Response to Reviewers' Comments

Response: We thank the anonymous reviewer for their comprehensive evaluation and thoughtful comments. We have addressed the reviewers' concern one by one. For clarity purpose, here we have listed the reviewers' comments in plain font, followed by our response in bold italics

5

Reviewer #1

This paper examines the characteristics and performance of vertical wind measured by China Radar Wind Profiler Network. The topic is interesting and has climate implications in evaluating and using the wind observations with their reliabilities from Wind Profiler site over China. The paper is well

10 organized and written. The findings of this study are worth of publication in the journal after minor revision. My comment on this paper is mainly related to the evaluation indexes used in the study, which may impact on some of the conclusions.

Response: Thanks for the reviewer's positive comments on our manuscript.

15 1. Which criteria are referenced for thresholds of the acceptable levels for these parameters including height, sample rate, confidence (Fig. 5), bias, and RMSE (Fig. 7) in the paper.

Response: Good question. In fact, no well-established criteria can be found in the current references for the setting of the parameters you mentioned. Generally, the criteria are formulated according to the needs of users. We hope to apply the radar wind profiler network data to

20 *continuous atmospheric boundary layer observations in the subsequent research. Therefore, it required that the effective detection height above 3 km, the acquisition rate above 60%, the confidence level reach 100%, the mean speed difference less than 4 m/s, and mean RMSD less than 6 m/s.*

To clarify this issue, we thoroughly revised the following paragraph in section 3.1: "In order to make the criteria of RWP network data consistent, we have to set corresponding screening criteria for each system index, which to some degrees reflects the needs of future applications. For instance, the RWP network data are expect to be used to derive boundary layer parameters, such as boundary layer height (Liu et al., 2019) and wind shear that are closely related to atmospheric pollution (Zhang et al., 2020). Therefore, it would be better for the effective detection height of RWP reaching 3 km, with the acquisition rate being above 60%. In addition, according to the user manual of RWP, only those wind profile data with a 100% confidence level are recommended."
Besides, in section 3.2, we rewrote the following paragraph:

"Here, the horizontal wind speed measurements at all levels ranging from 0 to 3 km are used to calculate the MSD and RMSD at each site. Moreover, the magnitude of mean speed difference (MMSD) and RMSD are set to be 4 m/s and 6 m/s, respectively, which serve as a target for acceptable criterion"

2. The ECMWF data set used for validation needs a brief introduction, including its uncertainty and reliability.
Response: Per your suggestion. By referring to previous studies on the assessment of ERA5 reanalysis, we added the following sentences in section 3. "In order to estimate the data accuracy, the wind profiles from RWP are compared with hourly wind measurements at 0.25 x 0.25-degree latitude/longitude grid from the fifth generation European Centre for Medium-range Weather Forecasts (ECMWF) atmospheric reanalysis of the global climate (ERA5, Hoffmann et al., 2019).

3. Note that South China Sea should be added in the Figures 1,3,4,7,8,910.
Response: Amended as suggested.

4. What does the "ABL" mean in the line 10 of the introduction? Acronyms must be explained in detail when the article first appears. Similar to MODIS at line 8 of page 11.

Response: The "ABL" refers to "planetary boundary layer (PBL)", which has been corrected to make it consistent throughout this manuscript. The "MODIS" is short for "the Moderate-resolution Imaging Spectroradiometer".

5   5. The word spacing at P3 L15 need to be modified.
Response: Amended as suggested.

6. For Figure 6, as stations in northwest show much difference with other stations in diurnal phase, any reason?

10 *Response: If I understand correctly, you should refer to Fig. 9. We think these differences may be caused by differences in climate and terrain. Northwest China is a semi-arid and plateau region, but most other sites are distributed in the plains.*

7. For better cover across the whole China, you should a station in the northwest to make

15 comprehensive comparison with ECMWF.
Response: Per your kind suggestion, the Nanjing site in the eastern China was replaced Wulumuqi, one site located in northwestern China. Also, the Zhuhai site was replaced with Zigui.

8. at P10 L18, diurnal phase and amplitude of the mean maximum wind at different heights are

20 almost same. Do authors have any ideas about the reasons that cause this phenomenon? So does the inconsistency for some northwest stations.
Response: Here, we present the statistical results of the diurnal phase and amplitude of the mean maximum wind at different heights. Due to the atmospheric wind field is affected by multiple factors such as vertical pressure, temperature gradient, terrain and climate. Therefore, it is hard to

25 *clarify the specific reason. We think it may be due to the downhill mountain winds or offshore winds.*

3

9. You used some station names in the text or other figures (e.g., names in figure 6), so should add the locations of these names in figure 1 for readerships.

Response: Due to there are many observation sties in Beijing and Shanghai area, it is hard to add
5 *station name in the Fig.1. Therefore, we add the latitude and longitude of the six stations in text for readers.*

10. Land use data from MODIS should be described in data section. Suggest that MODIS-based land use type should be added as background in Figure 10 for readerships.

10 *Response: Per your suggestion, the land cover data and their description has been added in section 4.2 of this revision. Now it reads as follows:*

"The MODIS Land Cover product is derived through a supervised decision-tree classification method. The land cover types are divided into 17 classes, including 11 natural vegetation classes, three human-altered classes, and three non-vegetated classes (Friedl et al., 2019)."

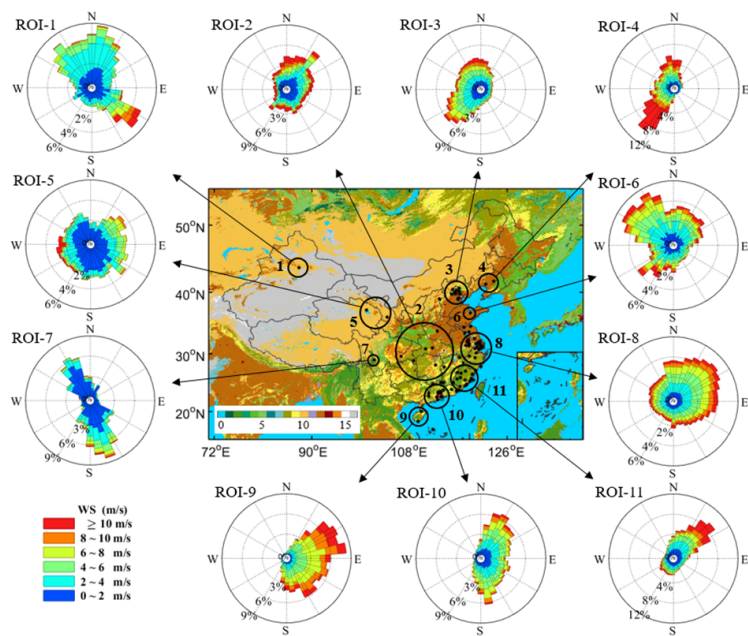15 *Moreover, the land cover data was added as background in the Fig.10.*

Figure 10. Spatial distribution of the statistical results of atmospheric wind fields at 500 m above ground level (AGL) for 11 regions of interest (ROIs). The wind rose plots over the 11 ROIs are calculated from hourly observations of wind direction and wind speed from November 2018 to March 2019. The land cover types 0–16 represent the Water, Evergreen Needleleaf forest, Evergreen Broadleaf forest, Deciduous Needleleaf forest, Deciduous Broadleaf forest, Mixed forest, Closed shrublands, Open shrublands, woody savannas, Savannas, Grasslands, Permanent Croplands, Urban and built-up, Cropland/Natural vegetation mosaic, Snow and ice, Barren or sparsely vegetated, respectively.

Reviewer #2

I found the manuscript interesting and reasonably well written, but it needs major revision in my opinion - both to improve clarity and to improve the English. There are also serious questions about the availability outside China of the data described.

Response: Thanks for your critical but valuable comments on our manuscript, which helps great in improving the quality of our manuscript. Please see the following point-by-point response to your comments.

1: It is good to know that there is a Chinese wind profiler network. As the authors say on page 4 "the dataset of nationwide profiler network in China has never been revealed". On page 13 they say that the data were provided via http://data.cma.cn/en/. I have looked at that web site and failed to find any mention of wind profilers - more information on data access should be provided. Does one need to register to see wind profiler data? A Chinese colleague looked at the Chinese version and couldn't find wind profilers mentioned there.

*Response: Good question. In consultation with the director of CMA data management department, we got to know that the RWP network is still under construction, and the data quality has to be assessed before release. Therefore, this motivates us make preliminary assessment of this dataset in this study. As long as the quality meets the national standard or numerical weather prediction, all of these measurements will be available to the public upon request through the website (*http://data.cma.cn/en/*). Nevertheless, it requires the user to register an account and submit an application form in order to get access. Currently, parts of the data are available for research. Therefore, in this revision, we modified the description of data availability. "The radar wind profiler data used in this paper can be provided for non-commercial research purposes upon request by email (Dr. Jianping Guo: jpguocams@gmail.com)."*

6

2: The other issue is real-time availability via the Global Telecommunications System (GTS). The abstract recommends the data for global numerical weather prediction -which rather assumes real-time usage. The other wind profiler networks mentioned all provide (or provided) reports via the

5   GTS. As with other comments in this review I expect to see a change in the main manuscript not just a note in the response to reviewers. In this case I want to see a statement as to if and when the data will be available via the GTS. Please contact CMA senior management as appropriate to find out.

Response: First of all, the other wind profiler network mentioned in our manuscript is operational, but this is not the case for the RWP network of China. This is one of the motivations

10 *for our study. In consultation with the several CMA senior officials, the RWP network data have to be further assessed before it becomes fully operational. As of 2017, it began to send the data to CMA headquarter. It will be shared via GTS in the next several years, which highly depends on the process of data quality assessment as well as data assimilation. The sharing of this dataset is expected to contribute to the numerical weather prediction and boundary layer meteorology*

15 *community.*

To clarify this issue, we added the following statement to section 2: "Due to the fact that the measurements from the RWP network of China have to be further assessed, the data sharing via global telecommunications system is expected to occur in the next several years, which highly depends on the process of data quality assessment."

20

3: The fate of the NPN and profiles from aircraft

The manuscript mentions the NOAA Profiler Network (NPN) and provides three references to it - this is fine. However, it should also mention that the NPN largely ceased to operate in 2014 and the last stations closed in 2017. See https://madis.ncep.noaa.gov/madis_npn.shtml. As I understand it the

25 profilers were reaching the end of their useful lives and it was decided not to replace them. One factor in their non-replacement was the growing number of profiles (wind and temperature) available

from aircraft. On a smaller scale most of the UK profiler network has shut in recent years for similar reasons. I am not saying this to imply that the Chinese profiler network should close, but to provide a rounded picture to readers the closure of the NPN and the availability of aircraft profiles should be mentioned.

5 *Response: Good point! The information you provided is of great importance. Per your kind suggestion, we added some descriptions mentioning the closure of the NPN and the availability of aircraft profiles in the introduction section, which shows as follows:*

"Nevertheless, probably due to the fact that the RWP reached the end of their useful lives, the NPN largely ceased to operate in 2014 and the last stations closed in 2017. As an alternative data
10 *source, the high-density airborne wind and temperature profiles from civil aviation industry gradually took over the role of RWP since then (https://madis.ncep.noaa.gov/madis_npn.shtml)."*

4: Operational monitoring of the Chinese network

The results in this manuscript, whilst useful, seem to be an isolated study. To get the most out of
15 such a network there should be near-real-time monitoring (daily, weekly or monthly) perhaps by comparison to CMA forecast fields. If one of the profilers seems to be performing badly then it should be checked out and perhaps subject to extra maintenance. Is there any such monitoring and feedback to the network managers? Was there any follow-up about the 17 "unrecommended" stations found by this study?

20 *Response: This network is currently not operational, and this work is an initial attempt to assess the data quality of RWP network of China. More importantly, another purpose of our manuscript is to let the atmospheric science community know the existence of such observational network. In the long run, the data will be disseminated to the public.*

Regarding how to get the most out of this network, we totally agree with you that we should
25 *compare the near-real-time monitoring at daily, weekly or monthly timescales against the CMA forecast fields, which is the focus of our future work. Thanks for your kind suggestions.*

In the meanwhile, the CMA officials have already known the preliminary assessment results of this network, since the coauthor of Dr. Lijuan Shi, one of the persons in charge of RWP operation and maintenance. reported the status of RWP network to her boss. The double-check and careful maintenance of the RWP instruments are undergoing at the 17 "unrecommended" stations.

5

5: Manuscript title: The web page gives this as "Characteristics and performance of vertical winds as observed by the radar wind profiler network of China" the manuscript as "A vertical wind profile dataset in China based on the operational radar wind profiler network" - they should be consistent. I have a slight preference for the first ("Characteristics ...") but "vertical winds" (suggests w

10 component) should be replaced by "wind profiles".

Response: Good suggestion! The title has been modified to "Characteristics and performance of wind profiles as observed by the radar wind profiler network of China"

6: page 1, line 10: 'are the foundation' - 'are a foundation'

15 *Response: It has been revised to "fundamental to"*

7: 1,12: 'JMA, NOAA, EUMETNET, and AGBoM' - unexplained acronyms. Particularly as "countries" are mentioned earlier in the sentence it seems better to use 'Japan, USA, various European countries and Australia'.

20 *Response: Amended as suggested.*

8: 1,13-14 'was presented, which consisted' - 'is presented, consisting' (improved English, like some of the other comments)

Response: Amended as suggested.

25

9: 1,15 'at various altitudes add 'but mainly in the boundary layer' or 'about 60% of them have a height range between 3 and 5 km' (my estimate from Figure 5a, the authors could be more precise)
Response: We have added 'but mainly in the boundary layer' after 'at various altitudes"

5   10: 1,22 'unrecommended' should be 'not recommended' here and later in the text.
Response: Amended as suggested.

11: 2,4 'Nash et al' - 'Nash and Oakley'
Response: Amended as suggested.

10
12: 2.1-14 There are a lot of references here, perhaps more than necessary.
Response: We have deleted some references.

13: 2,17 'Nash et al' - 'Nash and Oakley'
15 *Response: This reference has been deleted.*

14: 2,19 'vertical winds' - 'wind profiles'
Response: Amended as suggested.

20 15: 2,20 'much' – delete
Response: Amended as suggested.

16: 2,22-25 'Since 2018 ... use.' There have been satellite winds before (from cloud tracking and scatterometers), what is new is that Aeolus provides wind profiles (strictly speaking only line-of-
25 sight winds, ~ only one component). The text needs to be modified a bit.

"its dataset still not released for the public access and use" I understand that CMA is involved in the calibration/validation phase and has access to the Aeolus data. Significant work has been needed on bias correction of the winds, see https://www.ecmwf.int/en/about/media-centre/news/2020/ecmwf-startsassimilating-aeolus-wind-data (reference this or not as you wish). It is a proof of concept

5   satellite and I don't think I would expect public release of the data at this point.

Response: We appreciate your insightful comments. Given the fact that the Aeolus data has been released on May 12, 2020, in the introduction section we rewrote the related description as follows:

"The earliest space-borne wind products generally refer to the atmospheric motion vectors that are

10 *derived by tracking clouds or areas of water vapor through consecutive infrared remote sensing images (Schmetz et al., 1993; Velden et al., 2005). Later on, the vector winds over the ocean surface have been measured by the spaceborne microwave instruments such as SeaWinds onboard QuikSCAT (Bentamy et al., 1999; Draper and Long 2002). Since 2018, new satellite-based wind observational era set in with the launch of European space agency (ESA)'s Aeolus wind satellite*

15 *on which the direct-detection Doppler wind lidar ALADIN is accommodated, which provides line-of-sight winds along the satellite track (Reitebuch et al., 2009; Reitebuch 2012). As of 12 May 2020, the Aeolus data has gone public after the bias correction of the winds has been adequately made, which are now being distributed publicly to forecasting services and scientific users in less than three hours of measurements being made from space*

20 *(https://www.esa.int/Applications/Observing_the_Earth/Aeolus/Aeolus_goes_public)."*

17: 3,6 'vertical wind over regional scale' - 'regional scale wind fields'
Response: Amended as suggested.

25

18: 3,6-7 'and to fill the data gap left by field campaign' - delete this. NAWDEX and other field campaigns were never operational

Response: Amended as suggested.

5   19: 3,20 'Nash et al., 2000' - 'Nash and Oakley, 2001'

Response: Amended as suggested.

20: 3,24 'Government' – delete

Response: Amended as suggested.

10

21: 3,25 'produced' - 'produces'

Response: Amended as suggested.

22: 4,2 'the vertical' - 'vertical'

15 *Response: Amended as suggested.*

23: 4,17 'be' - 'been'

Response: Amended as suggested.

20   24: 4,21 'reference' - too strong, perhaps 'data source'

Response: Amended as suggested.

25: 5,4... suggestion 'The operational Chinese radar wind profiler network started in 2008 with 5 sites transmitting wind profiles to the headquarters ...' The note about 106 stations in March 2019

25   should be put in chronological order.

Response: Amended as suggested.

26: Page 5 general - more information about the various instruments should be given including height range and manufacturer. This might be best presented as a table which could include the number of instruments and the dates for which they operated.

5   *Response: Per your suggestion. We add a table detailing the various instruments in this section.*

Table 1. Instrument information of radar wind profiler network of China

Type of RWP	Identifier	Max detection height	Frequency	# of sites	Manufacturer
High Troposphere (CFL-16)	PA	8-10 km	440-450 MHz	3	CASIC
Low Troposphere (CFL-08)	PB	6-8 km	440-450 MHz	2	CASIC
Boundary layer	LC	3-5 km	1290 MHz	101	CASIC/CETC/CHG

CASIC: China Aerospace Science & Industry Corp.

CETC: China Electronics Technology Group Corp.

CHG: China Huayun Meteorological Technology Group Corp.

10

27: 5,18 'was' - 'is'

Response: Amended as suggested.

28: 5,22 'wind profilerr network: one is raw data and the other product data' - 'wind profiler
15 network: raw data and product data'

Response: Amended as suggested.

29: 6,3 "one's" – delete

13

Response: Amended as suggested.

30: 6,15 'generated for each observation site'
Response: Amended as suggested.

5

31: 6,16 suggestion 'A few sites use a low level detection mode with high sampling rate -these provide a vertical resolution of 60 m.'
Response: Amended as suggested.

10   32: 6,18 'the Fig.' - 'Fig.'
Response: Amended as suggested.

33: 6,19 'selected' - 'were selected'
Response: Amended as suggested.

15

34: 7,3 'tropospheric type I, tropospheric type II' - what does this mean? better covered in section 2
Response: "tropospheric type I and tropospheric type II" indicates high troposphere, low troposphere RWP, respectively. To avoid misunderstanding, we have revised the name of the types of RWP, which is detailed in the newly-added Table 1. The corresponding descriptions in section 2
20   *are as follows:*
"Table 1 shows the instrument information of RWP used in this study, which consist of three types of RWP: high troposphere, low troposphere and boundary layer RWPs. It can be seen that the majority of the radars are boundary layer RWP operating at L band (101 sites), and a few of sites are instrumented with tropospheric RWP operating at P band (5 sites)."

25

35: 7,5 'are inhomogeneous'

14

Response: Amended as suggested.

36: 7,10 'ECMWF wind data' - be more specific. From the mention of the Copernicus web site on page 13 I suspect that ERA5 reanalysis data has been used. This should be clearly stated and a

5 reference given (unfortunately I don't think there is a journal paper yet, but there are short articles in the ECMWF newsletter).

Response: Per your suggestion, we rewrote this sentence as follows:

"In order to estimate the data accuracy, the wind profiles from RWP are compared with hourly wind measurements at 0.25 x 0.25-degree latitude/longitude grid from the fifth generation

10 *European Centre for Medium-range Weather Forecasts (ECMWF) atmospheric reanalysis of the global climate (ERA5, Hoffmann et al., 2019).*

37: 7,11 'verify the accuracy' verify is too strong, perhaps 'estimate'

Response: Amended as suggested.

15

38: 8,5 "100% confidence" I wish I could be 100% confident about any observation! However, if that is how the data are labelled it may be best to stick with this.

Response: Agreed. The "confidence" is the quality flag of data. As indicated in the user manual of RWP, only those measurements with a 100% confidence level can be fully trusted. However, as

20 *your said, it is almost impossible for all observations are guaranteed to be 100% confident. Therefore, the data assessment is made based on the criterion of 100% confidence.*

39: Page 8 general: are there any features in common between the 'substandard' sites? Any pattern

25 emerging?

15

Response: There are a total of 14 substandard sites, and the emerging patterns for the substandard sites differ greatly, which means that not any common features were revealed for these sites.

5 40: 8,24 'inversion algorithm' - 'processing algorithm' better?
Response: Amended as suggested.

41: 8,24 'verify' - 'check'
Response: Amended as suggested.
10

42: 9,1 'applying these observation data' - 'using these observations'
Response: Amended as suggested.

43: 9,2 'Haseler, 2004' seems an odd reference in this context
15 *Response: We have deleted this reference.*

44: 9,5 'mean bias' - 'mean speed difference'? Either here or in the figure caption it should be made clear if this is 'RWP-ECMWF' or 'ECMWF-RWP' 'RMSE' - not explained, better to refer to 'RMSD - root-mean-square difference' Neither the profiler or ECMWF/ERA winds are error-free.
20 I assume that it is the vector difference - should be explicitly stated.
Response: Good suggestions. Per your kind suggestion, the "mean bias" was revised to "mean speed difference", which indicated the mean wind speed difference between RWP and ECMWF (RWP–ECMWF) at each height. Likewise, the "RMSE" was revised to "RMSD" (root-mean-square difference). All these suggestions have been taken in this revision.
25

45: 9,13 'mean absolute bias' - is this in wind speed? or u-, v- wind components? 'magnitude of the speed bias' would be clearer. 'RMSE' - is this on the vector difference?

Response: Per your suggestion, the sentence has been revised as follows:

"Here, the horizontal wind speed measurements at all levels ranging from 0 to 3 km are used to

5 *calculate the MSD and RMSD at each site. Moreover, the magnitude of mean speed difference (MMSD) and RMSD are set to be 4 m/s and 6 m/s, respectively, which serve as a target for acceptable criterion"*

46: 9,23 'The large difference ... is mostly related to flaws in the algorithm' What sort of flaws?

10 What is the evidence for this? Is it that bad data has not been screened out? (I think that some wind profilers deteriorate gradually over time, and regular maintenance, replacement of aging components is important. I'm not sure if this is as true of boundary layer profiles.)

Response: Per your suggestion. We modified this sentence. "The large difference may be caused by hardware or configuration problems, such as the aging of components. Therefore, it is

15 *important to conduct regular maintenance and replacement of aged components."*

47: 10,1 'performance can also be compared to the corresponding radiosonde' Has this been done? How well do the results match those vs ECMWF?

Response: This sentence has been deleted, since we did not do the comparison analysis.

20

48: 10,18 'mean maximum wind speed within the 24 h' Is this the maximum of the hourly speeds or the half-hourly speeds mentioned earlier? In either case I presume that it is an average over the whole 60 or 30 minutes. (Or perhaps 6-minute winds, Fig 2.) Please clarify.

Response: Amended as suggested. The "mean maximum wind speed" was replaced to "mean

25 *maximum hourly wind speed".*

49: 10,22 'morning ... early morning' 6-12 and 0-6 Beijing time. Clarify these and also'afternoon', 'evening'

Response: It has been clarified as follows:

"The occurrence time of maximum hourly wind speed is marked as early morning (0000–0600 Beijing time, BJT,), morning (0600–1200 BJT), afternoon (1200–1800 BJT), and evening (1800–2400 BJT), respectively.

50: 10,15 'Extreme weather detection' - 'Daily maximum winds' better Extreme weather usually means very rare events (say once a year) not daily maxima.

Response: Amended as suggested.

51: 10,16 'extreme weather' - 'diurnal cycle'

Response: Amended as suggested.

52: 10,23 'have an afternoon peak', 'have an evening peak' (not 'the')

Response: Amended as suggested.

53: 11,2 'heights'

Response: Amended as suggested.

54: 11,4 'is inconsistent' (sounds as if they are wrong), 'show a different pattern' better

Response: Amended as suggested.

55: 11,5 'twice' - 'two'

Response: Amended as suggested.

56: 11,5 'indicative that' (not 'of')

Response: Amended as suggested.

57: 11,12 'were selected'

5 *Response: Amended as suggested.*

58: 11,19 'Western China' (delete 'The')

Response: Amended as suggested.

10 59: 11,21 'western China' (delete 'the')

Response: Amended as suggested.

60: 11,23 'both the' – delete

Response: Amended as suggested.

15

61: 11,25 'the 30%' - delete 'the'; 'over the whole study period'

Response: Amended as suggested.

62: 12,1 'measurements'

20 *Response: Amended as suggested.*

63: 12,3 'wind turbines' - perhaps mention that winds from turbine height (60-100 m?) would be
useful for NWP (more useful than a 10 m wind from Synop stations)

Response: Amended as suggested. "The policymakers will determine whether the wind turbines

25 *(60-100 m above ground level) will be installed or not, aided by high-resolution model simulation*

analyses."

19

64: 12,9 'Wind profiles are of great ...'

Response: Amended as suggested.

5 65: 12,13 'consisted' - 'consists'

Response: Amended as suggested.

66: 12,18 'mean absolute bias' - see note on page 9, also state what is being used in the

comparison.

10 *Response: Per your suggestion. The "mean absolute bias" was revised to "magnitude of mean*

speed difference (MMSD)". The MMSD at each site were calculated from the horizontal wind

speed at all levels from 0 to 3 km between RWP and ECMWF.

67: 12,21 'extreme weather'? I expect they could be used for this, but this hasn't been

15 shown, see discussion on page 10.

Response: Per your suggestion. The "extreme weather" was revised to "daily maximum winds".

68: 13,20-21 two closing brackets ")" without opening ones "(".

Response: Amended as suggested.

20

69: Table 1. The caption should mention Figure 10, which is the closest to a definition of the ROIs.

Perhaps a table of all stations, (identifier, latitude, longitude, altitude, ROI, type of profiler, land

cover, quality flags) could be provided as an appendix or supplemental information. Column 2 of

table 1 should I think be 'Number of sites'.

25 *Response: Per your suggestion, we modified the Table, as shown below:*

Table 2. *Statistics of the number of sites and land cover types for the 11 regions of interest (ROI) in Fig. 10.*

Region of interest	Number of sites	Land cover types
1	1	Grassland
2	7	Cropland and Forest
3	10	Urban
4	2	Cropland
5	2	Grassland
6	1	Cropland
7	1	Grassland
8	27	Urban
9	2	Cropland and Forest
10	10	Urban
11	19	Urban and Forest

In addition, we added a table (Table S1) showing all stations (identifier, latitude, longitude, altitude, type of profiler, land cover) in the supplemental materials.

5

70: Figure 3. This could be quite interesting, but the panels are too small for readers to see clearly. My suggestion would be just to show four levels as in Figure 9 (probably the same four levels) and not bother with the stacked plot e).

Response: Per your suggestion. The Fig.3 was modified as following:

21
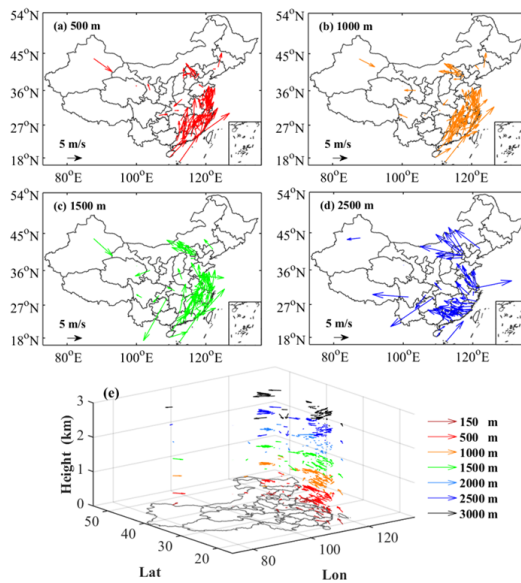
71: Figure 4 caption 'detection'

Response: This typo has been corrected as suggested.

5

72: Figure 6 'mean bias' - 'mean speed difference'?

Response: Amended as suggested.

73: Figure 7 'mean absolute bias' (whatever that means) and 'RMSE'. In this figure the values seem
10 to have been averaged over levels (all levels, or levels up to 3 km?), clarification is needed. See
discussion on page 9.

22

Response: You are right, and these values were calculated over all the levels up to 3 km. Per your suggestion. Therefore, the modified caption of Fig.7 now reads as follows: "Spatial distribution of (a) magnitude of the mean speed difference (MMSD) and (b) root-mean-square difference (RMSD) at each station during November 2018 to March 2019; the corresponding histogram
5 *represent the average difference in zonal direction; (c) and (d) are corresponding recommended (red dots) and non-recommended (blue dots) sites for (a) and (b), respectively. The MMSD and REMD at each station were derived from the measurements over all levels from 0–3 km."*

74: Figure 8. The histogram 8b) is superfluous, I would remove it. Suggestion for caption: 'The blue
10 dots represent the 89 recommended sites and red dots the 17 nonrecommended sites.'
Response: Amended as suggested.

Characteristics and performance of wind profiles as observed by the radar wind profiler network of China

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Abstract. Wind profiles are fundamental to the researches and applications in boundary layer meteorology, air quality, and numerical weather prediction. Large-scale wind profiles data have been previously documented from network observations in several countries, such as Japan, USA, various European countries and Australia, but the nationwide wind profiles observations are poorly understood in China. In this study, the salient characteristics and performance of wind profiles as observed by the radar wind profiler network of China is investigated. This network consists of more than 100 stations instrumented with 1290-MHz Doppler radar designed primarily for measuring vertical-resolved winds at various altitudes but mainly in the boundary layer. It has good spatial coverage, with much denser sites in coastal areas. The wind profiles observed by this network can provide the horizontal wind direction, horizontal wind speed, and vertical wind speed for every 120 m interval within the height of 0 to 3 km. The availability of the radar wind profiler network has been investigated in terms of effective detection height, data acquisition rate, data confidence, and data accuracy. Further comparison analysis with reanalysis data indicated that the observation data at 89 stations are recommended, and 17 stations are not recommended. The wind profiles can serve as important input dataset assimilated into numerical weather prediction systems at both regional and global scales.

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1 Introduction

It is increasingly recognized that the atmospheric wind profiles and its vertical wind shear are crucial to better understanding the more frequent extreme rainfall events (Huuskonen et al., 2014; Nash and Oakley, 2001; Weber et al., 1990), intensification of clear-air turbulence associated with aircraft safety

5 (Williams & Joshi, 2013), complicated aerosol-cloud-precipitation interaction (Fan et al. 2009; Guo et al. 2016a; 2019; Lee et al., 2016), and persistent particulate pollution episodes (Yang et al., 2019; Zhang et al., 2020). For the wind speed in the planetary boundary layer (PBL), the most striking feature is that the turning of winds with height dominates the whole PBL and beyond, which can be explained in terms of force vectors (drag, pressure gradient force, Coriolis force) at the surface and the top of the

10 PBL (pressure gradient force and Coriolis force) (Lemone et al., 2018). Under influences of large-scale dynamic forcing and land surface process, wind speed and direction will dramatically vary (Michelson & Bao, 2008), which poses a large challenge for models to simulate or forecast the variation of wind very well, especially in the PBL (Constantinescu et al., 2009; Guo et al., 2016b).

Radar wind profiler (RWP), which is generally Doppler radar that operates at either the VHF (30-300

15 MHz) or UHF (300-1000 MHz) frequency bands, has been widely applied to atmospheric wind field research (Dolman et al., 2018; Molod et al., 2015; Ishihara et al., 2006; Schlatter et al., 1994). To date, a large spectrum of field campaigns involved with the RWP observed wind profiles, especially over the regions with intensive anthropogenic and industrialized activities, have been conducted and their archived dataset has been increasingly receiving attention (Liu et al., 2019; Kottayil et al., 2016; Singh

20 et al., 2016; LeMone et al., 2013; Bianco et al. 2008; Le et al., 1998), most of which are based on ground-based remote sensed measurements. The earliest space-borne wind products generally refer to the atmospheric motion vectors that are derived by tracking clouds or areas of water vapor through consecutive infrared remote sensing images (Schmetz et al., 1993; Velden et al., 2005). Later on, the vector winds over the ocean surface have been measured by the spaceborne microwave instruments

25 such as SeaWinds onboard QuikSCAT (Bentamy et al., 1999; Draper and Long 2002). Since 2018,

new satellite-based wind observational era set in with the launch of European space agency (ESA)'s Aeolus wind satellite on which the direct-detection Doppler wind lidar ALADIN is accommodated, which provides line-of-sight winds along the satellite track (Reitebuch et al., 2009; Reitebuch 2012). As of 12 May 2020, the Aeolus data has gone public after the bias correction of the winds has been

5 adequately made, which are now being distributed publicly to forecasting services and scientific users in less than three hours of measurements being made from space (https://www.esa.int/Applications/Observing_the_Earth/Aeolus/Aeolus_goes_public). Moreover, aircraft-based observation of atmospheric wind profiles has been carried out worldwide (Lux et al., 2018; Marksteiner et al., 2018; Witschas et al., 2017; Chouza et al., 2016; Weissmann et al., 2005).

10 Especially in the North Atlantic Waveguide and Downstream Experiment (NAWDEX) campaign, the ALADIN team conducted several airborne wind measurement experiments for the validation of the Aeolus satellite winds product (Lux et al., 2020; Zhai et al., 2020).

To gain a full picture of regional scale wind fields, a number of RWP networks have been set up across the world. As early as 1990s, the demonstration wind profile network is deployed and maintained by

15 the National Oceanic Atmospheric Administration (NOAA), which is also termed NOAA profiler network (NPN) and operated at a frequency of 404 MHz (Schlatter et al., 1994; Vande Kamp, 1993; Weber at al., 1990). The second type of profiler is the 915-MHz boundary-layer profiler that is much smaller, transportable, commercially available but lacked height coverage compared with 404 MHz wind profiler, and thus is mainly used for NOAA research and outside agencies. Nevertheless,

20 probably due to the fact that the RWP reached the end of their useful lives, the NPN largely ceased to operate in 2014 and the last stations closed in 2017. As an alternative data source, the high-density airborne wind and temperature profiles from civil aviation industry gradually took over the role of RWP since then (https://madis.ncep.noaa.gov/madis_npn.shtml). To make the most out of the best sampling attributes of the abovementioned two types of wind profiler, a third type of profiler operated

25 at 449 MHz. Later on (in 1996),

the European Cooperation in Science and Technology framework (COST) initiated the project of Wind Initiative Network Demonstration in Europe (CWINDE). Under the framework of CWINDE, the European RWP network named E-PROFILE, as part of the EUMETNET Composite Observing System (EUCOS), is constructed, providing the monitoring of vertical profiles of wind across Europe

5 (Dibbern et al., 2001; Oakley et al., 2000; Nash and Oakley, 2000). Moreover, the Japan Meteorological Agency developed the operational wind profiler network in Japan in 2011, which is a nationwide network of 33 wind profiler currently in operation. The wind data have significant positive impact on improving numerical weather prediction (Ishihara et al., 2006). The Australian Bureau of Meteorology completed the installation of the Australian wind profiler network of 19 wind profiler in

10 2017 that runs at 55 MHz frequency band, which produces wind data of sufficient accuracy for presentation to forecasters and ingestion into global numerical weather prediction models (Dolman et al., 2018). The aforementioned networks have provided vertical profiles of wind for model assimilation through the Global Telecommunication System at regional or national scale (e.g., Benjamin et al., 2004; Chipilski et al., 2019), which was found to significantly improve the forecast of rainfall onset

15 and atmospheric pollution episode (Liu et al., 2019; Liu et al., 2018; Singh et al., 2016; LeMone et al., 2013; Du et al., 2012; Bianco et al. 2008; Angevine et al., 1994).

Given the considerable advantages over conventional ground-based in situ or remote sensing observations, wind profiler measurements have been well applied in a variety of applications in China, including air quality and weather forecast (Sun, 1994; Hu et al., 2010; Dong et al., 2011; Miao et al.

20 2018; Zhang et al., 2020). Nevertheless, the RWP is generally deployed at either specific regions or short time period. Recent model simulation work by assimilating wind measurements from a regional wind profiler network in North China indicated the network observation significantly improved the convective forecasting (Wang et al., 2020). Meanwhile, the extreme precipitation is continuously intensified under global warming and deteriorated atmospheric pollution, especially in Eastern Asian

25 countries such as China and India (Zhang et al., 2006; Pfahl et al., 2017; Guo et al., 2019; Li et al.,

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2020), which desperately needs the vertical wind observations. However, the characteristics and performance of nationwide profiler network in China has never been revealed, and the assessment of systematic observation performance and data accuracy are still lacking, to the best of our knowledge. This motivates us to evaluate the performance and accuracy of RWP network of China, ultimately in

5 an attempt to present a wind profile data as a new data source for numerical weather prediction or climate related studies. The remainder of this paper is organized as follow. The RWP network of China is briefly introduced in Section 2. The performance and accuracy are evaluated in Section 3. Section 4 will discuss the detailed application of wind profile data. A summary of results is presented in Section 5.

10 **2 Description of the RWP network**

This network began to be constructed dating back to 2008, when there are 5 sites having wind profiling measurements transmitted to the headquarter of China Meteorological Administration (CMA). The number of RWP sites continuously increased to 92 at the end of 2017, all of which are operating at 405 MHz frequency band. The RWP network of China is comprised of 106 stations until March 2019,

15 which is designed primarily for measuring winds at various altitudes. Afterwards, the working frequency band is changed to L band (1290 MHz), and the number increased to 128 at February 2020 (personal communication with Dr. Ruiyi Li from CMA). The Meteorological Observation Center (MOC) of CMA is responsible for the operation and maintenance of the nationwide wind profiler network. Table 1 shows the instrument information of RWP used in this study, which consist of three

20 types of RWP: high troposphere, low troposphere and boundary layer RWPs. It can be seen that the majority of the radars are boundary layer RWP operating at L band (101 sites), and a few of sites are instrumented with tropospheric RWP operating at P band (5 sites). Fig. 1 shows the spatial distribution of wind profiler network in China, which exhibits large spatial domain extending from the northernmost site located at Wulumuqi at 43.0°N, to the southernmost one at Nanhai at 17.0°N, and

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from the westernmost site also located at Wulumuqi at 87.0°E to the easternmost one in Shenyang at 123.0°E. The detail information of the RWP network of China is shown in Table S1.

The MOC/CMA is responsible for the maintenance and collection of wind measurements from the wind profiler network, as shown in Fig. 2. Specifically, the data transfer from radar sites to MOC/CMA is mainly done using Internet connections. The data center of CMA is established to efficiently process the data collected by Internet. There are two main types of data collected from the wind profilerr network: raw data and product data. The former data includes the power spectrum data files (indicated by FFT) and radial data files (indicated by RAD). The power spectrum data file is composed of file identification, basic parameters of the station, performance parameters, observation parameters and observation data. The power spectrum data file is dynamically generated in real time according to demand. The radial data files are twofold: one is reference information, such as the basic parameters of the station, radar performance parameters, and observation parameters; the other is the observation data of each beam at each sampling height, including sample height, velocity spectrum width, signal-to-noise ratio, and radial velocity. As for the product data, three main wind profile products are produced by the data center of CMA: (1) Real-time sampling data file (at 6-min intervals), mainly including the sampling height, horizontal wind direction, horizontal wind speed, vertical wind speed, horizontal credibility, vertical credibility, and Refractive Index Structure Parameter (C_n^2). An individual file will be produced for every 6-min detection and is marked as ROBS. (2) Half-hour data file (at 30-min intervals), which is broadly consistent with ROBS file in terms of both data content and format, except for the file produced for every half hour (48 files per day), and the file is marked as HOBS. (3) One-hour observation sampling data file (at 60-min intervals) with 24 files per day, which is marked as OOBS.

These wind profile products are generated for each observation site. The vertical resolution of wind profile data at most sites is 120 m. However, a few sites use a low level detection mode with high sampling rate, these provide a vertical resolution of 60 m. Examples of wind profile product are shown

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in Fig. 3. Seven different heights (150, 500, 1000, 1500, 2000, 2500, and 3000 m) are selected to show the atmospheric vertical wind field (Fig. 3e). It can provide the vertical profiles of horizontal wind direction, horizontal wind speed, and vertical wind speed. Those products are available for official duty use and for research and education. The observation data from November 2018 to March 2019

5 are used to evaluate the performance of the RWP network of China. Due to the fact that the measurements from the China RWP network have to be further assessed, the data sharing via global telecommunications system is expected to occur in the next several years, which highly depends on the process of data quality assessment.

3 Performance of the RWP network

10 The RWP network of China includes a variety of types of RWPs, including high troposphere, low troposphere and boundary layer RWPs. Due to the algorithms and setting parameters of different instruments are inconsistent, the system performance index and data accuracy are inhomogeneous. Therefore, it is necessary to evaluate the system performance index and data accuracy of the radars in the RWP network. This is a major step forward in the harmonization of the product generation and

15 data quality of the RWP network of China. Three system performance indicators on data application are investigated, including effective detection height, data acquisition rate, and data confidence. In order to estimate the data accuracy, the wind profiles from RWP are compared with hourly wind measurements at 0.25 x 0.25-degree latitude/longitude grid from the fifth generation European Centre for Medium-range Weather Forecasts (ECMWF) atmospheric reanalysis of the global climate (ERA5,

20 Hoffmann et al., 2019).

3.1 System performance index

The operation mode of the RWP network includes high, medium, and low detection modes, which can detect wind field information at different altitudes. High mode is generally used to detect the wind

fields at a height of 5–10 km above ground level (AGL). The medium and low modes is used to detect wind fields at a height of 0–5 km above the ground. We here define "effective detection height" as the effective detection height up to where wind measurements are available. Fig. 4a, b show the mean effective height detected by each RWP during the period from November 2018 to March 2019. There are 90 stations with an average height greater than 3 km; 10 of them can even reach more than 7 km. As for the acquisition rate, it refers to the ratio of the actual acquisition time to the total theoretical acquisition time, which is used to evaluate the normal operation of the wind profile radar. Fig. 4c, d represent the data acquisition rate of wind measurement at RWP network during the period from November 2018 to March 2019. The data collection rate of most sites is greater than 90%, while the data collection rate of 4 sites is less than 50%. Fig. 4e, 4f represent the average confidence of wind measurement at RWP network. Confidence is a credible parameter set by the system for the wind speed information at each sampling point, which is used to evaluate the credibility of the wind field information retrieved at each altitude position. The results indicates that there are 100 sites with more than 90% confidence, but 6 sites have less than 90% confidence.

In order to make the criteria of RWP network data consistent, we have to set corresponding screening criteria for each system index, which to some degrees reflects the needs of future applications. For instance, the RWP network data are expect to be used to derive boundary layer parameters, such as boundary layer height (Liu et al., 2019) and wind shear that are closely related to atmospheric pollution (Zhang et al., 2020). Therefore, it would be better for the effective detection height of RWP reaching 3 km, with the acquisition rate being above 60%. In addition, according to the user manual of RWP, only those wind profile data with a 100% confidence level are recommended. According to these criteria, the wind profile data at each site are screened, and the screening results are shown in Fig. 5. Fig. 5a shows the results of screening for effective detection height. The results show that the effective height detected by RWP of 102 stations meets this standard, and 4 stations are not up to the standard. The substandard sites are 54752, 58365, 58474, 58730. Fig. 5b shows the screening results of the data

acquisition rate. The results show that the data acquisition rate of 100 sites is satisfactory, and 6 sites are not up to standard. These substandard sites are 16078, 58158, 58460, 58927, 58933 and 59431. Fig. 5c shows the results of the confidence level screening. The results show that 100 sites are up to standard and 6 sites are substandard. The substandard sites are 54727, 54736, 54857, 57494, 58365

5   and 58460. Overall, 92 sites of the RWP network have a good system performance.

3.2 Data accuracy

The echo signal from RWP can be processed to provide the wind profile at RWP sites. However, it should be noted that the accuracy of wind profile data is also closely related to the processing algorithm. Therefore, the work to check the accuracy of the data is necessary before using these observations.

10   The comparison statistics against the wind profile data from ECMWF numerical model is an important monitoring tool (Huuskonen et al., 2014). Fig. 6 shows the comparison results between wind profile from RWP and that from ECMWF at six stations. The vertical validation range is from 0 to 3 km. The mean speed difference (MSD) and root-mean-square difference (RMSD) of horizontal wind speed between RWP and ECMWF (RWP–ECMWF) are calculated at each height. The red and blue dot lines

15   represent the MSD and RMSD at different heights, respectively. The vertical distribution of MSD at different sites is different, but almost of MSDs are less than 5 m/s. It is clear that a discrepancy does not automatically imply that the wind profile is in error, but in general a gross deviation with the model results can be considered as an indication of a radar error. Ishihara et al. (2006) evaluated the wind accuracy of Japanese RWP network by comparisons with the numerical weather prediction model

20   profiles, and the RMSD are around 3 m/s. Huuskonen et al. (2014) compared the wind profiles observed by EUMETNET with the ECMWF model profiles, and set 5 m/s RMSD as a target for acceptable wind observations.

Here, the horizontal wind speed measurements at all levels ranging from 0 to 3 km are used to calculate the MSD and RMSD at each site. Moreover, the magnitude of mean speed difference (MMSD) and

RMSD are set to be 4 m/s and 6 m/s, respectively, which serve as a target for acceptable criterion. Fig. 7 shows MMSD and mean RMSD from 0 to 3 km for all RWP, calculated by comparing with ECMWF wind data. It is seen that most of RWP meet consistently the acceptance criterion of 4 m/s MMSD and 6 m/s RMSD, while few radars also show larger differences. Moreover, the MMSD and RMSD of

5   RWP network has a certain spatial difference. According to the average difference in zonal direction (histogram in Fig.7), the RWPs at 28-32°N area have relatively large difference, where the zonal MMSD is larger than 2 m/s and zonal mean RMSD is larger than 5 m/s. The sites with MMSD greater than 4 m/s include 54857, 57494 and 59046; and the sites with RMSD greater than 6 m/s include 52889, 57494, 58448 and 59046. The wind data at these sites have large difference and are not recommended.

10   The large difference may be caused by either hardware or configuration problems, such as the aging of components. Therefore, it is important to conduct regular maintenance and replacement of aged components. In addition, there are eleven wind profile radar sites which are equipped with radiosonde (51463, 54342, 54511, 54727, 54857, 57494, 57516, 58238, 59758, 59948, and 59981).

Overall, the availability of RWP network of China can be evaluated by combining the system

15   performance index and data accuracy. Fig. 8 shows the spatial distribution and number of recommended and non-recommended sites. The availability of RWP network of China is 84%, which 89 stations are recommended, and 17 stations are not recommended. These non-recommended sites include: 16078, 52889, 54752, 54727, 54736, 54857, 57494, 58158, 58365, 58448, 58460, 58474, 58730, 58927, 58933, 59046, and 59431. For the sites with low height coverage or low data acquisition

20   rate, the data availability can be improved by changing the radar observation modes and increasing radar runtime. But for the sites with low confidence level or low data accuracy, which is caused by the inversion algorithm or the instrument system, it needs to choose the appropriate optimization method for specific problems. Some methods on data quality control are given in previous studies (Holleman, 2005).

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4 Applications of the RWP network

4.1 Daily maximum winds

The wind profile data can be used to monitor the diurnal cycle. Fig. 9 presents the spatial distribution of diurnal phase and amplitude of wind speed averaged during the period from November 2018 to

5 March 2019 according to mean maximum hourly wind speed within the 24 h. The occurrence time of maximum hourly wind speed is marked as early morning (0000–0600 Beijing time, BJT,), morning (0600–1200 BJT), afternoon (1200–1800 BJT), and evening (1800–2400 BJT), respectively. To highlight the vertical detection capabilities of wind radar, mean maximum wind speed at four different heights above ground level (500, 1000, 1500 and 2500 m) are investigated. As shown in the Fig. 9a (at

10 500 m), among the 106 observational sites, mean maximum wind speed occurs in the morning at 76 sites (about 71.9%), followed by 12 sites (11.3%) with peaks in the early morning. On the other hand, only 6 sites (5.5%) have an afternoon peak, whereas 12 sites (11.3%) have an evening peak. The story with respect to the diurnal phase and amplitude of mean maximum wind speed at other heights is almost the same (Fig. 9b-d). In terms of vertical direction, the occurrence timing of mean maximum

15 wind speed at most stations is consistent; but some stations of northwest China (Wulumuqi, Lanzhou and Qinghai) show a different pattern. Moreover, the amplitude of mean maximum wind speed at 2500 m height is two or three times than that at other height, indicative that the maximum wind speed increases with the height. In terms of the spatial pattern, mean maximum wind speed generally occurs in the morning in the coastal region of eastern China, with magnitude generally lower than 10 m/s. By

20 comparison, both early morning and afternoon peaks contribute almost equally to the diurnal cycle in the inland region.

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4.2 Regional wind field analysis

The wind profile data can also be used to investigate the regional wind field. As shown in Fig. 10, there are a total of 11 regions of interest (ROIs) selected for further analysis on the regional wind characteristics according to the spatial distribution of RWP stations as well as land cover (Table 2).

5 The land cover types data is obtained from the Moderate-resolution Imaging Spectroradiometer (MODIS). The MODIS Land Cover product is derived through a supervised decision-tree classification method. The land cover types are divided into 17 classes, including 11 natural vegetation classes, three human-altered classes, and three non-vegetated classes (Friedl et al., 2019). Fig. 10 shows the atmospheric wind field variation of each ROI at 500 m above ground level during the study

10 period. From the perspective of wind direction, the North China Plain is mainly southwest wind during the study period, the southwest wind at ROI 3 and 4 accounted for 40.3% and 48% respectively. The south China area is mainly dominated by northeast wind, such as ROI 8, 9, 10, and 11. The distribution of wind direction over central China is more uniform. Western China is dominated by northwest wind, and the percentages of northwest wind at ROI 1 is 45.8%. In terms of the spatial pattern wind speed,

15 the wind speed in western China is relatively low. The percentages of wind speed less than 4 m/s at ROI 1, 5, and 7 are 76.2%, 78.7%, and 83.2%, respectively. Moreover, the land cover type of ROI 1, 5, and 7 is grassland. By contrast, the wind speed in the central and eastern regions is significantly large, and 60% of the wind speed in most ROI can reach 6 m/s. Especially in coastal areas, such as ROI 4 and 9, 30% of wind speed is larger than 8 m/s over the whole study period.

20 In the long run, the accumulation of more wind profile measurements across China, especially in the lowest part of PBL, will provide a valuable benchmark database for assessment of wind power potentials and be useful for numerical weather prediction (Ishihara et al., 2006; Yim et al., 2007). The policymakers will determine whether the wind turbines (60-100 m above ground level) will be installed or not, aided by high-resolution model simulation analyses. Moreover, the real-time wind field data

25 can be used to predict typhoon and sandstorm paths (Ishihara et al., 2006; Huuskonen et al., 2014).

The RWP network of China can provide powerful data support for disaster warning and air pollution prevention.

5 Concluding remarks

The wind profiles are of great importance to the accuracy of numerical weather prediction model, the prediction of precipitation, the diffusion of air pollution, research on regional climate changes, and site selection of wind power plants. To the best of our knowledge, we for the first time reported on the height-resolved winds starting from ground surface to as high as 3-10 km, based on the RWP network of China, which consists of more than 100 RWP stations. It can provide the vertical profiles of horizontal wind direction, horizontal wind speed, and vertical wind speed. Then, the availability of the RWP network is investigated from system performance index and data accuracy. The evaluation criteria are that the effective detection height reachs 3 km, the data acquisition rate exceeds 60%, and the data confidence is 100%. In addition, in terms of data accuracy, the MMSD is better less than 4 m/s and RMSD is less than 6 m/s. Under this criterion, the availability of the RWP network of China is 84%, which 89 stations are recommended, and 17 stations are not recommended. Finally, the wind profile data has a wide range of applications, such as daily maximum winds detection and regional atmospheric wind field research. This RWP network would serve as a key data source on spatiotemporal distribution of atmospheric wind field in support of scientific researches related to renewable energy, severe weather, climate and climate change in the future.

Data availability

The radar wind profiler data used in this paper can be provided for non-commercial research purposes upon request by email (Dr. Jianping Guo: jpguocams@gmail.com). The ECWMF dataset can be downloaded from https://cds.climate.copernicus.eu/ (last accessed 24 February 2020). Instructions for use and data download methods can be found on the official website.

Author contributions

The study was completed with close cooperation between all authors. J. Guo and B. Liu designed the idea for assessing the radar wind profiler data in China; J. Guo and B. Liu conducted the data analyses and co-wrote the manuscript; L., Shi, Y. Zhang, Y. Ma and W. Gong discussed the experimental results, 5 and all coauthors helped reviewing the manuscript and the revisions.

Competing interests.

The authors declare that they have no conflict of interest.

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Tables:

Table 1. Instrument information of radar wind profiler network of China

Type of RWP	Identifier	Max detection height	Frequency	# of sites	Manufacturer
High Troposphere (CFL-16)	PA	8-10 km	440-450 MHz	3	CASIC
Low Troposphere (CFL-08)	PB	6-8 km	440-450 MHz	2	CASIC
Boundary layer	LC	3-5 km	1290 MHz	101	CASIC/CETC/CHG

5   CASIC: China Aerospace Science & Industry Corp.

CETC: China Electronics Technology Group Corp.

CHG: China Huayun Meteorological Technology Group Corp.

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Table 2. Statistics of the number of sites and land cover types for the 11 regions of interest (ROI) in Fig. 10.

Region of interest	Number of sites	Land cover types
1	1	Grassland
2	7	Cropland and Forest
3	10	Urban
4	2	Cropland
5	2	Grassland
6	1	Cropland
7	1	Grassland
8	27	Urban
9	2	Cropland and Forest
10	10	Urban
11	19	Urban and Forest

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Figures:
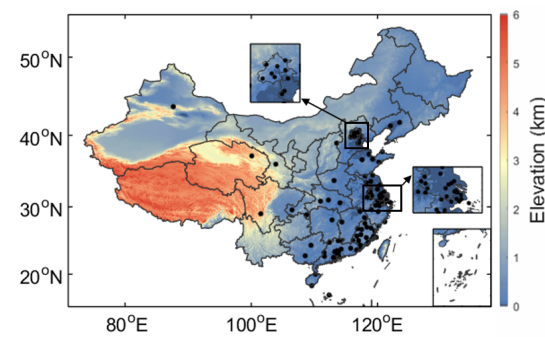
5   **Figure 1.** The site distribution of radar wind profiler network of China. Color bar means the elevation.
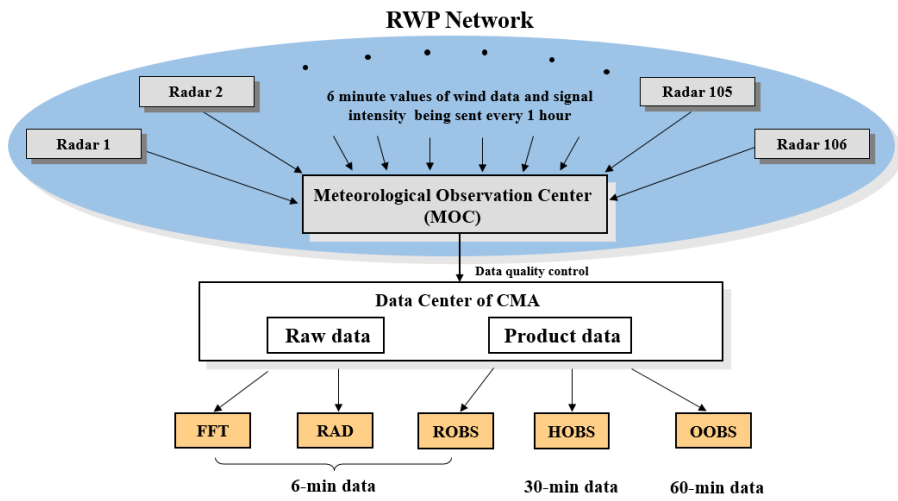
Figure 2. Data transmission framework of radar wind profiler network of China. The RWP network is maintained by the Meteorological Observation Center (MOC), China Meteorological Administration (CMA).

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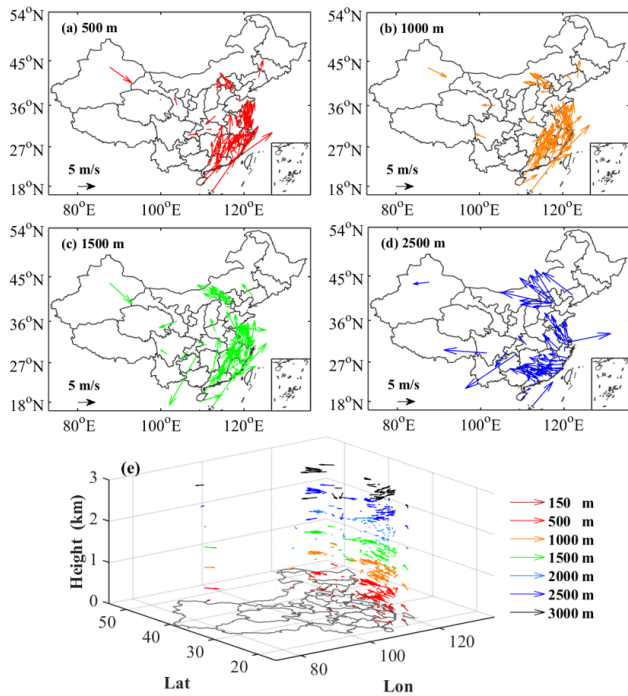
Figure 3. Spatial distribution of average wind field under different height: (a) 500 m, (b) 1000 m, (c) 1500 m, and (d) 2500 m above ground level (AGL). Also shown is (e) the three-dimensional atmospheric wind field observed by the radar wind profiler network of China.

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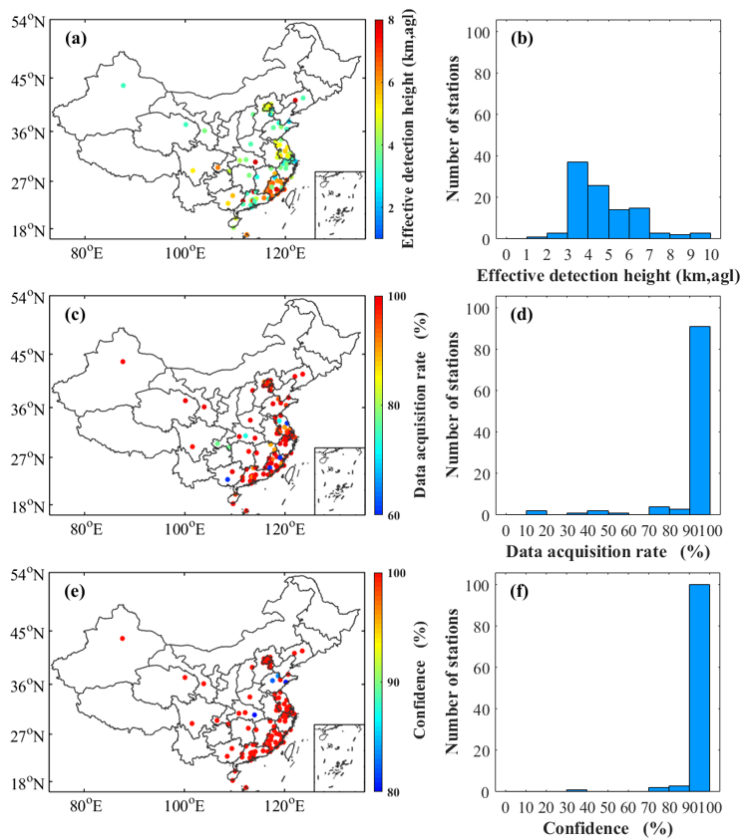
Figure 4. Spatial distribution of (a) mean effective detection height, (c) mean data acquisition rate, and (e) mean data confidence at each station during November 2018 to March 2019; (b), (d), and (f) correspond to the histograms for (a), (c), and (e), respectively.
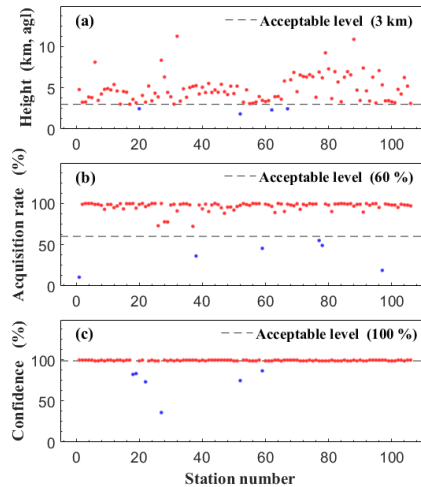
Figure 5. Recommended (red dots) and non-recommended sites (blue dots) of the radar wind profiler network by different performance metrics: (a) effective height detected by RWP, (c) data acquisition rate, and (e) data confidence. The horizontal gray lines indicate their corresponding acceptable threshold levels.
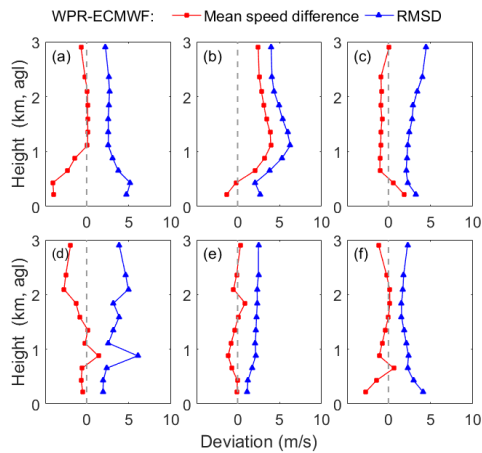
Figure 6. Comparison results between RWP and ECMWF at six RWP stations: (a) Beijing (116°E, 40°N), (b) Wulumuqi (87°E, 43°N), (c) Chongqing (106°E, 30°N), (d) Shanghai (121°E, 31°N), (e) Zigui (111°E, 31°N), and (f) Haikou (110°E, 20°N). The grey, red and blue dot lines represent the the reference line, mean speed difference and root-mean-square difference (RMSD), respectively.
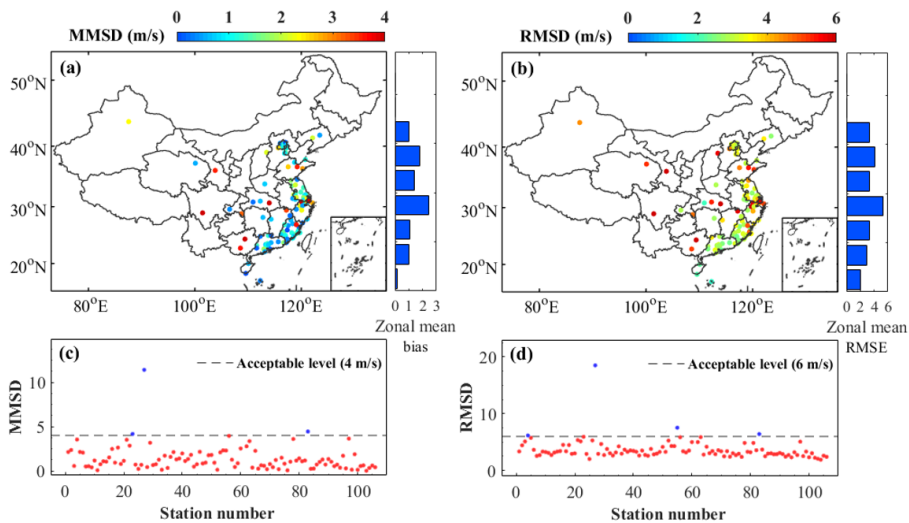
Figure 7. Spatial distribution of (a) magnitude of the mean speed difference (MMSD) and (b) root-mean-square difference (RMSD) at each station during November 2018 to March 2019; the corresponding histogram represent the average difference in zonal direction; (c) and (d) are corresponding recommended (red dots) and non-recommended (blue dots) sites for (a) and (b), respectively. The MMSD and REMD at each station were derived from the measurements over all levels from 0–3 km.
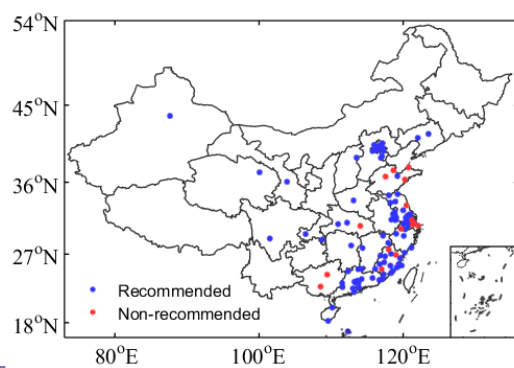
Figure 8. Recommended and non-recommended sites of the radar wind profiler network of China. The blue dots represent the 89 recommended sites and red dots the 17 non-recommended sites.
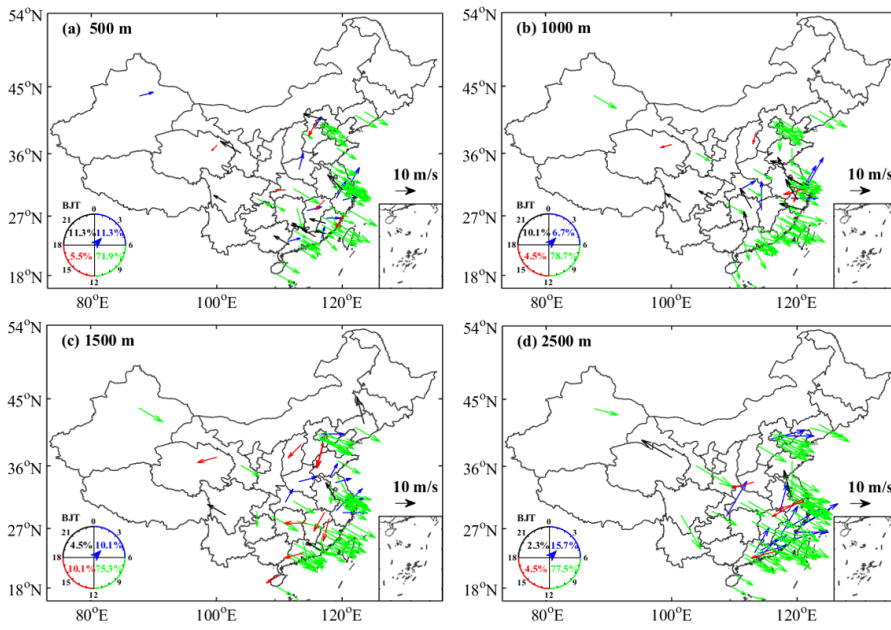
Figure 9. Diurnal phase and amplitude of mean maximum wind speed over the period from November 2018 to March 2019 at (a) 500 m, (b) 1000 m, (c) 1500 m, and (d) 2500 m above ground level (AGL). The direction towards which an arrow points denotes the Beijing time (BJT) when the maximum occurs (shown on the clock dial in the bottom left corner of each panel) and the arrow length represents magnitudes of mean maximum wind speed. The arrow color denotes varying diurnal phases: blue (0000–0600 BJT), green (0600–1200 BJT), red (1200–1800 BJT) and black (1800–2400 BJT).

Figure 10. Spatial distribution of the statistical results of atmospheric wind fields at 500 m above ground level (AGL) for 11 regions of interest (ROIs). The wind rose plots over the 11 ROIs are calculated from hourly observations of wind direction and wind speed from November 2018 to March
5 2019. The land cover types 0–16 represent the Water, Evergreen Needleleaf forest, Evergreen Broadleaf forest, Deciduous Needleleaf forest, Deciduous Broadleaf forest, Mixed forest, Closed shrublands, Open shrublands, woody savannas, Savannas, Grasslands, Permanent Croplands, Urban and built-up, Cropland/Natural vegetation mosaic, Snow and ice, Barren or sparsely vegetated, respectively.

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