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Response of the East Asian monsoon to solar cycle

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Outline

Significance and purpose

Solar role in climate change
A hiatus in global warming

Data and method

Data and samples
Choice of Time and space
The definition of rainband meridional shift index (RMSI)

Relationship between rainband and SSN

Evidences (Correlation; Difference; Wavelet analysis)
Physical connection (Diagnose analysis)

Conclusion

Significance

Natural factors influencing climate

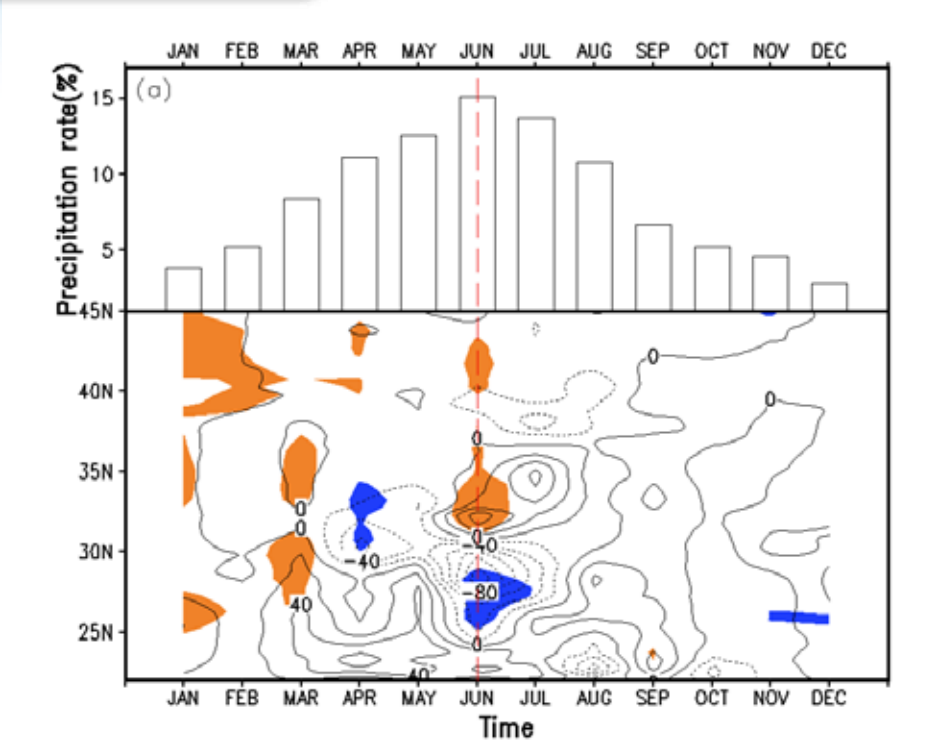
Solar role in climate change

A number of studies have exhibited correlations between solar cycle and climate, although it has long been a subject of controversy how much the climate system is influenced by solar variability

A hiatus in global warming

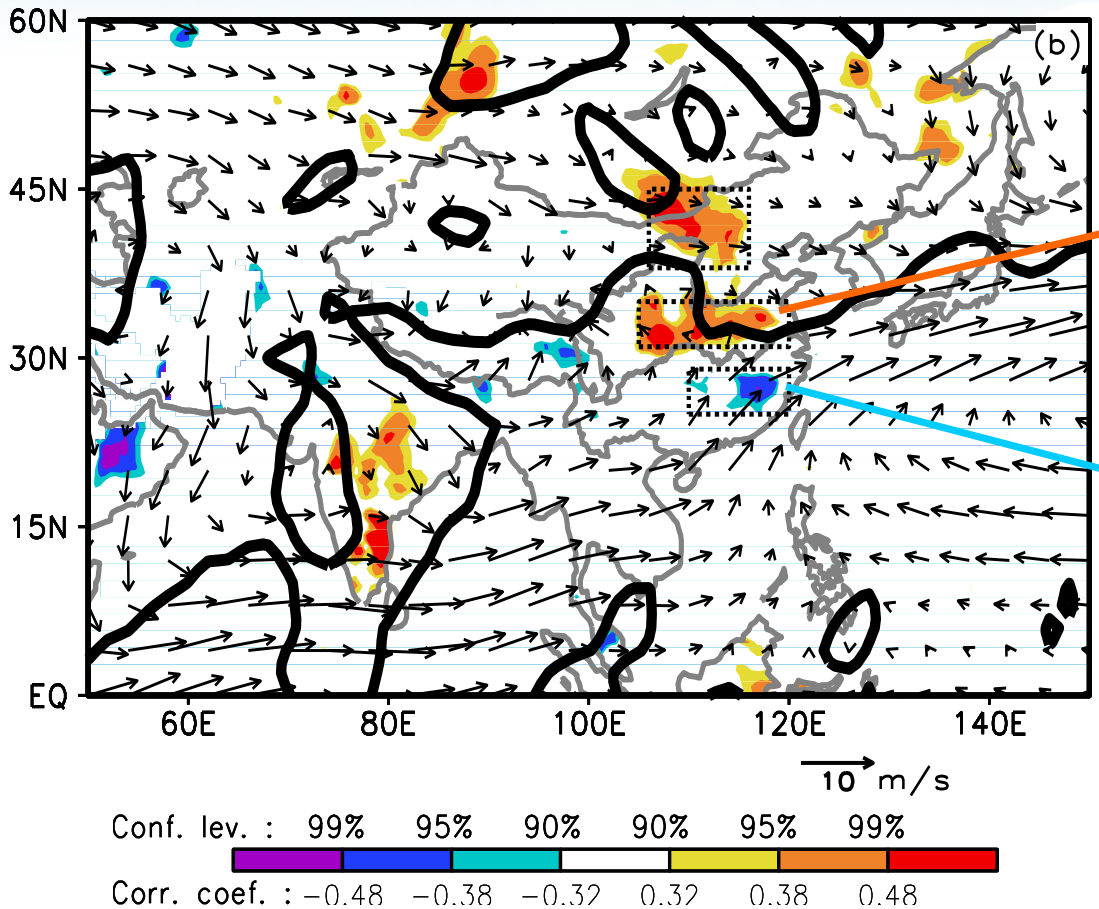
IPCC AR5 (2013) claimed that a hiatus in global warming of the past 15 Years could be caused by some combination of (a) internal climate variability, (b) missing radiative forcing (e.g., solar irradiance) and (c) model response error.

Why is our focus on China in June?



Upper: monthly mean precipitation rates averaged over 26°N-34°N along 115°E;
Lower: precipitation difference (contours) between MAX and MIN and significant correlations (shaded) between monthly precipitation and SSN.
Significance tests are based on Monte Carlo approach (from Zhao et al., 2012, JMSJ).

Why is our focus on China in the Huaihe River Basin (HRB) and the mid-lower Yangtze River Basin (YRB)?



The Huaihe River Basin (HRB)

The mid-lower Yangtze River Basin (YRB)

Significant simultaneous correlations (shaded) between June precipitation and SSN and 700 hPa (about 3000 m) wind. The thick solid contour are mean southerly velocity contours of 0 m/s, representing the margin of the East Asian summer monsoon (EASM) (Wang and Zhao, 2012, JGR)

HRB (105-122°E, 31-34°N) and YRB (105-122°E, 26-29°N) are chosen as main regions of space and June as period of time to be studied

Data

- The daily precipitation dataset for China from 1951 to 2012 is available from the National Meteorological Information Center (NMIC) of China that made the quality control.
- The monthly global land surface precipitation dataset used in this study is CRU TS 3.23 with 0.5° ×0.5° resolution from 1901 to 2014 compiled by the University of East Anglia Climatic Research Unit (CRU) [Mitchell and Jones, 2005].
- The data for monthly and yearly sunspot number (hereafter, SSN) as the primary proxy of solar activity in this study is from the NOAA.

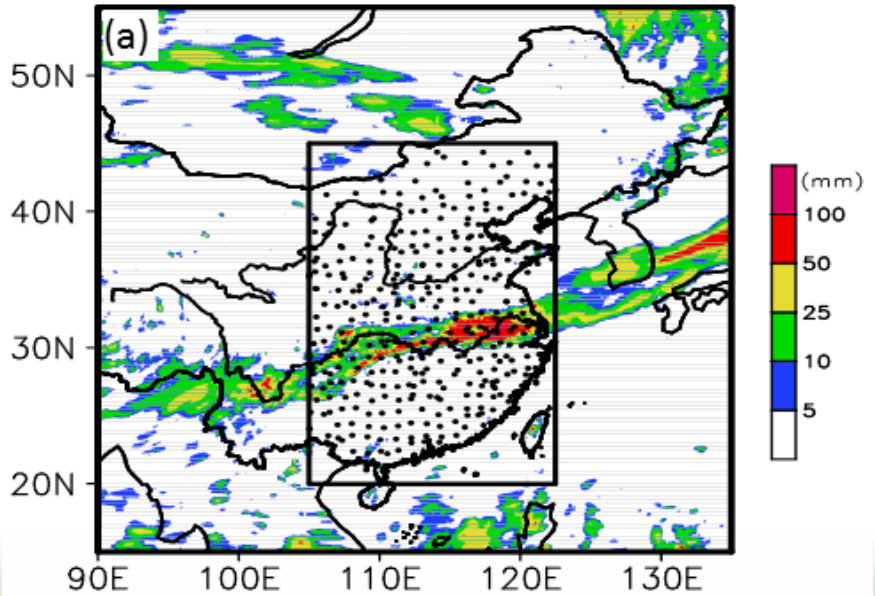
The Years of Maximum (MAX) and Minimum (MIN) of the SSN

MAX	1905	1917	1928	1937	1947	1957	1968	1979	1989	2000	2014
MIN	1901	1913	1923	1933	1944	1954	1964	1976	1986	1996	2008

Latitude of rainband (R_L)

The mean latitude of the rainband (MLRB, R_L) was obtained from the interpolated grid precipitation data. For each year, we selected each date span from within the summer half-year (1 April to 30 September), and the MLRB during this span was defined as the mean latitude of maximum precipitation at each longitude (with an interval of 0.5°) in the area enclosed by the box in the Figure

$$R_L = \frac{1}{n}\sum_{i=1}^{n}(Maxloc(\overline{R}_i))$$



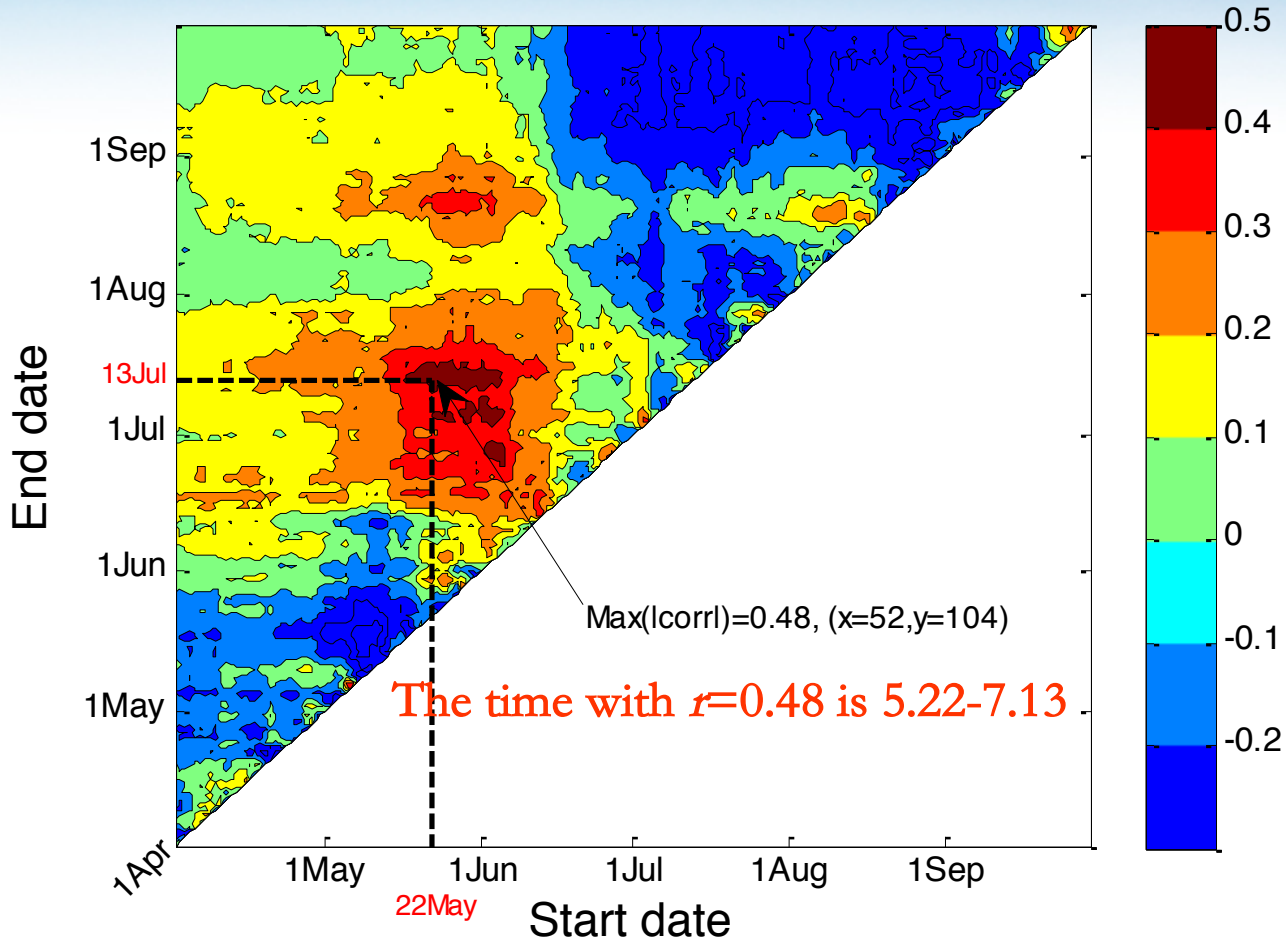
Method

1. Correlations between the annual SSN and yearly MLRB (mean latitude of the rainband) series for any time span in the northern summer half-year (1 Apr to 30 Sep). The shortest duration of the span is 1 day, and the longest span is 183 days, in each year from 1958 to 2012. The x and y axes indicate the start and end dates of the span, respectively.

2. We hope find the time period with the maximum correlation coefficient and its physical meaning.

So for each year the total number of all possible date spans between 1 April and 30 September is 16 836 (=183 + 182 + 181 + . . . +1). MLRBs with each the same span (e.g., starts on 18 April and ends on 26 June), but from all different years (1958–2012), form an MLRB time series with 55 [(2012-1958) +1] elements, so a total of 16 836 series were obtained. And 16 836 correlation coefficients between them and the SSN are obtained.

Results



Correlations between the annual SSN and yearly MLRB (mean latitude of the rainband) series for any time span in the northern summer half-year (1 Apr to 30 Sep) (Zhao and Wang, 2014, J. Clim.)

■Physical significance of the statistical result

Coincidence 1：the start date, 22 May —— is also the average onset date of the mei-yu season (main rainy season), when the East Asian summer monsoon (EASM) begins to influence the southest of mainland China with a large-scale quasizonal monsoon rainband (e.g., Tao and Chen 1987; Lau and Yang 1997; Wang and LinHo 2002; Chen 2004; Zheng et al. 2006)

Coincidence 2: the end date, 13 July —— is also the average date when the mei-yu rains ended in mainland China during the period 1958– 2000 (Xu et al. 2001)

- ✓ **The span with the highest correlation corresponds to a special climatological time: the East Asian mei-yu season (monsoon rainy season)**

The meiyu season

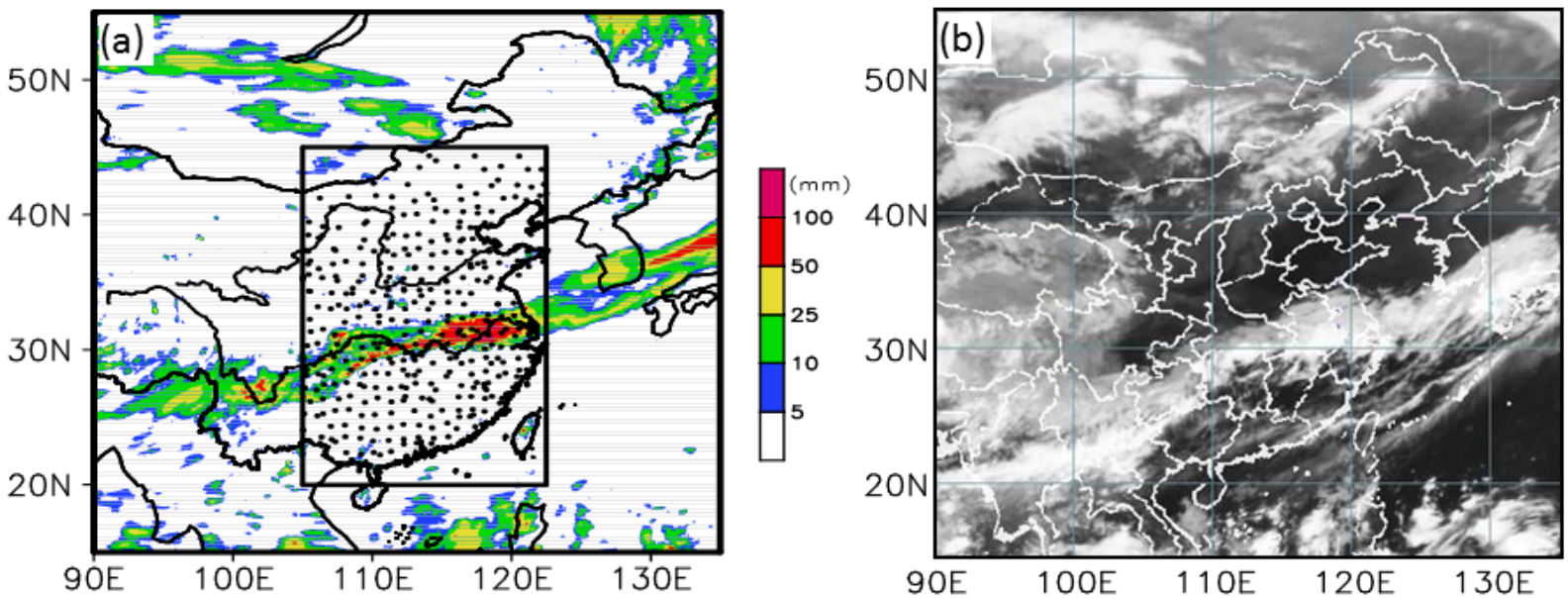
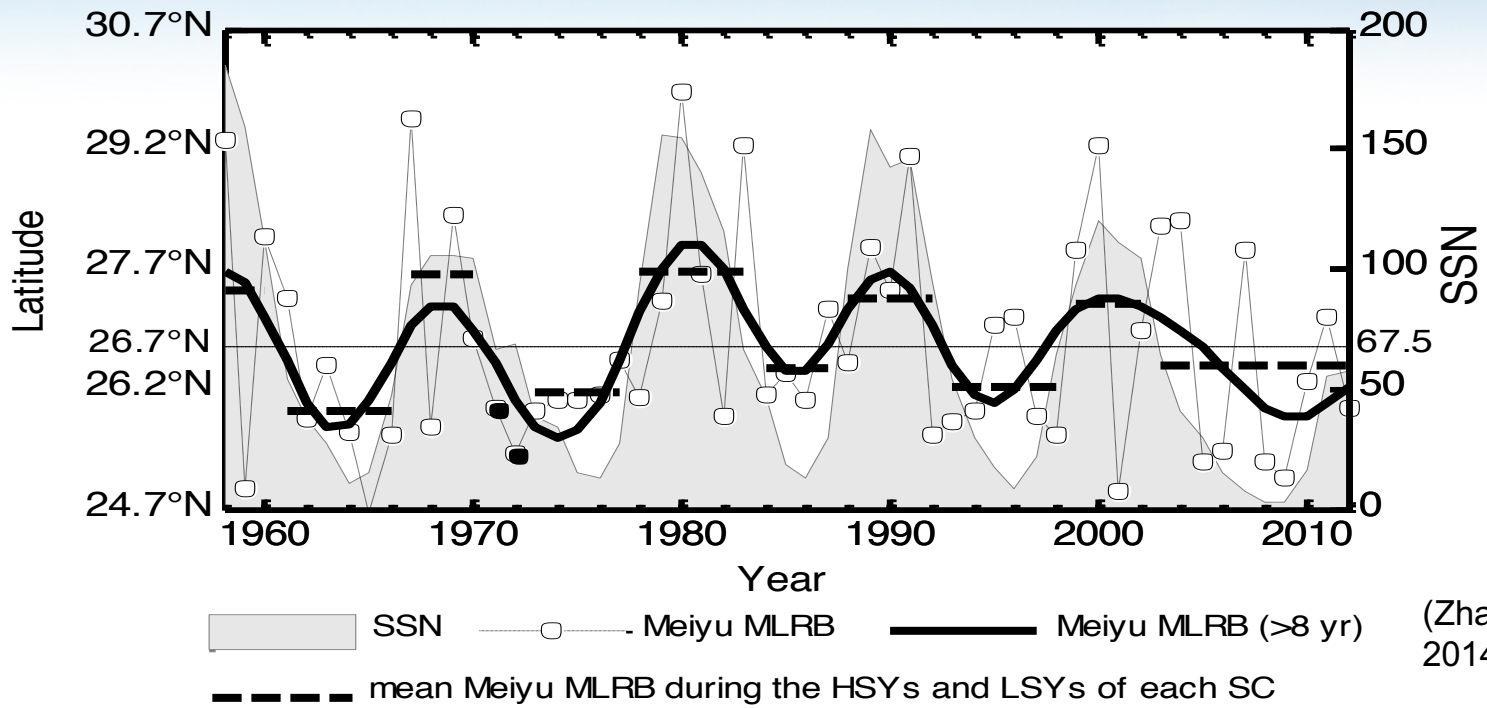


FIG. 1. (a) Distribution of observatories in the study area (boxed area: 105°E–122.5°E, 20°N–45°N) and precipitation on 5 July 2013 using the China NMIC merged precipitation dataset of Chinese auto-weather-station precipitation and CMORPH (US Climate Prediction Center's Morphing technique) precipitation product. (b) Chinese FY2E satellite infrared image on 13:00 UTC 5 July 2013.

Result



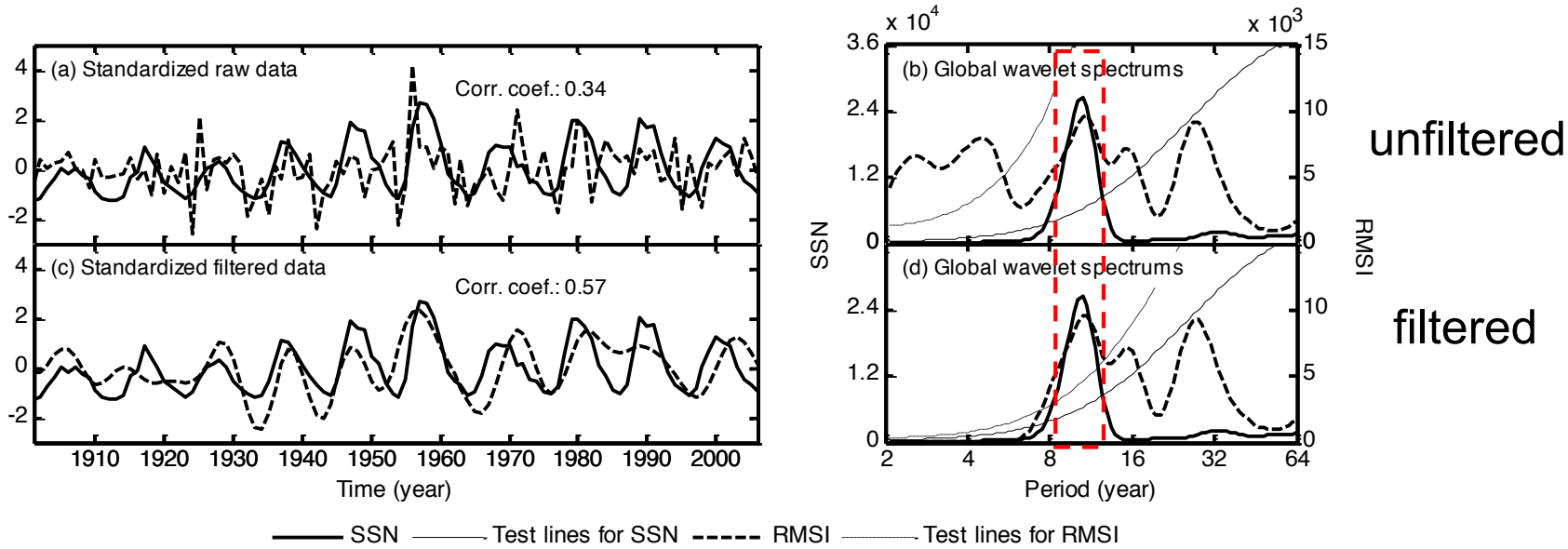
(Zhao and Wang, 2014, J. Clim.)

The correlation coefficient between the SSN and the 8-yr lowpass filtered mei-yu MLRB is 0.87

1） One can note that the mei-yu MLRB is often more to the north around the SSN peaks than that around the SSN valleys (1.2°)

2）During the high solar years, the mei-yu rainband latitude has larger variability than that during the low solar years. （$p<0.01$）

Wavelet spectrum analysis



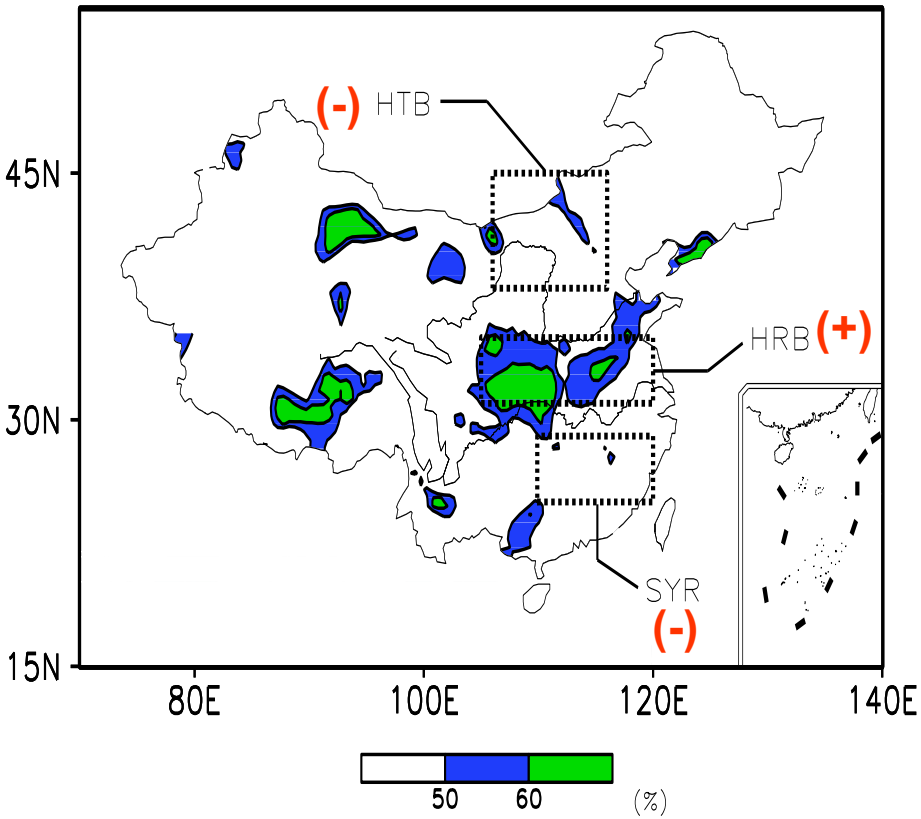
The correlations (0.34 and 0.57) are both > 99.9% confidence levels (Monte Carlo test).

After filtering, the global wavelet spectrums of the residue show a convincible quasi-11-year period.

These suggest that there is very likely a solar-cycle signal in the East Asian summer monsoon rainband.

Variance contribution

9–13 year vs low-frequency variation (>8 year)



Variance contribution (units: %) of the 9–13 year component of June precipitation in China for the long-period (>8 years) portion during 1901–2006 (Wang and Zhao, 2012, JGR)

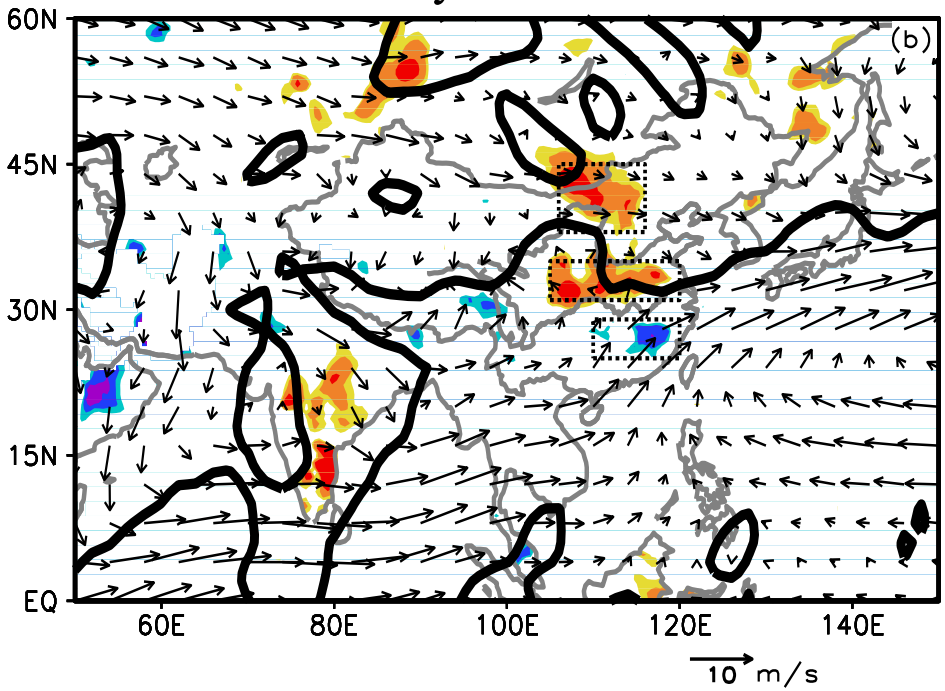
Significance

- "50%": the decadal component is the largest among low-frequency signals, and it dominates the long-period (>8 years) variation in the monsoon margin region.

■ Physical explanation

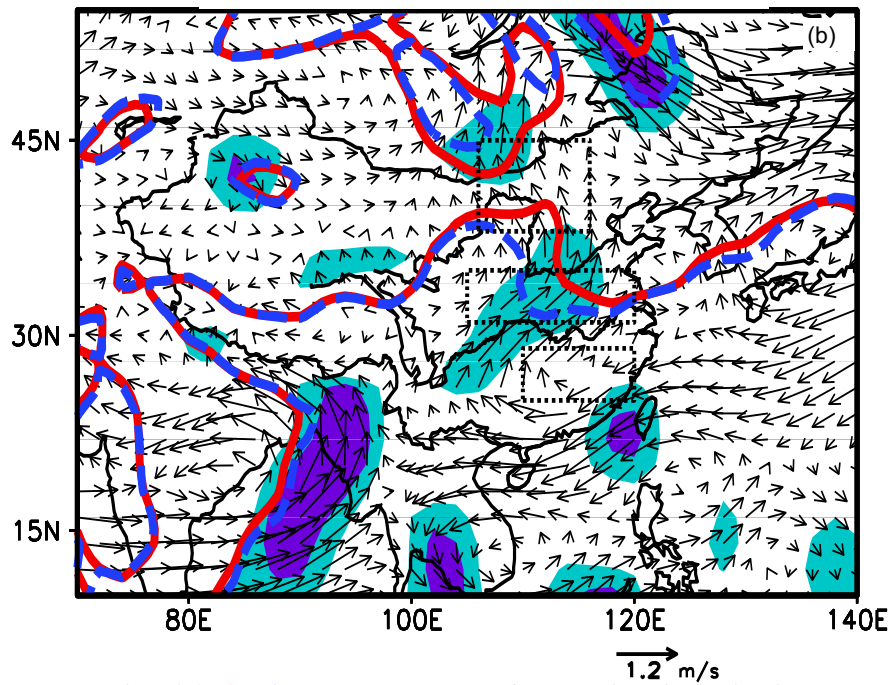
700hPa wind（June）

106-year mean



Black contours: 0 m/s southerly wind

Solar high－low

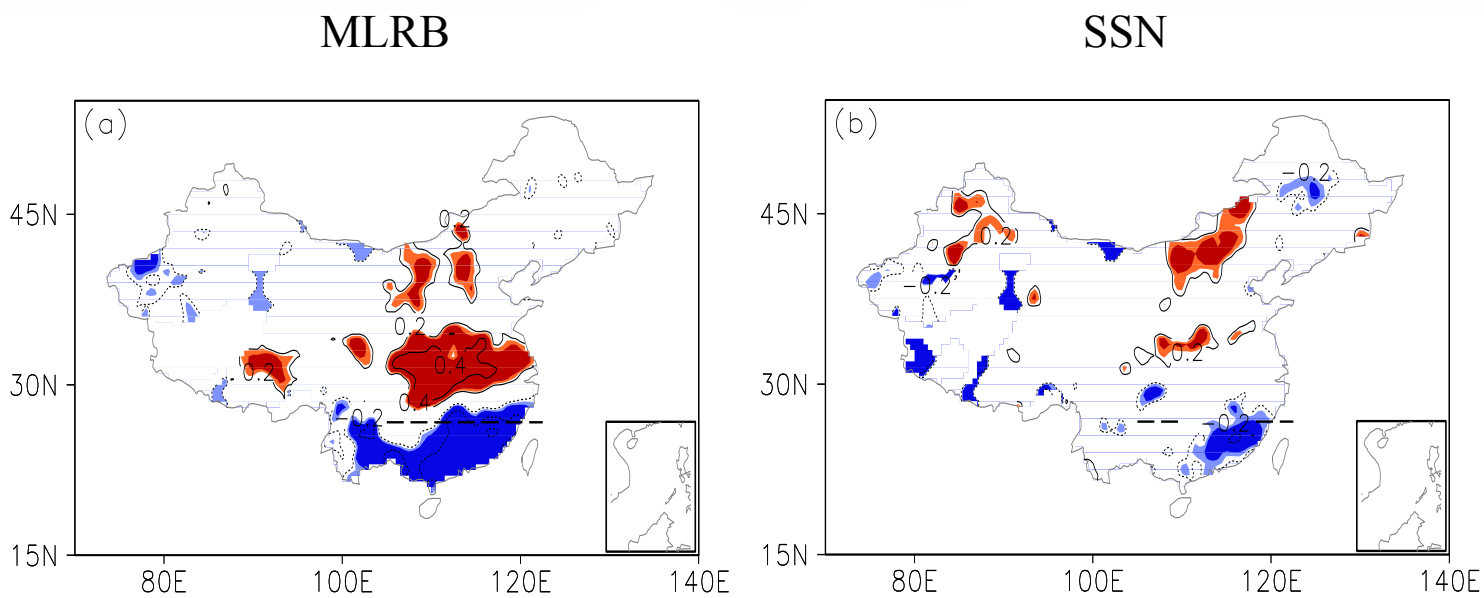


Solar high (low) year: 0 m/s southerly wind

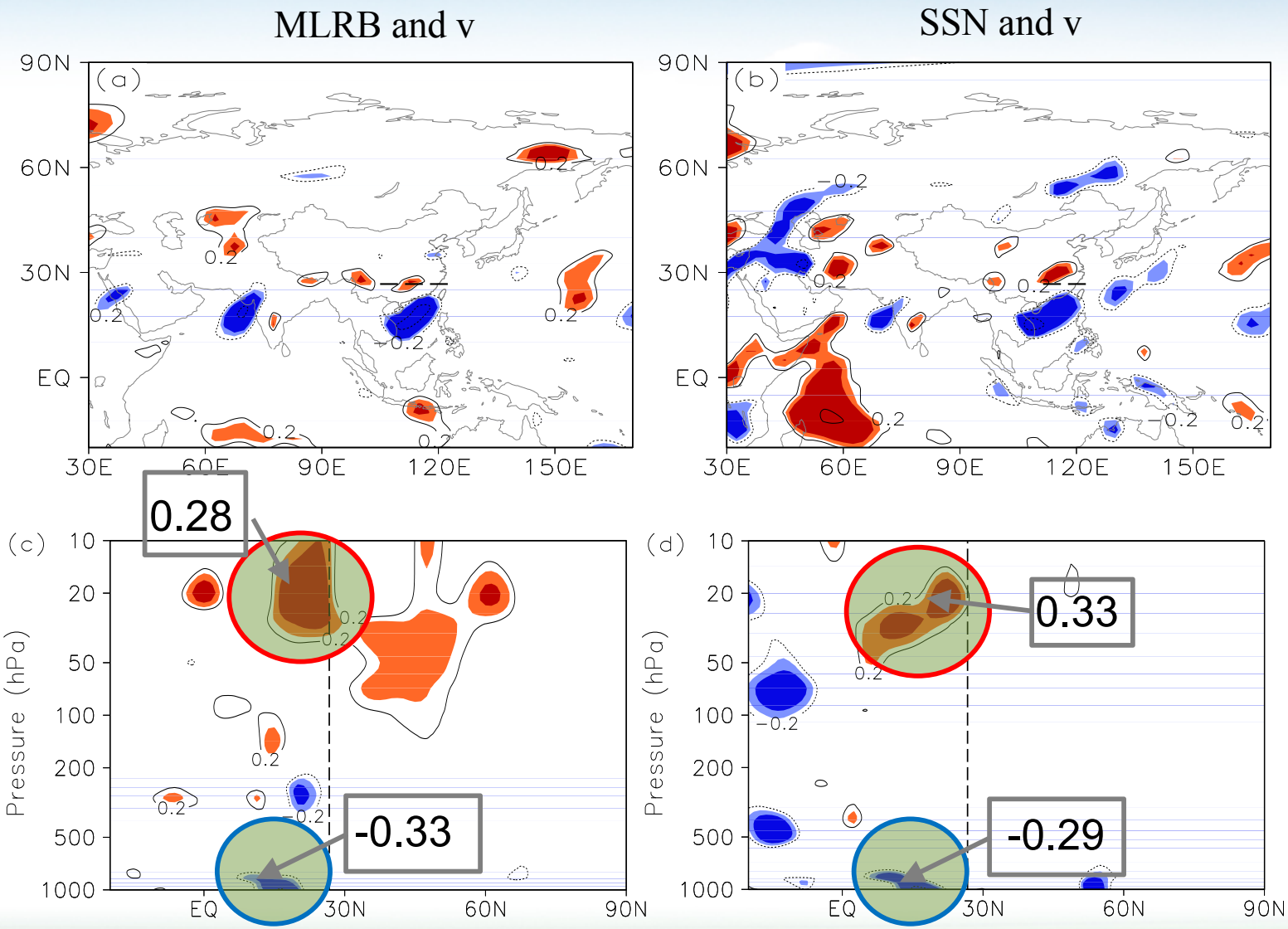
Shaded: significant regions（Wang and Zhao, 2012, JGR）

❖ In June during the high sunspot number (SSN) years, the influence of the EASM is significantly greater and more to the north than that during the low SSN years

Physical Verification

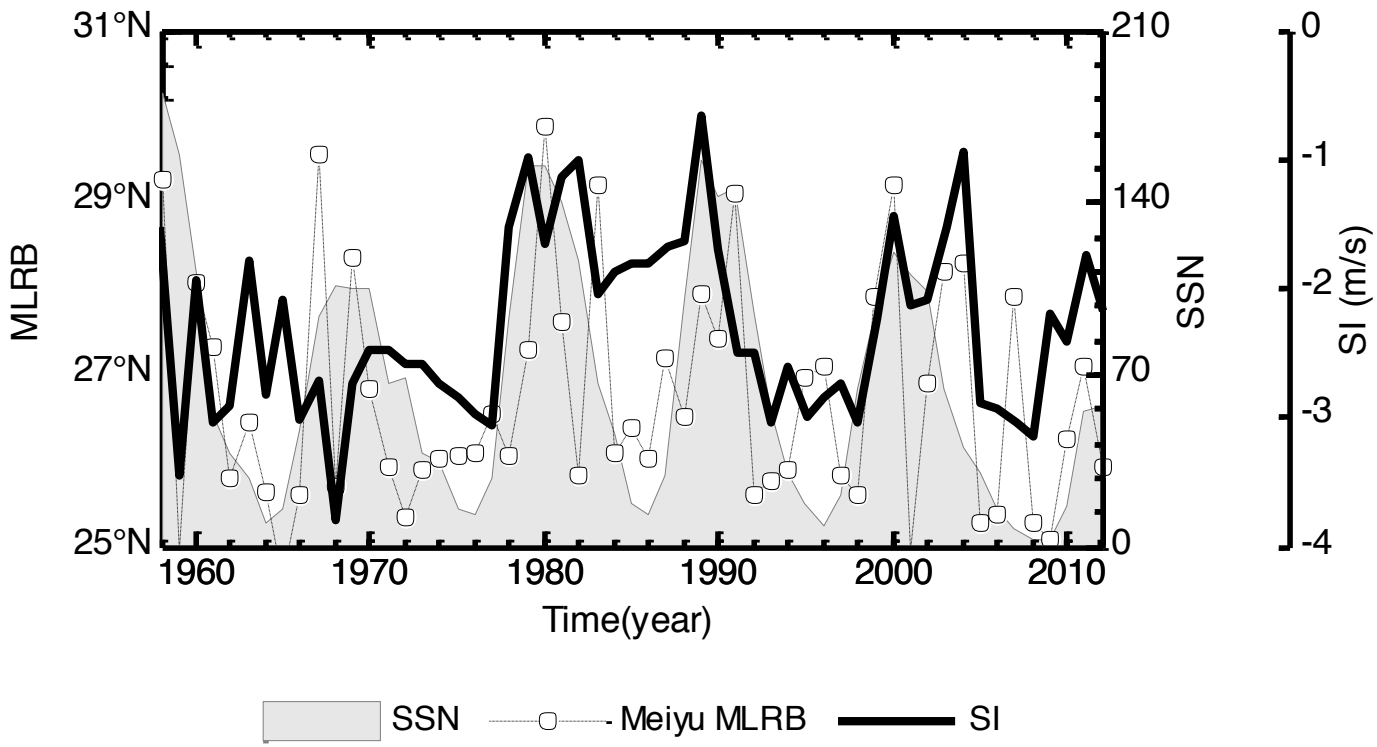


Correlation coefficient between (a) unfiltered MLRB or (b) annual SSN and the precipitation of China at each grid point during the East Asian mei-yu season for the last 55 years



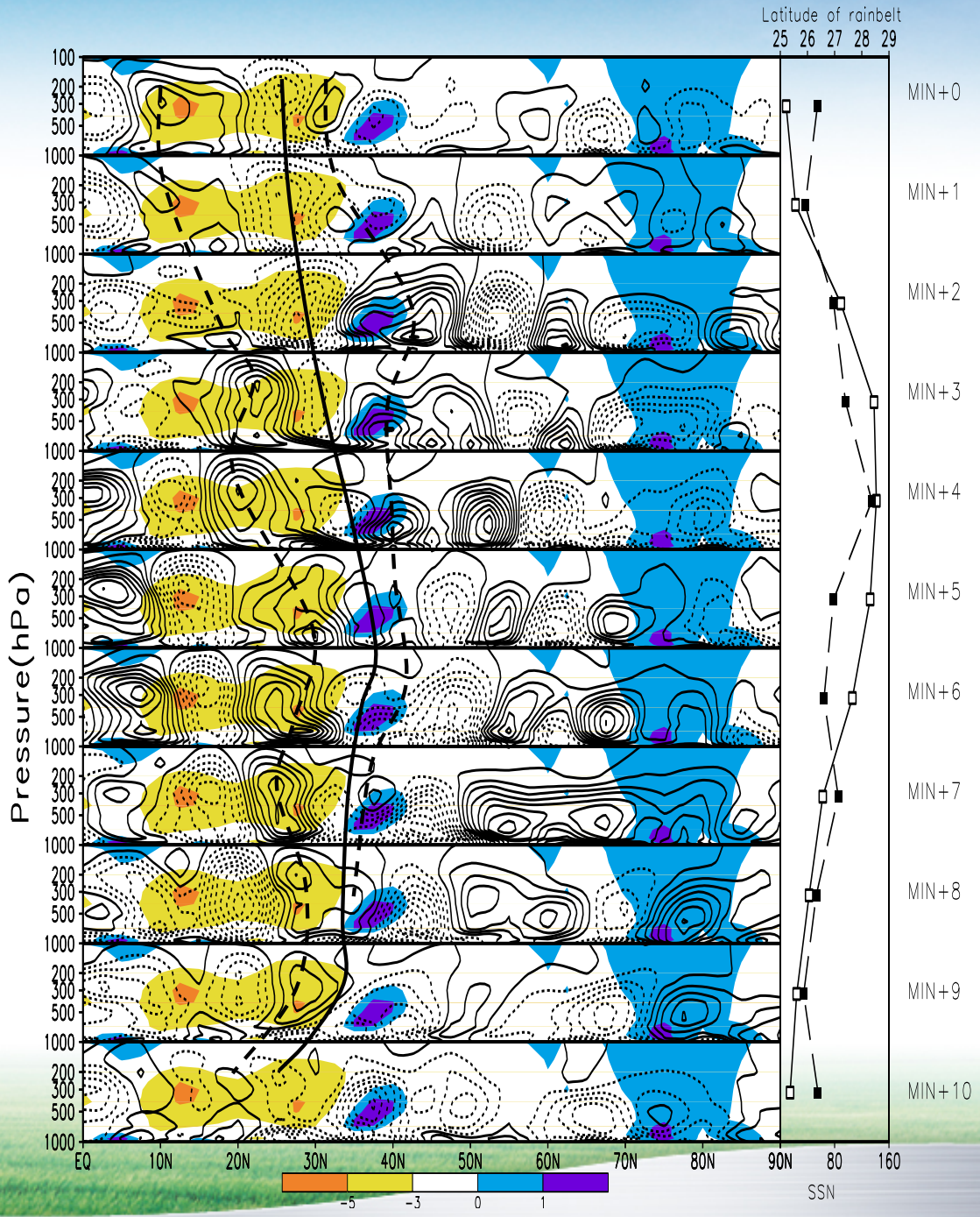
(red: positive correlation, southerly; blue: negative correlation, northerly)
(Zhao et al, 2017, JMR)

Up-down seesaw index（SI）: difference of meridional wind between (25°N, 20 hPa) and (20°N, 1000 hPa)



<u>*r*(SI and SSN)：0.42（99.8%） *r*(SI and rainband latitude): 0.41 > 0.3</u>

=> Up-down seesaw likely amplifying the solar signal through synergistic responses of two systems (monsoon and subtropical jet) (Zhao et al, 2017, JMR)


Latitude of rainbelt
25 26 27 28 29
MIN+0
MIN+1
MIN+2
MIN+3
MIN+4
MIN+5
MIN+6
MIN+7
MIN+8
MIN+9
MIN+10
Pressure(hPa)
100
200
300
500
1000
EQ
10N
20N
30N
40N
50N
60N
70N
80N
90N
80
160
SSN
-5
-3
0
1

Conclusion

1. This study provides evidence of the robust response of the East Asian monsoon rainband to the 11-yr solar cycle and first identify **the exact time period** with the strongest correlation.
2. This period just corresponds to the climatological-mean **East Asian mei-yu season**, characterized by a largescale quasi-zonal monsoon rainband (i.e., 22 May–13 July).
3. During the high SSN years, the mei-yu MLRB lies **1.2°** farther north, and the amplitude of its interannual variations increases when compared with low SSN years.
4. The robust response of monsoon rainband to solar forcing is related to an anomalous general atmospheric pattern with an **up–down** seesaw and a north–south seesaw over East Asia.

Thank You !

I am sorry for my English

My papers about solar cycle and monsoon:

Response manner:

Zhao Liang, Wang Jingsong*, Haijuan Zhao. Solar cycle signature in decadal variability of monsoon precipitation in China. *Journal of the Meteorological Society of Japan*, 2012, 90(1): 1～9, DOI:10.2151/jmsj.2012-101.

Response regions:

Wang Jingsong, Zhao Liang*. Statistical tests for a correlation between decadal variation in June precipitation in China and sunspot number. *JGR-Atmos*, 2012, 117(D23), D23117, doi:10.1029/2012JD018074.

Sensitive time:

Zhao Liang, Wang Jingsong*. Robust response of the East Asian monsoon rainband to solar variability. *J. Climate*, 2014, 27(8): 3043-3051, doi: http://dx.doi.org/10.1175/JCLI-D-13-00482.1.

A possible amplification mechanism:

Zhao Liang, Wang Jingsong, Liu Haiwen, Xiao Ziniu. Amplification of solar signal in summer monsoon rainband in China by a synergistic action of different dynamical responses. J. Meteor. Res., 2017, 31(1), 61-72, doi: 10.1007/s13351-016-6046-6.