The Effect of Variable Directions of Viewing on the Interpretation of Diurnal Variations Observed by Neutron Monitors

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Abstract

Conventional interpretations of the Cosmic Ray Diurnal Variation generally assume that the mean viewing direction of the stations concerned remains constant over each 24-hour period. At the lower end of the energy range to which ground-based neutron monitors respond, two effects combine to question the validity of this assumption. Firstly, distortion of the geomagnetic field by the solar wind causes the direction of viewing of a ground-based station at a specified energy to vary according to the local time-of-day. Secondly, there is a seasonal effect due to the tilt of the earth's rotation axis. At lower energies and some stations both these effects can be significant. Furthermore, the directions of viewing are also affected by the degree of disturbance in the geomagnetic field. We report here the results of calculating the directions of viewing for Mawson at representative neutron monitor energies for each three-hour period throughout 1999, using the Tsyganenko model of the geomagnetic field and the appropriate value of Kp for each period, and discuss how these results affect the interpretation of the observed diurnal variation.

1. INTRODUCTION

Initial studies of the diurnal variation (eg [7]) unavoidably assumed that the viewing direction of each neutron monitor used in the analyses remained constant throughout the period under review. Later analyses have tended to follow the same path, although variations in directions of viewing have been the subject of a number of papers (eg [3]).

Viewing directions are determined by the configuration of the magnetosphere and are therefore sensitive to time-of-day (the magnetosphere is compressed on the day side by the solar wind and is extended on the night side), to time-of-year (the sub-solar point oscillates between the tropics of Cancer and Capricorn during the year) and to the level of magnetic disturbance. As a preliminary study we have used the Tsyganenko [8] model of the geomagnetic field

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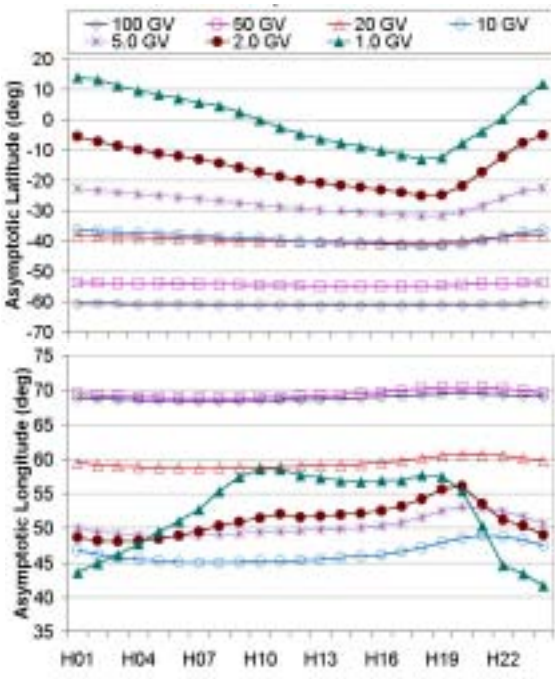

Fig. 1. Calculated hourly average asymptotic directions for Kp = 1.

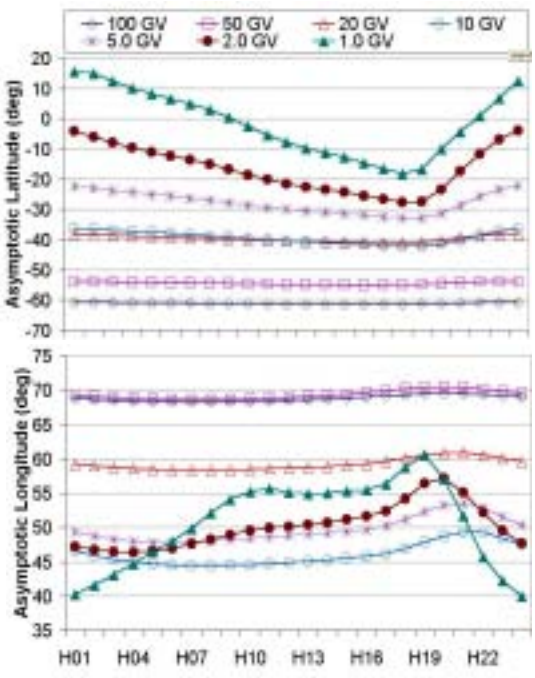

Fig. 2. Calculated hourly average asymptotic directions for observed Kp.

to calculate the asymptotic directions of arrival at the magnetopause of particles arriving vertically above the Mawson neutron monitor for each hour of 1999, using firstly an assumed Kp of 1 and then the actual value of Kp reported for the hour. These calculations have revealed that the magnetospheric configuration is a noticeable determinant for the asymptotic directions of arrival for primary cosmic rays having rigidities below ∼10 GV and becomes significant below ∼5 GV.

2. RESULTS

Broadly, for a given solar diurnal anisotropy the asymptotic latitude of arrival of primary particles affects the amplitude of the diurnal variation observed at a station whereas the asymptotic longitude affects the local time of maximum of the diurnal variation. Fig. 1 shows the annual average values of these quantities calculated for Mawson throughout 1999 for an assumed Kp of 1. Fig. 2 shows the same information but calculated using the values of Kp observed for each hour. All the figures show that the majority of the magnetospheric effects occur at rigidities below ∼5 GV. Neutron monitor yield functions reveal that only about 5% of the counting rate of a neutron monitor observing a flat spectrum variation arises from particles with rigidity below 5 GV. The solar diurnal anisotropy has only slight, if any, rigidity dependence ([5] and references therein) and therefore the calculated

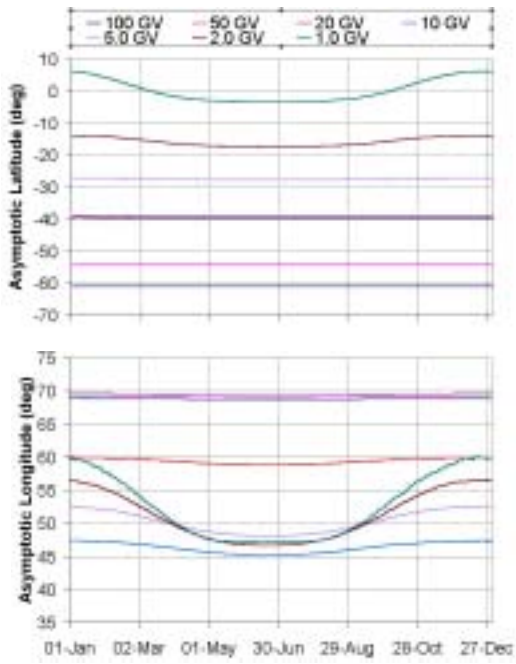

Fig. 3. Calculated daily average asymptotic directions for Kp = 1.

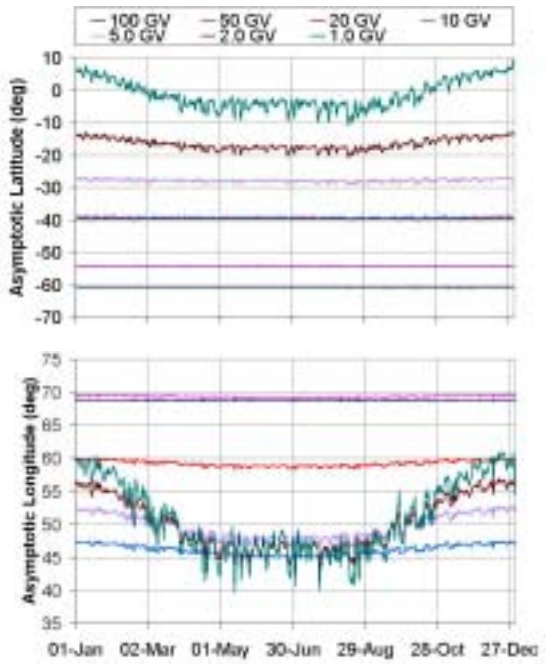

Fig. 4. Calculated daily average asymptotic directions for observed Kp.

changes in asymptotic direction through the day appear to be insufficient to have large effects on the interpretation of observed diurnal variations at Mawson. This assumption remains to be checked for particles arriving at inclined directions.

However a second issue arises. Figs. 3 and 4 show the daily mean asymptotic latitudes and longitudes calculated for Mawson for each day of 1999, again for Kp = 1 and for the observed Kp. There are considerable and systematic variations in the daily-mean asymptotic latitude of arrival of low-rigidity particles during the year. This will interact with the normal solar diurnal variation to produce a spurious variation in sidereal time, which in turn may have a significant input into calculations of radial and perpendicular gradients. Investigation of the magnitude of this effect has not yet been undertaken.

3. CONCLUSION

For long term studies of the solar diurnal variation it may not be necessary to go to the trouble of computing arrival directions for each hour of data. However this is not yet proven for studies of the radial and perpendicular gradients that rely on sidereal and solar time analyses [1, 2, 4, 5, 6].

4. REFERENCES

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