Recent studies on tropical cyclone landfalling in China

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1. Losses caused by tropical cyclones in China

China is one of the countries most severely affected by tropical cyclone in the Asia and Pacific region, with over 10,000 casualties and over US$2500 million economic losses annually on average (fig 1).

Fig. 1 Casualties and damages sustained by members of Typhoon Committee

Due to Tropical Cyclones (1985-1997)
(a) Injured, missing and death toll  (b) Economic losses

Extremely severe damage is always closely related to the landfalling of tropical cyclone. Due to the long coastline, the annually average number of tropical cyclone making landfall in China reaches 8 to 10 (fig.2).

1
According to statistics, about 80% of them make landfall in China from July to September, but none from December to April. The landfall position mainly centers in Guangdong Province (about 33%), Taiwan Province (about 19.8%) and Hainan Province (16.6%). Fig.3 show that the track of tropical cyclones landfall China during 1949 to 2001.
2. **Advance in operational forecast**

The importance of correctly forecasting typhoon track and its landfall position has always been recognized in China. Since the late of 1970s, several objective track forecast models were developed. From 1985, the performance (including distance error and forecast skill) of each model is assessed annually to help improve their forecast ability. Besides, the model that has negative forecast skill in two consecutive years will be banned to use officially.

Currently, objective track forecast models used operationally include three numerical models from Beijing, Shanghai and Guangzhou respectively, a statistical dynamic model and a consensus model from Shanghai, a probability circle model from Jiangsu Province, and a medium range track forecast model from Zhejiang Province. With the help of these models, the official forecast accuracy has been constantly improved, with the average distance errors about 150km and 300km for 24 and 48 hours forecast respectively (fig 4), and the distance error for land position forecast about 100km (fig 5).
3. Progress in the scientific research on landfall typhoon

Presently, the landfall process of typhoon and their accompanying severe weather and disaster are being paid great attention to by typhoon researchers. For example, the landfall typhoon is the emphasis of the WMO World Weather Research Program (WWRP), the United States Weather Research Program (USWRP) and some other projects of Australia, Japan, etc. The study of landfall typhoon has always been regarded as an important issue in China. Since the 8th five-year plan, some progress has been achieved in the following aspects:

1) The effect of topography on typhoon crossing Taiwan island

As a typhoon moves westward or northwestward toward Taiwan, its track will deflect to the right. It will turn to the left after crossing the island and to the right again in the Taiwan strait before it makes landfall in the mainland of China (fig 6). The first right-turn often occurs when the typhoon center is about 150km away from the island. The track deflection will not happen if the distance is over 400km. Another effect of Taiwan island on the track of typhoon is that the track is discontinuous on the two sides of the island. That is to say, to the leeward of the central mountain of Taiwan, usually in the mid-south of Taiwan Strait, a leeward depression is generated due to the interaction between the typhoon and the island, which substitutes the parental typhoon circulation.
According to statistics, tropical cyclones mostly decayed before landfall, but about 16% could strengthen sudden. And most of the tropical cyclones making landfall in the South China cause heavy rain in a large area to the east of the landfall position. While both the rainfall area and intensity to the west are smaller. For tropical cyclones making landfall in the East China, the heavy rain often occurs to the north of the landfall position. In addition, land spout is always triggered as typhoon makes landfall.

2) Decaying or sustaining of typhoon over land

Some typhoons decayed quickly after landfall, while some could sustain for a long time and caused severe damage to the inner part of China. There are also some re-intensifying as they reentered the sea and making several landfalls. The maximum landfall time is 4 (sustaining 129 hours). Typhoon making landfall in China averagely sustained 26 hours on land. In August, landfall typhoon could live longer on land than in the other months, with average sustaining duration about 40.8 hours (fig 7). The stronger the intensity was as typhoon made landfall, the longer it could sustain and the larger the weakening rate. For typhoons with maximum wind speed over 34m/s as making landfall, the average sustaining duration was over 38 hours.

![Fig. 7](image) monthly variation of average maintainable hours of landfall tropical cyclones

For typhoons making landfall to the west of Yangjiang, about 65.7% of them disappeared in 24 hours after landfall. The percentage is 59.3% for those making landfall between Yangjiang and Shantou, 40% between Shangtou and Fuding, while only 10% between Fuding and Shanghai. There is a trend that further north the landfall position, the longer a typhoon could sustain. For example, typhoons making landfall to the west of Yangjiang could only sustain 23.5 hours averagely, while for those between Fuding and Shanghai, the average is 62 hours (fig 8).

![Fig. 8](image) Average maintainable hours of landfall tropical cyclone in different underlying surface conditions

(A: Yangjiang    B: Shantou    C: Fuding    D: Shanghai)
The sustaining or decaying of typhoon over land is not related only to the landfall position. In fact, the typhoons with close landfall positions could also greatly differ in sustaining time. For example, both typhoon 9806 and 5612 made landfall to the south of Hangzhou Bay. The former disappeared in less than 12 hours after landfall, while the latter sustained 84 hours. Two other examples are typhoon 9802 and 7503. Both of them crossed Taiwan island and made landfall in Fujian. The former sustained not longer than 6 hours while the latter disappeared 108 hours after landfall. It’s also the same for typhoon 9908 and 9910 with the former sustaining 76 hours and the latter only 19 hours (fig 9).

Studies have shown that whether typhoon could sustain or not is also related to the water vapor transportation and the intrusion of weak cold air from the mid-latitude. It’s shown by a numerical experiment that if the water vapor transportation passage were cut off, typhoon 9711 should have disappeared in 24 hours after landfall (fig 10).

Fig. 9  Two landfalling typhoon tracks in 1999 typhoon sam (9908) sustaining hours in land and typhoon york (9910) only hours over land

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Fig. 10  Mesoscale model (MM5) simulation on 500hpa of typhoon 9711(winnie)
(a) Winnie sustain its circulation with the vapour transfer
3) The interaction between typhoon and Meiyu front

Statistics shows that typhoons close to China coast could always weaken Meiyu, or even break it off or end it, because they could absorb the water vapor transported from Bengali Bay, which should otherwise be transported from the monsoon area to the Meiyu front (fig 11). Among them, about 95% could weaken Meiyu obviously, and 86% could break Meiyu off or even end it. A typical example is typhoon 9106. Its landfall ended a Meiyu period over 50 days in 1991.

![Schematic Model for Vapour Transport Channel with Meiyu (a) Cut-off by a Landing Typhoon (b-c)](image)

**Fig. 11** Schematic model for vapour transport channel with Meiyu (a) cut-off by a landing typhoon