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Keynote Address III

Issues Related to Global Warming - Myths, Realities and Warnings

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1. Introduction

To some people, global warming itself is a myth. They are not so much as disputing that the temperatures of the earth's surface have been rising and will continue to rise, but they believe that the warming is due more to natural variations of the climate system than to human influence.

Global warming is a simple as well as a complex subject. It is simple in the sense that if we look at the energy budget of the earth as a whole, the conclusion is almost inevitable. That is, with industry and other human activities adding more carbon dioxide and other greenhouse gases into the atmosphere, an increasing amount of infra-red radiation emitted from the earth surface is absorbed by these gases and prevented from escaping to space, resulting in warming of the earth's surface. However, associated with global warming are complex changes in the climate system, that is, changes in the atmosphere, oceans and rivers, the land surface, polar ice caps and mountain glaciers, and living organisms. The physical, chemical and biological processes going on in the climate system are not yet completely understood or well modeled by scientists. Therefore in the description of climate change and their impacts, there are debates in the scientific community as well as myths in the public perception.

The following sections describe some of the myths and realities related to global warming that may be of concern to the insurance industry, and what the insurance industry should pay attention to. The descriptions will however be limited to the subjects on which studies have been carried out by the Hong Kong Observatory (HKO).

2. Global Warming and Tropical Cyclone Activity

One of the most intense and open debates among climate scientists is the change in tropical cyclone activity, that is, the change in the number of tropical cyclones forming every year, as well as the change in their maximum intensities, due to global warming. An increase in tropical cyclone activity can potentially increase losses in communities and thus in claims for the insurance industry. Some scientists have suggested that rising sea surface temperatures in a warming world will lead to more and stronger tropical cyclones. The case of the western North Pacific (an area bounded by 5^o - 45^oN, 100^o - 180^oE) is examined.

(i) Tropical cyclone activity

Using HKO's best track data, Yeung et al. (2005) found that between 1961 and 2004, the annual number of tropical cyclones occurring in the western North Pacific has been decreasing at a rate of about 1.6 per decade. Best tracks are tropical cyclone positions and intensities determined by post-analysis using all available pertinent data after the passage of each tropical cyclone. This decreasing trend, deduced using linear regression and Student's t-test, as well as the non-parametric Mann-Kendall test and Sen's slope estimator, is statistically significant at the 5% level. For typhoons which are tropical cyclones with maximum sustained wind speed exceeding 118 km/h, no statistically significant trend is identified (Figure 1). This suggests that there has been no increase in tropical cyclone intensity in the western North Pacific between 1961 and 2004.

Spectral analysis of the time series of annual tropical cyclone numbers in the western North Pacific using the Multi-Taper method (MTM) which has lower variance and higher resolution compared with more traditional Fourier transform methods yielded spectral peaks at 2.4, 3.4 and 18 years (Figure 2(a)). The 2.4-year spectral peak coincides with the periodicity of the Quasi-Biennial Oscillation (QBO) which is the change of the mean wind direction in the stratosphere between 20 and 24 km high over the tropics from east to west and from west to east every two to two and a half years. The 3.4-year peak is close to that of the El Niño-Southern Oscillation (ENSO) which is the large-scale and persistent warming or cooling of the equatorial central and eastern Pacific occurring once every three to four years on average. The 18-year spectral peak is possibly associated with the 15 to 25-year periodicity of the Pacific Decadal Oscillation (PDO), an ENSO-like oscillation in the Pacific on an inter-decadal time scale. However, the connection between tropical cyclone activity and PDO remains to be confirmed. It should be noted that the 3.4 year spectral peak exceeds the 95% confidence limit when tested against the red-noise spectrum. The situation is similar for typhoons, with the 3.4 and 3.9-year spectral peaks exceeding the 95% confidence limit of the red noise spectrum (Figure 2(b)).

Singular Spectrum Analysis (SSA) shows that inter-decadal variations and the long-term trend explain only about 26% of the variability of the annual number of tropical cyclones, and about 18% of the annual number of typhoons. Thus, inter-annual variations in particular ENSO seem to play a more important role in modulating tropical cyclone activity in the western North Pacific.

Similar findings are obtained for the South China Sea, that part of the western North Pacific bounded by 10^o - 25^oN, 105^o - 120^oE.

(ii) Activity of Category 4 and Category 5 typhoons

Some modeling studies have suggested that as the earth warms the intensity of the tropical cyclones will increase (IPCC 2001a). Using the best track data of the Joint Typhoon Warning Center (JTWC) in Hawaii, Webster et al. (2005) found that the activity of tropical cyclones meeting the criteria of Category 4 and Category 5 on the Saffir-Simpson Hurricane Scale (abbreviated here as CAT45) has been increasing in all ocean basins. Category 4 tropical cyclones have maximum winds near the centre between 210 and 249 km/h, and Category 5 tropical cyclones have maximum winds near the centre exceeding 249 km/h (WMO 1993). They represent the most intense tropical cyclones.

For the western North Pacific, Webster et al. (2005) found that in the two consecutive 15-year periods 1975-1989 and 1990-2004, CAT45 typhoons have increased from 25% of the total number of typhoons in that basin to 41%. No indication was given as to whether the difference is statistically significant.

However, using the HKO's best track data, it was found that the activity of CAT45 typhoons in the western North Pacific has in fact fallen by about half between the above 15-year periods, from 32% to 16%, a difference that is statistically significant at the 5% level (Table 1). This decreasing trend is supported by the best track data of the Regional Specialized Meteorological Center (RSMC) of the World Meteorological Organization (WMO) in Tokyo. Between 1977-1989 and 1990-2004, the proportion of CAT45 typhoons among all typhoons in the western North Pacific calculated from the best track data of RSMC Tokyo fell from 18% to 8%, a difference that is also statistically significant at the 5% level. Here, 1977 is used as the start year for the first period as it is the first year in which tropical cyclone intensity in terms of maximum wind speeds are given in RSMC Tokyo's best track data.

Table 1. Trend analysis of the ratios of CAT45 typhoons to all typhoons in the western North Pacific for different periods.

JWTC best track data (Webster et al. 2005)		HKO best track data		RSMC Tokyo best track data	
1975-1989	25%	1975-1989	32%	1977-1989	18%
1990-2004	41%	1990-2004	16%	1990-2004	8%

It is not very clear what are the reasons for the difference in the trends determined from the databases of JTWC, HKO and RSMC Tokyo. One possibility that has been suggested is that JTWC uses 1-minute mean wind speed while HKO and RSMC Tokyo and indeed most other warning centres in the western North Pacific uses 10-minute mean wind speed to assign tropical cyclone intensity. The intensities assigned by JTWC are higher especially for tropical cyclones with intensities exceeding 185 kilometres per hour (US Naval Research Laboratory 1998). Another contributing reason may be that in some cases different intensities were assigned to the same tropical cyclones by different centres even when they used the same wind speed criteria (Hoarau et. al. 2006, Lander and Guard 2006). Different starting years used in trend analysis can lead to different results (Knaff and Sampson 2006), and so can different analysis techniques (Landsea 2005).

Even if one accepts that there had been a rising trend in tropical cyclone activity as suggested by Webster et al. (2005) and Emanuel (2005), the physical reasons for the rise is also not yet well established. While some (Emanuel 2005, Webster et al. 2005, Trenberth 2005 and Anthes 2006) suggest that it is linked to a warming environment, others argue that this is due to natural multi-decadal oscillations (Goldenberg et al. 2001, Chan 2006). This is because sea surface temperature is only one of the factors affecting tropical cyclone genesis and intensity. Other factors such as prevalence of low altitude cyclonic circulations and the variation of the wind with height (McBride 1995) may not have changed in the long-term in favour of increasing tropical cyclone activity.

(iii) Tropical cyclone losses

Losses inflicted by tropical cyclones are dependent not only on tropical cyclone activity, but also on the preparedness of affected communities.

Preparedness include better infrastructure to withstand tropical cyclone inflicted destruction, better contingency plans, heightened awareness to avert loss, and better tropical cyclone warnings. In regard to better tropical cyclone warnings, the reality is that tropical cyclone track forecast errors have been decreasing steadily in recent years.

Figure 3 shows the 24-hour forecast track errors of the warnings issued by HKO, JTWC, RSMC Tokyo, BABJ (National Meteorological Center, China Meteorological Administration) and BCGZ (Guangzhou Regional Meteorological Center. These errors are the differences between HKO's best tracks and the 24-hour track forecasts issued by above warning centres in an operational environment during the passage of tropical cyclones. It can be seen from Figure 3 that between 1975 and 2004, the 24-hour track forecast errors have generally decreased from 200 km or more to less than 150 km for all warning centres.

Better tropical cyclone warnings might have been one reason for the lack of an upward trend in tropical cyclone related damage sustained in recent years by the 14 countries and territories around the western North Pacific which are represented on the Typhoon Committee jointly set up by the World Meteorological Organization and the United Nations Economic and Social Commission of the Asia and Pacific (ESCAP). Figure 4 shows the damage between 1985 and 2004. Pielke (2005) also noted that for the United States, the increased destructiveness of tropical cyclones in the past 30 years suggested by Emanuel (2005) has not been matched by a similar rise in hurricane losses. The lack of a marked upsurge in tropical cyclone related damages in Figure 4 can be contrasted with the almost tenfold increase in losses sustained globally between the 1950s and the 1990s on account of extreme weather including tropical cyclones (IPCC 2001a).

3. Heavy Rain and Droughts

A warming earth implies an intensified hydrological cycle, that is, an increase in evaporation and in rainfall (IPCC 2001a). Indeed, the global average precipitation has been increasing and is projected to increase in the rest of this century. Larger year-to-year variations in rainfall are also very likely over most areas where there is an increase in the mean precipitation (IPCC

2001a). An increase in the frequency of very heavy rainfall may result in more landslips and severe flooding, and thus more claims for the insurance industry. It should be noted that even a modern city can suffer heavy losses from a single heavy rain episode. For example, the heavy rain associated with Typhoon Nari in September 2001 caused severe flooding in Taipei, inflicting an insured damage of around US$ 500 million (Munich Re 2004). On the other hand, an increase in the frequency of severe droughts may result in more wildfires and impact on agriculture and other economic activities (IPCC 2001b), and thus also more claims for the insurance industry.

The increase in rainfall due to an enhanced hydrological cycle does not necessarily imply that droughts will decrease. By downscaling global climate model predictions to Hong Kong it was found that by the end of this century, the annual rainfall in Hong Kong would be about 10% higher than the present climatological normal (Figure 5). At the same time, extremely high and extremely low rainfall will both see an increase in frequency. This downscaling is achieved statistically using the regression method, with the rainfall over southern China forecast by global climate models as predictors, and the forecast annual rainfall in Hong Kong as the predictant. The regression relationship was built using observed rainfall in southern China as predictors and the observed rainfall in at the Hong Kong Observatory headquarters as the predictand in the period between 1951 and 2000. Details can be found in Wu et al. (2005).

In the past 120 years, the highest annual rainfall at the Hong Kong Observatory headquarters was 3343 mm recorded in 1997. In that year, rainstorms triggered severe flooding and numerous landslides in Hong Kong. The lowest annual rainfall was 901 mm recorded in 1963 when water supply was rationed once every four days. It is determined from the above downscaling exercise that in the 21st century there would be six years with annual rainfall above 3343 mm, and three years with annual rainfall less than 901 mm (Wu et al. 2005). This demonstrates that the frequency of drought, not only of heavy rain, will increase in a warming world.

4. Mean Sea Level Rise

One of the most talked about consequences of global warming is mean sea level rise. Expansion of the upper ocean, melting of polar ice caps and mountain glaciers will lead to an increase in ocean volume and a rise in the global mean sea level.

In the case of Hong Kong, in the past 50 years the mean sea level at Quarry Bay in the Victoria Harbour has risen by 0.12 m, at an average rate of 2.3 mm per year (Figure 6). The long-term sea level change at the Victoria Harbour agrees well with that in the South China Sea as determined by the State Oceanic Administration of China, and is consistent with the change of the mean sea level of the South China Sea in the past decade as measured by the remote sensing satellites jointly operated by the USA and France (Figure 7). Details can be found in Wong et al. (2003).

Figure 6 also shows that the inter-decadal change in the sea level in Victoria Harbour was particularly prominent in the past 15 years, with a steep rise of the annual mean sea level from 1987 to 1999 and a rapid fall after that. The above period coincides with the period with most rapid rise in the global average temperature since instrumental measurements of air temperature began in the 1860s. This suggests that global warming might be a factor in the sea level change in Hong Kong.

The implication of mean sea level rise is that similar storm surges would give rise to higher sea levels, increasing the chance of coastal flooding. With a mean sea level rise of 0.12 m in Hong Kong, the amount that the Victoria Harbour has risen in the past 50 years, a high water level say with a return period of 50 years originally would have its return period reduced to about 25 years, that is, by half.

The mean sea level rise of 0.12 m at the Victoria Harbour in the past 50 years happens to be near the lower end of the global mean sea level rise projected by IPCC (2001a) for the 21st century, which gives a range of 0.09 to 0.88 m. Were the mean sea level in Hong Kong to rise by 0.48 m, the mid-point between 0.09 m and 0.88 m, a high water level with a return period of 50 years originally would have its return period shorten to about three years. Were the mean sea level in Hong Kong to rise by 0.88 m, then that high water level would have an annual recurrence. The return period of maximum sea level corresponding to different amounts of mean sea level rise is shown in Figure 8, obtained from the Type 1 Extreme Value or Gumbel distribution. The possible consequences of the projected sea level rise, in terms of flooding and economic and social disruption, could be dire if no mitigation or adaptation measures were taken. In Hong Kong's case, allowance for a 10 mm rise in mean sea level per year has been recommended for the design of coastal engineering projects meeting certain criteria (Works Branch Technical Circular No. 6/90).

The same considerations also apply to tsunamis. More severe flooding would result from the same tsunami if the mean sea level becomes higher.

5. Warnings

(i) Tropical cyclone activity

According to the discussion in Section 2, if and how long-term tropical cyclone activity have changed is a question to which the answer is not yet unequivocal. It is a subject requiring further study. In the meantime, the insurance industry should be mindful that the conclusions one can draw on tropical cyclone activity is dependent on the use of different best track data sets, different periods of data, as well as the techniques of analysis.

Furthermore, Figure 1 shows that from 1998 onwards, tropical cyclone activity in the western North Pacific has entered a relatively quiet period. Given the inter-decadal variation in tropical cyclone activity with a dominant period of about 18 years, one can expect more tropical cyclones to occur when the quiet phase changes to the active phase, which can happen soon.

(ii) Heavy rain and droughts

Under global warming, not only heavy rain but droughts are likely to increase in frequency. Hong Kong's case as discussed in Section 3 serves as an example. The insurance industry should be aware of both possibilities. In Asia, drought is a bigger concern in arid areas where an increase in evaporation is not compensated by an increase in rainfall.

(iii) Mean sea level rise

The discussion in Section 4 amply demonstrates that mean sea level rise implies the likelihood of more frequent occurrences of flooding associated with storm surges even if there is no increase in tropical cyclone activity. The same considerations apply to tsunamis. The insurance industry should therefore be mindful of the possible increase in damage, especially in places where adaptation and mitigation measures have not yet been implemented.

6. Conclusions

With the western North Pacific as an example, it seems there is not yet a definitive answer to whether tropical cyclone activity has or will increase in a warming world. However, an increase in the number of tropical cyclones can be expected when the current quiet phase changes to an active phase in the western North Pacific, which can happen soon.

Against the background of global warming, many places can expect to see not only more heavy rain events, but also more droughts.

Sea level rise will cause the return periods of sea flooding associated with storm surges to be substantially shortened. It should be a matter of attention for the insurance industry especially for places where adaptation or mitigation measures have not yet been considered or implemented.

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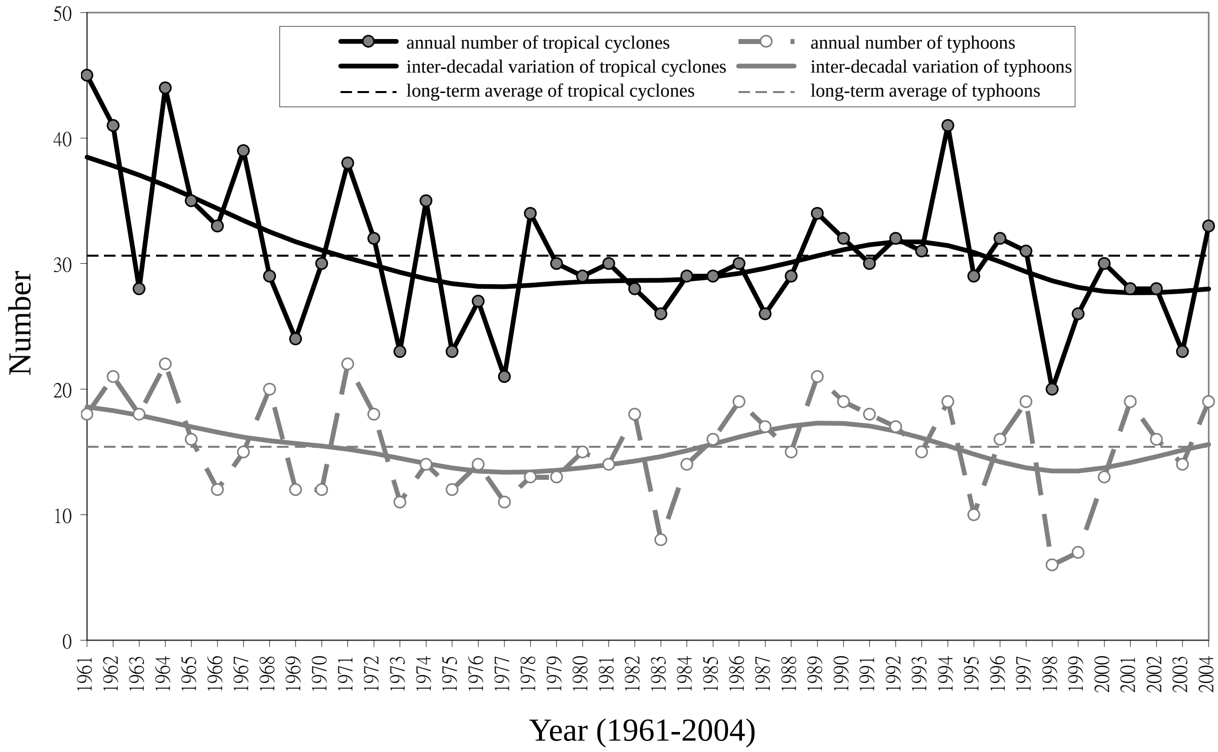

Figure 1. Time series of the annual number of tropical cyclones and typhoons in the western North Pacific. Inter-decadal variations (continuous lines) are highlighted by applying a Gaussian filter to remove variations with periodicities less than 10 years.

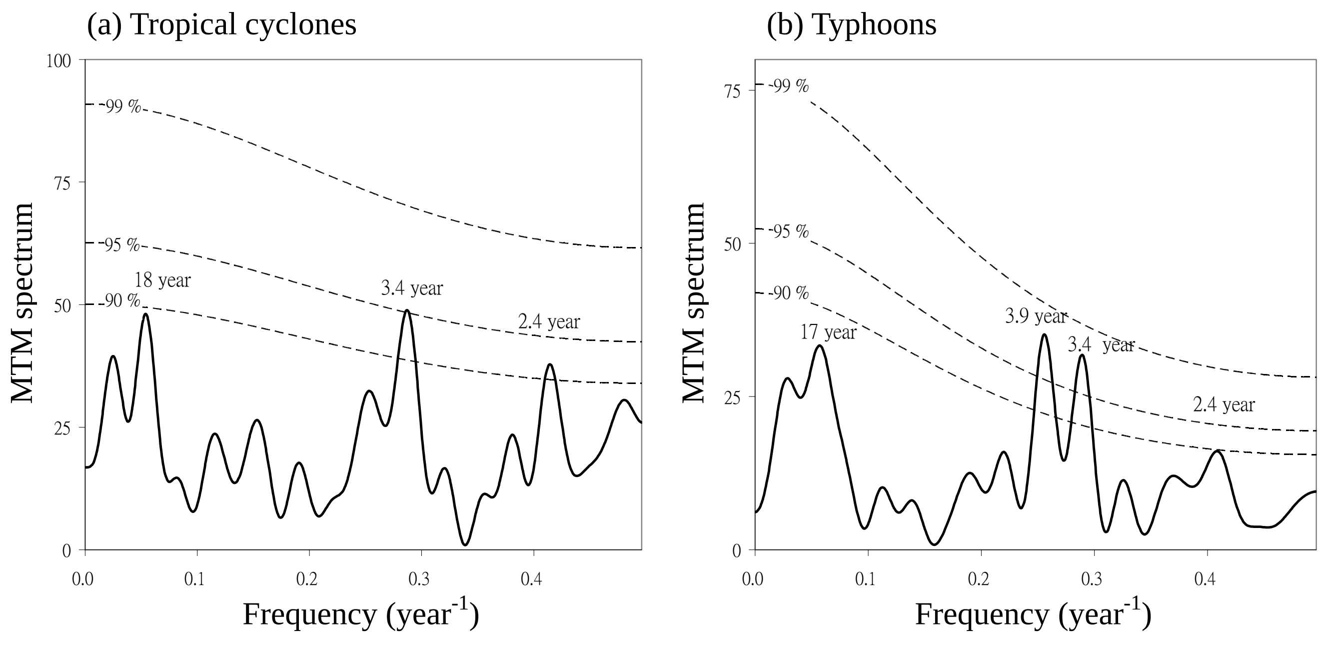

Figure 2. Multi-Taper Method (MTM) spectrum of the annual number of (a) tropical cyclones and (b) typhoons in the western North Pacific. The 90%, 95% and 99% confidence levels with respect to the red noise spectrum are shown by the dashed lines.

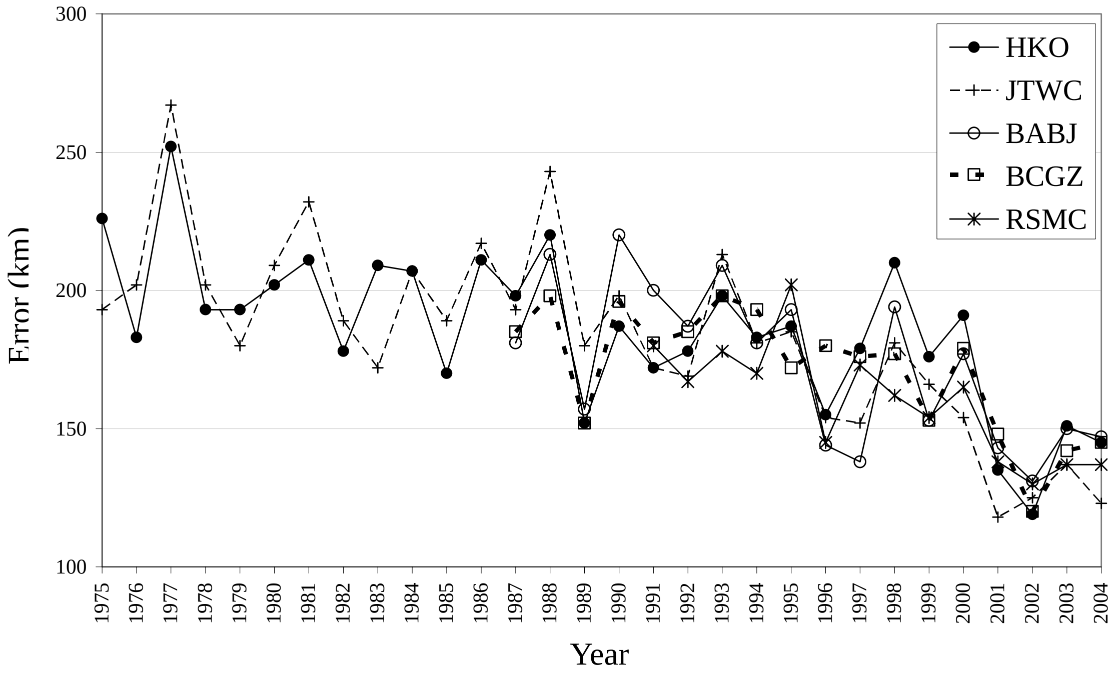

Figure 3. 24-hour tropical cyclone track forecast errors of the different warning centres. BABJ - National Meteorological Center, Beijing; BCGZ - Guangzhou Regional Meteorological Center; HKO - Hong Kong Observatory; JTWC- Joint Typhoon Warning Center; RSMC - Regional Specialized Meteorological Center Tokyo.

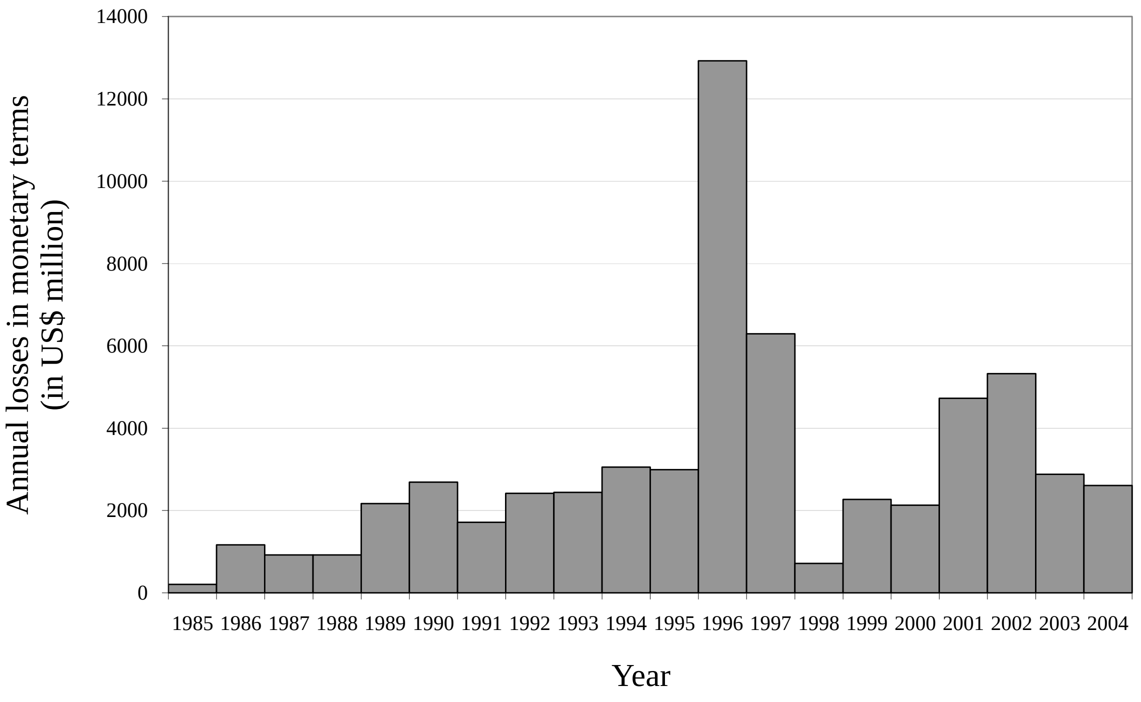

Figure 4. Tropical cyclone related damage sustained by Typhoon Committee countries/territories in the western North Pacific between 1985 and 2004.

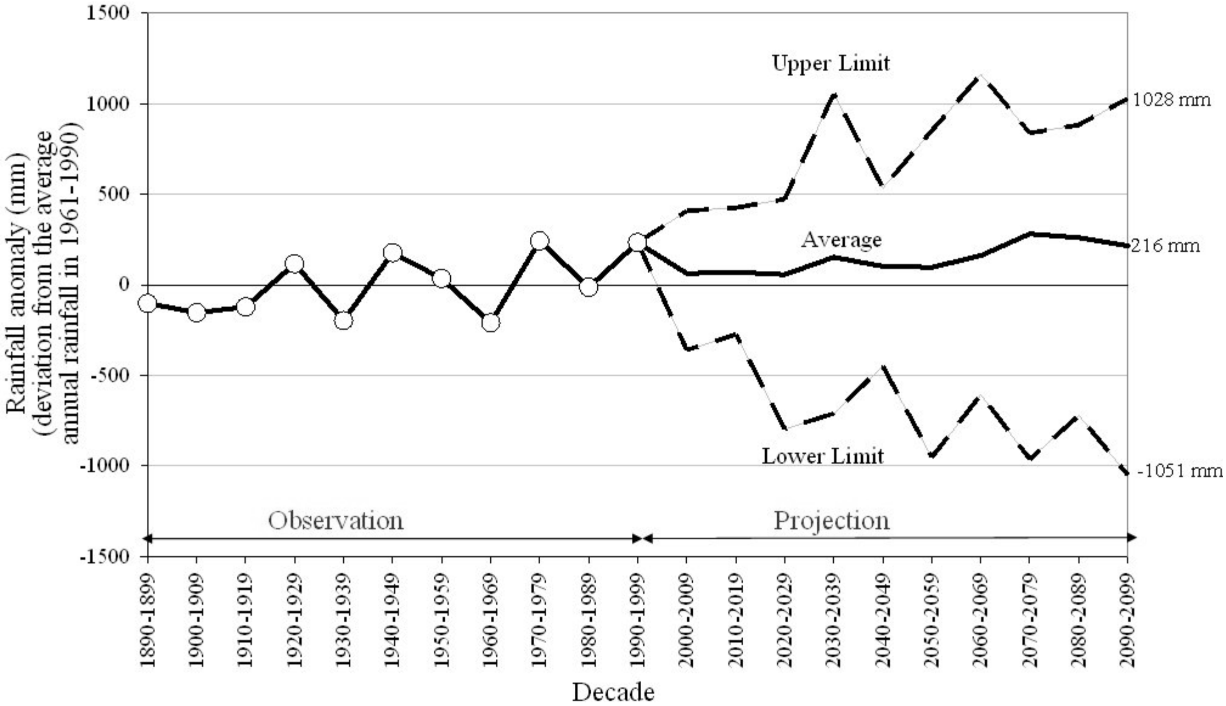

Figure 5. Past and projected changes in rainfall in Hong Kong.

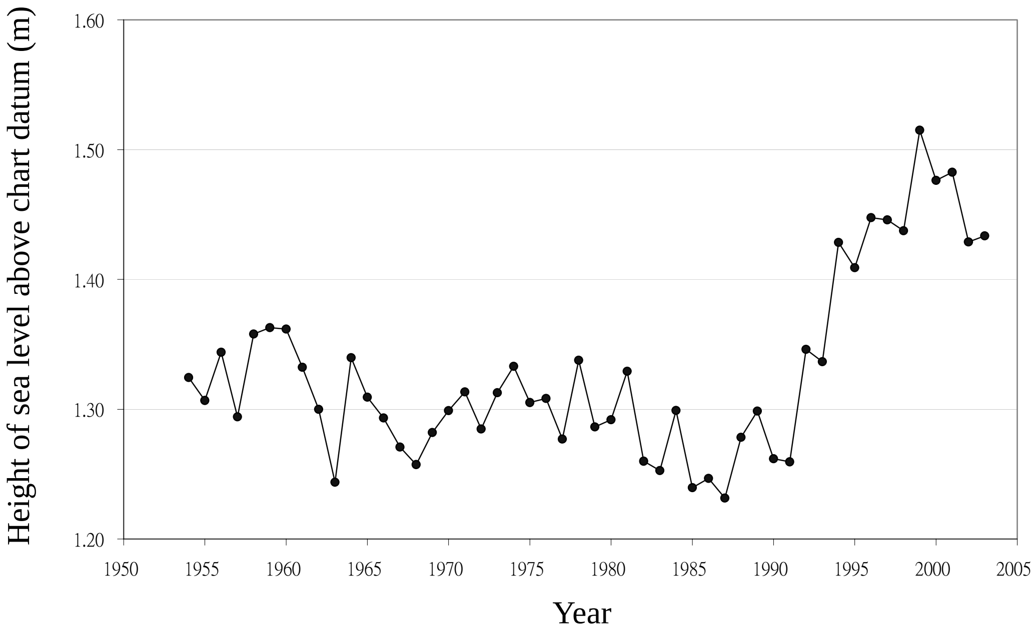

Figure 6. Annual mean sea level at Quarry Bay in the Victoria Harbour between 1954 and 2003.

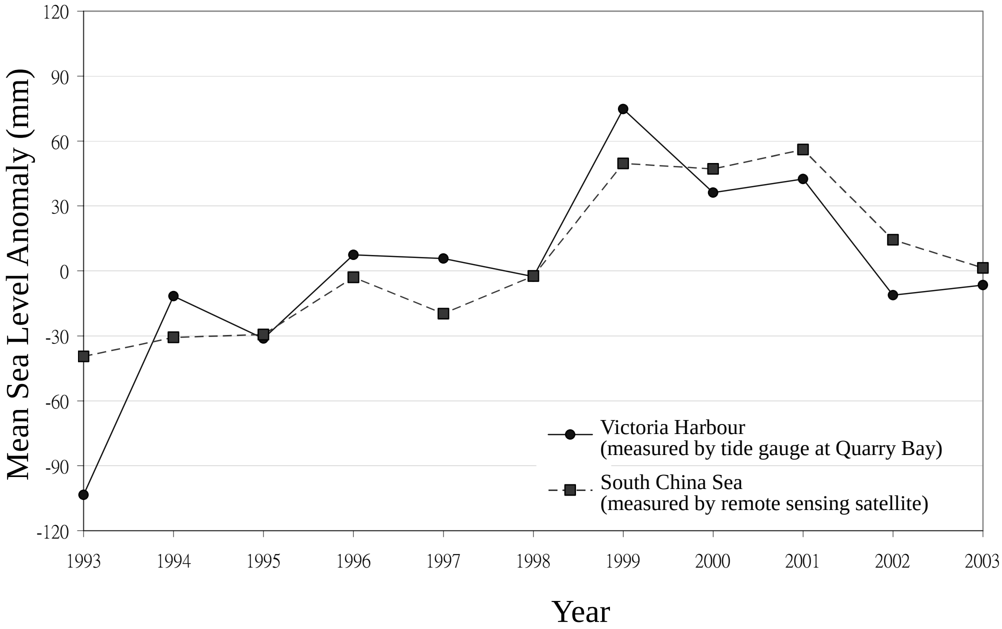

Figure 7. Annual mean sea level anomaly at the Victoria Harbour compared with that in the South China Sea.

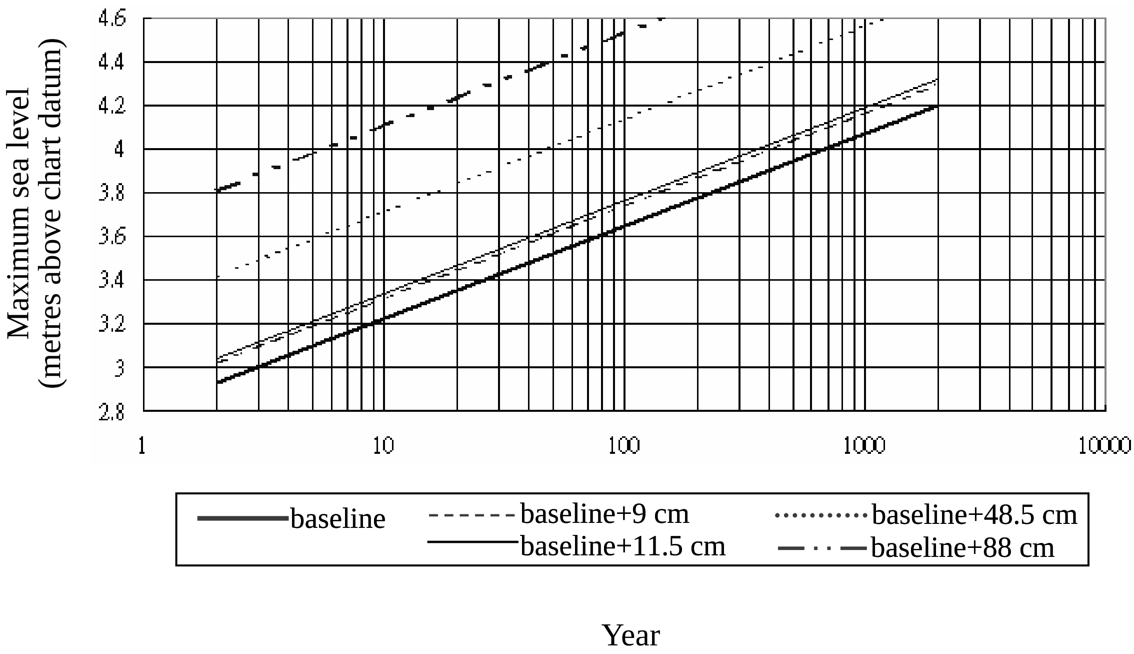

Figure 8. Return period of maximum sea level for different amounts of mean sea level rise in Hong Kong computed from the Type 1 Extreme Value or Gumbel distribution.