THE HONG KONG UNIVERSITY OF SCIENCE AND TECHNOLOGY

Ubiquitous Increase of Extreme Heat Stress under Global Warming

Eun-Soon IM & Thanh NGUYEN-XUAN & Liying QIU

&

RegCM4 CORDEX-CORE Team

ICRC-CORDEX 2019 International Conference on Regional Climate

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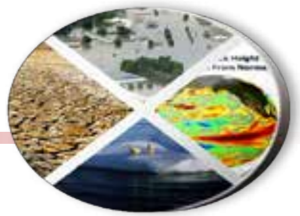
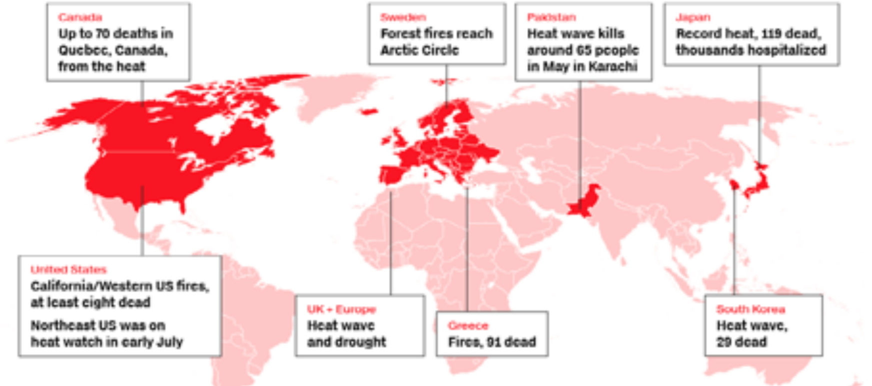
Record-Breaking Heatwave around the World



CNN World » Our climate plans are in pieces as killer summer shreds records

Global heat wave flashpoints since May 2018



CNN World · U.S. · Africa · Americas · Asia · Australia · China · Europe · Middle East · UK International Edition

Record-breaking temperatures leave 29 dead in South Korean heatwave

CNN World International

Are parts of India becoming too hot for humans?

The Guardian International edition

Heatwave seems to make manmade climate change real for Americans

The record-breaking high temperatures across much of North America appear to be shaping people's thinking, a survey finds

Temperatures hit new highs in European heatwave

Records are usually broken by tenths of a degree, but last week's heatwave was startling

South Korea sets all-time record high temperature amid deadly heat wave

BBC NEWS

Japan heatwave declared natural disaster as death toll mounts

113 degrees in France: why Europe is so vulnerable to extreme heat

All-time temperature records have been broken in the heat wave sweeping the continent.

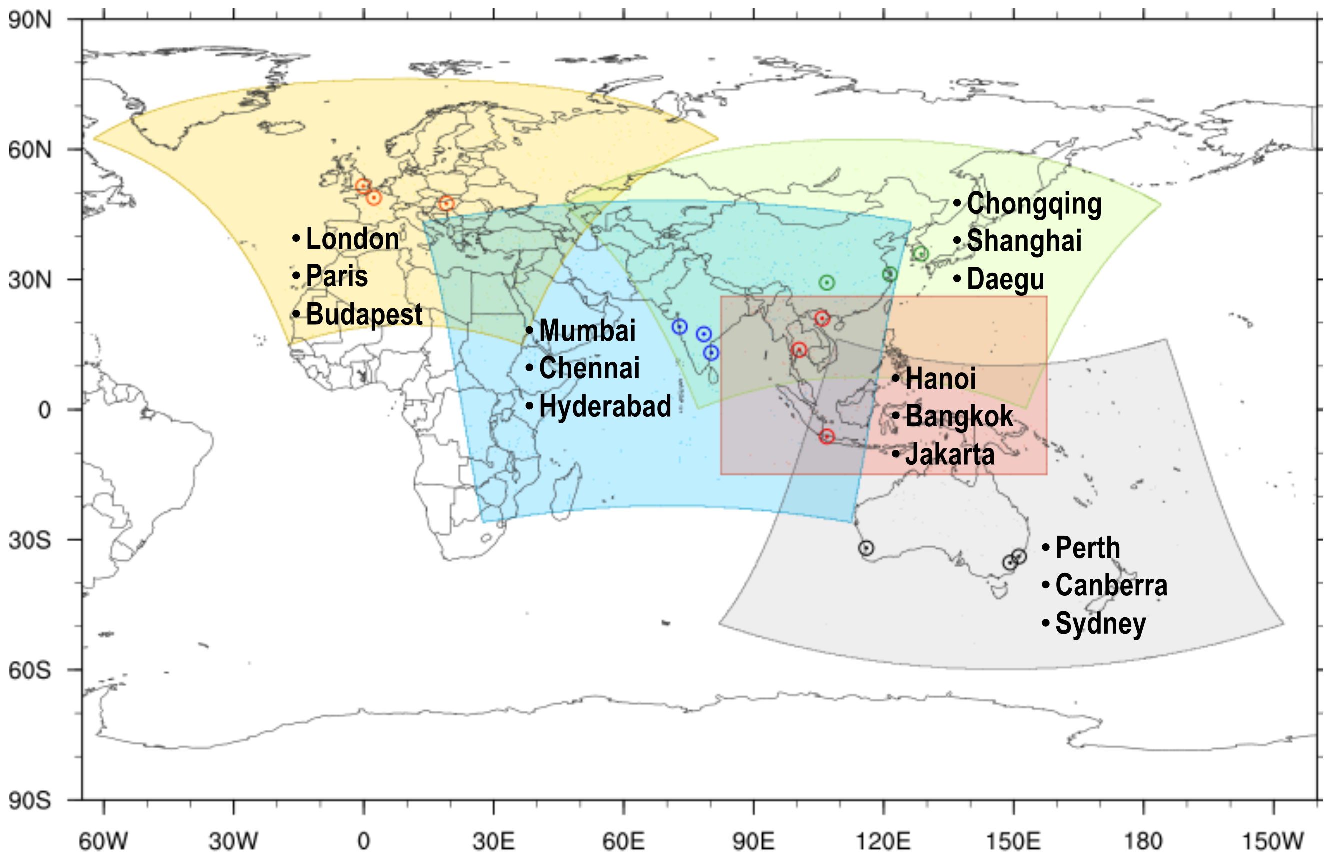
France 40C heatwave could break June records

Extreme heat is a vivid climate change signal

The length, intensity, and frequency of heat waves are on the rise, and Europe's searing weather this week comports with what scientists expect as the climate changes, though it will take some time to tease out the specific extent of humanity's role in the current wave.

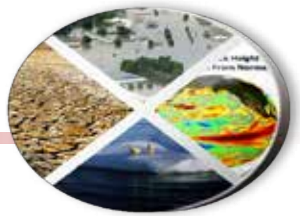
RegCM4 Simulations under CORDEX-CORE Framework

- Model : Regional Climate Model ver. 4 (RegCM4)
- ICBC : HadGCM2-ES & MPI ESM & NorESM
  driven by RCP8.5 scenario

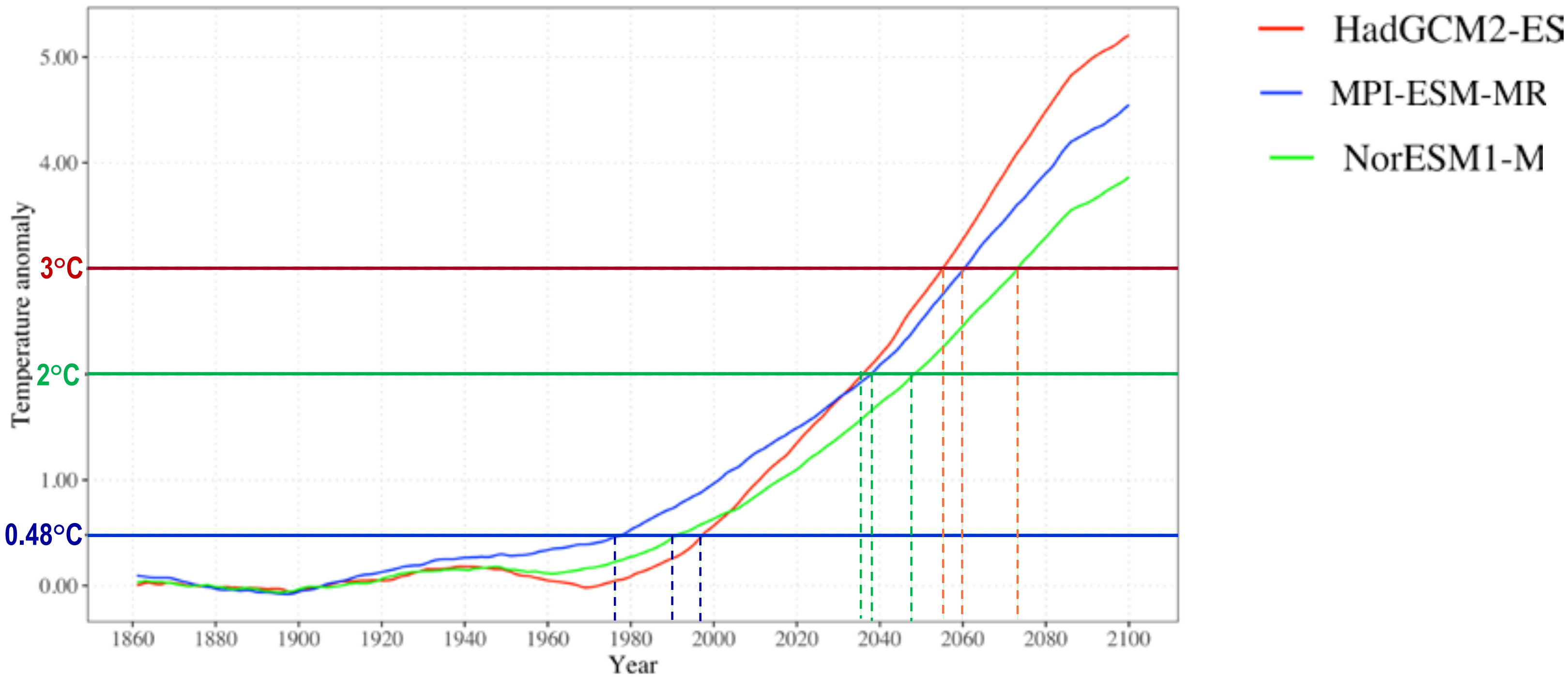


Domain	Resolution	HadGEM2	MPI-ESM	NorESM1
Europe	12.5km	O		
South Asia	25km		O	O
East Asia	25km	O	O	O
Southeast Asia	25km	O	O	O
Australia	25km	O	O	O

Selection of 0.48°C & 2°C & 3°C Warming Periods



- Individual GCMs have their own warming phase in response to emission forcing

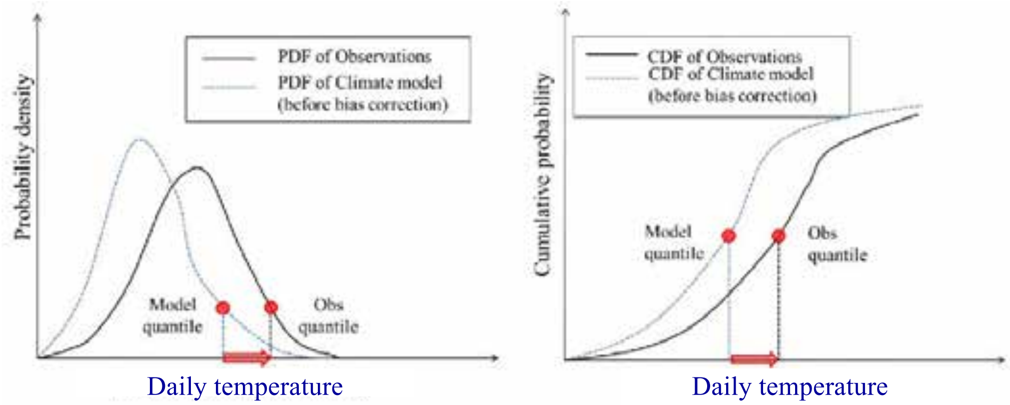


GCMs	0.48℃ Warming	2.0℃ Warming	3℃ Warming
MPI-ESM-MR	1978	2038	2060
NorES1-M	1991	2048	2073
HadGEM2-ES	1997	2036	2055

Bias Correction: Quantile Mapping

- Quantile mapping is applied to daily maximum temperature in order to remove systematic bias of raw output

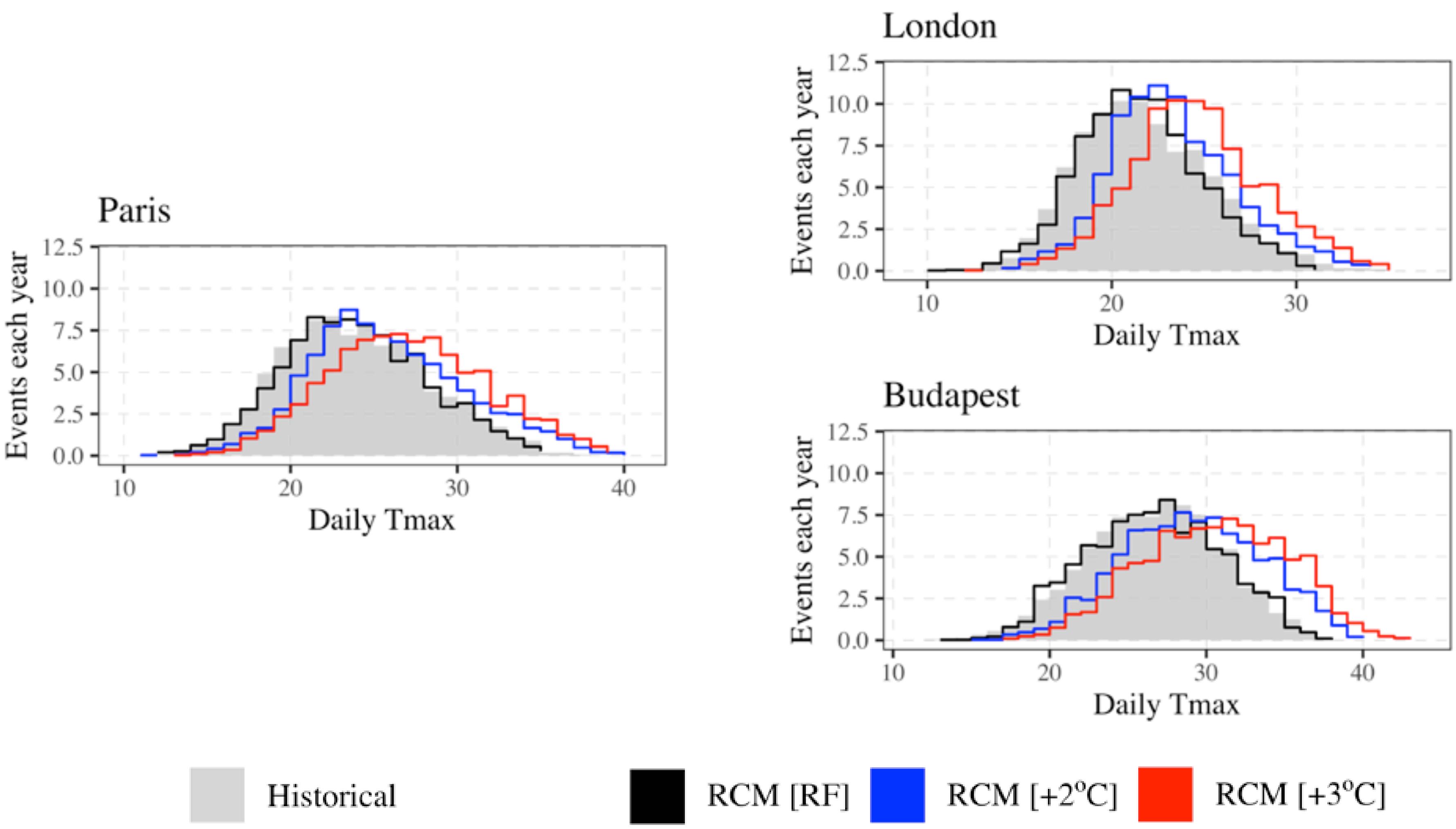
Schematic representation of the concept of QM



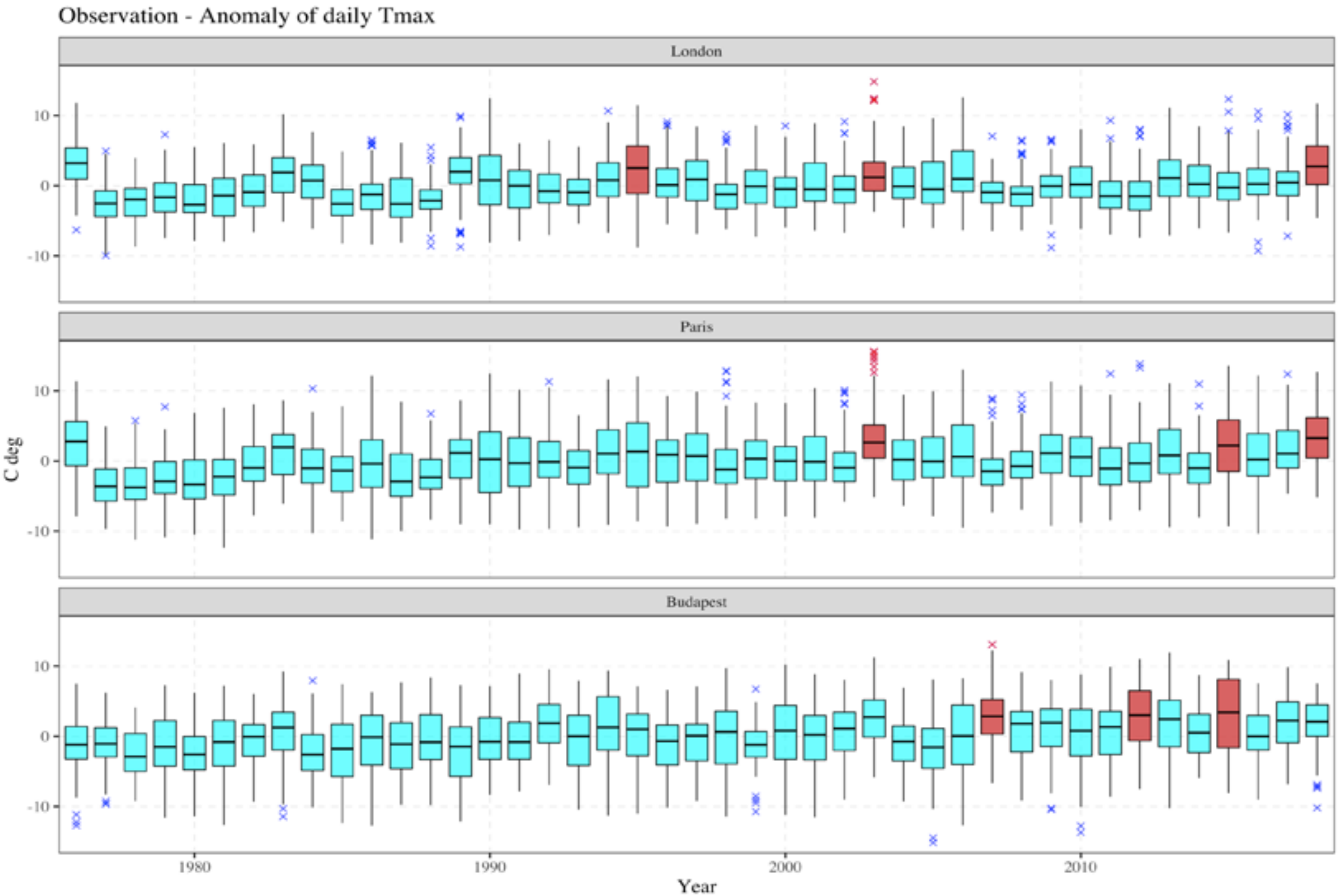
- Quality of observational data

Domain	Source	Resolution
Europe	E-OBS	0.1° x 0.1°
South Asia	India Meteorological Department	1° x 1°
East Asia	CN05.1 (China) + KMA Station (Korea)	0.25° + Stations
Southeast Asia	ERA-Interim	0.25°
Australia	Bureau of Meteorology, Australia	Stations

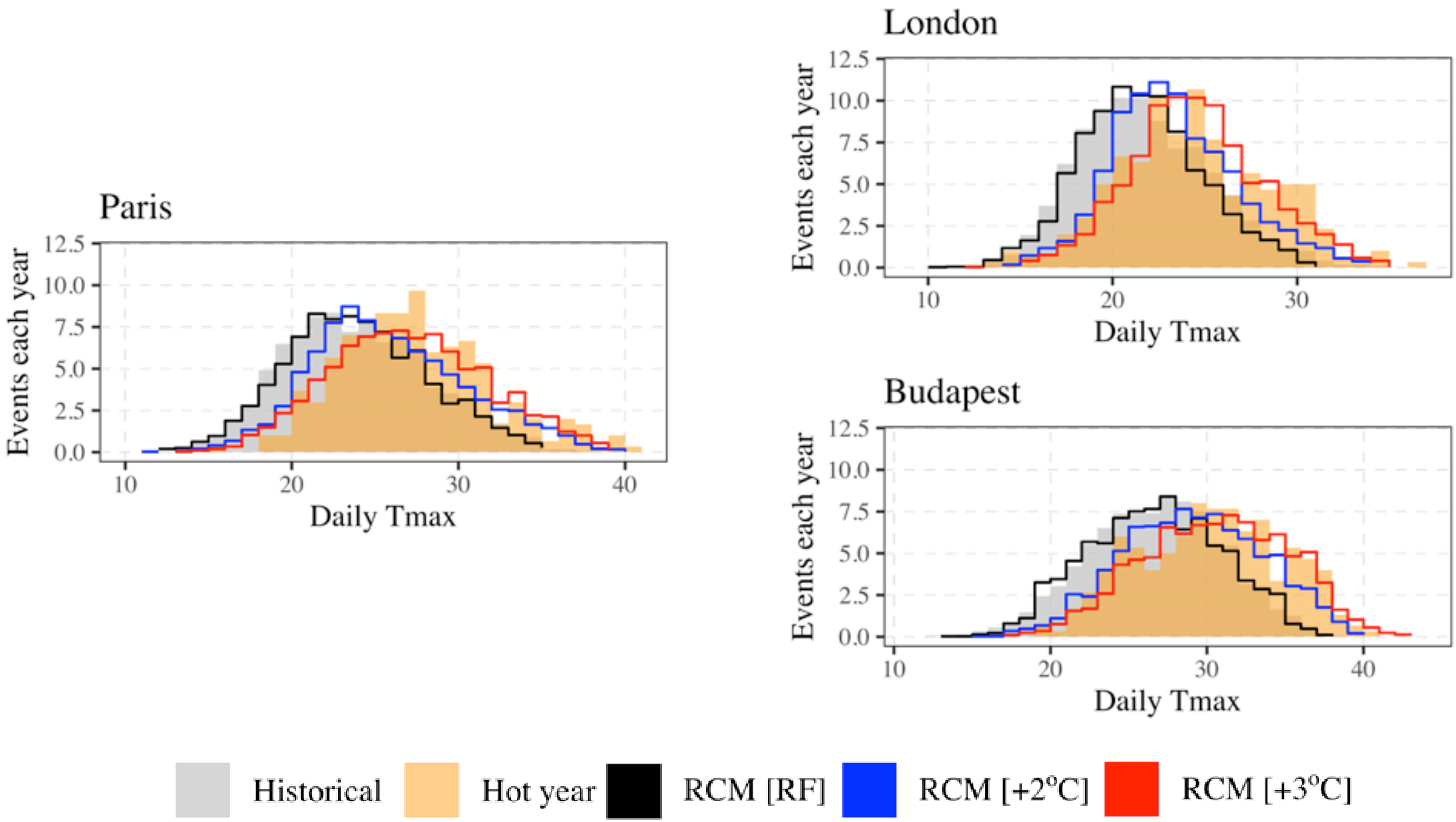
Frequency Distribution of Daily Tmax during the 3 Hottest Months



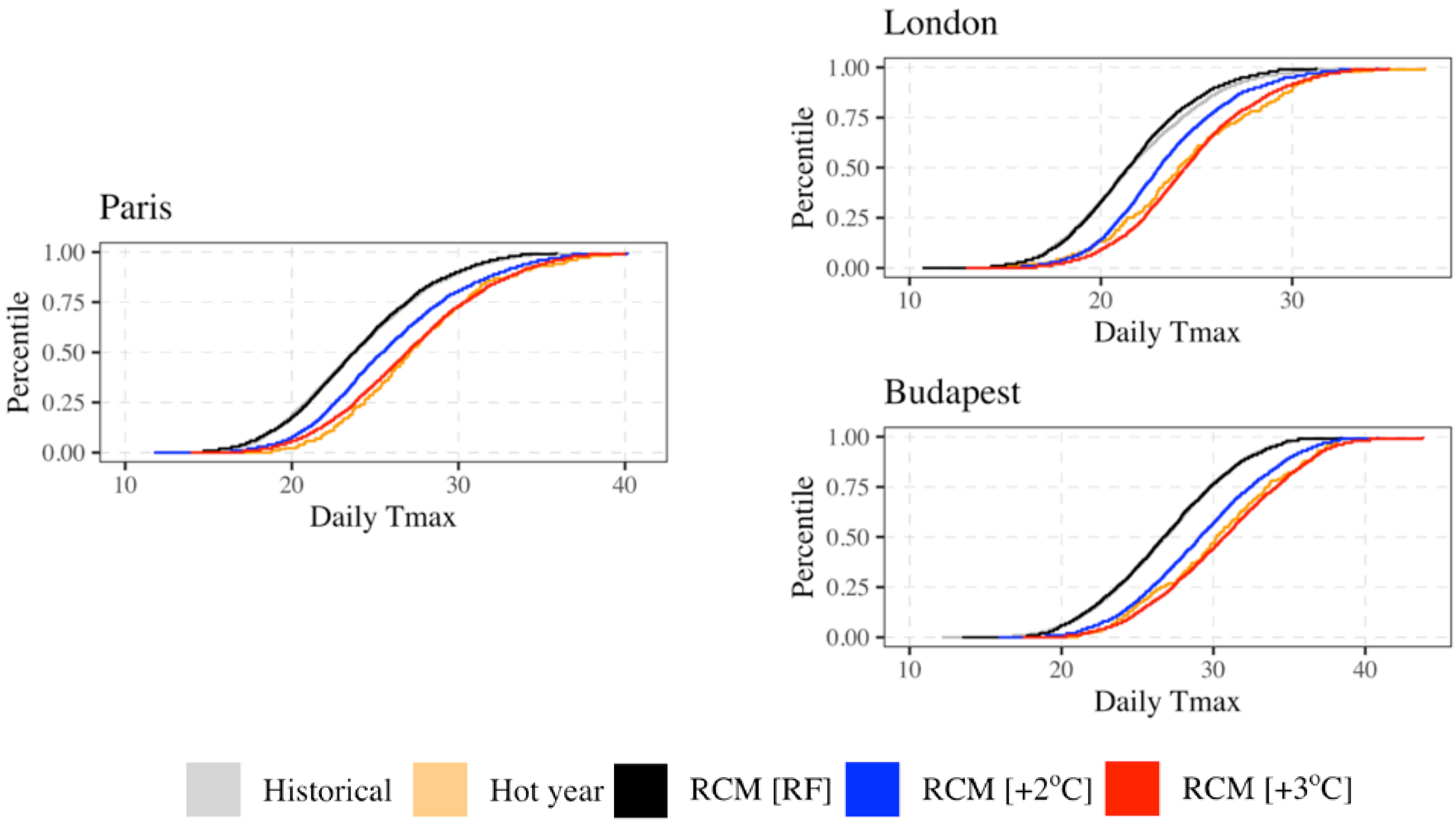
Interannual Variability of Tmax Anomaly



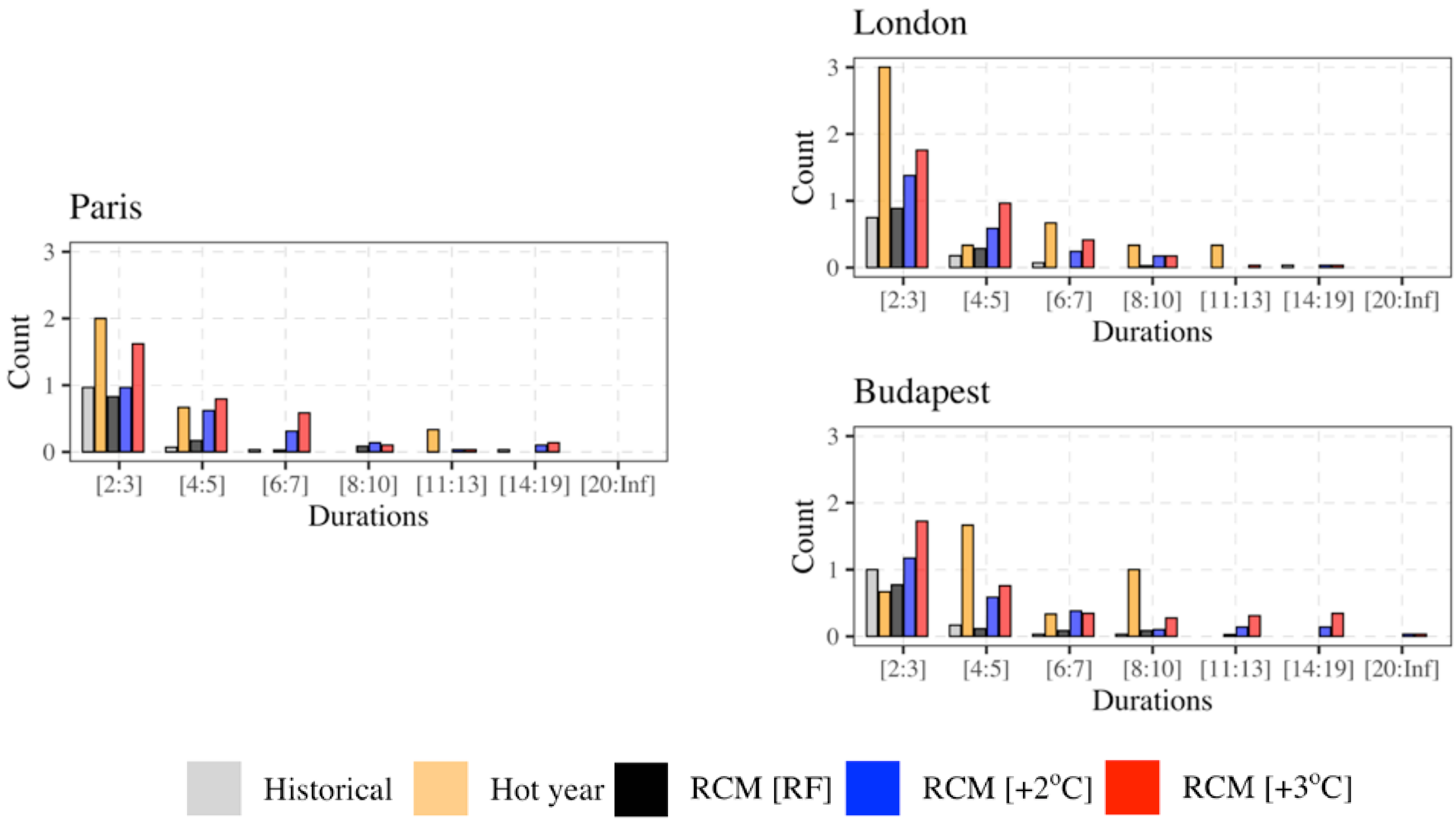
Frequency Distribution of Daily Tmax during the 3 Hottest Months



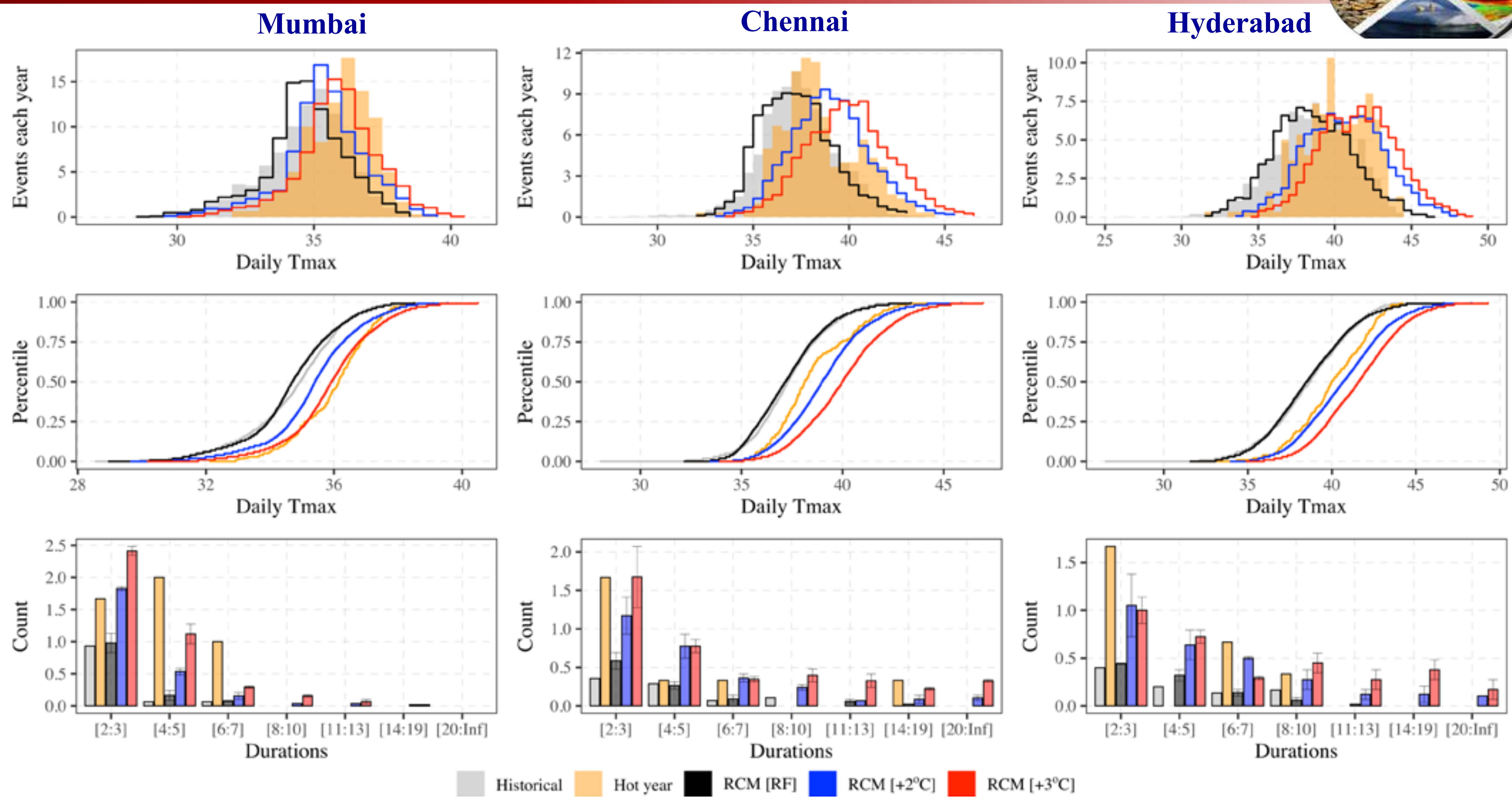
ECDF of Daily Tmax during the 3 hottest months



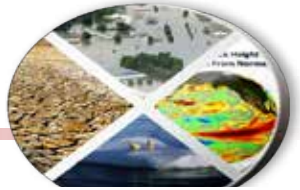
Consecutive Hot Days > 95th of Reference Tmax

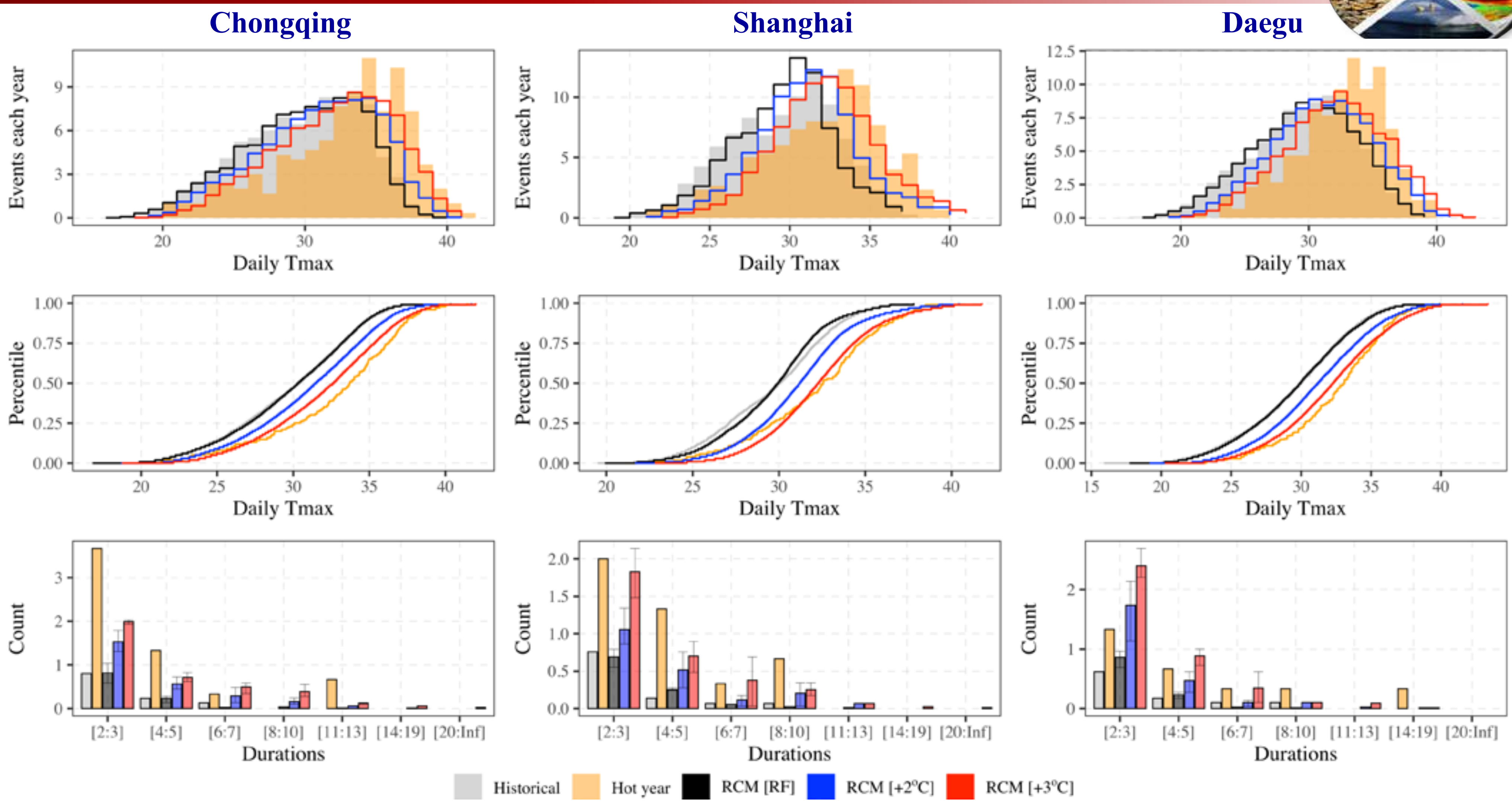


South Asia: Characteristics of Temperature Change

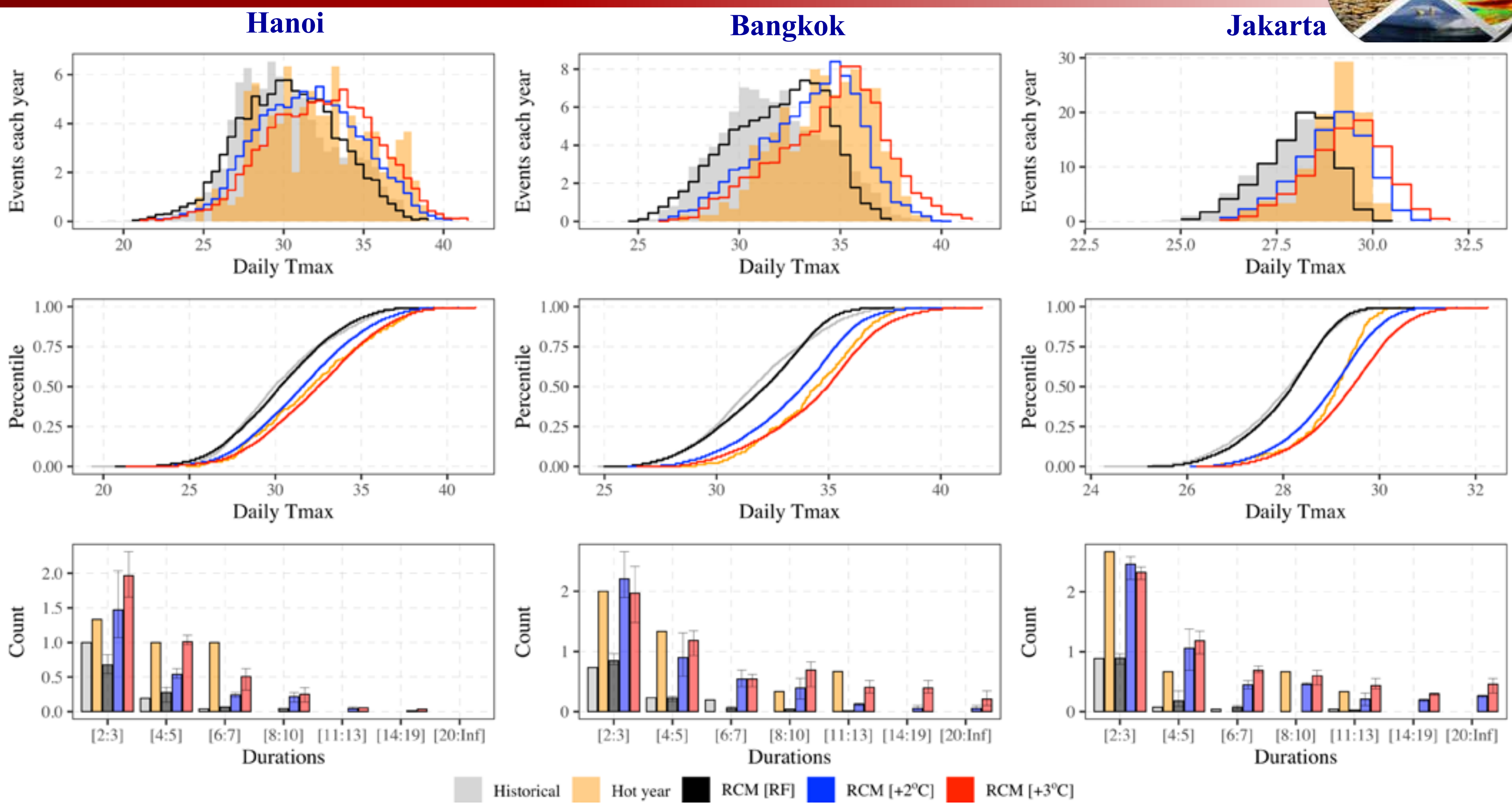


East Asia: Characteristics of Temperature Change

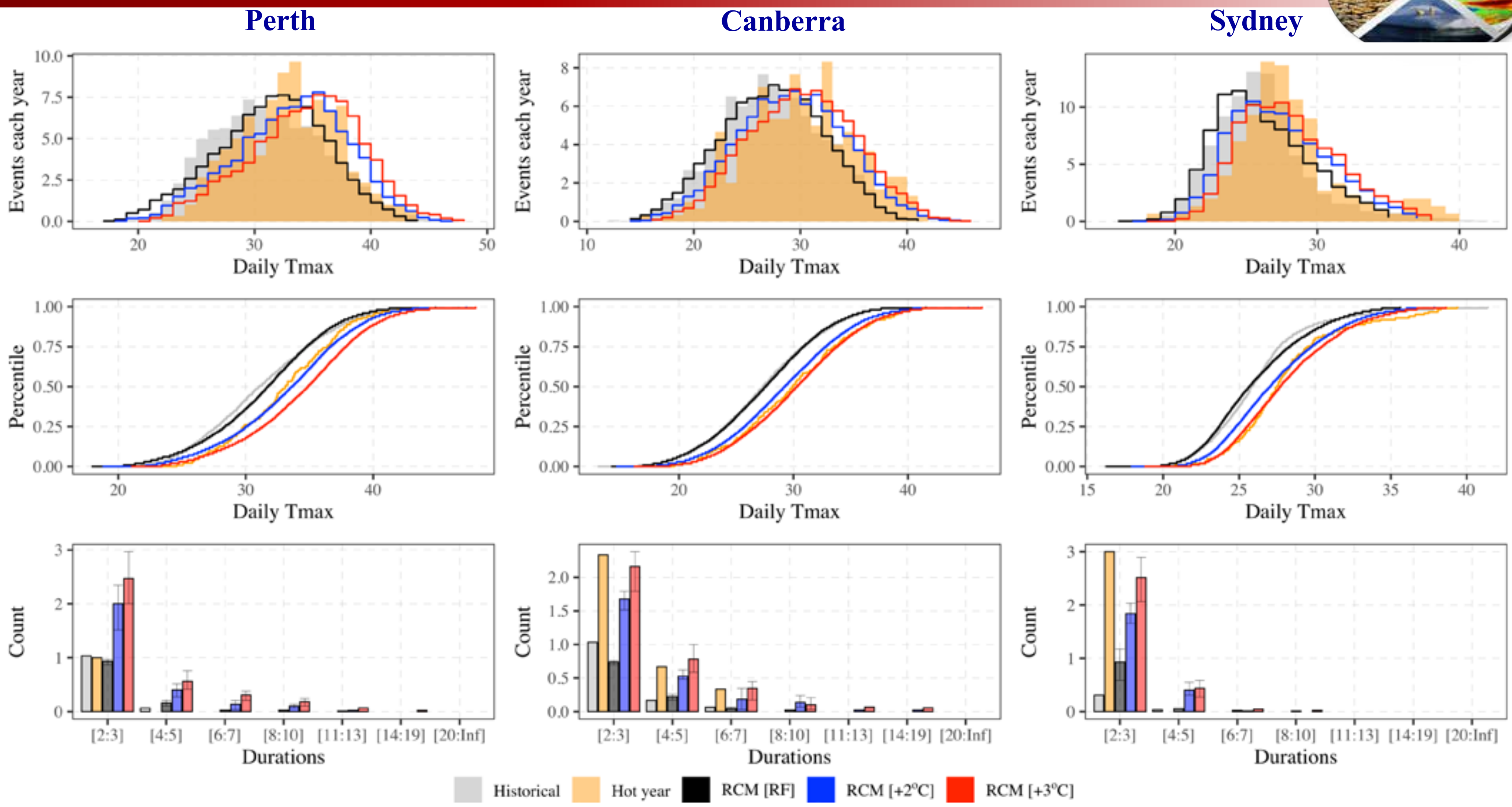




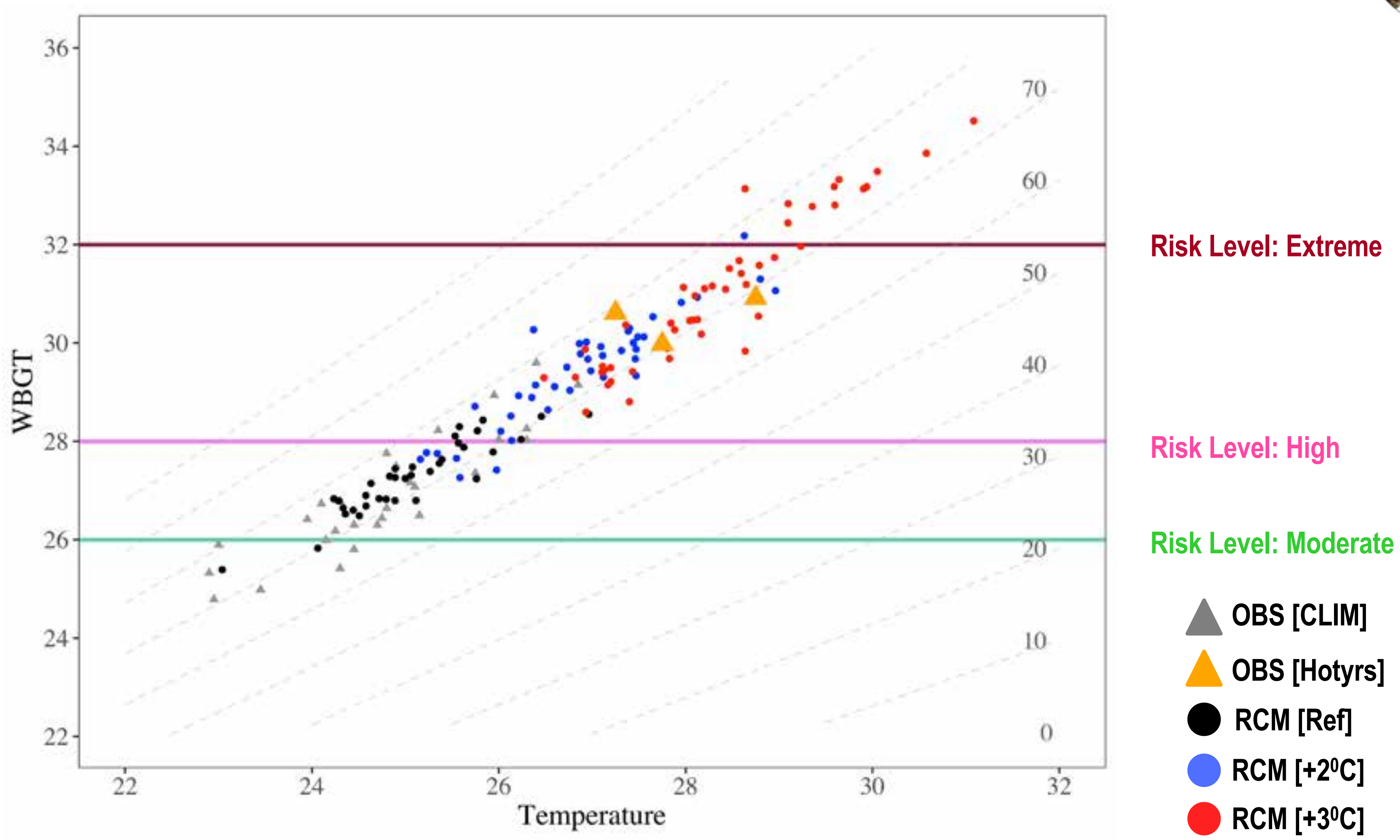
South East Asia: Characteristics of Temperature Change



Australia: Characteristics of Temperature Change



Intensification of Heat Stress



Take Home Message

- With the acceleration in global warming, extreme hot temperatures have emerged as one of the most prominent risks.

- The distinct behaviors of maximum temperature that appeared in historical extremes largely represent the statistical analog of the distribution pattern expected under 3^{o}C global warming based on fine-scale climate projections.

- The statistically extremely rare events will become increasingly normal if global average temperature is allowed to increase by 3^{o}C.

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Thank you for your attention!

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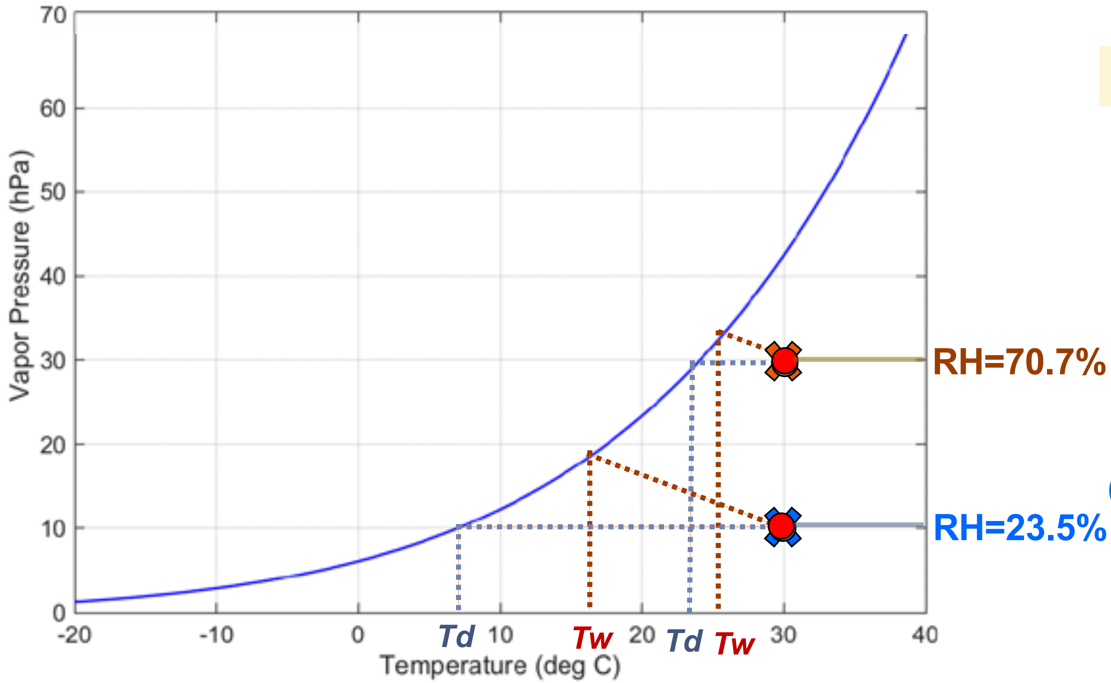
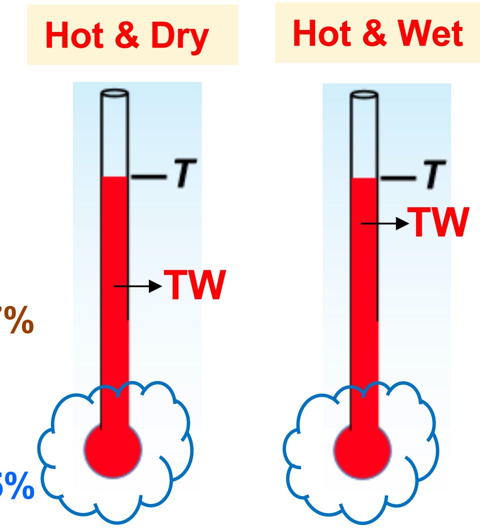
Concept of Wet-Bulb Temperature





- Wet-bulb temperature is particularly useful in human health applications associated with heat stress, because evaporation is the primary means by which bodies cool in hot environments; thus, when Tw is high, evaporative cooling is restricted and the body core temperature may rise (Davis et al. 2016).
- ***35℃*** is the threshold value of TW beyond which any exposure for more than 6-hour would likely be intolerable even for the fittest of humans resulting in hyperthermia. In current climate, TW rarely exceeds ***31℃***.

Various Metrics of Moist Temperature

❖ Wet-bulb temperature (T_w)

- Tw is the temperature at which air becomes saturated by evaporation at constant pressure.
- Tw is empirical value to which a wetted thermometer will drop under vaporation.
- Tw is particularly useful in human health applications associated with heat stress, because evaporation is the primary means by which bodies cool in hot environments.

$$T_w = T\,\mathrm{atan}[0.151\,977(\mathrm{RH\%} + 8.313\,659)^{1/2}] + \mathrm{atan}(T + \mathrm{RH\%}) - \mathrm{atan}(\mathrm{RH\%} - 1.676\,331) + 0.003\,918\,38(\mathrm{RH\%})^{3/2}\,\mathrm{atan}(0.023\,101\mathrm{RH\%}) - 4.686\,035.$$

[From Stull 2011]

❖ Wet-bulb globe temperature (WBGT)

- WBGT is the empirical combinations of T_w, T_a, and T_g to measure heat stress.

$$\mathrm{WBGT} = 0.7T_W + 0.2T_g + 0.1T_a$$

(where, T_g black globe temperature)
(where, T_w wet-bulb temperature)

$$\mathrm{WBGT} = 0.567T_a + 0.393e + 3.94$$

(where, e vapor pressure)

❖ Apparent temperature (T_{app})

- T_{app} combines temperature and humidity into a single index for the assessment of human comfort in the warm season.

$$T_{app} = 2.719 + 0.994T_a + 0.016(T_d)^2$$

(where, T_a dry-bulb temperature)
(where, T_d dew-point temperature)