Increasing heat risk in China's urban agglomerations

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Abstract

A heat danger day is defined as an extreme when the heat stress index (a combined temperature and humidity measure) exceeding 41 , warranting public heat alerts. This study assesses future heat risk (i.e., heat danger days times the population at risk) based on the latest Coupled Model Intercomparison Project phase 6 (CMIP6) projections. In recent decades (1995-2014) China's urban agglomerations (Beijing-Tianjin-Hebei, Yangtze River Delta, Middle Yangtze River, Chongqing-Chengdu, and Pearl River Delta) experienced no more than 3 heat danger days per year, but this number is projected to increase to 3-13 days during the population explosion period (2041-2060) under the high-emission pathways (SSP3-7.0 and SSP5-8.5). This increase will result in approximately 260 million people in these agglomerations facing more than 3 heat danger days annually, accounting for 19% of the total population of China, and will double the current level of overall heat risk. During the period 2081-2100, there will be 8-67 heat danger days per year, 60-90% of the urban agglomerations will exceed the current baseline number, and nearly 310 million people (39% of the total China population) will be exposed to the danger, with the overall heat risk exceeding 18 times the present level. The greatest risk is projected in the Pearl River Delta region with 67 heat danger days to occur annually under SSP5-8.5. With 65 million people (68% of the total population) experiencing increased heat danger days, the overall heat risk in the region will swell by a factor of 50. Conversely, under the low-emission pathways (SSP1-2.6 and SSP2-4.5), the annual heat danger days will remain similar to the present level or increase slightly. The result indicates the need to develop strategic plans to avoid the increased heat risk of urban agglomerations under high emission-population pathways.

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Abstract

A heat danger day is defined as an extreme when the heat stress index (a combined temperature and humidity measure) exceeding 41 °C, warranting public heat alerts. This study assesses future heat risk (i.e., heat danger days times the population at risk) based on the latest Coupled Model Intercomparison Project phase 6 (CMIP6) projections. In recent decades (1995-2014) China's urban agglomerations (Beijing-Tianjin-Hebei, Yangtze River Delta, Middle Yangtze River, Chongqing-Chengdu, and Pearl River Delta) experienced no more than 3 heat danger days per year, but this number is projected to increase to 3-13 days during the population explosion period (2041-2060) under the high-emission pathways (SSP3-7.0 and SSP5-8.5). This increase will result in approximately 260 million people in these agglomerations facing more than 3 heat danger days annually, accounting for 19% of the total population of China, and will double the current level of overall heat risk. During the period 2081-2100, there will be 8-67 heat danger days per year, 60-90% of the urban agglomerations will exceed the current baseline number, and nearly 310 million people (39% of the total China population) will be exposed to the danger, with the overall heat risk exceeding 18 times the present level. The greatest risk is projected in the Pearl River Delta region with 67 heat danger days to occur annually under SSP5-8.5. With 65 million people (68% of the total population) experiencing increased heat danger days, the overall heat risk in the region will swell by a factor of 50. Conversely, under the low-emission pathways (SSP1-2.6 and SSP2-4.5), the annual heat danger days will remain similar to the present level or increase slightly. The result indicates the need to develop strategic plans to avoid the increased heat risk of urban agglomerations under high emission-population pathways.

Increasing heat risk in China's urban agglomerations (Zhang et al., 2021)

Population explosion period **2041-2060** Highest warming period **2081-2100**

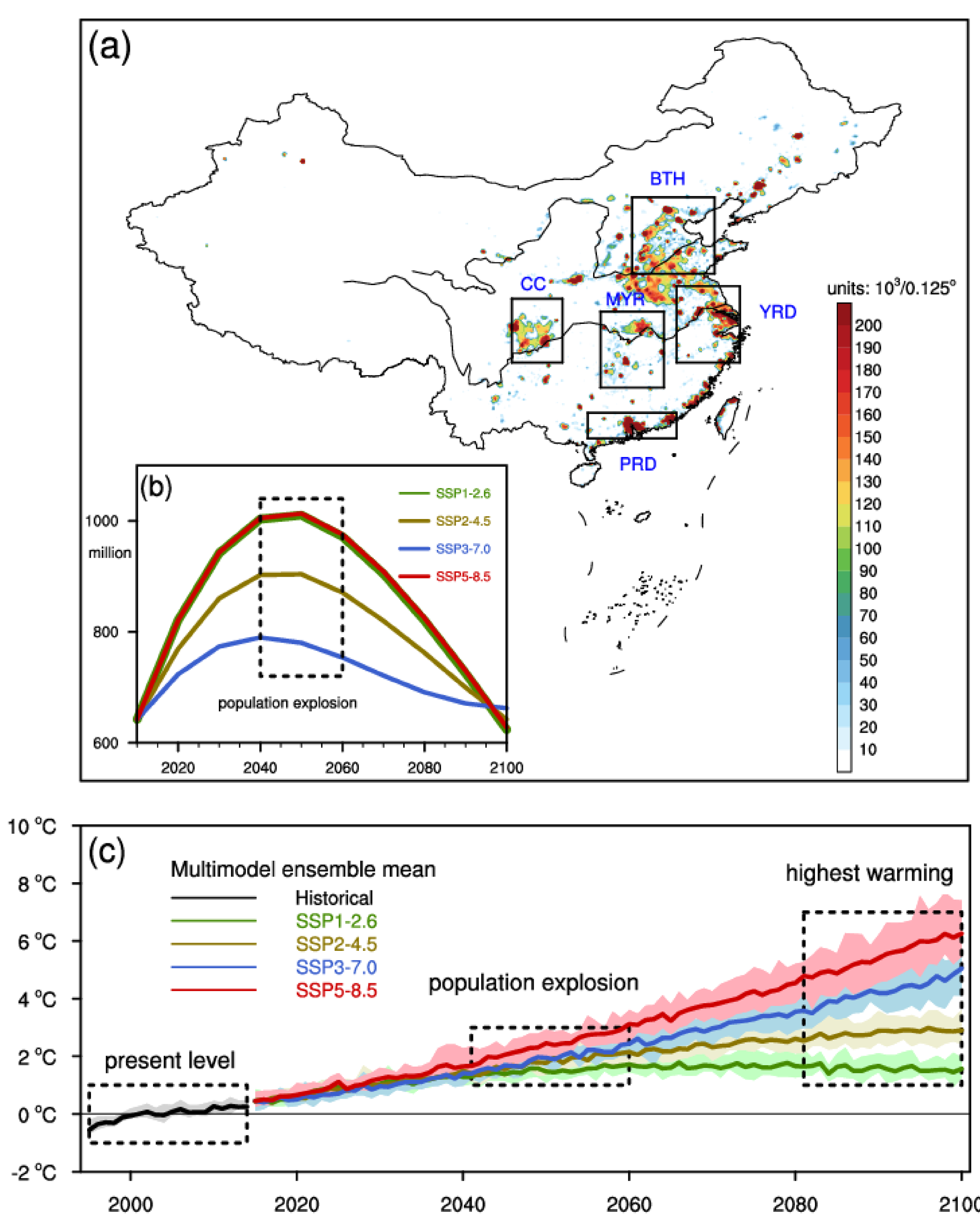

Figure 1. (a) Urban population density of China in 2010 [units: 10^3 per grid of 0.125° × 0.125°], with the five CUAs outlined in black boxes. (b) The time series of China's urban population from 2010 to 2100 (units: million), where the green, yellow, blue, and red lines indicate SSP1-2.6, SSP2-4.5, SSP3-7.0, and SSP5-8.5, respectively. (c) China's annual surface air temperature departures from the present level (1995-2014) during 1995-2100. The solid lines show the multimodel ensemble means, while the shaded areas indicate the 25th and 75th percentiles of the model spreads. The black line is for the present level (1995-2014), while the colored lines are for the projections (2015-2100) using the different SSP scenarios.

The warming is highest under **SSP5-8.5** and lowest under **SSP1-2.6**. Most CUAs would become drier. **The future heat stress trends mostly follow those of temperature**.

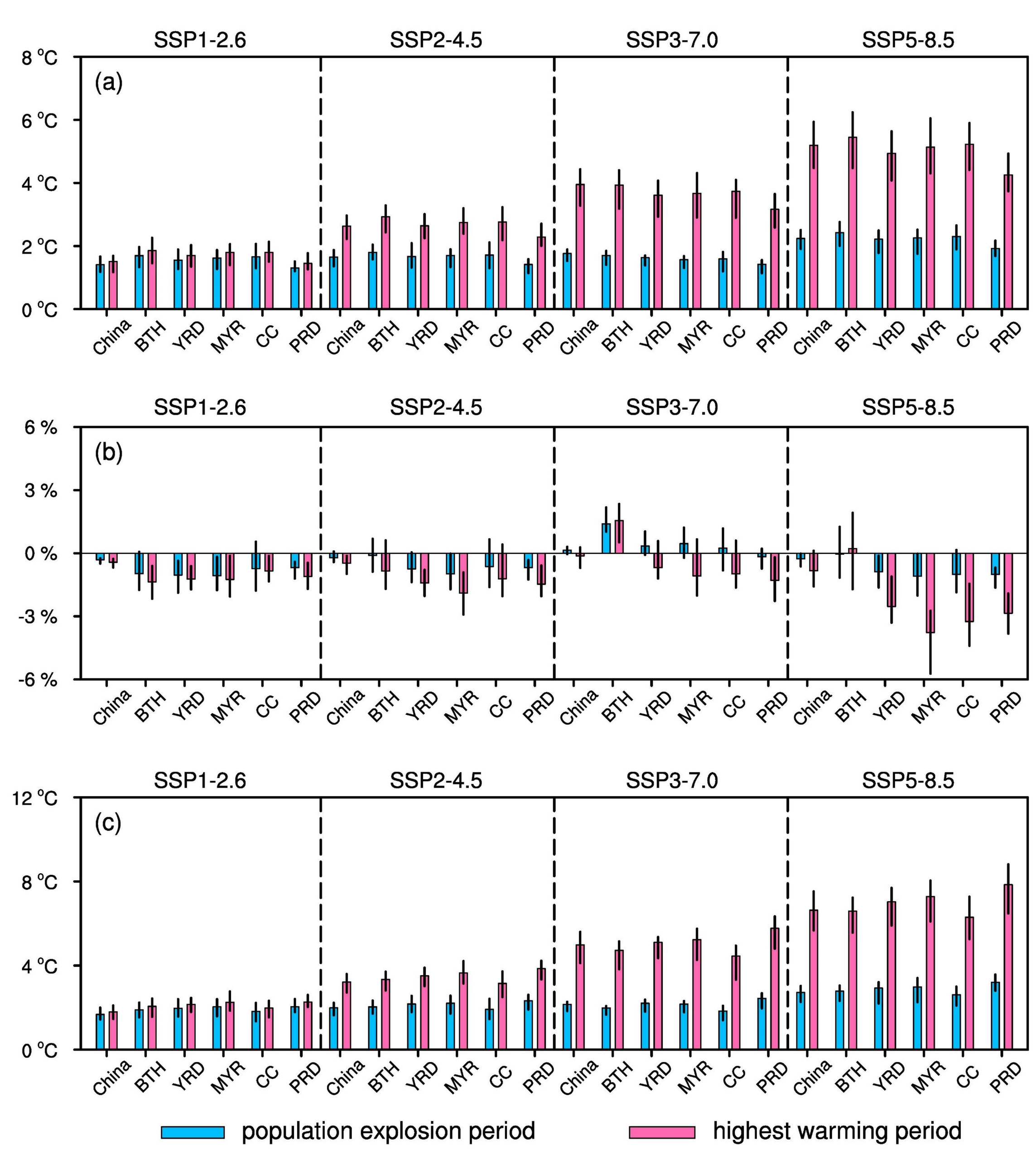

Figure 2. Projected changes in (a) surface air temperature (°C), (b) relative humidity (%), and (c) HSI (°C) for the population explosion (blue) and highest warming (red) periods. The vertical black line across the top of each bar (mean) depicts the 25th and 75th percentiles of all MME results.

Heat stress will increase faster than global warming, especially **for southern China under high-emission pathways**.

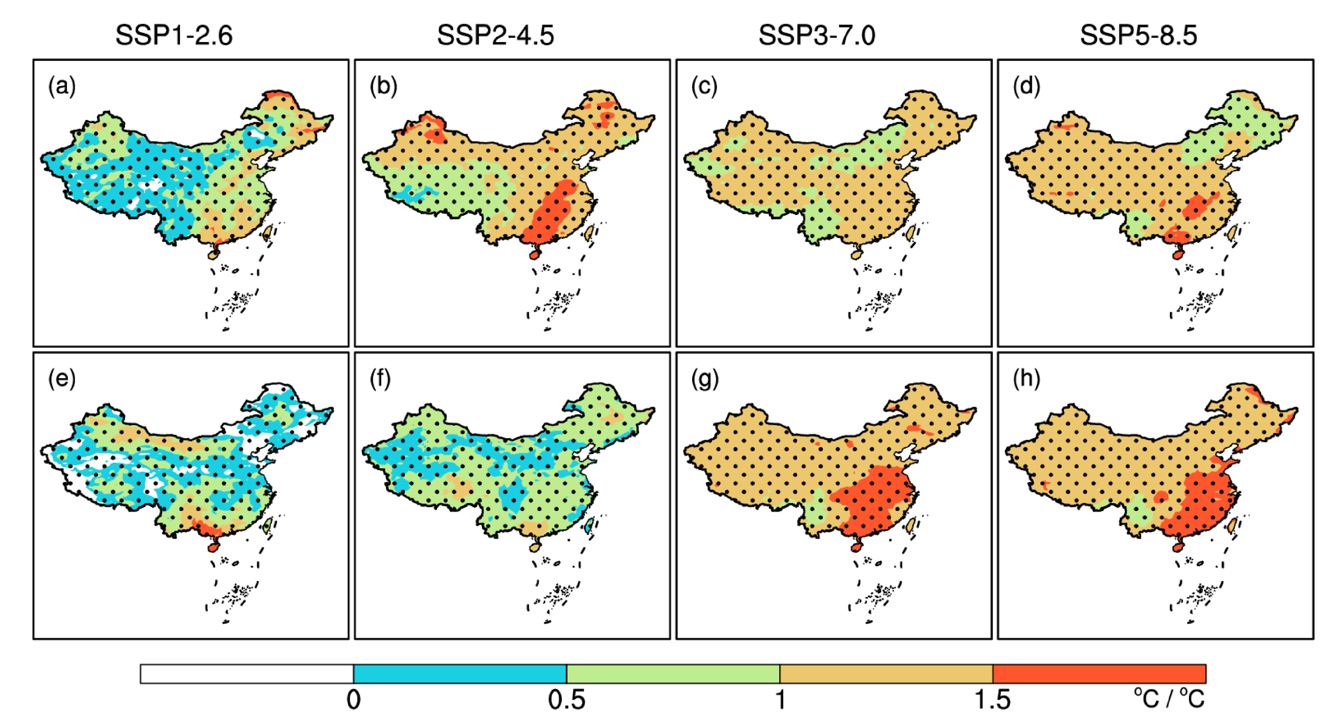

Figure 3. The MME mean HSI response rates to global warming under SSP1-2.6, SSP2-4.5, SSP3-7.0, and SSP5-8.5 (°C/°C) for the population explosion period (a-d) and the highest warming period (e-h). Dotted areas denote where at least 16 out of total 23 models agree on the sign of the change.

Heat risks would be the highest under SSP5-8.5 and the lowest under SSP1-2.6.

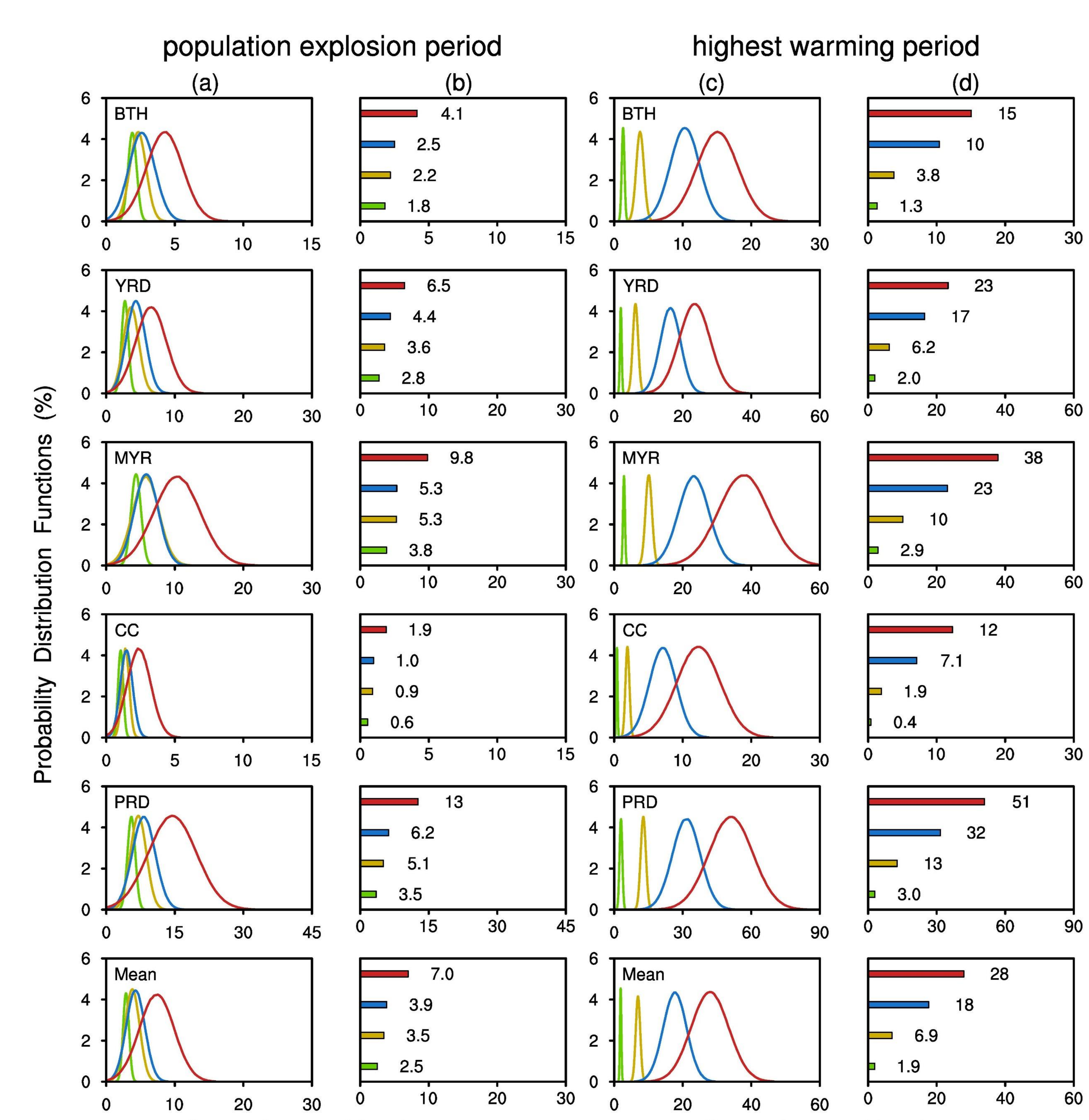

Figure 6. The probability density function (a, c) of heat risk changes from the present level at individual grids and regional averages (b, d) over the five CUAs under SSP1-2.6 (green), SSP2-4.5 (yellow), SSP3-7.0 (blue) and SSP5-8.5 (red) for the population explosion period (a, b) and the highest warming period (c, d).

The average number of heat danger days is smaller during the population explosion period than the highest warming period, and greater under the high-emission scenarios (SSP3-7.0 and SSP5-8.5) than the low-emission scenarios (SSP1-2.6 and SSP2-4.5). Future population exposure to the record-breaking heat danger days would be similar under SSP1-2.6 and SSP2-4.5, while much more under SSP3-7.0 and SSP5-8.5.

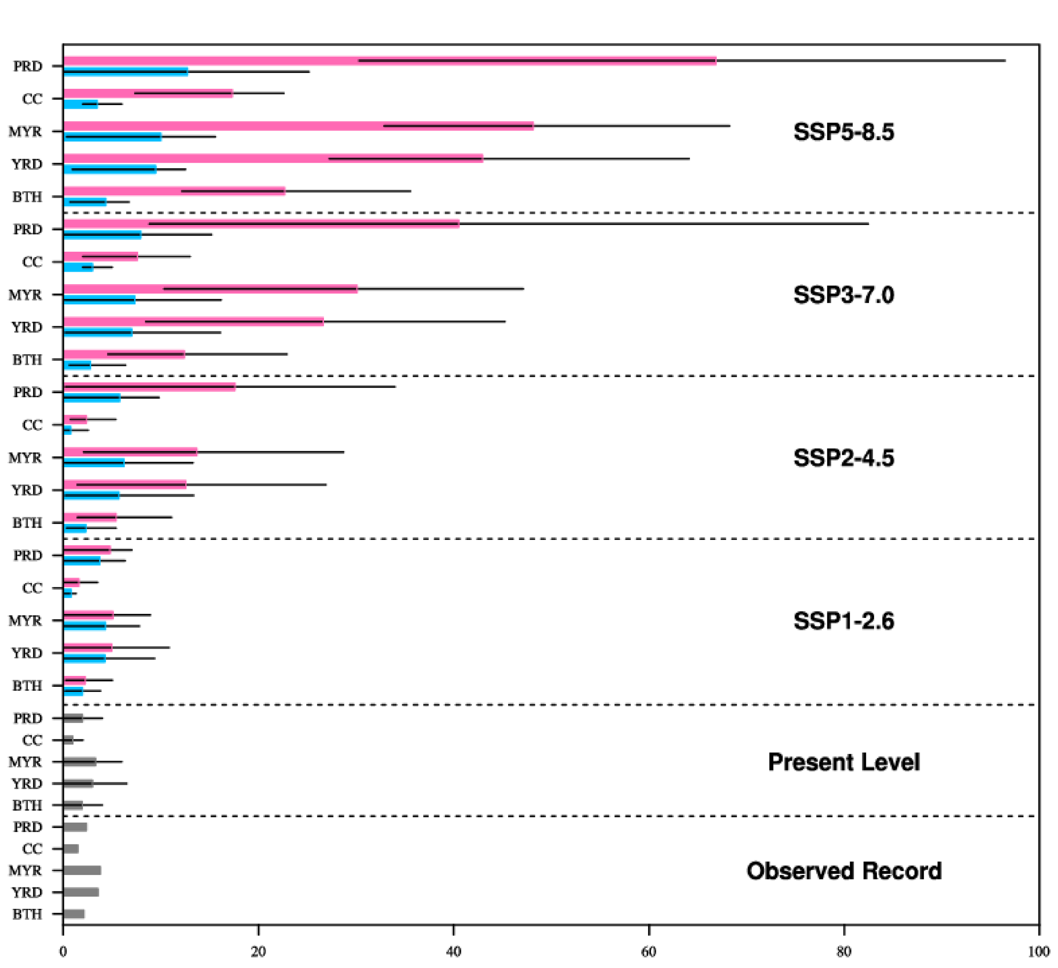

Figure 4. Heat danger days in each CUA as observed and simulated for the present and future scenarios. Gray bars depict the observed or simulated baseline, while blue and red bars show the MME mean results averaged during the population explosion and highest warming periods, respectively. The horizontal black line across the right end of each bar represents the 25th and 75th percentiles of all MME results.

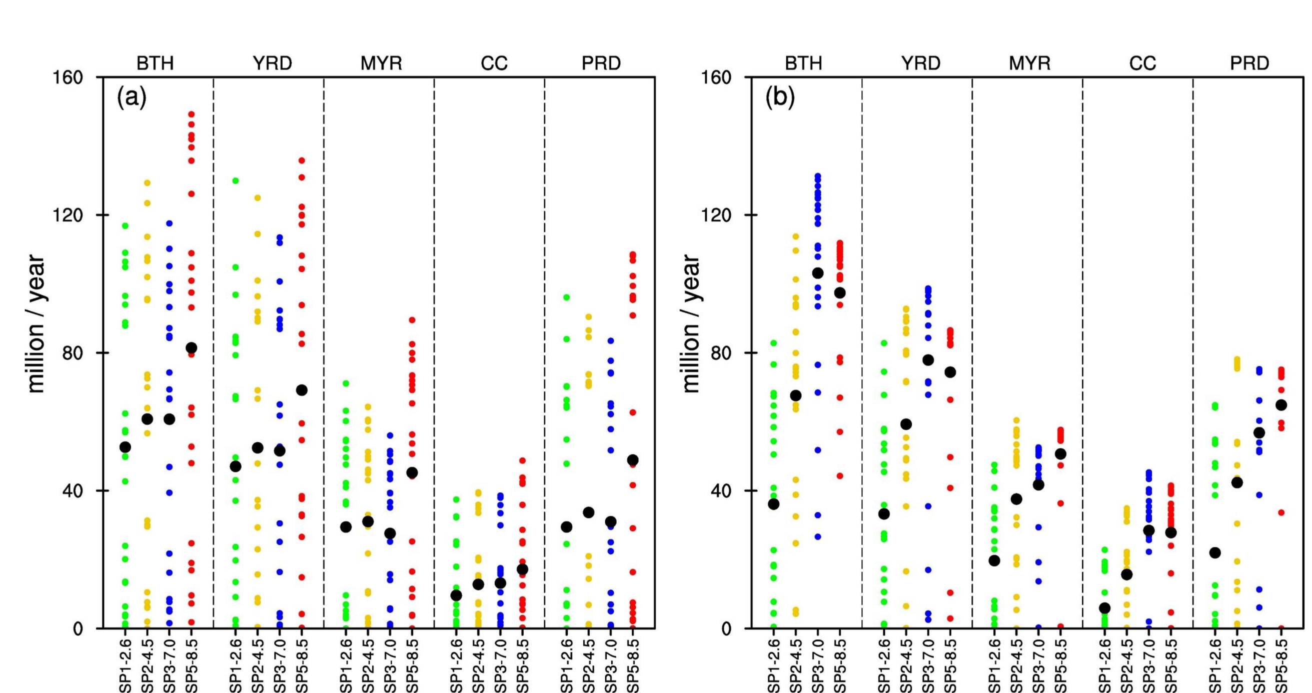

Figure 5. Projected urban population (units: million/year) living in the record-breaking areas during the population explosion (a) and highest warming (b) periods under SSP1-2.6 (green dots), SSP2-4.5 (yellow dots), SSP3-7.0 (blue dots), and SSP5-8.5 (red dots). The black dot is the MME mean, while all other color dots are from individual models.

Relative to the population explosion period, heat risks in the highest warming period would increase much more under high than low-emission scenarios.

Summary

Although the projected heat risks for 2041-2060 would not be as severe as 2081-2100, they would be still many times the present level. Given the devastation of the current heat stresses and only 20 years to reach the population explosion, strategic planning of potential heat risks becomes imperative and pressing for society and governments. On the other hand, heat danger days are projected to be similar to the present level under the low-emission pathway scenarios. The result reinforces the need to minimize global emissions and develop strategic plans to mitigate the escalated heat risk under high emission-population pathways, especially in urban agglomerations.

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