



State Key Laboratory of Numerical Modelling for Atmospheric Sciences
and Geophysical Fluid Dynamics(LASG)
Institute of Atmospheric Physics Chinese Academy of Sciences

Monsoon Activities in China

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CLIVAR AAMP10, Busan, Korea 18-19 June 2010





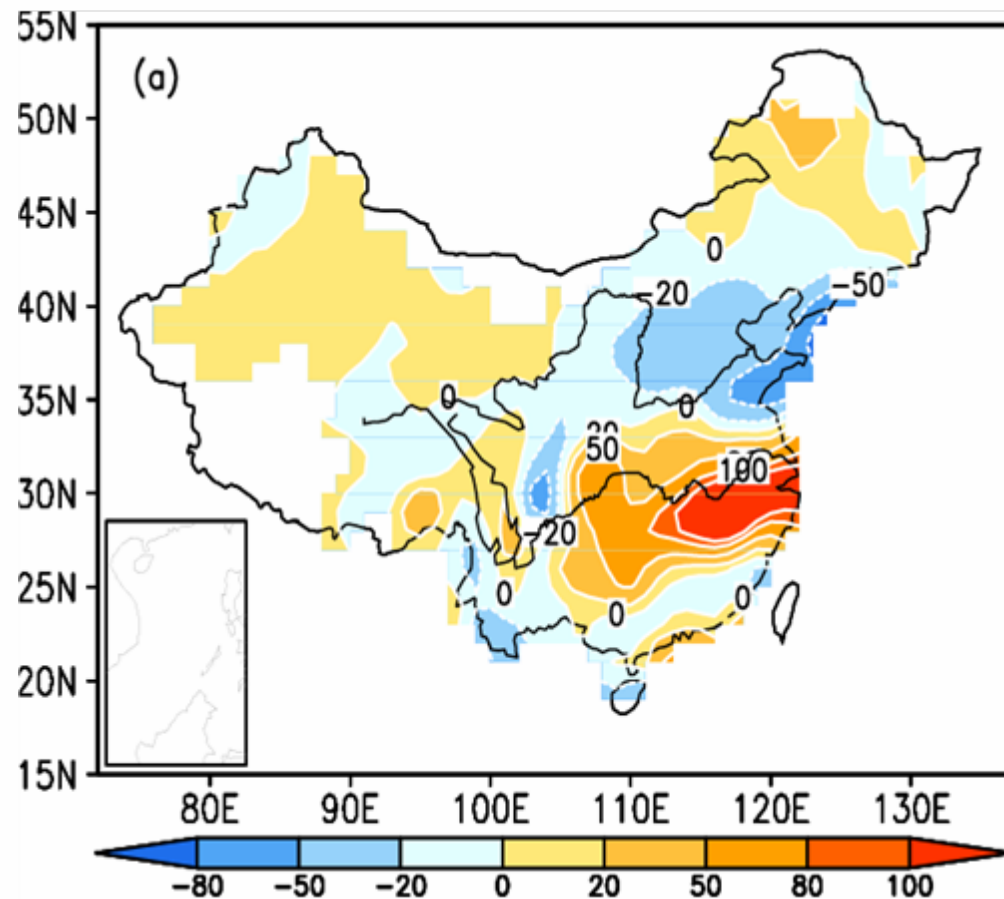
Outline

- **Variability of EASM**
 - Interdecadal variability
 - Interannual variability
 - Diurnal cycle & ISO
- **New Projects**
- **Suggested interactions with AAMP**





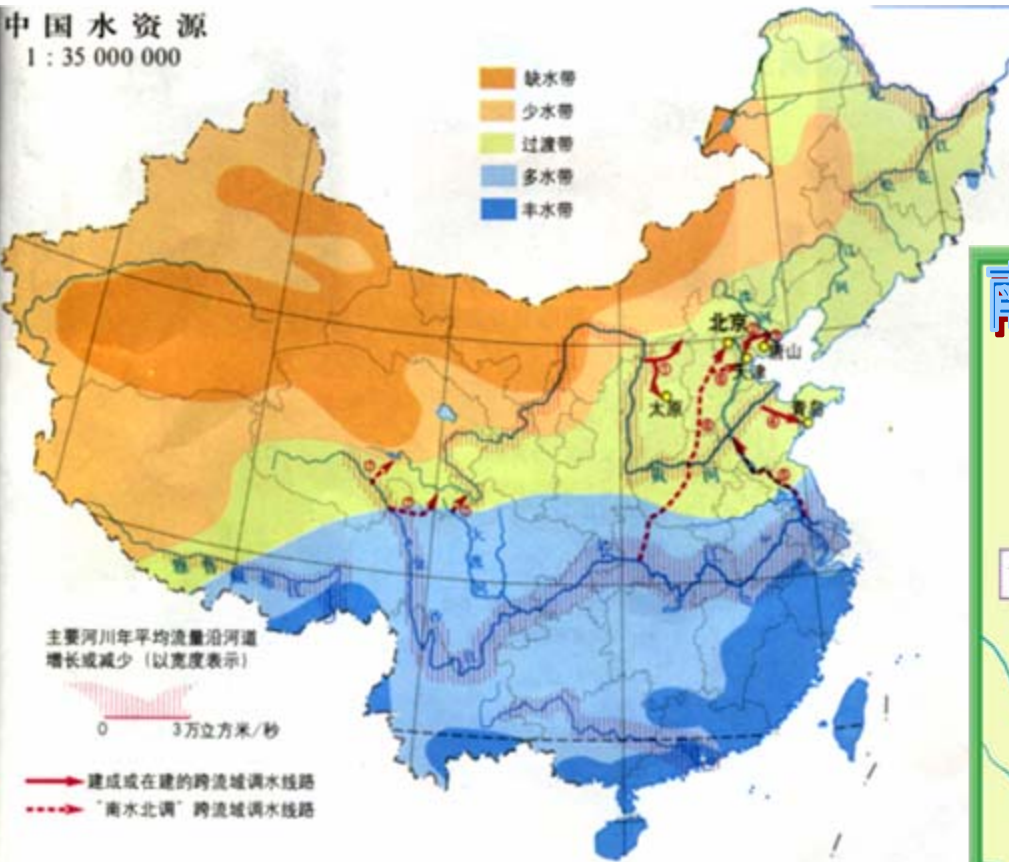
Focus



Changes of JJA Rainfall (1981-2000 minus 1958-1977)



中国水资源
1 : 35 000 000



南水北调路线示意



<http://www.nsb.gov.cn/zx/english/>



Proposed Mechanisms

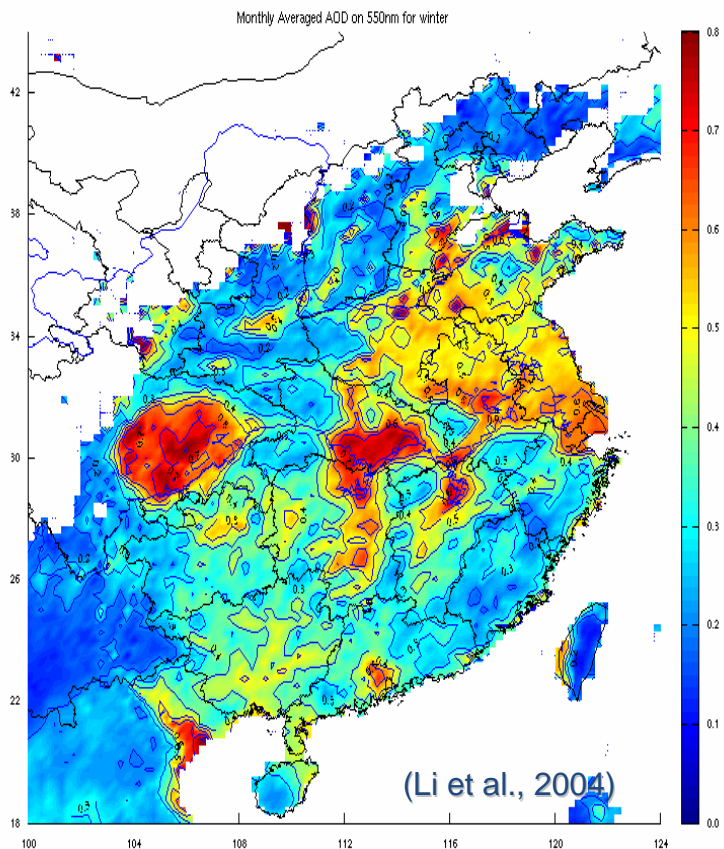


- ◆ Tropical Ocean warming (Hu, 1997; Gong and Ho, 2002; Zeng et al., 2007)
- ◆ Tibetan Plateau forcing (Wang et al., 2008; Duan and Wu, 2008)
- ◆ Aerosol forcing (Qian and Giorgi, 1999; Menon et al. 2002; Lau et al. 2006)
- ◆ Internal variability (Zhu and Wang 2002; Ding et al. 2007a,b)
- ◆

(Zhou et al. 2009, *Meteorologische Zeitschrift* for a Review)



Arguments on the mechanism



Climate Effects of Black Carbon Aerosols in China and India

Srabati Menon,^{1,2*} James Hansen,³ Larissa Nazarenko,^{1,2} Yunfeng Luo³

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 overgrazing, overlogging, 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 control 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 1950 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, bio-fuels, and outdoor biomass burning (8), are particularly large in China and India because of their high household biomass burning (9).

It is interesting to note that human-made aerosols contribute to a net change in China and India, because both being BC aerosols and reflective aerosols. In addition, reducing the amount of aerosols causes local cooling. Observed temperature trends in China and India in recent decades, like most of the world, reveal little warming (10), and in some seasons there is cooling, especially in the summer when aerosol effects would 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) 50200 12-layer climate model, which has been used to study the impact of aerosol forcings on global mean temperature (12). Figure 1 shows the (seasonally independent) added aerosol optical depth $\Delta\tau_{550}$ (0.55 μm) used in our climate model experiments (13). Over China, we take $\Delta\tau_{550}$ (0.35 μm) to be equal to τ_{550} (0.75 μm) measured in the 1990s (14, 15). Over India and the Indian Ocean, $\Delta\tau_{550}$ in our experiments is taken from chemical transport model simulations of satellite measurements (16). The resulting radiative forcings at the top of the atmosphere and surface (Fig. S1) are -0.7 W m^{-2} and -1.7 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

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REPORTS

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 150 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 flood 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 (21, 22), 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).

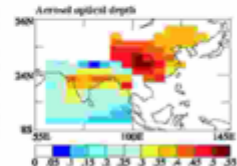
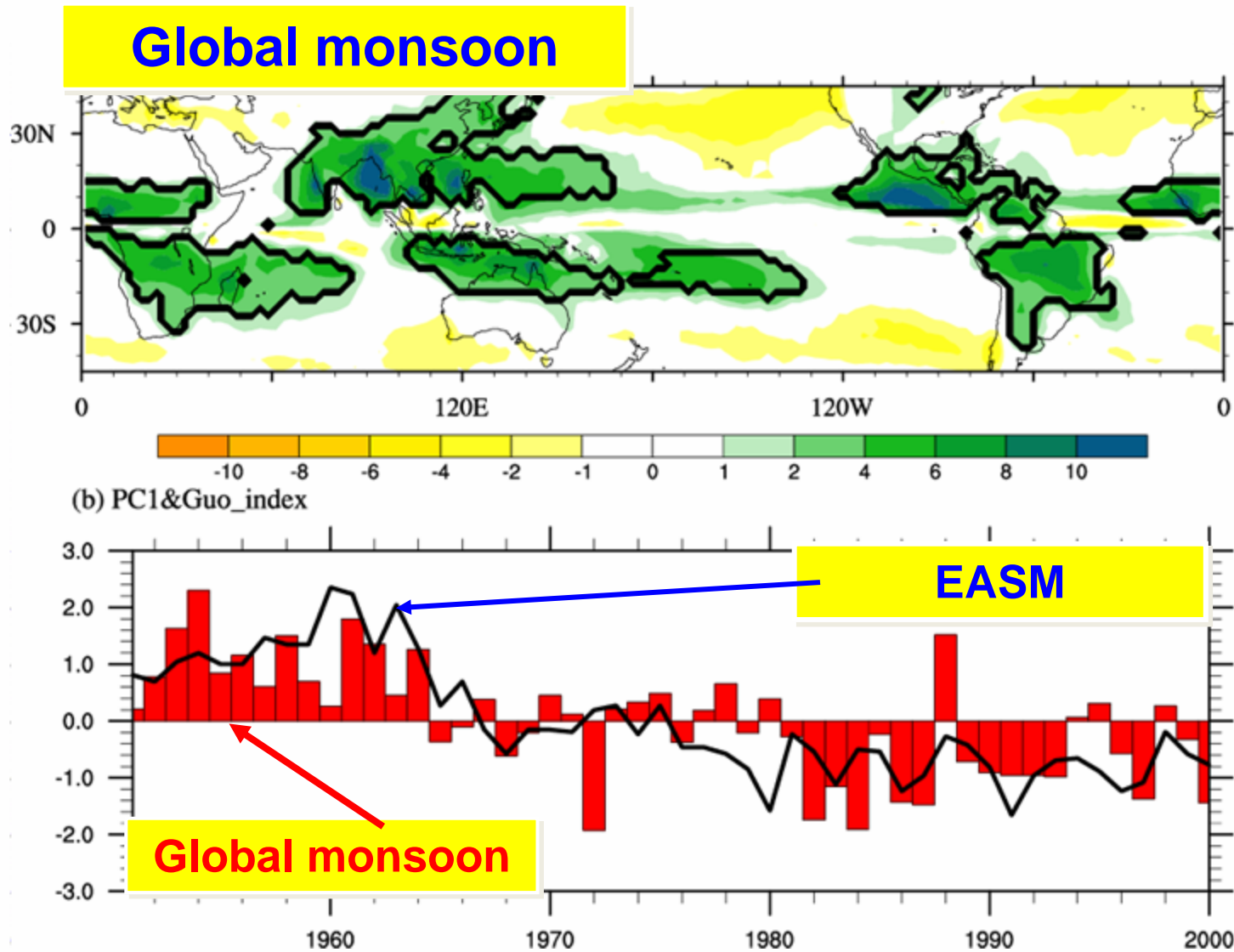


Fig. 1. Incremental aerosol optical depth $\Delta\tau_{550}$ (0.55 μm), which is used to drive the climate change simulations. Latitude and longitude are denoted.

Optical Thickness of 2001

SCIENCE 2002



(Wang and Ding 2006 GRL; Zhou et al. 2008 GRL; Zhou et al. 2008a J. Climate)



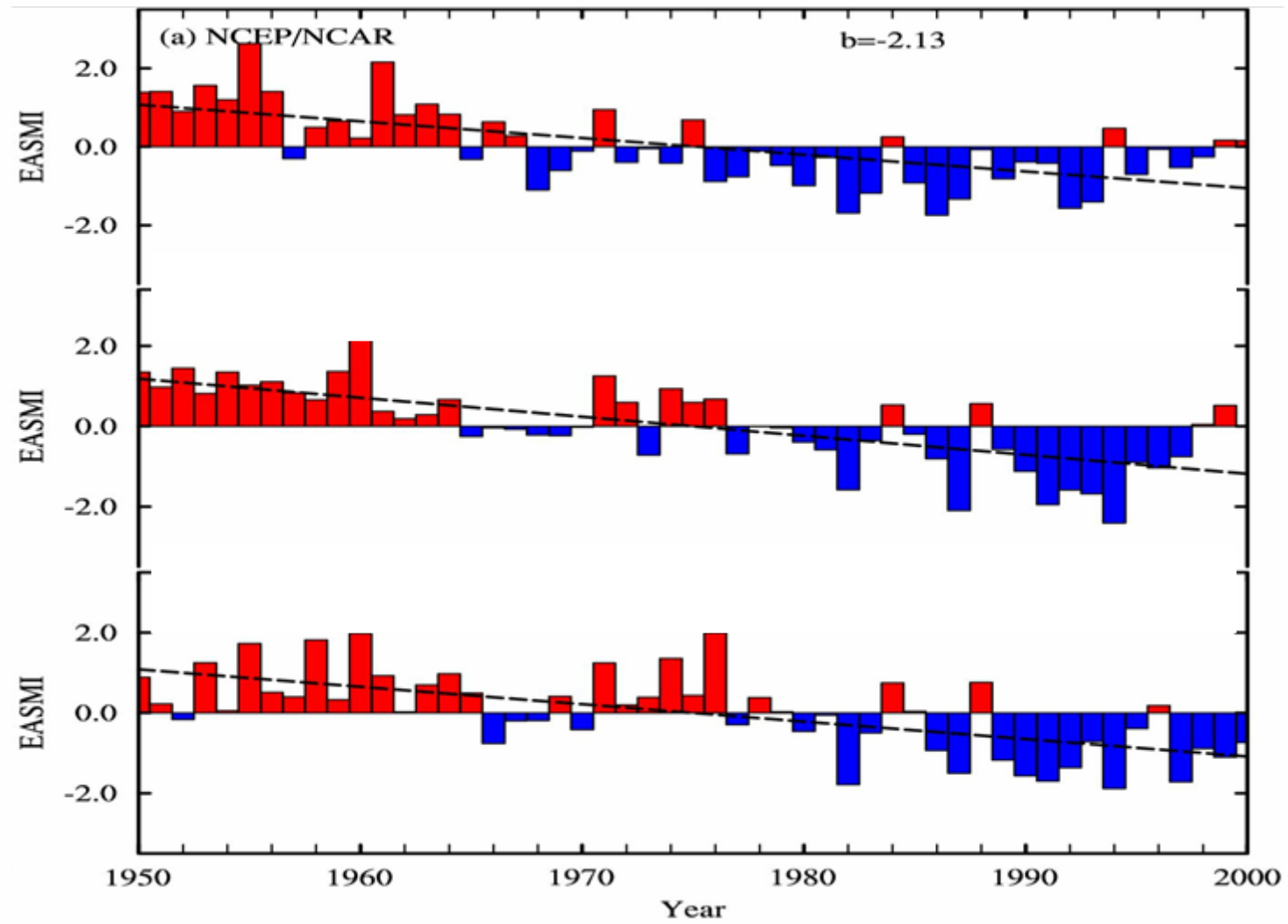
EASM index in the reanalysis and simulation



Reanalysis

GOGA

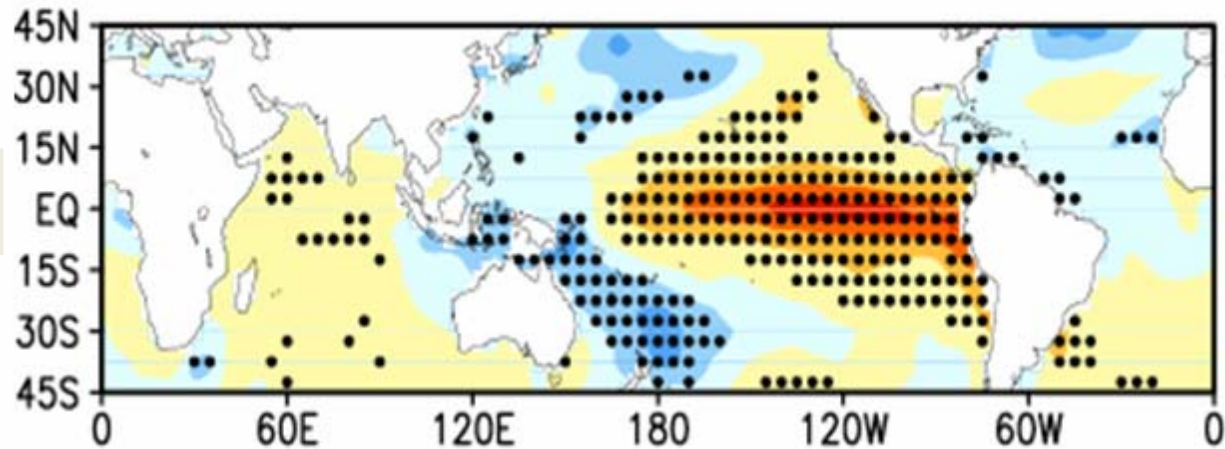
TOGA





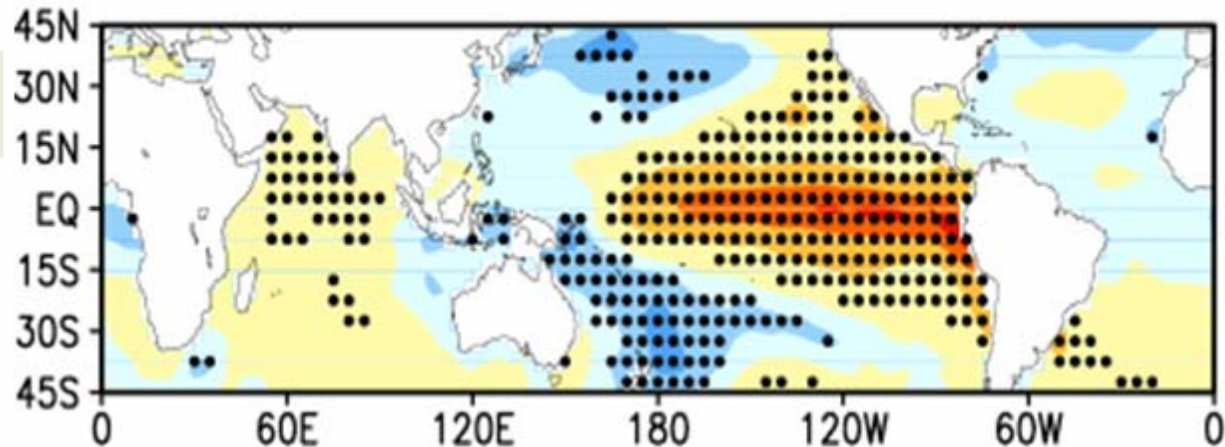
reanalysis

(b) trends in JJA SST(relative to obs. pc1)



Simulation

(c) trends in JJA SST(relative to sim. pc1)





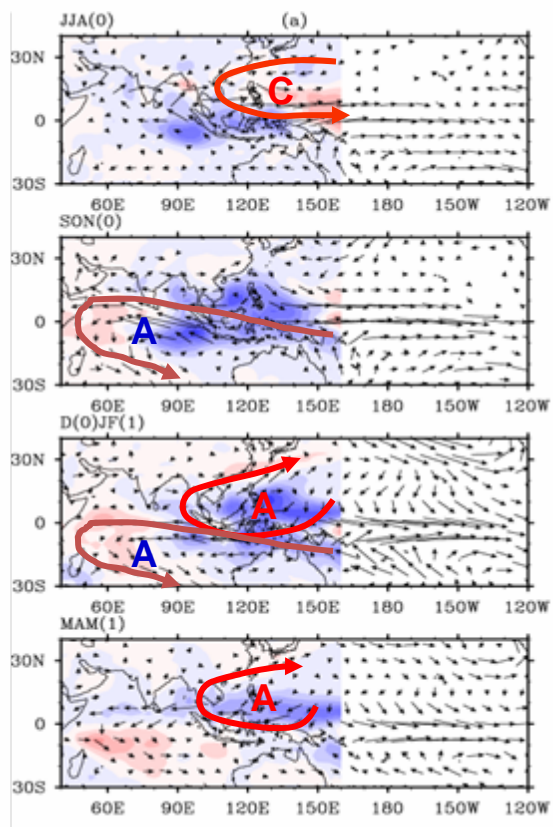
Focus

- **The Skill of AMIP models**
- **The Pacific and Indian Ocean forcing to EAM**
- **Teleconnection and statistical prediction**

Interannual variability modes of AAM

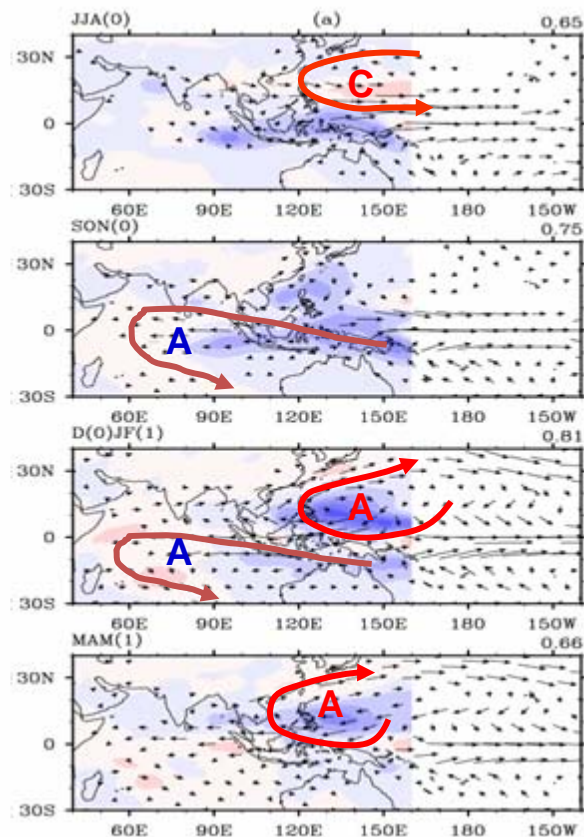
S-EOF analysis; from JJA(0) to MAM(1)

27.4%



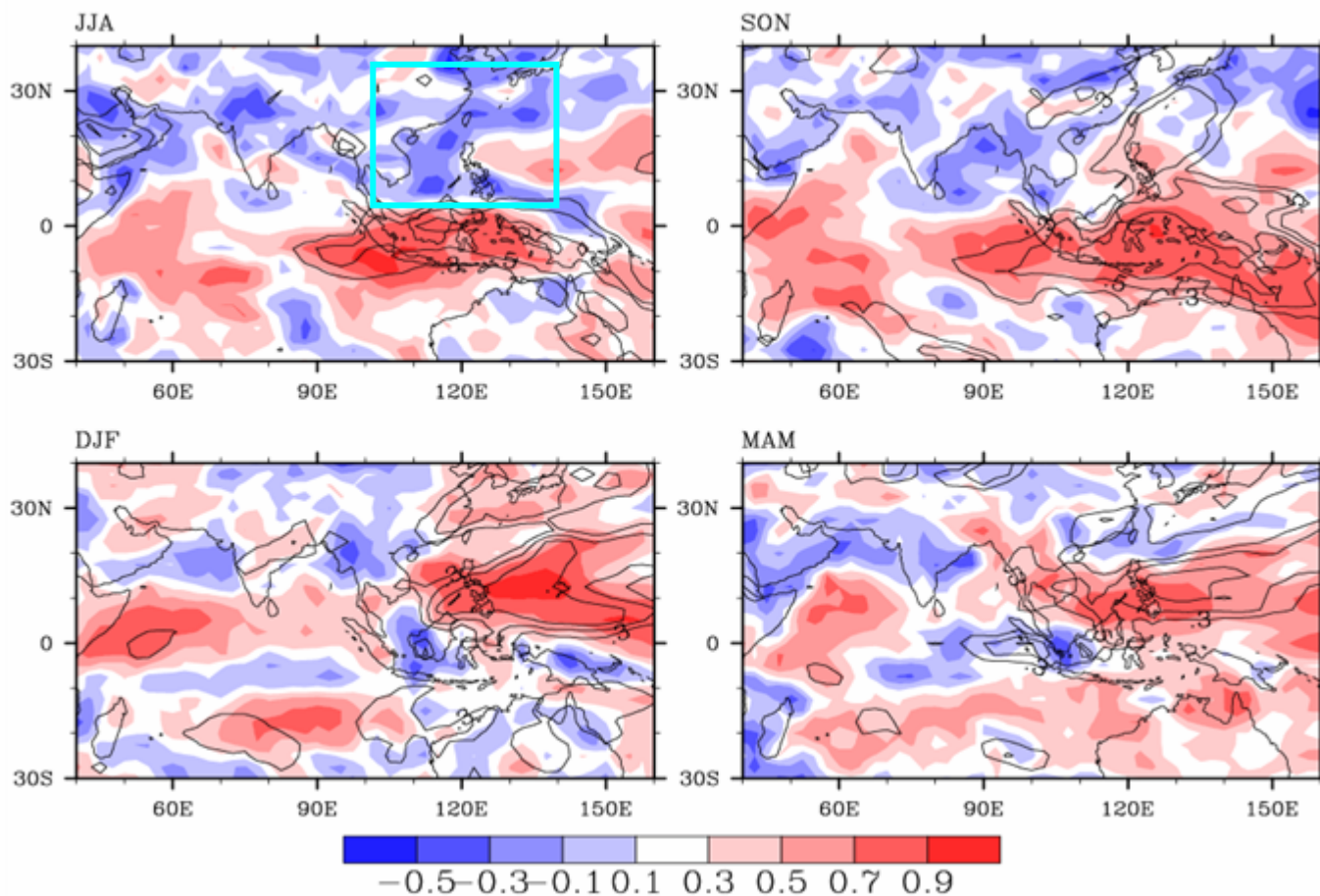
OBS

31.3%

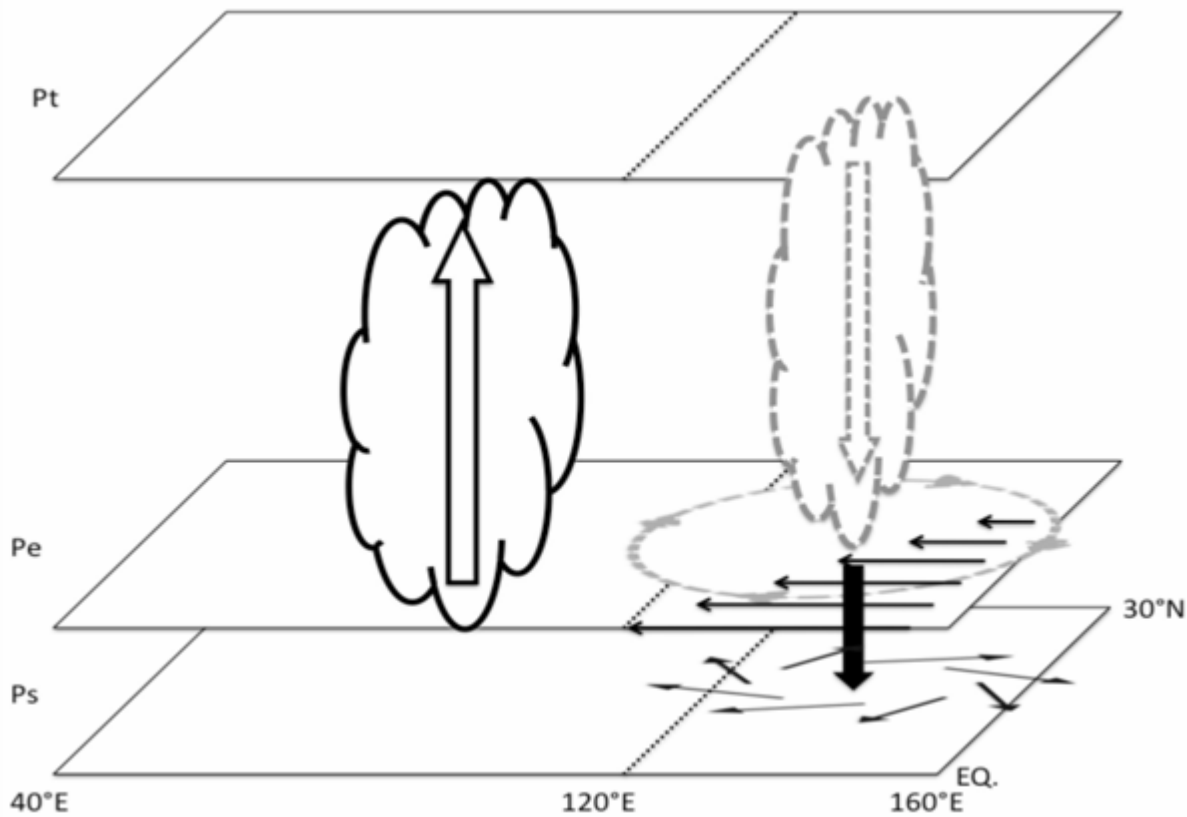


AMIP

Shading - Rainfall ; Vectors - 850 hPa wind



- High skill in tropical region
- Nearly no skill in summertime WNP monsoon area.
- Better in winter

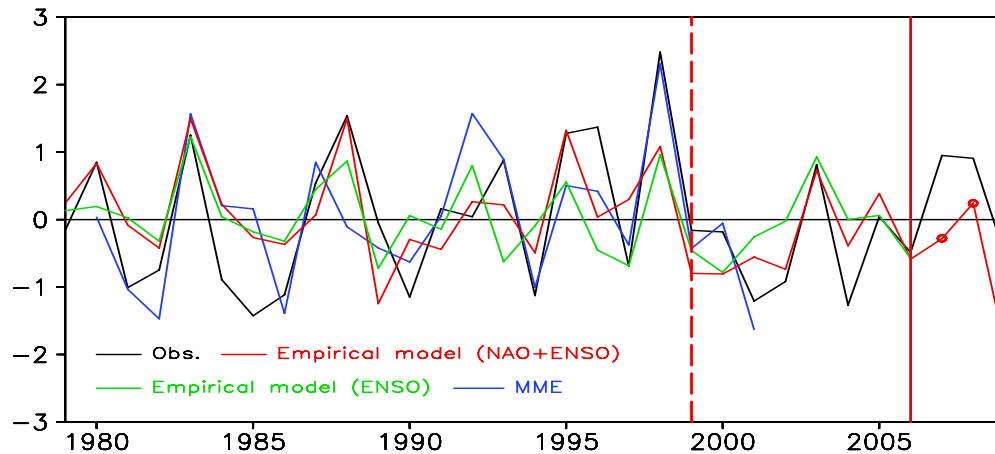
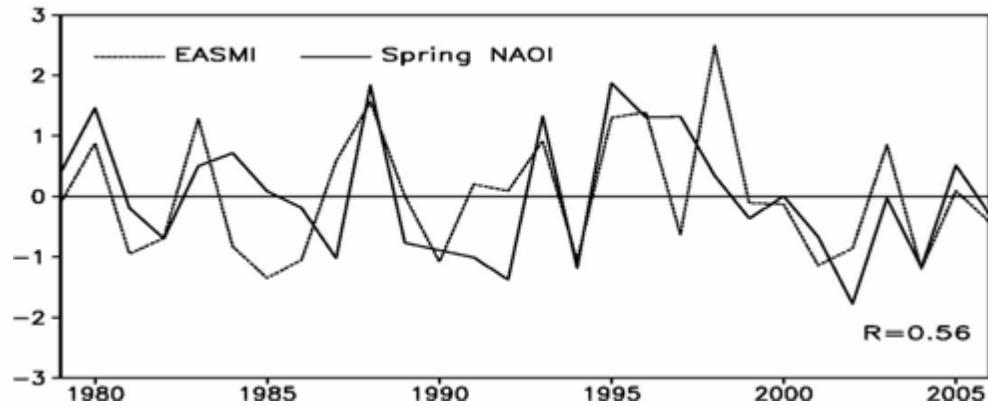


Wu et al. 2009 J. Climate

- ◆ During El Nino decaying summer, the WNPAC in June relies on the negative SSTA in the WNP.
- ◆ Following the growth of WNP monsoon trough in July and August, the IOBM impact gradually intensifies and drives the WNPAC in the Philippine Sea through atmospheric Kelvin wave forcing.



NAO and EASM: Empirical Prediction Model



EASM index in Observation, MME of 14 CGCM and statistical model

(Wu et al. 2009 JGR)



Focus

- Diagnostic analysis based on rain-gauge observations
- Analysis based on satellite data
- Discussion of the mechanism
- Regional modeling

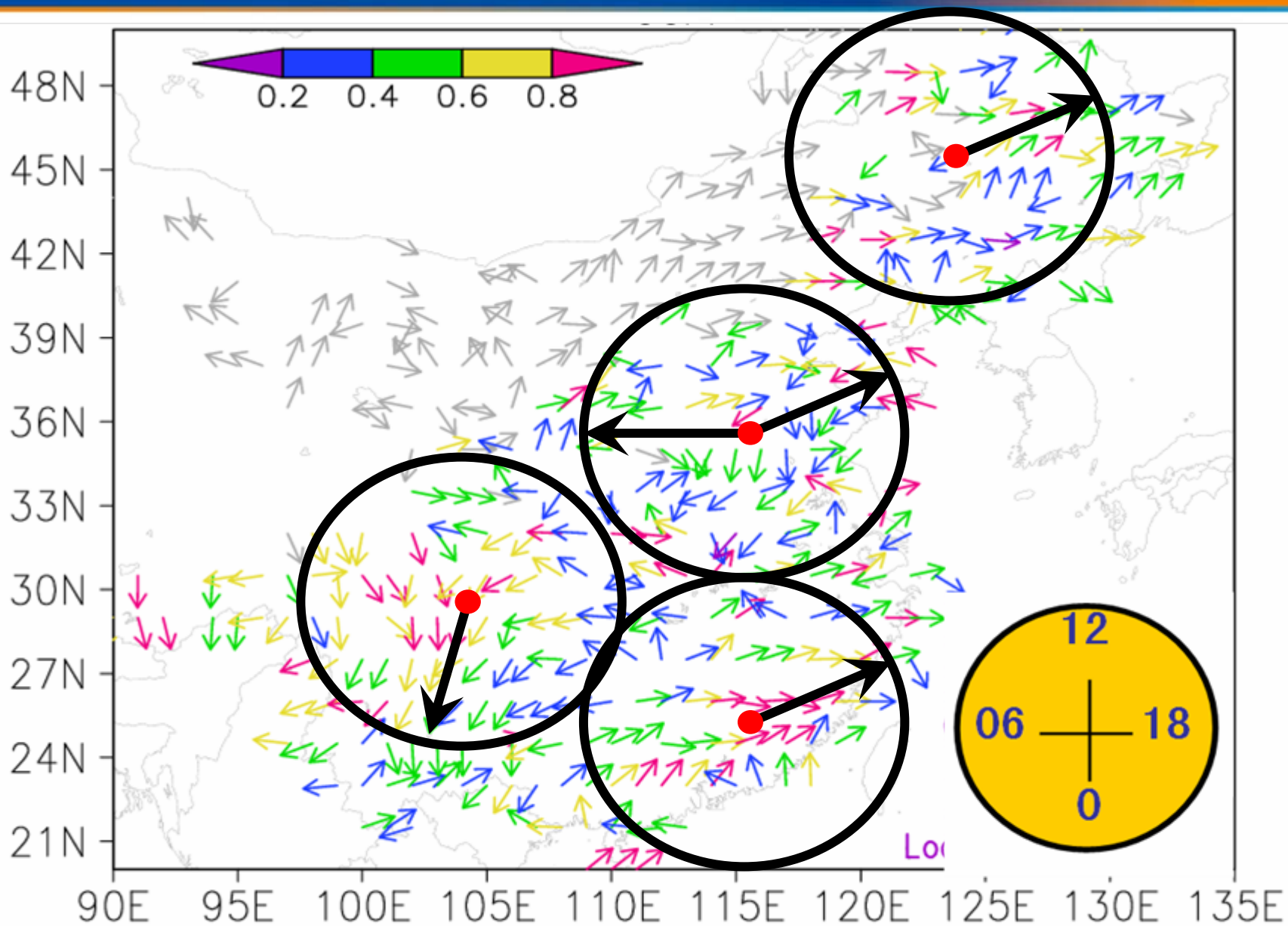
《夜雨寄北》



君问归期未有期，
巴山夜雨涨秋池。
何当共剪西窗烛，
却话巴山夜雨时。

—李商隐(813—858)

Diurnal Cycle of JJA precipitation





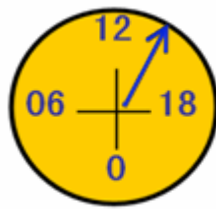
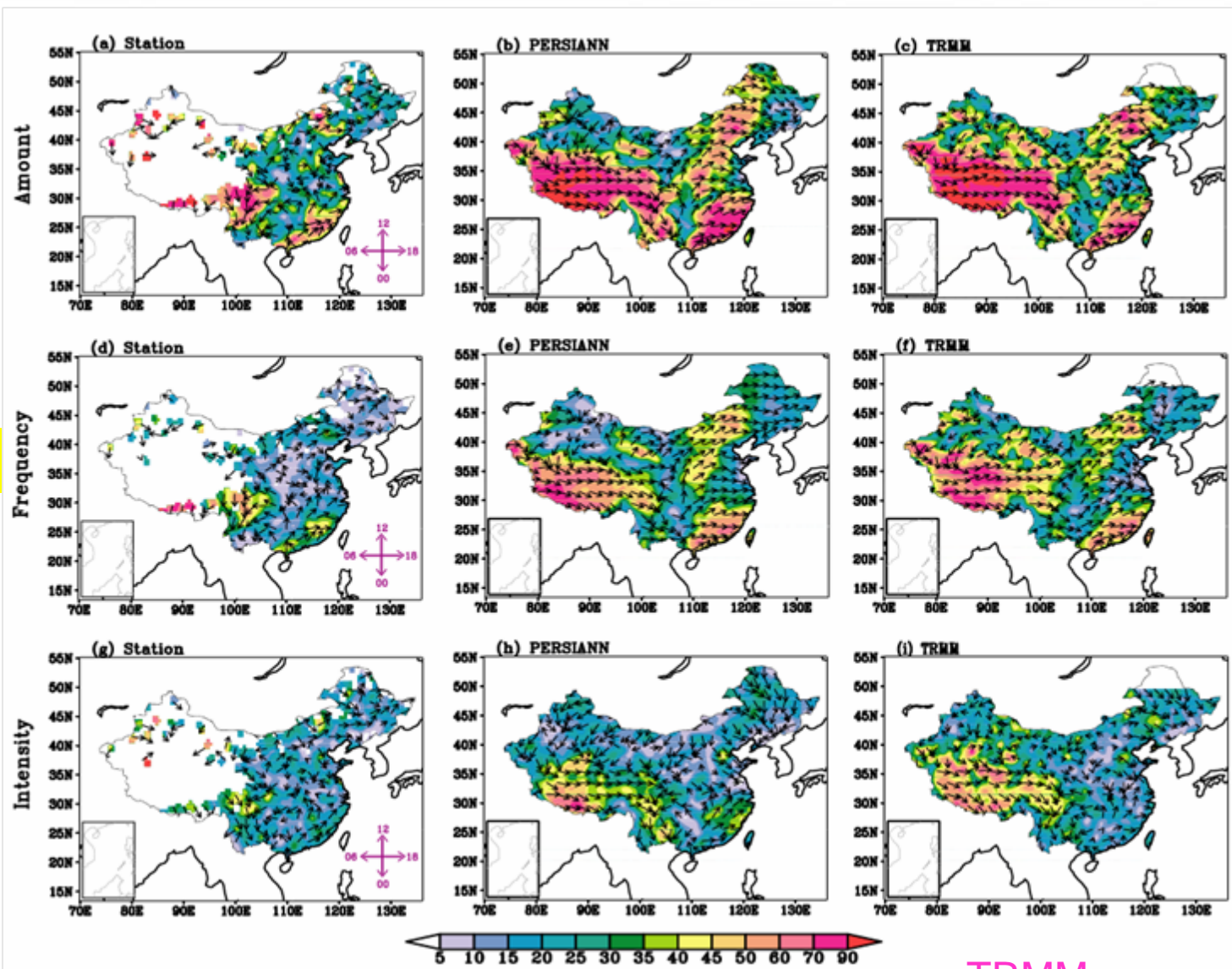
Spatial distributions of the amplitude (colors) and phase (arrows, LST) of the diurnal (24h, S1) harmonics of 2000-2004 mean JJA precipitation



Amount

Frequency

Intensity

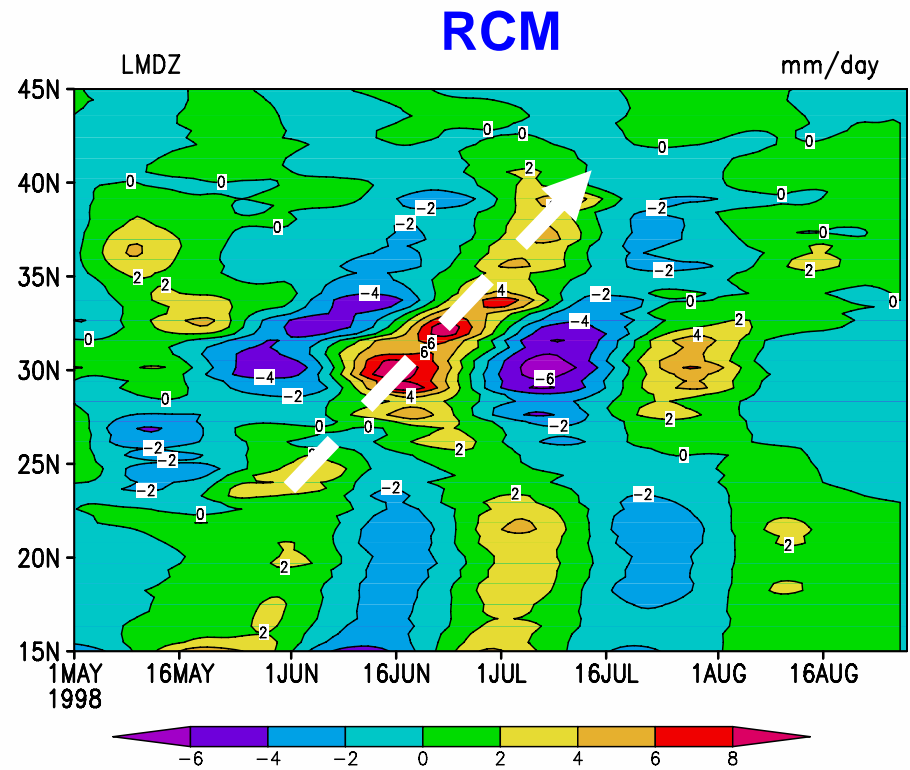
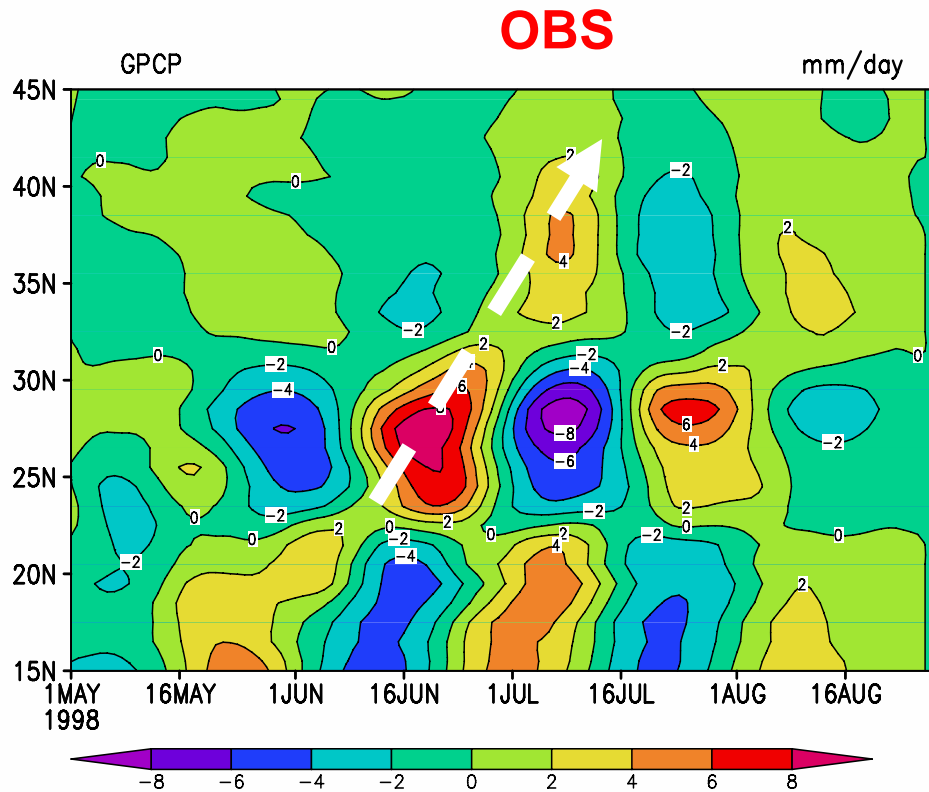


Rain-gauge

PERSIANN

TRMM

(Zhou et al. 2008b J. Climate)



30-60 days band-pass filtered rainfall along 105~122.5°E of 1998

(Sun D. 2010)



Two Review Papers



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

Zhou T., H. Hsu, J. Matsumoto, 2010: Summer Monsoons in East Asia, Indochina and the Western North Pacific, *Report of WMO 4th International Workshop on Monsoons (IWM-IV)*, *WMO Report Series*, in Press



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- **Variability of EASM**
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- **New Projects**
- **Suggested interactions with AAMP**





- ◆ **Ministry of Science & Technology (MOST)**
- ◆ **Chinese Academy of Sciences (CAS)**
- ◆ **National Natural Science Foundation of China (NSFC)**
- ◆ **China Meteorological Administration (CMA)**



1. Development of High Resolution Climate System Model

PI: R. YU

Period: 2010-2015; Budget: ~ 4.5 million USD

2. Development of Biogeochemistry model

PI: M. ZHANG

Period: 2010-2015; Budget: ~ 4.5 million USD

3. Attribution and Projection of Climate Change based on the Multi-Model Ensemble Simulations from CMIP5

PI: W. Dong

Period: 2010-2015; Budget: ~ 4.5 million USD

4. Air-Land-Sea Interactions in Asia and their role in Global Change

PI: J. Li

Period: 2010-2015; Budget: ~ 4.5 million USD

5. Reconstruction of the past 2000-yrs climate of China

PI: Q. Ge

Period: 2010-2015; Budget: ~ 4.5 million USD



1. Ocean-Atmosphere-Land Interaction and EASM Variability

PI: H. Wang & Y. Hou

Period: 2010-2011; Budget: ~ 2.5 million USD

2. Data Uncertainty and 20th century climate change over China

PI: Yang & Lu

Period: 2010-2015; Budget: ~ 5 million USD

3. Improvement of uncertainties in CAS climate system model

PI: Lin & Zhou

Period: 2010-2015; Budget: ~ 5 million USD

4. Aerosol emission in China and its climate impacts

PI: Cao & Liao

Period: 2010-2015; Budget: ~ 5 million USD

5. Reconstruction of climate records of China for the past 2000-yr

PI: Ge

Period: 2010-2015; Budget: ~ 5 million USD



Climate of China during the past millennium

PI: X. Zhou (CMA)

Period: 2009-2012; Budget: ~ 2.5 million USD

- **Sub-project-1: Reconstruction based on tree ring (PI: Y. Liu)**
- **Sub-project-2: Numerical simulation (PI: T. Zhou)**
- **Sub-project-3: Diagnosis and inter-comparison of proxy data (PI: P. Zhao)**

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- ◆ Detection and attribution of interdecadal EA monsoon variability
- ◆ Predictability of interdecadal monsoon variability (CMIP5 decadal prediction Exps)
- ◆ Future change of AAM in RCP Exps. (AR5)
- ◆ Monsoon variability in last millennial simulation

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' inside. The background is a blue globe with a map of Asia, and the bottom of the image has an orange gradient.

LASO

THANKS

www.lasg.ac.cn/staff/ztj/index_e.htm



Prominent Features



- ◆ S. China Flood N. China drought (Hu, 1997; Wang, 2001)
- ◆ Westward extension of WPSH (Hu, 1997; Gong and Ho, 2002)
- ◆ Zonal expansion of South Asian High (Zhang et al., 2000)
- ◆ Tropospheric cooling over E. Asia (Yu et al. 2004; Yu and Zhou, 2007)
- ◆ East Asian westerly jet (Yu et al. 2004; Schiemann et al., 2009)
- ◆ Spring rainfall change (Xin et al. 2006; Cai et al. 2009)
- ◆ Land-Sea thermal contrast change (Ding et al. 2007)
- ◆

(Zhou et al. 2009, *Meteorologische Zeitschrift* for a Review)



Warm, Cold, and Normal SST

