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^{7}Be concentrations in surface air over the Indian sector of the Southern Ocean and at two Japanese coastal Antarctic stations in the summers of 2014/15, 2016/17, and 2017/18

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Abstract: ^{7}Be concentrations in surface air samples collected over the course of three Japanese Antarctic Research Expedition (JARE) cruises were analyzed. Air sampling was performed daily or twice daily in December 2014 (JARE-56), from December 2016 to March 2017 (JARE-58), and in December 2017 (JARE-59). These data are valuable for resolving daily variations in ^{7}Be concentrations as they cover an extensive area of the Antarctic region for which there is currently little data. The data were collated in CSV format and are available from the National Institute of Polar Research (NIPR) at https://doi.org/10.17592/002.2022040392.

1. Background & Summary

^{7}Be concentration data in surface air samples collected at two Japanese stations in the Antarctic coastal region and in the Indian sector in the Southern Ocean aboard the Shirase, the Japanese icebreaker, were archived. The observations were carried out as part of the Japanese

Antarctic Research Expedition (JARE) programs during the summer seasons of 2014/15, 2016/17, and 2017/18. The archive contains numerous first-time observation data.

^{7}Be is a cosmogenic radionuclide produced mainly in the lower stratosphere and partially in the upper troposphere (one third to one fourth of the production)[1,2], and has a half-life of approximately 53.3 days. Since ^{7}Be is removed frequently from the atmosphere by precipitation, the concentration of ^{7}Be in the troposphere represents the rate of recent entrainment of stratospheric air. In the Antarctic, the major processes involved in stratospheric air entrainment are downwelling of the polar vortex and tropopause folding associated with synoptic-scale disturbances around the continent. Recently, Zhang *et al*. compiled a global dataset of ^{7}Be concentrations[3]. The surface atmospheric concentrations of ^{7}Be in the Antarctic were relatively high compared to those reported for the mid-latitudes in some studies[3,4,5], and yet other studies reported a decrease in the Antarctic region[6,7]. At present, the observation data are insufficient to resolve the above inconsistency. While some modeling studies have examined the production and transport of ^{7}Be globally[8,9], more observational data are required for the Antarctic region in order to validate the results of these models. This dataset contributes to eliminating some of the blanks for the Antarctic area.

2. Location and duration of ^{7}Be sampling

Figure 1 shows the locations of the sample sites, and Table 1 summarizes the observation periods and the number of samplings. Each plot in Fig. 1a indicates where a new filter was used for sampling aboard the *Shirase*, the Japanese icebreaker used for Antarctic expeditions. The four cruises aboard the *Shirase* are indicated by different symbols.

We started sampling when *Shirase* departed from Fremantle in Western Australia around the beginning of December. The *Shirase* headed south along the 110°E meridional line until the vessel was south of 60°S before turning westward for Syowa Station. Sampling was terminated at arrival at Syowa Station around the end of December. Data collected along the route from Fremantle to Syowa Station were acquired in 2014, 2016, and 2017, with collection suspended in the latter half of 2014 due to severe weather.

Shirase departed Syowa Station in mid-February and arrived at Sydney in Eastern Australia in late March. Data on this route were acquired once in 2017.

Figure 1b shows the locations of Syowa Station and site S17. Syowa Station is located on East Ongul Island, approximately 4 km from the coast of the Antarctic ice sheet (AIS). Site S17 is located on the AIS, about 15 km from the coast and at an altitude of approximately 610 m. The data at Syowa Station were acquired from December 2014 to January 2015 and those at site S17 were acquired in January 2015.

3. Sampling methods

An air sampler (HV500F, Shibata Scientific Technology Ltd., Japan) was used to collect air samples. The rate of surface air intake was 800 liters per minute and a glass filter (GB-100R, ADVANTEC Co., Ltd., Japan) was used to remove particles larger than 0.6 μm in diameter. A new glass fiber filter is used each time, and there is no contamination before installation. After collection, each sample was shielded with aluminum foil and stored. We did not consider any correction for the collection efficiency. The system was typically operated for 23 hours, but at site S17 and at some of the higher latitudes in the Southern Ocean, it was operated for 11.5 hours. The total volumes of air sampled were approximately 1100 m^3 and 550 m^3 in 23 hours and 11.5 hours, respectively. We converted the volume under the condition of 25°C and 1 atm.

4. Measurement and technical validation

The radioactivity of ^{7}Be was measured using two types of Ge detectors (GEM-20180-P and MCA-7700, GEM25-70 and MCA-7, Seiko EG&G Co., Ltd., Japan), installed at the Division of Radioisotope Experiments, Life Science Research Center, Gifu University. We shaped each filter to a thickness of 3 mm and a diameter of 48 mm and performed measurements for 6 to 10 hours depending on the time that had elapsed since the end of sampling. We used gamma reference standards (MX033U8PP, U-8 cup-type) obtained from the Japan Radioisotope Association (JRIA) for the calibration check.

The ^{7}Be concentration and the error (standard deviation, one-sigma) were estimated using the measured gross and background radioactivity after correcting for attenuation, self-absorption, detection efficiency, gamma-ray branching ratio, and collected air volume.

The background is determined analytically using the measurement results of the samples, respectively. The following procedure was used to determine the radioactivity concentration: 1) Peak search for the signal using the information of the γ-ray energy and the branching ratio of ^{7}Be; 2) Determination of the peak channel for the obtained peaks; 3) Determination of the background value for the obtained peaks; 4) Determination of the γ-ray energy from the channel information. Then, 5) peak area calculation, 6) Detection efficiency calculation, and 7) radioactivity calculation. The background value is obtained by fitting a linear function using the count values in the left and right baseline regions outside the peak region and integrating this function according to the channels in the peak region. In this measurement, radioactivity is considered detected when its measured count (peak area) is more significant than three times the measurement uncertainty (standard deviation of population fitted with Gaussian function).

Through the two detectors, the average gross count is 0.0120 cps (counts per second) and the average background count is 0.0063 cps. The physical attenuation of radioactivity is corrected to the value of radioactivity at the time of sample collection using the half-life of ^{7}Be. The calculations are

divided into three categories: during measurement, from sampling to measurement, and during sampling. Self-absorption correction was performed using a standard source of the same shape as the PP vessel U-8 used in the measurements to correct for detection efficiency. The standard source and container corrections are based on calibration data published by the Japan Radioisotope Association. For the absorption correction of the sample, the glass fiber filter material was specified as silicon dioxide (SiO2) and the self-absorption correction count calculated from the density, γ-ray energy, and interaction cross-section, approximately 1, was used. The detection efficiency is 3.74% for both detectors. ^{7}Be decays by orbital electron capture, and 10.5% of it decays to ^{7}Li with γ-rays of 478 keV. When calculating the radioactivity concentration, the counts are divided by this branching ratio.

The detection limit for ^{7}Be concentration measurements is dependent on the measurement time, the ^{7}Be net-count (the gross radioactivity count minus the background radioactivity count), and environmental radioactivity.

5. Data Records

We compiled the data into a single CSV-formatted file. The data can be accessed from the URL provided in the "Data citations" section below. A PDF-formatted file can also be obtained from the same directory.

Table 1 summarizes seven expedition categories (1 to 7) according to their locations and duration. Category-1 (Cat-1) contains data collected on the outbound voyage of *Shirase* from Fremantle to Syowa Station on JARE-56, Cat-2 contains data collected at Syowa Station on JARE-56, Cat-3 contains data collected at site S17 on JARE-56, Cat-4 contains data collected on the outbound voyage of *Shirase* from Fremantle to Syowa Station on JARE-58, Cat-5 contains data collected at site S17 on JARE-58, Cat-6 contains data collected on the return voyage of *Shirase* from Syowa Station to Sydney on JARE-58, and Cat-7 contains data collected on the outbound voyage of *Shirase* from Fremantle to Syowa Station on JARE-59.

The dates and the locations given indicate when sampling was started. The total number of samples collected was 181, including 91 samples that were collected at 12-hour intervals. A total of 21 samples were below the detection limit and there were three negative values. The dataset includes the following information.

The data is recorded in order from Cat-1 to Cat-7, with each line corresponding to one observation. The sequence of columns in each row is as follows: category number, year, month, date, hour, minute in UT (Universal Time), sampling duration, year, month, date, hour, minute in LT (Local Time), the difference between LT and UT, sampling locations (*Shirase*, Syowa Station, or the site S17), latitude (deg., negative values for the southern hemisphere), longitude (deg., positive values for the eastern hemisphere), sampling volume (m^3), the ^{7}Be concentration ($mBq \cdot m^{-3}$), the error ($mBq \cdot m^{-3}$), and the detection limit ($mBq \cdot m^{-3}$). When the ^{7}Be concentration was below the

detection limit, the value was recorded as "UDL" in the comments. The time and location are those at the start of sampling.

After the raw of “Comments,” we recorded the supplementary data, which are measuring duration (hour), gross count, gross count per second, background count, background count per second, net count, net count per second, the error of the count, and the error of the count per second.

6. Figures

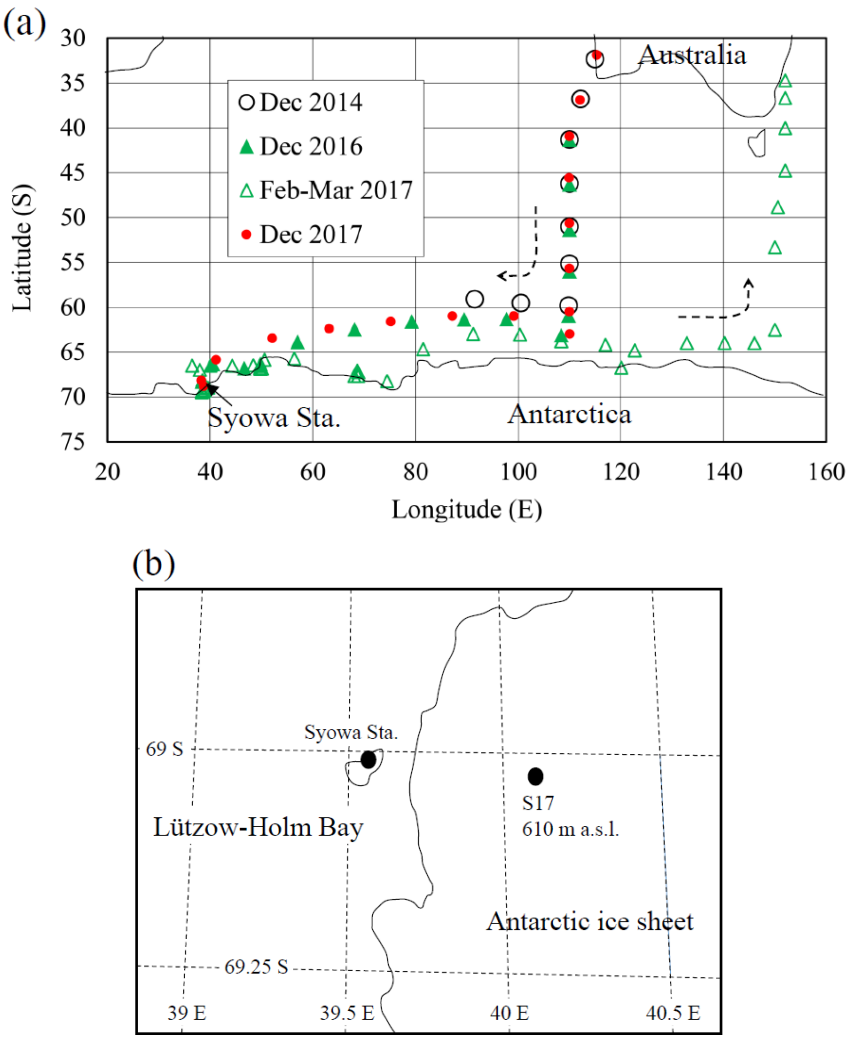

Figure 1. (a) Each plot indicates the location where sampling was started using a new air filter aboard the *Shirase*. The four types of symbols indicate a different cruise. (b) Map showing the locations of Syowa Station and the S17 site on the Antarctic ice sheet.

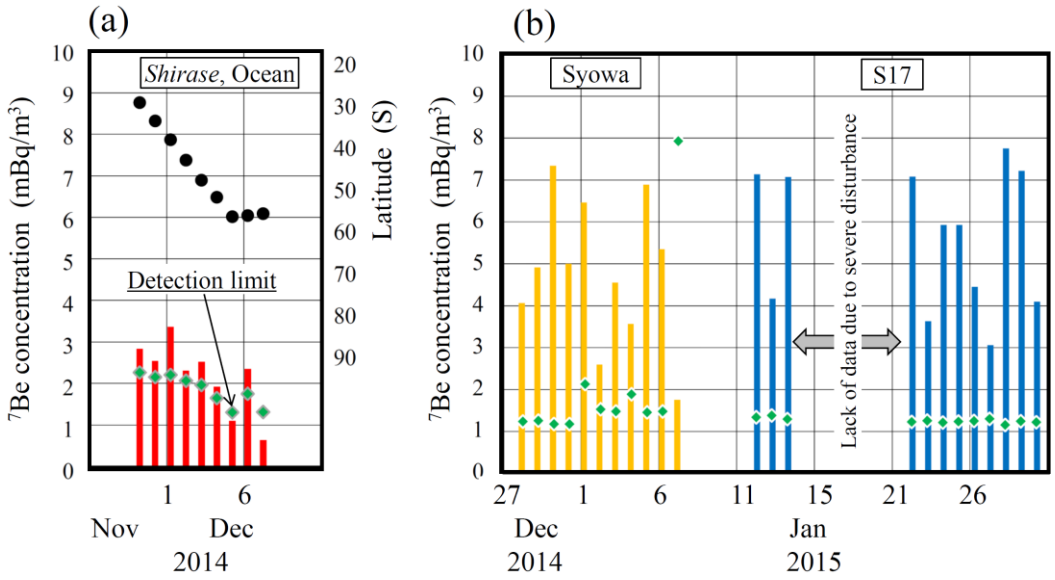

Figure 2. Representative time series data for the ^{7}Be sample concentrations obtained aboard the *Shirase* are indicated by red bars (a), at Syowa Station by yellow bars, and at the S17 site by blue bars (b). Green diamonds indicate the detection limits for the respective measurements. Black dots in (a) represent the latitude at the start of each sampling. A severe disturbance prevented the collection of data at the S17 site, resulting in a week-long gap in the data series.

7. Table

Table 1. Summary of observations and collected data

Category	JARE number	Sampling period*1	Location	Range in sampling coordinates*1 [Lat.(S), Long.(E)]	Number of samples	Sampling duration*2 (hours)	Range in the concentrations*3 (mBq/m^3)	Range in the detection limits (mBq/m^3)	Number of the BDL*4 samples	Number of negative values*5
Total (1 - 7)	56 - 59	-	-	-	181	-	0.90 - 11.42	0.59 - 7.93	20	3
1	56	29 Nov - 7 Dec 2014	Southern Ocean	[32.33, 114.96] - [59.10, 91.55]	9	24	1.92 - 3.37	1.31 - 2.27	2	0
2	56	28 Dec 2014 - 7 Jan 2015	Syowa Station	[69.01, 39.59]	11	24	2.59 - 7.55	1.21 - 8.16	1	0
3	56	13 - 31 Jan 2015	Site S17	[69.03, 40.09]	12	24	3.06 - 7.74	1.15 - 1.38	0	0
4	58	4 - 20 Dec 2016	Southern Ocean	[41.34, 110.00] - [68.28, 38.39]	17	24	1.99 - 7.54	1.24 - 1.78	6	0
5	58	28 Dec 2016 - 30 Jan 2017	Site S17	[69.03, 40.09]	66	12	2.75 - 11.42	1.68 - 3.87	3	1
6	58	11 - 24 Feb 2017	Southern Ocean	[69.30, 38.98] - [65.86, 50.57]	25	12	1.77 - 8.28	1.41 - 1.65	3	2
		25 Feb - 20 Mar 2017		[65.74, 56.42] - [34.71, 152.00]	23	24	0.90 - 8.46	0.59 - 1.15	3	0
7	59	2 - 19 Dec 2017	Southern Ocean	[31.86, 115.30] - [68.81, 38.74]	18	24	1.43 - 6.80	1.07 - 1.57	2	0

*1 Dates and coordinates indicate when and where sampling was initiated.
*2 Sampling duration varied depending on conditions.
*3 Range in the concentration of measurements above detection limits.
*4 BDL means that the measured concentrations were "blow the detection limit."
*5 Measured concentrations with negative values indicate that samples were below the detection limits.

Author contributions

Naohiko Hirasawa organized the ^{7}Be observation project, designated sampling sites, developed the methods employed at each site, and acted as the lead in drafting this manuscript. Taku Nakamura planned the ^{7}Be measurements and performed the measurements together with Miyoko Miwa. Miyoko Miwa, who is qualified to handle radioisotopes, conducted measurements, performed quality assessments, and was responsible for safety. Kazuma Aoki also assisted with performing measurements. Tetsuro Ojio and Kyohei Yamada operated the air sampler and prepared the filters at the observation sites. Shigeki Tasaka provided advice on numerous aspects of this project and assessed the quality of the radioactivity measurements.

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Data Citations

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