State Key Laboratory of Numerical Modelling for Atmospheric Sciences
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East Asian Summer Monsoon in a Warming World: Forcing from GHG, Aerosol and Natural variability

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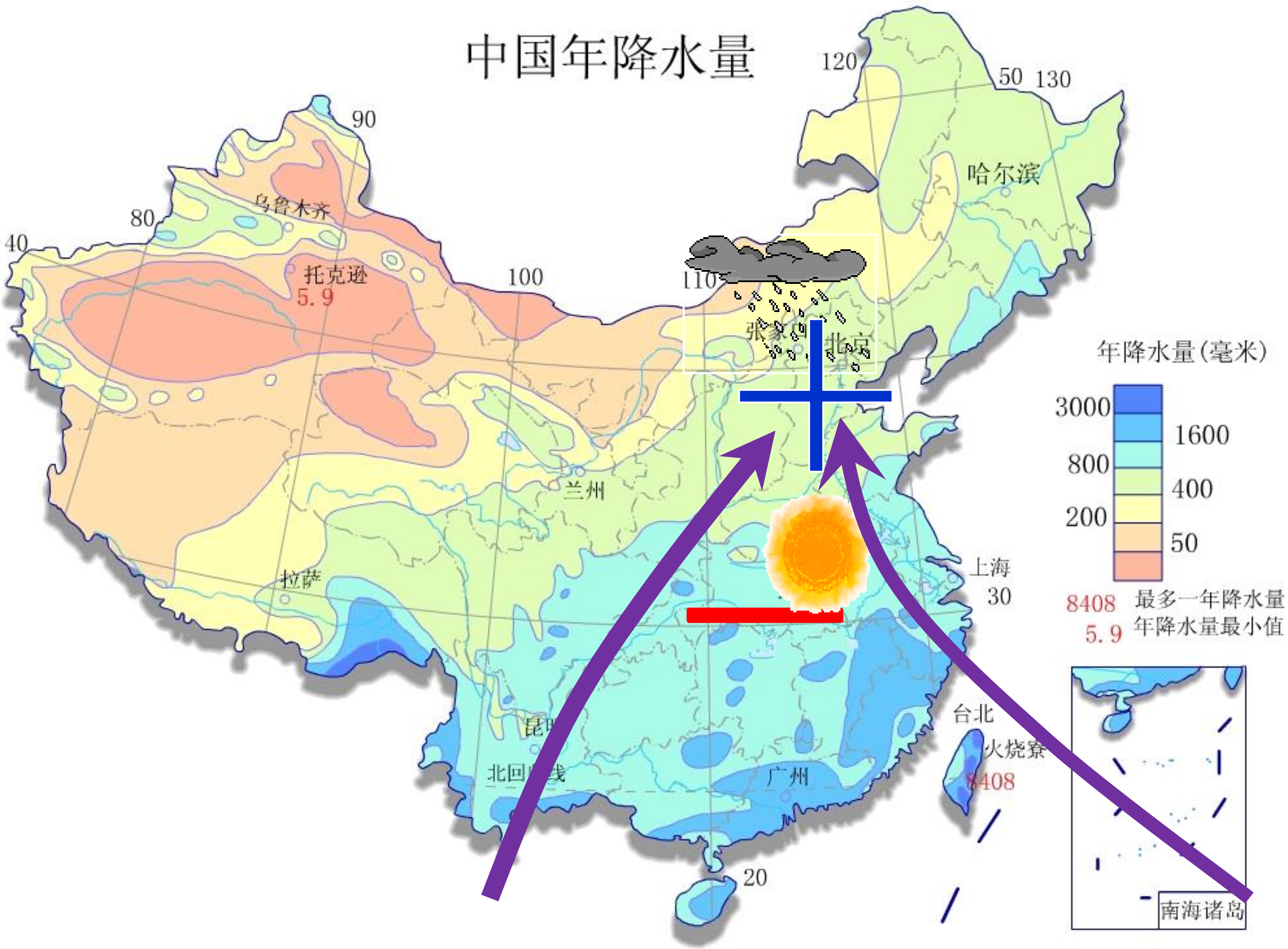
WCRP-JNU Training School on Monsoon Variability in Changing Climate
15-21 Jan 2017, Juju National University

Outline

- Background
- Natural variability driven by PDO
- Response to GHG and aerosol forcing
- Detectable Anthropogenic Shift toward Heavy Precipitation over Eastern China
- Summary

What is a Stronger Summer Monsoon ?



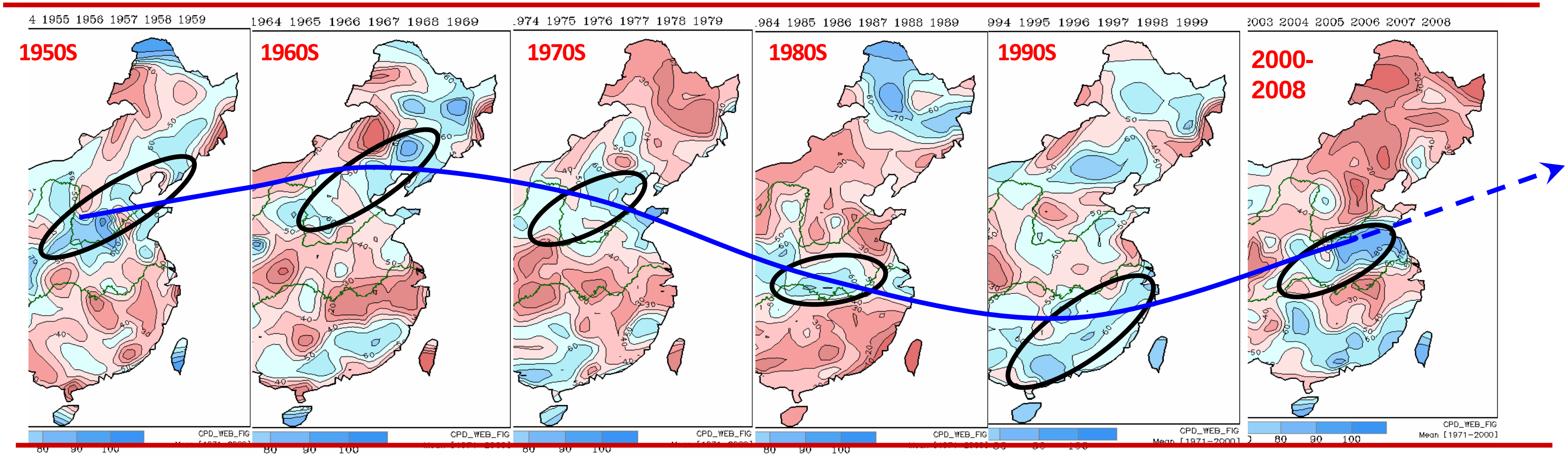
Monsoon: a seasonal reversal of surface wind

Without monsoon, EA would be covered by deserts

However, monsoon has been weakening in the 2nd half of 20th century

Decadal Changes of summer rainfall

20世纪　　蓝色：降雨频次高；红色：降雨频次低　　21世纪



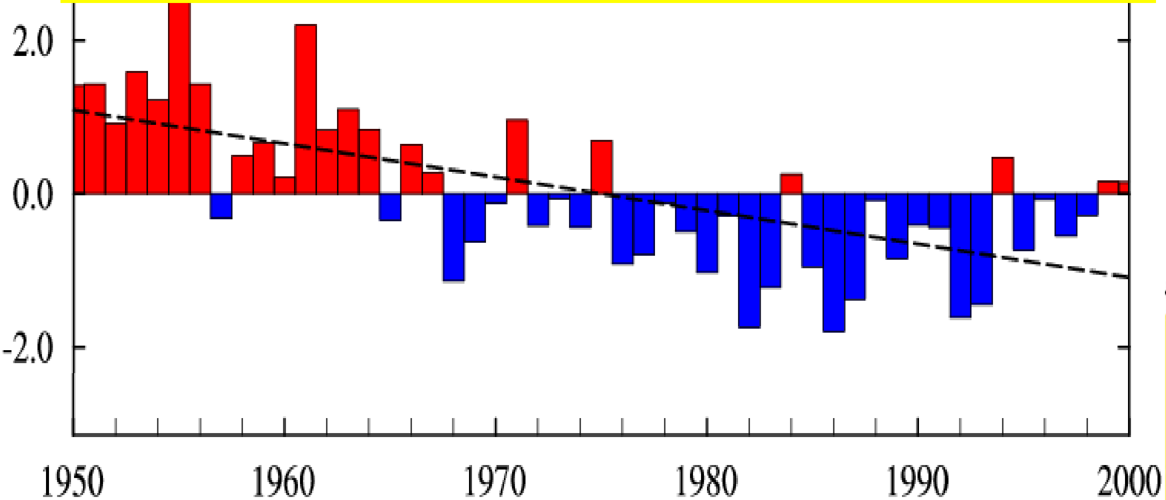
最高频次 90%　　最高频次 80%　　最高频次 60%　　最高频次 60%　　最高频次 70%

1970S　　Monsoon Weakening

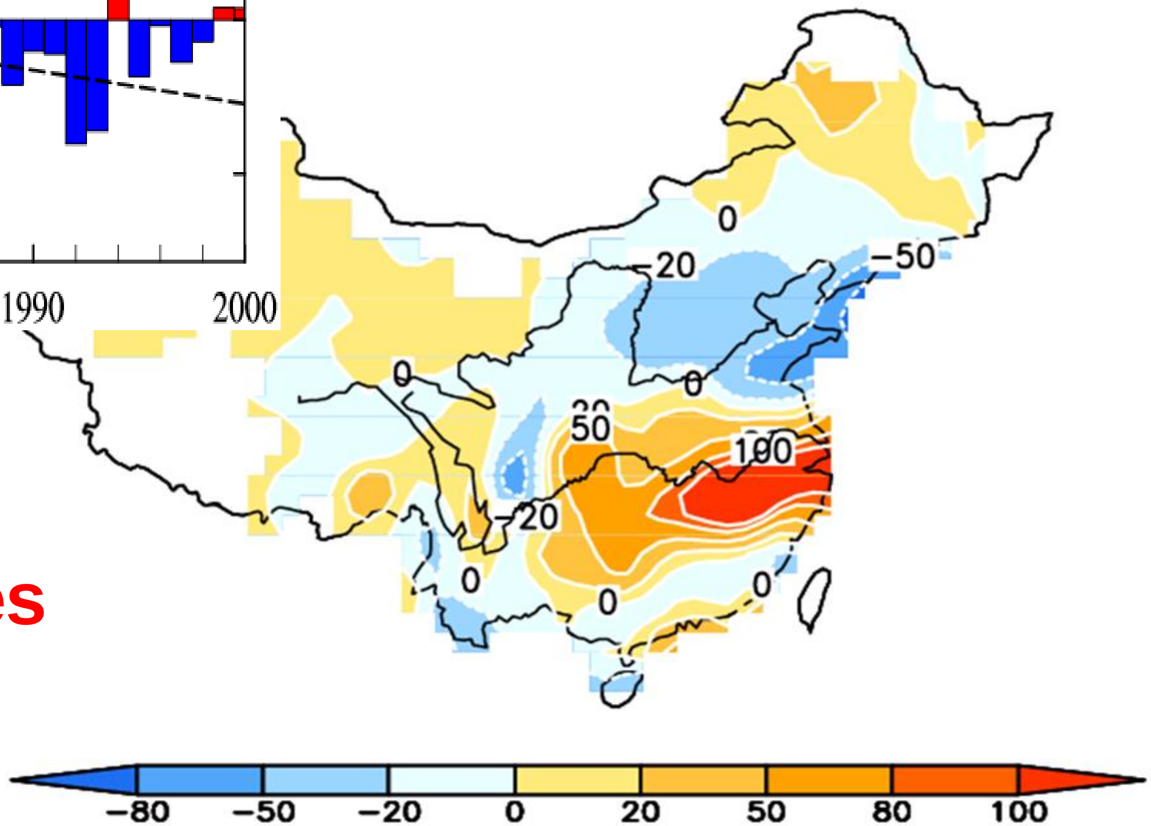
(After BCC, 2010)

Changes of EASM : Local Pattern

EA summer monsoon circulation index

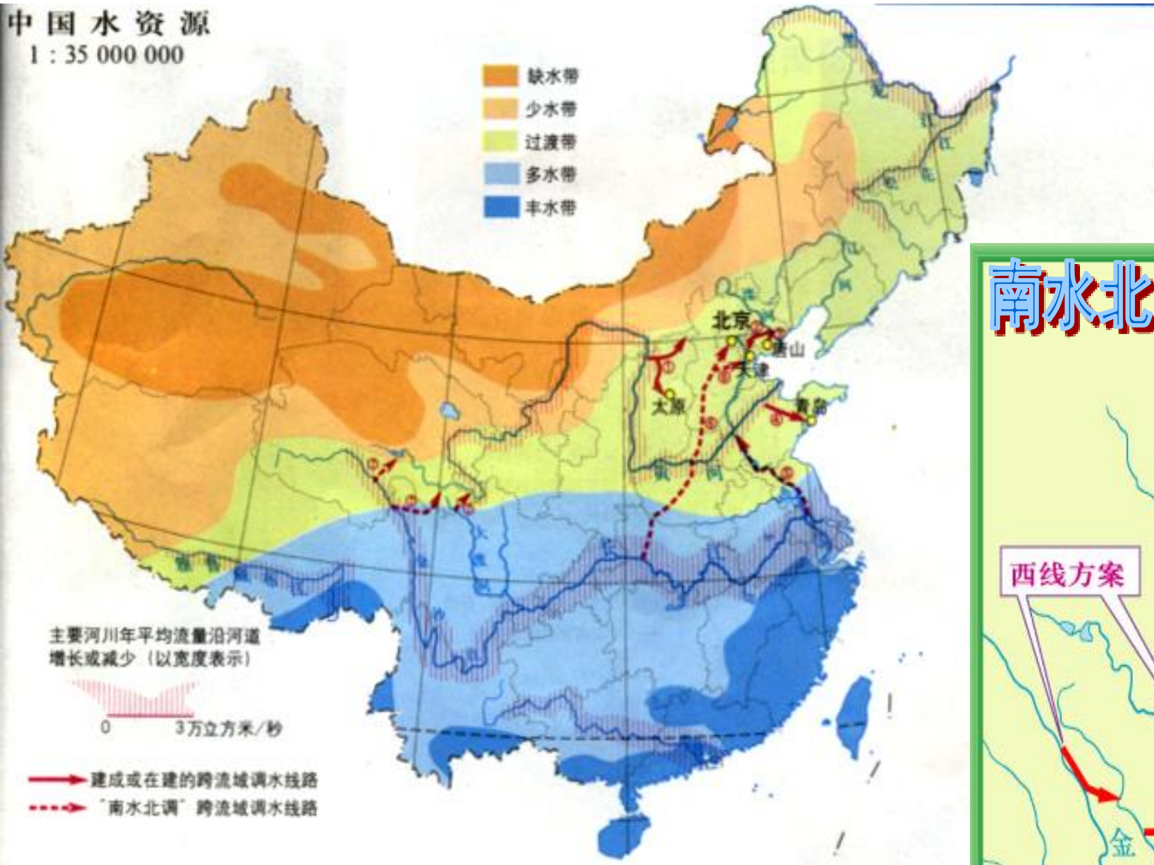


JJA Rainfall anomalies



Zhou, T., D. Gong, J. Li, B. Li, 2009: Detecting and understanding the multi-decadal variability of the East Asian Summer Monsoon – Recent progress and state of affairs. ***Meteorologische Zeitschrift***, 18 (4), 455-467

Transport water from YZ river to N. China by channels



http://www.nsbd.gov.cn/zx/english/

South-to-North Water Diversion Project

(http://www.nsbd.gov.cn/zx/english/20070308/)

Why did the monsoon show a weakening tendency :
Possible Mechanisms

- **Tibetan Plateau thermal forcing,**
- **internal variability,**
- **global warming, ect.**
- **PDO**
- **Aerosol forcing,**
- **Up to now:**

No consensus .

REPORTS

Climate Effects of Black Carbon Aerosols in China and India

Surabi Menon,[1,2]* James Hansen,[1] Larissa Nazarenko,[1,2] Yunfeng Luo[3]

In recent decades, there has been a tendency toward increased summer floods in south China, increased drought in north China, and moderate cooling in China and India while most of the world has been warming. We used a global climate model to investigate possible aerosol contributions to these trends. We found precipitation and temperature changes in the model that were comparable to those observed if the aerosols included a large proportion of absorbing black carbon ("soot"), similar to observed amounts. Absorbing aerosols heat the air, alter regional atmospheric stability and vertical motions, and affect the large-scale circulation and hydrologic cycle with significant regional climate effects.

China has been experiencing an increased severity of dust storms, commonly attributed to overfarming, overgrazing, and destruction of forests (*1*). Plumes of dust from north China, with adhered toxic contaminants, are cause for public health concern in China, Japan, and Korea, and some of the aerosols even reach the United States (*2*). Recent dust events have prompted Chinese officials to consider spending several hundred billion yuan (~$12 billion) in the next decade to increase forests and green belts to combat the dust storms (*3*). Such measures may be beneficial in any case. However, we suggest that the observed trend toward increased summer floods in south China and drought in north China (*4*), thought to be the largest change in precipitation trends since 950 A.D. (*4*), may have an alternative explanation: human-made absorbing aerosols in remote populous industrial regions that alter the regional atmospheric circulation and contribute to regional climate change. If our interpretation is correct, reducing the amount of anthropogenic black carbon aerosols, in addition to having human health benefits, may help diminish the intensity of floods in the south and droughts and dust storms in the north. Similar considerations may apply to India and neighboring regions such as Afghanistan, which have experienced recent droughts.

Atmospheric aerosols, which are fine particles suspended in the air, comprise a mixture of mainly sulfates, nitrates, carbonaceous (organic and black carbon) particles, sea salt, and mineral dust. Black (elemental) carbon (BC) is of special interest because it absorbs sunlight, heats the air, and contributes to global warming (*5, 6*), unlike most aerosols, which reflect sunlight to space and have a global cooling effect (*7*). BC emissions, a product of incomplete combustion from coal, diesel engines, biofuels, and outdoor biomass burning (*8*), are particularly large in China and India because of low-temperature household burning of biofuels and coal (*9*).

It is reasonable to anticipate that human-made aerosols may contribute to climate change in China and India, because both absorbing BC aerosols and reflective aerosols, such as sulfates, reduce the amount of sunlight reaching the ground and thus should tend to cause local cooling. Observed temperatures in China and India in recent decades, unlike most of the world, reveal little warming (*10*), and in some seasons there is cooling, especially in the summer when aerosol effects should be largest. The climate effect of aerosols is complicated, because aerosols have, in addition to their direct radiative effects, indirect effects on cloud properties (*7, 11*).

Here we report on climate model simulations of the direct radiative effect of aerosols in the region of China and India. We used the Goddard Institute for Space Studies (GISS) SI2000 12-layer climate model, which has been used to study the impact of several forcings on global mean temperature (*12*). Figure 1 shows the (seasonally independent) added aerosol optical depth $\Delta\tau_{aer}$ (0.55 μm) used in our climate model experiments (*13*). Over China, we take $\Delta\tau_{aer}$ (0.55 μm) to be equal to τ_{aer} (0.75 μm) measured in the 1990s (*14, 15*). Over India and the Indian Ocean, $\Delta\tau_{aer}$ in our experiments is taken from chemical transport model assimilations of satellite measurements (*16*). The resulting radiative forcings at the top of the atmosphere and surface (fig. S1) are ~+6 W m^{-2} and −17 W m^{-2}, respectively, over India and the Indian Ocean, which is comparable to values estimated by others (*17*).

We performed two primary experiments. In experiment A, we added the aerosols of Fig. 1 with aerosol single-scatter albedo (SSA) = 0.85 (*18*), which is representative of measurements from the Indian Ocean Experiment (INDOEX) (*17*) and industrial regions in China. We obtained such relatively "dark" aerosols by including an appropriate amount of BC, with the remainder being sulfate. In experiment B, we removed BC so that SSA = 1, i.e., the aerosols were "white." In both A and B, the sea surface temperature (SST), greenhouse gases, and other forcings were kept fixed at the same values as in the control run, so that the aerosols were the only forcing. Both experiments were run for 120 years.

Figure 2A shows the simulated summer [June, July, and August (JJA)] surface air temperature (T_s) changes. The aerosols with SSA = 0.85 yield cooling in China by 0.5 to 1 K (a consequence of the reduced solar radiation reaching the surface) but warming in most of the world [due to BC heating of the troposphere (*19*)]. Because of the long model run, the cooling in China and even the warming in many distant locations are highly significant (>99%), based on Student's *t* test (fig. S2). The simulated cooling in China is larger than the observed cooling there during the past 50 years (Fig. 2B), when most of the increase in aerosol amount probably occurred. This is as expected, because the simulations exclude the effect of increasing greenhouse gases (*20*).

The BC absorption in China and India causes a significant warming (>0.5 K) in the Sahara Desert region and in west and central Canada, despite the fixed SST. Because aerosols were unchanged outside the China/India region, this warming at a distance seems to be due to heating of tropospheric air over China and India, with dynamical export to the rest of the world, where the warmer troposphere can reduce convective and radiative cooling of the surface. Consistent with observations (*10, 21*), this warming does not occur over the south central United States, where the observed cooling trend is thought to be driven by warming in the tropical Pacific Ocean (*21, 22*).

Fig. 1. Incremental aerosol optical depth $\Delta\tau_{aer}$ (0.55 μm), which is used to drive the climate change simulations. Latitude and longitude are denoted.

[1]NASA Goddard Institute for Space Studies, New York, NY 10025, USA. [2]Center for Climate Systems Research, Columbia University, New York, NY 10025, USA. [3]National Science Foundation of China, Haidian, China.

*To whom correspondence should be addressed. E-mail: smenon@giss.nasa.gov

Zhou, T., D. Gong, J. Li, B. Li, 2009: Detecting and understanding the multi-decadal variability of the East Asian Summer Monsoon – Recent progress and state of affairs. ***Meteorologische Zeitschrift***, 18 (4), 455-467

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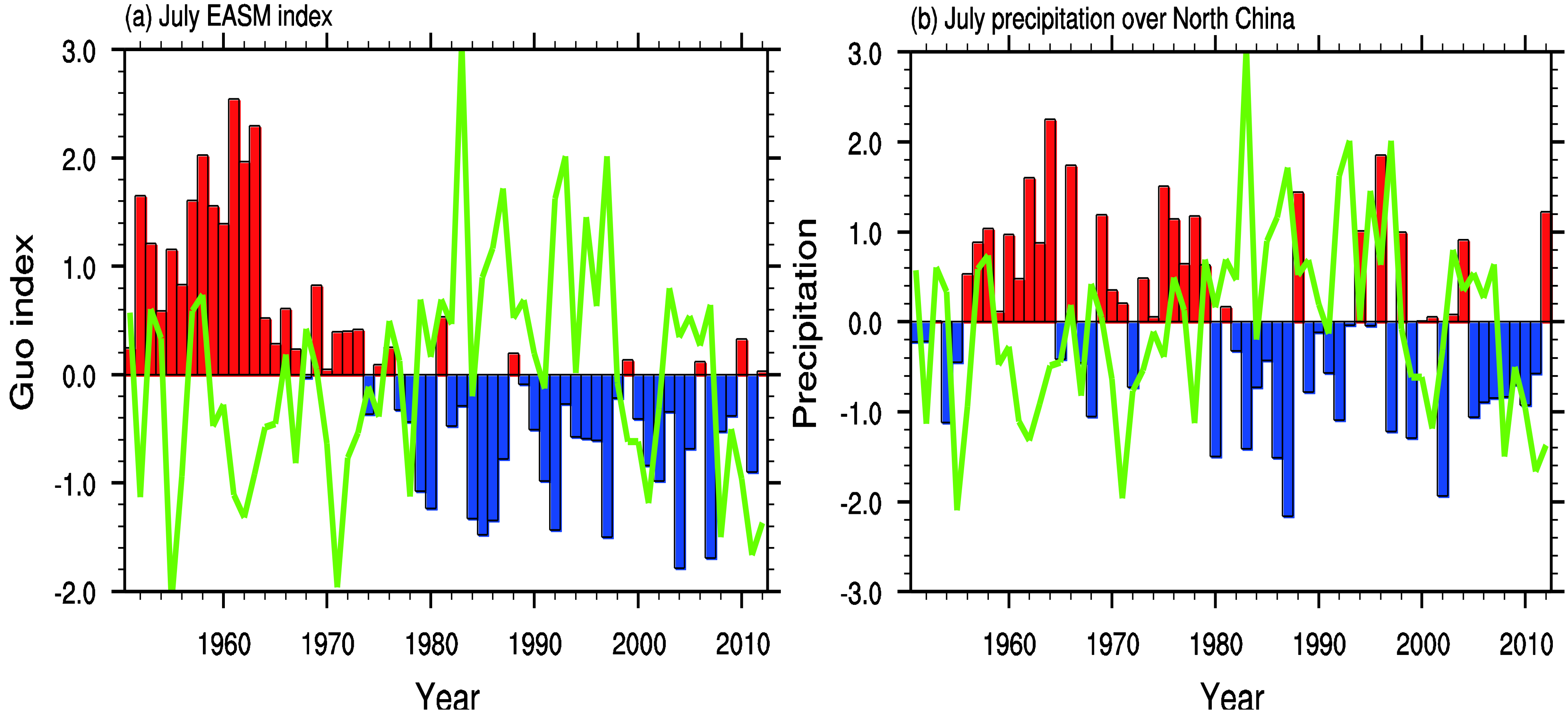
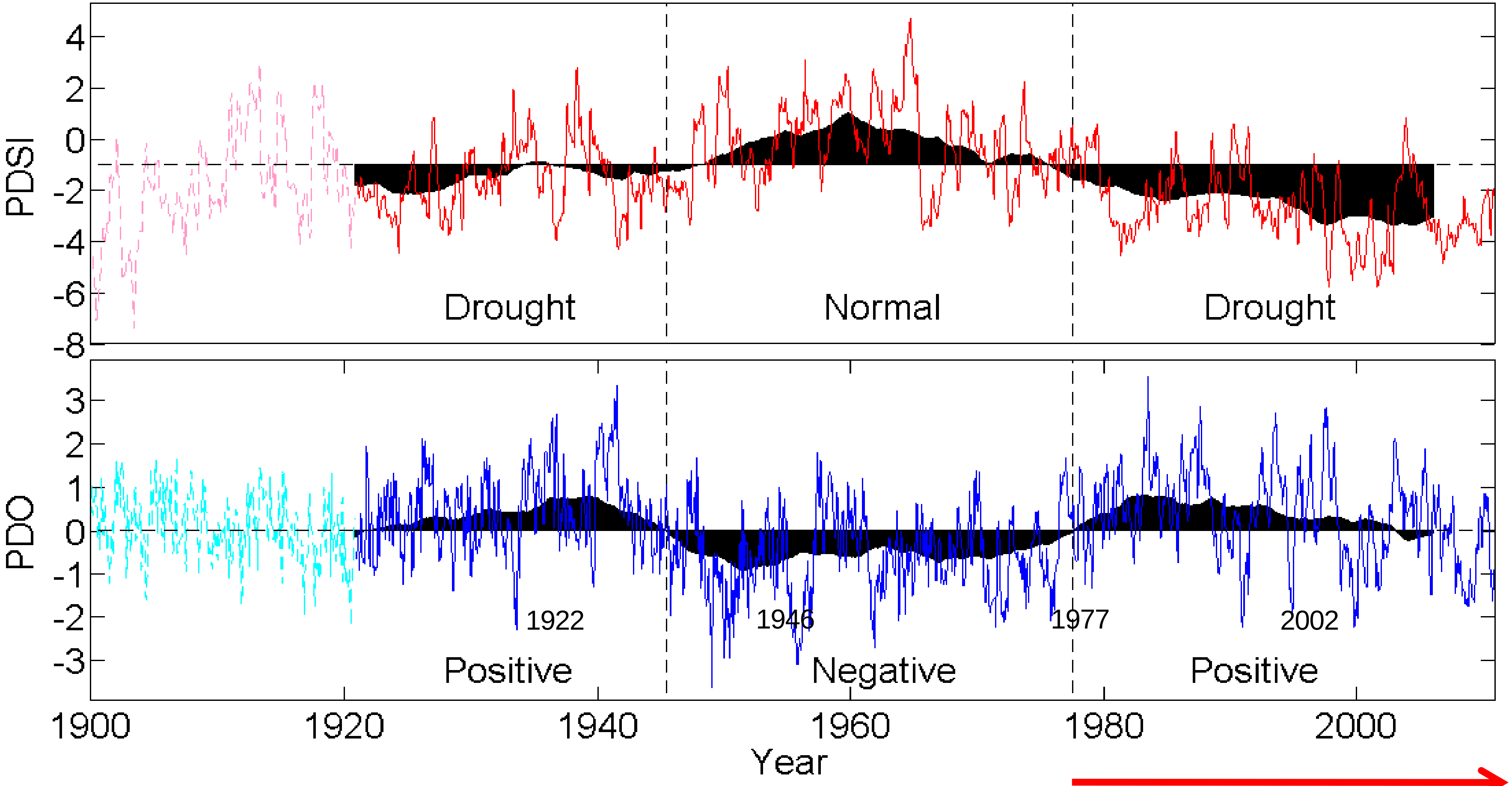
PDO and E. Asian monsoon

Monsoon index (bar) Green: PDO index Precipitation in N. China (bar)



Zhou, T., F. Song, R. Lin, X. Chen and X. Chen, 2013: The 2012 North China floods: Explaining an extreme rainfall event in the context of a long-term drying tendency [in "Explaining Extreme Events of 2012 from a Climate Perspective"]. ***Bulletin of the American Meteorological Society***, 94(9), S49-S51

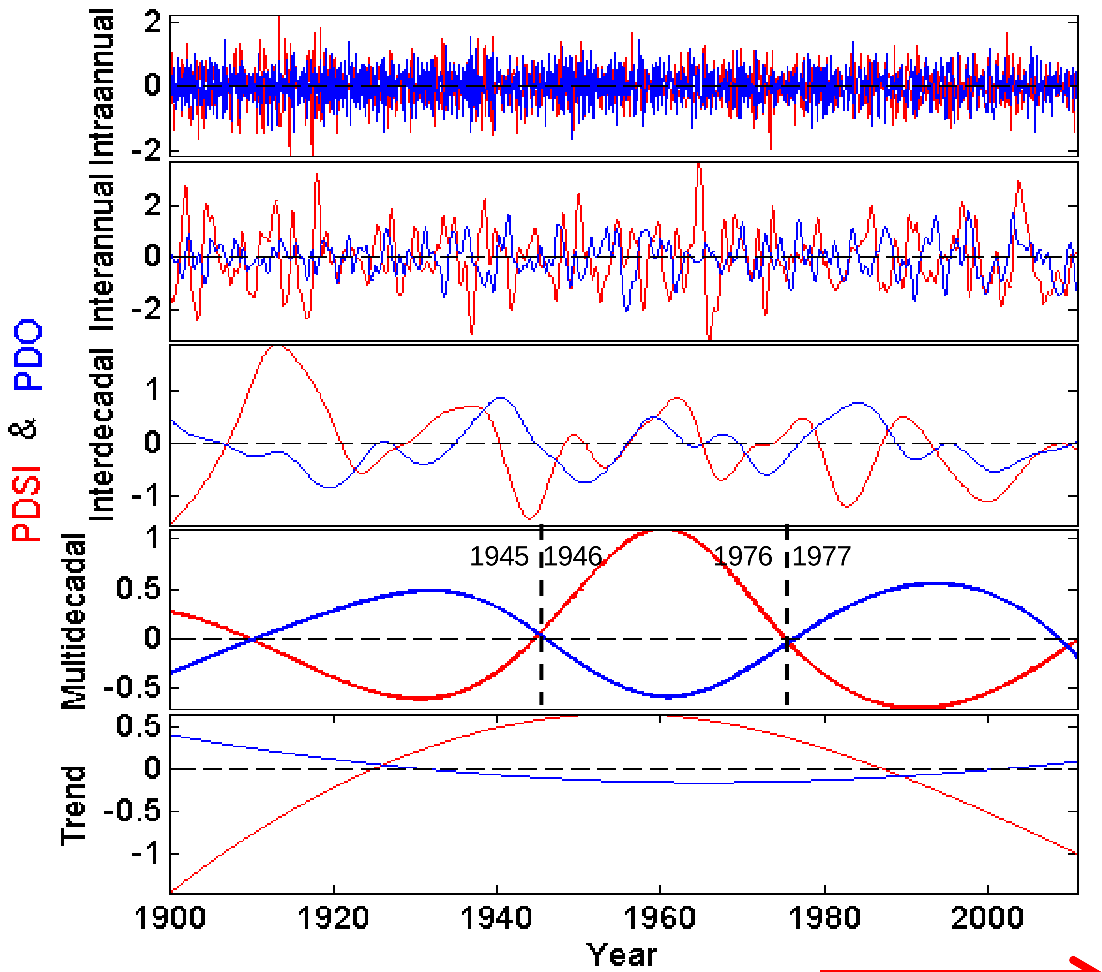
PDSI index in N. China and PDO index over the 20th century



Shading: 11 yrs smoothing

Qian C. and T. **Zhou**, 2013: Multidecadal variability of North China aridity and its relationship to PDO during 1900-2010, ***J. Climate***, DOI: 10.1175/JCLI-D-13-00235.1

EEMD analysis of PDSI and PDO indices



50-70 yrs (56)

Qian C. and **T. Zhou**, 2013: Multidecadal variability of North China aridity and its relationship to PDO during 1900-2010, ***J. Climate***, DOI: 10.1175/JCLI-D-13-00235.1

Model and Experiments

AMIP-type simulation is used to understand the driving of SST

	CAM3 (T85)	CAM3 (T42)	AM2.1 (FV)
GOGA	5	5	10
TOGA	5	5	N/A
ATM	N/A	10	N/A

Definition of EASM Index:

Normalized zonal wind shear between 850 and 200 hPa averaged within (20-40N,110-140E) (After Han and Wang, 2007)

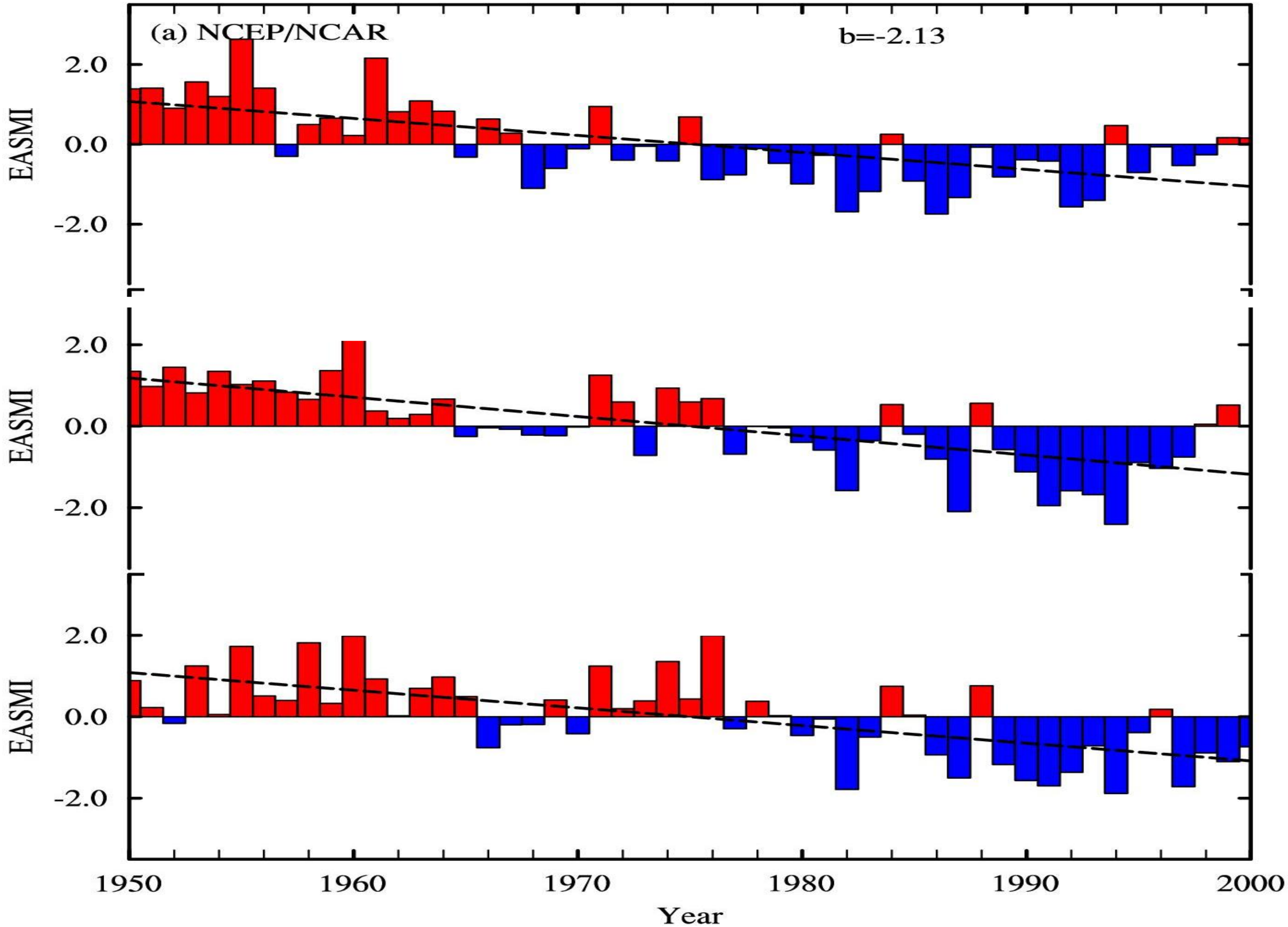
Li, Hongmei, A. Dai, **T. Zhou**, J. Lu, 2010: Responses of East Asian summer monsoon to historical SST and atmospheric forcing during 1950-2000, ***Climate Dynamics*, 34**, 501-514

EASM index in AGCM driven by observed SST

Reanalysis

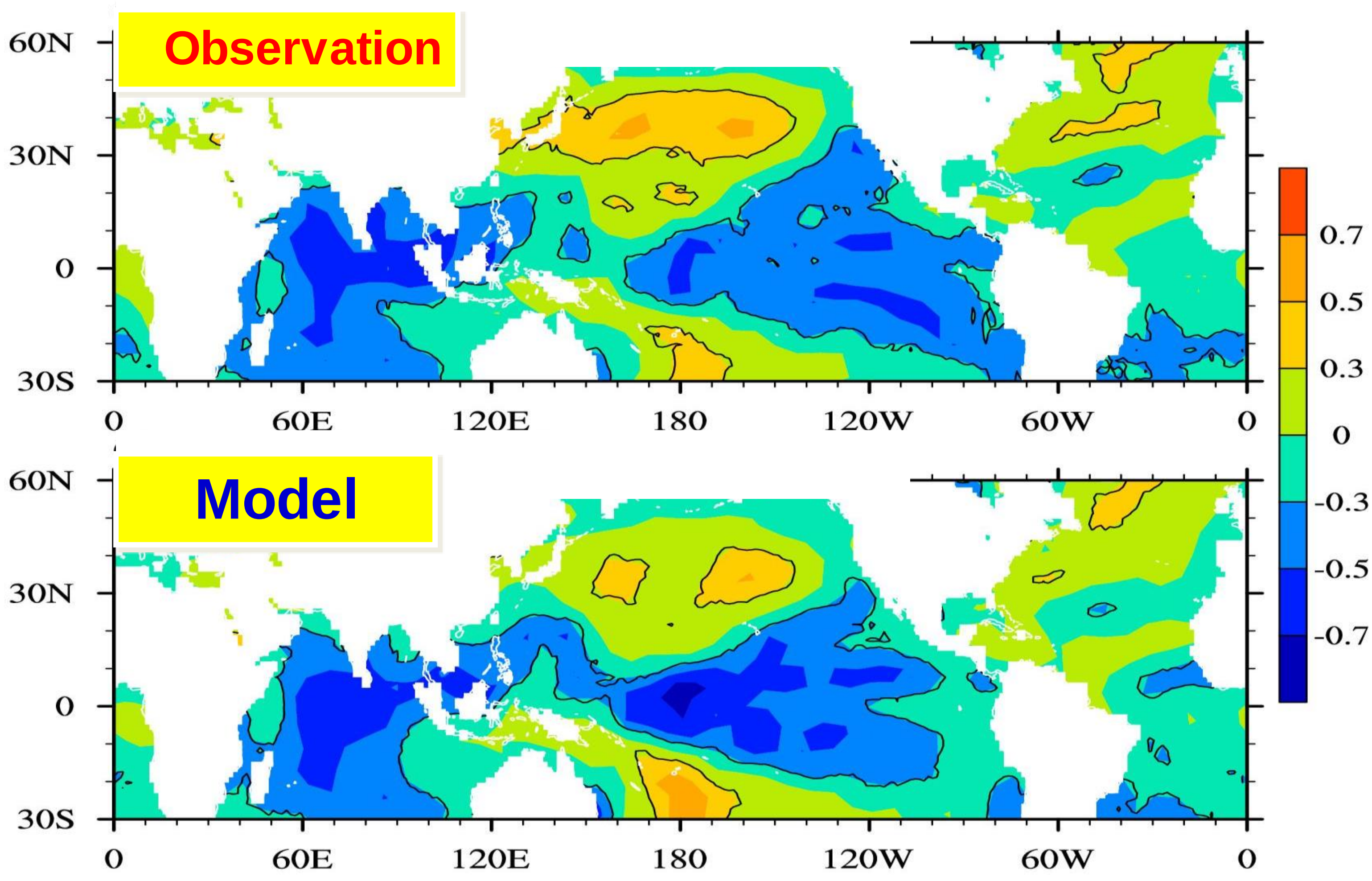
Global SST driven AGCM

Tropical SST driven AGCM



Li, Hongmei, A. Dai, **T. Zhou**, J. Lu, 2010: Responses of East Asian summer monsoon to historical SST and atmospheric forcing during 1950-2000, ***Climate Dynamics*, 34**, 501–514

Correlations between SSTA and EASM index

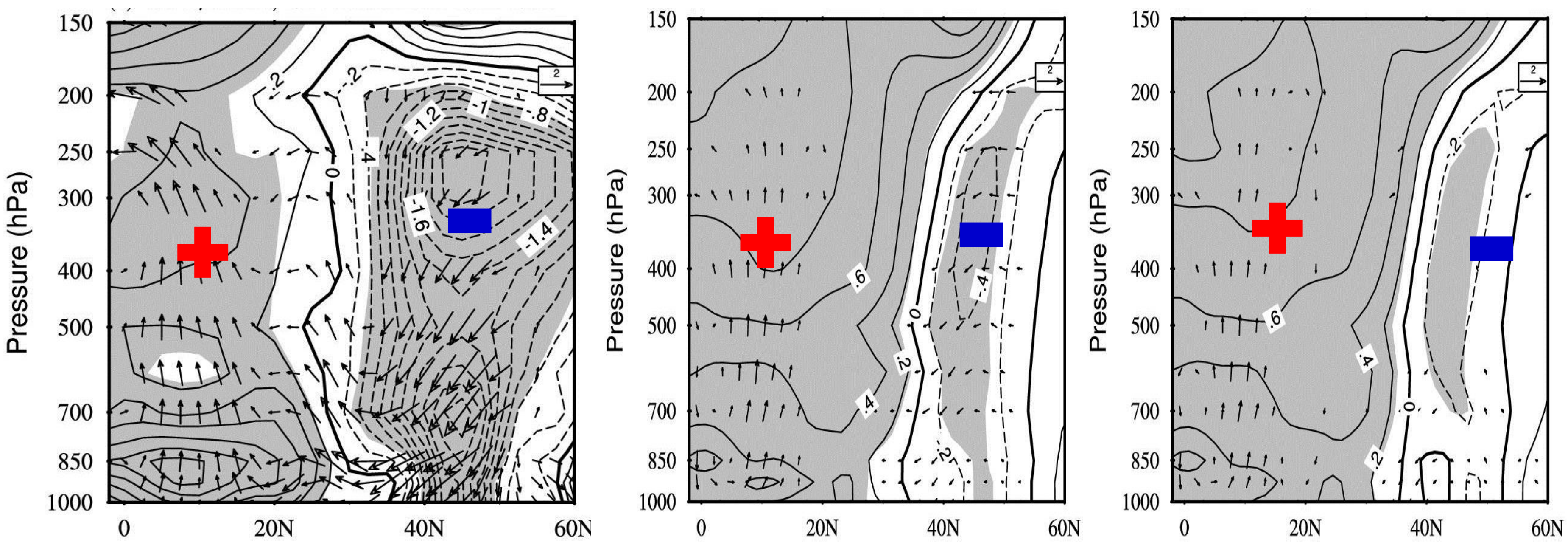


Li, Hongmei, A. Dai, **T. Zhou**, J. Lu, 2010: Responses of East Asian summer monsoon to historical SST and atmospheric forcing during 1950-2000, ***Climate Dynamics*, 34**, 501–514, DOI 10.1007/s00382-008-0482-7

Land-Sea Thermal Contrast change

(105-122° E average） **(1980-99) －(1958-79)**

Reanalysis **Global SST-forcing** **Tropical SST-forcing**



CLM **Cold Ocean** **Warm Land** **Cold Ocean** **Warm land** **Cold Ocean** **Warm land**

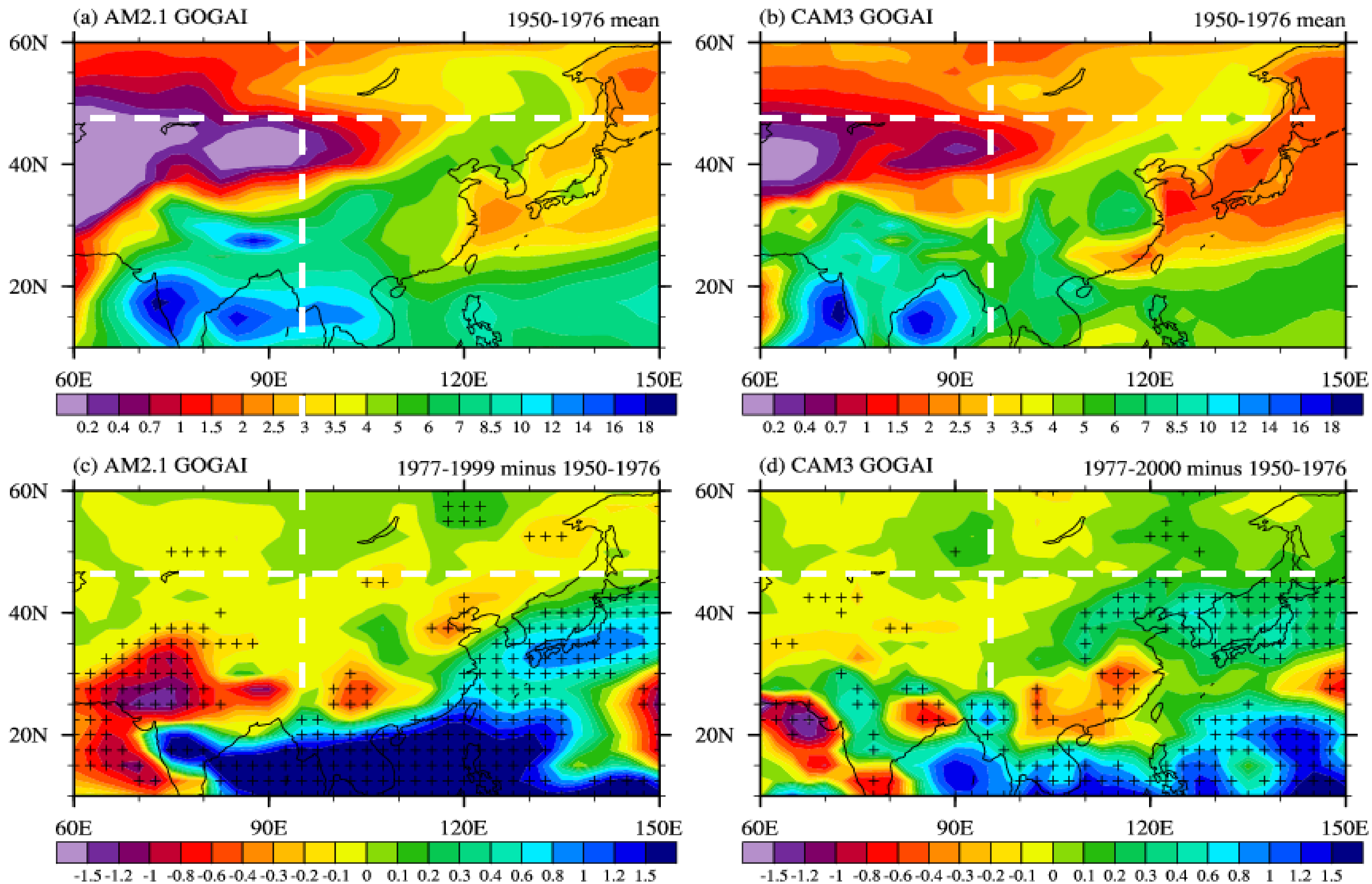
Li, Hongmei, A. Dai, T. Zhou, J. Lu, 2010: Responses of East Asian summer monsoon to historical SST and atmospheric forcing during 1950-2000, ***Climate Dynamics*, 34**, 501–514, DOI 10.1007/s00382-008-0482-7

Precipitation: Mean State and Inter-decadal change

GFDL AM2.1 | **NCAR CAM3**

Mean

Change



Point # 1

- Data diagnosis reveals an out of phase change of E. Asian summer monsoon circulation and PDO at inter-decadal time scale. This relationship is evident in both the past 50 yrs and the 20th century.
- When driven by historical SST, the AGCMs are able to reproduce to weakening tendency of E. Asian summer monsoon circulation. The response is dominated by the tropical lobe of PDO/IPO.
- *The simulation of monsoon rain band changes remains to be a challenge.*

Zhou, T., D. Gong, J. Li, B. Li, 2009: Detecting and understanding the multi-decadal variability of the East Asian Summer Monsoon – Recent progress and state of affairs. ***Meteorologische Zeitschrift***, 18 (4), 455-467

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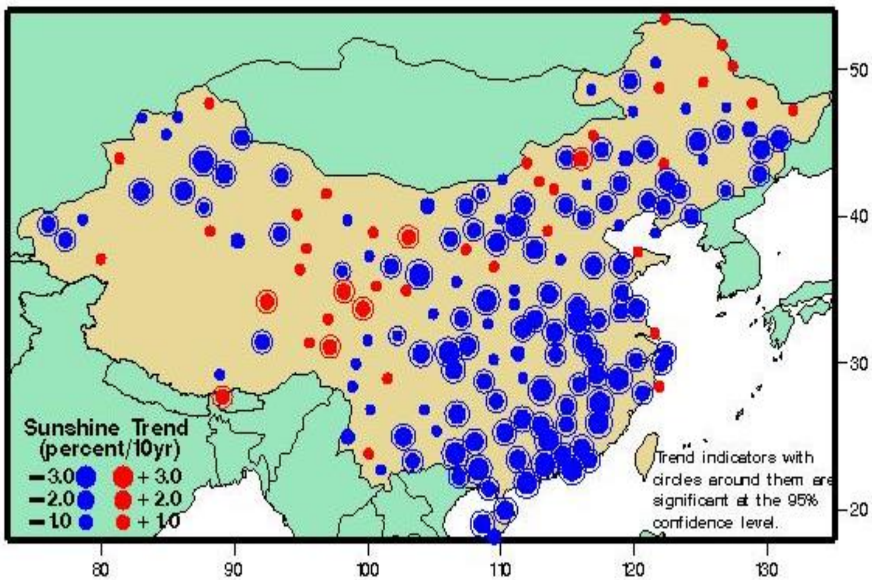
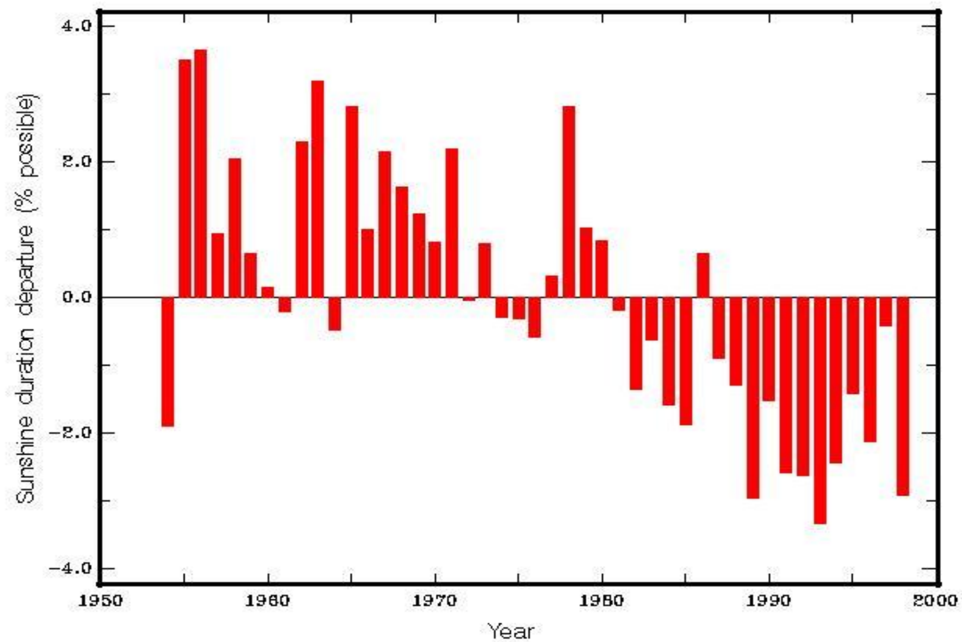
Reduction of sunshine duration



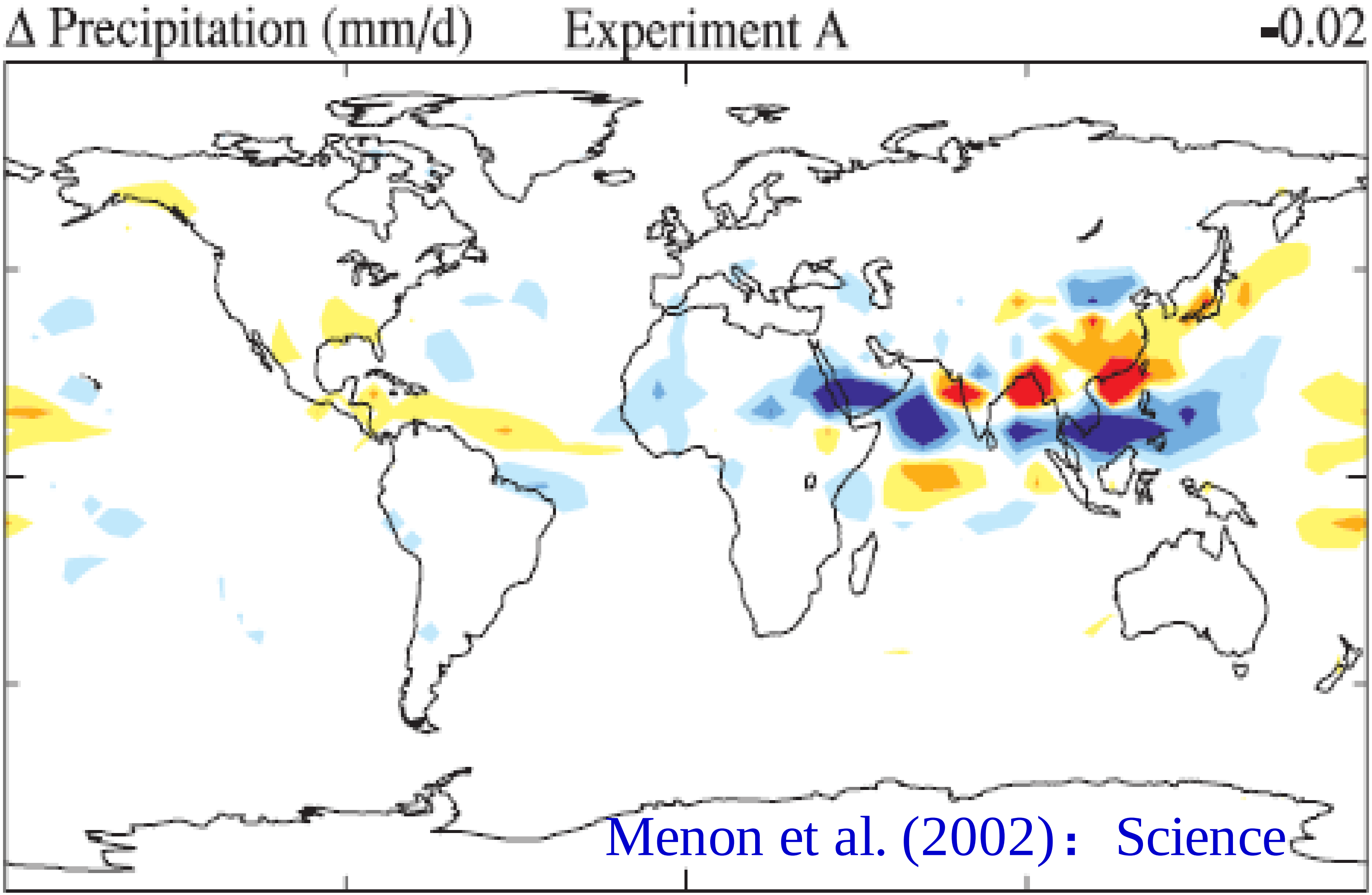
Trend in Sunshine Duration
(1954-1998)
(Kaiser and Qian, 2002)

Most stations: -2 to -3 %/decade

Average: -1.0%/decade



Black carbon



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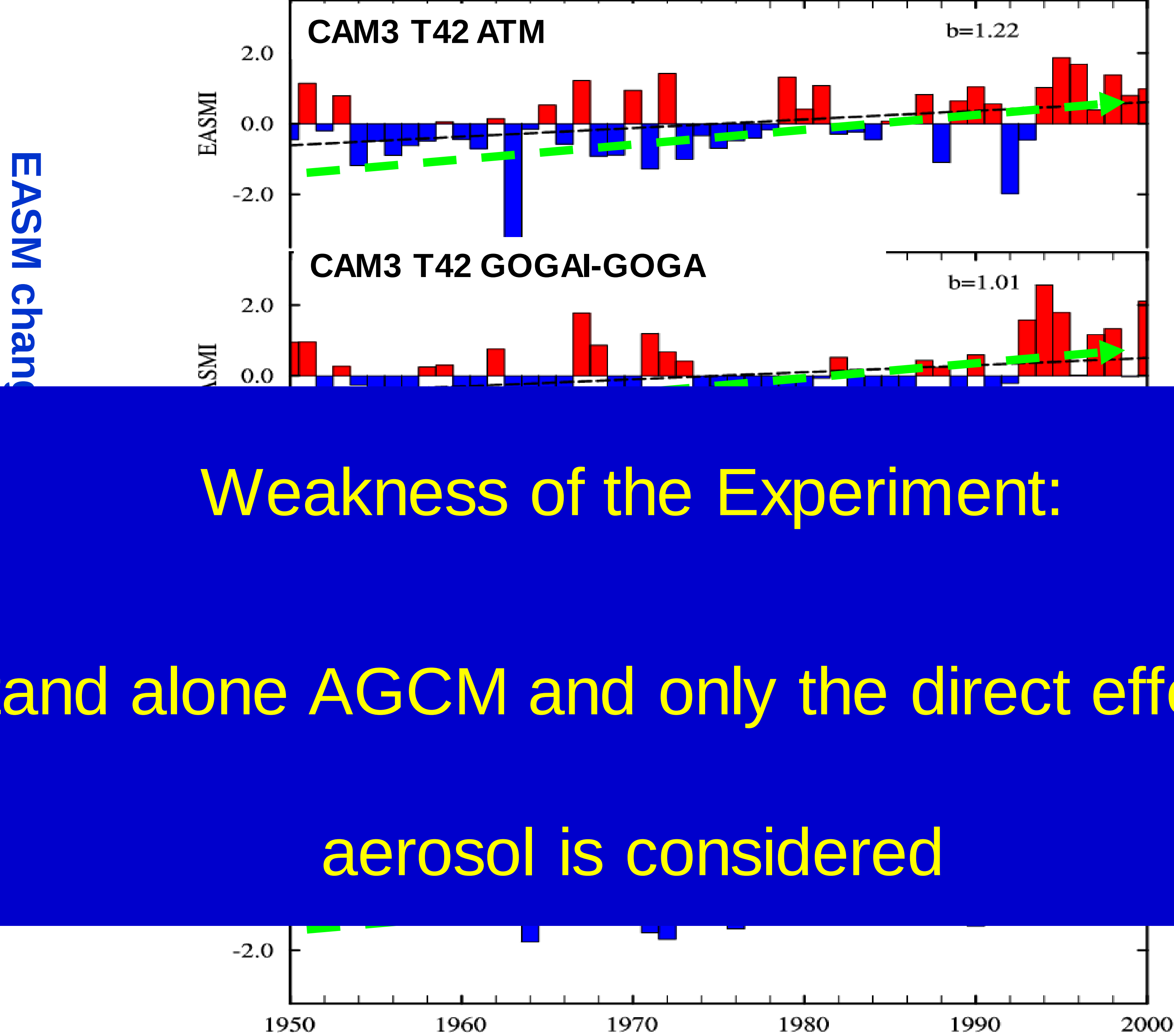


Weakness of the Experiment:

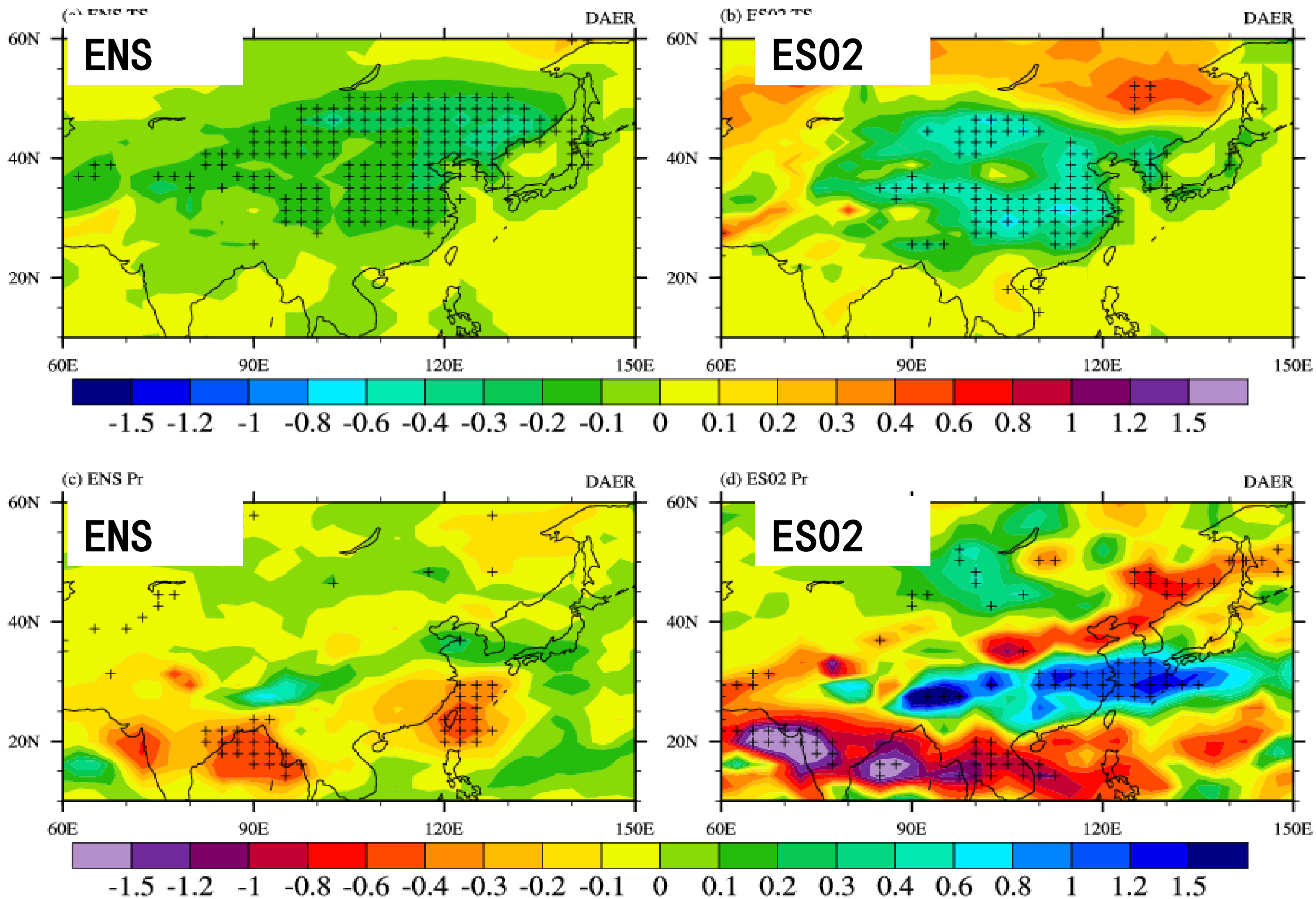
Stand alone AGCM and only the direct effect of aerosol is considered

Li, Hongmei, A. Dai, T. Zhou, J. Lu, 2010: Responses of East Asian summer monsoon to historical SST and atmospheric forcing during 1950-2000, ***Climate Dynamics*, 34**, 501–514, DOI 10.1007/s00382-008-0482-7

Direct effect of aerosol

SAT

PRCP



Li, Hongmei, A. Dai, T.Zhou, J. Lu, 2010: Responses of East Asian summer monsoon to historical SST and atmospheric forcing during 1950-2000, ***Climate Dynamics*, 34**, 501–514, DOI 10.1007/s00382-008-0482-7

New CMIP5 models

We examined the responses of East Asian summer monsoon (EASM) to natural (solar variability and volcanic aerosols) and anthropogenic (greenhouse gasses and aerosols) forcings simulated in the 17 latest Coupled Model Intercomparison Program phase 5 (CMIP5) models with 105 realizations.

The details of 17 CMIP5 models

No.	Model	Institute	Atmospheric resolution (lat*lon)	Member (35)
1	bcc-csm1-1	BCC/China	64*128	1
2	BNU-ESM	BNU/China	64*128	1
3	CanESM2	CCCma/Canada	64*128	5
4	CCSM4	NCAR/USA	192*288	3
5	CNRM-CM5	CNRM-CERFACS/France	128*256	6
6	CSIRO-Mk3-6-0	CSIRO-QCCCE/Australia	96*192	1
7	FGOALS-g2	IAP-THU/China	60*128	1
8	GFDL-CM3	NOAA GFDL/USA	90*144	1
9	GFDL-ESM2M	NOAA GFDL/USA	90*144	1
10	GISS-E2-H	NASA-GISS/USA	90*144	1
11	GISS-E2-R	NASA-GISS/USA	90*144	1
12	HadGEM2-ES	MOHC/UK	144*192	4
13	IPSL-CM5A-LR	IPSL/France	96*96	3
14	MIROC-ESM	MIROC/Japan	64*128	3
15	MIROC-ESM-CHEM	MIROC/Japan	64*128	1
16	MRI-CGCM3	MRI/Japan	160*320	1
17	NorESM1-M	NCC/Norway	96*144	1

Song F., **T. Zhou**, and Y. Qian, 2013: Responses of East Asian summer monsoon to natural and anthropogenic forcings in the 17 latest CMIP5 models. ***Geophysical Research Letters***, *10.1002/2013GL058705*

External forcing agents used in 17 CMIP5 Models

No.	Model	Natural forcings		Anthropogenic forcings	
		Solar	Volcanic	GHG	Aerosol
1	bcc-csm1-1	SOLARIS	A	IIASA	**C**
2	BNU-ESM	SOLARIS	A	IIASA	E1
3	CanESM2	SOLARIS	S	IIASA	E1
4	CCSM4	SOLARIS	A	IIASA	**C**
5	CNRM-CM5	SOLARIS	A	IIASA	E1
6	CSIRO-Mk3-6-0	SOLARIS	S	IIASA	E2
7	FGOALS-g2	SOLARIS	-	IIASA	**C**
8	GFDL-CM3	SOLARIS	S	IIASA	E1
9	GFDL-ESM2M	SOLARIS	S	IIASA	E1
10	GISS-E2-H	SOLARIS	S	IIASA	**C**
11	GISS-E2-R	SOLARIS	S	IIASA	**C**
12	HadGEM2-ES	SOLARIS	S	IIASA	E1
13	IPSL-CM5A-LR	SOLARIS	S	IIASA	E1
14	MIROC-ESM	SOLARIS	S	IIASA	E1
15	MIROC-ESM-CHEM	SOLARIS	S	IIASA	E1
16	MRI-CGCM3	SOLARIS	E	IIASA	E1
17	NorESM1-M	SOLARIS	A	IIASA	E1

S: Sato et al. (1993);
A: Ammann et al. (2003).

E: Emission is given;
C: Concentration is given.

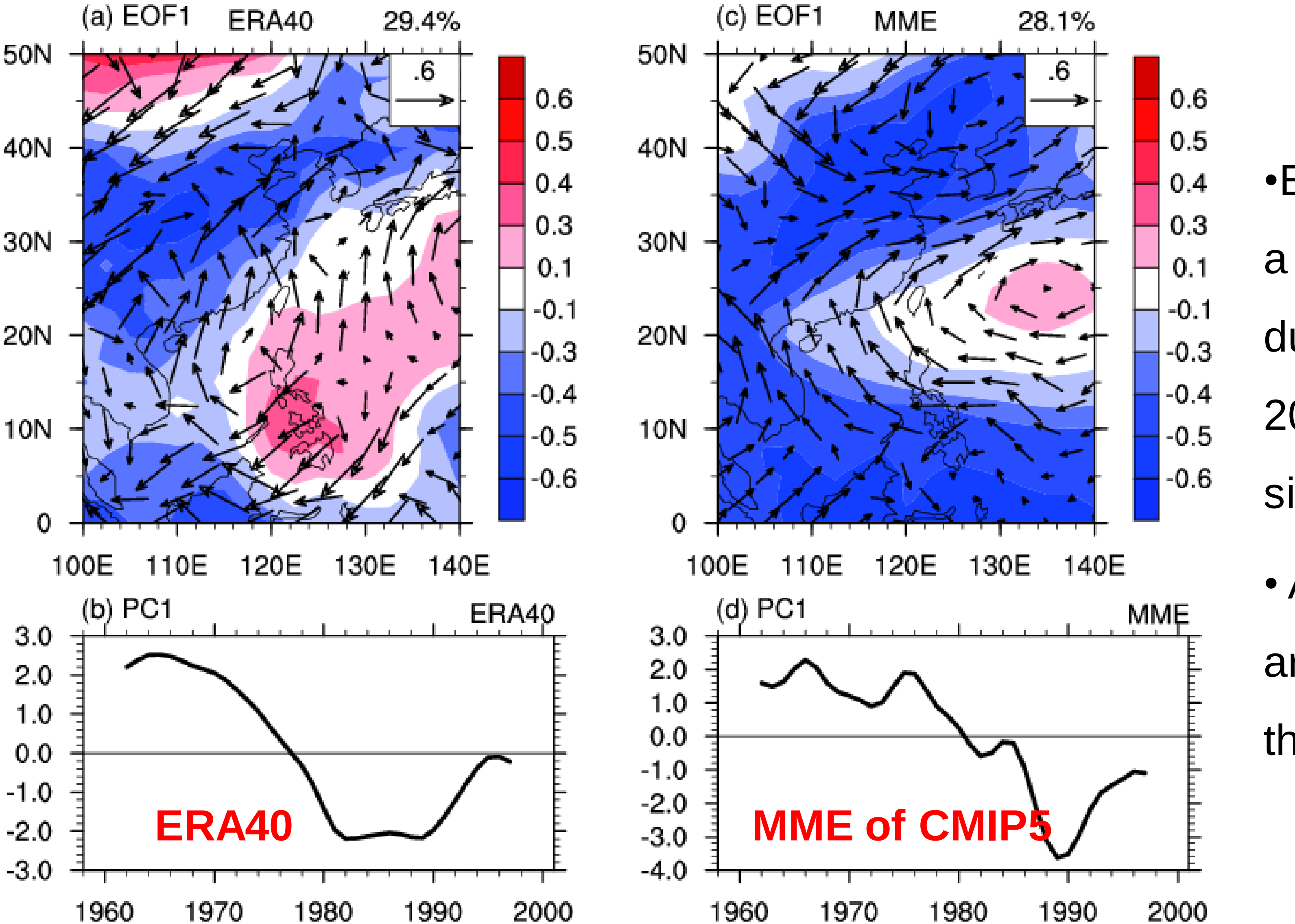
Details of three sets of CMIP5 experiments

Experiment description	CMIP5 label	Major purposes	Short name
Past ~1.5 centuries (1850–2005)	historical	Evaluation	**All-forcing**
historical simulation but with GhG forcing only	historicalGHG	Detection and attribution	**GHG-forcing**
historical simulation but with natural forcing only	historicalNat	Detection and attribution	**Natural-forcing**

- **According to Taylor et al. (2009), anthropogenic-forcing is estimated by All-forcing run minus Natural-forcing run.**
- **Aerosol-forcing is estimated by Anthropogenic-forcing run minus GHG-forcing run. 105 realizations are analyzed.**

Song F., **T. Zhou**, and Y. Qian, 2013: Responses of East Asian summer monsoon to natural and anthropogenic forcings in the 17 latest CMIP5 models. *Geophysical Research Letters, 10.1002/2013GL058705*

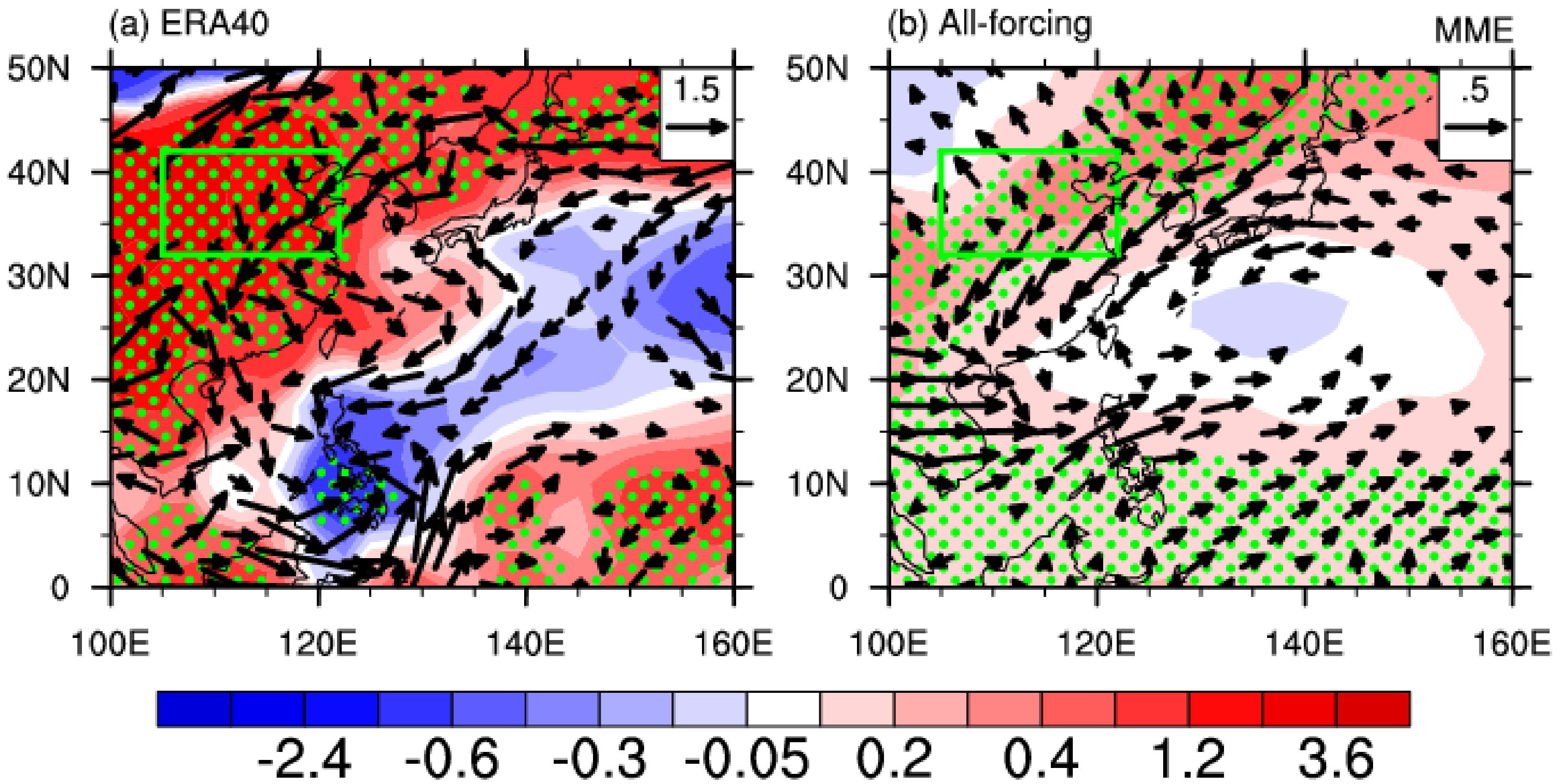
Multi-variate EOF1 of SLP and 850 hPa winds



- EOF1 features a weakening during 1958-2001, recovered since 1990s.
- Above features are evident in the simulation.

Song F., **T. Zhou**, and Y. Qian, 2013: Responses of East Asian summer monsoon to natural and anthropogenic forcings in the 17 latest CMIP5 models. *Geophysical Research Letters, 10.1002/2013GL058705*

Linear trends of SLP and 850 hPa winds (1958-2001)



ERA40 **MME of CMIP5**

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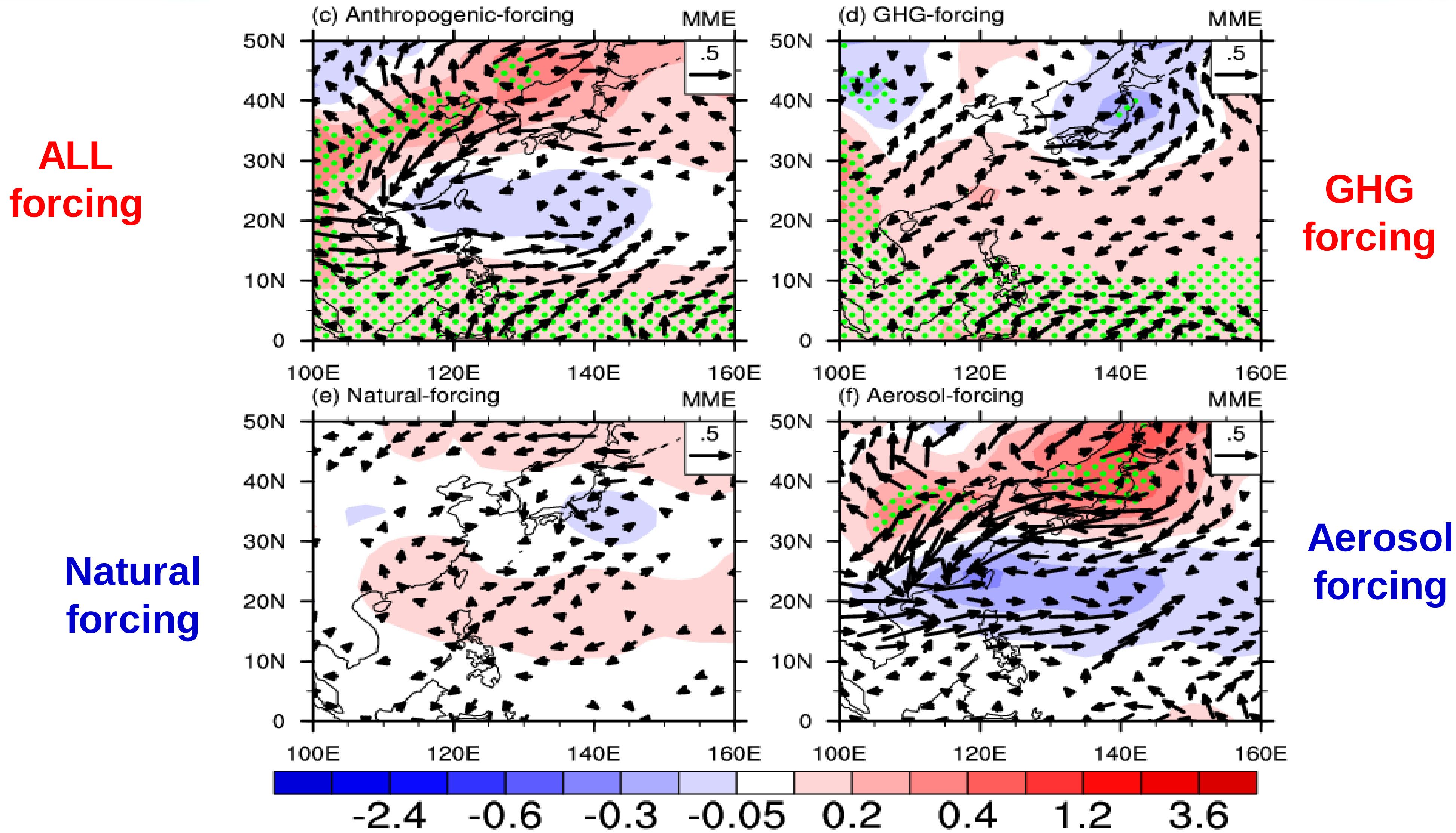
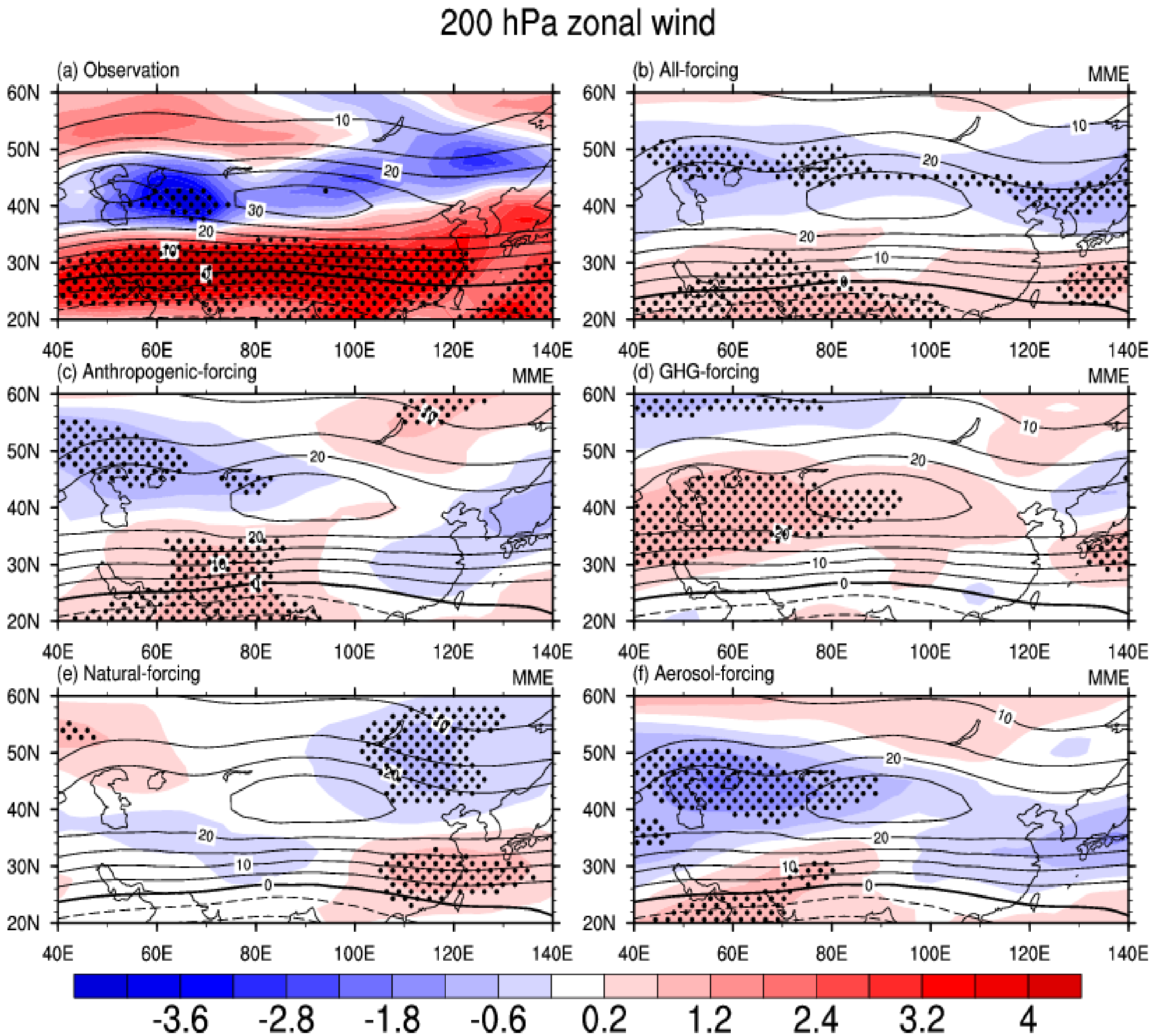


Song F., **T. Zhou**, and Y. Qian, 2013: Responses of East Asian summer monsoon to natural and anthropogenic forcings in the 17 latest CMIP5 models. *Geophysical Research Letters, 10.1002/2013GL058705*

Linear trends (shading) of 200 hPa zonal wind (58-01)



- The observed southward shift of East Asian subtropical jet (EASJ) has been reproduced in all-forcing runs but with weaker magnitude.
- **The southward shift of western part is attributed to aerosol-forcing**, while the southward shift of eastern part is attributed to natural-forcing.
- **The EASJ has intensified in the GHG-forcing runs.**

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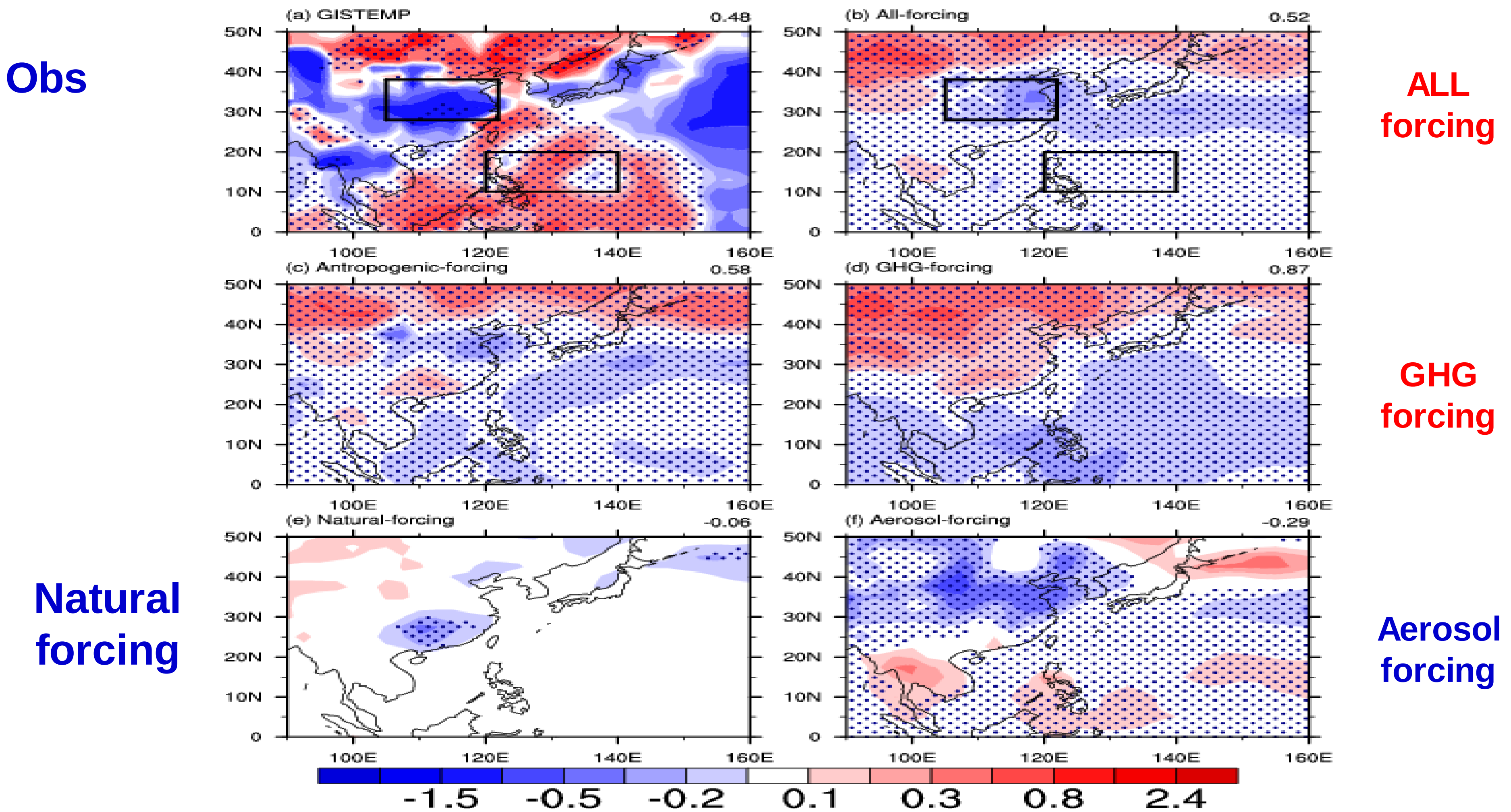
The linear trends of surface air temperature (58-01)



- **Aerosol forcing has led to the cooling over C. China**

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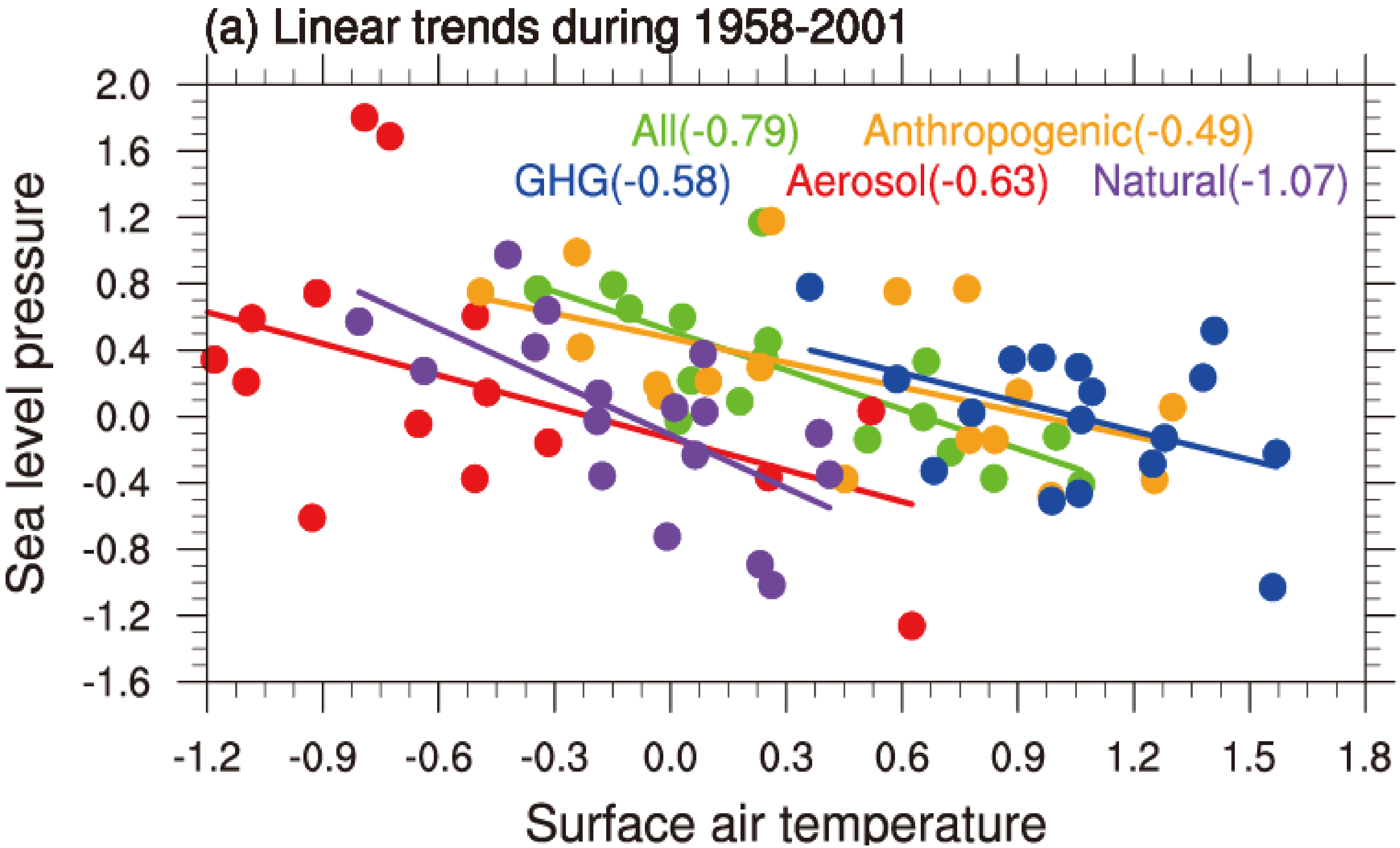
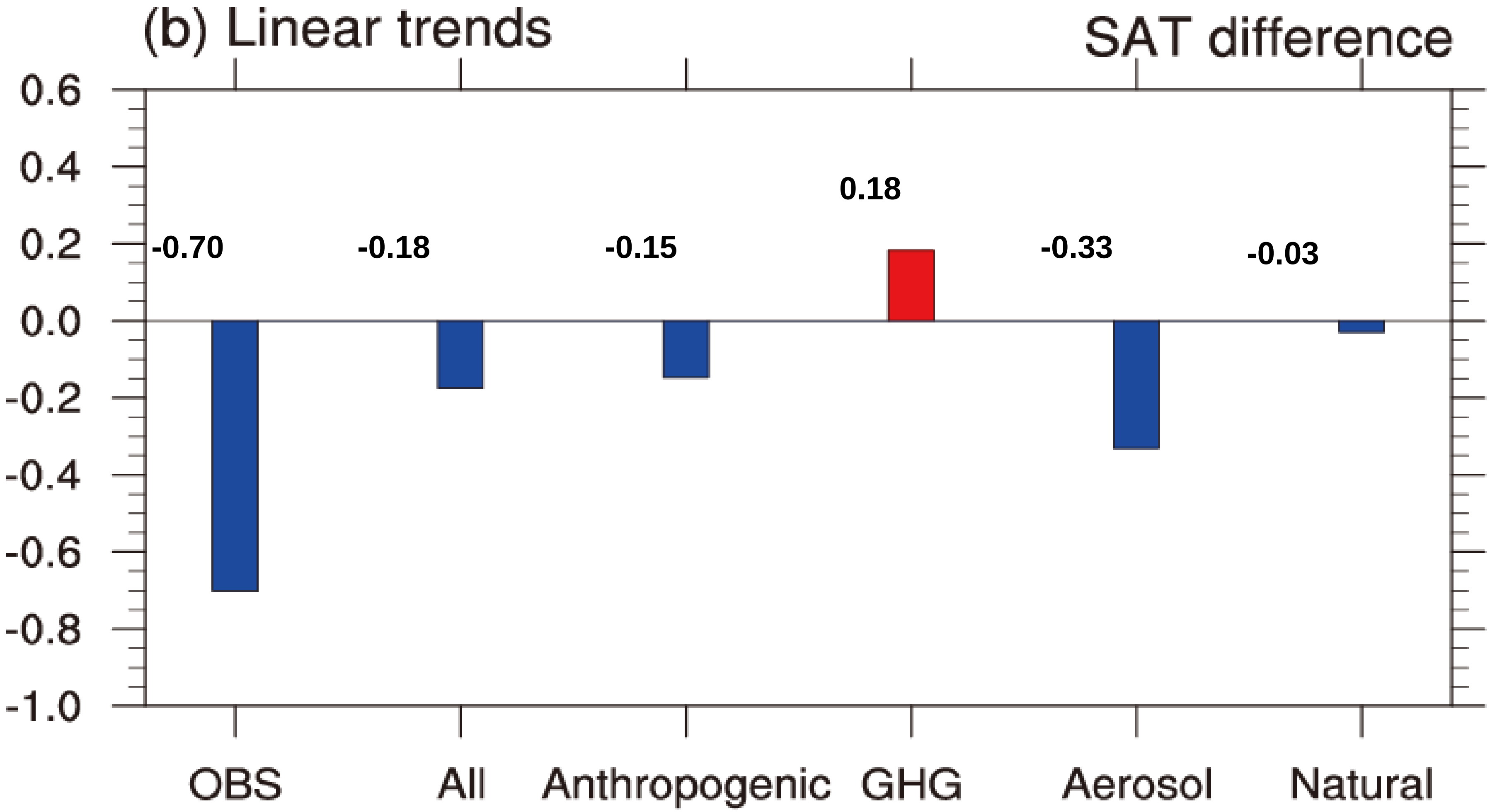
Higher SLP in N. China and surface cooling in central China



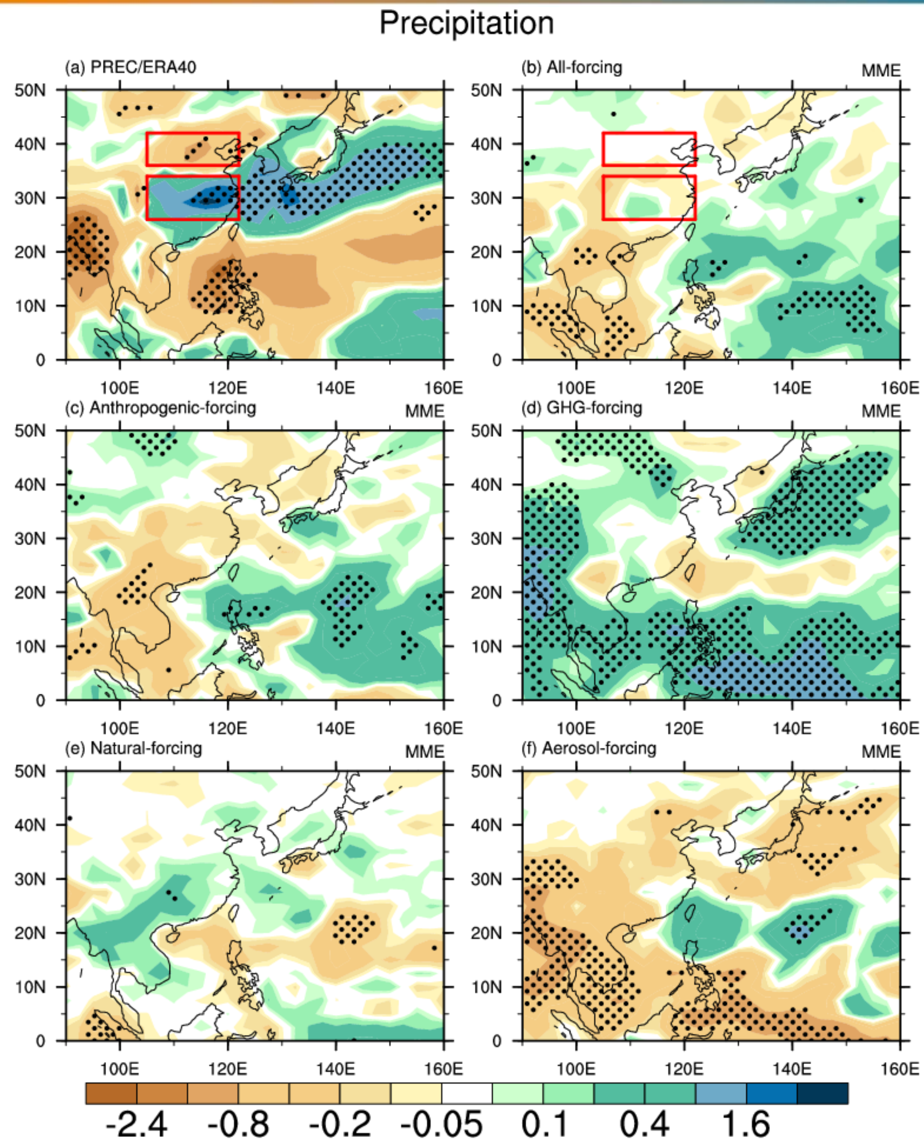
Surface cooling → weaker land-sea thermal contrast and higher SLP. → Weakened monsoon circulation.

Trends of Land-sea thermal contrast as a measure of EASM strength



The specified external forcing agents only account for **25.6%** of the observed monsoon weakening.

The linear trends of precipitation during 1958-2001



- **Weakness:**

CMIP5 models are unable to reproduce the precipitation anomalies due to their low resolutions

Song F., **T. Zhou**, and Y. Qian, 2013: Responses of East Asian summer monsoon to natural and anthropogenic forcings in the 17 latest CMIP5 models. *Geophysical Research Letters, 10.1002/2013GL058705*

Point # 2

- The observed weakening trend of low-level EASM circulation during 1958–2001 is ***partly and weakly*** reproduced under all-forcing runs. A comparison of separate forcing experiments reveals that the aerosol forcing plays a primary role in driving the weakened low-level monsoon circulation.
- The preferential cooling over continental East Asia caused by aerosol affects the monsoon circulation through reducing the land-sea thermal contrast and results in higher sea level pressure over northern China.
- The increasing GHG forcing is favorable for an enhanced monsoon circulation.
- The models still failed in the simulation of monsoon rainband changes.

Song F., **T. Zhou**, and Y. Qian, 2013: Responses of East Asian summer monsoon to natural and anthropogenic forcings in the 17 latest CMIP5 models. *Geophysical Research Letters, 10.1002/2013GL058705*

Outline

- Background
- Natural variability driven by PDO
- Response to GHG and aerosol forcing
- Detectable Anthropogenic Shift toward Heavy Precipitation over Eastern China
- Summary

Objectives

Are the observed changes in the amount distributions of Eastern China precipitation caused by external forcings and thus detectable?

Ma, S., **T. Zhou**, D. Stone, D. Polson, A. Dai, P. Stott, H. Storch, Y. Qian, C. Burke, P. Wu, L. Zou, and A. Ciavarella, 2016: Detectable anthropogenic shift toward heavy precipitation over eastern China. ***Journal of Climate***, doi:10.1175/JCLI-D-16-0311.1

Observation and Model Data

- **Observation**: daily Rain-gauge data from CMA
- **CMIP5 20c historical climate simulation**:

✓ALL forcing run :11 models, 54 ensemble members

✓ANThropogenic foring: 6 models,26 members

✓GHG forcing: 10 models,34 members

✓AA forcing: 8 models, 22 members

✓NATural forcing: 11 models,37 members

- PIcontrol: 10 models, ~ 6000 yrs

Ma, S., **T. Zhou**, D. Stone, D. Polson, A. Dai, P. Stott, H. Storch, Y. Qian, C. Burke, P. Wu, L. Zou, and A. Ciavarella, 2016: Detectable anthropogenic shift toward heavy precipitation over eastern China. ***Journal of Climate***, doi:10.1175/JCLI-D-16-0311.1

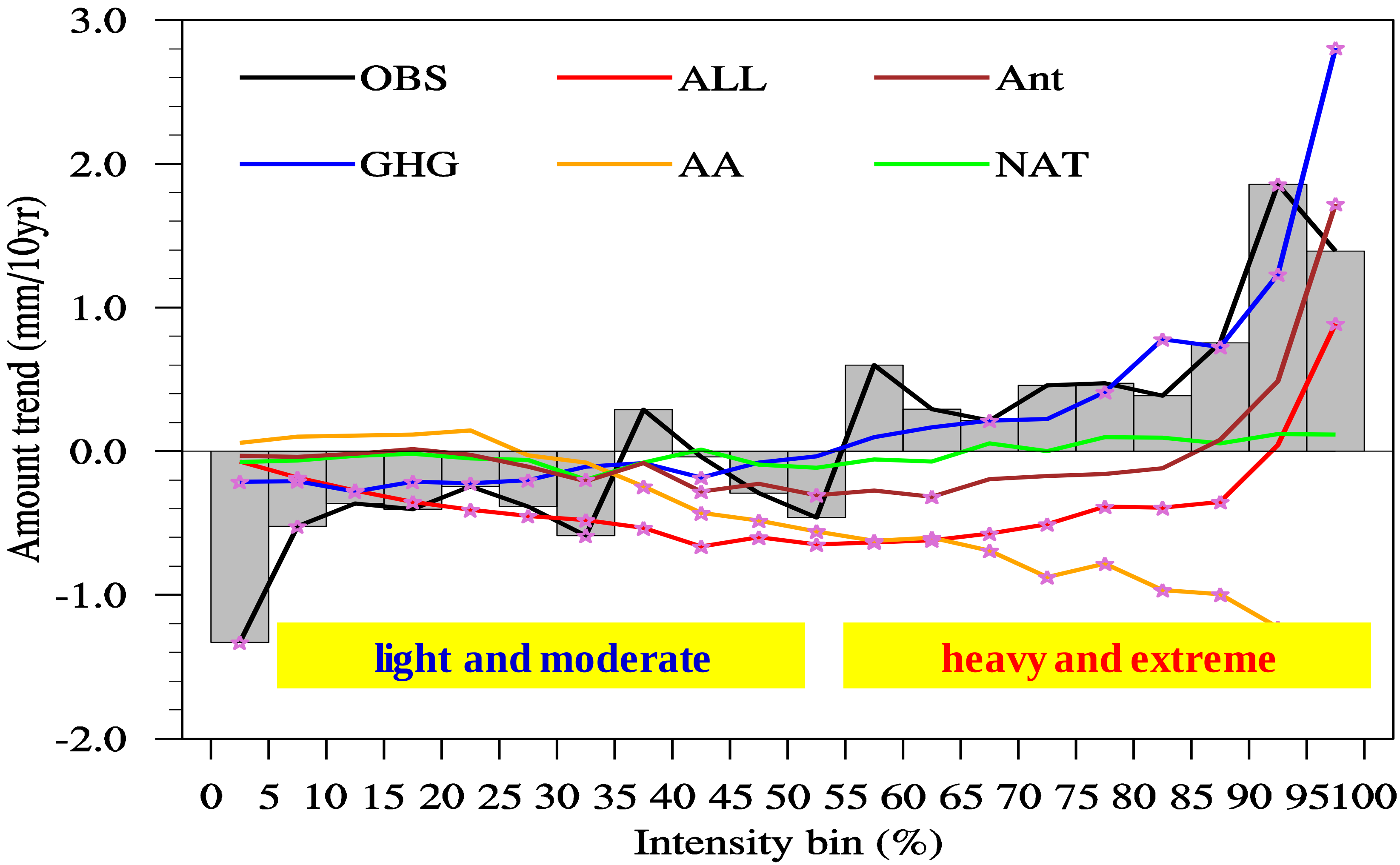
Optimal fingerprinting Method

Optimal fingerprinting--Total least squares detection method

$$y = \sum_{i=1}^{m} (X_i - \upsilon_i)\beta_i + \upsilon_0$$

- y, observed trend, a rank-n vector, where n is the number of daily precipitation intensity bins, with n=20 used in this analysis;
- X, fingerprints or anomalous signals, model simulated climate responses to external forcings, a matrix with one column for each external climate forcing;
- **υi, sampling noise**, estimated from the preindustrial control simulations and intra-ensemble differences;
- υ0, noise in the observations
- **β, scaling factors, inconsistent with 0 indicate a detectable signal, consistent with 1, then the model-simulated response patterns are consistent with the observed changes.**

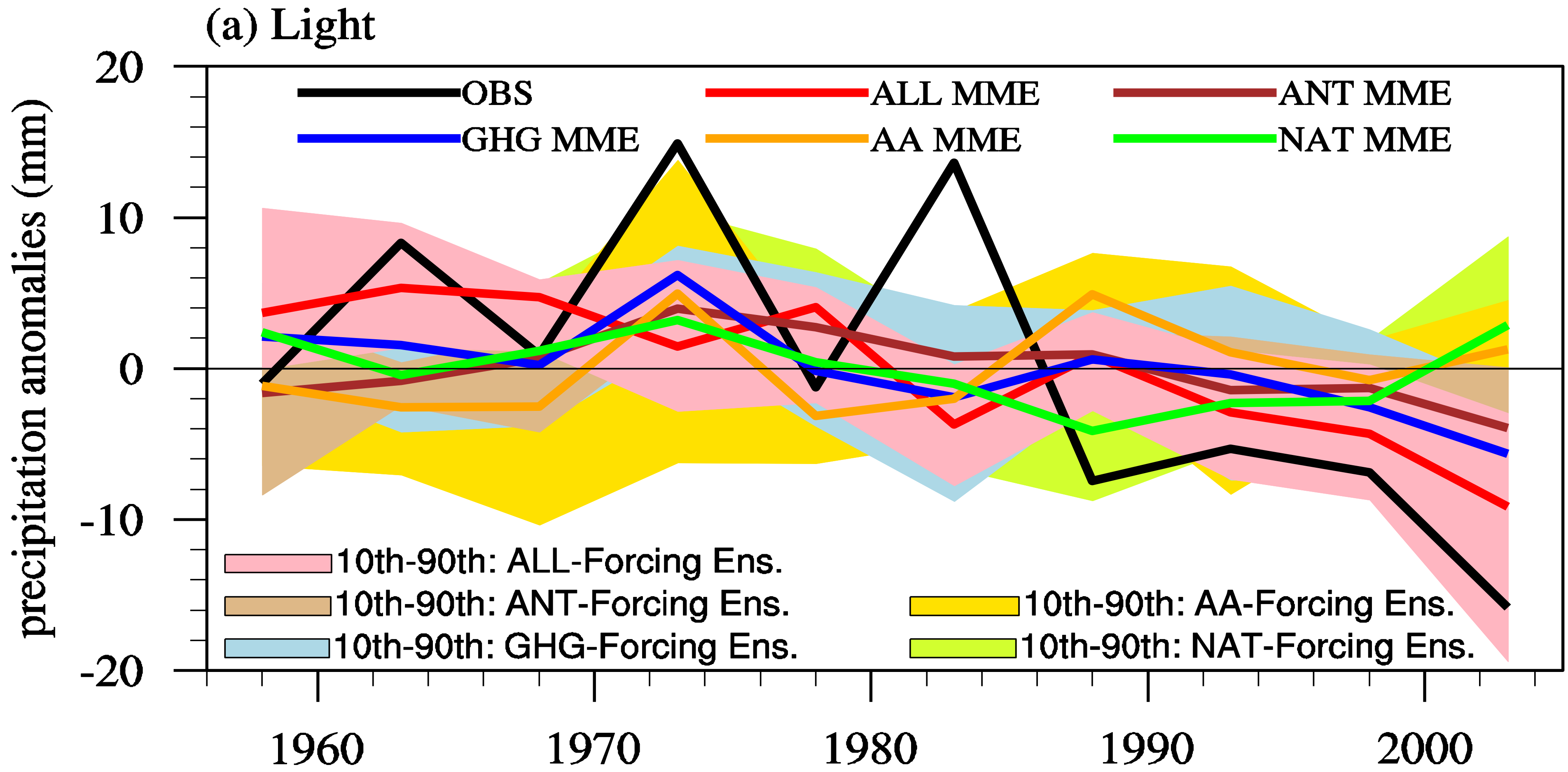
Trend of PDF in precipitation amount



Observation: a shift toward heavier precipitation

Simulation: The observed shift is well simulated with anthropogenic forcings.

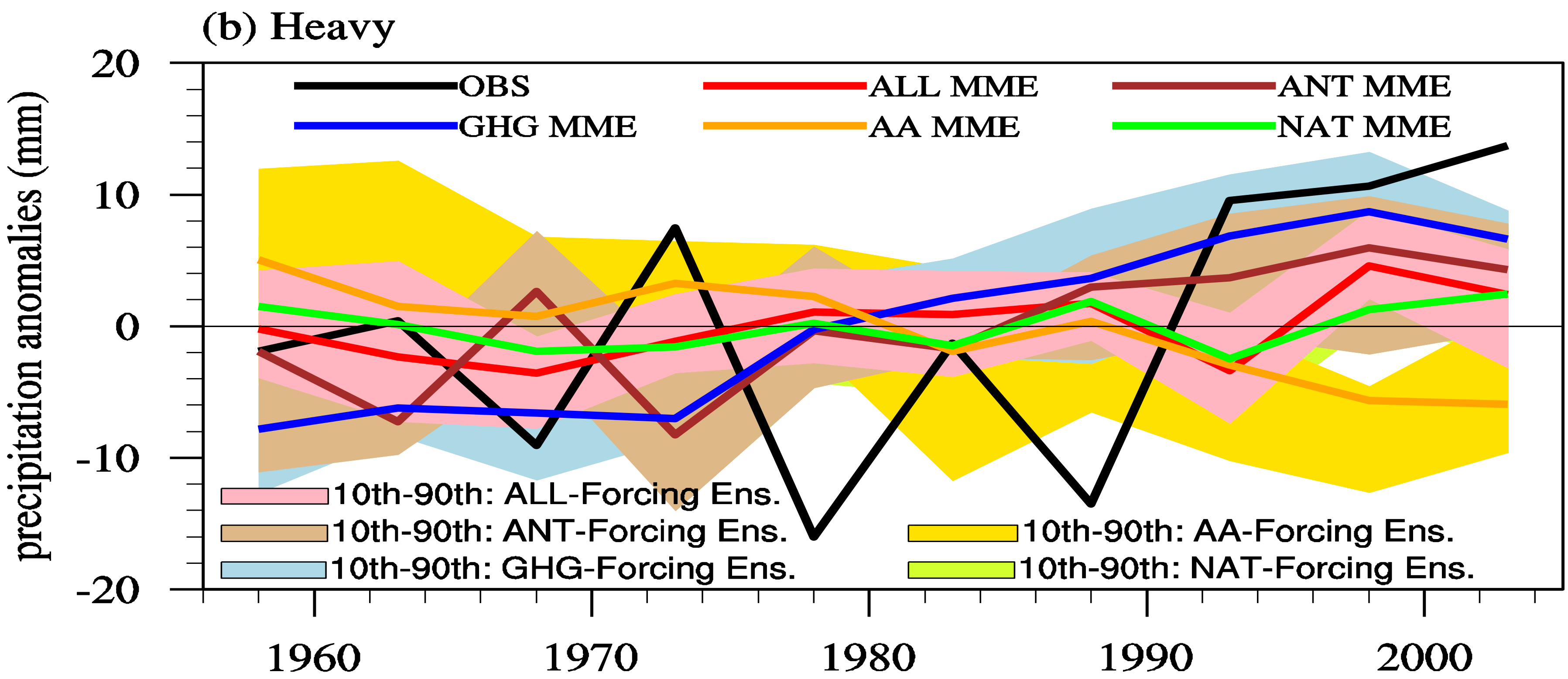
Five-year mean precipitation amount anomalies



Light precipitation: daily precipitation falls into the lowest **35%** intensity bins.

Decreasing trend in observed light precipitation. The simulations with GHG forcing show similar behavior as the observations.

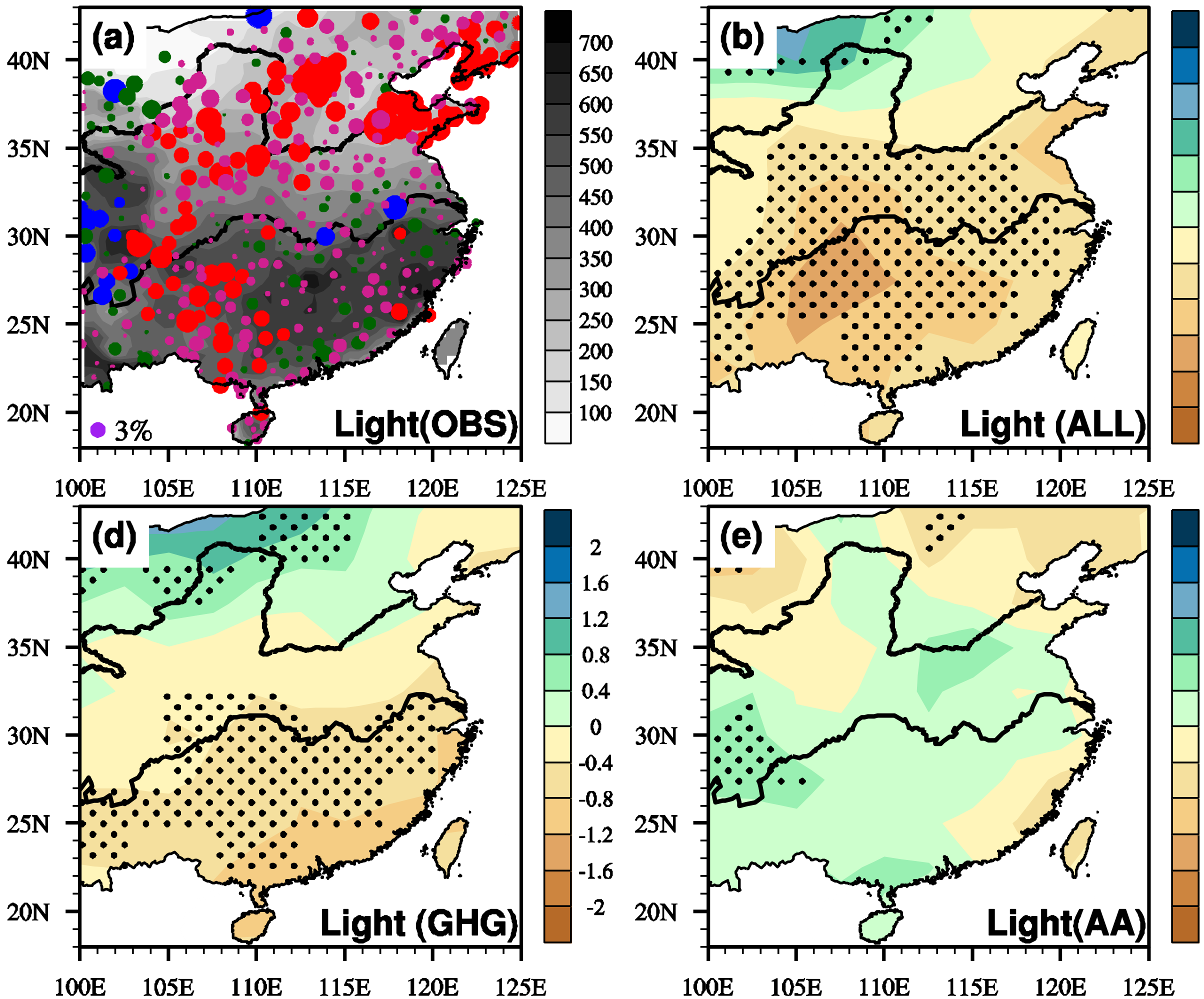
Five-year mean precipitation amount anomalies



Heavy precipitation: daily precipitation falls into the top **10%** intensity bins.

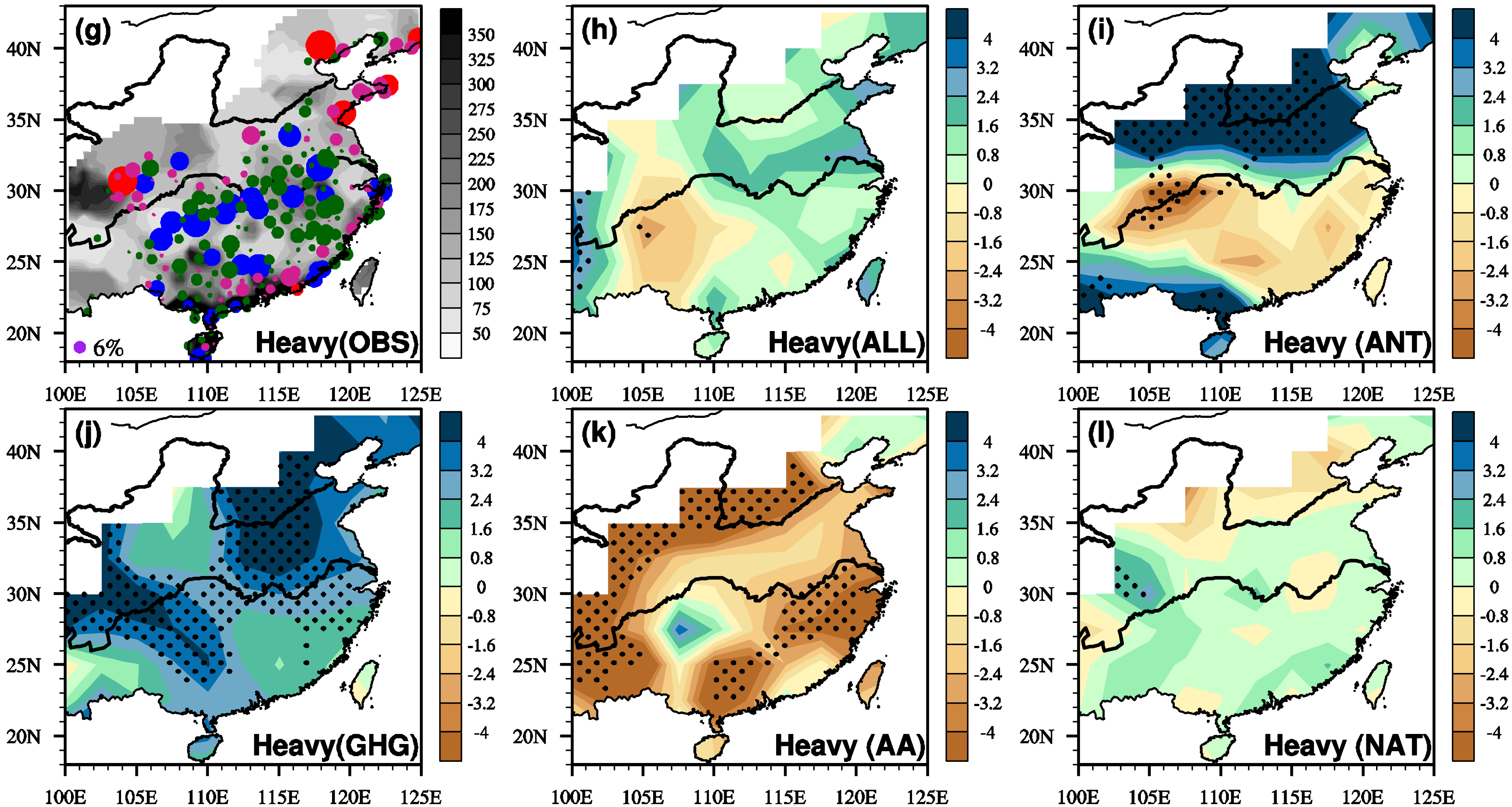
- **Observation:** increasing trend in heavy precipitation
- **Simulations:** Similar behavior as the observations in the simulation with GHGs.

Linear trends of light precipitation



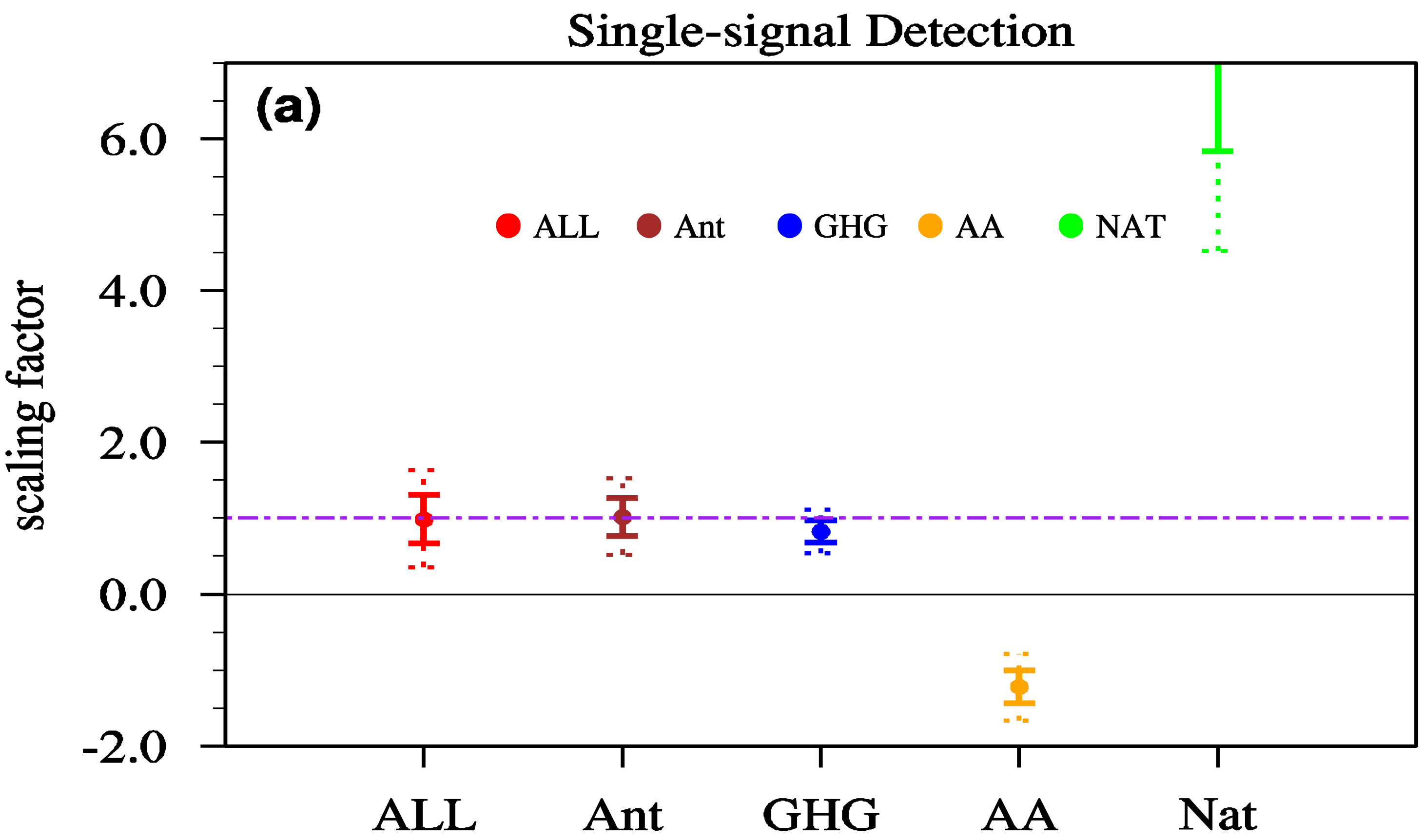
The observed decrease in light precipitation mainly come from the contribution of GHG forcing. Anthropogenic aerosols partly offset the contribution of the GHGs.

Linear trends of heavy precipitation



The observed increase of heavy precipitation is dominated by the GHG forcing.

Optimal detection



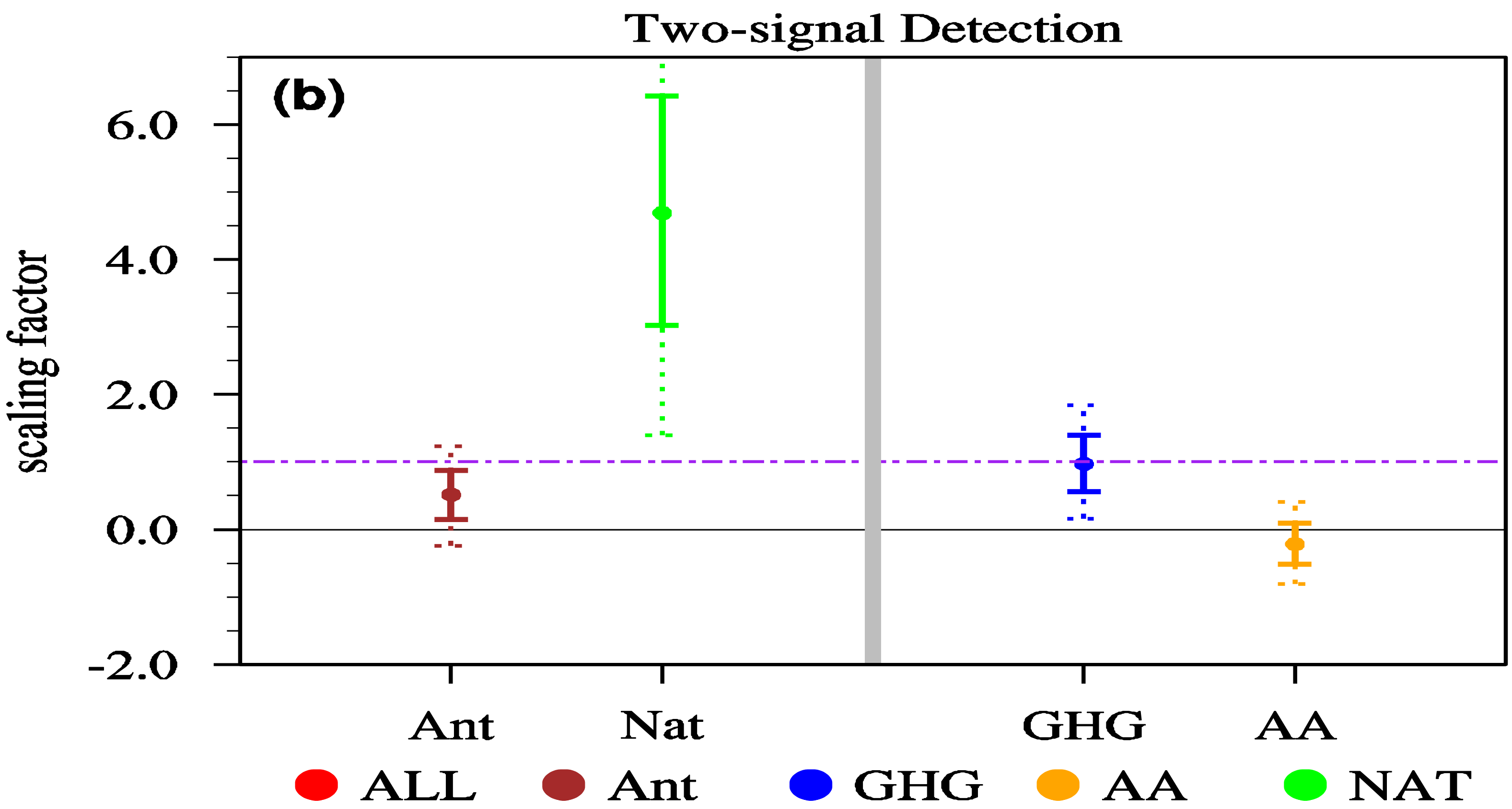
Solid symbols: best estimates of regression coefficients (β);

Solid error bars: 5-95% uncertainty ranges of β;

Dashed error bars: 5-95% uncertainty ranges of β when the internal variability is doubled.

- **ANT forcing determines** the forced changes in the ALL forcing run.
- The detected responses in ALL and ANT forcing runs are dominated by GHG forcing.

Optimal detection



- The detectable effect of ANT forcing can be separated from NAT forcing.
- The detectable effect of GHG forcing can also be separated from AA forcing.

Point # 3

- The anthropogenic forcing has a detectable and attributable influence on the amount distribution of daily precipitation over EC during the second half of the 20th century.
- The observed shift from weak precipitation to intense precipitation is due primarily to the contribution of GHG forcing, with AA forcing offsetting some of the effects of the GHG forcing.
- Increasing of moisture and changes of monsoon circulation , resulting mainly from GHG-induced warming, favors heavy precipitation over eastern China.

Summary

1. The weakening tendency of EASM during 1950-2000 is driven by the interdecadal changes of Tropical Ocean SSTA, which is a tropical lobe of IPO/PDO.
2. A comparison of CMIP5 separate forcing experiments reveals that the aerosol forcing has driven a weakened monsoon circulation, while the emission of GHG is favorable for a stronger monsoon circulation.
3. The anthropogenic forcing has a detectable and attributable influence on the amount distribution of daily precipitation over EC during the second half of the 20th century.

Some further readings

1. Ma, S., T. Zhou, D. Stone, D. Polson, A. Dai, P. Stott, H. Storch, Y. Qian, C. Burke, P. Wu, L. Zou, and A. Ciavarella, 2016: Detectable anthropogenic shift toward heavy precipitation over eastern China. ***Journal of Climate***, doi:10.1175/JCLI-D-16-0311.1
2. Song F., **T. Zhou**, and Y. Qian, 2013: Responses of East Asian summer monsoon to natural and anthropogenic forcings in the 17 latest CMIP5 models**.** ***Geophysical Research Letters,*** 10.1002/2013GL058705
3. **Zhou, T.,** F. Song, R. Lin, X. Chen and X. Chen, 2013: The 2012 North China floods: Explaining an extreme rainfall event in the context of a long-term drying tendency [in "Explaining Extreme Events of 2012 from a Climate Perspective"]. ***Bulletin of the American Meteorological Society***, 94(9), S49-S51
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LASG

http://www.lasg.ac.cn/staff/ztj

THANKS

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East Asian Summer Monsoon in a Warming World: Forcing from GHG, Aerosol and Natural variability

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WCRP-JNU Training School on Monsoon Variability in Changing Climate

15-21 Jan 2017, Juju National University