ELEMENTA
Science of the Anthropocene

ten Hoopen, P, et al. 2025. SOOSmap: Your gateway to Antarctic data discovery. *Elem Sci Anth*, 13: 1. DOI: https://doi.org/10.1525/elementa.2024.00099

PRACTICE BRIDGE

SOOSmap: Your gateway to Antarctic data discovery

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The Southern Ocean is central to global ocean mixing and climate regulation via its disproportionate uptake of human-induced heat and carbon dioxide, yet the underlying processes are still poorly understood. Coordinated and sustained effort in observation and modelling of Southern Ocean processes in the past, present and future is therefore critical for understanding and mitigating the changes underway. Free and equitable access to Southern Ocean data is a fundamental prerequisite to meeting this objective. Here, we present a tool for discovery of, and access to, existing Southern Ocean data—SOOSmap, Version 2 (soosmap.aq). SOOSmap is a gateway to physical, biogeochemical and biological open-access data, free for anyone to use, from ocean science experts to classroom students. SOOSmap was developed in a collaboration of the Southern Ocean Observing System and the European Marine Observations and Data Network Physics project, with the aim to provide an easy to use one-stop-shop for Southern Ocean data held in repositories around the world. In this article, we illustrate the different methods of data access within SOOSmap, describe SOOSmap in the context of other polar data resources and initiatives, demonstrate how SOOSmap can be put into practice by a variety of stakeholders, and instruct users on how they can get involved in the SOOS community and contribute new data to SOOSmap, which is fundamental for this tool to continue to be useful for informing policy and decision-making about changes occurring in the Southern Ocean.

Keywords: Antarctic, Physical, biogeochemical and biological oceanography, Data repository, Data integration, Southern Ocean Observing System (SOOS)

Introduction

The Southern Ocean plays a crucial role in the storage of heat and carbon, and is central to the global ocean circulation. Its icy habitats are essential for regulating the Earth's climate, and its role in supplying nutrients is vital for global marine ecosystems (Meredith et al., 2019; Henley et al., 2020; Murphy et al., 2021). Yet, the Southern Ocean remains one of the least observed ocean regions. Sustained and internationally coordinated Southern Ocean observations are therefore fundamental. Equally crucial is access to data from these observations, for the research community, managers of natural resources, ship and tourism operators as well as policymakers and educators. The Southern Ocean Observing System (SOOS) is an international initiative that was established with the mission to facilitate the sustained and coordinated collection

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and delivery of essential observations of the Southern Ocean to all stakeholders, which is critical to provide an understanding of the state of the Southern Ocean, to inform prediction of future states, and to assess the gaps in the observing system to coordinate further efforts (Newman et al., 2019; Tanhua et al., 2019; Newman et al., 2022).

There is a long-term need for increasingly capable data discovery systems that can provide access to the data that underpin evidence of Southern Ocean state and changes. The SOOS Data Management Sub-Committee (SOOS DMSC, 2022) has initiated the development of a discovery tool for Southern Ocean observational data—SOOSmap (soosmap.aq). Developed over several years and by multiple stakeholders, the platform has recently been redesigned to improve access to integrated datasets from a wide range of data providers and science disciplines. Here, we describe the SOOSmap infrastructure, its capabilities and new features as well as its connections to other polar data resources and initiatives. This Antarctic data gateway currently hosts over 50,000 observations and has the potential to integrate considerably more high-value Southern Ocean data. It includes operational data, research programmes data and delayed mode data. We welcome suggestions for SOOSmap dataset additions that would be of use to the Southern Ocean community. This paper also issues a call to action to all Southern Ocean data stakeholders to contribute to asset mapping and data sharing, facilitate data federation according to the FAIR data principles (whereby data are Findable, Accessible, Interoperable, Reusable; Wilkinson et al., 2016), support the Global Ocean Observing System (GOOS) Rolling Review of Requirements process for observations, and elevate the visibility of their crucial work.

SOOSmap — A gateway for data discovery

Repositories of Southern Ocean data are fragmented, sometimes hard to access and researchers may need to search across many repositories to find data, greatly restricting the potential uptake of globally important data and their use across disciplines. To assist the Southern Ocean community with visualising which observations were being taken in the Southern Ocean and from where, SOOS developed the idea to build maps of Southern Ocean observations. Initially, these maps were to be static; however, the challenge of keeping static maps up to date meant that a method was developed whereby web services were used to update these maps automatically with new observations added to curated and standardised datasets. In 2017, a relationship was fostered between SOOS and the European Marine Observation and Data Network (EMODnet) Physics (EMODnet, 2024a), with EMODnet offering to build SOOSmap using their existing web-mapping architecture.

EMODnet Physics is one of the seven domain-specific projects that constitute the EMODnet, a long-term marine initiative by the European Commission dedicated to facilitating the discovery and access of marine data and data products (Martín Míguez et al., 2019). EMODnet Physics serves as an upstream ocean data integration service, providing a single point of access to in-situ ocean physics time-series data, vertical profiles, data products, and metadata, all built with common standards, available free of charge and without restrictions. While implementing the programme's goals, EMODnet projects must develop strategies and tools to facilitate stakeholder engagement and interoperability. Considering the crucial role of the Southern Ocean in marine and climate science, the engagement between EMODnet Physics and SOOS became a natural and obvious milestone once EMODnet expanded to a global perspective.

Developed and hosted by EMODnet Physics, SOOSmap was launched later in 2017 and has improved significantly the visibility and accessibility of Southern Ocean data, allowing users to explore circumpolar datasets in a single interactive web portal. The SOOS DMSC and EMODnet Physics work across data centres around the world to make SOOSmap a comprehensive resource for discovering and accessing marine observations from the Southern Ocean. EMODnet Physics with support from the Southern Ocean Carbon and Heat Impact on Climate (SO-CHIC) project (SO-CHIC, 2024a) developed and launched a second updated version of SOOSmap in 2023, which is now maintained and updated with support from the Ocean-Cryosphere Exchanges in ANtarctica: Impacts on Climate and the Earth System (OCEAN:ICE, 2024) Horizon Europe project.

SOOSmap is an interactive web portal for oceanographic data visualisation and dissemination. Specifically, it allows users to discover and access circumpolar data generated from a variety of marine platforms by a multitude of data providers (international research centres and data assemblers, oceanographic repositories and marine infrastructures) in the Southern Ocean. The portal is designed for the scientific community to easily access well-curated and standardised Southern Ocean datasets generated by large and small international initiatives, such as Argo, the Data Buoy Cooperation Panel (DBCP), OceanSITES, the Global Ocean Ship-based Hydrographic Investigations Program (GO-SHIP), the Global Sea Level Observing System and the Ship Observation Team, which comprises the Volunteer Observing Ship and Ship of Opportunity Programme. It also includes data products for observations related to the sea floor, albatrosses, penguins, plankton, gene sequences and plastic pollution. Aggregating a multitude of data types on a single map can help to highlight gaps in observations and identify new collaborations or serve as an educational tool.

The Version 2 of SOOSmap implemented several updates. These include improved user experience with the SOOSmap graphical user interface, improvement of the responsiveness and loading speed of data layers, inclusion of complementary layers to ocean-physics data (e.g., penguin colonies, mooring buoys, gene sequences and plastic pollution data) and cleaning and improvement of metadata, links and citation of sources along with other improvements.

SOOSmap architecture

Largely based on the EMODnet Physics and SO-CHIC backend infrastructures, SOOSmap has three logical data

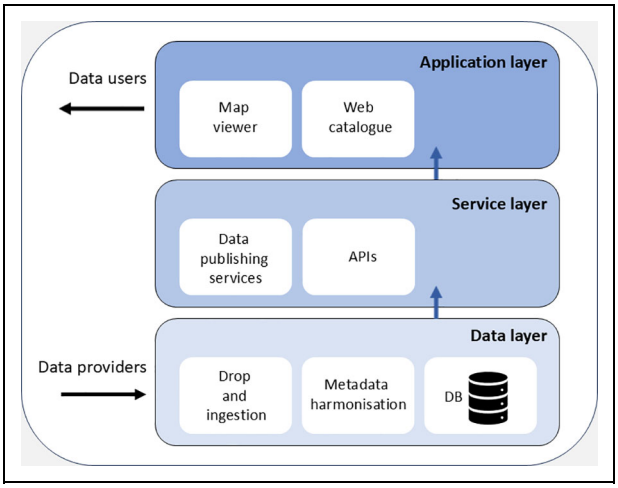

Figure 1. SOOSmap backend infrastructure: Logical layers. The SOOSmap architecture consists of a data layer, service layer and application layer. The data layer implements the federation of data from providers and metadata checks to generate the DataBase (DB). The service layer consists of a data server, geospatial services and application programming interface (API). The application layer is the graphical user interface of SOOSmap.

layers: a data link/ingestion layer, a data service layer and a data application layer (**Figure 1**). The data level is a combination of tools that implement the 'machinery' behind the publication of data and products into SOOSmap. This layer is hosted by EMODnet Physics and SO-CHIC and implements the federation with other services and marine data infrastructures (e.g., EMODnet Physics sources, Copernicus Marine Services or PANGAEA) or receives data from SOOS providers and SOOS-endorsed projects (e.g., SO-CHIC, OCEAN:ICE). This layer also applies metadata checks and mapping/normalisation according to controlled vocabularies (e.g., ISO8061 for time, SeaDataNet—BODC P02 for parameters and P06 for units). **Table 1** lists the main global conventions/attributes applied in SOOSmap.

Datasets are then made available under the service layer that is co-hosted by EMODnet and SO-CHIC and consists of an ERDDAP™ and a GeoServer instance (EMODnet, 2024b; 2024c; SO-CHIC, 2024b; 2024d). This layer implements FAIR catalogue (EMODnet, 2024d; SO-CHIC, 2024c), Open Geospatial Consortium Web Map Service and Web Feature Service and application programming interfaces (APIs) towards other applications. The application layer is the SOOSmap graphical user interface. The current version was developed by SO-CHIC and is now maintained by SO-CHIC and OCEAN:ICE projects.

SOOSmap user interface

SOOSmap can be accessed at https://www.soosmap.aq/. An overview of the main portal components is depicted in **Figure 2**. Users can select a map base layer and visualise datasets from a matrix of data platforms (columns) and data types (rows). Current platforms include, for example, ship, glider, drifting buoys or marine mammals. Data types and parameters include, for example, temperature, salinity, biogeochemistry, ice, sea level, biology or plastics. Users can also explore gridded data products or view data profiles and download data of the available parameters in the data format they prefer to work with (e.g., CSV, netCDF or JSON). More specifically, the SOOSmap graphical user interface is composed of four main components (**Figure 2**) as follows:

(A) **Base layer selection tool**, on the left-hand side, includes several thematically grouped layers. The layer source and description can be viewed by clicking on the information icon 'i'.

(B) **Dataset filter matrix**, on the right-hand side, consists of a matrix-like selection tool where columns represent platform types and rows represent parameters or groups of parameters for users to choose from. Each square in the matrix filters for datasets on the intersection of a column and a row. Users can select a single square, a single row or a single column. Datasets that match the applied filters are displayed in the dataset cards panel.

(C) **Dataset cards panel**, on the bottom, shows the available filtered datasets. Clicking on a data card selects the card and shows the data content and its metadata. Some data cards have plots available in the chart tab of the data card panel. These plots have controls enabling them to zoom to a specific time or depth or select available parameters. The web portal currently includes more than 50 data layers.

(D) **Map area**, in the middle, is central to SOOSmap and allows direct interaction with the data points displayed on the map. Users can filter data points by using a time control bar or draw a bounding box around an area of interest. Clicking on a data point opens a pop-up window with access to metadata of that data point. Some pop-up windows contain a platform page link that leads users to a new browser tab with available data plots, which have a set of display filters and data download options.

For example, to view EMODnet Physics CTD profile compilation (CTD) and the Scientific Committee on Antarctic Research (SCAR) Retrospective Analysis of Antarctic Tracking Data (RAATD):

- click on the *matrix* row with the thermometer icon and select the CTD data card from the *panel*;
- click on the *matrix* row with the biology icon and select the ATD data card from the *panel*;
- when the cards are selected, the eye icons in the top left-hand corner of the CTD and RAATD data cards become blue and a small box with the selected card name will appear above the *panel*. Data from both datasets are uploaded on the *map* and
- click on the map to explore the displayed points and features.

A tutorial for users describing in detail all SOOSmap components and how to use them is available at https://www.youtube.com/watch?v=yKa422aw-K0. The link to the tutorial is presented the first time a user accesses

Table 1. The main global attributes[a] and conventions applied in SOOSmap

Metadata Field	Vocabulary Exists	Link to Vocabulary	Vocabulary Governance
Platform id	na[b]	https://www.ocean-ops.org/ and https://vocab.ices.dk/?ref=1399	OCEANOPS/WMO ICES
Owner/provider institution	yes	https://edmo.seadatanet.org/	SeaDataNet
QC_method	na	doi	na
Data_mode	yes	NRT/DM/REP	EuroGOOS DATAMEQ
Variable names	yes	http://vocab.nerc.ac.uk/collection/P09/current/, http://vocab.nerc.ac.uk/collection/P02/current/, http://vocab.nerc.ac.uk/collection/P01/current/, http://vocab.nerc.ac.uk/collection/P07/current/, and https://cfconventions.org/Data/cf-standard-names/79/build/cf-standard-name-table.html	BODC:NVS, CF Standard Name Table v29
Unit	yes	https://vocab.nerc.ac.uk/collection/P06/current/	BODC:NVS
Quality flag scheme	yes	https://doi.org/10.13155/36149 and https://vocab.seadatanet.org/v_bodc_vocab_v2/search.asp?lib=L20	OceanSites and SeaDataNet
Time	yes	ISO8601	ISO
Datum	yes	WGS84	ISO
Country	yes	ISO3166	ISO
Licence	yes	https://creativecommons.org/	CC
INSPIRE	yes	ISO 19115	ISO/INSPIRE

[a]Each SOOSmap dataset is described with a number of metadata attributes that comply with community-approved standards and controlled vocabularies listed in the table.

[b]Not applicable.

SOOSmap. Moreover, the video can also be accessed directly from SOOSmap by clicking on the 'i - TUTORIAL' button in the top left-hand corner of the SOOSmap portal.

SOOSmap data

Physical oceanographic data are generally better curated and standardised, as well as available via a globally aggregated source, compared to biological data. SOOSmap was therefore originally built predominantly on physical oceanographic data. Currently, SOOSmap includes in-situ data from the GOOS networks (Argo, DBCP, OceanSites, Global Ocean Surface Underway Data, OceanGliders, GO-SHIP) and the main international (U.S. World Ocean Database, U.S. National Data Buoy Center, Australian Integrated Marine Observing System) and European (SeaDataNet, International Council for the Exploration of the Sea, Copernicus Marine Service In Situ Thematic Assembly Centre) aggregators. The most important source of profile data is the Argo network (about 4,000 platforms cycling every 10 days) and its extensions to deep ocean and biogeochemical parameters. It is complemented by expendable bathythermograph lines (about 50 lines, half active in 2018) and marine mammals in high latitudes. In delayed mode, the GO-SHIP CTD lines and other research cruise observations from the U.S. National Oceanographic Data Center, the Climate and Ocean Variability, Predictability, and Change programme and the Carbon Hydrographic Data Office are included. For time-series data, the most important source of observations is the DBCP network, operating more than 1,400 drifters and 20 Arctic buoys globally, as well as more than 400 moorings providing both atmospheric and oceanographic data. These data are complemented by the Global Ocean Surface Underway Data and Volunteer Observing Ship programmes, which provide sea surface temperature, sea surface salinity and surface carbon data. The Argo network also provides time series of temperature and salinity at the surface and at drifting depths, along with derived velocity information.

Using these in-situ data, users can analyse trends, create maps and generate gridded data products, also available in SOOSmap. Examples include the Coriolis Ocean Dataset for Reanalysis, developed by IFREMER for the Copernicus Marine Service and updated annually, and the SeaDataNet Regional Climatology products, developed by SeaDataNet partners using DIVA software and updated periodically (Simoncelli et al., 2020).

EMODnet Physics and the SOOS DMSC have been working to increase the availability of biogeochemical and biological data through SOOSmap, and this effort remains a priority moving forward. Currently, SOOSmap includes observational biological data across the kingdom Animalia, ranging from zooplankton (Southern Ocean Continuous Plankton Recorder Survey, epipelagic mesozooplankton distribution and abundance from BONGO nets) and krill (KRILLBASE: A database of Antarctic krill and salp densities in the Southern Ocean) to penguins (Antarctic Penguin Biogeography Project), albatrosses

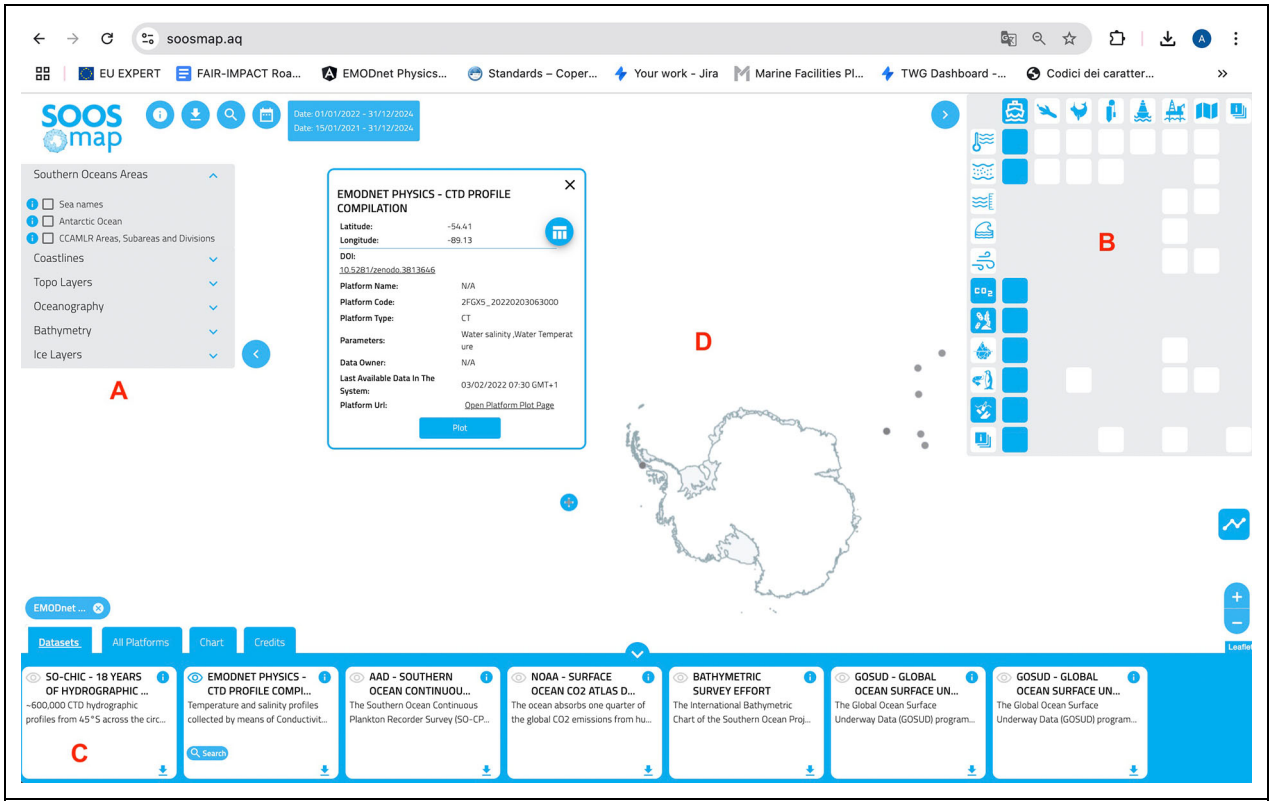

Figure 2. Overview of the SOOSmap user interface. Four main components of the interface include: (A) base layers, (B) dataset matrix, (C) dataset cards, and (D) data points on a map of Antarctica in polar stereographic projection.

(Albatrosses and Petrels Nesting Sites of species listed by the Agreement on the Conservation of Albatrosses and Petrels) and other sea birds (SCAR RAATD). Datasets from other research areas, such as those focused on ice (ASPeCt-Bio: Chlorophyll *a* in Antarctic sea ice from historical ice core datasets) or ocean pollution (SCAR Plastic in Polar Environments), are also emerging.

While many datasets have automated updates at various frequencies that are set by data providers, some updates have to be triggered manually. The SOOSmap developer team is now transitioning into a monitoring system that will assist in ensuring that datasets stay up-to-date.

Programmatic access to SOOSmap data

Programmatic access can be designed in Python to interact with ERDDAP instances hosting the SOOSmap datasets. As an example, the following code available from the public SOOSmap GitHub repository (GitHub_soosmap-public_m2m-code, 2024) builds an interactive map of the Antarctic, displaying Argo floats as circle markers with unique colours for easy identification, allowing users to explore their spatial distribution (**Figure 3a**). The code also fetches and cleans temperature and depth data for individual Argo floats, visualising them in temperature versus depth scatter plots to aid in understanding the temperature profiles of ocean layers. It supports data visualisation from multiple platforms, offering a comparative view across different locations and time frames (**Figure 3b**). Additionally, it is possible to make comparisons with climatologies (**Figure 3c**), which is crucial for understanding deviations from expected environmental conditions and assessing the impact of climatic changes over time.

SOOSmap new data integration

The infrastructure behind SOOSmap is scalable and can accommodate new datasets that fall into one of the following categories:

- datasets from physical, biogeochemical and biological oceanography observations that cover the latitudes approximately south of 50° and areas defined by the SOOS Regional Working Groups (SOOS RWG, 2025);
- datasets of Southern Ocean circumpolar interest and hosted by a national polar or oceanographic data repository that complies with the FAIR data principles;
- datasets held in a thematic data resource that provides data products relevant to the Southern Ocean (e.g., Copernicus Marine Service, Coriolis Global Data Assembly Center, Biodiversity.aq);
- datasets that are high-value compilations from SOOS-endorsed projects and programmes (SOOS, 2024) and
- datasets that are high-value compilations recommended by the SOOS community.

We welcome suggestions for new data additions into SOOSmap. Such suggestions can be made by completing the dataset form available from the public SOOSmap GitHub repository (GitHub_soosmap-public_new-dataset, 2024). The SOOS International Project Office, DMSC and EMODnet Physics team will review the suggestion, evaluate technical

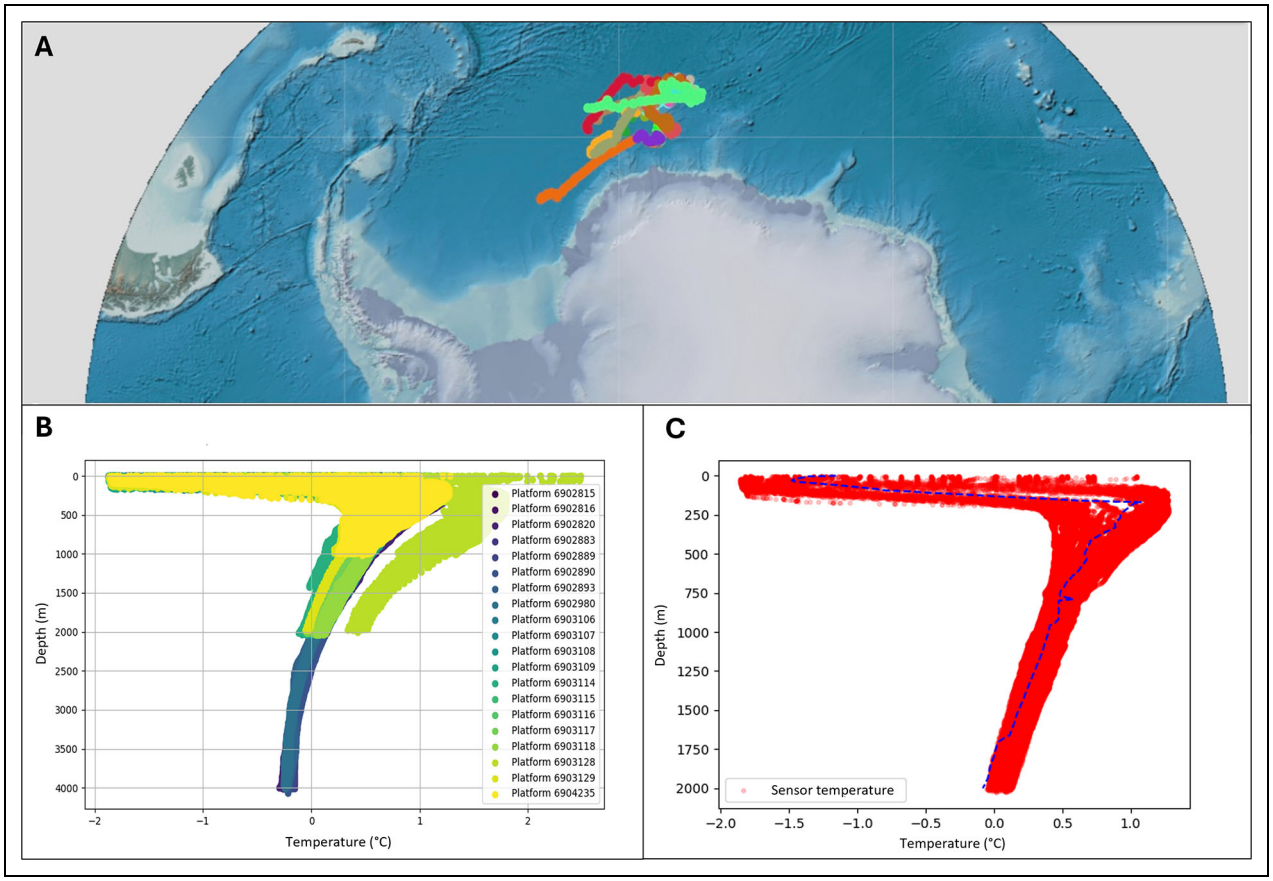

Figure 3. Output of the m2m code demonstrating the potential of programmatic access to SOOSmap using Python. (A) Spatial distribution of Argo floats on a polar projection map, with imagery provided by NOAA National Centers for Environmental Information, International Bathymetric Chart of the Southern Ocean and General Bathymetric Chart of the Oceans. (B) Scatter plot of temperature changes with increasing depth colour-coded for multiple Argo float platforms. (C) Comparison of climatology (dashed blue line) and scatter plot of temperature changes with increasing depth (red).

feasibility to integrate the dataset into SOOSmap and work with the data originators to make the data available.

The GitHub dataset form reflects general guidelines for data providers about data that can be accepted and integrated with SOOSmap. The guidelines can be accessed from the SOOSmap website (SOOSmap, 2025).

SOOSmap is only as useful as the data it displays. New FAIR data, ideally sustained and standardised, are critically important for this tool to continue to fulfil its role as a discovery gateway to Southern Ocean data that are FAIR and relevant to the community.

SOOSmap in the context of other polar data resources and initiatives

A number of initiatives and repositories support the SOOS mission and collaborate with the DMSC; their data holdings contribute or complement observations presented in SOOSmap. A few examples are highlighted here.

SCAR Standing Committee on Antarctic Data Management (SCADM)

SOOS and SCADM are continuing to collaborate closely with one another to generate better data interoperability and delivery. In 2022, the two groups collaborated with the Arctic Data Committee to create a guiding document recommending principles for aligning polar data policies (Tronstad et al., 2021). In turn, this document was used jointly to create the revised SCAR Data Policy (SCAR, 2022) and a new SOOS Data Policy (SOOS DMSC, 2022). The groups have also continued to hold the biennial Polar Data Forum series which brings together polar data specialists from government, academic institutions and industry with an emphasis on FAIR data delivery (Wilkinson et al., 2016), as well as the TRUST principles (Lin et al., 2020) for digital repositories (whereby operation of repositories adhere to Transparency, Responsibility, User-focus, Sustainability and Technology-driven) and the CARE principles (Carroll et al., 2020) for Indigenous data governance (i.e., guided by Collective benefits, Authority to control, Responsibility and Ethics). A focus of the most recent Polar Data Forum was identifying best practices when working with data collected by polar marine vessels, including sharing technological knowledge on acquisition systems, naming conventions, quality assurance and quality control and data transfer (Polar Data Forum, 2024). Upcoming joint project work between SCADM and SOOS DMSC will include creating tutorials and Frequently Asked Questions guides relating to data management fundamentals for researchers.

Commission for the Conservation of Antarctic Marine Living Resources (CCAMLR)

The CCAMLR was established by international convention in 1982 in response to increasing commercial interest in Antarctic krill resources. The Commission convenes each year to agree on a set of conservation measures that determine the use of marine living resources in the Antarctic, based on the best available science provided by the Scientific Committee for CCAMLR (SC-CCAMLR, 2023). For this purpose, CCAMLR members collect a variety of data which they report to the CCAMLR Secretariat. These data include fishery catch and effort data, data collected by scientific observers on board fishing vessels, ecosystem monitoring data at seabird and seal colonies, research survey data and krill acoustic monitoring data. Data reported to the Secretariat are available to CCAMLR members following the Rules for Access and Use of CCAMLR Data.

CCAMLR maintains a public repository, available to SOOSmap, with shapefiles that define the different CCAMLR administrative management areas, including the marine protected areas, the special areas for scientific study and the registry of vulnerable marine ecosystems. SOOS continues to work with the CCAMLR Secretariat on additional data that could be integrated into SOOSmap. For example, each year CCAMLR publishes its Statistical Bulletin and its Fishery Report, which contain summaries and catch and effort statistics for all fisheries in the CCAMLR Convention Area. These data are aggregated by area, month and taxon and, as they are publicly available, could potentially be integrated into SOOSmap. Through SOOSmap, CCAMLR obtained the SOOS mooring network dataset and the MAPPPD population counts dataset for inclusion in a spatial data visualisation tool (available to CCAMLR members only) which helped CCAMLR to harmonise its approach to management in Subarea 48.1 (West Antarctic Peninsula and South Shetland Islands). The SC-CCAMLR has requested the CCAMLR Secretariat to liaise with SOOS to make information that can be useful for CCAMLR in the context of climate change available through SOOSmap (paragraph 5.4 in SC-CCAMLR, 2023).

Polar Data Search

The Polar Data Search, formerly known as The Polar Data Discovery and Enhancement Research Working Group (POLDER, 2024) Polar Federated Search, amalgamates 25 multidisciplinary repositories housing various forms of polar data, indexed into a unified search interface, with this number expected to increase. Originally developed by the World Data System International Technology Office from 2021 to 2023, the customisable federated search website meets needs identified by the POLDER Working Group, a collaborative effort of the SOOS, the Arctic Data Committee and the SCADM under SCAR. The Polar Data Search utilises open-source software, offering the advantage of being freely accessible to various communities for creating their specific domain-focused search platforms. The challenge lies in the complexity of data discovery, with approximately 103 different data repositories within the POLDER group alone. Moreover, globally, not all polar-focused repositories are part of the POLDER space; some serve broader purposes, complicating data discoverability further. Researchers often find themselves individually scouring repositories, leading to time-consuming searches. To address this issue, a federated search system was implemented, wherein repositories voluntarily adopt semantic mark-up to be included, publicly disclosing their participation without altering existing harvesting structures. These datasets encompass diverse observations such as weather station records, narratives, organism counts, and ship/vessel instrument data covering nearly all natural variables. Given that not all data can be standardised and aggregated, federated metadata search emerges as a viable approach to enhance discoverability and maximise data value (Verhey et al., 2023).

Both the POLDER working group and SOOS plan to work collaboratively to link systems. This linking could potentially be achieved through the Polar Data Search indexing of EMODnet, to be included in the Polar Data Search holdings, and through the planned expansion of a Polar Data Search API. SOOSmap could benefit from this effort by discovering applicable datasets to integrate into the user interface. However, there are technical challenges associated with the different strategies: the Polar Data Search indexes strictly metadata and links back to the original dataset for access, whereas SOOSmap fetches the original data and integrates the data as described in the SOOSmap architecture section above.

Biodiversity.aq

The Ocean Biodiversity Information System (OBIS, 2024) and the Global Biodiversity Information Facility (GBIF, 2024) are the two largest global platforms for managing and disseminating biodiversity data. The former aims 'to be the most comprehensive data and information gateway on the diversity, distribution, and abundance of marine life', while the latter 'mobilises the data, skills, and technologies needed to make comprehensive biodiversity information freely available for science and decisions addressing biodiversity loss and sustainable development'. While distinct entities they use the same data standard (Darwin Core) and work together closely (OBIS and GBIF, 2024). The SCAR Antarctic Biodiversity Portal is the regional thematic node for both the sub-Antarctic and Southern Ocean Region. Biodiversity.aq finds its origin in the SCAR Marine Biodiversity Network (SCAR-MarBIN), established in 2005 as part of the Fourth International Polar Year and the Census of Antarctic Marine Life (CAML; Danis et al., 2013). The CAML was part of a decadal global effort, the Census of Marine Life (2000–2010), to assess and explain the diversity, distribution, and abundance of life in the oceans (Costello et al., 2010). Biodiversity.aq includes more than 2,000 datasets and more than 3 million marine occurrences. Not all of these data are made available to SOOSmap, but rather a selection of highly curated circumpolar datasets of particular relevance, including KRILLBASE, Southern Ocean Continuous Plankton Recorder Survey and RAATD.

PANGAEA

PANGAEA, the Data Publisher for Earth & Environmental Science, has an almost 30-year history as an open-access

library for archiving, publishing, and disseminating georeferenced data from the earth, environmental, and biodiversity sciences (PANGAEA, 2024a). The generic repository is operated as a joint facility of the Alfred Wegener Institute, Helmholtz Centre for Polar and Marine Research and the Center for Marine Environmental Sciences at the University of Bremen (Felden et al., 2023). Currently, it provides access to nearly 430,000 datasets, including over 30,000 from the Southern Ocean and Antarctica. PANGAEA archives data from expeditions worldwide, and it is the designated data archive for data originating from samples or measurements collected during campaigns of the RV *Polarstern* research vessel and from the German Antarctic research station, Neumayer III (Neumayer Station III, 2024). The well-developed interoperability framework of PANGAEA allows the most effective dissemination of metadata and data to all major internet search-engine registries, library catalogues, data portals, and other service providers such as EMODnet Physics and subsequently SOOSmap, and allows findability of data hosted by PANGAEA (PANGAEA, 2024b). However, the generic approach of the PANGAEA data model and data structure required by EMODnet present some challenges to automatic data and metadata extraction. These challenges have been approached successfully by the teams of EMODnet Physics and PANGAEA, and will be further extended to SOOSmap to provide an almost complete set of data and metadata.

OCADS/SOCAT/GLODAP

The Surface Ocean CO_2 Atlas (SOCAT, 2024) is a collection of surface ocean CO_2 observations quality-controlled by the science community. The Ocean Carbon and Acidification Data System (OCADS) published the new version of the SOCAT database, Version 2024 (SOCATv2024, 2024) that contains 38.6 million, quality-controlled, in-situ measurements of surface ocean fugacity of CO_2 (fCO_2) made between 1957 and 2023, with an estimated accuracy of better than 5 µatm. These extensive measurements performed in the Southern Ocean have been added to SOOSmap.

OCADS has also published the new version of the GLobal Ocean Data Analysis Project (GLODAP, 2024) dataset (GLODAPv2.2023, 2024). This dataset consists of data from 1,108 scientific cruises covering the global ocean between 1972 and 2021. It includes full depth discrete bottle measurements of salinity, oxygen, nitrate, silicic acid, phosphate, dissolved inorganic carbon (TCO_2), total alkalinity (TAlk), CO_2 fugacity, pH, chlorofluorocarbons (CFC-11, CFC-12, CFC-113 and CCl4), sulphur hexafluoride (SF6) and various isotopes and organic compounds. It was created by appending data from 23 cruises to GLODAPv2.2022 (Lauvset et al., 2022). The data for salinity, oxygen, nitrate, silicic acid, phosphate, TCO_2, TAlk, pH, CFC-11, CFC-12, CFC-113, CCl4 and SF6 were subjected to primary and secondary quality control. Corrections for severe biases in these data have been made, and outliers removed. However, corrections for differences in data related to any known or likely temporal trends or variations have not been made. These data are believed to be accurate to 0.005 in salinity, 1% in oxygen, 2% in nitrate, silicic acid and phosphate, 4 µmol kg^{-1} in TCO_2 and TAlk and 5% for the halogenated transient tracers and SF6. So far, SOOSmap contains climatologies of sea surface temperature and sea surface salinity, with the potential of additional parameters to be integrated.

SOOSmap — Community engagement and use

The SOOS DMSC consists of data professionals affiliated with national and international data repositories, who have expertise across a multitude of scientific disciplines and advise on the management and publishing of Southern Ocean data. Members of the DMSC provide a link to national and global data infrastructures in which they are involved. This link helps ensure that SOOSmap integrates the correct and most recent data products. Resources contributing to SOOSmap range from smaller national polar-focused repositories, such as the UK Polar Data Centre (UK PDC, 2024) or Australian Antarctic Data Centre (AADC, 2024), to large global ocean data aggregators, such as the EMODnet Physics or NOAA National Centre for Environmental Information (NOAA, 2024). Data repositories, large or small, can contribute datasets to SOOSmap, as long as the data are of Southern Ocean circumpolar interest and comply with the FAIR data principles. Integration of data into SOOSmap brings a number of benefits:

1. increasing discoverability and accessibility of the data;
2. sharing data across countries and disciplines, which enhances the impact and reduces duplication of data that are expensive to collect, particularly in polar regions;
3. promoting collaborations among nations, institutions and scientists and
4. supporting the principles of open science for advancement of research and data-driven decision-making.

The ethos of community engagement is fundamental for SOOSmap as a gateway to Southern Ocean data discovery. Hereby, we invite SOOSmap stakeholders to contact us with suggestions for SOOSmap dataset additions that would be of use to the Southern Ocean community. New data arriving from monitoring is critically important for this tool to continue to be useful.

SOOS is an open community that welcomes participation from all. It supports and advocates for active engagement from all interested parties and persons, including engagement in SOOS data activities and open nominations to join the SOOS DMSC. To join SOOS and see upcoming SOOS opportunities, visit soos.aq.

SOOSmap is used by the international scientific community for data discovery, data access and planning for future research activities (Henley et al., 2023; Gallagher et al., 2024). SOOSmap holds over 50,000 observations in standardised and aggregated datasets with coverage across the Southern Ocean. The sheer number of datasets makes SOOSmap a critical resource for a large number of Southern Ocean scientists and other researchers. However, even

more critical to its utility is the disciplinary range of data available, from temperature and salinity to CO_2 and chlorophyll concentrations to krill and penguin distributions. This range enables scientists to build an interdisciplinary understanding of Southern Ocean processes and their changes over multiple spatial and temporal scales. Having all of these diverse datasets available through one portal is a significant advantage for Southern Ocean researchers, as compared to having to search through multiple data providers and sources to gain such a comprehensive and well-integrated picture. A comparable resource is not available for most other major basins of the global ocean. However, SOOSmap does interface well with ocean observations available at the global scale, through the GOOS and other international observation programmes, such as Argo or Marine Mammals Exploring the Oceans Pole to Pole.

SOOSmap also has great utility in education, outreach and science communication. For example, it is used in teaching at the University of Edinburgh for Masters and undergraduate students, and has been used for public engagement at Edinburgh's 'Our Dynamic Earth' natural science centre. These uses beyond its core purpose of supporting scientific research attest to the value of SOOSmap and to supporting infrastructure in the broadest sense, perhaps even beyond what was originally envisaged. SOOSmap has also been showcased at the United Nations Climate Change Conferences (e.g., COP28 in Egypt), where it was used to engage ministers, negotiators and other policymakers in the importance of the Southern Ocean for global climate.

Conclusion

Data provided to SOOSmap are findable and accessible to a variable level. Having data integrated into SOOSmap improves and proves their FAIRness and creates a bridge between data and information. However, we cannot stop there. We need to continue integrating new FAIR datasets, ideally from sustained and standardised monitoring, that reveal changes occurring in the Southern Ocean and will contribute to informing policy and decision-making.

Delivering the breadth of observational data required to all stakeholders is an enormous task, greater than can be achieved by a single nation alone. The scale of this task was one of the motivators of the development of SOOS. In cutting across nations, programmes and other international initiatives, SOOS is in a unique position to identify and resolve inefficiencies in the Southern Ocean observing and data delivery system. SOOSmap is such an example. The successful collaboration between the SOOS DMSC, broader SOOS community, SO-CHIC, OCEAN:ICE, other SOOS-connected data and observing initiatives, and the significant in-kind contribution from EMODnet Physics, has enabled SOOS to greatly improve the visibility and accessibility of globally important Southern Ocean datasets. These datasets are crucial for improving our understanding of Southern Ocean ecosystems and processes, including the impacts they have on the global climate system, for informing predictions of future states, and for providing the best available science to inform policy and decision-making for the benefit of societies at national, regional and international levels.

In 2010, Griffiths (2010) highlighted the need for data portals that provide accurate and up-to-date information as a living resource for assessing future impacts on the region and a tool for scientists to advise on conservation planning. SOOSmap has put in practice this recommendation a decade later.

Data accessibility statement

All data mentioned in this article are available in the SOOSmap data portal soosmap.aq and described there with an abstract, citation and a DOI to each dataset, where available.

Acknowledgements

This paper was conducted by the Southern Ocean Observing System, a joint initiative of the Scientific Committee on Antarctic Research (SCAR) and Scientific Committee on Oceanic Research (SCOR). We would like to thank members of the Southern Ocean Observing System Data Management Sub-Committee and Scientific Steering Committee for valuable comments and suggestions. We wish to highlight contributions of Patrick Gorringe, Joana Beja and Taco de Bruin to the SOOSmap content development. Authors would like to thank Francesco Misurale, Monika Klim, and Marco Alba, who contributed to the technical development of SOOSmap. Activities were partially supported by the EC-UKRI OCEAN:ICE project (GA.101060452), the EU H2020 SOCHIC project (GA. 821001) and the EMODnet Physics (EASME/EMFF/2020/3.1.11/Lot4/SI2.838612).

Funding

This work has been supported by the EMODnet Physics, SO-CHIC and OCEAN:ICE projects and the Institute for Marine and Antarctic Studies, University of Tasmania.

Competing interests

The authors declare that the work was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

Author contributions

Contributed to conception and design: PtH, AN, AMH.
Drafted and/or revised the article: PtH, AN, AMH, PB, DDP, JF, SFH, JK, AK, MEM, AMT, APVP, CV.
Approved the submitted version for publication: PtH, AN, AMH, PB, DDP, JF, SFH, JK, AK, MEM, AMT, APVP, CV.

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How to cite this article: ten Hoopen, P, Novellino, A, Hancock, AM, Bricher, P, De Pooter, D, Felden, J, Henley, SF, Kool, J, Kozyr, A, Miller, ME, Treasure, AM, Van de Putte, AP, Verhey, C, and Data Management Sub-Committee, Southern Ocean Observing System. 2025. SOOSmap: Your gateway to Antarctic data discovery. *Elementa: Science of the Anthropocene* 13(1). DOI: https://doi.org/10.1525/elementa.2024.00099

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Knowledge Domain: Ocean Science

Part of an Elementa Special Feature: Understanding the Trajectory and Implication of a Changing Southern Ocean: The Need for an Integrated Observing System

Published: August 26, 2025 **Accepted:** June 26, 2025 **Submitted:** December 17, 2024

ELEMENTA Science of the Anthropocene

Elem Sci Anth is a peer-reviewed open access journal published by University of California Press.

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