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Diurnal Cycle of Precipitation over Eastern China

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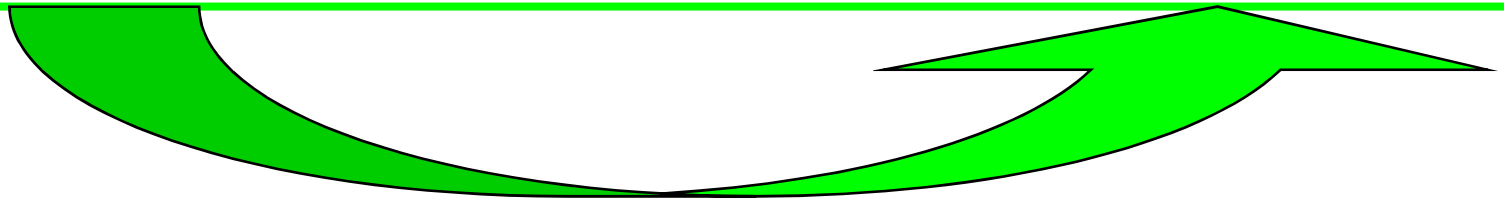
Outline

- Background
- Diurnal variations of summer precipitation
- Reliability of satellite data
- Rainfall duration and diurnal phase
- Southwest China *vs* Southeast China
- Summary
- References

Why Diurnal Cycle ?

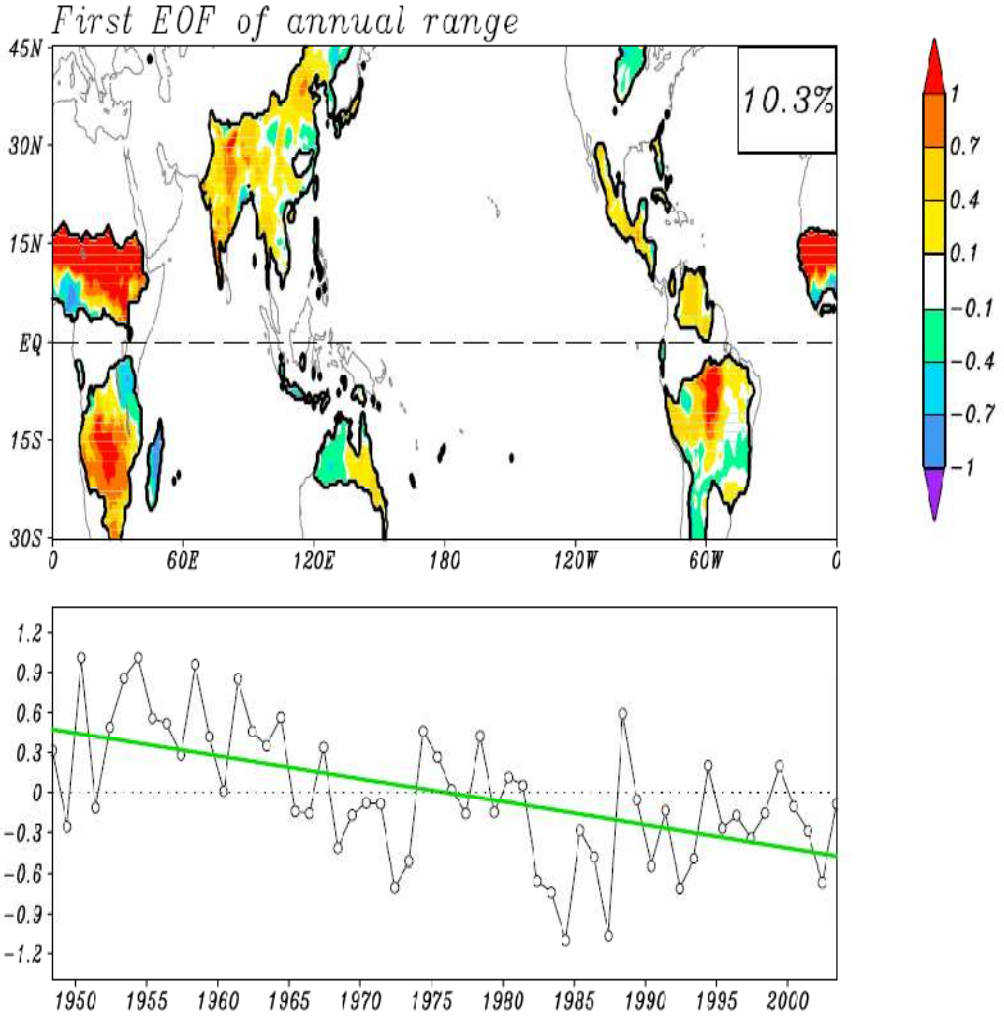
- Help us to understand not only the mechanism of rain formation but also the mechanism of the local climate.
- Provides an excellent test bed for validating parameterization schemes in numerical models.



More important for the modeling of Asian monsoon !

-- Two evidences

Evidence-1: An overall weakening tendency of global land monsoon precipitation in the last 56 years

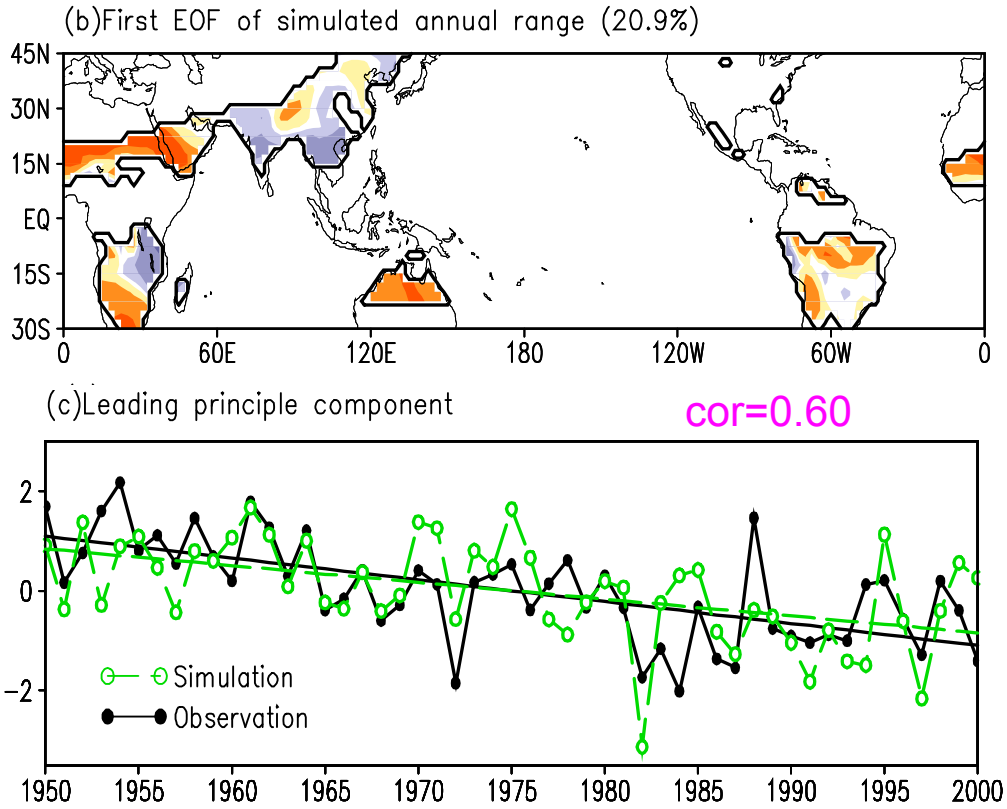


The EOF1 of normalized annual range anomalies (upper) and the corresponding PC (lower).

(Wang and Ding, 2006,GRL)

Global land monsoon precipitation change simulated by CAM2

(Global SST-driven, 15 realizations)



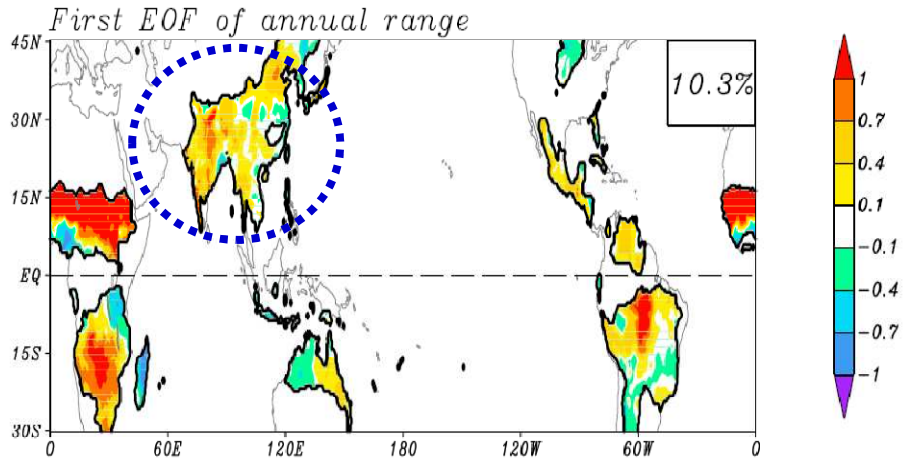
Rainfall Anomaly Pattern

Monsoon Rainfall index

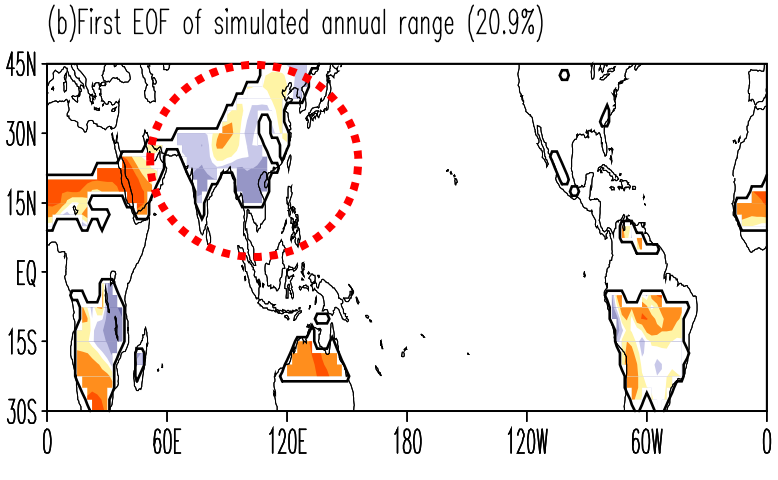
The first EOF of normalized annual range anomalies (upper) and the corresponding principle component or ARI (lower).

Zhou et al. 2008a J. Climate

Low skill of Asian monsoon rainfall in long-term change



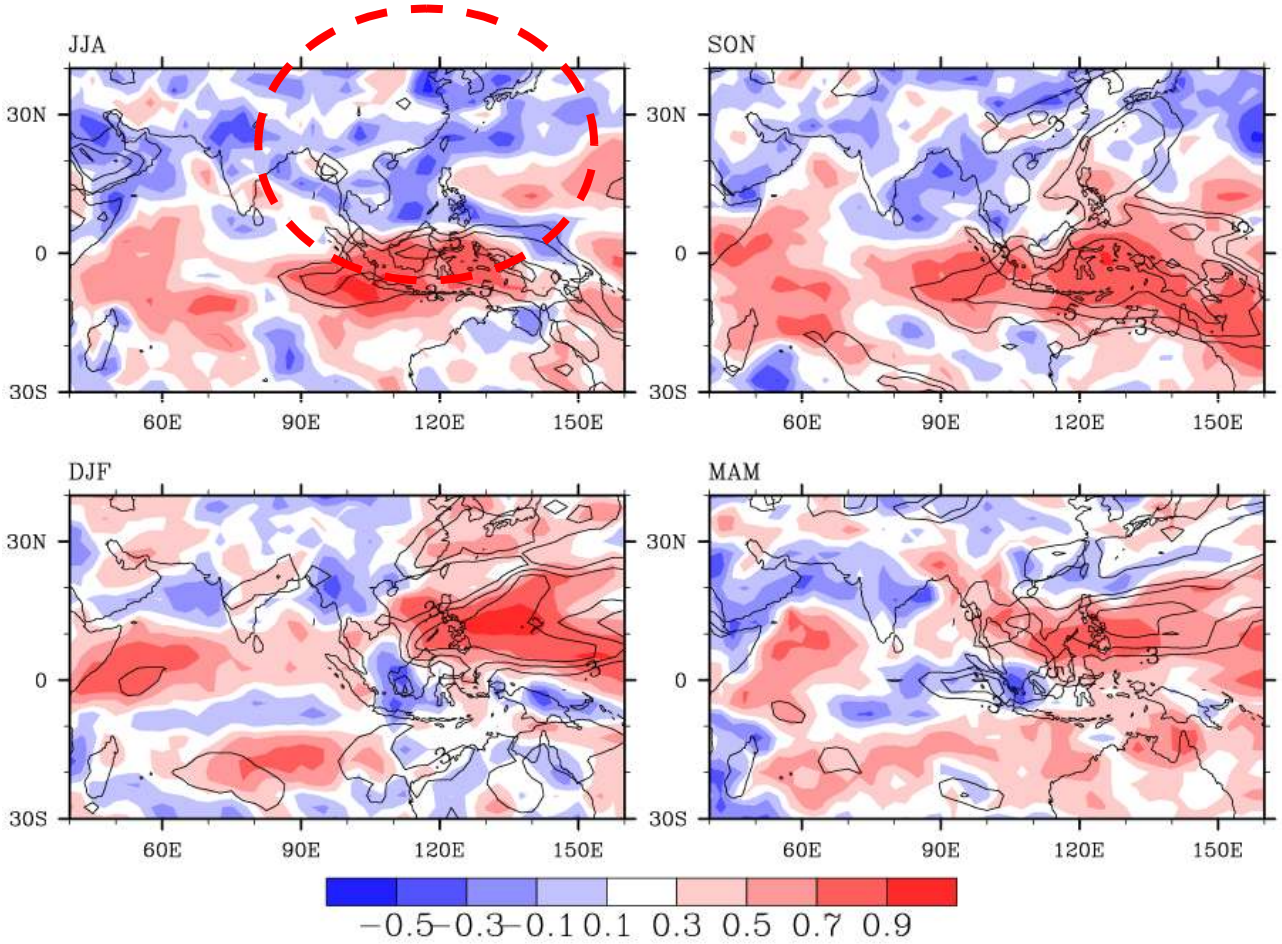
Observation



Simulation

Evidence-2: Low skill in Inter-annual variability

Correlation of Simulated (AMIP MME) and observed rainfall anomalies



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

Zhou et al. 2009a, J. Climate

Why Diurnal Cycle ?

Understanding the process of diurnal cycle may help us to improve the model physical package.

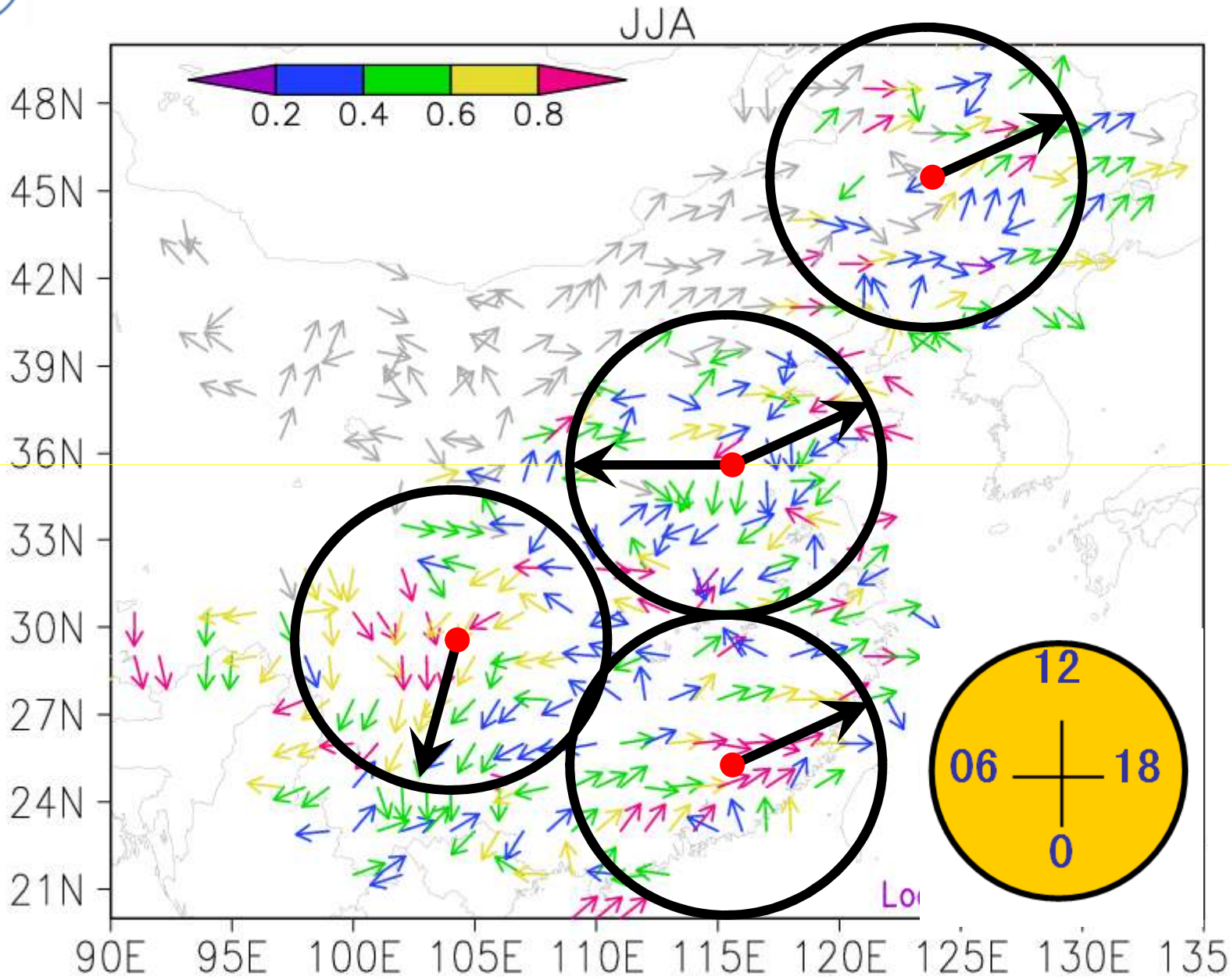
This is particularly important for Asian monsoon modeling.

How about the diurnal cycle of rainfall over East China, a typical monsoon area?

1 Diurnal variations of summer precipitation

- Hourly rain gauge records during 1991–2004 from 588 stations covering eastern China.
- Automatically recorded by siphon or tipping-bucket rain gauges.
- Quality-controlled by the **National Meteorological Information Center** (NMIC) of China Meteorological Administration (CMA).
- Used to quantify diurnal variations of summer (June-August or JJA) precipitation.

Diurnal Cycle of JJA precipitation



(Redrawn based on Yu et al, 2007a, GRL)

Diurnal cycle documented 1000-yrs ago in Chinese poem

《夜雨寄北》

君问归期未有期，

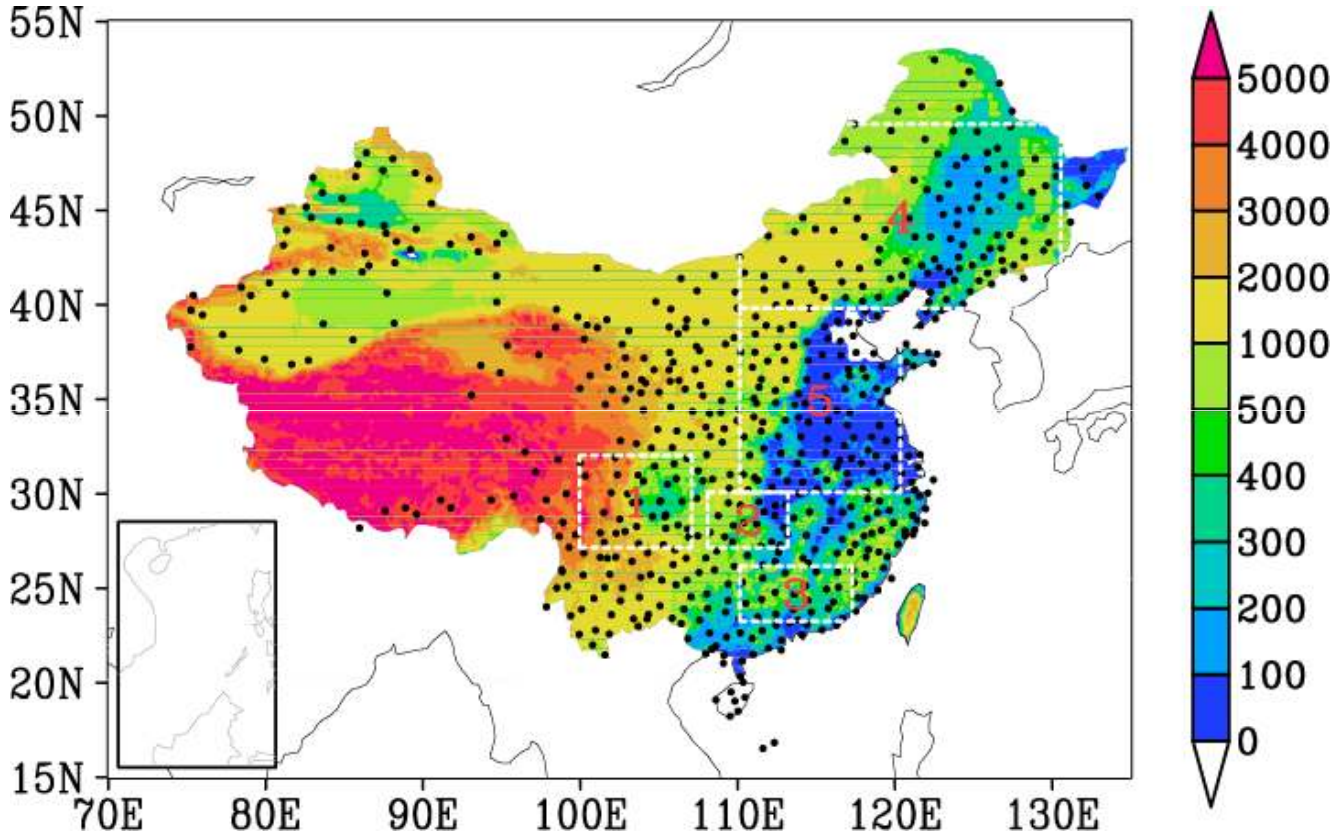
巴山夜雨涨秋池。

何当共剪西窗烛，

却话巴山夜雨时。

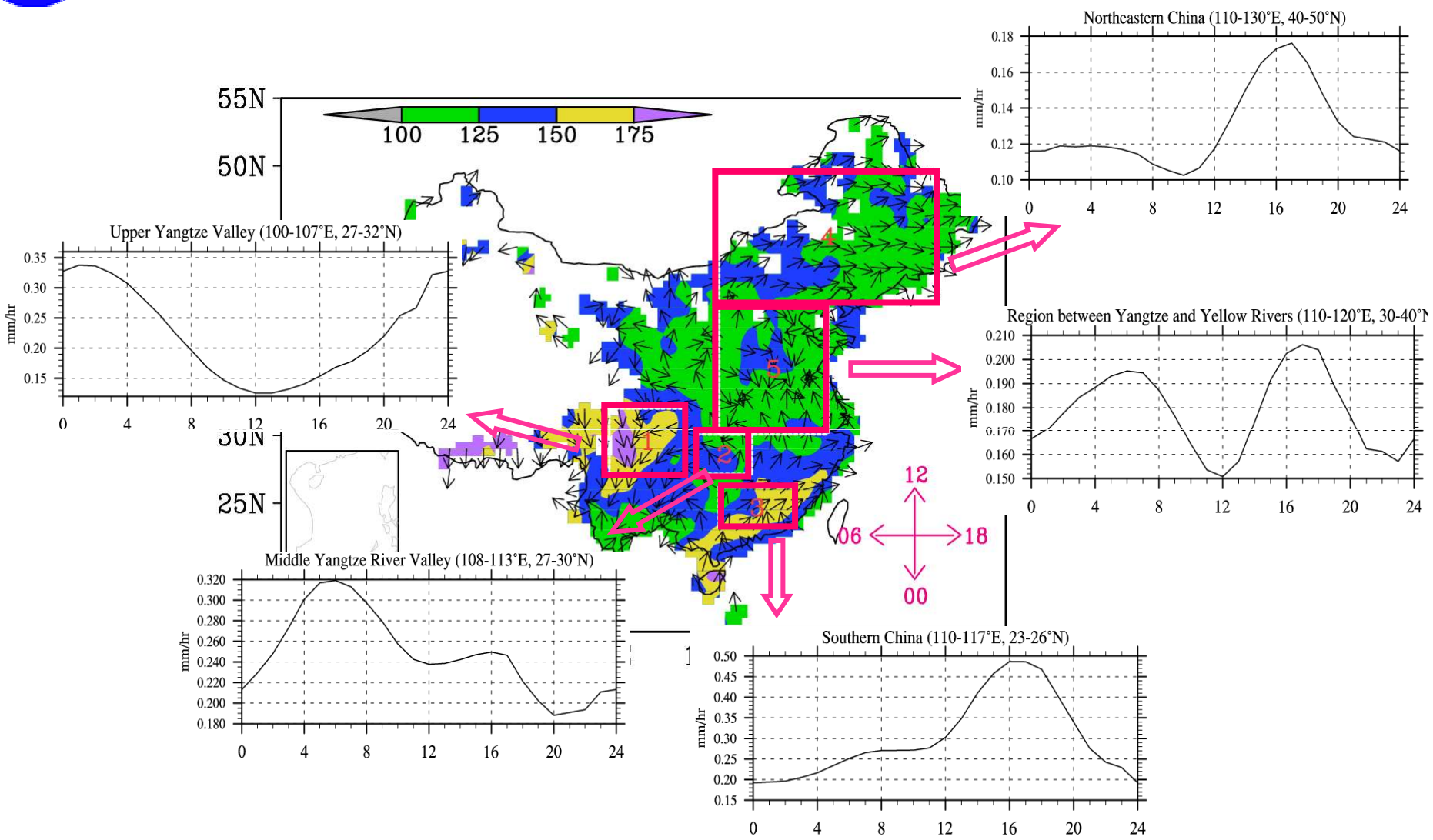
——李商隐(813—858)

Five typical target domains



(Zhou et al, 2008b, J. Climate)

Diurnal Cycle of JJA precipitation

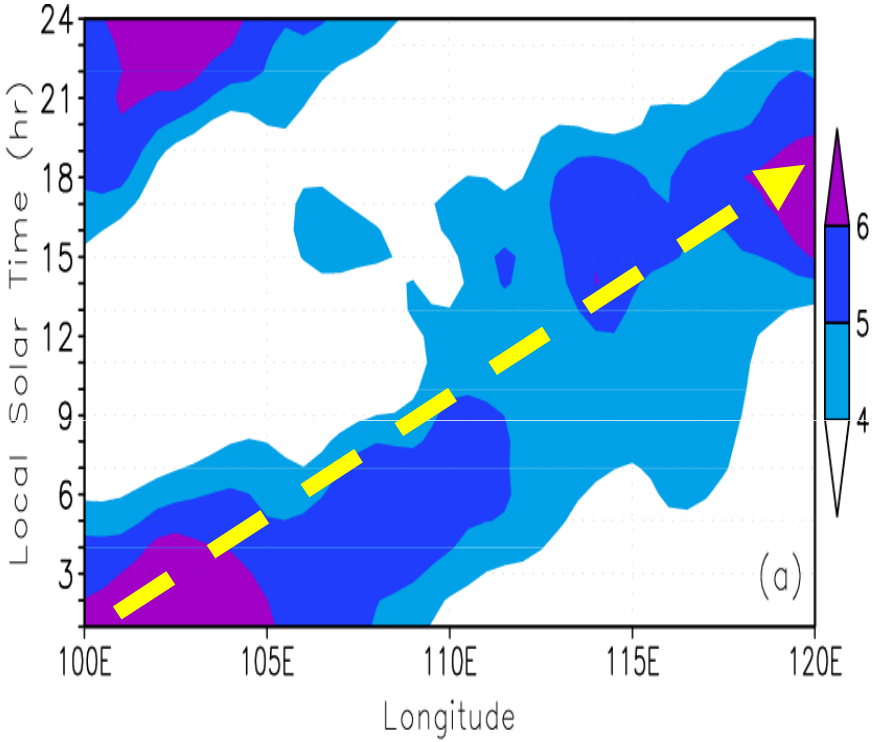


JJA (1991-2004) mean diurnal cycle amplitude (normalized by daily mean, shaded) and phase (LST, vector)

(Yu et al, 2007a GRL)

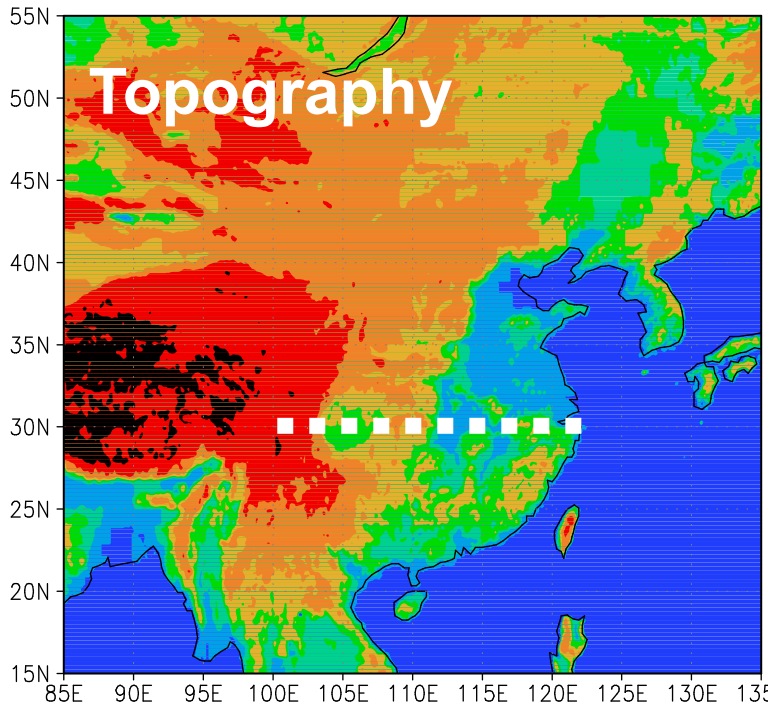
Hovmöller diagrams of diurnal variations in hourly precipitation

(percentage relative to the daily total rainfall amount, time-longitude cross section for the 27°-29°N zone)



Eastward "propagation" feature

(Yu et al, 2007a, GRL)



2 Reliability of satellite data

- TRMM 3B42 (3-hourly, 0.25°) precipitation data from 2000-2004. Derived by using an optimal combination of microwave rain estimates from TRMM, SSM/I (Special Sensor Microwave Imager), AMSR (Advanced Microwave Scanning Radiometer) and AMSU (Advanced Microwave Sounding Unit) to adjust IR estimates from geostationary IR observations (Huffman et al. 2007).

- PERSIANN (Precipitation Estimation from Remotely Sensed Information using Artificial Neural Networks) hourly precipitation data from 2000-2004 on a 0.25° grid (Hsu et al. 1999; Sorooshian et al. 2000).

- Both the PERSIANN and TRMM data were re-mapped onto the same 0.5 degree grid as the rain-gauge data .

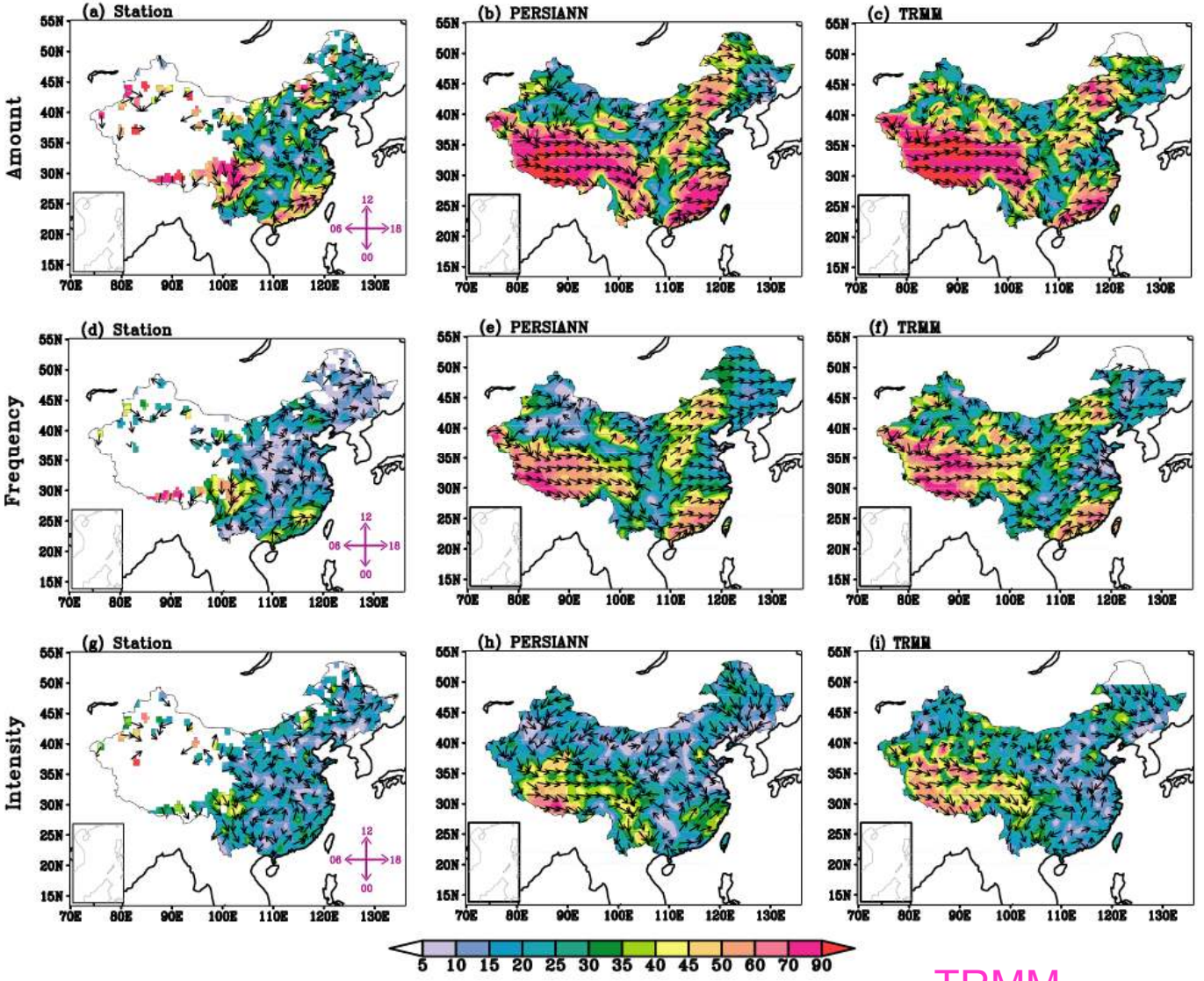
(Zhou et al, 2008b, J. Climate)

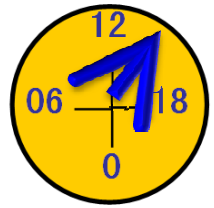
Spatial distributions of the amplitude (colors) and phase (arrows, LST, see phase clock) of the diurnal (24h, S1) harmonics of 2000-2004 mean JJA precipitation

Amount

Frequency

Intensity





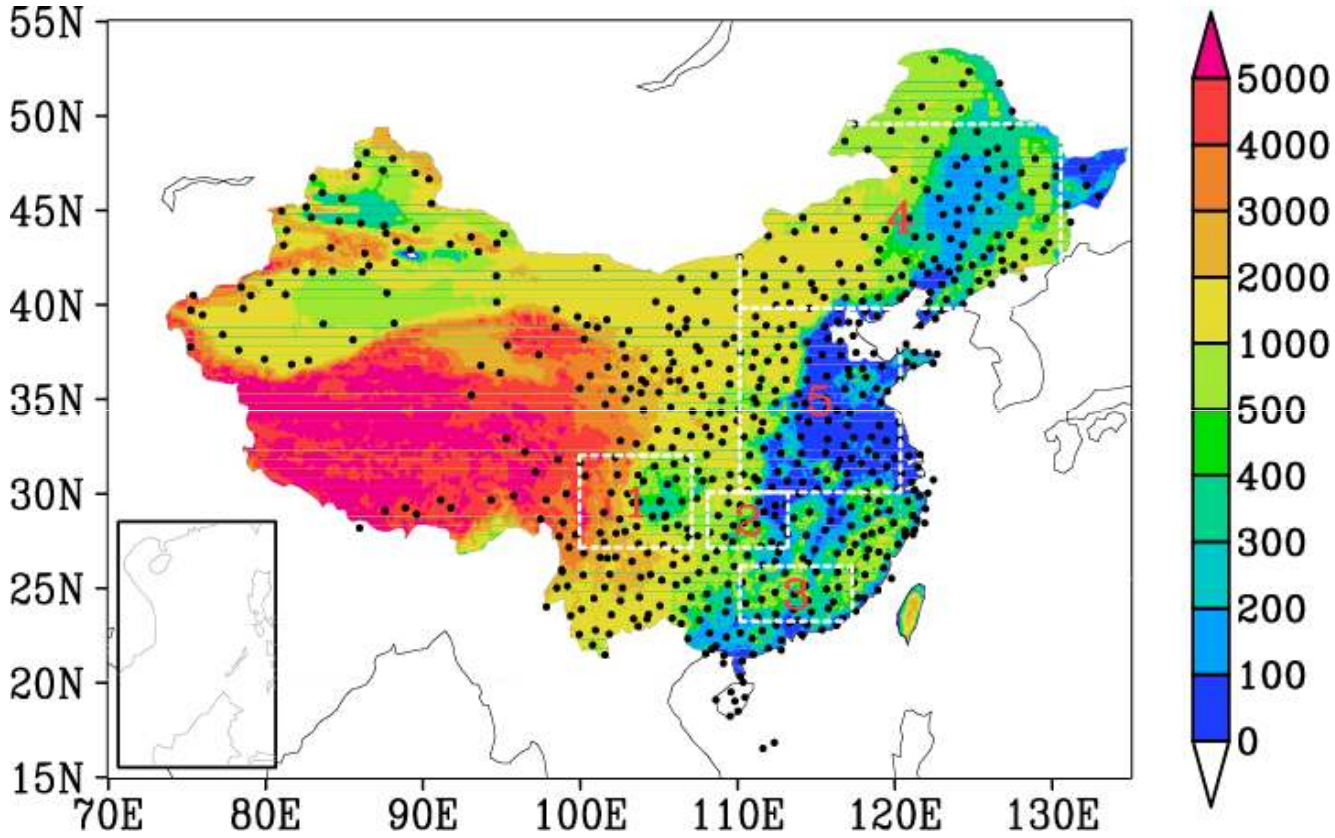
Rain-gauge

PERSIANN

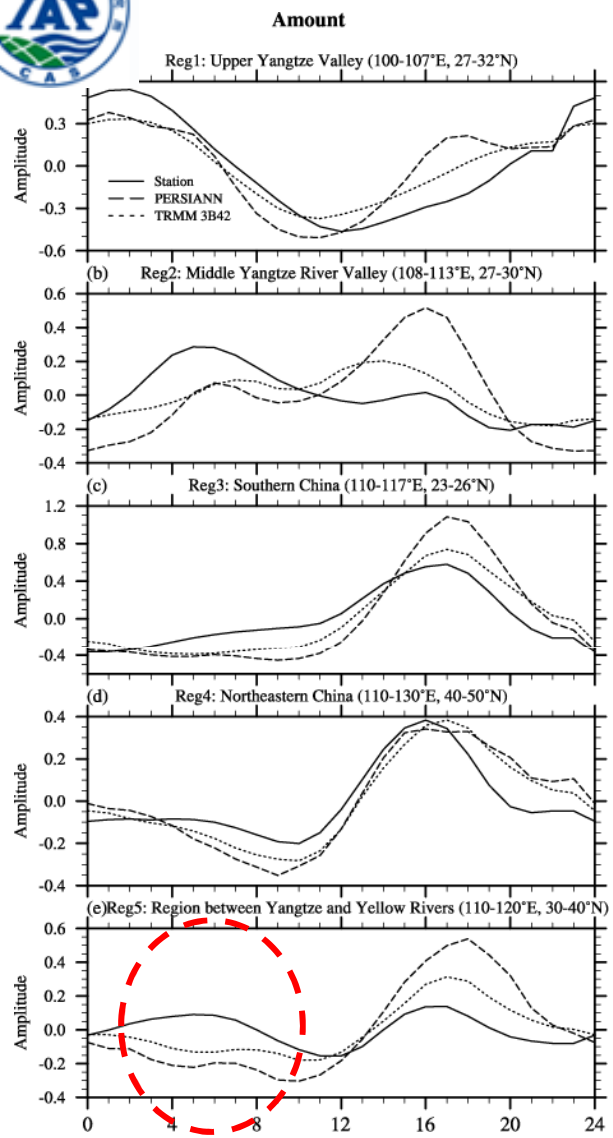
TRMM

(Zhou et al. 2008b J. Climate)

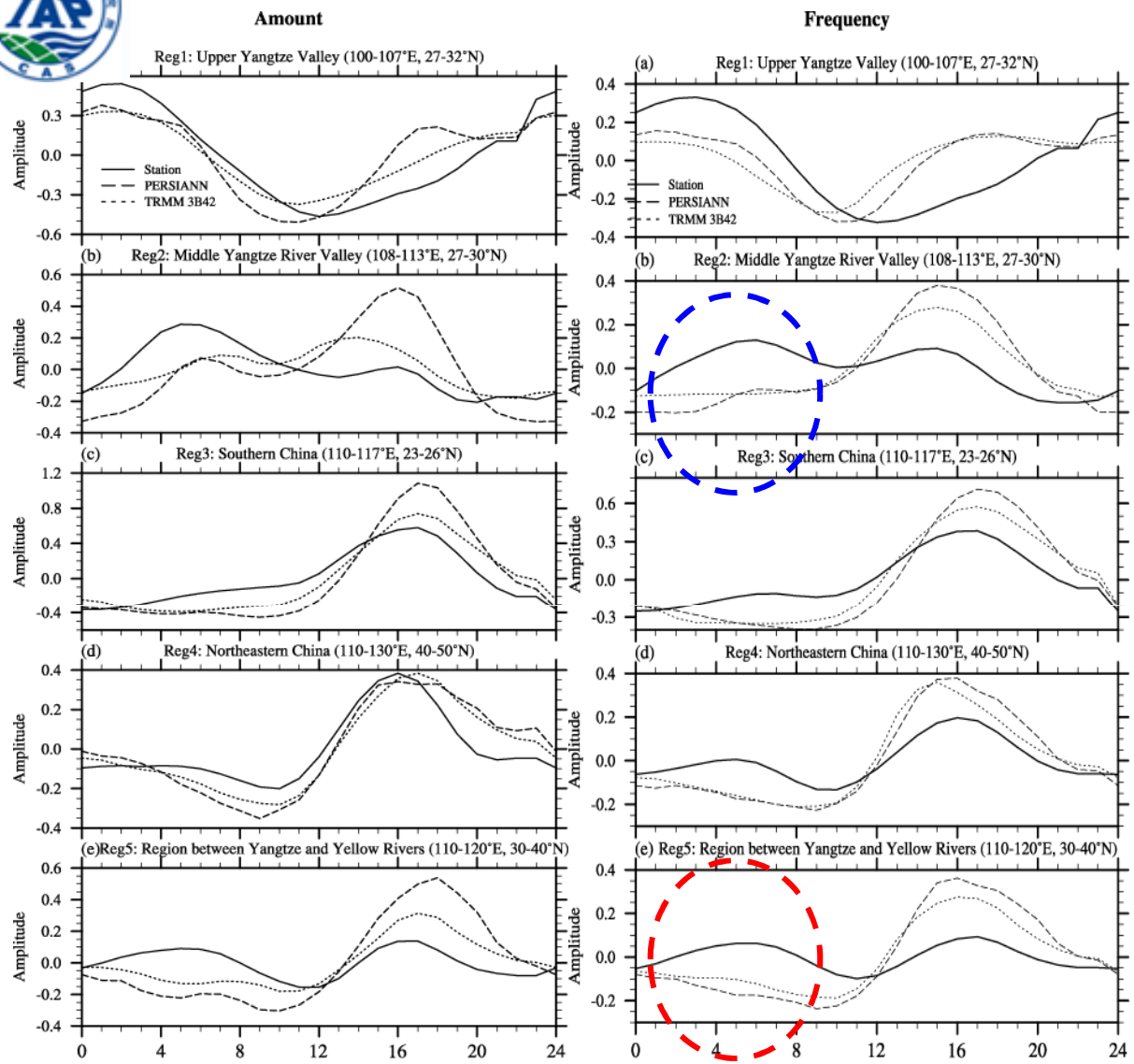
Five typical target domains



(Zhou et al, 2008b, J. Climate)



Mean diurnal cycle of JJA precipitation (normalized by the daily mean) averaged over the five selected regions from raingauge measurements (solid line) and two satellite products (Zhou et al. 2008b J. Climate).



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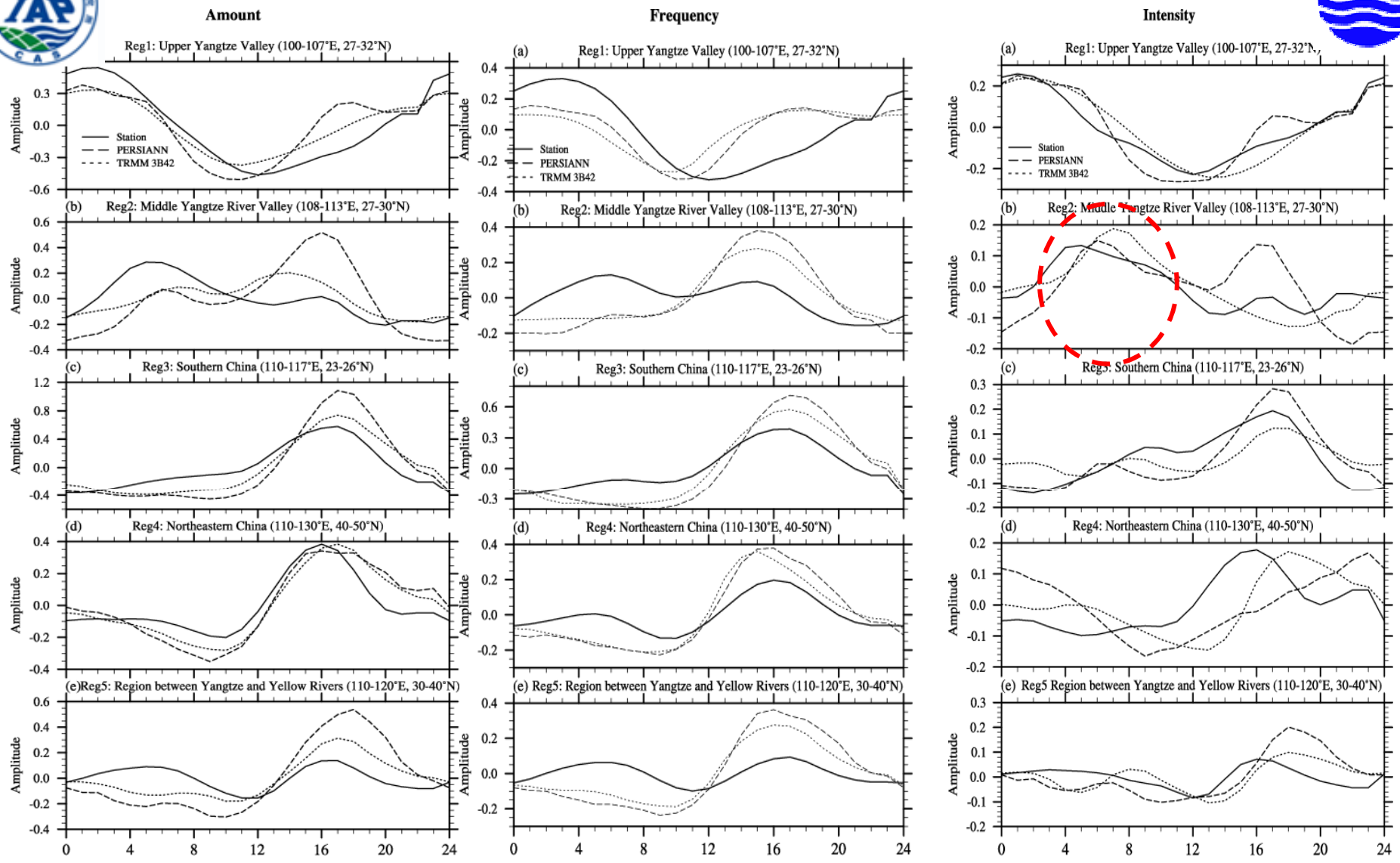


Mean diurnal cycle of JJA precipitation (normalized by the daily mean) averaged over the five selected regions from raingauge measurements (solid line) and two satellite products (Zhou et al. 2008b J. Climate).

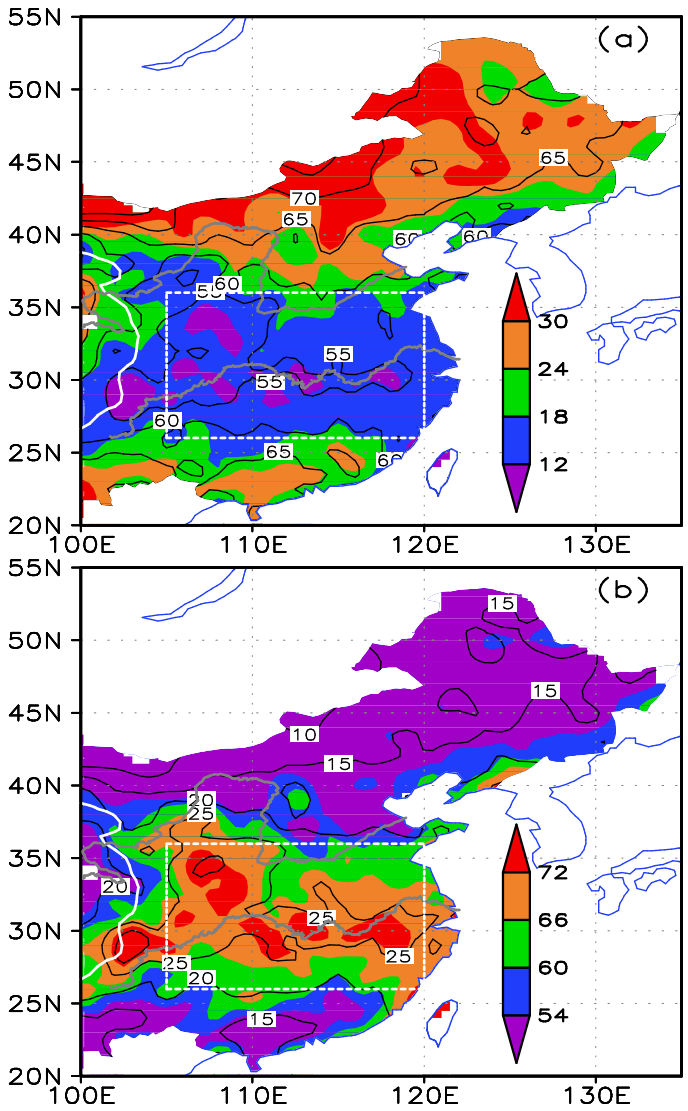
3 Rainfall duration and diurnal phase

- We classify the rainfall events according to rainfall duration time.
- Short duration rainfall events: lasting within 1-3 hrs
- Longer duration rainfall events: above 6 hours
- Focus on warm season (May to September) from 1991 to 2004.

(Yu et al, 2007b GRL)

Short

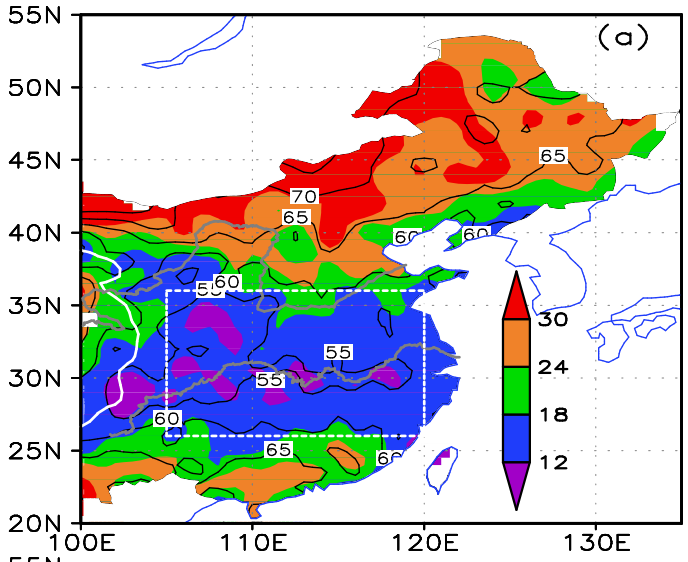
Long

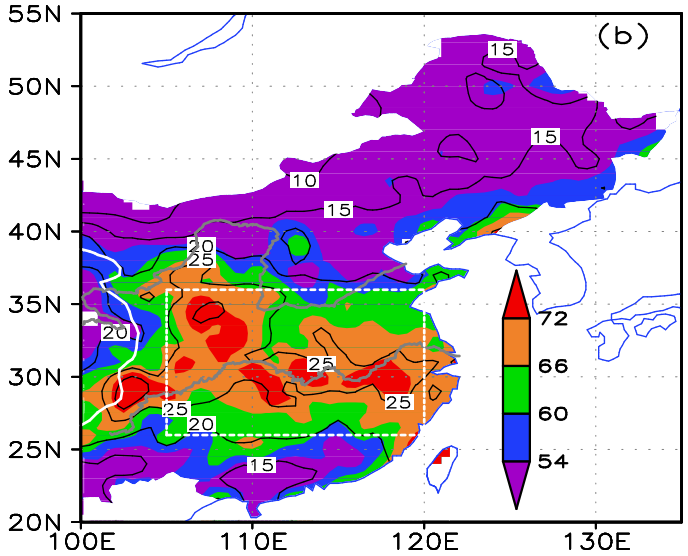


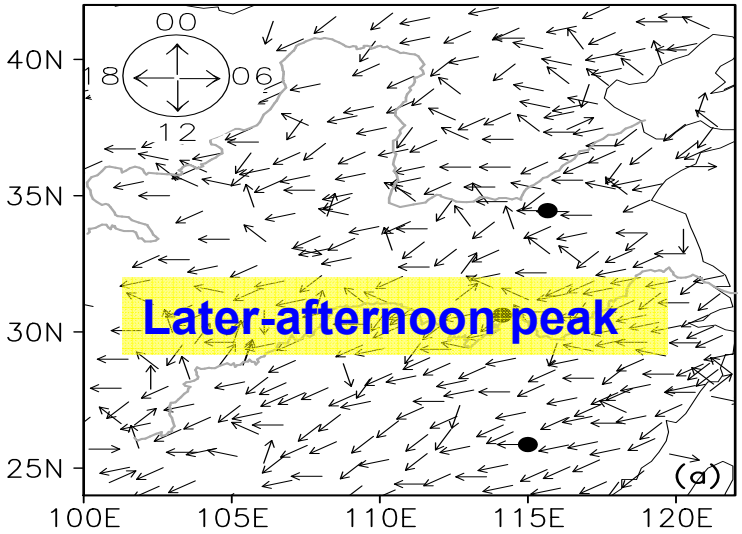
Percentages to the total rainfall in rainfall frequency (black isograms) and rainfall amount (colored) averaged from 1-3 hours (a) and more than 6 hours (b) duration rain events respectively (Yu et al. 2007b GRL).

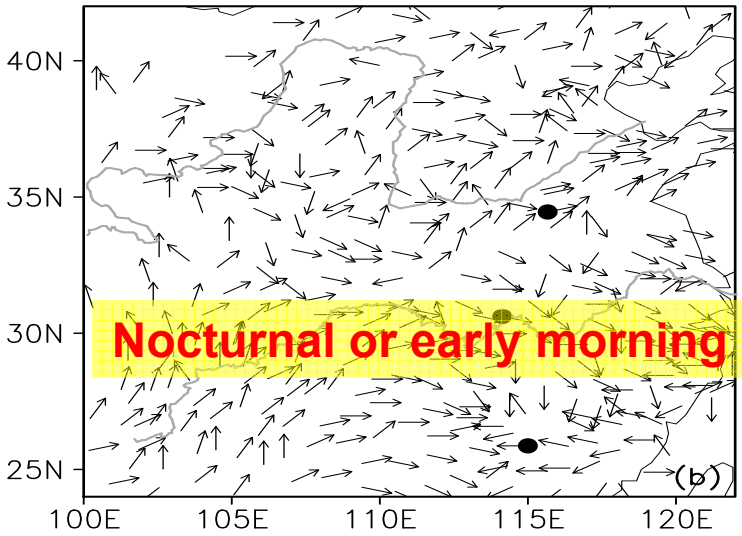
Short

Long



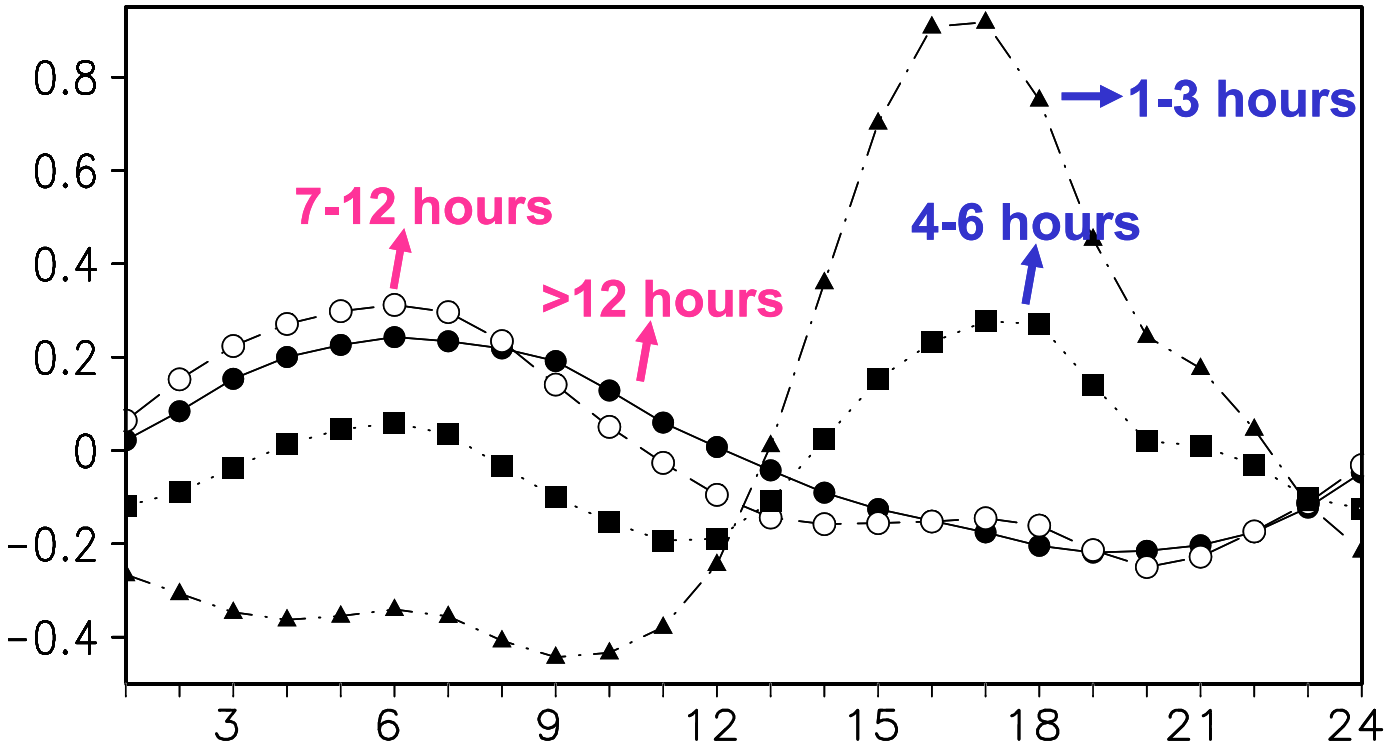






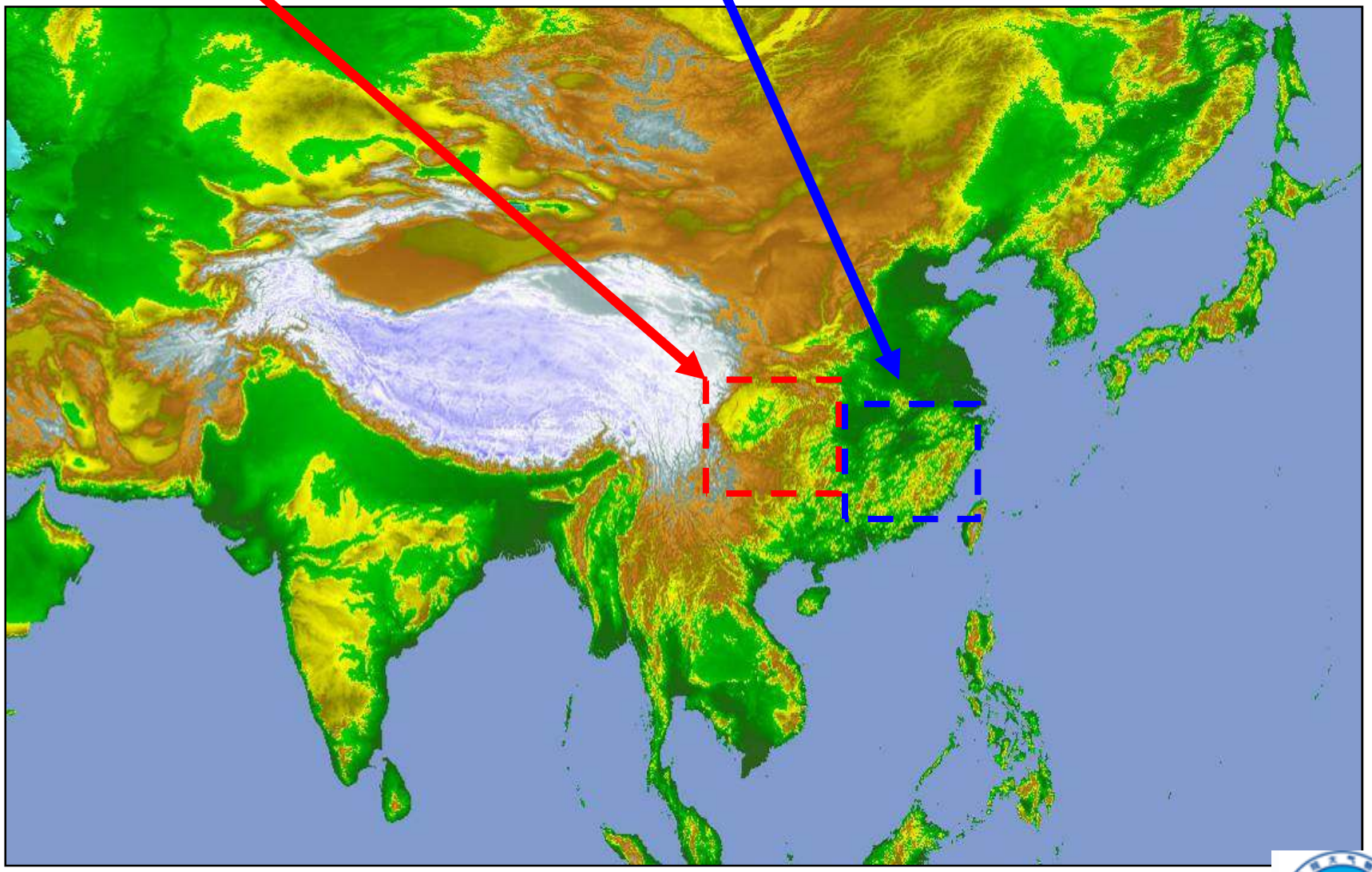
Percentages to the total rainfall in rainfall frequency (black isograms) and rainfall amount (colored) averaged from 1-3 hours (a) and more than 6 hours (b) duration rain events respectively (Yu et al. 2007b GRL).

Regional mean diurnal variations of precipitation (averaged in 103-120°E, 26-36°N) with different rainfall durations.

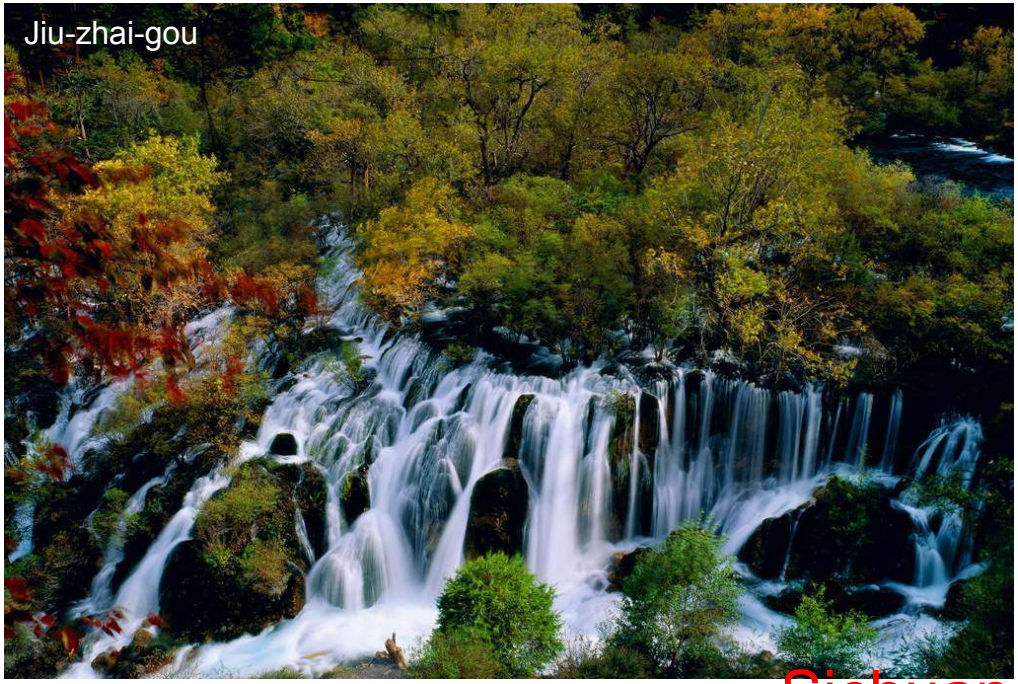


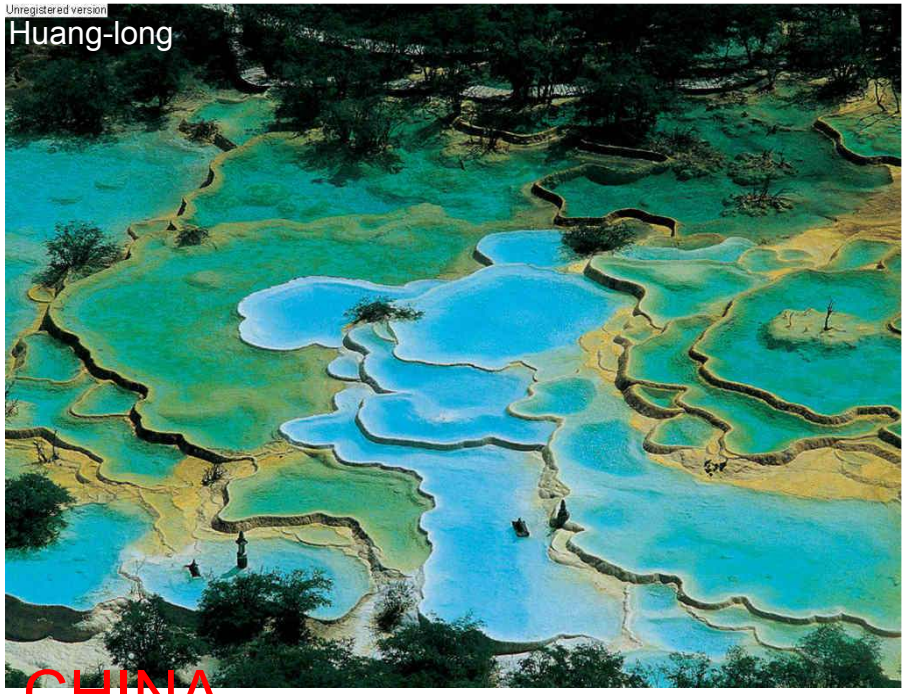
(Yu et al. 2007b GRL).

4 Southwest China *vs* Southeast China in diurnal cycle

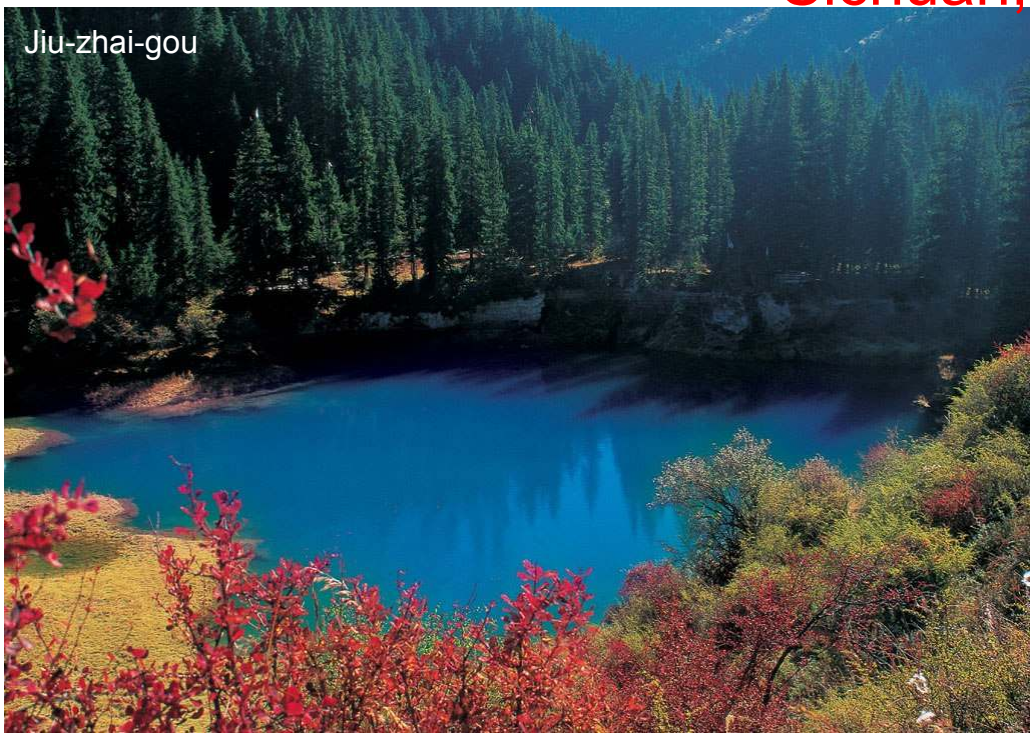


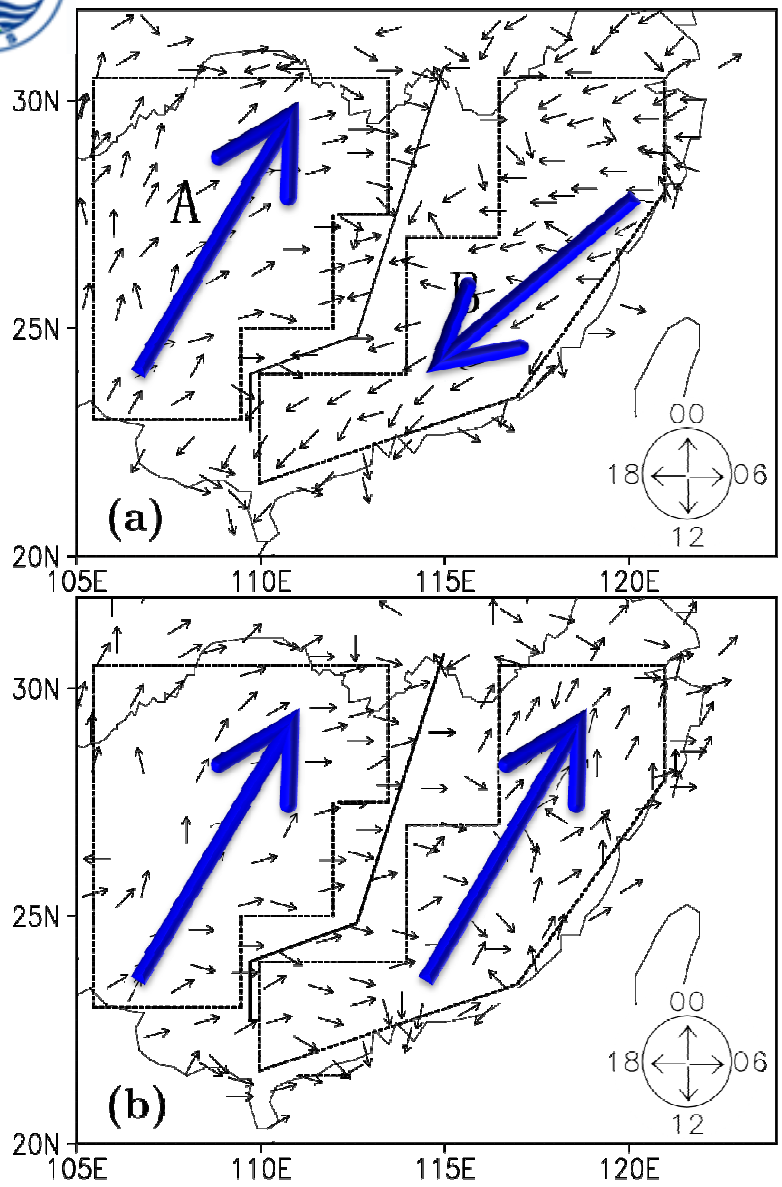
Sichuan





Sichuan, CHINA





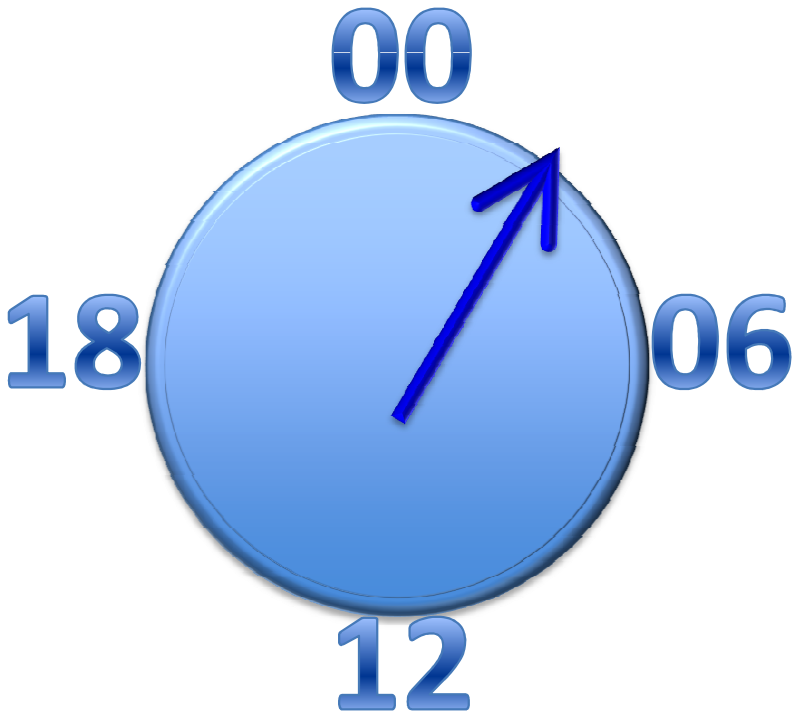
(Li et al, 2008 J. Climate)

Spatial distributions of the diurnal phase of precipitation.

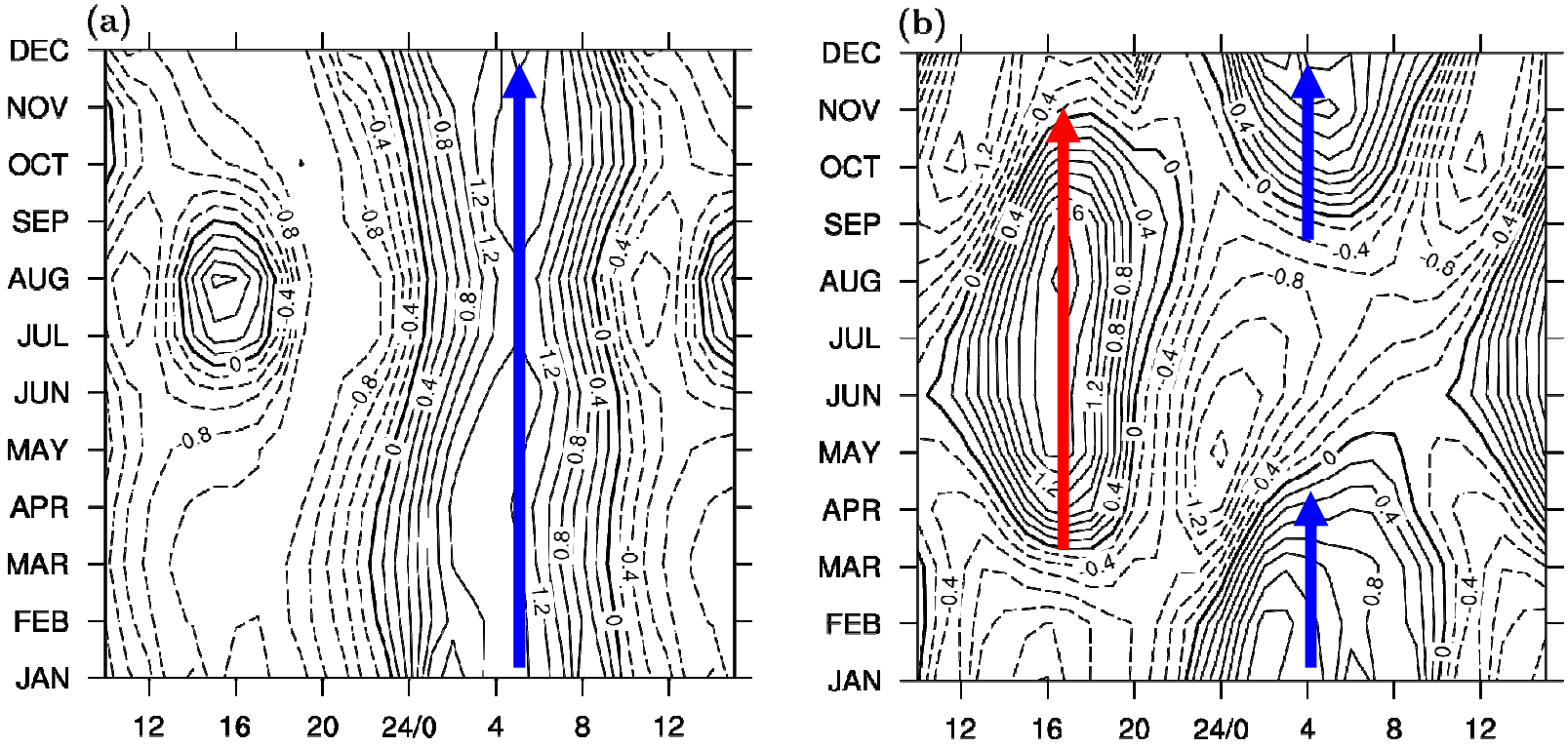
(a) all year (Jan– Dec)

(Similar for JJA)

(b) cold seasons (Nov–Mar)



Seasonal variation of the diurnal cycle

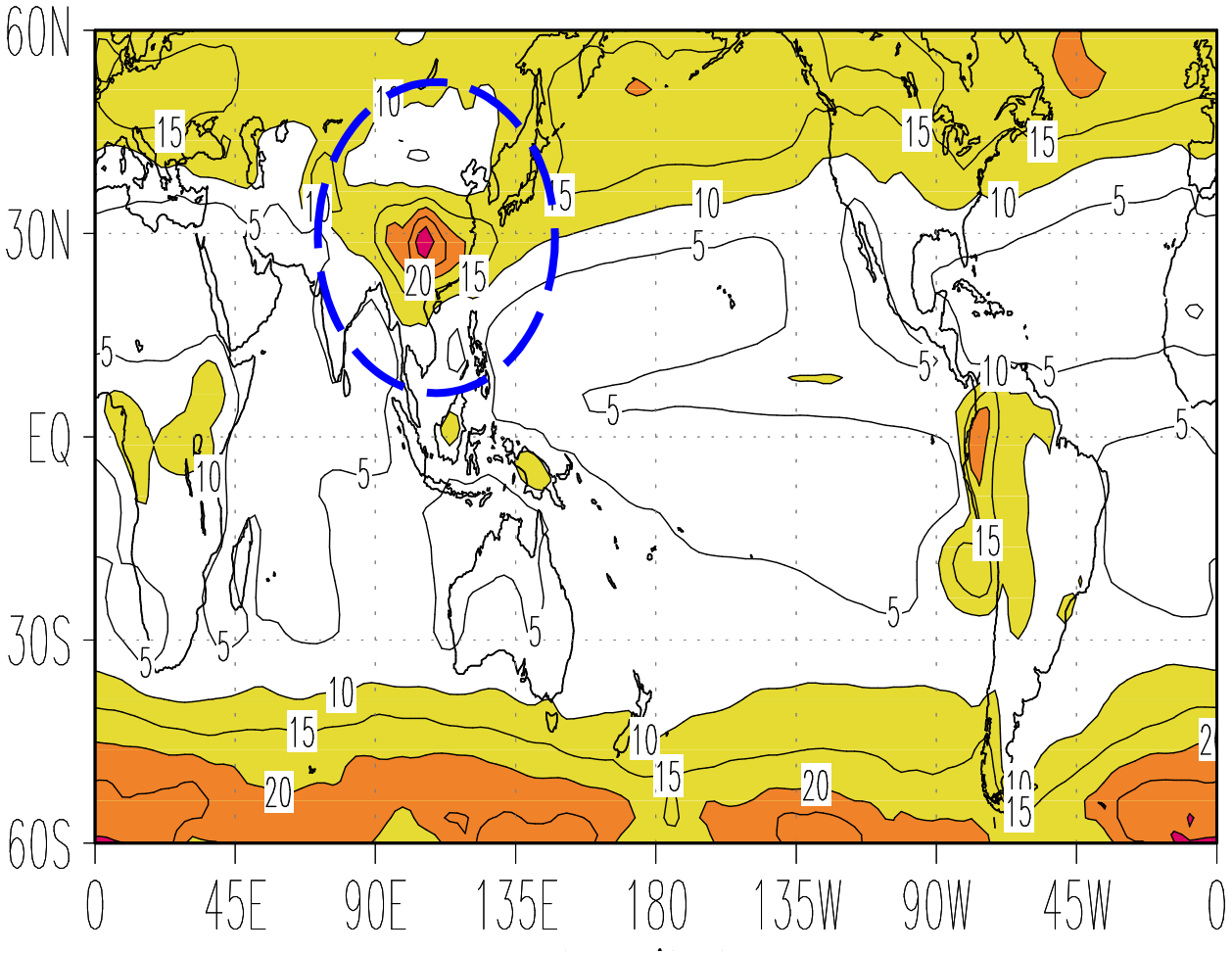


(a) Southwest (b) Southeast

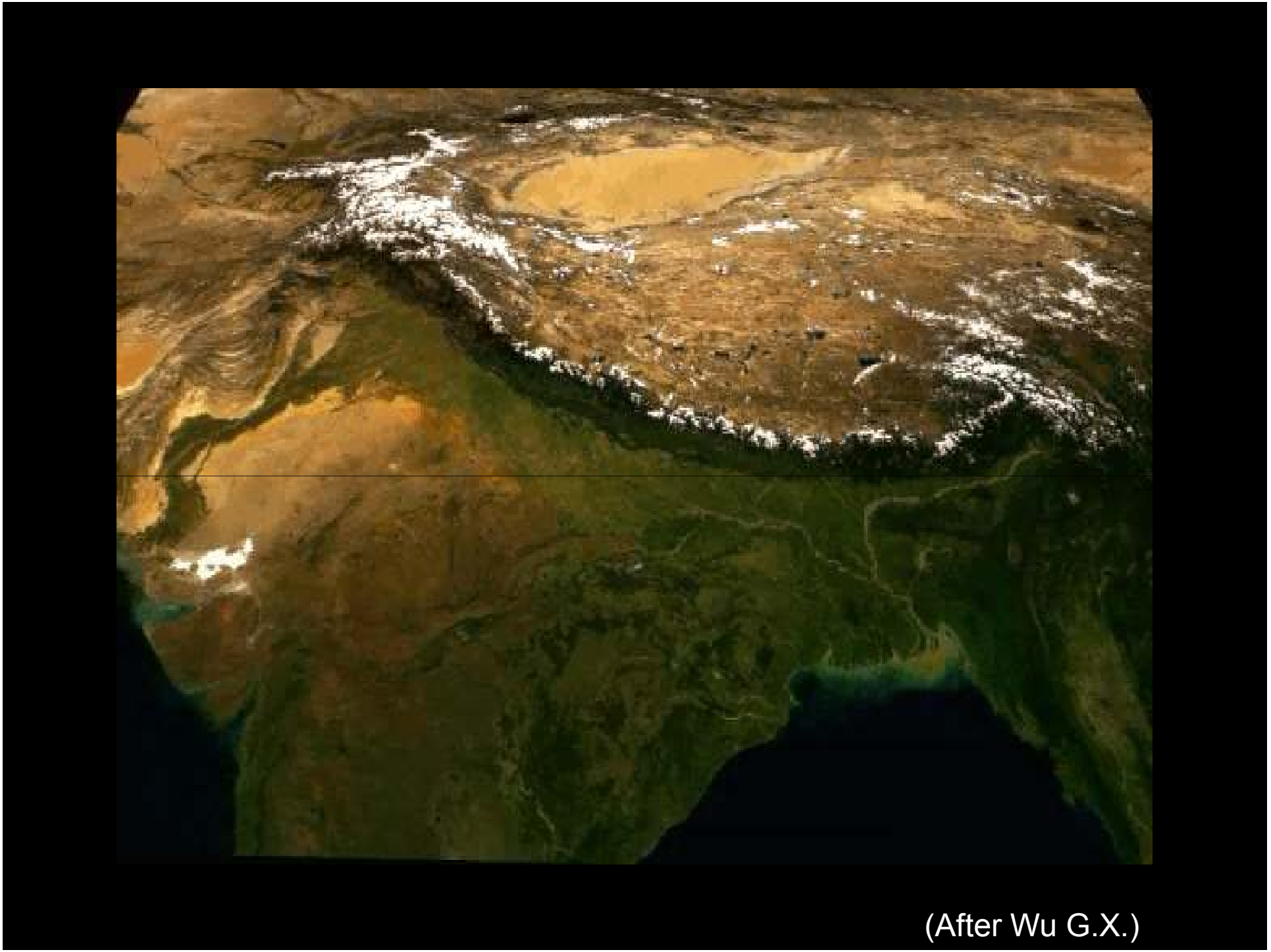
(Li et al, 2008 J. Climate)


Cloud over Southwest China

Annual mean stratus cloud based on ISCCP

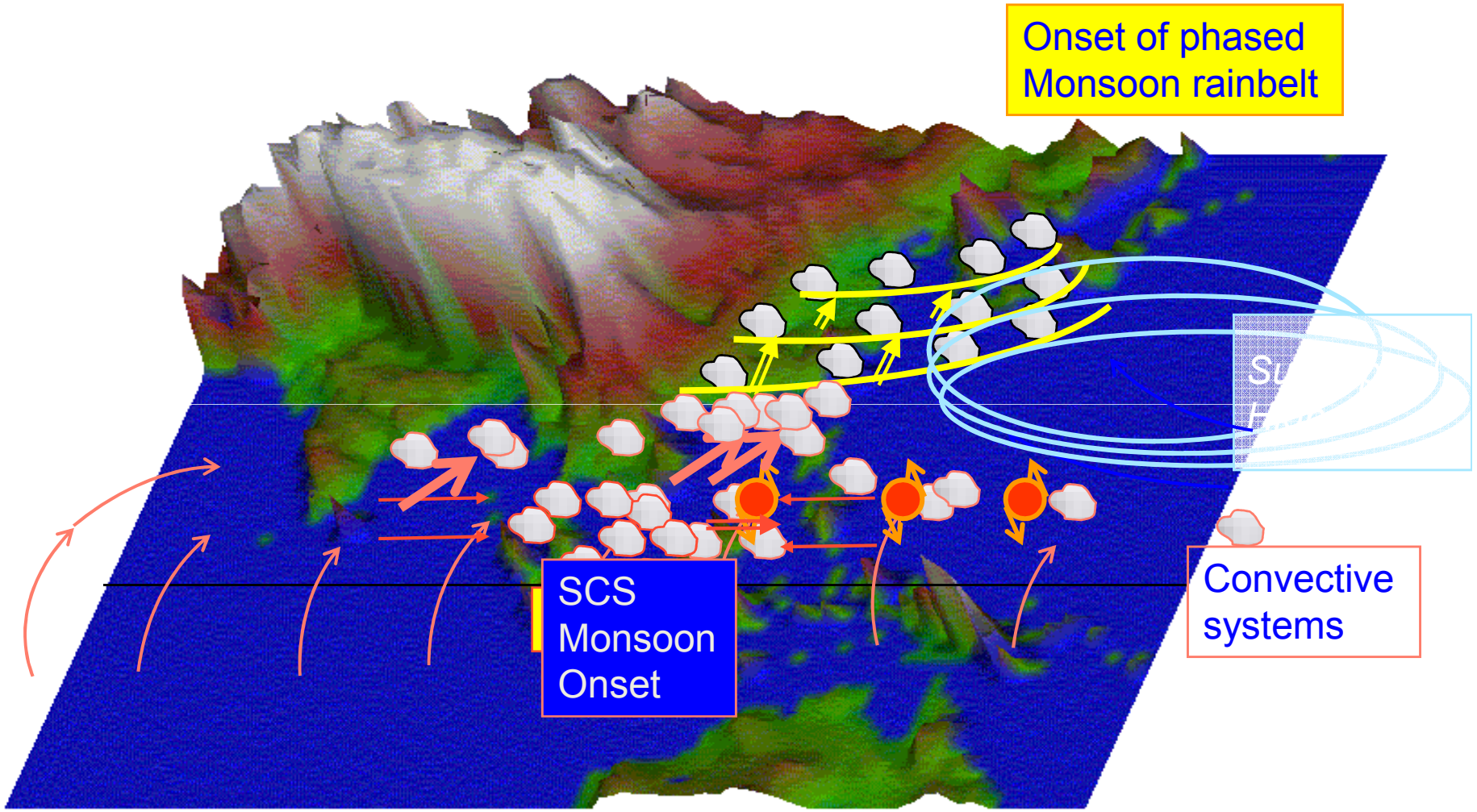


The plateau produces a large amount of middle cloud

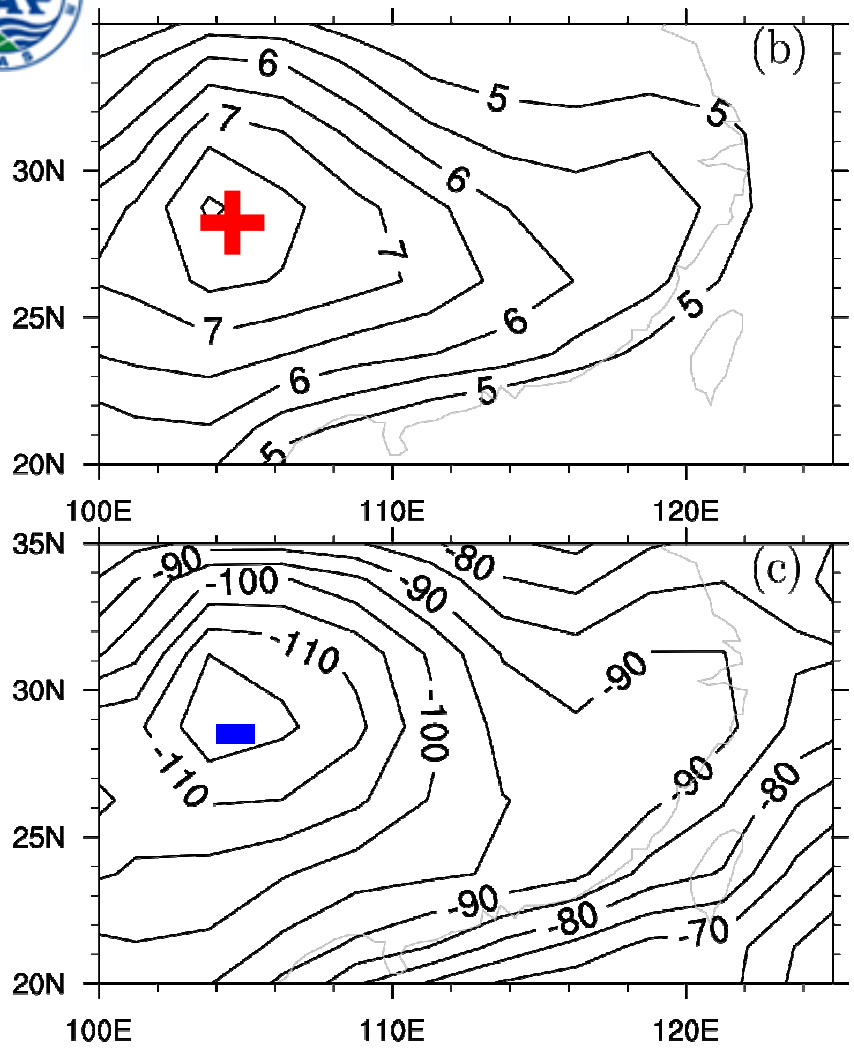


(After Wu G.X.)

East Asian Summer Monsoon



(after Sun C.)



Warm-season mean
cloud optical thickness
(ISCCP)

Warm-season mean
shortwave cloud radiative forcing
(ERBE)

Different radiation condition between Region A and B

(Li et al, 2008 J. Climate)

Summary

- The summer precipitation over eastern China has significant diurnal variations: A midnight maximum over the eastern part of the Tibetan Plateau is evident. The southern inland China and northeastern China have late afternoon maxima.
- The diurnal phases of summer precipitation over eastern China are highly determined by the duration of rainfall events: The short duration rainfall events (last for 1-3 hours) always peaks in later afternoon, while the long duration events (last for more than 6 hours) usually peaks during mid-night to noon with the maxima around early morning.
- The Southwest and Southeast China show different seasonal cycle of diurnal phase, partly due to the cloud radiation forcing difference.
- The TRMM 3B42 and PERSIANN data show reliable performances in deriving diurnal cycle of precipitation over E. China except for the region between the Yangtze and Yellow Rivers.

Some further reading for details of our work

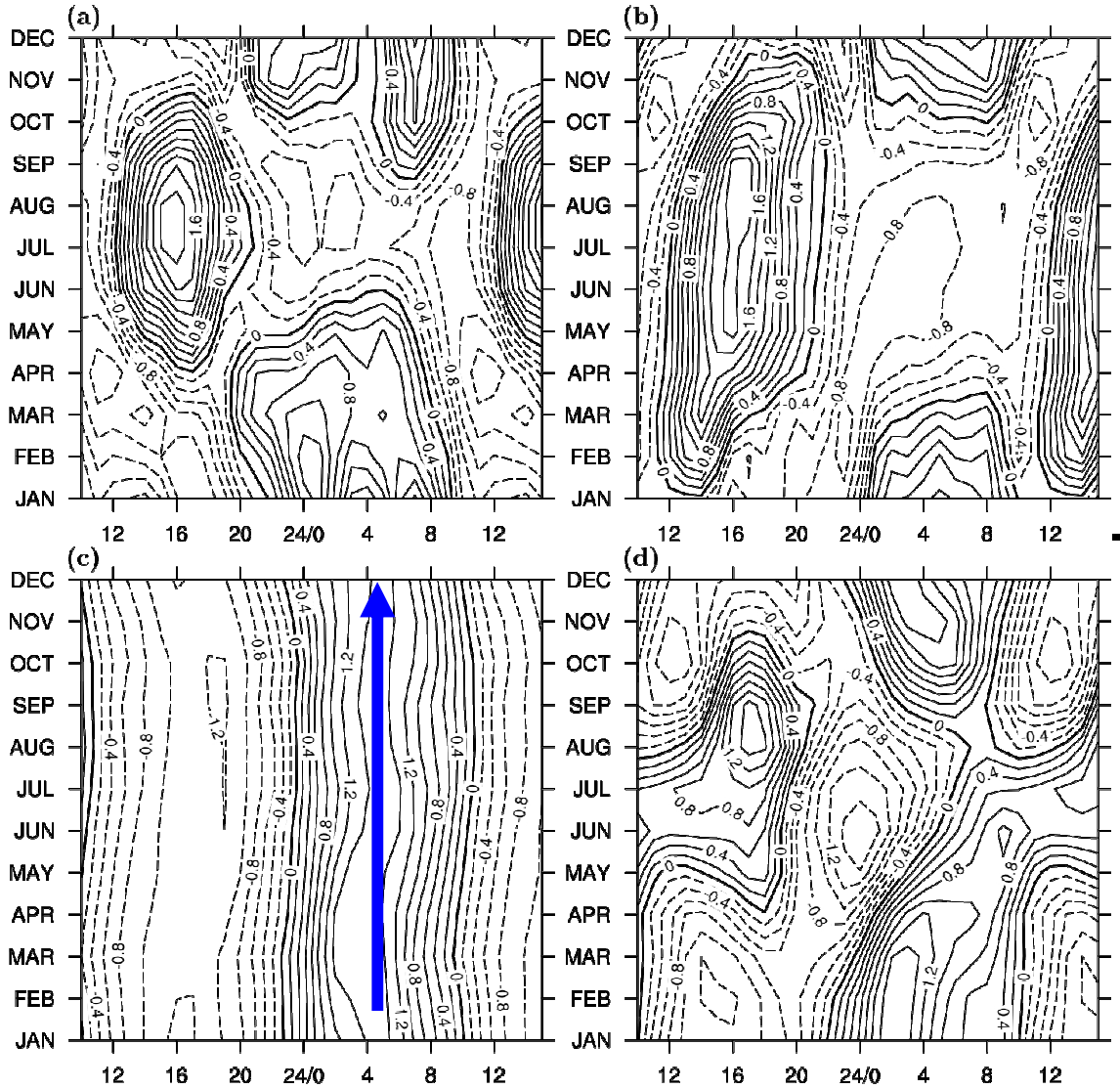
1. Yu, R., T. Zhou, A. Xiong, Y. Zhu, and J. Li, 2007a: Diurnal variations of summer precipitation over contiguous China. ***Geophysical Research Letters***, **34,** L01704.
2. Yu, R., Y. Xu, T. Zhou, and J. Li, 2007b: Relation between rainfall duration and diurnal variation in the warm season precipitation over central eastern China. ***Geophysical Research Letters***, **34,** L13703.
3. Chen, H., T. Zhou, R. Yu, and J. Li, 2008: Summer rain fall duration and its diurnal cycle over the US Great Plains. ***International Journal of Climatology***, DOI: 10.1002/joc1806.
4. Li, J., R. Yu, and T. Zhou, 2008: Seasonal variation of the diurnal cycle of rainfall in the southern contiguous China. ***J. Climate*****, 21**, 6036-6043.
5. Zhou, T., R. Yu, H. Chen, A. Dai, and Y. Pan, 2008: Summer Precipitation Frequency, Intensity, and Diurnal Cycle over China: A Comparison of Satellite Data with Rain Gauge Observations. ***J. Climate***, **21,** 3997-4010.
6. Zhou, T., B. Wu, and B. Wang, 2009b: How well do Atmospheric General Circulation Models capture the leading modes of the interannual variability of Asian-Australian Monsoon? ***J. Climate***, In Press
7. Zhou T., Yu R., Li H., et al. 2008a, Ocean forcing to changes in global monsoon precipitation over the recent half century, ***J. Climate***, 21, (15), 3833–3852

THANK YOU !

Improve climate models from diurnal cycle simulation

http://web.lasg.ac.cn/staff/ztj/index_e.htm

Seasonal variation of diurnal cycle



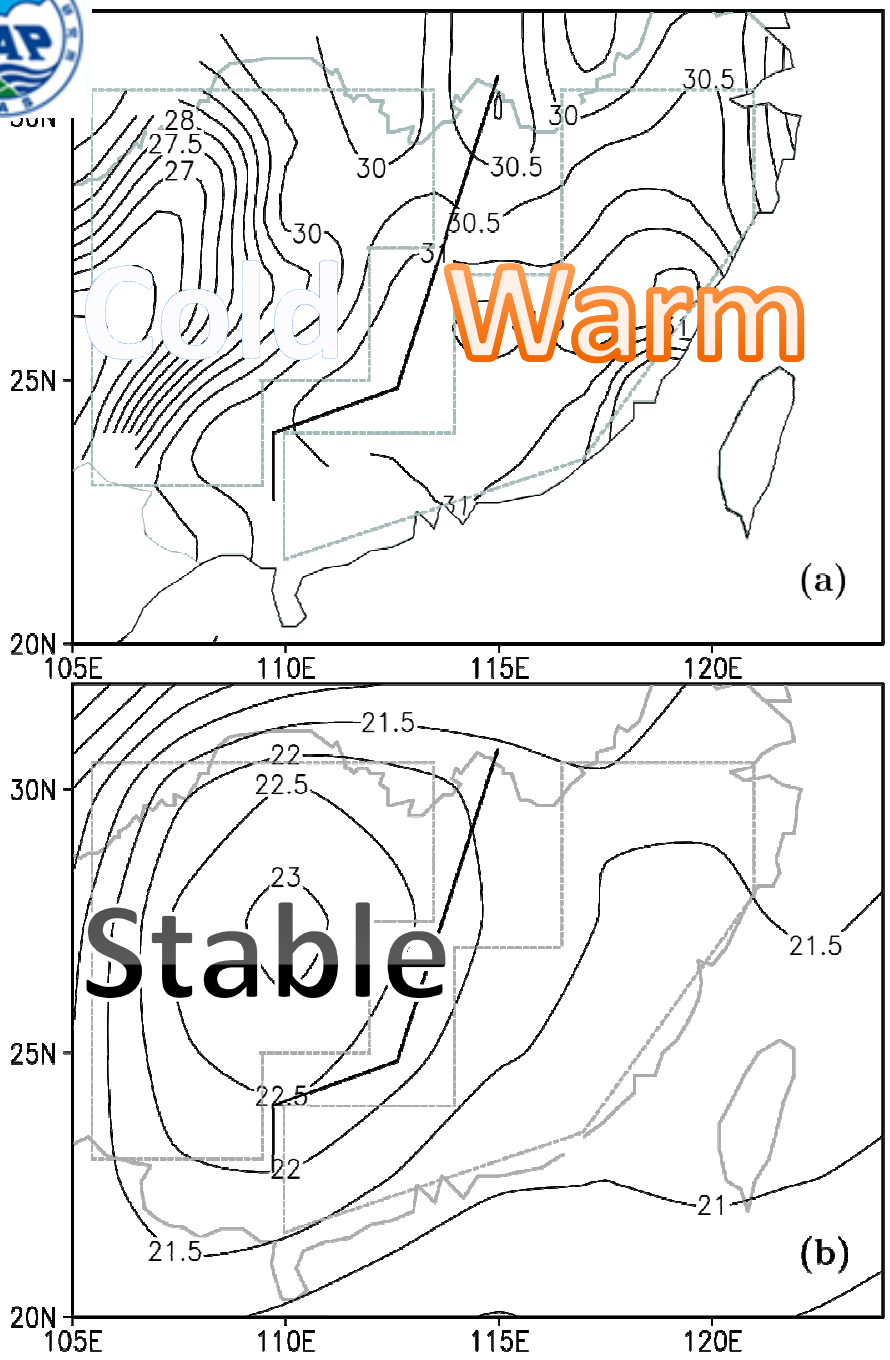
Short duration
1-3 hours

Long duration
>6 hours

Southwest

Southeast

(Li et al, 2008 J. Climate)



Station observed surface air temperature at 1400 LST in warm seasons

potential temperature difference between 500 and 850 hPa at 1400 BJT in warm seasons

(Li et al, 2008 J. Climate)