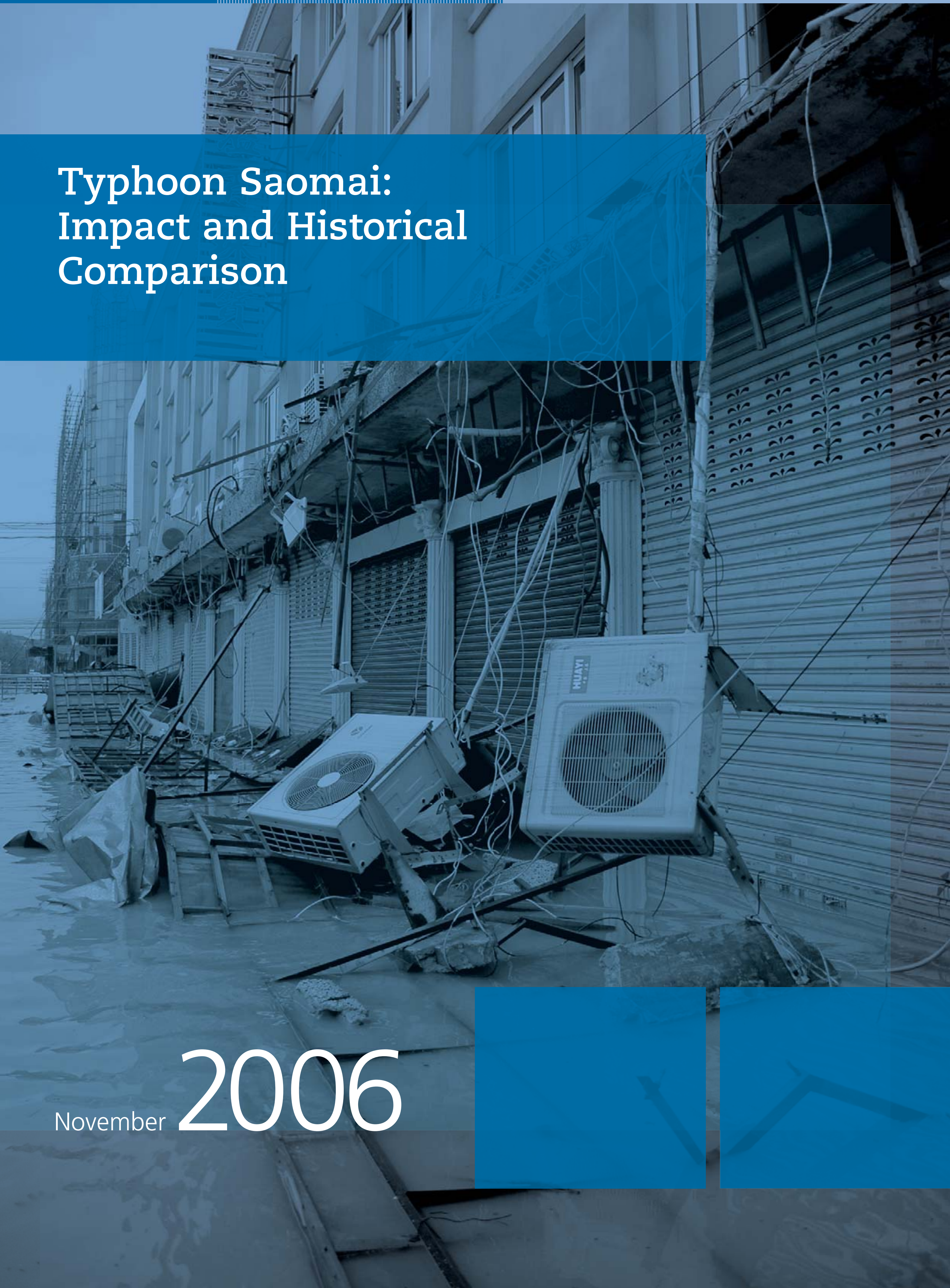
GUY CARPENTER

Typhoon Saomai: Impact and Historical Comparison



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Contents

Executive Overview

This report has been produced by Guy Carpenter's Instrat® unit following the landfall of Typhoon Saomai on 10 August 2006 in eastern China. It is split into two sections.

The first section provides a meteorological background to the typhoon, and how the storm affected the coastal provinces of China. The paper also describes the damage extent in the country and provides economic and insured loss estimates.

Significant observations from section one:

- Saomai battered the provinces of Zhejiang and Fujian with powerful winds and heavy rain as it made landfall, destroying tens of thousands of buildings, sinking more than 1,000 boats and downing power lines, which cut electricity in six cities.
- Saomai affected around 6 million people and displaced 1.7 million residents. Several ports were forced to close and the typhoon disrupted all forms of transport. At least 441 people were killed by the storm in China (although some unofficial estimates put the death toll at closer to 1,000).
- Saomai hit a region of China that remains relatively undeveloped and this is expected to limit insured losses triggered by the storm.
- Munich Re has estimated Saomai's total insured loss to be around 400 million yuan (US$50.5m), while AIR Worldwide expects insured costs to be between 500 million yuan and 1 billion yuan (US$63m and US$126m) – some 4% and 9% of the total economic loss.

The second section of the report explores the typhoon hazard in general in China and the threat it poses to the country's coastal provinces. The report indicates that different regions are exposed to different degrees of risk, with the highest risk located along the southern and eastern coast. Although the risk decreases in China's more northern regions, a significant threat remains for large northern cities such as Shanghai.

The report also analyses the frequency and intensity of previous landfalling tropical cyclones in China, focussing on the Saomai landfalling provinces of Zhejiang and Fujian. A comparison to the more regularly hit provinces of Guangdong and Hainan is also made.

Significant observations from section two:

- Between 1960 and 2005, 27 tropical cyclones made landfall in Zhejiang, giving an average of 0.6 events each year.
- Of the 27 tropical cyclones that made landfall in Zhejiang, 12 reached typhoon intensity (≥ 74 mph or 119 kmph). Typhoon Saomai was the strongest typhoon to make landfall in Zhejiang during the 46-year period.
- From 1960 to 2005, 50 tropical storms and typhoons made landfall in Fujian, giving an average of around 1.1 per year.
- Of the 50 tropical cyclones that made landfall in Fujian, 27 reached typhoon intensity, giving an average of 0.6 per year. The most powerful typhoon that came ashore in Fujian during the 46-year period was Typhoon Alice in 1966.

- The number of tropical cyclones making landfall in Guangdong and Hainan Province is significantly higher in comparison to Fujian or Zhejiang. Between 1960 and 2005, 168 tropical storms and typhoons came ashore in Guangdong and Hainan, giving an average of around 3.7 per year.

- Of the 168 tropical cyclones that made landfall in Guangdong and Hainan, 73 reached typhoon intensity, giving an average of 1.6 per year. Typhoon Ruby in 1964, with sustained wind speeds of around 120 mph (195 kmph) at landfall, was the strongest storm to make landfall in Guangdong and Hainan in the 46-year period.

Overall, the paper highlights that tropical cyclones are a persistent risk in China and, as insurance coverage grows in the country, it is something insurance companies will need to manage.

Section 1: Impact of Typhoon Saomai

Overview

On 10 August, Typhoon Saomai became the sixth tropical cyclone to hit China in 2006 when it made landfall at 09:25 UTC (17:25 local time) in Cangnan County near the city of Wenzhou in Zhejiang Province. Reports said the storm packed sustained winds of around 135 mph (220 kmph) and killed more than 440 people. Saomai brought destructive winds and heavy rain to the region, causing widespread damage. Chinese state media said Saomai was the most powerful storm to hit the country since August 1956, when a typhoon hit Zhejiang and killed around 5,000 people.

FIGURE 1: PATH OF TYPHOON SAOMAI

- Tropical Depression
- Tropical Storm
- Category 1
- Category 2
- Category 3
- Category 4
- Category 5
- Affected provinces

Meteorological Summary

Saomai developed into a tropical depression near the Caroline Islands on 4 August and strengthened into a tropical storm the following day. The storm continued to intensify and became a typhoon on 6 August. Saomai experienced rapid intensification over the next couple of days as it tracked north-west across the West Pacific towards Zhejiang Province. Saomai reached category 5 status on 9 August with sustained winds of around 160 mph (260 kmph) before weakening prior to landfall.

A wide range of landfalling wind speeds was reported for Saomai by different meteorological organisations, and the reasons for this are related to two significant factors. First, there are often wide variances for wind speed values in the West Pacific as measured by different organisations. This is due to the lack of wind recording stations that are located directly in the path of a tropical cyclone. Tropical cyclones rarely pass directly over measurement devices, and when they do, the stations are often incapacitated by the strong wind speeds. Therefore, there is heavy reliance on indirect estimates of surface wind speeds and directions such as wind data provided by aircraft, satellite cloud imagery and radar.

Secondly, and perhaps most importantly, as surface winds and gusts can change dramatically over short time intervals, it is necessary to define the length of time over which the winds are measured. For a tropical cyclone of varying intensity, longer wind averaging times will yield lower maximum winds. Unfortunately, different meteorological services use different averaging times.

Following World Meteorological Organisation (WMO) guidelines, most regions use a 10-minute average. However, the Joint Typhoon Warning Center (JTWC) and other organisations such as Guam and WMO Region IV (United States and Caribbean area) use a 1-minute standard average. A tropical cyclone defined as a typhoon using a 1-minute standard may not be defined as a typhoon using a 10-minute standard.

The JTWC, using the 1-minute mean wind speed calculation, said Saomai's landfall wind speeds were approaching 150 mph (240 kmph), which is a category 4 typhoon on the Saffir Simpson Scale. Meanwhile, the Hong Kong Observatory (HKO), using the 10-minute mean wind speed calculation, reported landfall winds at around 115 mph (185 kmph), indicating that the storm was a category 3 typhoon on the Saffir Simpson Scale. However, as detailed above, these two figures are not directly comparable.

By examining a large number of recorded wind speeds against time traces and damage reports, conversion factors from one averaging time to another have been derived. Depending on the methodology, there are some small differences in recommended conversion factors. For US interests, a factor of 0.88 is used in going from a 1-minute system to a 10-minute system while a factor of 1.14 is used to convert up from 10-minute to 1-minute. These conversions should be considered as average rather than absolute. There are many variations depending mainly on the frictional characteristics of the surface area and the atmospheric stability. Applying the conversion factor of 1.14 to the HKO recording of 115 mph (185 kmph) gives wind speeds of just over 131 mph (214 kmph) based on the US 1-minute intensity calculation, a category 4 typhoon.

TABLE 1: SAFFIR SIMPSON SCALE

Scale	Central Pressure (mb)	Winds (knots)	Winds (mph)	Surge (ft)	Damage
Tropical Depression	-	<34	<39	-	-
Tropical Storm	-	34–63	39–73	-	-
Category 1	>980	64–82	74–95	4–5	Minimal
Category 2	980–965	83–95	96–110	6–8	Moderate
Category 3	964–945	96–113	111–130	9–12	Extensive
Category 4	944–920	114–135	131–155	13–18	Extreme
Category 5	<920	>135	>155	>18	Catastrophe

After coming ashore in Zhejiang Province, Saomai tracked inland and almost immediately crossed the border into Fujian Province. The storm gradually lost intensity as it moved into Jiangxi Province before weakening into a tropical depression on 11 August and dissipating later that day.

FIGURE 2: FLOODING AFTER TYPHOON SAOMAI HIT WENZHOU CITY

Event Summary

Saomai battered the provinces of Zhejiang and Fujian with powerful winds and heavy rain as it made landfall, destroying tens of thousands of buildings, sinking more than 1,000 boats and downing power lines, which cut electricity in six cities. Zhejiang and Fujian were devastated by the storm and the State Flood Control and Drought Relief Headquarters said economic losses in both provinces reached 11.3 billion yuan (US$1.4bn). It added that 54,000 homes were destroyed, with 122,700 hectares (303,000 acres) of farmland ruined by the strong winds and floods. Saomai affected around 6 million people and displaced 1.7 million residents. Several ports were forced to close and the typhoon disrupted all forms of transport. At least 441 people were killed by the storm in China (although some unofficial estimates put the death toll at closer to 1,000).

The greater Wenzhou area in Zhejiang, with a population of around 7.4 million, declared a state of emergency after 18,000 houses were destroyed, the Civil Affairs Bureau of Wenzhou said. Around 2.5 million people were affected in the area and 193 people died. Reports said 3,850 industries were forced shut by Saomai in Wenzhou City, 80% of which had resumed production by 21 August. Severe flooding also hit Wenzhou, with more than 213,000 people lacking clean drinking water.

Elsewhere in Zhejiang, officials in Cangnan County declared a state of emergency after more than 1,000 houses were toppled in and around Mazhan. The towns of Longgang and Jinxiang in Cangnan County also sustained damage. A total of 450 schools were damaged in the county at a cost of around 25 million yuan (US$3.1m) and virtually all power lines were downed, causing widespread communication outages. Electricity was also cut to households in Xiapu City and flooding was reported in Taizhou City. Economic losses exceeded 4.5 billion yuan (US$560m) in Wenzhou and totalled 4.9 billion yuan (US$610m) in Zhejiang Province, according to Xinhua News Agency.

FIGURE 3: EXTENSIVE DAMAGE IN HONGLINGXIA VILLAGE NEAR THE TOWN OF JINXIANG

In neighbouring Fujian Province, more than 1.4 million people were affected by the typhoon and 32,700 houses were destroyed, reports said. Rainfall in the city of Fuding exceeded 12 inches (300mm) in 12 hours, destroying more than 10,000 homes and damaging 80,000 more, according to Xinhua. Fuding was severely hit, causing an economic loss of 3.1 billion yuan (US$388m) and killing around 200 people, emergency officials said. The city government allocated 104.9 million yuan (US$13.2m) for reconstruction and offered 5,000 yuan (US$625) compensation to each of the victims' families.

FIGURE 4: LOCATIONS IN ZHEJIANG AND FUJIAN DAMAGED BY TYPHOON SAOMAI

- Tropical Depression
- Tropical Storm
- Category 1
- Category 2
- Category 3
- Category 4
- Category 5
- Affected provinces
- Affected county
- Affected city
- Affected town

Elsewhere in Fujian, the coastal town of Shacheng was badly hit. Around 1,000 ships capsized and hundreds of fishermen died or went missing. Saomai also affected about 310,000 people in Fuzhou City and caused economic losses of at least 200 million yuan (US$25m), according to city officials. Strong winds were also felt in the cities of Zherong, Fu'an and Ningde, downing power lines and cutting power. The typhoon forced 234 factories and mines to shut in Fujian. The total economic loss in the province was estimated at 6.4 billion yuan (US$795m), reports said.

FIGURE 5: FLOODING AND WIND DAMAGE IN ZHEJIANG PROVINCE

After tracking across Zhejiang and Fujian, Saomai moved inland into Jiangxi Province. The province was the hardest hit area when Typhoon Kaemi hit China in July, and Saomai compounded the damage. Saomai destroyed six small reservoirs in Jiangxi and cost the province a total of 348 million yuan (US$45m) in economic losses, officials said. Meanwhile, in Anhui Province, inland from Zhejiang, local officials evacuated residents as the storm dumped heavy rain in the area and triggered flooding.

Prior to Saomai making landfall, Chinese authorities evacuated more than 1.5 million people (one million in Zhejiang and 569,000 in Fujian) to shelters and some 70,000 vessels were advised to return to harbour. Authorities in Wenzhou issued an alert before the storm came ashore, ordering all businesses to cease operations and prepare for the severe weather. Wenzhou airport was forced to close, stranding hundreds of passengers, while those that stayed in the city reinforced windows and doors, and stockpiled drinking water and food.

Earlier, Saomai hit the Japanese island chain of Okinawa with winds of up to 90 mph (145 kmph), causing nearly 100 domestic flights to be cancelled. Flight and ferry services in Taiwan were also disrupted. However, all warnings for Okinawa and Taiwan were lifted and no significant damage was reported.

FIGURE 6: EXTENSIVE STRUCTURAL DAMAGE IN CANGNAN COUNTY

Economic and Insured Losses

The economic consequences following Saomai's landfall in China were severe but the overall insured portion of the loss appears to be relatively minor. There was widespread property and crop damage while the region's infrastructure suffered major losses. Current estimates put the economic loss at more than 11.3 billion yuan (US$1.4bn).

However, Saomai hit a region of China that remains relatively undeveloped and this is expected to limit insured losses triggered by the storm. While insurance plays a prominent role in compensation for losses in regions such North America and Europe, it is still only a complementary method in China, where fiscal support, preferential policies and social donations are relied upon in many regions outside the major cities. Insurance compensations account for about 1% of losses incurred in disasters in China as a whole (although this percentage is rising and is variable based on location), which compares to more than 20% in Europe.

The greater Wenzhou area has prospered in recent years, but only a small fraction of the loss in the city is likely to be covered by insurance. Munich Re has estimated Saomai's total insured loss to be around 400 million yuan (US$50.5m), while AIR Worldwide expects insured costs to be between 500 million yuan and 1 billion yuan (US$63m and US$126m) – some 4% and 9% of the total economic loss.

FIGURE 7: A HOME IS DESTROYED IN ZHEJIANG PROVINCE

Source: China Photos/Getty Images

FIGURE 8: ALL BEACHFRONT FACILITIES AND RESTAURANTS WERE DESTROYED IN YANTING TOWN, ZHEJIANG PROVINCE

FIGURE 9: EXTENSIVE STRUCTURAL DAMAGE IN ZHEJIANG PROVINCE

Section 2: Typhoon Hazard in China

Historical Typhoon Losses in China

Several typhoons have caused significant damage in China over the years and this is illustrated by Table 2, which lists major historical events and the coastal provinces that incurred the greatest economic losses. Figure 10 represents the distribution of these losses.

TABLE 2: ECONOMIC LOSSES TRIGGERED BY SIGNIFICANT TYPHOONS THAT HIT CHINA BETWEEN 1989 AND 2005 (YUAN MILLION)

Source: China Oceanic Disaster Bulletin (1989-2005)

** 2006 Index Loss: The adjustment is made using inflation rates from the China Statistical Yearbook 1989-2005*

Affected Province	**Fred** (21 August 1994)	**Herb** (1 August 1996)	**Sally** (9 September 1996)	**Winnie** (18 August 1997)	**Dan** (9 October 1999)	**Prapiroon** (30 August 2000)	**Chebi** (23 June 2001)	**Sinlaku** (7 September 2002)	**Rananim*** (12 August 2004)	**Matsa*** (6 August 2005)	**Damrey** (26 September 2005)	**Longwang** (2 October 2005)	Total Province Loss	Total Province Loss US$m
Guangxi			2,555								58		2,613	331
Hainan											11,647		11,647	1,474
Guangdong			12,903								425		13,328	1,687
Fujian		4,600		200	4,000		4,520	3,260	1,010			7,467	25,057	3,172
Zhejiang	12,440	3,350		19,300		1,156		2,960	1,152	1,569			41,927	5,307
Shanghai				600		122		2	2	1,358			2,085	264
Jiangsu		436		3,000		5,500				147			9,083	1,150
Shandong				3,000						94			3,094	392
Liaoning										70			70	9
Hebei				600						92			692	88
Tianjin										220			220	28
Total	12,440	8,386	15,458	26,700	4,000	6,778	4,520	6,222	2,164	3,550	12,130	7,467	109,816	13,901
Yuan m*	13,983	9,804	18,071	28,821	4,234	7,276	4,833	6,607	2,289	3,614	12,348	7,601	119,481	
US$m*	1,772	1,241	2,287	3,648	536	921	612	836	290	457	1,563	962		15,125

Note: All wind speed figures quoted in this section are Hong Kong Observatory observations and are based on the World Meteorological Organisation guidelines, using a 10-minute wind speed average rather than the 1-minute intensities reported elsewhere in this report (see Meteorological Summary on pages 3-4 for a detailed explanation).

FIGURE 10: DISTRIBUTION OF MAJOR LOSSES CAUSED BY TYPHOONS ALONG THE CHINESE COAST BETWEEN 1989 AND 2005

US$m (Yuan million)

- <100 (<790)
- 100–400 (791–3,160)
- 401–1,700 (3,161–13,430)
- 1,701–3,200 (13,431–25,280)
- 3,200–5,500 (25,281–43,450)

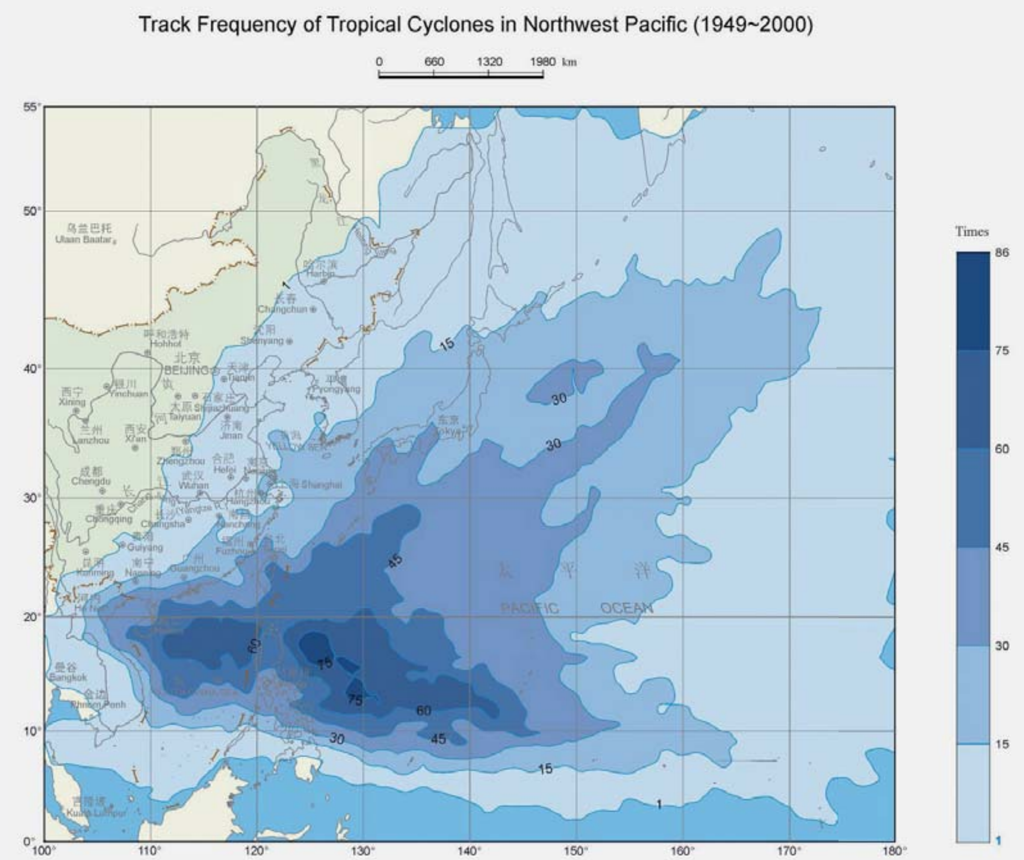
Source: China Oceanic Disaster Bulletin (1989 – 2005)

Landfalling Tropical Cyclones in China

Tropical cyclones are most likely to occur between June and October in the North-West Pacific basin, and China is affected by an average of seven landfalling tropical cyclones every year. However, there are some variations to this statistic. A map of historical tropical cyclone frequency between 1949 and 2000 (see Figure 11) indicates that different regions are exposed to different degrees of risk, with the highest risk located along the south mainland coast from Hainan to Hong Kong and on the east coast of Taiwan. Although the risk decreases in China's more northern regions, a significant threat remains for large northern cities such as Shanghai.

FIGURE 11: TRACK FREQUENCY OF TROPICAL CYCLONES IN THE NORTH-WEST PACIFIC BETWEEN 1949 AND 2000

Source: The Science Press and Beijing Normal University, 2004 – Taken from the Atlas of Natural Disaster System of China



This section of the report examines the climatological and interdecadal variations and the impact that the El Niño/Southern Oscillation (ENSO)[1] phenomenon has on China's exposed coastal provinces. It also compares Typhoon Saomai with previous landfalling typhoons that came ashore in Zhejiang and Fujian. A comparison is then made between events in Zhejiang and Fujian and landfalling typhoons in the provinces of Guangdong and Hainan.

1. The El Niño/Southern Oscillation (ENSO) is the name given to the phenomenon that describes the occasional deviations of the sea surface temperatures from their normal (climatological) values in the equatorial central and eastern Pacific Ocean, and the subsequent changes in the atmosphere corresponding to these deviations. A positive deviation (i.e. warmer water in the equatorial central and eastern Pacific but cooler in the equatorial western Pacific) is usually referred to as an El Niño event and a negative deviation (the reverse of the temperature deviation from an El Niño event) a La Niña event.

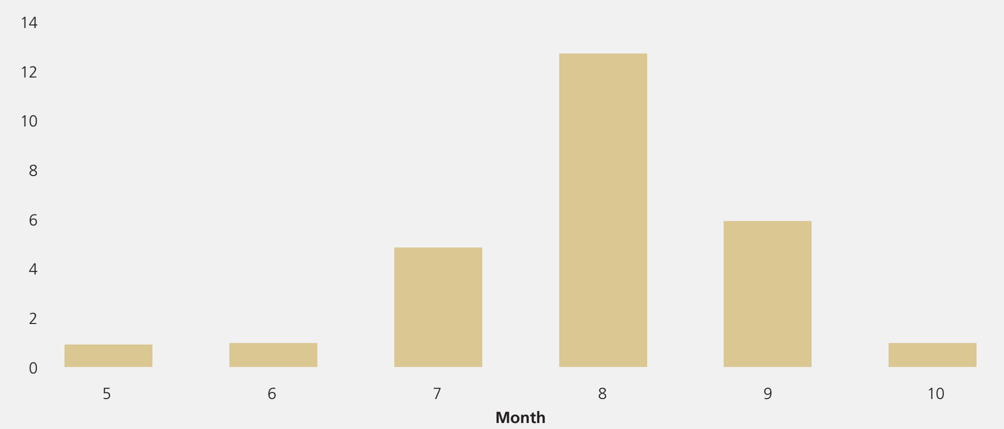
Landfalling Tropical Cyclones in Zhejiang

Between 1960 and 2005, 27 tropical cyclones made landfall in Zhejiang[2], giving an average of 0.6 events each year. However, compared to the other exposed coastal provinces of China (50 tropical cyclones hit Fujian during the same period and 168 hit Guangdong and Hainan), the figures indicate that the number of tropical cyclones coming ashore in Zhejiang is relatively low and accounts for only 11% of the total number making landfall in China each year.

Although the tropical cyclone landfall season in Zhejiang runs from May to October (see Figure 12), only one storm hit the province in May, June and October between 1960 and 2005. Therefore, the main landfall season in Zhejiang is considered to occur between July and September, with peak activity in August. The landfall date of Typhoon Saomai in August is therefore consistent with historical trends.

FIGURE 12: MONTHLY DISTRIBUTION OF TROPICAL STORMS AND TYPHOONS MAKING LANDFALL IN ZHEJIANG BETWEEN 1960 AND 2005

Source: Hong Kong Observatory



Of the 27 tropical cyclones that made landfall in Zhejiang, 12 reached typhoon intensity (≥ 74 mph or 119 kmph). According to the data, Typhoon Saomai was the strongest typhoon to make landfall in Zhejiang during the 46-year period with sustained wind speeds of around 115 mph (185 kmph) at landfall. The six most powerful typhoons to hit Zhejiang are shown in Table 3.

TABLE 3: SIX MOST POWERFUL TYPHOONS TO HIT ZHEJIANG BETWEEN 1960 AND 2005

Source: Hong Kong Observatory

Date	Typhoon Name	Intensity at Landfall mph (kmph)
10 August 2006	Saomai	115 (185)
12 August 2004	Rananim	100 (160)
11 September 2005	Khanun	100 (160)
3 October 1961	Tilda	90 (150)
18 August 1997	Winnie	90 (150)
5 August 2005	Matsa	90 (150)

Figure 13 shows the tracks of all 12 typhoons that made landfall in Zhejiang and they have surprisingly similar characteristics. Apart from two exceptions, they all formed east of the Philippines in the tropical western North Pacific south of 20°N and moved generally in a north-west to north-northwest direction before making landfall in the southern half of the Zhejiang coast. For the six most intense typhoons, with the exception of Saomai, all made landfall along a very small stretch of the Zhejiang coast between Taizhou City and the town of Furong (see Figure 14).

2. Data (6-hourly) based on best-track data extracted from the Hong Kong Observatory.

FIGURE 13: TRACKS OF TYPHOONS THAT MADE LANDFALL IN ZHEJIANG BETWEEN 1960 AND 2005

— Track of Typhoon Saomai

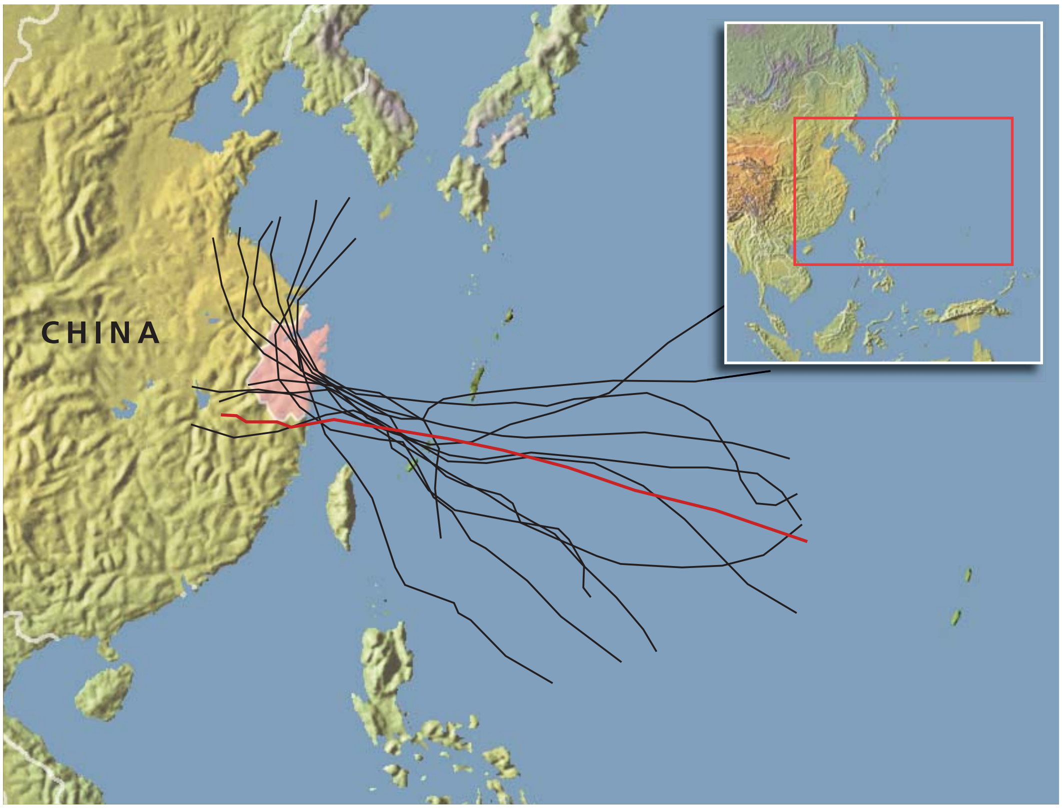
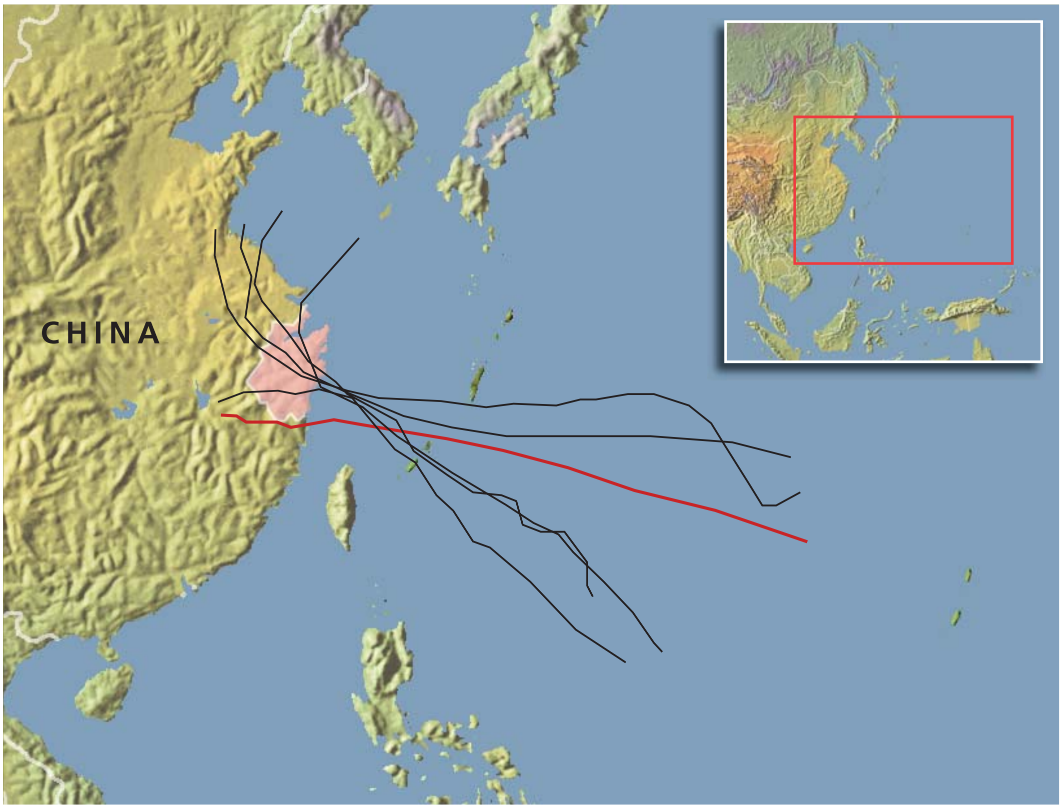


FIGURE 14: TRACKS OF THE SIX MOST POWERFUL TYPHOONS TO HIT ZHEJIANG

— Track of Typhoon Saomai



Summary

In most respects, Saomai's landfall was consistent with historical trends. Although its landfall point in Zhejiang was slightly south compared to other powerful typhoons, the storm hit the province during the peak of the landfall season and its track was very similar to those that previously came ashore in Zhejiang. The most significant difference was Saomai's intensity, which was the highest recorded in the last 46 years. However, it should be remembered that wind speed recordings for earlier typhoons might not have been as accurate as current estimates.

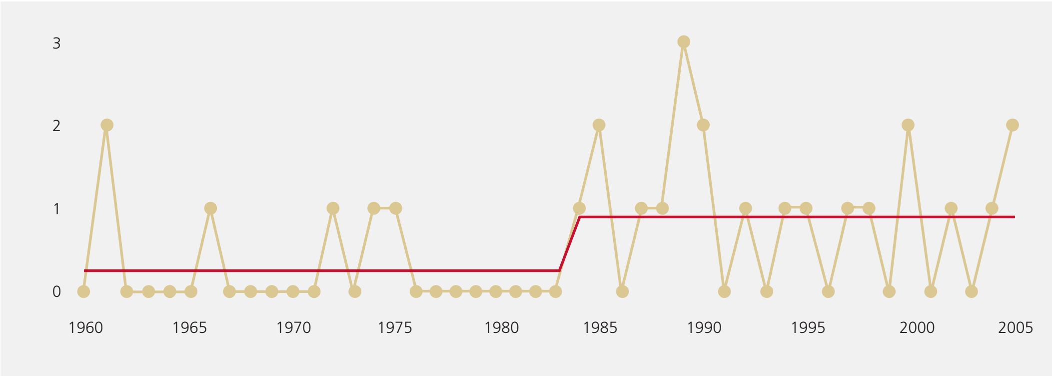
Interdecadal Variations

Saomai's powerful landfall winds, and the destruction left in the storm's wake, have fuelled much debate about whether more intense typhoons can be expected to hit Zhejiang in the future. The interdecadal variations of the frequency of landfalling typhoons in the province offer some explanation. Figure 15 suggests a possible increase in the annual number of landfalling tropical storms and typhoons in Zhejiang from 1984 onwards. During the low-frequency period of 1960 to 1983, the amount of landfalling storms in the province was around 0.25 per year. The mean frequency increased almost fourfold to 0.95 during the period of 1984 to 2005.

FIGURE 15: ANNUAL NUMBER OF LANDFALLING TROPICAL STORMS AND TYPHOONS IN ZHEJIANG BETWEEN 1960 AND 2005

— indicates the mean in the period of 1960–2005

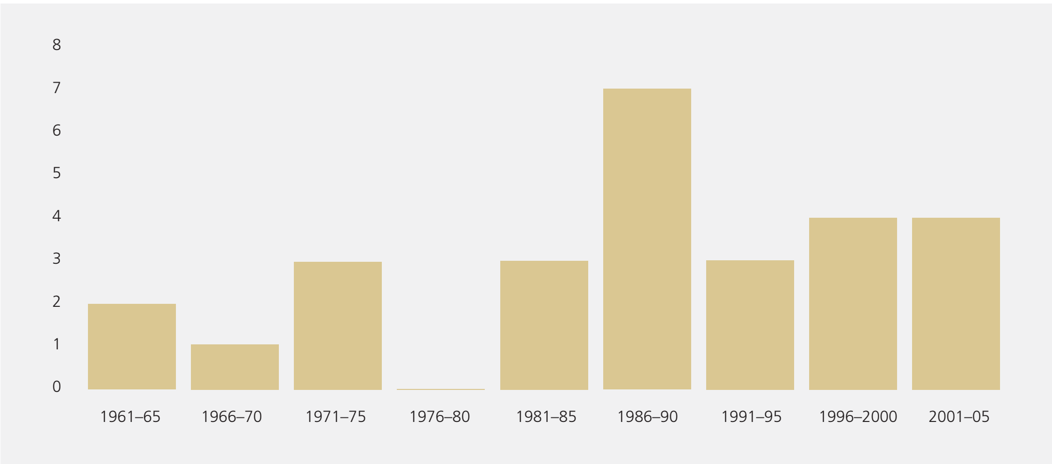
Source: Hong Kong Observatory



The increase can be seen more clearly by totalling the number of landfalling tropical storms and typhoons in Zhejiang into five-year groups (see Figure 16). Up to 1981, the number varies between zero and three for each period. However, from the 1980s onwards, at least three tropical cyclones made landfall in each five-year period, with a peak of seven between 1986 and 1990. This variation may be related to the interdecadal change in the tropical cyclones' tracks over the western North Pacific.

FIGURE 16: NUMBER OF TROPICAL STORMS AND TYPHOONS MAKING LANDFALL IN ZHEJIANG DURING EACH FIVE-YEAR PERIOD

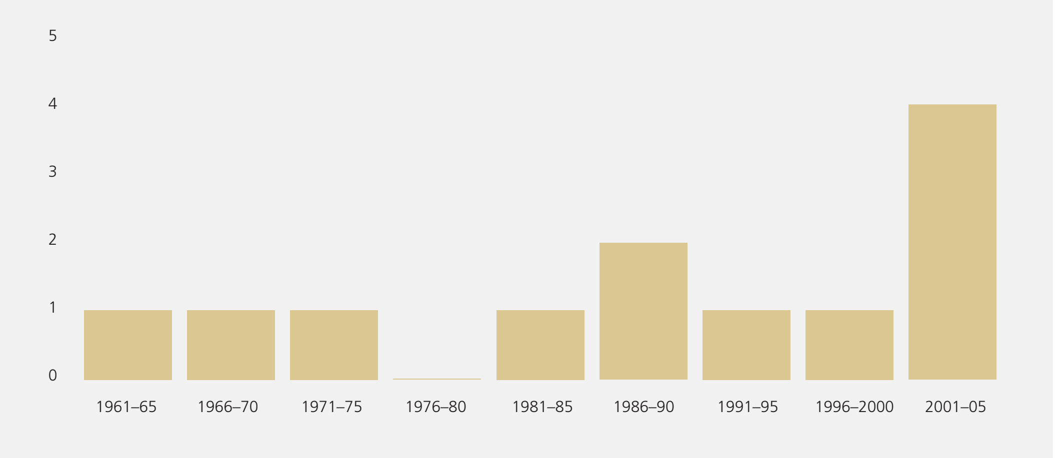
Source: Hong Kong Observatory



A similar but even more dramatic pattern can be seen in the frequency of typhoons hitting the province (see Figure 17). While at least one landfalling typhoon occurred in each of the five-year periods (apart from 1976-1980 when none hit), the period of 2001-2005 saw four landfalling typhoons. Moreover, Table 3 indicates that four of the six strongest typhoons that came ashore in Zhejiang occurred during the last three years.

FIGURE 17: NUMBER OF TYPHOONS MAKING LANDFALL IN ZHEJIANG DURING EACH FIVE-YEAR PERIOD

Source: Hong Kong Observatory



Therefore, there appears to be a rise in both the frequency and intensity of landfalling tropical storms and typhoons in Zhejiang over the last decade. Of course, this increasing trend requires further investigation.

Effect of El Niño/Southern Oscillation

Various studies have highlighted that ENSO has a significant impact on the frequency, intensity, location and track of tropical cyclones in the North-West Pacific basin.

A total of 13 El Niño events and 12 La Niña events occurred between 1960 and 2005. An average of 0.46 and 0.67 tropical cyclones made landfall in Zhejiang in El Niño and La Niña years respectively, suggesting ENSO does not have a significant impact on the frequency of landfalling storms in the province (see Table 4).

The intensity of the tropical cyclones coming ashore in Zhejiang, however, appears to be related to ENSO events (see Table 5). Of the eight landfalling tropical cyclones during a La Niña episode, only one reached typhoon intensity (around 13%). In contrast, five of the six landfalling tropical cyclones in El Niño years were typhoons (around 83%), showing the mean intensity of landfalling storms during an El Niño episode is significantly higher. Furthermore, as Table 3 shows, the six strongest typhoons to hit Zhejiang occurred in El Niño (1997 and 2004) or neutral years (1961, 2005 and 2006).

TABLE 4: FREQUENCY OF LANDFALLING TROPICAL CYCLONES IN ZHEJIANG DURING EL NIÑO, LA NIÑA AND NEUTRAL YEARS

Source: Hong Kong Observatory

ENSO Condition	Number of Years	Number of Landfalling Tropical Cyclones	Number of Landfalling Tropical Cyclones Per Year
El Niño	13	6	0.46
La Niña	12	8	0.67
Neutral	21	13	0.62

TABLE 5: INTENSITY OF LANDFALLING TROPICAL CYCLONES IN ZHEJIANG DURING EL NIÑO, LA NIÑA AND NEUTRAL YEARS

Source: Hong Kong Observatory

ENSO Condition	Number of Years	Number of Landfalling Tropical Storms	Number of Landfalling Typhoons	Mean Intensity mph (kmph)
El Niño	13	1	5	80 (125)
La Niña	12	7	1	60 (100)
Neutral	21	7	6	75 (120)

Therefore, based on the data from the last 46 years, it seems that the probability of a tropical cyclone with typhoon intensity making landfall in Zhejiang is higher during El Niño or neutral years and much lower during a La Niña episode. One possible explanation for this is that tropical cyclones tend to form further to the south-east during an El Niño episode, meaning they have more time to develop over the North-West Pacific and grow in intensity.

Summary

While Typhoon Saomai came ashore in Zhejiang during the peak season and its track was very similar to previous landfalling storms, it was the most intense typhoon to make landfall in the last 46 years. A further analysis of the historical records also suggests a recent increasing trend of both the frequency and intensity of tropical cyclones making landfall in Zhejiang. Furthermore, during an El Niño episode there appears to be a higher probability of powerful tropical cyclones hitting the province.

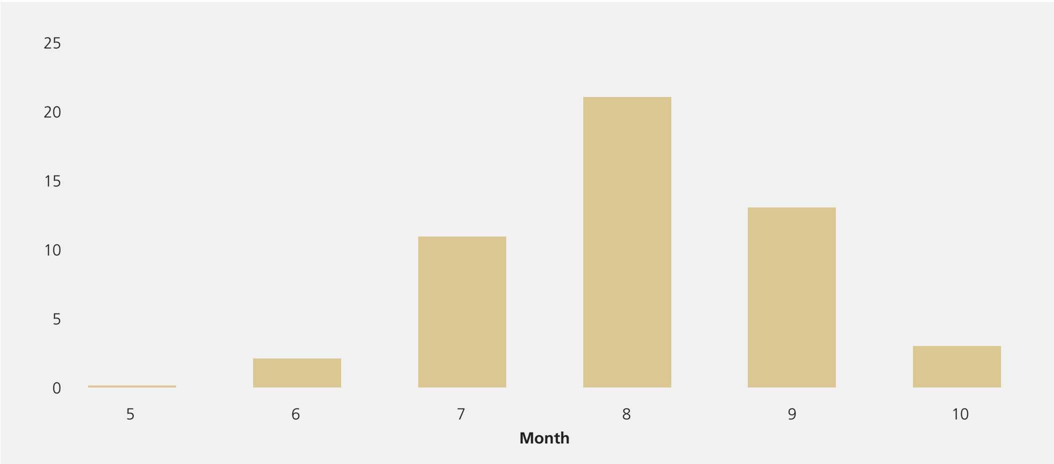
In the following sections, similar analyses are carried out for the provinces of Fujian, Guangdong and Hainan to provide a comparison with Zhejiang and illustrate how Saomai compares with other landfalling typhoons in these two provinces.

Landfalling Tropical Cyclones in Fujian

From 1960 to 2005, 50 tropical storms and typhoons made landfall in Fujian, giving an average of around 1.1 per year (compared with 0.6 for Zhejiang). Fujian's tropical cyclone landfall season is similar to Zhejiang, running from July and September with a peak in August (see Figure 18).

FIGURE 18: MONTHLY DISTRIBUTION OF TROPICAL STORMS AND TYPHOONS MAKING LANDFALL IN FUJIAN BETWEEN 1960 AND 2005

Source: Hong Kong Observatory



Of the 50 tropical cyclones that made landfall in Fujian, 27 reached typhoon intensity, giving an average of 0.6 per year. The most powerful typhoon that came ashore in Fujian during the 46-year period was Typhoon Alice in 1966. Alice's sustained wind speeds at landfall were 135 mph (215 kmph), around 20 mph (32 kmph) more powerful than Saomai. The seven most powerful typhoons to make landfall in Fujian are shown in Table 6.

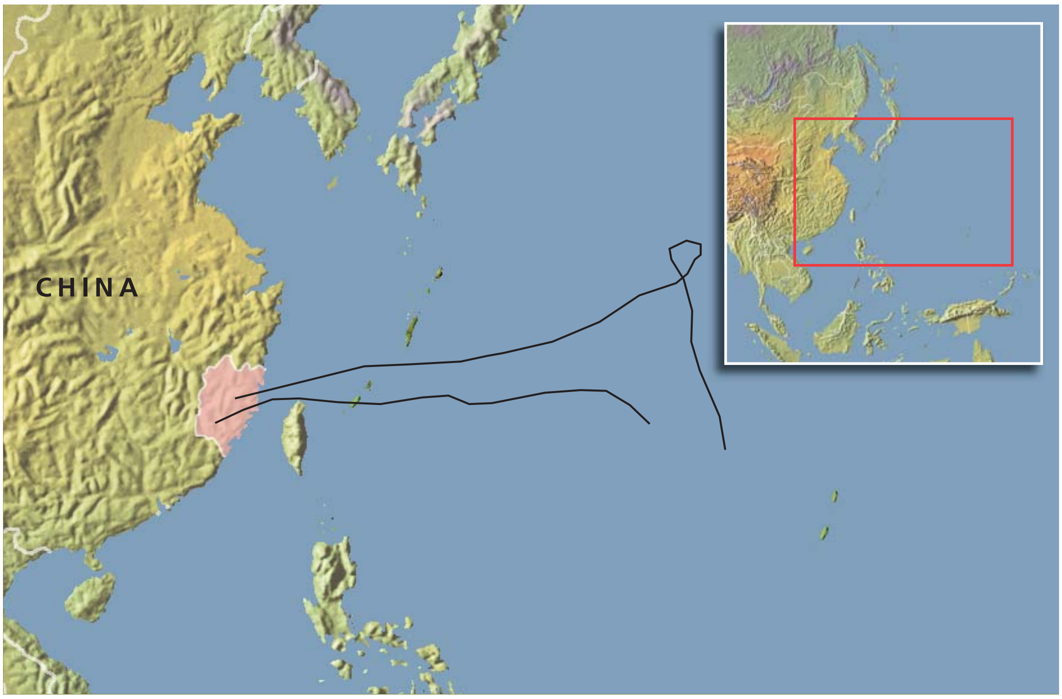
TABLE 6: SEVEN MOST POWERFUL TYPHOONS TO HIT FUJIAN BETWEEN 1960 AND 2005

Source: Hong Kong Observatory

Date	Typhoon Name	Intensity Near Landfall mph (kmph)
3 September 1966	Alice	135 (215)
23 August 1985	Nelson	105 (165)
1 August 1996	Herb	100 (160)
23 August 2000	Bilis	90 (150)
25 July 1983	Wayne	85 (140)
10 July 1994	Tim	85 (140)
9 October 1999	Dan	85 (140)

Most of the tropical cyclones that hit Fujian passed over Taiwan before making landfall in the province. Generally, due to interaction with the high terrain of Taiwan, the storms weakened significantly. Indeed, of the seven storms listed in Table 6, the two most powerful typhoons (Alice and Nelson) were the only ones that did not move through Taiwan (see Figure 19). They approached the Fujian coast on a westward course, passing north of Taiwan and making landfall in the northern half of the province.

FIGURE 19: TRACKS OF THE TWO STRONGEST TYPHOONS (ALICE AND NELSON) MAKING LANDFALL IN FUJIAN



Interdecadal Variations

Between 1960 and 2005, the number of typhoons that made landfall annually in Fujian varied between zero and three, with significant variations on both annual and interdecadal time scales (see Figure 20). There was a significant lull between 1986 and 1993 when no typhoon made landfall in the province. Although activity increased in the mid-1990s, and three typhoons hit the province in 2005, Figure 20 does not suggest an increasing trend. Grouping the years in five-year periods also gives a similar conclusion (see Figure 21).

FIGURE 20: ANNUAL NUMBER OF LANDFALLING TYPHOONS IN FUJIAN BETWEEN 1960 AND 2005

— indicates the mean in the period of 1960–2005

Source: Hong Kong Observatory

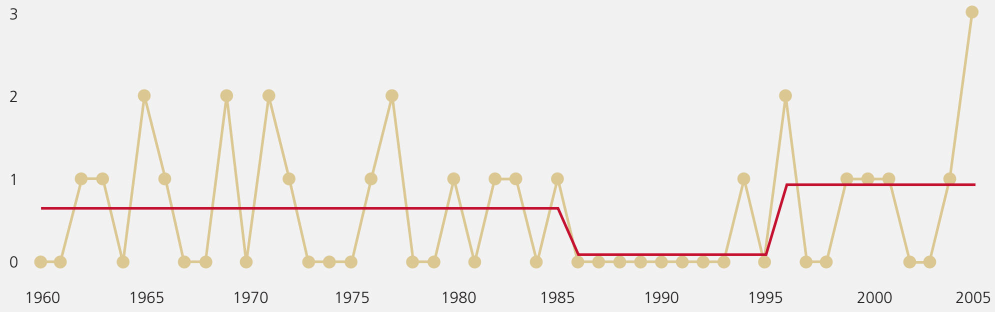
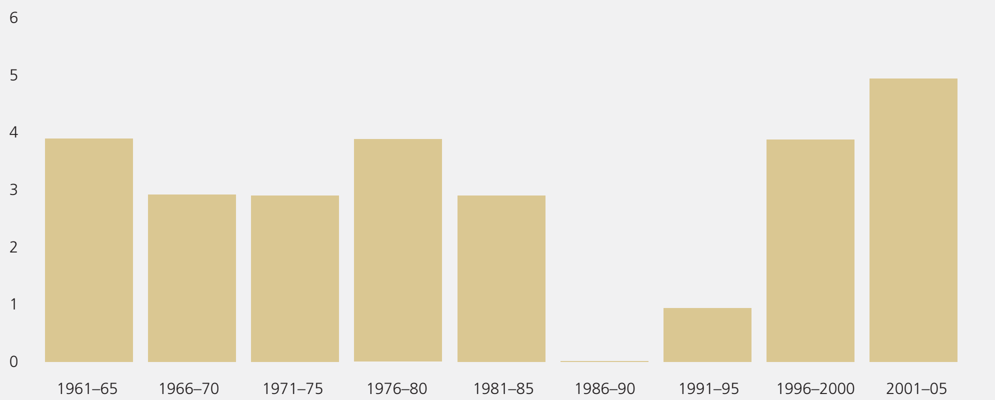


FIGURE 21: NUMBER OF TYPHOONS MAKING LANDFALL IN FUJIAN DURING EACH FIVE-YEAR PERIOD

Source: Hong Kong Observatory



Summary

In comparison with the most intense typhoons that have made landfall in Fujian, Saomai appears to have similar track characteristics in that it developed in the western North Pacific and tracked in a west to north-west direction. In terms of the interdecadal variation, the frequency of typhoons making landfall in Fujian does not show any increasing trend. The pattern is relatively consistent apart from a 10-year period of no typhoon landfall. An analysis of this frequency on an annual time scale relative to the occurrence of ENSO does not give any significant results and is therefore not shown.

Landfalling Tropical Cyclones in Guangdong and Hainan

The number of tropical cyclones making landfall in the provinces of Guangdong and Hainan is significantly higher in comparison to Zhejiang or Fujian. Between 1960 and 2005, 168 tropical storms and typhoons came ashore in Guangdong and Hainan, giving an average of around 3.7 per year. The tropical cyclone landfall season in Guangdong and Hainan runs between May and November, with peak activity occurring between July and September (see Figure 22).

Of the 168 tropical cyclones that made landfall in Guangdong and Hainan, 73 reached typhoon intensity, giving an average of 1.6 per year. Typhoon Ruby in 1964, with sustained wind speeds of around 120 mph (195 kmph) at landfall, was the strongest storm to hit Guangdong and Hainan in the 46-year period. The strength of Saomai is comparable to this intensity. The seven most powerful typhoons to make landfall in Guangdong and Hainan are shown in Table 7.

FIGURE 22: MONTHLY DISTRIBUTION OF TROPICAL STORMS AND TYPHOONS MAKING LANDFALL IN GUANGDONG AND HAINAN BETWEEN 1960 AND 2005

Source: Hong Kong Observatory

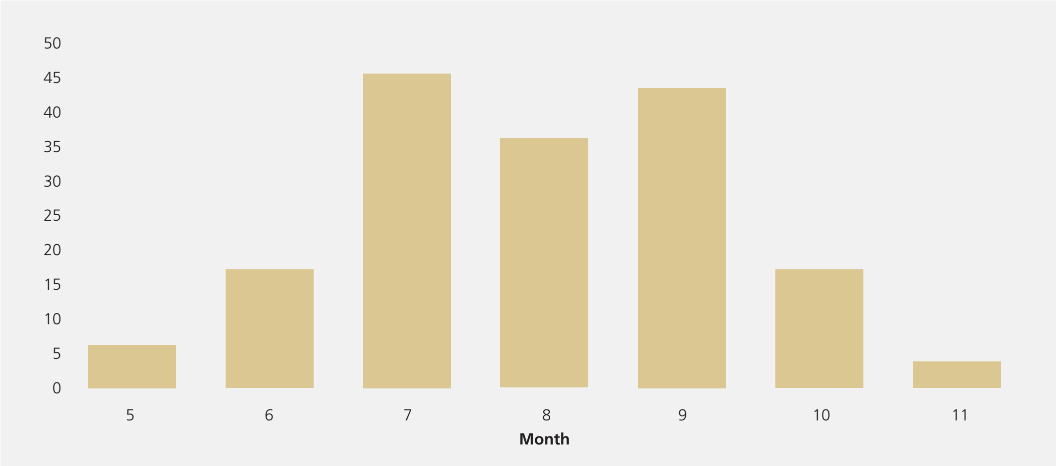


TABLE 7: SEVEN MOST POWERFUL TYPHOONS TO HIT GUANGDONG AND HAINAN BETWEEN 1960 AND 2005

Source: Hong Kong Observatory

Date	Typhoon Name	Intensity Near Landfall mph (kmph)
5 September 1964	Ruby	120 (195)
2 August 1979	Hope	115 (185)
25 September 2005	Damrey	110 (175)
1 September 1962	Wanda	105 (165)
28 July 1969	Viola	105 (165)
8 November 1972	Pamela	105 (165)
24 July 2003	Imbudo	105 (165)

The majority of the intense typhoons to come ashore in Guangdong and Hainan, such as Ruby (1964), Hope (1979), Wanda (1962) and Viola (1969), formed over the western North Pacific and reached a very high intensity (> 115 mph or 185 kmph). They entered the South China Sea through the Bashi or Balintang Channels, avoiding land interaction with the Philippines before making landfall in Guangdong (see Figure 23).

FIGURE 23: TRACKS OF FOUR OF THE MOST POWERFUL TYPHOONS (RUBY, HOPE, WANDA AND VIOLA) MAKING LANDFALL IN GUANGDONG

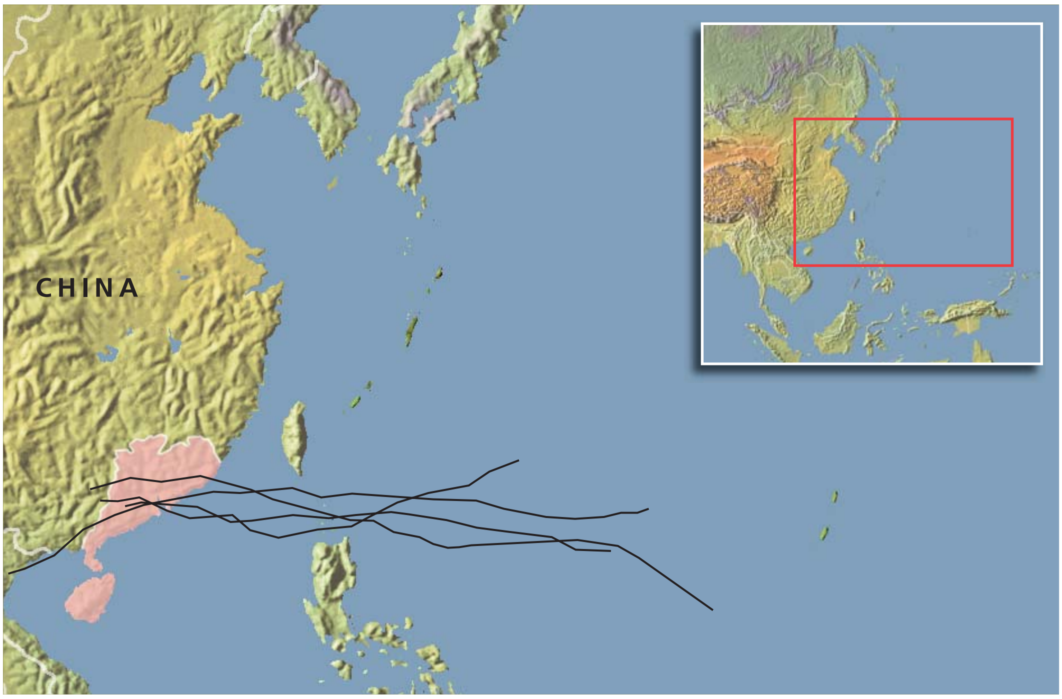
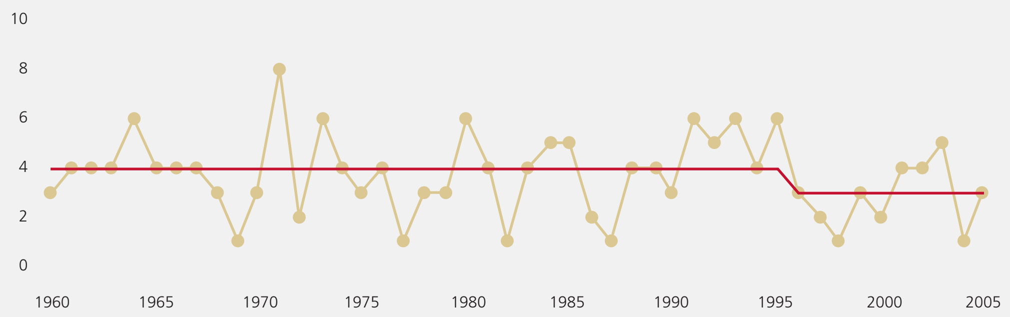


FIGURE 24: ANNUAL NUMBER OF LANDFALLING TROPICAL STORMS AND TYPHOONS IN GUANGDONG AND HAINAN BETWEEN 1960 AND 2005

— indicates the mean in the period of 1960–2005

Source: Hong Kong Observatory



Interdecadal Variations

The frequency of tropical cyclones making landfall in Guangdong and Hainan also shows significant annual variations, with a range of one per year to eight (see Figure 24). An analysis of the interdecadal variations identifies a small change around 1995, with the period thereafter having slightly fewer landfalling tropical cyclones. This decrease is seen more clearly when the numbers are grouped in five-year periods (see Figure 25). With the exception of the period of 1976 to 1980, a general decreasing pattern can be identified from 1971 to 1975, which differs to the trend in Zhejiang (see Figure 17).

Effect of El Niño/Southern Oscillation

An average of 1.1 and 2.2 typhoons made landfall in Guangdong and Hainan in El Niño and La Niña years respectively, indicating there is a higher probability of a typhoon making landfall in the province during a La Niña episode. This result is consistent with the findings of Chan (2000) and Liu and Chan (2003) and differs to the results for Zhejiang Province (see Table 4).

The strength of landfalling typhoons in Guangdong and Hainan, however, does not appear to be related to ENSO events as no significant difference was found in the mean intensity during El Niño or La Niña years.

TABLE 8: FREQUENCY OF LANDFALLING TYPHOONS IN GUANGDONG AND HAINAN DURING EL NIÑO, LA NIÑA AND NEUTRAL YEARS

Source: Hong Kong Observatory

ENSO Condition	Number of Years	Number of Landfalling Typhoons	Number of Landfalling Typhoons Per Year
El Niño	13	14	1.1
La Niña	12	26	2.2
Neutral	21	33	1.6

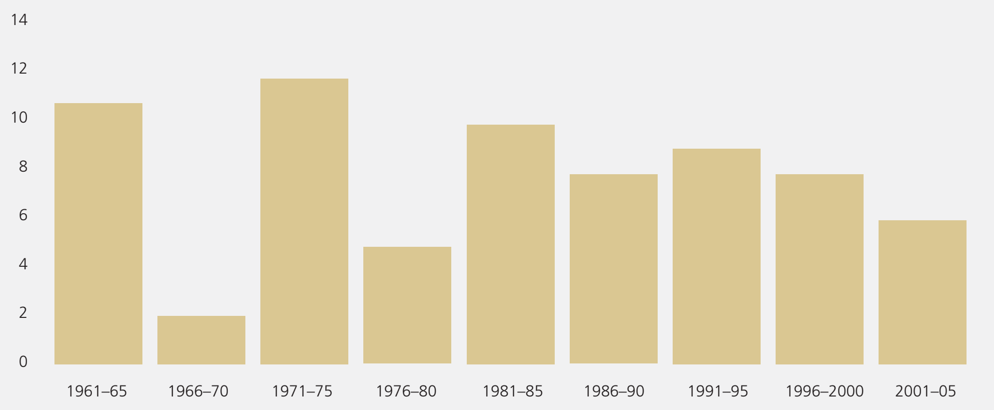
Summary

The results show that the frequency of landfalling tropical cyclones in Guangdong and Hainan is significantly higher in comparison to Zhejiang, while their strength is similar to Saomai's intensity. Again, all the powerful typhoons that hit Guangdong avoided land interaction and continued to intensify before coming ashore.

One of the most striking results was the opposing interannual and interdecadal variations between Zhejiang, Guangdong and Hainan. In terms of decadal variations, the frequency in Zhejiang appears to be on the increase while those in Guangdong and Hainan seem to be decreasing. For annual variations, ENSO has a large effect, with a higher frequency of landfalling typhoons in Zhejiang during El Niño years and lower in La Niña years, while the exact opposite occurs in Guangdong and Hainan.

FIGURE 25: NUMBER OF TYPHOONS MAKING LANDFALL IN GUANGDONG AND HAINAN DURING EACH FIVE-YEAR PERIOD

Source: Hong Kong Observatory



Comparison of Tropical Cyclone Landfall Frequencies between Zhejiang, Guangdong and Hainan

Due to the opposing trend in Zhejiang, Guangdong and Hainan, Instrat® has 'standardised' these frequencies to give a meaningful comparison. This is done by subtracting the annual frequencies by the average frequency, and then dividing the standard deviation of the sample. A value of 1 in a particular year means that the frequency has a value equal to one standard deviation more than the average (climatological) frequency.

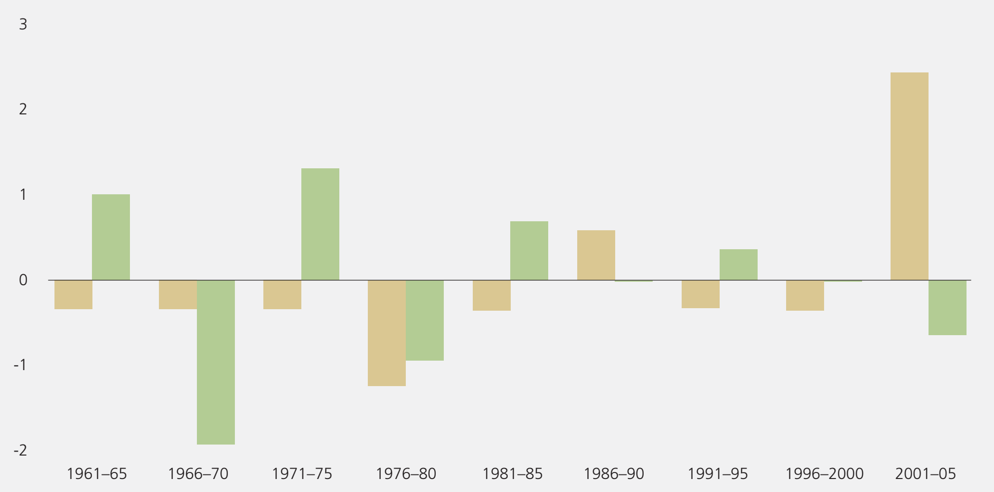
Interdecadal Variations

A correlation between the frequency of typhoon landfall in Zhejiang, Guangdong and Hainan yields a correlation coefficient of -0.30, which although not statistically significant, does suggest an 'anti-correlation' between these two frequencies. Indeed, Figure 26 shows that of the nine five-year periods, six have standardised anomalies of the opposite sign. Moreover, it is interesting to note the large increase in the standardised anomaly in the last five-year period for Zhejiang and the general decrease for Guangdong and Hainan since 1971-1975.

FIGURE 26: STANDARDISED ANOMALY OF THE NUMBER OF TYPHOONS MAKING LANDFALL IN ZHEJIANG, GUANGDONG AND HAINAN DURING EACH FIVE-YEAR PERIOD

Zhejiang
Guangdong and Hainan

Source: Hong Kong Observatory



Interannual Variations Related to ENSO

The focus here is on typhoons only and, as expected, the frequency making landfall in Zhejiang during El Niño years is 25% higher than normal (see Table 9). In Guangdong and Hainan, meanwhile, the frequency is 37% below normal. Conversely, during a La Niña episode, the reverse occurs with the frequency of landfalling typhoons in Zhejiang 36% below normal while the rate in Guangdong and Hainan is 42% above normal.

TABLE 9: STANDARDISED ANNUAL NUMBER OF LANDFALLING TYPHOONS IN ZHEJIANG, GUANGDONG AND HAINAN IN EL NIÑO AND LA NIÑA YEARS

Source: Hong Kong Observatory

ENSO Condition	Zhejiang	Guangdong and Hainan
El Niño	0.25	-0.37
La Niña	-0.36	0.42

Summary

A comparison of the landfall situation for typhoons in Zhejiang, Guangdong and Hainan shows that on interdecadal time scales, more typhoons are likely to hit Zhejiang over the next few years and fewer in Guangdong and Hainan. However, this conclusion could change with the occurrence of an ENSO episode.

Exposure Overview

The prospect of more tropical cyclone damage in Zhejiang is worrying for property owners in the region, but the extent of destruction is very much determined by building regulations. Since 1956, the National Infrastructure Committee, the National Planning Committee and the Ministry of Construction have been responsible for developing China's building regulations. As the country's codes and standards have evolved, the requirements have been influenced by many international regulations, including those in Russia, Japan, Australia, the United Kingdom, Canada and the United States. In the larger cities of China, where the number of construction projects has been vast in recent years, the influence of the current codes and standards are clearly evident as most buildings resemble those of any major international city. Conversely, the buildings that were built

FIGURE 27: TYPHOON SAOMAI RIPPED ROOFS OFF PROPERTIES AND BLEW IN WINDOWS, CAUSING EXTENSIVE STRUCTURAL DAMAGE IN SOME PLACES

in the 1970s and 1980s tend to be simpler in design and do not meet current standards, while those in less urbanised areas are older and were built when no wind loading standards existed.

In support of their codes and standards development, the Chinese conduct research activities in building design and fire protection in partnership with universities and other overseas organisations. China's Ministry of Public Security sponsors four research institutes located in Shanghai, Shenyang, Sichuan and Tianjin. Each institute has a specific area of research responsibility as well as codes and standards development.

The Ministry of Construction is responsible for the development, revision, and administration of China's construction standards. Construction standards are categorised into national standards, regional standards and local standards. National standards take precedence over all other regulations. Regional and local standards may have different requirements, particularly with respect to the different localised risks such as typhoon, earthquake and flood.

The Ministry of Construction last issued revisions to the National Construction Wind Loading Codes on 31 July 2001, but these did not become effective until 1 March 2002. The major change to these codes stipulated that buildings should be constructed to withstand wind loading with a recurrence interval of 50 years instead of the original 30 years.

According to AIR Worldwide, most houses in the region hit by Saomai were of masonry construction with heavy roofs which sustain considerable, primarily non-structural damage in wind speeds similar to those generated by Saomai. AIR added that while high-rise buildings are generally built to higher standards and performed well, some smaller commercial and industrial buildings with metal roofs were heavily damaged as they were unable to withstand the powerful winds.

FIGURE 28: FLOODING IN WENZHOU CITY

FIGURE 29: BUILDING DAMAGE IN ZHEJIANG PROVINCE

Conclusion

According to historical figures, landfalling tropical storms in Zhejiang are likely to occur every two years, and a typhoon every five years. Typhoon Saomai ranked top in terms of its strength relative to previous landfalling typhoons in Zhejiang and had similar intensities to those making landfall in Guangdong and Hainan. If the decadal trends identified in this report continue, typhoons of similar intensity are expected to make landfall in Zhejiang in the coming few years. The frequency of such occurrences might also be higher compared to previous decades. Conversely, the opposite is likely to occur in Guangdong and Hainan, as very few tropical cyclones have made landfall in these two provinces during the last few years, including 2006.

For the entire Chinese coast from Guangdong and Hainan to Zhejiang, the overall number of typhoon landfalls appears to be on the increase. This is mostly due to the significant rise in Zhejiang and Fujian. The decrease in the number of landfalling storms in Guangdong and Hainan apparently is not enough to offset this trend. This result is consistent with the recent findings of Wu et al. (2005) that suggest a westward shift in typhoon tracks. If this trend continues, more tropical cyclones affecting China can be expected to occur, with an increase along the eastern coast and a decrease in southern regions. However, it should be appreciated that the time sequence is relatively short and further research needs to be undertaken before any strong conclusions are made about change in frequency.

Whether a similar trend exists for tropical cyclone intensity is presently difficult to determine because of data quality issues. Recent discussions in the international tropical cyclone community have suggested that improvements in instrumentation (e.g. better resolution of anemometers, better satellite and radar imaging techniques) in recent years might have led to more accurate estimates of intensity. Therefore, the apparent increase in the maximum intensity of typhoons making landfall in China in recent years may partly be due to this factor.

From an insurance loss perspective, 2005 growth rates of China's non-life insurance and life insurance premiums were 12.7% and 11.8%, respectively, making it the 11th largest insurance market in the world. In contrast to the high growth rates, insurance penetration for China is 1.78% for life business and 0.92% for non-life, ranking it 50th in the world.

While insurance plays a prominent role in compensation for losses in regions such as North America and Europe, it is only a complementary method in China, where fiscal support, preferential policies and social donations are relied upon. Insurance compensations account for about 1% of losses incurred in disasters in China, which compares to more than 20% in Europe.

Swiss Re has estimated that a major catastrophe in China today could generate total economic losses exceeding 1 trillion yuan (US$126bn), or about 6% of China's GDP (2005), if triggered by one of the three principal natural perils (typhoon, flood or, the biggest threat, earthquake). At the currently low insurance penetration level, this would amount to insured losses exceeding 10 billion yuan (US$1.3bn), which, on a world scale and considering the size of China, is relatively low.

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Guy Carpenter would like to thank Professor Johnny Chan and his colleagues at City University of Hong Kong for their valuable contribution to the second section of this publication.

Professor Johnny Chan received his bachelor and master degrees in physics from the University of Hong Kong. After obtaining his PhD in atmospheric science from Colorado State University, USA, he received a US National Research Council Post-Doctoral Fellowship to perform research at the US Naval Postgraduate School. Later, he became an Adjunct Research Professor there.

Professor Chan returned to Hong Kong in 1986 to join the then Royal Observatory Hong Kong (now the Hong Kong Observatory) as a scientific officer. In 1989, he became a Senior Lecturer at the then City Polytechnic of Hong Kong and has been with the institution (now the City University of Hong Kong) since then. He is now the Chair Professor of Applied Physics and an Associate Dean of the Faculty of Science and Engineering. He is also a Croucher Foundation Senior Research Fellow.

Professor Chan is internationally renowned in the research areas of typhoons and monsoons. In recent years, he has also become actively involved in the study of air pollution over Hong Kong. He has written over 200 publications, including journal articles and conference papers.

Professor Chan is a member of the Committee on Tropical Meteorology and Tropical Cyclones of the American Meteorological Society, and of the Committee on Dynamic Meteorology of the Chinese Meteorological Society. He is also an editor of the *International Journal of Climatology, Advances in Atmospheric Sciences* and the *Acta Meteorologica Sinica*.

Professor Johnny C. L. Chan
Laboratory for Atmospheric Research,
Department of Physics & Mat. Sci.,
City University of Hong Kong
83 Tat Chee Avenue,
Kowloon,
Hong Kong, China

Tel: +852 2788 7820
Fax: +852 2788 7830
Email: Johnny.Chan@cityu.edu.hk

http://weather.cityu.edu.hk/staff/JChan.htm

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Questions or comments regarding this report should be addressed to:

Peter Cheesman
e: peter.cheesman@guycarp.com
t: +612 8864 8534

Lawrence Liao
e: lawrence.liao@guycarp.com
t: +852 2582 3530

Julian.Alovisi
e: julian.alovisi@guycarp.com
t: +44 20 7357 2967

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