

**Coordinated multi-ocean-basin forcing under global warming:
mechanisms driving interdecadal shifts in Eurasian precipitation
patterns**

Na Dong ^{1*,2}, Xiangde Xu ^{2*}, Renhe Zhang ¹

1 Department of Atmospheric and Oceanic Sciences & Institute of Atmospheric Sciences, Fudan University, Shanghai, 200438, China

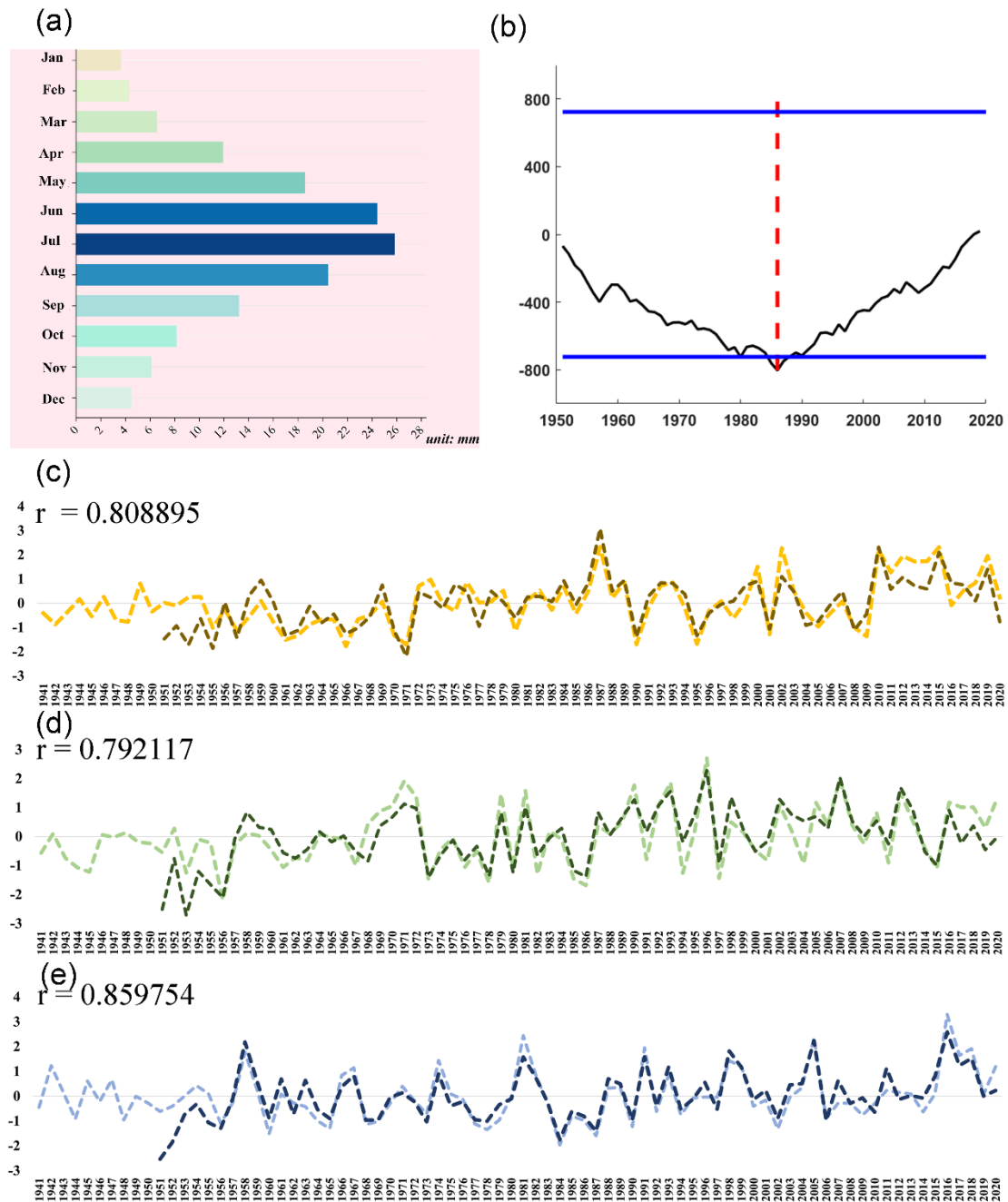
2 State Key Laboratory of Severe Weather, Chinese Academy of Meteorological Sciences, Beijing, 100081, China

* Corresponding author.

E-mail address: 23113020005@m.fudan.edu.cn (Na Dong).

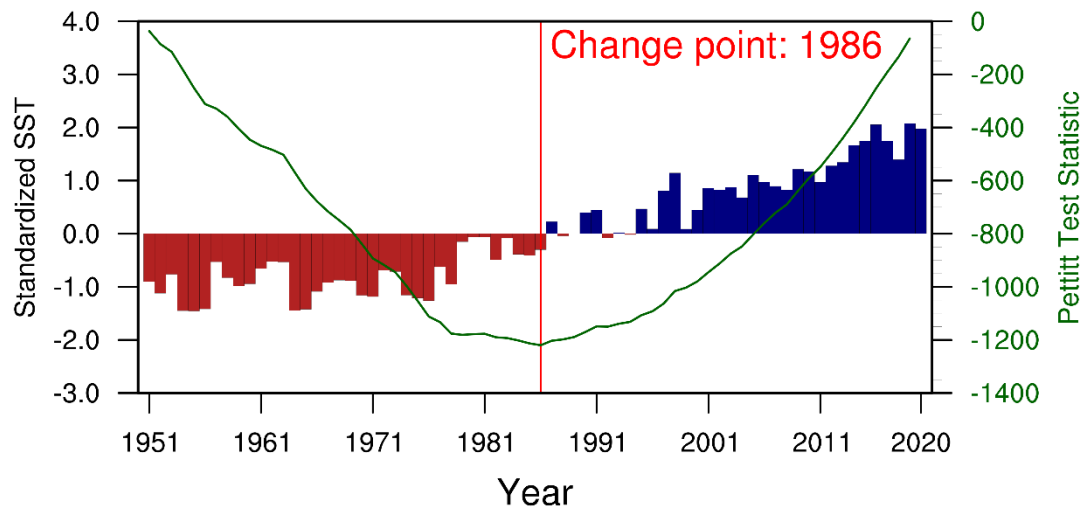
E-mail address: xuxd@cma.gov.cn (Xiangde Xu).

supplementary materials

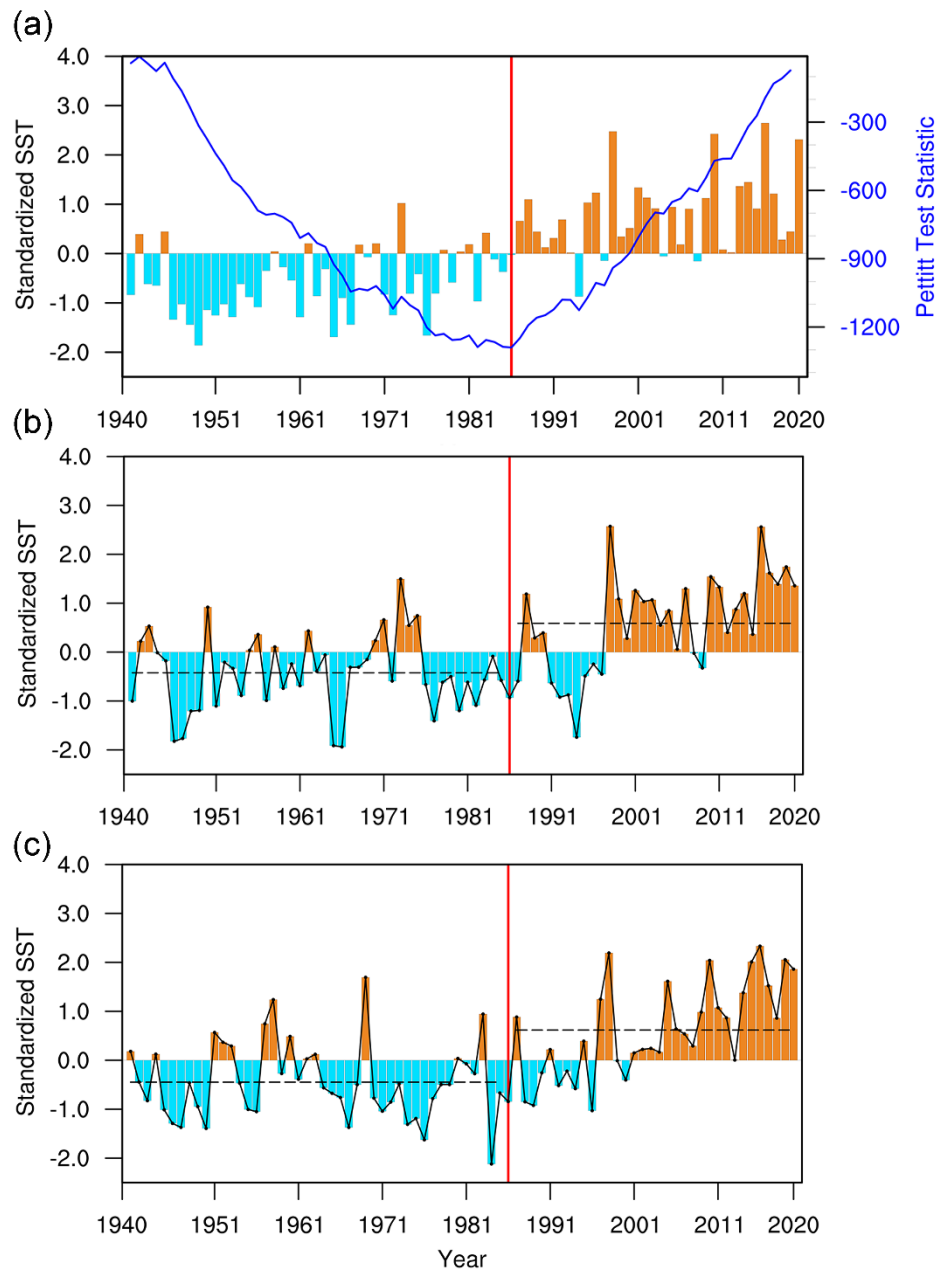


Supplementary Fig. 1| Comparison of GPCP and station-observed summer precipitation over the QTP. (a) The QTP-N monthly average precipitation during JJA of 1951-2020, (unit: mm), **(b)** the Pettitt test for the QTP-N precipitation (station observation data), **(c)** the interannual variation curve of standardized GPCP precipitation data and station observations data in the QTP-N in June, **(d)** the same as **c**, but for July, **(e)**

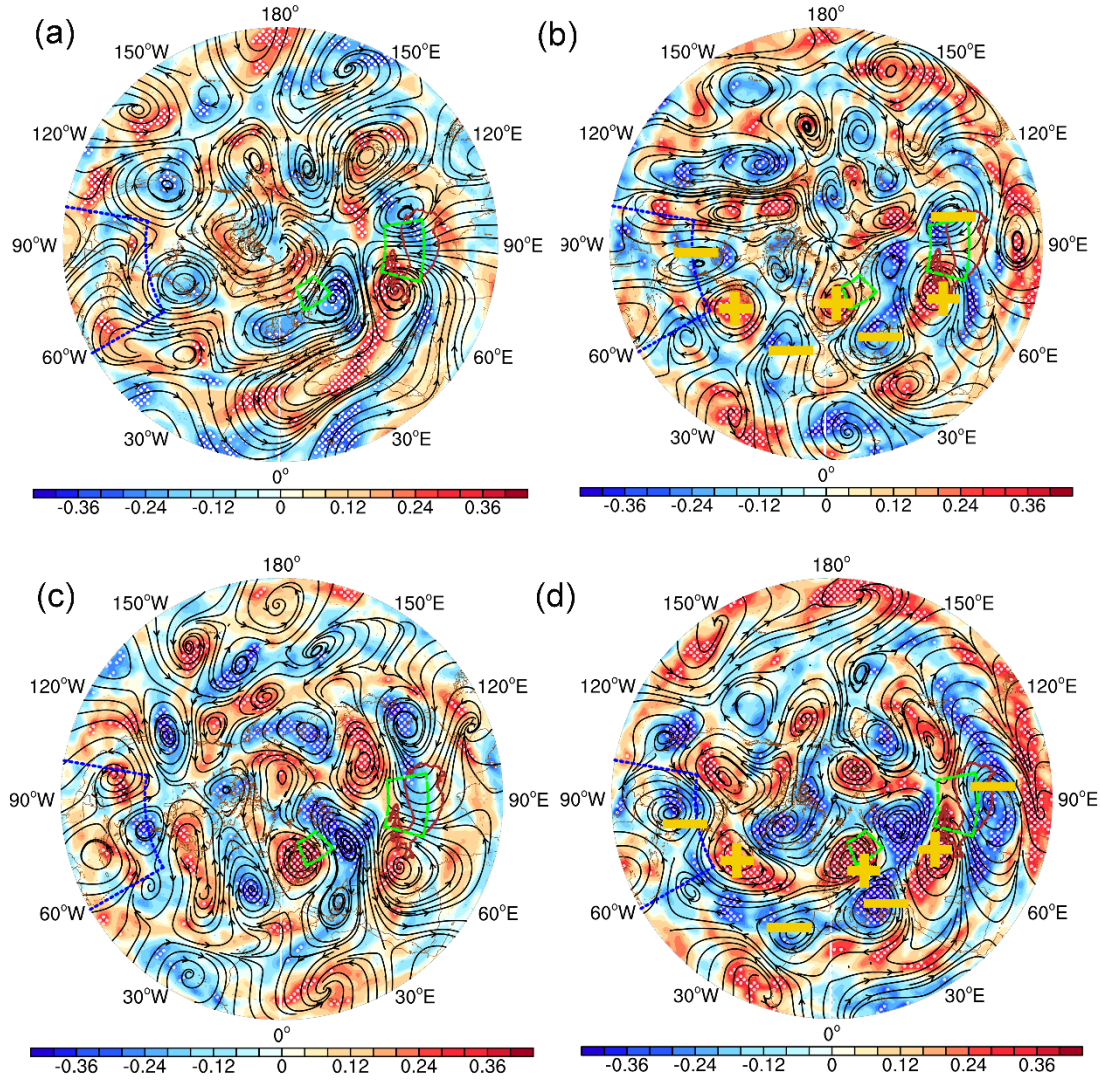
the same as **c**, but for August. The precipitation data obtained in China provided by the National Meteorological Information Center of China Meteorological Administration (<http://data.cma.cn>).



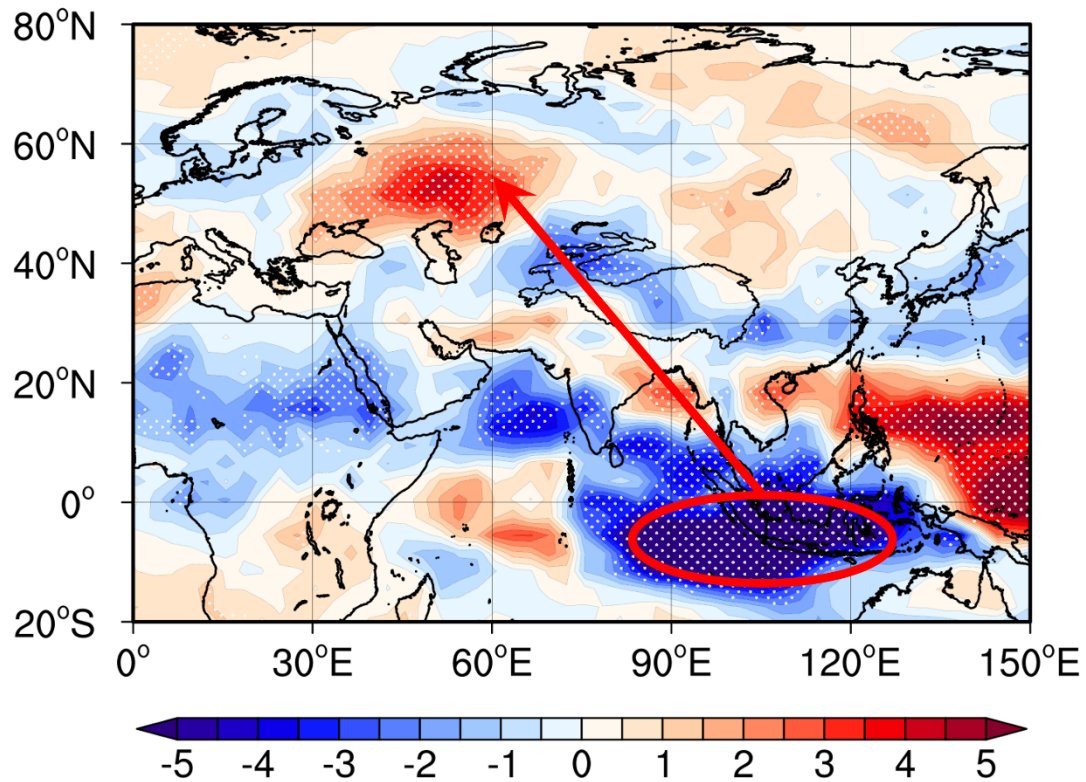
Supplementary Fig. 2| Interannual variation and abrupt change of global JJA SST. Time series of global standardized JJA SST and the Pettitt test.



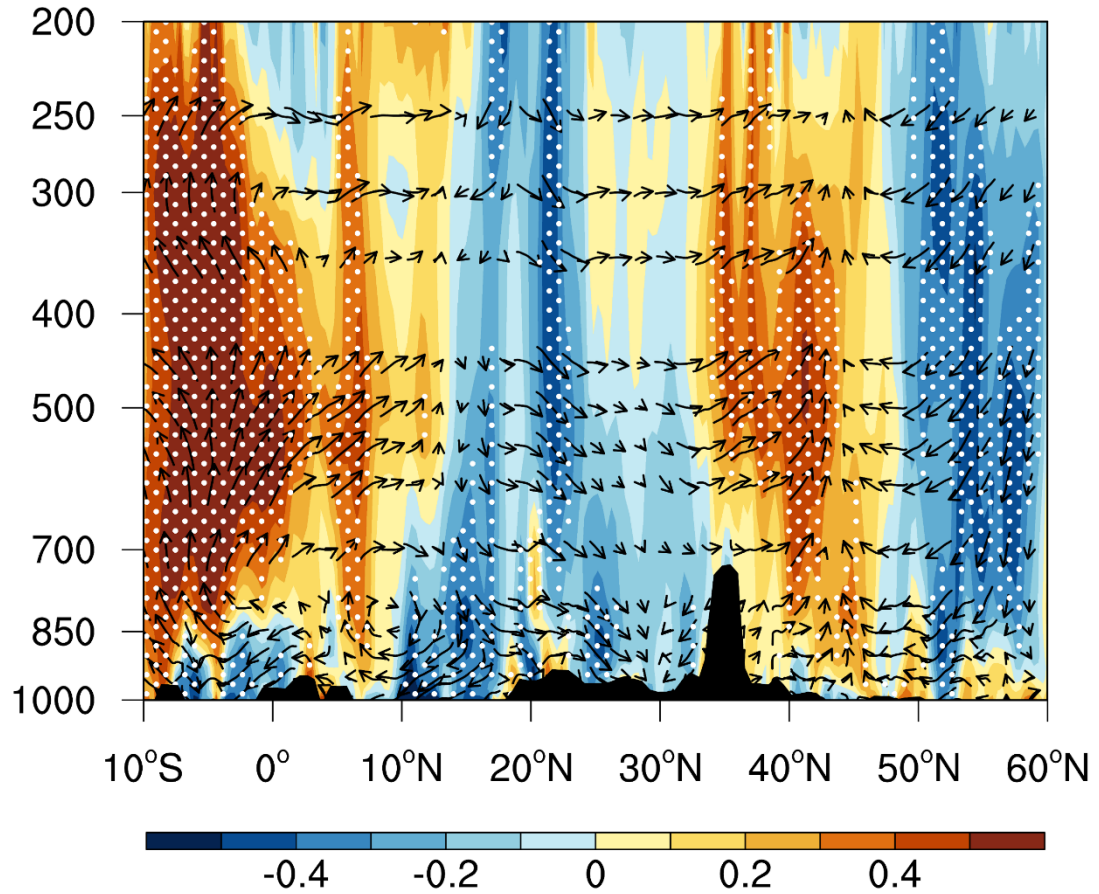
Supplementary Fig. 3| Interannual variation and abrupt change of JJA SST over key ocean basins. (a) Time series of standardized JJA SST in IP and the Pettitt test, **(b)** the same as **a**, but for the southwestern Pacific, **(c)** the same as **a**, but for North Atlantic.



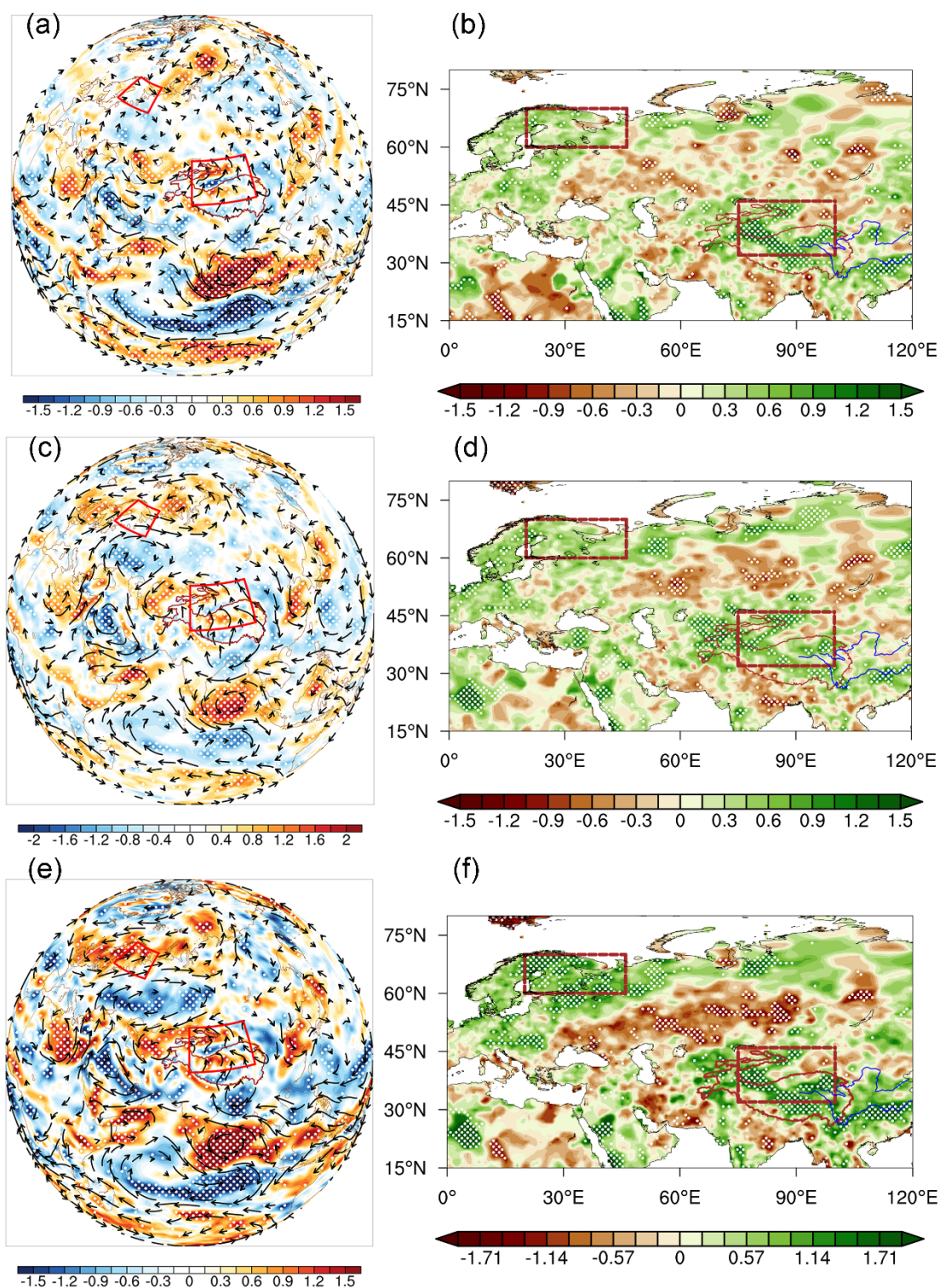
Supplementary Fig. 4| Correlation patterns of precipitation indices with upper-level circulations during P1 and P2. (a) Distribution of correlation coefficients between the time series of precipitation over the QTP-N and 200 hPa wind field during P1, contour: correlation coefficients between precipitation and vorticity, **(b)** as **a**, but during P2, **(c)** as **a**, but for the N.Eur, **(d)** as **b**, but for the N.Eur. The stippled regions indicate significant values at 90% confidence level according to the two-tailed Student's t test.



Supplementary Fig. 5| Convective anomalies induced by IP SST. Regressed OLR onto the standardized IP index during P2, unit: W m^{-2} . Stippled regions indicate significant values at 90% confidence level according to the two-tailed Student's t test. The red line denotes the wave train path from the Maritime Continent, across the Bay of Bengal and the west of the QTP-N to Europe.

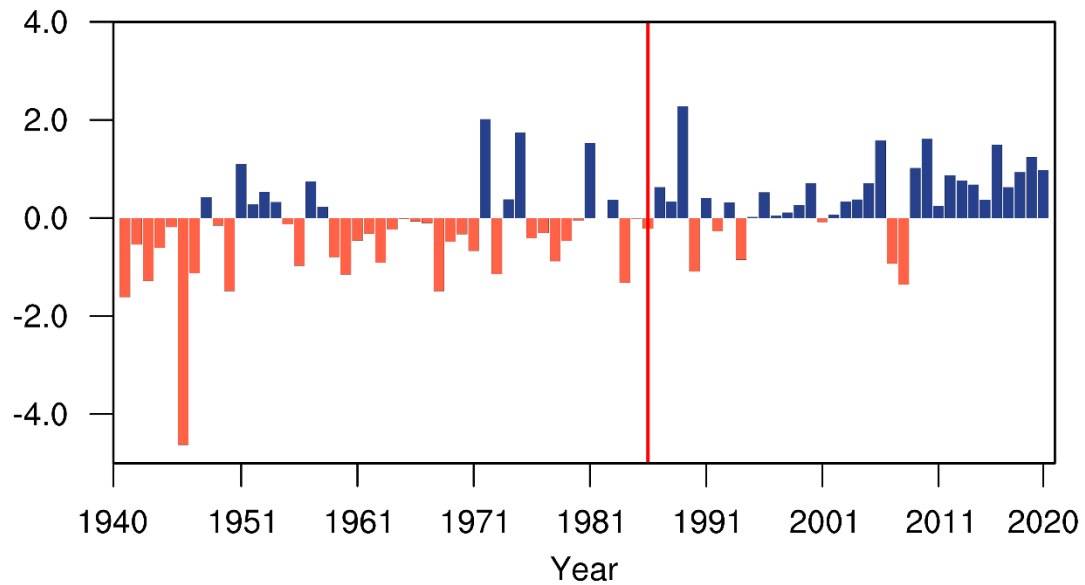


Supplementary Fig. 6| Circulation anomalies induced by IP SST. Distribution of correlation vectors between the IP index and the circulation ($v-\omega$) in a height–latitude cross section along the red path shown in Fig. 2b (from 10°S, 110°E to 55°N, 50°E) during JJA of P2. The shading indicates the correlation coefficient between the IP index and vertical velocity (vertical velocity multiplied by -100). The stippled regions indicate values significant at the 90% confidence level according to the two-tailed Student’s t test.

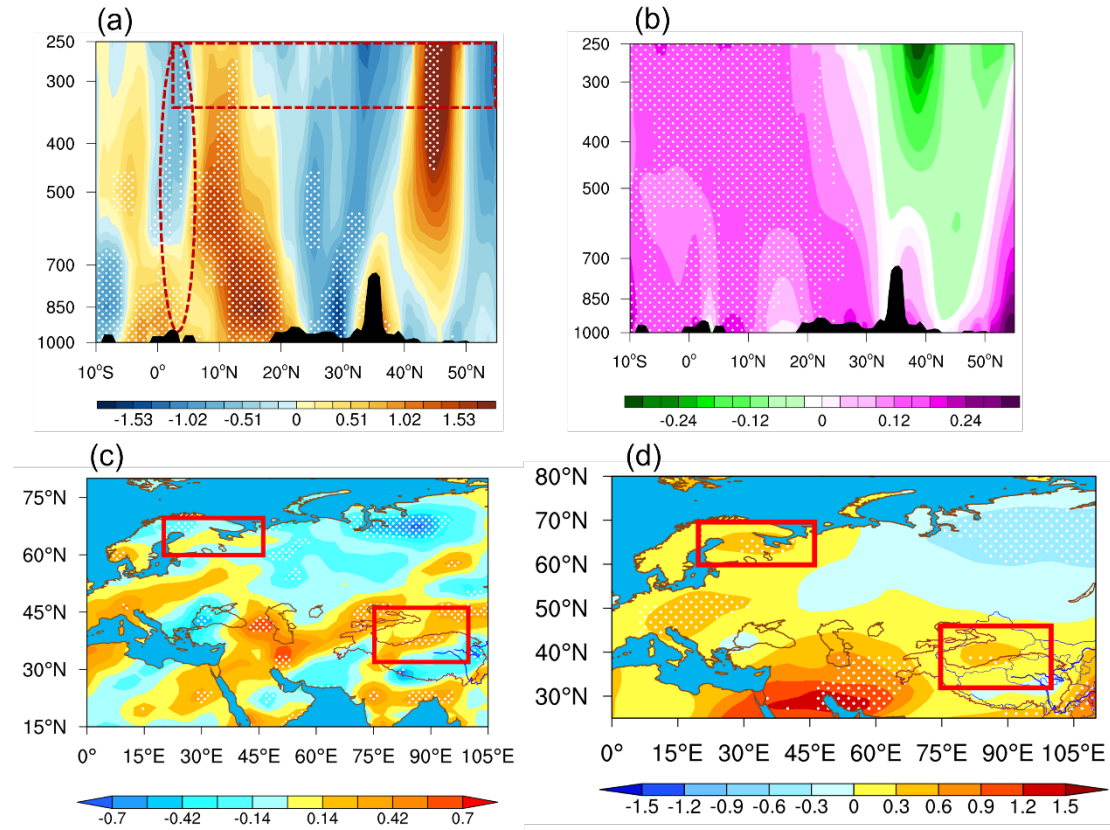


Supplementary Fig. 7| Composite differences of circulation and precipitation between high and low SST years over the IP and North Atlantic. (a) Distribution of the composite difference in the 700 hPa wind field between high and low IP SST years, contour: composite difference in

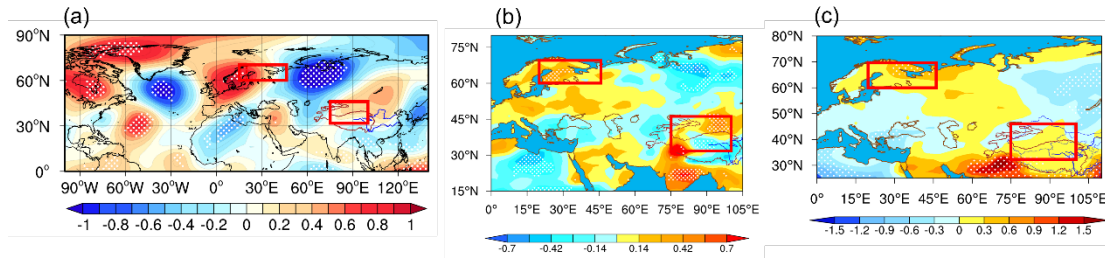
the 700 hPa vorticity, (unit: m s^{-1} and 10^{-5} s^{-1} , respectively), **(b)** as **a**, but for precipitation composite difference, unit: mm/month, **(c)** as **a**, but for North Atlantic SST, **(d)** as **c**, but for precipitation composite difference, **(e)** distribution of the composite difference in the 700 hPa wind field between high and low SST years (exceeding ± 1 standard deviation) both in the North Atlantic and IP concurrently, **(f)** as **e**, but for precipitation composite difference. The stippled regions indicate significant values at 90% confidence level according to the two-tailed Student's t test.



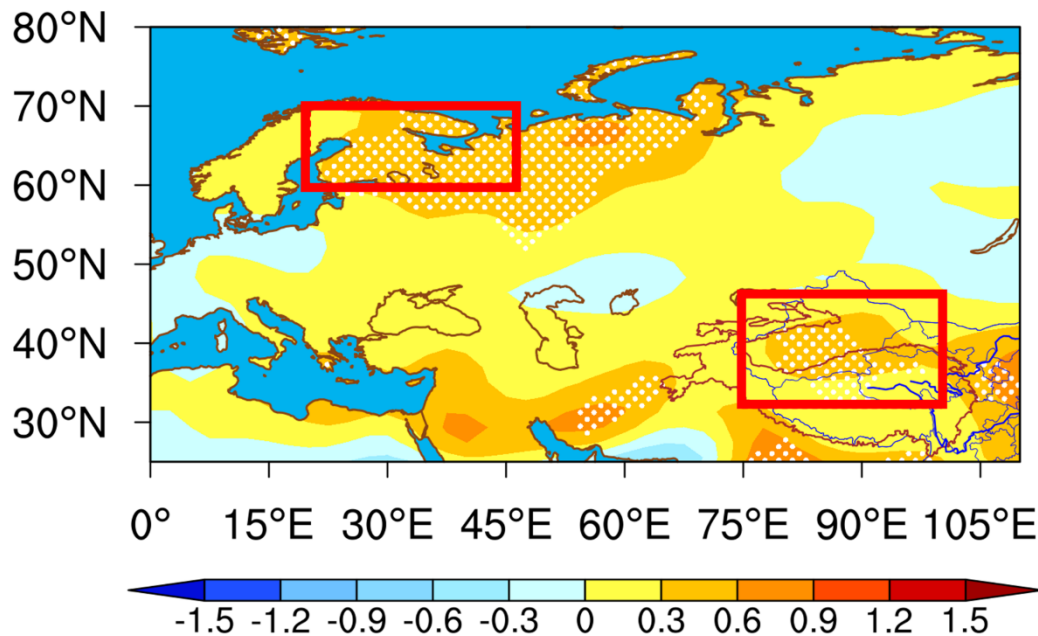
Supplementary Fig. 8| Interannual variation of moisture budget over the southern boundary of the QTP-N. Time series of standardized moisture budget for the southern boundary of the QTP-N.



Supplementary Fig. 9| Differences between the sensitivity experiment and the control experiment (IP-SENS). (a) Latitude-height cross-section of vorticity composite differences between the sensitivity and control experiments, along the red path shown in Fig. 2b (from 10°S, 110°E to 55°N, 50°E), unit: 10^{-6} s^{-1} , **(b)** same as **a**, but for temperature, unit: K, **(c)** composite differences in vertical velocity at 500 hPa between the sensitivity and control experiments (vertical velocity multiplied by -100), unit: Pa s^{-1} , **(d)** same as **c**, but for total (vertically integrated) precipitable water, unit: kg m^{-2} . Stippled areas indicate values significant at the 90% confidence level from a two-tailed Student's t test. The red box denotes the precipitation domain.



Supplementary Fig. 10| Differences between the sensitivity experiment and the control experiment (NA-SENS). (a) Composite differences in meridional wind at 200 hPa between the sensitivity and control experiments, unit: m s^{-1} , (b) same as a, but for vertical velocity at 500 hPa between the sensitivity and control experiments (vertical velocity multiplied by -100), unit: Pa s^{-1} , (c) same as b, but for total (vertically integrated) precipitable water, unit: kg m^{-2} . Stippled areas indicate values significant at the 90% confidence level from a two-tailed Student's t test. The red box denotes the precipitation domain.



Supplementary Fig. 11| Differences between the sensitivity experiment and the control experiment (SP-SENS). Composite differences for total (vertically integrated) precipitable water, unit: kg m^{-2} . Stippled areas

indicate values significant at the 90% confidence level from a two-tailed Student's t test. The red box denotes the precipitation domain.