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Impact of increased CO2 levels in tropical climate and its variability

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Impact of increased CO_2 levels in tropical climate and its variability

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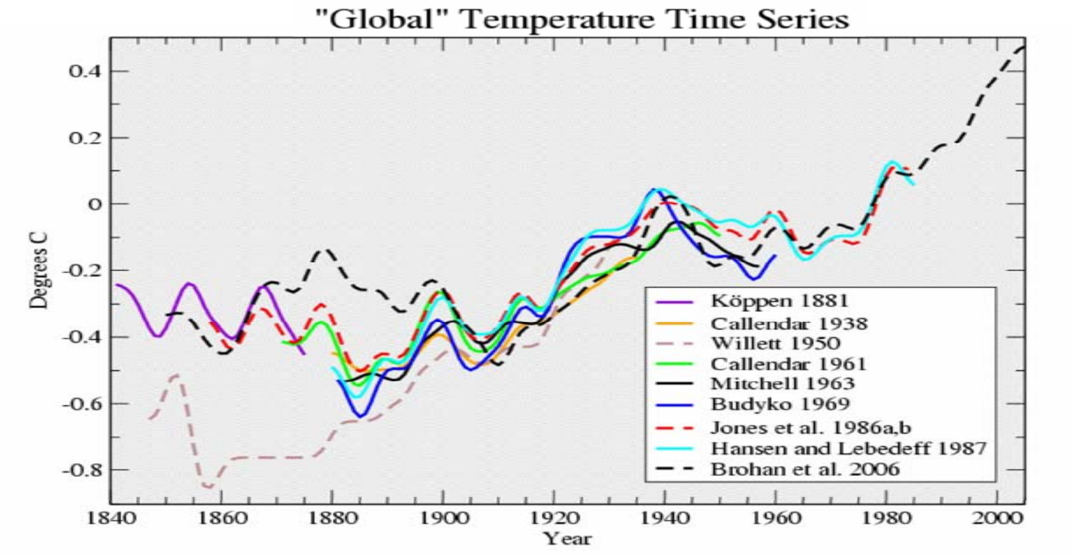
Outline

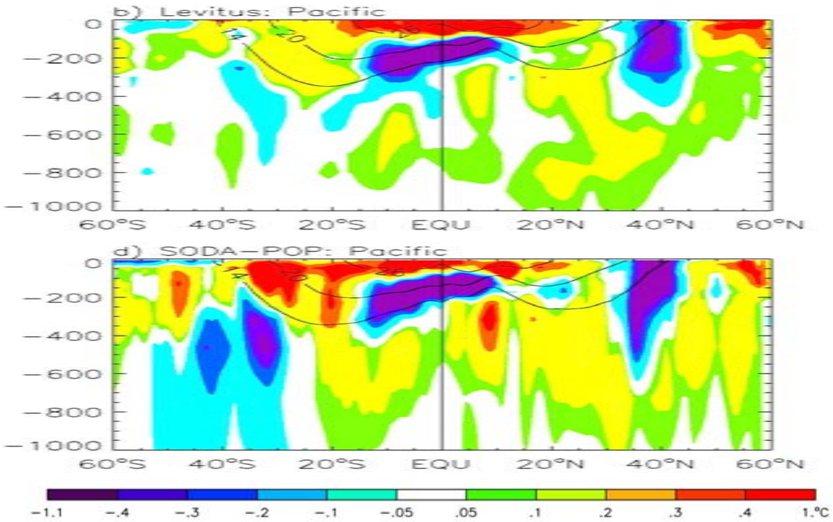
- Introduction
- Something about the model
- Setup of the experiment
- Mean state of tropics
- Analysis of the tropical variability
- Main conclusions

In the XX century the CO2 concentration in the atmosphere has increased. That increase has been accompanied by a raise in the global temperature (IPCC report, 1995; 2001)



Time series of surface temperature taken from land stations & ship reports. The longer one (black dashed) is a merging of land air temperature and sea surface temperature.

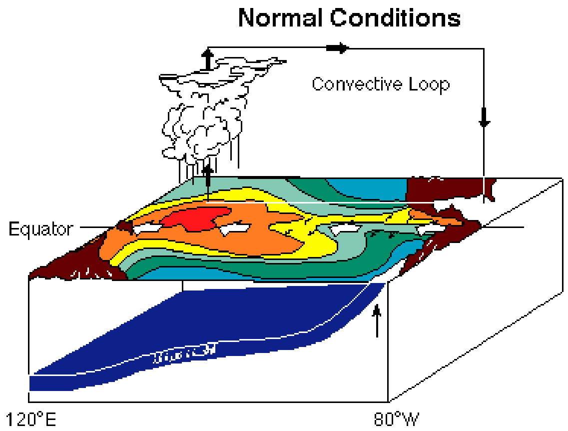
The general warming of global ocean has been associated to an increase in greenhouse gases concentration, which implies more surface heat flux into the ocean (e.g. Levitus et al., 2005)



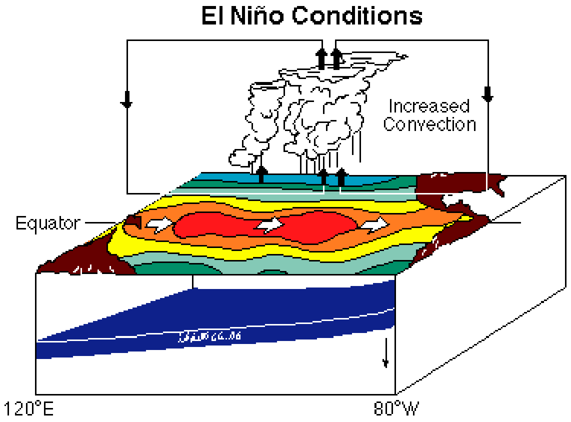
picture from Han et al.(2006)

A balanced heat budget at the ocean surface is a constraint for the thermal structure of the ocean: a decrease in heat loss in the higher latitudes may result in a deepened thermocline (Boccaletti et al., 2004)

ENSO is a free oscillation of the ocean-atmosphere system:
El Nino is the oceanic part, while Southern Oscillation is the atmospheric part

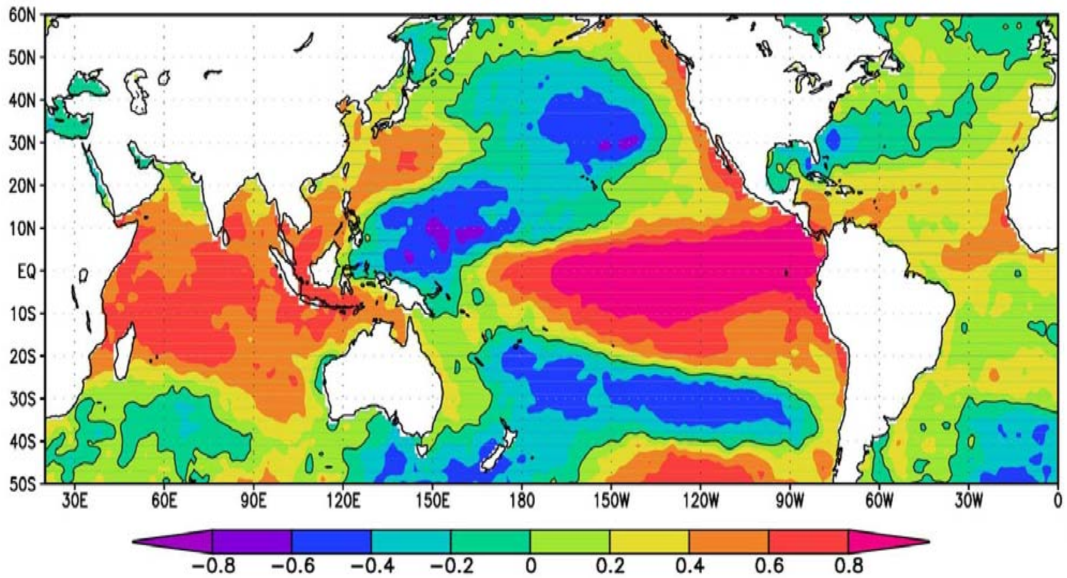


warm SST in the Western Equatorial Pacific Ocean and deep thermocline



warm SST move on the Eastern Pacific Ocean and shallow thermocline

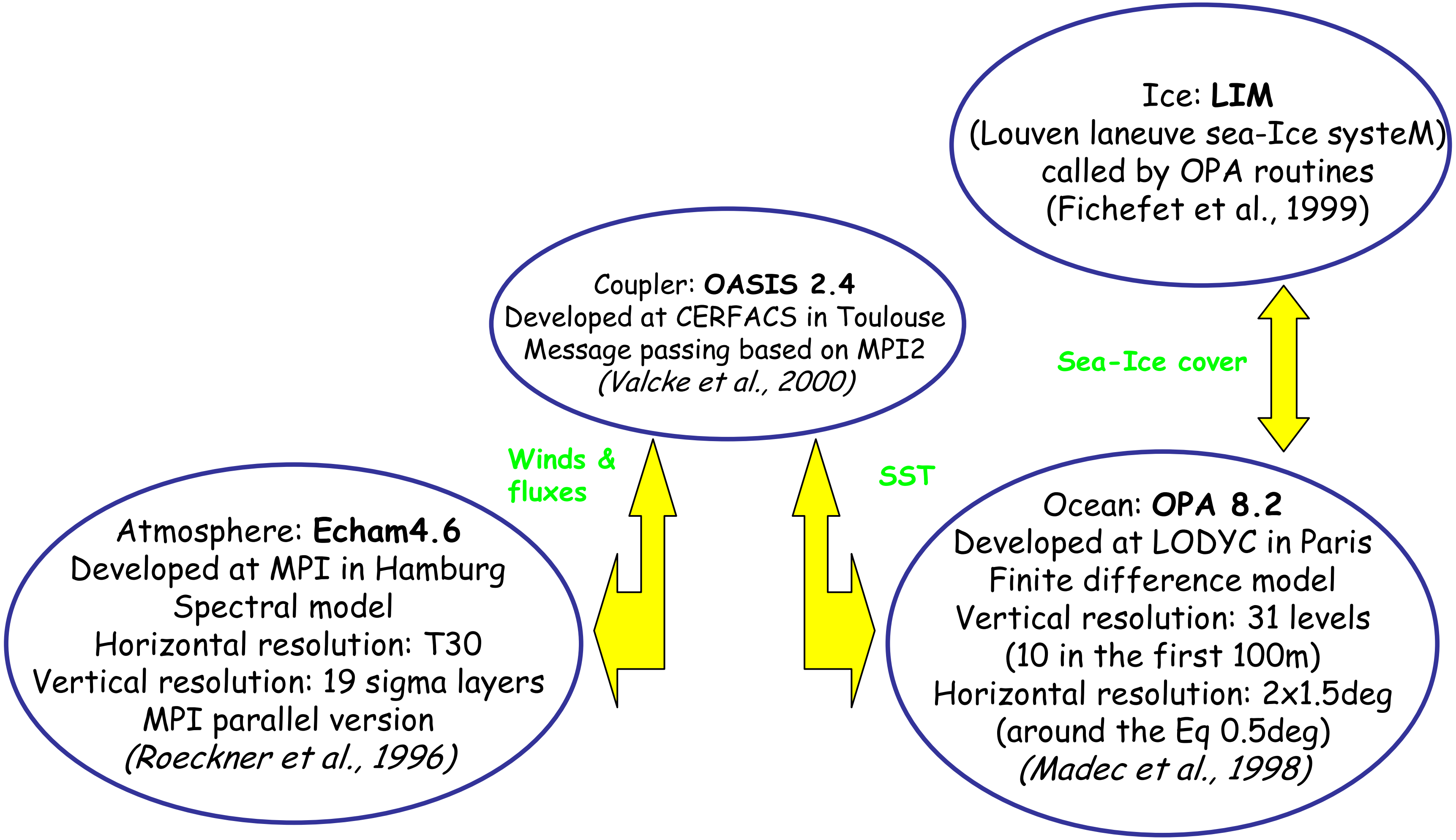
Correlation coefficients of JFM SST vs JFM NINO3
(HadISST, 1958-1999)



In the '90s El Nino occurred more frequently, but with reduced amplitude (Lau and Weng, 1999).
Possible causes:
- increase in CO2 concentration (e.g. Collins, 2000; Meehl et al., 2001)
- shift (westward) of the zonal wind stress observed after 1980 (e.g. An and Wang, 2000)
- interdecadal climate fluctuations (Gu and Philander, 1997)

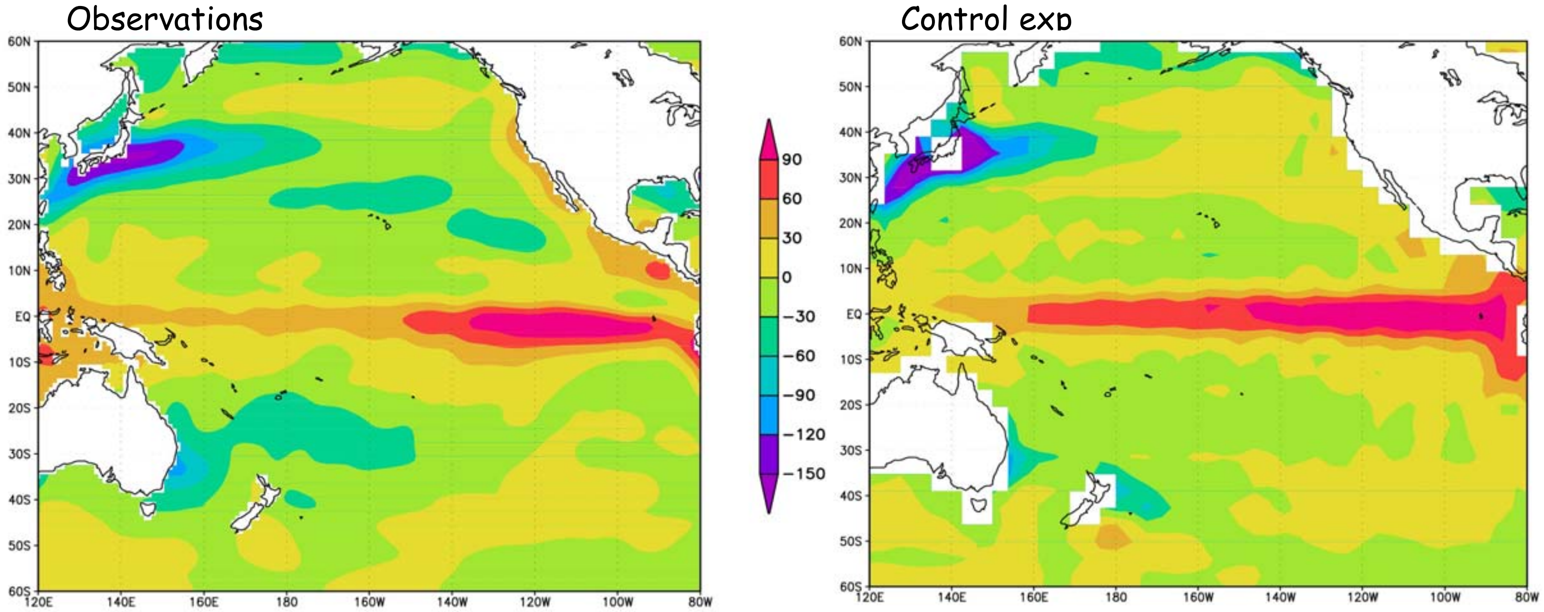
The SINTEXG CGCM

it is a atmosphere-ocean-ice coupled model developed at INGV following the background of the SINTEX model developed among the SINTEX EU-project

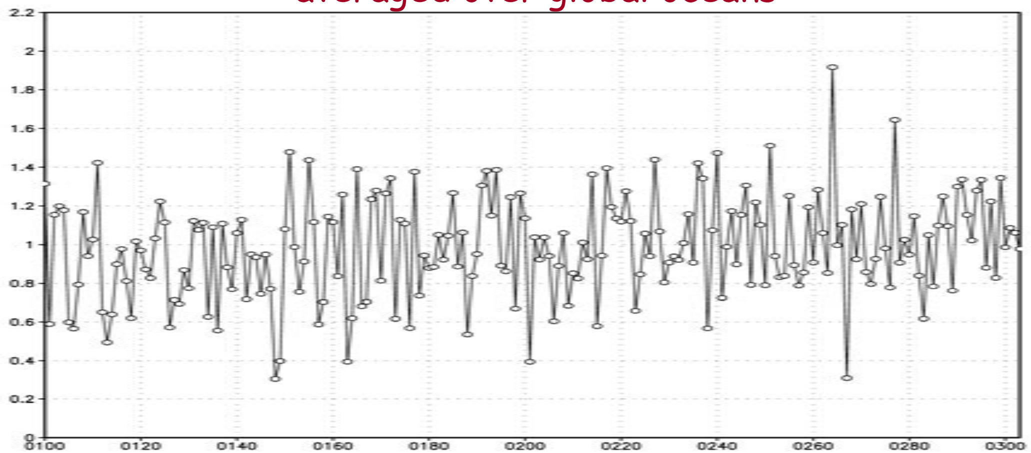


For a description of the mean climate simulated by the model see the web page:
https://www.cmcc.it/web/public/ANS/models/ingv-sxg

Annual mean surface SWR+LWR+SHF+LHF (W/m²)

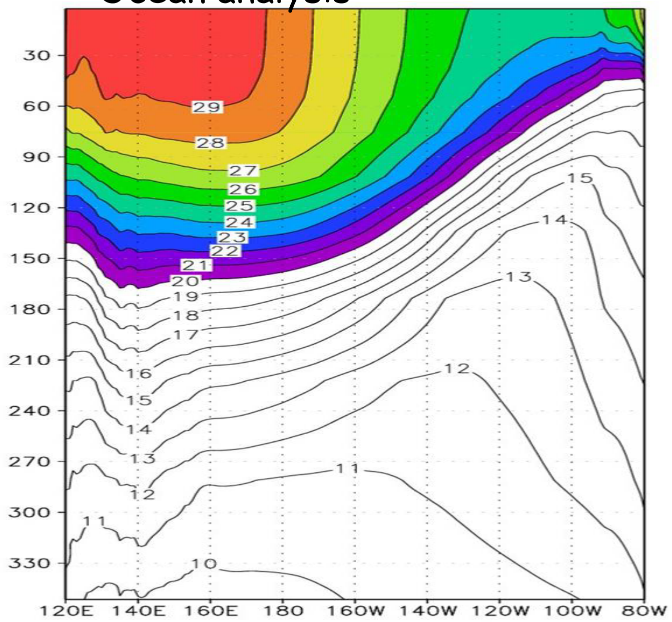


Annual SWR+LWR+LHF+SHF (W/m²)
averaged over global oceans

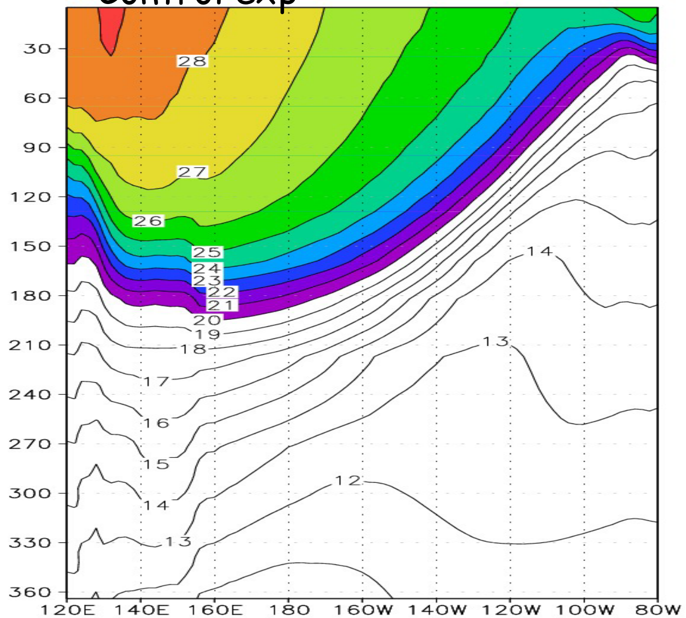


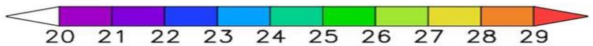
Mean temperature sections (˚C) at the Equator

Ocean analysis*



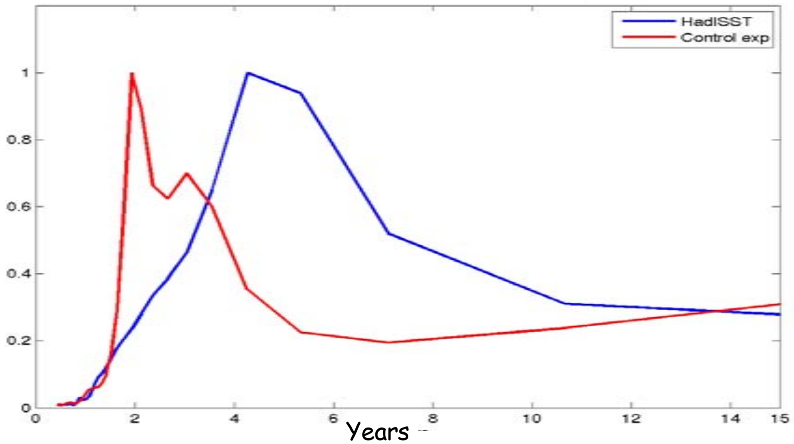
Control exp





*From Masina et al.(2004)

NINO3 index power spectrum
(covariance method)



Setup of the idealized experiments performed:

Control exp:
Fully coupled for 300 years
CO_2~ 353ppmv

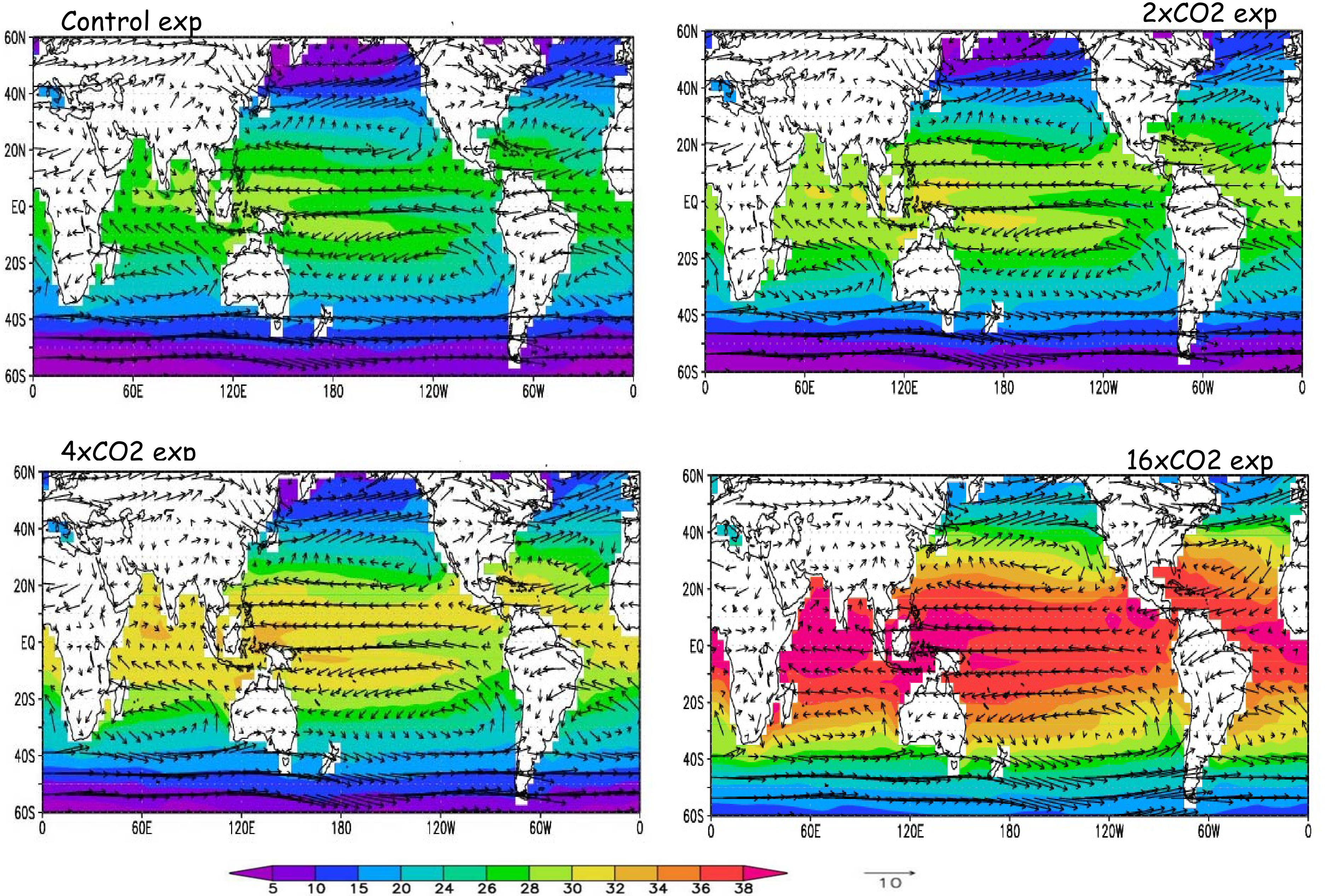
2xCO2 exp:
200 years of integration
CO_2 globally multiplied
by a factor of 2

4xCO2 exp:
200 years of integration
CO_2 globally multiplied
by a factor of 4

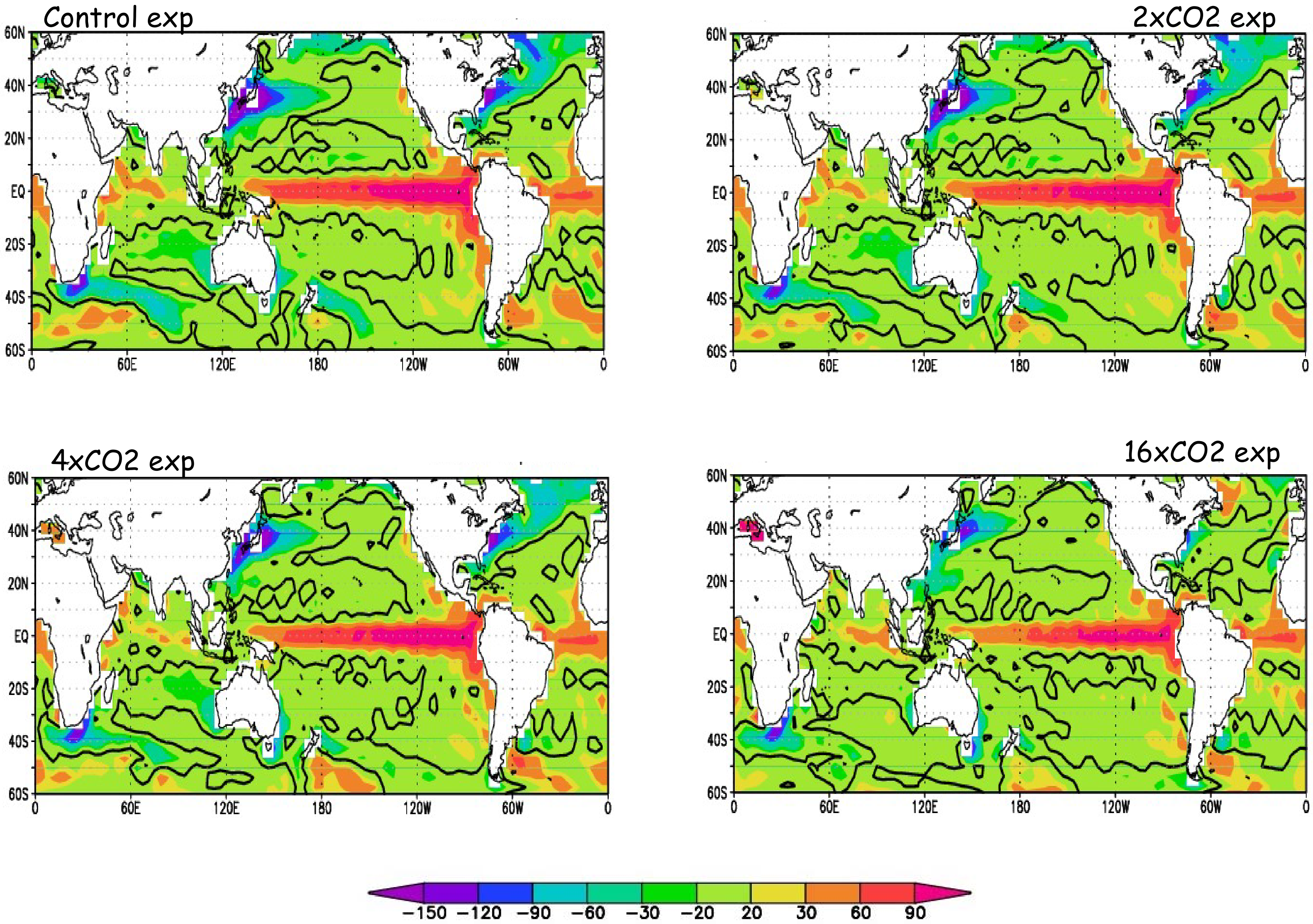
16xCO2 exp:
350 years of integration
CO_2 globally multiplied
by a factor of 16

All the analysis has be focused on the last 100 years of integration

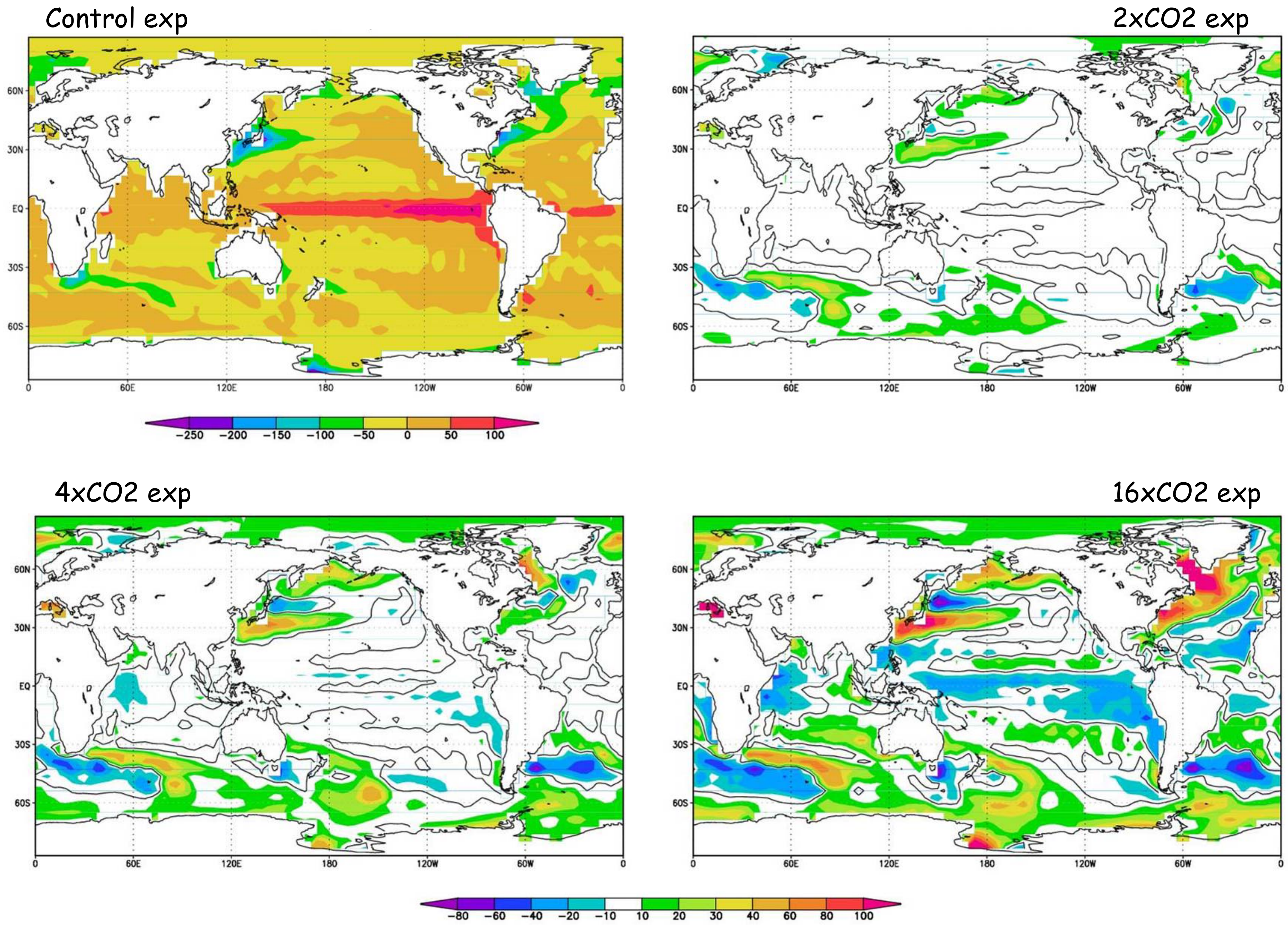
Annual mean SEA SURFACE TEMPERATURE (°C) & 850 mb WINDS (m/sec)



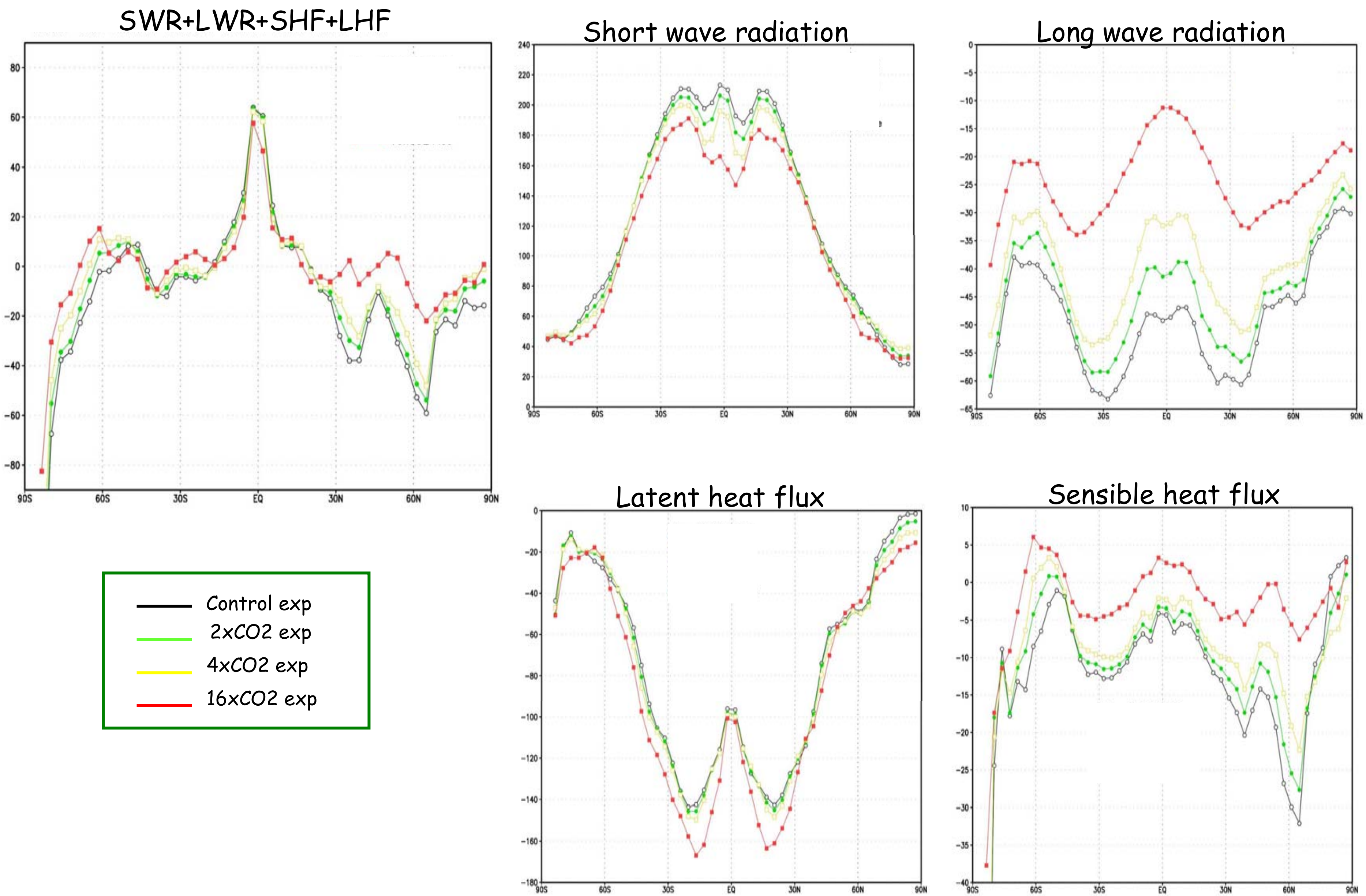
Annual mean surface SWR+LWR+SHF+LHF (W/m²)



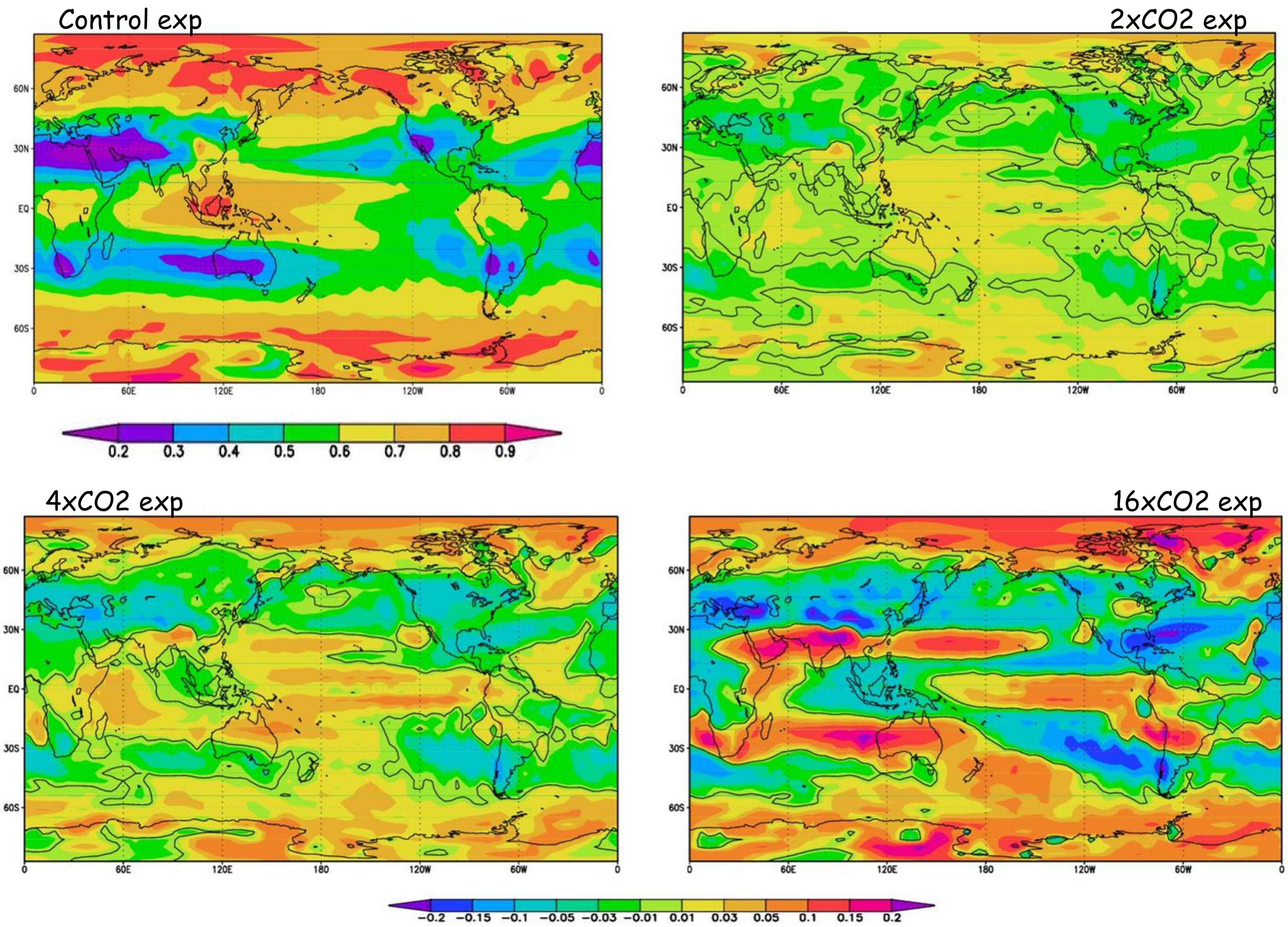
Annual mean surface SWR+LWR+SHF+LHF (W/m^2) & differences from the control exp



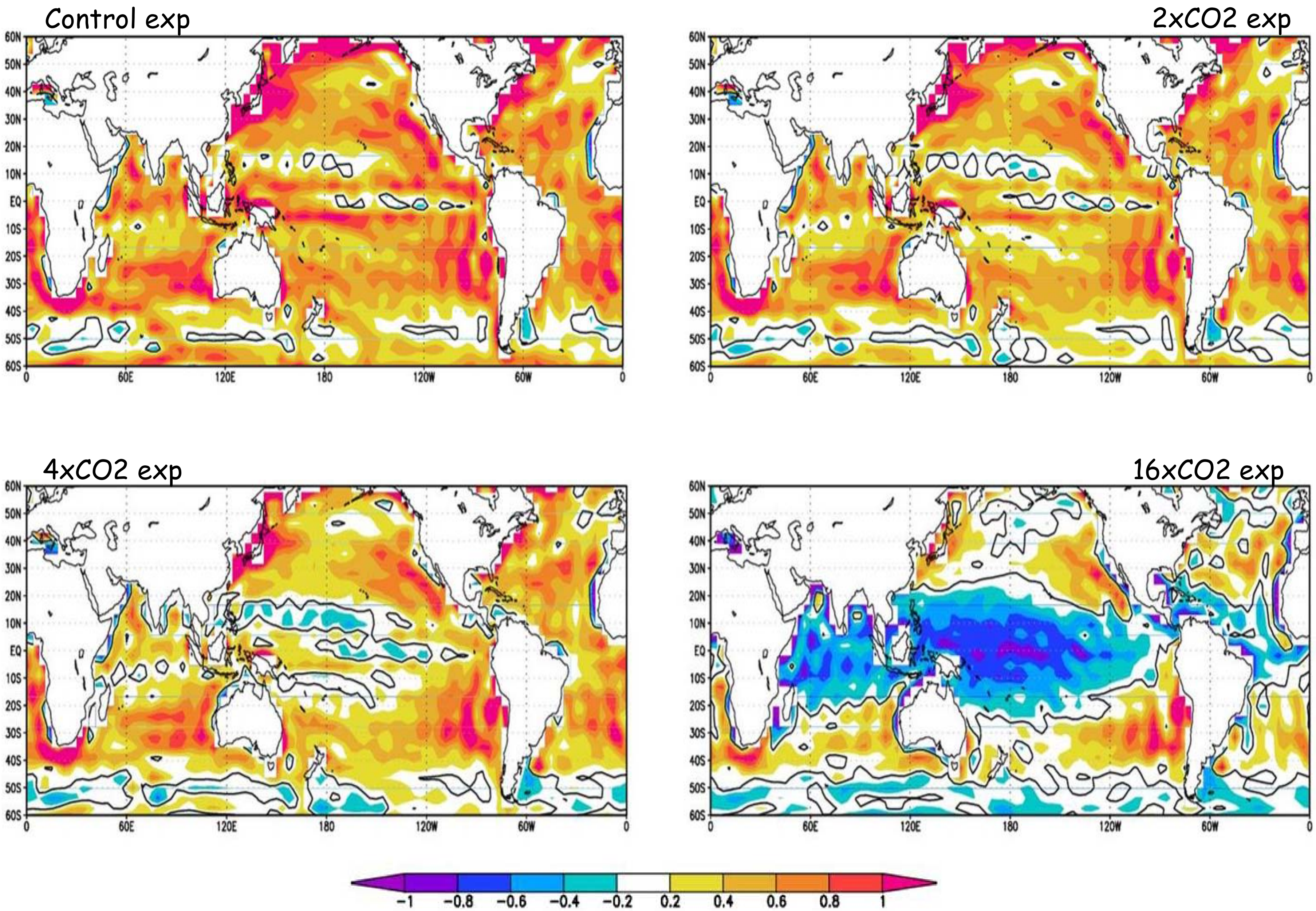
Total net surface heat flux & components (W/m^2)
(zonal means averaged over the global oceans)



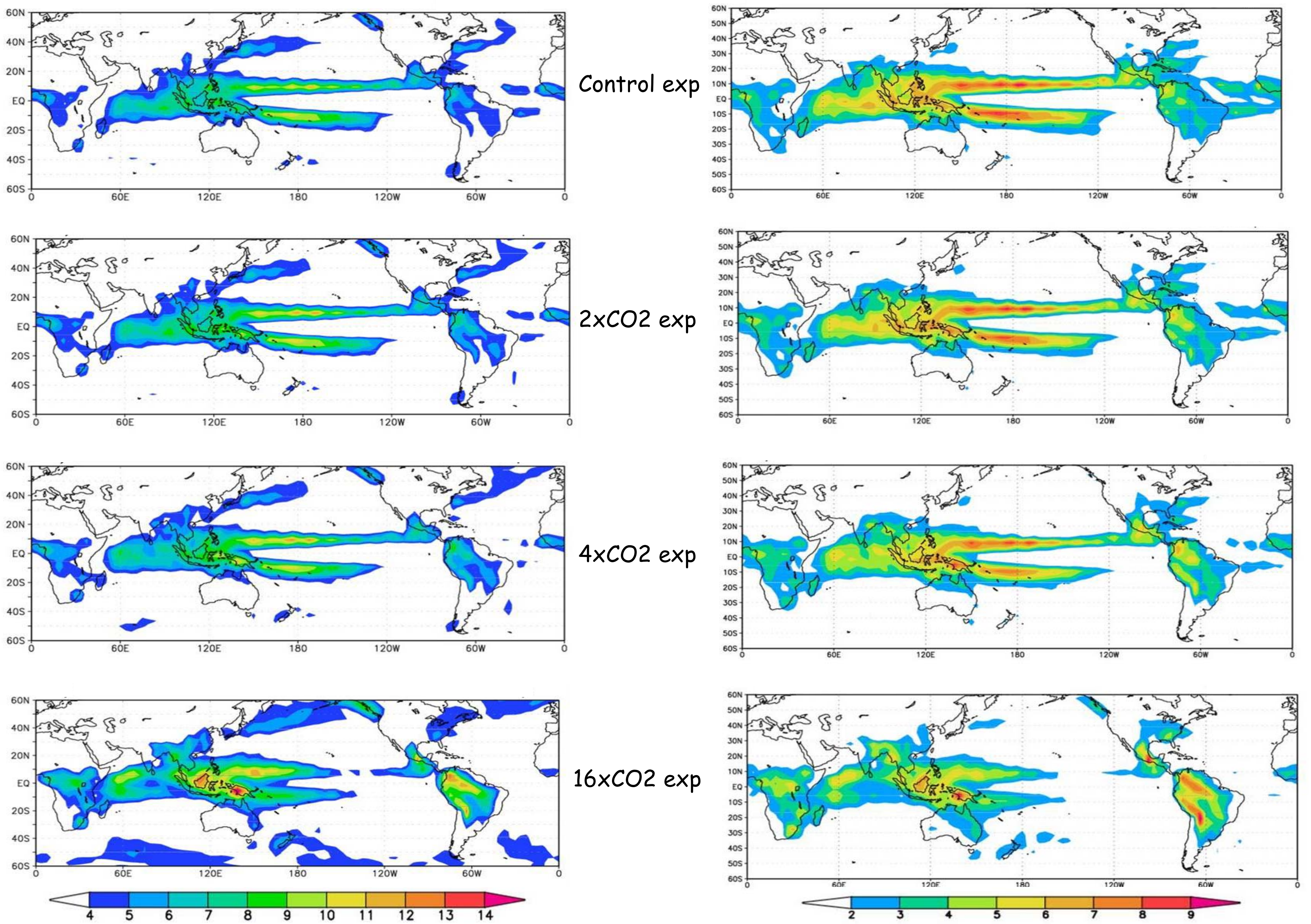
Annual mean total cloud cover (fract) & differences from the control exp



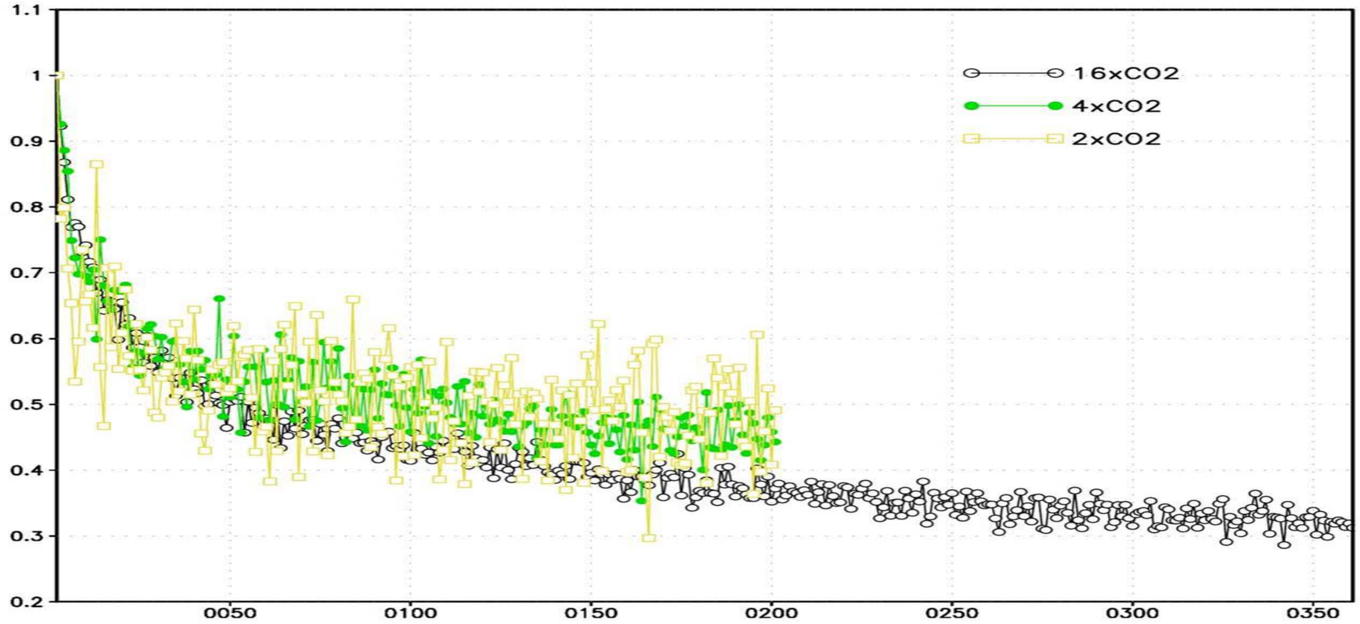
Annual mean SST minus 2m temperature (˚C)



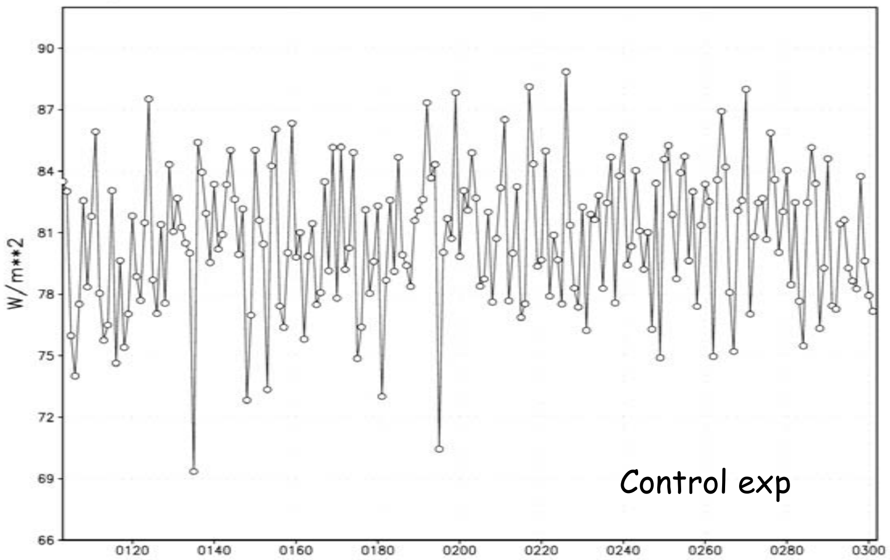
Annual mean total precipitation (mm/day) **Annual mean convective precipitation (mm/day)**

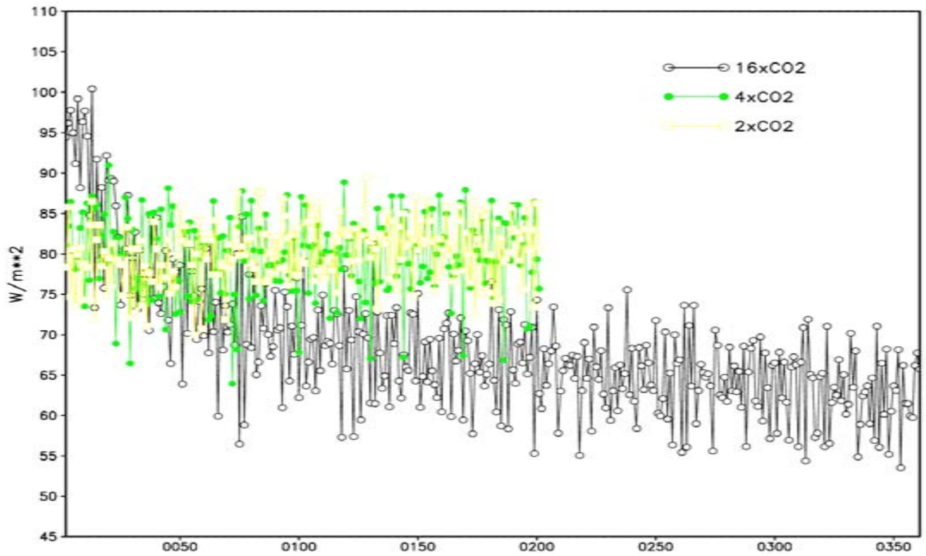


Fraction (with respect to 1st year) of annual mean SWR+LWR+SHF+LHF averaged over the global ocean

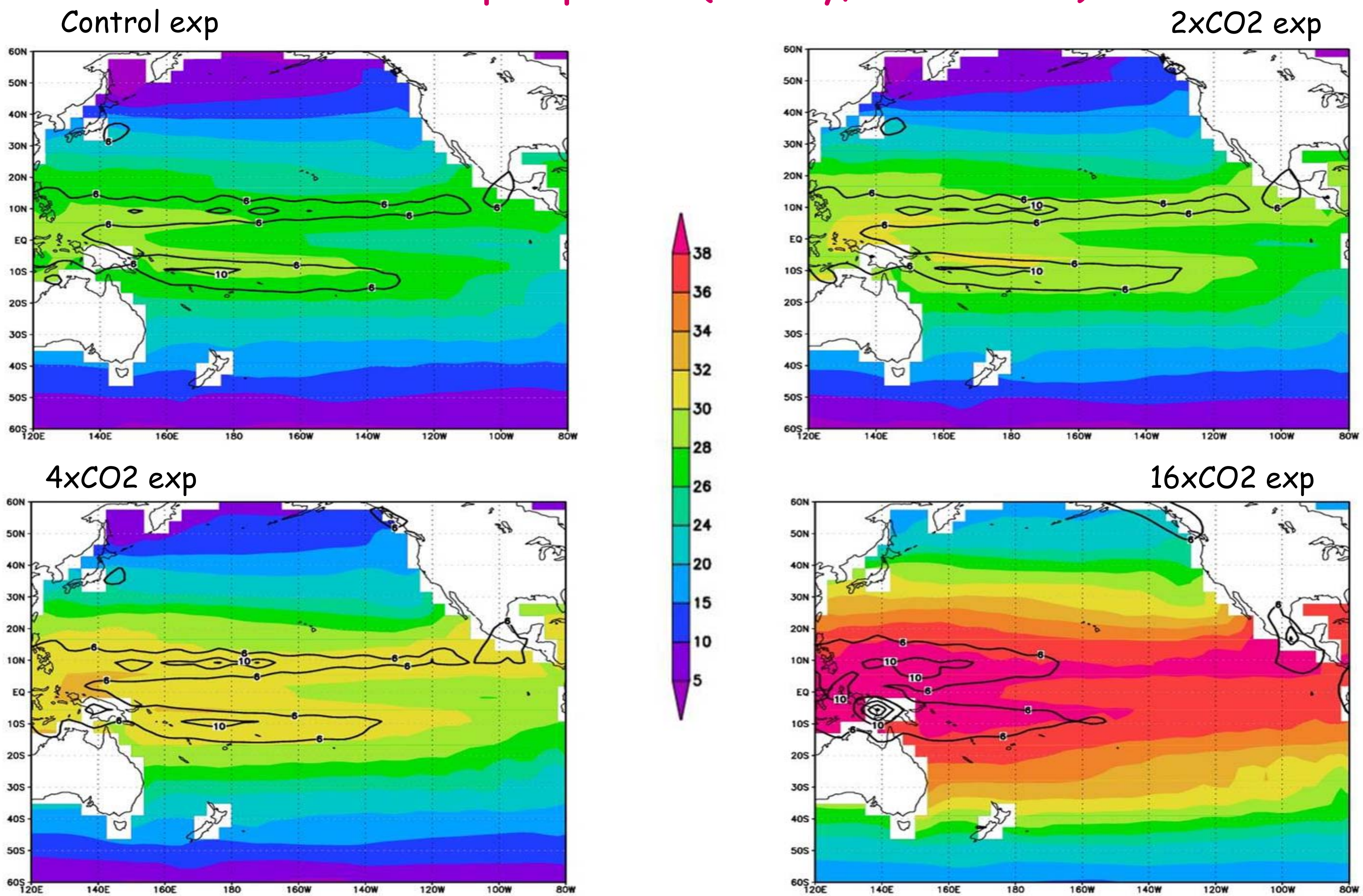


Annual mean SWR+LWR+SHF+LHF (W/m2) averaged over the Pacific Ocean





Annual mean SST (°C, shaded patterns) & annual mean total precipitation (mm/day, contour lines)



	Control exp	2xCO2 exp	4xCO2 exp	16xCO2 exp
E-W SST	2.9	2.7	2.6	1.4

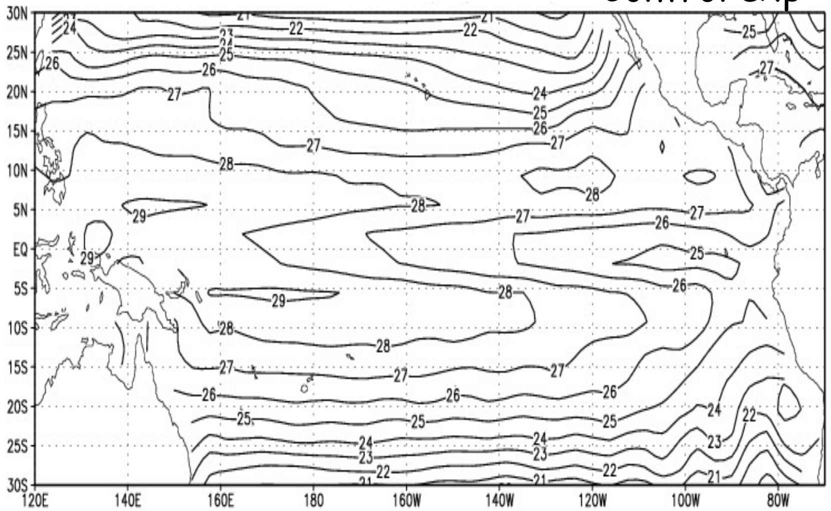
N.B. The max(dT/dx) moves towards west

What about the cold tongue ?

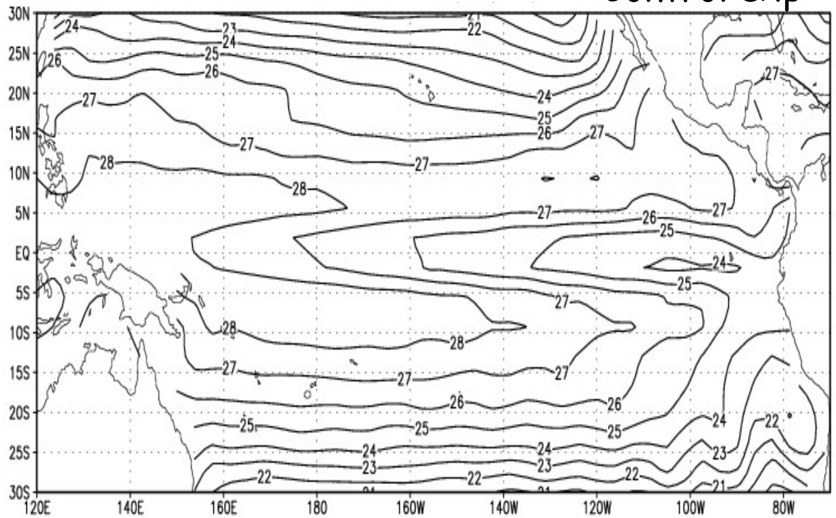
Coupled model without interactive ice

Coupled model with interactive ice

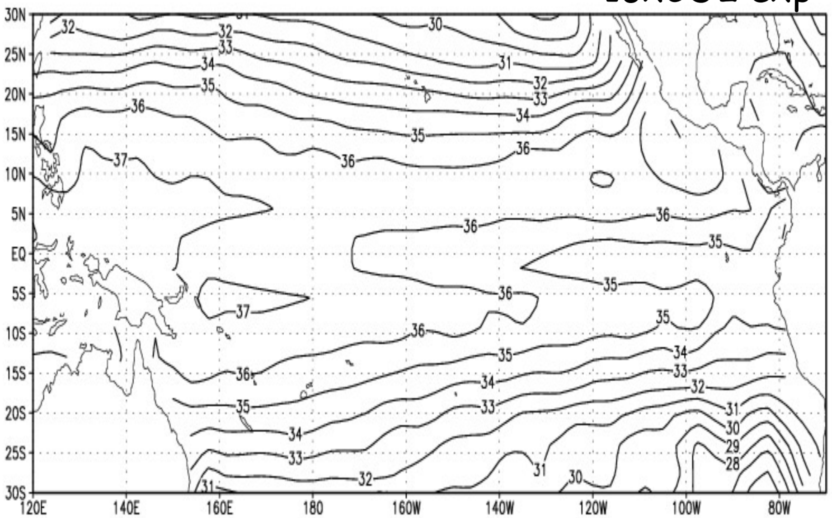
Control exp



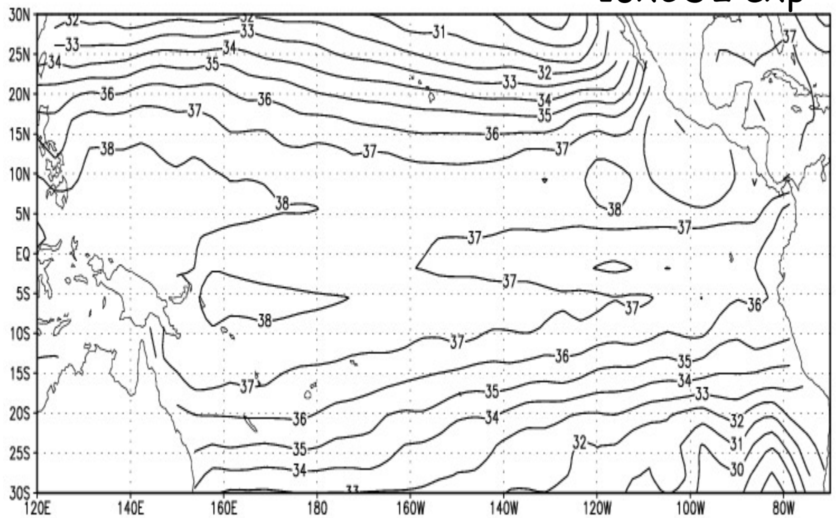
Control exp



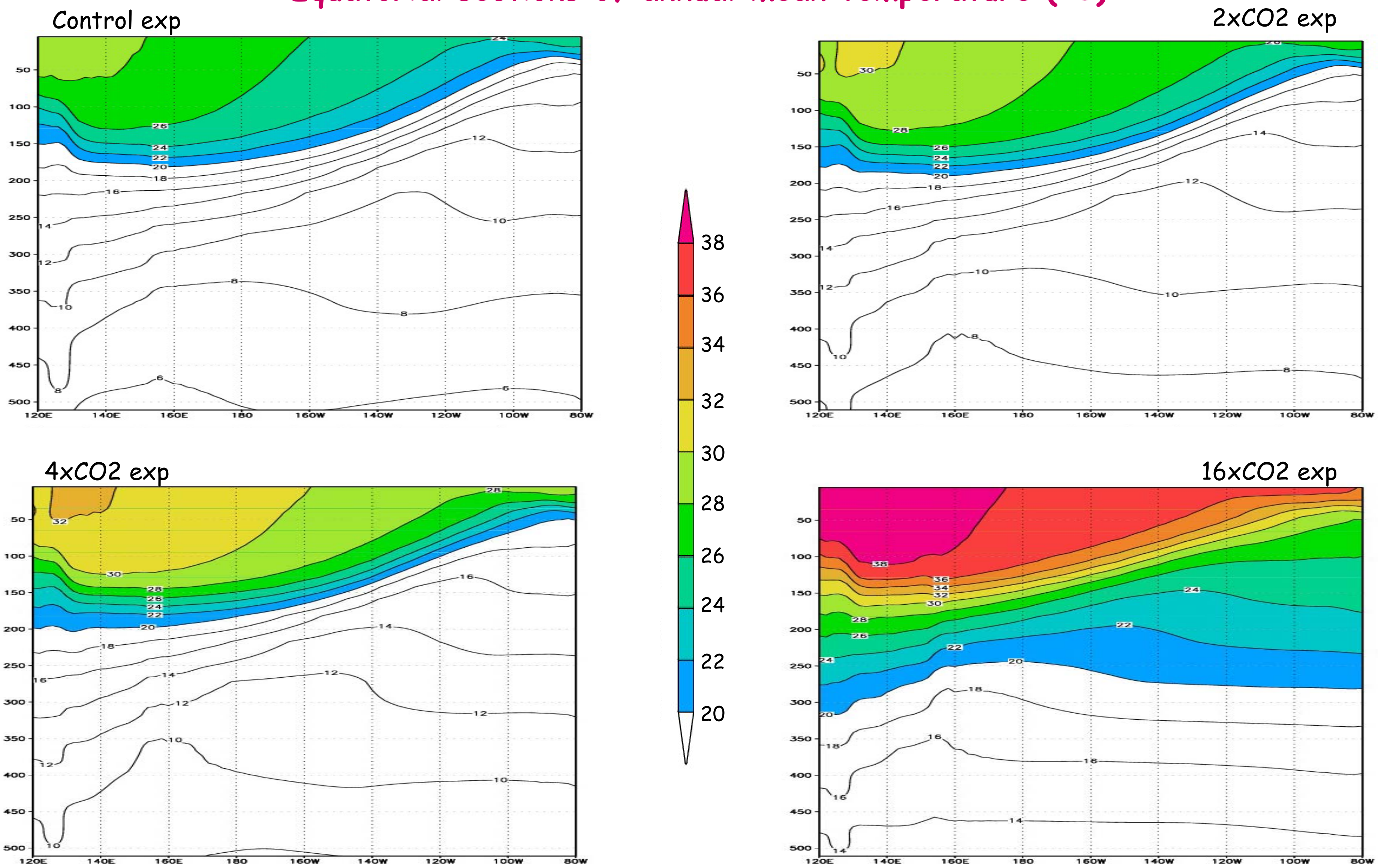
16xCO2 exp



16xCO2 exp



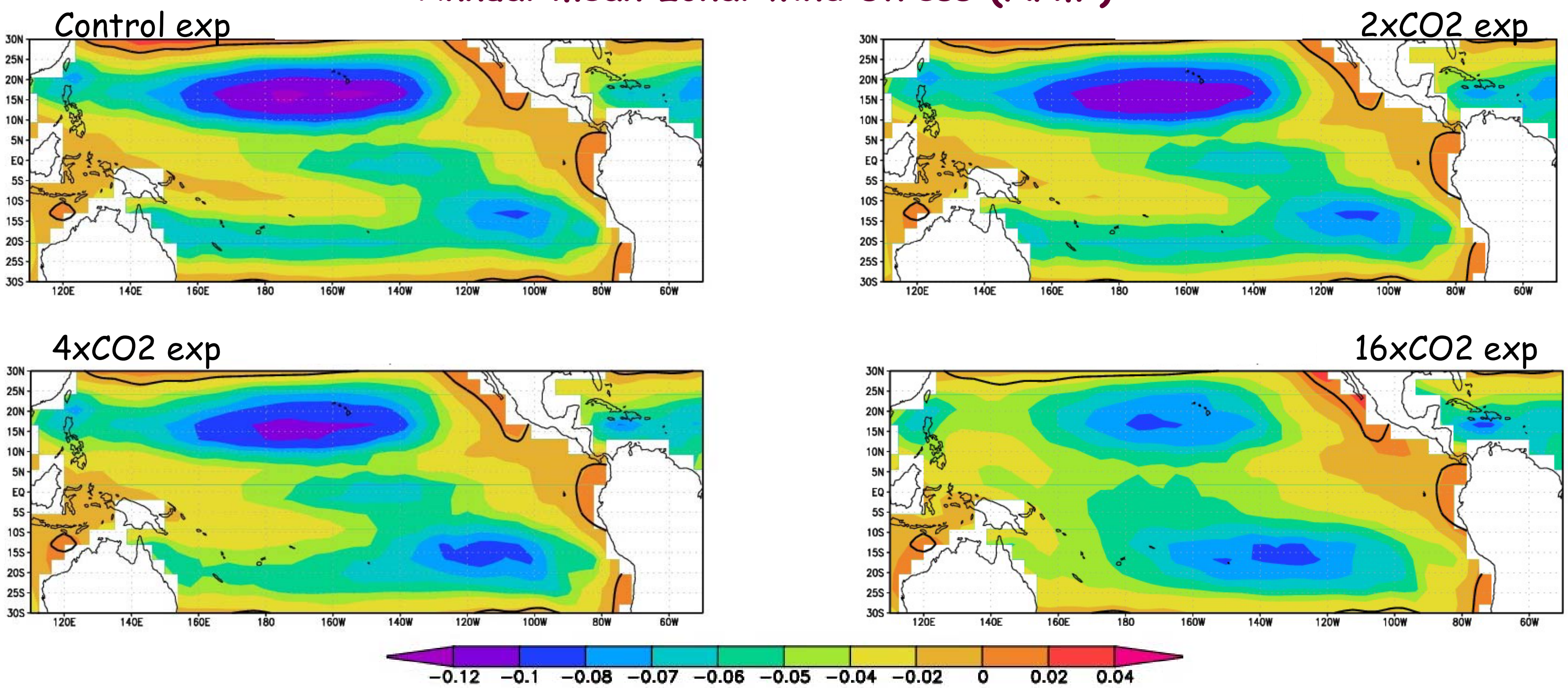
Equatorial sections of annual mean temperature (°C)



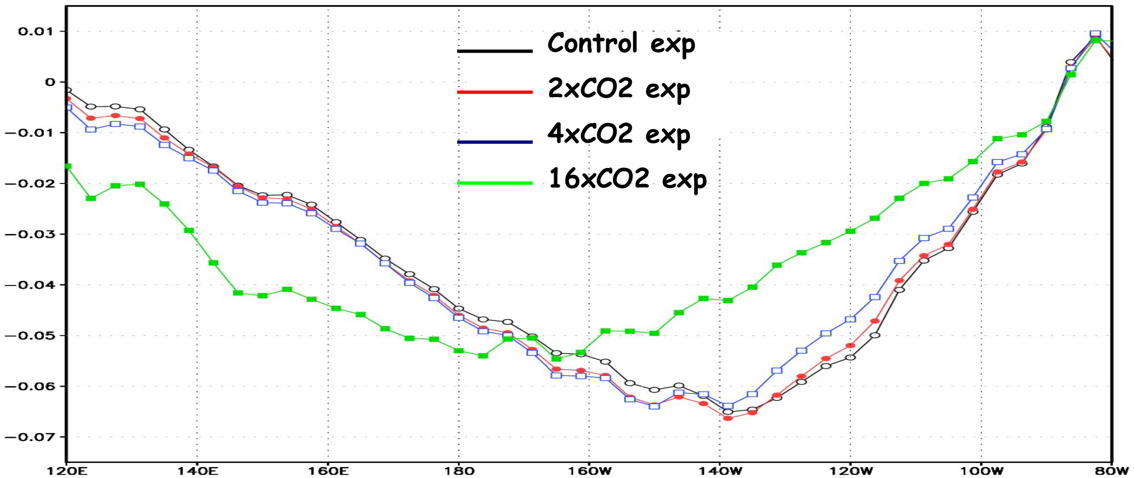
Thermocline slope

max(dT/dz)	Control exp	2xCO2 exp	4xCO2 exp	16xCO2 exp
140°W	129	129	117	85
110°W	65	65	65	45

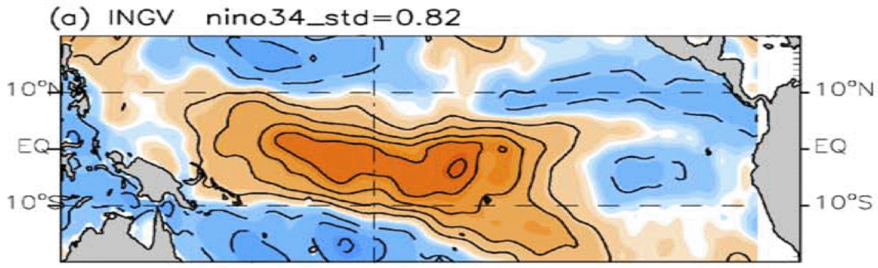
Annual mean zonal wind stress (N/m^2)



Annual mean zonal wind stress (N/m^2) averaged in the Eq Pacific Ocean



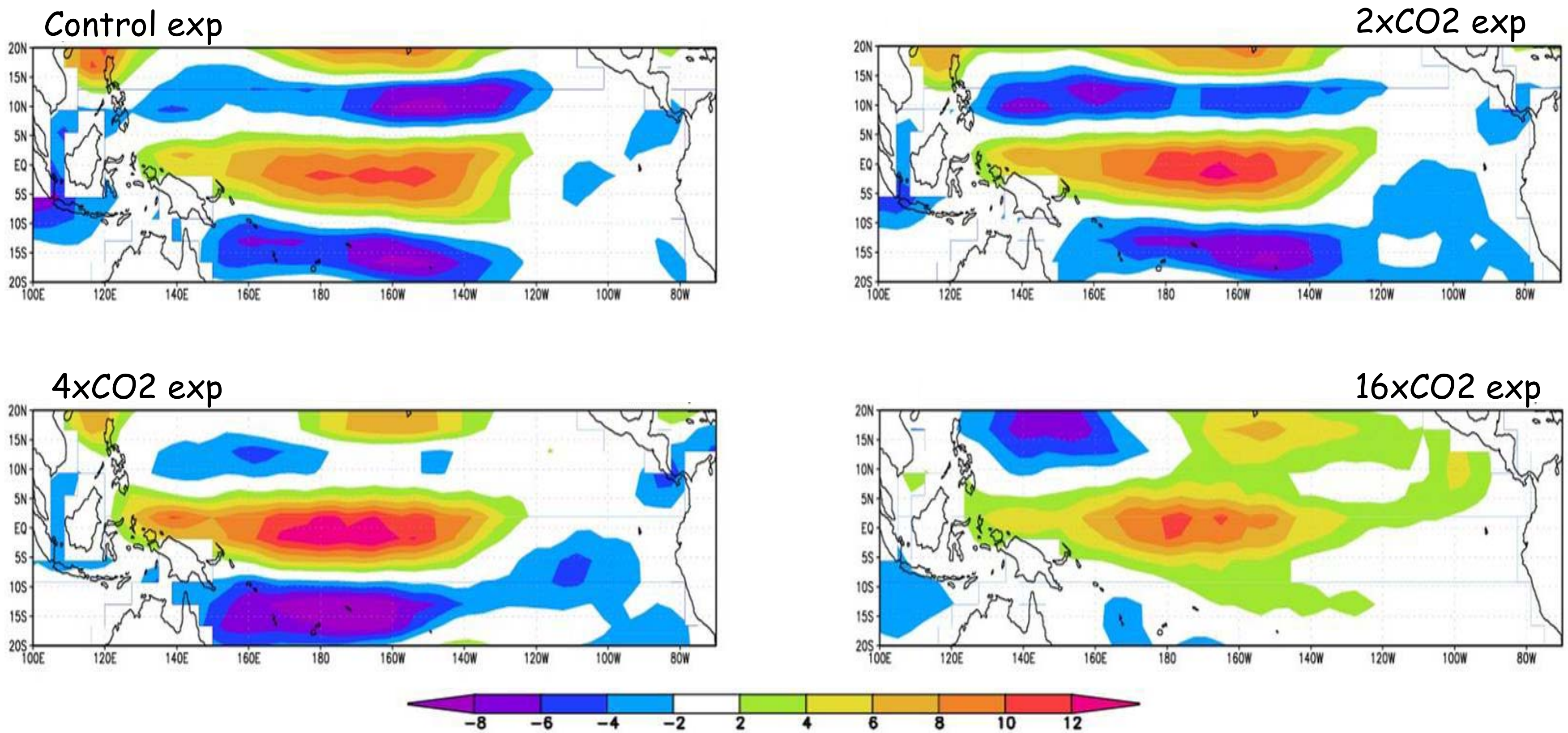
Regression coefficient (monthly zonal wind stress anomalies upon Nino3.4 index) & zonal average of zonal wind stress between 154°E and 120°W



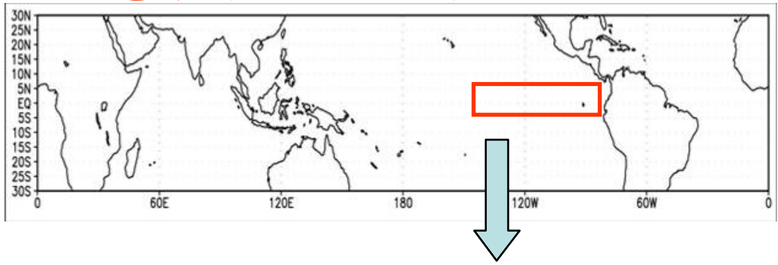
INGV Ocean analysis (from Capotondi et al., 2006)

Center of mass =

$$C = \frac{\int_0^{L_x} \overline{\tau^x}(x)\,x\,dx}{\int_0^{L_x} \overline{\tau^x}\,dx}$$

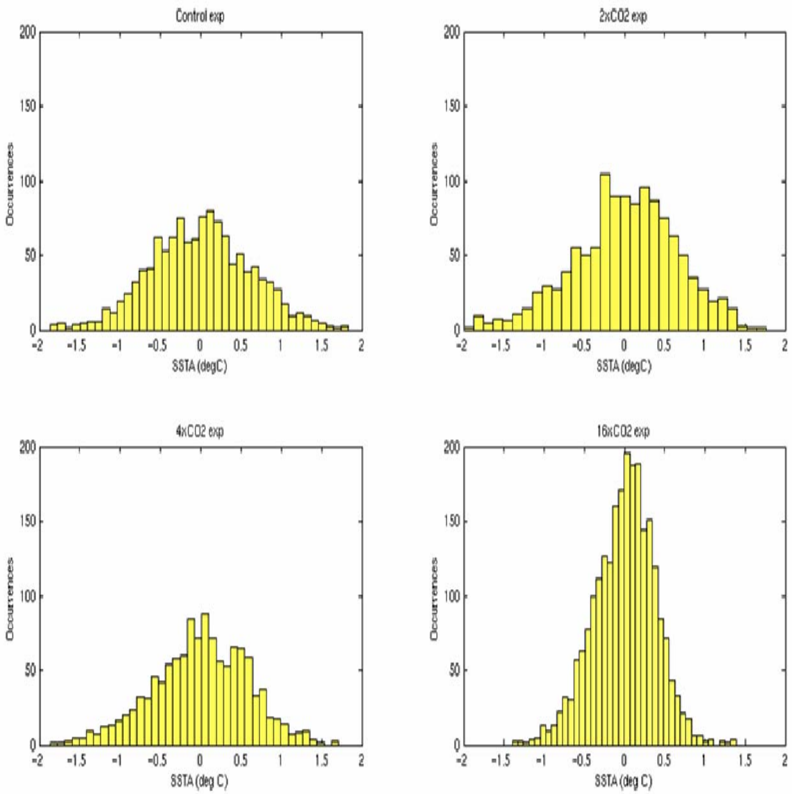


The El Nino Oscillation:

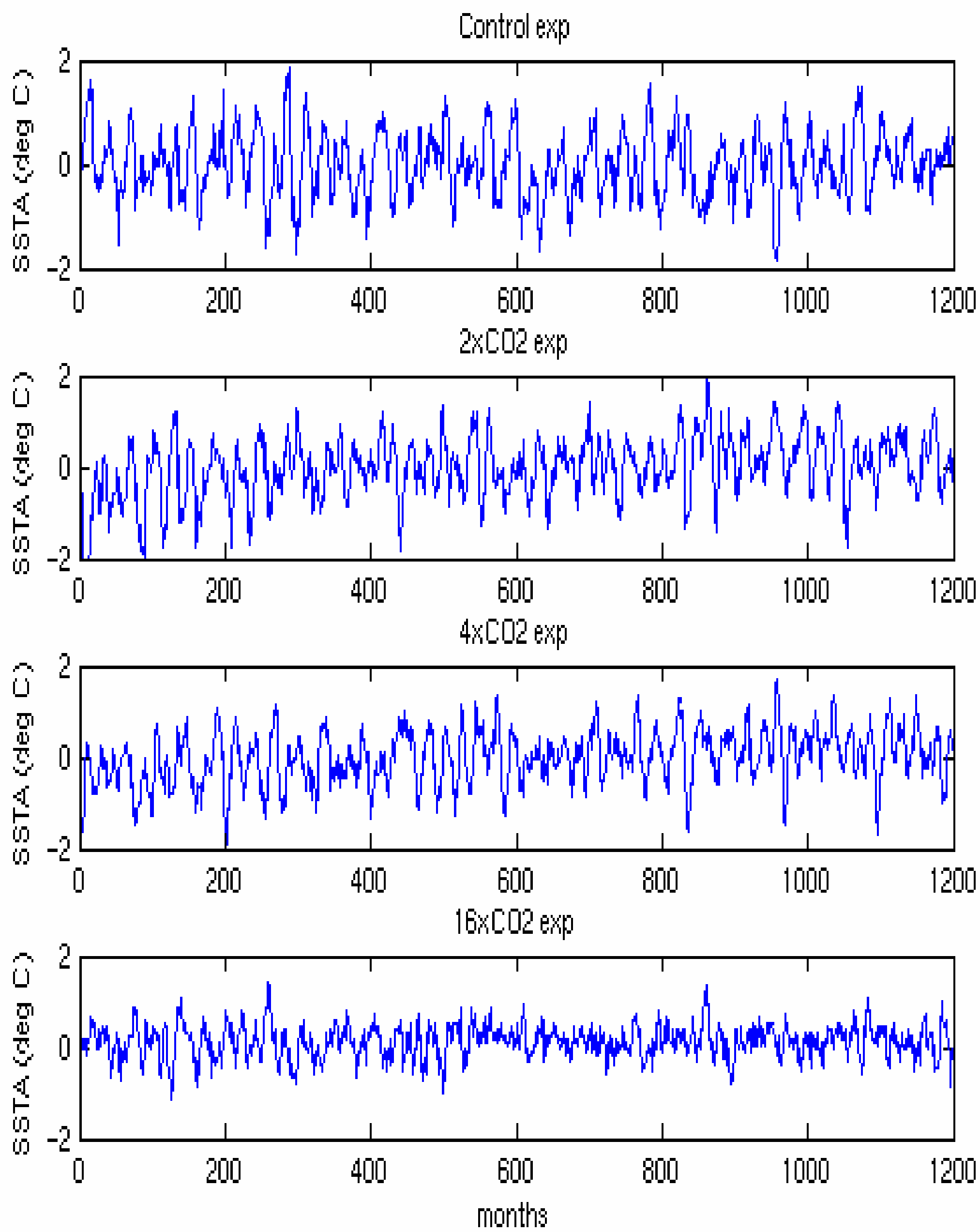


NINO3 region

Frequency distributions of monthly SST anomalies averaged in the NINO3 region

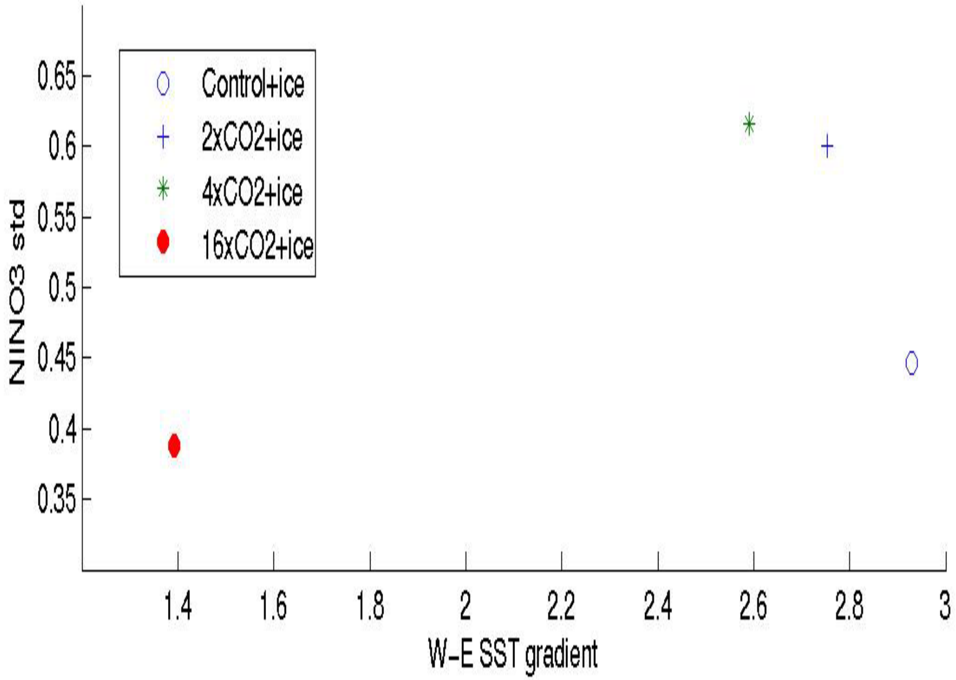


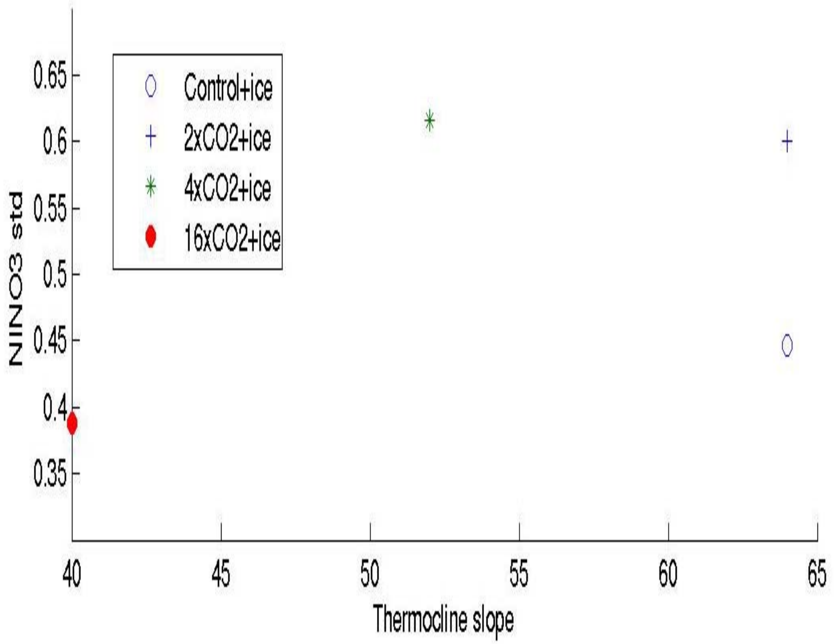
SST monthly anomalies in the NINO3 region



Mean variances (°C) for NINO3 SSTA

Control exp	2xCO2 exp	4xCO2 exp	16xCO2 exp
0.20	0.36	0.38	0.15





Establishment of permanent El Nino conditions ?

Main conclusions

- The increase in CO2 concentration induces a rise of the global temperature (at the surface, in the atmospheric column and in the ocean subsurface)
- Globally at the surface less heat gained at the equator is accompanied by less heat lost at high latitudes
- Two important players in the surface heat budget are the long-wave radiation (effects of clouds) and the sensible heat flux (changes of the stability at the ocean-atmopshere interface)
- The total precipitation tends to increase but in some regions (e.g. the western Pacific Ocean) the convective precipitation weakens
- In the equatorial Pacific Ocean the eastern and western sides warm differently: the zonal gradient of SST tend to decrease
- The sub-surface waters in the Equatorial Pacific Ocean warm and the thermocline slope (approximated as the difference between 110°W and 140°W) decreases
- The interannual variability in the Equatorial Pacific Ocean, defined in terms of the NINO3 index reveals an increase of the frequency of the oscillation and a decrease of the amplitude
- The “new” mean state at 16xCO2 suggest the establishment of permanent El Nino conditions

Future perspectives

- Further analysis about the role of cloud cover and SST feedback
- Analysis of longer time scales of variability (effects on the thermohaline circulation)