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The Latest on Climate Change in Hong Kong

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Abstract

The Hong Kong Observatory has been conducting meteorological observations in Hong Kong for over 120 years. The meteorological data collected over the years serve as an important basis for monitoring the climate change in Hong Kong. Against the background of global warming and urbanization, significant changes in the climate in Hong Kong have been observed, including increased temperature, enhanced rainfall and raised sea level. Studies of past occurrences of extreme temperature and rainfall in Hong Kong revealed that cold episodes are becoming rarer while very hot days and heavy rain events have become more frequent. Looking into the future, Hong Kong can expect even warmer weather, more variable rainfall, and a sea level that keeps rising. In this report, we shall take a look at the latest on the climate changes in Hong Kong and some of their implications to us.

1 Introduction

In recent years, climate change has become a hot topic of discussion globally. In 2007, the Fourth Assessment Report (AR4) of the United Nations Intergovernmental Panel on Climate Change (IPCC) concluded that warming of the climate system is unequivocal and most of the observed increase in globally-averaged temperatures since the mid-20th century is very likely (> 90% certain) due to the observed increase in man-made greenhouse-gas (GHG) concentrations (IPCC, 2007a).

In Hong Kong, since its establishment in 1883, the Hong Kong Observatory (HKO) has been monitoring various weather elements in Hong Kong, including air temperature and rainfall. In respect of monitoring of the sea level, measurements were made by tide gauges installed in Hong Kong since the 1950s. The meteorological and sea-level data collected over the years serve as a basis for studying the climate change in Hong Kong.

HKO has also conducted studies on the possible future trends of temperature and rainfall in Hong Kong and made projections up to the end of the 21st century based on the latest available IPCC assessments of global climate change. The results of the temperature and rainfall projections for Hong Kong in the 21st century offer the scientific basis for further studies on the subject, particularly on the assessment of Hong Kong's vulnerability, and adaptation and mitigation measures in connection with climate change.

In this paper, the latest on the climate changes in respect of temperature, rainfall and sea level in Hong Kong and their possible future trends will be reported. Moreover, some of their implications to Hong Kong will be briefly discussed.

2 Temperature

At the Hong Kong Observatory Headquarters, temperature readings are available since 1885, except for a break from 1940 to 1946 because of the World War II. Analysis of the annual mean temperature data showed that there was an average rise of 0.12°C per decade from 1885 to 2009 (Figure 1). Also, the increase in average temperature has been found to be accelerating since the latter half of the 20th century. As the Observatory is situated at the heart of Kowloon where development has been very active over the past fifty years, the temperature increase can be attributed to both global warming and local urbanization (Leung *et al.*, 2004; Lee *et al.*, 2006; Wu *et al.*, 2008).

Based on the global projections of the IPCC's AR4, Leung *et al.* (2007) conducted a study on the projections for the temperature in Hong Kong in the 21st century. The results depict a significantly warmer climate in Hong Kong in the 21st century with a range of temperature rises depending on the future greenhouse gas emission scenarios and urbanization level (Leung *et al.*, 2007). Against the 1980-1999 average of 23.1^{o}C, the annual mean temperature in Hong Kong in the decade 2090-2099 is expected to rise by about 4.8^{o}C with a range of 3.0 and 6.8^{o}C for the low and high end respectively.

Such an increase should not be dismissed, if we consider the knock-on effects of global warming, which include those on ecology, communicable and vector borne diseases (Chan *et al.* 2009), thermal stress (Leung *et al.* 2008), further use of energy for space cooling, and stress on crops and farming because of warming on the global scale (IPCC, 2007b).

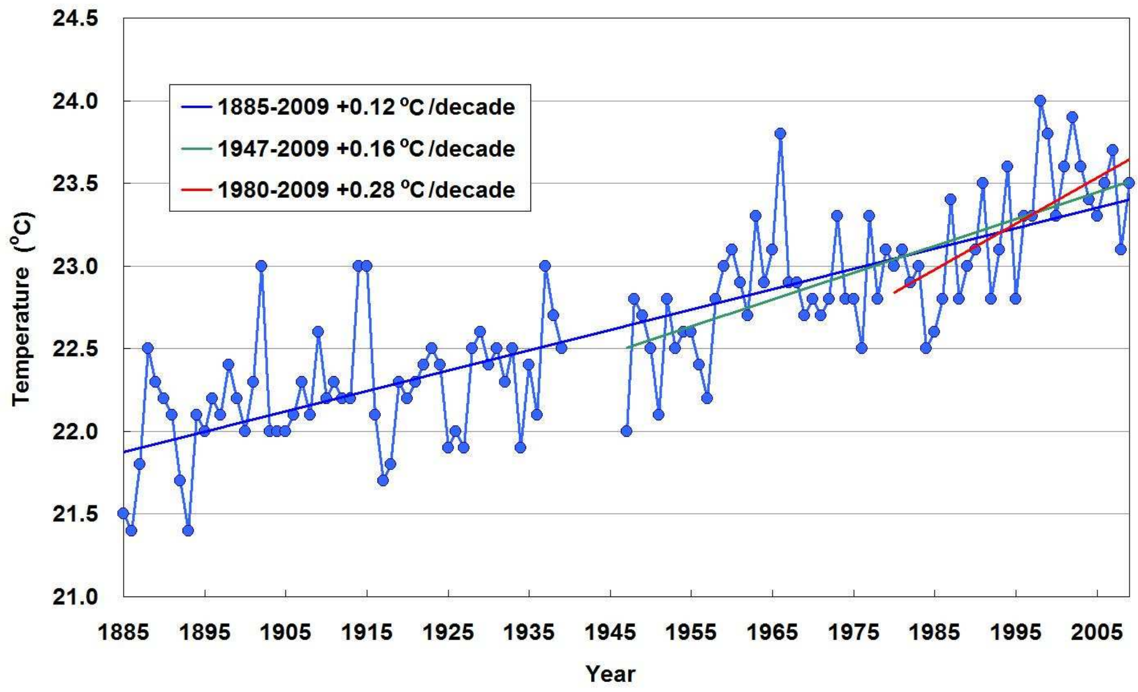

Figure 1 Annual mean temperature recorded at the Hong Kong Observatory Headquarters (1885-2009). Data are not available from 1940 to 1946 because of the World War II.

3 Rainfall

The annual rainfall recorded at the Hong Kong Observatory from 1884 to 2009 also showed a long term increasing trend, at a rate of about 25 mm per decade (Figure 2).

In respect of rainfall projection for Hong Kong based on results of IPCC AR4, the average annual rainfall is expected to increase by about 11% by the end of this century (Figure 3, Lee *et al.*, 2009). However, the projection also shows a decrease of up to 5% over the next few decades, till 2040s. This may, to a certain extent, reflect a possible decadal change in the rainfall of Hong Kong. The latter is consistent with the past trend and has generally been captured by some of the model projections.

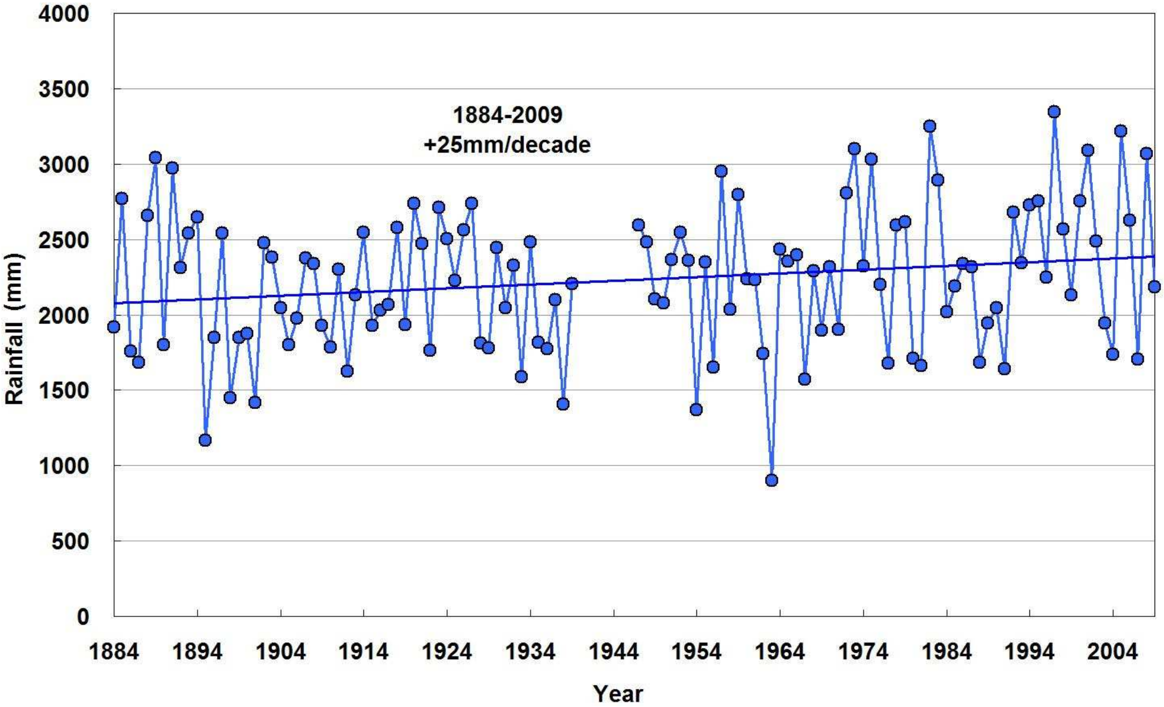

Figure 2 Annual rainfall recorded at the Hong Kong Observatory Headquarters (1884-2009). Data are not available from 1940 to 1946 because of the World War II..

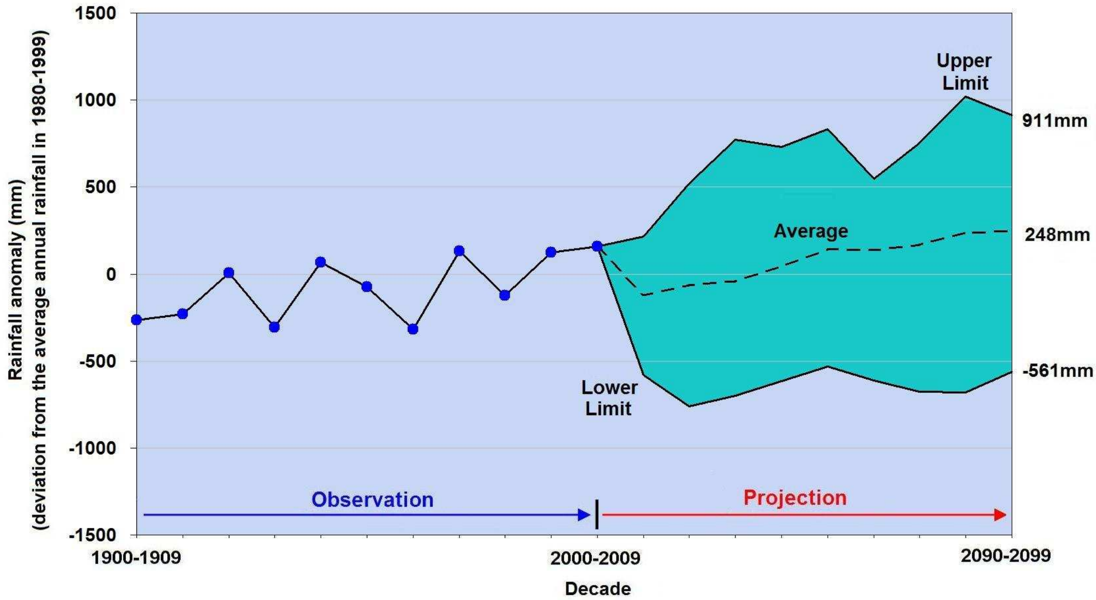

Figure 3 Past and projected change in annual rainfall for Hong Kong

This decrease in rainfall over the next few decades is of immediate concern, as it is set against increases in water consumption projected for both Hong Kong and Guangdong in south China. About 70% to 80% of fresh water supply in Hong Kong comes from Guangdong. While Hong Kong's water demand is expected to increase from about 950 million cubic metres (mcm) to 1300 mcm by 2030

(Water Supplies Department, 2007), Guangdong has its own anticipated growth and development which will create an increase in water demand from the present 46 billion cubic metres (bcm) to 52 bcm by 2020 (Water Resources Department of Guangdong Province, 2008; People's Government of Guangdong Province, 2007). So where will the water come from?

Unfortunately, despite the best intentions saving water in the city is not enough. We drink only a couple of litres a day, and the total daily use may be about 200 litres per capita. In comparison, it takes more than 10 000 litres to produce a kilogram bolt of cloth. The food we eat each day requires 2 000 to 5 000 litres to produce. It takes 15 000 litres to produce a kilogram of beef, compared with 2 000 litres for a kilogram of vegetable. The demand for water will grow further as the world gets richer, because affluence means that people are eating more meat.

So what can we do? A simple answer is to find ways to collect more water. After all, we are only extracting for our own use less than 10% of precipitation in the world. There are many ways. Examples include: more reservoirs and dams, but these may have ecological effect; more recycling and de-salination, but all these involve costs. One useful suggestion is to increase the water efficiency in agriculture which currently uses up 75% of the world's water. The amount of water required for growing meat (15 000 litres/kg), and for that matter growing vegetable (2 000 litres/kg), shows considerable room for improvement itself (*The Economist*, 2009). At the individual level we can also do our part to save water. It only involves a simple switch in lifestyle --- make sure we wear our clothes many times before disposal, and more importantly, gradually change our eating habit to less meat and more vegetable. It is healthier too.

4 Extreme temperature and rainfall

Besides the shifting of the mean temperature and total rainfall, climate change could also alter the frequency of extreme temperature and rainfall, resulting in significant socio-economical impacts (Frich *et al.*, 2002, WMO, 2009).

Using statistical analysis, Wong *et al.* (2009) studied the changes of extreme weather events in Hong Kong for the past 120 plus years. The results indicate that the intensity and frequency of occurrence of extreme events have a general rising trend. In 1900, an hourly rainfall of 100 millimetres or above corresponded to a return period of 37 years, but by 2000, this has shortened to 19 years. Thus, in 100 years' time, the occurrence of heavy rain has nearly doubled. In respect of temperature, the return period for a maximum temperature of 35 degrees Celsius has shortened from 34 years in 1900 to 5 years in 2000. On the other hand, the return period for a minimum of 4 degrees Celsius, has increased from 6 years to 150 years. In other words, days with extremely high temperatures have become more frequent while those with extremely low temperatures have become more infrequent.

5 Sea level rise

Observations since the 1960s show that the average temperature of the global ocean has increased to depths of at least 3000 metres, contributing to sea-level rise through thermal expansion of the sea water (IPCC, 2007a; Gouretski and Koltermann, 2007). Other contributions to sea-level rise include the loss of mountain ice (glaciers and snow cover) and land ice (e.g. Greenland), which transferred volumes of land water to the sea.

In Hong Kong, tide gauge records indicate the mean sea-level in the Victoria Harbour has risen about 14 cm (or an average rate of about 2.6 mm per year) during the period 1954 to 2009. The trend is similar to that observed by satellite remote sensing over the South China Sea since the early 1990s as well as on tide gauge records at other coastal stations in the region (Wong *et al.*, 2003).

Projected warming due to emission of greenhouse gases during the 21st century will continue to contribute to sea-level rise because of thermal expansion and loss of mountain and land ices. According to IPCC's AR4, the global sea level is projected to rise by up to 0.59 metre by the end of this century compared with that at the end of the last century (IPCC, 2007a). This is based on the projections provided by numerical climate models which have successfully explained the global sea-level rise observed in 1993-2003.

Over the past few years, both Greenland and the Antarctic were found to be losing ice mass (land ice) at a much faster rate (Guðfinna Aðalgeirsdóttir, 2008; Rignot *et al.*, 2008; Velicogna, 2009). The numerical climate models mentioned earlier on did not include ice flow dynamical processes which are responsible for the observed ice mass loss in Greenland and the Antarctic as the mechanism of these processes are not fully understood. IPCC's AR4 estimated that if contributions from such land ice masses were to grow linearly with the global average temperature change, the sea level is estimated to rise by a further 0.1 to 0.2 metre. Further, a recent study suggested that glacier melt alone (excluding the Greenland and Antarctic ice sheets) may raise the sea level 0.1 to 0.25 metre by the end of the 21st century (Meier et al., 2007), which is higher than the prediction in IPCC's AR4.

Other attempts to estimate the future sea-level rise include a recent study that relates the global average sea-level to temperature. By establishing a correlation between these two physical quantities for the past 120 years, the projection gives a maximum sea-level rise of 1.4 metres by the end of the 21st century (Rahmstorf, 2007). Worse still, some other researchers pointed out that lubrication of glaciers by melt water would constitute multiple positive feedbacks for the future and raise the upper bound of sea-level rise to 2 metres (Pfeffer *et al.*, 2008). On the basis of these more recent studies, it now looks likely that the sea-level rise estimates given in IPCC's AR4 may be conservative. In other words, the global sea level may rise by much more than 0.59 metre above that of the last century.

In Hong Kong, a major impact of sea level rise would be a possible increase in frequency and scale of sea flooding from storm surge brought about by tropical cyclones. For tropical cyclones that came close to Hong Kong, the associated storm surges would typically raise the sea level by 0.5 to 1.0 metre. This is high enough to cause sea flooding if the storm surge occurs near the astronomical high tide. Well-known cases of serious sea flooding due to storm surges in the past 50 years include Typhoon Wanda in 1962 and Typhoon Ellen in 1983. The most recent cases of inundation due to storm surges were caused by Typhoon Hagupit and Typhoon Koppu in 2008 and 2009 respectively.

Take thermal expansion of sea water as an example, which is a major contributor to sea-level rise in the past. IPCC AR4 projection in respect of thermal expansion alone is 0.41 metre by the end of this century. What does this mean for Hong Kong? Here are some figures on the return period of storm surges after a rise of 0.41 metre in the sea level :-

Table 1 : Magnitude of extreme sea levels at Victoria Harbour based on past data and a projected rise of 0.41 m (due to thermal expansion of seawater alone)

Extreme sea-level at Victoria Harbour		
Return period (year)	Extreme sea-level (mCD) based on past data	Extreme sea-level (mCD) after a mean sea-level rise of 0.41 m
2	2.9	3.3
5	3.1	3.5
10	3.3	3.7
20	3.4	3.8
50	3.5	4.0

Note: mCD = metres above Chart Datum.
Chart Datum is 0.146 metre below Principal Datum.

Thus, a rise of 0.4 m in the sea level in Hong Kong would turn a 50-year storm surge (about 3.5 metres above chart datum (mCD)) into a 5-year event.

With anticipated further rise in the mean sea-level during this century, sea flooding events in Hong Kong would become more frequent. A repeat of Typhoon Wanda would be unimaginable, because a raised mean sea level increases the chance and severity of coastal sea flooding. The magnitude of extreme sea levels in the Victoria Harbour based on past data, a projected rise in sea level of 0.59 metre (IPCC AR4 projection) and of 1.4 metres (projection by Rahmstorf (2007)) have been computed for different return periods. The results are presented in Table 2. They indicate that a rise of 0.59 m in the sea level in Hong Kong would turn a 50-year storm surge (about 3.5 metres above chart datum (mCD)) into a biennial event. With a projected sea-level rise of 1.4 metres, even a spring tide occurring in ordinary times (about 2.5 metres above CD, occurring about twice a month) would be enough to result in the record high brought by Typhoon Wanda in 1962 (about 3.96 mCD).

Table 2: Magnitude of extreme sea levels at Victoria Harbour based on past data, a projected rise of 0.59 m and of 1.4 m.(Lee *et al.*, 2010)

Extreme sea-levels at Victoria Harbour			
Return period (year)	Extreme sea-level (mCD) based on past data	Extreme sea-level (mCD) after a mean of sea-level rise of 0.59 m	Extreme sea-level (mCD) after a mean of sea-level rise of 1.4 m
2	2.9	3.5	4.3
5	3.1	3.7	4.5
10	3.3	3.8	4.7
20	3.4	4.0	4.8
50	3.5	4.1	4.9

Note: mCD = metres above Chart Datum.
Chart Datum is 0.146 metre below Principal Datum.

6 Summary

Against the background of global warming and urbanization, Hong Kong has experienced raised temperatures and enhanced rainfall over the past 125 years. There was also an observed rise of the mean sea level in the past half century. Studies of the past records of extreme temperature and rainfall in Hong Kong revealed that cold episodes have become rarer while very hot days and heavy rain events are becoming more frequent. Looking into the future, Hong Kong can expect even warmer weather, more variable rainfall, and a sea level that keeps rising. Further rise in the sea level will exacerbate storm surges during the passage of typhoons, with disastrous results. Adaption and mitigation measures are necessary.

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