Anonymous Referee #1

Received and published: 26 December 2014

General Comments : This deals with the few initial results obtained from WARE radar. The authors presented (1) comparison of wind obtained from WARE radar with radiosonde observations, (2) detection of tropopause height using WARE radar and its comparison with radiosonde derived tropopause height, (3) atmospheric gravity wave, (4) aspect sensitivity characteristics and (5) diurnal and semi-diurnal tides. System description of WARE radar with the wind comparisons with radiosonde observations was first published by Zhao et al. (2013). Whereas the present manuscript shows the combination of all the five points (results) mentioned above together. All the results presented here are not new and moreover detail investigations are not carried out in any of the result. This paper required a major revision before the manuscript is accepted for publication. Specific comments:

Major comments: (1) Tropopause height: Detection of tropopause height from radar is not established in this paper. Method needs to elaborate. (2) Gravity wave: GW analysis is not completed. Authors need to do more analysis to establish that gravity wave exists. If authors want to shows the presence of inertia gravity wave, then they need to prove it by further analysis and its causative mechanism. (3) Diurnal and semi-diurnal tides: Tidal nature in winds is well established feature. Instead, authors can extract the amplitude and phase of diurnal and semi-diurnal tides and wind field can be reconstruct and its comparison with the theoretical estimation. (4) L-17 : 'first time' rephrase the sentence, as nothing is new or first time.

Other specific comments : (1) Numerous typographical errors, e.g. Jein (Jain), Wave length (wavelength), many sentences are not completed. (2) L-17: 'first time' rephrase the sentence, as nothing is new or first time. (3) L-43/45: Expand MU and EAR (4) L-102-104 : Author can be briefly describe the three independent modes of operations. Is there any three independent radar specifications are designed, if so then it can be listed in a table. Is each mode of operation have different height (pulse width) and time

resolutions (5) L-116 : References are not required here. (6) Why authors are showing only the wind comparison of 11 Sept. 2011, which is already reported by Zhao et al. (2013). I feel radar is in operation since 2011 then some latest comparison will be good. (7) One of the potential of MST radar is to provide the direct measurement of vertical velocity. Thus, one profile of vertical velocity can be shown in this paper. (8) Instead of wind speed and direction, zonal and meridional wind can be shown. However, it's fine. (9) Mesospheric wind is a valuable parameter derived in this paper as the wind measurements in this height region is very scarce. Do the authors have any other independent measurements of winds nearby, e.g. any Meteor wind radar which can give the wind information from 80-100 km. (10) Does authors observed double tropopause structure as the radar is located at mid-latitude? (11) It seems that (Fig. 3) temperature measured from GPS based rawinsonde is smoothen too much, if so why? The height of the CPT from radiosonde measurement is about ~ 17 km, whereas from Radar it is about 14.5 km. How author can explain this difference in the measurements between radisonde and MST radar. (12) What is the meaning of blue dots in Fig.3. (13) The rate of aspect sensitivity per degree can be also estimated and compared with previously obtained e.g. Tsuda et al., 1997 (Tsuda, T., T. E. VanZandt, and H. Saito (1997), Zenith-angle dependence of VHF specular reflection echoes in the lower atmosphere, J. Atmos. Sol. Terr. Phys., 59, 761–775).

General Response:

We would like to express our heartfelt gratitude to the reviewer for giving us constructive and supportive suggestions which would help us to improve the quality of the paper. Our grateful thanks are also due to the reviewer for pointing out the typographical errors in the manuscript. In this revised version, we have followed the reviewer's suggestions and a major revision has been made accordingly.

We realize the reviewer's concern on the merit of this study. We agree with the reviewer that the experiment design using MST radar is not new. We would like to draw the reviewer's attention that it is an important addition to current

knowledge that we have followed this mature technique and constructed for the first time the MST radar system at Wuhan in China with reasonably validated results, which can act as a useful ingredient of the global ground-based network of studying the properties of the atmosphere and the ionosphere.

Even that the presented WARE results are preliminary, they are interesting for investigation. As stated in the manuscript, our results like tropopause determination, aspect sensitivity measurement and atmospheric wave observation indicate different feature with the regular pattern. However these results still needs further analysis. As more and more WARE data are collected for accumulation, comprehensive analyses, either a case study, multi-event study or statistical survey will be conducted with expectation of more findings as of the regional atmospheric characteristics in mid-latitude China.

Point by point response:

Major comments:

(1) Tropopause height: Detection of tropopause height from radar is not established in this paper. Method needs to elaborate.

Response:

We appreciate the reviewer's helpful comments. The location of tropopause in Figure 3(a) and 3(b) is determined by C_n^2 profile estimated from radar echo power. As shown in equation (4) in [Ghosh et al., 2001] and equation (5) in [Rao et al., 1997]. The C_n^2 reaches its peak value when the radar echo power is maximum near the tropopause region. Consequently, the location of maximum C_n^2 value implies the height of tropopause.

(2) Gravity wave: GW analysis is not completed. Authors need to do more analysis to establish that gravity wave exists. If authors want to shows the presence of inertia gravity wave, then they need to prove it by further analysis and its causative mechanism.

Response:

We appreciate the reviewer for raising this helpful comments. Characteristics of internal gravity waves (IGWs) can be investigated by wind field data. The employed quasi-monochromatic IGW extraction and analysis method, which is named as hodograph method, is following that presented by [Zhang and Yi, 2005; and references cited therein]. Since the generation and propagation properties of IGWs are so complex that any single source cannot fully account for the whole process, it is generally recognized that it is a combination of a number of possible sources that is responsible for the formation of IGWs, especially in the troposphere.

In the current paper, we just indicate the capability of WARE radar for investigating the IGWs. Based on hodograph and Lomb-Scarlge method, a statistical analysis of the IGWs observed by WARE radar has been recently reported by Qing et al. [2014]. Combining with the information of statistical 3-D wind field and some climatic characteristics of Hubei Province, atmospheric moist convection will contribute most in summer, whereas jet/front systems will contribute most in winter. One may expect seasonal variations to be tied to the varying importance of these sources

(3) Diurnal and semi-diurnal tides: Tidal nature in winds is well established feature. Instead, authors can extract the amplitude and phase of diurnal and semi-diurnal tides and wind field can be reconstruct and its comparison with the theoretical estimation.

Response:

We appreciate the reviewer for this valuable comments. Tidal horizontal wind amplitudes can reach to several tens of m/s in mesosphere and low thermosphere, which have been intensively studied for thirty years. However, due to the weak amplitude, tides in troposphere and lower stratosphere have not been subjected to adequate study. With the fine resolution of WARE radar (5 min time resolution and 150 m height resolution in low mode), we mainly focus on the captivity of extraction and analysis of the tides parameter in troposphere and lower stratosphere region in the presented paper.

(4) L-17: 'first time' rephrase the sentence, as nothing is new or first time.

Response:

We thank the reviewer for this helpful comments. In the original manuscript, "first time" means the first time to investigate these atmospheric phenomena by WARE radar at the mid-latitude China. We agree to reviewer that these findings are not new and the "first time" words could cause misunderstanding to readers. We have followed the reviewer's suggestion and rephrased the sentence in the revised manuscript.

Specific comments:

(1) Numerous typographical errors, e.g. Jein (Jain), Wave length (wavelength), many sentences are not completed.

Response:

We appreciate the reviewer for pointing out these error. We have made corresponding corrections in the revised manuscript.

(2) L-17: 'first time' rephrase the sentence, as nothing is new or first time.

Response:

We thank the reviewer for pointing out. We have make the corresponding corrections in the revised manuscript. Please see Lines 17 in the revised manuscript.

(3) L-43/45: Expand MU and EAR

Response:

We thank the reviewer for pointing out. We have make the corrections in the revised manuscript. Please see Lines 42 and 44 in the revised manuscript.

(4) L-102-104 : Author can be briefly describe the three independent modes of operations. Is there any three independent radar specifications are designed, if so then it can be listed in a table. Is each mode of operation have different height (pulse width)

and time resolutions.

Response:

We appreciate the reviewer for this important suggestions. We have followed the reviewer's suggestion and listed the primary parameters in the table 1 in the revised paper. A detailed specification can be found in Zhao et al., 2013.

(5) L-116 : References are not required here.

Response:

We thank the reviewer for the helpful suggestion. We have followed the suggestion and remove the reference.

(6) Why authors are showing only the wind comparison of 11 Sept. 2011, which is already reported by Zhao et al. (2013). I feel radar is in operation since 2011 then some latest comparison will be good.

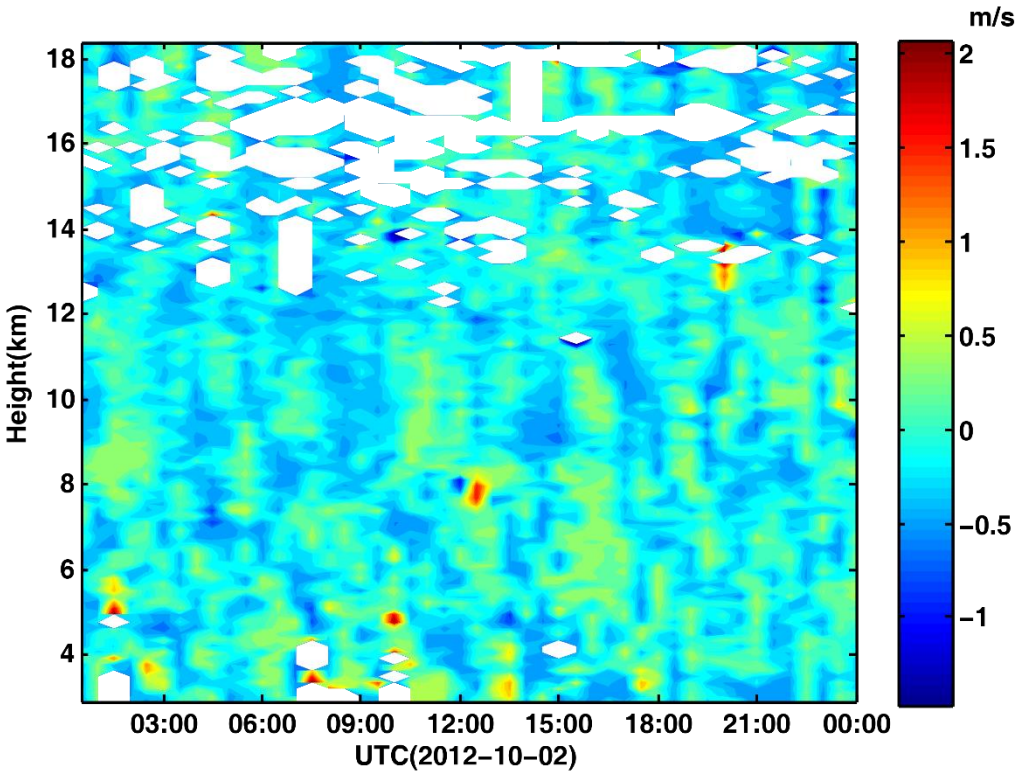
Response:

We thank the reviewer for the valuable suggestion. Up to now, we have just one experiment for comparing the rawinsonde and WARE data on September 11, 2011. Since there is a small airport nearby, occasional rawinsonde experiment is not easily permitted.

(7) One of the potential of MST radar is to provide the direct measurement of vertical velocity. Thus, one profile of vertical velocity can be shown in this paper.

Response:

We appreciate the reviewer for this valuable comment. We have provided a wind profile of vertical velocity for continuous 24 hours in the revised manuscript.



(8) Instead of wind speed and direction, zonal and meridional wind can be shown. However, it's fine.

Response:

We thank the review for this comment. We agreed with the reviewer that wind profiles can be shown like the figure 2(b). Profile of wind speed and direction can be easily transformed to zonal and meridional.

(9) Mesospheric wind is a valuable parameter derived in this paper as the wind measurements in this height region is very scarce. Do the authors have any other independent measurements of winds nearby, e.g. any Meteor wind radar which can give the wind information from 80-100 km.

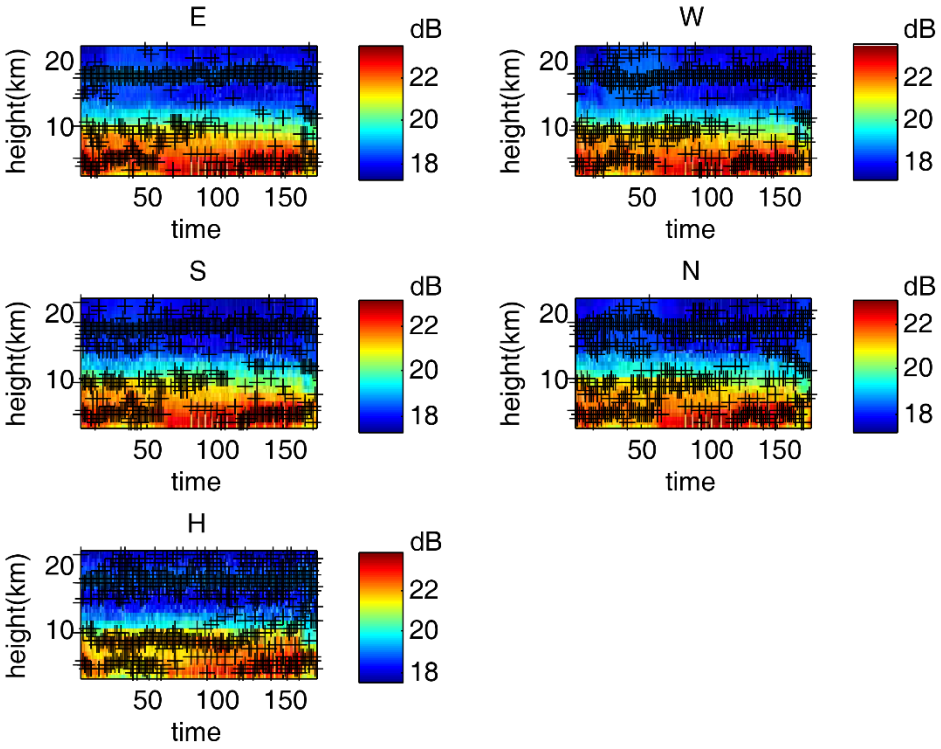
Response:

We thank the reviewer for the valuable suggestion. A meteor wind radar is now located about 200 km north of the WARE radar. However, currently we do not have access to the data.

(10) Does authors observed double tropopause structure as the radar is located at mid-latitude?

Response:

Yes! We have observed the double tropopause structure by WARE radar. The figure below is a possible example observed on Nov. 15, 2011 from 05:44 to 11:04 (LT) with the time resolution of 5 minutes and height resolution of 150 meters.



Recent studies have shown that the double tropopause structure are found numerously in the midlatitude. (Randel et al, 2007; Wang and Polvani, 2011; Peevey et al, 2012) However, detailed investigation on the statistical features and mechanism of double tropopause should be further discussed. Double tropopause structure studies will be one of our future works.

Randel, W. J., D. J. Seidel, and L. L. Pan (2007), Observational characteristics of double tropopauses, J. Geophys. Res., 112, D07309, doi:10.1029/2006JD007904.

Wang, S., and L. M. Polvani (2011), Double tropopause formation in idealized baroclinic life cycles: The key role of an initial tropopause inversion layer, J. Geophys. Res., 116, D05108, doi:10.1029/2010JD015118.

Peevey, T. R., J. C. Gille, C. E. Randall, and A. Kunz (2012), Investigation of double tropopause spatial and temporal global variability utilizing High Resolution Dynamics Limb Sounder temperature observations, J. Geophys. Res., 117, D01105,doi:10.1029/2011JD016443.

(11) It seems that (Fig. 3) temperature measured from GPS based rawinsonde is smoothen too much, if so why? The height of the CPT from radiosonde measurement is about ~17 km, whereas from Radar it is about 14.5 km. How author can explain this difference in the measurements between radisonde and MST radar.

Response:

We thank the reviewer for raising this comment. The measured temperature (blue dots) are fitted to get the blue line. The location of tropopause can be different according to different tropopause definitions and tropopause dynamics. [Yamamoto et al., 2003; Das et al., 2008] In addition, the tropopause is not just a thin layer but a transition region between the troposphere and stratosphere [Mehta et al., 2008]. Figure 3 demonstrate the difference between the cold point tropopause (CPT) from rawinsonde and radar tropopause. It should also be noted that the height resolution is 0.6 km in the medium operational mode, which add some uncertainties for radar tropopause location.

Yamamoto, M. K., M. Oyamatsu, T. Horinouchi, H. Hashiguchi, and S. Fukao, High time resolution determination of the tropical tropopause by the Equatorial Atmosphere Radar, Geophys. Res. Lett., 30(21), 2094, doi:10.1029/2003GL018072, 2003.

Das, S. S., A. R. Jain, K. K. Kumar, and D. Narayana Rao (2008), Diurnal variability of the tropical tropopause: Significance of VHF radar measurements, Radio Sci., 43, RS6003, doi:10.1029/2008RS003824.

Mehta, S. K., B. V. Krishna Murthy, D. N. Rao, M. V. Ratnam, K. Parameswaran, K. Rajeev, C. S. Raju, and K. G. Rao (2008), Identification of tropical

convective tropopause and its association with cold point tropopause, J. Geophys. Res., 113, D00B04, doi:10.1029/2007JD009625.

(12) What is the meaning of blue dots in Fig.3.

Response:

We appreciate the reviewer for pointing it out. The blue dots in Figure 3 is the temperature measured by rawinsonde. The blue line is the fitted curve from these dots. At the location of tropopause, a quadratic curve fitting is adopted.

(13) The rate of aspect sensitivity per degree can be also estimated and compared with previously obtained e.g. Tsuda et al., 1997 (Tsuda, T., T. E. VanZandt, and H. Saito (1997), Zenith-angle dependence of VHF specular reflection echoes in the lower atmosphere, J. Atmos. Sol. Terr. Phys., 59, 761–775).

Response:

We appreciate the reviewer for pointing out our negligence for this informative and helpful reference. Accordingly, we have revised this part by following the reviewer's suggestions. Please see Lines 248-258 in the revised manuscript.