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Wind Profile Characteristics during Typhoons over Wuyi Mountain Station (2016–2020)

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Abstract: High spatial and temporal resolution wind profile radar data is an important means to conduct real-time monitoring and analyze the three-dimensional atmospheric wind field conditions. In 2021, the “National Wind Profile Radar Station Network Layout Plan of China” puts forward the demand for dense construction of wind profile radar, which means that the wind profile radar data has become an important basic data for meteorological research. The process and results of the Wind profile dataset during Typhoons over Mt. Wuyi Station (2016–2020) dataset was developed based on the real-time sampling height with an observation interval of 6 min, including horizontal wind direction, horizontal wind speed, and vertical wind speed at each sampling height. The dataset is archived in .txt format and one observation result is archived as one .txt file, with 11,856 files totally, consisting of 3,906 data files on 201614 Moranti, 4,261 data files on 201709 Nesat and 201710 Haitang, and 3,689 data files on 201909 Lekima. The data size is compressed to one single file with 7.45 MB.

Keywords: wind profile radar; typhoon; Wuyi Mountain; 2016–2020

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CSTR: https://cstr.escience.org.cn/CSTR:20146.14.2021.03.12

Dataset Availability Statement:

The dataset supporting this paper was published and is accessible through the *Digital Journal of Global Change Data Repository* at: https://doi.org/10.3974/geodb.2021.07.05.V1 or https://cstr.escience.org.cn/CSTR:20146.11.2021.07.05.V1.

1 Introduction

As a new type of high-altitude detection remote sensing equipment, wind profile radar can make continuous observations unattended, providing high spatial and temporal resolution of the three-dimensional atmospheric wind field data, capable of real-time detection of changes in horizontal wind direction, horizontal wind speed, vertical wind speed, atmospheric refractive index structure constant and other meteorological elements at a vertical height of several hundred meters or even several thousand meters[1–4]. It plays an important role in real-time monitoring and analyzing the characteristics of vertical shear, jet stream, and convection at small-scale and medium-scale. It can be used to reflect and predict weather

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[2] Liao, K., Li, K. L., Dang, H. F., *et al*. Wind profile dataset during typhoons over Mt. Wuyi Station (2016–2020) [J/DB/OL]. *Digital Journal of Global Change Data Repository*, 2021. https://doi.org/10.3974/geodb.2021.07.05.V1. https://cstr.escience.org.cn/CSTR:20146.11.2021.07.05.V1.

conditions, simulate and warn weather disasters.

Wind profile radar technology in China began late 1980s[5]. Total 126 wind profile radars station had been built by 2020. The wind profile radar technology has become mature and has initially built a network of wind profile radar stations. On January 5th, 2021, the "National Wind Profile Radar Station Network Layout Plan of China" was initialed. The application analysis of wind profile radar data will gradually develop in depth, providing an important basis for safeguarding agricultural production, predicting aviation flight conditions and formulating disaster decision plans and so on.

In southeast coastal areas of China, typhoon disasters occur frequently in summer and autumn. Wuyi Mountain, located in southeast China, is frequently affected by typhoon disasters. Wuyi Mountain wind profile radar station was set up in 2013. It is one of the earlier wind profile radar stations in Fujian province. From 2016 to 2020, there were four typhoons affecting Wuyi Mountain, typhoon Moranti in 2016, typhoon Nesat and Haitang in 2017, and typhoon Lekima in 2019. The wind profile radar data reflects the three-dimensional wind field changes of typhoon, which has great research and application significance for understanding the weather process of the typhoon, revealing its wind field structure, indicating the future track characteristics, and predicting short-time heavy precipitation.

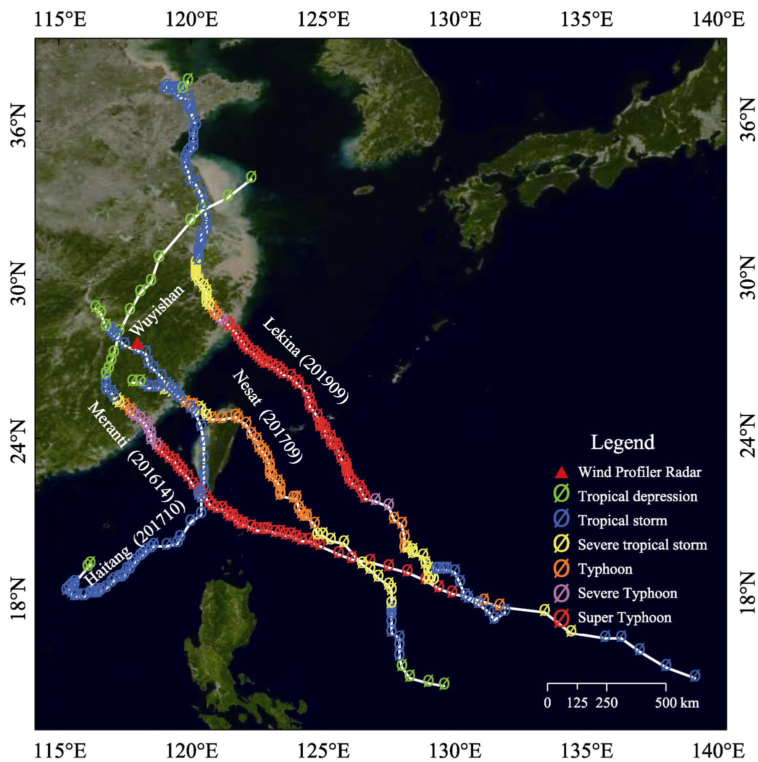


Figure 1 Map of Taiphone "Meranti", "Nesat", "Haitang" and "Lekima" moving paths

2 Metadata of the Dataset

The metadata of Wind profile dataset during typhoons over Mt. Wuyi Station (2016–2020) is summarized in Table 1. It includes the dataset full name, short name, authors, year of the dataset, temporal resolution, spatial resolution, data format, data size, data files, data publisher, and data sharing policy, etc.

Table 1 Metadata summary of the Wind profile dataset during typhoons over Mt. Wuyi Station (2016–2020)[6]

Items	Description
Dataset full name	Wind profile dataset during typhoons over Mt. Wuyi Station (2016–2020)
Dataset short name	WindProfile_MtWuyi
Authors	Liao, K. AAS-4210-2021, Fujian Key Laboratory of Severe Weather, liaokuo78@163.com Huang, X. Y. School of Geographical Sciences, Fujian Normal University, hxy1050250101@163.com Chen, Y. L. AAP-3042-2020, School of Geographical Sciences, Fujian Normal University, chenyl@fjnu.edu.cn
Geographical region	Wuyi Mountain
Year	2016–2020
Temporal resolution	6 min
Spatial resolution	The starting and ending detection heights are 60 m and 7,080 m respectively, with a vertical resolution of 60 m below 600 m height and 120 m above
Data format	.txt
Data size	7.45 MB (After being compressed)
Data files	It consists of three folders. They are 2016 (3,906 data files for “Meranti”), 2017 (3,689 data files for “Nesat” and “Haitang”), and 2019 (3,689 data files for “Lekima”). There are 11,856 data files in total during typhoons over Wuyi Mountain in corresponding years
Foundations	Metrological Bureau Foundation of Fujian Province of China (2020KX03)
Data publisher	Global Change Research Data Publishing & Repository, http://www.geodoi.ac.cn
Address	No. 11A, Datun Road, Chaoyang District, Beijing 100101, China
Data sharing policy	***Data*** from the Global Change Research Data Publishing & Repository includes metadata, datasets (in the *Digital Journal of Global Change Data Repository*), and publications (in the *Journal of Global Change Data & Discovery*). ***Data*** sharing policy includes: (1) ***Data*** are openly available and can be free downloaded via the Internet; (2) End users are encouraged to use ***Data*** subject to citation; (3) Users, who are by definition also value-added service providers, are welcome to redistribute ***Data*** subject to written permission from the GCdataPR Editorial Office and the issuance of a ***Data*** redistribution license; and (4) If ***Data*** are used to compile new datasets, the ‘ten per cent principal’ should be followed such that ***Data*** records utilized should not surpass 10% of the new dataset contents, while sources should be clearly noted in suitable places in the new dataset[7]
Communication and searchable system	DOI, CSTR, Crossref, DCI, CSCD, CNKI, SciEngine, WDS/ISC, GEOSS

3 Processes and Methods of Data Collection

The entire process of the dataset was divided into two parts. Firstly, the real-time observation data of wind profile radar was collected. Secondly, the wind speed and direction were calculated by using the observation data.

The wind profile dataset during typhoons over Mt. Wuyi Station (2016–2020) dataset was developed based on the observation data which was obtained from the CFL-03 boundary layer wind profile radar. The five-beam radial velocities (east, west, south, north, and center) data for five days (UTC) before and after the typhoon landing from 2016 to 2020 was collected. The wind speed and direction data on each height layer were calculated by using the five-beam radial velocity. The calculating methods are as follows[4,8,9].

(1) Calculate the horizontal wind vector. Assuming that the radial wind toward the radar is positive, and then the west wind is positive in the east-west wind vector and the south wind is positive in the north-south wind vector.

$$u_e = -V_{re} \times \csc\theta + V_{rz} \times \cot\theta \tag{1}$$

$$u_w = V_{rw} \times \csc\theta - V_{rz} \times \cot\theta \tag{2}$$

$$u_s = V_{rs} \times \csc\theta - V_{rz} \times \cot\theta \tag{3}$$

$$u_n = -V_{rn} \times \csc\theta + V_{rz} \times \cot\theta \tag{4}$$

where θ is the zenith angle of the tilt beam, and V_{rz}, V_{re}, V_{rw} , V_{rs}, and V_{rn} are the radial velocities of the middle, east, west, south, and north beams respectively. u_e, u_w, u_s, and u_n are the horizontal wind vectors of the east, west, south, and north beams respectively.

(2) Calculate the horizontal vector u, v, and vertical vector w of the three-dimensional wind field. w is the vertical wind speed.

$$u = 0.5 \times (u_e + u_w) \tag{5}$$

$$v = 0.5 \times (u_n + u_s) \tag{6}$$

$$w = V_{rz} \tag{7}$$

(3) Calculate horizontal wind speed and direction.

$$V = \sqrt{u \times u + v \times v} \tag{8}$$

$$\alpha = \mathrm{atan}\frac{u}{v} \tag{9}$$

$$\varnothing = \pi + \alpha \tag{10}$$

where V is the wind speed and Ø is the wind direction.

4 Data Results and Validation

4.1 Data Composition

The wind profile dataset during typhoons over Mt. Wuyi Station (2016–2020) consists of three folders. The dataset includes 3,906 data files on 201614 Moranti, 4,261 data files on 201709 Nesat and 201710 Haitang, and 3,689 data files on 201909 Lekima.

The dataset is the product data on the real-time sampling height of Wuyi wind profile radar station. The data was collected at an observation interval of 6 min in the five days (UTC) before and after the typhoon made landfall in mainland China. The periods were from September 10th, 2016 to September 20th, 2016, from July 25th, 2017 to August 5th, 2017, and from August 5th, 2019 to August 15th, 2019.

```
WNDOOBS  01.20
58730  0117.9850  027.6167  00224.2  LC  20160910160101
ROBS
00060  000.0  008.3  −000.1  100  100  4.4e−019
00120  357.3  008.3  0000.0  100  100  4.4e−019
00180  351.4  006.6  0000.0  100  100  4.4e−019
00240  283.7  009.1  −000.0  100  100  4.4e−019
00300  020.0  002.3  0000.1  100  100  4.4e−019
00360  026.6  002.6  0000.2  100  100  4.4e−019
00420  035.0  002.4  0000.3  100  100  4.4e−019
00480  068.2  002.1  0000.4  100  100  4.4e−019
00540  090.0  002.2  0000.5  100  100  4.4e−019
00600  095.2  002.2  0004.5  100  100  4.4e−019
00720  104.9  003.1  0004.4  100  100  4.4e−019
```

Figure 2 Data sample of the wind profile radar dataset

4.2 Data Description

The product data on the real-time sampling height of the wind profile radar consists of two parts, one is the reference information, including the basic parameters of the station, the other is the data part which was obtained at each sampling height, including the sampling height, horizontal wind direction, horizontal wind speed, vertical wind speed, horizontal direction reliability, vertical direction reliability, and atmospheric refractive index structure constant.

The product data produced by one observation was saved as one .txt file. Each group within the record was separated by a half-space and the missing group was denoted by the corresponding rated length "/". Each group of detection data (except for letter data) length less than the rated length, the integer part of the high was complemented 0 and the fractional part of the low was complemented 0. The positive sign was denoted by 0 and the negative sign was denoted by "–" (minus sign). The end of each record was terminated with a carriage return line feed "<CR><LF>".

The name of the file is Z_RADR_I_IIiii_yyyyMMddhhmmss_P_WPRD_雷达型号_产品标识.TXT. The yyyymmddhhmmss represents the observation time, which is expressed in world time. The following is a specific file for illustration, taking "Z_RADA_I_58730_20160910160101_P_WPRD_LC_ROBS.TXT" as an example. Z means domestic exchange file. RADA means radar data. IIiii after I means district station number. For example, 58730 denotes Wuyi Mountain Station number; 20160910160101 denotes observation at 16:01:01 UTC on September 10th, 2016. P denotes product data. WPRD denotes wind profile radar information. LC denotes radar model, indicating that this radar is an L-band boundary layer wind profile radar. ROBS is product identification, indicating the product data on the real-time sampling height.

The wind profile dataset is produced by using the data which was collected by the CFL-03 type boundary layer wind profile radar, which is a final product entered into the network by the China Meteorological Administration with mature and standardized technology.

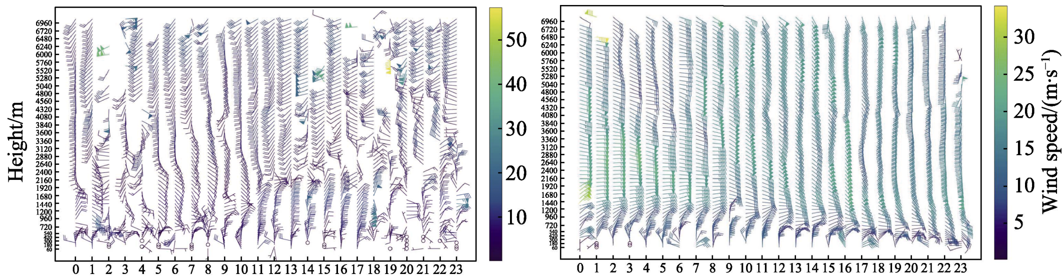
The first line WNDOOBS 01.20 denotes the keyword and the file version number. The second line denotes the station, radar, and observation time. 58730 denotes the name of the wind profile radar station, 0117.9850 denotes the longitude in degrees, 027.6167 denotes the latitude in degrees, and 00224.2 denotes the elevation of the observation site in meters. The third line ROBS denotes the observation data start.

Each number in the fourth line denotes the sampling height (m), horizontal wind direction (degrees), horizontal wind speed (m/s), vertical wind speed (m/s) upward as positive and downward as negative, horizontal directional reliability, vertical directional reliability, and atmospheric refractive index structure constant, respectively.

4.3 Data Products

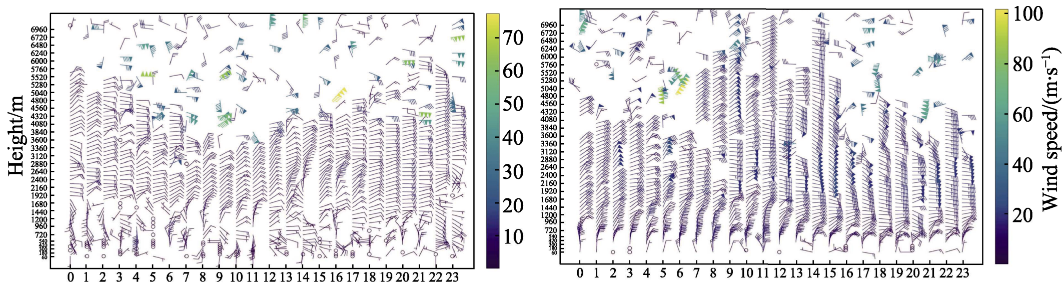
Typhoon 201614 Moranti was generated at 14:00 on September 10th, 2016. It landed on the coast of Xiangan, Xiamen at 3:05 on the 15th with a landfall level of severe typhoon and entered Jiangxi at 23:00 on the 15th. The National Meteorological Centre stopped its number at 2:00 on September 17th. Figure 3(a) shows that the wind direction of the upper air wind field above 4,000 m on the 11th was dominated by southwest winds, the station was located northwest of the typhoon, the typhoon had not yet had an impact on the upper air wind field in Wuyi Mountain. From 5:00 to 10:00, the wind direction shifted with the height and it became the warm advection, while the wind speed at the upper levels was enhanced, which was conducive to energy accumulation. At 10:00, there were obvious wind shear characteristics and the wind direction of the lower level turned to the northeast. At 11:00, the thickness of the lower-level northeast wind expanded, the wind speed at 1,500 m increased and the warm air lifted, triggering short-term heavy precipitation. The local rainfall from 10:00 to 12:00 accumulated rainfall amount of 32.3 mm. It shows that the wind profile radar data has obvious characteristics for short-term sudden heavy precipitation and can provide the basis for relevant departments to make early warnings in time. Figure 3(b) shows that the wind speed above 1,000 m on the 15th was getting stronger, indicating that the typhoon was getting closer to the radar station. The wind direction above 1,000 m gradually changed from easterly to southerly, after 9:00 the wind direction began to change to southeasterly, 19:00 had basically changed to southerly, corresponding to the actual movement path of the typhoon, the typhoon turned northward after 13:00, so the wind profile radar data can indicate the typhoon steering changes.

Typhoon 201709 Naset was generated on July 21th, 2017. It landed on the east coast of Yilan, Taiwan at 19:40 on the 29th and landed on Fuqing at 6:00 on the 30th with a landfall level of typhoon. The National Meteorological Centre stopped its number at 20:00 on July 30th. Typhoon 201710 Haitang was generated on July 26th, 2017. It landed on the coast of Pingdong, Taiwan at 17:30 on the 30th and landed Fuqing at 2:50 on the 31st with a landfall level of tropical storm. The National Meteorological Centre stopped its number at 8:00 on August 1st. Naset and Haitang created the first recorded record of landing in the same city within 24 hours, while the two typhoons occurred double typhoon effect, Haitang combined with Naset circulation entered Jiangxi at 16:00 on July 31st. Figure 4(a) shows that the lower wind field was relatively chaotic and the wind shear was not obvious on July 27th, which was not conducive to precipitation and the local rainfall was 0 mm in total on that day. Figure 4(b) shows that the wind direction was mainly easterly because the station was in the northwest of the typhoon landing direction. The shear near the ground was obvious, which was conducive to the development of precipitation. Typhoon Naset landed at 6:00, and then the wind speed in the middle and upper levels gradually increased, and the wind speed appeared pulsating characteristics.



(a) 11th September, 2016 (Unit: hour) (b) 15th September, 2016 (Unit: hour)

Figure 3 Map of hourly wind plumes before and during typhoon landing of 1614 Meranti



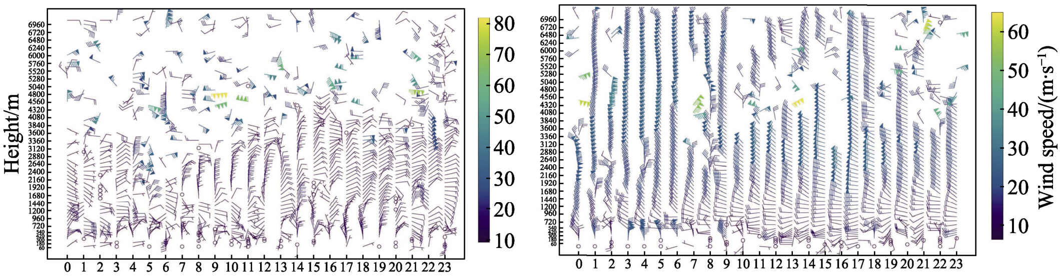
(a) 27th July, 2017 (Unit: hour) (b) 30th July, 2017 (Unit: hour)

Figure 4 Map of the hourly wind plumes before and during typhoon landing of 1709 Nesat

Typhoon 201909 Lekima was generated on August 4th, 2019. It landed on the coast of Wenling, Zhejiang at 1:45 on the 10th with a landfall level of super typhoon and landed on the coast of Qingdao, Shandong at 20:50 on August 11th again. The National Meteorological Centre stopped its number at 14:00 on August 13th. Figure 5(a) shows that the wind direction was scattered with obvious wind disturbance at the lower level and predominantly east wind direction at the middle and upper levels. Figure 5(b) shows that the wind direction reflected the characteristics of west wind on the southwest side of the typhoon because the station was on the southwest side of the typhoon. The wind shear occurred at a low level. There was obvious wind convergence at 18:00, which was favorable to the occurrence of precipitation.

4.4 Data Validation

An hourly wind plumes map based on this dataset processing method was compared with the wind plume map produced by the Wind Profile Radar Data Integrated Processing System (WPRIS) of Fujian Province Meteorological Information Center. Except for the color scale and the treatment of breeze (breeze is "circle" in this paper and breeze is "rod" in the system), the rest of the two are the same. The wind profile dataset during typhoons over Mt. Wuyi Station (2016–2020) calculated by using the original data can be judged to be correct.



(a) 6th August, 2019 (Unit: hour) (b) 10th August, 2019 (Unit: hour)

Figure 5 Map of the hourly wind plumes before and during typhoon landing of 1909 Lekima

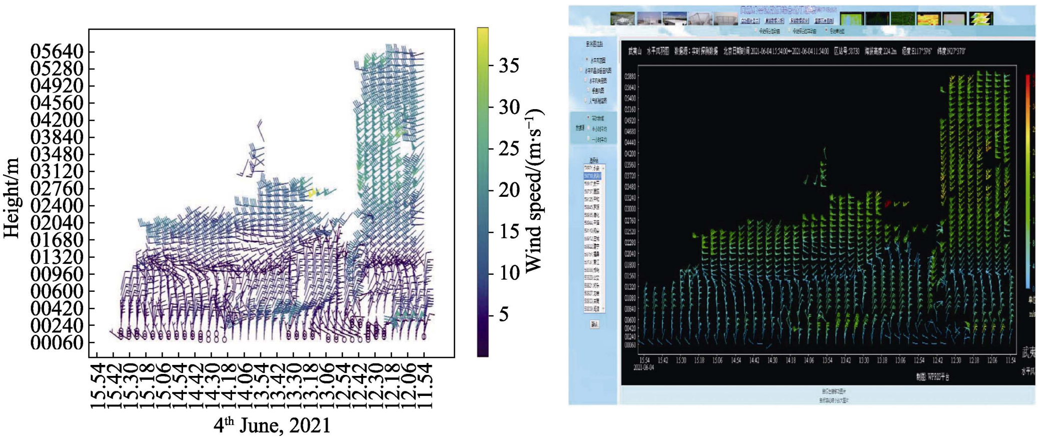


Figure 6 Comparison of data visualization between output mapping and displaying in the processing system (left is data visualization map, right is the data displaying in the processing system)

5 Discussion and Conclusion

Wind profile radar data provides the three-dimensional wind field data with high spatial and temporal resolution. The changes of horizontal wind direction by analyzing the wind plume map indicate the relative position between typhoon and monitoring stations. Meanwhile, some scholars have pointed out that the sinking phenomenon of wind plume map high wind area and typhoon steering has a certain indicator role[10]. Therefore, the wind field information of wind profile radar could be used to judge the relative position of typhoon by combining the location of monitoring radar stations, to provide the moving path of typhoon in real-time and simulate the path steering change of typhoon. In addition to the horizontal wind, the detailed horizontal wind speed data provided by the wind profile radar can also be used to predict the future typhoon wind speed change, to provide an important reference basis for preventing the violent wind disaster caused by typhoon. For precipitation, wind profile radar data can effectively detect wind direction and speed changes before and after the occurrence of typhoon heavy precipitation and local heavy precipitation[11]. The heavy precipitation on September 11, 2016, the local heavy precipitation, and the wind plume map shows that it had obvious air convergence and wind shear characteristics. The wind speed which increased rapidly in low-level was consistent with the occurrence of heavy precipitation at the same time[12]. The study points out that there is a correspondence between vertical wind speed and precipitation intensity[13]. The vertical wind speed reflects the strength of convection. Typhoon heavy precipitation is accompanied by an obvious upward movement of water vapor convergence. The large value of vertical speed has an obvious upward trend from lower to higher levels with time, indicating that water vapor is accumulating and rising, while the vertical speed at lower levels is not strong, indicating that water vapor is accumulating at higher levels[11]. This causes heavy precipitation in a period of time afterwards, and the weakening time of upward movement corresponds to the stop time of precipitation. Therefore, the horizontal wind direction, horizontal wind speed and vertical wind speed data provided by the wind profile radar data could be an important reference for the monitoring and early warning of the duration and intensity of local sudden heavy precipitation and typhoon heavy precipitation.

Author Contributions

Liao, K. designed the dataset and contributed to the data processing. Chen, Y. L. designed the algorithms of dataset. Huang, X. Y. contributed to the data validation. Liao, K. and Chen, Y. L. wrote the data paper.

Conflicts of Interest

The authors declare no conflicts of interest.

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