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Polar Data Science

Abstracts

Conveners: Masaki Kanao, Yoshimasa Tanaka, Kunio Takahashi,
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IDo1

The Principles of the ISC Data Collection, Management, Protection, and Distribution

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The International Seismological Centre (ISC) has the unique mission of producing the most definitive, complete and accurate long-term account of seismicity of the Earth, covering the entire period of instrumental seismology from 1904 till present. This work is based on a free and open exchange of parametric event data with several hundreds of seismological institutions, networks and observatories in over hundred countries around the world. The result – the Seismological Bulletin of the ISC and several associated datasets that are freely available to all and routinely used by the Geoscience research community and referenced in several hundreds of scientific articles each year.

Based on the examples from polar regions, we describe the ISC policies on collection, management and distribution of data from all major ISC datasets: the ISC Bulletin, the International Seismograph Station Registry, the Ground-Truth dataset, the ISC-GEM Global Instrumental Earthquake Catalogue, the ISC-EHB bulletin, the ISC Event Bibliography, the Seismological Dataset Repository and the ISC Electronic Archive of Printed Station/Network Bulletins.

We share our methods of data back up applicable to a small organization as well as our planning for possible disasters and consequent recovery of operations.

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IDo2

Activities of the Polar Environment Data Science Center of ROIS-DS: Current status and future perspective

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Current status and future perspective of the activities of the Polar Environment Data Science Center (PEDSC) are introduced. PEDSC has been established in the Joint Support-Center for Data Science Research (DS) of the Research Organization of Information and Systems (ROIS) in 2017. Purpose of the PEDSC is to promote collaboration with the data obtained by the research activities in the polar region, and to play a key role of the data activity in polar science to contribute to the global environment research. Current targets of the PEDSC are defined in the following seven categories (1) to construct a synthetic database for all the research fields of polar science, (2) to make the existing database systems (Science Database, IUGONET, ADS) upgraded and interoperable with each other, (3) to promote archiving, opening, and sharing of the time series digital data in each research field, (4) to promote archiving, opening, and sharing of the sample data in each research field, (5) to promote data publication through the "Polar Data Journal ", data journal of NIPR, (6) to promote collaboration with universities and other institutions in Japan and international communities, (7) to promote data science using the database and database system.
Figure 1 is a conceptual figure showing those tasks of the PEDC, and Figure 2 is a diagram of relationship among the NIPR, PEDSC, and external community associated with the seven tasks of the PEDSC.
Information on the activities of the PEDSC can be seen in the following WEB site: http://pedsc.rois.ac.jp/en/

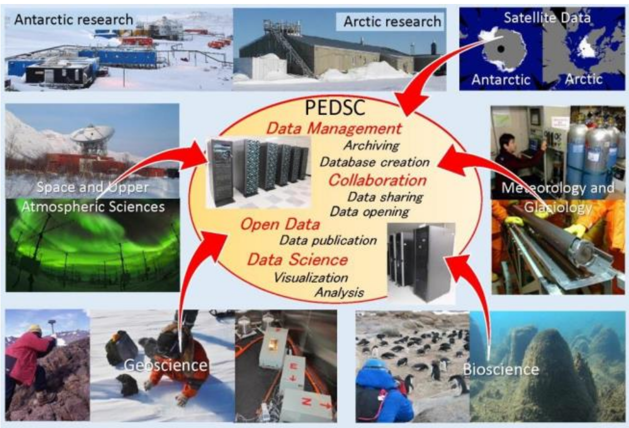

Figure 1. Conceptual figure showing those tasks of the PEDSC.

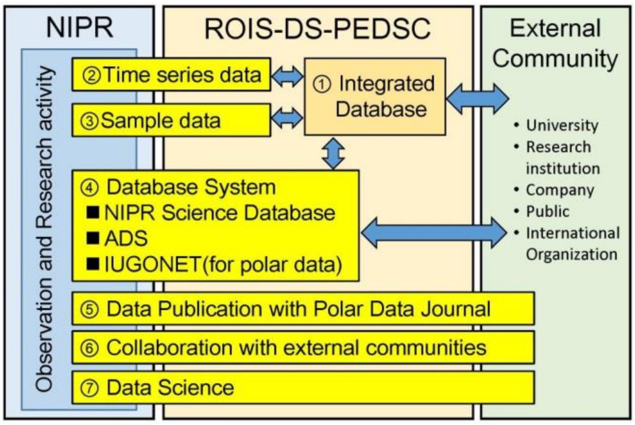

Figure 2. Diagram of relationship among the NIPR, PEDSC, and external community.

IDo3

Release of the AMIDER Website: Cross-disciplinary Research Database for Polar Science

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Polar Environment Data Science Center (PEDSC) of Joint Support-Center for Data Science Research (ROIS-DS), Research Organization of Information and Systems (ROIS), was established in 2017 with the aim of promoting the management, publication, and utilization of scientific data, primarily in polar science. Leveraging the diverse fields in polar science, such as life sciences, geosciences, and space sciences, we have developed a new research data-sharing platform, AMIDER (Advanced Multidisciplinary Integrated-Database for Exploring New Research), with collaborative institutes. AMIDER is characterized by its multidisciplinary database, which is applicable to diverse fields and data types, and its user-friendly design, which encourages access by non-expertized users. The catalog view (Figure 1) on the top page and search results pages consist of thumbnail images and snippets of each dataset, utilizing a general design in e-commerce or streaming sites to enhance user accessibility. Individual dataset pages offer functions that meet the needs of not only non-expertized users but also scientific specialists, such as a data download function where the observational period is selectable, and a display of specimen photos or data plots. Additionally, as a new initiative, related datasets are proposed to provide users with a "walk-around" experience between datasets, based on correlations and relationships between different datasets. Challenges for the future include extracting more interdisciplinary relationships through text analysis of metadata and a visualization of the relationships using network analysis. To improve the data curation process, which forms the basis of the research database, we are also exploring the development of a dedicated curation tool and the use of natural language processing for metadata creation. The AMIDER website (https://amider.rois.ac.jp/) began its public operation in April 2024. As of July 2024, over 15,000 metadata have been registered, and several hundreds of visitors are accessing the website every day. We will present the development, current status, and future perspective of the AMIDER.

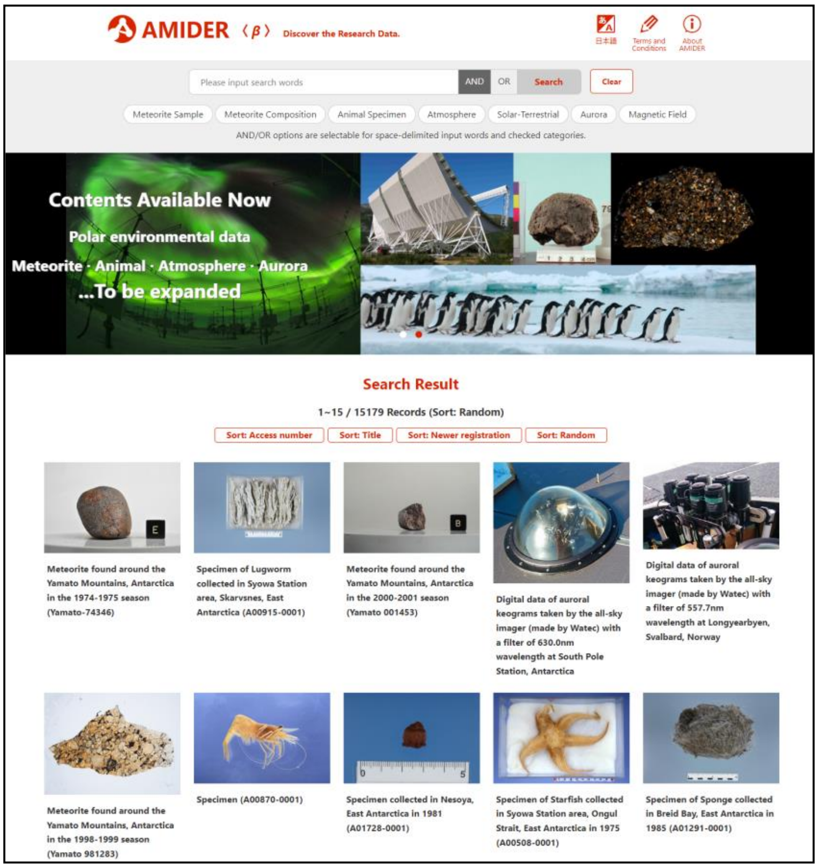

Figure 1. AMIDER's catalog view for diverse research data.

IDo4

New applications of machine learning technologies within the Australian Antarctic Data Centre

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Machine learning/AI technologies have increased greatly with respect to their availability, and potential application. The Australian Antarctic Data Centre (AADC) has been testing a number of these to better support its mission of curating and delivering Australia's collections of Antarctic information. The first is a joint collaboration with the University of Tasmania to use machine learning to automatically understand the content of data collections, to improve data consistency, and to automatically generate metadata. The AADC has also commenced using multiple Local Large Language Models (LLMs) and Generative Adversarial Networks (GANs) to investigate new ways of searching, retrieving, and extracting information from its data collections. This presentation will provide an overview of how these technologies have been implemented, as well as their potential use by other data centres.

IDo5

Polar data and local, regional, and international initiatives -- what's next (for action)

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[2] *Arctic Data Committee – co-chair*

Knowledge mobilization and data sharing are top priorities for researchers and communities of practice worldwide. While numerous initiatives are gaining momentum, Arctic research presents a unique challenge due to the region's diversity and the responsibilities that come with it. This presentation aims to showcase these initiatives at the international, national, and regional levels, specifically examining how they interconnect and build upon one another to amplify their impact. This impact stems from the complex and interdisciplinary research currently being conducted in polar regions and the associated challenges related to knowledge mobilization and knowledge-to-action frameworks. The presentation will explore bottom-up approaches to the flow of data from spatiotemporal configurations, with examples from initiatives such as community-based monitoring organizations, the Canadian Consortium for Arctic Data Interoperability (CCADI), and the Polar Data Search (PDS). Furthermore, it will emphasize the contributions of these initiatives and how they have benefited from coordination efforts by organizations such as the Arctic Data Committee (ADC) and the World Data System - International Technology Office (WDS-ITO). The polar region embodies a multitude of perspectives, and collaboration between interdisciplinary fields is essential to addressing the challenges of the open data movement, exemplified by the principle of 'as open as possible, as closed as necessary.'

IDo6

Beyond Data: What About Openness and FAIRness of Polar Sciences Samples?

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The Polar Sciences exemplify multidisciplinarity through their comprehensive study of the Earth's polar regions, encompassing diverse fields such as climatology, oceanography, glaciology, biology, geology, and anthropology. As a result, Polar Sciences research yields a diverse array of material samples that are crucial for a holistic understanding of the unique and complex ecosystems in the polar regions and their interactions with, and influence on, global systems.

- Ice cores from glaciers and ice sheets provide valuable records of past climates, revealing atmospheric composition, temperature fluctuations, and volcanic activity over thousands of years.
- Sediment cores from the ocean floor or lakes help reconstruct historical changes in sea level, glaciation patterns, and ecosystem dynamics.
- Biological specimens offer insights into the adaptations and biodiversity of life in extreme conditions.
- Snow/water and air samples are analyzed for pollutants and trace elements, contributing to studies on environmental contamination and atmospheric transport.
- Rock and soil samples aid in understanding geological processes, such as tectonic activity and glacial erosion, while meteorological data collected from various instruments support climate modelling.
- Indigenous artefacts offer valuable insights into the lives, traditions, and resilience of communities that have inhabited the Arctic environment for millennia. Artefacts not only highlight the importance of traditional knowledge in environmental stewardship and sustainable practices, but also evolution of such practices illustrate changes to the environment over time.

While the vital role that material samples play in Polar Sciences research is undeniable, the reality is that these samples are typically far from following the principles of FAIR and Open Science, with significant challenges existing in terms of sample traceability, interoperability, and data integration. Widespread adoption of persistent identifiers (PIDs) for Polar Sciences samples can address many of the current limitations associated with sample management.

The International Generic Sample Number (IGSN ID) is a PID specifically for material samples. It provides a globally unique and permanent reference to a sample, ensuring unambiguous identification of the sample throughout its lifecycle and enabling seamless linkages to its associated research outputs and entities. Functionally a Digital Object Identifier registered under DataCite services, the IGSN ID can be applied to all types of material samples from all research disciplines. In this regard, it is ideal for connecting the myriad multidisciplinary samples arising from Polar Sciences research.

By registering an IGSN ID for a material sample, a researcher provides rich metadata in the DataCite Metadata Schema, giving it a findable and accessible digital footprint, and increasing the potential for reuse of data about the sample or even of the sample itself. Researchers can thus enhance the veracity of their experiments and facilitate transparent reporting of their methods and results. Furthermore, utilization of IGSN IDs provides a standard framework for referencing samples across institutions and research projects, enabling interoperability and streamlining exchange of sample data.

With the Polar Sciences combining cutting-edge technology and traditional knowledge, it is highly important that research follows the CARE (Collective Benefit, Authority to Control, Responsibility, and Ethics) Principles for Indigenous Data Governance. This is especially true for material samples collected during Polar Sciences research endeavours. Indigenous community sovereignty of research outputs is supported in digital environments by the application of Local Contexts Notices and Labels, which can be captured in the sample metadata of IGSN IDs.

This presentation will introduce the IGSN ID and describe its use cases—highlighting practical IGSN ID implementation and discussing considerations for their adoption in material samples workflows. The presentation aims to encourage the Polar Sciences community to think about the Openness and FAIRness of not only digital objects, but also physical ones. By embracing PIDs for their material samples, Polar Sciences researchers can contribute to a more transparent, interconnected, and reproducible research landscape. This in turn will advance knowledge across the diverse multidisciplinary fields that comprise the Polar Sciences and that inform policies crucial for the preservation and sustainability of these fragile environments.

IDo7

EU-PolarNet2 White Paper with 80 recommendations for strengthening international collaborative Polar observations

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Global climate change is manifesting with alarming speed and severity, but nowhere are these changes more pronounced than in the polar regions.
Yet polar observations are currently sparse, with observing networks fragmented and lacking large-scale coordination. Identified gaps in current observation strategies open prospects for improvement in climate system understanding, funding strategies, prioritisation of observation, and in polar data management and sharing.

This talk will introduce the EU-PolarNet2 (funded by the EU-H2020) White Paper with 80 actionable policy-level recommendations, delivered to the European Commission in March 2024.
The primary objectives of the recommendations are to strengthen international polar observation to enhance understanding of polar environmental changes, as well as their effects on other areas of the Earth. Increased cooperation in observing the polar regions will create a coordinated system for continuous, standardised data and transnational polar observation and research actions of high societal relevance to support well-informed decision-making processes.
The proposed strategy seeks to join and consolidate the best assets, expertise, experience, and networks of existing polar initiatives. The overarching goal is to sustainably support long-term data collection and monitoring, fostering the integration of infrastructures and funding mechanisms currently operational at each pole.

The integration of existing initiatives from each pole is designed to align with societal needs while ensuring a cooperative approach to polar observations. The provided recommendations, tailored primarily for decision-makers, but also relevant for the scientific polar community, have been formulated through extensive workshops, meetings, and consultations involving a diverse range of experts, stakeholders and rights holders within the polar communities.

The topics of the recommendations encompass (Figure 1):

- Addressing user, stakeholder and rightsholder needs
- Strengthening data systems
- Advancing infrastructures and technology
- Enhancing funding mechanisms and fostering international cooperation
- Establishing effective governance and organisational structures
- Encouraging collaborative research efforts
- Emphasising societal relevance

Each topic, or 'pillar,' identified represents an area of natural common interest between the Arctic and the Antarctic. Actionable recommendations formulated in each pillar are presented, with some recommendations specifically formulated regarding the prioritisation, acquisition, standardisation, management, and sharing of data supporting polar science (Figure 2), including:
• Enhance the use of standards and collaboration among data management bodies, and secure funding for training in data management.
• Align existing polar data policies and promote the principles of making data findable, accessible, interoperable and reusable (FAIR).
• Establish overviews on polar observing assets to improve cost efficiency.

The EU-PolarNet2 White Paper, alongside a summary of the White Paper published under the form of a Policy Brief, are now openly accessible online (see References) and constitute a comprehensive guide for advancing international collaboration and efforts in polar observation.

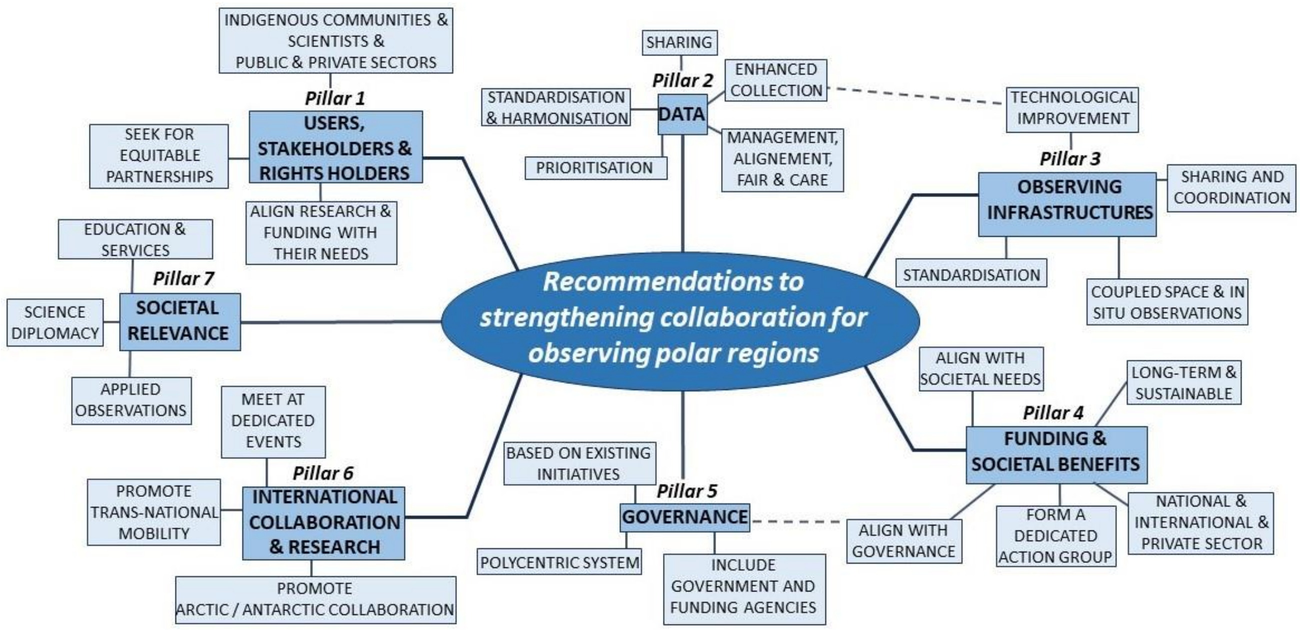

Figure 1. The main pillars and their main recommendations. Detailed recommendations for each pillar are presented in the White paper.

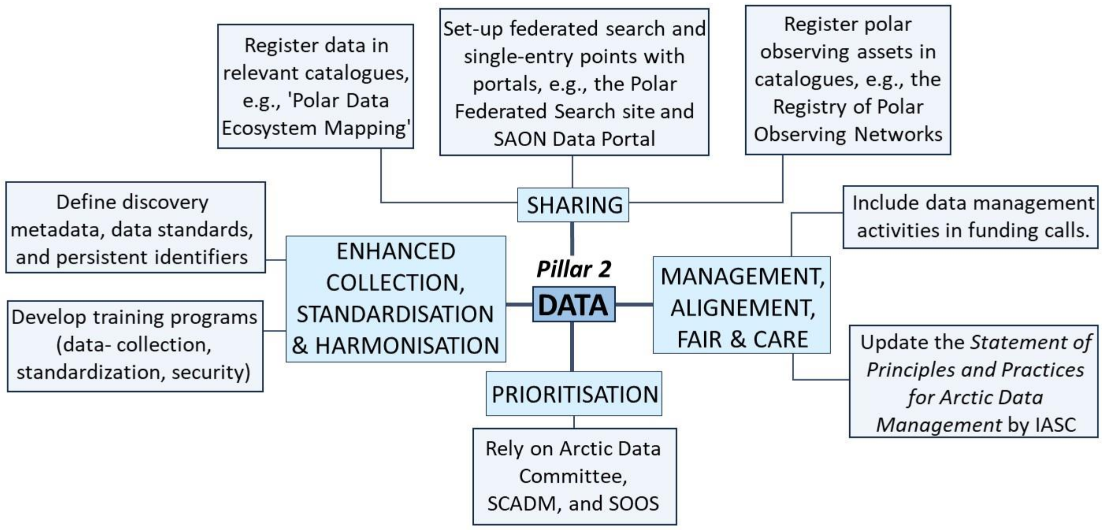

Figure 2. Recommendations for Pillar 2 of the White Paper, Strengthen collaboration to manage polar data.

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Bi-directional Neural Network for Polar Weather Forecasting

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A novel weather forecasting model for polar regions that leverages the power of neural networks. By training on historical polar weather data, the model can learn complex relationships between past conditions and future outcomes. The bi-directional LSTM is used to process input sequences simultaneously forward and backward, improving the model's ability to capture complex temporal dependencies and enhance the representation of time series data. Our proposed approach utilizes high-performance neural networks, to forecast air temperature over the next 24hrs to 48 hrs for the collected datasets such as Automated Weather Station (AWS) from Bharati Station, Antarctica. The Bi-directional model obtained the lowest RMSE of 0.000816, making it the best performance among all temperature prediction models.

The Bi-LSTM, contains two bidirectional LSTM layers with 128 units each, resulting in higher performance than the basic LSTM model by using bidirectional processing to capture both past and future contexts in the sequence. This architecture significantly improves the modeling of complex temporal patterns and leads to more accurate predictions of time series. Each layer contains 128 LSTM units, thereby increasing the capacity to capture contextual information and data dependencies in detail. This additional memory enables the model to learn complex relationships and improve its predictive accuracy. As a result, the model efficiently manages and integrates different types of information and generates more robust and reliable predictions than the standard LSTM model.

The 24-hour prediction is depicted in red in Figure 1(b), using Bi-LSTM model. Figure 1(a) showcases the validation of the temperature parameter using the Bi-LSTM model, with its corresponding 24-hour prediction shown in Figure 1 (b). The model configuration details and its RMSE value listed at Table 1.

Model Name	Epochs	Window Size	Hyperparameters	Batch Size	RMSE
Bi-LSTM	200	16	0.001	32	0.000816

Table 1 : Configuration parameters for the Bi-LSTM model

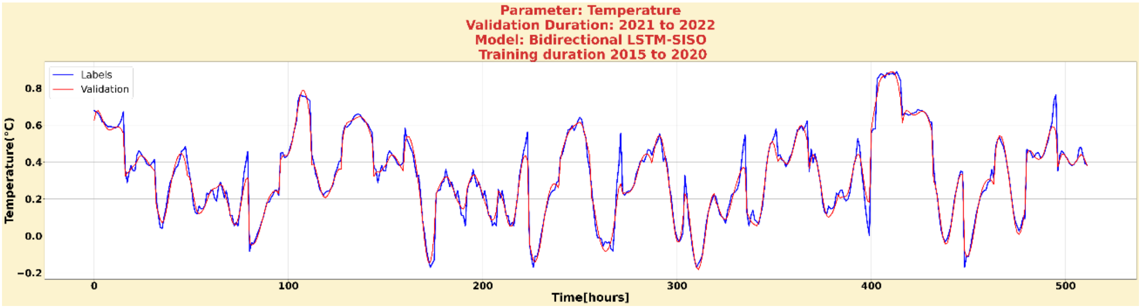

Figure 1(a) : Temperature validation using the Bi-LSTM model was conducted with training data from 2015 to 2020 and validation data from 2021 to 2022. The blue line represents the actual dataset, while the red line indicates the model's validation.

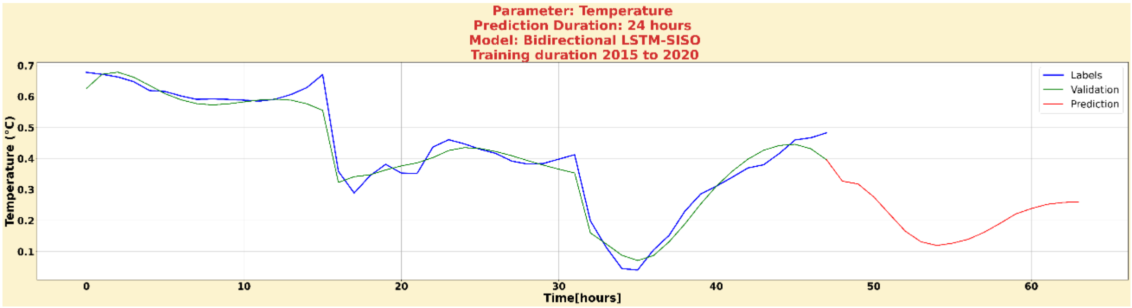

Figure 1(b) : Temperature prediction for a 24-hour period using the Bi-LSTM model was performed with data spanning from 2015 to 2022. The blue line illustrates the actual data, the green line represents the model's validation, and the red line shows the 24-hour temperature predictions.

IDo9

A comparison of manual and automatic methods for the detection of geological features within large 3D seismic data

Musa S.D. Manzi[1] and Gordon Cooper[1]
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The accurate delineation of subsurface geological features such as potholes or slump structures in 3D seismic data is key for optimizing mining and hydrocarbons operations, particularly in regions with complex geological settings. However, the current conventional seismic approach in structural interpretation (e.g., manual and automatic picking) is a time-consuming process that can take several months, depending on the complexity of the geology, size of the targeted geological features, size and quality of the data. This study presents some novel approaches to improve the interpretation speed of large seismic data and the detection accuracy of complex geological features such as gas-escape structures such as faults and pockmarks. This automated method uses a combination of spatial derivatives, statistical methods, and an automated seismic horizon-based interpretation approach. We demonstrate the effectiveness of our approach through a case study from an offshore deepwater basin in South Africa. The primary objective of the study is to enhance the accuracy and efficiency of structural delineation in seismic data, which is critical for hydrocarbon exploration. The results demonstrate a high level of accuracy in detecting geological structures, providing valuable insights into the hydrocarbons potential in South Africa.

The case study is from the 3D seismic data acquired in the deepwater Orange Basin in South Africa for oil and gas exploration. The 8 000 km² survey was conducted along the continental slope of western South Africa, at depths ranging from 1 to 2 km below sea level. For this study, Maduna et al. (2023) initially interpreted pockmarks on specific horizons using conventional attributes such as manual picking guided by seismic attributes. The conventional surface attributes used in the study area included surface smoothing, influential data, and edge detection. The influential data attribute, used as input data in our automated approach, highlights areas of rapid 3D geometric change. Following the application of these surface attributes, more than 950 pockmarks on the late Campanian surface and 85 on the current seafloor were manually delineated, a process requiring several days to complete. Our novel approach uses spatial derivatives, statistical methods and automated seismic interpretation approaches to detect and extract gas-escape structures such as pockmarks and faults in the study area, comparing these results with the conventional seismic interpretation methods used in Maduna et al. (2023) for pockmark identification, classification, and extraction.

The automated pockmark extraction method chosen was based on the Shape factor of the data. The shape of a surface can be calculated from the equation of Cooper (2020) and Roberts (2001):

$$S = \frac{2}{\pi}\tan^{-1}\left(\frac{\dfrac{\partial^2 f}{\partial x^2}+\dfrac{\partial^2 f}{\partial y^2}}{\sqrt{4\left(\dfrac{\partial^2 f}{\partial x \partial y}\right)^2+\left(\dfrac{\partial^2 f}{\partial x^2}\right)^2+\left(\dfrac{\partial^2 f}{\partial y^2}\right)^2-2\dfrac{\partial^2 f}{\partial x^2}\dfrac{\partial^2 f}{\partial y^2}}}\right)$$

Because the data possessed a strong regional trend and the shape factor calculation uses the first derivatives of the data (as well as the second), a quadratic trend surface was initially removed from it (Figure 1). The shape factor is a dimensionless number which ranges in value from -1 to +1. Positive values indicate features such as ridges and domes, while negative values indicate features such as valleys and bowls. The pockmarks that were extracted from the seismic data were inverted and appeared as near-circular hills, so the 0.5 contour value of the shape factor was extracted. The Shape factor was chosen rather than some edge-detection attribute because it is independent of the amplitude of the data. The area A, perimeter P, and circularity C of each contour was then computed, where C=4πA/P^2.

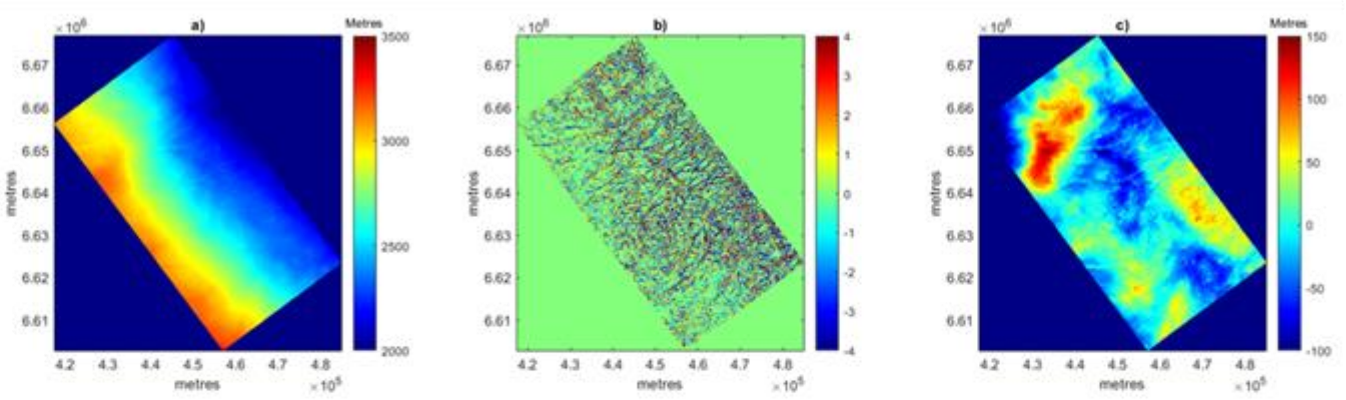

Figure 1. (a) Campanian surface. (b) Influential attribute. (c) Campanian surface after removal of regional trend surface.

C ranges from 0 to 1, where 1 is perfectly circular. For example, for a square C = 0.71 and for an equilateral triangle C = 0.60. A value of 0.80 was chosen based on trial and error, and contours with a smaller circularity value were rejected. Contours with very small and very large areas were also rejected. The former is usually related to single data point anomalies caused by noise, while the latter generally occurs when a contour intersects the edges of the dataset. Figure 2 compares the results from manual and automatic picking for a region of the dataset. Overall there were less automatic picks than manual ones (756 compared to 950) but many of the latter are questionable. However, the automated procedure tended to miss pockmarks that had highly deformed contours due to the presence of nearby features such as lineaments or other pockmarks. Overall 482 (64%) of the automatically picked pockmarks were coincident with the manual picks, but the statistic is misleading in that many picks were closely adjacent, and many manual picks were incorrect. The automated picking procedure only took 1-2s, enabling many runs with different parameter values to be tested.

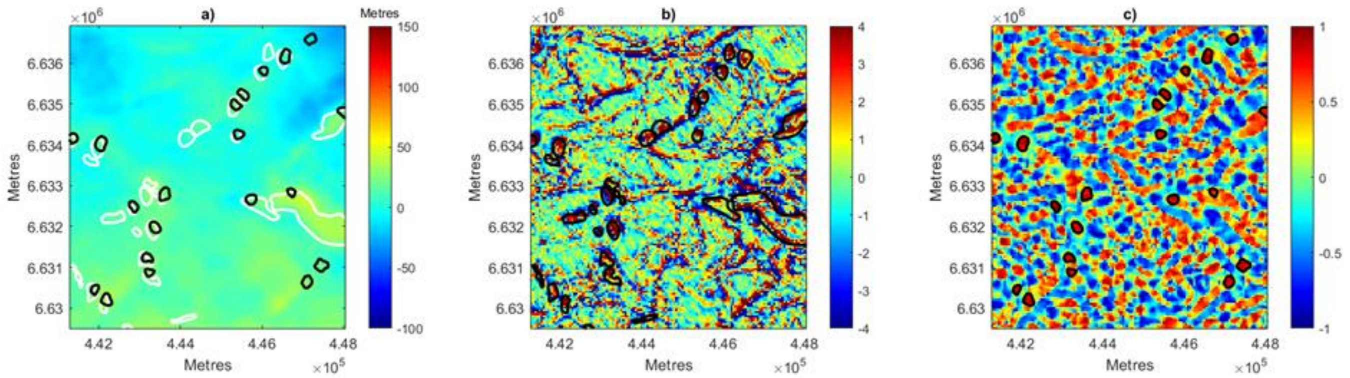

Figure 2. (a) Portion of Campanian surface with manual pockmark picks (white) and automatic picks (black) overlain. (b) Influent attribute with manual picks overlain in black. (c) Shape factor with automatic picks overlain in black.

Automated picking of faults was based on the contours of the maxima of the plan curvature (Roberts, 2001). The lineaments were produced from the plan curvature contours by fitting a quadratic polynomial function through them, and if the fit was poor the lineament was rejected. The quadratic function was used rather than a simple linear function because the lineaments were rarely exactly straight. In comparing the two methods, 1400 lineaments were picked manually while 1621 were found automatically. The automatic method was extremely fast and this allowed its various parameters to be tuned by trial and error until the best results were obtained. The optimum solution is clearly to consider the automatic interpretation as a first-pass result to be polished by the experienced human interpreter.

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IDo10

Wave attenuation in land-fast ice of varying ice thickness

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1. Introduction

The attenuation of waves in an ice-covered sea is an old and new research topic. The underlying mechanisms depend on the sea ice conditions and are classified into scattering by ice floes and dissipation in water and in the sea ice (Meylan et al. 2018). The scattering mechanism is most effective when the size of the ice floe D is of the same order as the wavelength λ. On the other hand, the relative motion of sea ice and fluid particles inevitably introduces a boundary layer where the energy is lost. For both mechanisms, the wave energy is considered to attenuate exponentially in distance. In the Marginal Ice Zone, where $O(D) \sim O(\lambda)$, both mechanisms may be in action. On the other hand, under the land-fast ice, where $O(D) \gg O(\lambda)$, the scattering mechanism inevitably is absent. We here introduce a unique observational result that shows a "linear decay of wave energy in distance" observed in the Lutzow-Holm Bay Antarctica. By eliminating the scattering mechanism, we investigate the possible impact of variation in sea ice thickness on wave attenuation due to dissipation.

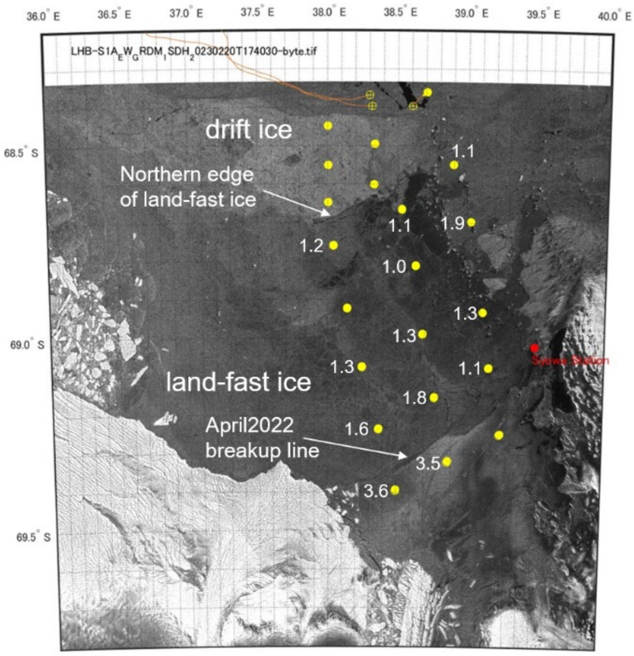

Fig. 1 Buoy locations of the JARE 64 deployment. Numbers indicate ice thickness

2. Observation

During the 64th Japanese Antarctic Research Expedition, we deployed 21 wave buoys on the land fast ice (15 buoys) and the drift ice (6 buoys). In March 2023, the buoys successfully detected the incoming wave events that led to drifts of the sea ice from the Lutzow-Holm Bay (Fig. 1). However, before the sequence of breakup events in March 2023, a few swell propagations were detected by the wave buoys. On February 7, 2023, 15 buoys on the land-fast ice detected a swell system of peak frequencies around 18 to 20 s. The corresponding wavelength λ is 500 to 600 m. The significant wave height attenuated from around 20 cm to a few centimeters over the distance of around 80 km from the north to the south (Fig. 2). The swell event lasted for about 15 hours, and the mean significant wave height and the standard deviation are shown in the left figure. By visual inspection, we note that the attenuation of the significant wave height does not follow an exponential decay (dotted curve). Nevertheless, the exponential decay rate as estimated from the two measurements gives a reasonable agreement with the attenuation rate observed by Voermans et al. (2021). Kohout et al. (2014) showed a somewhat "linear" decay of wave height for ice thickness over 3 m and accounted for the deviation from an exponential decay due to sea ice breakup. However, noting that the breakup event did not occur until March in Lutzow-Holm Bay, this possibility is excluded.

We provide an alternative explanation attributing the peculiar linear wave attenuation to the spatial variation of the sea ice thickness. The sea ice thickness was measured by drilling a hole where the buoys were deployed. On Jan. 4, 2023, and on Feb. 7, the helicopter landed on the sea ice whenever the weather allowed. We have measured the sea ice thickness of 13 locations of which one location was visited twice. Both the snow thickness and the ice thickness were measured, and the sea ice thickness is shown in Fig.1. A large change in the ice thickness from around 1.6 m to 3.5 m marks the transition from first-year ice to the multi-year ice that survived the 2022 April breakup event. In first-year ice, the ice thickness tends to increase from north to south (Fig. 2 right). The ice thickness change shown here is taken along the middle column of the 5 by 3 array of buoys.

3. Theory

Meylan et al. (2018) summarized different attenuation coefficient k_i based on different physics:

$$\frac{da}{dx} = -k_i a \qquad (1)$$

The attenuation coefficient k_i is known to depend on the incoming wave frequency. By assuming an energy loss in the Stokes boundary layer under the ice, i.e. assuming a rigid lid and no horizontal ice motion, we re-derive $k_i = \frac{1}{2}\sqrt{\frac{\nu}{2}}\omega^{3.5}g^{-2}$ first obtained by Weber (1987). An extension of Weber's formulation to consider frequency dependence of the "viscosity" of the highly viscous ice layer, Southerland et al. (2018) derived $k_i = \frac{1}{2}\sqrt{\frac{\nu_2}{2}}\omega^{3.5}g^{-2} \propto \frac{1}{4}\varepsilon h_i \omega^{4.0} g^{-2}$. Here the attenuation coefficient depends on the thickness of the ice h_i as the viscosity of the ice layer is empirically modeled as $\nu_2 = \frac{1}{2}\omega(\varepsilon h_i)^2$. However, it is apparent that this formula does not apply to the land-fast ice. Finally, a model with order 3 power law derives from a consideration of an energy loss represented by a square of velocity times the ice thickness: $h\left|\left[\frac{\partial\phi}{\partial x}\right]_{z=0}\right|^2$:

$$k_i = \frac{R}{2Ec_g} = \frac{R}{\rho g A^2 c_g} = \frac{h\eta}{\rho g^2}\omega^3 \qquad (2)$$

The loss of energy considered here represents a form drag applied to the bottom topography of the land-fast ice. Quantitatively, the magnitude depends on the geometry of the bottom of the land-fast ice and remains uncertain at this point. We, therefore, for simplicity, model the attenuation coefficient and a linear change of ice thickness in distance as follows:

$$k_i = c\,h(x) \text{ and } h = h(x) = h_0 + kx \qquad (3)$$

We ignored the frequency dependence of the attenuation rate because the wave spectrum is rather narrow. Up to the second order, the change in wave amplitude can be readily derived:

$$\eta(x) \sim \eta_0\left(1 - ch_0 x - c\left(\frac{k}{2} - c{h_0}^2\right)x^2\right) \qquad (4)$$

A fit of this formula to the observed data is shown in Fig. 2 left (red curve). It turns out that the coefficient of the quadratic term is nearly null and therefore, the decay of the wave height appears to be "linear".

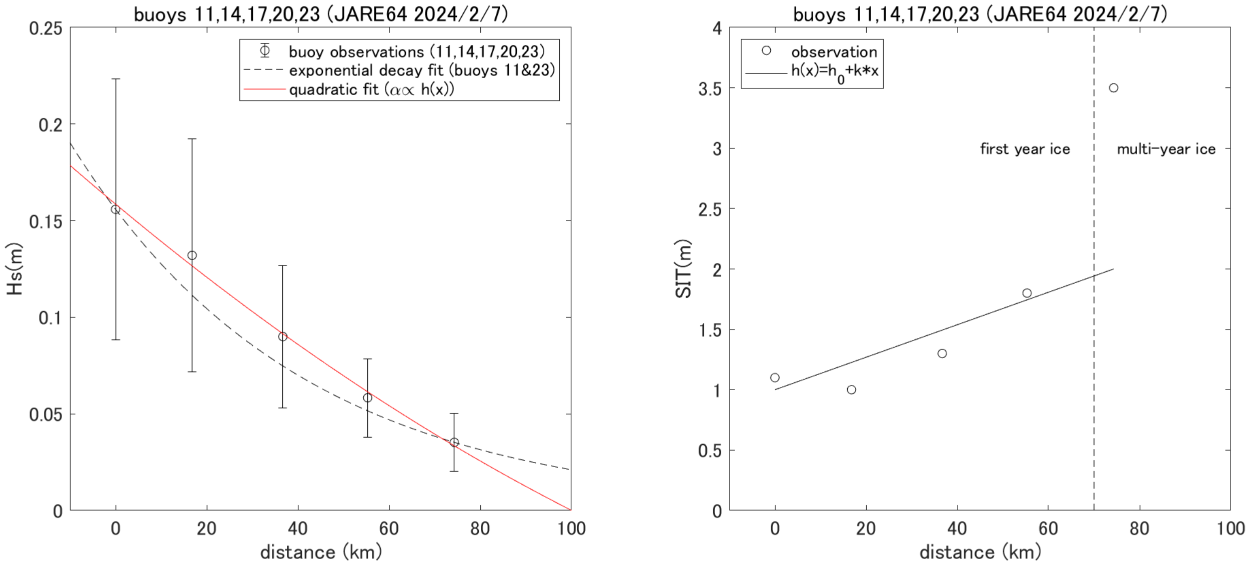

Figure 2. (left) Significant wave height variation from north to south along the middle column of the 5 by 3 array of buoys deployed on the land-fast ice. The dashed curve is an exponential decay from the two buoys. The red curve is a quadratic fit to the decaying wave height in distance. (right) Sea ice thickness changes along the middle column of the 5 by 3 array of buoys. A linear fit is given to the first-year ice.

4. Discussion

The seemingly linear attenuation was explained as due to a "linear" increase in ice thickness along the wave propagation direction. Whether this tendency is a unique feature of the Lutzow-Holm Bay or not remained a mystery until the JARE65 observation. In JARE65 (Austral summer of 2024), 21 wave buoys were deployed on the land-fast ice, and the ice thickness was measured at 18 locations. Surprisingly, the ice thickness variation differed completely from the JARE64 (Austral summer of 2023), see Nose et al. (2024, 15th Symposium on Poloar Science). The ice thickness is much thicker near the edge of the land-fast ice and was over 2 m in the central part of the land-fast ice. It is, therefore, conjectured that the wave attenuation will differ from the JARE64 expedition, and will be investigated further. Lastly, we will discuss the difference in the ice thickness of the first-year ice between 2023 and 2024 and propose a need for continuous monitoring of the ice thickness distribution in the bay.

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IDo11

Design of Antarctic Penetrator Network Observations Based on Icequake Analysis and Its Application to Planetary Seismic Observations

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[2] *Department of Solar System Sciences, Institute of Space and Astronautical Science (ISAS), JAXA*
[3] *Aerospace Engineering, Kochi University of Technology*

Setting up observational instruments and collecting high-quality data in natural sciences presents significant challenges, particularly in the tough environment of Antarctica. Active regions such as glaciers in inaccessible (unmanned) places make the installation of observation equipment difficult. Penetrators provide an effective solution by deploying instruments through high-speed impacts from aerial vehicles, enabling the establishment of safe and extensive observation networks in these inaccessible areas. This system not only enhances the safety of network construction but also reduces associated costs. Over the past few decades, we have developed specialized penetrators tailored for Antarctic conditions (Fig. 1).

Due to their installation in inaccessible areas, it is impossible for humans to retrieve the observed data directly. Instead, data is collected via satellites, which limits the volume of information that can be transmitted. We solved the data volume limitation issue by using the analysis results to automatically create and send catalogs of ice quakes and infrasound using the STA/LTA (Short-Term Average/Long-Term Average) method. In this presentation, we will show the results of our analysis of icequakes and infrasound data observed by Antarctic penetrators (Fig. 2) during the 2022 and 2023 years. We will also outline the design for a penetrator network observation plan for the Shirase and Langhovde glaciers in the 2024 year, combining existing observation sites (Fig. 3 and 4). Furthermore, we will discuss potential applications for seismic/infrasonic observations beyond Earth, highlighting how our findings could inform studies on planetary explorations.

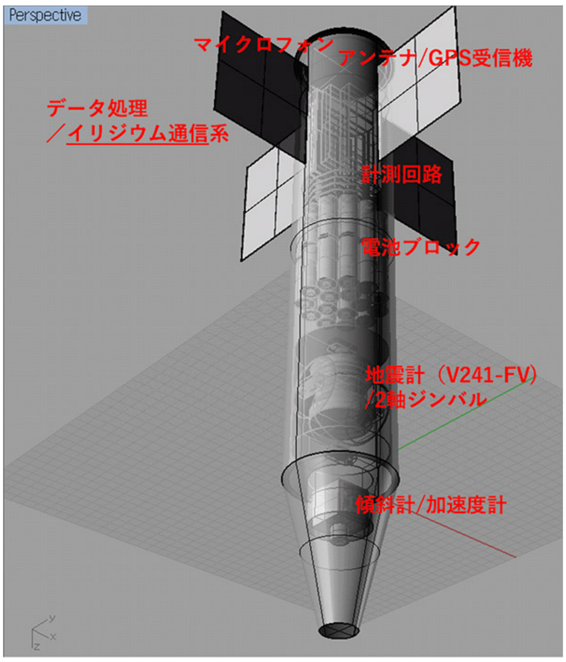

Figure 1: Antarctic penetrator with the instrumental package.

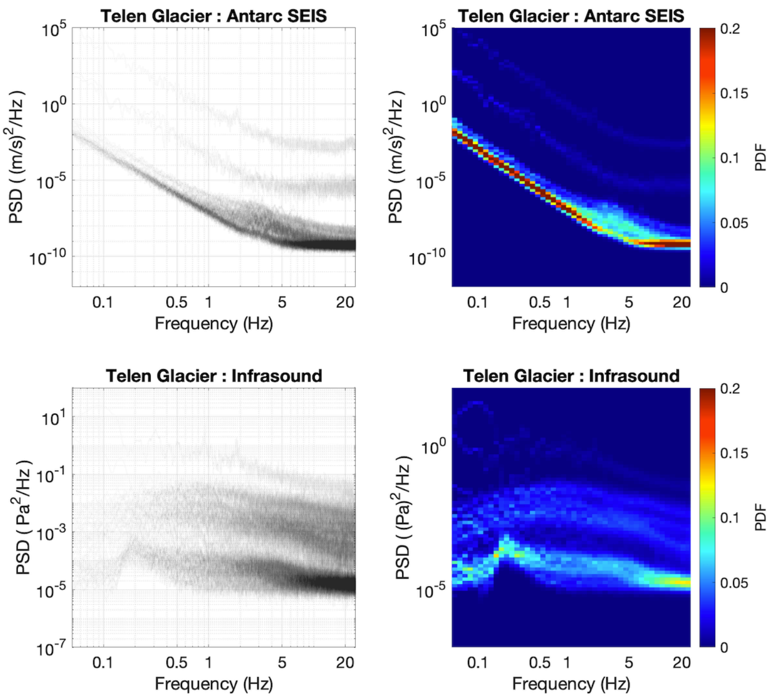

Figure 2: PSD analysis of seis/infrasound observation data on Telen glacier.

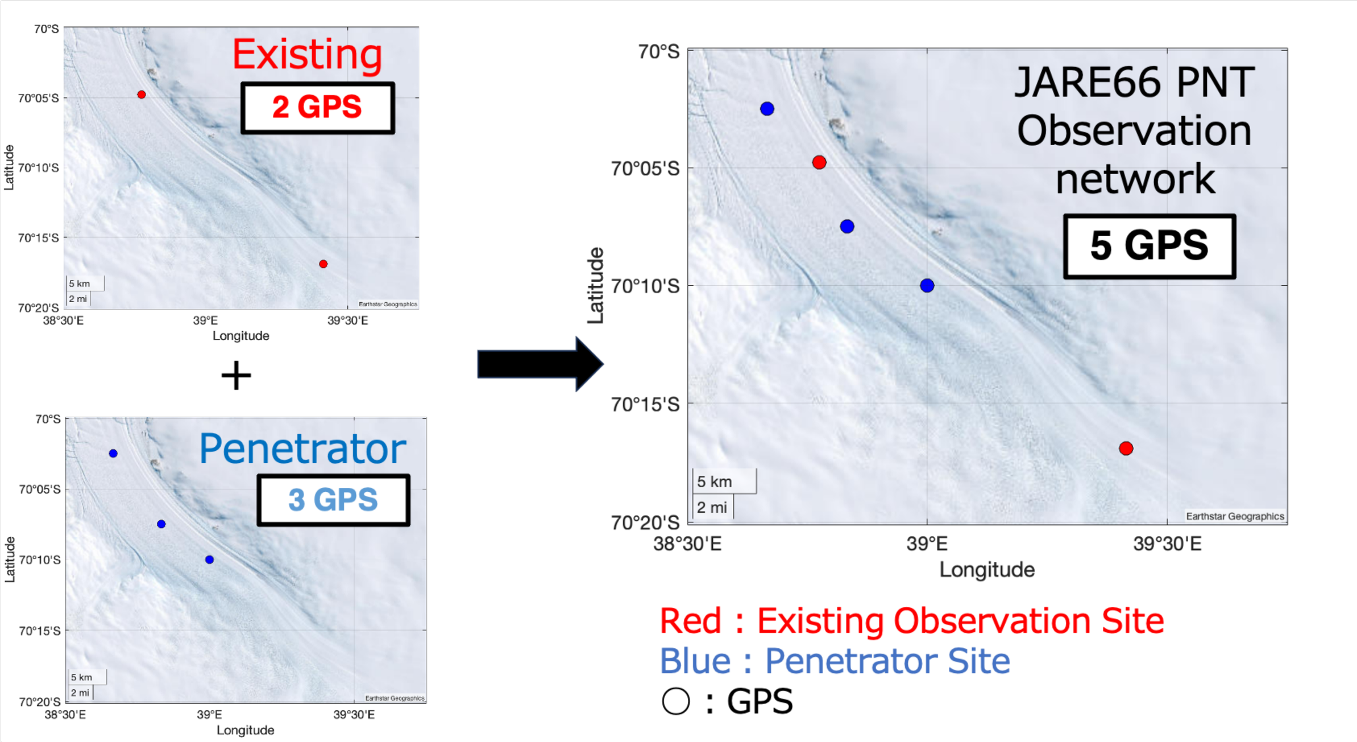

Figure 3: Mission design of Antarctic Penetrator Observation Network. We will install 3 penetrators (GPS) and form dense observational network combining existing observation sites on Shirase glacier.

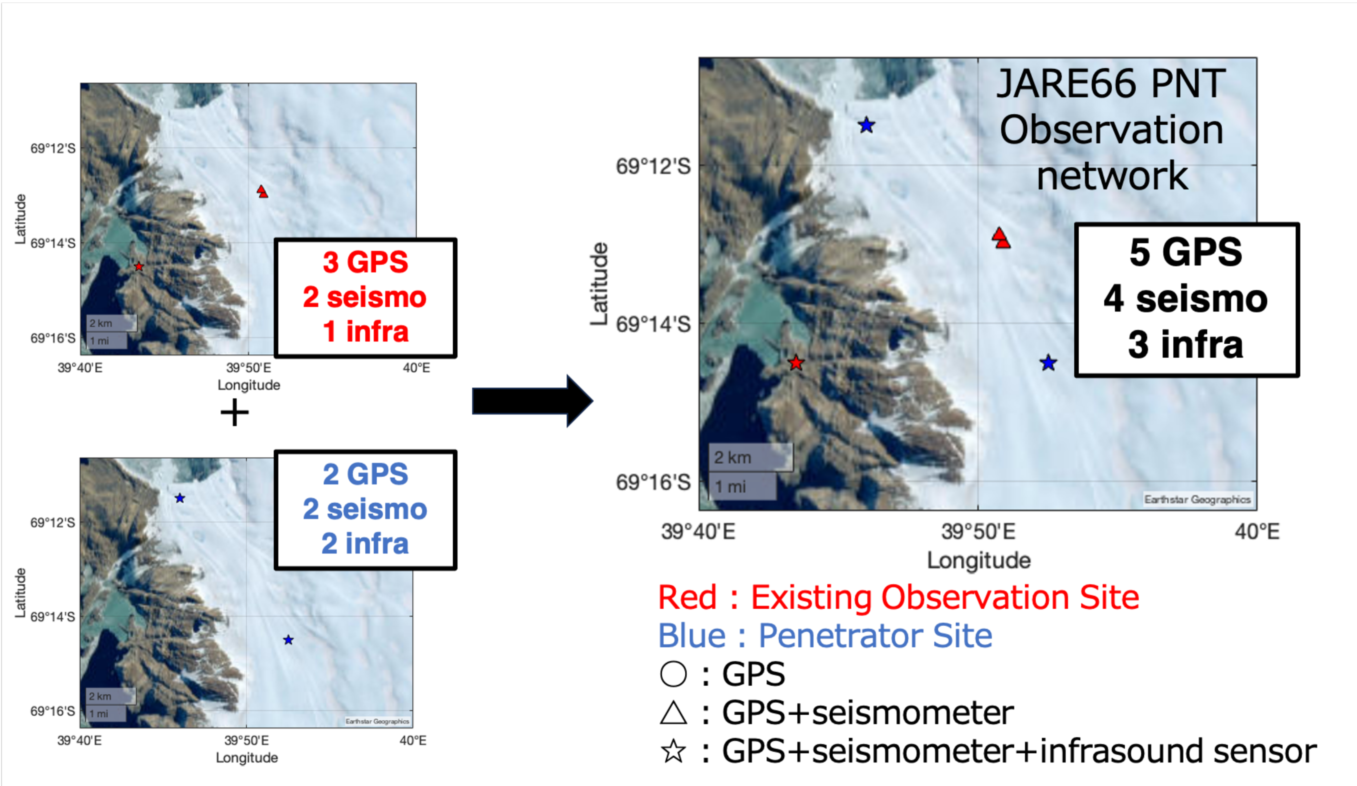

Figure 4: Mission design of Antarctic Penetrator Observation Network. We will install 2 penetrators and form wide observational network combining existing observation sites on Langhovde glacier.

IDo12

Detection of surface environmental variations using infrasound waves and their migrated sources in the Lützow-Holm Bay, East Antarctica

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Time-space variations of infrasound source locations for three years, 2019-2021, were studied by using a combination of two local arrays in the Lützow-Holm Bay region (LHB), Antarctica. The local arrays deployed at two coastal outcrops clearly detected temporal variations in signal frequency content as well as propagating directions during the three years. Many infrasound sources were detected with many to located to the north and north-west directions from the arrays. These events were generated within the Southern Indian Ocean and the northern part of LHB with frequency-content of a few seconds; these "microbaroms" are believed to originate from oceanic swells. From austral summer to fall additional infrasound sources are determined to be located to the north-east. These sources might be related to the effects of katabatic winds across the continental coastal area. Furthermore, several impulsive infrasound events during the winter had higher predominant frequencies of a few Hz, higher than the microbaroms. Based on a comparison of source locations with sea-ice and glacier distribution form MODIS satellite images, these high-frequency sporadic sources may be cryo-seismic signals associated with cryosphere dynamics near the local arrays. These results suggest that infrasound waves can be used to monitor surface environments in the coastal area of Antarctica.

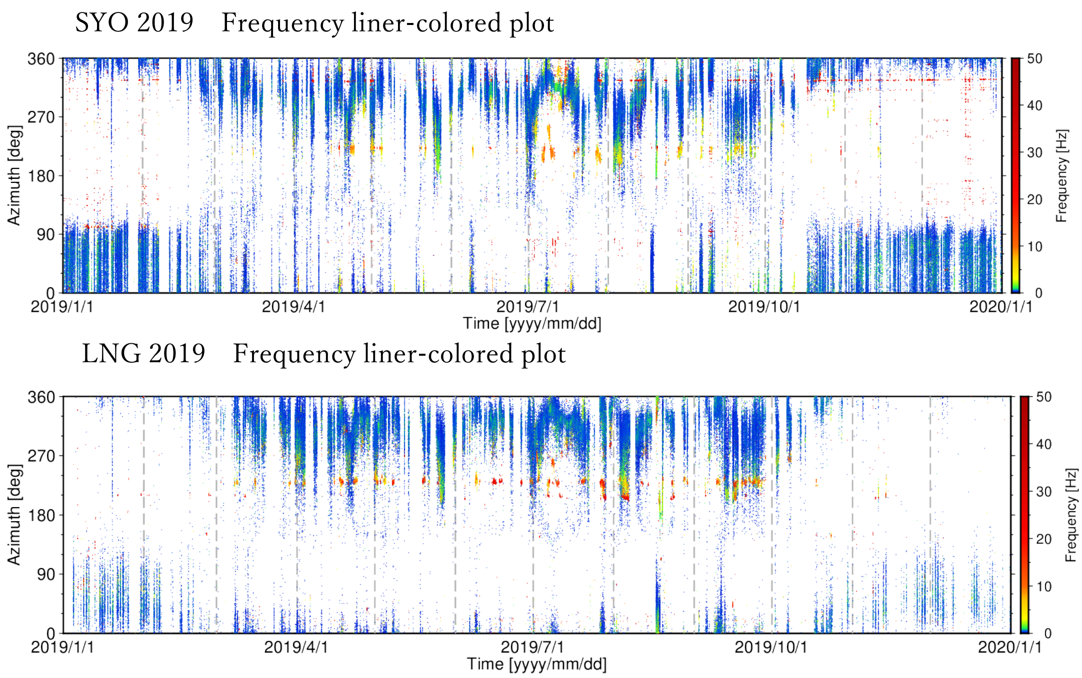

Figure 1. Time sequence of azimuthal variation in arrival orientation and frequency contents of the detected infrasound signals by PMCC analysis (from January 01 to December 31, 2019, represented by a single year panel). The vertical axis for each panel indicates the back-azimuth (station-to-source) directions for SYO and LNG arrays, respectively. Colored bars representing in right hand side for each panel correspond to the central frequency [Hz] for each detected source event (liner-colored plots).

IDp1

Last interglacial ice volume deduced from the worldwide database of relative sea-level and numerical modelling

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Understanding historical ice sheet fluctuations during previous warm periods is crucial to predicting future polar ice sheet melt and resulting sea level rise attributed to global warming. This study focuses on the Last Interglacial (LIG), approximately 125,000 years ago, when temperatures were slightly warmer than preindustrial levels, and sea levels stood 6-9 meters higher than present. By integrating a worldwide database of relative sea-level (RSL) observations with advanced numerical modeling, we aim to estimate the ice volume changes during this period.

Quantifying ice volume changes based on RSL observations is challenging due to the concurrent effects of solid Earth deformation caused by Glacial Isostatic Adjustment (GIA). To address this, we have developed a highly accurate numerical model to estimate the impact of GIA during the LIG. By combining this model with the comprehensive RSL database, we can more precisely constrain the alterations in polar ice sheet volumes.

Our approach involves comparing model simulations with RSL data from regions distant from former ice sheets, allowing us to isolate the signal of ice volume changes. This integrated analysis provides fundamental insights into the melting patterns of the Greenland and Antarctic ice sheets during the LIG.

In this presentation, we will elucidate the theoretical characteristics of RSL variations during the LIG as inferred from our GIA numerical modeling. Furthermore, we will discuss our estimates of the melting volume of the Antarctic ice sheet and its temporal evolution, derived from the synthesis of model simulations and the global RSL database. This research contributes to understanding ice sheet behavior in warmer climates, which is crucial for improving projections of future sea-level rise.

Developing an inventory of ice-marginal lake over Antarctic Ice Sheet

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Ice-maginal lakes in Antarctica are located between the coastal ice-free areas and the Antarctic Ice Sheet, its outlet glaciers, and the ice shelves. Some glacial lakes may experience sudden and unexpected drainage, known as glacial lake outburst flood (GLOF), which are a common concern for mountain regions in cryospheric environments except in Antarctica. We found sudden drainages from an ice-marignal lake in East Antarctica (Hata et al., 2023), providing a rare example of long-repeat drainage cycle. In Antarctica, however, little is known about the drarinage phenomena, resulting in a limited understanding of the role of ice-maringal lakes in the Antarctic environment. Although the mapping of glacial lakes are carried out in some regions in Antarctica and some inventories have been pubished recently, none have completed the construction for whole Antarctica, and their quality is not sufficiently high for further analysis. A lot of lakes are omitted even though they are indicated in local maps (e.g., Zhang et al., 2024; Gerrish et al., 2020). In this study, we aim to develop a comprehensive inventory of ice-maginal lakes in Antarctica to better understand GLOFs and potential impact on the surrounding environment.

We selected manual mapping by using optical satelite images to deliniate the outlines of ice-marginal lakes. We relyied on the Google Earth Engine (GEE) platform for the initial preparation of satellite images. Image selection, cloud masking, mosaicking are processed in GEE, thereafter we downloaded cloud-masked false-color composite image. We used Sentinel-2 satellite images, which have a spatial resolution as 10 m. Image acuisition period was set as summer season (December, January, and February) in 2017−2022. Manual deliniation was processed using QGIS software. Figure 1 shows an example from our inventory for Enderby Land (EBL) region. We identified 39 ice-marginal lakes in this region whereas the available inventory includes only 4 lakes. The lake areas range from 0.03×10^6 m^2 3.16×10^6 m^2, and elevations range 35.3−1062.8 m (Figure 1b and c). While the validation scheme is under development, we are planning to use surface slope, and time-series analysis by using digital elevation models. In thi presentation, we will present the latest inventory of ice-marginal lakes and discuss its potential use for further analysis.

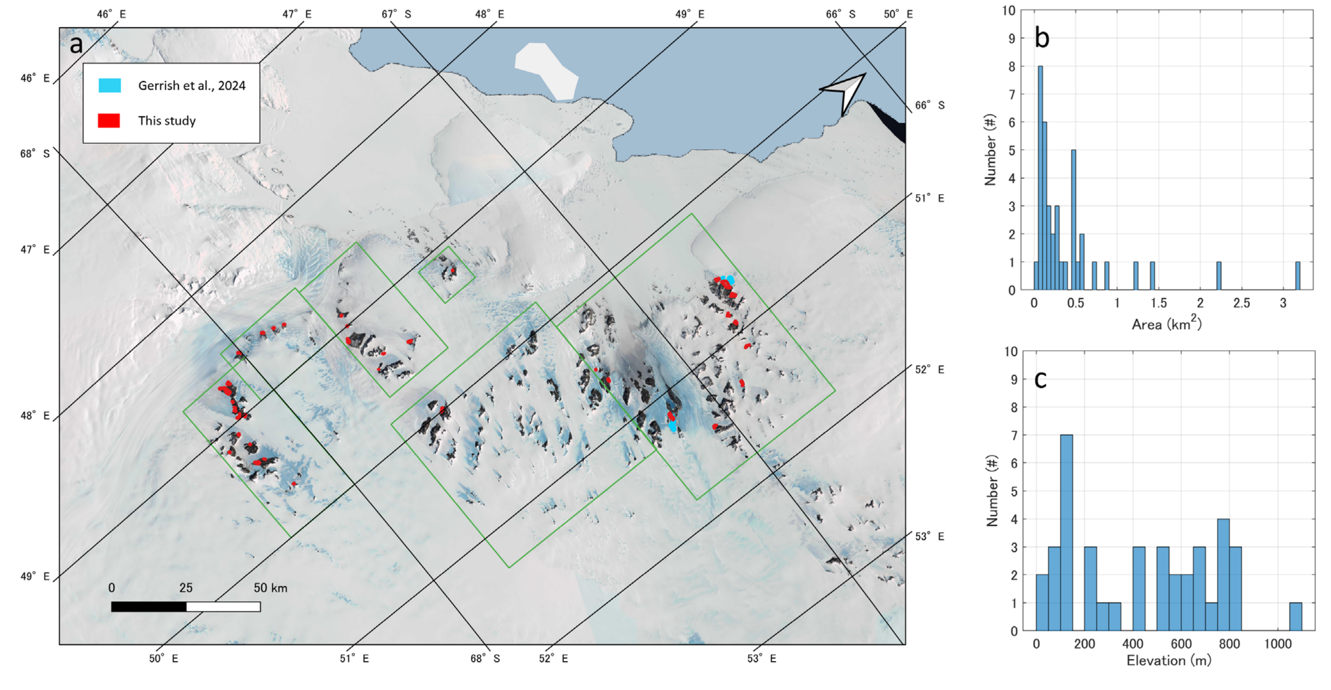

Figure 1. Distribution of ice-marginal lake in the EBL region, East Antarctica. The back-ground image is a cloud-masked Sentinel-2 false-color image. Red markers show the location of ice-marginal lakes, from the preliminary inventory of ice-marginal lakes in Antarctca. Cyan markers also show the glacial lakes from the inventroy from Gerrish et al., (2020). Green boxes are the region of interest of this study. Panels (b) and (c) show histograms of the area and elevation, respectively, of the ice-lakes in the EBL region.

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IDp3

Development of a data logger onboard the Antarctic penetrator and evaluation of trial operation

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Penetrator is an observation system that is dropped from the sky and penetrates the ground to install and record onboard instruments such as seismometer. Since it does not require installation work and has a simple structure, an observation network can be established at low cost in any region. Especially in regions such as Antarctica, where many areas are difficult for humans to reach, this system can make a significant contribution as a new unmanned observation system infrastructure. To demonstrate the feasibility of this project, it is essential to develop a logger for the penetrator that can perform unmanned observations without the need to retrieve equipment. In this presentation, we will show loggers for penetrators targeting unmanned observations and the results of trial operations on the Langhovde Glacier.

1) Development of a data logger for penetrator

The logger hardware configuration shown in Fig.1 was developed to meet the system requirements of observation, recording, and telemetry functions for operation in remote areas. Power consumption in this configuration was measured to be 150 [mWh]. If the on-board battery was at 50 % capacity due to low temperatures, the maximum continuous observation time would be approximately 2 weeks. Next, a control flowchart of the implemented functions is shown in Fig.2. We implemented a function that records the characteristics in a catalog list and saves the actual waveform to an SD card when an amplitude event is detected during continuous observation. To check the survival of loggers, weather data, attitude, position information, and catalog lists are automatically sent periodically. The system is also capable of sending external requests for settings and waveform data to the loggers, making it a highly flexible system.

2) Trial operation at Langhovde Glacier

In the trial operation during JARE65 in austral summer season, being operated with a helicopter, the developed instruments actually penetrated on the Langhovde Glacier, and immediately after confirming the health of the logger and seismometer on the actual operation, with recovering the system after 8 days of continuous operation. As a result, we confirmed that the system was operating normally immediately after the penetration into the glacier, and confirmed the survival of the system through periodic communication and system logs during the continuous operation. The effectiveness of the commands was also confirmed through the use of remote configuration commands to respond flexibly to local events for vibration events observed in the Langhovde glacier environment. Through this test operation, the basic functions required for long-term operation at the glacier were achieved with a certain level of quality. On the other hand, there are still issues to be resolved regarding power operation such as hibernation mode, long-term time accuracy assurance by RTC, and implementation of an appropriate trigger method, so an improved system will be studied at JARE66.

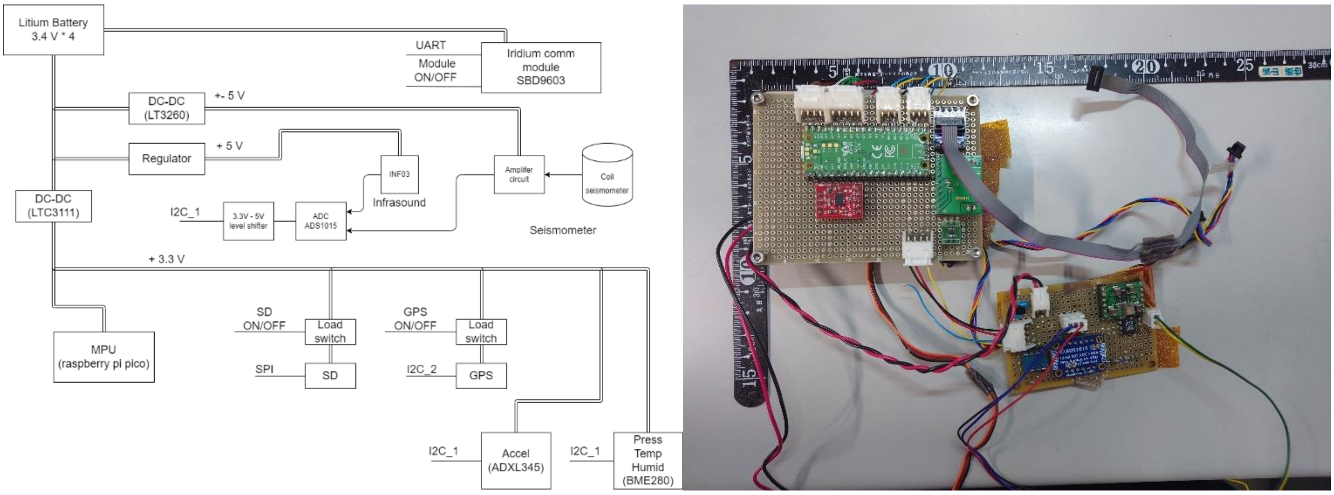

Figure 1, Hardware configuration diagram of the logger (left) and the actual logger board (right)

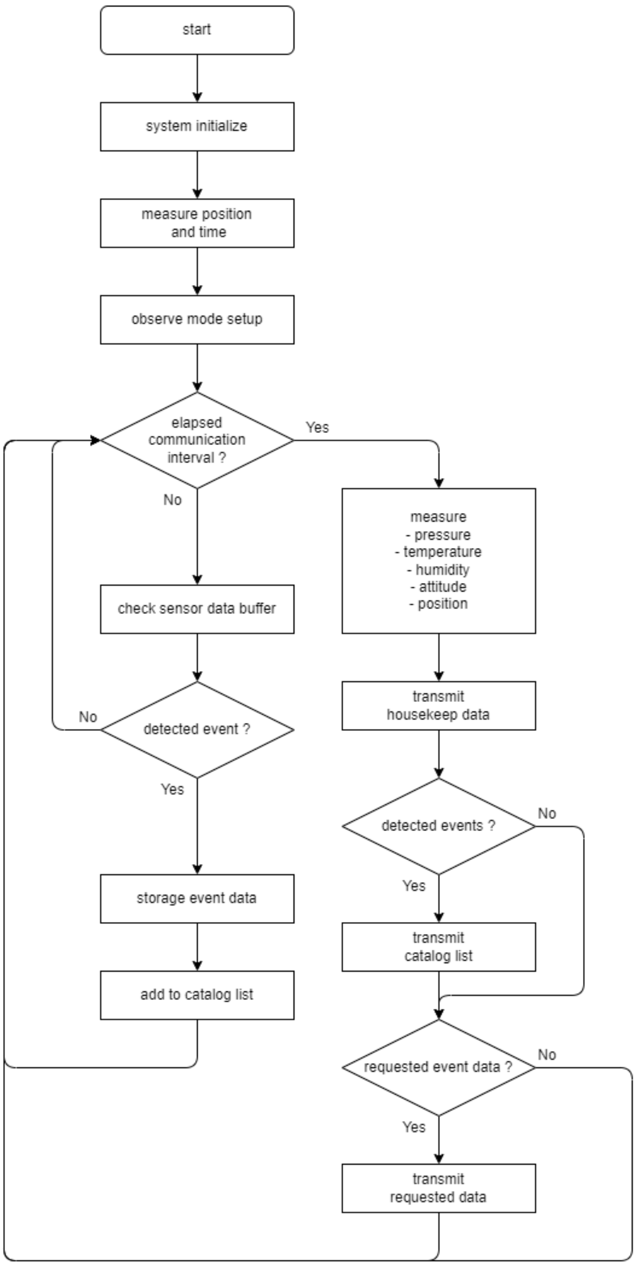

Figure 2, Logger control flowchart

IDp4

Development and publication of an online database of Antarctic microbial strain catalogs and genome information

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Fungi in Antarctica are concerned about the drastic shrinkage of their habitats due to global warming in recent years. However, only five species and eight strains of fungi isolated from near Syowa Station have been preserved by Japanese microbial culture collections. These fungi are also attracting attention as a new microbial resource because of their specific characteristics at cold temperatures. In this study, we aimed to construct a strain database and a genome database of Antarctic fungi, which have attracted attention as microbial resources but have rarely been preserved in Japanese microbial culture collections.

To construct a strain database, we first attempted to identify 600 strains isolated from samples taken from around Showa Station in Antarctica. The results were as follows. The 584 strains successfully amplified by PCR were sequenced by capillary sequencing.

As a result of DNA sequence analysis, 42 isolates were ascomycetes and could be classified into 15 genera and 15 species. 142 isolates were basidiomycetes and could be classified into 9 genera and 19 species. The remaining 400 isolates were bacterial, so the 16S rRNA, a bacterial marker gene, was amplified by PCR and its gene sequence was determined to confirm that the isolates were bacterial.

The strains identified to fungal species were cultured in yeast peptone dextrose liquid medium (YPD, Difco) and potato dextrose liquid medium at 10°C for 1 week with shaking. Each culture was dispensed into 1 mL of 2 mL cryovials, to which was added 1 mL of 40% glycerol solution containing 10% trehalose, assigned a strain number beginning with NIPR, and stored in a deep freezer at -80°C.

Strain number, species name, sample collection location, and marker gene sequence information are compiled into one database. The database is available on the website of the Bioscience Group of the National Institute of Polar Research (https://www.nipr.ac.jp/biology/).

Some strains were selected, and genomic DNA was extracted from these strains and whole genome sequence analysis was performed using a next-generation sequencer. Gene sequence and gene function predictions were then made from the whole genome sequences. These data are being constructed as a genome database of polar fungi. The genome database is currently in beta version with a password (https://antarcfungi.annotation.jp/), and is scheduled to be released without password on the website of the Bioscience Group, NIPR (https://www.nipr.ac.jp/Biology/) around October 2024.

By releasing the strain and genome databases of these Antarctic fungi, we aim to establish Antarctic fungi as a new microbial resource in the future.

Acknowledgments
This work was supported by the NIPR Research Project (KP-404), a JSPS Grant-in-Aid for Scientific Research(B) to M. Tsuji, A. Toyoda, Y. Tanizawa and S. Kudoh (no. 23K28280), Institution for Fermentation, Osaka, for General Re-search Grant to M. Tsuji (no. G-2022-1-007). This work was also supported by "Strategic Research Projects " grant from ROIS (Research Organization of Information and Systems) (no. 2022-SRP-01) to M.Tsuji and S. Kudoh., and by ROIS-DS-JOINT (013RP2023, 004RP2024) to M.Tsuji and S. Kudoh.

IDp5

Data analysis of cosmogenic nuclide Be-7 in Iceland and an approach for dataset construction

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[2]*ROIS-DS*, [3]*Iceland University*

Cosmogenic nuclide Be-7 is produced by the interaction of cosmic rays with atmospheric nitrogen and oxygen and falls with aerosols, so the concentration of Be-7 in the surface atmosphere (BEC) is affected by temporal variations in cosmic rays. Because cosmic rays reaching Earth are modulated by solar activity as they travel through the heliosphere, BEC variations include modulation profiles such as 27-day variations and 11-year solar cycles. On the other hand, cosmic rays are subject to latitudinal effects due to geomagnetic cut-off, so BEC also includes latitudinal effects. In addition, BEC varies with the motion of the global atmosphere that transports the aerosol. To investigate not only the 27-day variability and the 11-year solar cycle, but also the influence of polar latitudes on the seasonal variation of air mass motion, a daily Be-7 concentration monitoring system has been installed in Husafell, Iceland (64°N), where BEC has been continuously observed since September 2003. Figure 1 plots a data set of daily observations of Be-7 concentrations over a period of about 22 years since 2003. Data analysis on daily, monthly, and yearly variations using this data set is described. The quality of the data set, including the error range of each data set, will also be discussed. This is because this information is essential for contributing to open data in the polar science when publishing datasets.

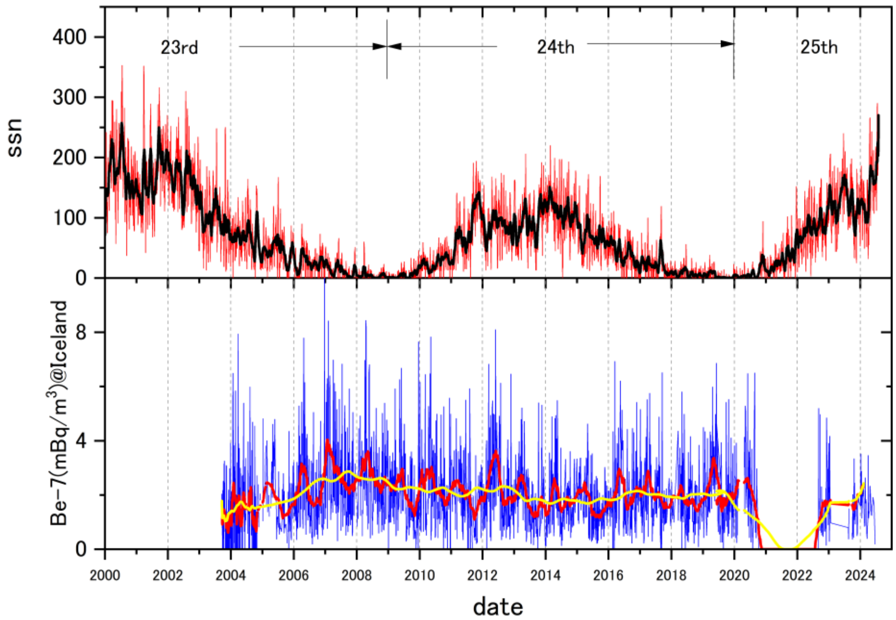

Figure 1. Daily profile of observed Be-7 concentration over approximately 22 years from 2003 in Iceland with together sunspots number.

First step of anomaly detection on PMPL Images at Syowa Station, Antarctica based on Generative AI

Kazue Suzuki[1], Kei Nakamitsu[1],
Masanori Yabuki[2], Naohiko Hirasawa[3] and Kazuyuki Nakamura[1]
[1]*Meiji University, JAPAN*
[2]*Kyoto University, JAPAN* [3]*National Institute of Polar Research, JAPAN*

GAN (Generative Adversarial Network) is a mechanism that allows the identification of prepared actual data and generated fake data to compete for generation and identification. GAN is a mechanism to identify the exact data that has been prepared and the fake data that has been generated. This mechanism can be applied to "anomaly detection," which detects anomalous data among normal ("real") data.

This study aims to apply this GAN-based anomaly detection method to long-term Polarized Micro Pulse Lidar (PMPL) observation images at Syowa Station, Antarctica, to detect aerosol layers automatically. Namely, it is an attempt to apply GAN to meteorological data. One of the prior studies is the "Weather GAN" (Li et al., 2021), which transforms the weather conditions in a photograph. This method recognizes rain and fog as anomalies and can generate images in good weather conditions, enabling photography regardless of weather conditions. As with Weather GAN, our method can potentially be applied to a wide variety of meteorological data. Meteorological data is one of the big data, and although it is registered in databases, it is often underutilized. This research aims to discover the importance of this valuable data and to promote its utilization.

GAN is an "adversarial" generative network, a type of generative AI that roughly consists of two networks, the Generator and the Discriminator, that compete. The network which ultimately produce data and information almost identical to the real thing. By applying "stationary" to the real data and "non-stationary" to the fake data, an unusual state is generated, which can be used as an "anomaly detection" method by assuming that some event has occurred.

Figure 1 shows the architecture of a typical GAN (Little et al., 2021). In this study, we plan to present the first step of anomaly detection for PMPL images observed at Syowa Station, Antarctica, using multiple GANs to verify the accuracy and strength of the anomaly detection.

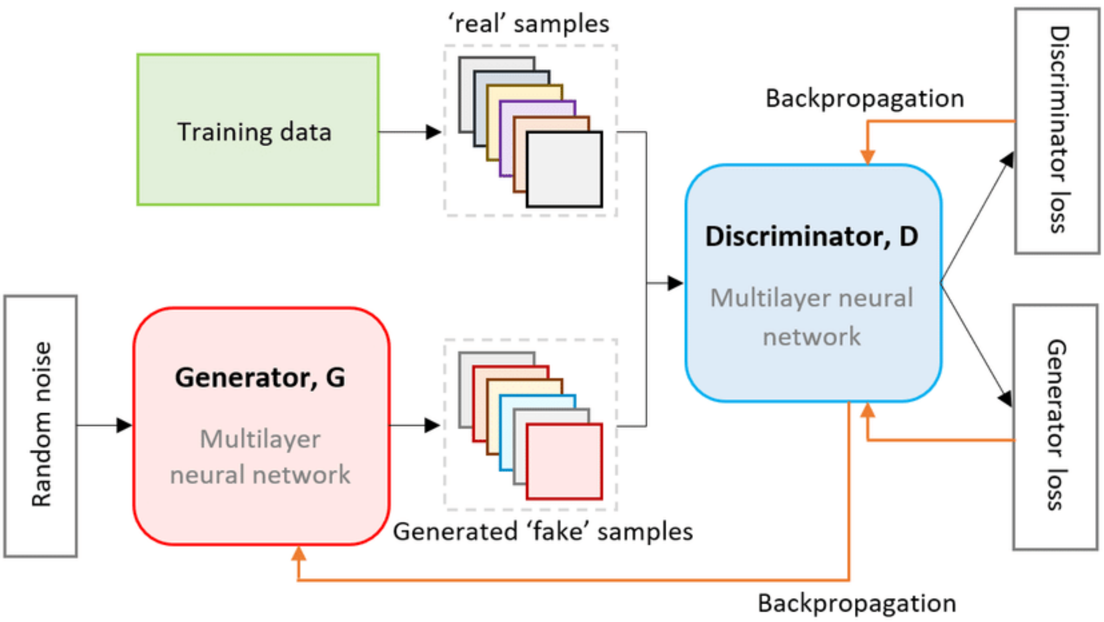

Figure 1. Example of GAN Architecture

References

[1] Xuelong Li, Kai Kou, Bin Zhao. (2021). Weather GAN: Multi-Domain Weather Translation Using Generative Adversarial Networks, https://arxiv.org/abs/2103.05422

[2] Little, Claire & Elliot, Mark & Allmendinger, Richard & Samani, Sahel. (2021). Generative Adversarial Networks for Synthetic Data Generation: A Comparative Study.

IDp7

Reanalysis of long-term aerosol and cloud records in the Antarctic and construction of their data library

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Atmospheric aerosols play important roles directly and indirectly in climate forcing through atmospheric radiation budgets. Additionally, aerosols related closely to atmospheric chemistry because heterogeneous reactions on aerosol particles act as one of essential sources of reactive species. Although Antarctica is the cleanest regions on the earth due to isolation from anthropogenic activities on the continents in the mid- and low- latitudes, clear seasonal cycles of aerosols have been observed in the Antarctic stations such as Syowa, South Pole, Neumayer, and Dumont d'Uurville (Tomasi et al., JGR, 2007; Weller et al., Tellus, 2011; Tomasi et al., AE, 2012; Asmi et al., ACP, 2013; Hara et al., APC, 2019; Hara et al., PDJ, 2023, 2024). Some datasets of aerosols and clouds have been obtained for longer than 20 years. Actually, aerosol measurements had been conducted at Syowa Station since 1997 (JARE38). To elucidate long-term trends of aerosols and clouds, and to provide these data taken from JARE for open-science, we have reanalyzed aerosol and cloud data taken at Syowa Station and Ice breaker Shirase since 1997.

In data reanalysis processes, data with measurement bias and local contamination were cheked and corrected to keep data quality for long-term periods and to be used for scientific research by same protocols and criteria as part of “The Collaboration Program at ROIS Joint Support-Center for Data Science Research”, as shown in Figure 1. Some of our data are already published for open-science in “Scientific Database” in NIPR (URL: https://scidbase.nipr.ac.jp/?ml_lang=en), for example, aerosol number concentrations, black carbon concentrations, lidar data, skyradiometer data, and so on. Actually several data papers were also published by Hirasawa et al. (PDJ, 2022a, 2022b, 2023) and Hara et al. (PDJ, 2023, 2024). Additionally, research papers on aerosol cycles in the Antarctic regeions by foreign scientists were published thorugh international data sharing (Humphries et al., ACP, 2023; Heintzenberg et al., Tellus, 2023). Currently, data reanalyses of other aerosol/cloud data have been progressed to publish data papers and scietific papers. We are going to show overview of our research activity made by “The Collaboration Program at ROIS Joint Support-Center for Data Science Research”.

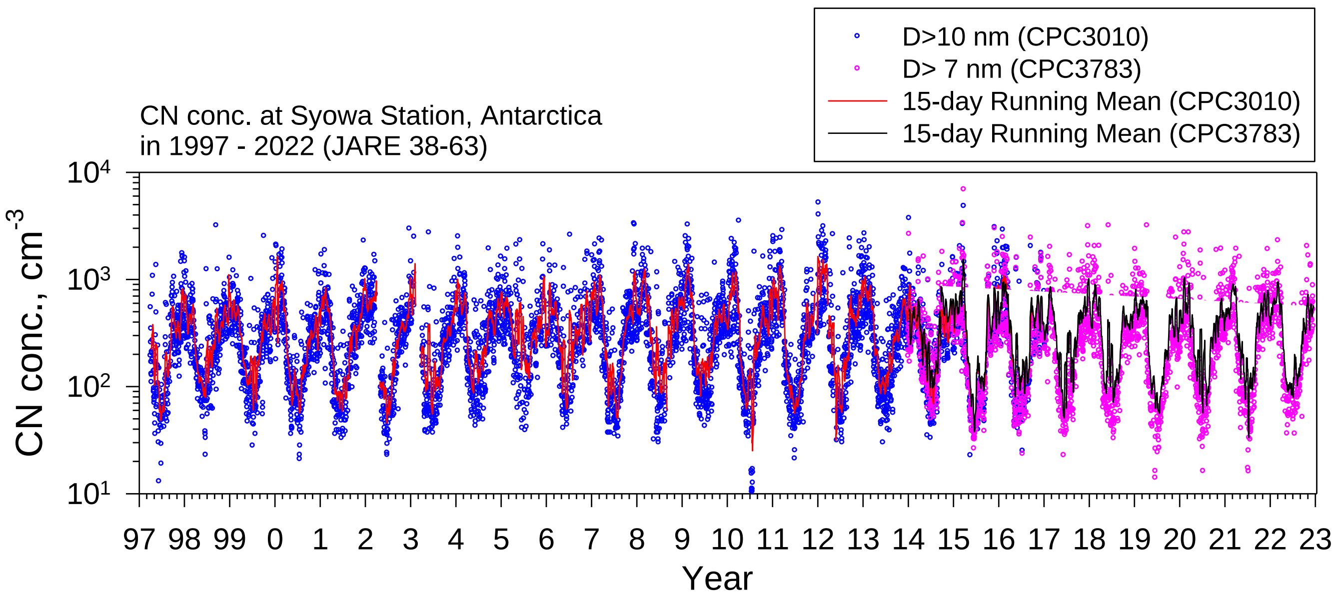

Figure 1. Seasonal features of daily-mean condensation nuclei (CN) concentrations at Syowa Station during 1997-2022.

IDp8

Introduction of Antarctic meteorology and climate data - Meteorology, Glaciology and Satellite -

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This presentation will introduce observations and data publications related to meteorology and climate monitoring that have been conducted for several decades at Syowa Station, on board the Shirase, and on the Antarctic ice sheet, including the progress made since last year. Specifically, (1) aerosol and cloud observations at Syowa Station and on board the Shirase, (2) precipitation and cloud observation at Syowa Station, (3) Automatic Weather Station (AWS) observations on the Antarctic ice sheet, and (4) satellite observations at Syowa Station will be covered.

Some of these observations have been initiated recently (e.g., the enhanced AWS and a Doppler radar) and some have been recently suspended (e.g., aerosol and cloud observations at Syowa Station and on board the Shirase). Some aerosol and cloud observations will be resumed for a limited period of time as new project observations.

Regarding data publication, quality-controlled data is finally being prepared, but at present, there are those that only publish raw data (e.g., the AWS) and those that have not yet established a complete publication system because the raw data volume is too large (e.g., the satellite). Most of these data are available in the "Science database[R1]" and "AWS[R2]", which are operated by the National Institute of Polar Research. Information on some external public sites and portals that aggregate relevant observations will be described on the poster.

References

R1. Science database: https://scidbase.nipr.ac.jp/modules/site/index.php?content_id=14&ml_lang=en
R2. ADS: https://ads.nipr.ac.jp/others/

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