Earth, Moon, and Planets (2004) 95: 101–107
DOI 10.1007/s11038-005-9007-0

LATITUDINAL VARIATIONS OF DIURNAL METEOR RATES

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(Received 15 October 2004; Accepted 26 May 2005)

Abstract. The presence of a diurnal variation in meteor activity is well established. The sporadic meteor count rates are higher on the local dawn side and lower on the local dusk side. This phenomenon is caused by the Earth's orbital motion and rotation. Meteor radar measurements have been compared from Esrange, Kiruna, Sweden, at 68° N, from Juliusruh, Germany, at 55° N, and from Ascension Island, at 8° S, to investigate how the diurnal variation depends on season at different latitudes. Data have been used from vernal and autumnal equinoxes and summer and winter solstices to locate the largest seasonal differences.

Keywords: Diurnal rate, latitudinal variation, meteor, meteor radar, NEP

1. Introduction

The goal of this study is to investigate diurnal meteor rate differences at different latitudes. The diurnal meteor event rate is expected to differ between latitudes, with a larger seasonal variation at higher latitudes because of the tilt of the Earth's axis (Ceplecha et al., 1998). Meteor radar data from high, mid and equatorial latitudes have been compared.

Being located just north of the Arctic Circle, the Esrange meteor radar provides an interesting viewing geometry. The antenna points almost towards the North Ecliptic Pole (NEP), and hence in the same direction, once every day. The meteor rate in this measurement configuration is also discussed.

2. Radar Parameters, Sites and Observations

The data used for this study was recorded by a SKiYMet all-sky interferometric meteor radar at each site. Electromagnetic pulses are radiated at a high pulse repetition frequency by the transmitter. After reflection on ionization trails of incident meteoroids, the echo is received by an array of five receiver antennas acting as an interferometer. We should note that detection only occurs for meteor trails perpendicular to the radar beam direction. For a complete description of SKiYMet meteor radars see Hocking et al. (2001).

Meteor radar data from high, mid and equatorial latitudes have been used, Esrange at 67.9° N, 21.1° E, Juliusruh at 54.6° N, 13.4° E, and Ascension Island at 8.0° S, 14.4° W, respectively. The Esrange and Ascension Island meteor radars operate at a frequency of 32.50 MHz in the 70–110 km height range. The corresponding figures for the Juliusruh radar are 32.55 MHz and 78–120 km. This radar was transferred to Andøya, Norway, in September 2001.

Data analyzed is from August 1999 to March 2004 for Esrange, from November 1999 to August 2001 for Juliusruh and from May 2001 to November 2003 for Ascension Island. We have chosen 5 days of data around each vernal/autumnal equinox and summer/winter solstice for all three meteor radars. The naming of the seasons applies to the northern hemisphere throughout the paper. Rejecting ambiguities, the mean diurnal meteor rate was calculated. The data sometimes contains many detections from the same meteor trail. Calculations of the time difference between consecutive meteor registrations show a large overweight on times between zero and 0.1 s and many of these detections have practically identical zenith and azimuth angles. Thus, we have defined ambiguous meteor registrations as those detected less than 0.1 s apart and have both azimuth and zenith angles within two degrees from each other. About 85% of these detections have indistinguishable time stamps. The method we have used to determine the sporadic meteor sources visible to the radars is described in Morton and Jones (1982).

3. Seasonal and Latitudinal Variations

The existence of a diurnal variation in meteor rates has already been described by Lovell (1954).

The seasonal diurnal meteor event rate variations at the three radar sites are shown in Figure 1. The shape of the diurnal meteor rate at equatorial latitudes is fairly constant throughout the Earth's orbit. At high latitudes, however, the 23.5° tilt of the Earth's axis makes the radar tilt towards or away from the sporadic meteor sources. The higher the latitude, the larger the effect. The characteristics of the sporadic meteor sources are described in,

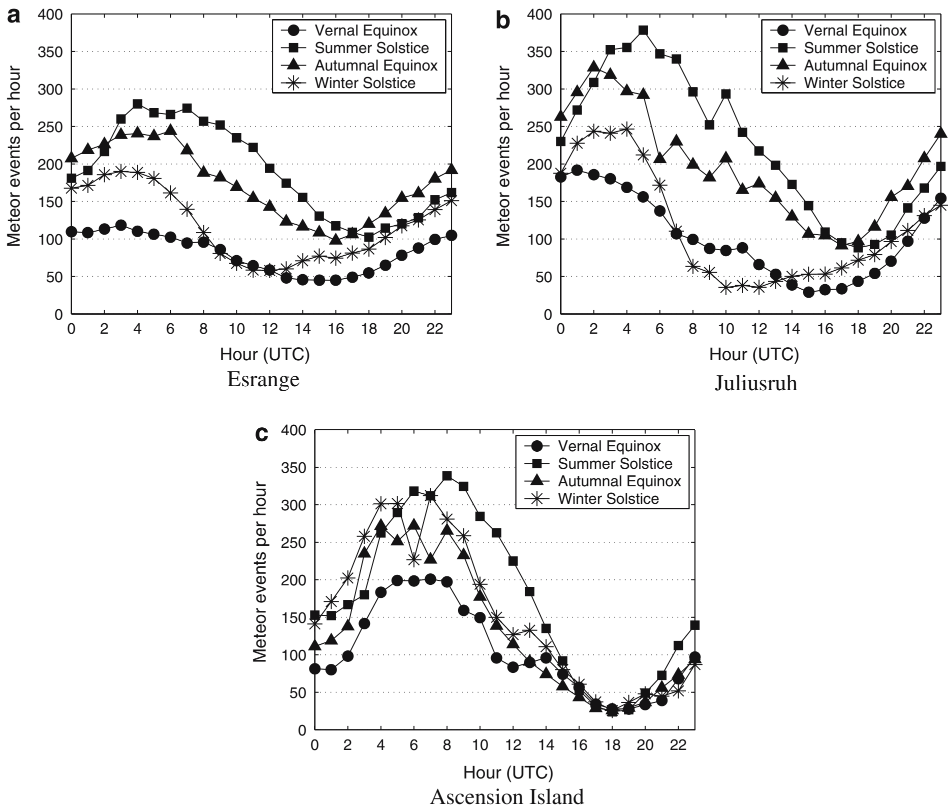

Figure 1. Average vernal/autumnal equinox and summer/winter solstice diurnal rate over all data available for (a) Esrange, (b) Juliusruh and (c) Ascension Island.

e.g., Jones and Brown (1993). A similar study on the diurnal and seasonal variability of the meteoric flux has also been conducted at the South Pole (Janches et al., 2004).

The vernal equinox diurnal meteor event rate at Esrange is very low at all hours and the rate fluctuation has small amplitude (Figure 1a). The meteor radar at Juliusruh also shows a low diurnal event rate at vernal equinox, Figure 1b, but higher amplitude than at Esrange. Figure 1c shows the diurnal rate on Ascension Island. The vernal equinox diurnal rate curve has lower amplitude than the other three curves, which have comparable amplitudes. This implies that the meteoroid distribution is not homogeneous. It appears to be less dense in the first half of the year, which has been pointed out by, e.g., Lovell (1954).

At summer solstice the diurnal rates at both Esrange and Juliusruh have higher amplitudes than at vernal equinox. Compared to the winter solstice rates, the rates are higher at summer solstice.

Figure 1a shows that the meteor rate at autumnal equinox at Esrange is high at all hours. The same is true for Juliusruh, but there the fluctuation amplitude is higher (Figure 1b).

The plots in Figure 2a–d are ordered by season. Figure 2a shows the vernal equinox meteor rate curves for all three radars, Figure 2b shows the summer solstice curves, Figure 2c the autumnal equinox curves and Figure 2d the winter solstice curves. The meteor rate at Esrange seems to have the lowest amplitude. At the same time as the maximum flux is the lowest at Esrange, the minimum flux is the highest at the same latitude.

The interferometric properties of the meteor radars have been used to visualize the sporadic meteor sources. Since the diurnal variation in meteor flux differs between latitudes and also seasons, we do not expect that the sources seen by the three radars are identical. The visibility of different sources also varies during the day, but only the seasonal differences are discussed here.

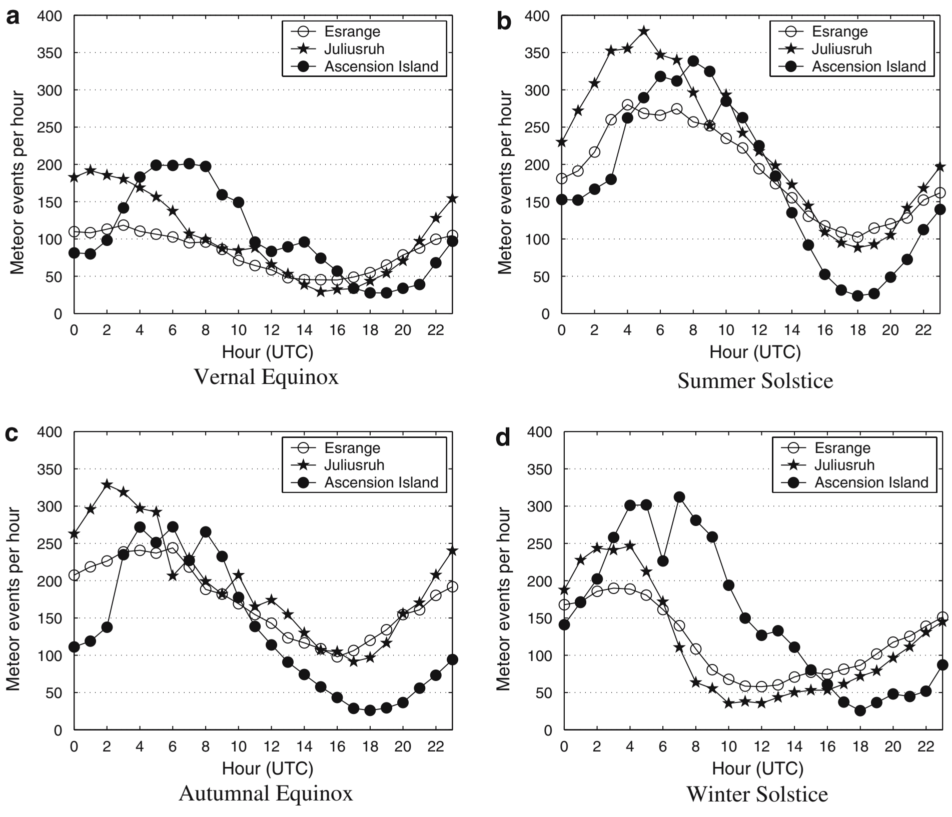

Figure 2. Diurnal meteor event rate at (a) vernal equinox, (b) summer solstice, (c) autumnal equinox and (d) winter solstice at different latitudes.

At vernal equinox the north pole of the Earth's axis is tilted opposite to the motion of the Earth. The sources seen by the Esrange meteor radar are mainly the north toroidal one, while the meteors detected at Juliusruh primarily come from the antihelion. Ascension Island sees a greater variety of sources, namely the helion (highest rate), the south apex, the antihelion and the south toroidal (lowest rate). The north toroidal can also be seen indistinctly.

At summer solstice, when the Earth's axis is tilted towards the Sun, all three meteor radars show similar source distributions. All radars show a high meteor rate at about the helion source, the peak being broadened towards the radiant of the Arietid shower, 7° N ecliptic latitude and 330° sun-centered longitude. No other sources can be seen in Esrange or in Juliusruh data, but Ascension Island data also show the antihelion source.

At autumnal equinox the direction of the tilt of the Earth's axis is opposite to the vernal equinox; the axis is tilted towards the motion of the Earth. The source distribution is different from the previously described ones in the sense that the Esrange meteor radar now sees the north apex as the strongest source, but the helion source is also visible. The strongest of the sources at mid-latitude is the antihelion one, but both the (north) apex and the helion sources are clearly distinguishable. The Ascension Island meteor radar sees primarily helion source meteors, but the detections also contain apex and antihelion meteors and some south toroidal ones.

At winter solstice, the Earth's axis is directed away from the Sun. The strongest source seen with the Esrange meteor radar seems to be the antihelion, but the north apex is also present. The Geminid meteor shower is also discernable at 12° N ecliptic latitude and 210° sun-centered longitude. The Geminids are also distinguishable in the Juliusruh data, which are quite similar to the Esrange data with the antihelion and north apex as the visible sources. The Geminids are only vaguely distinguishable at Ascension Island; the dominating sources are the north and south apex, the helion and the antihelion.

4. North Ecliptic Pole Geometry

Being located less than two degrees north of the Arctic Circle, the Esrange meteor radar points almost towards the NEP once every day. Hence, in this particular position the antenna always points perpendicular to the ecliptic plane. It should therefore picture the northern hemisphere meteoroid flux around the Earth's orbit as the source configuration is identical with respect to the radar. A similar study was done by Singer et al. (2004) for the Andøya meteor radar in Norway.

Taking the meteor flux for the hour closest to the NEP passage each day, Figure 3 shows the monthly average meteor rate for August 1999 to March

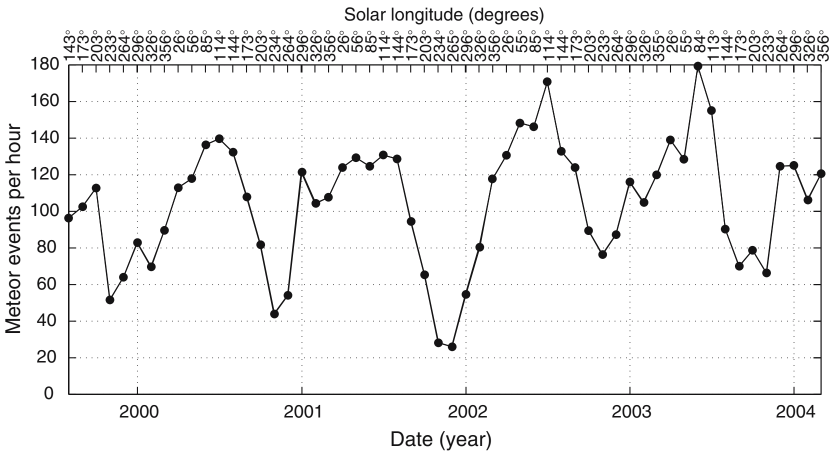

Figure 3. Monthly mean of the meteor rates with the north ecliptic pole (NEP) close to zenith at Esrange for the years late 1999 to early 2004.

2004. If the meteor flux were homogeneous, the meteor rate would be constant. However the flux is lower in winter than in summer, in agreement with Lovell (1954). The most prominent sporadic source is the north toroidal one during the first half of the year, and the north apex during the second half.

5. Conclusions

The largest difference in amplitude of the diurnal flux variation (from morning to evening) is at equatorial latitudes and is almost the same throughout the year. The lowest diurnal flux variation can be found at polar latitudes, where our observations show the highest degree of seasonal variation of the diurnal flux.

Radars at different latitudes see different sources. The sources also vary at different seasons.

Future work should include calculations on the collecting area of each radar for each sporadic source. Such a study would be useful in studying the strengths of the sporadic sources.

Acknowledgements

Two of the authors are financed by the Swedish National Graduate School of Space Technology. These authors gratefully acknowledge the additional financial support provided by the LOC of the Meteoroids 2004 Conference, London, ON, Canada. We thank M. Campbell-Brown for valuable comments which have improved this paper.

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