Analysis of Dual Polarization Radar Characteristics of Short-term Heavy Precipitation in Yushu Area

Wanshun XUE*, **Suonan Meiduo**, **Langjia Cuomu**, **Yuxiang ZHANG**

Yushu Meteorological Bureau, Yushu 815099, China

Abstract Based on the observation data of hourly precipitation and the dual polarization data of the new generation of weather radar in Yushu area from 2022 to 2023, the radar characteristics of 18 short-term heavy precipitation processes were studied through mathematical statistics and comparative analysis of cases. There were four radar detection ranges: within 50 km, within 100 km, within 150 km and beyond 150 km. The evolution laws of echo intensity, echo top height, vertically integrated liquid water (VIL), radial velocity, and dual polarization parameters at different distances were mainly analyzed. The results show that there were significant differences in the radar characteristics of short-term heavy precipitation at different detection distances. Moreover, dense flat large particles, echo parameters with specific thresholds, and appropriate movement speed were important conditions for the occurrence of short-term heavy precipitation. Meanwhile, the radar determination thresholds for short-term heavy precipitation at various detection distances were extracted to provide a scientific basis for the near-term forecast and early warning of short-term heavy precipitation in Yushu area.

Key words Short-term heavy precipitation; Dual polarization radar; Characteristics

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Short-term heavy precipitation refers to a precipitation process in which precipitation intensity is relatively high within a short period of time, and the precipitation per unit time reaches a certain standard. It is characterized by strong suddenness, high intensity, short duration and strong local nature[1]. Yushu Tibetan Autonomous Prefecture, which is located in the heart of the Qinghai - Xizang Plateau, has diverse climate and environment and complex habitat conditions. Due to the influence of warm and humid climate, the occurrence stations and rainfall intensity of short-term heavy precipitation have constantly set new historical records. Urban flooding, landslides and other disasters caused by Local sudden extreme short-term heavy precipitation have posed a serious threat to the fragile plateau ecosystem and infrastructure[2]. In this paper, based on the data from the new generation of dual polarization radar in Yushu, the radar echo characteristics of short-term heavy precipitation in Yushu area from 2022 to 2023 were systematically analyzed, and the identification thresholds of short-term heavy precipitation at different detection distances were initially constructed. The aim is to deepen the understanding of the movement and development laws of short-term heavy precipitation in plateau areas and provide scientific support for the near-term forecast and early warning business of short-term heavy precipitation.

1 Data and methods

Based on the hourly precipitation data of each meteorological observation station in Yushu area from 2022 to 2023, the *Regulations on Short-term and Near-term Weather Forecast Business* issued by the China Meteorological Administration, and local conditions and the possibility of disaster formation, precipitation weather with hourly rainfall of ≥15 mm was classified as short-term heavy precipitation. By using mathematical statistics and comparative analysis methods, the Doppler radar characteristics of 18 short-term heavy precipitation processes in Yushu area were compared based on the echo data of the new generation of weather radar in Yushu.

2 Analysis of echo characteristics of short-term heavy precipitation

2.1 Analysis of the features within the radar detection range of 50 km From 2022 to 2023, a total of 5 short-term heavy precipitation events occurred within the radar detection range of 50 km in Yushu area. They mainly appeared at night. Echo intensity was mostly above 45 dBZ, and the central intensity of the echoes was all ≥55 dBZ. The maximum appeared on August 27, 2022, up to 60 dBZ. The top height of the strong echo center was between 7 and 16 km, and the average top height of the echoes was 12 km. From the perspective of vertically integrated liquid water (VIL), VIL ranged from 1 to 22.5 kg/m^2, and was concentrated between 8 and 12 kg/m^2. Through the analysis of rainfall intensity, movement speed, and dual polarization data, it is found that the movement speed of short-term heavy precipitation echoes corresponding to low VIL was usually smaller, such as July 1, 2023. When high VIL was accompanied by high movement speed of echoes, rainfall intensity was relatively large[3-4], such as July 12, 2023. For instance, on July 12, 2023, the 1-hour non-hourly precipitation in Batang Township, Yushu City was 23.1 mm. During the precipitation process, the central intensity of the echoes was 45 - 50 dBZ. The echoes with CR > 45 dBZ continuously

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* Corresponding author.

scanned four times, while the echoes with CR > 40 dBZ continuously scanned nine times. VIL dropped sharply from 13.5 to 7.5 kg/m^2 at the beginning of the precipitation. The top height of the echoes (TOPS) remained at 7 – 8 km during the precipitation process, and the maximum reached 8.5 km. Average radial velocity was 23 m/s. According to the radar double-offset products, the entire layer of particles in the convection was large and dense, and they were mainly flat particles, thereby causing this heavy precipitation.

Within the radar detection range of 50 km, under the conditions of echo central intensity ≥45 dBZ, the top height of the echoes ≥8 km, VIL ranging from 8 to 12 kg/m^2 or greater, and movement speed ≥22 m/s, it can be determined that short-term heavy precipitation may happen when dual polarization parameters indicate the presence of dense flat large particles. As VIL is ≤8 kg/m^2, a comprehensive assessment should be made in combination with a small movement speed and related trigger conditions.

Table 1 Echo characteristics of five short-term heavy precipitation events within the radar detection range of 50 km in Yushu Prefecture

Date	Region	Time	Rainfall intensity mm/h	Central intensity dBZ	Dual polarization parameter ZDR//dB 0.5°	KDP//°/km 0.5°	CC 0.5°	VIL kg/m^2	V//m/s	Top height of the echoes//km
August 27, 2022	Yushu City	17:00 – 18:00	16.4	40 – 60	0 – 0.5	0 – 0.5	0.97 – 1	10 – 22.5	22	16.8
September 19, 2022	Chengduo County	22:00 – 23:00	15.2	45 – 59	– 0.5 – 0.5	0 – 0.4	0.96 – 1	9 – 13.5	23	15.0
July 11, 2023	Yushu City	21:00 – 22:00	17.0	48.5	– 1.0 – 2.0	0 – 2.0	0.96 – 1	1 – 2.0	18	7.0
July 12, 2023	Yushu City	21:00 – 22:00	15.7	58.0	0 – 1.3	0 – 1.5	0.98 – 1	10 – 13.5	23	8.0
July 12, 2023	Yushu City	20:00 – 21:00	23.1	55.5	– 0.2 – 0.8	0 – 1.2	0.98 – 1	8 – 12.5	27	15.3

2.2 Analysis of the features within the radar detection range of 100 km During 2022 – 2023, a total of 4 short-term heavy precipitation events occurred in Yushu Prefecture within the radar detection range of 100 km, mainly after the evening. The central intensity of the echoes was all ≥40 dBZ, and the maximum intensity was mostly > 50 dBZ, even reaching 55.5 dBZ on June 24, 2022. The central top height of the strong echoes was 9 – 16 km, and the average top height of the echoes was 13 km. The maximum of VIL was up to 8 – 27.5 kg/m^2, averaging 15 kg/m^2, all above 8 kg/m^2. By comparing the movement speed, rainfall intensity and dual polarization parameters, it is found that dense flat large particles were one of the conditions for the formation of short-term heavy precipitation, and high movement speed could also lead to an increase in rainfall intensity, such as on July 11, 2023. From 20:00 to 21:00, the 1-hour precipitation in Longbao Town, Yushu City reached 22.5 mm. From 19:00, convective monomers began to develop near Longbao Town, and the central intensity of the echoes exceeded 30 dBZ. During the precipitation process, the central intensity of the echoes remained between 45 and 50 dBZ, reaching the peak of 53.5 dBZ. The echoes with CR > 50 dBZ continuously scanned five times. VIL was 0 kg/m^2 before the precipitation began, jumped to 7 kg/m^2 at the start of precipitation, reached 17 kg/m^2 at 20:32, and then gradually decreased. According to the parameters of the radar at various elevations, there was convergence at low elevations, and the particles in the entire convection layer were large and dense.

Within the radar detection range of 100 km, under the conditions of echo central intensity ≥40 dBZ, echoes with CR > 45 dBZ continuously scanning more than six times, the top height of the echoes ≥8 km, VIL above 8 kg/m^2, and movement speed ≥ 22 m/s, it can be determined that short-term heavy precipitation may appear as dual polarization parameters show the presence of dense flat large particles in the convection.

Table 2 Echo characteristics of four short-term heavy precipitation events within the radar detection range of 100 km in Yushu Prefecture

Date	Region	Time	Rainfall intensity mm/h	Central intensity dBZ	Dual polarization parameter ZDR//dB 0.5°	KDP//°/km 0.5°	CC 0.5°	VIL kg/m^2	V//m/s	Top height of the echoes//km
June 24, 2022	Zaduo County	16:00 – 17:00	18.0	40 – 55.5	0.1 – 0.6	0	0.92 – 1	21.5 – 27.5	23	16.0
August 30, 2022	Zhiduo County	19:00 – 20:00	17.2	30 – 48.5	0 – 0.5	0 – 0.6	0.97 – 1	5.0 – 8.5	24	15.5
July 11, 2023	Yushu City	20:00 – 21:00	22.5	53.5	0.1 – 0.8	0	0.98 – 1	8.0 – 17.0	28	13.2
August 28, 2023	Chengduo County	23:00 – 00:00	18.8	53.5	0.1 – 0.2	0 – 0.8	0.99	8.0	24	9.0

2.3 Analysis of the features within the radar detection range of 150 km From 2022 to 2023, Yushu Prefecture experienced a total of 4 short-term heavy precipitation events within the radar detection range of 150 km, and they mainly appeared in the evening. The central intensity of the echoes was all > 45 dBZ, and the maximum intensity was mostly > 50 dBZ, even up to 58 dBZ on August 15, 2023. The top height of the strong echoes was ≥15 km. The maximum of VIL was 12 – 32 kg/m^2, averaging 17 kg/m^2, mostly above 7 kg/m^2. Dual polarization parameters show that in each process, there were dense flat large particles, and high rain intensity was often accompanied by high movement speed. For instance, the 1-hour precipitation in Yuegai Town, Qumalai County reached 22.5 mm from 17:00 to 18:00 on August 10, 2023. Before the precipitation occurred, there was dispersed convection in

the air above this area. The central intensity of the echoes reached 46 dBZ, and the echoes were constantly generating and fusing. By 16:54, the central intensity of the echoes reached 54 dBZ, and they gathered into a mass. The strong center continuously scanned three times. During the precipitation process, the intensity of the echoes was 40 – 50 dBZ, peaking 53 dBZ. VIL increased suddenly from 8 to 16.5 kg/m^2 before the precipitation began. At the beginning of the precipitation, VIL was 12 kg/m^2, and the maximum reached 19 kg/m^2, lasting for three times of scanning. Subsequently, it dropped to 8 kg/m^2, and remained around 5 kg/m^2. There was convergence at various elevations above Yuogai Town, with the average radial velocity of 27 m/s, and there were large and dense particles in the entire convection layer.

Within the radar detection range of 150 km, under the conditions of echo central intensity ≥45 dBZ, the top height of the echoes ≥15 km, VIL above 7 kg/m^2, and movement speed ≥22 m/s, it can be determined that short-term heavy precipitation may happen when the continuous influence of the strong echo center and high VIL lasts for more than 3 times of scanning and dual polarization parameters show that there are dense flat large particles in the convection.

Table 3 Echo characteristics of four short-term heavy precipitation events within the radar detection range of 150 km in Yushu Prefecture

Date	Region	Time	Rainfall intensity mm/h	Central intensity dBZ	Dual polarization parameter ZDR//dB 0.5°	Dual polarization parameter KDP//°/km 0.5°	Dual polarization parameter CC 0.5°	VIL kg/m^2	V//m/s	Top height of the echoes//km
September 2, 2022	Zhiduo County	16:00 – 17:00	16.0	56	−0.4 – 1.2	0 – 0.8	0.990	32.0	22	15
July 11, 2023	Chengduo County	16:00 – 17:00	16.8	48	0.1 – 0.6	0	0.980 – 1	6 – 12.5	20	15
August 10, 2023	Qumalai County	17:00 – 18:00	22.5	53	0 – 0.8	0 – 0.7	0.995	5 – 12.0	27	17
August 15, 2023	Nangqian County	17:00 – 18:00	17.2	58	−2.0 – 0.5	0 – 0.7	0.990	12 – 15.0	22	15

2.4 Analysis of the features beyond the radar detection range of 150 km During 2022 – 2023, there were a total of 5 short-term heavy precipitation events beyond the radar detection range of 150 km in Yushu Prefecture, and they mainly occurred at night. The central intensity of the echoes was mostly >45 dBZ, and the maximum was up to 55.5 dBZ on August 11, 2022. The top height of the strong echoes was mostly ≥13 km. The maximum of VIL was 9 – 28 kg/m^2. Dual polarization parameters reveal that flat large particles were present in some precipitation processes. For instance, from 19:00 to 20:00 on August 11, 2022, short-term heavy precipitation occurred in Yuogai Town, Qumalai County. Among them, the 1-hour precipitation at Changjiangdadui meteorological station in Yuegai Town, Qumalai County reached 33.9 mm, while the precipitation at the Qumalai national basic meteorological station from 19:20 to 20:20 was 20.7 mm. The combined reflectivity (CR) of the radar shows that convection had developed over Qumalai County since 18:00, with the echo intensity of around 40 dBZ. By 18:59, the intensity reached 45.5 dBZ. During the period of heavy precipitation, the central intensity of the strong echoes was 30 – 40 dBZ, peaking 47.5 dBZ. From 18:35 before the precipitation occurred, VIL showed a slow increase during each time of scanning, increasing by about 3 kg/m^2. By the time precipitation occurred, it reached 15 kg/m^2, and ranged from 5 to 10 kg/m^2 during the process. The top height of the echoes remained at around 14 km, reaching the peak of 17.1 km. The dual polarization parameters incicate that there were larger flat and round particles in the convective cloud system, which was conducive to the formation of precipitation.

Beyond the radar detection range of 150 km, there were indeed obvious deficiencies in the completeness and accuracy of the monitored products. For some individual cases, there were no valid data. Under the conditions of echo central intensity ≥45 dBZ, the top height of the echoes ≥13 km, and significant changes in VIL, it can be determined that short-term heavy precipitation may appear based on other monitoring data.

Table 4 Echo characteristics of four short-term heavy precipitation events beyond the radar detection range of 150 km in Yushu Prefecture

Date	Region	Time	Rainfall intensity mm/h	Central intensity dBZ	Dual polarization parameter ZDR//dB 0.5°	Dual polarization parameter KDP//°/km 0.5°	Dual polarization parameter CC 0.5°	VIL kg/m^2	V//m/s	Top height of the echoes//km
August 11, 2022	Qumalai County	19:00 – 20:00	33.9	40 – 55.5	0.1 – 0.6	0	0.92 – 1	22.0 – 28.0	23	14
August 13, 2022	Zhiduo County	21:00 – 22:00	17.2	30 – 48.5	0 – 0.5	0 – 0.6	0.97 – 1	5.0 – 8.5	24	13
August 20, 2022	Zaduo County	21:00 – 22:00	22.5	53.5	0.1 – 0.8	0	0.98 – 1	8.0 – 17.0	28	13
July 10, 2023	Chengduo County	19:00 – 20:00	19.7	40.0	–	–	–	–	–	12
July 12, 2023	Qumalai County	15:00 – 16:00	15.6	15.0	–	–	–	–	–	–

3 Conclusions

Based on the data of hourly precipitation and dual polarization radar data in Yushu area from 2022 to 2023, the characteristics of 18 short-term heavy precipitation processes within different radar detection ranges were systematically analyzed, and radar de-

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and three factors (absolute vorticity advection, temperature advection, and non-adiabatic heating).

(2) The explosive cyclones dominated by a single factor were generally weak or medium, while the number of strong explosive cyclones was relatively small, and there were no super explosive cyclones. Among these explosive cyclones, the explosive cyclones dominated by absolute vorticity advection were the weakest, while the strongest explosive cyclones were dominated by non-adiabatic heating.

(3) The proportion of strong and supper explosive cyclones dominated by two factors exceeded 60%. The combination of two factors was more likely to generate strong explosive cyclones than the single-factor dominant type and the combination of three factors, among which the influence was the greatest under the combined effect of temperature advection and non-adiabatic heating.

(4) In terms of seasonal characteristics, the explosive cyclones in the Kuroshio Current area mostly occurred in spring, followed by winter. There were basically no explosive cyclones in summer and autumn.

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termination indicators suitable for Yushu area were extracted.

(1) Within the range of 50 km, short-term heavy precipitation mostly occurred at night. The central intensity of the echoes was generally ≥45 dBZ (with the maximum of 60 dBZ), and the top height of the echoes was ≥8 km (with the average of about 12 km). VIL was mainly 8 – 12 kg/m^2, and radial velocity often exceeded 22 m/s. If dual polarization parameters show the presence of dense flat large particles, it can be determined that short-term heavy precipitation may occur. When VIL is lower than 8 kg/m^2, a comprehensive judgment should be made in combination with the movement speed and trigger conditions.

(2) When the detection range was 100 km, precipitation was concentrated after dusk. The echo intensity was generally ≥ 40 dBZ (the maximum exceeded 50 dBZ), and the top height of the echoes was ≥8 km (averaging 13 km). VIL was ≥8 kg/m^2 (the average maximum was 15 kg/m^2), and movement speed was ≥22 m/s. As the influence of strong echoes lasts for more than six times of scanning and dual polarization parameters show dense flat large particles, short-term heavy precipitation may happen. The above two indicators can be used as key judgment bases.

(3) Within the range of 150 km, heavy precipitation mainly occurred in the evening. The echo intensity was ≥45 dBZ (the maximum was up to 58 dBZ), and the top height of the echoes was ≥15 km. VIL was ≥7 kg/m^2 (the average maximum was 17 kg/m^2), and movement speed was ≥22 m/s. Short-term heavy precipitation may appear as the continuous influence of the strong echoes and high VIL lasts for more than 3 times of scanning and there are dense flat large particle signals. The two phenomena can be used as judgment conditions.

(4) In areas over 150 km away, precipitation mostly occurred at night, and flat large particles appeared in some processes. Due to the limitations of integrity and accuracy of radar data, it is necessary to comprehensively assess the possibility of short-term heavy precipitation under the conditions of echo intensity ≥45 dBZ, the top height of the echoess ≥13 km, and significant changes in VIL based on other monitoring data.

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