



State Key Laboratory of Numerical Modelling for Atmospheric Sciences
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Institute of Atmospheric Physics Chinese Academy of Sciences

Drought in East Asia

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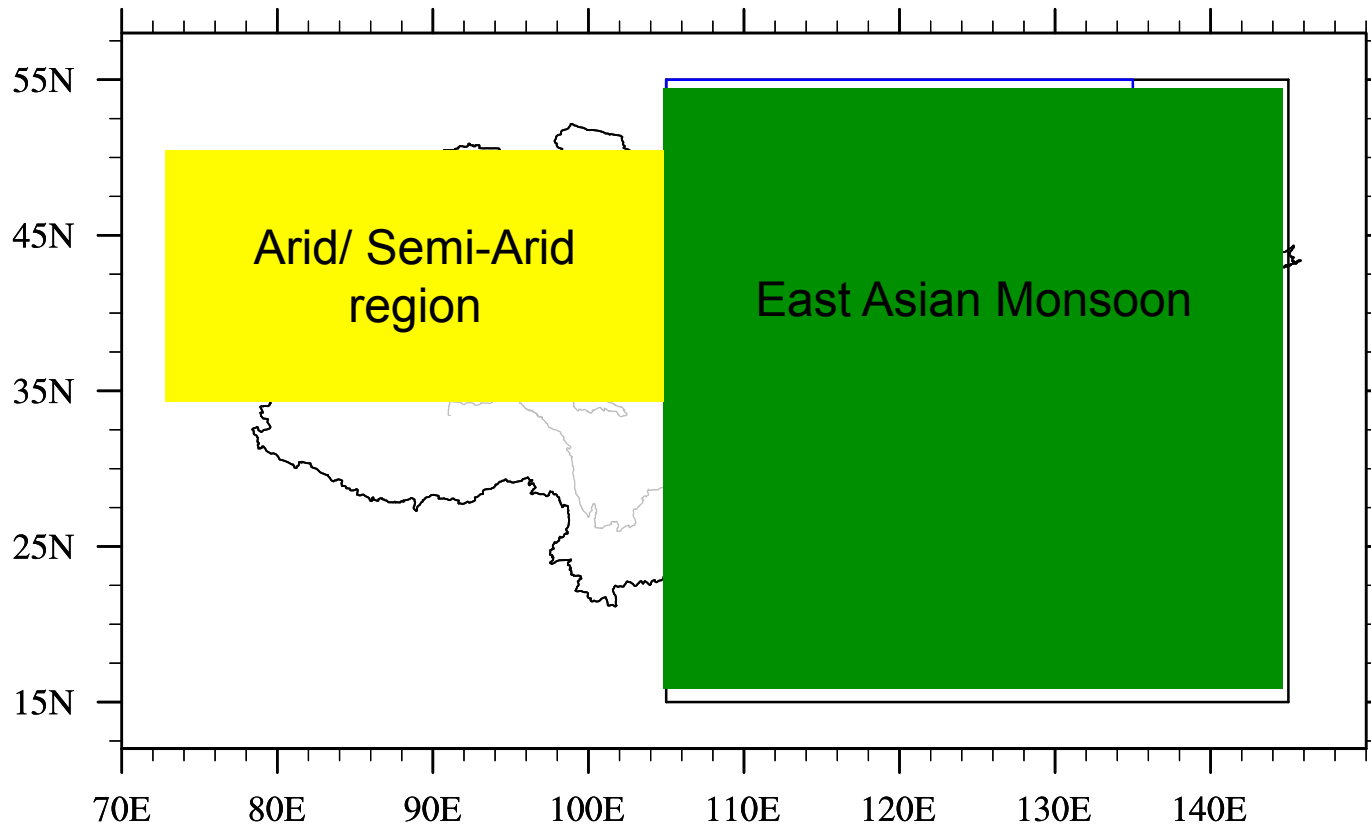
An International Global Drought Information System Workshop: Next Steps
Caltech, Pasadena, CA, Dec. 11 –13, 2014



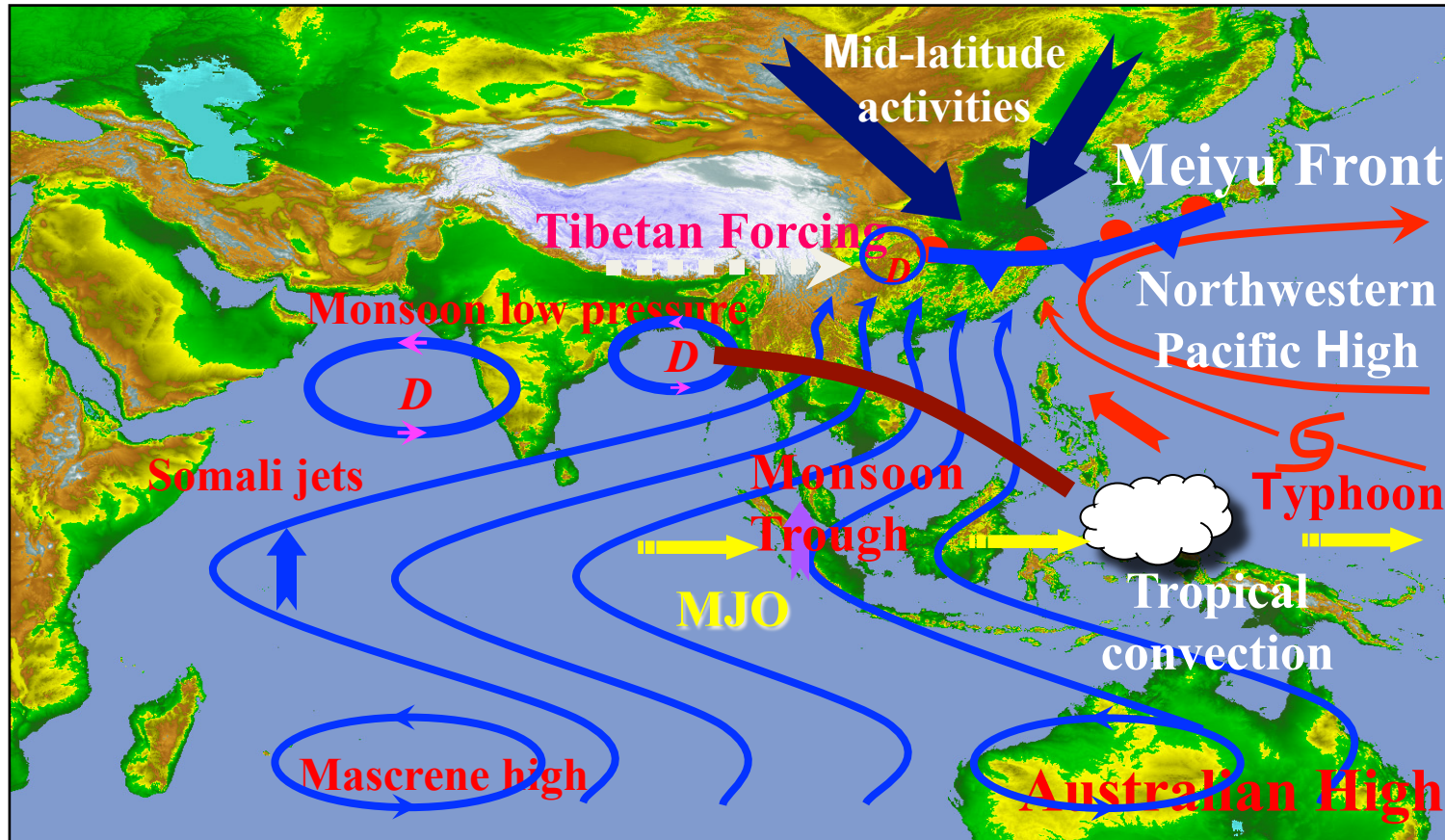
Outline

- ◆ Introduction
- ◆ Climate states of East Asian Drought
- ◆ Interannual variation of drought and the possible mechanisms
- ◆ Long-term trend of drought severity and extent
- ◆ Prediction and projection of drought
- ◆ Summary





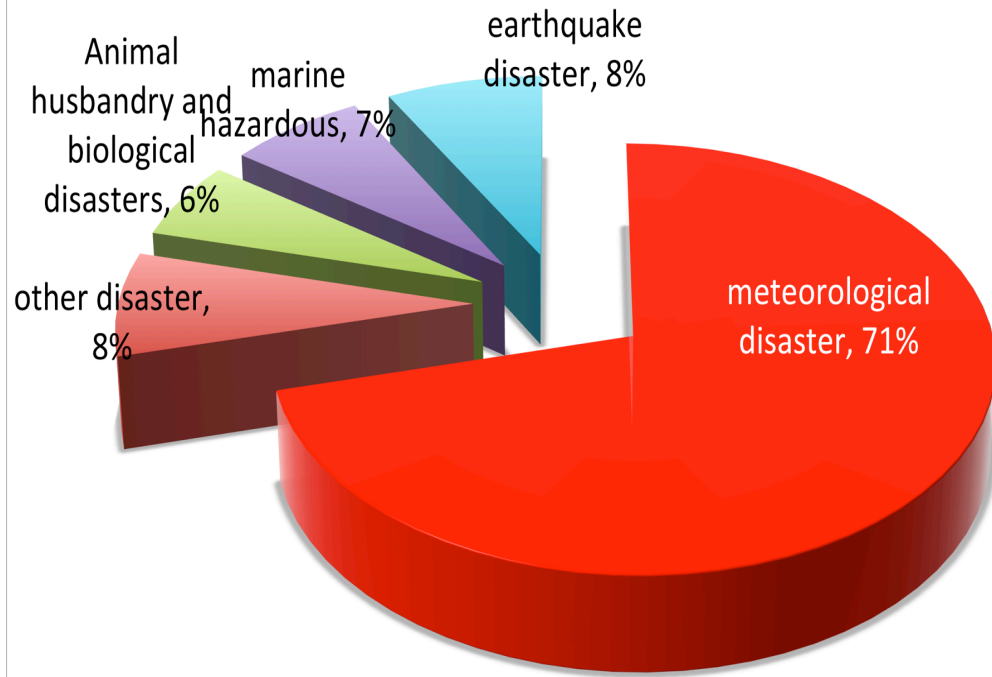
- ✓ East Asia mainly includes China, Japan, Korea and Mongolia
- ✓ East Asia is dominated by different climate zones. Its western part, located in the north of the Qinghai-Xizang Plateau, is a typical arid and semi-arid area. In contrast, east of 102.5°E is the typical monsoon domain.



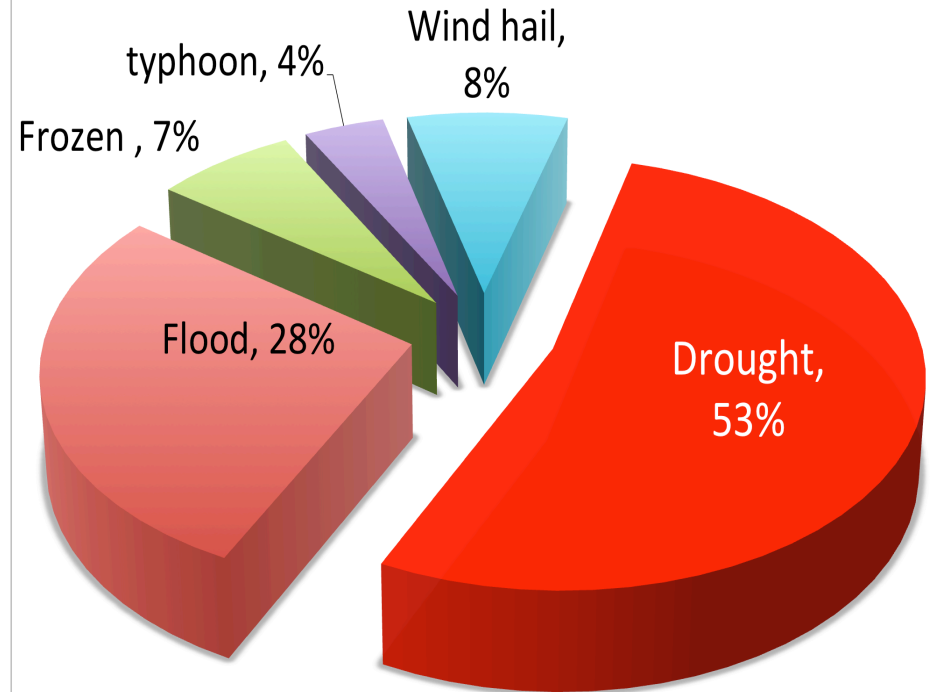
(Ding et al. 2008)

East Asian monsoon is a combination of tropical and sub-tropical monsoon. It has complex temporal and spatial variations.

Economic losses ratio of the main natural disasters



Affected area by major climate disaster



Every year there are many nature hazards happened in China, and bring huge economic losses.

Among these natural disasters, the affected area by drought is most.



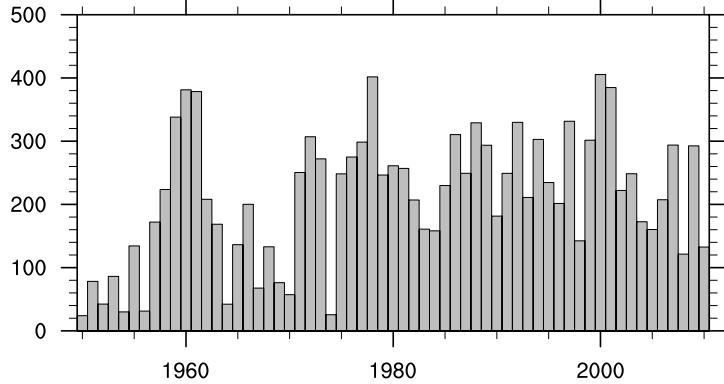
extreme drought years over China from 1900 to 2010



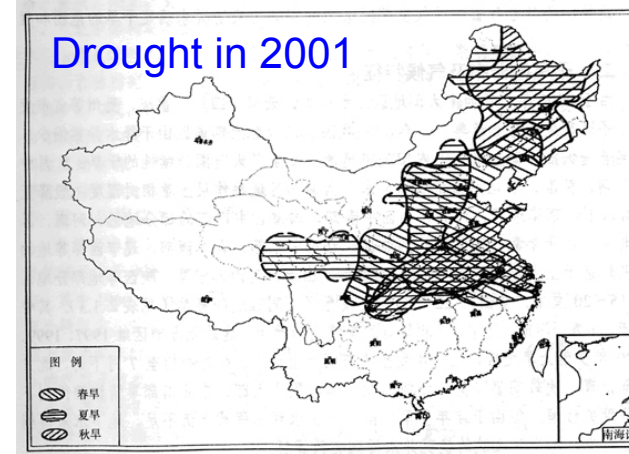
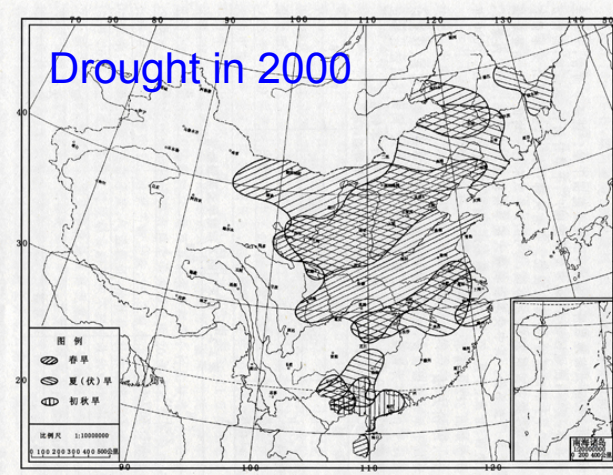
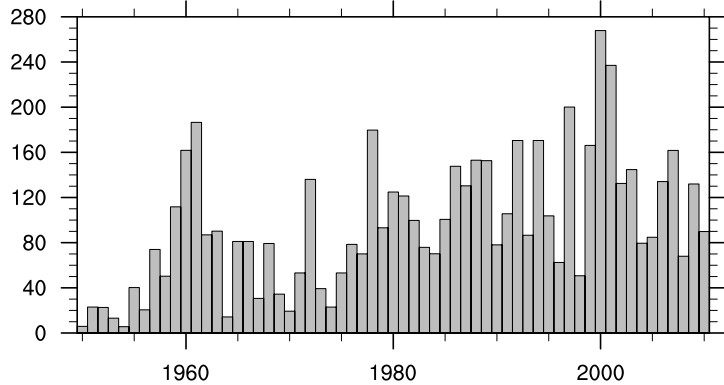
Year	Region	Year	Region
1900	Exceptional drought over China	1992	Drought over North China in winter and spring and South China in autumn
1928-29	Exceptional drought over China	1994	Drought over Yangtze- Huaihe River Valley in autumn
1936	Extreme drought over China	1997	Drought over North China in summer
1942	Severe drought over most regions of China	1999	Severe drought over North China
1959	Drought over central China in summer and autumn	2000	North China in spring and summer
1960	Drought over North China	2001	over North China and Yangtze River V alley from spring to summer
1961	Drought over North China in spring	2003	Drought over the south of the Yangtze River and South China in autumn
1972	Exceptional drought over China	2006	over Sichuan Province and Chongqing in autumn
1978	Exceptional drought over most regions of China	2009-2010	North China , Hebei, Shanxi and Liaoning; Southwest China, Yunnan, Guizhou, Guangxi and Sichuan



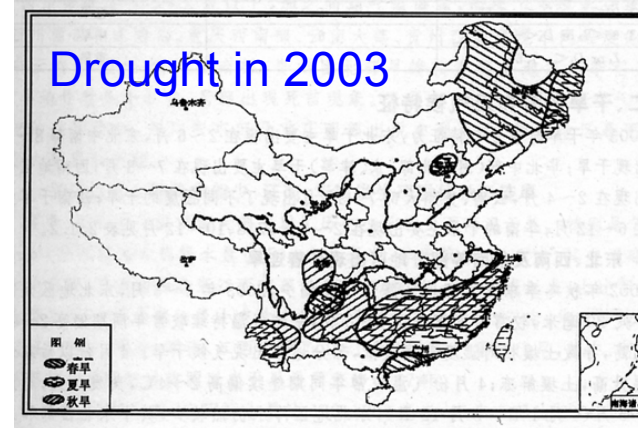
(a) Drought Affected area



(b) Drought Disaster area



(from CMA)



droughts that occurred in China during 1950–2010 can be clustered into three periods: 1959–1961, 1978–1982, and 1987–2003.

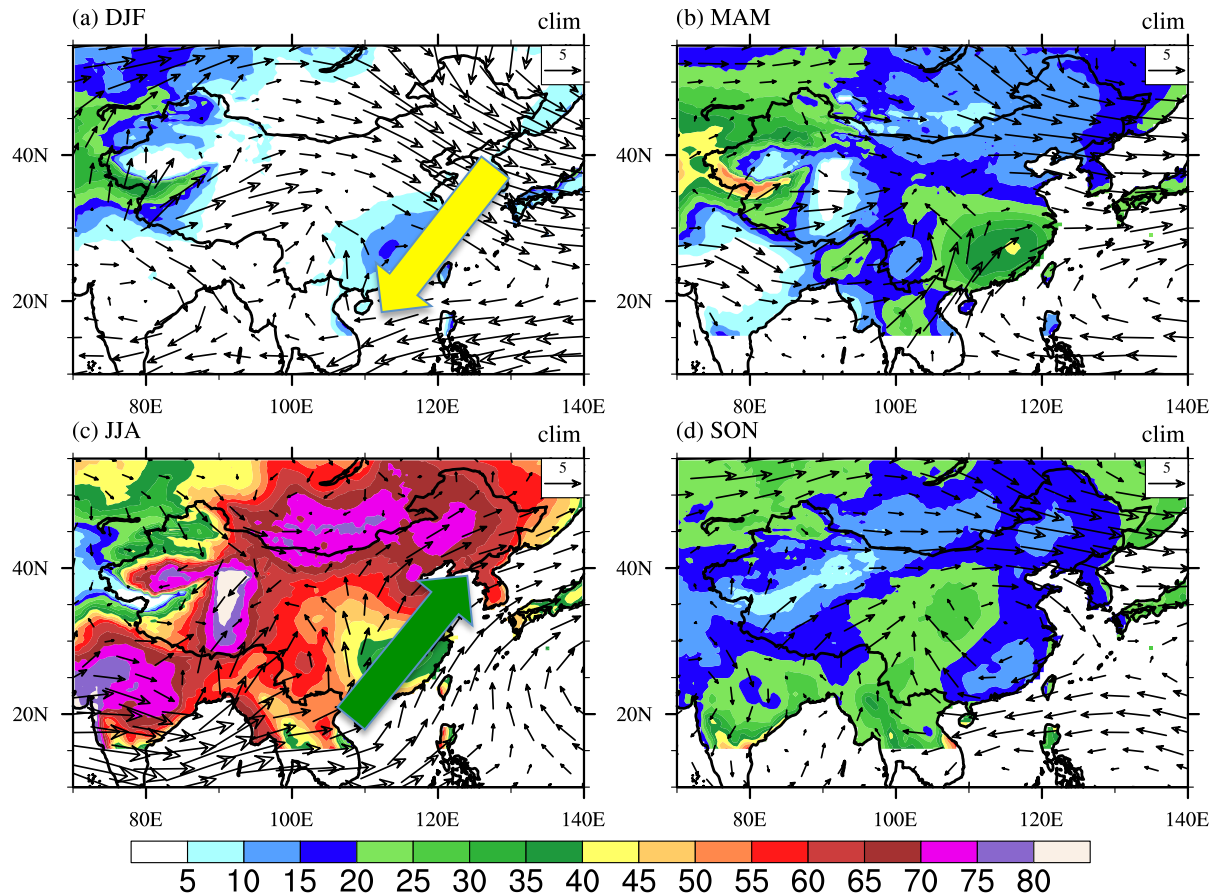
The top three years in terms of the maximum drought disaster area are 2000, 2001 and 1997.



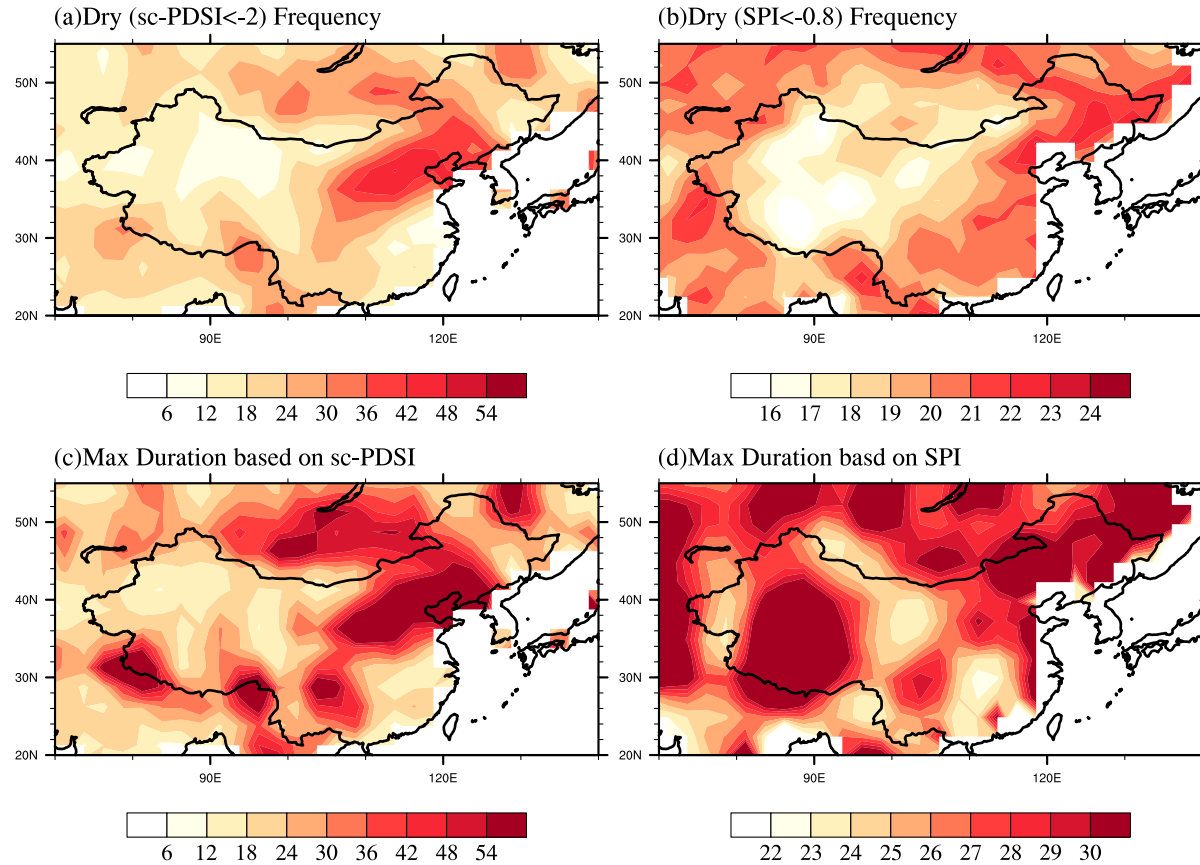
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- DJF: northerly wind (cold and dry air) along its east coastline. Precipitation is small.
- MAM: Largest rainfall percentage in South China. Precipitation percentage in southwestern and northeastern China is still very small. Considering the dry conditions in winter, spring drought in these two regions tends to occur.
- JJA: southwesterly winds flow. Rainband is dominated by the anticyclone circulation over the western Pacific.



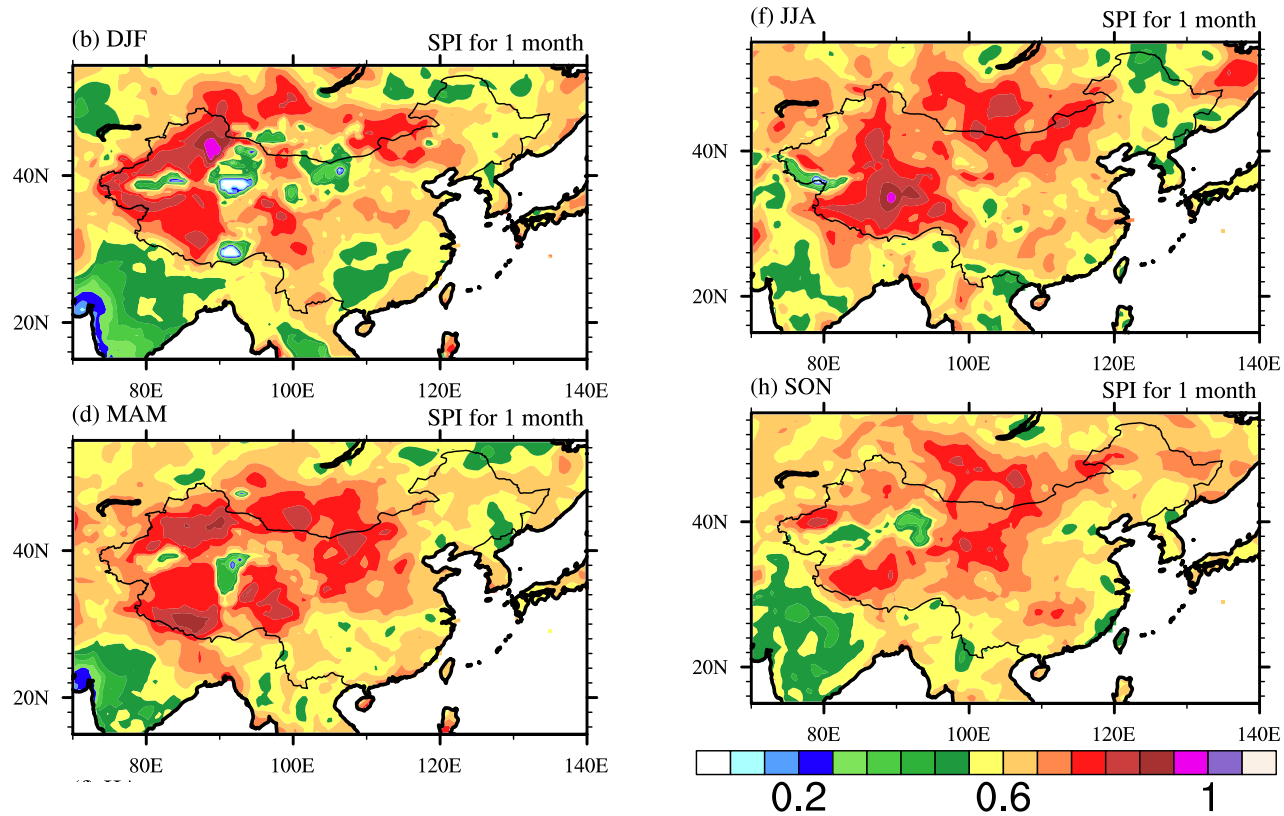
- ✓ sc-PDSI: highest drought frequency and maximum duration over North and Southwest China.
- ✓ SPI-12: can witness the two centers in sc-PDSI, with less magnitude than that in sc-PDSI. Another maximum drought duration center located in Northwest China. This difference is related to the definition of SPI, which only uses precipitation



Outline

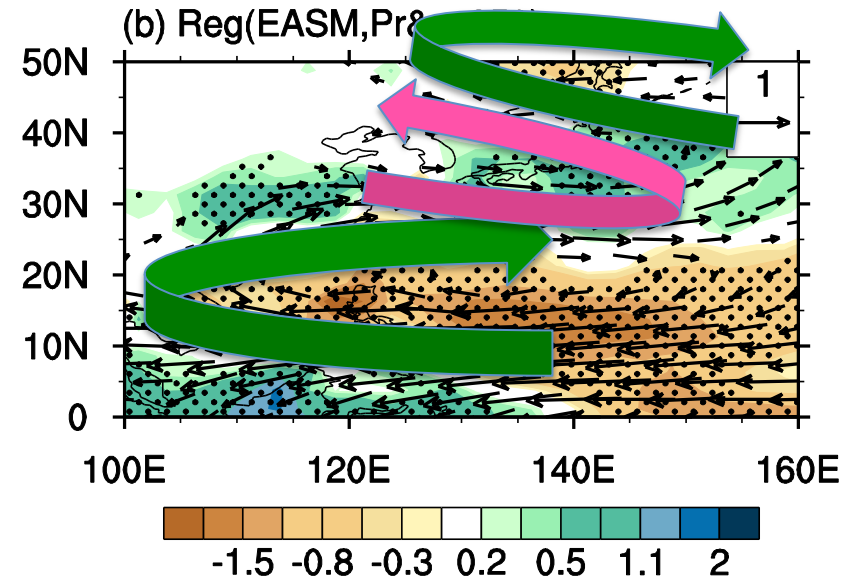
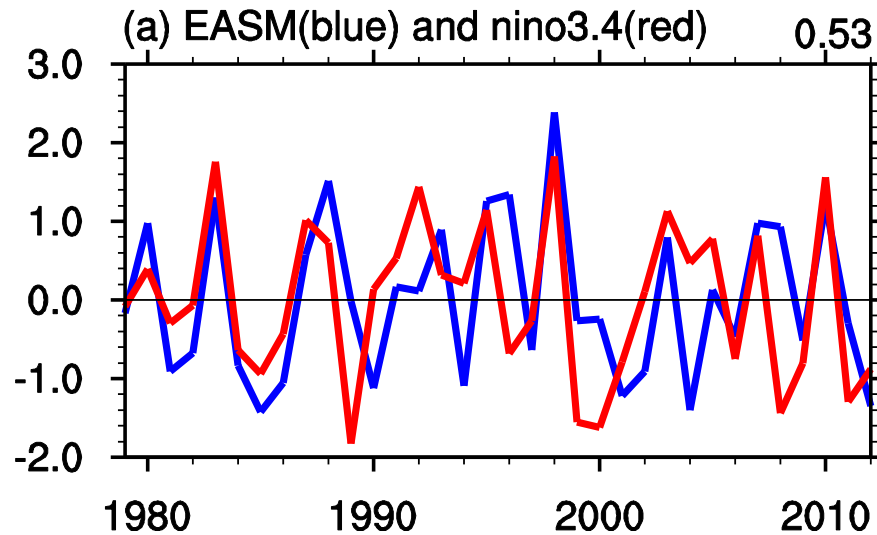
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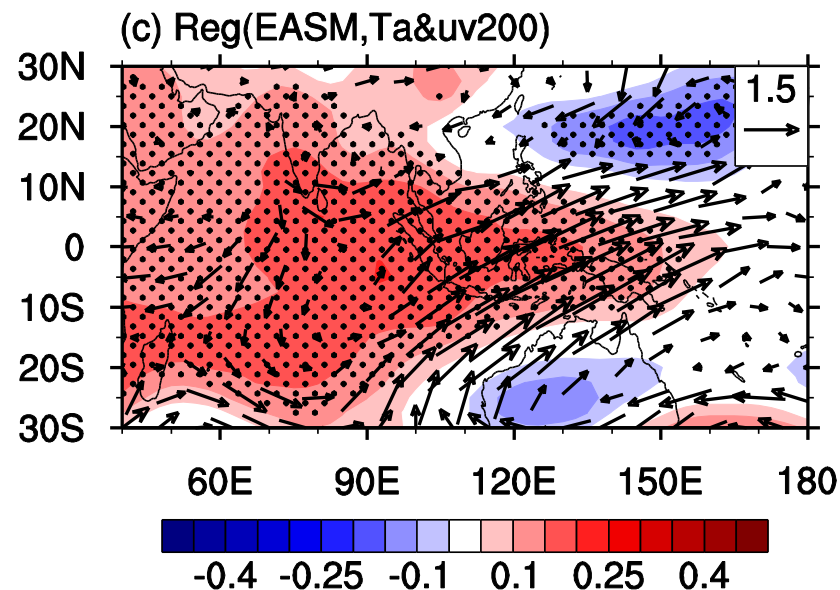
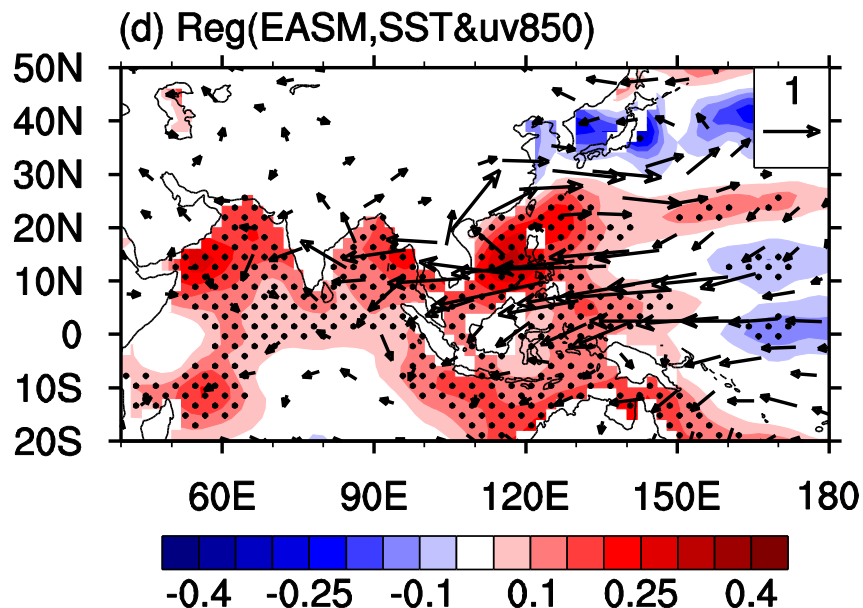
✧ Standard deviation of SPI:

- ✓ The largest variation is seen over the Northwest China in all seasons.
- ✓ The SPI over North China also witnesses large variation, especially in spring and summer.

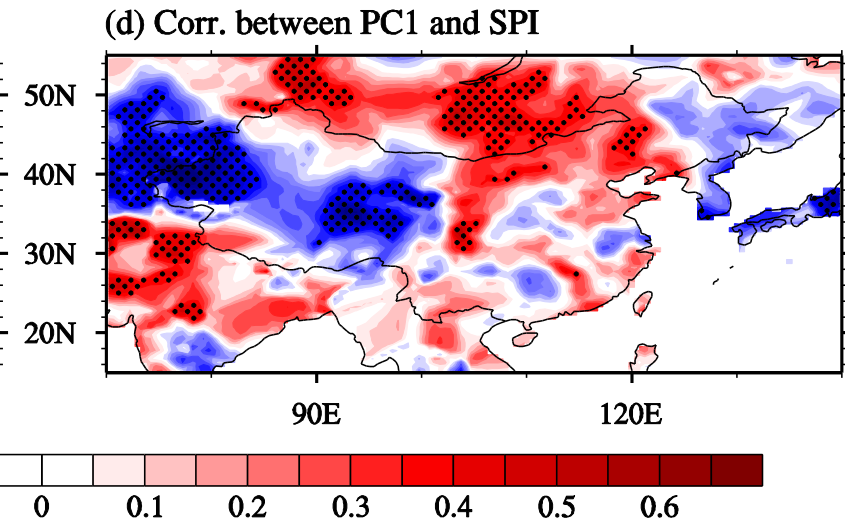
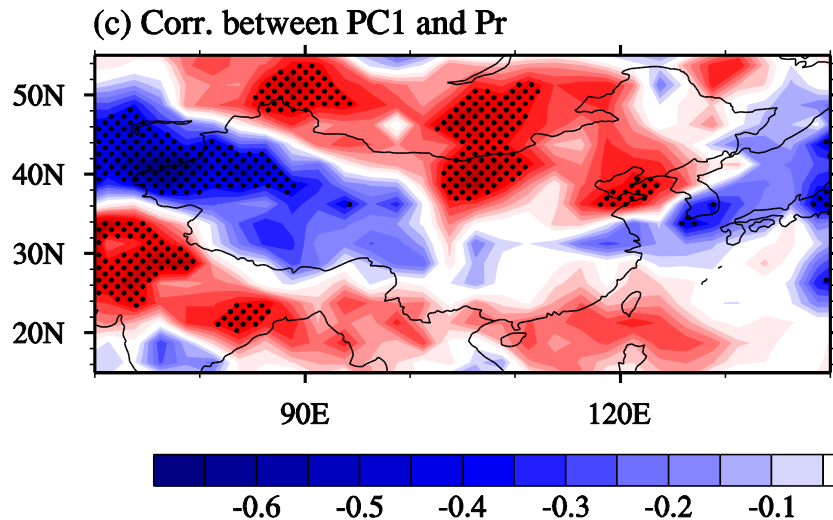
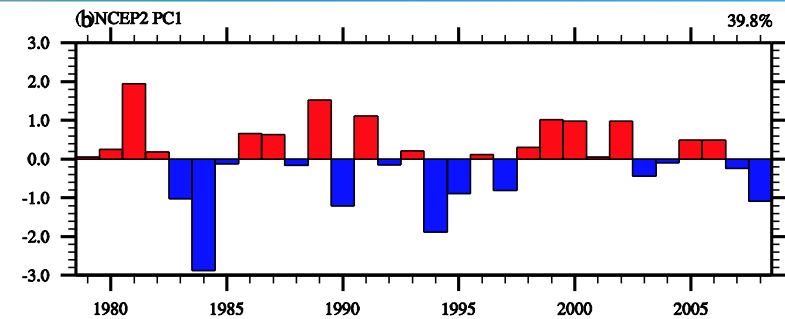
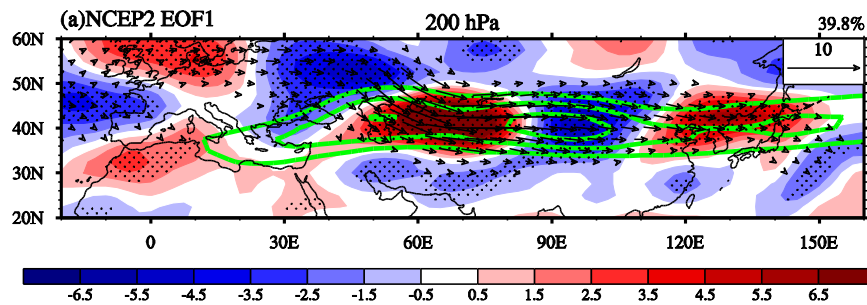


- ✓ Interannual variation of drought activities in eastern China are dominated by summer monsoon.
- ✓ In strong East Asian summer monsoon year, a meridional sandwich precipitation anomaly pattern and Rossby wave train along the East Asia.
- ✓ **Pacific-Japan or East Asian-Pacific teleconnection pattern** (Nitta 1987; Huang et al. 2007).
- ✓ It is forced by the anomalous heating over the western Pacific, which is driven SST anomalies associated with ENSO (Yang et al. 2007, 2010; Li et al. 2008; Xie et al. 2009; Wu et al. 2009, 2010).

Impact of SSTA during ENSO decaying summer on EASM



- In the decaying summer of El Nino, **Indian Ocean basin-wide warming**
 - enhanced precipitation over the Indian Ocean
 - warm the total troposphere (emerges as a Matsuno–Gill pattern)
 - Westerly winds over equatorial Indo–western Pacific region (Kelvin wave response of the Matsuno–Gill pattern)
 - anomalous anticyclone over the NWP.



- ✧ Silk Road is a propagation of stationary Rossby wave along the Asian jet in the upper troposphere (Lau et al. 2000; Wu and Wang 2002; Wu et al. 2003).
- ✧ A significant enhancement of precipitation is seen over North China.
- ✧ It is forced by Indian monsoon heating, and appears preferentially in summers preceding the peak phases of the cycle when ISM precipitation anomaly is evident (Ding et al. 2011).



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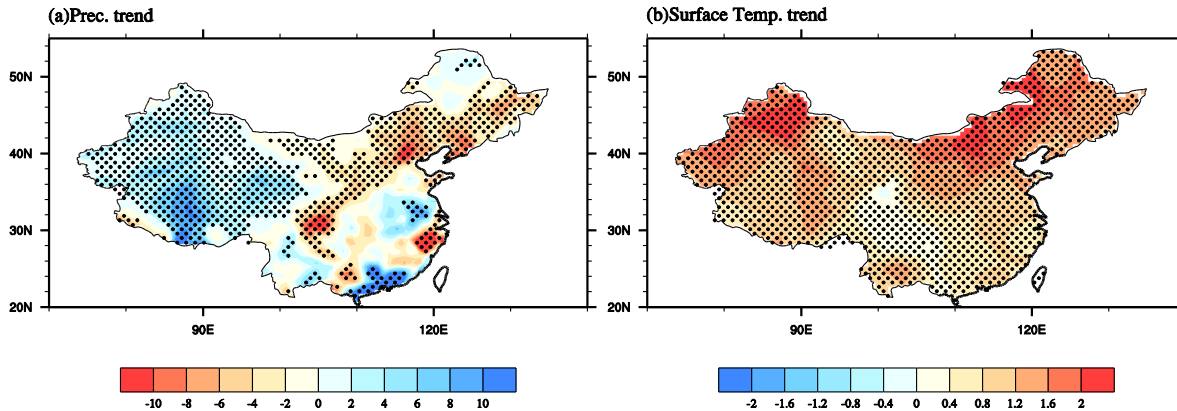




Linear trend of annual mean precipitation, surface temperature, sc-PDSI and SPI-12 during 1950–2009

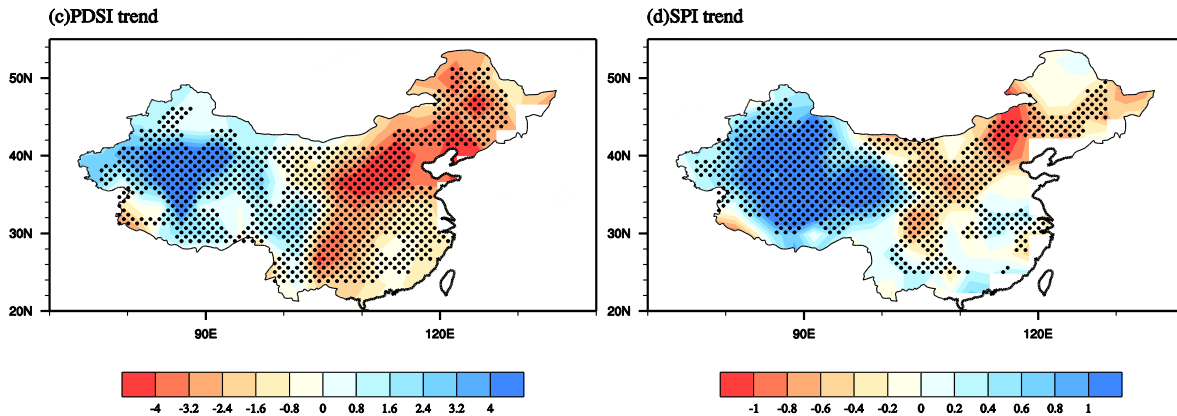


Pr



Temp

Sc-PDSI

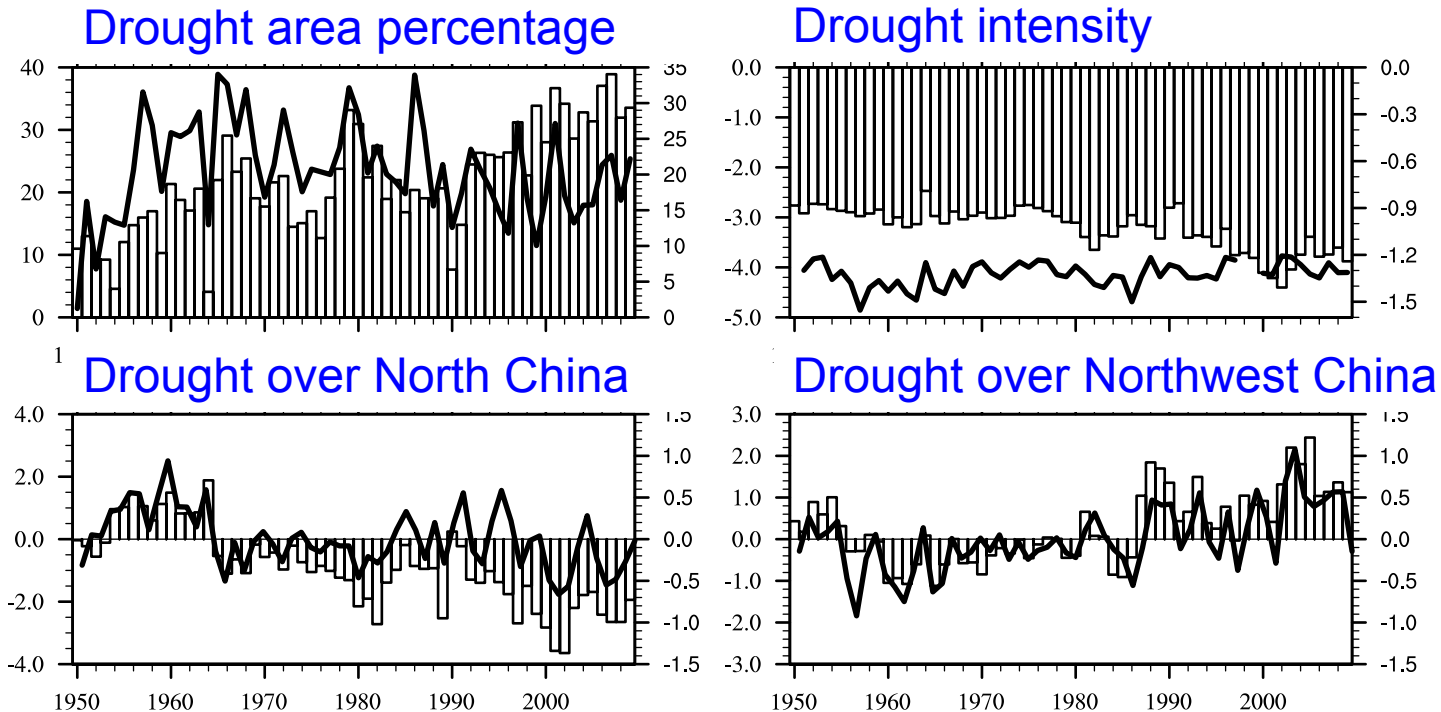


SPI

- ❑ Sc-PDSI and SPI-12: increasing trend over NW China, but a decreasing tendency over North China for 1950–2010
- ❑ The North China Drought is mainly caused by decreased precipitation and intensified by increasing temperature



drought area and intensity for 1950-2009

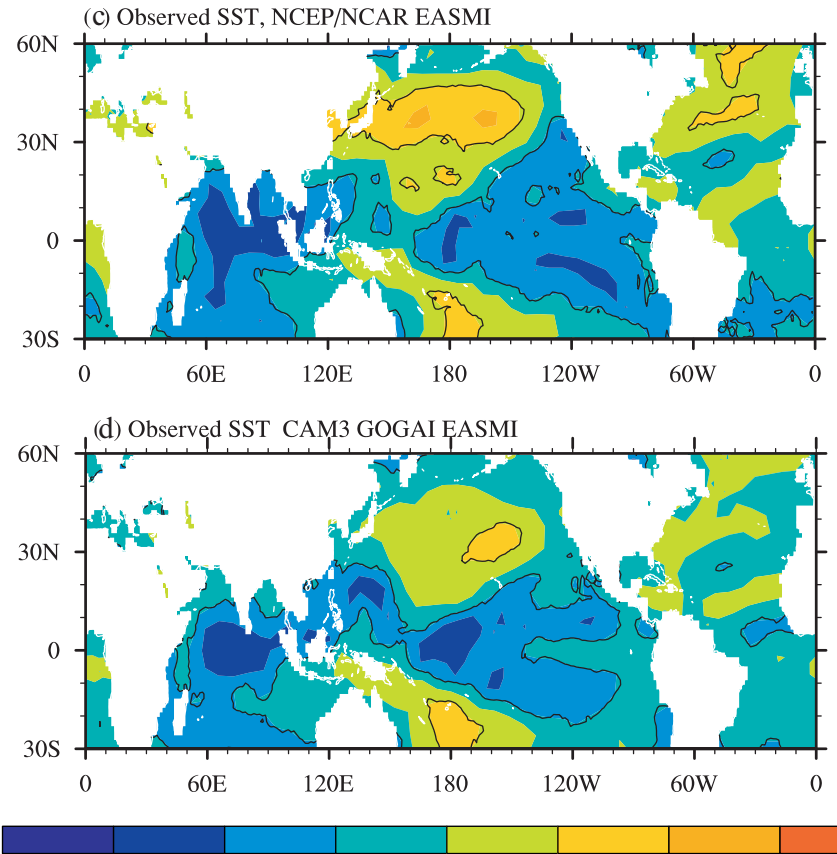
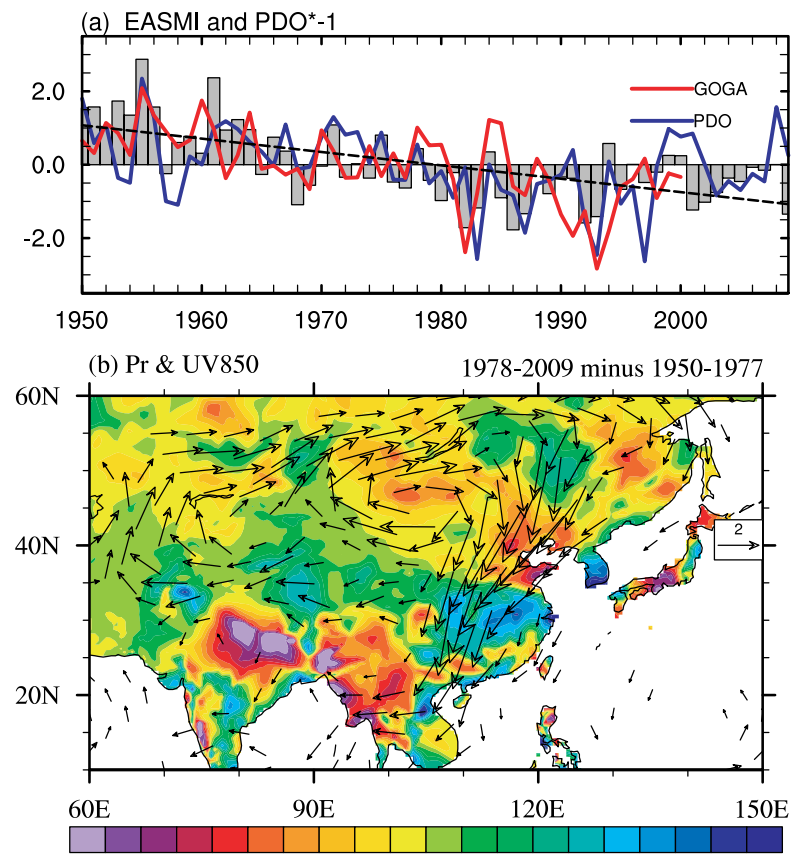


Bar: sc-PDSI, Line: SPI-12

- ❑ **Whole China:** A significant increasing trend of sc-PDSI in both drought area and intensity (PDSI < -2). It doesn't evident in SPI-12.
- ❑ **North China:** significant increasing drought tendency with a phase transition around 1970s.
- ❑ **NW China:** increasing trends with a phase transition around the late 1980s, which indicates that the drought condition of NW China gets relieved.



impact of PDO on decreasing trend of EASM



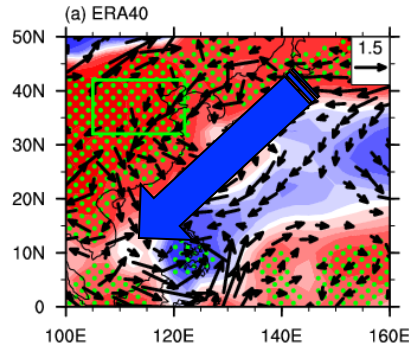
(Li et al. 2010 Clim. Dyn. 5)

- ✓ North China drought is related to the inter-decadal scale weakening of the EASM circulation.
- ✓ Significant anomalous northerly winds are seen along the East Asia.
- ✓ Both in observation and simulation, significant negative correlations over the tropical central and eastern Pacific and central Indian Ocean, while positive correlations exist over the North and South Pacific.

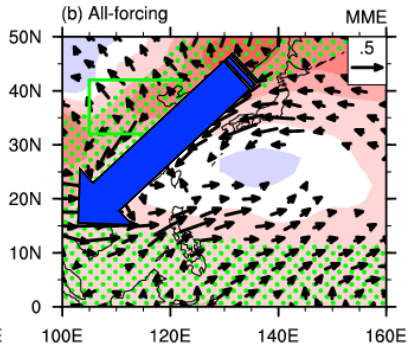


Linear trends of SLP and 850 hPa winds

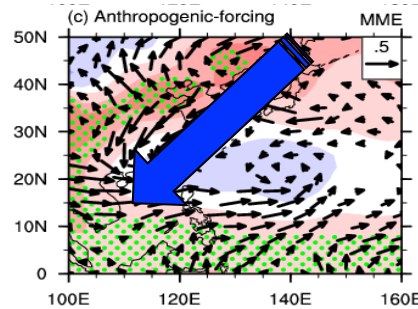
ERA40



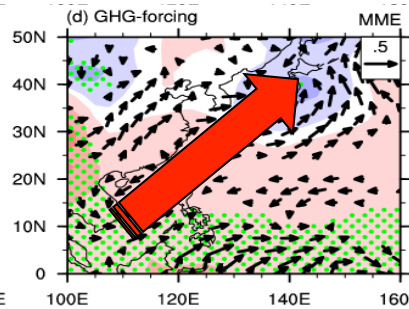
All-forcing



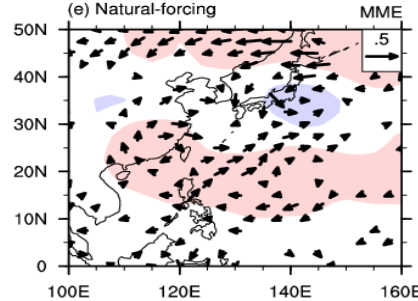
**Anthro.
forcing**



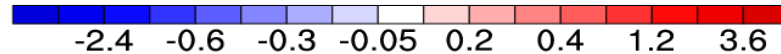
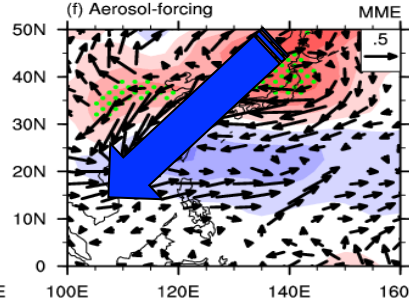
**GHG
forcing**



**Natural
forcing**

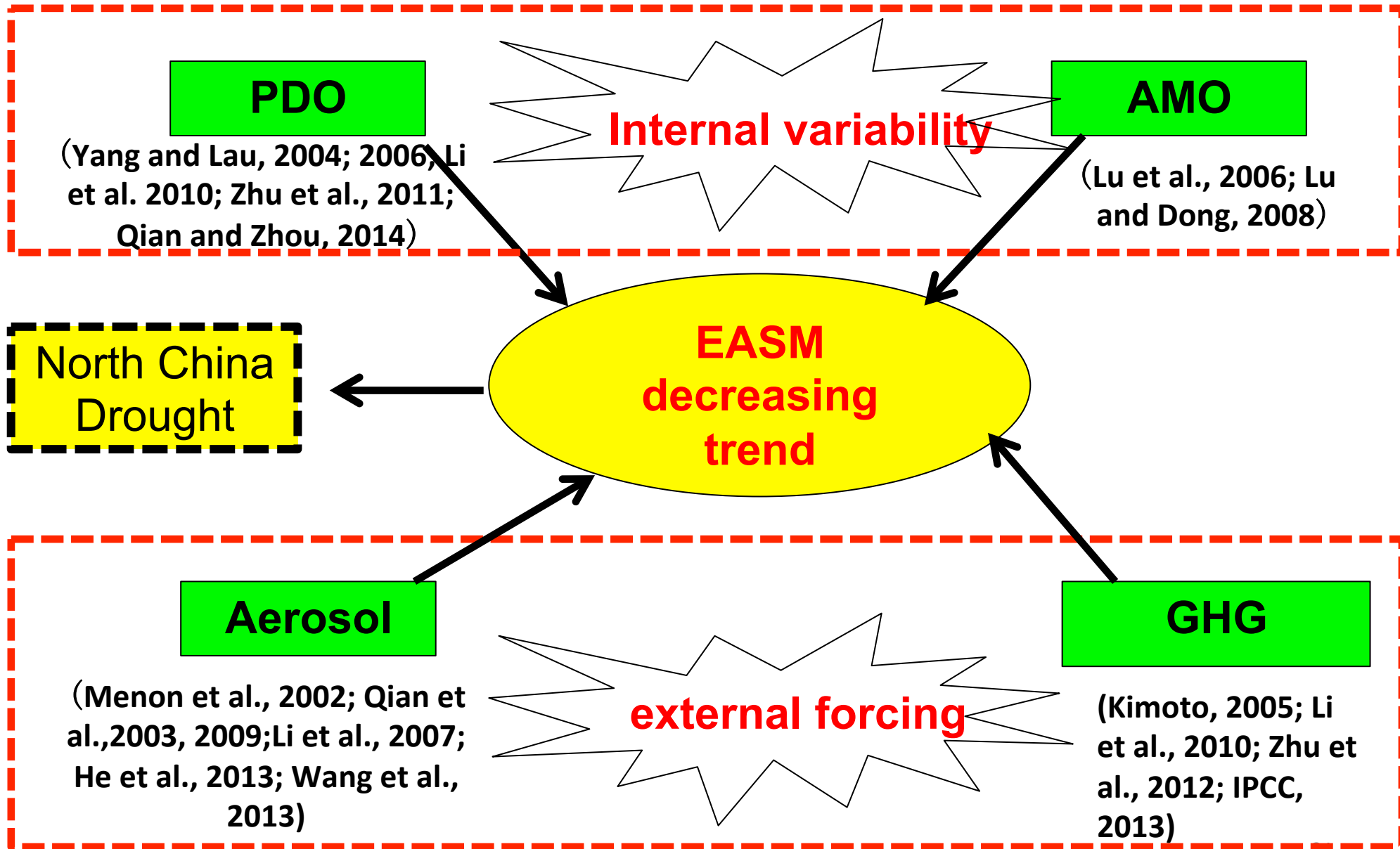


**Aerosol
forcing**



17 CMIP5 models, the aerosol forcing can drive a weakened monsoon, with far weaker magnitude than the observation.

The models fail to reproduce the observed precipitation changes (Song et al. 2014). ²⁰





Outline

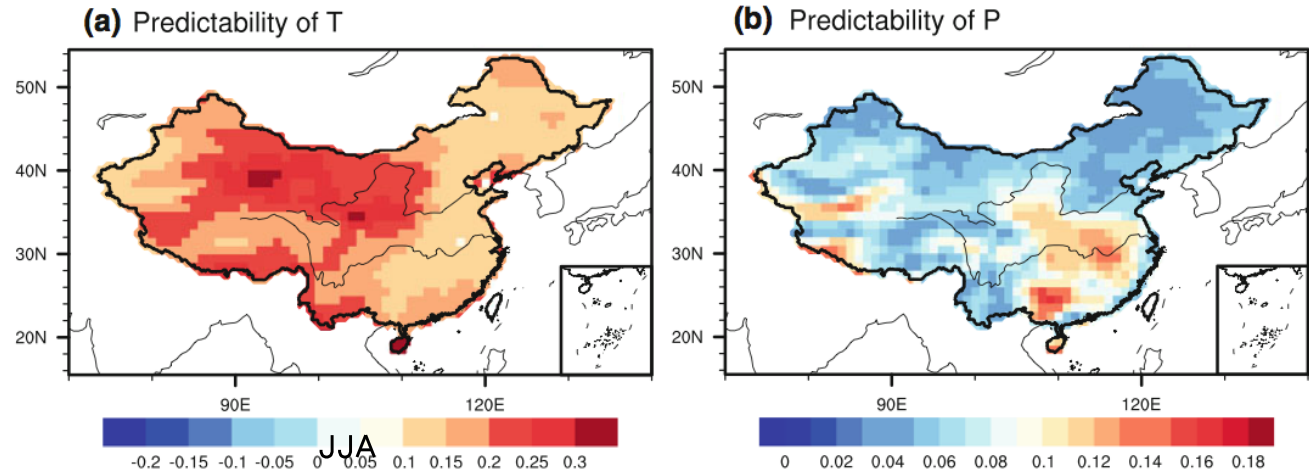
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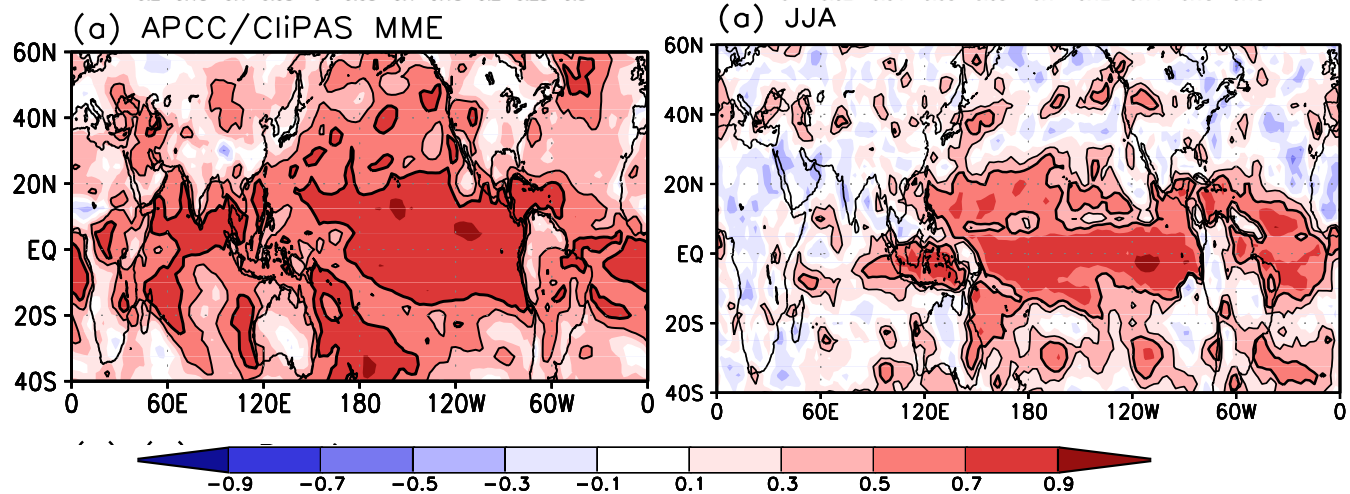
**NCEP CFSV2
for 1982-2009
lead 1 month**

Luo et al. 2013 *Clim. Dyn.*

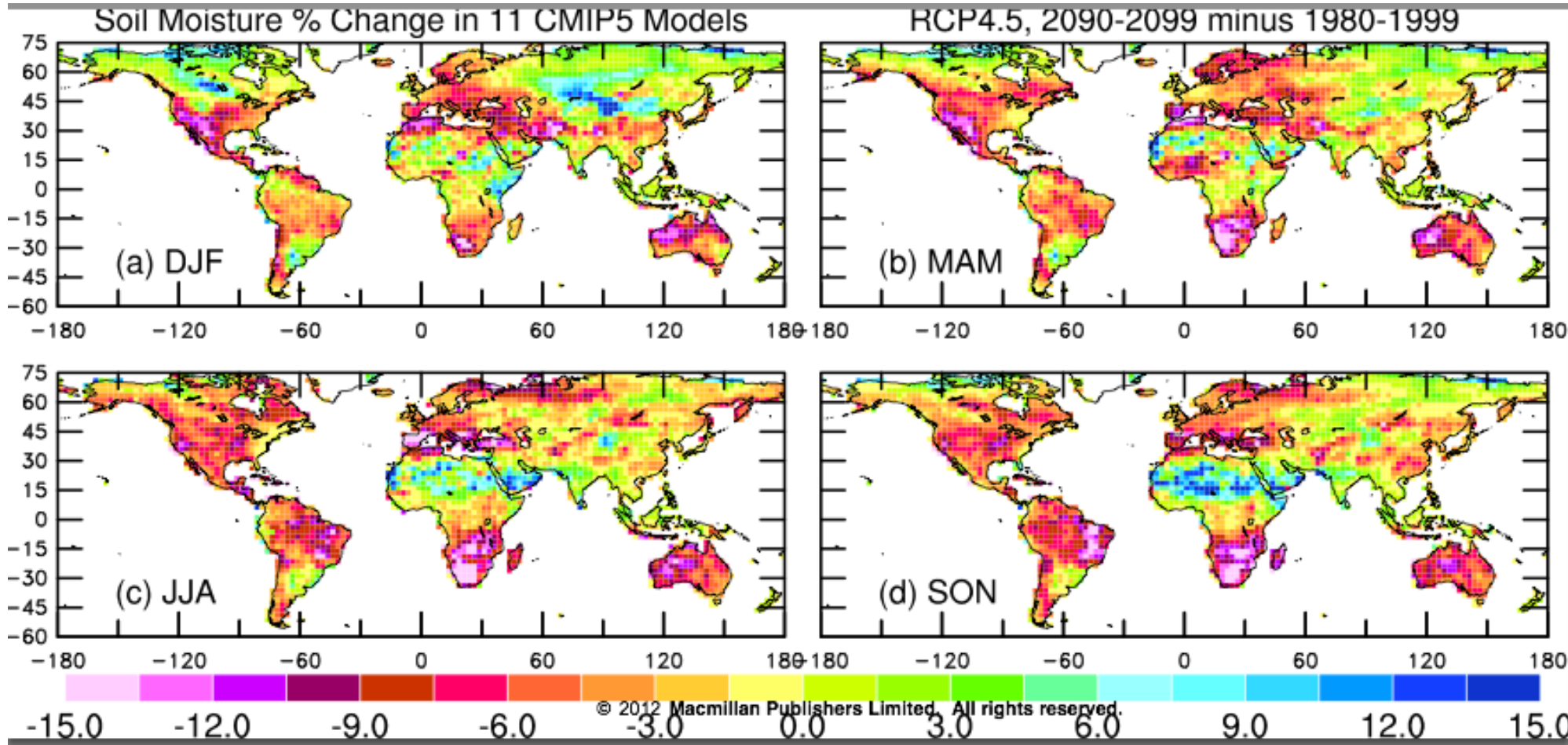


**APCC/CliPas for
1979-2003 lead 1
month**

Wang et al. 2009 *Clim. Dyn.*

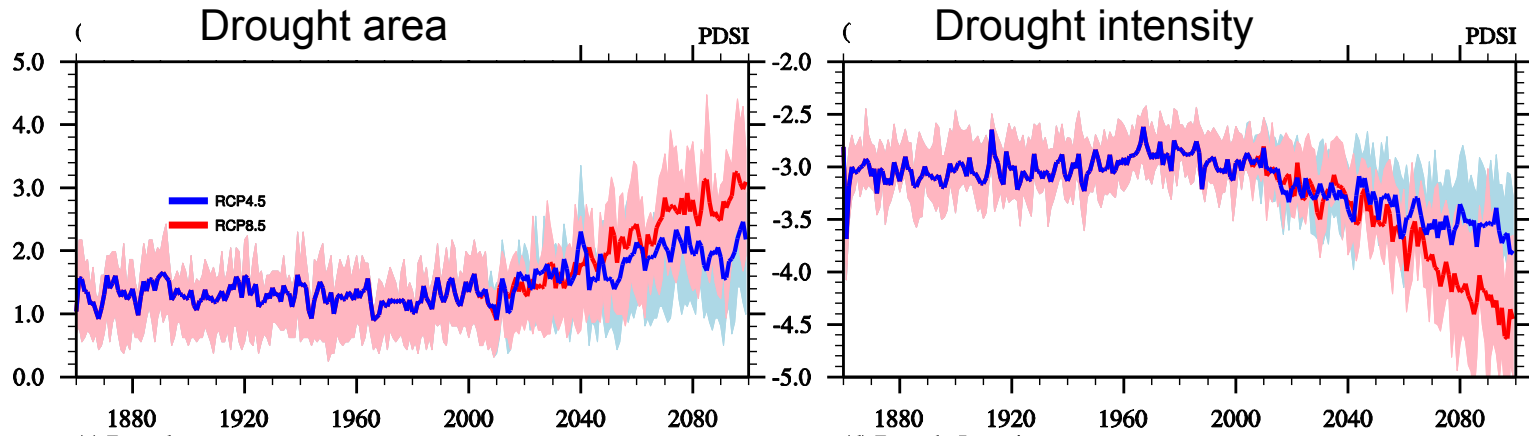


The forecasting skill of surface temperature and precipitation is almost zero in East Asia as derived from APCC/CliPAS hindcast results.

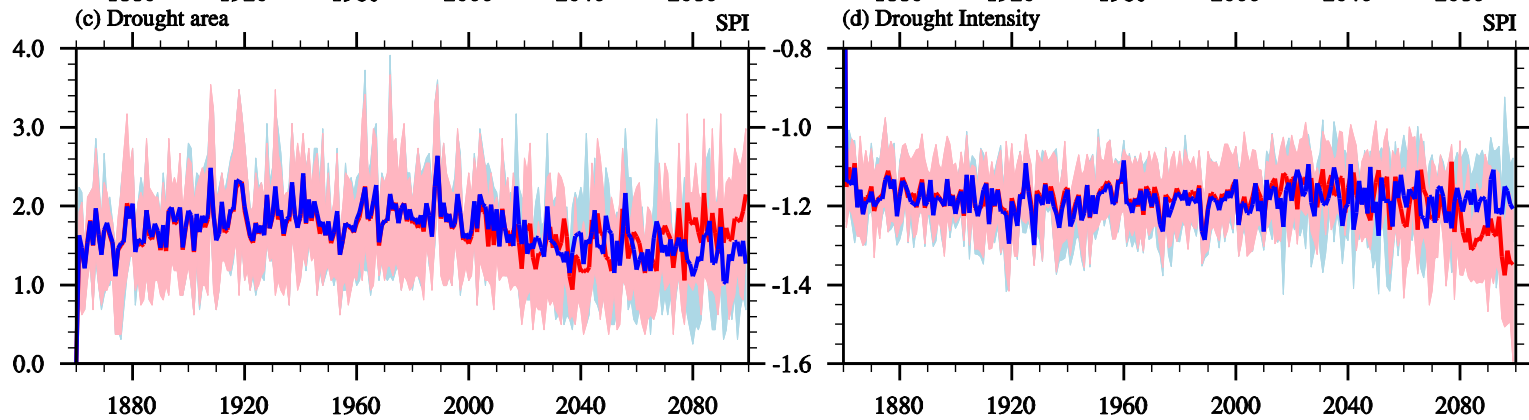




PDSI



SPI



- ❑ Based on PDSI, most climate models project an increasing drought frequency and intensity over China.
- ❑ Nevertheless, uncertainties exist due to the selection of climate models and the choice of drought index.



Concluding Remarks



- ◆ East Asia is greatly impacted by drought, centered North and Southwest China.
- ◆ Two teleconnection patterns dominate interannual drought in East Asian monsoon region
 - ✓ Pacific-Japan during El Niño decaying.
 - ✓ Silk Road, forced by Indian monsoon heating, influence North China.
- ◆ For 1950s to present, increasing drought is seen over North China and a decreasing tendency over Northwest China. The former is mainly driven by the phase transition of PDO.
- ◆ East Asian summer precipitation is poorly simulated and predicted
- ◆ Most climate models project an increasing drought frequency and intensity over southeastern Asia. Nevertheless, uncertainties exist due to the selection of climate models and the choice of drought index.



Further study needed



- 1. How can we better understand the influence of ENSO on short-term atmospheric variability associated with drought?**
- 2. Despite many studies having noticed the relationship between NW China drought and ENSO/AO, they have done so largely on the basis of statistical analyses; the underlying mechanisms remain unknown.**
- 3. The simulation and prediction skills of climate models with respect to East Asian drought are yet to be properly examined.**

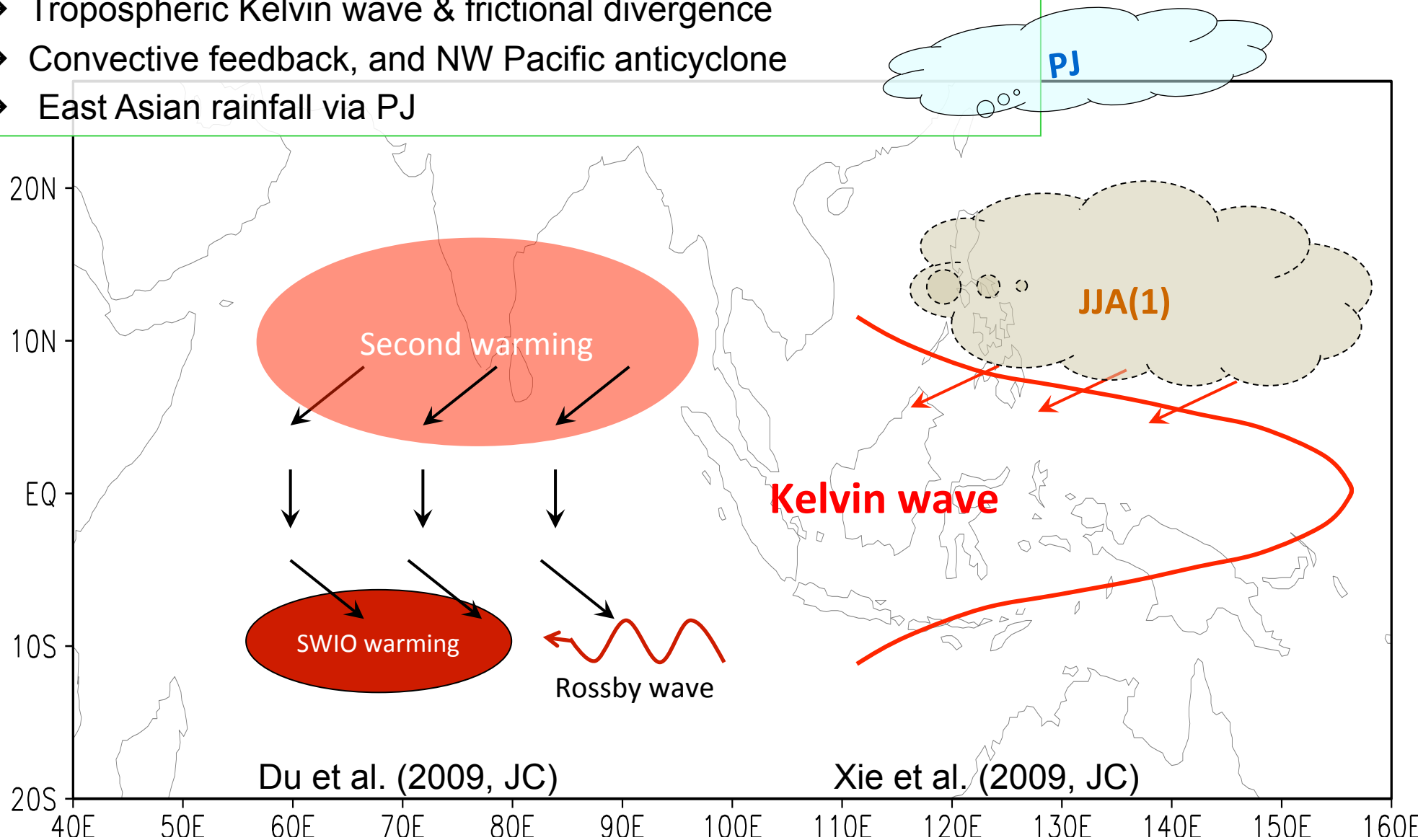
The logo features the letters 'LASO' in a bold, white, sans-serif font. The letter 'O' is replaced by a circular emblem with green and yellow wavy lines and the text 'LASG' in the center. The background is a blue globe with a white grid, set against a blue gradient background.

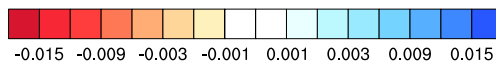
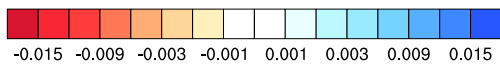
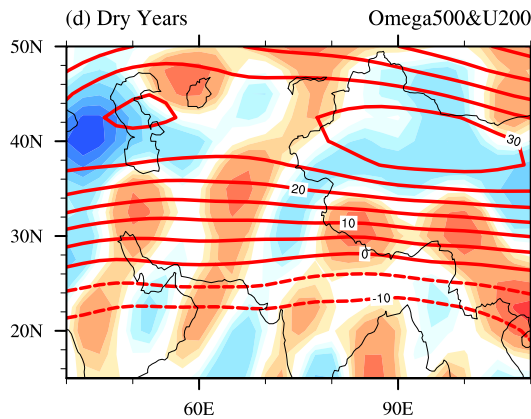
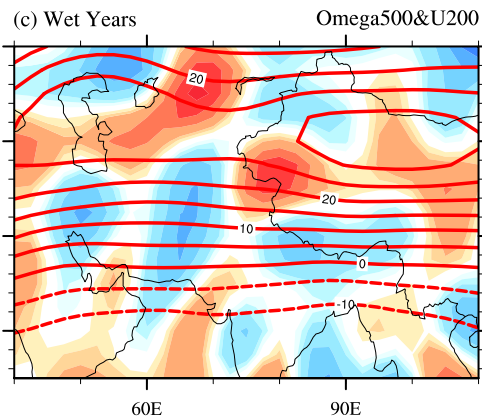
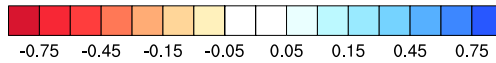
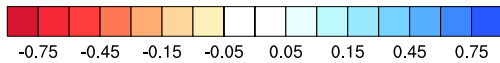
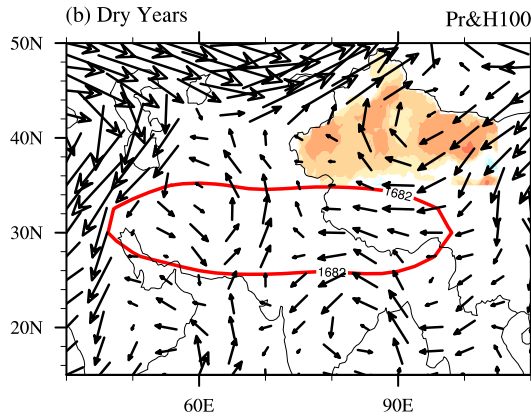
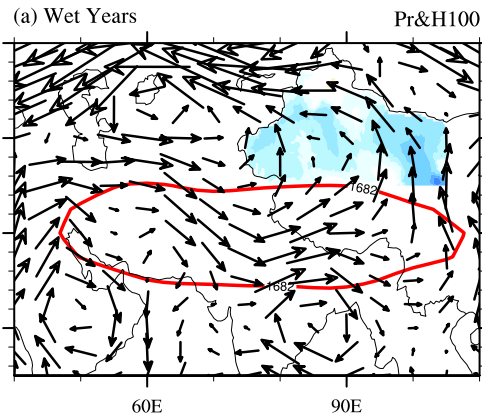
LASO

THANKS

El Nino teleconnection Ocean Rossby waves & persistent SST warming over SWIO Anti-symmetric wind pattern & persistent North IO warming

- Tropospheric Kelvin wave & frictional divergence
- Convective feedback, and NW Pacific anticyclone
- East Asian rainfall via PJ

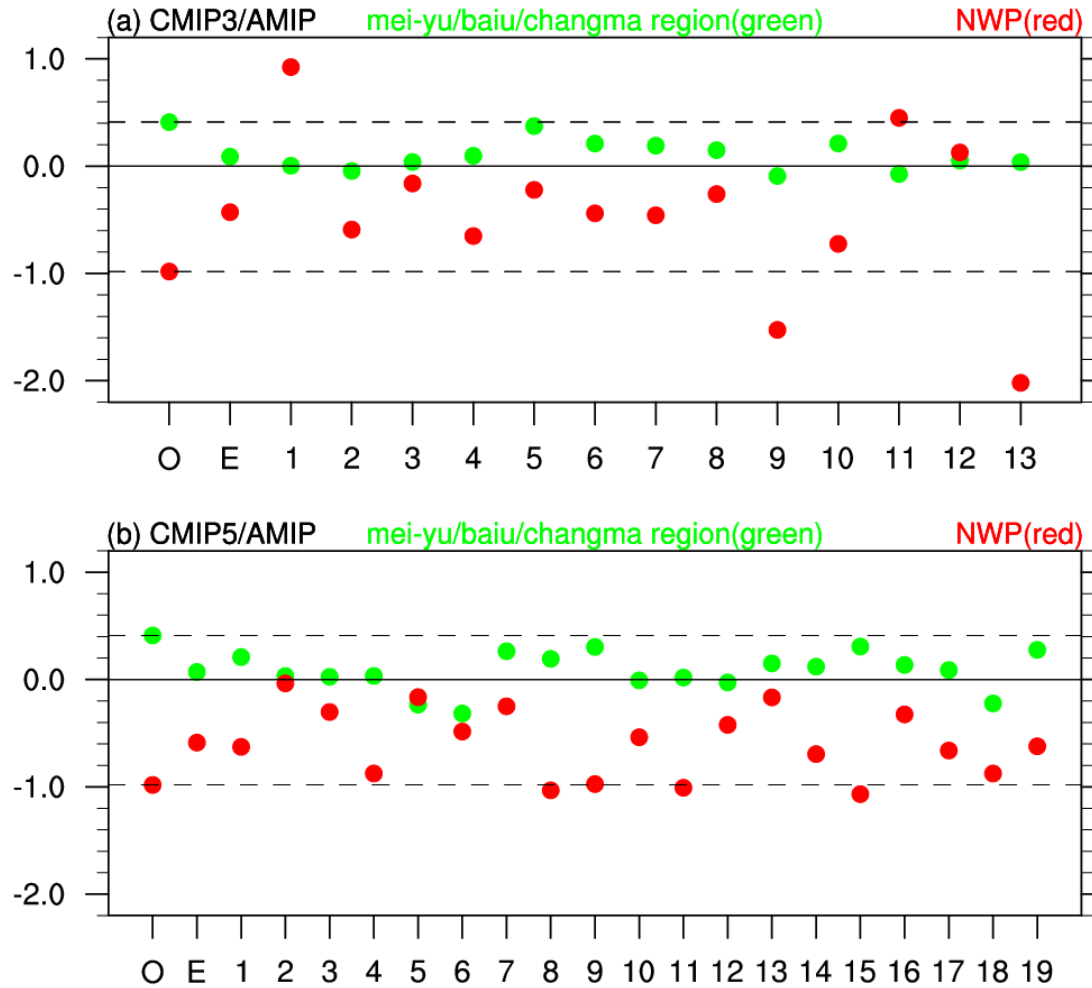




✧ Comparison with dry years, in wet years:

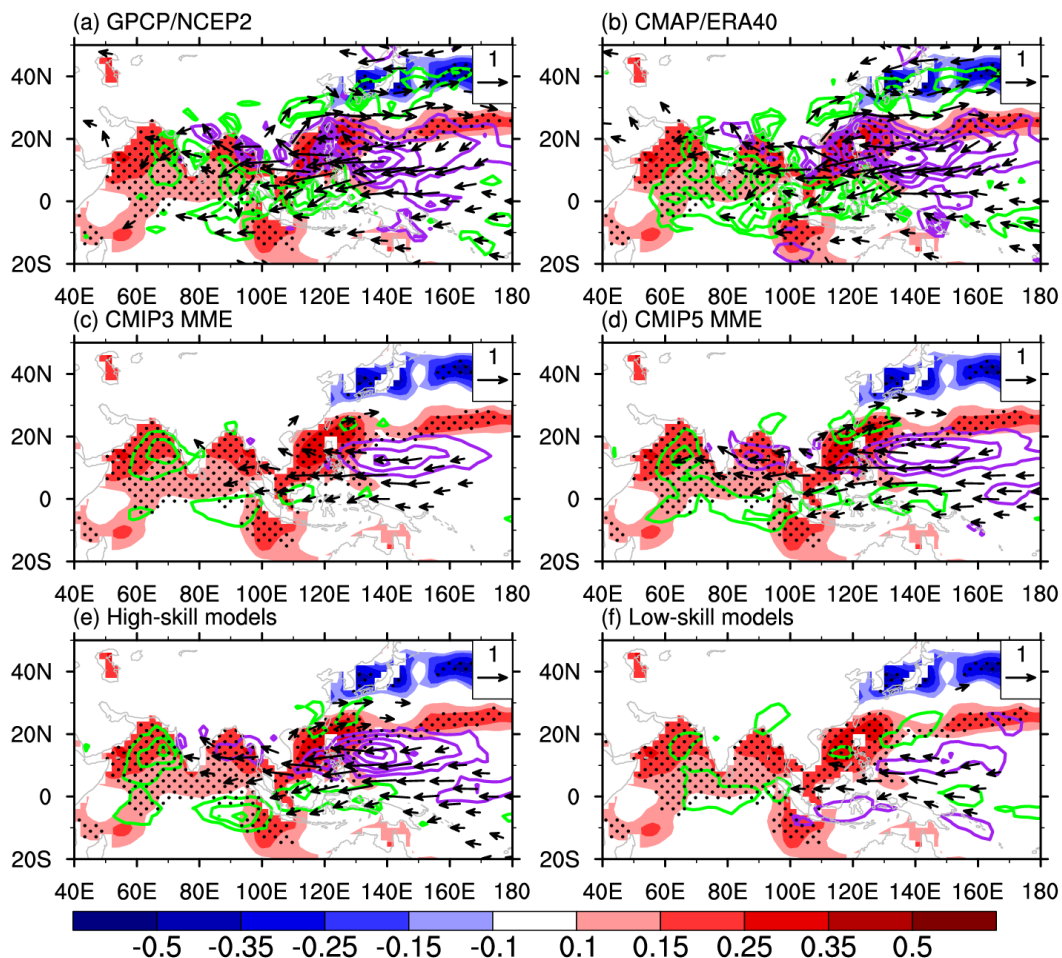
- ❶ South Asian High at 100 hPa shifts more
- ❷ mid-troposphere is dominated by an anomalous cyclone
- ❸ the westerly jet at 200 hPa north of the TP is weaker

✧ The circulation anomalies are related with the heating of the TP. In wet years, the heating of the TP is larger than normal and the heating effect of the TP is intensified.



- The rainfall anomalies in both regions are smaller than the observed, especially for meiyu-baiu region.

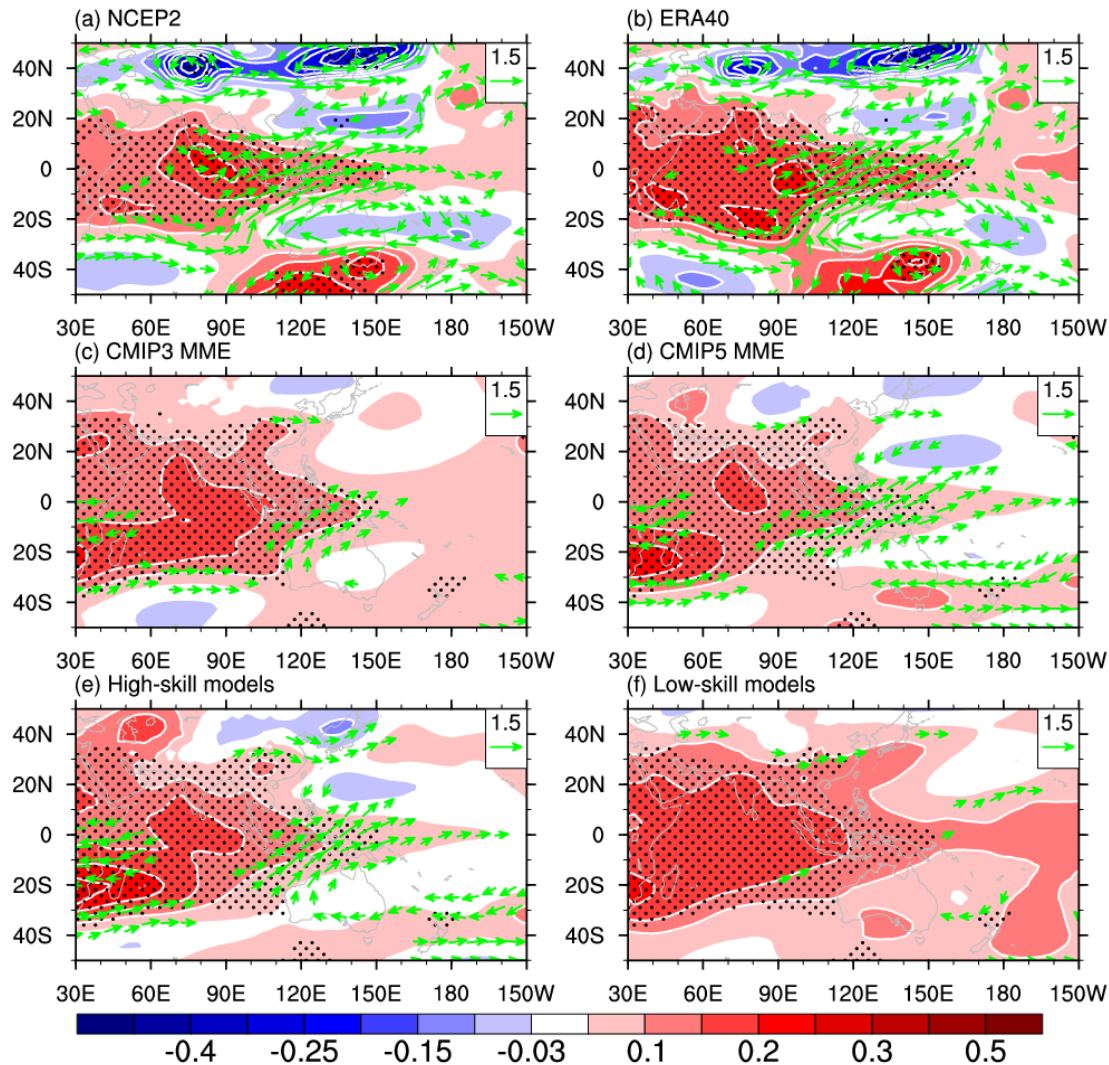
The SST, wind and precipitation regressed on the observed EASM index



- As the response to the same SST, the precipitation and Kelvin wave response are better simulated in high-skill models than low-skill models.

- The improvement from CMIP3 to CMIP5 is also evident.

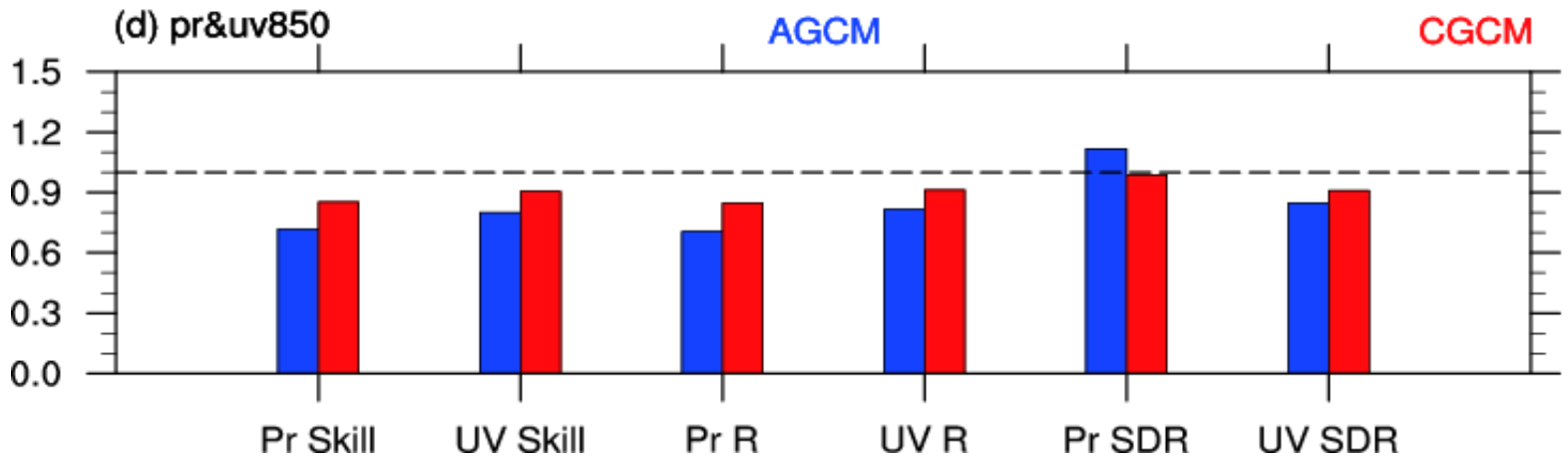
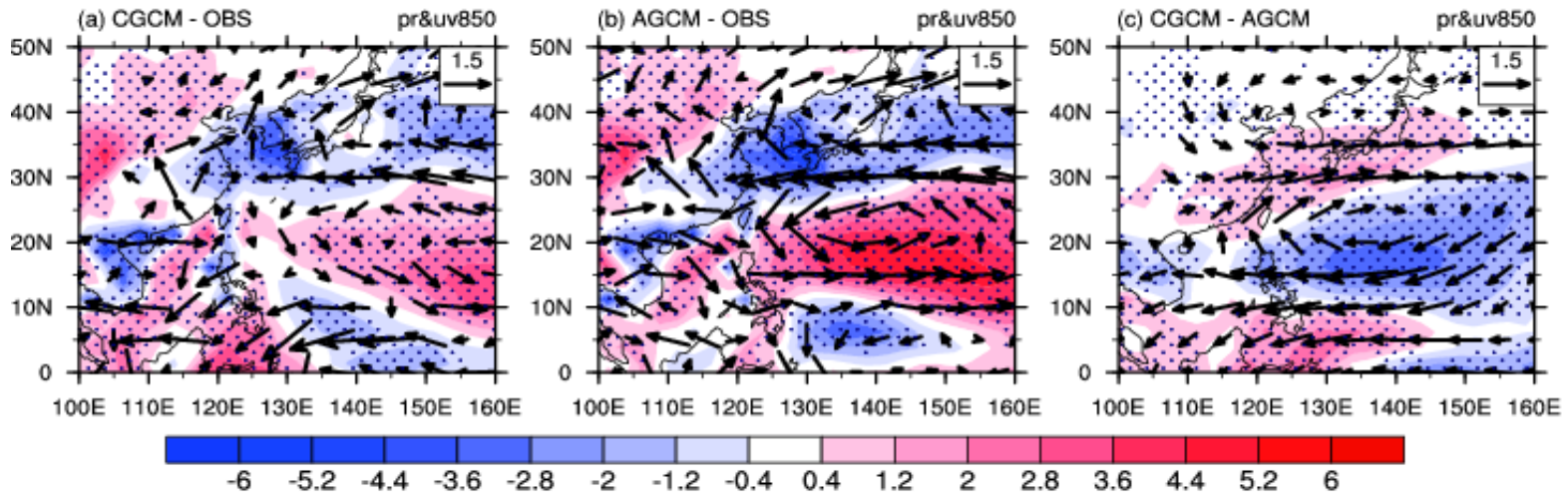
- The EASM is related to the Indian Ocean warming and positive precipitation anomalies over northwestern Indian ocean (NWIO) and tropical eastern Indian Ocean (TEIO). As the response to these precipitation anomalies, the Kelvin wave response occupies over the equatorial Indo-Pacific region.



- In the observation, Indian Ocean (IO) appears as the heat source for Gill pattern, with Rossby wave to the west and Kelvin wave to the east;
- The Gill-pattern shape and high-level Kelvin wave response is better capture in high-skill models.

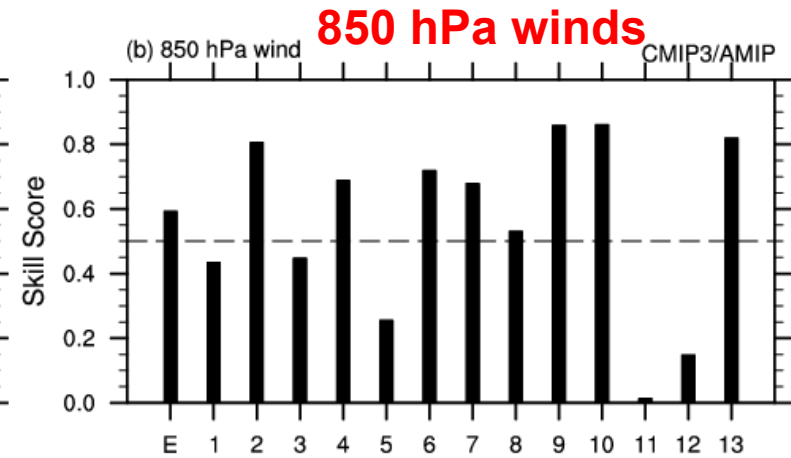
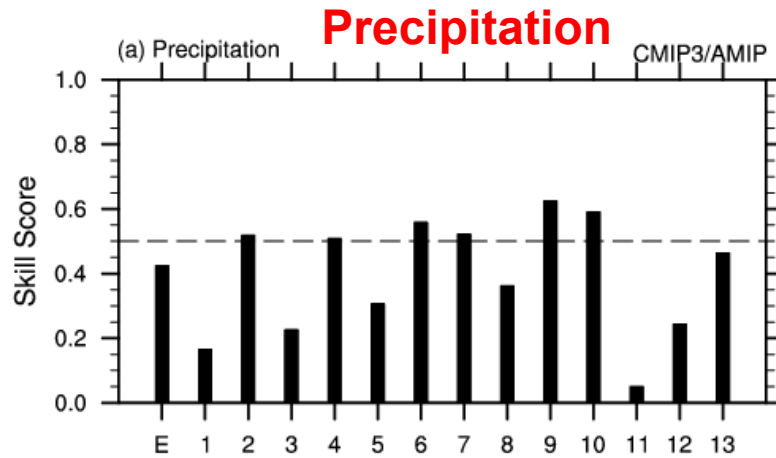
climatology simulated by CGCMs and AGCMs

Shaded: Pr Vector: UV850

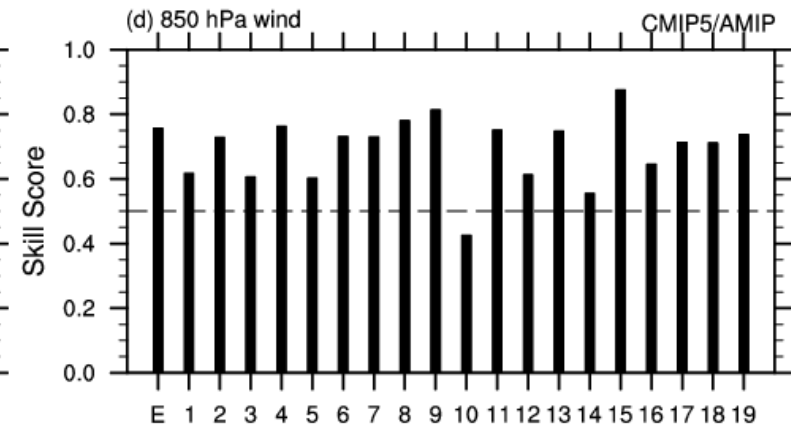
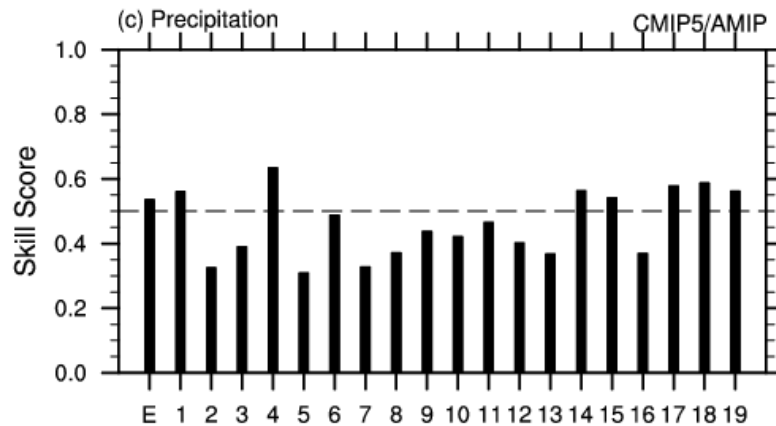




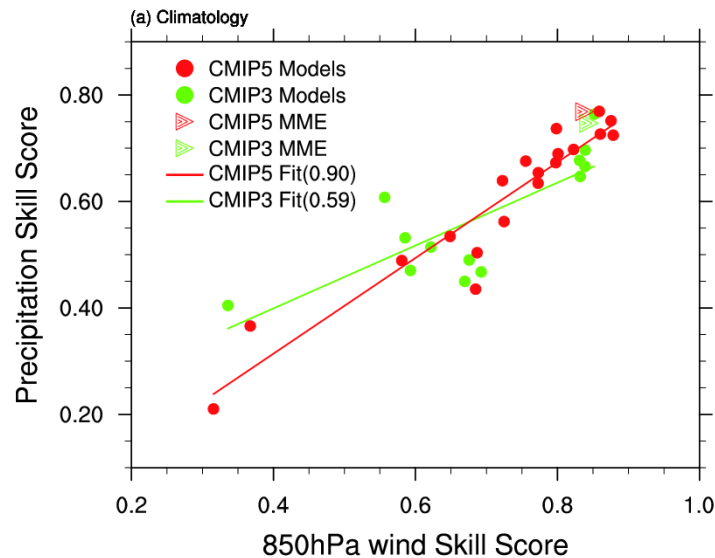
CMIP3



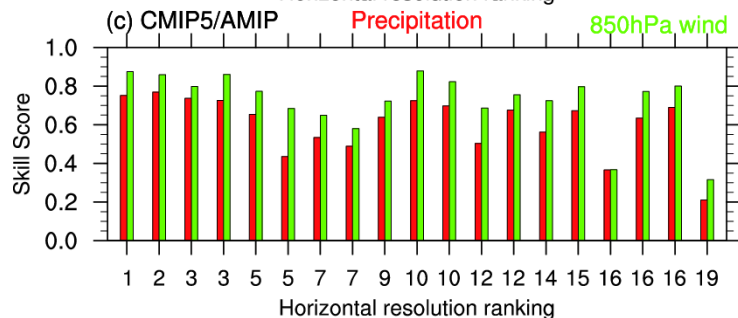
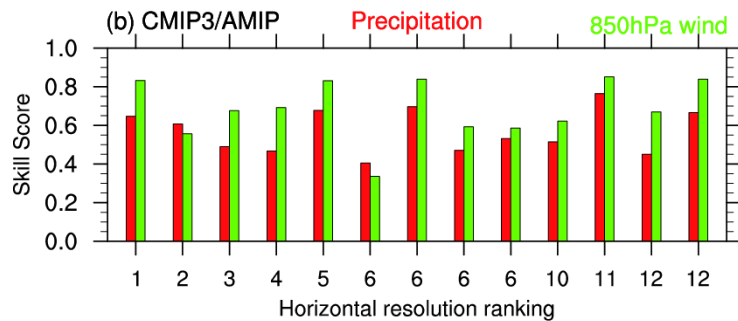
CMIP5



- The skill score of precipitation has improved from 0.43 in CMIP3 MME to 0.54 in CMIP5 MME, while the wind is improved from 0.59 to 0.76.



- The 850 hPa wind is better simulated than the precipitation;
- The skill score of precipitation and 850 hPa wind is positively correlated;
- This relationship indicates the improving precipitation simulation will also result in an improved wind.
- The skill score is independent of horizontal resolution.





Numerical Experiments

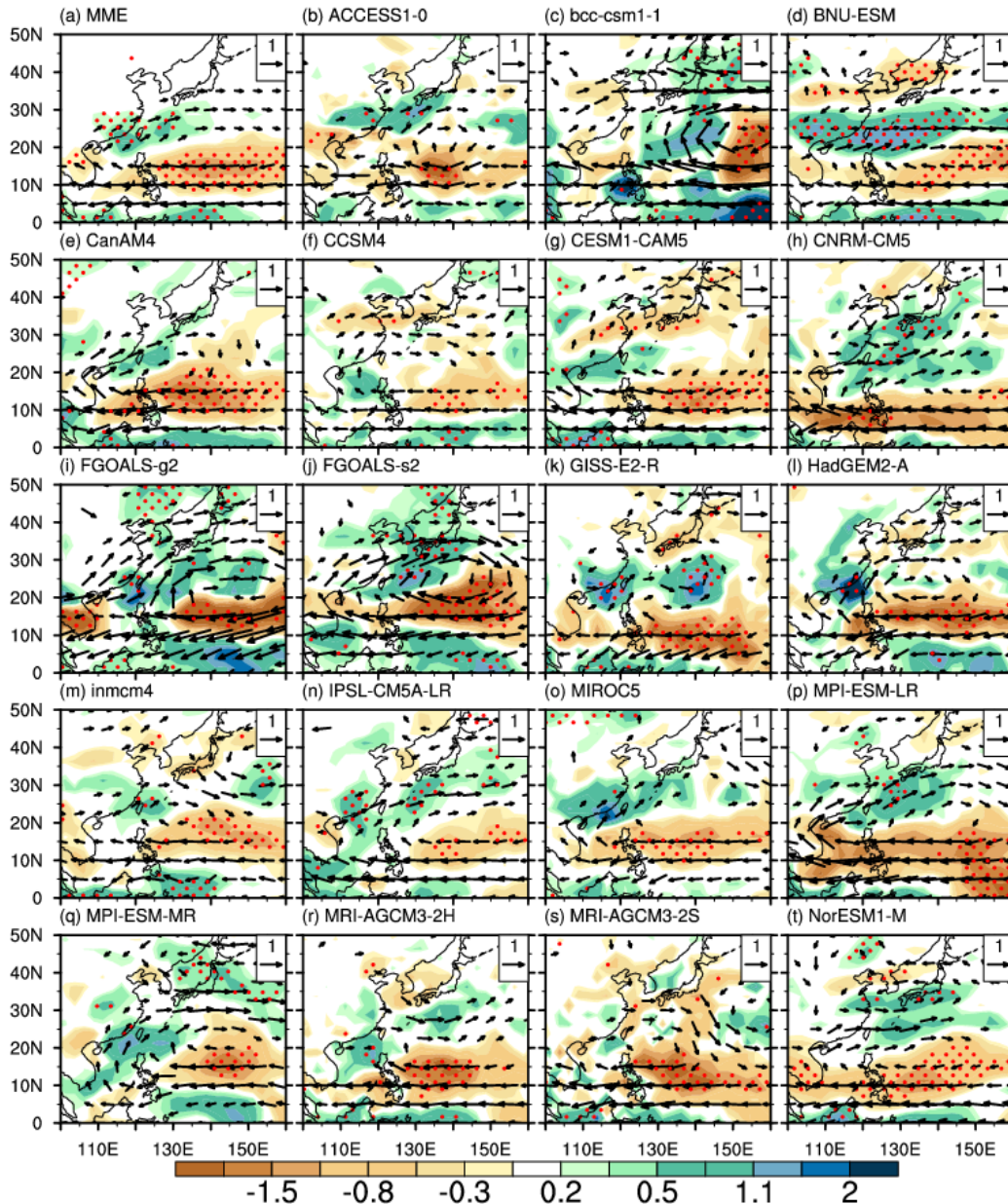


	CAM3 (T85)	CAM3 (T42)
GOGA	5	5
TOGA	5	5

EASM Index:

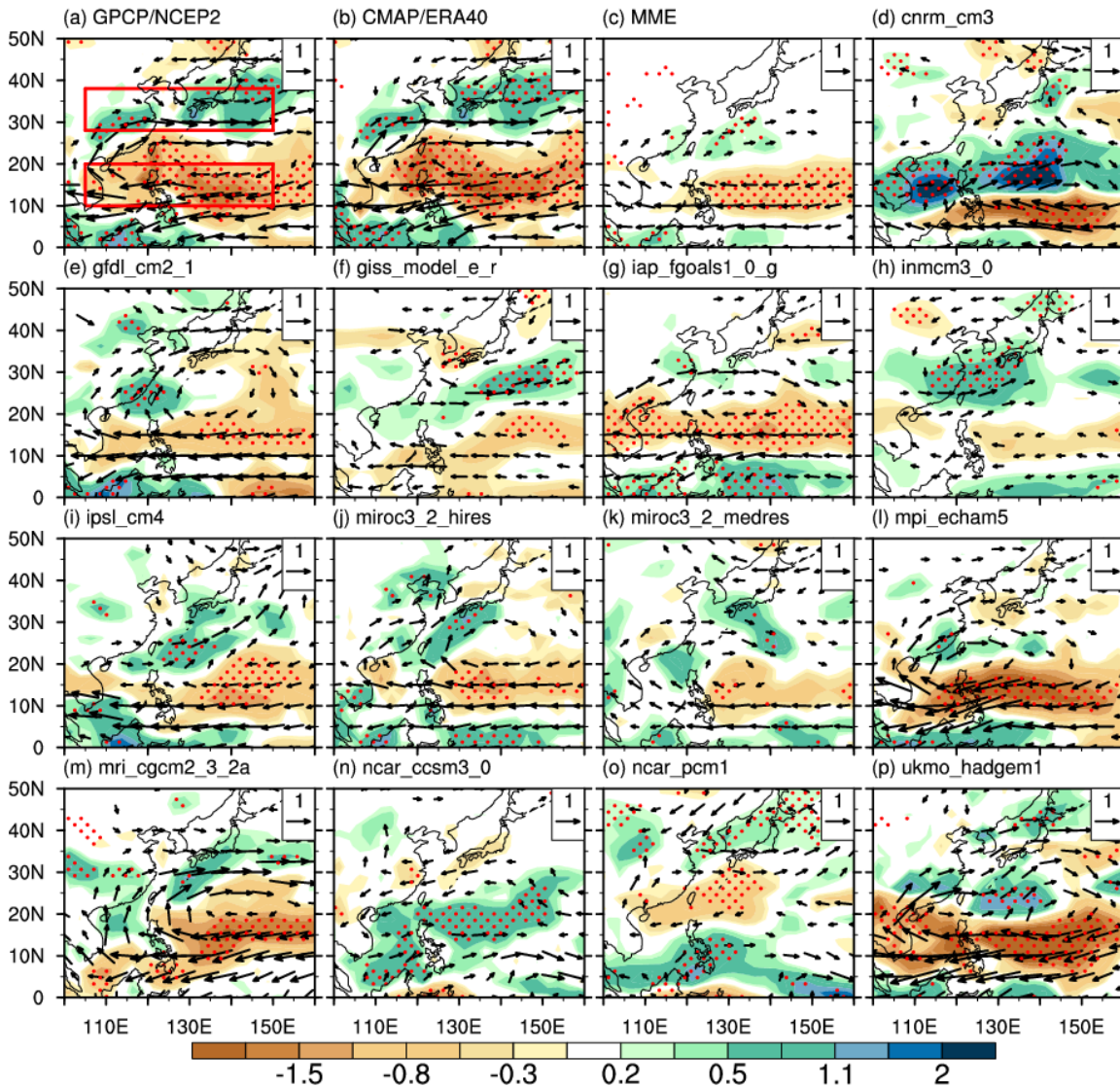
Normalized zonal wind shear between 850 and 200 hPa averaged within (20-40N,110-140E) (After Han and Wang, 2007)

(Li et al. 2010 Clm Dyn)



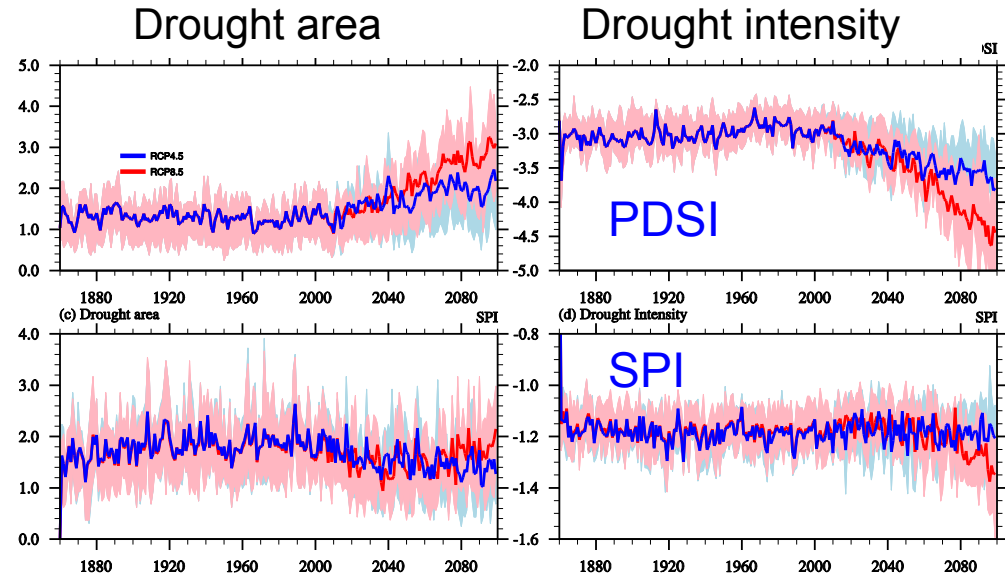
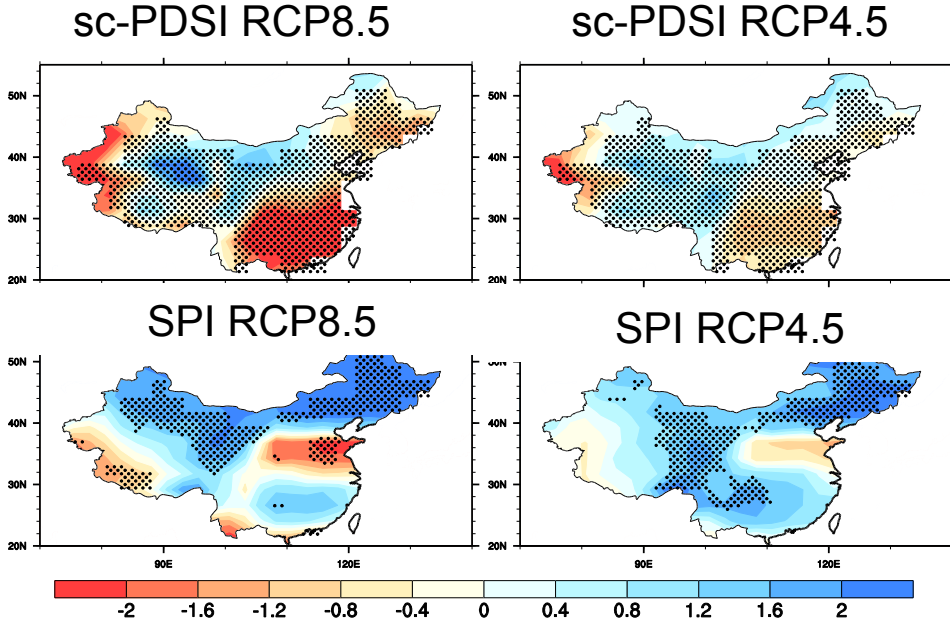
850 hPa wind and precipitation regressed on the observed EASM index

- Two main deficiencies of rainfall pattern simulation also exist: **weaker magnitude** and **more southward shift**;
- The magnitude in rainfall pattern is improved from CMIP3 to CMIP5.



850 hPa wind and precipitation regressed on the observed EASM index

- Two most evident features: western Pacific anti-cyclone (WPAC) and dipole rainfall pattern;
- The WPAC is better reproduced than the dipole rainfall pattern;
- Two main deficiencies: the weaker and southward shift of the dipole rainfall pattern.



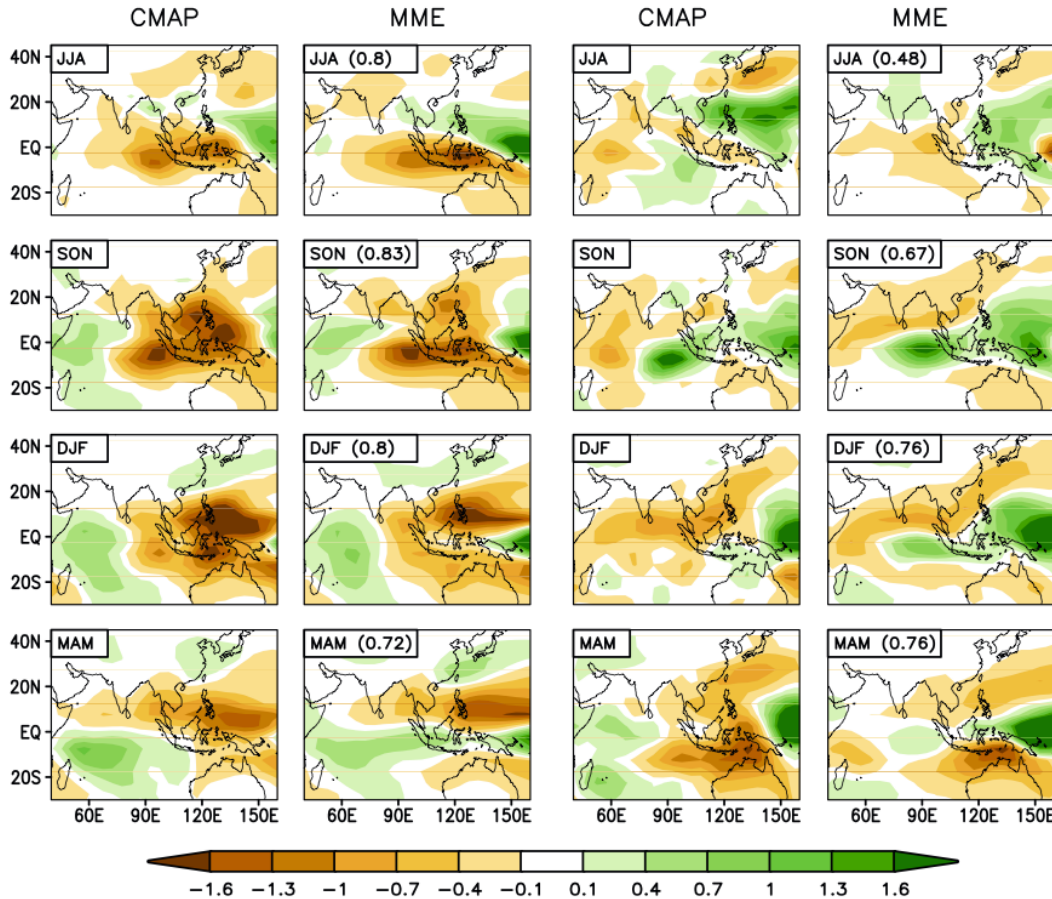
- ❑ Based on PDSI, most climate models project an increasing drought frequency and intensity over China.
- ❑ Nevertheless, uncertainties exist due to the selection of climate models and the choice of drought index.



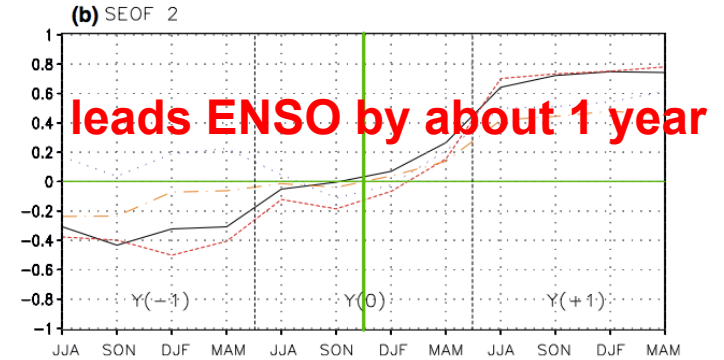
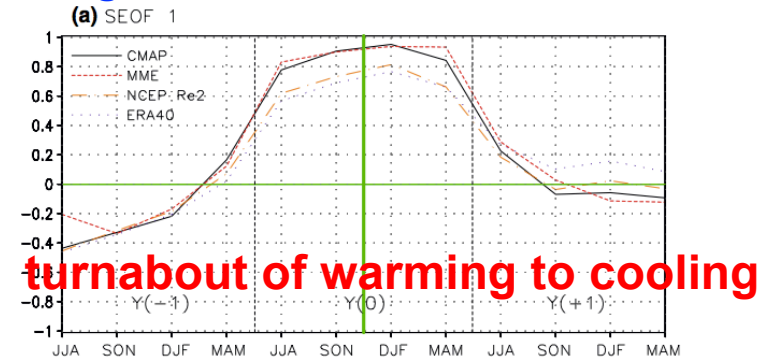
MME of CliPas and DEMETER for 1981-2001 lead 1 month

(a) The First SEOF Mode

(b) The Second SEOF Mode



Lead-lag correlation of PC and Nino3.4 index



Wang et al. 2008 Clim. Dyn.

- ✧ MME captures the spatial, seasonal, interannual variation of the first two leading modes of variability.
- ✧ The predictability arising from ENSO teleconnection and local monsoon-ocean interaction are captured by the models' MME.