

Trend analysis of ocean pCO₂ and the air-sea CO₂ flux in the North Pacific

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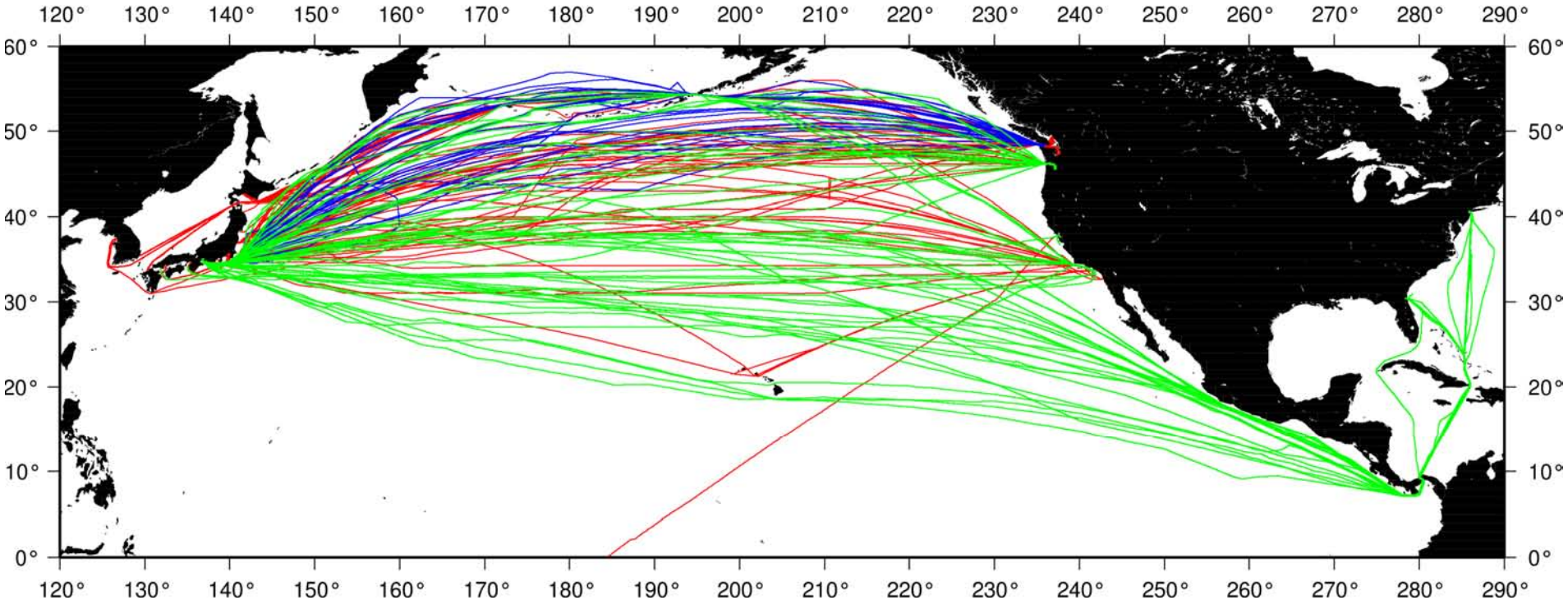
Acknowledgement

Observation was supported by the owners, captain and crew of M/V Skaugran, M/V Alligator Hope and M/V Pyxis.

We thank Global Environmental Forum and Kimoto Electri. Co., Ltd. for maintenance and MIRC for data management.

NIES CO₂ monitoring by VOS in the North Pacific

SK01 [Mar. 1995] – SK38 [Sep. 1999] & AH01 [Nov. 1999] – AH16 [May 2001] & PX74 [Jul. 2002] – PX104 [Apr. 2006]



— Skaugran — Alligator Hope — Pyxis

Mar. 1995 – Sep. 1999

Nov. 1999 – May 2001

Jul. 2002 – Present

Date are distributed at CIDIAC site.
<http://cdiac.ornl.gov/oceans/pco2inv.html>

CO₂ measuring system



Seawater CO₂ equilibrator

Ocean CO₂ is measured by the flow-through and Tandem-type gas liquid equilibrator.



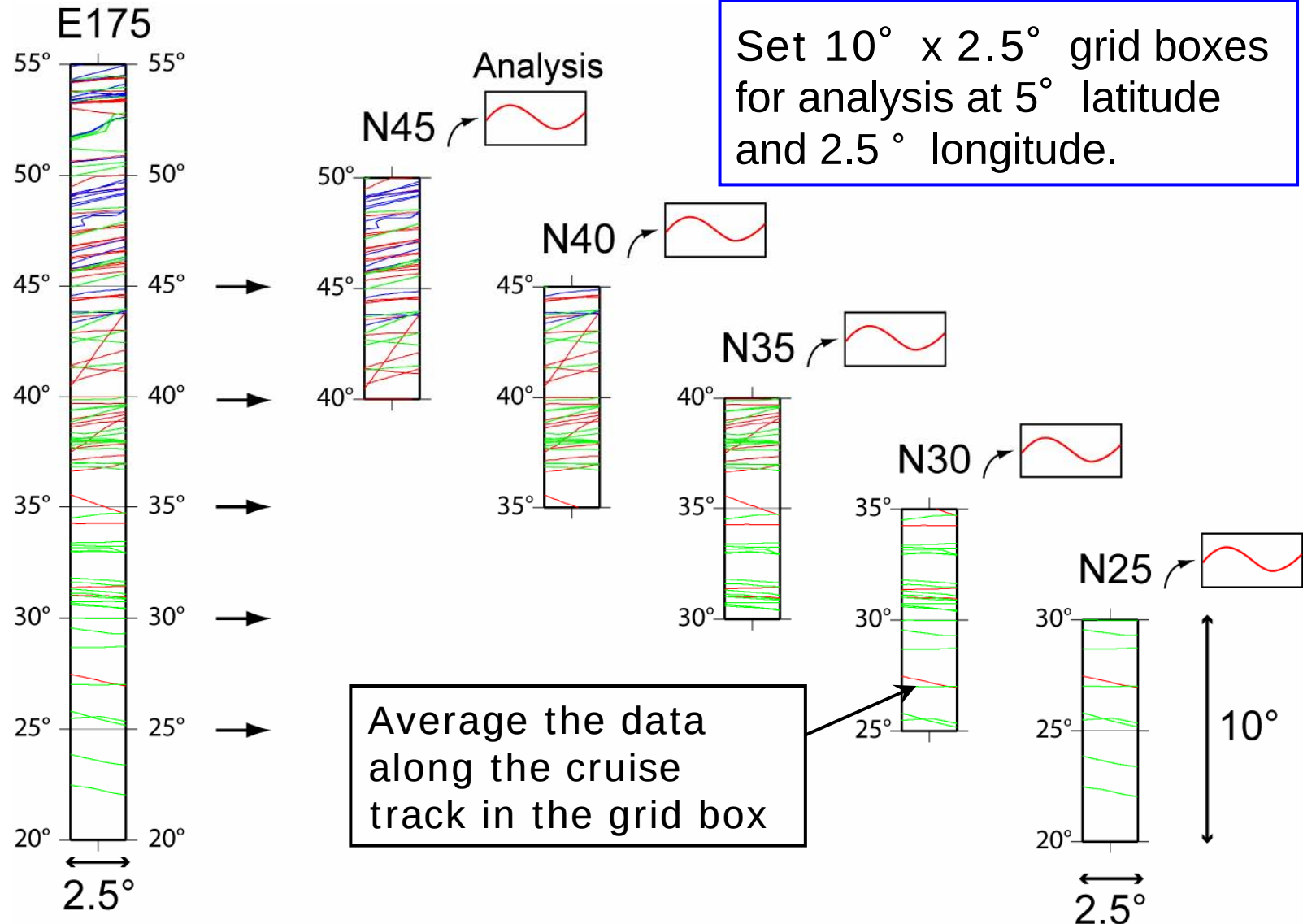
CO₂ measurement system

CO₂ is measured by a infrared gas analyzer (NDIR).

The Purposes of this study

- To analyze the trend of ocean CO_2 and calculate the climatology of ΔpCO_2 (= ocean - atmosphere) on the basis of the NIES VOS data from 1995 to 2005.
- To estimate the monthly air-sea CO_2 flux taking account of the decadal ΔpCO_2 trend and the ΔpCO_2 change by SST anomaly and examine the decadal trend of CO_2 flux.

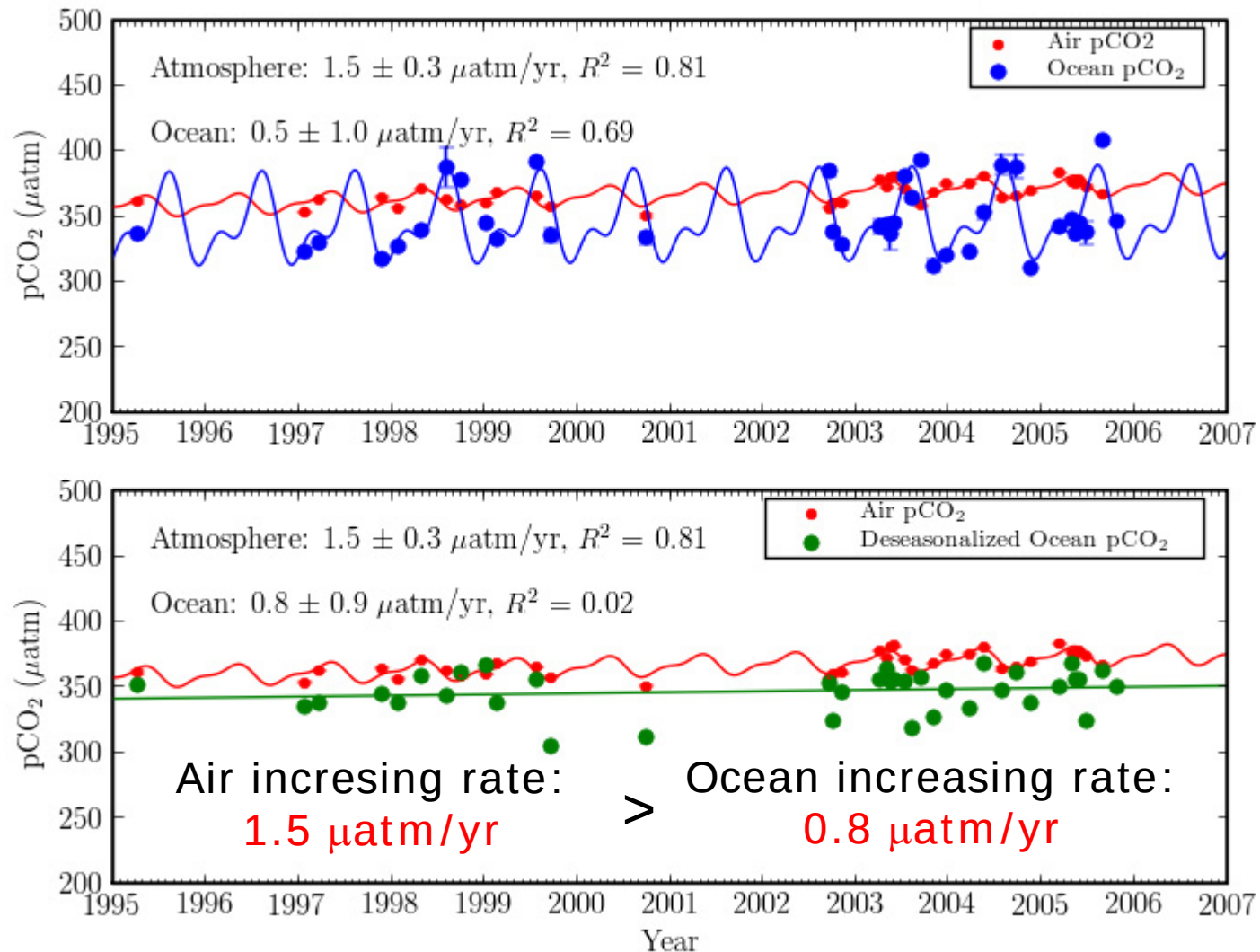
Data analysis



Time series of atmospheric and ocean CO₂



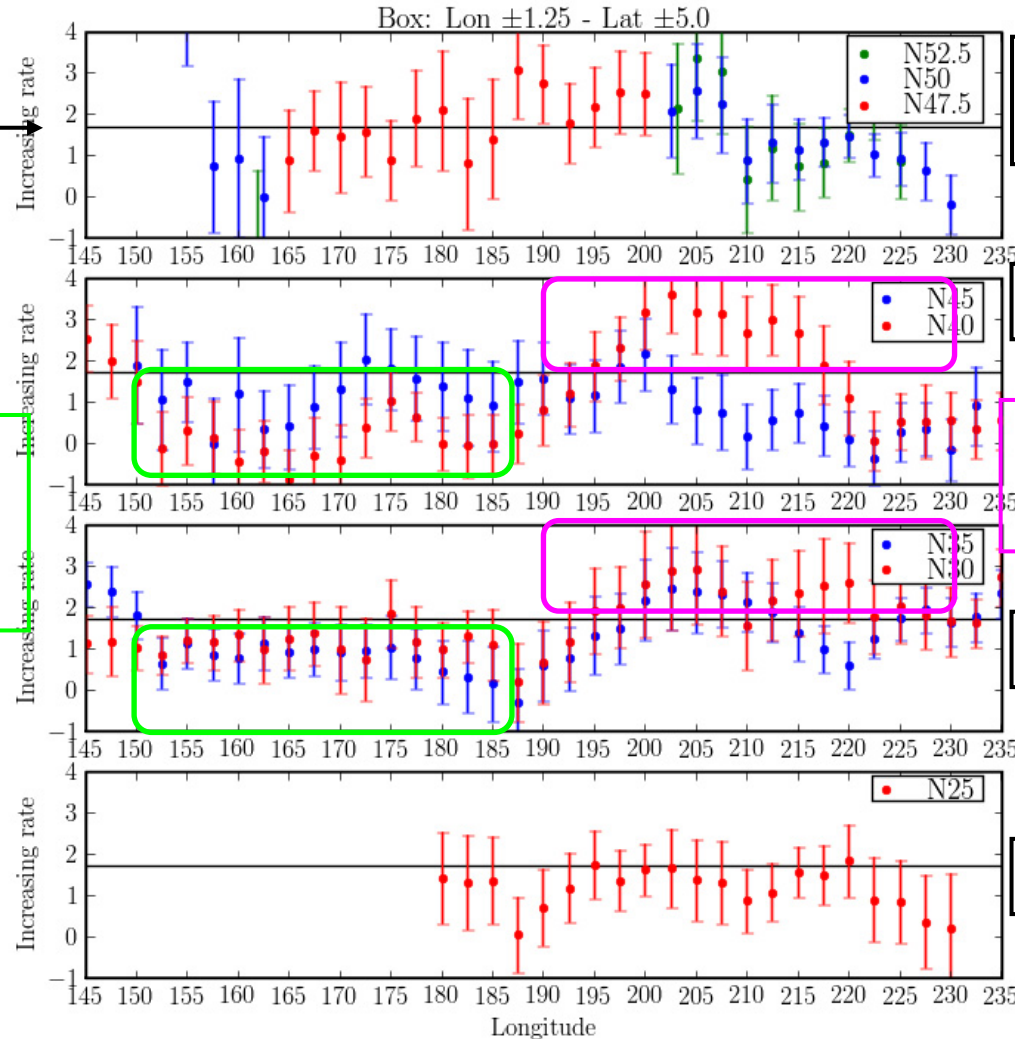
N40 / E190



Increasing rate of pCO₂

Mean
atmospheric
increasing rate
= 1.7 $\mu\text{atm/yr}$

Smaller than
atmosphere in
western area



N47.5 / N50
/ N52.5

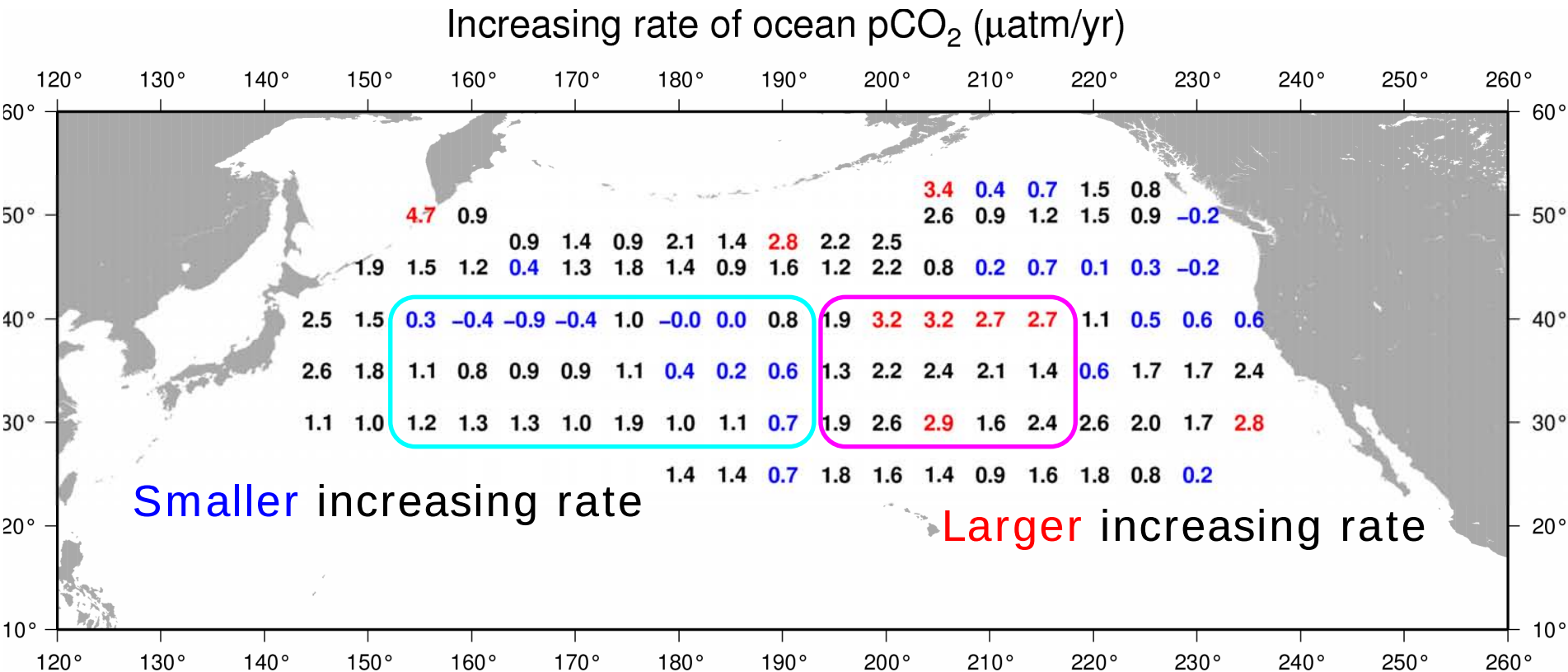
N40 / N45

Larger in
eastern area

N30 / N35

N25

Distribution map of increasing rate of ocean CO₂

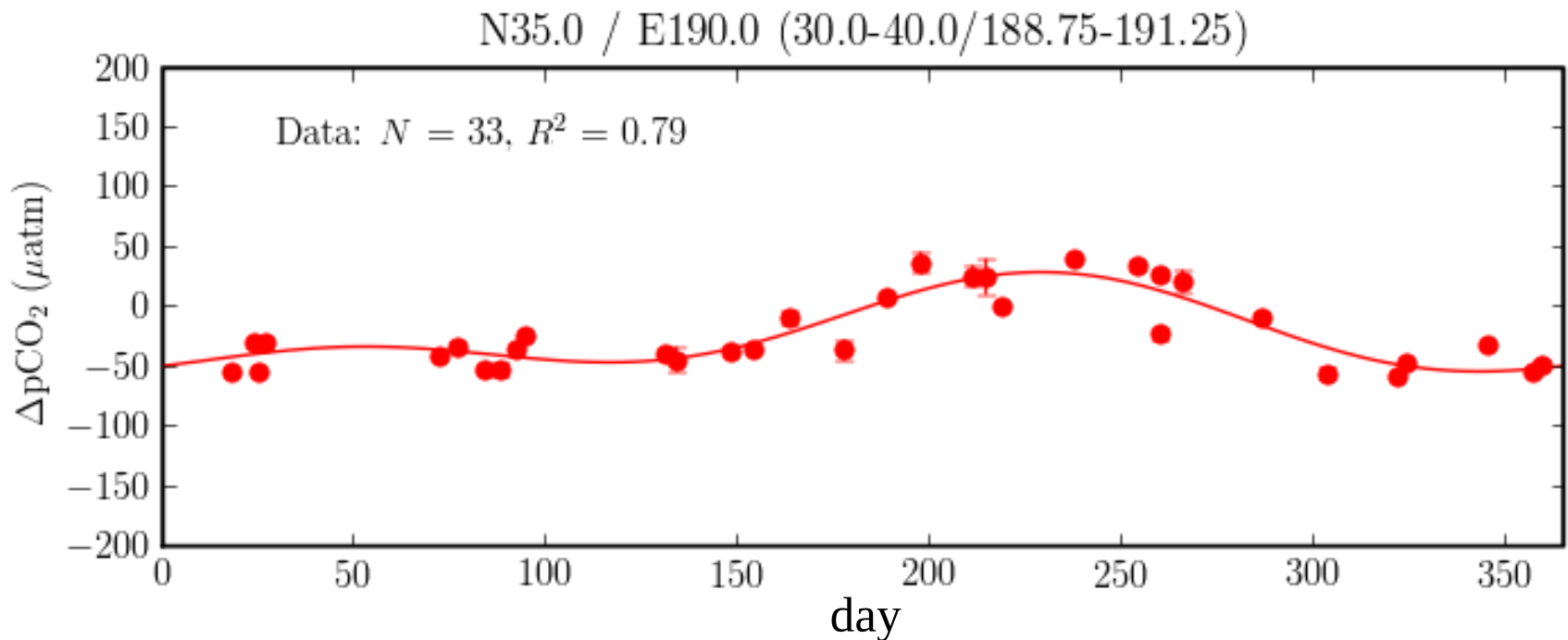


Larger value than 2.7 μatm/yr
smaller value than 0.7 μatm/yr

Estimation of Climatology

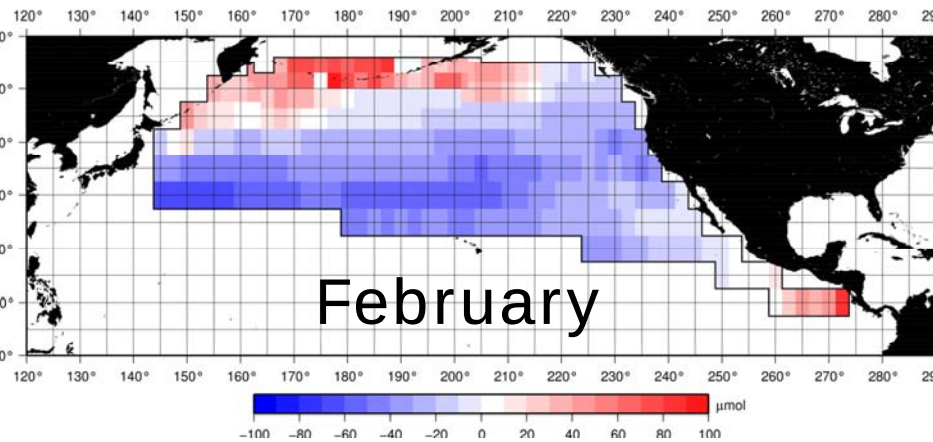
Fit a harmonic function with observational data

$$\Delta p\text{CO}_2 = a_0 \sin(2\pi t) + a_1 \cos(2\pi t) + a_2 \sin(4\pi t) + a_3 \cos(4\pi t) + a_4$$

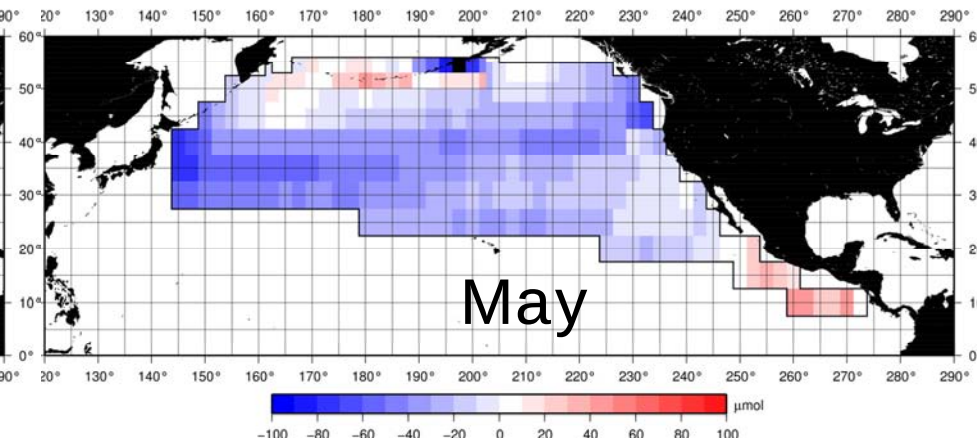


Climatology of $\Delta p\text{CO}_2$

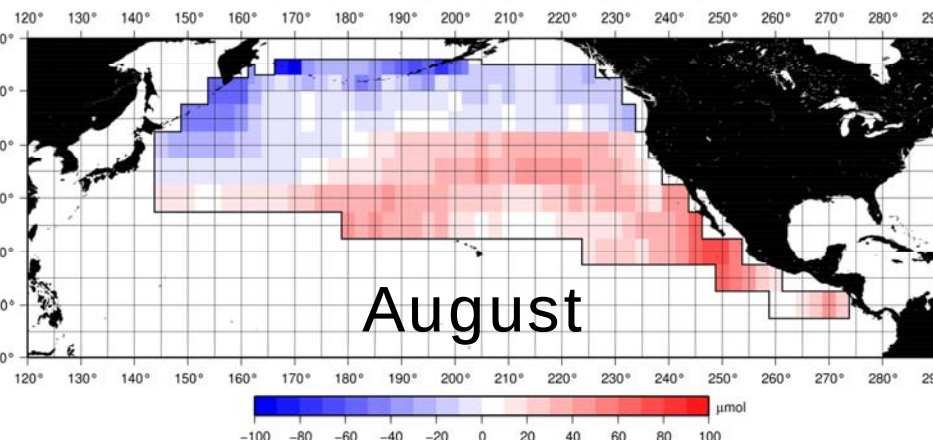
1995–2005 Climatology / ΔCO_2 / February



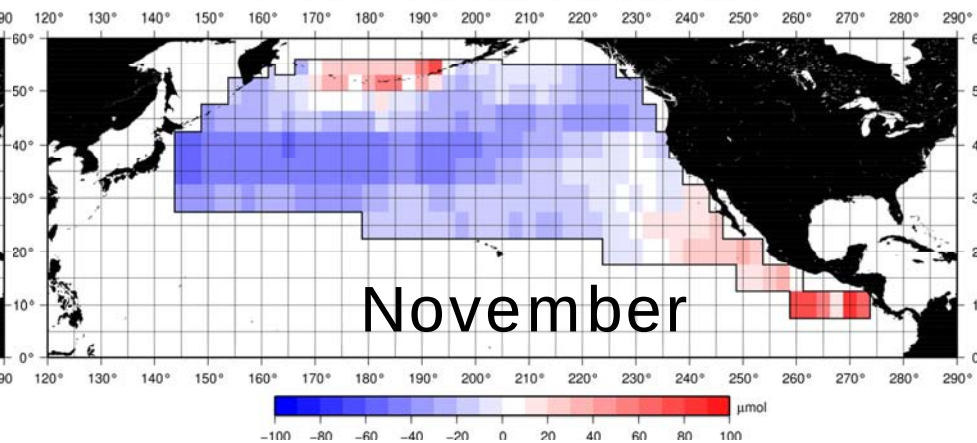
1995–2005 Climatology / ΔCO_2 / May



1995–2005 Climatology / ΔCO_2 / August



1995–2005 Climatology / ΔCO_2 / November



Estimation of CO₂ flux

1. Estimate the monthly $\Delta p\text{CO}_2$, considering the decadal trend of $\Delta p\text{CO}_2$ and $\Delta p\text{CO}_2$ change by SST anomaly.

$$\begin{aligned}\Delta p\text{CO}_2(t) &= p\text{CO}_2(t) - \text{CO}_{2\text{air}}(t) \\ &= \underbrace{\Delta p\text{CO}_{2\text{clim}}}_{\text{Climatology}} + \underbrace{\frac{\partial \Delta p\text{CO}_2}{\partial t} \Delta t}_{\text{Trend term}} + \underbrace{\frac{\partial p\text{CO}_2}{\partial \text{SST}} \Delta \text{SST}}_{\text{SST anomaly term}}\end{aligned}$$

Δt : Difference between the middle time of climatology and t

ΔSST : SST anomaly at t

2. Calculate the monthly CO₂ flux using the monthly mean wind speed, SST and SSS value

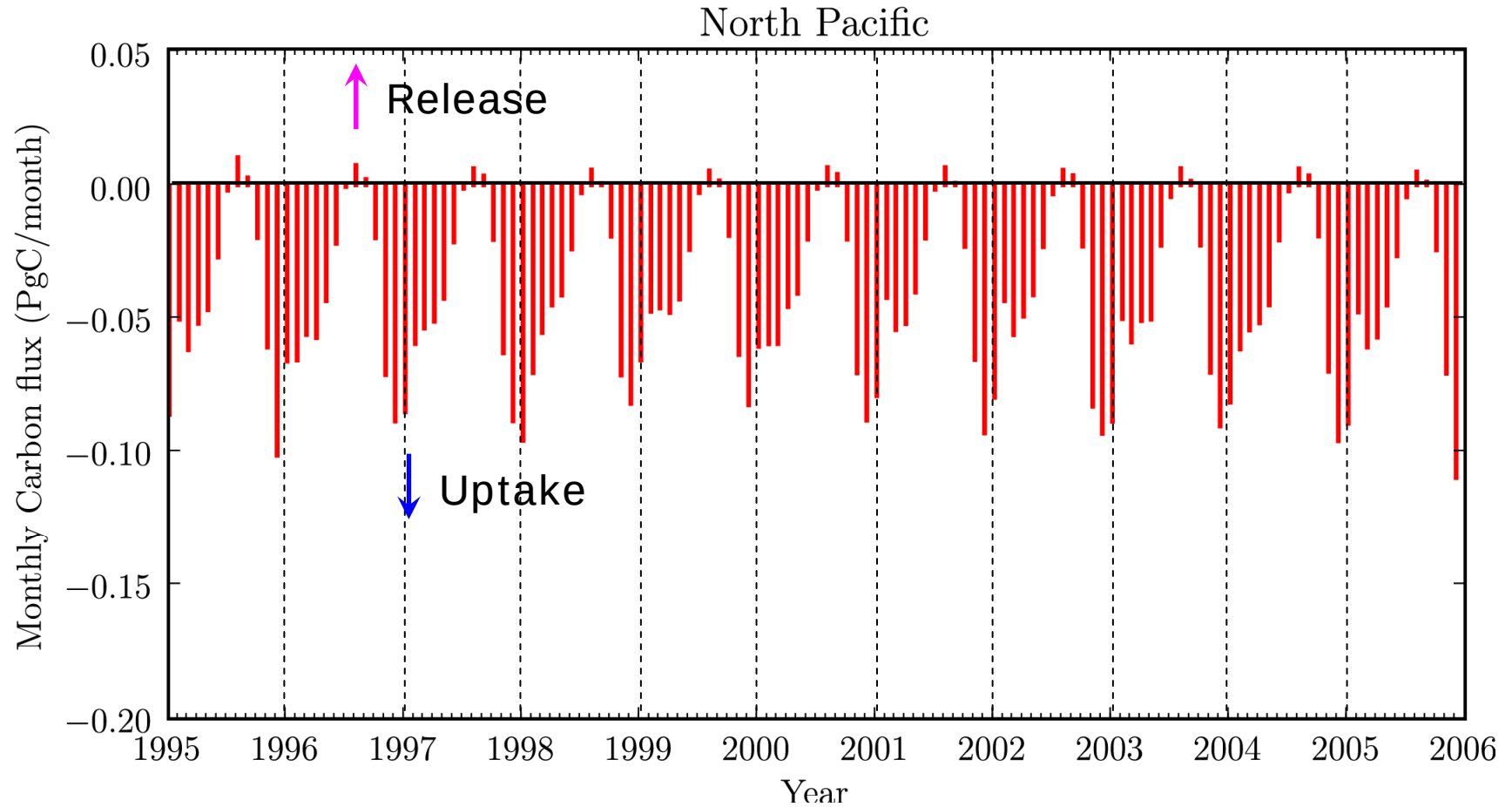
$$F(t) = S(\text{SST}, \text{SSS}) \cdot k_L(U_{10}, \text{SST}) \cdot \Delta p\text{CO}_2(t)$$

U_{10} : NCEP-DOE Reanalysis 2

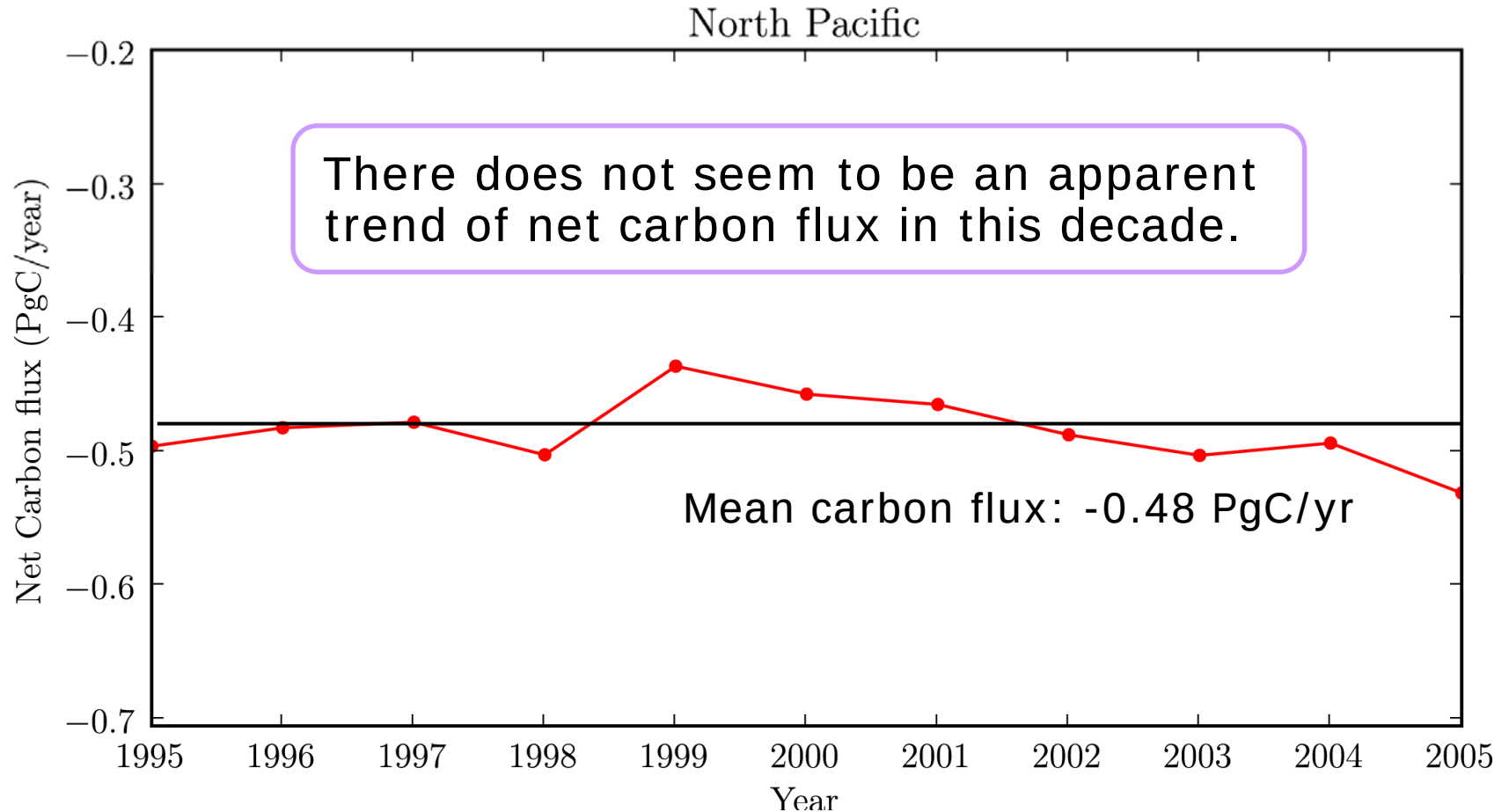
SST: NOAA Optimum Interpolation SST analysis data

SSS: ECCO-JPL Ocean data assimilation

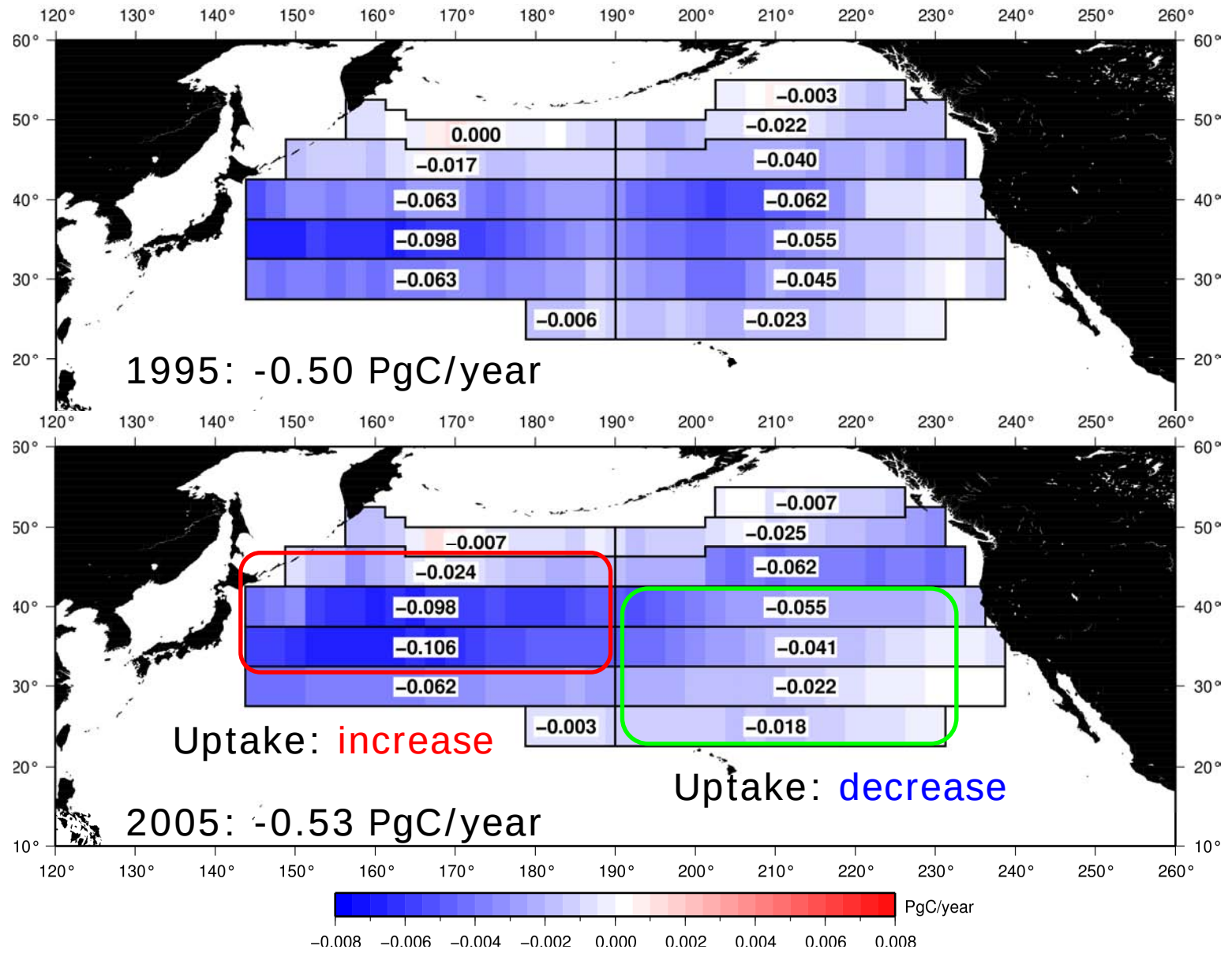
Time series of monthly carbon flux



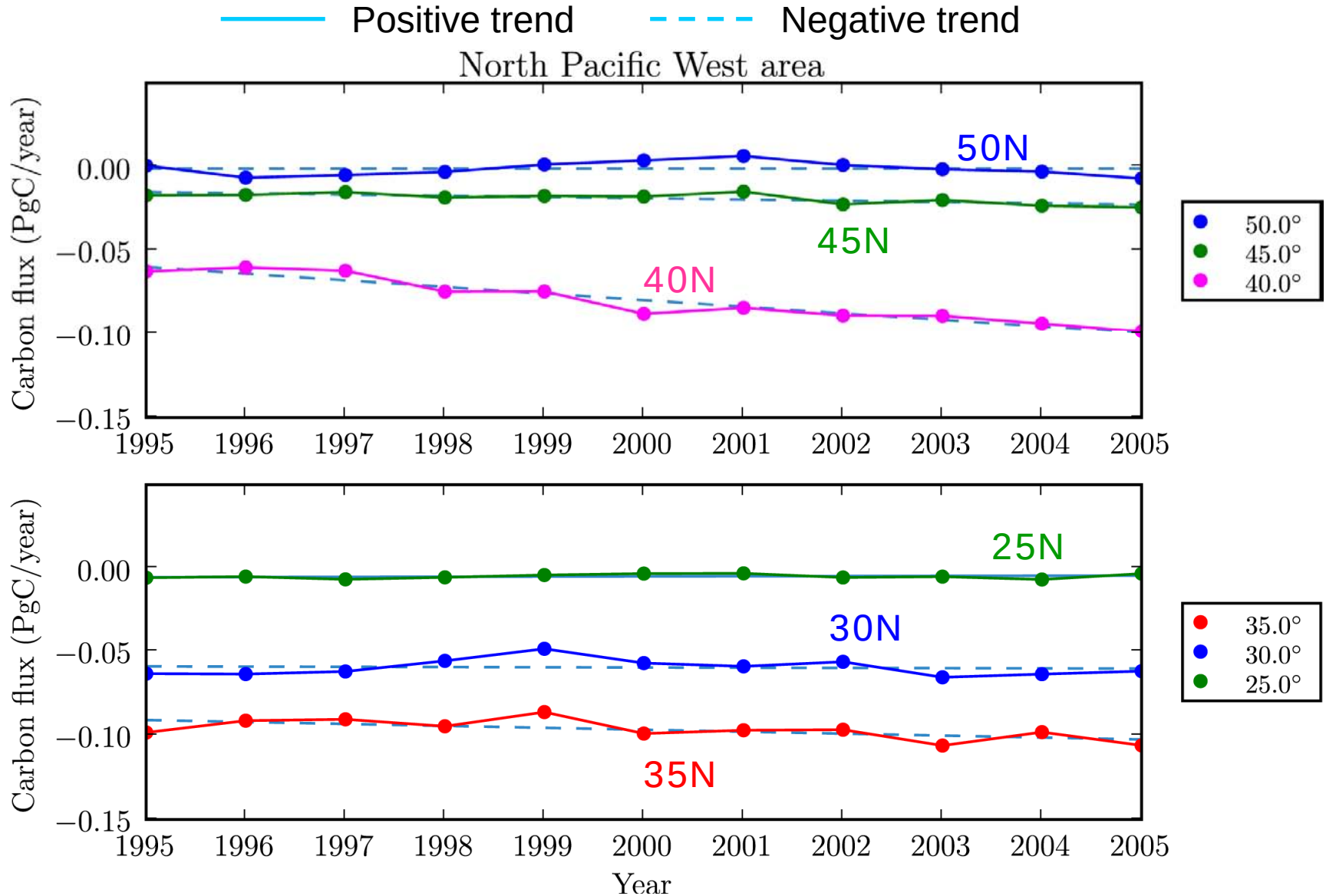
Time series of yearly carbon flux



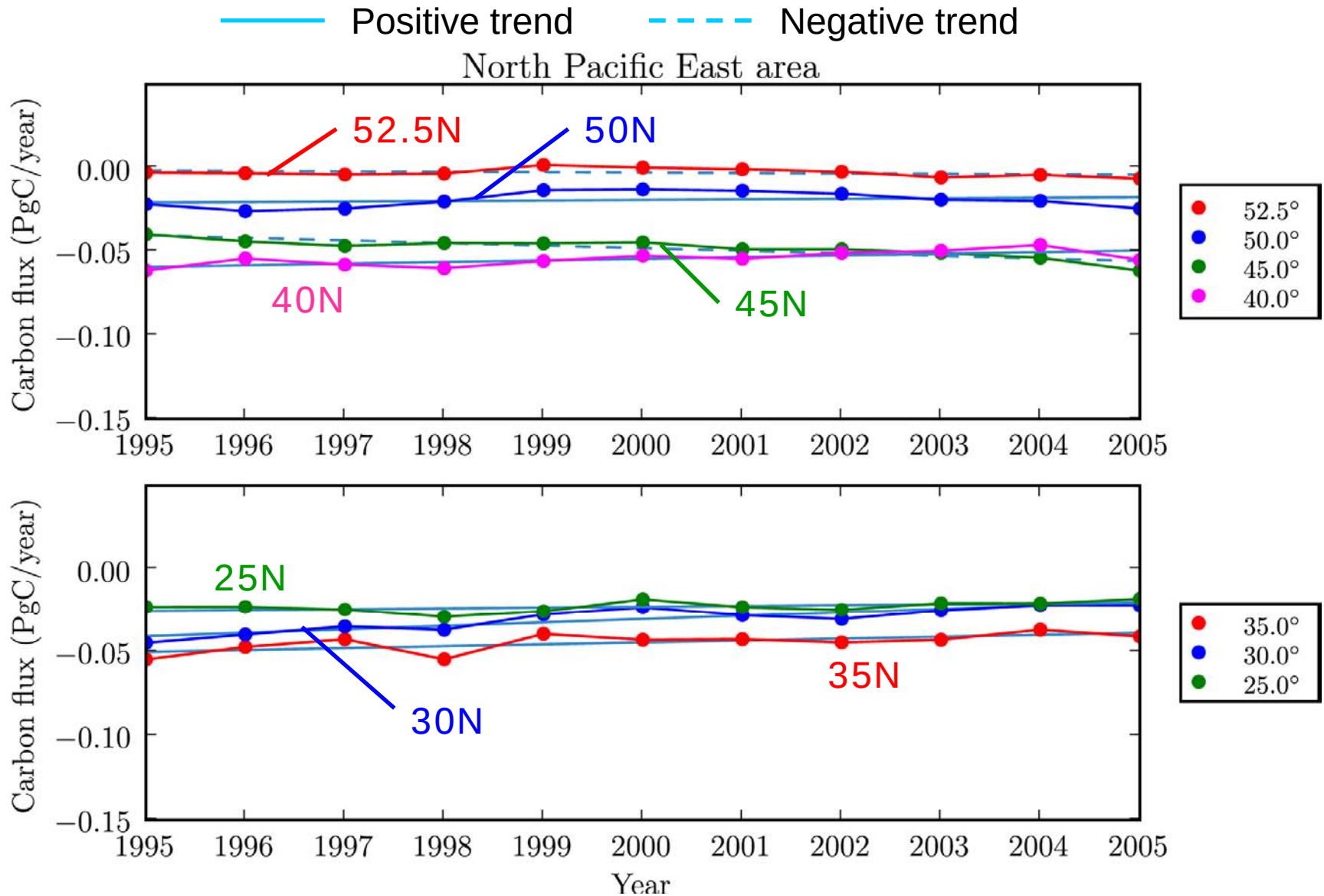
Change of ocean carbon flux map



Carbon flux at Western North Pacific



Carbon flux at Eastern North Pacific



Conclusions

- Increasing rate of ocean CO_2 is smaller than that of atmosphere in the western area and is larger in eastern area at mid-latitudinal North Pacific.
- There is not a significant trend of the net carbon flux in the whole North Pacific. However, oceanic carbon uptake in North Pacific tends to increase in western mid-latitudinal area and decrease in eastern mid-latitudinal area.