
Daily Variation of Cosmogenic Nuclide Be-7 Concentration in the Atmosphere and Solar Activities

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Abstract

Concentrations of cosmogenic radioisotope Be-7 in air were daily observed at Yamagata University during 2000 and 2002. From the power spectral analysis, the periodicity of the period of 26 days is shown for the daily Be-7 concentrations. The folding analysis shows that the phase delay of the Be-7 concentration was roughly 8 days to the sunspot number. These results indicate that the Be-7 concentrations in the air at ground level have 26-day periodicity as a component of time variations and it is caused by the solar modulation of galactic cosmic rays.

1. Introduction

Be-7 is a cosmogenic radioisotope produced by interaction between cosmic rays and elements in the atmosphere[1]. Cosmic rays approaching to the earth are affected by solar magnetic fields and hence the production rate of Be-7 depends on the solar activity. On the other hand, as Be-7s remain in the atmosphere for a certain residence time, the concentration of Be-7 in air mass reveals the atmospheric conditions[2]. Therefore, the time variation of the concentration of Be-7 in air at ground level indicates both solar modulation and variation of meteorological conditions.

The concentration of Be-7 in air at ground level shows time variations in the order of days, however, relationships between the short-term variation of the Be-7 concentration and solar activities are not known in detail [3]. Therefore, we have been observing the daily Be-7 concentration (BEC) since 2000 at Yamagata University. The analysis of the modulation pattern was carried out, focusing on clarifying a relationship between the daily variation of the Be-7 concentration in the air and the 27-day rotation period of the sun. As the index of solar activity, the number of sunspots(SSN) on each day was employed. Moreover, we compared the variation of BEC with the neutron data [4] that reflects the time variation of cosmic rays approaching to the earth.

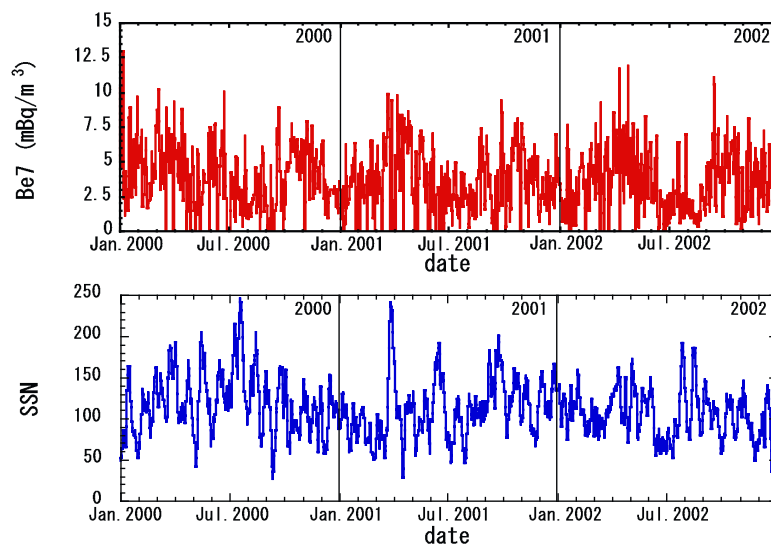


Fig. 1. Time profiles of the daily Be-7 concentrations and the sunspot numbers during 2000,2001 and 2002.

2. Observation

The daily Be-7 concentration in the air is continuously observed at the top of a building 15 m in height, at Yamagata University. The location is at $38^{\circ}15.2$ N, $140^{\circ}20.9$ E and its altitude is 152.2 m from sea level. A high-volume air sampler (HV-1000F) was employed for the collection of the air mass. The volume rate of the air mass intake is regulated to 1380 m^3 per 23 hours, with the accuracy of 0.02%. The dust in the air mass including Be-7 is trapped in a glass-fiber filter with the cross section of 203 mm x 254 mm (ADVANTEC GB-100R). The specific activity of the Be-7 in the filter was measured with a high-purity germanium gamma-ray detector GEM-25185, surrounded by shielding materials. The specific activity of the Be-7 was measured with 477.6 keV gamma ray.

3. Results and Discussion

Fig. 1 shows the daily profiles of the BEC in the air at ground level and the SSN [4] from 2000 to 2002. The seasonal variations are shown in the figure for the spring and the autumn for the BEC. To investigate the periodicity of the BEC and the SSN, the power spectral densities (PSDs) were calculated for the three years data of them. Fig. 2 shows the PSDs for the BEC, the SSN, and the Beijing neutron data as a function of period in unit of day. All of three PSDs show a peak at the period of 26 days that indicates the rotation period of the sun.

The three years daily data of the BEC, SSN, and the neutron data from

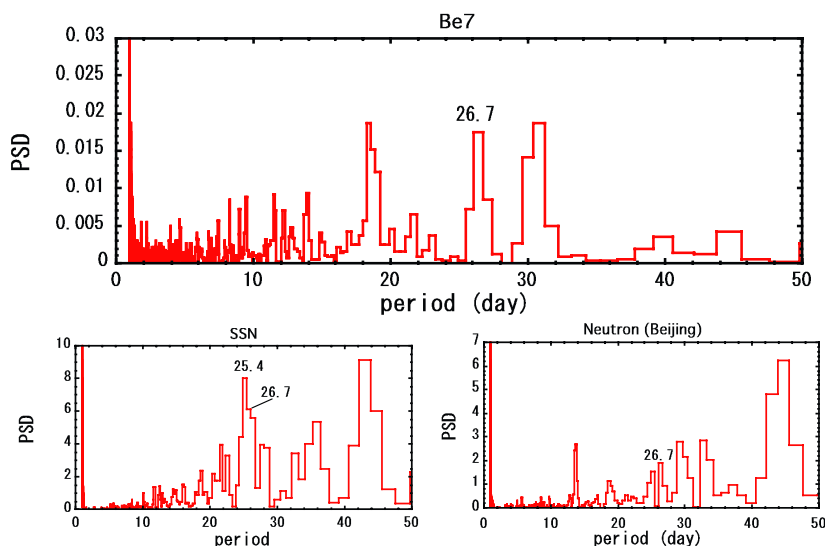


Fig. 2. Power spectral densities for each time series of the Be-7 concentration, the sunspot number and the Beijing neutron. All of spectra show a peak at 26.1 days that corresponds to the rotation period of the sun.

2000 to 2002 were folded with a same folding period of 26 days and normalized to the value per day, respectively. The neutron data were used for four observation sites of Beijing, Calgary, Kiel and Moscow. In Fig. 3, the moving averages of 5 points for all of the folding data are shown with the relative variations to their averages, respectively. The relative variations of the BEC, the SSN and the neutron were approximately 20%, 13% and 0.7% for the peak to peak, respectively. The phase for the minimum portions of the BEC and the neutrons are delayed approximately 8 days and 3 days, respectively, compared with that for the maximum portion of the SSN. The delay time of 3 days for the neutrons is inferred a propagation time from the sun to the earth for disturbances corresponding to the SSN, considering the travel time of solar wind plasma from the sun to the earth. Also, the phase delay of 5 days from the neutron to the BEC indicates an average residence time of the BEC in the troposphere. These indicate that the time variation with 26 days of the BEC is caused by the solar modulation of galactic cosmic rays.

However, it is a problem that the relative variation of the BEC are quite larger than that of the neutrons, although the variation pattern of the BEC is similar to that of the neutron. The difference can not clarify from simple comparison of both quantities, because the production rate of Be-7 is high in an altitude of the polar region with low cutoff rigidities and the Be-7 is transported from the high latitude to the middle one by air mass motion [5].

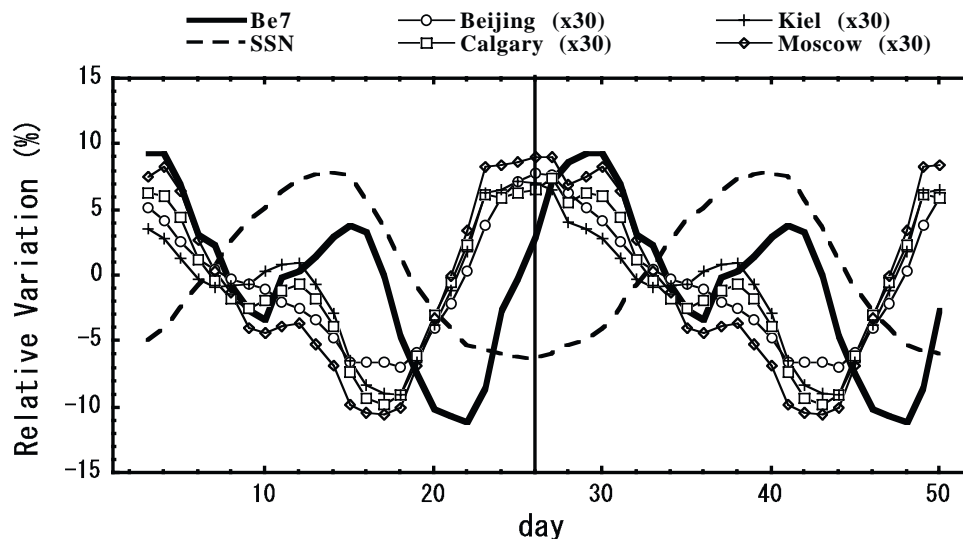


Fig. 3. Be-7 concentrations, SSN, and neutron data folded with the folding period of 26 days for the each time series. Note the neutrons are shown the net values multiplied by 30.

4. Conclusion

Daily Be-7 concentration in air at the ground level was continuously observed from 2000 to 2002 at Yamagata University. From the power spectral analysis, the periodicity of the period of 26 days was shown for the time series data of the BEC, the SSN and the neutron. The folding analysis for the BEC, the SSN, and the neutrons shows that the phase for the minimum portion of the BEC and neutrons are delayed approximately 8 days and 3 days from the phase for the maximum portion of the SSN. The delay time of the BEC indicates two kinds of effect due to traveling time of solar wind and residence time of Be-7. These results indicates that the Be-7 concentrations in the air at ground level have a 26-day periodicity and the time variation is caused by the solar modulation of galactic cosmic rays corresponding to the variation of the sunspot number due to the rotation of the sun.

5. References

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