

Global Warming Simulation by using the High-Resolution Climate model (K-1 Model)

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Contents

- Background for the high-resolution climate model
- Performance of the K-1 climate model
- Topics using the high-resolution climate model
 - Resolution impact
 - Evaluation of time-slice method
- Summary



Background(1)

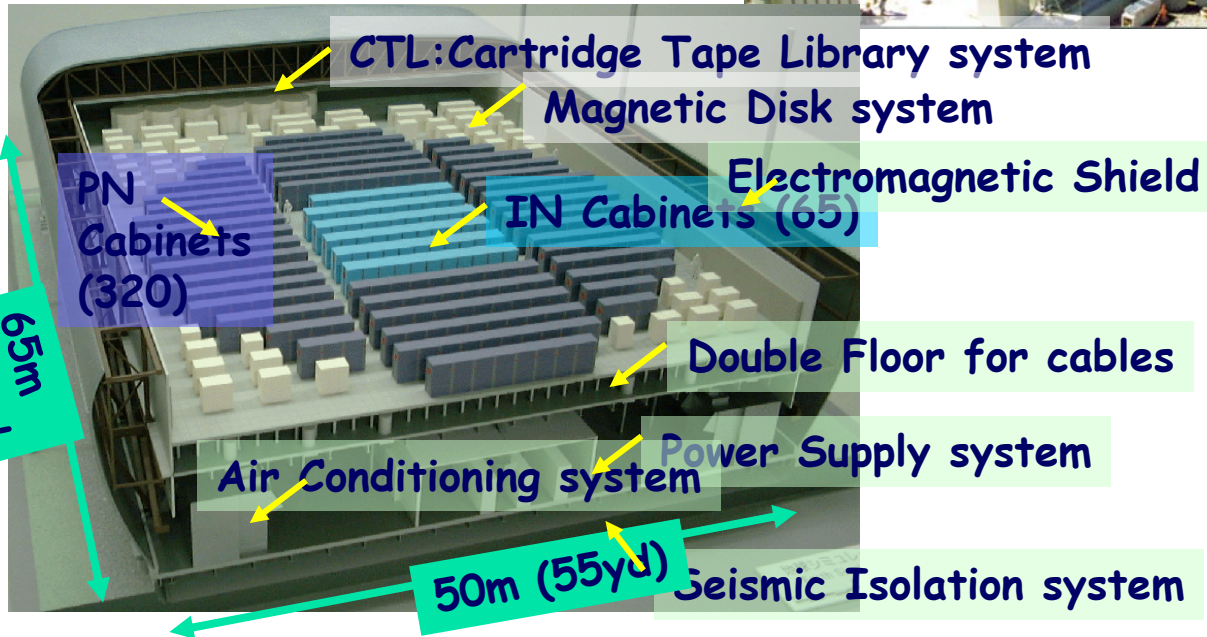
- Demand for more reliable assessment of the Climate Change in the regional-scale
 - **More** Processes and **More** resolution
- More processes
 - Carbon Cycle, Air-polution
- High spatial and temporal resolution
 - Extreme Events(Typhoon & Flood)



Background(2)

- Computer Capability
 - The Earth Simulator has opened a door to the new era!
- Observational aspects has been started
 - GEOS (Global Earth Observation System of Systems)
- A continuous support for infrastructures and human resources!

The Earth Simulator



TOP500 List for November 2002

R_{\max} and R_{peak} values are in GFlops. For more details about other fields, please click on the button "Explanation of the Fields"



DETAILS



EXPLANATION OF THE FIELDS

Rank	Manufacturer Computer/Process	R_{\max} R_{peak}	Installation Site Country/Year
1	NEC Earth-Simulator/ 5120	35860.00 40960.00	<u>Earth Simulator Center</u> Japan/2002
2	Hewlett-Packard ASCI Q - AlphaServer SC ES45/1.25 GHz/ 4096	7727.00 10240.00	<u>Los Alamos National Laboratory</u> USA/2002
3	Hewlett-Packard ASCI Q - AlphaServer SC ES45/1.25 GHz/ 4096	7727.00 10240.00	<u>Los Alamos National Laboratory</u> USA/2002
4	IBM ASCI White, SP Power3 375 MHz/ 8192	7226.00 12288.00	<u>Lawrence Livermore National Laboratory</u> USA/2000
5	Linux NetworX MCR Linux Cluster Xeon 2.4 GHz - Quadrics/ 2304	5694.00 11060.00	<u>Lawrence Livermore National Laboratory</u> USA/2002



K-1 Climate Model

- High resolution Climate Model
- T106L56+1/4x1/6 L48
- On-line Aerosol model(5 species of aerosols, such as Dust, Sea Salt, Sulfate, BC, and OC)
- Earth Simulator
- IPCC AR4



Model Performance

- Small scale features and large-scale features
- Orography related phenomena
- Baiu-Front

The CCSR/NIES/FRCGC Coupled Ocean-Atmosphere GCM for the Earth Simulator: *MIROC 3.2*

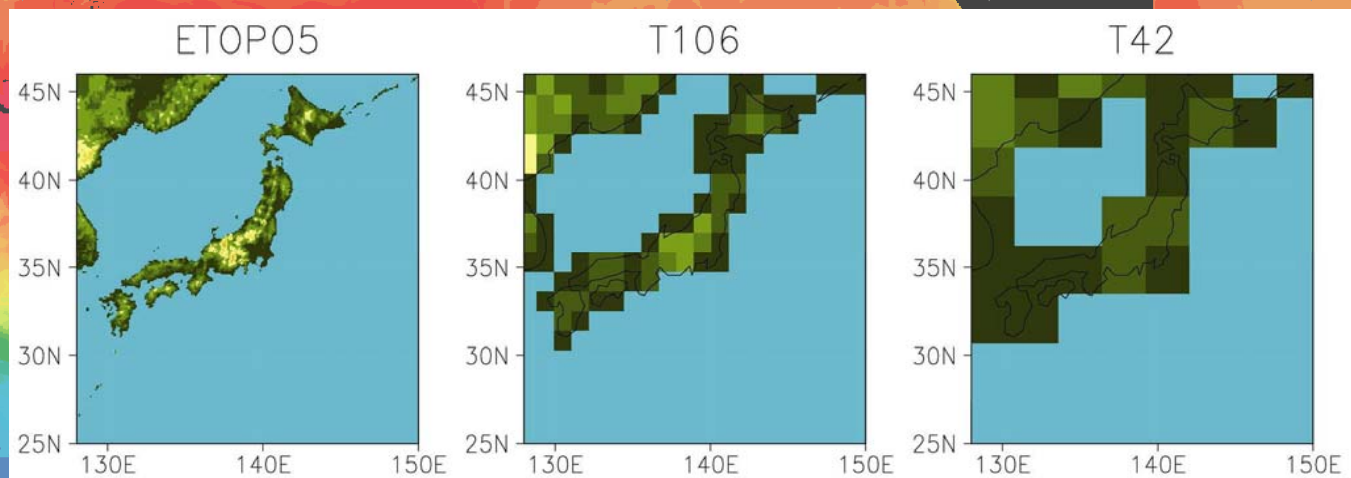


High-resolution version

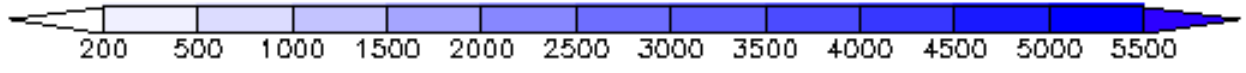
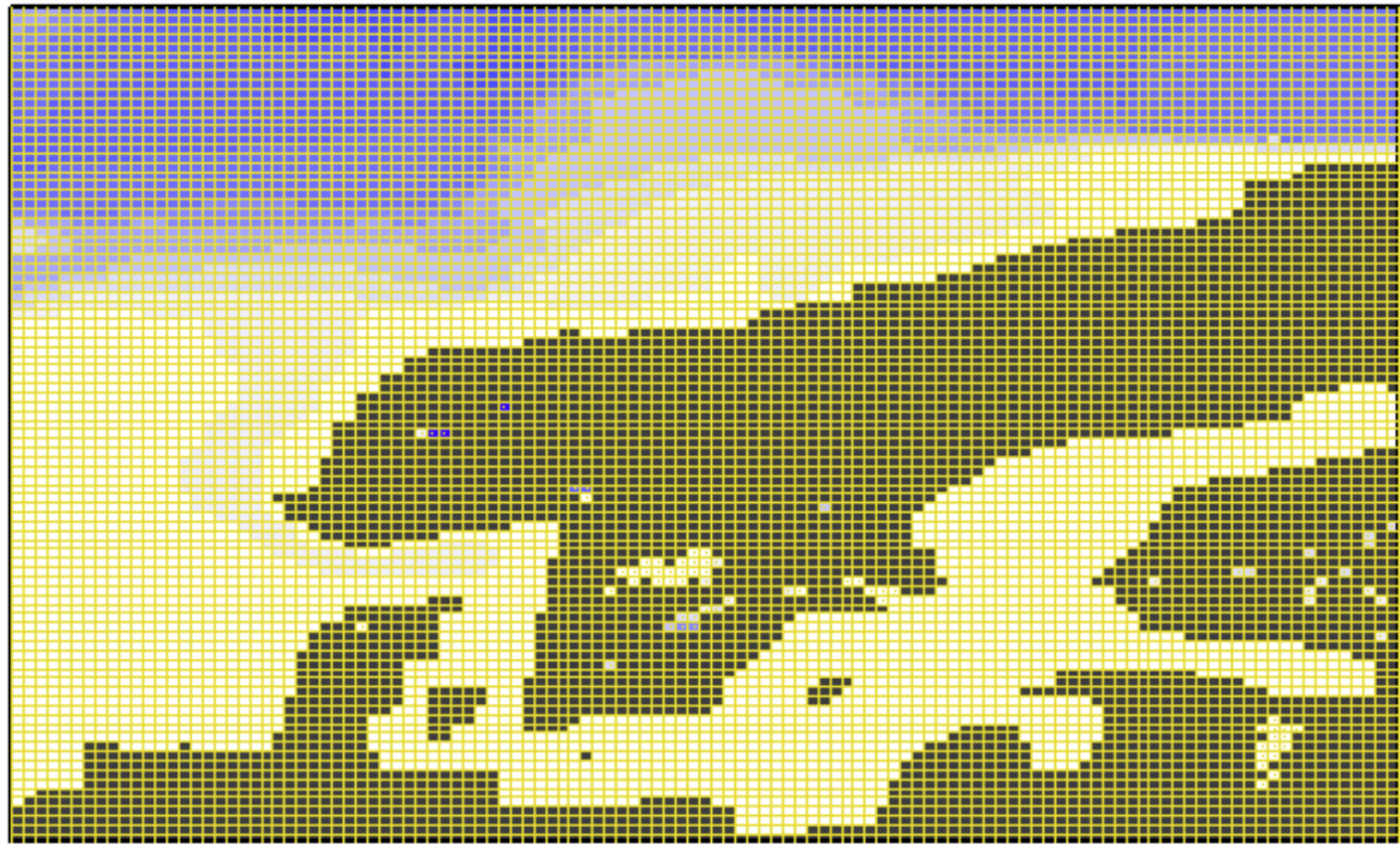
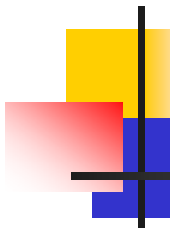
Atmos: T106 ($\sim 1.1^\circ$) L56 Ocean: $1/4^\circ \times 1/6^\circ$ L48
for regional as well as global climate change and extreme events

Medium-resolution version

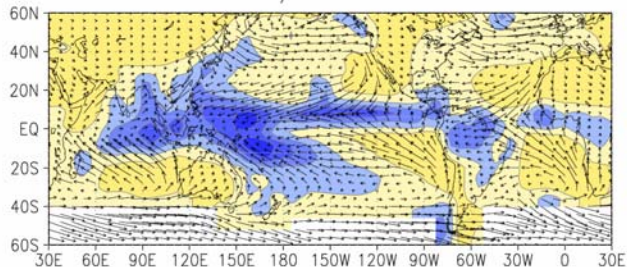
Atmos: T42 ($\sim 2.8^\circ$) L20 Ocean: $1.4^\circ \times (0.5^\circ - 1.4^\circ)$ L44
for many scenarios, ensembles and climate sensitivity issues...



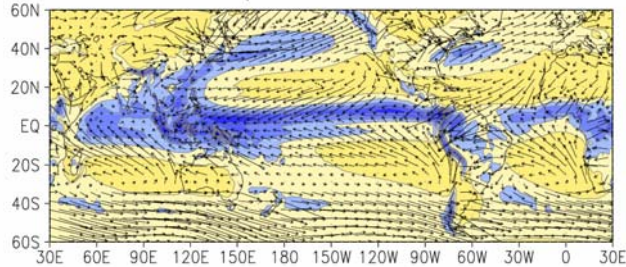
-2 0 2 4 6 8 10 12 14 16 18 20 22 24 26 28 [°C]



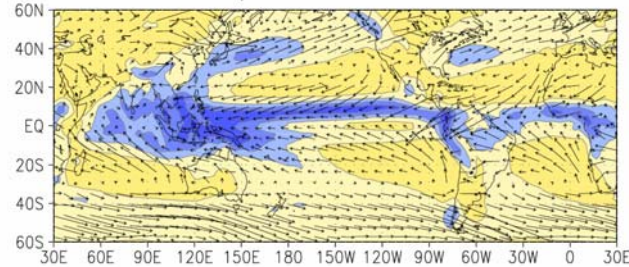
Rain/Wind Obs.



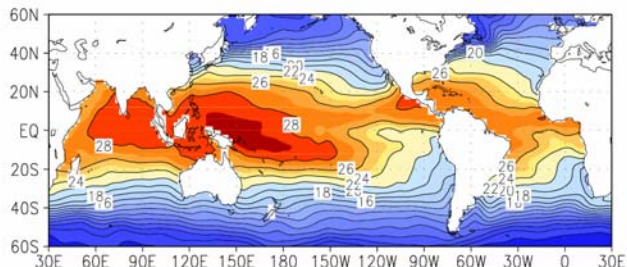
Rain/Wind Hi-CGCM



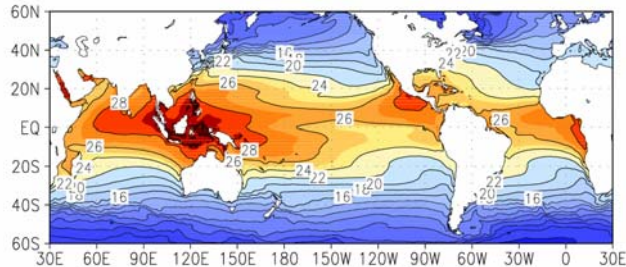
Rain/Wind Mid-CGCM



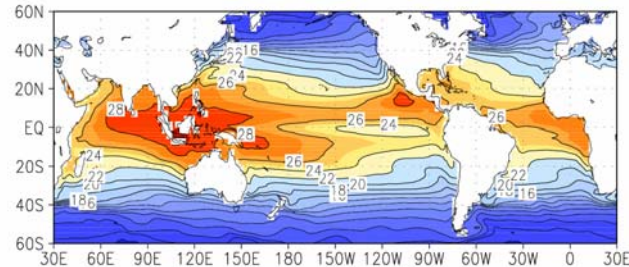
SST Obs.



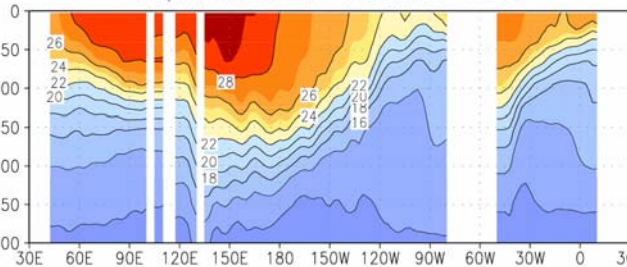
SST Hi-CGCM



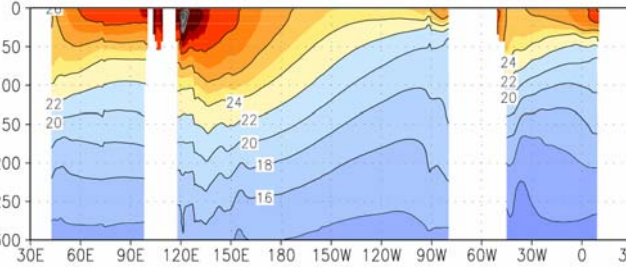
SST Mid-CGCM



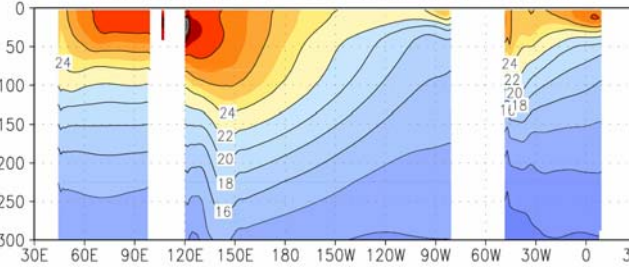
Equatorial X-section Obs.



Equatorial X-section Hi-CGCM

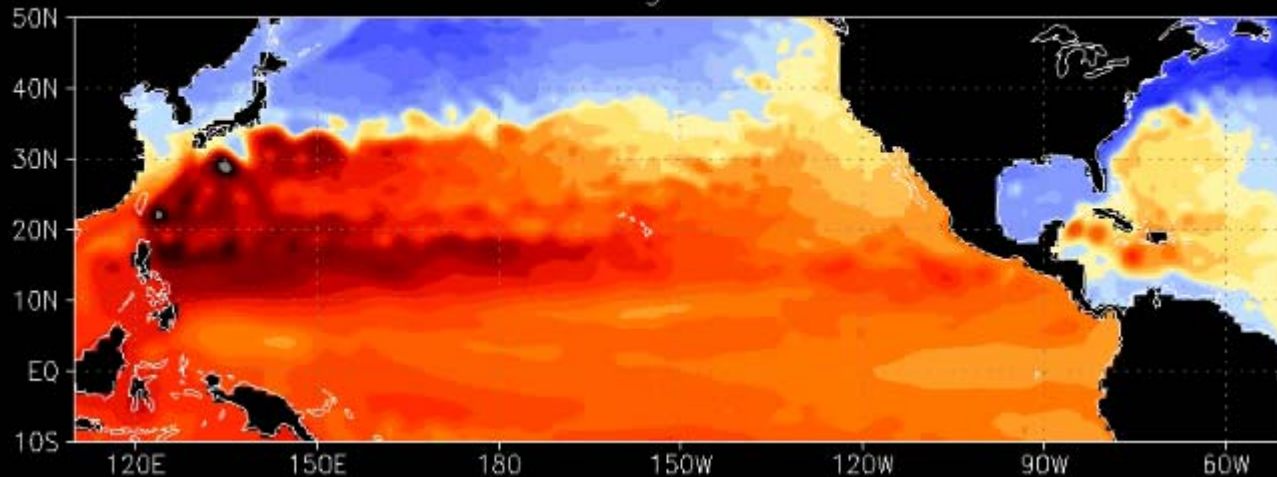


Equatorial X-section Mid-CGCM

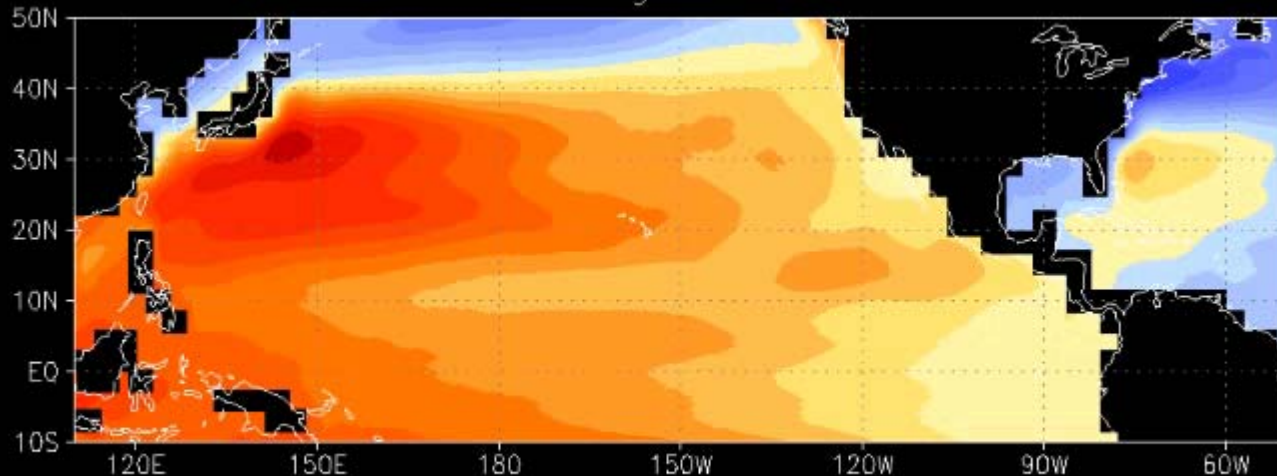


Hi-CGCM: a pilot 40-yr integration

Sea Surface Height Hi-CGCM JAN21



Sea Surface Height Mid-CGCM JAN21



1. Introduction

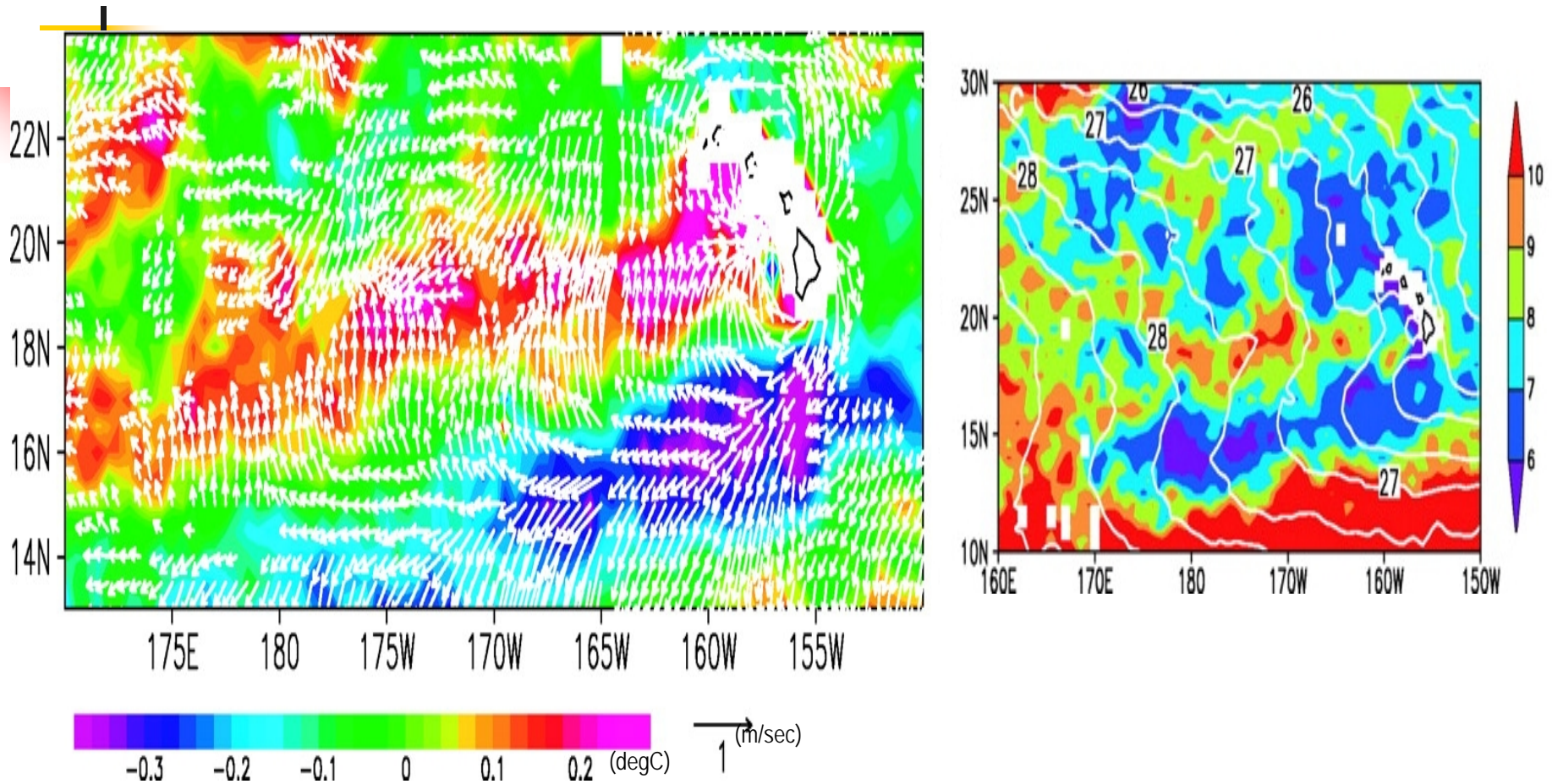
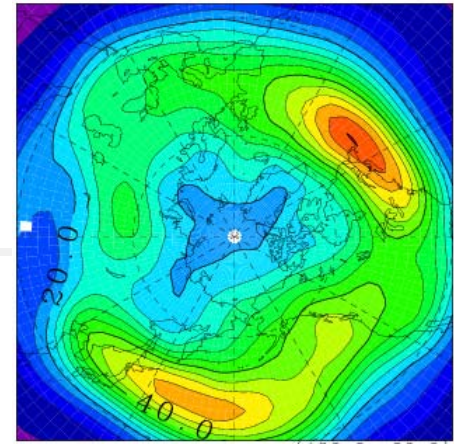
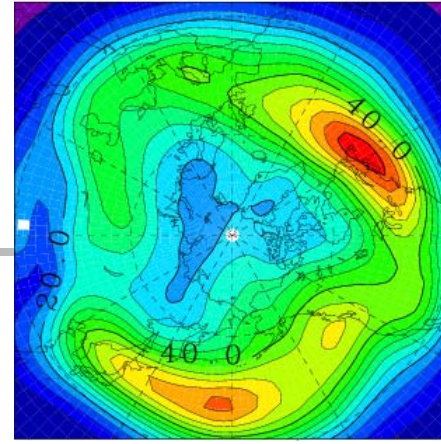
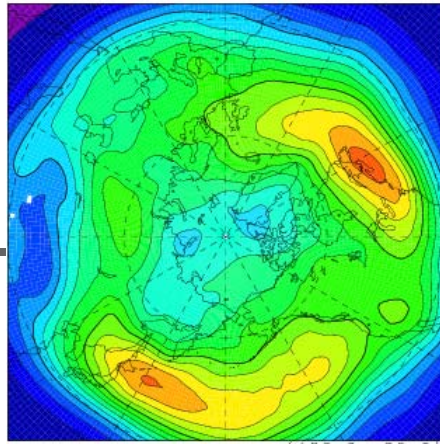
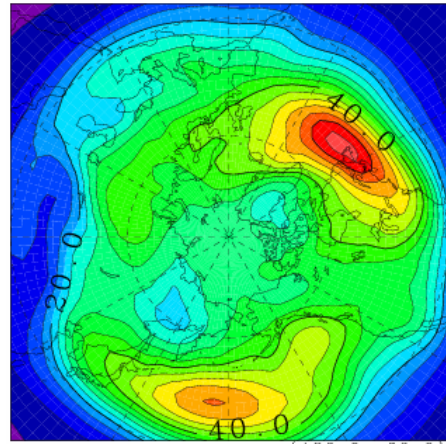


Figure 1. SST and surface wind anomaly from meridionally 8-degree moving averaged fields (a), and cloud liquid water (b) averaged from July to October 1999 (Xie et al. 2001). SST and cloud liquid water are observed from TRMM and surface wind is from QuickSCAT.

NH DJF

Highpass (2.5-6day) Eddy

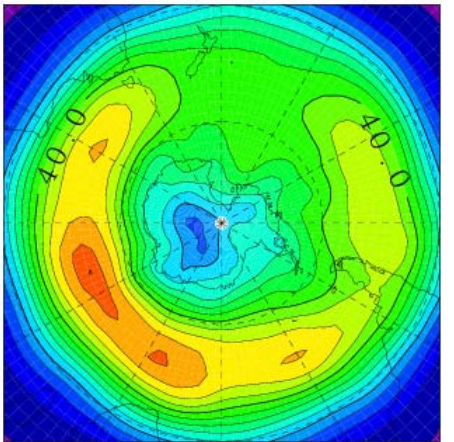
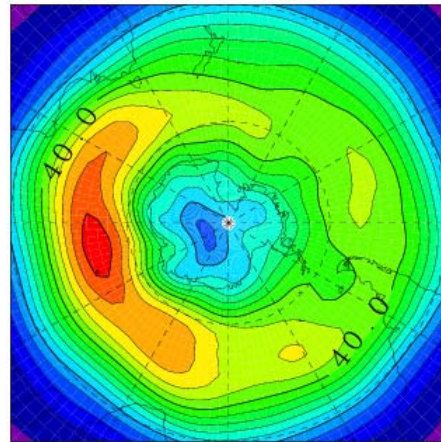
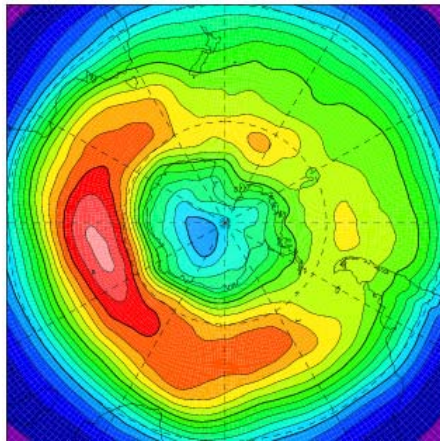
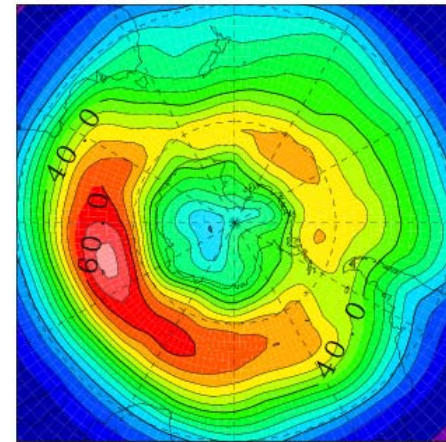


ERA40
SH JJA

T106L56
AGCM

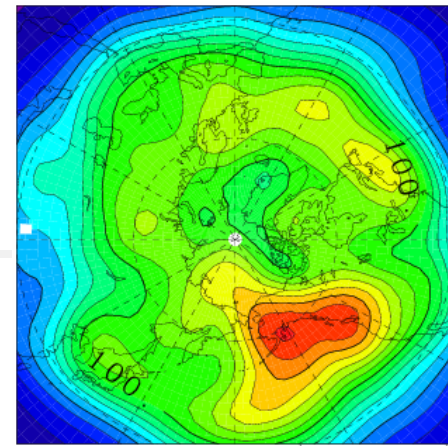
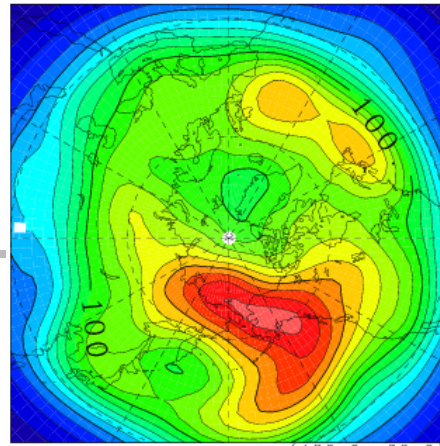
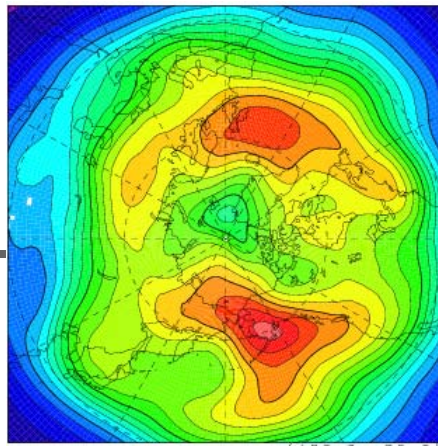
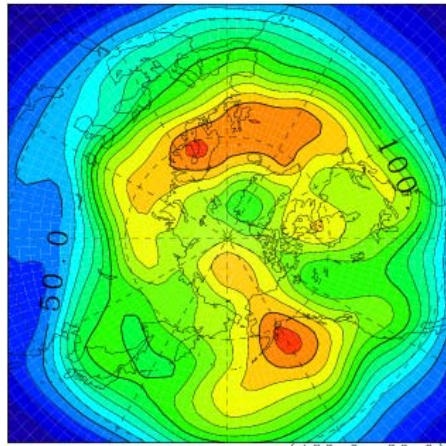
T42L56
AGCM

T42L20
AGCM



NH DJF

Lowpass (10-90day) Eddy

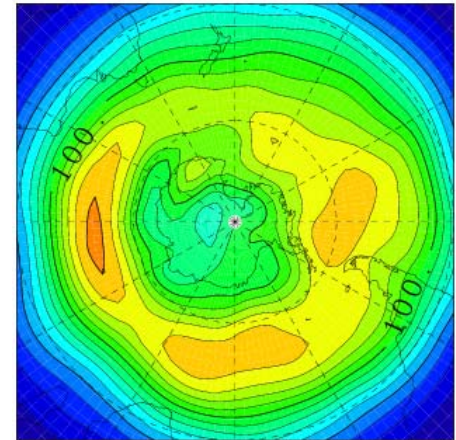
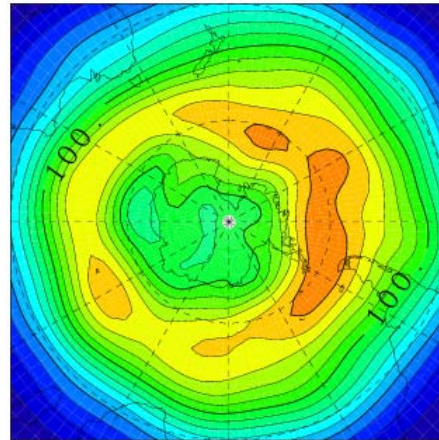
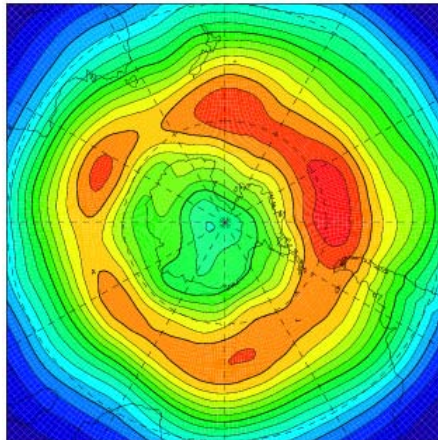
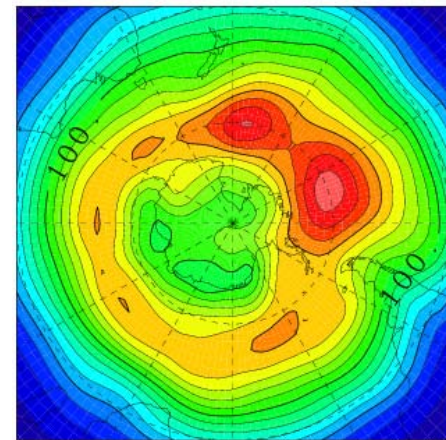


ERA40
SH JJA

T106L56
AGCM

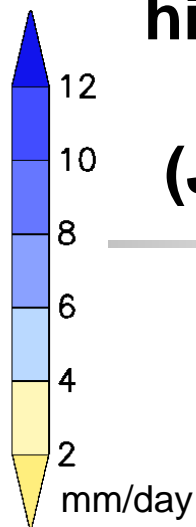
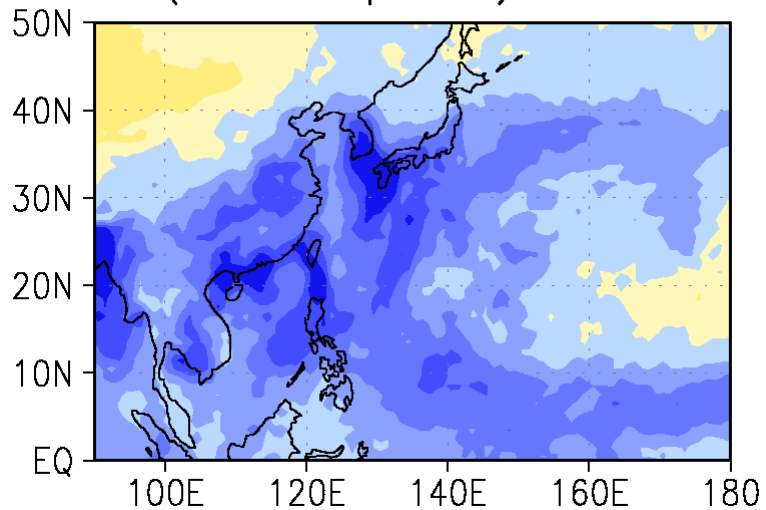
T42L56
AGCM

T42L20
AGCM



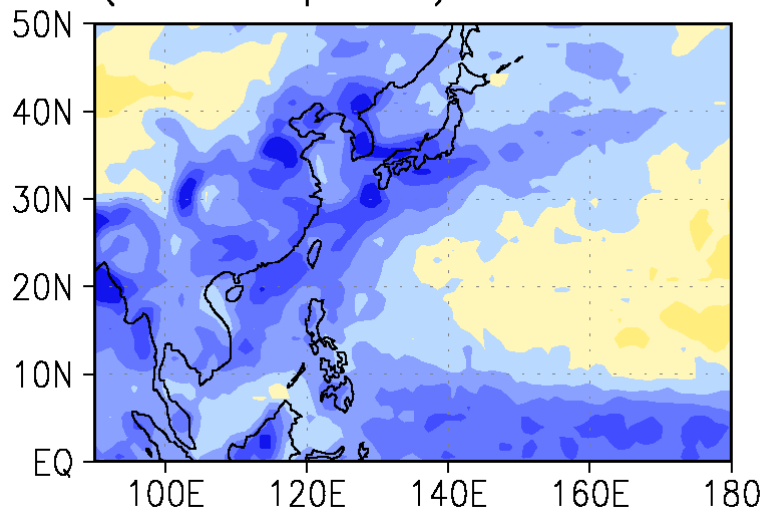
Standard deviation of high-frequency (<10days) rainfall variability (June-July; 6yr average)

std(hi-freq.rain) JJ Obs.

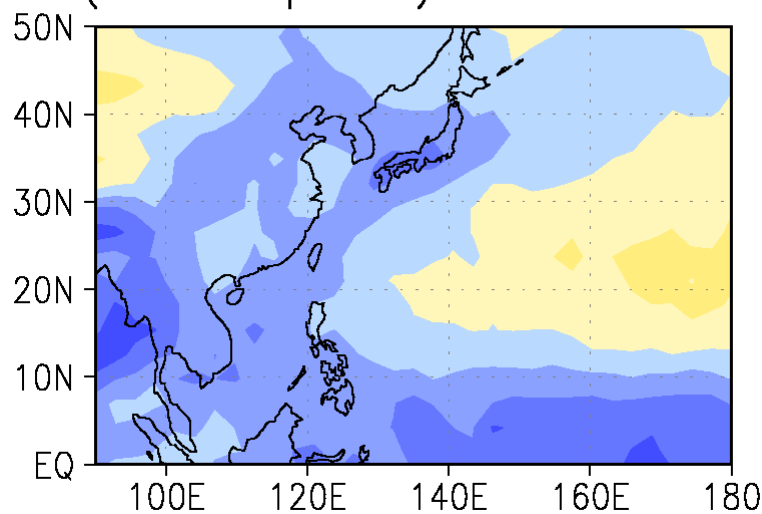


Satellite	
Hi-CGCM	Mid-CGCM

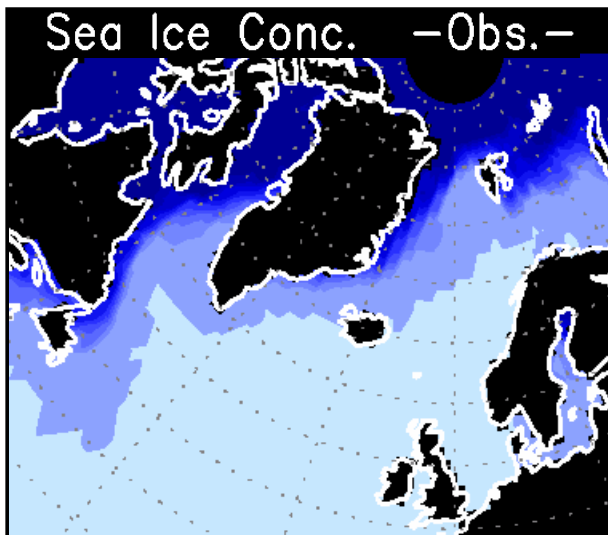
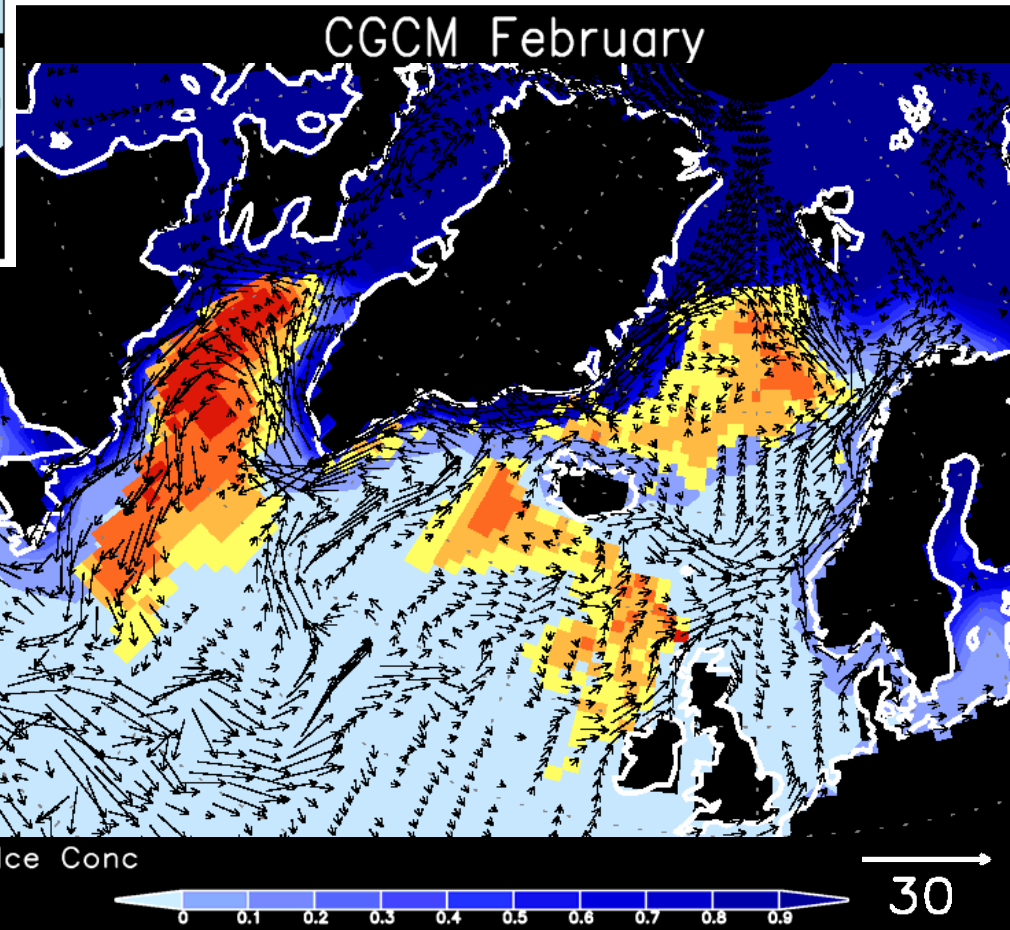
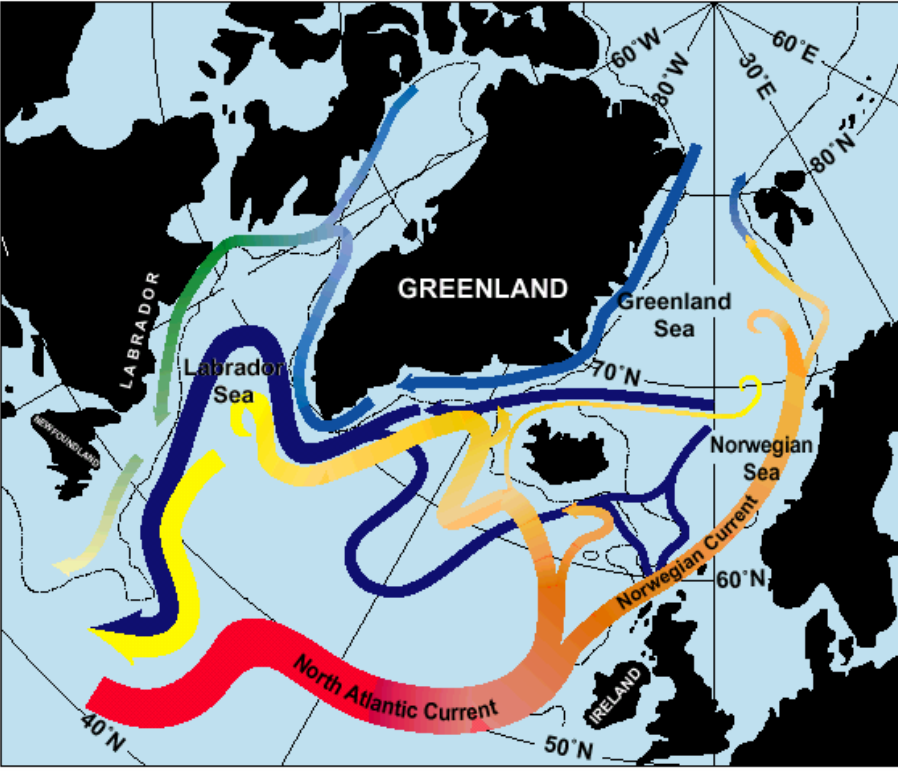
std(hi-freq.rain) JJ Hi-CGCM



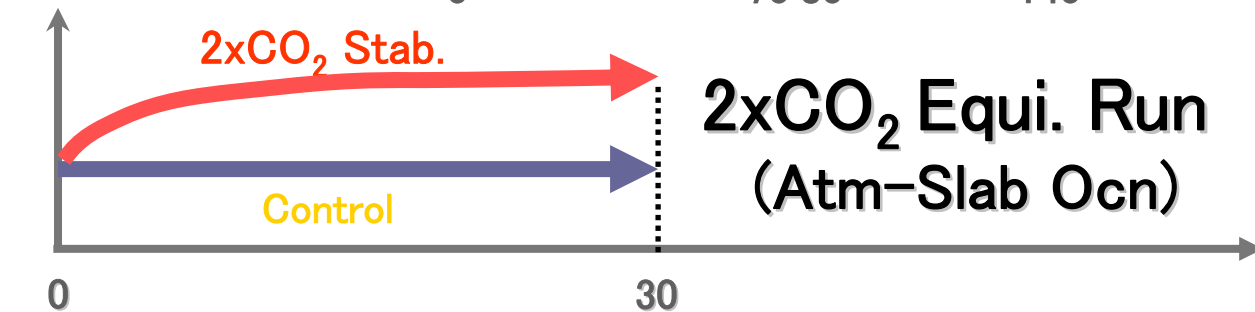
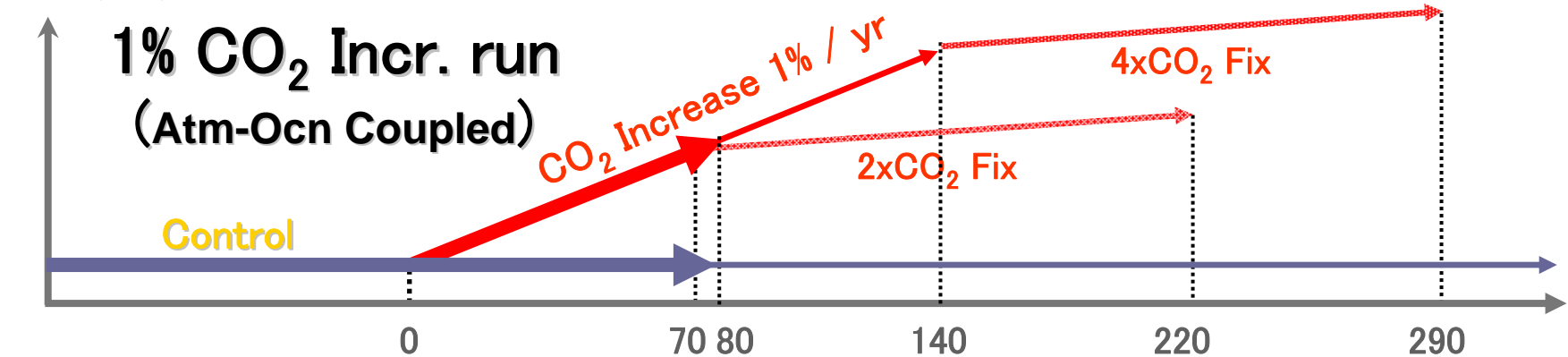
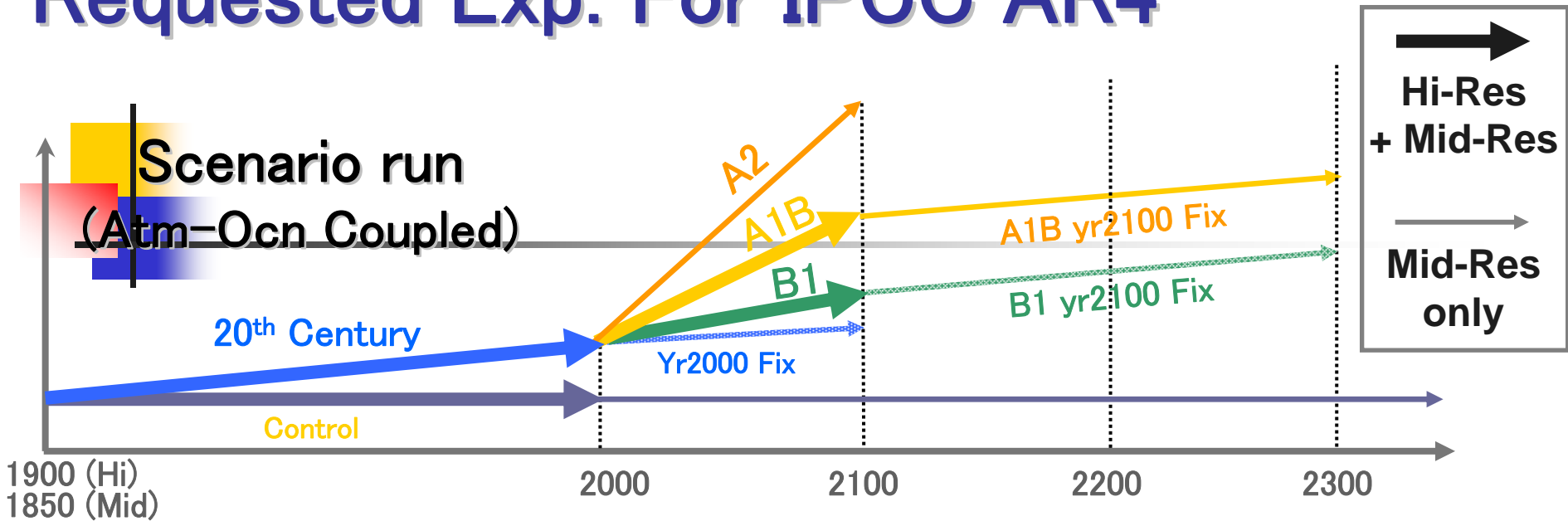
std(hi-freq.rain) JJ Mid-CGCM



Atlantic Thermohaline Circulation

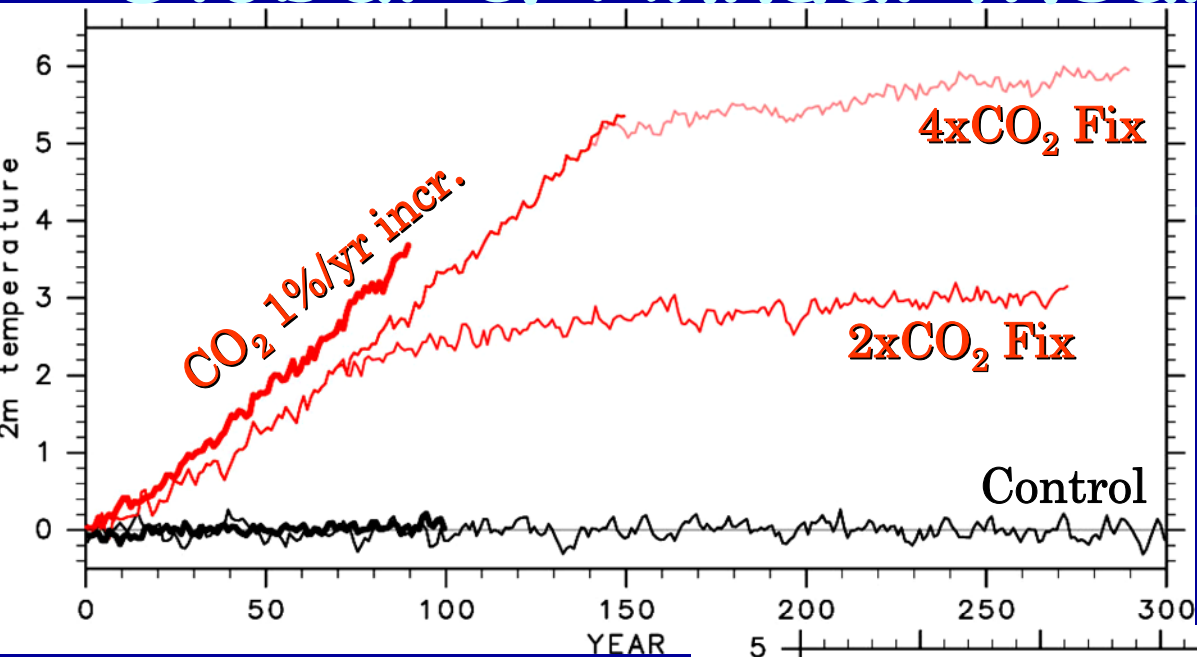


Requested Exp. For IPCC AR4



- Model Intercomp. Proj.**
- AMIP (Atmosphere)
 - OMIP (Ocean)
 - CFMIP (Cloud Forcing)

Global & Annual Mean SAT



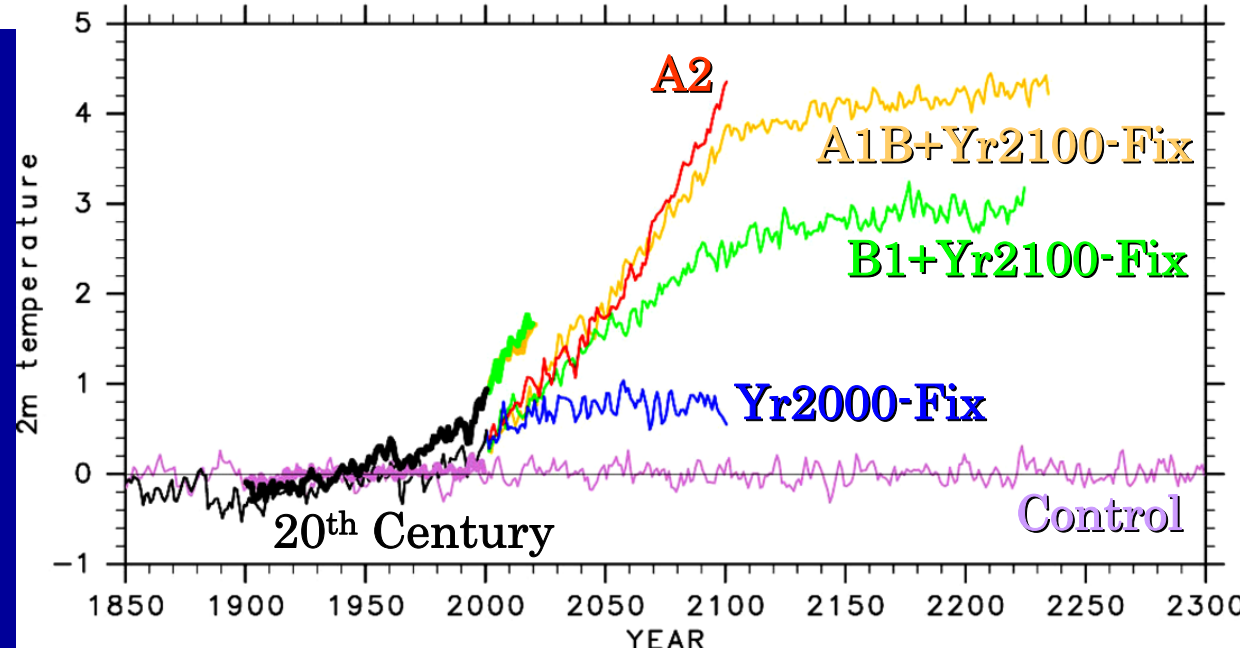
Results

w/ Hi-CGCM

(Thick curves)

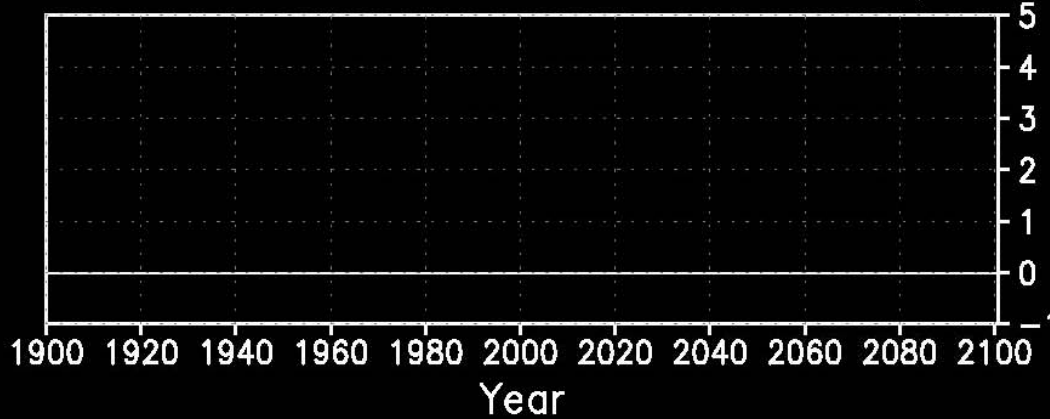
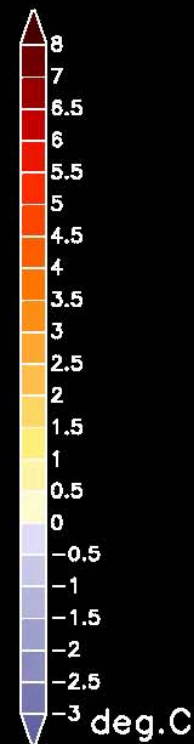
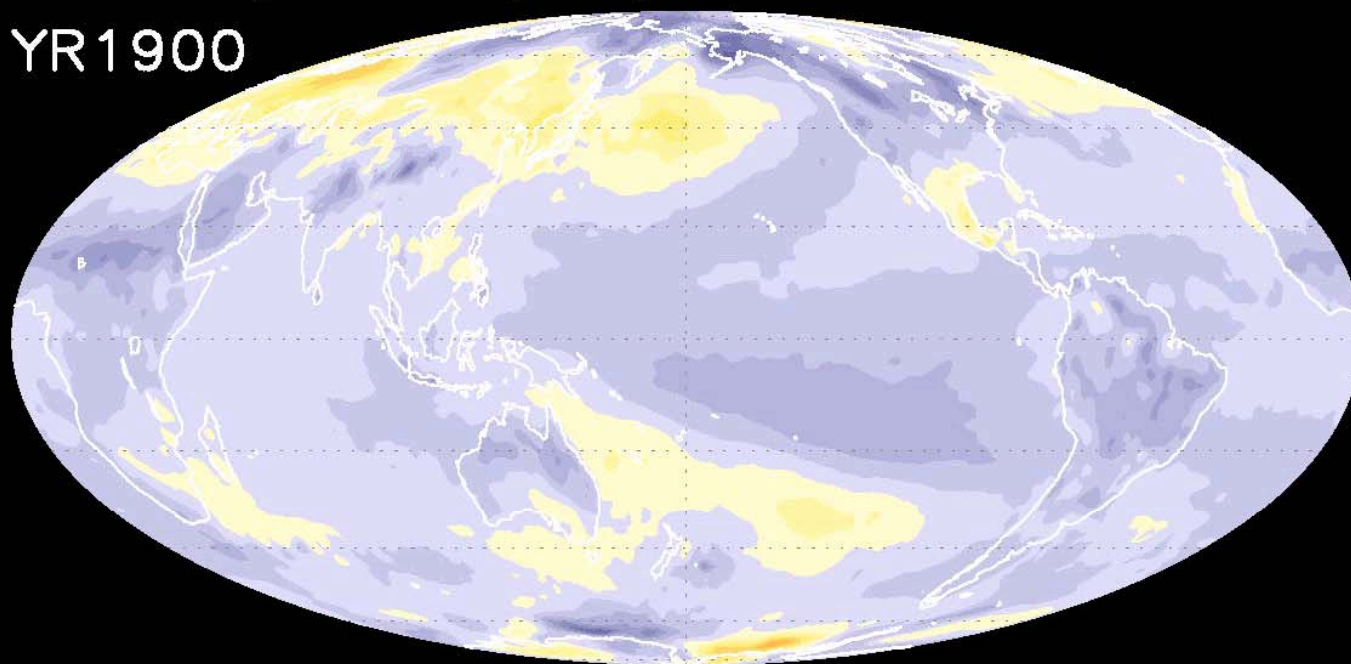
w/ Mid-CGCM

(Thin curves)

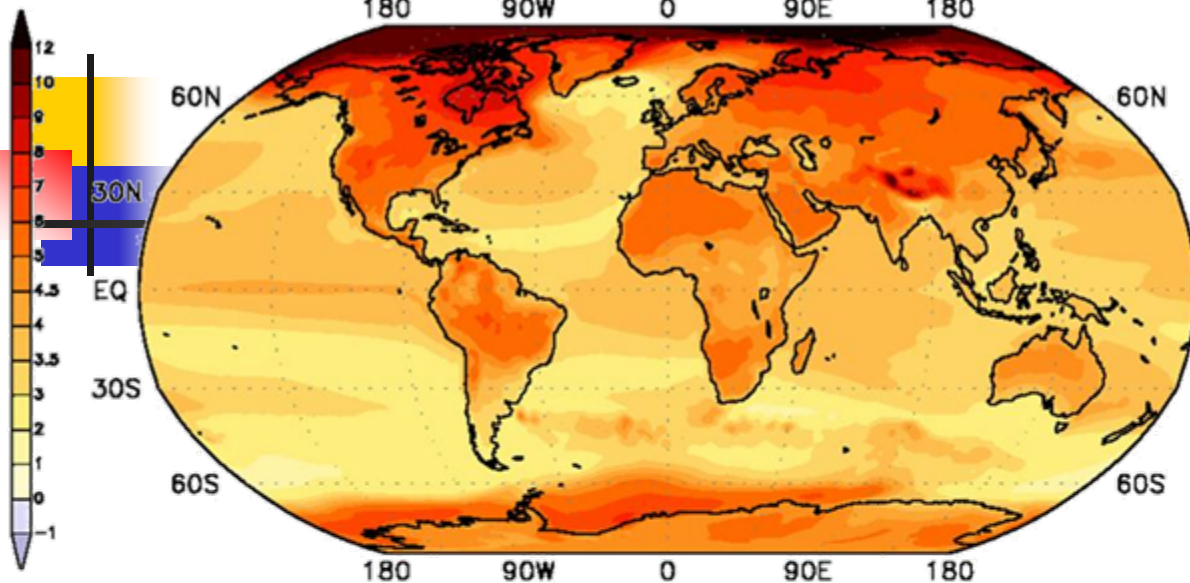


Global Warming Simulation by the CCSR/NIES/FRCGC Climate Model

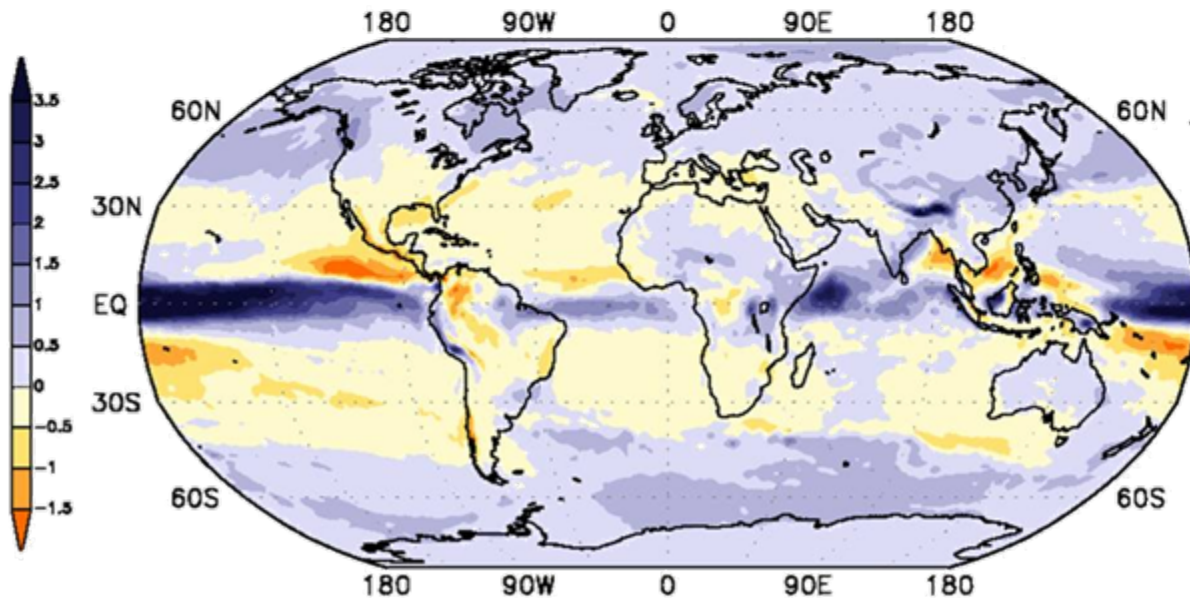
YR1900



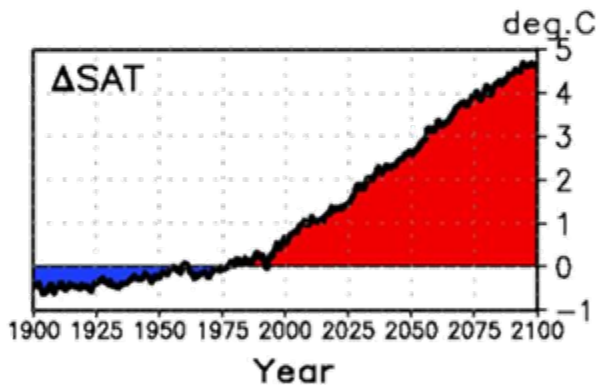
Global Warming Simulation by the CCSR/NIES/FRCGC Climate Model



ΔSAT
A1b(2071-2100)
-20C3M(1971-2000)

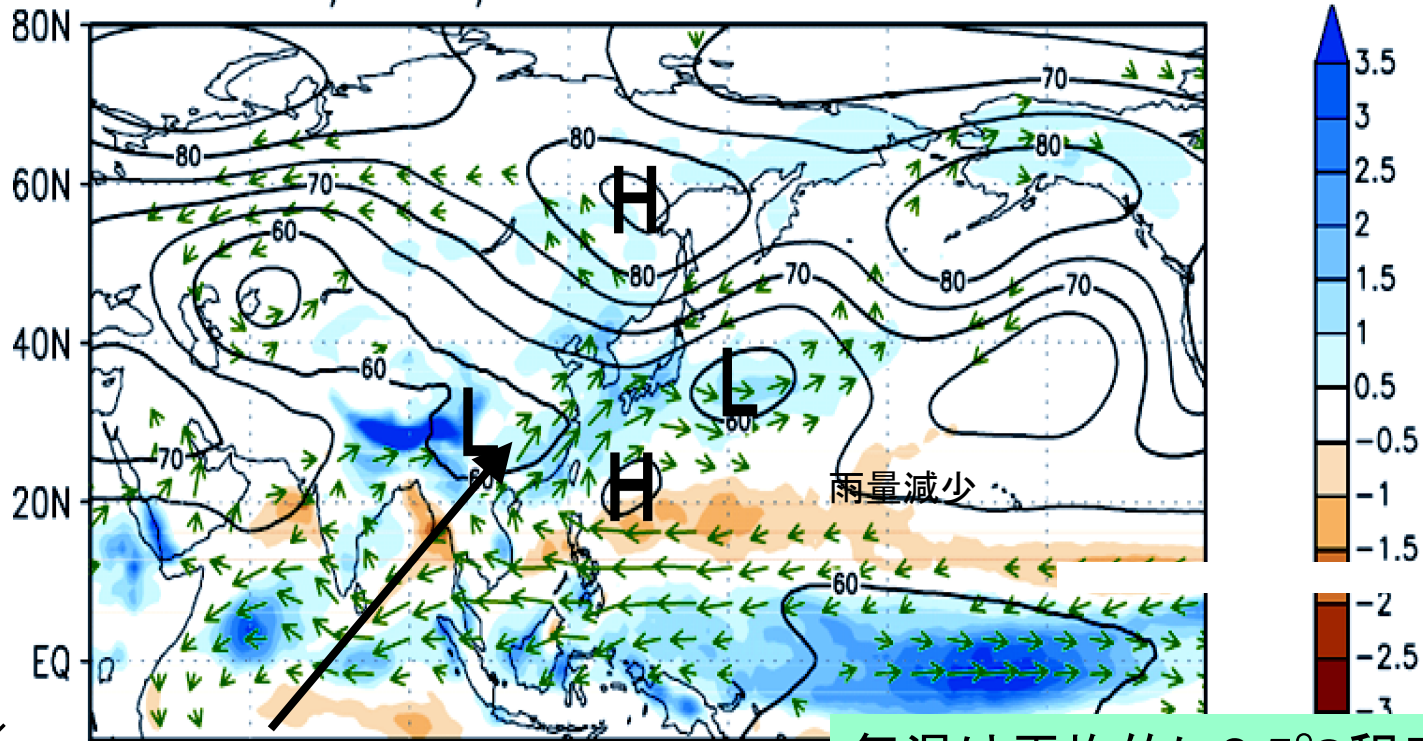


$\Delta Rain$
A1b(2071-2100)
-20C3M(1971-2000)



What happens in the summer around Japan in the future?

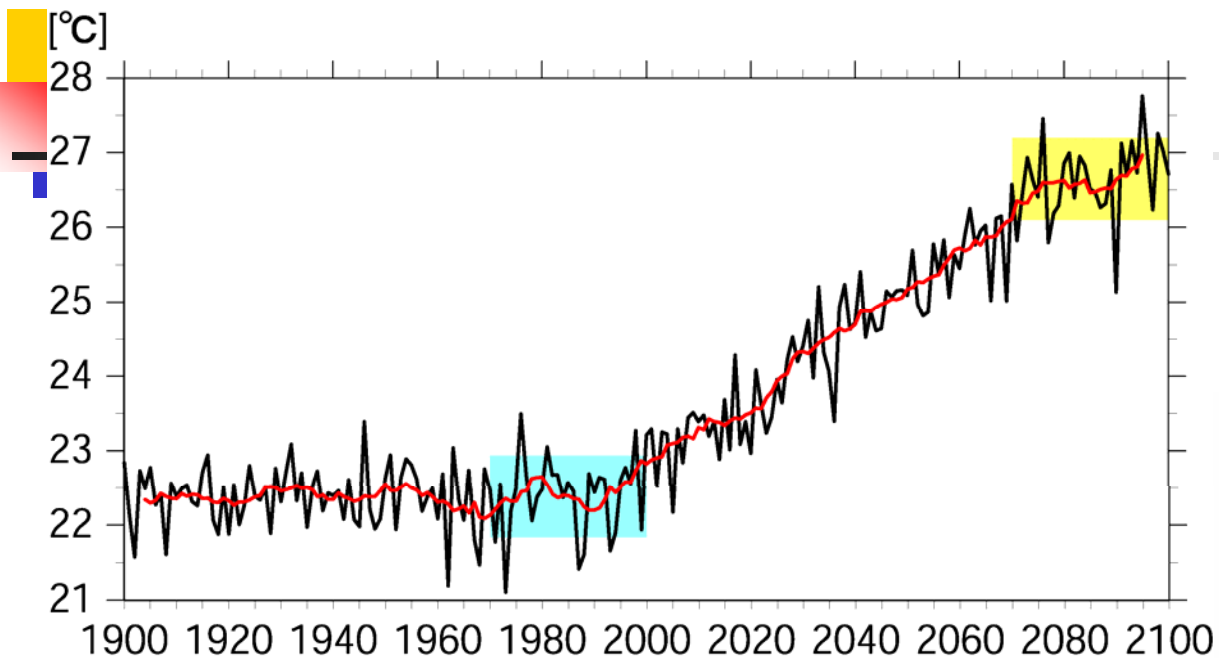
Rain/Z500/V850 2xCO2 - 1xCO2 JJA 雨量増加



雨量は平均的に増加(青色の領域)

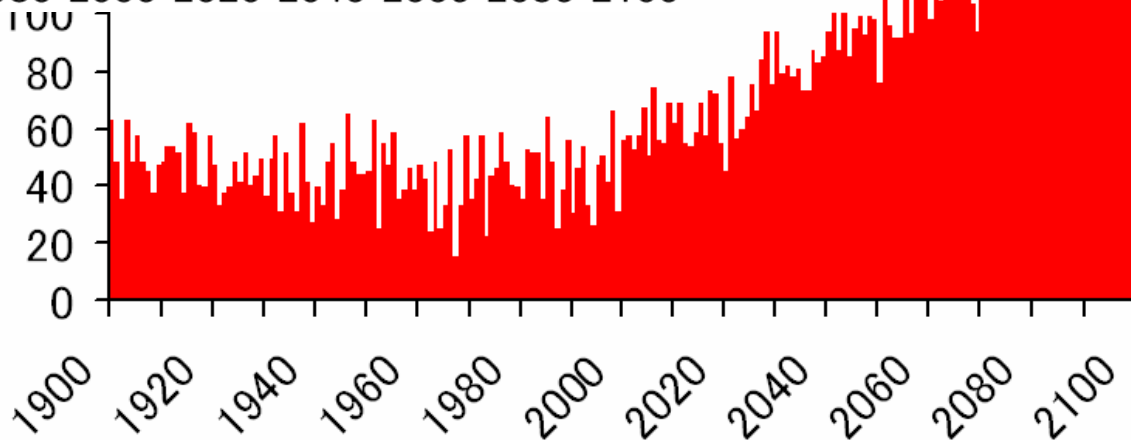
気温は平均的に2.5°C程度上昇

日本の真夏日日数と夏季平均気温の変化

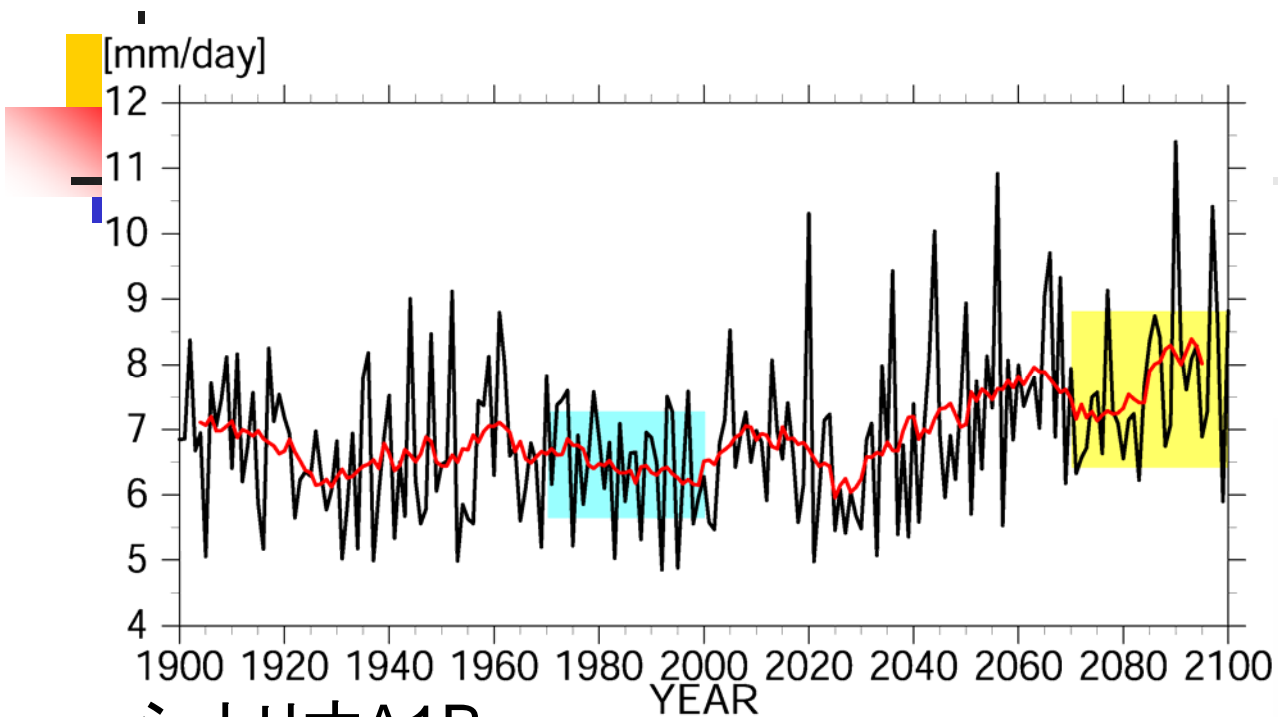


年々の変動幅
はほとんど変化
しない

シナリオA1B
全球平均気温は
100年間で
4.0°C上昇

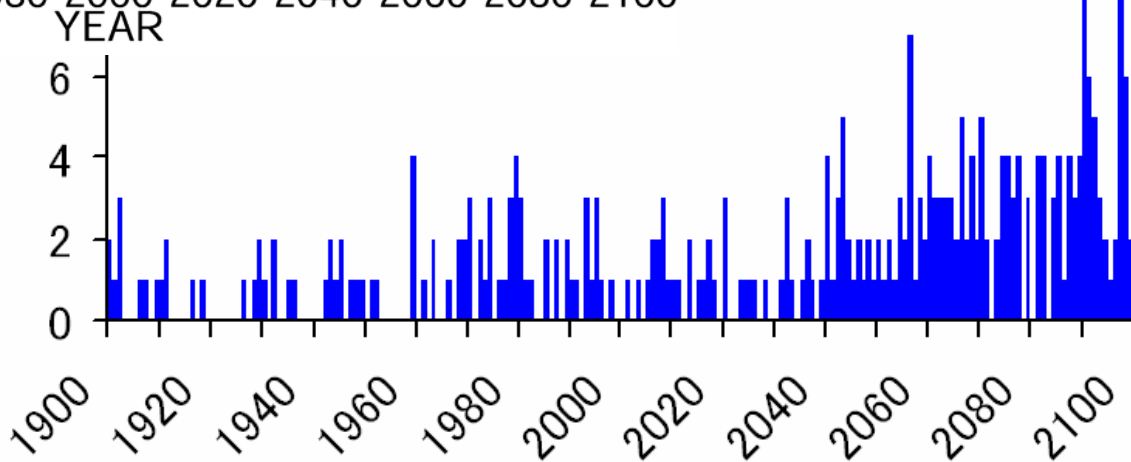


日本の夏季豪雨日数と夏季平均降水量の変化



年々の変動幅も大きくなる

シナリオA1B
全球平均降水量
は100年間で
6.4%増加

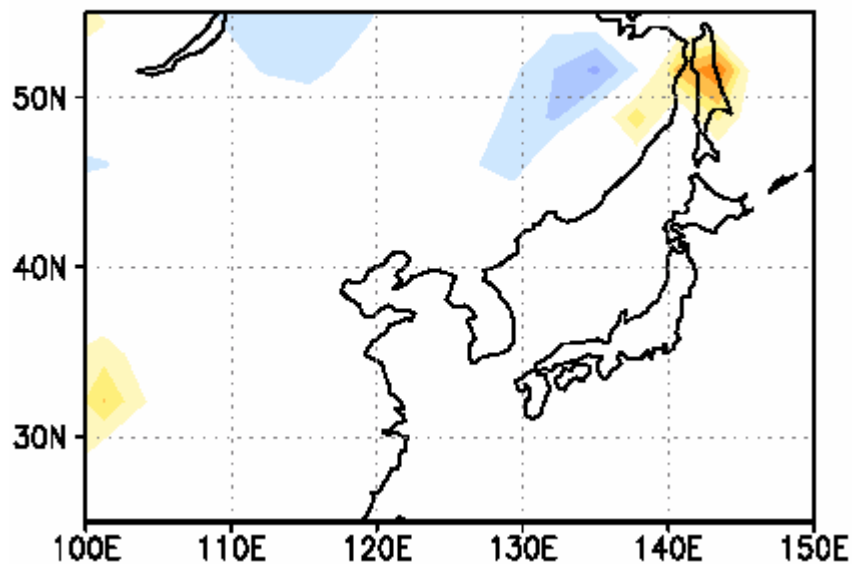


Snow under the global warming

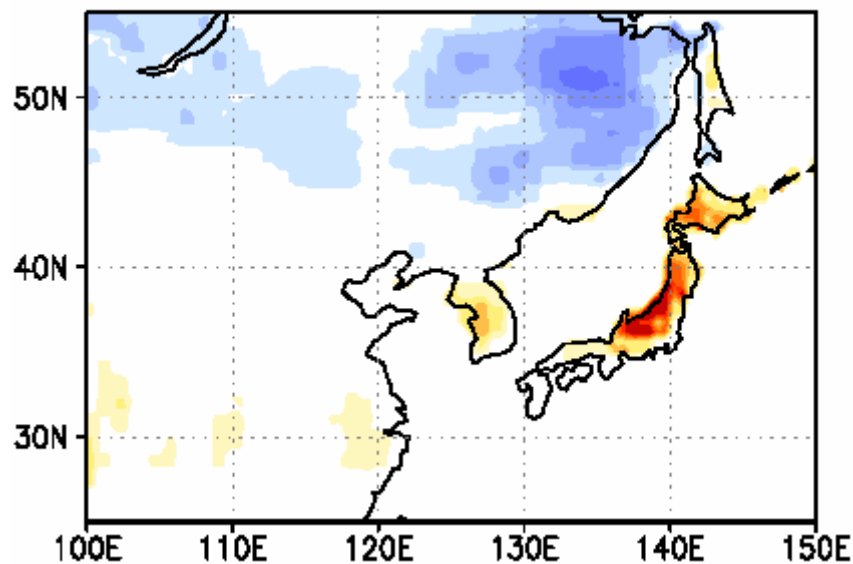
Mid-CGCM

Hi-CGCM

Snow 2xCO₂-1xCO₂ Mid-CGCM Jan

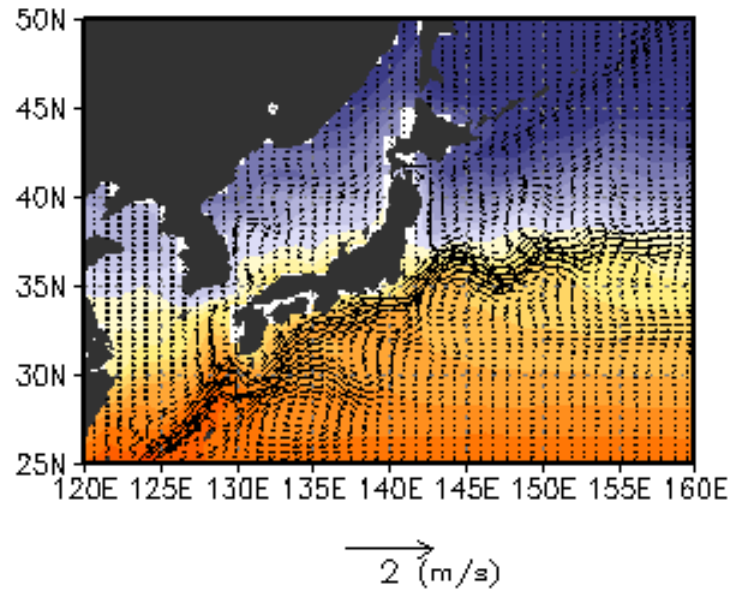


Snow 2xCO₂-1xCO₂ Hi-CGCM Jan

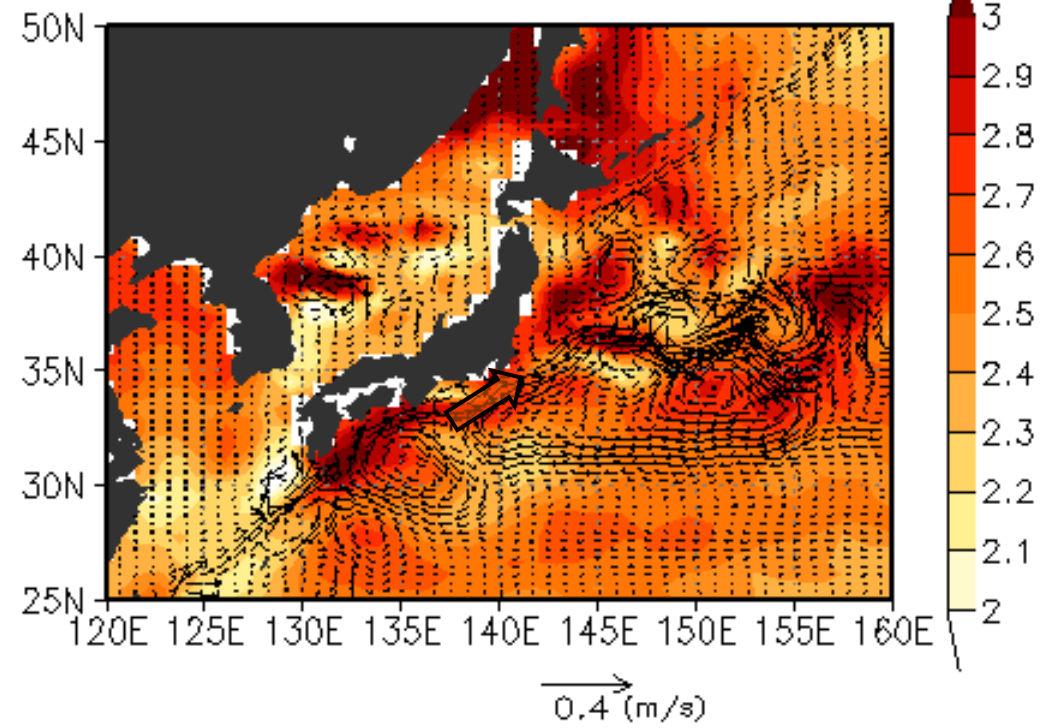


黒潮：温暖化時の変化

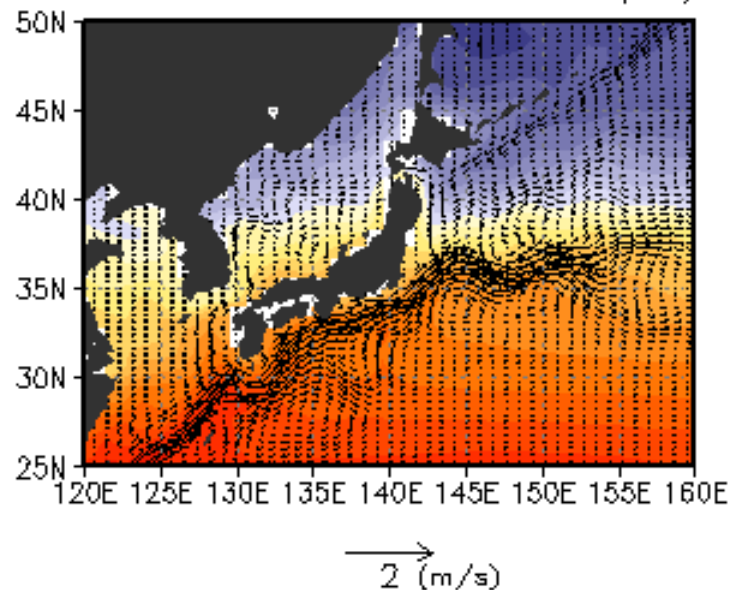
SST & ocean current at 100-m depth
(CONTROL)



SST & ocean current at 100-m depth
(CO2-CONTROL)

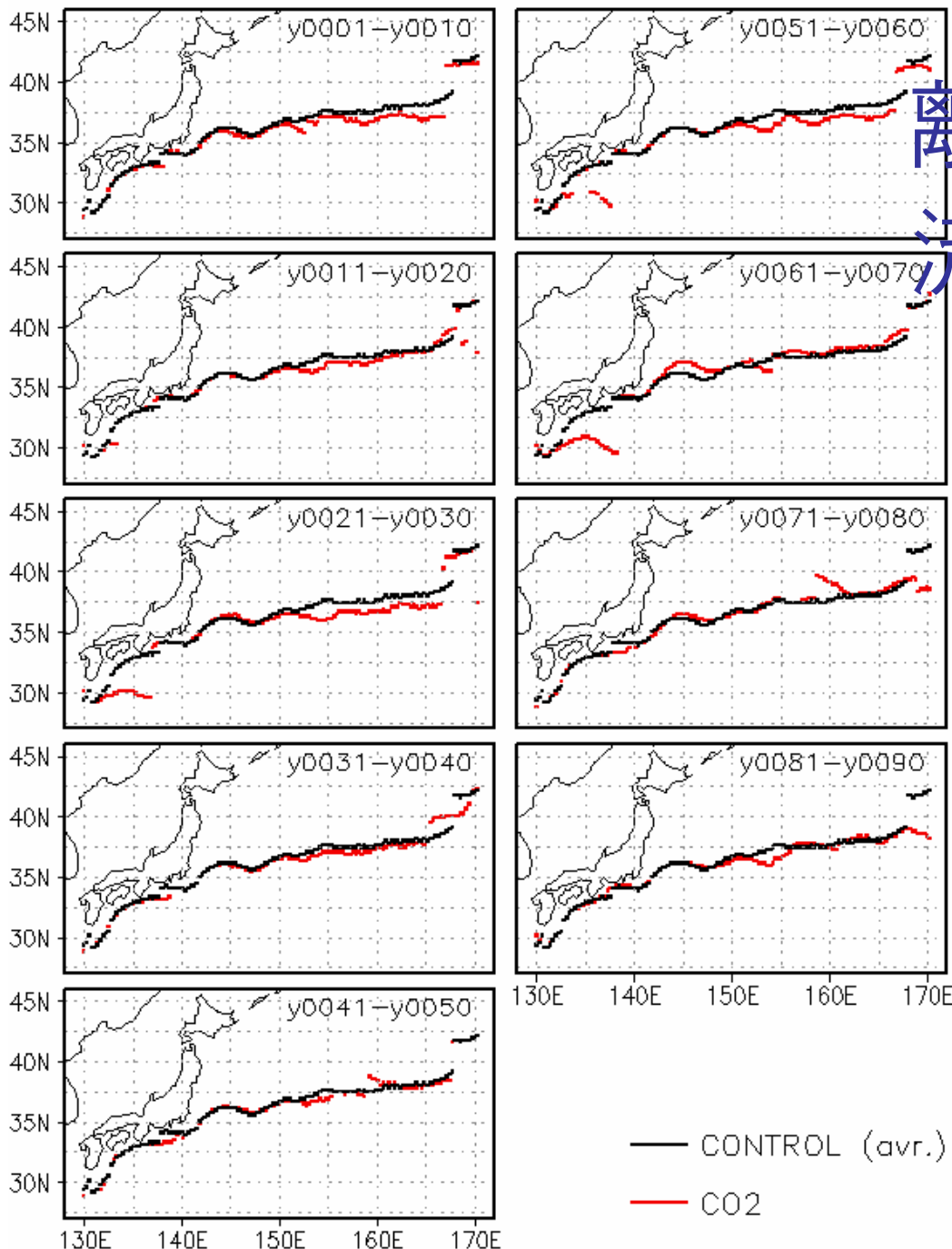


SST & ocean current at 100-m depth
(CO2)



離岸後の黒潮の流路

- 定義：各経度における月平均海面高度勾配が最大の緯度
- 温暖化に伴う黒潮続流の流軸緯度に大きな違いは見られない

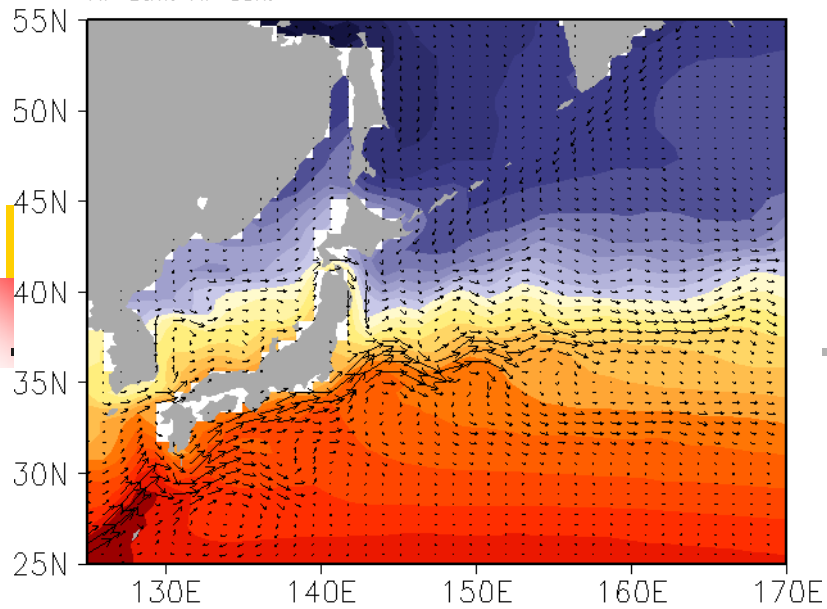




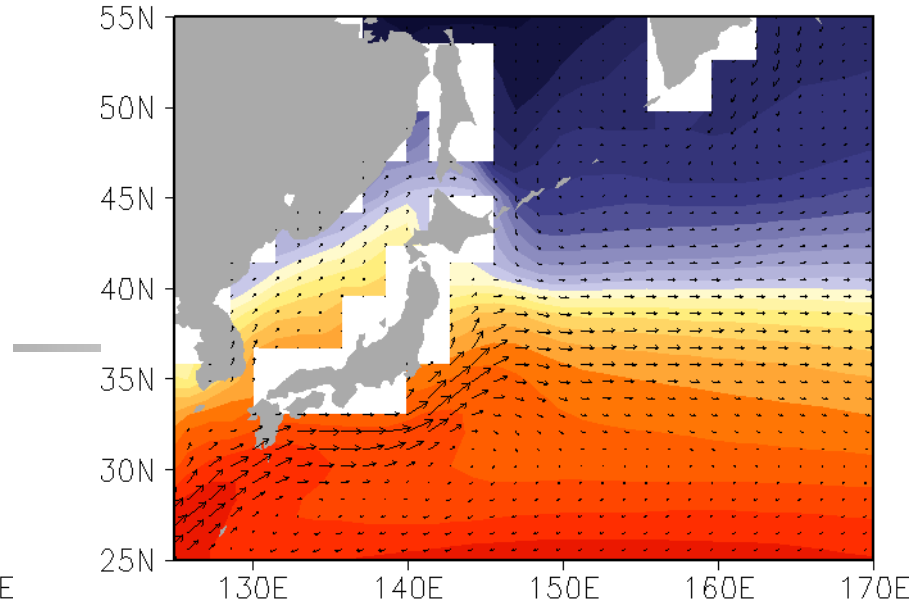
Resolution Effect

- High-res. AGCM
- High-res. OGCM
- Med.-res. AGCM
- Med.-res. OGCM
- Easy coupling no drift

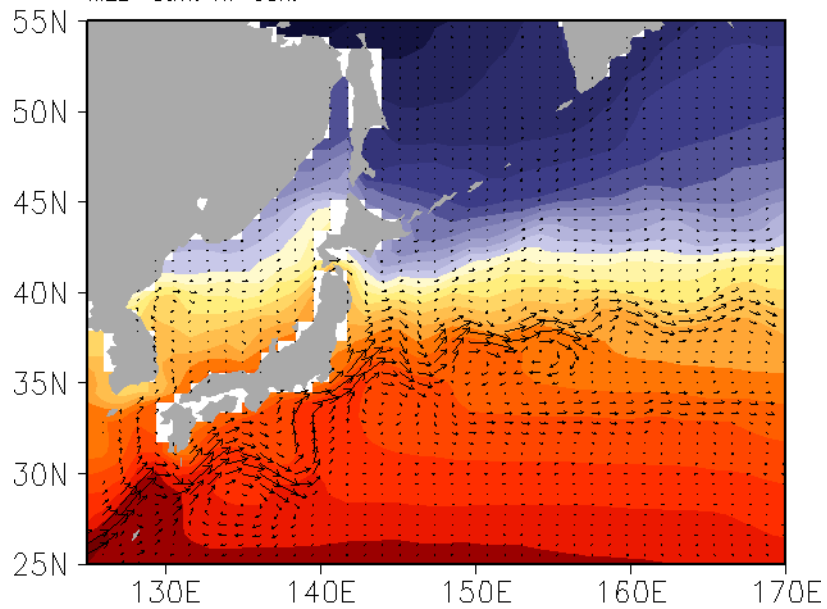
HI-atm. HI-ocn.



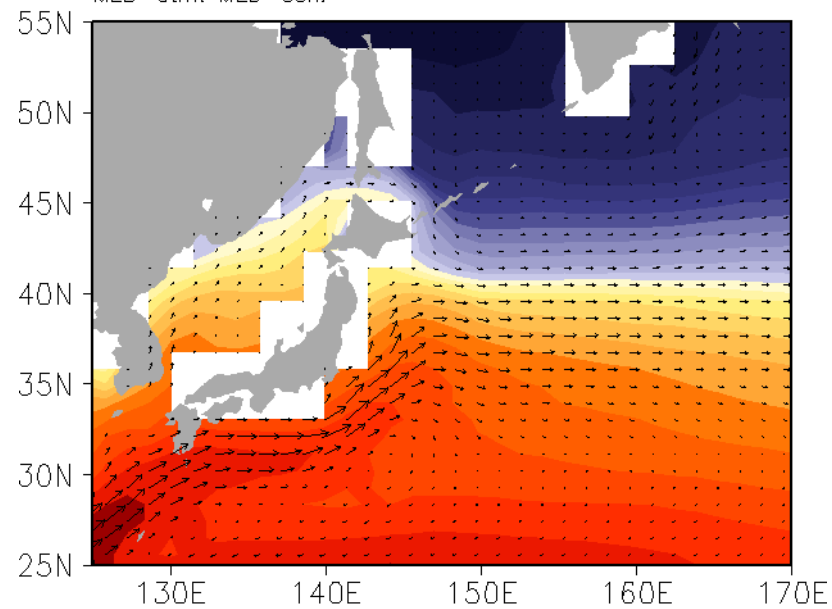
HI-atm. MED-ocn.



MED-atm. HI-ocn.



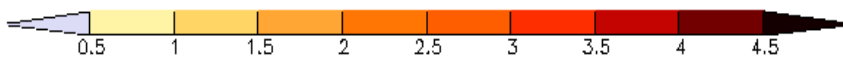
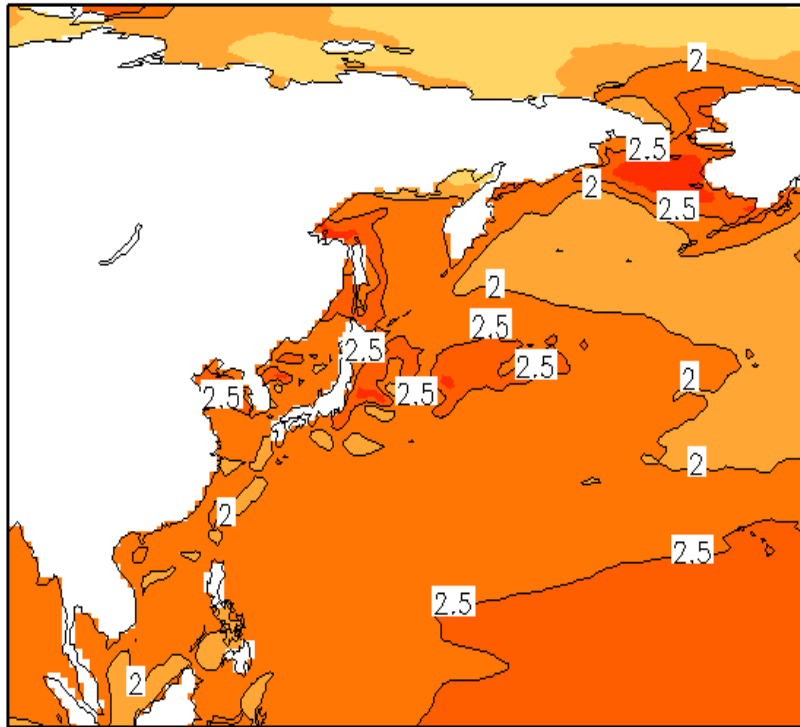
MED-atm. MED-ocn.



High-Res.

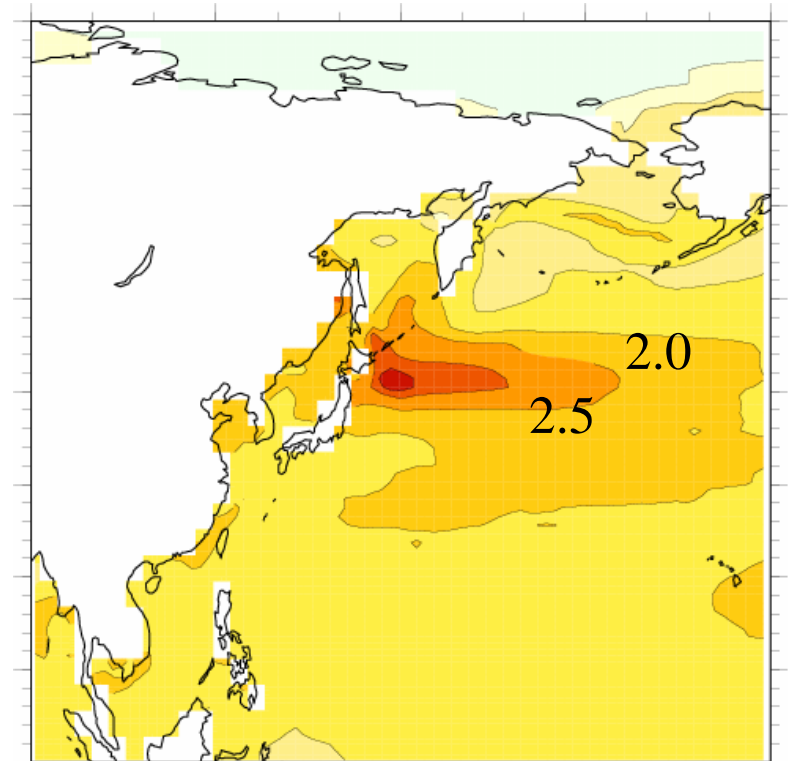


SST CO2(61-80)-CTL(1-100)

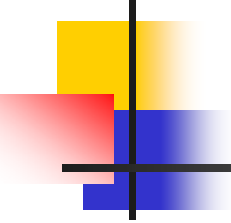


Medium-Res.

61-80 Medium



0 1 2 3 4 5 [K]

- 
-
- High-resolution is necessary to represent the Kuroshio



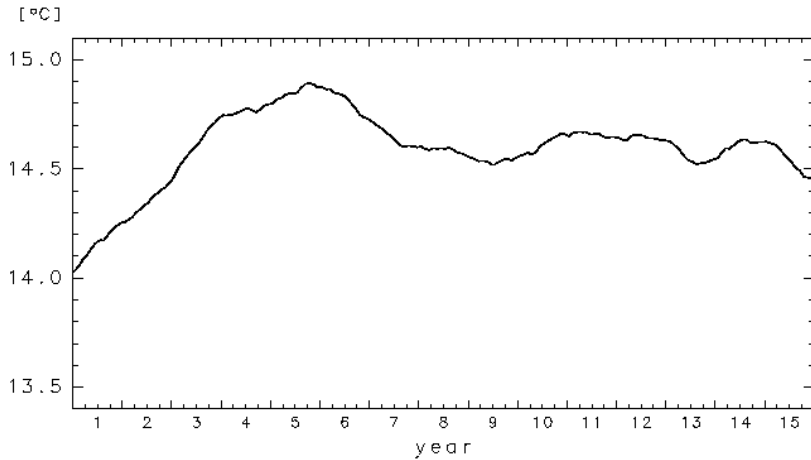
T213L56 AGCM

$1/4^\circ \times 1/6^\circ$ 48層 OCM

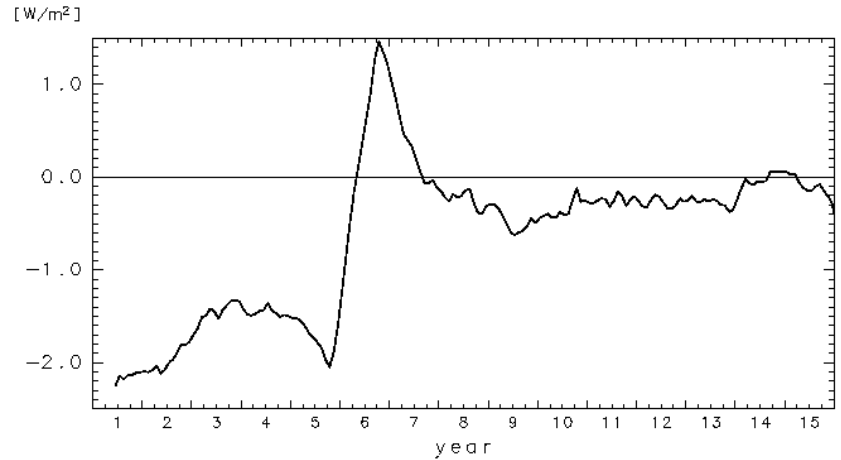
Climate Model

Trends

Ts(2m)



Radiation Balance at TOA



- ・ 温度が上昇

→ 5年目の途中よりパラメータ(放射・雲/エアロゾル関係)を微調整

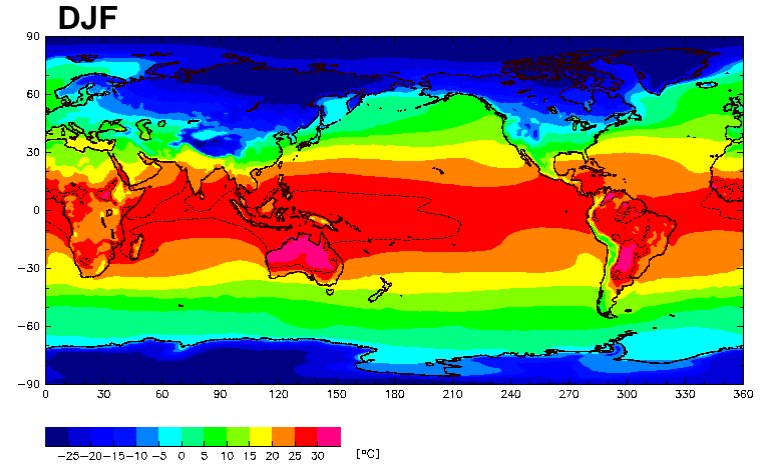
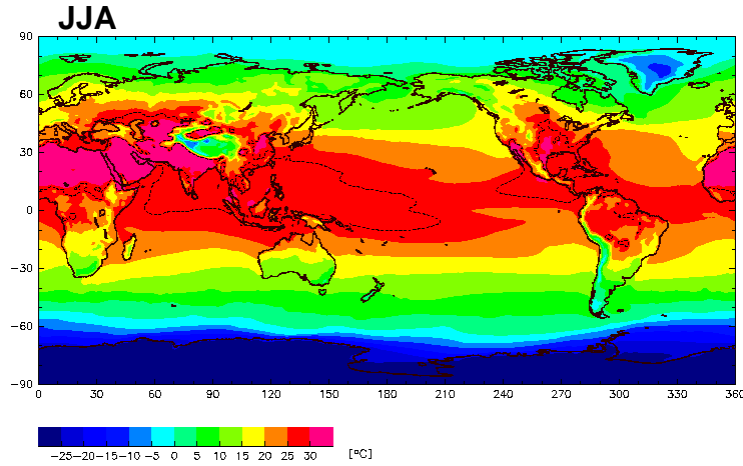
参考: 平均地上(2m)気温

- ・ T106結合モデル(100年平均) 13.9°C

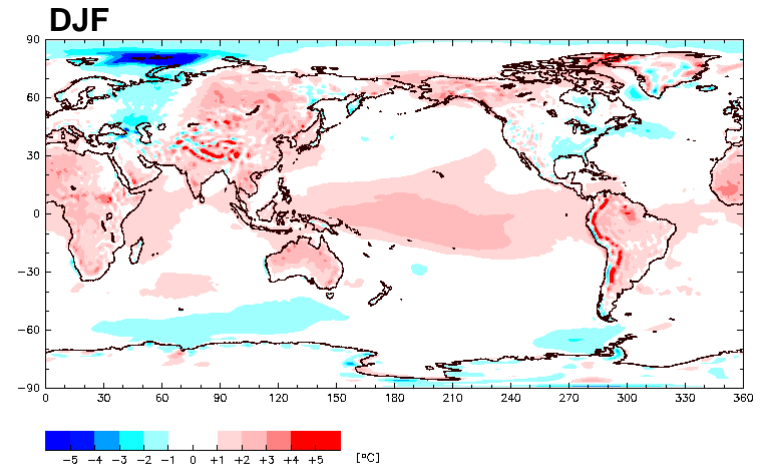
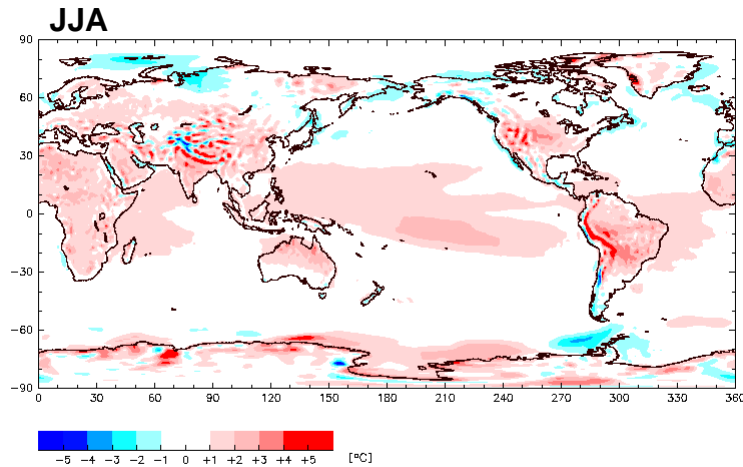
- ・ 中分解能(T42相当)結合モデル(500年平均) 13.4°C

地上気温 (T_2)

T213結合モデル(5年平均)



T106結合モデルとの差 [T213-T106(10年平均)]

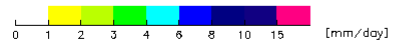
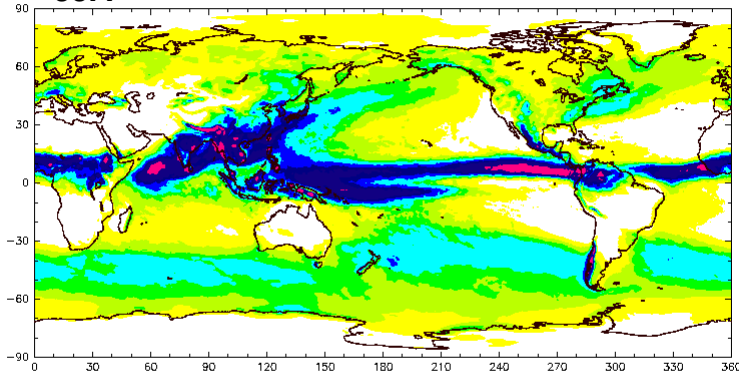


- ・ 熱帯海洋と大陸で1~2°C温度が高い

Precipitation

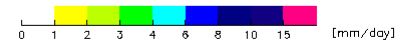
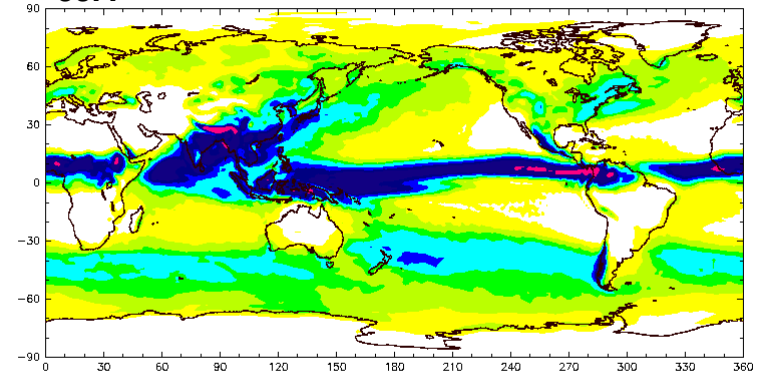
T213結合モデル(11~15年目の5年間平均)

JJA

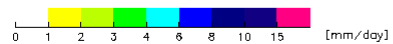
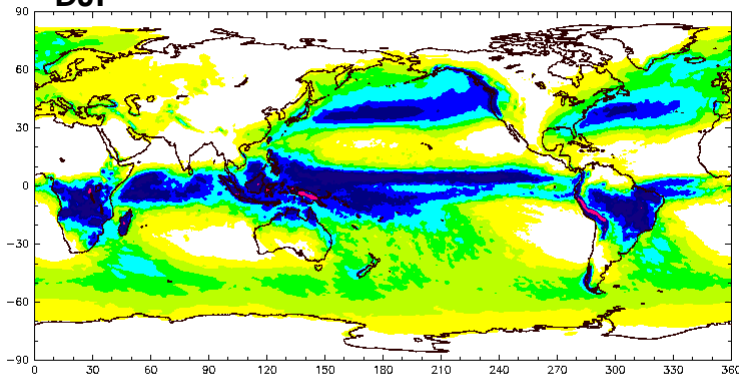


T106結合モデル(91~100年目の10年間平均)

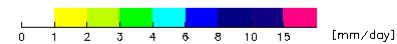
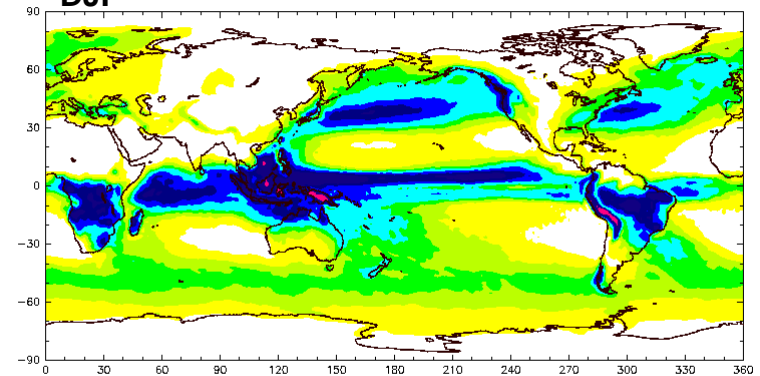
JJA



DJF



DJF

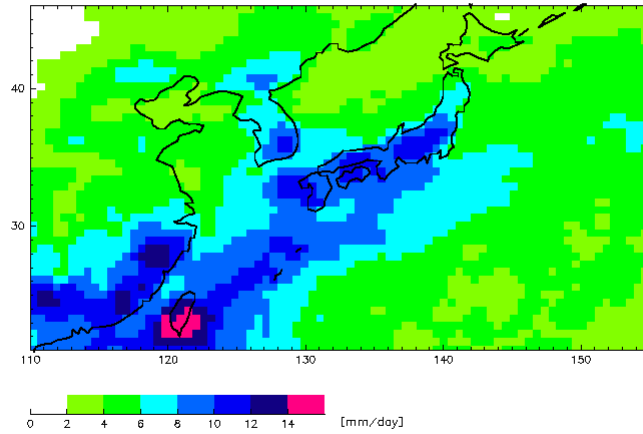


- ・ double ITCZ が強くなった

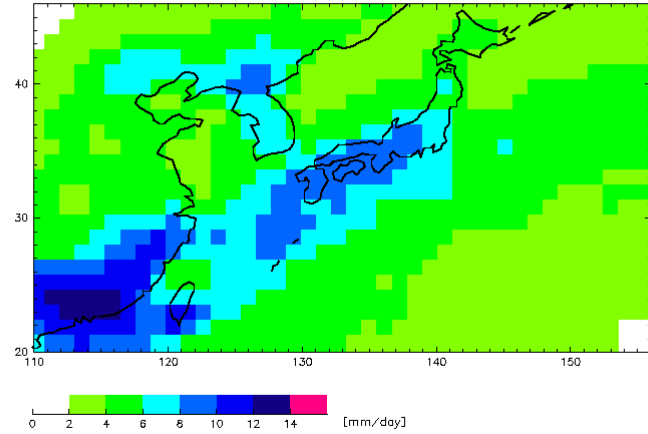
豪雨

JJA期間の平均降水量

T213結合モデル

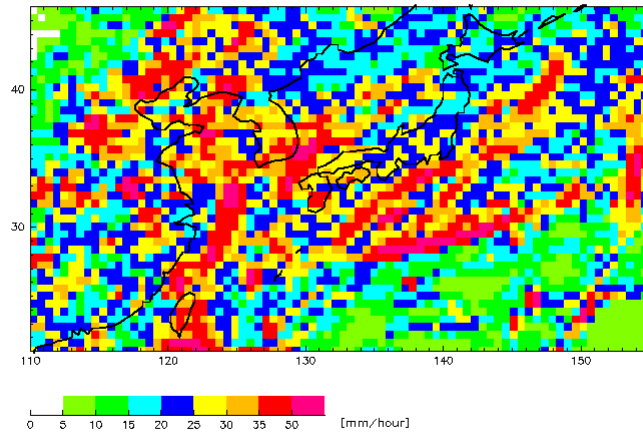


T106結合モデル

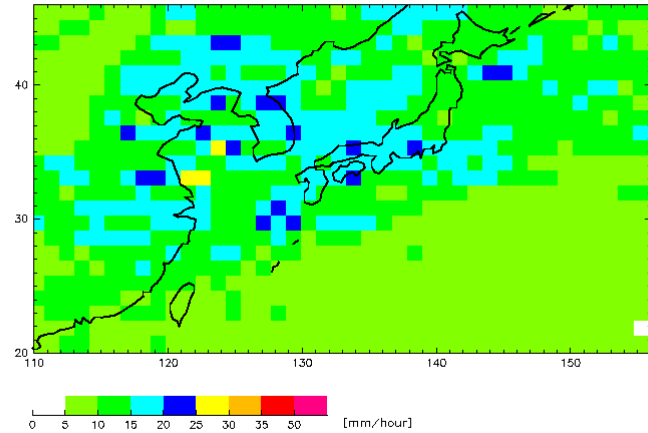


JJA期間中の1時間降水量の最大値

T213結合モデル



T106結合モデル



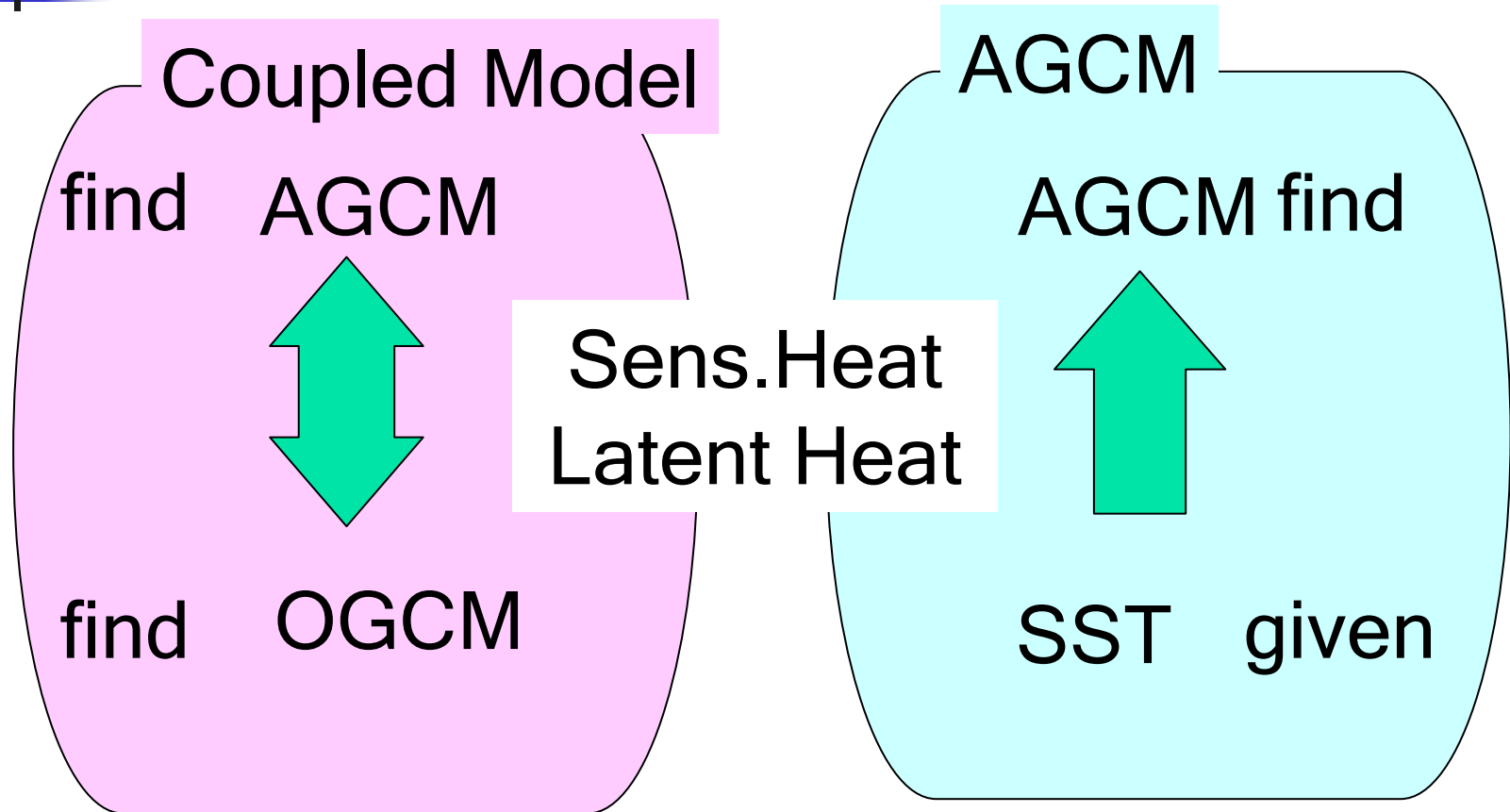
- ・ 平均値ではそれほど変わらないが、最大値はかなり大きくなり強い降水が表現されるようになる



Comparison between Coupled Run and AGCM run with SST given

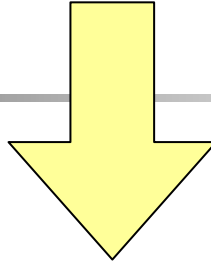
- Hi-res. Coupled RUN(T106L56)
- Hi-res.AGCM with SST by Coupled Run
- Present Climate and Global Warming Exp.

Issues of SST-given simulation





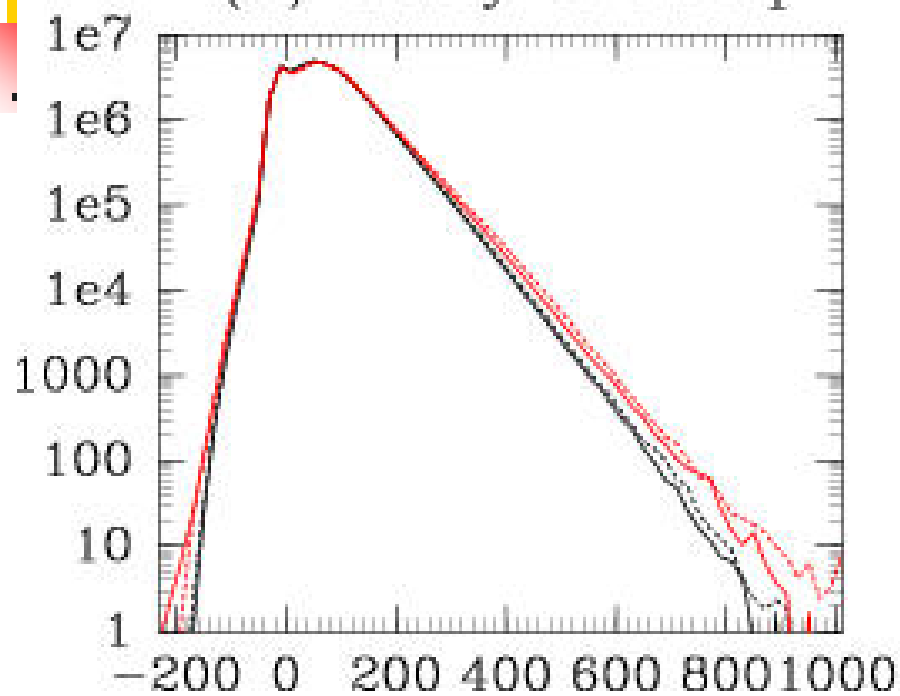
Time-slice Method is OK?



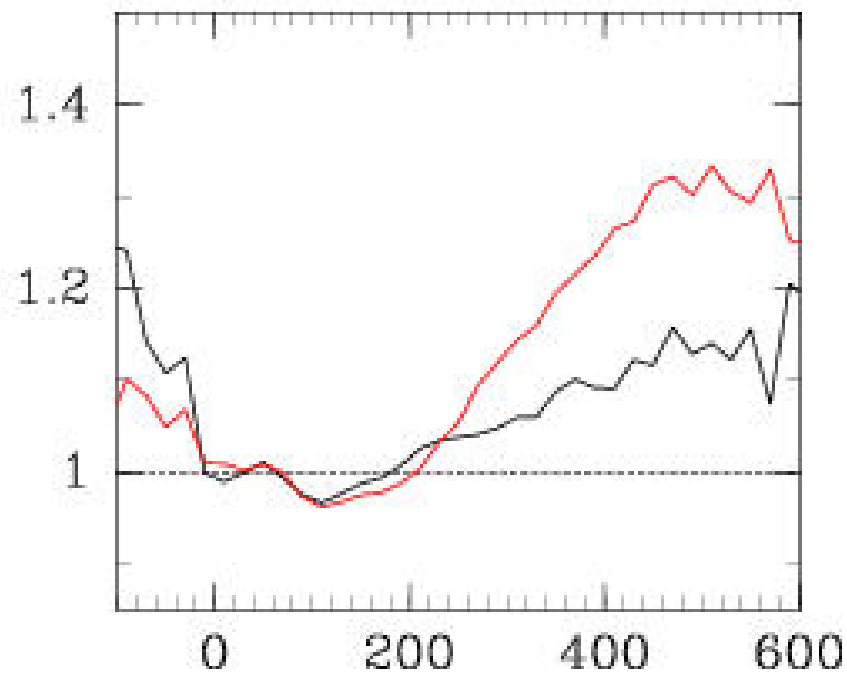
SST and Sea-Ice distribution
by the coupled model is given to
AGCM

Preset Climate and
warmer climate condition

(a) Daily E Freq



(b) AGCM/CGCM



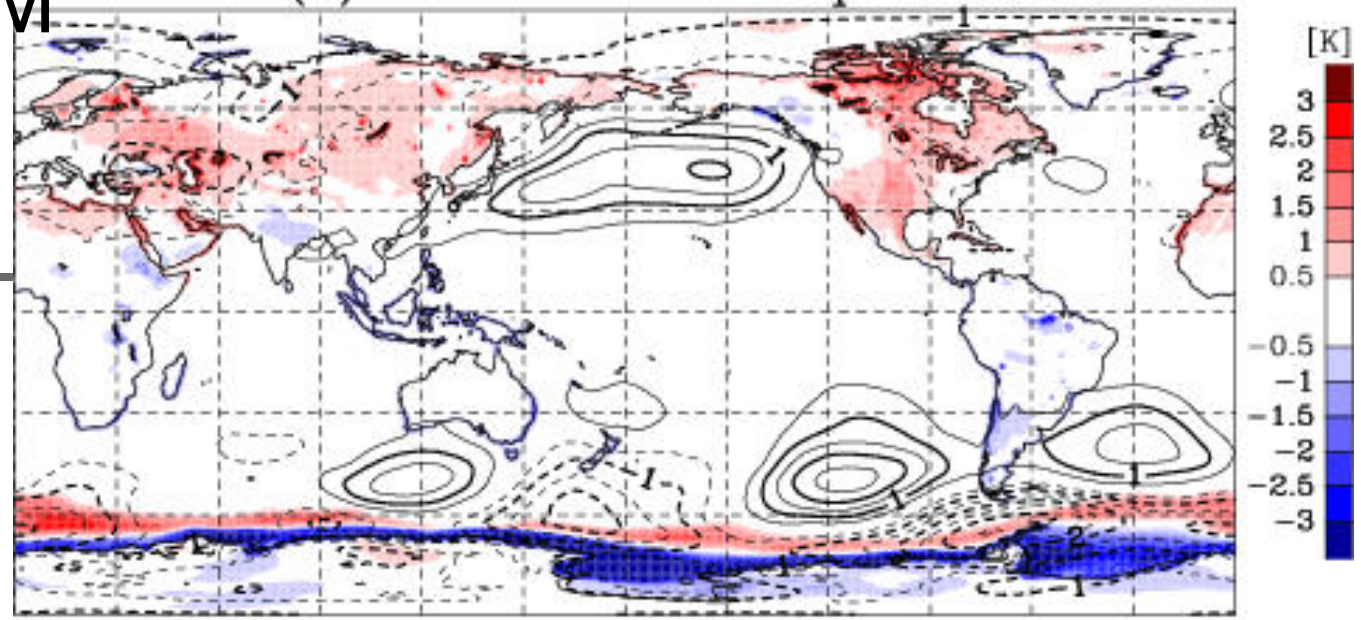
AGCM-CGCM

Present
Climate

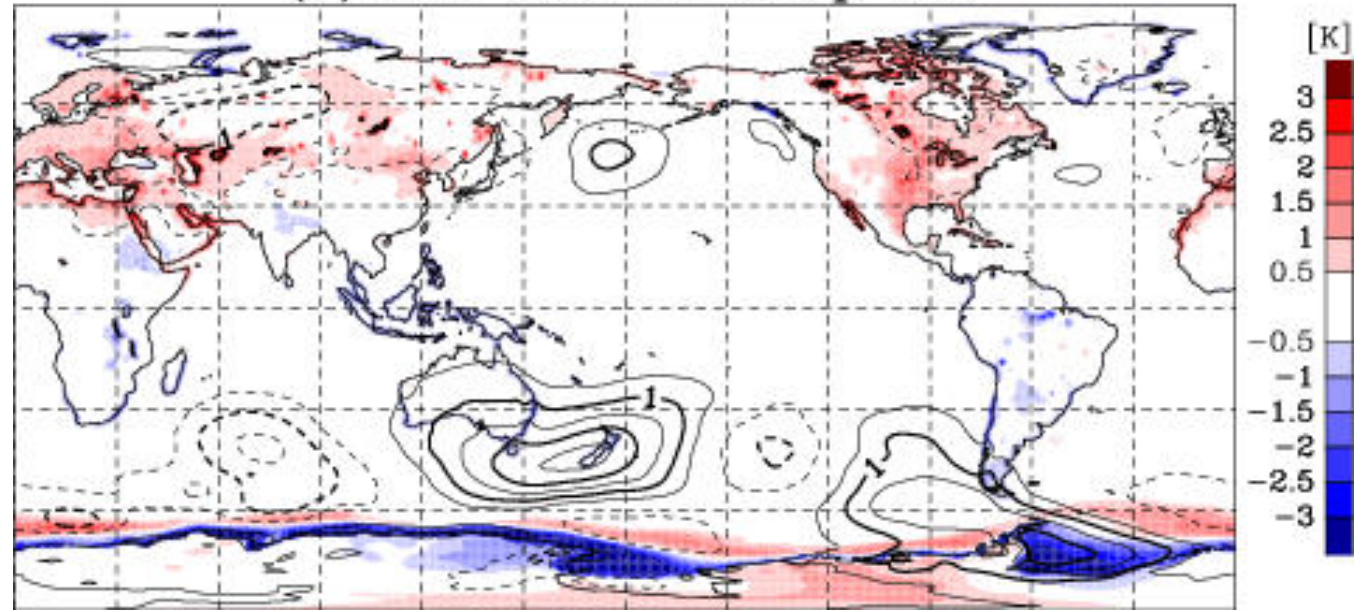
Ts, SLP
(JJA)

Warming

(a) A20-C20: Ts & slp JJA



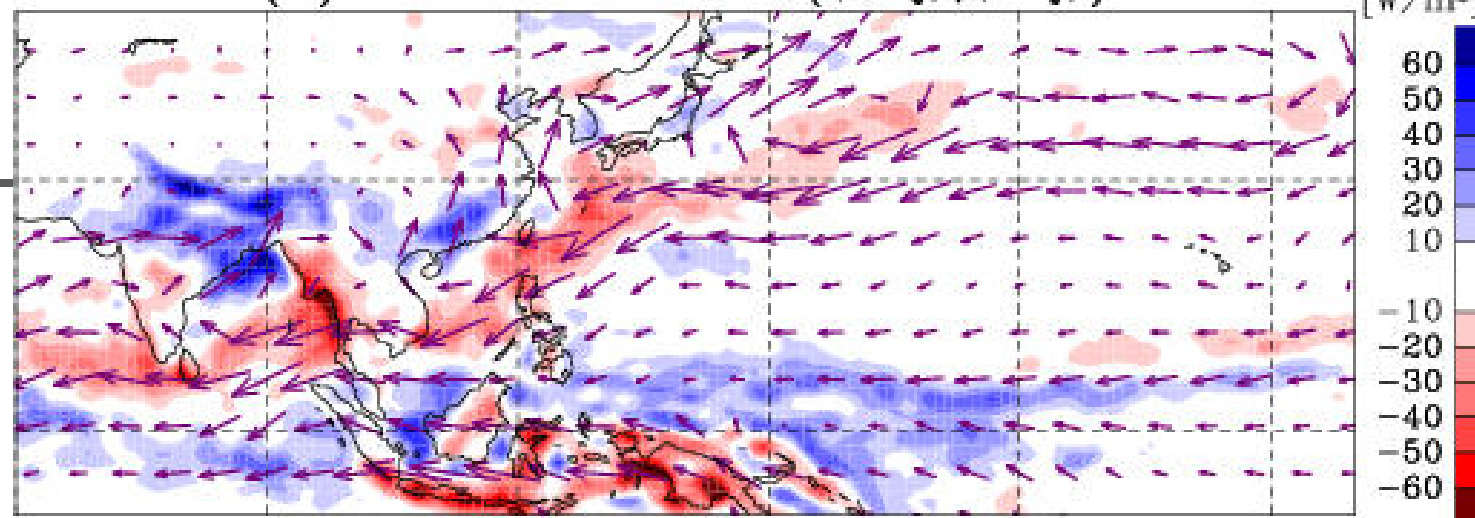
(b) A21-C21: Ts & slp JJA



AGCM-CGCM

Present

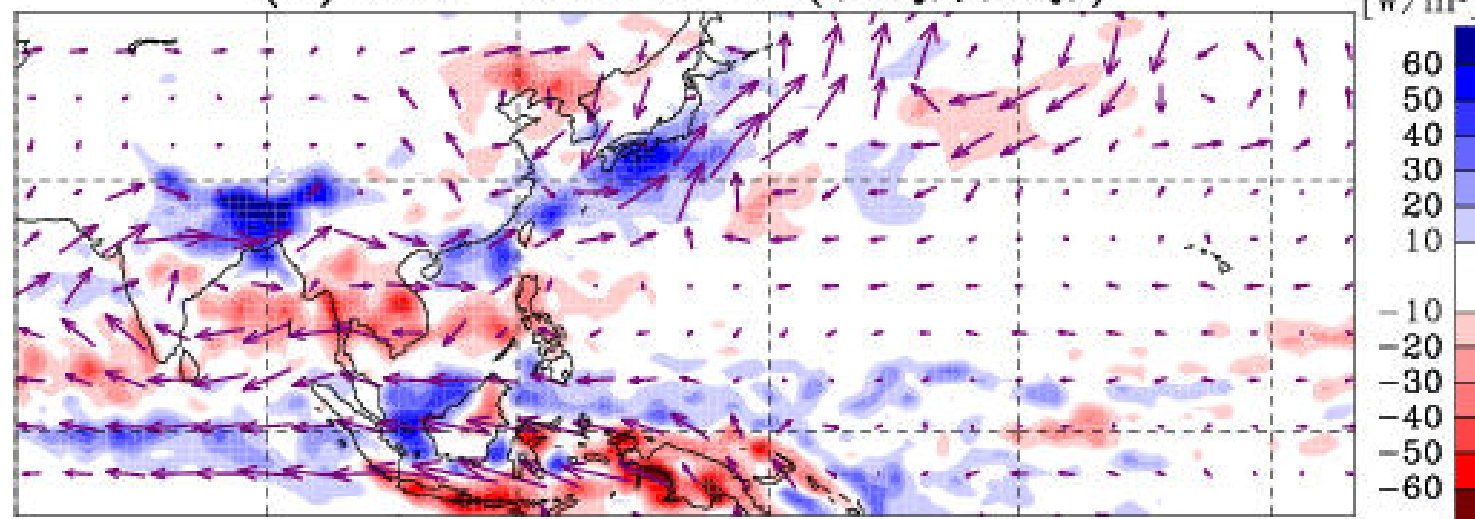
(a) A20-C20: P & ($\langle UQ \rangle, \langle VQ \rangle$)



Preci.
Flux

Warming

(b) A21-C21: P & ($\langle UQ \rangle, \langle VQ \rangle$)

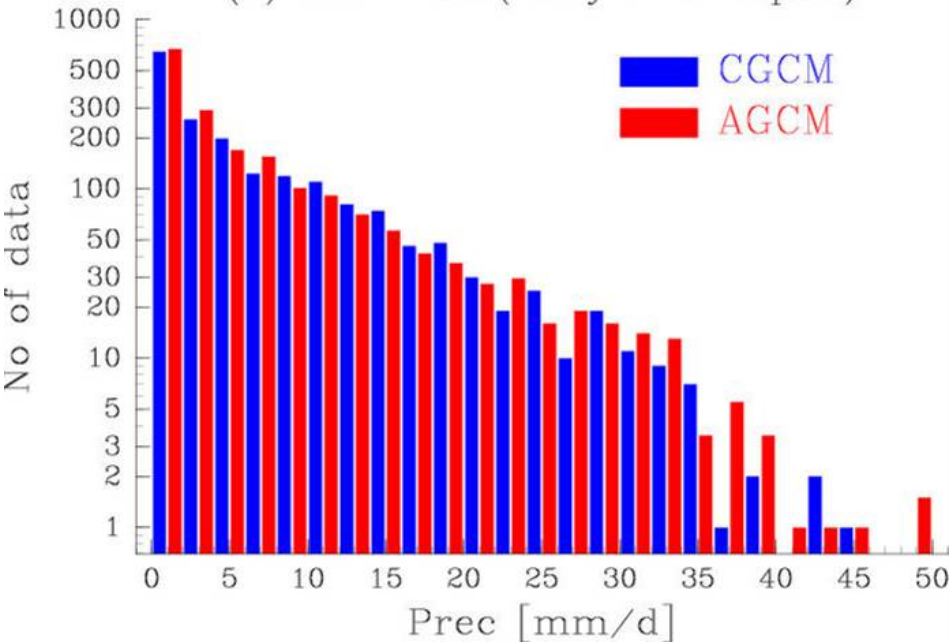


Freq. Dist. Of Precipitation around Japan

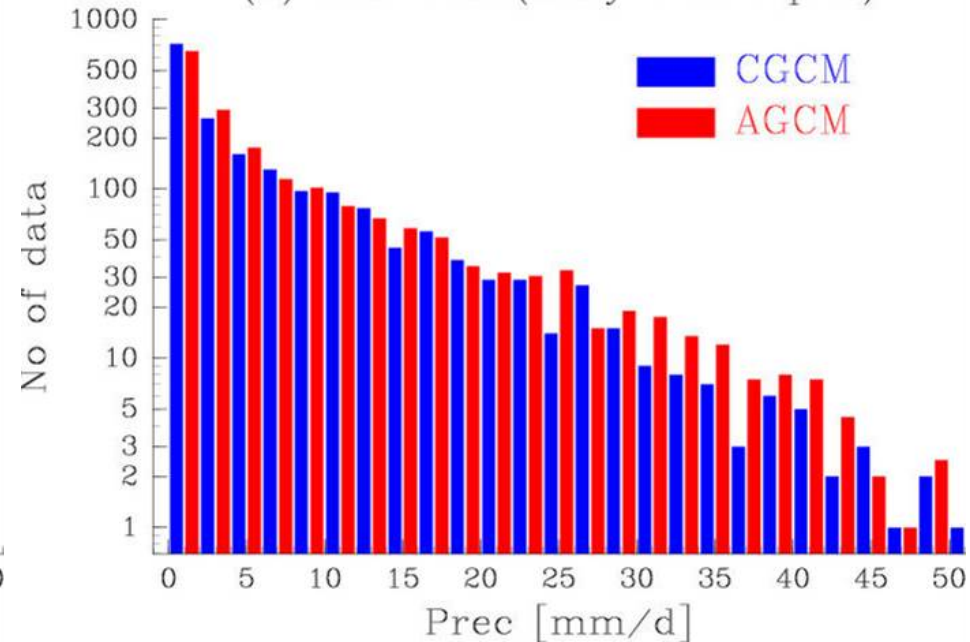
Present

Warming

(a) CTR: Prob(Daily P in Japan)



(b) CO2: Prob(Daily P in Japan)

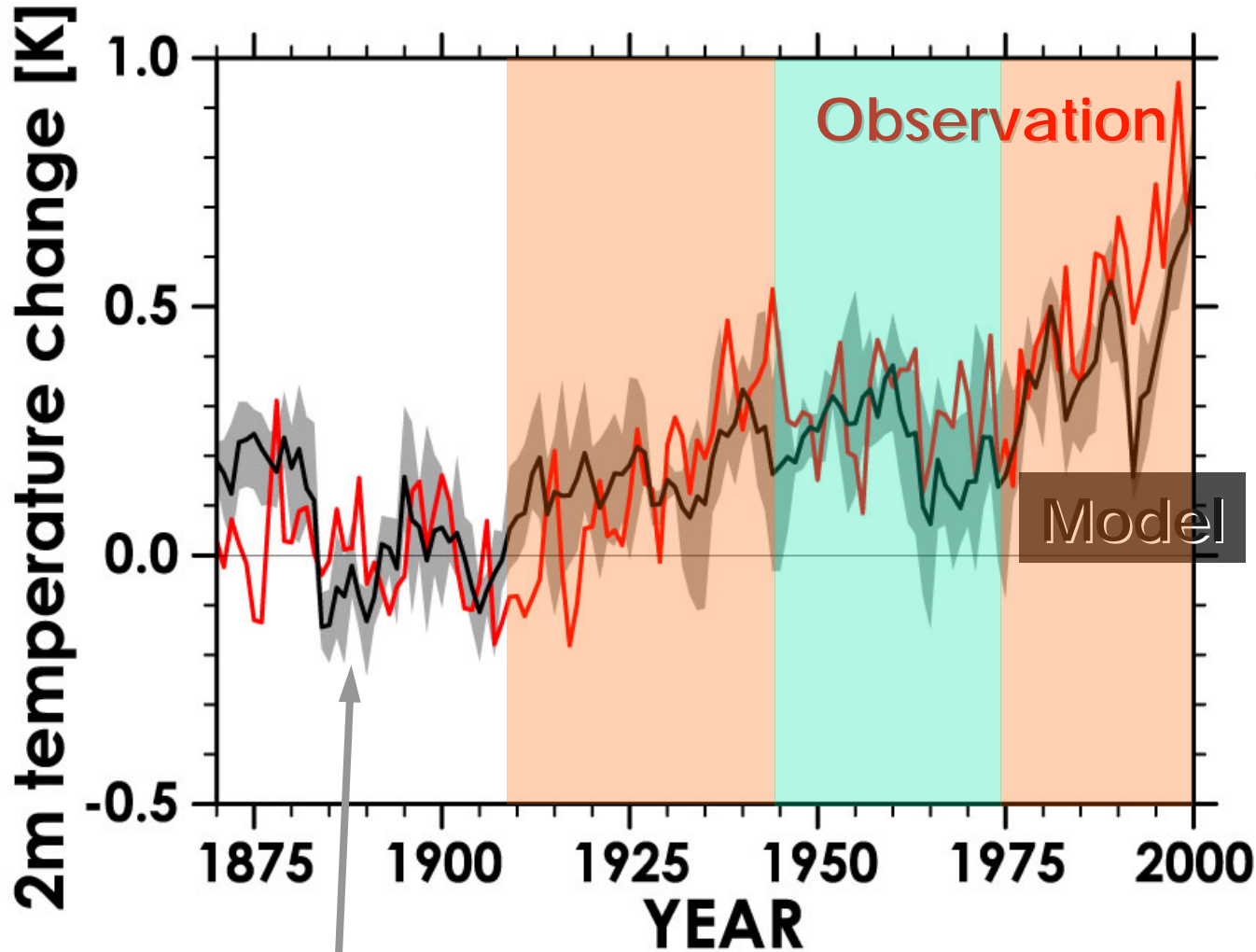




Without coupling. . .

- Evaporation tends to increase
- T_s over continents tends to increase.
- So far, large-scale feature is little different.

Annual Global Mean SAT Change



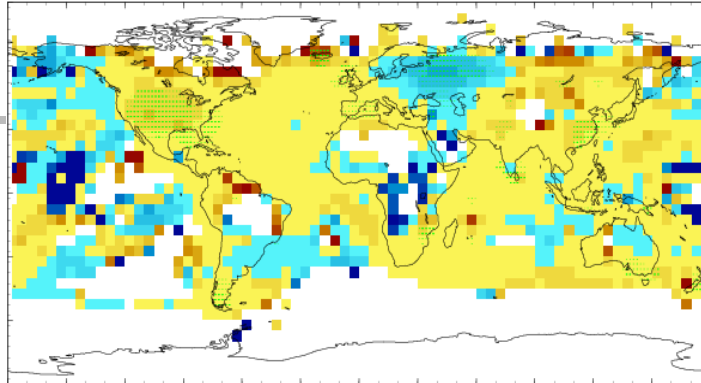
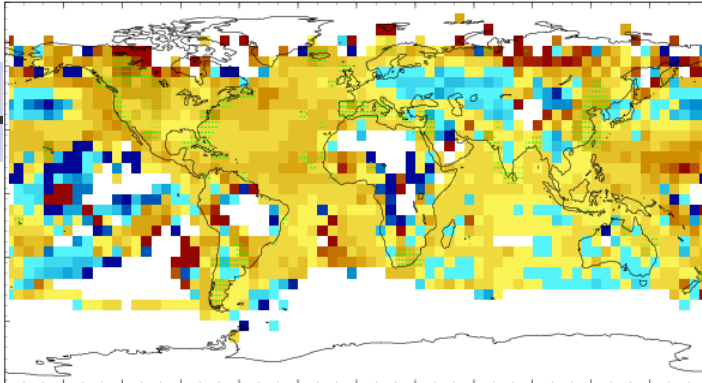
Maximum and minimum range of ensemble runs

Surface Temperature Trend

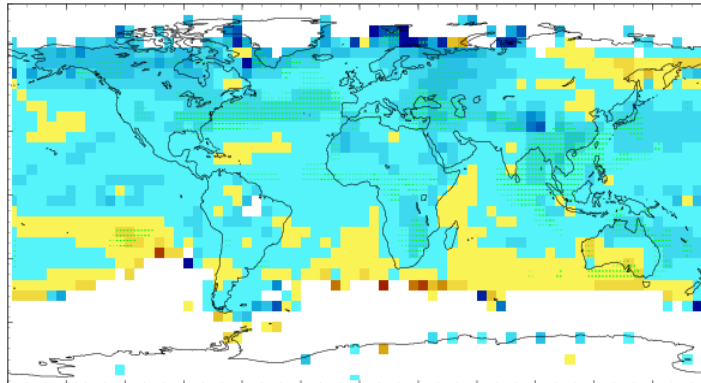
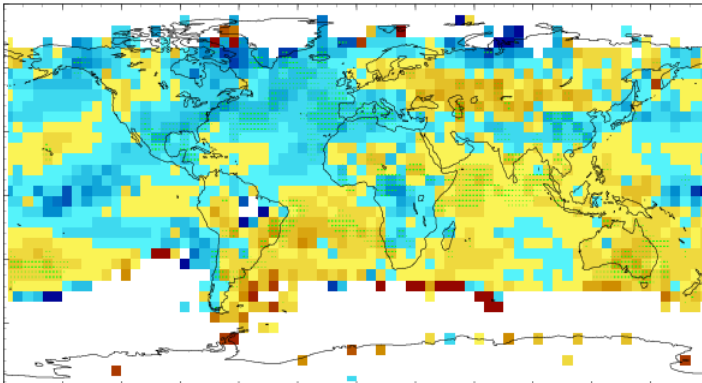
Observation

Model

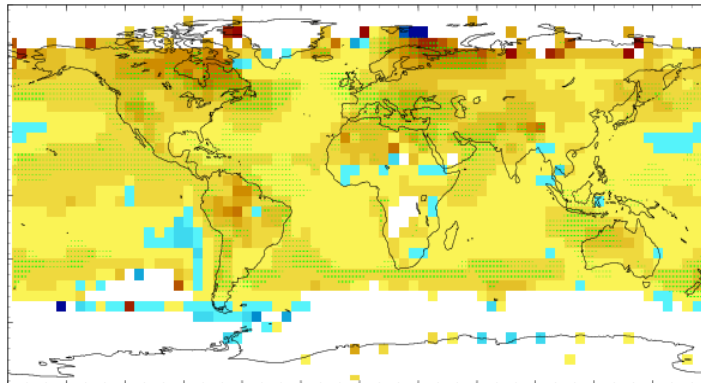
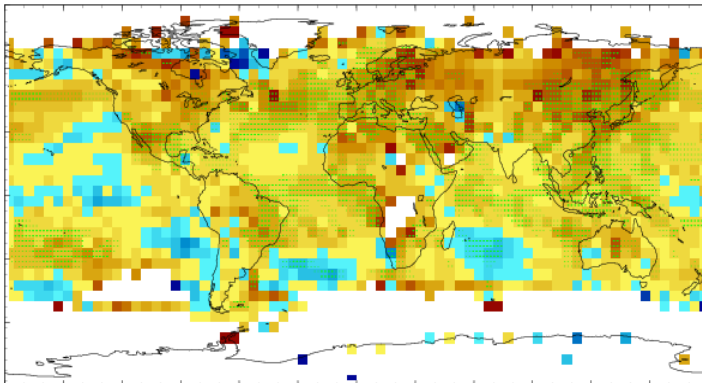
1910 → 1945



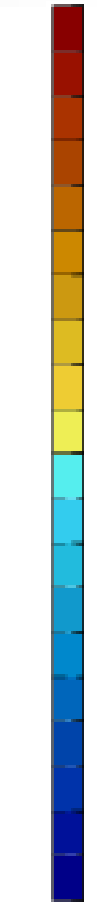
1946 → 1975



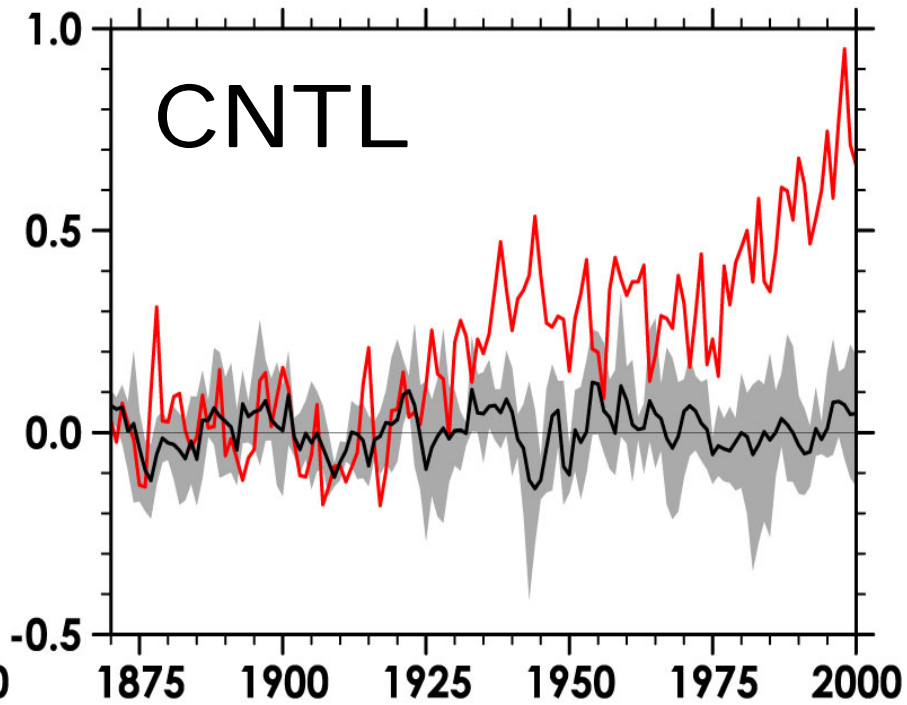
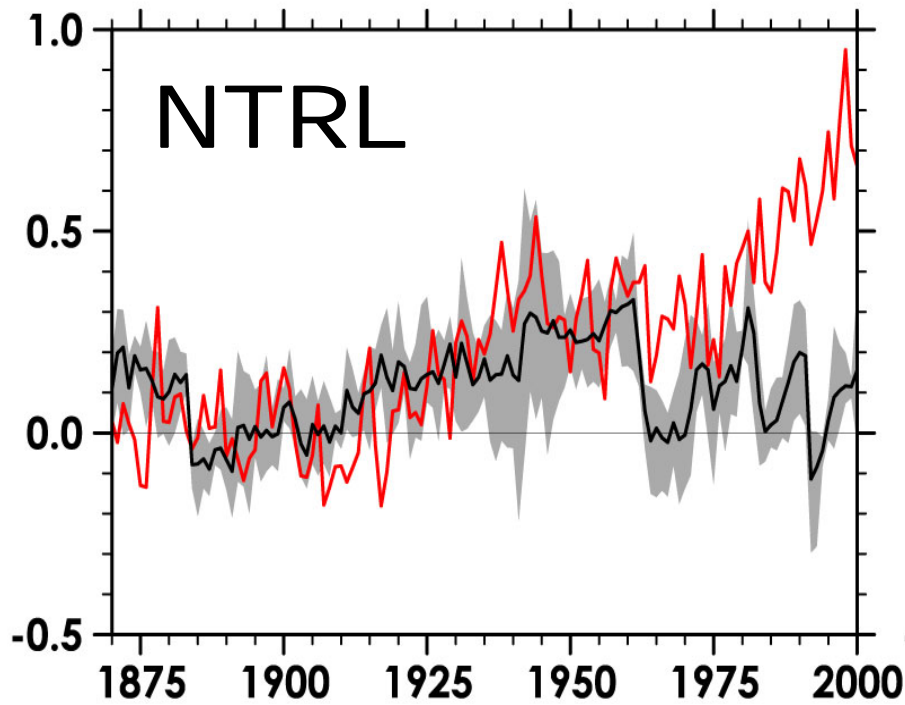
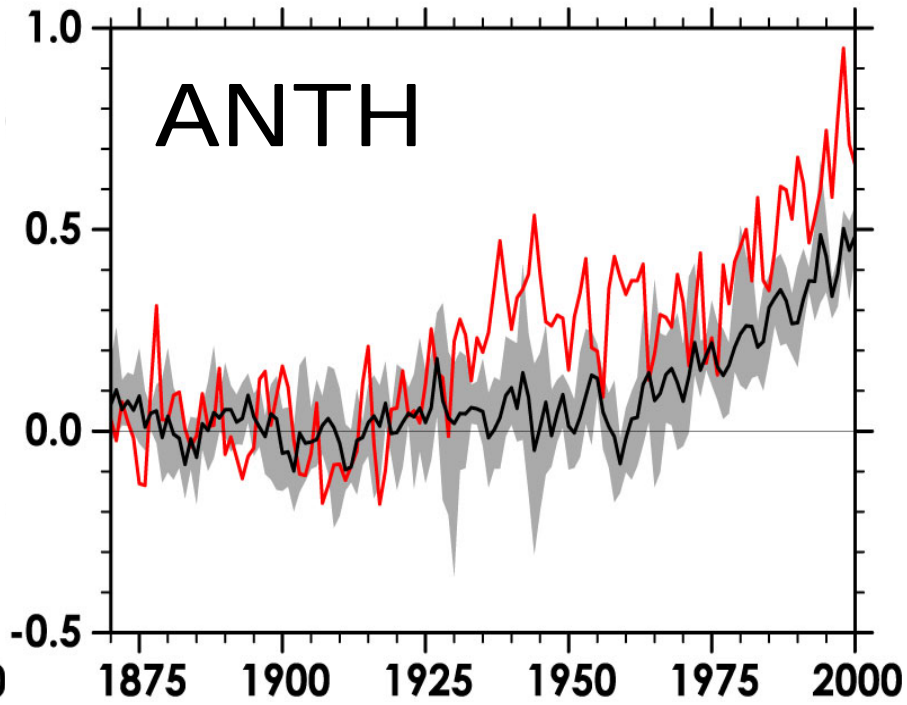
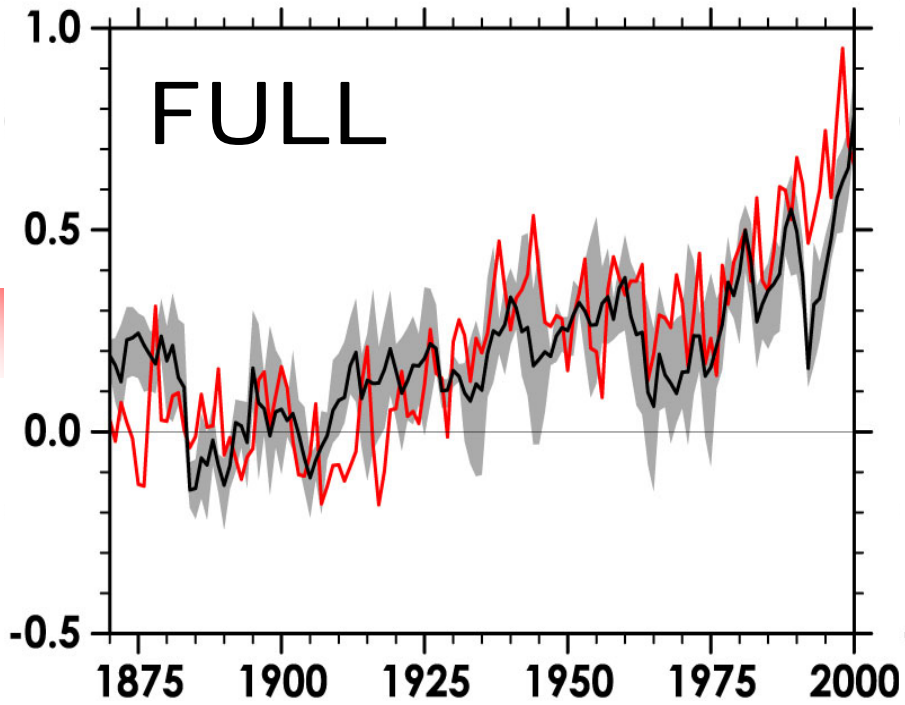
1976 → 2000



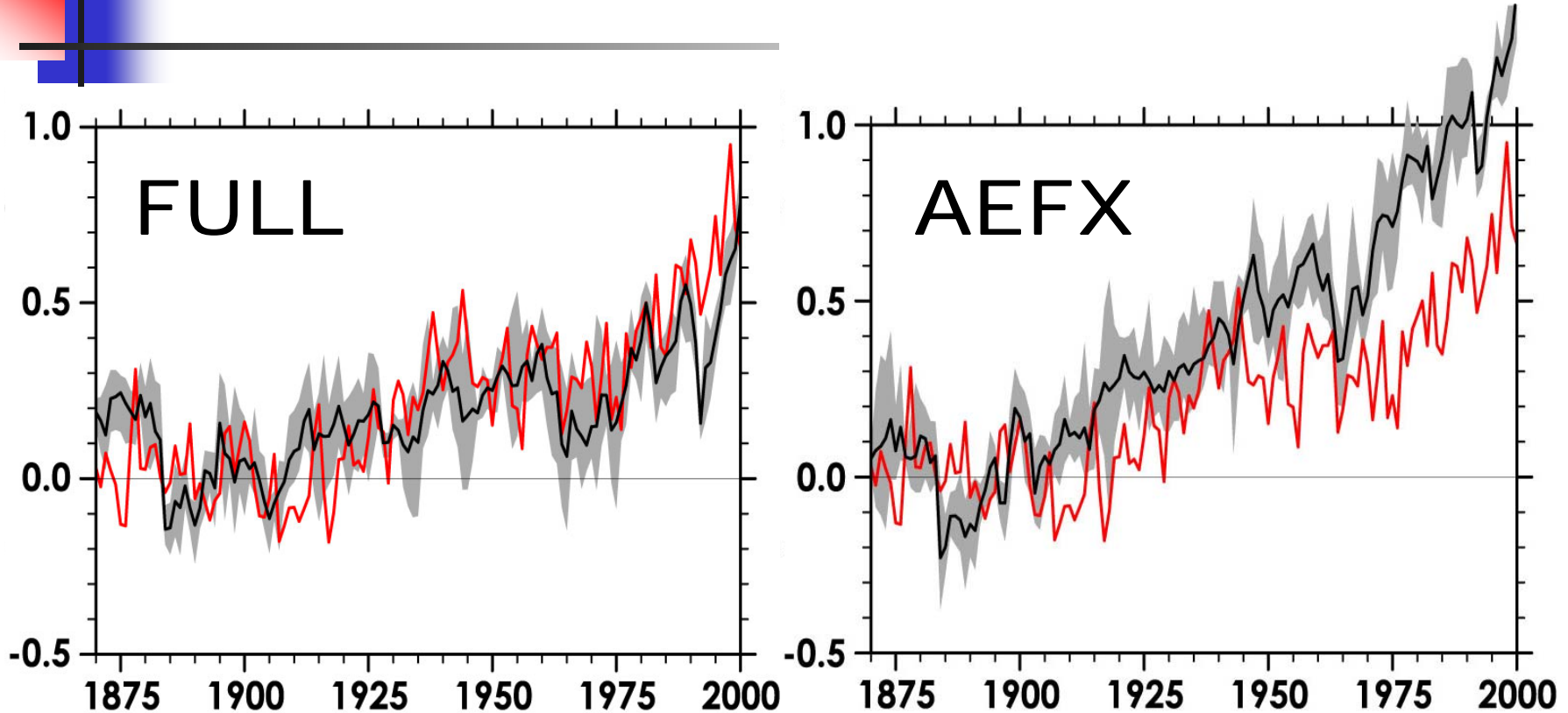
+1K
/10yr



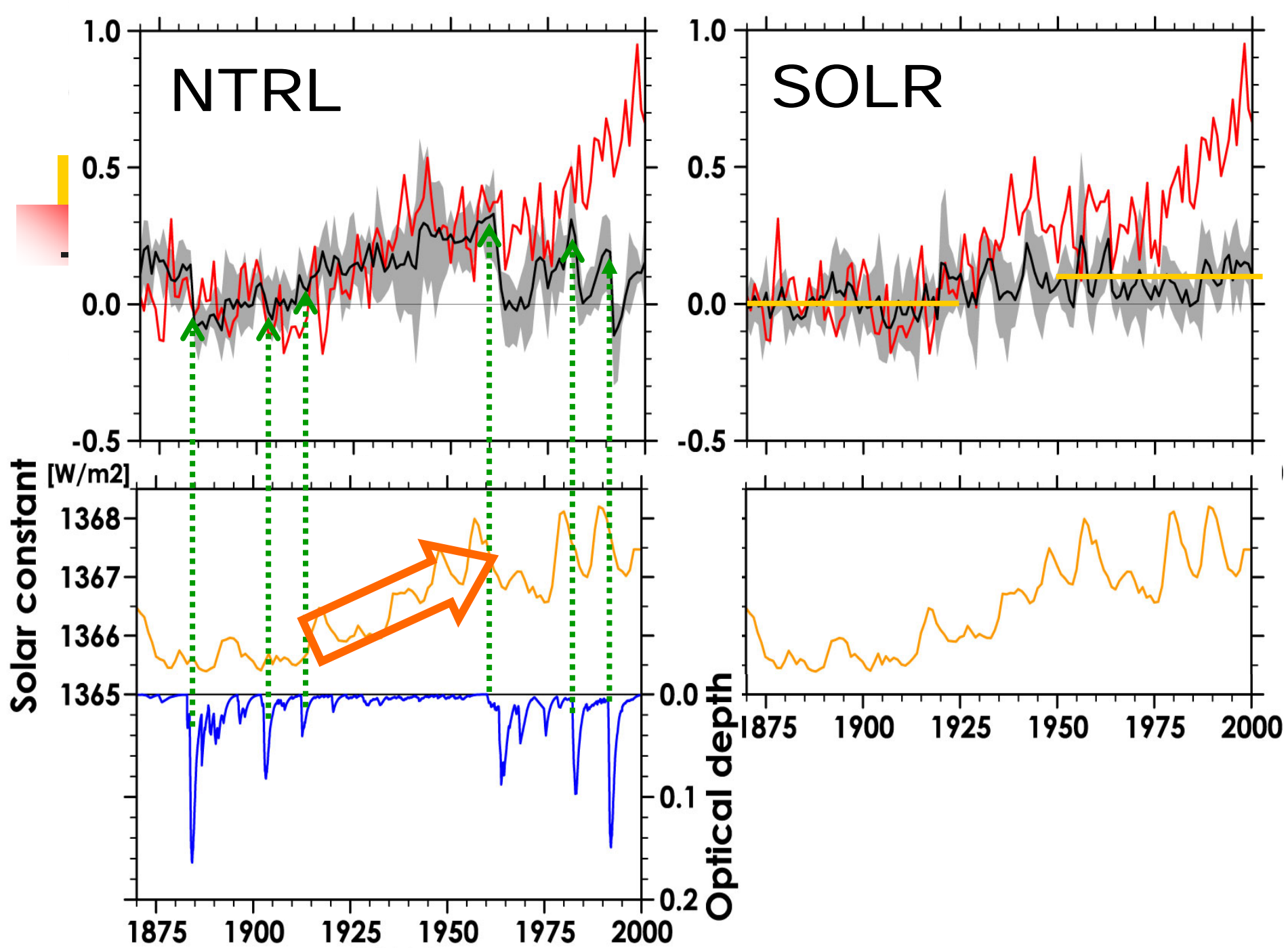
-1K
/10yr



If we prevent variations of SO_2 & BC emissions ...



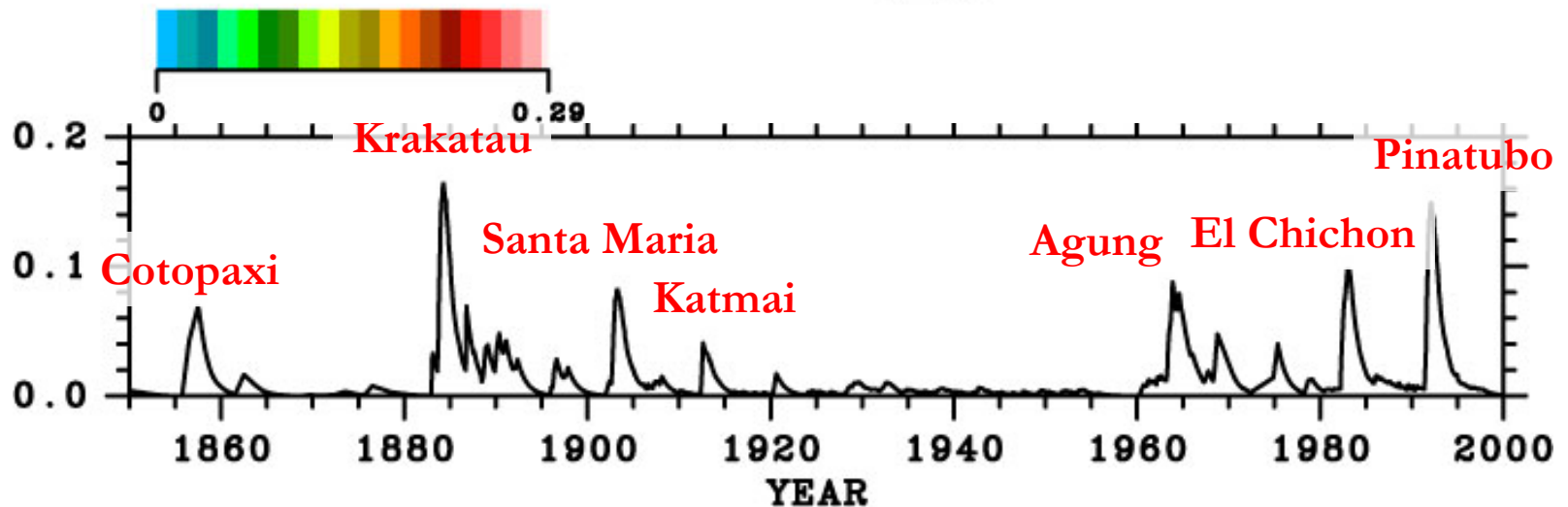
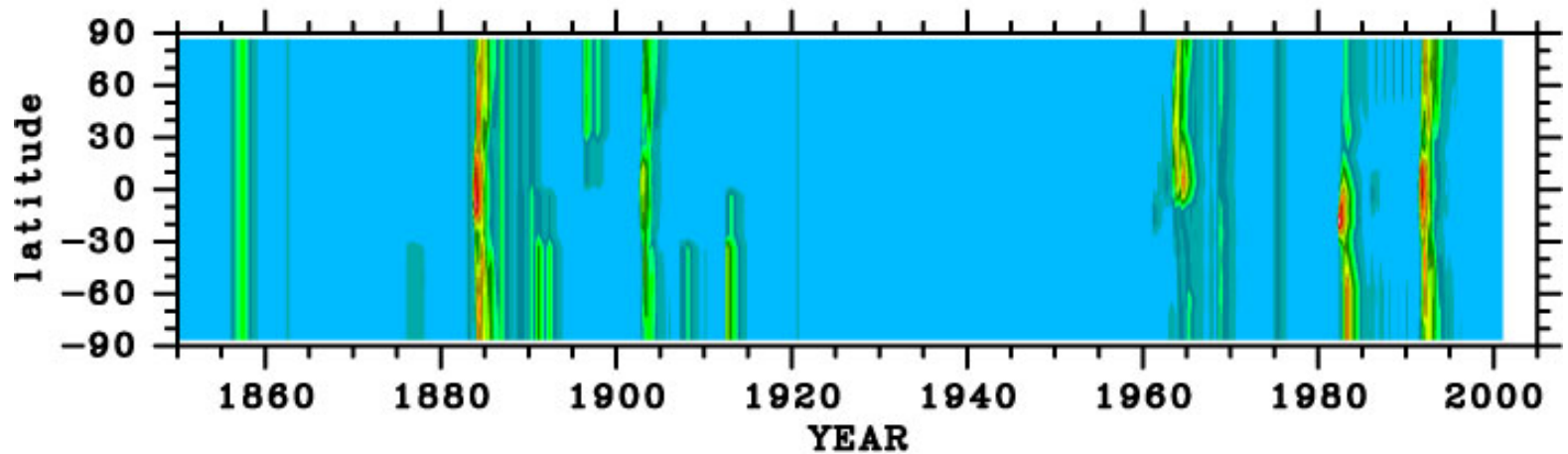
✓ **Aerosol cooling due to human activity offsets about 30% of GHG warming**



Volcanic Forcing in the Stratosphere

Variations of optical depth @ 550nm
of the stratospheric aerosols

(Sato et al., 1993)





Summary

- The K-1 climate model shows a reasonably good performance.
- Regional climate change can be discussed.
- Time-slice method seems to be acceptable for the large-scale feature
- 20C3 simulation suggests that warming after 80s may be due to CO2 increase.