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Cosmic ray diurnal anisotropy during different phases of the solar cycles 23 and 24

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Abstract: The diurnal variation of cosmic ray intensity for the time period 2001 to 2014 is studied. Data from two neutron monitor stations at Athens (Greece) and Oulu (Finland) are used. The amplitude and phase of the diurnal anisotropy vectors have been calculated on annual and monthly basis using Fourier analysis. From our analysis, it is resulted that there is a different behavior during the different phases of the solar cycles depended on the solar magnetic field polarity. Comparison with corresponding phases of other solar cycles has been performed. The characteristics of the diurnal anisotropy during extreme events of cosmic ray activity are also discussed.

1 Introduction

Cosmic rays are particles at very high energies from extraterrestrial sources within or outside of our Galaxy. The cosmic radiation has high stability and isotropy in galactic scale. Nevertheless, the Sun and the interplanetary magnetic field result in anisotropies and variations in both the energy spectrum and the intensity of cosmic radiation as a function of space, time and energy. The diurnal anisotropy of cosmic ray 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 cosmic radiation [1] [2]. The diurnal variation is mainly due to local anisotropy of galactic cosmic ray flux due to the convection by the solar wind and the diffusion along the interplanetary magnetic field (convective-diffusive theory) [3].

2 Data Analysis

Hourly corrected for pressure and efficiency values of the cosmic ray intensity from the Neutron Monitor stations of the University of Athens - ANEMOS (cut-off rigidity 8.53 GV, http://cosray.phys.uoa.gr/) and the University of Oulu (cut-off rigidity 0.81 GV, http://cosmicrays.oulu.fi/) have been used. These stations have the same geographic longitude, but different geographic latitude. The examined time period 2001-2014 covers the maximum, 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. The diurnal vectors are calculated for each day (amplitude and time of maximum) using Fourier analysis according to the Eq.(1):

$$I_i = f(t_i) = I_{mean} + A\cos(\omega t_i + \phi) \quad (1)$$

where I_{mean} is the daily average of cosmic ray intensity, A the amplitude and ϕ the phase of diurnal variation [4]. Our data have been normalized according to the I_{mean}. The calculated diurnal vectors are presented on a harmonic dial on monthly and annually basis.

3 Results and Conclusions

From our analysis it is concluded that:

- The diurnal time of maximum is observed to be around 12 hrs in UT for both stations, Athens and Oulu, whereas the diurnal amplitude is bigger in high latitudes (Oulu) comparing to middle ones - Athens [5].

- The annual diurnal amplitude follows the 11-year variation of the solar cycle, while the same does not seem to occur with the diurnal phase (Fig. 1). This is consistent with the results of [6], which support the correlation with the 11-year solar cycle, 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 [2]. In our case there is no evidence for a systematic phase shift on large scale for both stations for the examined period [6], characterized by a negative IMF polarity.
- The drift effect is of great importance for both stations and provides a simple explanation for the long term behavior of cosmic ray diurnal anisotropy [7], [8].
- A short term phase shift during the descending phase of the solar cycle 23 and the ascending phase of the solar cycle 24 is observed. The time of maximum is identical for both stations during the minimum (year 2009), whereas a great shift is observed during the maximum of solar cycle 23 (2002) and solar cycle 24 (2012).

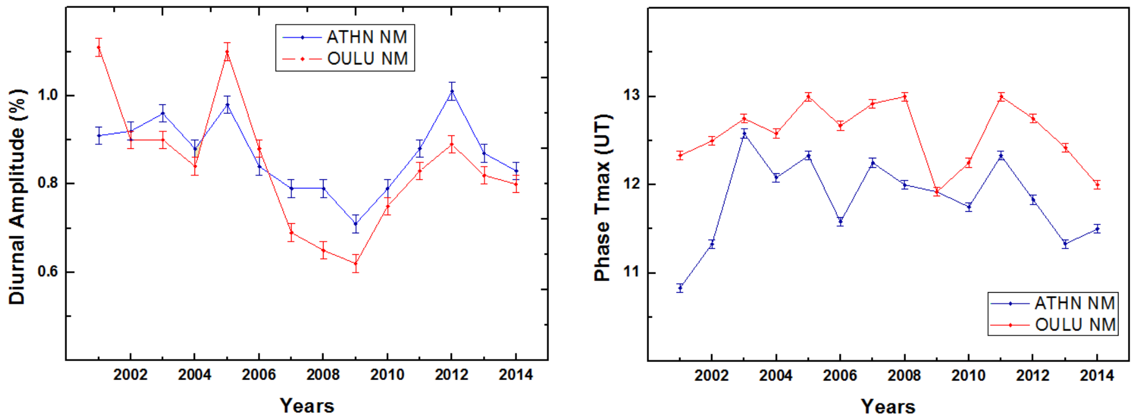

Figure 1: Annual distribution of the amplitude (left panel) and the time of maximum (right panel) of the diurnal anisotropy).

- The amplitude of the cosmic ray diurnal variation shows a great increase in the case of extreme solar events as GLEs, which is only observed by high latitude neutron monitor stations. Similarly a great increase in the cosmic ray diurnal amplitude is observed at middle latitude stations during geomagnetic effects. During Forbush decreases, variation in the phase is observed by both high and middle latitude stations, expressed as a reversal or a change in the direction of the diurnal vector, resulting in fluctuations and loops, due to the diffusive-convective mechanism [9].

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