Typhoon Nida’s rainfall characteristics in Guangzhou City based on Doppler radar estimation

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Abstract. Typhoon is one of the extreme weather systems that causes heavy rainfall in its passing area, which usually induces severe flooding and huge damages. Space-time distribution of Typhoon induced precipitation is quite uneven that is an important factor to cause disastrous flooding. Traditional precipitation observation by ground-based rain gauges network and conventional weather radar cannot provide high space-time resolution data for this analysis. In this study, estimated precipitation based on Guangzhou Doppler Radar, a newly developed weather radar installed in Guangzhou City, is employed to analysis the rainfall characteristics induced by typhoon Nida in 2016 in Guangzhou City, which has high rainfall space-time resolution that time resolution of 1 hour, the spatial resolution of 1km. The results show that the characteristics of rainfall spatial-temporal are uneven distribution. (1)During the typhoon Nida, rainfall in Guangzhou mainly concentrated in two periods: (a) 13 hours before landing and 2 hours after typhoon moving to Guangxi Autonomous Region; (b) 6 hours after typhoon moving to Guangxi to the time typhoon dissipated in the northern part of Guangxi. (2) During the typhoon landing until it moved to Guangxi Autonomous Region, the whole Guangzhou city covered by strong rainfall, and the largest rainfall appeared near the centre of typhoon; after typhoon disappeared, the rainfall in Guangzhou City gradually weakened and the rainfall trend started to weaken.(3) The position of heavy rainfall centre moved following typhoon track, it firstly appeared in the southeast of Guangzhou, then moved to the centre, and after typhoon moved to Guangxi, the heavy rainfall in Guangzhou happened in the west of Guangzhou. (4) In the future, calibrated radar data with high spatial-temporal resolution may be used to analyse the spatial-temporal distribution of precipitation during the typhoon.

1. Introduction
Typhoon Nida formed on northwest Pacific Ocean about 190 kilometers east of the Philippines at 09:00 (UTC, the same below) of 30 July in 2016, and became a typhoon in the Bashi Channel at 15:00 of 31 July, then moved northwest to mainland China. Nida landed at Philippines at 06:00 on July 31st at strong tropical storm level (28 m/s, 982hpa), then strengthened into typhoon level. The secondary landing was at Shenzhen of China at 19:35 on August 1st at typhoon level (42 m/s, 965hpa). It passed Guangdong province then weakened into a tropical depression in Guangxi at 15:00 of 2 August and disappeared in Guangxi province. NIDA affected on its way a range of provinces or regions, including Taiwan, Guangdong, Fujian, Hainan, Guangxi, Guizhou and Yunnan. As there was very high astronomical tide when Nida was landing, a high storm surge once-in-a-century was induced along the coast in southern China. 912 thousand people were affected, more than 4900 houses and 391000 hectare crop were damaged or affected, and direct economic losses reached $0.18 billion. Nida’s track is shown in Figure 1.
During Typhoon Nida’s evolution, heavy rainfall at downpour level appeared in the south of Guangdong province, while Guangzhou City, the capital city of southern China, was most seriously impacted. 75 percent of the total rain gauge stations in Guangzhou recorded a precipitation over 100mm (downpour level), 17 percent of the total rain gauge stations recorded a precipitation over 200mm. Nida made Guangzhou issued its first typhoon warning at red level since 2000, and its five boroughs, including Tianhe, Haizhu, Huangpu, Panyu and Nansha, also issued storm warning at red level. Under Nida serious impact, due to the combined effects of heavy rain and water pour backward, Tianhe and Panyu districts suffered from severe waterlogging. The depth of waterlogging in Tianhe district reached 1 meter, dozens of people in Panyu district got trapped because of waterlogging [2].

Figure 1. Track of typhoon Nida

In the past, typhoon monitoring was mainly based on meteorological satellites and conventional weather radars. However, satellite data were limited in space-time resolution, and conventional radars could only obtain intensity information, so it was difficult to conduct an in-depth study on the internal structure of typhoon induced precipitation. With the extensive application of Doppler radar technology, the weather radar in the domestic meteorological department has been gradually upgraded to a new generation of Doppler weather radar. The development and application of its products and its derivative products makes it possible to understand the structure of typhoon. Doppler weather radar’s high temporal resolution and high spatial resolution shows considerable advantages to improve the ability of short-term weather monitoring and forecasting [1]. Doppler weather radar data provide new means and data for analysing the temporal and spatial characteristics of typhoon induced precipitation.

In this paper, estimated precipitation with Doppler radar is adopted to study the space-time characteristics of rainfall induced by typhoon Nida in Guangzhou City, so to provide insight of flood formation induced by typhoon, and to facilitate the precipitation estimation and prediction, selection of appropriate hydrological model for flood forecasting and early flood warning.

2. Study Area and Data

2.1. Guangzhou Overview
Guangzhou is located in southern China, central and southern Guangdong Province, the central and northern fringe of the Pearl River Delta, the junction of the Three Rivers of the Xijiang River, the Beijiang River and the Dongjiang River, on the verge of the South China Sea. Guangzhou is located at 112° 57′ E to 114° 3′ E longitude and 22° 26′ N to 23° 56′ N latitude. Downtown is located at latitude 23° 06′ 32″ N, 113° 15′ 53″ E. The area of Guangzhou city is 7434 square kilometers,
consists of 11 municipal districts. Since the reform and opening up, Guangzhou's economic
development has made remarkable achievements, the industrial and agricultural production continued
to grow steadily and the foreign economic and trade boomed. In 2016, the GDP of Guangzhou was
1,961.094 billion yuan, ranking third in mainland China.

Guangzhou is located in the subtropical coast, the Tropic of Cancer goes through central and
southern of it. Climate is subtropical maritime monsoon, characterized as warm and rainy, adequate
light and heat, long summer, short frost period. Its annual average temperature of 20-22 degrees
Celsius makes it one of the highest annual average temperature among Chinese cities. Guangzhou
belongs to the hilly region, the terrain is northeast is high and low in the southwest. The northern part
is a hilly mountainous area where forests are concentrated. The northeastern part is a hilly region,
while the central part is a hilly basin area. The southern part is a coastal alluvial plain and an integral
part of the Pearl River Delta. Guangzhou is located in the wet area in the south. The river system in the
territory is well-developed. There are numerous rivers and streams with vast areas of water. There are
22 rivers with catchment area over 100 square kilometers and 1,368 rivers with river width over 5
meters. The total length of rivers is 5597.36 km, the river density is 0.75 km/km². Geographical
profile map of Guangzhou City is shown in Figure 2.

![Geographical profile map of Guangzhou City.](image)

Guangzhou flood season unevenly distributed, rare floods from November to March next year. The
flood season is from April to October. The highest flood season in May-June and the next in July-
August. In the view of geographical distribution, more heavy rains happen in Conghua and Zengcheng
in the north. Northern Guangzhou is a hilly region influenced by the terrain, the air rises in this area
and is also more prone to convective weather such as rainstorms, showers, hail and tornadoes in the
south.

2.2. Guangzhou Doppler weather radar

Guangdong is one of the most affected provinces in China suffering from tropical cyclones. According
to Guangdong’s weather and climate characteristics, combined with the topographical features, 10
stations of new generation Doppler weather radar are constructed across the province, S-band for the
same type of radar. Seven radars are already in operation, Guangzhou Station is located in the regional
center. Four stations, including Yangjiang, Shenzhen, Shantou and Zhanjiang, are located near the sea,
Shaoguan and Meizhou’s are at the provincial border. Coupled with neighbouring provinces such as Fujian, Hainan and Guangxi, data sharing was achieved and a weather radar network was formed for monitoring typhoons in the South China Sea and Western Pacific landing in Guangdong Province. As of 2009, radar data mosaic involved radars including the above-mentioned seven stations in Guangdong, besides, Beihai station and Liuzhou station in Guangxi province, Haikou station in Hainan province, Xiamen station in Fujian province are also involved [3].

Guangzhou Doppler Radar(GDR) station is located in the south of Panyu District, belonging to the new generation of Doppler weather radar of CINRAD/SA model [4][5]. The site of the radar station has an elevation of 143m, an erected height of 37.3m, a radar detection range of 460km and a radar measurement range of 230km. The whole Guangzhou City is in its full coverage as shown in Figure 3.

![Figure 3. Coverage of Guangzhou Doppler Radar(GDR)](image)

2.3. Radar based precipitation estimation

Precipitation induced by typhoon Nida was estimated by employing the radar rainfall algorithm based on the observed radar reflectivity conducted by Guangdong Provincial Meteorological Observatory [6][7]. Data time is from Aug 1st 08:00 to Aug 3rd 23:00, with time resolution of 1 hour, the spatial resolution of 1km, a total of 64 hours. The radar data was quality controlled before used for precipitation estimation, and the rain gauge precipitation at hourly step was used to calibrate the radar precipitation estimation. Figure 4 shows some of the estimated results.

![Figure 4. Part of GDR estimated precipitation](image)
3. Characteristics of Spatial and Temporal Distribution of Rainfall

3.1. Rainfall process
Typhoon Nida lasted from July 29th to August 3rd and landed at Shenzhen at 03:35 on August 2nd. According to all rainfall radar charts of Guangzhou, the rainfall in Guangzhou fell from Aug 1st 09:00 to Aug 3rd 05:00 (43 hours in total). Based on the radar estimation rainfall data, the rainfall in Guangzhou started from Aug 1st 09:00 and was mainly concentrated in the Conghua District and Huadu District in the north, then the rainfall trend moved to the south. Until typhoon landed in Shenzhen at 19:35 in the typhoon level, rainfall covered the whole Guangzhou city. Since typhoon entered Guangxi around Aug 2nd 08:00, the rainfall in Guangzhou gradually decreased at Aug 2nd 10:00. A large amount of rainfall occurred again at 15:00 and weakened until typhoon dissipated in the northern part of Guangxi at Aug 3rd 00:00. Typhoon rainfall concentrated in two periods: (1) Aug 1st 15:00-Aug 2nd 10:00; (2) Aug 2nd 14:00-Aug 3rd 00:00. Figure 5 shows rainfall in Guangzhou in the first stage (Aug 1st 15:00-Aug 2nd 10:00), while Figure 6 shows rainfall in Guangzhou in the second stage (Aug 2nd 14:00-Aug 3rd 00:00).

![Image](image_url)

**Figure 5.** Guangzhou’s rainfall during Nida in the first stage (Aug 1st 15:00-Aug 2nd 10:00).

3.1.1. First stage: Aug 1st 15:00-Aug 2nd 10:00. In this stage, the rainfall covers the entire city of Guangzhou. The heavy rainfall center spreads from southeast of Guangzhou(Zengcheng and Panyu District) to the center and northwest of Guangzhou(Tianhe and Huadu District). At 22:00 on Aug 1st, the heavy rainfall center moved to the centre of Guangzhou(Tianhe and Huangpu District) and then spreads around the Haizhu District to the surrounding near Baiyun District. It lasted four hours until Aug 2nd 01:00. And in Aug 2nd 05:00, after typhoon landed, Zengcheng District(near typhoon landing area) rained heavily. And the rest of the administrative districts witnessed less rainfall and the rainfall mainly concentrated in Conghua then.
3.1.2. Second stage: Aug 2nd 14:00-Aug 3rd 00:00. In this stage, typhoon has already entered Guangxi around Aug 2nd 08:00 and dissipated in the northern part of Guangxi at Aug 3rd 00:00. So typhoon centre was not in Guangdong province. The rain firstly concentrated in Panyu District, the maximum rainfall was also located in Panyu District at Aug 2nd 15:00. During this time, the rainfall in Panyu, Tianhe and Huangpu District were very large, but, rainfall of Zengcheng District and Conghua District were very small. The rainfall covered whole city was from Aug 1st 17:00 to Aug 2nd 08:00 (15 hours in total), that is, the heavy rain mainly concentrated in 6 hours before typhoon landing and 6 hours after landing.

3.2. Accumulated precipitation over districts

Accumulated precipitation over Guangzhou City and eleven districts of Guangzhou are shown in Figure 7. The heavy rain according to Figure 7 are concentrated in two periods: (1) Aug 1st 20:00-Aug 2nd 10:00; (2) Aug 2nd 14:00-Aug 3rd 03:00. They are similarly to Figure 5/6 described.

Eleven districts of Guangzhou, rainfall periods of time are summarized as follows:

Baiyun District: Aug 1st 18:00-Aug 2nd 09:00; Aug 2nd 15:00-20:00. The maximum rain happened in Aug 2nd 17:00 about 13mm.

Conghua District: Aug 1st 18:00-Aug 2nd 10:00; Aug 2nd 15:00-20:00; 08.03 03:00-06:00. The maximum rain happened in Aug 2nd 19:00 about 4mm.

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Figure 6. Guangzhou’s rainfall during Nida in the second stage (Aug 2nd 14:00-Aug 3rd 00:00).
(c) Precipitation over Haizhu District  
(d) Precipitation over Huadu District  
(e) Precipitation over Huangpu District  
(f) Precipitation over Liwan District  
(g) Precipitation over Panyu District  
(h) Precipitation over Nansha District  
(i) Precipitation over Tianhe District  
(j) Precipitation over Yuexiu District  
(k) Precipitation over Zengcheng District
(l) Accumulated precipitation over Guangzhou City

Figure 7. Accumulated precipitation over Guangzhou City and eleven Districts of Guangzhou

Haizhu District: Aug 1st 18:00-09:00; Aug 2nd 15:00-20:00; Aug 2nd 22:00-08.03 01:00. The maximum rain happened in Aug 2nd 16:00 about 23mm.
Huadu District: Aug 1st 19:00-Aug 2nd 09:00; Aug 2nd 15:00-08.03 03:00. The maximum rain happened in Aug 2nd 01:00 about 8mm.
Huangpu District: Aug 1st 18:00-Aug 2nd 07:00; Aug 2nd 14:00-19:00; 08.03 01:00-02:00. The maximum rain happened in Aug 2nd 17:00 about 19mm.
Liwan District: Aug 1st 15:00-Aug 2nd 08:00; Aug 2nd 15:00-08.03 00:00. The maximum rain happened in Aug 2nd 01:00 about 8mm.
Panyu District: Aug 1st 18:00-Aug 2nd 07:00; Aug 2nd 14:00-08.03 03:00. The maximum rain happened in Aug 2nd 15:00 about 33mm.
Nansha District: Aug 1st 10:00-11:00; Aug 1st 17:00-Aug 2nd 06:00; Aug 2nd 14:00-08.03 03:00. The maximum rain happened in Aug 2nd 15:00 about 15mm.
Tianhe District: Aug 1st 19:00-Aug 2nd 04:00; Aug 2nd 15:00-20:00. The maximum rain happened in Aug 2nd 15:00 about 32mm.
Yuexiu District: Aug 1st 18:00-Aug 2nd 07:00; Aug 2nd 15:00-19:00. The maximum rain happened in Aug 2nd 15:00 about 30mm.
Zengcheng District: Aug 1st 16:00-Aug 2nd 10:00. The maximum rain happened in Aug 2nd 07:00 about 6mm.

According to eleven districts’ rain periods and accumulated precipitation over Guangzhou City, we can find out every district’s rain period mainly concentrated in Aug 1st 18:00-Aug 2nd 09:00 and Aug 2nd 14:00-Aug 3rd 03:00. The maximum rain was in Panyu district about 33mm. And eight districts’ maximum rain happened during Aug 2nd 15:00-19:00. This is the period that typhoon has moved to Guangxi Autonomous Region.

3.3. Spatial-temporal distribution of rainfall

According to the rainfalls in all administrative districts, we can see that the heavy rain in Guangzhou is mainly concentrated in Huangpu District, Tianhe District, Zengcheng District, Nansha District and Panyu District, and the rainstorm always lasted 1-3h. Especially in the main urban area of Guangzhou (Tianhe, Haizhu, Huangpu, Panyu, Liwan, Yuexiu District) the rainstorm’s intensity was bigger, the rain per hour even attached about 30mm. The characteristics of rainfall spatial-temporal are uneven distribution. Heavy rain mainly concentrated in the area near the typhoon centre.

A heavy rain in Guangzhou period concentrated in two periods: (1) Aug 1st 15:00-Aug 2nd 10:00; (2) Aug 2nd 14:00-Aug 3rd 00:00. The first period is during typhoon landing, 13 hours before landing.
and 2 hours after typhoon moving to Guangxi Autonomous Region. The second period is from 6 hours after typhoon moving to Guangxi to the time typhoon dissipated in the northern part of Guangxi.

4. Conclusion

In this paper, we used the radar rainfall products to monitor the rainfall of typhoon Nida, and analysed the rainfall process and the spatial-temporal distribution of precipitation during the typhoon in Guangzhou. The conclusions are as follows:

(1) During the typhoon Nida, rainfall in Guangzhou mainly concentrated in two periods: (a) Aug 1st 15:00-Aug 2nd 10:00: 13 hours before landing and 2 hours after typhoon moving to Guangxi Autonomous Region; (b) Aug 2nd 14:00-Aug 3rd 00:00: 6 hours after typhoon moving to Guangxi to the time typhoon dissipated in the northern part of Guangxi.

(2) It takes 14 hours from the typhoon landing until it moved to Guangxi Autonomous Region. During this time, the whole Guangzhou city covered by strong rainfall, besides the largest rainfall appeared near the centre of typhoon. After typhoon moved into Guangxi Autonomous Region, the rainfall impact on Guangzhou City lasted 12 hours. After 12 hours, the rainfall in Guangzhou City gradually weakened and the rainfall trend started to weaken in the eastern part of Guangzhou City.

(3) The position of heavy rainfall centre moved following typhoon track, it firstly appeared in the southeast of Guangzhou, then moved to the centre, and after typhoon moved to Guangxi, the heavy rainfall in Guangzhou happened in the west of Guangzhou.

(4) In the future, during the heavy rain caused by typhoon, calibrated radar data with high spatial-temporal resolution may be used to analyze the spatial-temporal distribution of precipitation during the typhoon, the research also can be extended by comparing with another Radar data so that the new Guangzhou Doppler Radar is a benefit for future typhoon monitoring and prevent the influence made by typhoon rainfall and minimize the loss of people's life and property.

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