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The Latest on Climate Change in Hong Kong and its Implications for the Engineering Sector

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THE LATEST ON CLIMATE CHANGE IN HONG KONG AND ITS IMPLICATIONS FOR THE ENGINEERING SECTOR

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Abstract

Scientific studies to evaluate the observed climate trends in Hong Kong due to global warming and urbanization effects using the meteorological records of Hong Kong for the past 125 years have been carried out. Significant changes in the climate in Hong Kong were observed since the last century, including rising temperature and increasing rainfall. In particular, analysis of past extreme rainfall observations in Hong Kong revealed that heavy rain events have become more frequent. The annual total precipitation due to extreme rainfall events has also increased in the same period, indicating the increasing contribution of heavy rain to the annual rainfall. Looking into the future, Hong Kong can expect even warmer weather and more variable rainfall. In this report, we take a look at the latest on the climate changes in Hong Kong and some of their implications for the engineering sector.

Keywords

Climate Change, Global Warming, Extreme Rainfall, Hong Kong

1 Introduction

Rapid development of economic and industrial activities since the 18th century has led to much increased use of energy and resources. The rise in anthropogenic (i.e. human-induced) greenhouse gas concentrations in the atmosphere, including in particular the burning of fossil fuels, enhances the greenhouse effect and alters the Earth's energy balance. 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, i.e. more than 90% certain, due to the observed increase in man-made greenhouse gas (GHG) concentrations [IPCC, 2007].

Besides the rising temperature, climate change would also lead to global sea level rise, changes in hydrological cycles, and more frequent extreme weather events such as heat waves and heavy rain. All these changes in the climate could have implications on the operation and engineering design of our infrastructures.

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. Over the years studies have been carried out on the possible trends of temperature and rainfall in Hong Kong and projections have been made to the end of the 21st century based on the latest available IPCC assessments of global climate change.

This paper reports the latest on the climate changes in respect of temperature and rainfall in Hong Kong and their possible future trends, and discusses some of their implications for the engineering sector.

2 Temperature

Analysis of the temperature records at the HKO Headquarters showed that there was a significant rising trend (0.12 °C per decade) in the annual mean temperature from 1885 to 2009 (Figure 1). Specifically, the annual mean temperature rose from 22.0°C in the late 19th century (1891 - 1900) to 23.5°C in the past 10 years (2000-2009). In fact, the increase in temperature has been 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 degree of urbanization. Against the 1980-1999 average of 23.1°C, the annual mean temperature in Hong Kong in the decade 2090-2099 is expected to rise by about 4.8°C with a range of 3.0 and 6.8°C for the low and high end respectively.

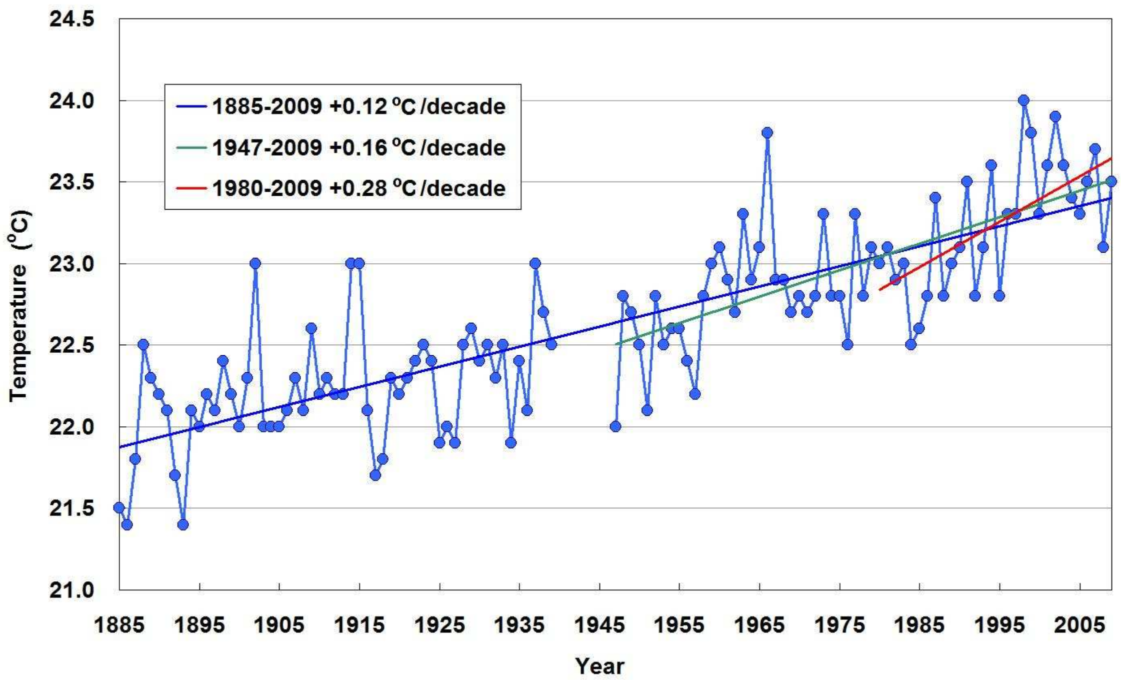

Figure 1 Annual mean temperature recorded at the Hong Kong Observatory Headquarters (1885-2009). Data are not available from 1940 to 1946 because of the World War II.

One of the possible impacts of increasing temperature is on the use of energy for space cooling as air-conditioning is the largest end-use in electricity in Hong Kong, accounting for about 34% of all electricity consumption in both domestic and commercial sectors.

In this regard, a climatic index, namely the cooling degree-day (CDD), which indicates how often and to what extent cooling will be required during a particular period, has been widely used to assess the climate influence on cooling energy consumption in subtropical climate [Lam, 1995]. Here, CDD is defined as the annual total of the differences between a reference temperature of 26.0 °C and the daily mean outside temperature for days with daily mean outside temperature above 26.0 °C [The Ministry of Housing and Urban-Rural Development, China, 2005].

Figure 2 shows the variation in the total CDD for Hong Kong from 1885 to 2009. An increasing trend was observed (statistically significant at 5% level). This trend was in line with the observed increase in the mean temperature in Hong Kong over the same period. As pointed out in the study by Lee et al. [2010], there is a statistically significant positive correlation between CDD and the electricity consumption per capita for both the domestic and commercial sectors in Hong Kong. The projected increase in the mean temperature implies a significant increase in CDD in the 21st century. Such an increase in CDD may have implications on the future energy demand for cooling if the current energy consumption pattern does not change.

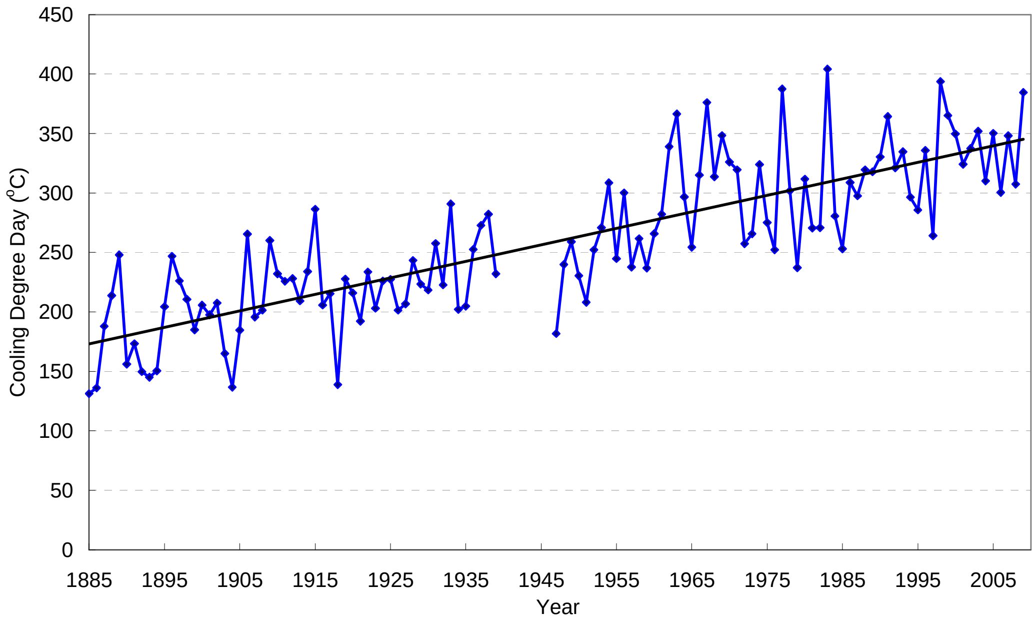

Figure 2 Time series of Cooling Degree-Day in Hong Kong (1885 -2009)

The rise in energy demand will exacerbate the impact of global warming. To combat this threat, it is apparent that renewable energy should be widely encouraged through the use of appropriate technologies. Of the various forms of renewables, solar and wind energy come out on top for Hong Kong, which has a sub-tropical climate and is gifted with plenty of sunlight as well as monsoon winds by virtue of its location along the south China coast.

A recent study to assess the potential of wind and solar energy resources in Hong Kong [Lee and Mok, 2010] indicated that both wind and solar energy are abundant in Hong Kong (Figures 3 and 4). For wind energy, a high wind energy potential is possible in such exposed places as hilltops and offshore waters. However, there are policy and other constraints. On the other hand, solar energy has the potential for more widespread application to buildings in Hong Kong through the use of devices such as PV panels and solar thermal collectors. According to the Stage 1 Study Report of “Study on the Potential Applications of Renewable Energy in Hong Kong”, the total surface areas of residential, public rental housing, commercial and industrial buildings and government, institution and community facilities in Hong Kong is about 93 km^2 [Electrical and Mechanical Services Department, 2002]. Assuming that 30% of this area (about 28 km^2), mainly on the rooftop of the buildings, can be used for installing PV-type solar panels of 20% efficiency at the optimal orientation (120^o) and tilting angle (40^o), the annual total solar thermal energy that can be collected will be about 24 TJ per day, or 5.4% of total electricity consumption in Hong Kong.

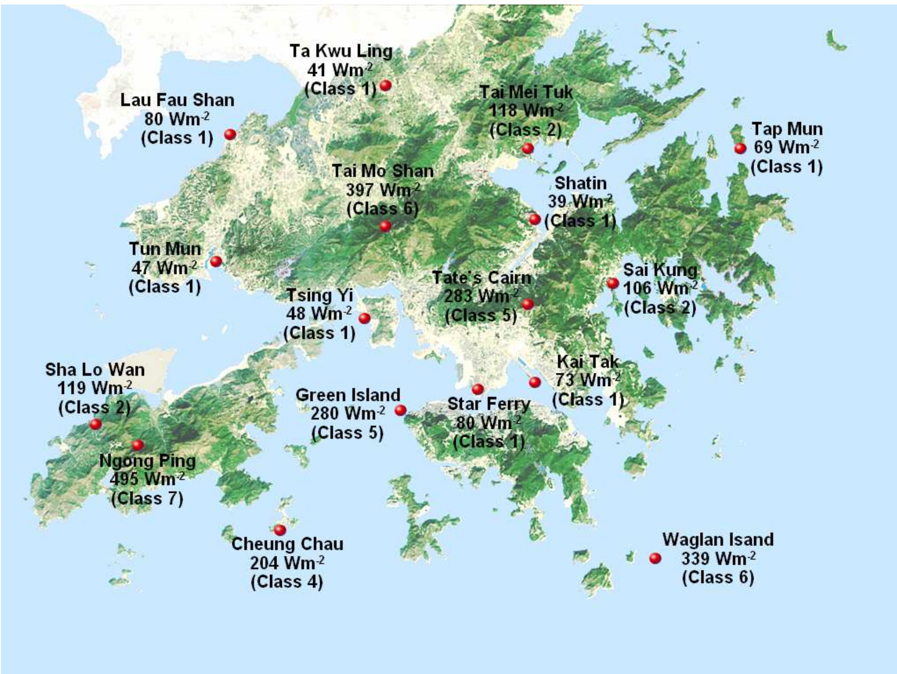

Figure 3 Distribution of mean wind power density in Hong Kong (Wind power class in brackets). It is considered that sites with *WPD* of Class 3 or higher are suitable for utility-scale wind power applications, whereas Class 4 or higher is preferred for large-scale wind farms (AWEA, 1995).

Figure 4 Average daily direct solar radiation levels to be received by a surface mounted at an optimal orientation of 120^{o} and tilting angle of 40 ^{o}, based on measurements at King's Park Meteorological Station, 2009.

3 Rainfall

The annual rainfall recorded at the Hong Kong Observatory from 1884 to 2009 shows a long term increasing trend, at a rate of about 25 mm per decade (Figure 5).

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 6, Lee et al., 2008). However, the projection also shows a decrease of up to 5% over the next few decades, till 2040s. This reflects, to a certain extent, a possible decadal change in the rainfall of 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?

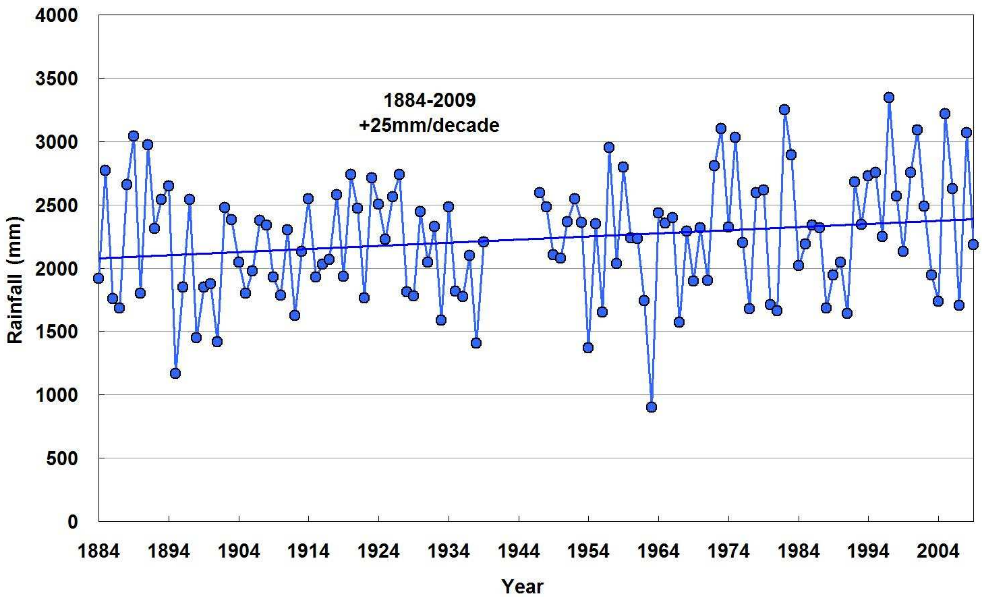

Figure 5 Annual rainfall recorded at the Hong Kong Observatory Headquarters (1884-2009). Data are not available from 1940 to 1946 because of the World War II.

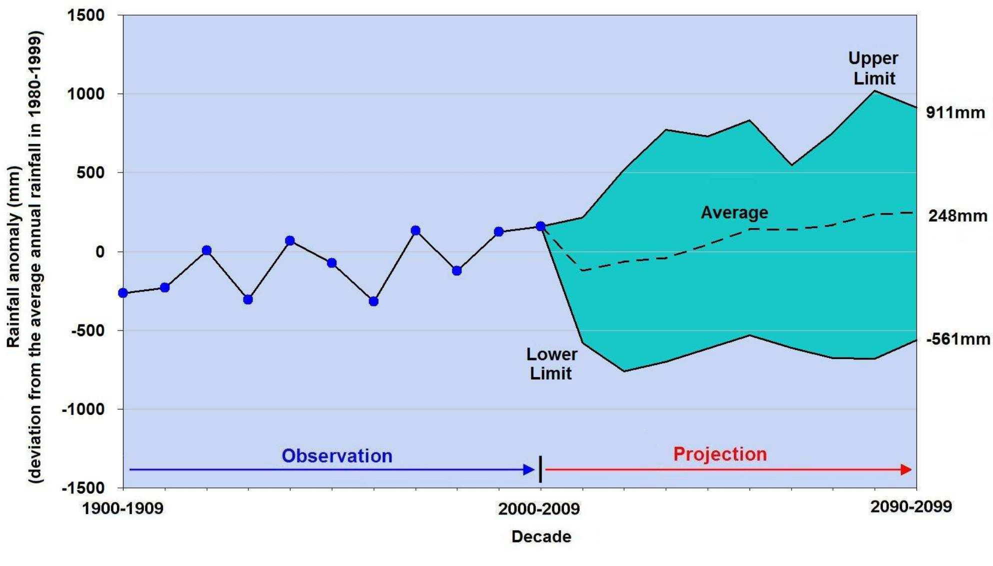

Figure 6 Past and projected change in annual rainfall for Hong Kong

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 is 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? There are three practical ways. The first, obviously, is to save water, which also saves energy as tap water takes energy to purify and transport. The second is to change our 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, which is healthier too. The third is to impress upon people the importance of efficiency in the use of water. Agriculture currently uses up over 70% of the world's water, and the figures above in respect of the amount of water used to grow cotton, vegetable and meat tell us that there is a lot of room for improvement.

4 Extreme rainfall events

Besides changes in the rainfall, climate change could also alter the frequency of occurrence and severity of extreme rainfall events, resulting in significant socio-economical impacts [Frich et al., 2002, WMO, 2009].

Using statistical analysis, Wong and Mok [2009] have studied the changes of extreme rainfall events in Hong Kong for the past 120 plus years. The results indicate that the intensity and frequency of occurrence of short-term heavy rain events in terms of 1- to 3-hourly rainfall 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. Table 1 shows examples of changes in the return periods of 1-hour, 2-hour and 3-hour rainfall from 1900 to 2000.

Let us now look at how heavy rain contributes to the total rainfall. If we define *R95p* as the annual total rainfall at the Hong Kong Observatory due to events exceeding the daily 95th percentile of the climatological normal (which is taken as the average annual total rainfall at the Hong Kong Observatory from 1971 to 2000 [Lee et al., 2006]), simple linear regression technique shows that *R95p* increased significantly by about 21 mm per decade from 1885 to 2009 (Figure 7). Moreover, if we define consecutive dry days as the annual maximum length of dry spell counting the maximum number of consecutive days with daily rainfall less than 1 mm during the period between April and September (the rainy season of Hong Kong), they also increased significantly (at the 5% level) at a rate of about 0.36 days per decade from 1885 to 2009. The results reveal that both the contribution of heavy rain to the yearly total and the period of consecutive dry days in the rain season increased with time.

Table 1 Return periods of 1-hour rainfall of 100 millimetres or above, 2-hour rainfall of 150 millimetres or above and 3-hour rainfall amount of 200 millimetres or above in 1900 and 2000 [Wong and Mok, 2009]

Extreme rainfall events	**Return Periods (year)**	
	in 1900	**in 2000**
1-hour rainfall >= 100 mm	37	18
2-hour rainfall>= 150 mm	32	14
3-hour rainfall>= 200 mm	40	21

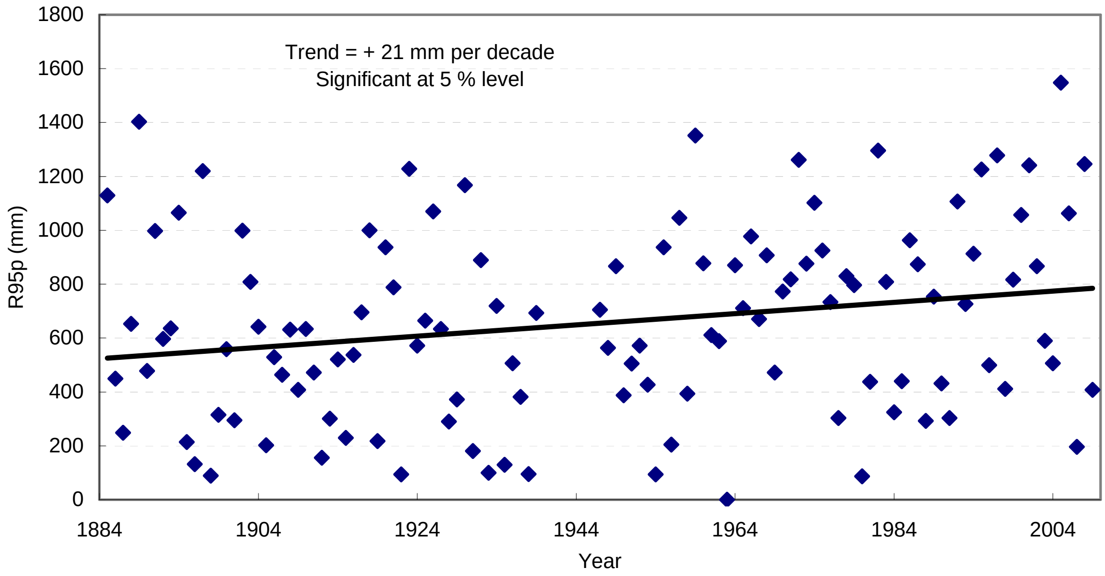

Figure 7 A rising trend in *R95p* of about 21 mm per decade from 1885 to 2009.

5 Summary

Against the background of global warming and urbanization, Hong Kong has experienced raised temperatures and enhanced rainfall over the past 125 years. Studies of the past records of extreme rainfall in Hong Kong revealed that heavy rain events are becoming more frequent. Looking into the future, Hong Kong can expect even warmer weather and more variable rainfall. To combat climate change, the use of renewable energy in Hong Kong has been briefly explored. All in all, climate change has implications for the engineering sector and should be taken into consideration during the planning and engineering design processes.

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