# Supplementary Information
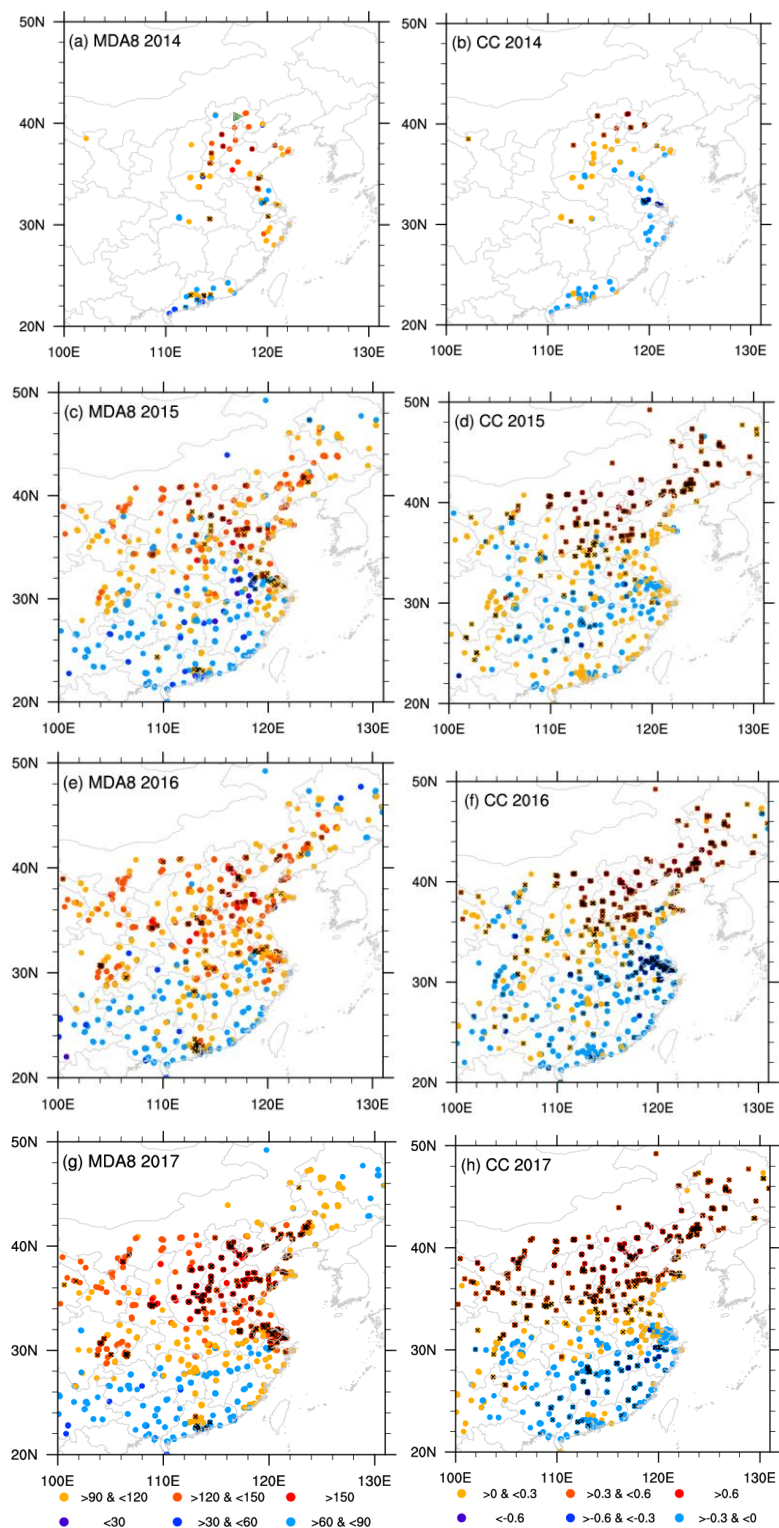


**Figure S1.** The distribution of the JJA mean MDA8 (a, c, e, g) and the correlation coefficients (b, d, f, h) between the daily MDA8 and SDZ MDA8 from 2014 to 2017. The black cross in panels a, c, e, and g indicate that the maximum daily MDA8 was larger than 265 μg/m³. The black cross in panels b, d, f, and h indicates that the CC was above the 95% confidence level. The green triple in panel (a) illustrates the location of the Shangdianzi site.
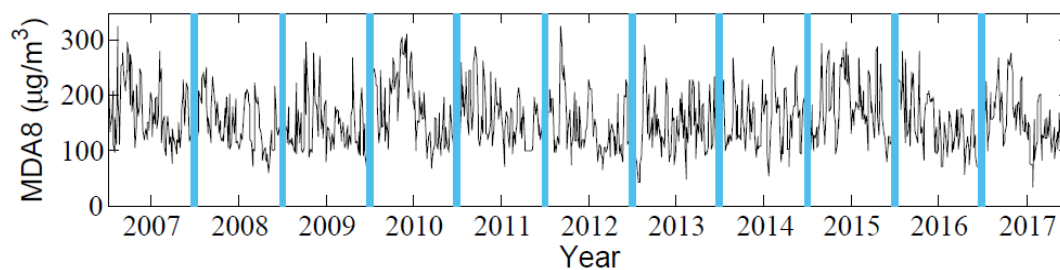
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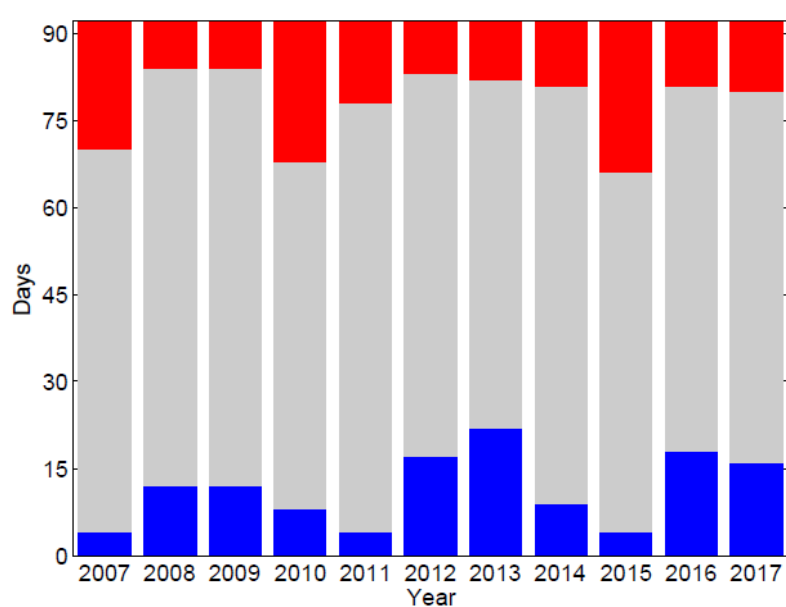**Figure S2.** The variation in the SDZ MDA8 from June to August during 2007–2017.



**Figure S3.** The number of days with MOP (red) and NOP (blue) events and the $O_3$ concentration between 100 and 215 µg/m³ (gray).
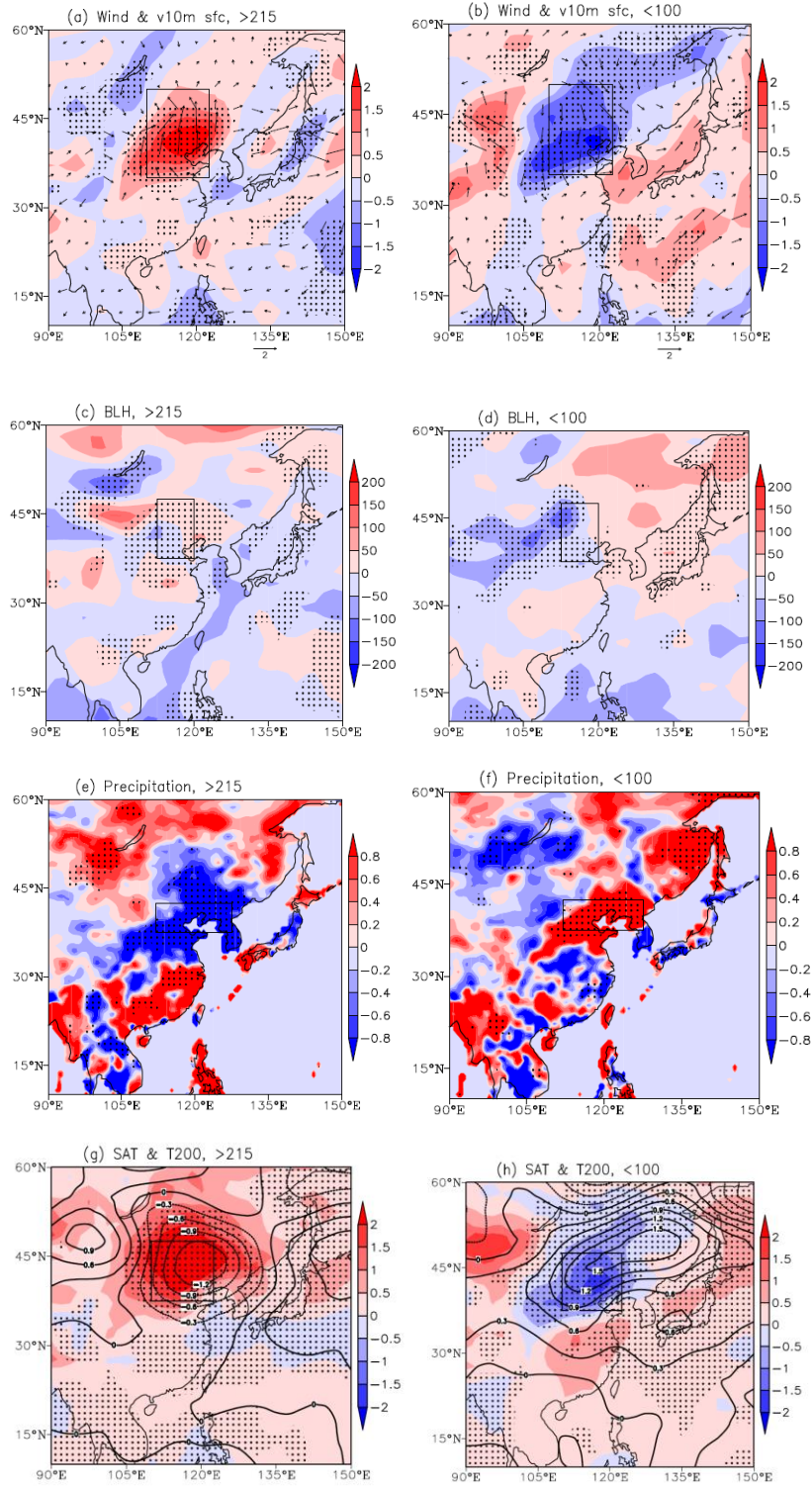
**Figure S4.** Composite of the meteorological conditions associated with different O3 events during 2007–2017. Results for MOP (a, c, e, g) and NOP (b, d, f, h) events included (a–b) surface wind (arrow) and v-wind (shading), (c–d) BLH (data range 2007–2014), (e–f) precipitation, (g–h) SAT, and temperature at 200 hPa. The black dots indicate that the composite passed the 95% confidence level. The boxes represent the area used to calculate the daily OWI. These composites were calculated using the NOAA datasets.
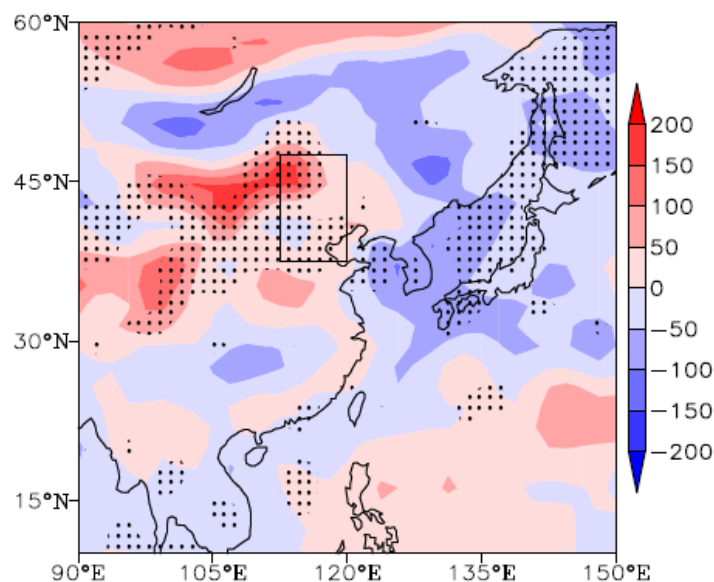
**Figure S5.** Differences in the boundary layer height between the MOP and NOP events during 2007–2014. The black dots denote that the composite passed the 95% confidence level. The boxes represent the area to calculate the daily OWI. These composites were calculated using the NOAA datasets.
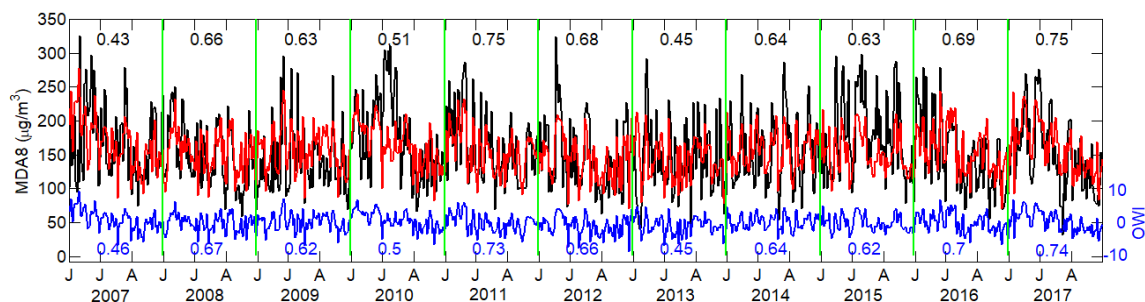


**Figure S6.** The variation in the daily (a) observational SDZ MDA8 (black), (b) fitting SDZ MDA8 (red), and (c) OWI (blue) from June to August during 2007–2017. The numbers are the correlation coefficients between the observational SDZ MDA8 and fitting SDZ MDA8 (red) and OWI (blue).
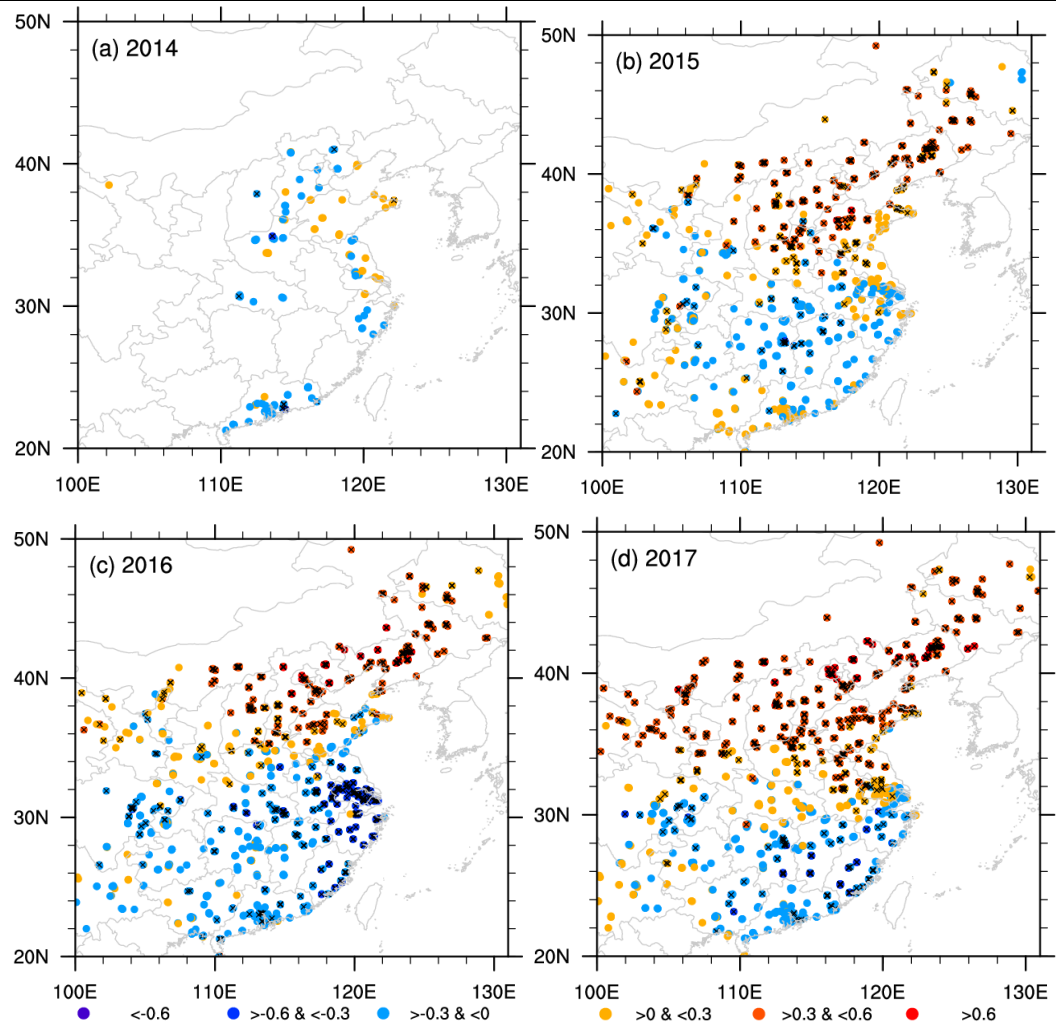
**Figure S7.** The correlation coefficients between the daily MDA8 and OWI from 2014 to 2017. The black crosses indicate that the CC was above the 95% confidence level.
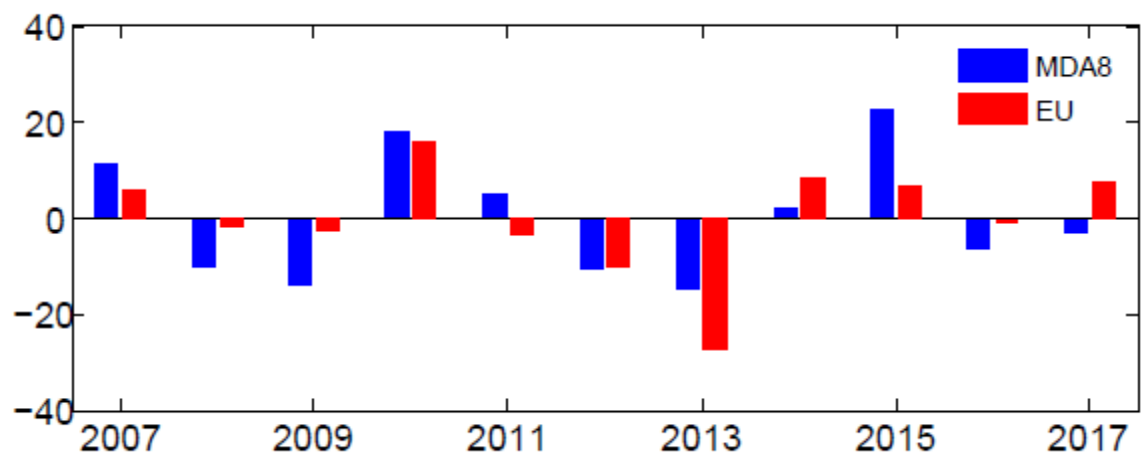


**Figure S8.** The variation in the JJA mean observational SDZ MDA8 (blue) and EUTP index (red) from 2007 to 2017.
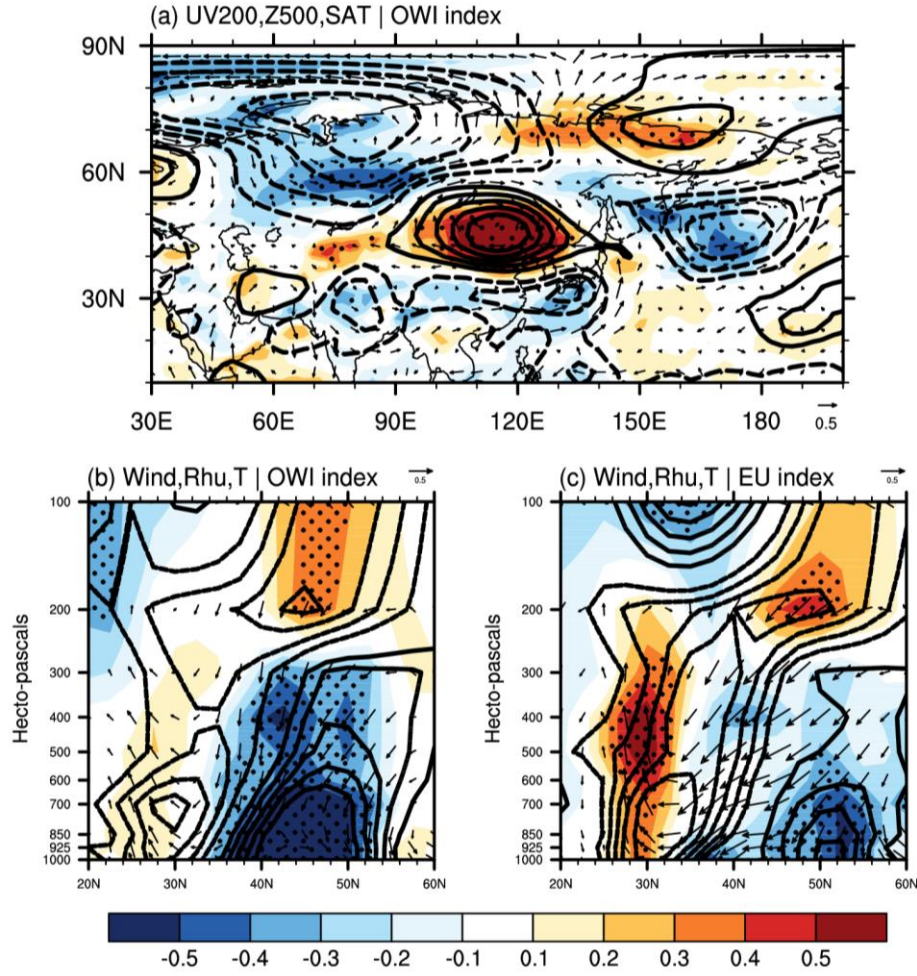
**Figure S9.** The associated atmospheric circulation. (a) The correlation coefficients between the JJA mean OWI and surface air temperature (shading), wind (arrow) at 200 hPa and geopotential height at 500 hPa (contour) from 1979 to 2017. The black dots indicate that the CC with surface air temperature was above the 95% confidence level. The cross-section (110°–125°E mean) correlation coefficients between JJA mean OWI (a), EUTP index (b) and relative humidity (shading), temperature (contour), wind (arrow, vertical speed multiplied by 100) from 1979 to 2017. The black dots indicate the CC with relative humidity exceeding the 95% confidence level (t test). The data used here are NOAA datasets.
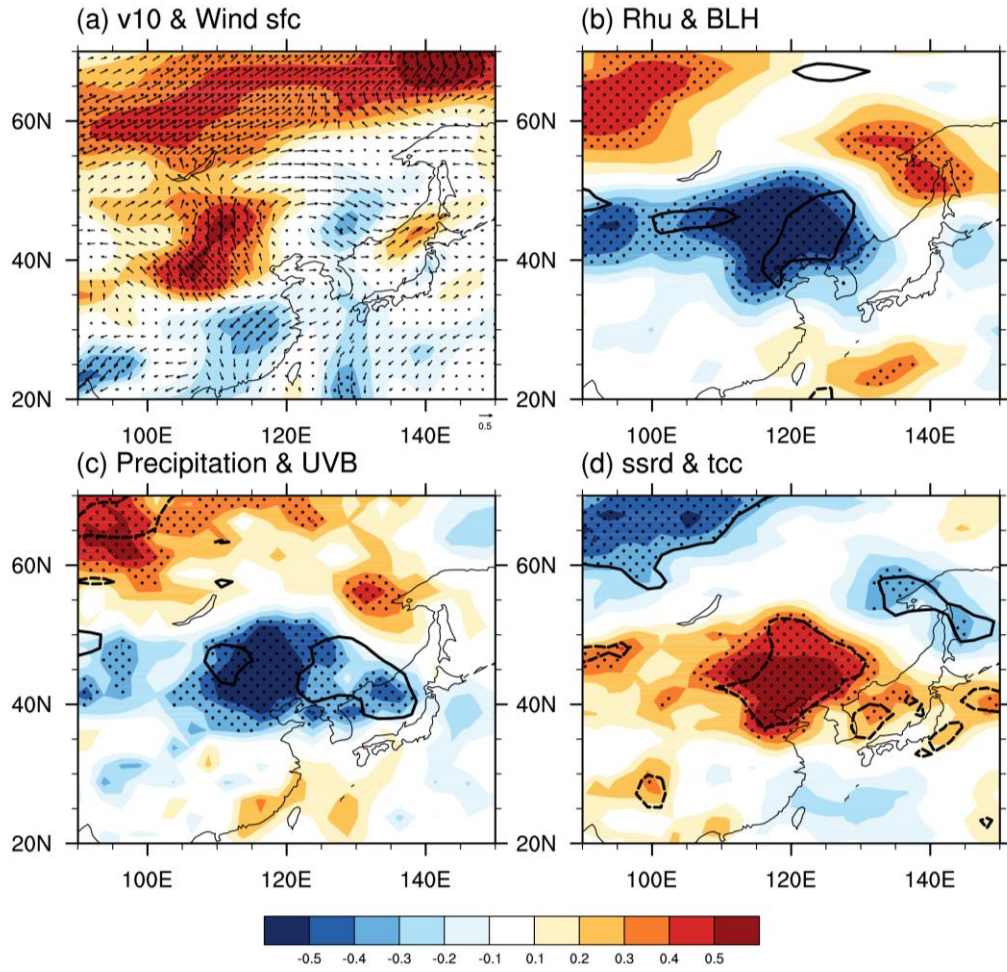
**Figure S10.** The correlation coefficients between the JJA mean OWI and (a) v wind at 10 m (shading), surface wind (arrow), (b) relative humidity near the surface (shading), boundary layer height (contour, data range 1979–2014), (c) precipitation (shading), downward UV radiation at the surface (contour, data range 1979–2014), (d) downward solar radiation at the surface (shading), the total cloud cover (contour) from 1979 to 2017. The black dots indicate that the CC with temperature was above the 95% confidence level. The contours plotted in panel (b–d) exceeded the 95% confidence level. The data used here are NOAA datasets.
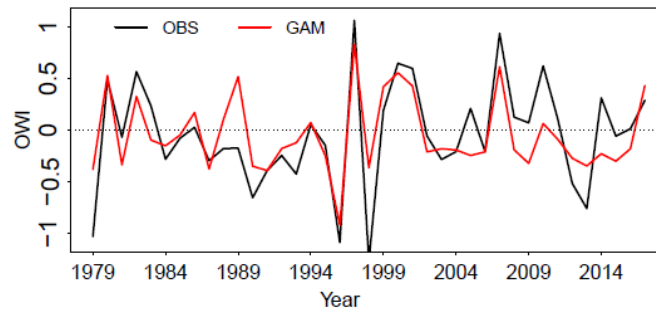


**Figure S11.** The variation in the observational OWI (black) and the fitted OWI by the generalized additive model (red) from 1979 to 201

**Figure S12.** The correlation coefficients between the May SI index and (a) surface air temperature (shading), geopotential height at 500 hPa (contour) from 1979 to 2017. (b) and precipitation (shading), surface wind (arrow), (c) downward UV radiation at the surface (shading, 1979–2014) and total cloud cover (contour) from 1979 to 2017. The black dots indicate that the CC with surface air temperature (a), precipitation (b) and downward UV radiation (c) was above the 95% confidence level. The data used here are NOAA datasets.