Analysis of the Causes of a Hail Weather in the Western Tarim Basin in July 2018

Aihong Jiang¹, Yanli Chen²*, Zhilong Wang¹, Dong Ren¹, Baojian Dong¹, Hui Xie¹

¹Tianmu Shuke City Meteorological Bureau, Xinjiang, Tumushu, 844000, China
²Tiemenguan Meteorological Bureau, Xinjiang, Tiemenguan 841007, Xinjiang, China

*Corresponding author e-mail: 25969195@qq.com

Abstract: Using the conventional data, sounding data, NCEP / NCAR 1° × 1° reanalysis data and new generation weather radar data of regional automatic weather stations, the paper analyzes the occurrence and development mechanism of a hail weather process in the western Tarim Basin on July 2, 2018. The results show that: (1) The main influence system of the hail weather was caused by the continuous splitting of short waves in the southern section of the lower Siberian trough crossing the Pamirs; the hail weather occurrence time section was mainly in the area where warm and low pressure and cold air meet, and the ground convergence was the trigger mechanism for this hail weather. (2) The easterly winds appearing in the eastern to central regions of the southern Xinjiang Basin played an air cushion role, and the emergence of ground heat and low pressure enhanced the convergence of the ground near the ground. (3) There was obvious wind speed convergence in the ground layer of the area from Kashi Prefecture to Tumxuk in Xinjiang prior to the generation of the convective cell storm, which was favorable to the occurrence of local hail weather. (4) The radar reflectivity factor strong center corresponds to the large value region of the reflectivity factor gradient, which has a good indication for the identification and early warning of the hail cloud, and the intensity of the echo top was presented as banded distribution and small range, large intensity gradient and fast moving speed. There were suspended echoes and weak echo regions on the reflectivity factor profile (RCS) map, with typical super cell characteristics.

1. Introduction

Tumxuk is located in the western part of the Tarim Basin in Xinjiang. It is located in the Kashgar area and the Kizilsu Kirghiz Autonomous Prefecture, with vast area and abundant resources. The area is bordered by the Taklimakan Desert in the east, the Pamir Plateau in the northwest, and the Karakorum Mountain in the south. The terrain of Tumxuk is intricate, and meteorological disasters and
secondary disasters such as hail, local heavy rain, wind, drought, flood, etc. often occur due to the wide disparity in surface properties; the meteorological disasters due to local short-term heavy rainfall, hail, windy dust (storm) cause the reduction of production in a large number of local crops such as cotton and red dates, which bring certain losses to local agricultural production and the lives of the people, seriously restricting the sustainable and healthy development of the local economy, and the situation of disaster prevention and mitigation is becoming increasingly severe.

Hail is a kind of severe weather caused by short-term strong convective weather. The hail in spring and summer is one of the most catastrophic weathers that are harmful to agricultural production. Although its impact is not significant, its duration is short, often accompanied by short-term winds, local short-term heavy precipitation and other severe weathers. The in-depth study of hail weather has always been a key area of concern for related schools at home and abroad, and has achieved certain scientific research results; foreign scholars have done a lot of analysis of radar data and applications in hail weather, and have also deeply analyzed the hail detection and early warning [1-3]. As China is one of the countries with the most hail disasters in the world, Chinese meteorologists have also done research and analysis on the weather conditions and hail weather occurrence of hail, and have obtained a lot of scientific research results [4-10]. Under the background of global warming, the severe weather such as short-term heavy precipitation and hail in Xinjiang has been frequently re-issued. In response to these situations, many meteorologists in Xinjiang have carried out many analysis and research from different focuses and perspectives., and a number of scientific conclusions have been drawn [11-15].

2. Data Selection

Because the high-altitude exploration data in the western Tarim Basin is relatively rare, in order to continuously improve the forecasting preparation rate based on the experience, this paper analyzes the occurrence and development mechanism of a hail weather process in the western Tarim Basin on July 2, 2018 using the conventional data, sounding data, NCEP / NCAR 1 ° × 1 ° reanalysis data and new generation weather radar data of regional automatic weather stations, in order to continuously summarize the forecasting experience of hail weather in the region, purposing to continuously improve the forecasting and warning level of hail in the future.

3. Weather Conditions

From the afternoon of July 2, 2018 to the night, there were thunderstorms, short-term heavy precipitation, local hail and other severe weather in the Tumxuk area in the western Tarim Basin, Xinjiang. After the manual operation, the heavy and intense falls occurred in 50th group located in the upstream of the 53rd group. The hail fell in the 53rd group (Fig.1) and it started from 21:20, lasted for about 15 minutes, and the maximum hail diameter was 15mm. The strong convective weather caused the serious damage to the cottons of the 50th and 53th groups in Tumxuk.

![Figure 1](image.png)

*Figure 1* The areas marked with five-pointed star are the falling areas of hail (79°26'E, 40°01'N)
4 Analysis of Hail Weather Environment

4.1 Circulation Background

In 500 hPa at 08:00 on July 2 (Fig. 2a), the mid-high latitude pole front was located southward, and a high-pressure ridge developed in the Caspian Sea. The northwest airflow in front of the ridge led the cold air to the south, making the long-wave trough south of Western Siberia gradually move eastward, and gradually formed cut-off vortex in the area north of the Balkhash Lake, and the western part of the southern Xinjiang basin is located at the bottom front of the cut-off vortex.

In 500 hPa at 20:50 on July 2 (Fig. 2b), the Caspian high ridge developed vigorously and was distributed in a square shape. The high pressure center reached 596 dpgm with the ridge point extending to the north of 50 °N. At this time, the wide low trough in the south of Western Siberia to Baikal was gradually strengthened, and there was a clear cold center to match it. The low-pressure trough in southern Siberia continued to split into short-waves. Weak fluctuations appeared in the temperature of each of 850 hPa, 700 hPa and 500 hPa layers in the western part of the Tarim Basin in Xinjiang, which also reflects the short-wave tough perturbation in this area (figure omitted). The front positive vorticity advection tends to produce an ascending motion. When the West Siberian trough began to affect the Xinjiang region, the low-pressure trough of Western Siberia continued to split short waves affected by the special terrain in the western part of Xinjiang, and began to affect the western part of Xinjiang, causing unstable convective weather in the region.

In 850 hPa ground flow field at 14:00 on July 2 (Fig. 2c), there was an obvious wind speed convergence center in the central part of the southern Xinjiang basin; In 850 hPa (figure omitted), the easterly airflow was maintained from the east to the west of the southern Xinjiang basin, which played an air cushion role, while carrying the dry heat flow in the central part of the basin to the cold and wet area in the western part of southern Xinjiang, causing the convergence of cold and warm air over the western part of southern Xinjiang, which was conducive to trigger strong local convective weather; at the same time, led by the low-level southwest airflow (Fig. 2d), the warm and humid air flow from the southern Bay of Bengal was continuously transported to the western part of the southern Xinjiang basin through the water vapor relay in the eastern part of the Qinghai-Tibet Plateau.

In summary, the hail weather was caused by the cold air over the southern section of the low trough of Western Siberia over the Pamirs, frequent short-wave activities, sufficient water vapor and obvious shear lines in the middle and lower layers. The strong convective weather occurring in the western Tarim Basin in Xinjiang provided convenient conditions for the hail.

From July 1st to July 3th, 2018, there were intermittent micro-predictions in the clusters around Tumxuk, Xinjiang. Among them, a 6.1 mm precipitation occurred in the 53rd group (hail falling area) in Tumxuk on July 1, which was very conducive to the water vapor circulation in the area, and provided favorable water vapor conditions for the occurrence of hail weather in the area on the afternoon of July 2. Due to the strong solar radiation during the day, the underlying surface was warmed up in the afternoon, affected by the split short wave, and it was easy to form an unstable layer featured as cold at top and warm at bottom, and the local convective weather occurred in the afternoon. This is also the reason for the occurrence of frequent thunderstorms in Tumxuk from July 1 to July 3.
Fig. 2(a) The circulation features in 500hpa at 8:00 on July 2

Fig. 2(b) The circulation features in 500hpa at 20:00 on July 2
4.2 Analysis of Ground Mesoscale System

At 17:00 on July 2, the thermal and low pressure developed vigorously in the Southern Xinjiang basin was strong (figure omitted). The low-pressure center in the Hetian area of southern Xinjiang was 997.5 hpa. At the same time, the thermal and low pressure (low-pressure center at 995 hpa) also appeared in the central and eastern parts of the southern Xinjiang Basin. According to the data of the regional automatic weather station, a long northerly wind appeared in the Kashgar area west of Tumxuk from 12:00 to 22:00 on July 2, with a maximum wind speed of 19.1m/s (occurrence time: 16:47), and the southwesterly wind appeared in the Tumxuk area; the wind speed convergence appeared near the ground, which was relatively consistent with the hailing area. It is concluded that the mesoscale low-pressure zone in the southern Xinjiang basin enhanced the convergence and uplift movement of the near-surface layer to a certain extent, and the convergence of near-surface wind
speed provided favorable conditions for the occurrence of this hail weather.

5 Analysis of Sounding Data

The occurrence of strong convective weather is the result of the concentrated release of potential unstable energy in the atmosphere. The larger the CAPE value is, the higher the velocity will be when the air block is higher the free convection height, and the more unstable the atmosphere will be. By making the skew T-log diagram of the hailing area (79.3E, 40.0N) in Tumxuk, Xinjiang at 14:00 and 20:00 on July 2, 2018, the convection parameters (Table 1) of the corresponding time period in the region were obtained. They show that the stability parameters of the hail weather reached the threshold of strong convective weather in the region. From the time variation of physical quantities such as k, LI, CAPE, CIN, etc., it can be seen that in the afternoon, as the temperature of the underlying surface gradually increased, the CAPE value of the 53th group of the Tumxuk also increased, and it rose to 1434 J/kg at 20:00 on July 2. The high-humidity and high-temperature regions correspond to each other, indicating that the uneven distribution of the underlying surface temperature and water vapor had a good correspondence with the thermal instability energy and the spatial distribution of the uplift index.

As the temperature of the underlying surface decreased, a sharp upward movement occurred at the boundary layer where the cold and warm flow met each other, resulting in the rapid release of unstable energy over the area. In the corresponding ground, where the 53rd group is located, the hail appeared, and accordingly, the CAPE value decreased significantly.

Table 1 The sounding physical quantity parameters of the ice-cold area in Tumxuk City from 14:00 to 20:00 on July 2

| Time   | K Index(℃) | TT Index(℃) | LI(℃) | Available potential energy of CAPE wet convection (J/kg) | CIN Convexion Suppression Effective of potential(J/kg) |
|--------|------------|-------------|--------|---------------------------------------------------------|-----------------------------------------------------|
| 14hours| 26         | 52          | -4     | 1294                                                    | 31                                                  |
| 20hours| 25         | 53          | -5     | 1434                                                    | 57                                                  |

6 Analysis of Doppler Radar Data

6.1 Evolution of Radar Combined Reflectivity Factor Characteristics (CR)

The radar data used is from the new generation weather radar (CINRAD/CC) in Tumxuk, Xinjiang. The volume scanning mode used is precipitation mode 1 (VCP21). According to the analysis of the combined reflectivity factor map from 20:12 to 22:09 on July 2, a common multi-monitor storm generated at 20:12 in the northerly direction of Tumxuk; from 20:23, the convective monomer storm front moved into the 51st group of Tumxuk (Fig. 3a), with a maximum reflectivity factor of 52 dBZ, and the 51-group moth-proof operation site began to operate. At 20:16, the convective storm got continuously strengthened during the southeast propagation (Fig. 3b), and it was distributed in a north-south direction with a faster moving speed. Its frontier moved into the 53th group in Tumxuk at 21:21 (Fig. 3c). The convective monomer storm center had an intensity maximum reflectivity factor > 54 dBZ, and the center echo top height of the strong echo center extended to 8 km, with the diameter range of about 13KM. This convective storm was featured as strong intensity, small range, and intensity concentration. With the increase of the workload in this area, the 21:42 echo intensity was weakened (Fig. 3d), and the strong echo top height was reduced to 4KM, and the operation effect was good.

6.2 Features of Reflectivity Factor Profile (RCS)

The reflectivity factor profile (RCS) shows the vertical distribution of the convective cell storm reflectivity factor, and can also monitor the convective development height of the strongest center of the reflectivity factor, which is a good indicator for the monitoring and warning of hail. From the
reflectivity factor profile (RCS) at 21:26 of the 53rd group of Tumxuk (Fig. 4a), the reflectivity factor gradient on the convective flood inflow side was the maximum due to the storm top divergence and the ambient wind field. Due to the influence of top divergence and ambient wind field, the echo profile (>20 dBZ) of the middle layer gradually extended to the lower inflow and suspended in the low-level weak echo region; from the low-level to the middle-high-level reflectivity factor, there were suspended echoes and weak returns. In the wave region (WER), the height of the 50 dBZ strong echo center rose to 7-8 km, and the entire echo top height reached 10 km. A relatively obvious hail cloud structure had been formed, and the corresponding ground 53rd group in Tumxuk appeared. The hail weather brought different degrees of damage to the cotton in the area. With the increase of the work intensity, although the suspended echo still exists, the center intensity and its echo height were significantly reduced (Fig. 4b), the cloud gradually dissipated, and gradually moved out of the 53rd group in Tumxuk at 21:58.

![Fig.3 The evolution of combined reflectivity factor from 20:07 to 22:09 on July 2, 2018 (in Dbz)](image-url)
7 Conclusions

(1) The main influence system of the hail weather was caused by the continuous splitting of short waves in the southern section of the lower Siberian trough crossing the Pamirs; the hail weather occurrence time section was mainly in the area where warm and low pressure and cold air meet, and the ground convergence was the trigger mechanism for this hail weather.

(2) The intermittent precipitation weather in the early period of the Tumxuk area in Xinjiang was very conducive to promoting the water vapor cycle in the region; at the same time, the easterly wind in the eastern to central part of the southern Xinjiang basin played an air cushion role. The emergence and enhancement of thermal and low pressure enhanced the convergence and lifting motion near the ground.

(3) In the early stage of convective monomer storm generation, there was wind speed convergence in the near-surface layer of the Kashgar area to the Tumxuk area in Xinjiang; the radiation warming effect and the rising movement in the afternoon were continuously strengthened, and these conditions were favorable for the occurrence of local hail weather.

(4) The strong center of the radar reflectivity factor corresponds to the maximum value of the reflectivity factor gradient, which has a good indication of the prediction of the falling area of the hail, and the intensity of the echo top was banded, with features of sample range, large intensity gradient, and fast moving speed. The strong echo (>50 dBZ) center height was more than 8 km, the entire echo top height was 10 km, so a distinct hail cloud structure had formed. There were suspended echoes and weak echo regions on the reflectivity factor profile (RCS), with typical super-cell characteristics and are one of the typical characteristics of the hail cloud, which is consistent with the occurrence time of hail.

As this paper only selected a case of hail in Tumxuk, Xinjiang in 2018, the conclusions drawn on this basis need to be further verified.

References

[1] Țapu Elvis,Apostol Liviu. Trajectories of Hail Cells with Potential of Generating Hailstorms in Moldova in 2016-2017[J]. Present Environment and Sustainable Development,2018,12(2).

[2] Roxana Cică,Sorin Burcea,Roxana Bojariu. Assessment of severe hailstorms and hail risk using weather radar data[J]. Meteorological Applications,2015,22(4).

[3] Kennedy, Patrick C,Rutledge, Steven A,Dolan, Brenda,Thaler, Eric. Observations of the 14 July 2011 Fort Collins Hailstorm: Implications for WSR-88D-Based Hail Detection and Warnings[J]. Weather and Forecasting,2014,29(3).

[4] Yu Xiaoding, Yao Xiuping, Xiong Tingnan, et al. The principle and application of the new generation of weather radar: revised [M]. Beijing: China Meteorological Administration Training Center, 2004: 1-3, 187-197.
[5] Zheng Xucheng, Da Buxi Latu, Su Lijuan, Fan Ruxia, Fang Xiaohong, Yu Shuiyan. Weather and environmental conditions and identification indicators of hail occurrence[J]. Journal of Arid Land Resources and Environment, 2018, 32(12): 117-122.

[6] Zheng Yuanyuan, Yu Xiaoding, Fang Wei, et al. Doppler radar observation and analysis of a typical supercell storm[J]. Acta Meteorologica Sinica, 2004, 62(3): 317-328.

[7] Wu Jiankun, Yu Xiaoding. A Survey of Doppler Weather Radar Detection and Early Warning Technology in Strong Hail Weather[J]. Journal of Arid Meteorology, 2009, 27(03): 197-206.

[8] Shi Lianmei, Zhao Zhipeng, Wang Xu. Temporal and Spatial Distribution Characteristics of Hail Disasters in Xinjiang from 1961 to 2014[J]. Journal of Glaciology and Geocryology, 2015, 37(04): 898-904.

[9] Wang Yanfeng, Huang Wubin, Wang Jujie, Huang Yuxia, Duan Bolong, Yang Yong. Analysis of Radar Echo Characteristics and Genesis of a Strong Hail in Tianshui, Gansu Province[J]. Plateau Meteorology, 2019, 38(02): 368-376.

[10] Re Su Li, Abula, Niu Shengjie, Abu Limiti Jiang, Abu Likmu, Baha Guli Wahad. Study on the prediction method of Xinjiang hail area [J]. Glacier frozen soil, 2015, 37 (04): 1041-1049.

[11] Chen Yanli. Diagnostic Analysis of the "5.27" Rainstorm Process in Tarim Basin in 2015[J]. Xinjiang Agricultural Reclamation Science and Technology, 2015, 38(09): 57-59

[12] Zeng Yong, Yang Lianmei. Analysis of the Causes of an Extreme Rainstorm Event in Western Xinjiang[J]. Plateau Meteorology, 2018, 37(05): 1220-1232.

[13] Zhang Lei, Zhang Jidong, Li Suli • Abula. Study on the Identification Index of Aksu Hail Weather in Southern Xinjiang[J]. Journal of Arid Meteorology, 2014, 32(04): 629-635, 2014, 32(04): 629-635.

[14] Zhang Junlan, Zhang Li. Climatic characteristics of strong hail weather in 50a in Xinjiang Aksu area[J]. Journal of Desert Research, 2011, 31(01): 236-241

[15] Wei Yong, Peng Jun, et al. Analysis of the Causes of a Hail Weather in the Middle of the North Slope of the Tianshan Mountains in Xinjiang[J]. Journal of Arid Meteorology, 2013, 31(04): 771-777