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Diurnal anisotropy of cosmic rays during intensive solar activity for the period 2001–2014

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HIGHLIGHTS

- The cosmic ray diurnal anisotropy is examined for two neutron monitors with the same longitude and different latitude.
- The diurnal amplitude seems to be varied with the different phases of the solar cycle for the examined time period 2001 to 2014.
- Changes of the diurnal anisotropy vectors are observed during extreme solar and cosmic ray events.

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ABSTRACT

The diurnal variation of cosmic ray intensity, based on the records of two neutron monitor stations at Athens (Greece) and Oulu (Finland) for the time period 2001 to 2014, is studied. This period covers the maximum and the descending phase of the solar cycle 23, the minimum of the solar cycles 23/24 and the ascending phase of the solar cycle 24.These two stations differ in their geographic latitude and magnetic threshold rigidity. The amplitude and phase of the diurnal anisotropy vectors have been calculated on annual and monthly basis.

From our analysis it is resulted that there is a different behaviour in the characteristics of the diurnal anisotropy during the different phases of the solar cycle, depended on the solar magnetic field polarity, but also during extreme events of solar activity, such as Ground Level Enhancements and cosmic ray events, such as Forbush decreases and magnetospheric events. These results may be useful to Space Weather forecasting and especially to Biomagnetic studies.

1. Introduction

Cosmic rays (CR) are particles at very high energies from extraterrestrial sources within or outside the Milky Way with high stability and isotropy in galactic scale. The intensity of galactic cosmic rays (GCR) recorded by ground based neutron monitors shows periodic and abrupt changes as the Sun and the interplanetary magnetic field (IMF) result in anisotropies and variations in both the energy spectrum and the intensity of CR as a function of space, time and energy called CR intensity modulation (Bieber et al., 2010).

The diurnal anisotropy of CR intensity is an anisotropic, short-term variation of local time with a periodicity of 24 hours due to the rotation of the Earth around its axis and consequently the rotation of cone detectors of CR, as shown in Fig. 1 (Pomerantz and Duggal, 1971; Ahluwalia, 1988). The diurnal variation is the result of complex phenomena involving the convection of GCR flux by the solar wind and the diffusion along the IMF, as discussed by the convective-diffusive theory (Sabbah, 2013), the asymmetry of the Earth's magnetosphere resulting in a daily variation of the local geomagnetic cut-off and the day-night difference in the atmospheric structure (Bieber et al., 2010). The characteristics of the diurnal variation (amplitude and phase) are also modulated by the latitude, the longitude and the altitude of the detectors location at Earth (Mailyan and Chilingarian, 2010).

The diurnal anisotropy depends on quite many parameters and its average annual features exhibit striking correlation with the 11-year solar cycle (SC), whereas the diurnal phase varies with a period of 22 years (one solar magnetic cycle) (Tiwari et al., 2012). The average amplitude of the diurnal anisotropy is 0.6%, as calculated by Forman and Gleeson, and in some cases may be as high as 1.5% (Forman and Gleeson, 1975). The solar diurnal variation of CR intensity shows a large day to day variability, which is a reflection of the continually changing conditions in the interplanetary space. The average characteristics of CR diurnal anisotropy are adequately explained by the corotational concept. This concept supports the average diurnal amplitude in space of 0.4% along the 18 h (LT) direction. The direction of the

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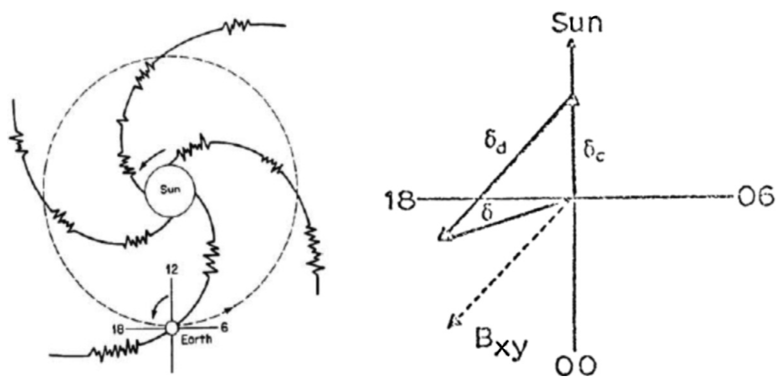

Fig. 1. Representation of the cosmic ray diurnal anisotropy model (left panel), and the convective-diffusion model of the diurnal variation of cosmic rays represented by the observed (δ), convective (δ_c) and diffusive (δ_d) anisotropy vectors and the IMF vector in the ecliptic plane (Bxy) for a typical day (right panel) (Mavromichalaki, 1989).

anisotropy is not correlated with the SC and shows a systematic shift towards early hours (Ananth et al., 1993; Kumar et al., 1990). The phase shift is found to be greater in stations with high cut-off rigidity. The diurnal variation during the ascending phase of the SC can also be explained in terms of the changes of the cut-off rigidity (Ahluwalia and Ericksen, 1971).

The shift of diurnal time maximum can be qualitatively understood in terms of the convective-diffusive mechanism (Forman and Gleeson, 1975), which relates the solar diurnal anisotropy of CR to the dynamics of the solar wind and of the IMF, either as an enhancement in the connective vector due to an increase in solar wind velocity accompanied by an increase in the value of diurnal anisotropy amplitude or as a decrease in the diffusive vector due to the increase in the value of $K_{\text{vert}}/K_{\text{horiz}}$ accompanied by a decrease in diurnal anisotropy amplitude. If both of them operate simultaneously, the diurnal amplitude may remain constant (Agrawal and Singh, 1975; Mavromichalaki, 1980). The diffusive anisotropy vector δ_d for each day is obtained by vector subtraction of the convective anisotropy δ_c from the observed anisotropy δ according to the relation $\vec{\delta} = \vec{\delta_c} + \vec{\delta_d}$ (Fig. 1). Via this mechanism, the large variation observed in phases and amplitudes can be understood on a day-to-day basis. Periods of unusually large amplitude often occur in trains of several days and cannot be explained by the co rotational concept (Mavromichalaki, 1980).

The CR intensity variations observed near the Earth are an integral result of numerous solar and heliospheric phenomena. The strong magnetic field and its associated fluctuations are responsible for the modulation of CR (Burlaga and Ness, 1998). This modulation also includes other CR variations that affect the diurnal variation, such as Ground Level Enhancements (GLEs), Forbush decreases (Fds) and geomagnetic effects (GEs). The characteristics of the diurnal anisotropy during extreme solar and CR events show a remarkable variation.

In this work, the diurnal anisotropy of CR intensity recorded at the Athens and Oulu neutron monitor stations during the time period 2001–2014, is calculated. This time period covers different phases of the last SCs 23 and 24 over which it was shown that the CR diurnal anisotropy presents different features. The diurnal variation during extreme solar and CR events recorded at these two stations located at the same geographic longitude and different latitude is also studied for the first time.

2. Data analysis

In order to study the diurnal anisotropy of CR, hourly corrected for pressure and efficiency values of the CR intensity from the neutron monitor (NM) stations of the National and Kapodistrian University of Athens - ANEMOS (http://cosray.phys.uoa.gr/) and of the University of Oulu (http://cosmicrays.oulu.fi/) have been used. Both of them provide high-resolution data in real time to the internet in graphical and digital form. They are located at about the same geographic longitude, but in different latitudes having consequently different cut-off rigidities 8.53 GV and 0.81 GV, respectively. The characteristics of these NMs are given in Table 1.

Table 1
Characteristics of Athens and Oulu NM stations.

	Athens NM	Oulu NM
Type	Super 6NM-64	9NM-64
Geographic latitude	37.58° N	65.05° N
Geographic longitude	23.47° E	25.47° E
Altitude	260 m asl	15 m asl
Cut-off rigidity R_c	8.53 GV	0.81 GV

The intensity of cosmic radiation as measured by the Athens NM is lower than the one measured by the Oulu NM, due to the different geographic latitude and consequently threshold magnetic rigidity Rc of each station. Thus, while the Athens NM detects neutrons originating from the reaction of the molecules of the atmosphere with particles of cosmic radiation with Rc> 8.53 GV, the Oulu NM records neutrons with Rc> 0.81 GV. The difference in Rc results in detecting a wider energy spectrum in Athens (Agrawal and Mishra, 2008).

The examined time period 2001–2014 covers the maximum, the descending phase of the SC 23, the extended minimum of the SC 23/24 and the ascending phase of the SC 24. The diurnal vectors for each day (amplitude and time of maximum) of this period were calculated using Fourier analysis according to the equation

$$I_i = f(t_i) = I_{mean} + A'(\cos \omega t_i + \varphi) \tag{1}$$

where I_{mean} is the daily average of CR intensity, A' and φ are the amplitude and the phase of diurnal variation, respectively (Firoz, 2008).

Our data have been normalized according to the equation:

$$A = \frac{I - I_{mean}}{I_{mean}} 100(\%) \tag{2}$$

where I_{mean} is the average CR intensity for each day and A is the percentage variation of the amplitude of the diurnal anisotropy.

The calculated diurnal vectors for the above period are presented on a harmonic dial on monthly and annually basis in polar diagrams, an example of which is appeared in Fig. 3 (Mavromichalaki, 1989). In such diagrams the diurnal anisotropy is represented by a vector of length proportional to the amplitude and in the direction of the maximum intensity. This vector represents the anisotropy field. At the polar diagrams, the quantity A is illustrated as a function of the phase, i.e. the time of the day at

Table 2
Mean annual values of the amplitude and phase (in UT and LT) of the diurnal anisotropy for Athens and Oulu NMs for the time period 2001–2014.

Years	Athens NM			Oulu NM		
	A (%)	*Tmax (UT)*	*Tmax (LT)*	*A* (%)	*Tmax (UT)*	*Tmax (LT)*
2001	0.91 ± 0.02	10.83 ± 0.05	17.23 ± 0.05	1.11 ± 0.02	12.33 ± 0.05	16.73 ± 0.05
2002	0.92 ± 0.02	11.33 ± 0.05	17.73 ± 0.05	0.90 ± 0.02	12.50 ± 0.05	16.90 ± 0.05
2003	0.96 ± 0.02	12.58 ± 0.05	18.98 ± 0.05	0.90 ± 0.02	12.75 ± 0.05	17.15 ± 0.05
2004	0.88 ± 0.02	12.08 ± 0.05	18.48 ± 0.05	0.84 ± 0.02	12.58 ± 0.05	16.98 ± 0.05
2005	0.98 ± 0.02	12.33 ± 0.05	18.73 ± 0.05	1.10 ± 0.02	13.00 ± 0.05	17.40 ± 0.05
2006	0.84 ± 0.02	11.58 ± 0.05	17.98 ± 0.05	0.88 ± 0.02	12.67 ± 0.05	17.07 ± 0.05
2007	0.79 ± 0.02	12.25 ± 0.05	18.65 ± 0.05	0.69 ± 0.02	12.92 ± 0.05	17.32 ± 0.05
2008	0.79 ± 0.02	12.00 ± 0.05	18.40 ± 0.05	0.65 ± 0.02	13.00 ± 0.05	17.40 ± 0.05
2009	0.71 ± 0.02	11.92 ± 0.05	18.32 ± 0.05	0.62 ± 0.02	11.92 ± 0.05	16.32 ± 0.05
2010	0.79 ± 0.02	11.75 ± 0.05	18.15 ± 0.05	0.75 ± 0.02	12.25 ± 0.05	16.65 ± 0.05
2011	0.88 ± 0.02	12.33 ± 0.05	18.73 ± 0.05	0.83 ± 0.02	13.00 ± 0.05	17.40 ± 0.05
2012	1.01 ± 0.02	11.58 ± 0.05	18.23 ± 0.05	0.89 ± 0.02	12.75 ± 0.05	17.15 ± 0.05
2013	0.87 ± 0.02	11.33 ± 0.05	17.73 ± 0.05	0.82 ± 0.02	12.42 ± 0.05	16.82 ± 0.05
2014	0.83 ± 0.02	11.50 ± 0.05	17.90 ± 0.05	0.80 ± 0.02	12.00 ± 0.05	16.40 ± 0.05

which the maximum occurs. Each angle displays the corresponding phase, while the length of the vectors corresponds respectively to the quantity A. In order to achieve this, the hours are converted to degrees (1h corresponds to 15 °) and simple vector calculus is used for the construction of the vectors. The mean annual values of the amplitude and the phase (in UT and LT) of the diurnal anisotropy with their errors for Athens and Oulu stations for the time period 2001–2014 are quoted in Table 2. Time profiles of these amplitudes and times of maximum in UT and LT during the different phases of the SC are presented in Fig. 2. The geomagnetic bending for each station is calculated by using the asymptotic cones via Tsyganenko96 magnetospheric model. Specifically the correction for Oulu station is:

$$LT_{OULU} = UT + 2 \; + \; 2.4 \tag{3}$$

whereas the respective equation for Athens station is:

$$LT_{ATHN} = UT + 2 \; + \; 4.4 \tag{4}$$

The factors 2.4 h for Oulu NM and 4.4 h for Athens NM are the corrections due to geomagnetic bending calculated by the Tsyganenko96 model.

The magnetic bending value for each NM station is calculated using its asymptotic longitude and the estimation of the angle between this point and the point of the maximum CR flux in the east direction. In our case this angle is found to be about 66° for Athens and 40° for Oulu. Then this value is converted to hours (1 h is 15 °), giving the corresponding correction for the geomagnetic bending (McCracken et al., 1965; Chaloupka, 1970; Mavromichalaki, 1989). The correction in the phase due to the geomagnetic bending is about two hours greater for Athens than for Oulu. The deflection angle would be similar for the two NMs, due to the same geographical longitude, but the deflection (and amplitude reduction) changes not only with the longitude, but also with the latitude which is considerably higher for Oulu (65.05° N) than for Athens (37.58° N). Primary particles arrive at a high latitude NM more along the geomagnetic field resulting in a relatively smaller geomagnetic deflection when compared with particles arriving at a low latitude NM.

The factor 2 in the Eqs. (3) and (4) is identical for the two stations as they both belong to the same meridian. The other factor is different though, as it is due to the different range of the asymptotic cone of each station. Therefore, a much narrower divergence between universal and local time is observed in Oulu than in Athens.

The diurnal anisotropy vectors for Athens and Oulu NMs are presented on a monthly basis for selected years of the examined period in Fig. 3. Finally, the diurnal anisotropy for both Athens and

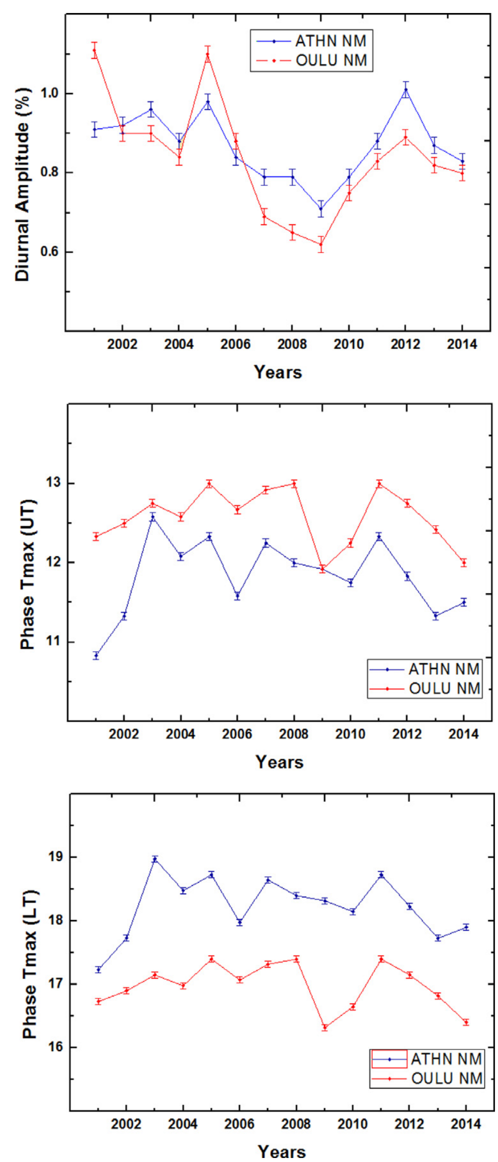

Fig. 2. The annual values of the amplitude (upper panel) and the time of maximum in UT and LT (middle and lower panels) of the diurnal anisotropy are presented.

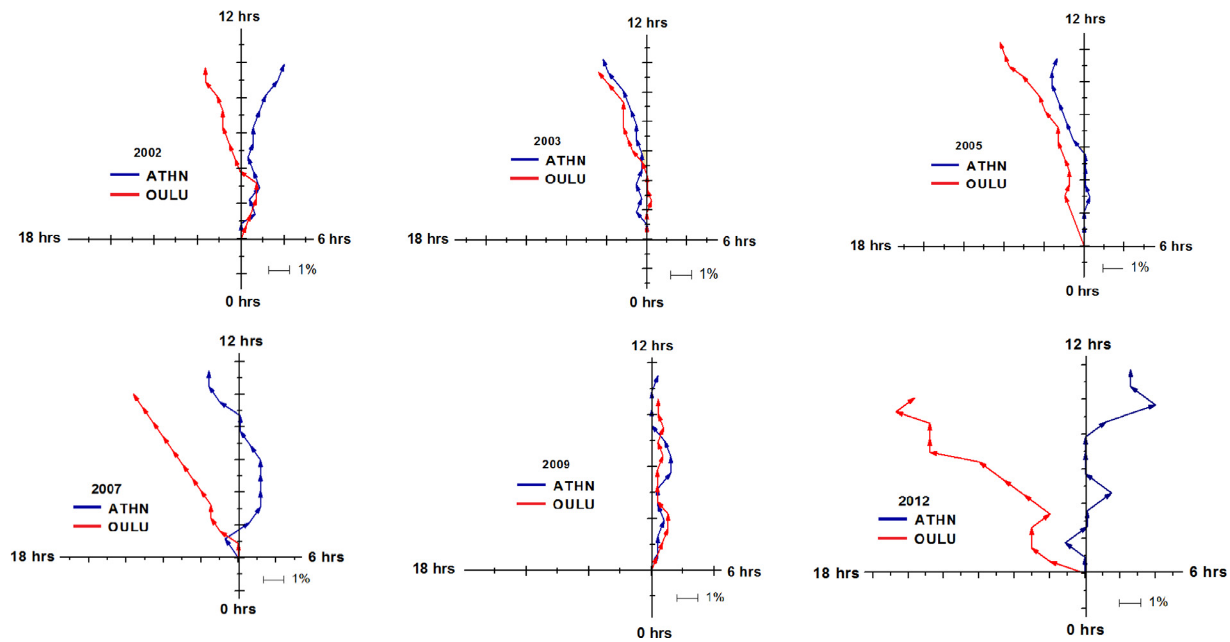

Fig. 3. Monthly diurnal anisotropy vectors for Athens and Oulu stations for selected years of the examined period.

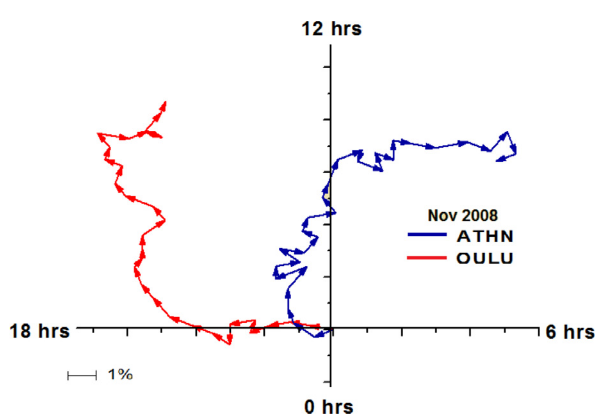

Fig. 4. Daily diurnal anisotropy vectors for a quiet month (November 2008).

Oulu NMs is presented during a quiet month in Fig. 4 and during periods of intensive solar and cosmic ray activity, such as GLEs, Forbush decreases and magnetospheric events in Fig. 5.

3. Diurnal variation during the solar cycle

Time profile of the calculated average annual values of the amplitude (A%) (upper panel) and the time of maximum in UT and LT (middle and lower panels) of the diurnal anisotropy for the time period 2001–2014 are illustrated in Fig. 2. It is outlined from this figure that the diurnal amplitude seems to follow the 11-year variation of the SC, while the same does not seem to occur with the diurnal phase. In both stations the yearly average diurnal amplitude presents a maximum value in the years 2001–2004 that is consistent with the primary (2001) and secondary (2003) maxima of the SC 23 and in the year 2013, maximum of the SC 24, while a clear minimum is presented in the years 2008–2009 that are coincided with the solar minima. This is consistent with the results of Tiwari et al. (2012) for the SCs 20, 21, 22 and 23, showing that the diurnal amplitude varies with a dominant period of 11-year solar activity cycle with the lowest values occurring at solar minima, and the highest values near the solar maxima or near the minima of the declining phase of solar activity, while the diurnal phase varies with a dominant period of 22-year solar magnetic cycle. The time of maximum is mostly influenced by the orientation of solar magnetic field, rather than by the phase of the solar activity like the diurnal amplitude.

Moreover, it is known that the solar magnetic field (SMF) reverses around each solar maximum activity (Ahluwalia, 1988). In our case the reversal of the SMF from positive to negative polarity was done at the year 2001 and from negative to positive polarity at the year 2012 (Svalgaard and Kamide, 2013). Another research supports that the north polarity was reversed during the time period of June-September 2000, while the south one was reversed during the period of May-August of 2001 (Dikpat and Wilson, 2003). This confirms the fact that in our case (Fig. 2) the phase remains constant during the same polarity of SMF. Normally, two components are present in the anisotropy, one in the corotation direction and one radially outward from the sun (radial anisotropy). The annual average diurnal amplitude is maximum during the declining phase of the SC 23, and remains stable during the minima period of solar activity (2007-2009), while it obtains the minimum value during the year 2009. Then, the annual average diurnal amplitude seems to be increased again during the ascending phase of SC 24.

According to Bieber and Chen (1991) the long term CR modulation is not only determined by the diffusive - convective mechanism, but also by the drift effect due to solar polar magnetic field reversal. All NMs show a 22-year cycle phase variation controlled by the drift effect regardless of their latitudinal location and cut-off rigidity. Additionally, NM stations in lower latitudes present an 11-year cycle variation because of the diffusion effect due to the IMF magnitude variations with the SC (Bieber et al., 2010), as it is clearly observed in the UT harmonic dial. Athens shows a greater disturbance than Oulu which is located in high latitude (small cut-off rigidity) and consequently is not greatly affected by the 11-year cycle phase variation. The diurnal phase remains constant in large scale during the entire period. It is also observed that there is no significant phase shift during the descending phase of the SC 23 and the phase remains invariant during the ascending phase of SC 24. These results are consistent

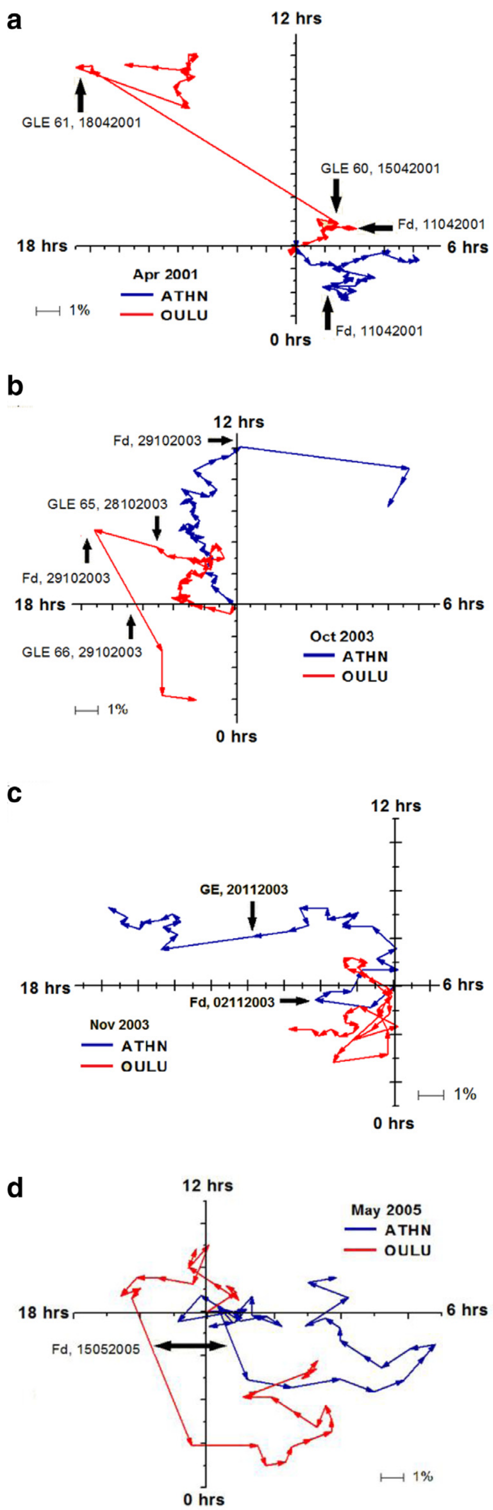

Fig. 5. Daily diurnal anisotropy vectors for selected extreme solar and cosmic ray events: during (a) April 2001, (b) October 2003, (c) November 2003 and (d) May 2005.

with the "odd-even SC model" proposed by Tiwari et al. (2012). Results for the Athens and Oulu NMs are consistent with the co-rotational model supporting the average diurnal amplitude along the 18 h (LT) direction (lower panel of Fig. 2).

The monthly diurnal anisotropy vectors for Athens and Oulu stations for selected years are presented in Fig. 3. A short term phase shift is observed during the years of the descending phase of the SC 23 and the years of the ascending phase of the SC 24. An identical phase shift to earlier hours during the SC minimum (year 2009) is observed for both stations (Agarwal and Mishra, 2008). It is interesting to note that in our case the diurnal phases are almost the same for the year 2009, whereas a significant shift is observed during the maximum of the SC 23 and SC 24, accordingly. Our results are in agreement with other researchers (Mailyan and Chilingarian, 2010; Tiwari et al., 2012).

4. Diurnal variation during solar and cosmic ray events

4.1. Ground recorded cosmic ray events

The CR intensity modulated by the solar activity presents many variations that affect the diurnal variation. The most important of them are the Ground Level Enhancements (GLEs), the Forbush decreases (Fds) and the magnetospheric events (GE). In this work a study of the diurnal variation over such events in order to reveal indexes of space weather activity and analyse their evolution in time is carried out for first time.

It is known that the Ground Level Enhancements (GLEs) of CR intensity occur when a solar flare accelerates protons to sufficiently high energies for these particles to propagate along the heliomagnetic field to the Earth and be detected as a sharp increase in the counting rate of a ground based cosmic ray detector (Plainaki et al., 2005; 2014). During the SC 23, a number of 16 such events were occurred whereas only one occurred during SC 24 till now (Andriopoulou et al., 2011; Papaioannou et al., 2014). From our analysis in this work it is resulted that when GLEs take place, a very large increase of the amplitude of diurnal anisotropy is observed. As expected, these events are much more evident by the Oulu NM, while in Athens it is almost impossible to record such events.

Moreover, a Forbush Decrease (Fd) is a sudden and rapid decrease in the intensity of the GCR component with duration of about one week, which is due to strong solar events, such as coronal mass ejections, and can be recorded on Earth by the NMs of the world wide network (Papailiou et al., 2012). The amplitude of these decreases is due to the different cut-off rigidity of each NM (Lingri et al., 2013). More specifically, in this work studying the diurnal vectors during the Fds over the period 2001–2014, it is noticed that a change of the direction and even reversal of the diurnal anisotropy vector is observed, resulting in strong fluctuations and loops. It is expected from the fact that the flux of cosmic radiation is not constant during the rotation of the Earth around its axis. These results are consistent with the diffusive-convective mechanism illustrated in the right panel of the Fig. 1 (Mavromichalaki, 1989). The flux variations during Fds can be equally observed by the two NMs, although the loops are more evident for the station of Oulu, due to higher latitude and smaller Rc.

Finally, a magnetospheric event (GE) is also a sharp increase of CR intensity during a geomagnetic storm due to the influence of the geomagnetic field and therefore due to geomagnetic cut-off rigidity changes. As a result, they become visible in middle geographic latitudes such as Athens and not in near polar regions such as Oulu (Belov et al., 2005; Mavromichalaki et al., 2013). NMs with Rc ranging from 6 to 9 GV are the most effective for recording major geomagnetic storms and definition of the maximum dRc changes (Tsyganenko et al., 2003). During the declining phase of the SC 23, many characteristic geomagnetic effects were observed with the most significant one on November 20, 2003, which is considered as the largest magnetic storm in the history of NMs (Mavromichalaki et al., 2013).

4.2. Case studies of diurnal variation

From our analysis during periods of intense solar activity over the years 2001 to 2014 covering the declining phase of the SC 23, the extended minimum of the SC 23/24 and the ascending phase of the SC 24, it is outlined that the harmonic dials of the diurnal anisotropy vectors exhibit very high ranges. For comparison, the diurnal vectors in a harmonic dial for both stations over the quiet month of November 2008 that is in the minimum of the SC23 characterized by low solar activity, are shown in Fig. 4. During this month, there are no particular variations of the diurnal anisotropy vectors on a daily basis. Typical examples of the diurnal vectors of selected extreme CR events during the examined period are illustrated in Figs 5a–d. Many reversals and changes of the vectors are observed during all these panels of this figure. Specifically:

In April 2001 presented in Fig. 5a, a reversal of the diurnal anisotropy vector for both stations is observed during the Fd of April 11, 2001. The GLE60 and GLE61 of April 15 and April 18 respectively, observed only by Oulu NM as a near polar station, present a very high increase in the diurnal amplitude. Nevertheless, great disturbances in the diurnal anisotropy are also observed in Athens NM.

In October 2003 presented in Fig. 5b, one of the most astonishing Halo CMEs (Mother of all Halos) took place on the 28/10/2003, provoking the GLE65 and a series of Fds. This GLE was recorded by the Oulu NM, while the Fd recorded with amplitude of 21% in Athens NM, causing a strong phase reversal in the diurnal vectors, is evident by both stations.

During the magnetospheric event of November 20, 2003 presented in Fig. 5c, a variation in the amplitude by 7% was recorded by the Athens NM and aurora was visible even from lower latitudes. This event was not detected by the Oulu NM with the corresponding diurnal vector remaining invariant, in opposite to the increased diurnal anisotropy of Athens NM directed to the corotational direction. The Fd reduction of this period was overspread by simultaneous increase in intensity due to the GE. The peculiarity of this storm is due to the fact that, based on the model Treiman, the ring current was in closest proximity to the centre of the Earth (Tsyganenko et al., 2003; Belov et al., 2005).

In May 2005 presented in Fig. 5d, a change in the direction of the diurnal anisotropy vector is also observed, resulting in strong fluctuations and loops, due to the Fd of May 11, 2005.

5. Conclusions

From the above analysis and results it is concluded that:

- The diurnal time of maximum is observed to be around 12 h in UT for both stations, Athens and Oulu, whereas the diurnal amplitude is bigger in high latitudes-Oulu comparing to middle ones-Athens (Mailyan and Chilingarian, 2010)
- The annual diurnal amplitude follows the 11-year variation of the SC, while the same doesn't seem to occur with the diurnal phase. This is consistent with the results of Tiwari et al. (2012), which support the correlation with the 11-year SC, while it is suggested that the diurnal phase varies with a period of 22 years (one solar magnetic cycle). The radial anisotropy vanishes during negative IMF polarity resulting in a phase shift to earlier hours (Ahluwalia, 1988). In our case there is no evidence for a systematic phase shift on large scale for both stations for the examined period (Tiwari et al., 2012).
- A short term phase shift during the descending phase of the SC 23 and the ascending phase of the SC 24 is observed (Fig. 3). The time of maximum is identical for both stations during the minimum (year 2009), whereas a great shift is observed during the maximum of SC 23 (year 2002) and SC 24 (year 2012).
- The drift effect is of great importance for both stations and provides a simple explanation for the long term behaviour of cosmic ray diurnal anisotropy (Bieber and Chen, 1991; Bieber et al., 2010).
- The amplitude of the CR diurnal variation shows a great increase during GLEs, which is only observed by high latitude neutron monitor stations.
- During Forbush decreases, a variation in the phase is observed by both stations, expressed as a reversal or a change in direction of the diurnal vector, resulting in fluctuations and loops, as the flux of cosmic radiation is not constant during the rotation of the Earth around its axis. These results are consistent with the diffusive-convective mechanism (Ahluwalia, 1988). Loops and reversals during Fds are evident in both high and middle latitude stations.
- Magnetospheric events mainly observed in middle latitude stations, are followed by a great increase in the CR diurnal amplitude, similar to the one observed in high latitude stations during GLEs.

Summarising, we can say that interesting suggestions outlined from our analysis on the diurnal anisotropy of the two NMs of Oulu and Athens for more than 11 years, will help to a more complete work using data sets of more NMs located over the world providing by the High resolution neutron monitor database-NMDB (http://www.nmdb.eu). The study of the diurnal variation will reveal indexes of space weather activity useful to technological and biological applications.

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