Online Supplemental Material

The evolving distribution of humidity conditional on temperature and implications for compound heat extremes across China in a warming world

Caixia Liang[a] and Jiacan Yuan*[,a,b]

[a]*Department of Atmospheric and Oceanic Sciences & Institute of Atmospheric Sciences & Shanghai Key Laboratory of Ocean–Land–Atmosphere Boundary Dynamics and Climate Change, Fudan University, Shanghai, China*

[b]*Shanghai Frontiers Science Center of Atmosphere–Ocean Interaction, Fudan University, Shanghai, China*

*Corresponding author.

E-mail address: jcyuan@fudan.edu.cn (J. Yuan).

This file includes:
Supplementary Tables S1–S2 and Figures S1–S4

Table S1. The number of stations distributed across the seven regions of China.

Region	Descriptive name	Number of stations
Region 1	Temperate humid and sub-humid Northeast China	33
Region 2	Temperate grassland of Inner Mongolia	32
Region 3	Warm-temperate humid and sub-humid North China	44
Region 4	Subtropical humid Central and South China	85
Region 5	Tropical humid South China	36
Region 6	Temperate and warm-temperate desert of Northwest China	26
Region 7	Qinghai–Tibetan Plateau	41
All		297

Table S2. Number of stations from East China with $Td'_{95,T'95}$ exceeding high values.

Global warming levels	Region	Number of stations	
		>24℃	>30℃
2.0 ℃	Region 1	16	0
	Region 2	0	0
	Region 3	28	0
	Region 4	62	0
	Region 5	26	0
4.5 ℃	Region 1	25	1
	Region 2	8	0
	Region 3	28	6
	Region 4	44	9
	Region 5	25	10

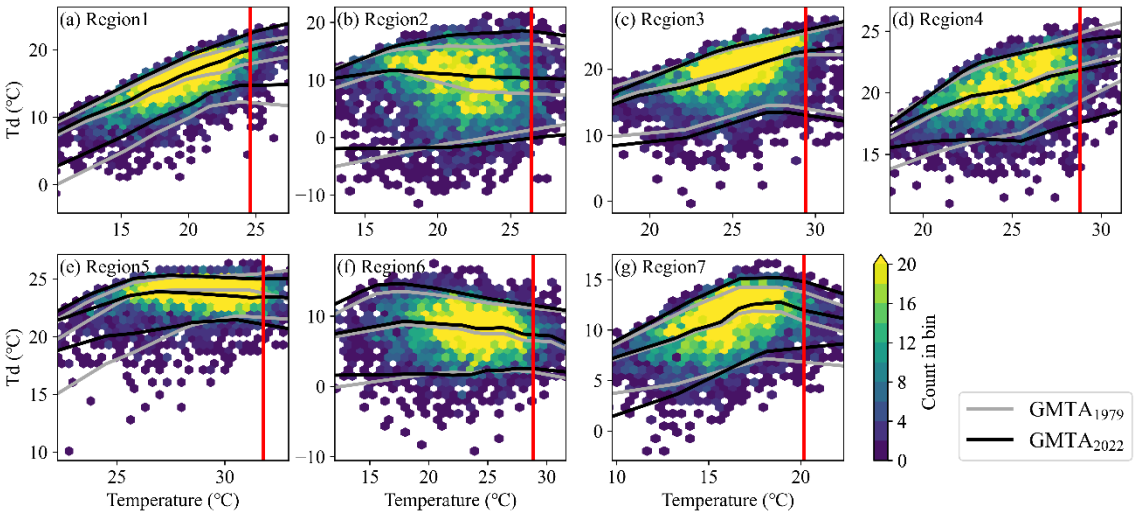

Fig. S1. Changes in the distribution of dew point conditional on local temperature in response to the GMTA derived by the quantile regression model. Gray (black) lines summarize the relationships between *T'* and *Td'* by the quantile smoothing spline fit conditional on the 1979 (grey lines) and 2022 (black lines) low-pass filtered GMTA for the 5th , 50th and 95th percentiles of *Td'*. The colored hexagons denote the joint distribution between summer daily-mean temperature and dew point at one of the stations in seven regions for 1979–2022. The vertical lines in (a–g) show the 95th percentile of temperature for the stations calculated over the full record. The 5th, 50th, and 95th quantile of *Td'* conditional on *T'* developed by the quantile regression model can skillfully capture the joint distribution between *T'* and *Td'*. The 5th quantile and 95th quantile of *Td'* respond differently to GMTA during high local temperatures (95th quantile) across regions. For instance, in region 4 and 5, Td'_{5} and Td'_{95} at T'_{95} (hereinafter referred to as $Td'_{5,T'95}$ and $Td'_{95,T'95}$) under the GMTA in 2022 are lower than under the GMTA in 1979, indicating an increase in dry-hot weather when the climate gets warmer. Conversely, in region 1, 6 and 7, $Td'_{5,T'95}$ and $Td'_{95,T'95}$ under the GMTA in 2022 are higher, indicating more humid-heat weather.

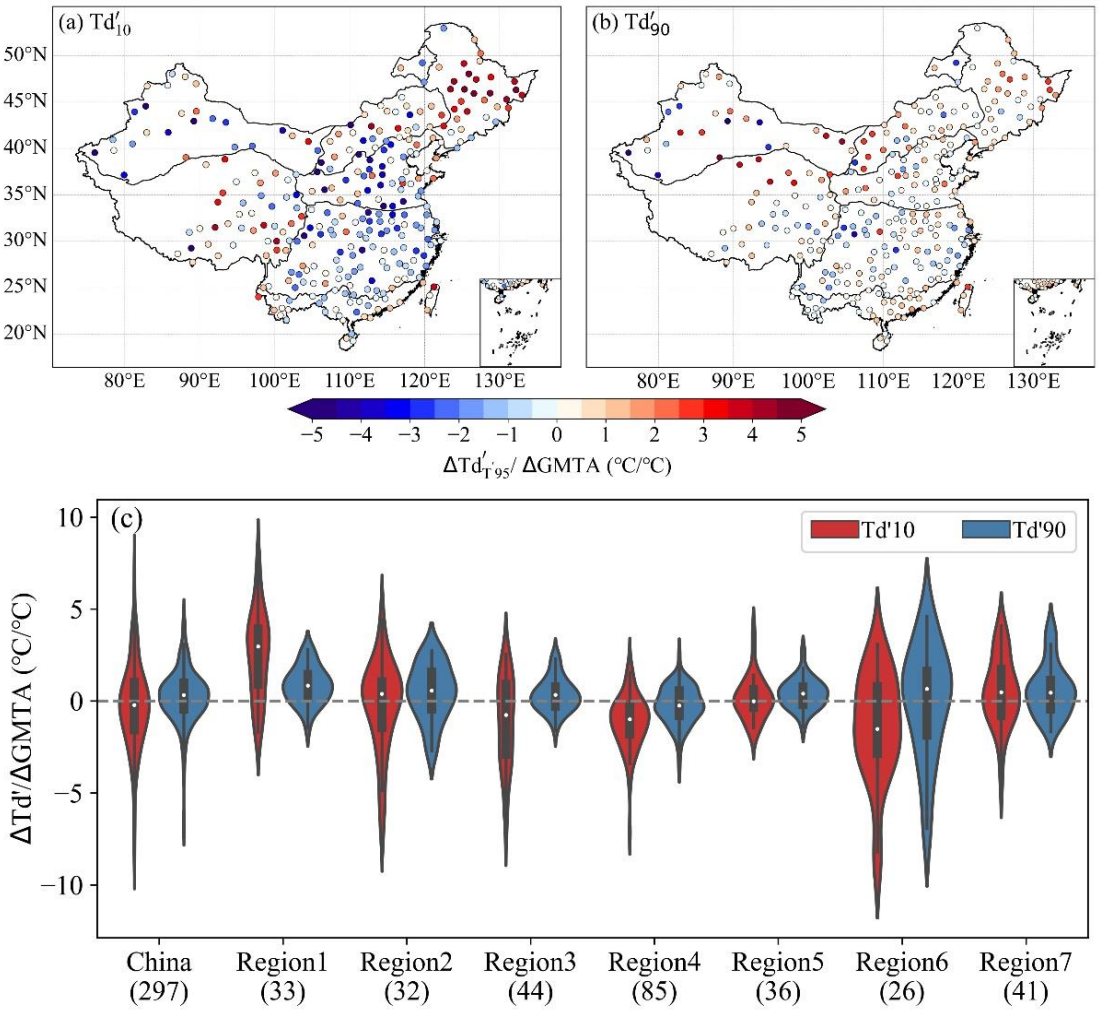

Fig. S2. (a) Spatial distribution of the estimated *Td* change rate in $Td'_{10,T'95}$ at selected HadISD stations across China. (b) The same as in (a) but for $Td'_{90,T'95}$. (c) Violin plot of the *Td* change rate in $Td'_{10,T'95}$ and $Td'_{90,T'95}$ at stations across China and in seven regions, respectively.

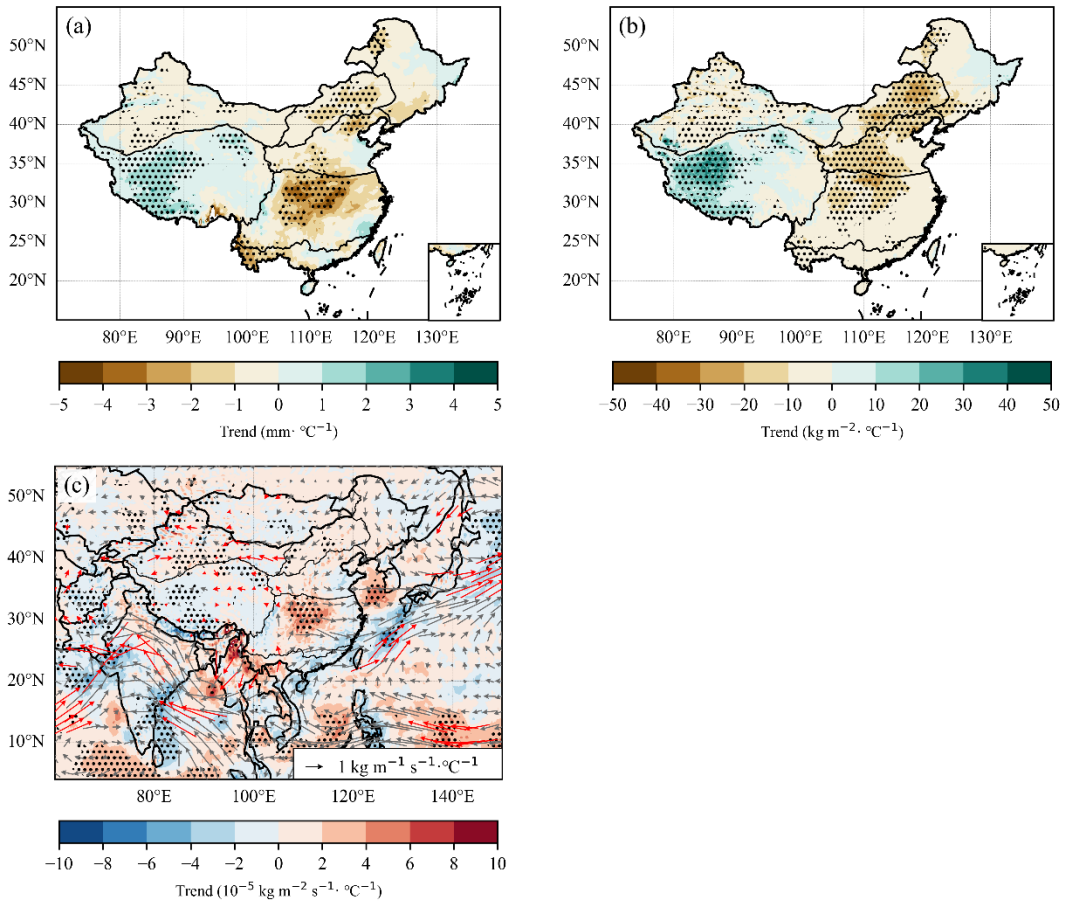

Fig. S3. Trends of (a) total precipitation, (b) soil moisture, and (c) 850-hPa water vapor flux (vectors; units: kg m^{-1} s^{-1} $℃^{-1}$) and the vertical integral of divergence of moisture flux (shading; units: kg m^{-2} s^{-1} $℃^{-1}$) with GMTA in summer from 1970 to 2022. Black dots and red vectors indicate areas where the trends are significant at the 95% confidence level.

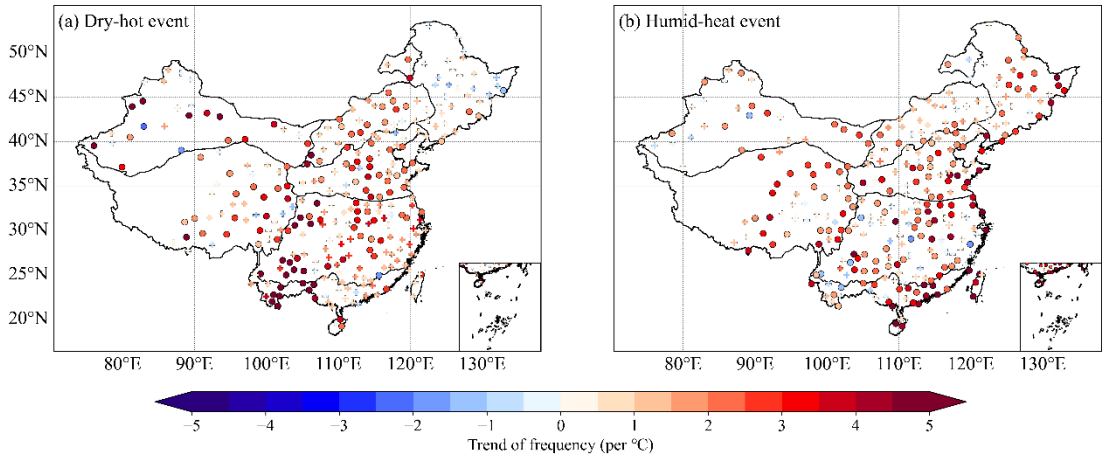

Fig. S4. Spatial distribution of the trend in the frequency of (a) dry-hot events and (b) humid-heat events in China with the GMTA during 1979–2022. Circles indicate trends that are significant at the 90% confidence level. The compound dry-hot events at each station are defined as those with temperatures above the 90th percentile from 1979 to 2022 and dew point temperatures below the temperature-dependent 10th percentile of dewpoint temperature, while compound humid-heat events are those with temperatures above the 90th percentile and dewpoint temperatures above the 90th percentile, using the dataset from HadISD v3.3.0.2022f.