Yearly variations in Be-7 concentrations in the surface air at Iceland and Japan for 16 years from 2003: Solar modulation of cosmogenic nuclide

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Be-7 concentrations (BEC) in surface air should be correlated to cosmic rays, because Be-7 is produced by interactions between cosmic rays and nitrogen and/or oxygen in the atmosphere, and then it falls down with aerosols. Since cosmic rays which reach the earth are modulated by the solar activities when travelling the heliosphere, the variation in BEC involve some modulation profiles such as 27-day variation and 11-year solar cycle. Daily Be-7 concentrations in surface air have been continuously observed at Yamagata (38° N), Japan since 2000. To investigate the latitude effect of 11-year solar cycle, we set up a daily observation system of Be-7 concentration at Husafell in Iceland located (64° N) and have been continuously observed BEC since September 2003 as well as in Japan. Figure 1 shows the yearly variations in the BEC in Iceland and at Yamagata, with the neutrons at Oulu and the sunspot number (SSN), respectively. Both the BECs and the cosmic ray neutrons produced in the atmosphere inversely vary corresponding to the variation in sunspot number, because the energy spectrum of incoming cosmic rays change with the variation of the solar magnetic fields. As shown in the SSN, the solar cycle 24 began in 2009 and then reached its maximum in 2014. After that the activity is descending to the minimum. The solar activity in 2019 is almost a minimum state.

Of three kinds of terms in the solar cycle 24, we compared the variations in BECs in Iceland and Yamagata, neutrons at Oulu, and SSN. The terms of 2009–2012, 2013-2015, and 2016-2019 are corresponding to the ascending, the plateau, and the descending periods of the solar activities, respectively. Table 1 shows the rates of variabilities of the four kinds of observed data on average in the first and the third terms to the second term. While the rates of BEC in Yamagata, neutron and SSN in the third term are greater than those in the first term, the rate of the BEC in Iceland in the third term is less than that in the first term. Moreover, the rates of BECs are approximately 2 to 3.5 times larger than the rates of neutrons implying a contribution of lower energy cosmic rays for the productions of Be-7s than of the neutrons. We describe comparison of the Be-7 concentrations between at Yamagata and in Iceland relating to the SSN and neutron monitor data for the solar modulation, involving the response of the BECs and air-mass motion at Iceland to the unusual 24th solar activity after 2009.

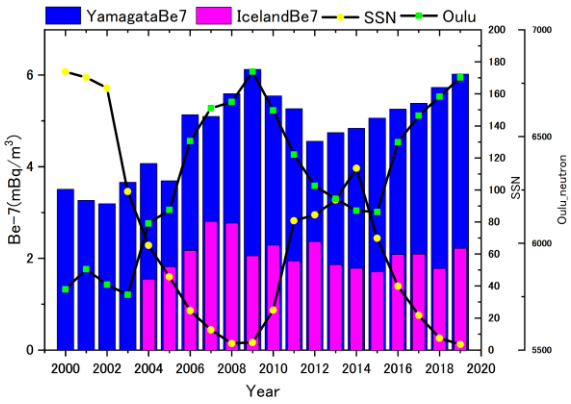

Figure 1. Yearly profiles of the Be-7 concentrations, the sunspot numbers, and the cosmic ray neutrons

Table 1. The rates of variabilities of the observed data in the periods before and after the period of the solar maximum in the cycle 24

	polar Lati. @Iceland	mid lati. @Yamagata	neutrons @Oulu	SSN
<2009-2012> /<2013-2015>	21.3%	10.1%	5.8%	-47.3%
<2016-2019> /<2013-2015>	14.6%	14.7%	7.5%	-80.3%