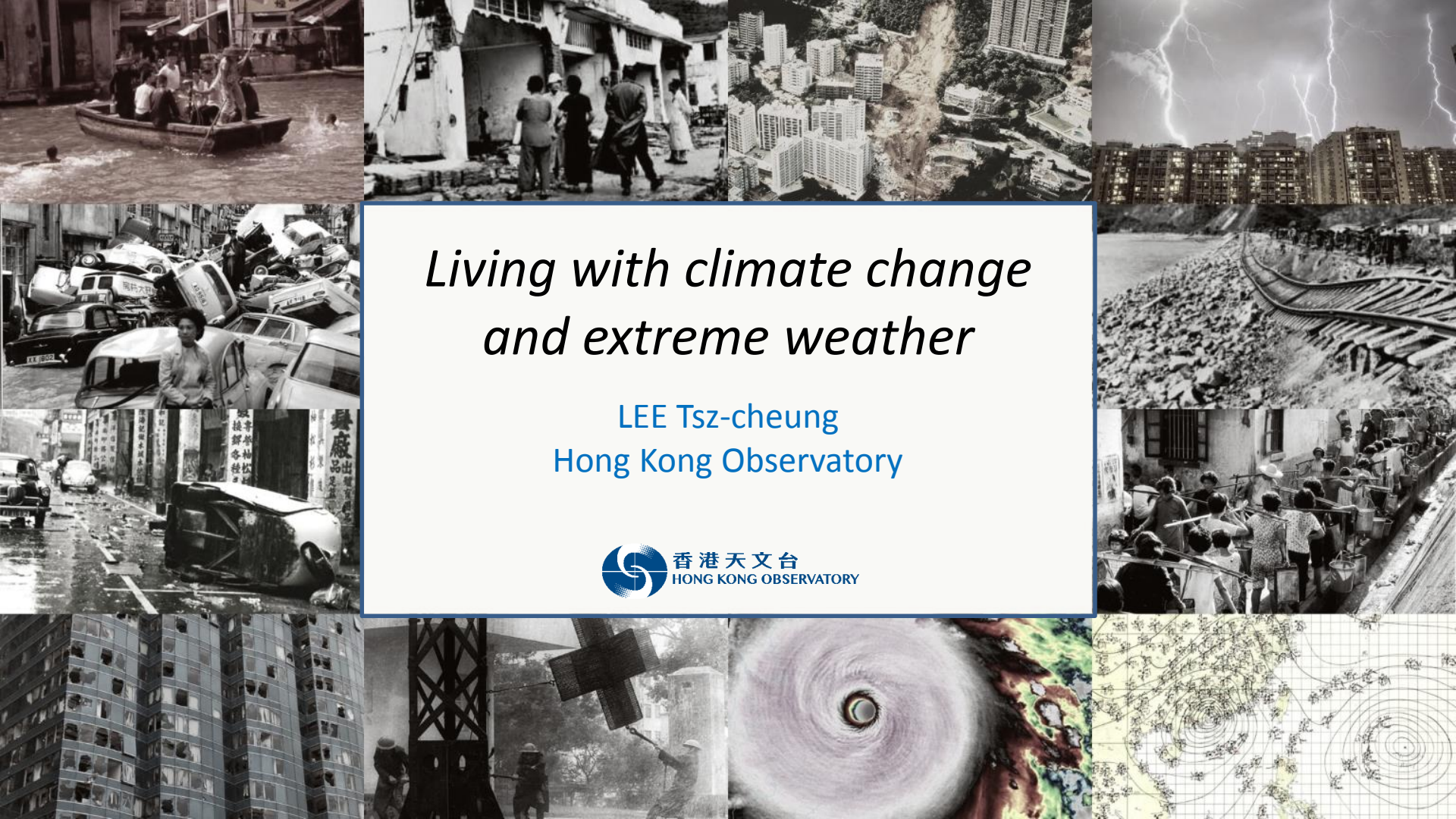


Living with climate change and extreme weather

LEE Tsz-cheung
Hong Kong Observatory

香港天文台
HONG KONG OBSERVATORY

Content

Climate change – where are we heading to ?

- CO_2 concentration
- Global mean temperature
- The 1.5°C target

Extreme weather in a changing climate

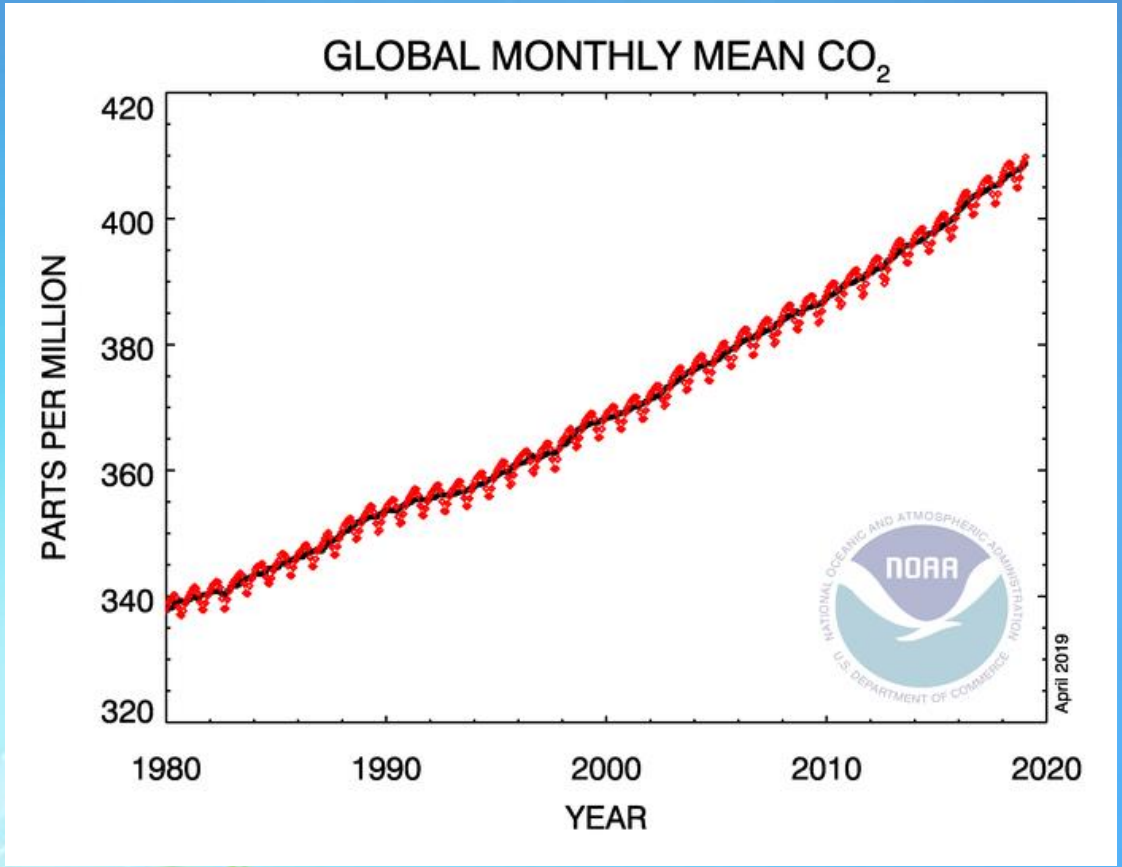
- Consequence of climate change
- Climate change in Hong Kong
- Extreme weather in Hong Kong
- Projections of future climate

Public education on climate change and energy saving

Concluding remarks

CO_2 concentration in recent decades

二氧化碳濃度
CO_2 concentration (ppm)



(photo source : NOAA, https://www.esrl.noaa.gov/gmd/ccgg/trends/gl_full.html)

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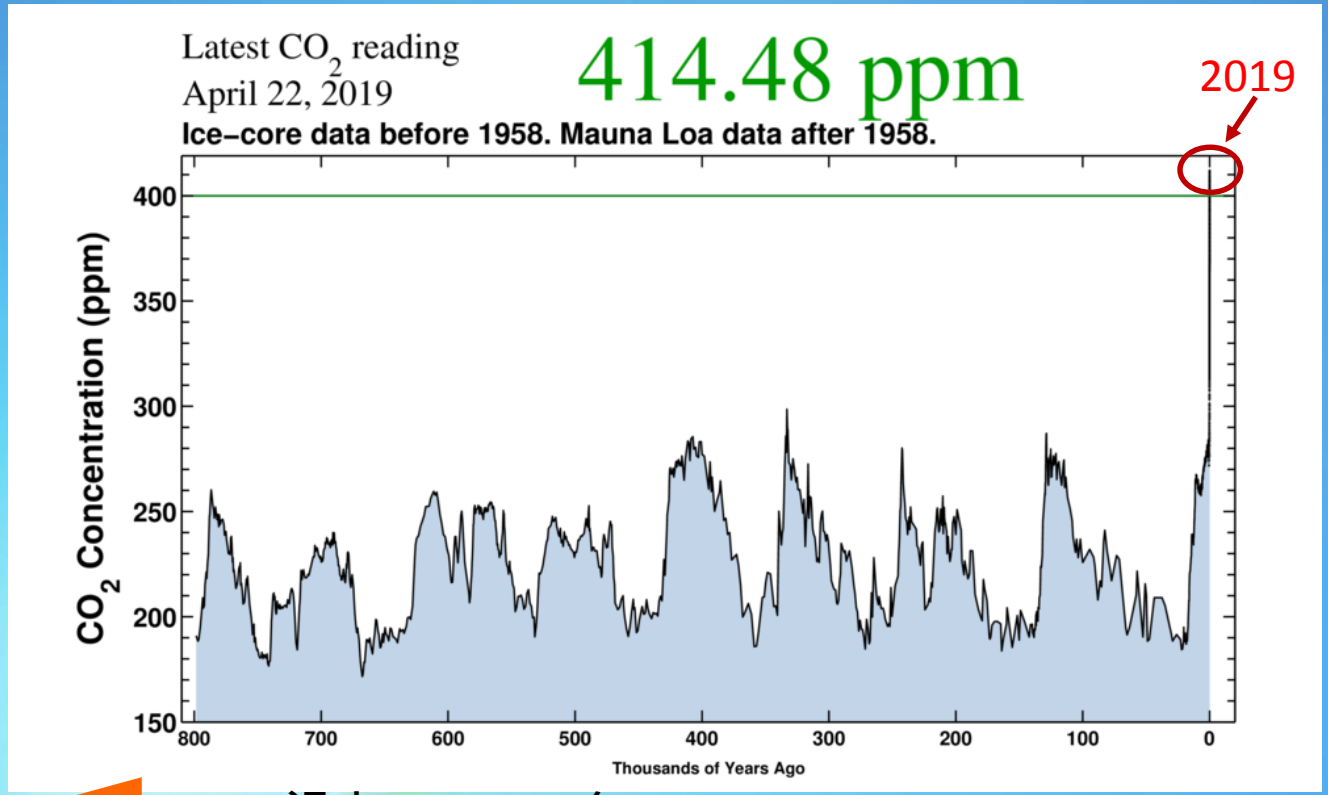
Unprecedented CO_2 concentration in 800,000 years



過去800,000年 The last 800,000 years

(source : https://scripps.ucsd.edu/programs/keelingcurve/wp-content/plugins/sio-bluemoon/graphs/co2_800k.pdf)

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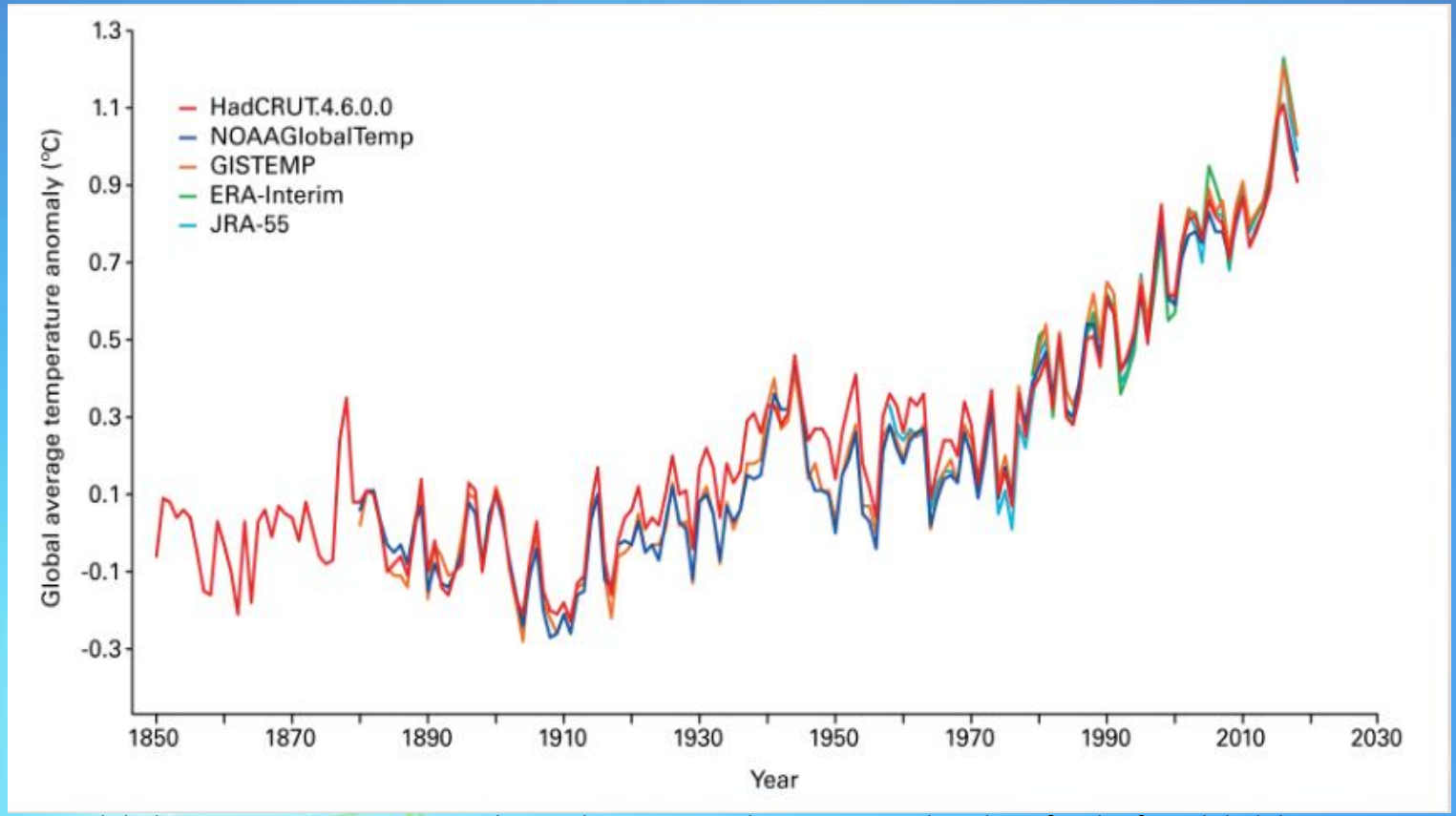
2015-2018 were the warmest 4 years on record



Global mean temperature anomalies with respect to the 1850-1900 baseline, for the five global datasets

(Source : WMO Statement on the state of the global climate in 2018)

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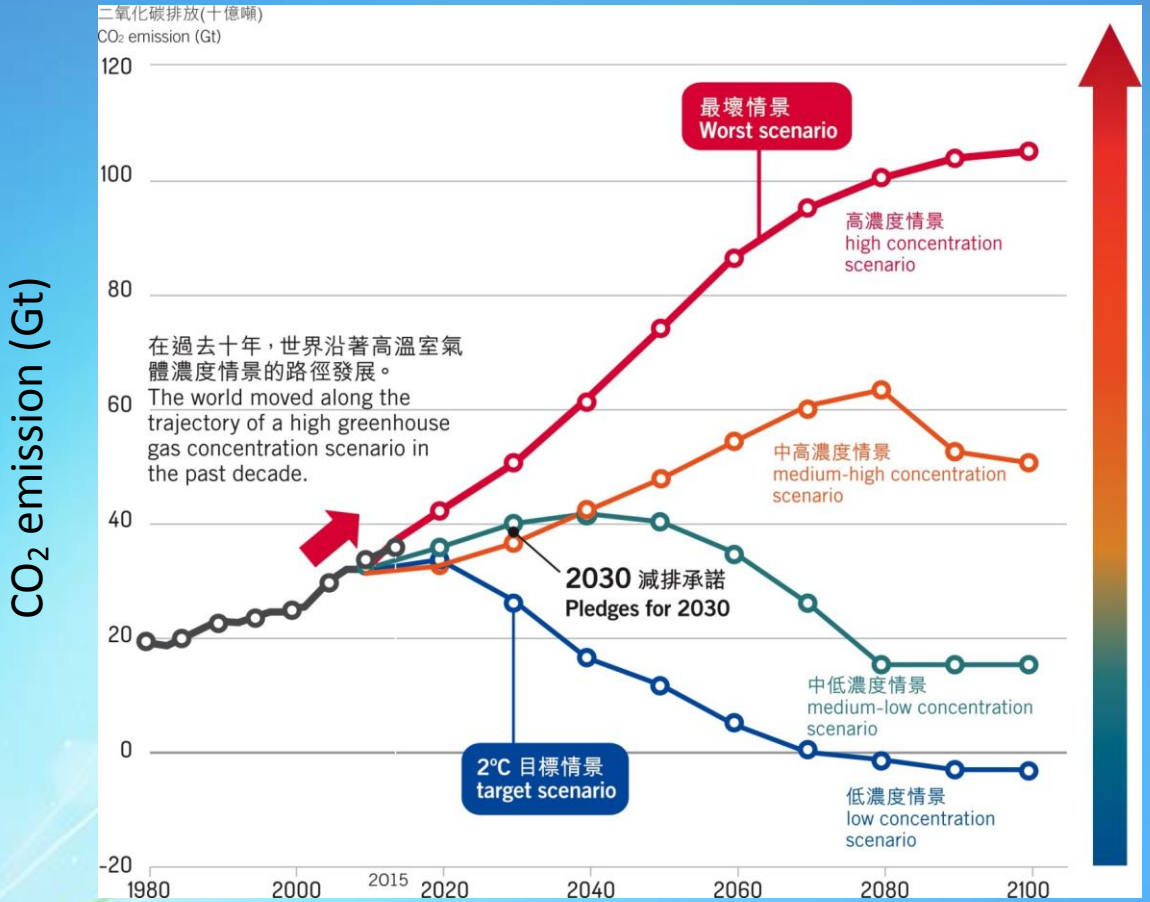
Where are we heading to?



CO_2 emission (Gt)

(Source : https://www.globalcarbonproject.org/carbonbudget/archive.htm)

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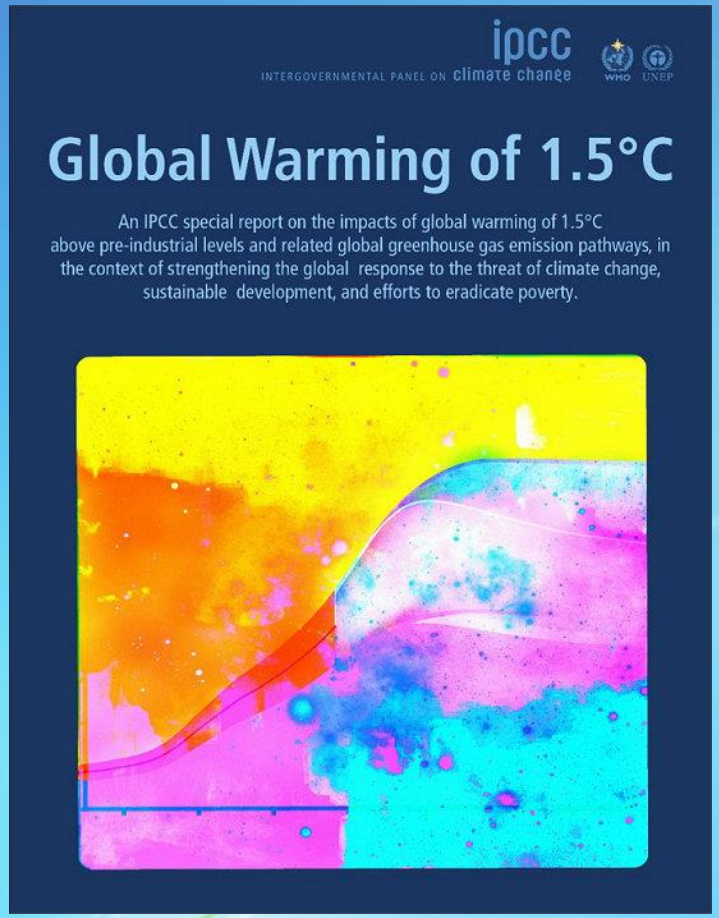
Special Report on Global Warming of 1.5ºC



The IPCC released the Special Report on Global Warming of 1.5˚C on 8 October 2018, making an urgent call for policymakers that limiting global warming to 1.5˚C would require rapid, far-reaching and unprecedented changes in all aspects of society.

The Special Report is available at https://www.ipcc.ch/report/sr15.

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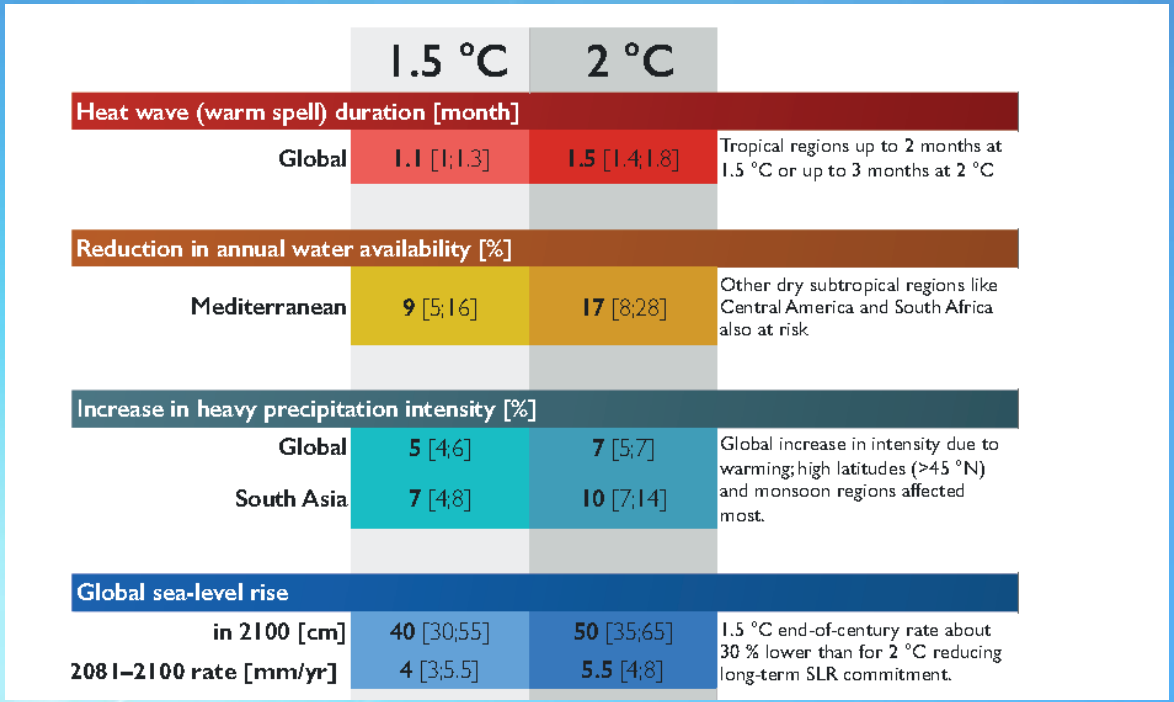
1.5°C vs 2°C world

Heat wave

Water resources

Extreme rainfall

Mean sea level rise



	1.5 °C	2 °C	
Heat wave (warm spell) duration [month]			
Global	1.1 [1;1.3]	1.5 [1.4;1.8]	Tropical regions up to 2 months at 1.5 °C or up to 3 months at 2 °C
Reduction in annual water availability [%]			
Mediterranean	9 [5;16]	17 [8;28]	Other dry subtropical regions like Central America and South Africa also at risk
Increase in heavy precipitation intensity [%]			
Global	5 [4;6]	7 [5;7]	Global increase in intensity due to warming; high latitudes (>45 °N) and monsoon regions affected most.
South Asia	7 [4;8]	10 [7;14]	
Global sea-level rise			
in 2100 [cm]	40 [30;55]	50 [35;65]	1.5 °C end-of-century rate about 30 % lower than for 2 °C reducing long-term SLR commitment.
2081–2100 rate [mm/yr]	4 [3;5.5]	5.5 [4;8]	

Longer

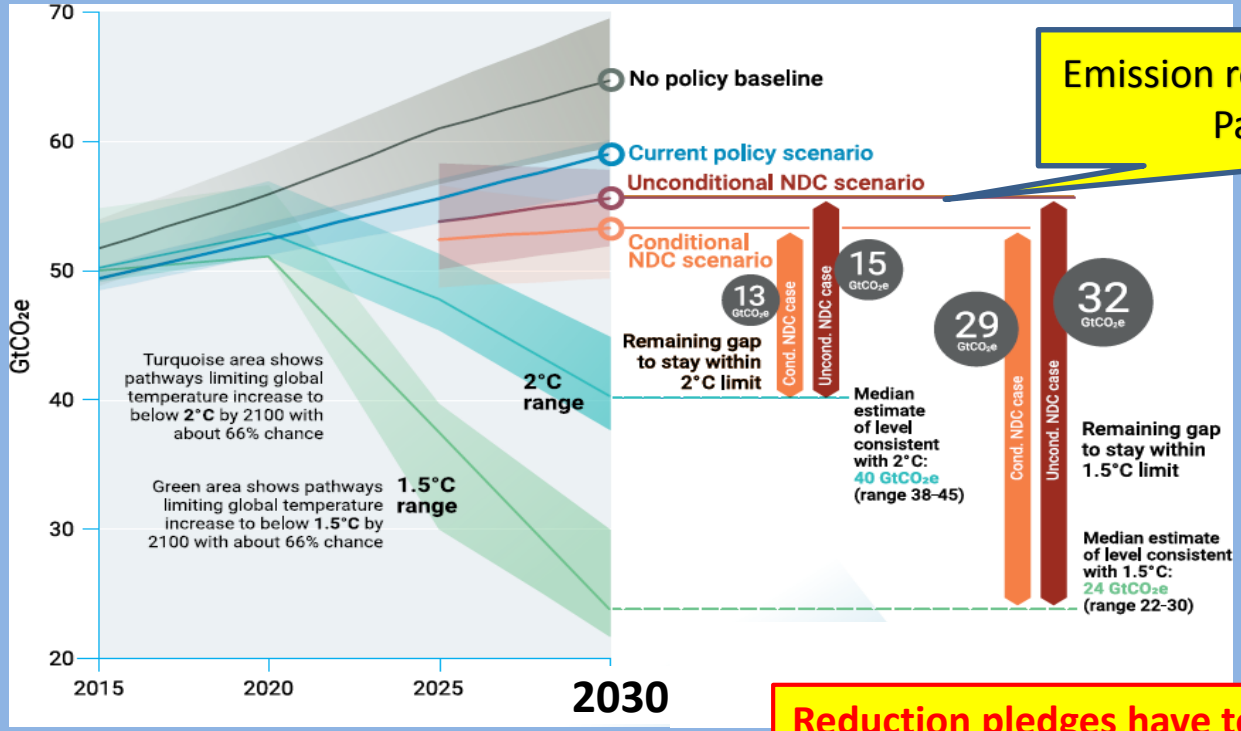
Drier

Increased intensity

Higher

(Source: Schleussner et al (2016))

Global warming of about 3.2°C by 2100 based on emission reduction pledges under Paris Agreement



Emission reduction pledges under Paris Agreement

Nationally determined contributions (NDCs) *embody efforts by each country to reduce national emissions and adapt to the impacts of climate change*

Reduction pledges have to increase fivefold in order to contain temperature rise within 1.5°C

(Source: Emissions Gap Report 2018)

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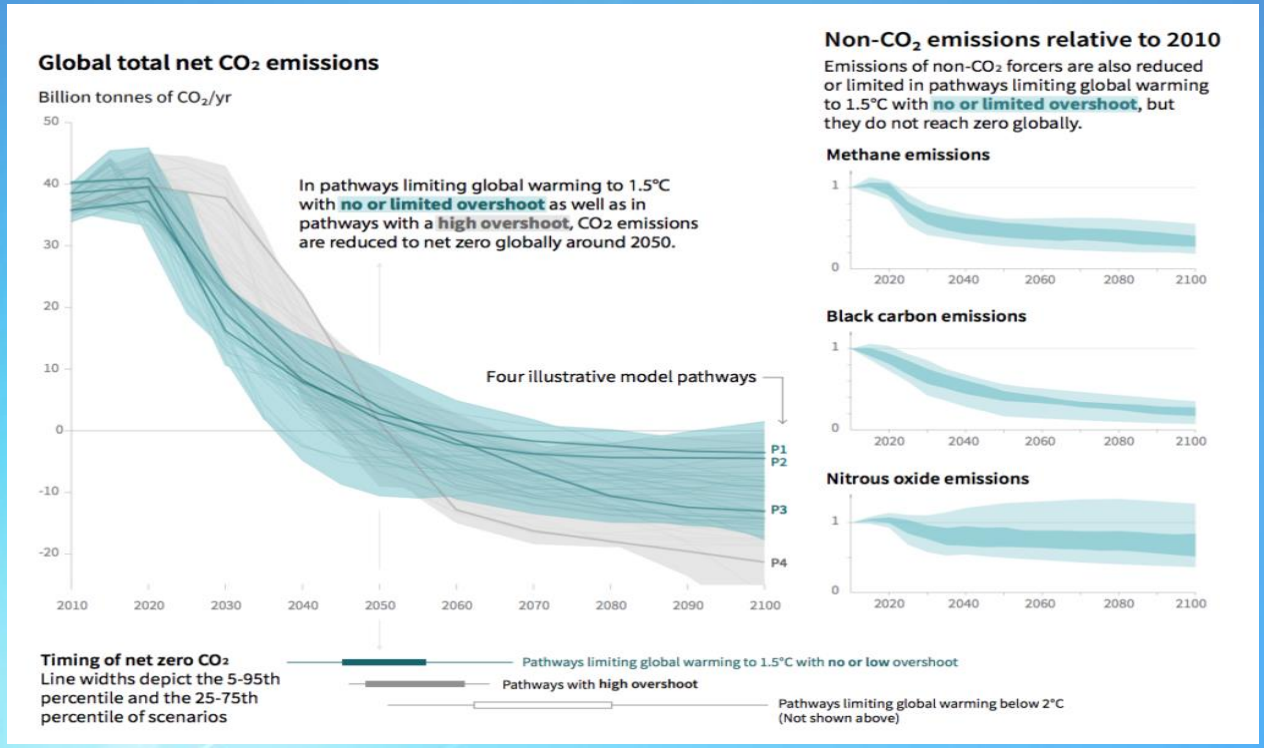
We need to achieve net zero CO_2 emissions at around 2050



Human-caused carbon emissions have to decline by about 40% from 2010 levels by 2030.

(Source: IPCC SR1.5C)

Extreme weather in a changing climate

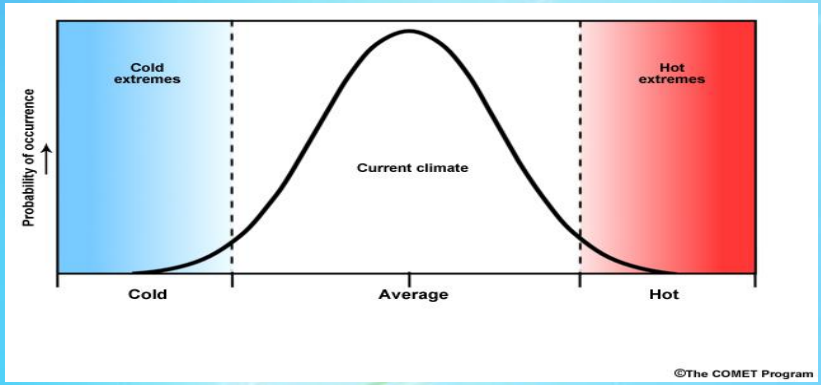
The Consequence of Global Warming

Enhance greenhouse effect	→	Rising temperature
Thermal expansion of sea water & melting of snow on land	→	Sea level rise
Change in atmospheric circulation and enhanced water cycle	→	Regional differences in precipitation and more frequent extreme weather and climate events

A brief overview of extreme weather and climate events

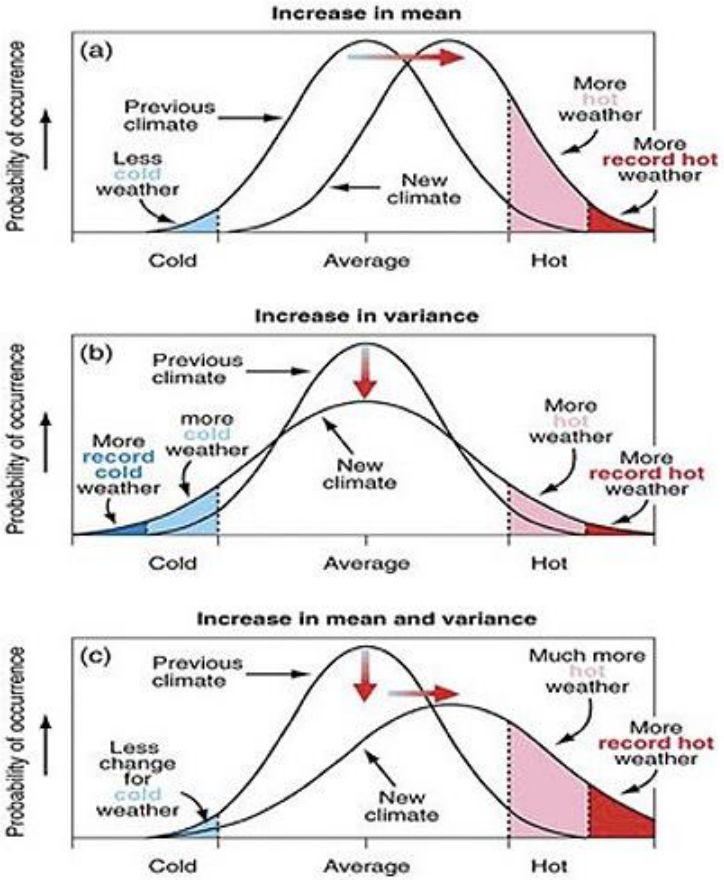
Extreme event is :

- An infrequent and/or unseasonal event which is significantly different from "the norm" in terms of frequency, severity, duration and/or timing
- May have significant impacts to various sectors of the society
- Usually caused by a combination of factors – ranging from large scale climate and weather systems to local weather interactions
- Climate change will likely increase the frequency of occurrence and severity of some extreme weather events (e.g. extreme temperatures, rainstorm, flooding, severe typhoons, drought, etc).



Taking temperature as an example, the probability of occurrence of a temperature usually follows a normal distribution with a very low probability of occurrence (usually less than 5%) for extremely high or low temperature.

Climate change and extreme temperature events



Small shifts in the mean and variance can significantly affect the frequency of occurrence of extremes

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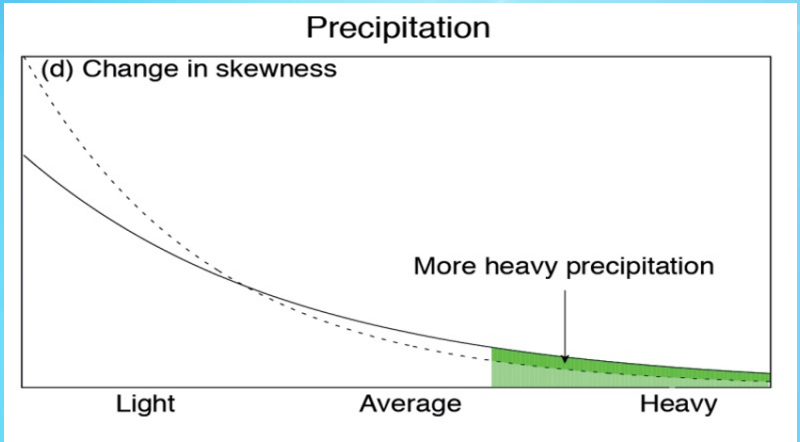
Climate change & extreme rainfall

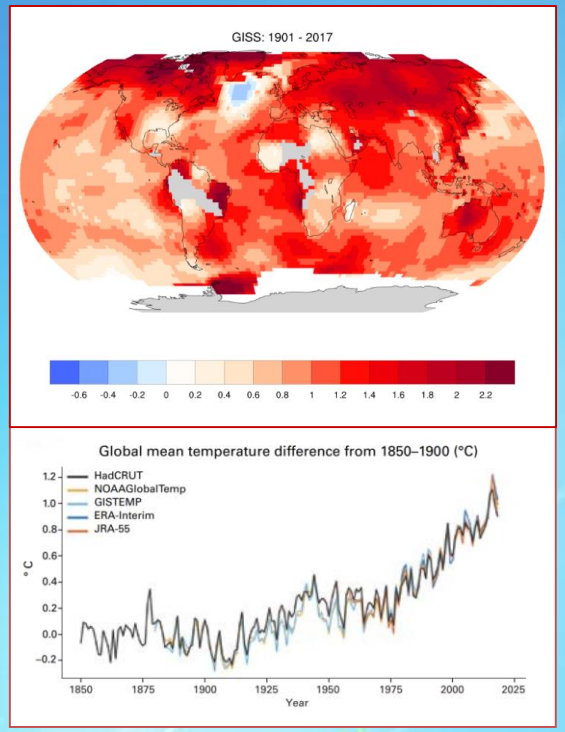
- A warmer atmosphere increases the water holding capacity (around 7% per degree rise in temperature)
- The warming may also enhance the hydrological cycle and atmospheric instability.
- A less stable atmosphere with more water vapour in the air will provide a more favourable condition for intense precipitation events.
- Increase the chance of occurrence of extreme precipitation, but decrease the frequency of light rain



It's harder to rain. But if it rains, it pours.

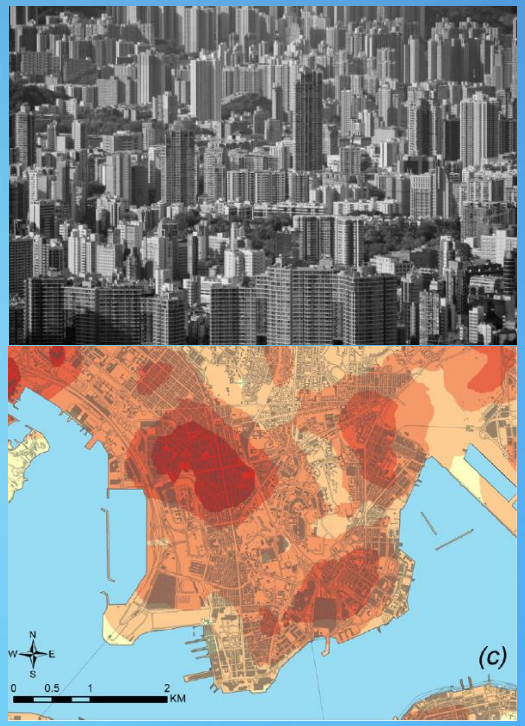
Climate change in Hong Kong

Global warming



+

Local urbanization effect



(Ref : Yuan et al., 2019 : Assessing spatial variability of extreme hot weather conditions in Hong Kong: A land use regression approach, Environmental Research, Volume 171, Pages 403-415 and WMO Statement on the state of the global climate in 2018)

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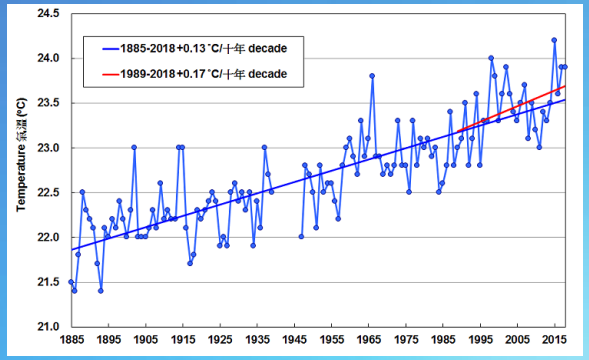
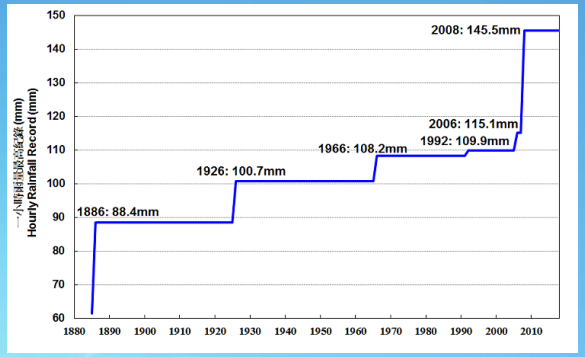
Observed climate change in Hong Kong

Increasing temperatures



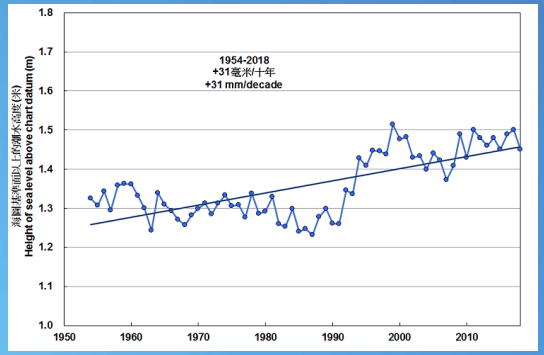
Annual mean temperature recorded at the HKOHq (1885-2018).

More variable rainfall

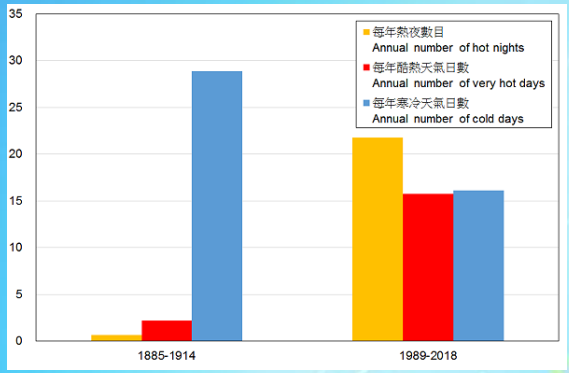


Hourly rainfall records at the HKOHq (1885-2018)

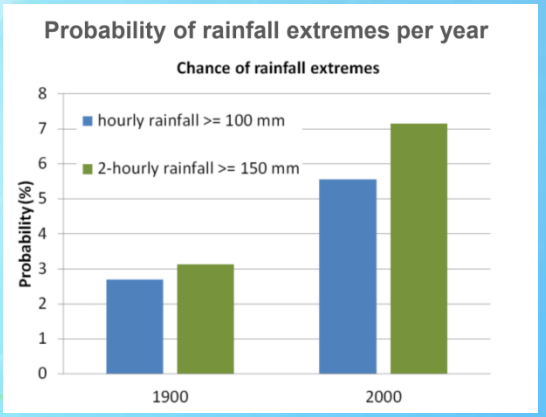
Rising sea level

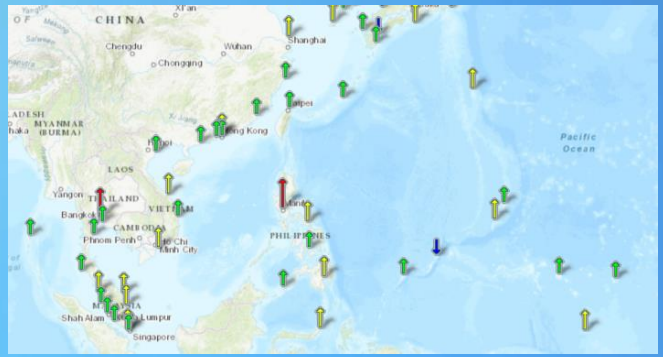


Annual mean sea level at Victoria Harbour (1954-2018)



Changes in the annual number of hot nights, very hot days and cold days in Hong Kong.





Sea level rise trend over Asia
https://tidesandcurrents.noaa.gov/sltrends/sltrends.html

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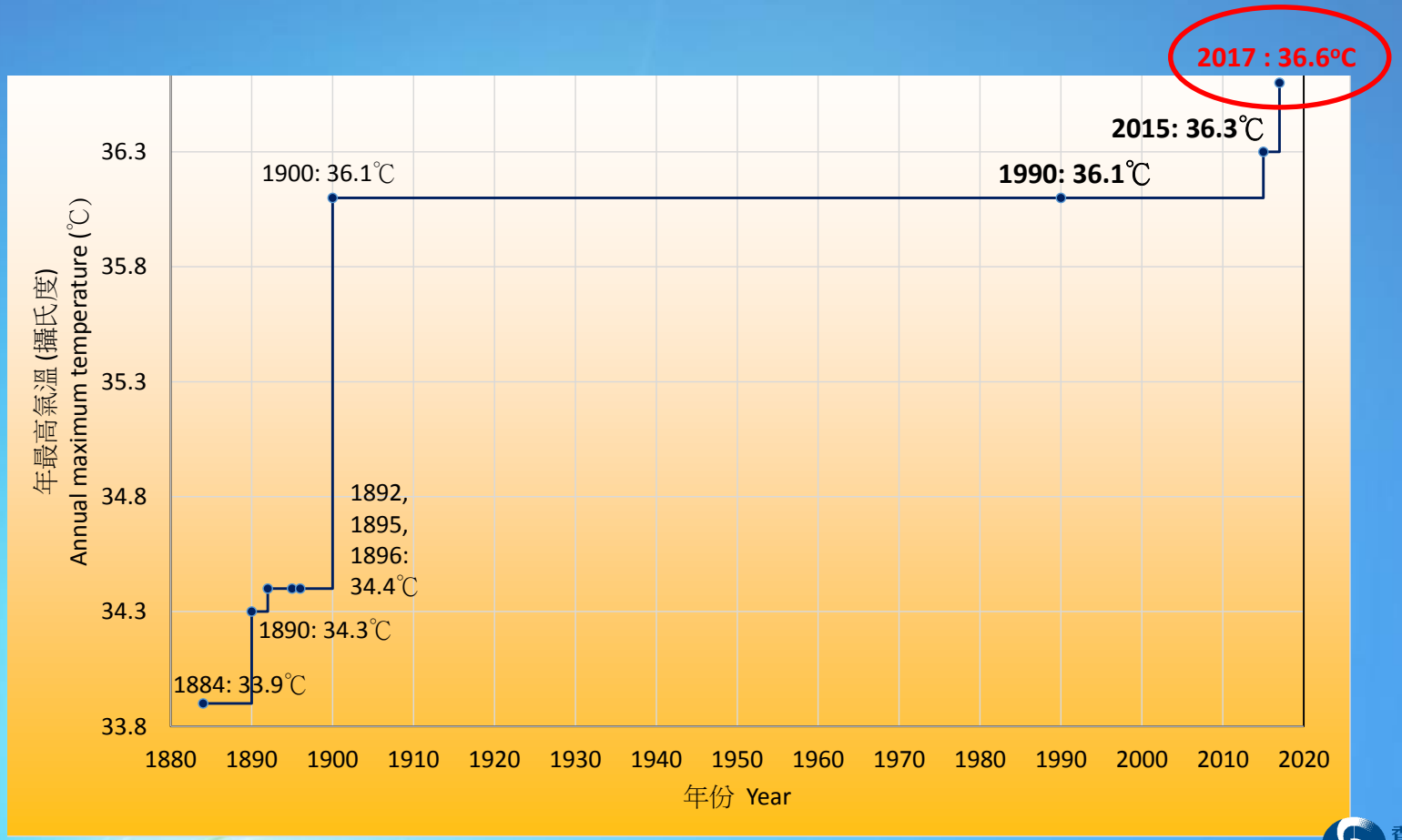
More record breaking high temperature events in Hong Kong in recent decades



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Some historical extreme weather events in Hong Kong

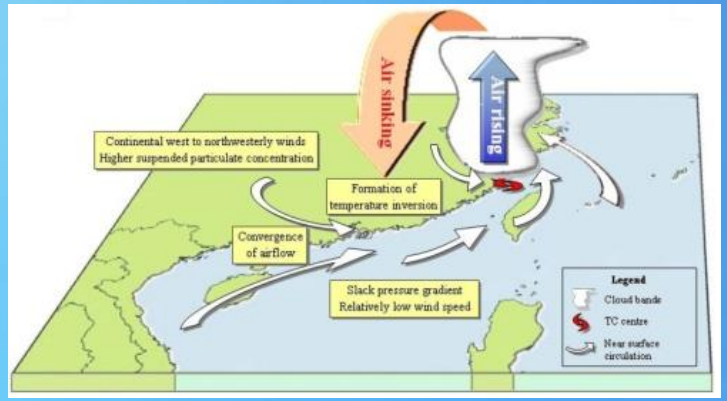
Extremely hot weather

The top four hottest day in Hong Kong on record

Date	HKOHq Max. Temperature (°C)	Remark
22 Aug 2017	36.6	Super Typhoon Hato
8 Aug 2015	36.3	Severe typhoon Soudelor
18 Aug 1990	36.1	Typhoon Yancy
19 Aug 1900	36.1	Tropical cyclone to the SE of Hong Kong

All four cases are associated with tropical cyclones near Taiwan and Luzon

- Subsiding continental airstream (hot air from the north)
- Slack pressure gradient with low wind speed near Hong Kong
- Fine and relatively dry weather with strong day heating



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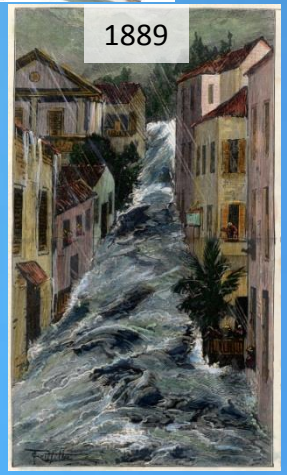
Rainstorms

Tropical cyclones, SW monsoon and trough of low pressure can bring heavy rain to Hong Kong, especially between May and September. Persistent heavy rain may cause serious flooding and disastrous landslides

Some extreme rainfall records in HKO Headquarters from 1884 to 2018

Period	Rainfall (mm)	Event
1 hour	145.5	**7 June 2008**
2 hours	190.5	**7 June 2008**
3 hours	243.9	**30 May 1889**
6 hours	430.6	**19 July 1926***
12 hours	526.7	**19 July 1926***
24 hours	697.1	**30 May 1889**

* The 1926 rainstorm is mainly related to landfalling tropical cyclone to the east of HK.



(photos : UK National Archives, CM Shun, GEO)

(References :
The phenomenal rainstorm in 1926 https://www.hko.gov.hk/blog/en/archives/00000135.htm
The great rainstorm of the century in 1889 https://www.hko.gov.hk/blog/en/archives/00000208.htm)

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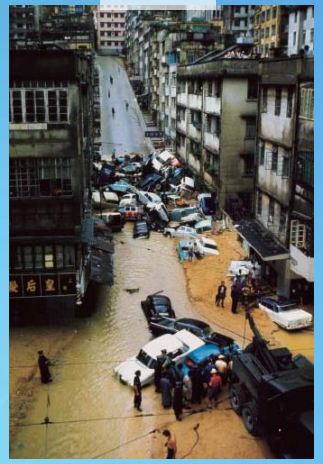
Some notorious rainstorm events in Hong Kong since 1960s

All these rainstorms are related to trough of low pressure in southern China

Event	Total Rainfall at HKO Hq during the period (mm)
11-13 June 1966	494.1
16-18 June 1972	652.3
7-9 May 1992	402.2
19-20 August 2005	546.2
6-7 June 2008	437.9

1966



1972

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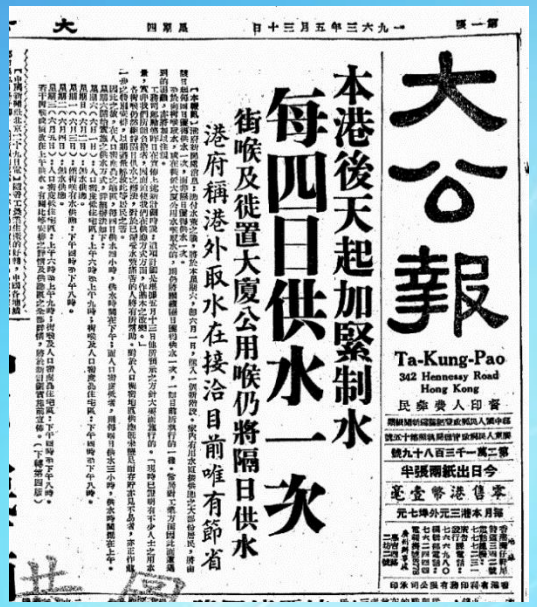
The extreme drought in 1962-1964

The total rainfall in Hong Kong in 1962 was only 1741 mm, well below the normal of about 2214 mm (1961-1990). The situation became even worse in 1963 with a total rainfall of 901 mm, the lowest on record.

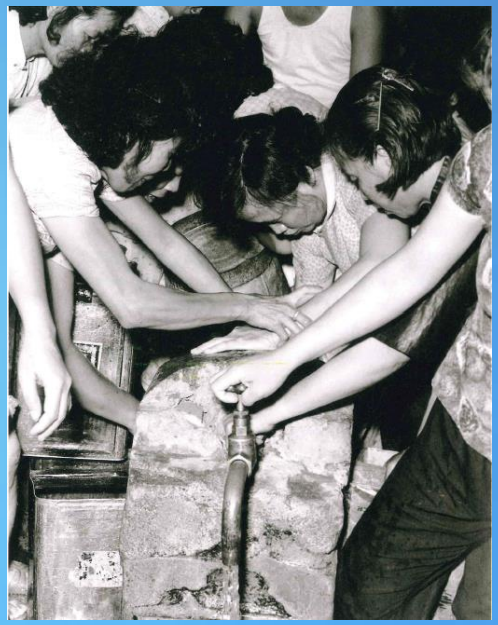


大公報

Ta-Kung-Pao
342 Hennessy Road
Hong Kong

本港後天起加緊制水
每四日供水一次
街喉及徙置大廈公用喉仍將隔日供水
港府稱港外取水在接洽目前唯有節省

Water rationing with water supply once every 4 days



Long queue at a public standpipe, 1963

(Source : GRS, http://www.grs.gov.hk/ws/online/GPM/tc/gallery/water.html)

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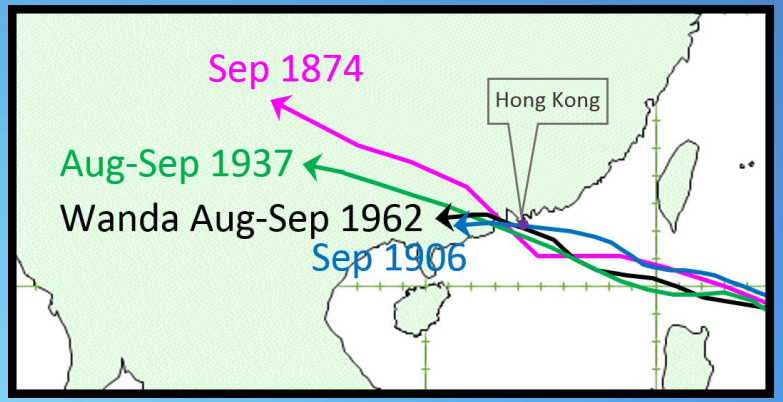
Some notorious historical typhoons in Hong Kong

Storm Surge - main cause of the high casualties/damages of historical typhoons

Tropical cyclone	Deaths in HK	Max storm surge# (m)	Max Sea Level# (mCD)
Sep 1874 (甲戌風災)	> 2000*	2.95+	5.20+
Sep 1906 (丙午風災)	~ 15000*	1.83^	3.35^
Sep 1937 (丁丑風災)	~ 11000*	1.98^	4.05^
Wanda in Sep 1962	183	1.77	3.96
Hato in Aug 2017	0	1.18	3.57
Mangkhut in Sep 2018	0	2.35	3.88



* based on press reports,
# at Victoria Harbour
+ Estimated by numerical model
^ based on tide pole observations, field surveys or reports of local residents. The operation of tide gauge network in Hong Kong commenced in 1952

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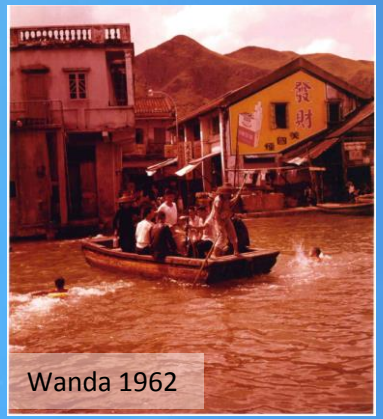

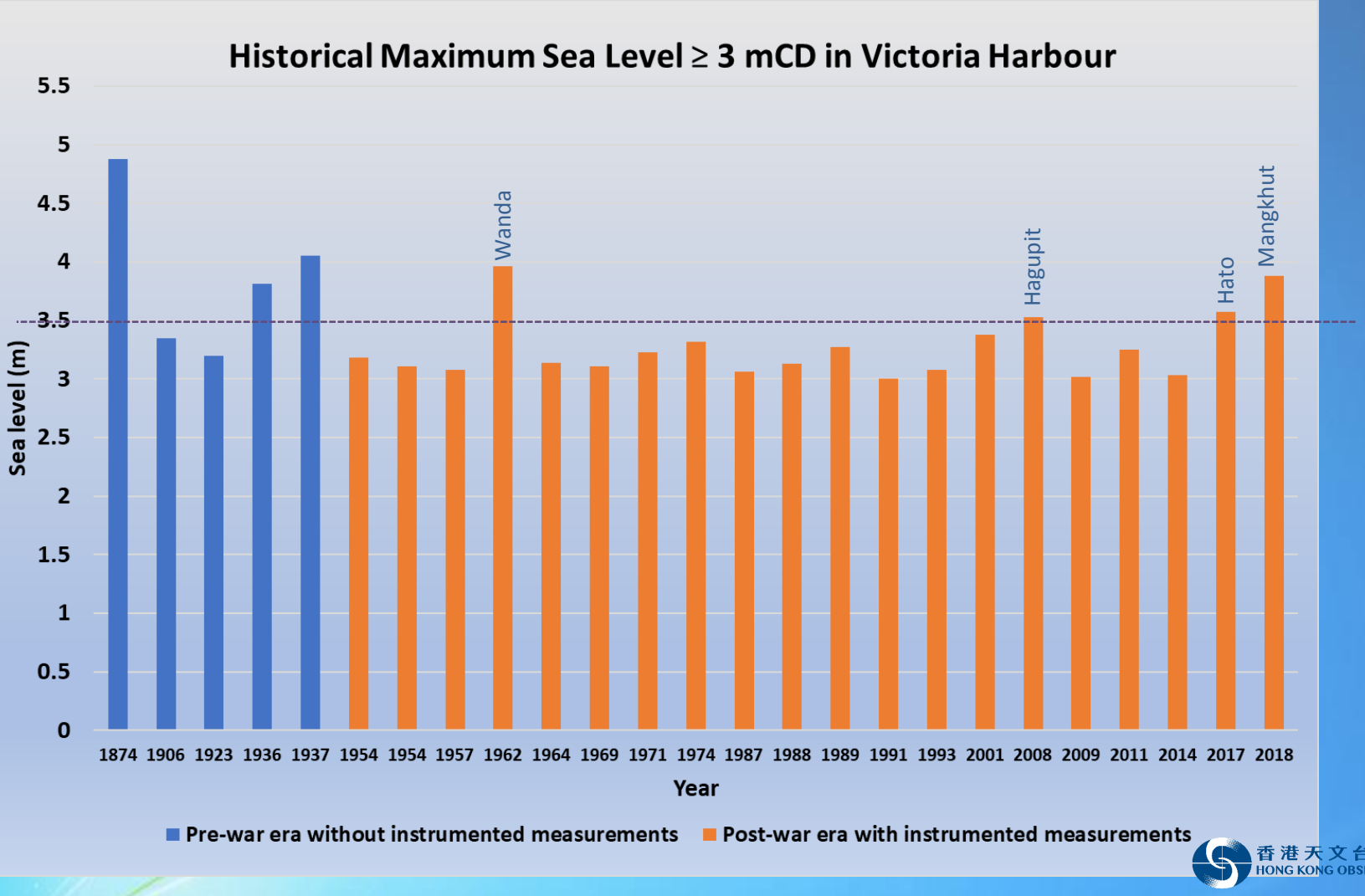

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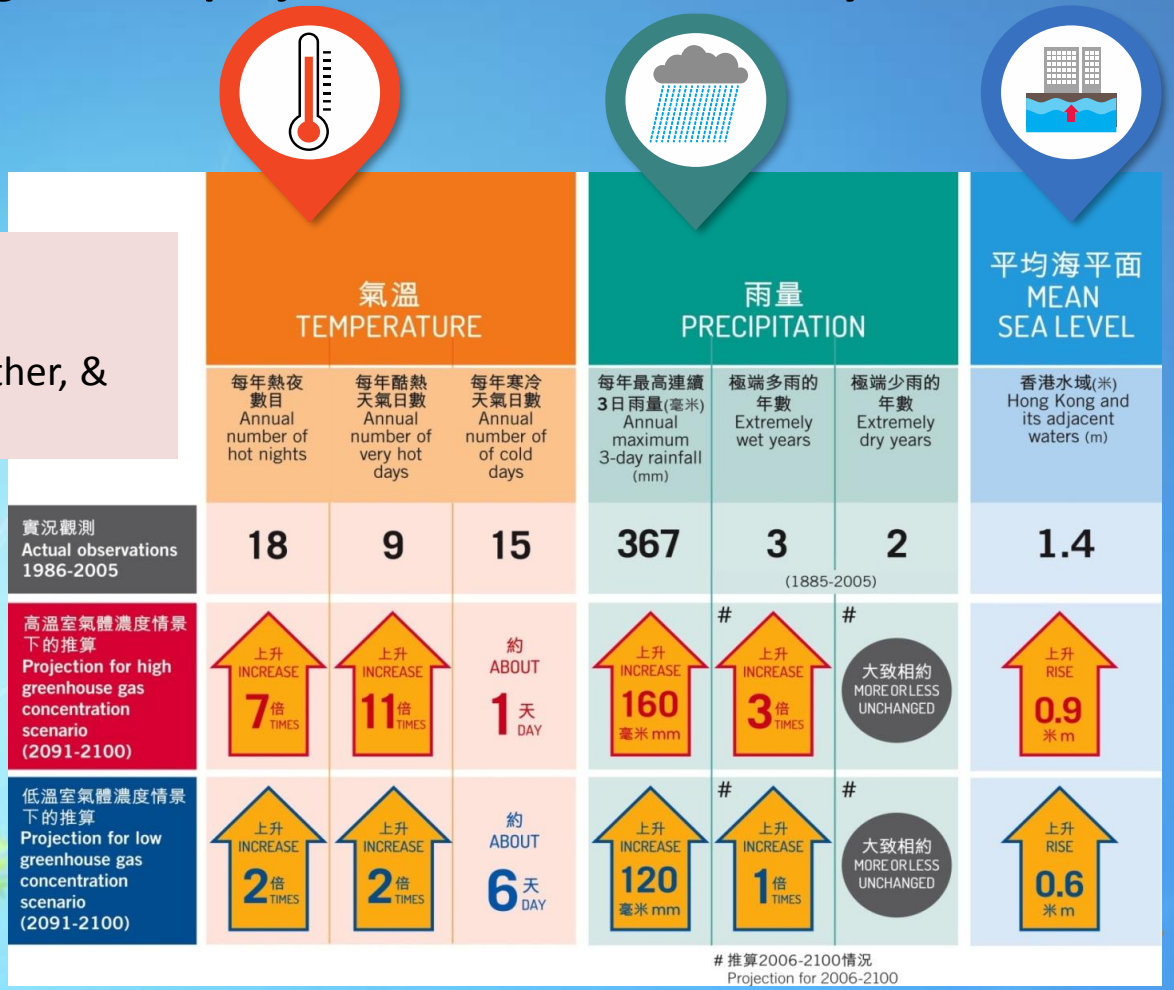
Hong Kong climate projections in the 21st century

Hong Kong climate projections in the 21st century

A warming climate with
- more variable rainfall,
- more frequent extreme weather, &
- rising sea level



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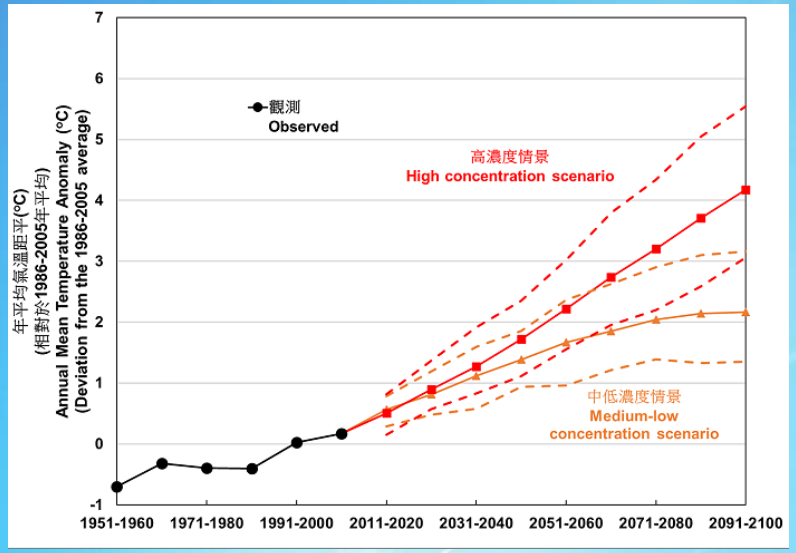
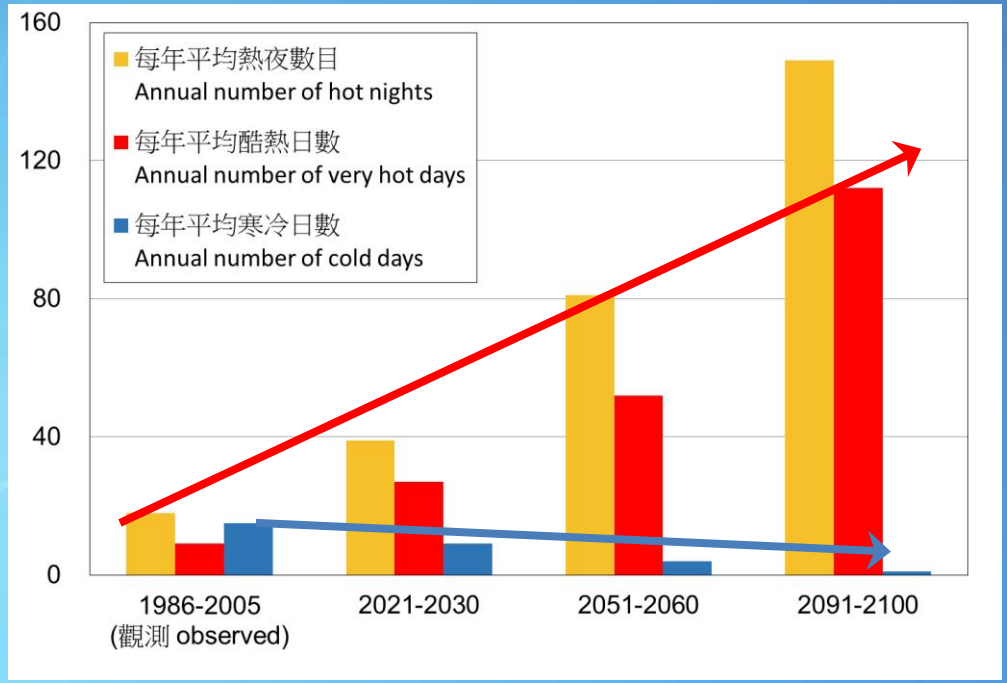
Annual temperature projection in HK

Under the high concentration scenario, the average temperature of Hong Kong will rise by 3-6 °C compared to the average of 1986-2005



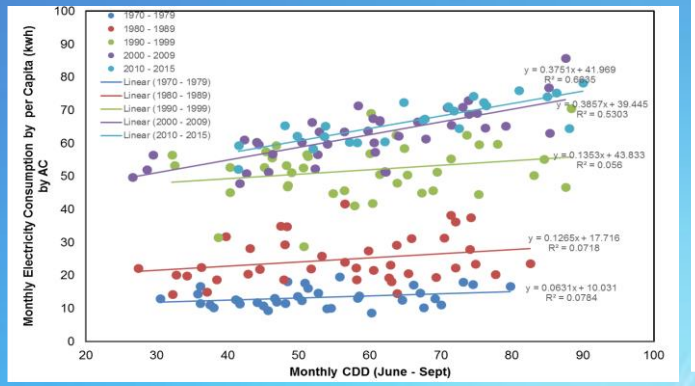
More very hot days, more hot nights, fewer cold days



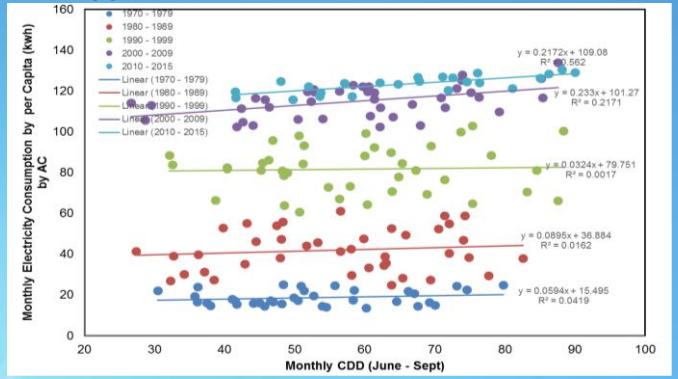
High concentration scenario

Impacts of high temperatures on electricity consumption

(a) Residential



(b) Commercial



(a) Residential

Decades	Slope (kWh/°C)	R	R^2	Significant?
1970–1979	0.06	0.28	0.08	No
1980–1989	0.13	0.27	0.07	No
1990–1999	0.14	0.23	0.06	No
2000–2009	0.39	0.72	0.53	Yes
2010–2015	0.38	0.81	0.66	Yes
1970–2015	0.53	0.36	0.13	Yes

(b) Commercial

Decades	Slope (kWh/°C)	R	R^2	Significant?
1970–1979	0.06	0.2	0.04	No
1980–1989	0.09	0.12	0.02	No
1990–1999	0.03	0.04	0.002	No
2000–2009	0.23	0.47	0.22	Yes
2010–2015	0.22	0.74	0.56	Yes
1970–2015	0.76	0.28	0.08	Yes

(c) Residential + Commercial

Decades	Slope (kWh/°C)	R	R^2	Significant?
1970–1979	0.12	0.24	0.06	No
1980–1989	0.21	0.19	0.04	No
1990–1999	0.17	0.13	0.02	No
2000–2009	0.62	0.65	0.42	Yes
2010–2015	0.59	0.89	0.79	Yes
1970–2015	1.29	0.31	0.1	Yes

(Source: Morakinyo et al., to be published (2019))

- The strength of the relationship between cooling energy consumption and cooling degree days (CDD) increases in recent decades
- **Projected increase of temperature implies an increase in cooling energy consumption**

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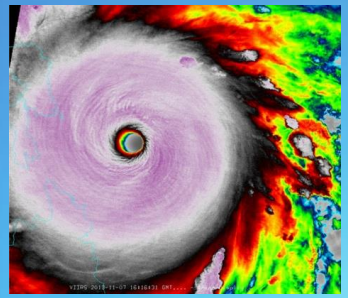
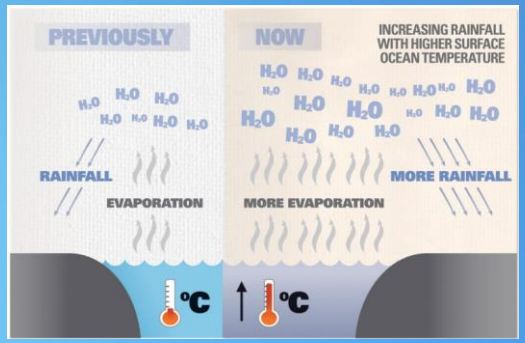
Climate change will fuel the future storms

Climate model projections continue to indicate increases in tropical cyclone (TC) risks in the future



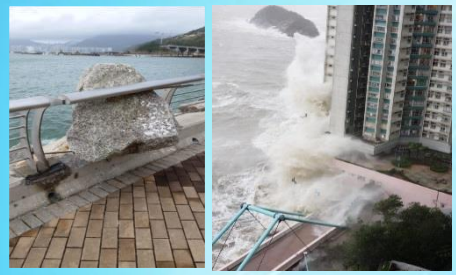
(Photo source: Dan Lindsey, NOAA)

Increase in TC intensity and proportion of very intense TCs



(Photo Source: Climate Commission)

Increase in TC rainfall rates due to a warmer atmosphere holding more water vapor



(Photos by Christina and H C Chan)

Storm surge will be exacerbated by future sea level rise. Plausible increase in TC induced extreme wind waves due to the projected increase in TC intensity may further aggravate the impacts of storm surge and sea level rise on coastal structures

(Ref : IWTC-9, Topic 7.1 https://www.wmo.int/pages/prog/arep/wwrp/tmr/documents/IWTC-9_Subtopic_7-1.pdf)

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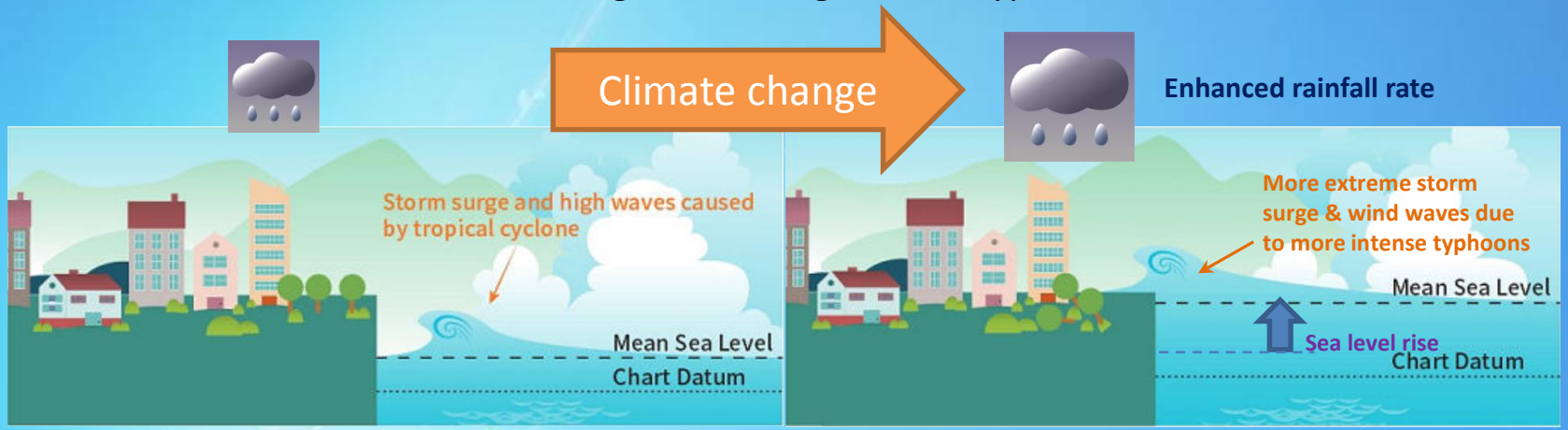
Potential multi-hazard impacts to coastal areas due to more heavy rain and more intense tropical cyclones

Heavy Rain + Storm Surge + Wind Wave + Sea-level Rise

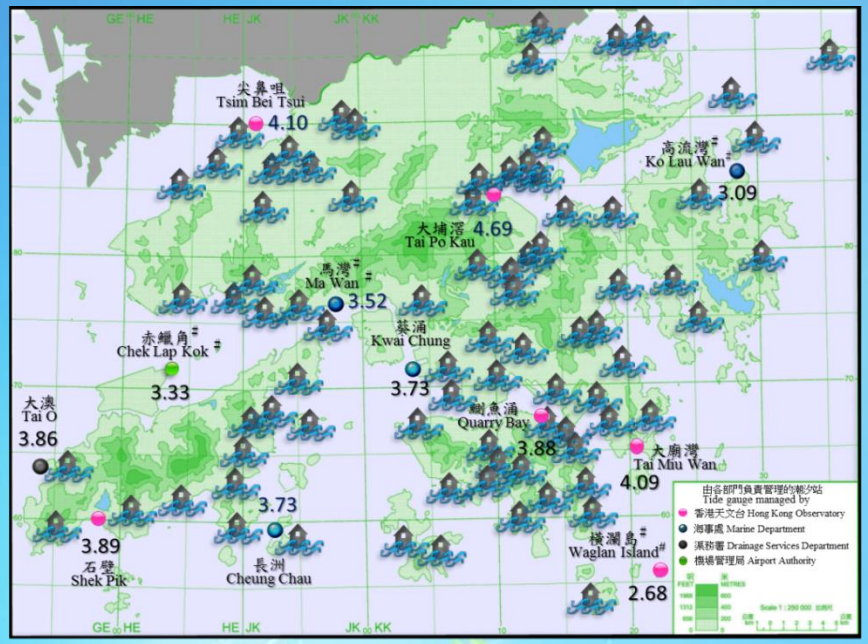
After sea-level rise, storm surges and wind waves can bring more frequent sea flooding to coastal low-lying areas. Rising sea level may also compromise the storm water drainage capacity and increase the chance of "backflow" during extreme high tide or typhoon situations.



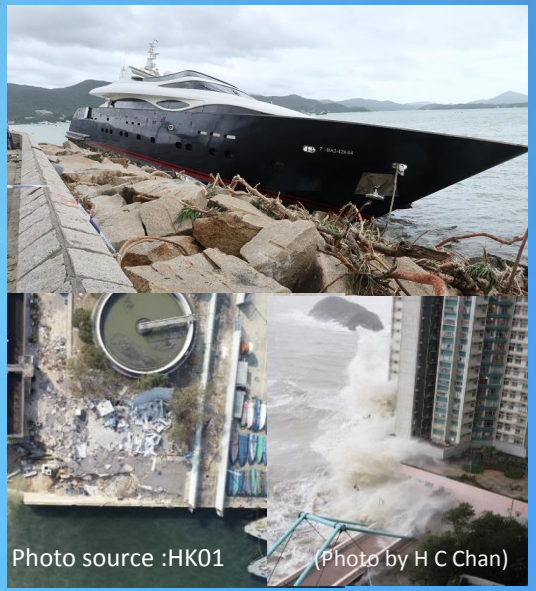
(For illustration purpose only, not to scale)

Example of severe coastal inundation / flooding – Super Typhoon Mangkhut on 16 September 2018

- Storm to hurricane force winds driving extreme wind waves
- Record breaking storm surge in many places (2.35m and 3.38 m at Victoria Harbour and Tolo Harbour respectively)
- Heavy rain (150 – 200 mm rainfall generally over HK)



There were serious flooding in many coastal and low-lying areas, substantial damages of coastal structures and buildings.



The maximum sea level recorded at various tide stations in Hong Kong and flood reports (not exhaustive) from government departments, news and social media during the passage of Mangkhut.

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Public education on climate change and energy saving

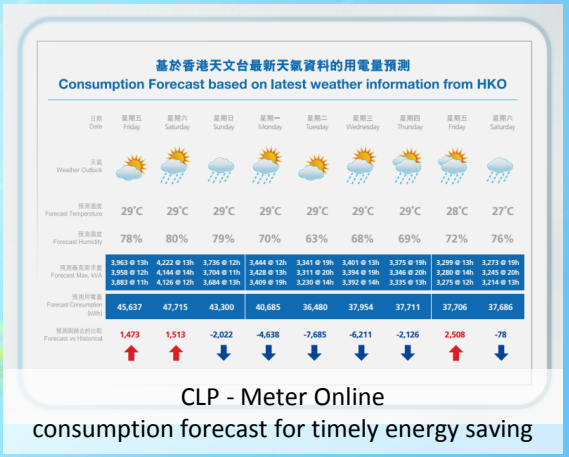
Some examples in collaboration with B/Ds, public utilities, professional bodies and organizations

School talks, Institution of Engineering and Technology (IET) Hong Kong

The "Climate Change - Our Response" exhibition
Science in the Public Service (SIPS)

Climate Change Exhibition on “Vanishing Glaciers”
Jockey Club Museum of Climate Change of the CUHK and Project Pressure (UK)

RTHK programme - The Climate Watcher



CLP - Meter Online
consumption forecast for timely energy saving

With the utility sector to encourage behavioural changes in mitigating climate change

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Public education on climate change and energy saving

Using different channels, (e.g. publications, social media, Open Day, etc.)

HKO-AFCD book on Climate Change and Biodiversity in Hong Kong

HKO-Ho Koon Geography E-learning Package about Climate Change

Climate change pamphlet

2019 HKO Open Day – Talk show on climate change

Facebook and IG posts on climate change and extreme weather

“Cool met stuff『氣象冷知識』” videos

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Concluding remarks

- Learn from the past, extreme weather, such as severe rainstorms and ferocious typhoons, can happen in Hong Kong and result in significant impacts to our society.

- Against the background of climate change, Hong Kong will expect even warmer weather, more variable and extreme rainfall, more frequent extreme weather and a sea level that keeps rising in the coming centuries. Latest research also indicates that tropical cyclone will likely become more intense and carry more rain in the future. The threat of storm surge will also increase due to sea level rise and more intense typhoons.

- To prepare for the future, what is adequate today may not be good enough in the foreseeable future. We need to :

- *make a concerted effort to raise public awareness on climate change and extreme weather*
- *act conscientiously and collectively to mitigate climate change impacts and reduce GHG emission with a view to ensuring Hong Kong's sustainable development, not only now but for the generations to come.*

Thank You !

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