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Observation of Leonid meteor shower and middle/upper atmosphere with the MU radar in 1998 - 2001

By

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Abstract: Meteor trail and head echo observations during the Leonid shower periods have been carried out using the middle and upper atmosphere (MU) radar, Shigaraki, Japan (35N, 136E) since 1990 and 1998, respectively. In 1998, 1999 and 2001, peak activities of Leonid meteor showers were observed with the same observational set-up. Characteristics of the outburst in the three years are displayed. The wind velocity profiles between 80 and 100 km altitudes were simultaneously determined with 1 km height and 30 minutes time resolutions with underdense meteor echoes. Significant local time variations in the orders of day-to-day, and year-to-year of the wind velocity profile and wind shear are exhibited, as they would affect significantly the evolution of persistent train.

1. INTRODUCTION

Meteors can be observed with radars in two ways. One is due to scattering by ionized meteor trails and the other is by means of scattering at the ionized region surrounding a meteoroid, i.e., a meteor head. The former observation is called a classical meteor radar observation (or, meteor trail observation) and the latter is radar meteor head observation.

With the MU radar (middle and upper atmosphere radar), a large VHF (46.5MHz, 1MW) atmospheric radar in Japan, meteors are observed with both techniques. For the meteor trail observation, a broad antenna beam is utilized in order to collect meteor echoes from various directions (Nakamura et al. 1991). In case of meteors with high impinging speed such as Leonid meteors, usually meteors brighter than the magnitude of about +3 can only be detected due to a fast diffusion of the ionized trail for the faint meteors. On the other hand, the meteor head

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observation uses a high-gain pencil beam, and mainly detects meteors fainter than magnitude of about +10, because of limited field of view using the antenna beam with 3.7 deg in FWHP.

In order to observe the enhanced activities of Leonid shower as expected around 1998 - 2001, the MU radar has been operated around the Leonid stream period in every November with the same observational set-up for meteor trail echoes since 1990. As a result, significant shower activities in 1998, 1999 and 2001 have been recorded with the same instrument. In this paper, the activity of Leonid storm observed by the meteor trail echoes with the MU radar in 1998, 1999 and 2001 are summarized. Also the neutral wind velocities during the Leonid activity observed with the MU radar are reported and these effect on the persistent train is discussed.

2. OBSERVATION

The MU radar is a monostatic pulse Doppler radar for the measurement of atmosphere at the altitude between 2 km and 600 km. The characteristics of the MU radar are an active phased array antenna for fast beam steering and a flexible system design for various observation set-up by means of computer controlled hardware (Fukao et al. 1985a; Fukao et al. 1985b). Meteor trail observation during the period of Leonids with the MU radar has been started in 1990, under a collaboration between RASC, Kyoto University and National Astronomical Observatory of Japan. The basic set-up of the radar is described in elsewhere (Nakamura et al. 1991; Nakamura et al. 1997). For the Leonid observations, pulse width of 8 μs with 16 bit complimentary code and 2.56 ms inter-pulse period (IPP) have been used, yielding 1.2 km range resolution for each meteor observation. For the twelve years between 1990 and 2001, Leonids observation has been carried out for two to fourteen days every year.

On the other hand, meteor head echo observation with the MU radar from started in 1998 by applying a sequential beam lobing (SBL) method used for space debris observation (Sato et al. 2000). Furthermore, in 2000 the head echo mode with monopulse interferometry was developed and radiant of faint meteors (as faint as +15 magnitude) were observed with an accuracy of 0.5 degree (Nishimura et al. 2001). The head echo observation has been carried out intermittently during the Leonid periods in 1998 - 2001, by alternating the observation modes of meteor trail echo (45 min/hr) and head echo (15 min/hr).

Figure 1 shows the distribution of radiants observed by the meteor head echo observation at 0337 – 1052 LT (UT+9) on November 18, 2000 (Nishimura 2001). It is noteworthy that there was no significant concentration of radiants at the expected Leonid radiant (R.A. 153 deg, Decl. +22 deg) or around this direction. The result was similar to the SBL method in 1998 (Sato et al. 2000), which suggests that there are no as faint meteors as +10 magnitude or less in the Leonid shower. Therefore, in the following year, 2001, we did not carry out meteor head observation with the MU radar at the time of the expected meteor shower peak, in order to observe a detailed time variation of the shower activity.

3. LEONIDS ACTIVITIES IN 1998, 1999 AND 2001

Because of the high impinging velocity (72 km/s), the Leonid meteors are most easily observed as high altitude (e.g. > 95 km), strong SNR, and long lasting echoes. Therefore, when we extract such meteor signals, the majority would be the Leonid meteors. Figure 2 shows hourly meteor echo rate (HR) for different echo intensities and different heights. The variation of the strongest (> 45 dB) and the highest (> 95 km) corresponds to the activity

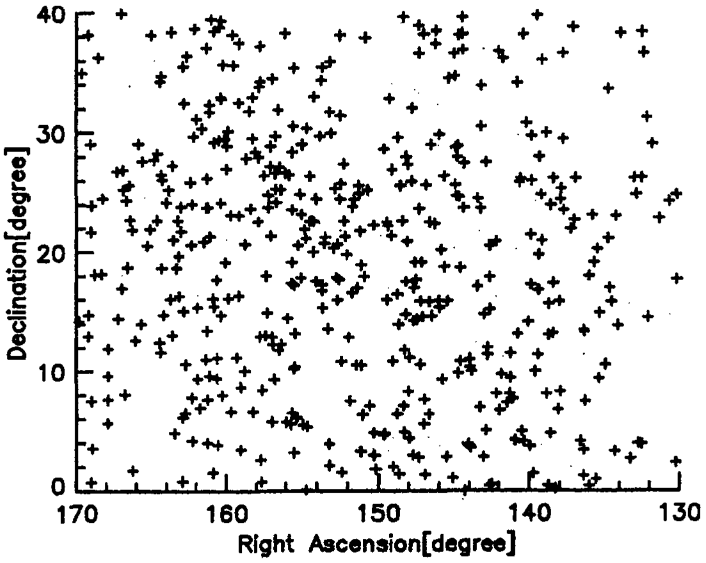

Fig. 1: Distribution of meteor radiant observed with the head echo mode of the MU radar on Novemver 18, 2000 (Nishimura 2001).

of Leonid meteor shower. As are seen in Figure 2, in 1998, a very strong activity with strong and high altitude meteors was observed between 06 and 11 LT on November 17 (21 UT on November 16 and 02 UT on November 17), which was about 20 hours earlier than the expected peak activity. At the same time, the significant activity was observed for long lasting (e.g. duration longer than 10 seconds) echoes.

In 1999, as shown in the middle panels of Figure 2, the significant shower activity was observed between 10 and 12 LT (01 and 03 UT) on November 18. The difference between the 1998 and the 1999 activities was that long lasting (> 10 sec) echoes were not conspicuous in 1999 and the strong echoes were not so significant, unlike the obserbation in 1998. Another difference was the duration of the storm activity. In 1998, the outburst lasted for more than 6 hours, while the peak activity lasted only around 1 hour in 1999.

In 2001, in the bottom panels of Figure 2, a very strong peak activity was found at 03 LT on November 19 (06 UT on November 18) for both strong and high altitude echoes. The outburst activity continued until 09 LT (00 UT). It is also noteworthy that the long lasting echoes were also outstanding in 2001. It is likely that in 2001 the echoes which are similar to 1998 (strong and long lasting) and those similar to 1999 (comparatively shorter and less strong) were both existent. The variation of the echo numbers suggests that the latter peak was around 03 LT and comparatively short (2 - 3 hours), but the former had a long enhancement if to 6 hours. Thus, our radar measurement indicates the most significant storm activity for both bright and comparatively fainter meteors were seen in 2001, than other years.

4. WIND VELOCITY AND WIND SHEAR

Figures 3, 4 and 5 show the zonal (eastward) and meridional (northward) wind velocity profiles determined every 30 minutes from the midnight (00 LT) to the morning (05 LT). For

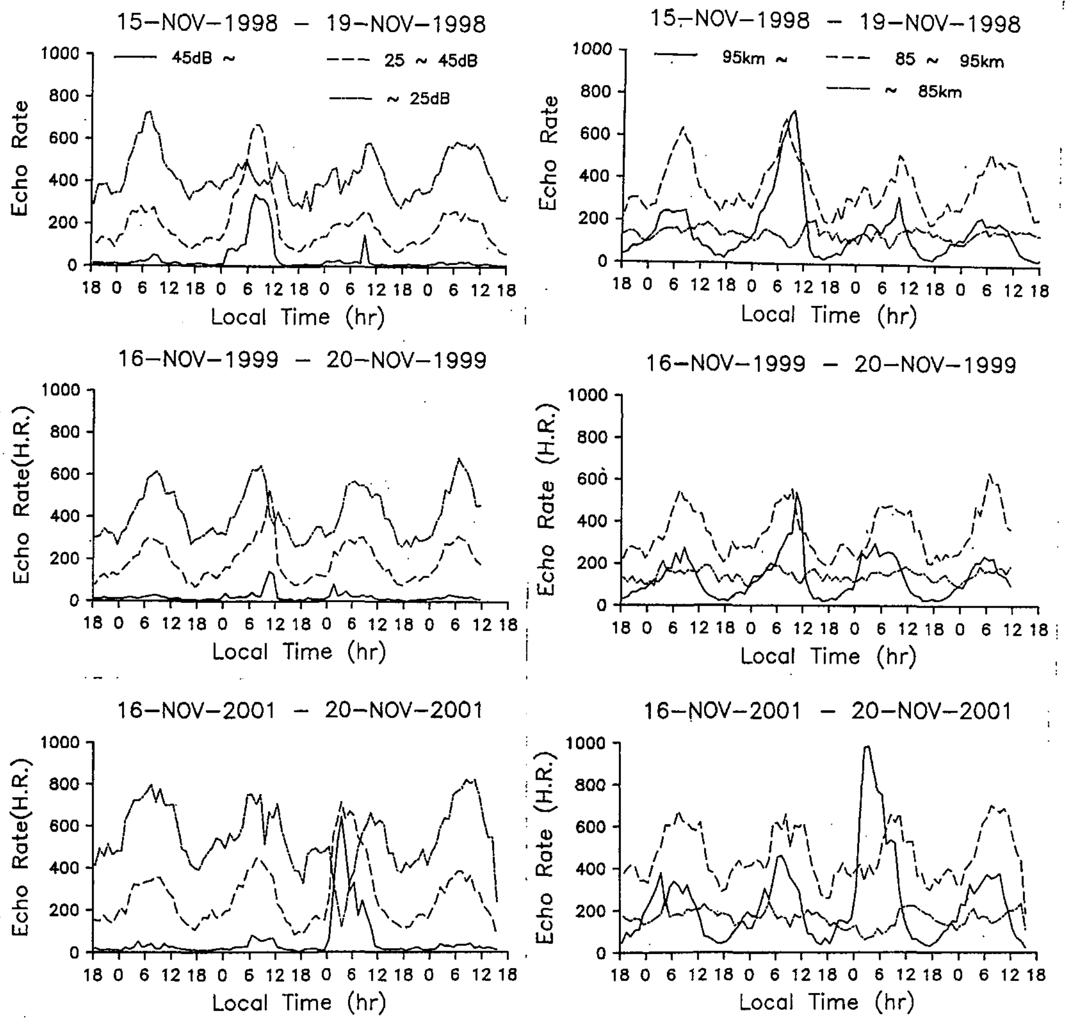

Fig. 2: Hourly rate of meteor echoes with the MU radar. The left panels show strong (> 45 dB SNR), medium (between 25 dB – 45 dB) and weak (< 25 dB) echoes, and the right panels show high (> 95 km), medium(between 85 – 95 km) and low (< 85 km) echoes. The top, middle and bottom panels correspond to 1998, 1999 and 2001.

each year of 1998, 1999 and 2001, the wind profiles of two nights including the night of the peak activity of Leonids were selected and plotted. The error bars are not displayed for all the profiles in order to avoid overlapping, but plotted only for the last profiles of the day (05 LT).

As seen in the profiles, wind velocities between 80 and 100 km altitudes could be determined from underdense echoes of meteors, of which the major part is due to sporadic meteors. In 1998, profiles on both November 17 and 18 show strong southward and westward wind shears (height variation of wind) between 85 and 95 km altitudes, where the persistent trains frequently appeared. The wavy structure of the wind velocity profile is interpreted as the existence of atmospheric tide (thermal tides) and gravity waves. The former wave is coherent and shows weak day-to-day variation, but the latter is not fixed to the local time and therefore the existence of the wave shows strong day-to-day variation. It is found that the amplitude of the wave structure was larger in November 18, and consequently the wind shear was larger,

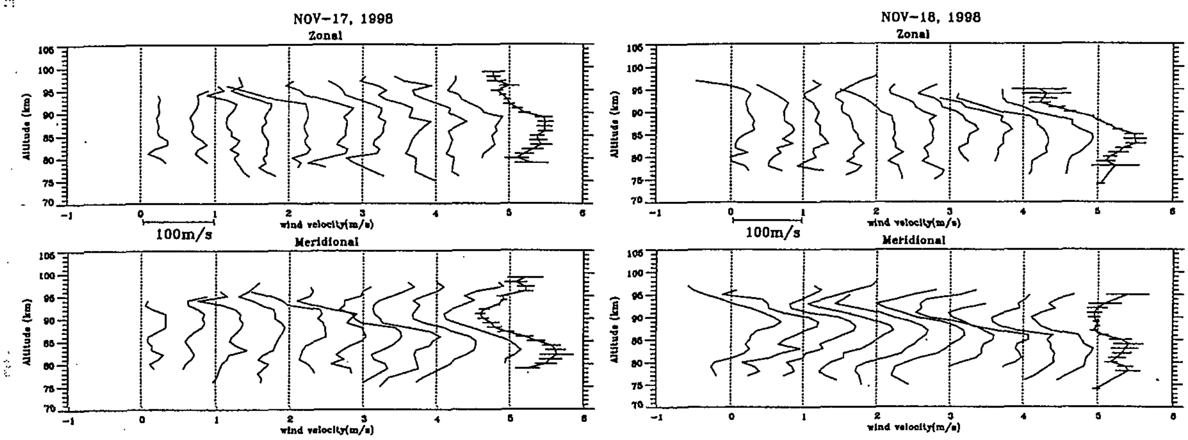

Fig. 3: Bihourly zonal (Top) and meridional (Bottom) wind profiles between 0 LT and 5 LT on November 17, 1998 (left) and November 18, 1998 (right).

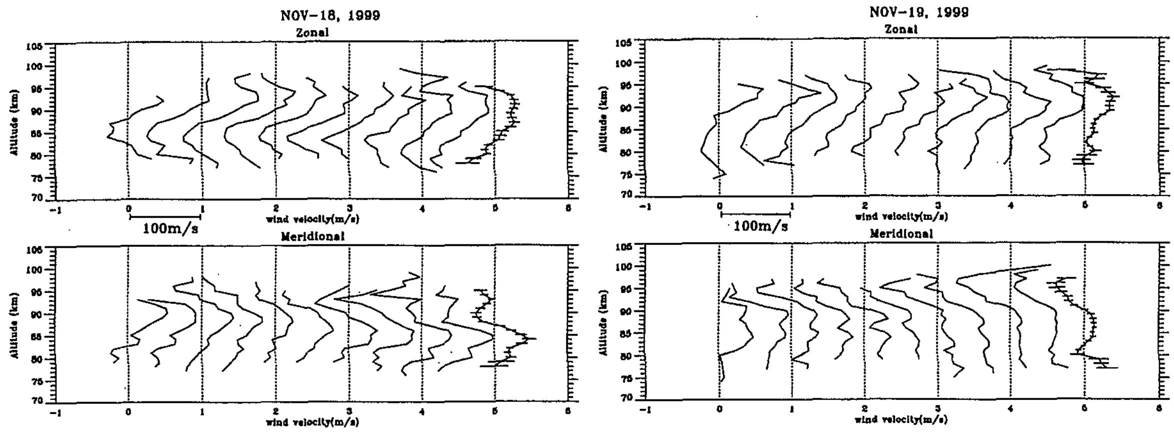

Fig. 4: The same as Figure 3 except for November 18, 1999 (left) and November 19, 1999 (right).

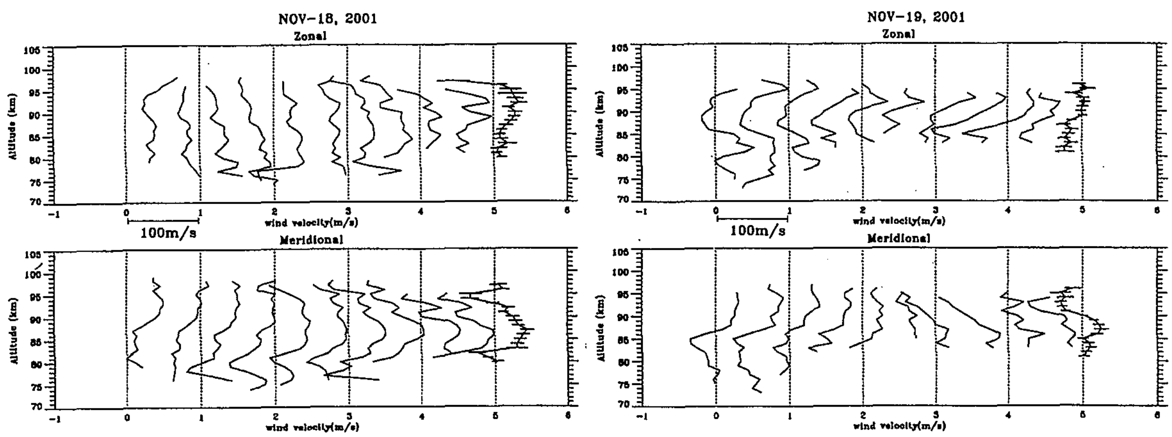

Fig. 5: The same as Figure 3 except for November 18, 2001 (left) and November 19, 2001 (right).

with the maximum wind shear of around 40 m/s. The morning of November 17 was the time when a severe storm with bright meteors were observed by the MU radar and other radars. At that moment, the sky condition was poor and optical observation of persistent trains was not successful. However, on November 18, the sky was clear over Japan and optical observation was successful. At 04:13 LT (UT+9) on November 18, a fireball which produced and a long lasting persistent train was observed from different sites near Mt. Fuji. The train lasted for more than 10 minutes and the shape was significantly distorted into a large spiral structure (Abe, S., private communication). Our wind measurement with the MU radar observed strong wind shear at around 86 – 90 km and this is consistent with the optical observation of the train by interpreting that the strong wind shear distorted the meteor trail significantly.

The profiles in 1999 was significantly different from the wind profile in 1998. First of all, the magnitude of wind shear was smaller in 1999 than in 1998. Furthermore, eastward wind shear was observed in 1999 between 85 and 95 km altitude, which was westward in 1998.

The wind velocities in 2001 again showed smaller wind shears than in 1998. On November 18, zonal wind shear was weakly westward, and meridional wind shear was first northward and then southward. On November 19, the preferential zonal shear was eastward, which was different from the previous night. On the other hand, the meridional shear was similar to the previous night, northward first and then southward afterwards. One characteristic of the wind profiles in 2001 was the existence of wavy structure with vertical wavelengths of about 5 km. Such small scale waves were not apparent in the other years.

Thus, we found that the wind velocity profiles are significantly different one year from another even around the Leonid shower period. Such a difference in wind profiles is important when we consider the formation of complicated shape of the persistent train. It is also possible that difference of the wind velocity profile may affect the duration of persistent train.

5. SUMMARY AND CONCLUSION

In this paper, we briefly summarized the activities of Leonid shower peaks in 1998, 1999 and 2001 observed with the MU radar, Japan. We found that the peak in 1998 was with bright fireballs and long (about 6 hours), while the peak in 1999 was rich in fainter meteors in visible light and lasted in a short periods (1 – 2 hours), as for the peak in 2001, it exhibited both types and durations (about 6 hours).

The wind velocity profiles during the Leonid periods were examined and we have found significant variation of the profiles such as intensity of wind shears (up to around 40 m/s/km at around 90 km), dominant vertical wavelength of wavy structure, etc. Such variations include day-to-day and year-to-year variations.

As significant numbers of persistent trains were observed during these several years for Leonid meteors, it would be of great interest, in future, to analyze such data by comparing with the wind profiles displayed here, in order to investigate dynamical effect of atmosphere on the persistent trains.

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