Analysis of a Winter Rainstorm Weather Process in Shaoguan in December 2013

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Abstract Based on conventional observation data, NCEP reanalysis data and observation data of automatic stations, a rainstorm weather process occurring in Shaoguan City during December 14 – 17, 2013 was analyzed. The results show that the main causes of the winter rainstorm in Shaoguan City were the strong southwest airflow at 500 and 700 hPa, high humidity, the influence of a low-pressure trough at 850 hPa, and the southward movement of cold air on the ground.

Key words Winter rainstorm; Circulation pattern; Physical quantity field; Shaoguan City

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Rainstorm weather, which is one of the most significant disastrous weather phenomena in China, has a major impact on people's lives, property and personal safety. It has always been of great concern to meteorologists and professional workers, and many meaningful achievements have been made[1–2]. There have been many studies on the causes of winter rainstorms. For instance, Luo Lv *et al.*[3] concluded that the continuous rainstorm process occurred under favorable conditions of strong subtropical high with stable position, active southern branch trough, and long-term confrontation between low-level cold and warm air masses near the Nanling Mountains. Ling Ying *et al.*[4] analyzed the climatic characteristics of winter rainstorm events, influencing systems and circulation backgrounds. Guo Liang *et al.*[5] found that the heavy precipitation in winter was generated by the coordination of multiple systems such as deep southern trough, low-level jet stream, strong cold air, and low-level strong shear line. Jia Xiaolong *et al.*[6] hold that the Madden – Julian Oscillation (MJO), as the intraseasonal oscillation of the atmosphere, affects the winter water vapor transport in the Bay of Bengal and the South China Sea by adjusting the subtropical high over the western Pacific and the southern branch trough over the Bay of Bengal. Qin Li *et al.*[7] believed that the abnormally strong and stable subtropical high caused the convergence of the rare southeast jet stream at the lower level, resulting in continuous winter rainstorms. Xie Longsheng *et al.*[8] pointed that winter rainstorms in Meizhou were mainly caused by the southward movement of cold air from the middle route, the eastward movement of the south trough, and the maintenance and influence of the shear line, and the abnormal intensity of the subtropical high, the position of the East Asian trough located further east, and the active south trough were the main reasons for the abnormally large number of rainstorm days in winter. Su Baixing *et al.*[9] analyzed winter rainstorms in Guangdong, summarized the weather situation at all levels, and believed that the enhancement of strong divergence field at 200 hPa and the southwest airflow at the middle and lower levels were favorable for the occurrence of winter rainstorms in Guangdong.

In order to understand the physical conditions for the occurrence of rainstorms in Shaoguan under the background of dry and cold climate, it is necessary to conduct in-depth research on the circulation system and physical mechanism for the occurrence of winter rainstorms. In this paper, based on conventional observational data, NCEP reanalysis data, and observational data of automatic stations, the rainstorm weather process in Shaoguan City from December 14 to 17, 2013 was analyzed to improve the forecast service for winter rainstorm weather and enhance the ability to prevent and mitigate meteorological disasters.

1 Weather situation

From December 14 to 17, 2013, under the combined influence of an upper-level trough, a low-level shear line and ground cold air, continuous heavy rainfall occurred in Shaoguan, Guangdong Province. The heavy rainfall in Shaoguan City mainly happened from December 16 to 17, and the centers of heavy precipitation appeared in Shixing, Nanxiong, Xinfeng, Qujiang and Wengyuan. Among them, the total precipitation in eight automatic weather stations in Qujiang, Shixing, Wengyuan, Xinfeng, Lechang, Nanxiong, Renhua and Ruyuan within these two days was 74.1, 80.9, 71.9, 77.2, 43.1, 80.4, 57.5 and 58.4 mm, respectively. The precipitation in Shixing within a single day reached as high as 52.7 mm, while that in Xinfeng and Nanxiong was up to 51.5 mm. The winter rainstorm process in Shaoguan City was characterized by long duration, wide influence range, low average temperature and large cumulative rainfall.

2 Analysis of circulation situation

2.1 Circulation situation at 500 hPa At 20:00 on December

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14, 2013, the zonal circulation in middle and high latitudes gradually shifted towards the meridional circulation. The high-pressure ridge continued to develop within the area of 80° – 90° E, 50° – 60° N. Near the coast area east of Northeast China, the northeast low pressure was always maintained. With the adjustment of the circulation in middle and high latitudes, small troughs kept splitting and moving eastwards, finally reaching the southern region. The longitude of the middle and low latitudes kept increasing, and the southern trough showed a gradually deepening trend. The southwest wind over Shaoguan increased. At 20:00 on December 15, the low pressure over the east of the northeast coastal area moved eastwards out of the sea. A new low-pressure system was established in the northeast region. Meanwhile, a blocking high-pressure system was gradually formed to the west of Lake Baikal in middle latitudes. The small trough continued to split and move southwards. The southern trough near 95° E continued to deepen and move eastwards. The intensity of the southwest airflow over Shaoguan City increased. Moreover, humidity showed a significant increasing trend. At 20:00 on December 16, there were two troughs and one ridge in middle and high latitudes. The small trough and the southern trough located in middle latitudes merged and deepened, and tended to move eastwards obviously. The southwest airflow over Shaoguan continued to strengthen, and the trend of humidity increase was not very obvious. At this time, the altitude field decreased significantly. At 20:00 on December 17, the northern and southern sections of upper-level trough in middle altitudes gradually moved eastwards, and the southwest airflow still controlled the entire Shaoguan area. At this time, the southwest airflow weakened, and the humidity decreased, while the height of the pressure field also reached its lowest point. At 20:00 on December 18, the upper-level trough in low and middle latitudes moved eastwards out of the sea, and the westerly airflow began to control Shaoguan area. Meanwhile, the humidity decreased, and the pressure field became too high. The heavy precipitation weather affecting Shaoguan area came to an end.

2.2 Circulation situation at 700 hPa At 20:00 on December 14, 2013, a low-pressure circulation was formed in the northwest of the Indochinese Peninsula. The low-pressure trough in the north was around 30° N. Under the influence of the low-pressure trough, the intensity of the southwest airflow over Shaoguan City increased. At 20:00 on December 15, a low-pressure trough separated from the low-pressure system, and reached the northwest region of Guangxi during its eastward movement. Shaoguan City was in the strong southwest jet stream in front of the trough. Wind speed was as high as 18 m/s, and humidity also increased. At 08:00 on December 16, the air over Shaoguan City was controlled by the southerly airflow, and the maximum wind speed was as high as 28 m/s. By 20:00, the low pressure located in the Indochinese Peninsula kept moving eastwards, and finally reached the southeast of Guizhou Province. The southwest airflow controlling the air over Shaoguan weakened, but humidity did not show a decreasing trend. At 20:00 on December 17, the low-pressure trough affecting Shaoguan City moved eastwards, and the area above Shaoguan was gradually controlled by westerly wind. At 20:00 on December 18, the low-pressure trough moved eastwards, and reached Fujian region. The weak westerly airflow controlled the entire airspace over Shaoguan.

2.3 Circulation situation at 850 hPa At 20:00 on December 14, 2013, there was a low pressure in the northwest of the Indochinese Peninsula, and the area above Shaoguan was precisely located in the southeast – east airflow. At 20:00 on December 15, the low-pressure circulation moved eastwards and reached the Beibu Gulf, and the low-pressure trough affected Shaoguan area. The air above Shaoguan was still dominated by the southeast – east airflow, but the intensity of the altitude field decreased, and the trend of humidity increase was not obvious. At 08:00 on December 16, the low-pressure circulation moved eastwards, and finally reached the west of Guangdong Province, while the height field in Shaoguan City slightly weakened. At 08:00 on December 17, the area over Shaoguan City was controlled by northerly airflow.

3 Diagnostic analysis of physical quantities

3.1 Water vapor conditions The vertical cross-sectional diagram of water vapor flux from 20:00 on December 14 to 20:00 on December 17, 2013 (Fig. 1) was analyzed. It was found that due to the intrusion of cold air from the ground to 850 hPa, the conditions of water vapor transport were poor. The water vapor transport was mainly concentrated at 700 – 500 hPa, and remained at a relatively strong level from December 15 to 17, ensuring that there were sufficient water vapor conditions in the precipitation area. At the beginning of the precipitation, the water vapor flux in Shaoguan area was between 10 and 12 g/(cm · hPa · s). By 08:00 on December 16, the central intensity of water vapor flux increased to 16 – 18 g/(cm · hPa · s), which was consistent with the period of the strongest precipitation in Shaoguan area.

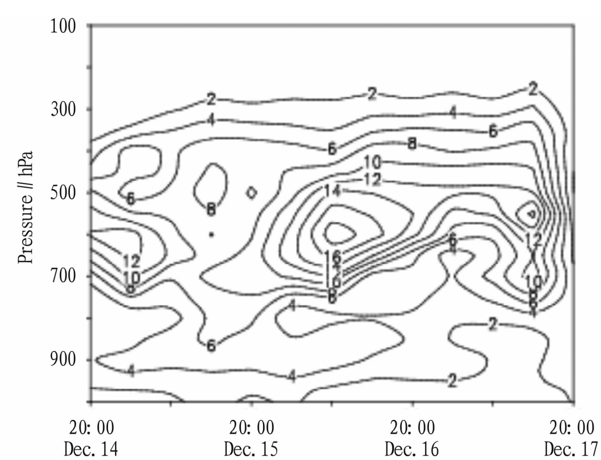

Fig. 1 Vertical profile of water vapor flux from 20:00 on December 14 to 20:00 on December 17 in 2013 [unit: g/(cm · hPa · s)]

3.2 Vertical motion Vertical motion is conducive to achieving energy conversion in the atmosphere. The condensation of water vapor during precipitation is also closely related to upward motion.

To a certain extent, vertical motion affects the occurrence and development of weather systems. From the profile of vertical velocity in the rainstorm center at 02:00 on December 16 (Fig. 2a), it can be seen that Shaoguan area was always been in a deep ascending motion zone. This ascending zone developed from the lower level all the way to 200 hPa, and the strongest ascending center was distributed at 500 hPa, with a center value of -280×10^{-2} hPa/s. The powerful ascending movement was respectively coordinated with low-altitude convergence and high-altitude divergence, which provided favorable conditions for the occurrence and development of rainstorm weather.

3.3 Large-scale uplift The daily potential pseudo-equivalent temperature was analyzed. It is found that there was always a front area of potential pseudo-equivalent temperature from the ground to 850 hPa. Moreover, during the northward movement, the front area gradually tilted, and continuously extends towards the altitude layer at 500 hPa. As shown in the vertical profile (Fig. 2b) of potential pseudo-equivalent temperature along 115° E in the precipitation concentration area, the surface front area was located within 21° – 25° N, with an extremely small slope. During the process of extending into the upper atmosphere, there was a distinct tendency to tilt northwards, and the largest front area was distributed at 925 – 850 hPa. At 700 – 500 hPa, a strong southwest airflow carried a large amount of warm and humid air moved upwards along the slightly sloping front area. This large-scale forced uplift effect of the front provided favorable dynamic conditions for the continuous rainstorm weather in Shaoguan.

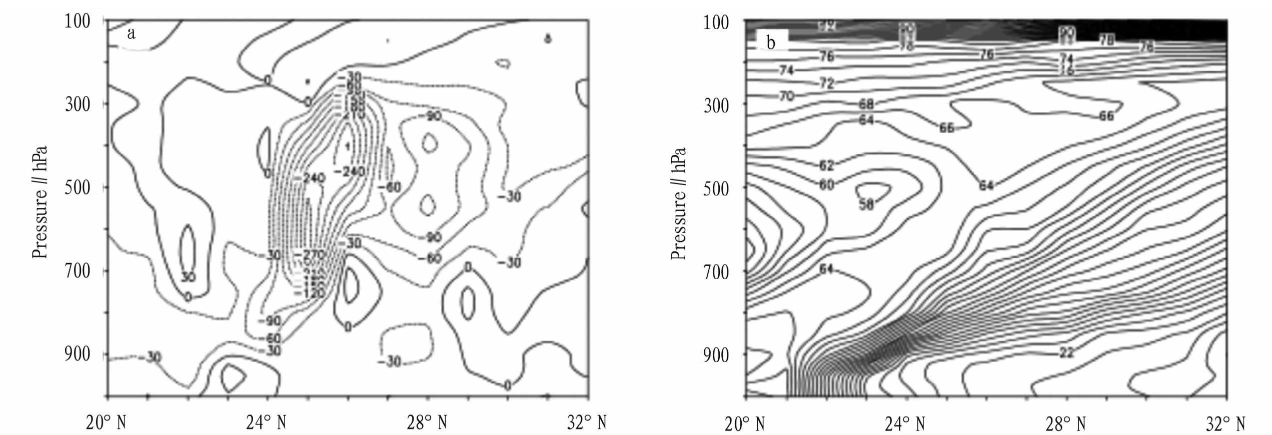

Fig. 2 Vertical profiles of vertical velocity (a, unit: 10^{-2} hPa/s) at 02:00 and potential pseudo-equivalent temperature (b, unit: ℃) at 08:00 along 115° E on December 16, 2013

4 Conclusions and discussion

In this paper, the rainstorm weather process that occurred in Shaoguan City during December 14 – 17, 2013 was analyzed based on conventional observation data, NCEP reanalysis data and observation data of automatic stations.

(1) The main causes of the winter rainstorm in Shaoguan City were the strong southwest airflow at 500 and 700 hPa, high humidity, the influence of a low-pressure trough at 850 hPa, and the southward movement of cold air on the ground.

(2) The occurrence of the winter rainstorm was closely related to abundant water vapor transport, strong convergence and ascending movement, and long duration, and it was even more closely associated with water vapor and dynamic conditions at 700 hPa.

(3) During this winter rainstorm, the northeast airflow remained consistently below 850 hPa, while the strong southwest airflow was present between 700 and 500 hPa. The southwest airflow climbed along the front area with a very small ground slope, causing continuous precipitation. Water vapor transportation was mainly concentrated at 700 – 500 hPa, and lasted for a long time, which provided favorable conditions for the occurrence of the rainstorm.

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