https://doi.org/10.20575/00000012
Polar Data Journal, Vol. 4, 45–54, February 2020

Infrasound observation at Japanese Antarctic Station "Syowa": 11 years observations and results

Yoshiaki ISHIHARA[1]*, Takahiko MURAYAMA[2], Masa-yuki YAMAMOTO[3], Takeshi MATSUSHIMA[4], and Masaki KANAO[5]

[1]Satellite Observation Center, Center for Global Environmental Research, National Institute for Environmental Studies, 16-2 Onogawa, Tsukuba, Ibaraki 305-8506.

[2]Japan Weather Association, Sunshine 60 Bldg. 55F, 3-1-1 Higashi-Ikebukuro, Toshima-ku, Tokyo 170-6055.

[3]Kochi University of Technology, 185 Miyanokuchi, Tosayamada-cho, Kami, Kochi 782-8502.

[4]Faculty of Science, Kyushu University, 2 Shinyama, Shimabara, Nagasaki 855-0843.

[5]National Institute of Polar Research, Research Organization of Information and Systems, 10–3 Midori-cho,Tachikawa, Tokyo 190-8518.

*Corresponding author. Yoshiaki ISHIHARA (ishihara.yoshiaki@nies.go.jp)

(Received December 26, 2018; Accepted September 12, 2019)

Abstract: Infrasound observation at Syowa Station (SYO), Antarctica started as one of the projects related to International Polar Year (IPY2007–2008) as one-sensor pilot observation, and after the pilot observation, we then migrate to 3-sensor arrayed observation. The obtained 11 years of infrasound data enable us to examine characteristics of infrasound behavior around SYO. Spectral analysis of recorded data clearly shows continuous arrivals of microbaroms from the southern ocean and weak annual change of the energy. Array analysis of the 3-sensor observation data detected infrasound signals generated by ice-related activities around SYO.

1. Background & Summary

The "infrasound" is human-inaudible sound (pressure wave) whose frequency range is cut-off frequency of sound (3.21 mHz, for a 15-degree C isothermal atmosphere) to 20 Hz, and the wave can be excited by large energy which propagates for several thousand kilometers along the Earth's surface[1]. Many geophysical phenomena, such as volcanic eruptions, earthquakes, tsunamis, thunders and sprites, fireballs, generate infrasound[2-7]. Because this frequency wave is common between atmospheric, oceanic, and solid earth vibrations, those waves are interacting with each other, and interaction itself generates infrasound. In the polar region, the cryosphere also plays an important role in the generation and propagation of infrasound. Therefore, infrasound measurement at Antarctica could be a new proxy for monitoring a regional environmental change in high southern latitude[8].

At present, a worldwide infrasound observation network has been established by the ComprehensiveNuclear-Test-Ban Treaty Organization (CTBTO). Because this network is designed to detect nuclear boom test, it can detect energetic infrasound generated some TNT tons level explosion from a few thousands of km in the range from each arrayed station. However, that is not sufficient for sensing and analyzing weaker infrasound, which is generated by various regional events. Furthermore, only two CTBTO's infrasound stations exist in the Antarctic region, and it is not enough for monitoring regional environmental change surrounding the remote continent.

From April 2008, we started infrasound observation at the Japanese Antarctic Station, "Syowa", then we tried to detect cryosphere originated and environmental change related signals of infrasound. Spectrograms of the infrasound recordings indicate continuously arriving of microbaroms, and weak annual variation of its energy as well (Figure 1). The cause of this variation is probably related to seasonal variations of sea-ice spreading area and thickness of sea-ice around the station[9-14]. Until now, we did not detect variations and/or trends of longer than annual modulation yet. We need to conduct continuous observations and precise monitoring of the energy of microbaroms to detect the effects of global environmental changes in the vicinity of Syowa Station.

2. Observation Site

Japanese infrasound observation at the Antarctic region started in April 2008. An infrasound sensor was installed at Syowa Station (SYO, 69.0 ◦S, 39.6 ◦E, WGS-84) inside the East Ongul Island, in the Lützow-Holm Bay (LHB) of East Antarctica (Figure 2) and started pilot observation as one of the projects of the International Polar Year (IPY2007–2008). Following the success of pilot observation, in January 2013, during austral summer in 2013, we extended one-sensor observation to 3-sensor arrayed observations at SYO (Table 1), and a few field stations were installed as well along the coast of the LHB. In this paper, we focused on infrasound observation and archived data at SYO.

3. Methods

3.1. Infrasound Observation System

The observation system is slightly different between each observation period. The first period was from April 2008 to December 2012 as the pilot observation, and the second period is from January 2013 to the present as an array observation.

The pilot observation was conducted for proof of the observing system concept and resistivity against the severe environmental conditions in the polar region. The observation system consists of two parts, one is the sensor-head part and the other is a digitizing-telemeter part. At SYO, we can use AC power supply and Internet access via a satellite communication system, therefore, only a sensor-head module was installed at outcrop in East Ongul Island and the logger and telemetry system were installed in seismograph hut. The sensor-head module consists of a sensor (condenser microphone type infrasound sensor; Chaparral Physics Model-2), an adiabatic wooden sensor box, and attached continuous porous hose-array. The 6-m radius hose array is designed to reduce wind generating noise by mechanical low-pass filter effects. The digitizing-telemeter part is consists of a data logger (DATAMARK LS-7000XT, by Hakusan Co.) and a micro-Linux Box (OpenBlockS).

Following the success of pilot observation, during austral summer in 2013, we extended one-sensor Observation at Syowa station to 3-sensor triangle arrayed observations whose spacing of about 100 m (Table 1). Also, the sensor was changed the Chaparral Physics Model-2 to Model-25 for expanding the dynamic range of recording, and the mechanical low-pass filtering system (hose array), which reduce wind noise, was re-designed (Figure 3).

3.2. Data Recording, Transfer and Quick Look Processing

The infrasound signals were transferred from the sensors to the data logger in the seismograph hut via analog data cables. The analog data were digitized sufficiently high sampling rate of 100 Hz with 24 bits by the logger then stored in a CF card of the logger, as well as transmitted to the micro-Linux Box also installed inside the same seismograph hut, connecting by ethernet. The data format of logger generation is a 1-minute long WIN format file. The 1-minute long WIN files will be concatenated 60 files into a 1-hour long file by micro-Linux Box at SYO station. The WIN is a de facto standard for file format and data transfer system of the Japanese short-period seismic network (http://eoc.eri.u-tokyo.ac.jp/WIN/).

In each day, 24 files of 1-hour long WIN format recorded yesterday will be automatically retrieved and stored by data server at the National Institute of Polar Research (NIPR) using satellite communication system between SYO and NIPR once a day (3:15 UTC), and then pushed to quick look analysis server at NIPR. After that, at 11:15 UTC every day, 1-hour long data files will convert into Seismic Analysis Code (SAC) format file, and then dynamic spectrum computation as well will be executed, and QL plot (6-hour long waveform and spectrogram) will be generated (Figure 4).

4. Data Records

Infrasound data (waveform and Power Spectral Density (PSD)) have been continuously archived at NIPR (for access details, see Data Citations).

Temporal coverage of the data is Apr. 2008 to Dec. 2018. The structure of the data filename is yymmddhh for the WIN format waveform file, yymmddhh.SYO.C* for SAC format waveform file, and PSD file as yyyymmdd.SYO.C*.spec.gz (Table 2). yymmddhh (yyyymmdd) indicates observation date and time (or observation date). yy (yyyy) is two (or four)-digit year, mm is two-digit month, dd is the two-digit day, and hh is two-digit hours. For the WIN format file, data file contains all array component waveforms. For SAC format waveform and PSD files, C* indicates an array component number (C1, C2, C3).

The details of theWIN waveform format are given at web manual page of theWIN system (http://wwweic.eri.utokyo.ac.jp/cgi-bin/show_man_en?winformat), and the SAC file format is also given at web manual page of Seismic Analysis Code (https://ds.iris.edu/files/sac-manual/manual/file_format.html). In addition, WIN requires a channel table file and is provided as old_syowa_channels.tbl (for pilot observation) and syowa_channels.tbl (for arrayed observation).

The volume of 11-years data is 155 GB for WIN format waveform, 239 GB for SAC format waveform, 2.6 TB for PSD, and 11 GB for QL plot files. Because of the limitation of the disk capacity of the archive site, PSD data is provided separately upon email request.

5. Technical Validation

In this section, we discuss the accuracy of infrasound observations. Our observation uses the Chaparral Model-25 infrasound Sensors with low gain mode. The frequency response of the sensor is flat to within +0, -3 dB from 0.08 Hz to 200 Hz, and self-noise is less than 0.63 $\mu Pa^2/Hz$ at 1 Hz. According to sensor specification, for above 0.1 Hz, recording waveforms could be used without any pre-processing. Below that frequency ranges, we have to deconvolve sensor response using transfer function with pole/zero data.

6. Author contribution

All authors designed the study and observation system. Y. Ishihara developed data transfer and quick look generation systems and performed spectral analysis. Y. Ishihara and T. Murayama performed the array analysis of the data. M.-Y. Yamamoto, T. Matsushima, and M. Kanao managed observation systems maintenance and logistics.

7. Competing interests

The authors declare no competing financial interests.

8. Figures

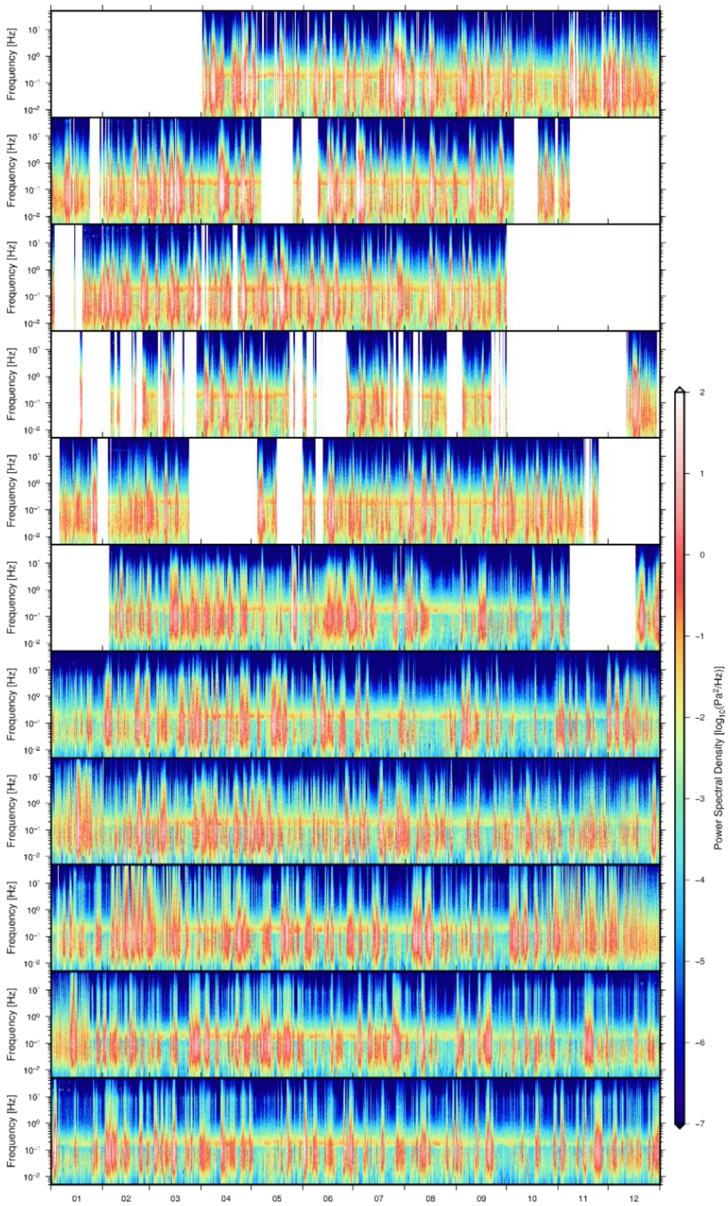

Figure 1: Spectrogram (Power spectral densities (PSD) of infrasound signals for eleven years (2008 (uppermost frame) to 2018 (bottom frame)) from the beginning of pilot observations at Syowa Station (SYO; one of the array sites; C1). The white-colored time zones correspond to the lack of data, otherwise, any errors occurred during the PSD processing. Predominant frequencies corresponding to the microbaroms (0.1 to 0.3 Hz bands) are clearly identified during the recording periods. The horizontal axis is the month of the year.

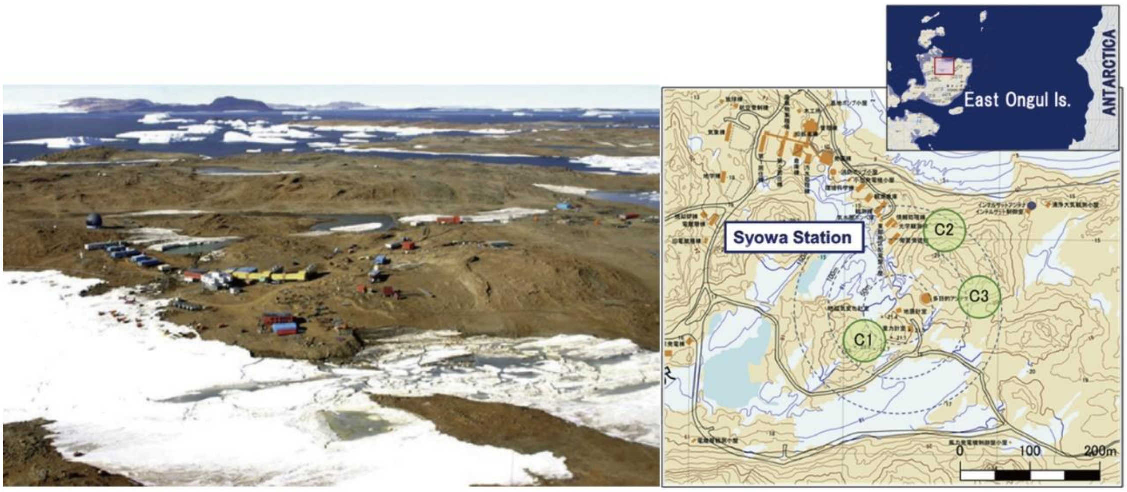

Figure 2: Overview of Syowa Station in East Ongul Island, LHB, and location of the infrasound array at Syowa Station. C1, C2, C3 indicate the location of each array component.

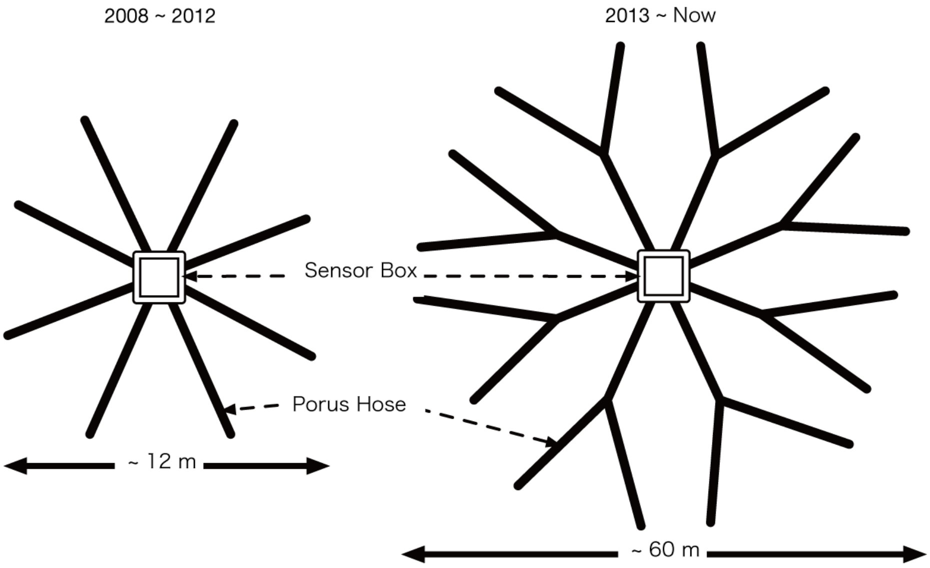

Figure 3: Schematic diagram of the observation with wind noise reducing hose array system at Syowa Station. (Left) Simple connection type porous hoses (8 set, 6 m each, the total diameter of hose array system is about 12 m) was used in the pilot observation periods. (Right) Multi-connection type porous hoses (8 set, total diameter of hose array system is about 60 m) is used in current array observation.

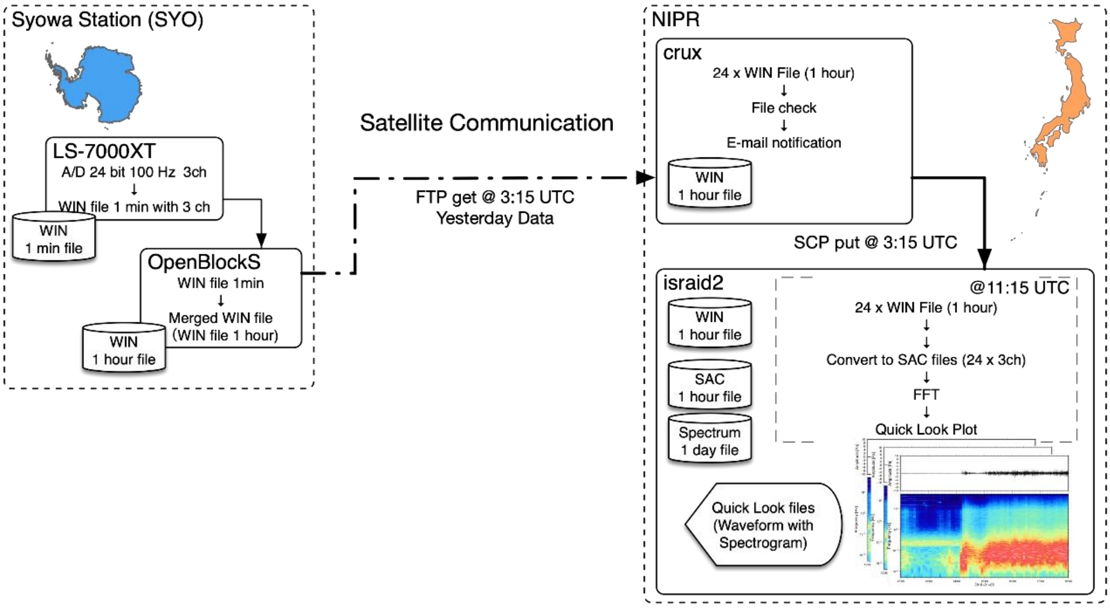

Figure 4: Schematic diagram of the data recording and transfer flow of the SYO infrasound observation system. (SYO) Infrasound signal is digitized by a datalogger (DATAMARK LS-7000XT) with 24 bit / 100 Hz sampling and then stored in the logger as a 1-minute WIN format file. At the same time, the data was copied to a small Linux box (OpenBlockS) and a merged WIN file (1-hour long WIN file) will be created and stored. (NIPR) Infrasound data files (1-hour long WIN files) recorded on the previous day are automatically transferred to master Linux server (crux) using satellite communication, then those files checked and stored. After that, those files transferred to another Linux workstation (israid2) and then file format conversion to SAC files, FFT analysis, Quick Look Plot processes are executed.

9. Tables

Table 1. Sensor locations at Syowa Station (2013 to Present)

Element	Sensor	Longitude	Latitude	Distance from Seismograph Hut
C1	Chaparral Model-25	39.584256 °	-69.006875 °	62.0 m
C2	Chaparral Model-25	39.587336 °	-69.005569 °	130.1 m
C3	Chaparral Model-25	39.588347 °	-69.006181 °	116.0 m

Table 2. List of data files

File names	Format	Short description
yymmddhh	WIN	1 hour long waveform (C1, C2, C3)
yymmddhh.SYO.C1	SAC	1 hour long waveform (C1)
yymmddhh.SYO.C2	SAC	1 hour long waveform (C2)
yymmddhh.SYO.C3	SAC	1 hour long waveform (C3)
yyyymmdd.SYO.C1.spec.gz	ascii (gzipped)	1 day long PSD (C1)*
yyyymmdd.SYO.C2.spec.gz	ascii (gzipped)	1 day long PSD (C2)*
yyyymmdd.SYO.C3.spec.gz	ascii (gzipped)	1 day long PSD (C3)*

*Because of limitation of disk capacity, PSD data is provided separately upon email request.

Acknowledgments

We would like to appreciate to many people who collaborated in the infrasound observations at SYO and around LHB, including members of the Japanese Antarctic Research Expeditions (JARE). Infrasound observation at SYO was partially supported by the Ministry of Education, Science, Sports and Culture, Grant-in-Aid for Young Scientists (B) 19740265, 2007 (P.I.: Dr. Yoshiaki Ishihara). This work was also supported by JSPS KAKENHI Grand Number 26241010 (P.I.: Dr. Masaki Kanao).

References

1. Headlin, M.A.H., Garces, M., Bass, H., Hayward, C., Herrin, G., Olson, J., and Wilson, C. Listening to the secret sounds of Earth's atmosphere. Eos Transactions American Geophysical Union. 2002, 83, p. 564-565. https://doi.org/10.1029/2002eo000383
2. Arai, N., Iwakuni, M., Watada, S., Imanishi, Y., Murayama, T. and Nogami, M. Atmospheric boundary waves excited by the tsunami generation related to the 2011 great Tohoku-Oki earthquake. Geophysical Research Letters. 2011, 38 (21), L00G18. https://doi.org/10.1029/2011gl049146
3. Matoza, R.S., Hedlin, M.A.H. and Garces, M.A. An infrasound array study of Mount St. Helens. Journal of Volcanology and Geothermal Research. 2007, 160 (3-4), p. 249-262. https://doi.org/10.1016/j.jvolgeores.2006.10.006
4. Arrowsmith, S.J., Hedlin, M.A.H., Ceranna, L. and Edwards, W. An analysis of infrasound signals from the June 3rd, 2004 fireball over Washingtonstate. InfraMatics. 2005, 10, p. 14-21.
5. Le Pichon, A., Blanc, E. and Drob, D. Probing high-altitude winds using infrasound. Journal of Geophysical Research. 2005, 110 (20), D20104. https://doi.org/10.1029/2005jd006020
6. Wilson, C.R. Auroral infrasound waves. Journal of Geophysical Research. 1969, 74 (7), p. 1812-1836. https://doi.org/10.1029/JA074i007p01812
7. Arrowsmith, S.J., Hedlin, M.A.H., Ceranna, L., Edwards, W. and Wilson, C.R. Infrasound from Auroral Electrojet Motions at I53US. InfraMatics. 2005, 10, p. 1-13.
8. Kanao, M., Maggi, A., Ishihara, Y., Stutzmann, E., Yamamoto, M.-Y., and Toyokuni, G. Characteristic atmosphere-ocean-solid earth interactions in the Antarctic coastal and marine environment inferred from seismic and infrasound recording at Syowa Station, East Antarctica. Geol. Soc. London, Spec. Publ. 2013, 381, p. 469–480. https://doi.org/10.1144/SP381.8
9. Yamamoto, M.-Y., Ishihara, Y., Kanao, M. Infrasonic Waves in Antarctica: A New Proxy for Monitoring Polar Environment. Int. J. Geosci.2013, 4 (4), p. 797-802. https://doi.org/10.4236/ijg.2013.44074
10. Ishihara, Y., Kanao, M., Yamamoto, M.-Y., Toda, S., Matsushima, T. and Murayama, T. Infrasound observations at Syowa Station, East Antarctica: Implications for detecting the surface environmental variations in the polar regions. Geosci. Front. 2015, 6 (2), p. 285–296. https://doi.org/10.1016/j.gsf.2013.12.012
11. Ishihara, Y., Yamamoto, M.-Y., Murayama, T., Matsushima, T., Kanao,

M. Long-Term Variations in Infrasound Signals Observed at Syowa Station, Antarctica: 2008-2014. InfraMatics. 2017, 3 (1), p. 1–10. https://doi.org/10.4236/inframatics.2017.31001

12. Murayama, T., Kanao, M., Yamamoto, M.-Y., Ishihara, Y., Matsushima, T., Kakinami, Y. Infrasound array observations in the Lützow-Holm Bay region, East Antarctica. Polar Sci. 2015, 9 (1), p. 35–50. https://doi.org/10.1016/j.polar.2014.07.005
13. Murayama, T., Kanao, M., Yamamoto, M.-Y., Ishihara, Y., Matsushima, T., Kakinami, Y., Okada, K., Miyamachi, H., Nakamoto, M., Takeuchi, Y., Toda, S. Time–space variations in infrasound sources related to environmental dynamics around Lützow–Holm Bay, east Antarctica. Polar Sci. 2017, 14, p. 39–48. https://doi.org/10.1016/j.polar.2017.10.001
14. Murayama, T., Kanao, M., Yamamoto, M.-Y., Ishihara, Y. Infrasound Signals and Their Source Location Inferred from Array Deployment in the Lützow-Holm Bay Region, East Antarctica: January-June 2015. Int.J. Geosci. 2017, 8 (2), p. 181–188. https://doi.org/10.4236/ijg.2017.82007

Data Citations

Ishihara, Y., T. Murayama, M. Yamamoto, T. Matsushima, M. Kanao, 2019, Infrasound observation at JapaneseAntarctic Station "Syowa": 11 years observations and results, 1.00, Arctic Data archive System (ADS), Japan, 2019. https://doi.org/10.17592/001.2019070501

Because of the limitation of the disk capacity of the archive site, PSD files are provided separately upon e-mail requests.