The Nippon Foundation-GEBCO

Seabed 2030 Project

100% of the ocean floor mapped by 2030

YEAR 4 ANNUAL REPORT
1 August 2020 – 31 July 2021

Authors: Seabed 2030 Project Team

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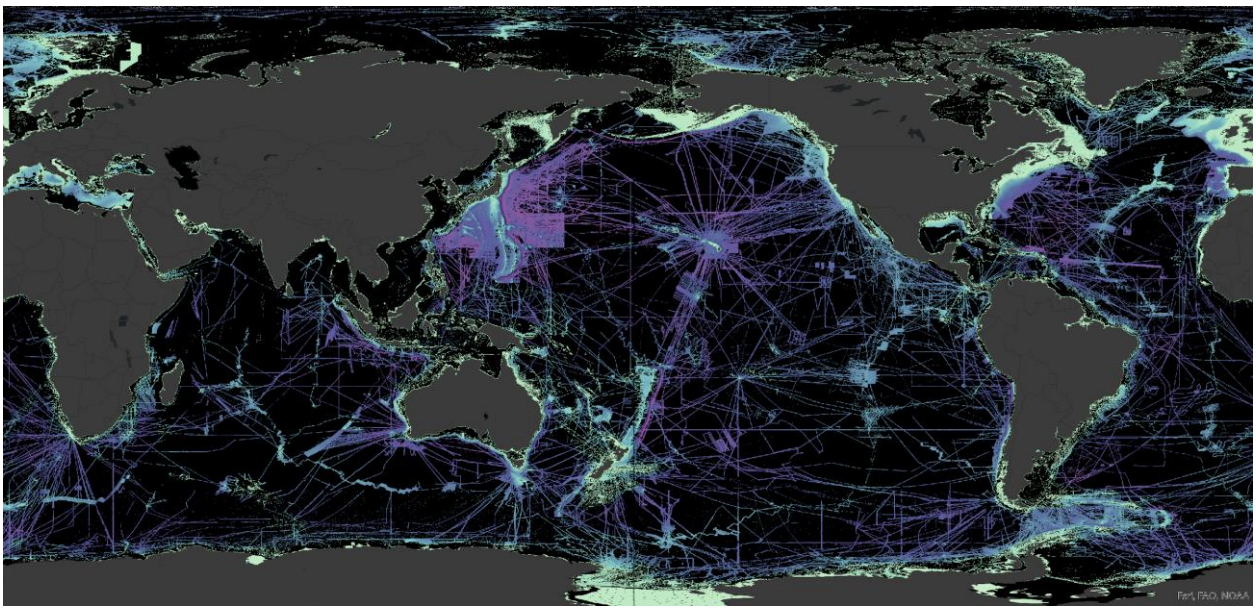

GEBCO 2021 TID

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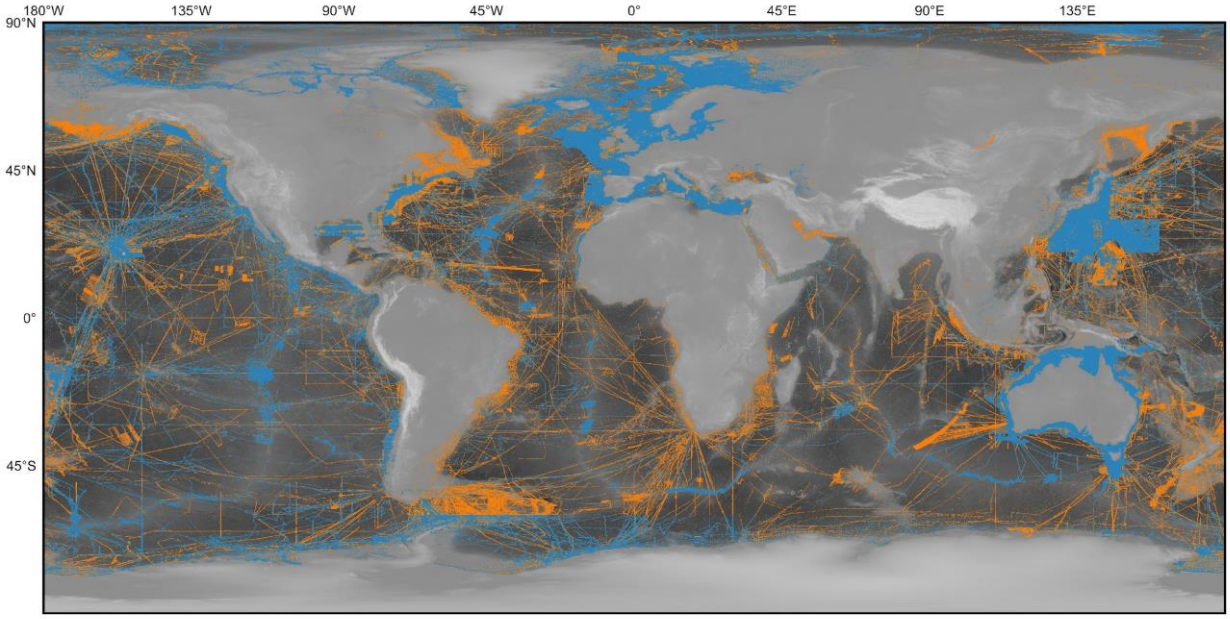


GEBCO 2021

Seabed 2030 Vision

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

Executive Summary

Year 4 has been another busy year for the Nippon Foundation-GEBCO Seabed 2030 Project. The COVID pandemic and impacts persisted throughout the period and significantly affected potential face-to-face engagement opportunities. Nonetheless, the team adapted to revised ways of working and so were undeterred from important engagement and outreach activities, the majority of which were conducted virtually whilst also delivering the main effort of gridding bathymetry.

The start and end of this operational year was punctuated by the *Two Oceans Two Technologies* ocean frontier technology initiative: with Seakit's *USV Maxlimer* operating in the Atlantic in August 2020; and *Saildrone Surveyor* operating in the Pacific beginning in July 2021. Both demonstrated the capabilities of operating uncrewed technology over-the-horizon whilst gathering bathymetry for Seabed 2030 and additional ocean observations for other sponsors. The Atlantic operation allowed proof of concept for nine Nippon Foundation GEBCO alumni, located in 8 different countries, to remotely operate the multibeam system and to post process data.

In between all this, much other activity has taken place with excellent collaboration, internally, between Seabed 2030 Centers and, externally, with a wide variety of data donors, GEBCO colleagues and supporters. Key components of this activity were the publication of new editions of IBCAO and IBCSO; and teamwork with Scripps Ocean Institute on a new version of SRTM+ as the base layer to the GEBCO Grid. In turn, this is delivering efficiencies in our overall gridding work. The latest version of the GEBCO Grid was released in June 2021 depicting 20.6% of ocean floor mapped, which is a relatively healthy increase bearing in mind the backdrop of the global pandemic and associated limitations placed on scheduled science missions and other data gathering programmes.

On the technology innovation level, we have seen work to develop a standalone Seabed 2030 File Uploader and, in parallel, we have been working with our partner Kongsberg Maritime (KM) to develop an equivalent file uploader installed in KM's own systems. Additionally on the technical front, we sponsored Satellite Derived Bathymetry activity in 3 locations in the Indian and South-West Pacific regions.

We also took the opportunity to reopen the Seabed 2030 online survey and share it across the global community. We now have responses from 800 stakeholders across 90 countries providing rich, detailed and thoughtful answers on priorities for seabed mapping. The next stage will be to conduct modelling to calculate benefits derived from mapping in identifiable hotspot areas and then begin formulating a global priority list.

At the strategic level, our bid to the first Call to Action was successful and, in June 2021, the Seabed 2030 Project was endorsed as a flagship programme of the UN Decade of Ocean Science. This was not before our MOU partner, Schmidt Ocean Institute "pinged in the New Year" with RV *Falkor* flying the official Seabed 2030 flag and gathering the very first public seafloor data of 2021 to mark the start of the inaugural year of the Ocean Decade. Later in 2021 we were also endorsed as one of the projects of the 2021 Paris Peace Forum where we were able to showcase Seabed 2030 across a wide sector of decision makers from government, industry, science and philanthropy.

Throughout we have had the customary sterling support from IHO's Data Centre for Digital Bathymetry (DCDB), not only for data ingest/repository activities but also in continuing to help us pursue a range of Crowd Sourced Bathymetry (CSB) initiatives.

We also had an opportunity to bolster the core Project team by establishing a new Head of Engagement and Development post which was filled in June 2021 following an international search process. The focus of this post is to take forward ocean frontier mapping initiatives and, as part of capacity building, to facilitate opportunities for alumni to support Seabed 2030 activities.

Overall, Year 4 has been a very productive year despite the challenges of COVID and lockdowns. This is testament to the overall teamwork ethos across the entire Seabed 2030 team. It is also, in no small measure, a result of the strategic leadership and strong support offered by the parent organisations of The Nippon Foundation, GEBCO, IHO and IOC.

Appendices

The following appendices support the main body of this report:

Document name
Appendix 1 - Year 4 Work Plan
Appendix 2 - Year 5 Bid Submission final document
Appendix 3 - Year 5 Work Plan as approved by NF Board
Appendix 4- Year 5 Financial Reports – Main Budget and Ocean Frontier Mapping
Appendix 5 - Year 5 Grant Agreement
Appendix 6 - *Wind in the Sails* Survey Responses Report, November 2021
Appendix 7 – Partners, Contributors & Supporters at end of Year 4
Appendix 8 – Year 4 Media Monitoring
Appendix 9 – Year 4 Events & Presentations

Introduction

This report details activities and progress achieved within the Year 4 period of 1 August 2020 to 31 July 2021 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 5th 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 and Development, the Project Administrator and the Heads of the Seabed 2030 Centers.

Year 4 Finance Report (Main Budget)

Associated documents:

- *The Nippon Foundation-GEBCO Seabed 2030 Project Year 4 Annual Report v1.0*

This report covers the fourth operational year of The Nippon Foundation-GEBCO Seabed 2030 Project from 1st August 2020 – 31st July 2021. The associated document: *The Nippon Foundation-GEBCO Seabed 2030 Project Year 4 Annual Report v1.0* provides a full account of the project achievements and work accomplished at Center level. This financial report focuses on the details of the project budget against actual spend. All unspent funds to be returned to the Nippon Foundation.

The Nippon Foundation-GEBCO Seabed 2030 Project - Year 4 Finance Report

Budget Line Item	Budget ($)	Expenditure ($)
1.1 Director costs	197,925	194,914
1.2 Deputy Director costs	0	0
1.3 Admin Support costs	143,152	143,182
2.1 Travel	25,927	15,202
2.2 Meetings	29,131	0
2.3 SAG	12,000	51,292 #
2.4 Comms & outreach	124,848	100,483
2.5 Director Operational Support costs	53,000	27,945
2.6 Admin Support travel	7,000	0
2.7 Audit Support	15,000	0
3.1 Columbia Uni Regional Centre	265,271	265,355
3.2 NIWA Regional Centre	265,271	265,313
3.3 AWI Regional Centre	265,271	265,313
3.4 Stockholm Uni Regional Centre	265,271	265,313
3.5 NOC Global Center	273,937	264,906
4.1 Special Project 1 - Greenland CSB	60,000	57,983
4.2 Special Project 2 - Global CSB Activity	100,000	40,489
4.3 Special Project 3 - Media Strategy Delivery	75,152	75,152
4.4 Special Project 4 - Use Case	70,000	122,172
4.5 Special Project 5 - SDB	0	75,089
5.1 Alumni Coordination	159,500	158,166
TOTAL	**2,407,656**	**2,388,269**
	Budget ($)	**Expenditure ($)**

 # Reprofiled: NF authorised surplus flex for SRTM enhancement activity

Surplus (Budget-Expenditure)	**19,387.00**

Ocean Frontier Mapping Financial Report (Phase 1, Aug 20-Jun 21)

This report covers the first operational phase of The Nippon Foundation-GEBCO Seabed 2030 Project Ocean Frontier Mapping programme between 1 August 2020 – 30 June 2021. (see breakdown at Section WP4, Task 4.1 D 4.1.1). All unspent funds to be returned to the Nippon Foundation.

The Nippon Foundation-GEBCO Seabed 2030 Project - Ocean Frontier Mapping Aug 20-Jun 21 Finance Report

Budget Line Item	Budget ($)	Expenditure ($)
1.1 Ocean Frontier Mapping	500,000	345,492
TOTAL	**500,000**	**345,492**
	Budget ($)	**Expenditure ($)**
Surplus (Budget-Expenditure)	**154,508.00**	

Center Information:

Seabed 2030 Center	Location	Lead
Southern Ocean Regional Center	Alfred Wegener Institute Helmholtz Centre for Polar and Marine Research, 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 is accountable to the GEBCO Guiding Committee (GGC) for the successful delivery of the annual work plan. The GGC also approves 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-on-Center activities in Year 4 and is followed by progress reports by 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 4 (2020/21) of the Seabed 2030 Regional Centre Southern Ocean were to finalise data workflows, to generate Seabed 2030 products, and to submit the International Bathymetric Chart of the Southern Ocean Version 2 (IBCSO v2) for publication in an international peer-reviewed journal. Seabed 2030, the progress of the RC-SO and IBCSO were presented at Hydrographic Commission on Antarctic Annual Meeting (HCA-17). The 3rd Arctic Antarctic and North Pacific Mapping Meeting (AANP-MM) was held virtually at the RC-SO.

Center Staff

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

Funds provided by Nippon Foundation for Year 4 supported 2.75 Full Time Equivalent (FTE) positions. In addition, 0.25 FTE were provided by AWI to the Seabed 2030 Project. 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 4 was characterised by finalising the data and gridding workflow called SEAHORSE (Fig. 1), generating the IBCSO v2 grid (Fig. 2), and submitting the IBCSO v2 release paper to an international peer-reviewed journal. After the first half of year 4, data integration for IBCSO v2 was complete and manuscript preparation started. The manuscript was submitted to Scientific Data (Dorschel B., Hehemann L., Viquerat S., Warnke F., Dreutter S., Schulze Tenberge Y., Accetella 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., Henderson Jencks J., 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., submitted. The International Bathymetric Chart of the Southern Ocean Version 2 (IBCSO v2). Scientific Data). In parallel, data acquisition, integration and cleaning continued.

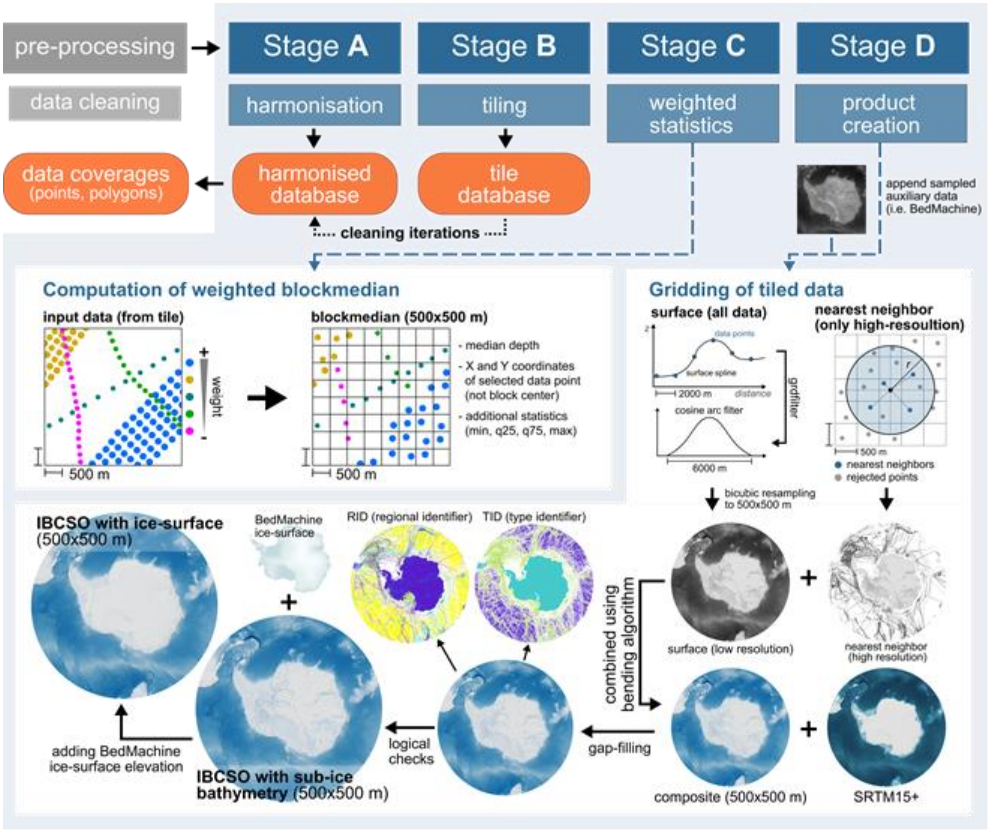


Figure 1) SEAHORSE workflow (from Dorschel et al., submitted).

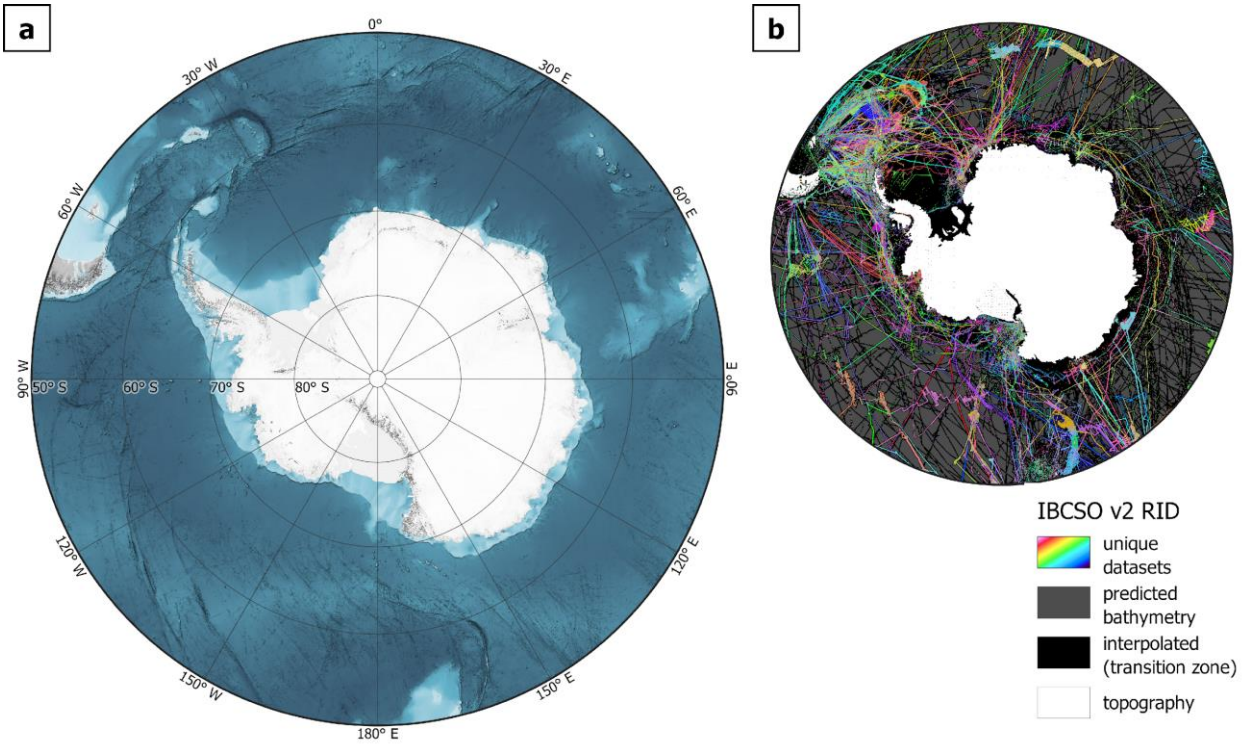


Figure 2) IBCSO v2 grid (a) and TID grid (b) (modified from Dorschel et al., submitted).

Major data and grid contributions

Over the course of Year 4, new data sets were continuously integrated in the RC-SO and IBCSO database. Table 1 highlights all data contributions larger than 100 Mb. Furthermore, a Bathymetric Data Supply Agreement was signed with the Korea Polar Research Institute (KOPRI) on 28 April 2021 and a Data Exploration License was prepared the UK Hydrographic Office.

Table 1. Data contributions larger than 100 Mb in Year 4.

Dataset	**Contributing Organisation**
PS118	Alfred Wegener Institute Helmholtz Centre for Polar and Marine Research (AWI)
PS123	Alfred Wegener Institute Helmholtz Centre for Polar and Marine Research (AWI)
PS124	Alfred Wegener Institute Helmholtz Centre for Polar and Marine Research (AWI)
SO272	Alfred Wegener Institute Helmholtz Centre for Polar and Marine Research (AWI)
65RAE	All-Russia Research Institute of Geology and Mineral Resources of the World Ocean (VNIIOkeangeologia)
DY087	British Antarctic Survey (BAS)

DY088	British Antarctic Survey (BAS)
NBP1902	British Antarctic Survey (BAS)
POWELL2020	Geological Survey of Spain (IGME)
TASMANDRAKE	Geological Survey of Spain (IGME)
AUSTREA2	Geoscience Australia
Macquarie_Ridge_1994	Geoscience Australia
williams_ridge	Geoscience Australia
IFREMER_Kerguelen_Islands	Institut FranÃ§ais de Recherche pour l'exploitation de la Mer (IFREMER)
OGS_TransitRSMacq	Istituto Nazionale di Oceanografia e di Geofisica Sperimentale (OGS)
MR08_06_Leg1	Japan Agency for Marine-Earth Science and Technology (JAMSTEC)
MR19_04_Leg3	Japan Agency for Marine-Earth Science and Technology (JAMSTEC)
ANA06B	Korea Polar Research Institute (KOPRI)
ANA07D	Korea Polar Research Institute (KOPRI)
ANA10B	Korea Polar Research Institute (KOPRI)
KOPRIdge_Leg01	Korea Polar Research Institute (KOPRI)
KOPRIdge_Leg02	Korea Polar Research Institute (KOPRI)
KOPRIdge_Leg03	Korea Polar Research Institute (KOPRI)
MB_WeddellSea_Antarctic_2013	Korea Polar Research Institute (KOPRI)
IN2018_V05	Marine National Facility (MNF)
in2019_v01	Marine National Facility (MNF)
IN2020_V01	Marine National Facility (MNF)
IN2020_V06	Marine National Facility (MNF)
IN2020_V06_EM710	Marine National Facility (MNF)
IN2020_V08	Marine National Facility (MNF)
IN2020_V09	Marine National Facility (MNF)
AT26_29	National Centers for Environmental Information (NCEI)
BMRG03MV_MB	National Centers for Environmental Information (NCEI)
COOK20MV_MB	National Centers for Environmental Information (NCEI)
EW0114_MB	National Centers for Environmental Information (NCEI)
EW9401	National Centers for Environmental Information (NCEI)
GENE02RR_MB	National Centers for Environmental Information (NCEI)
KN182L10	National Centers for Environmental Information (NCEI)
MV1016	National Centers for Environmental Information (NCEI)
MV1101	National Centers for Environmental Information (NCEI)
MV1102	National Centers for Environmental Information (NCEI)
MV1204	National Centers for Environmental Information (NCEI)
MV1205	National Centers for Environmental Information (NCEI)
NBP0101	National Centers for Environmental Information (NCEI)
NBP0501B	National Centers for Environmental Information (NCEI)
NBP0607A	National Centers for Environmental Information (NCEI)

NBP0804	National Centers for Environmental Information (NCEI)
NBP1202	National Centers for Environmental Information (NCEI)
NBP1210	National Centers for Environmental Information (NCEI)
NBP1310	National Centers for Environmental Information (NCEI)
NBP1310A	National Centers for Environmental Information (NCEI)
NBP1403	National Centers for Environmental Information (NCEI)
NBP1602	National Centers for Environmental Information (NCEI)
NBP1704	National Centers for Environmental Information (NCEI)
RB1606	National Centers for Environmental Information (NCEI)
RR0901	National Centers for Environmental Information (NCEI)
RR1202	National Centers for Environmental Information (NCEI)
RR1603	National Centers for Environmental Information (NCEI)
rub320121220_area2	National Centers for Environmental Information (NCEI)
rub320121220_area4	National Centers for Environmental Information (NCEI)
rub320161220_area6	National Centers for Environmental Information (NCEI)
sojn06mv_MB	National Centers for Environmental Information (NCEI)
vanc05mv_mb	National Centers for Environmental Information (NCEI)
VANC07MV	National Centers for Environmental Information (NCEI)
WEST02MV_MB	National Centers for Environmental Information (NCEI)
WEST03MV_MB	National Centers for Environmental Information (NCEI)
WEST07MV_MB	National Centers for Environmental Information (NCEI)
west08mv_MB	National Centers for Environmental Information (NCEI)
TAN0102_TAN0402_Adare_Hallett	National Institute of Water and Atmospheric Research Ltd (NIWA)
TAN2101	National Institute of Water and Atmospheric Research Ltd (NIWA)
ACE_Mertz_Glacier	Swiss Polar Institute (SPI)
ACE_Mertz_Glacier_polynya	Swiss Polar Institute (SPI)
ACE_Siple_Island	Swiss Polar Institute (SPI)

Financial report

All Year 4 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 PS124 with the German research icebreaker Polarstern.

Other activities

In December 2020, RC-SO hosted the virtual 3rd AANP-MM. Throughout Year 4, in-person events were impossible due to the COVID-19 pandemic. 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-17) held virtually in June 2020. The reports were well received.

Stakeholder Engagement and Outreach

In the scope of data acquisition, engagement with the wider mapping community is ongoing.

South and West Pacific Ocean Regional Center (SaWPaC)

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 4 (1 August 2020-31 July 2021) were:

1. Gathering, processing, assembling and gridding of bathymetric data collected in the SW Pacific region.
   - Including Schmidt Ocean Institute's research vessel Falkor collecting the first public seafloor data of the 2021 New Year, as part of their effort to support Seabed 2030.
   - Coordinating Satellite Derived Bathymetry product generation in the Federated States of Micronesia, Maldives and Madagascar.
2. Submission of the 15-arc sec resolution sparse grid to be integrated into the GEBCO_2021 grid release; initial delivery to GDACC was done on the 16th March 2021. Final SaWPaC_2020/2021 delivery populated ca. 23% [~28 M km^2] of the GEBCO_2021 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 21-23rd July 2021. 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 12 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, Guam, Fiji, Niue, the Solomon Islands and Kiribati.
Due to the restrictions in international travel, the Center was unable to host any alumni or students.

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, we also welcomed Mr Stuart Caie to the TMC. Stuart is a Senior Hydrographic Surveyor at LINZ.

SaWPaC Data Manager

Miss Jaya Roperez has FIG/IHO/ICA Category A Certificate in Hydrographic Surveying and is an alumnus 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. 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 2020/2021 delivery (direct measurements only) that was integrated into the GEBCO_2021 release covers ca. 23% of the GEBCO_2021 cells (15 arc sec grid cell size) for the SaWPaC regional extent.

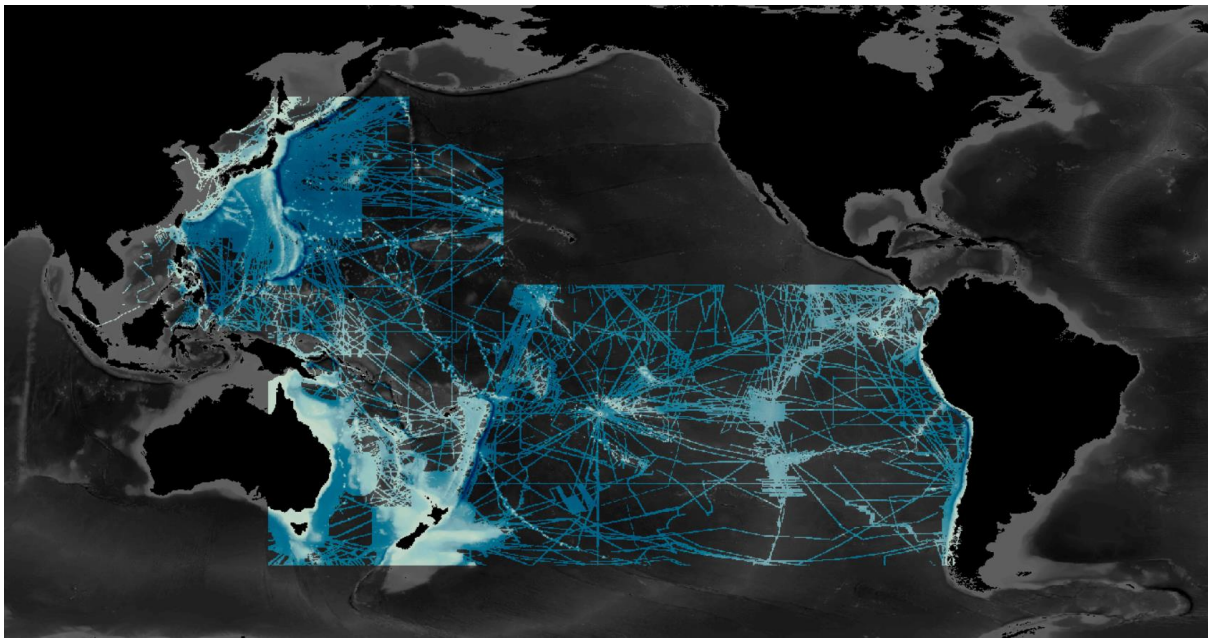


Figure 1. SaWPaC delivery 2020/2021 - bathymetric data layer, 15 arc sec sparse grid- overlain on the GEBCO_2021 gridded bathymetry.

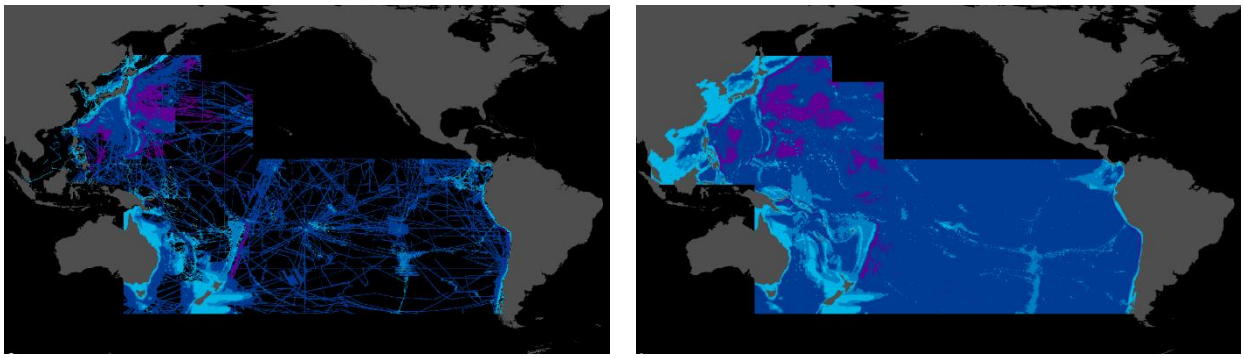


Figure 2. SaWPaC delivery 2020/2021 (left) and target Seabed 2030 - GEBCO coverage for the SW Pacific (right). Depths are coloured according to the ranges defined by the Seabed 2030 target grid resolution.

SaWPaC delivery 2020/2021 (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 2020 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 33rd GEBCO SCUFN Session; the 18th Meeting of the South West Pacific Hydrographic, and the 37th GEBCO Guiding Committee.

Conference/workshop presentations

Mackay, K. (2020) The Nippon Foundation – GEBCO Seabed 2030. 33rd GEBCO SCUFN VTC, on 9-10 November 2020.

Pallentin, A, and Mackay, K. (2020) Progress towards 100% of the World Ocean floor mapped by 2030. The Nippon Foundation-GEBCO Seabed 2030 Project. 22-25 November 2020.

Mackay, K. (2021) Report on the South and West Pacific Regional Data Center. 37th GEBCO Guiding Committee, 18-20 January 2021.

Mackay, K. (2021) Report on the South and West Pacific Regional Data Center. 18th IHO South West Pacific Regional Hydrographic Commission, 17-19 February 2021.

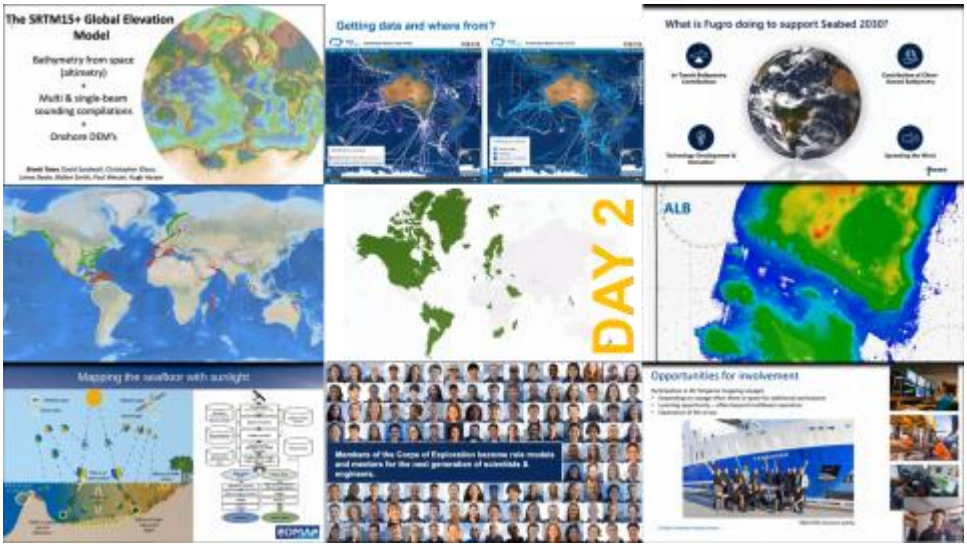
Mackay, K. (2021) The Nippon Foundation – GEBCO Seabed 2030. 34th GEBCO SCUFN VTC 02, on 7 June 2021.

Mackay, K., Roperez, J. (2021) Progress towards 100% of the World Ocean floor mapped by 2030. The Nippon Foundation-GEBCO Seabed 2030 Project. Australian Marine Sciences Association Conference, 27 June-2 July, 2021.

Roperez, J. (2021) Nippon Foundation-GEBCO Seabed 2030 initiative to map the global ocean floor. New Zealand Marine Sciences Society Conference. 5-8 July 2021.

Report of status of regional mapping committee

The third Regional Mapping Committee Meeting was held by SaWPaC as a virtual meeting, on July 21-23, 2021.



The following materials are available from this meeting:

- Circular and Agenda
- Meeting recording (per day)

The objectives of this meeting were to:

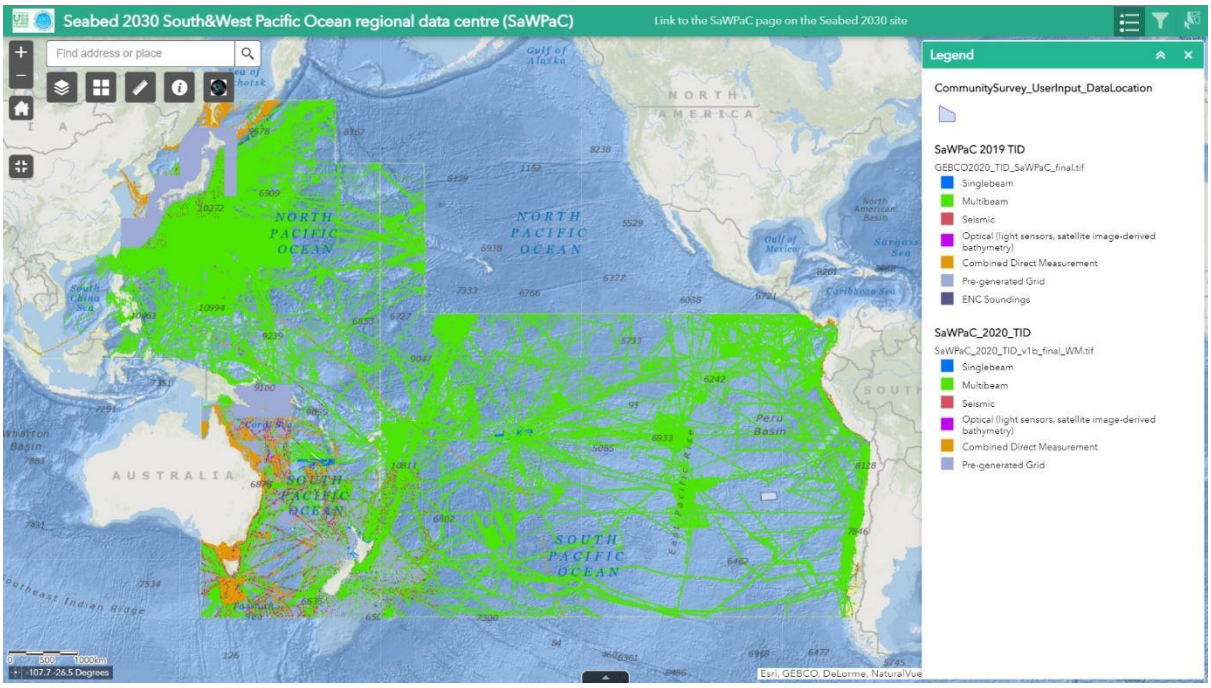
- Catch up with the Regional Mapping Committee with representatives from relevant organizations,
- Identify sources of bathymetric data in the SW Pacific region,
- Discuss methods and protocols of data sharing and management,
- Identify area of regional priority and upcoming mapping expeditions.

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

Major data and grid contributions

During Year 4, the SaWPaC regional inventory of bathymetric data was updated.

The major data contributors are NIWA, JAMSTEC, Geoscience Australia, NOAA NCEI and GMRT (LDEO).



Compilations and gridded contributions

Contributing Project/Organization	**Regional Data Set (incl. reference/link)**
Deakin University, Australia	**Seafloor mapping data, Victoria –** 10m grid http://dro.deakin.edu.au/view/DU:30043228
Deepreef Explorer	**High-resolution bathymetry model of the Great Barrier Reef and Coral Sea (gbr100).** V.5, 2017. Beaman, R.J., 2010. Project 3D-GBR: A high-resolution depth model for the Great Barrier Reef and Coral Sea. https://www.deepreef.org/bathymetry/65-3dgbr-bathy.html
Geersen, J., et al.	Geersen, J., Klaucke, I., Behrmann, J. H., Kopp, H., Tréhu, A. M., Reichert, C. (2018): **Multibeam bathymetry from SONNE cruises SO104 and SO244 and Marcus G. Langseth cruise MGL1610**. PANGAEA, https://doi.org/10.1594/PANGAEA.893033
Geoscience Australia	**High-resolution depth model for the Great Barrier Reef - 30 m** Beaman, R. J. (2018). High-resolution depth model for the Great Barrier Reef - 30 m. Geoscience Australia, Canberra, Australia. http://dx.doi.org/10.4225/25/5a207b36022d2

Geoscience Australia	**50m Multibeam Dataset of Australia 2018** http://dx.doi.org/10.26186/5c63832e3ed8e Parums, R., Spinoccia, M. 2019. 50m Multibeam Dataset of Australia 2018. Geoscience Australia, Canberra. MBES datasets collected in 1989-2018.
Geoscience Australia	**Australian Bathymetry and Topography Grid, June 2009 -** 250m (9arc-sec) grid. http://dx.doi.org/10.4225/25/53D99B6581B9A Whiteway, T. 2009. Australian Bathymetry and Topography Grid, June 2009. Record 2009/021. Geoscience Australia, Canberra. **Tasman and Coral Seas bathymetry survey (FK201228/GA4868) –** 64m grid 2021. Tasman and Coral Seas bathymetry survey (FK201228/GA4868). Geoscience Australia, Canberra. http://pid.geoscience.gov.au/dataset/ga/145279
GNS Science	**Romney and Vulcan 3D Seismic bathymetry grid** 50m grid. Bathymetric grid from processed 3D seismic data from the Romney and Vulcan prospect areas.
Goodliffe, Woodlark Basin grid	**Woodlark Basin multibeam bathymetry grid – 200m** Goodliffe, A. (2011). Woodlark Basin multibeam bathymetry grid. Interdisciplinary Earth Data Alliance (IEDA). http://dx.doi.org/10.1594/IEDA/100015
Japan Agency for Marine-Earth Science and Technology (JAMSTEC)	New **Japan Trench bathymetry**, 100m grid. Data collected after the big earthquake of March 2011.
Japan Oceanographic Data Centre (JODC)	**500m Gridded Bathymetry Data (J-EGG500)** https://jdoss1.jodc.go.jp/vpage/depth500_file.html
Japan Coast Guard, Hydrographic and Oceanographic Department (JHOD)	**30arc-sec grid**

Lamont-Doherty Earth Observatory, Columbia University	**GMRT v.3.8** https://www.gmrt.org/about/index.php 15arc-sec (~500m) grid
Land Information New Zealand (LINZ)	**Gridded MBES data** used to compile New Zealand navigation charts; **80 gridded datasets** (MBES, ALB, SDB) collected during hydrographic surveys (Tonga, Niue, Samoa)
Marine Geoscience Data System (MGDS)	**Gridded multibeam data** from 6 cruises
National Institute of Water and Atmospheric Research (NIWA)	**New Zealand bathymetry compilation - 250m grid** https://www.niwa.co.nz/our-science/oceans/bathymetry The compilation contains separate TIDs: multibeam, single beam, ENC soundings, chart contours, pre-generated grid.
National Geospatial-Intelligence Agency (NGA)	**6arc-sec global grids** (MBES and SBES data collected on multiple cruises)
NOAA NCEI Multibeam Bathymetry Database	**Gridded multibeam data** from 34 cruises
New South Wales Office of Environment and Heritage NSWOEH	**42 gridded MBES datasets**, 5m grids from bathymetry surveys carried out by the New South Wales Office of Environment and Heritage (Australia). https://catalogue-imos.aodn.org.au/geonetwork/srv/api/records/60160b01-8ffc-45ce-a6f4-ee70ce391ec6
Ocean Exploration Trust	**Gridded multibeam data** from 8 cruises of the RV "Nautilus" (2019) https://nautiluslive.org/expedition/2019
Pacific Islands Benthic Habitat Mapping Center (PIBHMC)	**65 gridded datasets** (multibeam and satellite-derived bathymetry) collected around the Pacific Islands (Commonwealth of Northern Mariana Islands (CNMI) and Guam; Northwest Hawaiian Islands; Pacific Remote Island Area; American Samoa)
Service Hydrographique et Océanographique de la Marine (SHOM)	Two 15arc-sec grids (multibeam and single beam data) contributed through the GDACC
SCUFN (GEBCO)	**32 datasets of proposal data** submitted to SCUFN by China
Taylor, Lau Back-Arc Basin grid	**Multibeam bathymetry compilation of the Lau Back-Arc**

	Basin – 100m Taylor, B. (2006). Multibeam bathymetry compilation of the Lau Back-Arc Basin. Interdisciplinary Earth Data Alliance (IEDA). http://dx.doi.org/10.1594/IEDA/100063
Weinrebe et al., Central America Pacific Margin grid	**Multibeam compilation of the Central America Pacific Margin** Weinrebe, W., et al. (2007). Multibeam bathymetry compilation of the Central America Pacific Margin. Interdisciplinary Earth Data Alliance (IEDA). http://dx.doi.org/10.1594/IEDA/100069
Weinrebe&Hasert, South East Pacific Ocean grids	**DTMs of the South East Pacific Ocean** created from a compilation of multibeam bathymetric data acquired during 18 cruises in 1995-2012. Weinrebe, R.W., Hasert, M. (2012). Bathymetric Charts of the South East Pacific with links to gridded datasets. PANGAEA, https://doi.org/10.1594/PANGAEA.785515
USGS	Palaseanu-Lovejoy, M., Poppenga, S.K., Danielson, J.J, Tyler, D.J., Gesch, D.B., Kottermair, M., Jalandoni, A., Carlson, E., Thatcher, C., and Barbee, M. (2017) **One Meter Topobathymetric Digital Elevation Model for Majuro Atoll, Republic of the Marshall Islands**, 1944 to 2016: U.S. Geological Survey data release, https://doi.org/10.5066/F7416VXX

Multibeam Survey Data

Source	**Description and Reference**
Alfred Wegener Institute for Polar and Marine Research (AWI)	6 Cruises of multibeam data in the South and West Pacific Ocean
Hawke's Bay Regional Council (HBRC)	3 surveys of multibeam data from the Wairoa Hard and Clive Hard areas of Hawke Bay, New Zealand
Japan Agency for Marine-Earth Science and Technology (JAMSTEC)	858 cruises in the South and West Pacific Ocean accessed through: Data and Sample Research System for Whole Cruise Information http://www.godac.jamstec.go.jp/darwin/e
Marine Geoscience Data System (MGDS)	9 cruises of multibeam data in the South and West Pacific Ocean

National Institute of Water and Atmospheric Research (NIWA)	6 cruises of multibeam data from around New Zealand waters
NOAA NCEI Multibeam Bathymetry Database	51 cruises of multibeam data in the South and West Pacific Ocean

Other contributions

Source	Description and Reference
Olex global bathymetry database	Single beam (and some multibeam) data collected by fishing vessels in the Pacific Ocean
Hydrographic Department, Royal Thai Navy (HDRTN)	ENC sounding and contours, Thailand

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 4 highlights

Activities at the Atlantic/Indian Oceans Regional Center (AIORC) have continued to focus on data assembly, the gathering and assembly of information about existing embargoed data, as well as stakeholder engagement. Despite the pandemic limiting our ability to travel, we have extended our data coverage and have strengthened our community of stakeholders. With respect to stakeholder engagement, we have continued to strengthen our relationships with Alumni from throughout the region, have increased engagement with IHO Regional Hydrographic Commissions, and have forged new relationships with colleagues surrounding the South Atlantic and Indian Oceans.

Technical highlights over the past year include enhancing and optimizing our use of the ESRI BIS solution for assembling regional data products and metadata. We developed a data-driven approach for assembling bathymetry content by computing a prioritization score that considers the TID, data sparseness, data quality, and whether or not the data were collected in transit or during a survey. This approach has allowed us to more intelligently assemble the data based on inherent characteristics of each data set. We also refined our characterization of TID within some of our largest pre-compiled grids (e.g. the DEM provided by the Directorate of Navigation and Hydrography Brazil), which has allowed us to better distinguish mapped from unmapped areas. Likewise, we worked closely with colleagues at the South and West Pacific Regional Center to normalize our characterization of data around Australia and ensure that TIDs and coverage maps are consistent.

Ongoing efforts at LDEO that complement the AIORC activities include processing and integration of US academic multibeam data for GMRT which continues to feed content into all regional data products for Seabed 2030. Within the GMRT project, workflows and tools for QA/QC of swath files, have been adapted and are now be distributed for use within the mapping community – both at sea and shoreside. This enables broader use of the tools and helps to establish a common quality standard. These tools are especially helpful when analyzing transit data that are often unconstrained by overlapping data from within the same expedition. These tools are now in use by individuals across the US academic community as well as the AIORC team. They are built with open-source packages and can be distributed on personal machines and Virtual Machines, both locally and in the cloud, providing a solid foundation for enhancing distributed data processing efforts that could be extended more broadly.

Over the past year, the AIORC staff included Nippon Foundation-GEBCO Alumnus Tinah Martin, Ms. Hayley Drennon, Dr. Frank Nitsche, and Mr. John Morton, with administrative support provided by Ms. Angie Martin and IT support from Mr. Ed Bohl and Mr. Eric Malikowski. For the summer of 2021, the Center welcomed 3 undergraduate students to assist with data processing: Ashlyn Whitmore, Hannah Berkimer, and Nathan McCuen, all from the College of Charleston. Due to the COVID-19 pandemic, these students participated in an entirely remote capacity, demonstrating that the tools, workflows, and infrastructure used at the AIORC can support a geographically distributed team working together in a shared virtual environment.

Regional Mapping progress

Stakeholder Engagement

- MACHC/IOCARIBE Webinar Series – Virtual, Sept-October 2020
  - In close collaboration with the Chair of the Meso-American Caribbean Hydrographic Commission (MACHC), the Seabed 2030/CSB coordinator for the MACHC, and the Director of the IHO Data Center for Digital Bathymetry, Vicki Ferrini planned and executed a four-part webinar series in Sept – Oct 2020. These sessions were jointly hosted by MACHC and IOCARIBE, and each session brought more than 50 stakeholders from around the region together to learn more about Seabed 2030 and how they can get involved. Topics covered include the benefits of Seabed 2030, how to access data, how to contribute data, and how to use the custom web application built in 2019 for coordination. A key outcome of this event was the development and adoption of the MACHC-IOCARIBE Seabed 2030 Strategy and Workplan, which is being championed by Ms. Cecilia Cortina (Mexico), an Alumnus of the Nippon Foundation – GEBCO Training Program who serves as the Seabed 2030/CSB Coordinator. Close engagement with this community is ongoing and the leadership and dedication of Ms. Cortina in these efforts are gratefully acknowledged. Presentations and recordings of the webinar series, as well as the strategy and work plan documents, are available on the MACHC website: https://www.iho-machc.org/seabed2030.html.
- Oceans 2020, Virtual, October 2020
  - Vicki Ferrini participated as an invited panelist in a session about the UN Decade of Ocean Science for Sustainable Development. Her presentation was an overview of Seabed 2030 aligned with the theme of *"a predicted and transparent ocean."* The session was moderated by Mr. Craig McLean (NOAA), and featured Dr. Jyotika Virmani (Schmidt Ocean Institute), Dr. Larry Mary, and others, and was targeted at an industry audience.
- Programa de Geologia e Geofisica Marinha (PGGM), Brazil (virtual), Oct 2020
  - Vicki Ferrini was invited to provide a presentation about Seabed 2030 and mapping efforts in the South Atlantic. This was an important engagement opportunity that strengthens connections with the Brazilian research community and was the first of several formal and informal conversations with members of this community. Dr. Alex Bastos, who participated in a previous Atlantic/Indian in-person Regional Mapping Meeting, and Dr. Marcelo Sperle, both leaders of PGGM, are gratefully acknowledged for their leadership and efforts to engage Seabed 2030 into their community.
- Southern African and Islands Hydrographic Commission, (Virtual), Feb 2021
  - Vicki Ferrini presented an overview of Seabed 2030 and status of mapping in the SAIHC region. The presentation is available on the SAIHC website at IHO.
- Seabed 2030 – IOC Africa Webinar Series, Feb 2021

  - Tinah Martin coordinated and led a 2-part webinar series focused on Mapping Around Africa. AIORC Team members participated in this event (Ferrini, Drennon, Nitsche), and the sessions were coordinated in collaboration with Mr. Mika Odido of IOCAFRICA. The session included an overview of Seabed 2030, provided by Ferrini, and presentations from several stakeholders in the region including government, academia, and industry perspectives. Speakers included: Mr. Mika Odido (IOCAFRICA), Mr. Israel Hasheela (Namibian Geological Survey), Dr. Veerle Huvenne (iAtlantic), Commander Christoff Theunissen (South African Navy Hydrographic Office and Seabed 2030 Coordinator for the Southern African and Islands Hydrographic Commission), Ms. Nicole du Plessis (South African Marine Research and Exploration Forum (SAMREF)). Each webinar also included question and answer sessions and discussions. The sessions were well-attended with more than 80 participants from 23 countries. Videos of the sessions are on the SCRUM YouTube Channel. The December 2021 Map the Gaps Symposium Redux event builds on this collaboration with colleagues at IOCAFRICA, whose efforts are gratefully acknowledged.

  - US and Canadian Hydrographic Commission (USCHC), March 2021

- Slides were provided to the Seabed 2030/CSB Coordinator for this RHC, Capt. Andy Armstrong (USA), who presented them at the meeting. These slides offered an update of coverage in the Atlantic portion of the USCHC region.

- North Sea Hydrographic Commission, April 2021
  - Slides were provided for inclusion in the Seabed 2030 presentation given at the North Sea Hydrographic Commission meeting by Prof. Martin Jakobsson and Mr. Jamie McMichael-Phillips.
- Explorers Club – Women of the Deep, Virtual, April 2021
  - After being selected as one of the inaugural Explorers 50 – fifty people changing the world that the world needs to know about, Vicki Ferrini was invited to participate in a panel discussion focusing on Women of the Explorers Club. Her presentation included promotion of the Nippon Foundation – GEBCO Seabed 2030 Project. Dr. Dawn Wright was also a panelist. The session was promoted by the Discovery Channel and was very broadly attended.
- European Geosciences Union– April 2021
  - Ferrini provided Seabed 2030 promotional materials (slides) for use during a session focused on seabed mapping. These slides were requested and presented by colleagues from Europe who previously helped to coordinate several seabed mapping sessions at previous scientific meetings.
- All Atlantic Side Event– June 2021
  - Ferrini helped to coordinate and execute a virtual side event focused on Atlantic Seabed Mapping and Exploration. The event was co-organized by the Seabed 2030 Regional Center for the Atlantic and Indian Oceans, the AORA Atlantic Seabed Mapping International Working Group (ASMIWG), the Atlantic Seafloor Partnership for Integrated Research and Exploration (ASPIRE), iAtlantic, and Mission Atlantic. The goal of the session was to extend the community and approaches taken in the North Atlantic to the South Atlantic, and to focus on lessons learned and opportunities for collaboration. Presenters and panelists of the event included: Terry Schaefer (NOAA), Kasey Cantwell (NOAA/ASPIRE), Jennifer Jencks (IHO DCDB), Tommy Furey (Marine Institute, Ireland/INFOMAR/ASMIWG), Vicki Ferrini (Lamont-Doherty Earth Observatory of Columbia University, Seabed 2030), Veerle Huvene (National Oceanography Center, UK / iAtlantic), Marcelo Sperle (Brazilian Marine Geology and Geophysics Program, Brazil), David O'Sullivan (Marine Institute, Ireland), and Kerry Howell (Univ. of Plymouth, UK/ Mission Atlantic), and Nuno Lourenço (University of Coimbra, Portugal /ASMIWG)

- North Indian Hydrographic Commission – July 2021
  - Slides were provided by AIORC to the Seabed 2030/CSB Coordinator for this RHC, Commander Rahul Bhatt (India), who presented them at the meeting. These slides offered an overview of Seabed 2030, information about how to access and contribute data, and an update of coverage in the region.
- Explorers Club 50 – July 2021
  - Ferrini gave invited (virtual) presentations in March 2020 to exchange ideas and approaches used in this regional mapping project.
- SouthWest Atlantic Hydrographic Commission (SWAtHC) – August 2021
  - Slides were provided by AIORC to Mr. Rodrigo Obino (Brazil, GGC member), who presented them at the meeting. The slides offered an overview of Seabed 2030, information about how to access and contribute data, and an update of coverage in the region. This is the second year Obino presented for Seabed 2030 at this meeting, and his efforts are gratefully acknowledged.

GEBCO-NF Alumni Engagement

- Virtual Training – March 2021

- AIORC team members, Hayley Drennon, Tinah Martin, and Vicki Ferrini, virtually taught a series of data processing classes as part of the Nippon Foundation-GEBCO Training Program at UNH. The students learned about how to process data with open-source tools including MBSystem and the distributable GMRT Tools and workflows. Data they processed has been included in the draft data compilation for the Atlantic/Indian region.

- North Indian Ocean Alumni Engagement
  - Tinah Martin coordinated and led multiple virtual engagement events with Alumni from around the North Indian Ocean. These sessions were focused on providing information about the status of mapping in the region and how Alumni can get involved. There have been several follow-up conversations and we are optimistic that we will be able to increase engagement of Alumni from this region.
- Created custom maps and flyers
  - In preparation for the Alumni engagement events, a template was produced to enable the rapid creation of distributable materials describing the project, how to get involved, and the status of mapping in the region. Examples are available in the AIORC section of the Seabed 2030 website.

Regional IHO/IOC Engagement

- IHO/IOC - GEBCO Subcommittee and Guiding Committee Meetings & GEBCO Symposium, January 2021.
- Regional Hydrographic Commission engagement (see above): USCHC, SWAtHC, MACHC, NSHC, NIOHC
- IOC Regional bodies: IOCARIBE, IOCAFRICA

Regional Mapping Committee Meetings

As described above RMC meetings in the past year have focused on the several communities in the North Atlantic, the South Atlantic, and the Indian Ocean. We have focused these engagement efforts to coalesce around existing and evolving communities, and we have convened and participated in several virtual events including webinar series.

Major data and grid contributions

The AIORC Team worked through the backlog of ENC data that had been provided to GEBCO over the years and made sure it was included in the GEBCO 2021 grid. This includes ENC data from Argentina, Bahrain, India, South Africa, Singapore, Ukraine, Uruguay, and Venezuela. Data assembled and contributed by John Hall, largely derived from his digitization efforts, was also reviewed and integrated. Direct data contributions for the region are from 43 organizations representing 24 countries, but the true number of organizations is much larger since several data contributions are syntheses that represent the efforts of many groups and nations.

Organizations that contributed data to the Atlantic/Indian Ocean regional data compilation as of GEBCO 2021:

Alfred Wegener Institute Helmholtz Centre for Polar and Marine Research (AWI)
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)
Center for Marine Environmental Sciences, University of Bremen (MARUM)
Direccion de Hidrografia y Navegacion (DHN) Venezuela
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
Global Multi-resolution Topography Data Synthesis (GMRT), at Lamont-Doherty Earth Observatory of Columbia University
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
Israel Oceanographic and Limnological Research (IOLR)
Japan Agency for Marine-Earth Science and Technology (JAMSTEC)
Laboratoire d'Etudes en Géophysique et Océanographie Spatiales (LEGOS)
Maritime and Port Authority of Singapore
National Geospatial-Intelligence Agency (NGA)
National Oceanic and Atmospheric Administration (NOAA)
National Oceanography Centre (NOC)
Olex AS
Royal Navy
Russia 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
University of Capetown
University of New Hampshire: Center for Coastal and Ocean Mapping/Joint Hydrographic Center (UNH/CCOM-JHC)
University of Wisconsin
US Dept. of the Interior, Bureau of Ocean Energy Management, Bureau of Ocean Energy Management (BOEM)

XPRIZE

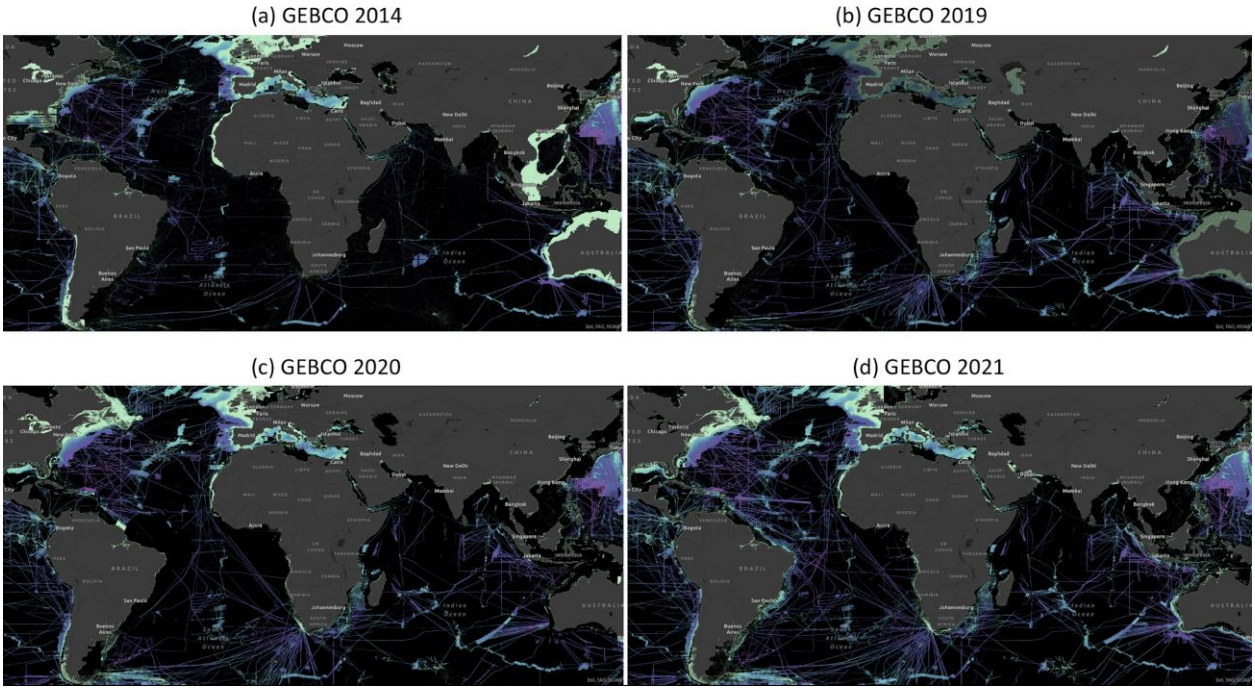


***Figure**: Visualization highlighting gaps in data coverage throughout the AIORC region with each release of the GEBCO grid: (a) GEBCO 2014, (b) GEBCO 2019, (c) GEBCO 2020, (d) GEBCO 2021. In all panels, areas that are considered "unmapped" are shown in black. Note that some large areas that are shown 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 2021 (d) represents the most extensive data coverage for the region that is based on direct measurement. By removing interpolated areas from "pregenerated grids" we can better visualize for stakeholders and the public where the true gaps in data exist throughout the region.*

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).

Summary

Arctic Ocean

The Stockholm University (SU) team continued to use and develop gridding and statistical routines for high-performance computing (HPC) environments. The developed routines were used to calculate statistics of the mapped area of the entire World ocean by the Seabed 2030 project and to generate the International Bathymetric Chart of the Arctic Ocean (IBCAO) 4.1 grid, which served as the base for the Arctic regional area during year 4. The statistical routine was ported to Amazon Web Services (AWS) and the developed code was placed in GitHub for public access. During year 4, the SU-team has incorporated >600 datasets, out of which the major contributions were from NGA. Additional data have been accessed from NOAA NCEI, R2R, NHS web service and AWI. The SU and UNH teams have engaged with Kongsberg to develop a "Seabed 2030 uploader" that will make it possible for vessels with Kongsberg multibeam systems to easy share their acquired bathymetric data directly with the Seabed 2030 project using cloud services. In addition, the uploader can be used as a standalone tool to share GeoTIFF files of multibeam surveys with the Seabed 2030 project. The tool is now being tested by the Seabed 2030 project as well as the broader community. Two of the SU-team were onboard icebreaker *Oden* to collect bathymetric data during the SAS (Synoptic Arctic Survey) expedition. *Oden* became the first icebreaker ever to reach the unmapped North Greenland continental shelf west of Morris Jesup Rise from north. Within the Ocean Frontiers initiative, a crowd-source bathymetry program has been initiated during year 4. The project is led by the Greenland Institute of Natural Resources in Nuuk and the goal is to equip vessels (fishing boats as well as other vessels) with loggers for bathymetric data collection around Greenland.

North Pacific:

This past year, the UNH team continued to use ESRI BIS to generate its North Pacific 2021 grid submission. A total of **123 new data sets** were incorporated into the 2021 North Pacific grid. The new data sets comprised both composite sets and individual surveys. Final grid mergers with the global compilations (i.e. GMRT) were done outside of ESRI. Additional data sets have been identified for the 2022 submission. Presently, the UNH team is also working on processing single beam data from NOAA NCEI to include in future submissions. In addition to the continuous search for, processing and updating of North Pacific data sets, the UNH team also developed a number of on-line tools to help the overall efforts of the Seabed 2030 team including the development of: 1- an interactive, web-based tool for serving and exploring North Pacific (and other data sets); 2 on-line, interactive tools for assessing the quality of data in the GEBCO grid;3- on-line, interactive tools for accessing the quality of SRTM data; an on-line tool for exploring the entire GEBCO grid through an interactive globe, and; 4- software to ingest data from the R/V Pressure Drop for import into the DCDB and NCEI. UNH also supported two very successful Ocean Frontier Mapping initiatives: 1- the transit of the Icebreaker HEALY through the Northwest Passage; and, as part of the *Two Oceans Two Technologies (*TOTT) initiative, the transit of the autonomous sailing vessel Saildrone Surveyor from San Francisco to Hawaii. In both cases tens of thousands of sq kms of unmapped seafloor was mapped and will become part of the GEBCO grid.

Center Staff

Stockholm University

- Ms Caroline Bringensparr, data manager/analyst

- Dr Carlos Castro, data manager/analyst
- Mr Björn Eriksson, system administrator
- 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

Arctic Ocean Region

Within the Arctic Ocean region, >600 new datasets were incorporated of which the major contributions were from NGA. Additional data have been downloaded from the NOAA NCEI, R2R, and NHS web services to be assessed. There were about 100 data sets found in NOAA NCEI & R2R that have not been used in previous IBCAO versions. These will require processing before they can contribute to the IBCAO grid. Ten new expeditions were provided by AWI and 10 expeditions by the US icebreaker Healy have been identified. Single beam data from US nuclear submarines provided through the SCICEX (Scientific Ice Expeditions) program are being re-accessed to be incorporated into the next version of IBCAO.

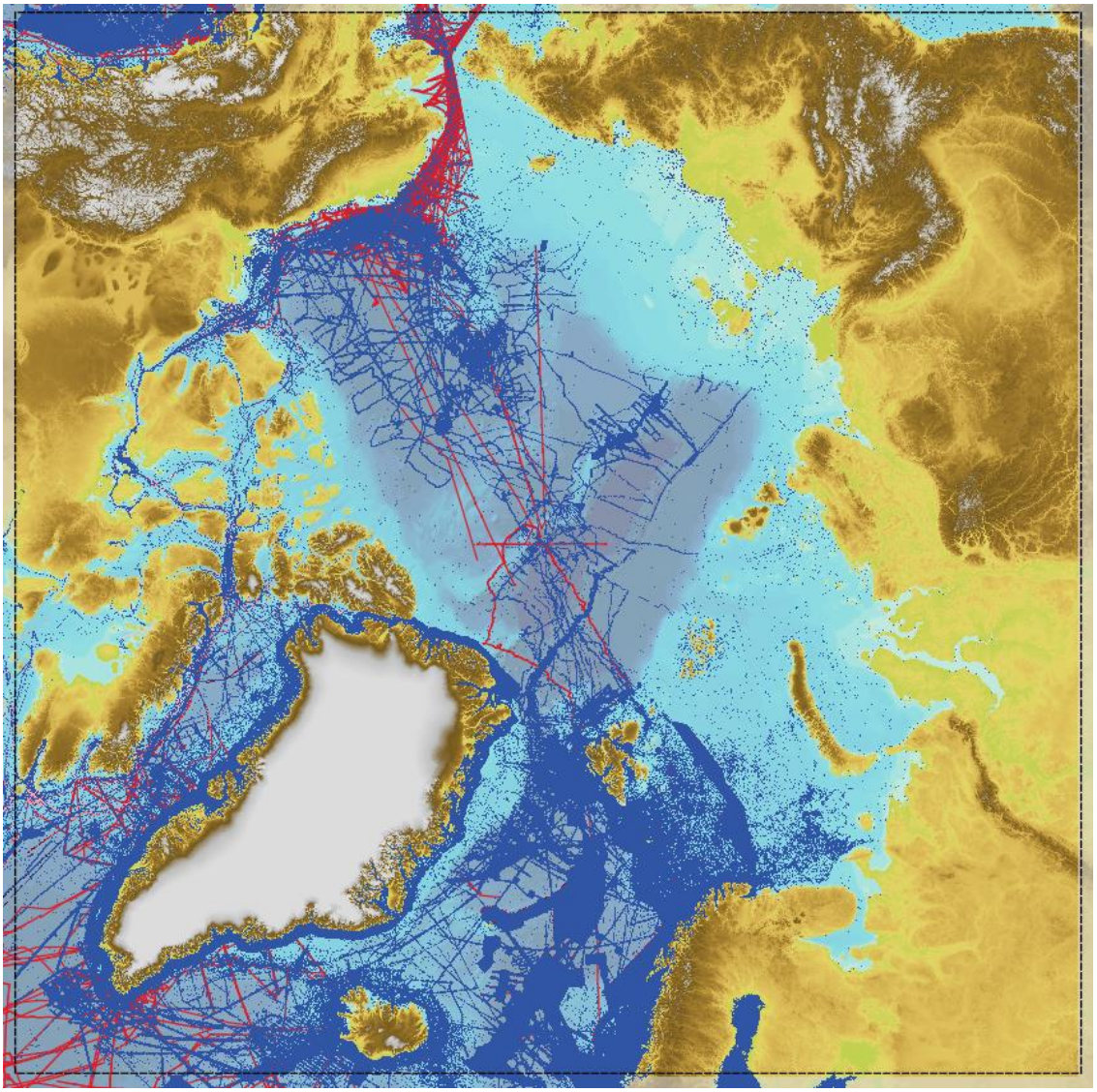


Figure 1: *Map of the IBCAO region showing data in red that are currently being processed to be included in the next IBCAO 4.2 grid, which will contribute to the 2022 version of the global GEBCO grid.*

North Pacific Region

This past year, the UNH team continued to use ESRI BIS to generate its North Pacific 2021 grid submission. A total of **123 new data sets** were incorporated into the 2021 North Pacific grid (Figure 2). The new datasets comprised both composite sets and individual surveys. Final grid mergers with the global compilations (i.e. GMRT) were done outside of ESRI. Additional data sets have been identified for the 2022 submission. Presently, the UNH team is also working on processing single beam data from NOAA NCEI to include in future submissions.


Earthstar Geographics

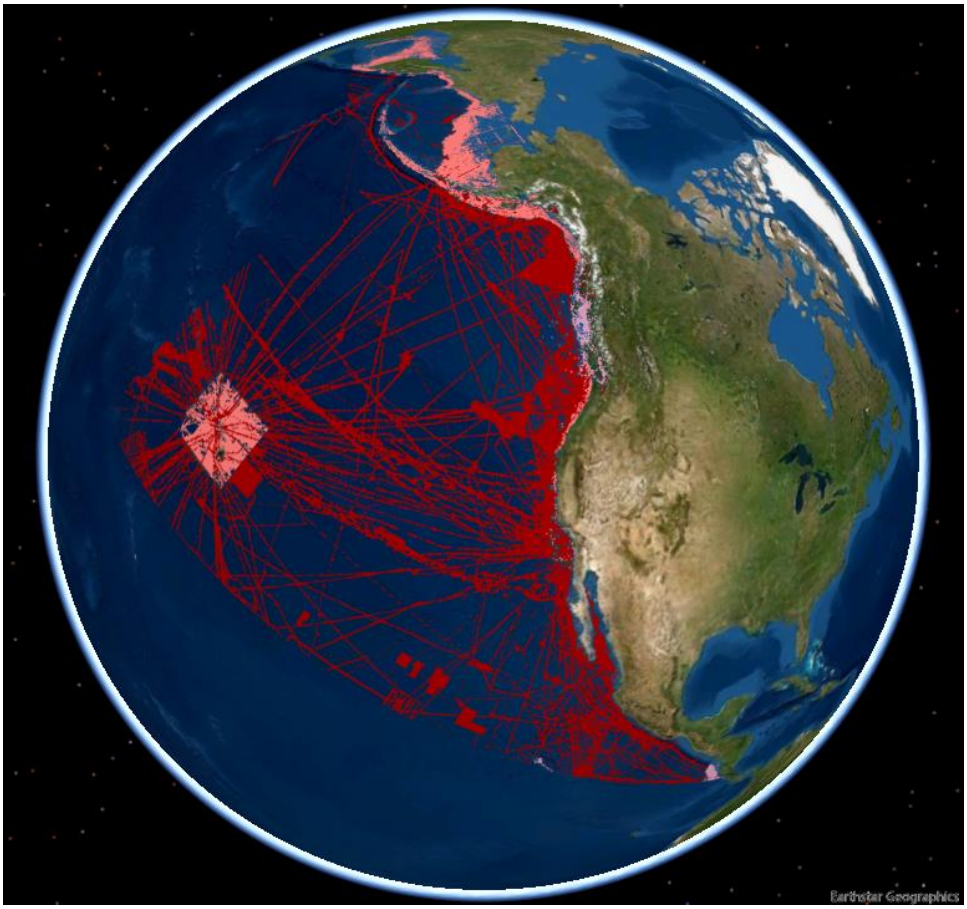


Figure 2: *North Pacific 2021 bathymetric grid (upper), TID (lower) standard GEBCO made/world imagery background.*

Major data and grid contributions

Multibeam Data from the Arctic Region:

Contributing organization	Ship	Country	Data type	Comment
Norwegian Hydrographic Service (NHS)		Norway	Compilation	DTM 50 m, with new data
EMODnet Bathymetry			Compilation	New grid 2020
National Geospatial-Intelligence Agency (NGA)		United States	Mixed sources	Major contribution to Seabed 2030, thinned to 6 arc-seconds
Alfred Wegener Institute (AWI)	RV Polarstern	Germany	MB data	New cruises: PS70, 87, 88, 99, 100, 101, 116
British Antarctic Survey (BAS)		United Kingdom	MB data	New cruises
NOAA NCEI	CCGS Amundsen	Canada	MB data	Data from 2003-2006
NOAA NCEI	CG Healy	United	MB data	New cruises: HLY0806, 1202,

		States		1301, 1303, 1401, 1403, 1603
Greenland Institute of Natural Resources (GINR)		Greenland, Denmark	MB data	Five new datasets from 2018-2019
Geological Institute, Russian Academy of Sciences (GIN RAS)	RV Akademik Nikolaj Strakhov	Russia	MB data	Higher resolution and data additions
Bedmachine		Greenland, Denmark	MB data	Replaced model with multibeam data included in the model
Center for Marine Environmental Sciences, University of Bremen (MARUM), and Alfred Wegener Institute (AWI)	RV Maria S. Merian		MB data	New cruises: MSM 5-3, 44, 56, 76, 95
NOAA NCEI	RV Thomas G. Thompson		MB data	TN250
Stockholm University	IB Oden	Sweden	MB data	Added cruises: ASCOS 2008, Arctic Ocean 2018

Potential sources for the 2022 grid:

- CHS Nonna 10, new version to be made available
- NHS, new data added since last year
- SCICEX
- Oden-SAS2021, expedition from summer 2021

Identified raw multibeam data available at Rolling Deck to Repository (R2R) and NOAA NCEI:

Cruise name	**Ship**
AR30-01	Armstrong
AR30-01	Armstrong
AR35-01	Armstrong
AR35-01	Armstrong
AR45	Armstrong
AR46	Armstrong
AR47	Armstrong
AR47	Armstrong
AR7-01	Armstrong

AR7-01	Armstrong
AR7-02	Armstrong
AR7-02	Armstrong
AT30-01	Atlantis
AT30-03	Atlantis
AT32	Atlantis
AT34	Atlantis
AT38	Atlantis
AT40-03	Atlantis
HLY0301	Healy
HLY0401	Healy
HLY04TH	Healy
HLY1403	Healy
HLY1701	Healy
HLY1701	Healy
HLY1704	Healy
HLY1704	Healy
HLY17TC	Healy
HLY17TC	Healy
HLY17TD	Healy
HLY17TD	Healy
HLY17TE	Healy
HLY17TE	Healy
HLY18TC	Healy
HLY18TC	Healy
HLY18TD	Healy
HLY18TD	Healy
HLY18TE	Healy
HLY18TE	Healy
HLY19TB	Healy
HLY19TB	Healy
HLY19TD	Healy
HLY19TD	Healy
HLY2001	Healy
HLY2001	Healy
HLY20TC	Healy
HLY20TD	Healy
HLY20TD	Healy
KM0308	Kilo Moana
KM0308	Kilo Moana
KM0310	Kilo Moana
KM0310	Kilo Moana
KM0312	Kilo Moana

KM0312	Kilo Moana
KM0314	Kilo Moana
KM0314	Kilo Moana
KM1811	Kilo Moana
KN189-03	Knorr
KN192-03	Knorr
KN195-09	Knorr
KN195-11	Knorr
KN196-03	Knorr
KN199-03	Knorr
KN200-02	Knorr
KN201	Knorr
KN203-01	Knorr
KN213-03	Knorr
KN216-03	Knorr
KN221-01	Knorr
KN221-04	Knorr
MGL0814	Langseth
MGL1108	Langseth
MGL1109	Langseth
MGL1110	Langseth
MGL1113	Langseth
MGL1308	Langseth
MGL1310	Langseth
MGL1902	Langseth
MGL1903	Langseth
MGL1907	Langseth
MGL2002	Langseth
MGL2003	Langseth
MGL2004	Langseth
MGLN44MV	Melville
MGLN46MV	Melville
MV1310	Melville
NA097	Nautilus
RR1814	Revelle
SKQ201501T	Sikuliaq
SKQ201501T	Sikuliaq
SKQ201502T	Sikuliaq
SKQ201502T	Sikuliaq
SKQ201503T	Sikuliaq
SKQ201503T	Sikuliaq
SKQ201504T	Sikuliaq
SKQ201504T	Sikuliaq

SKQ201506T	Sikuliaq
SKQ201507T	Sikuliaq
SKQ201507T	Sikuliaq
SKQ201508S	Sikuliaq
SKQ201508S	Sikuliaq
SKQ201513T	Sikuliaq
SKQ201611T	Sikuliaq
SKQ201614T	Sikuliaq
SKQ201706T	Sikuliaq
SKQ201706T	Sikuliaq
SKQ201710T	Sikuliaq
SKQ201710T	Sikuliaq
SKQ201711T	Sikuliaq
SKQ201711T	Sikuliaq
SKQ201714T	Sikuliaq
SKQ201809T	Sikuliaq
SKQ201810S	Sikuliaq
SKQ201811S	Sikuliaq
SKQ201811S	Sikuliaq
SKQ201812T	Sikuliaq
SKQ201815T	Sikuliaq
SKQ201816S	Sikuliaq
SKQ201817T	Sikuliaq
SKQ201820T	Sikuliaq
SKQ201822S	Sikuliaq
SKQ201913T	Sikuliaq
SKQ201914S	Sikuliaq
SKQ201915S	Sikuliaq
SKQ201915S	Sikuliaq
SKQ201916S	Sikuliaq
SKQ201918S	Sikuliaq
SKQ201918S	Sikuliaq
SKQ201919S	Sikuliaq
SKQ201922T	Sikuliaq
SKQ201924S	Sikuliaq
SKQ202004T	Sikuliaq
SKQ202006S	Sikuliaq
SKQ202008S	Sikuliaq
SKQ202008S	Sikuliaq
SKQ202010S	Sikuliaq
SKQ202010S	Sikuliaq
SKQ202012S	Sikuliaq
SKQ202012S	Sikuliaq

SKQ202013S	Sikuliaq
SKQ202013S	Sikuliaq
SKQ202014S	Sikuliaq
SKQ202014S	Sikuliaq
SKQ202015T	Sikuliaq
TN263	Thompson
TN323	Thompson
TN324	Thompson

Multibeam Data from the Pacific Region:

The 123 new data sets incorporated into the 2021 North Pacific grid are detailed below:

The UNH team incorporated 3 composite grids into the NorPAC 2021 final grid submission:

- **Canadian Hydrographic Service** Data via CHS's **NONNA 100m grid**, this grid is a combination of multibeam and singlebeam data.

- **SOEST**'s grid of multibeam data surrounding **Hawaii** (~56m).

- **NOAA NCEI's composite grids** of all NOS hydrographic multibeam .bag data, which was downsampled to merge with the Seabed 2030 dataset in ArcGIS BIS. This composite grid is updated periodically with new .bag files by NCEI and will need to be revisited in the future.

A total of 120 individual multibeam surveys were incorporated into the 2021 grid. Contributions included final grids from the Caladan Oceanic Pressure Drop, and 2 surveys on the Kilo Moana provided by German scientists at BGR. An existing CCOM survey grid from the Healy/ ECS was also included.

The remaining surveys were swath datasets available via NCEI, mostly through the R2R process for American research vessels. (UNOLS, NOAA and USCG research vessels, and other non-profit, and private platforms). Swath data was then processed and cleaned to import it into the BIS to generate a grid.

Most data were available via NOAA/ NCEI or will be:

- 82 surveys from U.S. Academic Fleet vessels (included the 2 German Kilo Moana grids) were included in the 2021 submission.

- 14 surveys were from NOAA NCEI and U.S. Government agency research platforms, the Healy (USCG) and Ron Brown (NOAA).

- 23 surveys were from the Falkor and Pressure Drop were included in the 2021 submission.

Canadian Data:

- 1 Ocean Networks Canada multibeam swath dataset.

2021 Contribution		Final grids Contributed		
US Academic Fleet/ Final Cleaned Product provided rather than raw swath data				
Vessel	**Dataset Name**	**Year**	**Contributing Country**	**Contributing organization**
Kilo Moana	BGR_E1_250m-KM0821	2008	Germany	BGR
Kilo Moana	BGR_W1_250m-KM0924	2009	Germany	BGR

2021 Contribution	Swath data Contributed	
US Academic Fleet/ UNOLS Data Archived on NCEI		
Vessel	**Dataset Name**	**Year**
Atlantis	AT26-19	2014
Atlantis	AT26-20	2014
Atlantis	AT37-11	2017
Atlantis	AT37-12	2017
Ewing	EW0205	2002
Ewing	EW0206	2002
Kilo Moana	KM1714	2017
Kilo Moana	KM1807	2018
Kilo Moana	KM1810	2018
Kilo Moana	KM1812	2018
Marcus G Langseth	MGL1704	2017
Marcus G Langseth	MGL1705	2018
Melville	VANC32MV	2004

Roger Revelle	ALAR01RR	1998
Roger Revelle	LPRS07RR	2002
Roger Revelle	NECR06RR	2000
Roger Revelle	RR1609	2016
Roger Revelle	RR1610	2016
Roger Revelle	RR1612	2016
Roger Revelle	RR1710	2017
Roger Revelle	RR1711	2017
Roger Revelle	RR1712	2017
Roger Revelle	RR1713	2017
Roger Revelle	RR1714	2017
Roger Revelle	RR1715	2017
Roger Revelle	RR1716	2017
Roger Revelle	RR1718	2017
Roger Revelle	RR1719	2017
Roger Revelle	RR1801	2018
Roger Revelle	RR1803	2018
Roger Revelle	RR1805	2017
Roger Revelle	RR1806	2018
Roger Revelle	RR1808	2018
Roger Revelle	RR1812	2018
Roger Revelle	SEAW06RR	2001
Sally Ride	SR1612	2016
Sally Ride	SR1614	2016

Sally Ride	SR1701	2017
Sally Ride	SR1702	2017
Sally Ride	SR1704	2017
Sally Ride	SR1706	2017
Sally Ride	SR1707	2017
Sally Ride	SR1711	2017
Sally Ride	SR1713	2017
Sally Ride	SR1714	2017
Sally Ride	SR1716	2017
Sally Ride	SR1802	2018
Sally Ride	SR1804	2018
Sally Ride	SR1805	2018
Sally Ride	SR1809	2018
Sally Ride	SR1810	2018
Sally Ride	SR1811	2018
Sally Ride	SR1813	2018
Sally Ride	SR1814	2018
Sally Ride	SR1815	2018
Sikuliaq	SKQ201606S	2016
Sikuliaq	SKQ201607S	2016
Sikuliaq	SKQ201611T	2016
Sikuliaq	SKQ201615S	2016
Sikuliaq	SKQ201616T	2016
Sikuliaq	SKQ201701S	2017

Sikuliaq	SKQ201704S	2017
Sikuliaq	SKQ201705S	2017
Sikuliaq	SKQ201706T	2017
Sikuliaq	SKQ201710T	2017
Sikuliaq	SKQ201711T	2017
Sikuliaq	SKQ201714T	2017
Sikuliaq	SKQ201715S	2017
Sikuliaq	SKQ201716T	2017
Sikuliaq	SKQ201804S	2018
Sikuliaq	SKQ201805T	2018
Sikuliaq	SKQ201806S	2018
Sikuliaq	SKQ201807T	2018
Sikuliaq	SKQ201808S	2018
Sikuliaq	SKQ201809T	2018
Sikuliaq	SKQ201812T	2018
Sikuliaq	SKQ201815T	2018
Sikuliaq	SKQ201817T	2018
Sikuliaq	SKQ201820T	2018
Sikuliaq	SKQ201915S	2019

2021 Contribution	**Swath data used**	
NOAA/ USCG Research Platforms Data Archived on NCEI		
Vessel	**Dataset Name**	**Year**

Ron Brown	RB1601	2016
Ron Brown	RB1602	2016
Ron Brown	RB1603	2016
Ron Brown	RB1604	2016
Ron Brown	RB1605	2016
Ron Brown	RB1606	2016
Ron Brown	RB-18-05	2018
Ron Brown	RB-18-06	2018
Healy	HLY1603_ECS_Beringian	2016
Healy	HLY17TC	2017
Healy	HLY17TD	2017
Healy	HLY17TD	2017
Healy	HLY18TC	2018
Healy	HLY18TD	2018

2021 Contribution	**Swath data used**		
Private/ Non- Profit U.S. data/ NCEI			
Vessel	**Dataset name**	**Year**	**Contributing organization**
Pressure Drop	PD21HI01_Hawaii_50m	2021	Caladan Oceanic
Falkor	FK170602	2017	SOI
Falkor	FK170612	2017	SOI
Falkor	FK170825	2017	SOI

Falkor	FK180722	2018	SOI
Falkor	FK180731	2018	SOI
Falkor	FK180824	2018	SOI
Falkor	FK181005	2018	SOI
Falkor	FK181031	2018	SOI
Falkor	FK181210	2018	SOI
Falkor	FK190106	2021	SOI
Falkor	FK190211	2019	SOI
Falkor	FK190315	2019	SOI
Falkor	FK190612	2021	SOI
Falkor	FK190709	2021	SOI
Falkor	FK190726		SOI
Falkor	FK190831		SOI
Falkor	FK191005	2019	SOI
Final grids provided			
Pressure Drop	PD20AL01_Transit_Aleutians	2020	Caladan Oceanic
Pressure Drop	PD20AL02_Aleutian_Trench	2020	Caladan Oceanic
Pressure Drop	PD20AL02_Aleutian_Trench	2020	Caladan Oceanic
Pressure Drop	PD20AL03_Transit_DutchHarbor	2020	Caladan Oceanic
Pressure Drop	PD20KK01	2020	Caladan Oceanic

Composite Grid References:
CHS NONNA 100 (Covers both the Arctic and parts of the Pacific regions)
Canadian Hydrographic Service, Fisheries and Oceans Canada
Date Published: 2018-10-11
https://open.canada.ca/data/en/dataset/d3881c4c-650d-4070-bf9b-1e00aabf0a1d

Gridded multibeam bathymetric data from surveys archived at NOAA's National Centers for Environmental

Information (NCEI) (Covers both the Arctic and parts of the Pacific regions)
NOAA National Centers for Environmental Information (NCEI)
Created: Apr 7, 2017, updated Early 2021 version used.
https://noaa.maps.arcgis.com/home/item.html?id=0441041574c544dc9b6b8a513cad5e95

Main Hawaiian Islands Multibeam Bathymetry and Backscatter Synthesis/ and Falkor 60m Data
Hawaii Mapping Research Group
The School of Ocean and Earth Science and Technology (SOEST)
The University of Hawaii and Manoa
MHI Synthesis Report 2016
http://www.soest.hawaii.edu/hmrg/multibeam/index.php

Data Sources Identified for the 2022 Compilation Thus Far:

Source	Data type	Contribution Via
NGA	6-sec .dat	GDACC
Five Deeps	Grids/ raw	Larry/NCEI
Sandwell & Lonsdale	MB-SYSTEM raw	GDACC/direct
China SCUFN data	grids	SaWPac
Ocean Exploration Trust	Grids	direct

Potential Sources for the 2022 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. Cruises on R2R not yet at NCEI, and a few new cruises being uploaded to NCEI

Other activities

Seabed 2030 File Uploader

In a collaborative project with Kongsberg Maritime, a file uploader has been developed by their programmers for the purpose of making it as simple as possible for owners of Kongsberg EM multibeam echosounders to provide data to the Seabed 2030 project. The uploader can either be setup to directly share data from the Kongsberg multibeam acquisition software SIS (Version 4 or 5) or to facilitate uploading of processed grids from surveys in GeoTIFF-format. The latter implies that the File Uploader can be used by anyone that likes to contribute GeoTIFFs to Seabed 2030, not only operators of EM systems. A minimum set of metadata is required to be filled in by the data provider in the currently available beta version when GeoTIFF files are

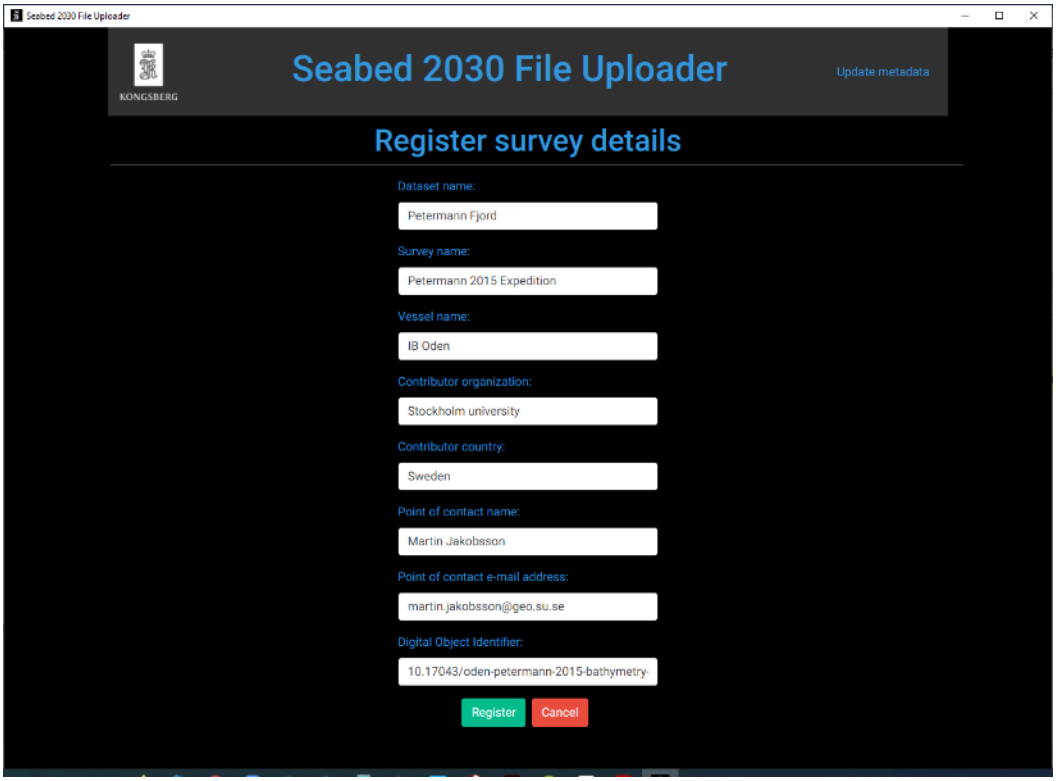
uploaded, while additional metadata about the acquisition system are being automatically acquired when the Uploader share data directly from SIS. The data is uploaded to the cloud (Microsoft Azure) where Kongsberg holds storage. The Seabed 2030 Center are then able to retrieve the data from the cloud.

A development workshop was held at Stockholm University's marine station on the island Askö in the Southern Stockholm Archipelago Sept 6-9 (Figs 3 and 4). Digital Technology Director Arne Hestnes and program developer Glenn Markussen from Kongsberg participated. The Stockholm university Research Vessel *Electra* could be used as a test platform as it has a Kongsberg EM2040 multibeam installed, which is operated with SIS.

Figure 3: *Programmer Glenn Markussen and Digital Technology Director Arne Hestnes from Kongsberg in the survey room of RV Electra.*

Figure 4: *Stockholm University research station on the island Askö, southern archipelago of Stockholm. RV Electra was used as a test platform during the development of the File Uploader.*


Seabed 2030 File Uploader
KONGSBERG
Seabed 2030 File Uploader
Update metadata
SEABED 2030
THE NIPPON FOUNDATION
GEBCO
IHO
Contribute data
Vision
100% of the World Ocean floor mapped by 2030
Mission
Produce the definitive map of the World Ocean floor by 2030 to empower the world to make policy decisions, use the ocean sustainability and undertake scientific research based on details bathymetric information of the Earth's seabed


Seabed 2030 File Uploader
KONGSBERG
Seabed 2030 File Uploader
Update metadata
Register survey details
Dataset name:
Petermann Fjord
Survey name:
Petermann 2015 Expedition
Vessel name:
IB Oden
Contributor organization:
Stockholm university
Contributor country:
Sweden
Point of contact name:
Martin Jakobsson
Point of contact e-mail address:
martin.jakobsson@geo.su.se
Digital Object Identifier:
10.17043/oden-petermann-2015-bathymetry-
Register
Cancel

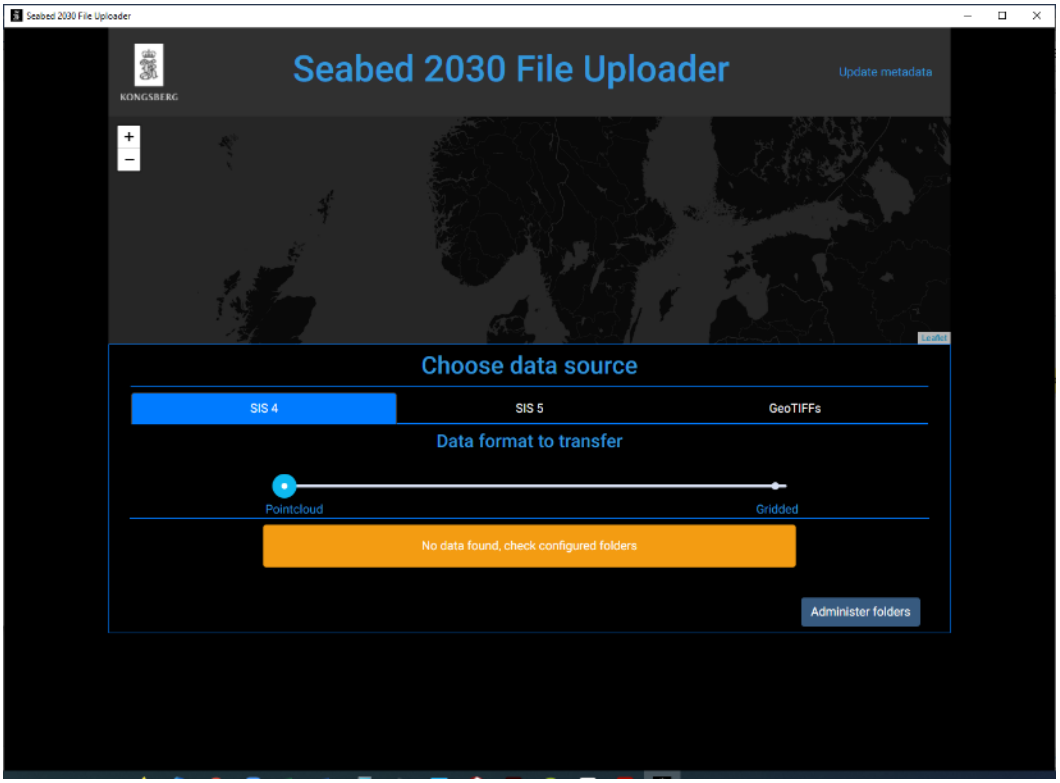


Figure 5: *Screen dumps showing the developed Seabed 2030 File Uploader.*

North Pacific Interactive GEBCO 2021 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 two versions of the North Pacific Data Management application, one as a webmap (see Figure 6 or https://bit.ly/3Hy0Xtu) and one as a web application (https://bit.ly/2Zmzwxw). Both tools have 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.

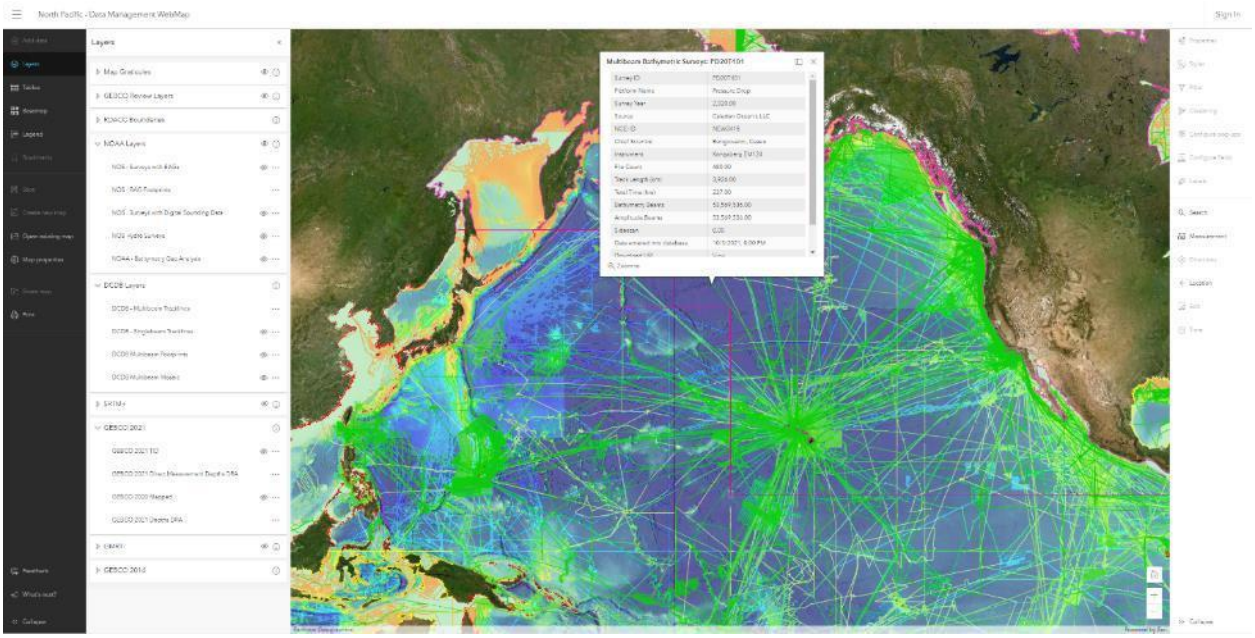


Figure 6: *The North Pacific data management webmap allows for the easy assessment of available data by aggregating publicly available webservices and those service created by the North Pacific team in one spot.*

Online Interactive GEBCO 2021 Grid Quality Assessment Tool:

During the Spring of 2021, the UNH team developed multiple 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 2021 bathymetry grid. Building on the development of the 2020 review application, 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.

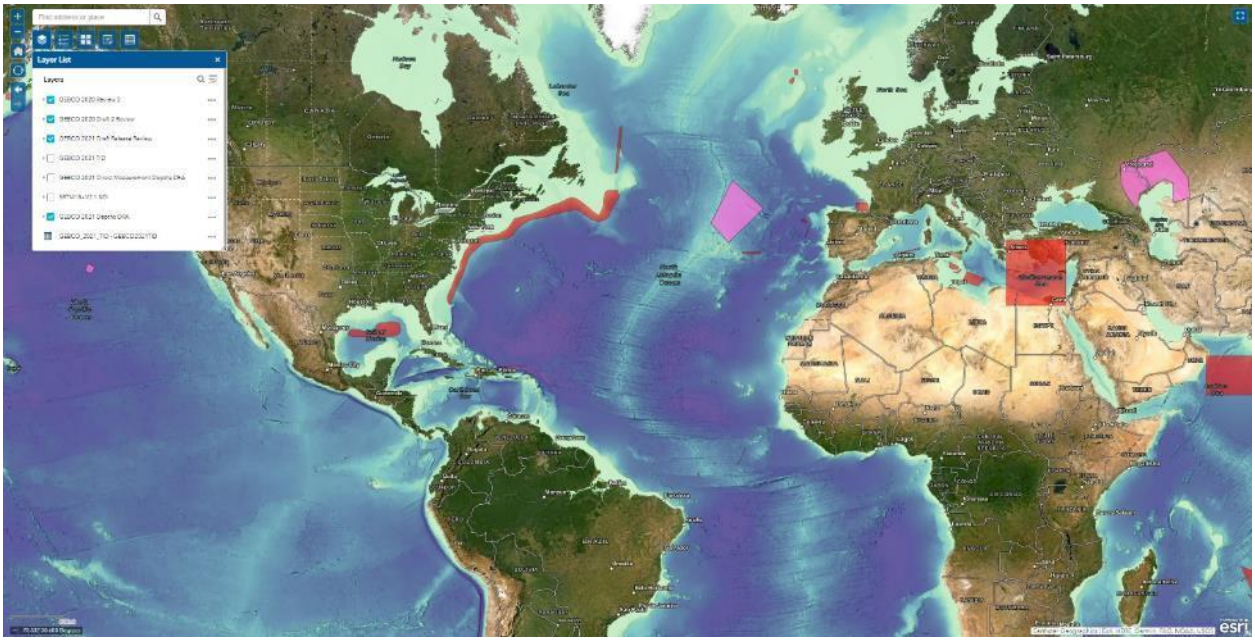


***Figure 7**: Screen shot from the GEBCO 2021 data review web application hosted on the UNH GIS portal, showing a newly designed review application used to assess the GEBCO 2021 draft releases. Users can graphically annotate areas identified that require further inspection.*

Online Interactive SRTM+ Grid Quality Assessment Tool:

As well as reviewing the contributed datasets to the Seabed 2030 program, it was also necessary to review the SRTM+ draft releases which are used as the underlay for the GEBCO grid. Using the same the same techniques developed for the GEBCO 2021 review, the North Pacific team created 2 review apps (one for draft release of SRTM+ version 2.1 and one for draft release of SRTM+version 2.3; Figure 8). These apps allowed the Global Community to review each draft prior to the integration of the draft with their respective GEBCO grids.

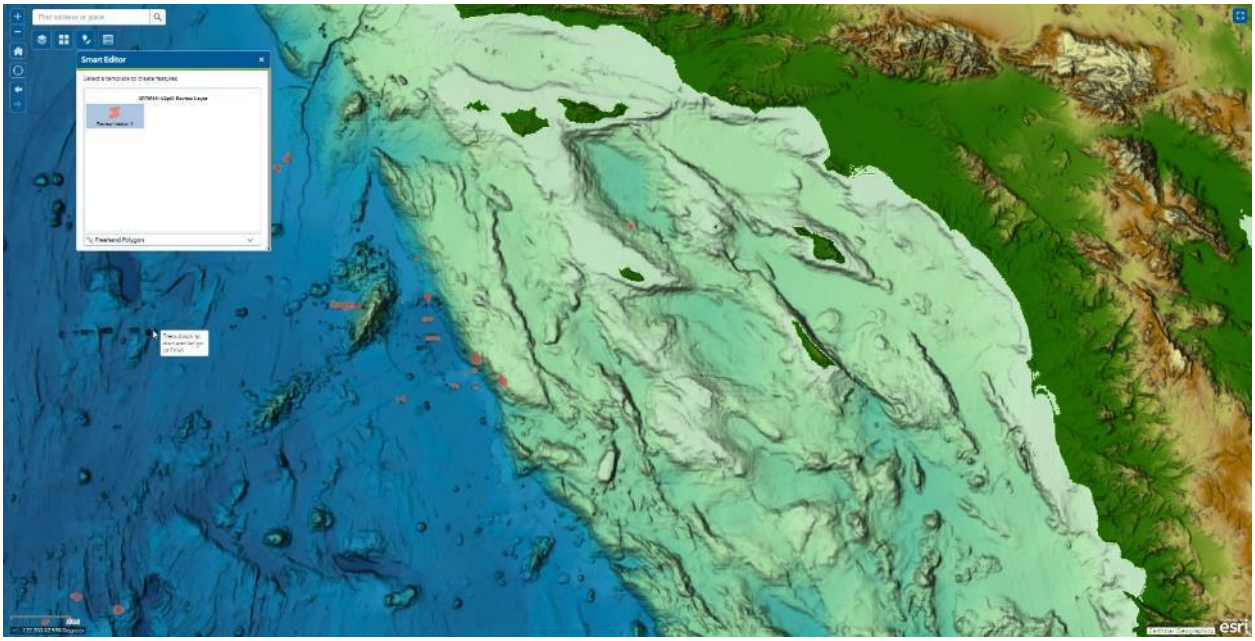


***Figure 8**: Screen shot from the SRTM+2.3 data review web application hosted on the UNH GIS portal, showing a newly designed review application used to assess the SRTM+ draft releases. Users can graphically annotate areas identified that require further inspection.*

Online Interactive Visualization Tools: GEBCO Globe

The GEBCO 2021 bathymetry grid is difficult to work with and to visualize (as was the GEBCO 2020 grid), 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 2021 dataset which is available from the UNH GIS Portal at https://bit.ly/3CoQkVT or shown as the top image in Figure 9. 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 bottom images of Figure 9 or https://bit.ly/3FmOd6W) which now includes an elevation layer, allowing for oblique vertically exaggerated views of the GEBCO 2021 grid to be generated. This viewer will also allow 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.

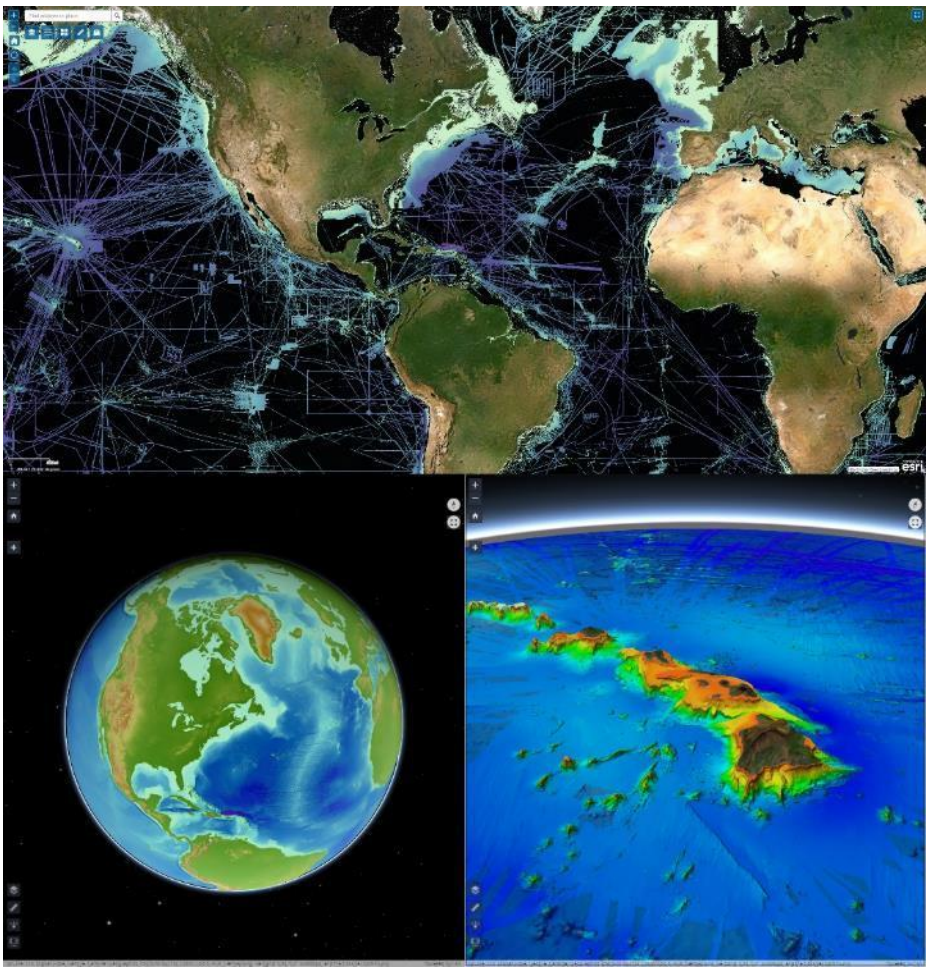


***Figure 9**: Screen shot from the web applications which are hosted on the UNH GIS portal*

(https://maps.ccom.unh.edu) , The top image shows a "flat" map of the GEBCO 2021 grid (https://bit.ly/3CoQkVT), with areas not determined by direct measurement being blacked out. The bottom two images show the new 3D global visualization of GEBCO 2021 bathymetry grid (https://bit.ly/3FmOd6W) which now also has an elevation layer loaded to allow for viewing the data obliquely with a vertical exaggeration.

Enhanced BathyGlobe: Gap-Filler Survey Planning Tool:

The BathyGlobe application, reported on last year 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.

GEBCO bathmetry is provided as a background for planning and GEBCO depth values used to calculate an estimated swath width at every point along each survey line. GapFiller allows the user to interactively lay transit tracks down in the context of existing data (to maximize gap filling) and also offers automate techniques to optimize coverage including a method for adjusting lines so that they abut existing lines with a pre-defined overlap (e.g. 10%) and a method for creating and filling polygon areas, taking depth variability into account.

A voyage-planning menu appears in the upper right, enabling waypoints to be placed, repositioned, or deleted in the Mercator view. As waypoints are added, the application computes the swath width based on user definable parameters (e.g., 4x water depth) and on the GEBCO bathymetry. The estimated coverage is displayed as a transparent surface. Since the application will mostly be used to fill regions where multibeam coverage does not exist, that coverage will normally be computed based on satellite-derived predicted bathymetry. However, where planned tracklines abut existing mapped areas, the estimated overlap will be more accurate (Figure 10).

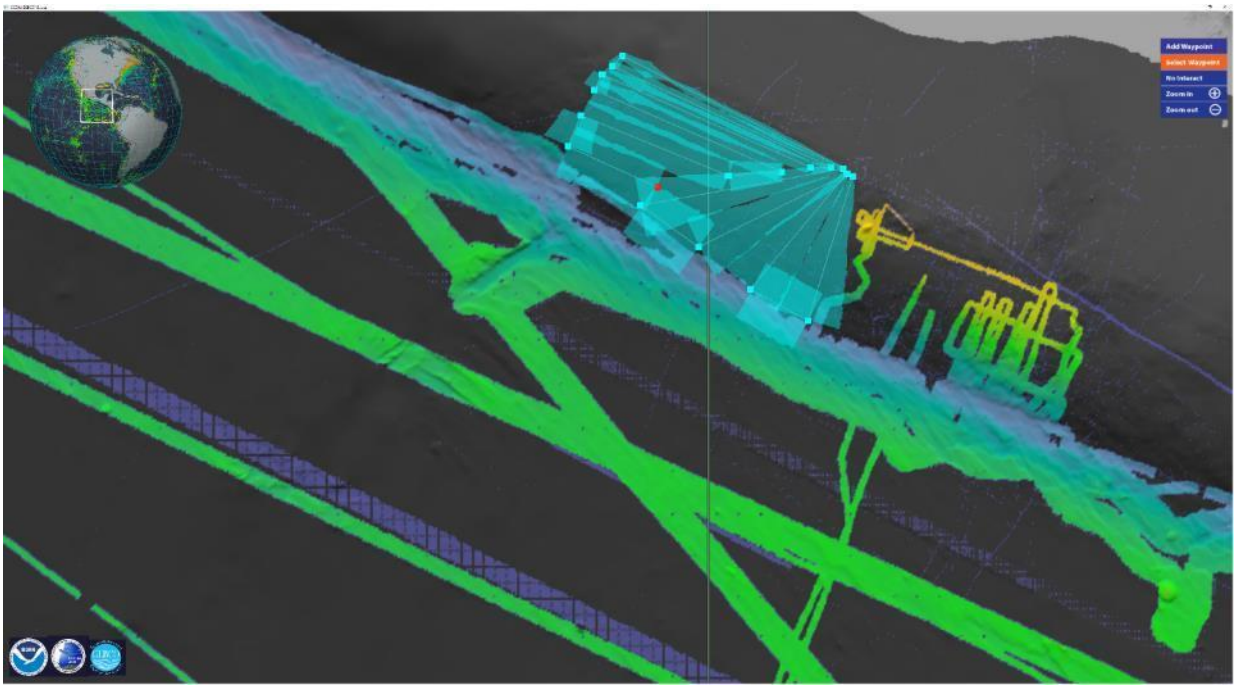


***Figure 10**: A screenshot from the BathyGlobe GapFiller application.*

Features of Bath Globe GapFiller

1) *Automatic overlap adjustments:* Ideally, when planning transits, new swaths should abut and slightly overlap existing mapped areas. To support the planning of tracklines meeting this requirement, the GapFiller application can adjust overlap with existing mapped areas to meet a specified amount of overlap (e.g., 10%). See Figure 11.
2) *Polygon filling:* GapFiller allows the user to draw a polygon, which can then be filled automatically with planned track lines. As polygons are filled the overlap of successive swaths is automatically adjusted based on local depth estimates. Multiple polygons can be linked to form a survey plan. See Figure 12.
3) *Plan statistics.* GapFiller can compute mapping statistics, based on a transit or survey plan. These include total area mapped, overlap with existing mapping, self-overlap, and area of new mapping.

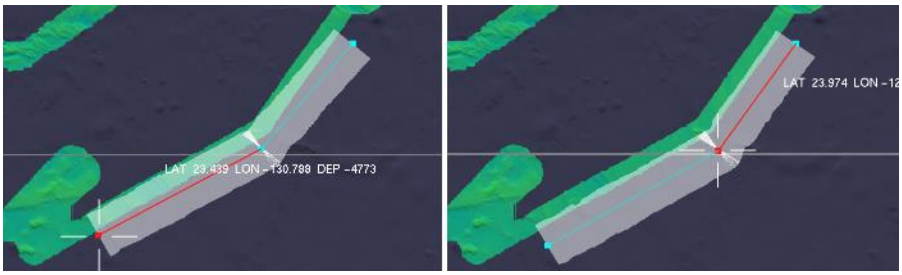


***Figure 11**: On the left are two planned mapping legs. On the right, the positions of the waypoints have been automatically adjusted to achieve 10% overlap with existing multibeam mapping.*

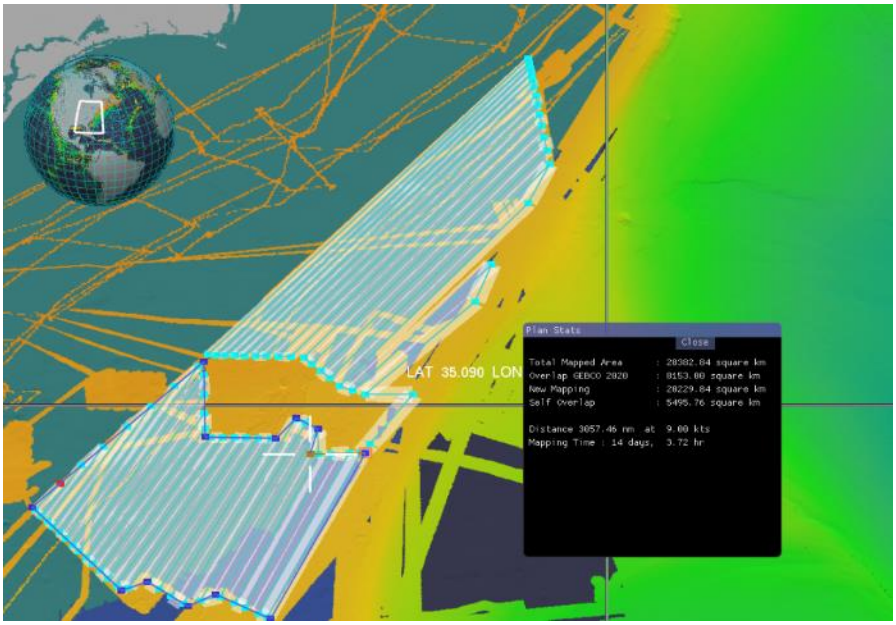


***Figure 12**: A set of tracklines automatically generated based on two hand-drawn polygons*.

GapFiller was very successfully used to optimize gap coverage in the planning of the Ocean Mapping Initiatives that brought the Saildrone Surveyor across the Pacific from San Francisco to Hawaii and for the transit of the HEALY through the Northwest Passage (Figure 13).

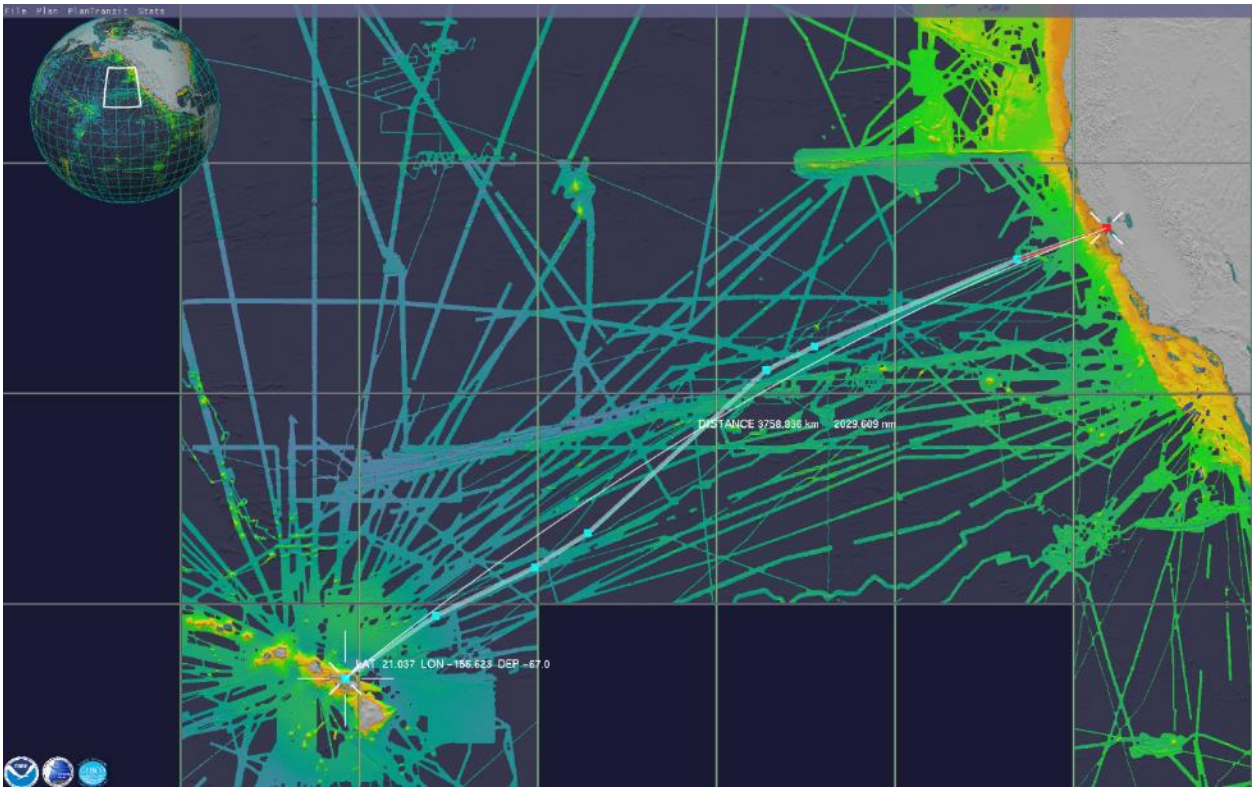


Figure 13: *GapFiller being used to plan transit of Saildrone Surveyor from San Francisco to Hawaii.*

Script to allow NCEI to ingest Pressure Drop multibeam data:

During the spring of 2021 the North Pacific staff developed an easy-to-use script which reformatted the data distribution from DSSV Pressure Drop into a format that could be more easily ingested into the archive at NOAA's National Center for Environmental Information (NCEI) (Figure 14). This script, which was written in the Bash command language and was designed to work with the well-defined data distribution provided by the Pressure Drop in order to reorganize the data the data into a structure more compatible with NCEI's data ingest scripts.

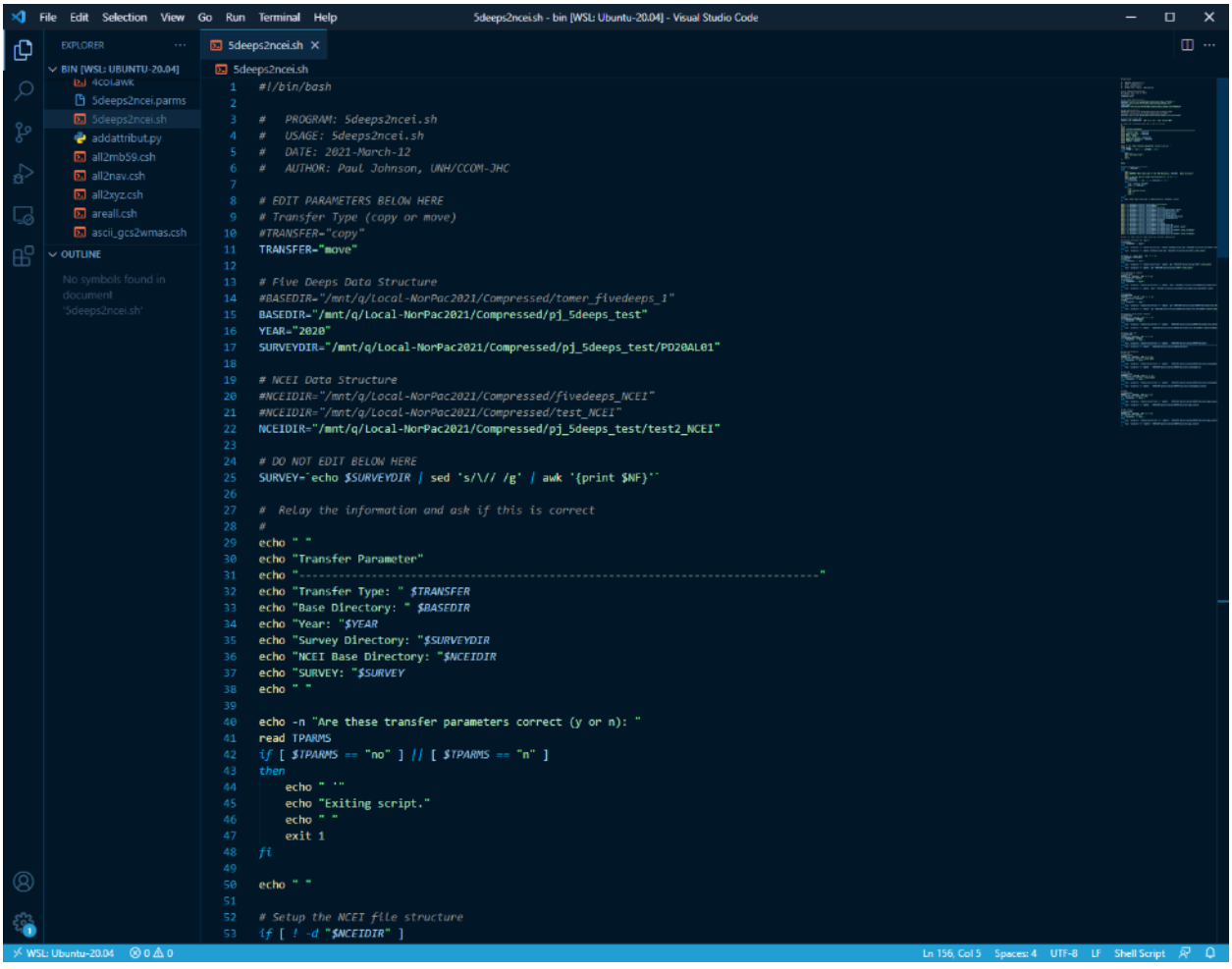


Figure 14: *Header of script which reformats the Pressure Drop data distribution into a form for easier import into the archive at NOAA's National Center for Environmental Information (NCEI) .*

Ingest NCEI Single-beam data sets:

678 single beam surveys dating from 1990 to present were obtained from NCEI by direct request. These data can be found through the trackline/ single beam data viewer at NOAA's NCEI that fit within a general box

bounding box. (These data do include some NOAA NOS OCS surveys, which are part of other compilations.)

A subset of these surveys is within the North Pacific region (Figure 15). These are undergoing processing to remove noise and fliers within QPS Qimera (Figure 16).

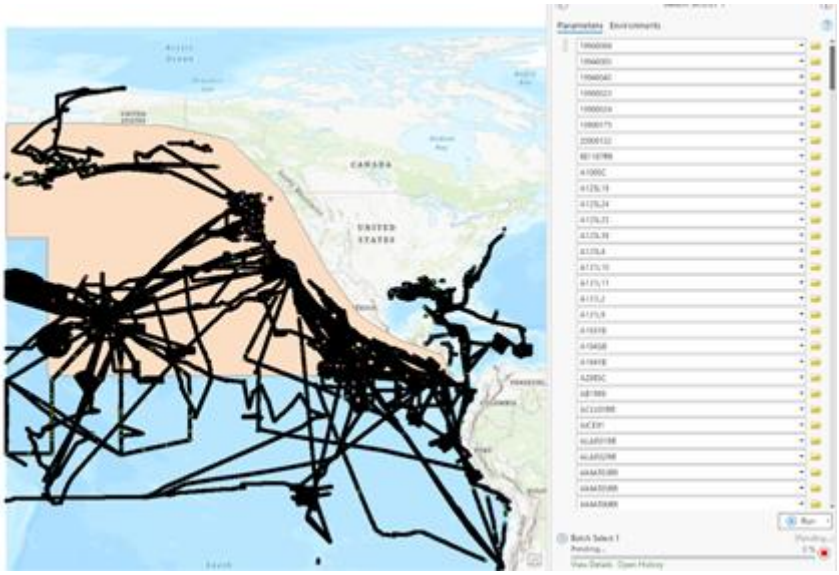


Figure 15: *Pale Orange Polygon being used to select singlebeam track lines provided by NOAA's NCEI in the area of North Pacific.*

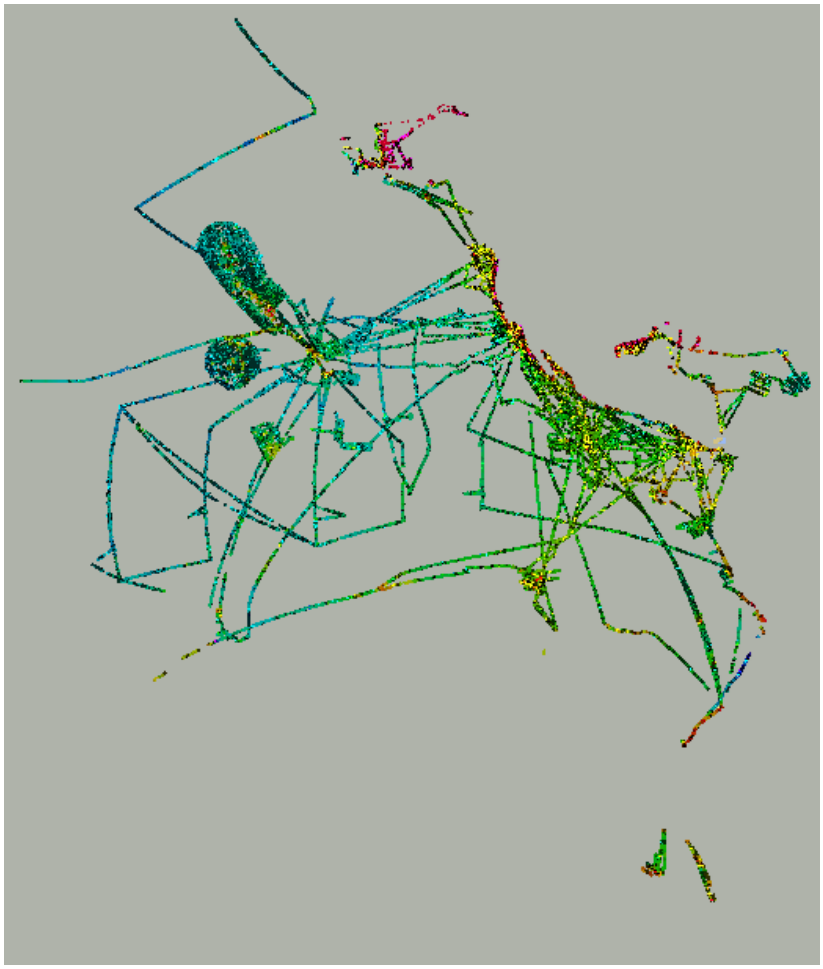


Figure 16: *Single beam data lines are being processed within Qimera to remove noise from the data.*

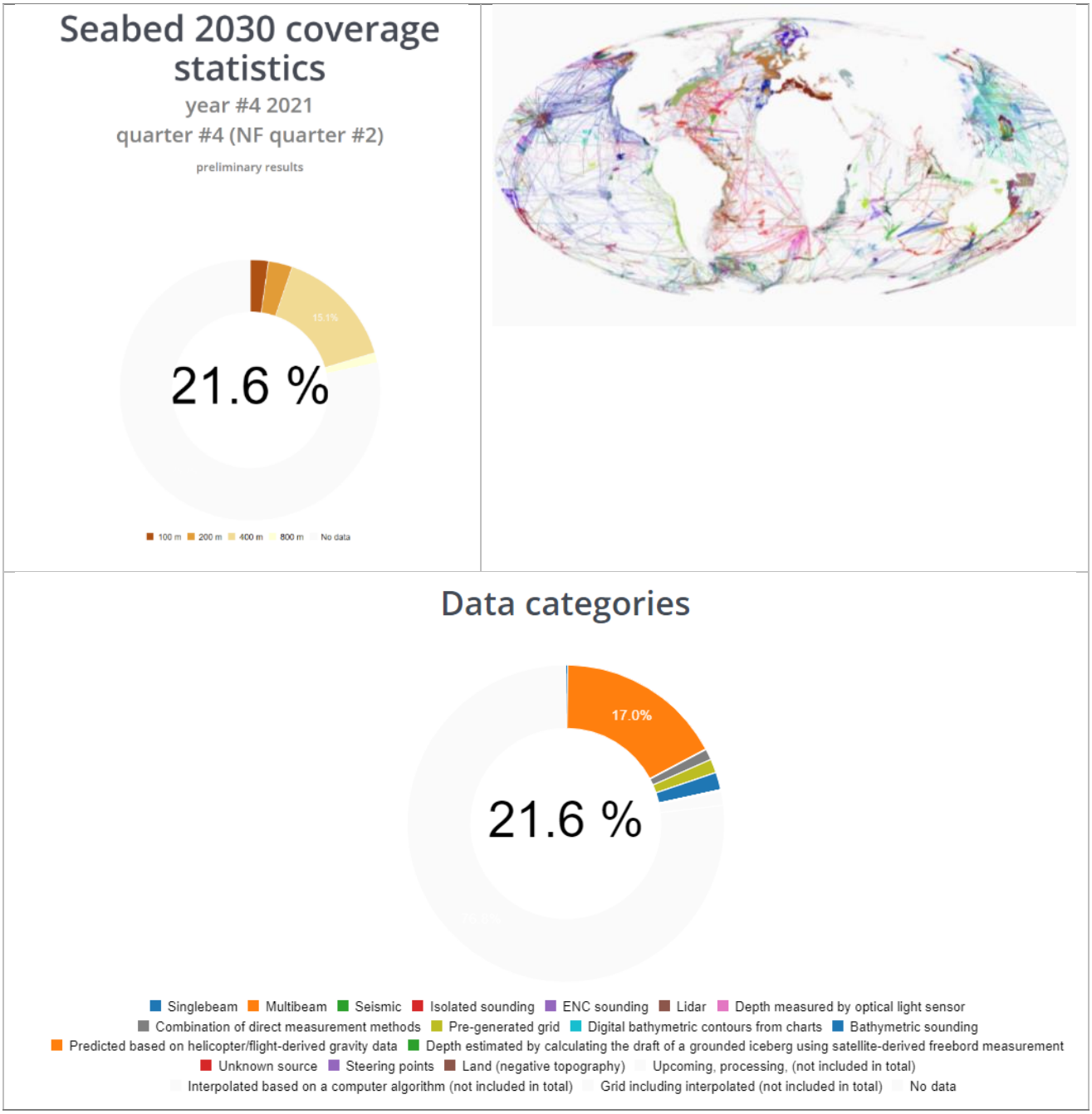
Implementing distributed computing and cloud computing on Amazon Web Services

The SU Team used to run the gridding of the seafloor using a well-known standard software library named Generic Mapping Tools (GMT). The grid cell-size used to be 500x500 m. As computational resources are more efficient and cheaper now we decided to increase the resolution to 100 m, resulting in a data increase of 2500 %. The data volume became too large to read into the memory of an ordinary workstation.

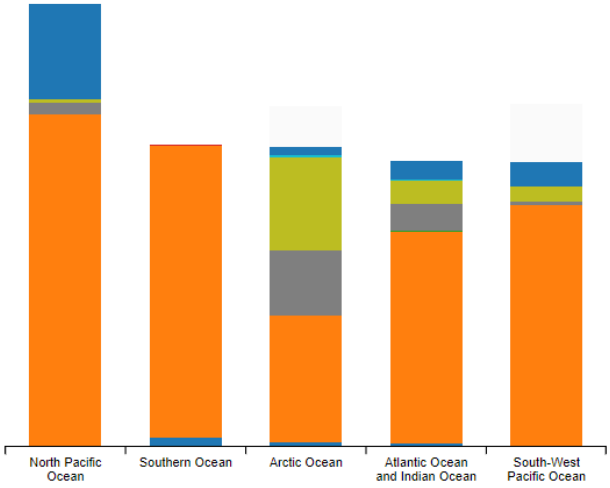
In order to process this large amount of data we used distributed computing which partitions the data in small pieces and process each partition independently. We use a library for distributed computing in the script language Python which is well-known in the scientific community. Moreover, we migrated the calculation to the Swedish National Supercomputing Centre where we have access to a parallel computer cluster. We now use three computer nodes with 1 TB of total RAM to process the data. The calculation executes more than 20 times faster using this method compared to the traditional method using a single workstation.

The previous year 3, we had started to migrate to Amazon Web Services (AWS), which makes it possible for authorised users to upload to, store and process the data in the system using a standard web browser. We

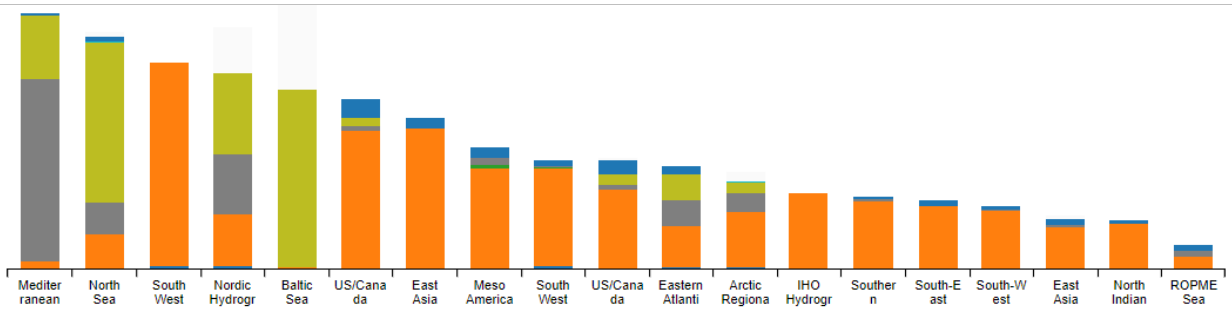
also aim to integrate a previously developed metadata system into the AWS framework, to help us manage the extensive amounts of datasets. The approach makes it possible for anyone to contribute and upload data to the system and view the resulting grid almost immediately using a web browser. The calculation of the statistics is also now fully operations in the AWS environment. The calculated statistics is now being published as inhouse information for the Seabed 2030 centers in a series of graphs shown in Figure 17.



Data centres



Regional hydrographic commissions



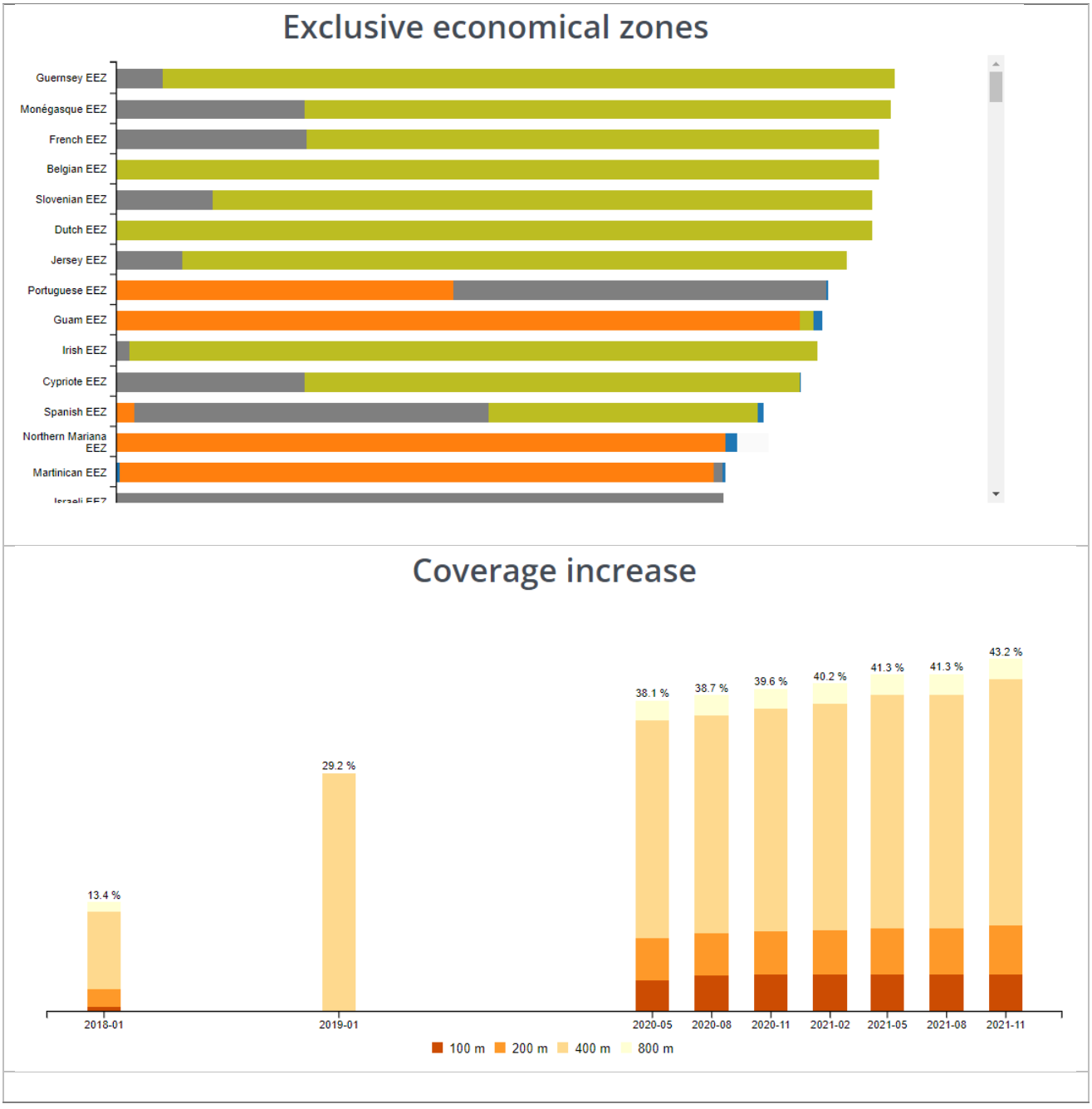


Figure 17: *Examples of statistics compiled with the tool developed by the SU Team.*

Ocean Frontier Mapping Initiatives:

HEALY 2021 – Northwest Pacific Transit:

The HEALY departed Seward Alaska on 25 August 2021 at 1300 L (local time) and arrived in Nuuk Greenland at 0900 on 13 September after traveling a total of approximately 5250 nautical miles. The transit started south of the Aleutians, through Unimak Pass, north through the Bering Sea, Bering Straits

and into Chukchi Sea, then paralleling the North Slope of Alaska across the shelf and upper slope of Canada Basin and finally entering the Northwest Passage through Amundsen Gulf and traveling along what is known as “Route 2” – south of Banks Island to the Prince of Wales Strait, up the Prince of Wales Strait into McClure Sound/Viscount Melville Sound, to the Barrow Strait and then out Lancaster Sound into the Baffin Bay (Figure 18).

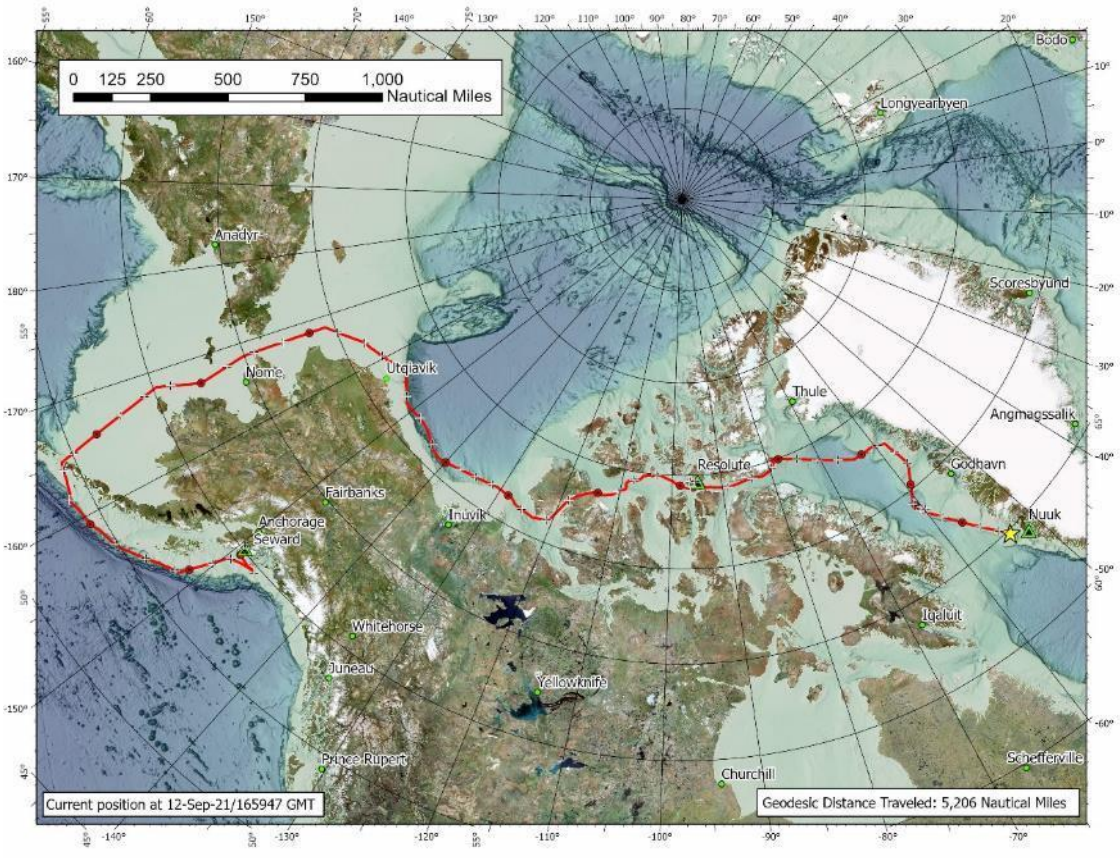


Figure 18: *Ship track for HLY21TD*

A fundamental requirement of the cruise was the need to be offshore Resolute on the morning of the 6 of September to participate in joint (with the Canadian Coast Guard) Search and Rescue (SAR) exercises and a visit of distinguished visitors (DVs) including the Commandant of the Coast Guard (ADM Karl Schultz), the Commissioner of the Canadian Coast Guard (Mario Pelletier), and the Canadian Coast Guard Assistant Commissioner Arctic Region (Neil O’Rourke).

Working within this time constraint we optimized our track to cover a number of areas where mapping data did not exist (see Chief Scientist Log) and conduct a detailed survey of a high priority Canadian Hydrographic Service corridor near Resolute (see Chief Scientist Log). In all, **20,637 sq km of seafloor were mapped during the expedition, including 12,177 sq km of previously unmapped**

seafloor, a particularly significant number given the remoteness of the region. Additional time became available at the end of the cruise on the approach to Nuuk Greenland, allowing an approximately **2350 sq km area to be mapped in relatively deep water off Disko Bay** on behalf of the Greenland Institute of Marine Resources (see Chief Scientist Log).

In addition to the mapping, continuous gravity measurements were made from gravimeters (both the ship's original BGS gravimeter and a newly installed DgS gravimeter). To monitor ocean freshening (decreasing salinity, in part, from and fertilization of the ocean, continuous (every 5 seconds ~10,000,000 measurements) isotope samples from water vapor ($\delta^{18}O$, $\delta^{17}O$, δD) and sea water ($\delta^{18}O$, δD) were collected as well as atmospheric carbon isotope ($\delta^{13}C$) and CO^2 and CH^4 (methane) concentrations. To examine net community primary production, the ratios of the dissolved gas pairs O_2/N_2 and O_2/Ar were continuously measured (again about 10,000,000 measurements) and to ground-truth these measurements, 500 particulate organic carbon samples were taken by filtration.

Four ice buoys were launched on behalf of the Canadian Environmental Service, 2 CTD stations were occupied, and 58 XBTs and 57 XCTDs were deployed over the course of the cruise. A detailed cruise report can be found at: https://universitysystemnh-my.sharepoint.com/:b:/g/personal/pdi28_usnh_edu/EQC60ZSsxutKvQQ-AF9ejyUBnzwS4R1MAUQ85TD8388HVA?e=RBtSzF

Saildrone Across the Pacific:

The Nippon Foundation-Seabed 2030 Ocean Frontier Mapping initiative made a significant contribution to the collection of new unmapped seafloor data and contributed to the first demonstration of an exciting new seafloor mapping technology through its support of the maiden voyage of the Saildrone SURVEYOR from San Francisco to Honolulu Hawaii in June and July of 2021. 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 19 provides the specifications of, and sensor suites on, the Saildrone SURVEYOR.

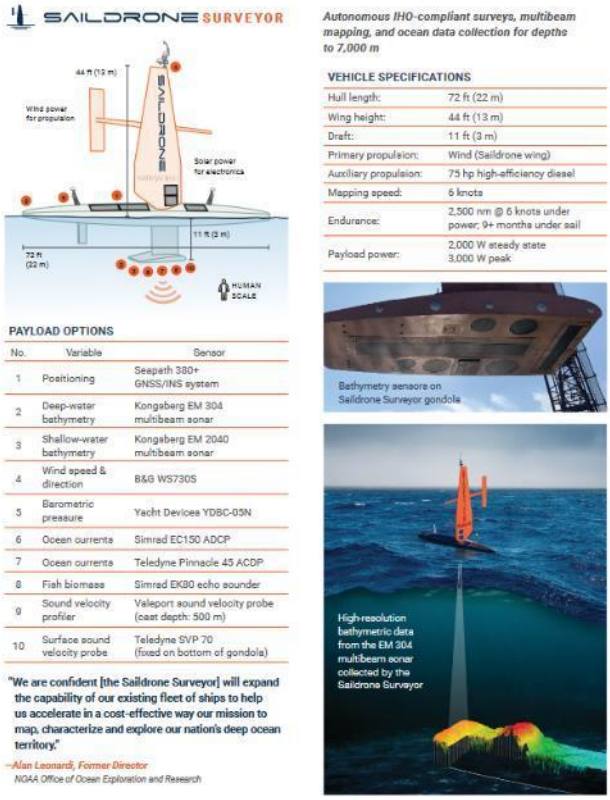


***Figure 19**: Specifications for Saildrone SURVEYOR*

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 *Two Oceans Two Technologies* Ocean Frontier Mapping initiative. This funding paid for the incremental effort to divert the route to maximize the collection of new data. The effort was quite successful in this goal (Figure 20). In total **18,491 sq. km** of previously unmapped seafloor was mapped representing almost 75% of the entire route, which was quite an accomplishment on such a well-

transited route.

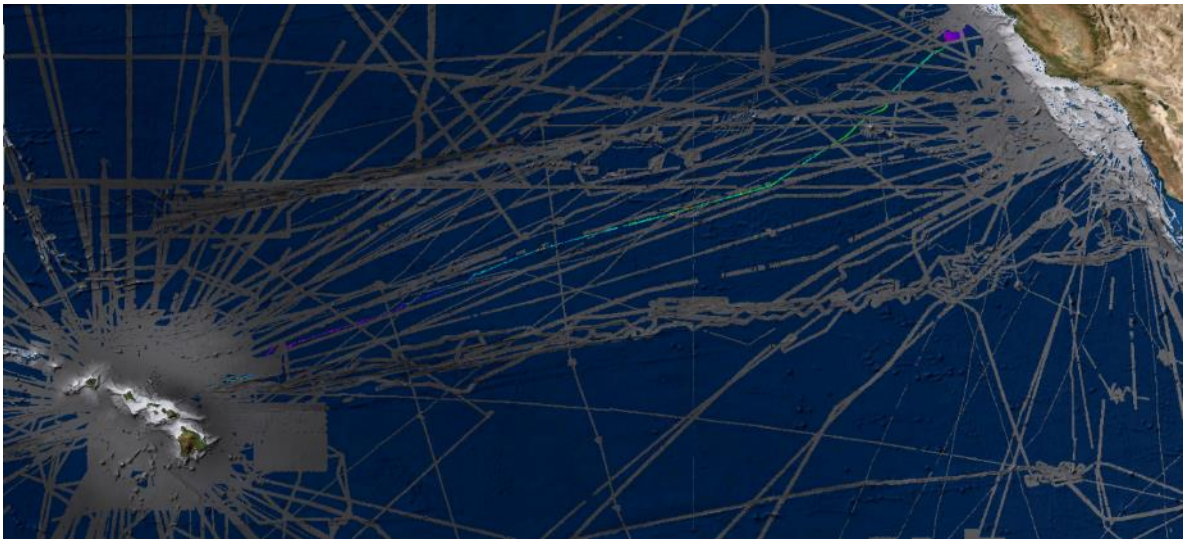


***Figure 20**: Route optimized to fill mapping gaps. Saildrone data (colored) superimposed on date in the GEBCO 2021 compilation. Out of 24,987 sq km covered in the transit 18,491 sq km represented previously unmapped seafloor.*

Data quality was excellent throughout transit even to depths beyond 5000 m (Figure 21). Post cruise, data were processed by Nippon Foundation-GEBCO UNH alumni and submitted to the Regional Data Center and the DCDB. Details of the data processing and data quality are presented in the attached Data Processing Report.

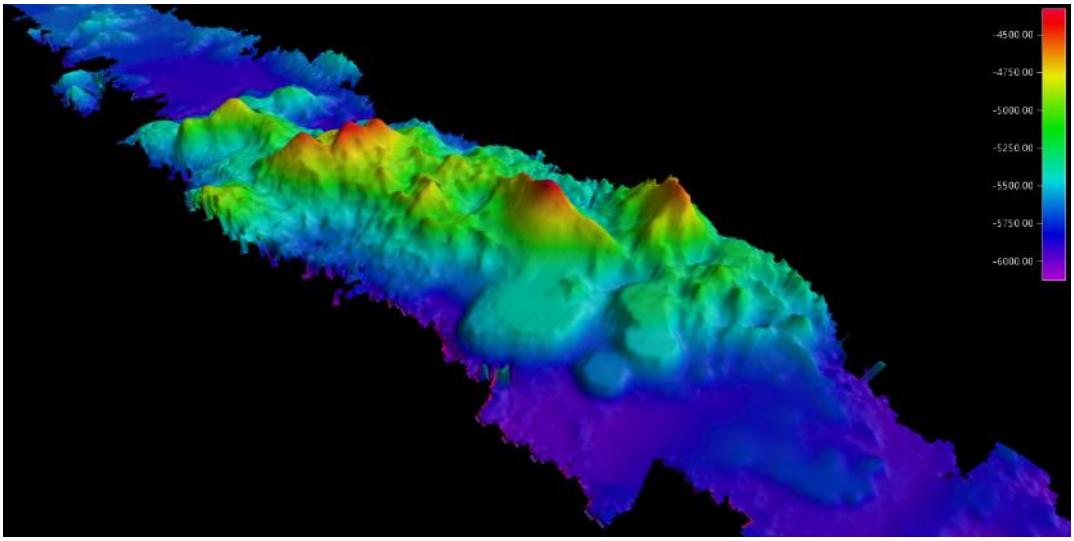


***Figure 21**: Example of data quality at 5000-6000 m water depth from Saildrone Surveyor*

The advantage of the collecting multibeam data under sail (quiet vessel) became apparent as swath width increased by almost 20% when compared to achievable swath while motoring (Figure 22).

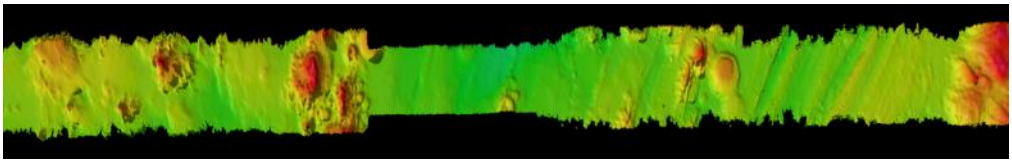


***Figure 22**: Example multibeam trackline during transit mission, gridded at 100m resolution. Note change in swath width when changing from motoring to sailing.*

Summary of cruise statistics:

- 28 days at sea
- 3,650 km line km surveyed
- 24,987 km^2 mapped
- 18,491 km^2 unmapped seafloor mapped
- Depths greater than 5500m surveyed
- 56 eDNA samples plus four controls collected
- Continuous monitoring of a range of environmental variables (wind, wave, currents, temp, etc.)
- EK-80 data collected at select locations

Daily products were sent ashore to provide situational awareness to participants and stakeholders via the SAILDRONE Mission Portal. Real-time data telemetry constraints and limitations began to be explored during transit as well as the collection of data that will help with understanding trade-offs of sailing vs motoring to optimize bathymetric data collection and overall system endurance and performance (subject of UNH MSc thesis). Most importantly, the cruise has established without question that long-term, unmanned missions using an environmentally friendly sail and wind-powered vessel can be maintained for long-periods of time collecting high quality bathymetric data in remote parts of the ocean. This is an important step forward in demonstrating new technologies that can help meet the objectives of the Nippon Foundation-GEBCO Seabed 2030 Project.

Oden – Synoptic Arctic Survey (SAS) 2021

Two members of the SU team joined the SAS2021 expedition with Swedish icebreaker Oden to the Arctic Ocean. Oden left Helsingborg, Sweden July 25 for the transit to the ice edge northeast of Svalbard. On August 2 the expedition stated with crossing the Amundsen basin and the Gakkel ridge, aiming for the North pole which was reached on August 16. From there Oden followed the Lomonosov south, towards the Greenland shelf area, which was reached in early September. The expedition ended at the Yermak Plateau September 11, when Oden commenced the transit back to Helsingborg, returning September 19. See cruise track in Figure 23. Multibeam data was collected

continuously during transit between stations and whenever possible at stations, in accordance with other shipboard projects.

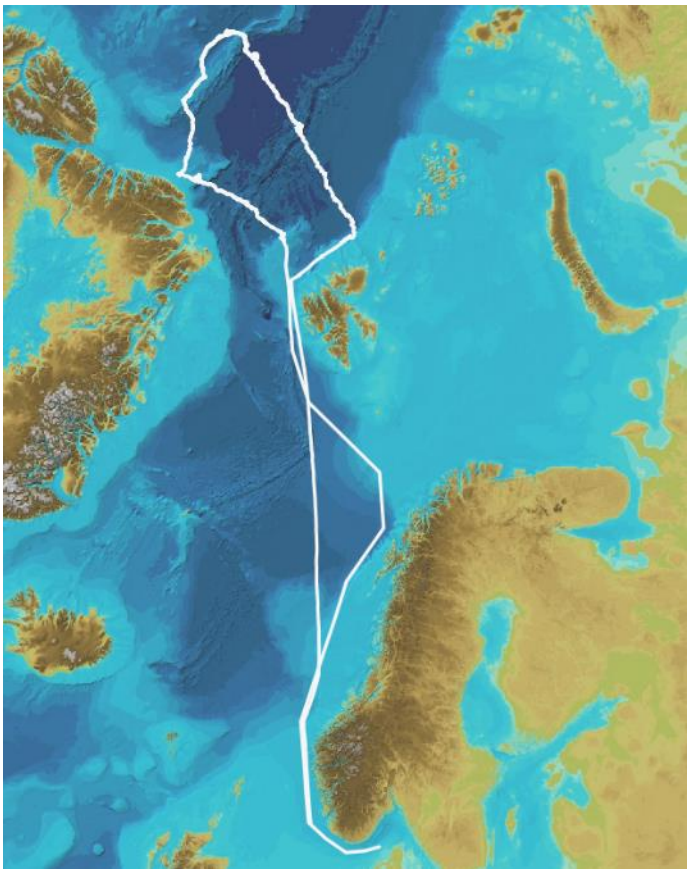


Figure 23: *Cruise track for Oden SAS2021 expedition and transit to and from Sweden to the Arctic Ocean.*

As the first surface vessel ever, *Oden* reached the Greenland shelf around Morris Jessup Rise from the north and successfully mapped an area of previously unmapped seafloor, at optimal weather and ice conditions. An example of the geomorphology of the seafloor in the area are extensive glacial lineations, which can be seen in Figure 24.

Summary of cruise statistics:

- 61 days, out of which 41 was expedition time
- 7,490 km cruise track, including transit
- Continuous collection of EK80, complements MB data in locations where no MB data could be collected.

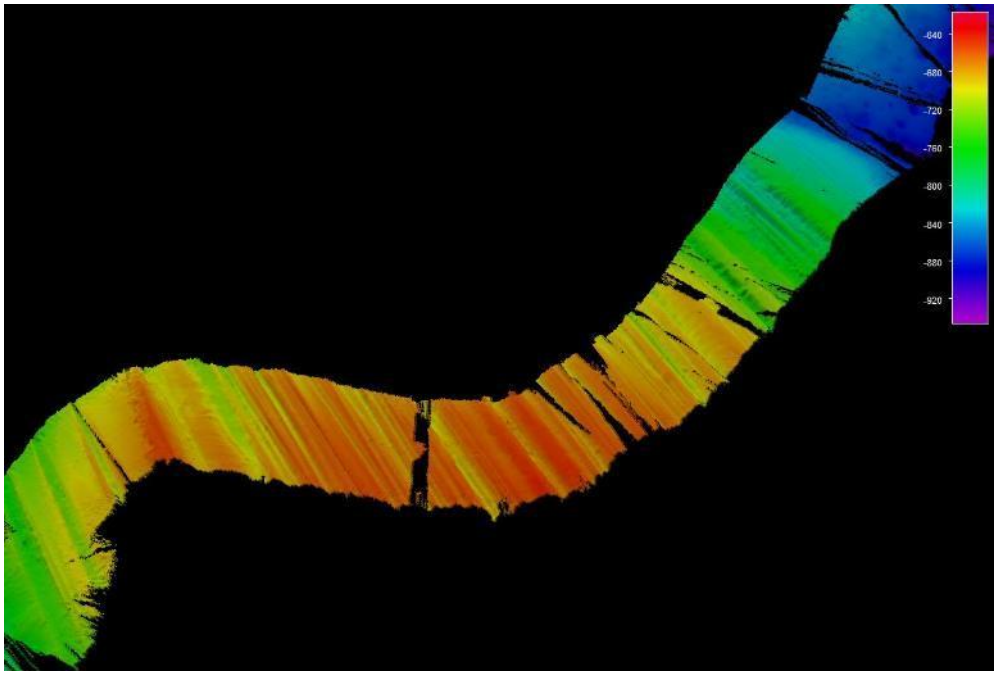


***Figure 24**: Glacial lineations at ca 600 m depth at Morris Jessup Rise, multibeam data collected during the SAS21 Oden cruise.*

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.

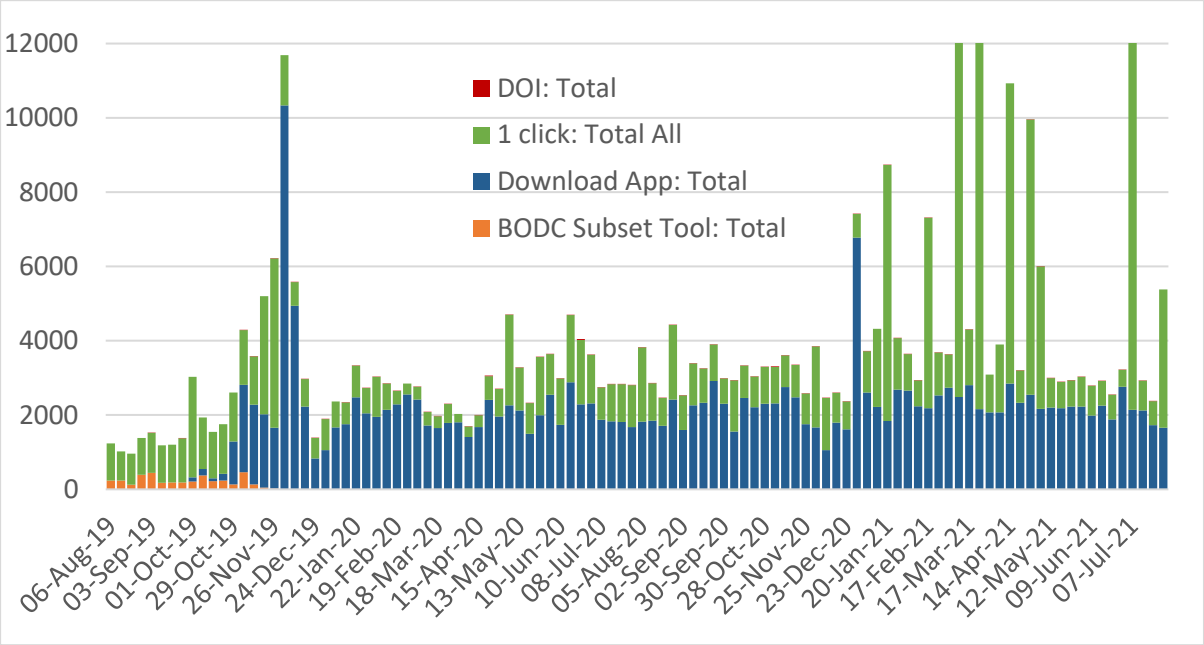
Center Lead: Helen Snaith.

Summary

During Year 4 of the project, the Global Center has continued to focus on effective development and delivery of the global gridded products, and has also been developing the metadata standards and collection to support reporting for the project.

The final GEBCO_2021 global bathymetry grid and associated type identifier (TID) grid was released in July 2021, based on the SRTM+ v2.2 base grid with regional center inputs merged to create the global products. A second version of the grid has been generated this year providing under-ice bathymetry/topography, to enhance the standard ice-surface version of the grid. The new dataset was allocated a new doi. Consistent with previous releases, the products are now 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 4. The pre-release version of the grid was available for one-click download from May 2021.

Downloads have increased from an average of 3035/week in year 3 to 4614/week in year 4. The data download service has been enhanced to allow creation and download of image versions of the bathymetry and also to allow selection of any one of the Seabed2030 generated global gridded products. The 2021 grid was released in this application at the end of year 4 and since then we have seen a further increase in the number of weekly downloads.

The Seabed 2030 website has been migrated to a cloud platform, using a drupal content management system. There was no change to the design of content as a result of the move. As a result, all Seabed2030 partners now have access to the content management system, and the update process has been simplified, allowing more regular updating and content refresh. The new site has been maintained during the year, with all News events as required, and additional Partners added to the appropriate pages. Data contributors are highlighted on the GEBCO website.

Center Staff

The Global Center still has a full staff complement, with three staff working on the Seabed 2030 Project (Helen Snaith, Pauline Weatherall and Chris Thompson).

Major data and grid contributions

GEBCO 2020 bathymetric Grid Development

As with previous releases, the GEBCO_2021 data set is a global elevation model for oceans and land on a 15 arc-second interval grid. In addition, for the 2021 release, a version has been generated which

includes under-ice topography/bathymetry information for Greenland and Antarctica. 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+ v2.2, 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 sounding based on satellite-derived gravity data. In February and March 2021 the Global Center coordinated feedback from the Seabed 2030 Technical Team to help to identify errors in the updated v2.1 SRTM grid. This led to the generation of a new version of the data set for use as a base for the GEBCO grid.

A first draft of the GEBCO_2021 grid was compiled in April 2021 at the Global Center, combining input from the Regional Centers. The grid was made available for review to Seabed 2030 Project colleagues and GEBCO's Technical and Regional Mapping teams. After coordinating the reviews and updates with the Regional Centers, an updated global grid was developed in May.

Incorporating edits from the review process, a pre-release version of the GEBCO_2021 Grid was made available from GEBCO's web site in May, as a single global NetCDF version. With the finalised release being made available in July 2021.

Staff at the Global Center produced documentation to accompany the grid and provided the necessary information for the minting of a DOI for the data set. Information concerning the organisations contributing data sets for inclusion in the GEBCO grid was included on GEBCO's web site: https://www.gebco.net/about_us/acknowledgements/our_data_contributors/.

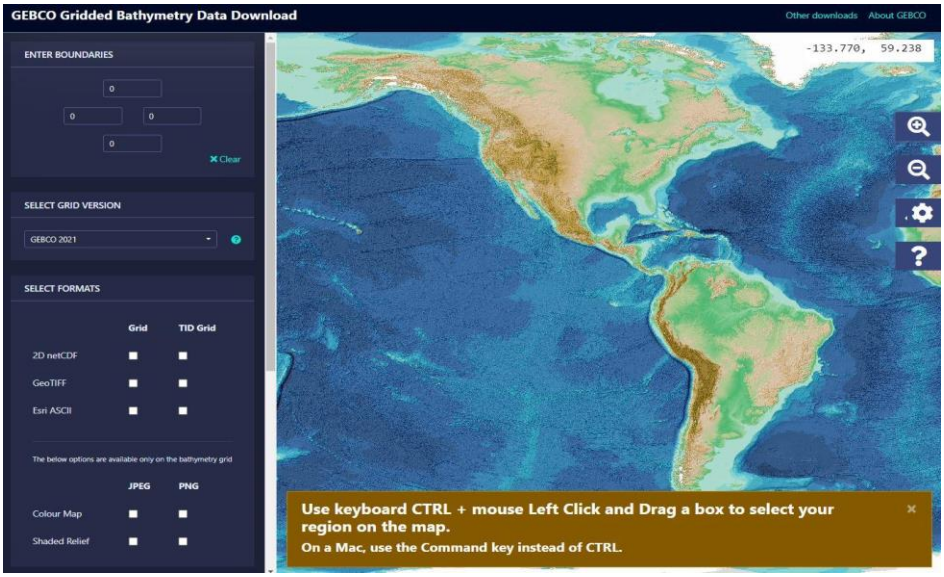
Data Distribution

As with previous GEBCO grid releases, the GEBCO_2021 Grid is made available through a number of routes. Data for direct download from GEBCO's web site, as a global grid in netCDF format or as a set of tiles in data GeoTiff or Esri ASCII raster formats https://www.gebco.net/data_and_products/gridded_bathymetry_data/.

During the year, the download application used to provide access to the grid for user-defined geographic areas has been updated. The application now supports the following functionality:

- Access to the GEBCO_2021 Grid and TID Grid
- Access to previous GEBCO grid releases: GEBCO_2020 and GEBCO_2019
- The capability to download bathymetry data in the form of an image file (JPEG or PNG)

The provision of image formats was as direct response to user feedback, and the number of requests for manual generation of imagery.

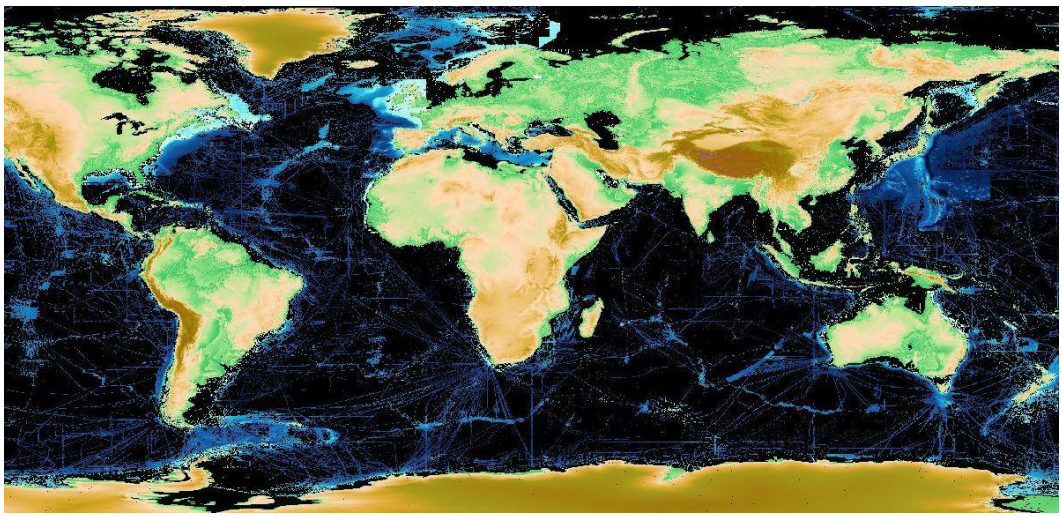


The updated GEBCO download application (https://download.gebco.net)

Access to GEBCO's grids through Web Map Services (WMS)

The Global Center have continued to enhance the WMS access to the data, and have developed WMS layers (https://www.gebco.net/data_and_products/gebco_web_services/web_map_service/) based on the GEBCO_2021 Grid, including the grid displayed as a:

- shaded relief image
- 'flat map' image, colour-coded for elevation (supporting querying of elevation information)
- 'flat map' image, colour-coded for elevation, showing areas based on measured data only
- TID grid cells based on measured data shown in black
- TID grid cells colour-coded by TID value



Layer from the GEBCO WMS showing regions based on measured data only – areas based on interpolation, prediction or pre-generated grids are shown in black

Development of a data source metadata

In order to be able to provide information on the data sets included in the GEBCO grid, the Global Center have been developing a system to hold and query metadata.

The system is based around the storage of the metadata in a PostgreSQL database. This is supported by Python code and Jupyter notebooks that facilitate reporting of key statistics from the data. Currently used at the Global Center, it is aimed in the future to make the metadata system available to the wider technical community.

For the GEBCO_2021 Grid release, the Regional Centers have provided metadata for the source data sets used in the generation of their regional grids. This metadata has been compiled into a single data file at the Global Center. Work has then been done to harmonize the metadata, ensuring a unique name is used for each contributing organisation. The Global Center is investigating the use of controlled vocabularies within the metadata system.

In collaboration with the GEBCO Metadata Working Group, a metadata template and guidelines for contributing data to GEBCO have been generated and made available from GEBCO's web site (https://www.gebco.net/about_us/contributing_data/).

Financial report

Seabed 2030 funded 1.5 FTE of the staff time in year 4 of operation. Additional contribution of at least 0.5FTE was provided from central British Oceanographic Data Centre funds to further support year 4 of operations.

Other activities

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 Seabed2030 and GEBCO Facebook and Twitter. As the access point to the Seabed 2030 Project and the data products, we provide user support to product users and statistics on data access and usage for GEBCO.

At the beginning of the year, the Seabed 2030 website was migrated from an internal, BODC hosted, server, to a cloud platform, and the content was migrated from the previous Dreamweaver-based files to a drupal content management system. There was no change to the design of content as a result of the move. There was no downtime of the website as a result of the migration.

Since the migration, all Seabed2030 technical team members now have access to the content management system, and the update process has been simplified, allowing more regular updating and content refresh. The new site has been maintained during the year, with all News events as required, and additional Partners added to the appropriate pages. Data contributors are highlighted on the GEBCO website.

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. Since March 2020, the new Project Administrator post, also based within BODC, has provided additional support for meeting organisation and reporting.

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, supported the Project through the communications team, in editing News items, press releases and other articles. The Center Head provided an article for environmental Scientist in their Decade of Ocean Science Special in March 2021. Center staff have also regularly provided bespoke imagery for users in a range of publications and presentations.

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

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 4 effort working with the NOAA NCEI Software Development Team on 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.

Main Year activities

- DCDB Infrastructure Enhancements:
    - Began 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.
    - Continued 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.
    - Finalized improved crowdsourced bathymetry (CSB) pipeline that should be deployed in early 2022. Current pipeline has been out of commission since October 2020. 2020-2021 contributed data has been archived but not made discoverable to the public.
    - Deployed a cloud-hosted continuous point store. Moving to the cloud will allow for CSB data (and theoretically all bathymetric data sources) to be stored as a seamless collection of points. The vision is to provide a variety of enhanced services along with the data itself, such as the ability for users to generate bathymetric grids of a given area using user-specified resolution, to retrieve data density information, and better support the guiding of future data collection efforts.
    - Implemented numerous enhancements to the IHO DCDB Data Viewer (ncei.noaa.gov/maps/iho_dcdb/).
- Collaborated with Seabed 2030 Director on outreach to government agencies and organizations to participate in CSB Regional Programs. Data loggers were distributed to three regional CSB mapping projects as a proof of concept (Institute for Marine Technology & the South African Navy Hydrographic Office, Palau Bureau of Marine Transportation and Greenland Institute of Natural Resources. The intent is to (1) collect data in underserved areas, (2) grow excitement about the CSB initiative and (3) develop a repeatable regional CSB mapping project strategy. Due to COVID-19, the speed in which the data loggers were ordered and distributed was greatly impacted and the roll out of these loggers to the communities is expected to also be severely delayed.

Data submission

The DCDB has archived over 4.1 TB uncompressed (2.5TB compressed) of multibeam bathymetry data from 168 surveys and 12 sources. This includes:

- 15 surveys from 2 vessels contributed by National Oceanic and Atmospheric Administration (NOAA)
- 3 surveys from 1 vessel contributed by NOAA's Atlantic Oceanographic and Meteorological Laboratory

- 26 surveys from 6 vessels contributed by Fugro Geoservices
- 1 survey from 1 vessel contributed by Geological Survey of Ireland (GSI)
- 6 surveys from 3 vessels contributed by Marine Geoscience Data System (MGDS)
- 1 survey from 1 vessel contributed by NOAA/Woods Hole Oceanographic Institute
- 1 survey from 1 vessel contributed by National Oceanic and Atmospheric Administration (NOAA/AOML/OAR)
- 3 surveys from 1 vessel contributed by National Oceanic and Atmospheric Administration (NOAA/PMEL)
- 8 surveys from 1 vessel contributed by Royal Netherlands Institute for Sea Research (NIOZ)
- 2 surveys from 2 vessels contributed by NOAA Office of Ocean Exploration and Research (OER)
- 93 surveys from 12 vessels contributed by UNOLS Rolling Deck to Repository (R2R)
- 8 surveys from 1 vessel with files contributed by both R2R and MGDS
- 1 survey from 1 vessel contributed by University of New Hampshire, Center for Coastal and Ocean Mapping (UNH/CCOM)

The DCDB established a crowdsourced bathymetry data transfer pipeline with Navico C-MAP, a navigation software company, and is currently finalizing onboarding with the Great Lakes Observing System and M2Ocean.

Other activities

- As Chair of the IHO Crowdsourced Bathymetry Working Group (CSBWG), DCDB Director drafted a formal letter (IRCC12-08A.2) to the IHO Inter-Regional Coordination Committee (IRCC) titled, "*CSBWG paper on raising the awareness of CSB within RHCs and proposed actions within RHCs to support the IHO CSB initiative.*" The IRCC reacted positively and agreed to:
    - Modify the current "RHC Seabed 2030 Coordinator" to a joint "RHC CSB/Seabed 2030 Coordinator." This person will serve as a member of the IHO CSBWG and as the point of contact to the relevant Seabed 2030 regional centers.
    - Permanently add CSB and Seabed 2030 initiatives as an agenda item at future RHC meetings.
- Led IHO Crowdsourced Bathymetry Working Group 9 (remotely) in March 2021.
- Georgie Zelenek, IHO DCDB data manager, attended the Seabed 2030 Arctic-Antarctic and North Pacific Mapping Meeting in December 2020 and presented on the role of the DCDB, current activities, and tools the DCDB could provide to data collectors.
- Christie Reiser, IHO DCDB data manager, attended (virtually) the Seabed 2030 South & West Pacific Mapping Meeting in July 2021 and presented on the role of the DCDB, current activities, and tools the DCDB could provide to data collectors.
- Continue to support US Bathymetry Data Gap Analysis (iocm.noaa.gov/seabed-2030-bathymetry.html)

Project Update by work stream

The endorsed Year 4 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

Global Center have contacted several institutes with global holdings to support release of data, notably iFremer and SHOM. Also, through David Sandwell, secured release of NGA data holdings.

Instigated the 'contribute data' page and google form, allowing us to be notified of new / unknown data.

Task 1.2 Publish Data Product – IBCAO v4.0 published 2020

D1.2.1 – Updates to be published fall 2020 and spring 2021

IBCAO 4.1 was completed during the spring of 2021 and made available for download on the GEBCO web site. The IBCAO 4.1 grid was provided in a geographic version for the GEBCO 2021 grid. The Arctic region had a coverage of 21.34 % during the second quarter of 2021.

Task 1.3 Publish Data Product – IBCSO v2.0 published 2019

D1.3.1 – Updates to be published

IBCSO v2 release paper submitted to an international peer-reviewed journal.

During the first half of year 4, data integration for IBCSO v2 was complete and manuscript preparation started.

Task 1.4 Publish Data Product – GEBCO 2021

D1.4.1 – GEBCO grid is published by 31 March 2021

The pre-release available was available on 25 May 2021 and the final release, after review and edits by Regional Centers, was made available in 2 formats, complete with TID grids, in July 2021.

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 statistics system has been ported to the AWS and tested. It is now in operation on AWS.

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

This work is ongoing and will be continued in the early part of Year 5. IBCAO and IBSCO latest versions are available through the GEBCO website.

Task 2.3 Further development of Bathy Globe

D2.3.1 – Add capabilities of Bathy Globe

Product delivered during Year 4 and will be subject to continuous improvement by UNH staff.

Task 2.4 Publish map and list of Seabed 2030 Priority Areas

D2.4.1 – 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.

Task 2.5 Deliver the next generation GEBCO product

D2.5.1 – Publish a multi-resolution GEBCO product

Work is ongoing 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 – Publish Seabed 2030 Technology Innovation Strategy

Early planning is in progress; inaugural meeting with a professional support provider planned for late August 2021 (Year 5).

WP4: Mapping Activities

Task 4.1 Progress the Mapping the Ocean Frontiers

D4.1.1 – Set up a structure for the program, identify expeditions to be supported and acquire new data

The Nippon Foundation provided $500K of XPrize winnings to fund a separate Ocean frontier Mapping project (as per the seabed 20930 Year 3 Report). Of this $345K was committed to the *Two Oceans Two Technologies* (TOTT) initiative to cover alumni costs, media footage and Saildrone incremental mapping days. COVID restrictions precluded alumni involvement in the 2 scheduled RRS Discovery missions and so there was a refocus on provision of mappers onboard DSSV Pressure Drop for 3 legs (circa 60 days) where alumni costs were $32K. Surplus funds of $155K will be returned to the Nippon Foundation as per grant requirements.

Planning is underway for Phase 2 of work funded by the Ocean Frontier Mapping grant provided by The Nippon Foundation. The Head of Engagement & Development is taking a lead role in the identification of suitable bids

As a separate activity, areas within the Federated States of Micronesia, Maldives and Madagascar have ben identified as candidate areas for satellite derived bathymetry and Seabed 2030 has worked with EOMap, TCarta and Argans to deliver product in these areas that will be shared with the coastal state and included within the GEBCO Grid. This activity has been coordinated by the South & West Pacific Center on behalf of Seabed 2030.

Task 4.2 Greenland Crowd Sourced Project

D4.2.1 – Oversee Greenland Crowd Source Initiative

The 'Collaborative Mapping Greenland' Project is ongoing and to date two vessels have been fitted with data loggers as a pilot. Data has been collected as part of the pilot and will be delivered to Seabed 2030 and DCDB pending the outcome of permit negotiations. The team in Greenland are currently working with the Hydrographic Office to clarify how CSB data should be handled at authority level.

Task 4.3 Accelerate Crowd Sourcing activity

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

COVID restrictions limited Year 4 activity. Nonetheless project activity in Palau, South Africa and Greenland. Loggers rolled out and in-country supporters engaging with local communities. Extensive liaison with IHO's CSBWG and DCDB Director. Engagement with International Chamber of Shipping, World Ocean Council, BSM and several min-projects already underway. Discussions underway with UNH and a provider of low-cost data loggers.

WP5 Management

WP5.1 Operational Management

Task 5.1.1 Secure Year 5 funding

D5.1.1 – Year 5 Work Plan and Budget approved.

Engagement with GGC Chair & NF. Bid submitted to NF for approval. Uplift of $50K per Center approved – this was to cover increasing overhead costs at each center (which traditionally have been covered by "national contributions" which are subject to increasingly downward budgetary pressures across each institution. Funding secured at $3M (up from $2.4M in Year 4).

Task 5.1.2 Year 4 Financial Management

D5.1.2 – Year 4 finance ledger is accurate and Project run to budget.

Year 4 accounts reconciled. See Financial appendix. 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 4 Annual Report submitted to GGC.

To be submitted at main GGC in April 2022.

Task 5.1.4 Mid-Year Reporting to GGC

D5.1.4 – Mid-Year report submitted to GGC

Mid period report delivered to GGC at May 2021 meeting.

Task 5.1.5 Periodic Project Reporting to Sponsors

D5.1.5 – Sponsors meetings held as required by Sponsors

Sponsors meetings were held virtually in October 2020 and May 2021.

Task 5.1.6 Engage with the GEBCO community

D5.1.6 – Diary of Year 4 engagement demonstrating GEBCO contribution to Seabed 2030

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

WP5.2 Strategic Direction

Task 5.2.1 Engage with user community

D5.2.1 – Robust use case evidence documented and GEBCO product users active in Seabed 2030

Wind-In-The-Sails Project; Use Case/Survey activity extended throughout Year 4 and into Year 5. Survey closed July 2021 and results delivered. Work extended to embrace production of Global Priority List in early Year 5. We now have responses from 800 stakeholders across 90 countries providing rich, detailed and thoughtful answers on priorities for seabed mapping. The next stage will be to conduct modelling to calculate benefits derived from mapping in identifiable hotspot areas and then begin formulating a global priority list.

Task 5.2.2 Solicit external strategic advice/input

D5.2.2 – Improve Seabed 2030 strategy through external advice

There has been engagement across a wide field of advisers including Sponsors, the Strategic Advisory Group, the GEBCO community and other parties interested in Seabed 2030 work.

Task 5.2.3 Position Seabed 2030 globally

D5.2.3 – Seabed 2030 acknowledged as key global initiative

Project endorsed as a UN Decade Action, June 2021 and endorsed by the Paris Peace Forum July 2021.

Task 5.2.4 Build strong partnerships

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

Currently are some 157 organisations that pledge support to Seabed 2030 in some way. Further details are listed at Appendix 7. 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 4, 18 MOU agreements were in place as well as a software agreement with QPS.

WP5.3 Communication

Task 5.3.1 Deliver Media Strategy

D5.3.1 – Publish Media Strategy

Media Strategy published (and reported to GGC) in Year 3. This task should read “Deliver Media Strategy”. This has happened multi-channels of social, mainstream media, newsletters and, where appropriate, articles and submissions to external publications. See also Y4 Media Monitoring, Appendix 8.

Task 5.3.2 Refresh Seabed 2030 media content across all channels

D5.3.2 – Rebranding, content management and new content

Ongoing engagement with Raitt Orr, ENP Media and freelance content expert.

Task 5.3.3 Promote Seabed 2030 at external events and meetings

D5.3.3 – Catalogue of events and meetings attended

A list of events attended, and presentations made, is at Appendix 9. In person events are starting to be scheduled following COVID-19 related cancellations/postponements and some events are also returning in a hybrid format.

Task 5.3.4 Acknowledge partner contributions

D5.3.4 – Seabed 2030 website

All strategic partners have their own collective page on the Seabed 2030 website and are incorporated into press releases and news articles, as and when relevant.

Metadata is currently being collated to allow dynamic reporting of contributions in current / future grid releases.

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

Seabed 2030 continues to seek opportunities for capacity development and a greater engagement of GEBCO-Nippon Foundation Alumni in the project. The Head of Engagement and Development was recruited during Year 4 and is now regularly engaging with Alumni. Alumni were employed on the Caladan Oceanic and TOTT missions during Year 4.