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Tropical Cyclone Research in Asia: Hong Kong and Macao

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Abstract. Due to climate change, the emergence of extreme weather has affected the global economic activities, human life, and the environmental sustainability. Tropical cyclones are considered as notable destructive weather systems, especially in coastal areas. This study aims to investigate the common features of the most destructive and devastating tropical cyclones in Hong Kong and Macao. A total of three representative tropical cyclones were selected for each city. The considered tropical cyclones were analyzed in terms of different attributes, including the year of occurrence, maximum wind speed, lowest pressure, total deaths, and total monetary losses. The results from the conducted analysis indicate that the costliest tropical cyclones were recorded in Hong Kong and Macao. In particular, the damages caused by typhoons Hato and Mangkhut totalled over \$10 billion. Furthermore, this study discusses the need for the development of climate change mitigation strategies as well as increasing the public awareness regarding climate change and its consequences. The findings from this study can be further used by the relevant stakeholders to address the climate change effects on tropical cyclone occurrence as well as to design adaptation and resilience strategies against tropical cyclones in the forthcoming years.

1. Introduction

Tropical cyclones are considered as remarkable destructive weather systems, especially in exposed coastal areas [1]. Typhoons are classified as tropical cyclones. The weakest tropical cyclones are generally referred to as tropical depressions. The tropical cyclone becomes a tropical storm when the maximum sustained winds become 39 mph [2]. If the maximum sustained winds reach 74 mph, then the tropical cyclone will be classified as either typhoon or hurricane depending on the origin of this tropical cyclone [2]. The tropical cyclones, originated in the Northwest Pacific, are referred to as typhoons. In the meantime, the countries that are located in the South Pacific and Indian Ocean still



use the generic term “tropical cyclone” despite changes in the maximum speed of sustained winds. Tropical cyclone disasters are the most serious natural disasters. Because their frequency of occurrence is higher as compared to other hazards (e.g., earthquake disasters), their cumulative losses are substantial. The impact of tropical cyclones has become a major concern, as many tropical cyclones bring a series of extreme weather events such as severe storms, heavy rainfall, and large floods. These may have an adverse impact on infrastructures (e.g., highways, air terminals, and ports), damage to cargo, human welfare, casualties, serious financial loss, travel delays, building damage, and the diversion of navigation channels [3-6].

Under the influence of climate change, the power of super typhoons is increasing. Global warming research suggests that ongoing global climate change will possibly alter tropical cyclone shift prevailing, frequency, and intensity. Some of the tropical cyclone paths are viewed as abnormal since 2004 [7]. For example, super Typhoon Mangkhut was the most intense typhoon occurred in Hong Kong since Typhoon Ellen in 1983. This was the longest typhoon warning signal number that lasted for 10 hours. As such, the super typhoon with longer duration caused more damage and resulted in additional challenges during the rescue efforts [8]. The event induced the normal public transportation services to be suspended because strong winds knocked down 47,000 trees, blocked a number of highways, and caused severe flooding in several seaside residential areas. Over 200 people were injured, and a direct economic loss exceeded US\$930 million [9,10]. Another super typhoon Hato was the deadliest recorded typhoon striking Macau in 53 years. As a result, 153 injuries and 12 fatalities were reported. Also, Macau has suffered a direct economic loss of US\$1.56 billion [8].

2. Typhoons in Asia: Hong Kong and Macau

China is one of the Asian countries most affected by tropical cyclones. In recent years, the average annual loss caused by tropical cyclones is more than 10 billion yuan. Within China region, Hong Kong and Macau are favorable in generating typhoons because of the coastal areas, subtropical climate, and distinct seasons. In terms of the geographical location, Hong Kong and Macau are in the Pearl River Delta. The distance from Macau to Hong Kong is 61 kilometers, which is equivalent to 38 miles air travel distance (i.e., 0.07 hours journey time) (<https://www.distancefromto.net/>). Therefore, the tropical cyclones, which occurred in Hong Kong and Macau, will be analyzed as representative tropical cyclones of the Asian region.

Based on the information from Hong Kong Observatory and Macau Geophysical and Meteorological Bureau, No. 1 signal is identified as “standby” and No. 3 is recognized as “strong wind”. This study primarily considered strong tropical cyclones in Asia, such as “gale or storm” (No. 8 signal), “increasing gale or storm” (No. 9 signal), and “typhoon” (No. 10 signal). The recorded storms in Hong Kong and Macau since 1960 are summarized in Table 1. Starting from 1960, 65 storms have been recorded in Hong Kong and Macau. It was found that at least Hong Kong or Macau had one strong tropical cyclone per year. In terms of storm level, 68% of storms that occurred between 1960 and 2019 are No. 8 signal, 11% of storms are No. 9 signal, and 21% of storms are No. 10 signal. Reviewing the past 60 years, a severe tropical cyclone period was recorded between 1960 and 1969. The frequency of storms was the highest and contributed around 43% of hurricanes over the half century. Interestingly, the number of hurricanes was decreasing between 1970 and 2009, but started rising again in 2010.

Table 1. The number of recorded storms in Hong Kong and Macau since 1960.

Period	No. 8 signal	No. 9 signal	No. 10 signal	Total
1960-1969	8	1	6	15
1970-1979	6	2	3	11
1980-1989	8	0	1	9
1990-1999	8	2	1	11

2000-2009	7	2	0	9
2010-2019	7	0	3	10
Total	44	7	14	65

Table 2. The list of costliest storms in Hong Kong and Macau since 2000.

a/a	Storm	Year	Maximum Wind Speed (mph)	Lowest pressure (hPa)	Total Deaths	Total Losses
1	Hato	2017	132	945.4	12 deaths in Macau	\$6.41 billion
2	Mangkhut	2018	180	956.4	0	\$3.77 billion
3	Vicente	2012	140	964.2	0	\$350.9 million
4	Dujuan	2003	145	950	0	\$392 million
5	Nuri	2008	115	955	2 deaths in Hong Kong	\$85 million

Source: Hong Kong Observatory, 2019

2.1. Hato

At 12:00 noon time on August 23, 2017, Storm Hato was located on the offshore surface of about 75 kilometers southeast of Zhuhai City, Guangdong Province. The maximum wind speed near the center was 48 meters per second, the wind force exceeded level 15, and the minimum pressure of the center was 945 hPa (Table 2). The radius of the seven-level wind circle was 220-280 kilometers, the radius of the ten-level wind circle was 70-80 kilometers, and the radius of the twelve-level wind circle was 50 kilometers. It landed on the southern coast of Zhuhai City, Guangdong Province at around 12:50 p.m. The minimum air pressure at the center of the landing was 950 hPa. The maximum wind speed near the center was 45 meters per second as well as the wind force exceeded level 14. The typhoon struck the entire Zhuhai city suddenly. Hence, most of the trees were all blown down by the strong wind. Also, the T-shaped steel rods and concrete poles were knocked down and cut off by the strong wind. In this incident, Hong Kong and Macau also suffered considerable fatalities including 129 injuries in Hong Kong as well as 12 deaths and 244 injuries in Macau. Indeed, huge economic losses were around USD 511 million in Hong Kong and USD 1.56 billion in Macau. Interestingly, Macau has hoisted the No. 10 typhoon signal for the first time in eighteen years since Typhoon York occurred in 1999 [9,11].

2.2. Mangkhut

At 6:00 a.m. on September 16, 2018, Storm Mangkhut was located in the northeast sea of the South China Sea, where it was about 420 kilometers southeast of Taishan City, Guangdong Province. The maximum wind speed near the center was 50 meters per second, the wind force exceeded level 15, and the lowest pressure was 940 hPa. In addition, a seven-level wind circle radius was 400-550 kilometers, a ten-level wind circle radius was 150-270 kilometers, and a twelve-level wind circle radius was 60-80 kilometers. Since it was difficult to confirm the typhoon circulation center and the intensity continued to weaken, the Central Meteorological Observatory stopped numbering it. Both Hong Kong and Macau Observatories further reduced it to a low pressure area. Even so, the minimum pressure of the center measured by Hong Kong and Macau reached 956.4 hPa. The impact of wind and rain was serious as it induced severe damages to the southern, eastern and western Guangdong, Hong Kong, and Macau. Simple outdoor buildings such as low-rise buildings, low-rise self-built houses, billboards, marine fishing net cages, and small vessels were either completely destroyed or seriously damaged [9,11].

3. Discussion and Conclusion

As one of the consequences of extreme climate change, we found that there is an increasing trend of transformation from weak tropical cyclones (i.e., tropical depressions) into super typhoons in the 21 century. The impacts and level of risk from overtopping, erosion, and flooding become more obvious [12]. The World Meteorological Organization [13] identifies risk as “expected loss of lives, people injured, damage to property and disruption of economic activities due to a particular hazard in a given area and referenced period”. In other words, the risk can be defined as a chance of developing a dangerous action (or process) that will negatively affect property, environment, and people [12]. Based on a detailed review of the typhoons in Asia, the following common features of the tropical cyclones have been identified: (1) the paths experience significant changes; (2) large change in intensity; (3) storm surge history is rare for many tropical cyclones; (4) strong follow-up rainfall; and (5) travel paths and landing points are extremely favorable for strong impacts. Moreover, hurricanes and typhoons that occurred after 2000 have caused a significant number of fatalities and resulted in substantial property damages. Fatalities and property damages can be also explained by the rapid growth in population and wealth across the coastal areas [7,14]. This is a time for a paradigm shift in how we change people’s behavior and perception towards climate change and major tropical cyclones.

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