Heat stress in future Hong Kong

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Background

It is expected that the greenhouse gases emission will follow the high end Representative Concentration Pathway 8.5 (RCP 8.5) as argued in Peter et al. 2012, thus greenhouse warming will most likely continue at a rapid rate. Previous studies evaluated the impact of hot weather on human health and labour capacity (e.g. Lee et al. 2016; Sahu et al. 2013; Yi and Chan 2017). This study provides a survey of the heat stress in future Hong Kong.

Data and methodology

Hourly air temperature and relative humidity data from the Headquarter of Hong Kong Observatory (HKO, in Tsim Sha Tsui) 1979 – 2015 are used in this study. Daily maximum near surface air temperature and daily mean mixing ratio from 14 / 11 climate models in the Coupled Model Intercomparison Projection phase 5 (CMIP5) are also used (more information can be found in the next section). For future projection, only the data from the RCP 8.5 experiment are used since it is the closest to observation since 2006. Bias correction is applied to the CMIP5 model outputs against HKO data.

We focuses on the daily maximum heat stress in summer (June, July and August, JJA) in Hong Kong from 1979 to 2049. The heat stress is measured by Heat Index (Steadman 1979; Rothfusz 1990), which depends on air temperature and relative humidity. It is advised that different mitigation measure should be taken when Heat Index is at different bands (**Table 1**):

Table 1. List of risk levels and corresponding bands of heat index

Heat Index (°C)	Risk level / Mitigation measure
27 – 32	Caution
32 – 41	Extreme caution
41 – 54	Danger
54 or more	Extreme danger

Source: https://www.weather.gov/safety/heat-index

In this study, hot day is defined as a day with daily maximum Heat Index greater than 41 °C, i.e. at least the "danger" level.

Period 1 (P1) and period 2 (P2) are defined as periods 1979 – 2005 and 2023 – 2049 respectively.

CMIP5 models

Daily maximum temperature from 14 CMIP5 models are used for the projection. 11 of these models also have daily mean absolute humidity available (humidity data in the rest 3 models were not accessible at the time of writing).

Table 2. List of CMIP5 models used in this study

ACCESS1-0	BNU-ESM	CCSM4	CESM1-CAM5	CMCC-CMS
B	B	A	B	A
CSIRO-Mk3.6	GFDL-CM3	HadGEM2-AO	INMCM4	IPSL-CM5A-LR
B	B	B	B	B
MIROC-ESM	MPI-ESM-LR	MRI-CGCM3	NorESM1-M	
B	A	B	B	

A: Only daily maximum temperature available
B: Both daily maximum temperature and daily mean absolute humidity available

Result: Vapour mixing ratio in Hong Kong

From 1979 to 2015, the observed mixing ratio at daily temperature peak remains constant at around 20 g kg^{-1} regardless of the temperature. At this level, the 41 °C Heat Index threshold is crossed at a temperature 33 °C (**Figure 1a**). This allows the use of 33 °C criterion for hot day in this period 1. The invariability of humidity can also be reproduced by the 11 CMIP5 models throughout the study period (**Figure 1b**). Note that the humidity at the time of daily temperature peak is not available. Here, we use daily mean humidity as a proxy.

From P1 to P2, the trim mean of the change in mixing ratio is 1.26 g kg^{-1}. The temperature threshold for hot day then drops to 32 °C in P2 as a result (**Table 3**).

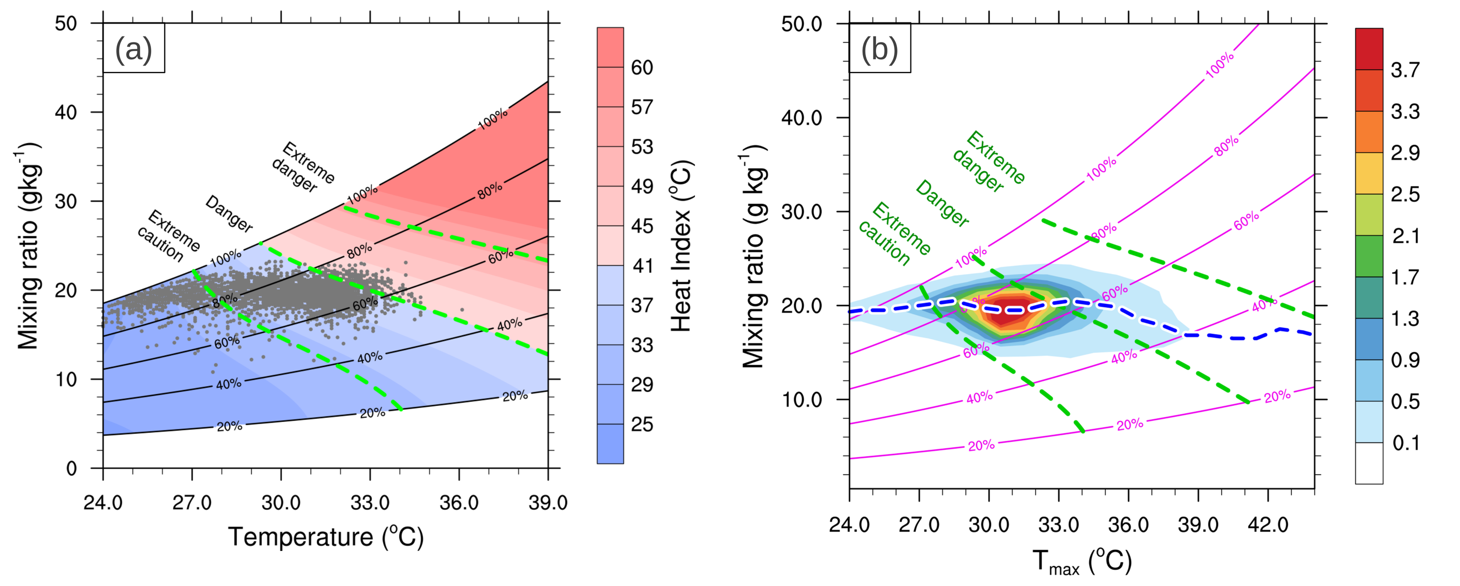


Figure 1. (**a**) Grey dots show daily maximum temperature at the Headquarter of HKO and corresponding mixing ratio. Shading shows the Heat Index. (**b**) Shading shows the probabilistic distribution of daily maximum temperature and daily mean mixing ratio in the 11 CMIP5 models. Blue thick line marks the most probable mixing ratio. On both plots, green dashed lines are the minimum Heat Index for "Extreme caution", "Danger" and "Extreme danger" bands.

Table 3. Increase in mixing ratio from P1 to P2 in g kg^{-1}

ACCESS1-0	BNU-ESM	CESM1-CAM5	CSIRO-Mk3.6	GFDL_CM3	HadGEM2-AO
1.37	1.28	1.47	1.61	2.19*	0.97
IPSL-CM5A-LR	MIROC-ESM	MRI-CGCM3	NorESM1-M	INMCM4	
1.58	0.78	1.03	1.21	0.72*	

* Outliers. Not included in the trim mean

Result: Change in number of hot days and their intensity

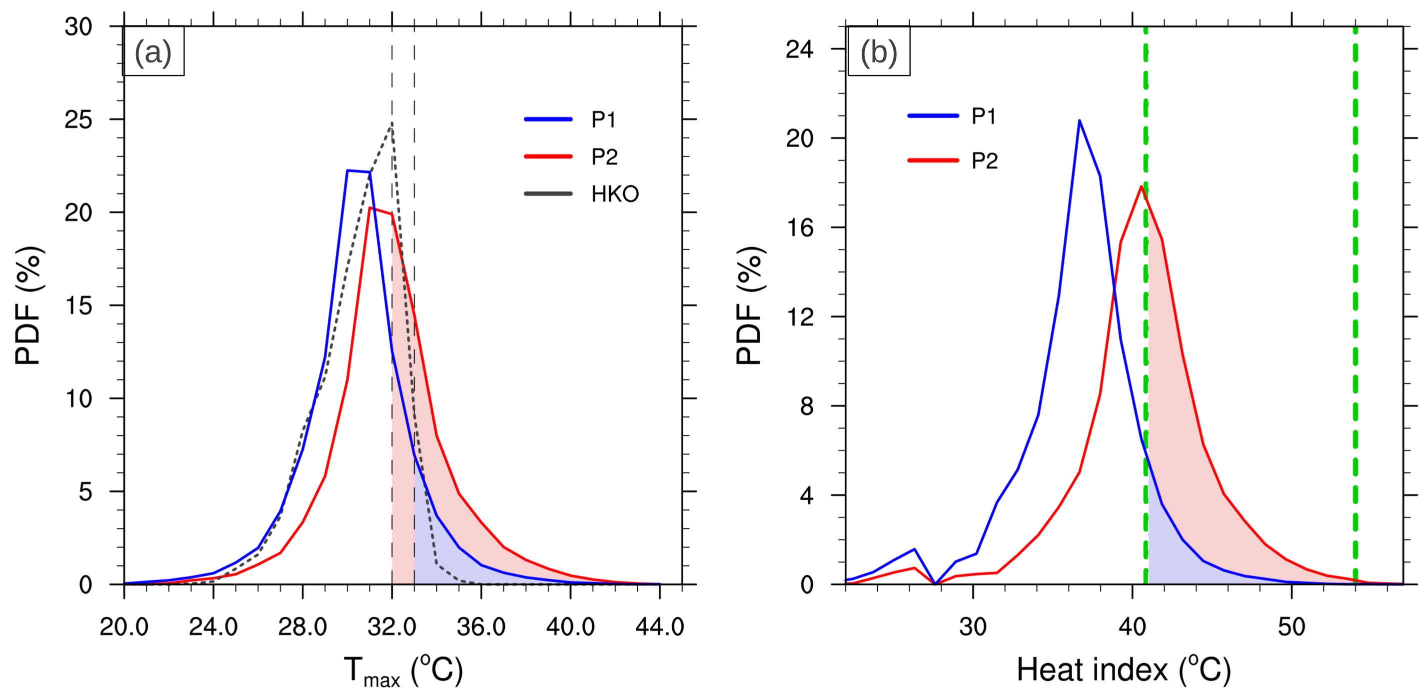
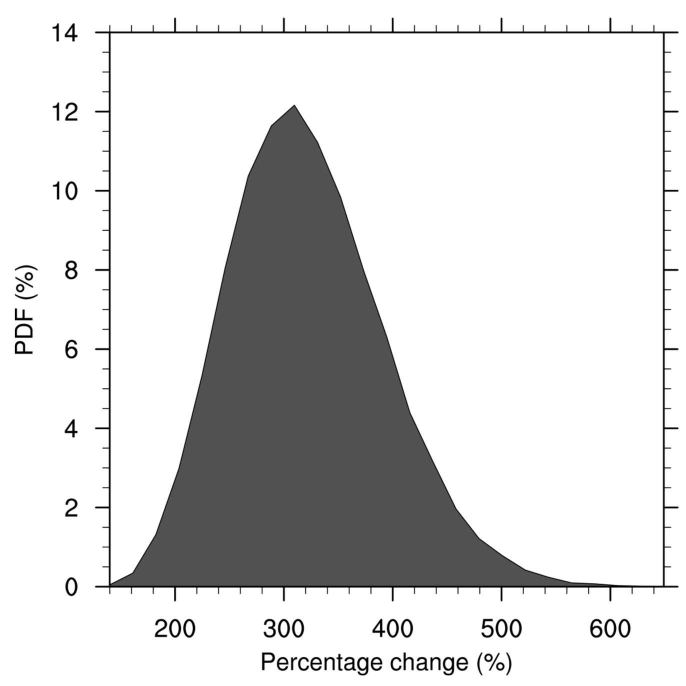


Figure 2. (**a**) Distribution of daily maximum temperature in (blue) P1 and (red) P2 in the 14 CMIP5 models and (grey) HKO observations. (**b**) Same as (**a**) but for Heat Index in the models. The two green dashed lines shows the minimum Heat Index for "danger" and "extreme danger" bands.

Figure 2a shows that the rightward shift (warming) in the temperature distribution from P1 to P2. Together with the increase in humidity, the number of hot days is expected to increase drastically. However, the average intensity of the hot days will not change much as the increase in expected value of Heat Index is 0.6 °C only (**Figure 2b**).



The bootstrapped 90 percent confidence interval of the mean percentage change in number of hot day among the models is 216% to 447% (**Figure 3**). This leads to. on average, 7.1 – 14.7 more hot days every year from P1 to P2.

Figure 3. Bootstrapped percentage change in number of hot days from P1 to P2. Note that results from two models are excluded in the statistics as outliers.

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