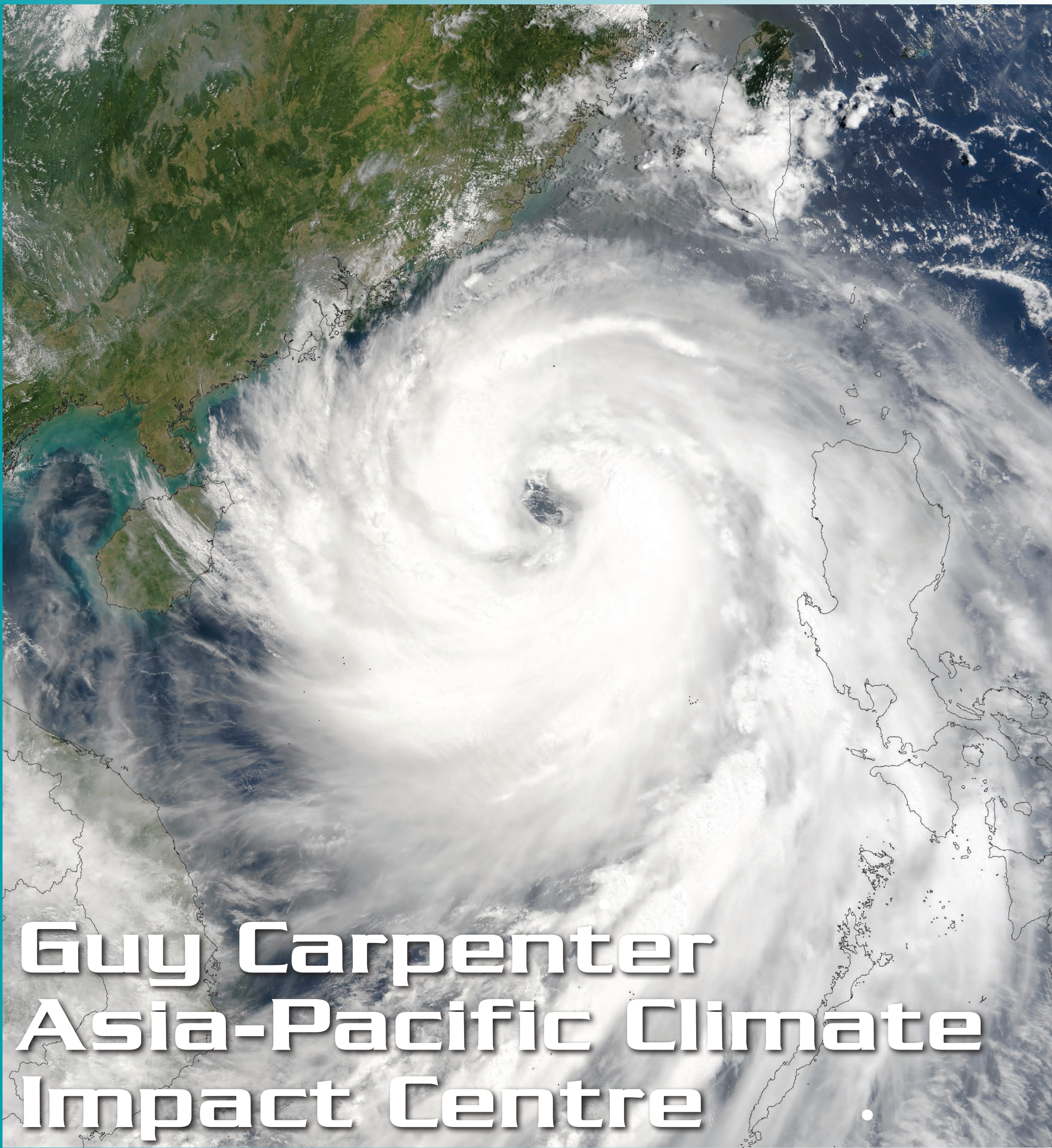


Guy Carpenter Asia-Pacific Climate Impact Centre

Annual Report 2009

香港城市大學
City University of Hong Kong

GCACIC
Guy Carpenter Asia-Pacific Climate Impact Centre
City University of Hong Kong

Executive Summary

This is the first Annual Report of the *Guy Carpenter Asia-Pacific Climate Impact Centre* since its inception in June 2008. Research activities during the period June 2008 to December 2009 are briefly described.

These activities mainly fall into four groups: typhoons/tropical cyclones, monsoons, general climate, and air pollution studies. In the area of tropical cyclones, we developed seasonal forecast schemes for real-time predictions of tropical cyclone activities in various regions of Asia, as well as studied the variations of tropical cyclone activity in these regions and provided physical explanations of such variations, based on analyses of atmospheric and oceanographic data. We also examined the possible effect of global warming on tropical cyclone activity. In the area of monsoons, we investigated the possible reasons for the cold winter of 2008, and the interdecadal variability of both the summer and winter monsoon circulations in East Asia, and provided physical explanations of such variabilities. In addition, we developed the capability of simulating and modeling the monsoon activity in East Asia with a global climate model. In the studies of general climate, we mainly focused on how global warming might affect/have affected the frequency of occurrence of the El Niño phenomenon, as well as sea-level changes and ocean currents. Our studies on air pollution examined the changes in aerosol and trace gas concentrations due to human activities, which will form a basis for understanding how such activities may affect local climate.

Looking ahead, we expect that our research activities will continue in these areas. We will focus both on the understanding of the physical causes of changes of various climate phenomena that have impact on the Asia-Pacific region and on the predictions of such phenomena as well as their projections under different global warming scenarios. These studies will be based on both statistical analyses of past data and computer simulations.

Contents

I. Introduction

The Guy Carpenter Asia-Pacific Climate Impact Centre was established in June 2008 through a donation from Guy Carpenter and Company and matching funding from the Universities Grants Committee of the Hong Kong Special Administrative Region Government and City University of Hong Kong. The mission of the Centre is to become a leading centre in the Asia-Pacific region in research on climate-related perils, particularly those in the region. The research of the Centre focuses on enhancing the understanding of climate-related perils occurring in the Asia-Pacific region and of catastrophic risk throughout the region, as well as making predictions of the occurrence of climate-related perils in the region.

This is the first Annual Report of the Centre and covers the activities of the Centre from its inception to the end of December 2009. Major results from research projects supported wholly or partly by the Centre are summarized. Publications arising from these projects are also listed. Copies of the publications are included as an Appendix in the electronic version of the report and in a CD attached to the printed version. We hope that this report will provide the reader with a quick view of the research in which the Centre was engaged during the past 18 months.

II. Research Projects

A. Typhoons/Tropical Cyclones

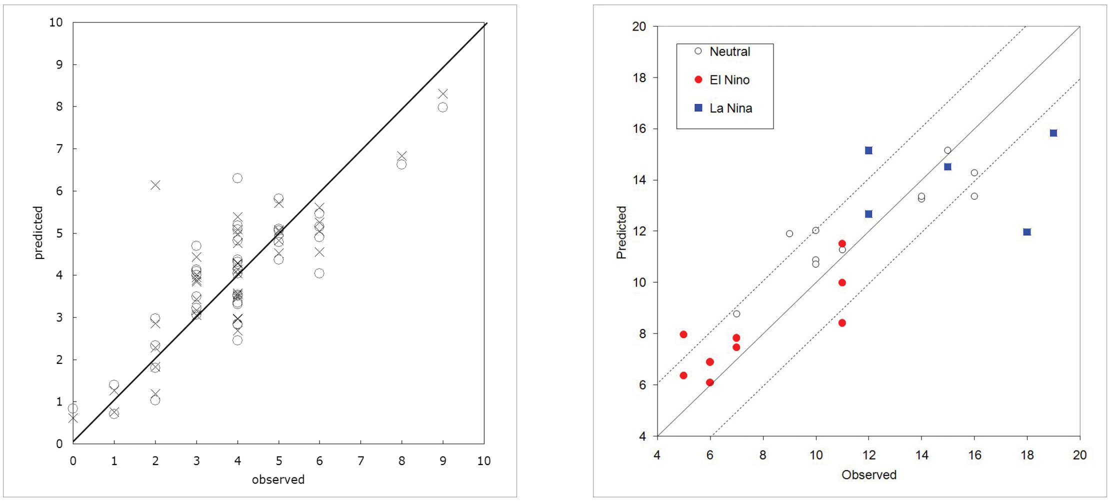
1. Seasonal predictions of tropical cyclone activity

(PI: Johnny Chan)

Seasonal predictions of tropical cyclone activity have been a main thrust of the group, even before the launch of the Centre. Here, different types of prediction methods and for different regions of the world are presented.

Since 2000, the Director of the Centre, Prof. Johnny Chan, has been issuing seasonal predictions of tropical cyclone (TC) activity over the western North Pacific through the Laboratory for Atmospheric Research at City University of Hong Kong. Beginning in 2009, these predictions are issued through the Centre. In addition to the prediction of TC activity over the western North Pacific, two other predictions are made: the number of landfalling TCs along the South China coast and the number of TCs affecting the Australian region. Details of all the predictions can be found at http://www.cityu.edu.hk/gcacic/forecast.htm. The skills of these two predictions are shown in Figure 1. Further descriptions of these two new predictions can be found in Goh and Chan (2009a) and Liu and Chan (2010).

These predictions are purely statistical with predictors from the atmospheric and oceanographic conditions prior to the TC season. This assumes that those conditions that affect TC behaviour can be predicted by those from the pre-season. However, with the significant advances in climate prediction using numerical models, these conditions can be predicted correctly to a large extent so that it is possible to make seasonal TC forecasts based on these numerical predictions. Here two approaches are taken.



(a) (b)

Figure 1. Scatterplot of the hindcasted vs observed values for the number of tropical cyclones (a) making landfall along the South China coast, and (b) in the Australian region. The solid line represents the prefect prediction. In (a), the crosses and circles represent predictions from the dependent and cross-validated samples respectively. In (b), the two dashed lines are parallel to the solid line and deviate from it by a value that corresponds to the standard error of the predictions. Solid circles and squares indicate the TC seasons associated with the El Niño and La Niña events.

The first is referred to as statistical-dynamical in which the numerical predictions made for the past years are statistically correlated with the actual number of TCs that occurred to produce a regression equation. Substituting the predictions for the future then gives a forecast of future TC activity. This approach has been tested for the number of landfalling TCs in various sections of the US coast and the forecasts are found to be rather skillful especially for the East Coast of the US (Figure 2; also see details in Chiu 2009). Currently, the same approach is tested for landfalling TCs in South China and around Hong Kong. It is planned that this technique will be extended to all regions of the Asia Pacific.

The second is a pure dynamical approach in which the numerical predictions from a global model are downscaled to a regional climate model that has a higher resolution so that the TCs can be better identified. This approach has been tested for the entire western North Pacific region and the climatology simulated by the regional climate model is very similar to that observed (Figure 3). After further testing, such an approach will be adopted for predicting future TC activity. If global predictions for the coming TC season are used, this approach will yield TC forecasts for the season. If the global predictions are for climate projections for the study of the effects of global warming, the same approach will also give projections of TC activity under different global warming scenarios. Both of these studies will be undertaken.

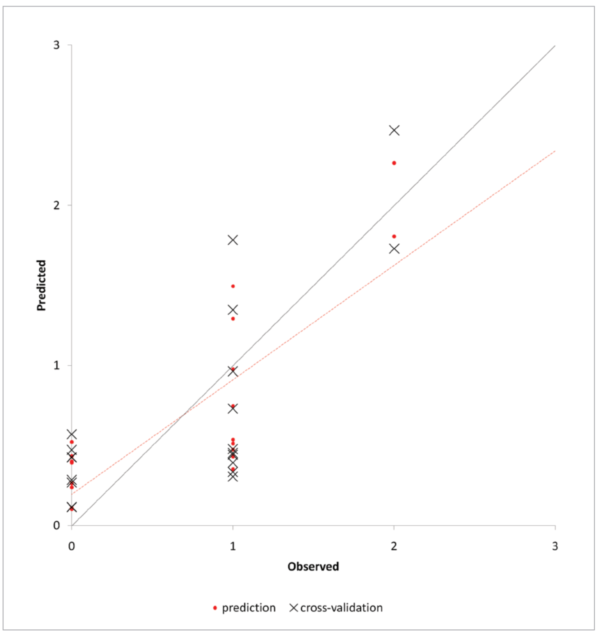


Figure 2. Scatterplot of predicted against observed number of landfalling TCs along the East Coast of the US. Solid line represents the perfect prediction, red dots and crosses represent predictions from the dependent and cross-validation samples and dashed line represents the linear relationship between the observations and the cross-validated predictions.

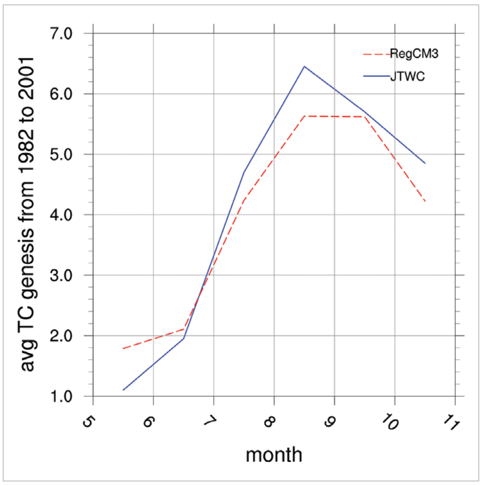


Figure 3. Climatology of tropical cyclone genesis in the western North Pacific during 1982-2001 simulated from a regional climate model (red) and from observations (blue).

2. Variability of tropical cyclone activity on various time scales

To identify and understand how TC activity varies on time scales ranging from interannual to interdecadal, three studies have been undertaken during the period, each of which is described below.

Interannual and interdecadal variations of landfalling TCs in East Asia (PI: Johnny Chan)

Variations of the number of tropical cyclones making landfall are found to have cycles ranging from a few years to over a decade, but without a significant trend.

This study examines the variations in the annual number of landfalling TCs (ATCs) in various parts of East Asia during the period 1945–2004. The East Asian region is divided into three sub-regions: South (south China, Vietnam and the Philippines), Middle (east China), and North (Korean Peninsula and Japan). Variations in the annual number on various time scales in each region are examined separately. An important finding from the time series analysis is that none of the ATC time series shows a significant linear trend, which suggests that global warming has not led to a higher frequency of landfalling tropical cyclones or typhoons in any of the regions in Asia. Instead, each time series shows large inter-annual (2–8 years) and multi-decadal (16–32 years) variations (Figure 4). In some periods, the annual number of ATCs varies in unison among all regions of Asia. In others, one region would have an above-normal number of landfalling events, while the other regions have below-normal numbers. In general, at multi-decadal time scales, the number of ATCs in each region correlates very well with that of the total number of TCs over the western North Pacific. Further details of this study can be found in Chan and Xu (2009).

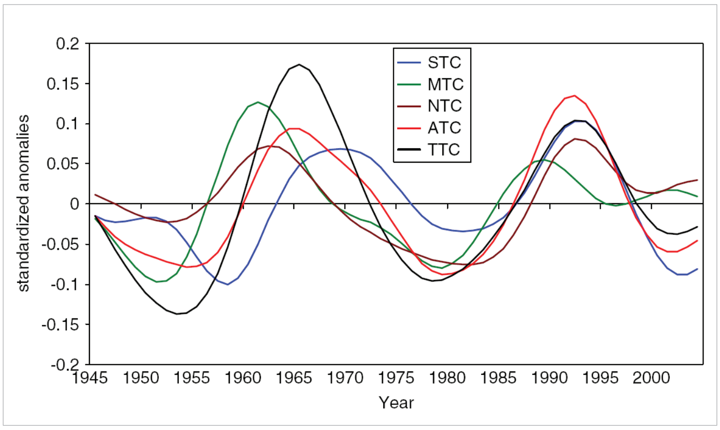


Figure 4. 16–32-year reconstructed series of the number of landfalling tropical cyclones in southern part (STC), middle part (MTC) and northern part (NTC) of East Asia. ATC and TTC are the total number of landfalling tropical cyclones in East Asia and the total number of tropical cyclones in the entire western North Pacific respectively.

Interannual and interdecadal variations of TCs in the South China Sea
(PI: Johnny Chan)

Variations of tropical cyclone activity in the South China Sea are found to have cycles that are linked to the El Niño-Southern Oscillation and the Pacific Decadal Oscillation.

This study attempts to identify the factors affecting annual TC activity in the South China Sea (SCS) using data during the period 1965 to 2005. The results indicate that the total number of TCs and number of TCs entering the SCS from the western North Pacific are below normal in El Niño events but above normal during La Niña events (Table 1). However, for TCs formed inside the SCS, the difference in numbers between the two phases of the El Niño-Southern Oscillation (ENSO) is not as obvious. In addition, the positive phase of the Pacific Decadal Oscillation (PDO) generally favours less TCs in all categories, while the negative PDO phase favours more. These results may be explained by the fact that the ENSO and the PDO affect TC behaviour through altering the conditions in the WNP to be favourable or unfavourable for TC genesis and movement into the SCS. Further details of this study can be found in Goh and Chan (2009b).

Table 1. TC occurrences in the South China Sea during El Niño (EN) and La Niña (LN) events for the whole, early (May to Aug) and late (Sep to Dec) seasons. x/y represents x years in which TC number is above normal/y years in which TC number is below normal.

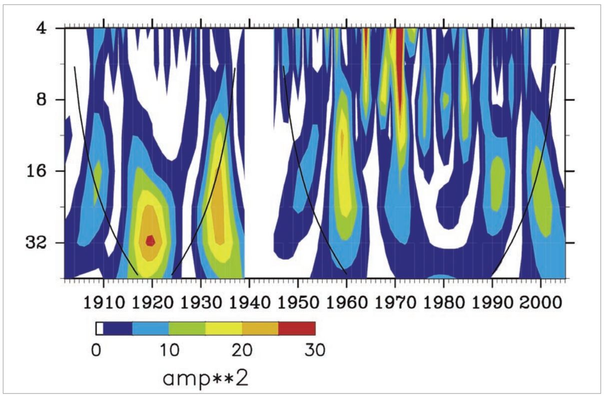
EN (12 events)			LN (10 events)		
Whole	Early	Late	Whole	Early	Late
1/5	2/1	0/5	5/1	3/3	7/0

Interdecadal variations of TCs landfall in the Philippines since 1902
(PI: Dr. Hisayuki Kubota of Japan Agency for Marine-Earth Science and Technology)

Variations of the number of tropical cyclones making landfall in the Philippines over the last 100 years are found to have cycles that are linked to the El Niño-Southern Oscillation and the Pacific Decadal Oscillation.

To study the variations of TC landfall for a longer period, a dataset of TC landfall numbers in the Philippines (TLP) is created from a combination of historical observation records of the Monthly Bulletins of Philippine Weather Bureau and Joint Warning Typhoon Center best-track data for the period of 1902 to 2005. Interdecadal variability of TLP is found to be related to different phases of the El Niño/Southern Oscillation (ENSO) and the Pacific Decadal Oscillation (PDO). The annual TLP has an apparent oscillation of about 32 years before 1939 and an oscillation of about 10–22 years after 1945 (Figure 5). No long-term trend is found. During the low PDO phase, the annual TLP decreases (increases) significantly in El Niño (La Niña) years. During high PDO phase, however, the difference in annual TLP between different ENSO phases becomes unclear. These results suggest that natural variability related to ENSO and PDO phases appears to prevail in the interdecadal variability of TLP. Further details of this study can be found in Kubota and Chan (2009).

Figure 5. Wavelet power spectrum of annual number of tropical cyclones making landfall in the Philippines using real-valued Mexican-hat wavelet. Wavelet is performed separately before 1939 using data from the Monthly Bulletins of the Philippine Weather Bureau and after 1945 using data from the US Joint Typhoon Warning Center. The thick curve indicates the edge effects.



Different impacts of two kinds of Pacific Ocean warming on TC frequency over the western North Pacific

(PI: Francis Tam)

In recent years, El Niño events have undergone a shift of behaviour, presumably because of the changing global climate. How this new flavour of El Niño – coined ENSO Modoki – affects the TC activity over the western North Pacific is discussed in this study.

This present study examines the relationship of ENSO Modoki and canonical ENSO, respectively, with TC frequency over the western North Pacific (WNP) for the period 1960-2008 during the boreal summer. It is found that TC frequency over the WNP is significantly positively correlated with the ENSO Modoki index. On the other hand, the Niño-3 index has a markedly negative (positive) correlation with the TC frequency in the northern (southeastern) portion of the WNP. Such differences can be attributed to circulation changes associated with the two different types of Pacific warming. In response to the anomalous diabatic heating related to El Niño Modoki, a large-scale cyclonic anomaly forms over the WNP. In contrast, during the canonical El Niño years, zonally-elongated heating source and sink exhibit a meridional dipole pattern, which induces an anti-cyclonic anomaly in the subtropics and a cyclonic anomaly near the equatorial central Pacific (Figure 6). Numerical experiments under the realistic mean state and heating profiles validate that the anomalous circulation responses to heating play essential roles in different modulations of two kinds of Pacific Ocean warming on the TC frequency. Further details of this study can be found in Chen and Tam (2010).

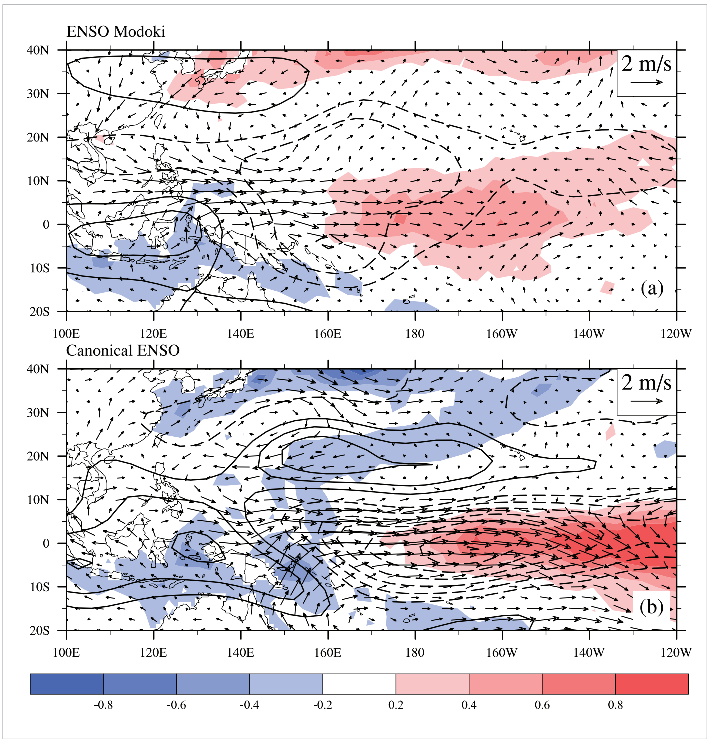


Figure 6. Composites of anomalous SST (shading; units: °C), 850 hPa winds (vectors, see scale arrow at the upper right) and OLR (dash/solid contours indicating negative/positive values; contour interval 3Wm^{-2}; zero contours omitted) during JJA for (a) El Niño Modoki and (b) canonical El Niño events. OLR anomalies are computed based on data starting from 1980 and with a T15 truncation applied for clarity.

3. Understanding the controls of tropical cyclone activity

To understand the possible controls of TC activity on climate scales, which is important in the investigation of possible effects of global warming on TC activity, two studies have been undertaken during the period, each of which is described below.

Relationship between typhoon activity and ocean heat content
(PI: A. Wada, Meteorological Research Institute of Japan Meteorological Agency)

In addition to sea-surface temperature, this study examines how typhoon activity in the western North Pacific may be related to the amount of heat energy in the ocean available for tropical cyclone development.

To study how the ocean might affect TC activity, a 44-year mean distribution of tropical cyclone heat potential (TCHP), a measure of the oceanic heat content from the surface to the 26°C-isotherm depth, shows that TCHP is locally high in the western North Pacific (WNP). TCHP varies on interannual time scales and has a relationship with tropical cyclone (TC) activity (Figure 7). The third mode of an empirical orthogonal function analysis of TCHP shows that an increase in the total number of TCs is accompanied with a warm central Pacific and cool WNP. Negative TCHP anomalies in the WNP suggest that an increase in total number of TCs results in cooling due to their passages. On the other hand, the first mode shows that the number of super typhoons increases in mature El Niño years. An increase in accumulated TCHP is related to the increase in the number of super typhoons due to long duration. Further details of this study can be found in Wada and Chan (2008).

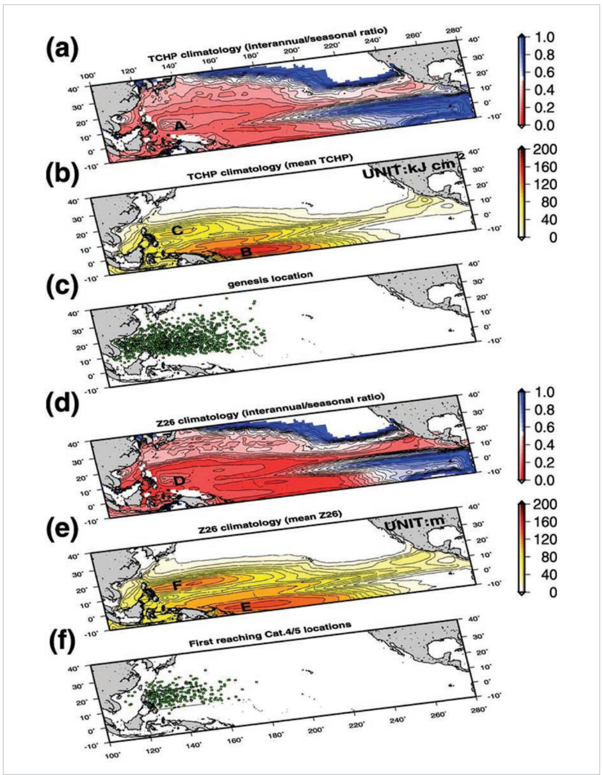


Figure 7. Horizontal distributions of (a) the ratio of root mean square of tropical cyclone heat potential (TCHP) anomaly deviated from monthly mean TCHP for 44 years to that of the anomaly deviated from annual mean tropical cyclone heat potential for 44 years, (b) TCHP averaged from 1961 to 2004, (c) genesis locations from JTWC best-track data, (d) as in Figure 7a except for Z26, (e) as in Figure 7b except for Z26, and (f) as in Figure 7c except for the locations of TCs first reaching an intensity corresponding to category 4 on the Saffir-Simpson scale. Labels A–F show high ratio of TCHP (A), high TCHPs (B, C), high ratio of Z26 (D) and high Z26s (E, F).

Thermodynamic control on the climate of intense TCs
(PI: Johnny Chan)

Thermodynamic control on the climate of intense tropical cyclones is found mainly for those in the Atlantic basin. For most of the other basins, the dynamic control is much more important, which may have strong implications on how global warming may affect the frequency of occurrence of intense tropical cyclones.

How thermodynamic factors control the climate of intense TCs is investigated in this study by examining the relationship between the seasonally averaged maximum potential intensity (MPI, used as a representative index of the thermodynamic forcing) over an ocean basin where TCs form and the seasonal frequency of occurrence of intense TCs. It is found that only in the Atlantic does the MPI have a statistically significant relationship with the number of intense TCs, explaining about 40 per cent of the variance. In other ocean basins, there is either no correlation or the correlation is not statistically significant (Figure 8). In other words, only in the Atlantic are thermodynamic factors responsible, but still only to a certain extent, for the climate variations of intense TCs. In other ocean basins, it appears that the dynamic factors are much more dominant. Such a conclusion has important implications in considering whether global warming may influence the future climate of intense TCs. Further details of this study can be found in Chan (2009).

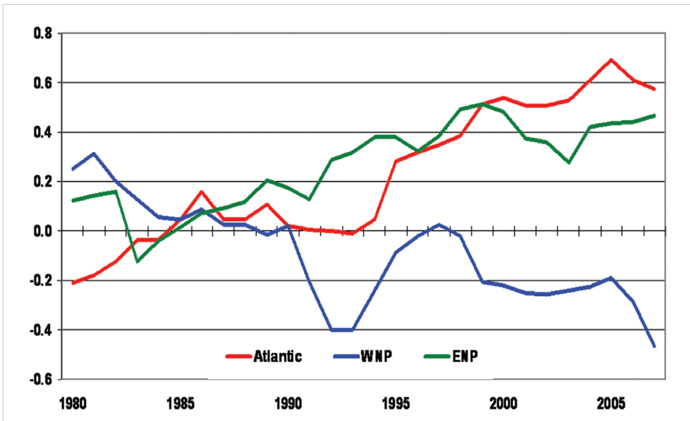


Figure 8. Twenty-one-year correlations between the number of Category 4/5 tropical cyclones and the maximum potential intensity in the Atlantic, western North Pacific (WNP) and eastern North Pacific (ENP). Critical value for 95 per cent significance is 0.43.

B. Monsoon studies

1. Mechanisms for the extreme cold weather in southern China in 2008

(PI: Wen Zhou)

An investigation on the unusual severity of January 2008 snowstorm indicates that the persistent blocking high over Siberia led the strong cold Siberian air down to central and southern China.

In January 2008, central and southern China experienced persistent low temperatures, freezing rain, and snow. The large-scale conditions associated with the occurrence and development of these snowstorms are examined in order to identify the key synoptic controls leading to this event. Three main factors are identified: (a) the persistent blocking high over Siberia, which remained quasi-stationary around 65°E for three weeks, led to advection of dry and cold Siberian air down to central and southern China; (b) a strong persistent southwesterly flow associated with the western Pacific subtropical high led to enhanced moisture advection from the Bay of Bengal into central and southern China (Figure 9); and (c) the deep inversion layer in the lower troposphere associated with the extended snow cover over most of central and southern China. The combination of these three factors is likely responsible for the unusual severity of the event, and hence a long return period. Further descriptions of these snowstorms can be found in Zhou et al. (2009).

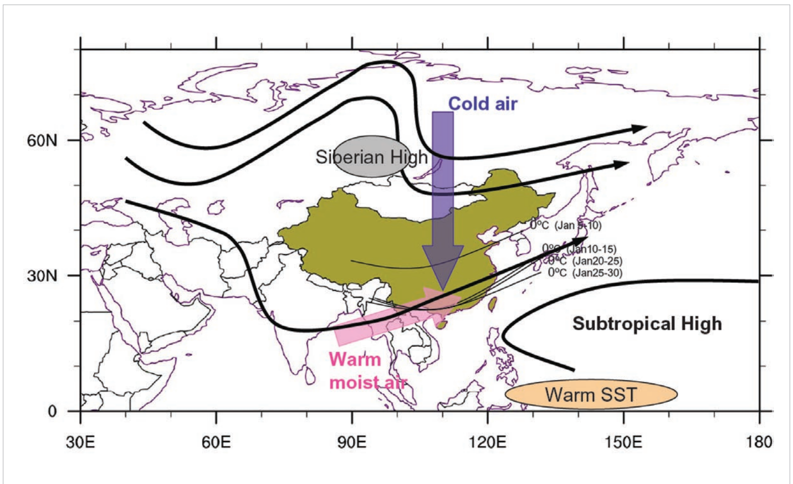


Figure 9. A schematic showing the flow pattern at ~ 500 hPa in the Northern Hemisphere middle latitudes in January 2008. The thin lines over China represent the locations of the zero-degree isotherm during each of the periods labeled next to these lines. The thick line east of the Philippines represents the boundary of the subtropical high, and beige ellipse illustrates the area of anomalously high sea-surface temperature associated with La Niña conditions. The two wide arrows indicate the direction of the flow of warm and moist air from the south (pink arrow) and of cold air from the north (blue arrow).

2. Changes in the East Asia monsoons around the mid-1970s

Summer monsoon circulation
(PI: Wen Zhou)

The present study indicates that the weakened East Asia summer monsoon is due to a significant change in the early-summer meridional teleconnection occurring around the late 1970s.

The present study indicates a significant change in the early-summer meridional teleconnection around the late 1970s based on the ERA-40 reanalysis data during 1958-2001. Although this meridional teleconnection appears as a dominant mode during the whole analysis period, a close inspection reveals that the teleconnection becomes obscure considerably after the late 1970s. Before the late 1970s, the meridional displacement of the East Asian upper-tropospheric jet stream has a statistically significant relationship with both the zonal shift of the WNP subtropical high and the rainfall anomaly in the tropical WNP. After the late 1970s, however, this tropical-extratropical interaction is disrupted. We hypothesize that such a change is due to the weakening of vertical easterly shear over the tropical WNP in June after the late 1970s. Before the late 1970s, the easterly vertical shear permits the coupling of external mode and internal mode excited by the tropical WNP precipitation anomaly and results in a significant barotropic response, which is necessary for the meridional teleconnection over the WNP-East Asia. After the late 1970s, the near-zero vertical shear is unfavourable for such a coupling and thus weakens the meridional teleconnection (Figure 10). More details of this study can be found in Lin et al. (2009).

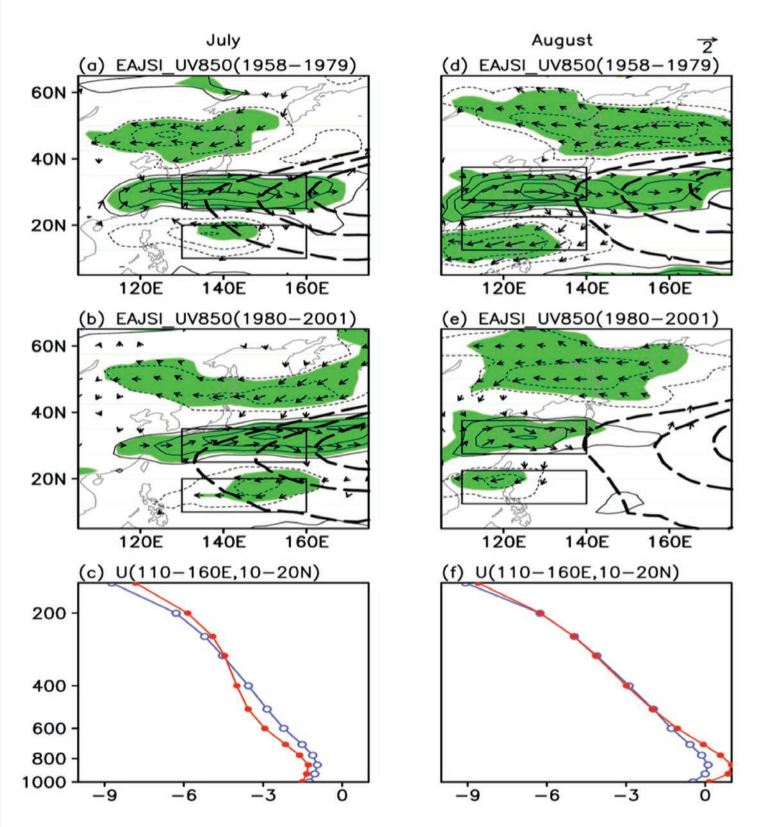


Figure 10. Horizontal winds (vector) and zonal wind (thin con- tour) at 850 hPa regressed upon the East Asia Jet Stream index during 1958 – 1979 and 1980 – 2001 in July (a, b) and August (d, e). Shading denotes significance for U850 at the confidence level of 95%, contour interval is 0.5 m /s and zero contours are omitted. The thick dashed lines depict the 850-hPa western North Pacific subtropical high averaged for 1958 – 1979 in (a, b) and 1980 – 2001 in (d, e). (c) and (f) depict the vertical distribution of basic zonal wind averaged over the tropical WNP (10° – 20°N, 110° – 160 °E) during 1958 – 1979 (blank circles) and 1980 – 2001 (filled circles) in July (c) and August (f).

Winter monsoon circulation
(PI: Wen Zhou)

This study examines the climate shift around the mid 1970s and what contributes to the higher frequency of warm winters in East Asia region after 1976/1977. It is also found that the monsoon seasonal variation is quite different after 2000. The winter monsoon season period is shortened.

This study examines the variability of blocking over the Ural Mountain region in the boreal winter and its relationship with the East Asian winter climate. The climate shift around the mid 1970s has been shown to exert a significant influence on the blocking pattern. In contrast with the years before 1976/1977, the Ural blocking signal after 1976/1977 is found to propagate less into the stratosphere and more eastward in the troposphere to East Asia, which therefore exerts more influence on the East Asian winter climate. This enhanced Ural blocking – East Asian climate relationship amplifies the impact of Ural blocking on East Asia and, with the background of decreasing Ural blocking, contributes to the higher frequency of warm winters in this region. Further analyses suggest that the NAM (North Annular Mode)-related stratospheric polar vortex strength and its modulation on the propagation of atmospheric stationary waves can account for this change, with the key area being located in the North Atlantic region (Figure 11). Further details of this study can be found in Wang et al (2009a).

It is also found that during the boreal winter, a positive phase of the Antarctic Oscillation (AAO) is associated with anomalous easterlies in middle-low latitudes (30–40°N) and anomalous westerlies in middle-high latitudes (45–65°N) of the upper troposphere about 25–40 days later. A reverse wind direction occurs during the negative phase. While there is also a response in the zonal winds in the tropics, namely over the central-eastern Pacific, to some extent, these tropical zonal wind anomalies can trigger a Pacific /North American teleconnection patterns (PNA)-like quasi-stationary Rossby waves that propagate into the Northern Hemisphere and gradually evolve into patterns which resemble the North Atlantic teleconnection patterns. These quasi-stationary Rossby waves might give rise to anomalous eddy momentum flux convergence and divergence to accelerate anomalous zonal winds in the Northern Hemisphere. Detailed descriptions of these signatures of the AAO in the Northern Hemisphere can be found in Song et al. (2009).

Moreover, the seasonal evolution of East Asian winter monsoon (EAWM) and its long-term changes after 2000 are examined by using the NCEP/NCAR reanalysis and Chinese station observational datasets (Figures 12-13). A monsoon tendency index (MTI), which is defined as the temporal difference of the East Asian monsoon index, indicates that the winter monsoon setup is postponed in autumn, while the setup is quickened in early winter. In mid winter, the EAWM breakdown process is accelerated but lingered in late winter. We suggest that the postponement of the monsoon setup in autumn may be caused by strong global warming at the lower levels, which further limits the setup time period and leads to the quickening of setup process in early winter. Meanwhile, a north-south seesaw of temperature tendency change in China can be observed in December and February, which may be related to the large-scale circulation changes in the stratosphere, characterized by a polar warming in mid winter and polar cooling in early spring. This linkage is possibly caused by the dynamical coupling between stratosphere and troposphere via the variation of planetary wave activities. In spring, the EAWM breakdown speed is decreased, which favors the revival of EAWM in East Asia. More detailed results can be found in Ke et al. (2009).

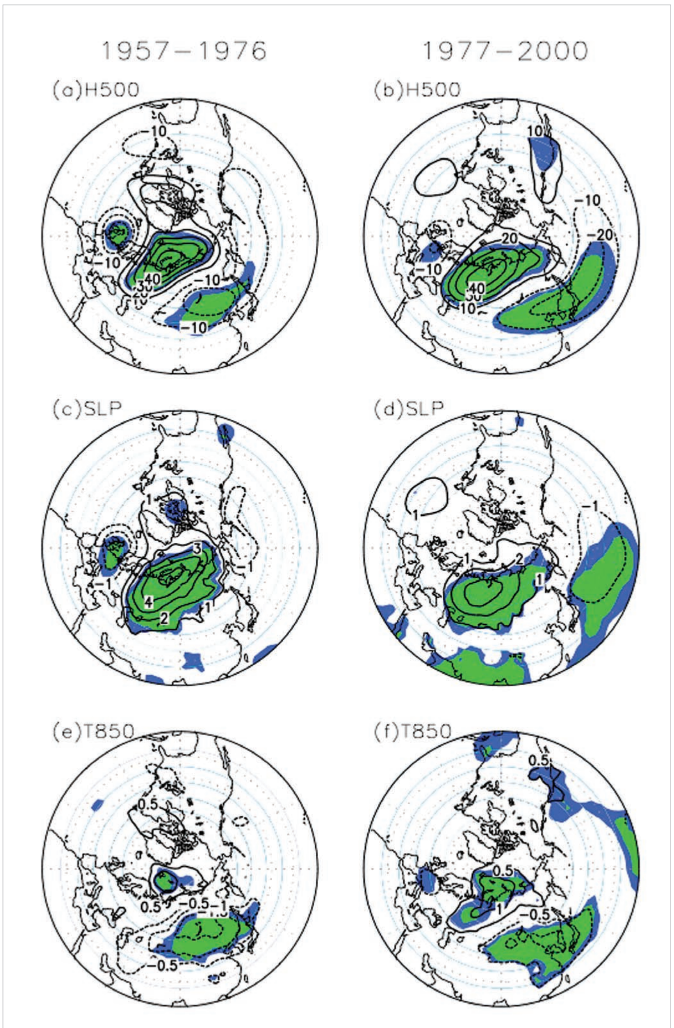


Figure 11. The regression (contour)/correlation (shading) of detrended winter mean (a) 500-hPa geopotential height, (c) SLP, and (e) 850-hPa air temperature on detrended winter mean UBI for the period 1957 – 1976. (b), (d), (f) are the same as (a), (c), (e), but for the period 1977 – 2000. Contour intervals are 10 gpm in (a) and (b), 1 hPa in (c) and (d), and 0.5 °C in (e) and (f). Dark and light shading indicates the 99% and 95% confidence level, respectively.

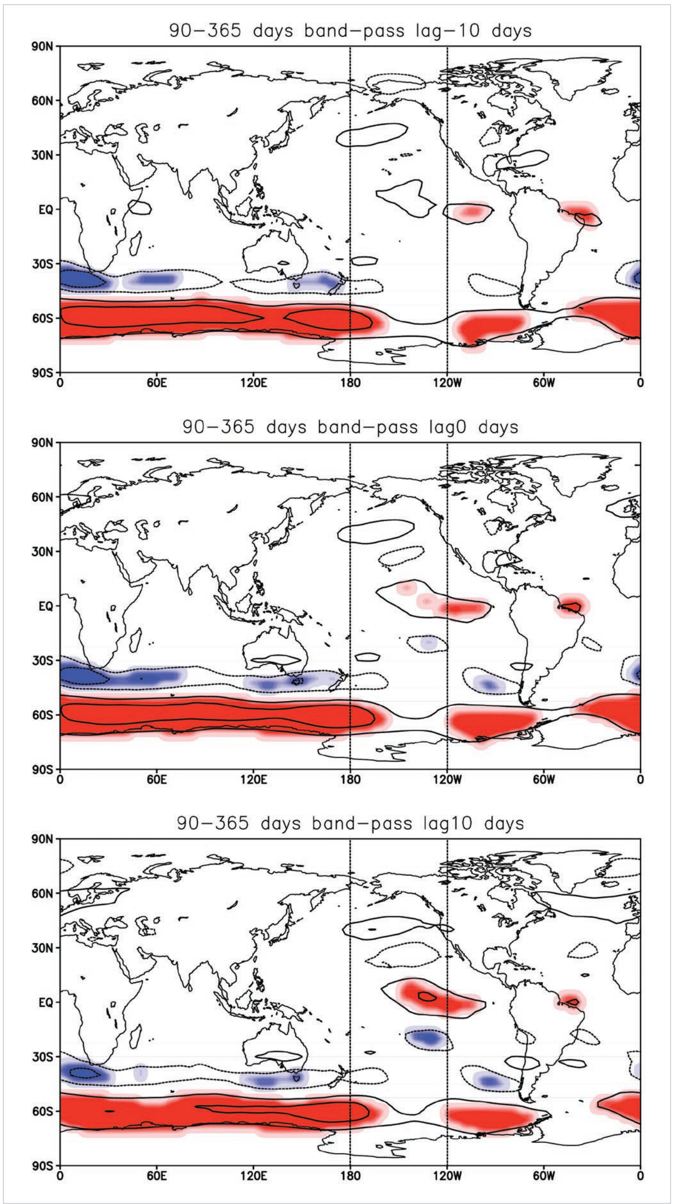


Figure 12. Zonal wind anomalies at 200-hPa regressed on the daily Antarctic Oscillation index at lags -10 days (top), lags 0 days (middle) and lag+10 days (bottom). Shading denotes correlations exceeding the 95% confidence level based on the t-statistic.

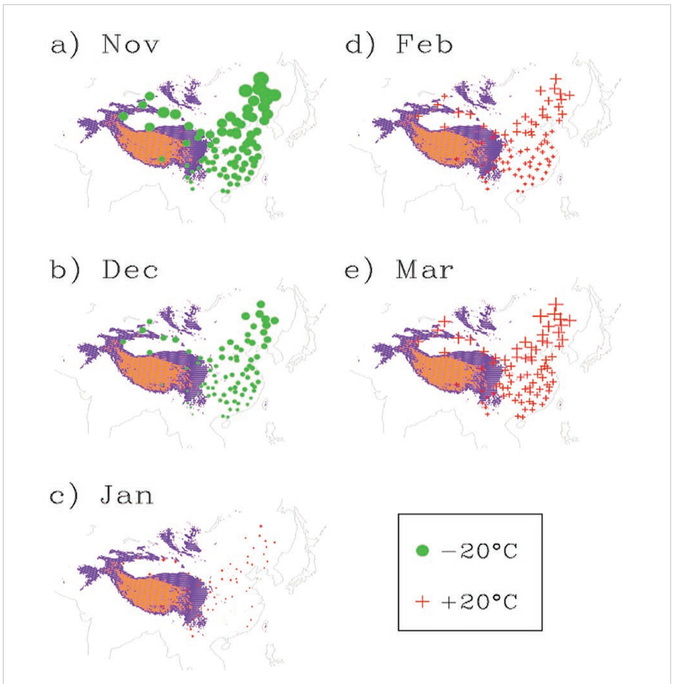


Figure 13. The climatology (30 yrs mean from 1971 to 2000) of temperature tendency (the difference of temperature between lagged one month and leading one month, refers to the text for the exact definition and example) in China using station observational data: a) November, b) December, c) January, d) February and e) March. Positive values are shown with plus sign and negative values with open circle. The size of mark is proportional to the temperature tendency value.

3. Prediction of the South China Sea summer monsoon onset

(PI: Johnny Chan)

The South China Sea summer monsoon onset is found to be triggered by a correct phasing of the 30-60-day oscillation and the synoptic-scale circulation from the mid latitudes.

Previous studies have suggested that the South China Sea (SCS) summer monsoon onset is concurrent with the arrival of a 30–60-day northward-propagating trough. On the other hand, from a synoptic viewpoint, some studies pointed out that the arrival of a mid-latitude front may be the triggering mechanism of the SCSSM onset. This study attempts to link these two viewpoints and to investigate their relative role in inducing the SCSSM onset. Composites of low-level zonal winds, geopotential heights and temperatures during the 1991–1999 SCSSM onsets based on the European Centre for Medium Range Weather Forecast ERA-40 data indicate that both the Madden and Julian Oscillation (MJO)/Kelvin waves and mid-latitude trough are apparently involved in the onset. The MJO/Kelvin waves play a major role in inducing the large-scale easterly-westerly shift over the central SCS, while the effect of the acceleration of westerlies ahead of the mid-latitude trough is limited to the northern SCS only. Numerical experiments using a regional climate model further demonstrate that the MJO/Kelvin waves control the timing of the onset by changing the background meridional geopotential height gradient over the SCS. When the MJO is at its peak phase over the Maritime continent, it imposes a positive meridional geopotential height gradient over the SCS such that easterly winds are induced, which significantly reduces the strength of a mid-latitude trough. After the equatorial convection has dissipated, a Rossby-wave response is induced, leading to the formation of a northward-moving trough. When this trough moves northward, the meridional geopotential height gradient is reversed and westerly winds are induced. At the same time, if a mid-latitude trough arrives in south China, the westerlies associated with the mid-latitude trough will strengthen because of the background meridional geopotential height gradient, which gives the impression that both the northward-moving trough and mid-latitude trough are in phase and work together to induce the onset (Figure 14). Further description can be found in Tong et al. (2009).

4. High-resolution model simulations of the East Asian monsoon

(PI: Francis Tam)

Numerical models capable of simulating the Asian monsoon and its various circulation elements will serve as a powerful tool for understanding the Asian climate variability. Here we seek to establish a suite of high-resolution models for studying the monsoon.

In this on-going work, the East Asian monsoon, including its seasonal evolution and inter-annual variations, is simulated using high-resolution numerical models. We have carried out climatological runs using the ECHAM5 atmospheric GCM up to T159 resolution (about 75 x 75 km). It is found that the model is able to reproduce MJO and TC-like structures (Figure 15). We will examine the potential of using the RegCM3 regional climate model for dynamical downscaling, in order to simulate the monsoon circulation with even higher resolutions. The reproducibility of monsoon variations by prescribing inter-annually varying SST will also be examined. The goal is to setup a high-resolution climate modeling system capable of capturing monsoon and TC variability on inter-annual or longer time scales.

5. How do the two types of Pacific Ocean warming affect the East Asian/western north Pacific summer monsoon?

(PI: Francis Tam)

ENSO is the most important contributor of global climate variability on the interannual time scale. Here we delineate the impacts of the two different flavours of ENSO on the East Asian climate.

This on-going work seeks to substantiate the findings of Chen and Tam (2010). In particular, dynamical processes responsible for the impact of the two types of ENSO on the East Asian/western north Pacific monsoon will be examined. This will be done by analyzing the observed summer monsoon evolution during Pacific warming events. Diagnosis based on observations will be further corroborated with numerical experiments using an anomaly model, which allows one to simulate the circulation response to prescribed diabatic heating perturbations. The effect of the different heating distributions associated with the two types of ENSO on the monsoon circulation will be studied in detail.

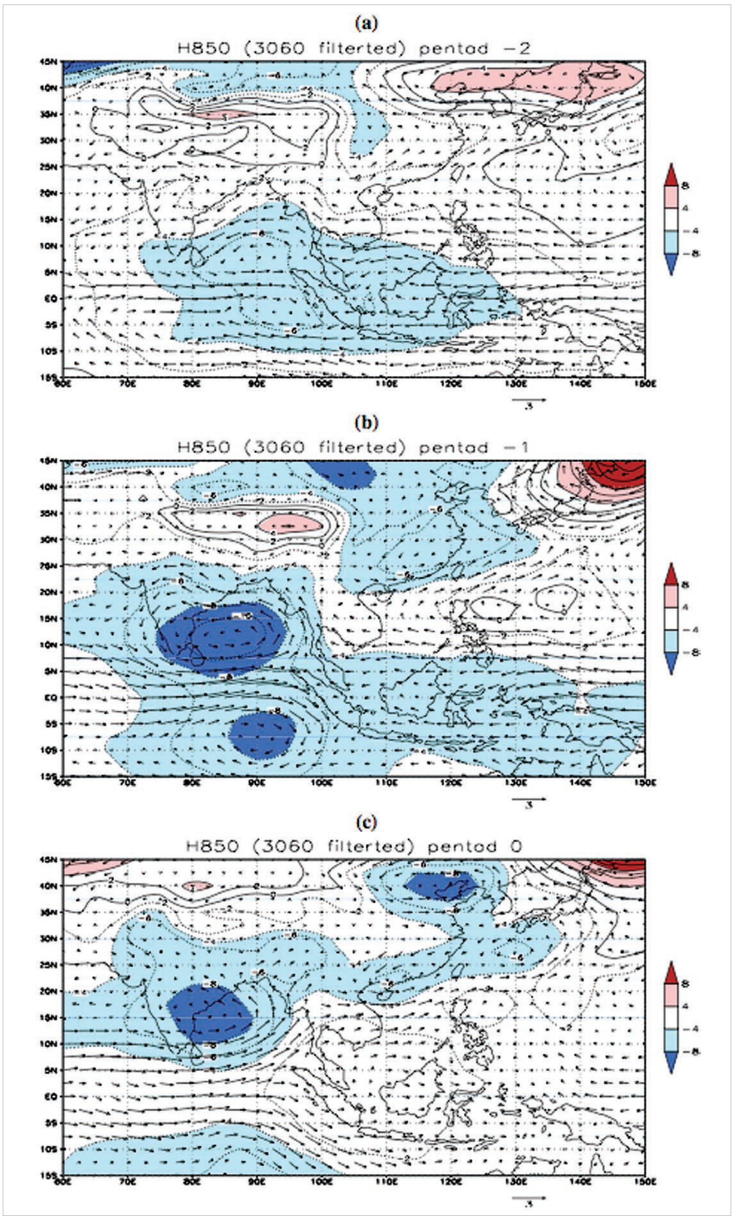


Figure 14. A total of 30–60-day filtered composite 850-hPa geopotential height anomalies (m) and wind vectors (m s^{-1}) in (a) pentad -1, (b) pentad -2 and (c) pentad 0. Height anomalies < (>) -4 m (4 m) are shaded in blue (red) .

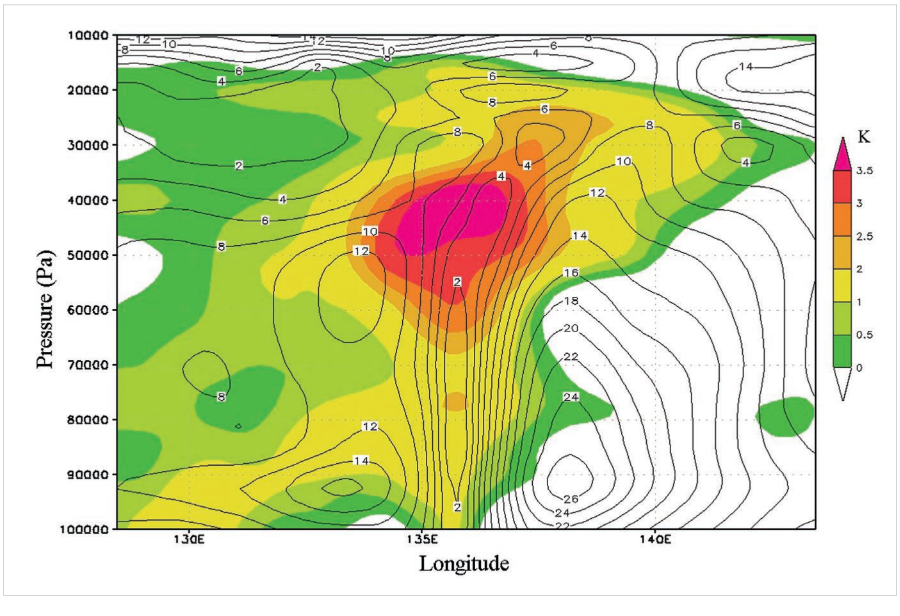


Figure 15. Vertical cross section of wind speed (contours; units: m s^{-1}) and temperature deviation relative to a 15°x15° region (shading, see scale bar at bottom; units: °C) associated with a TC-like structure simulated by the ECHAM5 atmospheric GCM at T159 resolution.

C. General climate studies

1. ENSO variations under global warming scenarios

(PI: Wen Zhou)

The frequency of El Niño events is related to the Atlantic Multidecadal Oscillation while that of La Niña events is associated with the Pacific Decadal Oscillation.

This study investigates the decadal variability of El Niño and La Niña occurrence in observations and examines that variability in a set of 20th century climate simulations (20C3M) of coupled general circulation models (CGCMs) in the Intergovernmental Panel on Climate Change (IPCC) Fourth Assessment Report (AR4).Wavelet analyses reveal that the observed frequency of El Niño events displays significant decadal variability with a period of about 12 years during 1920-1940, whereas the frequency of La Niña events shows significant decadal variations with a spectral peak at 16 years throughout the 20th century (Figure 16). Moreover, the frequencies of El Niño and La Niña events are influenced by different factors that are responsible for planetary teleconnections. The frequency of El Niño events is related to the Atlantic Multidecadal Oscillation while that of La Niña events is associated with the Pacific Decadal Oscillation. Among the 15 IPCC AR4 CGCMs surveyed, CSIRO and MIROC_MEDRES CGCMs can reproduce the decadal variability of ENSO activity, and simulate partly its relationship with the Pacific and north Atlantic sea-surface temperature anomalies. Detailed information can be found in Wang et al. (2009b).

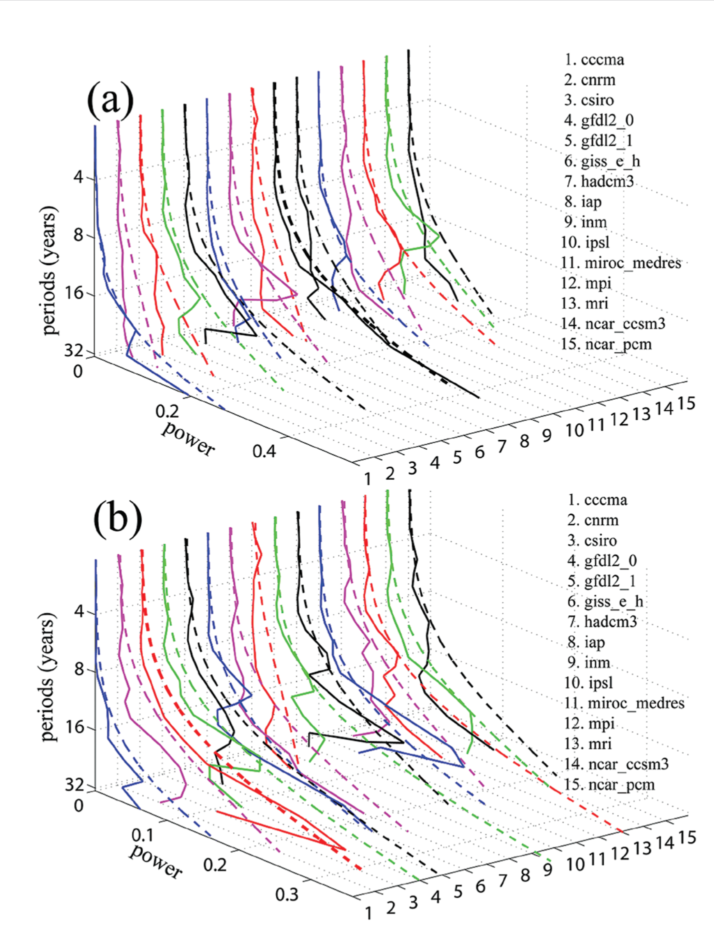


Figure 16. The global wavelet spectra of the indices (a) El Niño and (b) La Niña activity for the 15 IPCC AR4 CGCMs. The dashed lines indicate 95% confidence level. The mother wavelet is the Morlet wavelet.

2. Throughflow and sea level changes in the South China Sea under global warming scenarios

This study shows that the strengthening of the easterly wind anomaly east of the Luzon Strait plays an important role in the increase of Luzon strait transport after 1975 and ENSO activities are very important in the throughflow and Sea level rise in the South China Sea.

Throughflow
(PI: Wen Zhou)

This study investigates changes in the Indonesian-South China Sea throughflow – measured by the Luzon Strait Transport (LST) – associated with the 1976/77 regime shift using the Island Rule theory and the Simple Ocean Data

Assimilation dataset. Results show that LST has increased after 1975. Such changes are induced by variations in wind stress associated with the regime shift. The strengthening of the easterly wind anomaly east of the Luzon Strait plays an important role in the increase of LST after 1975. After 1975, the Kuroshio Current strengthens and the Mindanao Current weakens in response to a decrease in the total transport of the North Equatorial Current. Both the North Equatorial Countercurrent and the South Equatorial Current weaken after 1975, and an anomalous cyclonic circulation in the western equatorial Pacific prevents the tropical Pacific water from entering the Indian Ocean directly (Figure 17). More detailed information can be described in Liu et al. (2010).

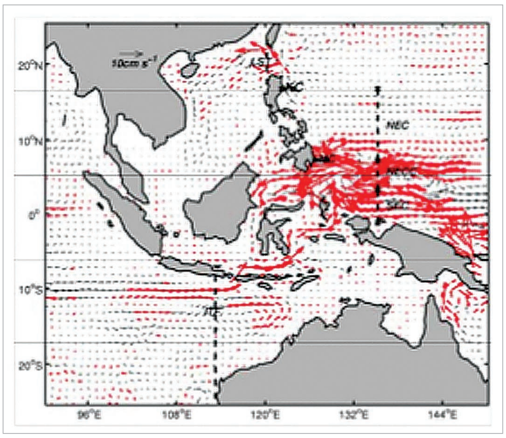


Figure 17. Ocean circulation difference (1976–2001 minus 1958–1975) averaged in the upper 465 m. Units: cm s^{-1}. The red vector indicates significant difference with a confidence level of 95%. Regions with water depth shallower than 100 m are stippled.

Sea level changes
(PI: Wen Zhou)

It seems that the sea level rise near the coastal areas of South China might be related to the early winter cooling after 2000, while the mean sea level decrease in South China Sea could be related to the higher frequency of El Niño events after 2000.

This study is to evaluate the impact of sea level change in the northern South China Sea on Hong Kong and Pearl River delta region. The rising sea level will cause an increase in the frequency of storm surges along the coastal region associated with tropical cyclones and an intensification of floods, causing erosion of coastal lowlands and the shore and the retreat of the shoreline. This would lead to increased differences between the high and low tides, which brings about stronger effects of waves, allowing more seawater to flow into river estuaries, affecting the mangroves and coral reef ecosystem along the coast and damaging the balance of the ecosystem. This would pose serious threats to the survival of human and economic development. Under the global warming scenario, the frequencies and strengths of extreme weather situations in South China have both increased significantly, and the continuously rising sea level will further deteriorate the Pearl River delta regions. The socio-economic security and development of the coastal area will be under serious threat. Detailed study about why and how the sea level change in the northern South China Sea is associated with a changing climate will be conducted in our future work (Figure 18).

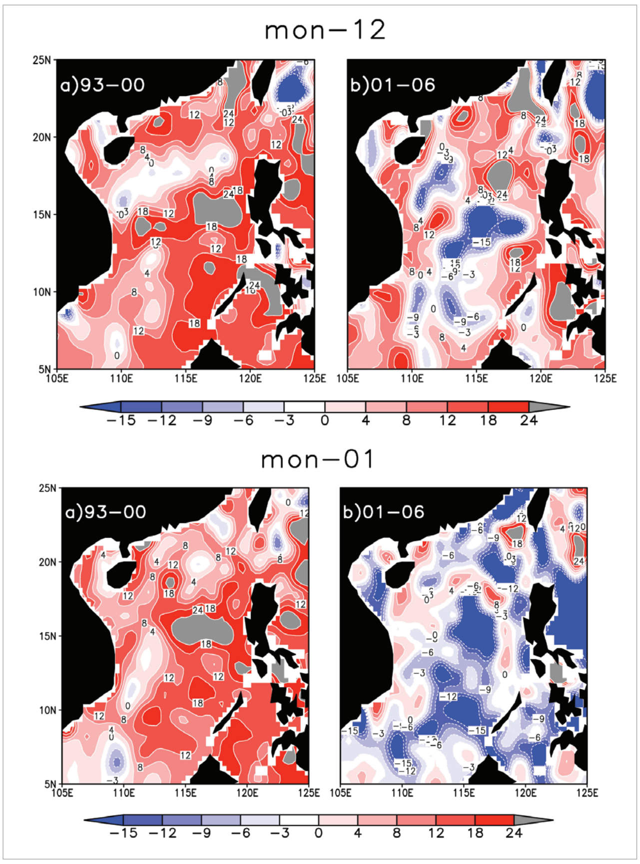


Figure 18. Sea level trend over South China Sea in December and January after 2000.

D. Air pollution studies

1. NO_2 DOAS measurements in Hong Kong
(PI: Mark Wenig)

The objective of this project is to further the understanding of the anthropogenic impact on the environment, especially the climate system and atmospheric composition.

NO_2 plays a significant role in atmospheric chemistry. In the troposphere it is one of the most significant precursors of photochemical ozone production and nitric acid. Although direct absorption of UV and visible radiation by tropospheric NO_2 does not contribute to global atmospheric forcing significantly, local maxima of up to 0.1 to 0.15Wm^{-2} can be reached, especially in megacities like Hong Kong.

This project measures NO_2 concentrations in the air using an optical remote sensing instrument. NO_2 is a pollutant with influence on public health, the climate system and atmospheric composition. This project aims to further the understanding of anthropogenic impacts on the environment by performing continuous monitoring of the air quality.

In this project we set up a new long-path DOAS instrument to measure NO_2 concentrations in Hong Kong. The measurement consists of sending a focused light beam from a xenon lamp through the atmosphere onto a retro reflector which sends the signal back to the instrument where the light is collected using a telescope and analyzed using a spectrometer (see Figure 19), resulting in information about column concentrations of NO_2. It can measure in different modes, e.g. it can look directly into the sun or it can scan different targets. Currently the instrument is set up at the CityU dome (Figure 20) and the measuring light path is across campus. Since it is an active DOAS instrument, meaning it has a light source, it can also measure at night, so that a full daily cycle can be measured (Figure 21).

Because of the very high accuracy of this instrument system and its spatial averaging capability the resulting data set can be used for air quality monitoring in Hong Kong and also for satellite measurement validation.

It is planned to set up more retro reflectors because the instrument is a scanning instrument, which means it can scan several retro reflectors and measure the NO_2 concentration along several light paths in different directions to determine a spatial distribution.

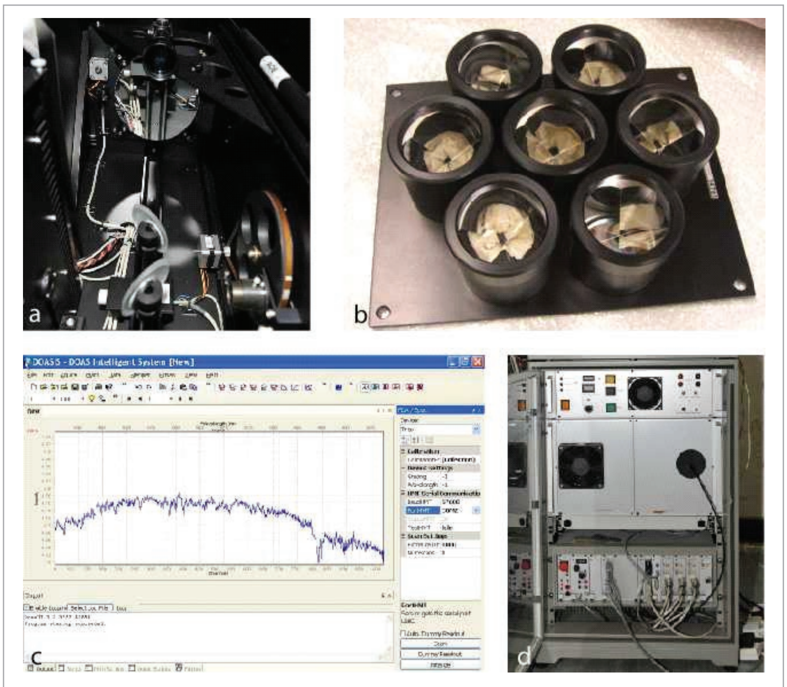


Figure 19. The long-path DOAS measuring system. **a** lamp and telescope **b** retro reflector **c** the controller software DOASIS **d** spectrometer and controller.

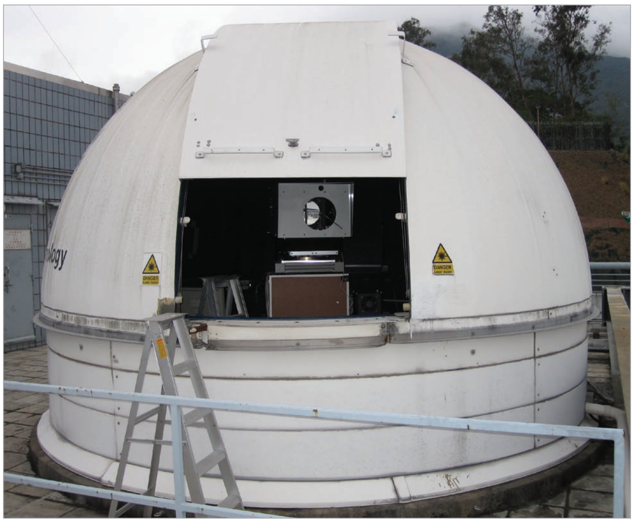


Figure 20. The setup of the long-path DOAS system in the CityU dome.

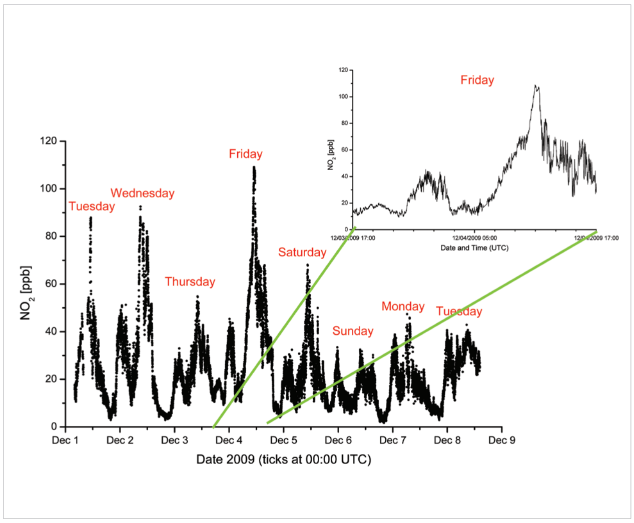


Figure 21. First results of the NO_2 DOAS measurements.

2. *Urban ozone episodes in autumn in Hong Kong*

(PI: Mark Wenig)

This project analyzes the so-called urban ozone episodes which are days with unusually high concentrations of ozone in summer or autumn. The autumn episodes especially increased significantly in the last couple of years and we studied the role of air temperature as a factor in the emergence of those autumn episodes.

This project studies urban photochemical episodes accompanied by unusually high ozone concentrations in the urban area of Hong Kong. These episodes usually occurred only in summer time since 1990, but starting in 2000 additional autumn episodes could be observed as well. During those episodes the ozone concentrations exceeded the Hong Kong Air Quality Objective and reached an hourly maximum of 332 μg m^{-3} in September 2005. The maximum ozone concentrations of both summer and autumn episodes seem to be on an upward trend.

We studied the role of the air temperature as a factor in the emergence of those autumn episodes. Significant correlations could be found between the maximum hourly ozone concentrations and the maximum and mean air temperatures during autumn months whereas the association between ozone and particulates is weaker.

The overall upward trend for air temperatures in autumn occurs at a time when the mean air temperatures in Hong Kong have been on the rise for over 120 years from 1885 to 2007, amidst the global warming trend.

Photochemical pollution is prevalent in Hong Kong and is often associated with tropical storms which affect Hong Kong in both summer and autumn. The suburban photochemical problem has become increasingly serious, especially in summer.

Regression analysis showed that the maximum hourly ozone concentrations have significant positive correlations with maximum and mean temperatures (r=0.6 and 0.5, respectively) for the autumn months (Figure 22).

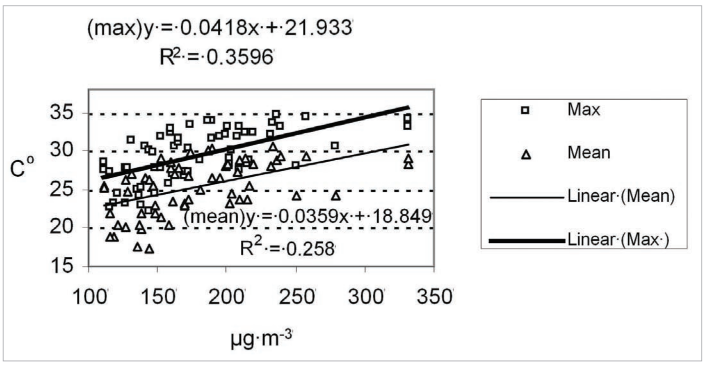


Figure 22. Maximum ozone concentrations in autumn versus maximum and mean air temperatures, Hong Kong (Sha Tin, Tai Po) 1997–2007 (from *Lee et al.*, 2009)

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Research Briefs

Predictions of Seasonal Tropical Cyclone Activity over the Western North Pacific for 2008

Updated Prediction of Seasonal Tropical Cyclone Activity over the Western North Pacific for 2008

Chan, J. C. L. and W. Zhou, 2008: The January/February 2008 Persistent Low Temperatures and Snowy/Icy Weather in Southern China: Meteorological Causes and Return Periods

2009 Predictions of (1) Seasonal Tropical Cyclone Activity over the Western North Pacific, and (2) Number of Tropical Cyclones Making Landfall in South China

2009 Updated Predictions of (1) Seasonal Tropical Cyclone Activity over the Western North Pacific, and (2) Number of Tropical Cyclones Making Landfall in South China

2009/10 Predictions of Seasonal Tropical Cyclone Activity in the Australian Region

Summary and Looking Ahead

During the past 18 months, our research activities have been quite extensive, focusing on four areas: typhoons/tropical cyclones, monsoons, general climate, and air pollution studies. In the area of tropical cyclones, we developed seasonal forecast schemes for real-time predictions of tropical cyclone activities in various regions of Asia, as well as studied the variations of tropical cyclone activity in these regions and provided physical explanations of such variations, based on analyses of atmospheric and oceanographic data. We also examined the possible effect of global warming on tropical cyclone activity. In the area of monsoons, we investigated the possible reasons for the cold winter of 2008, and the interdecadal variability of both the summer and winter monsoon circulations in East Asia, and provided physical explanations of such variabilities. In addition, we developed the capability of simulating and modeling the monsoon activity in East Asia with a global climate model. In the studies of general climate, we mainly focused on how global warming might affect/have affected the frequency of occurrence of the El Niño phenomenon, as well as sea-level changes and ocean currents. Our studies on air pollution examined the changes in aerosol and trace gas concentrations due to human activities, which will form a basis for understanding how such activities may affect local climate.

Looking ahead, we expect that our research activities will continue in these areas. We will focus both on the understanding of the physical causes of changes of various climate phenomena that have impact on the Asia-Pacific region and on the predictions of such phenomena as well as their projections under different global warming scenarios. These studies will be based on both statistical analyses of past data and computer simulations.

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Prof. Ronghui Huang	Honorary Professor (Academician, Chinese Academy of Sciences)
Dr. Mark Wenig	Assistant Professor
Dr. Wen Zhou	Assistant Professor
Dr. Francis Tam	Lecturer

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Prof. Yihui Ding	Academician, Chinese Academy of Engineering
Lord Prof. Julian Hunt	Professor, University College London, Fellow of Royal Society

Researchers

Appointed by Centre

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Dr. Huang Wan-ru	Research Fellow
Dr. Wong Lap Mho	Research Fellow
Dr. Lee Yuk Chun	Research Fellow
Mr. Liu Kin Sik	Senior Research Assistant
Ms. Cheng Juan	Senior Research Assistant
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Mr. Goh Zung Ching	Research Assistant
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