Cycle-to-Cycle Changes in the Diurnal Variation of Galactic Cosmic Rays

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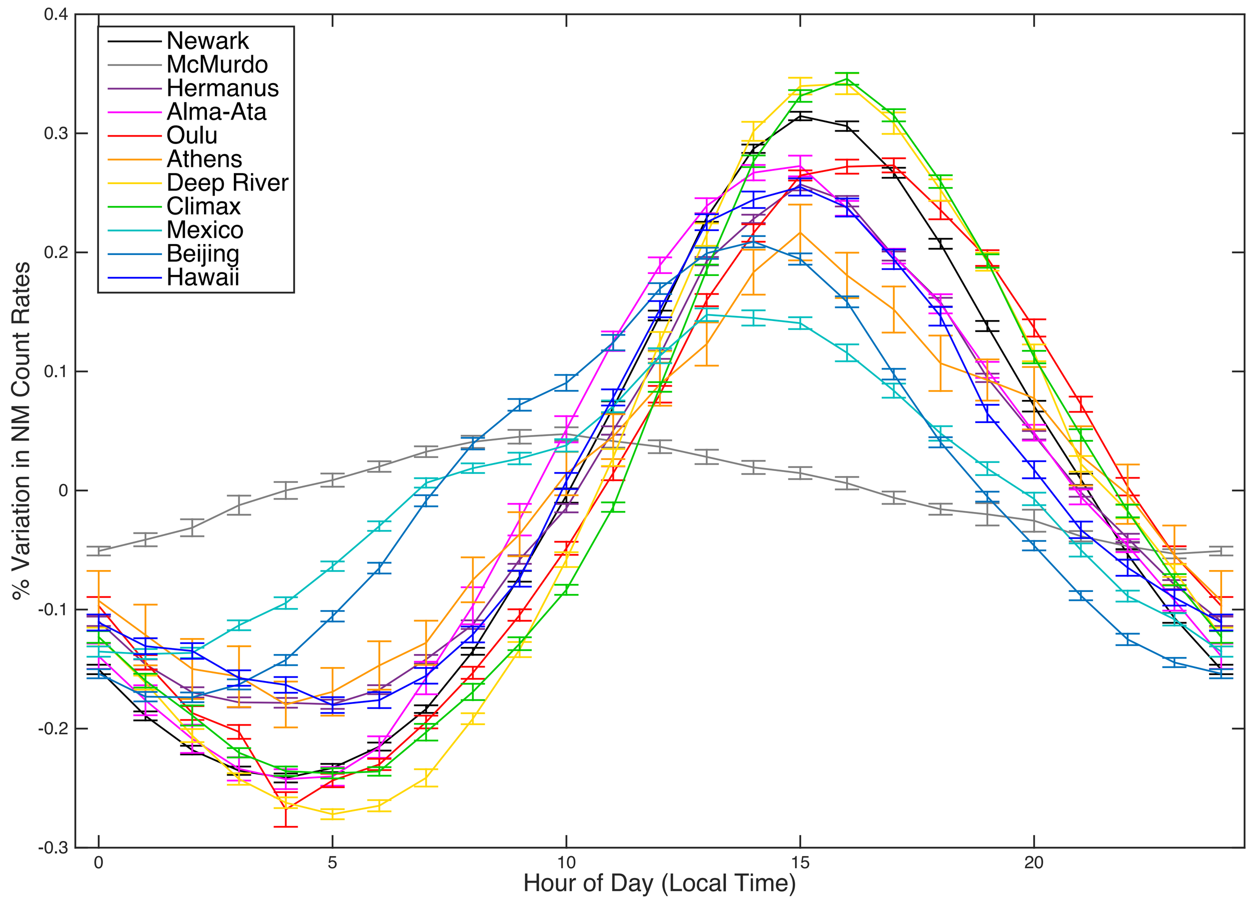
1. Introduction to the Diurnal Variation

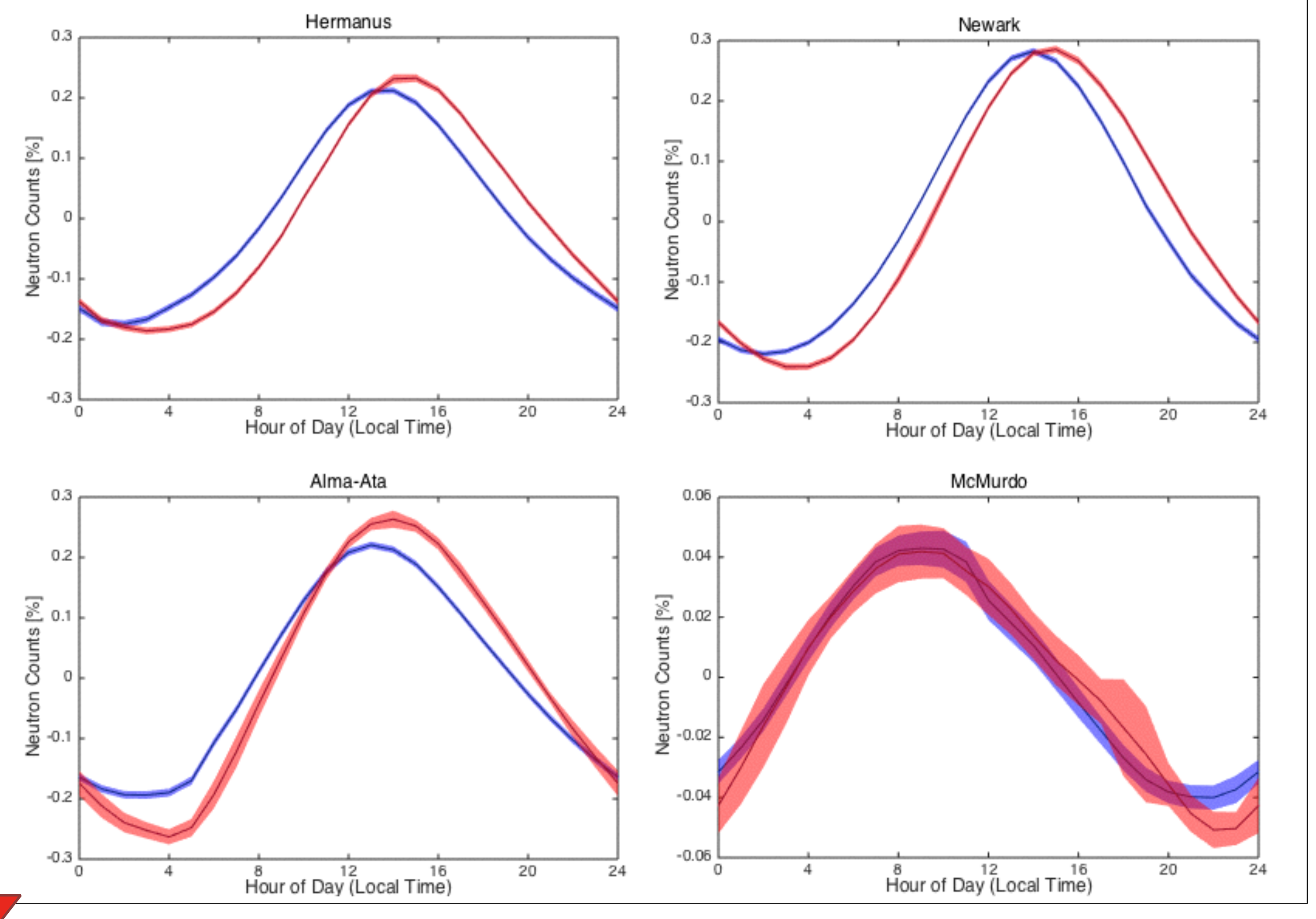
Galactic cosmic rays (GCRs) are high-energy charged particle from outside of our solar system. In the atmosphere, they interact with air molecules and provide a cascade of secondary particles. Neutrons are one such secondary and are detected by neutron monitors around the globe. Neutron monitor (NM) count rates (a good proxy for GCR flux incident in the atmosphere), frequently display a diurnal variation. By taking the mean daily variation of count rates for a large selection of NMs, we observe a peak in this variation between 2-5pm, as seen in the figure below. Some NMs, for example McMurdo (Antarctica), have a wide range of acceptance angles into the heliosphere due to their polar locations and so do not show the same observation.



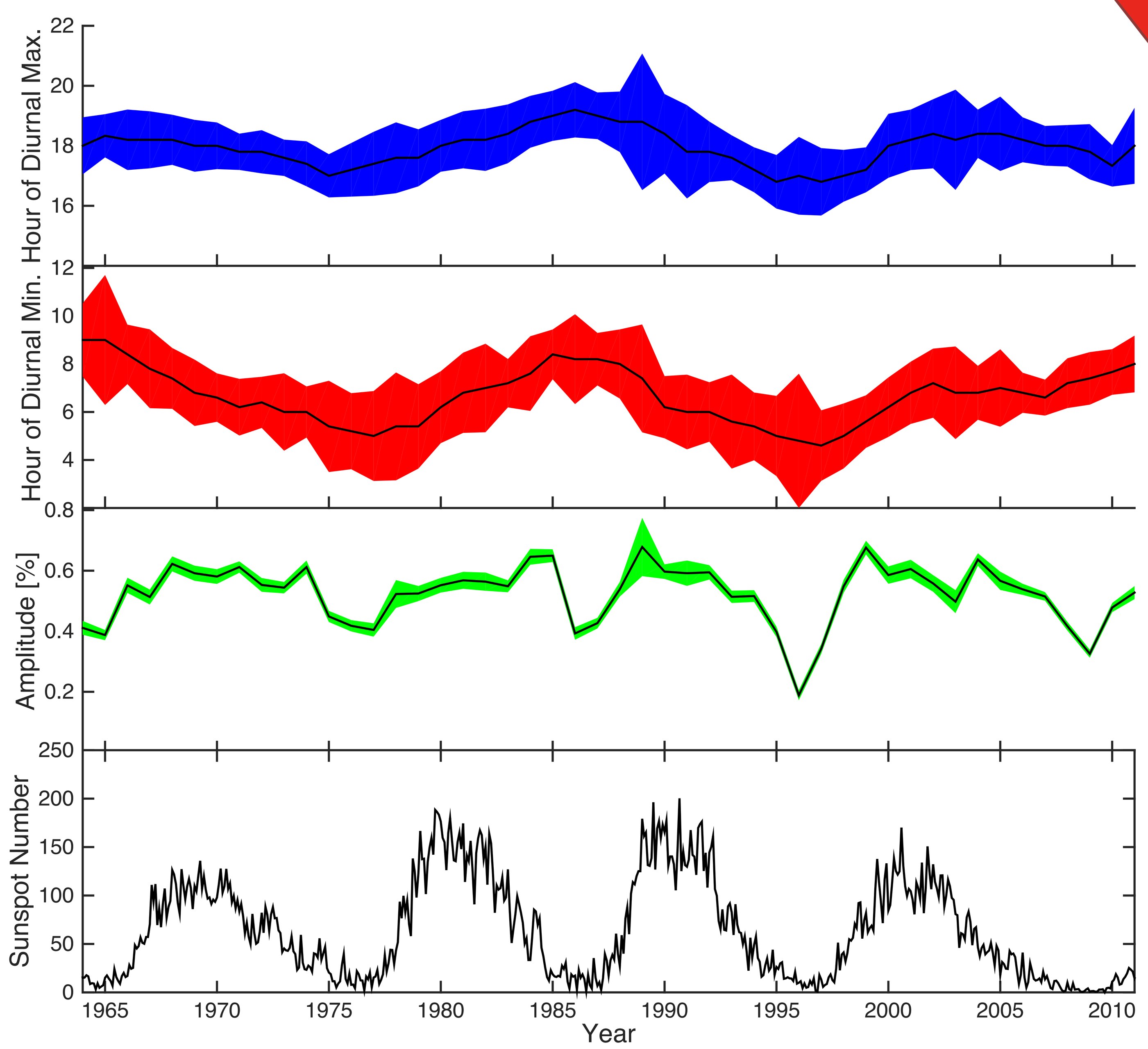
2. Changes with Heliospheric Polarity

At approximately solar maximum, the Sun reverses magnetic polarity. This has the implication of changing the dominant trajectories taken through the heliosphere by GCRs via particle drifts. The entire length of each NM's data series is split by whether the dominant solar polarity was positive (A>0) or negative (A<0) using polarity reversal times from Thomas et al. (2014). The variation in solar magnetic polarity for Hermanus (South Africa), Newark (USA), Alma-Ata (Kazakhstan) and McMurdo (Antarctica) is displayed in the figure on the right.

Each of the first three NMs show show a delay in the hour of maximum count rates of 1-2 hours between A>0 and A<0 cycles. McMurdo has a slight delay, only pronounced in the minimum of the variation, where a difference in amplitude is also observed. There is only small changes in the amplitude of the other NMs. By comparing with solar wind parameters (not shown) we find that this effect is not due to changes in the solar wind. This, is likely due to the different cosmic ray drift patterns between A<0 and A>0 cycles (Jokipii et al., 1997).



3. 22-Year Variations in Maxima/Minima Times

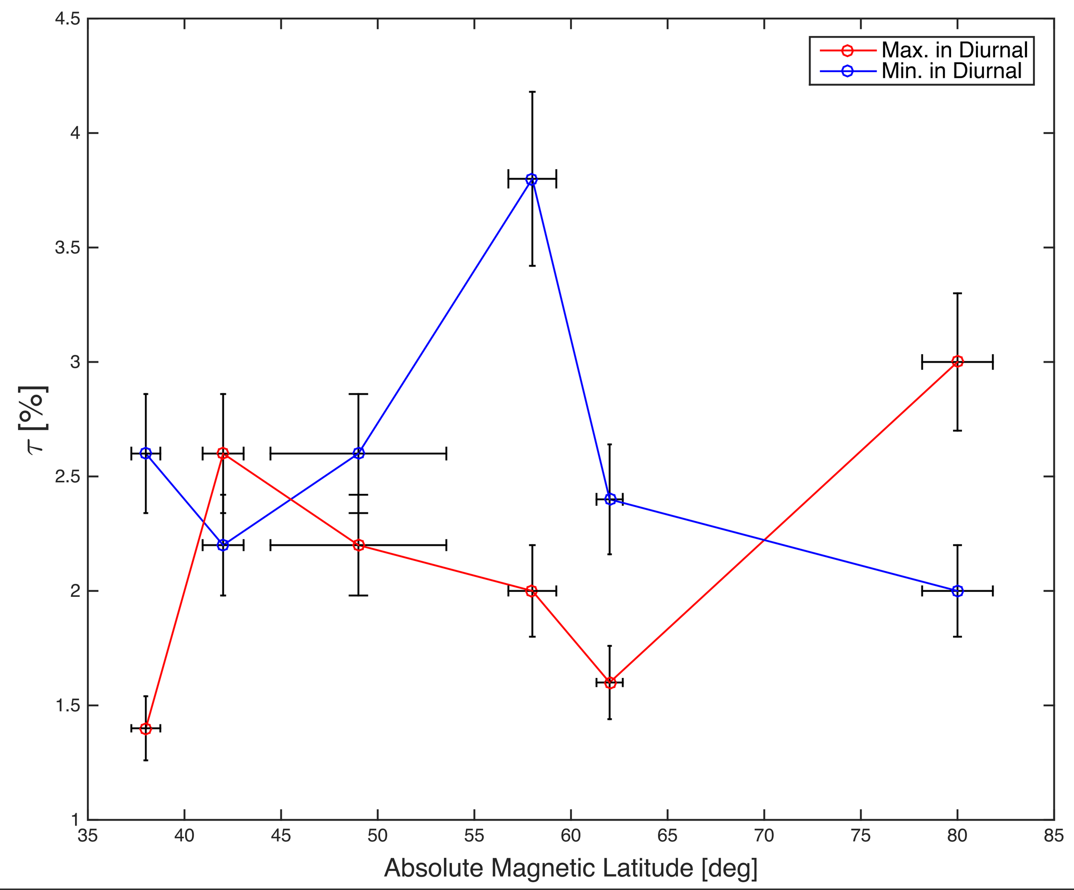


We now compare how the timings of the maxima and minima of the diurnal variation have changed over the time-spans of each of the neutron monitor data series. The figure on the left shows time-series of the yearly time of maxima (blue) and minima (red), the amplitude of the variation (green) and the international sunspot record (black), here used as a proxy for solar activity. The uncertainty is taken to be the width of the diurnal peak at a height of the maximum mean NM count rates. The amplitude is calculated as the difference between the maxima and minima of the daily, NM count rates for each year, which are normalised to account for long term changes in GCR flux.

Both the maxima and the minima times vary in a 22-year cycle, confirming the results of Bieber & Chen (1991). The maxima and minima are also in phase with both of the peaks and the troughs of the 22-year cycle occurring later in the day during the solar minima in the late 1980s and earlier during the solar minima of the late 1970s and 1990s. The solar minimum of the late 1960s is slightly different, with a much larger shift towards a later minimum in the diurnal variation than a later maximum. The latest hour of the maximum/minimum in the variations had not been reached as of 2012 in this figure, which could be symptomatic of the unusual behaviour of the Sun during this period (e.g. Barnard et al. (2011).

4. No Change with Magnetic Latitude of Station.

For each neutron monitor, the magnetic latitude is calculated from its co-ordinates and the current geomagnetic field using the international geomagnetic reference field model. The figure shows the absolute magnetic latitude of each NM used in the study against the absolute change in the time of the NM count rate maximum between A<0 and A>0 cycles, denoted τ_p (red in Figure 6) and the change in the minimum time, denoted τ_t (blue). To calculate τ_p and τ_t, we find the latest time of the maximum in the DV between 1980 and 1990 (when the peak occurred at the latest time of the whole time-series shown in Figures 3 - 5) and subtract the earliest time of the maximum between 1970 and 1980 (the earliest peaks in the time-series). We find no latitudinal trend in τ but that maximum and minimum timings vary opposing in time-of-day.



Acknowledgements

We thank the Bartol Research Institute of the University of Delaware for the neutron monitor data from McMurdo and Newark, which is supported by NSF grant ATM-0527878, the University of Oulu for the Oulu neutron monitor data, and the Ionosphere Institute of Kazakhstan Republic for the Alma-Ata neutron monitor data. This work was supported by a STFC grant supervised by Prof. C. Owen.

References

1 - Barnard et al., 2011, Geophys. Res. Let.
2 - Bieber & Chen, 1991, Ap. J.
3 - Jokipii, Levy & Hubbard, 1977, Ap. J.
4 - Thomas, Owens & Lockwood, 2014, Sol. Phys.

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Conclusions and Summary

We investigate the mean diurnal variation of GCR flux using the global neutron monitor (NM) network. We divide all NM data between times when the dominant solar magnetic polarity was either positive and negative. We find that the diurnal variation changes phase by 1-2 hours between the two polarity states for all non-polar NMs. Polar NMs, such as McMurdo, show little variation in phase due to the wide range of longitudes over which GCRs can arrive around polar regions, but do show differences in the amplitude of the cycles. Our results confirm the presence of a 22-year variation in the phase of the diurnal variation. However not all NMs show the same trend. An analysis of the magnetic latitude dependence of the diurnal variation shows that the time-of-day of the peak and trough of this variation gives opposing changes in the amplitude of the 22-year change. This could be explained either by changes in galactic cosmic ray drifts through the heliosphere between the two solar polarities.