香港天文台
HONG KONG OBSERVATORY

Building a Resilient, Healthy and Safe Community: Big Data Applications

CHENG Cho-ming
Director of the Hong Kong Observatory

Why a need for resilient, healthy and safe Community?

- Every community is prone to the adverse impacts from disasters
- One major risk comes from climate change
- Climate change is gradual, but its impacts can be sudden and disastrous
- Disaster risk reduction (DRR) is a major contribution to building a resilient, healthy and safe community

Mission of the Hong Kong Observatory

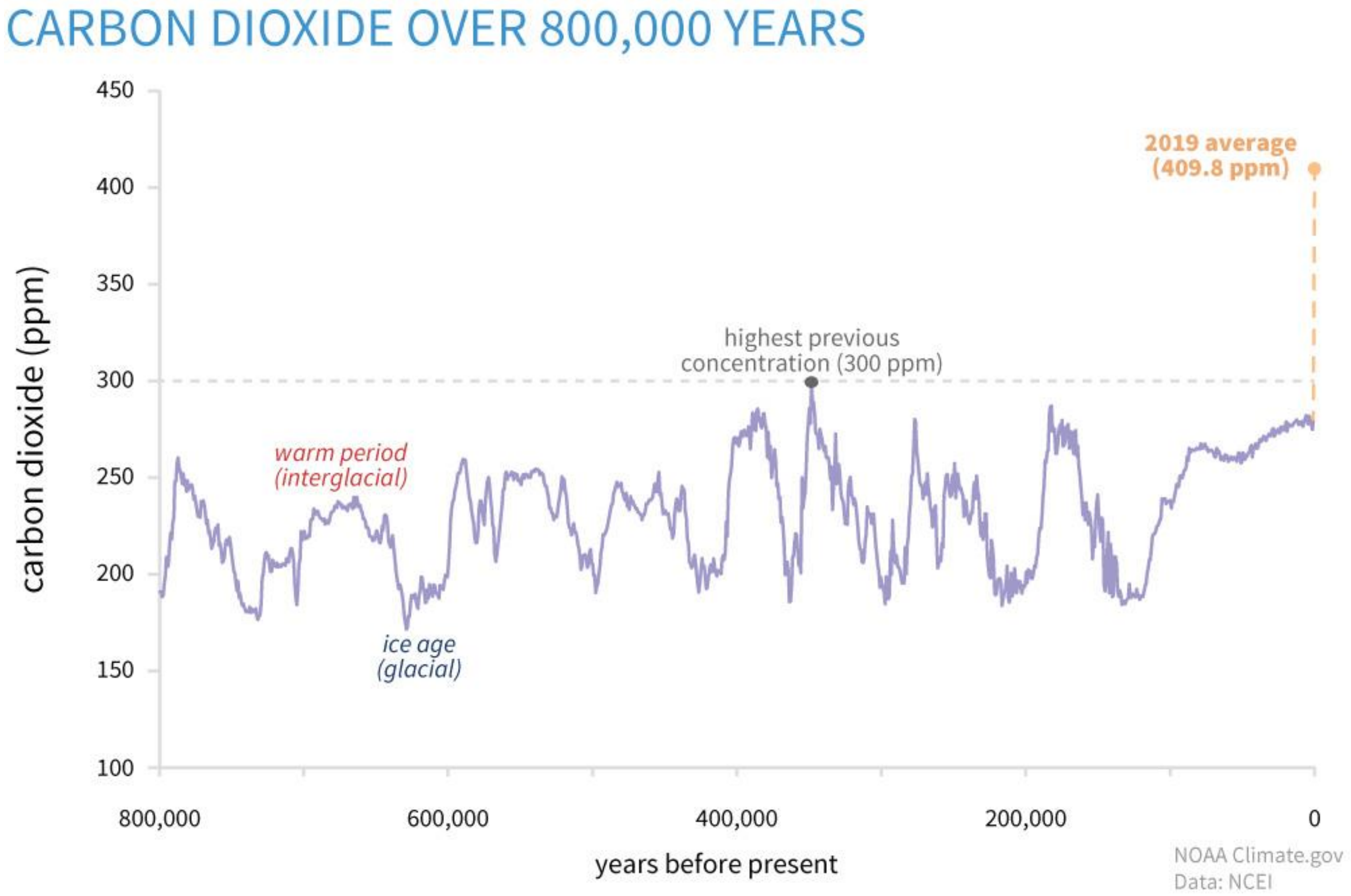
Vision

Be a model of excellence
in protecting lives and building together a better society
through science.

Mission

To provide people-oriented quality services in meteorology and related fields,
and to enhance the society's capability in natural disaster prevention and response,
through science, innovation and partnership.

Climate change – caused by release of greenhouse gases



Climate change – warming up of the Earth

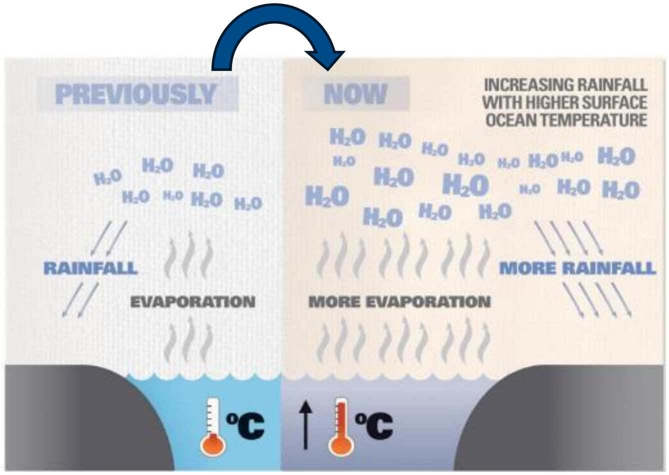
Global average temperatures in 1850-2019 compared to pre-industrial level

1.1-1.2°C

Top 6 hottest years (not yet include 2020) = 2014-2019

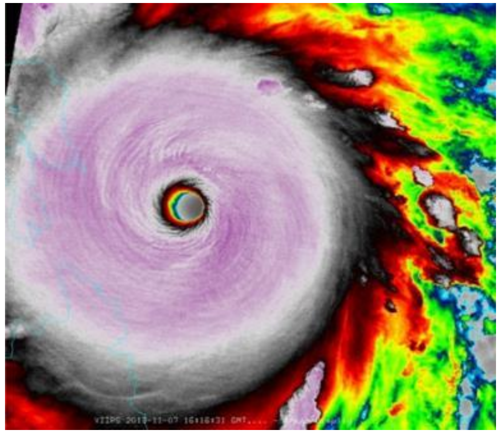
Climate change – Stronger storms

Rise in sea temperature causes more rainfall



(Climate Commission)

Higher proportion of stronger tropical cyclones

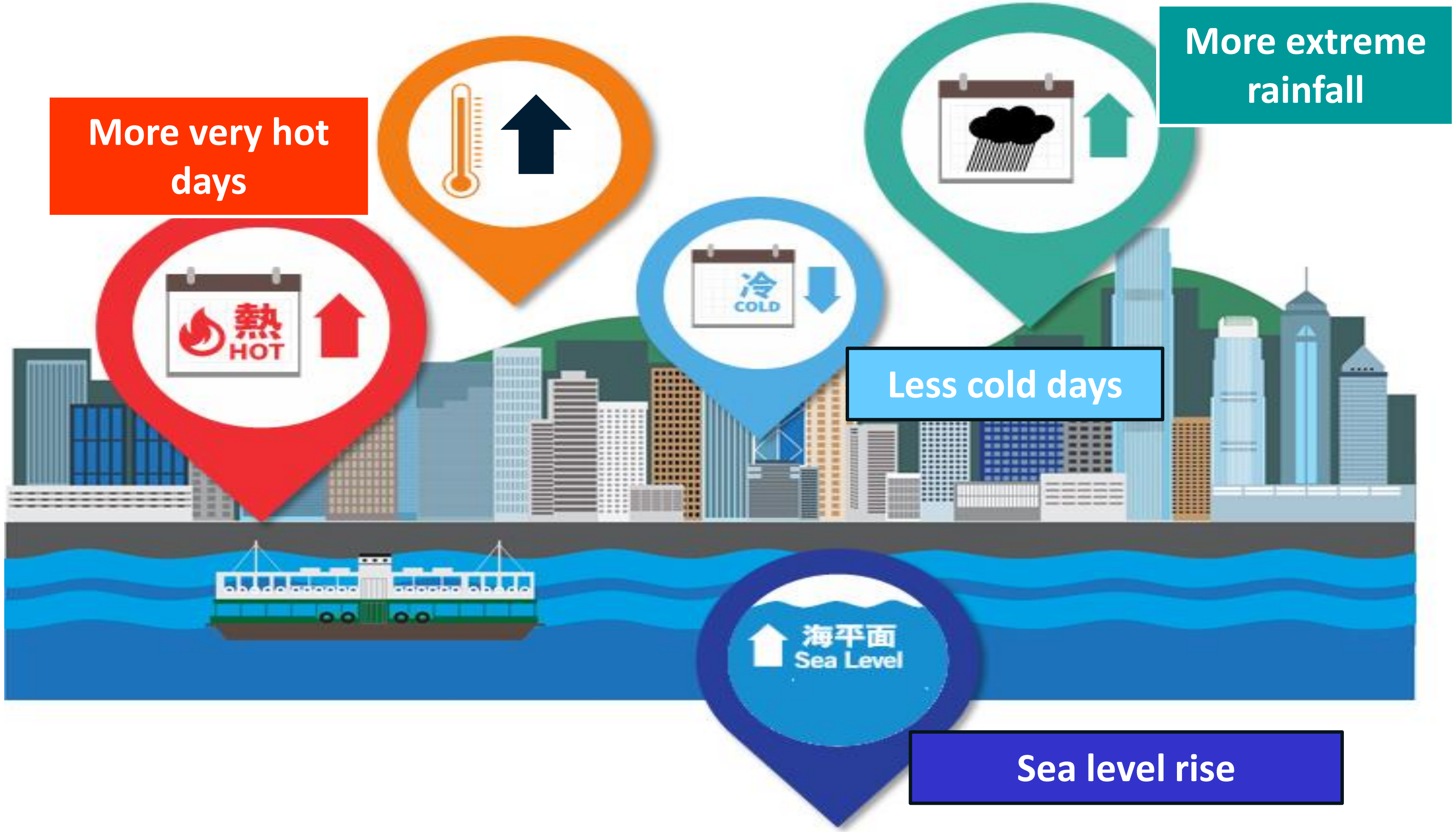


(Dan Lindsey, NOAA)

Sea level rise + Stronger storms + Storm surge = higher impacts to coastal regions

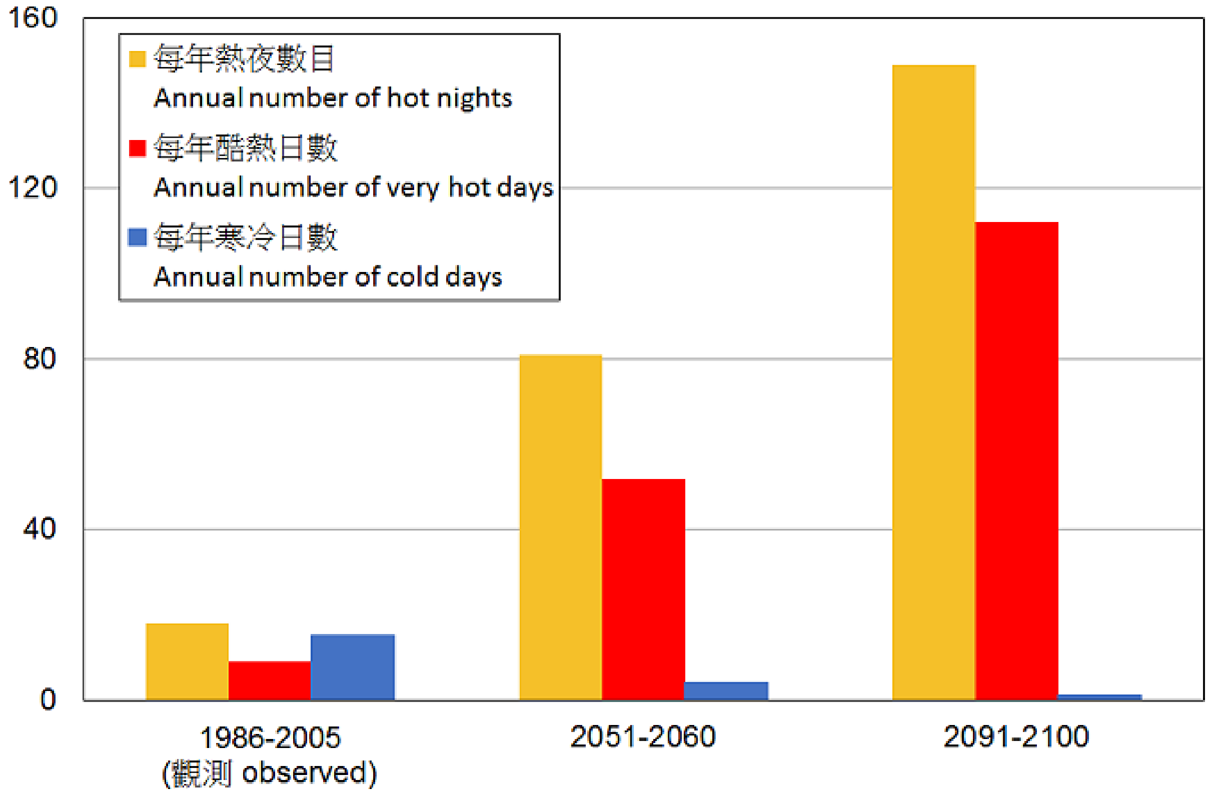
(Christina and H C Chan)

Climate change @ Hong Kong

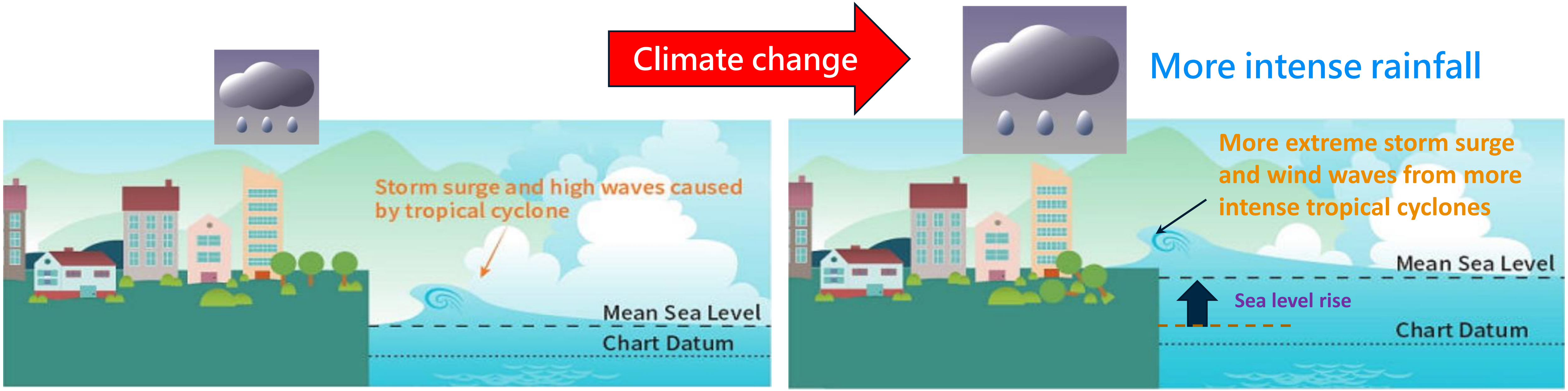


Climate change – Impacts to Hong Kong

- Hot night *(Daily minimum temperature>=28°C)*
  - 1986-2005: averaged 18 days/year
  - End of 21st century: 149 days/year
- Very Hot Day (Daily maximum temperature>=33°C)
  - 1986-2005: averaged 9 days/year
  - End of 21st century : 112 days/year
- Cold Day *(Daily minimum temperature <=12°C)*
  - 1986-2005: averaged 15 days/year
  - End of 21st century : 1 day/year

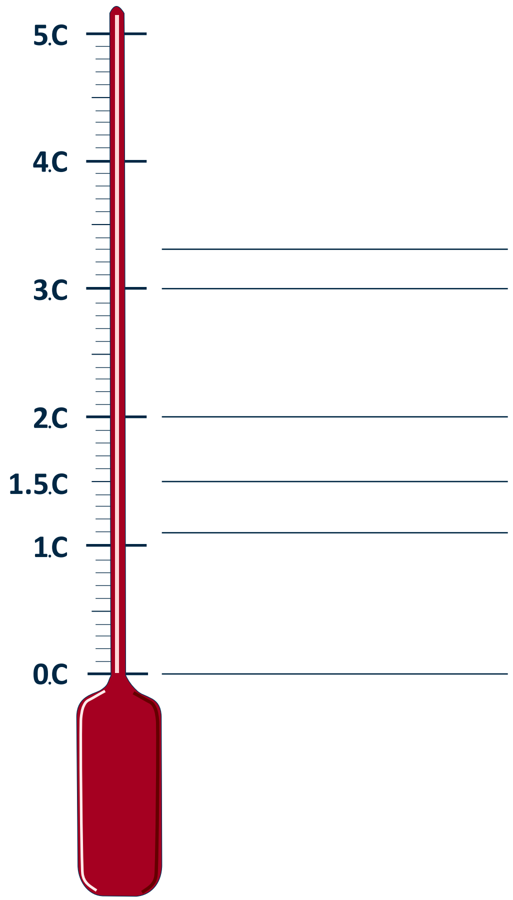


Climate change – storm surge



Climate change – Stronger storms – Greater impacts

Global actions – Paris Agreement & where are we?



If emissions continue along current trend

If countries fulfill their voluntary pledges

2.0C : Upper limit set by Paris Agreement

1.5C : Paris Agreement goal

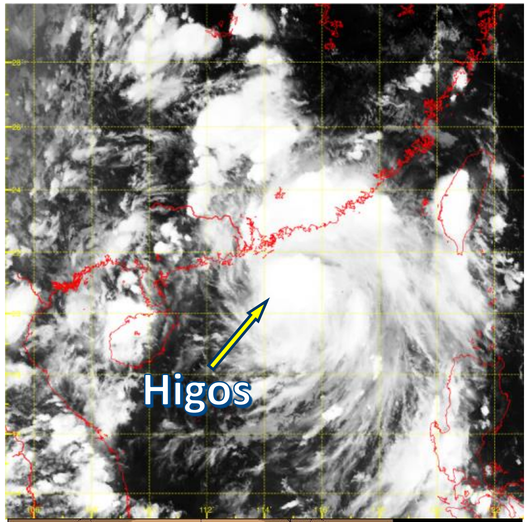
Level in 2019

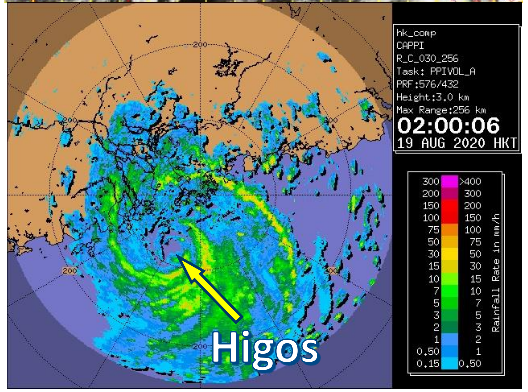
0C: Pre-industrial level

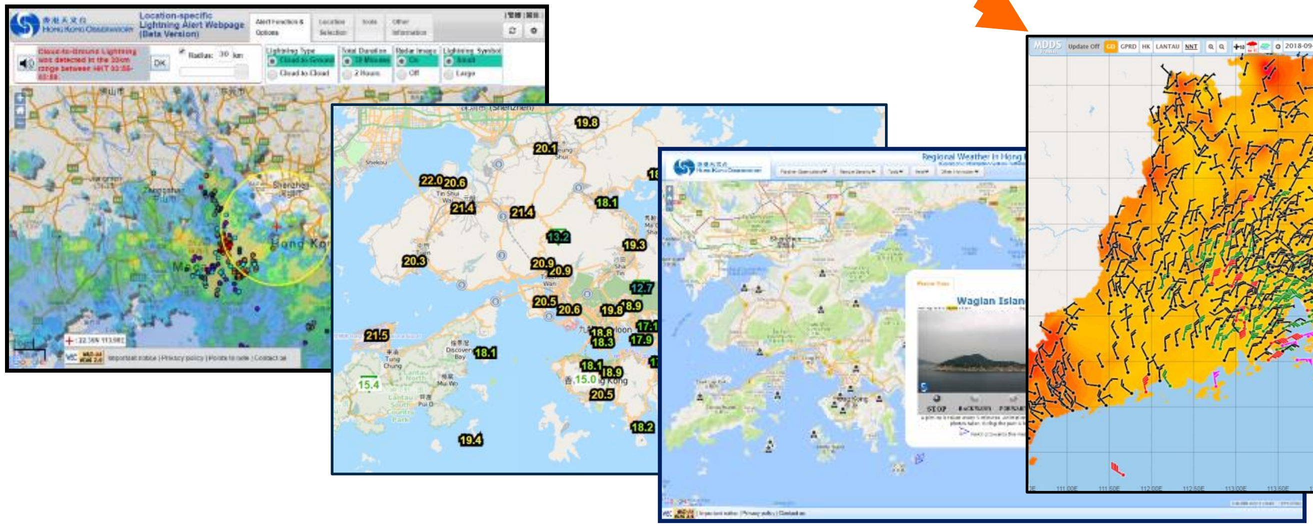
Global Actions – UN Sustainable Development Goals (SDG)

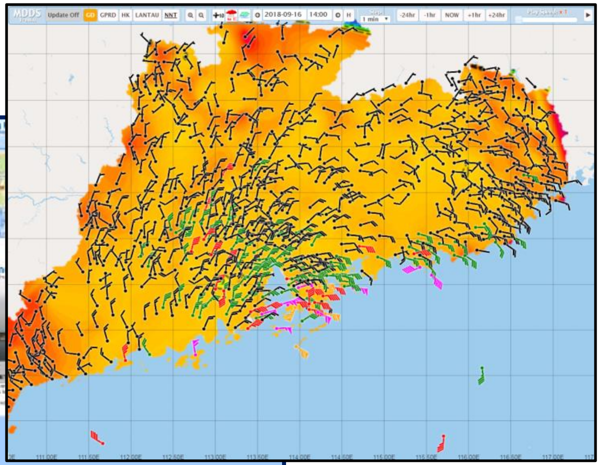
Big data era


Polar-orbiting Meteorological Satellite
極軌氣象衛星
Geostationary Meteorological Satellite
地球同步氣象衛星
Radiosonde
無線電探空儀
Weather Radar
天氣雷達
Voluntary Observing Ship 志願觀測船
Aircraft
Meteorological Observing Station
地面觀測站


Higos


hk_comp
CAPPI
R_C_030_256
Task: PPIVOL_A
PRF:576/432
Height:3.0 km
Max Range:256 km
02:00:06
19 AUG 2020 HKT
Higos

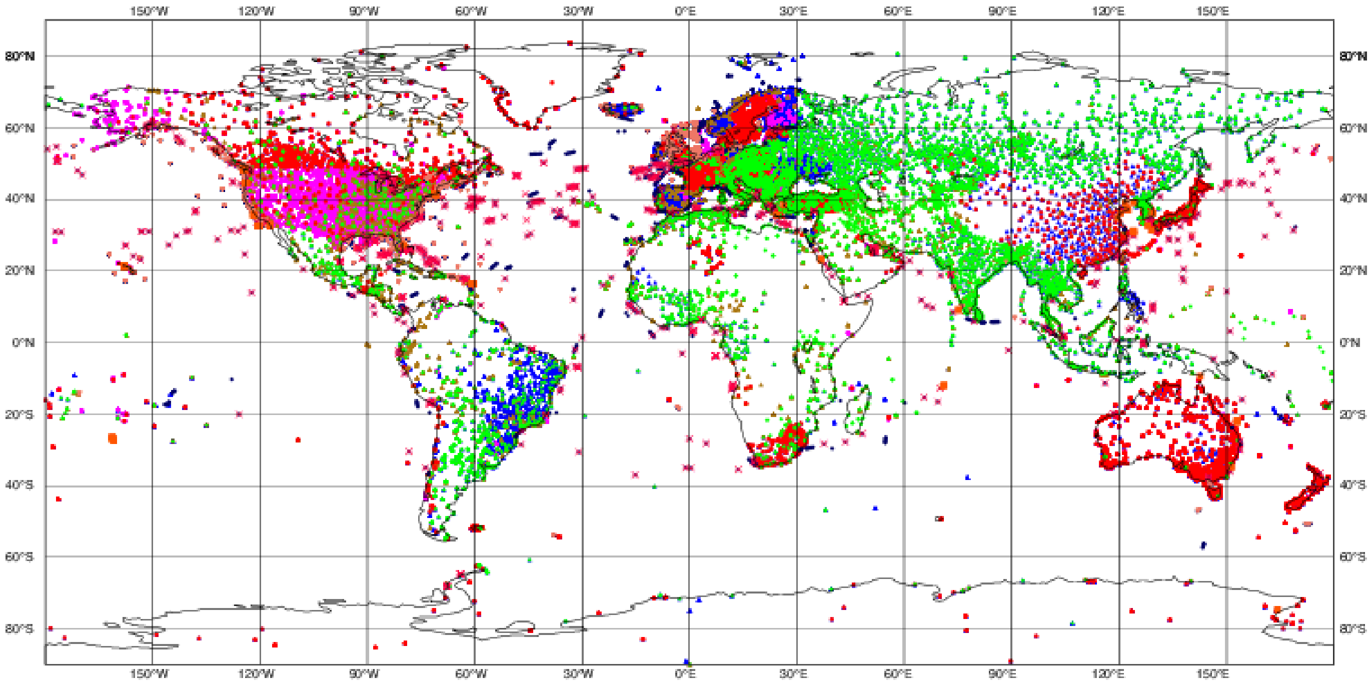

Location-specific Lightning Alert Webpage (Beta Version)
Waglan Island



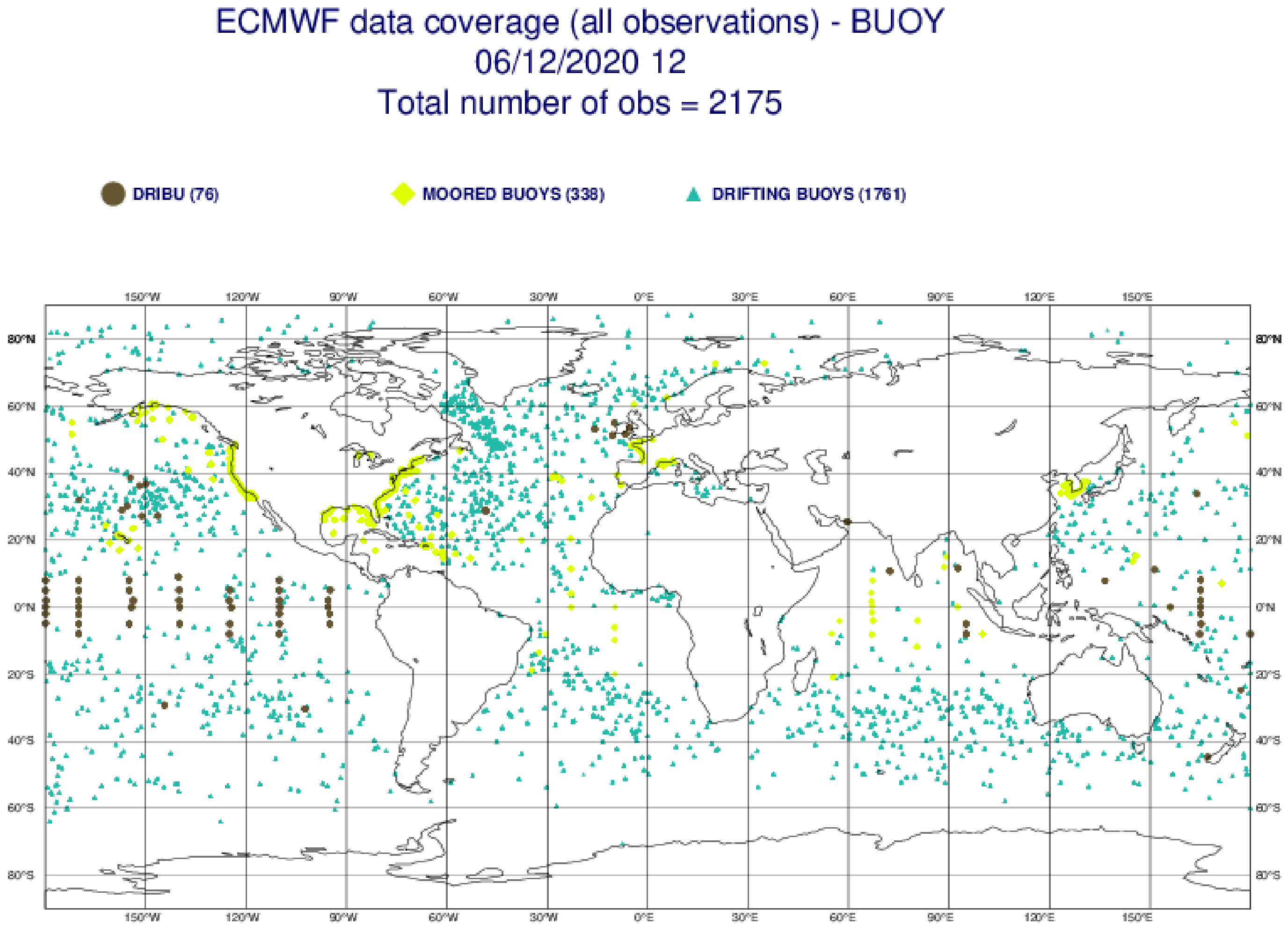
Big data – global data

ECMWF data coverage (all observations) - SYNOP-SHIP-METAR
06/12/2020 12
Total number of obs = 124282

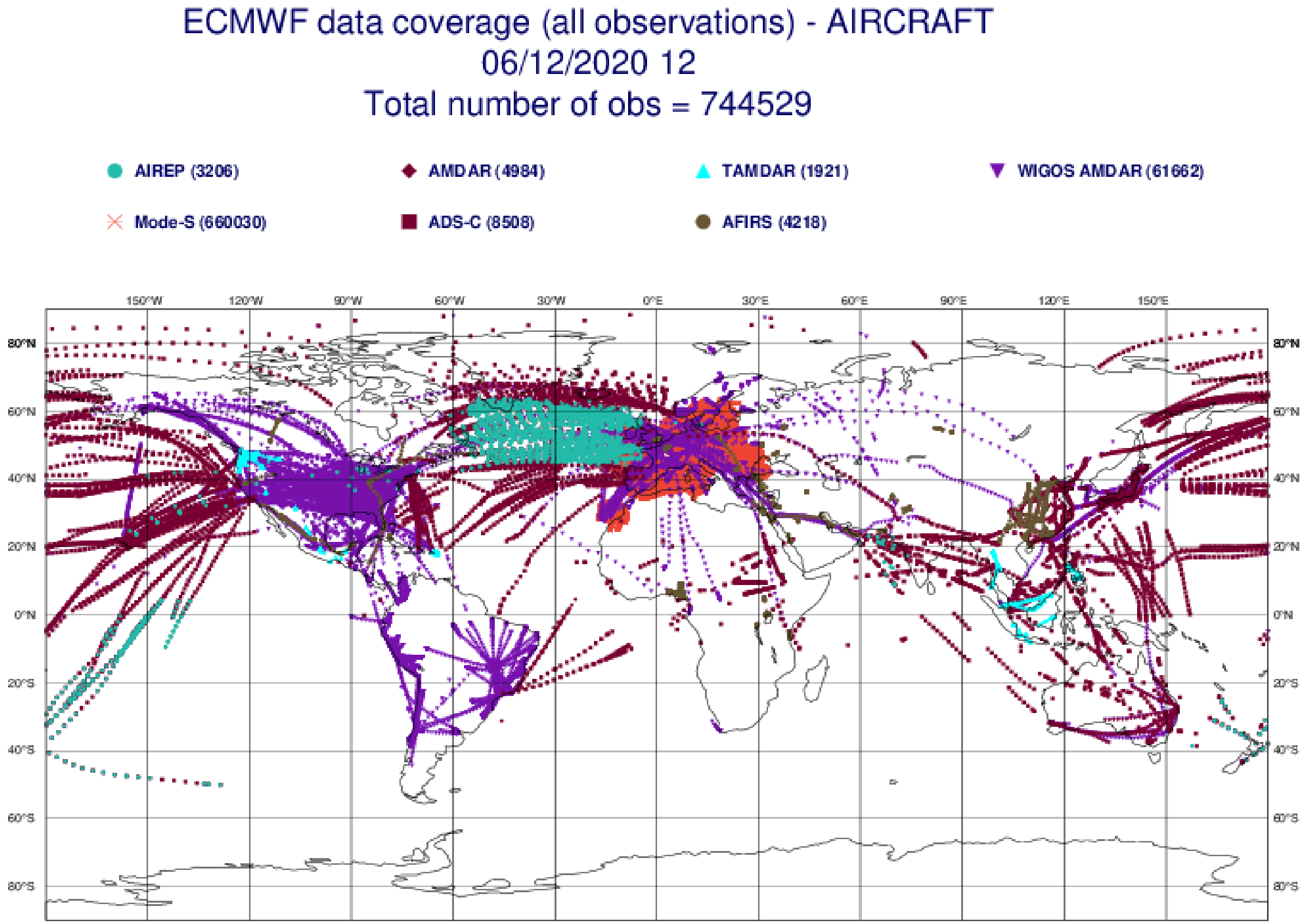
- Automatic Land SYNOP (13594)
- Manual Land SYNOP (9479)
- METAR (19584)
- Automatic SHIP (3003)
- SHIP (774)
- Abbreviated SHIP (105)
- Automatic METAR (35458)
- BUFR SHIP SYNOP (4721)
- BUFR LAND SYNOP (37564)



Big data – global data



Big data – global data



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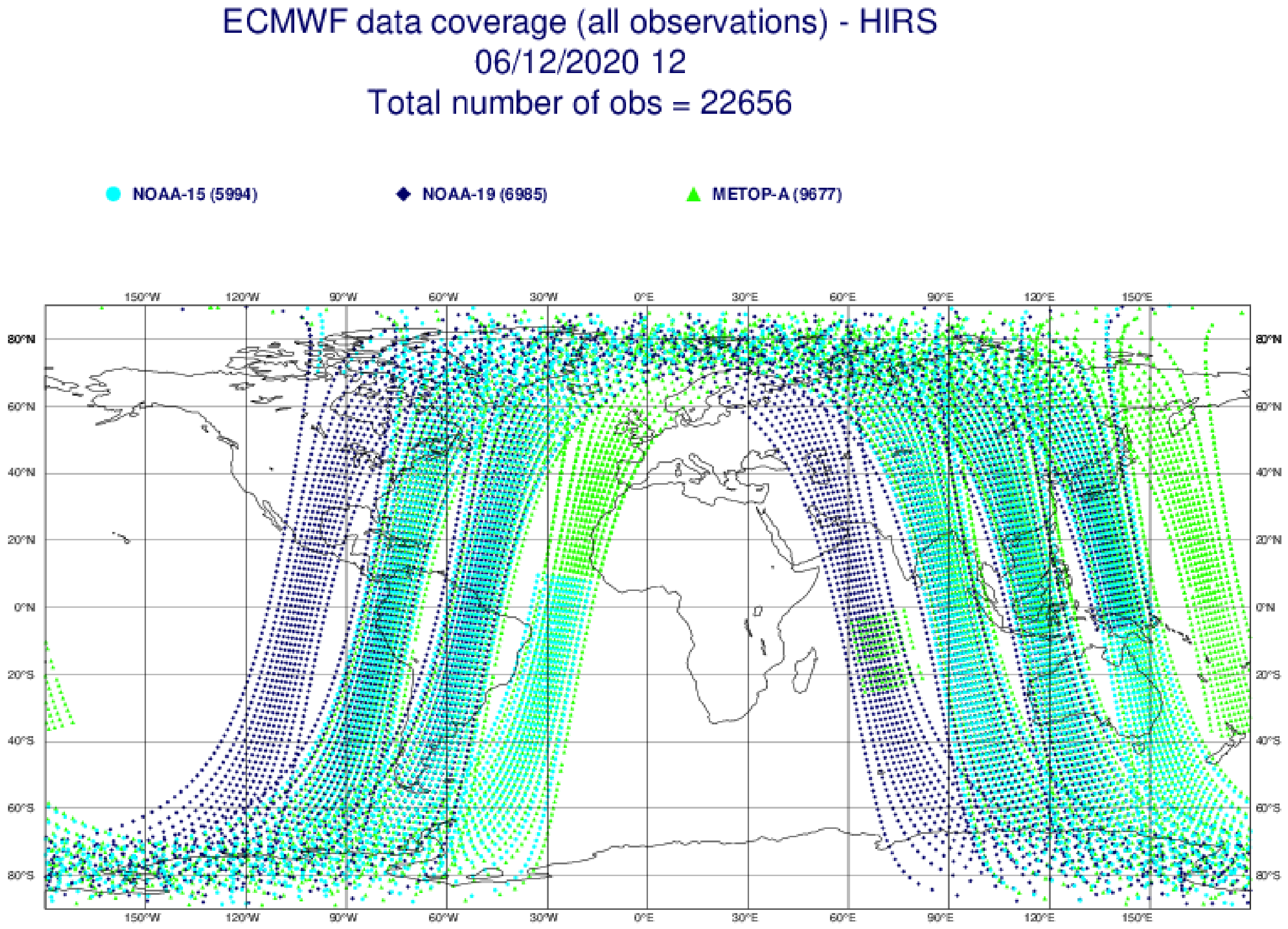
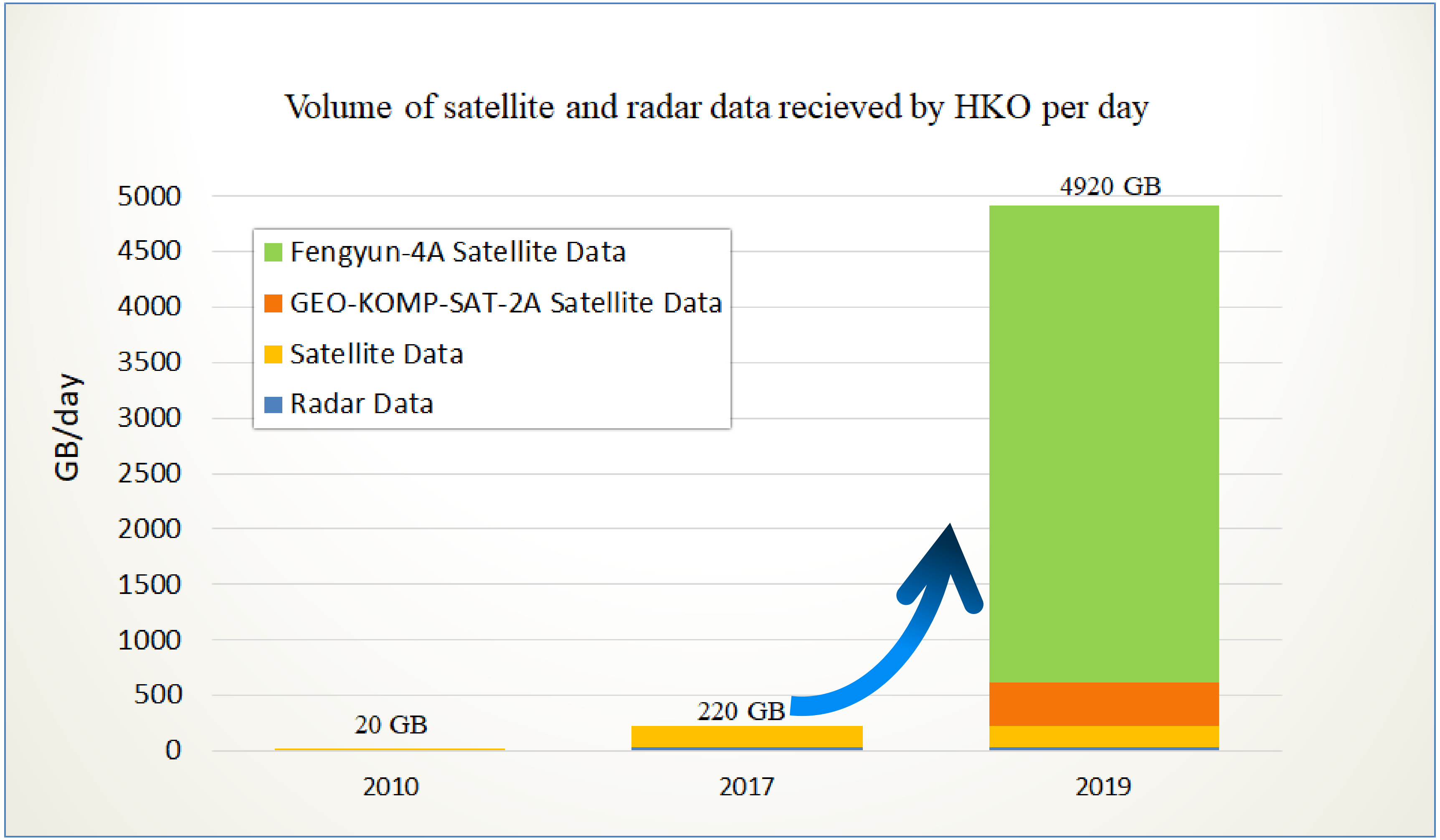
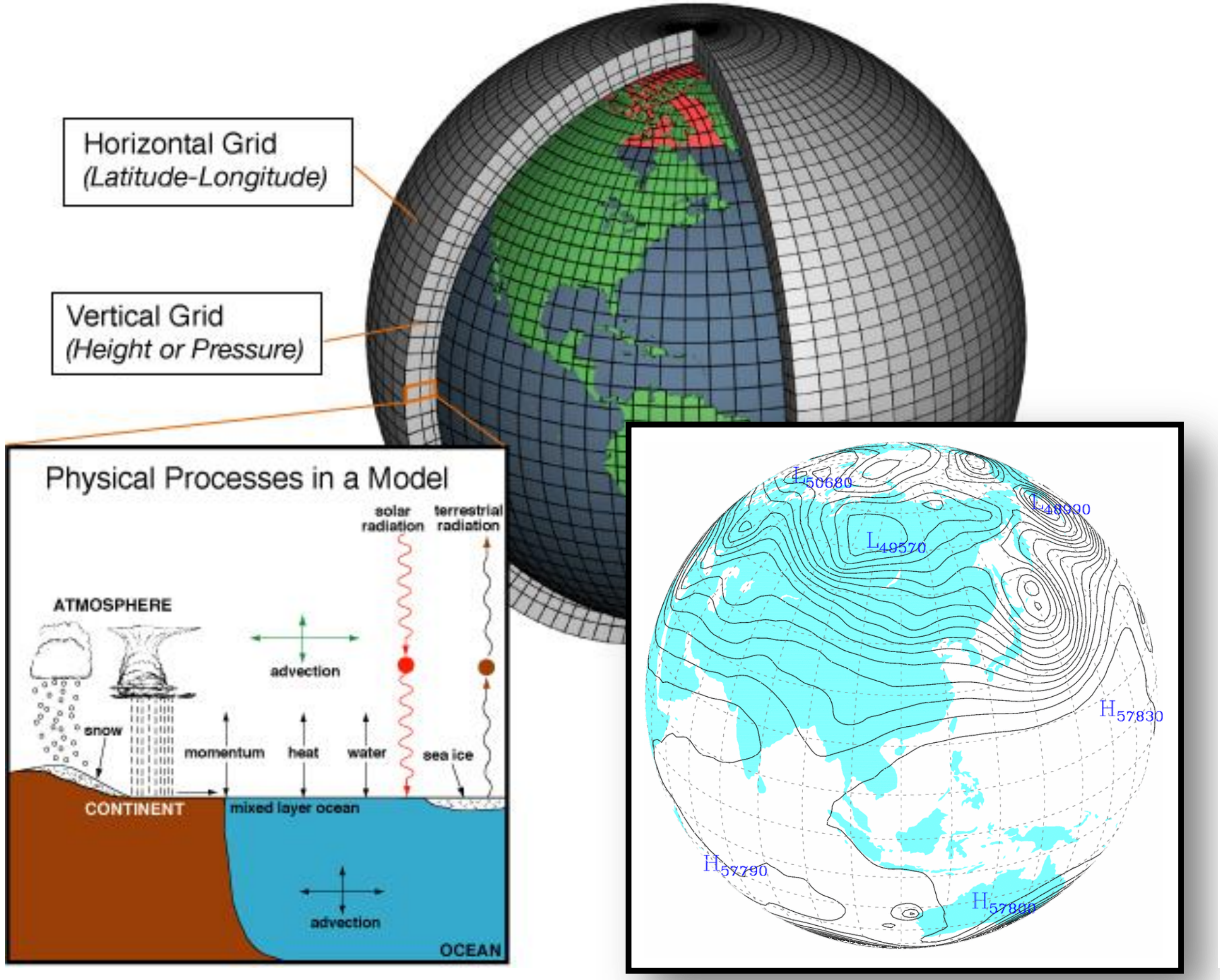
Big data – global data



Big data @ HKO – Radar and satellite data



Big data – Computer model



- Conservation of momentum :

$$\frac{d}{dt}\boldsymbol{V} = -\frac{1}{\rho}\nabla P - 2\boldsymbol{\Omega}\times\boldsymbol{V} + \boldsymbol{g} + \boldsymbol{F}_r$$

- Conservation of mass :

$$\frac{d\rho}{dt} + \rho\nabla\cdot\boldsymbol{V} = 0$$

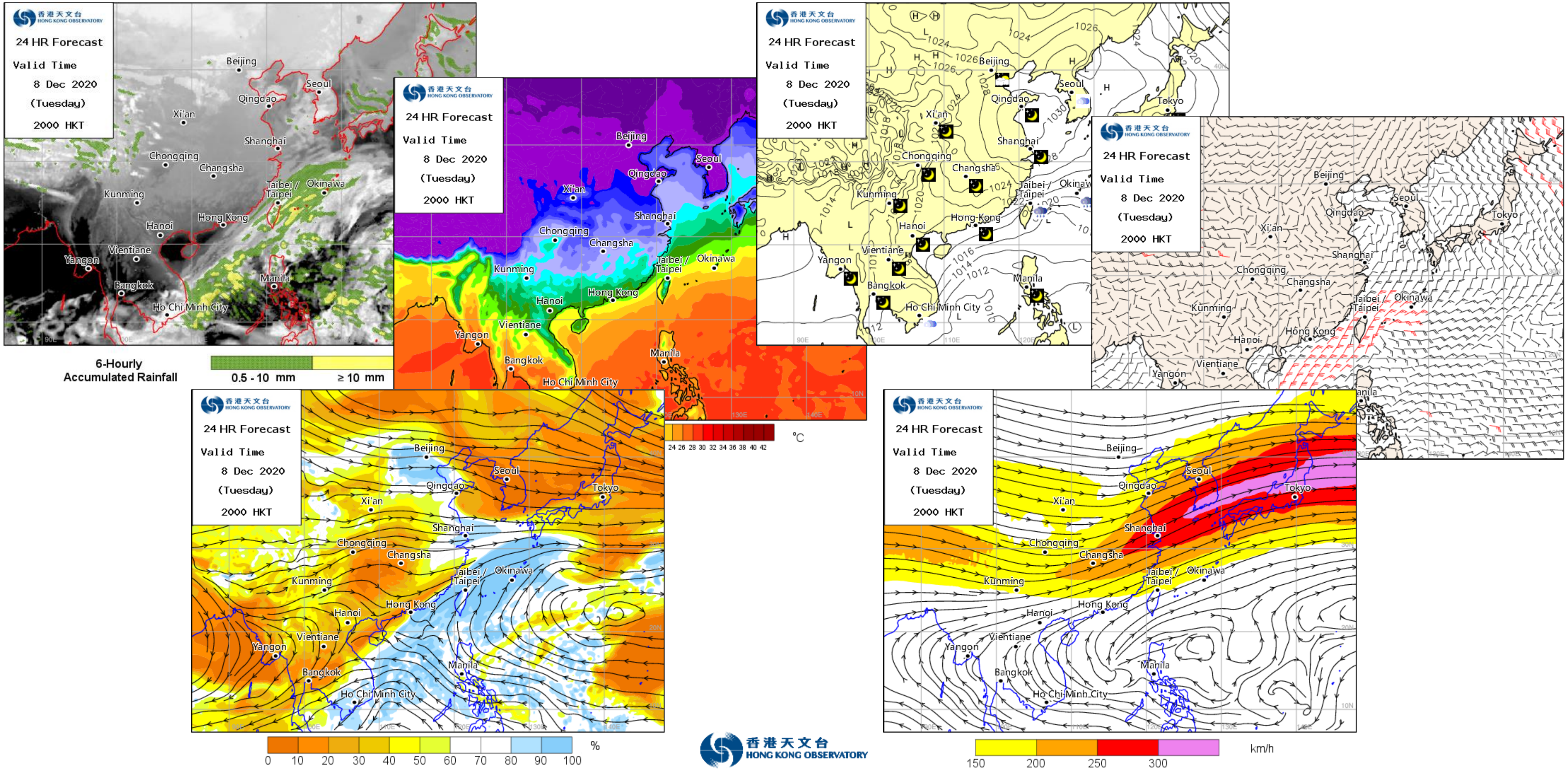
- Conservation of energy :

$$c_p\frac{dT}{dt} - \alpha\frac{dP}{dt} = Q - L\frac{dq}{dt} - c_l m_l\frac{dT}{dt}$$

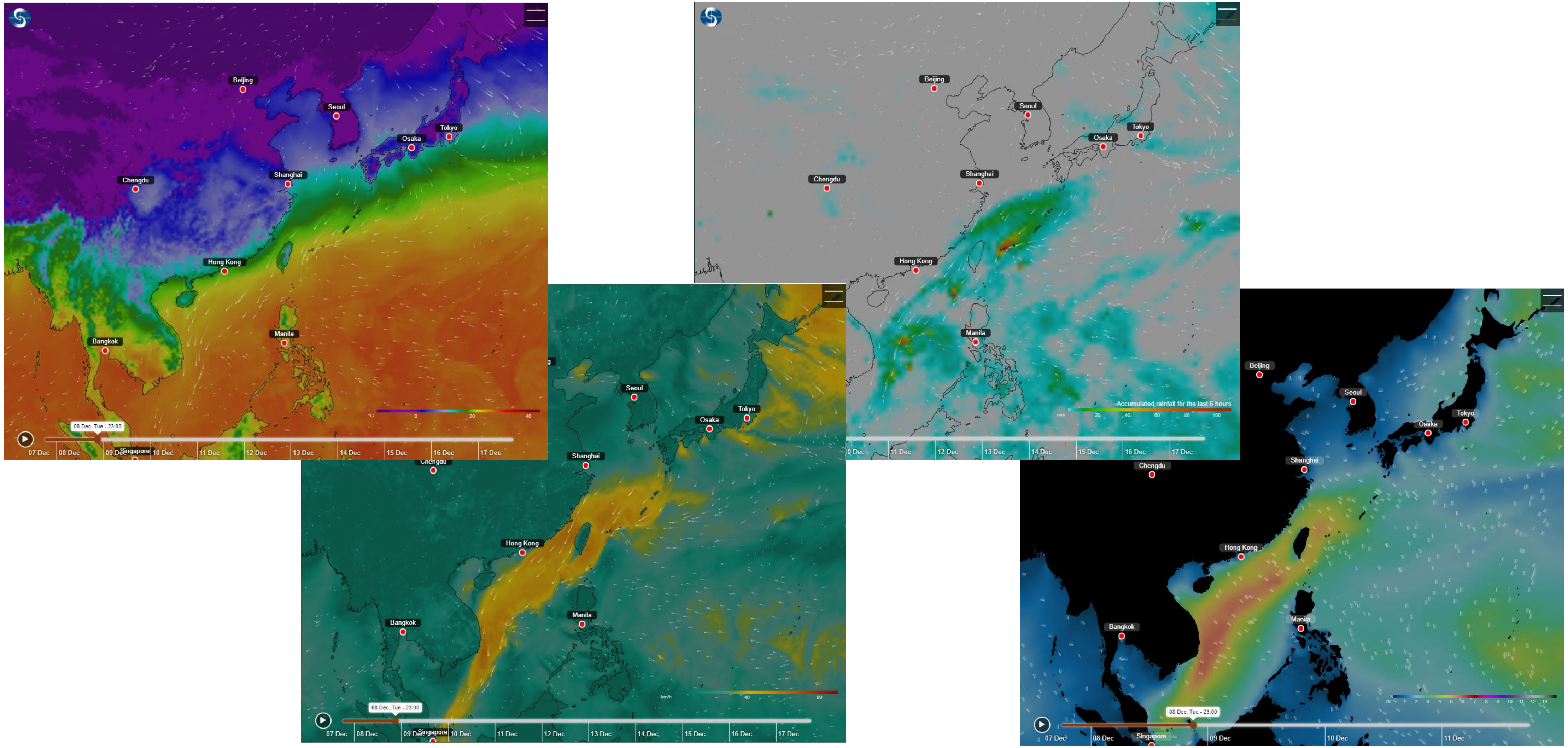
- Conservation of water species : $\frac{dq}{dt} = \frac{S}{\rho}$

- Equation of state : $P = \rho R T_v$

Big data – Computer model data (static products)



Big data – Computer model data (interactive products)



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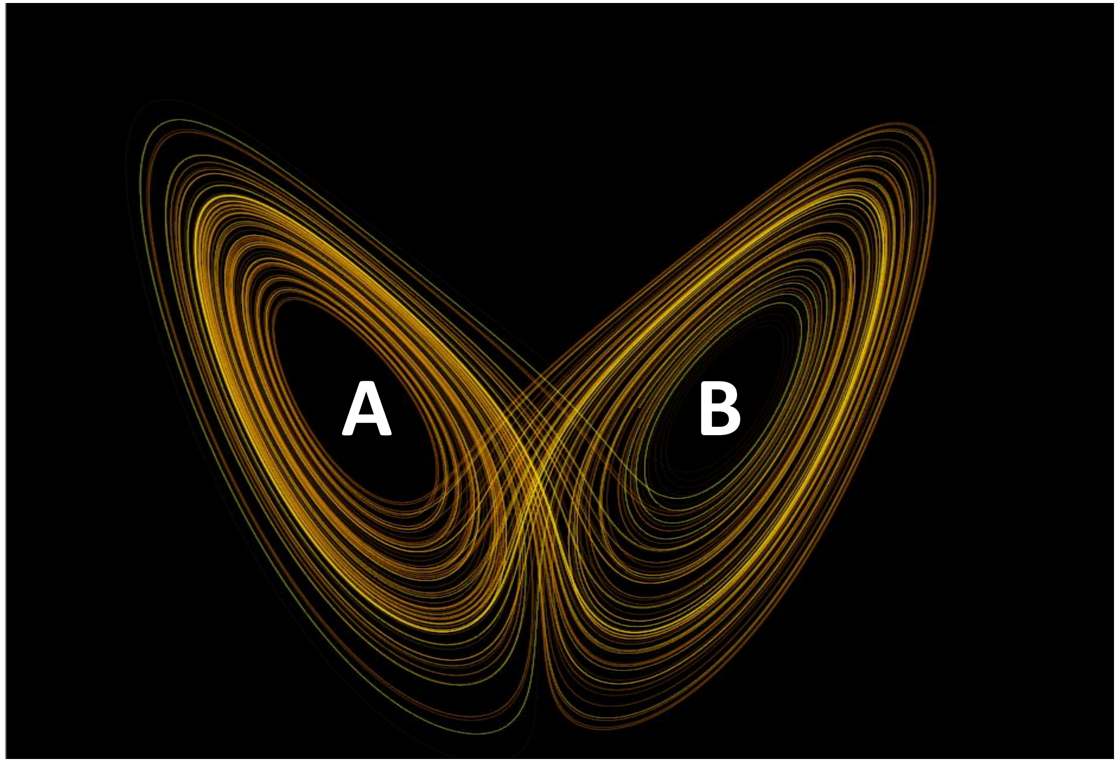
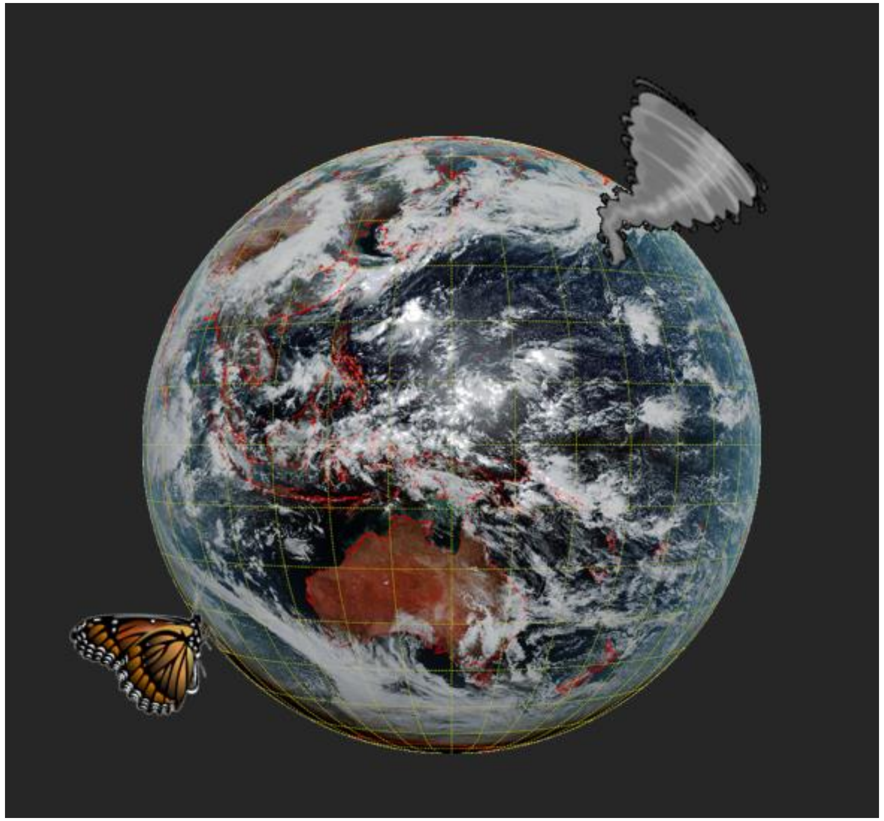
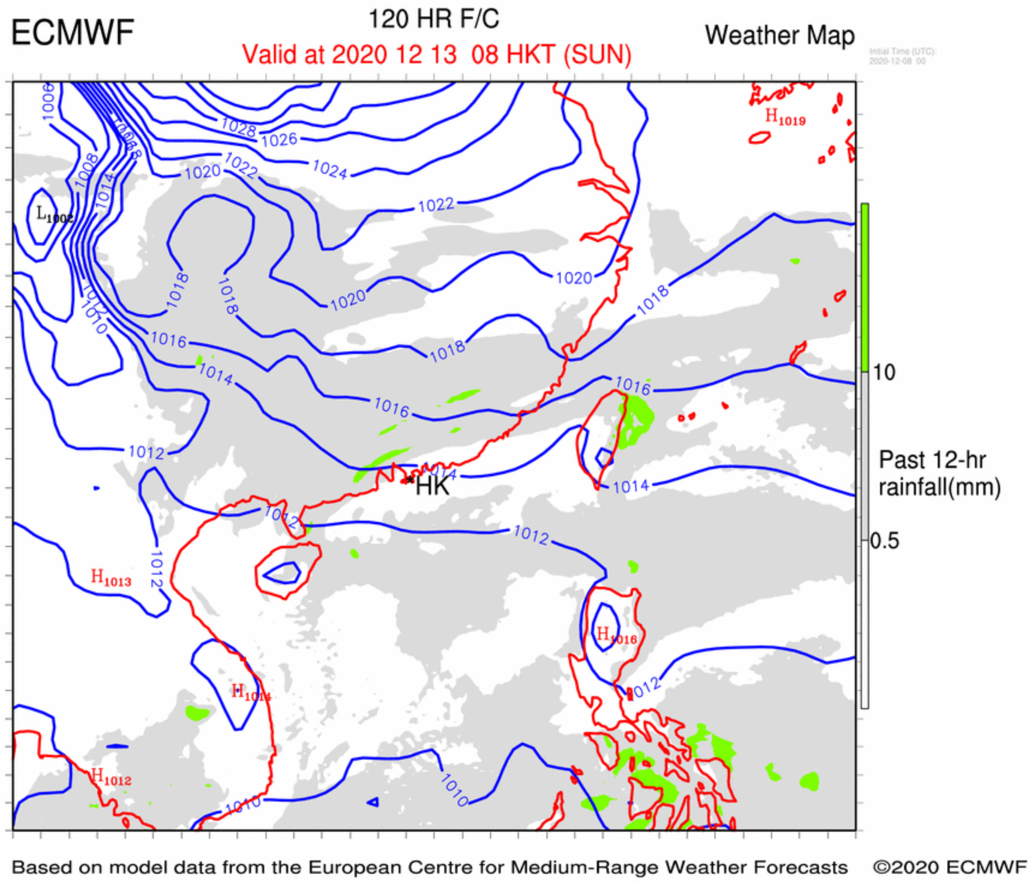
Butterfly effect: uncertainty in prediction

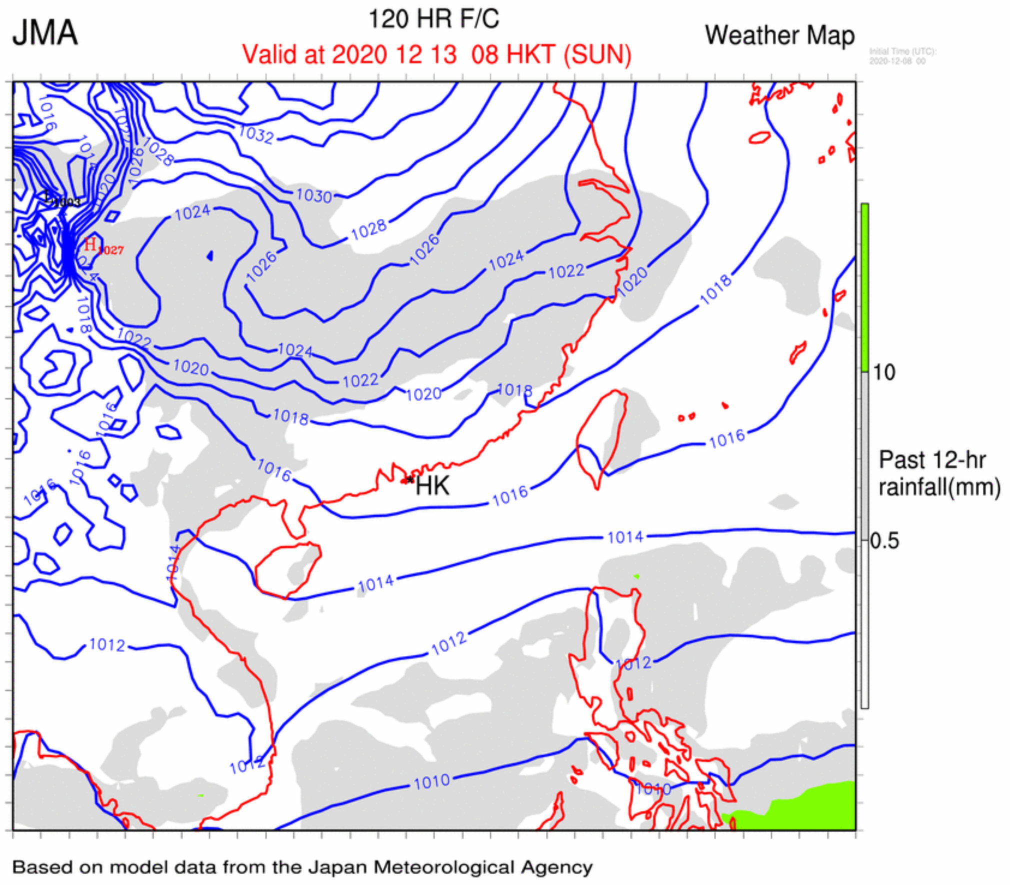


https://en.wikipedia.org/wiki/Butterfly_effect

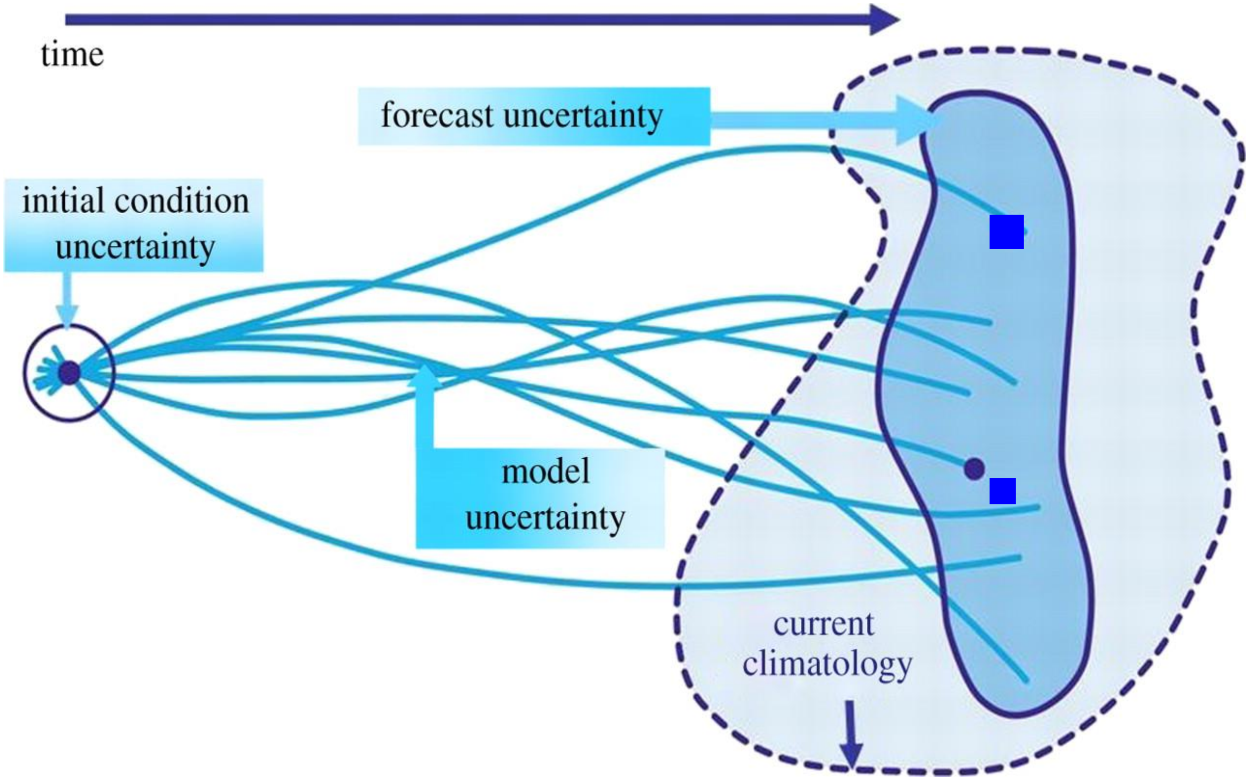


Butterfly effect: uncertainty in prediction



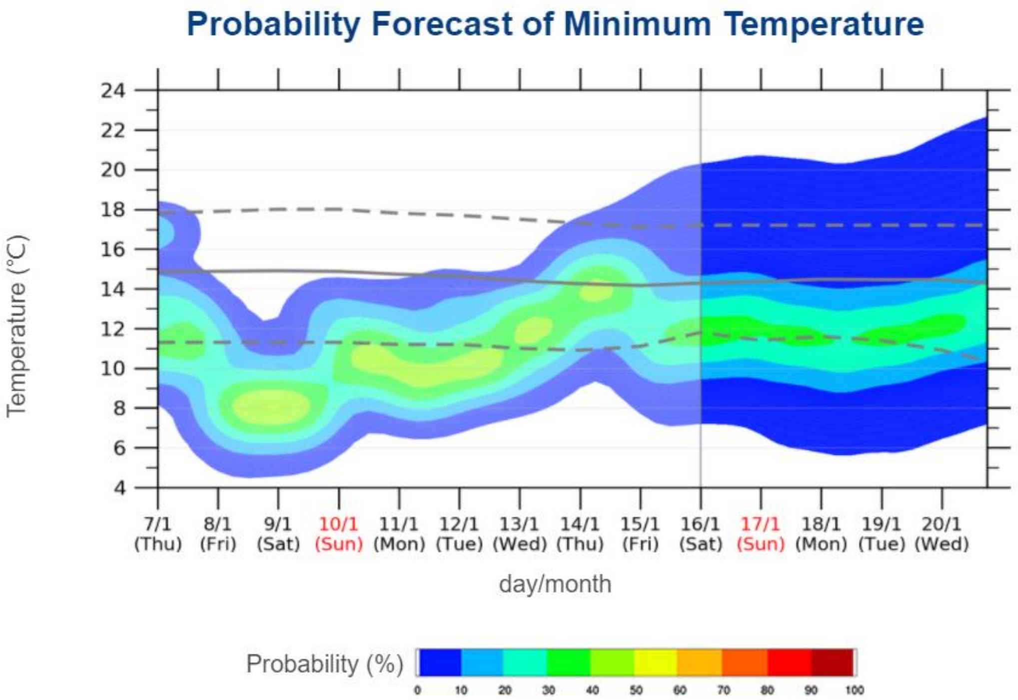


Butterfly effect: uncertainty in prediction

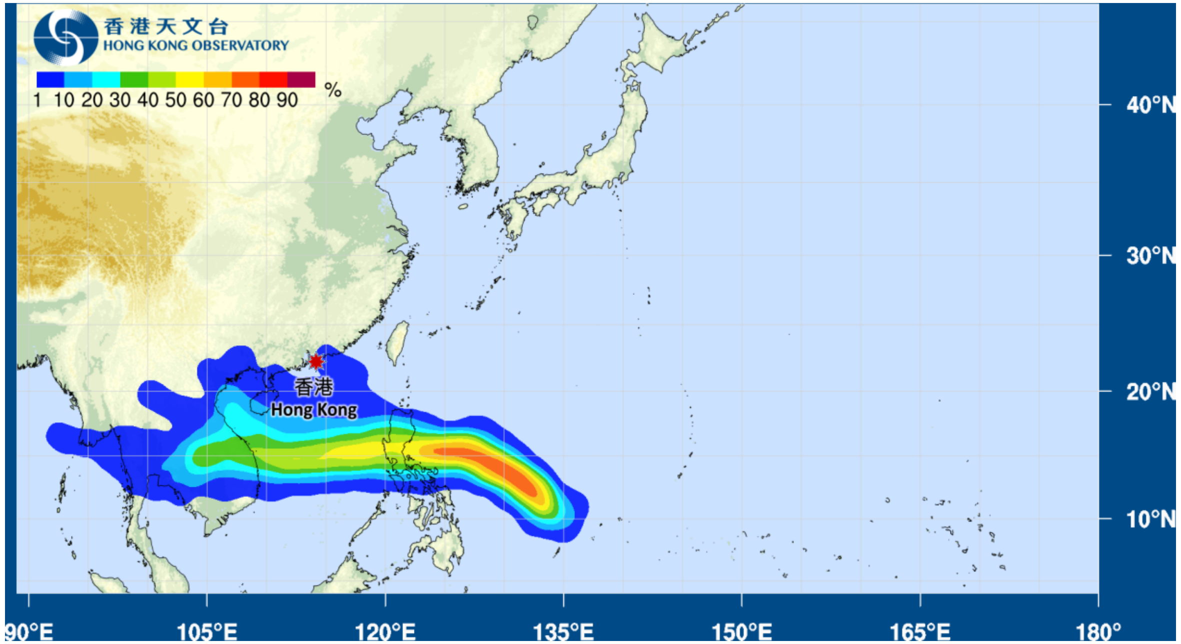


（Credit: Julia Slingo & Tim Palmer (2011)）

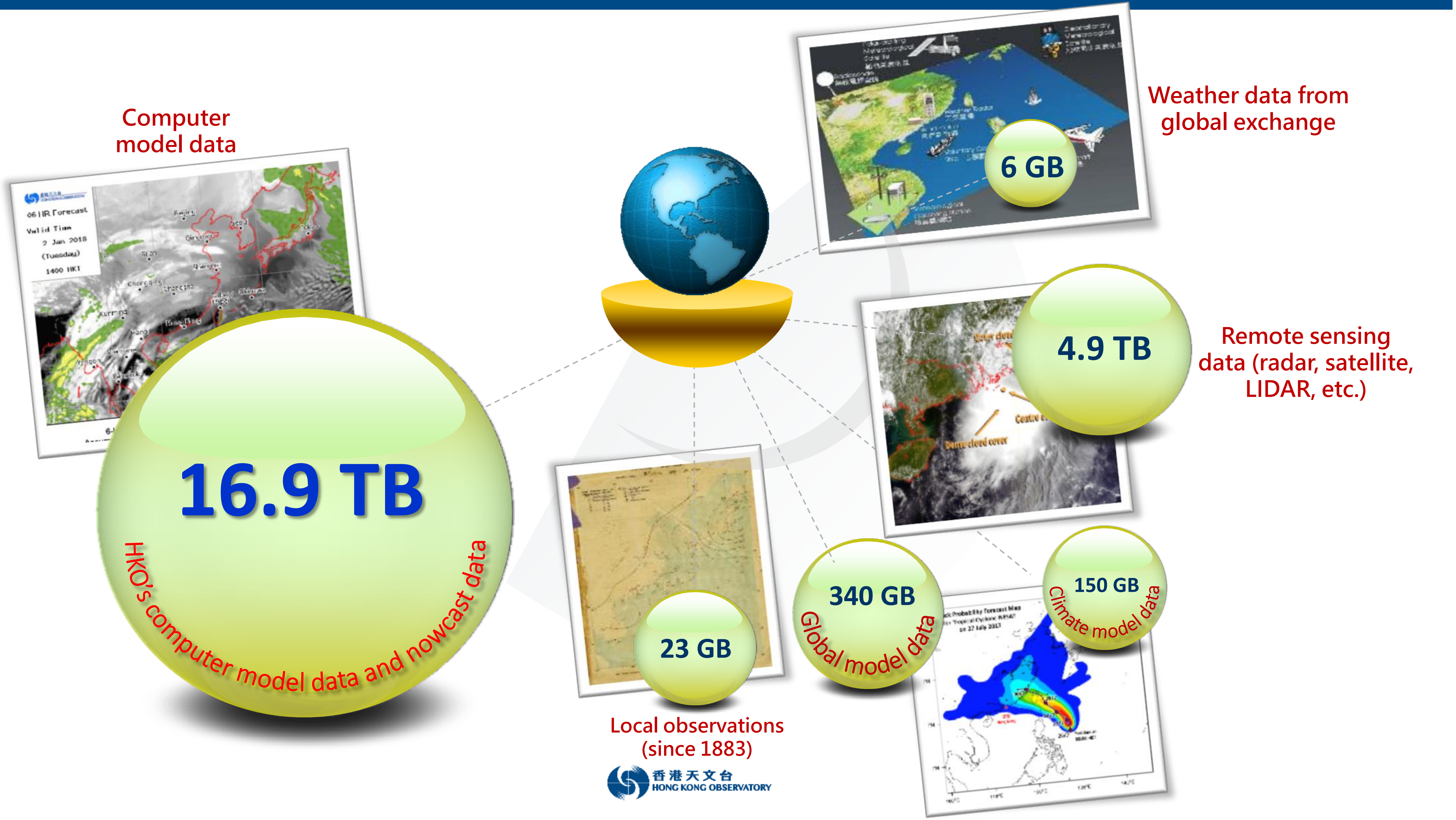
Big data – Computer model data



Tropical cyclone track probability forecast



Big data @ HKO – meteorological. Daily total ~ 22.3 TB



Big data @ HKO – non-meteorological. Daily total ~ 92 GB

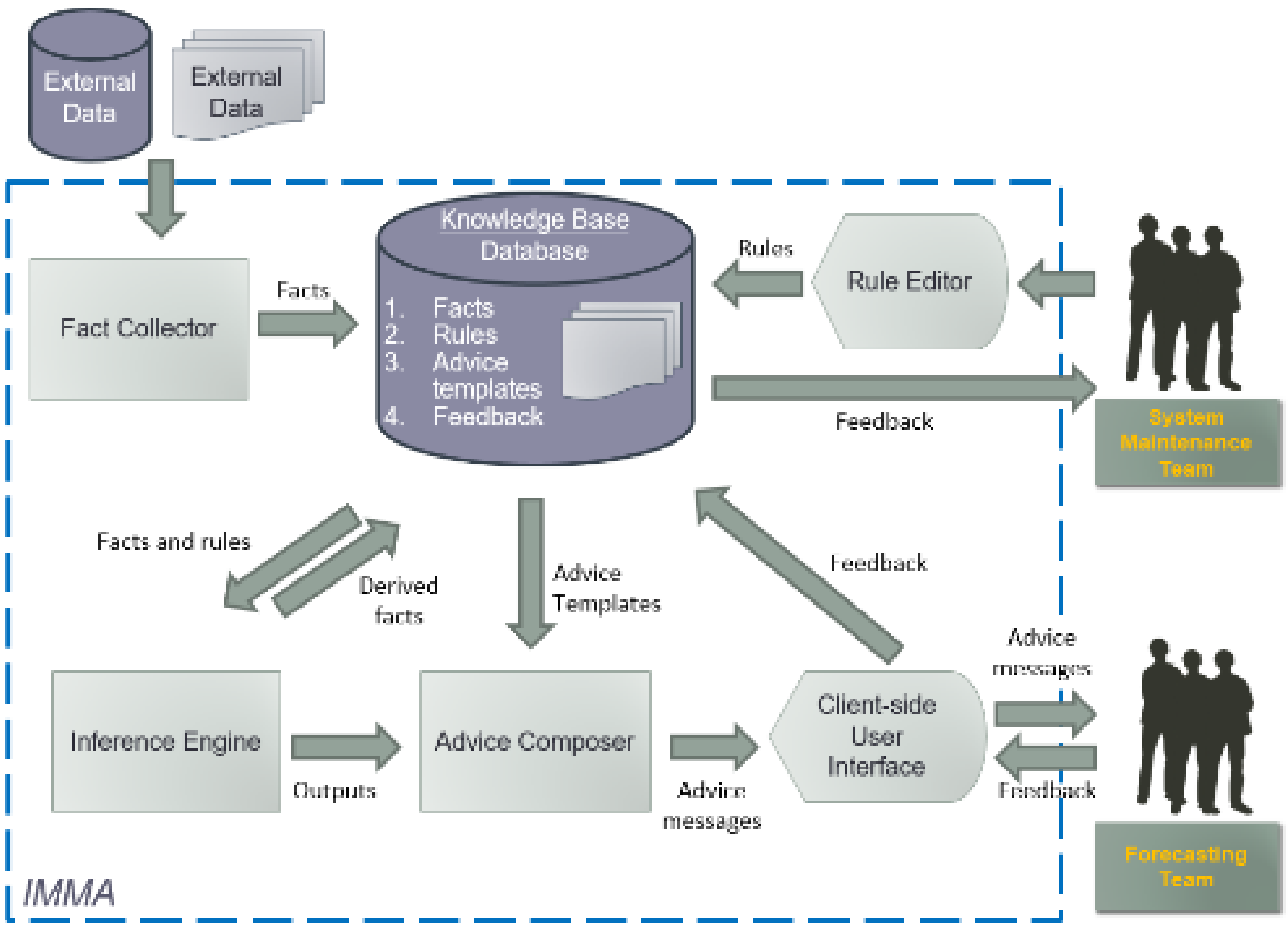
Application of big data – weather monitoring

- Monitoring and detection of extreme weather
- Forecast and warning of extreme weather
- Contingency measures to deal with expected extreme weather
- How big data comes into play?

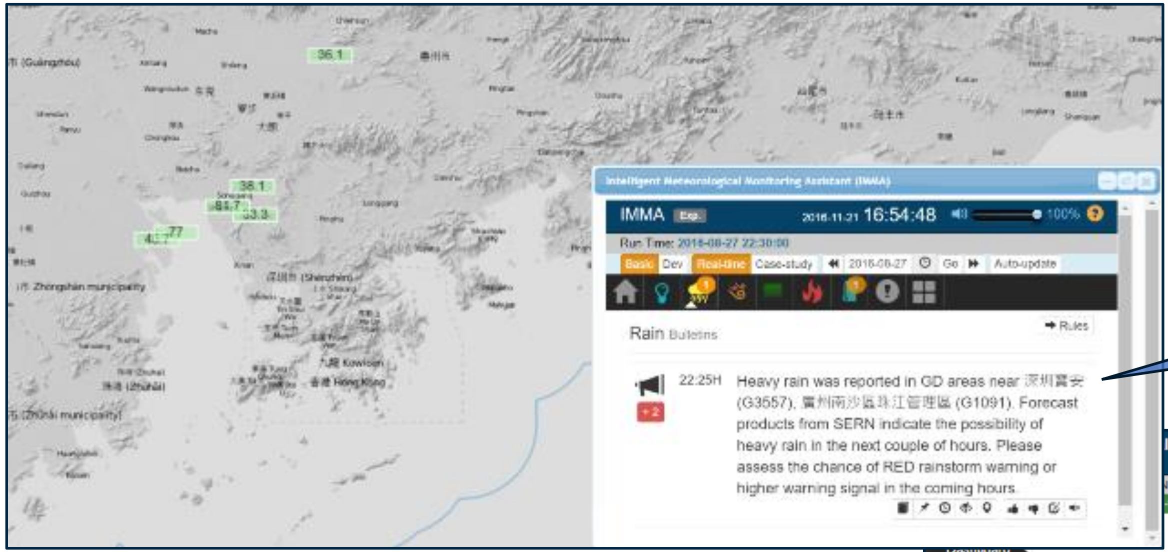
Application of big data – weather monitoring

Intelligent Meteorological Monitoring Assistant (IMMA)

- In-house developed expert system to support weather decision making
- Automatic processing and translation of weather data into intelligence and actionable advice based on rules (wisdom)



Application of big data – weather monitoring



"Heavy rain reported in Guangdong, rainfall nowcast system also suggested possible heavy rain shortly. Please consider the need for a RED Rainstorm Warning"

"Shenzhen issued fire danger/drought warning, please assess the need for a fire danger warning in the coming hours."

"Neighbouring stations reported haze/mist/fog or reduced visibility. Please assess the chance of haze/mist/fog with reduced visibility locally."

Application of big data – weather monitoring

- Alert of reports of severe weather in neighbouring areas
- Detection of record-breaking events in HK
- Alert forecasters of emerging weather conditions as compared to forecast / warnings in effect

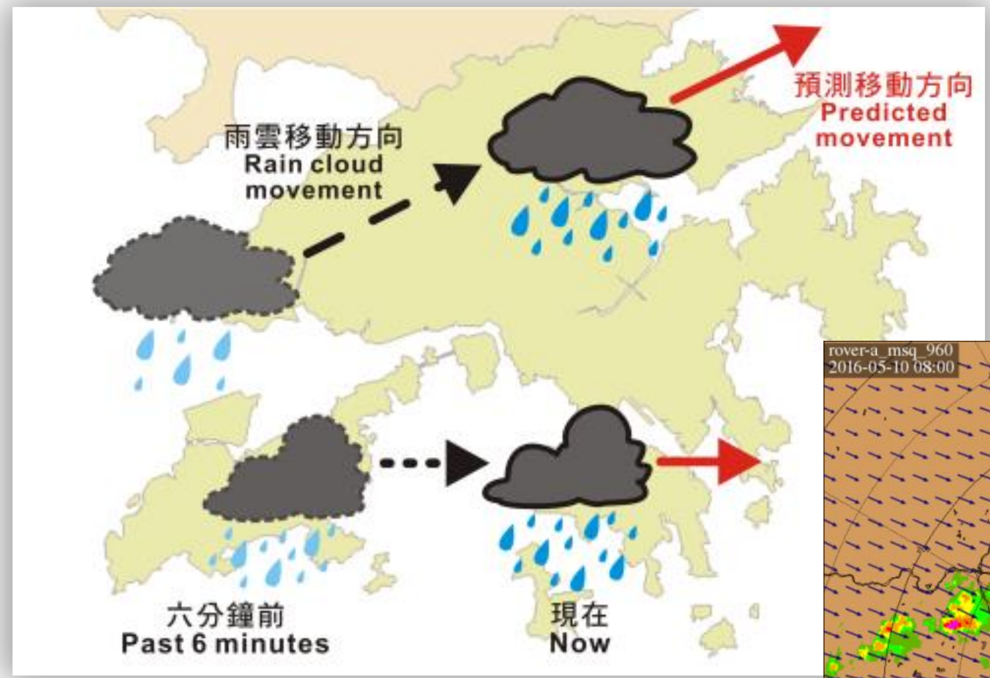
- Performance
  - >650,000 data points processed every minute
  - 8 seconds to perform cycle run once every 5 minutes
  - 300+ conditions plus 260+ rules for advice generation

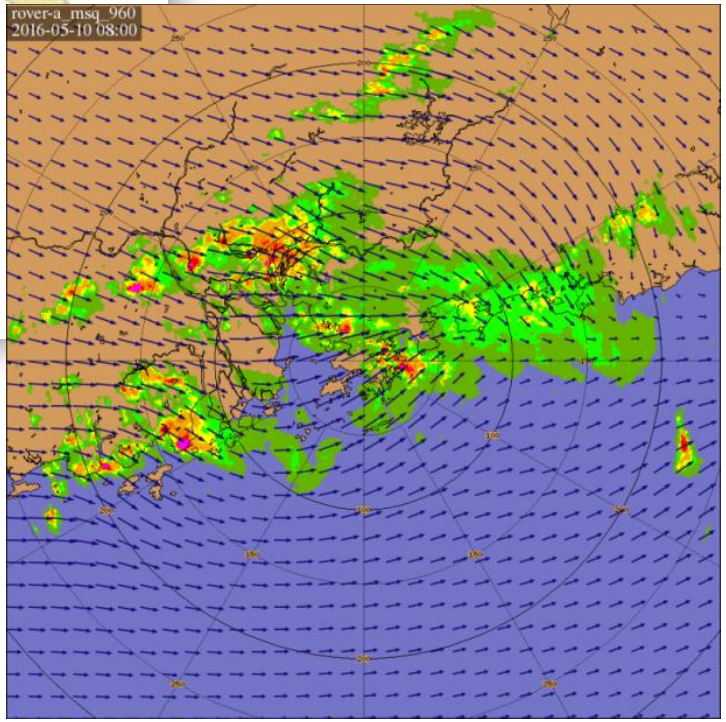
Application of big data – severe weather warning

Nowcasting

- Nowcasting = tracking the motion of rain areas by weather radar and forecast the future locations of severe weather in coming few hours

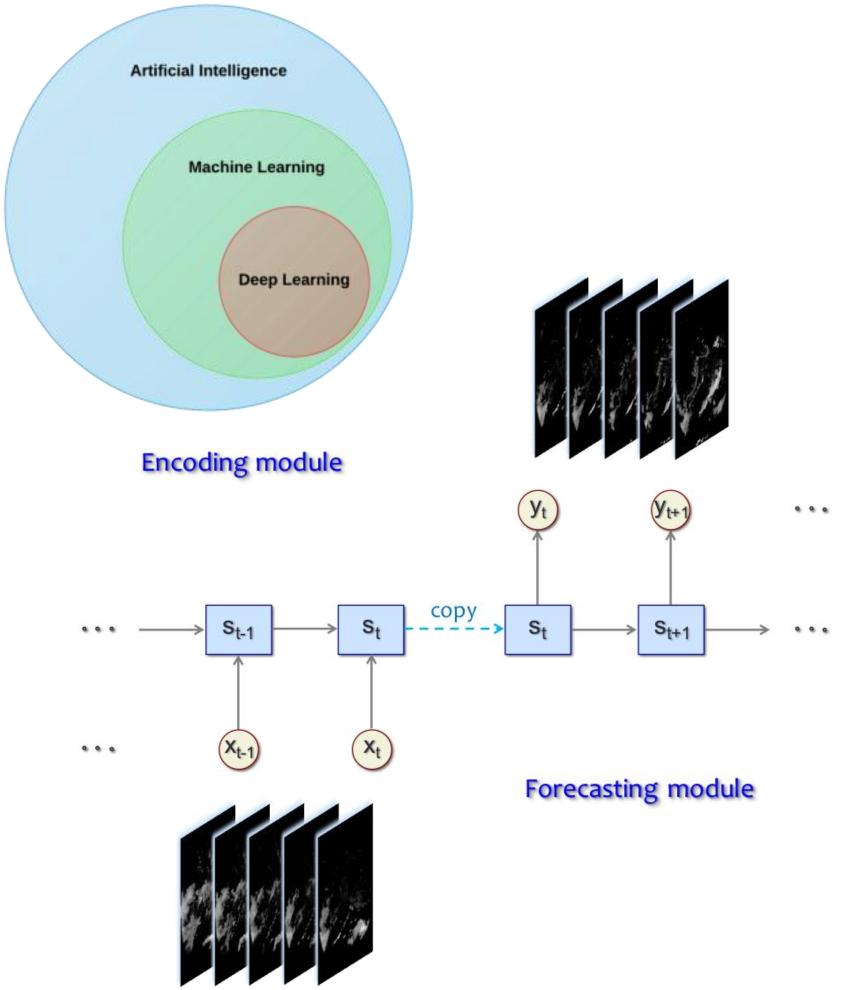
- Key product to support warning of rainstorms, thunderstorms, etc.

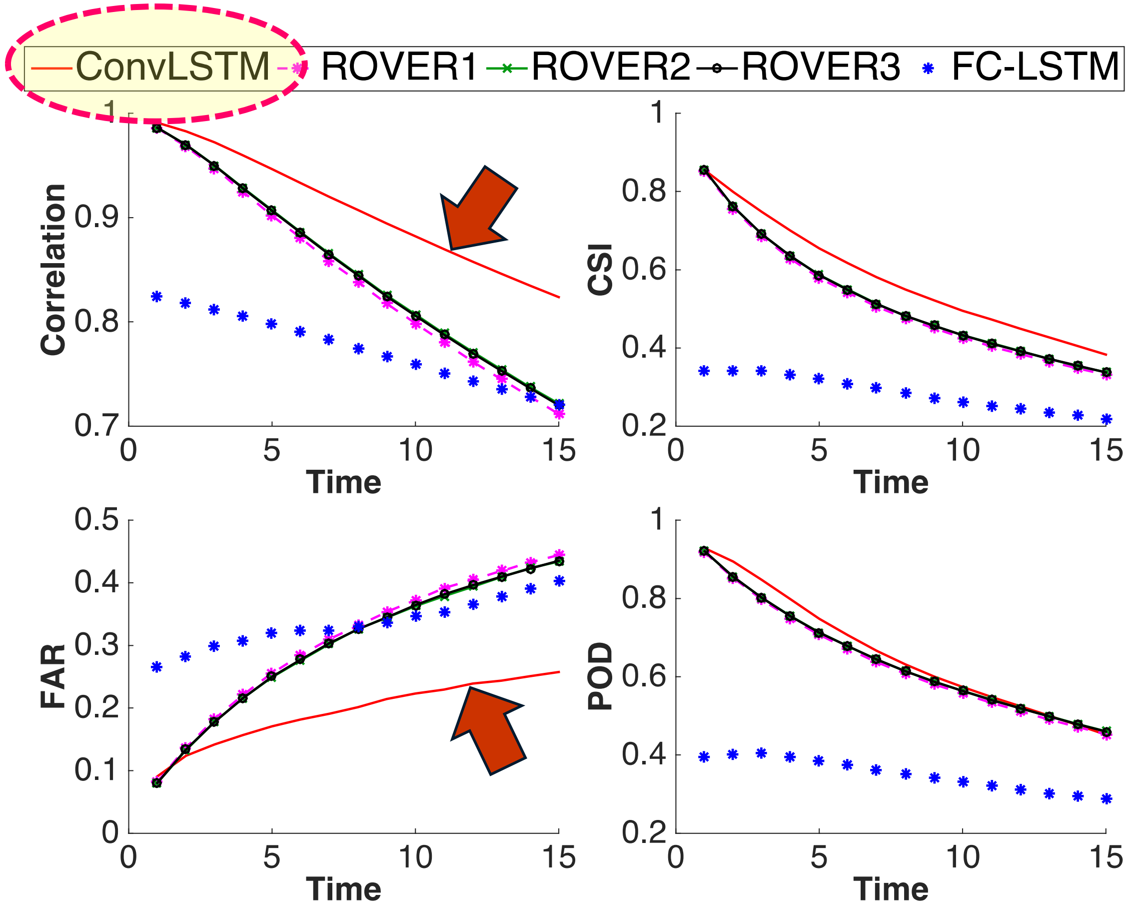




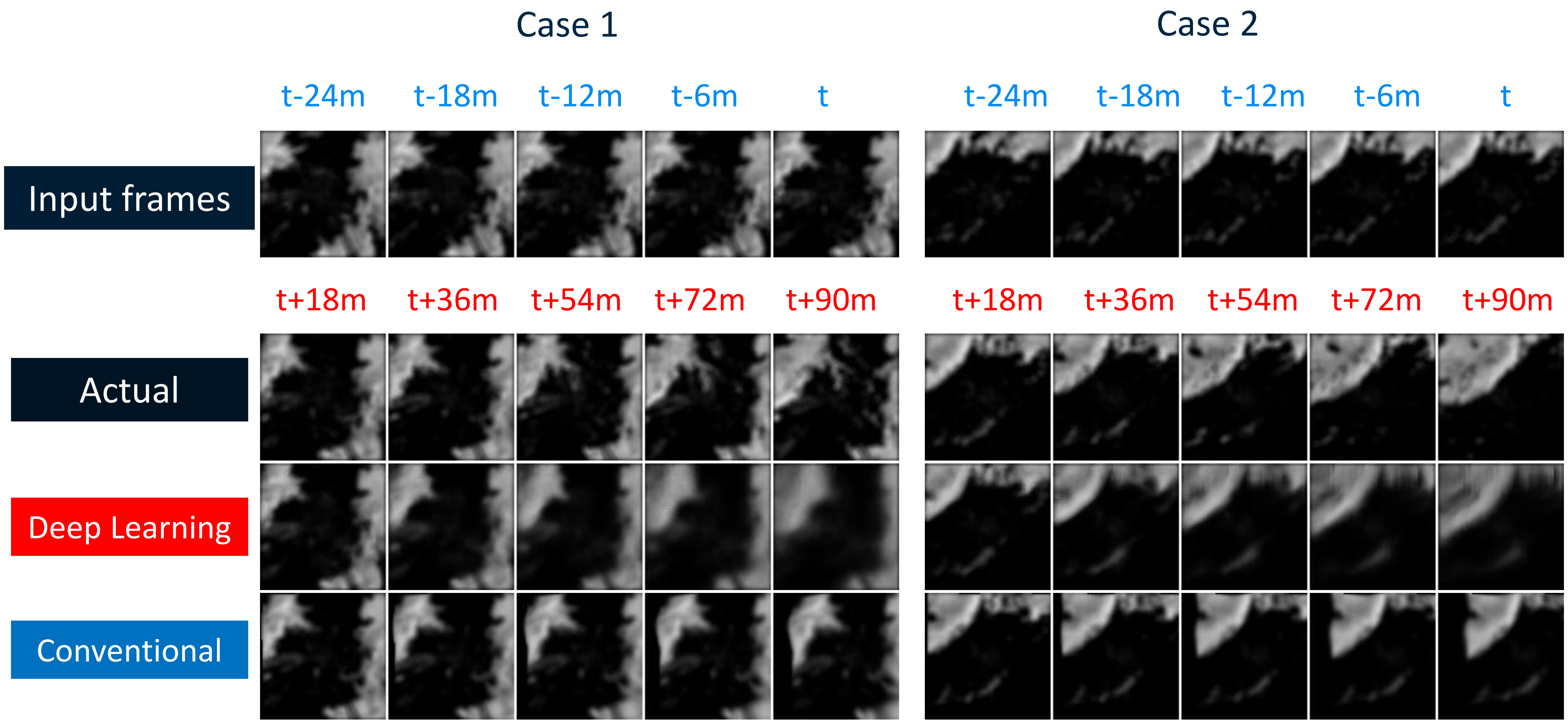
Application of big data – severe weather warning

Nowcasting using **Deep Learning**



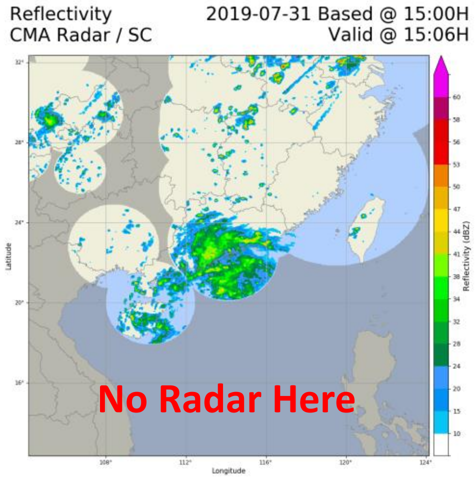


Application of big data – severe weather warning

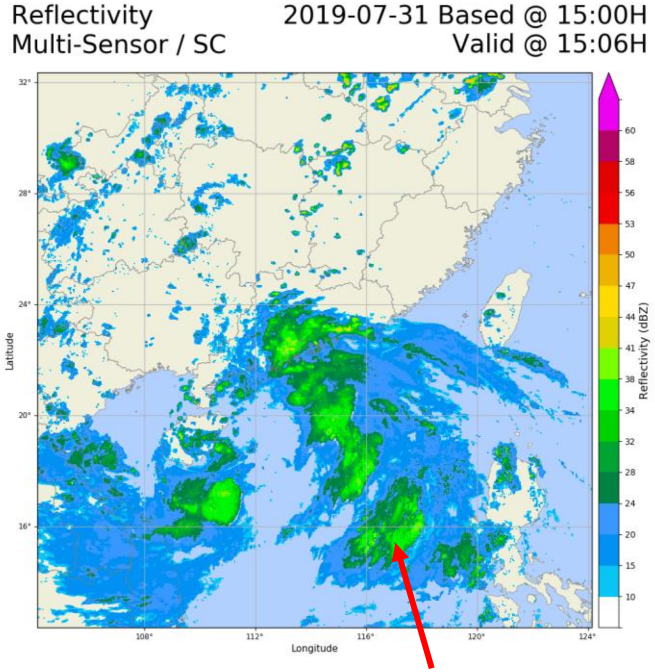


Application of big data – severe weather warning

Radars can detect rain, but have limited geographical coverage



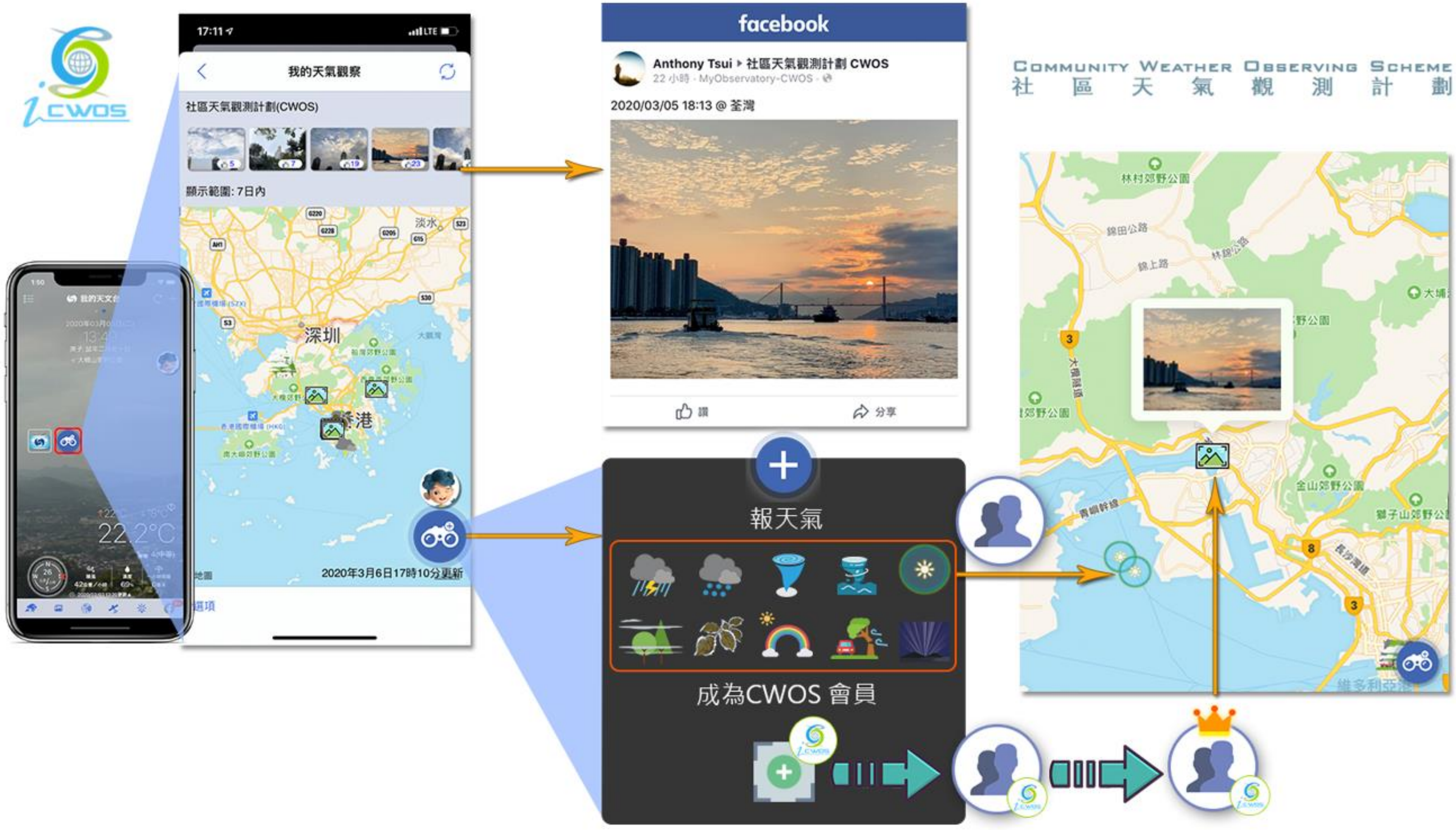
Satellites have wide coverage, but only detect cloud, NOT rain



Raining areas far away by blending radar and satellites data using **neural network model**

Application of big data – crowdsourcing

Application of big data – crowdsourcing (planned)



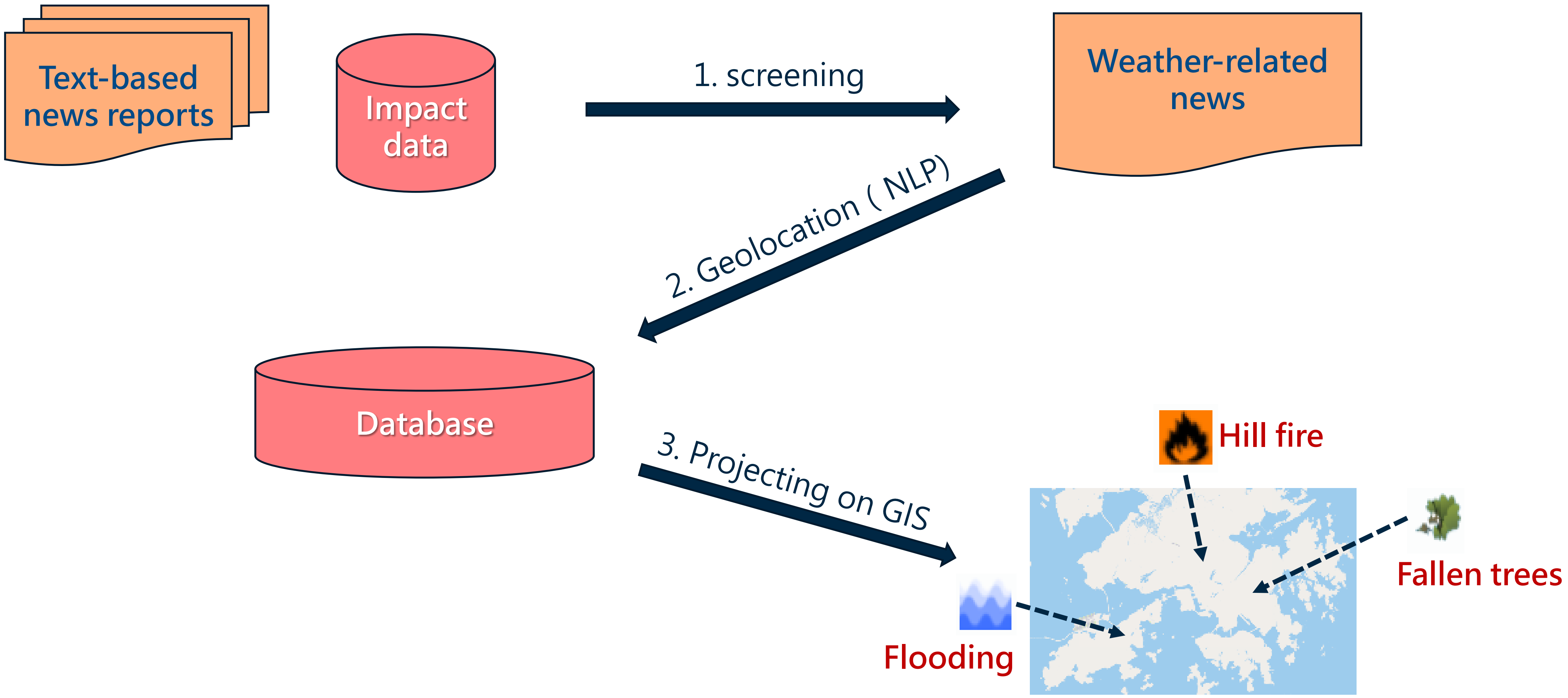
Application of big data – Use of non-meteorological data

Transport Department:
Traffic information

Information Services Department:
Fallen trees, flooding, hill fire, etc

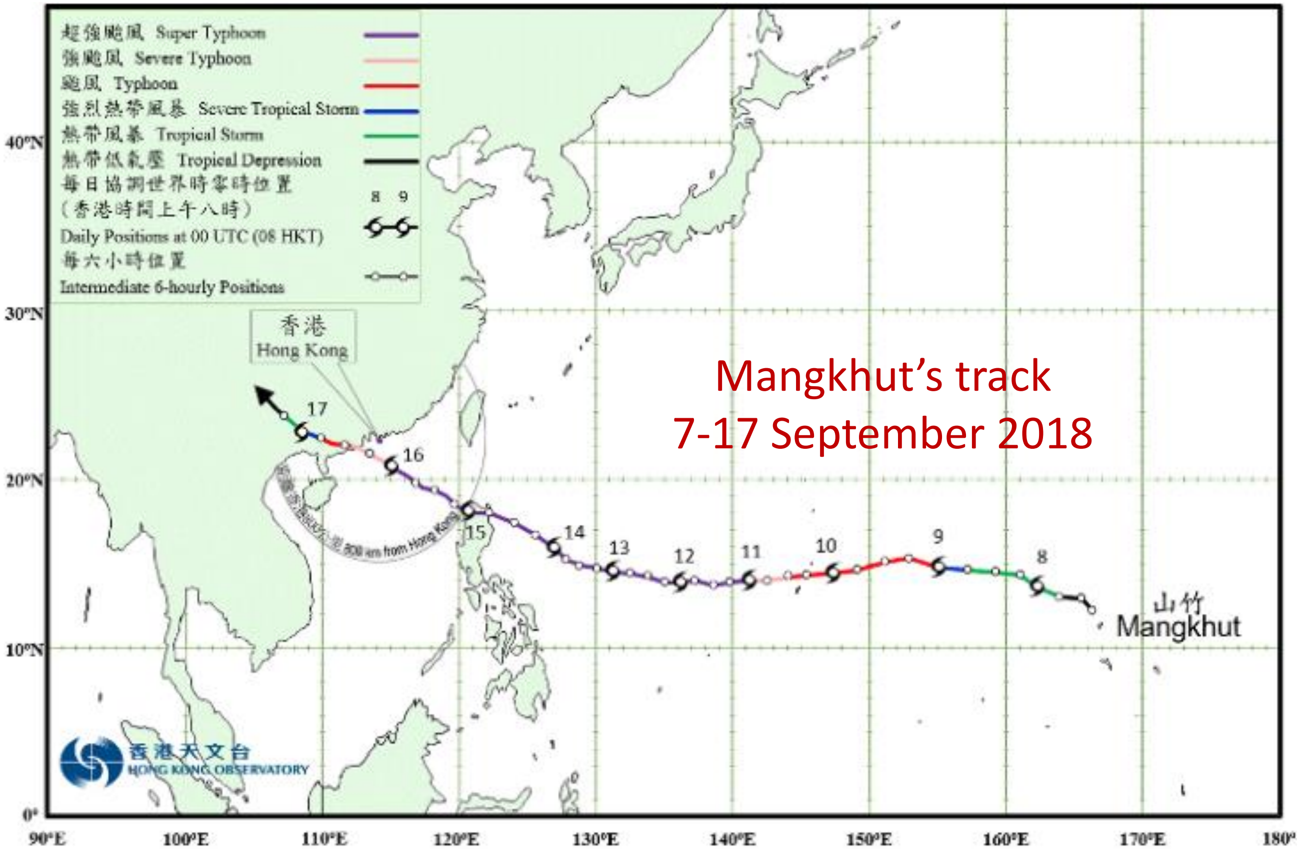
HKO

Application of big data – Use of non-meteorological data



Application of big data – Use of non-meteorological data

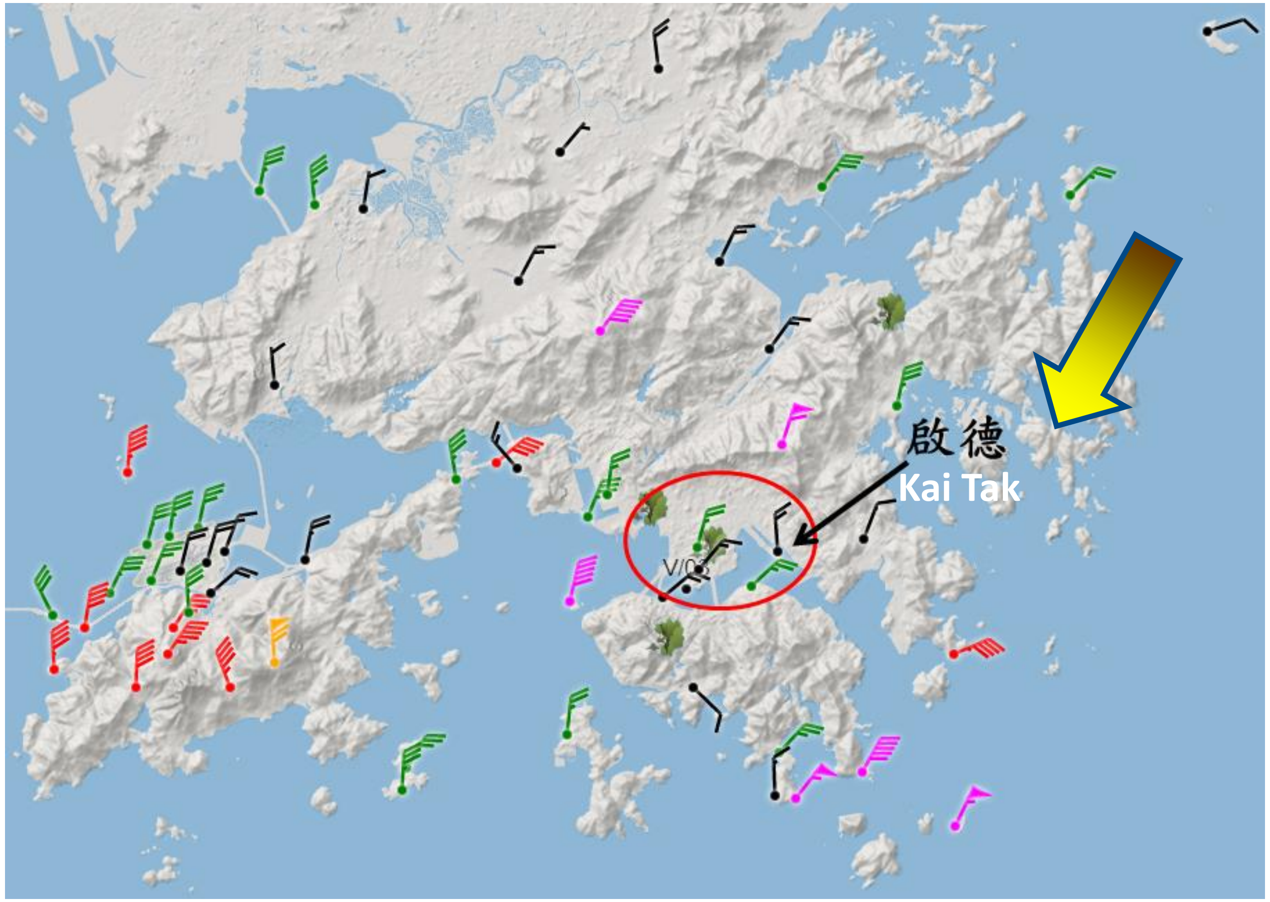
16 September 2018 Mangkhut - Fallen trees



Application of big data – Use of non-meteorological data

<u>16 September morning</u>

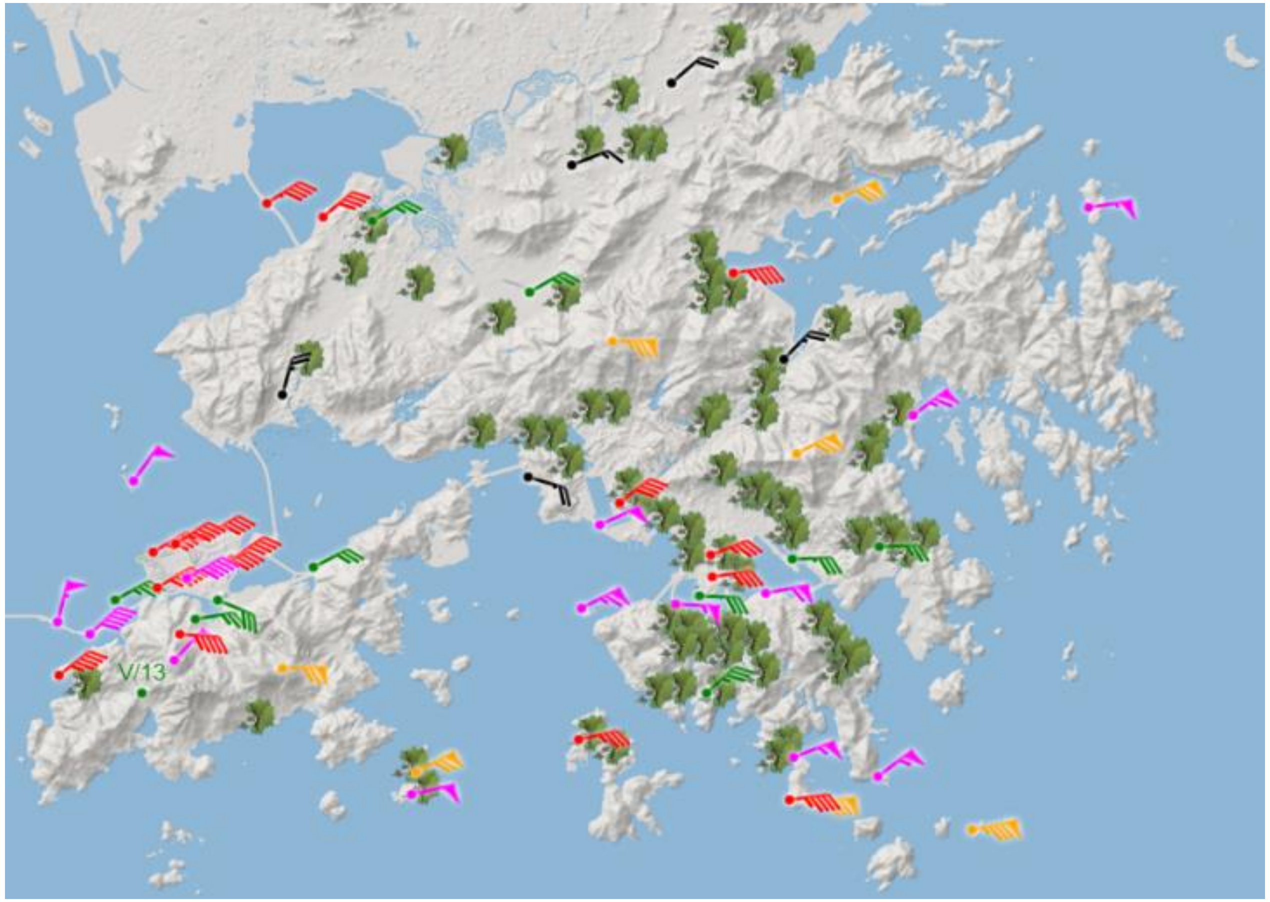
- North to northeasterly winds. "Weaker" winds in urban areas (red ellipse) owing to topographic effect
- Gales or stronger winds on high ground and offshore areas. Some reports of fallen trees (green icon)



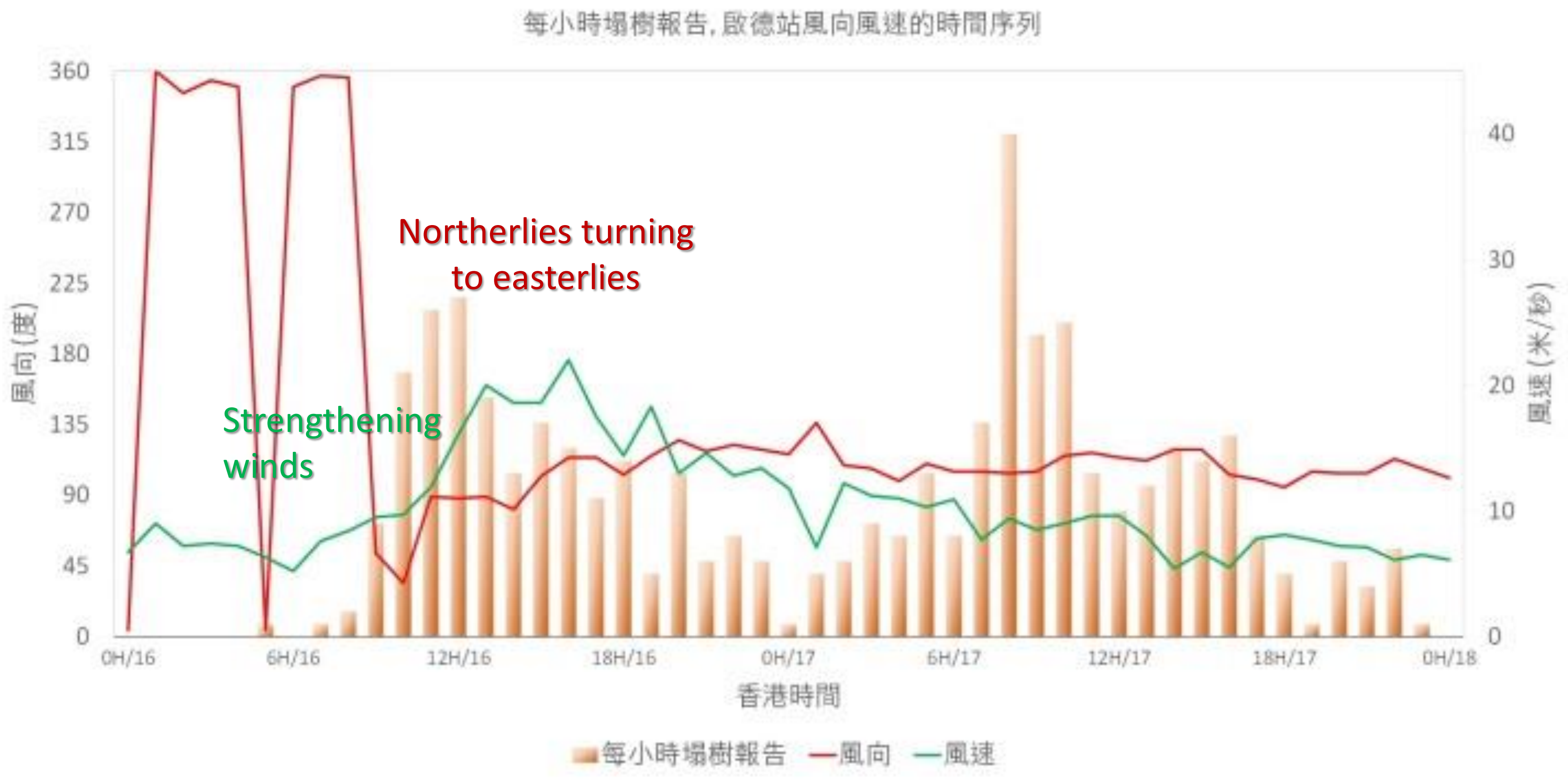
Application of big data – Use of non-meteorological data

<u>16 September afternoon</u>

- Winds strengthening from the east
- Previously sheltered areas exposed to violent winds. Surge of fallen tree reports in 4 hours.



Application of big data – Use of non-meteorological data



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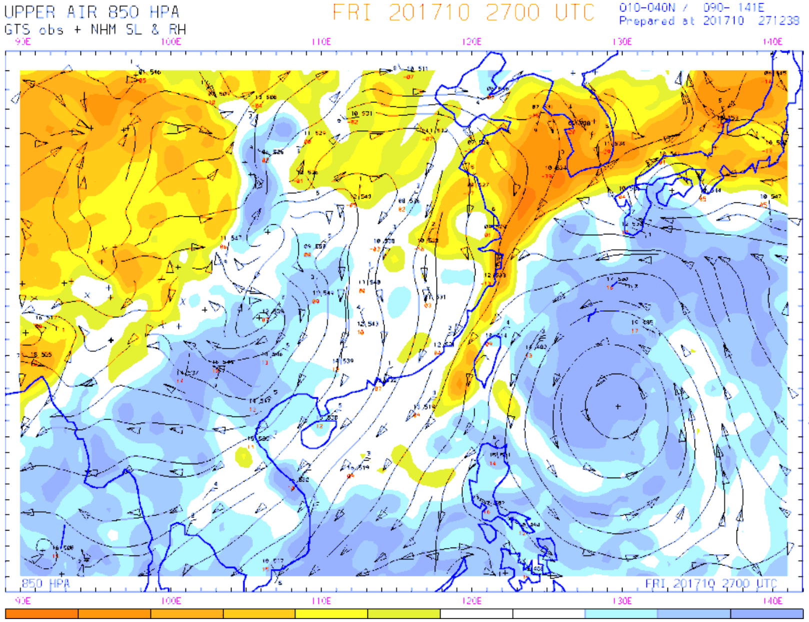
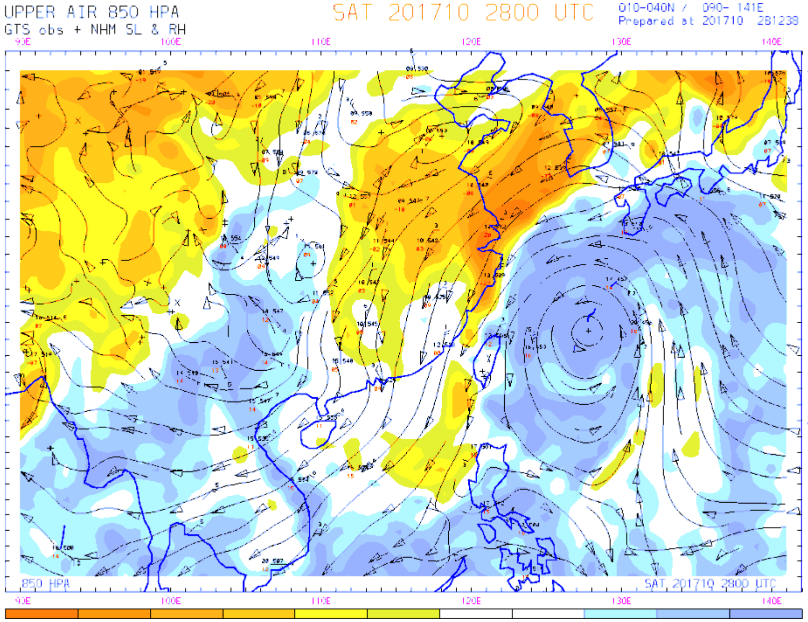
Application of big data – Use of non-meteorological data

Dry condition and public holiday - Hill fire

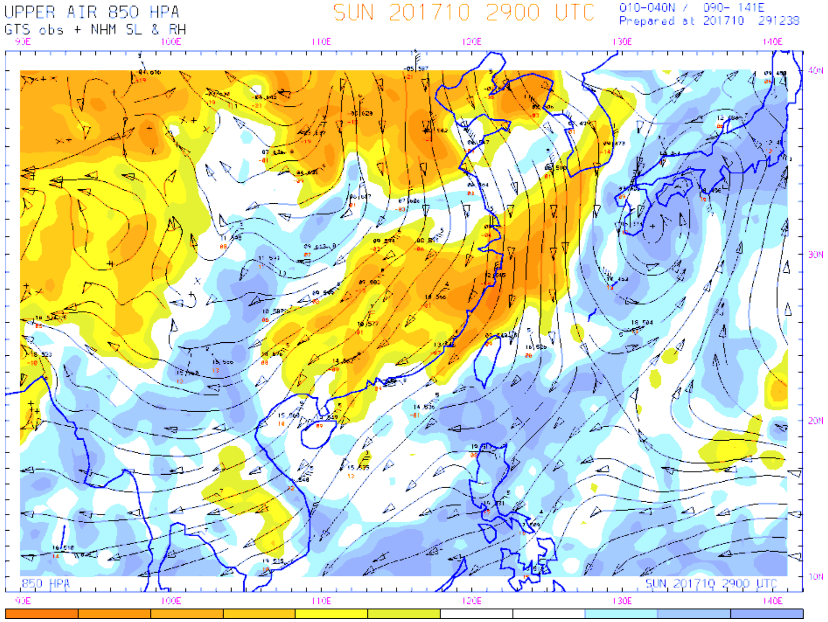
Wind flow at 1.5 km above sea level (black lines) relative humidity (colour)



8 am on 27 Oct 2017



8 am on 28 Oct 2017



8 am on 29 Oct 2017

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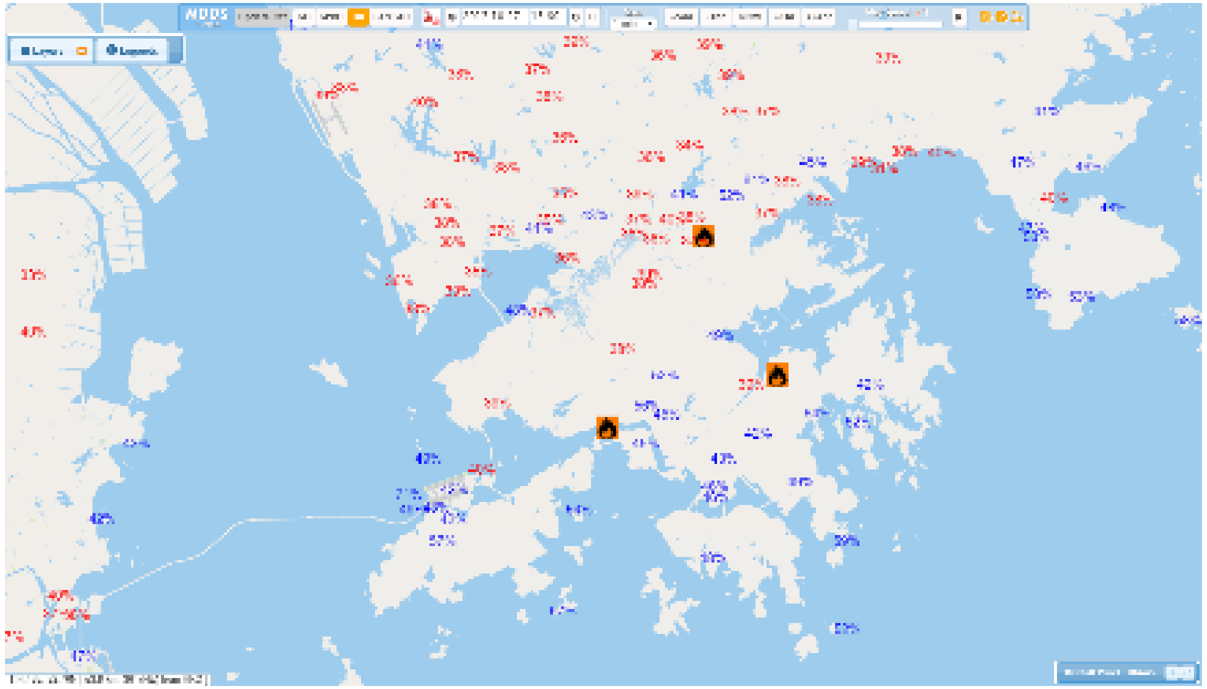
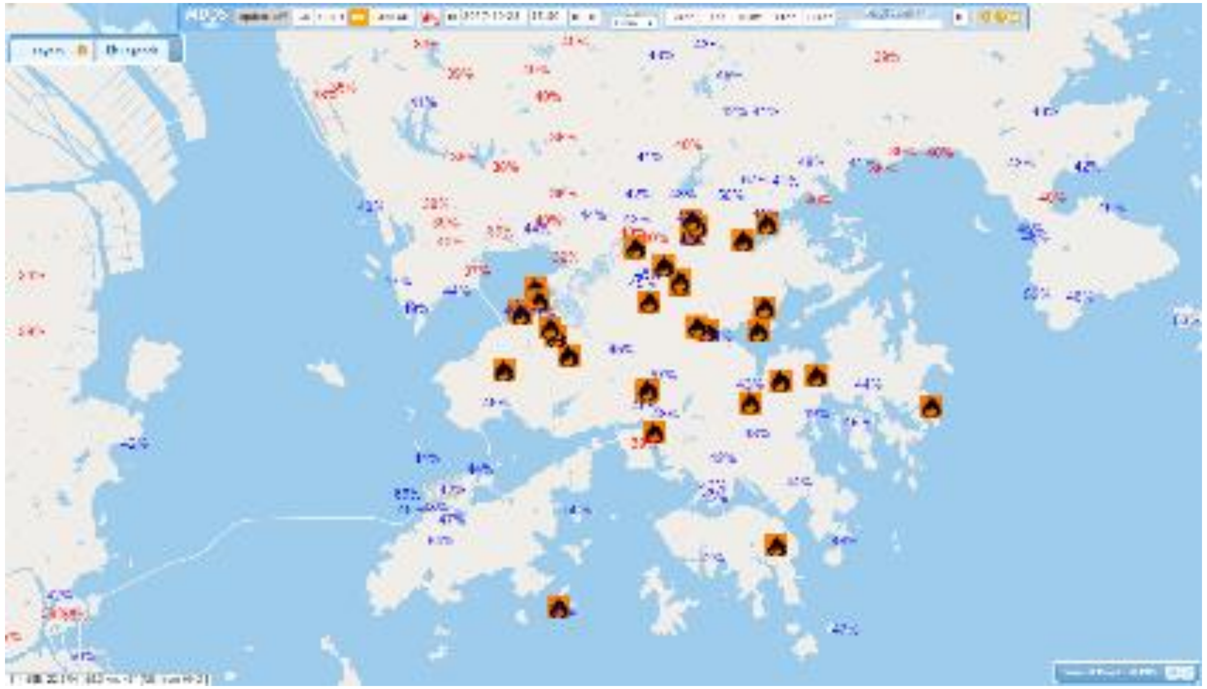
Application of big data – Use of non-meteorological data



3 hill fire reports up to 3:30 pm on 27 Oct 2017

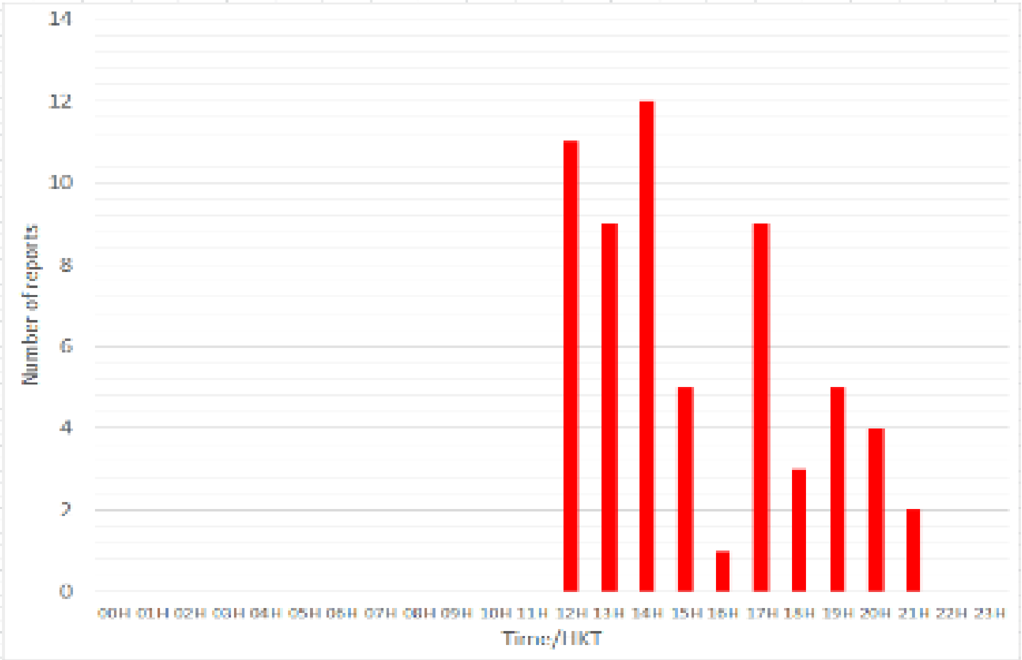


32 hill fire reports up to 3:30 pm on 28 Oct 2017

27 Oct (left) even drier than 28 Oct (right; Chung Yeung Festival)!

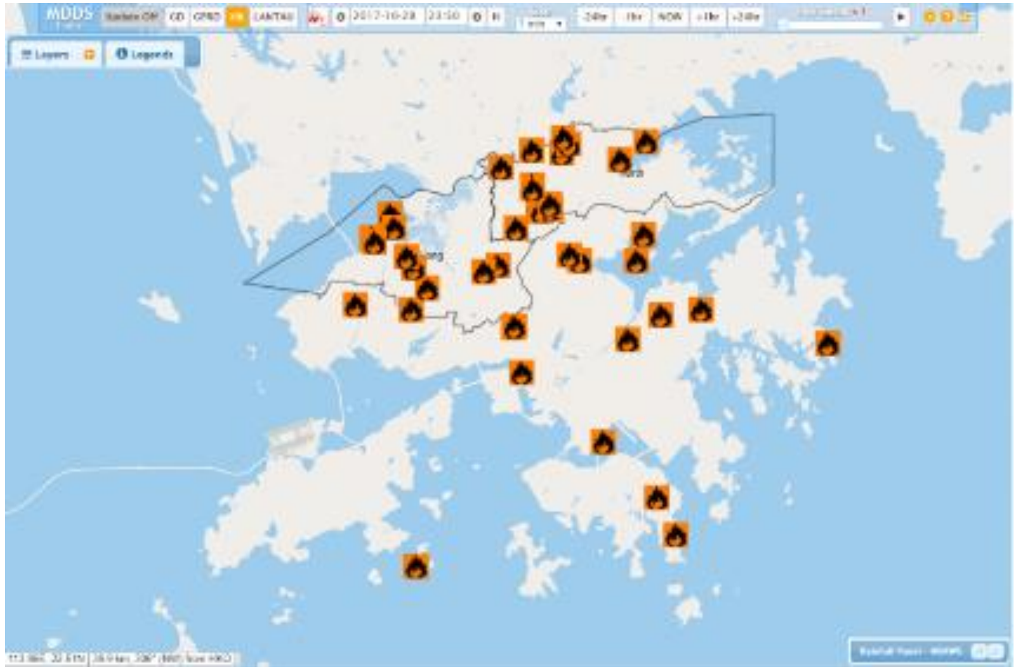
Application of big data – Use of non-meteorological data

Hill fire reported from midday to midnight



Time series of hill fire reports on 28 Oct 2017

Most hill fire reported in New Territories



Locations of hill fire reports on same day

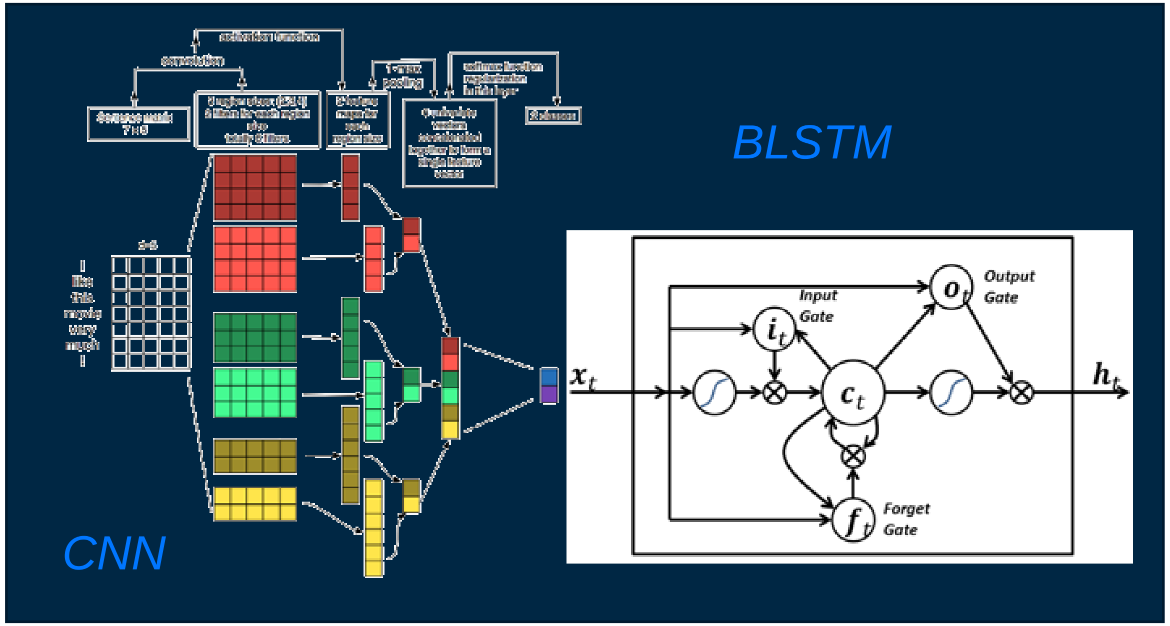
Application of big data – Road traffic

Analyse traffic condition from news

Application of big data – Road traffic

Input online traffic news

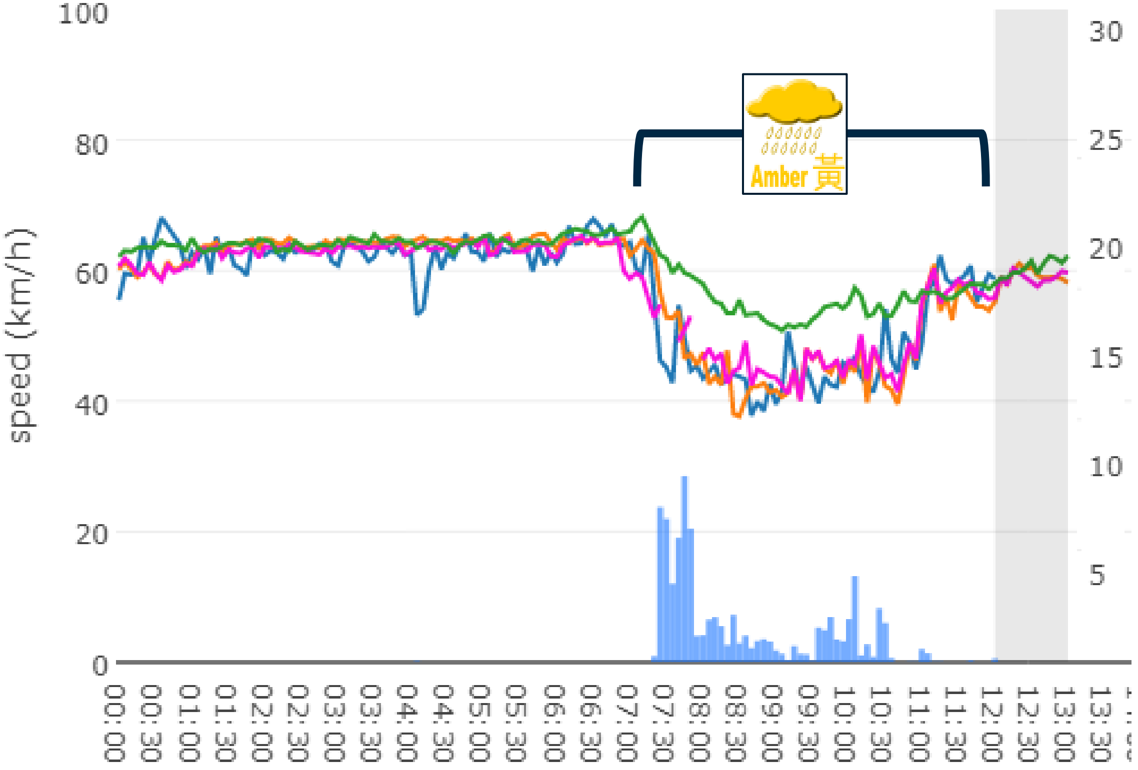
“窩打老道往沙田方向，近映月臺一段擠塞，龍尾：羅福道”



Present the affected road segments on GIS platform

Application of big data – Road traffic

- Learn the correlation between rainfall amount and traffic speed
- Aim at predicting impact on road traffic due to rain



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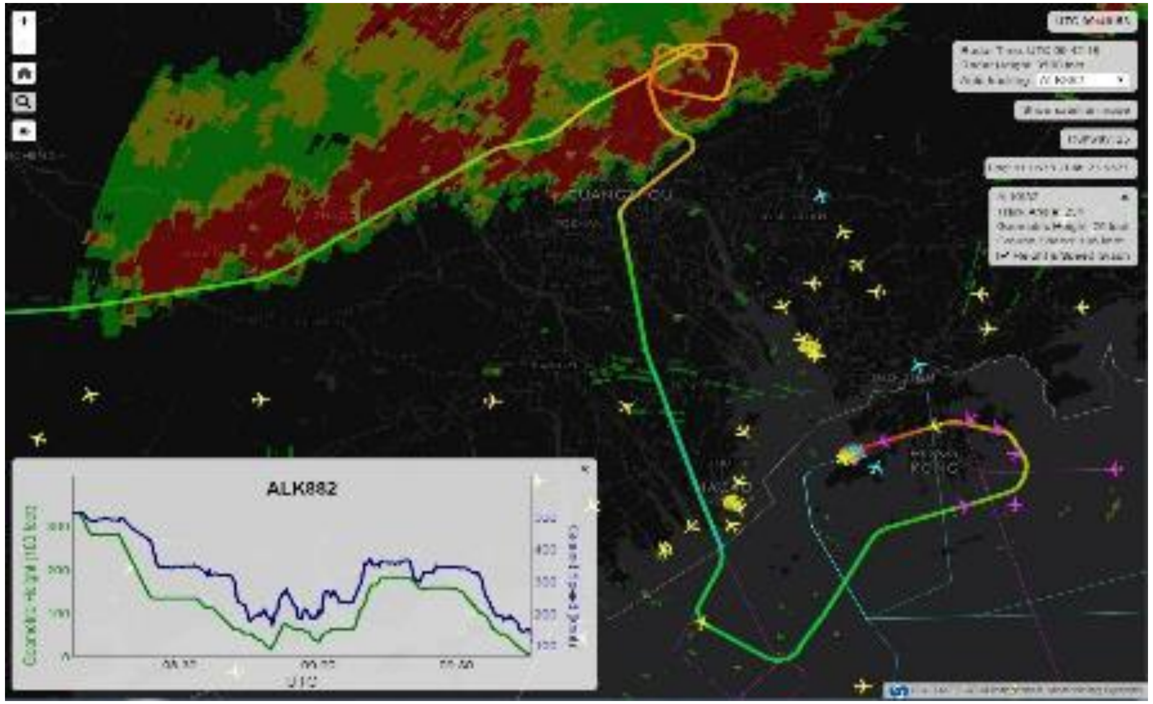
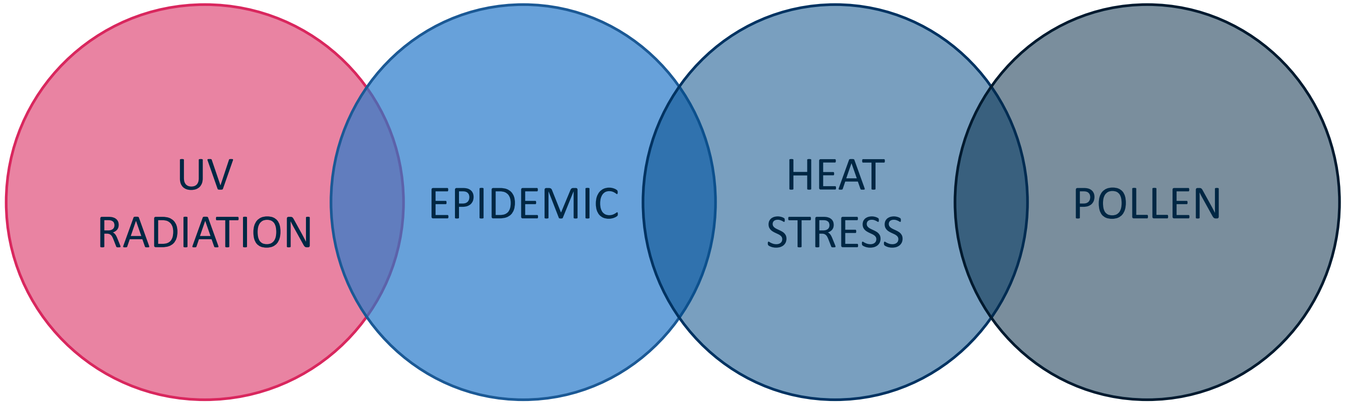
Application of big data – Air traffic

- Hazardous Weather also a crucial factor for air traffic safety and efficiency
  - ➔ reduction of airport and air space capacity, affecting aviation safety
- Avoidance of hazardous weather for safety concern
  - ➔ increase in flight delays, diversion and fuel consumption



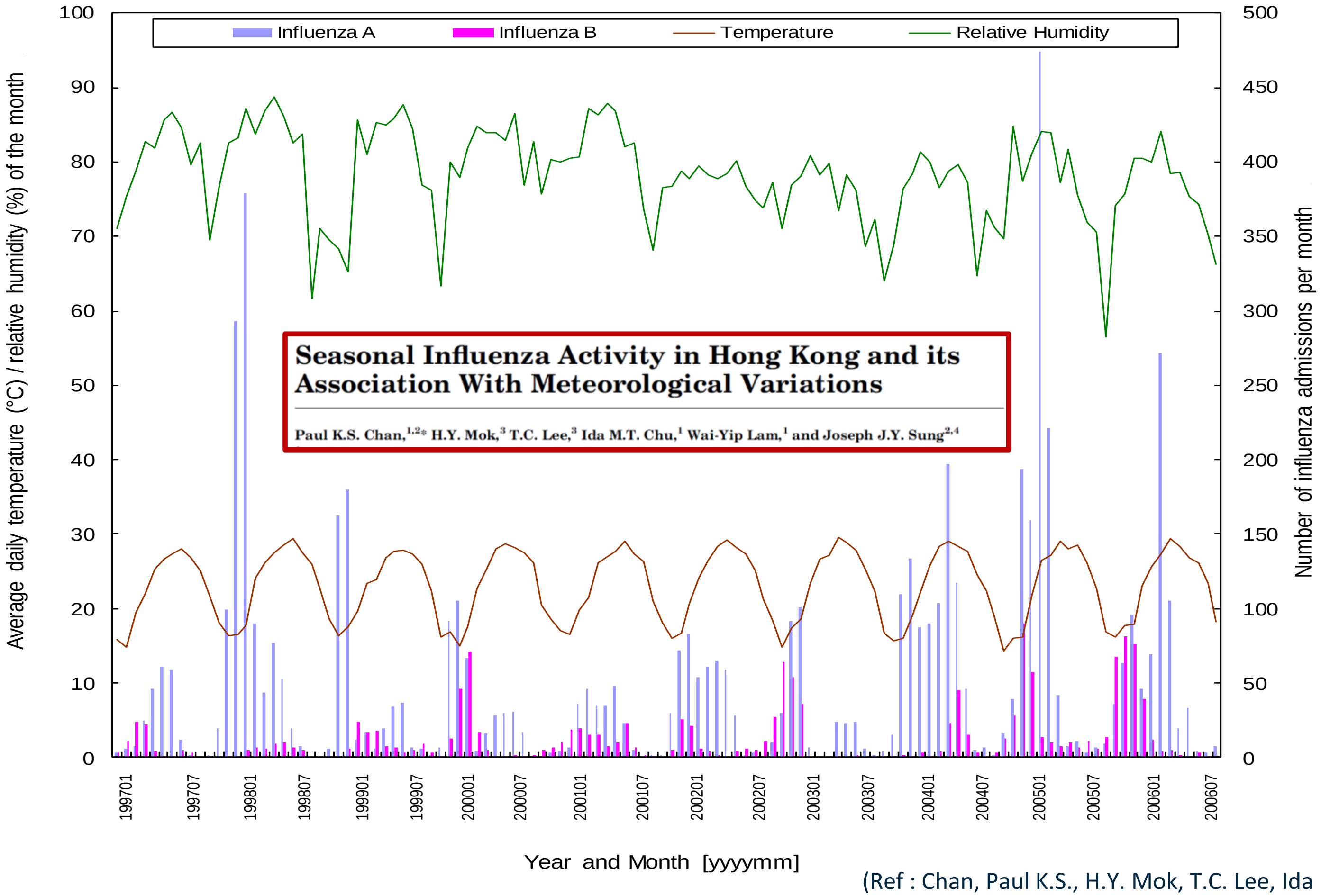
Application of big data – Weather x Health

- Extreme weather & climate change pose genuine threat to public health
- Big data analytics on health & weather data, e.g. heart rate, temperature, RH etc. may help generate personalized advice
- Partnership and data sharing being explored with relevant authorities/private sectors



Application of big data – Weather x Health

- Correlation of weather and influenza



(Ref : Chan, Paul K.S., H.Y. Mok, T.C. Lee, Ida M.T. Chu, W.Y. Lam and Joseph J.Y. Sung, 2009 : Seasonal Influenza Activity in Hong Kong and its Association With Meteorological Variation, Journal of Medical Virology 81:1797–1806)

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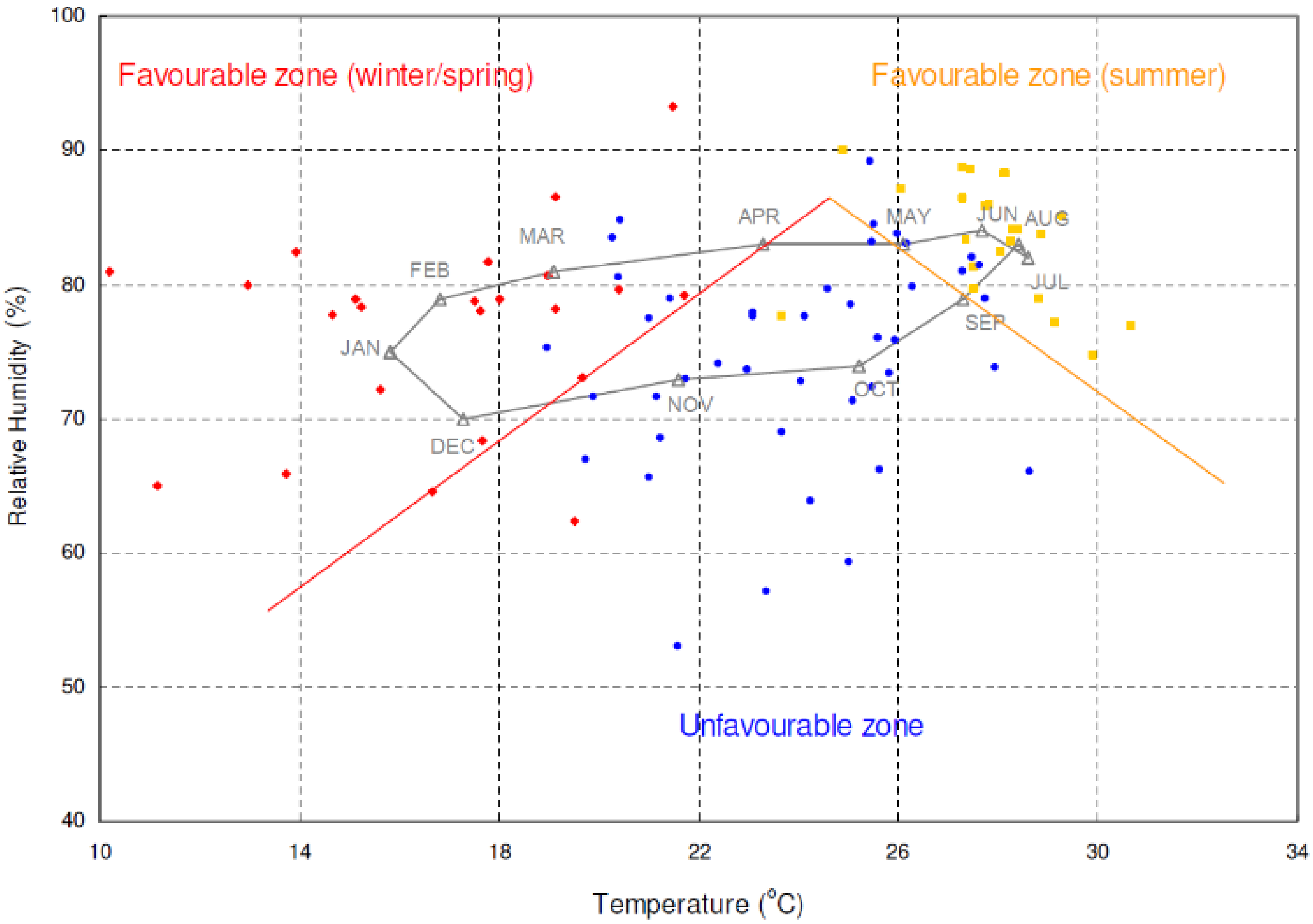
Application of big data – Weather x Health



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Application of big data – Smart weather sensing

Integrated urban weather monitoring and data sharing platform for smart city

Hong Kong Science Museum (LCSD)

Mong Kok Roadside Air Quality Monitoring Station (EPD)

Meteorological measurement (AWMS)

Lamppost type (1)

Measure: Temperature (T)
Relative humidity (RH)

Dimension: ~ 22 cm (Φ) x 25 cm (h)

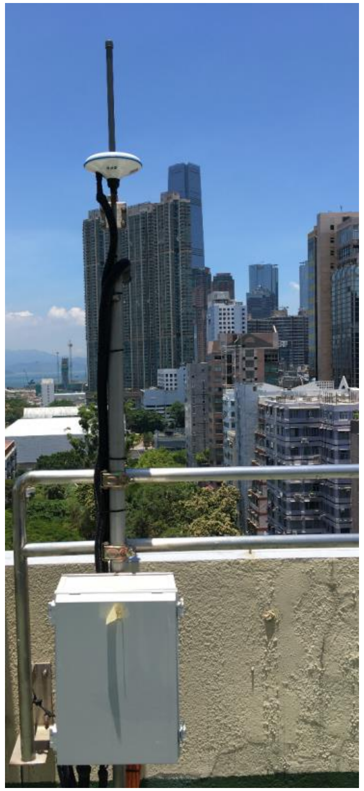
Solar Powered

Lamppost type (2)

Measure: Temperature (T)
Relative humidity (RH)
Wind speed and direction (v_s, v_d)
Rainfall (mm/h)/Solar radiation (W/m^2)

Dimension: ~ 16 cm (Φ) x 35 cm (h)

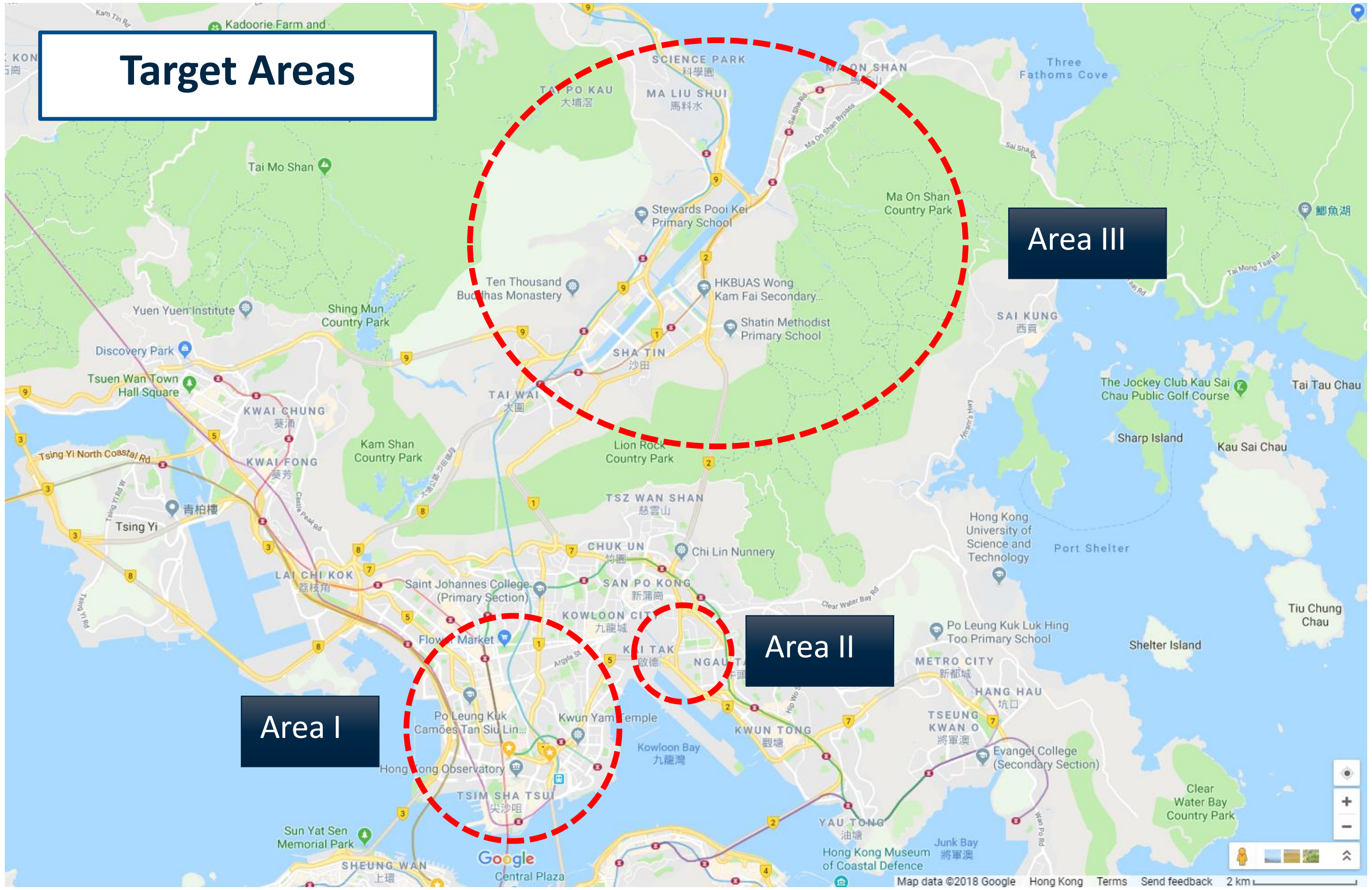
Data communication LoRaWAN



LoRa gateway station

Application of big data – Smart weather sensing

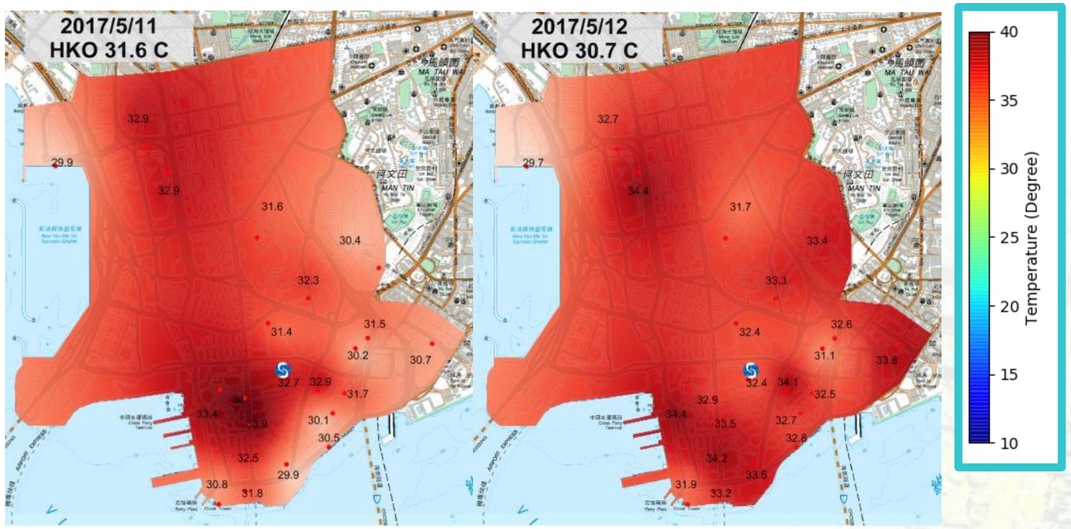
LoRaWAN Network Extension

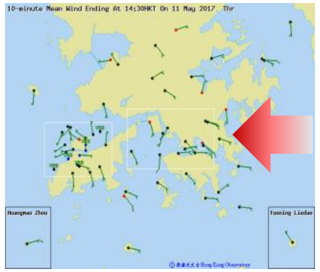


Application of big data – Smart weather sensing

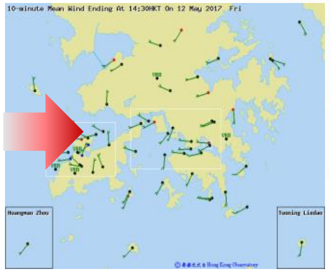
Development of urban-scale forecast and impact-based warnings

Previous study results

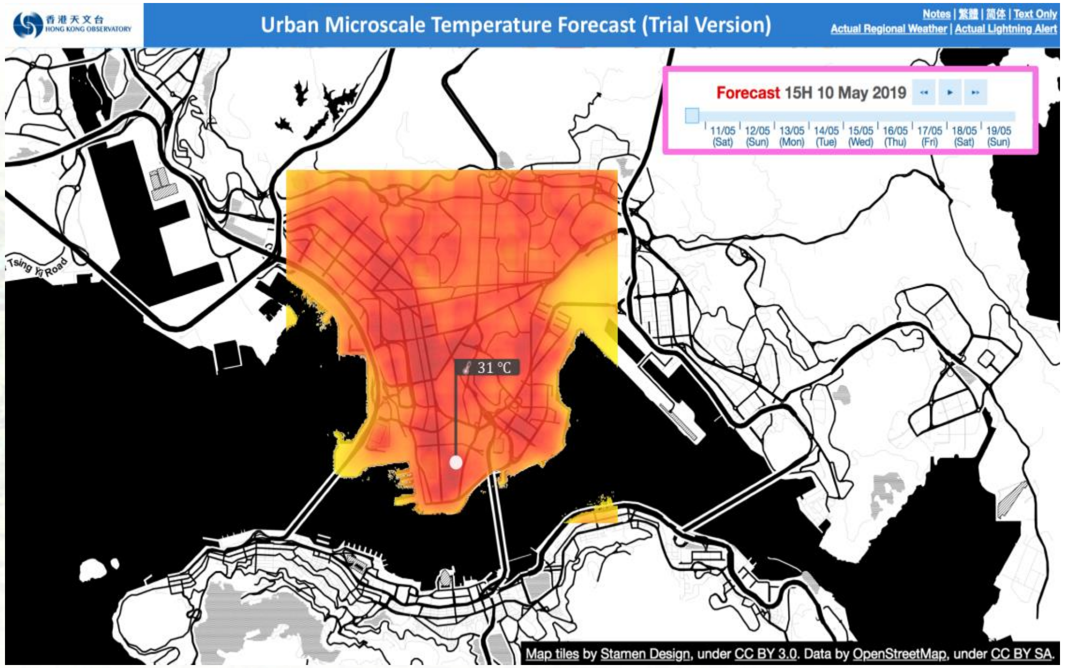




Easterlies



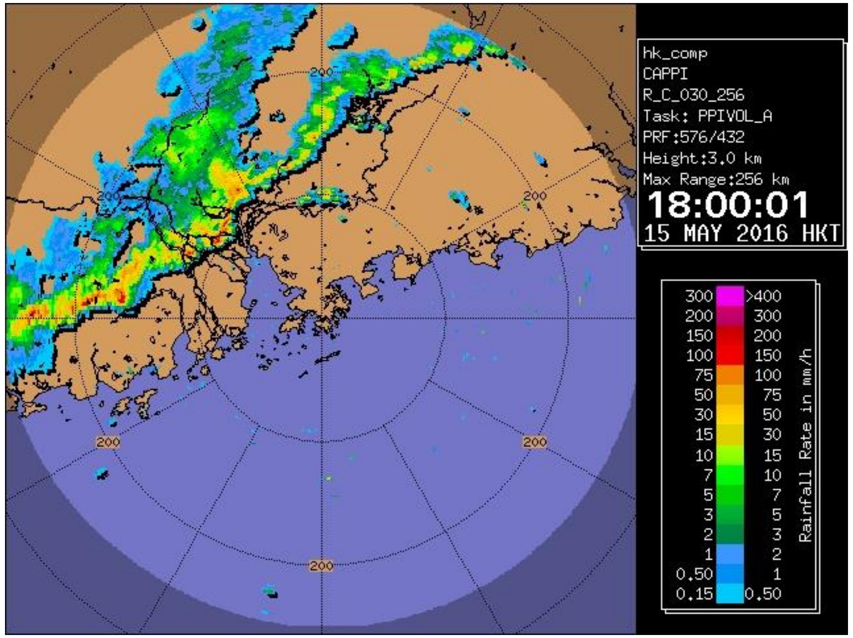
Westerlies



Conclusion

- Emergence of Big Data presents both challenges and opportunities to HKO
- Innovative use of Big Data and AI on both meteorological and non-meteorological data, offers huge potential in enhancing weather services
- Future efforts in developing impact-based weather forecasts will increasingly rely on Big Data and AI technologies

THANK YOU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CAPPI
R_C_030_256
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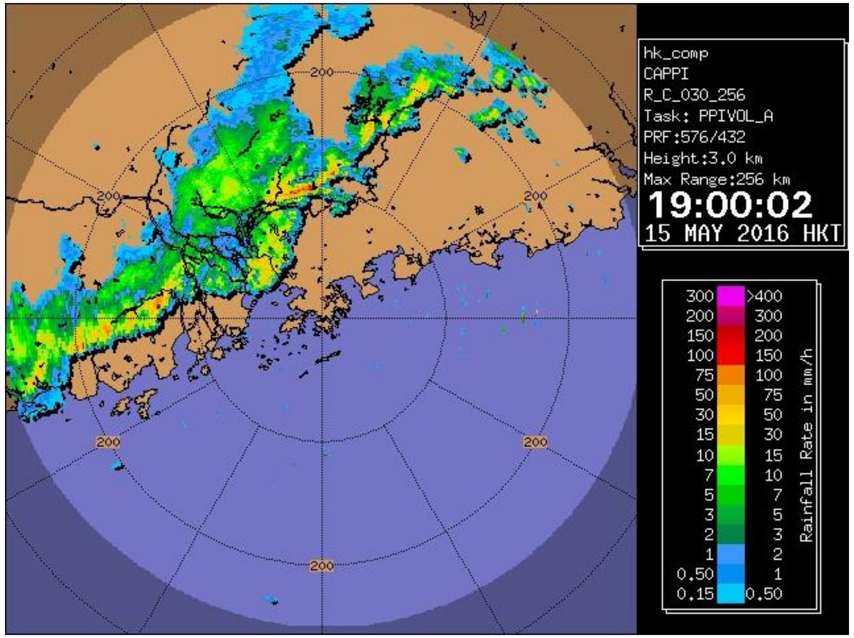
PRF:576/432
Height:3.0 km
Max Range:256 km
18:00:01
15 MAY 2016 HKT
300 >400
200 300
150 200
100 150
75 100
50 75
30 50
15 30
10 15
7 10
5 7
3 5
2 3
1 2
0.50 1
0.15 0.50
Rainfall Rate in mm/h
200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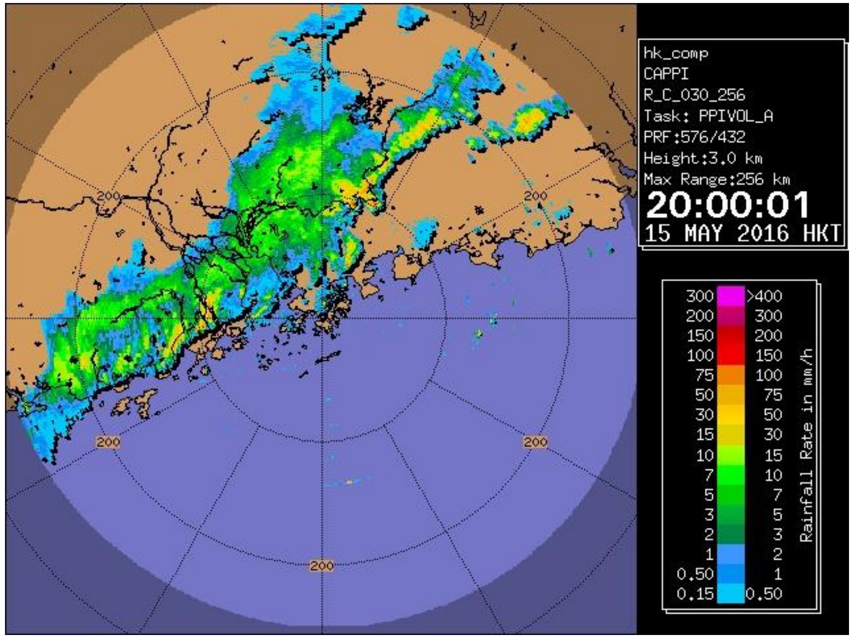
300 >400
200 300
150 200
100 150
75 100
50 75
30 50
15 30
10 15
7 10
5 7
3 5
2 3
1 2
0.50 1
0.15 0.50
Rainfall Rate in mm/h
200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Task: PPIVOL_A
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Height:3.0 km
Max Range:256 km
20:00:01
15 MAY 2016 HKT
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0.50 1
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Rainfall Rate in mm/h
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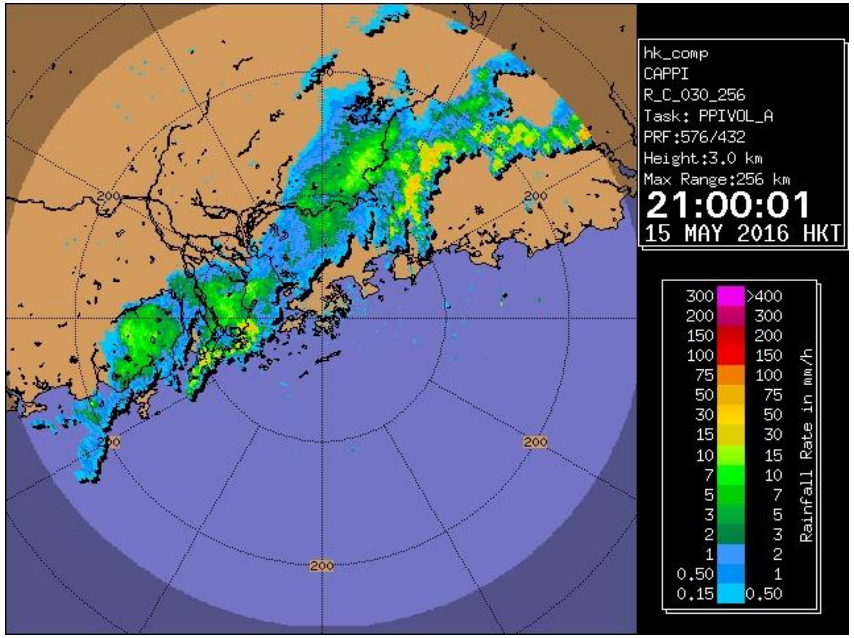
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0.50 1
0.15 0.50
Rainfall Rate in mm/h
200