

# The study of daily variation of cosmic ray anisotropy for the period of 1991 to 2004

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Based on the long term trend of daily variation of the first three harmonics for Haleakala neutron monitor station has been analyzed. In our analysis the diurnal phase has continuously changed to earlier hours from 1991 to 1994 with some what decreasing amplitudes. The change of diurnal vector during the 11 year solar cycle is not very different than that reported for earlier solar cycles. In fact larger changes during the 11 years period have been observed during alternate solar cycles. The semi diurnal vectors for Haleakala neutron monitor station are also shown for 1991 to 2004 for each year. Where it has been observed that the semi diurnal phase changes to later hours with maximum amplitudes in 1997 and 1998. The tri-diurnal phase continuously changes to earlier hours from 1991 to 1995 and later hours from 1996 to 2000. However, the phase during the year 2000 is in the fourth quadrant, whereas for all other years they are concentrated around 180 degree.

## 1. Introduction

Earlier studies reported the characteristics of the first three harmonics of daily variation of cosmic ray intensity [1-6]. The amplitudes and time of maximum of all the three components (diurnal, semi-diurnal and tri-diurnal) usually show 11 and 22 year variability. The daily variations of cosmic ray intensity have generally been studied by using the hourly data recorded by ground-based high counting rate super neutron monitors. These monitors are operating continuously for almost four decades at various locations on the earth's surface and their worldwide locations are well distributed both in latitude and longitude. In this research work, we have done analysis to study the variational profile of cosmic ray daily variation, using the hourly values of Haleakala station during the interval 1989 to 2004, which represents the maximum of solar cycle 22 to and ascending phase of solar cycle 23.

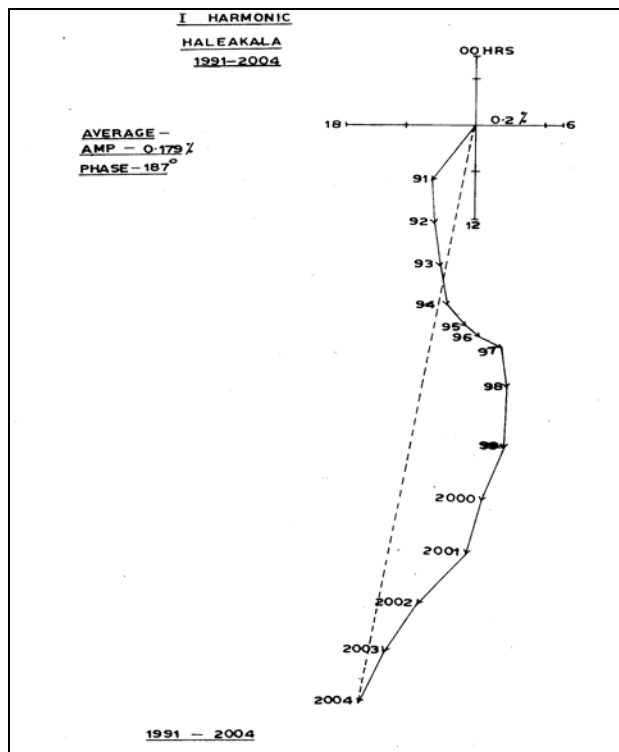
## 2. Discussion

The annual average values have been plotted end-to-end for the period of 1991 to 2004. The overall average value is shown in the Figure 1 and Figure 2 by a dashed line for the Haleakala neutron monitor station.

From the figures we very clearly notice that the diurnal phase has continuously changed to earlier hours from 1991 to 1997 with some decreasing amplitudes. It is found that the behaviour of diurnal amplitude and phase during the descending phase of solar activity in previous solar cycle 22 and during this solar cycle 23 is quite different. We have deduced the averages amplitude and phase for the period of 1991-2004 using the hourly values of Haleakala neutron monitor as given below:

$$r^1_{\text{avg}} (1991-2004) = 0.179\%$$

$$\phi^1_{\text{avg}} (1991-2004) = 187^\circ$$



**Figure1.** Yearly average vectors for diurnal variation of cosmic ray intensity observed by neutron monitor at Haleakala for 1991 to 2004.

The change of diurnal vector during the 11-year solar cycle is not very different than that reported for earlier solar cycle i.e. larger changes during the 11-year period has been observed during alternate solar cycles. The diurnal anisotropy is also related with sunspot cycle. The amplitude and phase of the diurnal anisotropy changes with a period of one or two solar cycle [7]. Similar analysis has been extended for the semi and tri-diurnal anisotropies. It is observed from Figure. 2 that the semi-diurnal phase changes to earlier values till 1997. However, maximum amplitudes are observed in the years of 1993, 1994 and 2004.

The overall average for the entire period for Haleakala station is found to be:

$$r^2_{\text{avg}} (1991-2004) = 0.147\%;$$

$$\phi^2_{\text{avg}} (1991-2004) = 334^\circ$$

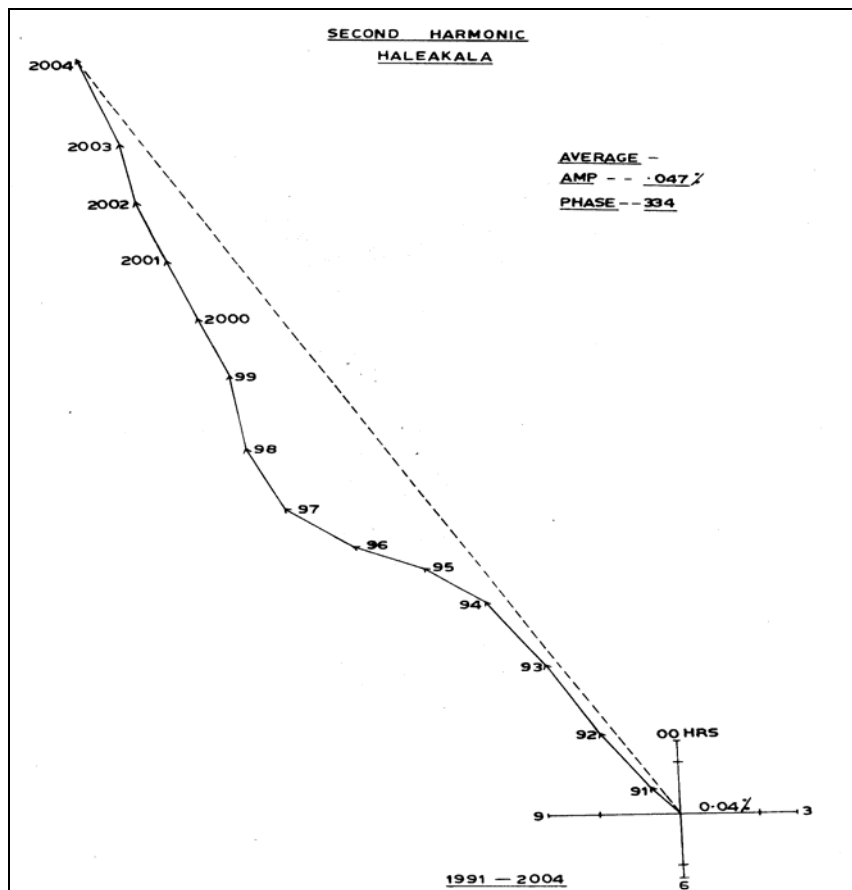
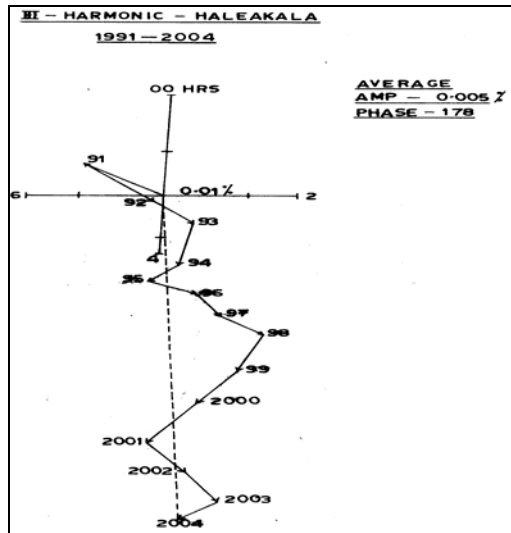


Figure 2. Yearly average vectors for semi-diurnal variation of cosmic ray intensity observed by neutron monitor at Haleakala for 1991 to 2004.

Similar set of values for Haleakala station are shown for the semi-diurnal and tri-diurnal variation in the figures 2 and 3 for the years 1991-2004. The overall vector shown by the dashed line as shown in Figure 3. It is found that the overall average vector for the entire period (1991-2004) for Haleakala station is

$$r^3_{\text{avg}}(1991-2004) = 0.0057\%;$$

$$\phi^3_{\text{avg}}(1991-2004) = 178^\circ$$



**Figure 3.** Yearly average vectors for tri-diurnal variation of cosmic ray intensity observed by neutron monitor at Haleakala for 1991 to 2004.

### 3. Conclusion

Eleven year variations in first three years are observed for the period of 1991 to 2004. Diurnal phase has been shifted to earlier hours from 1991 to 1994, with decreasing amplitude. Semi-diurnal phase changes to later hours with maximum amplitude in 1997 and 1998. The tri-diurnal phase changes to earlier hours from 1991 to 1995 and later hours from 1996 to 2000.

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