On the atmospheric background for the occurrence of three heat wave types in East China

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1 Background

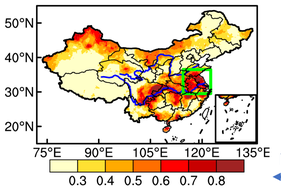

Fig.1 Spatial distribution of the frequency of compound HWs averaged from 1961 to 2016. East China is outlined by green rectangle.

East China is a hotspot where compound HWs occur most frequently across China.

Heat waves (HWs) can be classified into three types: **daytime HWs** (occurring only in daytime), **nighttime HWs** (occurring only in nighttime), and **daytime-nighttime compound HWs** (occurring simultaneously in daytime and nighttime).

Compared with daytime HWs, nighttime HWs have greater adverse effects particularly on human health. Such damages are further amplified on the occasion of compound HWs.

The understanding of associated physical mechanisms underlying the occurrence of compound HWs remains open and some issues have yet to be well addressed.

2 Data and Methods

Data:

The CN05.1 gridded daily maximum and minimum temperatures (Tmax/Tmin) with a horizontal resolution of 0.25 °×0.25 °.

The daily and 6-hourly atmospheric reanalysis data at 2.5°×2.5 ° are derived from NCEP/NCAR.

Definition of heat waves:

(a) **Compound HW**: at least three consecutive days with simultaneous occurrence of hot days and hot nights (i.e. Tmax ⩾ 90th percentile and Tmin ⩾ 90th percentile).

(b) **Daytime HW**: at least three consecutive hot days but without any following hot nights.

(c) **Nighttime HW**: at least three consecutive hot nights but without any preceding hot days.

The composite analysis is applied after removing the influence of seasonal cycle. The significance is estimated via the student's *t*-test.

3.1 Spatiotemporal characteristics of HWs

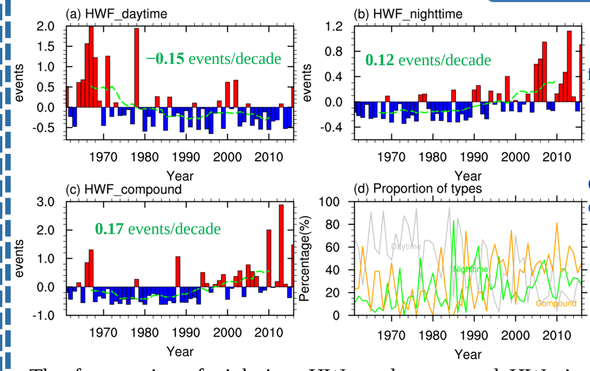

Fig.2 Temporal changes of the frequencies (bar) of (a) daytime HWs, (b) nighttime HWs, and (c) compound HWs averaged over East China. (d) Proportions of daytime HWs (grey line), nighttime HWs (green line), and compound HWs (orange line) to the total HW events.

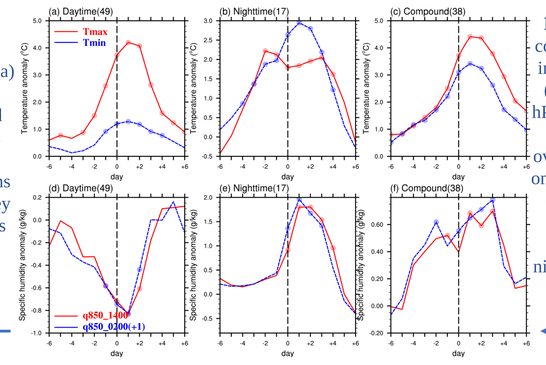

Fig.3 Evolution of composite anomalies in (a–c) Tmax/Tmin (°C) and (d–f) 850 hPa specific humidity (g kg^{-1}) averaged over East China from onset-6 to onset+6 for (left-hand panels) daytime, (middle-hand panels) nighttime, and (right-hand panels) compound HWs.

The frequencies of nighttime HWs and compound HWs in East China exhibit considerable increasing trends since the 1960s, while the frequency of daytime HWs shows a decreasing trend. Consequently, the proportion of compound HWs to the total HWs becomes increasingly higher in recent decade.

The evolution of local temperature and humidity conditions is different. Daytime (nighttime) HWs reflect a dry-hot (moisture-hot) nature. For compound HWs, the Tmax and Tmin both increase significantly, concurrent with above-normal humidity.

3.2 Associated atmospheric background

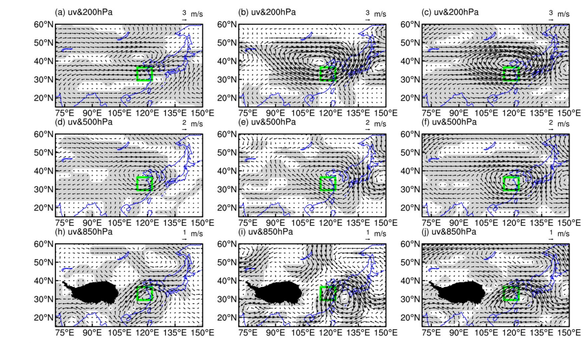

Fig.4 Composite anomalies of horizontal winds (m s^{-1}) at (a–c) 200 hPa, (d–f) 500 hPa, and (h–j) 850 hPa for (left-hand panels) daytime, (middle-hand panels) nighttime, and (right-hand panels) compound HWs.

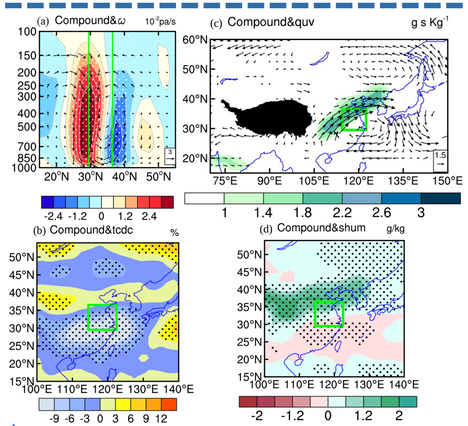

Fig.5 Composite anomalies of (a) latitude-height cross section of meridional wind (vector, m s^{-1}) and vertical velocity (vector and shading, 10^{-2} Pa s^{-1}) averaged along 114.5°–122.5°E, (b) total cloud cover (%), (c) water vapor flux (vector, g s kg^{-1}) and its absolute value (shading), and (d) specific humidity (g kg^{-1}) at 850 hPa for compound HWs.

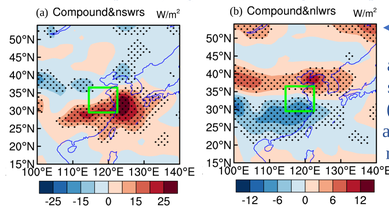

Fig.6 Composite anomalies of (a) net shortwave radiation (W m^{-2}) at daytime, and (b) net longwave radiation (W m^{-2}) at nighttime for compound HWs.

Strong subsidence to the south part of East China and a decrease of cloud cover favor more shortwave radiation to reach the surface. Such a distribution of moisture anomalies benefits the increase (decrease) of downward longwave radiation to the north (south) of East China during nighttime.

3.3 Evolution of large-scale circulations

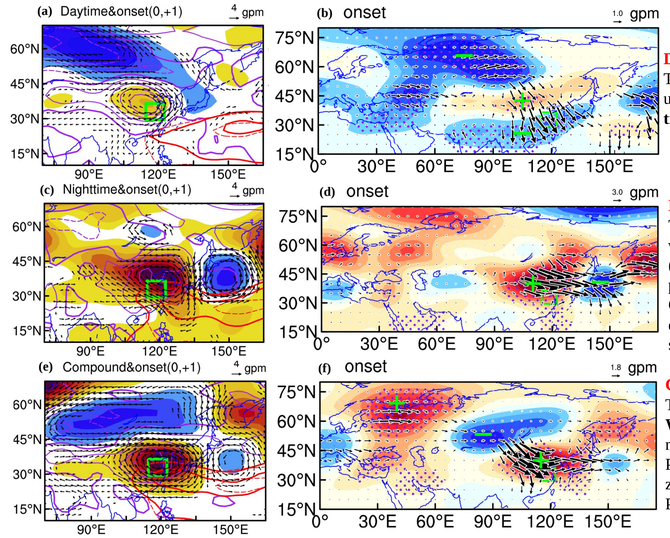

Fig.7 Composite anomalies of (left-hand panels) air temperature at 1000 hPa (purple contour, °C), geopotential height (shading, gpm), horizontal winds at 500 hPa (vector, m s^{-1}) and (right-hand panels) 200 hPa geopotential height (shading, gpm) and wave activity flux (vector, m^2 s^{-2}) on onset day of (a, b) daytime HWs, (c, d) nighttime HWs, and (e, f) compound HWs.

Daytime HWs:

The downstream propagation of an upper-tropospheric **meridional wave train** originating from western Siberia.

Nighttime HWs:

The **northwestward extension of the western Pacific subtropical high (WPSH)** and a **zonal teleconnection pattern** emanating from the east to the Caspian Sea and propagating downstream along the westerly jet stream.

Compound HWs:

The **northwestward extension of the WPSH** and the **wave train** propagates meridionally from the Scandinavian Peninsula to East China first and then zonally downstream to the western Pacific.

4 Summary

(1) The frequencies of nighttime HWs and **compound HWs in East China exhibit considerable increasing trends since the 1960s**, with larger increasing rate for compound HWs (0.17 events per decade) than for nighttime HWs (0.12 events per decade). In contrast, the frequency of daytime HWs shows a decreasing trend (−0.15 events per decade).

(2) The evolution of local temperature and humidity conditions is different for the occurrences of three HW types. Daytime HWs are shown to be formed rapidly and occur under anomalous dry conditions. However, significant increases in the Tmin and humidity are prerequisite for the occurrence of nighttime HWs. For compound HWs, the Tmax and Tmin both increase significantly, concurrent with above-normal humidity.

(3) The large-scale atmospheric circulations responsible for the occurrences of three HW types over East China are featured by **the anticyclonic circulation anomalies** from the upper troposphere to the lower troposphere. However, **their locations and intensities appear somewhat different, causing different configuration of vertical motion, cloud, humidity, and radiation.** The occurrence of compound HWs corresponds to the combination of conditions for daytime and nighttime HWs.

(4) Further investigation indicates that **nighttime and compound HWs are accompanied with the northwestward extension of the WPSH**. In addition, the formation of daytime HWs links to the downstream propagation of an upper-tropospheric meridional wave train, whereas nighttime HWs are related to a zonal teleconnection pattern. **The wave train related to compound HWs shares the features of daytime and nighttime HWs**

Reference: Xie W, Zhou B. 2023. On the atmospheric background for the occurrence of three heat wave types in East China. *Weather and Climate Extremes*, 39: 100539. https://doi.org/10.1016/j.wace.2022.100539.