

ANALYSIS OF TROPICAL STORMS MAKING LANDFALL ON CHINA AND THE USA AND OF DISASTER MITIGATION IN THE LAST DECADE

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INTRODUCTION

Both China and the United States are most affected by tropical storms in the world. Two hundred and fifty tropical storms which occupy 37 per cent of all tropical storms originating in the Western North Pacific made landfall on the People's Republic of China (PRC) during the 1960–89 period at an average of 8.0 per year. Eighty-one tropical storms, which make up 30 per cent of all tropical storms originating in the North Atlantic during the same period, made landfall on the USA (Vega, 1991) at an average of 2.5 per year.

Most of both countries' coastal areas hit by tropical storms are highly concentrated with population and economic infrastructure. Serious losses of lives and property damage are caused by the tropical storms making landfall. The major reasons for the loss of life and property damage are strong wind, torrential rain and tidal surge. Compared to tropical storms occurring throughout history, the loss of human life associated with tropical cyclones is decreasing as tropical storm warning services and dissemination are popularized, except for more sophisticated storm warning procedures. This paper analyses the annual frequency, interseasonal variation and landfall zone of tropical storms making landfall on the coastal areas of China and eastern areas of America. The damage caused by the tropical storms making landfall is also discussed in this paper. The data used in this paper are respectively from the *Tropical Cyclone Annual Report* (1949–92) edited and published by the Shanghai Meteorological Bureau (SMB), PRC, and from *North Atlantic Cyclones* edited by the National Hurricane Center (NHC) and presented in *Mariners Weather Log*, NOAA, USA. The tropical storms which are defined in this paper include typhoons and hurricanes but do not include tropical depressions.

ANNUAL FREQUENCY

The annual frequency of tropical storms making landfall on the PRC is highly varied, with a maximum of twelve in 1961, 1967, 1974 and 1989 and a minimum of four in 1982. The annual frequency of tropical storms making landfall on the USA ranges between seven in 1969 and one in 1977.

Based on the data from 1949–90, the annual frequency of tropical storms making landfall on the PRC correlates to the El Niño event. There is an average of 6.5 tropical storms making landfall on the PRC within an El Niño year. But there is an average of nine storms in a non-Niño year.

The number of landfalls in 1974, a non-Niño year, reached a maximum value as large as twelve within the past forty years and in 1982, an El Niño year, reached a minimum value of four. The reason is that the descending air over the Western North Pacific near the equator causes an anomaly while the upward moving air over the equatorial Eastern Pacific where the sea surface temperature is high also leads to the occurrence of an anomaly.

As the descending motion over the Western North Pacific goes against the formation and development of tropical storms, the number of tropical storms landfall on China decreases in an El Niño year (Pan, 1982). But the analysis in the paper reveals that the annual number of tropical storms landfall in the United States has no correlation with El Niño events based on the data from the *Mariners Weather Log*, NOAA. It reveals that the El Niño event has more significant effects on the weather systems over the Western North Pacific than the weather systems over the North Atlantic.

INTERSEASONAL VARIABILITY

The six months of a year which are recognized in the PRC and the USA as being official tropical storm season are June, July, August, September, October and November. Storms making landfall on the PRC before June or after November are very rare.

Tropical storms which made landfall on the PRC from July through September occupy 80 per cent of all tropical storms making landfall. July is the most active month with sixty-nine storms making landfall. There is a sharp slope next to June. The active season for tropical storms making landfall on the USA is one month later than that on the PRC. There is a slope next to July. The months of August and September, with twenty-six and twenty-seven of the landfalls on the USA, respectively, are the most active of all months (Vega, 1991).

LANDFALL ZONES

The coastline of China and the eastern coastline of America are respectively divided into several zones in which tropical storms may strike.

It must be pointed out that the coastline geometry is a determining factor in the boundaries of each landfall zone as natural breaks in the coastline were utilized for consistency and such coastline geometry is available for issuing tropical storm warning.

The coastline of the PRC from the Guangxi-Vinnar border to Liaoning-Korean border is divided into five landfall zones. Those zones are as follows:

- Zone 1: From the Guangxi-Vinnar border to Guangdong provincial boundaries;
- Zone 2: From Guangdong to Fujian provincial boundaries including coastline of Hainan province;
- Zone 3: From Fujian to Zhejiang provincial boundaries including coastline of Taiwan province;
- Zone 4: From Zhejiang to Shanghai then to Jiangsu provincial boundaries; and
- Zone 5: From Jiangsu to the Liaoning-Korean Border.

Before June and after October, tropical storms only make landfall on zones 1 and 2 near the south of 25° N latitude. During the months of July, August and September, tropical storms may strike nearly anywhere in the PRC. There has been a high frequency in zone 2, with 48

per cent of all landfall storms.

The eastern coastline of America from the Texas–Mexican border to the Maine–Canadian border is divided into nine landfall zones. The last zone (zone 9) has a much greater area than any of the others, but it has a much lower frequency due to its higher latitude.

It is noted that there are two major reasons for the higher frequency of the storms making landfall on the PRC than on the USA. Firstly, the annual number of tropical storms occurring in the Western North Pacific is larger than in the North Atlantic. The second reason is that the main landfall zones in the PRC lay to the south of 23° N latitude. However, the main landfall zones in the United States, except for Florida state, lay to the north of 30° N latitude where most storm tracks in summer change their directions and storms move eastward along the north of the subtropical high in the north hemisphere and off the coastline.

PREPARING DAMAGE AND PREVENTION

Tropical storms reaching the coastline threaten building constructions. After the storms make landfall, although they weaken in intensity, they cause heavy rainfall and flood since the warmer and much more humid air from the tropical ocean is combined with the cooler air from the westerly belt in the areas of middle latitude. More losses of life and property damage are caused by such storms. Based on the damage statistics from the PRC and the USA, the damage from tropical storms have markedly increased in the last decade. It is expected that the more economic infrastructures we have, the greater will be the property damage caused by tropical storms.

The greater damage caused by the tropical storms making landfall on the PRC relates to the suddenly intensive tropical storms occurring near the coastline (Zhou, 1991). Typhoon Bill became a tropical storm over the East China Sea on 7 August 1988. Based on the climatology statistics of the tropical storms making landfall at Zhejiang province, it seemed likely that Bill would soon weaken its intensity when it was about to make landfall. However, it suddenly escalated into a typhoon with a central pressure of 980 millibars and 70–knot winds. Its central pressure continued to drop to 970 millibars three hours later and made landfall at Xiangan, Zhejiang province.

Bill then battered Hangzhou City, a tourist attraction in China, when its eye passed through the city. Bill was responsible for 1 billion yuan RMB in property damage. The greater property damage in the PRC also relates to the multiplicity of landfall. The multiplicity of landfall here means that more storms make landfall within a shorter coastline during a shorter period of time (Zhou, 1991). In the summer of 1990, five typhoons and tropical storms made landfall at the Fujian–Zhejiang provincial boundaries including the coastline of Taiwan province within a period of a hundred days. One of those, Typhoon Yancy, stayed for sixty hours and circled four times within the Taiwan Channel, passing in and out the coast of Fujian province three times. Because of the multiplicity, Yancy caused more losses of life and damage of 50 billion yuan RMB.

More than 70 per cent of United States' tropical storm–spawned damage is caused by intense hurricanes even though they comprise only 20 per cent of all landfall on the United States (Landsea, 1993). Some high category hurricanes defined by the Saffir–Simpson Intensity scale struck the continental United States in the last decade and caused high economic damage.

Gilbert of 1988, the strongest hurricane in the western hemisphere, was responsible for the US\$50 million in damage (Gross, 1989). Hugo in 1989 struck South Carolina and was responsible for twenty-four deaths and US\$5.9 billion in damage (Vega, 1990). Hurricane Andrew of 1992 struck south Florida and Mississippi as well as Louisiana. It resulted in losses of life and damage of US\$2.5 billion (Mayfield, 1993).

The majority of landfall zones in the PRC and the USA has a highly concentrated population. It is very important for people to mitigate disasters. Aside from more sophisticated warning, all kinds of warning services and disseminations are vital to mitigate disasters from tropical storms.

In the PRC, the Typhoon Warning Dissemination System (TWDS) has been used for many years. The TWDS consists of high frequency transmitters. Its objective is to disseminate warning and updated information from the local meteorology centre to the local government and all circles of society as soon as possible. In the PRC, the government pays great attention to storm and typhoon warning because local policies of prevention are made by local governments. In addition, communities, schools and businesses also need typhoon warning and much updated information so that the public can promptly implement prevention management, according to the policies made by local governments.

The TWDS has been popularized in the majority of areas of the coastline, specially in coastal multitudinous cities. For example, tropical storm Lola originating over the Western North Pacific made landfall at Shanghai City in 1989. When the public received the typhoon warning and updated information from the local TWDS, the inhabitants worked in close coordination with the local government and prompted effective evacuation and secured property within twenty-four hours before Lola made landfall. No person died as a result of Lola in this city. During the years 1949-89, three tropical storms made landfall at Shanghai City. Of those, two tropical storms, Gloria of 1977 and Babe of 1949, made landfall at this city before the TWDS was established. But Gloria was responsible for 176 deaths and Babe for 1,673 deaths. It shows that TWDS plays a vital role in disaster mitigation.

The Hurricane Hotline, a pattern of warning services and dissemination, has been established by NOAA, USA, since 1985 (reported 1989). This public service is provided by the National Weather Service, NBC News, and USA Today. The hotline can be reached from anywhere in the US. The public can obtain the most updated hurricane information or understand the storm's stage from the hotline so that they can prepare for evacuation. Because of the Hurricane Hotline, two deaths resulted from Gilbert and fifty-nine deaths from Hugo, respectively. Compared to Hurricane Camille of 1969 which resulted in 256 deaths (Vega, 1991), Gilbert's and Hugo's impacts were eclipsed.

CONCLUSIONS

Based on the data during the period 1960-89, a total of 250 typhoons and tropical storms made landfall on the PRC and eighty-one tropical storms and hurricanes on the USA. The following statistical results are obtained from this study:

- (1) The annual frequency of tropical storms making landfall on the PRC correlates with the El Niño event. But the annual frequency of landfall on the USA from the Western North Pacific has a positive correlation with those making landfall on the PRC.
- (2) The six months of the year recognized as being the official tropical storm season in the PRC and in the USA are June, July, August, September, October and November. The

active season for tropical storms making landfall on the PRC is one month earlier than that on the USA.

- (3) The greater damage caused by tropical storms in China correlates to the sudden intensive tropical storms and multiplicity of the landfall. Some high category storms defined by the Saffir-Simpson Intensity scale struck the continental United States in the last decade and resulted in more costly damage.
- (4) The property damage caused by tropical storms making landfall has increased over the last decade due to highly concentrated populations and economic infrastructures. Compared to the tropical storms occurring during the previous ten years, however, the loss of life associated with tropical storms has decreased due to the Typhoon Warning Dissemination System (TWDS) in the PRC and the Hurricane Hotline in the USA.

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