Seasonal and interannual variation of oceanic carbon cycling in the western and eastern tropical-subtropical Pacific: A physical-biogeochemical modelling study

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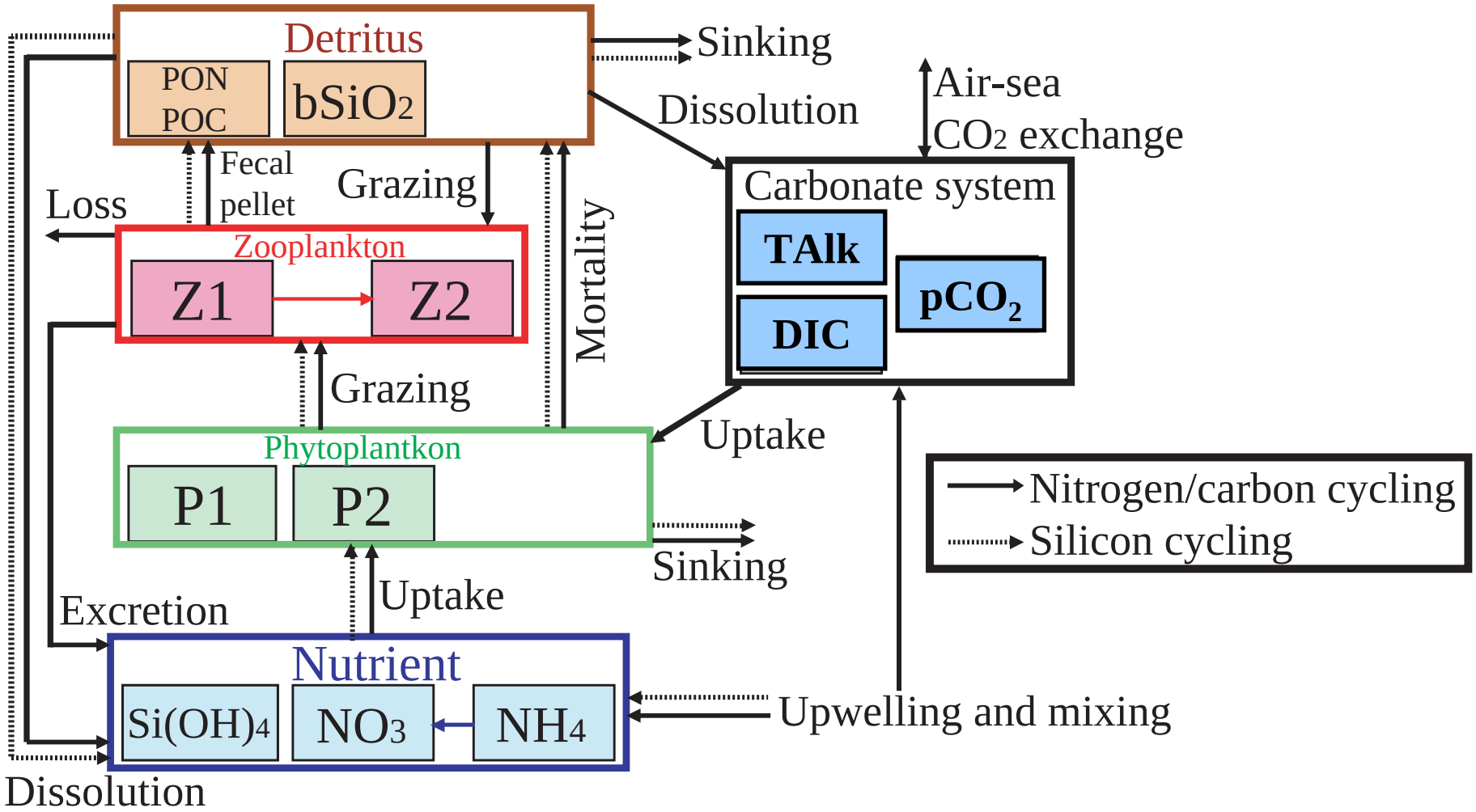
Oceanic carbon cycling in the tropical-subtropical Pacific

- **High interannual and decadal variability induced by:**
  - **Global warming**
  - **El Nino and Southern Oscillation (ENSO)**
  - **Pacific Decadal Oscillation (PDO)**
  - **Tropical Instability Waves (TIWs) and so on**
- **Very few previous modelling studies have focused on the carbon cycling in the western part of this basin!!**

To elucidate processes controlling pCO_{2sea} variation (esp. focusing on the interannual variation) in the entire tropical-subtropical Pacific by using a physical-biogeochemical model

Carbon, Silicate, Nitrogen Ecosystem (CoSINE) Model

(*e.g.* Chai *et al.*, 2002; Dugdale *et al.*, 2002)



Coupled with 3D Physical model: ROMS (Regional Ocean Model System)

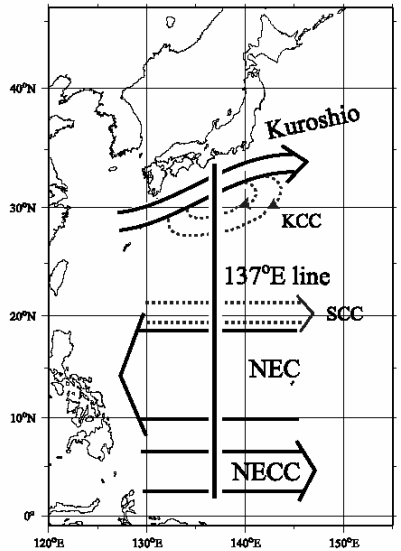
(e.g. Wang and Chao,2004; Liu et al.,2008)

Model domain: 45°S-65°N, 99°E-70°W S-coordinate
Analyzed years: 1990-2004
Resolution: Monthly, 0.5°×0.5°
Forced by NCEP reanalysis data
Mauna Loa pCO_{2air}
OCMIP-2's CO_2 system
Wanninkhof et al. (1992)'s gas exchange parameterization

Data for validating model results

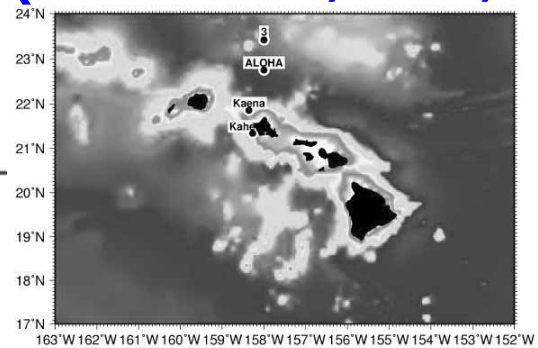
Western subtropical Pacific

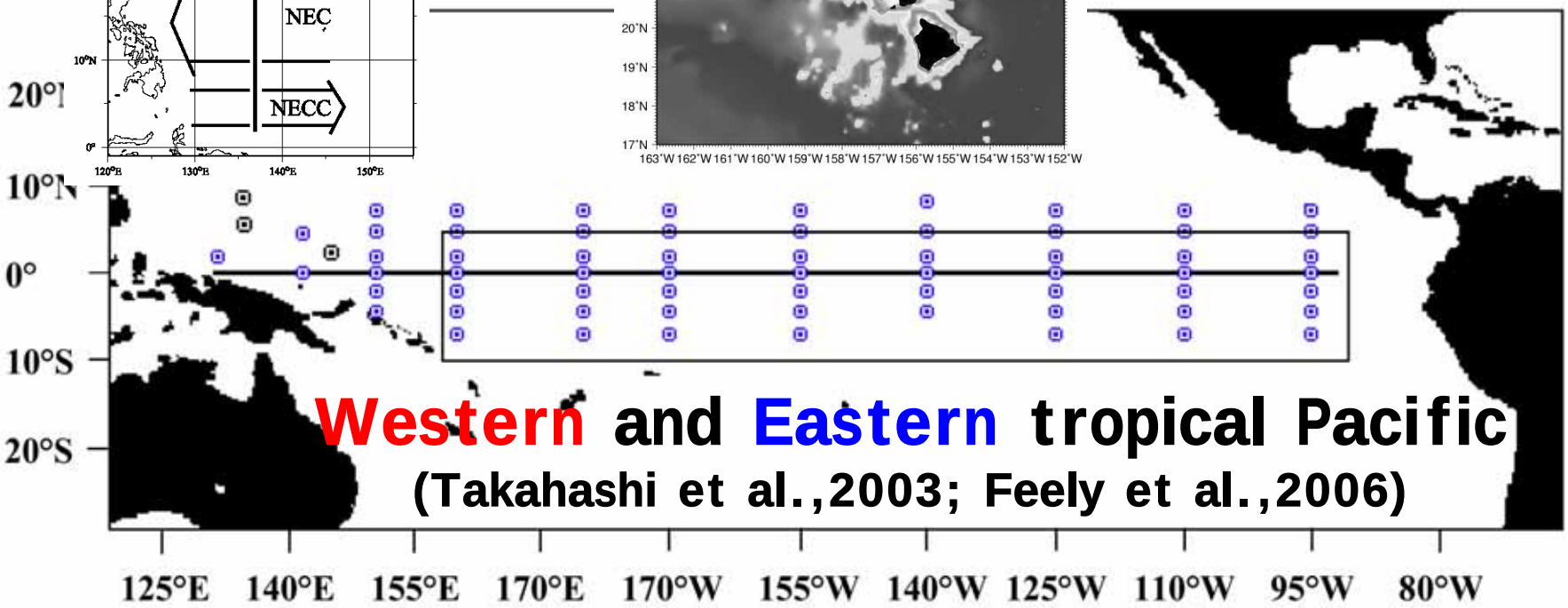
(Inoue et al.,1995; Midorikawa et al.,2005)



Eastern Subtropical Pacific

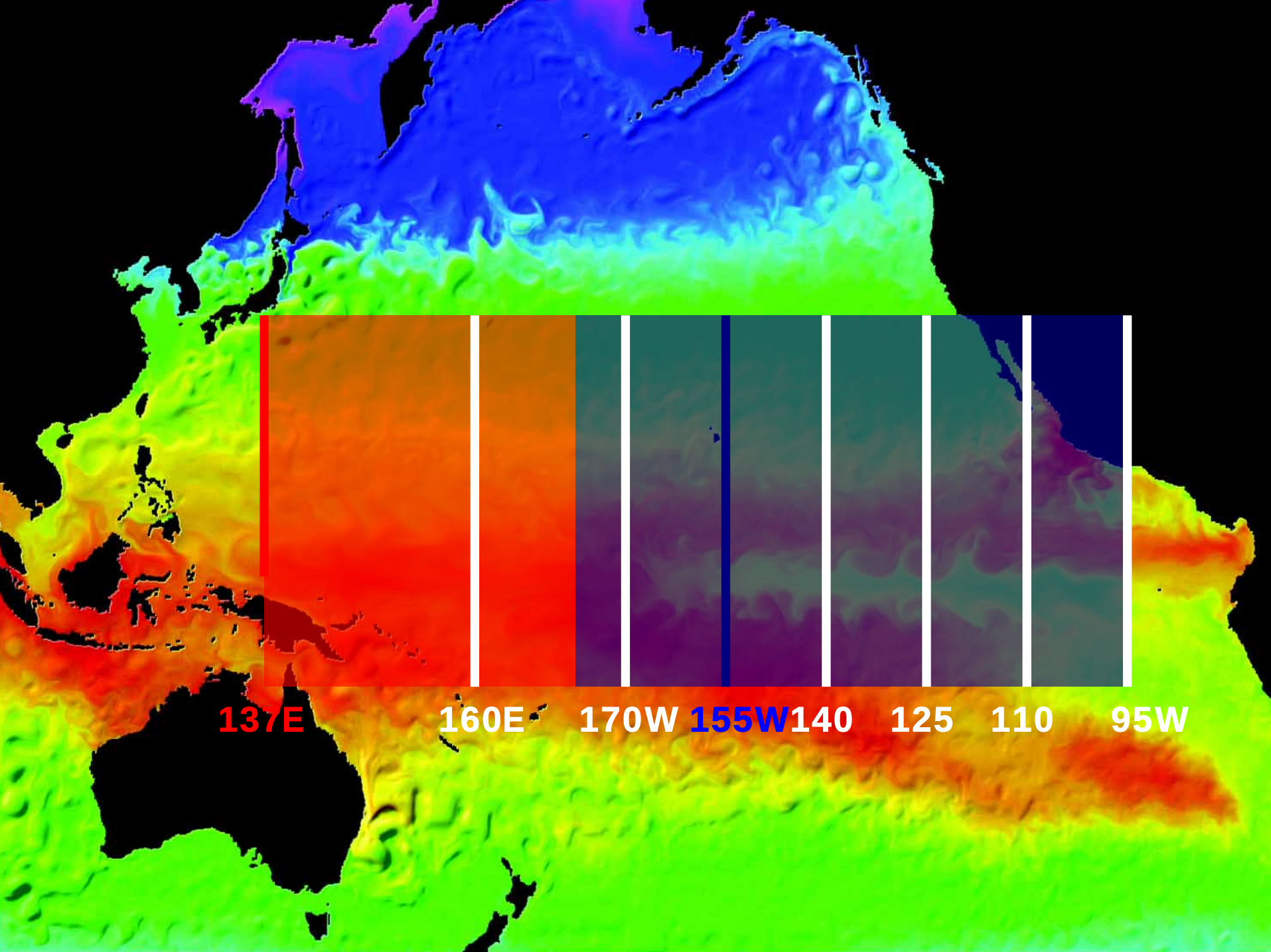
(Dore et al.,2003; Keeling et al.,2004)



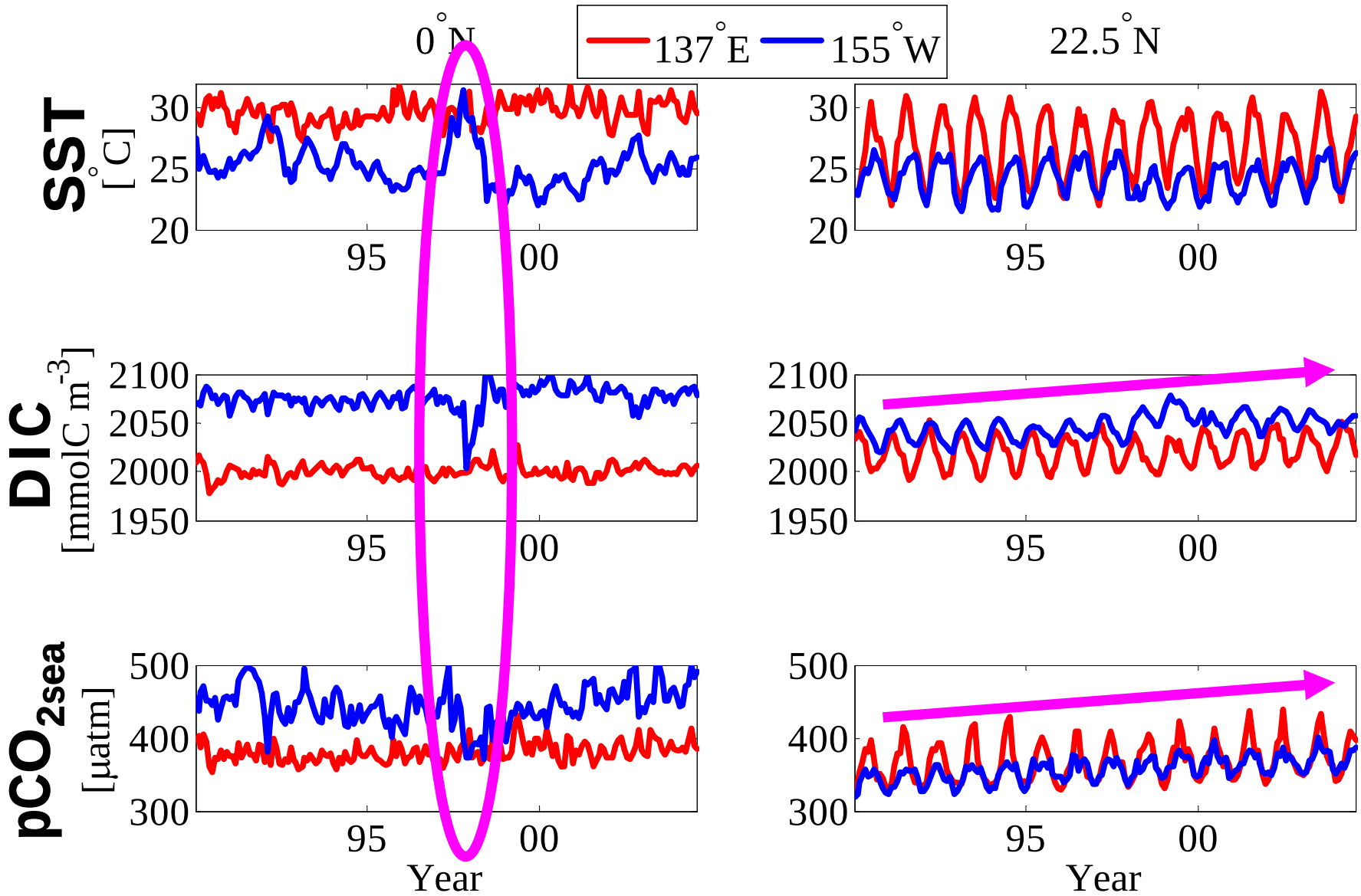


Western and Eastern tropical Pacific

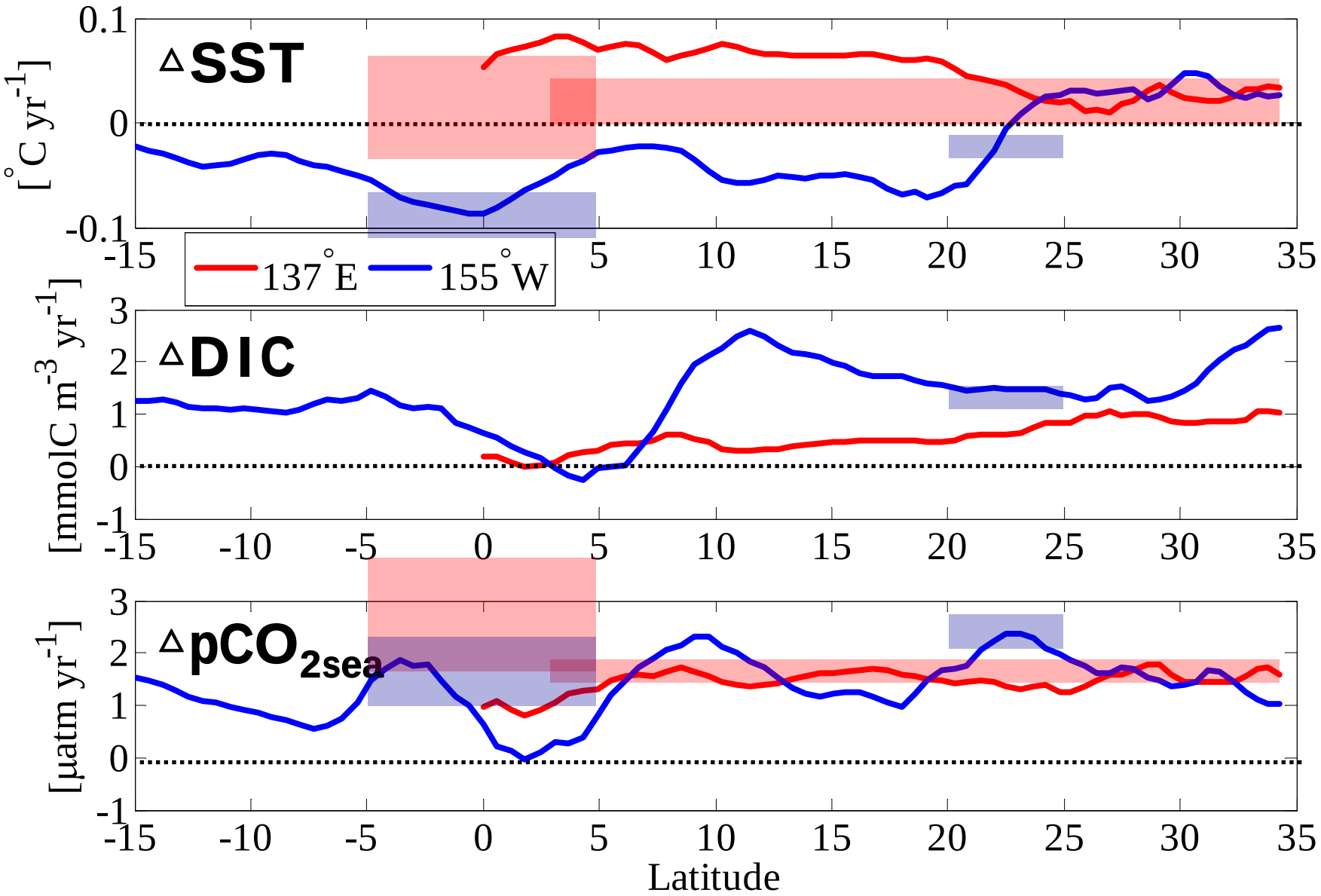
(Takahashi et al.,2003; Feely et al.,2006)


137E
160E
170W
155W
140
125
110
95W

Interannual variation



Interanuual change rate

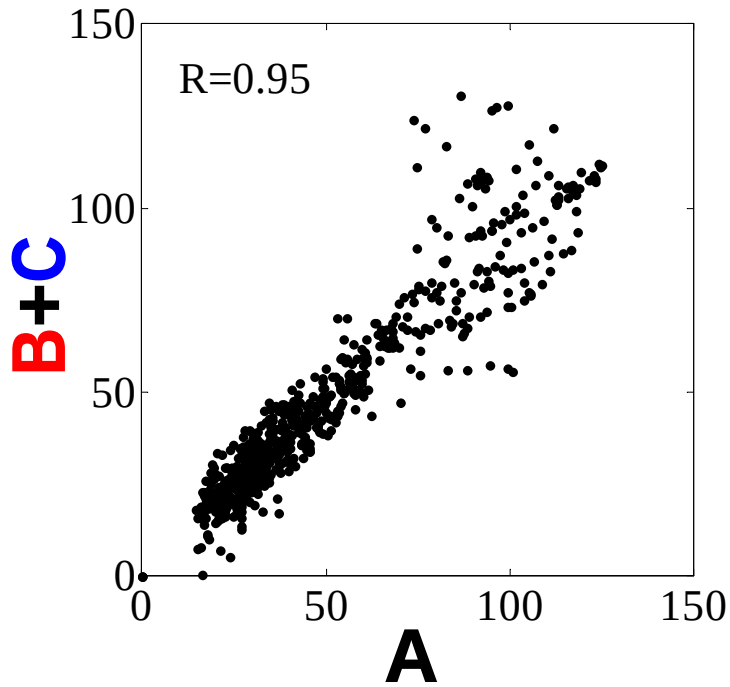


pCO_{2sea} change by SST and DIC

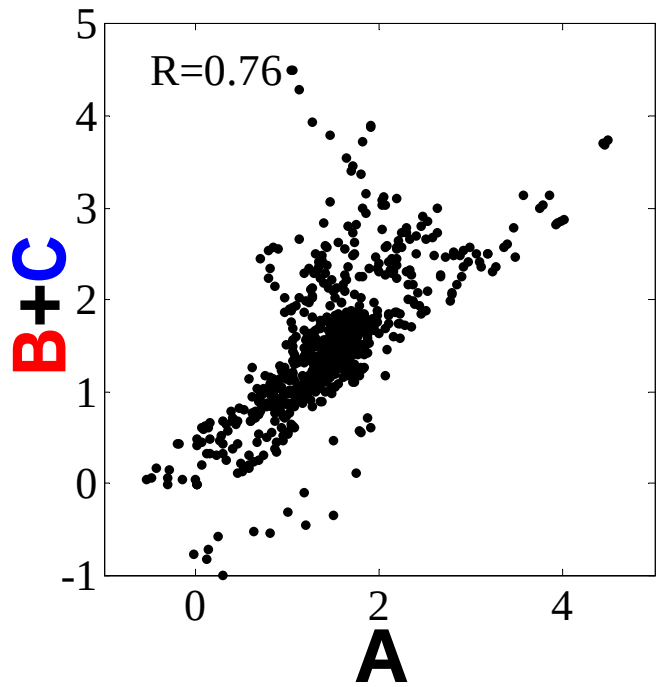
Thermodynamic relationship (Takahashi et al.,1993)

$$\underbrace{\frac{dpCO_{2sea}}{dt}}_{A} = \underbrace{\frac{\partial pCO_{2sea}}{\partial T}\frac{dT}{dt}}_{B} + \underbrace{\frac{\partial pCO_{2sea}}{\partial DIC}\frac{dDIC}{dt}}_{C} + \cancel{\frac{\partial pCO_{2sea}}{\partial S}\frac{dS}{dt}} + \cancel{\frac{\partial pCO_{2sea}}{\partial TAlk}\frac{dTAlk}{dt}}$$

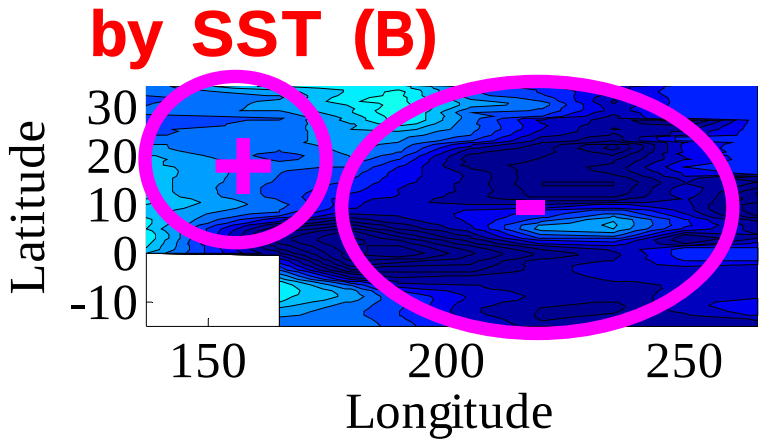
Seasonal pCO_{2sea} change [μatm]

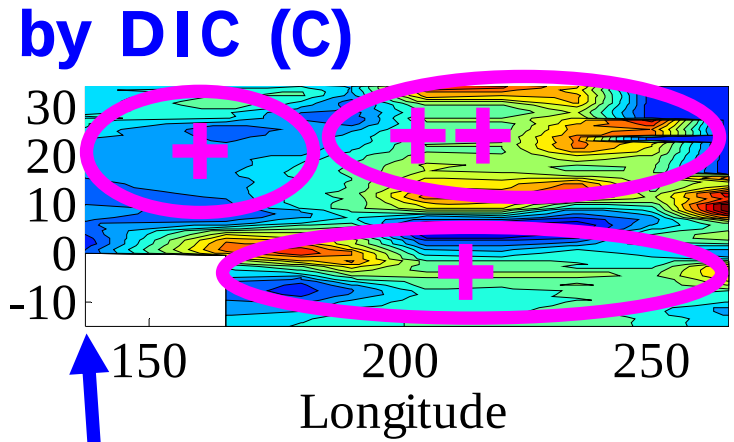


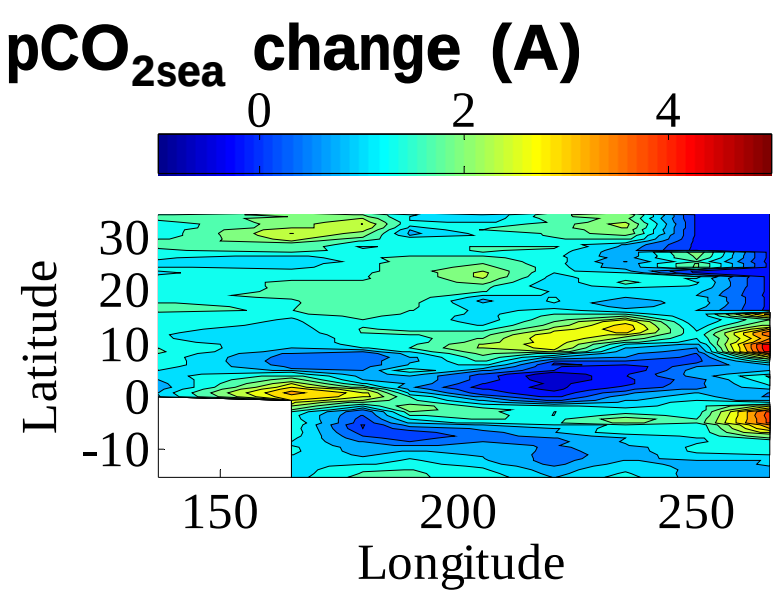
Interannual pCO_{2sea} change rate [μatm yr^{-1}]



Interannual pCO_{2sea} change by SST and DIC







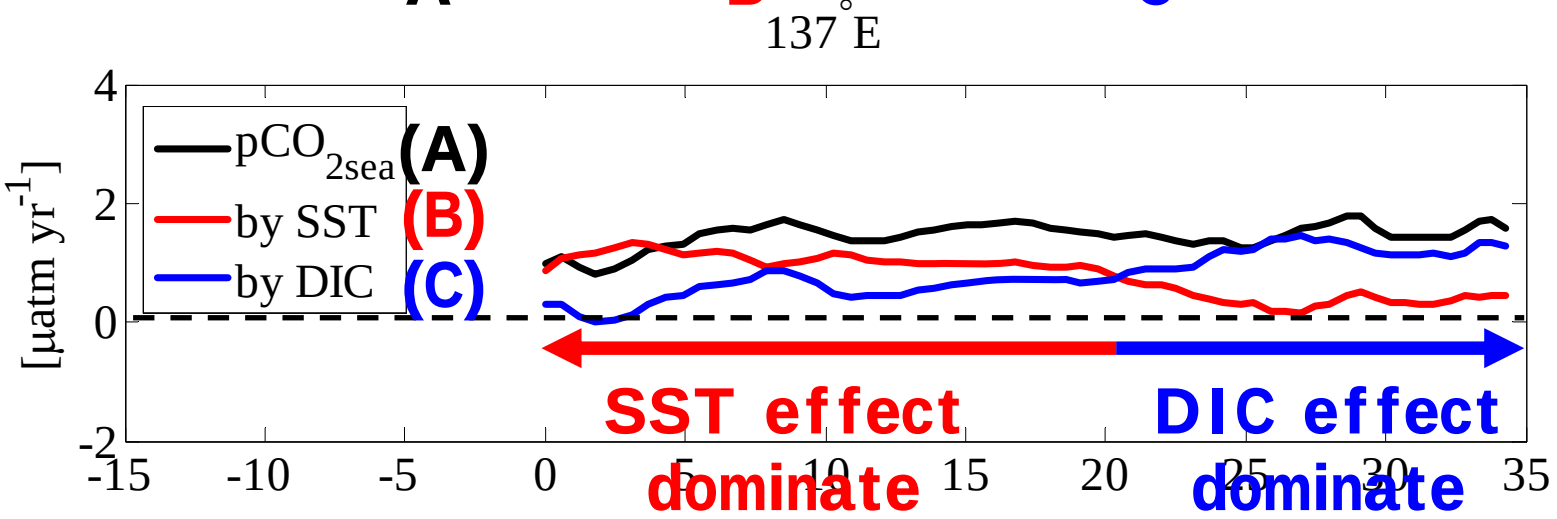
$$\frac{dpCO_{2sea}}{dt} = \frac{\partial pCO_{2sea}}{\partial T}\frac{dT}{dt} + \frac{\partial pCO_{2sea}}{\partial DIC}\frac{dDIC}{dt}$$

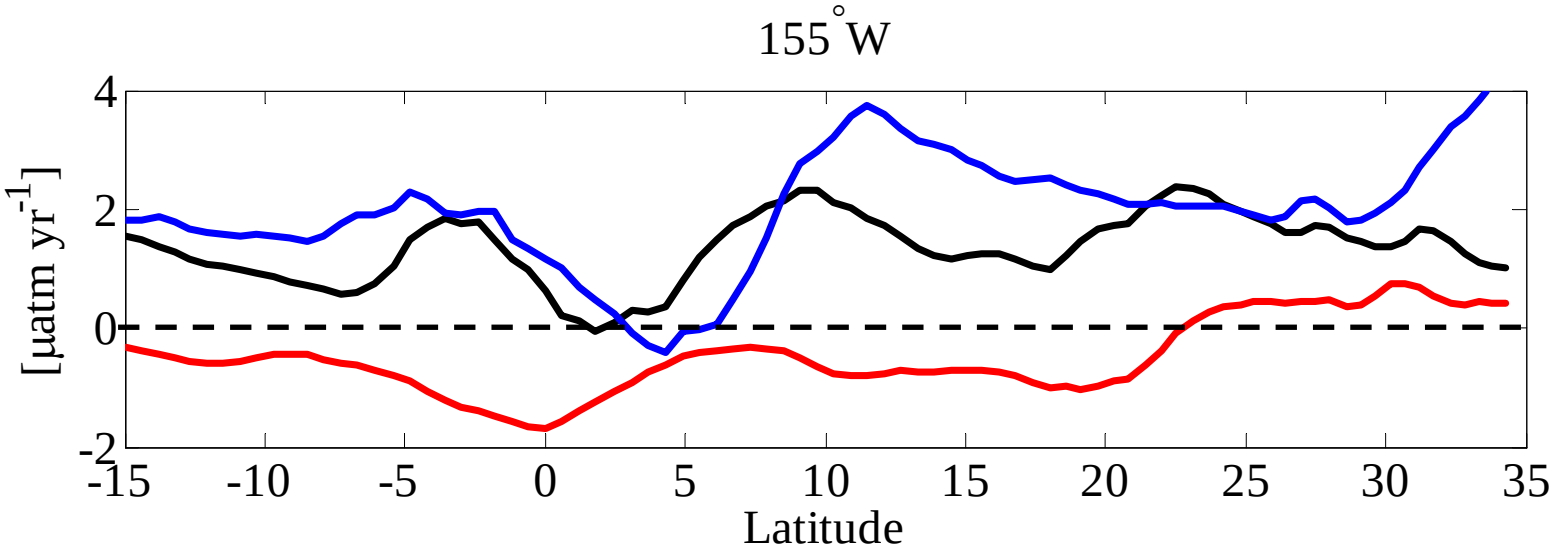
(A) (B) (C)

Interannual pCO_{2sea} change by SST and DIC

$$\frac{dpCO_{2sea}}{dt} = \frac{\partial pCO_{2sea}}{\partial T}\frac{dT}{dt} + \frac{\partial pCO_{2sea}}{\partial DIC}\frac{dDIC}{dt}$$

A B C



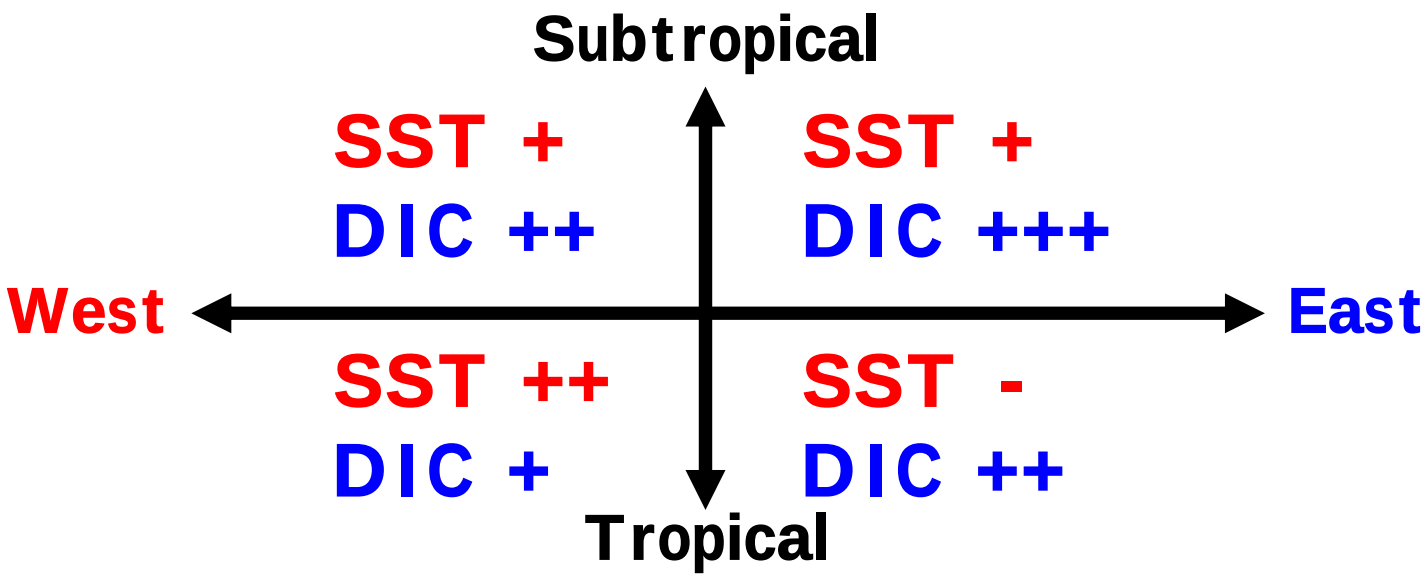


Summary

pCO_{2sea} in the entire tropical-subtropical Pacific

- The observed seasonal and interannual variation are reproduced well by the model

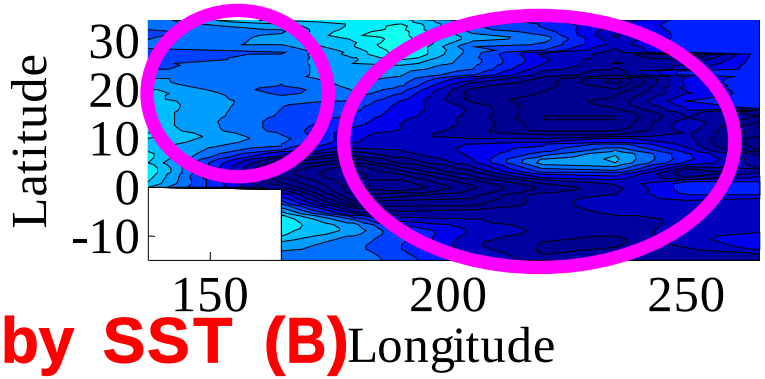
- Major controlling factor of the interannual variability is different with location



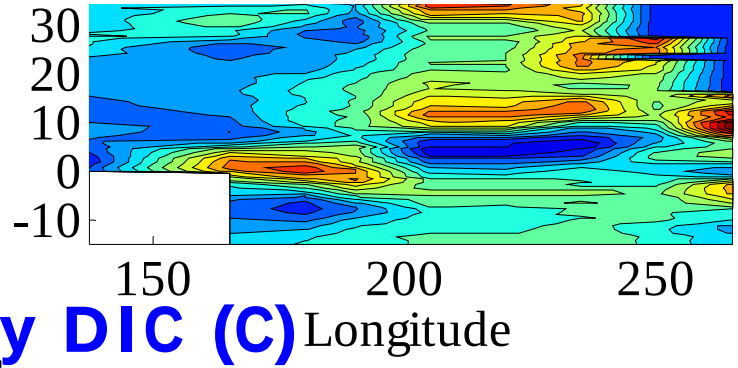
Interannual pCO_{2sea} change by SST and DIC

$$\frac{dpCO_{2sea}}{dt} = \frac{\partial pCO_{2sea}}{\partial T}\frac{dT}{dt} + \frac{\partial pCO_{2sea}}{\partial DIC}\frac{dDIC}{dt}$$

A B C

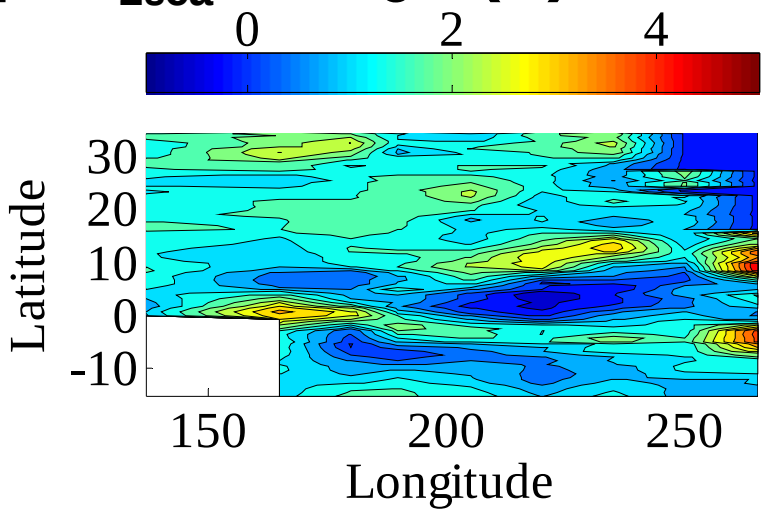


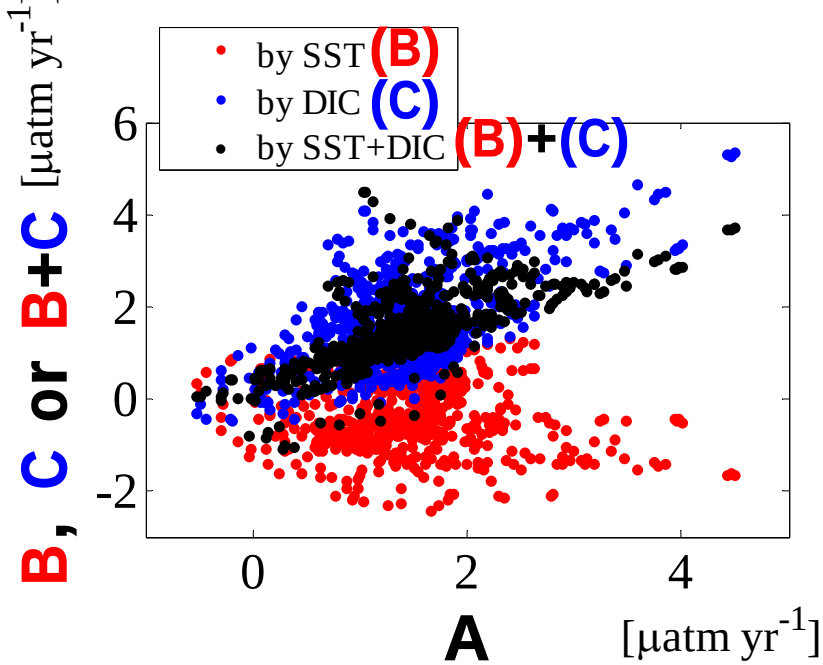
by SST (B)



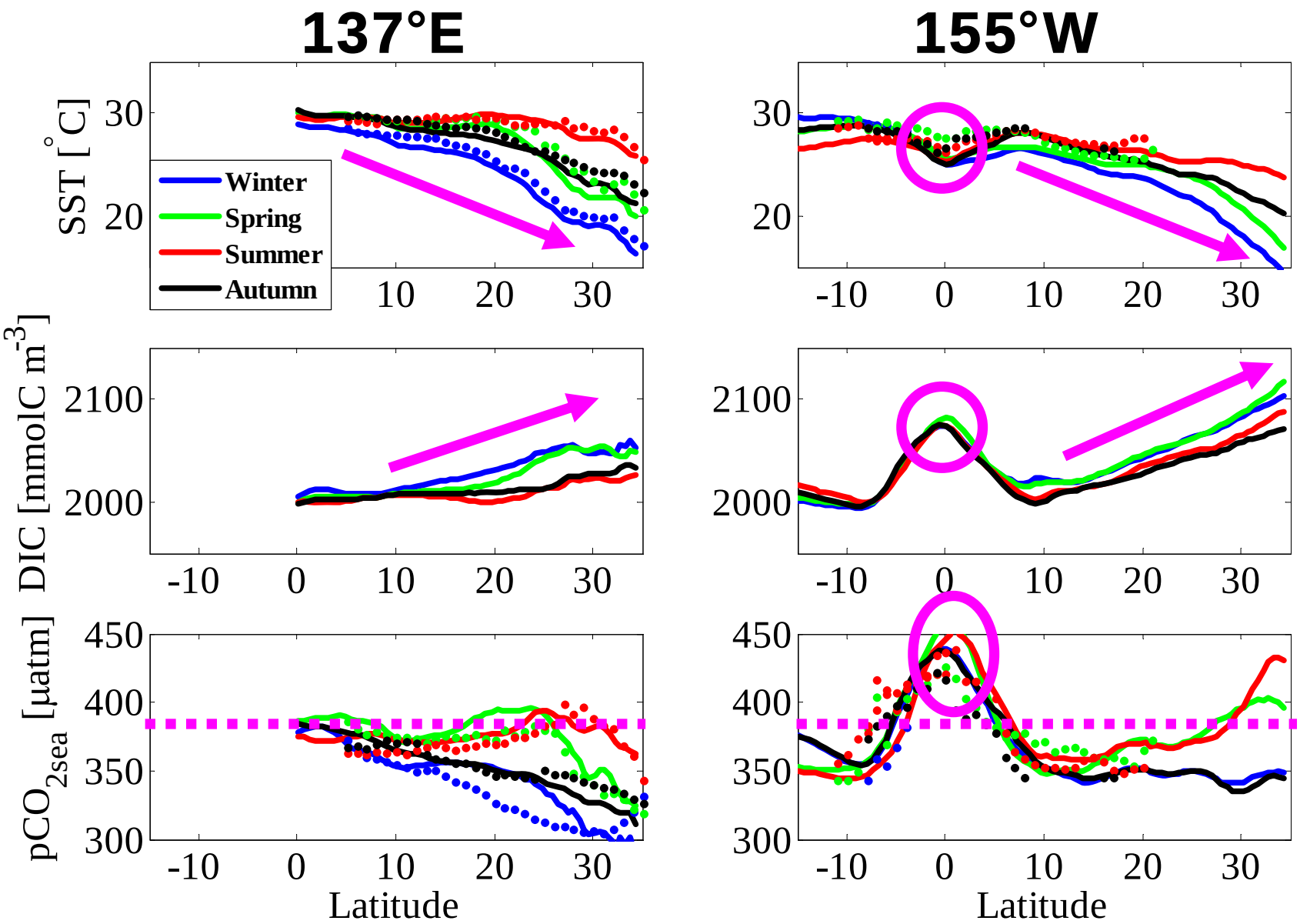
by DIC (C)

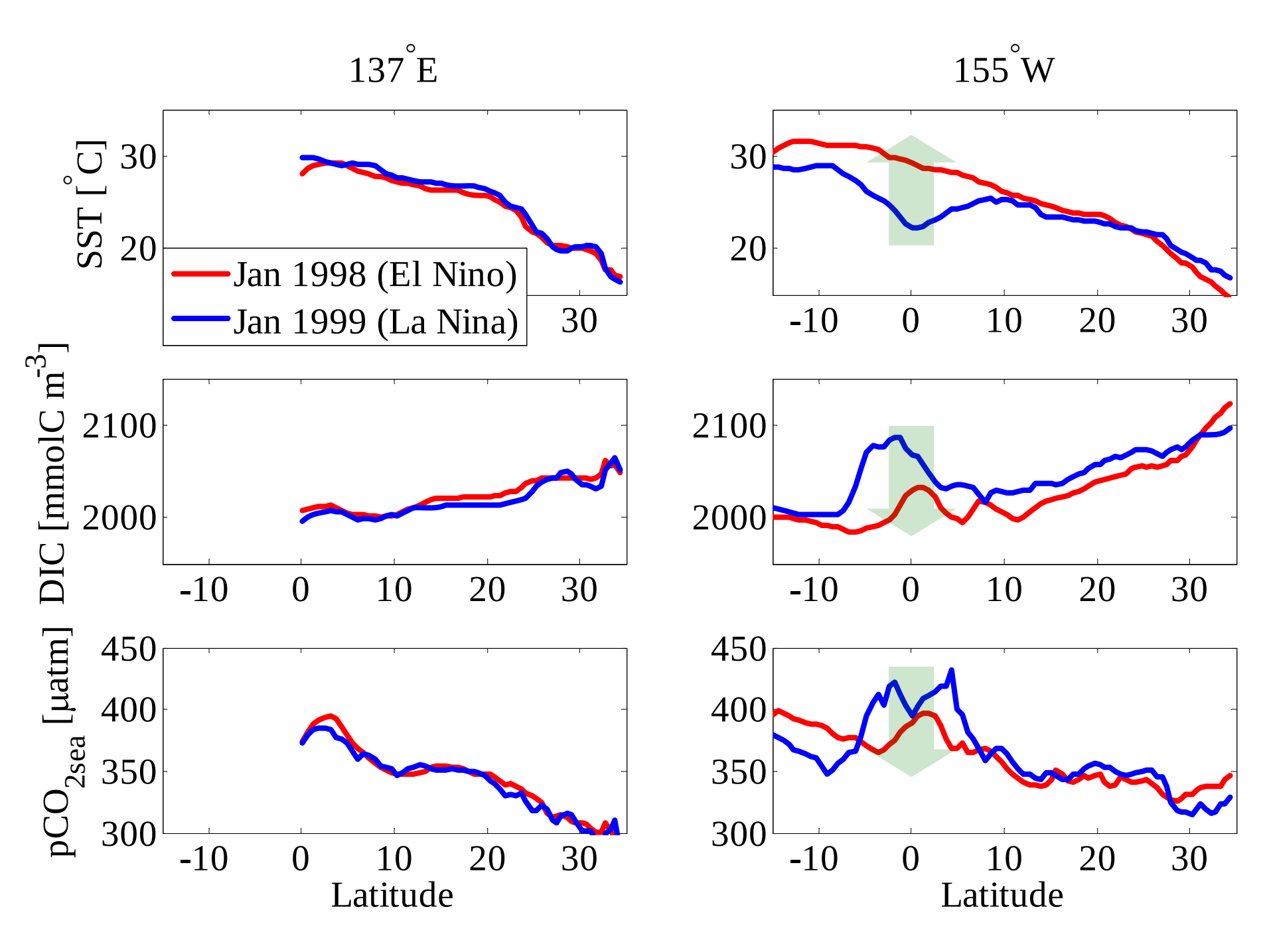
pCO_{2sea} change (A)

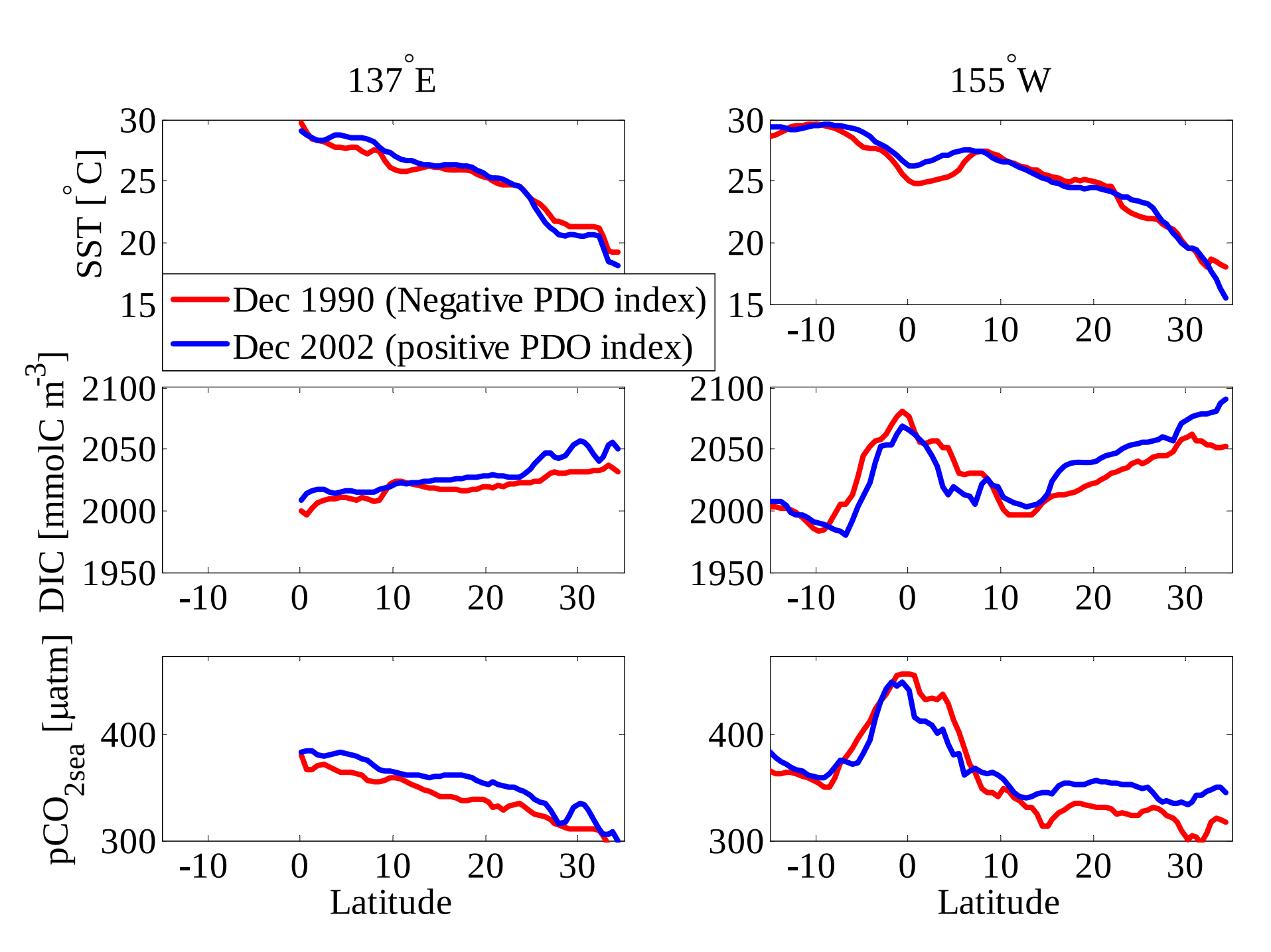


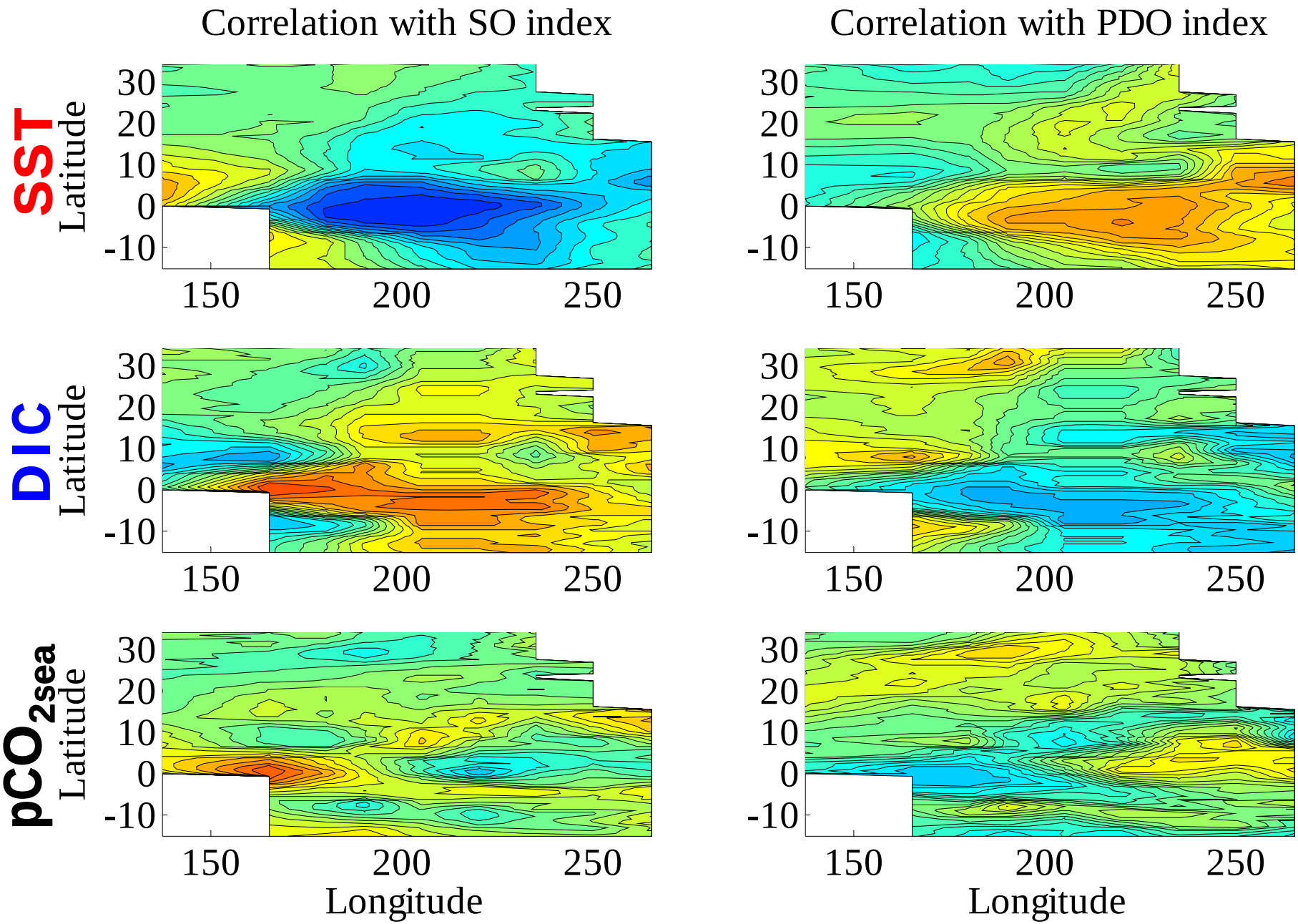


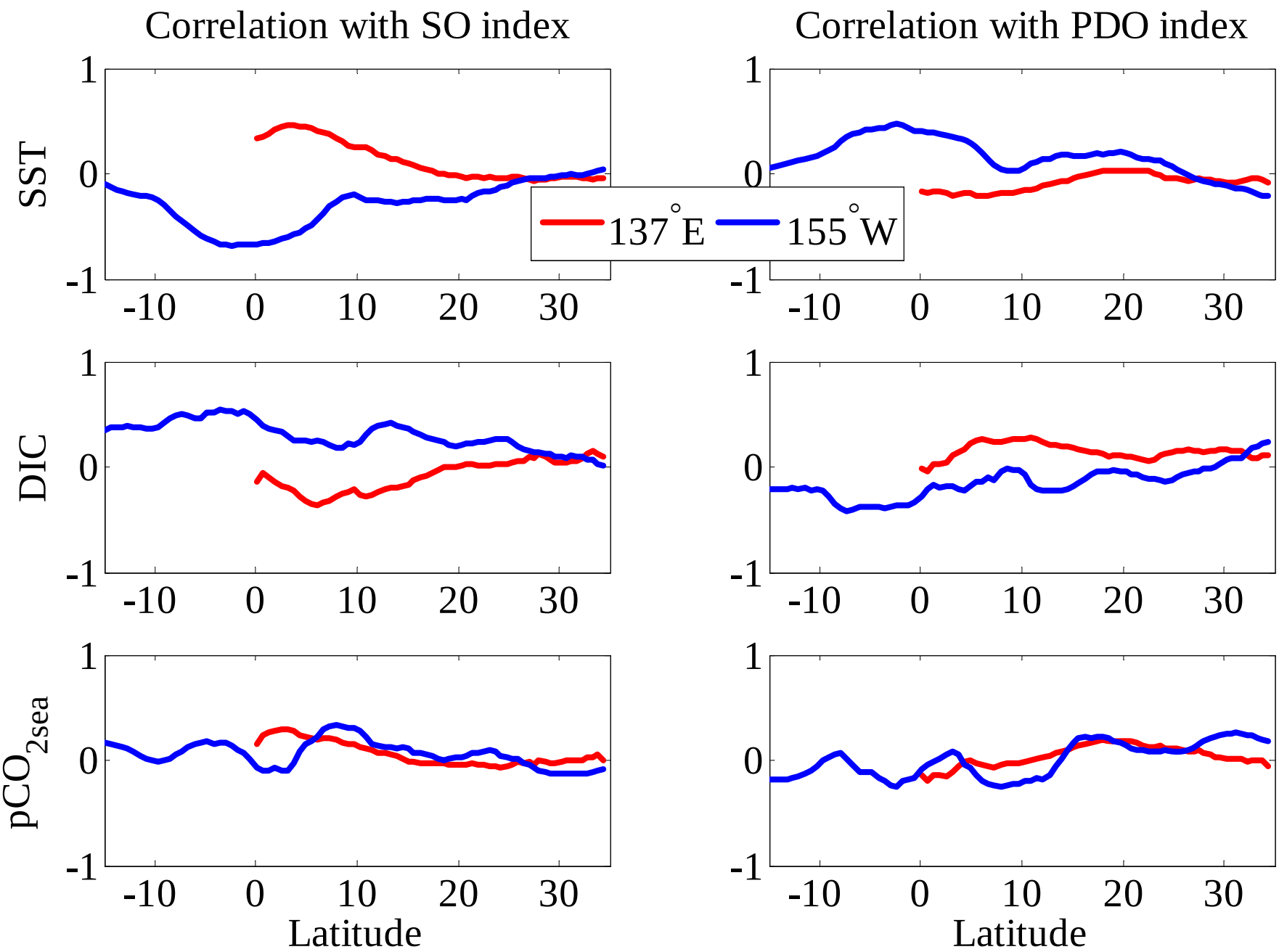
Seasonal variation

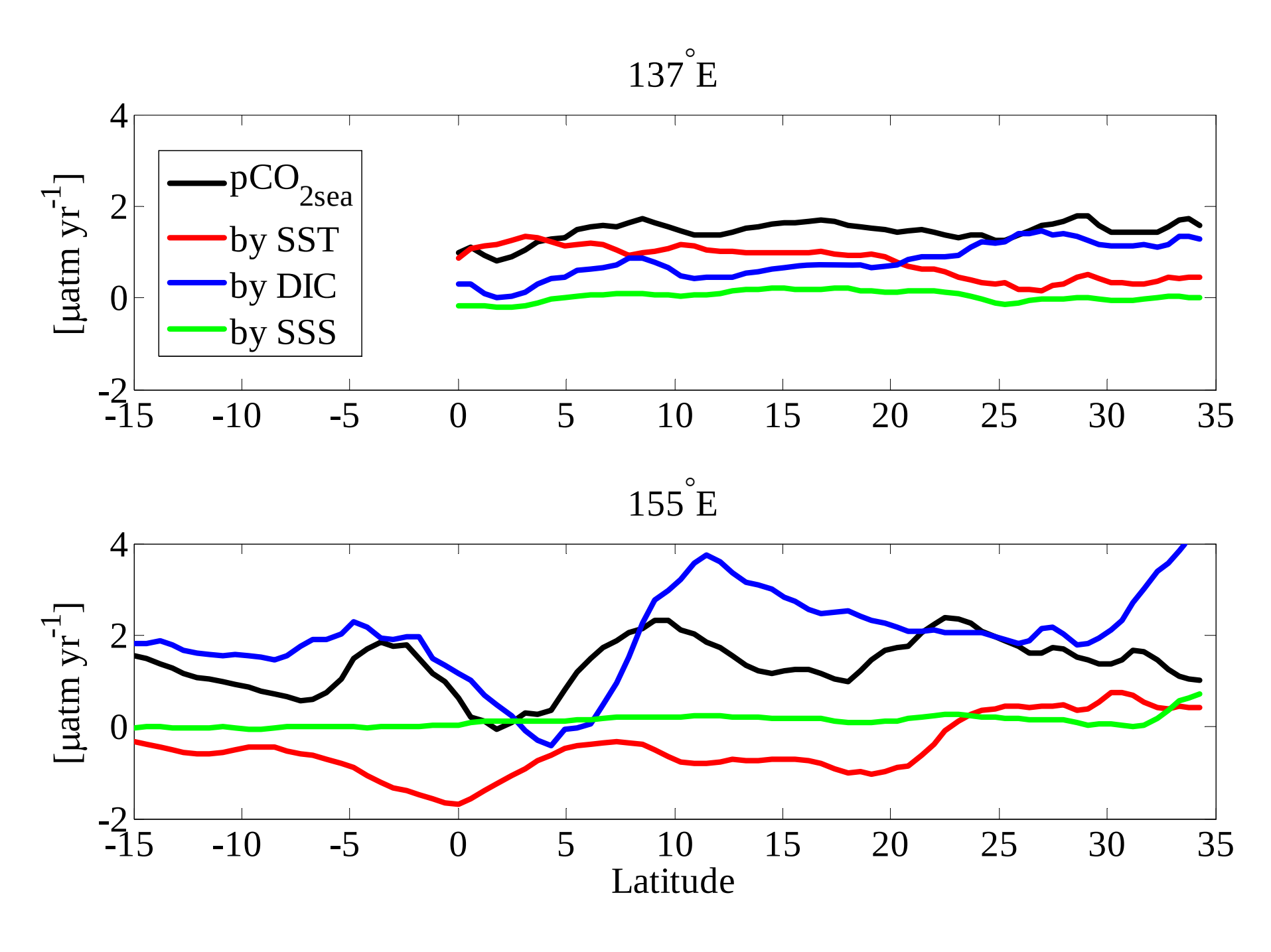



137°E
155°W
SST [°C]
DIC [mmolC m-3]
pCO2sea [µatm]
Jan 1998 (El Nino)
Jan 1999 (La Nina)
Latitude
Latitude

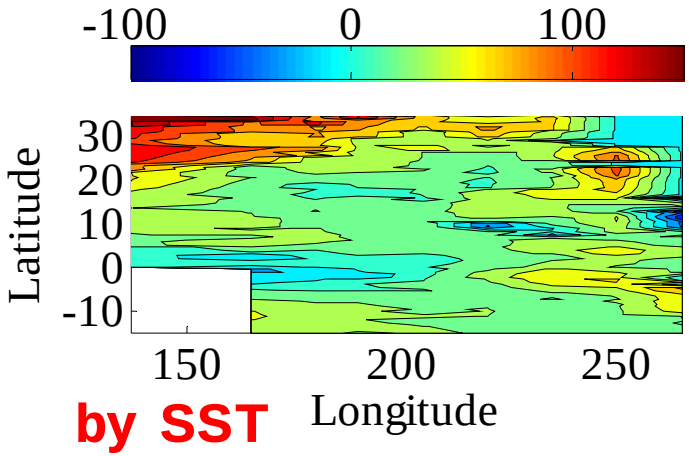

137°E
155°W
SST [°C]
DIC [mmolC m-3]
pCO2sea [µatm]
Dec 1990 (Negative PDO index)
Dec 2002 (positive PDO index)
30
25
20
15
2100
2050
2000
1950
400
300
-10
0
10
20
30
Latitude


Correlation with SO index
Correlation with PDO index
SST
DIC
pCO2sea
Latitude
Longitude
30
20
10
0
-10
150
200
250

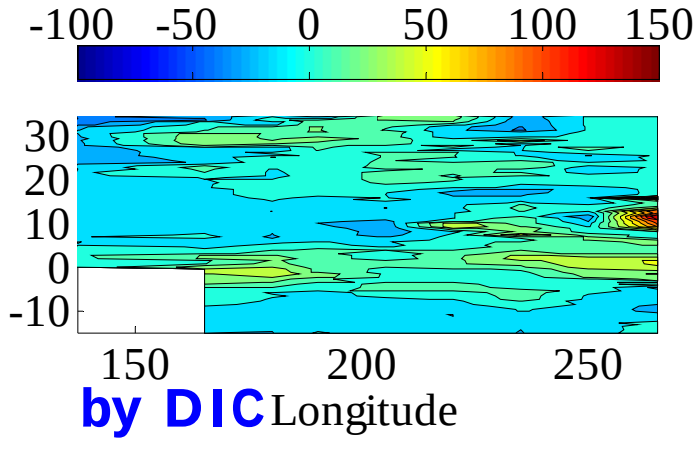

Correlation with SO index
Correlation with PDO index
SST
DIC
pCO2sea
137°E
155°W
1
0
-1
-10
0
10
20
30
Latitude


137°E
155°E
pCO2sea
by SST
by DIC
by SSS
[μatm yr-1]
Latitude
4
2
0
-2
-15
-10
-5
0
5
10
15
20
25
30
35

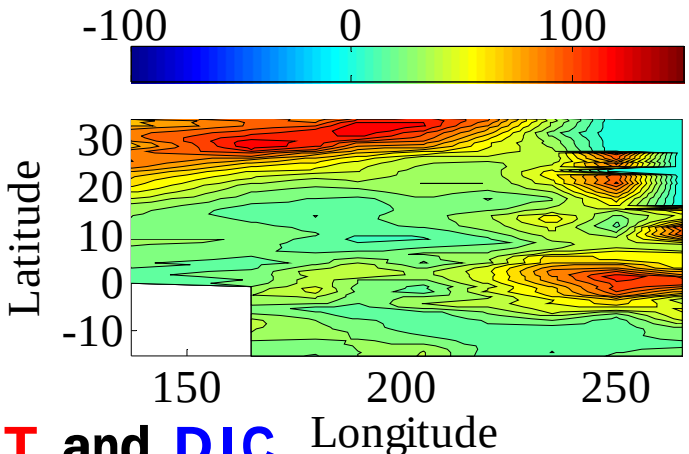
Seasonal pCO_{2sea} change by SST and DIC



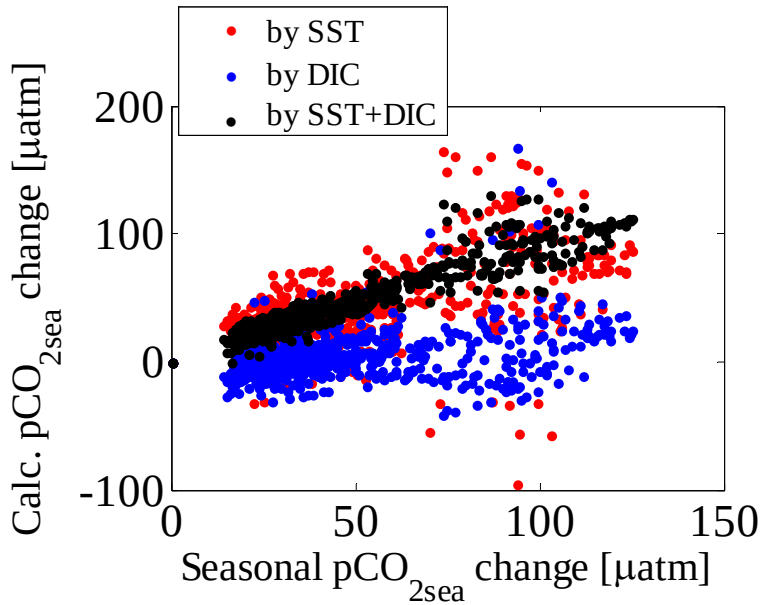
by SST



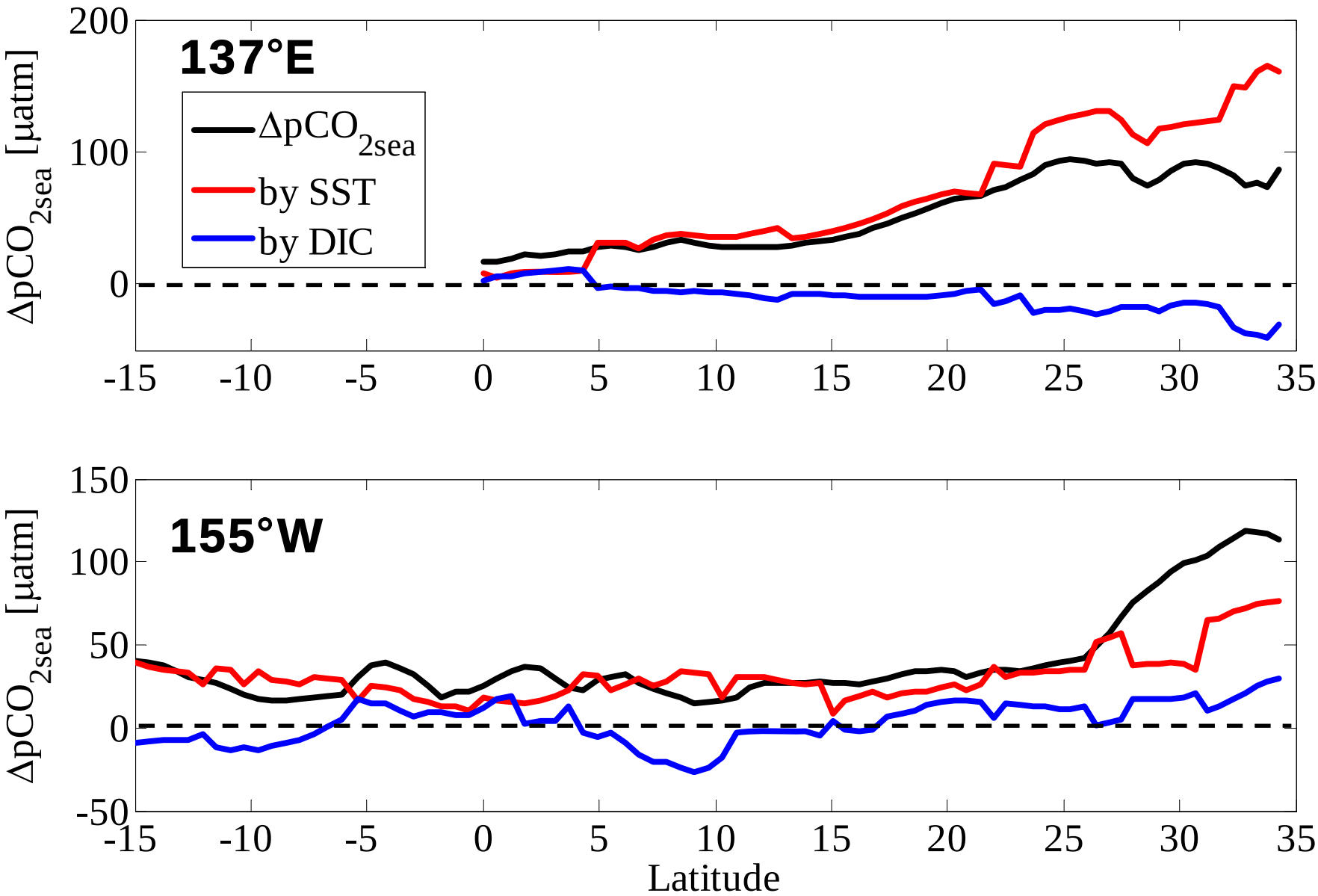
by DIC



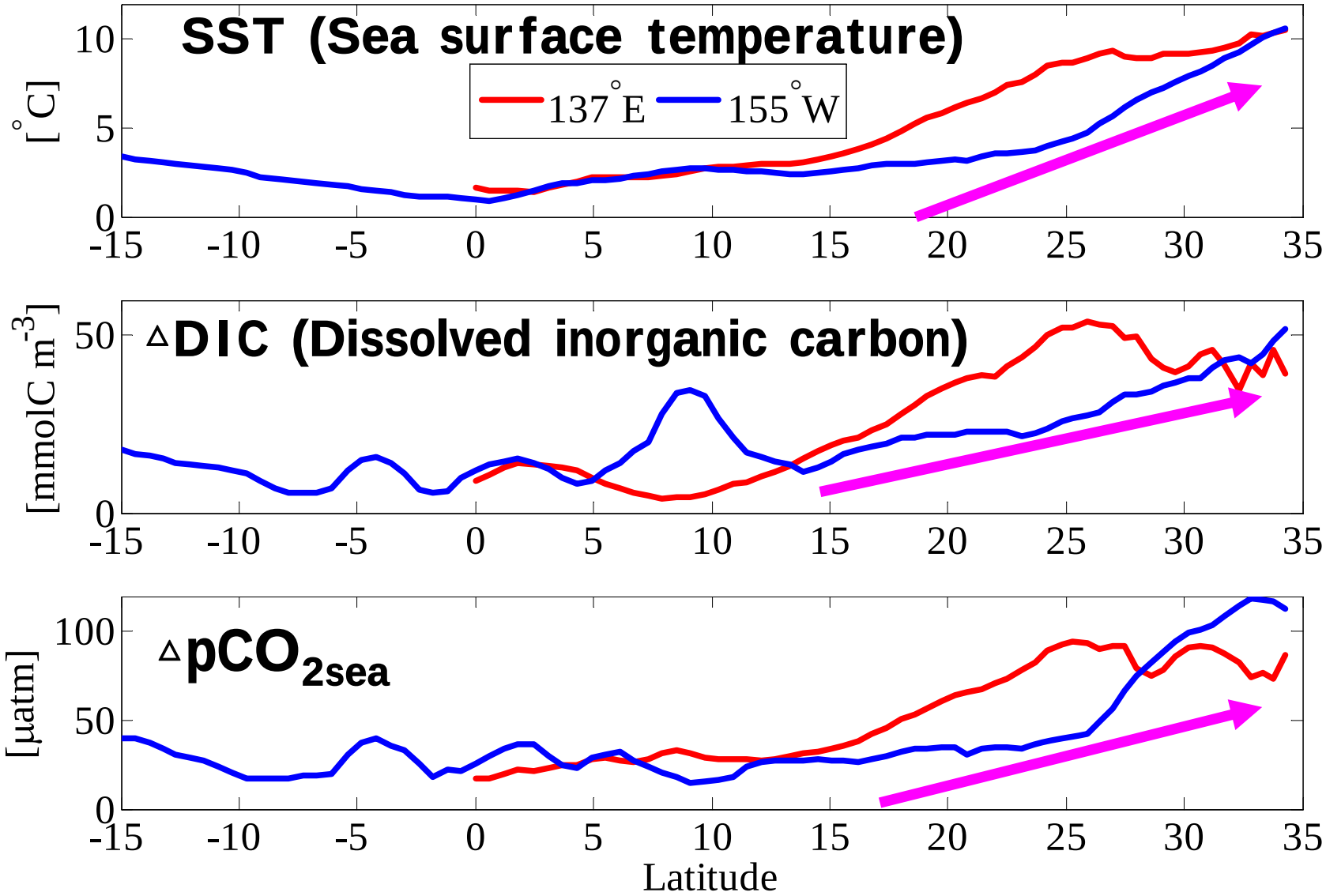
by SST and DIC



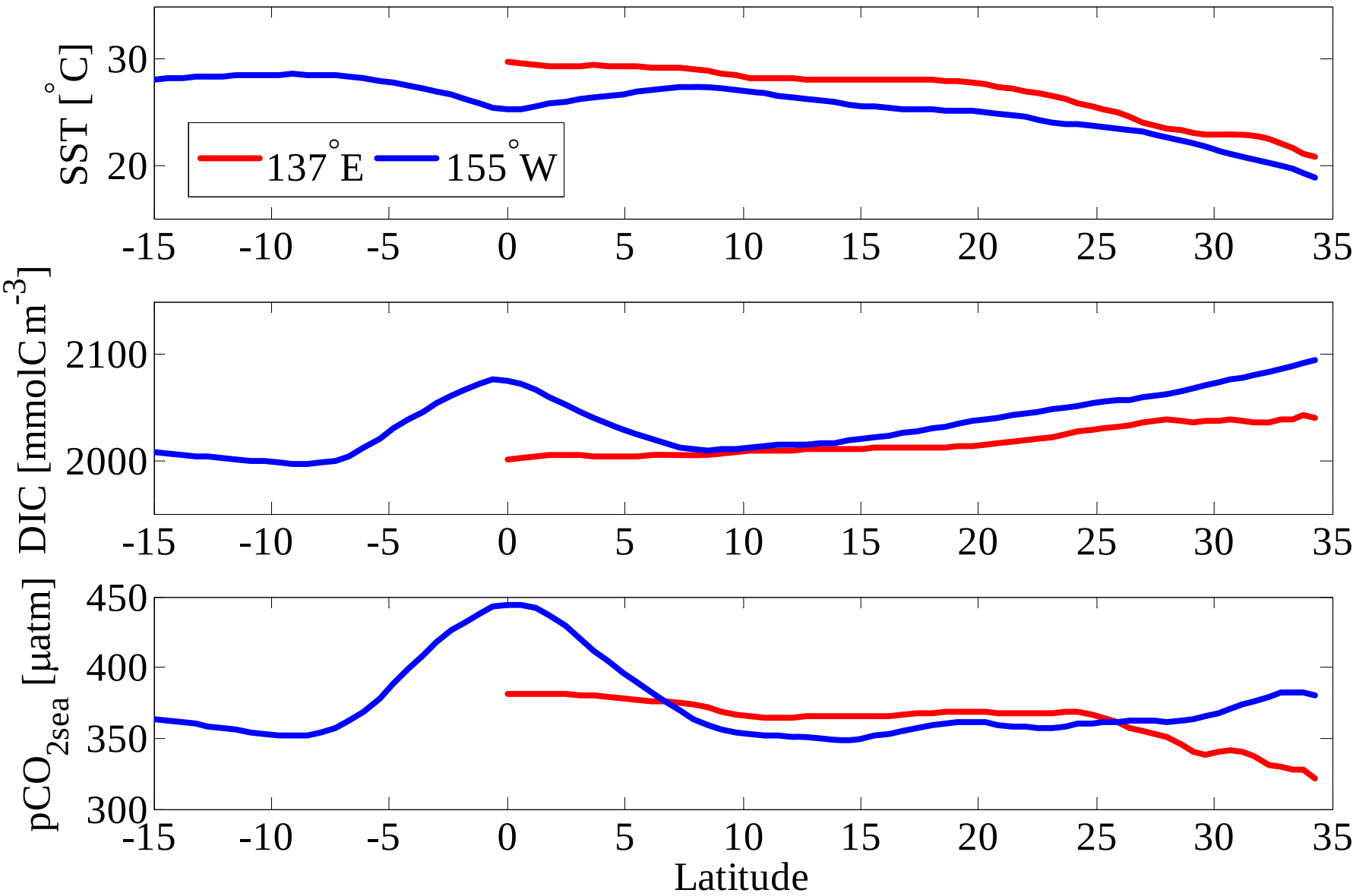
Seasonal pCO_{2sea} change by SST and DIC



Seasonal amplitude



Modeled annual-mean SST, DIC and pCO_{2sea}



pCO_{2sea} change by SST and DIC

Thermodynamic relationships (Takahashi et al., 1993)

$$dpCO_{2sea} = \frac{\partial pCO_{2sea}}{\partial T} dT + \frac{\partial pCO_{2sea}}{\partial DIC} dDIC + \frac{\partial pCO_{2sea}}{\partial S} dS + \frac{\partial pCO_{2sea}}{\partial TAlk} dTAlk,$$

$$= 0.0423\ pCO_{2sea}$$

$$= 8 \frac{pCO_{2sea}}{DIC}$$

$$dpCO_{2sea} \approx \frac{\partial pCO_{2sea}}{\partial T} dT + \frac{\partial pCO_{2sea}}{\partial DIC} dDIC$$