# Recent Climate Change Modeling Work at NCAR

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# Outline

- NCAR Coupled Climate Models
- Climate Change Simulations
- Comparisons with Current Climate
- 20th century and future climate changes
- N. Atlantic Ocean Circulation Changes

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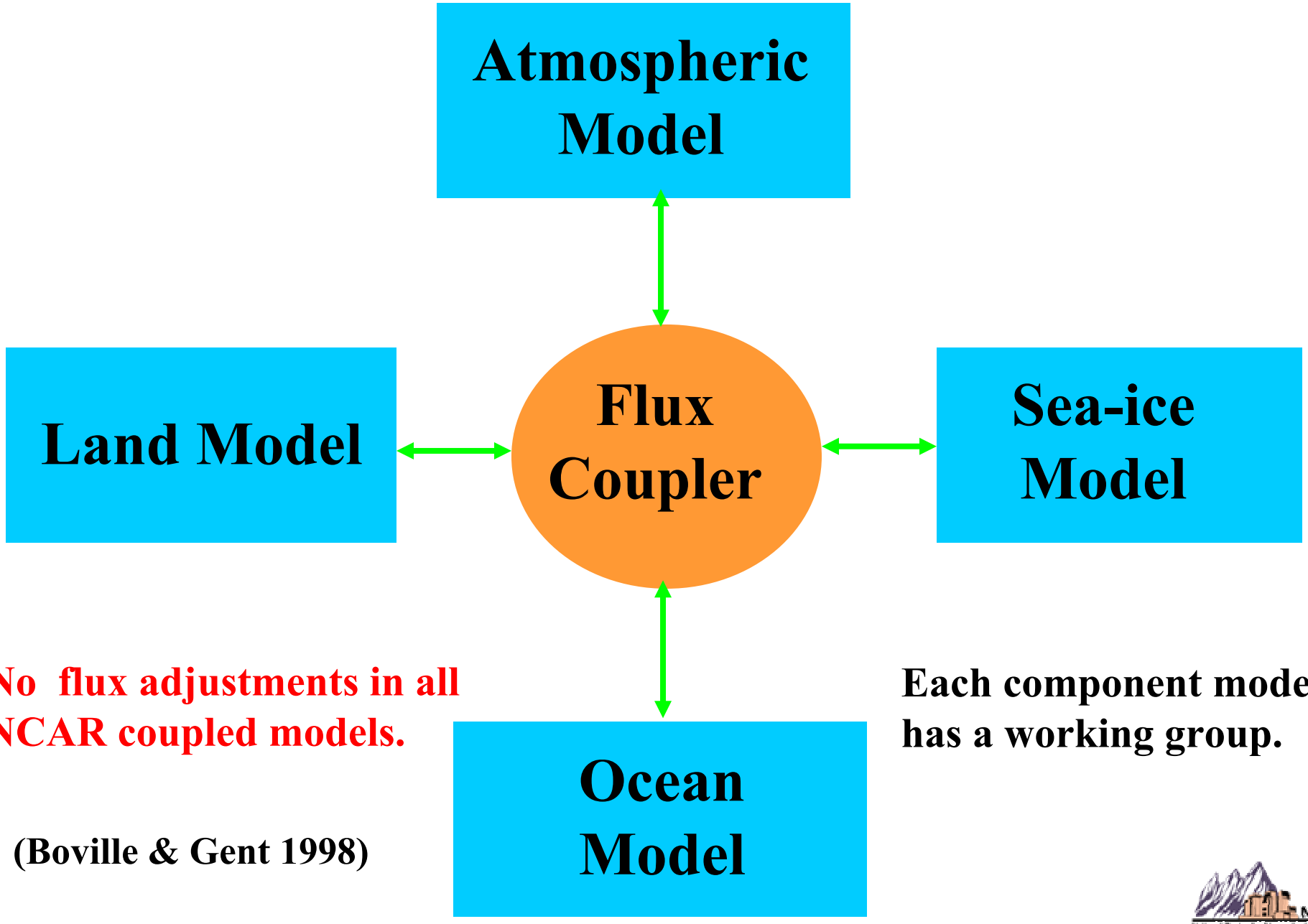
# NCAR Coupled Model Structure




No flux adjustments in all NCAR coupled models.

Each component model has a working group.

(Boville & Gent 1998)

| Name | AGCM | OGCM | Land | Sea-ice |
|---|---|---|---|---|
| **CSM** v.1.3 (1998) | CCM3: spectral model, T42 (2.8º), 18 layers, dt=20min (1hr for rad.) Zhang-McFarlane conv. scheme | modified MOM, 2.4º lon,1.2-2.3º lat., 45 layers, dt=30min | LSM 1.0 on T42 grid, dt= 20 min | thermodynamic, run on OGCM grid, dt=1 hr |
| **PCM** (1999) | CCM3: **~2.1**ºC equilibrium warming for 2x$CO_2$ | POP, displaced N.P., ~2/3º horizon. resol., 32 layers, dt=2 hr | LSM 1.0 | from Zhang &Hibler('97),dx= 27km,1 icelayer 2 thermodyn. Layers |
| **CCSM** (2002) **CCSM2** (2003) | CAM2: T42/T85, 26 L New LW H2O model Generalized cld overlap Prognostic cld water Modified cov. mass flux Topographic filter | POP, N.P. over Greenland, <1.0º resol., 40 layers, Gent-Mc. eddy param., K-prof. param. for vert. mixing | CLM: improved sfc flux; multi.soil & snow layers 0.5º river routing | Dynamic/ thermodynamic model with a sfc snow layer. |

**CSM = Climate Sytem Model** **PCM = Parallel Climate Model**

**CCSM = Community Climate System Model**

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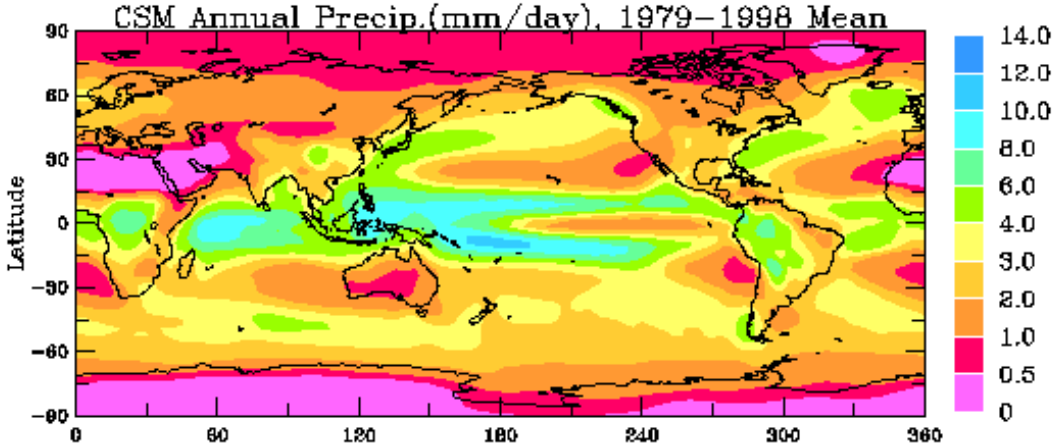
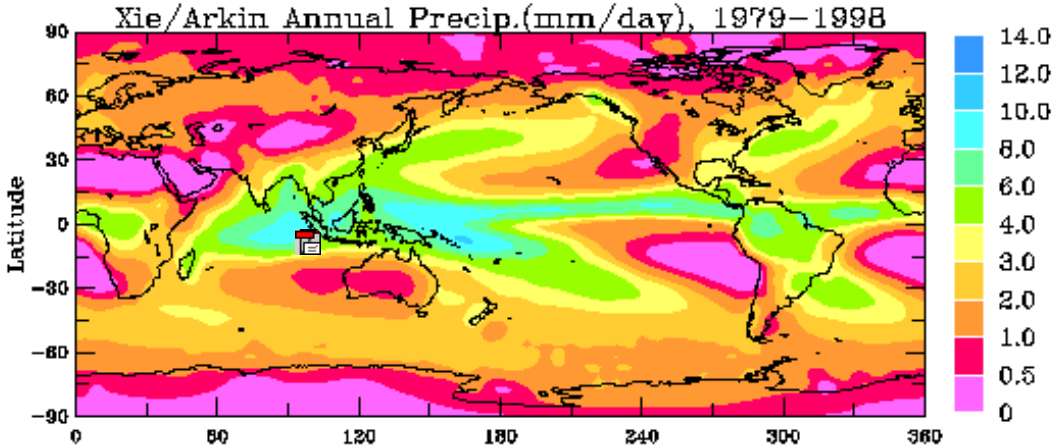
# Annual Precip

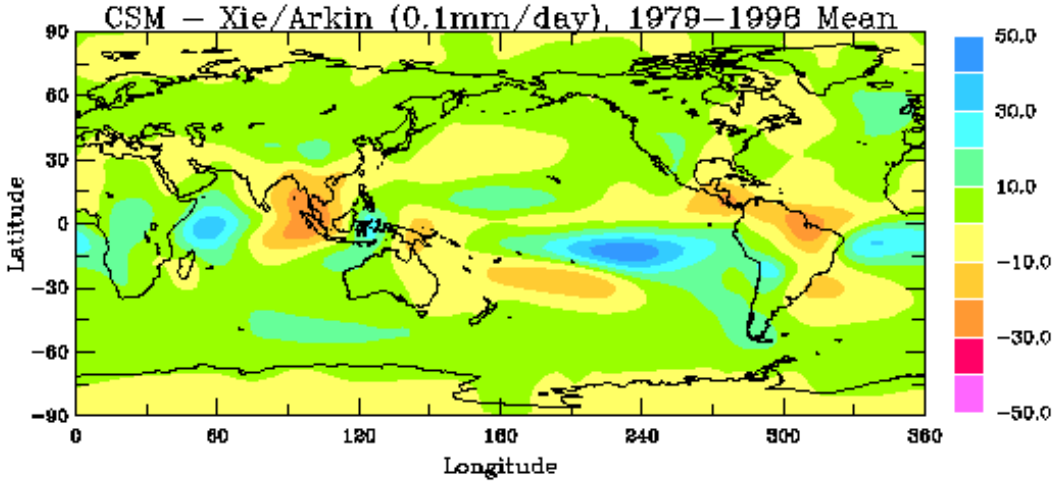
**CSM**



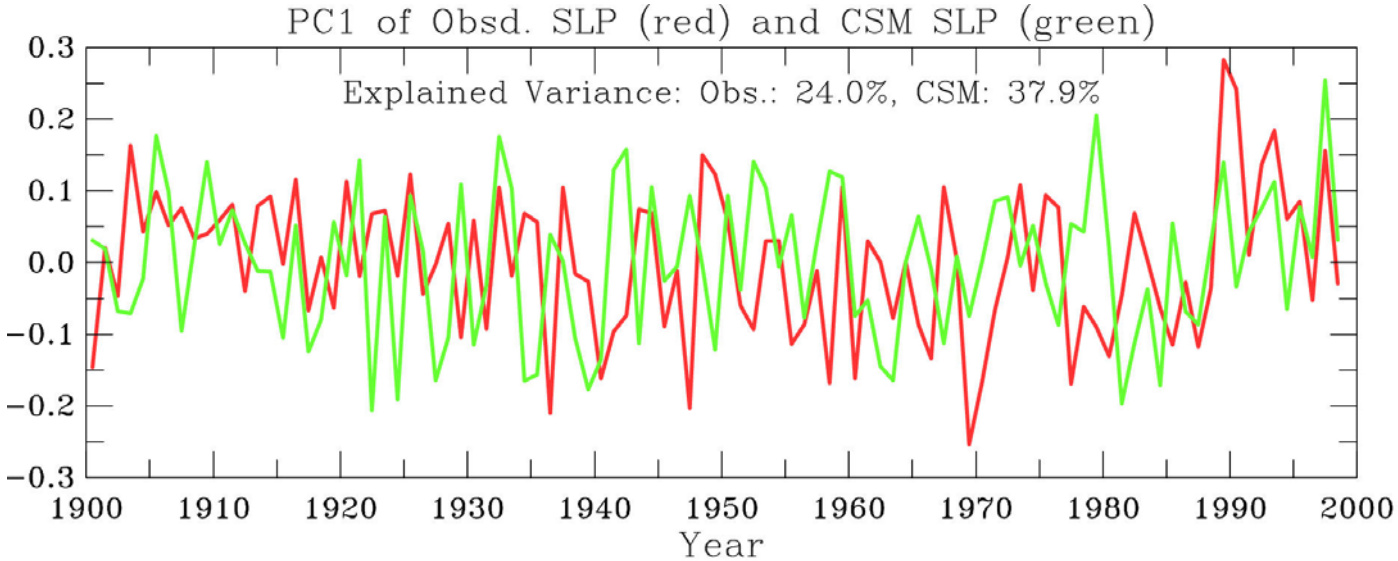

**Obs. (CMAP)**



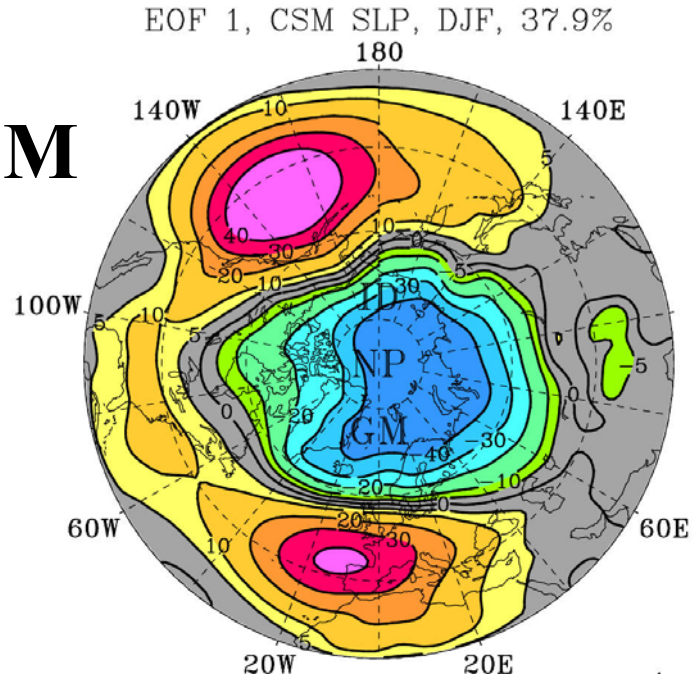

**CSM – Obs.**

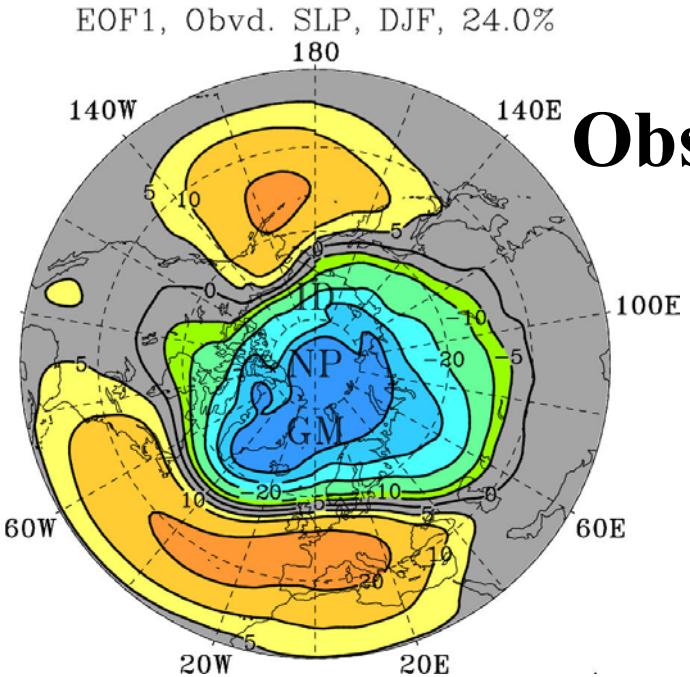


# EOF 1 of DJF SLP → Arctic Oscillation



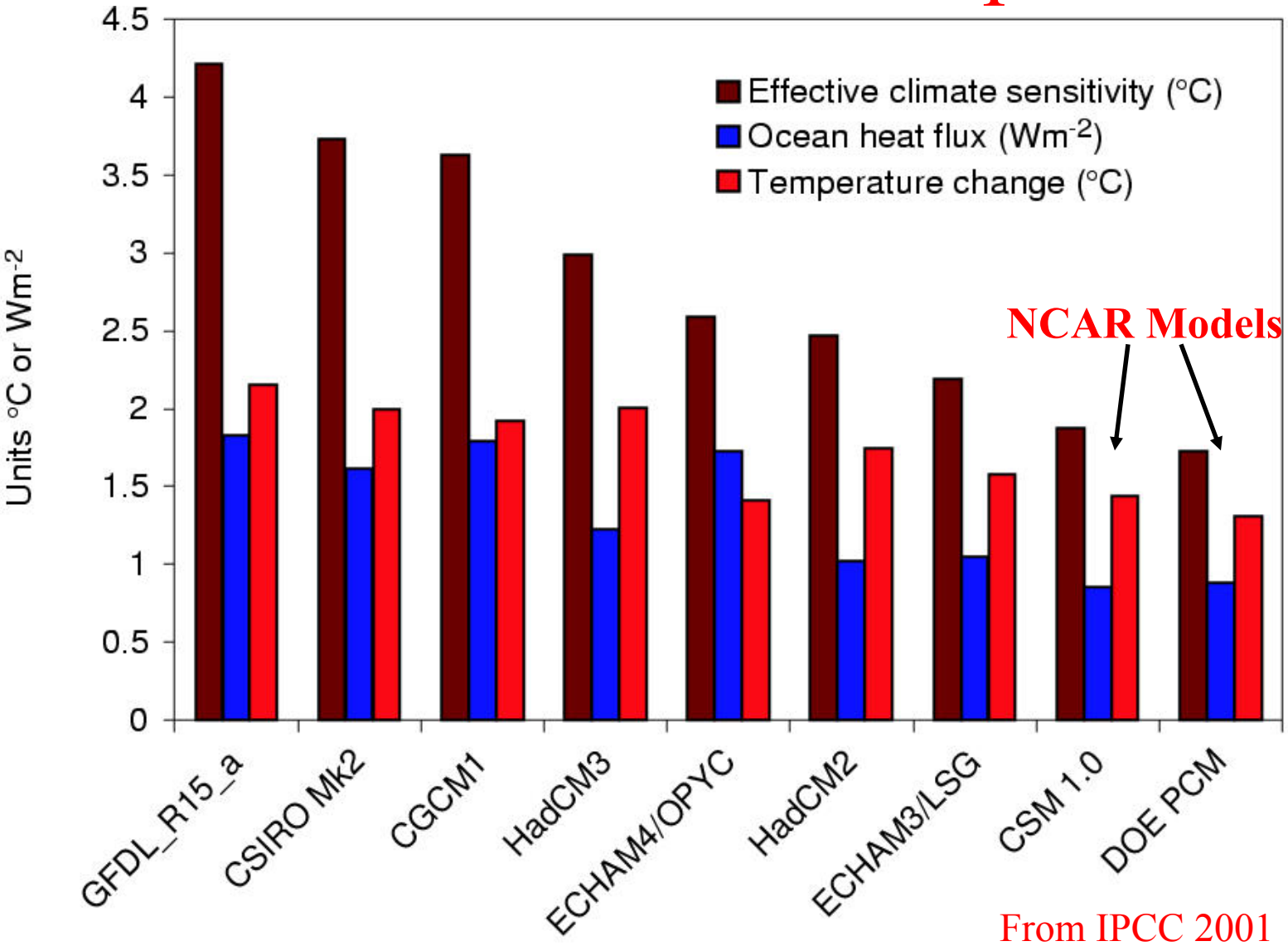

CSM




Obs.

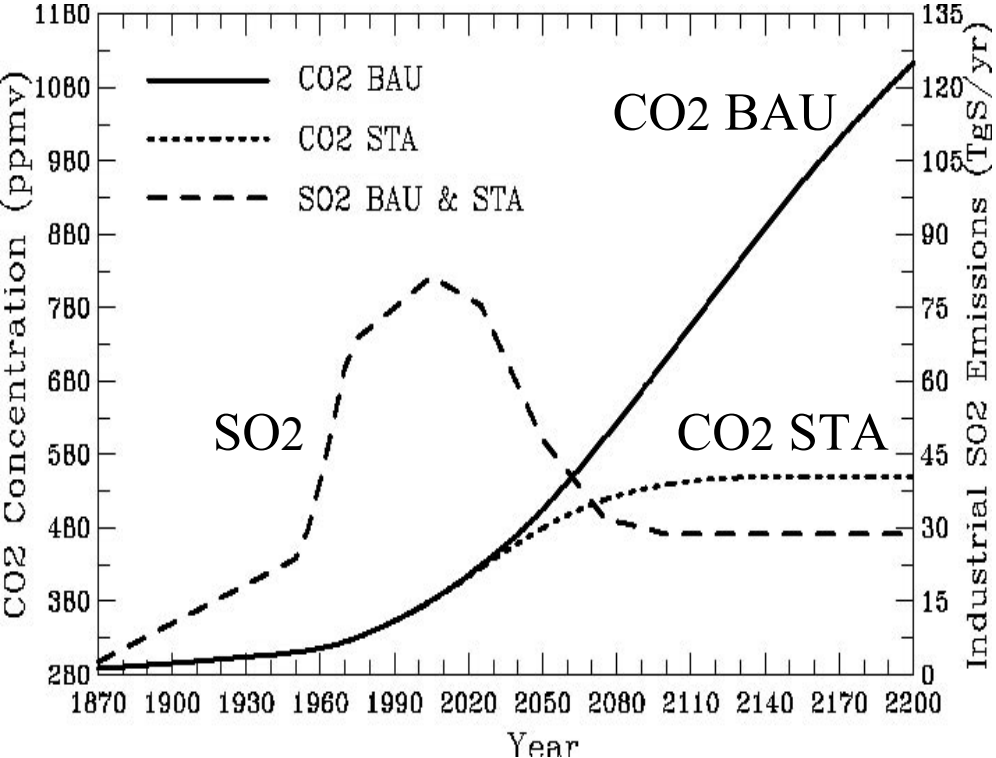
# Climate Sensitive Comparison




From IPCC 2001

# Forcing Scenarios

- **1870-1996**: **$CO_2$, $CH_4$, $N_2O$, $O_3$, CFCs, $SO_2$ based on observations Solar forcing from Hoyt & Schatten'93; volcanic forci**
- **1997-2200: a business-as-usual (BAU) and a $CO_2$ stabilization (STA) scenario. Interactive S chemistry. $O_3$ recovers since late 1990s, reaches the early 1980s level by 2100**




- **2201-2450: $CO_2$ STA path is reversed, i.e. symmetric around 2200. Others const.**

**$CO_2$ Levels in ppmv:**

| | 2000 | 2100 | 2200 | 2300 | 2400 |
|---|---|---|---|---|---|
| BAU | 371 | 711 | 1114 | | |
| STA | 371 | 539 | 550 | 539 | 371 |

## PCM Simulations. See http://www-pcmdi.llnl.gov/ for data availability.

| Forcing | Period | Ensemble Size |
|---|---|---|
| Control Run (fixed 1870 forcing) | 1500 yrs | |
| **Historical Runs (obs.-based forcing):** | | |
| Volcanoes only | 1870-1999 | 4 |
| Ozone only | 1870-1999 | 4 |
| Greenhouse gases (GHG) only | 1870-1999 | 4 |
| Sulfate aerosols (direct) only | 1870-1999 | 4 |
| Solar only | 1870-1999 | 4 |
| Solar+ozone | 1870-1999 | 4 |
| Solar+volcanoes | 1870-1999 | 4 |
| Solar+volcanoes+ozone | 1870-1999 | 4 |
| GHG+ozone | 1870-1999 | 4 |
| GHG+sulfates | 1870-1999 | 4 |
| GHG+sulfates+ozone | 1870-1999 | 10 |
| GHG+sulfates+ozone+solar | 1870-1999 | 4 |
| GHG+sulfates+ozone+solar+volcano | 1870-1999 | 4 |
| **Future Runs (projected forcing):** | | |
| ACACIA Business as Usual (BAU) | 2000-2099 | 5 |
| | 2100-2200 | 1 |
| ACACIA $CO_2$ Stabilization (STA) | 2000-2100 | 5 |
| | 2100-2200 | 1 |
| IPCC SRES A2, B2, and A1B | 2000-2100 | 1 each |
| IPCC SRES A1FI and B1 | 2000-2100 | 5 each |
| 20th century stabilization (five members) | | |
| **Other Runs:** | | |
| 1%/yr $CO_2$ increase to $2xCO_2$ | 1-80 | 5 |
| to $4xCO_2$ | 80-160 | 1 |
| Fixed at $2xCO_2$ | 150 years | 1 |
| Fixed at $4xCO_2$ | 150 years | 1 |
| Fixed at 1990 forcing | 300 years | 1 |
| Land surface change (in progress) | 1870-2000 | |

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# Select Papers Analyzing the Simulations

- **20th Century Climate:**

  **Amman et al. (2003, GRL); Dai et al. (2001, JC); Dai et al. (2001, BAMS); Meehl et al. (2003a, JC); Meehl et al. (2003b, JC)**

- **Future Climates:**

  **Dai et al. (2001, JC); Dai et al. (2001, BAMS); Dai et al. (2001, GRL); Meehl & Arblaster (2003)**

- **Ocean Changes:**

  **Barnett et al. (2001, Science); Dai et al. (2003, JC); Hu et al. (2003, JC).**

- **See http://www.cgd.ucar.edu/pcm/ for more info.**

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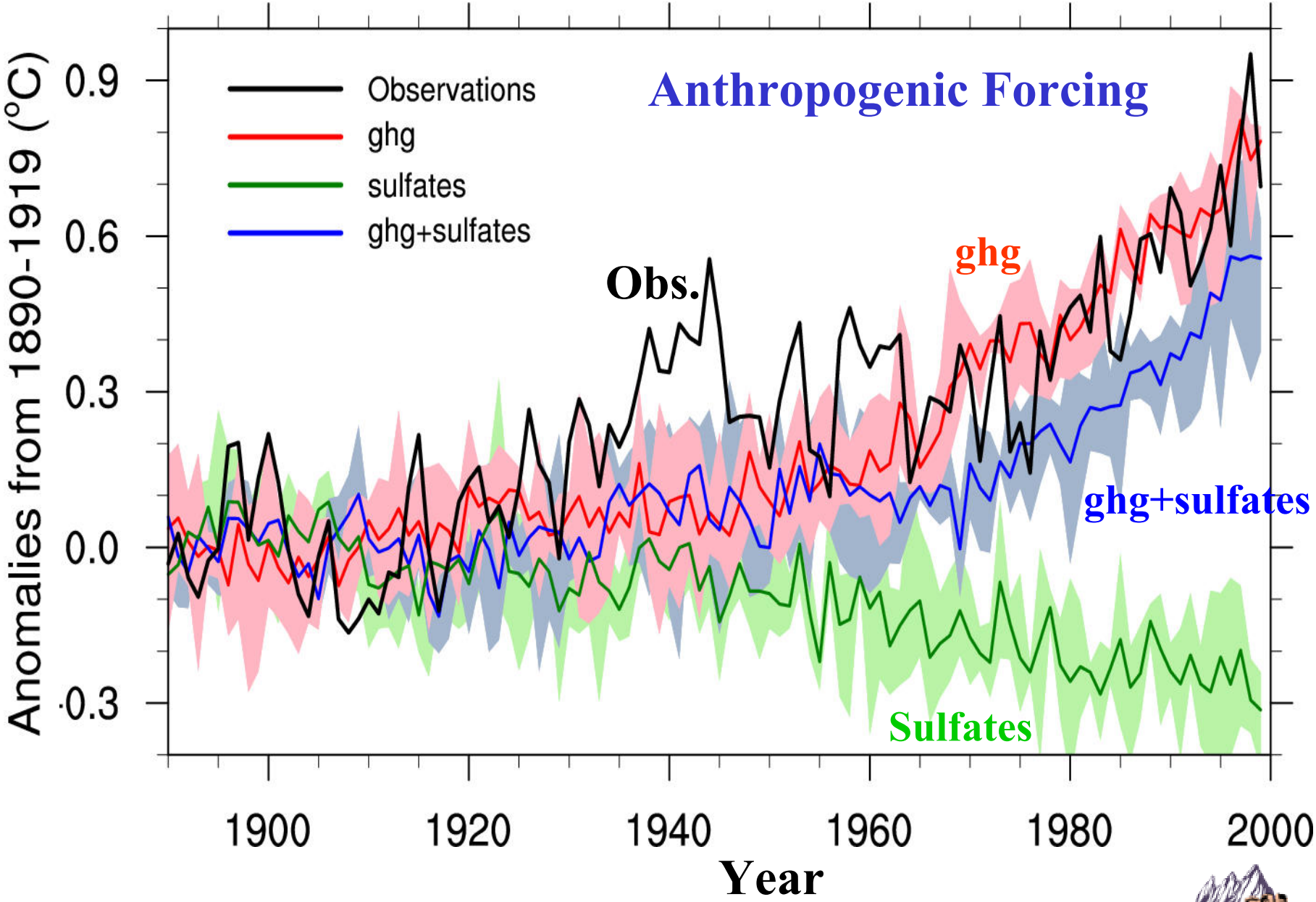
# PCM Simulated 20th Century Global Temp.



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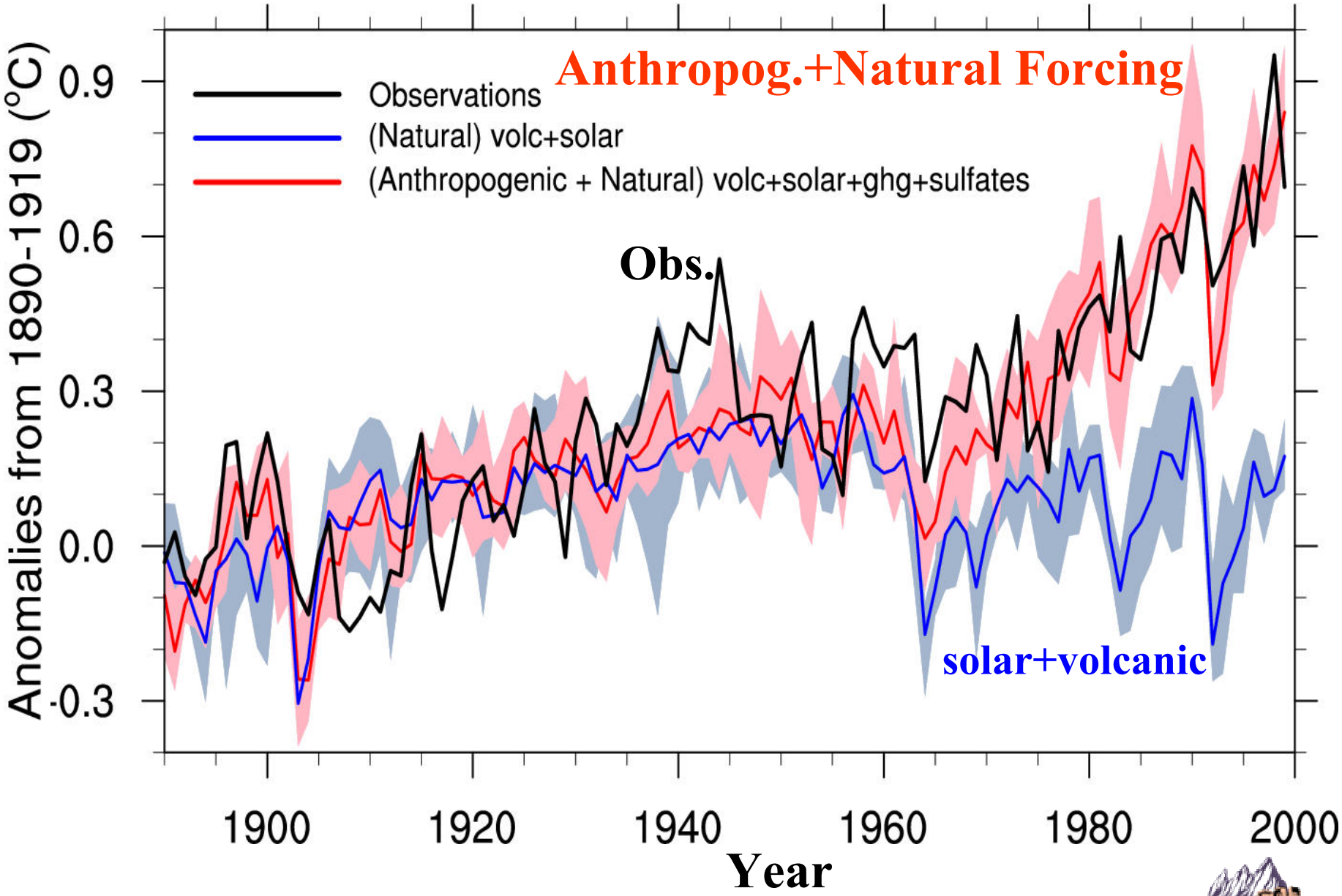
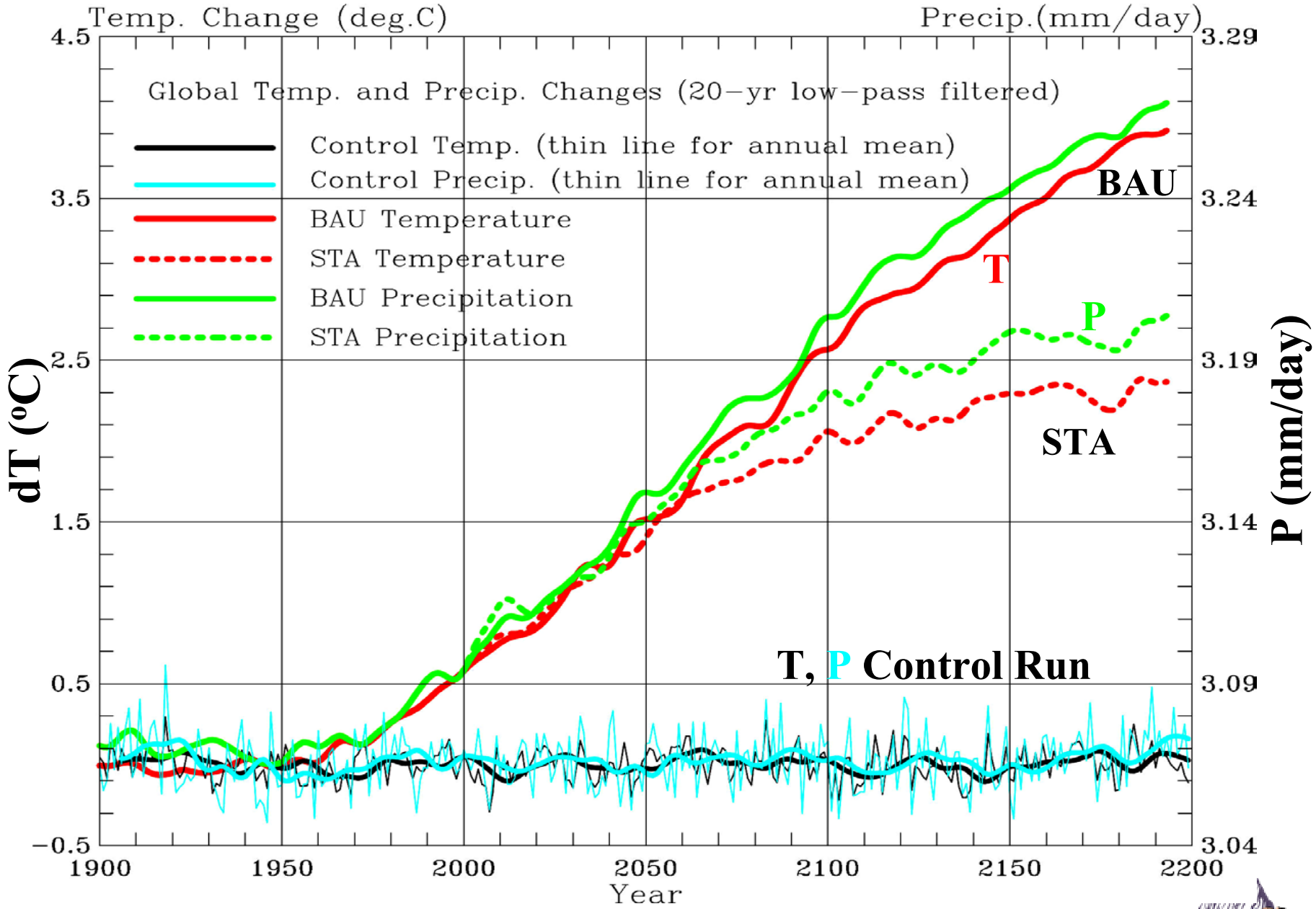
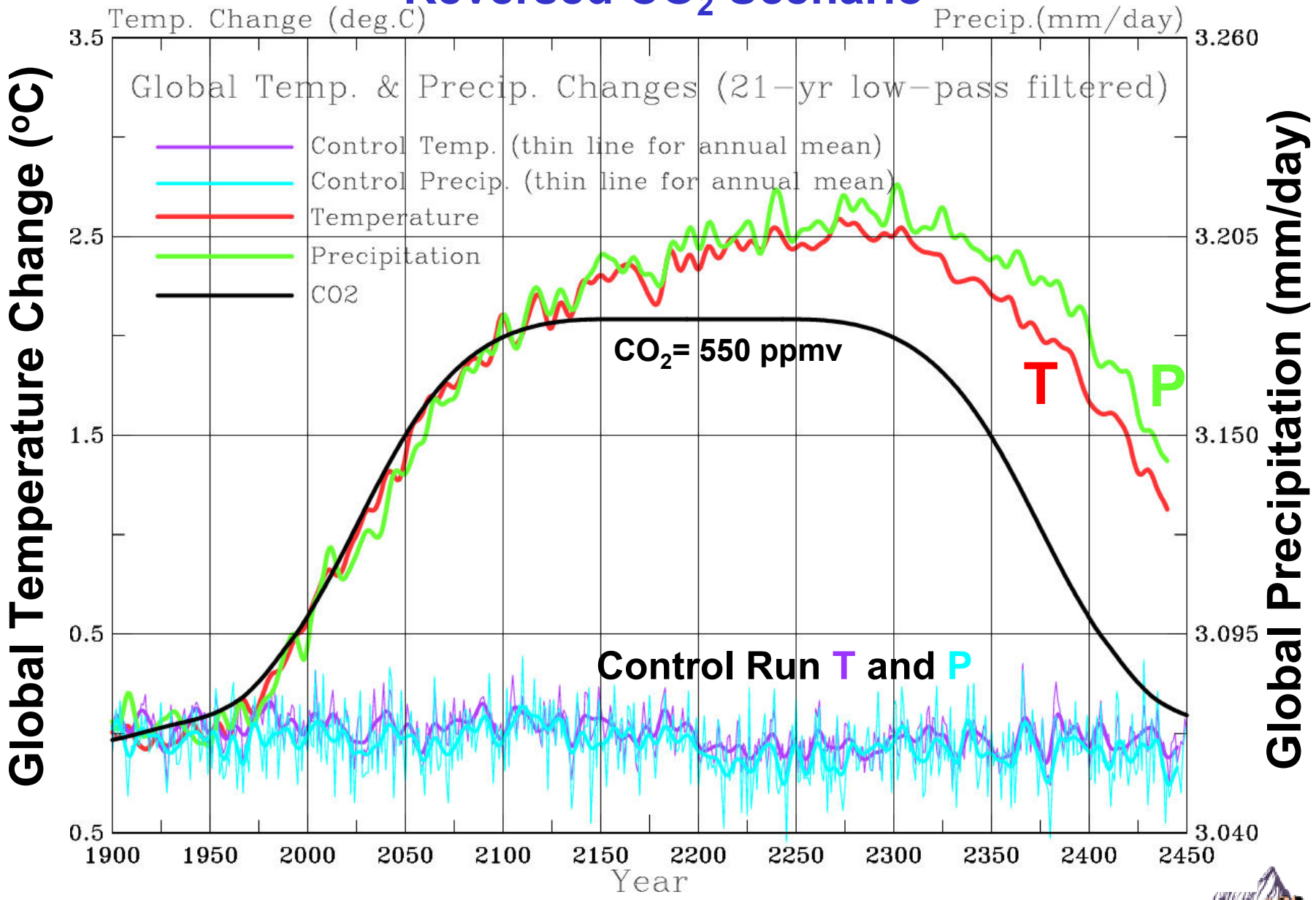


# PCM Projected Future Global T & P Change

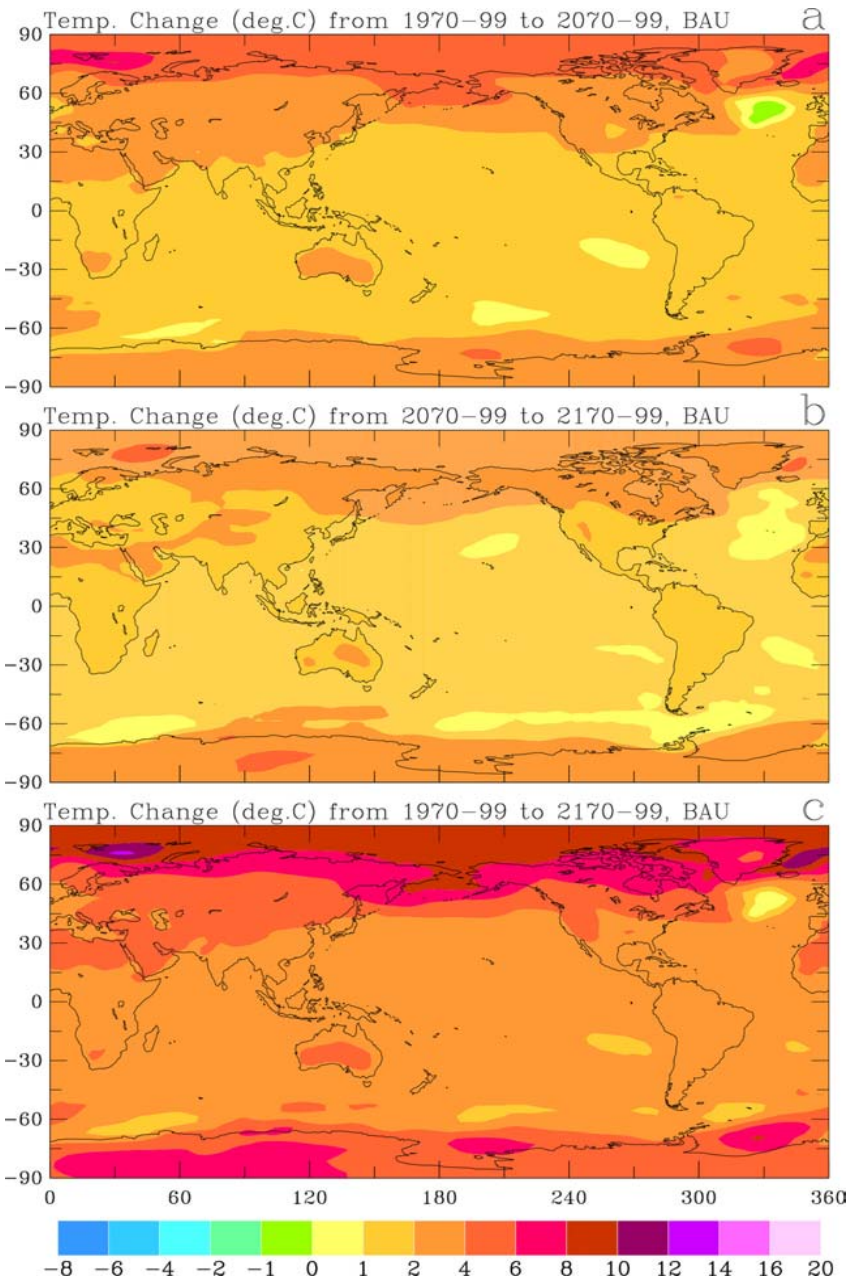


# Global Temperature and Precipitation

## Reversed $CO_2$ Scenario



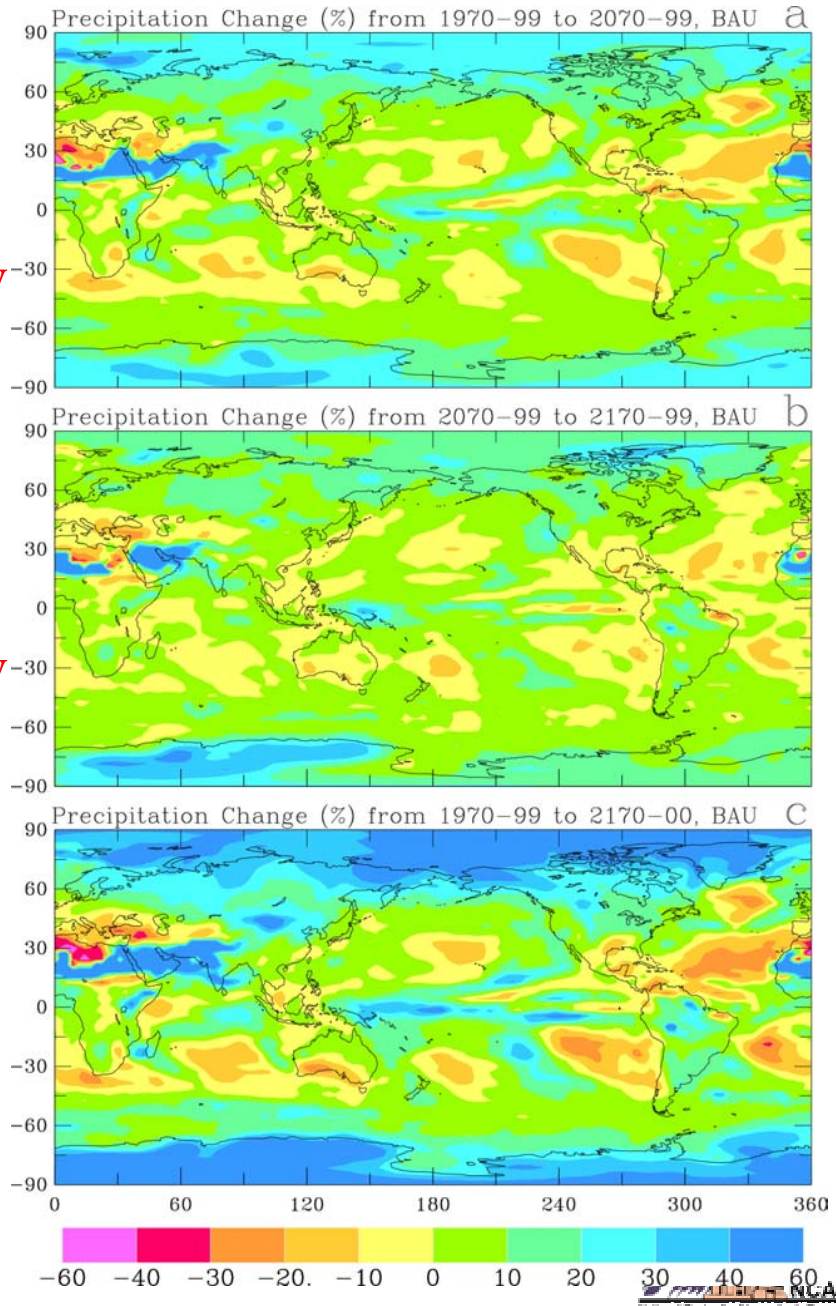
# Temperature Change (ºC) BAU Precipitation Change (%)




21st century

22nd century

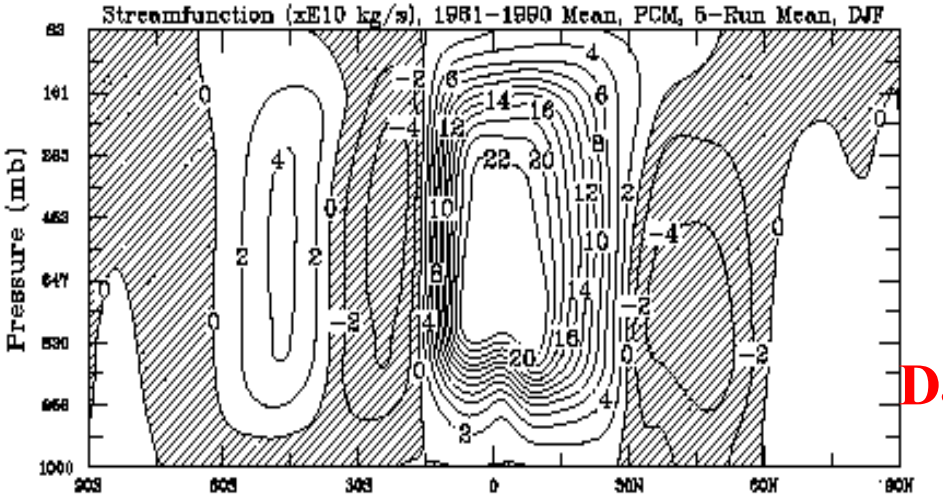
21st + 22nd

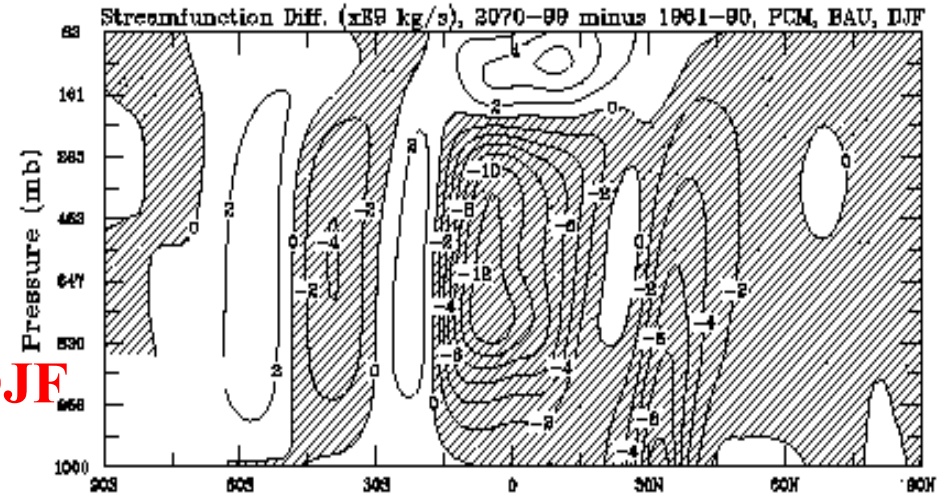


# Atmospheric Meridional Streamfunction

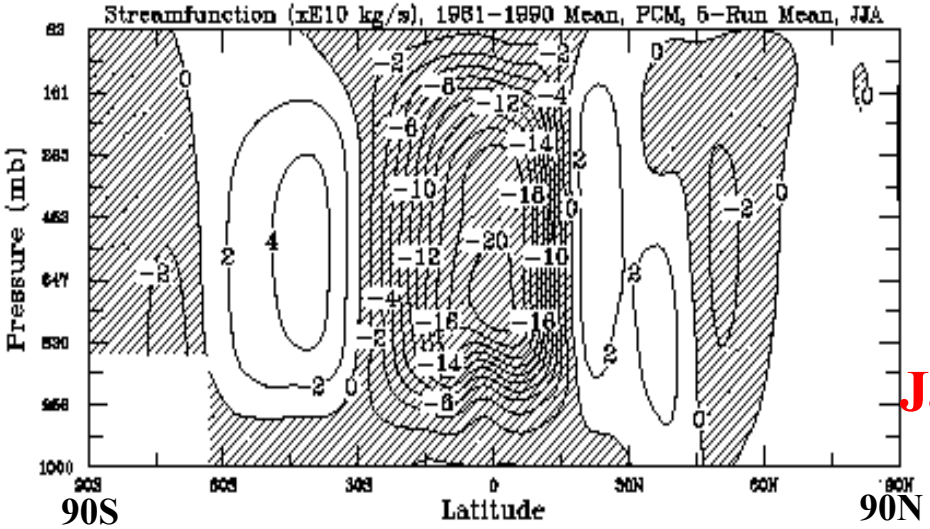
## 1961-1990 Mean, PCM

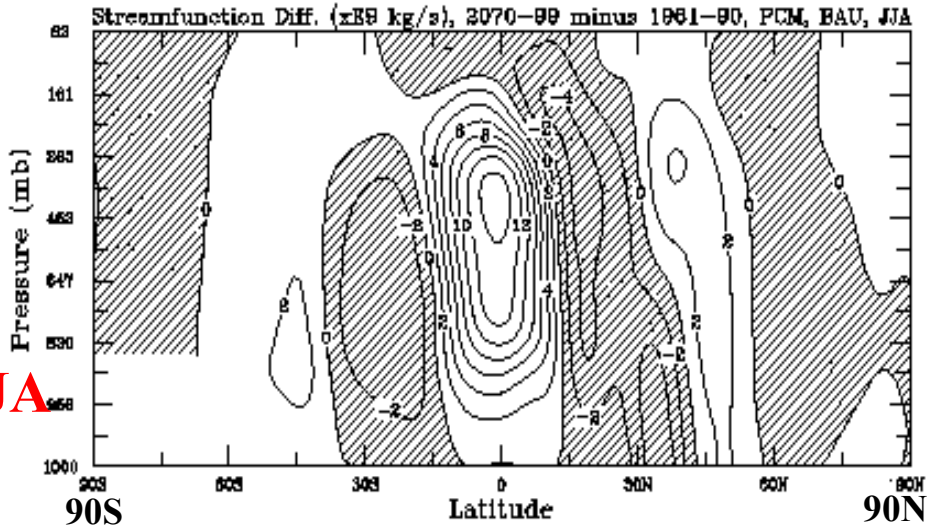
## 2070-99 minus 1961-90




DJF




JJA

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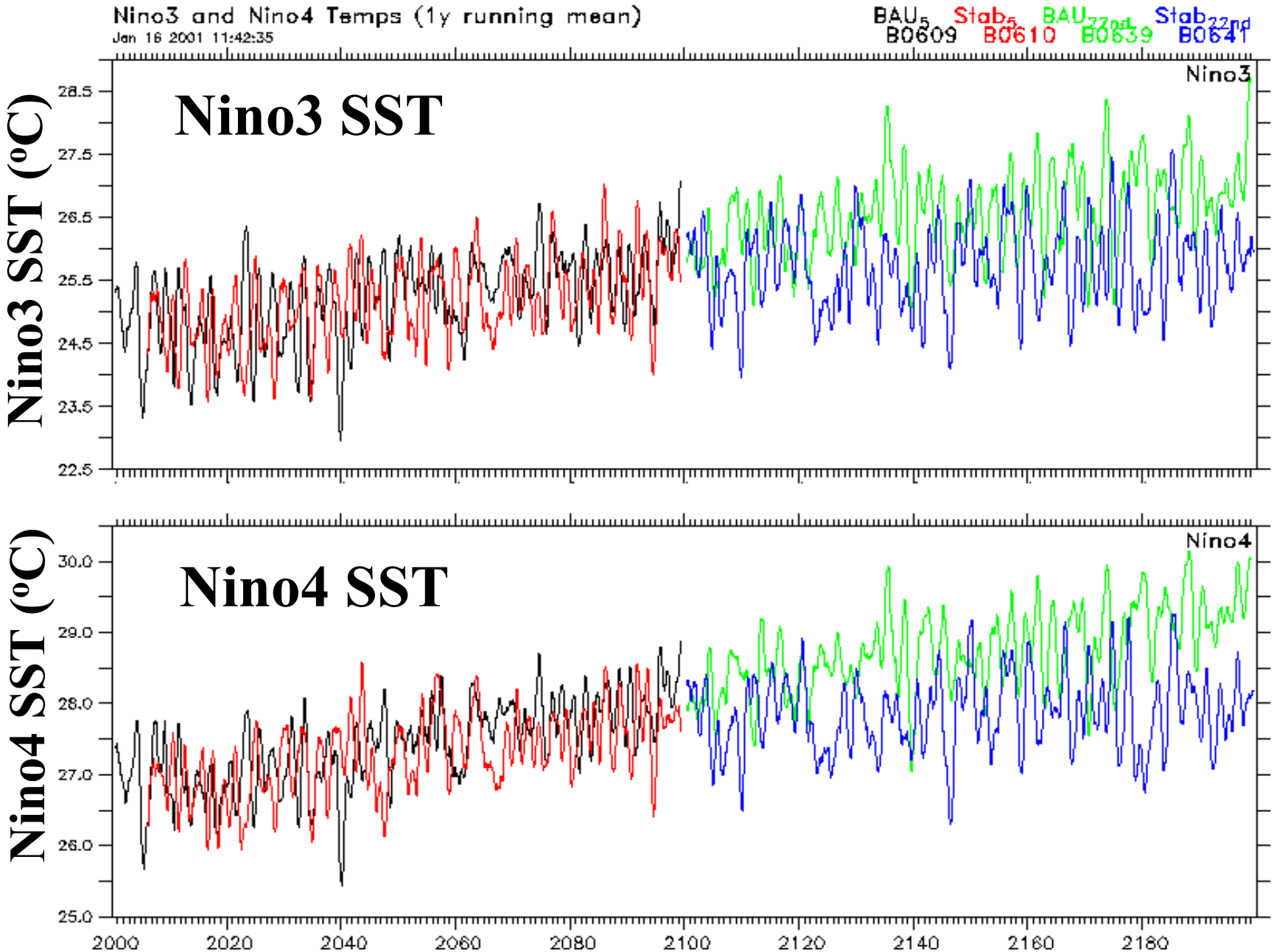
# ENSO SST Index for the 21st and 22nd Century

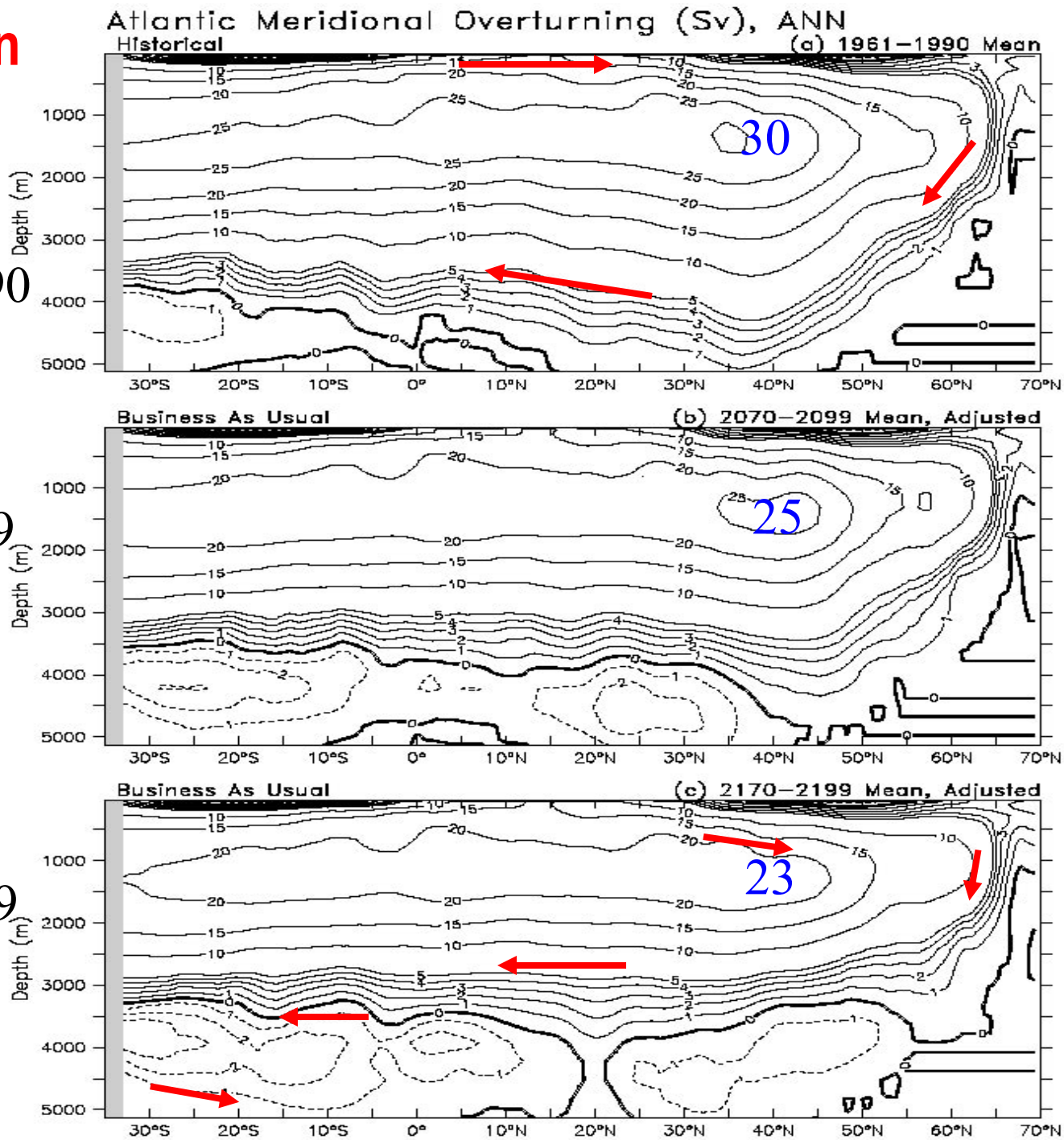


# Atlantic Ocean Overturning Circulation

1961-1990

2070-2099
BAU

2170-2199
BAU

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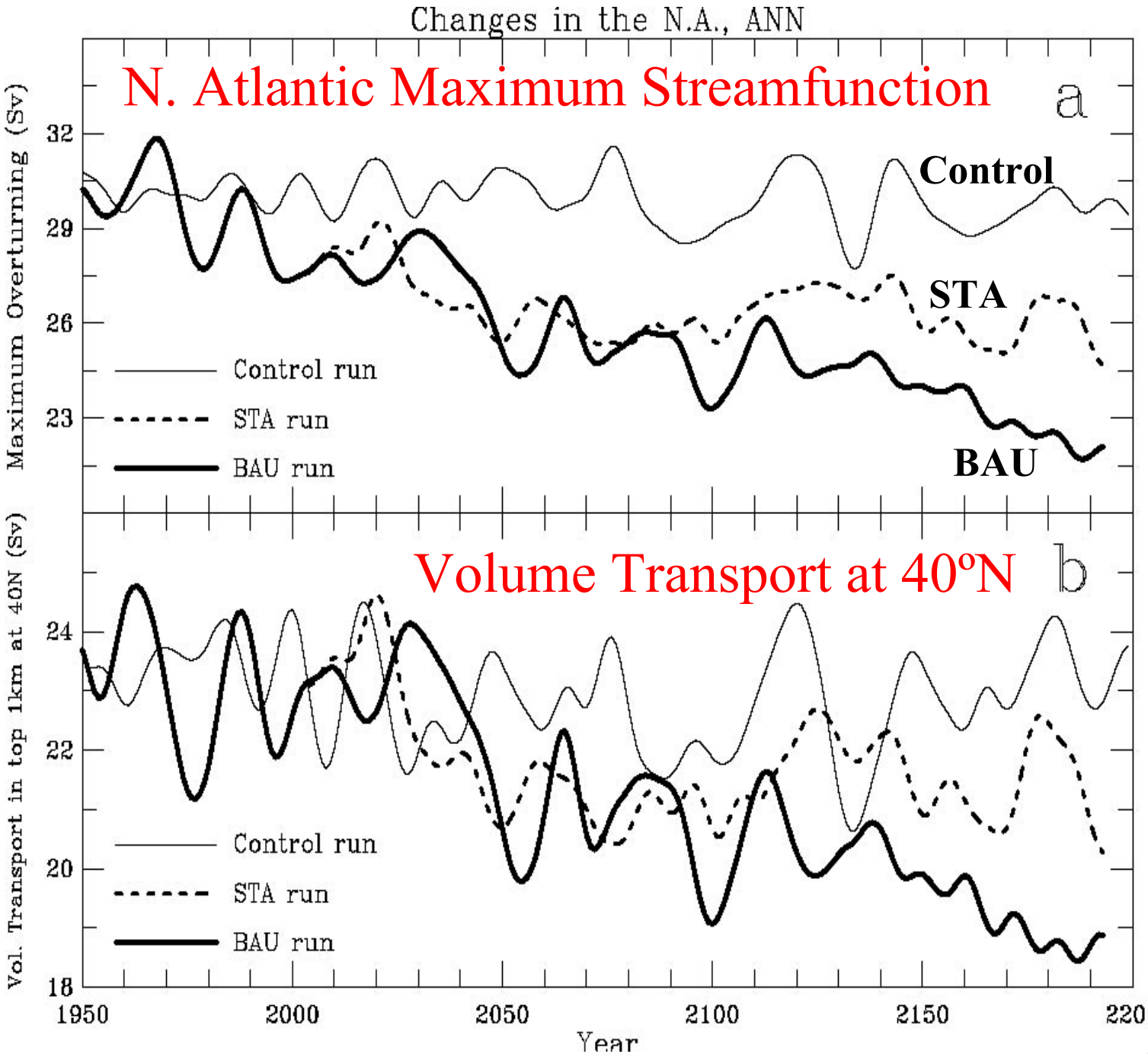
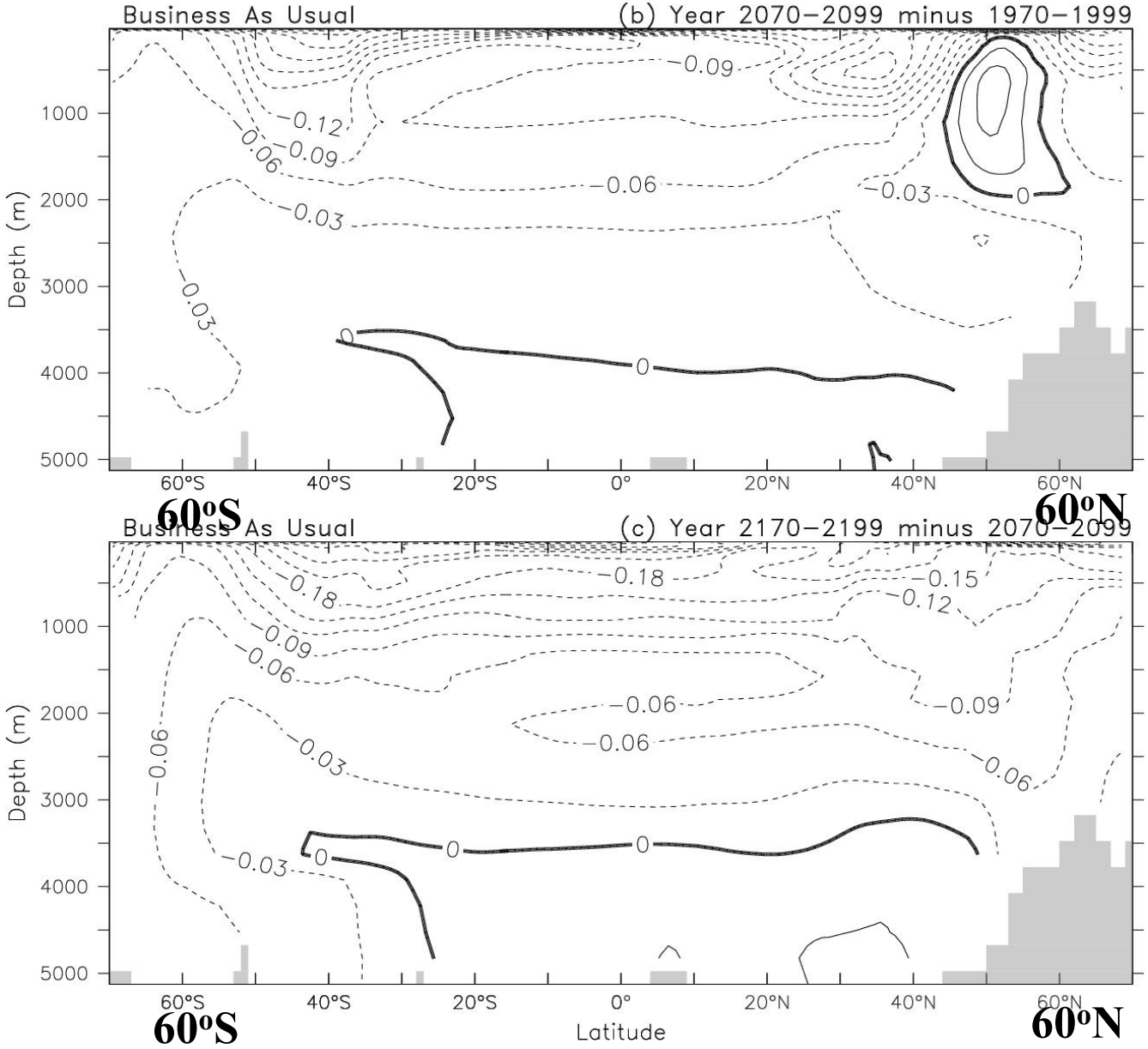

Changes in the N.A., ANN
N. Atlantic Maximum Streamfunction
a
Control
STA
BAU
Maximum Overturning (Sv)
32
29
26
23
Control run
STA run
BAU run
Volume Transport at 40ºN
b
Vol. Transport in top 1km at 40N (Sv)
24
22
20
18
Control run
STA run
BAU run
1950
2000
2050
2100
2150
2200
Year

# Ocean Density Change, BAU Scenario




2070-2099 minus 1970-1999

2170-2199 minus 2070-2099

# Summary

- In the PCM, solar and volcanic forcing is responsible for the warming in the first half of the 20th century while the ghg+sulfates account for the warming since the 1970s.
- The PCM projects a global warming of ~2.0ºC in the 21st century under the BAU scenario. Stabilizing CO2 around 550 ppm by 2150 reduces the warming by ~0.5 ºC with similar T and P change patterns.
- Global precipitation increases by ~3.3% (2.4%) under the BAU (STA) scenario in the 21st century.
- The Hadley circulation weakens by ~10% under the BAU scenario, partly due to enhanced warming in the upper troposphere in the tropics.
- In the PCM, Atlantic THC weakens by 12% in the 21st century under the BAU scenario, and by additional 10% in the 22nd century if $CO_2$ keeps rising.
- The THC weakening results from larger warming in the upper oceans and in the northern Atlantic Ocean than in the deeper and southern oceans.

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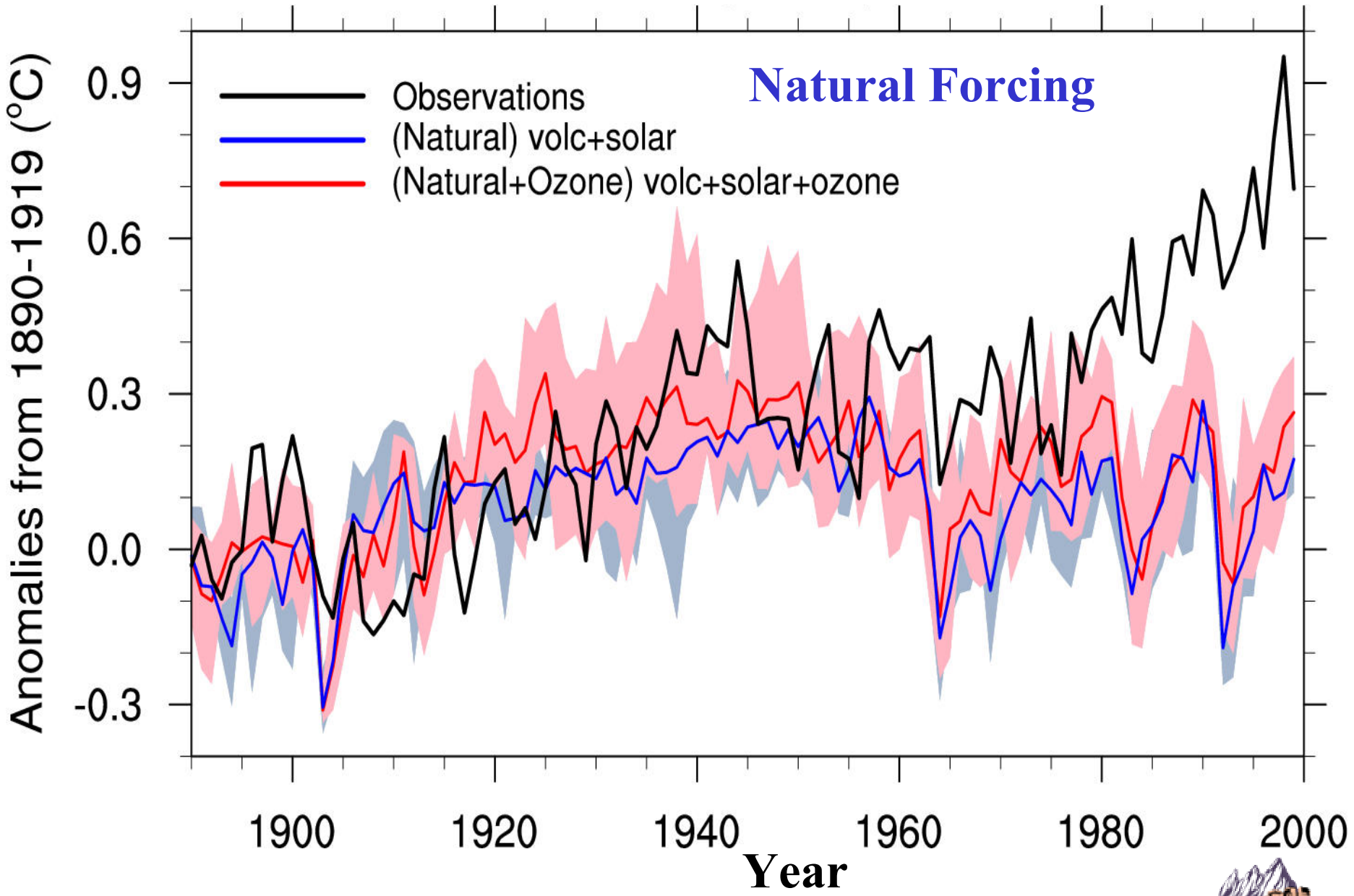
# End!

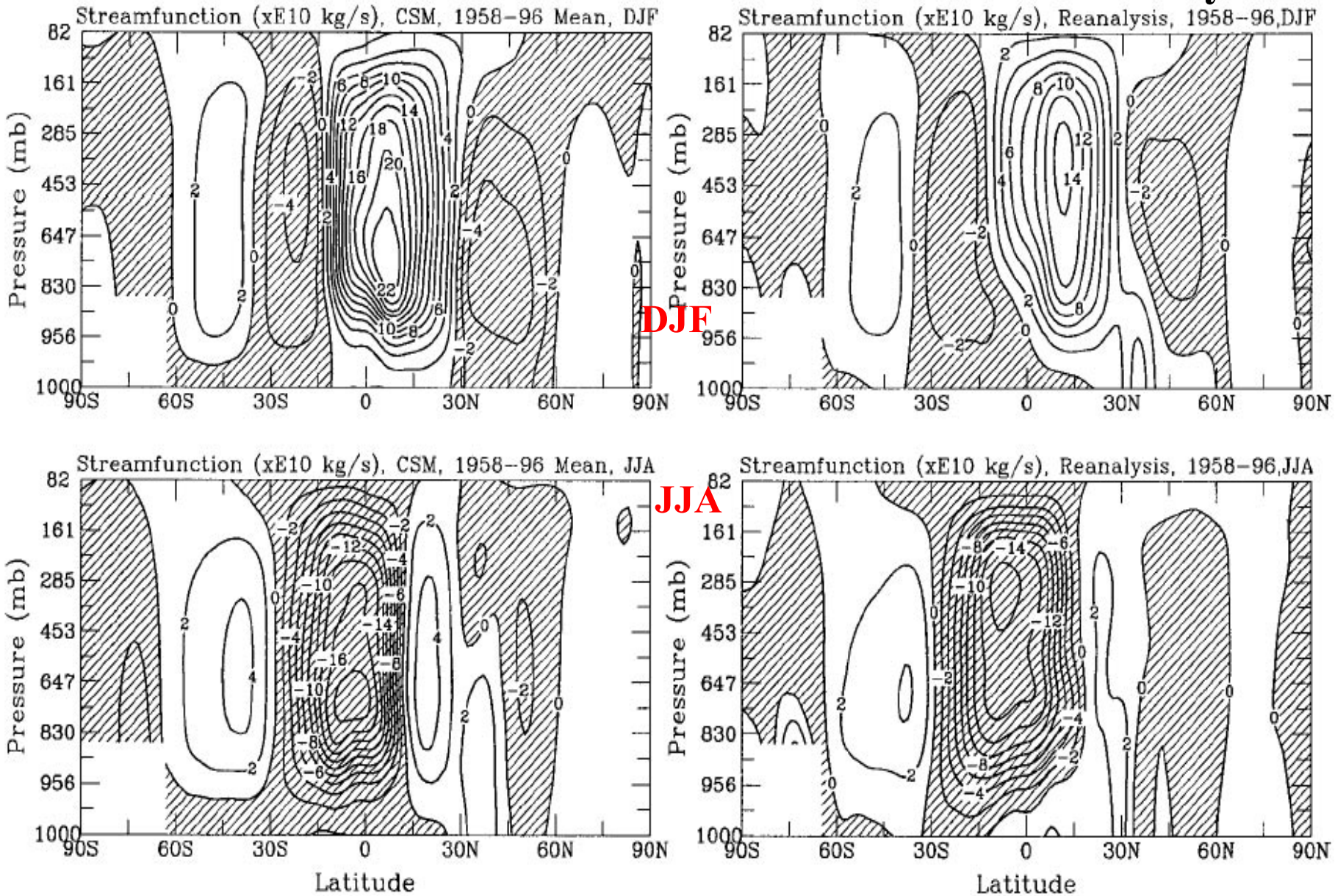
# PCM Simulated Global Temp.



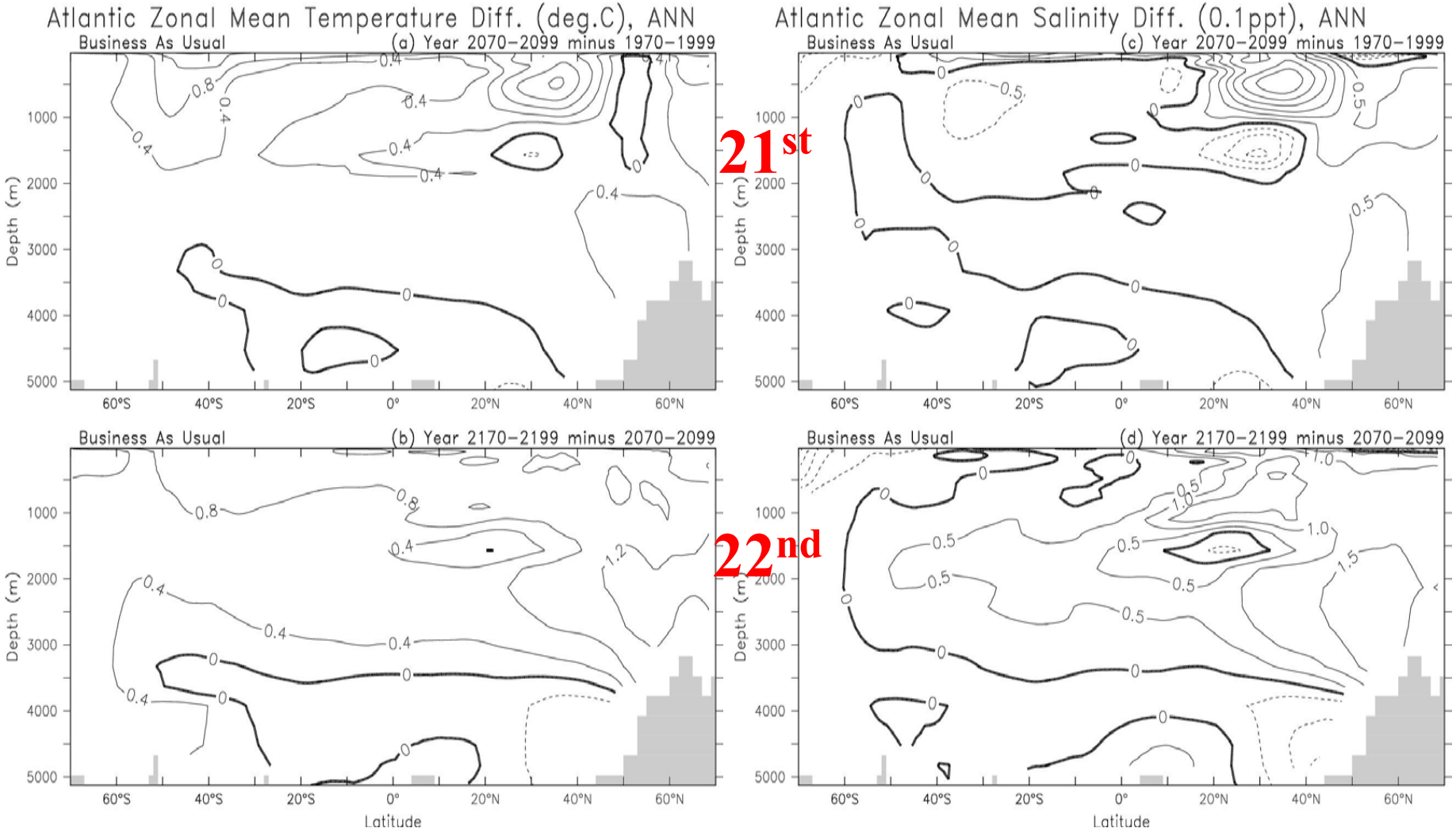
# Zonal Mean Streamfunction

## CSM

## NCEP/NCAR Reanalysis



# BAU Scenario

## Temp. Change

## Salinity Change