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## THE RESEARCH ON RELATIONSHIP BETWEEN OUTER CIRCULATION OF TROPICAL CYCLONES AND HIGH TEMPERATURE WEATHER IN GUANGZHOU

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**Abstract:** Using historical synoptic data, the surface observation data of Guangzhou, the data in the *Yearbook on Tropical Cyclones* of P. R. China, and NCEP/NCAR reanalysis data of geopotential height, vertical velocity from June to September over the years 1983 to 2004, and defining three days or more in succession with daily maximum temperature over 35°C as a process of high temperature weather, this work analyzes the relationship between the activity of tropical cyclones and the disastrous high temperature weather in Guangzhou. The result shows that disastrous high temperature weather in Guangzhou is closely related to the outer circulation of tropical cyclones, and high temperatures weather over 37°C occur mainly when tropical cyclones move in the range from 400 to 1600 km southeast or east to Guangzhou. Furthermore, rapid temperature increase with descending motion resulting from tropical cyclones is the major factor that induces disastrous high temperature weather in Guangzhou when the city is controlled by the subtropical high.

**Key words:** disastrous high temperature; tropical cyclones; warming by descending motion

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### 1 INTRODUCTION

Locating on the Tropic of Cancer and facing the South China Sea, Guangzhou is of the monsoon climate of subtropics. Daily maximum temperatures are usually below 35°C, though it has long and hot summer. When there are tropical cyclones in the Pacific Ocean west of 130°E, including the South China Sea, daily maximum temperatures rose to 35°C and above and can last for several days in a row. For instance, disastrous high temperatures, rare in history, occurred in Guangzhou when Typhoon No.0407 (Mindulle) was active from the Bashi Strait to the island of Taiwan. The highest temperatures were above 35°C for seven consecutive days from June 27 to July 3, 2004, with July 1 having the highest in the process (39.1°C). The high temperature and humidity, together with dew point at 31 – 33°C, put the human comfort index larger than 90 and at the extremely uncomfortable level, as calculated with the equation  $(L_d=0.72(T+T_w)+40.6)^{[1]}$ .

At present, there are quite a number of studies in

China on high temperature weather as caused by the continental high during prime summer<sup>[2, 3]</sup>. Being comprehensive in analysis, they lack work on the internal mechanisms for tropical cyclones and disastrous high temperature weather. This work will analyze and study the relationships between tropical cyclones and high temperatures in Guangzhou using the principles and methods of synoptics and statistics, has detailed assessment of the process in which Mindulle caused high temperatures in Guangzhou, with attempts to identify the mechanisms and causes for their generation and look for clues for the forecasting of high temperatures in Guangzhou.

### 2 DEFINITION AND STATISTICS

According to our definition, a disastrous high temperature process is defined to occur if daily maximum temperatures  $\geq 35^\circ\text{C}$  for three days or more. Statistics and analyzed data used in the work include conventional data for June, July, August and

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September in 1983 – 2004, reanalysis data from NCEP/NCAR, surface observations from Guangzhou station and yearbook information for the period. The principle for the statistical and analytical work is the following. When there are tropical cyclones in the west Pacific west of 130°E and south of 26°N and the northeast South China Sea east of 114°E and north of 16°N, together with the subtropical high controlling the south of China and no cold air affecting Guangdong, the periphery circulation of the tropical cyclone is defined to be related with the disastrous high temperatures in Guangzhou.

As shown in the statistical results, there are 35 processes of disastrous high temperatures in the city over the 21 years. 28 of them are associated with tropical cyclones and seven are not. There is no such case in which high temperature weather is absent even though tropical cyclones with the set conditions do appear. For the seven unrelated processes, daily maximum temperatures are mostly between 35°C and 36°C. Weather with daily maximum temperatures more than 37°C mostly occur when tropical cyclones are over waters 400 – 1600 km southeast or east of Guangzhou. Extremes tend to appear when tropical cyclones are active in areas from the Bashi Straits to the island of Taiwan. Tropical cyclones No.8918 (unnamed), No.9012 (Yancy), Mindulle and Rananim (No.0414) are such cases, of which Typhoon Mindulle is the one that had the most serious impact. It can be held that disastrous high temperatures in Guangzhou have close links with the activity of tropical cyclones.

### 3 SYNOPTIC BACKGROUND AND CAUSATION FOR HIGH TEMPERATURES

As pointed out by some studies, the direct cause for sustained high temperatures is the subtropical high that has stable control, though the case of Guangzhou is contributed by multiple factors. In summer, the subtropical high dominates the south of China and it is fine, calm with few clouds within the continental high. Intense radiation, descending airflows at the middle and lower levels and substantial warming by descending motion characterize the subtropical high lingering for a long time over the region. It is prone to form a kind of “steaming cookware” weather over a large area with the aid of highly humid air, making it one of the general patterns of summer high temperatures. The subtropical high is also one of the regimes that play an important role in the weather in Guangzhou. In fact, daily maximum temperatures are mostly below 35°C in Guangzhou, for it is usually on the southern side of the subtropical high with the southeasterly flow over it (Fig.1). When the tropical

cyclone is in the area from the west Pacific and northeastern South China Sea and on the way to come towards the coast of south China, weather patterns change dramatically so that the city is to the east or southeast of the continental high that is stable and seldom moves, with the middle and lower levels shifted to the dominance of the northerlies. The pattern in which the middle- and lower- level airflows and meteorological elements change with Mindulle approaching northwestward to head for the island of Taiwan well describes the change in circulation and internal mechanisms for the generation and dissipation of disastrous high temperatures in Guangzhou. On June 26, 2004, Mindulle was over waters east of the Philippines, more than 2000 km southeast of Guangzhou. As shown in the 500-hPa upper-level chart at 08:00 (Fig.2), for the subtropical high, the field of

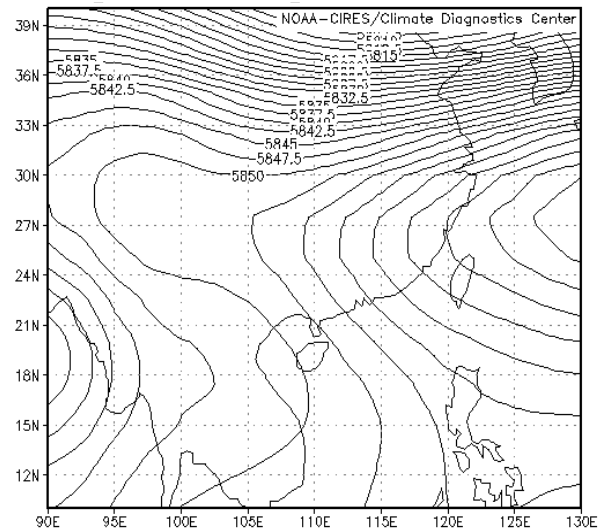


Fig.1 Long-term mean at 500 hPa. Unit: gpm; contour interval: 25 gpm.

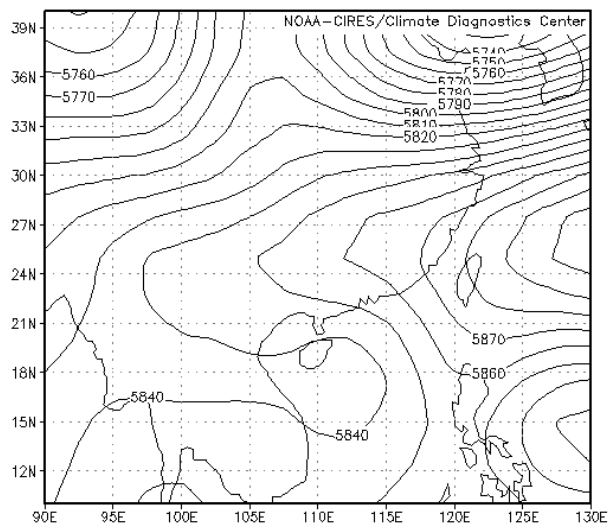


Fig.2 Same as Fig.1 but for 08:00 June 26.

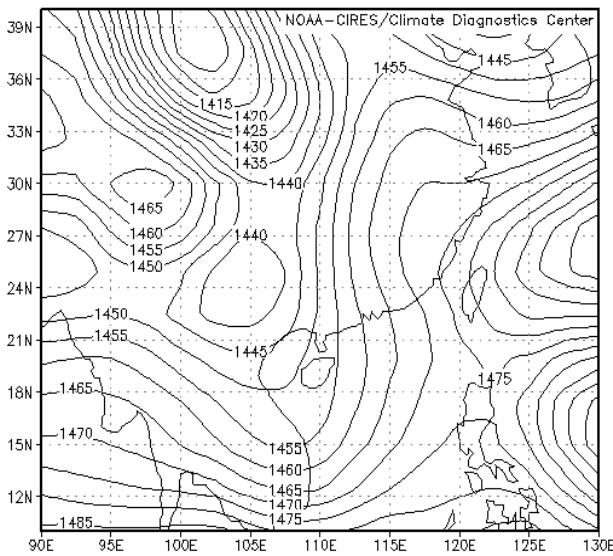


Fig.3 Same as Fig.1 but for 08:00 June 26 at 850 hPa.

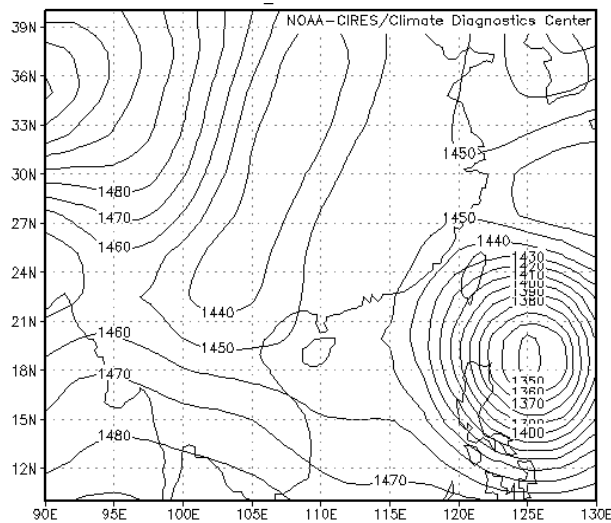


Fig.4 Same as Fig.1 but for 08:00 June 29 at 850 hPa.

geopotential height is similar to that of multi-year average (Fig.1) and SSE wind prevailed at the middle and lower levels of the city (Fig.3). The maximum temperature was 34.0°C that day. At 08:00 June 29, 2004, Mindulle was close to the Bashi Straits, or about 1200 km from Guangzhou, when the subtropical high was split to two rings, one on the east and the other on the west. The city was now on the southeast of the continental high and in the northeasterly. With isobaric contours few and far between at lower levels in the south of China, Guangzhou was inside the area of homogeneous pressure and in the state of quasi calmness.

The tropical cyclone is a cyclonic vortex that is powerful and deep, with airflows converging at lower levels and rising along the center while water vapor

condense and fall; the airflows flow out of the typhoon top to mix with surrounding air and descent to lower levels again at places some distance away<sup>[5]</sup>. Based on this principle, the descending motion in and around Guangzhou intensified substantially, which displayed as pronounced change in the vertical velocity at 850 hPa. At 14:00 June 26, 2004, Guangzhou was in an area of weak ascending motion (Fig.5). By 14:00 June 30, 2004, the area of ascending motion had evolved into one of descending motion (Fig.6). From the zonal cross sections of vertical  $p$  velocity through the city (Fig.7 and Fig.8), one knows well how the vertical motion of upper-level airflows distributed when Mindulle did not have any effect at 12:00 June 26 and when it came near the city at 12:00 June 30. By 12:00 June 30, the descending motion had increased in size

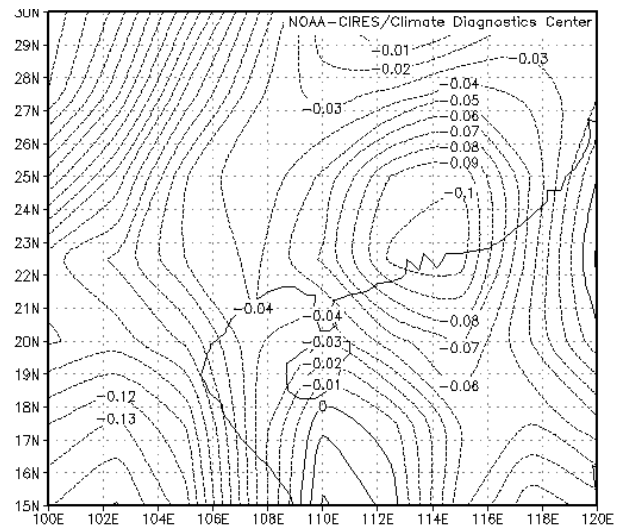


Fig.5 Vertical velocity  $p$  for 14:00 June 26 at 850 hPa. Unit: Pa/s.

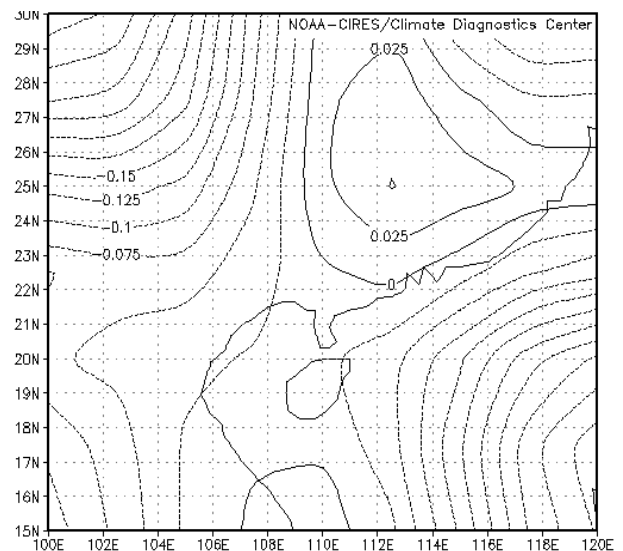


Fig.6 Same as Fig.5 but for 14:00 June 30 at 850 hPa.

between 112 – 116°E, with the value for center increasing to 0.05 Pa/s. Guangzhou (23.1°N, 113.3°E) was near the centre and its daily maximum temperature can increase to an area between 34.5°C and 38.9°C, suggesting significant warming by descending motion which appeared at the periphery of the tropical cyclone. For analyses of other aspects, refer to the Chinese edition of the journal.

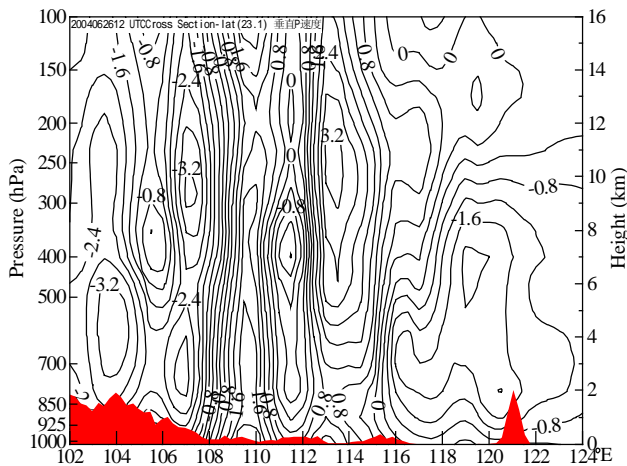


Fig.7 Cross section of zonal vertical velocity  $p$  for 20:00 June 26. Unit:  $10^{-2}$  Pa/s.

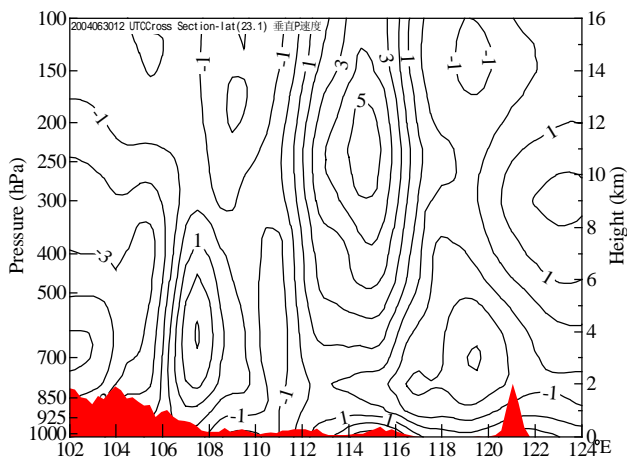


Fig.8 Cross section of zonal vertical velocity  $p$  for 20:00 June 30. Unit:  $10^{-2}$  Pa/s.

#### 4 CONCLUSIONS AND DISCUSSIONS

As shown in the analysis of this paper, intense warming by descending motion caused by the periphery

circulation of tropical cyclones is playing an important role in the generation of disastrous high temperatures in Guangzhou. Of course, there must be intense warming by solar radiation due to the control of the continental high is in the first place. In June – September when Guangzhou is in the control of the stable continental high and has relatively high basic temperature, forecasts or pre-warnings of disastrous high temperatures are likely to be issued for the city if a tropical cyclone is getting close to the northwestern Pacific west of 135°E or the South China Sea. Besides, the descending airflows at the periphery of tropical cyclones are also essential for the formation of high temperatures in the coastal cities in the south of China, as evidenced from the analysis of the structure and distribution of synoptic systems. The results of this study are also useful in the forecasting of high temperatures for these areas.

In routine weather forecasting, track and direction of the movement, wind force and precipitation tropical cyclones bring about at and after landfall are the primary concerns while teleconnecting effect imposed by them are less taken care of. As a matter of fact, the tropical cyclones that are frequently active over the west Pacific and South China Sea are affecting the weather in Guangzhou through a number of ways and high temperatures are just one of them. It deserves more effort to probe into the teleconnection between the tropical cyclone and the weather in Guangzhou.

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