The Nippon Foundation-GEBCO

Seabed 2030 Project

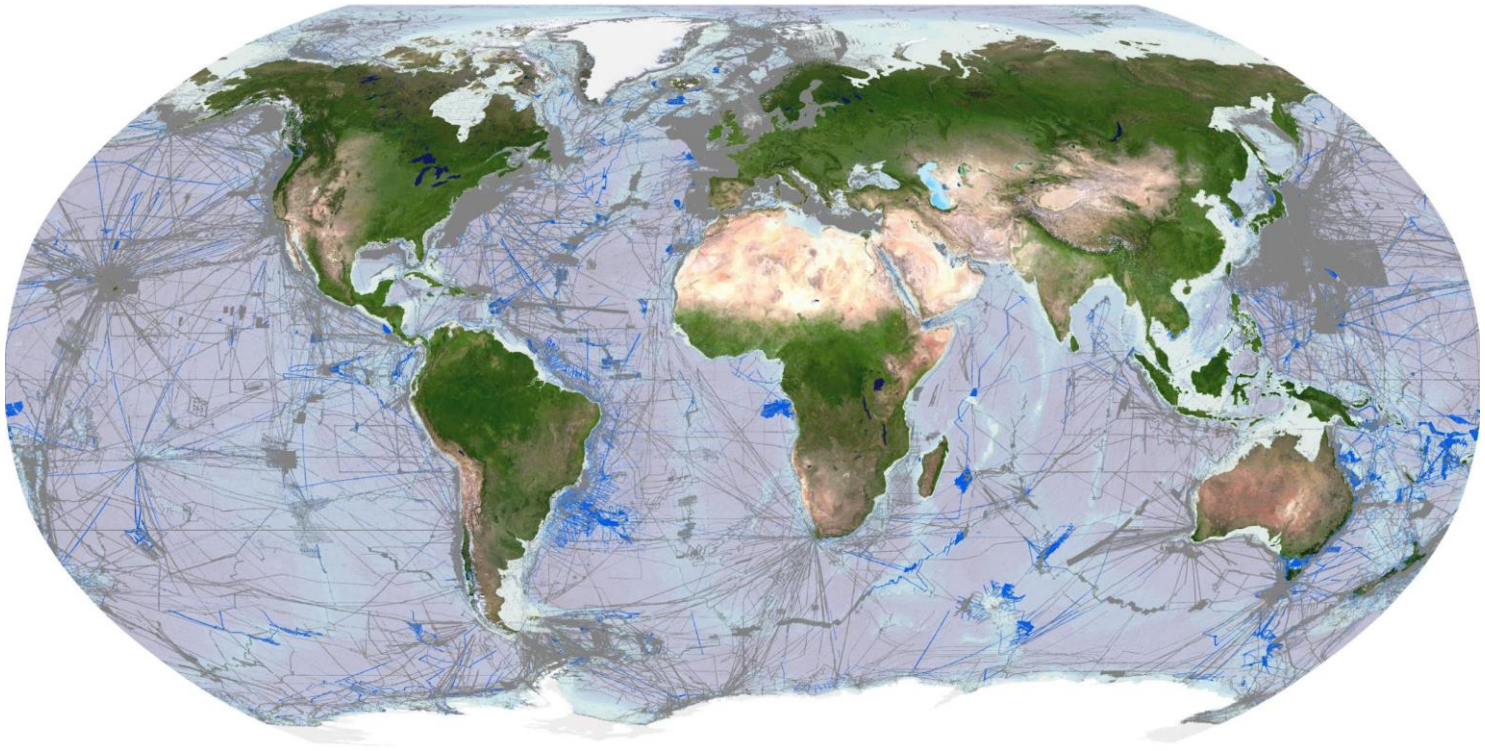
100% of the ocean floor mapped by 2030

YEAR 5 ANNUAL REPORT (INTERIM)

1 August 2021 – 31 July 2022

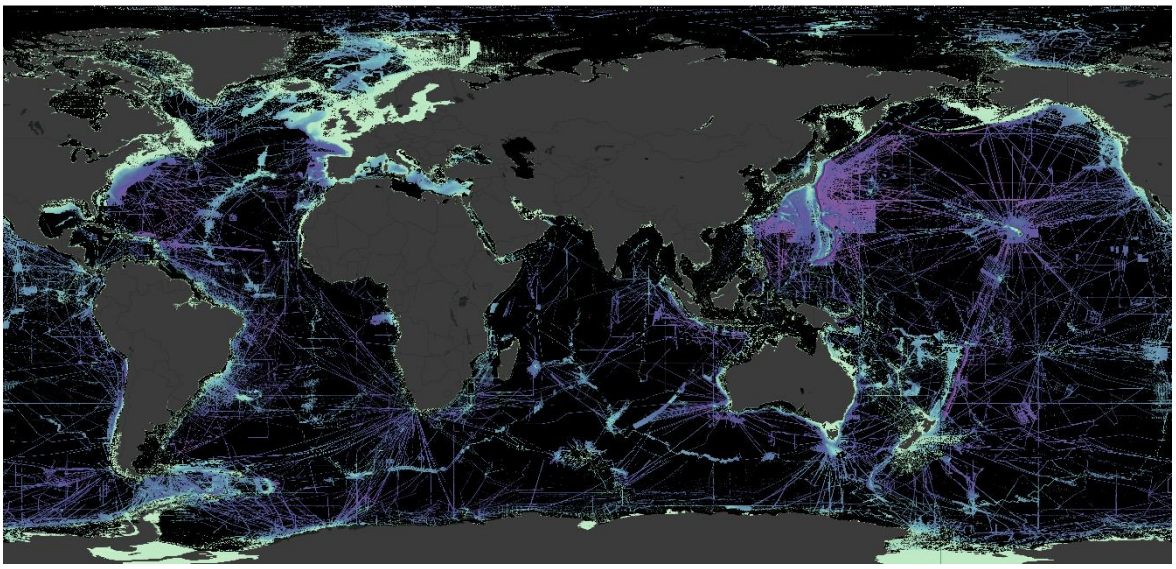
Authors: Seabed 2030 Project Team

Jamie McMichael-Phillips, Martin Jakobsson, Helen Snaith, Vicki Ferrini, Boris Dorschel, Kevin Mackay, Larry Mayer, Jennifer Cheveaux, Shereen Sharma, Kira Coley, Steve Hall.



GEBCO Grid 2022 (blue) v 2021 (dark grey) coverage comparison

Contents



Unmapped Ocean v2022 GEBCO_2022

Seabed 2030 Vision

By 2030, the World's oceans are fully mapped and the freely-available GEBCO Grid is a complete map of the global ocean bathymetry.

Executive Summary

Year 5 has delivered the headline of **23.4% of the World Ocean mapped** based on the addition to the GEBCO Grid of 10.13 million square kilometres of fresh data – an area equivalent to the size of Europe. Underlying this great achievement have been the huge volumes of work across our Seabed 2030 Centers and respective Host Institutions; IHO's DCDB and the GEBCO Community together with ever-increasing numbers of data contributors and mapping stakeholders.

The year began in July 2022 whilst the COVID pandemic was prevalent across many countries but starting to wane in some regions, and our work and engagement has been a mixture of virtual and face to face. In Q1, we saw completion of the final component of the "Two Oceans Two Technologies" (TOTT*/* Ocean Frontier Mapping work with partners conducting the Saildrone USV transit mission between San Francisco and Hawaii. This demonstrated significant progress in the operation of uncrewed technology for ocean mapping whilst also delivering new data along the route. Innovation elsewhere continued at pace with further development and testing of a Bathymetry Contribution Form allowing anyone to upload data via a web browser and a standard internet connection. Based on the same framework used for statistical calculations, early work is now underway on automatic grid generation and will be developed further in collaboration with all the Seabed 2030 Centers and experts from the GEBCO Community. Similarly, we have seen refinements to the Grid viewing package that allows GEBCO colleagues and Centers to visualize and comment more effectively on draft releases. Other activity is in train to develop a technical vision, whilst also collaborating in initiatives to explore web applications for the public and participation in wider development of gap filling applications.

Data contributions increased from the previous year and, in addition to our regional programmes in support of IHO's Crowdsourced Bathymetry (CSB) initiative, we are seeing increasing interest across a diverse community of owners and operators of superyachts and small vessels who wish to help gather new depth information. To support the harvesting of this bathymetry, we have established a Trusted Node at the Global Center and, with the invaluable assistance of DCDB, UNH and others from IHO's CSB Working Group, have been developing data handling routines. Also, we now have a CSB Technical Advisor operating remotely to provide basic on-call support for logger installation.

We have seen the release of IBCAO v4.2 and the commendable publication of IBCSO v2 in the *Scientific Data* journal. There has been synchronisation with South African, Portuguese and French colleagues to access substantial data compilations; and again, with French colleagues, to initiate transit mapping which we anticipate will increase in scope. We have continued to coordinate Satellite Derived Bathymetry in data sparse areas; and we have been privileged to be involved in the NIWA-Nippon Foundation "Tonga Eruption Site Mapping Project" (TESMaP) with NIWA's RV *Tangaroa* operating in the initial phase and SEAKIT's USV *Maxlimer* operating in the final phase. Here we worked with TESMaP Partners and Nippon Foundation-GEBCO Fellows (Alumni) in mission planning and data acquisition. As part of wider Ocean Frontier Mapping activity, we also supported the Glacier-Ocean Mapping and Research Interdisciplinary Effort (GO-MARIE) in Greenland undertaken by the Ocean Research Project team, bolstered by Alumni mappers, onboard RV *Marie Tharp*. We have also seen our Center Staff, in their Host Institution roles, undertake Ocean Frontier mapping as part of wider science programmes in the Arctic, Atlantic, Pacific and Southern Ocean.

New additions to the (non-Center) core team include Head of Communications and Decade Initiatives and Head of Partnerships, providing welcome enhancement in these growing fields of activity. More widely, DCDB has continued to provide excellent support, not only in CSB field activities and in its repository role but also via infrastructure enhancements, and improvements in both CSB pipeline and storage, and in multibeam archiving. We have benefited appreciably from the SRTM15+ development work undertaken by Scripps Institution of Oceanography, which has resulted in GEBCO Grid improvements.

We have also made progress with Phase 2 of the Wind in the Sails (WITS) mapping prioritisation supporting

project. This is a complex field of activity and we have consolidated reports cataloguing premium models for seabed mapping benefits analysis and detailing a potential model suitable for Seabed 2030 to implement.

There has been a huge number of in-person and virtual meetings, workshops and conferences during this year. All have been important and have necessitated participation by individuals across the entire Seabed 2030 Team. At a strategic level, these have included: briefing at the 2021 Paris Peace Forum; presenting in the Green Zone at the 2021 UN Climate Change Conference (COP26); and alongside The Nippon Foundation, IHO and IOC, hosting an in-person and live-streamed Side Event at the 2022 UN Ocean Conference. We drew the latter to a successful conclusion with a MOU signing with NOAA underscoring the long-standing support given to us since our establishment. This has added to the increase in new MOUs, undertaken in Y5, with industry, philanthropy and, at government level, the UK Hydrographic Office.

Within the Ocean Decade, our visibility is growing and, following the 2nd Decadal Call to Action and subsequent announcement of new endorsed Actions, we were delighted that one regional mapping project has aligned with Seabed 2030. We anticipate others will align in Year 6 and beyond.

Overall, it has been a busy and productive year for the Seabed 203 Project, none of which would have been achieved without strong collaboration across the entire Project team and the steadfast support of our parent organisations of The Nippon Foundation, GEBCO, IHO, IOC combined with that of a growing stakeholder community.

Appendices

The following appendices support the main body of this report:

Document name
Appendix 1 - Year 5 Work Plan
Appendix 2 – Tech Innovation: 2a - Vision Statement 2b – Summary Slides
Appendix 3 - Year 6 Bid Submission final document
Appendix 4 - Year 6 Work Plan as approved by NF Board
Appendix 5 - Year 6 Grant Agreement
Appendix 6 - Year 5 Financial Reports: **6a Main Budget* 6b Ocean Frontier Mapping Dec 21 – Dec 22 (interim report)
Appendix 7 – Wind in the Sails (WITS) Reports: 7a – WITS Summary Report (text) 7b – WITS Summary Report (slides) 7c - Catalogue of Premium Models for Seabed Mapping Benefits Analysis 7d - Proposed model for Seabed 2030 – Seabed Mapping Benefits Analysis and Prioritisation
Appendix 8 - Partners, Contributors & Supporters to end of Year 5
Appendix 9 - Year 5 Media Monitoring
Appendix 10 - Year 5 key events attended

**Under reconciliation - to be inserted as Appendix 6a by January 2023*

Introduction

This report details activities and progress achieved within the Year 5 period of 1 August 2021 to 31 July 2022 and fulfils annual reporting obligations for The Nippon Foundation grant award and the GEBCO Guiding Committee (GGC). *It is offered initially in draft pending GGC ratification.*

Entering its 6th year of activity, The Nippon Foundation – GEBCO Seabed 2030 Project (Seabed 2030) is a collaborative project between The Nippon Foundation and GEBCO to inspire the complete mapping of the world's ocean by 2030 and to compile all bathymetric data into the freely- available GEBCO Ocean Map.

Working under the auspices of the International Hydrographic Office (IHO) and UNESCO- Intergovernmental Oceanographic Commission (IOC), GEBCO has a 100-year history of ocean floor mapping. Seabed 2030, launched at the United Nations Ocean Conference in 2017, is building a global community of ocean mappers, hydrographers, scientists, industry and the public to discover and publish all existing bathymetric data.
Seabed 2030 also advocates for new mapping expeditions to map the gaps in our knowledge of the seafloor and provide the world with the definitive map of the world's bathymetry.

Seabed 2030 is built on a global network of 4 Regional Centers and one Global Center, in association with the IHO Data Center for Digital Bathymetry (DCDB). Management of the project is the responsibility of the Project Team, consisting of; the Project Director, the Head of Engagement & Development, the Head of Partnerships, the Head of Communications & Decade Initiatives, the Project Administrator and the Heads of the Seabed 2030 Centers.

Year 5 Finance Report (Main Budget)

The finance report covering the fifth operational year of The Nippon Foundation-GEBCO Seabed 2030 Project from 1st August 2021 – 31st July 2022 is currently under reconciliation and is to be inserted (as Appendix 6a) by January 2023.

Ocean Frontier Mapping Interim Finance Report (December 21 - December 22)

This report (see Appendix 6b) covers the Nippon Foundation-GEBCO Seabed 2030 Project Ocean Frontier Mapping programme, period December 2021 – December 2022 (see further information at *Task 4.1 'Progress Mapping the Ocean Frontiers*).

Figures correct as of 18 October 2022.

All unspent funds to be returned to The Nippon Foundation.*

Budget item	Budget	Allocated	Proposed/allocated/ spent	Available to be allocated
1.1 Ocean Frontier Mapping	456,000	260,580	260,580	195,420
TOTAL	**456,000**	**260,580**	**260,580**	**195,420**
		Allocated	Proposed/allocated/ spent	Available to be allocated

**Further bids may be received before the end of the funding period (December 2022). Figures to be updated in January 2023.*

Center Information

Seabed 2030 Center	Location	Lead
Southern Ocean Regional Center	Alfred Wegener Institute Helmholtz Centre for Polar and Marine Research, Bremerhaven, Germany	Dr Boris Dorschel
South and West Pacific Ocean Regional Center	National Institute of Water and Atmospheric Research, Wellington, New Zealand	Mr Kevin Mackay
Atlantic and Indian Oceans Regional Center	Lamont-Doherty Earth Observatory, Columbia University, United States of America	Dr Vicki Ferrini
Arctic and North Pacific Oceans Regional Center	Joint Center: Department of Geological Sciences, Stockholm University (SU), Swede Center for Coastal and Ocean Mapping, University of New Hampshire (UNH), USA	Co-Leads: Prof Martin Jakobsson (SU) & Prof Larry Mayer (UNH)
Global Center	British Oceanographic Data Centre, National Oceanography Centre, United Kingdom.	Dr Helen Snaith
IHO Data Center for Digital Bathymetry	National Oceanic and Atmospheric Administration's National Centers for Environmental Information in Boulder, Colorado, USA	Jennifer Jencks

The project works on an annual work plan and budget approved by The Nippon Foundation as the funding agent. As a project of an IHO working group, Seabed 2030 reports to the GEBCO Guiding Committee (GGC) on the delivery of the annual work plan. The GGC also endorses the annual work plan and the annual report from the previous year.

The work plan is structured across 5 work packages:

- WP1: Data: Sourcing and publishing the data
- WP2: Systems and tools: Building the technical systems to manage and deliver the grid
- WP3: Technology Innovation
- WP4: Mapping the Gaps
- WP5: Management
  - WP5.1: Operational Management
  - WP5.2: Strategic direction
  - WP5.3: Communication and Outreach
  - WP5.4: Capacity Development

Further details of the project can be found on the Seabed 2030 website.

This report continues with reports from each Center's activities in Year 5 and is followed by progress reports on each work package.

Seabed 2030 Center Reports

Southern Ocean Regional Center

Location: Alfred Wegener Institute Helmholtz Centre for Polar and Marine Research.

Center Lead: Boris Dorschel.

Summary

The main activities of Year 5 (2021/22) of the Seabed 2030 Regional Centre Southern Ocean was the publication of IBCSO v2 in *Scientific Data*, an international peer-reviewed journal. Furthermore, the progress of the RC-SO and IBCSO were presented at Hydrographic Commission on Antarctic Annual Meeting (HCA-18) and at the 4th Arctic Antarctic and North Pacific Mapping Meeting (AANP-MM) held as hybrid meeting at the University of Stockholm from the 21 to 24 March 2022.

Center Staff

- Boris Dorschel, Head of the Bathymetry Working Group
- Sacha Viquerat, Data Manager, Programmer
- Patrick Schwarzbach, Data Manager, Outreach
- Laura Hehemann, Data Manager and GIS Technician
- Fynn Warnke, Data Manager, Programmer
- Simon Dreutter, Hydrographer, Cartographer, Data Manager
- Yvonne Schulze Tenberge, Metadata Database

Funds provided by Nippon Foundation for Year 5 supported 2.75 Full Time Equivalent (FTE) positions. In addition, 0.25 FTE were provided by AWI to the Seabed 2030 Project. L. Hehemann and F. Warnke provide continued support to Seabed 2030 in the frame of a mini-job in total 0.1 FTE. Additional 0.5 FTE B. Dorschel, 0.3 FTE S. Dreutter, and 0.2 FTE by Y Schulze Tenberge (all AWI) were provided to the Seabed 2030 Project

Regional Mapping progress

Year 5 activities were centred around the publication of the International Bathymetric Chart of the Southern Ocean Version 2 (IBCSO v2). Submitted early in year 5, the manuscript was finally published in June 2022: Dorschel B., Hehemann L., Viquerat S., Warnke F., Dreutter S., Schulze Tenberge Y., Accettella D., An L., Barrios F., Bazhenova E., Black J., Bohoyo F., Davey C., De Santis L., Escutia Dotti C., Fremand A.C., Fretwell P.T., Gales J.A., Gao J., Gasperini L., Greenbaum J.S., Jencks J.H., Hogan K., Hong J.K., Jakobsson M., Jensen L., Kool J., Larin S., Larter R.D., Leitchenkov G., Loubrieu B., Mackay K., Mayer L., Millan R., Morlighem M., Navidad F., Nitsche

F.O., Nogi Y., Pertuisot C., Post A.L., Pritchard H.D., Purser A., Rebesco M., Rignot E., Roberts J.L., Rovere M., Ryzhov I., Sauli C., Schmitt T., Silvano A., Smith J., Snaith H., Tate A.J., Tinto K.J., Vandenbossche P., Weatherall P., Wintersteller P., Yang C., Zhang T., Arndt J.E., 2022. The International Bathymetric Chart of the Southern Ocean Version 2. Scientific Data 9, 275, https://doi.org/10.1038/s41597-022-01366-7.
Leading up to the publication, we redid the overall social media and web presence of IBCSO including the IBCSO website https://ibcso.org/, IBCSO on the GEBCO website, IBCSO on twitter, IBCSO expert group in Scientific Committee on Antarctic Research (SCAR). All these information outlets are continuously updated.

The moratorium on the article was lifted on the 7 June 2022. IBCSO v2 is published as open access paper and is thus freely, publicly available (Fig. 1). All scripts that have been developed for IBCSO v2 can be found at https://github.com/SeaBed2030/IBCSO_v2_Dorschel_et_al_2022. A digital chart of IBCSO v2 (Fig. 2) as well as data products can be downloaded from the Pangaea website at https://doi.org/10.1594/PANGAEA.937574 (Fig. 3).

www.nature.com/scientificdata

scientific data

OPEN

DATA DESCRIPTOR

Check for updates

The International Bathymetric Chart of the Southern Ocean Version 2

Boris Dorschel *et al.*#

The Southern Ocean surrounding Antarctica is a region that is key to a range of climatic and oceanographic processes with worldwide effects, and is characterised by high biological productivity and biodiversity. Since 2013, the International Bathymetric Chart of the Southern Ocean (IBCSO) has represented the most comprehensive compilation of bathymetry for the Southern Ocean south of 60°S. Recently, the IBCSO Project has combined its efforts with the Nippon Foundation – GEBCO Seabed 2030 Project supporting the goal of mapping the world's oceans by 2030. New datasets initiated a second version of IBCSO (IBCSO v2). This version extends to 50°S (covering approximately 2.4 times the area of seafloor of the previous version) including the gateways of the Antarctic Circumpolar Current and the Antarctic circumpolar frontal systems. Due to increased (multibeam) data coverage, IBCSO v2 significantly improves the overall representation of the Southern Ocean seafloor and resolves many submarine landforms in more detail. This makes IBCSO v2 the most authoritative seafloor map of the area south of 50°S.

Background & Summary

The Southern Ocean is a major component of the coupled ocean-atmosphere climate system[1] and includes the largest ocean current on earth, the Antarctic Circumpolar Current (ACC). It is furthermore the most important ocean region for the uptake of anthropogenic CO_2 and heat from the atmosphere[2,3], and cold and dense bottom waters form on the shelves surrounding Antarctica[4,5]. Interactions of the Southern Ocean with Antarctic glaciers and ice shelves are the main drivers of present, past, and future Antarctic ice sheet mass balance[6] and thus global sea-level change. Biologically, the Southern Ocean is a high-productivity area[7] with high biodiversity[8]. The Southern Ocean is also one of the most remote and harshest areas of the world with extensive sea-ice cover and year-round severe weather conditions. Despite its remoteness and hostility, human activities are increasingly extending into this distant part of the world, examples including research, fisheries, and tourism. Precise bathymetric information as e.g. provided by the International Bathymetric Chart of the Southern Ocean (IBCSO) and the Digital Bathymetric Model of the Drake Passage (DBM-BATDRAKE)[9] are paramount to better understand the Southern Ocean and its processes as well as for human activities and conservation and management measures[10]. IBCSO aims to provide the most comprehensive compilation of bathymetric data for this region.

IBCSO was initiated in 2006 with the first version published by Arndt *et al.* in 2013[11]. It is the southern equivalent of the International Bathymetric Chart of the Arctic Ocean (IBCAO), which was originally produced in 2000 and recently released its fourth version[12,13]. Both initiatives are regional mapping projects of the General Bathymetric Chart of the Oceans (GEBCO). GEBCO is a project under the auspices of the International Hydrographic Organization (IHO) and the Intergovernmental Oceanographic Commission (IOC) with the goal to produce the authoritative map of the world's oceans. Furthermore, IBCSO has combined its efforts with and is supported by the Nippon Foundation – GEBCO Seabed 2030 Project launched in 2017 by the Nippon Foundation of Japan and GEBCO[14]. The IBCSO Project is also an integral part of the Antarctic research community and an expert group of the Scientific Committee on Antarctic Research (SCAR).

Initially, IBCSO was limited to the Antarctic Treaty area covering the area south of 60°S with a resolution of 500 m × 500 m in a Polar Stereographic projection[11]. Following the release of Version 1, the user community expressed the wish for an IBCSO reaching to 50°S to cover the entire ACC and the Antarctic circumpolar frontal systems. This request, the growing demand for bathymetric information of the Southern Ocean, and the

#A full list of authors and their affiliations appears at the end of the paper.

Figure 1) the cover page of the IBCSO v2 paper

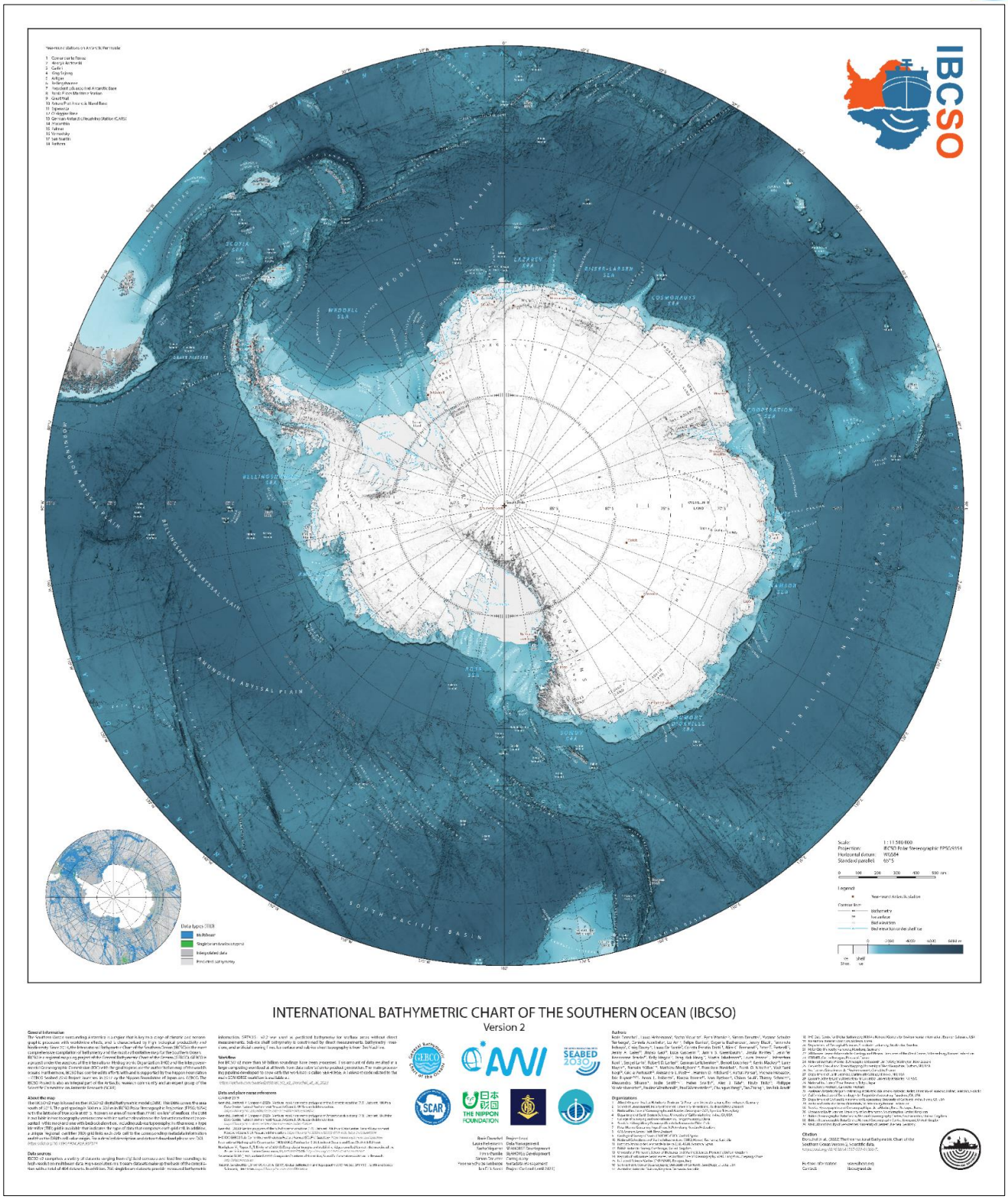
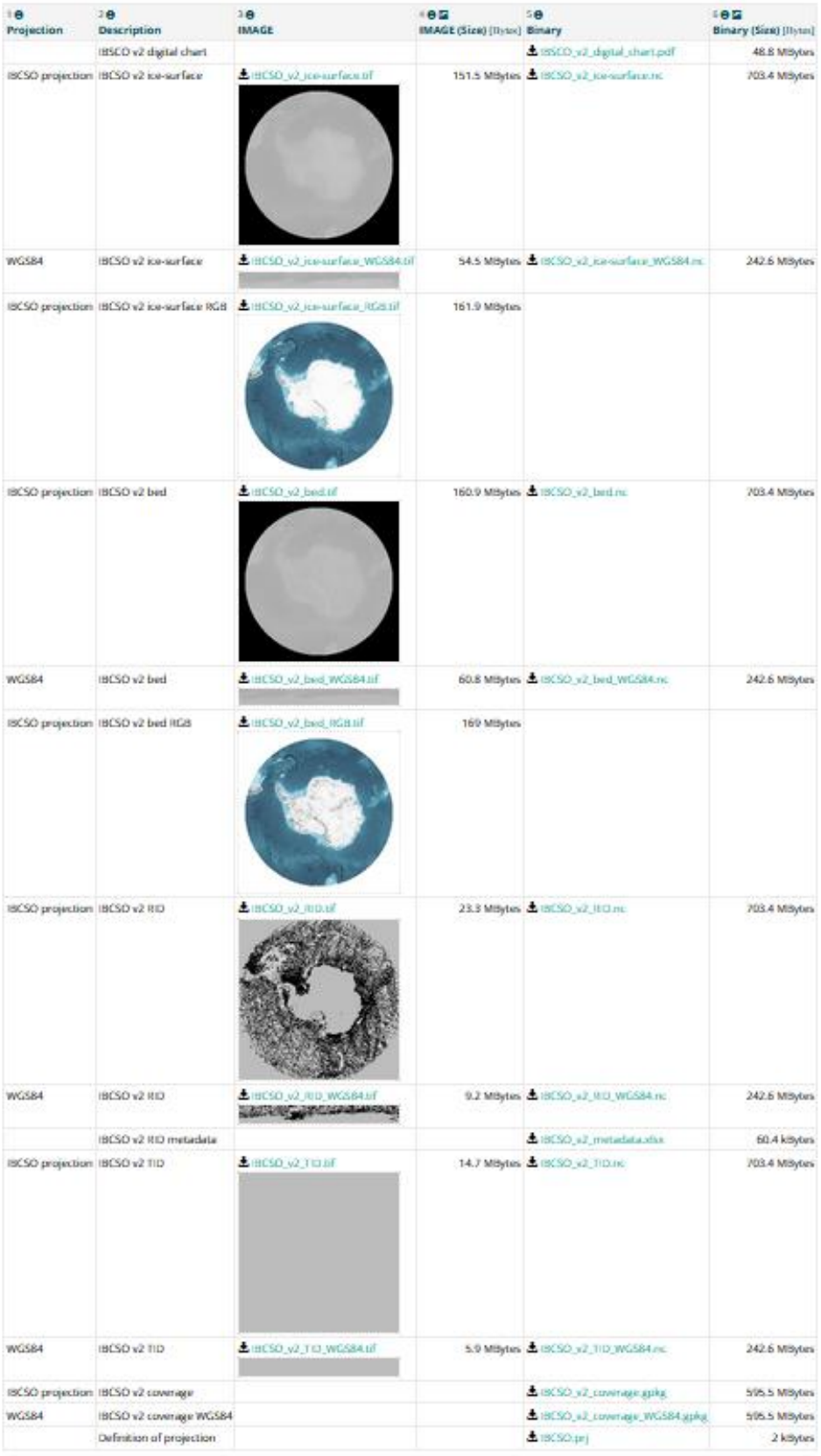


Figure 2) Digital Chart of IBCSO v2. Hard copies of this chart will soon be available for distribution.



Projection	Description	IMAGE	IMAGE (Size) [Bytes]	Binary	Binary (Size) [Bytes]
	IBCSO v2 digital chart			IBCSO_v2_digital_chart.pdf	48.8 MBytes
IBCSO projection	IBCSO v2 ice-surface	IBCSO_v2_ice-surface.tif	151.5 MBytes	IBCSO_v2_ice-surface.nc	703.4 MBytes
WGS84	IBCSO v2 ice-surface	IBCSO_v2_ice-surface_WGS84.tif	54.5 MBytes	IBCSO_v2_ice-surface_WGS84.nc	242.6 MBytes
IBCSO projection	IBCSO v2 ice-surface RGB	IBCSO_v2_ice-surface_RGB.tif	161.9 MBytes		
IBCSO projection	IBCSO v2 bed	IBCSO_v2_bed.tif	160.9 MBytes	IBCSO_v2_bed.nc	703.4 MBytes
WGS84	IBCSO v2 bed	IBCSO_v2_bed_WGS84.tif	60.8 MBytes	IBCSO_v2_bed_WGS84.nc	242.6 MBytes
IBCSO projection	IBCSO v2 bed RGB	IBCSO_v2_bed_RGB.tif	169 MBytes		
IBCSO projection	IBCSO v2 RID	IBCSO_v2_RID.tif	23.3 MBytes	IBCSO_v2_RID.nc	703.4 MBytes
WGS84	IBCSO v2 RID	IBCSO_v2_RID_WGS84.tif	9.2 MBytes	IBCSO_v2_RID_WGS84.nc	242.6 MBytes
	IBCSO v2 RID metadata			IBCSO_v2_metadata.xlsx	60.4 kBytes
IBCSO projection	IBCSO v2 TID	IBCSO_v2_TID.tif	14.7 MBytes	IBCSO_v2_TID.nc	703.4 MBytes
WGS84	IBCSO v2 TID	IBCSO_v2_TID_WGS84.tif	5.9 MBytes	IBCSO_v2_TID_WGS84.nc	242.6 MBytes
IBCSO projection	IBCSO v2 coverage			IBCSO_v2_coverage.gpkg	595.5 MBytes
WGS84	IBCSO v2 coverage WGS84			IBCSO_v2_coverage_WGS84.gpkg	595.5 MBytes
	Definition of projection			IBCSO.prj	2 kBytes

Figure 3) Overview of the IBCSO v2 data products in Pangaea at https://doi.org/10.1594/PANGAEA.937574.

IBCSO v2 is included in the GEBCO 2022 release. In parallel, data acquisition, integration and cleaning continued.

Major data and grid contributions

Over the course of Year 5, new data sets were continuously integrated in the RC-SO and IBCSO database. Table 1 highlights all data contributions larger than 100 Mb.

Table 1. Data contributions in Year 5.

Dataset	Contributing Organisation
SST_PD19ST02	British Geological Survey
RA3082019	Directorate of Hydrography and Navigation
GEBCO_BRAZIL_RA307	Directorate of Hydrography and Navigation
RA3372020	Directorate of Hydrography and Navigation
GA229	Geoscience Australia
GA227	Geoscience Australia
GA228	Geoscience Australia
kerguelen_2011_mbes	Geoscience Australia
kerguelen_2011_sbes	Geoscience Australia
29HE20160306	Royal Institute and Observatory of the Spanish Navy
29SG20181116	Royal Institute and Observatory of the Spanish Navy
29SG20190213	Royal Institute and Observatory of the Spanish Navy
29SG20111128	Royal Institute and Observatory of the Spanish Navy
29HE20120507	Royal Institute and Observatory of the Spanish Navy
29HE20190214	Royal Institute and Observatory of the Spanish Navy
29HE20160103	Royal Institute and Observatory of the Spanish Navy
29HE20170208	Royal Institute and Observatory of the Spanish Navy
29SG20190227	Royal Institute and Observatory of the Spanish Navy
29HE20130320	Royal Institute and Observatory of the Spanish Navy
ELT04	Marine Geoscience Data System
IN2016_V01	Marine National Facility
TR195967	National Geospatial Agency
TR182302	National Geospatial Agency
TR181381	National Geospatial Agency
NGA16411	National Geospatial Agency
SU182644	National Geospatial Agency
TR194563	National Geospatial Agency
TR179434	National Geospatial Agency
TR171508	National Geospatial Agency
NGA16410	National Geospatial Agency
NGA16428	National Geospatial Agency
TR192430	National Geospatial Agency
TR179674	National Geospatial Agency
NGA16422	National Geospatial Agency
TR179734	National Geospatial Agency
TR164266	National Geospatial Agency
TR182917	National Geospatial Agency
sj44_55m	National Geospatial Agency
TR164152	National Geospatial Agency
TR143617	National Geospatial Agency
TR182278	National Geospatial Agency
TR170776	National Geospatial Agency
TR189310	National Geospatial Agency

TR180808	National Geospatial Agency
TR164779	National Geospatial Agency
SU204388	National Geospatial Agency
TR190591	National Geospatial Agency
TR172921	National Geospatial Agency
TR182296	National Geospatial Agency
TR192772	National Geospatial Agency
TR171949	National Geospatial Agency
1010089	National Geospatial Agency
TR182284	National Geospatial Agency
1010136	National Geospatial Agency
NGA16416	National Geospatial Agency
si50_40m	National Geospatial Agency
TR183835	National Geospatial Agency
TR174970	National Geospatial Agency
NGA16429	National Geospatial Agency
TR193546	National Geospatial Agency
TR139357	National Geospatial Agency
88010056	National Geospatial Agency
TR216181	National Geospatial Agency
NGA16417	National Geospatial Agency
5010011	National Geospatial Agency
TR171256	National Geospatial Agency
TR171724	National Geospatial Agency
5040026	National Geospatial Agency
TR190150	National Geospatial Agency
TR163936	National Geospatial Agency
M29_1_ed	National Geospatial Agency
GENE03RR_MB	National Geospatial Agency
TR186607	National Geospatial Agency
TR166501	National Geospatial Agency
TR173962	National Geospatial Agency
NGA_50	National Geospatial Agency
NGA_6	National Geospatial Agency
NGA_350	National Geospatial Agency
NGA_1435	National Geospatial Agency
NGA_6973	National Geospatial Agency
NGA_4674	National Geospatial Agency
NGA_175	National Geospatial Agency
NGA_220	National Geospatial Agency
NGA_3430	National Geospatial Agency
NGA_9665	National Geospatial Agency
NGA_13692	National Geospatial Agency
NGA_375	National Geospatial Agency
NGA_12473	National Geospatial Agency
NGA_632	National Geospatial Agency
NGA_224	National Geospatial Agency
NGA_3	National Geospatial Agency
NGA_10274	National Geospatial Agency
NGA_5286	National Geospatial Agency
NGA_158	National Geospatial Agency
NGA_12864	National Geospatial Agency
NGA_2964	National Geospatial Agency

NGA_13716	National Geospatial Agency
NGA_9846	National Geospatial Agency
NGA_11125	National Geospatial Agency
NGA_11644	National Geospatial Agency
NGA_13725	National Geospatial Agency
NGA_13726	National Geospatial Agency
NGA_10	National Geospatial Agency
NGA_11647	National Geospatial Agency
NGA_217	National Geospatial Agency
NGA_12858	National Geospatial Agency
NGA_13881	National Geospatial Agency
NGA_100	National Geospatial Agency
NGA_15075	National Geospatial Agency
NGA_13733	National Geospatial Agency
s30w85_200_200_F1_R2_z	National Geospatial Agency
TR228181	National Geospatial Agency
sj45_40m	National Geospatial Agency
EW0114	National Geospatial Agency
NGA_13877	National Geospatial Agency
NGA_21960	National Geospatial Agency
NGA_28054	National Geospatial Agency
NGA_24359	National Geospatial Agency
NGA_15750	National Geospatial Agency
NGA_62665	National Geospatial Agency
NGA_41083	National Geospatial Agency
NGA_23383	National Geospatial Agency
NGA_25171	National Geospatial Agency
NGA_26259	National Geospatial Agency
NGA_26366	National Geospatial Agency
NGA_13729	National Geospatial Agency
s30w75_200_200_F1_R2_z	National Geospatial Agency
NGA_90364	National Geospatial Agency
NGA_20067	National Geospatial Agency
NGA_71567	National Geospatial Agency
NGA_18372	National Geospatial Agency
NGA_46069	National Geospatial Agency
sk44_42m	National Geospatial Agency
NGA_90188	National Geospatial Agency
NGA_11111	National Geospatial Agency
NGA_60160	National Geospatial Agency
sj46_46m	National Geospatial Agency
1020060	National Geospatial Agency
TR231580	National Geospatial Agency
NGA_22249	National Geospatial Agency
NGA_20681	National Geospatial Agency
NGA_73467	National Geospatial Agency
TR153232	National Geospatial Agency
TR219934	National Geospatial Agency
NGA_126	National Geospatial Agency
NGA_99998	National Geospatial Agency
NGA_159	National Geospatial Agency
NGA_1	National Geospatial Agency
NGA_44	National Geospatial Agency

NGA_43	National Geospatial Agency
NGA_4	National Geospatial Agency
KH16-01	National Geospatial Agency
RR1202	National Center for Environmental Information
NBP0908	National Center for Environmental Information
Piloto_Pardo_Seamount	Hydrographic and Oceanographic Service of the Chilean Navy
HI534	United Kingdom Hydrographic Office
HI679	United Kingdom Hydrographic Office
HI976	United Kingdom Hydrographic Office
HI679	United Kingdom Hydrographic Office
HI1049	United Kingdom Hydrographic Office
HI108	United Kingdom Hydrographic Office
HI976	United Kingdom Hydrographic Office
HI833	United Kingdom Hydrographic Office
HI835	United Kingdom Hydrographic Office
HI976	United Kingdom Hydrographic Office
HI1049	United Kingdom Hydrographic Office
HI834	United Kingdom Hydrographic Office
HI782	United Kingdom Hydrographic Office
HI783	United Kingdom Hydrographic Office
HI782	United Kingdom Hydrographic Office
HI724	United Kingdom Hydrographic Office
HI834	United Kingdom Hydrographic Office
HI679	United Kingdom Hydrographic Office
HI836	United Kingdom Hydrographic Office
HI1197	United Kingdom Hydrographic Office
HI1551	United Kingdom Hydrographic Office
HI1551	United Kingdom Hydrographic Office
HI835	United Kingdom Hydrographic Office
HI1551	United Kingdom Hydrographic Office
131895	United Kingdom Hydrographic Office
131895	United Kingdom Hydrographic Office
131895	United Kingdom Hydrographic Office
HI783	United Kingdom Hydrographic Office
HI1551	United Kingdom Hydrographic Office
HI836	United Kingdom Hydrographic Office
HI1551	United Kingdom Hydrographic Office
HI1128	United Kingdom Hydrographic Office
HI834	United Kingdom Hydrographic Office
HI906	United Kingdom Hydrographic Office
HI722	United Kingdom Hydrographic Office
HI1551	United Kingdom Hydrographic Office
181584	United Kingdom Hydrographic Office
HI1197	United Kingdom Hydrographic Office
HI976	United Kingdom Hydrographic Office
HI440	United Kingdom Hydrographic Office
HI784	United Kingdom Hydrographic Office
9731	United Kingdom Hydrographic Office
181584	United Kingdom Hydrographic Office
HI1551	United Kingdom Hydrographic Office
HI1285	United Kingdom Hydrographic Office
HI679	United Kingdom Hydrographic Office
HI836	United Kingdom Hydrographic Office

HI1551	United Kingdom Hydrographic Office
HI1551	United Kingdom Hydrographic Office
181584	United Kingdom Hydrographic Office
HI976	United Kingdom Hydrographic Office
HI1551	United Kingdom Hydrographic Office
HI1056	United Kingdom Hydrographic Office
HI679	United Kingdom Hydrographic Office
131895	United Kingdom Hydrographic Office
HI833	United Kingdom Hydrographic Office
HI679	United Kingdom Hydrographic Office
HI975	United Kingdom Hydrographic Office
181584	United Kingdom Hydrographic Office
HI833	United Kingdom Hydrographic Office
181584	United Kingdom Hydrographic Office
HI833	United Kingdom Hydrographic Office
HI918	United Kingdom Hydrographic Office
HI1129	United Kingdom Hydrographic Office
HI974	United Kingdom Hydrographic Office
HI785	United Kingdom Hydrographic Office
HI679	United Kingdom Hydrographic Office
HI1130	United Kingdom Hydrographic Office

Financial report

All Year 5 funds were allocated for staff and data acquisition. Throughout the year, two student-labour were employed for 40 hour per month for data cleaning. In addition, funds were used to support bathymetric data acquisition during Expedition PS127, PS128, and PS130 with the German research icebreaker Polarstern.

Other activities

In March 2021, the L. Hehemann and B. Dorschel participated in the 4th AANP-MM at Stockholm University. In the EU Horizon 2020 project iAtlantic, Boris Dorschel is Deputy Chair of the Expedition Coordination Working Group. This provides an overview of bathymetric data collected in the frame of the iAtlantic project with the aim to facilitate data contributions to Seabed 2030.

Report of status of regional mapping committee

L. Hehmann provided progress reports of IBCSO and GEBCO at the Hydrographic Commission on Antarctic Annual Meeting (HCA-18) in Berlin in May 2022. The reports were well received.

Stakeholder Engagement and Outreach

Following the publication, public media reported on IBCSO. Metrics on the outreach can be found at https://www.nature.com/articles/s41597-022-01366-7/metrics. Also, The BBC, National Geographic (Fig. 4), and a local German television station featured IBCSO v2 after its release.

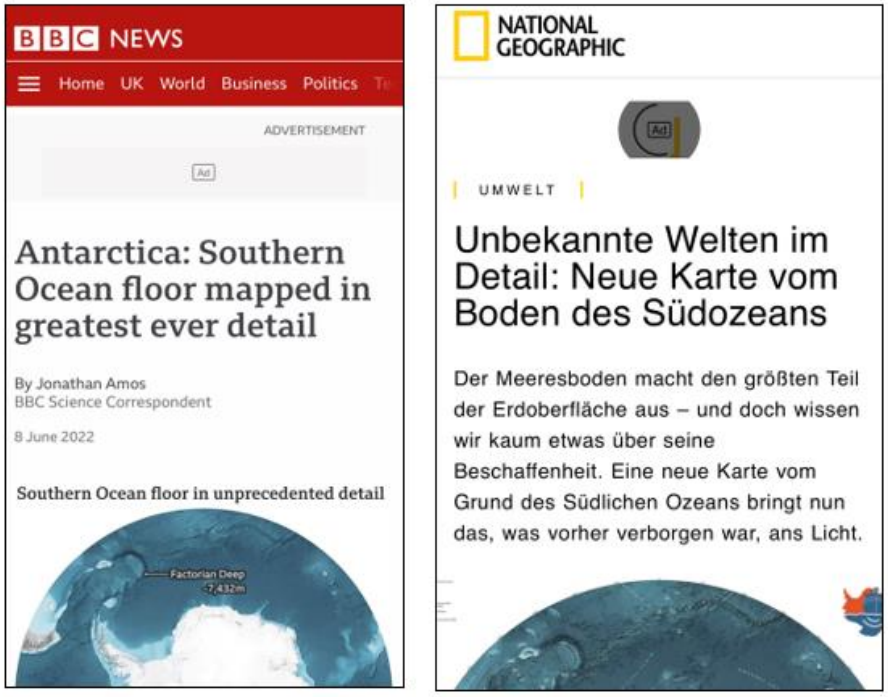


Figure 4) Examples of media coverage.

South and West Pacific Ocean Regional Center

Location: National Institute of Water and Atmospheric Research, Wellington, New Zealand.

Centre Lead: Kevin Mackay.

Summary

The main achievements of the South and West Pacific Centre (SaWPaC) during Year 5 (1 August 2021 - 31 July 2022) were:

1. Gathering, processing, assembling, and gridding of bathymetric data collected in the SW Pacific region.
   - Including supporting the planning and acquisition of seabed mapping for the NIWA/Nippon Foundation Tonga Eruption Seabed Mapping Expedition (TeSMAP).
   - Coordinating Satellite Derived Bathymetry product generation in the Federated States of Micronesia, French Polynesia, and Philippines.
2. Submission of the 15-arc sec resolution sparse grid to be integrated into the GEBCO_2022 grid release; initial delivery to GDACC was done on the 8$^{th\ of}$ April 2022. Final SaWPaC_2021/2022 delivery populated ca. 24.3% [~30 M km^2] of the GEBCO_2022 cells for the SaWPaC regional extent [~123.5 M km^2].
3. Preparation of the regional inventory of bathymetric data, and identification of unmapped areas. This included:
   - Continued development of ArcGIS Online viewers to visualize the coverage of bathymetric data holdings of the SaWPaC and other institutes conducting ocean mapping in the SW Pacific region.

- Identification of potential sources to be explored and data holders to be contacted.

4. Organisation and running of the annual Regional Mapping Committee. This meeting was held in an on-line forum on 5-7th July 2022. One of the SaWPaC's work priorities is developing network and strengthening connections with the Regional Mapping Community.
5. Promotion of the Seabed 2030 project and SaWPaC: multiple research conferences, meeting with stakeholders.
6. Communication and outreach:
   - Promotion of the Seabed 2030 project and SaWPaC through multiple international conferences, seminars, individual meeting with stakeholders, and media interviews. A total of 13 presentations were made at various events.
7. Networking and education:

   SaWPaC has been engaged various regional organisations and stakeholders throughout the last year in Australia, New Zealand, Japan, Palau, Papua New Guinea, Fiji, Niue, French Polynesia, Philippines, and Kiribati.
   Due to the restrictions in international travel, the Center was unable to host any alumni or students. These restrictions are now lifted, and alumni are expected to be hosted in Year 6.

Centre Staff

The Centre is based at NIWA Wellington and led by Mr. Kevin Mackay (NIWA Programme Leader: Environmental Information Management). The Centre Lead is supported in his task by a Seabed 2030 Data Manager (Miss Jaya Roperez) and a Technical Management Committee (TMC). This year, Dr Vaughan Stagpoole announced that he would be reducing his involvement in the TMC. In his stead, we welcomed Dr Brook Tozer from GNS Science. Dr Tozer is a geophysicist who worked with Dr Dave Sandwell to produce the SRTM+ global bathymetry and topography dataset that underpins GEBCO_2022.

SaWPaC Data Manager

Miss Jaya Roperez has FIG/IHO/ICA Category A Certificate in Hydrographic Surveying and is an alum of the NF/GEBCO Training programme at UNH. She is a founding member of a non-profit organization Map the Gaps and was an active member of the NF-GEBCO team in the Shell Ocean Discovery XPRIZE competition.

Technical Management Committee (TMC)

The SaWPaC TMC includes representatives of NIWA, GNS Science (Institute of Geological and Nuclear Sciences) and Toitū Te Whenua Land Information New Zealand (LINZ) - which is the New Zealand Hydrographic Authority):

- Dr. Helen Neil, Operations General Manager, NIWA.
- Mr. Arne Pallentin, GIS Coordinator and Seafloor mapping leader, NIWA
- Dr. Vaughan Stagpoole; Head of Marine Geoscience Department, GNS Science.
- Dr. Brook Tozer; Geophysicist, GNS Science
- Dr. Jenny Black, IBCSO editorial member; Data Technician, GNS Science.
- Mr. Adam Greenland, New Zealand National Hydrographer, Chairman of the IHO South West Pacific Regional Hydrographic Commission; LINZ.
- Mr Stuart Caie, CSB-GEBCO-Seabed 2030 Regional Coordinator for the IHO South West Pacific Regional Hydrographic Commission; LINZ.
- Mr. Glen Rowe, Senior Tide Analyst, Hydrographic Authority, LINZ.
- Dr. Tilmann Steinmetz, GIS Data Analyst & Administrator, NIWA. Tilmann retired from the TMC in April 2019 but continues to support the SaWPaC work in terms of GIS consultancy and expertise.

TMC meetings were held monthly in an on-line forum. Records of the agendas and minutes of the TMC meetings are kept at NIWA. These TMC meetings aim:

- to follow up on the progress of the SaWPaC technical and administrative work,
- to provide updates on participation in meetings/conferences aiming to promote Seabed 2030 and seek bathymetric data,
- to identify upcoming actions.

Regional Mapping progress

SaWPaC 2021/2022 delivery (direct measurements only) that was integrated into the GEBCO_2022 release covers ca. 24.3% of the GEBCO_2022 cells (15 arc sec grid cell size) for the SaWPaC regional extent.

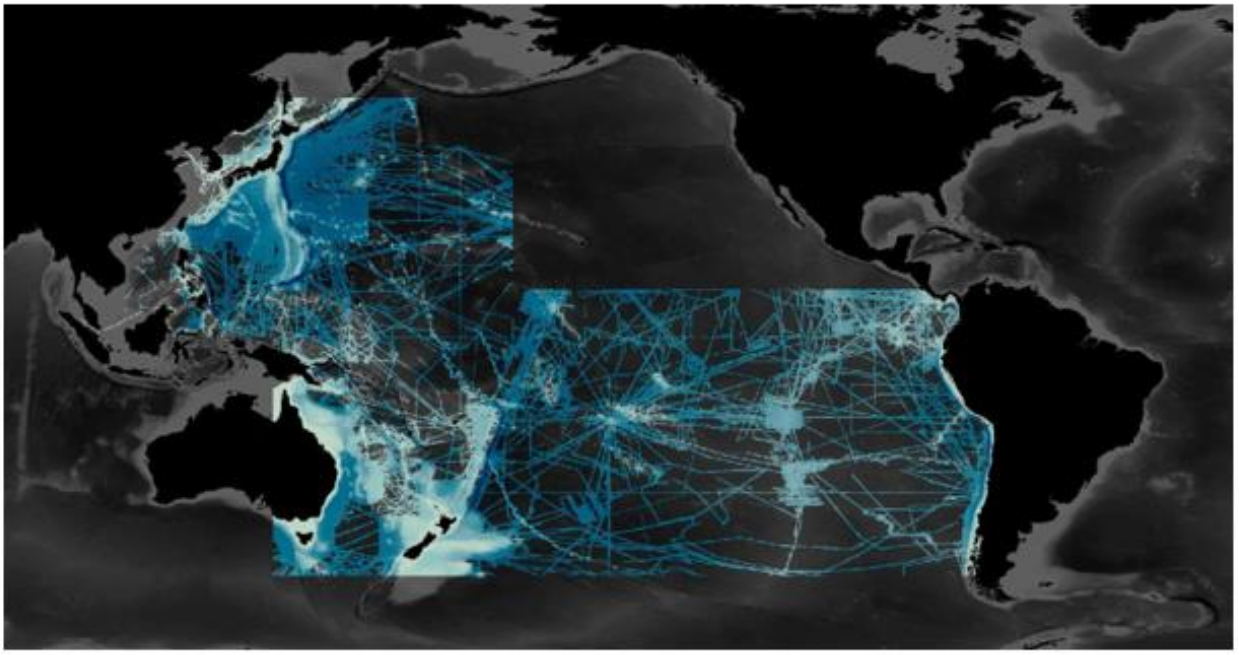


Figure 1. SaWPaC delivery 2021/2022 - bathymetric data layer, 15 arc sec sparse grid- overlain on the GEBCO_2022 gridded bathymetry.

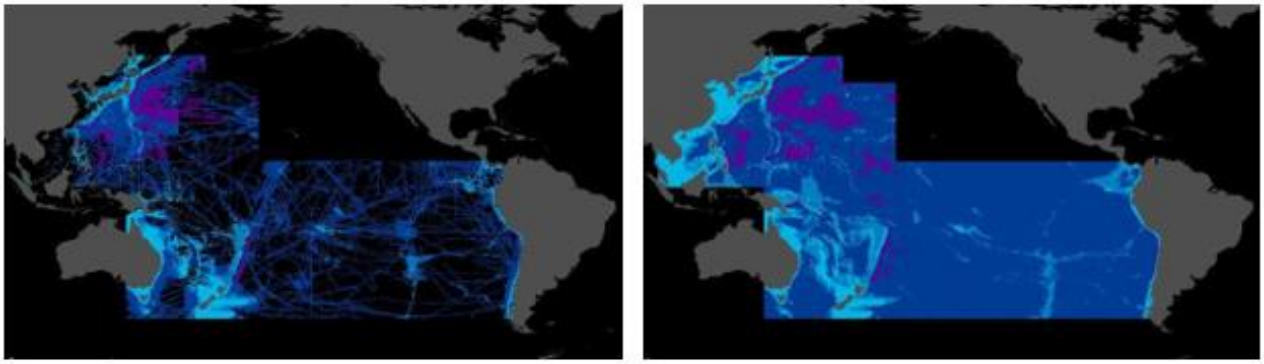


Figure 2. SaWPaC delivery 2021/2022 (left) and target Seabed 2030 - GEBCO coverage for the SW Pacific (right). Depths are coloured according to the ranges defined by the Seabed 2030 target grid resolution.

To enable the community visualize the data delivered in 2022 and current bathymetric data holdings, SaWPaC keep an updated webmap app using ArcGIS online viewer. More advanced ArcGIS users can access and download different open source layers through the NIWA open data page.

Stakeholder Engagement and Outreach

Members of the SaWPaC Technical Management Committee presented the Seabed 2030 Project at various regional conferences, workshops and seminars, as listed below.

The centre activities were also presented at IOC/IHO meetings in the region, including the 34th GEBCO SCUFN Session; the 19th Meeting of the South West Pacific Hydrographic, and the 38th GEBCO Guiding Committee.

Conference/workshop presentations

Mackay, K. (2021) Report on the South and West Pacific Regional Data Center. 14th IHO East Asia Hydrographic Commission, VTC 10 December 2021.

Mackay, K. (2022) The Nippon Foundation – GEBCO Seabed 2030. 35th Part 1 GEBCO SCUFN hybrid event, on 14-18 March 2022.

Mackay, K. (2022) Seafloor mapping and Seabed 2030. OneOceanScience Panel, One Ocean Summit, VTC 5-6 February 2022.

Mackay, K. (2022) Report on the South and West Pacific Regional Data Center. 19th IHO South West Pacific Regional Hydrographic Commission, VTC 23-25 February 2022.

Mackay, K. and Roperez, J. (2022) Seabed 2030: Leveraging diversity and community to map the Pacific. IN02 Small Islands, Big Ocean – ecological, physical and human connections in the Pacific Session, Ocean Sciences 2022, hybrid 24 February – 4 March 2022.

Mackay, K. (2022) The Nippon Foundation – GEBCO Seabed 2030. IHO S-5B Hydrographic Community Awareness Program, 9 June 2022.

Mackay, K., Clark, M., Seabrook, S. and McInerney, J. (2022) NIWA/Nippon Foundation undersea mapping of Hunga Tonga-Hunga Ha'apai volcano, Cities on Volcanoes 11, hybrid 12-17 June 2022.

Mackay, K. and Roperez, J. (2022) The Nippon Foundation – GEBCO Seabed 2030. World Hydro Day, LINZ, 21 June 2022.

Mackay, K., Clark, M., Seabrook, S. and McInerney, J. (2022) NIWA/Nippon Foundation undersea mapping of Hunga Tonga-Hunga Ha'apai volcano, Australiasian Hydrographic Society AGM, Wellington 8 July 2022.

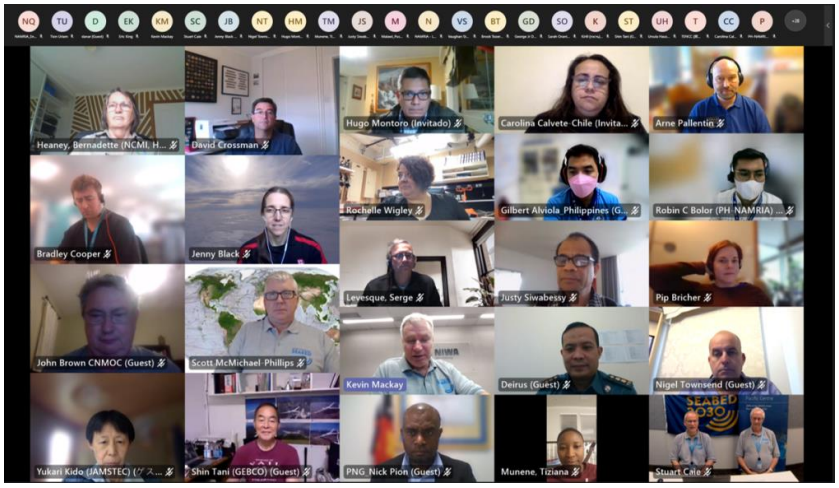
SWPHC Webinar series (2022). The IHO South West Pacific Regional Hydrographic Commission (SWPHC), in conjunction with SaWPaC and the IHO Data Center for Digital Bathymetry (DCDB) hosted a Seabed 2030 webinar series May-July 2022. This series was host by Stuart Caie in his role as the SWPHC CSB-GEBCO-Seabed 2030 Regional Coordinator. Four webinars were given:

1. **SWPHC Seabed 2030 Webinar #1:** Where are we now? Introduction, Goals & Status of Mapping in the Region
2. **SWPHC Seabed 2030 Webinar #2**: Building the Map. How do we build the map? How can you access & contribute data?
3. **SWPHC Seabed 2030 Webinar #3**: CSB and the role of HOs and other data collectors
4. **SWPHC Seabed 2030 Webinar #4**: Moving ahead together: Summary, next steps and wrap-up

Videos and copies of the presentations of the webinars can be found here.

Report of status of regional mapping committee

The fourth Regional Mapping Committee Meeting was held by SaWPaC as a virtual meeting, on July 5-27th, 2022.



The following materials are available from this meeting:

- Circular and Agenda
- Meeting recording (per day)

The objectives of this meeting were to:

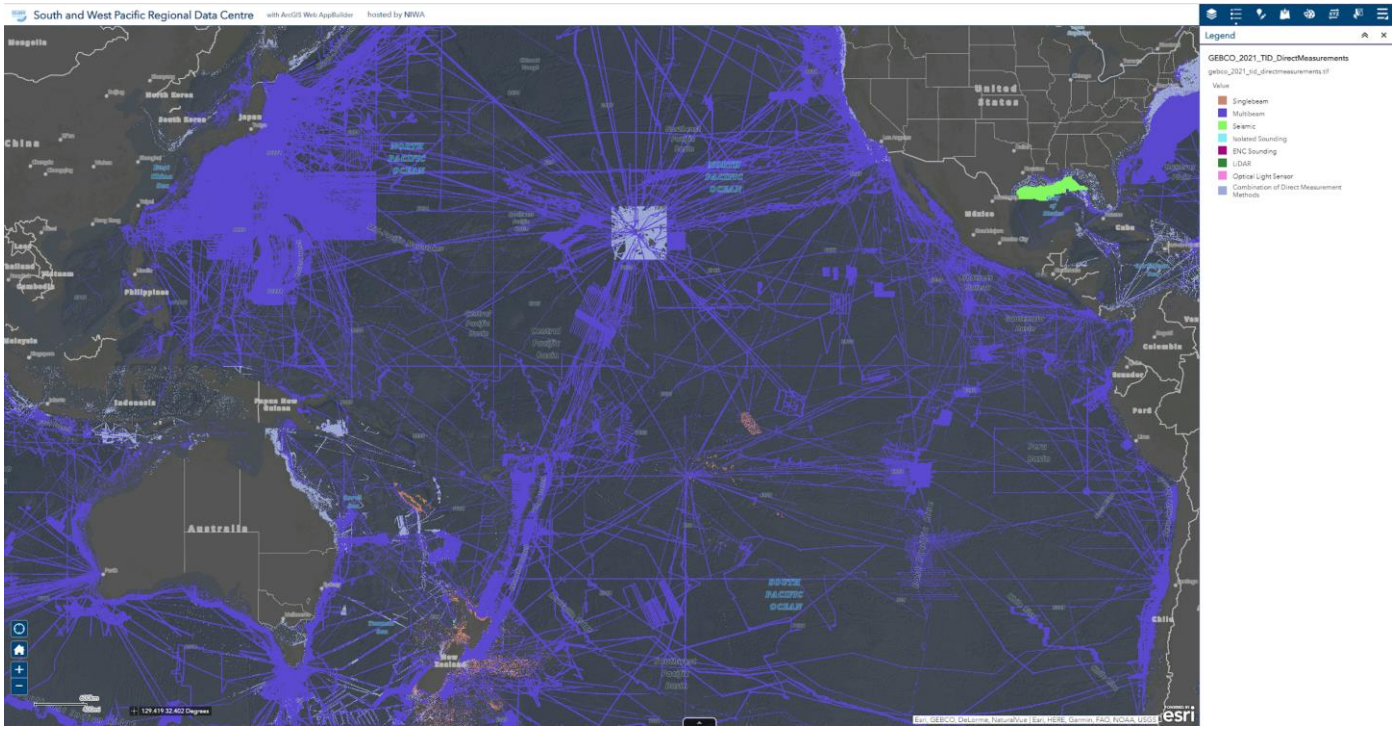
- Catch up with the Regional Mapping Committee with representatives from relevant organizations,
- Identify sources of bathymetric data in the SW Pacific region,
- Discuss methods and protocols of data sharing and management,
- Identify area of regional priority and upcoming mapping expeditions.

About seventy delegates from eighteen countries from the Pacific region participated in the meeting.

Major data and grid contributions

During Year 5, the SaWPaC regional inventory of bathymetric data was updated.

The major data contributors are NIWA, LINZ, JAMSTEC, AusSeabed, IHO DCDB and GMRT (LDEO).



Compilations and gridded contributions

Organizations that contributed data to the South and West Pacifc Ocean regional data compilation as of GEBCO 2022:

Alfred Wegener Institute for Polar and Marine Research (AWI)
AusSeabed, Australia
Caladan Oceanic LLC
Calypso Science, New Zealand
CSIRO, Australia
Deakin University, Australia

Deepreef Explorer
EOMAP
Geoscience Australia
GNS Science, New Zealand
Hawke's Bay Regional Council (HBRC), New Zealand
IFREMER, France
Japan Agency for Marine- Earth Science and Technology (JAMSTEC)
Japan Oceanographic Data Centre (JODC)
Japan Coast Guard, Hydrographic and Oceanographic Department (JHOD)
Lamont-Doherty Earth Observatory, Columbia University (GMRT)
Toitu Te Whenua Land Information New Zealand (LINZ)
Marine Geoscience Data System (MGDS)
National Geospatial-Intelligence Agency (NGA)
National Institute of Water and Atmospheric Research (NIWA)
National Oceanographic Centre, UK
National Research Institute for Earth Science and Disaster Resilience, Japan
NOAA NCEI Multibeam Bathymetry Database (IHO DCDB)
New South Wales Office of Environment and Heritage NSWOEH, Australia
Ocean Exploration Trust
PANGAEA
UNOLS R2R
Waikato District Council, New Zealand

NIWA/Nippon Foundation Tonga Eruption Seabed Mapping Expedition (TeSMAP)

Hunga Tonga - Hunga Ha'apai (HTHH), one of 22 volcanoes in the waters around the Kingdom of Tonga, erupted violently on 15th January 2022. This eruption was the largest of three volcanic events in the last decade. Prior to the eruption the volcano caldera sat approximately 150 m below sea level and part of the volcano connected the islands of Hunga Tonga and Hunga Ha'apai making them a single landmass. Following the eruption, no part of the volcano is now above water and the islands of Hunga Tonga and Hunga Ha'apai were reduced in size. It is expected similarly dramatic changes have occurred in the underwater topography. Submarine cable breakages show impacts up to 50 km from the volcano caldera, implying changes to the seabed over an area of at least 2,000 km^2.

In April 2022, NIWA and the Nippon Foundation, in collaboration with Seabed 2030 through SaWPac, undertook seabed mapping expedition to the waters around HTHH using the *RV Tangaroa*. Over 22,000km^2 was mapped, of which 14,000km^2 was previously unmapped.

Seabed mapping over the caldera of HTHH commenced in late July 2022 using the *USV Maxlimer*, an uncrewed surface vessel from Sea Kit International. The mapping component of TeSMAP is expected to be completed by the end of August 2022.

Seabed data from TeSMAP will be included in the delivery for the GEBCO_2023 grid product.

Financial report

All funds were allocated to seabed mapping activities.

Atlantic and Indian Oceans Regional Center

Location: Lamont-Doherty Earth Observatory, Columbia University, United States of America.

Center Lead: Vicki Ferrini.

Overview

The Atlantic and Indian Ocean Regional Center (AIORC) focuses on most of the Atlantic and Indian Oceans, the Mediterranean Sea and the Black Sea, Red Sea, and Persian Gulf. The region represents an area of ~140.7 million km2, which represents ~39% of the global ocean (361.9 million km2). Approximately 53.9 million km2 (38%) of the region falls within EEZs, and it is bounded by 117 countries on six continents.

AIORC is fortunate to have many national and international efforts focused on seabed mapping within the region which are significant sources of high-quality data. There are many Regional Hydrographic Commissions that fall within, or partially within, the AIORC region and the AIORC has developed strong relationships with many of them. There are numerous GEBCO subcommittee members that fall within the region, as well as 66 alumni from 33 countries that are the backbone of our community of stakeholders. While there are large areas of the AIORC region that are actively being mapped and stewarded by partners in national and international efforts, there remain several large data sets that have not yet been shared for inclusion in the GEBCO grid. Likewise, there are many nations that lack the resources to conduct seabed mapping on their own. The long-term plan to complete mapping the AIORC region involves a combination of continued advocacy and stakeholder engagement, promotion and use of crowdsourced bathymetry and new technologies, and a concerted effort to build capacity, particularly in the developing nations within the region.

Year 5 Highlights

The Atlantic and Indian Oceans Regional Center (AIORC) has focused its efforts on technical work related to data discovery and assembling a high-quality data compilation for the region, as well as strengthening and increasing collaborations in support of ocean mapping throughout the region. Stakeholder engagement continues to be a high priority for the Center as we endeavor to facilitate collaboration, promote data sharing, and gain capacity. Toward this end we have continued to pursue our strategy of strong engagement with several key communities including (1) IHO Regional Hydrographic Commissions, (2) IOC regional bodies, (3) Nippon Foundation - GEBCO Alumni from throughout the region, (4) academic researchers, and (4) industry players who acquire and share data. The team actively seeks out opportunities to build bridges between sectors and stakeholders by attending conferences and sharing information about the importance and impact of the Project. The investment in ongoing community engagement by the AIORC Team, and the entire Seabed 2030 and GEBCO community, appears to be accelerating the contribution of data contributions have increased and data coverage throughout both the Atlantic and Indian Oceans has increased tremendously (Figure 1).

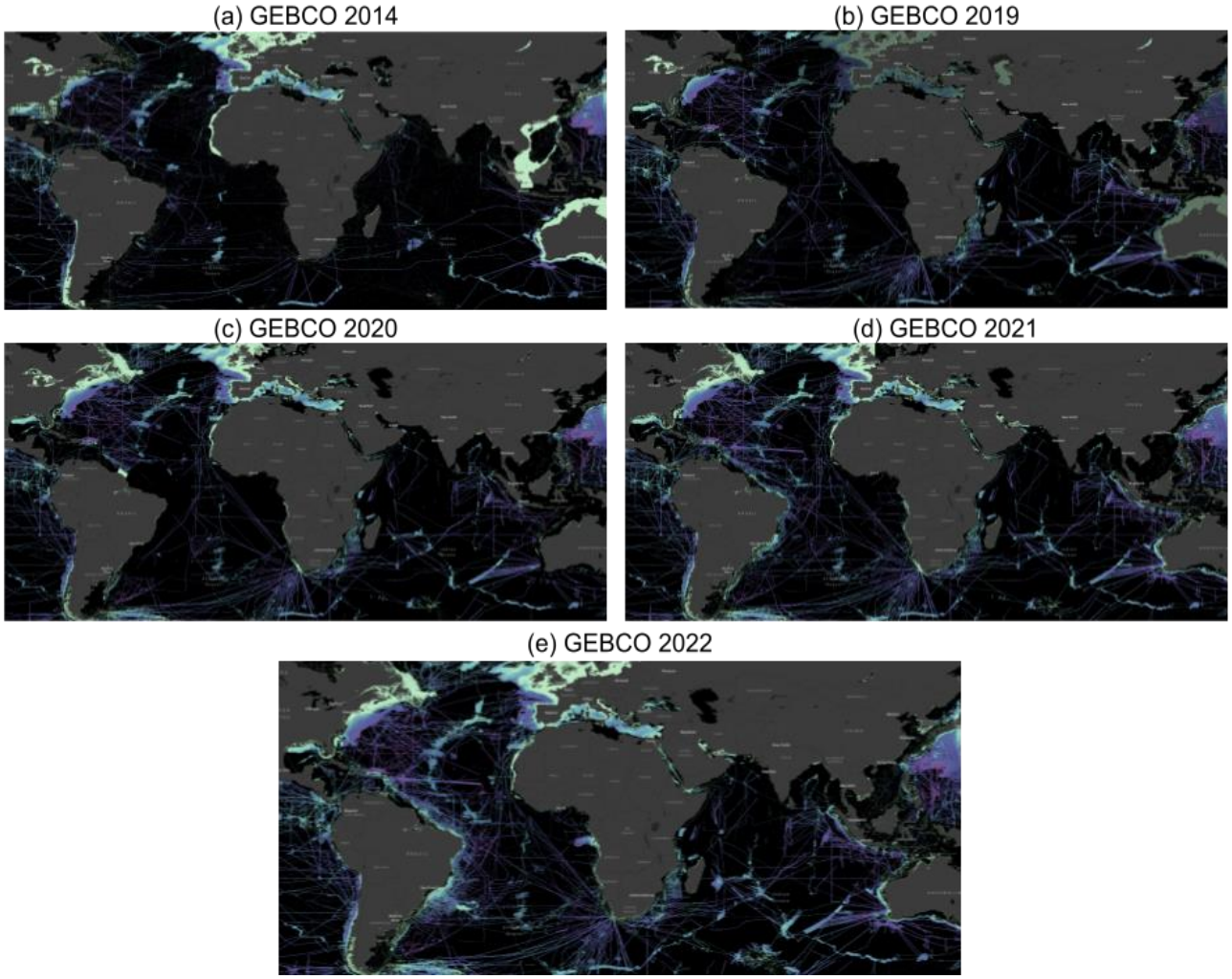


Figure1: Visualization highlighting gaps in data coverage throughout the AIORC region with each release of the GEBCO grid: (a) GEBCO 2014, (b) GEBCO 2019, (c) GEBCO 2020, (d) GEBCO 2021, (e) GEBCO 2022. In all panels, areas that are considered "unmapped" are shown in black. Note that some large areas that are shown as "mapped" in GEBCO2014 and GEBCO2019 are "unmapped" in later versions of the grid (e.g. around Australia). This is because the location of underlying data have been better constrained with respect to TID, and interpolated portions of contributed grids have been recategorized as "unmapped." The data coverage shown in GEBCO 2022 (e) represents the most extensive data coverage for the region that is based on direct measurement.

The AIORC is supported by its staff including Dr. Vicki Ferrini (Head), Ms. Hayley Drennon, Ms. Tinah Martin (Nippon Foundation-GEBCO Alumnus), Dr. Frank Nitsche, and Mr. John Morton, with administrative support provided by Ms. Angela Martin and IT support from Dr. Gilles Guerin. The Atlantic and Indian Center also strengthened collaborations with colleagues in Canada by hosting a short visit from postdoctoral scientist from Dalhousie University, Dr. Benjamin Misiuk, who assisted in data integration efforts.

This year, the Center welcomed 4 undergraduate students to assist with data processing as Summer Bathymetry Data Apprentices. These early career individuals worked with the AIORC team, and the GMRT Team at LDEO, to accelerate data assembly efforts by processing and reviewing data, and by helping to exercise tools, workflows and documentation. In 2022, two of these students, Mr. Benjamin Ross and Ms. Madeline Langer, participated remotely from the College of Charleston in South Carolina. Two other students based in New York, Ms. Layla Xholi from Laguardia Community College and Ms. Sheila Cáceres of The City College of New York also joined the team on the Lamont campus. In addition to working with data, these students participated in the 2022 Regional Mapping

Community Meeting and moderated sessions during the event. Both students are eager to continue working with the team to continue to assist with data preparation and assembly.

Regional Mapping progress

Technical Highlights

Based on feedback from the community, we were able to address data quality issues to improve the quality of the Atlantic/Indian Oceans compilation. With additional input from stakeholders regarding the spatial distribution of source data supporting gridded data contributions we have also refined our TID grids. This allows us to better distinguish "mapped" for "unmapped" areas.

Efforts to standardize data quality to accelerate the pace of integration of data into the global synthesis have been greatly enhanced by the tools made publicly available by the GMRT project at Lamont. This is used as a tool to process raw swath files into high quality products that are staged for broad public distribution through the IHO DCDB, and also expedites integration of data into the data compilation. The tool and workflow is also used to review processed swath files prior to integration to ensure that data are of sufficiently high quality to be integrated. While the GMRT team uses this tool and workflow to focus on data from the US Academic Research Fleet, the Seabed 2030 team at LDEO uses it to focus on international data and industry data (e.g. Fugro transits).

Toward the goal of delivering the GEBCO product at multiple resolutions we have explored the developing aspects of a data assembly approach that will allow us to easily deliver products at the specified target resolutions based on water depth as was defined in Mayer et al., 2019. The recent data contribution from the Portuguese Hydrographic Office has served as an ideal dataset to test this approach and to explore the logic necessary for the workflow. We look forward to furthering this concept in the coming year and helping to deliver the GEBCO grid at multiple resolutions.

Our work with custom web applications, such as the MACHC-IOCARIBE Seabed 2030 web app, has continued to help stakeholders access important metadata and geospatial representations of data coverage. This is an activity that is relatively low effort because it utilizes authoritative web services offered and/or consolidated by the IHO DCDB. We used these tools and others, such as GeoMapApp, to help community members identify data gaps both within the Atlantic/Indian Oceans and in other regions, so they could optimize the use of transit time to acquire data to fill gaps in coverage.

Coordination with French colleagues from multiple groups has yielded new contributions of French data into the compilation. This effort has also led to some initial transit mapping efforts in coordination with French colleagues and the French research fleet.

Stakeholder Engagement Highlights

Over the course of the year, AIORC Team members participated in multiple activities to engage with stakeholders. These activities included a variety of formats. In collaboration with the Director of the IHO DCDB/Chair of the CSB working group, several video calls were convened with Dr Ferrini and Seabed 2030/CSB Coordinators for Regional Hydrographic Commissions to discuss the status of mapping in the region and to provide information and slides to be presented at meetings. The team also provided information and details in support of the MACHC/IOCARIBE's successful bid to the Ocean Decade Action (https://www.oceandecade.org/actions/machc-iocaribe-seabed-2030-project/).

- US National Ocean Mapping, Exploration, and Characterization (NOMEC) Council UN Decade Satellite Event– September 2021
  - Dr. Ferrini was an invited speaker in an event which aimed to discuss how the NOMEC initiative will advance ocean-based climate solutions and tie into international programs such as the Nippon-Foundation Seabed

2030 Project. Ferrini reflected on the success of The Seabed 2030 Project and presented synergies and opportunities between The Project and NOMEC.

- Eastern Atlantic Hydrographic Commission Webinar– September 2021
  - Dr. Ferrini was invited to speak about the project and to provide an update of coverage on the region. Emphasizing the cooperation and effort of all within the region, the talk generated follow-up conversations with Portugal about their Seamap2030 Project.
- 17th International Congress of Brazilian Geophysical Society (PGGM) Webinar– November 2021
  - Dr. Ferrini attended a virtual round table focused on mapping in the South Atlantic. Discussions with Brazilian colleagues, regarding strategy for funding mapping within the region, as well as identifying data sharing opportunities.
- Meso American & Caribbean Sea Hydrographic Commission (MACHC) Webinar– November 2021
  - Building on successful partnership with MACHC members and observers, this invited presentation offered a summary of available tools and solutions for gridding bathymetry data. Discussions from this webinar strengthened collaboration and identified data that had not yet been contributed to the project.
- Southern and East African and Islands Regional Group for Safety of Navigation and Marine Environment Protection (SEAIGNEP) – November 2021
  - SEAIGNEP's meeting presented goals shared internationally of collaboration in the sharing and exchange of information and technical support, promote and improve resources, and the participation in sustaining regional and national strategies. Building upon on previous engagement with stakeholders from the region, Dr. Ferrini offered an update on mapping status in the Southern and East Africa Island region.
- Map the Gaps Symposium: Mapping around Africa Session– December 2021
  - Map the Gaps convened a global event on bathymetry on behalf of GEBCO. Ms. Drennon co-organized and presented project status updates for this broadly attended event which also featured topics such as mapping and data processing technology, deep water exploration, mapping missions, policy, and diversity, equity & inclusion. Dr. Ferrini convened a session built upon the successful webinar series the center convened in Feb 2021, which brought together several colleagues working in and around Africa, leading to new data discoveries.
- Pre-conference workshop Regional Kick-Off Conference on the UN Decade of Ocean Science – January 2022
  - This workshop focused on the local stakeholder engagement to assess the strengths and weaknesses of the participants as well as identify regional gaps for the UN Decade fulfillment. Ms. Martin participated in the workshop to contribute to the discussion and gather knowledge on stakeholders needs. The output of the workshop was presented at the "African Conference on Priority setting and partnership development for the UN Decade of Ocean Science for Sustainable Development".
- International Indian Ocean Science Conference (IIOSC-2022) – March 2022
  - The IIOSC hosted a session on geology, geophysics, and seabed mapping of the Indian Ocean. Dr. Ferrini presented an abstract overviewing the Nippon Foundation - GEBCO Seabed 2030 Project and information about the current state of knowledge about seabed mapping data coverage and suggestions for how to come together to address this gap in observational data. Co-authors of the presentation included 2 GEBCO - Nippon Foundation Alumni, Ms. Tinah Martin and Mr. Vasu Mahale, as well as GEBCO Guiding Committee Member Ms. Kim Picard.
- 2022 National Ocean Exploration Forum (NOEF) - Ocean Exploration: BLUEPRINT 2032– March 2022
  - The 2022 National Ocean Exploration Forum invited Dr. Ferrini as a panelist and participant to help envision short and long term actionable milestones to guide the community to shared priorities in ocean exploration. Ferrini Ms. Colleen Peters of Saildrone co-authored a white paper presented 5 and 10 year opportunities, discussed ways to accelerate open data, data access equity, and Seabed 2030 goals and achievements. A vision statement of an ocean exploration community of practice that fosters networks of expertise for data gathering, management, access, and use was presented and discussed at the Forum.
- Arctic-Antarctic and North Pacific Mapping Meeting– March 2022
  - The meeting's goals were to review progress, identify and unlock datasets, and develop strategies to coordinate and promote new mapping initiatives. Dr. Nitsche presented US data from Antarctica as well as participated in discussions and represented the Atlantic and Indian Regional Center.
- American Museum of Natural History Spring Luncheon: Science, Society, and Our Environment – May 2022
  - The American Museum of Natural History convened an expert panel to discuss The Decade of Ocean

Science's most pressing issue of scientific development in ocean deoxygenation, sustainable capital investment, and long-term rehabilitation of the largest ecosystem on Earth. Dr. Ferrini highlighted the importance of a complete ocean map, supporting the sustainable development goals of the decade and how international projects such as Nippon Foundation GEBCO Seabed 2030 burgeons ocean conservation.

- UN Ocean Conference Side Event: Mapping for People and Planet" – June 2022
  - The event showcased Seabed 2030 as an example of successful multi-sector collaboration, provided participants with insight into how Seabed 2030 is collaborating with partners, and aimed to inspire global stakeholders to mobilize and coordinate cross-sector to enable a 100% mapped ocean. Ms. Martin participated as a panelist during this event, discussing the benefits of ocean mapping and how the global community benefits from joint seabed mapping initiatives
- Ocean Data and Information Network (ODIN) for Africa Steering Group– Ongoing
  - Ms. Martin joined the steering committee reviving the ODINAFRICA project (2022-2030). A biweekly meeting led by the office of IOCAFRICA to revive the project is set with the tasks to organize and advance the strategic plan and the kick off of the project. The goal of the project is to adopt a multi-stakeholder approach towards achieving improved collection, processing, sharing and access to ocean-related data and information.
- South and West Pacific Regional Community Mapping Meeting - July 2022
  - Dr Ferrini provided two updates at this meeting. One update was focused on Atlantic and Indian Oceans status and progress, and one update focused on tools made available by GMRT for community use to help with data curation and quality control.
- Atlantic/Indian Oceans Regional Community Mapping Meeting– July 2022
  - The 2022 regional community mapping meeting featured 20 speakers (5 from Seabed2030), and had nearly 100 registrants. The entire AIORC Team, and Seabed 2030 Director, participated in presenting to the community and encouraging discussion. Focused on the Atlantic and Indian Ocean Mapping community, the goals of the meeting were to share information, connect the community, and discuss opportunities.
- The Fourth Sino-Africa Forum on Marine Science and Technology– July 2022
  - The Forum discussed actions and workplan to carry out China-Africa cooperation and promote win-win cooperation on marine and science technology. Tinah Martin was invited to participate as a panelist in the session "Data and knowledge management and capacity building". A recorded introduction to Seabed 2030 was provided to the organizers for participation since the forum dates overlap with the Atlantic and Indian Ocean Regional Mapping Community Virtual meeting.

GEBCO - Nippon Foundation Alumni Engagement

- Ms. Martin provided support to the Alumni Mr. Amon Kimeli and Ms. Victoria Obura on the training "Fundamentals of Ocean Floor Mapping" they organized with the Ocean Teacher Global Academy
- Two Alumni, Ms. Tinah Martin and Mr. Vasu Mahale co-authored the paper that was presented at the IIOSC meeting in March 2022.

Regional IHO/IOC Engagement

- IHO Regional Hydrographic Commission engagement: MACHC, MBSHC, NIOHC, EAtHC, SAIHC, SWAtHC
- IOC Regional bodies: IOCARIBE, IOCAFRICA

2022 Atlantic and Indian Oceans Regional Mapping Community Meeting

A two-day Regional Mapping Community Virtual Meeting was held on July 27 and 28th, 2022. The meeting gathered nearly 100 participants from 30 countries around the world and showcased 21 presentations reporting on technical advances, uses of seabed mapping data and progress toward collaboration (Figure 2). During the meeting, the discussions and presentations helped participants to better understand Seabed 2030 Project's goals and how their participation is essential to achieving a 100% mapped ocean floor.

Figure 2: Countries of participants in the 2022 Atlantic-Indian Regional Mapping Community Meeting

Following welcoming remarks from the Director of the Lamont-Doherty Earth Observatory, introductory comments from the Seabed 2030 Project Director described the overall goals, approach and progress of the project. The Head of the Regional Center then highlighted progress achieved within the Atlantic and Indian Oceans over the past 5 years thanks to collaboration and cooperation of individuals and organizations across the maritime sector. Data Managers from the team described the approach used to assemble the regional bathymetry grid and corresponding metadata for the region, and presented increases in coverage 2014 and an overview of how to visualize areas of the ocean that are supported with direct measurement, to better identify remaining data gaps.

Community presentations on the first day emphasized the need to optimize both data acquisition mechanisms and access to scientific data gathered during survey campaigns and transits. Publicly available tools and efforts to leverage transits to acquire mapping showcase the advantages of this approach and serve as a reminder of the importance of acquiring data whenever possible, and the value of coordinating to strategically map gaps in coverage. The key messages from technical discussions focused on the opportunity for the community to improve skills and capacity using diverse tools and platforms that are available, the value of starting collaboration, and the importance of sharing data to advance seafloor mapping in the region.

Community presentations on the second day of the meeting focused on use cases of bathymetric data that highlight the importance of seafloor mapping and regional global efforts to share and integrate data. Communication of planned data collection activities, coupled with innovations in sharing and accessing data, are positively impacting our collective efforts and are a pillar of the global quest to map the ocean floor by 2030.

Major data contributions

Ongoing integration of data acquired and made available in the IHO DCDB is a primary focus of the AIORC Team. The team focuses their efforts on international data in the DCDB, CSB data, data acquired during Fugro transits, and processed data delivered by the Pressure Drop. Data acquired aboard the US Academic Research Fleet is processed and delivered to the Seabed 2030 Project globally via GMRT, with the most recent version (v4.0) providing more than 1,300 total cruises of data. Additional sources of large volumes of data that are reviewed and integrated annually include data made available through European archives (e.g. Pangaea), and from the AusSeabed effort. At the time of the writing of this report, data contributions for the region have come from more than 50 organizations, projects and individuals in 39 nations, but the true number of contributing organizations is much larger since several data contributions are syntheses that represent the efforts of many. A few highlight datasets are described below.

SeaMap 2030

As a part of Portugal's efforts to map 100% of their maritime spaces by 2030 The Instituto Hidrográfico of Portugal has made available their current data compilation which covers more than 2 million km2. These data add significant coverage in the North Atlantic (Figure 3) and are actively being integrated into the regional compilation.

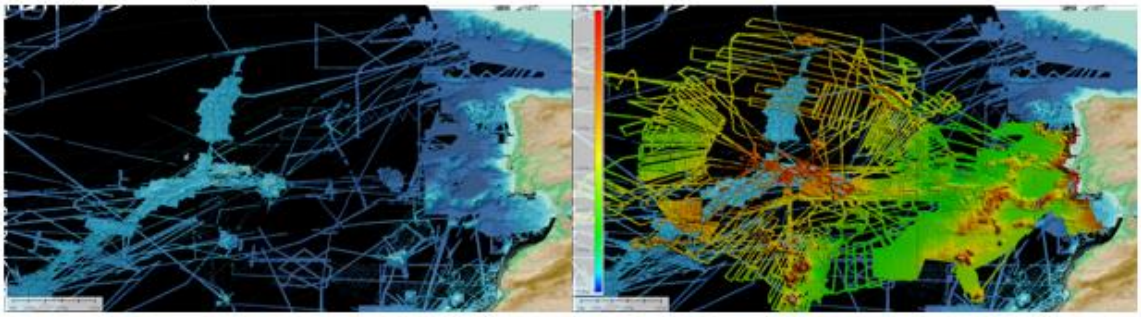


Figure 3: Left: GEBCO 2022 data coverage (black indicates areas not yet mapped). Right, GEBCO 2022 data coverage with SEAMAP compilation from the Instituto Hidrográfico of Portugal overlain.

South African National Hydrographic Office

To support the mapping of the waters around South Africa, the South African Navy Hydrographic Office (SANHO) made a large contribution consisting of varying data types that is currently under review for integration into the regional compilation. The SANHO contribution includes data from multiple sectors and a variety of acquisition techniques including CSB. Much of these data are sparse but when combined with other contributions from the region will add significant coverage and improve the underlying grid. Due to the variable quality of these data, we are actively developing and testing modified data management and integration workflows to best utilize and integrate the data contribution.

Satellite Derived Bathymetry

The AIORC received and integrated Satellite Derived Bathymetry for the Maldives and near Madagascar which was integrated into GEBCO 2022. Additional SDB data coverage, most notably from the Caribbean, is actively being integrated into the compilation and will be included in GEBCO 2023.

Contributing organizations for the Atlantic/Indian Ocean region as of the GEBCO 2022 Compilation:

Alfred Wegener Institute Helmholtz Centre for Polar and Marine Research (AWI)
ARGANS
AusSeabed
Bahrain Hydrographic Survey Directorate
British Antarctic Survey (BAS)
British Oceanographic Data Centre (BODC) of the National Oceanography Center (NOC)
Bundesanstalt für Geowissenschaften und Rohstoffe (BGR) - Federal Institute for Geosciences and Natural Resources
Canadian Hydrographic Service (CHS)
Centre National de la Recherche Scientifique (CNRS)
Direccion de Hidrografia y Navegacion (DHN) Venezuela

Directorate of Hydrography and Navigation Brazilian Navy
Directorate of Navigation and Hydrography Brazil
European Marine Observation and Data Network (EMODnet)
Geological Institute, Russian Academy of Sciences (GIN RAS)
Geological Survey of Spain (IGME)
GEOMAR Helmholtz Centre for Ocean Research
Geoscience Australia (GA)
Global Multi-resolution Topography Data Synthesis (GMRT)
Hydrographic Service for the Navy, Ministry of the Defence of Argentina
Hydrographic Service of the Royal Netherlands Navy
Indian Naval Hydrographic Department (INHD)
Institut de Physique du Globe de Paris (IPGP)
Institut Français de Recherche pour l'exploitation de la Mer (IFREMER)
Institute of Marine Sciences (ISMAR) - CNR
International Hydrographic Organization Data Centre for Digital Bathymetry (IHO DCDB)
Israel Oceanographic and Limnological Research (IOLR)
Japan Agency for Marine-Earth Science and Technology (JAMSTEC)
Laboratoire d'Etudes en Géophysique et Océanographie Spatiales (LEGOS)
Marine Geoscience Data System (MGDS)
Marinha Portuguesa - Instituto Hidrográfico
Maritime and Port Authority of Singapore
Marum - Center for Marine Environmental Sciences, University of Bremen (MARUM)
National Geospatial-Intelligence Agency (NGA)
National Oceanic and Atmospheric Administration (NOAA)
National Oceanic and Atmospheric Administration, National Centers for Environmental Information (NOAA NCEI)
National Oceanic and Atmospheric Administration, Office for Coastal Management
National Oceanography Centre (NOC)
Olex AS
Royal Navy
Russian Academy of Sciences
Sea-Kit
Service Hydrographique et Océanographique de la Marine (SHOM)
Servicio de Oceanografia, Hidrografia Y Meteorologia de la Armada
South African Navy Hydrographic Office (SANHO)

State Hydrographic Service of Ukraine
TCarta
University of Capetown
University of New Hampshire and its Center for Coastal and Ocean Mapping/Joint Hydrographic Center (UNH/CCOM-JHC)
University of Wisconsin
US Department of the Interior, Bureau of Ocean Energy Management, Bureau of Ocean Energy Management (BOEM)
UTM-CSIC Data Centre
XPRIZE

Financial report

All funds were allocated to seabed mapping activities.

Arctic and North Pacific Oceans Regional Center

Locations: Department of Geological Sciences, Stockholm University (SU), Sweden/Center for Coastal and Ocean Mapping, University of New Hampshire (UNH), USA.

Centre co-Leads: Martin Jakobsson (SU) & Larry Mayer (UNH)

Center Staff

Stockholm University

- Ms Caroline Bringensparr, Data Manager/Analyst
- Mr Björn Eriksson, System Administrator
- Dr Silvia Salas, Data Manager/Analyst
- Dr Rezwann Mohammad, Scientific Programmer

Center for Coastal and Ocean Mapping, University of New Hampshire

- Mr Paul Johnson, Data Manager
- Dr Juliet Kinney, Data Analyst

Regional Mapping Progress

Summary: Arctic Ocean Region

The SU team uses a gridding workflow that has been developed inhouse over the course of the Seabed 2030 Project to compile the GEBCO 2022 grid for the Arctic region. This workflow operates on the National Supercomputer Centre in Sweden (NSC). It generates grids on a polar stereographic projection, with the specific projection parameters used for the International Bathymetric Chart of the Arctic Ocean (IBCAO), as well as calculates coverage statistics and compiles a geographic grid for the GEBCO grid. The workflow is written in

Python, calls for some GMT (Generic Mapping Tools) routines, and is now ready to deliver grids at multiple resolutions. This workflow is now being further developed only use Python, and to be operated on Amazon Web Service (AWS), which is described in this report. During Year 5 of the Seabed 2030 project >100 bathymetric data sets were included, of which some were recently acquired while some were retrieved from archives and re-processed (Figure 1). These datasets are further specified in Tables in this report. Year 5 also included development of a data uploaded that complements the uploader provided by Kongsberg during Year 4. The goal has been to develop a bathymetric data uploader that captures the necessary meta data and funnels the data directly to the gridding workflow.

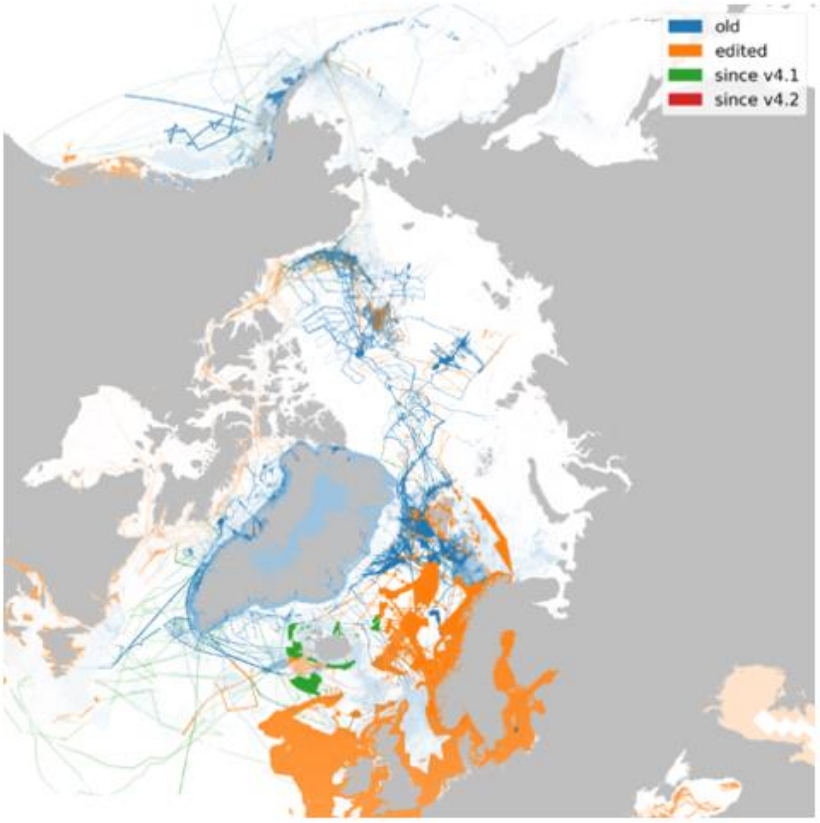


Figure 1: *Map of the IBCAO region showing i) old data that were included in previous versions before IBCAO 4.1 grid (blue), ii) data that are edited and updated in IBCAO 4.1 and 4.2 grids (orange), iii) new data that are included in IBCAO 4.1 grid (green), and iv) new data that are included in IBCAO 4.2 grid (red). All the data will contribute to the 2023 version of the global GEBCO grid and IBCAO 5.0. (Note that "edited" may imply only partial edits or updates to large compilation data sets.)*

Summary: North Pacific Region

This past year, the UNH team continued to use ESRI BIS to generate its North Pacific 2022 grid submission. A total of **16 new multibeam surveys** were incorporated into the 2022 North Pacific grid (Figure 2). The new datasets comprised both composite sets and individual surveys. Final grids were merged with the global compilation GMRT 4.0 within ESRI BIS for the 2022 grid. **32 existing surveys were revised** to improve grid quality. Additional data sets have been identified for the 2023 submission. The UNH team plans on further QC of the processed single beam data from NOAA NCEI to before incorporating it into future submissions. The 2022 grid compilation involved a large effort to rebuild the ESRI BIS system in WGS84 using a script- based approach.

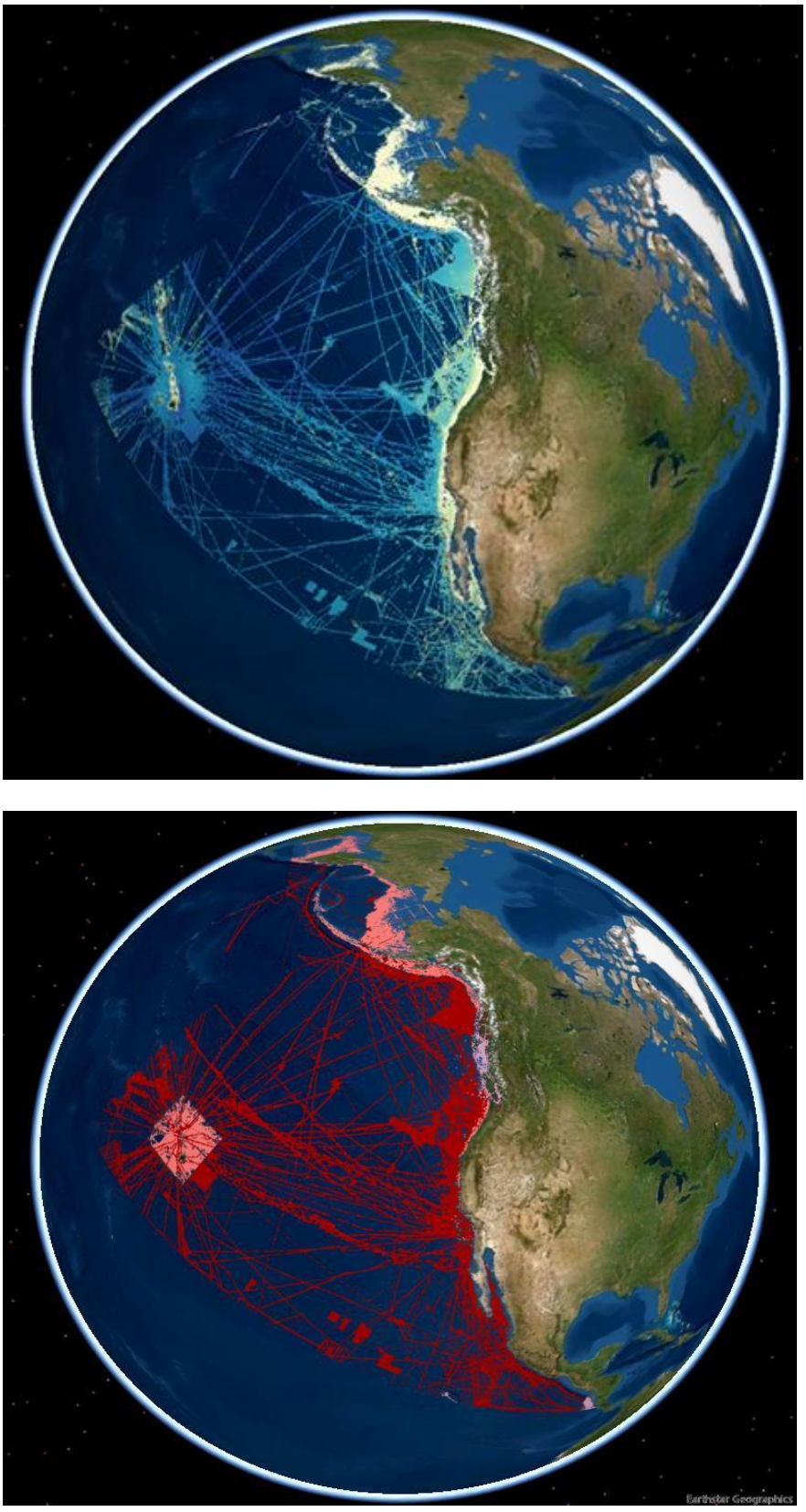


Figure 2: *North Pacific 2022bathymetric grid (upper), TID (lower) standard GEBCO made/world imagery background.*

Major data and grid contributions

Data from the Arctic Region:

The new and updated data in the Arctic region during Year 5 are here listed in a set of tables.

Revisited and edited data included in previous gridded Seabed 2030 compilations

Dataset	Contributing Organization	Data Category
ARK: VIII/3, IV/3, XII, XXVI/3, XXIX/3(PS94)	Alfred Wegener Institute Helmholtz Centre for Polar and Marine Research (AWI)	Multibeam
Amundsen OMG	Canadian Hydrographic Service (CHS)	Multibeam
CHS fieldsheet data batch 2011bc	Canadian Hydrographic Service (CHS)	Singlebeam
CHS NONNA 100	Canadian Hydrographic Service (CHS)	Combination of direct measurement methods
Echo general, echo general Canada shelf, echo general central AO	Mixed sources of unknown origin	Singlebeam
GMTED 2010	U. S. Geological Survey (USGS); National Geospatial – Intelligence Agency (NGA)	Land
Greenland shelves	Cartographer Norman Cherkis	Digital bathymetric contours from charts
Hawkbill 99 LR	United States Navy	Multibeam
HDNO	The Head Department of Navigation and Oceanography (HDNO)	Digital bathymetric contours from charts
HLY: 0203, 0302, 0405C, 0503, 0503CB1, 0703B, 0703C, 1202_2012, 1603_2016	University of New Hampshire, Center for Coastal and Ocean Mapping, Joint Hydrographic Center (UNH/CCOM-JHC)	Multibeam
Marum Norwegian sea HE449 south	Center for Marine Environmental Sciences, University of Bremen (MARUM)	Multibeam
OLEX 60-90W/70-90N	Olex AS	Combination of direct measurement methods
Siberian shelf	Digitized depth contours from bathymetric maps	Digital bathymetric contours from charts
Swerus 2014 leg1	Stockholm University, Department of Geological Sciences	Multibeam
Uummannaq 2015	National Aeronautics and Space Administration - Oceans Melting Greenland, Jet Propulsion Laboratory California Institute of Technology (NASA-OMG)	Multibeam
LSSL 2014 MB Arctic, LSSL 2014 JOIS	Geological Survey of Canada (GSC); Canadian Hydrographic Service (CHS)	Multibeam
JR106N	British Antarctic Survey (BAS)	Multibeam
Greenland shelves artificial, HDNO artificial	Stockholm University, Department of Geological Sciences	Steering points
HLY: 1101_part01, 1101_part02, 1103_part01, 1103_part02, 1103_part03, 1201_part01, 1201_part02, 1203_part01, 1203_part02	Rolling Deck to Repository (R2R)	Multibeam
NHS_DTM	Norwegian Hydrographic Service (NHS)	Combination of direct measurement methods

EMODnet 2020	European Marine Observation and Data Network (EMODnet)	Combination of direct measurement methods
Ascos 2008	Stockholm University, Department of Geological Sciences	Multibeam
NGA 300 C2004-2006 & NECanada database	National Geospatial – Intelligence Agency (NGA)	Combination of direct measurement methods

New data since IBCAO 4.1 May 2021

Dataset	Contributing Organization	Data Category
Oden-SAS 2021 (2 datasets)	Stockholm University	Multibeam
MFRI-Iceland 2021	Marine and Freshwater Research Institute	Multibeam
SCICEX 2011-2016 (6 datasets)	United States Navy	Singlebeam
EWXXXX (3 datasets) KNXXX-XX (20 datasets) 64PE263, 650610_p_100, 64PE400, MGLN45MV, FD170001 HLYXXXX (14 datasets) SKQXXXXXXX 2015-2020 (32 datasets) ARXX-XX (8 datasets)	National Oceanic and Atmospheric Administration, National Centers for Environmental Information (NOAA NCEI)	Multibeam

New data since IBCAO 4.2 May 2022

Dataset	Contributing Organization	Data Category
Ikka Fjord 2019	Canadian Hydrographic Service (CHS)	Multibeam
EMODnet 2020	European Marine Observation and Data Network (EMODnet)	Interpolated based on a computer algorithm
Petermann skidbladner 2015	Stockholm University	Multibeam
ARA 2013-2018: 04B, 05B, 07C 09C	Alaska Fisheries Science Center - National Oceanic and Atmospheric Administration's National Marine Fisheries Service (NOAA Alaskan Fisheries)	Unknown source
H12228 &H12229 2010, H12751 2015	National Oceanic and Atmospheric Administration (NOAA)	Combination of direct measurement methods
OMG 2020-2021 (6 datasets)	National Aeronautics and Space Administration – Oceans Melting Greenland, Jet Propulsion Laboratory California Institute of Technology (NASA-OMG)	Multibeam
OMG 2015-2016 (2 datasets)	National Aeronautics and Space Administration – Oceans Melting Greenland, Jet Propulsion	Singlebeam

	Laboratory California Institute of Technology (NASA-OMG)	

New data not yet included (some are compilations which have been updated with new data, e.g. Bedmachine and NONNA)

Dataset	Contributing Organization	Data Category
Oden-SAS 2021 transit 1, Oden NW Greenland	Stockholm University, Department of Geological Sciences	Multibeam
Bedmachine Greenland 2022	University of California Irvine - Department of Earth System Science	Pre-generated grid
KM0309, AT30-01, AT30-02, AR 30-05, SKQ201504T, MGL0814, TN249, MSM28, MGL1310, MSM 43, FS201108, BELL01, KN166L11, KN203-04 HLY: 18TD, 0102, 0103, 1001, 1104, 1403	National Oceanic and Atmospheric Administration, National Centers for Environmental Information (NOAA NCEI)	Multibeam
LK19-BIOS 2019 (3 datasets)	Aarhus University & Geological Survey of Denmark and Greenland (GEUS)	Multibeam
ARA: 08C, 010C, O12C, MBE: 2011, 2012	Korea Polar Research Institute (KOPRI)	Unknown source
SO276, SO280, SO286	Senckenberg am Meer - German Centre for Marine Biodiversity Research (DZMB)	
JR18007, JR17005, JR106, JR288, HUD94008, DY053	National Oceanography Centre - British Oceanographic Data Centre (BODC)	Singlebeam
ARA: 03B1, 03B2 04C_fugawi	Korea Polar Research Institute (KOPRI)	Multibeam
ARK: XXVII/3, XXIX/2.1 (PS93_1), XXII/1A (PS70_1A), XXII/1B (PS70_1B), XXII/1C (PS70_1C) PS: 88_1, 99_1, 100, 101, 116, MSM76, MSM95, AWI 2021	Alfred Wegener Institute Helmholtz Centre for Polar and Marine Research (AWI)	Multibeam
Baffin Bay bathymetry	Nunaoil A/S	Singlebeam
GNSW	Geological Survey of Denmark and Greenland (GEUS)	Pre-generated grid
NEG_DBM	Alfred Wegener Institute Helmholtz Centre for Polar and Marine Research (AWI)	Pre-generated grid
NEG_Greenland, Nunaoil West Greenland	Nunaoil A/S	Pre-generated grid
NGA_Melville	National Geospatial - Intelligence Agency (NGA)	Singlebeam
NGDC data	National Oceanic and Atmospheric Administration (NOAA)	Pre-generated grid
Seamount, Skjoldungen	Natural History Museum, University of Copenhagen	Multibeam
Sisak 3, Sisak 7	Greenland Institute of Natural Resources	Singlebeam
Station Nord 2001, Thule 94, Umanak 1991 depths	Geological Survey of Denmark and Greenland (GEUS)	Unknown source
Timmiarmiut	Geological Survey of Denmark and Greenland (GEUS)	Multibeam
USS 2011 Connecticut, USS 2011 NewHampshire, USS 20121120 Topeka ED	United States Navy	Singlebeam
ORP_feb2016, ORP_Inglefield2016	National Aeronautics and Space Administration – Oceans Melting Greenland, Jet Propulsion	Singlebeam

	Laboratory California Institute of Technology (NASA-OMG)	
JR: 75, 219, 253, 269A, 269B	British Antarctic Survey (BAS)	Multibeam
HLY1502 MGL1112: P1, P2, P3 SKQ: 201914S, 202004T, 202013S_EM302, 202013S_EM710, 202014S_EM302	Rolling Deck to Repository (R2R)	Multibeam
Bedmachine new sources	University of California Irvine - Department of Earth System Science	Singlebeam
CHS NONNA 100	Canadian Hydrographic Service (CHS)	Combination of direct measurement methods

Data from the Pacific Region:

The 16 new data sets incorporated into the 2022 North Pacific grid are detailed below:
A total of 15 individual multibeam surveys were incorporated into the 2021 grid. Contributions included final grids from the Caladan Oceanic Pressure Drop, Ocean Exploration Trust. The Northwest Passage CCOM Healy grid was also included. China SCUFN multibeam grids of seamounts were also incorporated, this data was only provided as a gridded product.
Most data were available via NOAA/ NCEI or will be:
• 8 surveys plus associated transits from Ocean Exploration Trust were included in the 2022 submission.
• 1 Saildrone Survey was included in the 2022 submission.
• 4 surveys were from the Pressure Drop were included in the 2022 submission.
Three surveys benefitted from collaborative funding to ensure higher quality data was collected & processed in areas of the Ocean with no multibeam data while ships were in the area. (Nippon Foundation Ocean Frontier Mapping Project, and NOAA OCS funding examples).

US Vessel Multibeam Data Benefitting from SB2030 effort

2022 Contribution		**Swath data & grids provided**	
Multiple funding US Vessels (direct from contributor to SB2030 & NCEI)			
Vessel	**Dataset name**	**Year**	**Contributing organization (Same as Source)**
Pressure Drop	P21_NOAA	2021	Caladan Oceanic; National Oceanic and Atmospheric Administration, National Ocean Service (NOAA NOS)
Saildrone	SD-1200-0001	2021	Saildrone; University of New Hampshire, Center for Coastal and Ocean Mapping, Joint Hydrographic Center (UNH/CCOM-JHC); funded by Nippon Foundation Ocean Frontier Mapping Project
Healy	HLY21TD_NorthwestPassage	2021	United States Coast Guard; University of New Hampshire, Center for Coastal and Ocean Mapping, Joint Hydrographic Center (UNH/CCOM-JHC); funded by Nippon Foundation Ocean Frontier Mapping

			Project

(*Saildrone and Healy were previously processed at The Center)

Private/ Non- Profit U.S. data

2022 Contribution		Swath data & grids provided	
Private/ Non- Profit U.S. data (direct from contributor to SB2030 & NCEI)			
Vessel	**Dataset name**	**Year**	**Contributing organization (Same as Source)**
Nautilus	NA126	2021	Ocean Exploration Trust (OET)
Nautilus	NA127	2021	Ocean Exploration Trust (OET)
Nautilus	NA128	2021	Ocean Exploration Trust (OET)
Nautilus	NA130	2021	Ocean Exploration Trust (OET)
Nautilus	NA132	2021	Ocean Exploration Trust (OET)
Nautilus	NA133	2021	Ocean Exploration Trust (OET)
Nautilus	NA134	2021	Ocean Exploration Trust (OET)
Nautilus	NA135	2021	Ocean Exploration Trust (OET)
Pressure Drop	PD22_Transit_Iquique_SalinaCruz	2022	Caladan Oceanic
Pressure Drop	PD22_Transit_SalinaCruz_San_Diego	2022	Caladan Oceanic
Pressure Drop	PD21HI01	2021	Caladan Oceanic

*Nautilus includes transit surveys to and from Survey Areas, and subset surveys areas under one Cruise Number.

China Multibeam - Only grids provided

Source	Data type	Contribution Via
China SCUFN data (SCUFN_2017)	grids	SaWPac

Cleaning of Grids in previous releases as part of the North Pacific Grid improvements for 2022:

2022 Revised Grids

gebco_grid_status	dataset_name
2021	SKQ201805T
2021	EW0206
2021	FK190709
2020	MGL1110
2020	MV1406
2021	RR1610

2021	SKQ201915S
2021	SKQ201606S
2021	AT37-12
2021	SKQ201611T
2021	MV1308
2020	RB1604
2021	HLY17TC
2021	SKQ20141S
2020	FK151005
2020	EX1504L4
2021	FK180824
2021	RR1805
2020	EX1701
2020	EX1705
2021	RR1713
2021	RR1715
2021	RR1718
2020	EX1504L1
2020	EX1504L3
2020	EX1505
2020	EX1602
2020	EX1608
2020	EX1609
2020	EX1706
2020	EX1708
2021	RR1610

Composite Grid References:

GMRT 4.0 (2022) https://www.gmrt.org

Ryan, W.B.F., S.M. Carbotte, J.O. Coplan, S. O'Hara, A. Melkonian, R. Arko, R.A. Weissel, V. Ferrini, A. Goodwillie, F. Nitsche, J. Bonczkowski, and R. Zemsky (2009), Global Multi-Resolution Topography synthesis, Geochem. Geophys. Geosyst., 10, Q03014, doi: 10.1029/2008GC002332

Note: SRTM (Sandwell & Lonsdale) is added by the GDACC to the final global grid.

Data Sources Identified for the 2023 Compilation Thus Far:

Data Sources for 2023 Compilation

Source	Data type	Contribution Via
NGA	6-sec .dat	GDACC
Five Deeps	Grids/ raw	Larry/NCEI
New NONNA surface	Grid/ rest service	CHS
Ocean Exploration Trust	Grids	direct

The NGA data set requires a lot of cross referencing against surveys listed directly as NorPac sources, checks against NCEI and composite sources including GRMT holdings. A lot of data management is required before QC and further evaluation to identity new sources and prioritize bringing in quality data. Other GDACC

contributions in shallow water that are mostly single beam need to be assessed.

Processed in 2022 awaiting final QC and Compilation

Source	Data type	Contribution Via
Single Beam for North Pacific at NCEI	Single Beam	NCEI

Potential Sources for the 2023 Compilation from Repository Sources Identified Thus Far:

1. 29 cruise datasets from Pangea.de
2. 13 cruise datasets from Ocean Networks Canada
3. CHS track soundings (NONNA)
4. 28 Cruises on NCEI
5. Cruises on R2R not yet at NCEI
6. Queen Charlotte Fault Alaska, USGS Survey (data not released yet)

We have started to cross check several potential sources with NCEI holdings as well as what is in composite grids already incorporated. The most unincorporated data has been in newly collected data, some of the older data was found listed elsewhere with different identifier codes or within compilations. Comparison with GMRT 4.0 before processing any of the above data is planned.

Transition from GUI to Script BIS:

The 2022 grid compilation involved a large effort to rebuild the ESRI BIS system in WGS84 using a script- based approach. A key part of rebuilding the BIS was updating metadata and BIS schemas to include more information. Improvements included updating information on Source and Contributing Organizations of existing source grids to improve attribution of sources of data that is provided to NCEI.

The move to a script-based approach for utilizing the Bathymetry Extension and BIS databases in ESRI ArcMap, allows the BIS to be rebuilt quickly once codes are established.

There have been quite a few challenges associated with the transitioning to a script-based approach. Schemas need to match metadata imports, especially if one is using xml enumerated fields to enforce spelling/ exact terminology. BIS scripting is only supported in Python 2, as that is what ArcMap utilizes. However, ArcPro utilizes Python 3. This means quite a few scripts are in Python 3, and some are in Python 2 to take advantage of the power of python modules and improved efficiency of tools in ArcPro. A time- consuming task has been to track down the correct information for some cruises as even NCEI does not always have the correct information listed under ‘source’ on their website if a ‘default’ value was used.

A major issue with using the BIS has been the handling of footprints and source diagrams. Unfortunately, this issue was not resolved with using ArcMap scripts, as it is not just a memory/ rendering issue. Multiple other programs including Global Mapper were used as part of the 2022 process.

Improvements to the grid assembly by leveraging metadata:

The 2022 grid assembly process included sorting data by TID (multibeam, singlebeam, direct measurements), and other rules to address data quality. Attributes were added for future use in compilation regarding quality metrics. For example, attributes about level of QC processing on a survey, position quality, metrics notes while doing QC such as noise level in individual surveys/ or grids, sound velocity issues etc. Inventory of the attributes, and how the BIS rules may be adjusted to take fuller advantage of these new attributes needs

Other activities

Seabed 2030 Bathymetry Contribution Form

The Stockholm University team has developed a bathymetry contribution service using a web form accessible to anyone with a web browser and a standard internet connection shown in Figure 3. The data contribution form is split into four parts described below.

1. Dataset information (metadata)
2. Contact information and consents
3. Bathymetry data file
4. Optional metadata

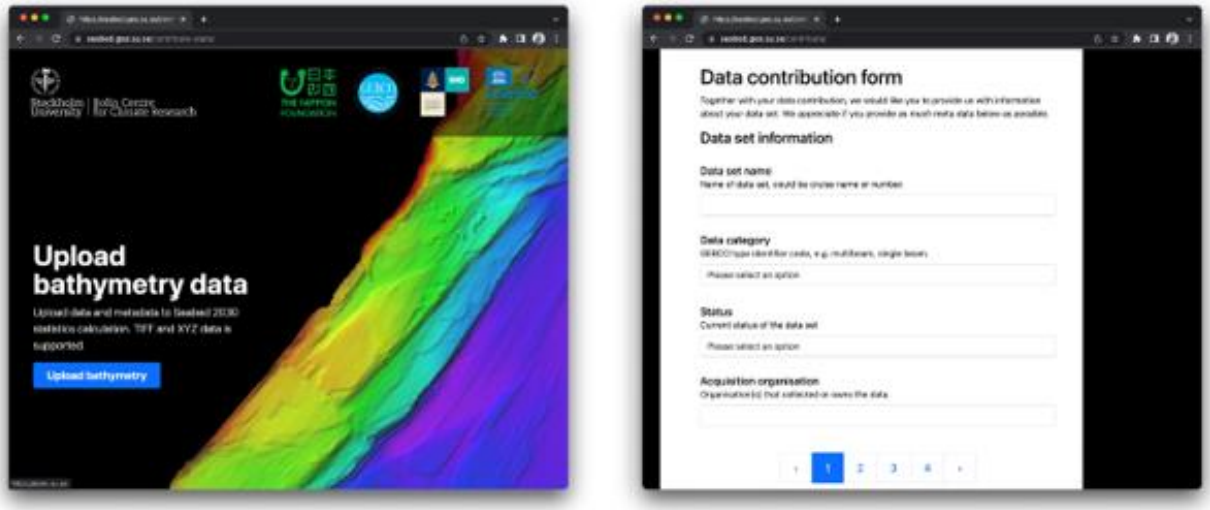


Figure 3: *Seabed 2030 bathymetry contribution form.*

Data and metadata are directly uploaded to Amazon Web Services where they are stored and can be accessed using their web interface by anyone with permission and by the statistical computation system that the SU-team has developed at Amazon Web Services.
The SU-team has also developed a version of the service that can upload multiple datasets concurrently. More than 1200 datasets were successfully uploaded to Amazon Web Services on one occasion. This makes it possible for all Seabed centres to share all their data using the form in order to calculate the coverage statistics.

Development of a data processing system at Amazon Web Services

The SU team has continued the development of a data processing system at Amazon Web Services. Since last year we run the statistical coverage calculation at Amazon Web Services. During the spring we developed a

bathymetry data contribution web form in the same computing environment at Amazon Web Services described above.

The team has also started the work for automating the grid generation using the same computational framework and environment as the statistical coverage calculation, using python utilising cloud computing technologies, distributed computing and vectorized computing. It is considerably faster than the old gridding method using Generic Mapping Tools (GMT). A preliminary test result is shown in Figure 4 using all data contributed for the statistical coverage calculation. While each centre uses their own gridding algorithm, and will continue to do so, we tested the capacity of the gridding workflow we developed on Amazon Web Services for the entire world.

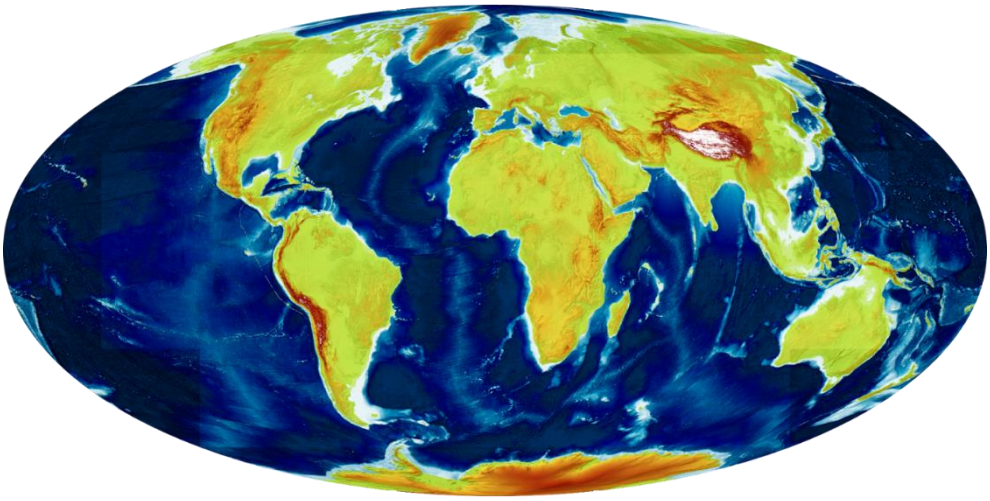


Figure 4: *Seabed 2030 generated grid.*

We are slowly approaching the vision of a fully automated processing system without any manual interaction using 100 % open-source software stack with:

1. a web interface for data contribution submitted to Amazon Web Services
2. a simple structure of data and metadata stored in repositories at Amazon Web Services
3. statistical coverage calculation using the data and metadata, at the target Seabed 2030 resolutions 100, 200, 400 and 800 metres, performed at Amazon Web Services, using python, producing a raster map (in geotiff data format) and data tables (in json data format), presented in a simple web page
4. grid generation using the same data and metadata, in variable resolutions at the target Seabed 2030 resolutions 100, 200, 400 and 800 metres, performed at Amazon Web Services, using python, producing raster maps (in geotiff data format)
5. present the grid in a simple web map

6. develop an update mode in order to speed up the calculation by only processing the modified data and regions since the previous calculation, to present a result nearly immediately after data contribution.

The first three items in the list above are currently operational and list item four is currently functional but needs some major adjustments in order to give satisfactory results. One important adjustment is to change the projection from Cylindrical Equal-Area projection, used in the coverage calculation, to possibly spherical Mercator projection and stereographic projections for the polar regions.

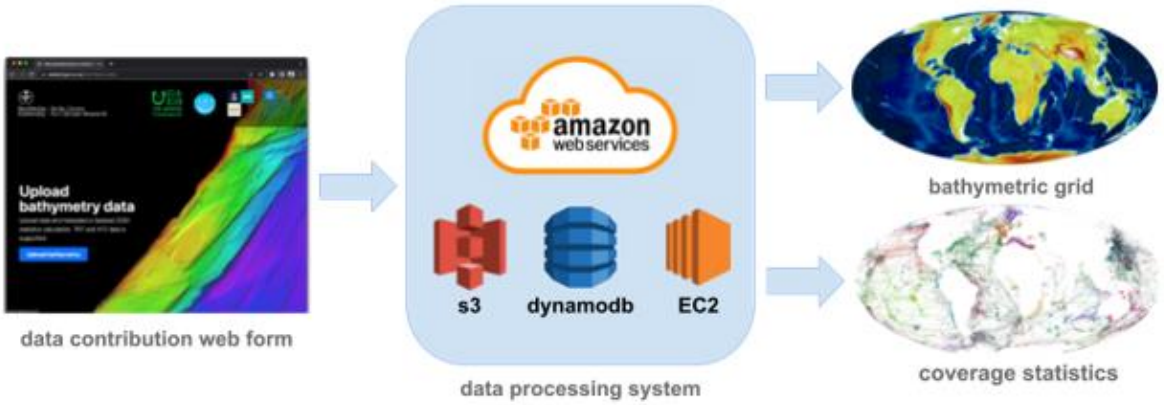


Figure 5: Scheme of Seabed 2030 fully automated system.

North Pacific Interactive GEBCO 2022 Map Service Tool:

One of the many challenges of assembling the yearly GEBCO grid has been the ability to manage the datasets contributing to each version of the grid, as well as determining the availability of new datasets in relationship to the existing ones. To assist with this effort, the North Pacific team has created a North Pacific Data Management web application: (https://gis.ccom.unh.edu/portal/apps/instant/sidebar/index.html?appid=3a2015e273c341aa91e09f86407285bc or Figure XXXX2). The webapp has abilities that are similar to desktop GIS applications, allowing either the North Pacific team members or the general public to easily: 1.) assess the spatial relationship of integrated datasets to either the bathymetric data or the type identifier grids, 2.) query the DCDB's publicly available web services for the availability of new datasets, and 3.) examine the North Pacific's products and the GEBCO products relationship to other data sources including NOAA datasets (BAGS, Digital Survey, Hydro Survey, Gap Analysis, etc.), DCDB datasets (single beam track lines, multibeam tracklines, etc), and the Global Multi-Resolution Topography grid. This service was updated this year with the new GEBCO 2022 grid and was migrated to a new UNH/CCOM-JHC server to allow for easier interaction with the data.

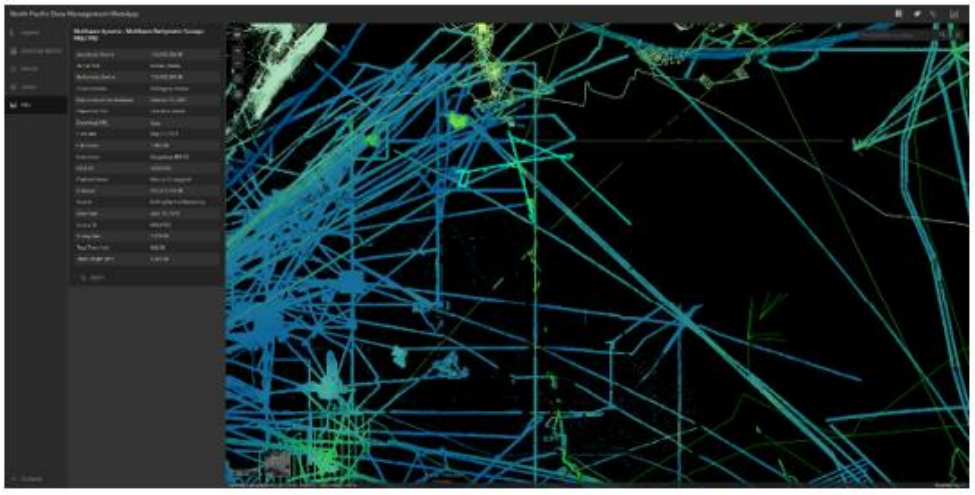


Figure 6: *The 2022 North Pacific data management WebApp allows for the easy assessment of available data by aggregating publicly available webservices and those service created by the North Pacific team in one spot.*

Online Interactive GEBCO 2022 Grid Quality Assessment Tool:

During the Spring of 2022, the UNH team developed a new interactive web applications that allowed each of the Seabed 2030 RDACCs, the Global Center, and members of the GEBCO Technical Sub-Committee on Ocean Mapping (TSCOM) to visualize and comment on the draft releases of the GEBCO 2022 bathymetry grid. Building on the development of the 2020 and 2021 review applications, the new web application's interface displays the draft version of the grid as a multi-directional hillshade (shaded relief) illuminated bathymetry with an optional overlay of the TID, as well as an editable comments layer. Within this interface (Figure 7), the Seabed 2030 community can draw freehand shapes, polygons, or other defined shapes that contain embedded metadata documentation including the reviewer/agency name, the type of data issue, the version of the grid, and any comments or observations. Each of these metadata fields are logged within a database on the UNH GIS server, which in turn can be exported to a shapefiles at the request of any of the RDACCs or the Global Center. This interface has allowed a global collaborative approach to data quality assessment of large-scale datasets prior to them being released to the public.

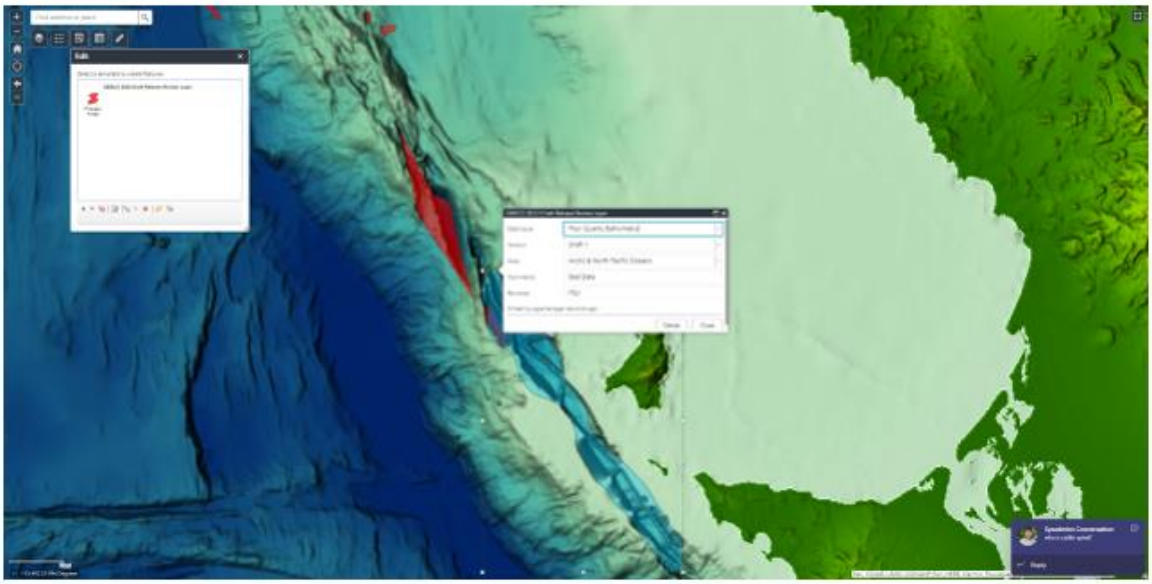


Figure 7: *Screen shot from the GEBCO 2022 data review web application hosted on the UNH GIS portal, showing a newly designed review application used to assess the GEBCO 2022 draft releases. Users can graphically annotate areas identified that require further inspection.*

Online Interactive Visualization Tools: GEBCO Globe

The GEBCO 2022 bathymetry grid is difficult to work with and to visualize (as was the GEBCO 2020 and 2021 grids), due to its very large size, 86,400 x 43,200 grid nodes The North Pacific team has continued to explore how to push the envelope on providing the general public with easy-to-use web applications to visualize and interact with the GEBCO grid datasets. There is now a more refined version of the "flat" map viewing application for the GEBCO 2022 dataset which is available from the UNH GIS Portal at https://gis.ccom.unh.edu/portal/apps/instant/basic/index.htmlappid=8db748ecdca44e75b673ba69eee1472a or shown as the top image in Figure 8. This version of the web application allows for the display of the bathymetry layer with a dynamically adjusted color palette based on the range of depths in the viewer. Over this, users can toggle a mask layer to black out regions which were not determined through direct measurements. The North Pacific team has also created a new 3D Global viewer (see top right and bottom images of Figure XXXX4 or https://gis.ccom.unh.edu/portal/apps/instant/3dviewer/index.html?appid=b19220958baa43b1869a4689efe2b050) which now includes an elevation layer with a 5x vertical exaggeration which allows for oblique views of the GEBCO 2022 grid to be generated. This viewer now also allows the users to toggle on and off a mask layer, just like the "flat" map version mentioned above, as well as a color shaded-relief version of the direct measurement bathymetry data, and a Type Identifier (TID) layer. A new feature that was added in 2022 is the ability of the glove to automatically rotate for visualization of the whole globe.

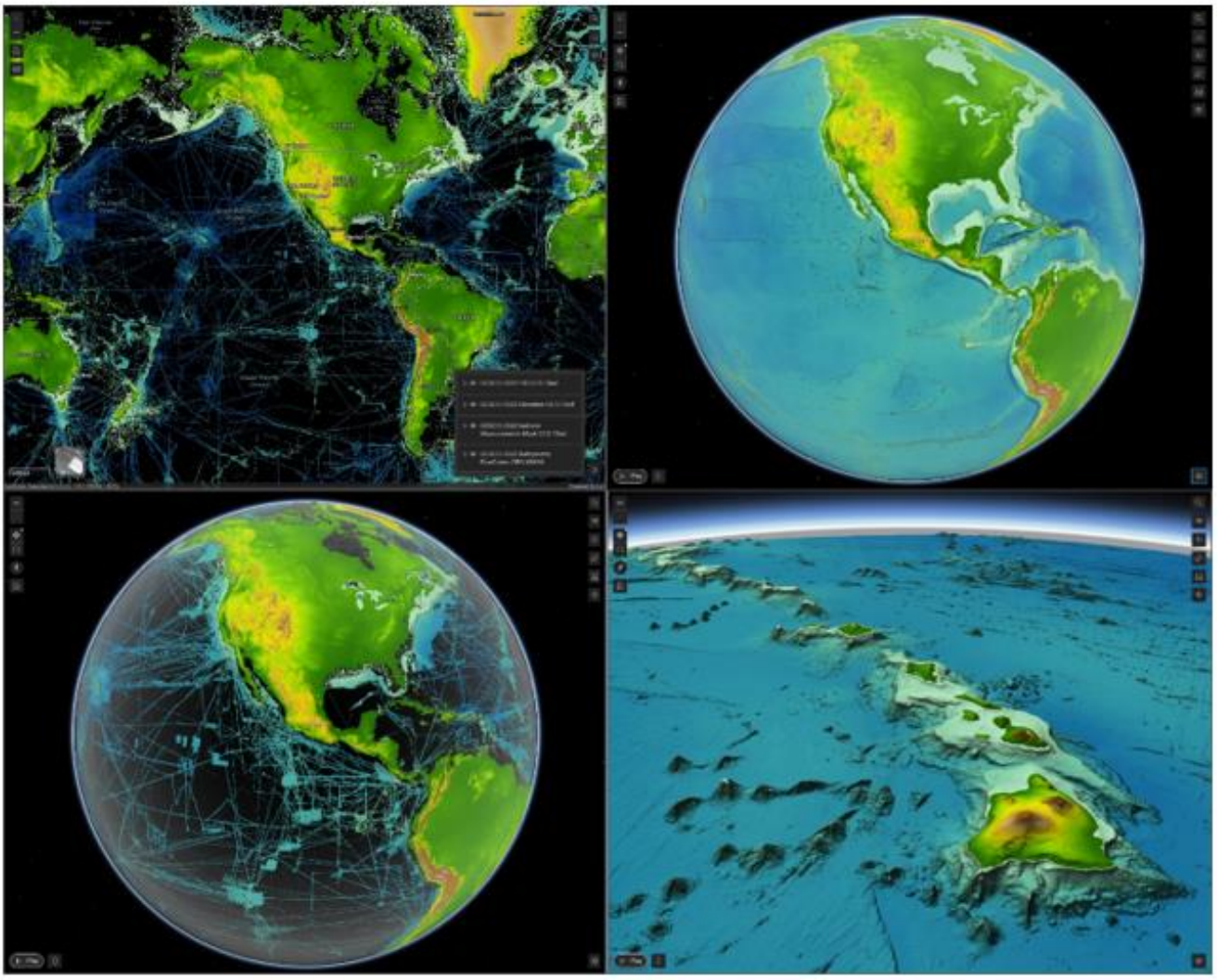


Figure 8: *Screen shot from the web applications which are hosted on the UNH GIS portal (https://gis.ccom.unh.edu). The top-left image shows a "flat" map of the GEBCO 2022 grid (https://gis.ccom.unh.edu/portal/apps/instant/basic/index.html?appid=8db748ecdca44e75b673ba69eee1472a), with areas not determined by direct measurement being blacked out. The top-right and bottom images show the new 3D global visualization of GEBCO 2022 bathymetry grid (https://gis.ccom.unh.edu/portal/apps/instant/3dviewer/index.html?appid=b19220958baa43b1869a4689efe2b050) which now also has an updated elevation layer loaded to allow for viewing the data obliquely with a 5x vertical exaggeration.*

Enhanced BathyGlobe: Gap-Filler Survey Planning Tool:

The BathyGlobe application, reported on over the past few years and designed to allow the interactive display of bathymetric coverage at true scale (so that one can truly see how sparse coverage is) is built in a modular fashion, with components that can be combined in alternative ways for various applications. Taking advantage of this is a 'gap filling' cruise planning application, has been developed (and now offered independently from BathyGlobe as "GapFiller") that allows the optimization of new coverage during survey planning for situations where multibeam mapping will be done either in transit or in traditional full-coverage situations.

BathyGlobe GapFiller

The GapFiller application was first reported in 2020. It is a BathyGlobe spinoff designed to support voyage

planning with a view to filling gaps in existing multibeam coverage, especially during transits. It does overlap adjustments to help the planner set waypoints such that a new swath overlaps and existing swath by a designated amount, e.g. 10%. The premise is that to achieve the goals of the global mapping enterprise, a strategy of systematically abutting existing lines will be better in the long term than the "greedy" algorithm of simply seeking to fill the most unmapped area in transit planning. This past year, a number of improvements and additions have been made to GapFiller:

Better Overlap Adjustment Algorithm

The original overlap adjustment algorithm worked as follows: The planner would lay down a pair of waypoints defining a line that partially overlapped a previously mapped line. The program would compute the estimated swath width along the line taking both predicted and mapped bathymetry into account. Following this, the percentage overlap between the estimated line and the existing line was calculated at every point along the planned swath. A linear regression was then used to fit a line through the overlap percentage values. Finally, the regression parameters were used to adjust the waypoints to achieve a constant fixed overlap along the length of the planned swath.

This algorithm worked well in cases where the previous line was fairly straight and without gaps or ragged edges. But when this was not the case, it suffered from the shortcoming of all least-squared methods, namely the fact that outliers have an overly large influence. Various methods were devised to attempt to remedy this problem, such as detecting and ignoring gaps in prior swaths, these added complexity to the code and the results were not robust.

A new algorithm has been developed which is much more robust and reliable. Instead of being based on linear regression, it is based on techniques derived from image processing. A custom edge detecting filter was developed that uses arrays of samples, designed to give the strongest response when the filter overlaps an existing multibeam edge by a designated amount. If a region of seabed is labeled such that all mapped regions are given a value of +1 and all unmapped regions are given a value of -1, the filters response will be maximal when the edge overlaps by the specified amount.

As illustrated in Figure 9, the sampling can be made asymmetric with sample points more widely spaced on the new mapping side than on the previously mapped side. When a previously mapped swath is perfectly straight this has no effect on overlap. But in cases where there are irregularities in existing coverage this makes the method more tolerant of too much overlap compared to too little overlap. In general, this method is far more robust to gaps in prior mapping and other irregularities in the data. Figure 41 (right) shows the application of the method where both a gap and an excursion are present.

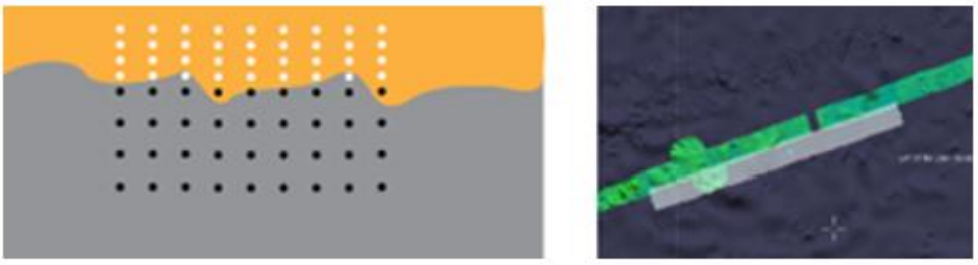


Figure 9 *(left) A filter custom designed to adjust overlap in planned multibeam swaths. (right) A example of its application.*

Arctic Version of Gap Filler

The Gap Filler application was developed using a Mercator projection which is not suitable for Arctic applications. So that the methods could be used in the Arctic, a new version was developed using a polar stereographic projection for use with IBCAO data. A screen is illustrated in Figure 10. This version was used for the recent Healy Northwest Passage transit, and it has been enthusiastically received by Greenlandic hydrographers with whom we are working closely. To make it compatible with the original Mercator GapFiller, it can ingest sets of waypoints that crossed into the Arctic region, not displaying those outside of the IBCAO dataset.

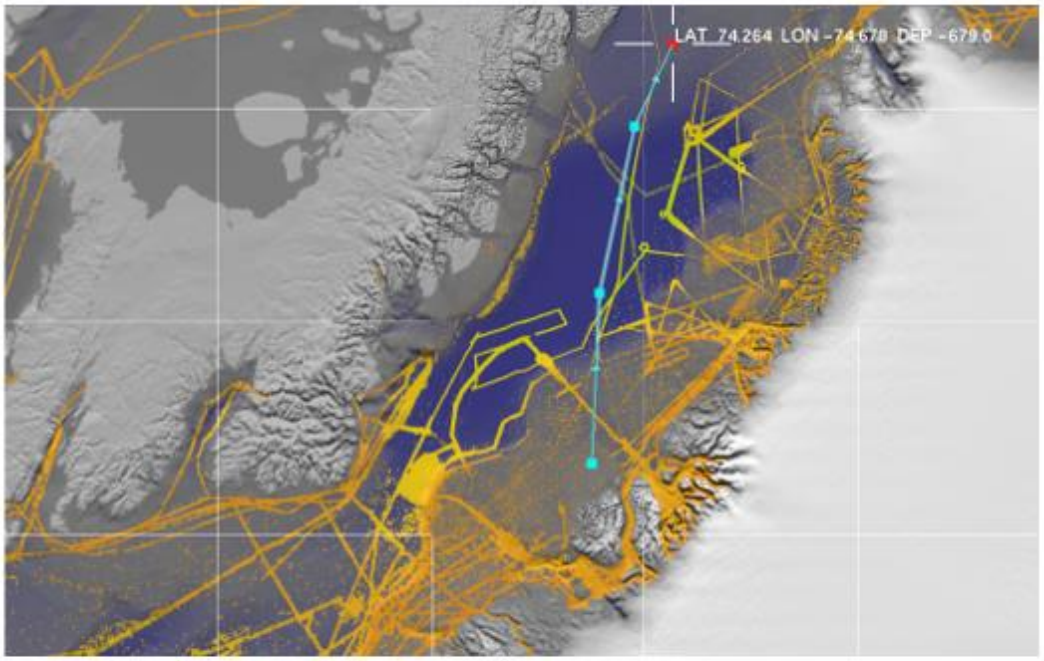


Figure 10. *Arctic version of GapFiller used for planning NW Passage Transect.*

Global GapFiller

Having two versions of the GapFiller is clearly undesirable for anyone planning a mapping cruise which spans both Arctic and sub-arctic regions. Although this could be accomplished by doing part of the planning using the original Mercator application for subarctic regions and the Polar stereographic application for Arcic regions a unified version would be clearly desirable and would obviate to need to maintain two different versions. The Global GapFiller was develop as a solution Figure 11.

The strategy used for the Global GapFiller has been to ingest both GEBCO and IBCAO tiles in their native grids (Lat/Lon and Polar Stereographic respectively). These are displayed to the user in the form of a locally defined stereographic projection while retaining their native formats internally. The method requires that projection transformations be done internally (between local Stereographic, Geographic Coordinates, Mercator and Polar Stereographic) as required, but in a way that is invisible to the user who only sees a single view and points labeled with Geographic Coordinates.

Whenever a point is sampled, if it is above 68 deg N. the attributes and depth values are taken from IBCAO. If it is below this latitude they are taken form GEBCO.

At the time of this report, this version is complete with respect to the projection transformation. However some of the features, such as polygon filling have not been integrated and tested.

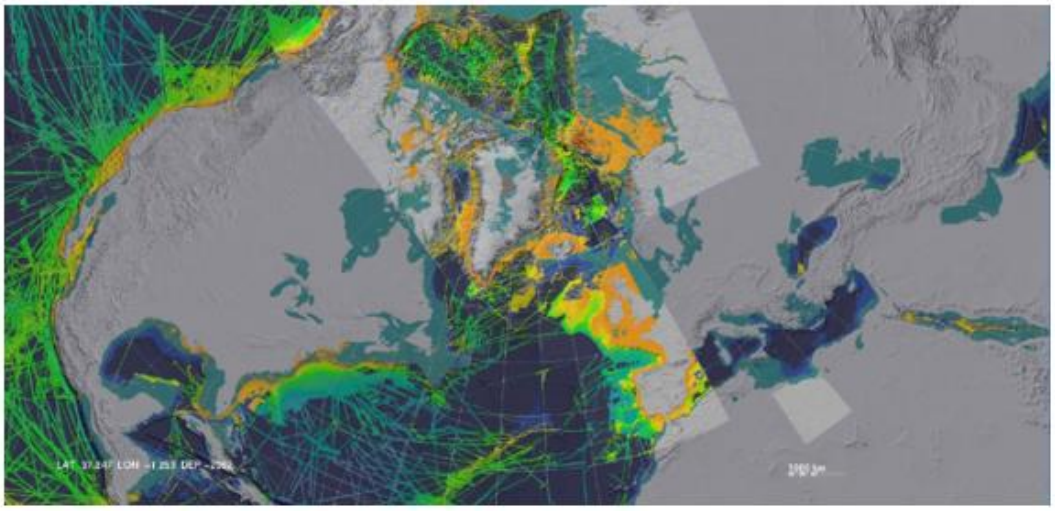


Figure 11. *Global GapFiller combining IBCAO in Arctic polar regions and GEBCO 2022 data set in non-arctic regions.*

Real-world extinction curves:

Another addition to GapFiller this year, is the addition of real-world extinction curves (derived from Multibeam Advisory Committee field testing on multibeam sonars), for the calculation of coverage for a given sonar type and/or specific vessel. This effort has just begun and will be reported on in more detail in the next progress report.

Ingest NCEI Single-beam data sets:

342 single beam surveys dating from 1990 to present were kept after filtering out the sub-bottom profile data from the 589 trackline files obtained from NCEI in the North Pacific region. These data can be found through the NCEI's Marine Trackline Geophysical database/ single beam data viewer at NOAA's NCEI that fit within a general box bounding box. The database contains data in an "MGD77" format from different sources, including the US, universities, and government agencies worldwide. (These data do include some NOAA NOS OCS surveys, which are part of other compilations.) We used the GEODAS shapefile maker to convert the MGD77T formats to create shapefiles (points) of single beams. The MGD77T formats comprise the header and data records files. Data was projected to WGS84 after this conversion to points. Older data (such as from the 90's) used a slightly different format that used -9999's to show no data. The newer singlebeam data, however, doesn't use numeric values to represent no data. The data was filtered to remove points with no depths values assigned to it and those with -999999 (error) depth values.

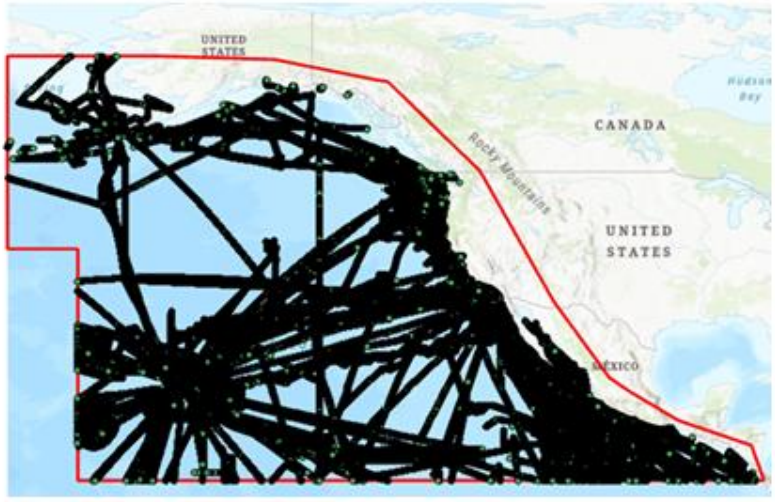


Figure 12. Singlebeam track lines provided by NOAA's NCEI cropped to the area of North Pacific.

Figure 13: Single beam data lines viewed within Qimera

Further processing:

1. The remaining points were compared with the 2021GEBCO grid elevations.

2. We calculated the absolute depth and percentage differences between the points and GEBCO.
   We then kept values with 4% or less difference between the GEBCO 2021 grid and the single beam grid.

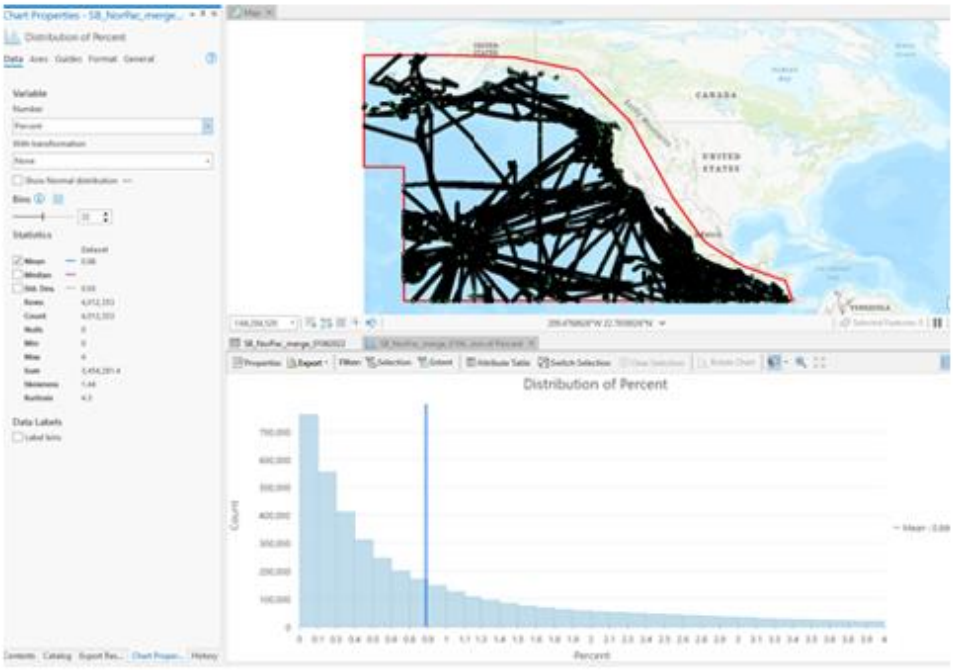


Figure 14: Filtering of data in ArcPro

Michael Bogonko did most of the processing of the single beam. Further QC will be done before incorporating in the 2023 grid. We anticipate based on experiences with OLEX and GMRT that we will have some challenges with incorporating the large volume single beam grids, which our work with scripts and work outside of ESRI BIS may help with.

Ocean Frontier Mapping Initiatives:

SAS (Synoptic Arctic Survey)

Two from the SU team (Bringensparr and Castro) participated in the Synoptic Arctic Survey (SAS) 2021 with Swedish Icebreaker *Oden* as multibeam operators. This made it possible to collect data during the entire expedition, which covered a large area of the central Arctic Ocean including parts of Amundsen Basin, Nansen Basin, the North Pole, Lomonosov Ridge, Morris Jessup Rise and the Yermak Plateau (Figure 15). The expedition is the Swedish contribution to the SAS Program, a coordinated effort focusing on the status and change of the Arctic ecosystem. The expedition started Northeast of Svalbard and ended on the Yermak Plateau, it lasted from August 2 to September 11, 2021. The main scientific goal was to investigate the present state and ongoing transformations of the marine ecosystem. More than 12,000 km^2 multibeam bathymetry was collected, out of which >70% covers previously unmapped seafloor.

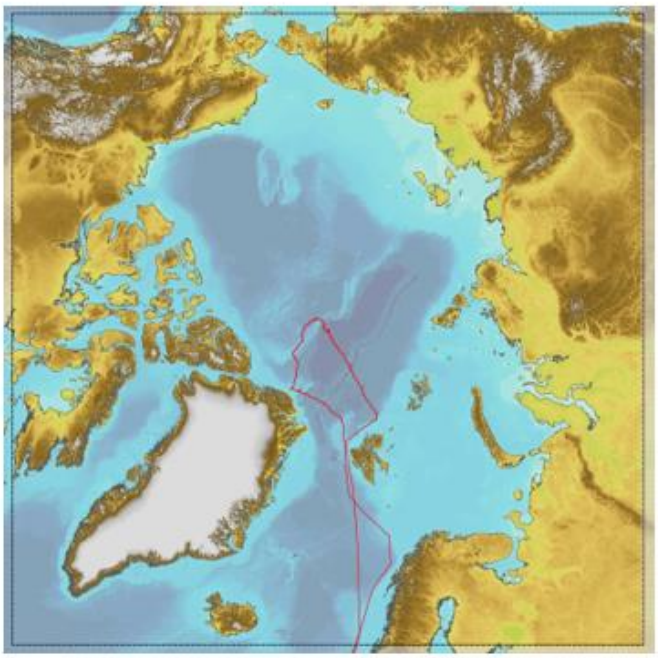


Figure 15: *Cruise track of the Synoptic Arctic Survey (SAS) 2021 with Swedish Icebreaker Oden. Multibeam bathymetry was collected continuously during the cruise.*

Saildrone Aluetian Mapping:

Work initiated through the support of the The Nippon Foundation-Seabed 2030 Ocean Frontier Mapping initiative through its support of the maiden voyage of the Saildrone SURVEYOR from San Francisco to Honolulu Hawaii in June and July of 2021, continued in 2022 with support of NOAA's Office of Ocean Exploration. The Saildrone SURVEYOR is a unique 22 m autonomous sailing craft built specifically for long, uncrewed ocean voyages and the collection of deep-water bathymetric data along with a range of other important environmental data. The Saildrone Surveyor is equipped with both a Kongsberg EM 304 and an EM2040 multibeam echo sounder providing high-resolution mapping capability in both shallow water and deep waters to depths as great as 7,000 meters. The Surveyor also carries two Acoustic Doppler Current Profilers (ADCPs) to measure ocean currents, a full suite of fisheries (EK80) echo-sounders and a range of environmental sensors. All sensors are operated and monitored remotely. Figure 16 provides the specifications of, and sensor suites on, the Saildrone SURVEYOR.

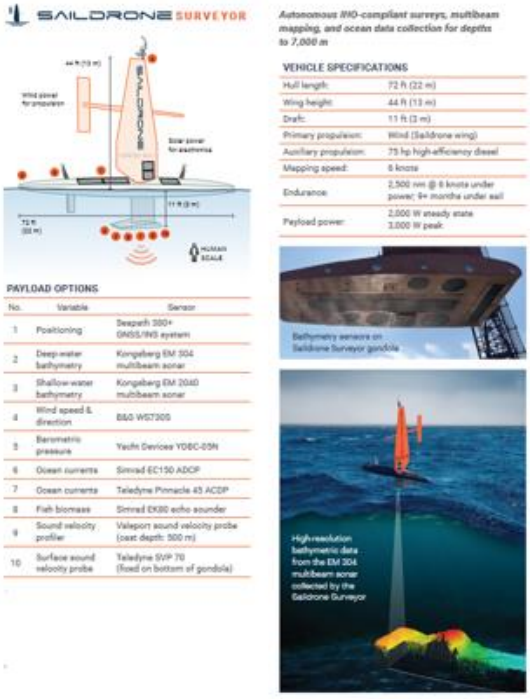


Figure 16 – Specifications for Saildrone SURVEYOR

The Saildrone Surveyor was developed in part through a public-private partnership with the University of New Hampshire (UNH) and the Monterey Bay Aquarium Research Institute (MBARI) to integrate and test sensors on the Saildrone SURVEYOR for mapping the seafloor and revealing life in the water column. UNH has taken responsibility for the testing and verification of the mapping sensors and MBARI has installed a system for collecting environmental DNA (eDNA) samples from the water column. These samples provide DNA originating from the sloughed-off skin, mucus, and excrement of a wide variety of marine animals—which will reveal the genetic composition of organisms inhabiting the water. This aspect of the development including the initial seagoing acceptance tests was supported by the National Oceanic and Atmospheric Administration (NOAA) Office of Ocean Exploration and Research (OER) through the National Oceanographic Partnership Program (NOPP) through funding to UNH. The implementation and concept of operations of the system that were established through the NOAA funding were then put to a full test on the trans-Pacific mapping transit from San Francisco to Honolulu that was funded, in part, by the Nippon Foundation-Seabed 2030 Ocean Frontier Mapping initiative. This year's effort, entirely funding by NOAA, demonstrates the impact of the initial funding for technology development provided by the Nippon Foundation.

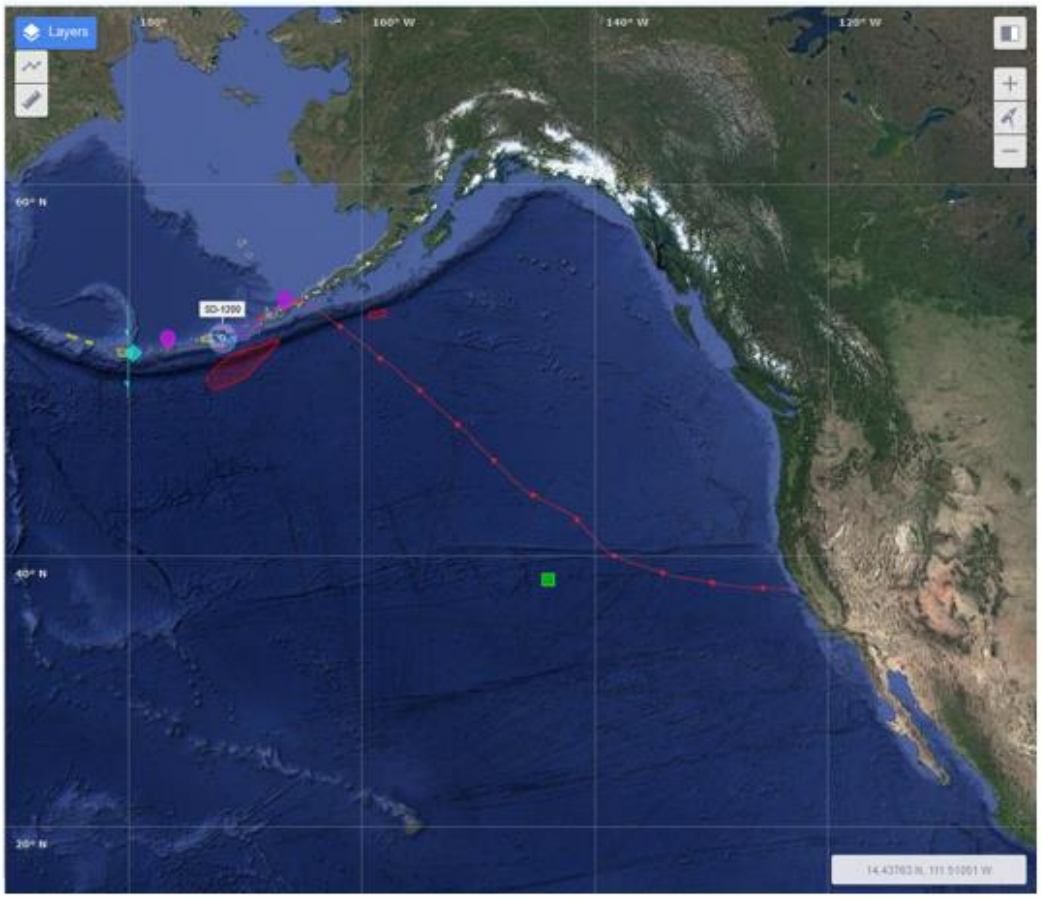


Figure 17. *Route of Saildrone SURVEYOR for Aleutian Mapping Mission. The SURVEYOR departed Alameda Ca, on 9 July 2022 and arrived in Dutch Harbor on 8 August. After a brief maintenance period the SURVEYOR embarked on its mission mapping both shallow and deep water areas (see below)*

After an approximately 30 day autonomous transit from Alameda CA to Dutch Harbor Alaska (Figure 17). The Saildrone SURVEYOR embarked on a dedicated mapping and eDNA sampling mission at high priority shallow and deep-water sites around the Aleutian Islands (Figure 18). These sites represent unmapped areas of particular interest to various U.S. federal agencies (NOAA Ocean Exploration, NOAA Office of Coast Survey, U.S. Geological Survey and others). The mission is still underway and so far, data quality has been excellent, despite, sometimes harsh weather conditions.

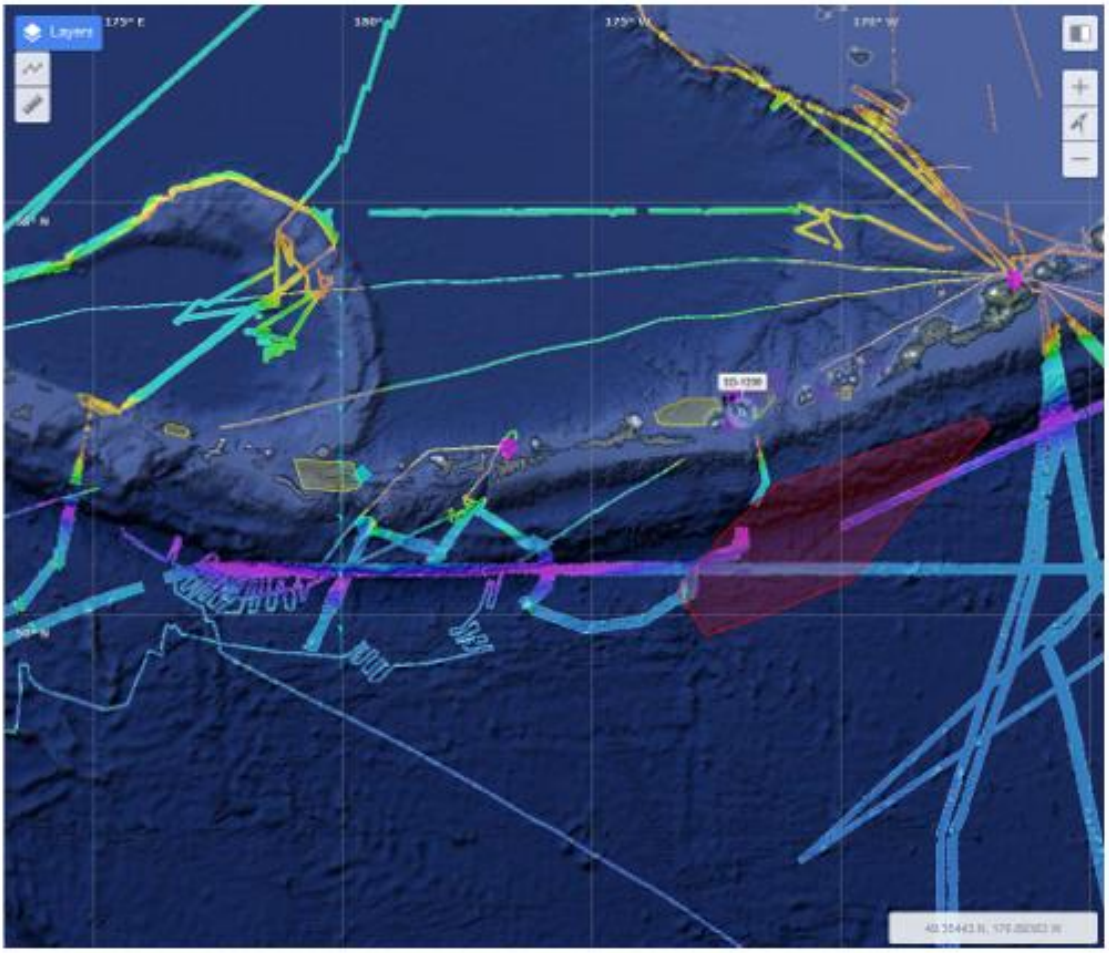


Figure 17. *High priority sites to be surveyed by Saildrone SURVEYOR during Aleutian Mapping Program.*

The mission is continuing as this report is being written. To date, the mission has been 51 days long and travelled 4102.9 nm; full details of the mission will be reported in next year's progress report.

Financial Report

All funds have been apportioned to Seabed 2030 activities at SU and UNH.

Global Center

Location: British Oceanographic Data Centre, National Oceanography Centre, United Kingdom.

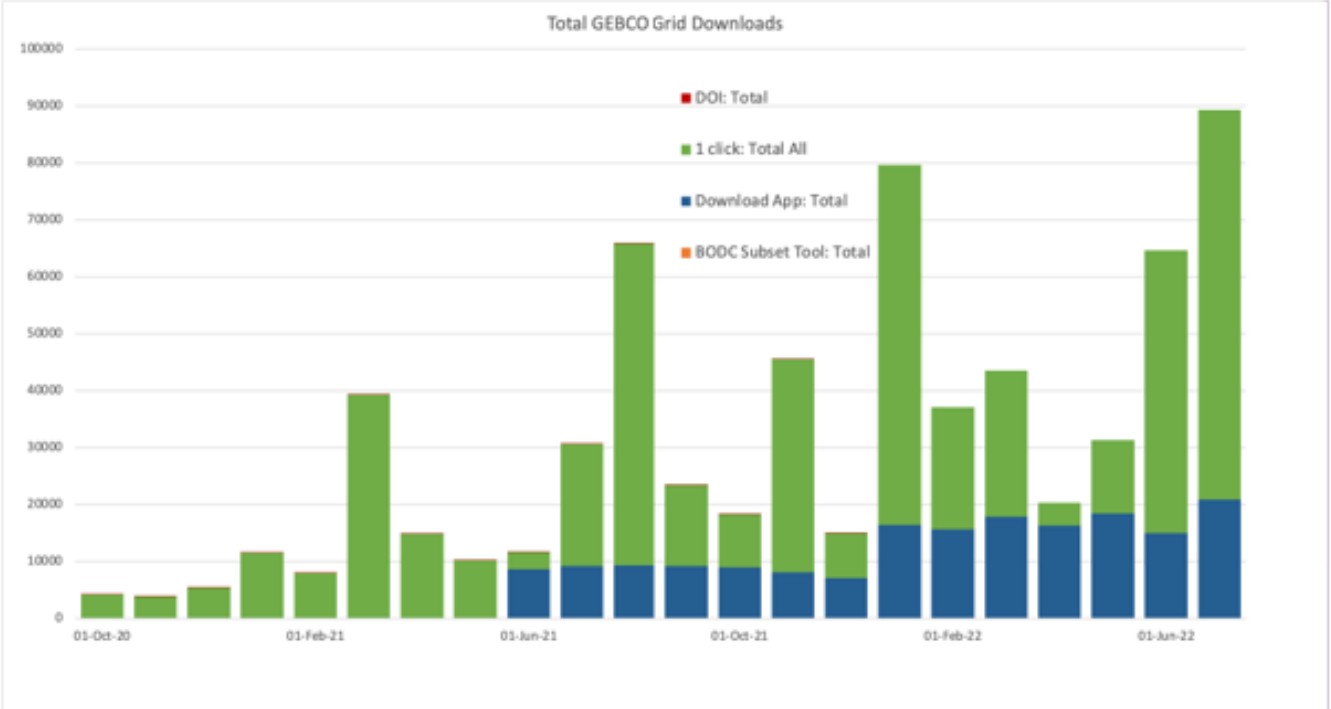
Center Lead: Helen Snaith.

Summary

During Year 5 of the project, the Global Center has continued to focus on effective development and delivery of the global gridded products, and collection of the metadata according to the agreed standards to support reporting for the project. During this period, the Global Center has also been developing a procedure to become

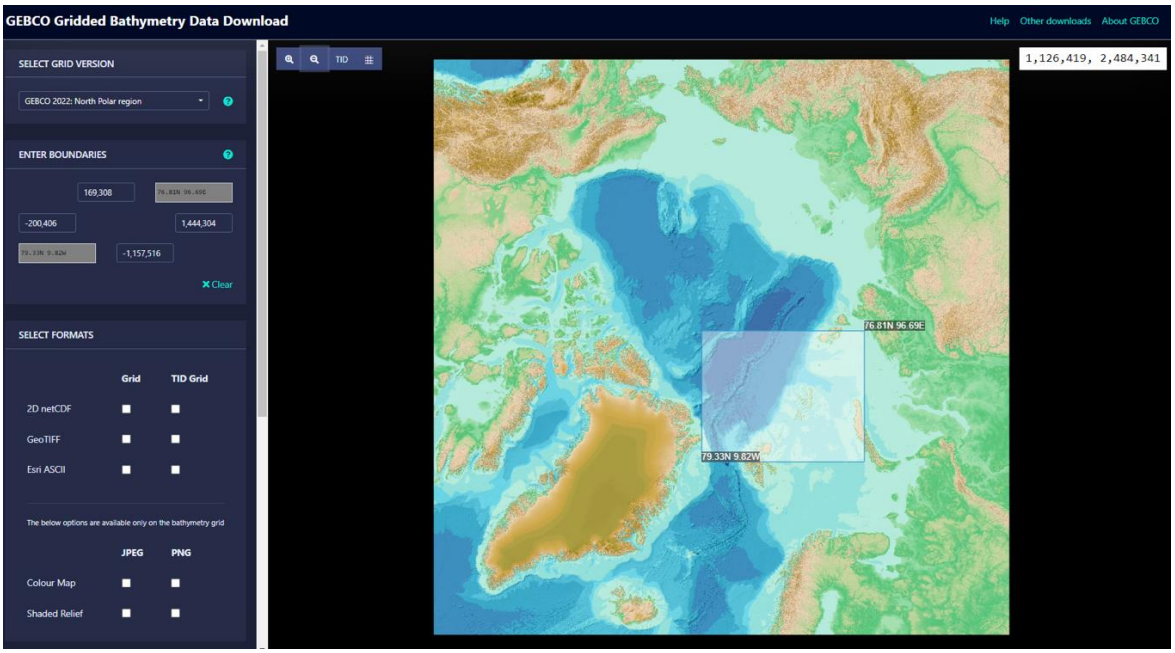
the ‘Seabed 2030 trusted node’ for Crowd Sourced Bathymetry.

The final GEBCO_2022 global bathymetry grid and associated type identifier (TID) grid was released in June 2022, based on the SRTM+ v2.4 base grid with Regional Center inputs merged to create the global products, providing both an under-ice bathymetry/topography and the standard ice-surface version of the grid. The new dataset was allocated a new doi. Consistent with previous releases, the products are available in a number of different formats: globally as a single CF-compliant NetCDF file or as a package of GeoTIFF or ESRI ASCII format tiles and also through a dedicated data download service developed within the project.



Total Downloads of the GEBCO gridded products during Year 5

There were almost three times the number of downloads of bathymetry products in year 5 (344,840) as in year 4 (119,627). This equates to more than 6,600 per week
. A significant enhancement to grid delivery for 2022 has been the addition of high latitude grids in polar stereographic coordinates, in a number of formats, for direct download and through the download application.



Selecting a subset of the Arctic area grid through the GEBCO grid download app.

Working in close collaboration with colleagues at CCOM, who have developed a processing workflow for CSB data, the Global Center has successfully received and processed data from a small number of yachts through the Seabed 2030 CSB programme. The Center is now able to act as a 'trusted node' for the project, delivering data to the IHO DCDB. The intention is to provide a data delivery route for contributors who do not, yet, have an established trusted node. This may be extended where larger groups are unable to provide their own trusted node service.

The Seabed 2030 website has been maintained during the year, with the project team able to add news and events as required and add additional partners to the appropriate pages. The Drupal interface remains stable and simple to operate for users, allowing frequent site updates. Data contributors are highlighted on the GEBCO website.

Center Staff

The Global Center still has a full staff complement, with three staff working regularly on the Seabed 2030 Project (Helen Snaith, Pauline Weatherall and Chris Thompson). During Year 5, we have been utilising the development team in an agile software development framework, providing a wide range of additional skills to the project.

Major data and grid contributions

As with previous releases, the GEBCO_2022 data set is a global elevation model for oceans and land on a 15 arc-second interval grid. We have continued to generate a version which includes under-ice topography/bathymetry information for Greenland and Antarctica, as was provided in 2021. The grid is accompanied by a Type Identifier (TID) Grid, indicating the type of data that the corresponding grid cell in the bathymetric grid is based on.

Outside of the polar regions, the grid uses as a base SRTM15+ v2.4, produced by David Sandwell and colleagues at Scripps Institution of Oceanography (SIO). This data set is based on a database of ship track soundings with interpolation between soundings based on satellite-derived gravity data. Throughout 2021 and 2021 the Global Center has coordinated with the SIO group responsible for the SRTM15+ development to continue to identify problem areas and improve the grid, resulting in the v2.4 SRTM grid used here.

The Global Center also investigated improved methods for merging the Regional Center partial grids into the base grid. The 2020 and 2021 grids used a simple pasting methodology to allow clear identification of the new data and reduce the impact of unintended 'edge' effects in the final grid. This left some clearly anomalous 'cliff-edge' effects in the 2021 grid. As the discrepancies between data are now reduced, and with input from the technical team supported by the GEBCO Technical Sub Committee (TSCOM) Representative, it was decided to apply a remove-restore methodology to provide a more continuous surface. A draft grid using this process was produced in early 2022 and the Global Center coordinated feedback from the Seabed 2030 Technical Team, TSCOM and GEBCO Sub Committee for Undersea Mapping before creating the final product.

Crowd Sourced Bathymetry

During Year 5, the Global Center has been working with colleagues at CCOM to create a workflow for Crowd Sourced Bathymetry submitted to Seabed 2030. CCOM have developed a version-controlled code base that provides tools to:

- Convert a number of data logger formats to a single flexible format (that is used for their own data loggers).
- Add essential metadata to the logger files to identify the data source and processing.
- Convert the logger format files to geo-located json format files suitable for upload to the IHO DCDB.
- Submit the data files to DCDB through a secure Amazon Web Service.

This code base has been developed into a workflow suitable for accepting a number of different data streams being delivered through some of the Seabed 2030 partner programmes, such as the *SeaKeepers* initiative. Whilst there are still some teething issues regarding provision of appropriate metadata, this has allowed the Global Center to act as a 'Trusted Node' for DCDB for these contributors. The development of an MOU with Terradepth has also allowed access to their 'Absolute Ocean' cloud-based platform, which will be used to provide a visualisation of the data files for the data contributors. This is currently undergoing testing.

Financial report

All funds were allocated to seabed mapping activities.

Other activities

In collaboration with members of TSCOM, the Global Center has investigated providing a service to allow simple ship-route planning based on the location of data gaps. The agreed approach is that a TSCOM working group will first develop a simple 'data – nodata' layer, based on existing published data, that can be readily used in an online GIS service. The Global Center will provde the hosting service for the layer, together with the applications to use the layer to plot simple routes. The preparatory work has been carried out at the Global Center to provide a cloud-hosted service that can be used for the application. The service will be extensible to allow regular updating of the data layer and to provide access to more extensive metadata associated with the data sources as this is later developed.
Global Center staff continue to support the primary communications mechanisms for the Seabed 2030 Project. As well as maintaining the website and website content, we provide content to the Seabed 2030 and GEBCO Facebook and Twitter accounts. As the access point to the Seabed 2030 Project and the GEBCO data products, we provide user support to product users and statistics on data access and usage for GEBCO.
The Seabed 2030 website has been maintained during the year on the Drupal-based cloud service. There has been no down time of the site over the year. The Global Center acts as moderator for content provided to the site by project staff and the communications team. The Global Center also ensures that the GEBCO website is

updated with the essential data product information and supporting documentation generated from the Project, including lists of contributors.
We also maintain the internal project communications tools (email accounts, wiki and document repositories). The Global Centre staff also facilitate the monthly technical team meetings.
Whilst travel has been curtailed by COVID restrictions, Center staff have had limited opportunity for contribution to wider national and international meetings. However, Center staff have provided regular input for the Project Newsletter, and have supported the Project through the Communications Team, in editing news items, press releases and other articles.

IHO Data Center for Digital Bathymetry

Location: National Oceanic and Atmospheric Administration's National Centers for Environmental Information (NOAA NCEI) in Boulder, Colorado, USA.

DCDB Director: Jennifer Jencks

DCDB Data Managers: Jess Nation, Christie Reiser, Georgie Zelenak

Summary

The IHO Data Center for Digital Bathymetry (DCDB) is the recognized IHO repository for all deep ocean bathymetric data collected by hydrographic, oceanographic and other vessels. Since 1990, NOAA's NCEI (formally NGDC) has hosted the DCDB. In support of the IHO Crowdsourced Bathymetry (CSB) Initiative, the DCDB built and supports a data pipeline that also allows for the ingest, discovery and access of CSB data.

In addition to data archiving, the bathymetry team focused much of their Year 5 effort continuing their work with the NOAA NCEI Software Development Team on enhancement and implementation of new end-to-end data pipelines for both CSB and multibeam bathymetry that will ultimately allow for a much more flexible inclusion of data.

The DCDB Director also continued to focus on outreach efforts towards the IHO Regional Hydrographic Commissions (RHC) by producing regionally-specific presentations on the data sharing and the CSB effort and co-organizing webinars for the Meso-American and Caribbean (MACHC) and SouthWest Pacific (SWPHC) Hydrographic Commissions. DCDB Data Managers also attended (virtually and in person) all Seabed 2030 Regional Center meetings.

DCDB Infrastructure Enhancements

- Progressed transition from current (outdated, inflexible) multibeam bathymetry database to new schema that will enable a better system for versioning of processed swath files, discovery of backscatter and ancillary files, efficient tracking of metadata for more complex datasets, and management of products associated with multiple surveys.
- Progressed build out of a new end-to-end multibeam archiving system. The system will feature increased automation (more efficient archiving times), improve error handling and notifications and include flexible options for future file readers and plugins. Enhancements will enable the ability to handle new multibeam data formats, new platforms (eg: uncrewed systems), processed data, and products.
- Deployed improved crowdsourced bathymetry (CSB) pipeline. Previous pipeline had been out of commission for over a year. 2020-2021 contributed data has now been ingested and made discoverable

to the public.

- Deployed a cloud-hosted continuous point store. Moving to the cloud will allow for CSB data (and eventually all bathymetric data sources) to be stored as a seamless collection of points. The CSB data are currently available either through the NOAA Big Data Program or through the DCDB viewer. Moving to the cloud now allows for CSB data to be stored as a seamless collection of points. The end user can now query this point store to extract just the data of interest and request that a grid be created from the results.

- Implemented numerous enhancements to the IHO DCDB Data Viewer (ncei.noaa.gov/maps/iho_dcdb/).

Data submission

The DCDB has archived over 2.5 TB uncompressed (1.4 TB compressed) of multibeam bathymetry data from 206 surveys and 24 sources. This includes:

- 55 surveys from 10 vessels contributed by UNOLS Rolling Deck to Repository (R2R).
- 28 surveys from 3 vessels contributed by Fugro Geoservices.
- 18 surveys from 3 vessels contributed by Marine Geoscience Data System (MGDS).
- 15 surveys from 6 vessels contributed by National Oceanic and Atmospheric Administration (NOAA); including 4 surveys from 1 vessel contributed by NOAA Ocean Exploration and Research (OE)
- 71 survey packages from 1 vessel contributed by Caladan Oceanic LLC.
- 7 surveys from 1 vessel contributed by Global Multi-Resolution Topography Data Synthesis (GMRT).
- 3 surveys from 1 vessel contributed by University of New Hampshire, Center for Coastal and Ocean Mapping (UNH/CCOM).
- 2 surveys from 1 vessel contributed by the Bureau of Ocean Energy Management (BOEM).
- 1 survey from 1 vessel contributed by the East China Sea Branch of State Oceanic Administration.
- 1 survey from 1 vessel contributed by the United States Geological Survey (USGS).
- 1 survey from 1 vessel contributed by University of Texas Institute for Geophysics.

Over the last year, the DCDB continued to bring in crowdsourced bathymetry data from Rosepoint Navigation System, FarSounder Inc, PGS and MacGregor Germany. New pipeline establishments are currently underway with Seabed 2030, Navico C-Map, M2Ocean, Great Lakes Observing System (GLOS), and Aquamap.

It is worth noting that the estimated seafloor mapped by the DCDB Archive holdings was calculated to be ~12%.

Crowdsourced Bathymetry Initiative

- The Director of the IHO DCDB continues to serve as the Chair of the IHO Crowdsourced Bathymetry Working Group (CSBWG).

- The CSBWG held its 11th meeting (virtually), from 14-16 September 2021. The CSBWG12 was a hybrid meeting, from 7-10 March 2022, hosted by the IHO Secretariat in Monaco. The main focus of these meetings was to progress and finalize the updated IHO Publication *B-12: CSB Guidance on Crowdsourced Bathymetry*. Edition 3.0 is currently out to Member States for approval.

- The DCDB Director meets monthly with both the Seabed 2030 Director and Project Administrator Coordinator. These meetings allow for communication and coordination on several ongoing Seabed 2030-funded CSB activities. Through partnership with and funding by the NF-GEBCO Seabed 2030 Project, a supply of generic data loggers has been purchased and distributed to numerous CSB projects. The intent is for this to be a great way to (1) collect data in underserved areas, (2) grow excitement

about the CSB initiative, (3) develop a repeatable regional CSB mapping project strategy.

- Over the last 2 years the CSBWG has also focused on developing community or sector specific informational flyers in an attempt to highlight the special needs and concerns from within each group. Flyers were created for the following groups: Superyacht, Fisheries, Cruise Ships, Navigation Software/Hardware Producers, Hydrographic Offices, Marine Science Research, Marine Contractors. The flyers can be accessed here: *iho.int/en/communication-material.*

Other Seabed 2030-related activities

- Jennifer Jencks, along with Stuart Caie (SWPHC Seabed 2030/CSB Coordinator) and Kevin Mackay (Seabed 2030 Regional Lead) organized a four-part South-West Pacific Regional Hydrographic Commission Seabed 2030/CSB Webinar Series throughout May and June 2022.

- Georgie Zelenek, IHO DCDB data manager, virtually attended both the Lakebed 2030 Conference (September 2021) and the Seabed 2030 Arctic-Antarctic and North Pacific Mapping Meeting (March 2022) and presented on the role of the DCDB, current activities, tools the DCDB could provide to data collectors for submitting data, and an update of the Crowdsourced Bathymetry Initiative.

- Christie Reiser, IHO DCDB data manager, attended the Seabed 2030 South and West Pacific Mapping Meeting (virtually; July 2022) and the Atlantic and Indian Oceans Mapping Meeting (in-person; July 2022) and presented on the role of the DCDB, current activities, tools the DCDB could provide to data collectors for submitting data, and an update of the Crowdsourced Bathymetry Initiative.

- Continue to support US Bathymetry Data Gap Analysis (iocm.noaa.gov/seabed-2030-bathymetry.html)

Core team updates

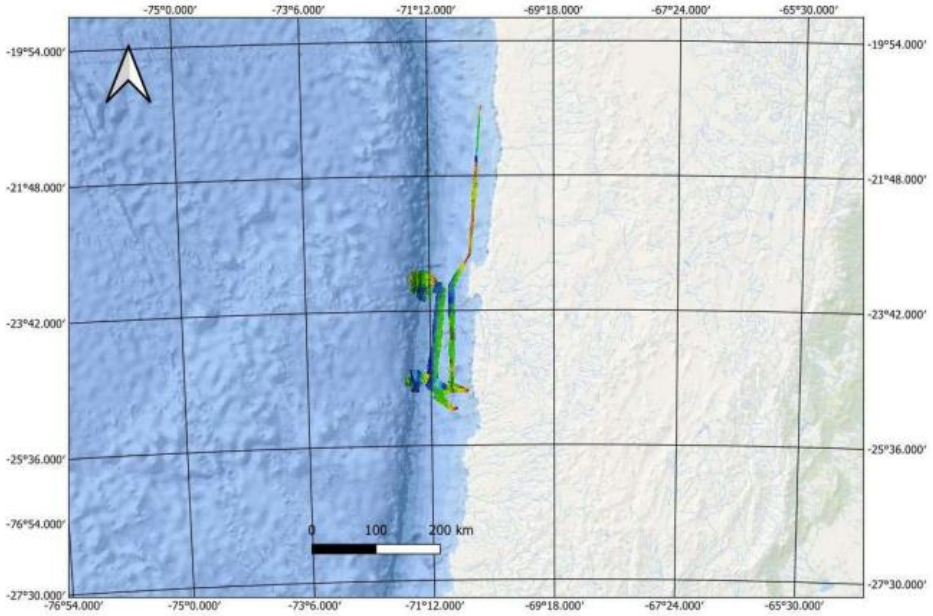
Head of Engagement and Development

Ocean Frontier Mapping (OFM)

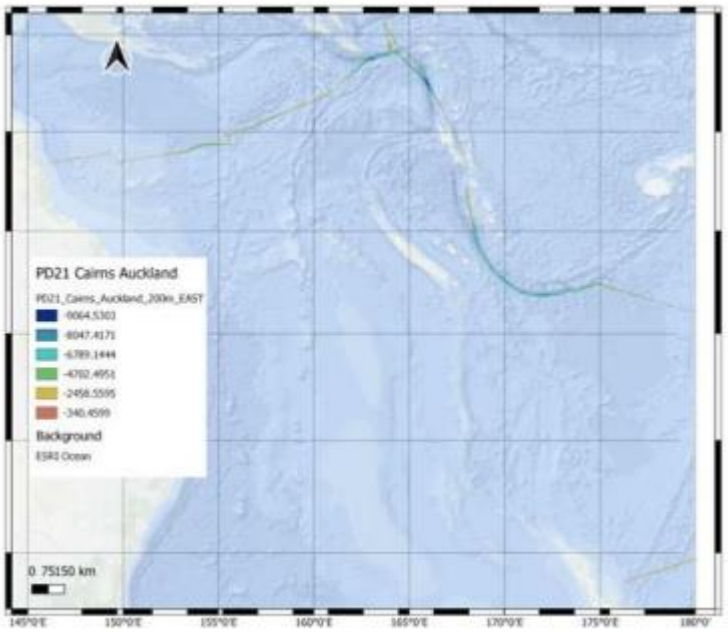
The Nippon Foundation remained keen to support the Ocean Frontier Mapping initiatives that were initiated previously in Year 4 and so endorsed a subsequent bid from Seabed 2030 for period December 2021 – December 2022 for a total sum of $456,000.

The majority of this was to fund travel, subsistence and time for mapping support drawn from the Nippon Foundation-GEBCO alumni. A smaller portion was set aside to fund dedicated incremental mapping days for the 2022 Glacier-Oceans Mapping & Research Interdisciplinary Effort (GO-MARIE) led by the Annapolis-based non-profit organization (NPO), the Ocean Research Project (ORP).

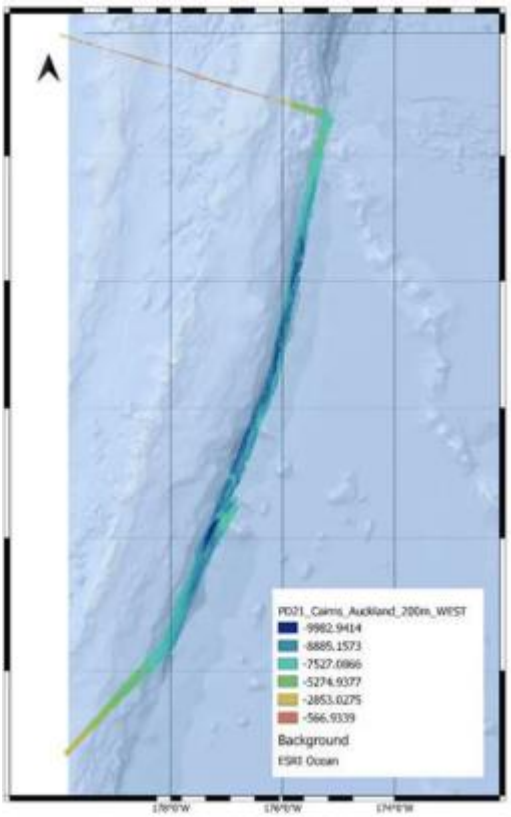
Caladan Oceanic generously provided space onboard for mappers to support transit legs for their 2021/22 Pacific expedition, namely: Auckland to Valparaiso, Cairns to Auckland and Valparaiso to Chile legs run between December 2021 and March 2022. Working alongside the Map The Gaps (MtG) NPO, were able to place mappers onboard Caladan's DSSV *Pressure Drop* whilst also funding some remote mappers to support the onboard team. The datasets have been made available to the relevant Seabed 2030 Data Centers. Of note Caladan continued other extensive mapping in the Pacific at their own expense (ship time and mappers) and this data has been donated for use in the GEBCO Grid. The figures below show the areas in which transit data was gathered by Seabed 2030 funded Alumni mappers.



Coverage of data collected during transit from Valparaiso to Iquique



Coverage of data collected during transit from Cairns to Auckland



Coverage of data collected during transit from New Hebrides to Kermadec Trench.

GO-MARIE: South Greenland 2022 onboard R/V Marie Tharp

To quote from ORP, "*GO-MARIE- (Glacier-Oceans Mapping & Research Interdisciplinary Effort) is the motivation for the maiden voyage of the organization's flagship, the R/V Marie Tharp, a 22m overall Bruce Roberts steel schooner. The ship's name honors an under-recognized scientist for developing the first detailed maps of the ocean seafloor.*"

The project attracted a number of external sponsors and sought to extend mapping and multi-objective scientific exploration in glacial impacted coastal areas. We were delighted to collaborate with OPR to fund 25 dedicated mapping days within the wider mission; and also to collaborate with OPR and MtG to fund alumni mappers. The latter collaboration included pre-mission training and equipment familiarisation and then operational mapping in the coastal areas off Greenland.

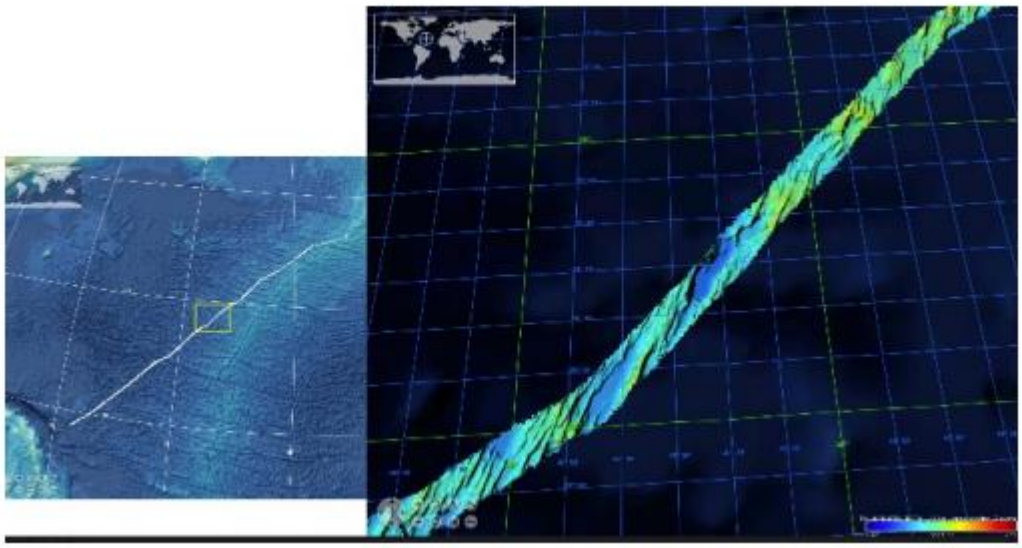
The mission completed in September 2022 and final data processing and reporting are in progress. These deliverables will be made available to Seabed 2030 once finalised.

Survey plan supplied by Nicole Trenholm, expedition leader GO-MARIE project

Ifremer

We were delighted to be able to collaborate with L'Institut Français de Recherche pour l'Exploitation de la Mer (Ifremer) in gathering transit data between Horta (Azores) and Point-a-Pitre onboard RV *Pourquoi Pas?* Seabed 2030 was able to augment the onboard team through provision of one MBES operator. The success of this mission has set the tone for future productive collaboration between Seabed 2030 and Ifremer in mapping activities to improve the GEBCO Grid.

Dr Vicki Ferrini, and Ms Tinah Martin, both of the Atlantic and Indian Oceans Regional Center, were extensively engaged in this collaboration: Dr Ferrini was the principal technical point of contact and Ms. Martin (also a member of the Nippon Foundation-GEBCO alumni) processed the datasets.



Coverage of data collected during transit Azores – French Antilles – N/O Pourquoi Pas?

Alumni Engagement & Development Plan (AEDP)

In line with supporting the Ocean frontier mapping activities, the alumni have been involved in various capacities during Year 5. Their involvement has ranged from survey planning and mobilisation of vessels, providing support as online surveyors and data processing. During Year 5, Seabed 2030 collaborated with Kongsberg Maritime (KM) to develop and deliver the SeaKoMaP solution, with the unified goal of optimizing the processing of bathymetric data. SeaKoMaP, an acronym which stands for Seabed 2030 Kongsberg Maritime Cloud Processing, will allow Seabed 2030 to leverage its extensive alumni network as a means of simplifying some of the many valid processes, from data collection to the publishing of seafloor maps. SeaKoMap solution is managed by the Seabed 2030 Head of Engagement and Development and is currently being used for TESMap (below) data Quality Control.

TESMaP

The NIWA-Nippon Foundation Tonga Eruption Seabed Mapping Project (TESMaP) is being funded by The Nippon Foundation. This project provided a rare opportunity to improve understanding of the nature and impact of a major volcanic eruption. NIWA scientists sailed to Tonga to survey the ocean around the Hunga-Tonga Hunga-Ha'apai (HT–HH) volcano and surrounding regions. They surveyed thousands of square kilometres of the seafloor and collected video images of the eruption's impact from NIWA's research vessel, *RV Tangaroa*. Jaya Roperez (alumni) was part of this voyage. The second phase of the survey utilised SEA-KIT International's Uncrewed Surface Vessel (USV) *Maxlimer* to conduct further mapping. For the USV phase, the Head of Engagement and Development was the Chief Scientist and was supported by a team of alumni. Pre-mission, the alumni team produced survey mission plans and continuously reviewed as operations progressed. The alumni were engaged in providing remote online survey support and data quality assurances. Following the completion of the field work, the alumni are now continuing with data processing and reporting. This project will conclude at the end of 2022.

Seabed 2030 website

Following feedback from GGC38, we have placed a small section, under the "Get Involved" tab, setting our details for Ocean Frontier Mapping (OFM) proposals with a link to be used by those wishing to submit.

Head of Partnerships

Steve Hall joined the Seabed 2030 team as Head of Partnerships in March 2022 during the Oceanology International trade show and conference in London.

In April, Seabed 2030 was well represented at the 38th GGC meeting at the International Hydrographic Organisation and at several key conferences in the following months. Notably, we were invited to present at the GEOHAB 2022 conference in Venice and at the Marine Measurement Forum at Port Solent, UK.

In June, we met representatives of Kongsberg in Norway to further build partner relations, discuss new remote survey technologies, and tour the manufacturing facilities for mapping equipment and Hugin AUVs.

Several signings of Memoranda of Understandings have taken place between Seabed 2030 and a number of key organisations. Most notably, we announced a partnership with NOAA at the UN Ocean Conference in Lisbon.

In addition to contributing to the Year 5 partnerships, work is underway for Year 6 signings from private and public sector organisations across the world in countries including Argentina, Belgium, Brazil, Canada, France,

India, Indonesia, Kiribati, Nigeria, Northern Ireland, Philippines, Scotland, UK and USA.

Head of Communications and Decade Initiatives

Kira Coley joined Seabed 2030 in March 2022 on a part time basis as Head of Communications and Decade Initiatives. In her role at Seabed 2030, Kira is responsible for managing the overall communications strategy and outreach activities, coordinating engagement with the UN's Ocean Decade, as well as acting as the main contact for ad-hoc media enquiries.

In March, IFL Science interviewed our partners EV Nautilus about Seabed 2030 and the importance of mapping the ocean floor, which received more than 1,600 views on YouTube.

Seabed 2030 was directly invited to contribute an article to the *Marine Technology Society Ocean Decade* special issue. The story titled 'A Global Ocean Map is Not an Ambition, But a Necessity to Support the Ocean Decade' was submitted and published on 8th June in coordination with World Oceans Day.

As part of a social media campaign in June, Seabed 2030 produced and published a video message for World Ocean's Day in collaboration with our media partners ENP Media.

In June, Seabed 2030 attended the UN Ocean Conference in Lisbon, Portugal. Out of over 500 applications, our proposal to hold an official side event was accepted. On 29 June, the side event 'Seabed 2030: Mapping for the people and planet" was successfully held as a hybrid event, attracting 200 people online and approx. 50 people in person. The live stream has since been promoted online and has had over 300 views to date.

Seabed 2030 was featured in a special report by Scientific American on ocean discoveries in July 2022 in an article titled 'High Tech Seafloor Mapping is Finding Surprising Structure Everywhere'. It includes images on the Ryder Expedition lead by two of Seabed 2030's Center Heads. Scientific American reaches more than 10 million people around the world each month through its website, print and digital editions, newsletters and app and millions more through social media and other platforms.

The organisers of the Naked Scientists podcast invited us to speak on their show in July. It is one of the first podcasts to exist and is now one of the world's most popular science shows, achieving over 50 million programme downloads in the last 5 years. As a direct result of this interview, Seabed 2030 have received several other interview requests and invites from major national radio shows in New Zealand, as well as other smaller outlets in the UK.

Other notable activities include an interview with National Geographic, several radio interviews with international outlets including the BBC and CNN, article submissions to trade publications, and contributions to an ocean mapping exhibit at the Dynamic Earth science museum in Scotland.

Project Update by work stream

The endorsed Year 5 Work Plan is at Appendix 1.

Work Package	Description
WP1	Data
WP2	Systems and tools
WP3	Technology Innovation
WP4	Mapping Activities
WP5	Management
WP5.1	• Operational Management
WP5.2	• Strategic direction
WP5.3	• Communication
WP5.4	• Capacity Development

WP1: Data

Task 1.1. Secure data contributions from different communities

D1.1.1 – Increased data contributions from different organizations

The Global Center has continued to monitor the input to the potential data contributions google form setup previously, allowing us to be notified of new / unknown data. We are investigating what additional data sets located in the BODC/NOC archives can be contributed to Seabed 2030. During 2021/2022 7 grids, based on multibeam data, have been contributed. Colleagues have been made aware of single beam bathymetry data sets that can be accessed directly via BODC's data download systems. The Global Center has been involved in acting as a Trusted Node for Crowdsourced Bathymetry Data and investigating the delivery of this data to the IHO DCDB.

Task 1.2 Data Product – IBCAO published 2022

D1.2.1 – Updates to be published fall 2021 and spring 2022

IBCAO 4.2 was completed during the spring of 2022 and made available for download on the GEBCO web. The Arctic Seabed region, which is slightly larger than the coverage of IBCAO grid, had a coverage of 23.4 % during the second quarter of 2022.

Task 1.3 Data Product – IBCSO v3.0 published 2022

D1.3.1 – Updates to be published

IBCSO v2 was published in June 2022 as open access publication. All data products and code associated with the publication are also publicly available. The ocean floor south of 50°S had a coverage of 23.6 % during the third quarter of 2022.

Task 1.4 Publish Data Product – GEBCO 2022

D1.4.1 – GEBCO grid is published by 21 June 2022

The GEBCO_2022 Grid was published by the Global Center in July 2022 and is available to download via GEBCO's web site and as a Web Map Service.

WP2: System and tools

Task 2.1 Further development of mapping statistics system

D2.1.1 – System that can deliver statistics regularly based on input data from RDACCs

The data coverage statistic system developed on AWS has been implemented and augmented with a data upload functionality that captures the necessary metadata and places the data directly into the calculation routines.

Task 2.2. Development of the GEBCO grid download tool

D2.2.1 – Add the handling of the Polar regions; download of Polar stereographic grids

The Global Center has updated the GEBCO grid download app in July 2022 to allow the delivery of data for polar regions in polar stereographic co-ordinates.

Task 2.3 Further development of Bathy Globe

D2.3.1 – Add capabilities of Bathy Globe

Latest version delivered during Year 5 (based on GEBCO_2021 data); product will be subject to continuous improvement and updating by UNH staff.

Task 2.4 Publish map and list of Seabed 2030 Priority Areas

D2.4.1 – Based on further WITS activity. Tools to support dynamic planning by external data contributors for ship transits and science missions

Work is ongoing with SCRUM to identify and highlight priority areas. CCOM and AWI are developing and promoting tools in support of cruise planning. Discussions are ongoing with TSCOM regarding tools being developed. 'Wind in the Sails' project work ongoing with aim to produce global mapping prioritization model.

Task 2.5 Deliver the next generation GEBCO product

D2.5.1 – Publish a multi-resolution GEBCO product

The Regional Centers are investigating how to leverage existing processing chains to provide higher resolution products in areas where the contributed data are sufficient resolution to support this. The Global Center will ensure consistent delivery mechanisms are provided for these products.

Task 2.6 Establish GDACC as a CSB Trusted Node

D2.6.1 – Based on IHO standards and guidance, establish Trusted Node. Engage with contributors and deliver data to IHO-DCDB.

Global Center established as Trusted Node, and work has taken place to align workflows with IHO-DCDB and agree best practice. First datasets have now progressed through the system.

Task 2.7 Grid quality improvement

D2.7.1 – Based on collaboration with Scripps Ocean Institute for SRTM15+ updates.

Work commenced in Year 4 has been ongoing throughout Year 5 and reviews are currently ongoing internally to agree on solutions regarding definitions and resolutions.

WP3: Technology Innovation

Task 3.1. Establish a Seabed 2030 Technology Innovation strategy

D3.1.1 – Seek professional input and publish Seabed 2030 Technology Innovation Strategy.

During Year 5, the Project received professional support in drafting a Technology Innovation Vision discussing elements including use of remotely operated and autonomous technology, cloud computing and machine learning. Details are attached at Appendices 2a and 2b.

WP4: Mapping Activities

Task 4.1 Progress Mapping the Ocean Frontiers

D4.1.1 – Identify expeditions to be supported and acquire new data.

The Nippon Foundation provided $456K of XPrize winnings to fund a separate Ocean frontier Mapping as requested in a bid for period 1 December 2021 to 31 December 2022. Of this $296,000 was allocated to the Caladan Oceanic Expedition. Transit data collection was achieved from Auckland to Valparaiso, Cairns to Auckland and Valparaiso to Chile expeditions. The allocated funds covered alumni costs for travel and payment for their services as onboard mappers and remote data processing. The datasets have been made available to the relevant Seabed 2030 data center.

GO-MARIE South Greenland project requested a sum of $125,000 for 25 dedicated mapping days. Two alumni were costed to provide support for mobilization, survey operations, post mission data processing and reporting. The total cost of alumni involved in the project was accounted at $60,861.24. Final data processing and reporting are in progress. These deliverables will be made available to Seabed 2030 once finalized.

Transit data collection from Horta (Azores) to Point-a-Pitre onboard Pourquoi Pas was conducted by Ifremer. This initiative was costed at €13,150.80 to support the service of one MBES operator. Dr Vicki Ferrini, Head of the Atlantic and Indian Regional Center, served as the primary point of contact for Seabed 2030.

At the end of the grant period, 31 December 2022, surplus funds will be returned to the Nippon Foundation as per grant requirements.

Task 4.2 Greenland Crowd Sourced Project

D4.2.1 – Continue to oversee Greenland Crowd Source Initiative.

The 'Collaborative Mapping Greenland' Project is ongoing, and vessels are being fitted with data loggers as a pilot. Data collected as part of the pilot will be delivered to Seabed 2030 and DCDB.

The project team has collaborated with local fishermen in North-West Greenland and have received and are now processing data from those areas. New collaborations have been initiated in the northernmost settlements and the locals are eager to participate.

The current version of the Seabed 2030 compilation has been shared with the participants for offline use. They have reported great success in utilizing the bathymetric information for exploring new fishing grounds, which has proven to be a great possibility for the small settlements.

Task 4.3 Continue to accelerate Crowd Sourcing activity

D4.3.1 – In liaison with IHO CSBWG, significantly increase crowd sourced data submissions.

Crowd Sourced Bathymetry (CSB) activity in Palau, South Africa and Greenland is picking up following COVID-19 restrictions during Year 3/Year 4. Loggers rolled out and Alumni providing technical/installation support and engaging with participants. Extensive liaison with IHO's CSBWG and DCDB Director. Discussions are still underway with UNH and a provider of low-cost data loggers; roll out is expected in early-mid Year 6. A greater interest in CSB activity is being observed from super-yacht owners and associated networks. The International Seakeepers Society has been very enthusiastic in participating in CSB activities and has been rolling our data loggers to its membership. Similarly, we are supporting the IHO-Yacht Club of Monaco Letter of Understanding which seeks to leverage CSB opportunities within the backdrop of "Monaco, Capital of Advanced Yachting"

Having established a "Seabed 2030 CSB Trusted Node" within GDACC, continuous improvements are being made to flowlines to ensure data in the right format is provided to DCDB. UNH, DCDB and colleagues from IHO's CSBWG have been hugely supportive here.

We have also set up a remote tech service that provides an on-call support to vessel operators for installation of loggers.

WP5 Management

WP5.1 Operational Management

Task 5.1.1 Secure Year 6 funding

D5.1.1 – Year 6 Work Plan and Budget approved.

Engagement with GGC Chair & NF. Bid submitted to NF for approval. No uplift on Year 5 funding requested for Year 6 due to a nil rate of inflation being applied. Funding secured at US$2,999,724. See Appendix 3 (Y6 Bid), Appendix 4 (Y6 Work Plan) and Appendix 5 (Grant Agreement).

Task 5.1.2 Year 5 Financial Management

D5.1.2 – Year 5 finance ledger is accurate and Project run to budget.

Year 5 accounts to be reconciled within 3 months of Year end. Surplus funds to be returned to the Nippon Foundation in accordance with Grant requirements.

Task 5.1.3 Annual Project Reporting to GGC

D5.1.3 – Year 5 Annual Report submitted to GGC.

To be submitted within 3 months of Year end. Provisional report to be presented at GGC39 31 Oct – 1 Nov 22.

Task 5.1.4 Intersessional reporting to GGC

D5.1.4 – Intersessional reports presented to GGC.

Quarterly reports submitted to GGC via GEBCO Secretary throughout Year 5.

Task 5.1.5 Periodic Project Reporting to Sponsors

D5.1.5 – Sponsors meetings held as required by Sponsors.

Sponsors meeting was held virtually in early August 2022 (meeting slightly late due to scheduling issues in May/June 2022).

Quarterly reports submitted to Sponsors throughout Year 5, including accompanying progress meetings between the Project Director and NF.

Task 5.1.6 Engage with the GEBCO community

D5.1.6 – Diary of Year 5 engagement demonstrating GEBCO contribution to Seabed 2030.

Records maintained of all GEBCO Sub-Committee work by the Chair of each group.

Task 5.1.7 Recruit Assistant Director

D5.1.7 – Assistant Director in post by January 2022.

Successful recruitments of the Head of Partnerships and the Head of Communications & Decade Initiatives during Year 5 (both 0.5FTE).

WP5.2 Strategic Direction

Task 5.2.1 Engage with user community

D5.2.1 – Robust use case evidence documented (via WITS work) and GEBCO product users active in Seabed 2030

A summary of completed and planned 'Wind in the Sails' (WITS) project activity is at Appendix 7a (text) and Appendix 7b (Slides). It is also detailed here:

Phase 1 - Y3 & Y4

- A rapid evidence review of the extant ocean mapping strategies and programmes gathering seabed data outside SB2030. (Phase 1 - Y3&Y4)
- Identification of survey models being used by governments and other agencies (including academia and industry) that may aid the development of a global model for SB2030.
- An initial online survey to acquire a global cross-sectional understanding of the requirements, priorities of users/actors in the maritime domain for bathymetric data (443 responses from 65 nations) resulted in:
  - A data report identifying 93 potential data sources for SB2030.
  - A survey prioritisation review based on the findings of the first online survey.
- Two articles were published promoting SB2030: one from a Blue Economy perspective and a second covering crowd sourcing data opportunities and techniques.
- A technology review to determine the use of technology to increase the rate of bathymetric data collection.
- Based on the success of the first survey a second mirrored online survey was issued, and the combined responses of both surveys total 796 responses across 90 countries. From this survey:
  - A second data report identifies another 55 potential sources of data for SB2030.
  - A survey findings report reviews the combined responses of both surveys.
- A detailed quantitative analysis report on the online survey findings identifying specific regional seabed mapping needs.

Phase 2 - Y5

- A comprehensive report cataloguing premium models for seabed mapping benefits analysis.
  - See Appendix 7c
- A detailed report proposing a potential model for Seabed 2030 to implement based on seabed mapping benefits analysis and prioritisation.
  - See Appendix 7d

Planned activity for Y6

- Production of Seabed 2030 parameters, and Production of Seabed 2030 benefits documentation – Value Chain, Executive Fact Sheet, Value Proposition, and a set of Use Case Evidence.
- Targeted community engagement to inform both benefits analysis and global prioritisation work, (inc by survey and one to one informed user engagement).
- Develop the proposed approach into a documented methodology (Level 3 business process documentation produced). And provide a tool review and design, with a prototyping of a tailored prioritisation tool workflow for Seabed 2030 (likely to be deferred to Y7).

Task 5.2.2 Solicit external strategic advice/input

D5.2.2 – Improve Seabed 2030 strategy through external advice.

There has been ongoing engagement across a wide field of advisers including Sponsors, the Strategic Advisory Group, the GEBCO community and other parties interested in Seabed 2030 work. We also plan to contribute to, and benefit from, the wider GEBCO Strategy work.

Task 5.2.3 Position Seabed 2030 globally

D5.2.3 – Seabed 2030 acknowledged as key global initiative.

As a Decadal Flagship Programme, Seabed 2030 continues to work alongside the UN Decade team and other global initiatives. We were delighted that the MACHC-IOCARIBE Seabed 2030 Project has been endorsed as a Decade action and supporting project. We understand that others may follow.

We continue to seek opportunities to participate in high profile events with a view to growing its network and collaboration opportunities. At the strategic level: we participated in:

- The 2021 Paris Peace Forum (Nov 21);
- The 2021 the UN Climate Change Conference (COP26) (Nov 21) – Green Zone Event
- The One Ocean Summit (Feb 22)
- The 2022 Economist World Ocean Summit (Mar 22)
- The 2022 UN Ocean Conference (Jun 22)
    - delivering the 'Seabed 2030: Mapping for the people and planet" event attracting 178 people online and approximately 55 people in person.

In addition to our Centers running successful Regional Mapping Meetings, we have also participated in a breadth of other for a where we have been able to position Seabed 2030 globally there include:

- International Indian Ocean Science Conference
- Ocean Sciences 2022
- Oceanology International 2022
- International Indian Ocean Science Conference 2022
- Monaco Ocean Week -Ocean Decade Event
- 2022 National Ocean Exploration Forum
- American Museum of Natural History Spring Luncheon.
- GEOHAB22.
- Marine Measurement Forum 2022.
- Canadian Hydrographic Conference.
- The Fourth Sino-Africa Forum on Marine Science and Technology

Task 5.2.4 Build strong partnerships

D5.2.4 – Partners make significant contribution to Seabed 2030 success.

Currently are some 192 organisations that kindly pledge support to Seabed 2030 in some way (see Appendix 8). Groups are defined as follows:

Partners: Organizations making a significant and ongoing contribution to Seabed 2030 through an

agreed plan of action as defined in a formal MOU or sponsorship licence (for software).

Data Contributors: Organizations contributing data to Seabed 2030. No formal MOU exists.

Supporters: Organizations or individuals who, whilst having no data to contribute, wish to provide strong support to the Seabed 2030 mission. No formal MOU exists.

As of the end of Year 5, 31 MOU agreements were in place as well as a renewed software agreement with QPS.

Task 5.2.5 Engage with widest possible community

D5.2.5 – Public event in 2023 – early planning in 2021/22.

Deferred until 2024 or later, noting that the Alumni conference in Tokyo is now scheduled for July 2023.

WP5.3 Communication

Task 5.3.1 Deliver Media Strategy

D5.3.1 - Deliver against published Media Strategy

Delivery on content in line with the published Media Strategy across multi-channels of social, mainstream media, newsletters and, where appropriate, articles and submissions to external publications is ongoing (see Year 5 Media Monitoring, (Appendix 9).

Articles have been published in several trade and high-profile media outlets, including Scientific American, BBC, and Hydro International. Development of the media strategy is ongoing and is now under the remit of the new Heads of Communications (to be launched in Year 6).

Task 5.3.2 Seabed 2030 media content across all channels

D5.3.2 – Ongoing process to deliver new content

Ongoing external engagement with Shearwater Global and ENP Media via Head of Communications & Decade Initiatives.

Notable activities include extensive support provided during the UN Ocean Conference side event, the production of press releases announcing new MOU/partnerships, social media expansion and management and the creation of an updated campaign video and video address in acknowledgment of World Oceans Day.

Task 5.3.3 Promote Seabed 2030 at external events and meetings

D5.3.3 – Catalogue of events and meetings attended

A list of Year 5 events and presentations is at Appendix 10. Ongoing attendance at key events and meetings virtually and in person where COVID restrictions permit; raise awareness of Seabed 2030 and increase network of potential stakeholders, MOU partners and data contributors.

Task 5.3.4 Acknowledge partner contributions

D5.3.4 – Seabed 2030 website

The Global Center has updated the list of organizations who have contributed data to the GEBCO Grid. The list is made available via GEBCO's web site.

WP5.4 Capacity Development

Task 5.4.1 Engage Alumni in Seabed 2030 activities

D5.4.1 – Manage Alumni coordination across appropriate Seabed 2030 activities.

In line to support the Ocean frontier mapping activities, the alumni have been involved in various capacities during Y5 as mentioned under section Task 4.1 Progress Mapping the Ocean Frontiers. The involvement of the alumni ranges from survey planning and mobilization of vessels, providing support as online surveyors and data processing. During Y5, Seabed 2030 has collaborated with Kongsberg Maritime (KM), to develop and deliver the SeaKoMaP solution, with the unified goal of optimizing the processing of bathymetric data. SeaKoMaP, an acronym which stands for Seabed 2030 Kongsberg Maritime Cloud Processing, will allow Seabed 2030 to leverage its extensive alumni network as a means of simplifying some of the many valid processes, from data collection to the publishing of seafloor maps. The SeaKoMap solution is managed by the Seabed 2030 Head of Engagement and Development and is currently being used for TESMaP data quality assurance.

The alumni team were intensively involved in the TESMaP project. This project provided a rare opportunity to improve understanding of the nature and impact of a major volcanic eruption. NIWA scientists sailed to Tonga to survey the ocean around the Hunga-Tonga Hunga-Ha'apai (HT–HH) volcano and surrounding regions. They surveyed thousands of square kilometers of the seafloor and collected video images of the eruption's impact from NIWA's research vessel, *RV Tangaroa*. Jaya Roperez (alumni) was part of this voyage. The second phase of the survey utilized SEA-KIT International's Uncrewed Surface Vessel *(USV) Maxlimer* to conduct further mapping. For the USV phase, the Head of Engagement and Development was the Chief Scientist and was supported by a team of alumni. Pre-mission, the alumni team produced survey mission plans and continuously reviewed this as the operations progressed. The alumni were engaged in providing remote online survey support and data quality assurances. Following the completion of the field work, the alumni are now continuing with data processing and reporting.