Climate change experiments with a Hi-res. climate model

~ *current status and future plans* ~

The K-1 Japan Project Team*

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4 Research Organization for Information Science & Technology (RIST)

CCSR UNIV. TOKYO

NIES

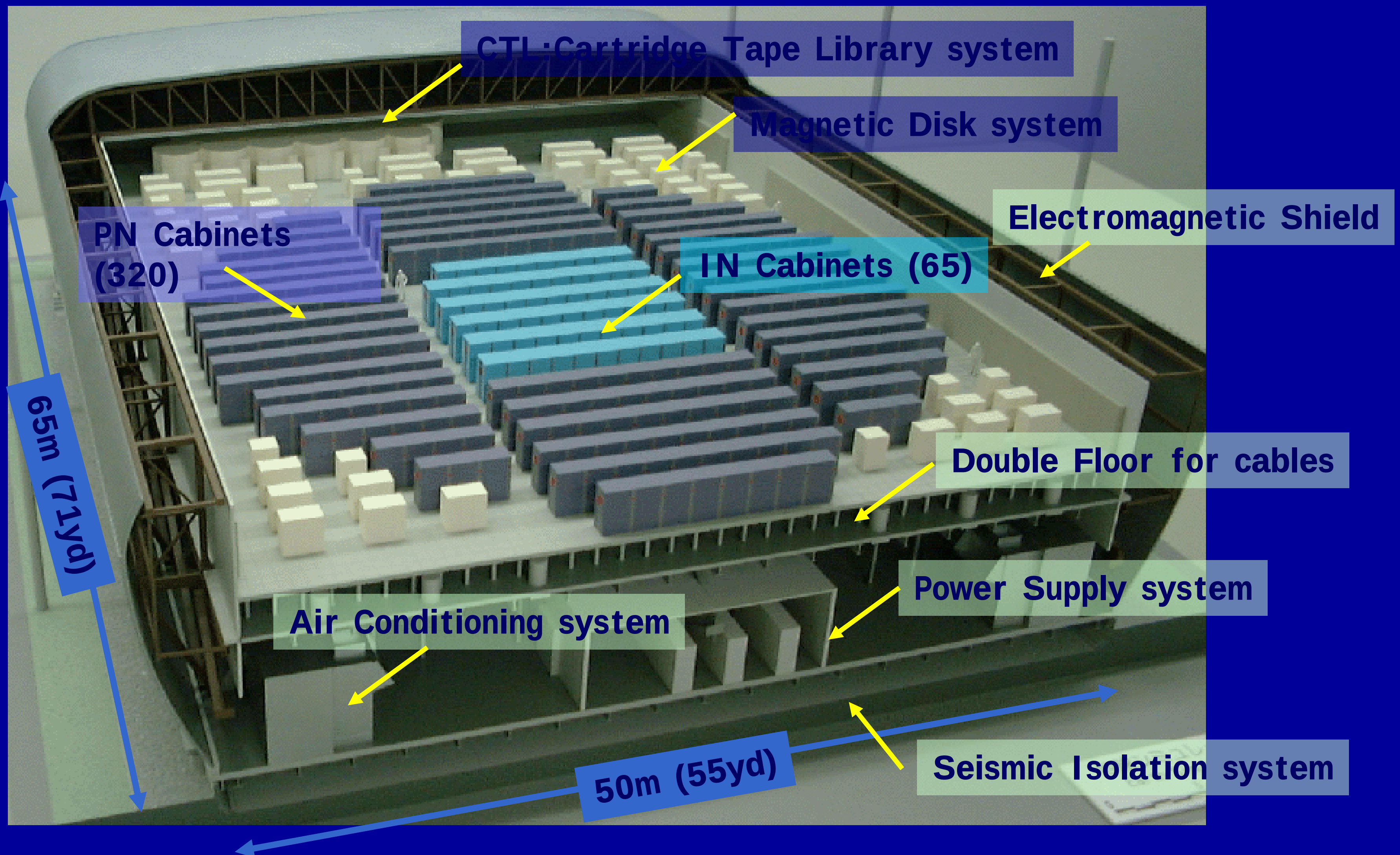
FRSGC Frontier Research System for Global Change

What is "The K-1 Project" ?

- Joint project : CCSR + NIES + FRSGC
- Funded by Ministry of Education, Culture, Sports, Science and Technology of Japan
- First item of Research Revolution 2002
- "Kyousei Project Dai 1 Kadai" in Japanese

- Develop a high-resolution climate models for the Earth Simulator
- Contribute to the IPCC AR4
- Understand dynamics of climate system

The Earth Simulator

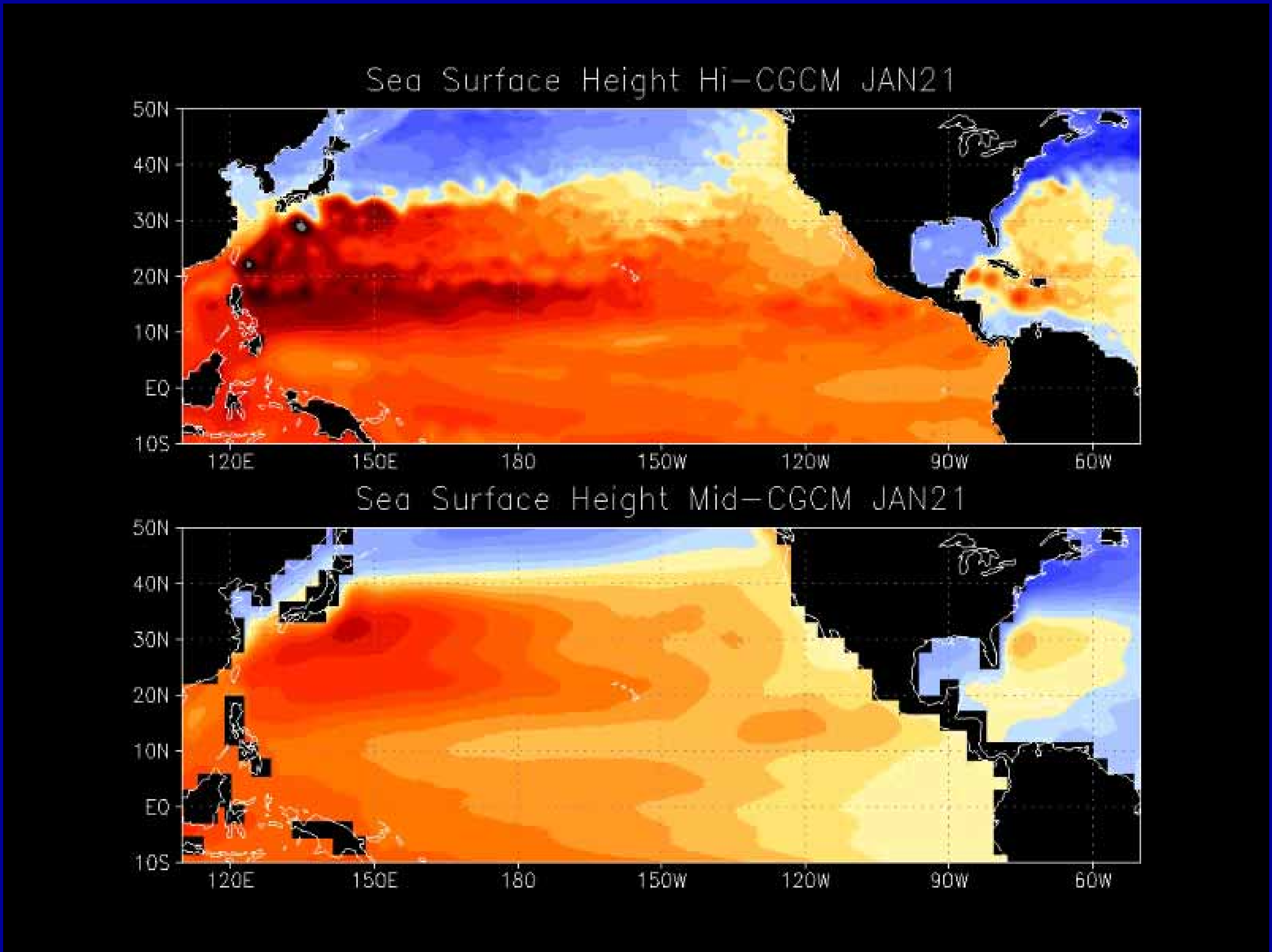


The CCSR/NIES/FRSGC Coupled Ocean-Atmosphere GCM for the Earth Simulator: *MIROC 3.1*

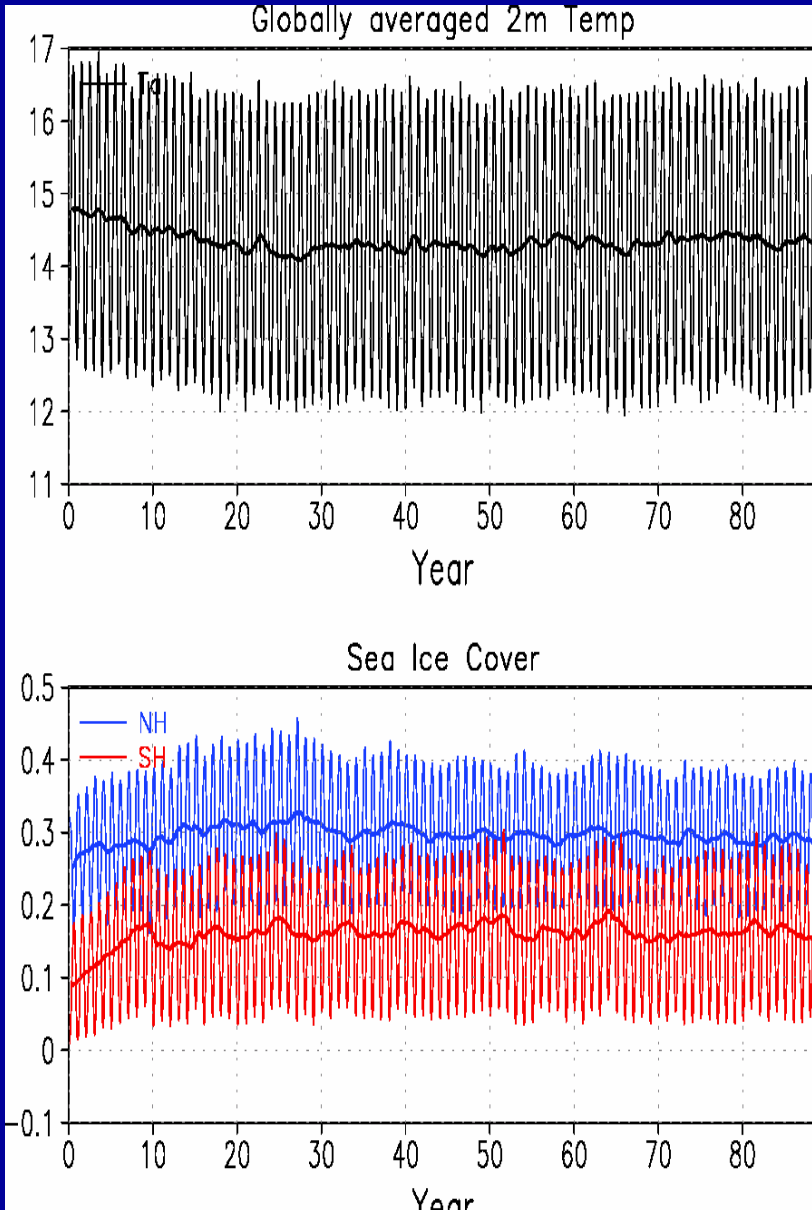
- Atmosphere: Spectral T106 (120km) 56 levels
- Ocean & Ice: Grid $1/4^{o}$x$1/6^{o}$ 48 levels
- Land: $1/2^{o}$x$1/2^{o}$ MATSIRO SVATS model
- River: $1/2^{o}$x$1/2^{o}$ TRIP river routing model
- Parallelized with MPI on 80PE for atmos. and 608PE for ocean (13% of whole ES)
- Atmos. and ocean run simultaneously on separate PE groups (MPMD coupling).

No flux correction applied

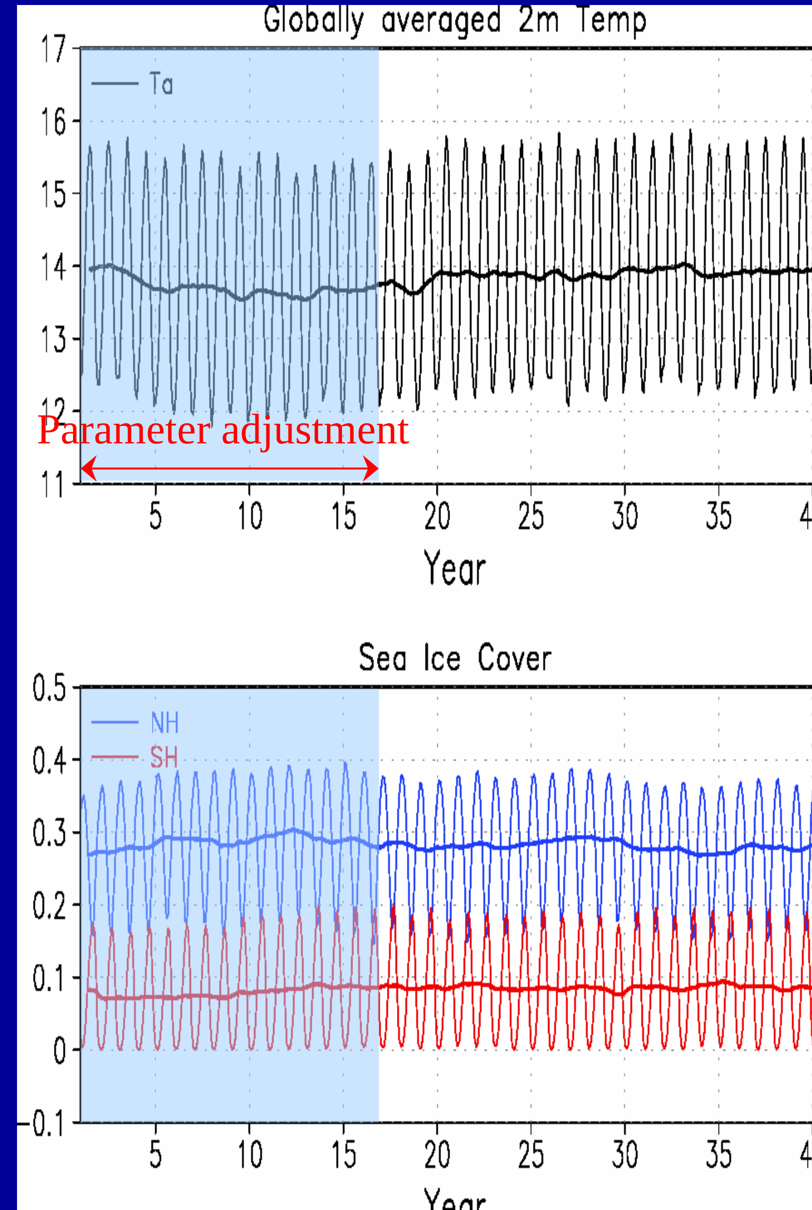
Hi-CGCM: a pilot 40-yr integration



Mid-CGCM*



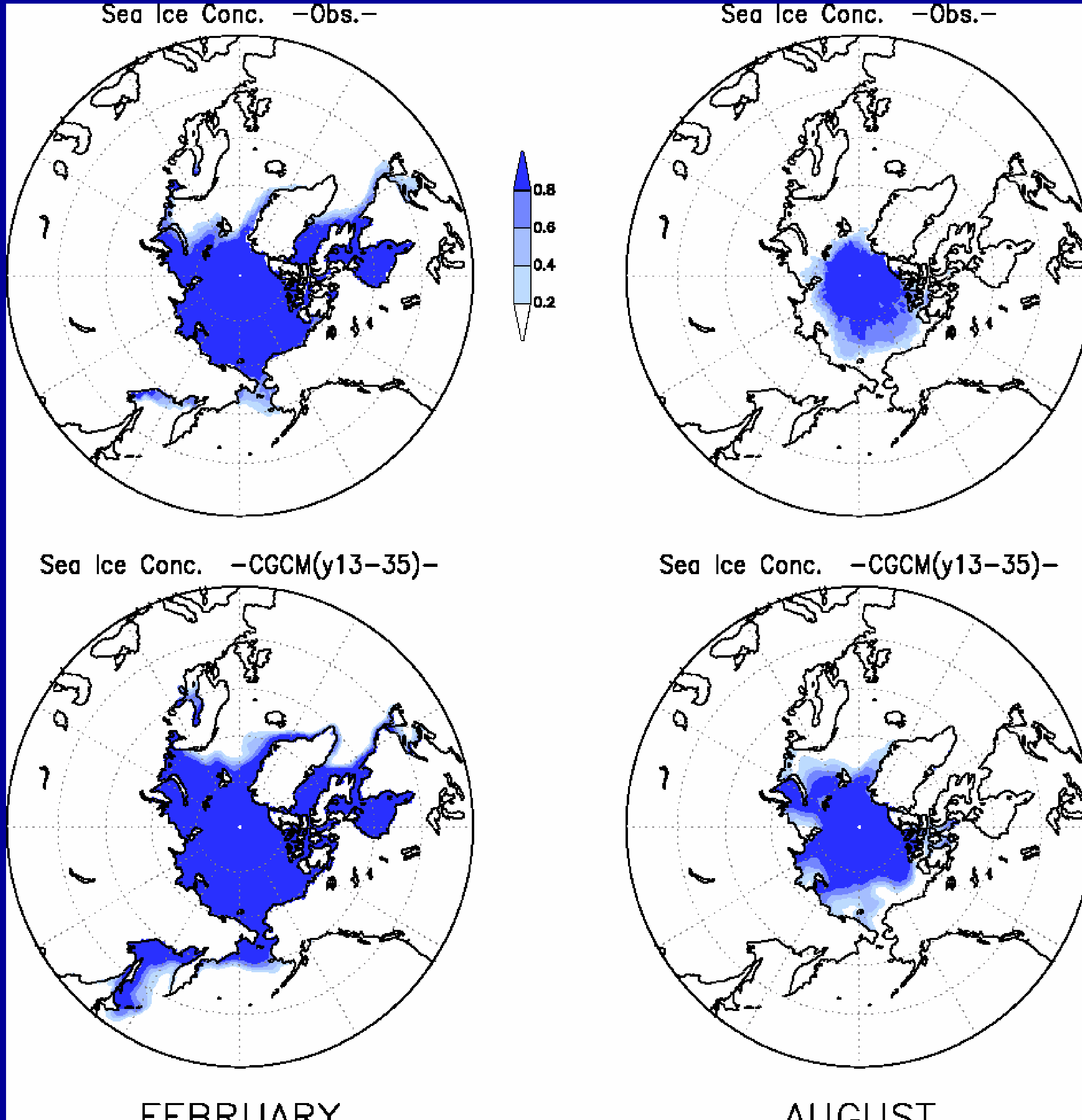
Hi-CGCM



*T42L20+1^{o}x1.4^{o}L43

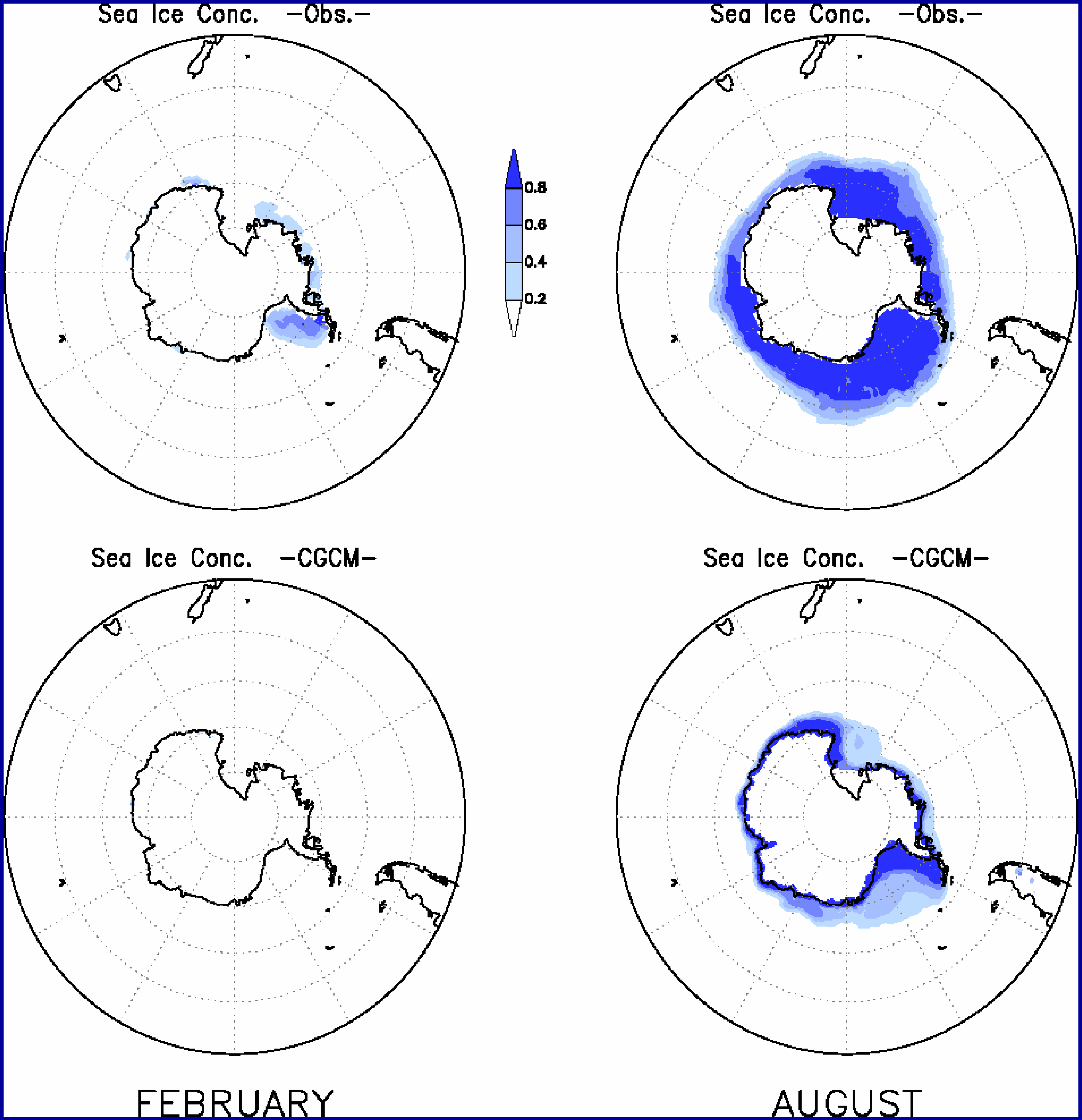
Obs.

Hi-CGCM



Sea Ice Conc. -Obs.-
Sea Ice Conc. -Obs.-
0.8
0.6
0.4
0.2
Sea Ice Conc. -CGCM(y13-35)-
Sea Ice Conc. -CGCM(y13-35)-
FEBRUARY
AUGUST

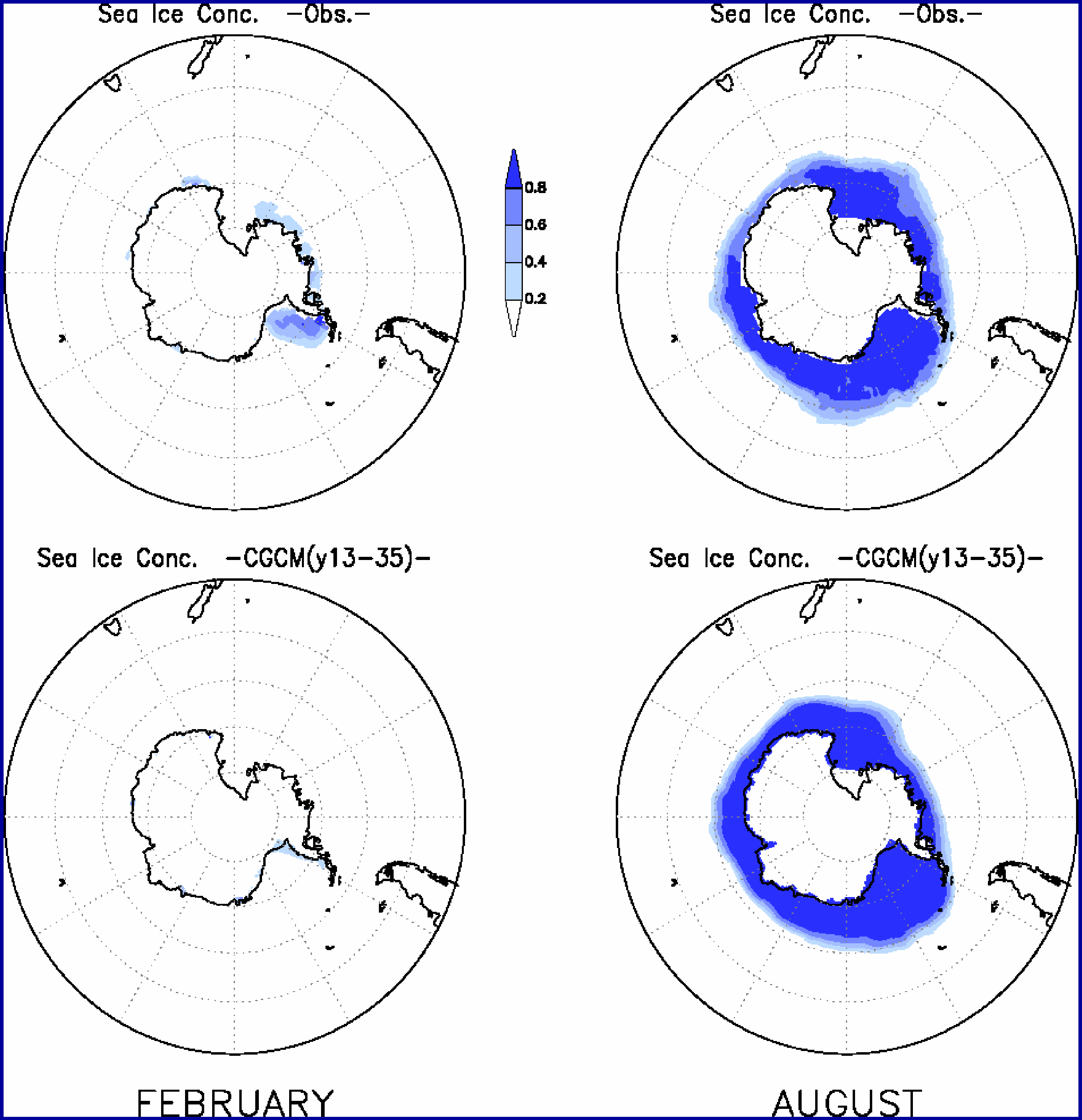
Obs.



Hi-CGCM
(test)

Obs.

Hi-CGCM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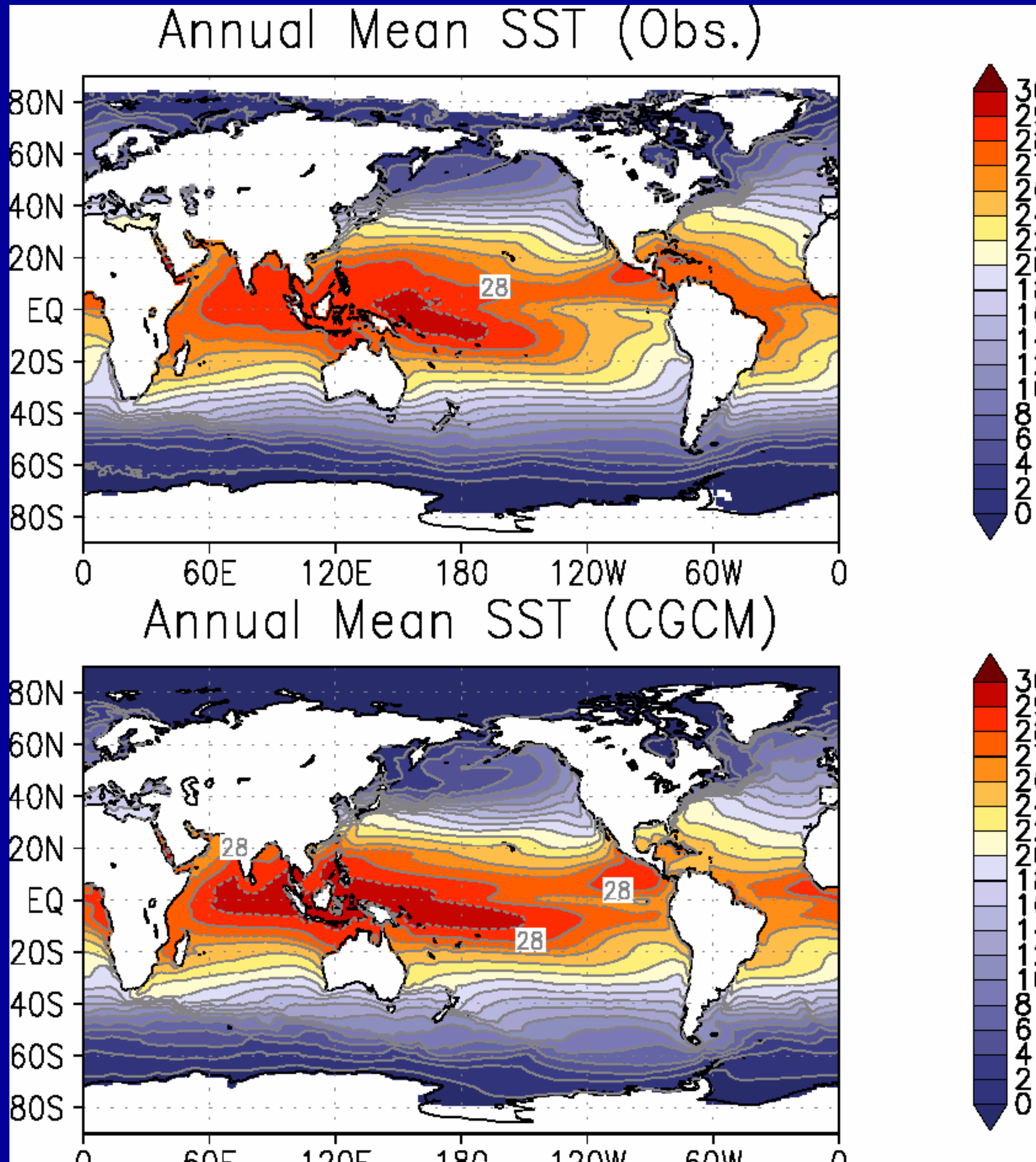
FEBRUARY
AUGUST

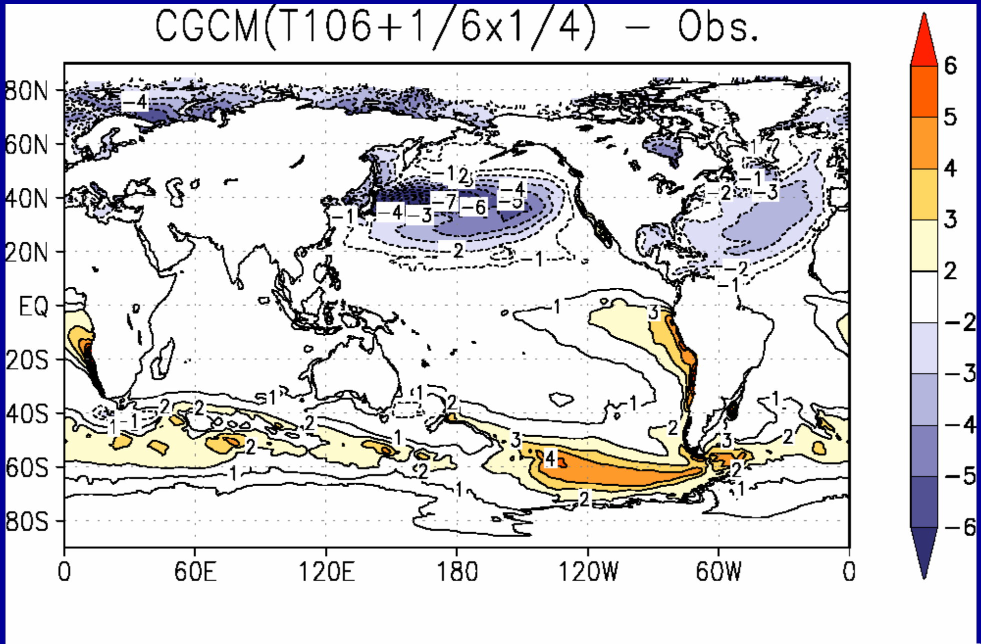
Obs.

Hi-CGCM

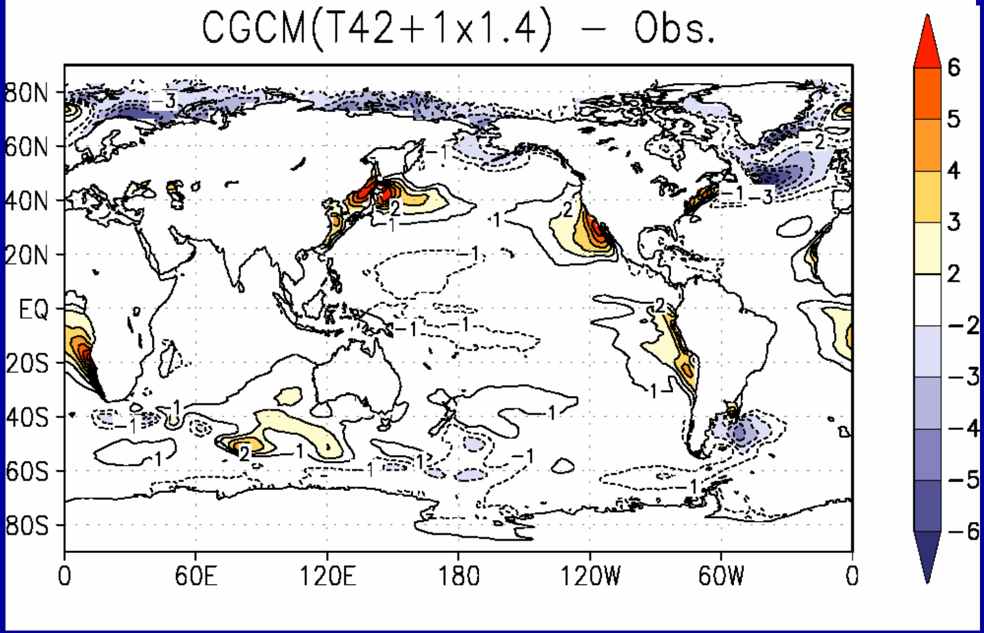


Annual Mean SST (Obs.)
80N
60N
40N
20N
EQ
20S
40S
60S
80S
0
60E
120E
180
120W
60W
0
28
30
29
28
27
26
24
22
20
18
16
14
12
10
8
6
4
2
0
Annual Mean SST (CGCM)
28
28
28

Hi-CGCM



Mid-CGCM

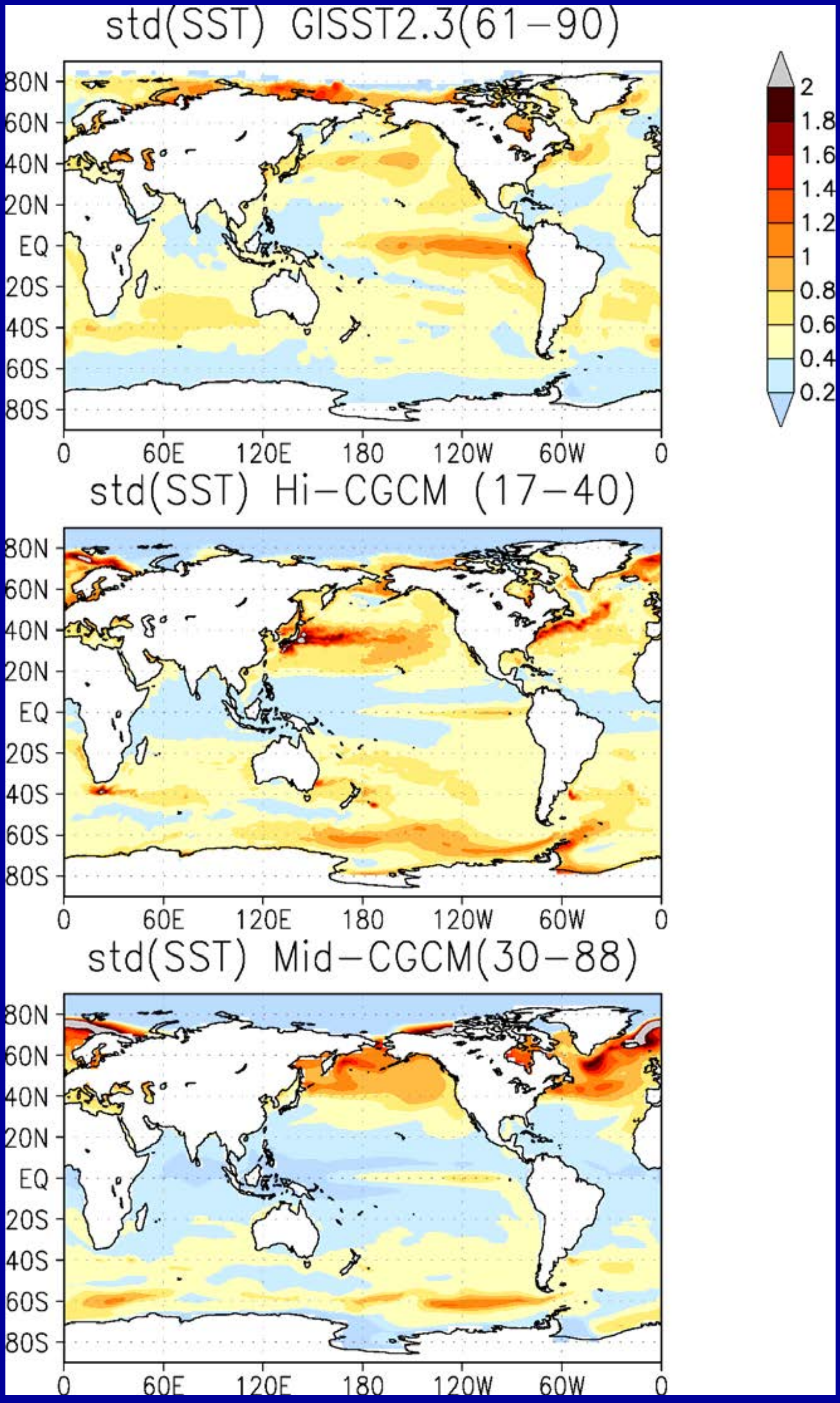


Standard Deviation of SST

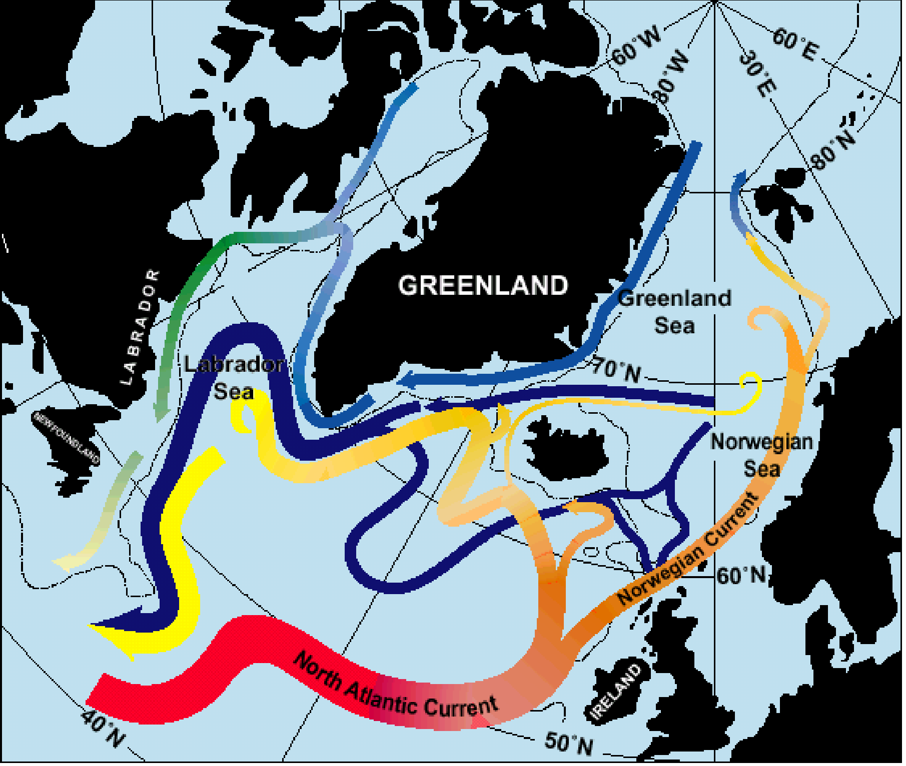
Obs.

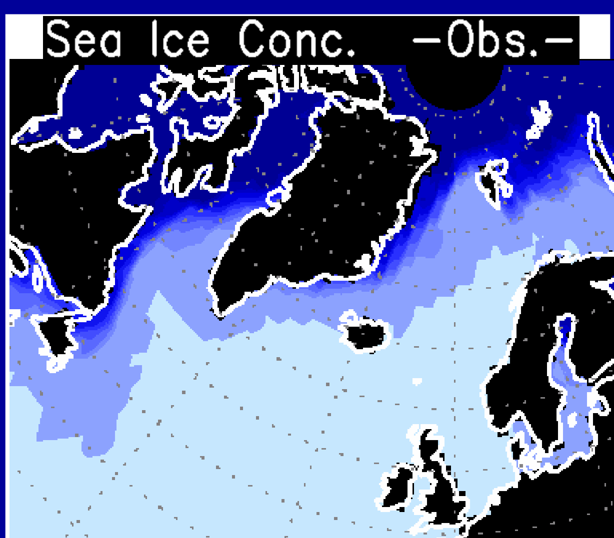
Hi-CGCM

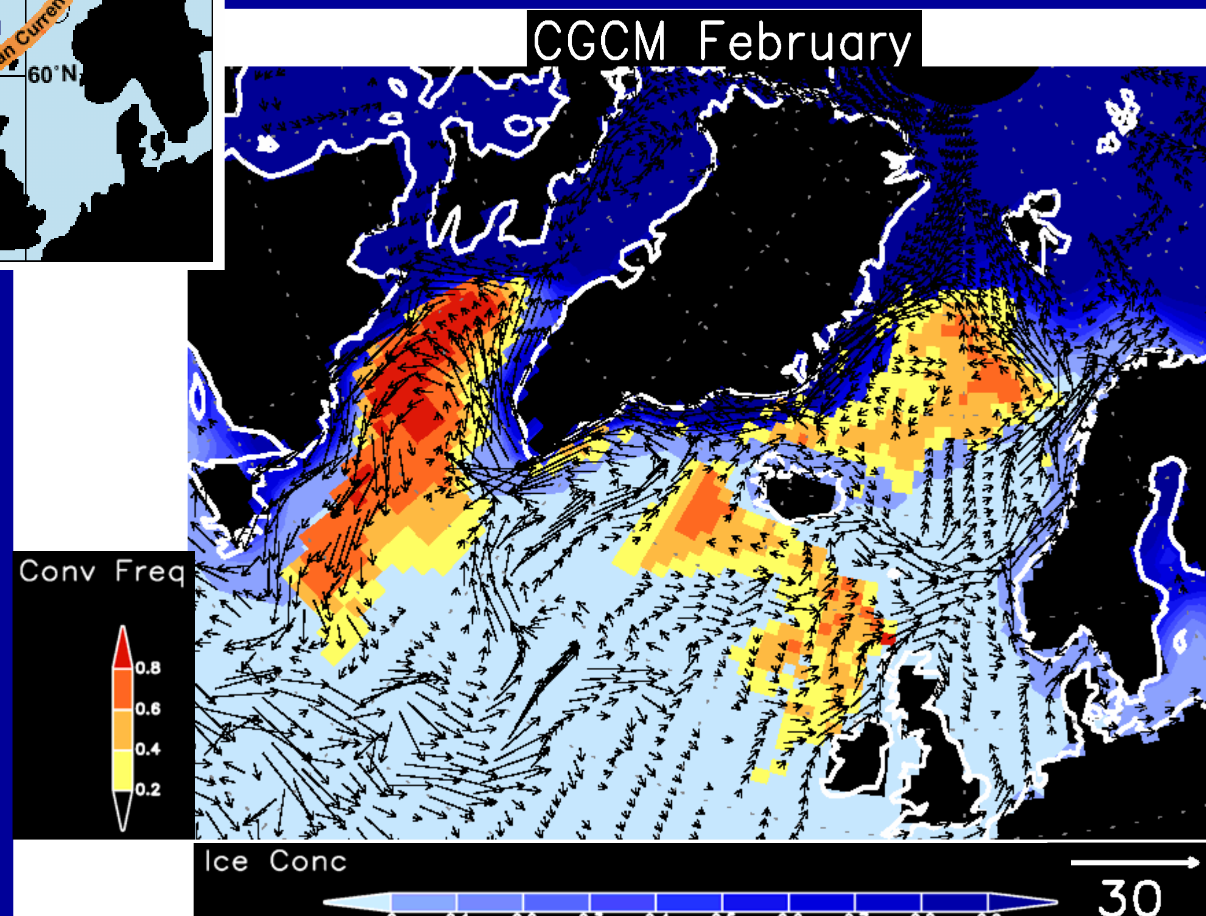
Mid-CGCM



Atlantic Thermohaline Circulation



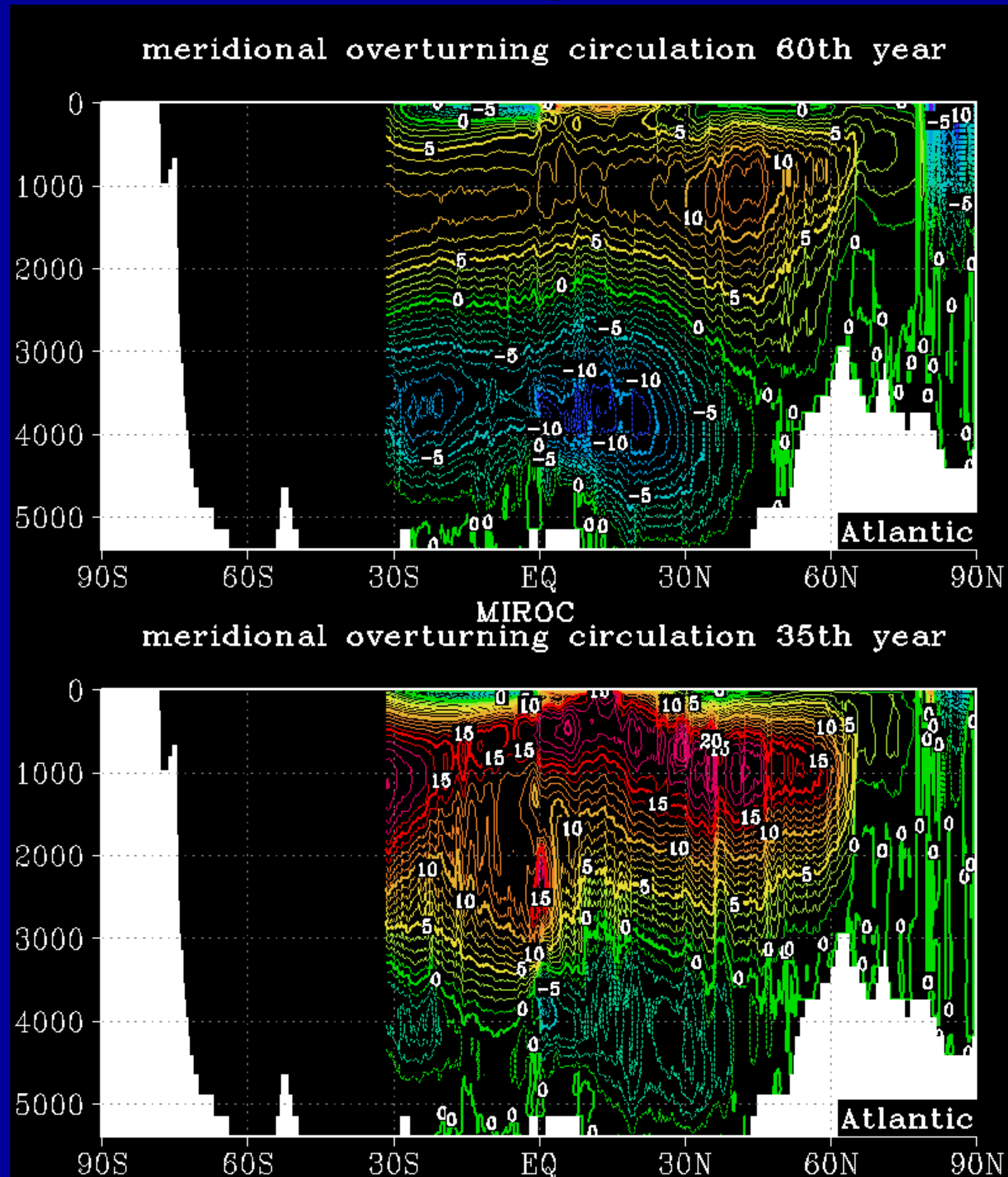




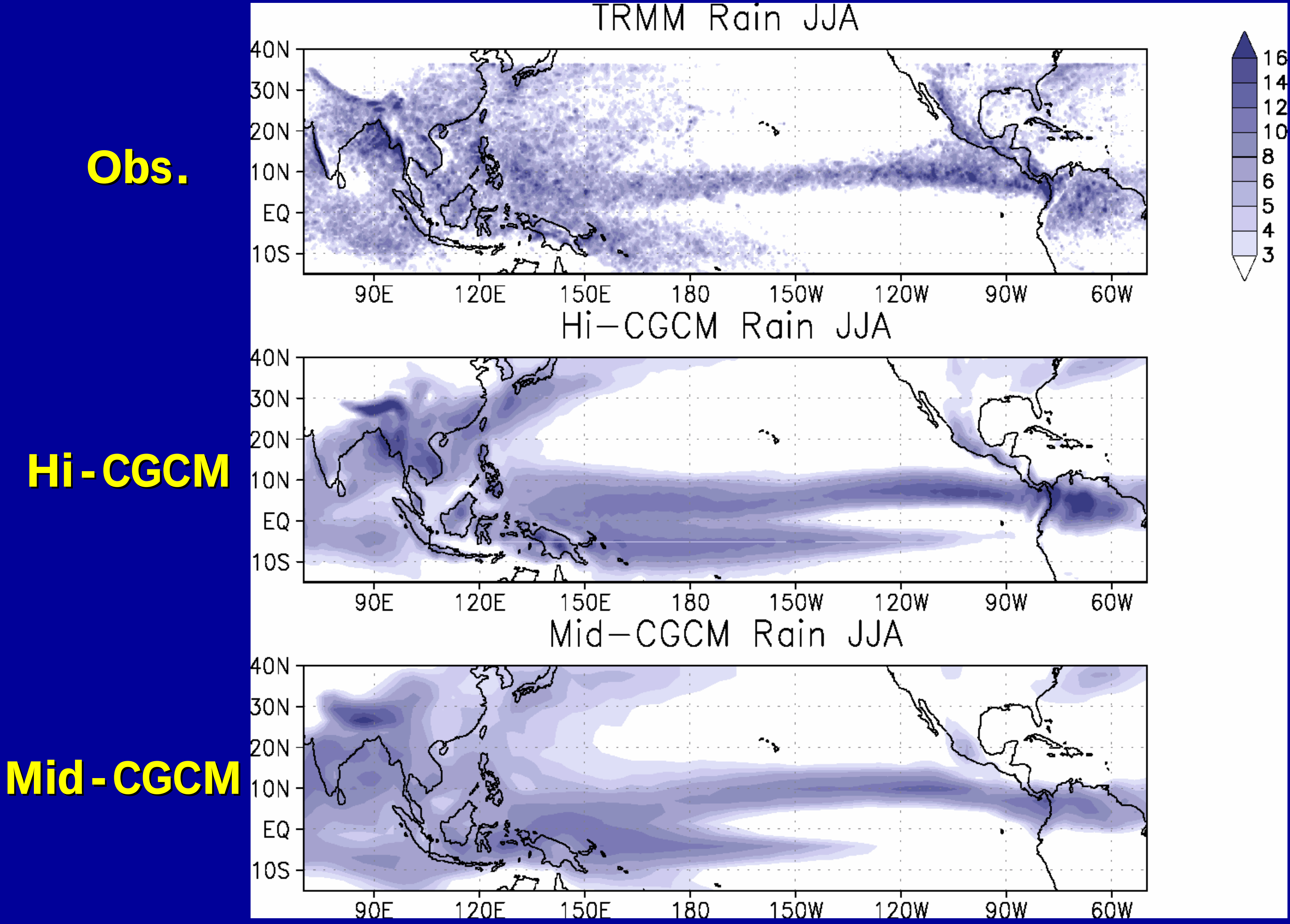
Atlantic Overturning Circulation

OGCM

Hi-CGCM

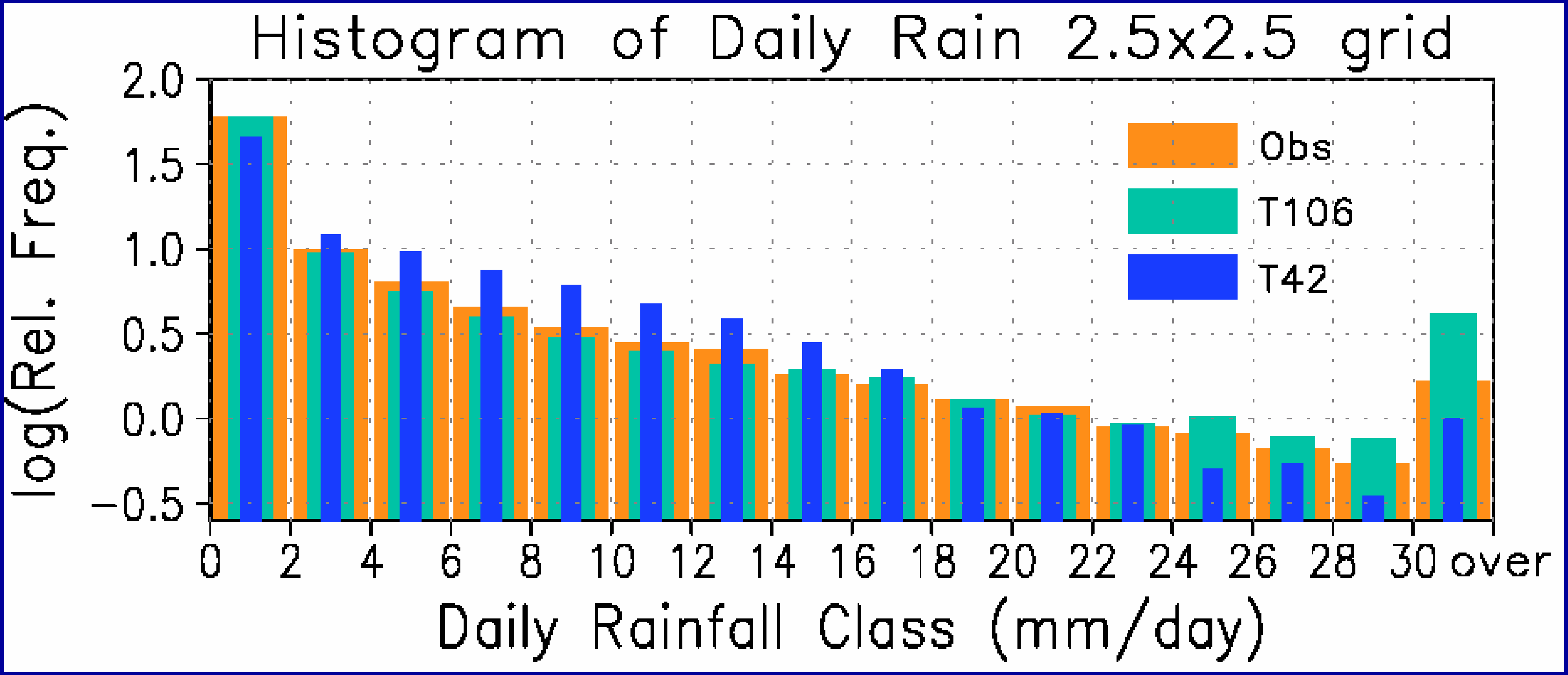


JJA precipitation



Looking at higher moment statistics?

-Verification of daily rainfall frequency over Japan - (120-140E, 30N-40N)



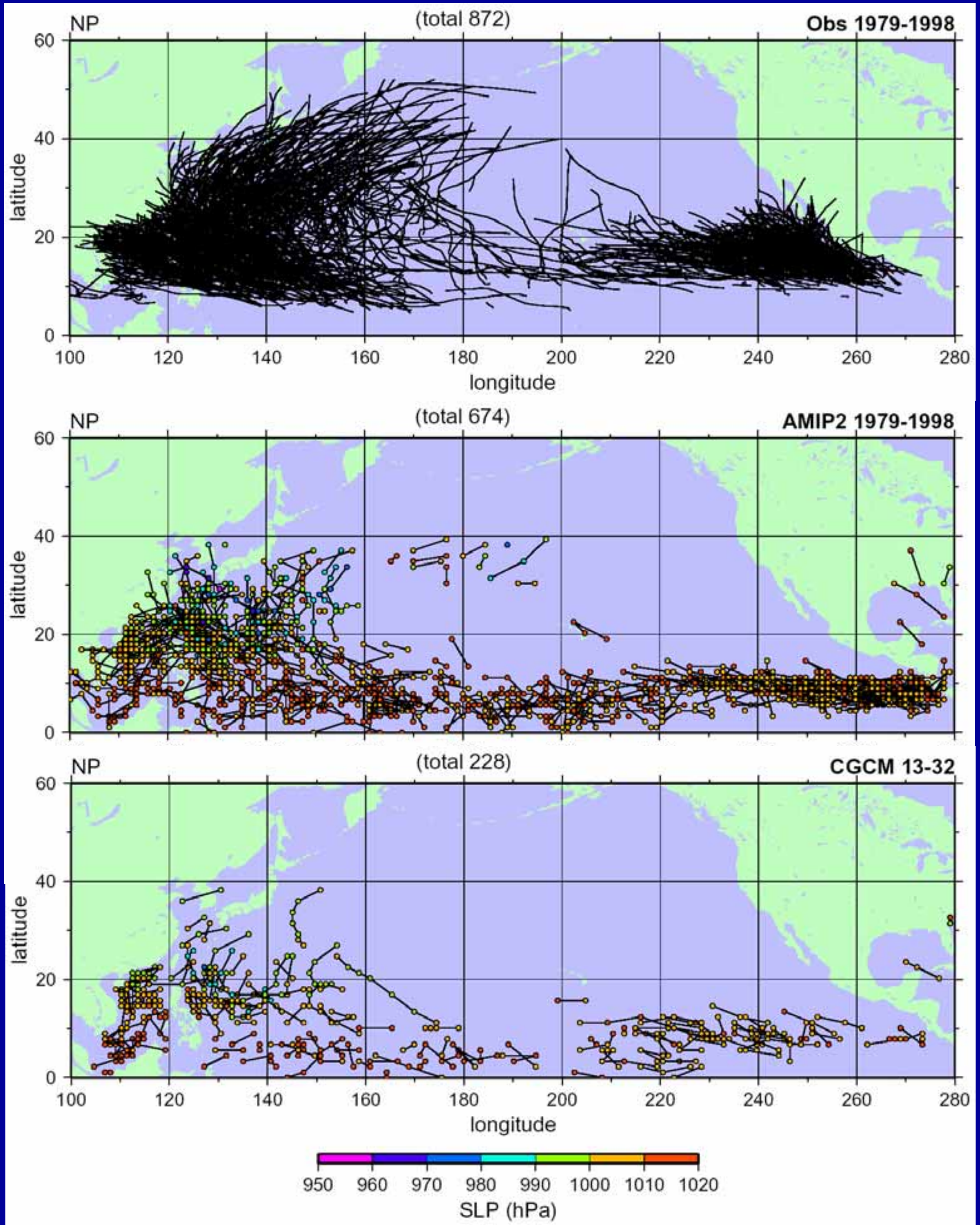
CGCM results

Tropical Cyclone Tracks

Observed (872)

AGCM (674)

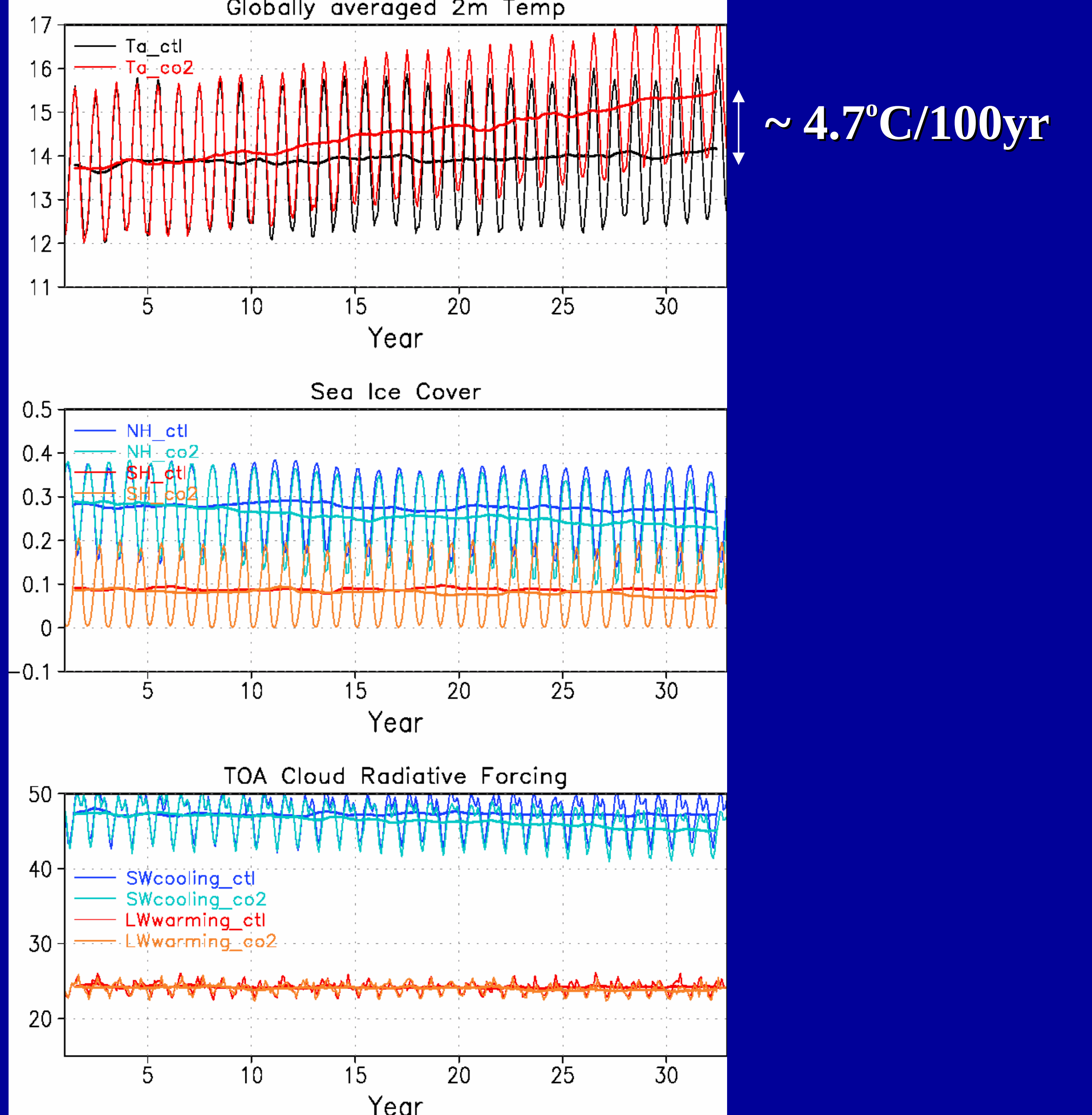
CGCM (228)

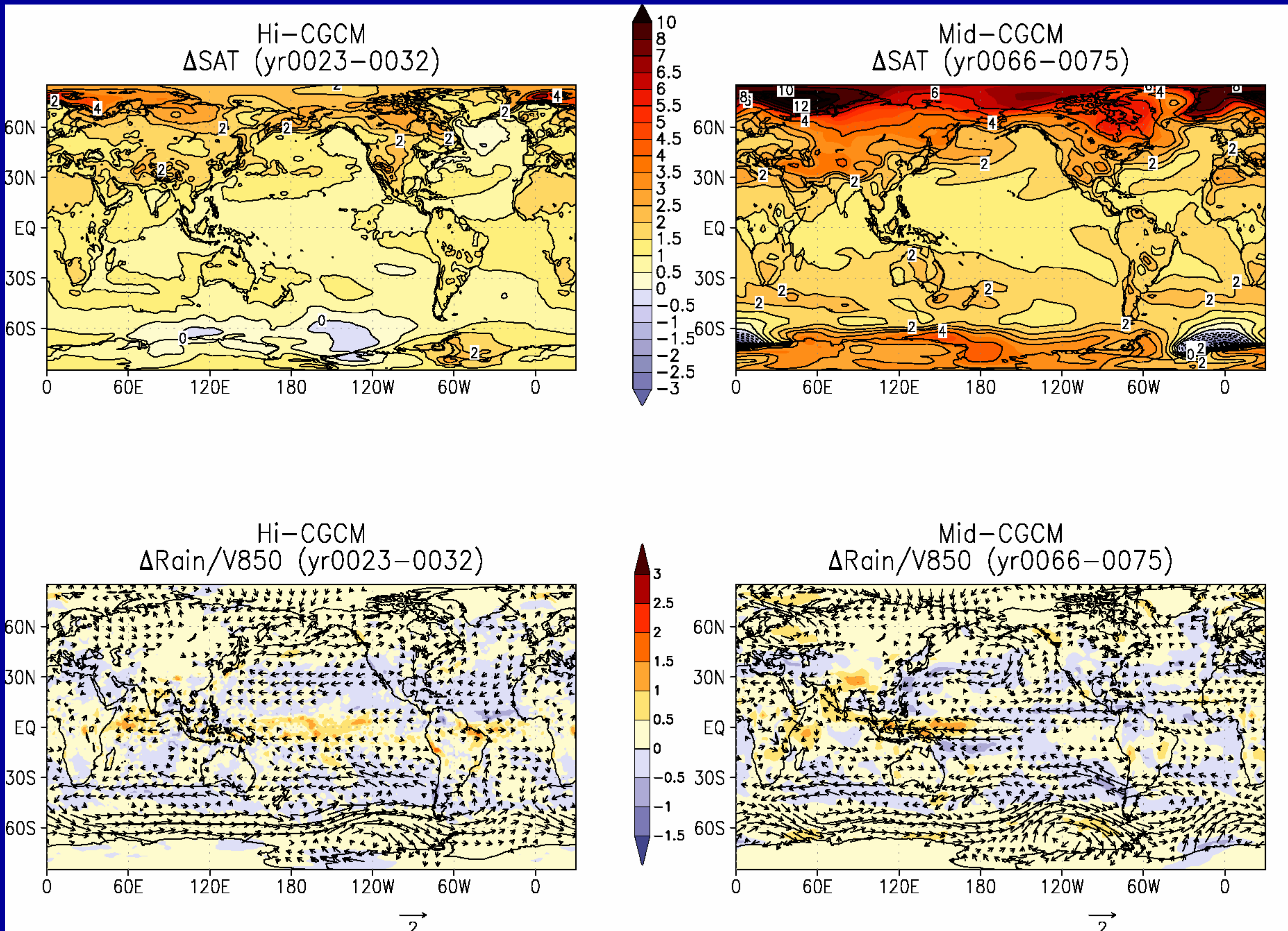


The K-1 Japan Project team is supposed to conduct...

- CMIP-type run (1% per year increase in CO_2)
- 20th century climate reproduction
- SRES scenario runs
  - A1B and B1 scenarios with Hi-CGCM
  - All 6 marker scenarios with Mid-CGCM
- Stabilization runs
  - Nominal 750 ppmv stab. after 2100 (SRES A1B)
  - Nominal 550 ppmv stab. after 2100 (SRES B1)
  - Should we do non-CO_2 GHG scenario runs ???

A pilot CMIP-type experiment with Hi-CGCM




Hi−CGCM
ΔSAT (yr0023−0032)
Mid−CGCM
ΔSAT (yr0066−0075)
10
8
7
6.5
6
5.5
5
4.5
4
3.5
3
2.5
2
1.5
1
0.5
0
−0.5
−1
−1.5
−2
−2.5
−3
Hi−CGCM
ΔRain/V850 (yr0023−0032)
Mid−CGCM
ΔRain/V850 (yr0066−0075)
3
2.5
2
1.5
1
0.5
0
−0.5
−1
−1.5
60N
30N
EQ
30S
60S
0
60E
120E
180
120W
60W
0
2

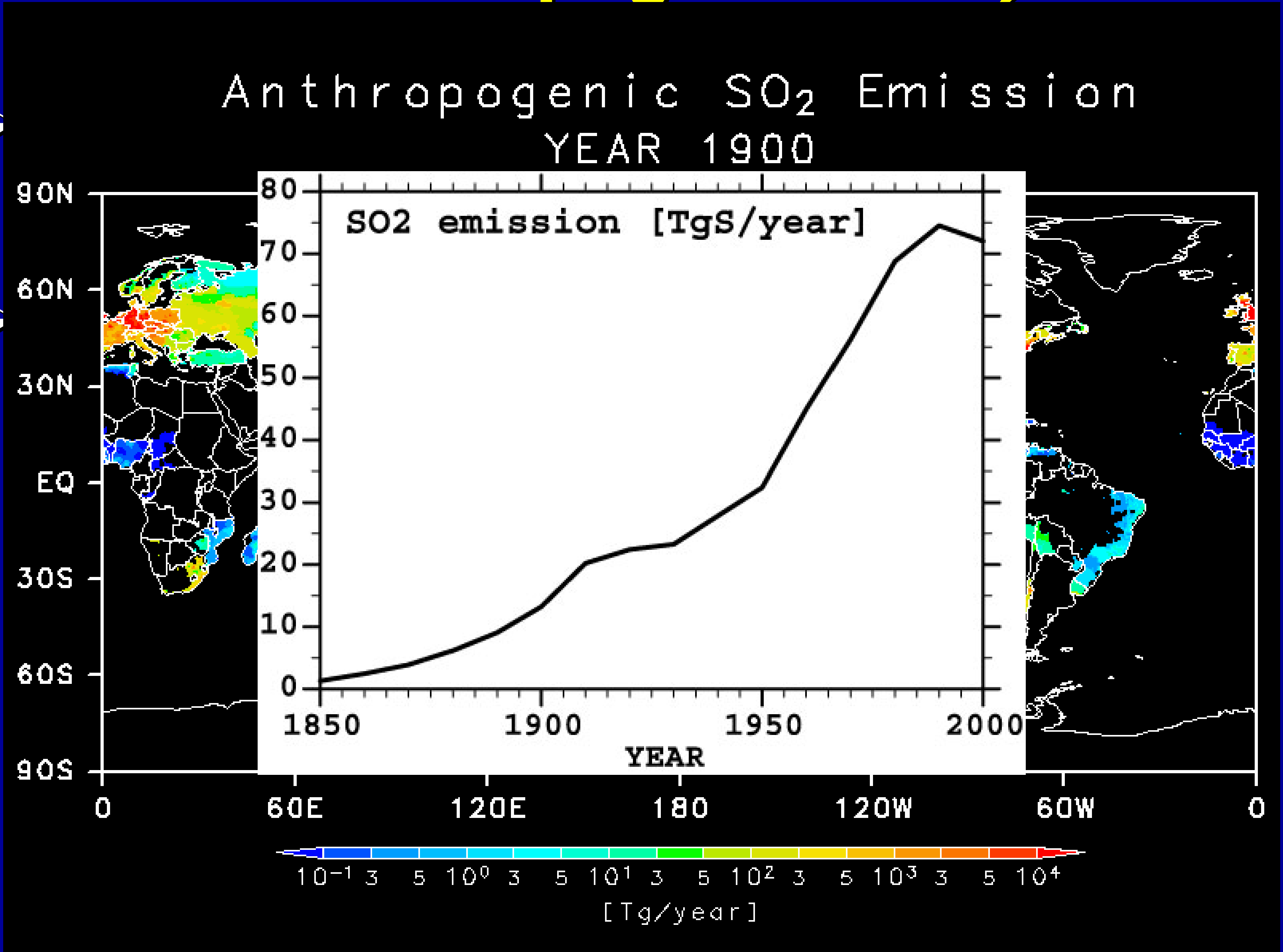
20th century run

- External forcing fields are completed
- Coupled with aerosol transport model
- Include major four species of aerosols (sulfate, carbonaceous, sea salt, and soil dust)
- Include 1st and 2nd kind indirect effect
- Preliminary runs are conducted by using the middle resolution AGCM forced by HadISST & HadICE

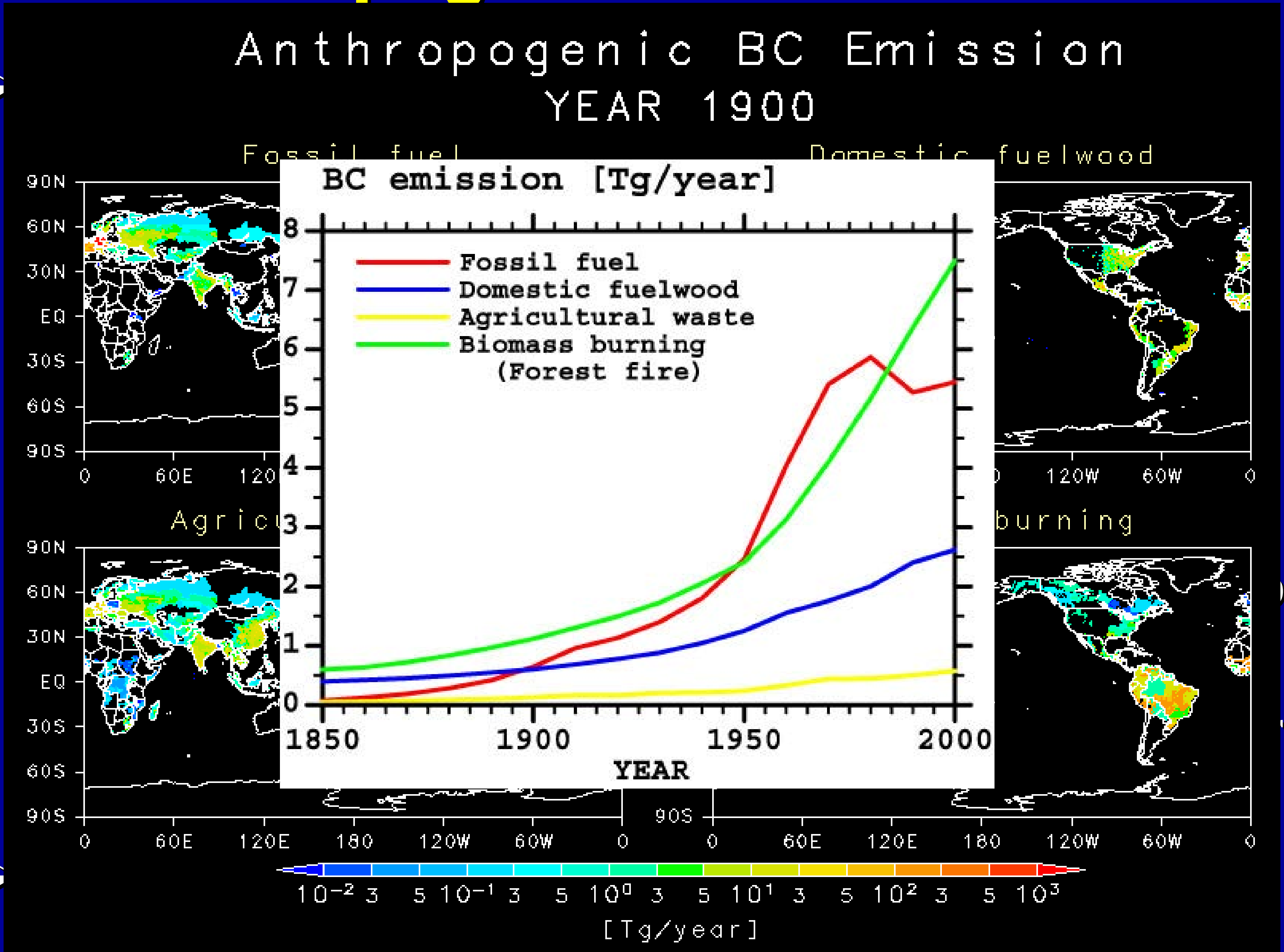
External Forcings

- Natural forcings
  - ✓ Solar variability (Lean et al., 1995)
  - ✓ Volcanic aerosols in the stratosphere (Sato et al., 1993)
  - ✓ Terpene and continuous volcanic eruptions
- Anthropogenic forcings
  - ✓ Well-mixed greenhouse gases
  - ✓ Stratospheric ozone depletion
  - ✓ Tropospheric ozone increase
  - ✓ Sulfate aerosols due to fossil fuel use
  - ✓ Carbonaceous aerosols due to fossil fuel combustion, agricultural waste burning, fuelwood consumption, and forest fires
- Sea salt and soil dust aerosols are calculated from meteorological variables (wind speed, soil moisture, etc.) and are not considered as external forcing

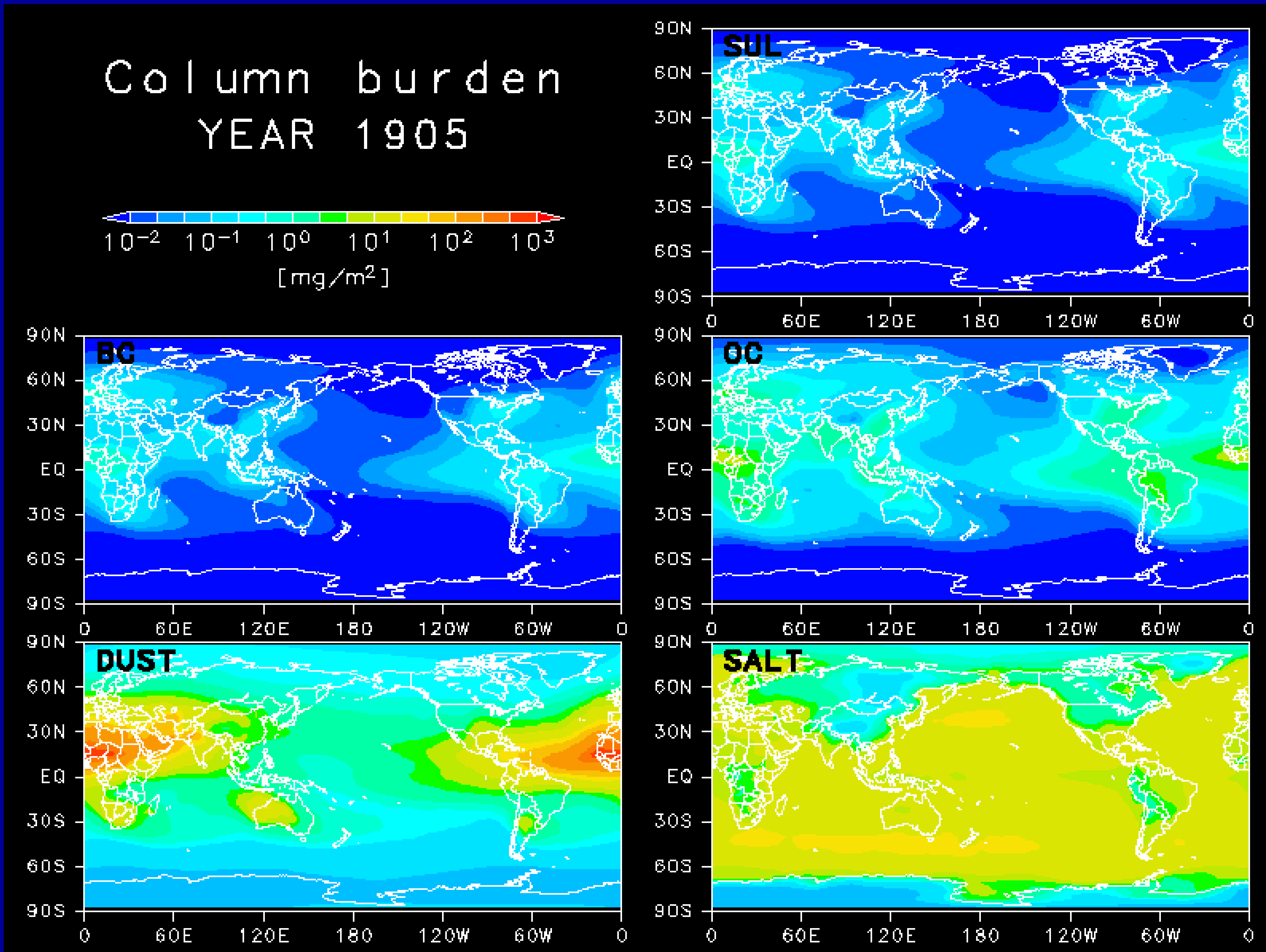
Historical Emission of Anthropogenic SO_2



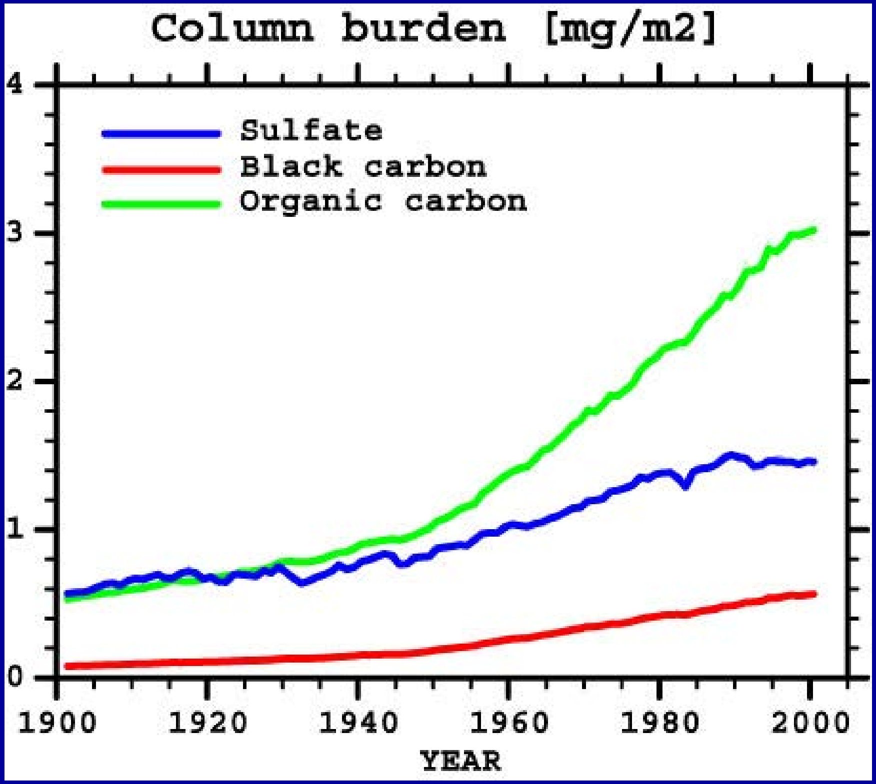
Historical Emission of Anthropogenic Black Carbon

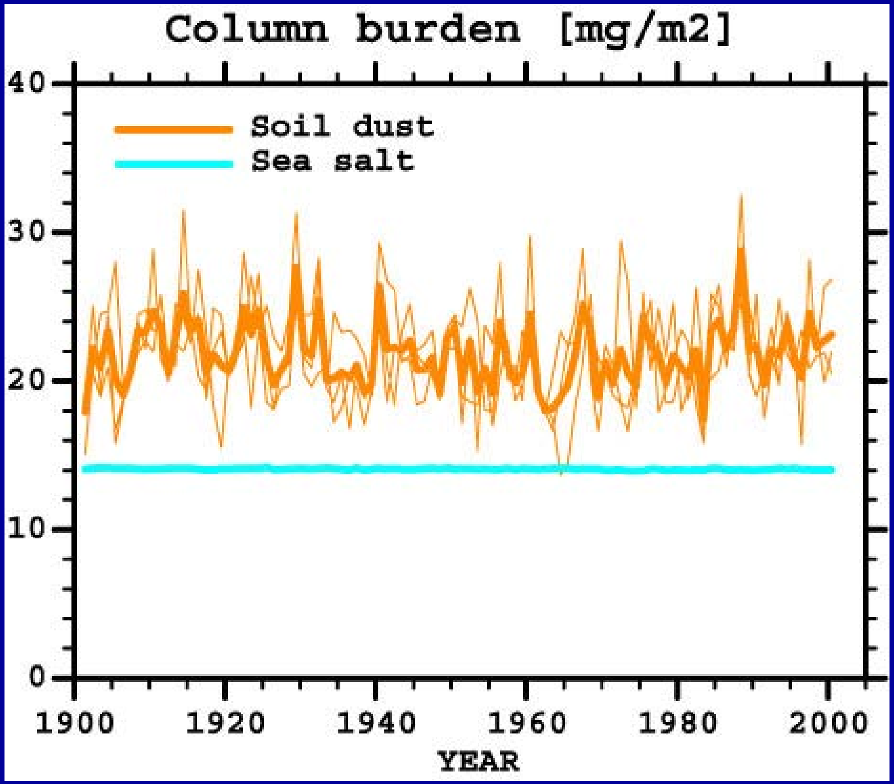


Simulated Column Aerosol Burden

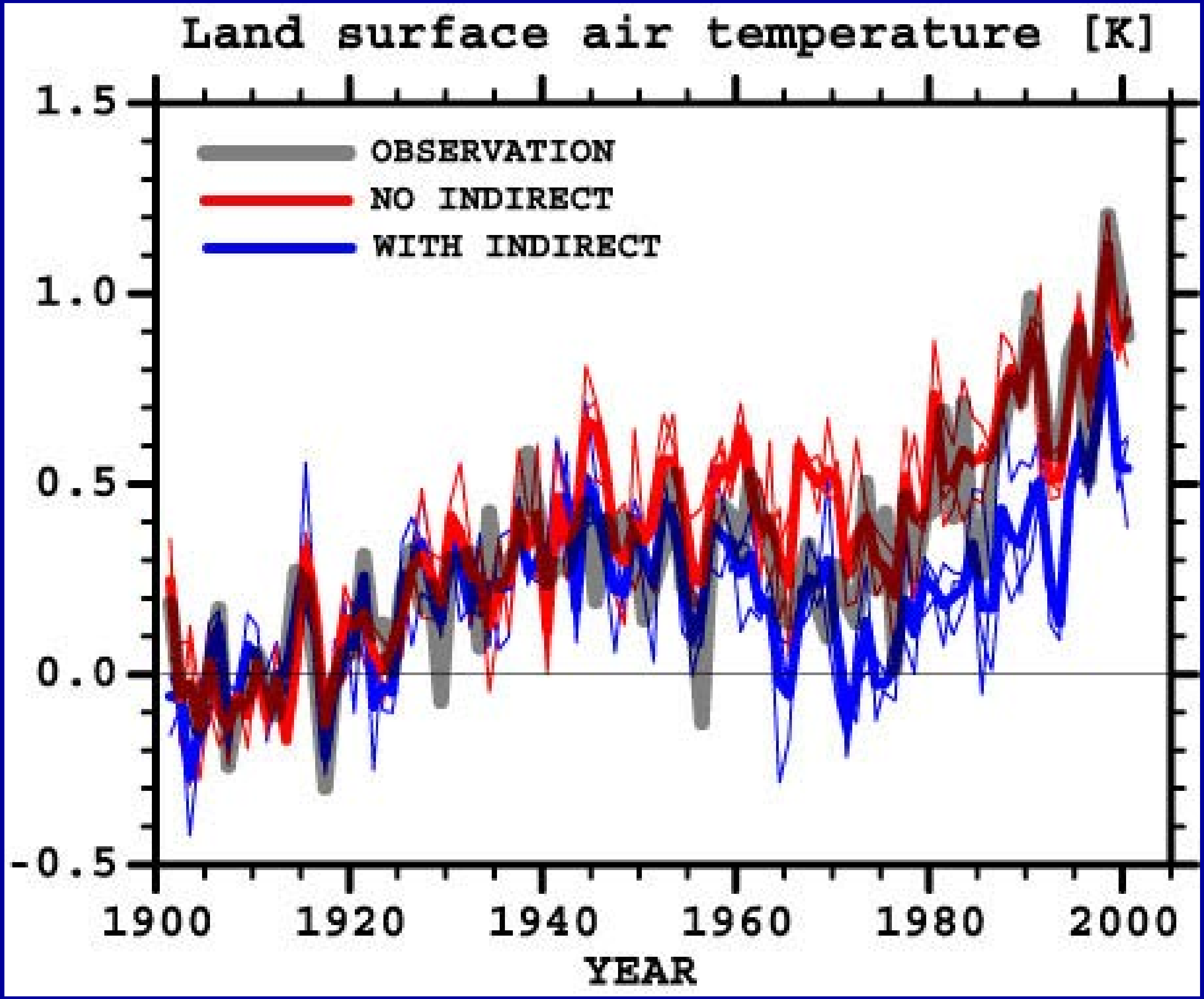


Simulated Column Aerosol Burden

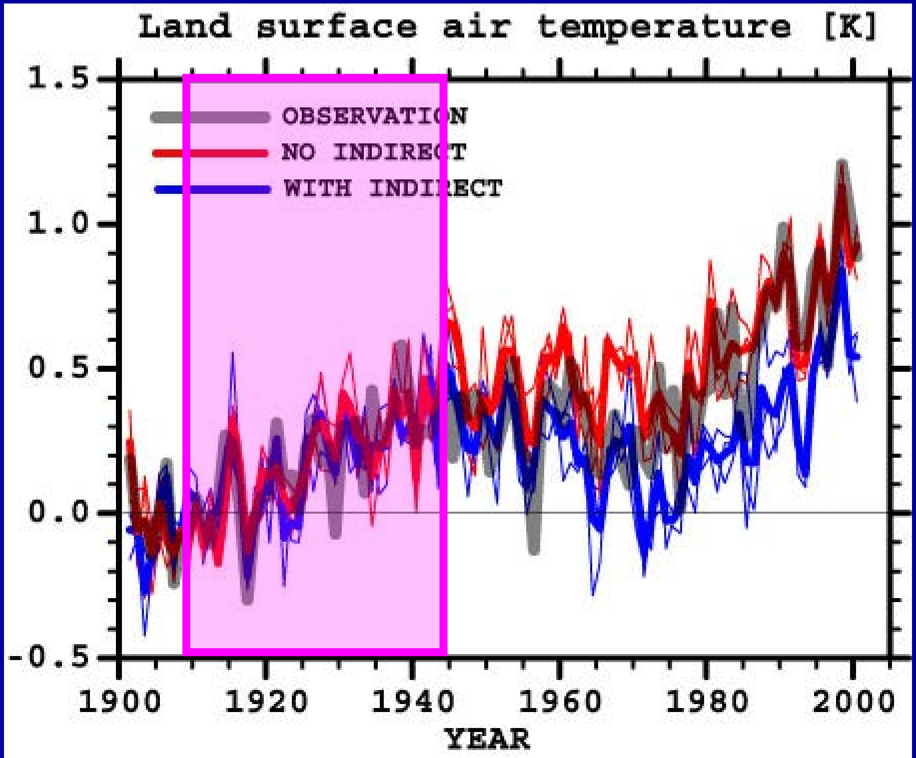


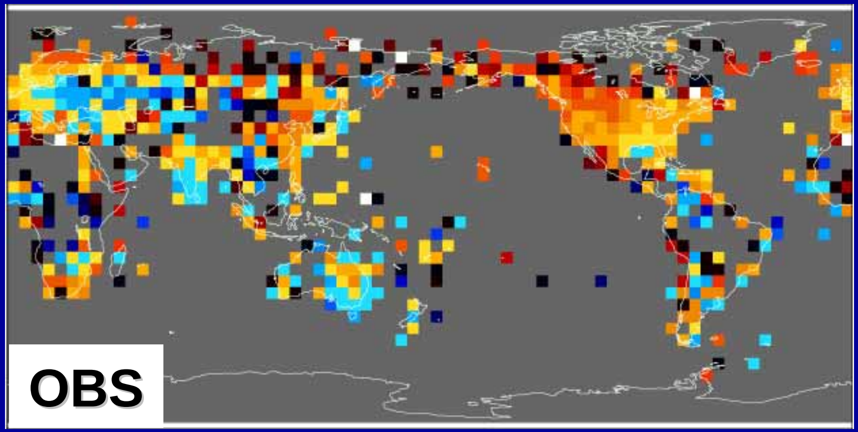


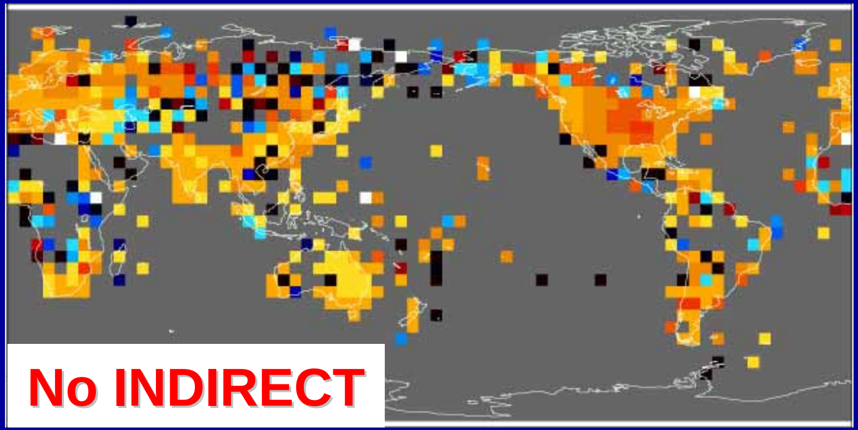
Global & Annual Mean SAT Change

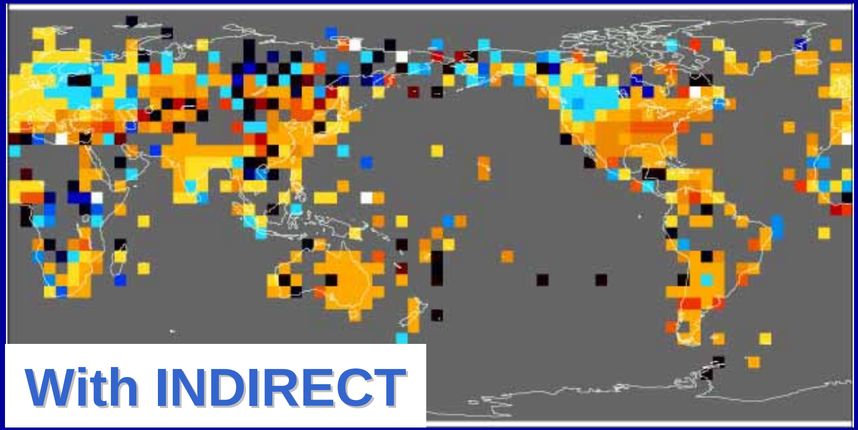


Linear temperature trend (1910-1945)

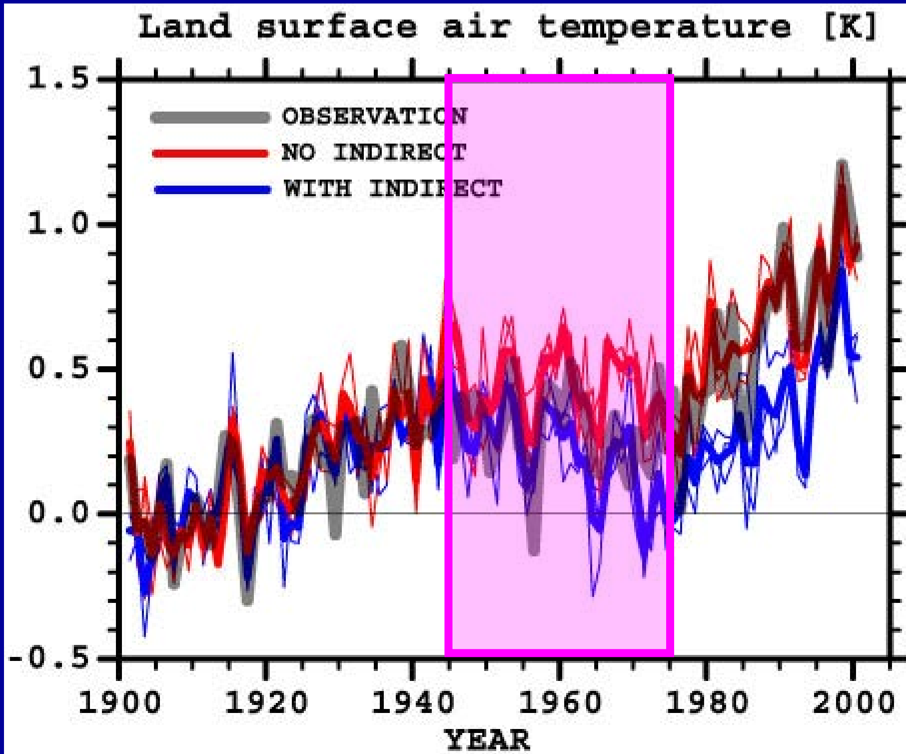


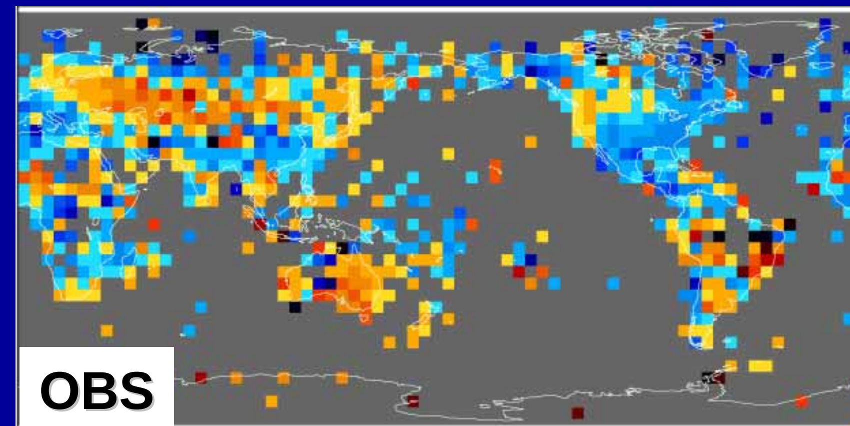


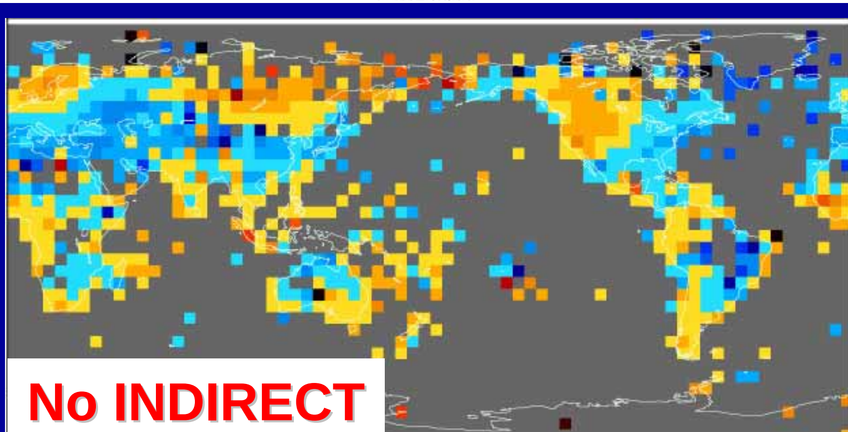


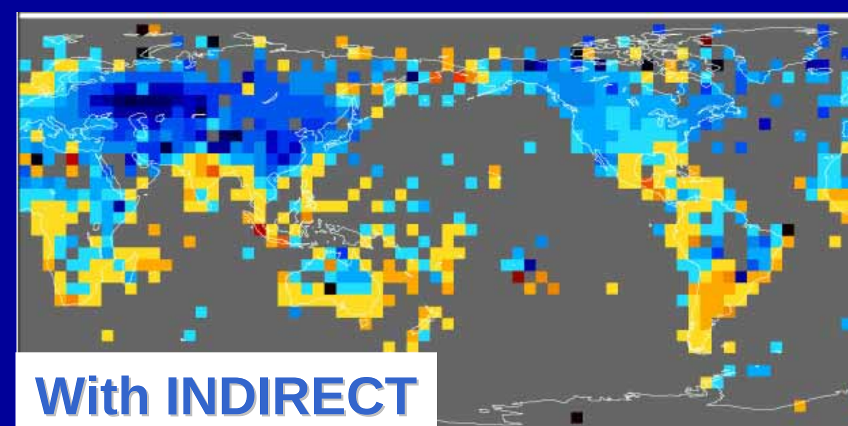


Linear temperature trend (1946-1975)

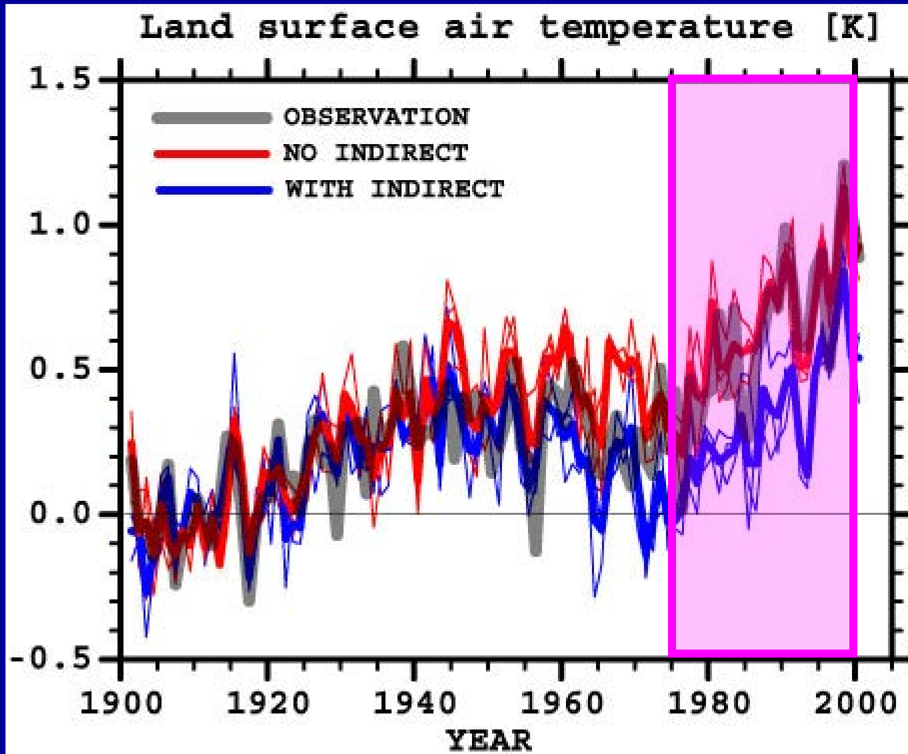


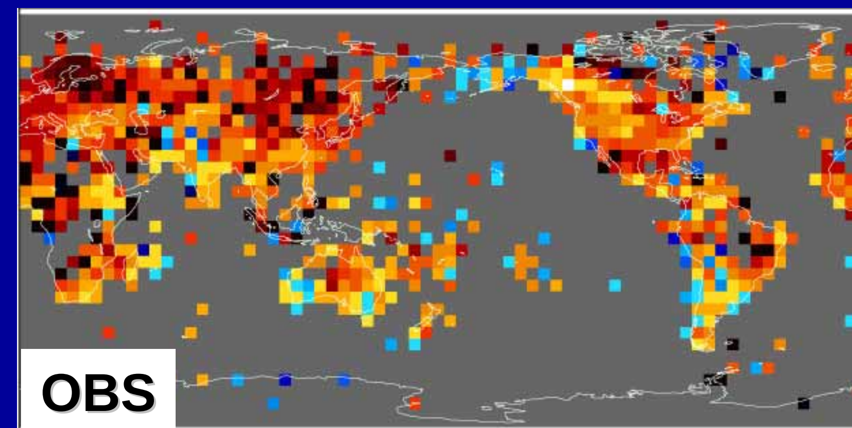


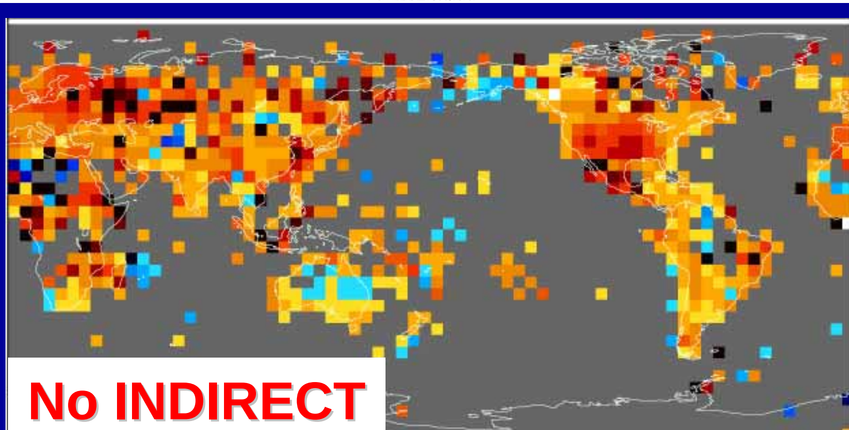


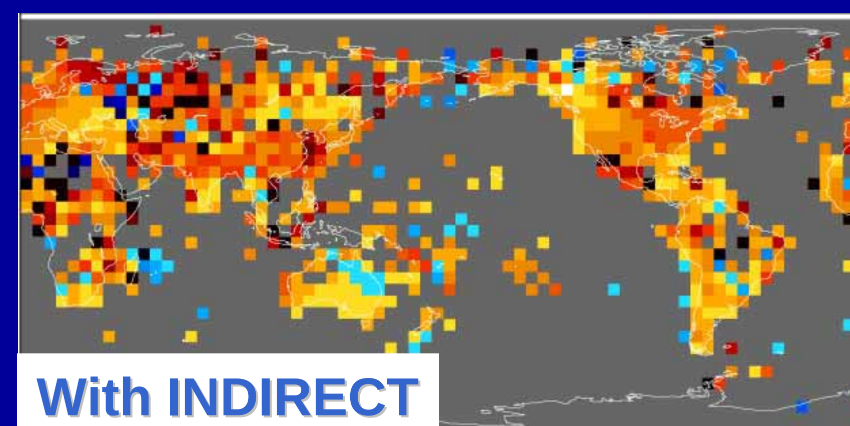


Linear temperature trend (1976-2000)

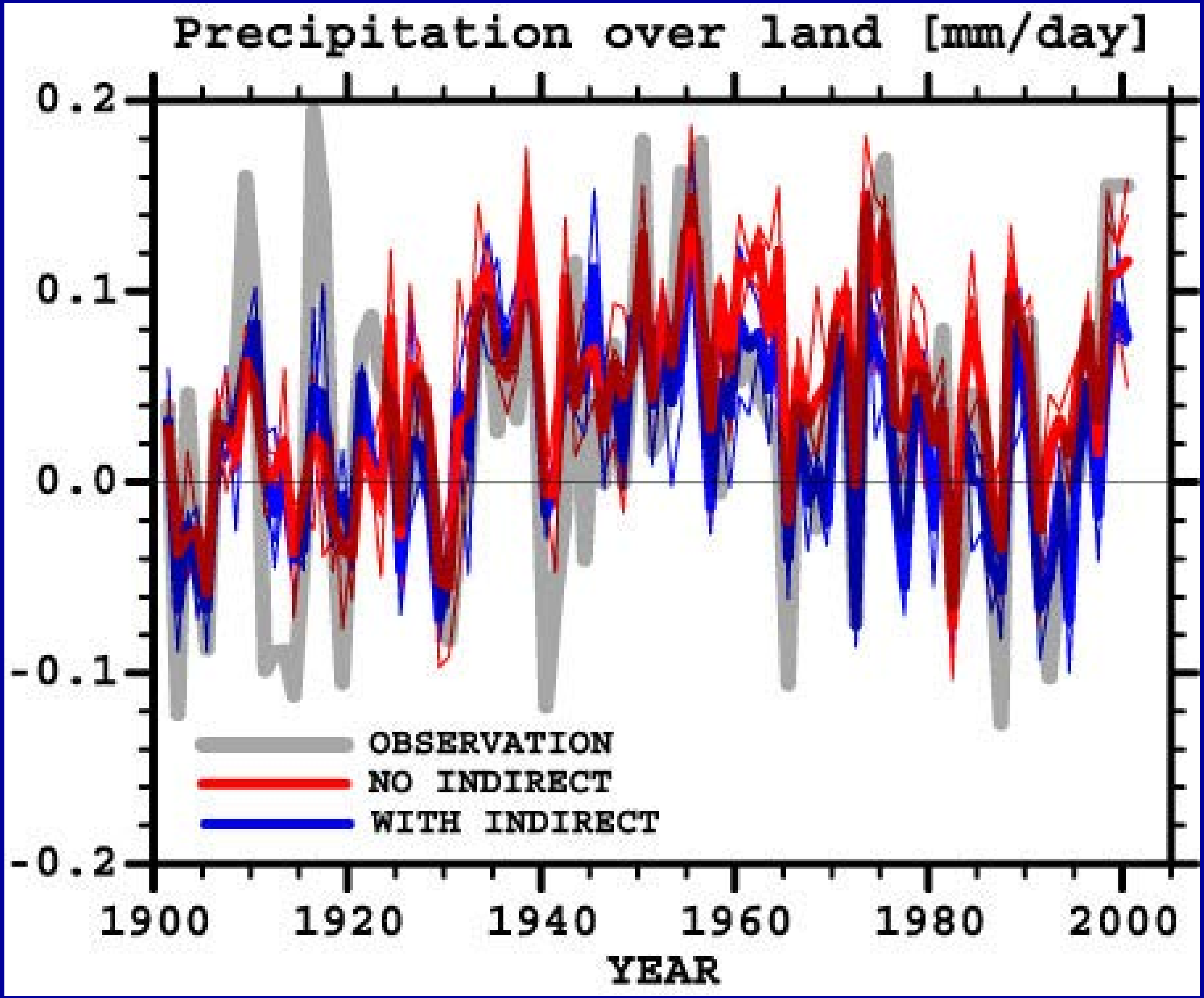




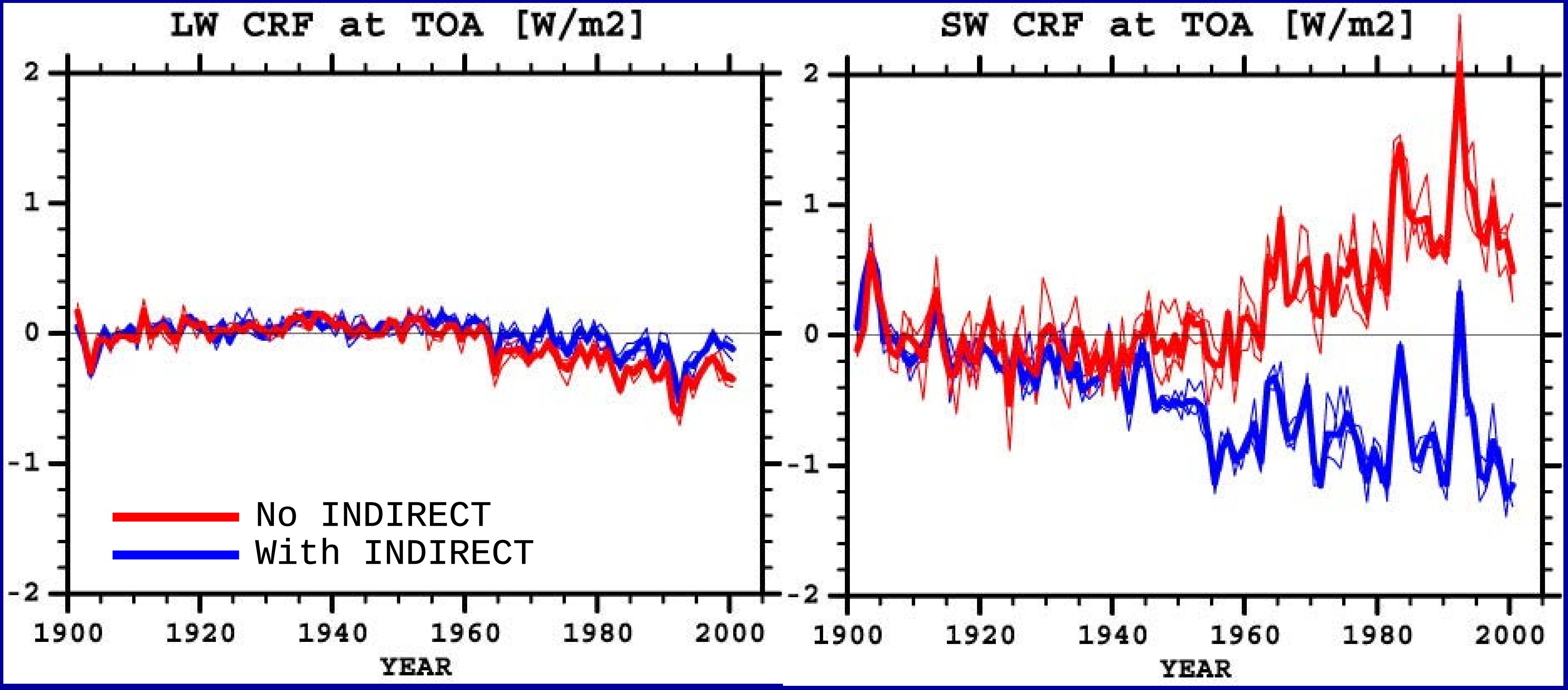




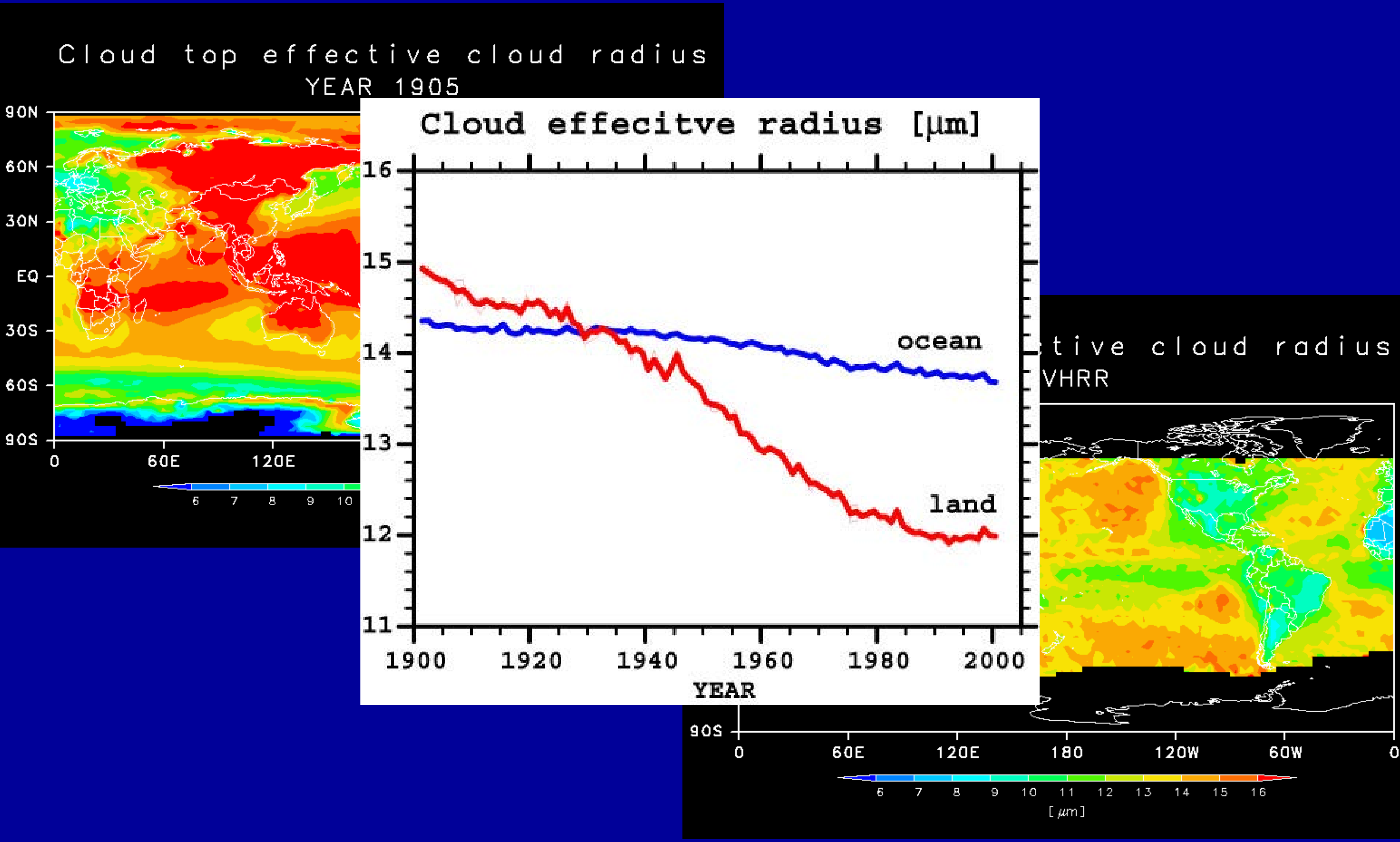
Global & Annual Mean Precip. Change



Global & Annual Mean Changes in Cloud Radiative Forcing



Cloud Top Effective Cloud Radius

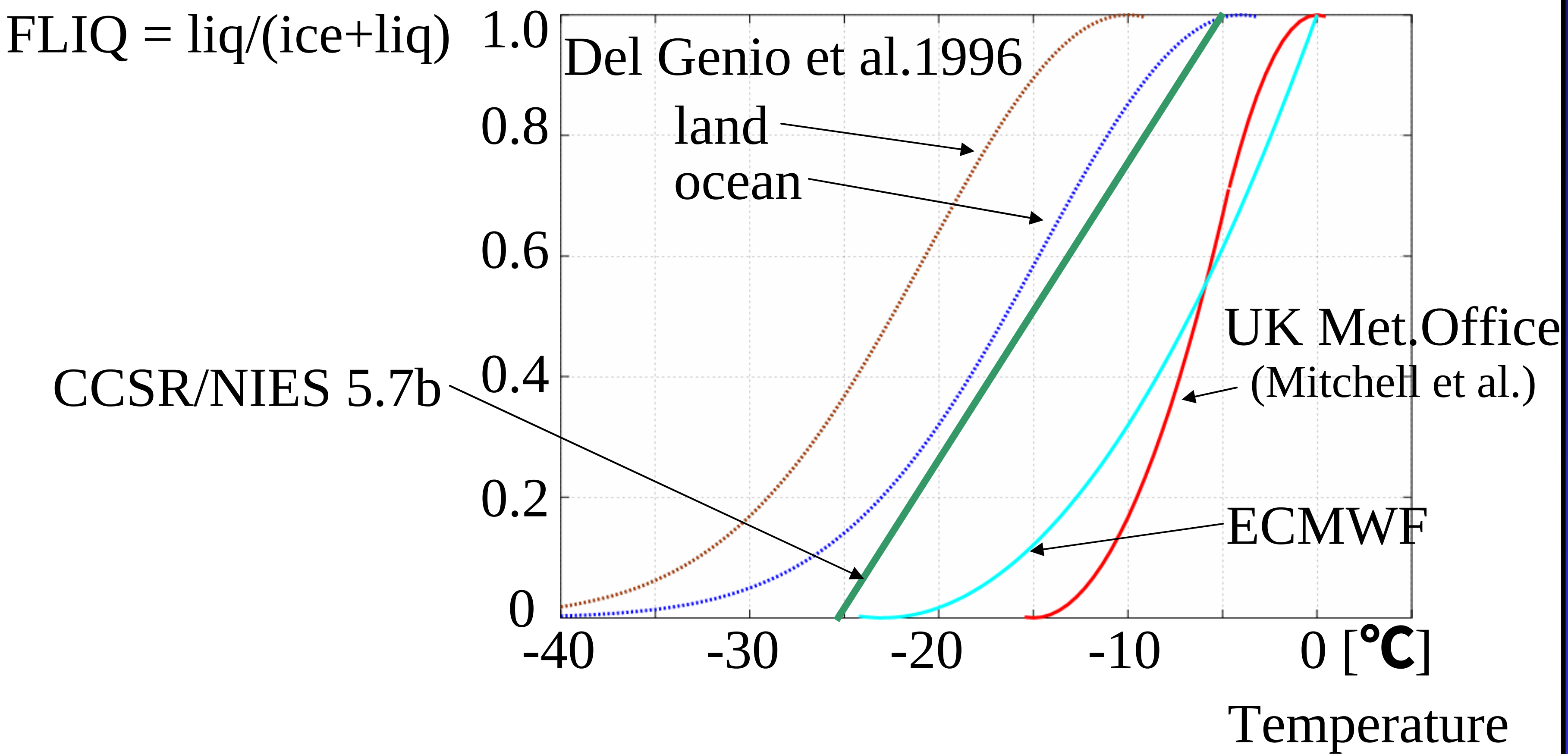


Climate sensitivity

- Highly sensitive to cloud water phase diagnosis
- Further observation needed for evaluation

How should cloud water phase be determined ?

Empirical functions for cloud water phase diagnosis

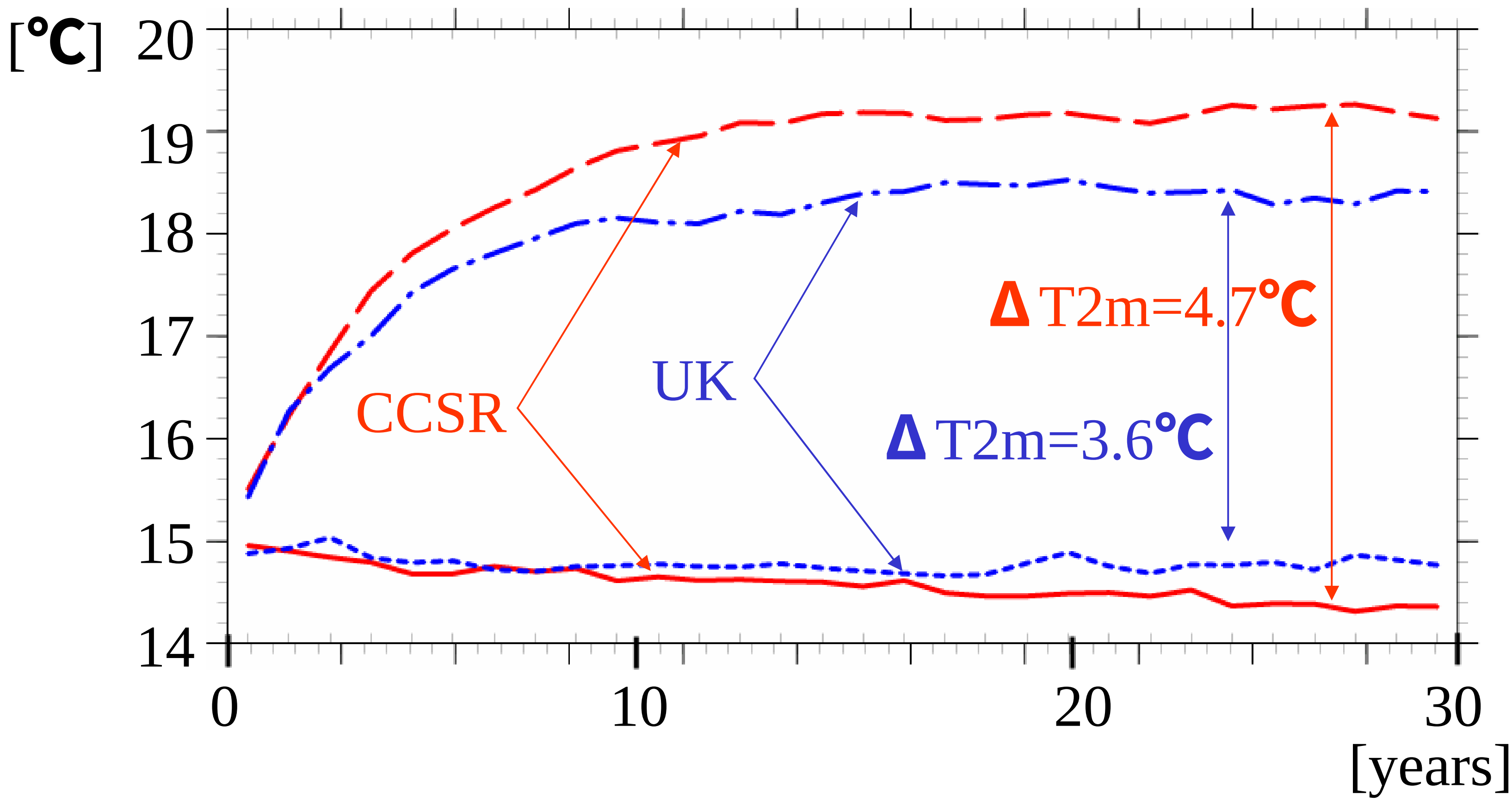


. . . further observation needed for evaluation.

Is climate sensitivity affected by modifying FLIQ (CCSR→UK)?

Doubled CO2 sensitivity

Global-annual mean 2m temperature



Doubled CO_2 sensitivity is 1.1oC lower for UK-type than CCSR.

Summary

- Hi- & Mid-CGCMs have been integrated successfully without flux adjustment.
- Resolution helps for resolving smaller-scale disturbances.
  - Able to discuss changes in regional weather, including Baiu-frontal rainfall
- An improved version of the Hi-CGCM by the end of FY2003
  - Introduction of an on-line aerosol transport; direct, 1st and 2nd indirect effects
  - Better organized tropical convective systems; typhoons, … , and ENSO
  - More control over climate sensitivity, high-latitude oceanic eddies and NADW

Thank you for your attention !