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# Anomalies in Daily Anisotropy During the Transition Period of Solar Cycles 24 and 25

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**Abstract:** ***The behavior of the diurnal variability of cosmic rays during the transition period of solar cycles 24 and 25 have been investigated in the present study. Cosmic ray anisotropy exhibited a characteristic feature from 2018 to 2021 at the end of solar activity cycle 24 and the beginning of solar cycle 25; characterized by a remarkably reduced diurnal amplitude and an unconventional low - phase distribution. Observations were carried out using data from eight neutron monitors with 2.0 to 7.0 GV cut - off rigidity over a long period of five and a half solar cycles. Significant discrepancies were observed in the amplitude and phase of the first harmonic of cosmic ray variation. The GCR modulation during solar minima 24/25 differs significantly from previous solar minima in several respects, particularly in terms of the low number of sunspots, weak interplanetary magnetic fields, and turbulence. According to the analysis, this anomaly is observed throughout various rigidities and latitudes, implying a global impact.***

**Keywords:** Cosmic rays, Diurnal anisotropy, Solar polar magnetic field, Polarity Reversal

## 1. Introduction

The Sun is the primary controller of the heliospheric structure and manages solar activity levels. It has a significant impact on the speed and strength of the solar wind and the distribution of cosmic ray flux in space [1]. It would be interesting to compare changes in the intensity of cosmic ray radiation during the ascending and descending phases of various solar cycles and polarity sun's magnetic field as well. Comparative analyses of diurnal anisotropy in various solar activity cycles can significantly enhance our understanding of solar dynamics and their implications.

Galactic cosmic rays (GCRs) traversing through space and approaching the heliosphere are characterized by various cyclic modulations because they encounter an outward - moving turbulent solar wind in the IMF. As the sun's activity begins to change from one cycle to the next, the modulation of cosmic rays is expected to change during the transition period between the two solar cycles. These findings provide important inferences for our understanding of the level of the Sun's activity that can inform future space weather.

The amplitude of diurnal variability of CRs exhibits an correlation with 11 - year solar cycle, whereas, the phase is correlated with the 22 - year Hale cycle [2], [3]. These observations support the incorporation of gradient and curvature drifts in the theory of cosmic ray transport within the heliosphere [4]. Phase also depends on cut - off rigidity, as the cut - off rigidity increases, the phase tends to appear towards earlier directions [5].

Solar cycle 23 exhibits exceptional behaviour characterized by an extended and deep minimum phase [6], [7]. This cycle lasted for 12.3 years, starting in August 1996, and ending in December 2008. Solar Cycle 24 was marked by an unusual calmness, characterized by notably low sunspots numbers, remarkable flat Heliospheric Current Sheet (HCS) and a quiet state of the interplanetary magnetic field and its turbulence [8]. [9] that Solar Cycle 25 (SC - 25) will likely be as feeble as SC - 24. They suggest that the Sun has probably entered a secular minimum period, on the basis of historical data, this phase is expected to last for two more cycles, namely SC - 25 and SC - 26.

The GCR flux was high during the transition from SC - 23 to SC - 24 [10], which was marked by a deep and long minimum [11]. From October 2005 to May 2010, there were 817 days with no sunspots and a record number of 801 less sunspot days [12], which was the coolest and weakest in terms of solar wind and magnetic field in the last four cycles [13]. However, Solar Cycle 24 started late and progressed at a remarkably slow pace toward the maximum phase [13], [14]. During the early part of 2018, around April, the sun began to show signs of the reverse magnetic polarity of sunspots, signaling the onset of SC - 25. The appearance of these poleward reversed polarity sunspots suggests a transition to SC - 25 [15].

The influence of drift on the temporal variations within the energy spectrum of the 11 - year galactic cosmic ray (GCR) cycle appears to be minimal across both positive and negative solar magnetic polarity states qA>0 and qA<O, respectively, as indicated by [16] Conversely, [11], [17] noted that the amplitude of diurnal anisotropy is almost same for both polarity conditions. Furthermore, there is a significant shift in the phase of the diurnal anisotropy vector to earlier hours when the solar polar magnetic field (SPMF) is positive, in contrast to the phase position during negative SPMF conditions in the same hemisphere, as observed by [17], [18], [19]. During two distinct solar minimum periods: solar minimum 23/24 (2007–2009) and solar minimum 24/25 (2017–2018), the period of solar minimum 23/24 is marked by a negative heliospheric magnetic field polarity (qA <0) and solar minimum 24/25, marked by a positive heliospheric magnetic field polarity (qA>0). A noticeable drift effect is evident during the solar minimum 24/25 [8]. (Fu et al., 2021) observed that the solar minimum of cycle 24/25 showed significant deviations from the previous solar minima. They stated that, these deviations were manifested in many aspects, such as a reduced number of sunspots, an unusually low inclination of the heliospheric current sheet, infrequent coronal mass ejections, a weak interplanetary magnetic field, and reduced turbulence. The degree of solar modulation could be decreased by changes of these solar parameters. Based on the observed differences between the two cycles, [21] predicted that, there will be marginally less intense solar activity during the 25th solar cycle than that during the 24th solar cycle.

The transition period between two solar cycles 24/25 is the subject interest because it provides a unique opportunity to study the effects on cosmic ray propagation and modulation with changes in solar activity. In this study, we focus on the first harmonic of the daily variation of cosmic rays during the transition period between solar cycles 24 and 25. We analyzed data from eight neutron monitors of rigidity ranging from 2.0 GV to 7.0 GV and found a significant anomaly in the amplitude and phase of the first harmonic 24/25 solar cycle. This anomaly is present over a range of rigidities, latitudes, and longitudes, indicating a broad effect.

## 2. Literature Survey

Diurnal variability of cosmic ray intensity depicts changes in cosmic ray intensity with periodicity of 24 - hour. It is important to understand the process of diurnal variability over a short and long term, and the understanding the various mechanisms governing the variability. The diurnal variability of cosmic rays is a complicated process that occurs in the heliosphere and is affected by multiple factors. Despite the sophistication of solar parameters, a single factor cannot fully explain the variations in cosmic rays [22].

[23] were the first who relate the diurnal variations in intensity found at ground - based detectors to an abundance of cosmic ray particles coming from the asymptotic 1800 - h local time direction. Generally, cosmic rays of energy from 1.5 GeV to a few hundred GeV responded by ground - based detectors. [24] first systematically examined the features of diurnal anisotropy from observations with ground - based detectors. [25] later developed the method of variational coefficients to measure the characteristics of diurnal anisotropy in space from ground - based cosmic ray intensity observations. In 1965, [26] postulated that the observed variability in diurnal amplitude could be attributed to the origin of a temporally evolving universe. Subsequently, [27] concluded that the primary source of solar diurnal variation is the progressive increase in upper cut - off rigidity related to anomalous anisotropy. However [28] suggest that at a cut - off rigidity of 2 to 2.5 GV, the amplitude of the diurnal anisotropy first increases with decreasing solar activity. Diurnal anisotropy in cosmic ray intensity are indicative of spatial flow patterns, which are basisically linked to the dynamic interplay of diffusion, convection, energy dynamics. [29] highlighted that continued study of diurnal vaiability, along with other modulations of cosmic ray intensity, is important for the advancement of knowledge in the field of cosmic rays.

Further research by [30] showed that the amplitude of diurnal anisotropy depends on variations in one sunspot cycle, while its phase on two sunspot cycles. [31] found that the phase of diurnal variability is subject to a 22 - year cycle, which is related to changes in the polarity of the solar polar magnetic field. They also found that, changes in the annual mean of diurnal amplitude correspond to the amplitude of the interplanetary magnetic field (IMF). Overall, the amplitude of the diurnal anisotropy exhibits an 11 - year periodicity while the time of the maximum exhibits a 22 - year periodicity, which aligns with the polarity of the Sun's magnetic field [31], [32], [33], [34].

## 3. Data Analysis

Neutron monitors are ground - based detectors, measure the flux of secondary neutrons produced by primary cosmic rays that interact with the Earth's atmosphere. About 147 neutron monitor (NM) stations are located around the world, and data from these stations can be accessed through various online databases [26] We used pressure - corrected hourly time - resolution cosmic ray count rates from eight neutron monitors with different cut - off rigidities (2.0 GV to 7.0 GV) located in both hemispheres of the Earth. Table 1 presents the station specifications, including their location and cut - off rigidities. The harmonic analysis (Fourier analysis) method was employed to assess the amplitude and phase of the diurnal variability in cosmic ray intensity from 1964 to 2022. We excluded amplitude vectors >0.7% from annual average, as these values are related to ground - level enhancement and transient disturbances in the heliosphere. Transient disturbances associated with coronal mass ejections (CMEs) and solar flares are observed. The amplitude and phase of diurnal anisotropy have been calculated for a network of 08 neutron monitors spaning 59 years. To quantify the degree of anomaly, statistical methods were applied to assess the significance of observed differences in amplitude and phase shifting from their typical values and other relevant statistical techniques. We compared the results of the transition period between solar cycles with data from solar cycle 20 to early 25.

**Table I**

| SN | Neutron Monitor | Vertical cut - off rigidity | Latitude | Longitude | Span |
|---|---|---|---|---|---|
| 1 | NEWARK | 2.09 GV | 39.70 N | ( - 75.70) W | 1964–2022 |
| 2 | KIEL | 2.36 GV | 54.30 N | 10.10 W | 1964–2018 |
| 3 | MOSCOW | 2.43 GV | 55.47 N | 37.32 E | 1964 - 2022 |
| 4 | LOMNICKY STIT | 3.98 GV | 49.20 N | 20.22 E | 1964 - 2022 |
| 5 | JUNGFRAUJOCH | 4.50 GV | 46.55 N | 7.98 E | 1964 - 2022 |
| 6 | HERMANUS | 4.58 GV | ( - 34.42) S | 19.23 E | 1964 - 2020 |
| 7 | ALMA - ATA | 6.60 GV | 43.14 N | 76.60 E | 1974 - 2022 |
| 8 | POTCHEFSTROOM | 7.00 GV | ( - 26.68) S | 27.10 E | 1972 - 2021 |

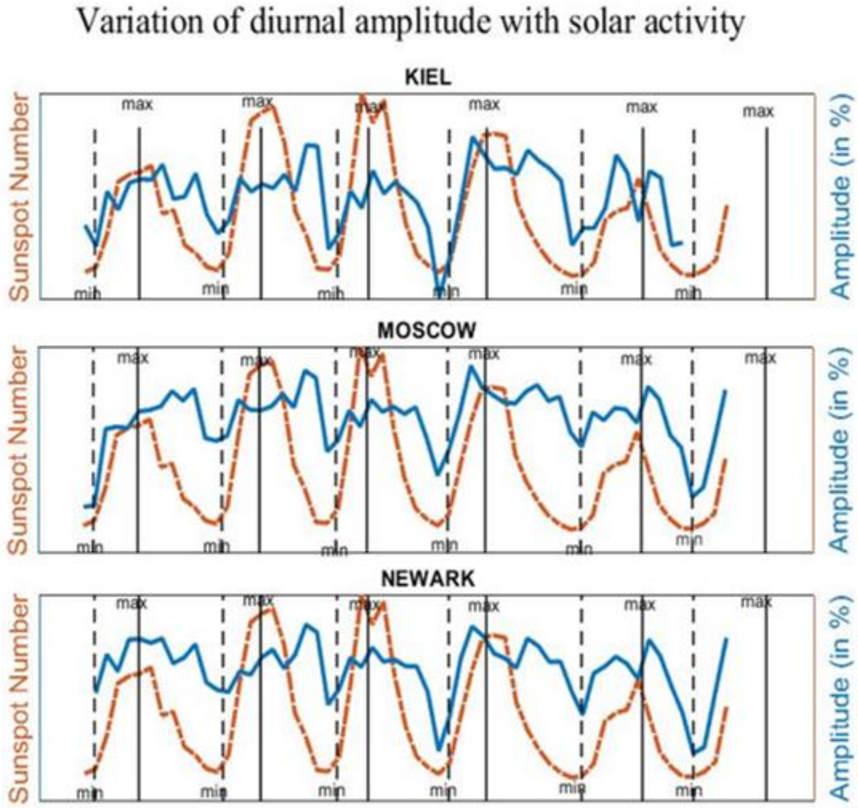
## 4. Observational Results and Discussion

In this study, data from eight neutron monitoring stations were analysed to study the amplitude and the time of maximum diurnal anisotropy of GCR. The analysis of diurnal anisotropy has been conducted with solar activity and the the polarity reversal of the SPMF. Keeping in mind the convenience of data visualization the group of 8 NMs of off - rigidity ranges from 2.0 GV to 7.0 GV, divided into two groups.

Figures (1 to 4) and Fig (7 to 10) show that, how the diurnal anisotropy changes with the solar cycle, and Figures (5–6) and figures (11–12) with the reversal of the SPMF. The observations indicates the following features as demonstrated by the above mentioned figures: The diurnal anisotropy is higher when the sun is more active and less when solar activity is weaker, follows an 11 - year cycle with some lagging, result consistent with [2], [6]. Figure (1 - 2) clearly illustrates that the amplitude of diurnal anisotropy fluctuated randomly during the periods of 1966 - 74, 1978 - 84, 1988 - 94, and 2010 - 15 for all neutron monitor stations in this observation, which correspond to solar maxima. A significant reduction in the diurnal amplitude was observed in 1986, 1996, and 2008, and it remained low during the solar activity minimum, particularly for mid - rigidity MM stations (Group - I). A remarkably low amplitude and phase shifting to early hours has been obtained in near 1996, such anomaly also reported by [27] in his observation. The amplitude is fluctuated and high near the periods close to the solar activity maximum. Amidst these fluctuations, a peak is seen in the 1984 at the Moscow NM station. In the Hermanus and Potchefstroom NM stations, the diurnal amplitude was also lower in SC 20/21. An unusal distribution of phase from 1966 to 1974 has been observed at Lomnicky Stit NM station. The amplitude of diurnal anisotropy decreased again to lower levels during 1974–76, 1985–86, 1996–97, 2008–09, and 2020–21 and slowly increased during the ascending phase of solar cycles 21 and 24. A time lag was observed in the solar minima of 2008 at mid - rigidity, and the amplitude was ahead in the solar minima of 1976 and 1986.

The modulation of galactic cosmic ray (GCR) intensity demonstrates a sharp dependence on solar variability, or sunspot numbers (SSNs), during the ascending phase of Solar Cycle 24. However an dip corresponding maximum obtained at Kiel NM station. The amplitude of daily anisotropy near solar minimum has a more stable structure during solar cycles 20/21 in 1975–76, 22/23 in 1995–96, 23/24 in 2007–2009, and early 25/25 in 2018–2020, whereas during 1966–1971, 1978–82, 1989–92, 2002–2004, and 2012–2014 have a more unpredictable nature near solar maximum. The amplitude obtained in the period 2019–2020 on almost all neutron monitors is lower than that obtained in 1996–97.

In calculating the average diurnal amplitude in the ascending and descending phases of the solar cycle, no definite rule can be applied to amplitude change for all NM stations, the amplitude of the diurnal variability in the ascending phase of SC - 20, SC - 21, and SC - 23 is less and it is greater in descending phase (Figure 3 - 4). Although the findings for Solar Cycles 22 and 24 are different, the amplitude is observed to be higher during the ascending phase of the solar cycle and lower during the descending phase. The overall vector average diurnal amplitude of the ascending period of odd and even solar cycles remains invariant from one ascending period to the other, or even in between the even and odd solar cycles. For the Hermanus NM station, except SC - 024, in all solar cycles' amplitude was less in the ascending phase and greater in the descending phase. Data from Moscow NM shows discrepancy from others in SC - 23.



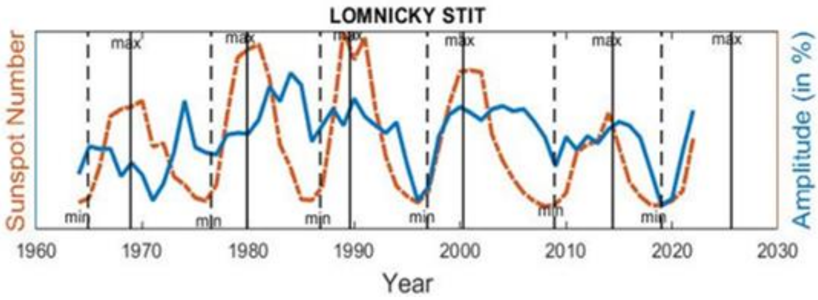



**Figure 2:** Illustrates the variation of amplitude of the diurnal isotropy vector with solar activity for the neutron monitors Kiel, Moscow, Newark, and Lomnicky Stit. In the above, the dotted lines represent the years of the solar cycle in which solar activity is minimum and the continuous lines represent the years in which it is maximum.

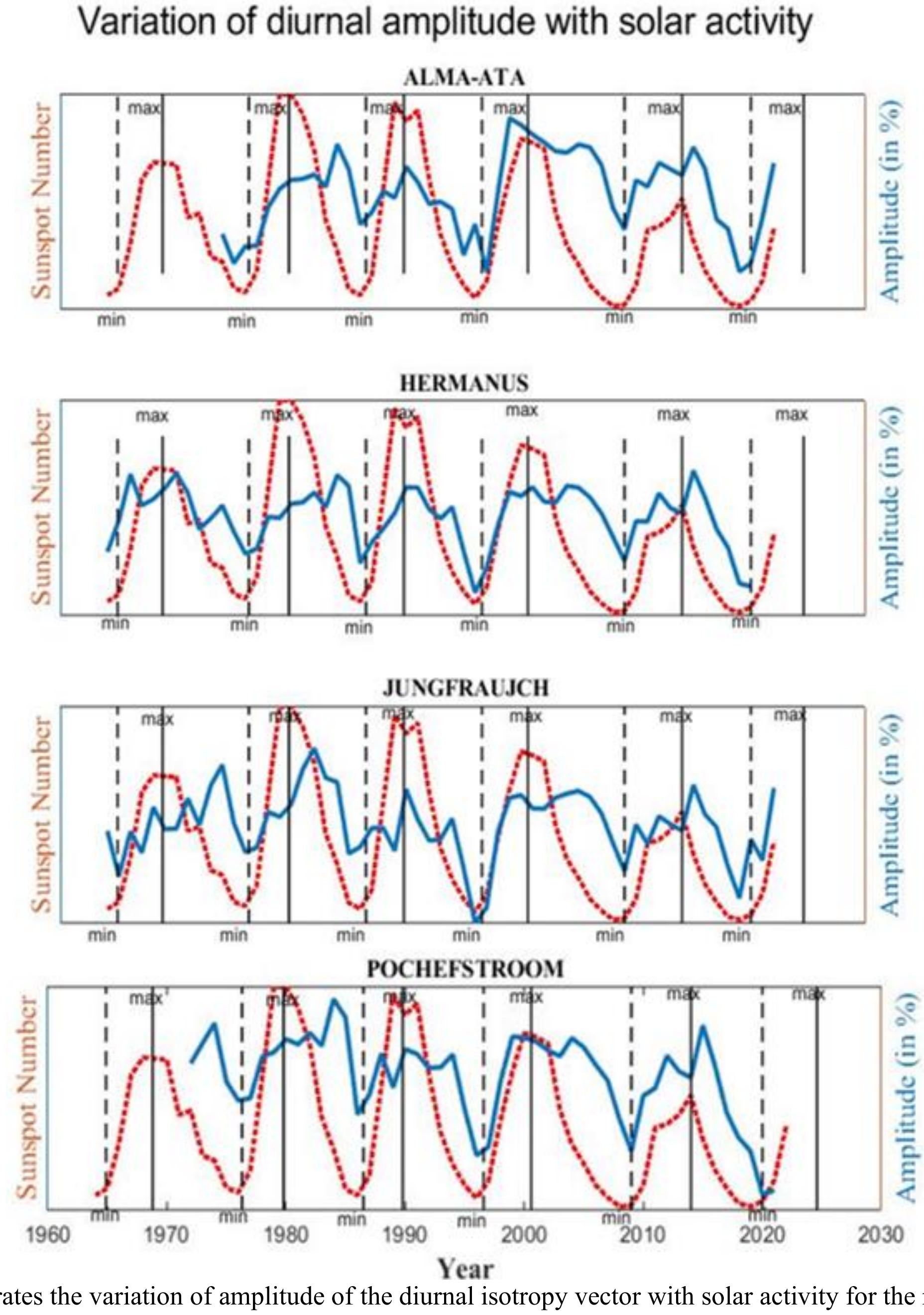



**Figure 3:** Illustrates the variation of amplitude of the diurnal isotropy vector with solar activity for the neutron monitors Alma-ATA, Hermanus, Jungfraujch, and Potchefstroom. In the above, the dotted lines represent the years of the solar cycle in which solar activity is minimum and the continuous lines represent the years in which it is maximum

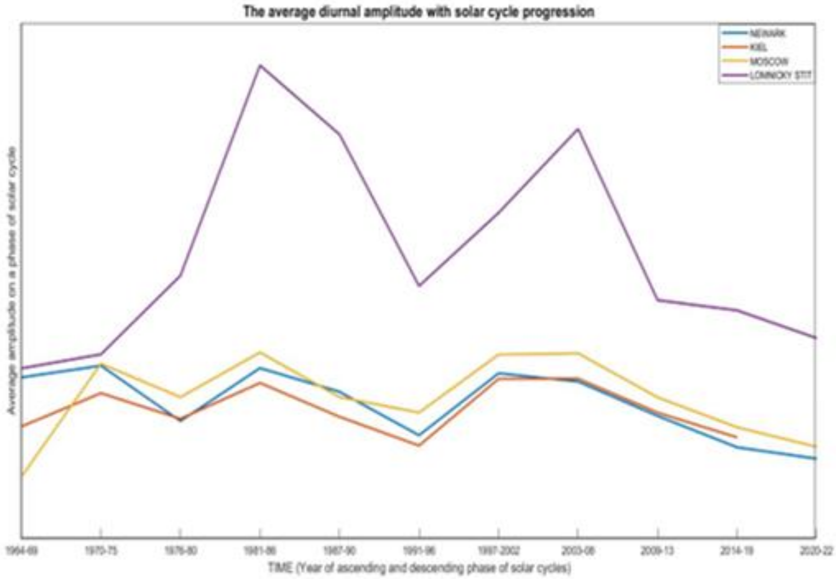



**Figure 4:** Illustrates variation of the average of amplitude of diurnal anisotropy over a phase of solar cycle with the progression of the solar cycle for the neutron monitor Newark, Kiel, Moscow and Lomnicky Stit.

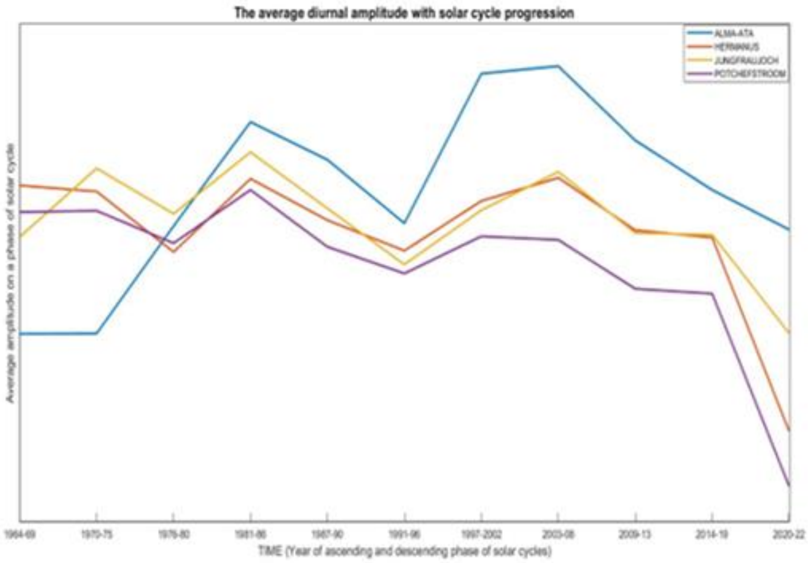



**Figure 5:** Illustrates the variation of amplitude of the diurnal isotropy vector with solar activity for the neutron monitors Alma-Ata, Jungfraujch, Potchefstroom and Hermanus.

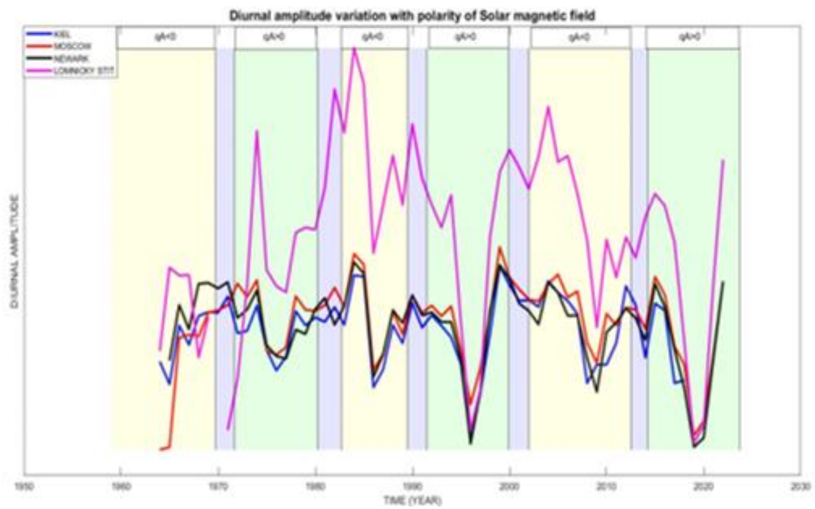



**Figure 6:** Illustrates variation of amplitude diurnal anisotropy vector with polarity epoch of SPMF the neutron monitors Newark, Kiel, Moscow and Lomnicky Stit. Vertical yellow strips indicate negative polarity epoch and green ones indicate positive polarity epoch of SPMF.

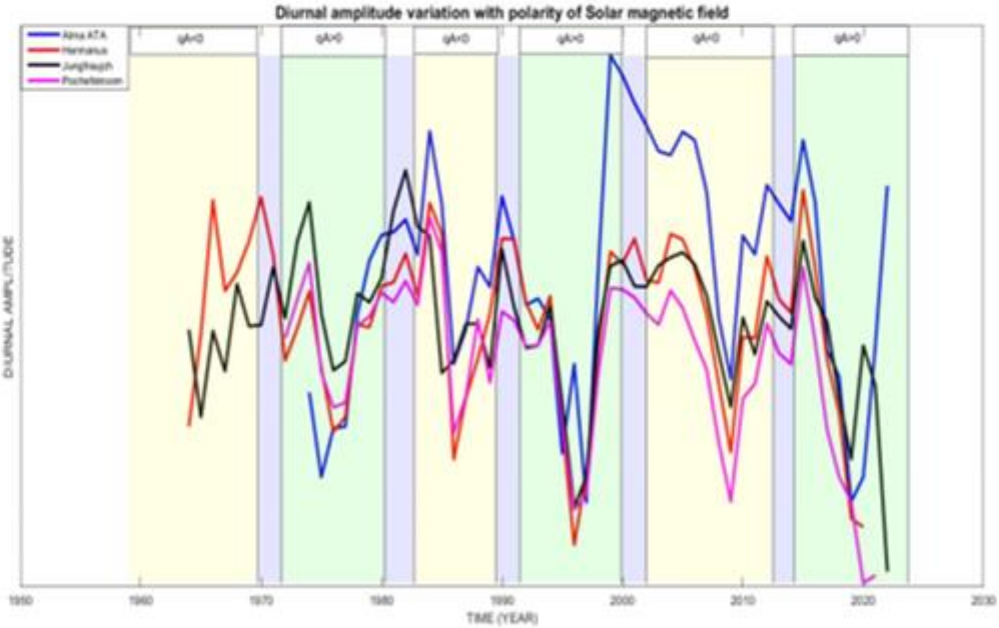



**Figure 7:** Illustrates variation of amplitude diurnal anisotropy vector with polarity epoch of SPMF the neutron monitors Alma-Ata, Hermanus, Jungfraujch and Potchefstroom. Vertical yellow strips indicate negative polarity epoch and green ones indicate positive polarity epoch of SPMF.

It is clear from Figures (5 - 6) that the diurnal amplitude decreases in both the negative and positive polarity states of the SPMF, although this decline in amplitude is greater in SC - 23/24 and 24/25. The amplitude remains approximately constant during polarity reversal. The difference between the positive and negative SPMF cases was more pronounced during the early phase of SC - 25. Figures (5 - 6) show the change in diurnal amplitude with the polarity reversal of the SPMF, which clearly shows that during polarity reversal when the SPMF weakens, the diurnal amplitude is found to be almost flat. The diurnal amplitude was found to be less in the period of the positive polarity of SPMF. In the present study, the amplitude of the diurnal variation of the cosmic ray and the time of its maximum was studied in conjunction with solar activity and polarity reversal of the SPMF by analysing data obtained from 8 neutron monitoring stations. The diurnal amplitude is very low when qA > 0 in (1996) solar cycles 23/24, which is not seen in any previous solar cycle, although the amplitude is even lower when qA > 0 in positive polarity of solar cycle 24/25. The amplitude of diurnal anisotropy at NMs of cut - off rigidity 2 to 7.0 GV about 65 - 67 per cent less than that of the overall average value.

The phase of diurnal anisotropy also changes, which is the time of day when the amplitude reaches its maximum level. The phase change is also periodic, occurring with a frequency of 22 years, which is the time taken for the SPMF to flip and return to its original state. The phase shift starts when the SPMF changes from negative to positive and reaches its minimum near the next solar minimum (Figure 7 - 8). The anomaly is observed for Kiel NM station in 1964, for Jungfraujch NM in 1996, and Potchefstroom NM station in 2020. The phase for the Lomnicky Stit NM station is distributed randomly between 86 - 06. Two minima were observed in 1996 and 2000 for Alma - ATA NM station.

When the diurnal anisotropy is averaged over the entire solar cycle, there is no significant difference between different cycles or between even and odd cycles, the same is true for the phase. This means that the diurnal anisotropy is mainly influenced by the solar activity and the solar magnetic field. Figure (9 - 10) depict the variation of average value of diurnal phase with solar cycle progression. The time of maximum of diurnal anisotropy is shifted towards later hours in the ascending phase of even solar cycles and it is shifted towards early hours in descending phase and vice versa in odd solar cycles.

The results obtained from observations as shown in figure (9 - 10) for cut - off rigidity 2.00 to 7.0 GeV show that with a few exceptions, the time maximum is greater ascending phase and less or shifts to earlier hours in the descending phase of even solar cycle 20, 22 and 24. There is a large diurnal phase shift to earlier hours during the descending period of even SC - 20, 22 and 24 as compared to almost no shift in the diurnal phase during the descending period of odd solar cycles. The results for odd solar cycles 21 and 23 are opposite to those for even solar cycles, with an anomaly in SC - 20 for the Jungfrauch NM station in the group with high cut - off rigidity. This is consistent with the results of [3], [28]

The long - term modulation of GCRs in the energy range of 2.0 to 7.0 GeV in solar cycles with polarity inversion of the SPMF is investigated in this paper. The analysis spans from 1964 to 2022, which covers six intervals of positive and negative SPMF. We are particularly focused on the response of the diurnal variability of cosmic rays with the long - term decline of SPMF strength in the SC - 24/25, which reached the lowest level in 2018 - 2020/21.

The phase shift to earlier hours commences after the solar polarity reverses from negative (qA < 0) to positive (qA > 0) states, which occurred in 1971, 1991, and 2014. This shift persists until the subsequent solar minimum, which took place in 1976, 1995 - 96, and 2019 - 20, reaching its minimum phase at or near solar minimum, and then starts recovering towards the pre - reversal level. These observations suggest that the time of maximum is influenced by the orientation of the solar magnetic field rather than by solar activity and/or co - rotating high - speed streams (M. Singh & Badruddin, 2006). According to [30], the drift patterns of GCRs depend on the SPMF polarity, such that positively charged particles drift inward from the solar poles to the equator and outward along the wavy current sheet when the SPMF is positive (qA>0), and the opposite occurs when the SPMF is negative (qA<0).

To present a general view of the phase of anisotropy across different heliospheric polarity states, Figure (13 to 16) illustrates the vector diagrams on 24 - h harmonic dial for each negative polarity period (qA < 0) during 1964–1970, 1981–1990, and 2002 - 2012, as well as each positive polarity period (qA > 0) during 1972–1980, 1992–2000, and 2014 - 2022. The comparison of average amplitudes across these polarity states (qA < 0 and qA > 0) reveals that they are comparable except last polarity states. However, there is a noticeable phase shift towards earlier hours in the average vectors during the positive polarity epochs (qA > 0), and shifts towards later hours in negative polarity states.

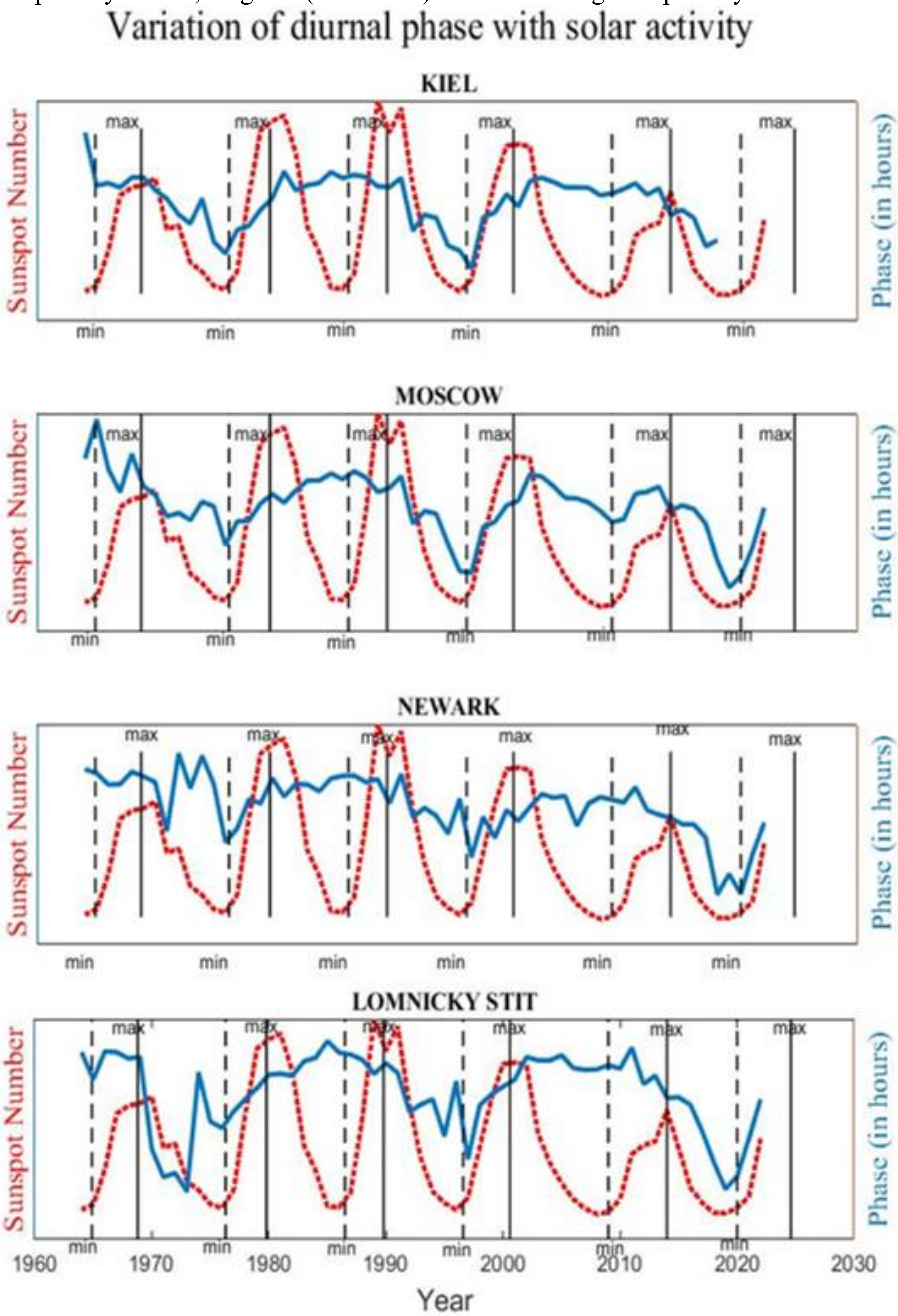



**Figure 8:** illustrates the variation of time of maximum (in hours) of the diurnal isotropy vector with solar activity for the neutron monitors Kiel, Moscow, Newark, and Lomnicky Stit. In the above, the dotted lines represent the years of the solar cycle in which solar activity is minimum and the continuous lines represent the years in which it is maximum.

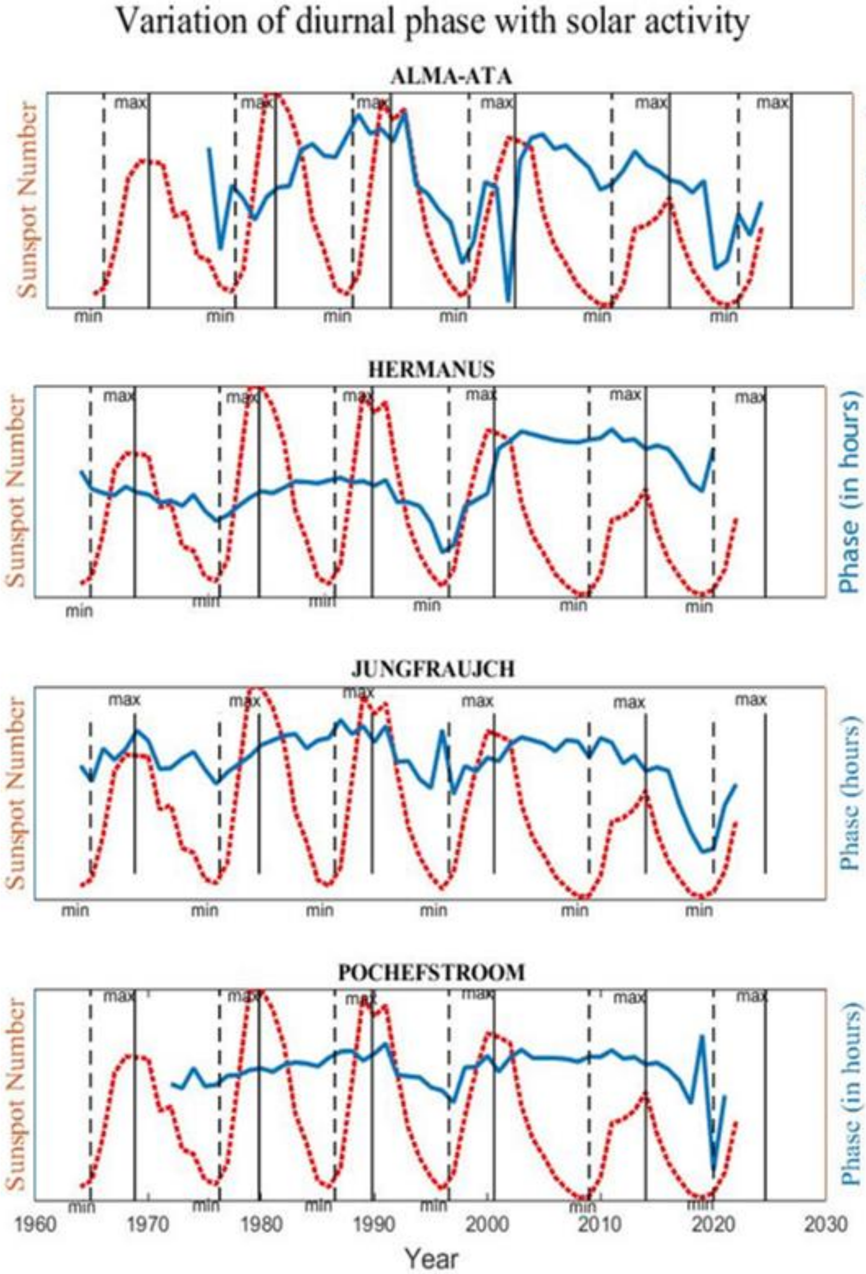



**Figure 9:** Illustrates the variation of time of maximum (in hours) of the diurnal isotropy vector with solar activity for the neutron monitors Alma-Ata, Hermanus, Jungfraujch, and Potchefstroom. In the above, the dotted lines represent the years of the solar cycle in which solar activity is minimum and the continuous lines represent the years in which it is maximum.

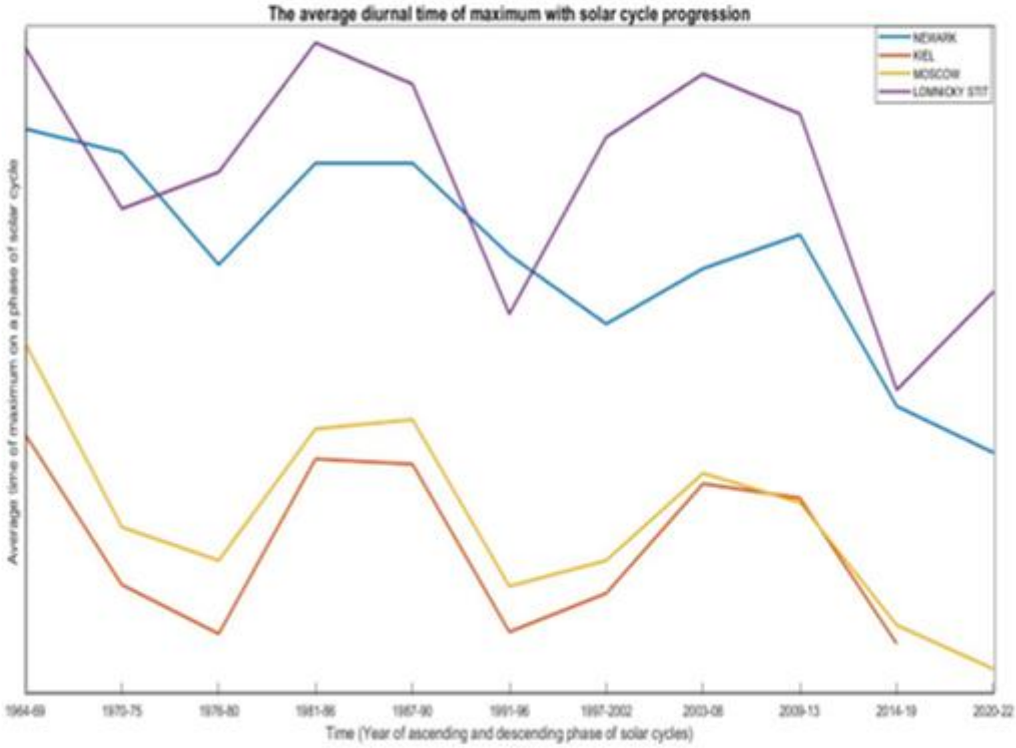



**Figure 10:** Illustrates variation of the average of time of maximum (in hours) over a phase of solar cycle with the progression of the solar cycle for the neutron monitor Newark, Kiel, Moscow and Lomnicky Stit.

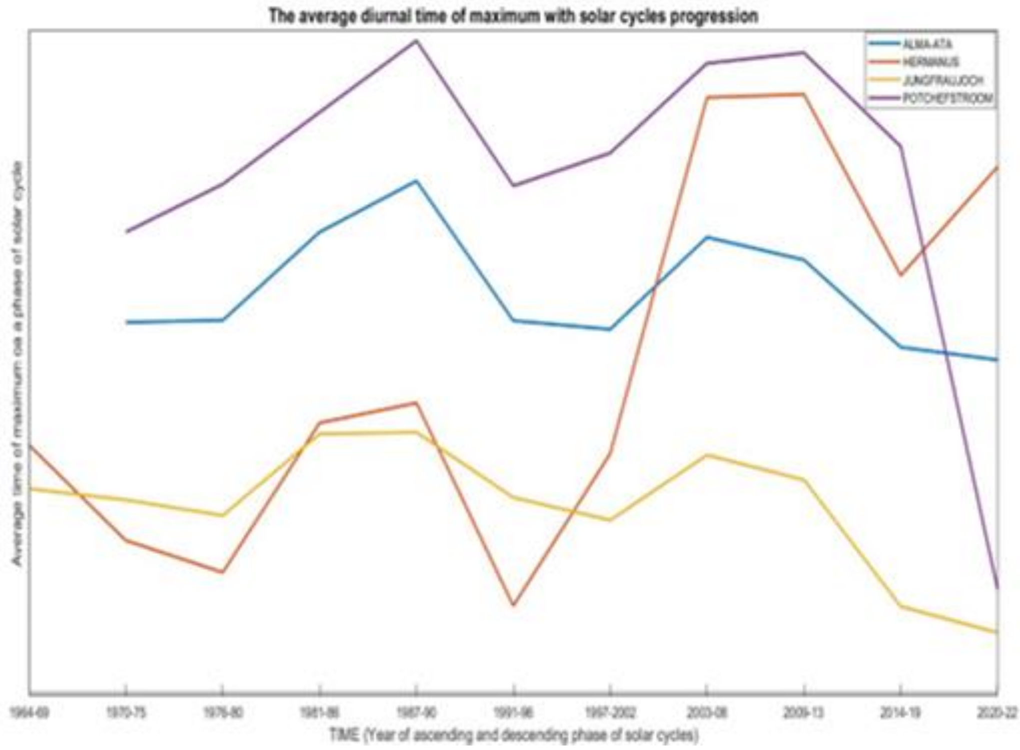



**Figure 11:** Illustrates variation of the average of time of maximum (in hours) over a phase of solar cycle with the progression of the solar cycle for the neutron monitor Alma-Ata, Hermanus, Jungfraujch and Potchefstroom.

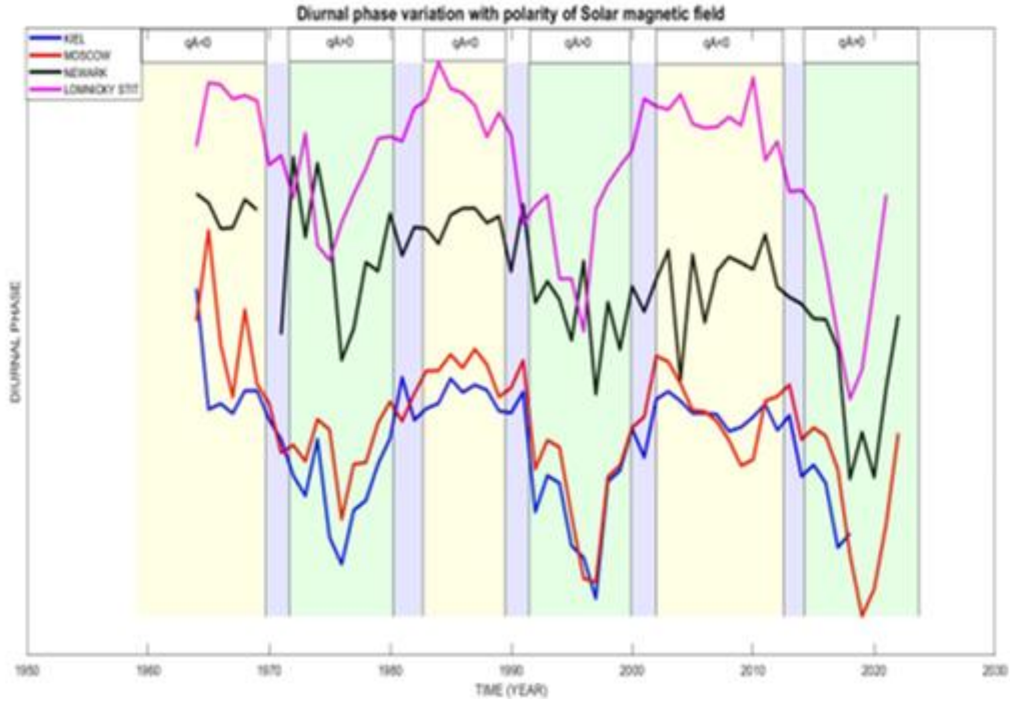



**Figure 12:** Illustrates variation of phase of diurnal anisotropy vector with polarity epoch of SPMF the neutron monitors Newark, Kiel, Moscow and Lomnicky Stit. Vertical yellow strips indicate negative polarity epoch and green ones indicate positive polarity epoch of SPMF.

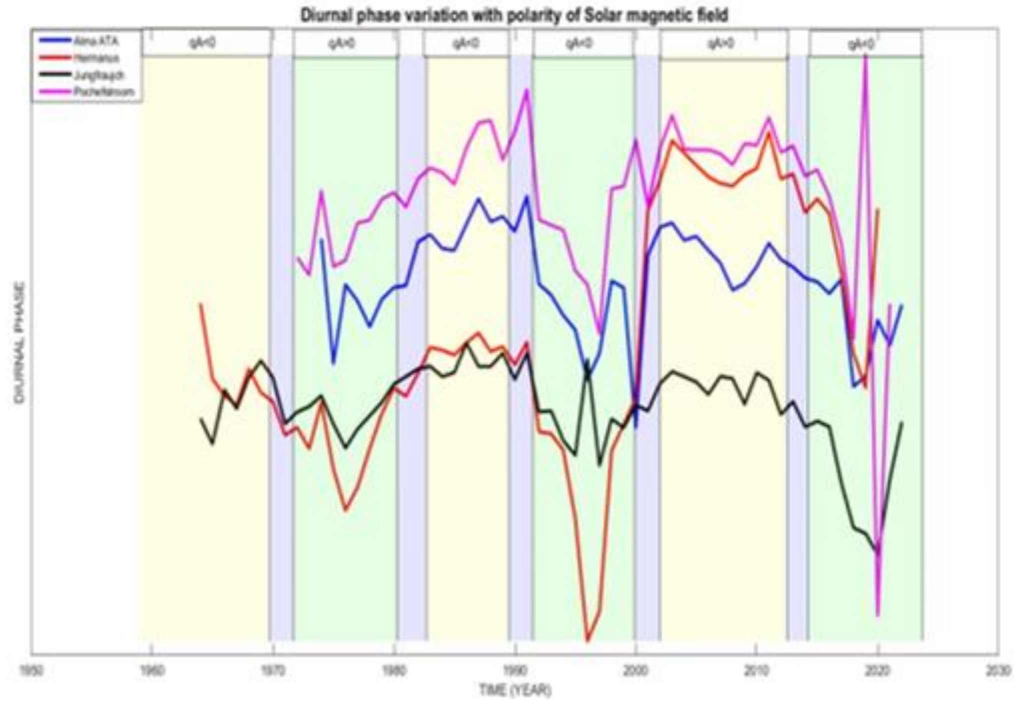



**Figure 12:** illustrates variation of phase of diurnal anisotropy vector with polarity epoch of SPMF the neutron monitors Alma-Ata, Hermanus, Jungfraujch and Potchefstroom Vertical yellow strips indicate negative polarity epoch and green ones indicate positive polarity epoch of SPMF

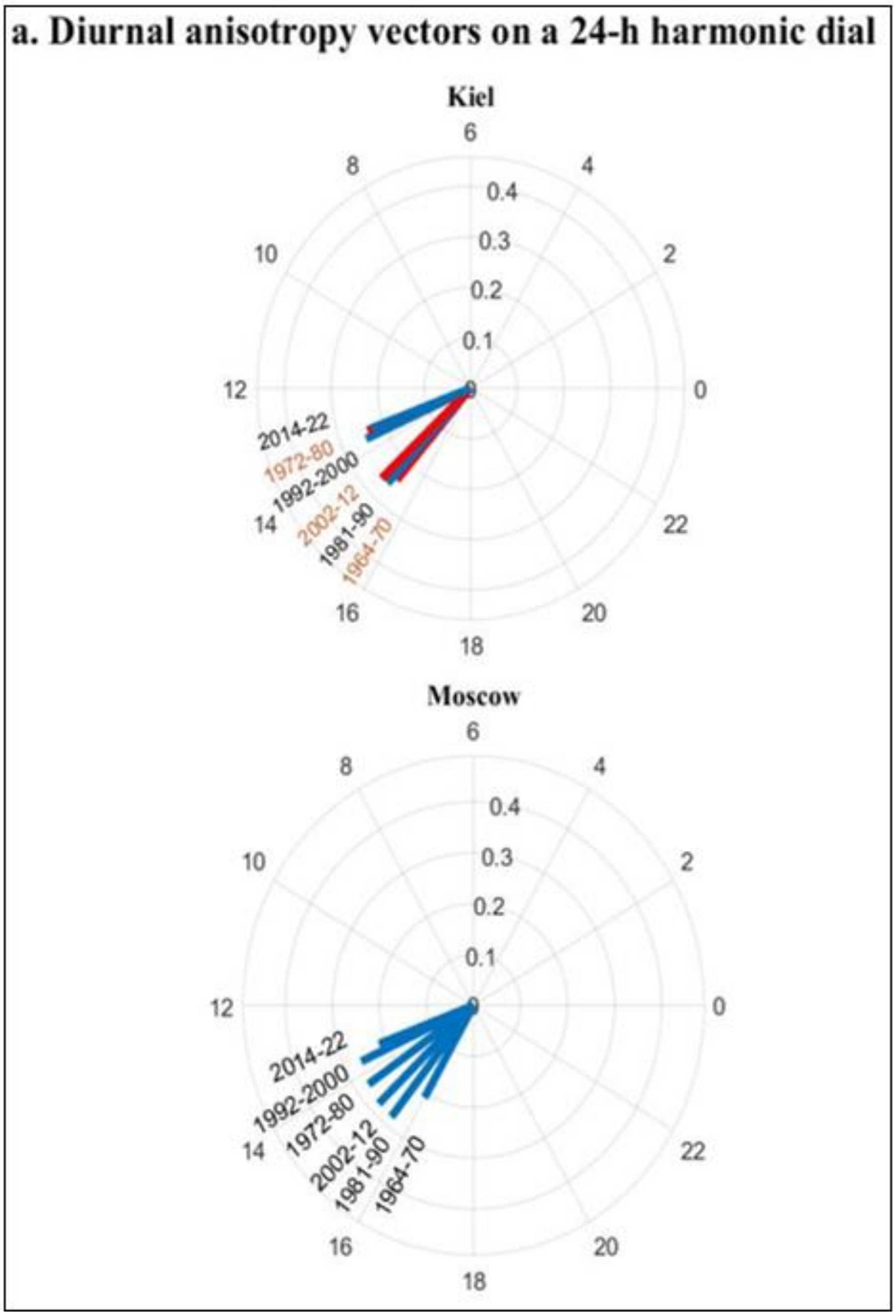



**Figure 13:** Average phase of diurnal anisotropy vectors on a 24-hour harmonic scale, taken over the polarity epoch for Neutron Monitor stations in Alma-ATA and Hermanus.

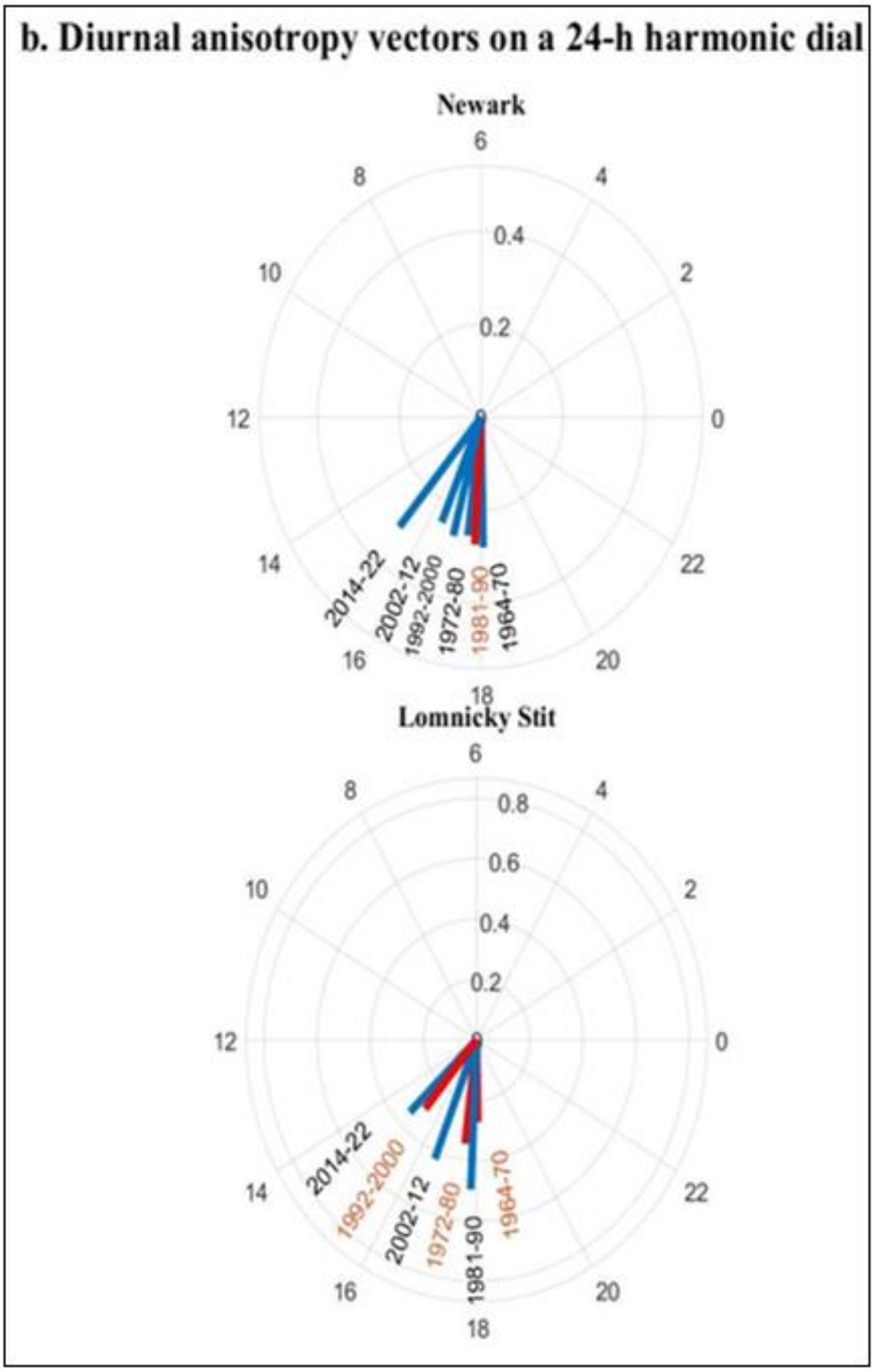



**Figure 14**: Average phase of diurnal anisotropy vectors on a 24-hour harmonic scale, taken over the polarity epoch for Neutron Monitor stations in Newark and Lomnicky Stit.

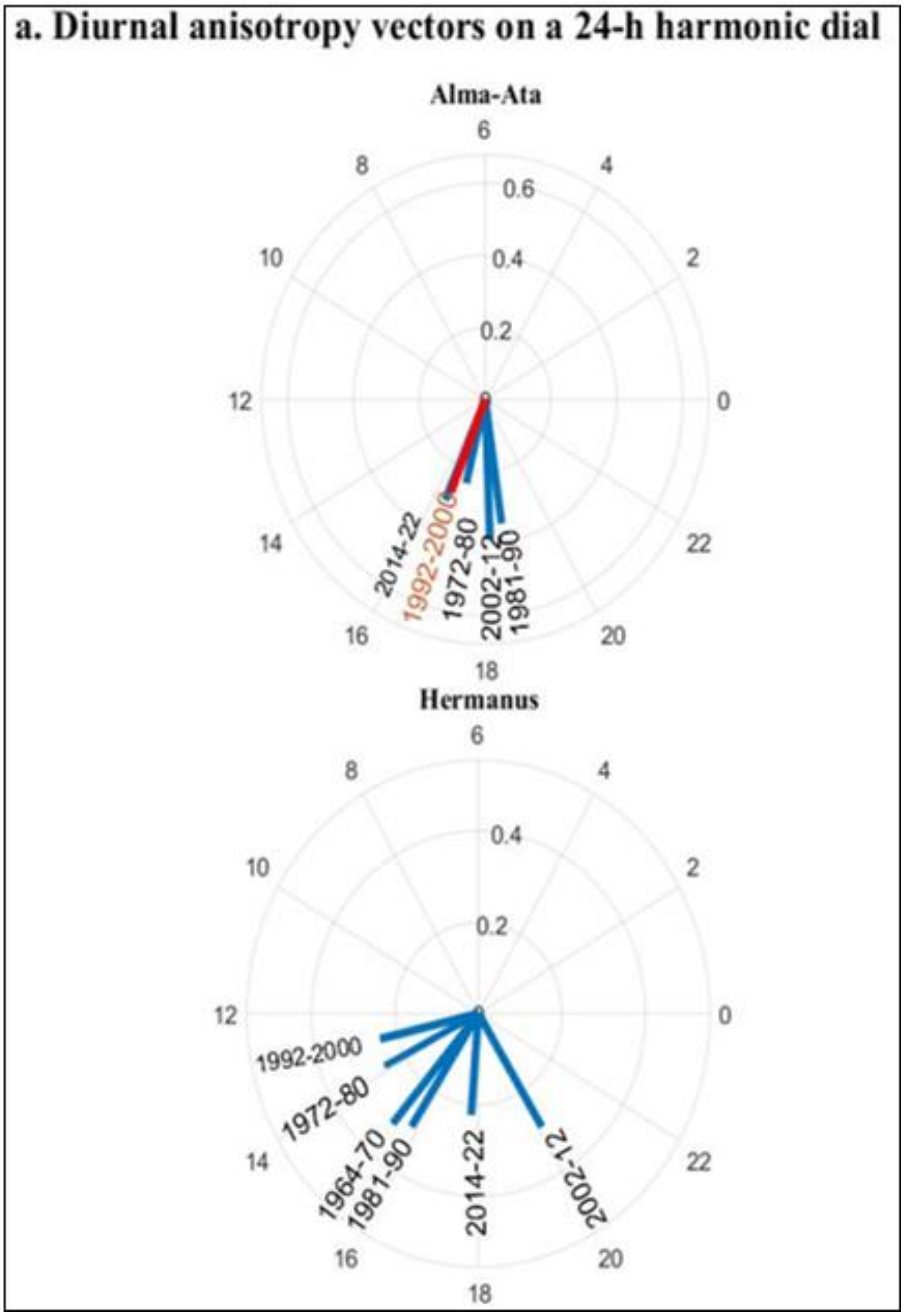



**Figure 15:** Average phase of diurnal anisotropy vectors on a 24-hour harmonic scale, taken over the polarity epoch for Neutron Monitor stations in Alma-Ata, Hermanus.

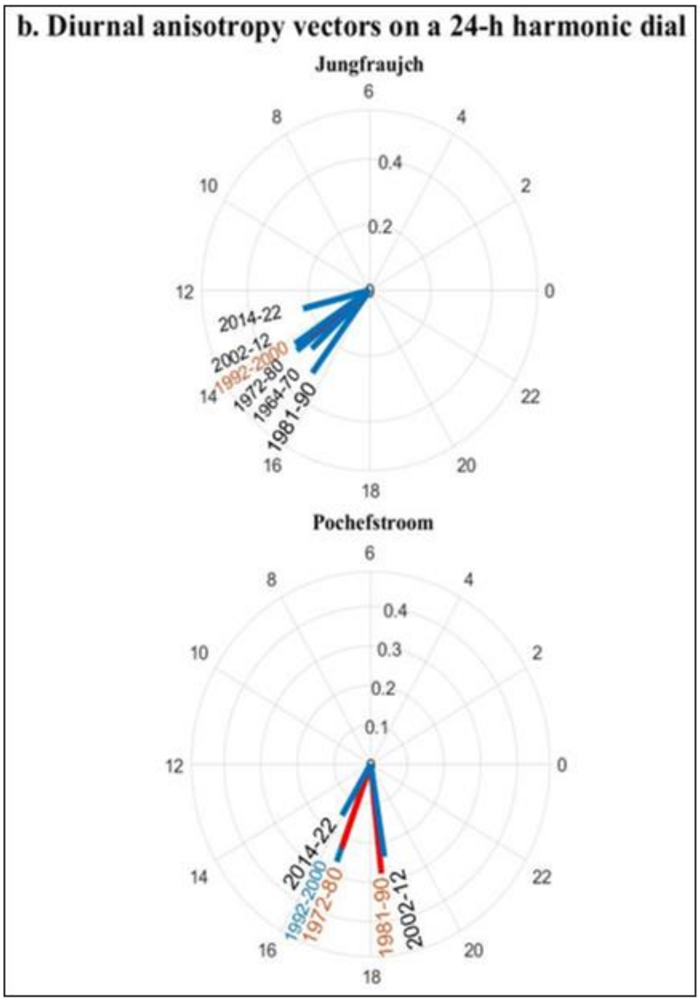



**Figure 16:** Average phase of diurnal anisotropy vectors on a 24-hour harmonic scale, taken over the polarity epoch for Neutron Monitor stations in Jungfraujch and Potchefstroom.

The findings of studies indicate that the peak galactic cosmic ray (GCR) intensities during the solar minimum in 2019–2020 surpassed previous records, and these intensities are the highest observed since the advent of the space age [31]. In contrast, the diurnal anisotropy is found to be low in the above period, which is due to the weakening of the SPMF. The SPMF started to weaken from SC - 23/24 and became weaker in SC - 24/25. Further weakening is likely because the amplitude and phase of the diurnal variability were found to be the lowest in the history of observation period of 59 years. These results are consistent with those of [32]The long - term variations in cosmic rays during cycles 23–24 demonstrate a diminishing SPMF. A comparative analysis of these variations with those from previous cycles (21–22) reveals the characteristics of the modulation in the last two cycles. The study also reveals that the cosmic ray modulation environment during the [30]solar minimum 24/25 differs significantly from previous solar minima in several aspects, including notably low sunspot numbers, extremely low inclination of the heliospheric current sheet, infrequent coronal mass ejections, weak interplanetary magnetic field, and turbulence. These alterations are favourable for reducing the level of solar modulation [30].

## 5. Conclusion

The results of our investigation into the diurnal variations of cosmic ray studies, in correlation with the solar activity and polarity reversal SPMF, from solar cycle - 20 to early 25, are as follows:

1) The diurnal amplitude is significantly influenced by solar activity, undergoes an 11 - year solar cycle within the heliosphere. The cycle peaks at the solar maximum and vice versa, with some deviations. This study confirmed a positive correlation between daily sunspot numbers and diurnal amplitude.
2) The analysis also verifies that diurnal amplitude lags in sunspot numbers epecially solar cycles up to 23. A decrease in the diurnal amplitude was observed during the solar cycle minimums of 20/21, 21/22, 22/23, 23/24, and early 24/25.
3) The modulation of galactic cosmic ray (GCR) intensity shows a stronger dependence on solar activity during the ascending phase of the solar cycle 24. The GCR diurnal amplitude progresses from a more persistent structure near the solar minimum to a more random character near the solar maximum between Solar Cycles 20/21 in 1975 - 76, 22/23 in 1995 - 96, 23/24 in 2007 – 2009, and early 25 2018–2020 to a more random character in and near the solar maximum in 1966–71, 1978–82, 89–92, 2002–2004, and 2012–2014.
4) The amplitude of the diurnal anisotropy during the transition periods of solar cycles 24 and 25 was found to be the lowest in the history of the our observation period of 59 years, which is a large anomaly and emphasizes the weakening of the upcoming solar cycle. A similar

anomaly was also seen in Solar Cycle 22/23, resulting in weak Solar Cycles 23 and 24.

5) The time of maximum is subject to a 22 - year periodicity, with minimums occurring in 1976, 1996, and 2019. The phase tends to shift toward earlier hours from 1992, with a slight increase toward the co - rotational direction. From 2011 to 2012, it again adopted a consistent trend of shifting toward early hours.
6) The time of maximum exhibits an odd and even rule, with lower values in the ascending phase and higher values in the descending phase of the even solar cycle and its counterpart in the odd solar cycle.
7) The time of maximum evolved from a more persistent structure near the solar minimum to a more random character near the solar maximum, particularly at Lomnicky Stit during 1972–74 and 1999–2004.
8) The time of maximum shift toward earlier hours for positive polarity (qA>0) of the SPMF, whereas for negative polarity (qA<0), they shift toward later hours. The phase in 2014–22 (qA>0) was found to be much lower than its theoretical value of 18 hrs, which appears to follow the anomaly in amplitude, except for the results of Hermanus NM station. The theory of GCR modulation, including diffusion and drift, can explain these results. The global drift due to the gradient and curvature of the heliospheric magnetic field is manifested in the radial component of the anisotropy. For the qA < 0 cycle, it is directed away from the Sun, but for the qA > 0 magnetic cycle, it is directed toward the Sun. This type of drift effect is the source of the 22 - year variation in the anisotropy of GCRs [8].

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