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Size distribution of aerosols attached by cosmogenic nuclide Be-7 in the atmosphere at the TA telescope station

SATOSHI KIKUCHI[1], HIROHISA SAKURAI[1], SHUICHI GUNJI[1], FUYUKI TOKANAI[1], FUMITAKA YANAGISAWA[2], EMIKO INUI[3], SHIGEHARU UDO[4]
[1]*Department of Physics, Yamagata University*
[2]*Department of Earth and Environmental Sciences, Yamagata University*
[3]*Radioisotope Laboratory, Yamagata University*
[4]*Institute for Cosmic Ray Research, University of Tokyo*
kikuchi@ksprite.kj.yamagata-u.ac.jp

Abstract: To study the behavior of the cosmogenic nuclides in the atmosphere, we have been observing aerosols and cosmogenic nuclide Be-7s at the TA telescope station, Utah, USA (39.1° N, 112.9° W). Using an Andersen air sampler, we sampled separately the aerosols by 5 classes approximately from 0.1 μm to 10.0 μm.
The sizes of aerosol particles are less than ϕ 10 μm. The range of the aerosol concentration [particles/m^3] was from 2.7×10^4 to 4.5×10^5. Most of Be-7s are attached to the aerosols less than 1.1 μm with the concentration of a few mBq/m^3. The Be-7 concentrations are strongly correlated to the solar radiations in the monthly variations.

Introduction

Be-7 is a familiar cosmogenic nuclide in the atmosphere. It is produced by interaction between cosmic rays and nitrogen or oxygen in the atmosphere. After Be-7 is oxidized and attaches to aerosols, the aerosols with Be-7s fall down to the ground.

As the Be-7s are produced at the stratosphere and the upper troposphere, the aerosols with Be-7s collected at the ground level have the information of the altitude. Generally, the size of aerosols above the altitude of 3 km is smaller than 1 μm[1]. Hence, it is possible to investigate the altitude distribution of Be-7s from the size distribution of aerosols attached by the Be-7s.

The Telescope Array (TA) experiment[2] is the project studying cosmic rays with energies above 10^{19} eV. It looks for the super-GZK (E > 10^{20} eV) events observed by AGASA (the Akeno Giant Air Shower Array). The observatory, which is located in the desert in Millard County, Utah, USA (39.1° N, 112.9° W), is a hybrid detector system consisting of Surface Detectors (SD) and Fluorescence Detectors (FD). FD detect air scintillation lights produced by a high energy cosmic ray from the ground. Since the energy of a cosmic ray is determined from the quantity of the scintillation lights, it is very important to estimate the attenuation of the lights from the emission point to the telescope. As light scattering and absorption in the attenuation are caused by the aerosols in the atmosphere, it is necessary to know the behavior of the aerosols at the environment of the TA station.

We contribute to the TA experiment supplying basic data concerning the aerosols in the vicinity of TA with the relationships between the aerosols and the Be-7s.

Experiment

Aerosols and Be-7s are observed on the roof of the Black Rock Mesa (BRM) station (39.2° N, 112.7° W, alt.:1403 m, height:13 m above the ground), which is the one of FD stations of the TA project. The station is located in the desert in Utah.

An Andersen air sampler (AH-600F) manufactured by Shibata-Kagaku Company, which is operational under all weather conditions, has been employed for the collection and size classification of aerosols. It has 5 stages for the size classification of aerosols. Each of these stages has the holes of different size by it, and the intake air which pass through them impact the filter. The ranges of size classification on the stages are "$\phi \leq 1.1\,\mu$m", "$1.1 < \phi < 2.0\,\mu$m", "$2.0 < \phi < 3.3\,\mu$m", "$3.3 < \phi < 7.0\,\mu$m" and "$\phi \geq 7.0\,\mu$m". These ranges means the sizes of aerodynamic diameters since all particles trapped are classified by the aerodynamic mechanism of this sampler. The aerosols which Be-7s attach to are trapped in the silica fiber filter on the appropriate stage according to their sizes. The volume intake rate of air is regulated to 566 L/min (20 °C, 1 atm).

We measured the Be-7 concentrations for each aerosol size using the HPGe gamma-ray detector GCW3023 (CANBERRA) at the 20 m underground laboratory of the Institute for Cosmic Ray Research (ICRR), University of Tokyo. In this laboratory, the background radioactivity level is 0.006 cpm on the equivalent channel to the gamma-ray energy of Be-7. Since the radioactivities of Be-7 (γ : 477.6 keV, HL:53.28 days) in the each stage samples are very low, only such a laboratory enables to measure them.

Moreover, a portable high-volume air sampler (HV-500F) manufactured by Shibata-Kagaku Company has been employed for the measurement of the size distributions of aerosols. This sampler was set near the Andersen sampler, and the both always ran at the same time. Aerosols are trapped in the POLYFLON filters (PF040) using the sampler, and analyzed the samples extracted from the filter by the flow particle image analyzer (FPIA-2000). The analyzer cannot measure water-soluble particles to use water for the extraction of the aerosols. The POLYFLON filter is chosen because of the characteristics of water-resistant. The measurement range of this analyzer is $0.60 \leq \phi$ (equivalent diameter) ≤ 400.0 [μm]. Also, water-soluble ions are measured by ion chromatography analysis extracting from the POLYFLON filter.

Further, the daily Be-7 concentrations have been continuously observed at Delta City near BRM station using the general air sampler (HV-1000F) with the glass fiber filter (ADVANTEC GB-100R) since Oct.2005. The radioactivities of the samples by this observation have been measured with another HPGe detector GEM-25185 (ORTEC) at the laboratory on the ground.

Results and Discussion

1. The size of aerosols

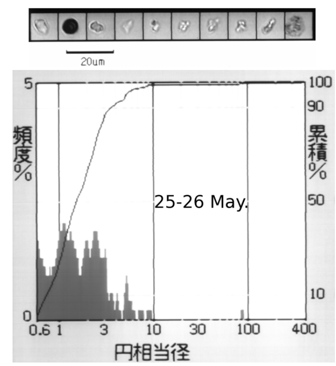

Figure 1: The images and the size distribution of aerosol particles

Figure 1 shows the size distribution of aerosol particles and the image analyzed by FPIA-2000. This analyzer takes the picture of aerosol one by one, and measures the size of the aerosol from the picture. The x-axis shows the diameter [μm] equivalent to a circle shape, and the y-axis is the frequency [%] to the whole particles. The each size distribution observed for continuous 5 days indicates the following things: 1) The sizes of all particles are less than $\phi\,10\,\mu$m. 2) Each distribution has two peaks at approximately $\phi\,1\,\mu$m and $3\,\mu$m. 3) The range of the aerosol concentration [particles/m^3] was from 2.7×10^4 to 4.5×10^5.

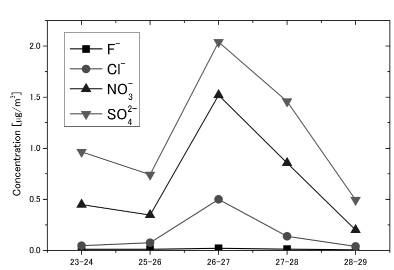

Figure 2: The ion concentrations

Figure 2 shows the variations of the water-soluble ion concentrations for the aerosols. The concentrations on “26th-27th” are higher than the other days because of the low pressure passage. Except that day, the average ion concentrations of “F^-”, “Cl^-”, “NO_3^-” and “SO_4^{2-}” are 0.01, 0.08, 0.46 and 0.92 $\mu g/m^3$, respectively. In the vicinity of Utah, there is a report that the average concentrations of “NO_3^-” and “SO_4^{2-}” are 0.5 and 2.2, respectively[3].

2. The size spectrum of the Be-7 concentration

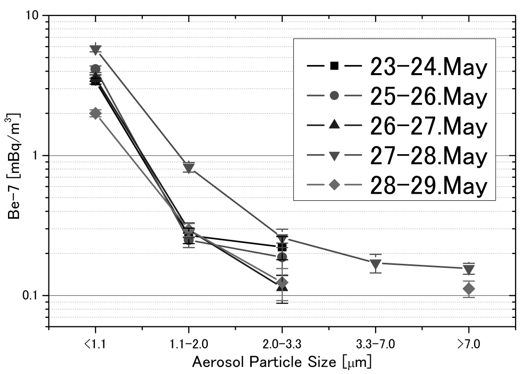

Figure 3: Be-7 concentration at each size classification stage

Figure 3 shows the Be-7 concentrations at each size classification stage for the 5 days. All of data are decreasing as a function of the size. The line of “27-28.May” which shows higher concentrations than the others is for the sample collected on the next day of the low pressure passage.

The size distributions of the Be-7 concentrations indicate the following things: 1) Most of Be-7s are attached to the aerosols less than 1.1 μm with the concentration of a few mBq/m^3. 2) The Be-7s are constantly attached to the aerosols greater than 2 μm and the concentrations are one tenth for the less 1.1 μm.

3. The attachment rate of the Be-7 to aerosol

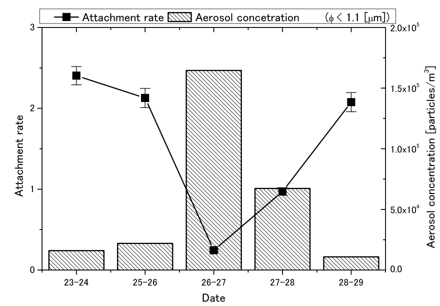

Figure 4: Attachment rate of Be-7s to an aerosol ($\phi \leq 1.1\,\mu$m)

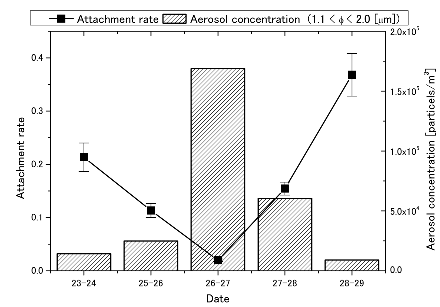

Figure 5: Attachment rate of Be-7s to an aerosol ($1.1 < \phi < 2.0\,\mu$m)

Figure 4 and Figure 5 show the attachment rate of Be-7s and the aerosol concentrations for 5-day sampling to the aerosols in $\phi \leq 1.1\,\mu$m and $1.1 < \phi < 2.0\,\mu$m. The attachment rate is calculated using the number concentrations of Be-7s at each stage from the radioactivities and the number concentrations of aerosols from the size distribution corresponding to the each stage.

The “26th-27th” is the day of the low pressure passage. Since the aerosol particles near the ground surface flow upward due to the updraft of low pressure, the aerosol concentrations at the time were higher than the others. And the updraft presumably prevent the aerosols in the upper atmosphere from falling down to the ground. Thus as the updraft make the aerosol concentration without Be-7s high, the attachment rate decreases. This phenomenon implies that the aerosols attached by Be-7s come down only from the upper atmosphere.

Excepting the low pressure effect, the attachment rate for $\phi \leq 1.1\,\mu$m is approximately 2 Be-7s per an aerosol particle as the upper limit, because of the measured aerosol size down to $0.6\,\mu$m. Also, the rate for $1.1 < \phi < 2.0\,\mu$m is approximately from 0.1 to 0.4.

4. Relationship between the Be-7 concentration and the solar radiation

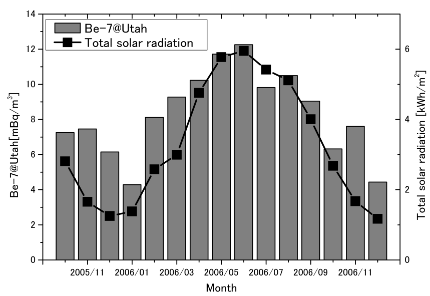

Figure 6: Comparison of monthly variation between the Be-7 concentrations and the solar radiations

We have been continuously observing the daily Be-7 concentrations at Delta City. Figure 6 shows the comparison of the monthly variation between the Be-7 concentrations and the solar radiations. The solar radiations are measured at Delta City by CEMP[4]. Both of the variations indicate a good correlation. The correlation coefficients of the daily and the monthly are 0.63 and 0.91, respectively. As the ground surface is heated by solar radiations, the convection of air mass become to be more active at intense solar radiations. The air mass motions presumably promote the down-drift of the air mass with the higher concentrations of Be-7 at the upper troposphere. The rate of the Be-7 concentrations is 1.27 $\left[\frac{\mathrm{mBq/m^3}}{\mathrm{kWh/m2}}\right]$ to the solar radiations.

Conclusion

To study the behavior of the cosmogenic nuclides in the atmosphere, we have been observing aerosols and cosmogenic nuclide Be-7s in Utah, USA. We have measured each Be-7 concentration for 5 size classification stages approximately from $0.1\,\mu$m to $10.0\,\mu$m and the size distribution of aerosol particles. From those data, the attachment rates of Be-7s to an aerosol are calculated.

The size distribution observed for continuous 5 days indicates the following things: 1) The sizes of all particles are less than $\phi\,10\,\mu$m. 2) The distribution has two peaks at approximately $\phi\,1\,\mu$m and $3\,\mu$m. 3) The range of the aerosol concentration [particles/m^3] was from 2.7×10^4 to 4.5×10^5. The average ion concentrations of "F^-", "Cl^-", "NO_3^-" and "SO_4^{2-}" are 0.01, 0.08, 0.46 and $0.92\,\mu$g/m^3, respectively.

The size distributions of the Be-7 concentrations indicate the following things: 1) Most of Be-7s are attached to the aerosols less than $1.1\,\mu$m with the concentration of a few mBq/m^3. 2) The Be-7s are constantly attached to the aerosols greater than $2\,\mu$m and the concentrations are one tenth for the less $1.1\,\mu$m.

The attachment rate for $\phi \leq 1.1\,\mu$m is approximately 2 Be-7s per an aerosol particle as the upper limit. Also, the rate for $1.1 < \phi < 2.0\,\mu$m is approximately from 0.1 to 0.4.

The correlation coefficients between the Be-7 concentrations and the solar radiations of the daily and the monthly are 0.63 and 0.91, respectively. The Be-7 concentrations are strongly correlated to the solar radiations in the monthly variations.

References

[1] Kazuo Osada. Free tropospheric aerosols based on airplane and mountain observations. *Journal of aerosol research*, 15(4):335–342, 2000.

[2] Telescope array project. `http://www.telescopearray.org/`.

[3] NATIONAL RESEARCH COUNCIL Committee on Medical and Biologic Effects of Environmental Pollutants, editor. *AIRBORNE PARTICLES*. University Park Press, 1979.

[4] Community environmental monitoring program. `http://www.wrcc.dri.edu/cemp/`.