RISKS OF STORM SURGE & EXTREME WAVES IN HONG KONG

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Agenda

● Review of historical storm surge events in HK

● Super Typhoons Hato (2017) and Mangkhut (2018)

● A warming world

● Heightened risks under the effects of climate change

● Concluding remarks
REVIEW OF HISTORICAL STORM SURGE EVENTS IN HK
What is Storm Surge?

- Storm surge is a raised sea brought by tropical cyclones.
- Winds of a tropical cyclone are the main culprit for rise in sea level, while its low pressure contributes to a lesser extent.
- Damage will be more significant if arrival of the surge coincides with spring tide or astronomical high tide of the day.
The geography of Hong Kong suggests that it is vulnerable to storm surges when winds come from the east or south.

This could be visualized if we bear in mind that a tropical cyclone's winds blow in a counter-clockwise direction.

Some Facts about Storm Surge in HK

Sever Typhoon Mangkhut approaching HK in September 2018
Deadliest Typhoons in Hong Kong History

<table>
<thead>
<tr>
<th>Tropical cyclone</th>
<th>Number of deaths in Hong Kong</th>
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<tbody>
<tr>
<td>Typhoon in September 1874</td>
<td>&gt; 2000*</td>
</tr>
<tr>
<td>Typhoon in September 1906</td>
<td>~ 15000*</td>
</tr>
<tr>
<td>Typhoon in September 1937</td>
<td>~ 11000*</td>
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<tr>
<td>Super Typhoon Wanda 1962</td>
<td>183</td>
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Storm surge is likely one of the main causes of high casualties in the 1874, 1906, 1937 and 1962 (Wanda) events.
Common Characteristics of Deadliest Typhoons

- Winds on the right semicircle are usually stronger than those on the left semicircle – the “dangerous semicircle”

High waves hitting breakwaters. Credit: Kyodo via AP
Ferocious strike of Super Typhoon Hato (2017) and Mangkhut (2018)
A timely reminder of the proximity of extreme weather

Widespread damage by destructive winds and severe storm surge
Hato - Super typhoon (closest approach 60 km WSW) with a very compact core

Mangkhut – Severe typhoon (closest approach 100 km SSW), but with extensive circulation
Flood reports during the passage of Hato

Flood reports during the passage of Mangkhut
SUPER TYPHOON MANGKHUT
SEPTEMBER 2018

• **Most intense TC in 2018** hitting the south China coast

• **Highest tropical cyclone warning signal**, No. 10 in Hong Kong lasting for 10 hours

• Brought **record-high storm surge** of 2-3 m & **extreme wind waves** to HK, causing serious flooding in low-lying coastal areas and damages to coastal structures

• Ferocious winds **blew down trees** (60 000+) and **shattering windows & glass walls**
Reports of power interruption & water supply gathered from news and social media during passage of Mangkhut
Impact - trees
Impact - buildings
Impact - others
Impacts – Storm surge
Impacts – overtopping waves
Wave Simulation for Mangkhut (2018) using Nearshore Wave Model

Locations of Tide gauge stations and wave recorders (CEDD)
Observed Track of Mangkhut
Worse Scenario: Mangkhut not crossing Luzon + storm surge coincides with high tide of the day

Victoria Harbour
- Sea level over 5 m!
- 3.88 mCD observed

Tolo Harbour
- Sea level over 7 m!
- 4.71 mCD observed
Inundation in Tai Po Old Market

Tai Po
Reference Tide station : TPK 4.71mCD
FLOOD EXTENT / DEPTH MAP BASED ON SEA LEVEL

Observed track of Mangkhut

Forecast track of Mangkhut a few days earlier
A WARMING WORLD
"We live with the highest concentration of CO$_2$ in the atmosphere for 3 million years"

"The four warmest years on record have been in the past four years (2015-2018)"

Prof. Petteri Taalas, Secretary-General of WMO @ the 2019 Global Platform for Disaster Risk Reduction in May 2019
• Highest seasonal peak recorded in 61 years of observations on top of Hawaii's largest volcano surpassing 414 ppm in May 2019

Temperature across the globe the 3rd highest for Jan–May in the 140-year record
Ongoing Heatwave in Europe

https://severe.worldweather.wmo.int/v2/
Climate Change @ Hong Kong

- More very hot days
- Less cold days
- More extreme rainfall
- Rising sea level
HEIGHTENED RISKS UNDER THE EFFECTS OF CLIMATE CHANGE
RISING SEA LEVEL

- ACCORDING TO IPCC AR5, GLOBAL MEAN SEA LEVEL ROSE AT 1.7 MM/YEAR DURING 1901-2010
- IN HK, MEAN SEA LEVEL HAS BEEN RISING AT 3.1 MM/YEAR SINCE 1954
Projection of Mean Sea Level Rise under climate change for Hong Kong

Mean sea level in Hong Kong and adjacent waters expected to rise by \(~1\) m towards the end of century (high greenhouse gas concentration scenario)
SEA LEVEL RISE PROJECTIONS (2100-2500)

- Sea level will continue to rise well beyond 2100, though the magnitude & rate depends on future emission pathways.

- Marine ice sheet instability in Antarctica and/or irreversible loss of the Greenland ice sheet could result in multi-metre rise in sea level over hundreds to thousands of years.

Source: IPCC AR5
Climate Change Fuels the Future Storms

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

- Increase in TC intensity and proportion of very intense TCs due to warmer ocean
- Increase in TC rainfall rates due to a warmer atmosphere holding more water vapor
- 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.

(Photos by Christina and H C Chan)

HEAVY RAIN + STORM SURGE + WIND WAVES + SEA LEVEL RISE

With rising sea level, storm surges and wind waves can bring more frequent sea flooding to coastal low-lying areas. It may also compromise storm water drainage capacity and increase the chance of “backwater” during extreme high tide or typhoon situations.
Global warming of about 3.2°C by 2100 based on emission reduction pledges under Paris Agreement.

Emission reduction pledges have to increase fivefold in order to contain temperature rise within 1.5°C.

2017: 53.5 GtCO₂

Source: UNEP Emissions Gap Report 2018
Concluding Remarks

- Learning from the past, devastating typhoons did happen in HK and resulted in significant impacts to our society.

- Climate change is expected to alter climatic extremes. Hong Kong will expect a sea level that keeps rising in coming centuries. Tropical cyclones will likely become more intense and carry more rain. Just a matter of time for another typhoon to batter HK in a way more destructive than Mangkhut did.

- What is adequate today may not be good enough in the foreseeable future. We should not be complacent but take aggressive steps to mitigate the effects of climate change and ensure Hong Kong’s safe and sustainable development, not only for now but for the generations to come.

- Resilience should be central to infrastructure design and operation in future, allowing systems to resume operation quickly after extreme weather events. Formulation of effective emergency preparedness measures should also be required.
Thank You!
HKO @ CLIMATE READY

• MITIGATION – PUBLIC EDUCATION AND OUTREACH ACTIVITIES

• ADAPTATION – CLIMATE PROJECTION AND INFORMATION SERVICES FOR STAKEHOLDERS

• RESILIENCE – FORECAST AND WARNING OF EXTREME WEATHER; PROMOTE PUBLIC AWARENESS OF DISASTER PREVENTION
Tropical Cyclone Metrics

I. All TC frequency
II. Cat 4-5 frequency
III. Lifetime Max Intensity
IV. Precipitation rate

Figure 14.17 | General consensus assessment of the numerical experiments described in Supplementary Material Tables 14.SM.1 to 14.SM.4. All values represent expected percent change in the average over period 2081–2100 relative to 2000–2019, under an A1B-like scenario, based on expert judgement after subjective normalization of the model projections. Four metrics were considered: the percent change in (I) the total annual frequency of tropical storms, (II) the annual frequency of Category 4 and 5 storms, (III) the mean Lifetime Maximum Intensity (LMI; the maximum intensity achieved during a storm’s lifetime) and (IV) the precipitation rate within 200 km of storm centre at the time of LMI. For each metric plotted, the solid blue line is the best guess of the expected percent change, and the coloured bar provides the 67% (likely) confidence interval for this value (note that this interval ranges across −100% to +200% for the annual frequency of Category 4 and 5 storms in the North Atlantic). Where a metric is not plotted, there are insufficient data (denoted ‘Insf. d.’) available to complete an assessment. A randomly drawn (and coloured) selection of historical storm tracks are underlain to identify regions of tropical cyclone activity.
Historical Maximum Sea Level ≥ 3 mCD in Victoria Harbour

Year


Sea level (m)

0 0.5 1 1.5 2 2.5 3 3.5 4 4.5 5 5.5

Pre-war era without instrumented measurements  Post-war era with instrumented measurements

1874: Mangkhut
1937: Hato
1954: Wanda
1969: Hagupit
1991: Hato
1974: Mangkhut
1906: Hato
1923: Wanda
1936: Hato
1957: Mangkhut
1962: Hato
1969: Wanda
1971: Hato
1987: Wanda
1989: Hato
2001: Wanda
2008: Hato
2009: Wanda
2011: Hato
2014: Wanda
2017: Hato
2018: Wanda
Flood-Prone Locations for Storm Surge Alerts
Impact analysis

Reports of interruption of power and water supply (not exhaustive) from news and social media during the passage of Mangkhut on 16 September 2018.

Display of hydrological information (red/blue colour refers to water level above/below alert thresholds), fallen tree (🪦), landslide (🪤) and flood (🌊) reports (not exhaustive) in Hong Kong during the passage of Mangkhut on 16 September 2018.
Storm damage information from crowdsourcing

Crowdsourcing through
• Facebook
• MyObservatory app (upcoming)

Interactive Map of Storm Damage by Mangkhut
Opportunities - Public Education

Educational videos with multi-hazards of typhoon (storm surge, heavy rain, high winds and waves) had been posted on HKO FB before the passage of typhoons so as to remind the public on the potential threats from typhoon.
Carrying Important Messages in MyObservatory App

- GENERATE AUTOMATIC PUSH NOTIFICATIONS TO SHARE EMERGENCY NOTICE FROM SECURITY BUREAU FOR WIDER CIRCULATION (AROUND 7.8 MILLION DOWNLOADS)