ISSI meeting

The East Asian summer monsoon and impact of snow cover over HTP

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Feb.2017 Bejing

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Institute of 极地气象研究所 Polar Meteorology

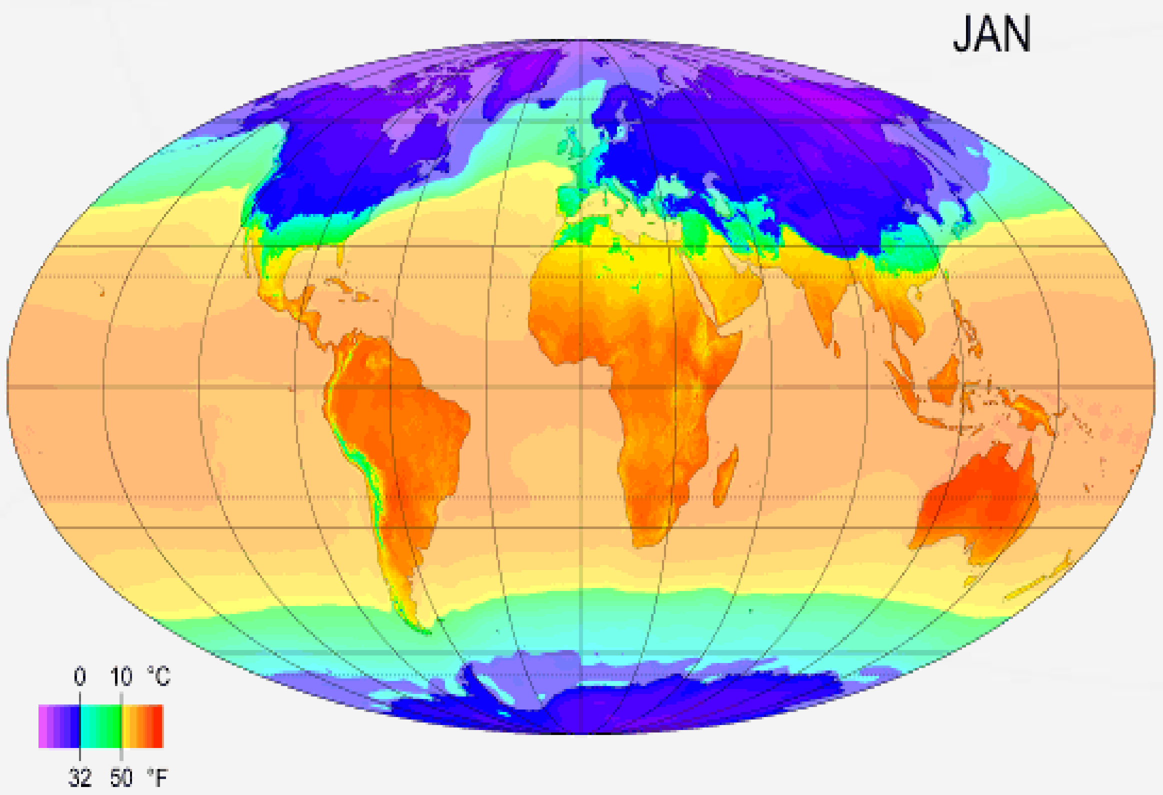
Outline

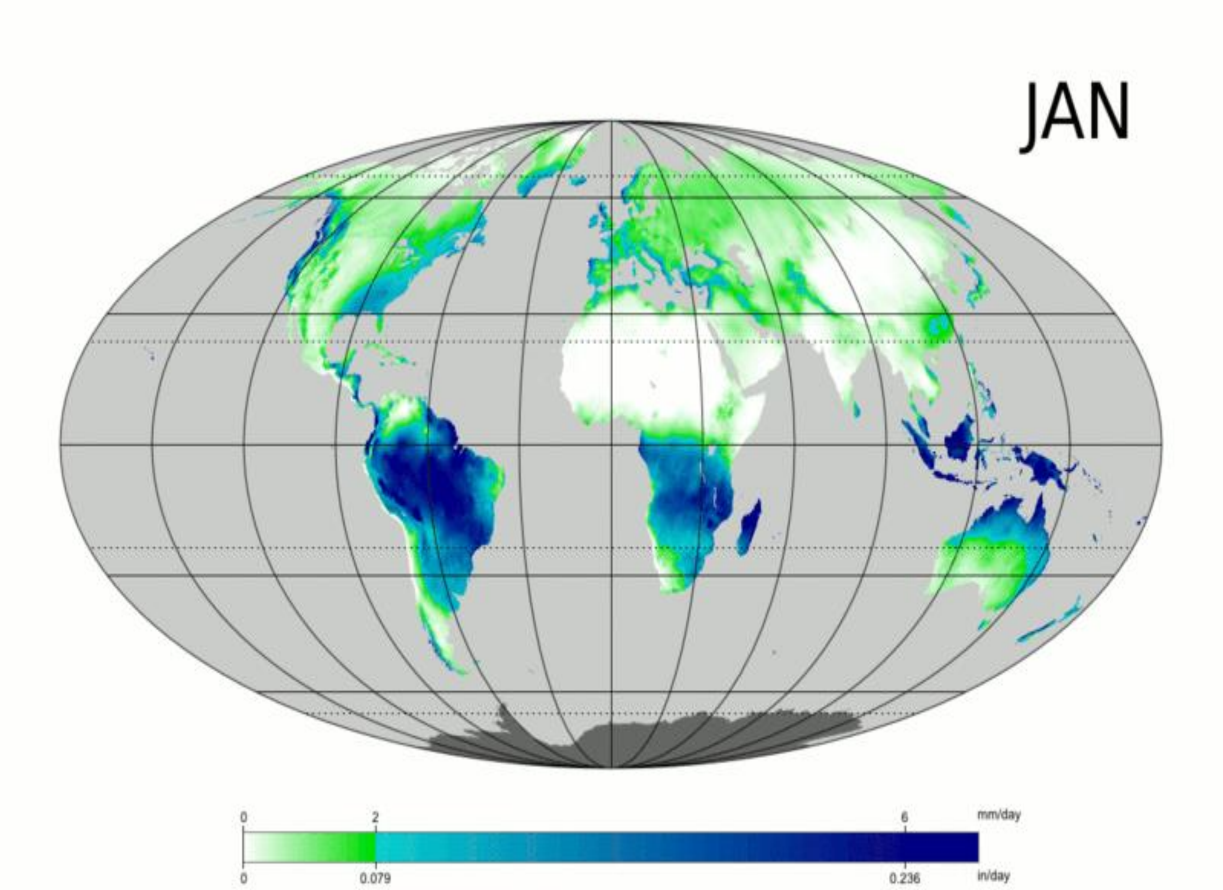
- **East Asian Summer Monsoon**

  Seasonal cycle; Subseasonal and interannual variation

- **Impact of Snow Cover over HTP**
- **Summary**
- **Open discussion**

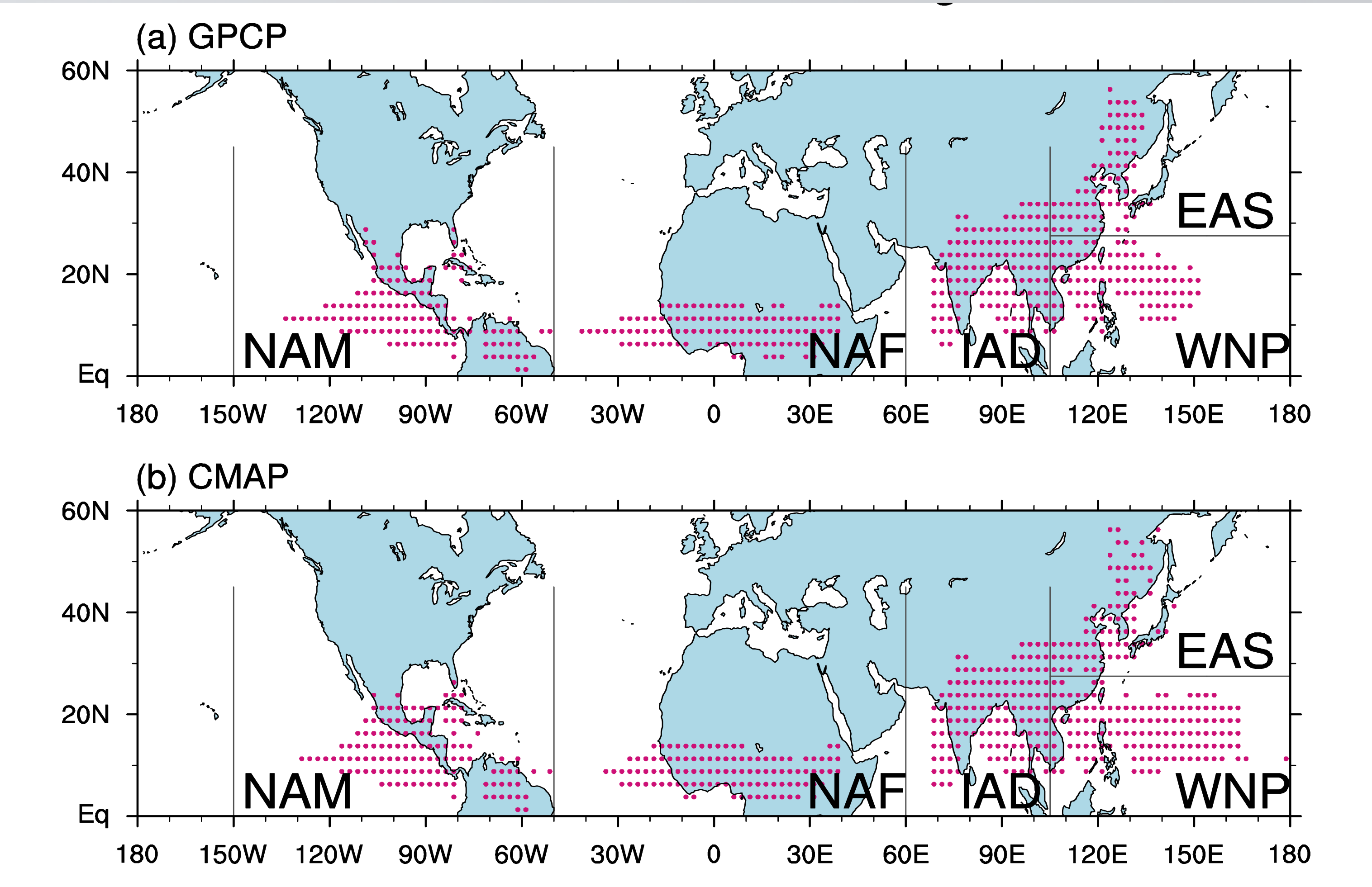
East Asian Summer Monsoon: Seasonal Cycle



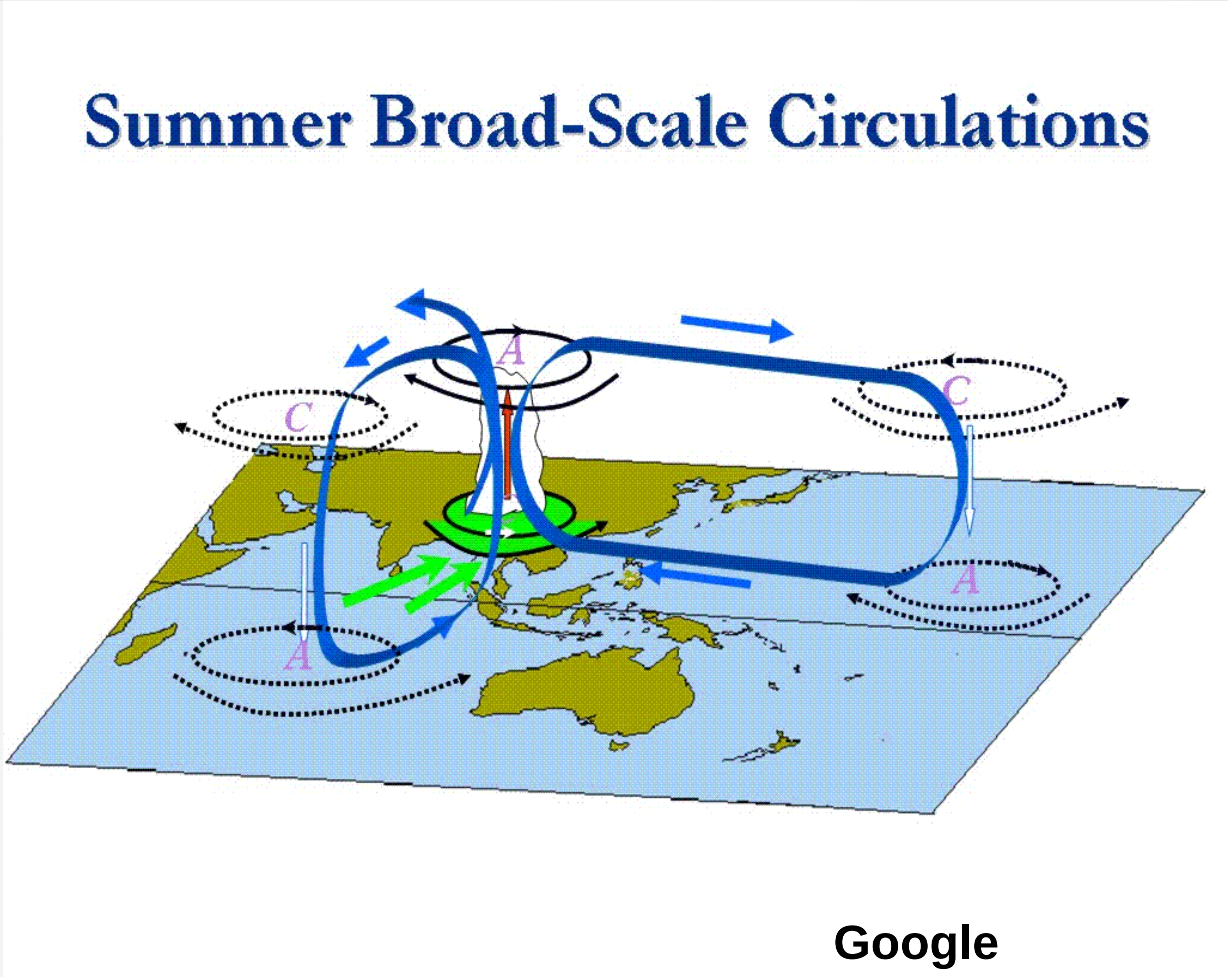


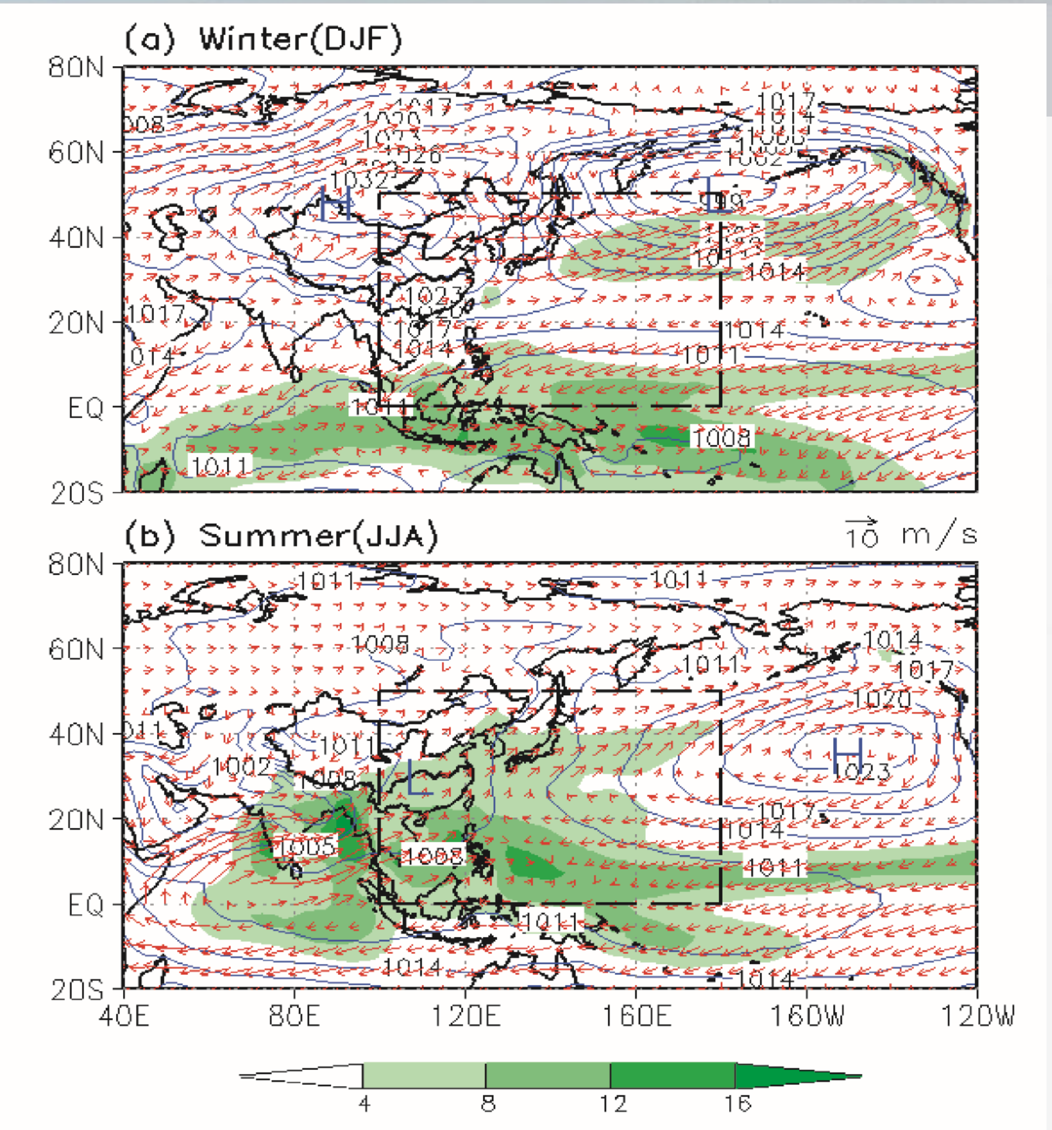
Seasonal cycle of air surface temperature (left) and rainfall (right). Google search

East Asian Summer Monsoon: Seasonal Cycle



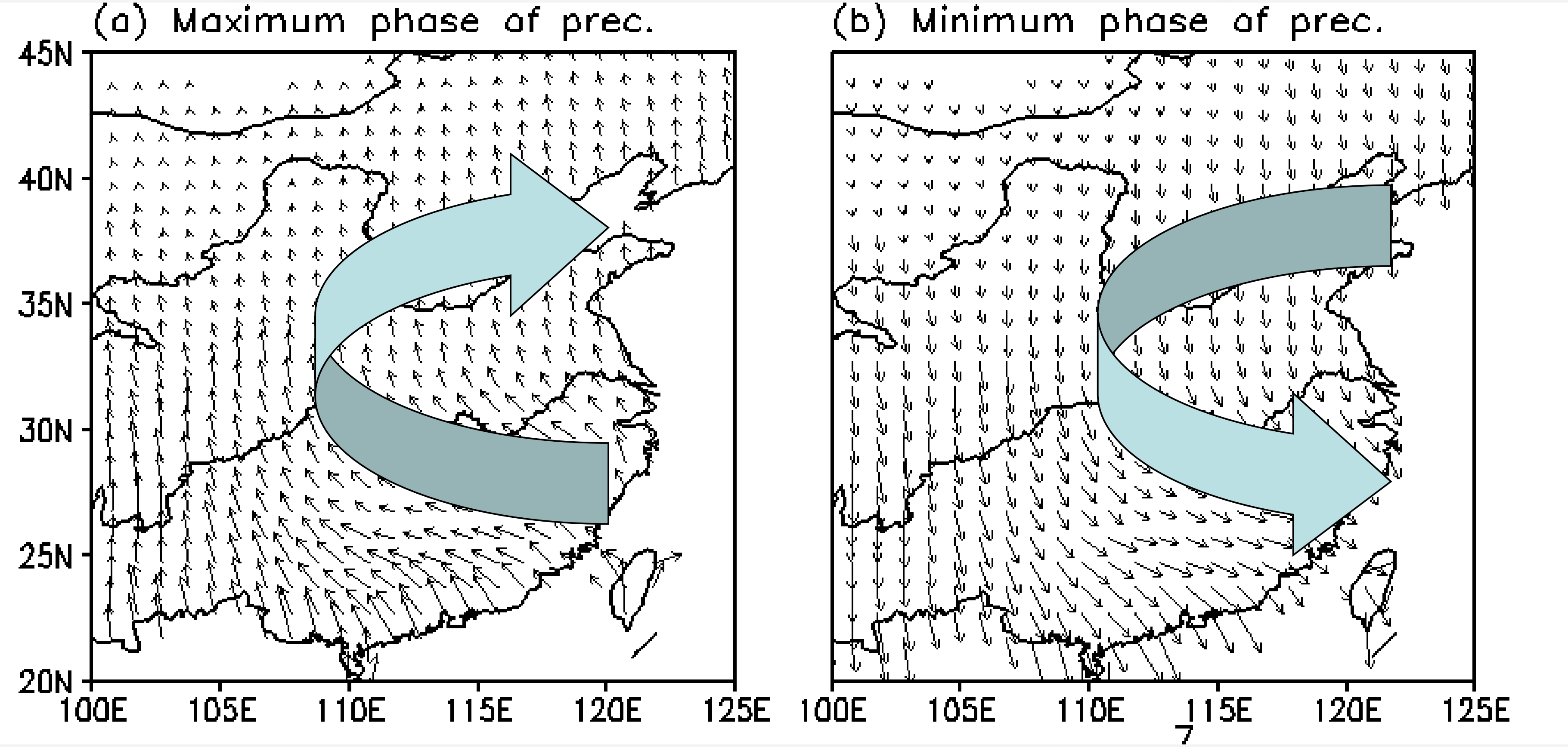
Boreal summer monsoon regions, following the definition by Wang et al. (2013)

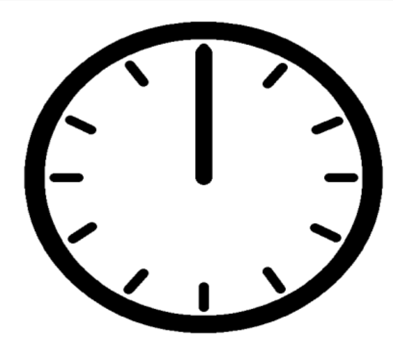


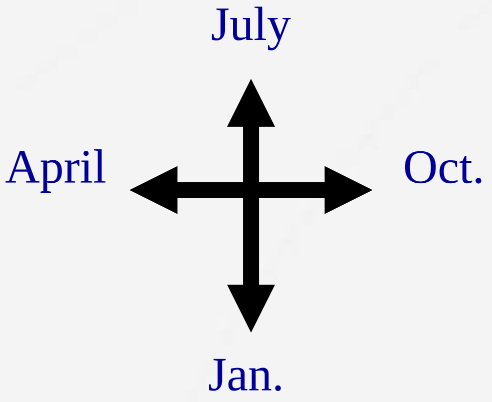


Zhu, C., W. Lee, H. Kang, and C. Park, 2005: A proper monsoon index for seasonal and interannual variations of the East Asian monsoon. Geophys. Res. Lett.,32,L02811,doi:10.1029/2004GL021295.

East Asian Summer Monsoon: Seasonal Cycle







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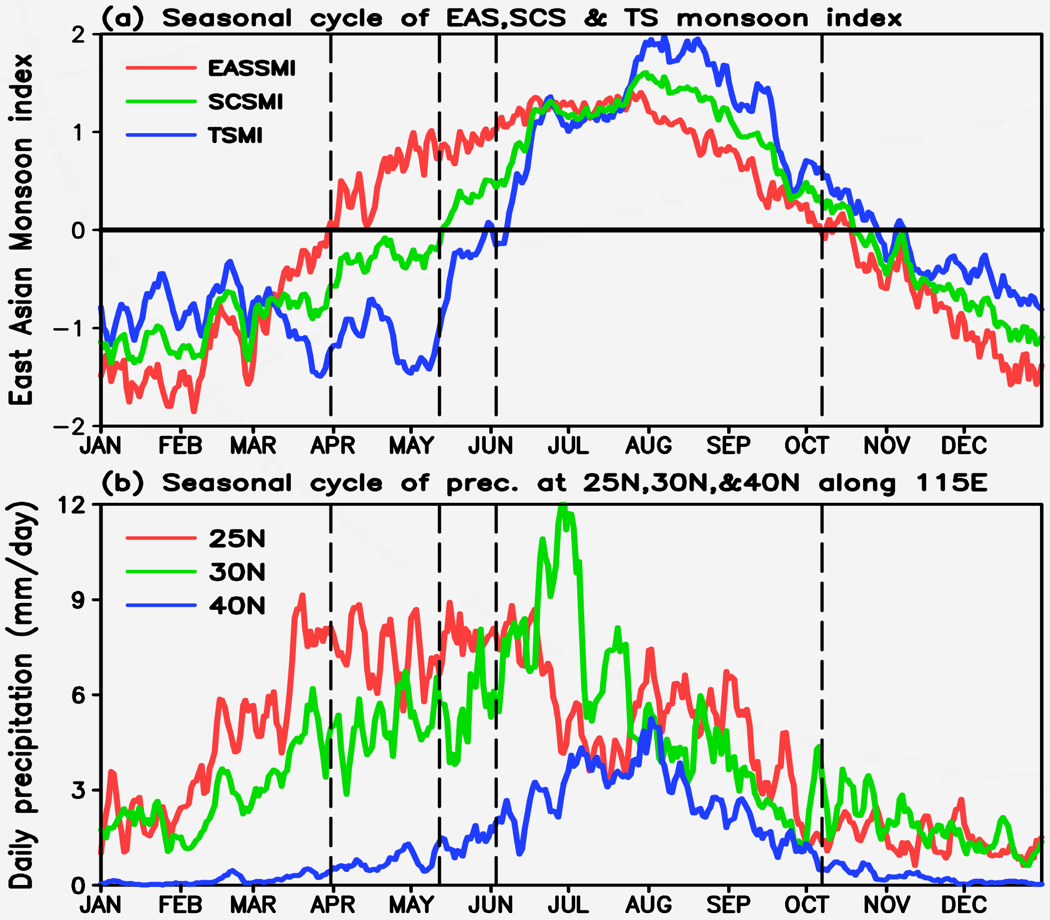
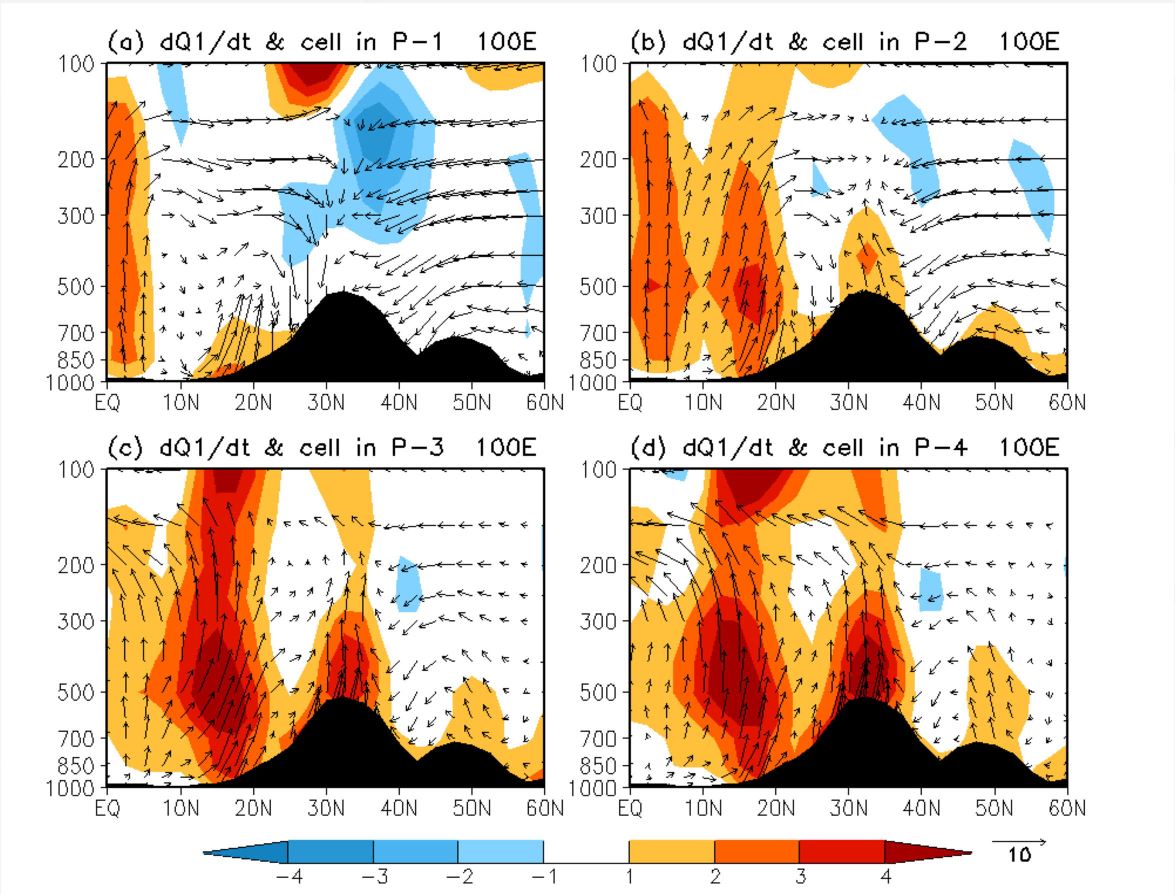
Zhu C., Zhou X J, Zhao P, et al, 2011: Onset of East Asian subtropical summer monsoon and rainy season in China. Sci China Earth Sci,54:1845–1853, doi: 10.1007/s11430-011-4284-0

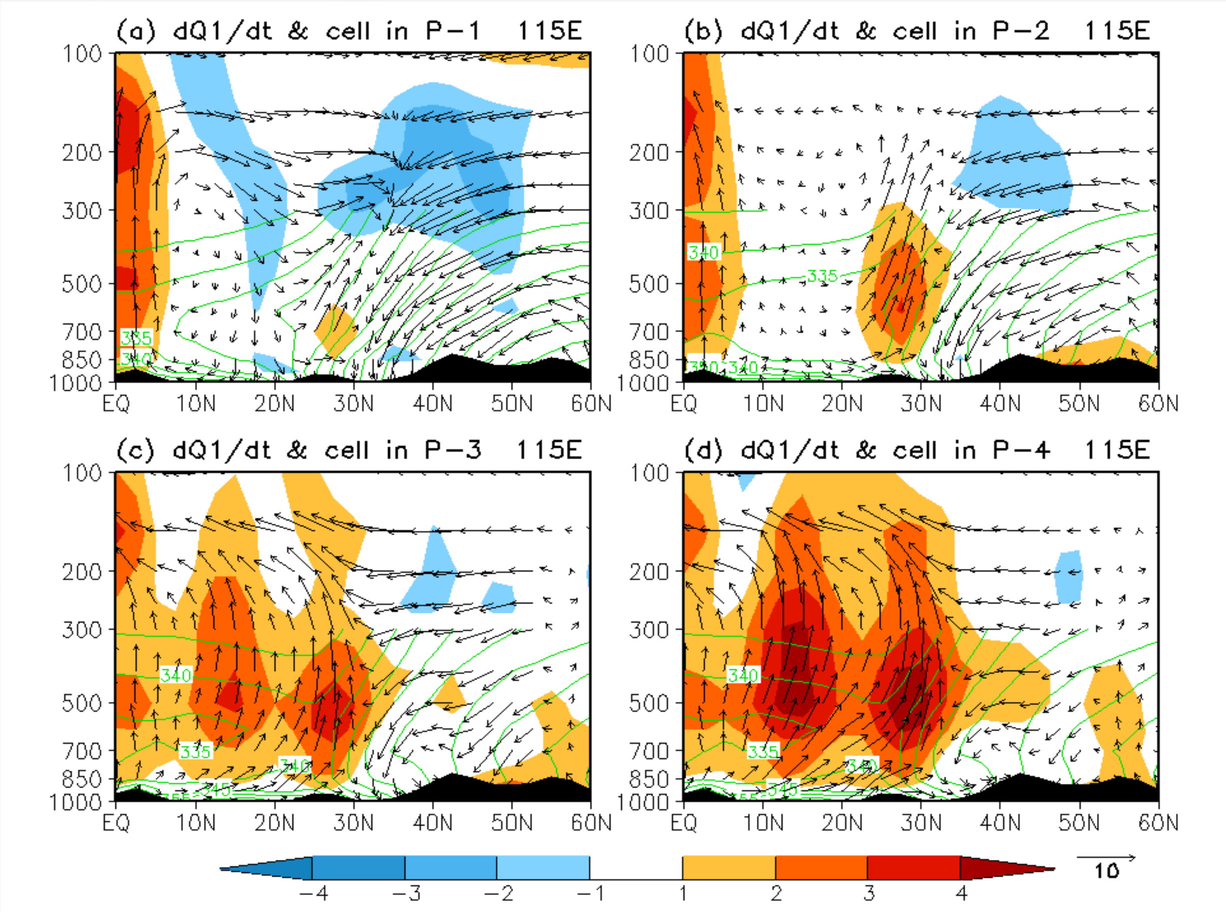
East Asian Summer Monsoon: Seasonal Cycle

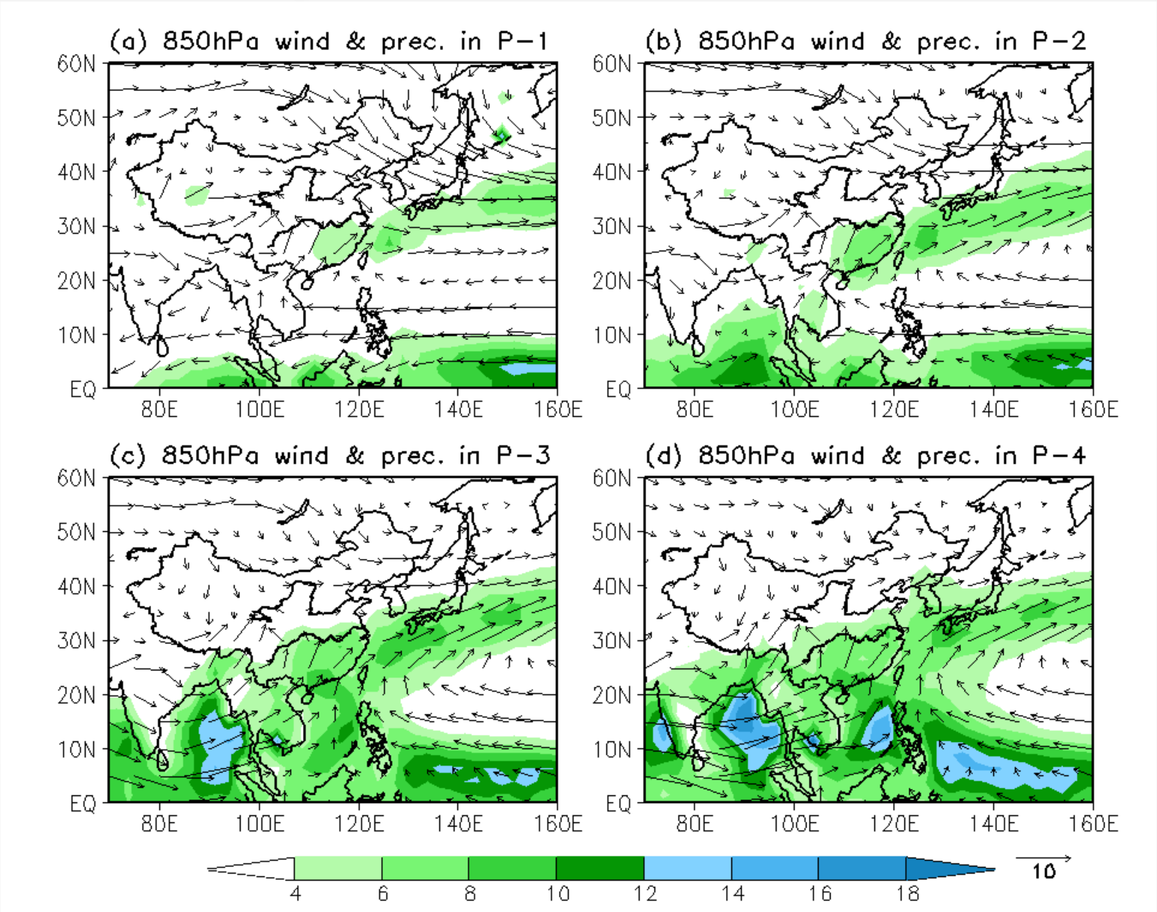




Zhu C., Zhou X J, Zhao P, et al, 2011: Onset of East Asian subtropical summer monsoon and rainy season in China. Sci China Earth Sci,54:1845–1853, doi: 10.1007/s11430-011-4284-0

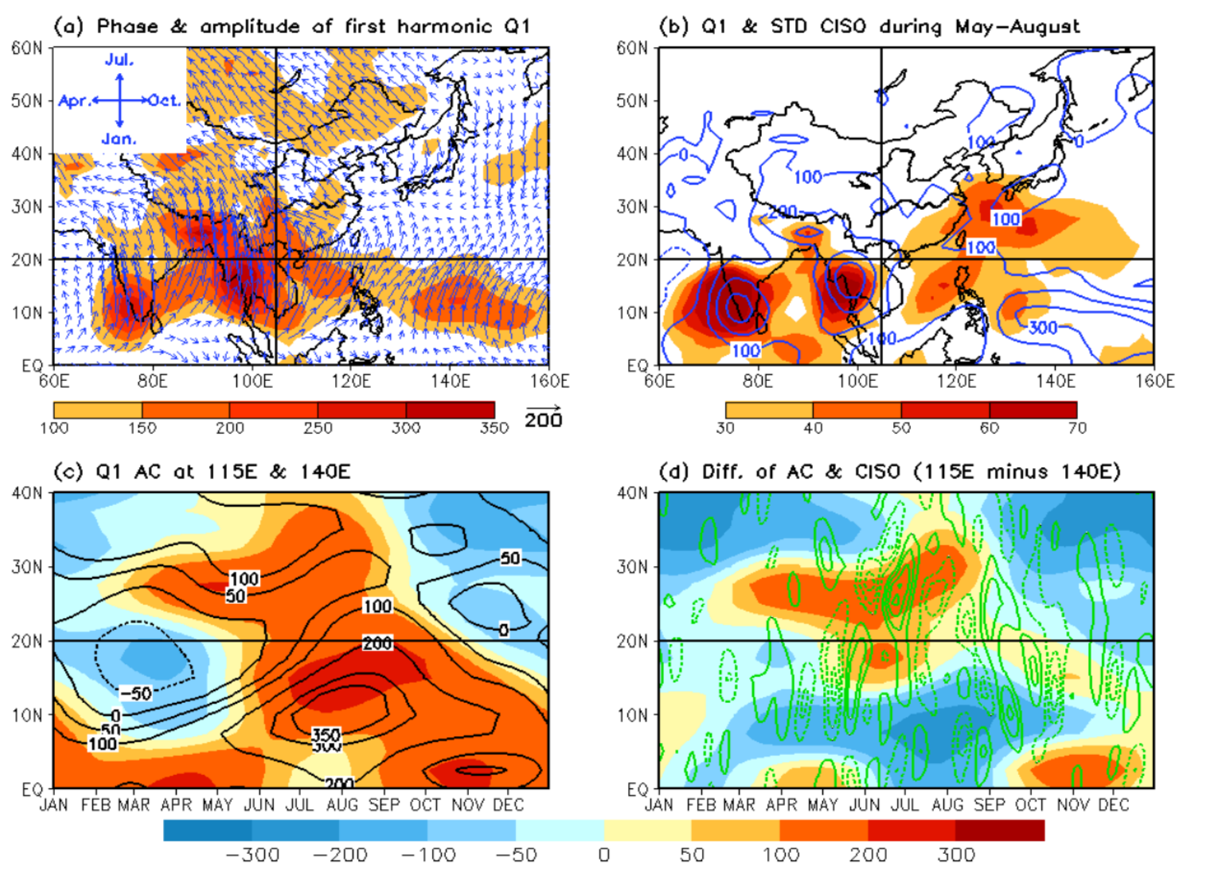
East Asian Summer Monsoon: Seasonal Cycle

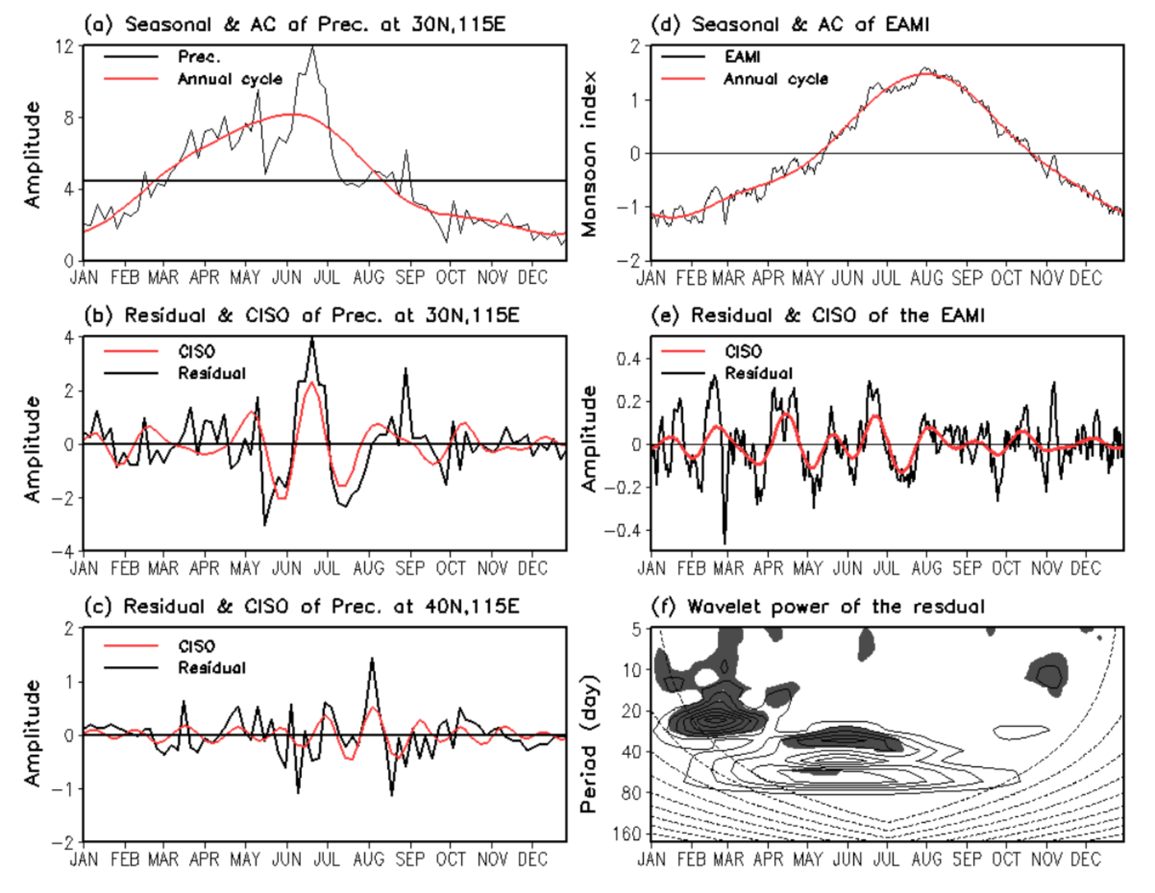




Zhu C., Zhou X J, Zhao P, et al, 2011: Onset of East Asian subtropical summer monsoon and rainy season in China. Sci China Earth Sci,54:1845–1853, doi: 10.1007/s11430-011-4284-0

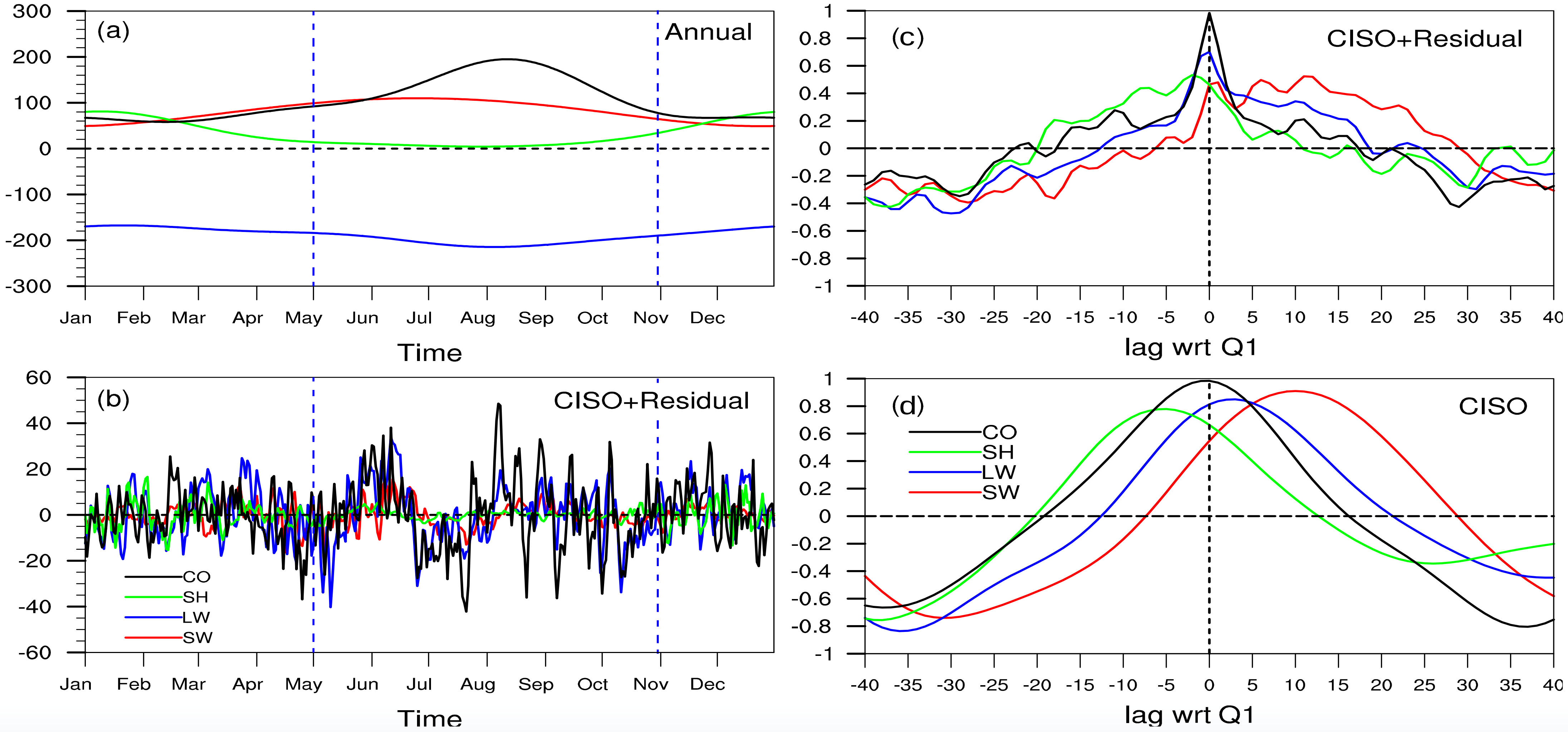
Sub-seasonal Oscillation of EASM in Climatology





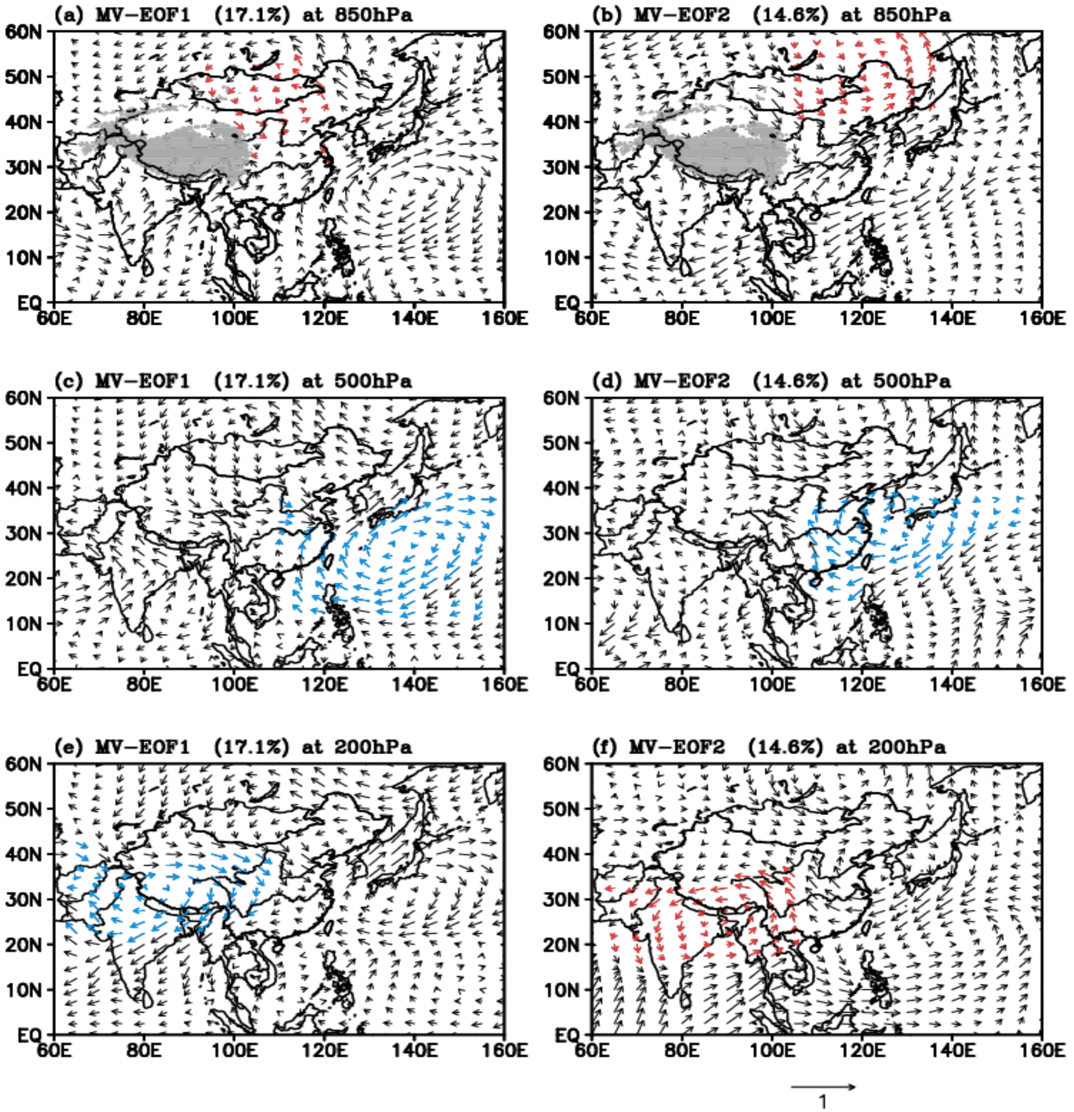
Song, Zehao, Congwen Zhu, Jingzhi Su, and Boqi Liu, 2016: Coupling modes of climatological intraseasonal oscillation in the East Asian summer monsoon. J. Climate, 29 (17), 6363-6382. DOI: 10.1175/JCLI-D-15-0794.1

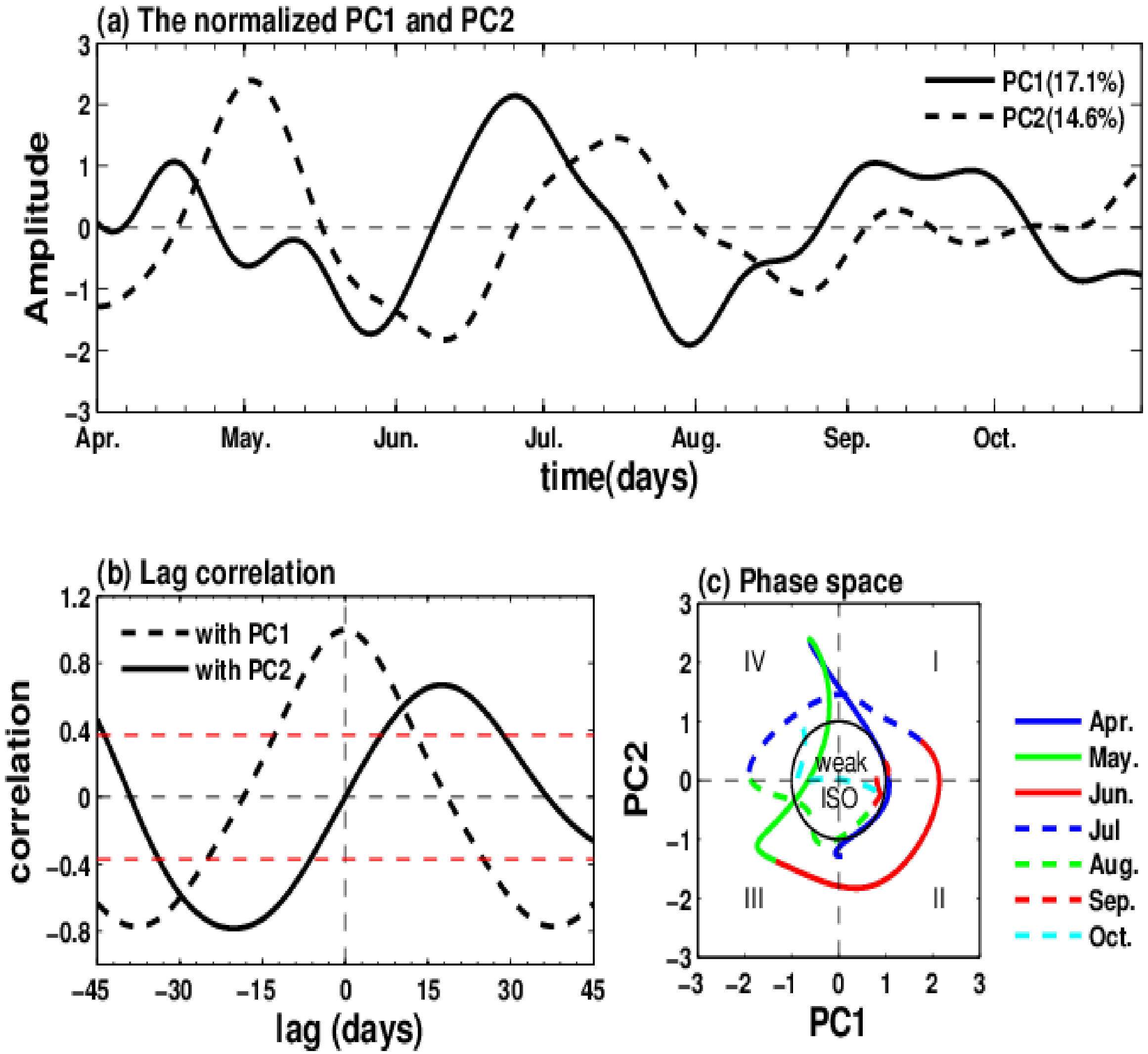
Q1（SH+CO+RC, RC=LW+SW）



Song et al. J.Climate,2016

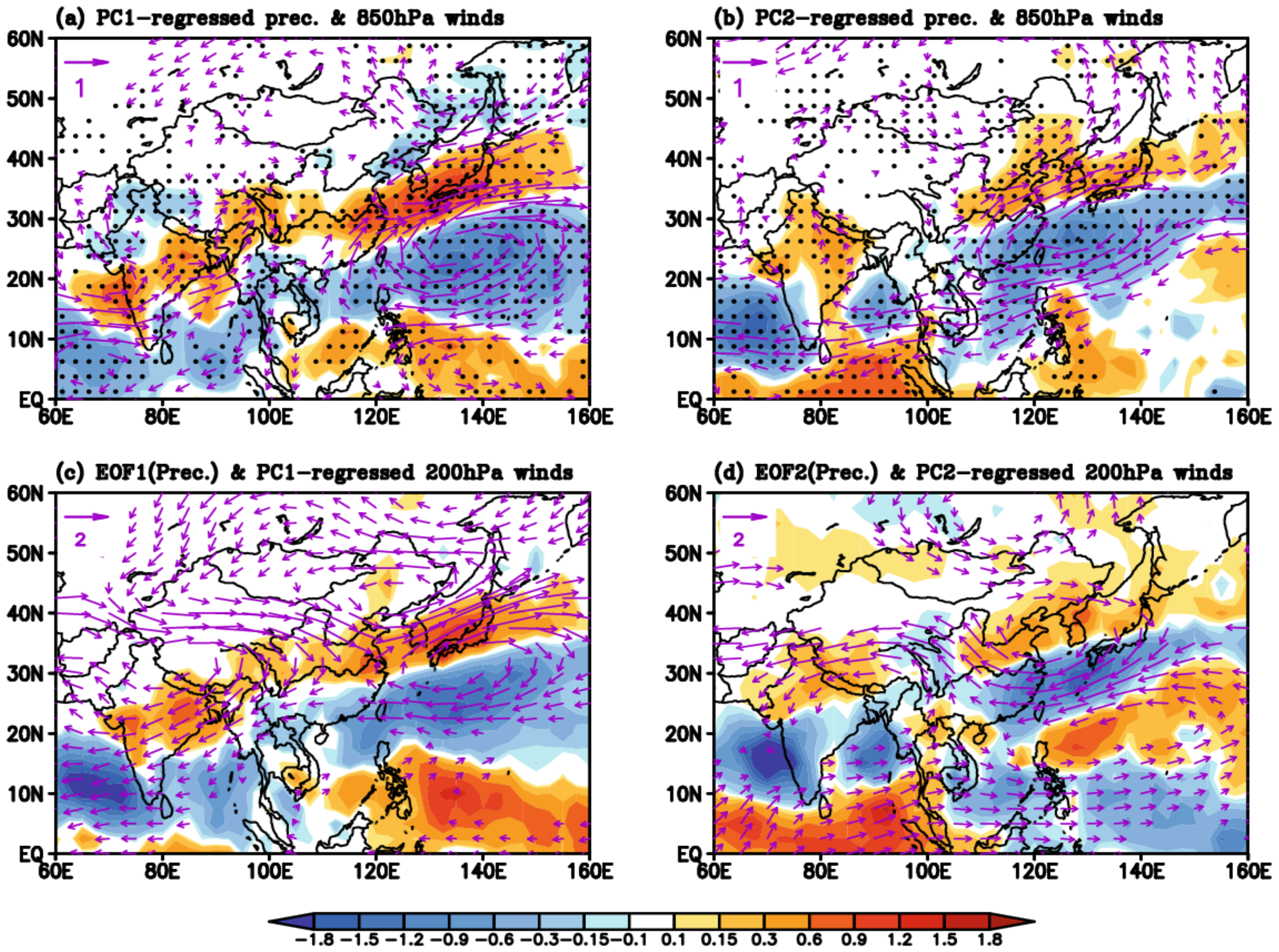
Dominant modes of CISO in EASM





Song et al. J.Climate,2016

Associated with activity of rain-belt

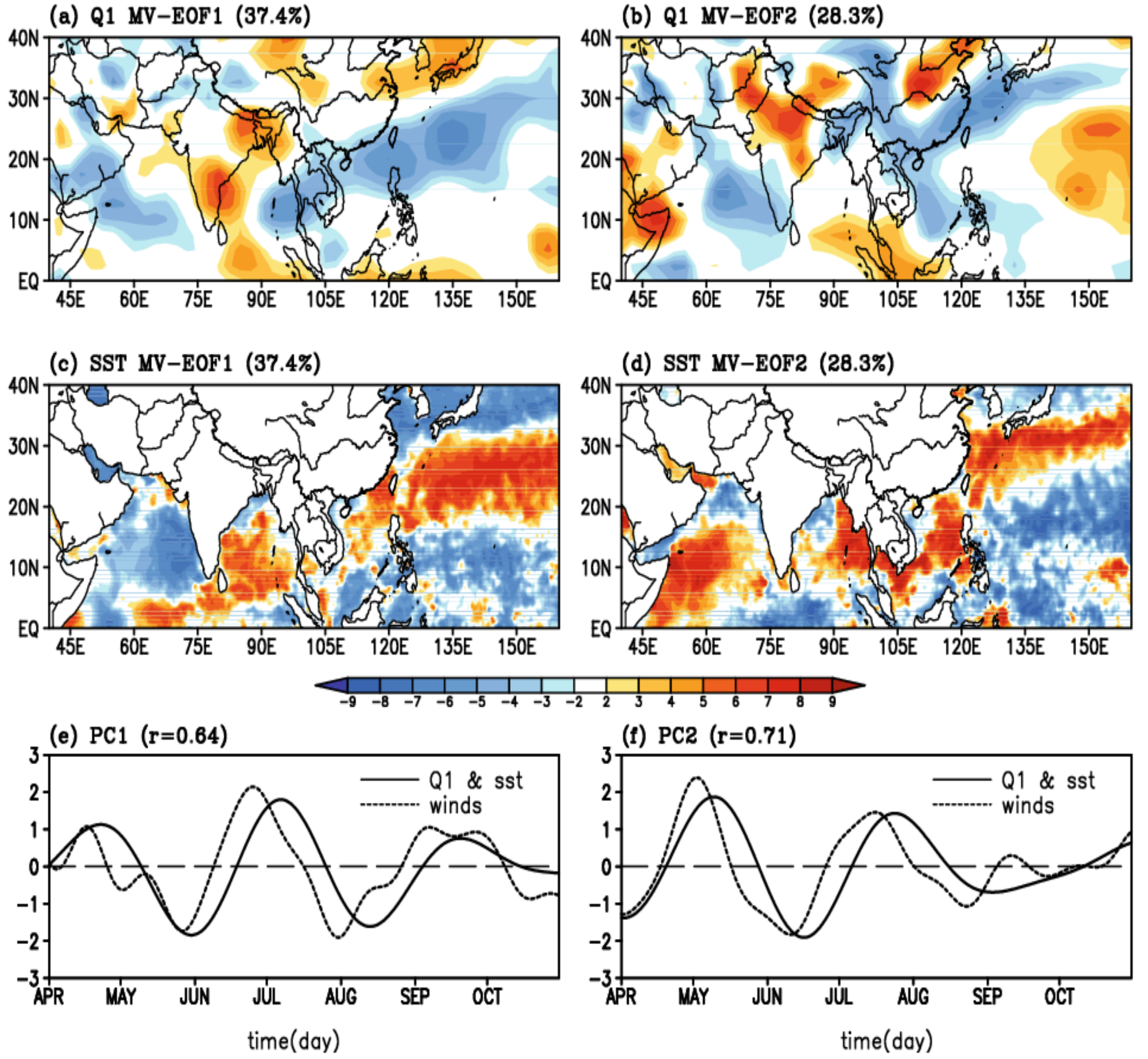


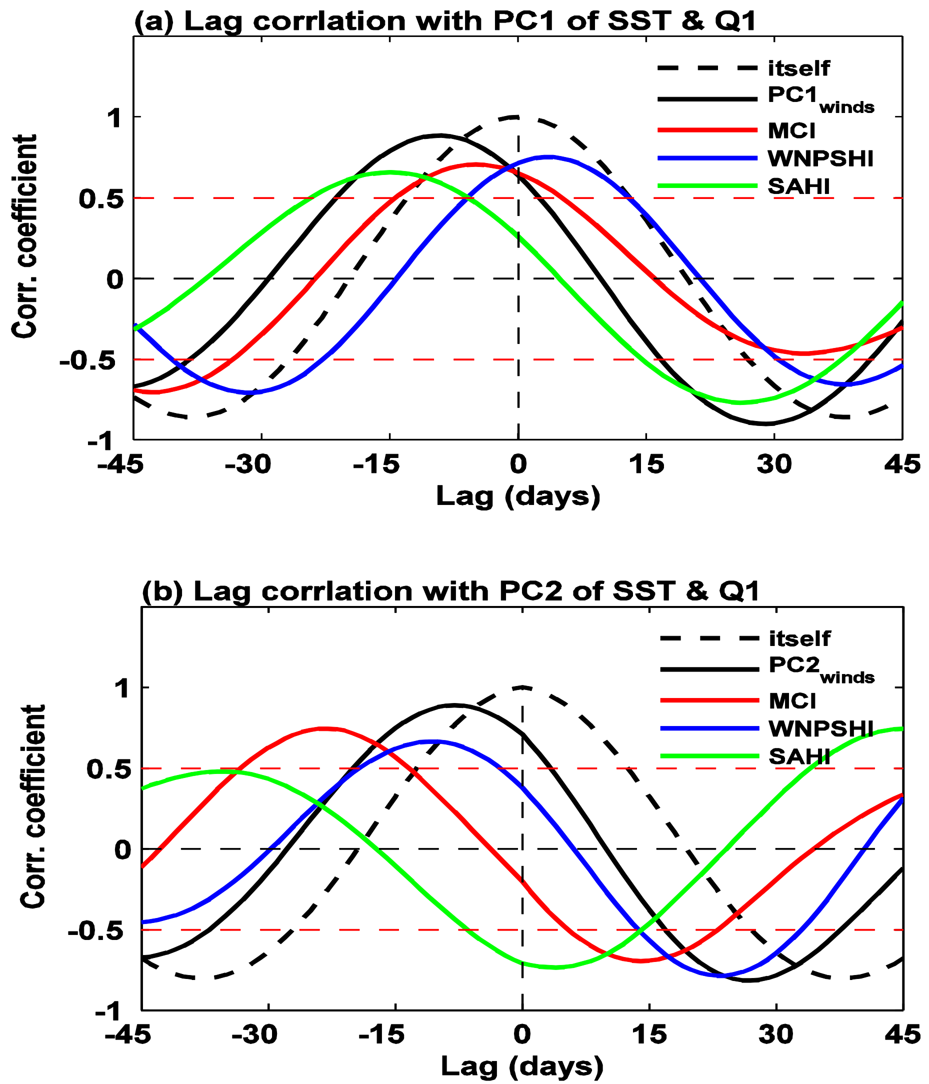
Mode1:
Enhanced MC, WPA, and SAH with triple pattern of rainfall pattern over Asia-Pacific region.

Mode2:
Eastward shift of MC, NW-moved WPA, and weakening of SAH, with dipole rainfall pattern.

Song, Zehao, Congwen Zhu, Jingzhi Su, and Boqi Liu, 2016: Coupling modes of climatological intraseasonal oscillation in the East Asian summer monsoon. J. Climate, 29 (17), 6363-6382. DOI: 10.1175/JCLI-D-15-0794.1

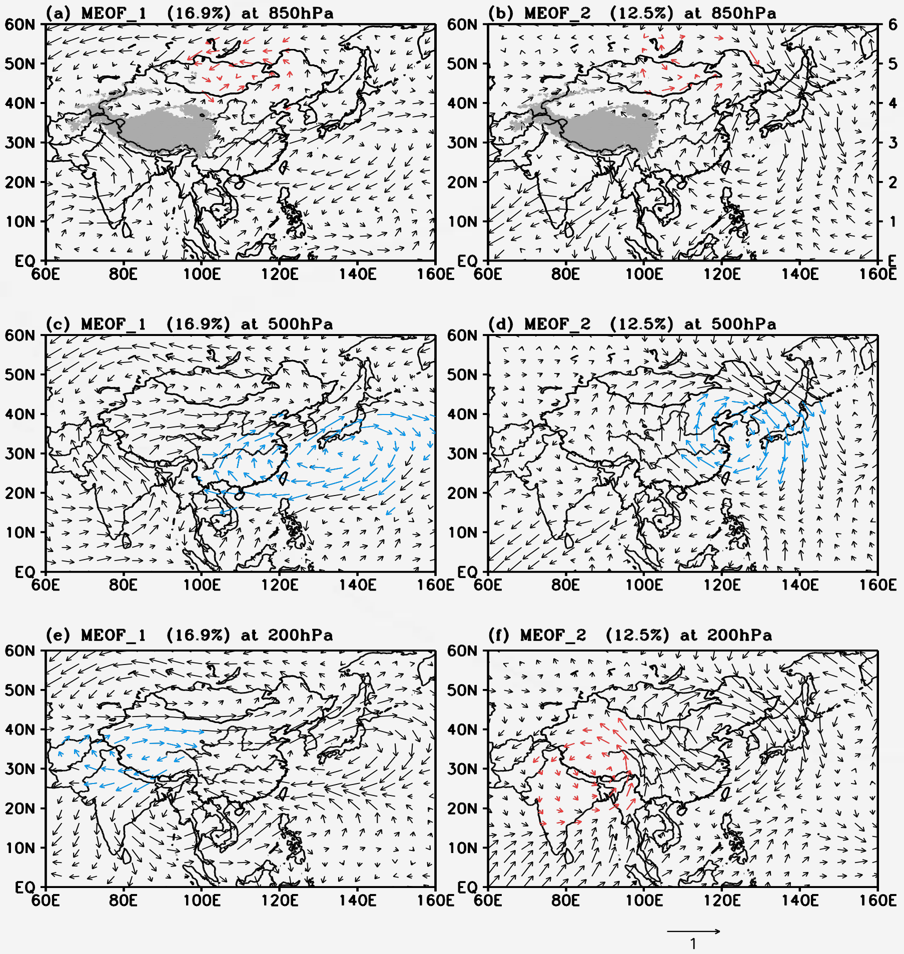
Coupling with air-sea interaction

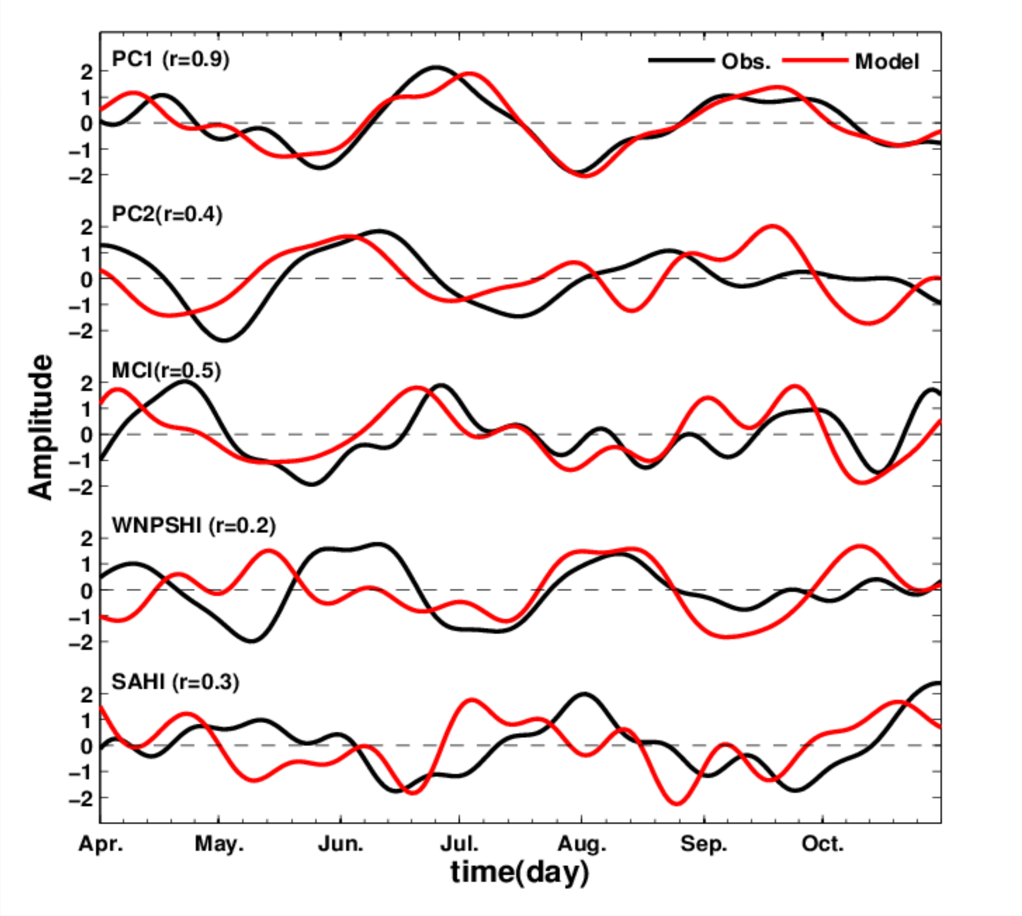




Song et al. J.Climate,2016

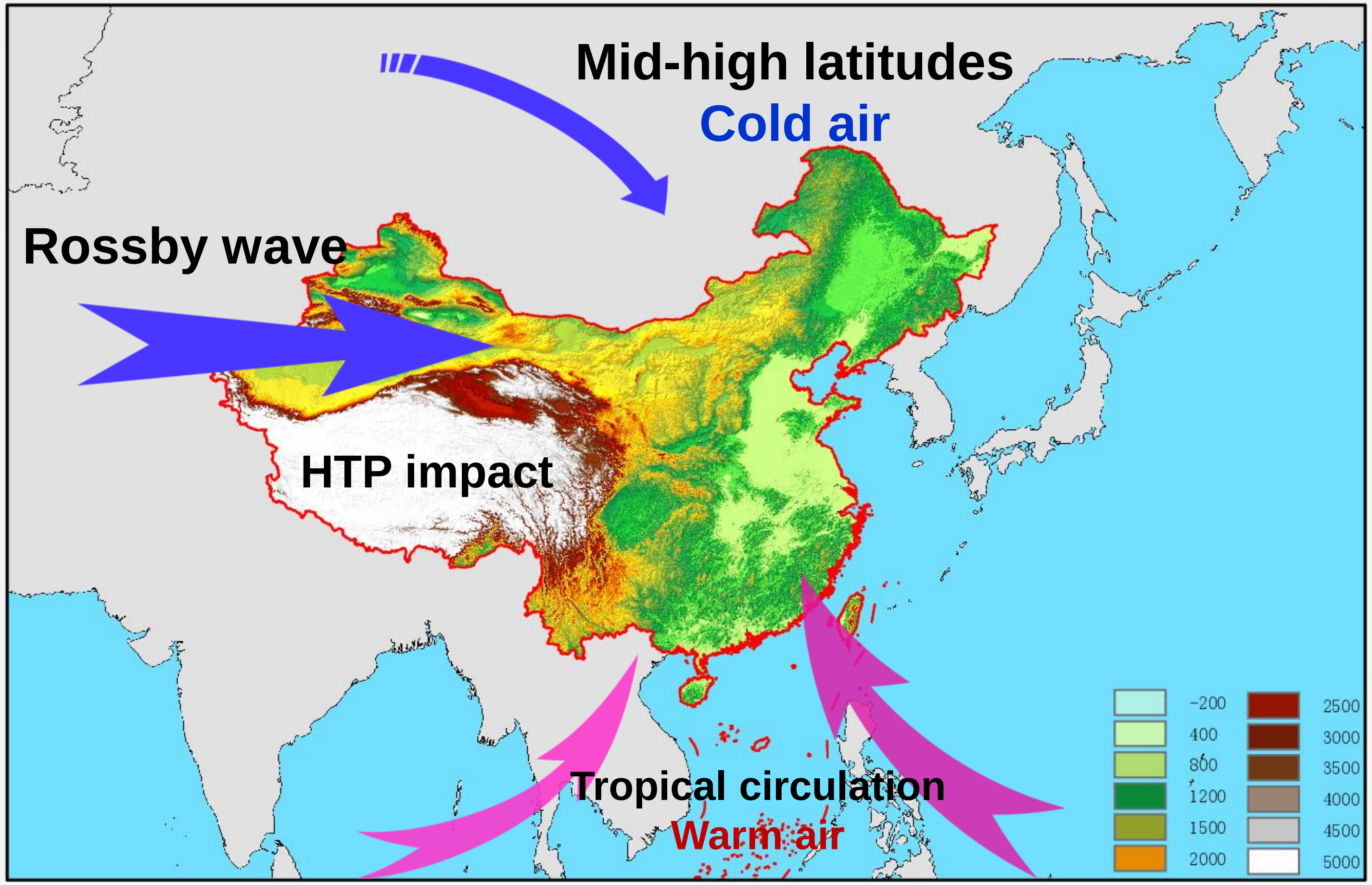
Model simulation（ECHAM5.4）

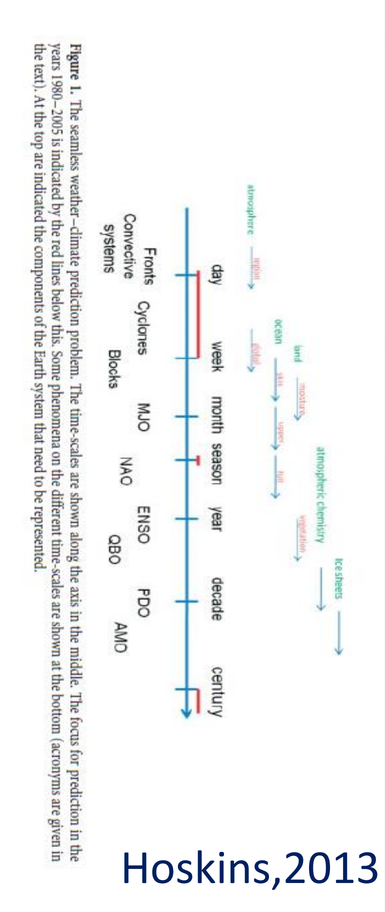




Song Zehao, Congwen Zhu, Jingzhi Su, and Boqi Liu, 2016: Coupling modes of climatological intraseasonal oscillation in the East Asian summer monsoon. J. Climate, DOI: 10.1175/JCLI-D-15-0794.1

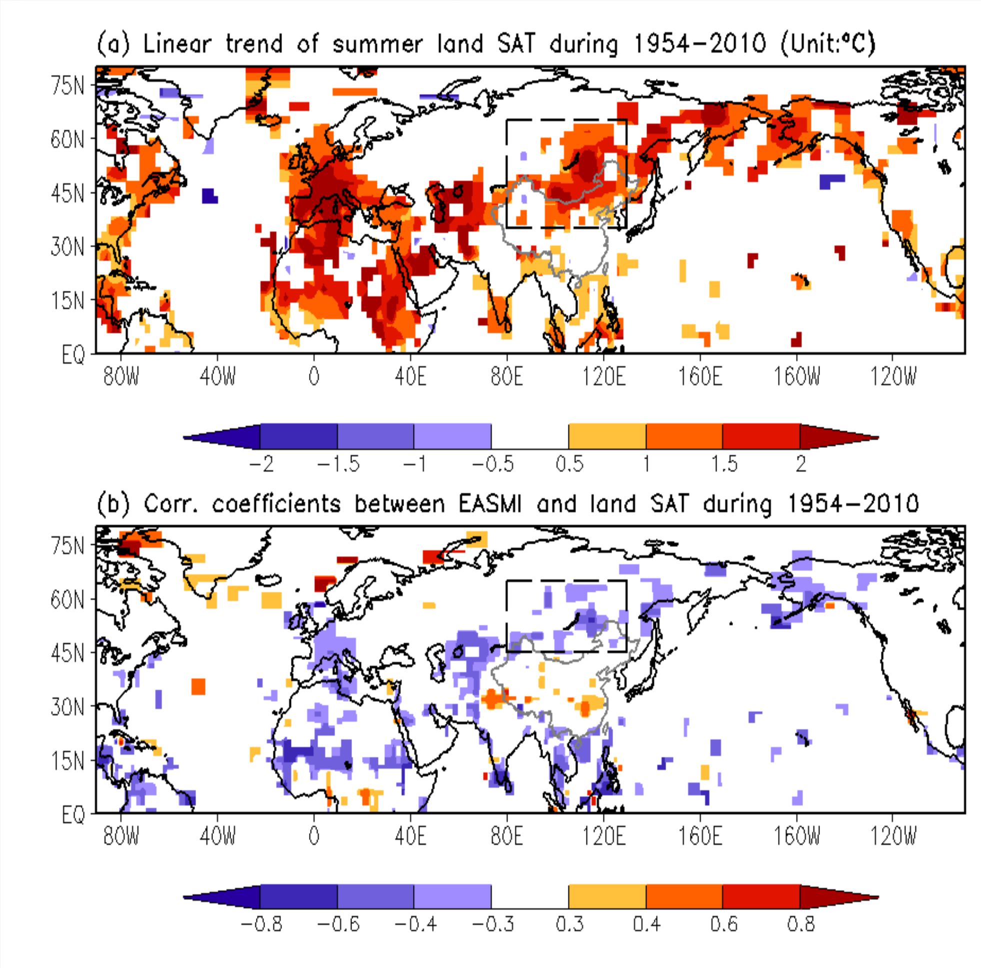
Impact factors of EASM & time scales

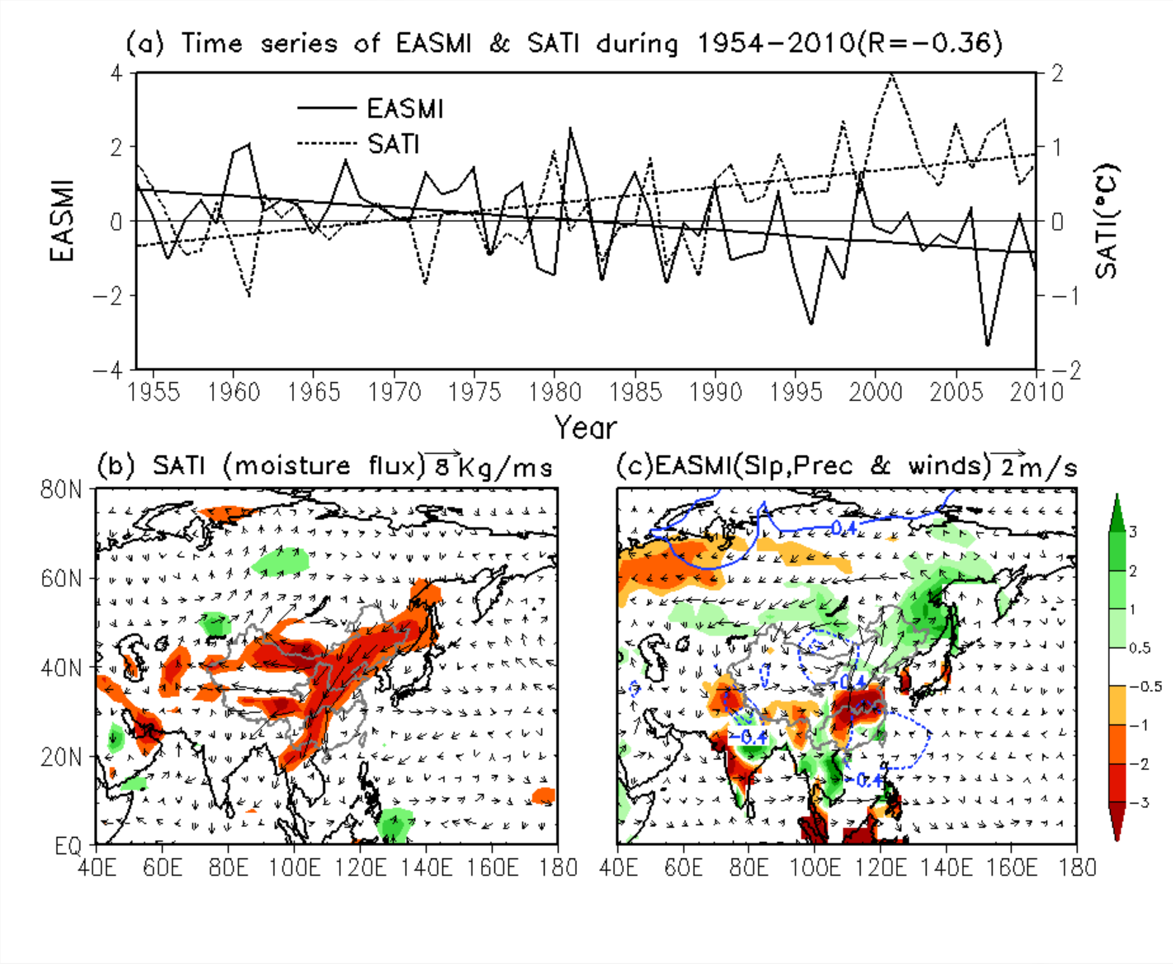




Picture is provided by Dr. Sun Jianqi

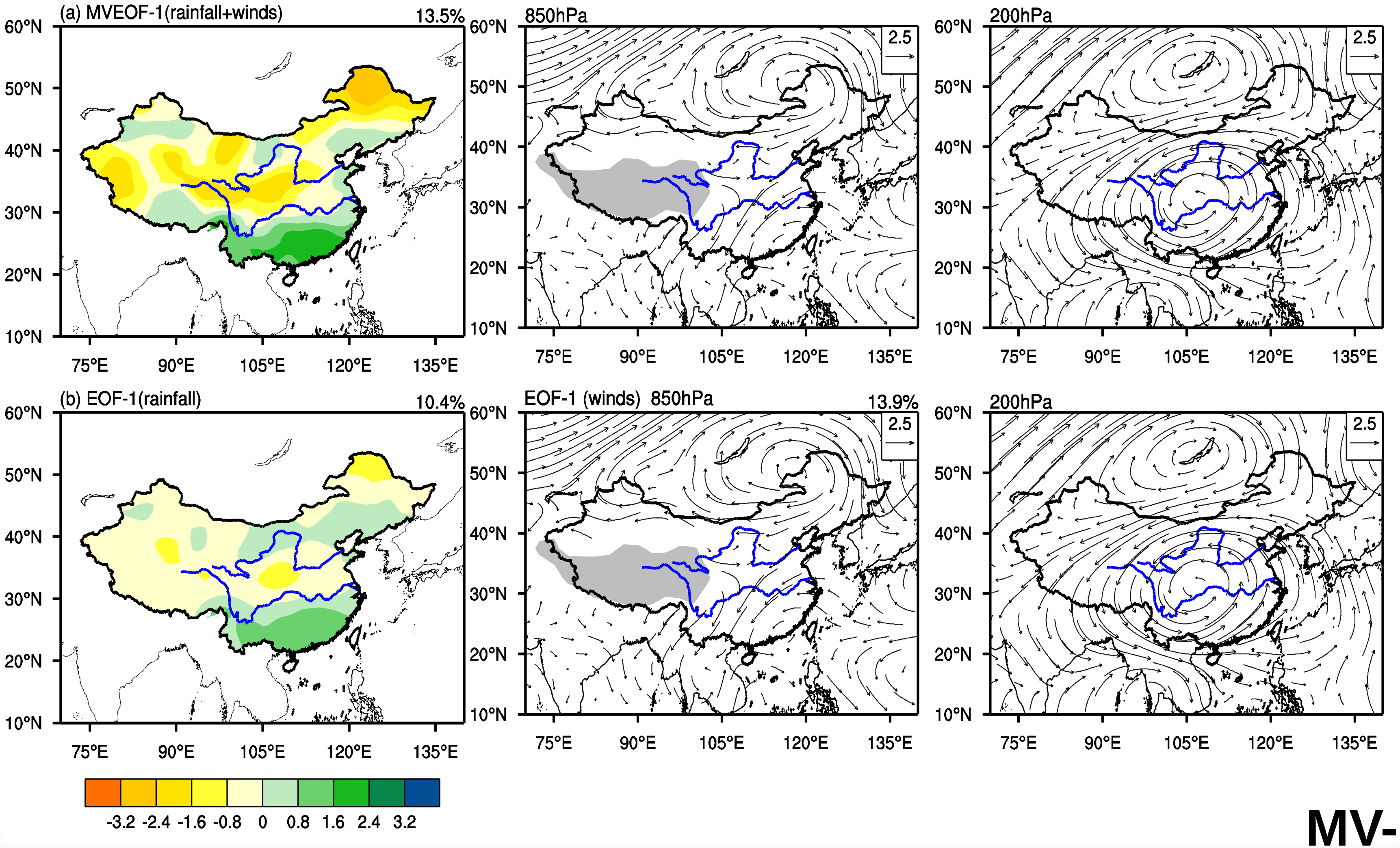
Impact of Global Warming





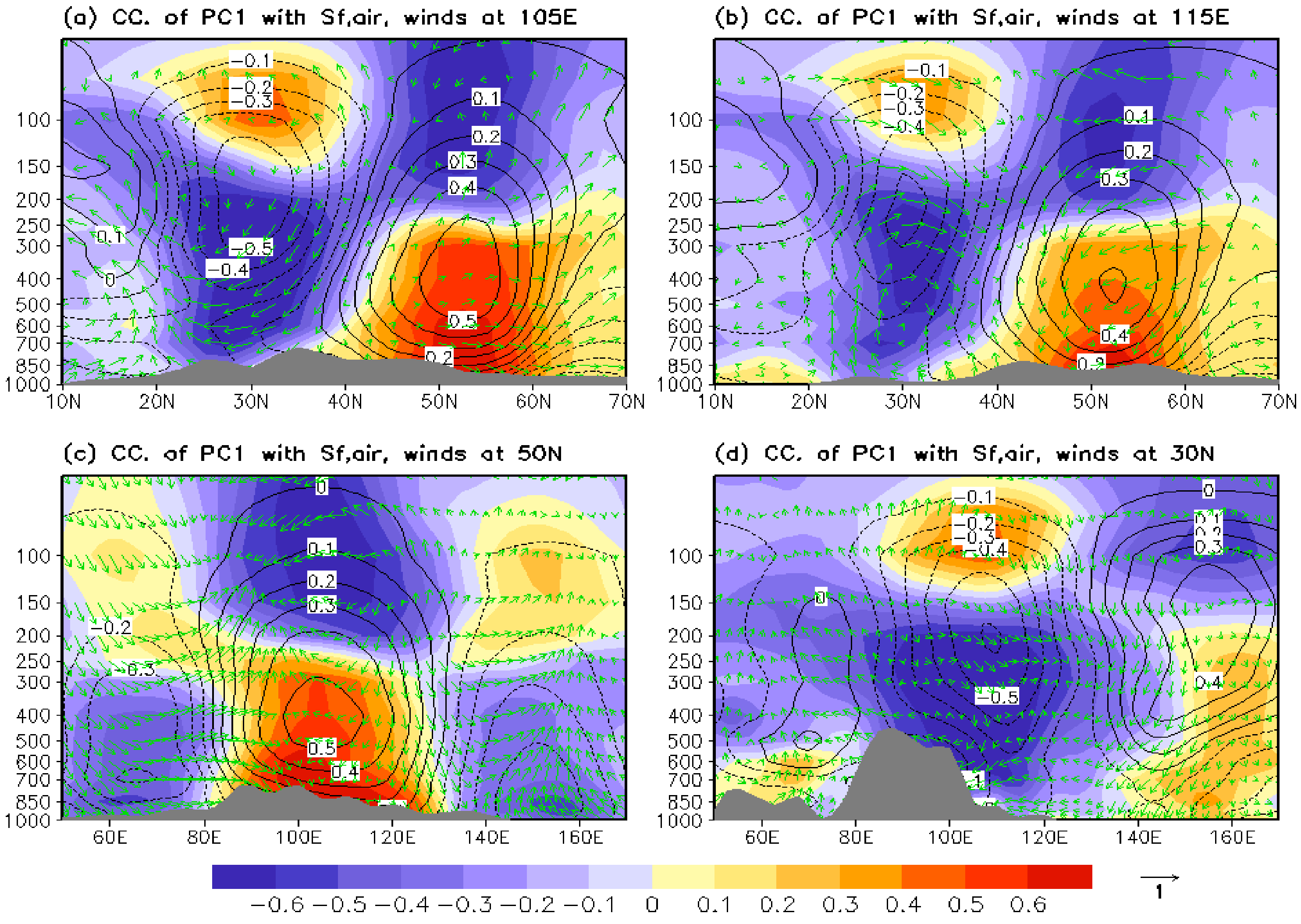
Zhu, C., B. Wang, W. Qian, and B. Zhang, 2012: Recent weakening of northern East Asian summer monsoon: A possible response to global warming, Geophys. Res. Lett., 39, L09701, doi:10.1029/2012GL051155.

Interannual variation of EASM

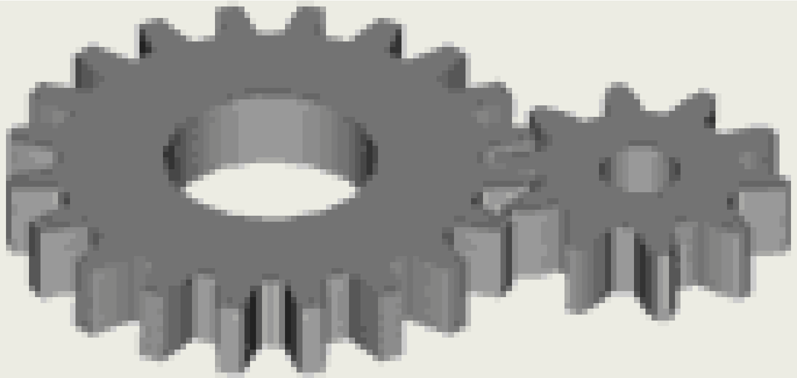


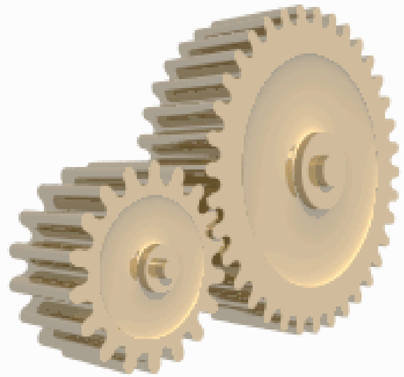
MV-EOF mode1

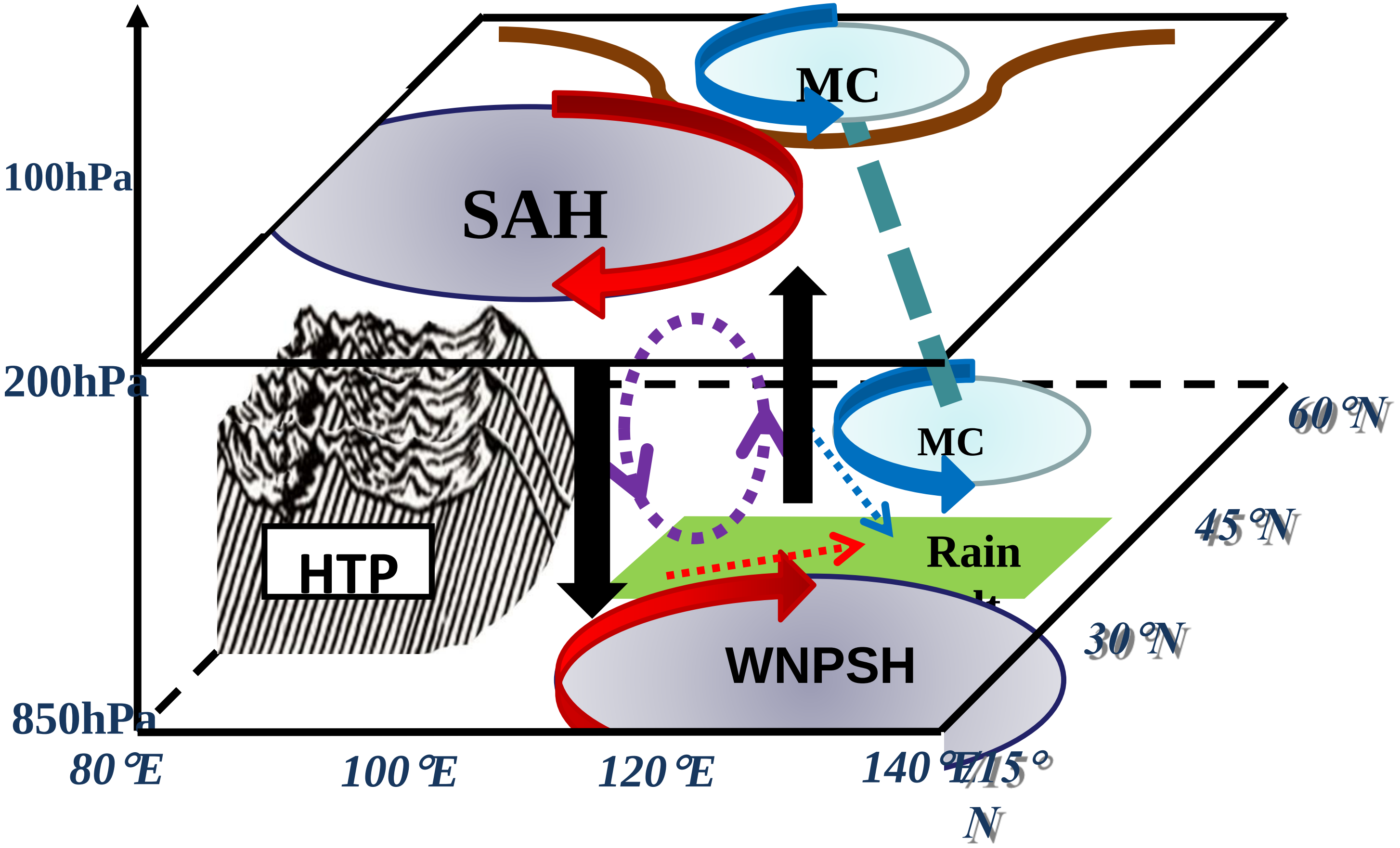
Vertical profile of EASM coupling mode



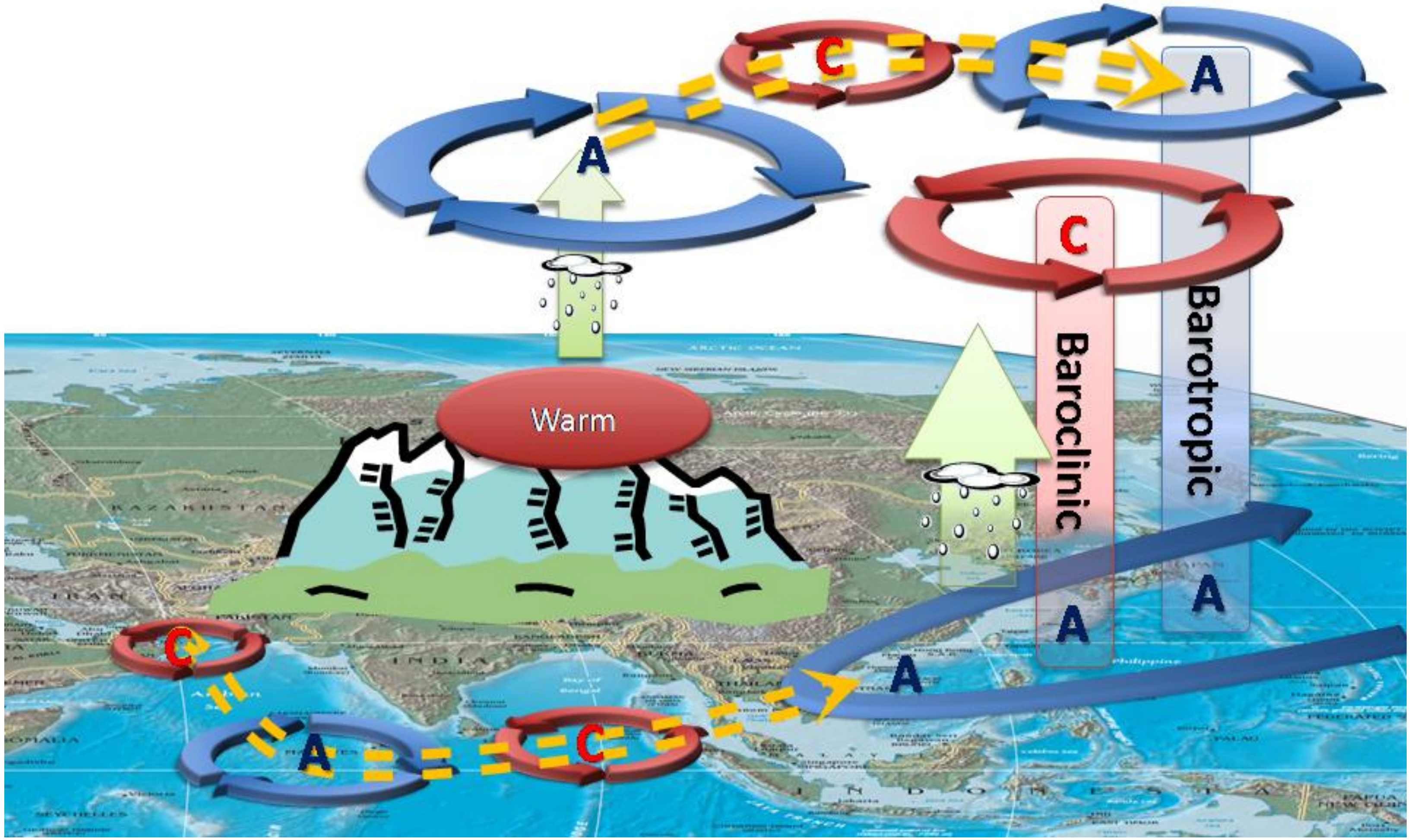
Coupling mode of EASM







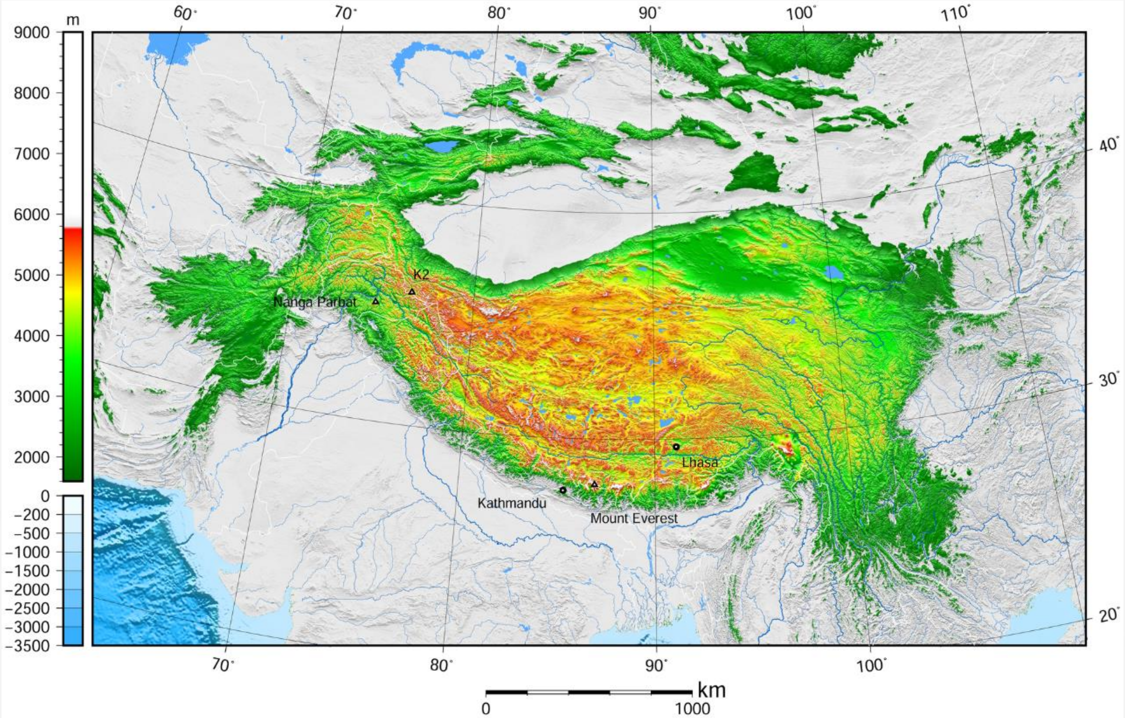
Impacts of HTP heating



Wang, B., Q. Bao, B. Hoskins, G. Wu, and Y. Liu, 2008: Tibetan Plateau warming and precipitation changes in East Asia. *Geophys. Res. Lett.*, **35**, L14702, doi:10.1029/2008GL034330

Impact of snow cover on EASM

Via effect of 1. albedo; 2 hydrology



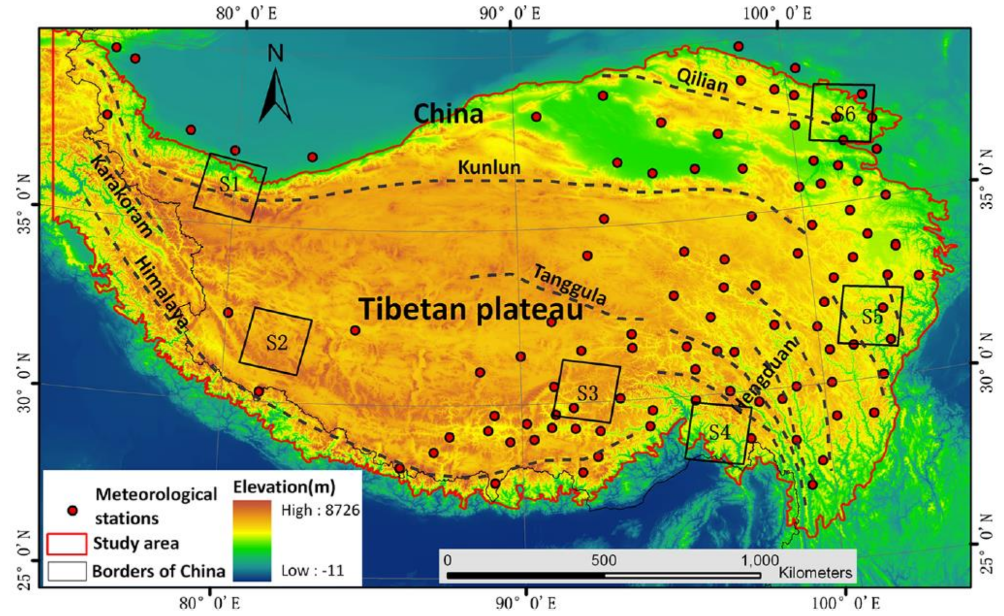


Fig. 1 Location and the extent of the study area. The six black boxes outline the area covered by Landsat scenes show in Table 1.

Zhiguang Tang; Jian Wang; Hongyi Li; Lili Yan J.2013: Spatiotemporal changes of snow cover over the Tibetan plateau based on cloud-removed moderate resolution imaging spectroradiometer fractional snow cover product from 2001 to 2011. Appl. Remote Sens.7(1):073582. doi: 10.1117/1.JRS.7.073582

Annual cycle of snow cover over HTP

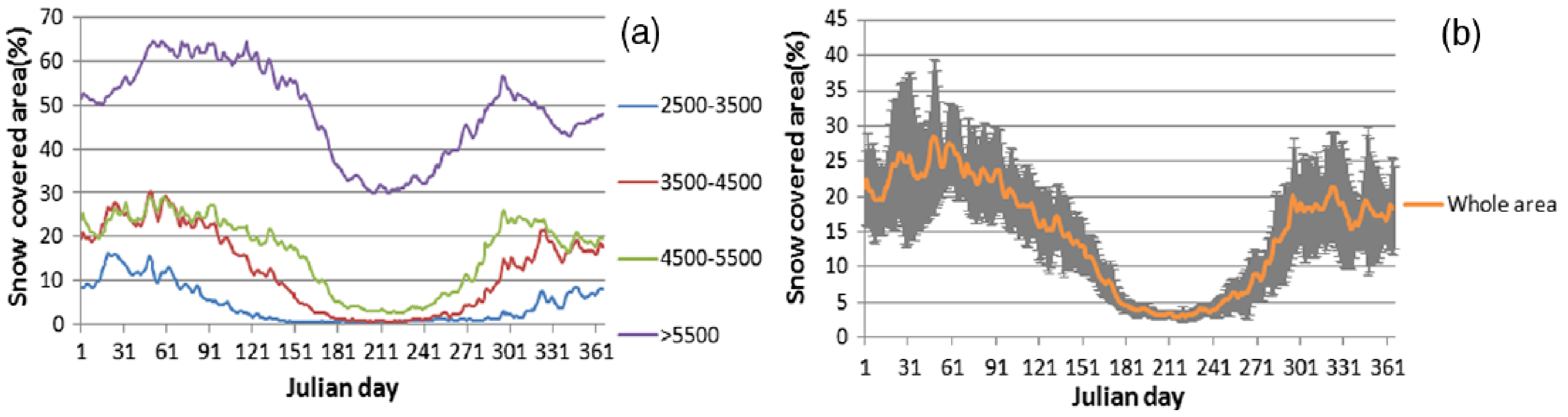


Fig. 6 (a) The annual cycle of snow cover (%) for four different elevation zones and (b) the whole area of the TP. The values are averages of 11 years from 2001 to 2011. The error bars in figure (b) show the standard deviation, indicating the interannual variations of snow cover from 2001 to 2011.

Tang et al., 2013: Journal of Applied Remote Sensing

Trends of snow cover, interannual variation, and its correlation with temperature 2001-2011

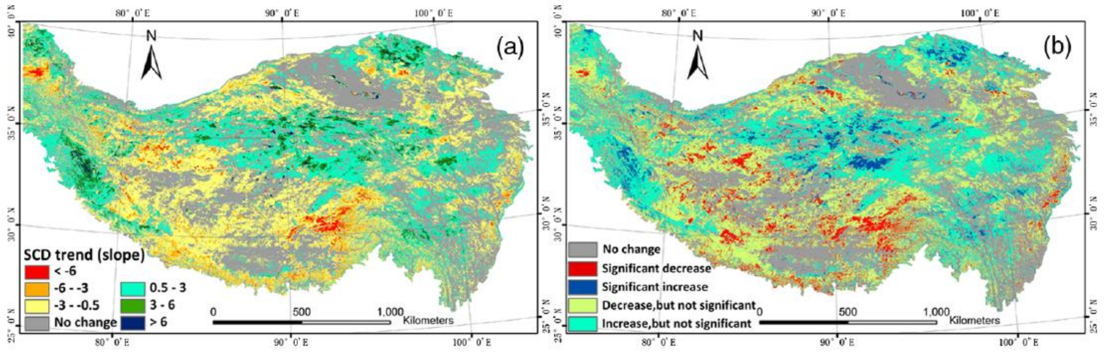


Fig. 8 Snow-covered days (SCD) trend from 2001 to 2011: (a) trend and (b) significance of trend. Trends are termed significant for pixels in which $p < 0.05$.

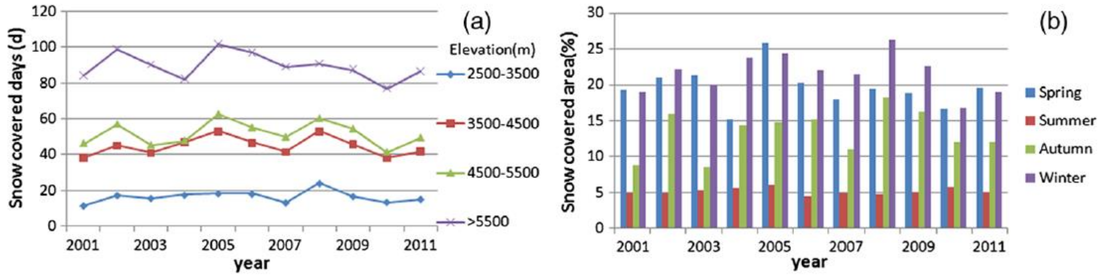


Fig. 9 (a) Inter-annual variation of the average snow-covered days (SCD) for different elevation zones and (b) average snow-covered area (SCA) (%) for different seasons of the whole TP from 2001 to 2011.

Table 3 Pearson correlation coefficients between monthly snow cover and temperature at different elevation zones in the TP from 2001 to 2011.

	Elevations (m)				
Months	<3500	3500 to 4500	4500 to 5500	>5500	Whole
Jan	–0.531	–0.284	–0.599	–0.544	–0.447
Feb	–0.881**	–0.738**	–0.618*	–0.450	–0.708*
Mar	–0.211	–0.209	–0.589	–0.486	–0.386
Apr	–0.315	–0.430	–0.756**	–0.799**	–0.612*
May	–0.71*	–0.640*	–0.838**	–0.770**	–0.699*
Jun	N.A.	0.324	–0.134	–0.389	0.071
Jul	N.A.	N.A.	–0.263	–0.467	–0.277
Aug	N.A.	N.A.	–0.810**	–0.707*	–0.795**
Sep	N.A.	–0.577	–0.793**	–0.821**	–0.592
Qct	–0.544	–0.148	–0.445	–0.520	–0.432
Nov	–0.621*	–0.200	–0.367	–0.326	–0.430
Dec	–0.048	0.122	–0.063	–0.275	0.190

Note: ** and * indicate statistical significance at the 0.01 and 0.05 level, respectively. The periods in which the snow covers are less than 2% are represented by “N.A.” (meaning “not available”).

Tang et al., 2013: Journal of Applied Remote Sensing

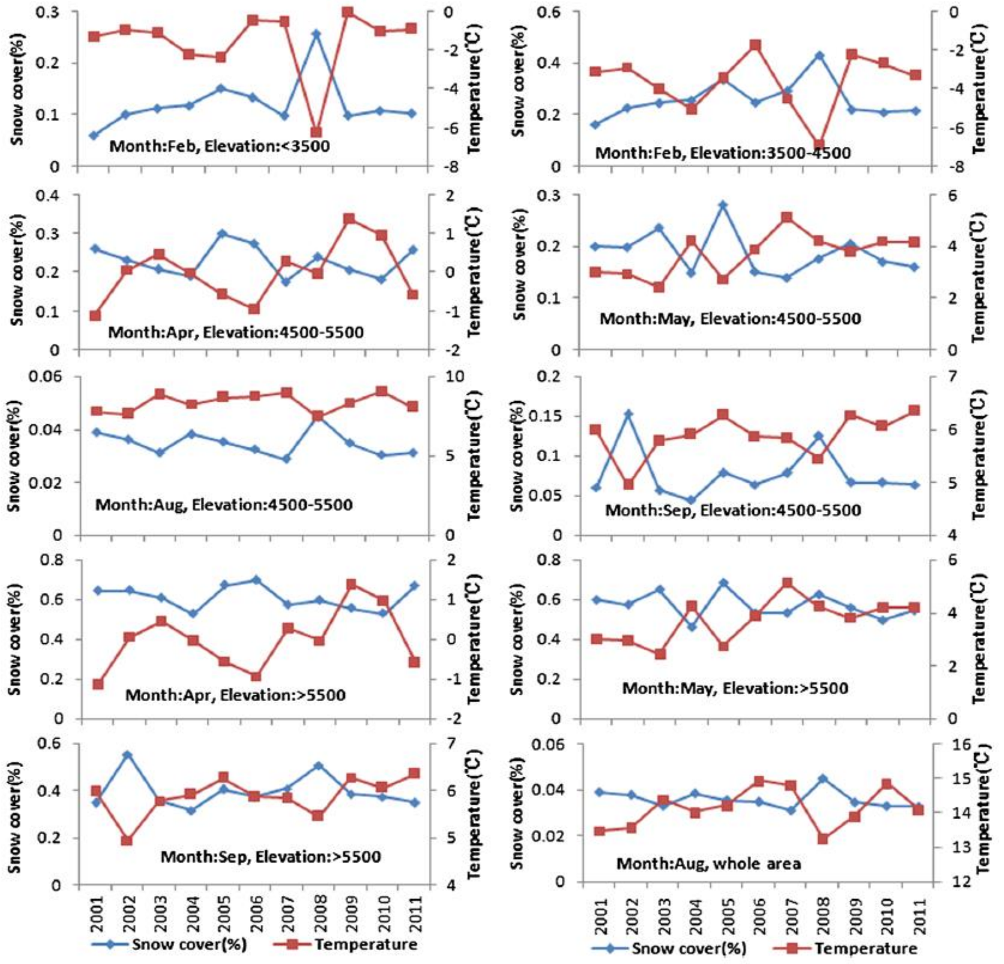


Fig. 10 Variability of snow cover (%) and temperature in the months (and elevation zones) with reasonably high correlation coefficients (statistical significance at the 0.01 level) from 2001 to 2011.

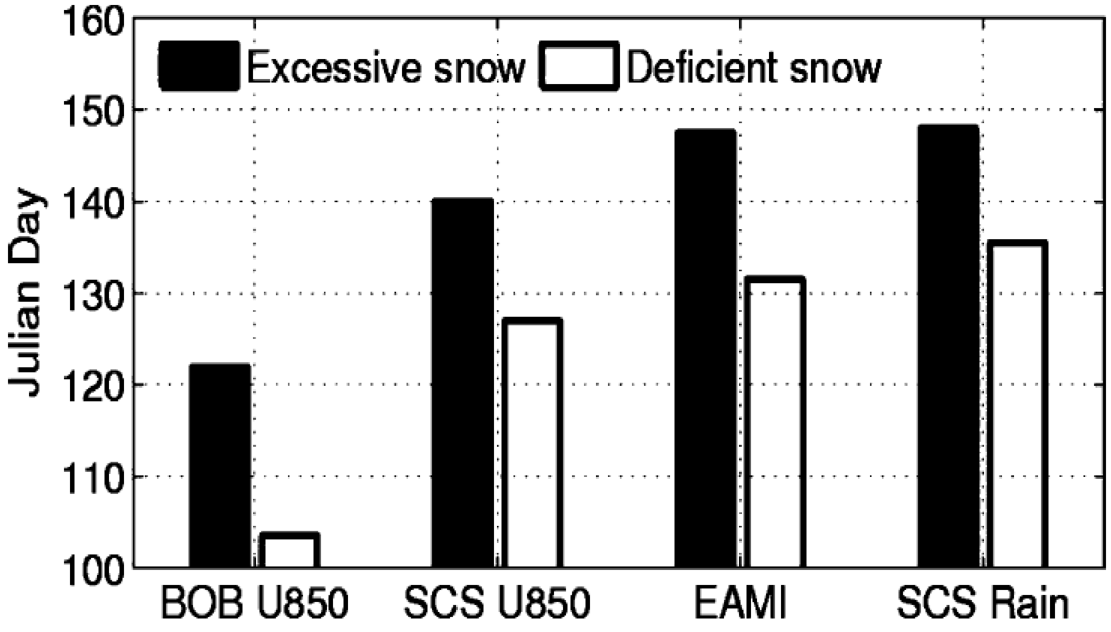
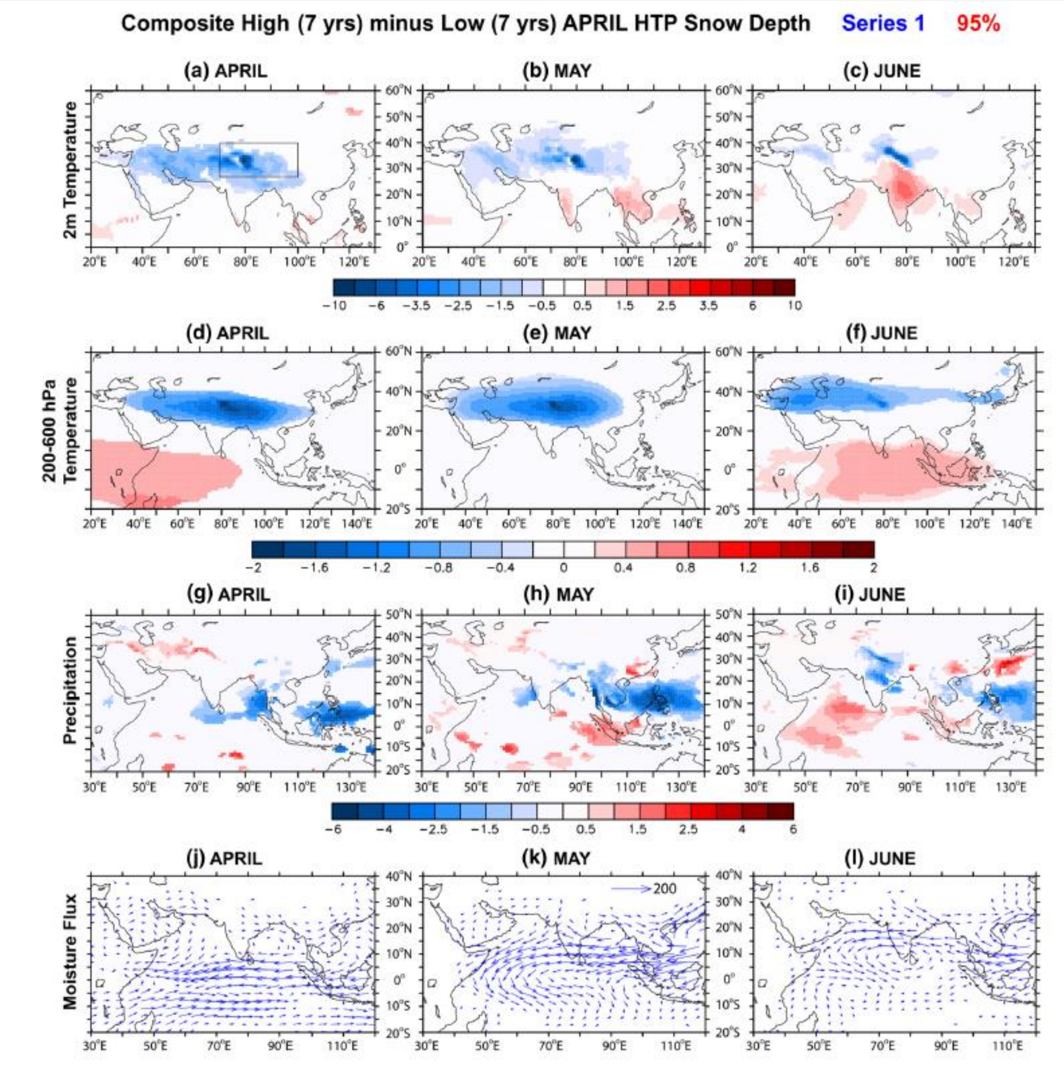
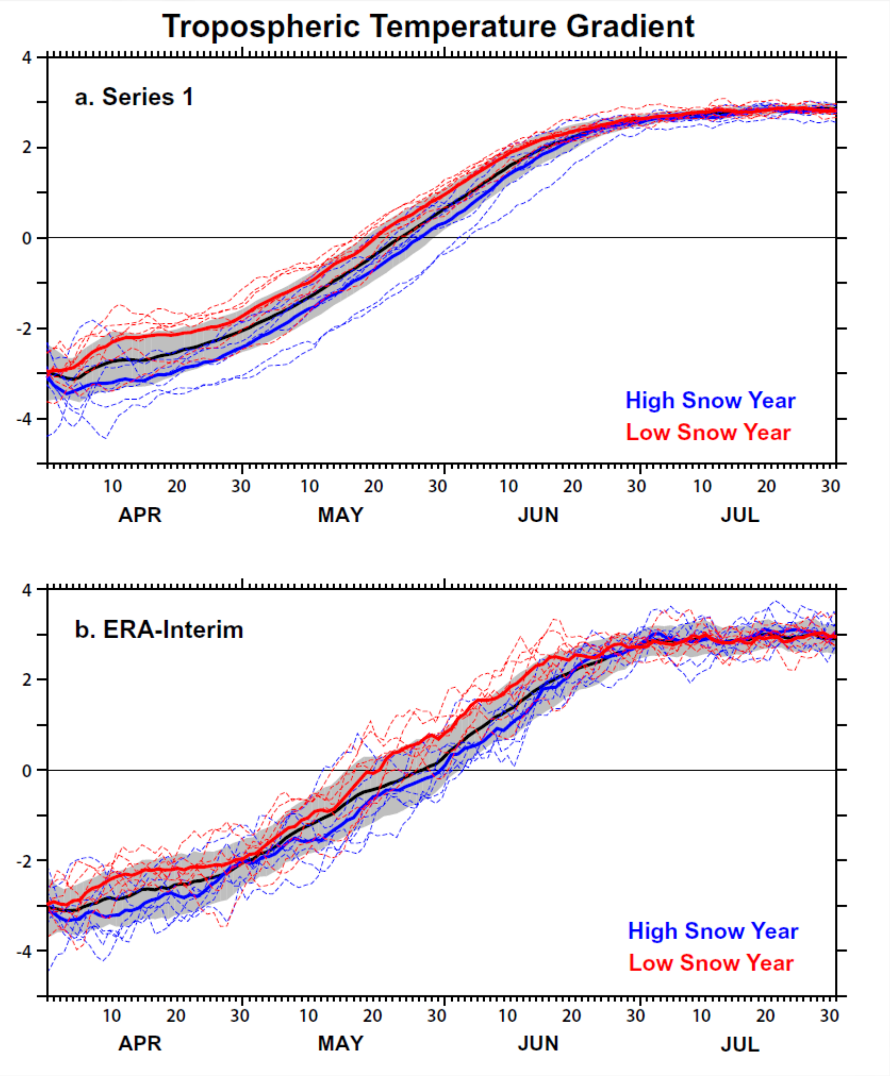


Fig. 14 Mean onset date of EASM in the typical excessive snow (ES, positive anomaly) and deficient snow (DS, negative anomaly) years, based on the different criteria. *First and second column* are the onset date of westerly wind at 850 hPa in the Bay of Bengal (BOB) and the South China Sea (SCS). The *third column* is the onset date of EAMI and *fourth column* is the onset date of intense rainfall over SCS (mean daily rainfall >5 mm/day based on the TRMM 3B42 dataset)

Tang et al., 2013: Journal of Applied Remote Sensing

Pu and Xu., 2008: Theor Appl Climatol





[Senan et al., 2016: Impact of springtime Himalayan–Tibetan Plateau snowpack on the onset of the Indian summer monsoon in coupled seasonal forecasts]. Climate Dynamics

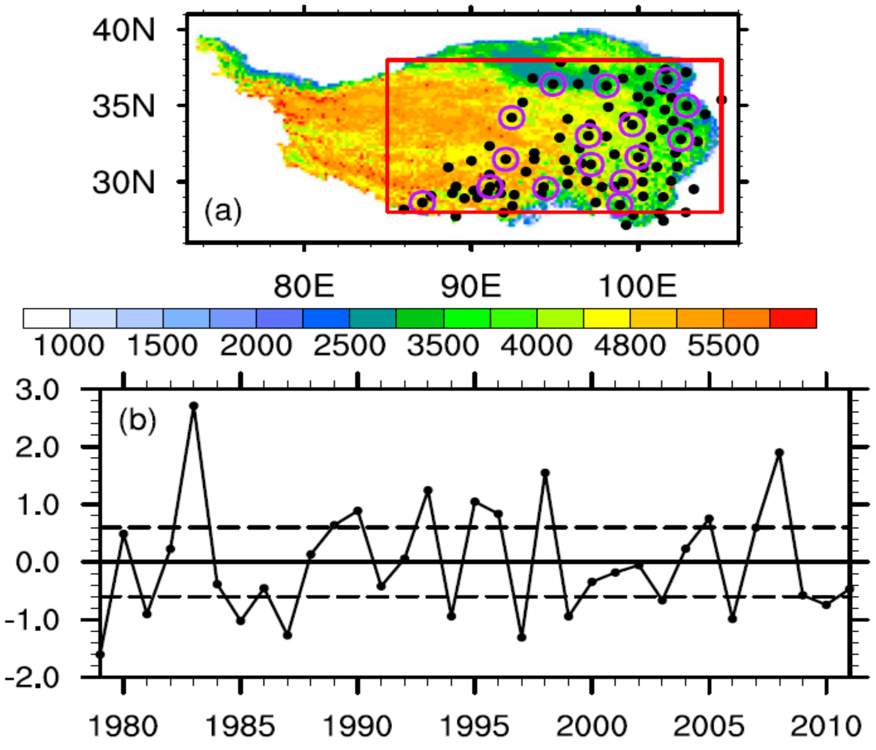


FIG. 1. (a) Spatial distribution of 92 surface meteorological stations (black dots) including 16 radiosonde stations (purple open circles), across the TP. The red rectangle represents the central and eastern TP (28°–38°N, 85°–105°E). The colored shading denotes topography ≥ 1000 m above sea level. (b) Time series of the standardized winter NSCD index, averaged across the 92 stations (Fig. 1a, black dots) over the TP from 1979 to 2011 with the linear trend removed. The dashed lines indicate ±0.6 standard deviations.

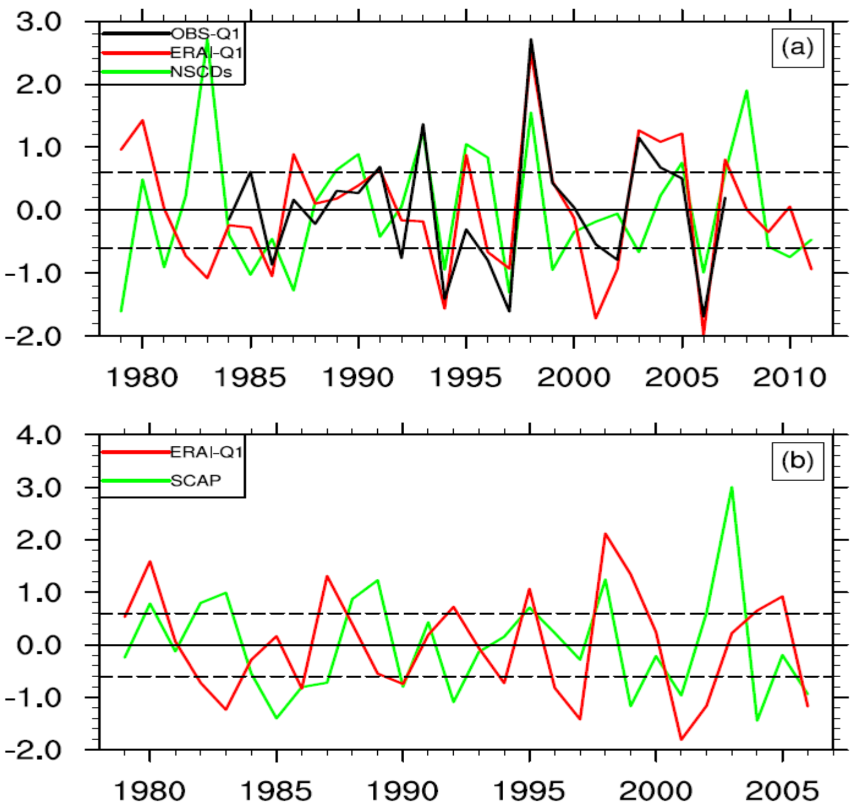


FIG. 7. The standardized interannual time series of the atmospheric apparent heat source and NSCD and SCAP indices across the TP: (a) NSCD index in winter (green line), summer ERA-Interim Q_1 (red line), and summer atmospheric heat source–sink (black line) over the central and eastern TP (ERA-Interim Q_1 interpolated to the 92 stations by bilinear interpolation); and (b) SCAP index over the western TP and Himalayas (green line) in May and the summer Q_1 (red line), averaged from the grid points with altitude >3000 m. Dashed lines indicate ±0.6 standard deviations.

Zhixiang Xiao and Anmin Duan, 2016: Impacts of Tibetan Plateau snow cover on the interannual variability of the East Asian summer monsoon. J. Climate, *DOI:* http://dx.doi.org/10.1175/JCLI-D-16-0029.1

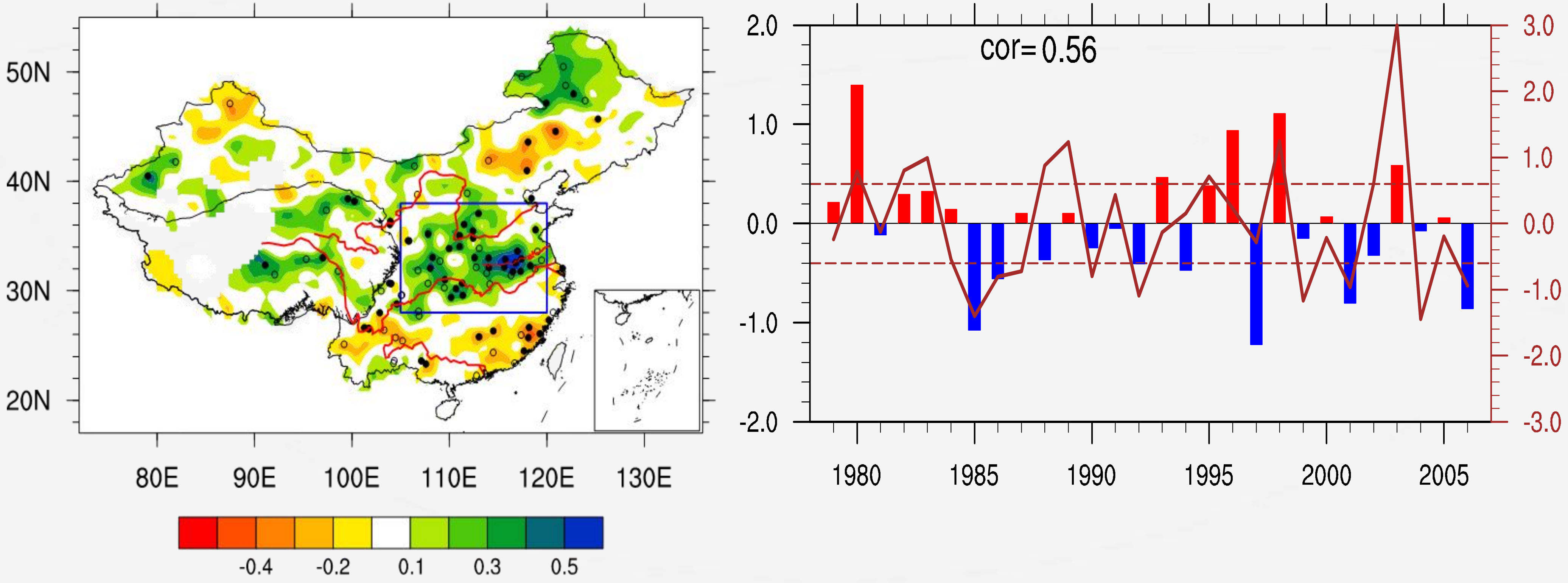
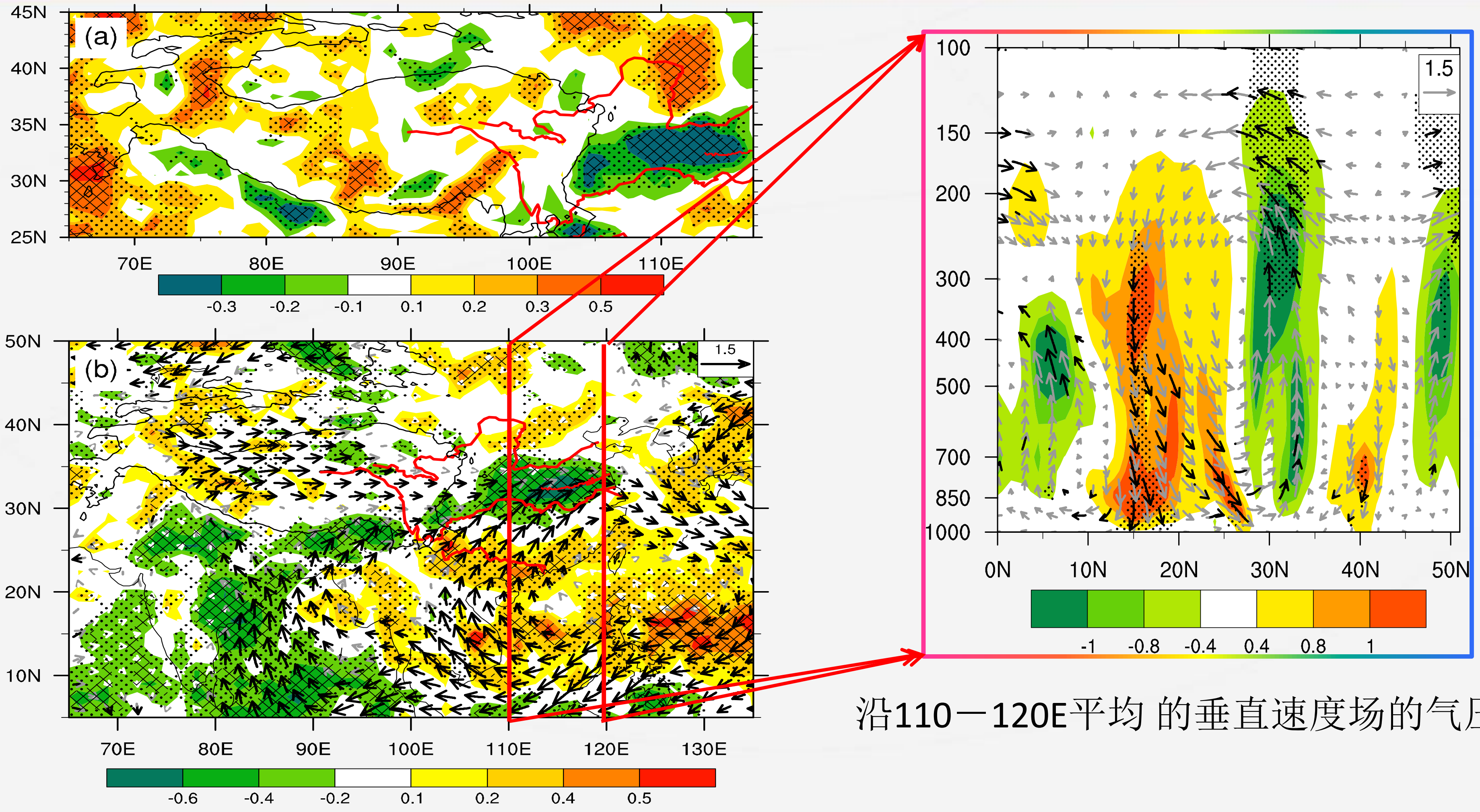


Fig.9a & Fig.10 Correlation of snow cover area proportion (SCAP) index in May with summer rainfall in China during 1979-2006

Zhixiang Xiao and Anmin Duan, 2016: Impacts of Tibetan Plateau snow cover on the interannual variability of the East Asian summer monsoon. J. Climate, *DOI:* http://dx.doi.org/10.1175/JCLI-D-16-0029.1

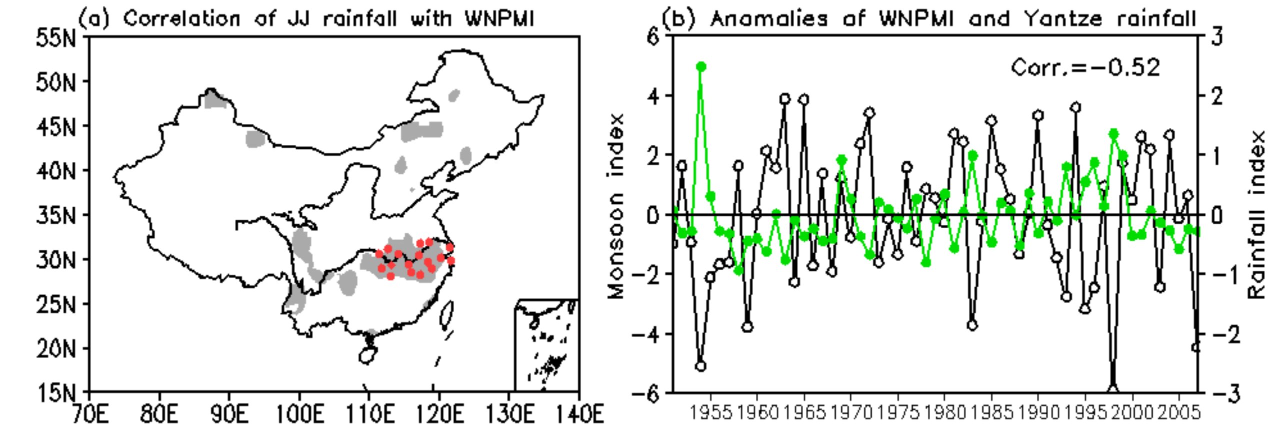


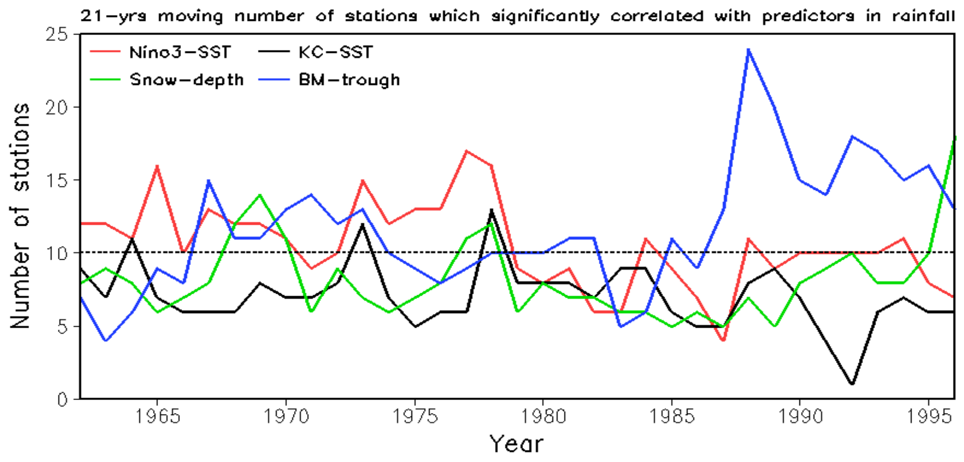
沿110－120E平均 的垂直速度场的气压－纬度剖面

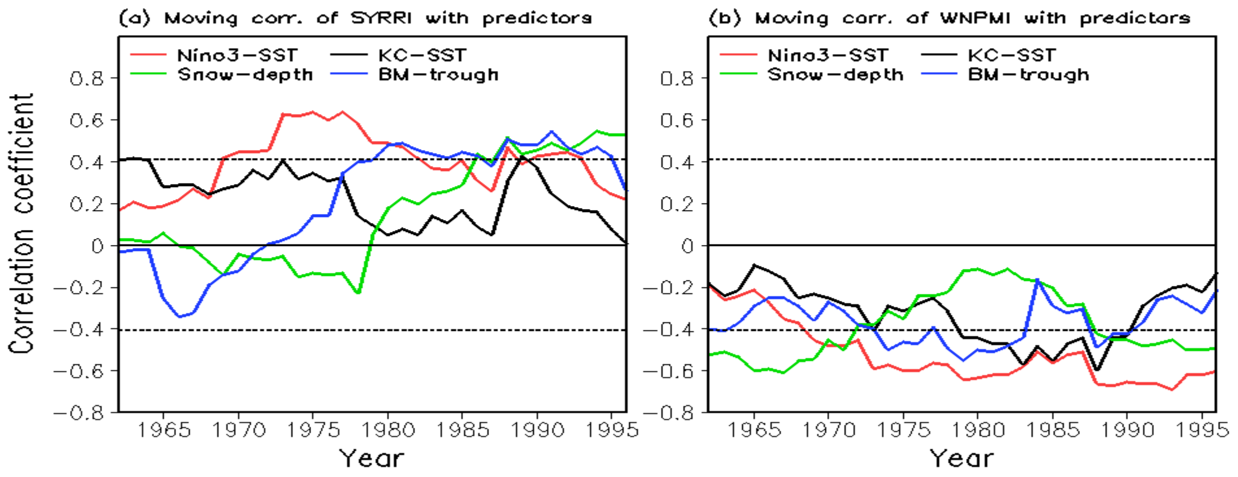
1979-2006年高原5月积雪指数SCAP回归的夏季地表蒸散发（a, 单位：mm/day），整层积分水汽通量（b, 矢量, 单位：kg m^{-1} s^{-1}）以及水汽通量散度（b, 阴影, 单位：10^{-5} kg s^{-1} m^{-2}）。矢量箭头表示通过95%的置信水平。

Zhixiang Xiao and Anmin Duan, 2016: Impacts of Tibetan Plateau snow cover on the interannual variability of the East Asian summer monsoon. J. Climate, *DOI:* http://dx.doi.org/10.1175/JCLI-D-16-0029.1

Unstable relationship between snow depth & rainfall







In contrast to Nino3 SST index, snow depth over the HTP region is not a good predictor used for seasonal rainfall forecast in EASM.

Summary

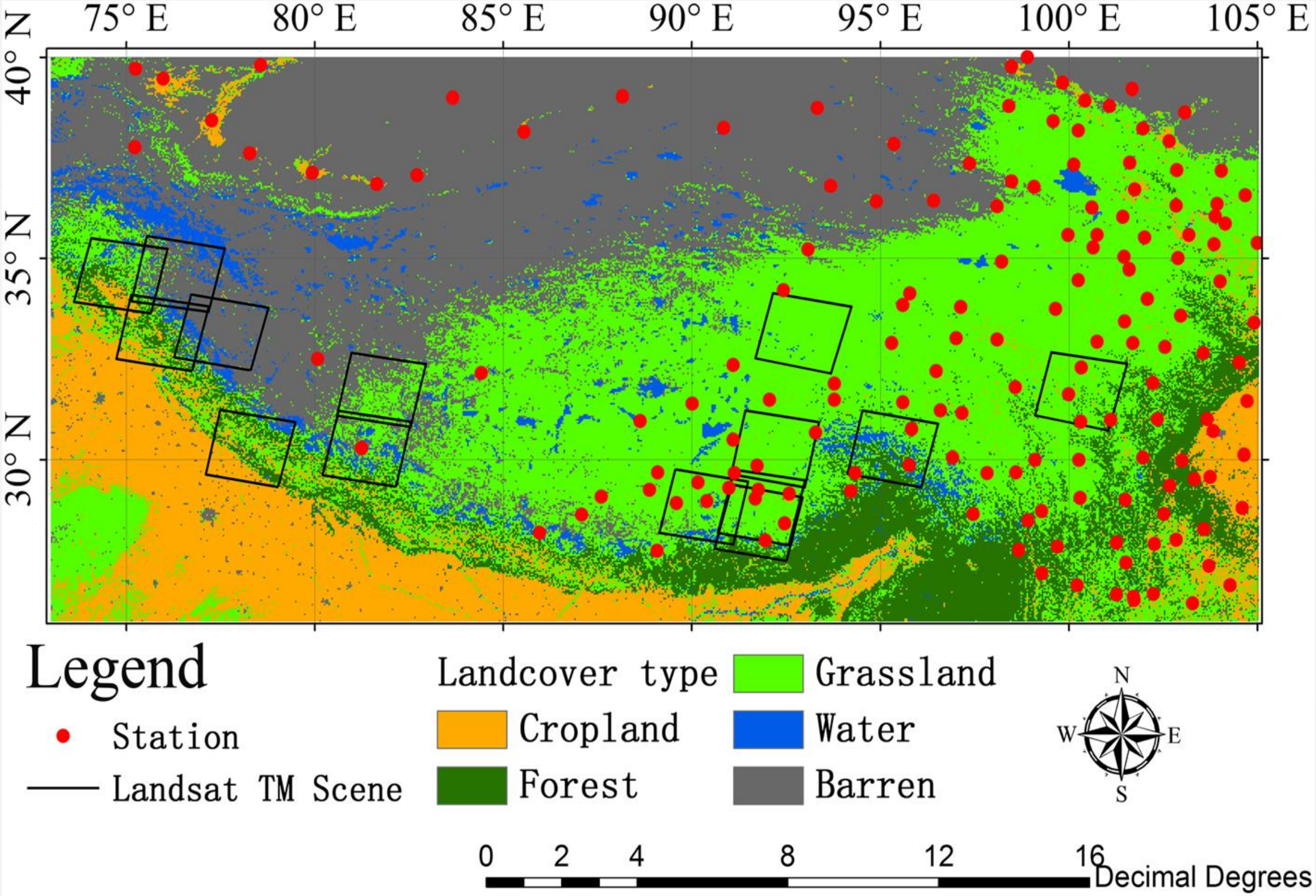
- The EASM is a combined system of subtropical, tropical monsoon. The abrupt enhanced summer rainfall is observed in April, mid-May, and Jun, corresponding to the timing of subtropical, SCS, and tropical monsoon onset;

- The coupling of MC, WPA, and SAH determines the interannual variability of EASM. Of which, the SAH is possibly linked to the snow cover over the HTP region;

- The impact of snow cover on the EASM is clear, but its joint impact with other factors (such as SST) is not clear.

- One season leading of EASM forecast requires a real-time, accurate snow products over the HTP region. While, how could we achieve this goal is a great challenge.

Open discussion



Data quality of satellite-observed snow data because of the complex background over HTP.

Yang, J., L. Jiang, C. B. M é nard, K. Luojus, J. Lemmetyinen, and J. Pulliainen, 2015: Evaluation of snow products over the Tibetan Plateau. Hydrol. Processes, 29, 3247–3260, doi: 10.1002/ hyp.10427

Open discussion

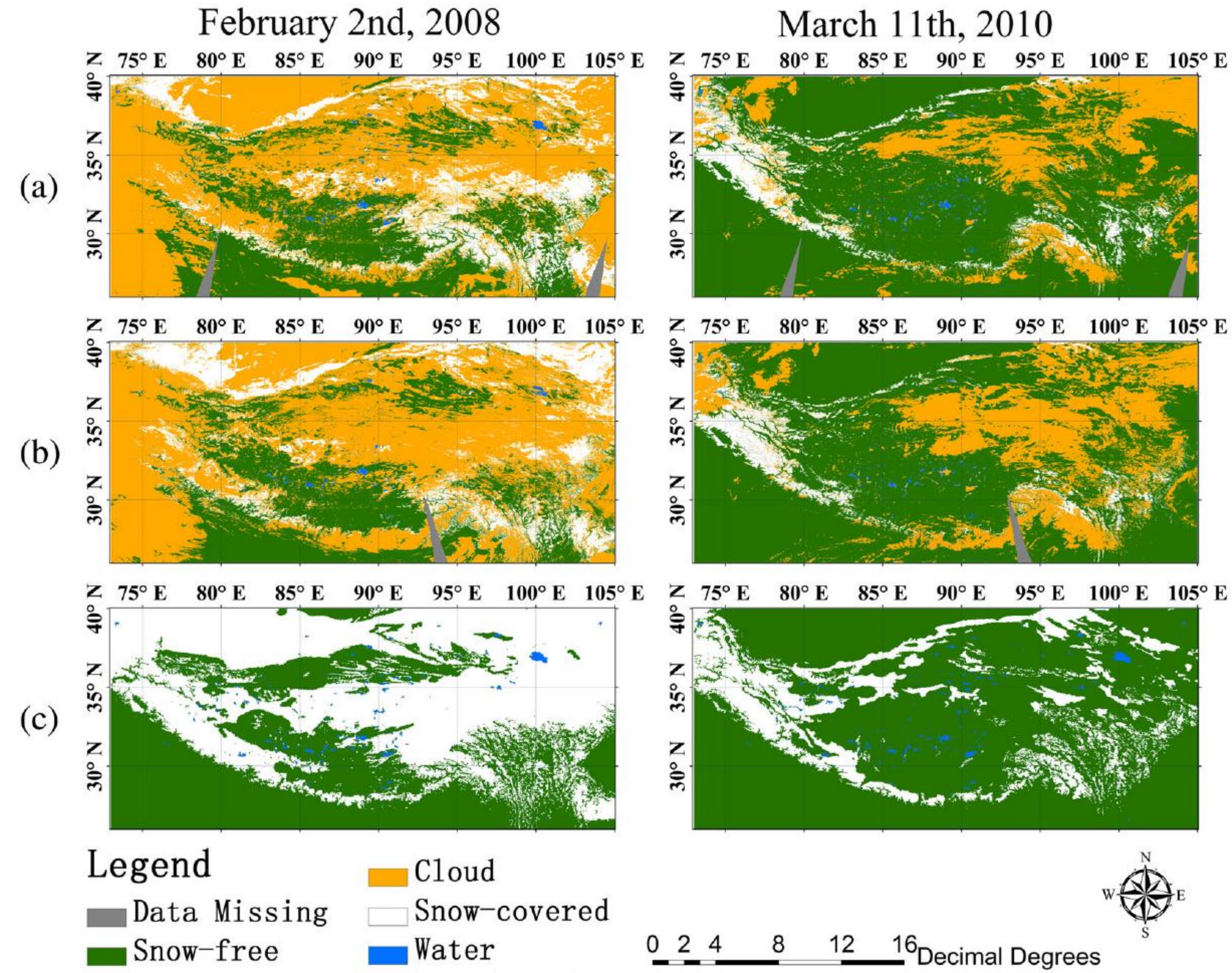


Figure 2. MOD10A1 (a), MYD10A1 (b) and Ice Mapping System (IMS) (c) snow cover images over the Tibetan Plateau on 2 February 2008 and 11 March 2010

Yang et al., 2015: Evaluation of snow products over the Tibetan Plateau. Hydrol. Process. DOI: 10.1002/hyp.10427

Open discussion

Which component of Snow data we should focus in our team ?

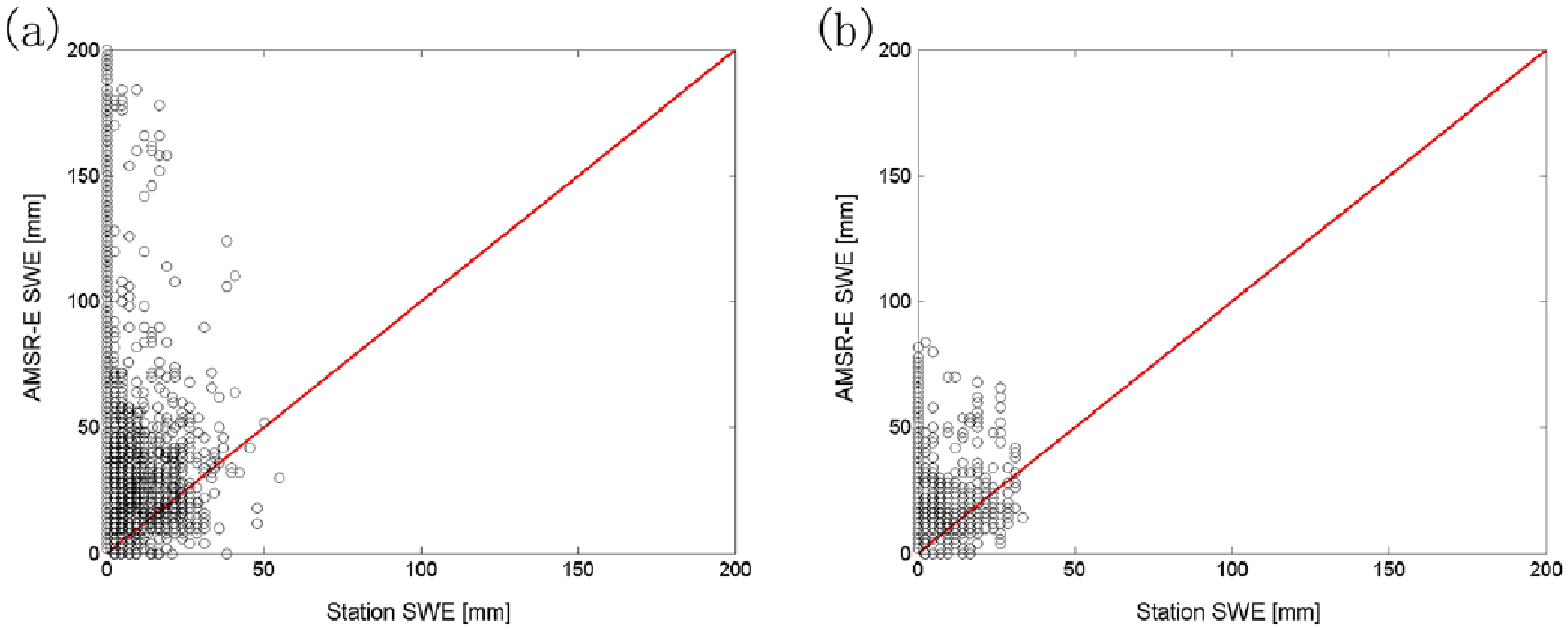


Figure 12. Comparison of AMSR-E and station Snow Water Equivalent over the Tibetan Plateau in 2007–2010 snow seasons in grassland (a) and barren (b) land cover type, respectively

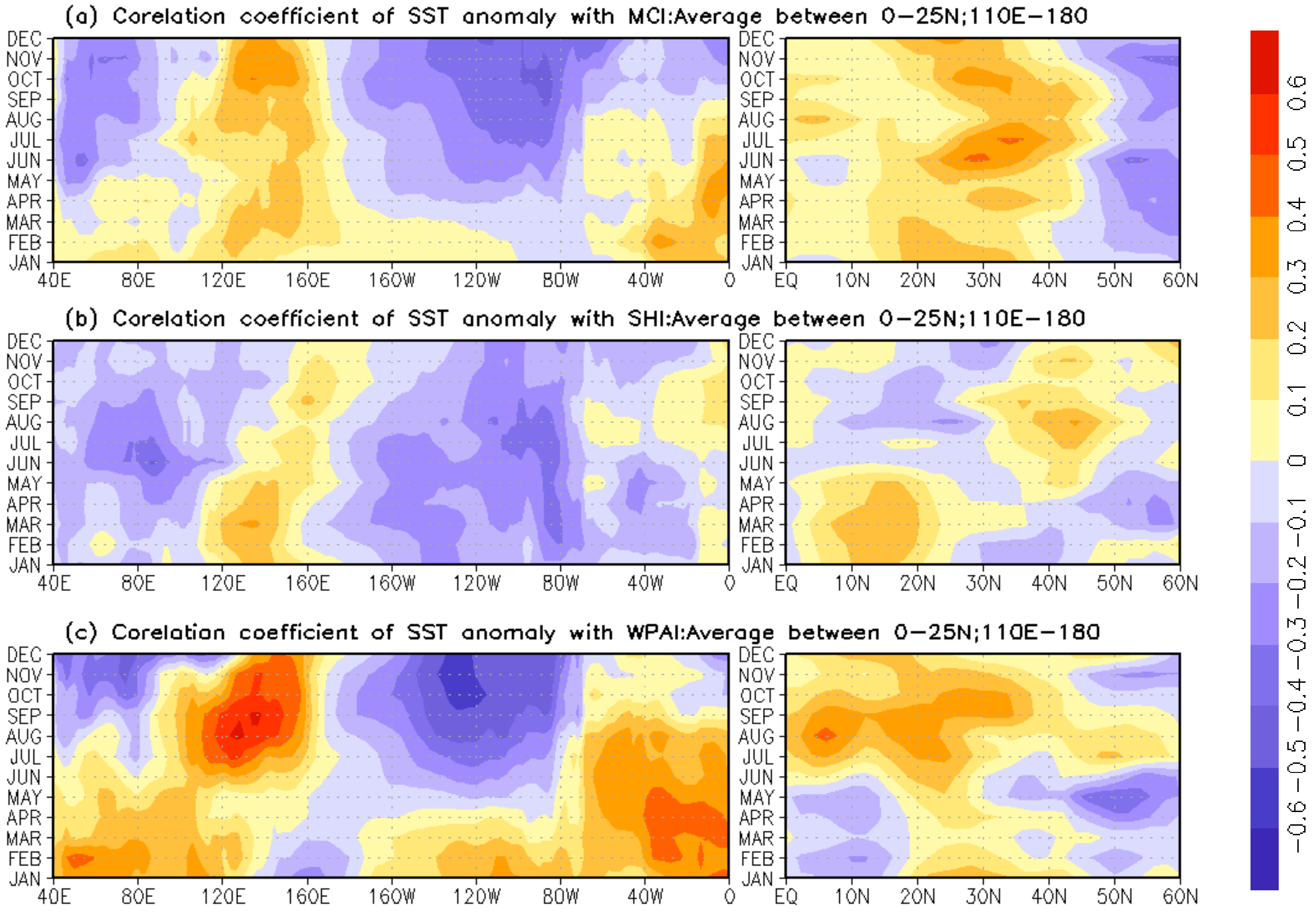
Yang et al., 2015: Evaluation of snow products over the Tibetan Plateau. Hydrol. Process. DOI: 10.1002/hyp.10427

Correlations of PC1 with detrend SSTA during 1979-2015

Mongolian cyclone

South Asian High

Western Pacific Anticyclone



Ending remarks

- **The HTP region is a very challenging area for all aspects of research on verification, model-dataset/satellite-dataset comparison, data assimilation (Gianpaolo in last E-mail)**

- Satellite observations provide spatially integrated measurements with global coverage which makes them of high interest to provide consistent snow information for climate and NWP (Rosnay et al., 2014). Snow cover has a small errors, in contrast other component?

- It is GREAT! if we focus on the WINTER 2015-2016 (from 01 September 2015 to 31 May 2016) to conduct our study. A case may help us to evaluate the impact of snow on EASM, in contrast to the SST forcing (Super El Nino/2015-16).

Thank you very much！

References

1. Zhu, C., W. Lee, H. Kang, and C. Park, 2005: A proper monsoon index for seasonal and interannual variations of the East Asian monsoon. Geophys. Res. Lett.,32,L02811,doi:10.1029/2004GL021295.
2. Pu, Z., L. Xu, and V. V. Salomonson, 2007: MODIS/Terra observed seasonal variations of snow cover over the Tibetan Plateau. Geophys. Res. Lett., 34, L06706, doi:10.1029/2007GL029262.
3. Wang, B., Q. Bao, B. Hoskins, G. Wu, and Y. Liu, 2008: Tibetan Plateau warming and precipitation changes in East Asia. *Geophys. Res. Lett.*, **35**, L14702, doi:10.1029/2008GL034330.
4. Zhu C., Zhou X J, Zhao P, et al, 2011: Onset of East Asian subtropical summer monsoon and rainy season in China. Sci China Earth Sci,54:1845–1853, doi: 10.1007/s11430-011-4284-0
5. Zhiguang Tang; Jian Wang; Hongyi Li; Lili Yan J.2013: Spatiotemporal changes of snow cover over the Tibetan plateau based on cloud-removed moderate resolution imaging spectroradiometer fractional snow cover product from 2001 to 2011. Appl. Remote Sens.7(1):073582. doi: 10.1117/1.JRS.7.073582
6. Yang, J., L. Jiang, C. B. M é nard, K. Luojus, J. Lemmetyinen, and J. Pulliainen, 2015: Evaluation of snow products over the Tibetan Plateau. Hydrol. Processes, 29, 3247–3260, doi: 10.1002/ hyp.10427
7. Zhixiang Xiao and Anmin Duan, 2016: Impacts of Tibetan Plateau snow cover on the interannual variability of the East Asian summer monsoon. J. Climate, *DOI:* http://dx.doi.org/10.1175/JCLI-D-16-0029.1