

## Comparison observations between the MU radar and the Kyoto meteor radar

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We have performed a comparison between the MU radar and the Kyoto meteor radar on August 14-15, 1984. The MU radar provided vertical, zonal and meridional wind components in the 65- to 85-km region during daylight hours when echoes from the turbulent scattering were intense. Meteor echoes were also received by the MU radar, and utilized to measure winds at meteor heights. Comparisons among these MU radar measurements and Kyoto meteor radar observations have shown fairly consistent wind profiles at 65- to 105-km altitudes. To interpret differences in the wind fields observed in 2 successive days, it was necessary to consider the behavior of quasi 2-day oscillation deduced from long-duration Kyoto meteor radar observations.

### 1. INTRODUCTION

There are many well-established techniques for the measurement of wind fields in the mesosphere [Gage and VanZandt, 1981]. In the last two decades, many attempts have been done to make comparisons among different techniques by using data collected with each technique. Meteorological rocket soundings were compared with partial reflection drift measurements [Vincent *et al.*, 1973] and large ground-based VHF and UHF radars [Fukao *et al.*, 1979; Fukuyama, 1981; Smith and Fritts, 1984]. Meteor radar measurements were also compared with partial reflection drift measurements [Felgate *et al.*, 1975; Wright *et al.*, 1976; Stubbs, 1973], and incoherent scatter observations [Bernard, 1974; Walker, 1979; Mathews *et al.*, 1981]. They have shown good overall agreement between techniques which seem to provide equivalent wind fields in the mesosphere, although some discrepancies were found because of temporal and spatial differences between sites and the averaging or smoothing of wind fields because of

the different time-height resolutions implicit in each technique. Comparison observations are needed to understand the limitations and advantages of different techniques.

Simultaneous observations of mesospheric winds were carried out on 2 consecutive days by using the MU (middle and upper atmosphere) radar and the Kyoto meteor radar. The purpose of this work is to make a comparison of the two kinds of data.

### 2. MU RADAR

The observational techniques of the MU radar (34°51'N, 136°06'E) have been described by Kato *et al.* [1984] and elsewhere in this issue [Fukao *et al.*, this issue *a, b*]. Mesospheric observations were made on August 14-15, 1984. Since the MU radar was still under construction, we used only 361 TR modules (19/25 of the final system) which operate at a peak transmitted power of approximately 750 kW. The sensitivity of the radar for the turbulent scattering was 0.58 of the final system. The transmitted pulse was phase-modulated by 16-bit complementary codes with a baud length of 2  $\mu$ s. The IPP was 800  $\mu$ s, so that the duty factor was 0.04. The antenna main beam was steered every interpulse period (IPP) and pointed in the vertical direction and then toward

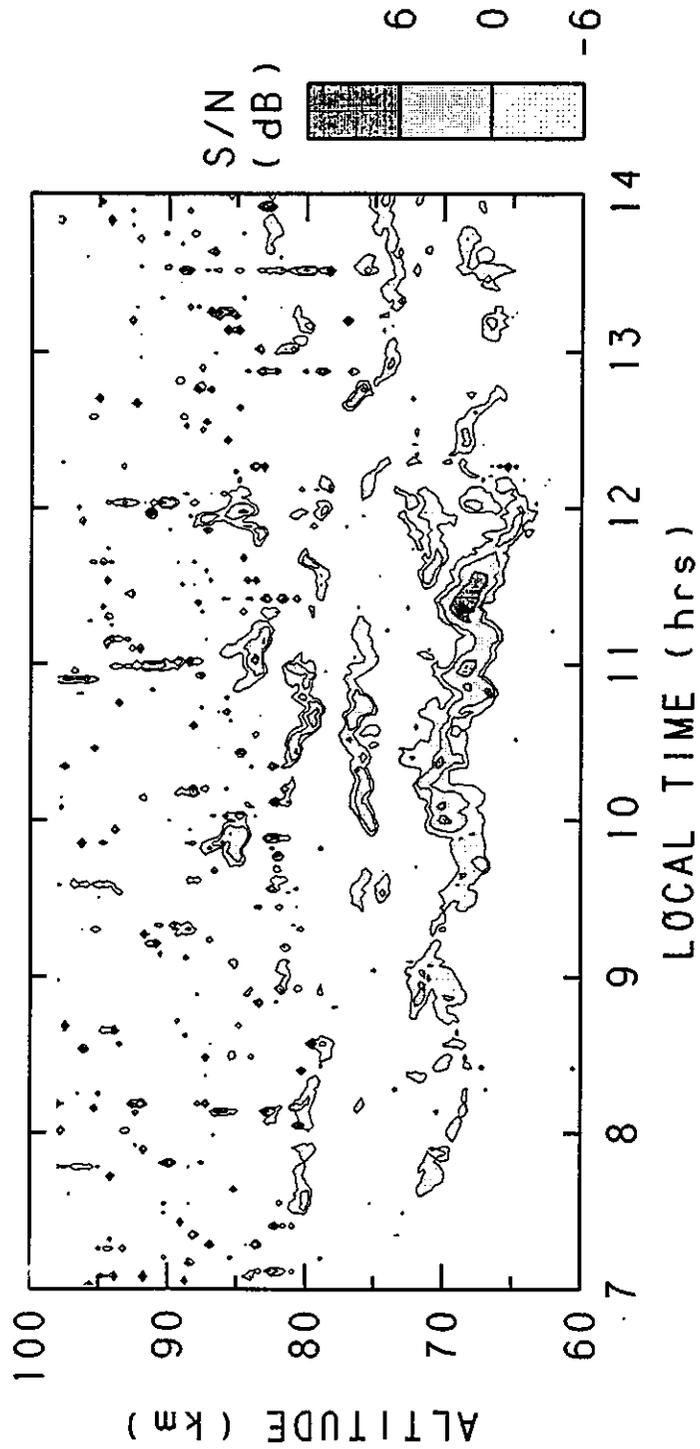


Fig. 1. Signal-to-noise ratio in the vertical direction versus height and local time on August 15, 1984, with a height resolution of 300 m and time resolution of approximately 2 min.

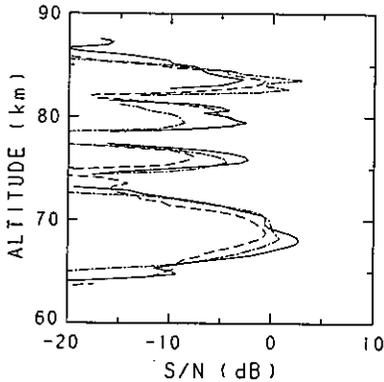


Fig. 2. Mean signal to noise ratio between 1000 and 1200 LT on August 15, 1984, in the vertical (solid curves), northward (dashed curves), and eastward (dashed-dotted curves) directions.

the north and the east at a zenith angle of  $10^\circ$ . Quadrature signals were sampled at intervals of 300 m from 60 km to 98.1 km and were coherently integrated over 30 pulses for echoes in each direction. The signals were transferred into power spectra by using the 128-point FFT, and then the spectra were incoherently accumulated 10 times. The power spectra were recorded on magnetic tape every 105 s.

Based on the intrinsic time-height resolution of the data, contours of echo intensity in the vertical direction during 700–1400 LT on August 15 are shown in Figure 1. At 65- to 85-km altitudes, intense turbulent layers were observed, which show wavelike structures propagating slowly downward, although the general echo intensity was unfortunately weak during the observations. Above 80 km, strong intermittent meteor echoes were frequently detected.

Figure 2 shows height profiles of echo intensity integrated over 1000–1200 LT on August 15 in the vertical and the two oblique directions. Below about 80 km the signal power was largest in the vertical direction by several decibels, a feature which has previously been reported for Jicamarca observations [Fukao *et al.*, 1979]. For the turbulent layer at 82- to 85-km altitudes, the weakest power was detected in the vertical direction, and the eastward pointing antenna received more power than the northward beam. The turbulent layer detected from the vertical observation at 83-km altitude around 1100 LT, shown in Figure 1, was also observed in the eastward direction with larger mean intensity and longer duration. On the other hand, turbulent layers at 85 km around 1000 and 1200 LT appeared less clearly in the eastward direction than in the vertical. The northward observation showed similar feature of the

turbulent layers in the 82- to 85-km region to that from the vertical observation, although small-scale variation of the layers differed. Thus the turbulent layers in the 82- to 85-km region seem to have spatial variation within a horizontal scale of 20 km, a typical beam separation distance, a temporal scale of several minutes, and a drifting time for the layers between different beam positions. The turbulent echo power at 82- to 85-km altitudes in the eastward direction might be enhanced above others, not because the turbulent layers have intrinsic structure to give larger scattering in the oblique direction than the vertical, but rather because the more turbulent echo power was occasionally received in the eastward direction.

We have taken two approaches to infer the wind profile in the 65- to 95-km region.

1. Meteor echoes are removed by using their discontinuous nature along time and height before the integration of power spectra. Then, ten records of power spectra are incoherently integrated. Eastward and northward horizontal wind velocities are calculated taking the vertical wind velocity into account. This analysis is applicable for constructing the wind profile below about 80 km.

2. In the region above 80 km, where meteor echoes dominate turbulent scattering, we have utilized meteor echoes to deduce wind profiles as has been applied to Poker Flat MST radar observations [Avery *et al.*, 1983]. Meteor echoes were received intermittently, so that they usually did not give a complete set of radial wind velocities in three directions at the same time. Therefore the horizontal wind velocity was estimated with the assumption of zero vertical velocity. Because meteor echoes are not necessarily received in the direction of antenna bore

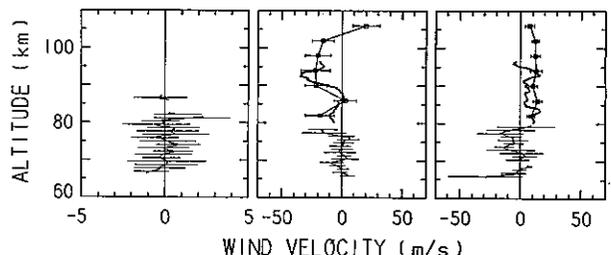


Fig. 3. Mean wind profiles for (left) vertical, (center) northward, and (right) eastward components observed between 0800 and 1400 LT on August 14, 1984. MU radar measurements using the turbulent scattering (solid curves with bars) and meteor echoes (thick solid curves) are compared with Kyoto meteor radar observations (squares).

sight, accumulation over a longer period than the first method is needed to find the average radial wind in the collecting volume of the main beam. Furthermore, since we did not discriminate against meteor echoes received in the side lobes of the antenna, there is a possibility that radial wind velocities in the directions other than that of the main beam may contaminate to the accumulated wind velocities.

To remove random fluctuation of the wind fields, the wind profiles deduced from methods 1 and 2 were smoothed over three and five adjacent altitudes, respectively.

### 3. KYOTO METEOR RADAR

The Kyoto meteor radar constructed in 1977 is located approximately 700 m west of the MU radar. It operates at 31.57 MHz and 10-kW peak transmitted power with a duty factor of 0.084. Kyoto meteor radar has been regularly monitoring mean winds, planetary waves and atmospheric tides at 80- to 110-km altitudes [Aso *et al.*, 1980; Tsuda *et al.*, 1983; Ito *et al.*, 1984].

For observations in August 1984, the antennas were pointed in the eastward direction at an elevation angle of 45°. At meteor heights, the mean horizontal separation between the meteor radar observations and the MU radar observation region is approximately 100 km. Because the antenna beam width is fairly large, the meteor echoes can be distributed widely in azimuth. Thus the observed radial wind velocity usually contains both zonal and meridional components. A fitting analysis, using time-height bins of 2 hours  $\times$  4 km, can usually provide

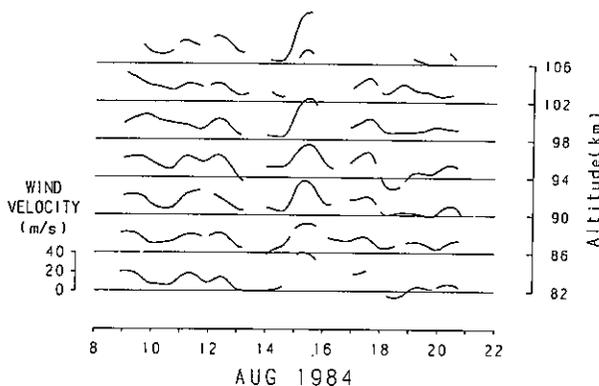


Fig. 5. Eastward wind velocities observed by the Kyoto meteor radar after filtering short-period components less than 32 hours.

both components by using measurements of the arrival angle for each meteor echo obtained with an interferometer installed in the system. However, the zonal component is more reliably determined than the meridional component. The number of meteor echoes varies diurnally with the maximum rate occurring early in the morning, and the rate is sometimes insufficient to deduce the vertical profile of wind fields around sunset.

### 4. RESULTS

Figures 3 and 4 show the mean wind profiles of the vertical, northward and eastward components observed between 65 and 100 km measured from the MU radar observations during 0800–1400 LT on August 14 and 15. The two kinds of measurements by the MU radar as described in section 2 show a fairly continuous and smooth variation with altitude. Bars for the MU radar measurements using turbulent scattering indicate the standard deviation of the wind fields during the observation period.

Kyoto meteor radar observations of wind profiles in the 82- to 106-km region on August 14 and 15 are also shown in Figures 3 and 4. The height range does not overlap with that of the MU radar measurements using turbulent echoes. However, a continuity of vertical profiles with different techniques is recognized on both days. Comparisons of the two kinds of meteor wind measurements by the MU radar and the Kyoto meteor radar show that overall wind profiles agree quite well as in Figure 3. Large wind shears at around 90 km for both northward and eastward components were well deduced in Figure 4, although differences are recognized at 82-km altitude. The me-

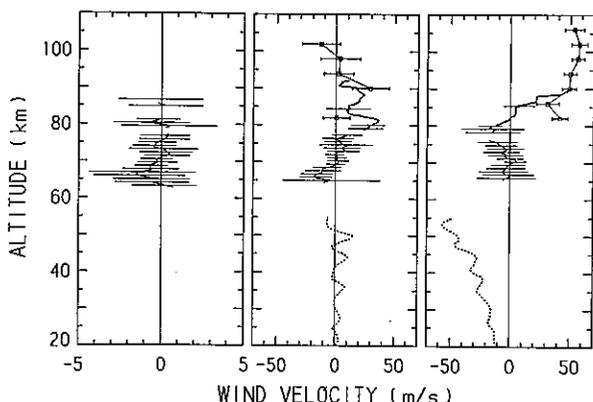


Fig. 4. The same as Figure 3 for observations on August 15, 1984. Rocket measurements of wind profiles are also plotted (dotted curves).

ridional component from meteor radar observations at 86 and 106 km could not be delineated because of large deviation in the fitting analysis. Discrepancies might be attributed, first, to the smoothing of smaller scale waves in the relatively large searching volume of the Kyoto meteor radar and, second, to the less uniform temporal distribution of meteors at 82 km altitude.

Figure 4 also shows meteorological rocket measurements made at 1120 LT over Ryori (39°02'N, 141°50'E) located approximately 700 km northeast of the MU radar. Although MU radar observations did not overlap over the altitude range where the rocket measurements were carried out, the vertical profiles seem to show overall continuity.

In Figures 3 and 4 we notice that the amplitude of the vertical component was less than 2 m/s throughout the region and did not show distinct day-to-day variation. However, considerable day-to-day differences are recognized between horizontal wind profiles above 80-km altitude. The amplitudes of the zonal components were as small as 10–15 m/s on August 14, while they ranged from 30 to 60 m/s accompanied with a large wind shear at 80–90 km in the following day. The meridional component was generally southward on August 14 and became northward on August 15. In each wind component, small-scale fluctuations with short vertical wavelengths were superimposed on the mean profiles.

The oscillations with periods longer than 32 hours are plotted in Figure 5 for the zonal component detected from Kyoto meteor radar observations in the period August 9–20, 1984. The quasi 2-day oscillation seems to have been enhanced in the period of comparison observations, producing differences in background wind fields on August 14 and 15. The amplitude of the zonal component was thus small on the first day but became large on the following day.

## 5. CONCLUSION

We have deduced wind profiles in the mesosphere from both turbulent scatterings and meteor echoes for MU radar observations and Kyoto meteor radar measurements. Comparisons of the wind measurements among these different techniques showed fairly continuous vertical profiles in the 65- to 105-km region.

In this paper, we attempt to show the advantages of cooperative observations between the MU radar and the Kyoto meteor radar, with each system complementing each other. The MU radar can provide

wind fields at the 65- to 85-km altitude with high altitude resolution during daylight hours when turbulent layers are well developed. The MU radar can also measure the wind profile by using meteor echoes. However, it is not feasible to use the MU radar continuously over long periods only for observations of the mesosphere because of many demands on this facility for various kinds of measurements of both the middle and the upper atmosphere. Therefore it seems suitable to observe with the MU radar primarily the precise structure of temporal and spatial variations of wind fields for limited periods.

On the other hand, the Kyoto meteor radar can continuously monitor the wind field at 85- to 105-km altitudes at a relatively low cost compared with the MU radar operation, although the time-height resolution was considerably less than the MU radar and therefore less sensitive to the smaller-scale wind motions. The meteor radar observations are complementary to the MU radar observations in that they provide the fundamental state of synoptic scale wind motions such as mean winds, planetary waves, and atmospheric tides. The cooperation of both radars will be profitable in explaining the observed wind fields in terms of waves with various scales.

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