For discussion
on 18 August 2015

TFWL/04/2015

The Science of Climate Change

PURPOSE

This paper provides an overview of global climate change and its impacts on Victoria Harbour.

GLOBAL CLIMATE CHANGE

2. The Fifth Assessment Report (AR5) of Working Group I of the Intergovernmental Panel on Climate Change (IPCC) [1], the result of a collaborative effort of some 260 climate scientists from 39 countries in the world, re-affirmed the unequivocal warming of the Earth's climate system and concluded that many changes observed since the 1950s were unprecedented over decades to millennia. AR5 also delivered a clear consensus reached by climate scientists worldwide that climate change was induced by human activities.

3. Since the Industrial Revolution, human activities have released more and more greenhouse gases into the atmosphere. The atmospheric concentration of carbon dioxide, the most important greenhouse gas as well as the main driver of global climate change in the last hundred years or so, has increased by over 40 per cent since pre-industrial times. The increase is primarily due to the burning of fossil fuels and secondarily due to deforestation. Present-day concentration of carbon dioxide is the highest in the last 800,000 years according to instrumental records and ice core analyses [2].

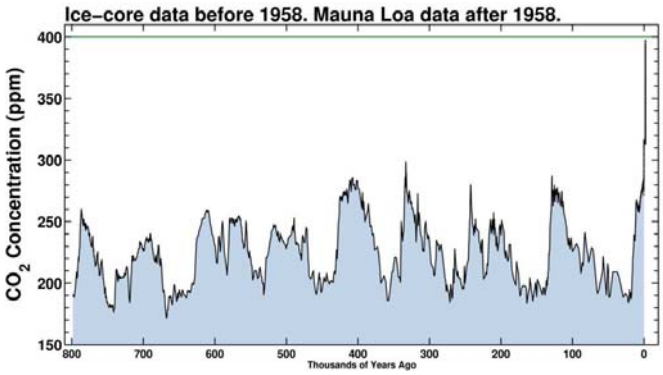

Figure 1 Recent atmospheric carbon dioxide concentration reaching unprecedented level in the past 800,000 years. (Source: WMO [2])

4. As a result of heat trapped by greenhouse gases over decades, almost every corner of the globe has experienced a warming trend throughout the 20th century. The first decade of the 21st century has been the warmest since 1850, and 2014 is the hottest year since the beginning of instrumental records in the mid-19th century [3]. The recent warming is so abrupt that it has totally reversed the long-term cooling trend in the last 5,000 years [4].

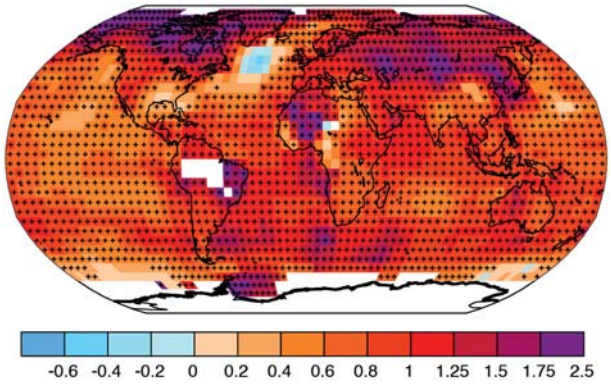

Figure 2 Warming trends during 1901-2012 in °C. (Source: IPCC, 2013 [1])

5. More than just an increase in the average temperature, a warming climate has a number of serious consequences. As the climate normal shifts to the warm side, the odds for extreme heat will correspondingly increase. Studies showed that the risk of heat waves in recent decades, such as the 2003 European heat wave that killed 70,000 people [5], had been enhanced by human-induced warming [6]. A more recent example was the Australian annual temperature in 2013, a record-high since 1910 that would have been impossible to achieve without the greenhouse gases released by human activities according to climate model simulations [7].

6. Ocean warming leads to more evaporation of sea water and releases more water vapour into the atmosphere. A warmer atmosphere has the capacity to hold more water vapour and, combined with an over-heated land surface, will enhance the likelihood of heavy rain. More land areas have experienced an increase in heavy precipitation since the mid-20th century. Extreme rainfall events have become more frequent in a warmer climate. For instance, the United Kingdom and Europe were battered by successive storms in the winter of 2013/2014, with England and Wales having its wettest winter since 1766.

7. More than 90% of the heat trapped by greenhouse gases goes to heating up the oceans. Thermal expansion of sea water and melting of land-based ice and snow will lead to a global sea level rise. The rate of sea level rise since the mid-19th century has apparently accelerated when compared to the mean rate in the previous two millennia. Rising sea level will increase not only the chance of coastal flooding but also accentuate the threat of storm surges brought by cyclones. Unusually high water levels will become a real threat with potential catastrophic consequences when high tides coincide with storm surges.

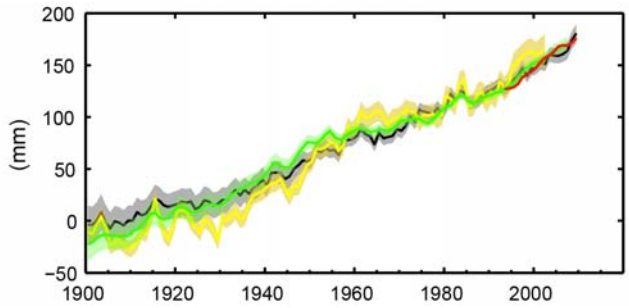

Figure 3 Global average sea level change relative to the 1900-1905 average. Lines or shades (indicating the uncertainty ranges) in different colours represent analyses of different independent datasets (black: Church and White, 2011 [8], yellow: Jevrejeva *et al.*, 2008 [9], green: Ray and Douglas, 2011 [10], red: Nerem *et al.*, 2010 [11]). (Source: IPCC, 2013 [1])

Figure 4 Devastating storm surge associated with Hurricane Sandy in New Jersey, US, in 2012. (Source: Mark C. Olsen, US Air Force)

WHAT THE FUTURE HOLDS

8. AR5 presented projections under various scenarios (in terms of low, medium-low, medium-high, and high greenhouse gas concentration) corresponding to a range of options we have in responding to the climate change challenges. The latest observations of carbon dioxide emission have unfortunately suggested that the world is still moving along the trajectory of a high greenhouse gas concentration scenario, under which global mean temperature is expected to increase by four degrees by the end of the 21st century. With more high temperature extremes and fewer low temperature extremes, it is very likely that heat waves will occur with a higher frequency and persist for a longer duration despite the occasional outbreaks of cold episodes in winter.

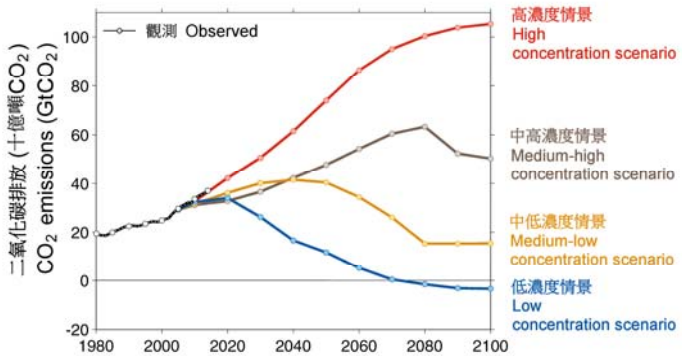

Figure 5 Carbon dioxide emissions associated with different greenhouse gas concentration scenarios shown in coloured lines. Observations are plotted in black. (Source: Global Carbon Project [12])

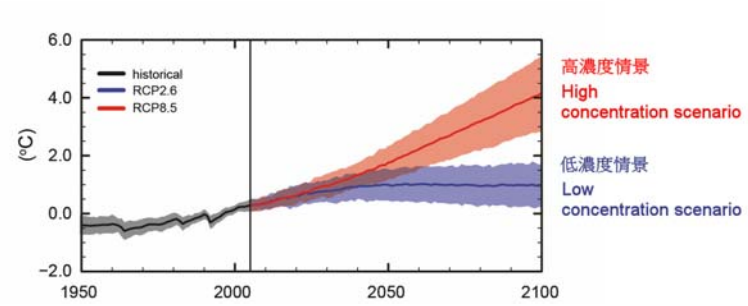

Figure 6 Projected global average surface temperature change (relative to the average of 1986-2005) under the high (red) and low (blue) greenhouse gas concentration scenarios. (Source: IPCC, 2013 [1])

9. In a warmer world, extreme precipitation events will very likely become more intense and more frequent over most of the mid-latitude land masses and over the wet tropical regions by the end of this century. Meanwhile, the risk of drought remains in many parts of the world, with substantial increases expected in the Mediterranean, Central and South America, Australia and southern Africa.

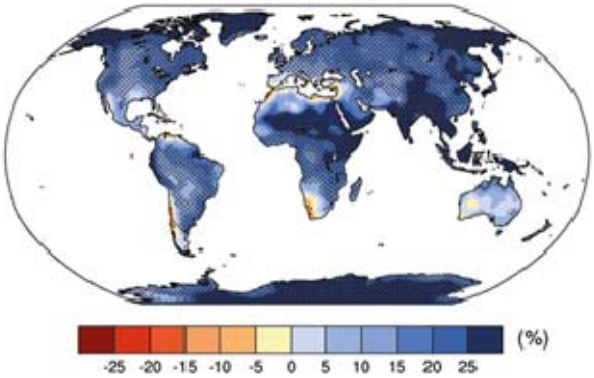

Figure 7 Projected percentage change in annual maximum 5-day precipitation in 2081-2100, relative to 1981-2000, under the high greenhouse gas concentration scenario. (Source: IPCC, 2013 [1])

10. Under the high greenhouse gas concentration scenario, global mean sea level towards the end of this century (2081-2100) is likely to rise 0.45-0.82 m relative to the average of 1986-2005.

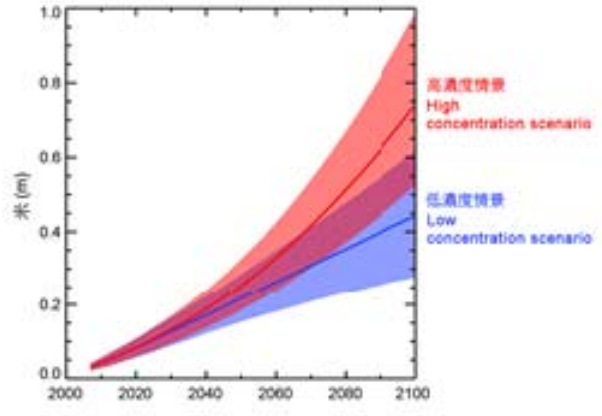

Figure 8 Projected global mean sea level rise relative to the average of 1986-2005 under the high (red solid line) and low (blue solid line) greenhouse gas concentration scenarios. Shaded areas represent the likely range of the projection for the two scenarios. (Source: IPCC, 2013 [1])

OBSERVED CLIMATE CHANGE IN HONG KONG

11. Analysis of the century-long temperature records kept by the Hong Kong Observatory shows that Hong Kong has experienced a significant long-term warming trend. As Hong Kong has become a densely populated city over the past century, the effects of urbanization also play a role in warming up the city and the contribution is estimated to be up to 50% of the warming according to studies conducted by the Observatory [13].

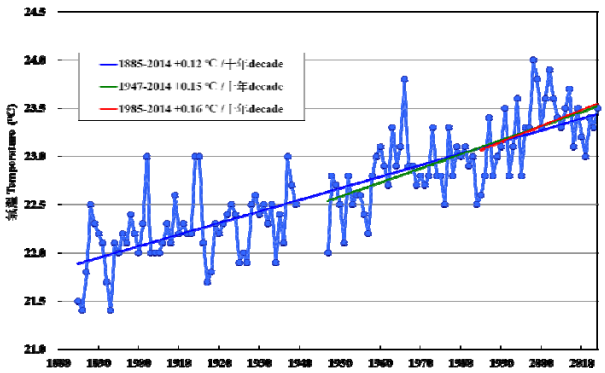

Figure 9 Annual mean temperatures recorded at the Hong Kong Observatory headquarters (1885-2014). Data not available from 1940 to 1946.

12. In line with the global warming trend, the number of hot nights and very hot days in Hong Kong has increased while the number of cold days has decreased. A very cold event of 4°C or

below occurring once in several years in the early 20th century is now very unlikely to recur, while the chance of very hot days with temperatures of 35 °C or above is expected to jump to once in a few years by the early 21st century.

13. Extreme precipitation events have become more frequent. While it used to take several decades to break the record in the past, the hourly rainfall record at the Hong Kong Observatory headquarters was broken quite a few times in the past several decades, and the latest by a significant margin. A more sophisticated analysis of the rainfall data shows that the chance of hourly rainfall of 100 mm or more has doubled over the past century.

14. Tide gauge records in the Victoria Harbour since 1954 show an unambiguous rise of mean sea level during this period. The rising trend was consistent with satellite observations and tide gauge records at other coastal stations in the region.

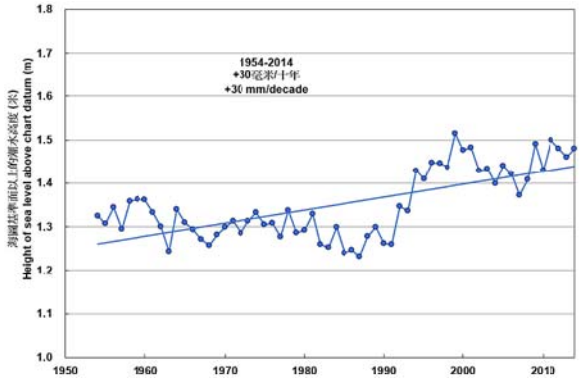

Figure 10 Annual mean sea levels at the Victoria Harbour (1954-2014).

FUTURE HONG KONG IN A WARMING WORLD

15. Under the high greenhouse gas concentration scenario, the annual mean temperature of Hong Kong in the decade 2091-2100 is expected to rise by 3-6 °C relative to the average of 1986-2005, according to projections made by the Hong Kong Observatory based on the AR5 results. With a warming climate, the chance of breaking high temperature records will increase.

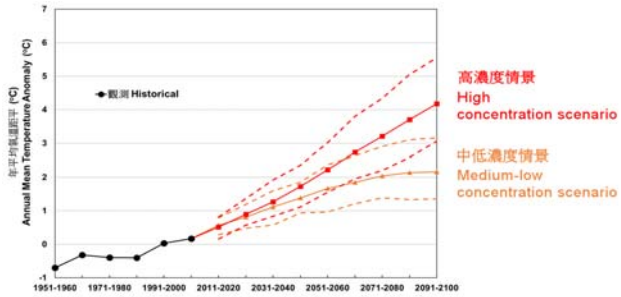

Figure 11 Projected changes in the annual temperatures of Hong Kong relative to the average of 1986-2005 under the high (red) and medium-low (orange) greenhouse gas concentration scenarios (solid lines plot the mean values while dashed lines show the likely range of projection results). Historical observations are plotted in black.

16. Under the high greenhouse gas concentration scenario, the annual number of hot nights (days with a minimum temperature of 28°C or above) and very hot days (days with a maximum temperature of 33°C or above) are expected to increase significantly in the 21st century, while the annual number of cold days (days with a minimum temperature of 12°C or below) is expected to drop. By the decade of 2021-2030, the annual number of hot nights and very hot days would double and triple respectively, compared to the average of 1986-2005.

17. The annual rainfall of Hong Kong in the late 21st century is expected to rise by about 180 mm when compared to the average of 1986-2005 under the high greenhouse gas concentration scenario. Of even more interest, however, is a significant increase in the number of extremely wet years, from three in 1885-2005 to about 12 in 2006-2100. On the other hand, the number of extremely dry years in Hong Kong is expected to remain about the same.

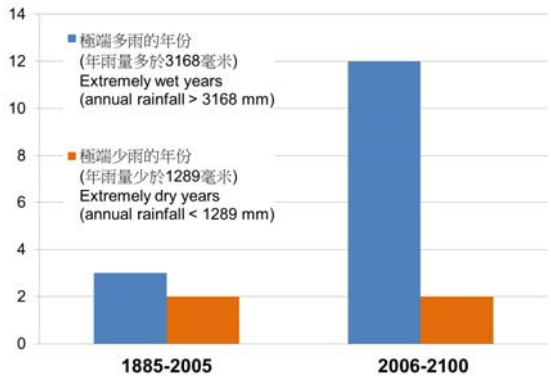

Figure 12 Occurrences of extremely wet (blue) and extremely dry (orange) years in Hong Kong in the past and in the future under the high greenhouse gas concentration scenario.

18. Under the high greenhouse gas concentration scenario, the annual mean sea level in Hong Kong and its adjacent waters in 2081-2100 is expected to rise by 0.63 – 1.07 m relative to the average of 1986-2005 [14].

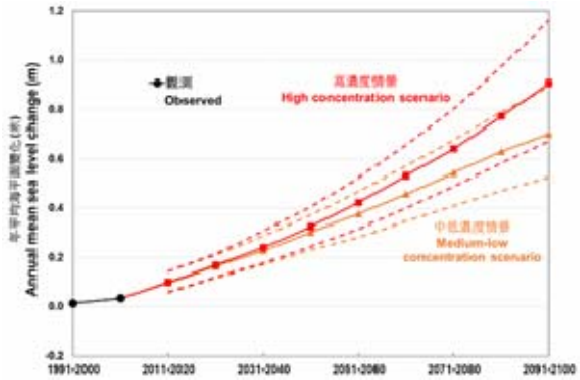

Figure 13 Projected changes in the mean sea level in Hong Kong and its adjacent waters relative to the average of 1986-2005 under the high (red) and medium-low (orange) greenhouse gas concentration scenarios (solid lines plot the mean values while dashed lines show the likely range of projection results). Historical observations are shown in black.

19. With a warming climate, the mean sea level in Hong Kong and its adjacent waters is expected to continue rising for the rest of the 21st century, and the threat of storm surges brought by tropical cyclones will correspondingly increase. A sea level of 3.5 mCD that can cause serious flooding in certain low-lying areas in Hong Kong, such as the one brought by Typhoon Hagupit in 2008, is a 1-in-50 year event today. It would however become a 1-in-5 year to 1-in-10 year event by 2021-2040 regardless of the

greenhouse gas concentration scenario, and a recurrent event every year by the end of the 21st century under the high concentration scenario, assuming that overall tropical cyclone activities in the region remain by and large the same.

SUMMARY

20. The comprehensive assessment made in IPCC AR5 re-affirmed the unequivocal warming of the Earth's climate. Some of the changes observed in the climate system were unprecedented on time scales from decades to millennia. The scientific consensus on the cause of the warming is overwhelming with the abrupt rise in atmospheric greenhouse gas concentration due to human influence pinpointed as the dominant cause.

21. Laws of physics tell us that a warming climate could lead to serious consequences, e.g. more extreme heat, enhanced water cycle bringing more extreme rainfall by and large but more droughts to certain regions, rising seas bringing more coastal flooding and enhancing storm surge threats. Such effects have been emerging in recent decades, and Hong Kong is not immune to the clear and present danger brought by climate change as well as its long-term impact in the future.

Hong Kong Observatory
August 2015

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