1.7 Year Quasi-Periodicity in Cosmic Ray Intensity Variation

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Abstract

It has been reported previously that ~ 1.7 year quasi-periodicity is seen in cosmic ray intensity variation observed at several Neutron Monitors (NMs) and Voyager spacecrafts by using of wavelet transform technique. We have extended cosmic ray energy by using of muon data and confirm that the quasi-periodicity exists. The time evolution of the quasi-periodic component shows its peak in 1987. Comparing wavelet power of NMs with maximums in 1982 and 1990, there is one peak for the energy region between two peaks for NMs. Additionally, wavelet power spectrum of the recurrent component was examined for the solar cycle 19, 20, 21 and 22 by using of Climax NM data. The result indicates that the quasi-periodicity is more importantly contributing to cosmic ray intensity variation during the cycle 21 than the cycle 19.

Introduction

Previous studies clarified the existence of periodicity longer than the diurnal component in several space plasma parameters and cosmic ray intensity variations (e.g. Valdes-Garicia et al.[1], Mursula and Zieger[2]). Recently, wavelet transform technique has been introduced to analyse periodicities in cosmic ray intensity variations. Kudela et al.[3] reported relative dominance of ~ 1.7 and ~ 1.3year quasi-periodicity during the solar cycles 21 and 22, respectively, to other cycles by using of several Neutron Monitors (NMs). Kato et al.[4][5] reported that the general trend of the quasi-periodicity is similar between low energy (70 MeV/n) and a few GeV particles observed at Voyager spacecrafts and NMs, respectively. It is natural to be curious about the time evolution of these quasi-periodic component in higher energy. In this paper, we report the result of wavelet analysis of the ~ 1.7 year quasi-periodicity in higher energy data observed by the Nagoya muon telescope.

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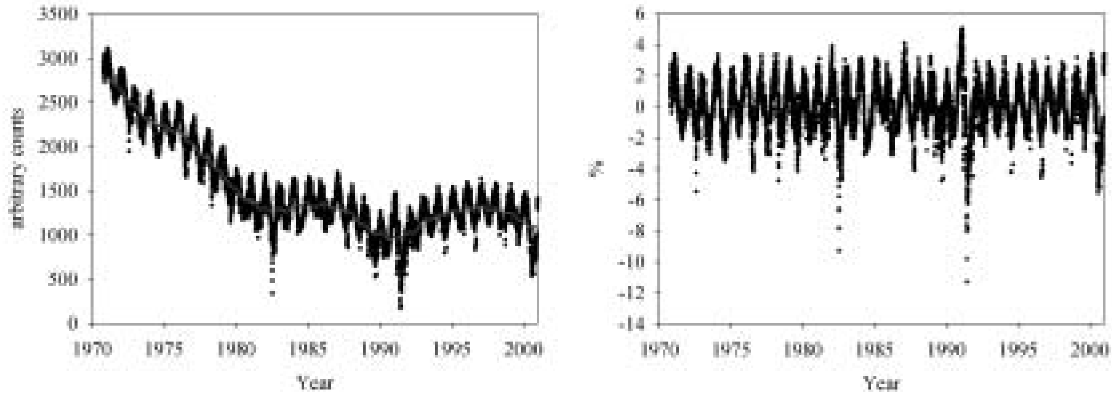

Fig. 1. Daily averaged cosmic ray intensity variation from 1970 to 2000 observed by the Nagoya muon telescope (left). Filtered data for getting rid of instrumental decrement (right).

Analysis

The pressure-corrected hourly cont rate of muons recorded at the Nagoya muon observatory has been used to probe $\sim$ 1.7 year quasi-periodicity at higher energy. The muons are observed with multi-directional telescope at the observatory and the count rate in the vertical channel of the incident direction has been analysed in this paper. The effective geomagnetic cut-off rigidity of the component at Nagoya is 11.5 GV.

The temporal variation of the daily muon count rate from 1973 to 2000 is shown in figure 1. The deterioration of the instruments is the main cause of decrement of the intensity until 1980. Running average technique has been used for getting rid of this instrumental variation. The filtered data are shown in figure 2. The seasonal intensity variation due to the atmospheric temperature effect can be clearly seen in the figure.

Analysis has been performed by using of the mother wavelet

$$\varphi(x) = \frac{1}{2\sqrt{\pi}\sigma} exp(-\frac{x^2}{\sigma^2}) exp(ix)$$

which is called the Gabor wavelet, with the $\sigma = 16$. It is difficult to estimate a frequency resolution for the mother wavelet under the multi-wave conditions. As a frequency resolution for a stable monochromatic wave is $\sim$10 10 percent is selected as provisional error.

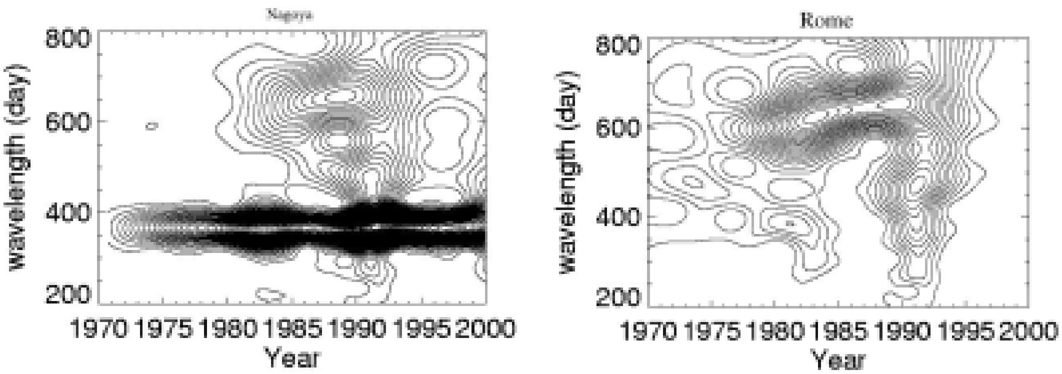

Fig. 2. Contour of wavelet power of the muon count rate at Nagoya (left) and NM at Rome (right).

summary and discussion

The contour of the wavelet power derived by the wavelet analysis is shown in figure 2 (left). The large enhancement at 1 year is due to the atmospheric temperature variation. There is the ~ 1.7 year quasi-periodic component is dominant during solar cycle 21 with maximum around 1987. The general property of the contour is quite similar to that for NMs, which is shown in figure 2 (right). Two peaks of $\sim$1.0 year component can also be seen in 1983 and 1991. The peak in 1991 might be corresponding to ~ 1.3 year periodicity in the NM data. Another example of NM is also shown in figure 3 (left). Results are summarised in table 1.

Table 1. Peak wavelength and the time of maximum wavelet power.

Data Source	peak wavelength (year)	maximum year
Voyager1 and 2	1.79 ± 0.18	1982
NMs	1.70 ± 0.17	1982
Nagoya	1.78 ± 0.18	1987

The ~ 1.7 and ~ 1.0 year, which is ~ 1.3 year for NMs, quasi-periodic component dominate during the solar cycle 21 and 22, respectively. It is known that the Interplanetary Magnetic Field (IMF) variation is well corresponding to the cosmic ray intensity variation. Recently, using the solar wind and Kp index, Mursula and Zieger[2] showed that ~ 1.3 year quasi-periodicity dominates during the even solar cycle and also found dominant quasi-periodicity are shifted to $\sim 1.5 \sim 1.7$ year during odd cycle. Thus, it is useful to compare the cycle 19 and 20 for probing mechanisms creating the quasi-periodic variation. Figure 3

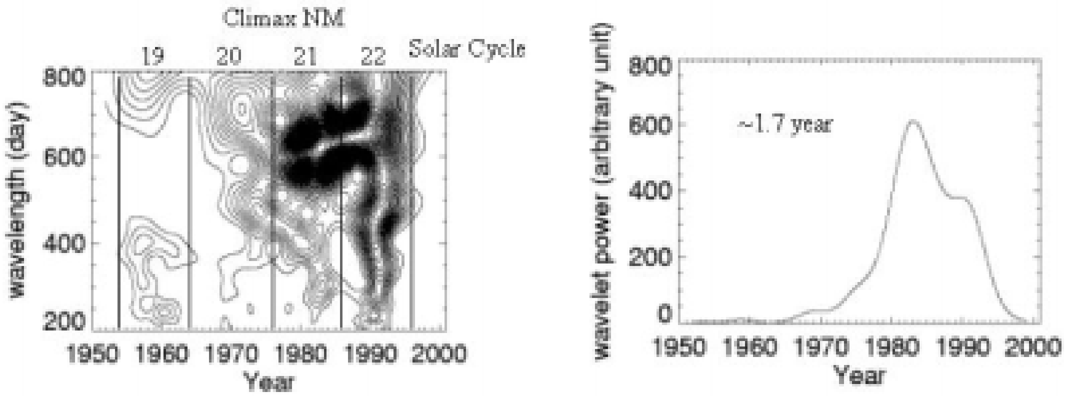

Fig. 3. Contour of wavelet power for Climax NM covering four solar cycle, 19, 20, 21 and 22. There is no enhancement at ~ 1.8 year component during the cycle 19.

shows contour (left) and spectrum (right) of wavelet power of the Climax NM data during the cycle 19 $\sim$ 22. There is no significant enhancement of the ~ 1.7 year component in the cycle 19. On the other hand, it seems that the ~ 1.1 year component enhances in the cycle 19. Thus, ~ 1.7 quasi-periodic variation in NM data exist only in the cycle 21, at least during these four solar cycle. During the cycle 19 and 21, the sun has the same magnetic polarity. This might indicate the magnetic polarity is not sufficient condition to create the ~ 1.7 quasi-periodicity in cosmic ray intensity. Kudela et al.[3] also reported ~ 1.3 year quasi-periodicity shows a better correspondence to the IMF than the ~ 1.7 year variation. Therefore, there would be different condition to create the quasi-periodicity in cosmic ray intensity variation during the cycle 21 to the cycle 19.

Acknoeledgements

Climax and Rome (SVIRO) NM are supported by National Science Foundation Grant ATM-9912341 and the long-term IFSI/CNR-UNIRoma3 COLLABORATION.

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