Simultaneous and collocated observation of meteors by two all-sky meteor radars

Jinsong Chen*[1, 2, 3], ***Na Li***[1], ***Jiyao Xu***[2]

[1]National Key Laboratory of Electromagnetic Environment, China Research Institute of Radio Wave Propagation, Qingdao, 266107, China,

[2] State Key Laboratory of Space Weather, Center for Space Sciences and Applied Research, Chinese Academy of Sciences, Beijing, China, jschen@spaceweather.ac.cn

[3] Graduate University of Chinese Academy of Science, Beijing, China

Abstract

Based on the data during a special experiment in 2013, we give a comparison on the meteor parameter observed by two all-sky meteor radars, in order to check if the value about meteors estimated from the all-sky meteor radar is dependent on frequency used by the radar. A special computer algorithm has been developed to find out the same meteor observed by two radars simultaneously, but the number is much less than the expected value. Some important parameter, such as radial velocity, meteoroid speed and diffusion coefficient has been compared between two radars, and good agreement is found on radial velocity as well as obvious discrepancies are also shown on meteoroid speed and diffusion coefficient.

1. Introduction

Meteor studies by radar have a long history. While the earliest observations were predominantly for astronomical purposes, atmospheric observations were late made by measuring the radial drift velocity of the meteor trail left by meteoroid burning up for investigation of atmospheric dynamics in the mesospheric and lower thermospheric (MLT) region. In order to improve the meteor rates and to some extent, the capability to learn about the atmosphere accordingly, recent advances in personal computers and digitization technology have resulted in a suite of instruments used for online meteor observations. A dedicated example is the all-sky interferometric meteor radar using an antenna configuration designed to yield unambiguous meteor angle of arrival while minimizing mutual antenna coupling [1, 2]. They are capable of estimating count rates of up to twenty thousand meteor echoes per day, which has allowed the development of new techniques for estimating atmospheric parameters, such as to estimate absolute atmospheric temperature [3].

In the late 2000s China Research Institute of Radio wave Propagation (CRIRP) has further expanded its research program to monitor the Earth's middle and upper atmosphere. In attempt to study the dynamics of the MLT region in lower latitude over China, the Kunming atmosphere radar facility (KARF) consisting of a MF radar, an all-sky meteor radar and a ST Doppler radar with meteor radar capability was installed at Kunming Radio Observatory (25.6^{o}N, 103.8^{o}E), 130 km northeast of Kunming city, which is the capital city of Yunnan Province, in August 2008 by CRIRP. Since then, continuous observation of winds in the MLT has been underway [4]. KARF gives us an opportunity to implement a simultaneous and collocated observation of meteors by two all-sky meteor radars.

In this paper, we give a comparison on the meteor parameter observed by two all-sky meteor radars based on the data during a special experiment in 2013, in order to check if the value about meteors estimated from the all-sky meteor radar is dependent on frequency used by the radar.

2. The Kunming all-sky meteor radars

Currently there are two all-sky meteor radars running in the Kunming site, of which one is individual and other is attached to the ST radar system. These two radars are quite identical rather than the different operating frequency: one with 37.5MHz and the other 53.1MHz, which both are manufactured by Atmospheric Radar Systems (ATRAD). The all-sky meteor radars described in this paper use a peak power of 20 kW for 37.5MHz and 40 kW for 53.1MHz with the same maximum duty cycle of 8% for coded pulses. The antenna array consists of a single pair of crossed dipoles for transmission, providing all-sky illumination, and five pairs of crossed dipoles for reception [1, 2]. The antenna array consists of a pairs cross dipoles for transmission and five pairs cross dipoles for reception. The transmitting system is capable of producing single or coded Gaussian shaped pulses with a wide range of peak powers and pulse lengths. The radar data acquisition system consists of 5 receiving channels, and allows a wide range of receiver bandwidths and range and time sampling parameters. Radar control and data acquisition is performed by a WindowsNT-based “acquisition” PC fitted with data acquisition hardware and software acquiring data with 16-bit resolution. The control program provides considerable flexibility in experimental sequencing and scheduling. Data acquired by the acquisition PC is transferred to a Linux based “analysis” PC providing user interface to the radar, including analysis, display and all radar system configuration. The all-sky meteor radar can be operated using either Ordinary (O) mode circular or linear polarization for transmission. For circular transmission, each transmit module is connected to a separate dipole of the transmit antenna, and appropriate cable length is used to produce phase of 0^{o} and 180^{o} at the transmit antennas dipoles. The receiving antennas are arranged in two perpendicular arms with spacing of 2 and 2.5 wave lengths. This antenna configuration is designed to minimize the effects of antenna coupling while maintaining the ability to unambiguously resolve meteor angle of arrival. Typical results indicate the Kunming all-sky meteor radars obtain annual count rate variation of between 12,000 and 20,000 meteors per day.

3. Results

Figure 1 displays the variation of meteor rate observed by two radars per day during this experiment and the number of the same meteor observed by two radars simultaneously, which has been chosen by a special computer algorithm. It is shown in figure 1 that the 37.5MHz meteor radar is able to observe more meteors than 53.1MHz radar as expected because the radar with low frequency will be more sensitive to weak meteors. However, it is strange to see that the number observed by two radars is much less than expected, which was also found by some researchers before [5], as it is hard to learn why many meteors detected by one radar will generally be missed by the other. In a word to completely understand the reason for the result further investigation is still needed.

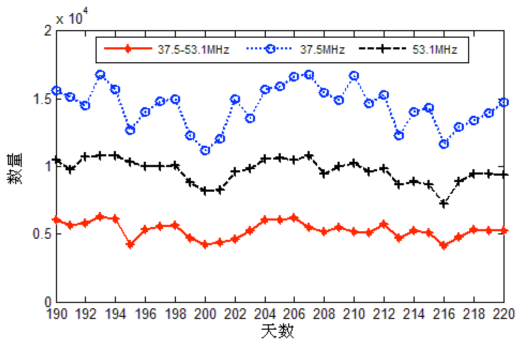

Figure 1. The blue line presents the meteor rate observed per day by the 37.5MHz meteor radar, and the black line is the number by the 53.1MHz meteor radar. Finally the red line shows the meteor number

observed by two radars simultaneously.

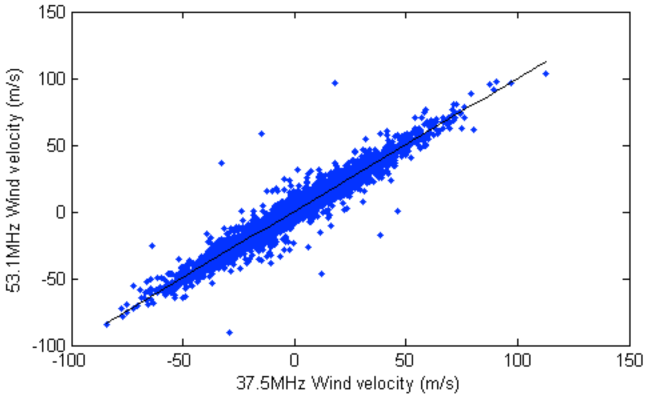

Figure 2. The scatterplot of radial velocity observed by two all-sky meteor radars

Figure 2 presents the scatterplot of the radial velocity observed by two all-sky meteor radars in a typical day and a fine agreement between two radars is shown, which imply that all-sky meteor radars with different frequency will not affect the result of wind. The latest all-sky meteor radar is able to measure the meteoroid speed, which produces the meteor trail [6], and a comparison on the meteoroid speed measured by two radars is plotted in figure 3. An obvious discrepancy is shown in the meteoroid speed, which indicates the radar with 53.1MHz may underestimate the speed up to 20%. The current method to estimate the meteoroid speed seems to depend on the operating frequency to some extent.

Figure 4 shows the diffusion coefficient calculated from the decay time of meteor echoes, in which a significant disagreement is seen again. As the diffusion coefficient always is used to retrieve the atmospheric temperature and density in meteor region, according to the result the operating frequency may play some effects on the estimated temperature as discussed in other literature [7].

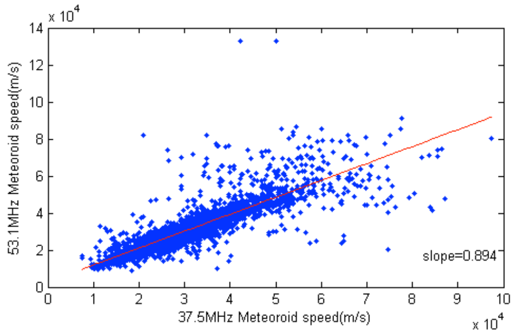

Figure 3. The same to figure 2 but for meteoroid speed

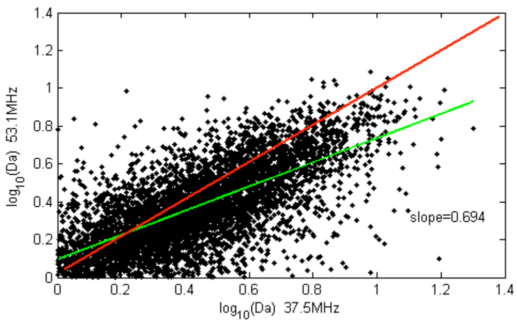

Figure 4. The same to figure 2 but for diffusion coefficient

4. Conclusion

In this paper, we give a comparison on the meteor parameter observed by two all-sky meteor radars based on the data during a special experiment in 2013, in order to check if the value about meteors estimated from the all-sky meteor radar is dependent on frequency used by the radar. A special computer algorithm has been developed to find out the same meteor observed by two radars simultaneously, but the number is much less than the expected value. Some important parameter, such as radial velocity, meteoroid speed and diffusion coefficient has been compared between two radars, and good agreement is found on radial velocity as well as obvious discrepancies are also shown on meteoroid speed and diffusion coefficient.

5. Acknowledgments

The KARF belongs to and is operated by China Research institute of Radio wave Propagation (CRIRP). The project has been funded by the National Natural Science Foundation of China under Grants 41104102.

6. References

1. D. A. Holdsworth, I. M. Reid, M. A. Cervera. Buckland Park all-sky interfermotric meteor radar. Radio. Science, 2004, 39, RS5009, doi:10.1029/2003RS003014.
2. W. K. Hocking, B. Fuller, B. Vandepeer. Real-time determination of meteor-related parameters utilizing modern digital technology, Journal of Atmospheric and Terrestrial Physics, 2001, 63:155-169.
3. W. K. Hocking, Temperatures using radar-meteor decay times, *Geophys. Res. Lett.*, 1999, 26(21), 3297–3300.
4. L. Zhao, J. S. Chen, Z. H. Ding, First observations of tidal oscillations by an MF radar over Kunming (25.6^{o}N, 103.8^{o}E), *Journal of Atmospheric and Solar-Terrestrial Physics*, 2011, doi:10.1016/j.jastp,2011.4.016.
5. T. A. Valentic, J. P. Avery, S. K. Avery, M. A. Cevera, W. G. Elford, R. A. Vincent, I. M. Reid, A comparison of meteor radar systems at Buckland Park. *Radio Science*, 1996, 31(6):1313-1329.
6. D. A. Holdsworth, W. G. Elford, R. A. Vincent, I. M. Reid, D. J. Murphy, W. Singer, All-sky interferometric meteor radar meteoroid speed estimation using the Fresnel transform, *Ann. Geophys.*, 2007, 25, 385–398.
7. J. P. Younger, I. M. Reid, R. A. Vincent, D. A. Holdsworth, Modeling and observing the effect of aerosols on meteor radar measurements of the atmosphere, *Geophys. Res. Lett.*, 2008, 35, L15812, doi:10.1029/2008GL033763.