Seasonal Variations in ^{7}Be Radioactivity Measured at Ground Level

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Abstract

^{7}Be radioactive nuclei with a half-life of 53.3 days result from spallation reactions of galactic cosmic rays and solar energetic particles with N and O nuclei in the Earth's atmosphere. The ground-level measurement of ^{7}Be radioactivity in 2002-2003 shows seasonal variations which are enhanced in spring and fall seasons. In addition, ^{210}Pb radioactivity which is of terrestrial origin exhibits a similar trend of temporal variations. The variations are due to not the solar activity but the atmospheric effect. We discuss the possibility of the air mass mixing between the stratosphere anf troposphere to explain the measured seasonal variations.

1. Introduction

Galactic cosmic rays (GCR) and solar energetic particles (SEP) interact with the Earth's atmospheric nuclei and produce many different isotopes. In particular, ^{7}Be is a short-lived radioisotope (half-life is 53.3 days) which result from nuclear reaction of energetic protons with atmospheric N and O nuclei. GCR produce about two thirds of ^{7}Be in the stratosphere and one third in the upper troposphere (Lal and Peters, 1967). The ^{7}Be emits a gamma-ray line at 478 keV from the electron-capture process. The ^{7}Be production rate is expected to exhibit the 11 years-period of solar activity because the GCR intensity varies with the solar activity. Moreover, a highly intense solar protons arrive at the Earth in association with a large solar proton event, though it is extremely rare. In fact, a surprising large concentration of ^{7}Be associated with SEP events was measured with the satellites above 320 km (Fishman et al., 1991; Phillips et al., 2001).

On the other hand, the study of ^{7}Be in the atmosphere provides important information on atmospheric transport processes. The source distribution of GCR-produced ^{7}Be peaks around 20 km in altitude (Lal and Peters, 1967). Produced ^{7}Be nuclei rapidly attach to aerosol particle in the upper atmosphere and fall to the Earth's surface. The ground-level measurement of ^{7}Be radioactivity gives a clue on the air mass mixing between the stratosphere and troposphere.

In this paper we show the temporal variations in ^{7}Be radioactivity on the surface in 2002-2003 and discuss the possibility of the air mass motion in the upper atmosphere.

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2. Ground-level Measurement of ^{7}Be

We have started the ground-level measurement of ^{7}Be radioactivity using a high-volume air sampler. A weekly deposition of ^{7}Be has beem measured in Tokyo since January, 2002. The air sampler is located on the roof of building of School of Science of Rikkyo University. It has a collecting power of 1000 liters of air per one minute. The dry deposition sample is collected on the glass-fibre filter and several radioisotopes attach to the dry deposition sample. Gamma-rays emitted from these radioisopes is measured with a gamma-ray spectrometer. The spectrometer consists of a high-purity coaxial Ge gamma-ray detector surrounded with a 10 cm thick lead shield. The effective volume of the Ge detector is 90 cm^3 and the photopeak efficiency at 511 keV is 0.05. The energy resolution is 1.2 keV (FWHM) at 478 keV. The lead shield of 10 cm thickness enables to reduce the background radiation level significantly. Pulse height spectrum analysis is made with a computer-based analyzer (4096 energy channels). A typical gamma-ray spectraum of the dry sample in 20-2100 keV is shown in Fig. 1. We see the strongest ^{7}Be line at 478 keV. The lines at 46.5, 511 and 1461 keV result from ^{210}Pb, positron annihilation and ^{40}K, respectively. The expanded gamma-ray spectrum around the ^{7}Be line is exhibited in Fig. 2. We determine ^{7}Be radioactivity taking account a decay of ^{7}Be (half-life of 53.3 days).

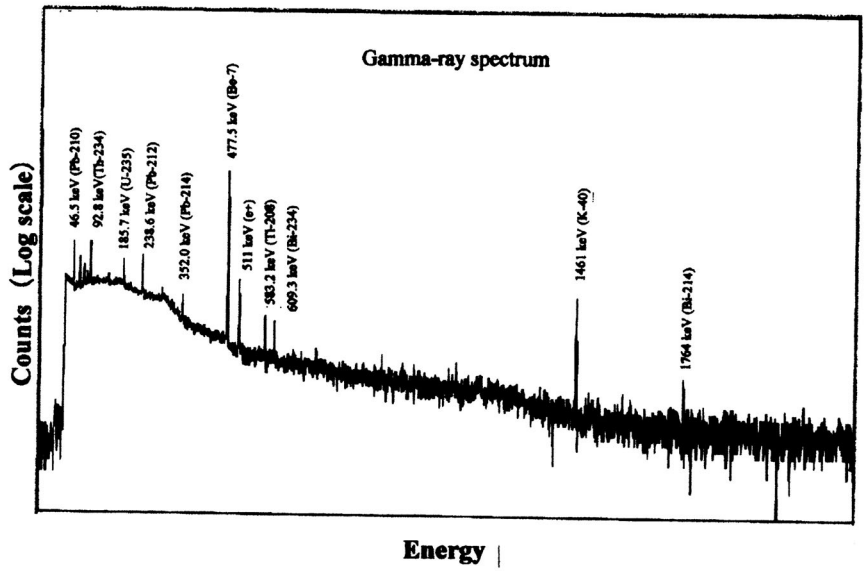

Fig. 1. Gamma-ray spectrum of the dry deposit sample.

First we show the time variations in the weekly dry deposit of ^{7}Be in January 2002- May 2003 in Fig. 3. The data indicate definite temporal variations in the ^{7}Be radioactivity. There are enhancements in the ^{7}Be radioactivity in April

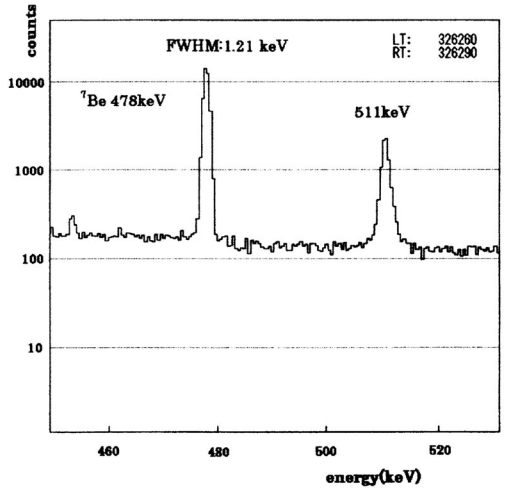

Fig. 2. Expanded gamma-ray spectrum of the ^{7}Be line.

and November. The April peak is more significant than the November peak. In this period there was no extraordinary intense SEP event such as the July 14 event in 2000, suggesting that the measured enhancements in the ^{7}Be radioactivity is not due to the solar effect. We propose that these enhncements result from the atmospheric effect.

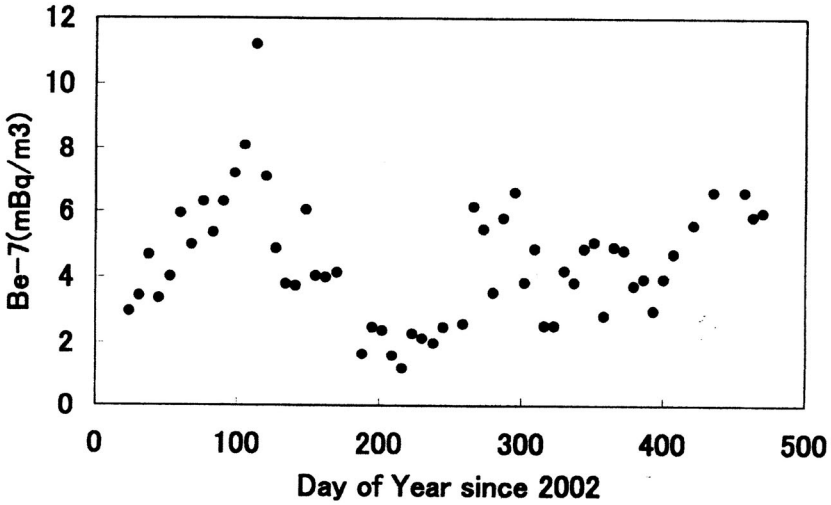

Fig. 3. Time variations in ^{7}Be radioactivity in January 2002 - May 20003.

3. Discussion

GCR produce most of ^{7}Be in the stratosphere and the mean residense time is thought to be 14 months from the long-term temporal variations in ^{90}Sr radioactivity (Rehfeld and Heimann, 1995). This mean residense time is much longer than the half life of ^{7}Be. ^{90}Sr is an artificial radioisotope deu to neuclear weapon test in high altitudes. On the othe hand, the mean residense time of ^{7}Be produced in the troposphere by GCR is 22-35 days (Martell and Moore, 1974; Bleichrodt, 1978).The tropospheric ^{7}Be contribute to the ^{7}Be radioactivity at the ground level. If the ground-level ^{7}Be radioactivity significantly enhances, it is expected that the stratospheric ^{7}Be suddenly fall to the troposphere by the atmospheric effect.

As a possible mechanism, Reiter (1975) suggested stratospheric/ tropospheric air mass exchange process and Shapiro (1980) proposed that turbulent mixing within tropopause folds as a mechanism for the exchange of chemical constituents between the stratosphere and troposphere. Implications on stratosphere/troposphere air exchange were discussed from the distribution of ^{7}Be in the troposphere (Viezee and Singh, 1980). Dibb (1989) and Feely et al. (1989) indicated that the stratospheric/tropospheric air mass mixing takes place in spring.

The seasonal variation in the ^{7}Be radioactivity at the ground level is likely due to air mass mixing in spring and fall seasopns between the stratosphere and troposphere. We have simultaneously measured the time variations in the ^{2}10Pb radiaoctivity (gamma-ray line at 46.5 keV). It shows the similar seasonal variations to that of ^{7}Be radioactivity. ^{210}Pb is its daughter nucleus of ^{238}U and a part of ^{210}Pb is emanated out of the Earth's crust into the higher atmosphere. The ^{210}Pb data seem to support the seasonal air mass mixing between the stratosphere and troposphere.

4. References

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