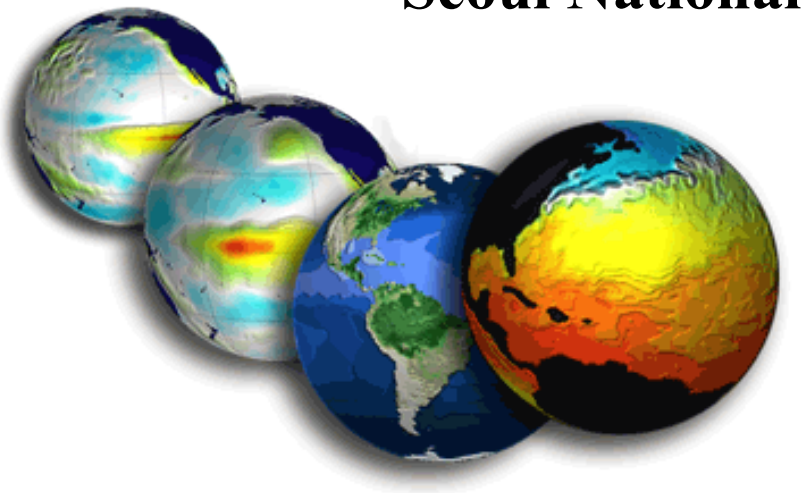
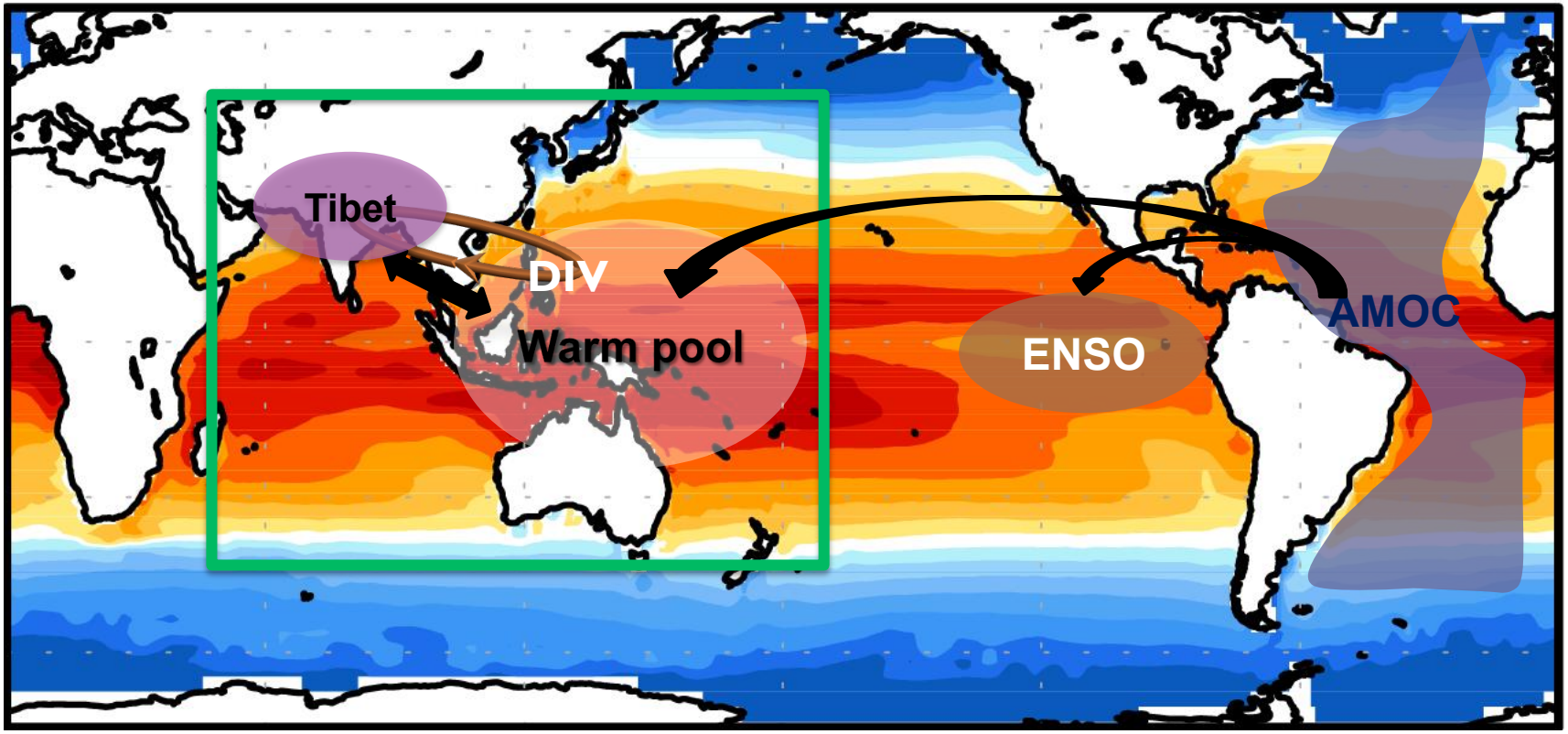
Role of the Western Pacific on Monsoon circulation and Pacific response to Atlantic SSTA

In-Sik Kang, Hyun-Ho No, Fred Kucharski
Seoul National University and ICTP



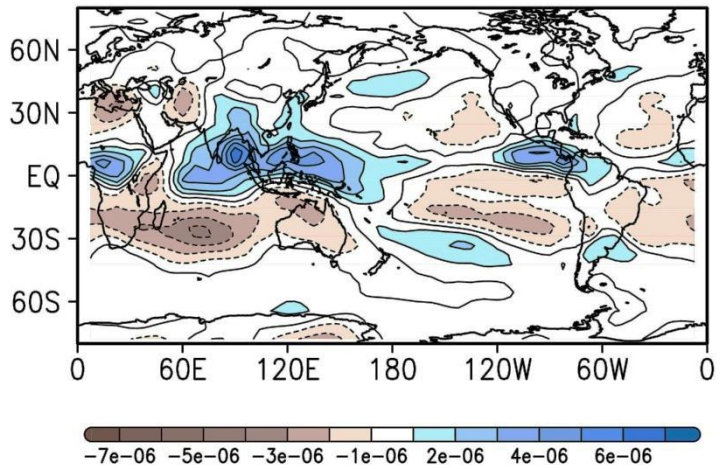


1) Local balance between the Tibetan anti-cyclonic circulation and Western Pacific divergence.

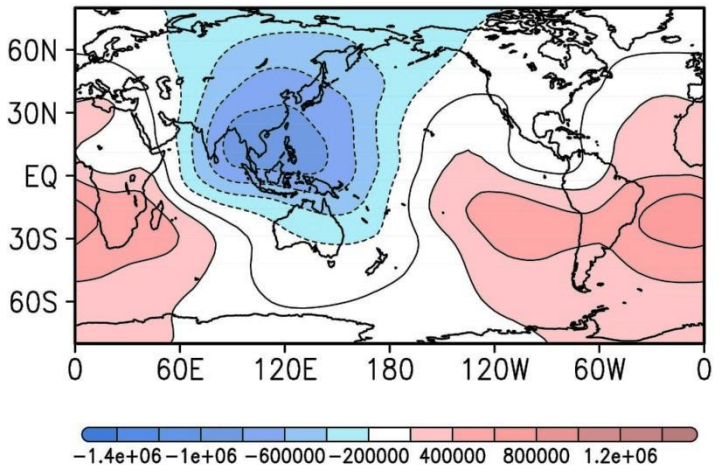
2) Warm pool (western pacific) effect of teleconnection from the Atlantic Ocean.

Observational Summer mean pattern

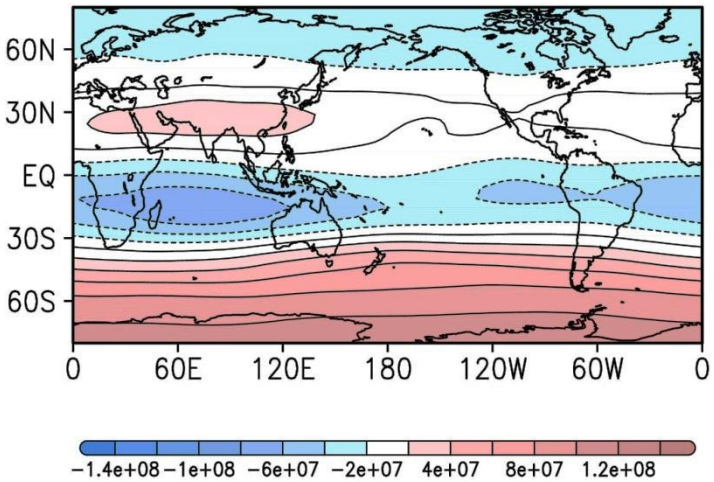
(a) Divergence



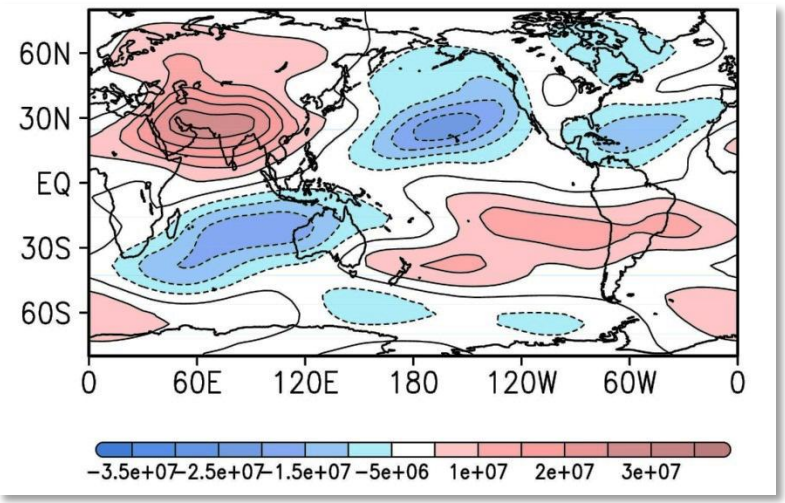
(b) Velocity Potential



(c) Streamfunction

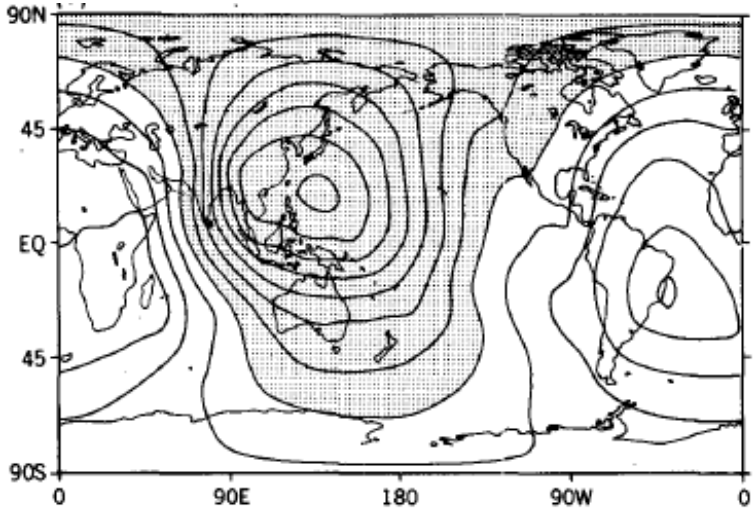


(d) Streamfunction removed zonal mean

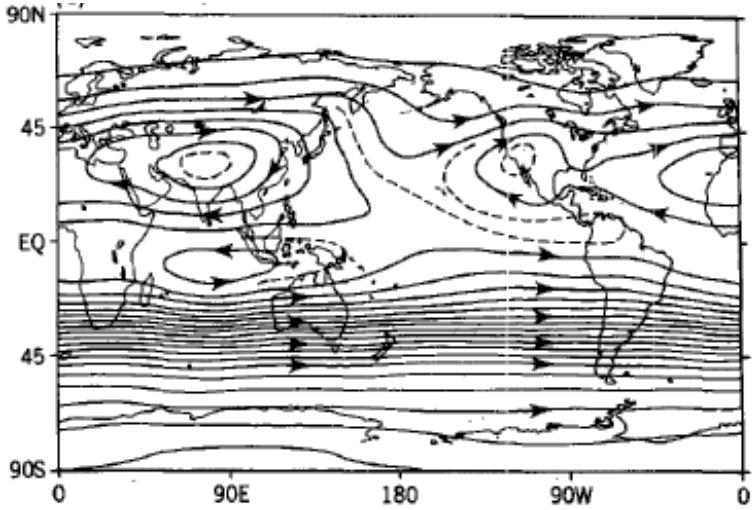


Global Circulation Model

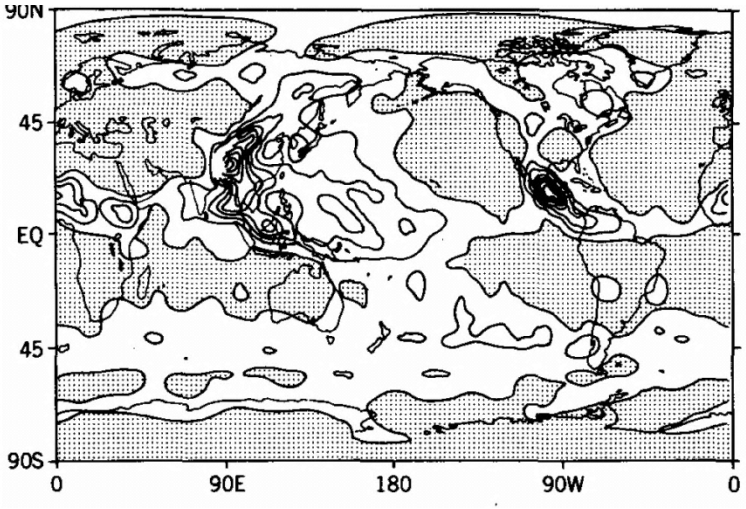
(a) Velocity potential



(b) Streamfunction



(c) Precipitation

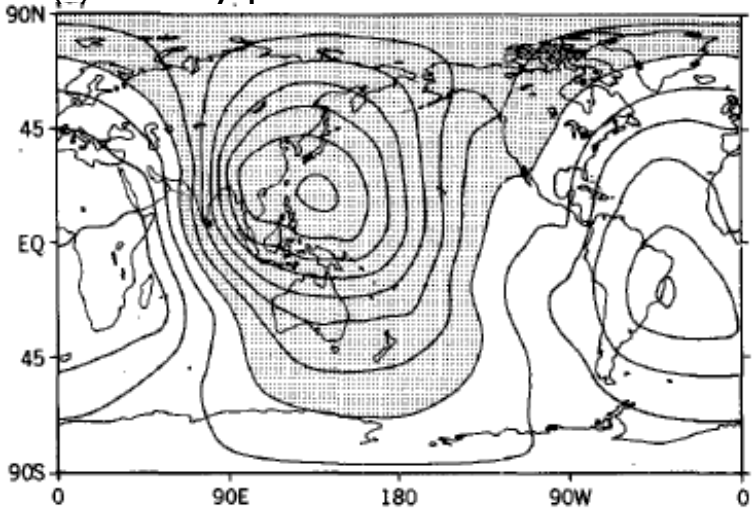


GFDL spectral GCM

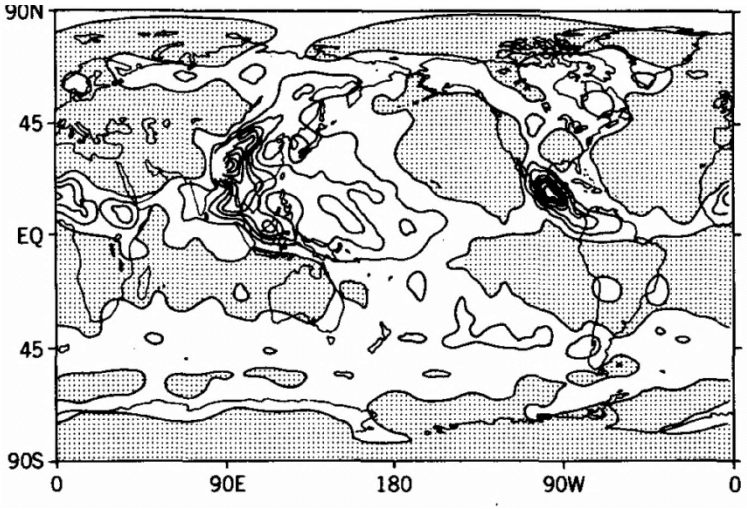
Source : Kang and Held (1986)
"Linear and Nonlinear Diagnostic Models of Sta tionary Eddies in the Upper Troposphere durin g Northern Summer"

Global Circulation Model

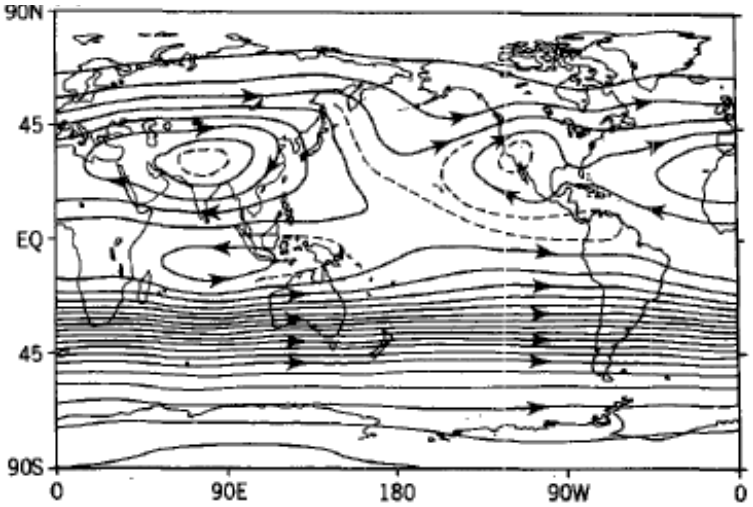
(a) Velocity potential



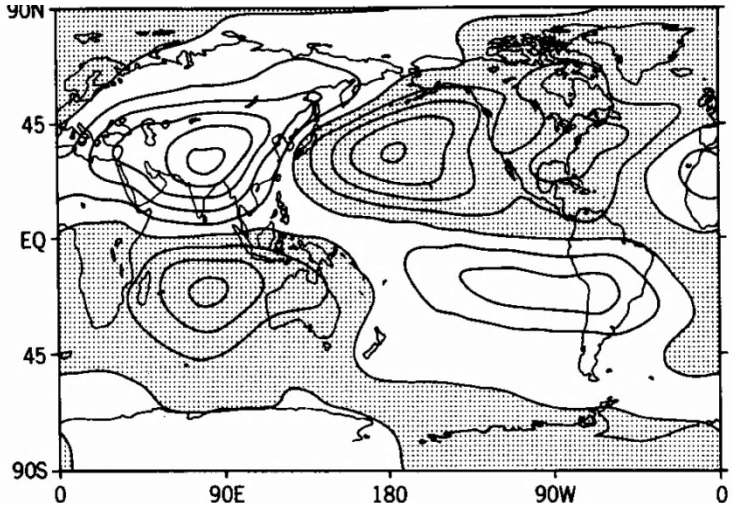
(c) Precipitation



(b) Streamfunction



(d) Streamfunction removed zonal mean

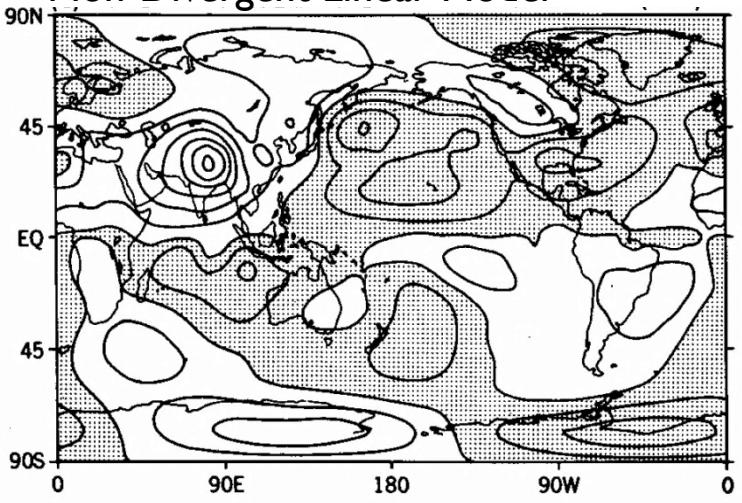


Linear barotropic model

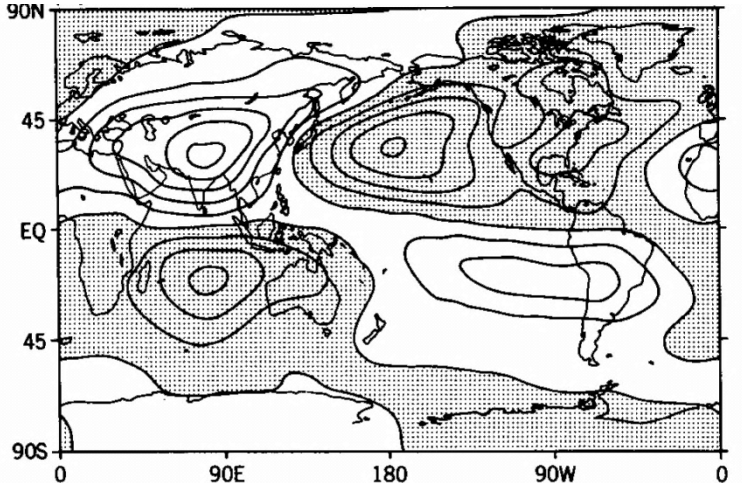
- Eddy streamfunction computed with linear models with $\mathcal{K}$ = 1/10day.

  Contour interval is 5×10^6 m^2/s.

Non-Divergent Linear Model



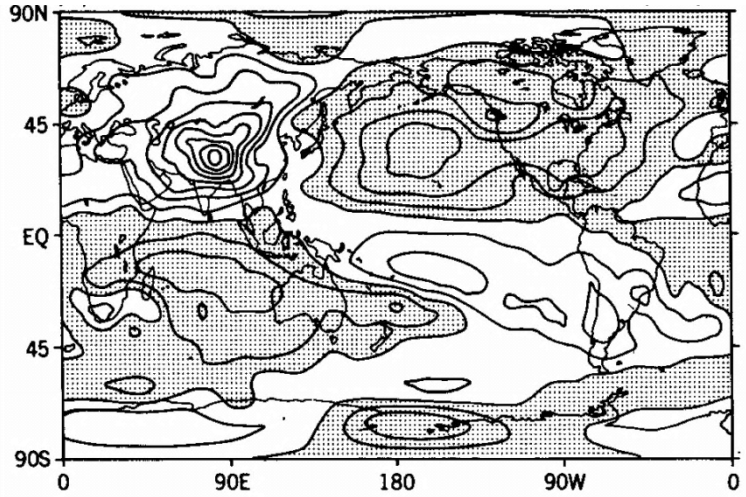
Streamfunction removed zonal mean from GCM



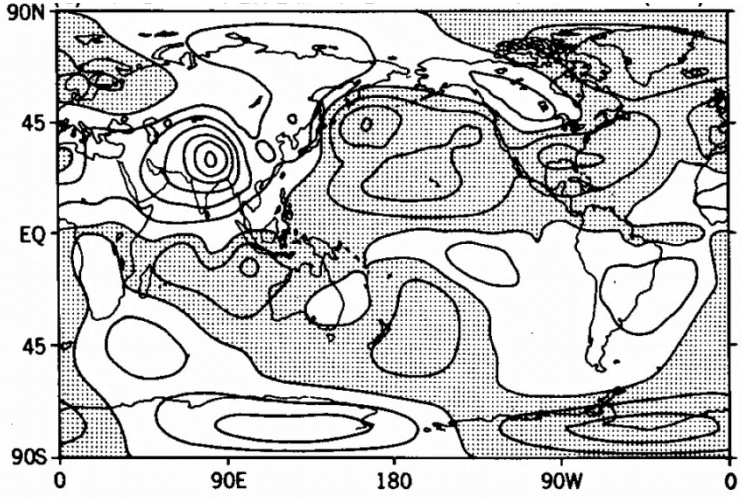
$$0 = -u\,\partial\zeta'/\partial x + \beta\,\partial\psi'/\partial x - fD - \kappa\zeta$$

Linear barotropic model

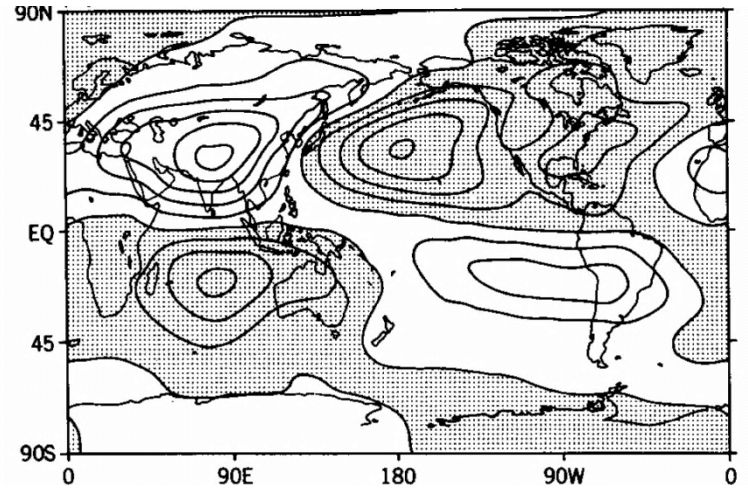
Sverdrup Balance $-\beta v^{\uparrow} = -fD^{\uparrow} - \kappa\zeta$



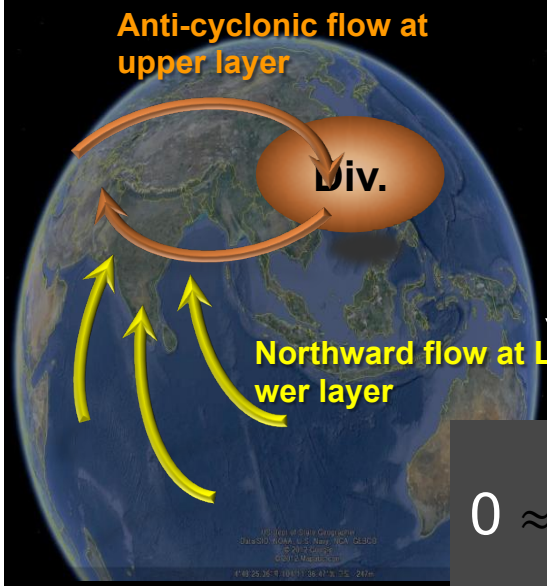
Non-Divergent Linear Model



Streamfunction removed zonal mean from GCM



Sverdrup Balance :



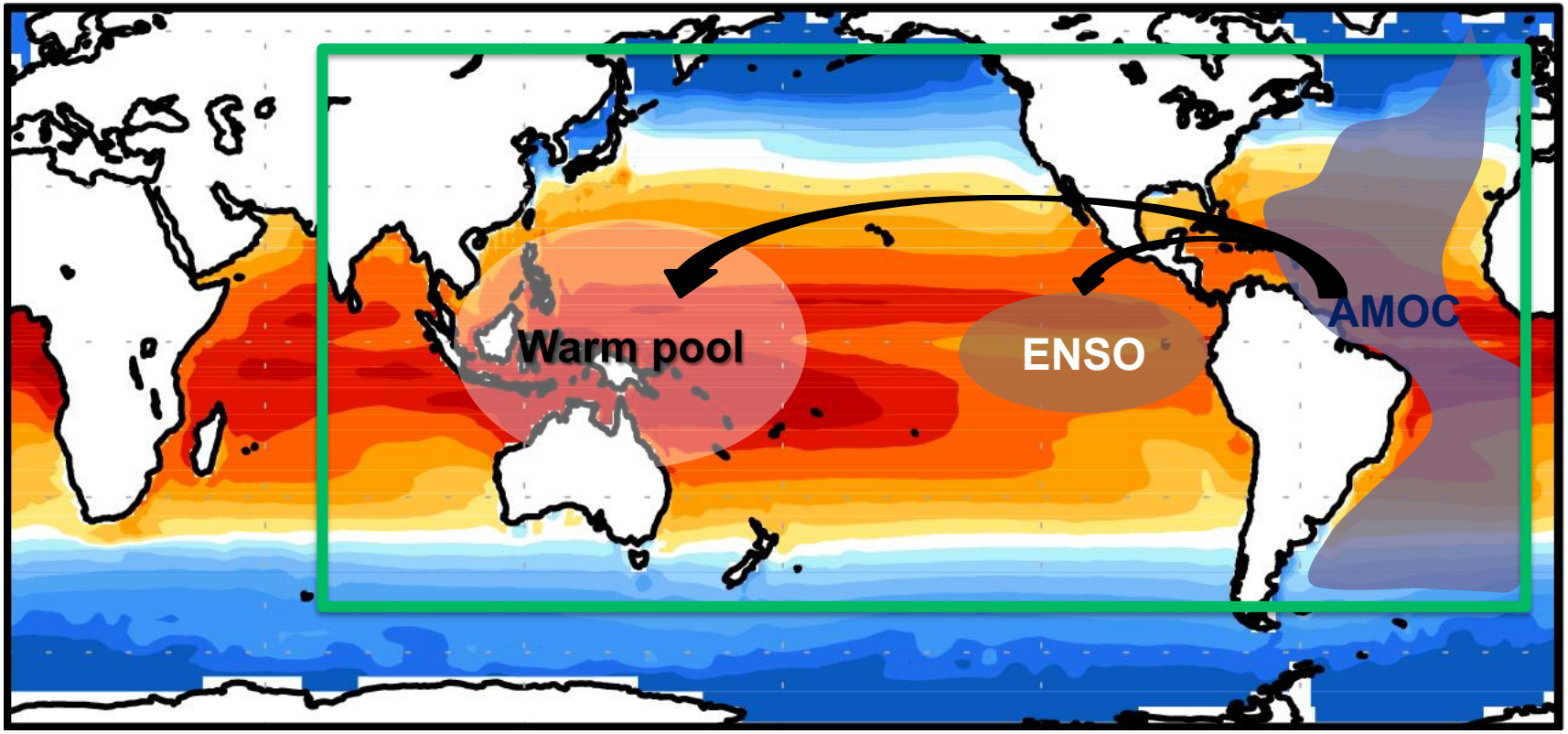
Large scale monsoon flow during boreal summer is ma intained low Western Pacific – Indian divergence field with Sverdrup Balance

$$0 \approx \partial\zeta/\partial t = -V_\psi \cdot \nabla(\zeta+f) - fD - \kappa\zeta$$

$$0 = \oint\!\!\oint_{closedcircle} \uparrow_\psi (\nabla\cdot[V_\psi (\zeta+f)] - fD - \kappa\zeta)\, ds$$

$$0 = \iint \uparrow_\psi \nabla\cdot[V_\psi (\zeta+f)]ds - \iint \uparrow_\psi fD\, ds - \kappa \iint \uparrow_\psi \zeta\, ds$$

0



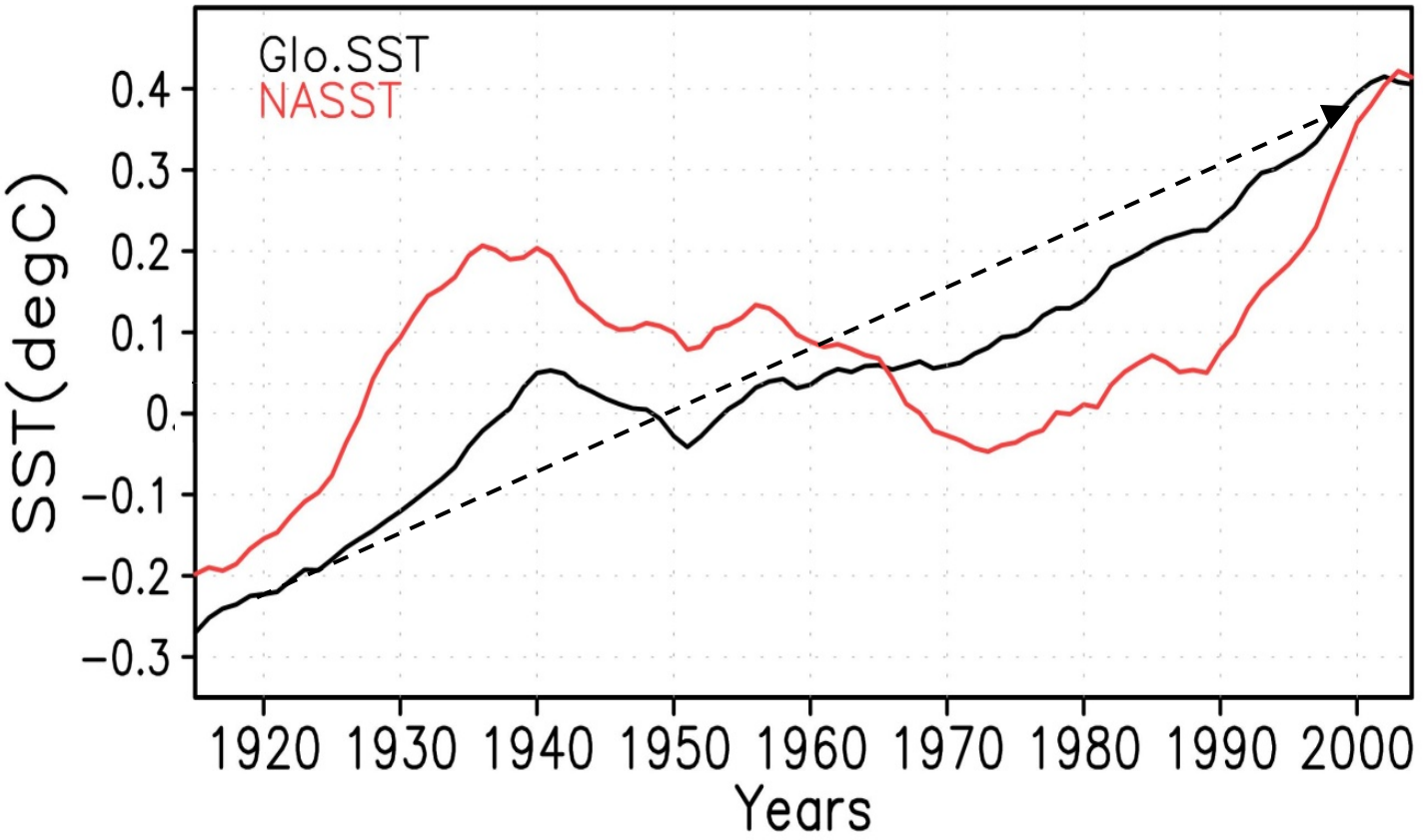
1) Local balance between the Tibetan anti-cyclonic circulation and Western Pacific divergence.

2) Warm pool (western pacific) effect of teleconnection from the Atlantic Ocean.

Atlantic warming from Observation

- Observations: 11year Moving Averaged Sea Surface Temperature

Data: ERSST(v.3)

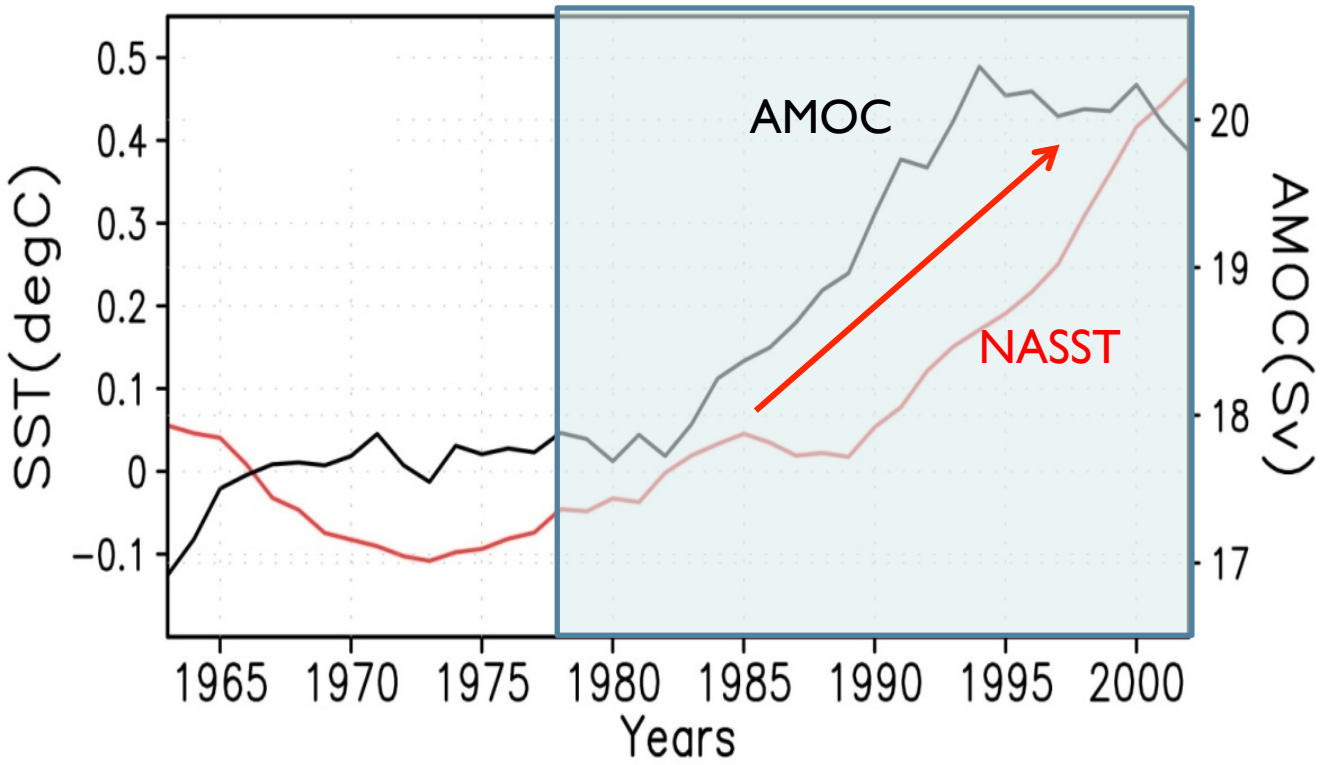


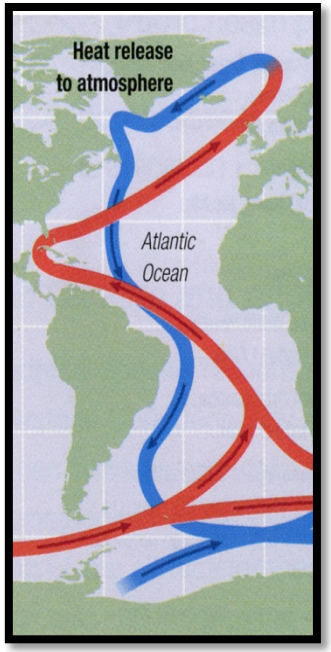
- **Glo.SST** :
  Globally averaged SST
- NASST:
  North Atlantic averaged SST

Atlantic warming from Observation

- 11year Moving Averaged (1963-2002)

	Vars.	Period	Used Data	Method
North **A**tlantic **SST**	SST	1915-2002	ERSST(v.3)	Area mean (70W -20E, 0–90N)
Atlantic **M**eridional **O**vertu rning **C**iruclation	Meridional Strea mfunction	1963-2002	SODA	Maximum value between 30N and 40N

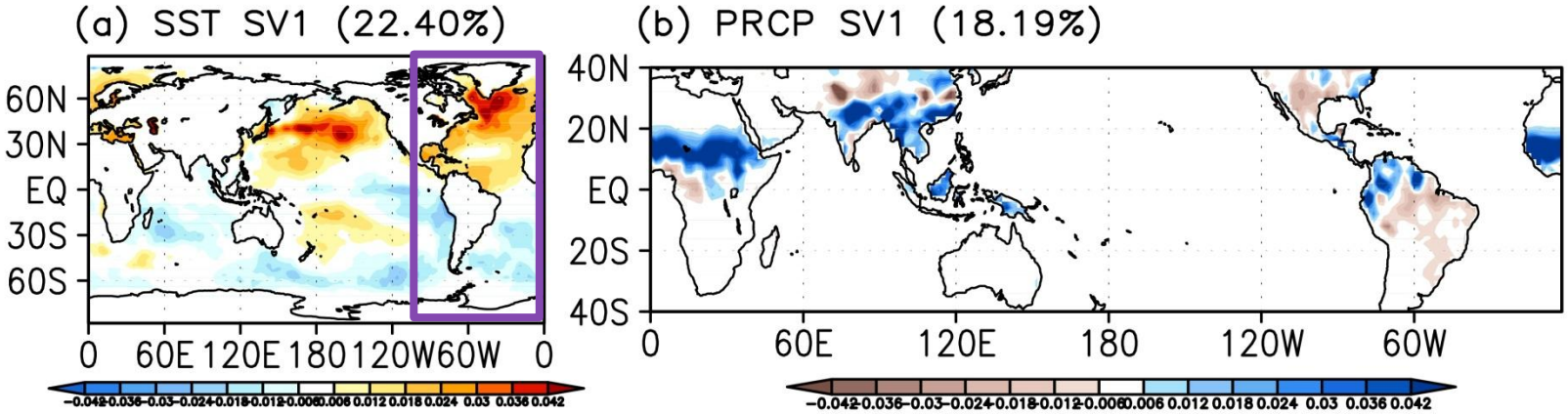


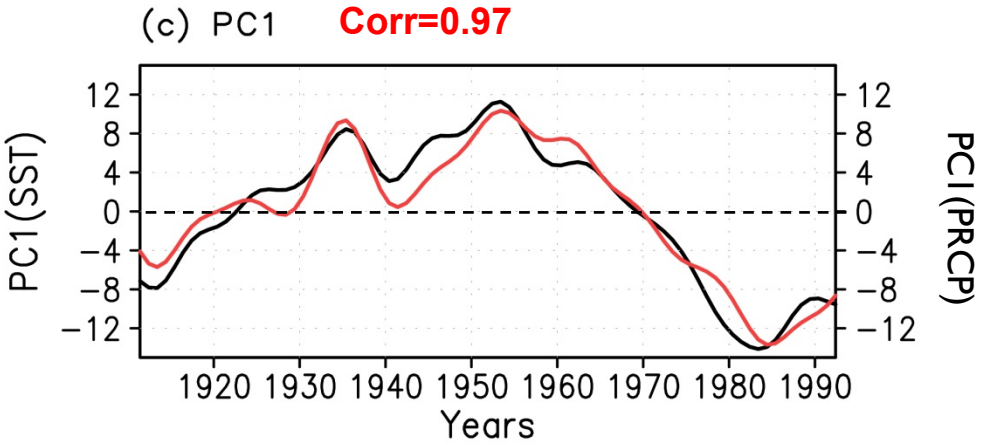


Atlantic warming from Observation

- SVD analysis with SST and JJA Precipitation

	Period	Used Data	Method	
SST(K)	1915-2002	ERSST(v.3)	Detrended	10 year Low-pass filtered
Precipitation(mm/day)	1963-2002	CRU	JJA mean	



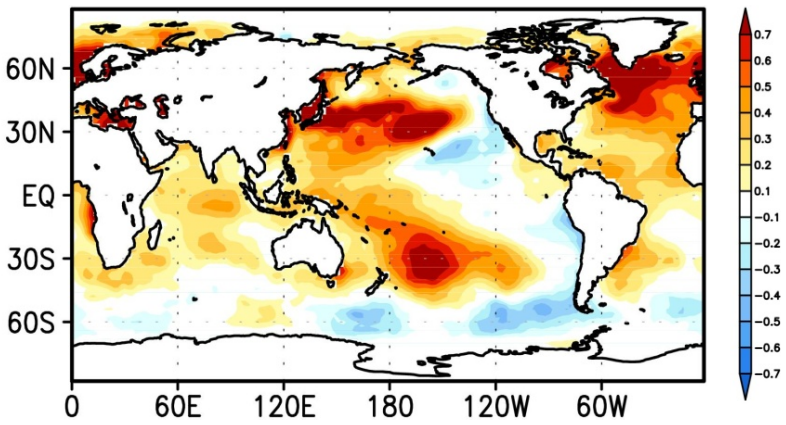


★ The **A**tlantic **M**eridional **O**vert urning **C**irculation(AMOC) could be and important driver for Glo bal climate variability.

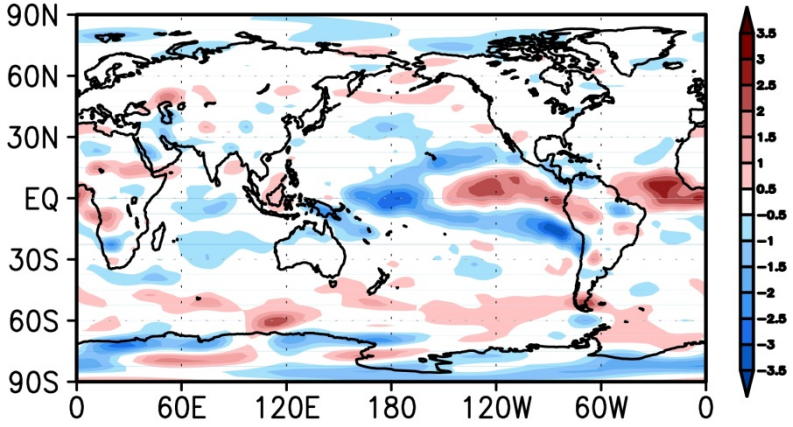
Atlantic warming from Observation

- **Differences** between 1980s and 2000s [00-09] – [80_89]

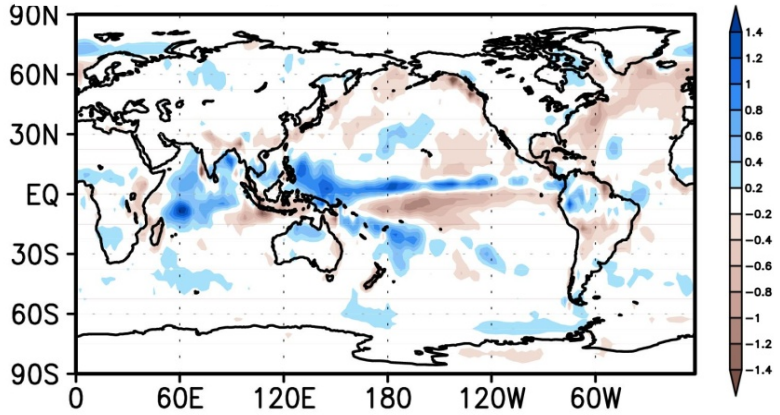
(1) SST (ERSST)



(2) U850(m/s) (NCEP1)



(3) PRCP(mm/day) (CMAP)



★ From 1980 to 2009
: Increasing SST in the Atlantic

Contribute to the Pacific anomalies

AGCM Experiments

1. Aqua planet Experiment

   - Control R : Zonal-mean SST

   - Anomaly R : Zonal-mean SST + Atlantic SSTA

2. Warm Pool run

   - Control R : Zonal-mean SST + Warm Pool

   - Anomaly R : Zonal-mean SSST + Warm Pool + Atlantic SSTA

3. Realistic SST run

   - Control R : Observed Climatological SST

   - Anomaly R : Observed Climatological SST + Observed Atlantic SSTA

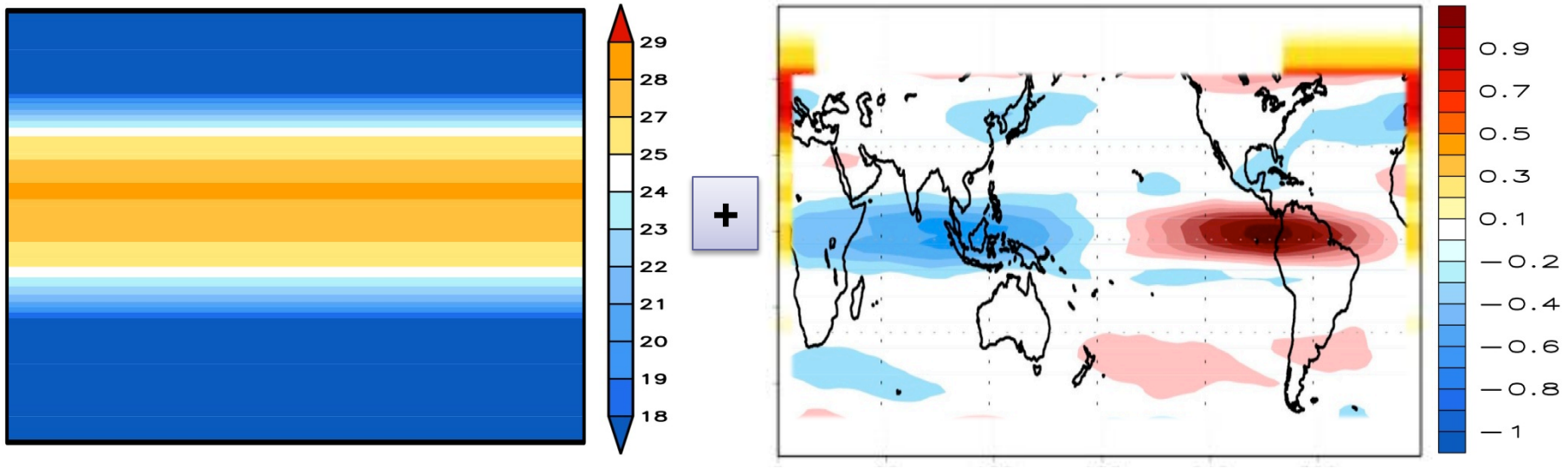
Aqua planet experiment

- Results from AQUA PLANET

  [Ideal.ATL Forcing] – [No Forc.]

AQUA Planet — The world that wholly covered with the ocean.

Anomalous U850 (m/s)

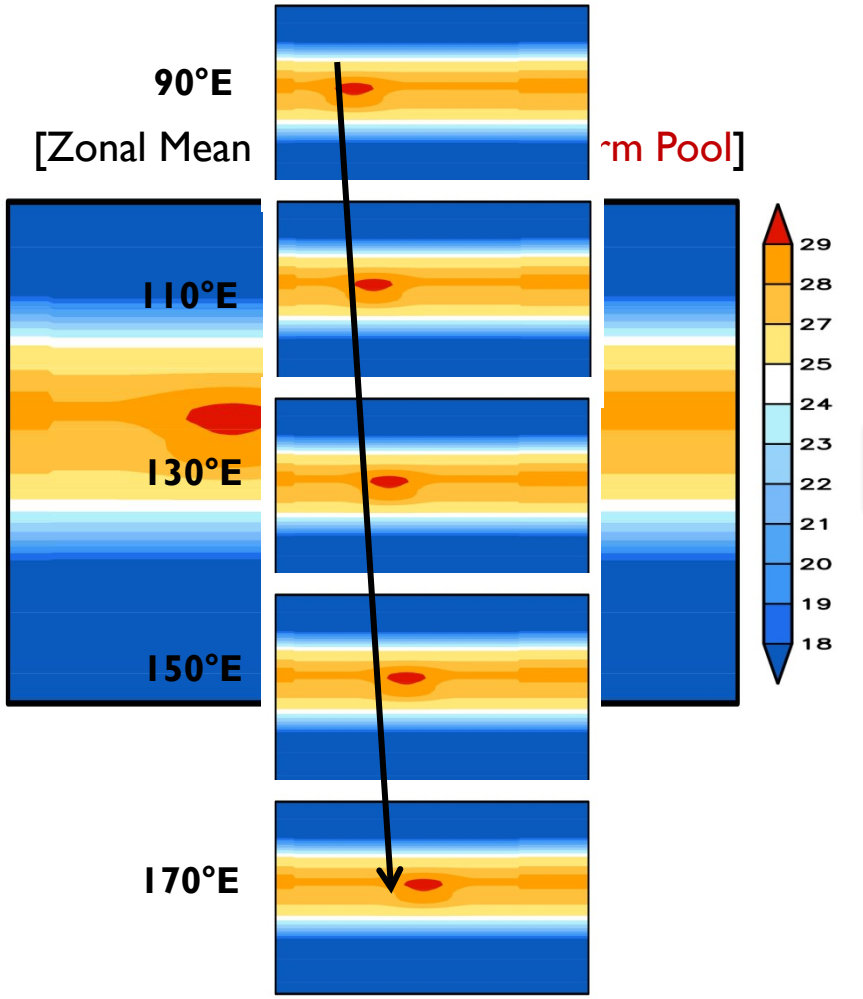


Warm Pool run

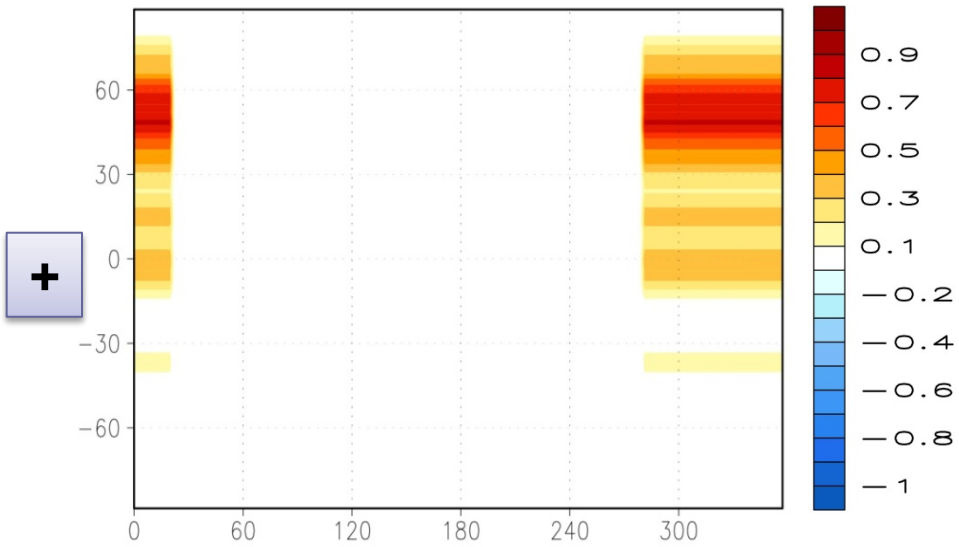
- Considering an idealized Warm Pool

Model : SNU AGCM (ver. spectral)
11yrs Perpetual run (Use 2~11yr)

[Zonal Mean SST + Idealized Warm Pool]



[Ideal ATL forcing]



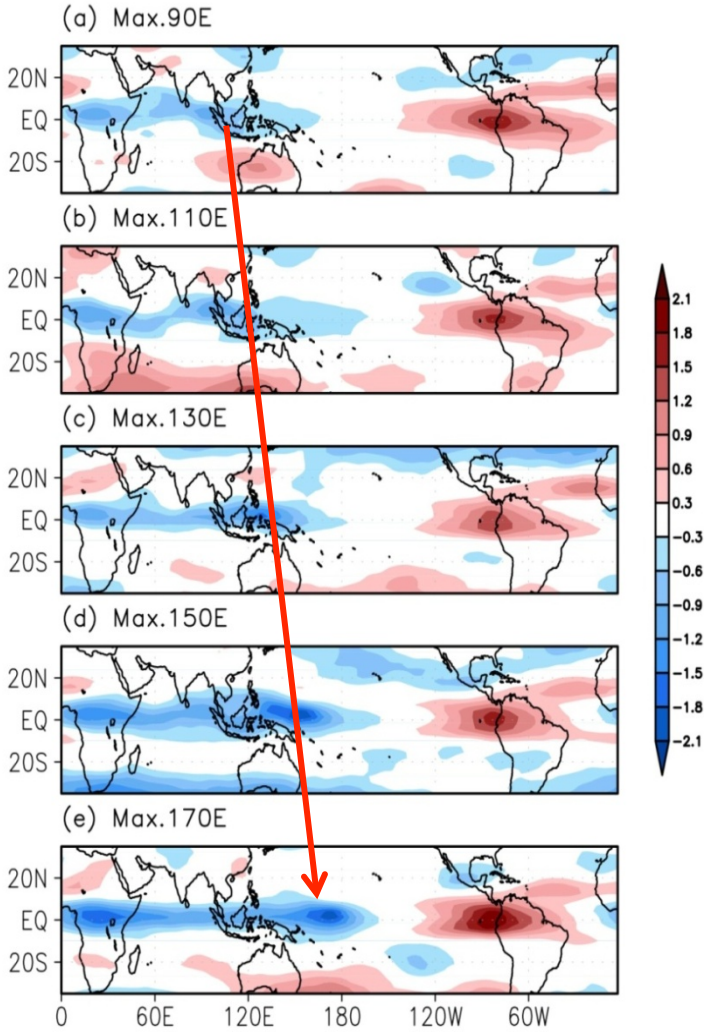
Effects of Warm Pool in the Equatorial Pacific

- Considering an idealized Warm Pool
  - Longitudinal location of Maximum SST

Hong, Kang, Ham (2012, APJAS)

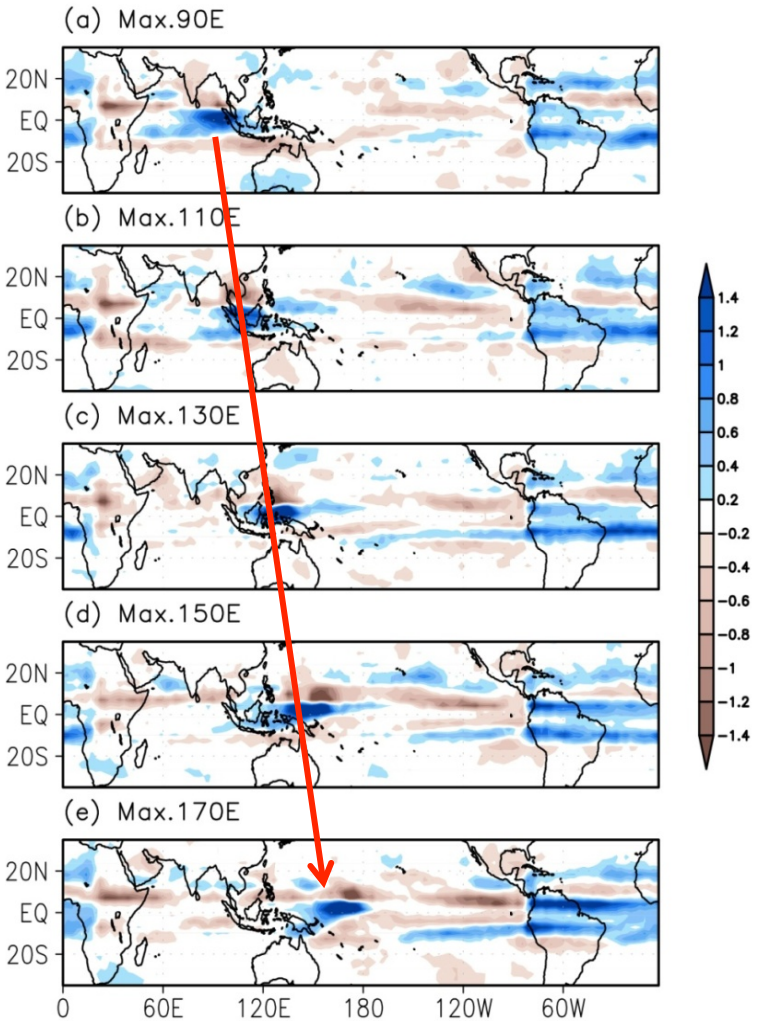
[Zonal Mean SST + Idealized Warm Pool]

(2) Anomalous U850 (m/s)

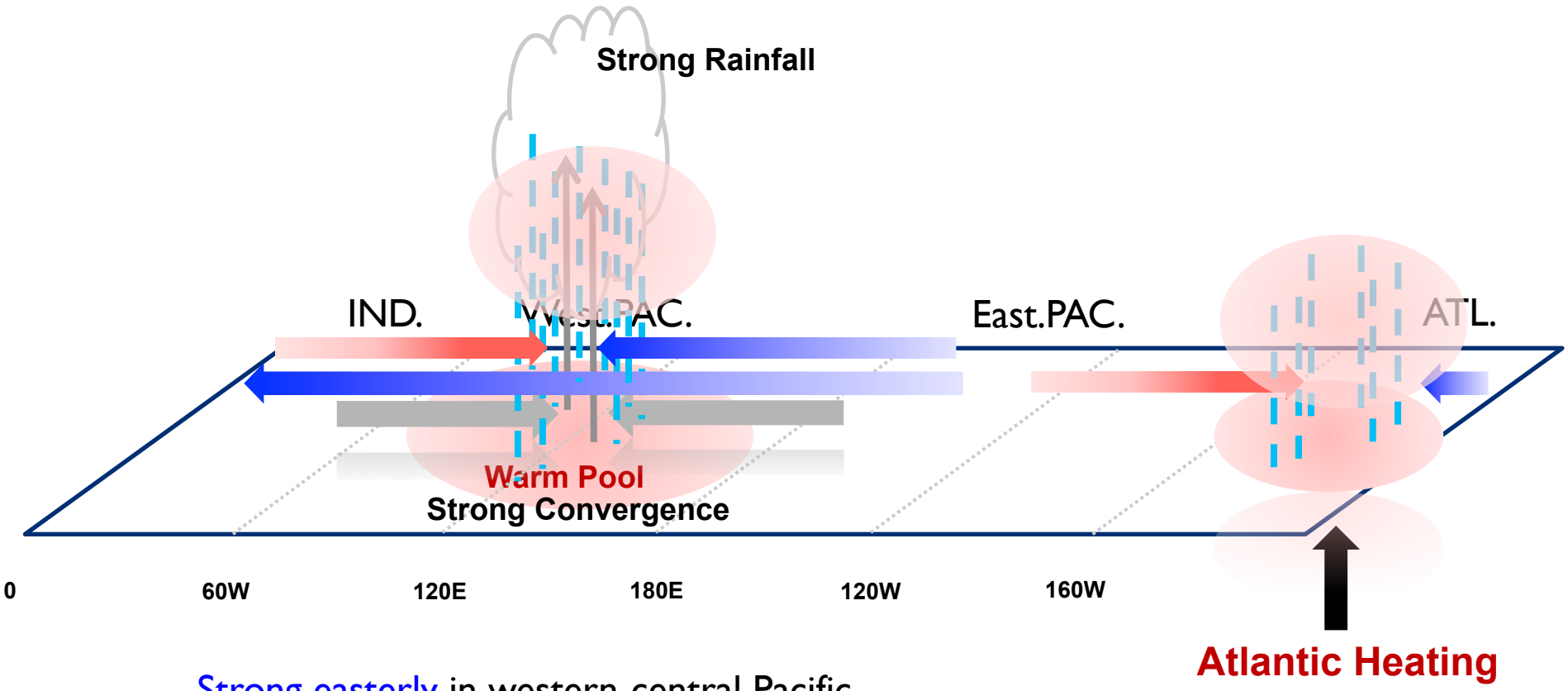


[Ideal.ATL Forcing] – [No Forc.]

(1) Anomalous Precipitation (mm/day)



Role of Warm Pool



Strong easterly in western-central Pacific,

Increasing Precipitation in western Pacific

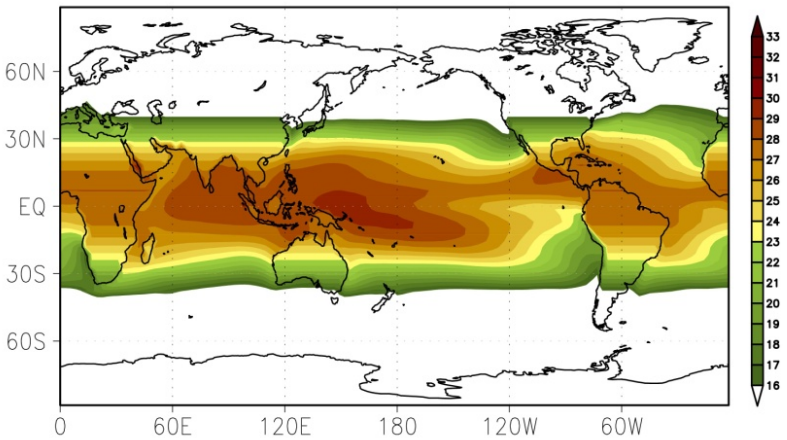
.

Realistic SST run

- Experimental design with atmospheric GCM

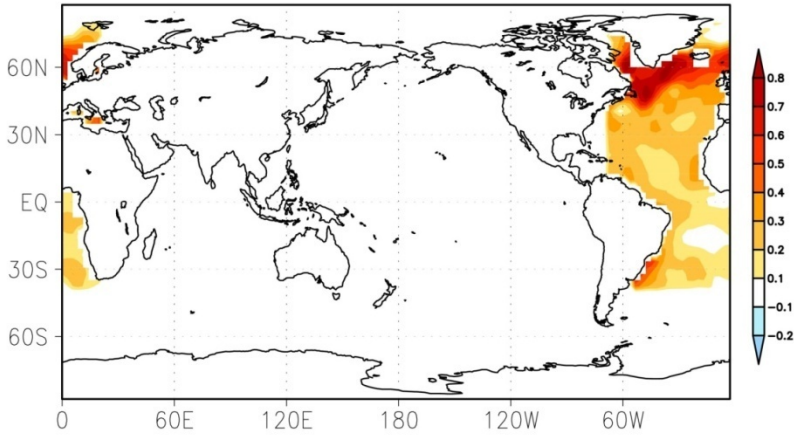
  ✓ SST Boundary Condition

[Clim. SST]



+

[Real. ATL Forcing]



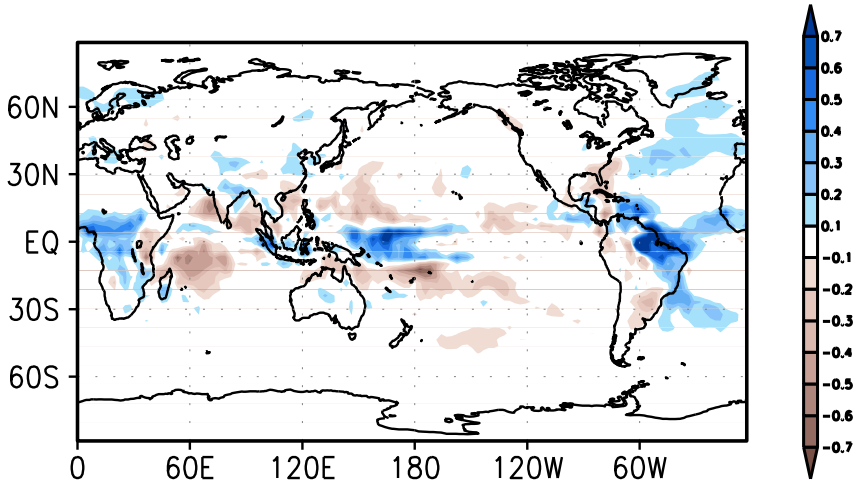
SNU AGCM
50yrs of integration
T42 Horizontal resolution
21vertical level
Cumulus Momentum Transport included

Responses to Atlantic heating in SNU AGCM

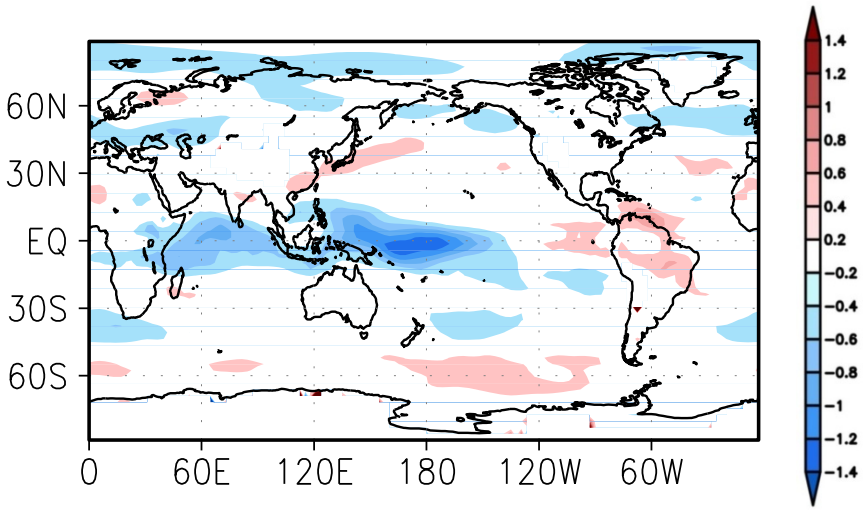
- Results from **SNUAGCM**

[Real.ATL Forcing] – [No Forc.] : Mean difference ➡ " Anomalous"

(1) Anomalous PRCP (mm/day)



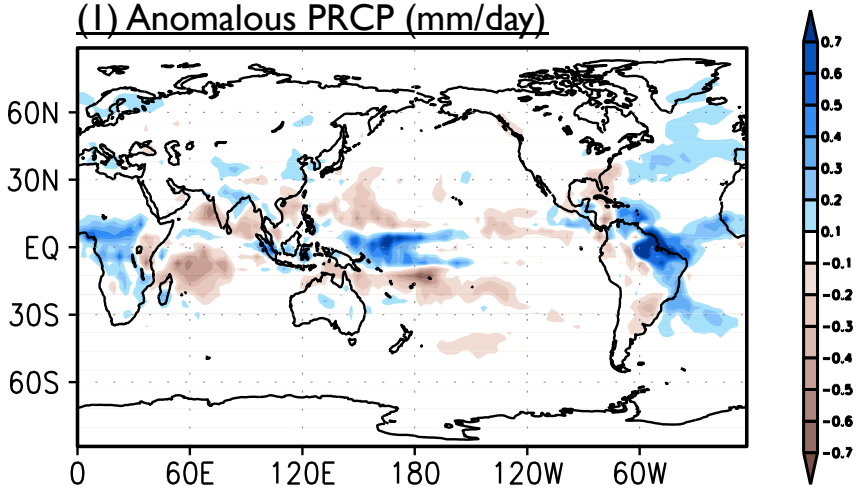
(2) Anomalous U850 (m/s)



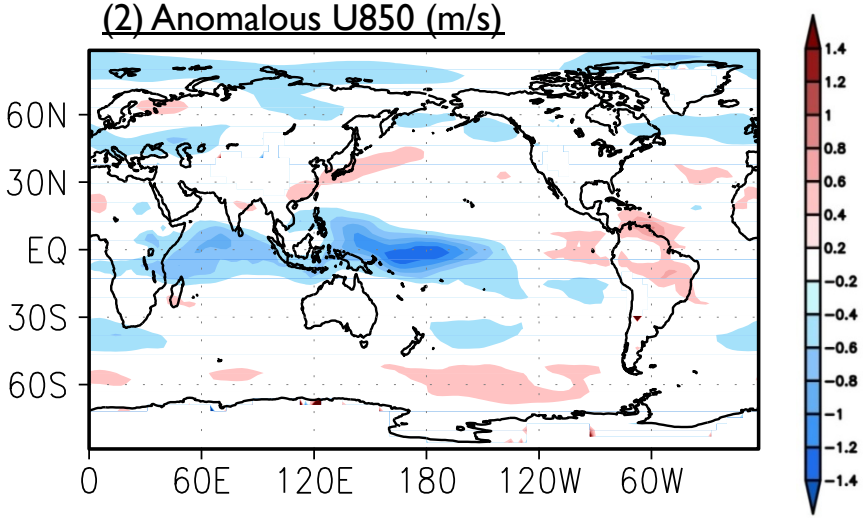
Responses to Atlantic heating in SNU AGCM

- Results from **SNUAGCM**

(1) Anomalous PRCP (mm/day)

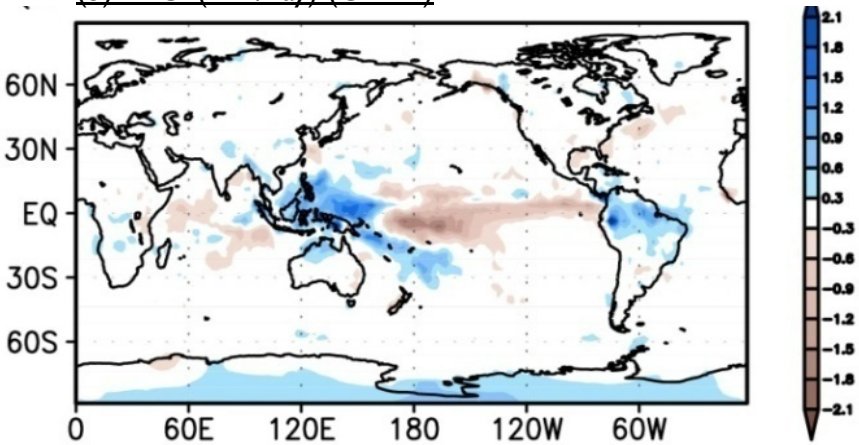


(2) Anomalous U850 (m/s)

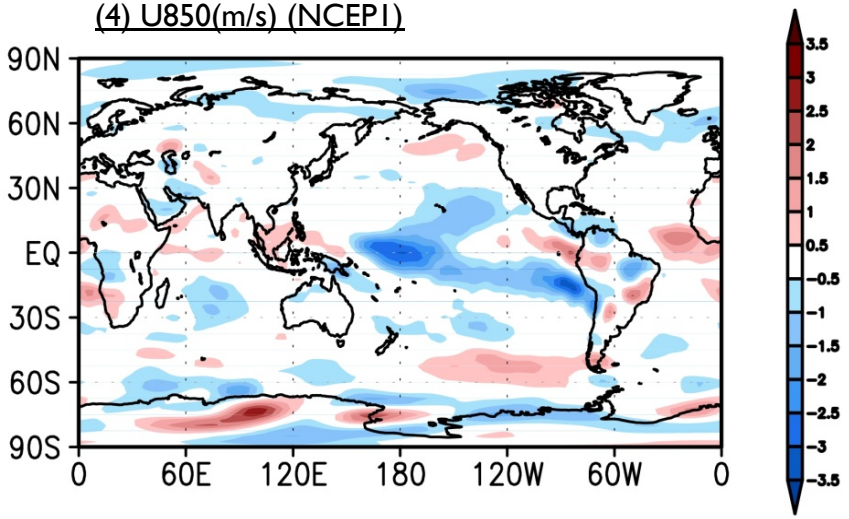


- **Differences** between 2000s and 1990s **(from Observations)**

(3) PRCP(mm/day) (CMAP)



(4) U850(m/s) (NCEP1)



CGCM Experiments

1. Control Run

   - Atlantic Ocean : **SST Nudging** with model climatology

   - other Oceans : Free run

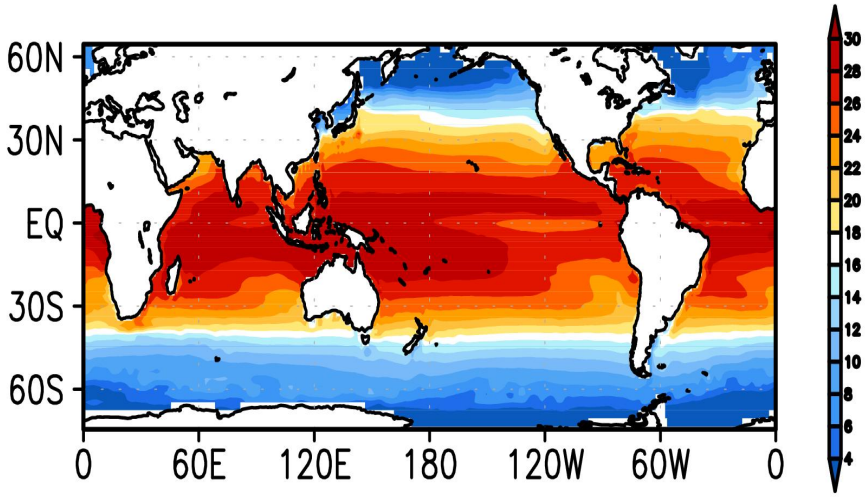
2. Anomaly Run

   - Atlantic Ocean : **SST Nudging** with model climatology + observed SSTA

   - other Oceans : Free run

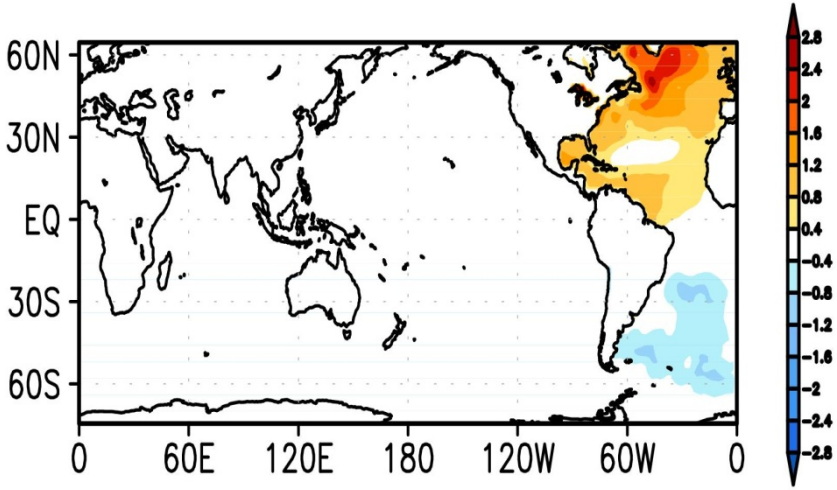
Experimental design with Coupled GCM

[model climatology SST]



+

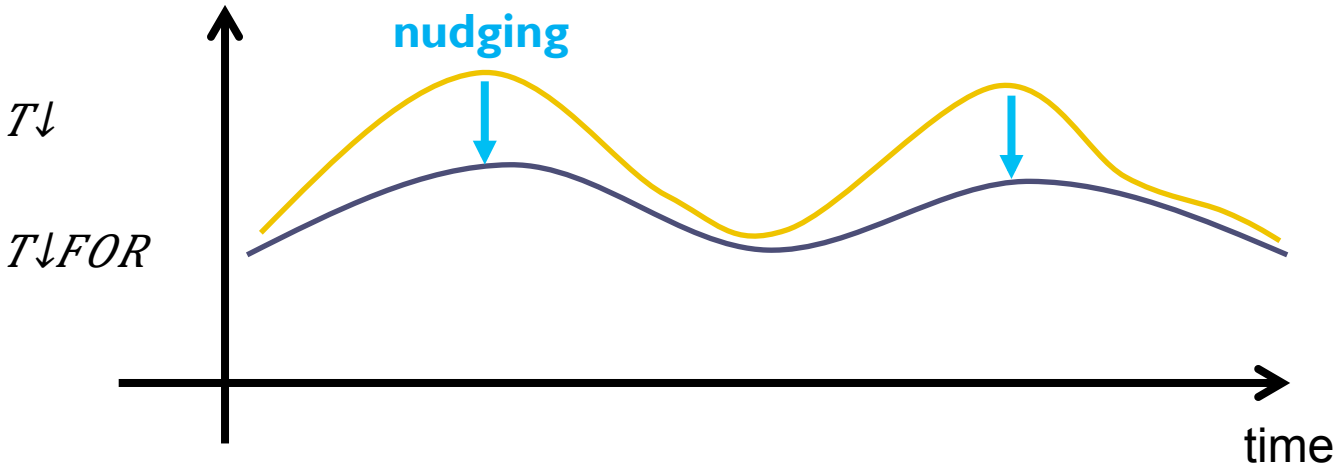
[SST anomaly forcing]



➡ Atlantic SST anomaly from SVD analysis between global SST and summer PRCP

SNU CGCM
40yrs of integration
T42 Horizontal resolution
Atm : 20vertical level / Ocn : 32 vertical level

Nudging method



Nudging equation for temperature

$$\partial T/\partial t = -v\cdot\nabla T + Q/\rho C\downarrow P \, H + T\downarrow FOR - T\downarrow /\tau\downarrow T$$

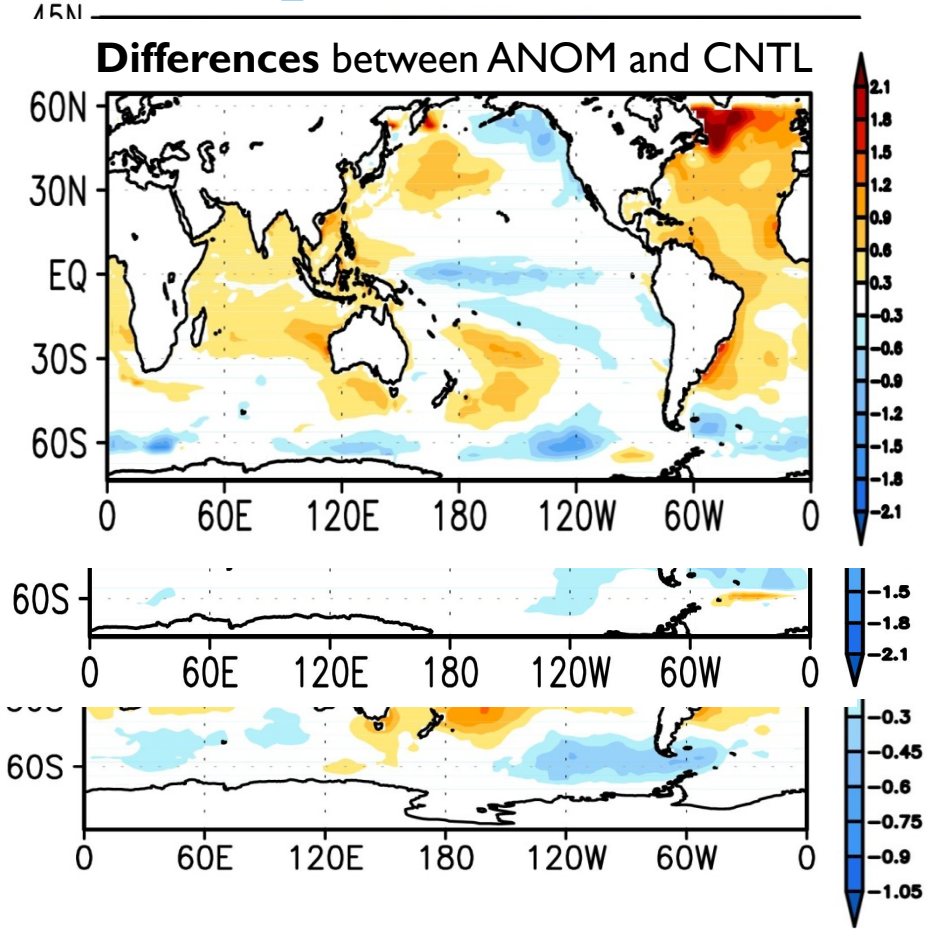
- $T\downarrow$: model SST
- $T\downarrow FOR$: CNTL_EXP - **CGCM climatology**
  ANOM_EXP - **CGCM climatology + Atlantic SST anomaly**
- $\tau\downarrow T\downarrow$: relaxation time scale **1 day**

Annual mean state

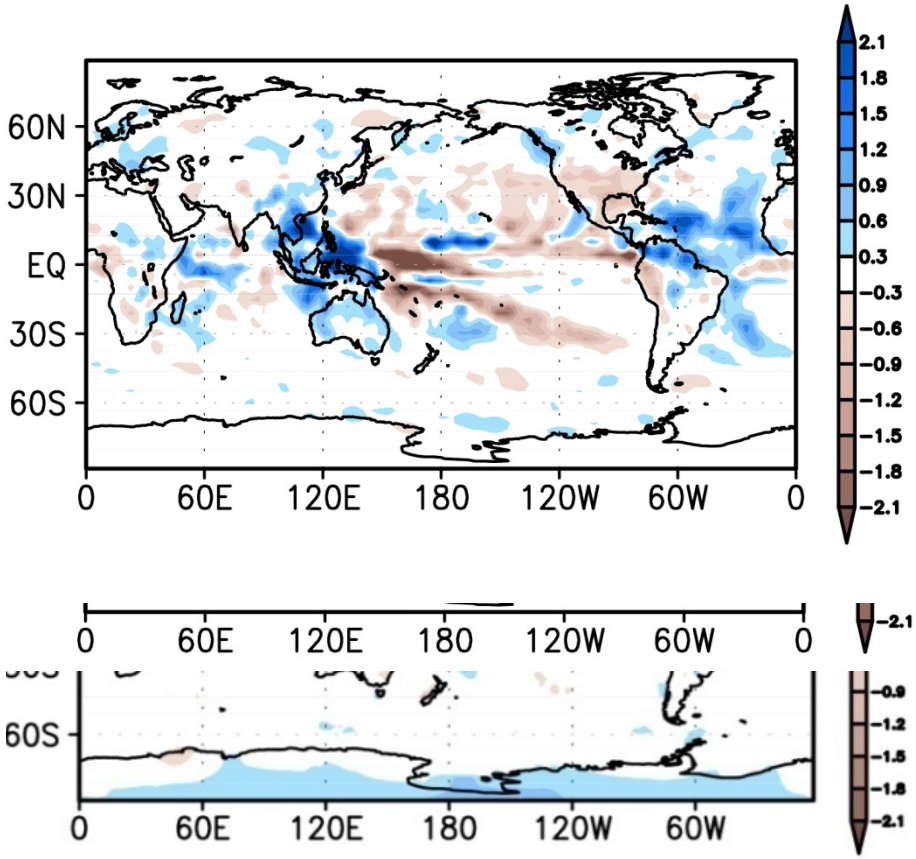
Model: SNU CGCM
40yrs (Use later 30yr)

- Result from a COUPLED GCM Experiment
  - Annual mean SST(℃) and PRCP(mm/day)

- **CNTL_EXP**



- **CNTL_EXP**

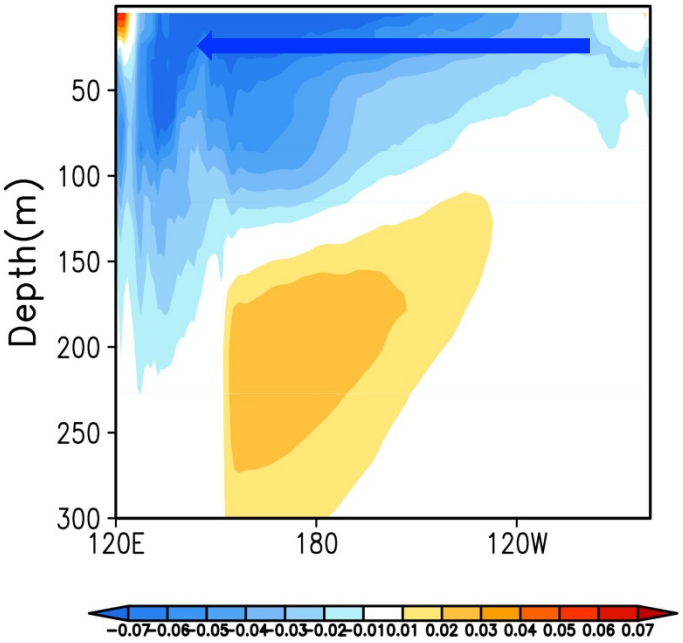


Annual mean difference of current

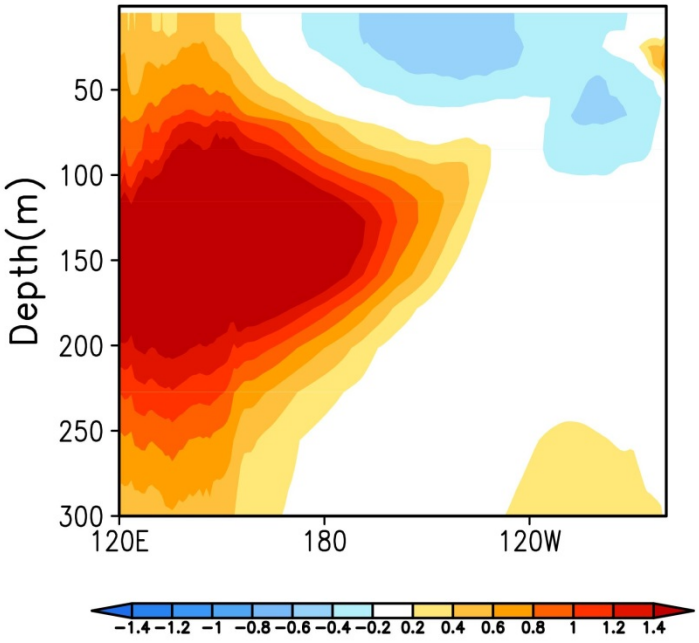
Model : SNU CGCM
40yrs (Use later 30yr)

- Result from a COUPLED GCM Experiment
  - zonal current (m/s) and temperature (℃)

Zonal current (m/s)

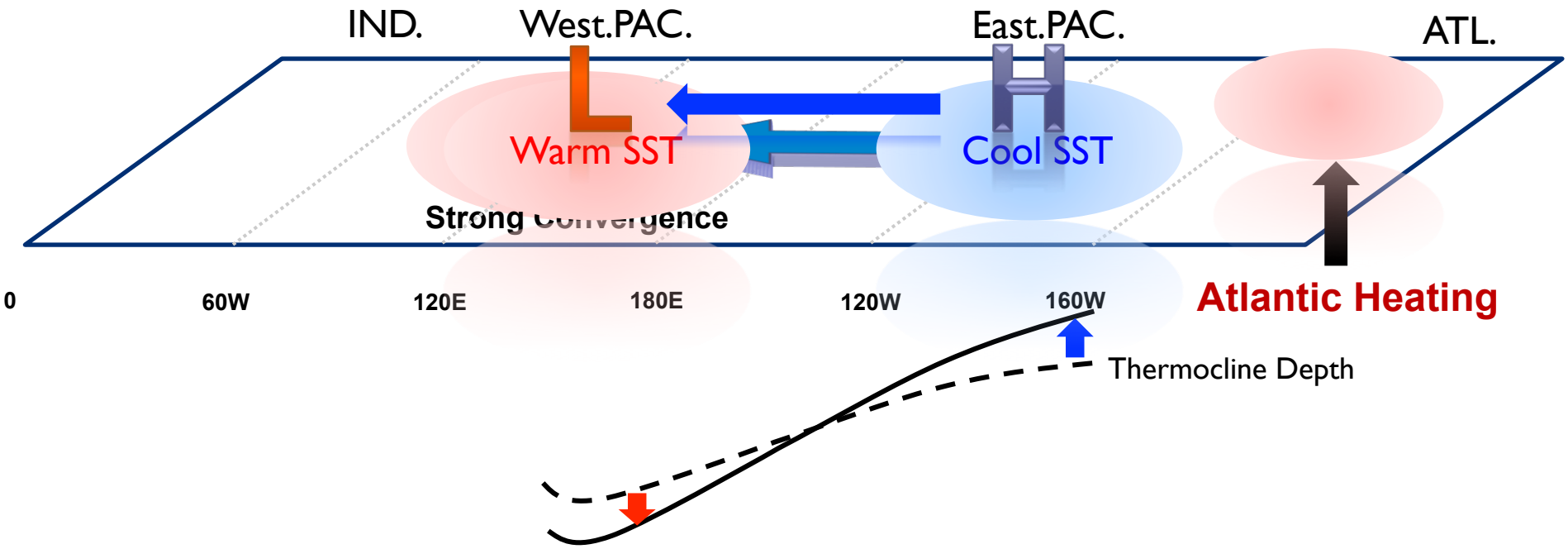


Temperature (℃)



5S-5N averaged value

Oceanic Feedback

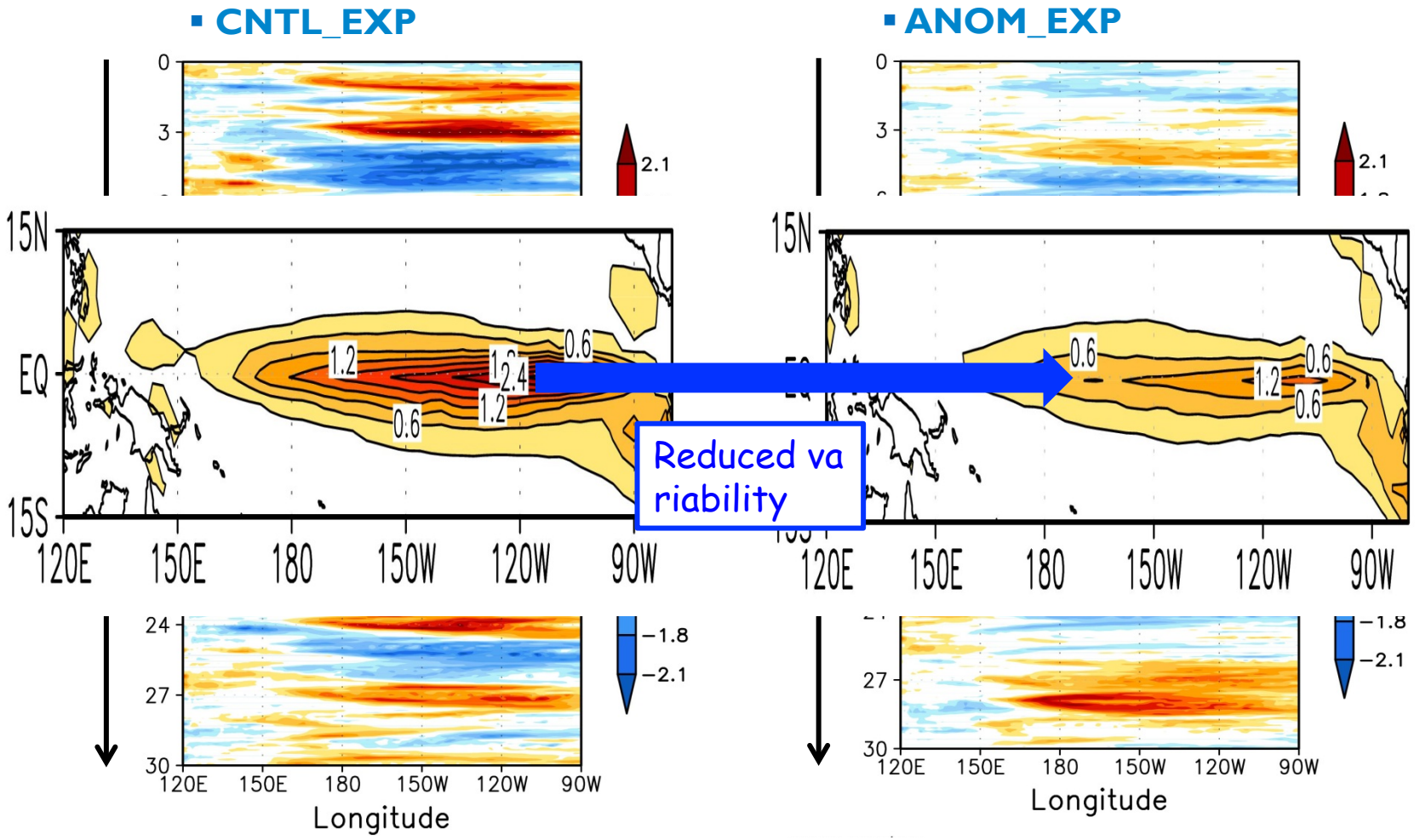


Deep thermocline in the west, shallow in the east

ENSO variance

Model : SNU CGCM
40yrs (Use later 30yr)

- Result from Coupled GCM Experiment (nudging method)
  - SST anomalies(℃) and Standard deviation of SST anomaly



5S-5N averaged val

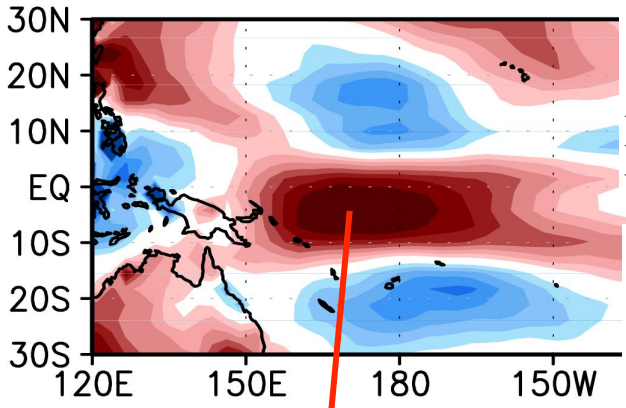
Regressed wind stress onto NINO3.4 index

- Result from a COUPLED GCM Experiment

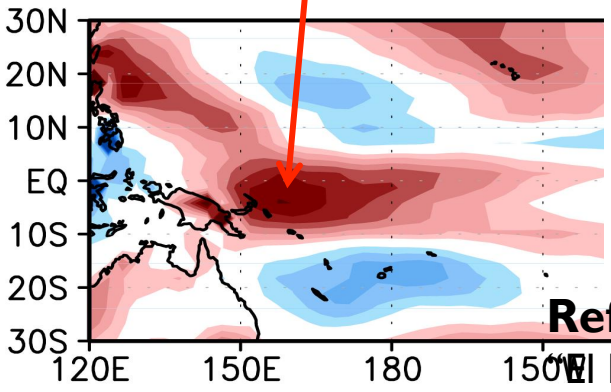
Model : SNU CGCM
40yrs (Use later 30yr)

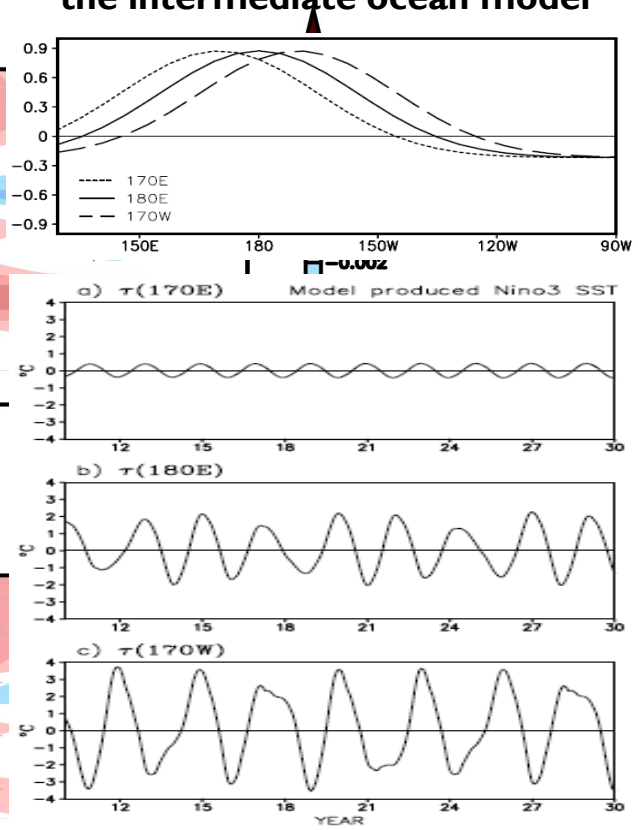
- **The statistical atmosphere and the intermediate ocean model**

- **CNTL_EXP**



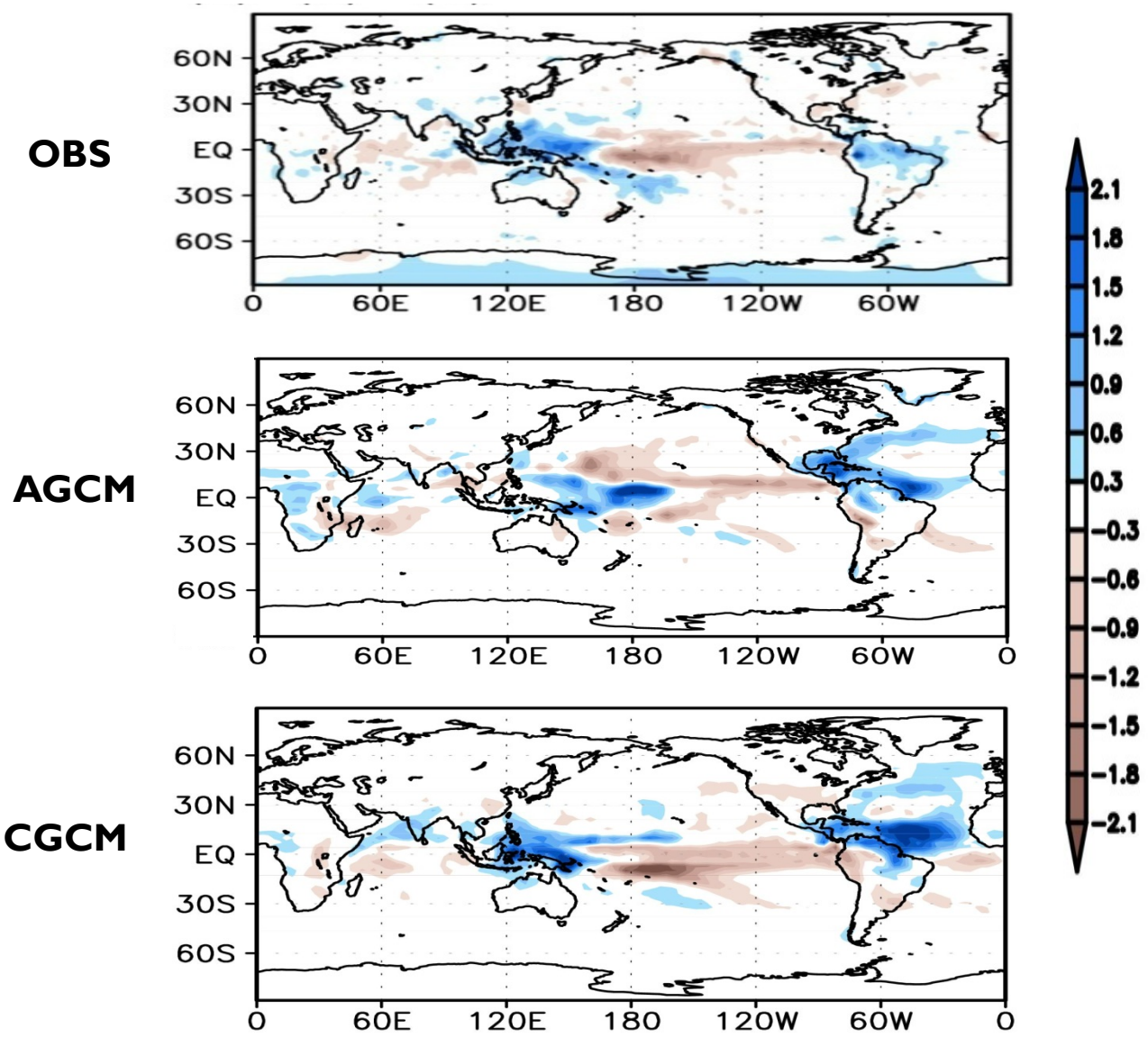
- **ANOM_EXP**





Reference : KANG and KUG (2002) "El Niño and La Niña sea surface temperature anomalies : Asymmetry characteristics associated with their wind stress anomalies"

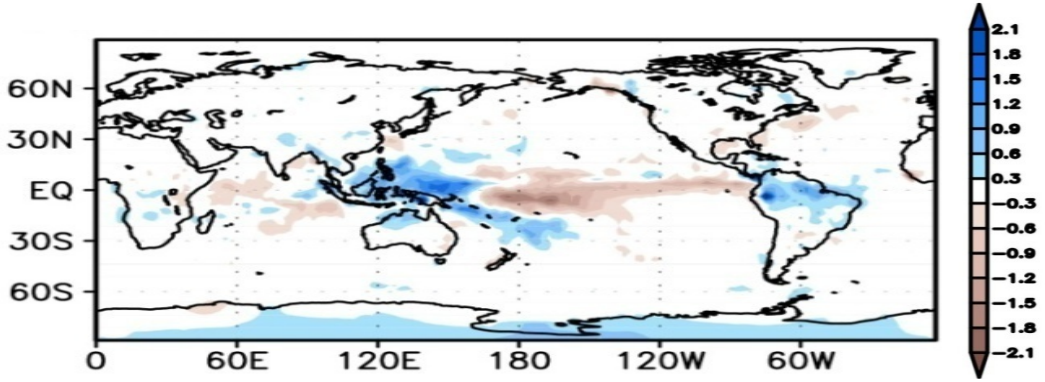
Difference of Annual mean PRCP



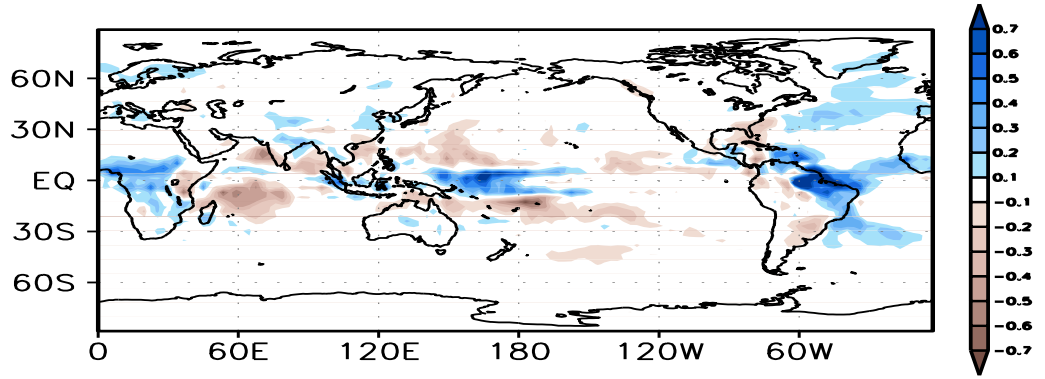
Unit : mm/day

Difference of Annual mean PRCP

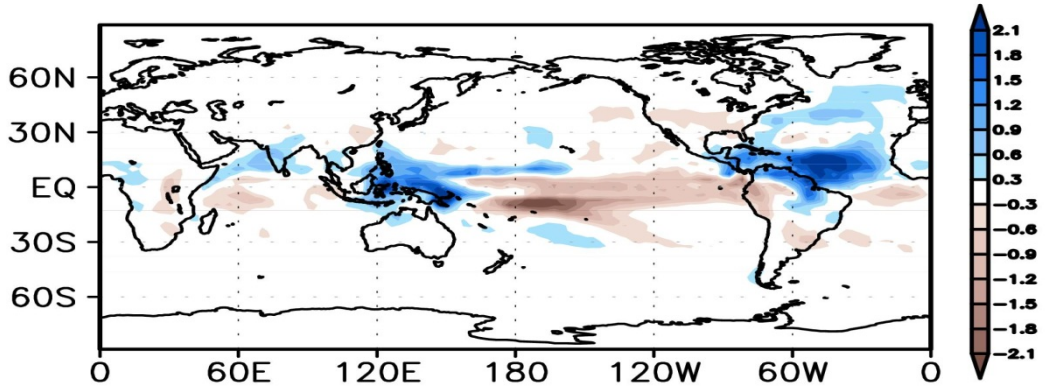
OBS



AGCM



CGCM



Atlantic SSTA associated with natural decadal variability

Atlatnic

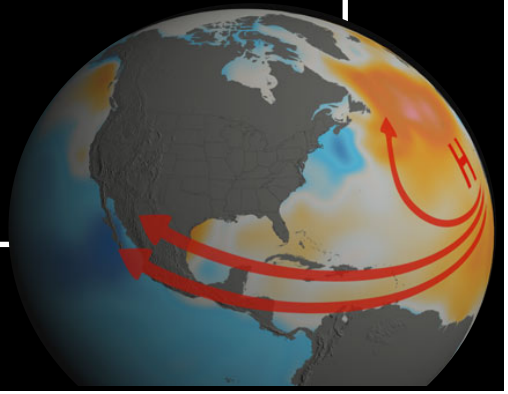
- Natural variability exists in the Atlantic with decadal time scales.
- Atlantic SSTA has been warmed during recent decades regardless of global warming.

Atmosphere & Ocean

- This induces change in wind and current fields.

Changes in the Pacific

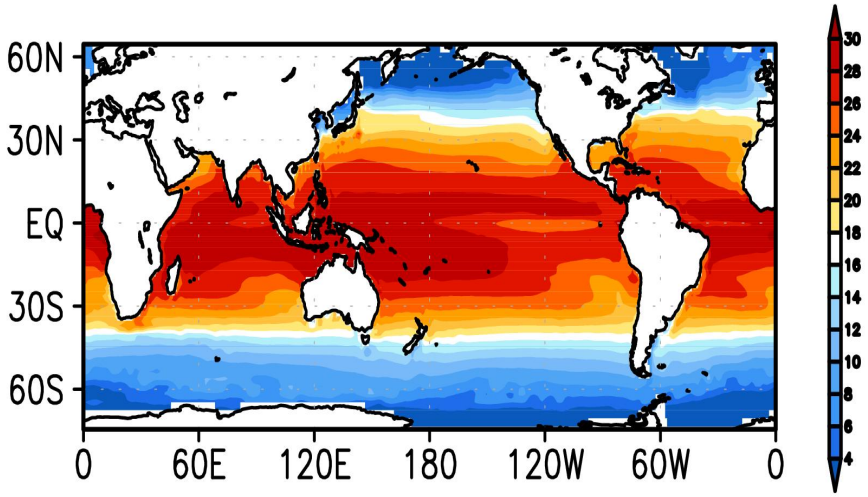
- It is intensified by the effect from Warm pool, showing stronger easterly and inc reased precipitation over the Western/Central Pacific.
- Consequently, ENSO variance has been reduced.



Thank you for your attention.

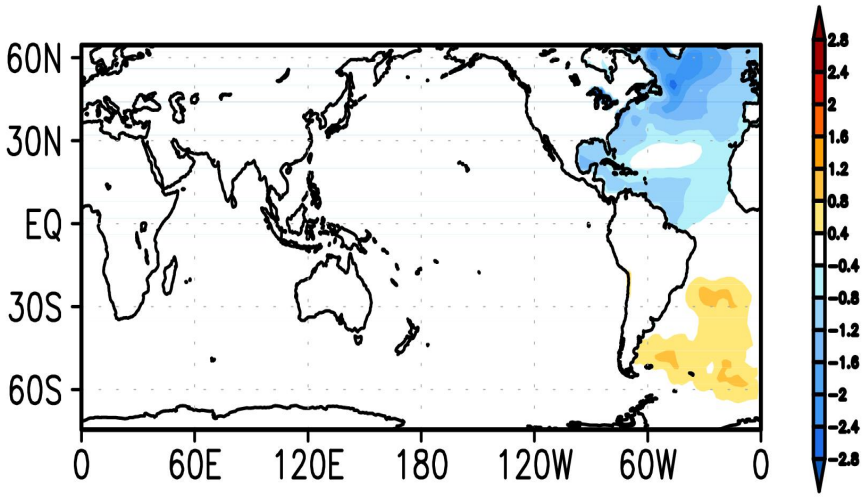
Experimental design with Coupled GCM

[model climatology SST]



+

[SST anomaly forcing]



➡ Inverse Atlantic SST anomaly from SVD analysis between global SST and summer PRCP

SNU CGCM
11yrs of integration
T42 Horizontal resolution
Atm : 20vertical level / Ocn : 32 vertical level

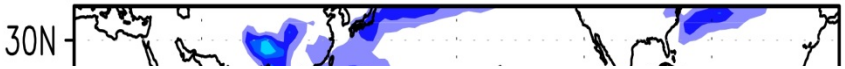
Annual mean state

Model : SNU CGCM
11yrs (Use later 5yr)

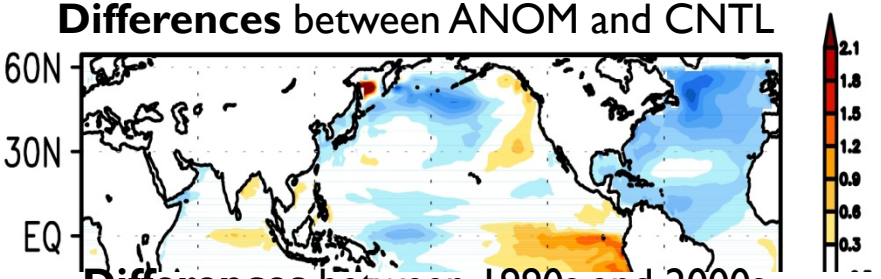
- Result from a COUPLED GCM Experiment
  - Annual mean SST(℃) and PRCP(mm/day)

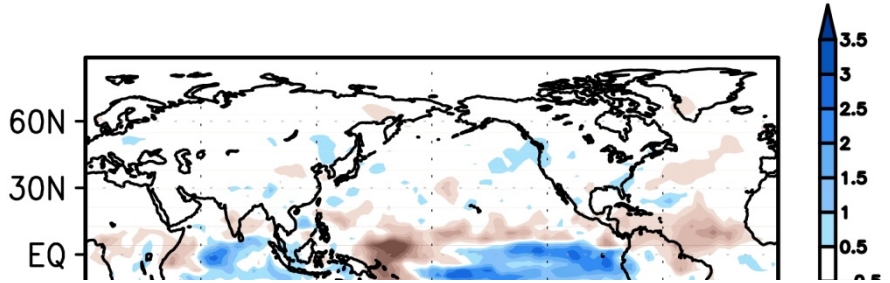
▪ CNTL_EXP

▪ CNTL_EXP

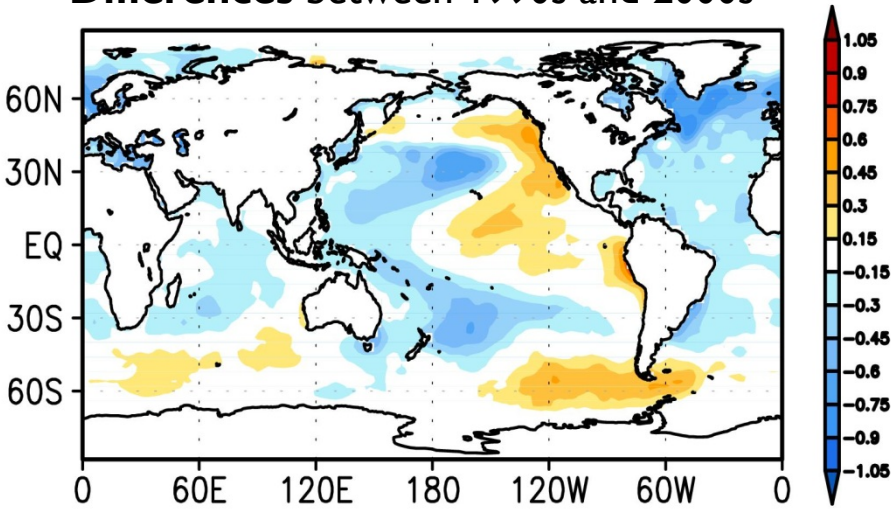


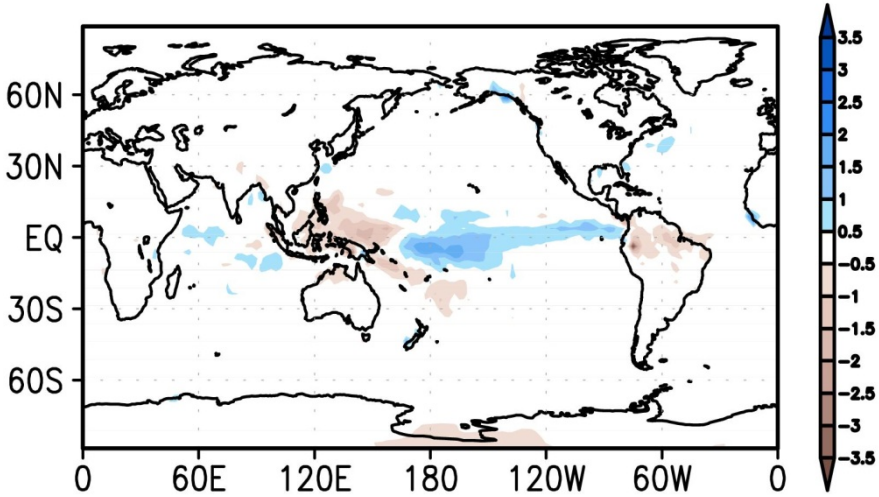
Differences between ANOM and CNTL





Differences between 1990s and 2000s





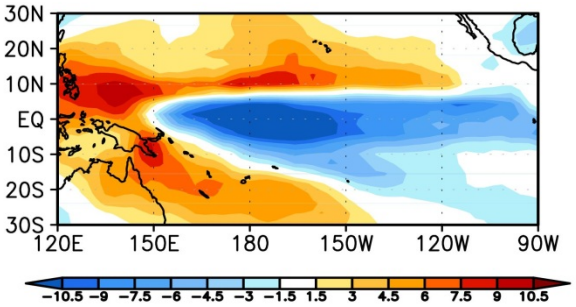
Regressed onto NINO3.4 index

- Result from a COUPLED GCM Experiment

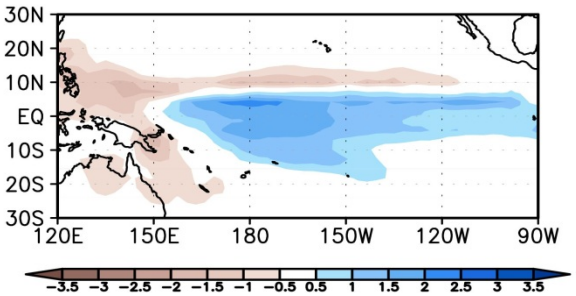
Model : SNU CGCM
40yrs (Use later 30yr)

- **CNTL_EXP**

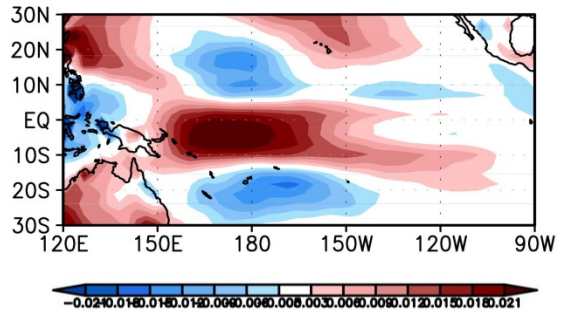
OLR



PRCP

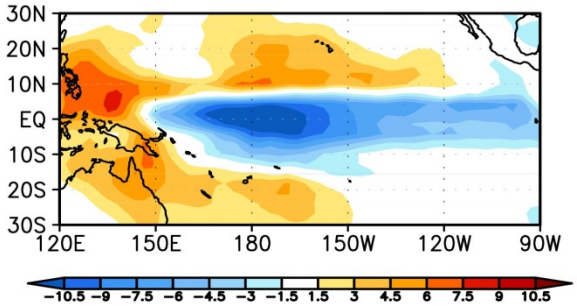


WIND S
RESS

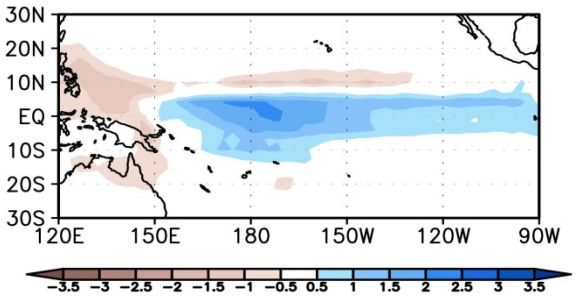


- **ANOM_EXP**

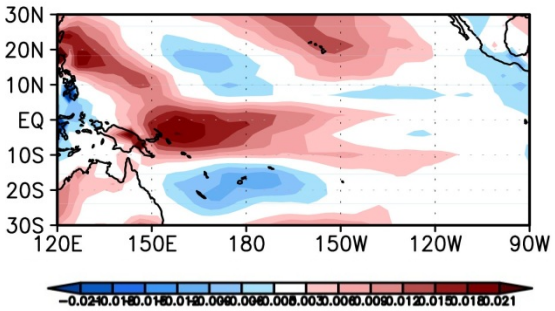
OLR



PRCP



WIND S
RESS

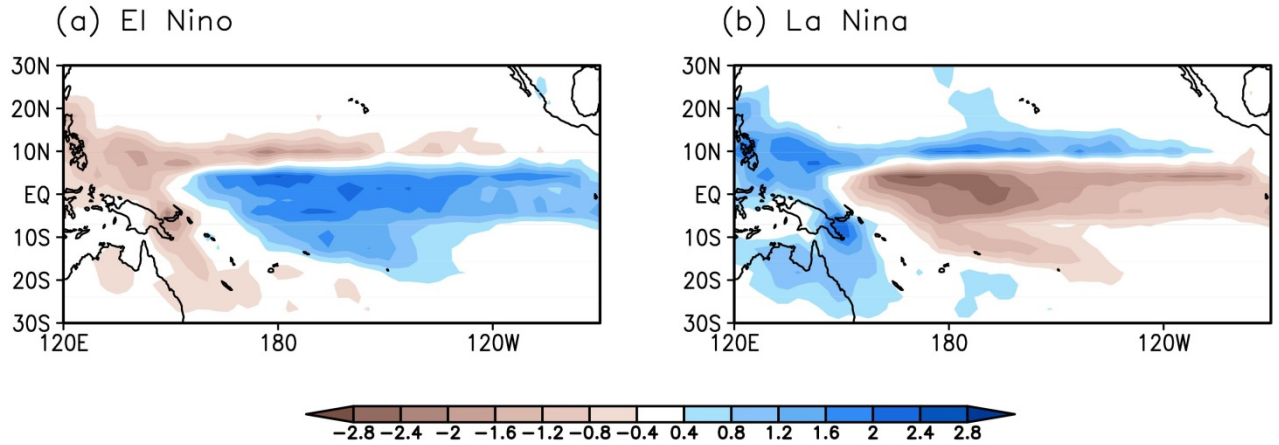


Composite of Precipitation with NINO 3.4 Index

- Result from a COUPLED GCM Experiment

Model : SNU CGCM
40yrs (Use later 30yr)

- **CNTL_EXP**



- **ANOM_EXP**