THE INFLUENCE OF THE ATMOSPHERE ON RADAR METEOR RATES

W. G. Elford.
Department of Physics, University of Adelaide,
South Australia. 5000

The majority of radio studies of meteors have been carried out at frequencies higher than 17MHz and most of the rate observation at frequencies above 30MHz. At these frequencies a severe height selection of meteors occurs. In Figure 1(a) are shown the normalized height distributions of sporadic meteors observed at Adelaide on frequencies of 27MHz and 2MHz (Brown, 1976). The sharp cutoff of the latter distribution below 87 km is instrumental. The difference in the height distributions is due to the effect of the finite diameter of a meteor trail on its radar detectability. If the trail diameter is $\ll \lambda$ signals from the near and far edges reinforce but as the trail expands due to diffusion and the diameter becomes $\sim \lambda/4$, interference reduces the amplitude. A meteor trail, produced by a particle with a velocity of 30 km s^{-1} , has an initial diameter of 0.4m at 80 km, 2.0m at 104 km and 4.0m at 116 km.

For typical meteor radar systems, ($\lambda \sim$ 4-10m), the maximum value of the radar echo and hence the probability of detection is strongly dependent on the diffusion coefficient. The probability falls off rapidly with increasing height. Only for long wavelength radars ($\lambda > 50$m) will the effect of initial diameter and diffusion on the detectability be negligible. Thus we interpret Figure 1(a) in terms of the inability of the 27MHz system to detect meteors above about 100 km.

Laboratory studies of the diffusion of electrons and ions in gases show that the diffusion coefficient, D, varies as T^2/p where T and p are the gas temperature and pressure. In the atmosphere a change in the temperature at a given level has a relatively small effect on the pressure which is a measure of the weight of the atmosphere above that level. Thus to a first order $\delta D/D \simeq 2\,\delta T/T$. The full range of values of δT is not known for the meteor region. However, the mean summer and winter temperature profiles can be obtained from the reference atmosphere CIRA-72 and the values for a latitude of 60°N are shown in Figure 1(b). At 90 km $\delta T/T = \pm .17$, so that $\delta D/D \simeq \pm .34$.

A reduction in temperature at the height where meteors form will

I. Halliday and B. A. McIntosh (eds.), Solid Particles in the Solar System, 101–104.

https://doi.org/10.1017/S0074180900066547 Published online by Cambridge University Press

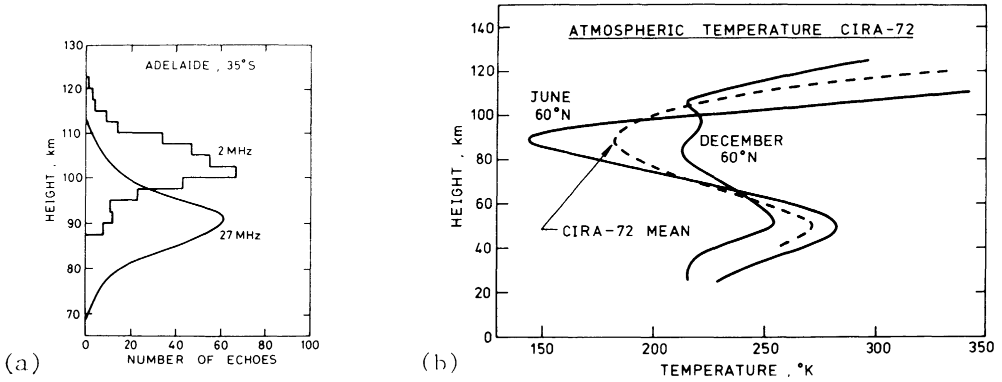

Figure 1. (a) Height distributions of radio meteors at 2 and 27MHz,
(b) Atmospheric temperature profile for 60° N, (CIRA-72).

thus reduce the rate of expansion of meteor trails so that the strength of the radar echo is increased and there is a greater probability of its detection. Further, a reduction in the diffusion coefficient increases the duration of the echo and hence increases the probability of the echo being detected by a pulse system. Thus a decrease in atmospheric temperature increases the radar meteor rate by inhibiting diffusion.

A further factor in determining the radar meteor rate is the distribution of ionization along the trail, which is also affected by the atmospheric temperature profile. The transformation of a given ionization profile from, say, an isothermal atmosphere to a summer or

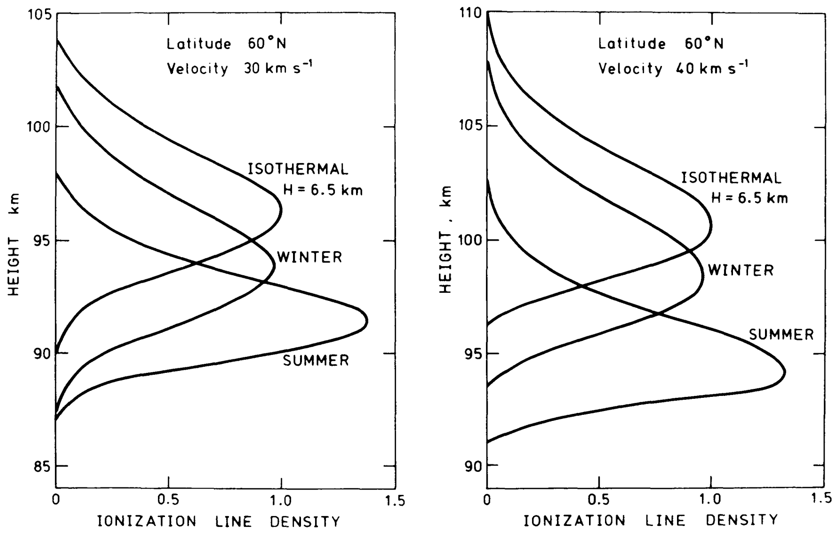

Figure 2. Ionization profiles in non-isothermal atmospheres.

https://doi.org/10.1017/S0074180900066547 Published online by Cambridge University Press

winter type atmosphere can be carried out exactly. The mass lost by a particle in reaching a particular level in the atmosphere depends on the pressure difference between that level and the start of the trail. In general, at the heights in two different atmospheres where an ablating particle has the same instantaneous mass, the air densities differ. The ratio of the ionization densities at these two heights is then given by the ratio of the atmospheric densities. Typical results are shown in Figure 2 for a latitude of 60° N and meteor velocities of 30 and 40 km s^{-1}. The analysis is quite general and does not require an assumption of constant velocity for the meteoroid and it also can take into account energy loss due to radiation. The radar detection probability analysis discussed earlier has been applied to the ionization profiles shown in Figure 2 and to similar profiles applicable to other latitudes. The results are theoretical height distributions of meteor echoes, and a typical example is shown in Figure 3 for the radar system at Christchurch, New Zealand (40° S).

The integrated radar rate is higher in summer than in winter, the ratio being 1.33 for $s = 2.0$ and 1.72 for $s = 2.5$, where s is the exponent in the mass distribution law. These values refer to meteors of velocity 30 km s^{-1}. For a velocity of 40 km s^{-1} the ratios are 10-15% larger. Thus the radar rate observed during the summer at a particular site will differ from that observed during winter without any change in the incident meteor flux.

The annual variation in the total meteor flux is symmetric about the equinoxes. A variation in the radar detectability from summer to winter will add a modulation to the incident flux and cause the autumnal maximum and spring minimum in the observed radar rates to

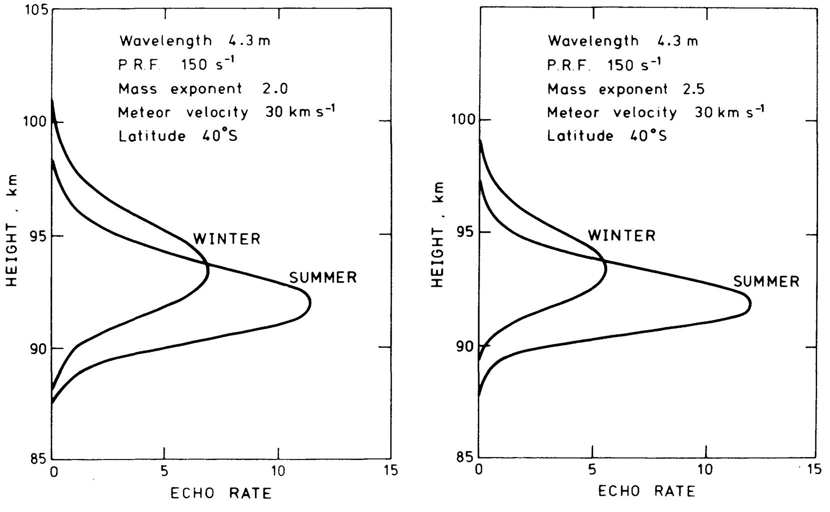

Figure 3. Height distributions of radar meteors.

https://doi.org/10.1017/S0074180900066547 Published online by Cambridge University Press

occur somewhat earlier than the equinoxes. Due to the presence of meteor shower activity the effect would be difficult to detect.

The variation in the atmosphere from summer to winter will also affect the heights of meteors with the same velocity. Thus a meteor shower occurring in summer or winter and observed simultaneously in both hemispheres should give different height distributions. Such a comparison is restricted to the relatively few low declination streams.

In addition to the annual change in temperature of the atmosphere it is now known that there is a significant daily variation. The incoherent scatter studies at St. Nancy, France and Millstone Hill, U.S.A. show that at heights between 105 and 130 km there is a semi-diurnal change of 50°K (Evans, 1978). The variation at a height of 90 km is not known but a value of half that at 105 km would have a significant effect on both heights and rates of radar meteors.

The mechanism described here could account for the radar meteor rate variations that correlate with solar activity(Lindblad, 1967, 1978), and also for the world-wide anomalous increase in rates in 1963 (McIntosh and Millman, 1964). The latter situation would have required a world-wide cooling at 90 km of the same magnitude as occurs between winter and summer at medium latitudes.

REFERENCES

Brown, N.: 1976, J. Atmos. Terr. Phys., 38, 83.
Evans, J.V.: 1978, Rev. Geophys. Space Phys., 16, 195.
Lindblad, B.A.: 1967, Space Res., VII, 1029.
Lindblad, B.A.: 1978, Nature, 273, 732.
McIntosh, B.A. and Millman, P.M.: 1964, Science, 146, 1457.

DISCUSSION

Reply to *Baggaley*: The 27 MHz radar is a continuous-wave system.

Reply to *Zook*: The synoptic year of meteor radar data of the Harvard-Smithsonian project was taken at a wavelength of about 8m. I believe that this body of data is very deficient in high-altitude meteors, and hence contains a relatively low proportion of high-velocity meteors.

https://doi.org/10.1017/S0074180900066547 Published online by Cambridge University Press