# National Comparative Analysis of Parallel Observations of Precipitation Weather Phenomena: Postprint

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## Abstract

Using parallel observation and comparative observation data of precipitation phenomena from 2363 meteorological stations nationwide during 2017-08 to 2018-08, a comparative analysis was conducted on automatic observation data of five precipitation phenomena—rain, snow, drizzle, hail, and sleet—from the perspectives of data completeness and accuracy. The results show: (1) The process capture rates for rain, snow, and drizzle phenomena are the highest, at 66.9%, 69.2%, and 50.1% respectively; the hourly capture rate for hail is the highest at 51.8%; and all capture rate indicators for sleet are relatively low. (2) The miss rate for drizzle is the highest at 65.9%, followed by snow at 35.6%, and the miss rate for hail is the lowest at 16.2%; the misclassification rates for drizzle and rain are relatively low, while those for sleet and hail are relatively high; drizzle and hail have a high proportion of misclassifications as rain, rain has a high proportion of misclassifications as drizzle, snow has a high proportion of misclassifications as drizzle and rain, while sleet often appears as alternating drizzle, rain, and snow; there are numerous stations with false alarms for drizzle and hail. (3) Precipitation phenomenon instruments can achieve minute-level identification of precipitation phenomena; however, compared with manual observations, issues of missed detection, misclassification, and false alarm exist. Quality control is required at the data acquisition end of meteorological stations, the precipitation phenomenon identification algorithm needs continuous optimization, and integration with other weather elements should be implemented for comprehensive identification of precipitation phenomena, thereby improving the instrument capture rate for precipitation weather phenomena and reducing the miss rate, misclassification rate, and false alarm rate.

# Full Text

## Comparative Analysis of Parallel Observations of Precipitation Phenomena Across China

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### Abstract

Using parallel observation data from 2,363 meteorological stations across China, this study compares automatic and manual observations of five precipitation phenomena—rain, snow, drizzle, hail, and sleet—focusing on data integrity and accuracy (with outliers removed). Results show that: (1) For process capture rates during complete precipitation events, rain (66.9%), snow (69.2%), and drizzle (50.1%) performed better than sleet and hail, while hail achieved the highest hourly capture rate at 51.8%. (2) Regarding miss rates, drizzle exhibited the highest rate (65.9%), followed by snow (35.6%), with hail showing the lowest (16.2%). (3) Misreport rates were relatively low for drizzle, rain, and snow, but higher for sleet and hail. Specifically, drizzle and hail were frequently misreported as rain; rain was often misreported as drizzle; and snow was commonly misreported as either drizzle or rain. Sleet events frequently alternated among drizzle, rain, and snow. (4) Empty report rates were notably high for both drizzle and hail at numerous stations. Although disdrometers can identify precipitation phenomena at minute-level resolution, they exhibit miss, misreport, and empty report issues compared with manual observations. Therefore, quality control procedures should be implemented at data collection terminals, precipitation identification algorithms must be continuously optimized, and comprehensive identification should incorporate additional meteorological elements to improve capture rates while reducing miss, misreport, and empty report rates.

**Keywords:** precipitation phenomenon; parallel observation; data accuracy; capture rate; miss rate; misreport rate; empty report rate

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Precipitation phenomena are closely related to human life and activities. Among the various meteorological disasters affecting China, many are associated with precipitation. While automatic precipitation amount observation was implemented at national meteorological stations beginning in 2000, precipitation *phenomena* have long been observed manually in China. With the advancement of meteorological services, manual observation—characterized by strong subjectivity and low frequency—can no longer meet service demands, necessitating timely, accurate, and continuous automated observation of precipitation phenomena. Addressing this challenge requires both improved identification methods and instrumental automation.

Recent domestic research on precipitation phenomenon identification has yielded numerous results. Instruments based on optical principles can not only detect precipitation occurrence but also distinguish precipitation types (rain, snow, hail, mixed precipitation) while obtaining detailed particle information. Common international instruments include the Finnish Vaisala PWD12/PWD22 weather sensors, British FD12P precipitation sensors, German Biral VPF-730 and OTT Parsivel disdrometers, and American PWS100. China has developed the CJY-2C precipitation phenomenon instrument. Multiple comparative trials have been conducted, including a three-month experiment at Beijing National Reference Station in 2014 using OWI-430, VPF-730, Campbell, and CJY-2C/T instruments. Results showed significant differences between automatic and manual records, with some devices exhibiting substantial miss and misreport issues.

According to parallel observation regulations, each station must conduct at least one year of comparative observations. During the first year, automatic results are recorded only, without processing abnormal data. After one year, erroneous data should be quality-controlled and corrected. From an objective evaluation perspective, this study analyzes first-year parallel observation data from 2,363 stations nationwide, comparing automatic and manual observations in terms of data integrity and accuracy to support operational application of automatic precipitation phenomenon data.

## 1 Data Sources and Methods

### 1.1 Data Sources

Analysis data were obtained from parallel observations at 2,363 national meteorological stations between August 2017 and August 2018. Instruments from four manufacturers included three models: CJY-2C (29.8%), OWI-430 (36.9%), and MPW11 (23.7%), with national distribution shown in Figure 1. During data processing, abnormal instrument-identified values were removed. The five instrument-identified phenomena were drizzle, rain, snow, sleet, and hail. Showers, snow showers, and shower-like sleet observed manually were respectively categorized as rain, snow, and sleet for evaluation. Manual observations served as the reference standard for statistical analysis of automatic data capture, miss, misreport, and empty report rates during daytime (08:00–20:00). Nighttime observations were excluded due to lack of start/end time records in manual observations.

### 1.2 Data Integrity Statistics

Using daily data as the basic unit, missing data rates were calculated for each manufacturer:

Total missing rate = (s/S) × 100%

where $s$ is actual observation days and $S$ is expected observation days.

### 1.3 Evaluation Metrics

**1.3.1 Capture Rate Metrics** Capture rates were defined at three temporal scales:

- **Minute capture rate**: Percentage of minutes when both manual and automatic observations recorded the phenomenon ($b$) relative to total minutes with manual observation ($B$): (b/B) × 100%
- **Hour capture rate**: Percentage of hours when automatic observation recorded the phenomenon ($c$) relative to total hours with manual observation ($C$): (c/C) × 100%
- **Process capture rate**: Percentage of precipitation events correctly identified by automatic observation ($a$) relative to total events observed manually ($A$): (a/A) × 100%

A precipitation process was defined as an event with intervals less than 15 minutes. For hour capture rate statistics, hail took precedence if present. For other phenomena, the type with the most minutes in a given hour was recorded. For process capture rate, manual observations served as the reference; if instruments identified hail during a process, hail was recorded. If multiple phenomena were identified, the type with the most minutes was recorded as the instrument-observed phenomenon.

#### 1.3.2 Non-Capture Rate Metrics

- **Miss rate**: Percentage of minutes when manual observation recorded a phenomenon but automatic observation did not ($d$) relative to total manual observation minutes ($B$): (d/B) × 100%
- **Misreport rate**: Percentage of minutes when automatic observation incorrectly identified a phenomenon ($e$) relative to total manual observation minutes ($B$): (e/B) × 100%
- **Missing report rate**: Percentage of minutes with missing automatic data ($f$) relative to total manual observation minutes ($E$): (f/E) × 100%
- **Empty report rate**: Percentage of minutes when automatic observation recorded a phenomenon that manual observation did not ($f$) relative to minutes with no manual observation ($D$): (f/D) × 100%

## 2.1 Data Integrity Analysis

Summing expected and actual observation days across all stations yielded a national missing data rate of 0.3%. Yunnan, Ningxia, Xinjiang, Hebei, and Chongqing exhibited higher rates above 5%, with Xinjiang reaching 13.9%, followed by Chongqing (11.8%) and Hebei (11.5%). Beijing, Sichuan, Tianjin, Anhui, Shandong, Shanxi, Guangxi, Fujian, Guizhou, and Liaoning had rates below 5%, while remaining provinces ranged between 5% and 10%. Primary causes were inadequate instrument maintenance and unfamiliarity with data acquisition software, resulting in untimely data generation and upload.

### 2.2.1 Rainfall Phenomenon

All 2,363 stations recorded rainfall (Figure 2). National minute capture rate was 46.7%, hour capture rate 60.8%, and process capture rate 66.9%, with a miss rate of 34.9% and misreport rate of 25%. Provincial minute capture rates ranged from 25% to 73%, lowest in Guizhou and highest in Tianjin, with Beijing, Fujian, Heilongjiang, Jilin, and Inner Mongolia exceeding 60%. Hour capture rates ranged from 37.2% to 84.3%, lowest in Guizhou and highest in Tianjin, with Henan, Hebei, and Tibet exceeding 70%. Process capture rates ranged from 47.6% to 88.1%, lowest in Guizhou and highest in Tianjin, with Liaoning, Shanxi, Anhui, and seven other provinces exceeding 80%. Miss rates varied from 13.5% to 52.6%, lowest in Tianjin and highest in Guizhou, with Gansu also below 20%. Misreport rates ranged from 2% to 26.6%, lowest in Jilin and highest in Hunan, with Anhui, Beijing, and seven provinces below 10%. When misreport occurred, rain was frequently misreported as drizzle, with Zhejiang and Hunan showing the highest average rates above 15%. Some provinces also misreported rain as snow, sleet, or hail. Empty report rates were below 5% at 99.5% of stations, with Tibet slightly higher at 5.2% and other provinces below 5%.

National rainfall minute capture rates were relatively low, improving for hour capture and highest for process capture. This pattern held across provinces, with Tianjin, Jilin, Inner Mongolia, and Fujian performing best and Guizhou, Hunan, and Hainan worst. Variations correlated with precipitation frequency, intensity, instruments, and algorithms. Provinces using the OWI-430 model showed higher capture rates. Misreport primarily involved identifying rain as drizzle, with occasional misidentification as snow, sleet, or hail.

### 2.2.2 Snowfall Phenomenon

Snowfall occurred at 1,343 stations (Figure 3). National minute capture rate was 50.3%, hour capture rate 64.5%, and process capture rate 69.2%, with a miss rate of 35.6% and misreport rate of 16.2%. Provincial minute capture rates ranged from 5.3% to 75.7%, lowest in Guizhou and highest in Gansu, with Inner Mongolia, Ningxia, Anhui, Jiangsu, and Heilongjiang exceeding 60%. Hour capture rates ranged from 10.8% to 87.1%, lowest in Yunnan and highest in

Inner Mongolia, with Ningxia, Anhui, Shandong, Gansu, Jiangsu, Liaoning, and Heilongjiang exceeding 70%. Process capture rates ranged from 16.7% to 89.1%, lowest in Yunnan and highest in Inner Mongolia, with Tianjin, Ningxia, Anhui, Shandong, Jiangsu, Hubei, Gansu, Liaoning, and Heilongjiang also exceeding 70%. Miss rates varied from 12.9% to 76.7%, lowest in Anhui and highest in Guizhou, with Inner Mongolia, Tianjin, Ningxia, Anhui, Zhejiang, Gansu, and Heilongjiang below 30%. Misreport rates ranged from 0% to 12.3%, lowest in Jilin and highest in Hunan, with Anhui, Beijing, and eight provinces below 5%. When misreport occurred, snow was typically misreported as drizzle, rain, or sleet, with occasional misreport as hail in Hebei and Shaanxi. Empty report rates were below 5% at 99.6% of stations, with Inner Mongolia, Gansu, and Heilongjiang slightly higher and other provinces below 5%.

National snowfall minute capture rates were low, improving for hour capture and highest for process capture. This pattern held across provinces, with Inner Mongolia, Ningxia, Gansu, and Heilongjiang performing best and Yunnan, Sichuan, and Guizhou worst. Snowfall occurred primarily in northern China, with rare southern events causing large capture rate variations. Blowing snow, willow catkins, and dandelion seeds were often misidentified as snow, while snow was sometimes misreported as drizzle, rain, or sleet, with occasional hail misreport.

### 2.2.3 Sleet Phenomenon

Sleet occurred at 551 stations (Figure 4). National minute capture rate was 29.9%, hour capture rate 50.1%, and process capture rate 61.4%, with a miss rate of 51.8% and misreport rate of 29.9%. Provincial minute capture rates ranged from 0% to 86.2%, with Yunnan, Beijing, and nine provinces below 20% and Shanxi highest. Hour capture rates ranged from 0% to 80.5%, with Yunnan, Beijing, Tianjin, and nine provinces below 30% and Shanxi highest. Process capture rates ranged from 0% to 88.4%, with Yunnan, Beijing, Tianjin, and ten provinces below 30% and Shanxi highest. Miss rates varied from 8.7% to 85.4%, lowest in Anhui and highest in Guizhou, with Zhejiang, Hubei, Gansu, and Fujian below 40%. Misreport rates ranged from 3% to 86.2%, lowest in Yunnan and highest in Anhui, with all provinces except Guizhou and Qinghai showing rates above 20%. When misreport occurred, sleet was typically misreported as drizzle, rain, or snow, with occasional hail misreport in Beijing, Jilin, Sichuan, Hebei, and Shaanxi. Hunan showed the highest average misreport rate as drizzle (27.7%), followed by Tianjin, Shandong, and Zhejiang. Most provinces showed high misreport rates as rain, with Anhui, Guangdong, and Guangxi exceeding 40%. Misreport as snow was also common, with Gansu reaching 85.7%. Empty report rates were below 5% at 99.5% of stations, with Inner Mongolia and Gansu slightly higher and other provinces below 5%.

National sleet minute, hour, and process capture rates were all low, not exceeding 65%. Provincial rates were similarly poor, with Shanxi performing best. Sleet showed high miss and misreport rates, with combined rates exceeding 70% nationally and in most provinces. Sleet is difficult to identify, with low occurrence frequency contributing to poor overall capture rates. When sleet occurred, instruments typically misidentified it as drizzle, rain, or snow, with occasional hail misreport.

### 2.2.4 Hail Phenomenon

Hail occurred at 1,006 stations (Figure 5). National minute capture rate was 21.1%, hour capture rate 51.8%, and process capture rate 45.3%, with a miss rate of 57.6% and misreport rate of 16.2%. Provincial analyses were limited by low hail event counts; Tianjin, Guangdong, Jiangsu, Zhejiang, Fujian, and Chongqing recorded fewer than 10 minutes of hail, making results unrepresentative. Excluding these provinces, minute capture rates ranged from 25.2% to 100%, lowest in Anhui and highest in Jilin. Hour capture rates ranged from 59.3% to 100%, lowest in Anhui and highest in Jilin. Process capture rates ranged from 48.5% to 100%, lowest in Anhui and highest in Jilin. Miss rates ranged from 0% to 51.7%, lowest in Anhui and highest in Guangxi. Misreport rates ranged from 0% to 24%, lowest in Henan and highest in Anhui. When misreport occurred, most provinces showed hail misreported as rain, with occasional misreport as drizzle, snow, or sleet.

Empty report rates were below 5% at 99.5% of stations, with 1,006 stations showing no manual hail observation. Individual station rates ranged from 0% to 2.38%, with Hebei and Shaanxi at 0.01%-0.02% and other provinces below 0.01%. National hail minute capture rates were lowest, hour capture rates best, and process capture rates intermediate. Provincial patterns were inconsistent, with Anhui performing worst and Jilin best. Large provincial variations reflected hail' s rarity, causing polarized capture rates (0% or 100%). Southern provinces frequently misreported heavy precipitation as hail.

### 2.2.5 Drizzle Phenomenon

Drizzle occurred at 1,729 stations (Figure 6). National minute capture rate was 21.7%, hour capture rate 35.1%, and process capture rate 50.1%, with a miss rate of 65.9% and misreport rate of 51.8%. Tianjin, Ningxia, Beijing, Jilin, and Hainan had fewer than 10 stations recording drizzle, making results unrepresentative. Excluding these provinces, minute capture rates ranged from 16.4% to 94.5%, lowest in Fujian and highest in Zhejiang and Gansu. Hour capture rates ranged from 0.9% to 24%, lowest in Yunnan and highest in Zhejiang, with Anhui, Xinjiang, Gansu, and Heilongjiang exceeding 20%. Process capture rates ranged from 8% to 78%, lowest in Shaanxi and highest in Gansu, with Inner Mongolia, Xinjiang, Hebei, Zhejiang, and Heilongjiang exceeding 50%. Miss rates ranged from 17.5% to 85.7%, lowest in Zhejiang and highest in Yunnan, with Inner Mongolia and Ningxia exceeding 80%. Misreport rates ranged from 3.8% to 86.2%, lowest in Zhejiang and highest in Fujian. When misreport occurred, drizzle was typically misreported as rain, though Ningxia, Anhui, and Heilongjiang showed some misreport as snow, and Anhui occasionally misreported as hail. Yunnan, Inner Mongolia, Tianjin, Ningxia, Anhui, Jiangxi, Zhejiang, Tibet, and Heilongjiang showed high misreport rates as rain, exceeding 17.5%, with Inner Mongolia and Ningxia reaching 27.7%.

Empty report rates were below 5% at 95.6% of stations, with 1,729 stations showing manual absence of drizzle. Individual station rates ranged from 0% to 12.8%, with 99.5% of stations below 5% and 95.6% below 10%. Zhejiang and Hunan showed the highest provincial rates at 10.8% and 10.6%, respectively, with other provinces below 10%.

National drizzle minute capture rates were lowest, hour capture rates intermediate, and process capture rates highest. This pattern held across provinces, with Zhejiang and Gansu showing the best minute capture rates (exceeding 60%) and Yunnan, Sichuan, Guangdong, Jiangxi, Henan, Hubei, Fujian, Guizhou, and Chongqing the worst (below 20%). Drizzle identification proved difficult, with large provincial variations stemming from discrepancies between instrumental and manual observation standards. Instruments identify drizzle based on raindrop size distribution, with accuracy depending on sensor sensitivity and algorithms. A typical rain event might be manually recorded simply as rain, while instruments could show alternating drizzle and rain. Additionally, dust in northern stations and fog/high humidity in southern stations were often misidentified as drizzle.

## 4 Conclusions

Based on parallel observation data from 2,363 meteorological stations, this study compared automatic and manual precipitation observations, yielding the following conclusions:

1. **Capture Rates**: For rain, snow, and drizzle, process capture rates were highest, hour capture rates intermediate, and minute capture rates lowest. Sleet showed low capture rates across all three scales. Hail exhibited the highest hour capture rate, intermediate process capture rate, and lowest minute capture rate.

2. **Miss and Empty Report Rates**: Drizzle showed the highest miss rate (65.9%) and substantial empty report rates, with 95.6% of empty-report stations showing no manual drizzle observation. Snow had the second-highest miss rate (35.6%). Hail showed the lowest miss rate (16.2%) but high empty report rates, with 99.5% of hail-reporting stations showing no manual hail observation. Rain had relatively low miss rates, while sleet miss rates mostly exceeded 50%.

3. **Misreport Rates**: Drizzle, rain, and snow had relatively low misreport rates, while sleet and hail had higher rates. When misreport occurred, drizzle and hail were frequently misreported as rain; rain was often misreported as drizzle; snow was commonly misreported as drizzle or rain; and sleet frequently alternated among drizzle, rain, and snow.

Automated precipitation observation represents the inevitable trend in meteorological modernization. Previous comparative studies were limited in geographic scope, lacking national representativeness. This large-scale parallel observation provides essential preparation for operational deployment of precipitation phenomenon instruments and holds significant implications for data application. Results demonstrate that disdrometers achieve minute-level resolution and greater sensitivity to precipitation process variations than manual observations, often showing alternating phenomena within a single event. The current observation standard defining a precipitation process as within 15 minutes cannot be applied to instrumental data. Observation accuracy depends on algorithm performance, with high-frequency phenomena (rain and snow) showing better capture rates than low-frequency ones. Instrument maintenance also affects performance, causing varying degrees of miss, misreport, and empty report issues (e.g., misidentifying blowing snow, willow catkins, and dandelion seeds as snow; dust as drizzle). These findings provide important guidance for operational deployment. Future efforts should enhance instrument maintenance, implement data quality control at collection terminals, optimize identification algorithms, and integrate additional weather elements for comprehensive identification. Concurrently, surface observation standards should be revised to accommodate automation trends.

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## Figures

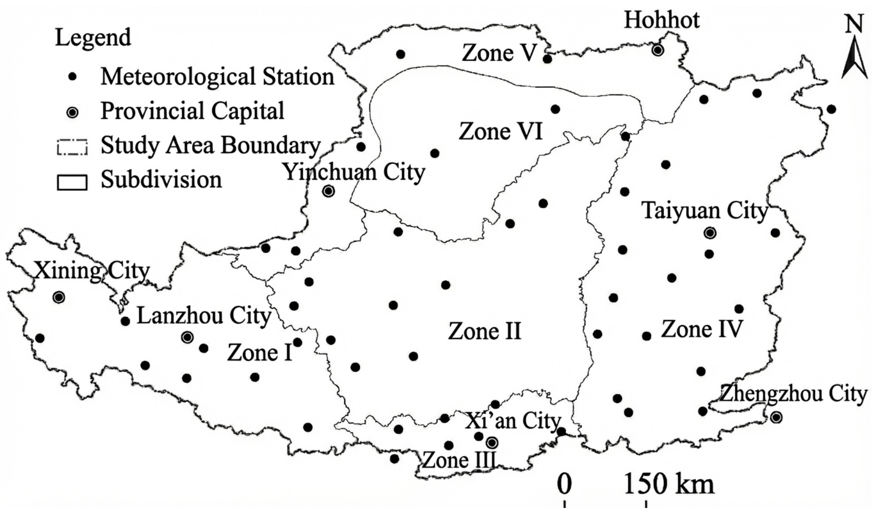


Figure 1: Figure 1

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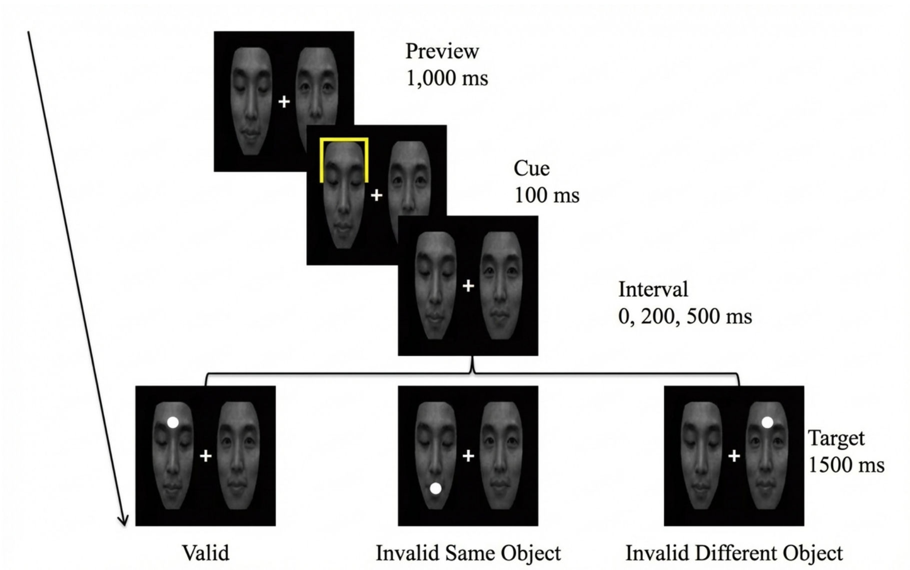


Figure 2: Figure 2