# East Asian Climate Variability and Change
## (A Brief Review)

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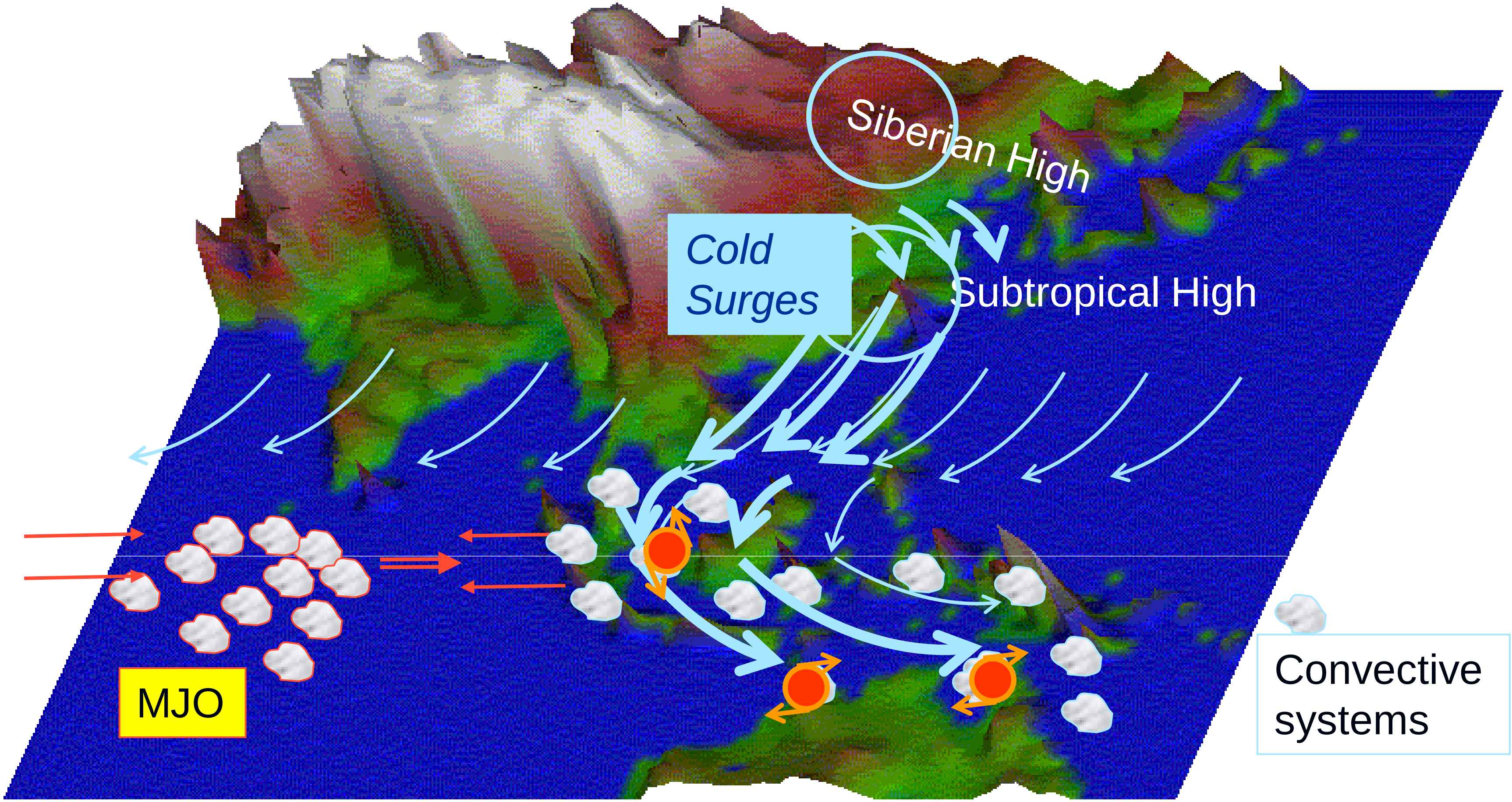
DSWS, Tsukuba, October 2017

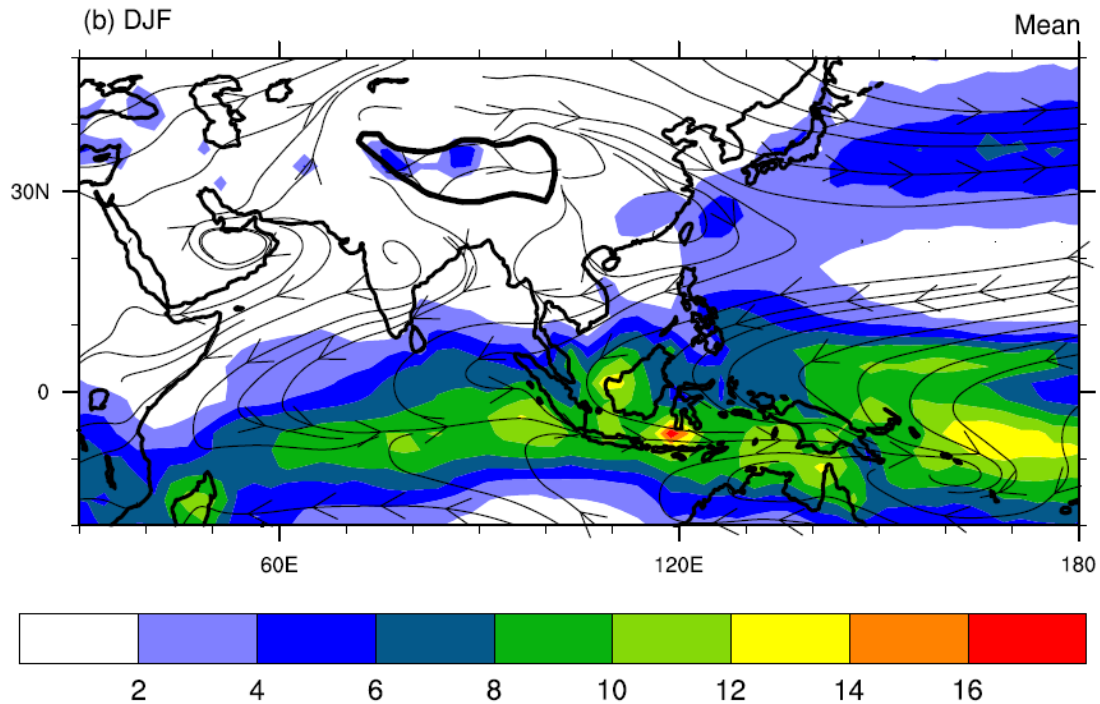
# East Asian Winter Monsoon




courtesy of C.-P. Chang

# Winter Climate Variability

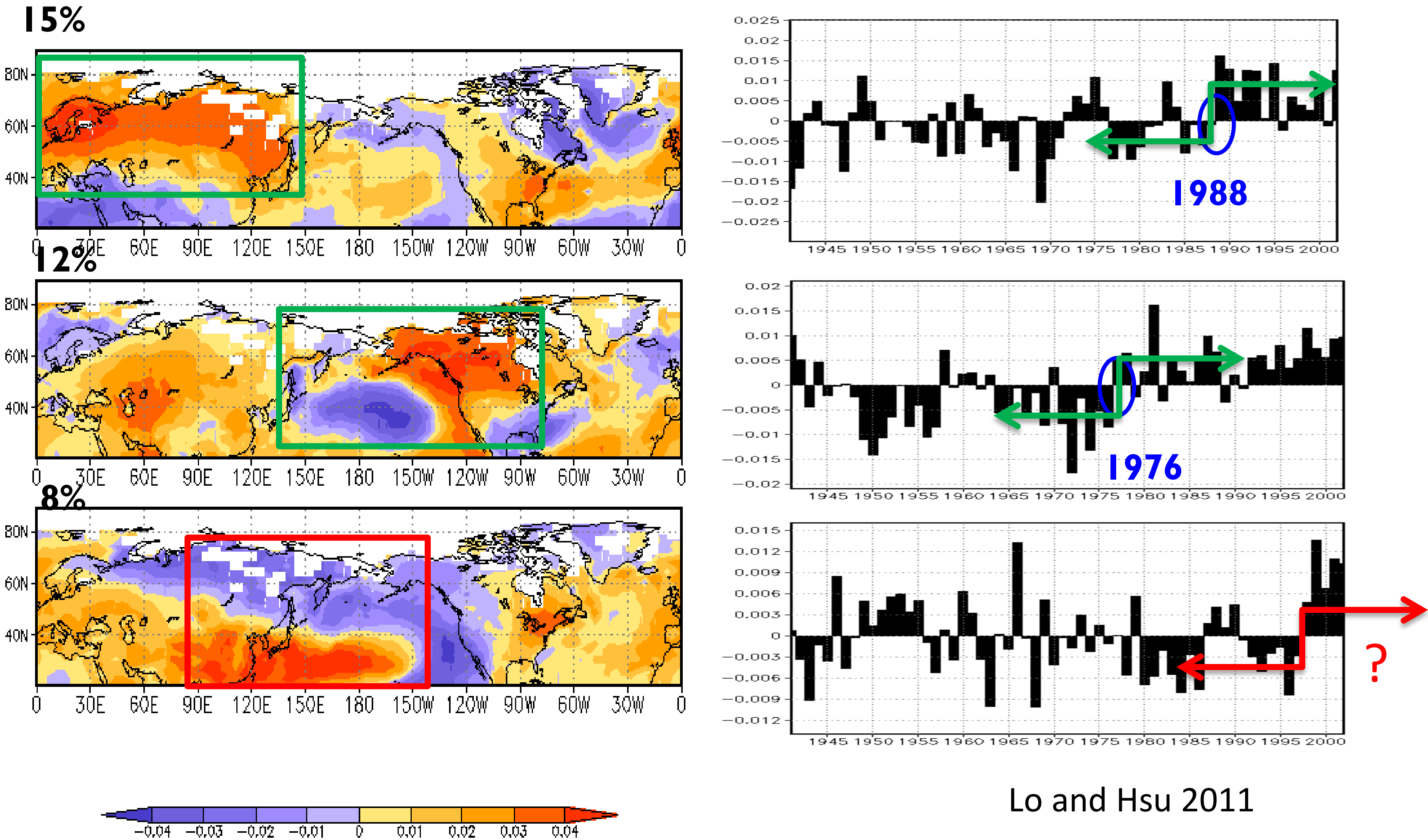
Need to understand as part of global system



# Regime Shift and Change in Dominant Modes

## Mechanisms?

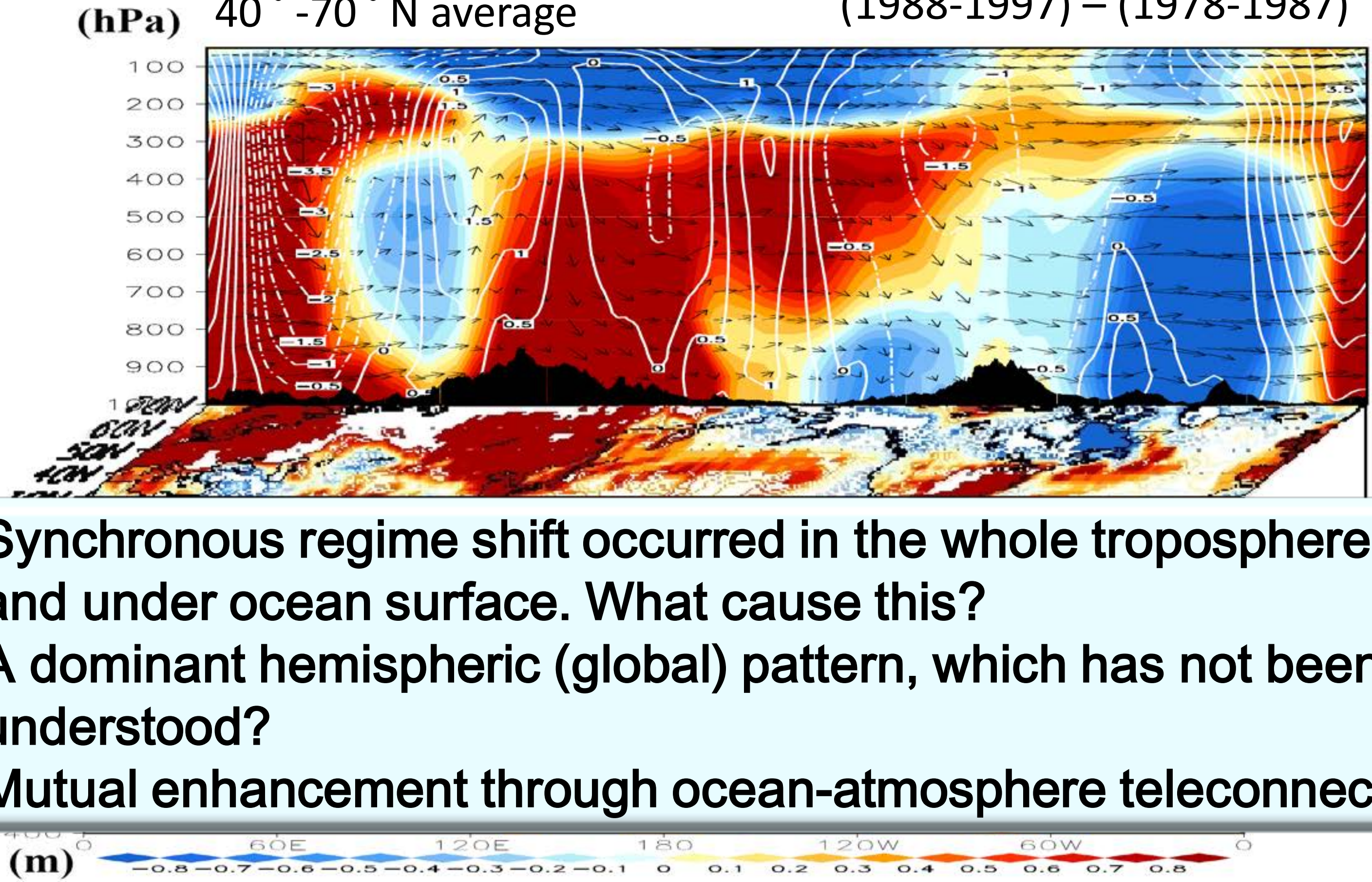
### CRU+Hadisst temperature 1941-2002 (JFM)




Lo and Hsu 2011

# Late 1980s Warming in East Asia (associated with NAO/AO)

40˚-70˚N average (1988-1997) – (1978-1987)




- Synchronous regime shift occurred in the whole troposphere, on and under ocean surface. What cause this?
- A dominant hemispheric (global) pattern, which has not been well understood?
- Mutual enhancement through ocean-atmosphere teleconnection?

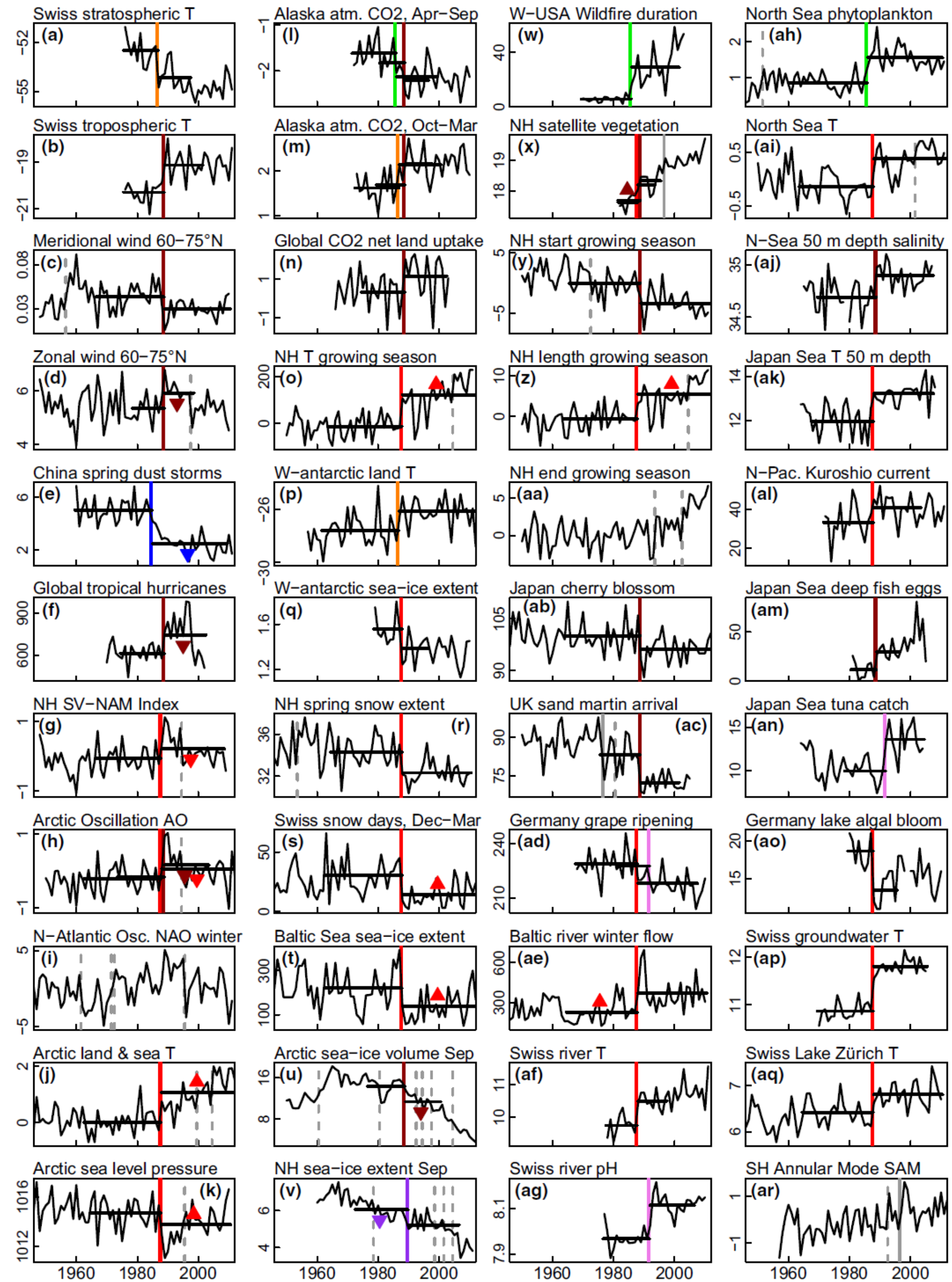
shaded: temperature contour: v-wind arrow: u-w wind

Lo, T.-T.

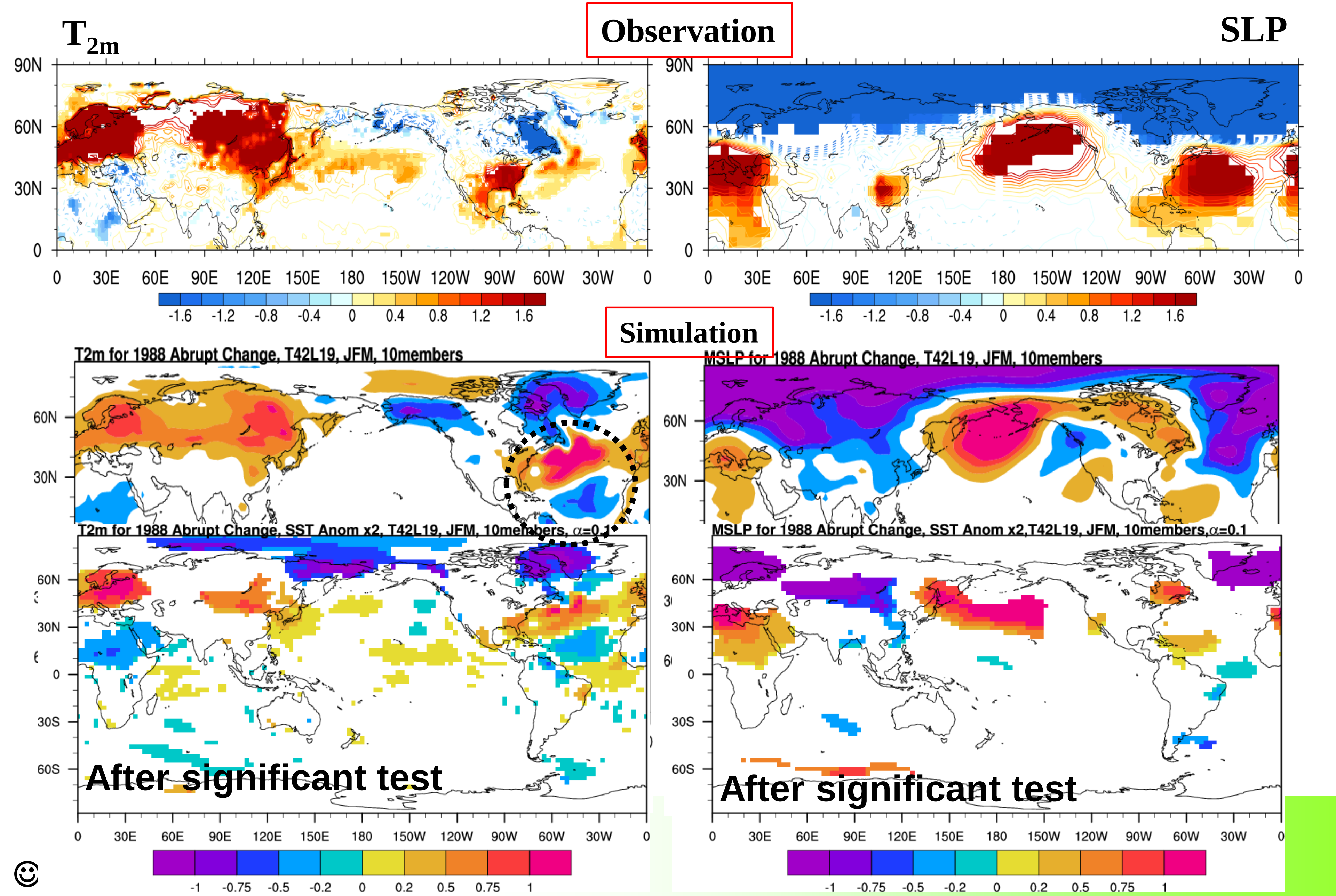
# Global impacts of the 1980s regime shift

Reid et al., 2015
Global Change Biology,
doi: 10.1111/gcb.13106

- China dust storm (decreased)
- Global Tropical cyclone (increased)
- $CO_2$ land uptake (increased)
- Antarctic sea ice/Baltic sea ice (d)
- NH spring snow (decreased)
- Starting growing season (NH)
- Japan Sea T 50m (higher)
- Japan cherry blossom (earlier)
- Japan Sea tuna catch (more)
- Kuroshio current (stronger)
- German grape ripening (earlier)
- North Sea phytoplankton (increased)
- AO (negative → positive)
- …



# EA warming can be simulated by SSTA forcing in the North Atlantic

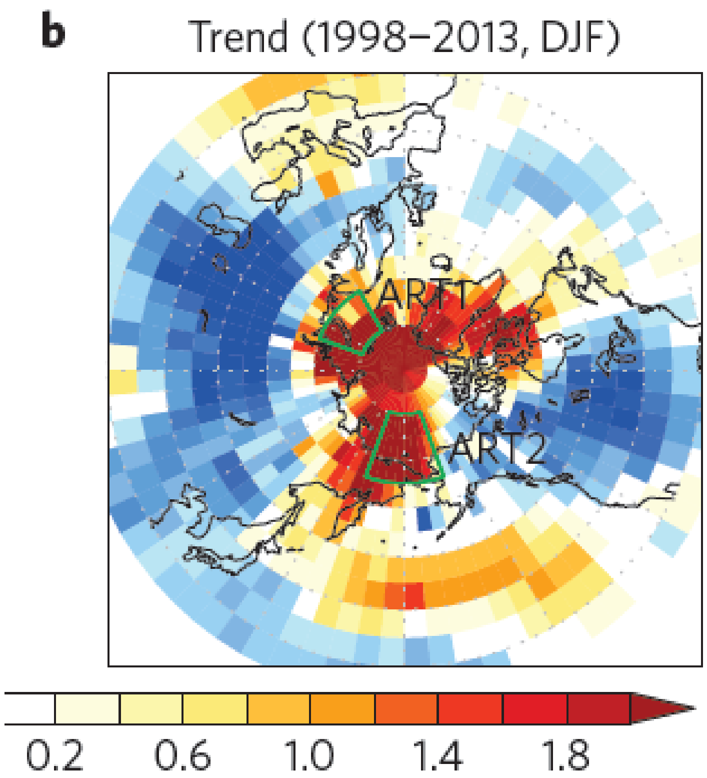


# East Asia winter and Barents-Kara Sea SAT after 1979/80 (interannual time scale)

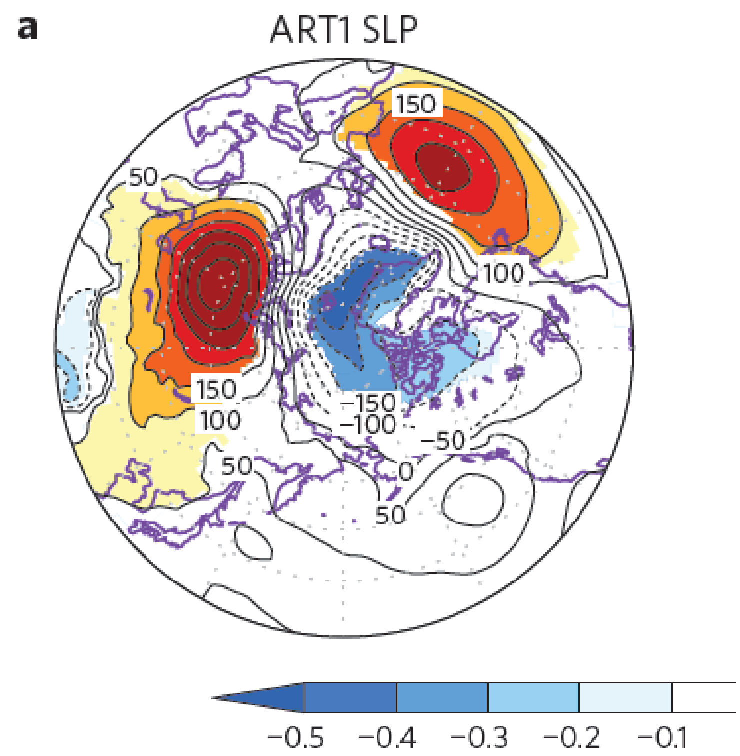
"…severe winters (1979/80 – 2013/14) across East Asia are associated with anomalous warmth in the Barents–Kara Sea region …"

(Kug et al. 2015, Nature Geoscience; similar in Mori et al. 2015; Kim and Son, 2016; Petoukov and Semenov 2010, …)

**SAT trend**



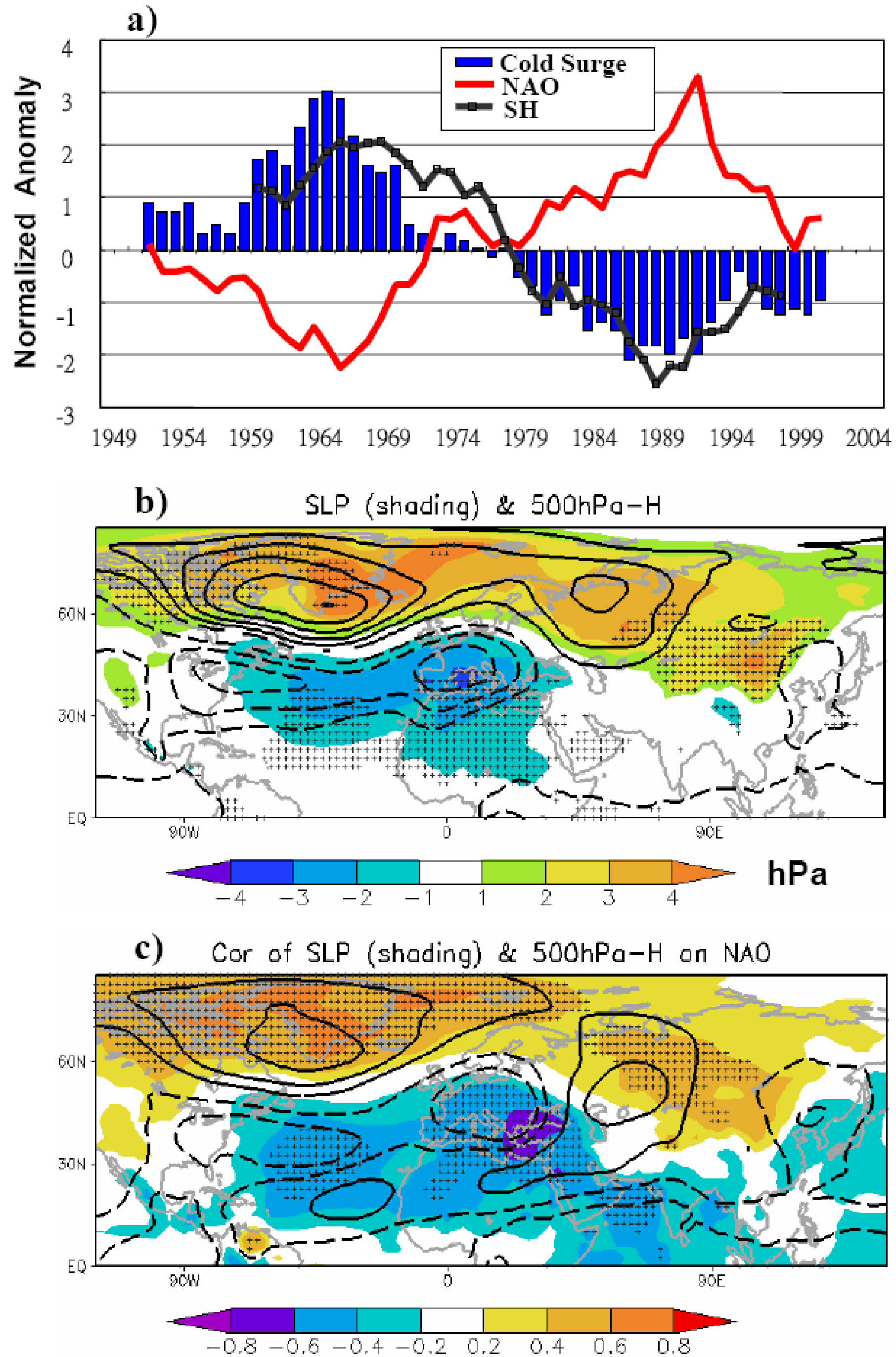

**Correlation (detrended)**



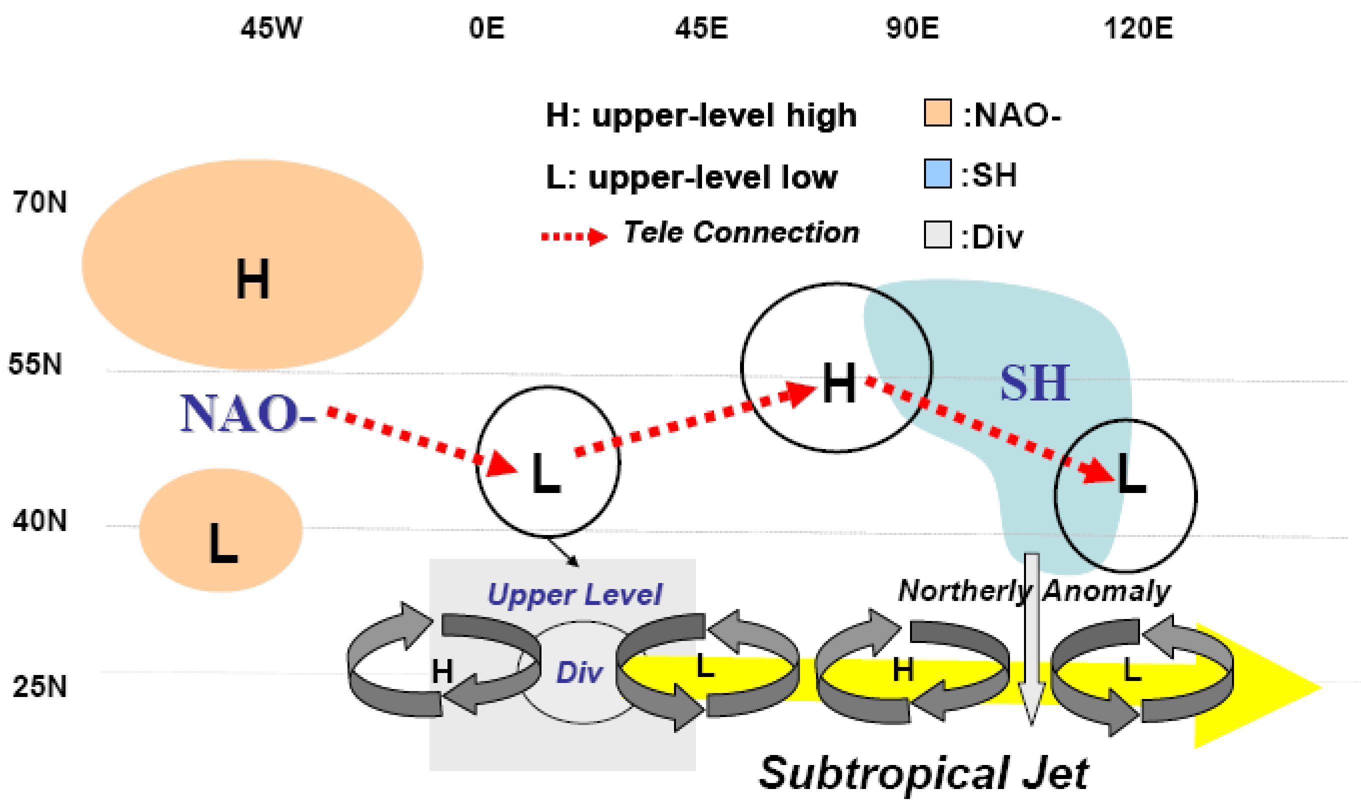
**Positive Decadal Correlation:**
**NAO and Cold Surge Frequency**
**in Taiwan (correlation ~ -0.9)**

(Hong, Hsu, Chia, and Wu, 2008, GRL)

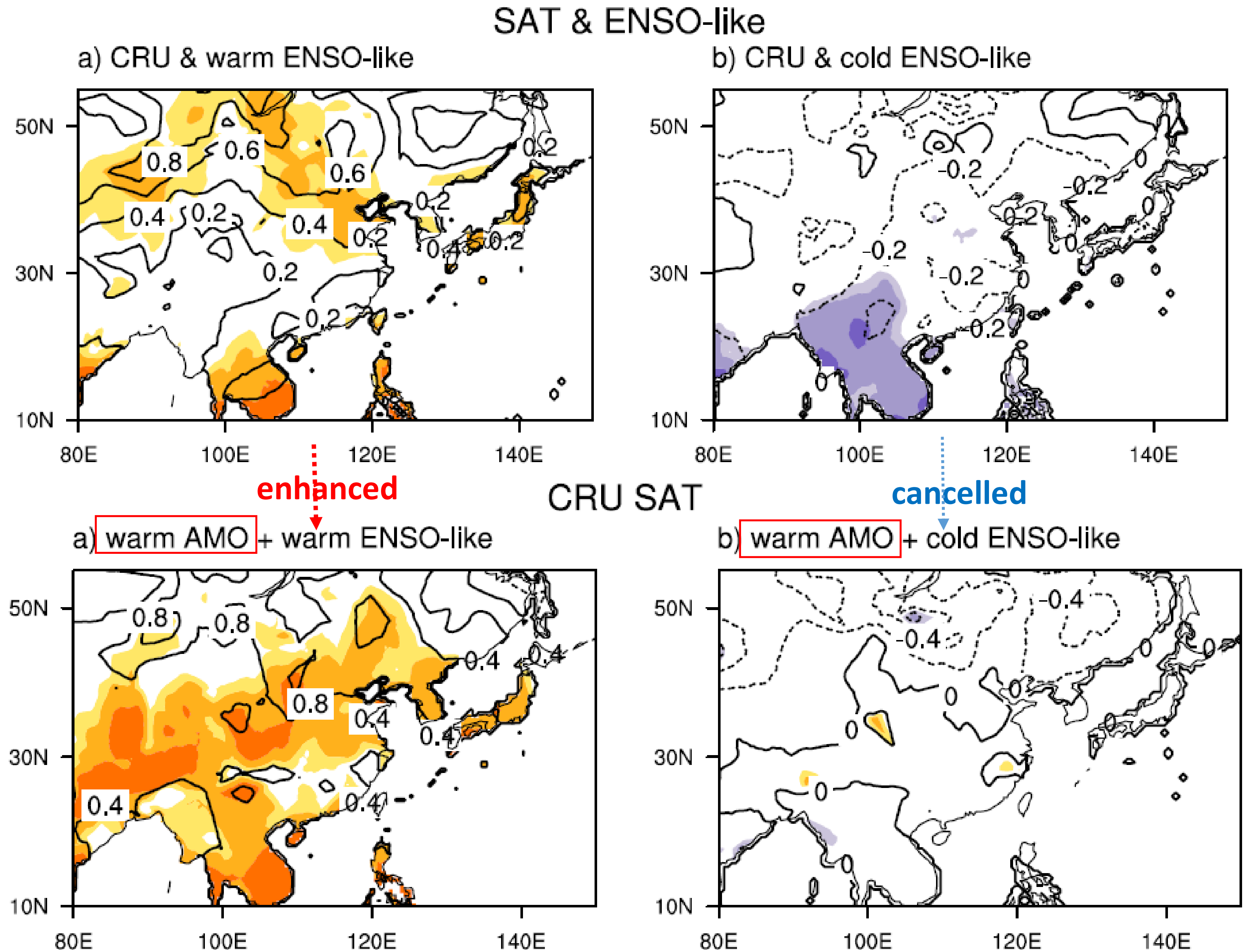
- Similar pattern in interannual and interdecadal time scale
- Cause and Effect?
  - NAO/AO like perturbation
  - Barents-Kara Sea SSTa
  - others



- **Downstream impacts (of North Atlantic/Europe) on East Asian climate/weather through Rossby wave-like propagation (waveguides)**
- **How will this change in the warming future?**



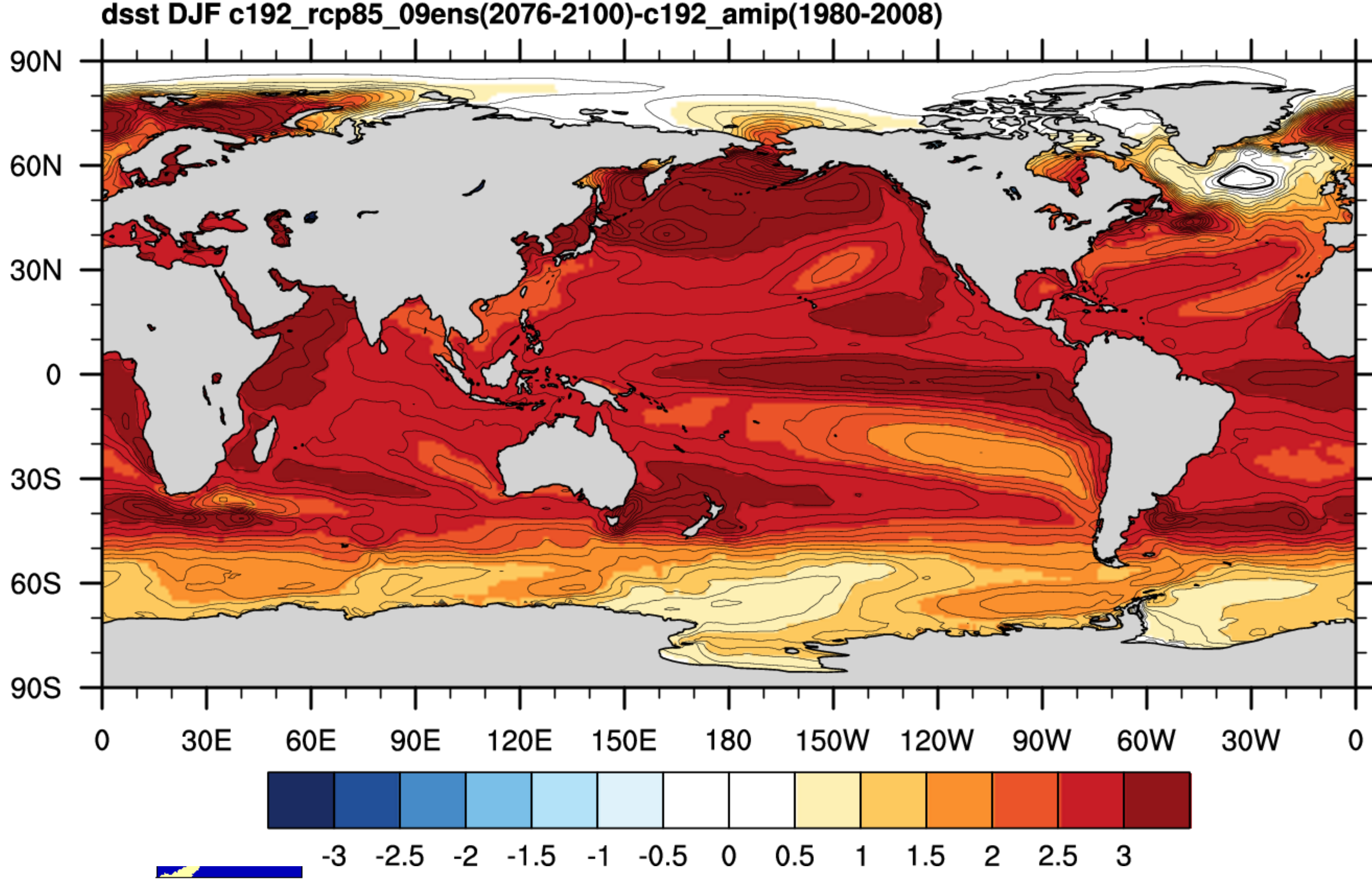
# Combined effect of ENSO and AMO (Hao and He, 2017, J. Climate)



# Future Change Projection

## HiRAM/GFDL: 1979-2008, 2075-2100 (RCP8.5)

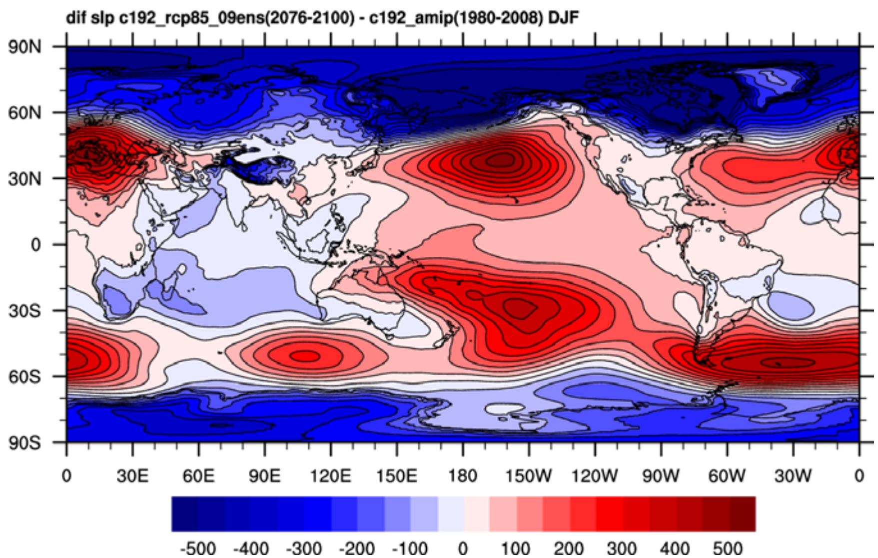
Same ensemble SSTa used in MRI-AGCM20



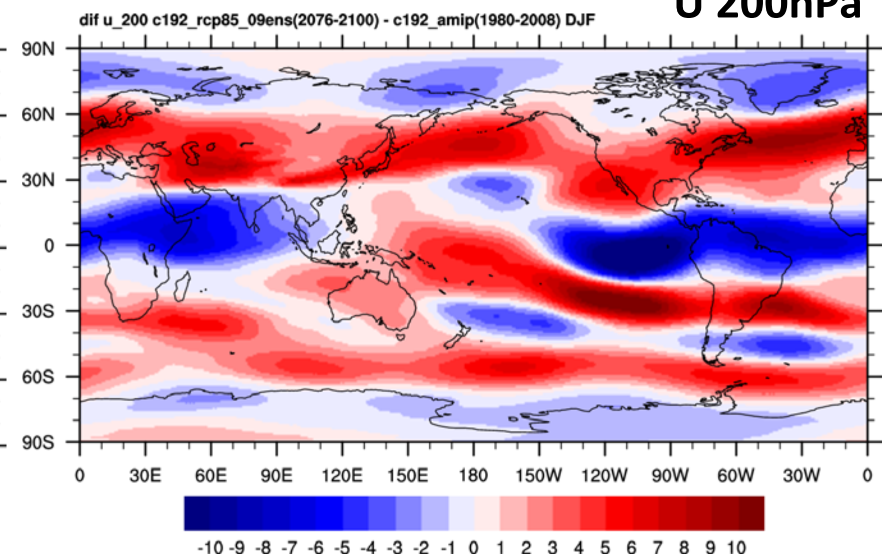
# Projected Future Changes under RCP8.5

(using 50/25-km HiRAM forced by ensemble SST changes)

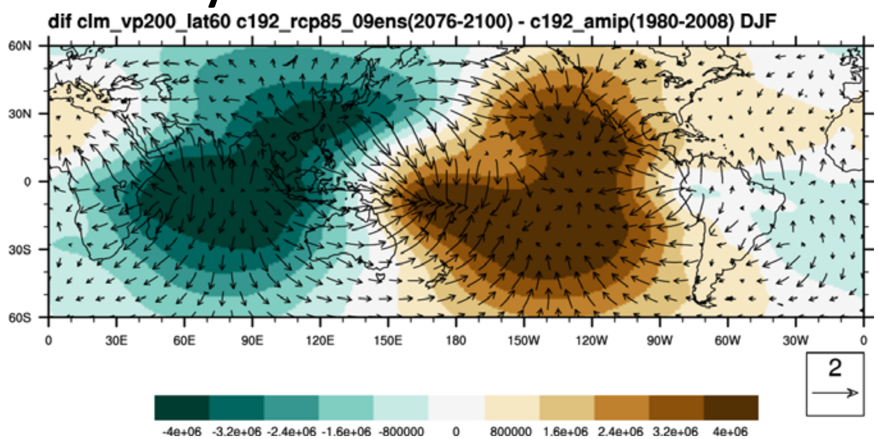
**SLP**



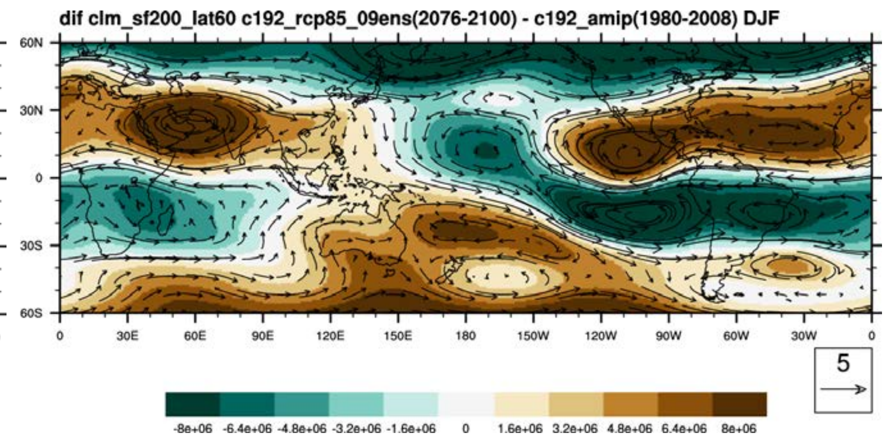

**U 200hPa**



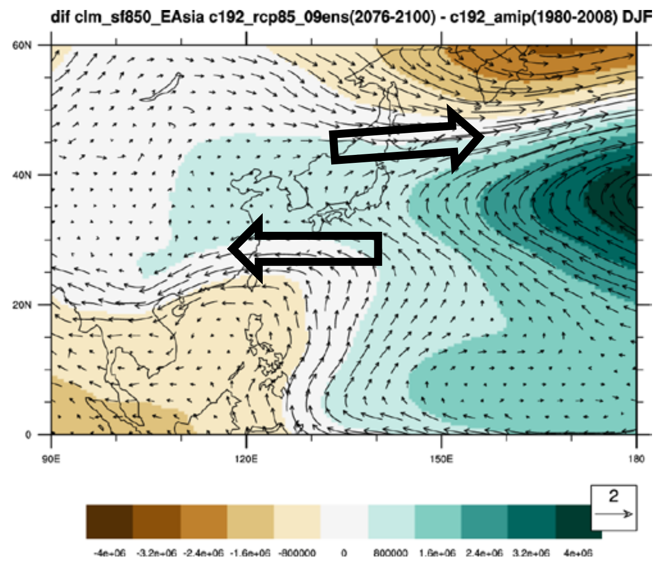

**Velocity Potential 200 hPa**



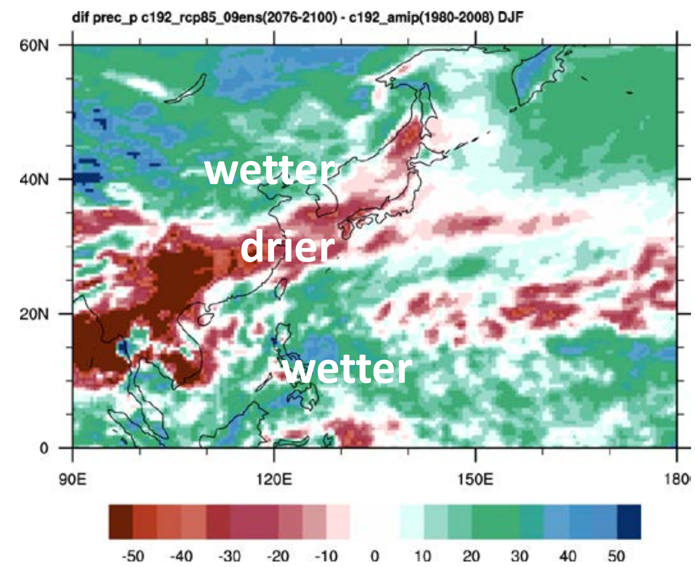

**Streamfunction 200 hPa**

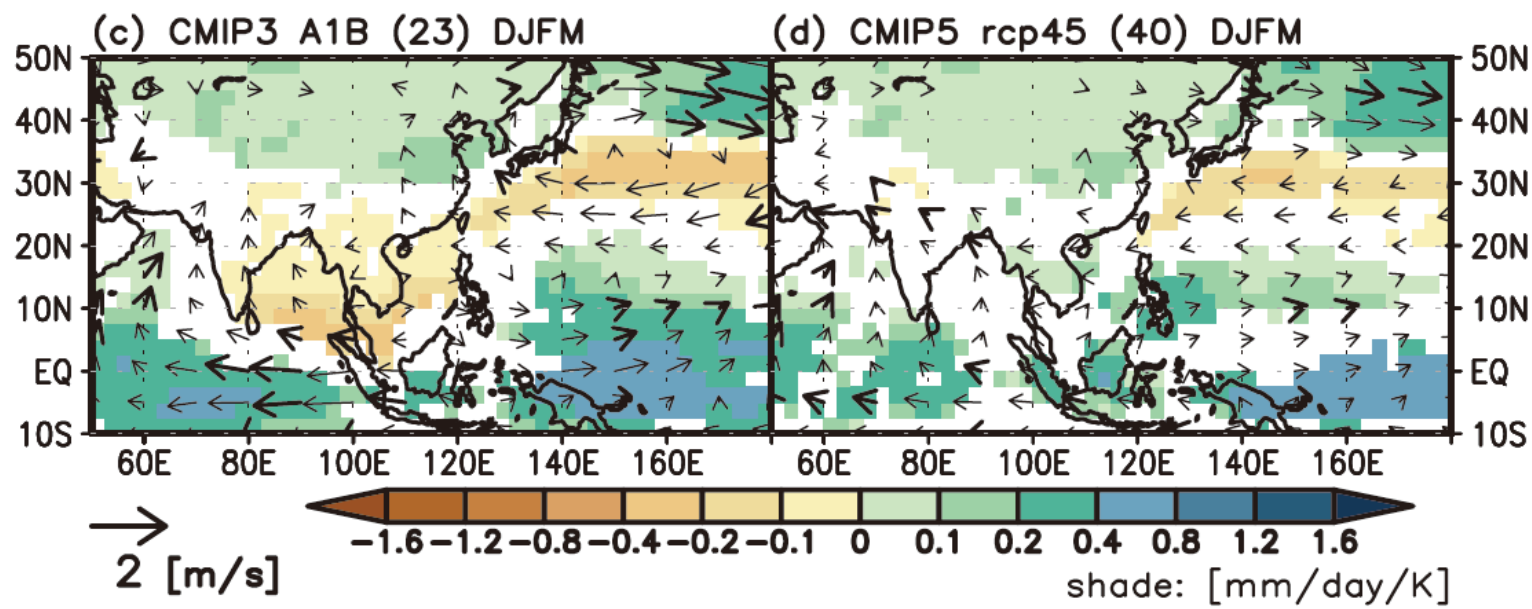


## 850 hPa Stream Function

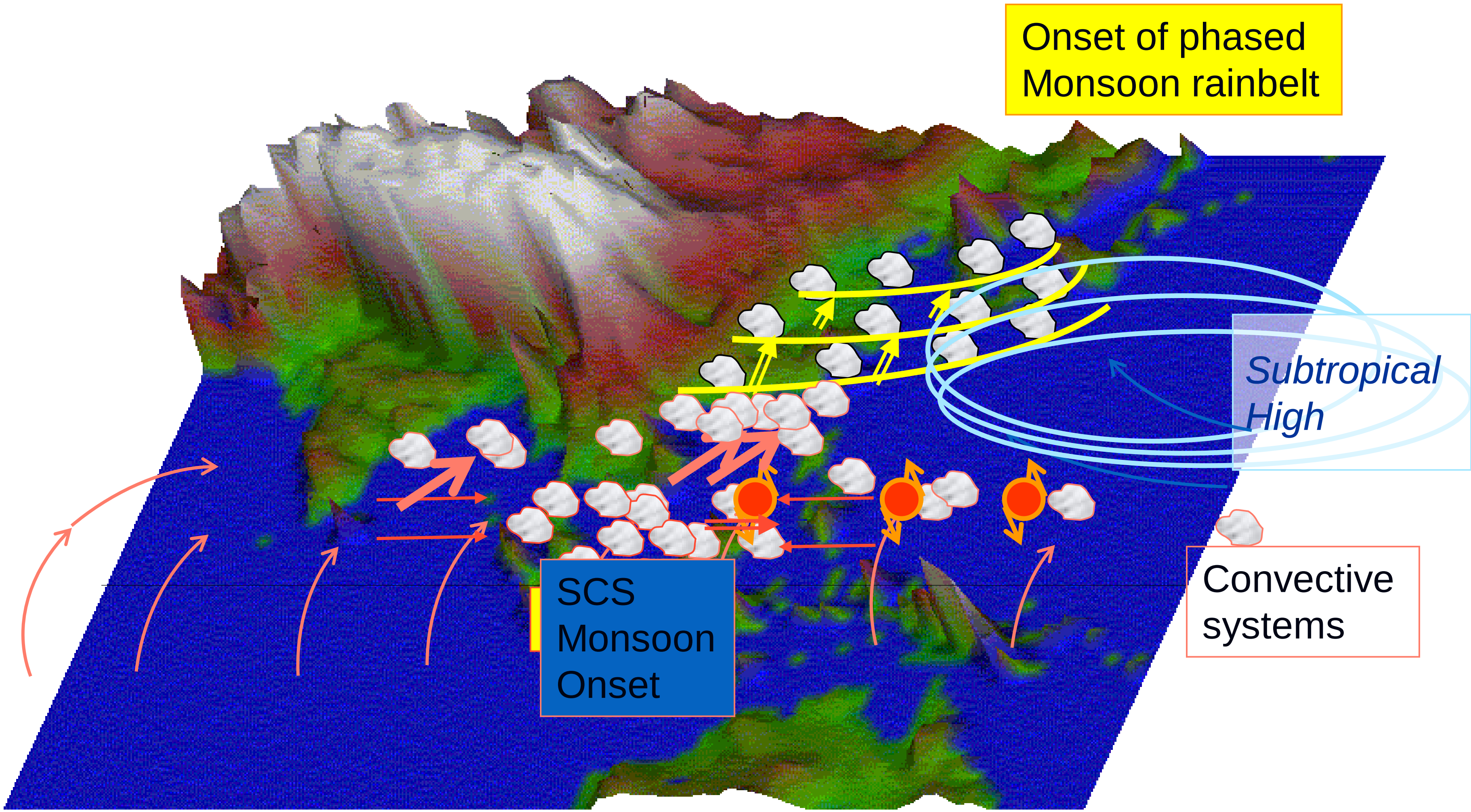



## Precipitation



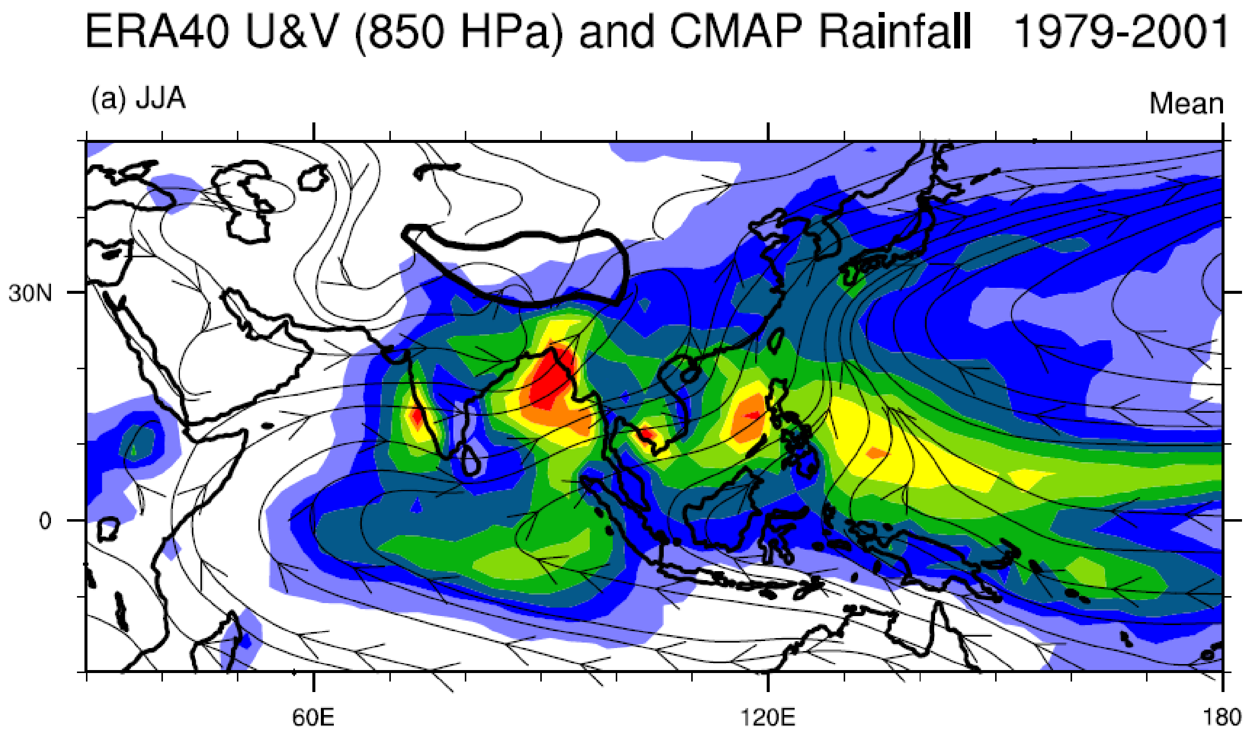
# East Asian Summer Monsoon

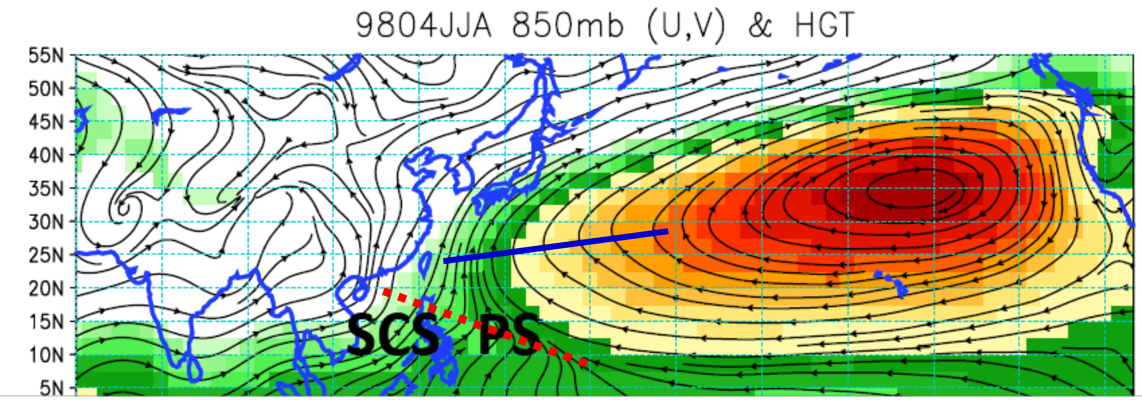



courtesy of C.-P. Chang

# Summer Climate Variability

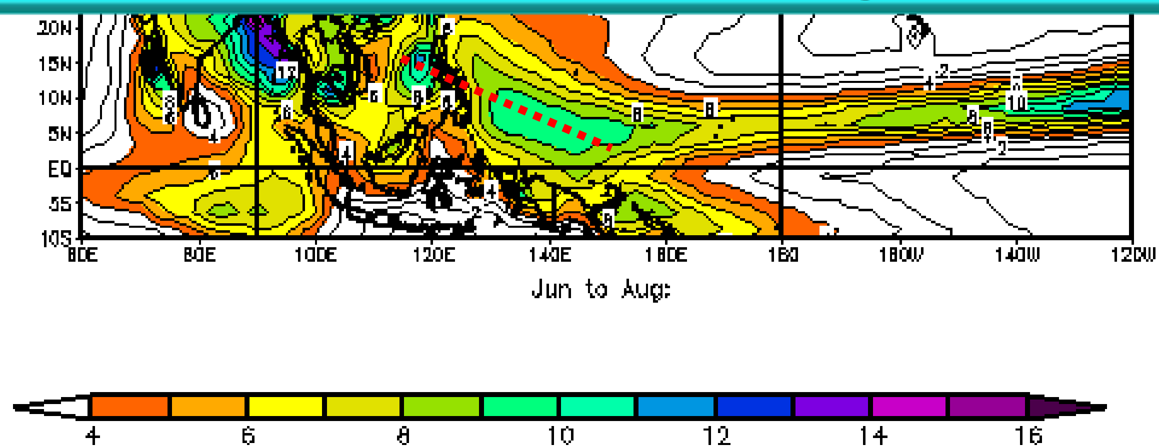
Multiscale Nature; Convection-Circulation coupling






One of key factors affecting weather and climate in the tropical Western North Pacific –

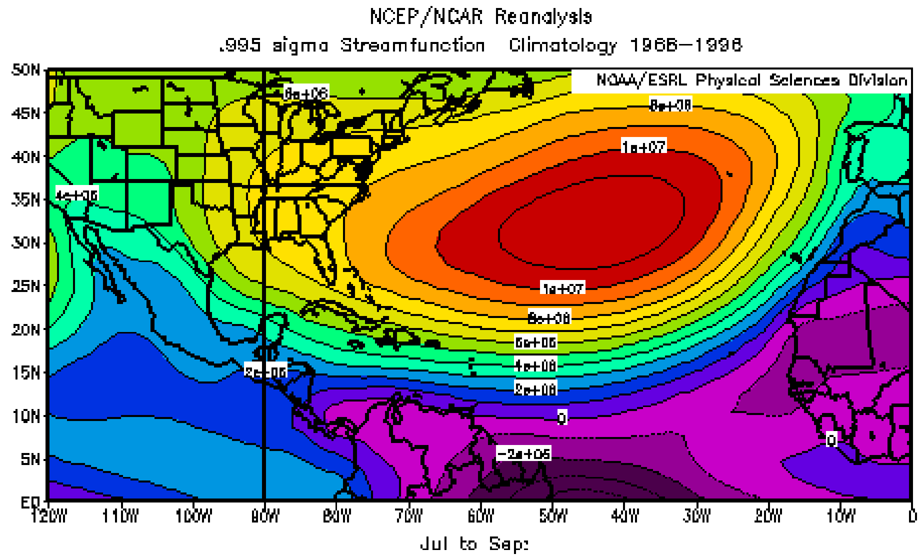
Fluctuation of anticyclonic ridge (ACR) and monsoon trough (MT)



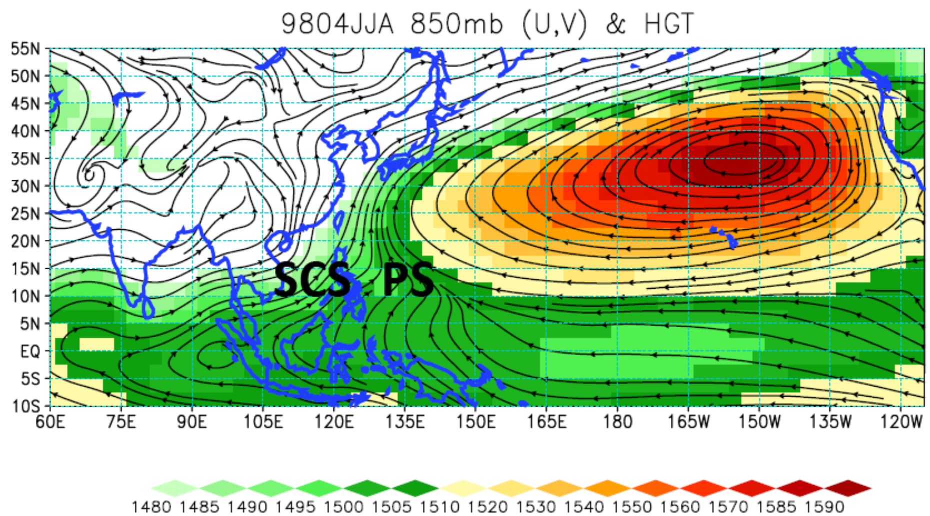
# Interesting Contrast bet. Mean Circulation in North Atlantic/North Amer. and WNP/Asia

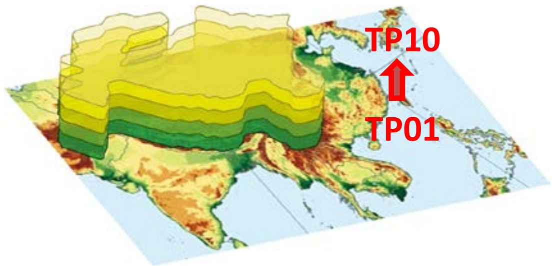
## - No monsoon trough in the NA/NA region

**North Atlantic/ North American**

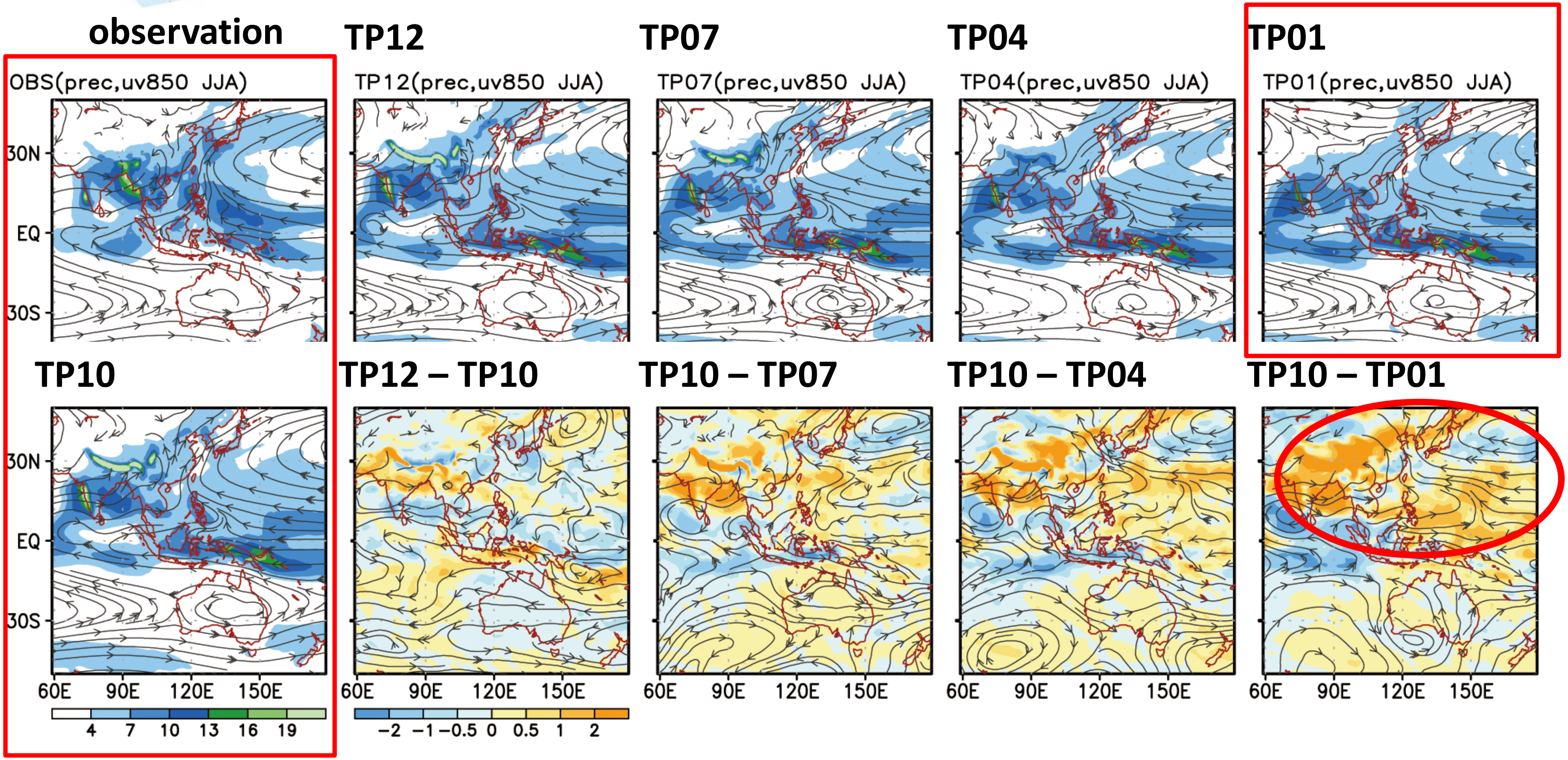



**Western North Pacific**






# Topographic effect enhances summer monsoon flow (trough) and precipitation




## JJA (Precipitation, 850hPa winds)

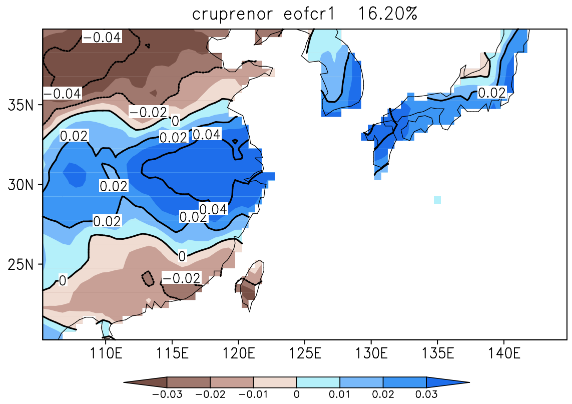
C.-H. Wu

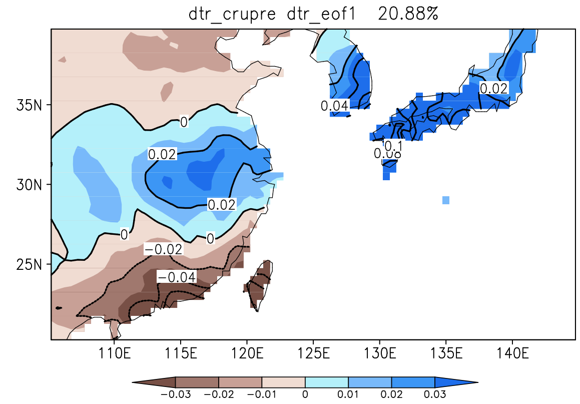
# **Tripolar Rainfall Pattern** (CRU rainfall)

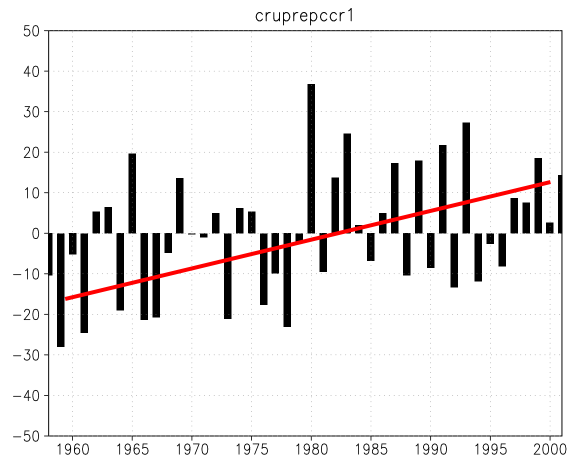
## (**Pacific-Japan Pattern)**

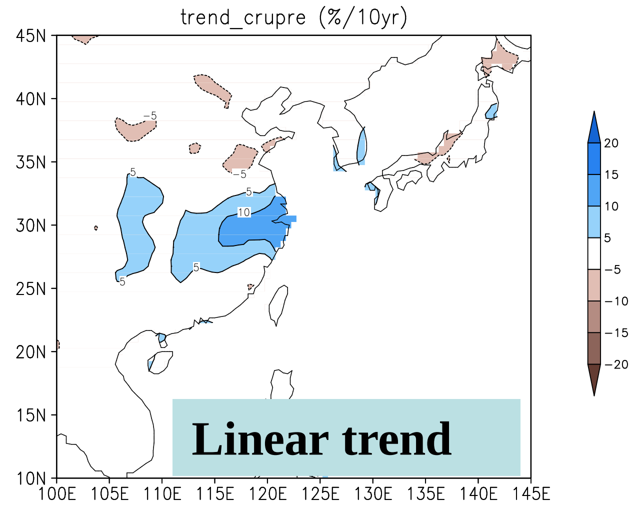
## multiple (cross) time scales and mechanism

**decadal+interannual** **interannual**

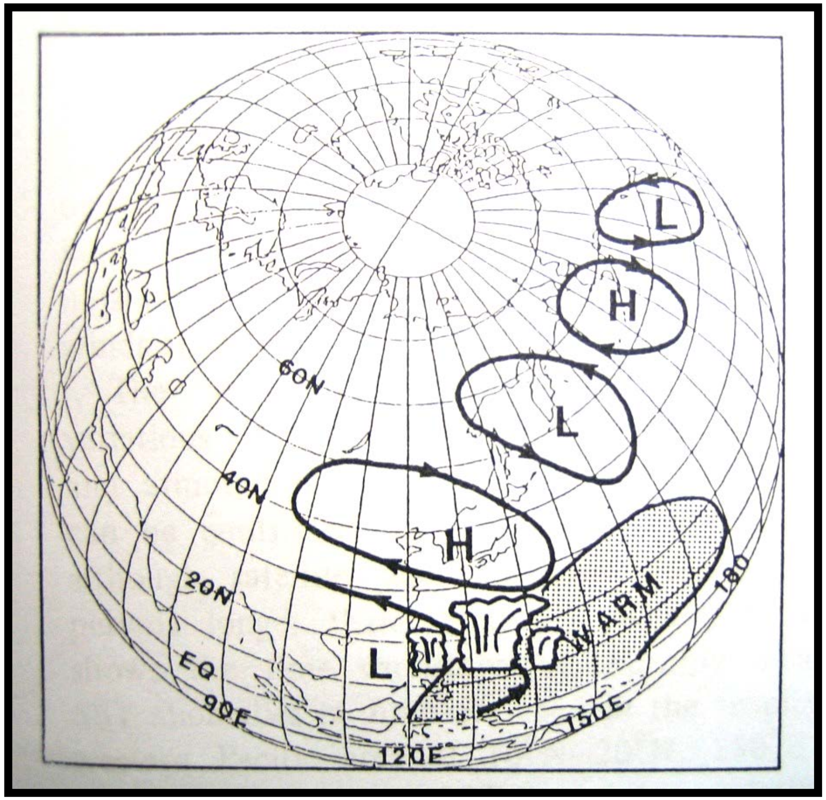


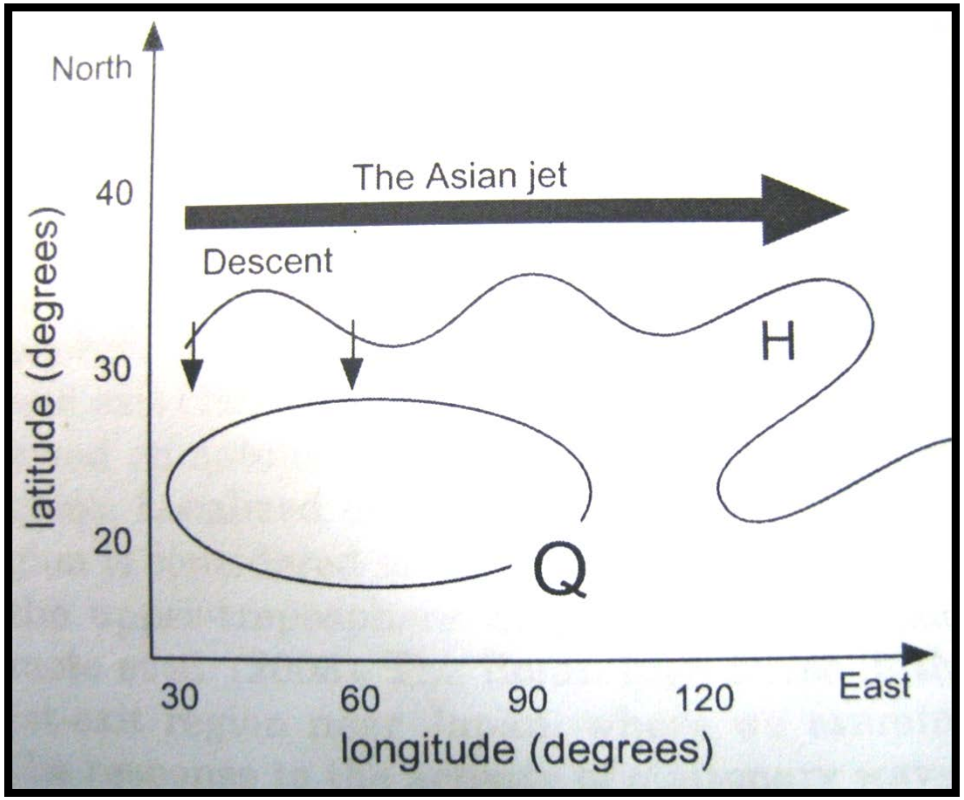



**Nitta (1987) …**
**Pacific Japan Pattern**




**Enomoto et al. (2003) …**
**Silk Road Pattern**



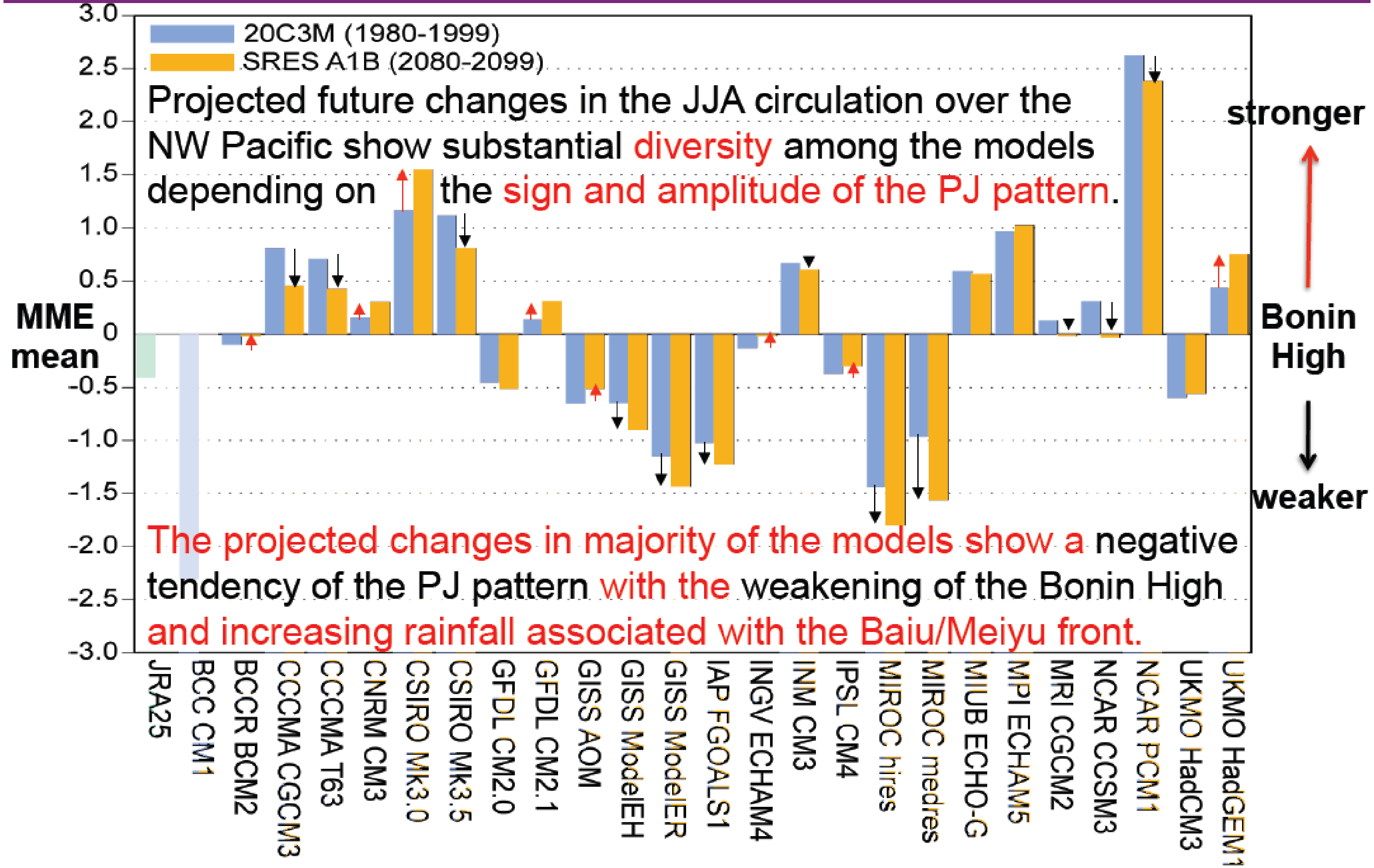

- **Wave-like perturbations forced by tropical WP or Tibetan heating**
- **ENSO effect**
- **Downstream propagation from Eurasian continent**

→ **Can be easily induced by various perturbation and forcing**

→ **Intrinsic mode?** **(Kosaka and Nakamura, Hsu et al., Hirota and Takahashi, …)**

## Projection of model bias and future projection (both from 20C MME climatology) in JJA 850-mb vorticity onto inter-model EOF1 (PJ-signal)

Kosaka, Nakamura (2010, submitted to JC)

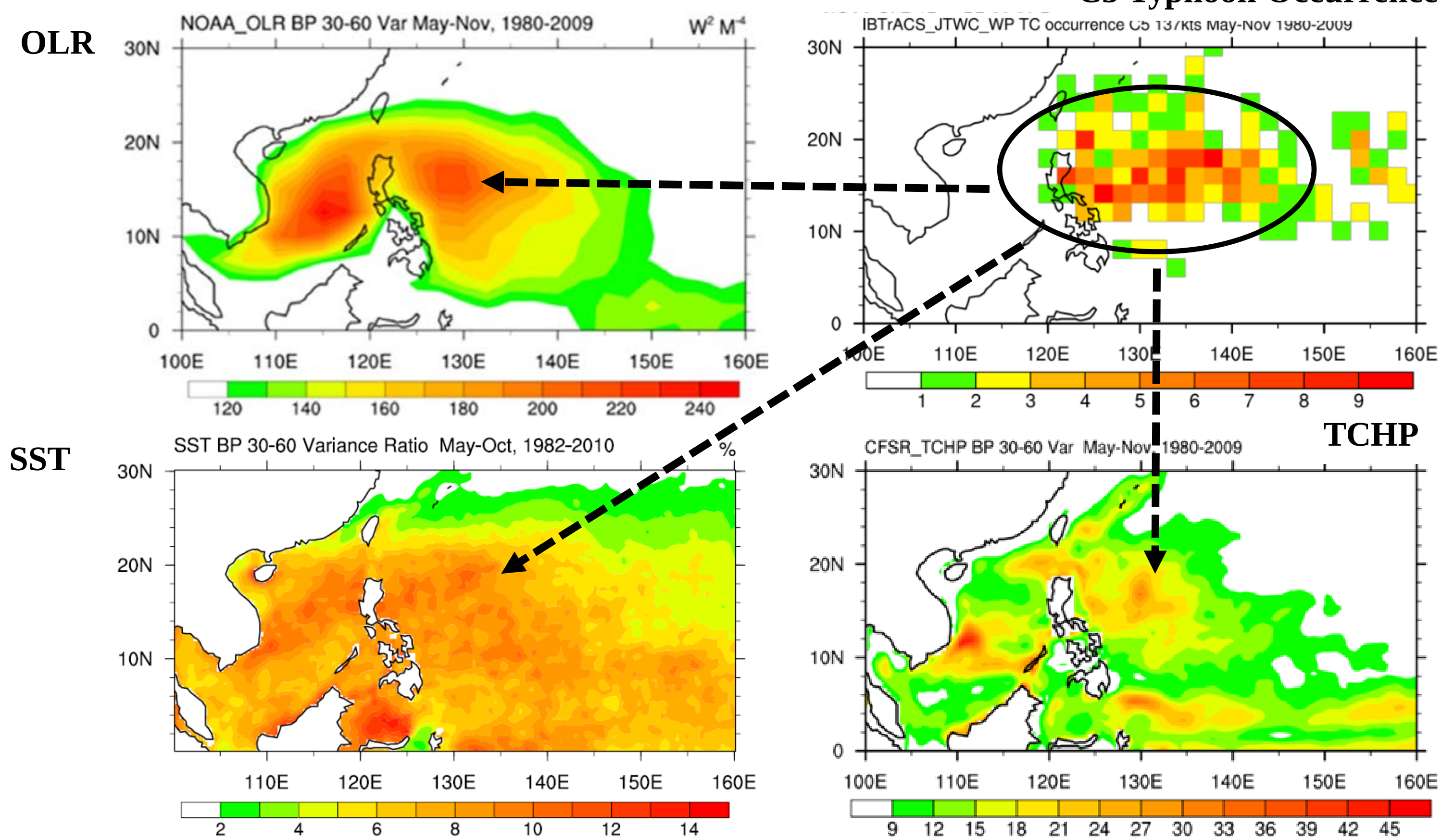



courtesy of Nakamura

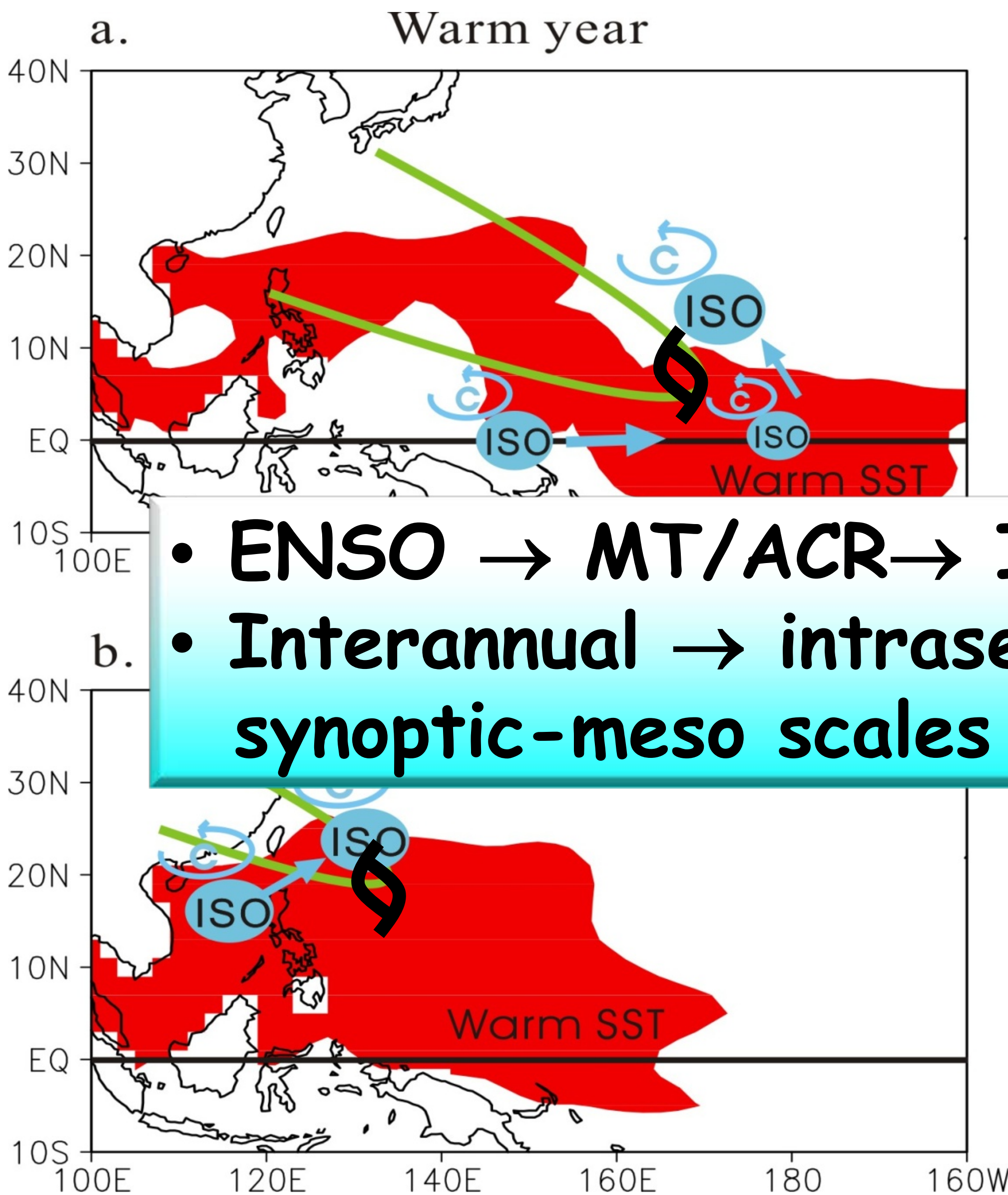
# Multiscale Interaction in the Tropical Western North Pacific

## Hot Spots of A-O coupled Intraseasonal Oscillation (30-60 day) and TC during May-October (Hsu, 2005, 2010)

**C5 Typhoon Occurrence collocated with intraseasonal convection and TCHP variation**




Hsu and Weng, 2001, *J. Climate*; Weng and Hsu, 2017, *GRL*




1. Warm SST extends southeastward.
2. Monsoon trough extends southeastward.
3. 30-60day ISO and TC activity shifts sourtheastward

- **ENSO → MT/ACR→ ISO and TC**
- **Interannual → intraseasonal, synoptic-meso scales**

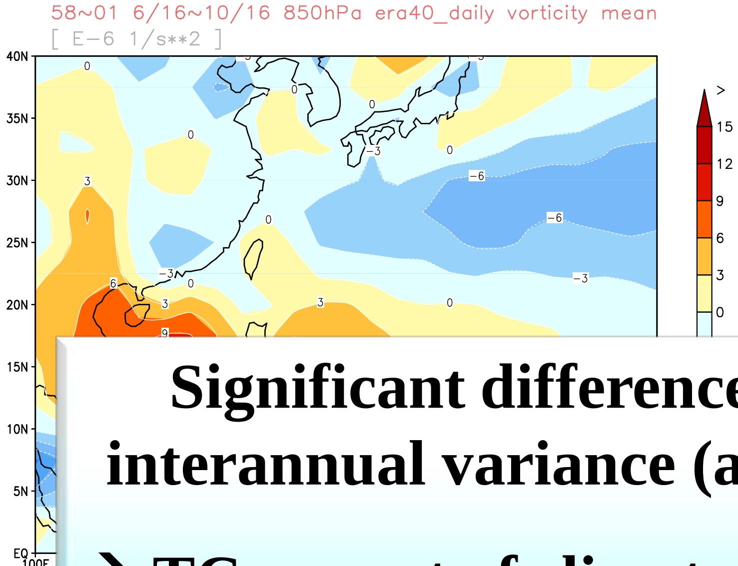
northwestward.

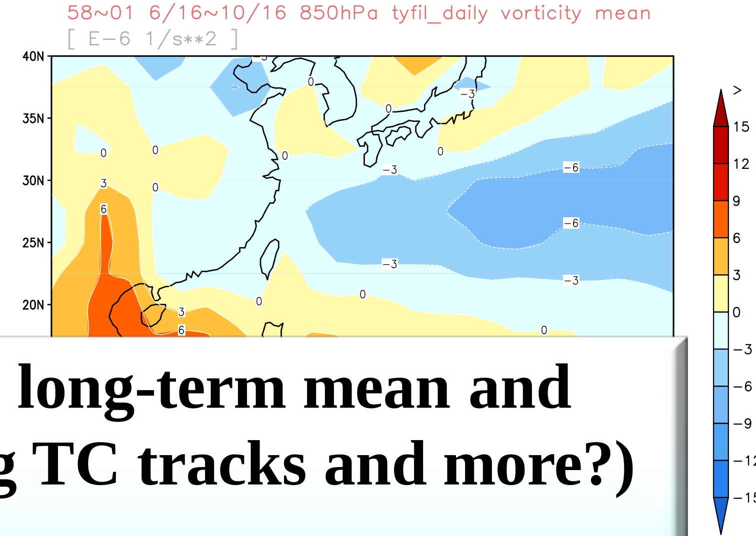
2. Monsoon trough retreats northwestward.
3. 30-60day ISO and TC activity shifts northwestward.

鄒治華(Tsou)、徐邦琪(Hsu)

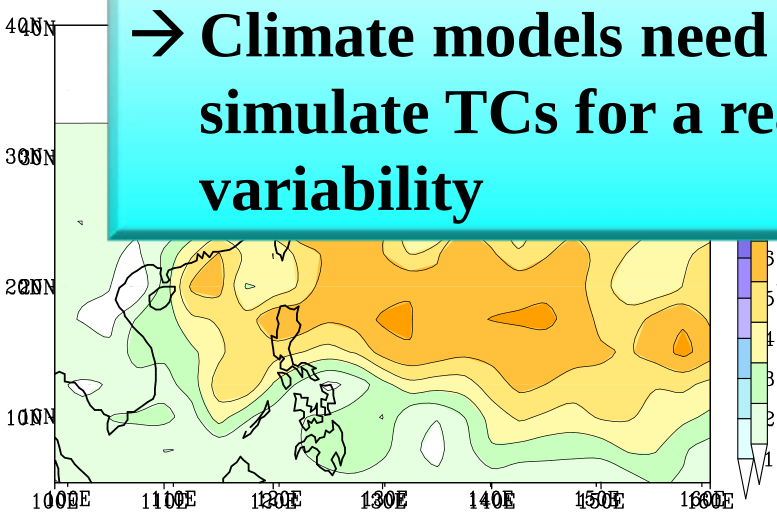
# TC contribution to Climate Variability

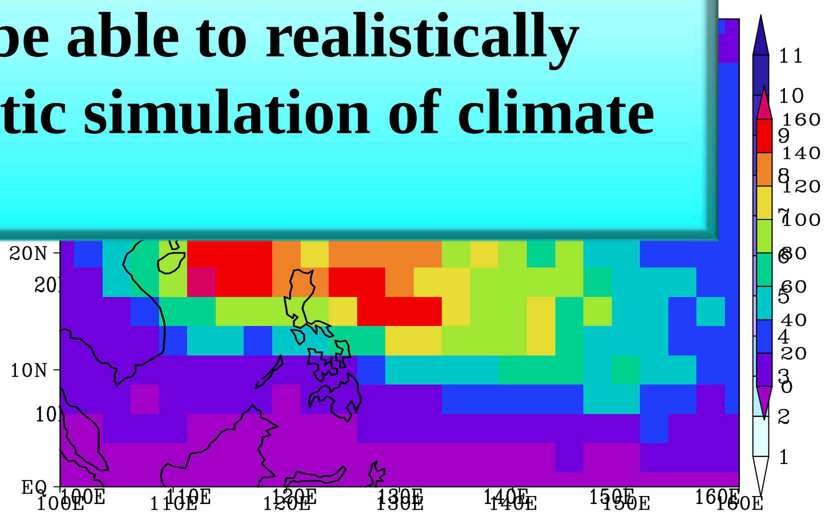
**44-year mean** **original** **1958-2001 JJASO 850 hPa vorticity** **TC-removed** Hsu et al. 2008




**Interannu**





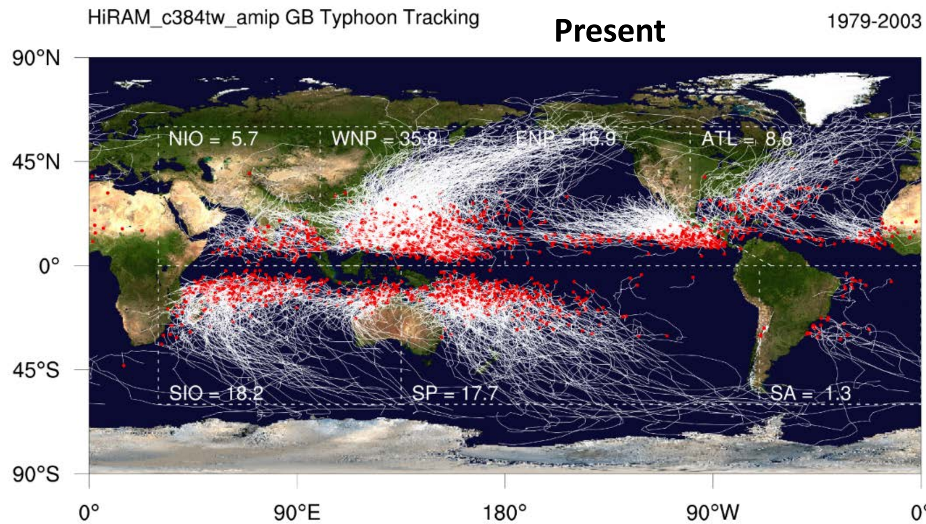
**Significant differences in long-term mean and interannual variance (along TC tracks and more?)**

**→ TC as part of climate variability**

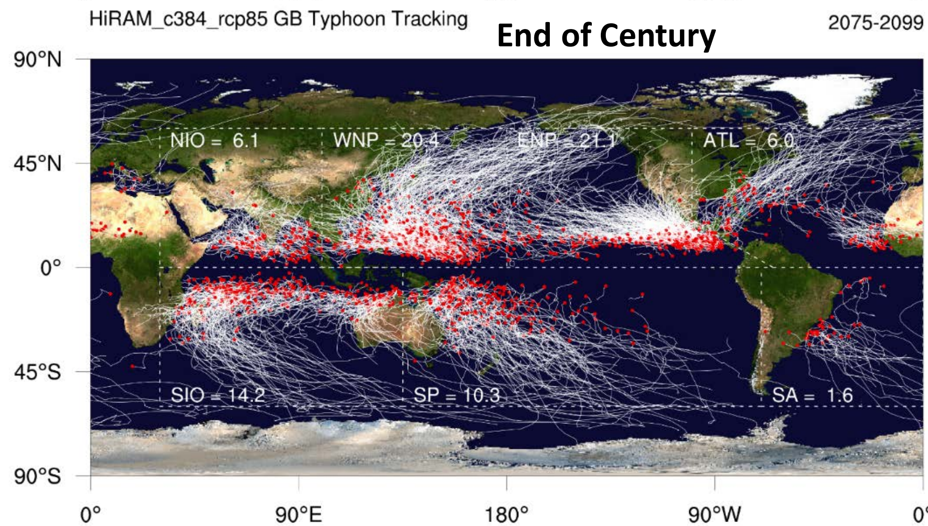
**→ Climate models need to be able to realistically simulate TCs for a realistic simulation of climate variability**

# Future Changes in TC Activity
## (HiRAM)

Present

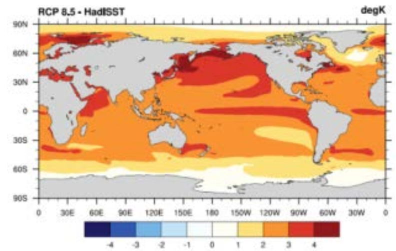



End of Century

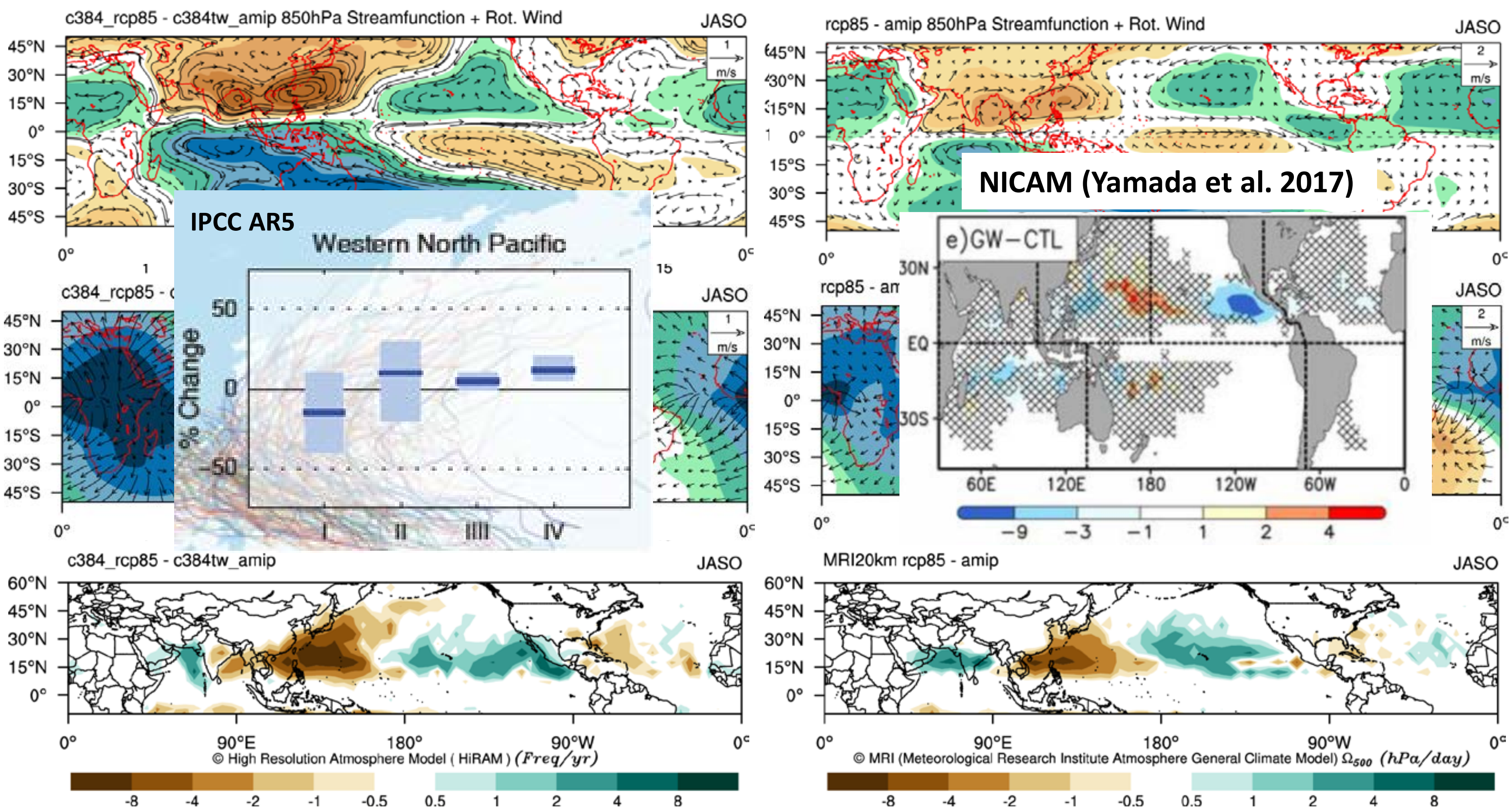



**TC Projection (C384)**
similar in C192

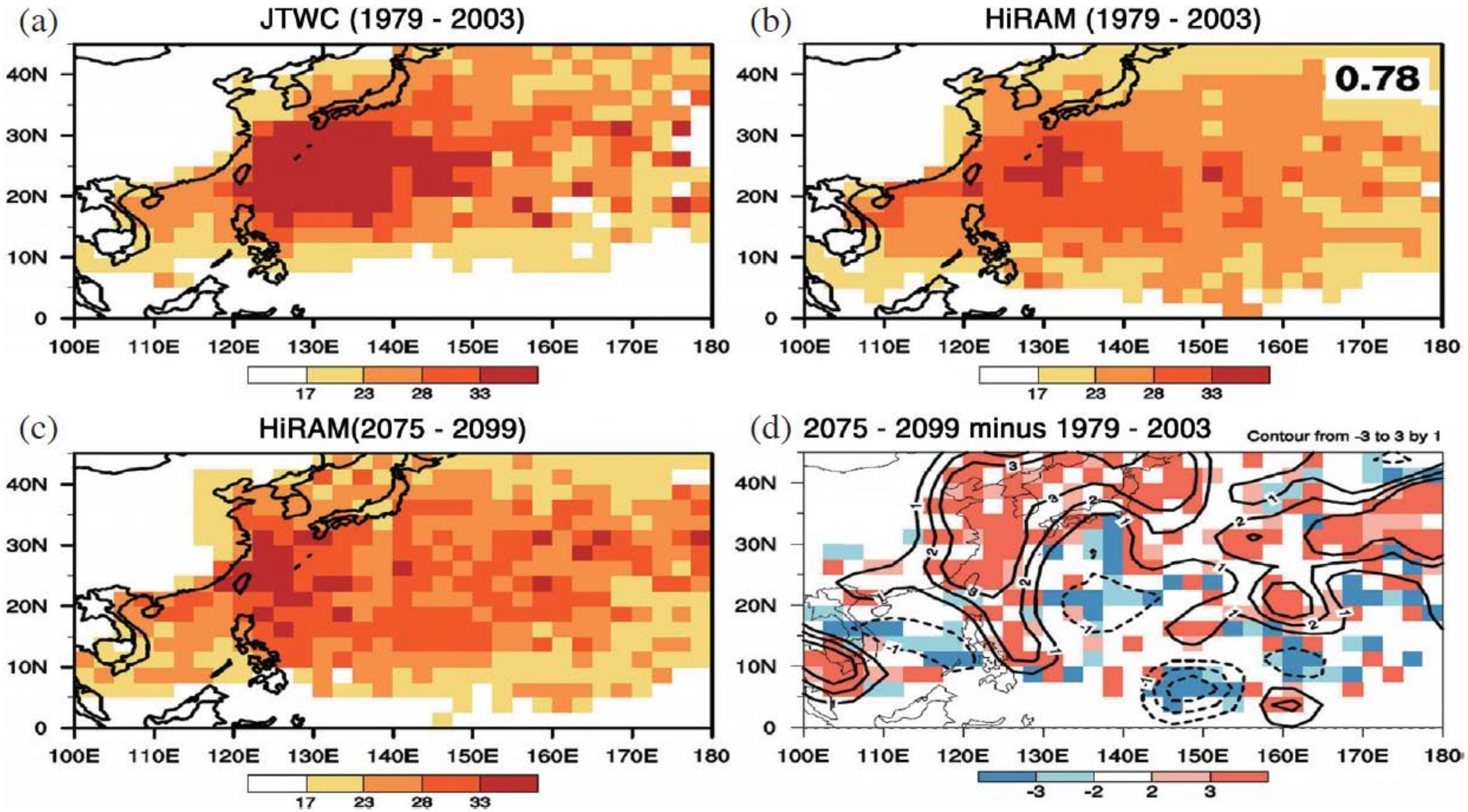
| TC Counts | AMIP | RCP8.5 |
|---|---|---|
| NIO | 5.7 | 6.1 |
| WNP | 35.8 ⇨ | 20.4 |
| ENP | 15.9 | 21.1 |
| ATL | 8.6 | 6.0 |
| SIO | 18.2 | 14.2 |
| SP | 17.7 | 10.3 |
| SA | 1.3 | 1.6 |




# HiRAM C384 vs. MRI AGCM20km



# TS intensity distribution (JJASON)



# Changes in ISO and TC genesis in the western North Pacific

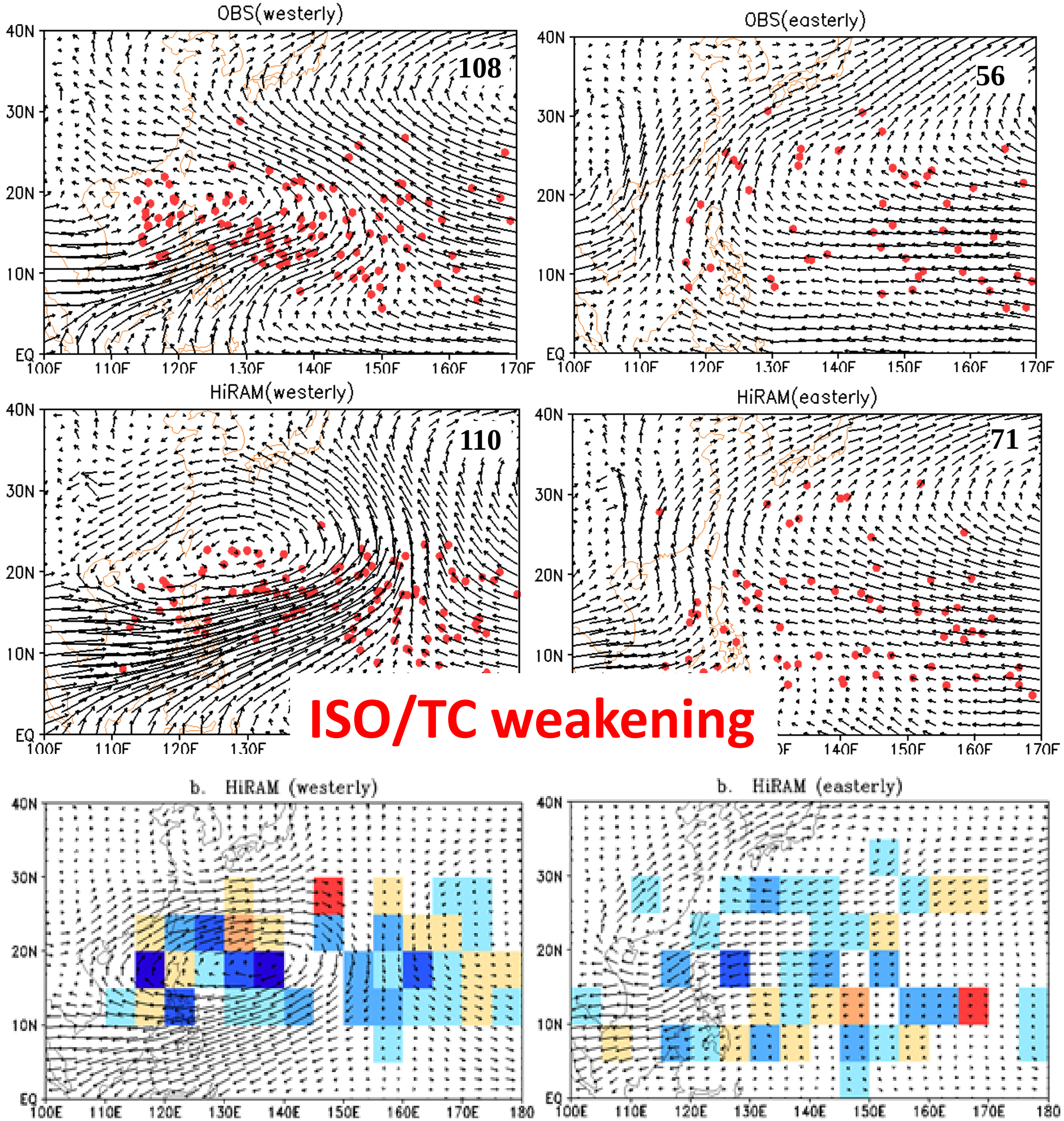
**(Jul.-Sept.)**

**ISO Westerly phase** | **ISO Easterly phase**

**JTWC**

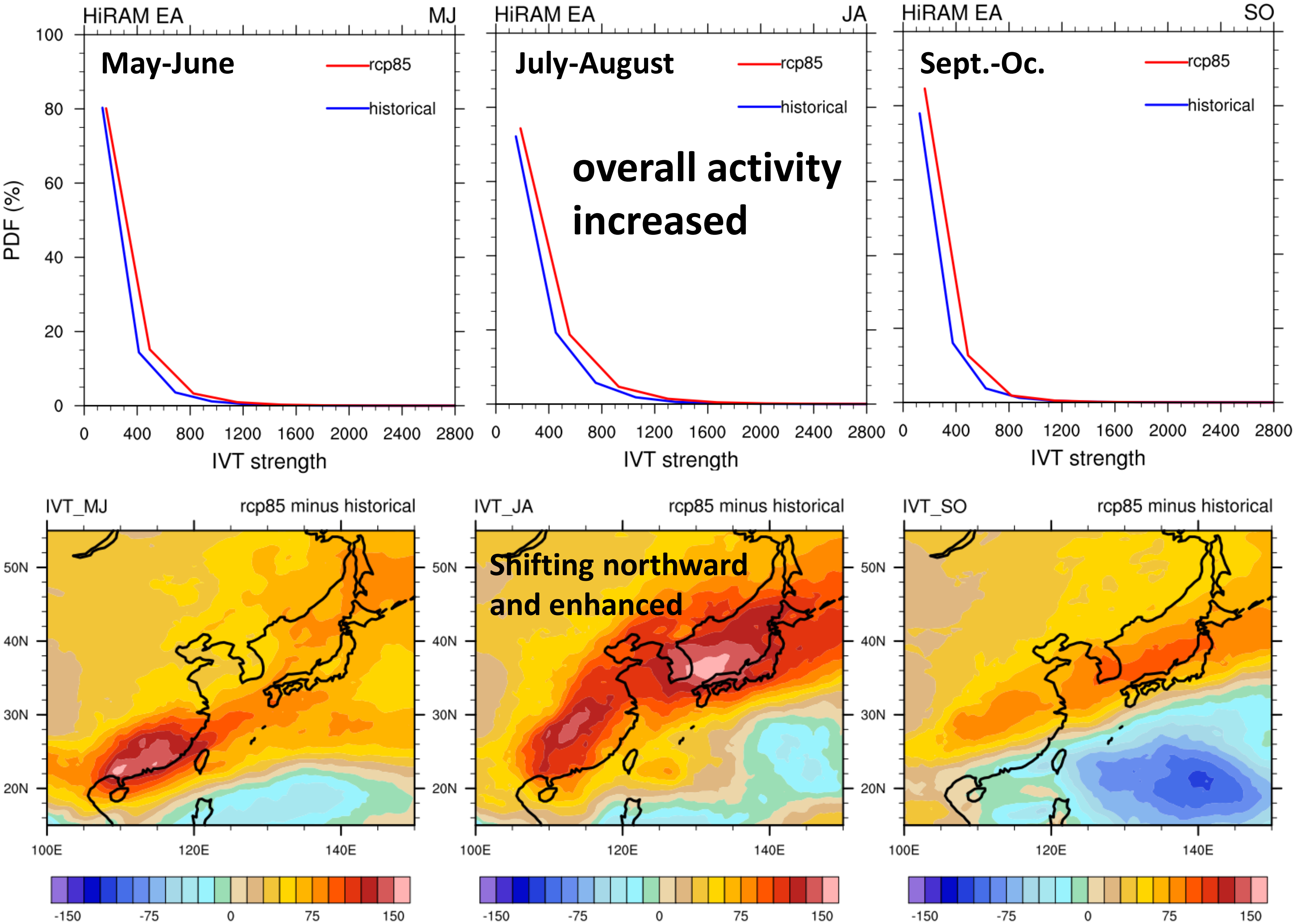
**HiRAM**

**2075-2099**
**Minus**
**1979-2003**

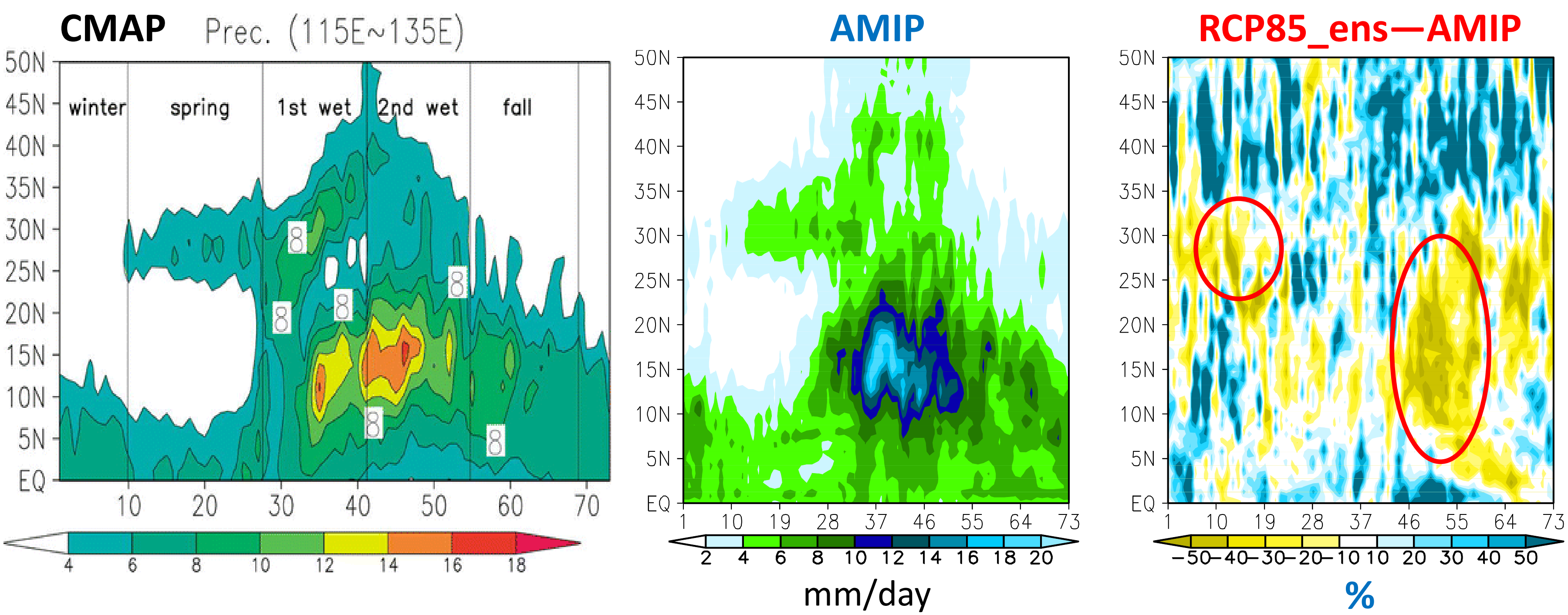



(C.-H. Tsou)

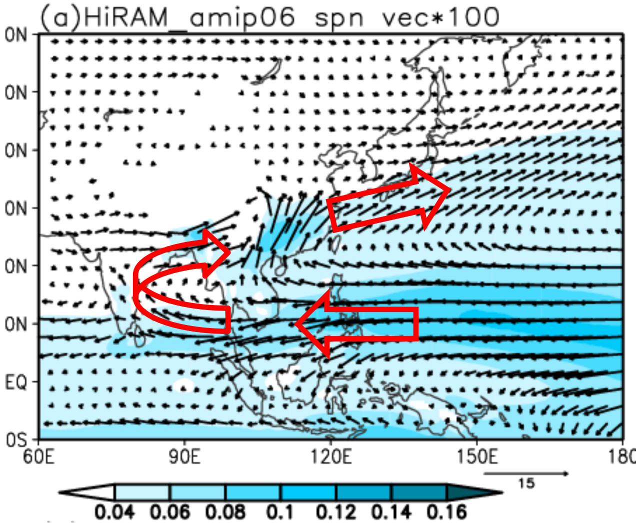
# Changes in Atmospheric River Activity

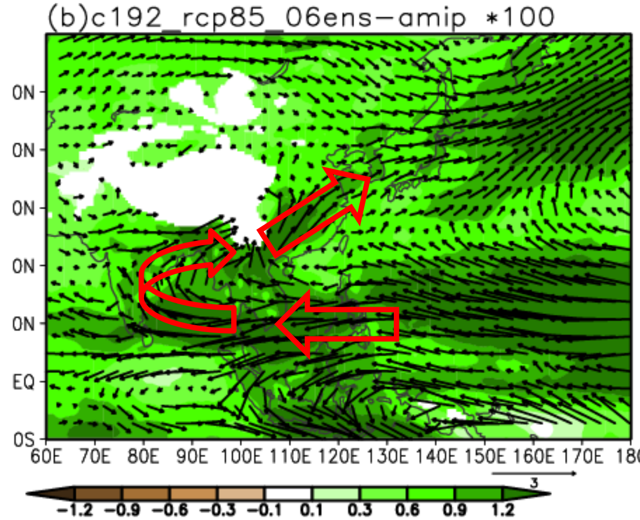


# Changes in Annual Precipitation Cycle Projected by HiRAM



# Spring 2/15-5/15

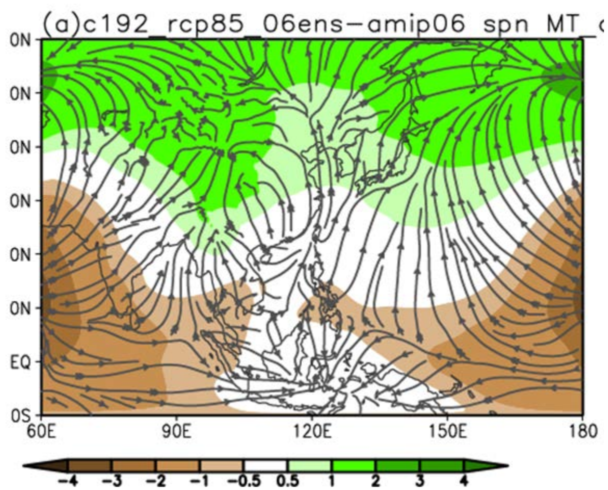



## Enhanced anticyclonic circulation and moisture transport

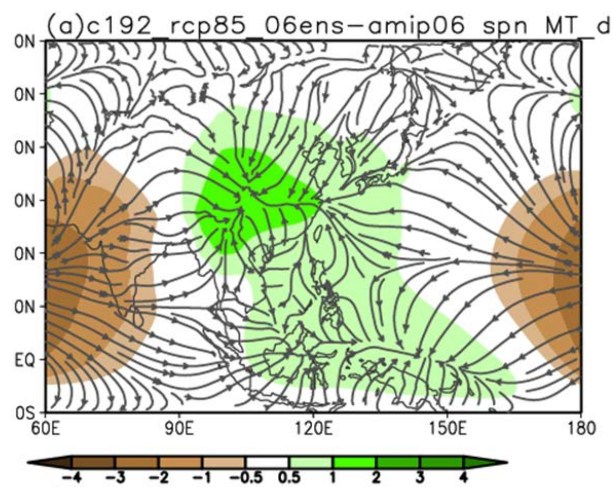
850hPa moisture transport
vector: uq,vq
shading: $(uq^2+vq^2)^{1/2}$

**850hPa moisture transport**

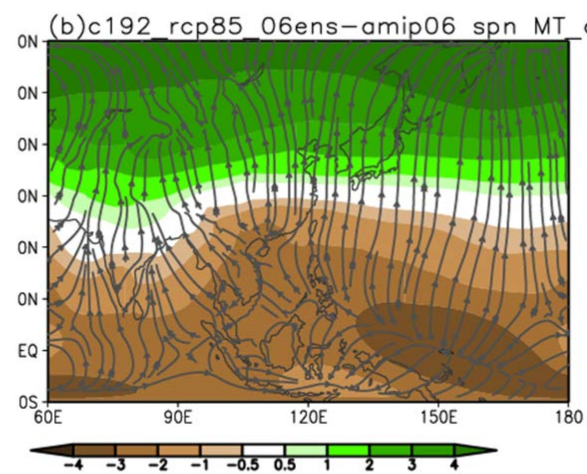


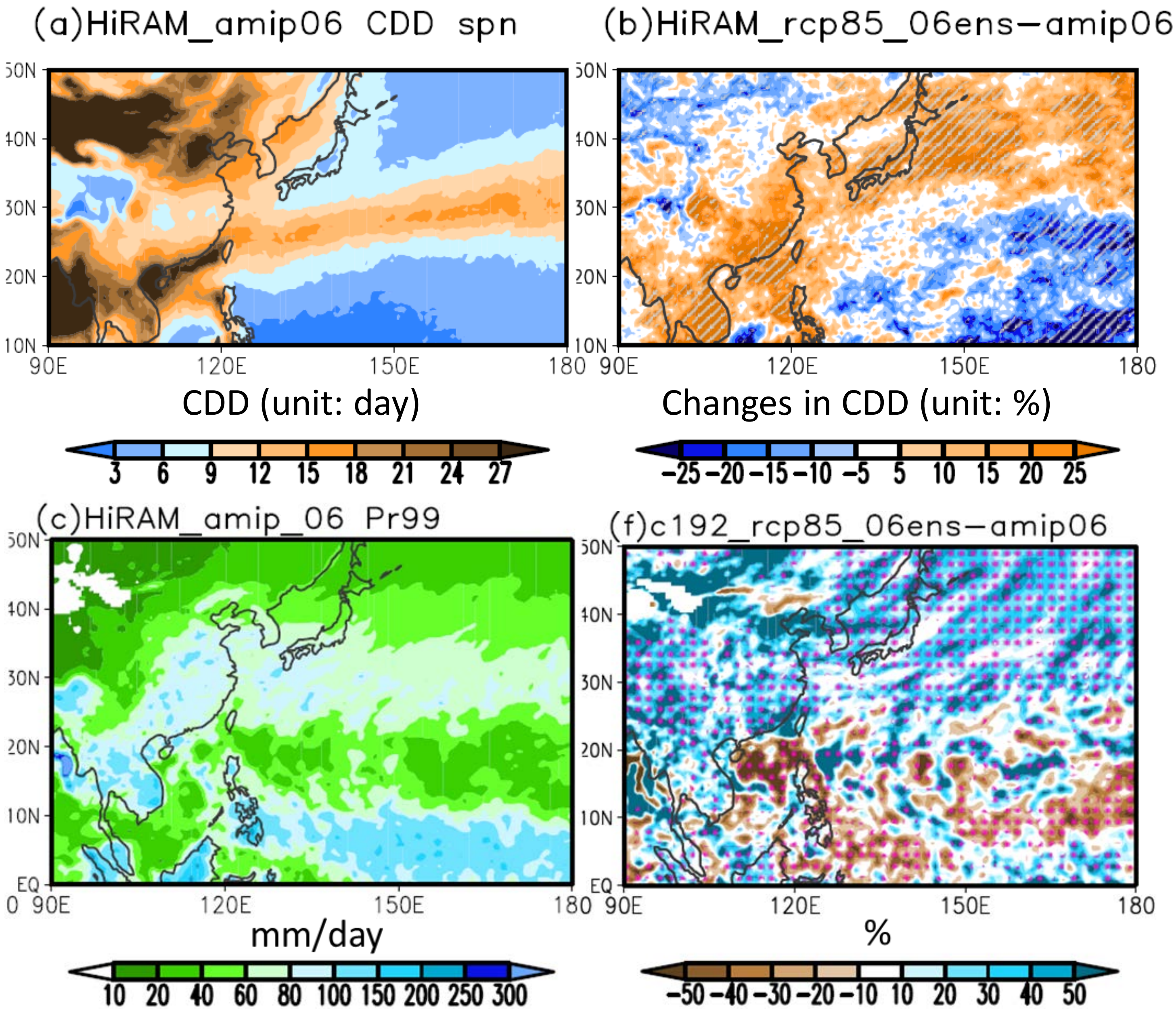

**Difference associated with**

**thermodynamic part (increased q)**




**dynamic part (changes in u,v)**



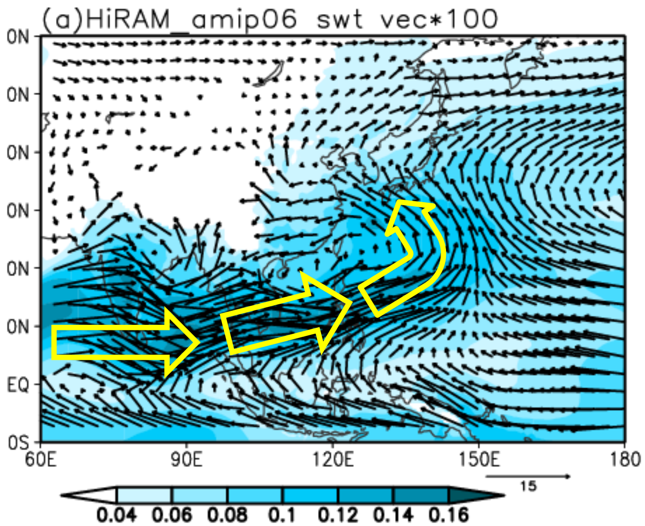


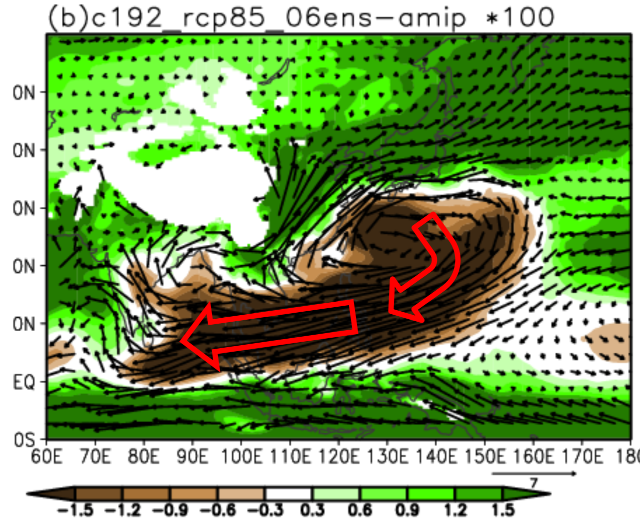

**Spring CDD**

**Extreme Rainfall (Pr99)**

Hatched regions: 5% significance

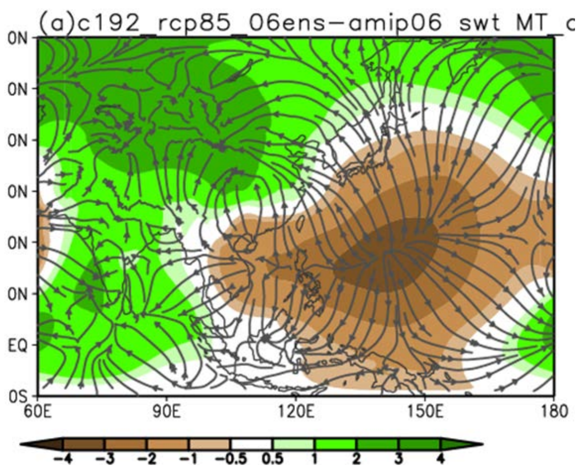
# Typhoon Season 7/25-9/27



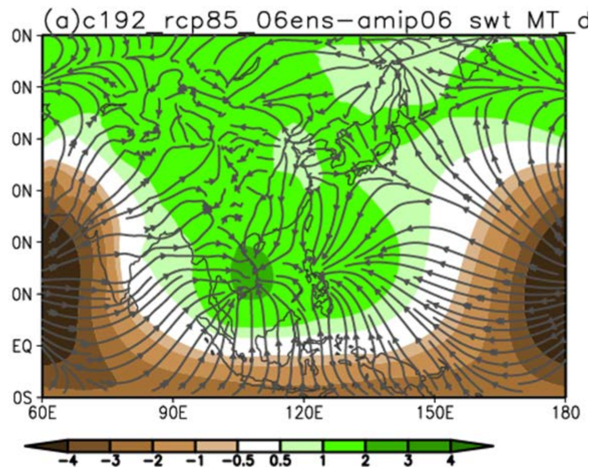

850hPa moisture transport
vector: uq,vq
shading: $(uq^2+vq^2)^{1/2}$

**850hPa moisture transport**

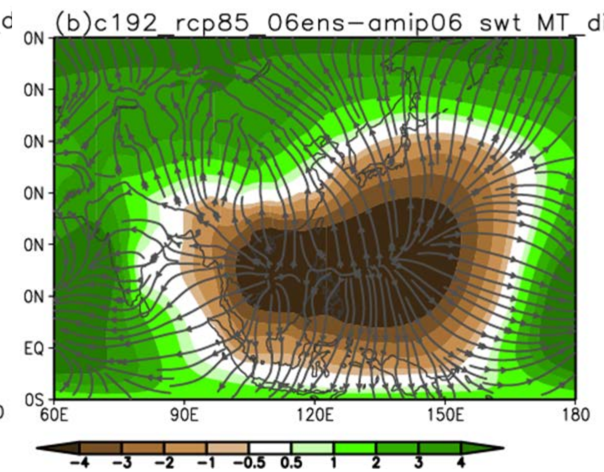


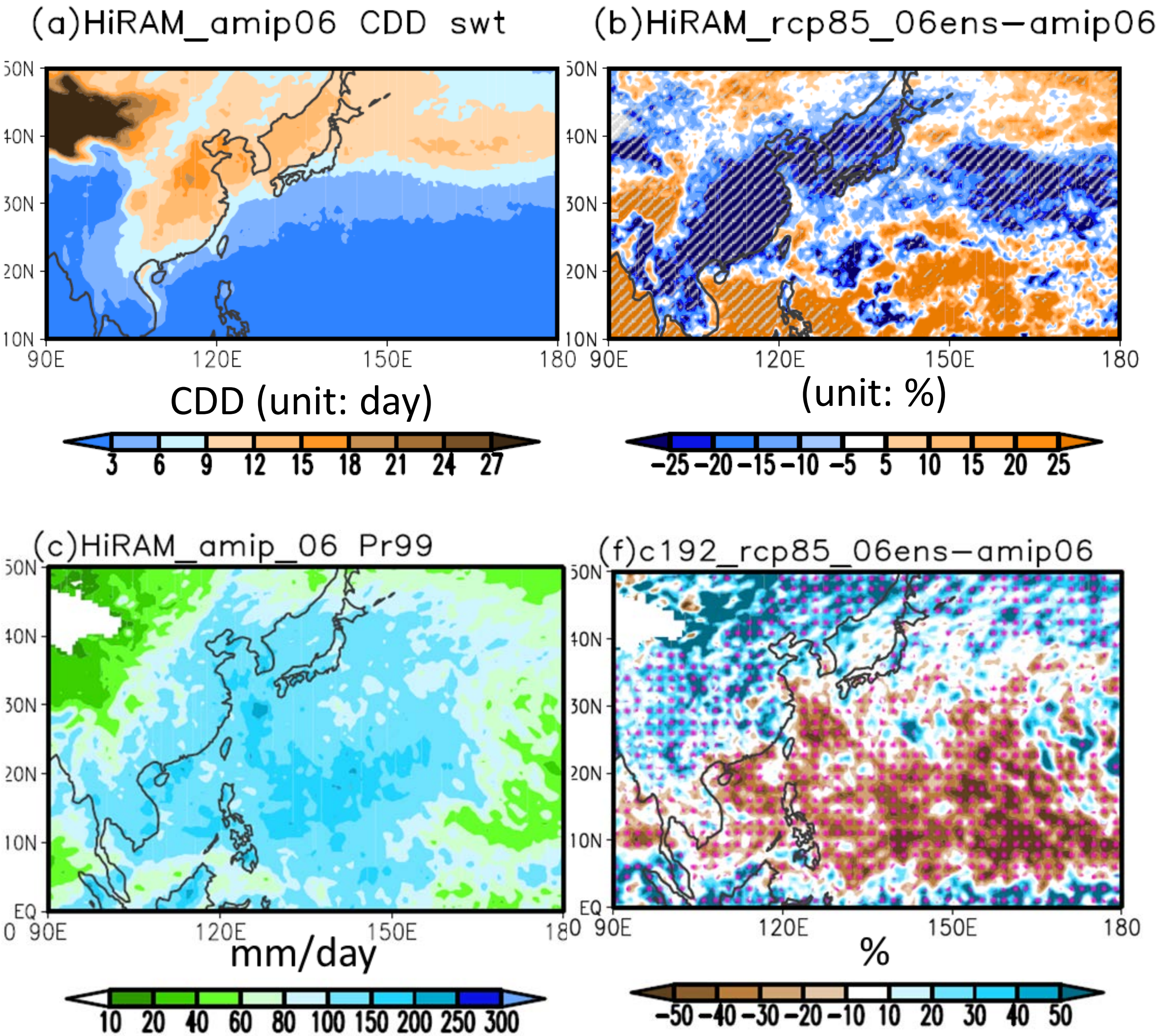

**Difference associated with**

**thermodynamic part (increased q)**




**dynamic part (changes in u,v)**






**Typhoon Season CDD**

**Extreme Rainfall (Pr99)**

Hatched regions: 5% significance

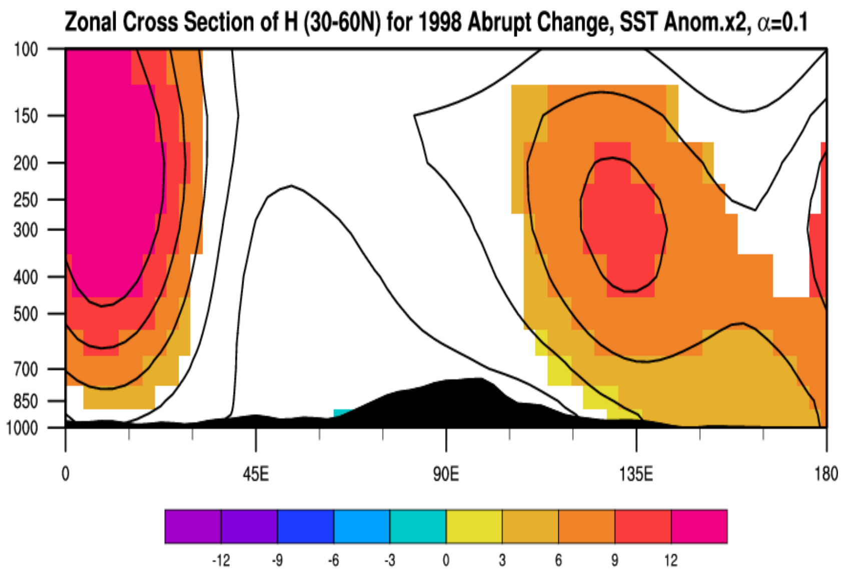
# Thank you for Your Attention
# Questions and Comments?

TCCIP
Taiwan Climate Change projection and adaptation Information Platform

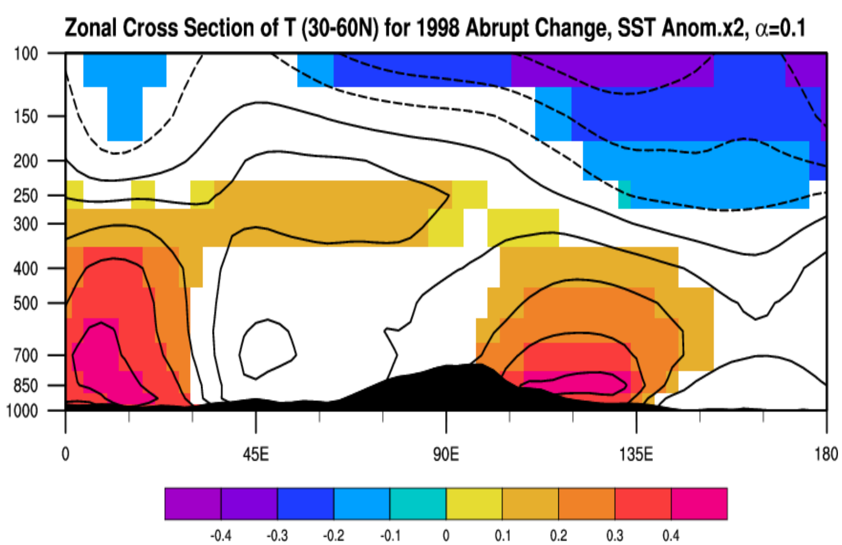
LABORATORY FOR CLIMATE CHANGE RESEARCH
CCliCS

# SSTA×2 simulation

## Geopotential height

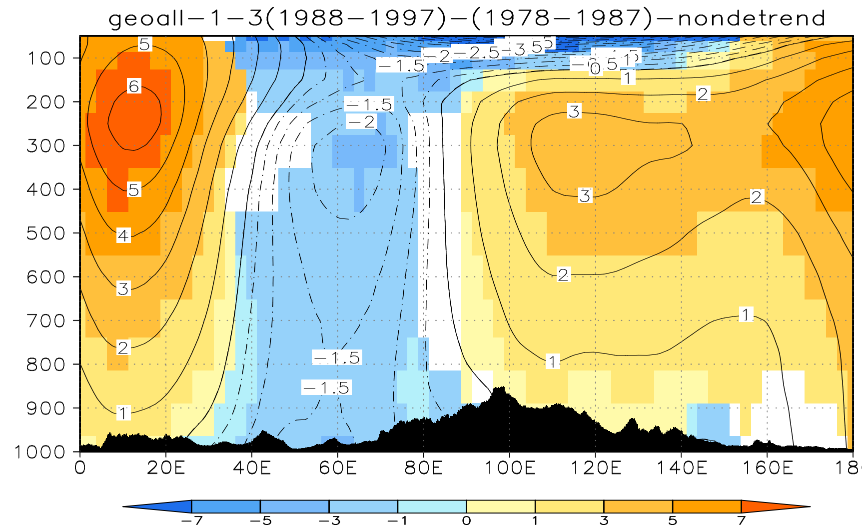



## Temperature

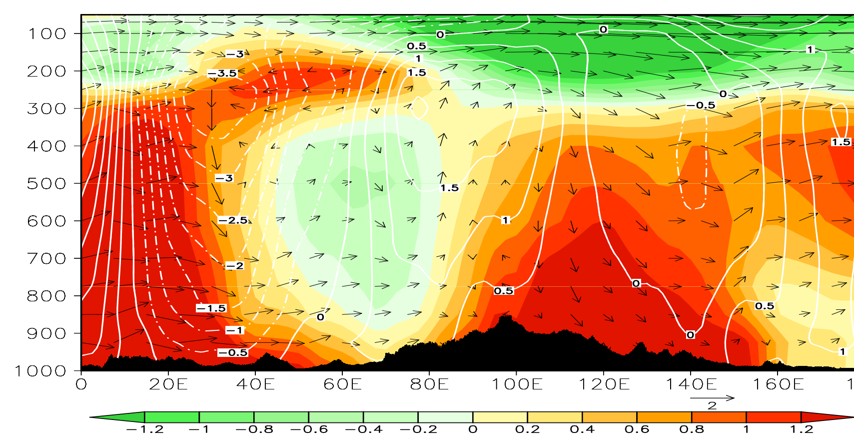



# Observation

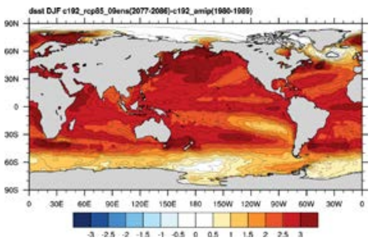
## Geopotential height

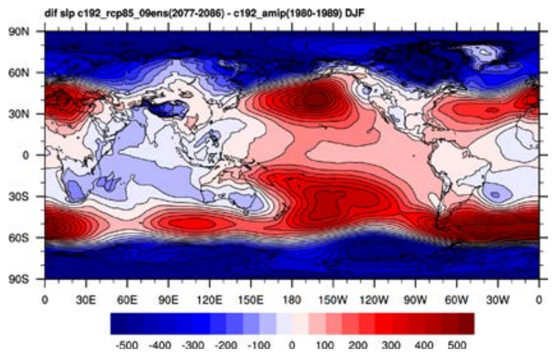


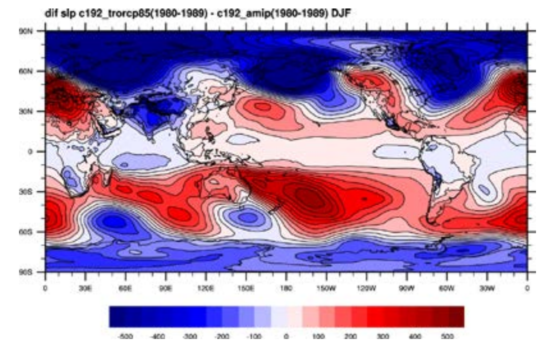

## Temperature

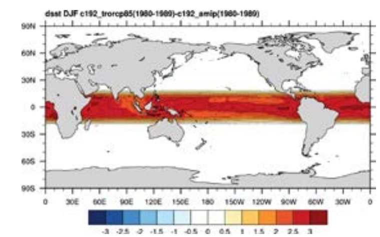


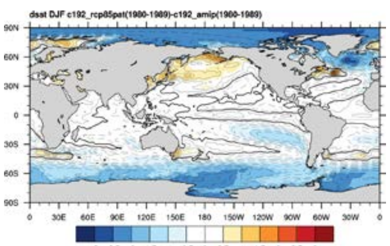
# Relative Contribution of SST Anomaly Pattern

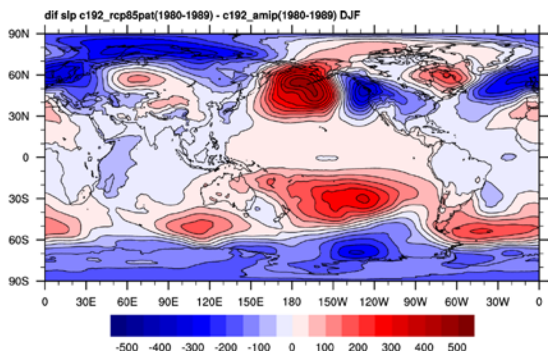


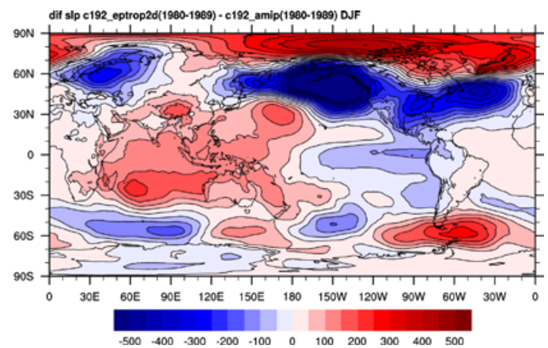



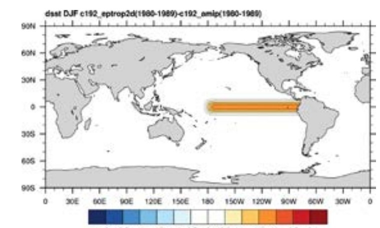



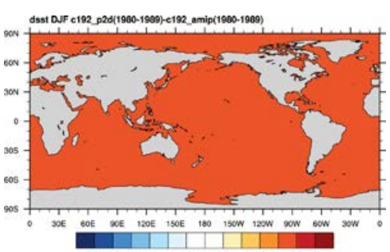



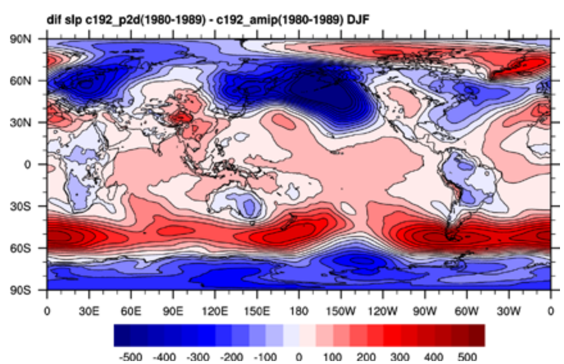



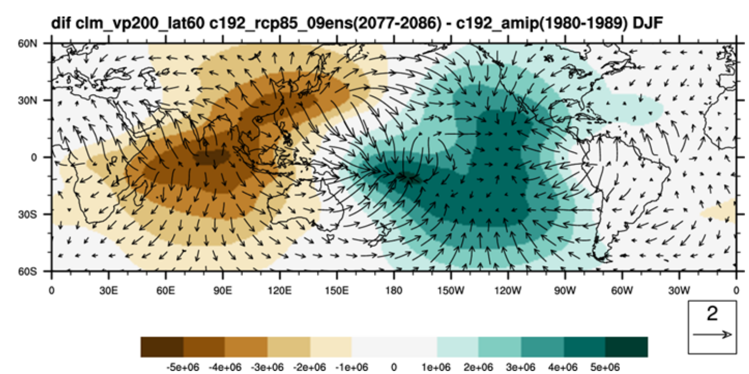



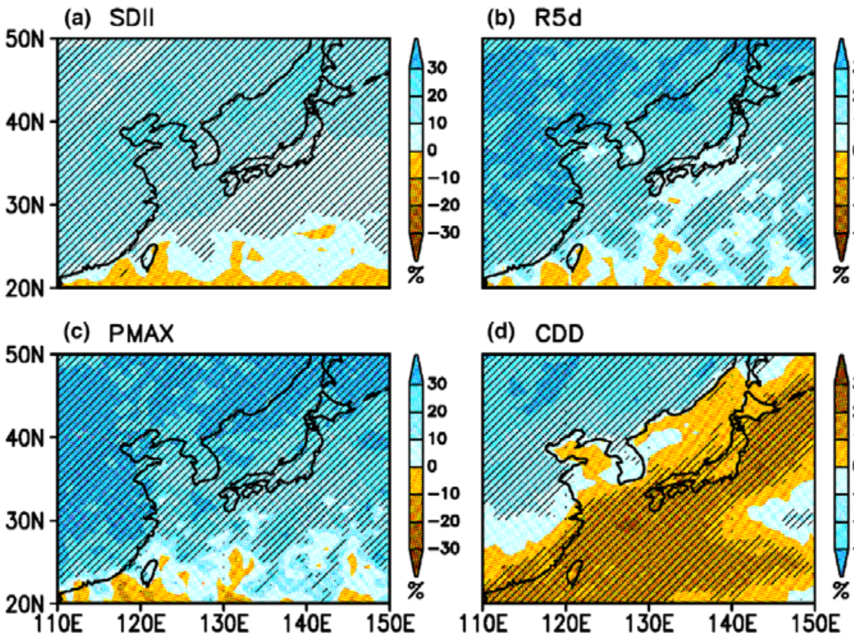




**El Nino-like effect suppressed by Indian warming effect**



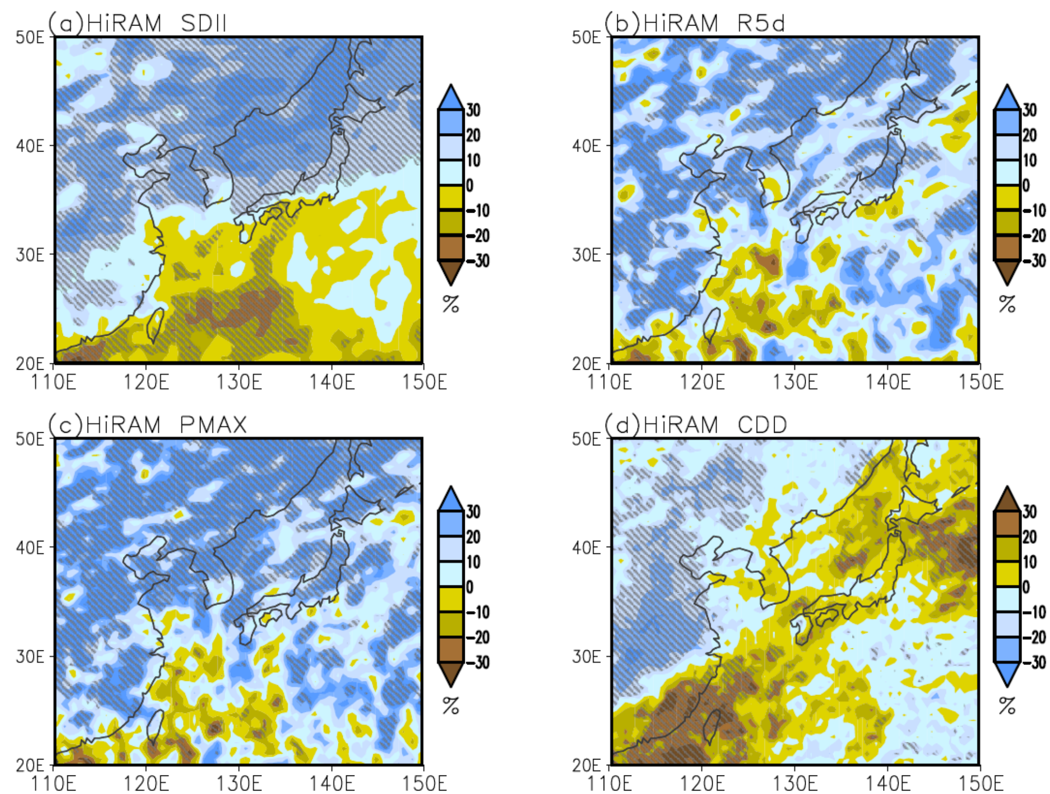
# Extreme Precipitation Comparison between MRI and HiRAM



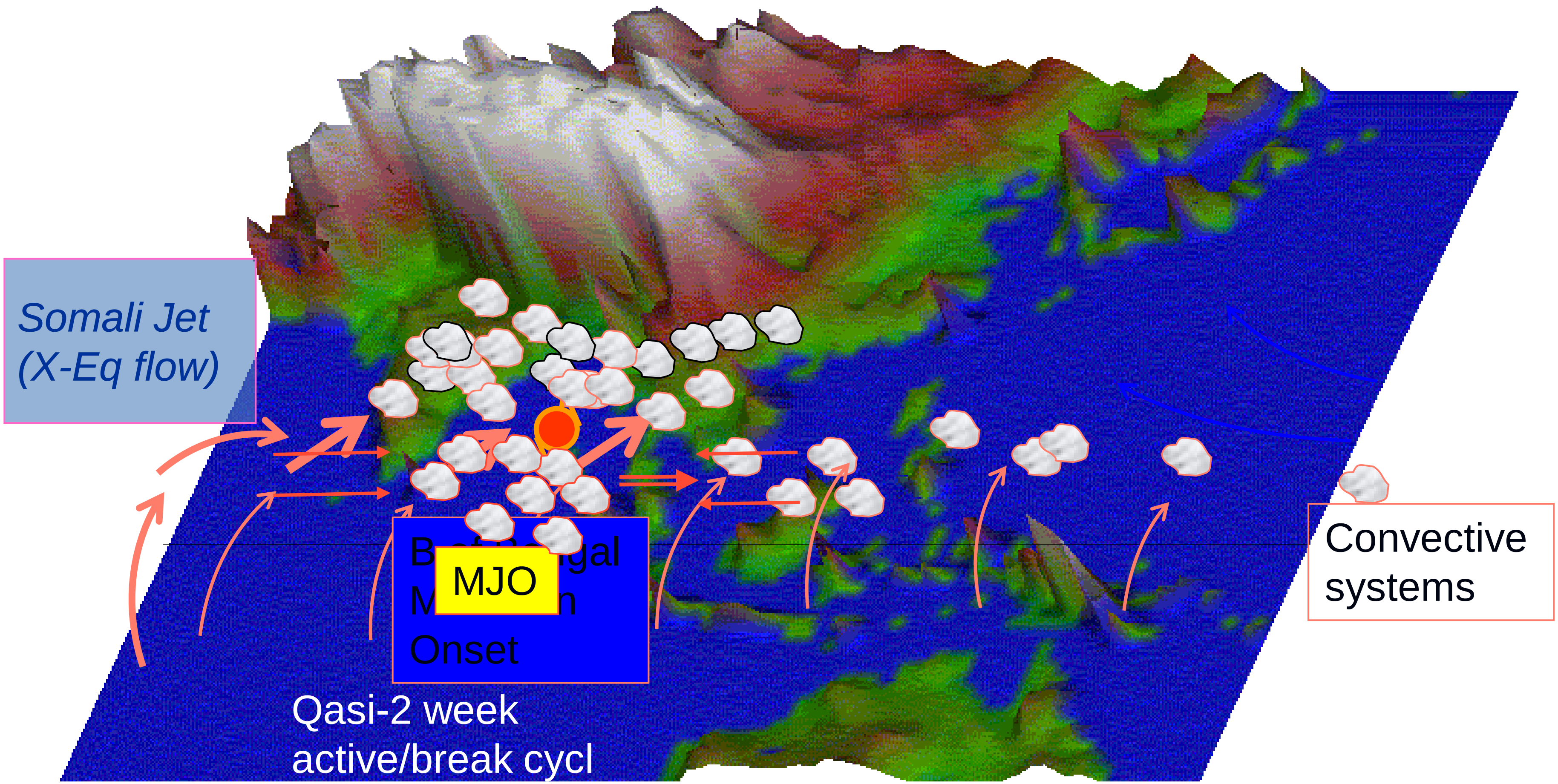

MRI(Kusunoki 2017)

**Fig. 9** Future changes in extreme precipitation events (annual statistics) projected by the all simulations. Unit is %. *Hatched regions* show changes above the 95% significance

HiRAM_C192



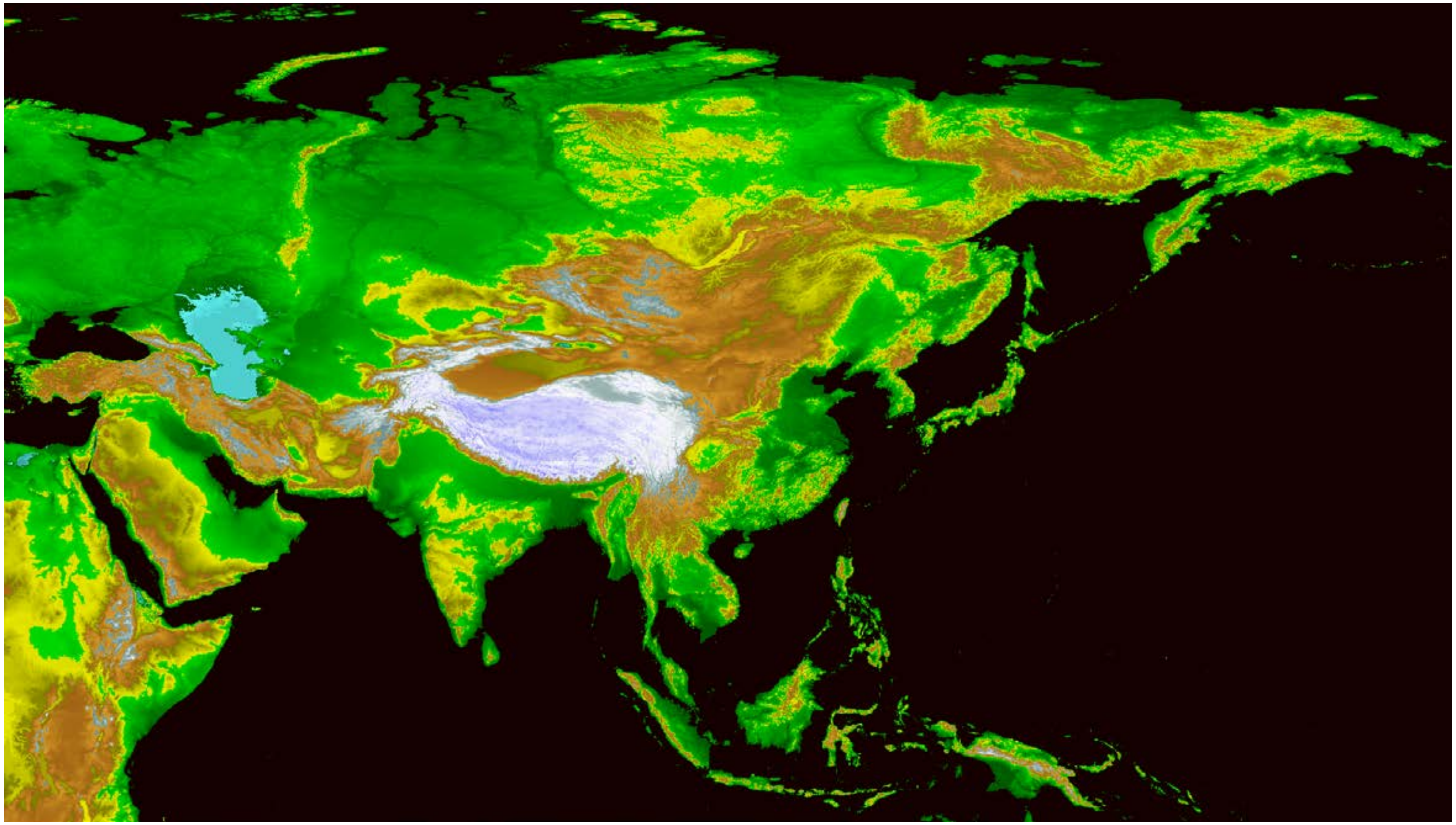
# South Asian Summer Monsoon




courtesy of C.-P. Chang

# Mean Climatology

## Role of Topography

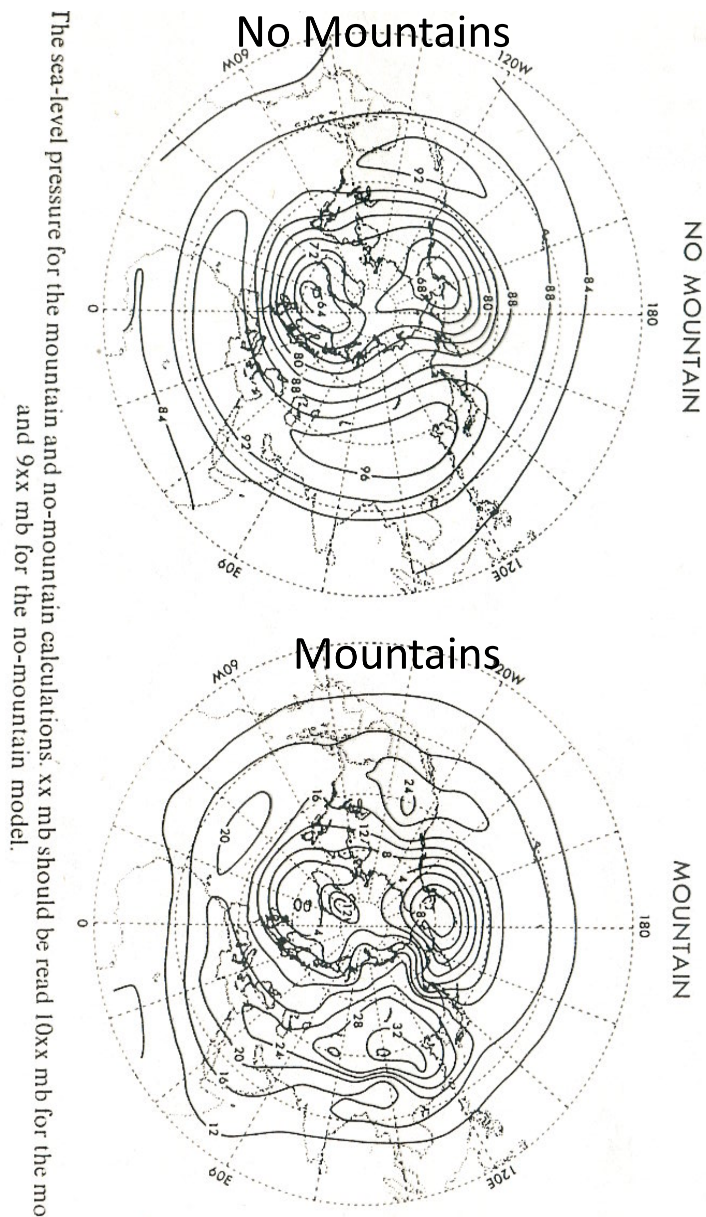


# Topographic Effect
## - Boreal Winter

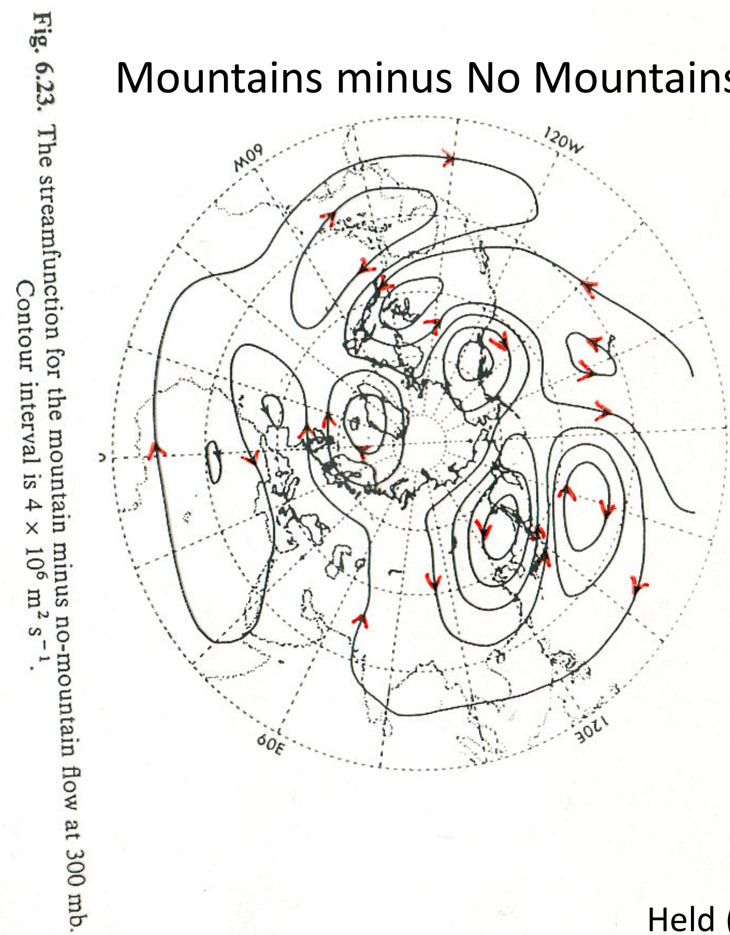
**Sea Level Pressure**

No Mountains

Mountains

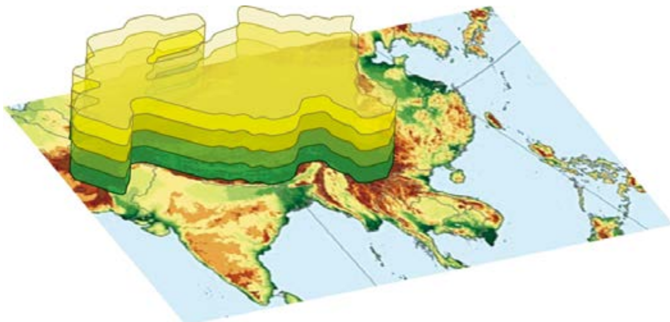



Mountains minus No Mountains

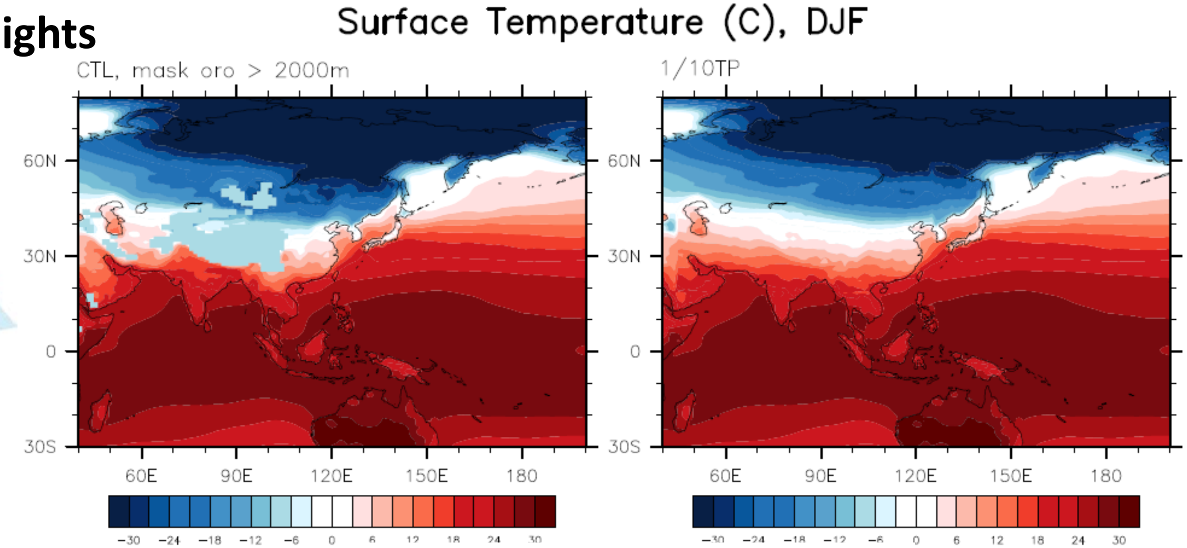



Held (1983)

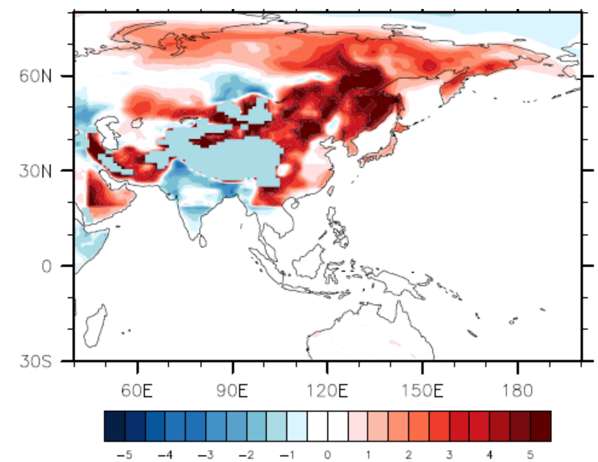
**Effect of the Tibetan Plateau**
**- Simulations with different heights**



**100% topography** **10% topography**




**10% minus 100% topography**

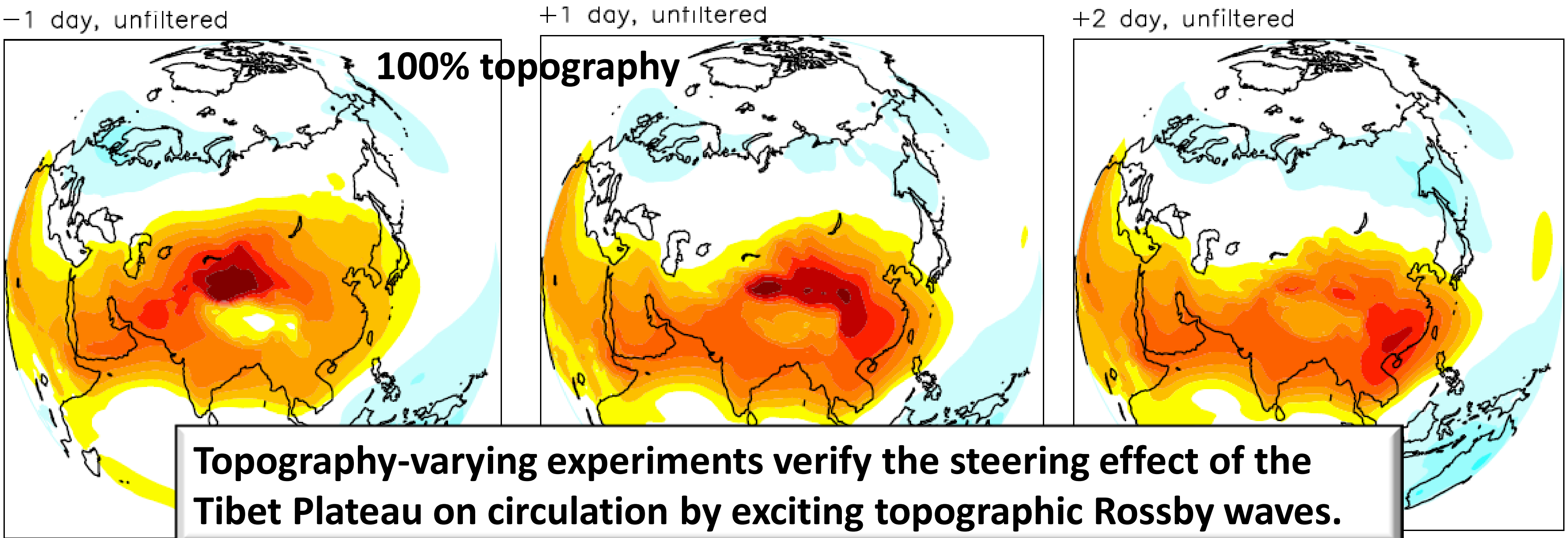



**Warmer winter with lower Tibet**

Tseng, Wu, and Hsu

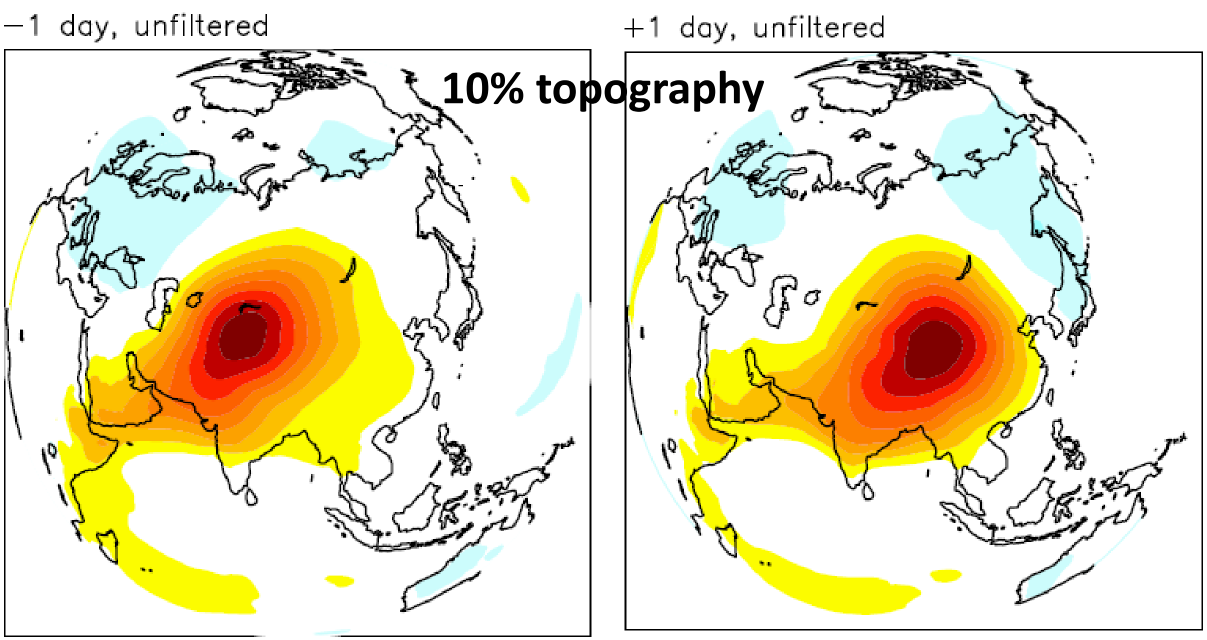
# Low-level synoptic fluctuation propagating around the Tibetan Plateau

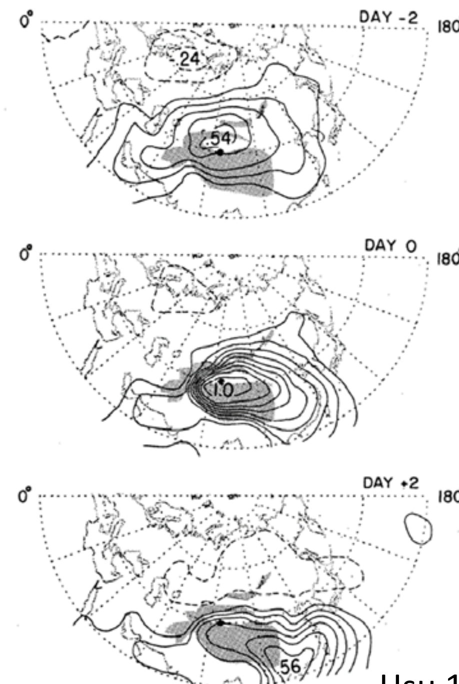
**100% topography**




**Topography-varying experiments verify the steering effect of the Tibet Plateau on circulation by exciting topographic Rossby waves.**

**10% topography**

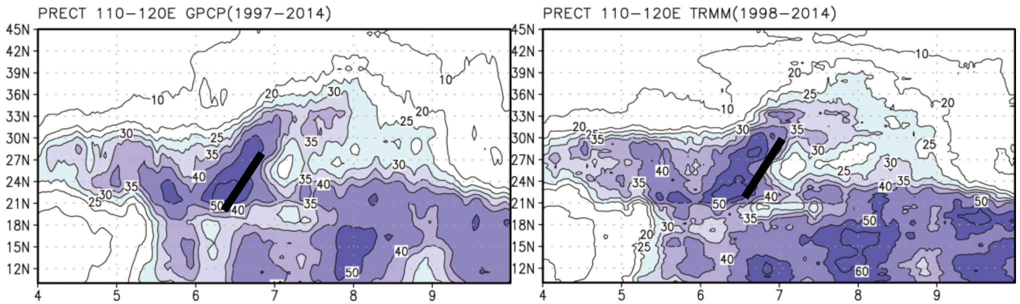


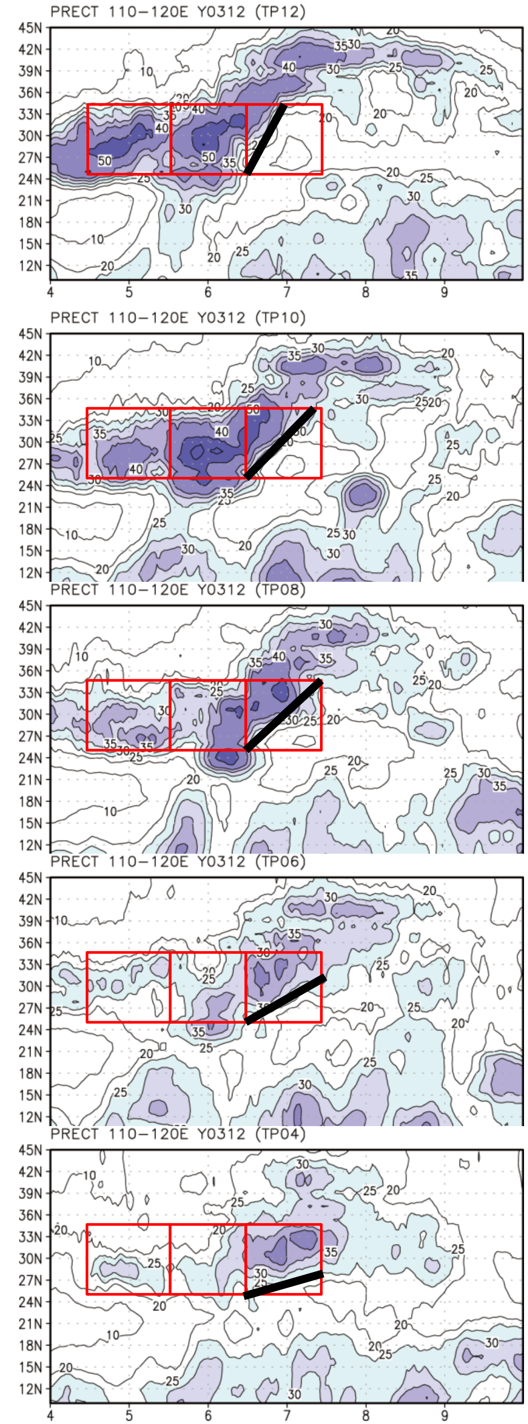

Hsu 1985

## Observation

*GPCP(1997-2014)* *TRMM(1998-2014)*




## Simulation




1.2

1.0

0.8

0.6

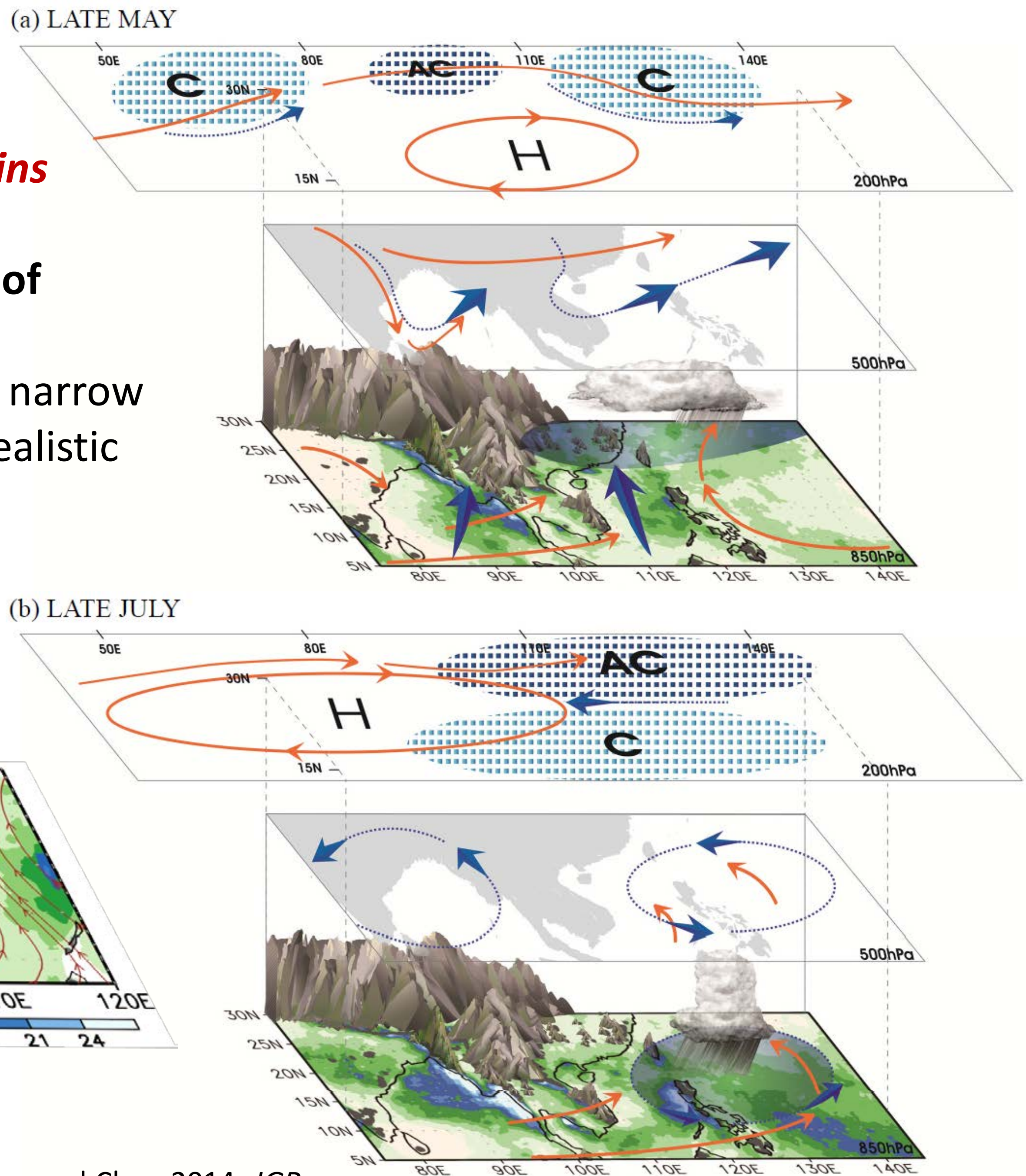
0.4

**Topography enhances the seasonal *northward march* from spring to summer.**

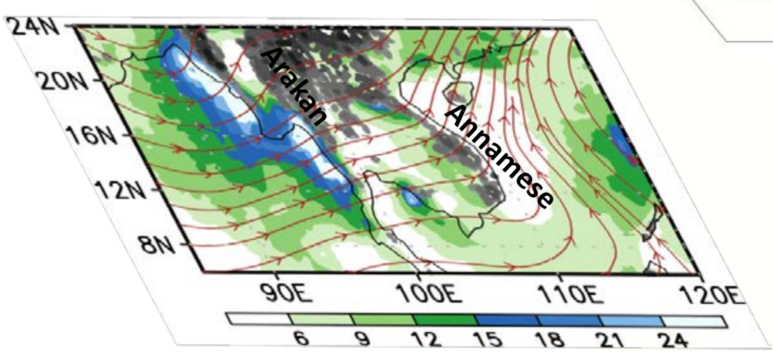
- **The higher, the stronger**

C.-H. Wu

***Effects of narrow mountains***
in the Indochina Peninsula
on ***subseasonal evolution*** **of**
**Asian summer monsoon**
- Proper representation of narrow mountains is needed for realistic simulations.




Annamese Mountains
Arakan Mountains

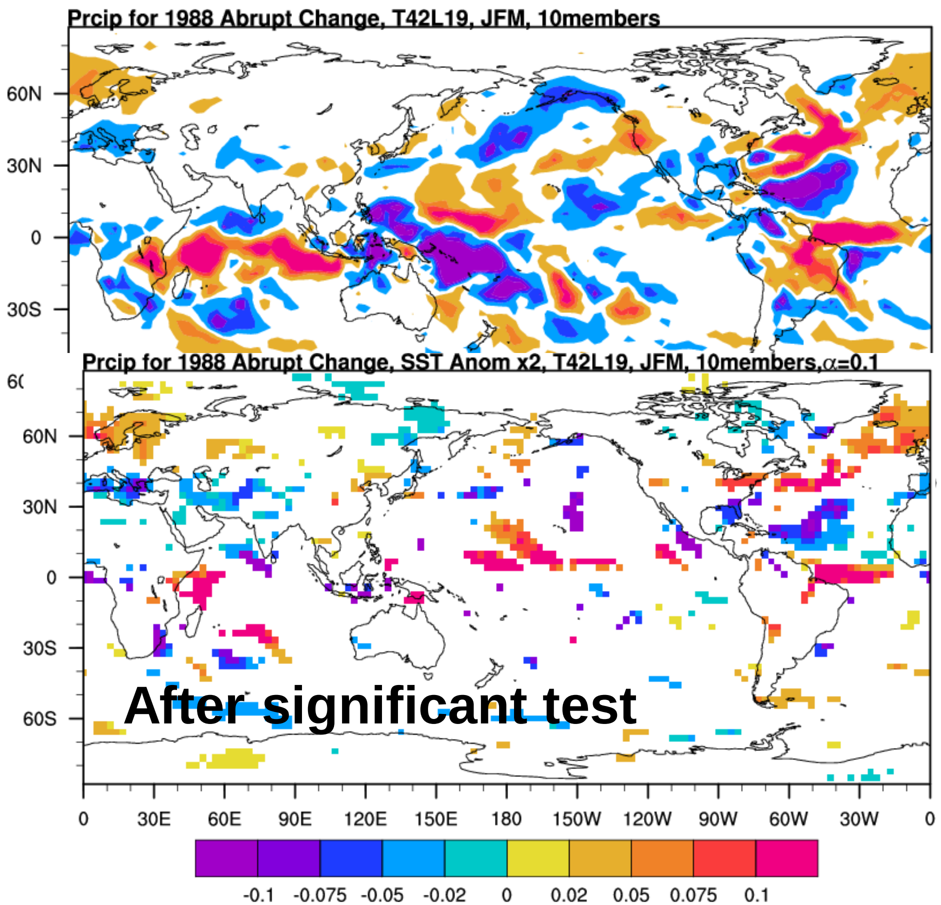



Wu, Hsu, and Chou 2014, *JGR;* Wu, Hsu, and Chou 2014, *JGR*

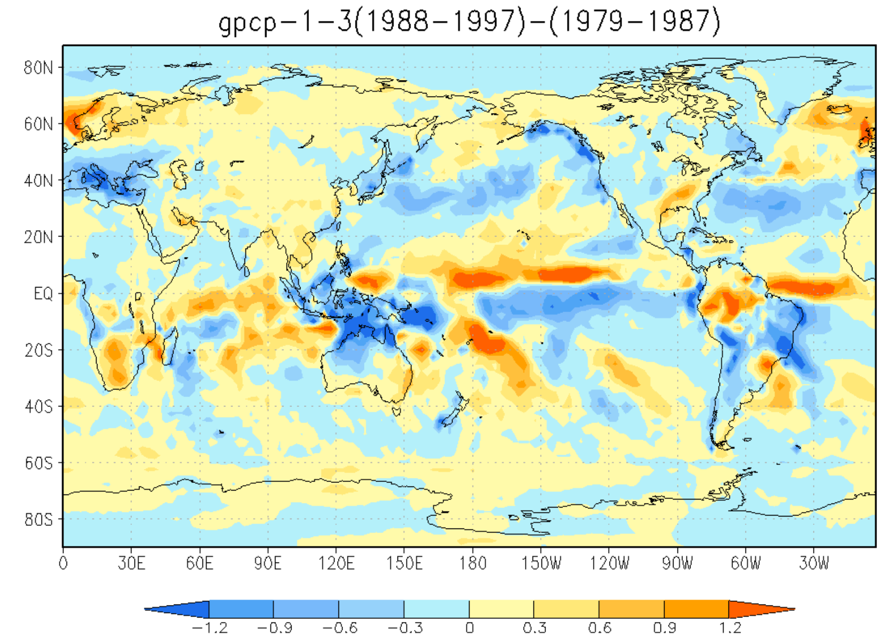
# Simulation of late 1980s regime shift

- ❖ Model : ECHAM5, T42L19
- ❖ Anomaly Run SST Pattern : 1988-1997 minus 1978-1987, only over North Atlantic, **amplitude x1, x2 and x4**
- ❖ Control Run = climatological SST
- ❖ **10 (20) members** from 01Jan-20Jan 1988 initial conditions
- ❖ length of each simulation was 10 year and year 4-10 were calculated.
- ❖ Only focus on JFM

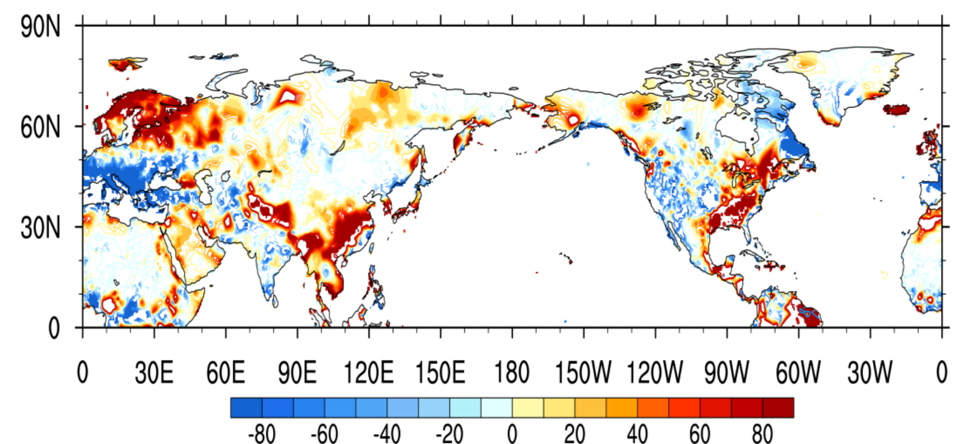
# Even precipitation?

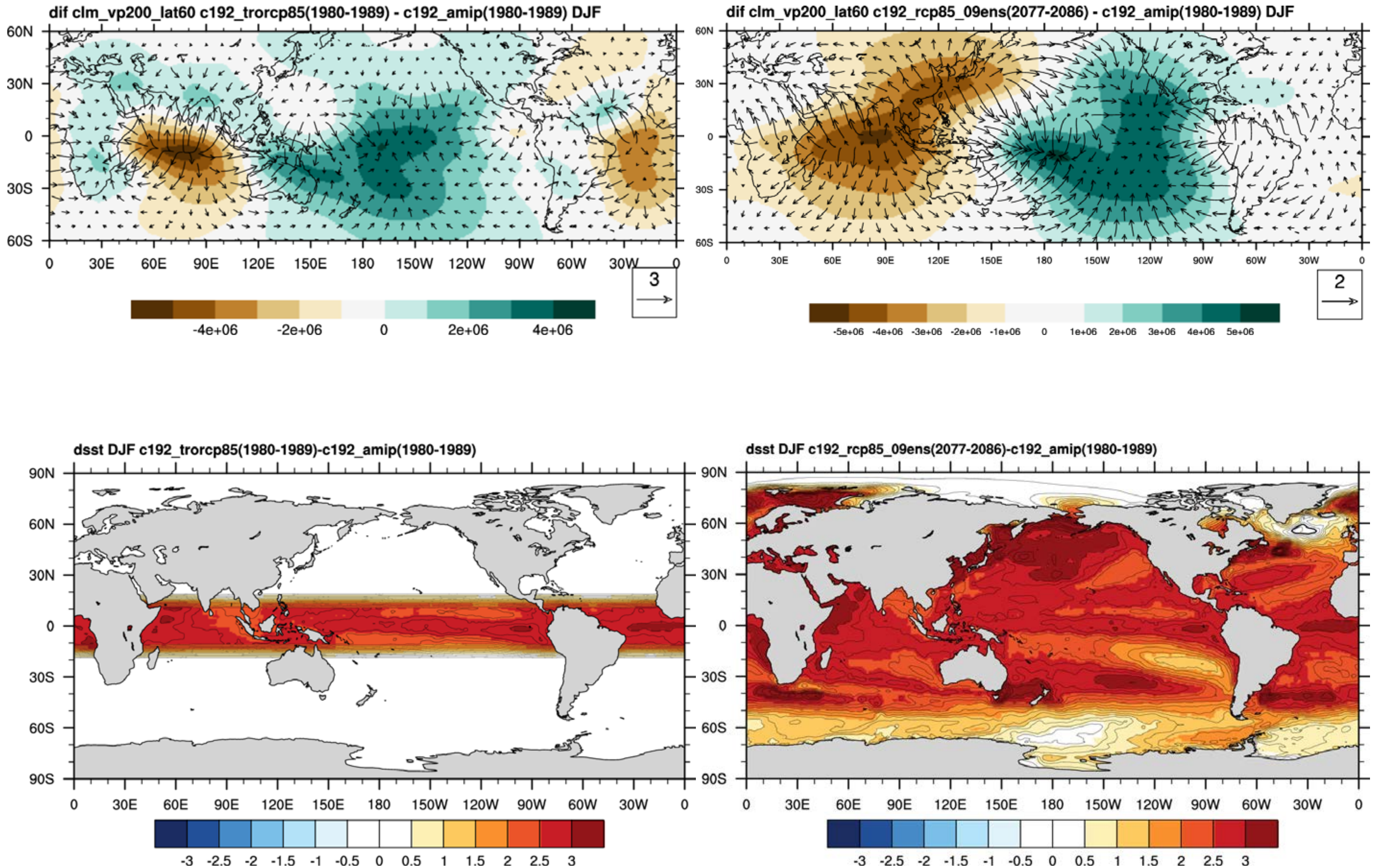



## GPCP

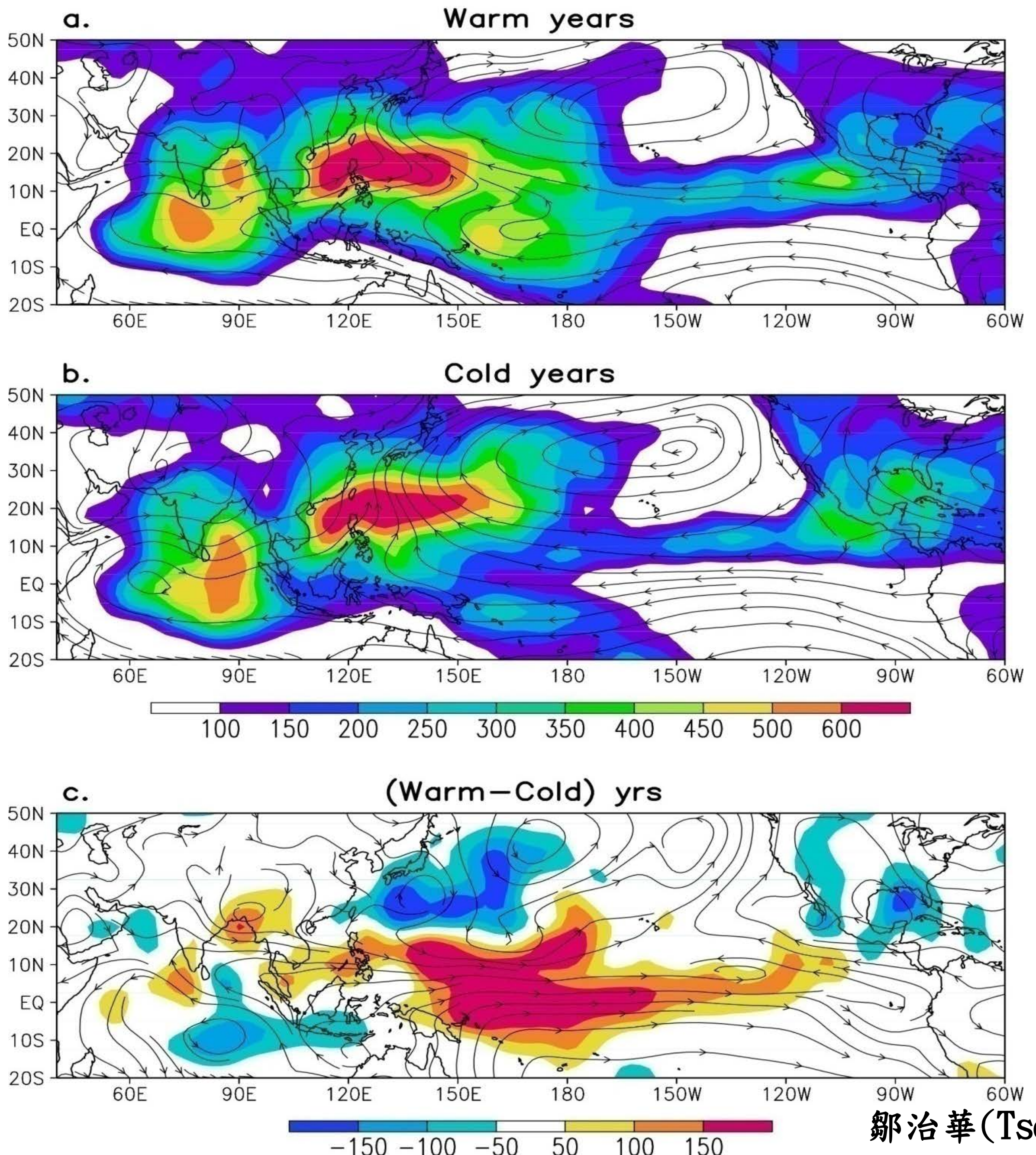



## CRU




dif clm_vp200_lat60 c192_trorcp85(1980-1989) - c192_amip(1980-1989) DJF
60N
30N
0
30S
60S
0
30E
60E
90E
120E
150E
180
150W
120W
90W
60W
30W
3
-4e+06
-2e+06
2e+06
4e+06
dif clm_vp200_lat60 c192_rcp85_09ens(2077-2086) - c192_amip(1980-1989) DJF
2
-5e+06
-4e+06
-3e+06
-2e+06
-1e+06
1e+06
2e+06
3e+06
4e+06
5e+06
dsst DJF c192_trorcp85(1980-1989)-c192_amip(1980-1989)
90N
60N
30N
30S
60S
90S
-3
-2.5
-2
-1.5
-1
-0.5
0.5
1
1.5
2
2.5
3
dsst DJF c192_rcp85_09ens(2077-2086)-c192_amip(1980-1989)

# 30-60day OLR var. and 850hPa streamline (JAS) composite



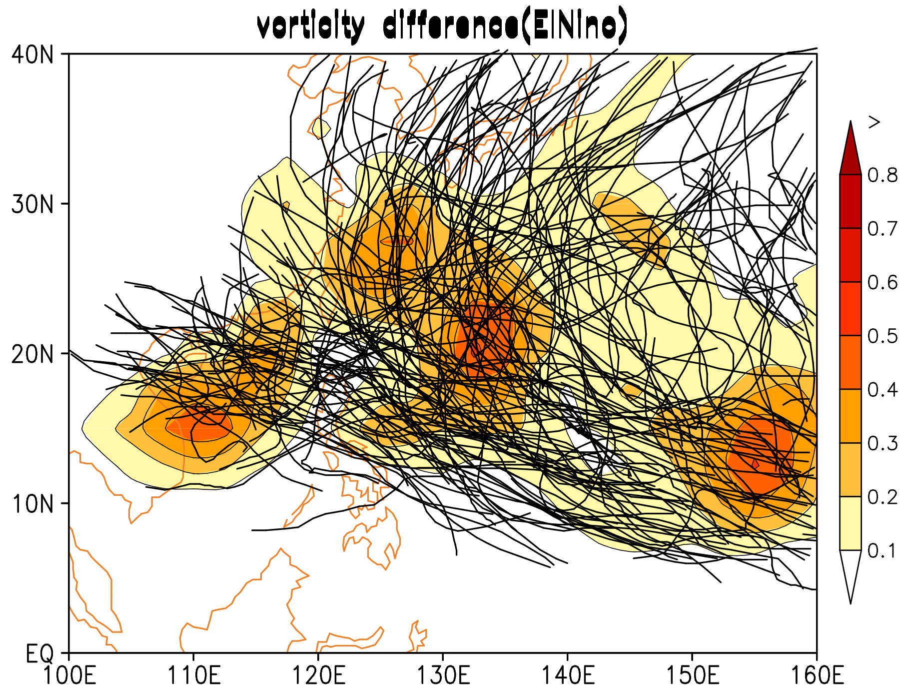

El Niño

La Niña

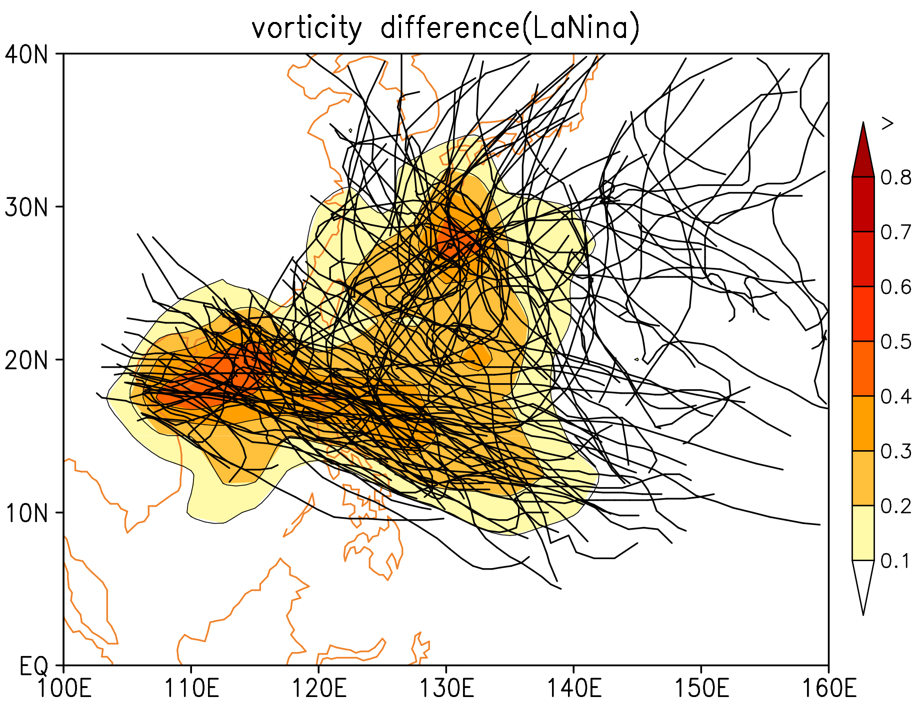
鄒治華(Tsou)、徐邦琪(Hsu)

# TC also modulated by ENSO

## El Nino




## La Nina



Multiple time scale nature

- Secular trend + Interdecadal-decadal variation + Interannual variation + Seasonal evolution + Intraseasonal and sub-seasonal variation + ..

- Example：

  decadal vs. abrupt change (oscillation vs. shift)

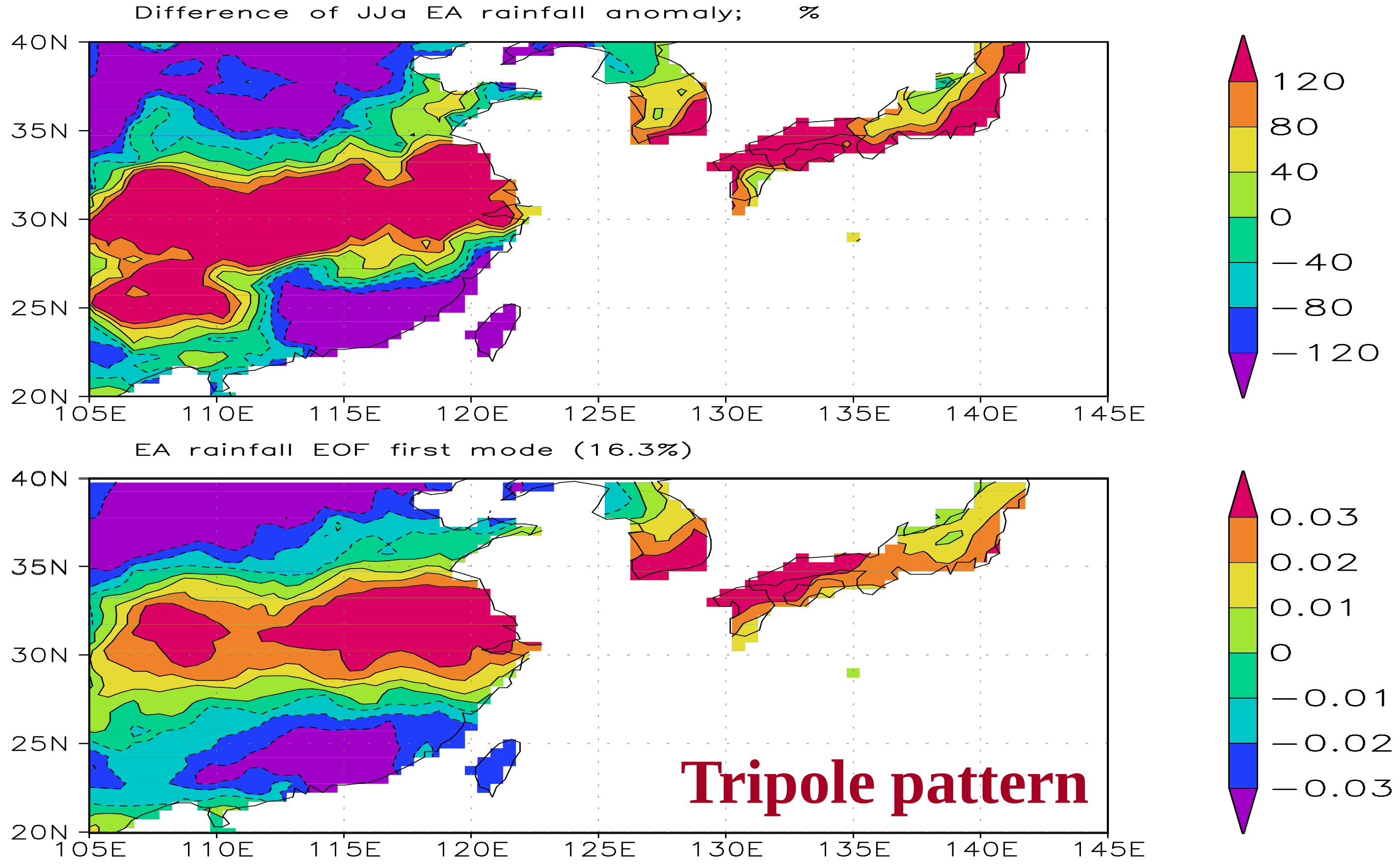
  decadal+interannual

  Intraseasonal Oscillation (ISO, MJO, 季內震盪) vs. monsoon onset

  TC vs. ISO, interannual, decadal-interdecadal

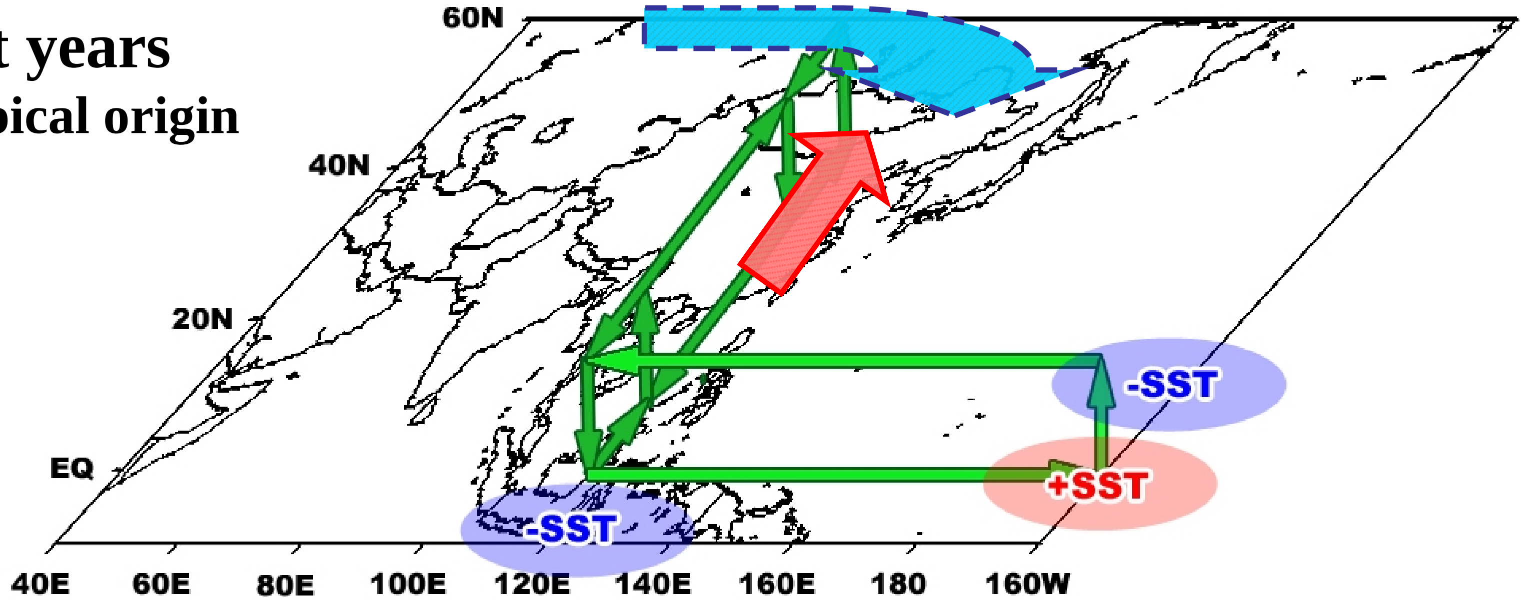
# Also related to diabatic heating over Tibet

## Rainfall Composites (8 strong cases - 8 weak cases)

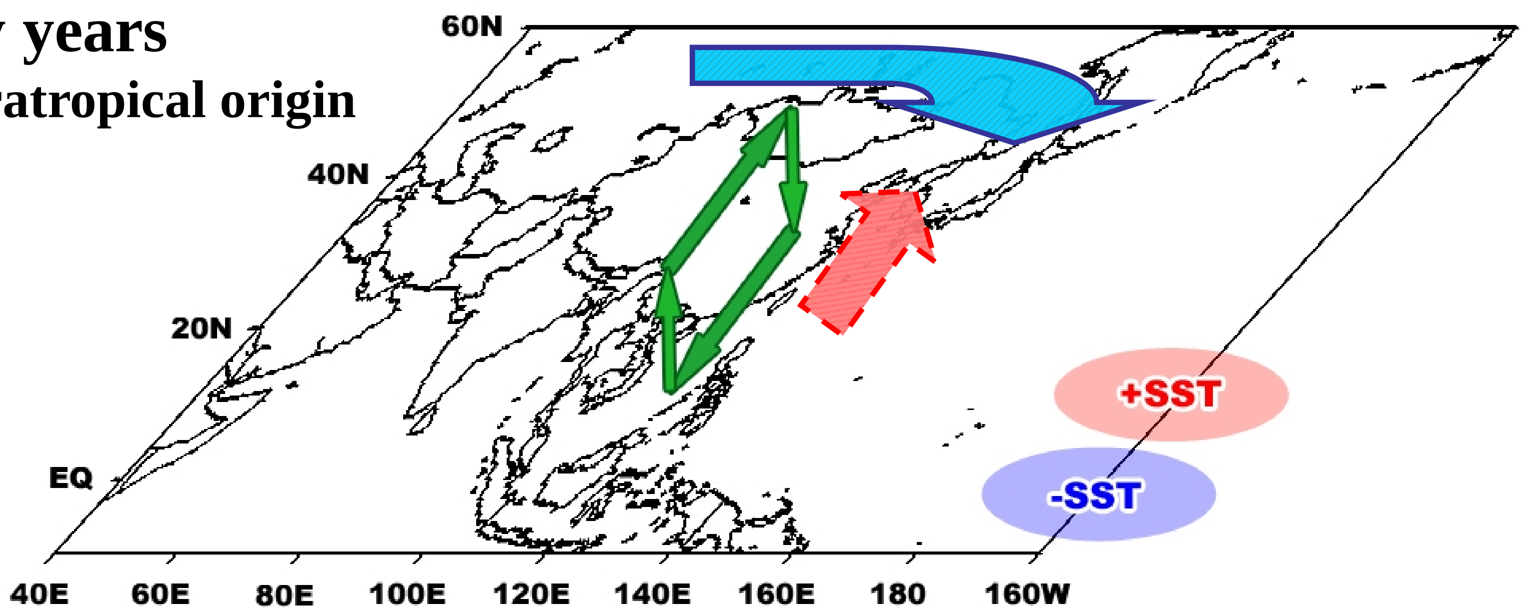



Hsu and Liu, GRL, 2003

## Wet years
**Tropical origin**

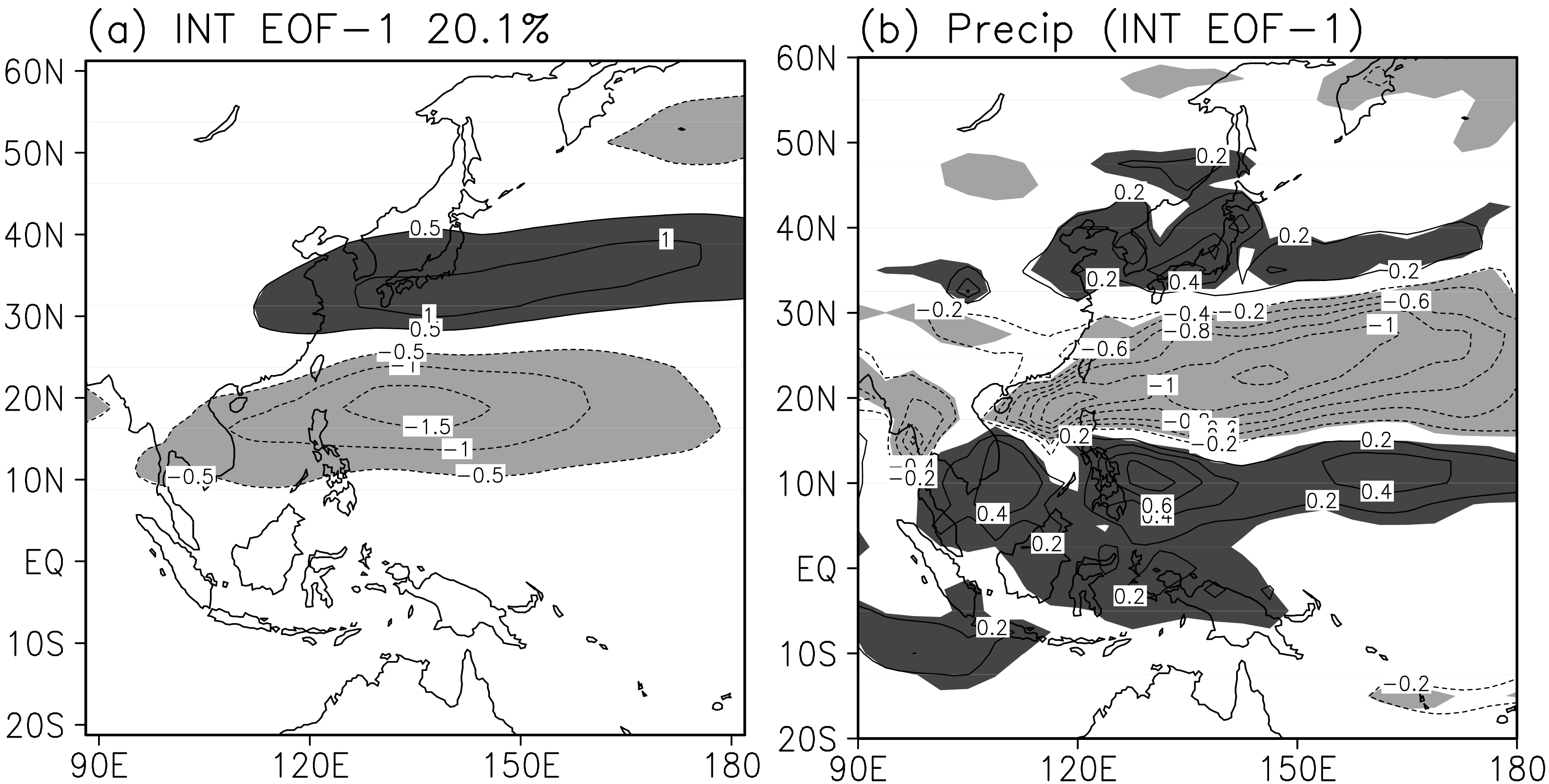



## Dry years
**Extratropical origin**



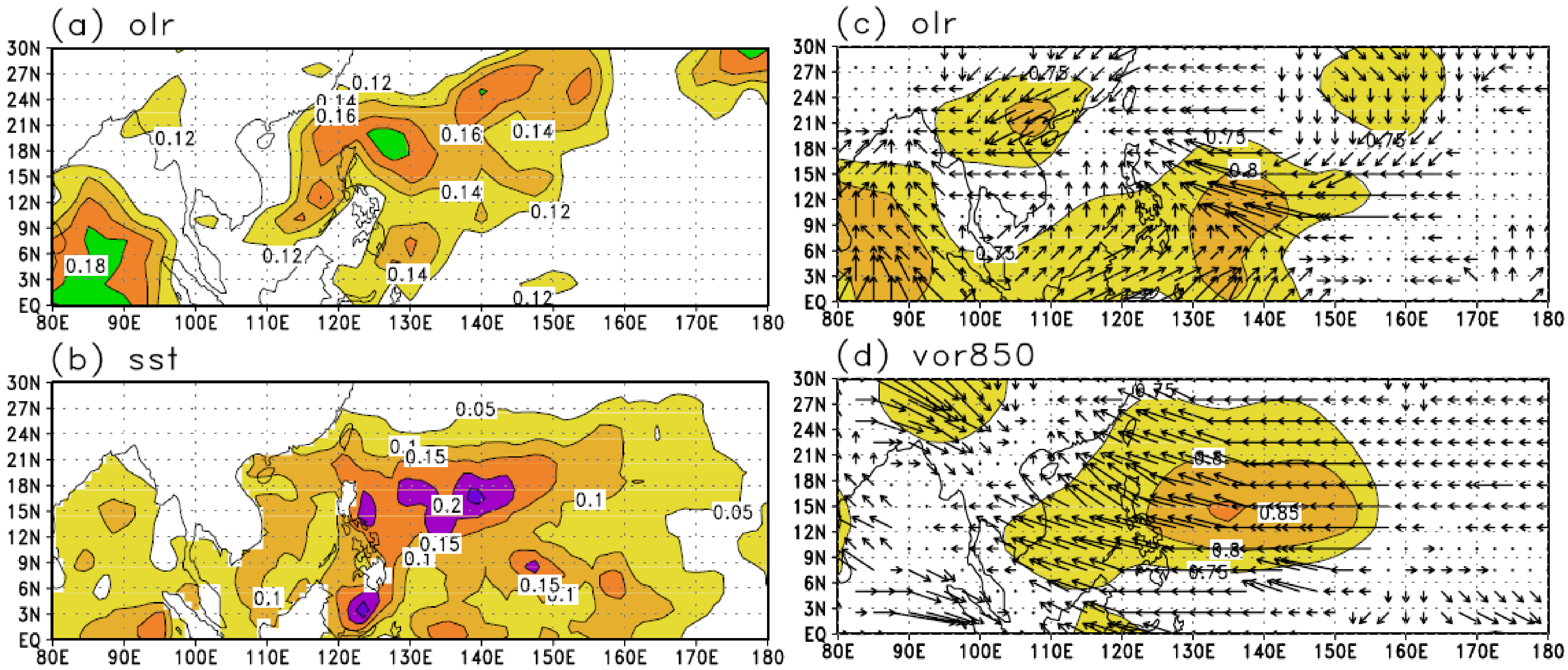

Hsu and Lin (*J. Climate*, 2007)

# intrinsic mode of mean flow?
# can be triggered by various forcing?



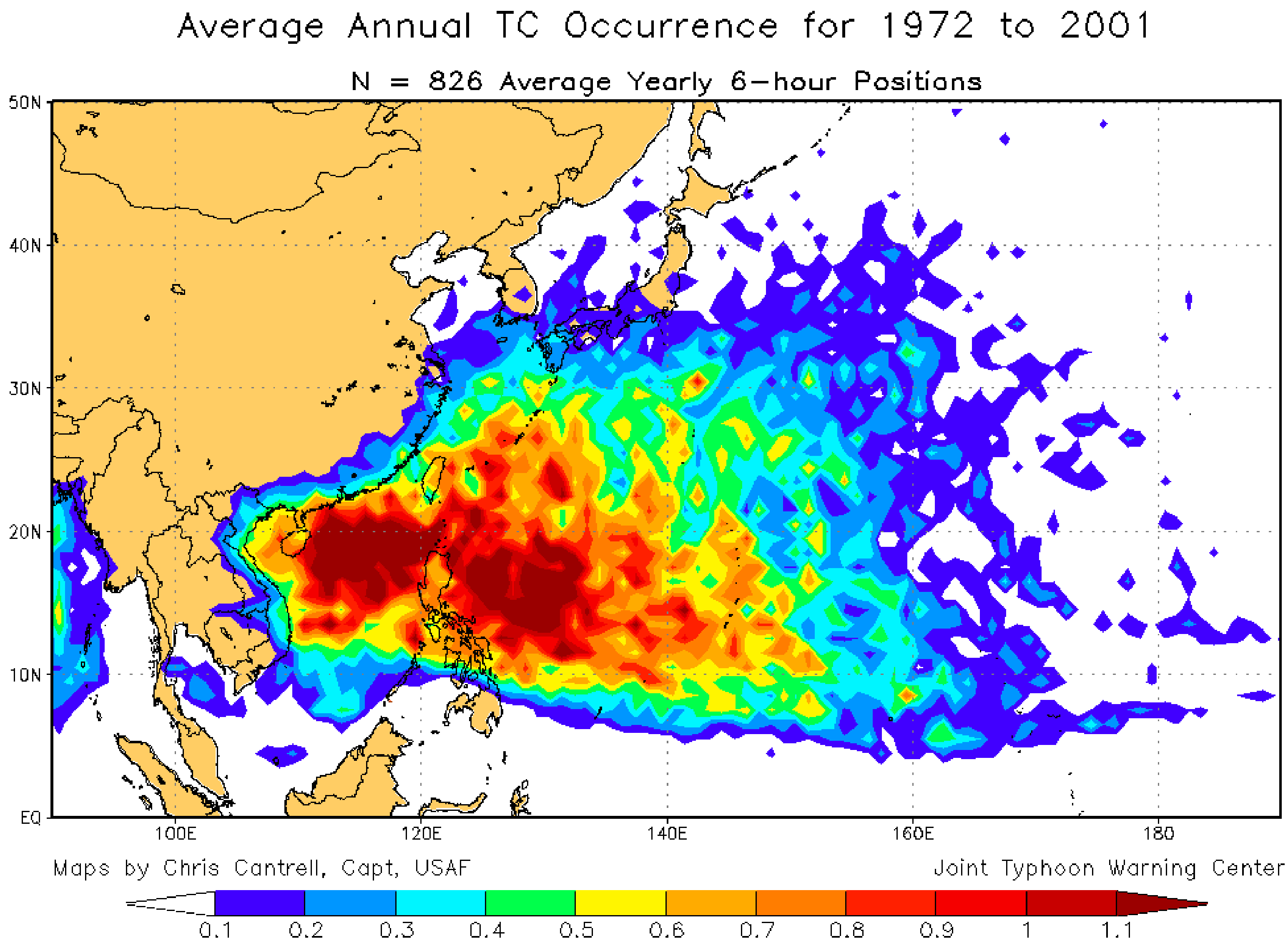

(Lu et al., 2006, JMSJ)

# Multiscale Interaction in the Tropical Western North Pacific
# Hot Spots of Intraseasonal Oscillation (Hsu, 2005, 2010)

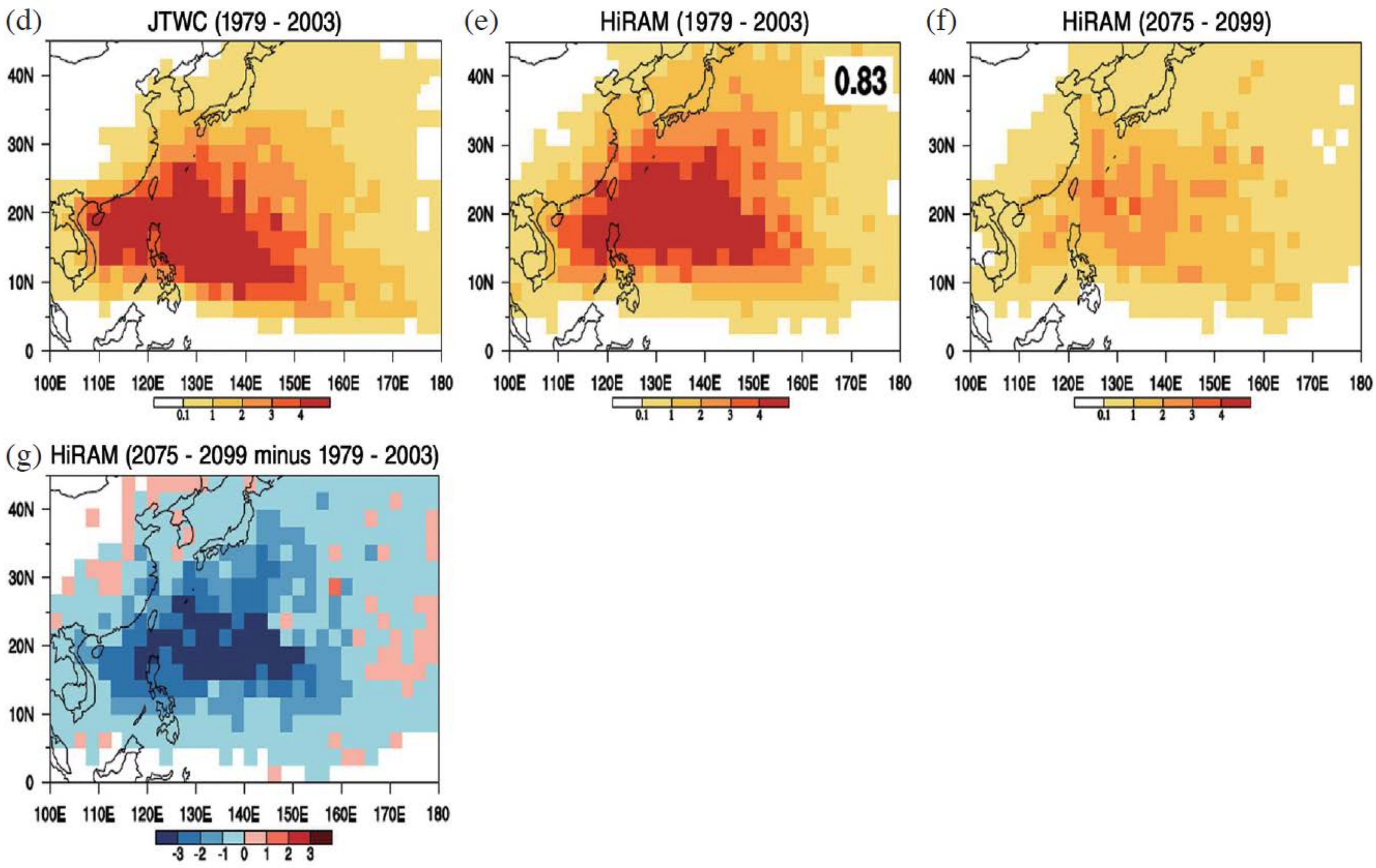



Hsu and Weng, 2001, J. Climate

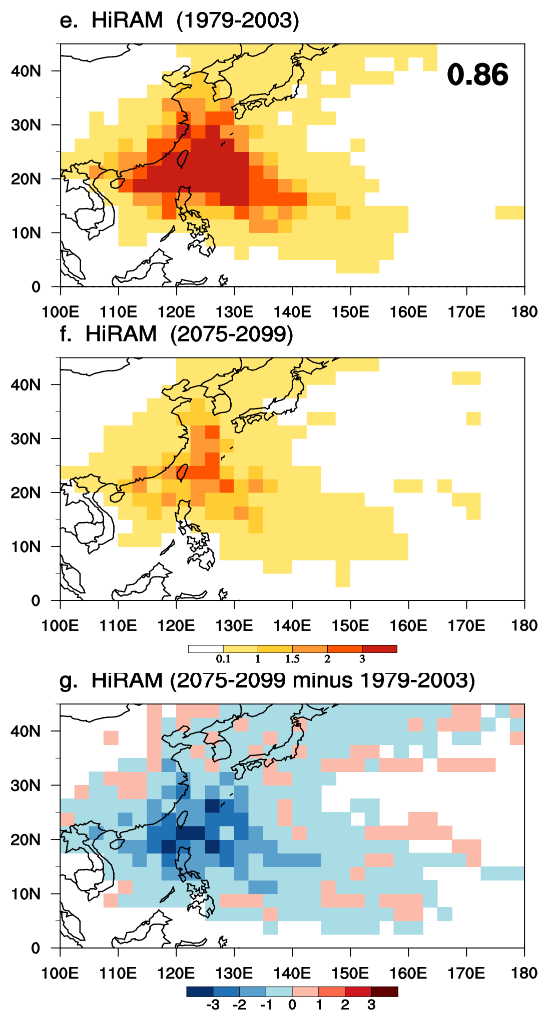
# Breeding and Play Ground of TCs

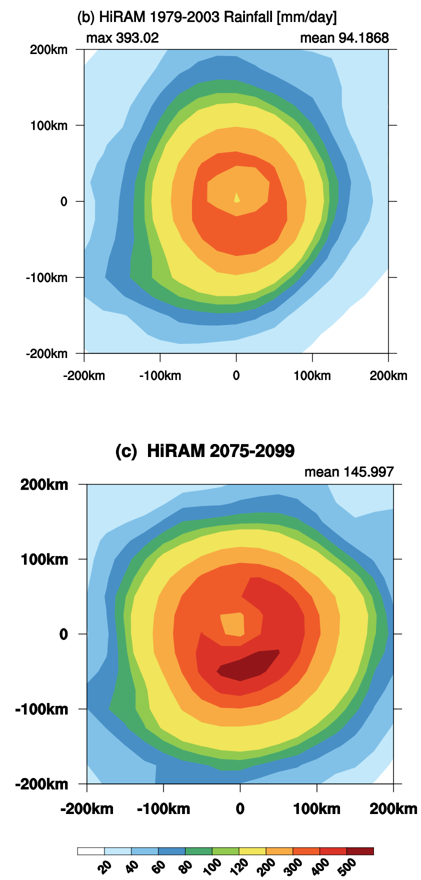


# **TS Frequency** (JJASON)



# Changes in typhoon (affecting Taiwan) frequency and strength



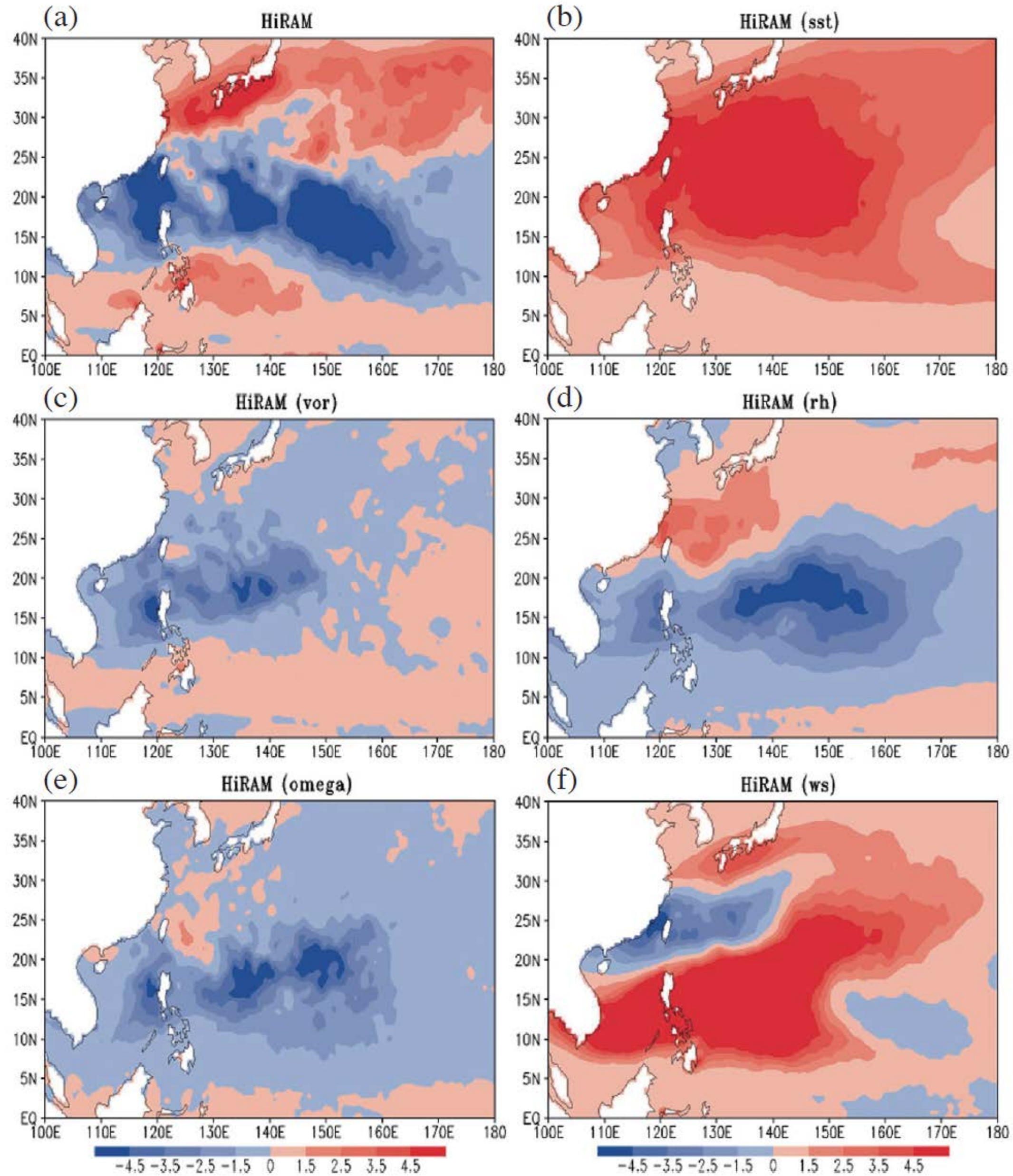




- **Significantly reduced in number but strengthened**
- **Rainfall within 200 and 100 km radius increased by 44 and 20 %**

Tsou et al., 2016, TAO

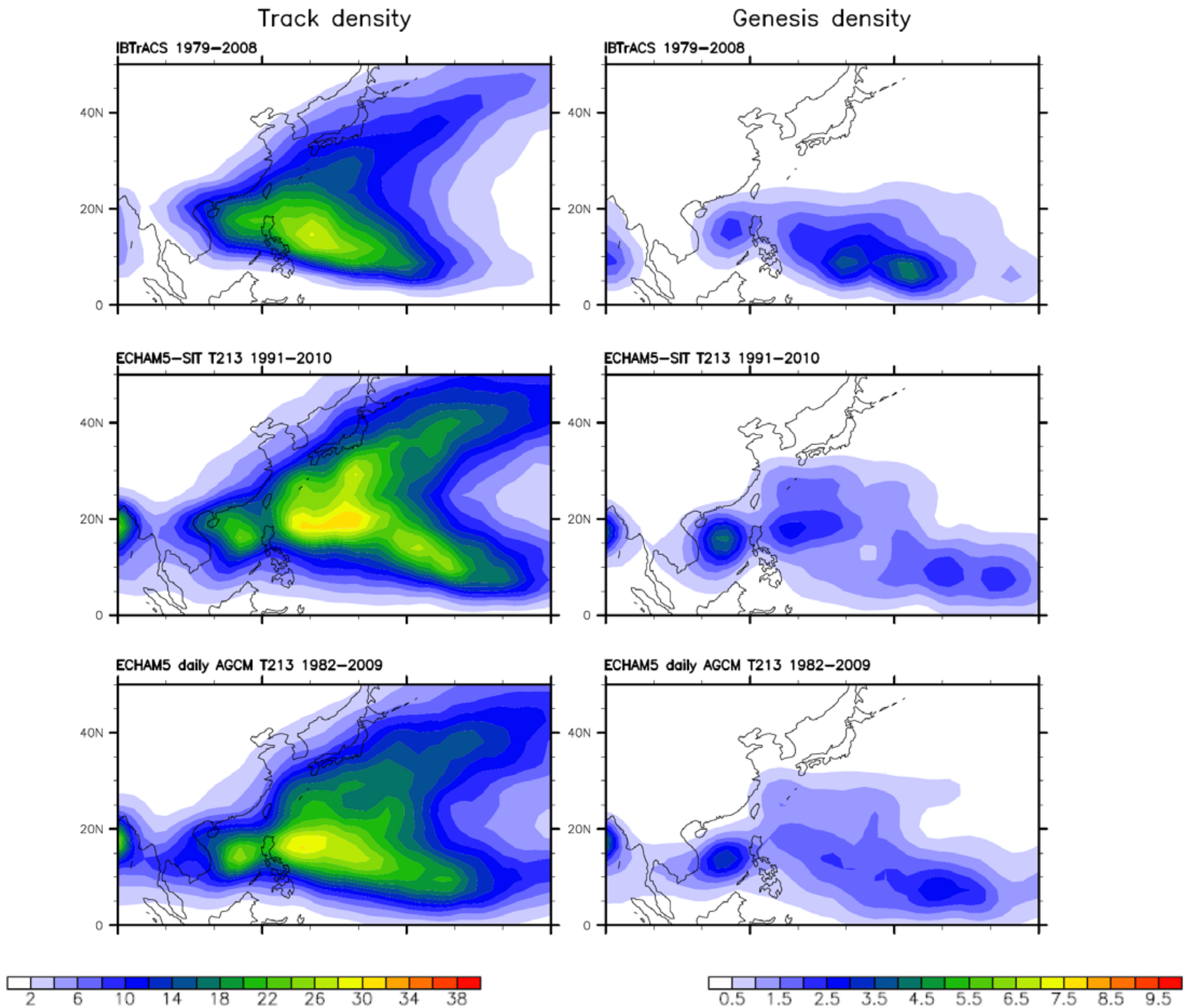
FIG. Distribution of TWCN TS track frequency (shaded, unit: numbers per 2.5° longitude/latitude per season period) in JUN.-NOV.

# GPI Changes

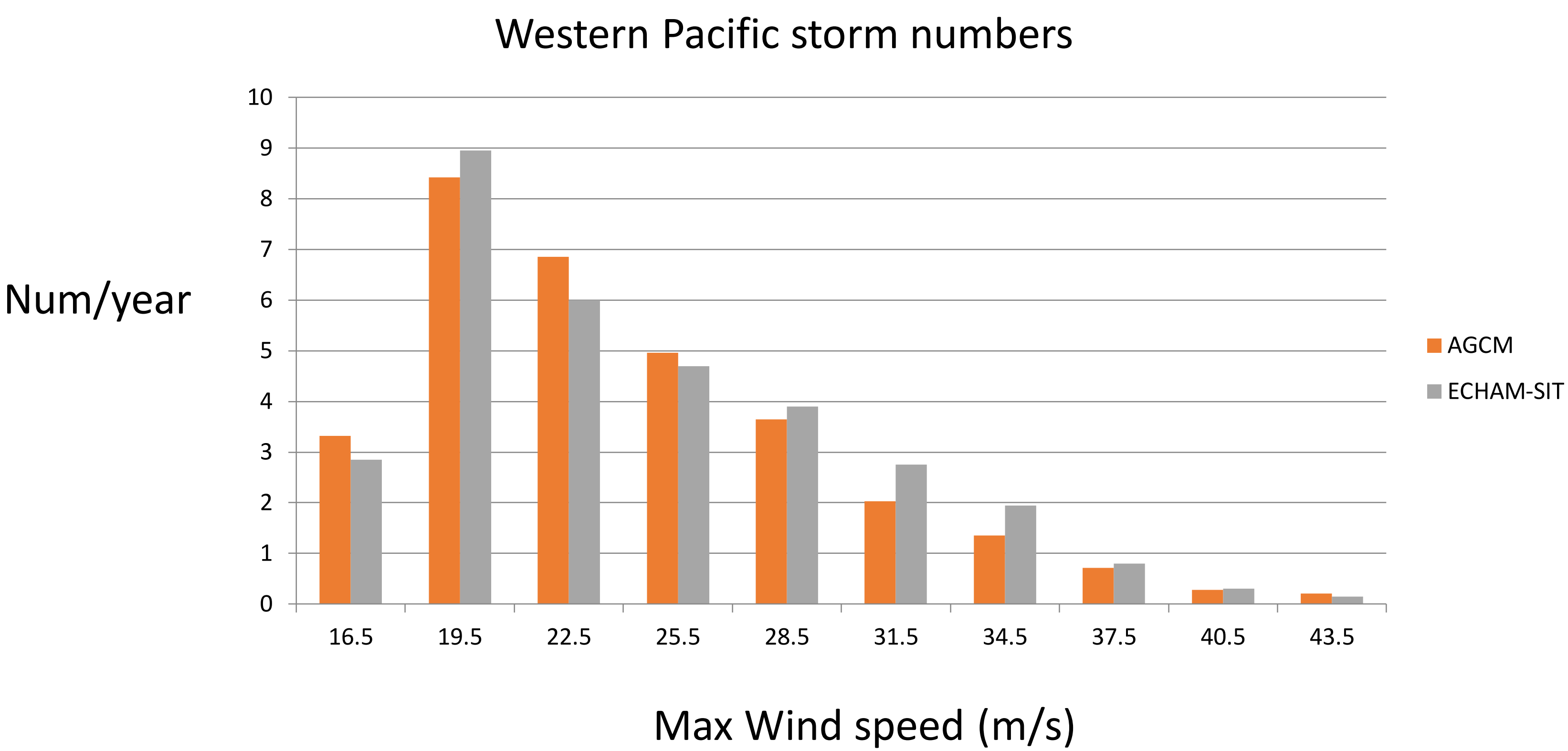


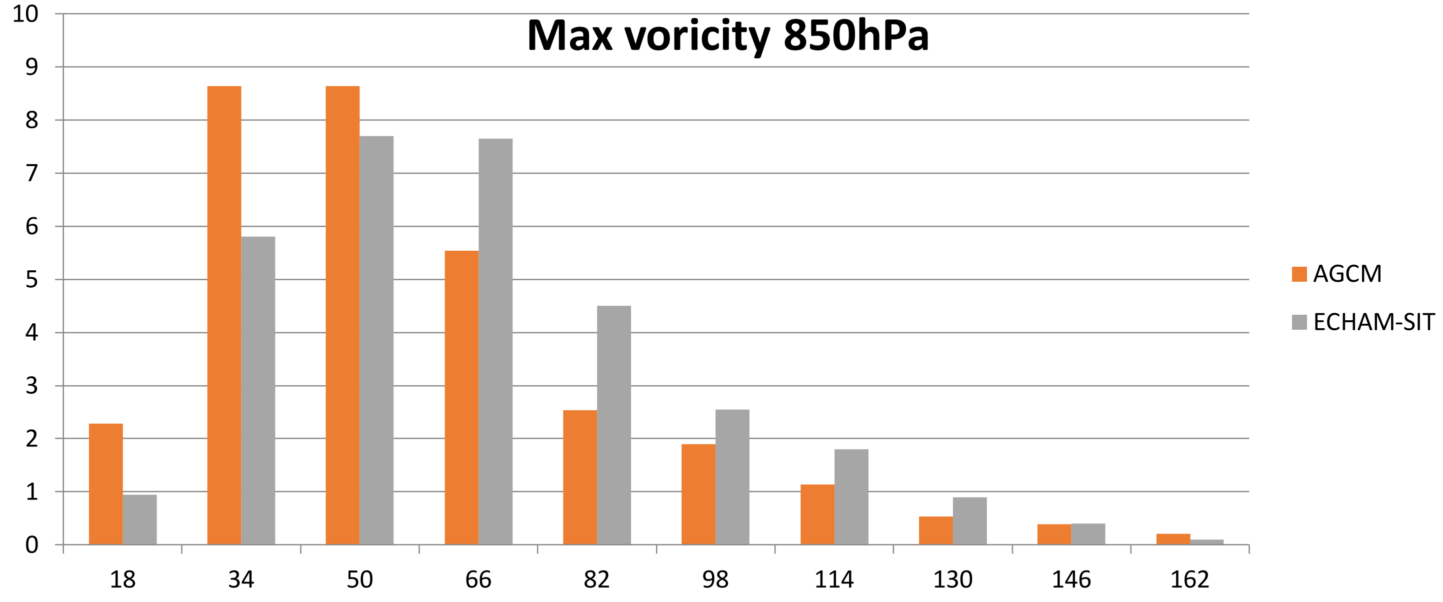
(a)
HiRAM
(b)
HiRAM (sst)
(c)
HiRAM (vor)
(d)
HiRAM (rh)
(e)
HiRAM (omega)
(f)
HiRAM (ws)
40N
35N
30N
25N
20N
15N
10N
5N
EQ
100E
110E
120E
130E
140E
150E
160E
170E
180
-4.5 -3.5 -2.5 -1.5 0 1.5 2.5 3.5 4.5

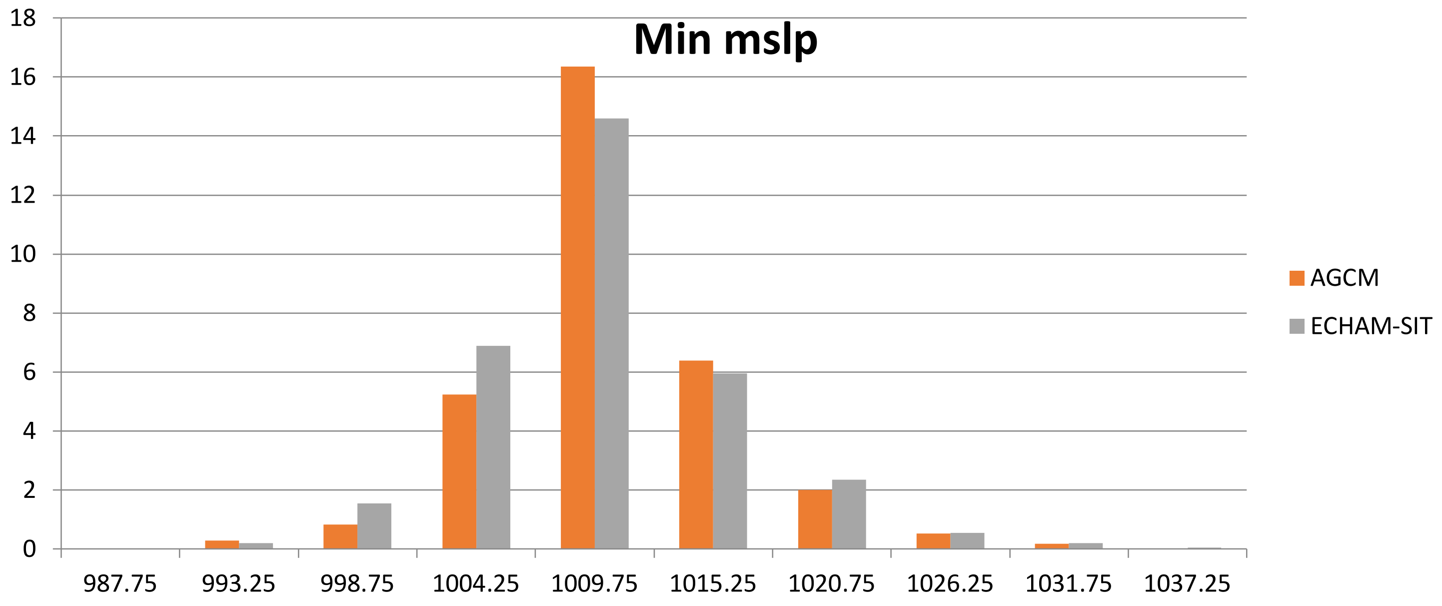
# ECHAM5 T213: AGCM (uncoupled) vs. AGCM-SIT (coupled)



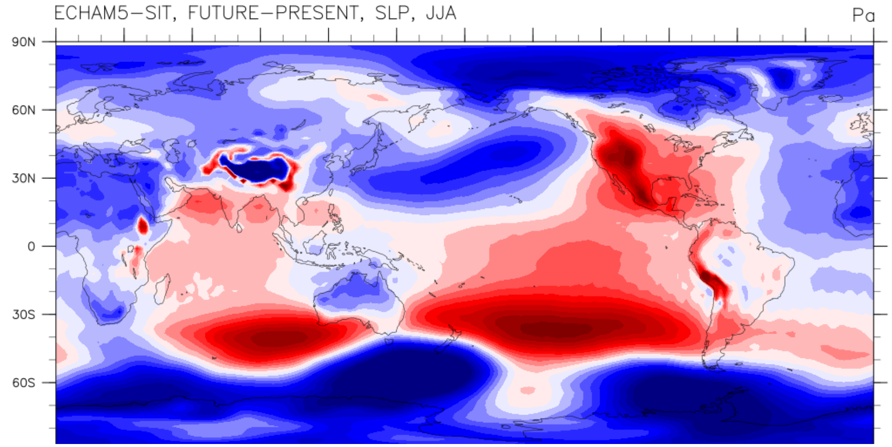
| | AGCM (daily OISST)<br>28 years | ECHAM5-SIT<br>20 years |
|---|---|---|
| NH | 74.5 | 77.1 |
| WP | 31.8 | 32.4 |

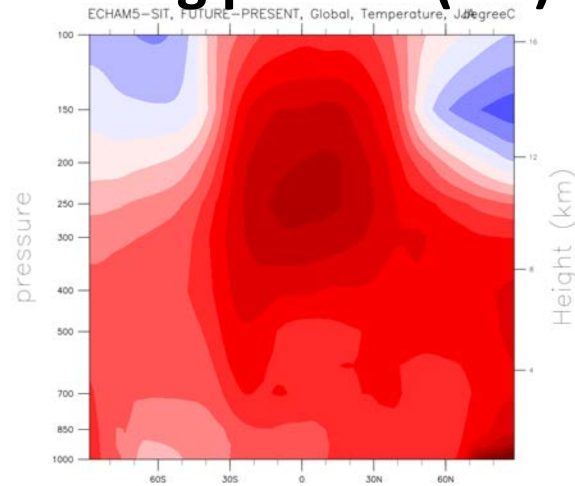


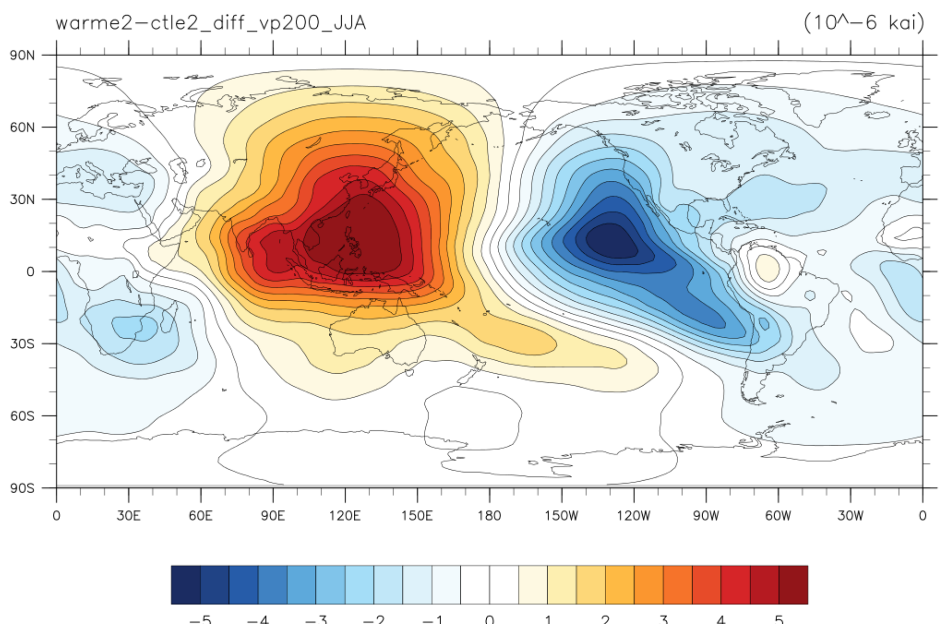

Max voricity 850hPa
10
9
8
7
6
5
4
3
2
1
0
18
34
50
66
82
98
114
130
146
162
AGCM
ECHAM-SIT

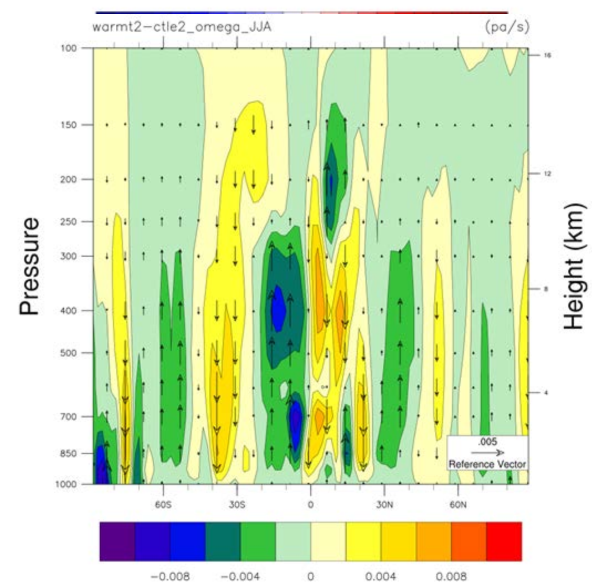

Min mslp
18
16
14
12
10
8
6
4
2
0
987.75
993.25
998.75
1004.25
1009.75
1015.25
1020.75
1026.25
1031.75
1037.25
AGCM
ECHAM-SIT

# Similar response in another RCP8.5 warming simulation using ECHAM5-SIT with different SST warming pattern (JJA)



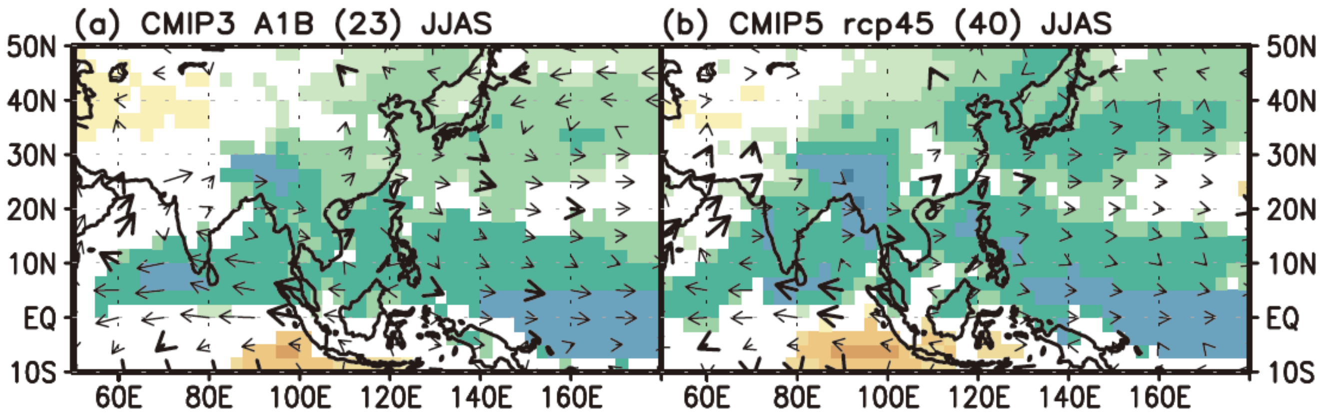



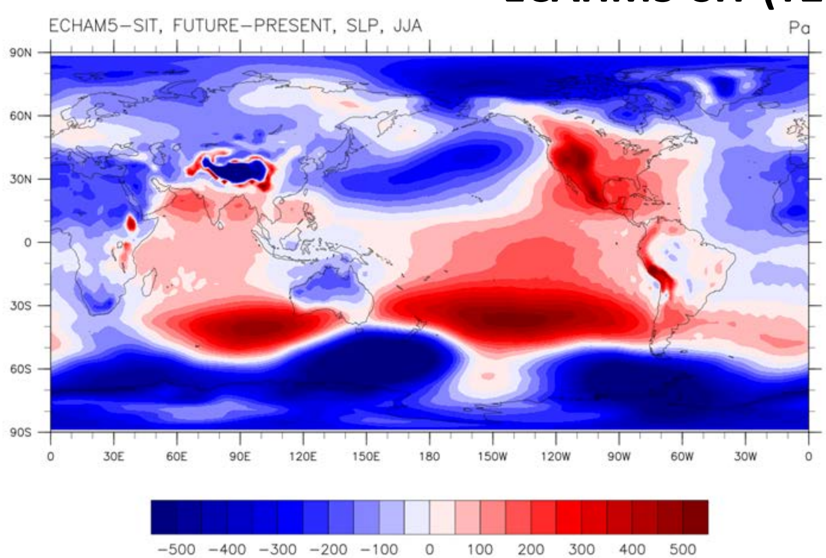



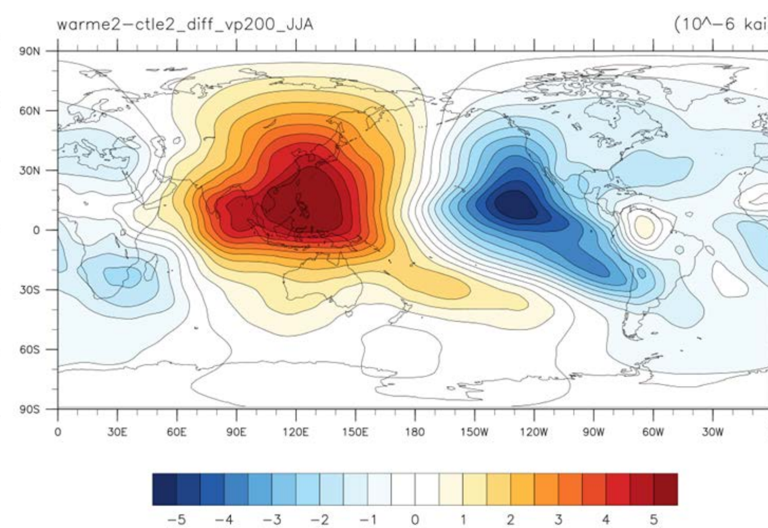

W.-L. Tseng, June Chang

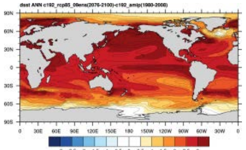
# Comparison with other models (not resolving TCs)

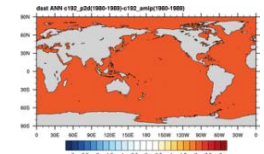


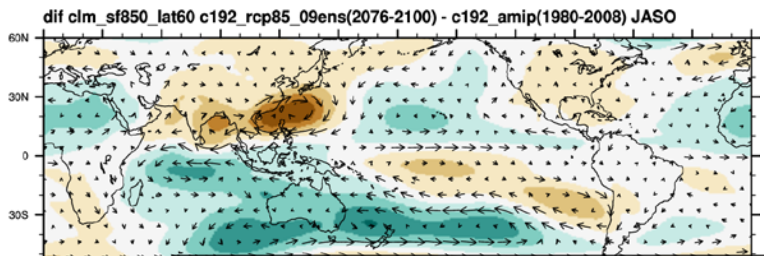

## ECAHM5-SIT (T213), TC resolving

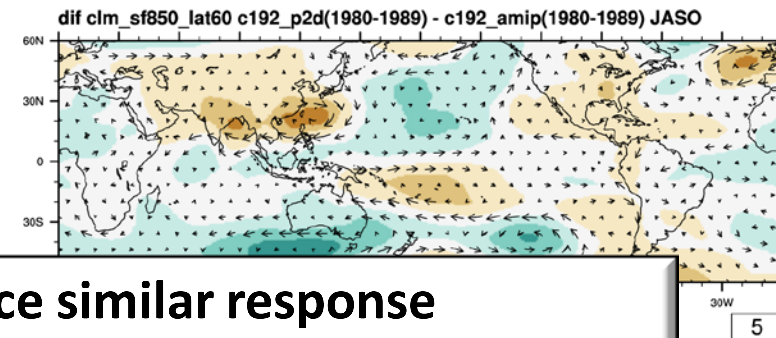


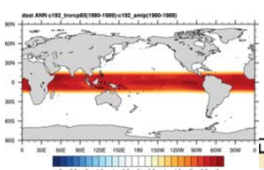


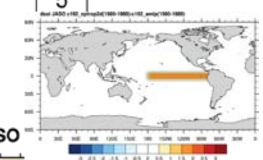


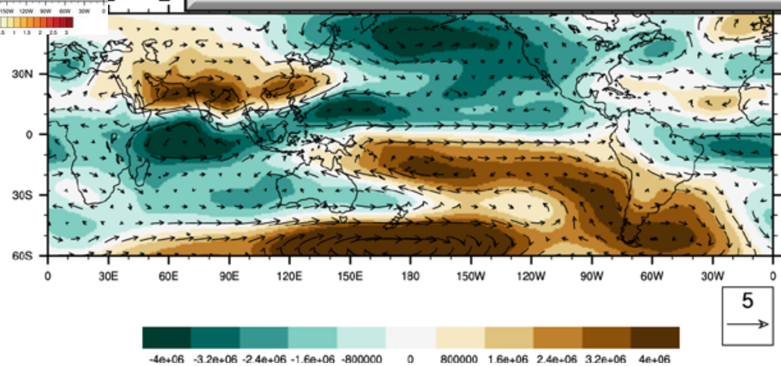


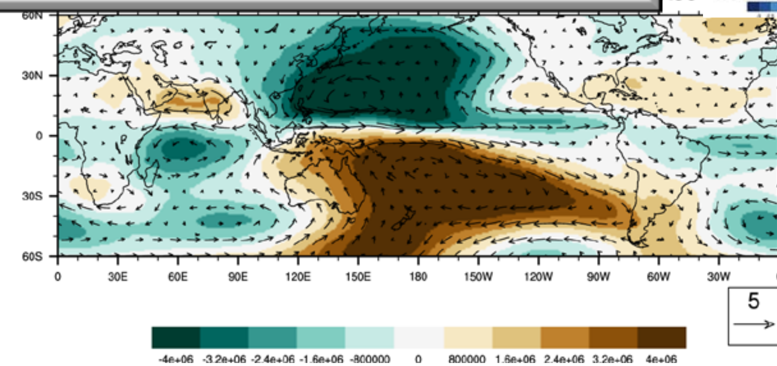




- Different SSTAs produce similar response
- but not El Niño-like SSTA
- Relatively insensitive to regional structure of SSTA







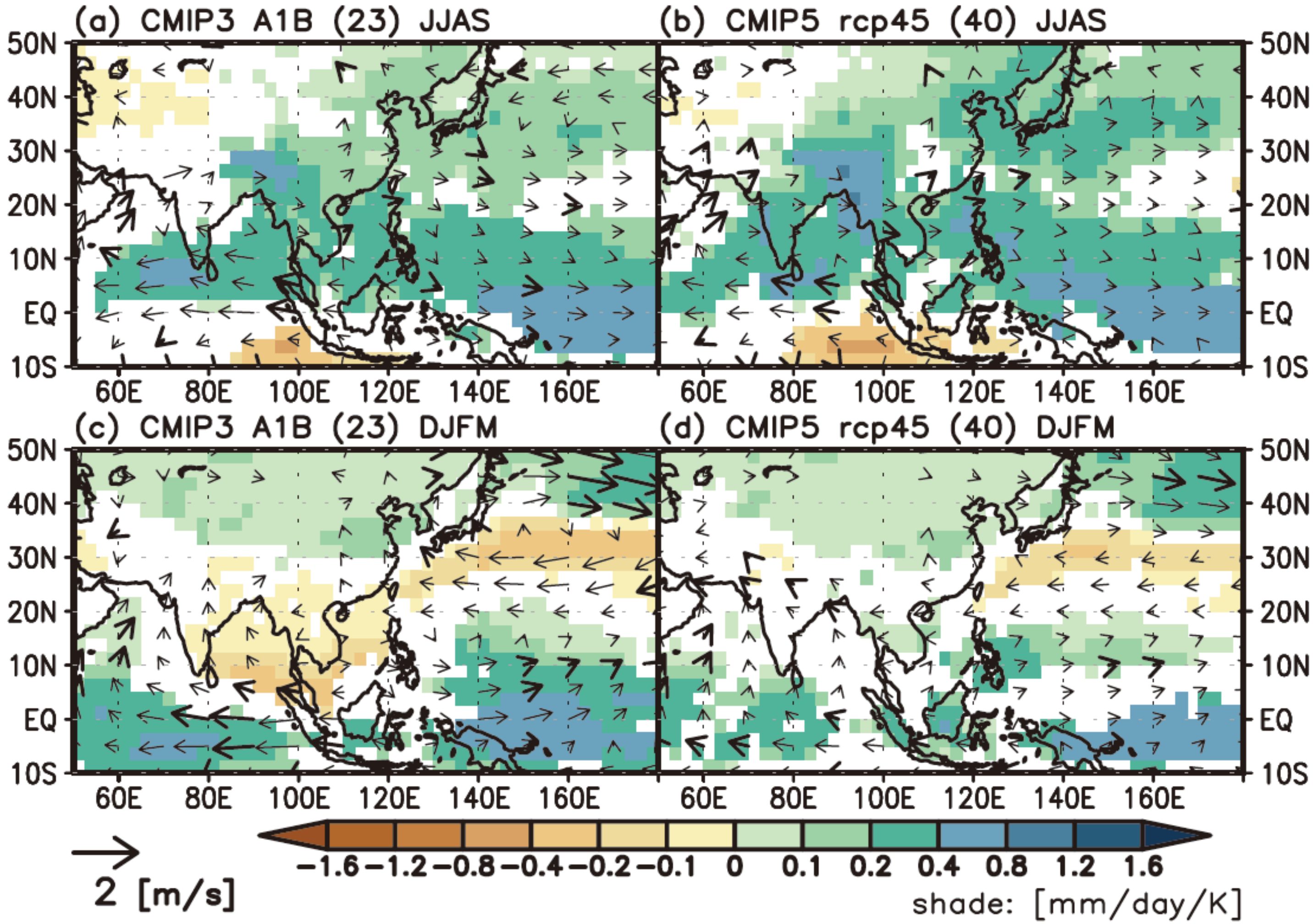
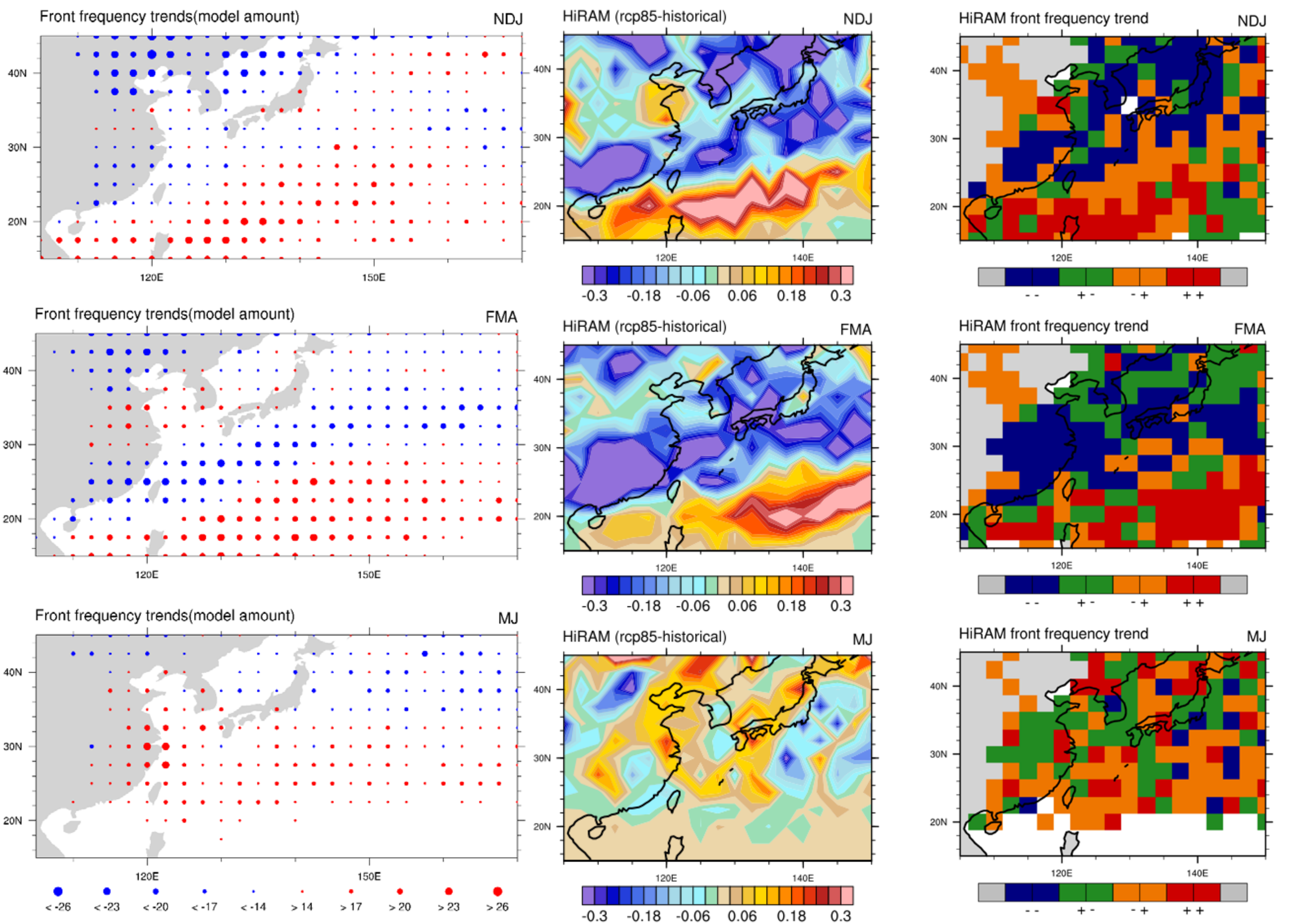



Fig. 8. Future changes in (a, b) June–September, and (c, d) December–March mean precipitation and 850 hPa wind fields. (a, c) A 23-model CMIP3 MME under the SRES A1B scenario, and (b, d) 40-model CMIP5 MME under the RCP4.5 scenario with a common 2.5° by 2.5° grid. Grid points where two-thirds of models agree on the sign of the changes are shaded for precipitation and shown in bold vectors for both zonal and meridional winds.

Kitoh, A., 2017, *JMSJ*, **95**, 7-33

# Front frequency change

HiRAM(RCP8.5-historical) (NF-historical) (RCP8.5-NF)



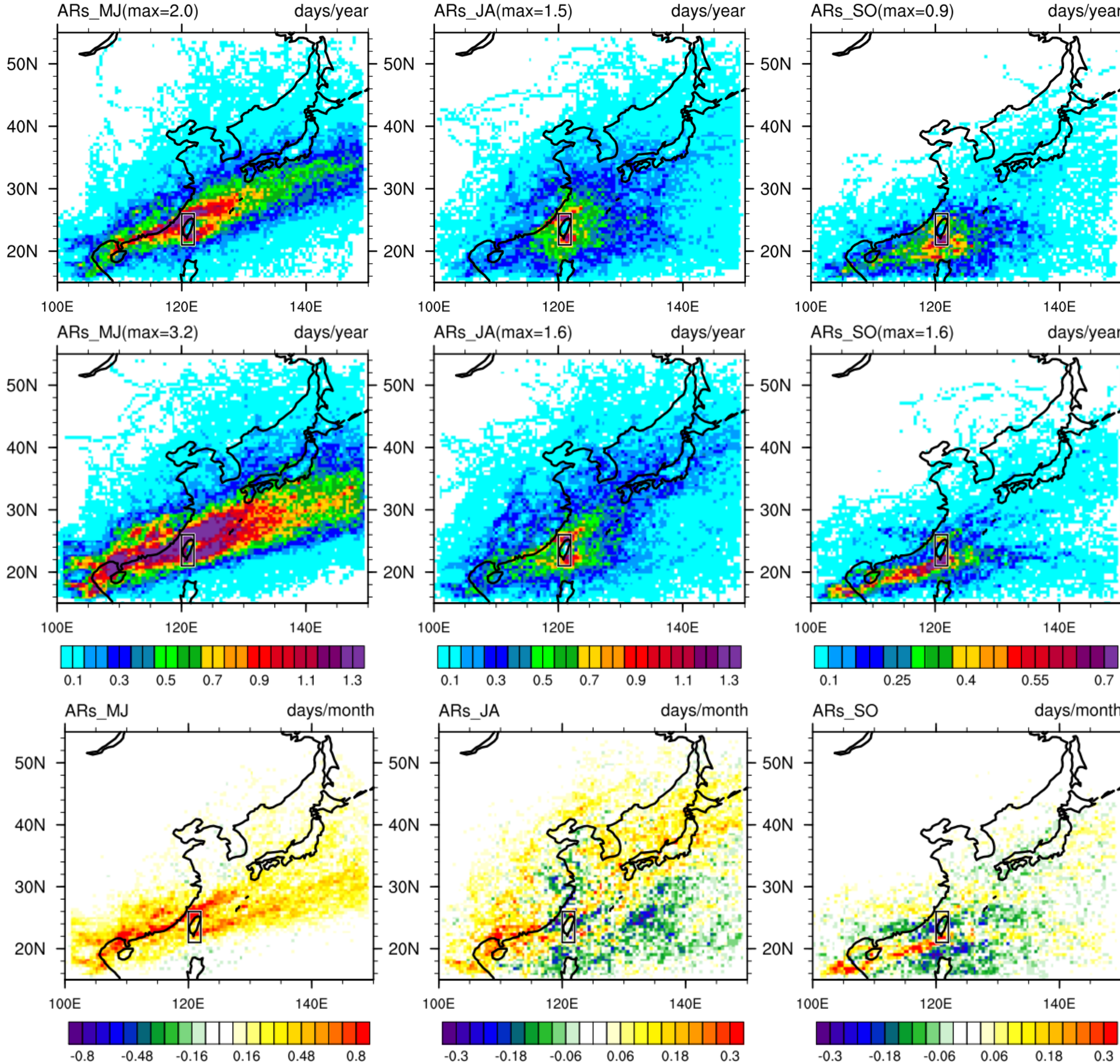

CMIP5 (RCP85-historical)

**Atmospheric River Frequency (passed Taiwan)**

HiRAM historical

HiRAM rcp85

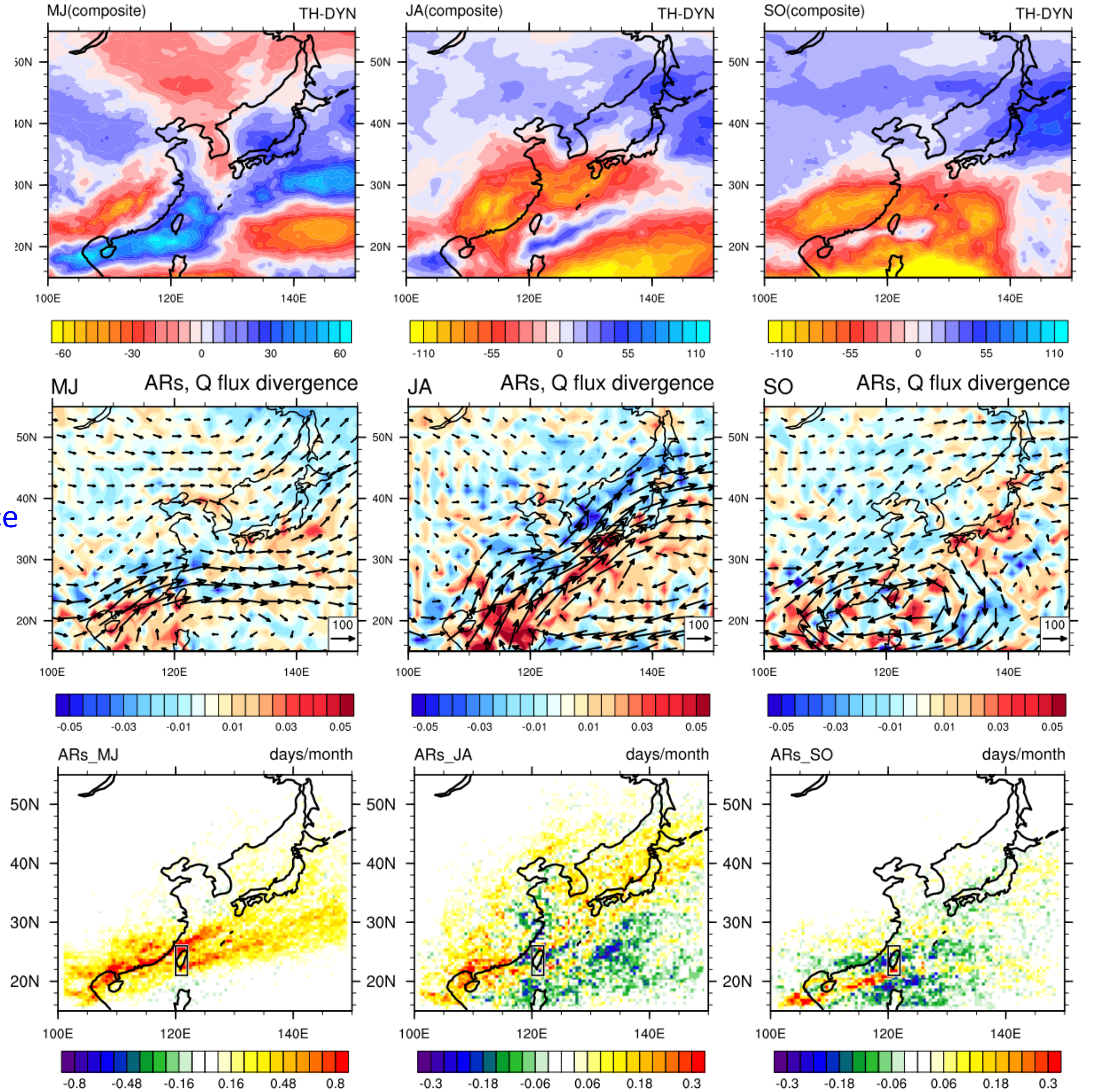
Rcp85-historical



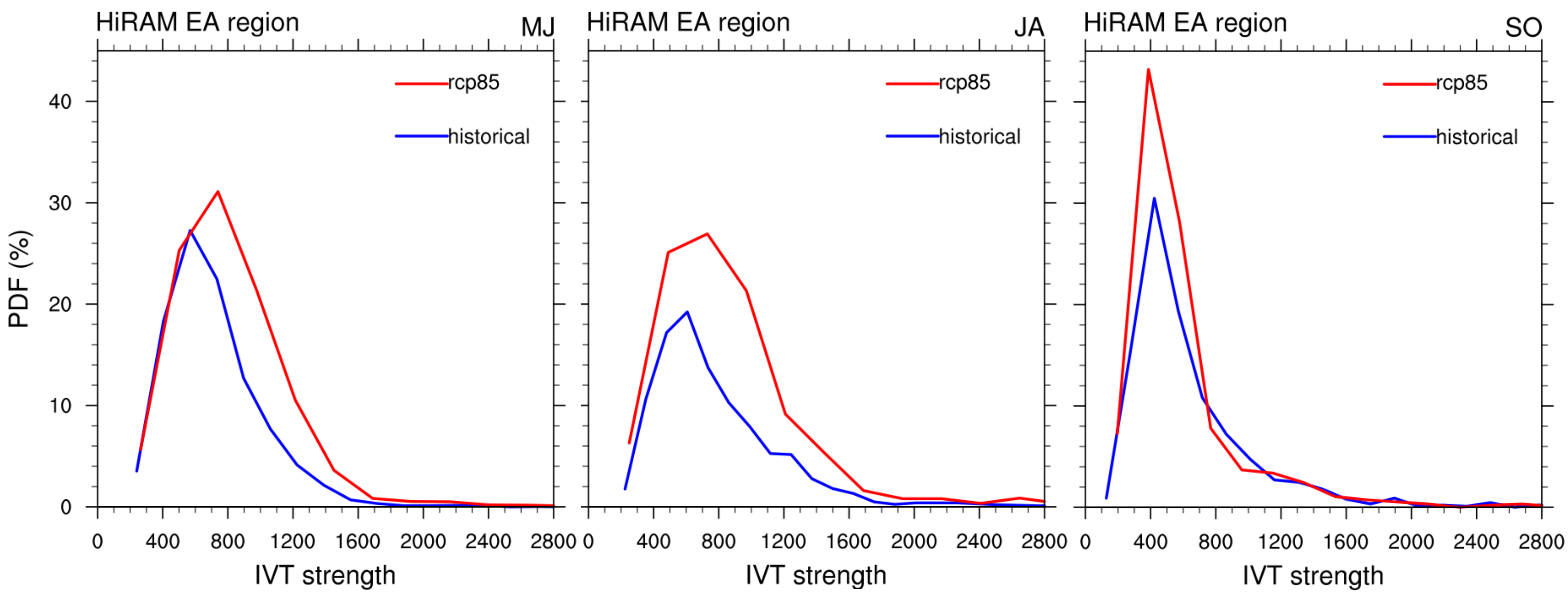
thermodynamic
- dynamic response

Moisture flux&divergence
Composite difference
(rcp85 minus historical)

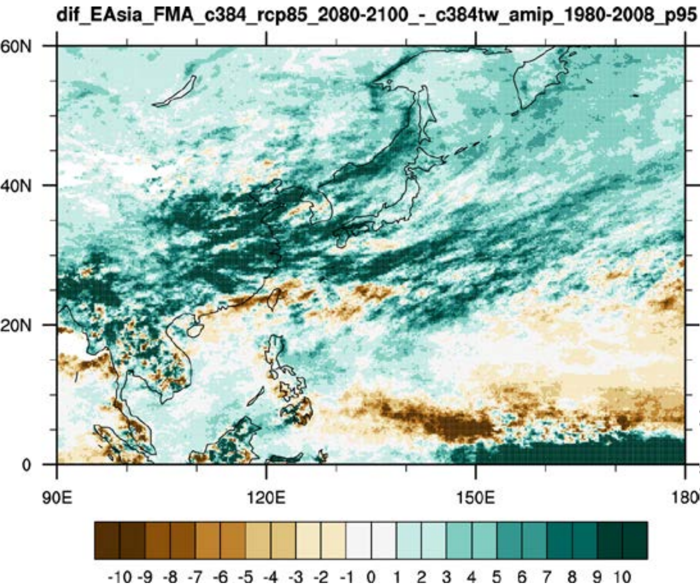
AR frequency
Rcp85-historical



# IVT strength probability density function

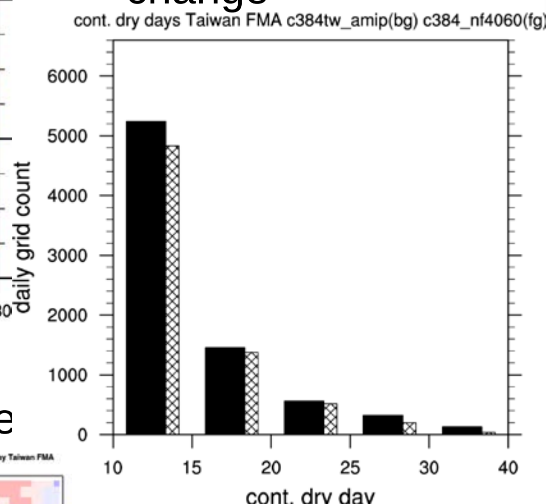


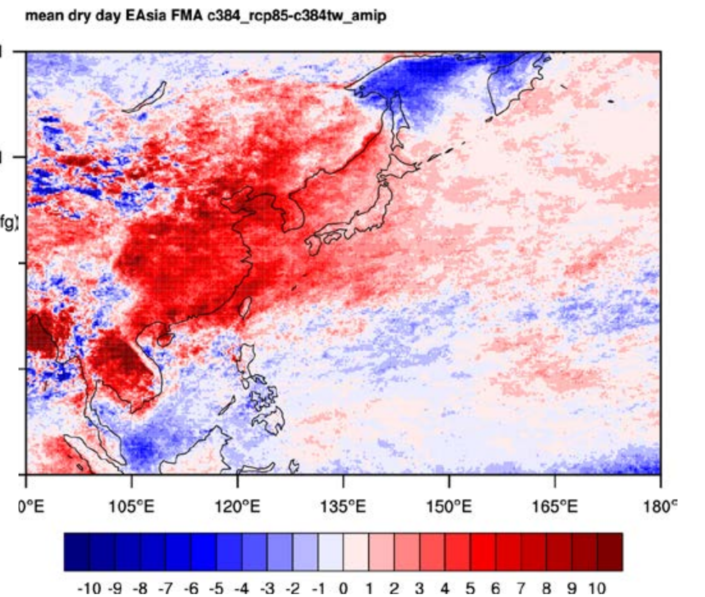
# Spring Rainfall in Warmer climate

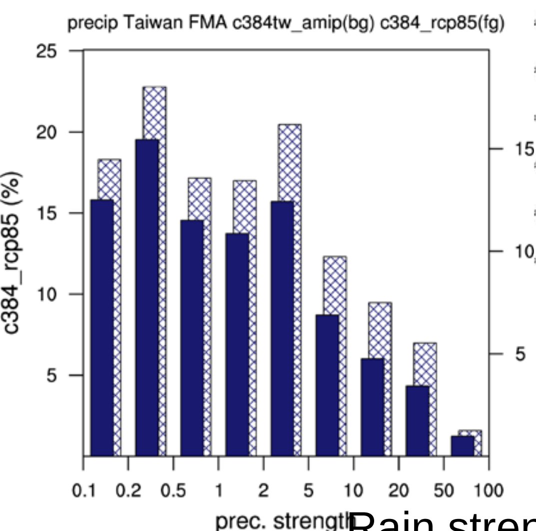


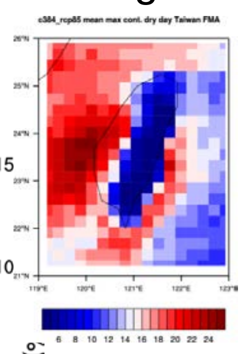

95% tile rain fall strength change

Mean yearly max continous dry day change

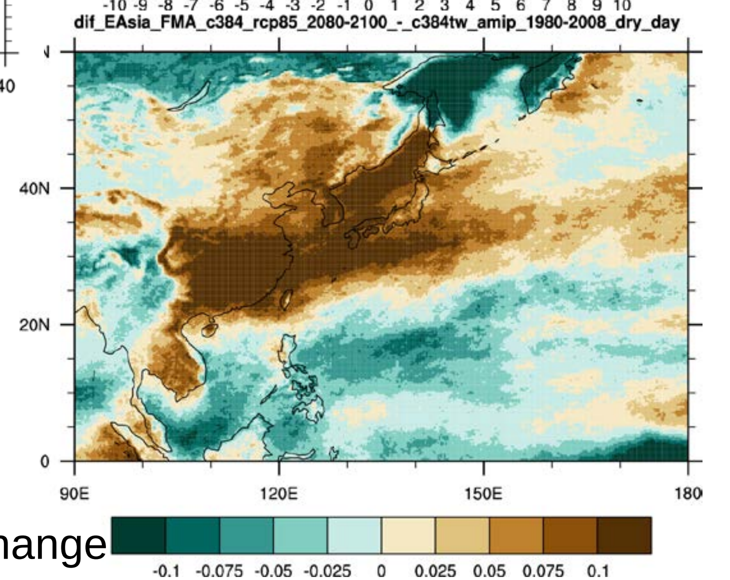


Rain strength change




Dry day ratio change