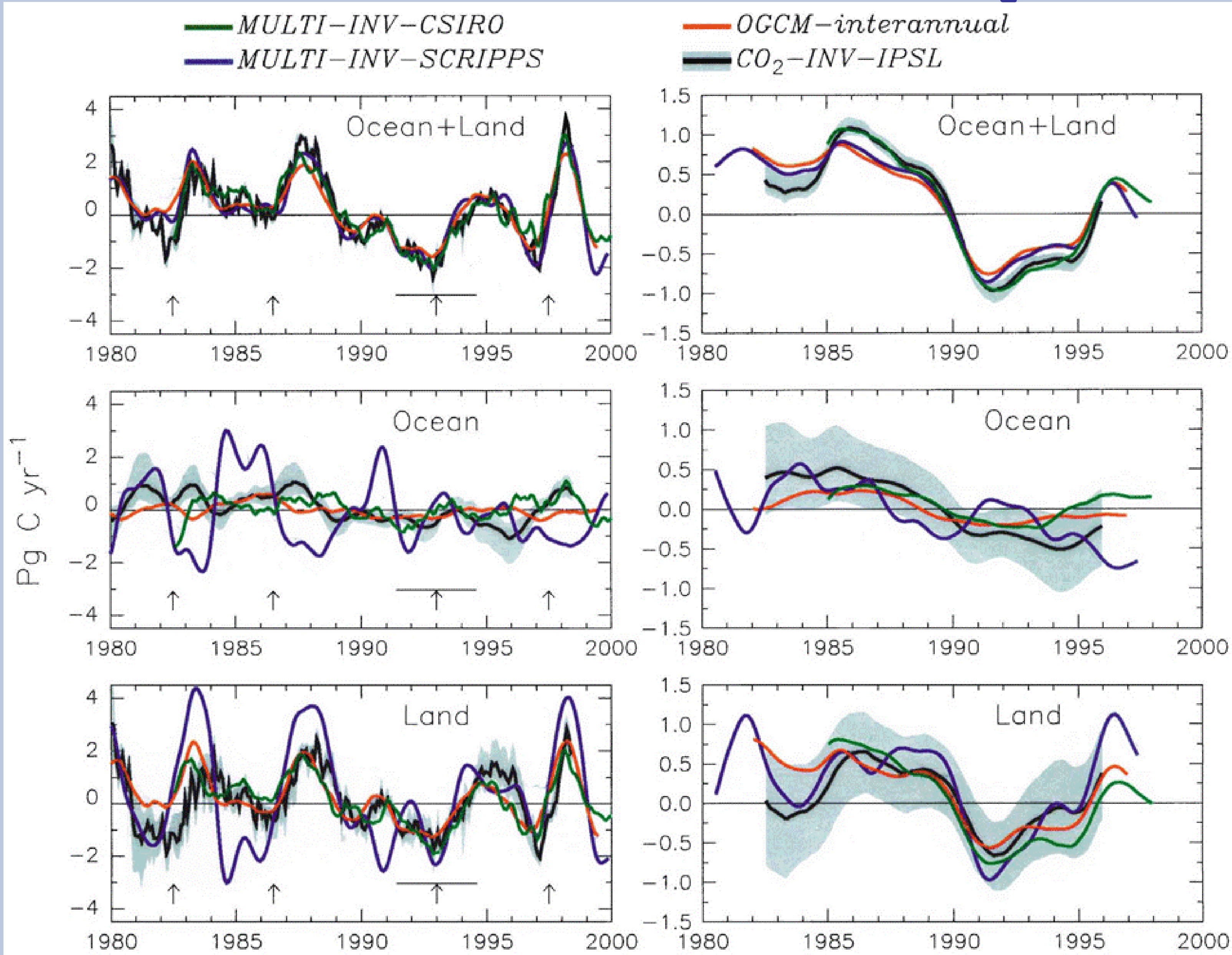
Winter   Summer



Watanabe et al. (submitted)

EASTERN PACIFIC 137°E

LAND-OCEAN PARTITIONING OF ANOMALOUS CO_2 FLUXES



LeQuere et al. 2003)