Interannual to Decadal Variability in Equatorial Pacific pCO2 and surface CO2 fluxes

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GOALS

1. Extension of OCMIP (Ocean Carbon Model Intercomparison Project): Use variety of NCEP-forced models to evaluate air-sea CO2 flux variability for equatorial Pacific: are model results convergent?

2. Long-timescale variability: “Regime shifts” of 1976/77 and 1997/98: CO2 signal?

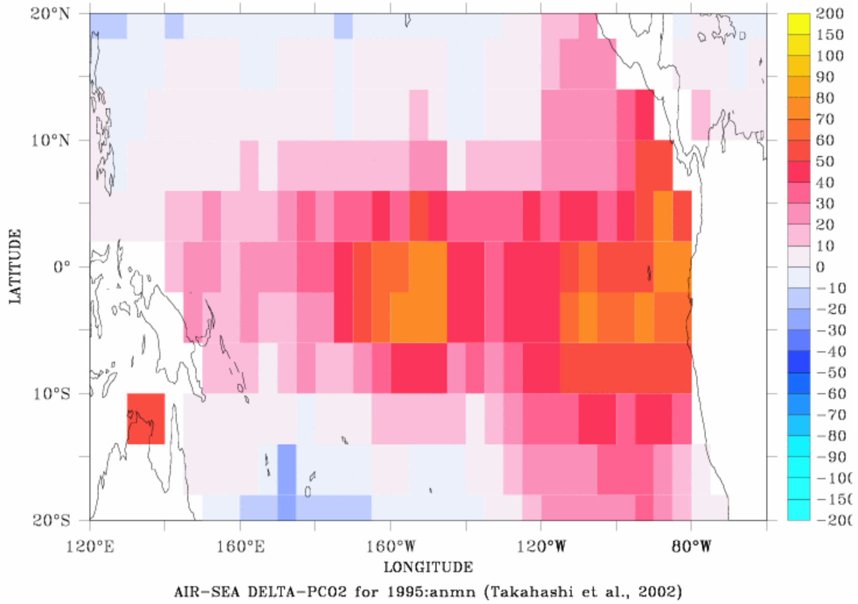
3. Application of model results to measurement community?

NCEP-FORCED MODEL EXPERIMENTS

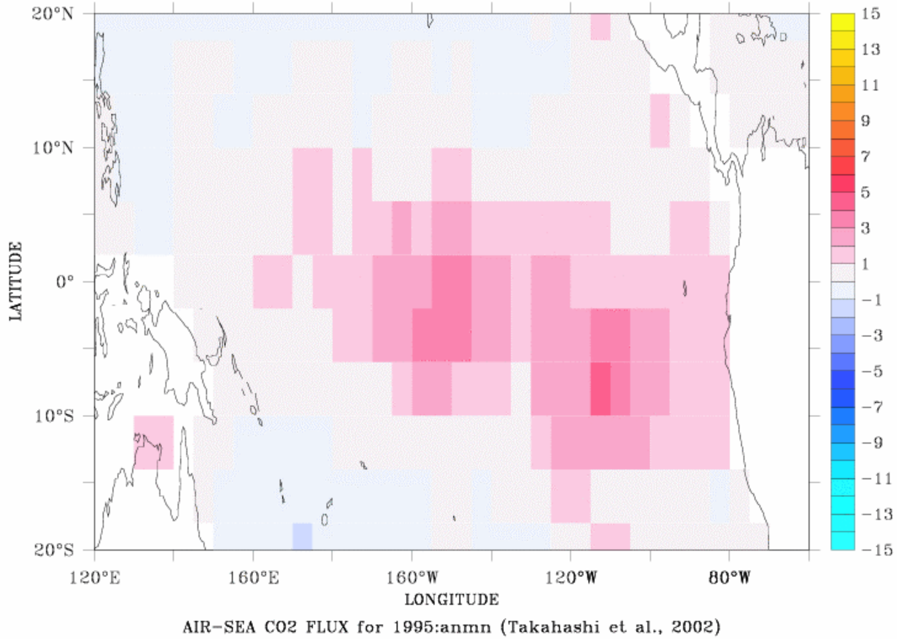
- NCOM (University of Maine)
- MPIOM1-HAMMOC5 (MPI Hamburg)
- MITgcm (University of Wisconsin)
- ORCA2/PISCES (LODYC)
- ORCA2/PISCEST (MPI Jena, Germany)
- COCO-NEMURO (Frontier, Japan)
- Gent-Cane (University of Maryland)

DATA PRODUCTS (TAKAHASHI, 2002)

AIR-SEA ΔpCO2



AIR-SEA CO2 FLUX



Does Sea surface pCO2 “track” atmosphere?

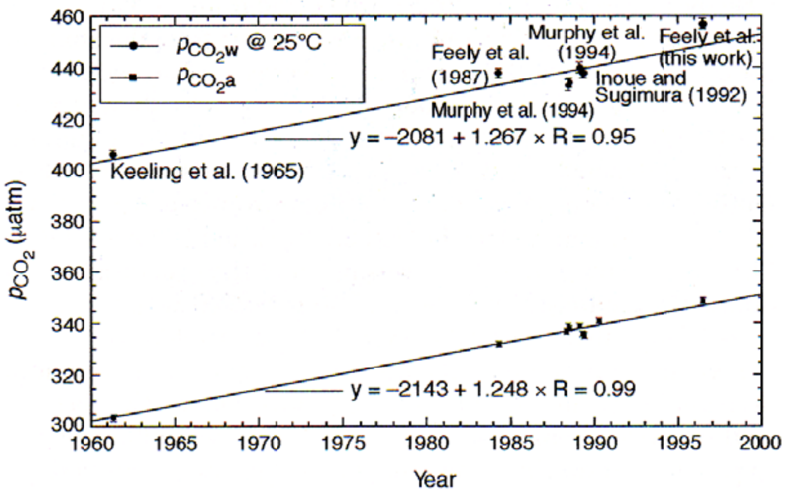
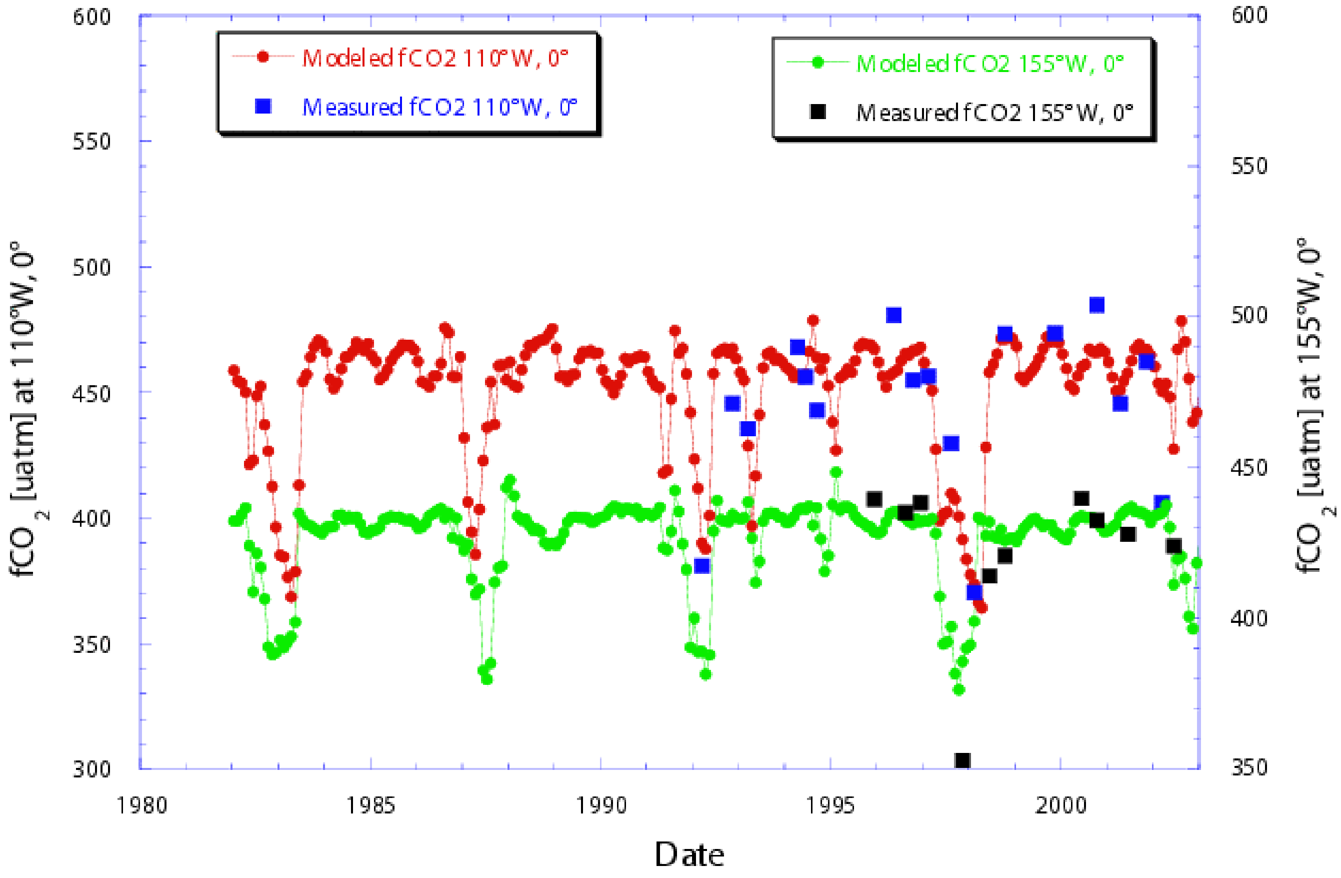


Figure 3 Long time series of seawater and atmospheric p_{CO_2}. The region of coverage is the central equatorial Pacific between 140° W and 160° W. The seawater values have been corrected to a constant temperature of 25 °C to remove the effect of temperature on CO_2 solubility. Data sources: 1961, Keeling *et al.*[30]; 1984, Feely *et al.*[7]; 1988, Murphy *et al.*[25]; 1989, Murphy *et al.*[25]; 1989, Inoue and Sugimura[8]; 1996, Feely *et al.* (this work).

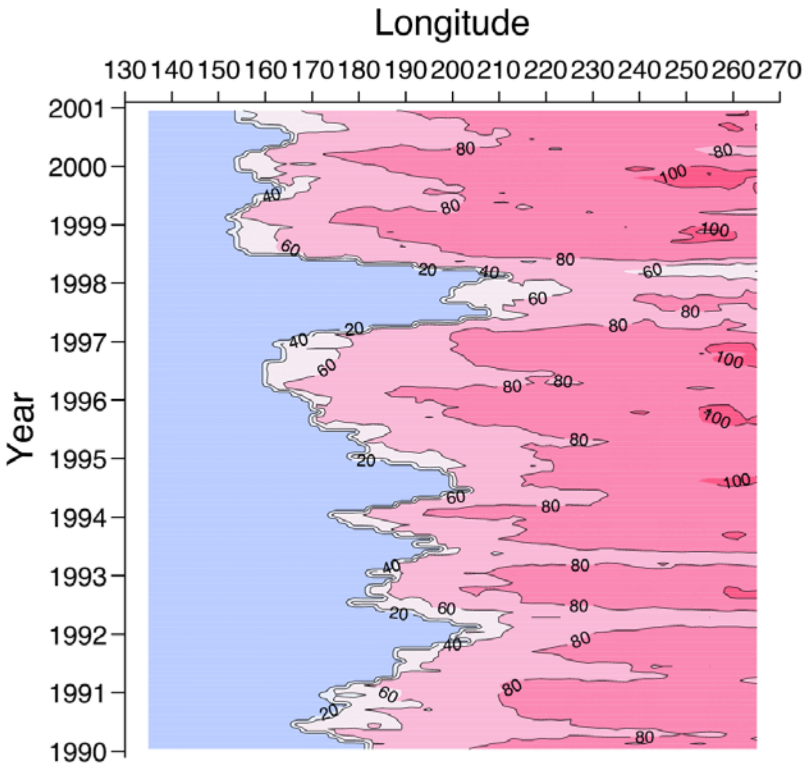
Feely et al., 1999

Cosca et al.



Modeled fCO2 110°W, 0°
Measured fCO2 110°W, 0°
Modeled fCO2 155°W, 0°
Measured fCO2 155°W, 0°
600
550
500
450
400
350
300
600
550
500
450
400
350
1980
1985
1990
1995
2000
Date
fCO2 [uatm] at 110°W, 0°
fCO2 [uatm] at 155°W, 0°

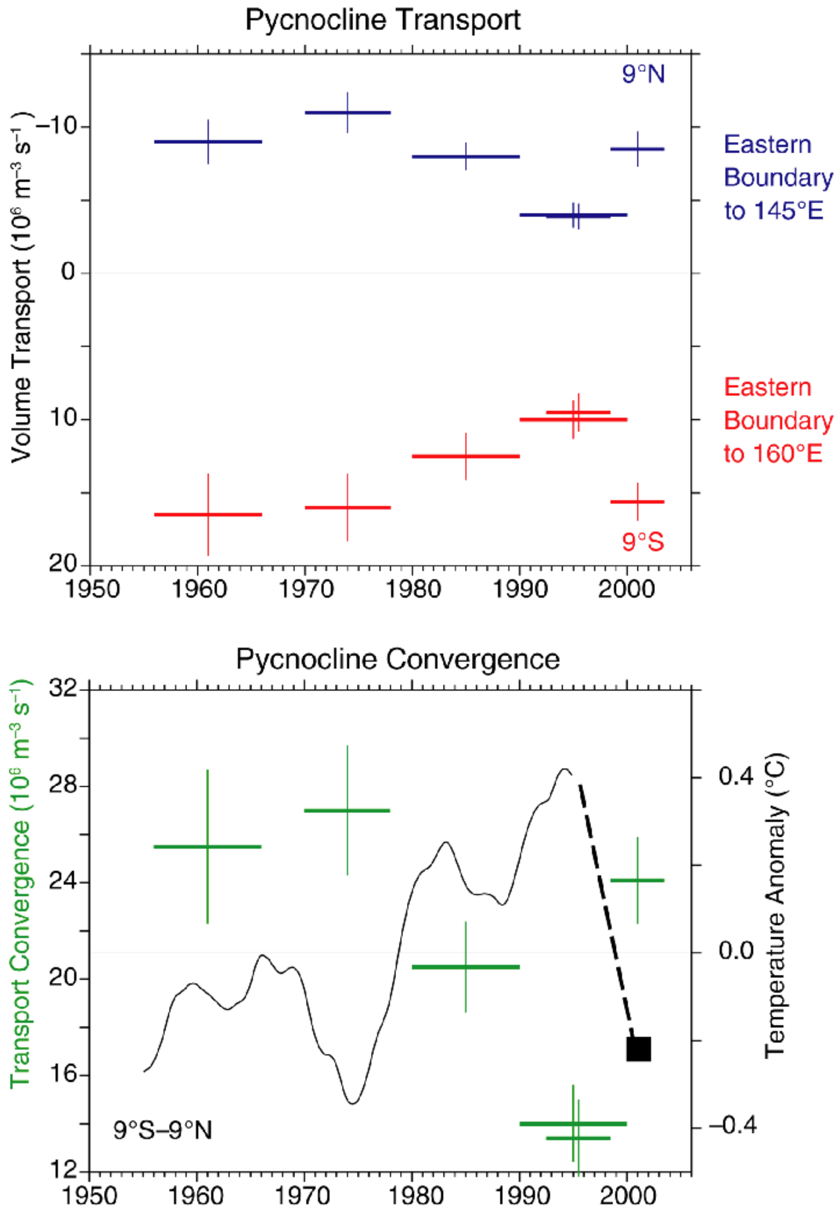
ΔpCO2 along Equator (Ishii et al, 2004)



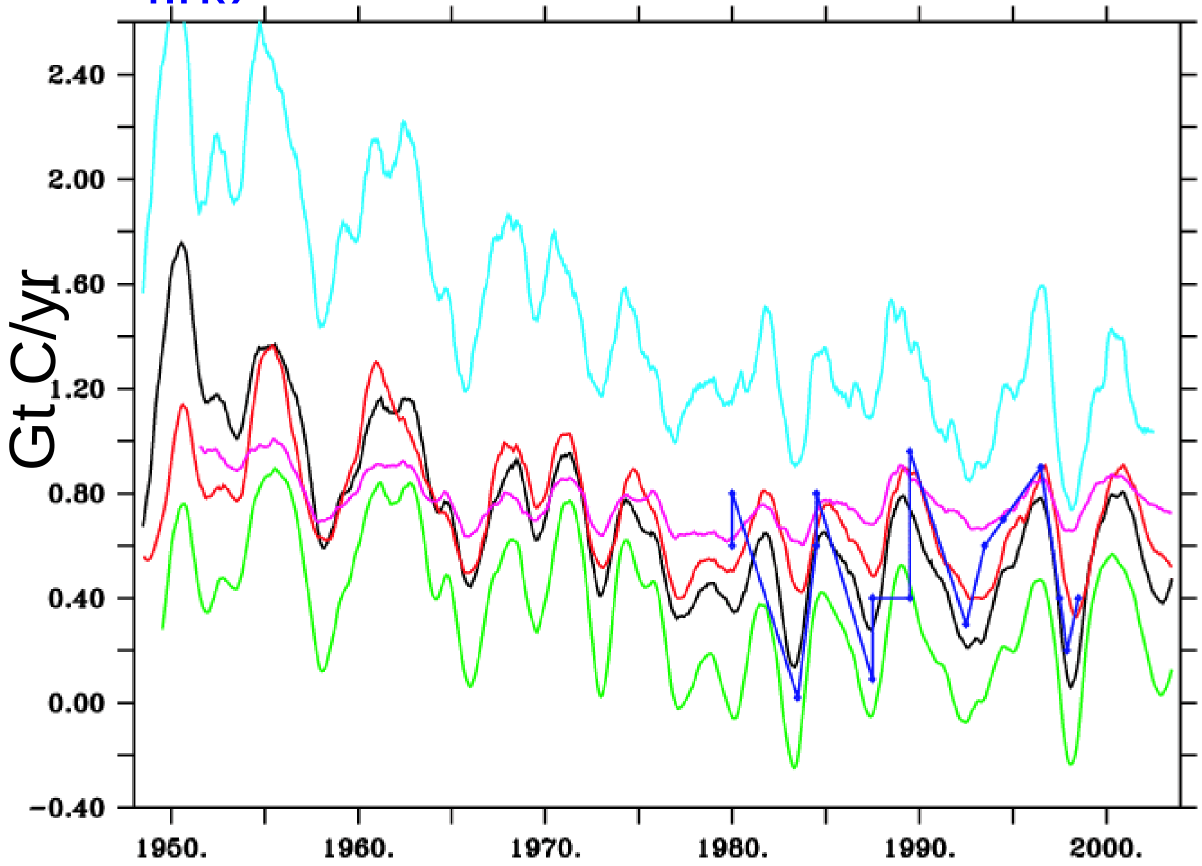
Changes in sea surface ΔpCO2 over period 1990-2001

Zhang and McPhaden (GRL, 2004)

Extension of earlier study (McPhaden and Zhang, 2002), argues for return to pre-1976 condition after 1997/1998 El Nino event in large-scale circulation of Equatorial Pacific



Equatorial Pacific (15°N-15°S) CO_2 outgassing flux



Black = ORCA2-PISCES (LODYC, France)
Red = MPI-OM1/HAMMOC5 (MPI, Hamburg, Ger
Pink = Gent-Cane etc. (Univeristy of Maryland)
Green = ORCA2-PISCES-T (MPI Jena, Germany)
Lt.Blue = COCO-NEMURO

Dark Blue: data product from Feely et al. 2002

Models tend to capture “amplitude” of interannual variability during 1980s and 1990s;
Evidence for decadal “shift” in 1976/77, but no strong “shift” following 1997/98 El Nino event

CO2 outgassing flux (monthly mean & filtered): 1980-2003

Black = ORCA2-PISCES (LODYC, France)
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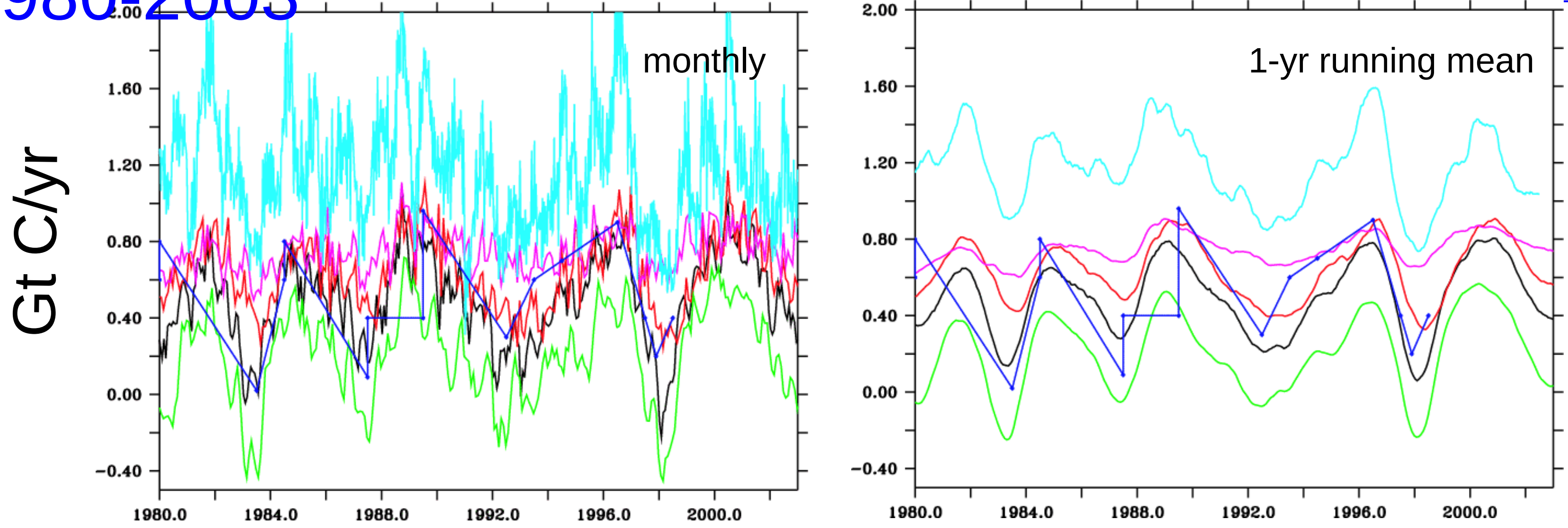
Lt.Blue=COCO-NEMURO [Frontier]

Dark Blue: data product of Feely et al. 2002



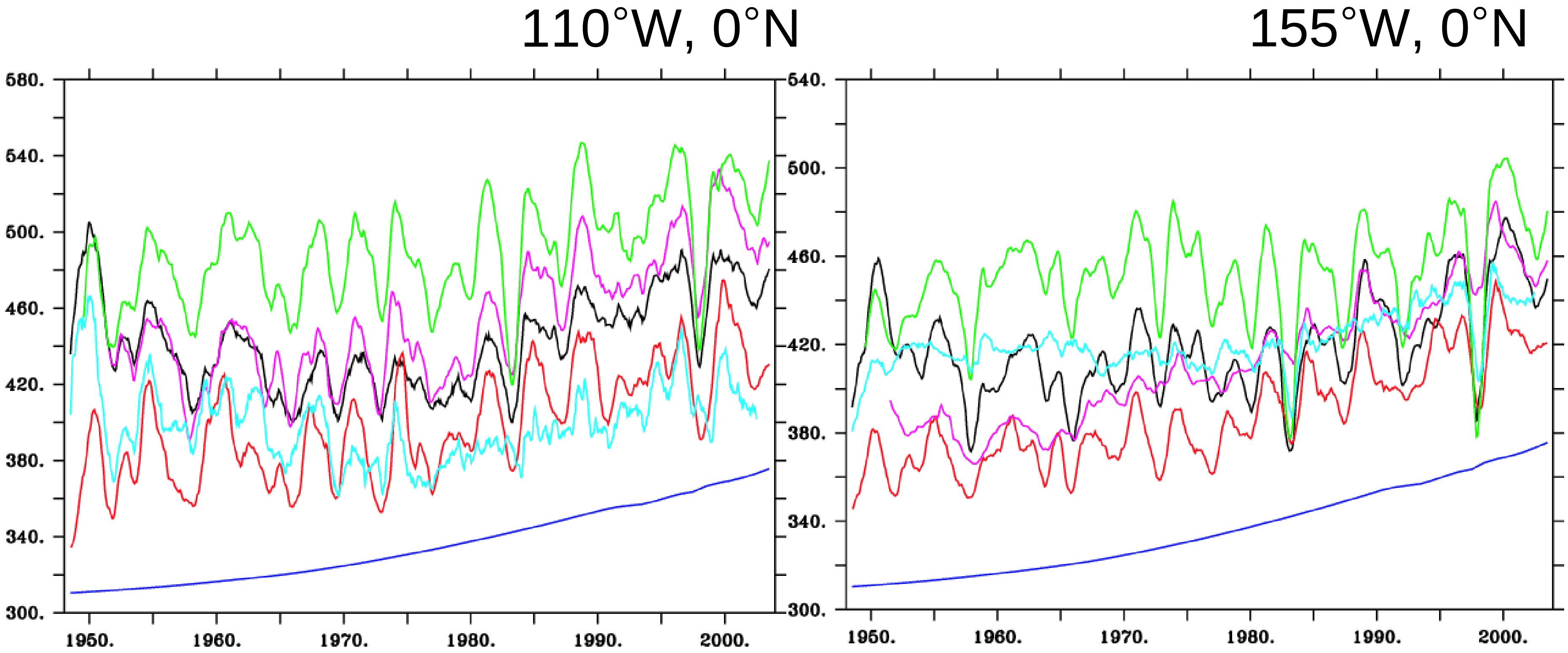
Models exhibit relatively consistent temporal variability
However, differ in “mean state”;

One model with weekly output (COCO-NEMURO) emphasizes significant variability over wide range of timescales

Sea Surface pCO2 over 1948-2003 (model results with 1-year running mean filter)

Black = ORCA2-PISCES (LODYC, France)
Red = MPI-OM1/HAMMOC5 (MPI, Hamburg, Germany)
Pink = Gent-Cane etc. (University of Maryland)
Green = ORCA2-PISCES-T (MPI Jena, Germany)
Lt.Blue = COCO-NEMURO

Dark Blue: atmospheric CO2



Models exhibit increase in sea surface pCO2 over 1948-2003, but does surface ocean track atmosphere?

Sea Surface Δ**pCO2** over 1948-2003

Black = ORCA2-PISCES (LODYC, France)
Red = MPI-OM1/HAMMOC5 (MPI, Hamburg, Germany)
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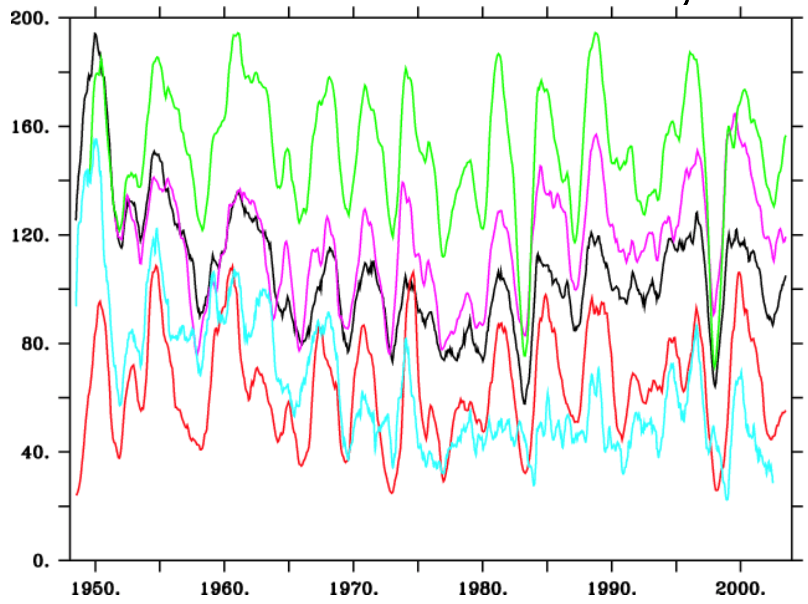
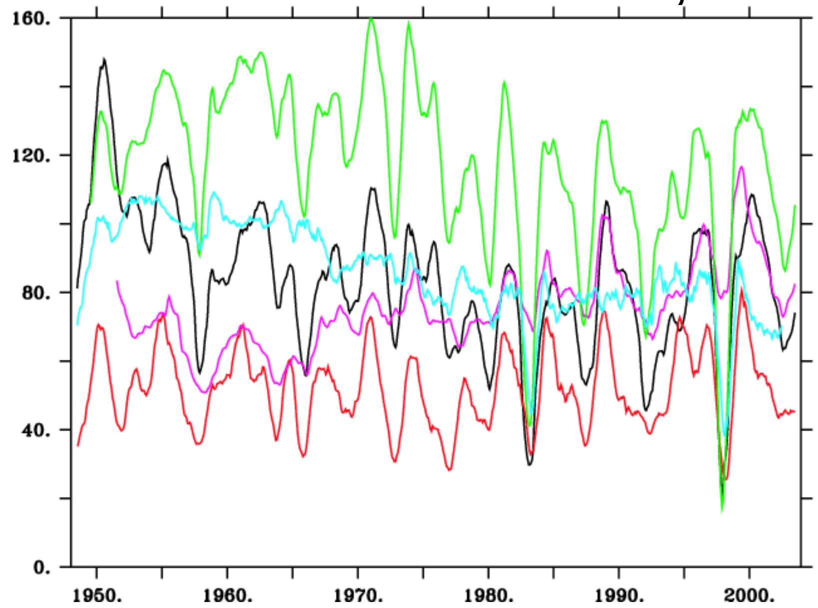
110°W, 0°N



155°W, 0°N



At 155°W, models with larger ΔpCO2 are not tracking atmosphere; Realistic ??? For computationally expensive runs difficult to separate model drift from “signal” (need for control run without anthropogenic CO2 transient)

Significant variability over range of timescales - potential for aliasing problems with few observations

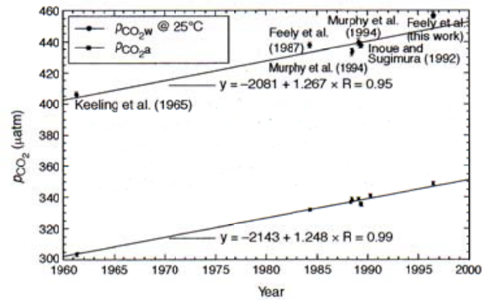
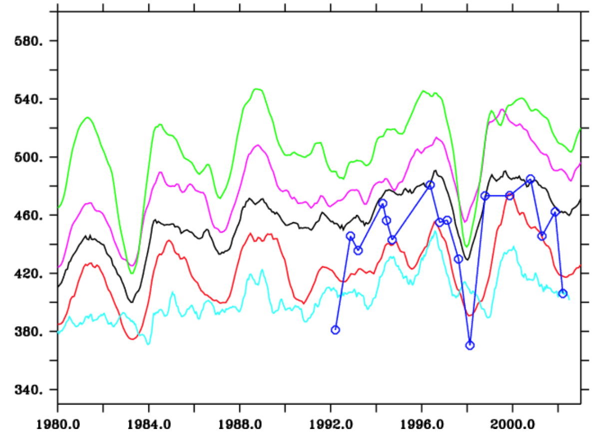


Figure 3 Long time series of seawater and atmospheric p_{CO_2}. The region of coverage is the central equatorial Pacific between 140° W and 160° W. The seawater values have been corrected to a constant temperature of 25 °C to remove the effect of temperature on CO_2 solubility. Data sources: 1961, Keeling *et al.*[30]; 1984, Feely *et al.*[7]; 1988, Murphy *et al.*[25]; 1989, Murphy *et al.*[25]; 1989, Inoue and Sugimura[8]; 1996, Feely *et al.* (this work).

MODEL-DATA COMPARISON AT 110°W, 0°N

pCO2 at 110°W, 0°N (1yr running mean)



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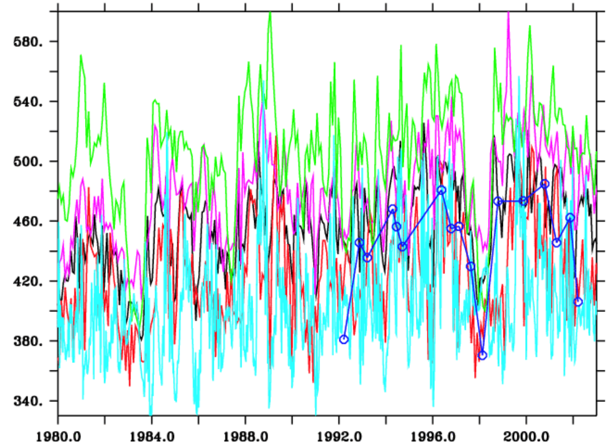
Green = ORCA2-PISCES-T (MPI Jena, Germany)
Lt.Blue = COCO-NEMURO

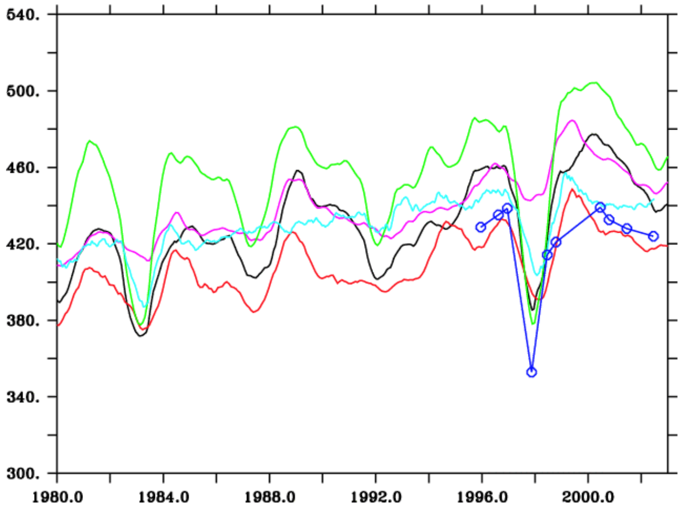
Dark Blue: data provided by Cathy Cosca

pCO2 at 110°W, 0°N (unfiltered)



MODEL-DATA COMPARISON AT 155°W, 0°N

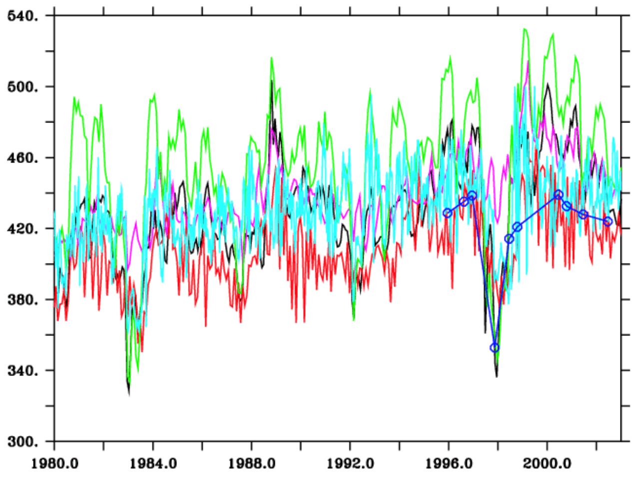
pCO2 at 155°W (1yr running mean)



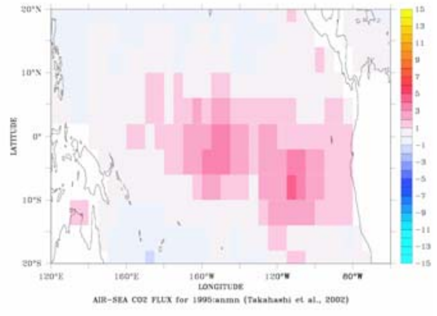
Black = ORCA2-PISCES (LODYC, France)
Red = MPI-OM1/HAMMOC5 (MPI, Hamburg, Germany)
Pink = Gent-Cane etc. (University of Maryland)
Green = ORCA2-PISCES-T (MPI Jena, Germany)
Lt.Blue = COCO-NEMURO

Dark Blue: data provided by Cathy Cosca

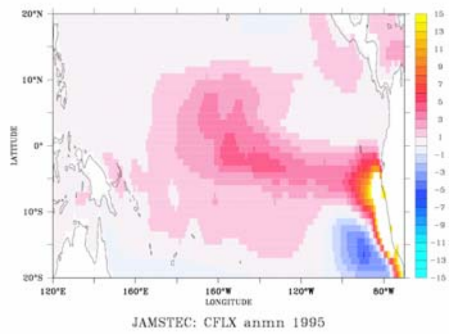
pCO2 at 155°W (1yr running mean)



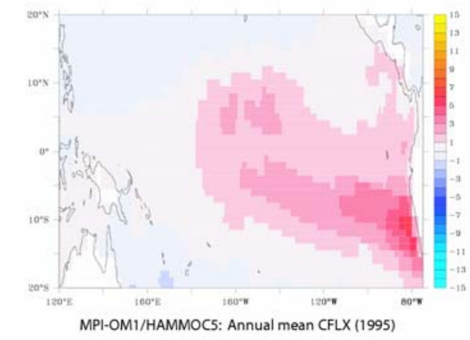
DATA (Takahashi)



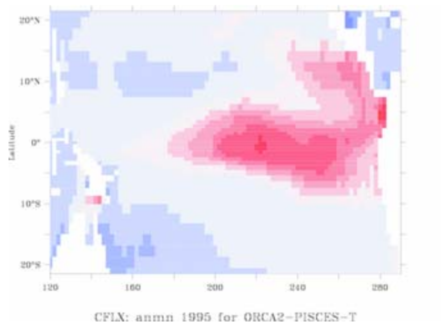
COC-NEMURO model



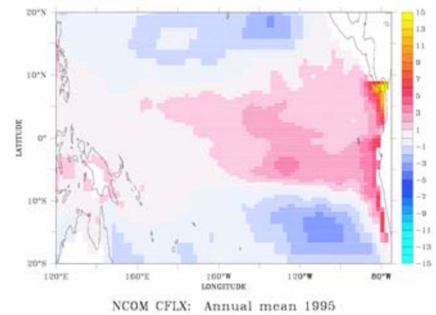
MPI-OM1/HAMMOC5 model



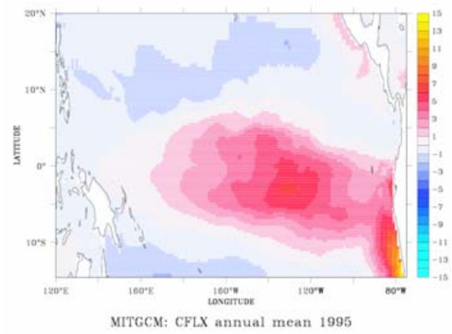
ORCA2/PISCES-T (Jena)



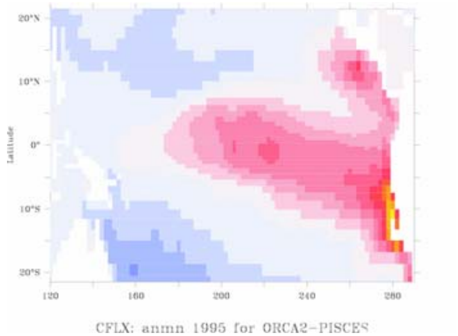
NCOM (U. Maine)



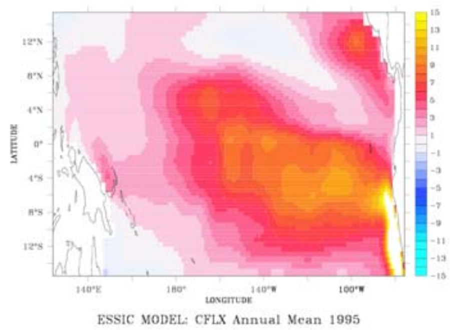
MIT model



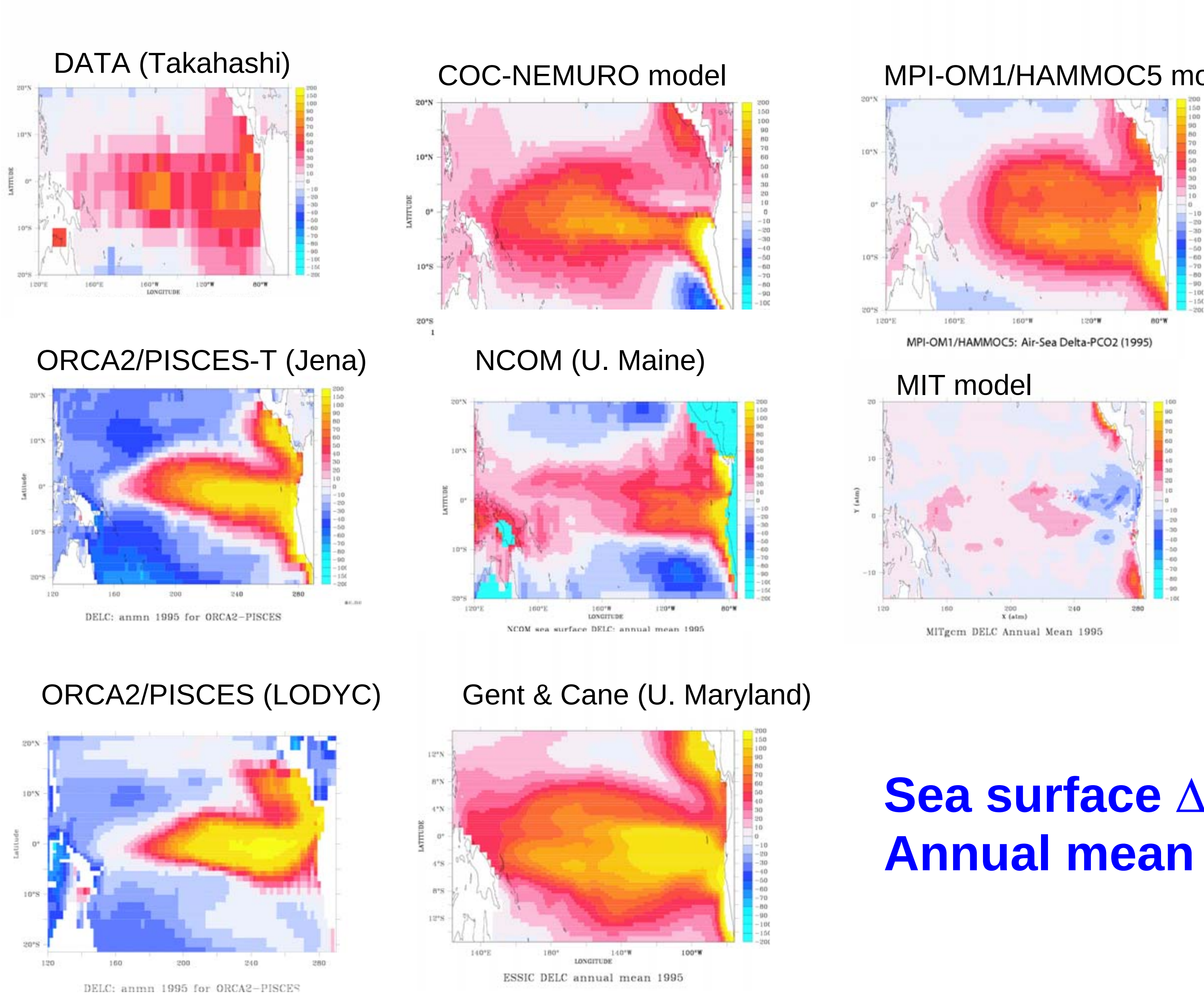
ORCA2/PISCES (LODYC)



Gent & Cane (U. Maryland)

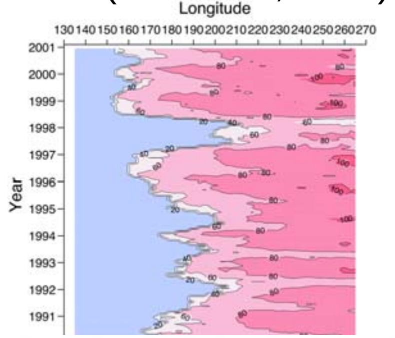


Air-Sea CO2 FLUX (moles/m^2/year) Annual mean for 1995

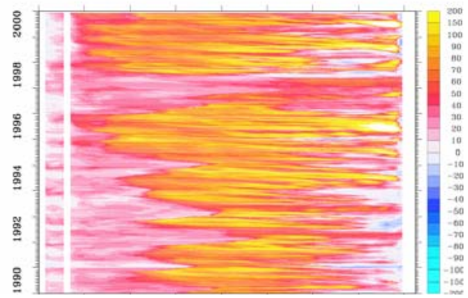


Sea surface ΔpCO2 Annual mean for 1995

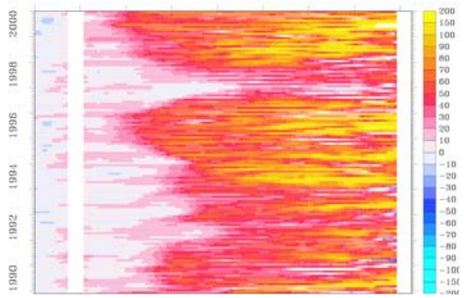
DATA (Ishii et al., 2004)



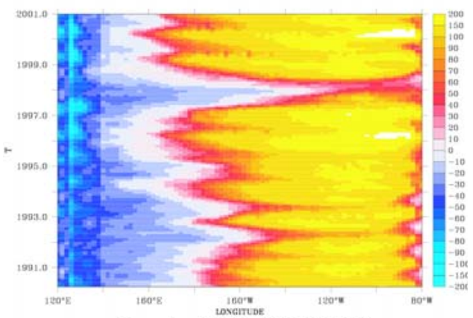
COC-NEMURO model



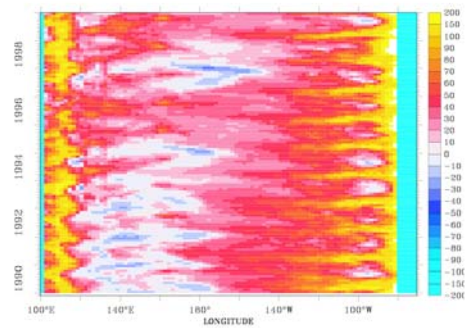
MPI-OM1/HAMMOC5 model



ORCA2/PISCES-T (Jena)

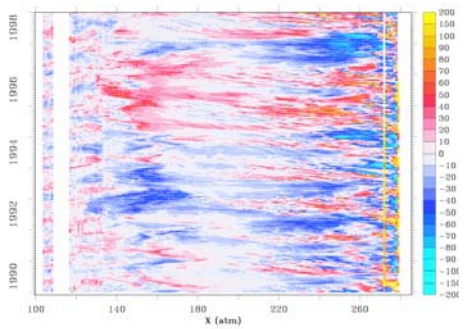


NCOM (U. Maine)



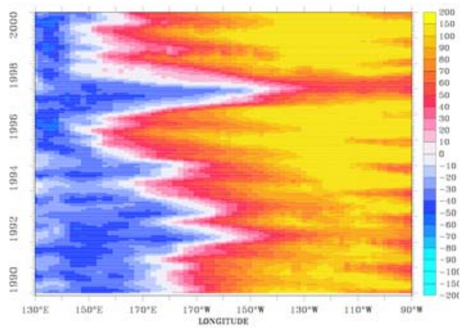
NCOM DELC 1990−1999

MIT model



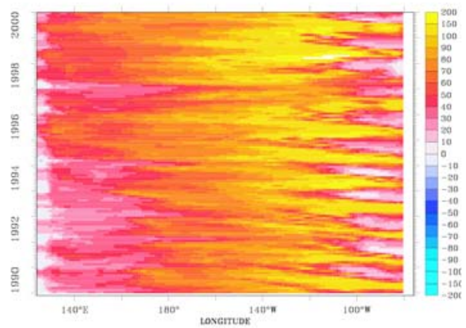
MITgcm DELC along 0°N (1990-1998)

ORCA2/PISCES (LODYC)



SS PCO2 for ORCA2/PISCES

Gent & Cane (U. Maryland)

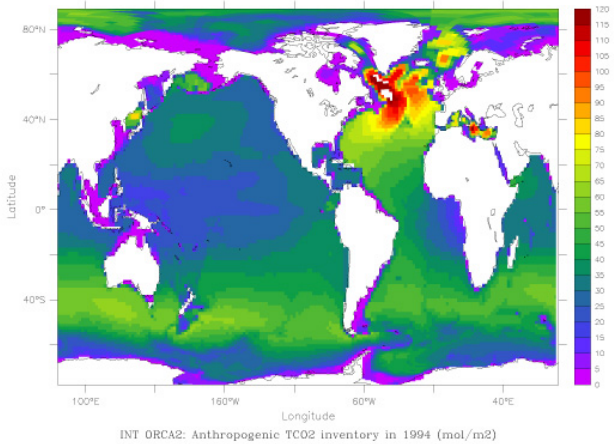


Partial pressure of CO2 (ppm)

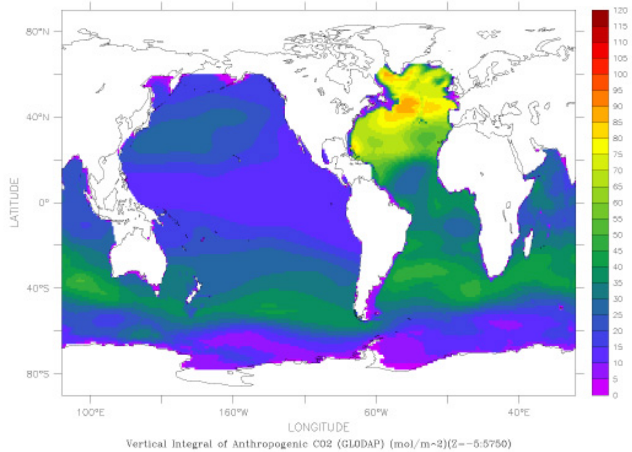
Hovmoller diagrams of ΔpCO_2 along equator

SENSITIVITY OF ANTHROPOGENIC CO2 UPTAKE IN 19
TO CLIMATOLOGICAL/INTERANNUAL FORCING FIELD

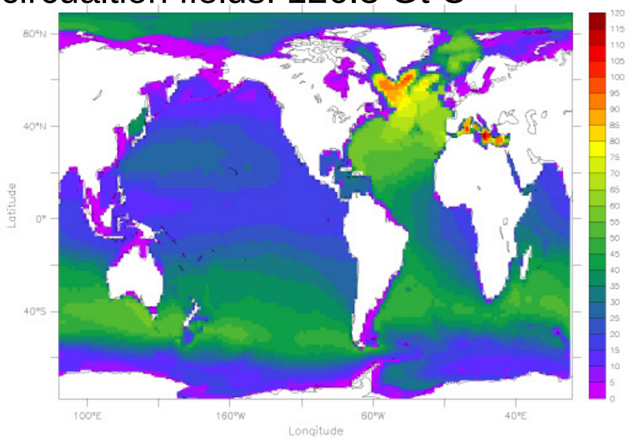
ORCA2-PISCES online with interannual
NCEP forcing: 154.9 Gt C



Sabine et al. (2004): 118 Gt C



ORCA2-PISCES offline with
climatological
(monthly mean) NCEP-forced
circualtion fields: 126.3 Gt C



=>23% larger with interannually varying forcing fields!!!

CONCLUSIONS

- Despite differences in mean state, models generally agree on amplitude of equatorial CO_2 outgassing variability over 1980s and 1990s
- NCEP-forced models exhibit “shift” in 1970s, but no equivalent “shift” is evident for post 1997/1998 period
- Models reveal large variability for equatorial surface pCO_2 values over wide range of timescales
- Importance of including “control run” (w/o anthrogenic CO_2 forcing) given impossibility for the moment of running models to steady state