Heat-related health impacts in subtropical cities: Global Overview and Research Frontiers in Hong Kong

Prof Emily YY Chan
Professor and Director, CCOUC/CGH, Chinese University of Hong Kong
Outline

- Introduction
  • Understanding the Impact
    - Hong Kong-Subtropical city
    - Climate change impact on meteorological patterns: Temperature
    - How to measure Heat-health impact?
  Identify the thresholds
  • Identify the thresholds
  • Science to support policy
    - What have we learnt and response?
    - Conclusion-Next
Division of Global Health and Humanitarian Medicine,
JC School of Public health and Primary Care, Faculty of Medicine,
Chinese University of Hong Kong

Key area: Global Health, Humanitarian and disaster Medicine, Climate and Planetary health, Extreme age and health, Global Policy and interventions programs in Non-communicable and Communicable diseases

Affiliated Centers

Core Members of Division of Global Health and Humanitarian Medicine (2018)
Collaborating Centre for Oxford University and CUHK for Disaster and Medical Humanitarian Response (CCOUC)

- Established in 2011, The Chinese University of Hong Kong
- Mission: To serve as a platform for research, education, and community knowledge transfer in the areas of disaster and medical humanitarian crisis policy development, planning and response

- Co-Chair, WHO Thematic Platform for Health Emergency & Disaster Risk Management (H-EDRM) Research Group
- Member, UNISDR Asia Science Technology and Academia Advisory Group (ASTAAG)
- Director, Integrated Research on Disaster Risk (IRDR)* International Centre of Excellence (ICoE)

*IRDR is an international research platform co-sponsored by the International Council for Science, the International Social Science Council, and United Nations Office for Disaster Risk Reduction. CCOUC is one of the 13 IRDR ICoE
Thematic Research Network for Health Emergency and Disaster Risk Management (H-EDRM)

Health EDRM: the systematic analysis and management of health risks surrounding emergencies and disasters by reducing the hazards and vulnerability along with extending preparedness, response, and recovery measures.
Health-EDRM and Global Policies

Sendai Framework for Disaster Risk Reduction
2015 - 2030

United Nations Climate Change

Sustainable Development Goals

1. No Poverty
2. Zero Hunger
3. Good Health and Well-being
4. Quality Education
5. Gender Equality
6. Clean Water and Sanitation
7. Affordable and Clean Energy
8. Decent Work and Economic Growth
9. Industry, Innovation and Infrastructure
10. Reduced Inequalities
11. Sustainable Cities and Communities
12. Responsible Consumption and Production
13. Climate Action
14. Life Below Water
15. Life on Land
16. Peace, Justice and Strong Institutions
17. Partnerships for the Goals
Health-EDRM: **Health-Emergency and Disaster Risk Management**

Interventions can be divided by *when* they should be implemented:

<table>
<thead>
<tr>
<th>PRIMARY:</th>
<th>to prevent health risk <strong>before</strong> the disaster</th>
<th><strong>EXAMPLE:</strong> childhood vaccination programmes, and early warning systems: <em>Impact driven Warning</em></th>
</tr>
</thead>
<tbody>
<tr>
<td>SECONDARY:</td>
<td>to prevent health risks <strong>after</strong> the disaster</td>
<td><strong>EXAMPLE:</strong> emergency vaccination campaigns, knowing how to prepare ORS</td>
</tr>
<tr>
<td>TERTIARY:</td>
<td>to reduce the impact <strong>after</strong> disaster</td>
<td><strong>EXAMPLE:</strong> using ORS, provide first aid (physical and psychological), and healthcare staff specifically trained for disaster-related injury/disease outbreak</td>
</tr>
</tbody>
</table>
UNDERSTAND THE IMPACT
Temperature and precipitation projection given different Representative Concentration Pathway from IPCC AR5
Climate zone in the world

Areas of the world with subtropical climates

https://en.wikipedia.org/wiki/List_of_locations_with_a_subtropical_climate
THE URBAN STORY

THE CASE OF HONG KONG
Beijing

Hong Kong

Population: 7,300,000

GDP per capita: US$ 42,290

Climate: Sub-tropical (Hot summer and mild winter)
Hong Kong’s Climate and Geography (1)

• **South-eastern tip of China**

• **Three main territories**
  Hong Kong Island, Kowloon Peninsula, and New Territories (includes outlying islands)

• **Total area:** 1,106.34 km²

• **Total population:** approx. 7.34 million (2016)
  - Population density: 6,780 people per square kilometre
  - Dense urban development resulted in significant long-term decrease in local wind speed in the past few decades
Hong Kong Climate and Geography (2)

- **Sub-tropical** climate with hot humid summers
- July and September prone to tropical cyclones
- Summer afternoon temperatures often exceed 31 °C but winter can drop below 10 °C
- On average 10 very hot days in a year (maximum temperature reaching over 33 °C)

Hong Kong recorded its hottest temperature in 50 years (36.6 °C) on 22 August 2017 (max. temperature at King’s Park)
Calendar Heat Map of Daily Mean Temperature Jan 2010– Dec 2014

Data Source: Hong Kong Observatory, Daily Mean Temperature 2010.01.01-2014.12.31

Data Source: Hong Kong Census and Statistics Department, Daily Mortality 2010.01.01-2014.12.31
HONG KONG
For the 21\textsuperscript{st} century, as an urban city, Hong Kong has

<table>
<thead>
<tr>
<th>Issues</th>
<th>Situation (Globally)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Globalization</td>
<td>Annually, HK has 10 times as much transient migrants than local population</td>
</tr>
<tr>
<td>Income inequality</td>
<td>The \textbf{HIGHEST INCOME INEQUALITY} in developed regions</td>
</tr>
<tr>
<td>Environmental stress</td>
<td>One of the \textit{highest population density}</td>
</tr>
<tr>
<td>Urbanization</td>
<td>98% of the city is urbanized.</td>
</tr>
<tr>
<td>Emergency Risk</td>
<td>Experiences with \textit{global public health crisis} such as SARS(2003), H7N9 (2012)</td>
</tr>
<tr>
<td>Impact of Climate Change</td>
<td>The \textbf{HIGHEST increase} in average urban temperature in the past century</td>
</tr>
</tbody>
</table>

Has a relatively Robust and linked up population based, electronic record system that might allow systematic study of the impact of climate change

The 250+ m skyscrapers over the World

2018, Hong Kong rank 1st globally

HK boasts 7687 high-rise buildings and 303 incredible skyscrapers (>150M). Majority of skyscrapers in Hong Kong is used predominantly as residential buildings.

https://www.skyscraper.city/showthread.php?t=1708845
### Monthly Average Temperature and Rainfall

**30-year period**

<table>
<thead>
<tr>
<th></th>
<th>Data Period</th>
<th>Jan</th>
<th>Feb</th>
<th>Mar</th>
<th>Apr</th>
<th>May</th>
<th>Jun</th>
<th>Jul</th>
<th>Aug</th>
<th>Sep</th>
<th>Oct</th>
<th>Nov</th>
<th>Dec</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Mean Maximum Temp.</strong></td>
<td>1981-2010</td>
<td>18.6</td>
<td>18.9</td>
<td>21.4</td>
<td>25.0</td>
<td>28.4</td>
<td>30.2</td>
<td>31.4</td>
<td>31.1</td>
<td>30.1</td>
<td>27.8</td>
<td>24.1</td>
<td>20.2</td>
</tr>
<tr>
<td><strong>Mean Minimum Temp.</strong></td>
<td>1981-2010</td>
<td>14.5</td>
<td>15.0</td>
<td>17.2</td>
<td>20.8</td>
<td>24.1</td>
<td>26.2</td>
<td>26.8</td>
<td>26.6</td>
<td>25.8</td>
<td>23.7</td>
<td>19.8</td>
<td>15.9</td>
</tr>
<tr>
<td><strong>Rainfall Amount</strong></td>
<td>1981-2010</td>
<td>24.7</td>
<td>54.4</td>
<td>82.2</td>
<td>174.7</td>
<td>304.7</td>
<td>456.1</td>
<td>376.5</td>
<td>432.2</td>
<td>327.6</td>
<td>100.9</td>
<td>37.6</td>
<td>26.8</td>
</tr>
<tr>
<td><strong>Days with Rain</strong></td>
<td>1981-2010</td>
<td>5.4</td>
<td>9.1</td>
<td>10.9</td>
<td>12.0</td>
<td>14.7</td>
<td>19.1</td>
<td>17.6</td>
<td>16.9</td>
<td>14.7</td>
<td>7.4</td>
<td>5.5</td>
<td>4.5</td>
</tr>
</tbody>
</table>

**Chart details:**
- **Temperature (°C):** The chart shows the monthly average temperature from January to December. The line graph illustrates the trend, with temperature peaks in July and August and troughs in January and February.
- **Rainfall (mm):** The bar chart represents the monthly rainfall amount, with July and August showing the highest rainfall.
- **Legend:**
  - **Rainfall Amount** (Green bars)
  - **Mean Max. Temperature** (Red line)
  - **Mean Min. Temperature** (Blue line)
Air temperature at 12:50 HKT on 16 DEC 2018 (°C)

M : Under Maintenance / Data Temporarily Not Available

Station higher than 500 metres above mean sea level
Chloropleth map showing mean Urban Heat Island Index (UHII) for Tertiary Planning Units (TPUs) in Hong Kong

Mean UHII by TPU

High: 7.55
Low: 1.35

Climate change in Hong Kong

**Temperature Changes**
- Increased 1.5 to 3°C
- Extreme temperature days (above 33°C or below 12°C) will increase

**Rainfall Changes**
- Number of very wet years: increased 4 times
- Extreme Rainfall: 180 mm

**Sea-level Rise**
- Sea level Rise: 30mm per decades
- 3.53M for Typhoon Hagupit; 3.96M For Typhoon Wanda (1962); 4.05 M (1937)

**More Disasters**
  - 16 major urban floods with island population evacuated, 58 injury
  - 400 flights cancelled
  - 4500 Trees collapsed, Rotated 2 Boeing planes

---

Number of very wet years: increased 4 times
Extreme Rainfall: 180 mm
Sea level Rise: 30mm per decades
- 16 major urban floods with island population evacuated, 58 injury
- 400 flights cancelled
- 4500 Trees collapsed, Rotated 2 Boeing planes
Projecting future urbanization and its impact on summer heat stress under different climate change scenarios in 2030 in the Pearl River Delta Region

Daytime Temperature
Nighttime Temperature
Average wet-bulb global temperature

WRF Simulation Results at 2m Height above the Ground Level

Increase temperature 2-3; Reduce windspeed; “Danger” category the whole day


- Pak Shing YEUNG, Jimmy Chi-Hung FUNG, Chao REN, Yong XU, Kangning Huang, Jiye Leng (2018) Projecting future urbanization and its impact on local climate in the Pearl River Delta* (reference number: NCLIM-18071259), International Journal of Climatology (under review)
Hotspot Areas Detection in nighttime (red colour: $T \geq 28$deg C)

It is found that urban areas in Hong Kong cannot be cooled down in the night.

HK high dense built-environment traps heat in the nighttime in summer which potentially causes more hot-nights and heat-health risk, especially for the older people.

Extreme Hot Weather and Mortality in Hong Kong

- Different types of extreme hot weather events
- All-cause, cardiovascular, and respiratory mortality
- More consecutive hot nights contribute to higher mortality risk
- Non-consecutive hot days or nights are also found to contribute to short-term mortality risk.

Higher mortality risk
- Prolonged night-time hot weather

Short-term mortality risk
- Non-consecutive but frequent occurrence

<table>
<thead>
<tr>
<th>Model</th>
<th>All-cause mortality</th>
<th>Cardiovascular mortality</th>
<th>Respiratory mortality</th>
</tr>
</thead>
<tbody>
<tr>
<td>Baseline ($T_{\text{max}} \geq 33 ^\circ C$)</td>
<td>3.67% [3.53%, 3.81%]*</td>
<td>3.87% [3.55%, 4.18%]*</td>
<td>3.54% [3.24%, 3.85%]*</td>
</tr>
<tr>
<td>Three consecutive VHDs</td>
<td>7.97% [7.14%, 8.80%]*</td>
<td>8.36% [6.53%, 10.19%]*</td>
<td>7.06% [5.32%, 8.80%]*</td>
</tr>
<tr>
<td>Three consecutive HNs</td>
<td>7.37% [7.14%, 7.61%]*</td>
<td>7.41% [6.88%, 7.94%]*</td>
<td>7.26% [6.77%, 7.75%]*</td>
</tr>
<tr>
<td>Five consecutive VHDs</td>
<td>4.90% [3.59%, 6.21%]*</td>
<td>9.64% [6.75%, 12.54%]*</td>
<td>0.78% [-2.01%, 3.56%]*</td>
</tr>
<tr>
<td>Five consecutive HNs</td>
<td>7.99% [7.64%, 8.35%]*</td>
<td>7.74% [6.93%, 8.55%]*</td>
<td>8.13% [7.38%, 8.88%]*</td>
</tr>
<tr>
<td>At least three VHDs and three HNs within a 7-day period</td>
<td>1.46% [1.22%, 1.71%]*</td>
<td>1.82% [1.29%, 2.36%]*</td>
<td>1.80% [1.28%, 2.32%]*</td>
</tr>
<tr>
<td>At least five VHDs and five HNs within a 7-day period</td>
<td>5.32% [4.59%, 6.04%]*</td>
<td>5.74% [4.18%, 7.29%]*</td>
<td>6.23% [4.62%, 7.85%]*</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Model</th>
<th>All-cause mortality (lag 0–1)</th>
<th>All-cause mortality (lag 2–3)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Baseline ($T_{\text{max}} \geq 33 ^\circ C$)</td>
<td>5.91% [5.72%, 6.10%]*</td>
<td>1.09% [0.88%, 1.30%]*</td>
</tr>
<tr>
<td>Three consecutive VHDs</td>
<td>10.23% [9.02%, 11.45%]*</td>
<td>6.60% [5.67%, 7.52%]*</td>
</tr>
<tr>
<td>Five consecutive HNs</td>
<td>10.95% [10.48%, 11.42%]*</td>
<td>5.24% [4.72%, 5.77%]*</td>
</tr>
<tr>
<td>At least five VHDs and five HNs within a 7-day period</td>
<td>15.61% [14.52%, 16.70%]*</td>
<td>-2.00% [-2.83%, -1.17%]*</td>
</tr>
</tbody>
</table>

Summary: Metereological findings

- Hong Kong Subtropical Climate (Hottest time: May – Sept)
- Vertical-based City
- Intra-city variation (Heat Island Effect)
- Seasonal Variation in mortality*

Temperature Impact of Climate change
- Reduce wind speed
- Losing night time cooling
- 2-3 degree increase than current scenario (WBGT)
WHAT IS THE CURRENT KNOWLEDGE AND FINDINGS IN TEMPERATURE AND HEALTH?
Seasonal fluctuation of death by cause (internal causes)

Monthly Death by Cause of Death

ICD10: C00-C97, D00-D48
ICD10: I00-I99
ICD10: J00-J99
All other cause
Temperature Stress

- Effect temperature that would generate pressure or discomfort on the human body

- **Heat Impact**: If heat energy (generated by metabolism) cannot be dissipated in time, the body temperature will continue to rise until a level is reached which may trigger heatstroke, thus becoming life threatening.
Extreme Temperature

Basic Health Needs
- Air Pollution
- Affected supply of food
- Temperature regulation measures may not be adequate enough

Change in environment
- Change in air temperature

Basic Infrastructure
- Increased demand of electricity
- Increased burden of electrical appliance
- Deformation of road

Population Move

Infectious Diseases
- Respiratory Disease
- Vector-borne diseases
- Food-borne diseases

Non-communicable diseases
- Cardiovascular diseases
- Brain diseases
- Worsening of chronic diseases

Injuries
- Accidents
- Heat Stroke

Health Damage (Physical, Mental & Social)
- Increase in death, injuries and illness

Increase the burden of public health system
Increase in the demand of social welfare
Prerequisites for “Bottom Up Resilience” in Public Health Protection

- Awareness that a problem exists
- A sense that the problem matters
- An understanding of what causes the problem
- The capacity to influence
- Political will to influence the problem

Health Impact Pyramid

- Death
- Hospital admission
- Medical help-seeking (e.g., visiting clinic)
- Self-medication or self-care
- Mild symptoms, discomfort

Severity of impact

Proportion of affected population

Easier to observe
Harder to observe
## Modeling Methods and DATA

<table>
<thead>
<tr>
<th>Outcome Dimensions</th>
<th>Outcome Indicators</th>
<th>Sources</th>
<th>Coverage</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mortality</td>
<td>Causes of Death (By age, gender, district, socio-economic status)</td>
<td>Hong Kong Census and Statistic. Government of HKSAR, PRC China</td>
<td>99%</td>
</tr>
<tr>
<td>Morbidity</td>
<td>Daily Hospital Admissions; ICD 9 &amp; ICD 10.</td>
<td>Hong Kong Hospital Authority. Government of HKSAR, PRC China.</td>
<td>83%</td>
</tr>
<tr>
<td>Practices: Health</td>
<td>Hotline calls, Reasons for calls, outcomes of calls</td>
<td>PE Link(HK Government Subsidized NGOs target vulnerable population)</td>
<td>75%</td>
</tr>
<tr>
<td>Seeking behavior</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Practices: Self-</td>
<td>Self-reported activities. Semi-structured</td>
<td>Randomized, Population based, computerized telephone survey</td>
<td>96%</td>
</tr>
<tr>
<td>reported self help</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Practices: Behavior</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>changes</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Perception: Attitude</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Knowledge</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Time-series temperature-health studies

1) Basic Model: Generalized Additive Model

\[ E \left[ \text{daily record of admissions/deaths} \right] = \text{mean temperature} + \text{mean RH} + \text{mean wind speed}^* + \text{total solar radiation}^* + \text{mean level air-pollutants}^* + \text{long term trend} + \text{seasonal trend} + \text{holiday effect} + \text{day-of-week} + \text{same day rainfall} \]

2) Stratified analysis with: Season, Gender, Age, Disease subtypes (ICD 9 and ICD 10),

*Variables were included when substantial associations were observed.
Health Impact Pyramid

- Death
- Hospital admission
- Medical help-seeking (e.g., visiting clinic)
- Self-medication or self-care
- Mild symptoms, discomfort

Severity of impact

Proportion of affected population

Easier to observe
Harder to observe
The GAM model: Mortality Outcomes

The Generalized additive model (GAM) and distributed lag non-linear model (DLNM)

Log(E[daily no. of non-accidental and non-cancer death]) =

\[
\text{cb}(\text{Temperature}, \text{df}=3; \text{lag}, \text{df}=4) + \text{cb}(\text{Relative humidity}, \text{df}=3; \text{lag}, \text{df}=4) + \\
\text{cb}(\text{sqrt.wind_speed}, \text{df}=3; \text{lag}, \text{df}=4) + \text{cb}(\text{Sunshine hours}, \text{df}=3; \text{lag}, \text{df}=4) + \\
\text{cb}(\text{NO}_2, \text{df}=2; \text{lag}, \text{df}=4) + \text{cb}(\text{O}_3, \text{df}=2; \text{lag}, \text{df}=4) + \text{cb}(\text{SO}_2, \text{df}=2; \text{lag}, \text{df}=4) + \text{cb}(\text{PM}_{2.5}, \text{df}=2; \text{lag}, \text{df}=4) + \\
\text{s}(\text{DOS}, k=9) + \text{s}(\text{DOY}, k=8) + \text{factor}(\text{DOW}) + \text{factor}(\text{Holiday})
\]

- \text{cb}: crossbasis of independent variables built up with \text{dlnm()} package in R
- \text{s}(): smoothing function of independent variables
- \text{k}: limitation of degree of freedom in smoothing function
- **Metrological variables**: Daily mean temperature, daily mean relative humidity, daily mean square root of wind speed and daily sunshine hours
- **air pollutants**: NO$_2$, O$_3$, SO$_2$ and PM$_{2.5}$
- \text{DOS}: Day of study (1,2,3...,3287)
- \text{DOY}: Day of year (1,2,3, ...,365/366)
- \text{factor}(): indicator of categorical independent variables
- \text{DOW}: Day of week (Monday, Tuesday...,Sunday)
- \text{Holiday}: Public Holiday in Hong Kong (including Sunday)
Mortality data management

All cause death with valid date of death
(n=383,395, 100%)

Nonaccidental death
(n=368,081, 96.01%)

Non-accidental and non-cancer death
(n=246,584, 64.32%)

Non-accidental & non-cancer death with valid TPU code
(n=243,345, 63.47%)

Data for analysis (excluding special TPU code)
(n=242,784, 63.33%)

Accidental Deaths
(n=15,314, 3.99%)

Cancer Deaths
(n=121,497, 31.69%)

Deaths without TPU code
(n=3,239, 0.84%)

Death in special TPU code
(n=560, 0.15%)

61: Vietnamese migrants
74: Illegal immigrants
84: Transients
91: Marine
92: Military Camp
XXX: Unknown
Overall Mortality and Hot temperature Relationship

An average 1°C increase in daily mean temperature above 28.2°C was associated with an estimated 1.8% increase in mortality. Women, men less than 75 years old, people living in low socioeconomic districts, those with unknown residence and married people were more vulnerable.

Non-cancer-related causes such as cardiovascular and respiratory infection-related deaths were more sensitive to high temperature effects.

Hong Kong compare to other cities in the world


Liu S, Chan EYY, Goggins WB, Lam HCY Do Socioeconomic Factors Affect the Effect of Cold Temperature on Health Outcomes in Subtropical City? Dec 2018
Overall cumulative effect of temperature
Ref = 24.7°C (50th percentile of temperature)

Overall cumulative association and temperature distribution
Daily Mean Temperature Jan 2007 - Dec 2015

1st
11.3°C
Extreme cold

50th
24.7°C
Median

99th
30.6°C
Extreme hot

Findings
Findings

Age: 0-64 vs 65+ years
Lag-response effect at 1st, 5th, 95th and 99th percentile by SDI level

The lag effect for both cold and hot is not significant in younger group.

Both cold and hot effect are more immediate for high SDI groups.
Summary

• Overall cumulative effect of cold temperature is stronger than hot on mortality

• The cold and hot effect on mortality varies between SDI groups
  – **Cold** – The effect was significant in all SDI groups with the strongest effect was observed in the better-off group.
  – **Hot** – The effect was only significant in the group with lowest socioeconomic status.

• Female and older people living in more deprived neighbourhood are associated with higher effect of hot temperature, whereas cold temperature are associated with significantly higher mortality risk across all socioeconomic groups.

• Conclusion:
  – **Hot effect** was specifically more susceptible for poorer population, whilst **cold effect** tends to be more universal to all population regardless personal and neighbourhood characteristics.

Liu S, Chan EYY, Goggins WB, Lam HCY Do Socioeconomic Factors Affect the Effect of Cold Temperature on Health Outcomes in Subtropical City? Dec 2018 (Rouledege)
Health Impact Pyramid

- Death
- Hospital admission
- Medical help-seeking (e.g. visiting clinic)
- Self-medication or self-care
- Mild symptoms, discomfort

Severity of impact

Proportion of affected population

Easier to observe

Harder to observe
### Research Methods: Modelling

<table>
<thead>
<tr>
<th>Outcome Dimensions</th>
<th>Outcome Indicators</th>
<th>Sources</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mortality</td>
<td>Causes of Death (By age, gender, district, socio-economic status)</td>
<td><strong>Retrospective:</strong> Hong Kong Census and Statistic. Government of HKSAR, PRC China</td>
</tr>
<tr>
<td>Morbidity</td>
<td>Daily Hospital Admissions; ICD 9 &amp; ICD 10.</td>
<td><strong>Retrospective:</strong> Hong Kong Hospital Authority. Government of HKSAR, PRC China.</td>
</tr>
</tbody>
</table>
| Practices: Health Seeking behavior | Hotline calls, Reasons for calls, outcomes of calls                  | **Retrospective:** PE Link(HK Government Subsidized NGOs target vulnerable population)  
**Cross Sectional:** Randomized, Population based, computerized telephone survey |
| Practices: Self-reported self help | Self-reported activities. Semi-structured                          | **Cross-Sectional:** Randomized, Population based, computerized telephone survey |
| Practices: Behavior changes |                                                                      |                                                                         |
| Perception: Attitude     |                                                                      |                                                                         |
| Knowledge                |                                                                      |                                                                         |
The GAM model: Morbidity Outcomes

The Generalized additive model (GAM) and distributed lag non-linear model (DLNM)

\[
\log(E[\text{daily no. of cause-specific admissions}]) =
\]

\[
\begin{align*}
&\text{cb(temp, df=3; lag, df=4)} + \text{cb(humid, df=3; lag, df=4)} \\
&\quad + \text{cb(sqrt.wind\_speed, df=3; lag, df=4)} + \text{cb(solrad, df=3; lag, df=4)} \\
&\quad + \text{cb(air\_pollutants, df=2; lag, df=4)} + \text{cb(influenza, df=2; lag, df=4)} \\
&\quad + s(sqrt.Rain,k=3) + s(DOS,k=7) + s(DOY,k=5) + \text{factor(DOW)} + \text{factor(Holiday)}
\end{align*}
\]

- \text{cb}: crossbasis of independent variables built up with dlnm() package in R
- \text{s()}: smoothing function of independent variables
- \text{k}: limitation of degree of freedom in smoothing function
- \text{factor()}: indicator of categorical independent variables
- \text{air pollutants}: PM_{10}, SO_{2}, NO_{2} or O_{3}
- \text{DOS}: Day of study (1,2,3,...,3227)
- \text{DOY}: Day of year (1,2,3,...,365/366)
- \text{DOW}: Day of week (1,2,3,...,7)
- \text{Holiday}: Public Holiday in Hong Kong
Hospital Admissions* and Heat

- Overall, hospitalizations increased by 4.5% for every 1 °C increase in mean daily temperature above 29.0 °C.
- Peak 3-6 days after a hot day.
- Elevated temperatures affect morbidity to a greater degree than colder temperatures. (4.5% in hot vs. 1.4% in cold)

**DAILY ISCHAEMIC/HAEMORRHAGIC STROKE ADMISSIONS**
- 22°C threshold for IS
- Stronger association among elders and women
- Mean daily temperature was negatively associated

**DAILY HEART FAILURE ADMISSIONS**
- Increase with elders in high and low humidity
- 11°C vs 25°C (cumulative to 23 days)
  - Hospitalization (RR=2.63)
  - Mortality (RR=3.13)

**ASTHMA ADMISSION**
- RR=1.19 (30°C vs 27°C, lag 0-3 days)
- RR=1.33 (12°C vs 25°C, lag 0-3 days)
- Greater effect with greater temperature variation (emergency admissions)

**GENERAL HOSPITAL ADMISSIONS**
- Increase of infectious disease admission, including respiratory infections, for hot and cold weather
- Increase cardiovascular disease

**COPD & PNEUMONIA ADMISSION**
- For Elderly people only (60+)
- Pneumonia increased when >28°C (lag 0-2 days)
- Cumulative pneumonia (RR=1.10) and COPD (RR=1.06), 30°C vs 25°C, lag 0-2 days
- Cumulative pneumonia (RR=1.47) and COPD (RR=1.64), 12°C vs 21°C, lag 0-20 days

**TEMPERATURE-RELATED RESEARCH**

**HAND FOOT AND MOUTH DISEASE ADMISSION**
- Increasing trend between 8-20°C (plateau = 25°C)
- Moderate rainfall, stronger winds, and solar radiation also associated with more admissions

**AGE-STANDARDIZED OVERALL MORTALITY**
- Define extreme heat: >29.3°C. Cold: <27.5°C
- Comparing IQR of degree-day (NOV-OCT)
  - 10 hot degree-days: 1.9% increase
  - 200 cold degree-days: 3.1% increase

**MENTAL HEALTH ADMISSION**
- 28°C vs 19.4°C (lag 0-2 days)
- All mental disorder (RR=1.09)
  - Transient mental disorder (RR=1.51)
  - Episodic mood disorder (RR=1.34)
  - Drug-related disorder (RR=1.13)
- Depressive disorders had lower risk at low temperatures

**AWARENESS- VHWW**
- Increase with higher education, in women, middle-aged group
- <40% aware of community's heat preparedness plan

**MORTALITY**
- Increase for non-cancer & respiratory patients
- Increased for women, low SES, married people, and those with unknown residence

**HELP-SEEKING BEHAVIOUR**
- For elders, calls start between 30°C-32°C
- For women, calls start between 28°C-30°C
- For men, calls start between 31°C-33°C
### Scientific evidences of temperature-health studies in Hong Kong by CCOUC team

- **Linear association:**

<table>
<thead>
<tr>
<th>Temperature</th>
<th>Mortality</th>
<th>Hospital Admissions</th>
<th>Unintentional Injury Admissions</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Hot weather</strong></td>
<td><strong>↑ 1.8% of mortality</strong> (Threshold = 28.2°C)</td>
<td><strong>↑ 4.5% of hospital admissions</strong> (Threshold = 29°C)</td>
<td><strong>↑ 1.9% of unintentional injury admissions</strong> (&gt;29°C)</td>
</tr>
<tr>
<td><strong>Cold weather</strong></td>
<td><strong>↑ 1.4% of hospital admissions</strong> (8.2-26.9°C)</td>
<td><strong>↑ 1.6% of Ischemic stroke admissions</strong> (Threshold = 22°C)</td>
<td><strong>↑ 2.1% of cardiovascular disease admissions</strong> (8.2–26.9 °C)</td>
</tr>
<tr>
<td></td>
<td><strong>↑ 2.4% of unintentional injury admissions</strong> (8.2–26.9 °C)</td>
<td></td>
<td><strong>↑ 2.7% of Haemorrhagic stroke admissions</strong> (8.2-31.8°C)</td>
</tr>
</tbody>
</table>

Remarks: Mean daily no. of admissions ~1,077 (1998-2009)
**Temperature and Asthma**

**Hot**
- Hospitalizations were lowest at 27°C, peak at 30°C, then plateaued between 30°C and 32°C.
- Higher humidity and ozone levels

**Cold**
- Temperature was inversely associated with asthma
- Low humidity

- RR=1.19 (30°C vs 27°C, lag 0-3 days)
- RR=1.33 (12°C vs 25°C, lag 0-3 days)
- Greater effect with greater temperature variation (emergency admissions)

---

Findings

5% of 22-70 years old.

>330,000 people* suffering from asthma.


Temperature and acute myocardial infarction hospitalizations for diabetes mellitus

- A total of 53,769 AMI admissions between 2002 and 2011 were included.
- DM patients had a higher increased risk of AMI admissions than non-DM patients during extreme temperatures.
- AMI admissions risks among DM patients rise sharply in both high and low temperatures, with a stronger effect in low temperatures.
- AMI admissions risk among non-DM patients only increased mildly in low temperatures.
Mental disorder and temperature

- 44,600 admissions between 2002 and 2011 were included.
- A positive linear temperature–mental-disorder admissions association starting at 20 degree in warm subtropical region
- Most prominent among older people (<75).

Findings

Transient mental disorders
RR 1.51 CI 95% (1.00, 2.27)

Episodic mood disorders
RR 1.34 CI 95% (1.05, 1.71)

Drug-related mental disorders
RR 1.13 CI 95% (1.00, 1.27)

The lagged 0–2 days RR at 28 °C (temperature at the 75th percentile vs. temperature at the 25th percentile at 19.4 °C) was 1.09 (95% confidence interval (1.03, 1.15))
Thermal-Health impacts

• Thermal stress (hot or cold weather conditions) is strongly linked with higher mortality and hospitality rates in Hong Kong
  – Especially in urban, humid summers, and areas with decreasing ventilations
  – May have significant health impact for:
    • the elderly
    • people with chronic diseases
    • outdoor workers
    • underprivileged individuals living in congested environments

Frequency of health-related help-seeking calls by elderly started to increase when:
• daily maximum temperature > around 30-32 °C
• mean relative humidity > around 70-74%
Hospital admissions ↑ by 4.5% for every increase of 1°C above 29°C

Hospital admissions ↑ by 1.4% for every decrease of 1°C within the 8.2-26.9°C range

Mortality ↑ by 1.8% for every increase of 1°C above 28.2°C

Cumulative mortality* ↑ by 3.8% for every decrease of 1°C

Hot Season

Cold Season

Health-related calls ↑ when max. temp. reaches 30-32°C. About 49% of calls were for explicit health-related reasons

2% Required medical care
95% Professional Medical Health (Western 70.0%/Chinese 25.0%)
5% Self-Care only

1.9% Heatstroke

Mild symptoms and Discomfort

Help-seeking e.g. Clinic attendance

Death

Behavioral changes#

66.9% Have symptoms

67.1% reported changes

* Cumulative mortality is used because the lagged effect of coldness towards mortality is estimated to be 3 weeks. # Behavioral changes include amount of physical activity, appetite, frequency of social activity, mood and sleeping quality
Summary: Heat Health findings

Temperature Impact on Health

Death
• 1.8% increase above 28.2
• Vulnerable subgroup
• Heat effect remains apparent on mortality in Social Deprived Groups
• Overall pattern similar but more specific effect in colder temperature

Hospitalization
• 4.5 % hospitalization above 29C
• Threshold various with disease subgroup

*Winter is known to accumulate more mortality
CASES OF COLLABORATION
SERVICE ENHANCEMENT
TEMPERATURE WARNING SYSTEM IN HONG KONG
The impact of cold and hot weather on senior citizens in Hong Kong

- Hong Kong Observatory (HKO) collaborates with Senior Citizen Home Safety Association (SCHSA)
- Daily number of hospitalization for those Personal Emergency Link (PE-Link) callers (PE(H))
- Correlation between PE(H) and temperatures and relative humidity

Variation of the average normalized daily number of PE-Link callers who required subsequent hospitalization (PE) at different ranges of daily maximum temperature ($T_{\text{max}}$) at 2°C intervals

Variation of the average normalized daily number of PE-Link callers who required subsequent hospitalization (PE) at different ranges of daily minimum temperature ($T_{\text{min}}$) at 2°C intervals

Variation of the average normalized daily number of PE-Link callers who required subsequent hospitalization (PE) at different ranges of daily mean relative humidity (RH) at 5% intervals in the cool season (October to April)

When the maximum temperature was higher than 30°C, the number of hospitalized PE-Link users increased as temperature rose. The figures were more than 7% higher when the temperature reached 34°C or above.
Exemplary case in WHO-WMO report

– success story of collaboration between HKO and SCHSA for better elderly care services showcased in WHO-WMO Climate Services for Health – Case Studies
Heat-Health Warning

Joint guidance by The World Meteorological Organization (WMO) and World Health Organization (WHO).

Elements that should be included in a heat-health warning system:

- **Weather forecasts** of high temperatures (may include humidity)
- Method for assessing how future weather patterns may evolve in terms of range of health outcomes
- Determination of heat-stress threshold for action
- System of graded alerts/actions for communicating to the general public for specific target groups
Threshold for Public Warning

- UN/WHO Emergency thresholds: **Doubles** Crude Mortality Rate and Under 5 Mortality (U5MR)
- This is **not useful** for developed urban communities


<table>
<thead>
<tr>
<th>Temperature (°C)</th>
<th>&lt;10</th>
<th>10-14</th>
<th>15-19</th>
<th>20-24</th>
<th>25-26</th>
<th>27-29</th>
<th>&gt;29</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Frequency</td>
<td>1</td>
<td>43</td>
<td>388</td>
<td>484</td>
<td>79</td>
<td>14</td>
<td>2</td>
<td>1011</td>
</tr>
<tr>
<td>Valid Percent</td>
<td>0.10%</td>
<td>4.25%</td>
<td>38.38%</td>
<td>47.87%</td>
<td>7.81%</td>
<td>1.38%</td>
<td>0.20%</td>
<td>100.00%</td>
</tr>
</tbody>
</table>

**Chan, Goggins et al 2012**
Threshold temperatures of increasing health risks in Hong Kong

People reported to feel most comfortable!

Cold threshold

Hot threshold

21 COPD admissions ≥ 60 years
22 Ischaemic Stroke admissions
23 Heart failure admissions
26 All hospital admissions
27 Asthma admissions
28 All mortality
29 Help seeking call for elderly
30 Daily mean temperature range during 2002-2011

Daily mean temperature (°C)
Heat Warning in Hong Kong

- Since 2000, The Hong Kong Observatory (HKO) established a single-tier ‘very hot weather’ warning system
- The main index considered was **Weather stress index (WSI)**. Net effect temperature (NET). It takes into account air temperature, wind speed, and relative humidity Along with dry bulb temperature, used to measure for “Very Hot Weather Warning”
- A newly developed **Hong Kong Heat Index (HKHI)** was considered for issuing VHWW since 2014
- A 2-tier warning system was established with the HKHI index

In 2016 alone, 38 of such warnings were issued, the most of any year even accounting for retrospective temperature recordings
**Wet Bulb Globe Temperature (WBGT)**

<table>
<thead>
<tr>
<th>Measurement</th>
<th>Description</th>
<th>Air temperature</th>
<th>Wind speed</th>
<th>Solar radiation</th>
<th>Humidity</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ta*</td>
<td>Thermometer shielded from the sunshine</td>
<td>✓</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Tnw</td>
<td>Thermometer covered with wet wick exposed to sunshine</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>Tg</td>
<td>Thermometer installed inside a black hollow copper globe</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td></td>
</tr>
</tbody>
</table>

Most widely used equation: \( WBGT = 0.7 \times Tnw + 0.2 \times Tg + 0.1 \times Ta \)

- Measurable parameters without the need for complex calculations from different weather elements
- However, the weighted coefficients were obtained based on North American climate for US Army and Marine Corps training camps. May not be suited for Hong Kong
The development of the Hong Kong Heat Index (HKHI) for enhancing the heat stress information service

- HKO collaborates with the JC School of Public Health and Primary Care, CUHK to develop a new HKHI
- Enhance the Very Hot Weather Warning (VHWW) with the adoption of a new heat stress index as a component of criteria.
- Provide scientific basis for introducing new special advisory to the public to supplement the VHWW to cover occasional cases in summer that the weather is rather hot but yet marginally below the criteria of issuing VHWW and to serve as additional advice to remind (through Observatory’s Special Weather Tips) the public to take due attention.

\[
\text{HKHI} = 0.8 \, T_{nw} + 0.05 \, T_{g} + 0.15 \, T_{a}
\]
Data and Analysis Methods

\[ \text{HKHI} = a \times T_{nw} + b \times T_g + c \times T_a \]  
\[(\text{Celsius)}\]

• All possible combinations of \(a\), \(b\) and \(c\) were tried (searching step at 0.05 between 0 and 1) to express the:

a) The largest excess hospitalization ratio (EHR) at 90\(^{th}\) percentile of HKHI

• 90\(^{th}\) percentile is adopted since many climate and health studies take this as a threshold in defining heat wave or extreme high temperature events

b) The excess hospitalization ratio demonstrating an expose-response relationship at every age group

Excess hospitalization rate (EHR) = daily hospitalization rate corresponding for that percentile of HKHI mean hospitalization rate of the same day group and year
Excess hospitalization ratio with different percentiles of daily maximum HKHI

- The EHR ratios associated with the 90th percentile of HKHI were:
  - 1.022 for infectious disease
  - 1.021 for respiratory diseases
  - 1.020 for cardiovascular diseases
- In particular, the ratio for CVD even rose rapidly to 1.052 at the 95th percentile
Collaborating Centre for Oxford University and CUHK for Disaster and Medical Humanitarian Response
CCOUC 災害與人道救援研究所

Coefficients for HKHI versus WBGT

\[ \text{HKHI} = 0.8 \times Tnw + 0.05 \times Tg + 0.15 \times Ta \]

\[ \text{WBGT} = 0.7 \times Tnw + 0.20 \times Tg + 0.10 \times Ta \]

Larger Tnw since Hong Kong has a relative higher humidity

Based on records between 2007-2011:
27.2 days met the criteria for VHWW per year using the new HKHI, close to the 25.2 days in the original criteria.
Two-tier Warning System

**Excess hospitalization ratio** with different percentiles of daily maximum HKHI

- An WGBT formula optimized for Hong Kong’s weather was formed, named the HKHI
- HKHI performed better than WBGT and NET in reflecting the health risk under high temperature conditions (hospitalization)

Data:
Daily total non-accidental hospitalizations during working days

Health Message

• HKO will issue the warnings
• Warnings are broadcasted over radio and television
• Government departments such as Home Affairs Department are contacted to take action, such as open temporary shelters
• HKO provides health guidelines in official website:
  – Health warnings for outdoor workers, elderly persons or persons with chronic diseases
  – Suggests to keep ventilation in indoor areas
  – Suggests people to should check in and pay attention to vulnerable populations
• If warning persists, observatory will repeat special announcements to remind the public
Weather Information Acquisition

- Weather information dissemination is significant for protecting the well-being of communities, especially during extreme climatic events.
- A type of preparedness that enhances local capacity to limit losses caused by hazards and minimize potential health impacts.
- Understanding the current and preferred channels of acquisitioning weather information could urge providers to better meet user needs.
- Cross-sectional telephone survey of Hong Kong residents >15 years old. (n=1017 valid samples)
Comparison between current and preferred channels of weather information acquisition in Hong Kong, 2016.

- 73.1% of respondents were using their preferred channel
- Television was the most popular channel used (50.1%), followed by smartphone apps (32.0%), and radio (8.0%)
- Among those not using their preferred channel, 61.3% considered switching to smartphone app (45-60 years old)
- Smartphone ownership was inversely related to age

Is 2017 heat warning effective?

Hong Kong recorded its hottest temperature in 50 years (36.6 °C) on 22 August 2017 (max. temperature at King’s Park)

- 87% were aware of the heat warning issued by HKO.
- 45.3% also regarded high temperature would not affect their health at all.
- 28.8% among >65-year group had neglected the health risk.
- During the heatwave, 37.2-97.5% had applied at least one personal heat protective measures.

---


Table 1. Logistic Regression of Heat-related Protective Behaviours
The majority of respondents (87.2%) did not perceive Hong Kong as a natural disaster-susceptible city.

More than half (57.1%) reported beliefs that the local population had lower disaster awareness than other global cities.

Infectious disease outbreak (74.0%), typhoon (12.9%), and fire (7.3%) were ranked as the most likely population-based disasters to occur.

Only 1.2% perceived extreme weather as a potential threat.

Source: Chan, Yue, Lee et al. (2016)
Lessons Learnt in Hong Kong

• Leadership!
• Increase awareness of the issues by various disciplines
• Academic should adopt the topic
• Cross-disciplinary collaborations
• Impact driven research outcomes
• Platform for training and exchange
• Policy support
Climate Change Monitoring and Future Projections in Hong Kong

Projected annual maximum daily rainfall and annual maximum 3-day rainfall in Hong Kong under the medium-low and high greenhouse gas concentration scenarios.

Annual mean temperature expected to increase 1.5-3.5°C in 2091-2100.
Research Paper Submission

**Journal:** IJERPH International Journal of Environmental Research and Public Health (Impact Factor 2.1)

**Special Issue:** Health-Related Emergency Disaster Risk Management (Health-EDRM)

**Guest Editors:** Prof. Dr. Emily Ying Yang Chan and Dr. Holly Ching Yu Lam

**Deadline:** 31 October 2018

**Contact:**
Prof. Emily Ying Yang Chan,
Assistant Dean, JC School of Public Health and Primary Care, Faculty of Medicine, The Chinese University of Hong Kong, Hong Kong, China.
E-mail: emily.chan@cuhk.edu.hk
Website: [http://ccouc.org/prof-emily-chan](http://ccouc.org/prof-emily-chan)

**Interests:** H-EDRM, Climate change and health, Health risk profiling, Vulnerability index, Evidence based interventions in H-EDRM
Contact Us

- Website: http://ccouc.org
- Email: ccouc@cuhk.edu.hk
- Tel: +852 2252 8850
- Fax: +852 2647 6547

- Address: Room 308, School of Public Health and Primary Care, Prince of Wales Hospital, Sha Tin, Hong Kong
THANKYOU!
Affected by the subsiding continental airstream associated with the outer circulation of severe typhoon Soudelor, the weather in HK became very hot on 8 August 2015.

The temperatures at the Hong Kong Observatory rose to a maximum of 36.3 °C on the afternoon of 8 August 2015, the second highest on record since 1884.

Provided by DR TC Lee, HKO
On 24 January 2016 (Sunday), due to an intense cold surge, 120+ people stranded on Tai Mo Shan and nearby peaks. Over 60 of them were taken to hospitals.

Source: Hong Kong Observatory
Study background (1): The cold wave January 2016

Coldest day since 1957

<table>
<thead>
<tr>
<th>Date</th>
<th>Max</th>
<th>Mean</th>
<th>Min</th>
</tr>
</thead>
<tbody>
<tr>
<td>15/1/2016</td>
<td>16.1</td>
<td>15.1</td>
<td>14.5</td>
</tr>
<tr>
<td>16/1/2016</td>
<td>17.1</td>
<td>16.4</td>
<td>15.5</td>
</tr>
<tr>
<td>17/1/2016</td>
<td>20.6</td>
<td>17.8</td>
<td>14.8</td>
</tr>
<tr>
<td>18/1/2016</td>
<td>17.8</td>
<td>15.2</td>
<td>11.9</td>
</tr>
<tr>
<td>19/1/2016</td>
<td>17.6</td>
<td>16.4</td>
<td>15.3</td>
</tr>
<tr>
<td>20/1/2016</td>
<td>16.8</td>
<td>15.5</td>
<td>14.8</td>
</tr>
<tr>
<td>21/1/2016</td>
<td>17.1</td>
<td>16.1</td>
<td>15.1</td>
</tr>
<tr>
<td>22/1/2016</td>
<td>16.2</td>
<td>14.1</td>
<td>10.3</td>
</tr>
<tr>
<td>23/1/2016</td>
<td>10.4</td>
<td>8.5</td>
<td>7.0</td>
</tr>
<tr>
<td>24/1/2016</td>
<td>7.1</td>
<td>4.9</td>
<td>3.1</td>
</tr>
<tr>
<td>25/1/2016</td>
<td>10.8</td>
<td>7.4</td>
<td>4.3</td>
</tr>
<tr>
<td>26/1/2016</td>
<td>13.5</td>
<td>10.4</td>
<td>8.1</td>
</tr>
<tr>
<td>27/1/2016</td>
<td>15.3</td>
<td>13</td>
<td>9.8</td>
</tr>
<tr>
<td>28/1/2016</td>
<td>17.4</td>
<td>16.1</td>
<td>14.8</td>
</tr>
<tr>
<td>29/1/2016</td>
<td>17.4</td>
<td>16.6</td>
<td>15.9</td>
</tr>
<tr>
<td>30/1/2016</td>
<td>19.9</td>
<td>17.6</td>
<td>16.2</td>
</tr>
<tr>
<td>31/1/2016</td>
<td>16.2</td>
<td>15.7</td>
<td>15.3</td>
</tr>
<tr>
<td>1/2/2016</td>
<td>15.6</td>
<td>12.4</td>
<td>10.7</td>
</tr>
<tr>
<td>2/2/2016</td>
<td>11.2</td>
<td>10.4</td>
<td>9.4</td>
</tr>
<tr>
<td>3/2/2016</td>
<td>14.3</td>
<td>12.5</td>
<td>10.3</td>
</tr>
<tr>
<td>4/2/2016</td>
<td>18.8</td>
<td>15.2</td>
<td>13.3</td>
</tr>
</tbody>
</table>

Source: Hong Kong Observatory
Prerequisites for “Bottom Up Resilience” in Public Health Prevention

- Awareness that a problem exists
- A sense that the problem matters
- An understanding of what causes the problem
- The capacity to influence
- Political will to influence the problem
