The Nippon Foundation - GEBCO

Seabed 2030 Project

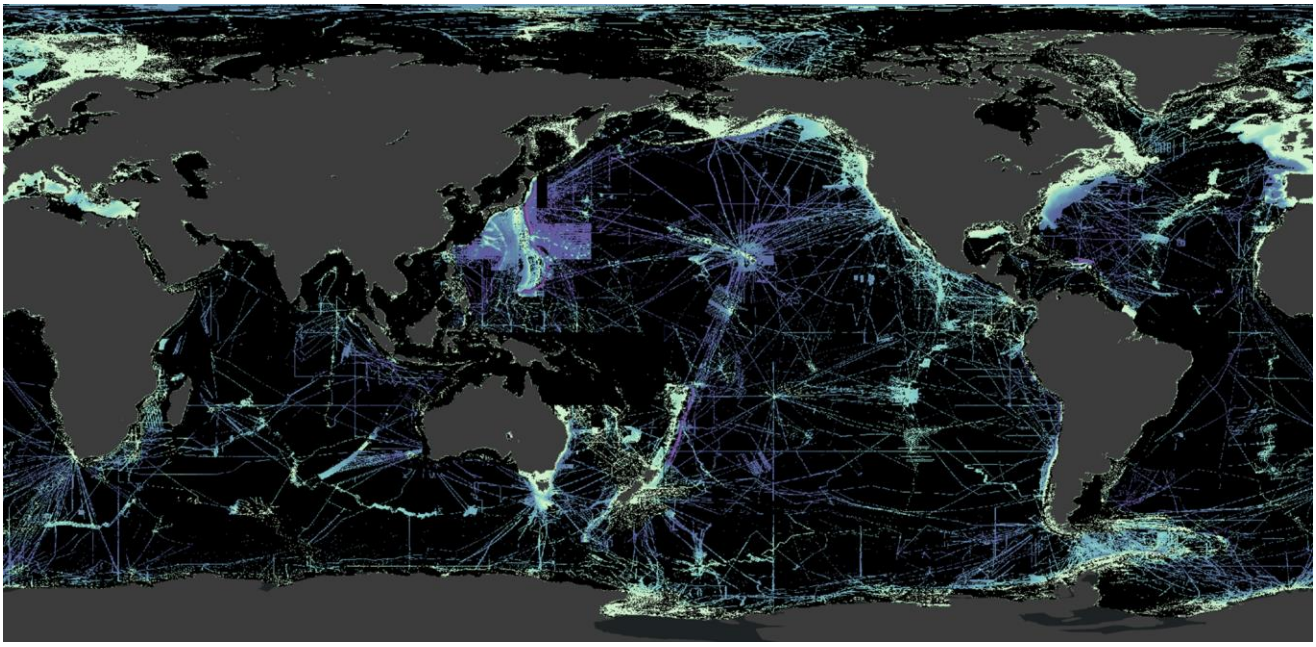
100% of the ocean floor mapped by 2030

Year 3 Report

September 2020

Authors: Seabed 2030 Project Team

Jamie McMichael-Philips, Martin Jakobsson, Helen Snaith, Vicki Ferrini, Boris Dorschel, Kevin Mackay, Larry Mayer, Jennifer Cheveaux



GEBCO 2020 TID

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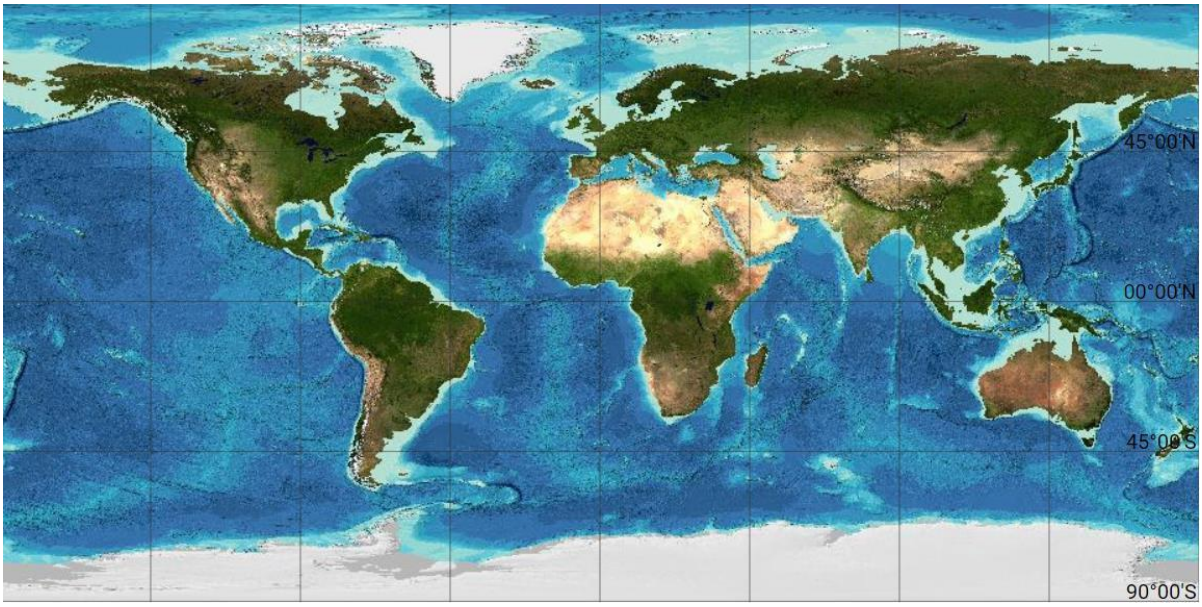


GEBCO 2019

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 3 has been the second full year of operation for The Nippon Foundation-GEBCO Seabed 2030 Project (Seabed 2030) and has been set against the global backdrop and challenges of the COVID global pandemic for a significant part of the period. This has allowed a demonstration of the true resilience of the geographically dispersed Project Team members who have shown real strength in overcoming the disruption of remote working to provide continuity of activities across the majority of work streams. The Team has delivered the 2020 GEBCO Grid with almost one fifth, or 19%, of the world ocean floor now mapped.

In the early part of the reporting year we saw changes of leadership with the new Director assuming duties in December 2019 at the same time as a change-over of the Head of the South & West Pacific Regional Centre. Our full time Project Administrator joined in March 2020.

In October 2019, the Project facilitated a successful Vision to Action event at the Royal Society in London. Here a wide variety of stakeholders, supporters and senior leaders came together in the presence of The Nippon Foundation Chairman to focus on the future of Seabed 2030. Chairman Sasakawa announced three initiatives to support increased data acquisition through collaboration in the fields of Crowd Sourced Bathymetry (CSB), Ocean Frontier Mapping (OFM) and innovation.

Building on this and the successes of the OFM pilot project within the Ryder 2019 expedition, a new OFM process supported by a Mapping Committee has been established. The remit is to make informed choices for funding additional mapping days and/or multibeam sonar operators within existing eligible missions and a plan of activities for Year 4 is in place.

Supported by key country stakeholders in Greenland, Palau and South Africa, the Project has rolled out a number of CSB data loggers as part of a demonstration into the ease and utility of gathering such data and also to encourage wider participation in collection.

Innovation strategy work is still ongoing and the Team has been active in engaging across a broad sector of technical stakeholders to determine future areas of collaboration and opportunity. In addition to collection of data and gridding, focus areas also include use of web services for handling big data. Within the Project, innovative work has seen development of a new statistics tools that allow a speedier and even more accurate assessment of mapping progress.

In spite of COVID-related disruption, Team members, supported by others within the GEBCO community, have been able to participate in a large number of national and international fora at all levels: in person in the early part of the reporting year; and at virtual events in the latter part. This has allowed the Seabed 2030 message to be broadcast, calls for action to be made, and industry and technical engagement to take place. Maintaining the engagement theme, amongst an extensive network of partners, contributors and supporters, the number Memoranda of Understanding that are in place has doubled to 8 with more to follow.

The Wind in the Sails use case study was commissioned to better collate and quantify the value and benefits of seabed mapping and to seek user views on areas of priority. This has further raised awareness of Seabed 2030 across a wider of community of organisations and individuals that use geospatial data. The Phase 1 findings are still under internal review but of the 366 respondents, over 27% indicate they have, or will have, data to contribute. This is very welcome news.

Project media activity has been surged over the course of the year there have been over 130 articles published globally in which Seabed 2030 is mentioned. The highlight was the high-profile articles published in June 2020 heralding the Project's involvement in launch of the 2020 GEBCO Grid. A Media Strategy has been prepared which looks holistically across all aspects of Project external communications. Work is ongoing to deliver against this and a start has been made in refreshing and upgrading the Seabed 2030 website to make it easier to manage, to look more contemporary and to contain new content. The first regular newsletter, in depth, has been published and subsequent editions will appear on a regular basis.

The Strategic Advisory Group has been reconstituted and will meet after in the early part of Year 4. Together with 2 external advisers sitting on the Mapping Committee, the Project has the ability to draw upon vast range of external experience and advice.

The value of the GEBCO-Nippon Foundation Alumni to the field of ocean mapping, and more specifically to Seabed 2030, is widely recognised. There has been extensive discussion on ways of involving individuals within the Project. A team are already involved in supporting the Two Oceans Two Technologies ocean frontier mapping activity that has been commissioned in the Atlantic and the Pacific for Year 4. There are plans in place to establish, again in Year 4, an Alumni Coordinator role within the Project that will deliver a comprehensive plan that utilizes the skills and experience of members of the Alumni to support a wide range of Seabed 2030 activities.

Invaluable work across all the Centres has continued apace on a range of activities that include the publication of IBCAO v4.0; progression of IBCSO v2.0 revisions; and leveraging tools to improve multibeam integration. Development and subsequent delivery of the 2020 Grid alongside the new type identifier (TID) grid was a significant achievement; as was delivery of the download app which has resulted in a 10-fold increase in user download requests. In addition to the technical skills, experience and gravitas required to do the job and to represent Seabed 2030, the Center Teams have significant expertise in engagement and have well developed, and increasing, networks of contacts and contributors that continue to support the Project.

Strong support and leadership from IHO's Data Center for Digital Bathymetry (DCDB) has also been evident and there has been much work not only on data ingestion but also on collaboration to improve the data submission process and also on CSB field trials.

Year 3 has been highly productive. Collaborative work and professionalism are evident amongst the Team and, the Project continues to receive the welcome leadership and support from The Nippon Foundation, GEBCO, IHO and IOC. Without losing sight of the huge resource implications in achieving the mission to deliver 100% mapping of the seabed by the year 2030, Seabed 2030 is well placed to begin Year 4 and continue work that is complimentary to, and support of, not only UN Sustainable Development Goal 14 but also, the work of the UN Decade of Ocean Science in its inaugural year and beyond.

Appendices

The following appendices support the main body of this report:

Document name
Appendix 1 - Year 3 Work Plan
Appendix 2 - Greenland Mapping Project
Appendix 3a - Ocean Frontier Mapping Process
Appendix 3b - Ocean Frontier Mapping Bid to NF
Appendix 3c - Ocean Frontier Mapping Grant
Appendix 4a - Year 4 Bid Submission final document
Appendix 4b - Year 4 Draft Programme to NF
Appendix 4c - Year 4 Standalone Financials
Appendix 4d - Year 4 Grant
Appendix 5 - *Wind in the Sails* Phase 1 Report
Appendix 6 – Partners, Contributors & Supporters
Appendix 7 – Media Strategy
Appendix 8 – First Newsletter *In Depth* 14 July 2020
Appendix 9 – Year 3 Media Monitoring
Appendix 10 – Year 3 Events & Presentations
Appendix 11 – Year 2 Finance Report to The Nippon Foundation
Appendix 12a – Year 3 Finance Report to The Nippon Foundation (draft)
Appendix 12b – Enclosure to Year 3 Finance Report (draft)

Introduction

This report of details activities and progress achieved within the Year 3 period of 1 August 2019 to 31 July 2020 and fulfils annual reporting obligations to The Nippon Foundation grant award the GEBCO Guiding Committee (GGC).

Entering into its 4th 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 years 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 1 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 Project Administrator and the heads of the Seabed 2030 Centers.

Center Information:

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 their activities in Year 3 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 year3 (2019/20) of the Seabed 2030 Regional Centre Southern Ocean was to develop data workflows and to streamline Seabed 2030 product production. This process is almost finished. In addition, Seabed 2030 and IBCSO were presented at international and national conferences and workshops.

Center Staff

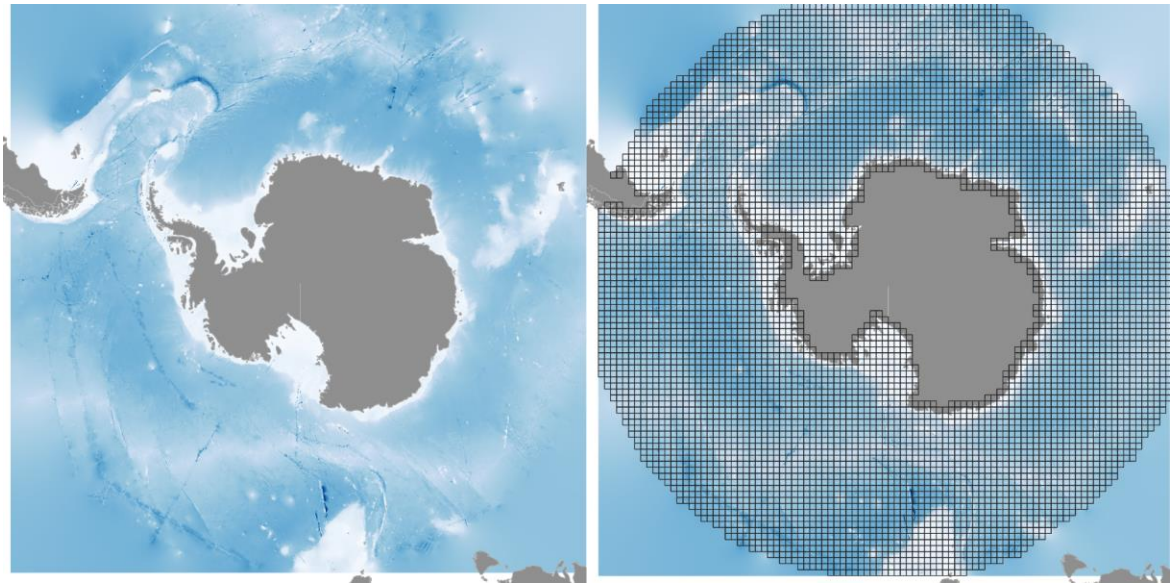
- Boris Dorschel, head of the bathymetry working group
- Laura Hehemann, data manager and GIS technician
- Sacha Viquerat, data manager programmer
- Fynn Warnke, data manager, programmer
- Simon Dreutter, hydrographer, data manager

For the 3rd year funds provided by Nippon Foundation supports 3.75 Full Time Equivalent (FTE). In addition, 0.25 FTE is funded from AWI for Seabed 2030 funds. Furthermore, additional 0.5 FTE are provided by B. Dorschel and S. Dreutter by AWI.

Regional Mapping progress

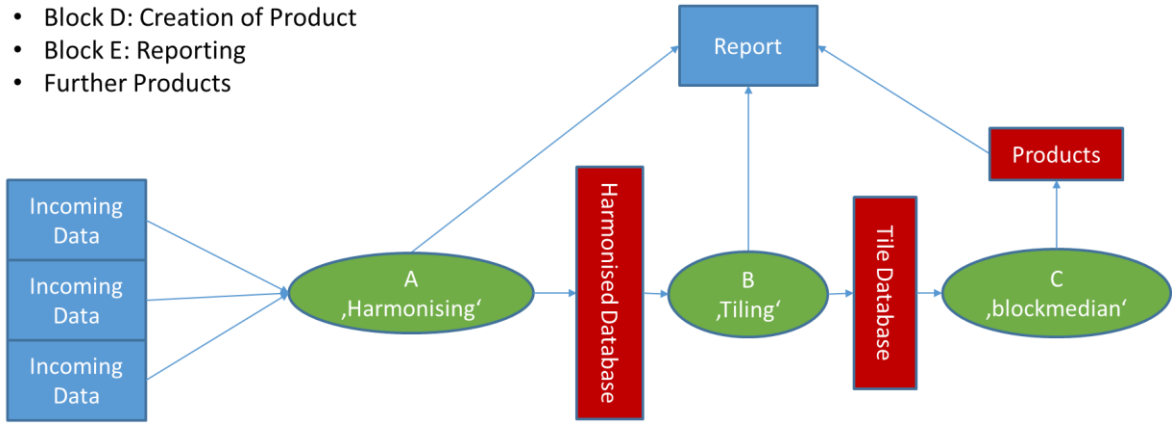
Following the establishment phase of the Regional Centre Southern Ocean RC-SO, the 3rd year was dedicated to optimising data and product production workflows. In addition, seabed 2030 and IBCSO were presented at national in international meeting.

The extension from the IBCSO area south of 60°S to the RC-SO are south of 50°S required a different methodological approach compared to IBCSO version 1. During the past year, the data integration routines were adapted to enhanced data volumes. All product related calculations are now performed in parallel on the super-computing facilities at AWI. With the new workflow, for IBCSO v2, data integration is completed and data cleaning has commenced. This is expected to be finished in September 2020. Delay in the production of IBCSO v2 are due to unforeseen problems during the transfer of workflows to the new hardware infrastructure. These problems are now resolved. Furthermore, a meta-data database was set up to improve workflows and to allow for improved statistical analyses of the base data for IOCSO v2. The meta-data database follows the EMODnet guidelines for meta-data and is in agreement with the meta-data concept used at the University of Stockholm for the International Bathymetric Chart of the Arctic Ocean (IBCAO). Throughout year 3, data acquisition was ongoing.



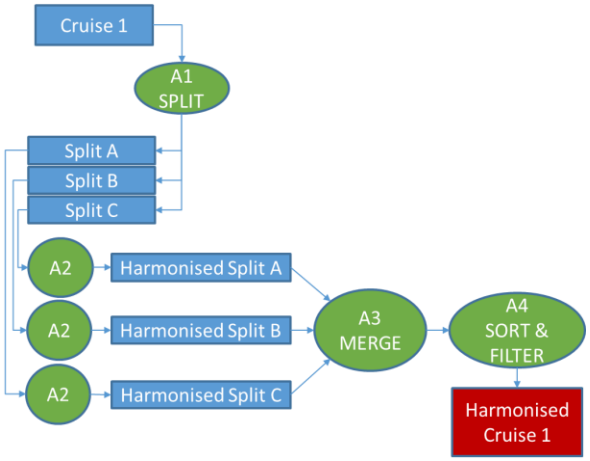
Tiling of the area south of 50°S for data workflows and parallel computing. Image S. Viquerat.

- Block A: harmonisation of incoming data sets
- Block B: Creation of tiles based on full dataset
- Block C: calculation of weighted blockmedian (gmt)
- Block D: Creation of Product
- Block E: Reporting
- Further Products

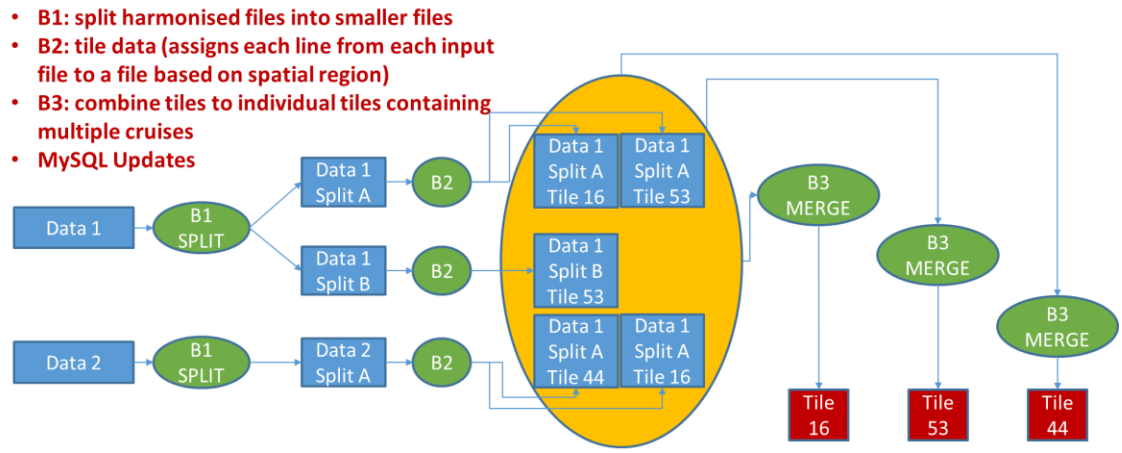


Data workflow for IBCSO v2. "Blocks" represent major processing units. Image S. Viquerat

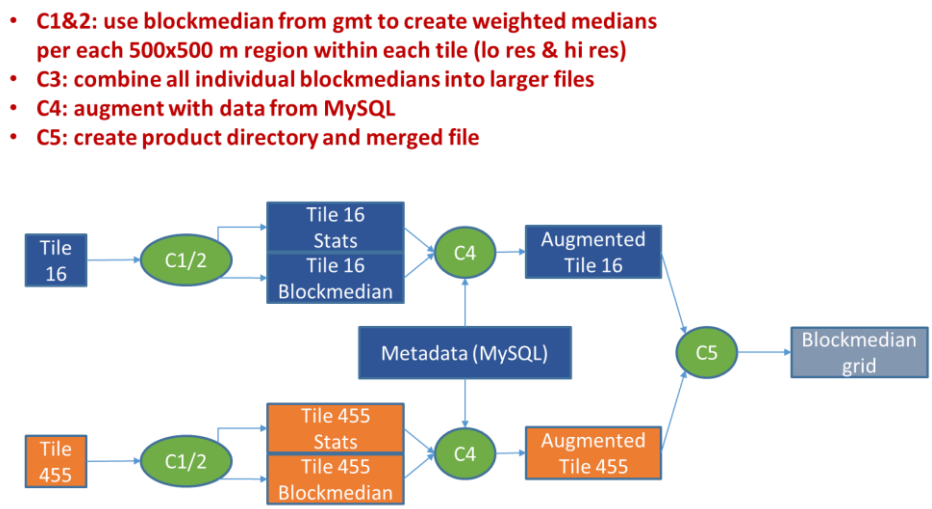
- **A1: split incoming files into smaller files**
- **A2: harmonise data (extract x,y,z (round to 1m, error fixing), project coordinates into target EPSG etc.)**
- **A3: merge split files back to single file**
- **A4: sort and remove duplicates in harmonised files**
- **Also: couple of metadata updates (MySQL)**



Detailed illustration of the harmonisation process. Harmonisation of incoming expeditions and preparation of data sets for parallel computing. Image S. Viquerat.



Detailed illustration of the tiling process optimised for parallel computing. Image S. Viquerat.



Detailed illustration of the grid calculation using the weighted block median function in GMT. Image S. Viquerat.

The regional mapping committee Southern Ocean (RMC-SO) will soon be approached to comment the first draft of the IBCSO v2. It is envisaged to extend RMC-SO over the course of the next year.

Major data and grid contributions

Over the course of the past year, new data sets were integrated continuously in the RC-SO and IBCSO database.

Financial report

As addressed in last year's interim report, all staff funds have been allocated. During year 3 two student-labour were employed for 40 hour per month for data cleaning. Additional cost to the Seabed 2030 Project, were the participation of one person at the ISAS conference and of three people at the 36th SCRUM, TSCOM and GEBCO science day and the subsequent Arctic, Antarctic and North Pacific mapping meeting in Portsmouth, New Hampshire (USA), 04 – 10 November 2019. Furthermore, funds were used to support bathymetric data acquisition during Expedition PS120 with the German research icebreaker *Polarstern* and during expedition SO272 with the German RV Sonne.

Other activities

Participation of the AWI Bathymetry team in several workshops including the European Geophysical Union (EGU) general assembly 2020 and the American Geophysical Union (AGU) general assembly 2019. Presenting Seabed 2030 at the meeting of the German IOC section in February 2020. 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.

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 3 (1 August 2019-31 July 2020) were:

1. Gathering, assembling and gridding of bathymetric data collected in the SW Pacific region.
2. Submission of the 15-arc sec resolution sparse grid to be integrated into the GEBCO_2020 grid release; delivery to GDACC was done on the 20th October 2019. SaWPaC 2019 delivery populated ca. 23.8 % [~29 M km^2] of the GEBCO_2019 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 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 scheduled to be held in March 2020, but due to the Covid-19 pandemic, this meeting will be held in an on-line forum on 23-24th June 2020. 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 21 presentations were made at various events.

7. Networking and education:

   SaWPaC hosted short-term interns from academic institutions that maintain educational programmes leading towards an FIG/IHO/ICA Cat. A certificate in Hydrography:

   - ENSTA Bretagne (French State Engineering School and Research Institute for innovation in defence, maritime development and hi-tech companies) Eng. Dipl. in Hydrography & Oceanography and M.Sc. in Hydrography programmes;
   - Royal Malaysian Navy;
   - Nippon Foundation-GEBCO University of New Hampshire post-baccalaureate Certificate program in Ocean Mapping.

Centre Staff

The Centre is based at NIWA Wellington and led by Mr. Kevin Mackay (NIWA Programme Leader: Environmental Information Management). Kevin replaced Dr. Geoffroy Lamarche, who left NIWA in November 2019. The Centre Lead is supported in his task by a Seabed 2030 Manager (Dr Evgenia Bazhenova) and a Technical Management Committee (TMC).

<u>SaWPaC Data Manager</u>

Dr. Evgenia Bazhenova is the Seabed 2030 Centre Manager. Evgenia holds a PhD from the University of Bremen (2012), and an FIG/IHO/ICA Cat. A certificate in Hydrography (2016) and is a 2016 alumnus of the NF-GEBCO UNH Training programme in 2016. She also was an active member of the NF-GEBCO team in the Shell Ocean Discovery XPRIZE competition.

The SaWPaC TMC includes representatives of NIWA, GNS Science (Institute of Geological and Nuclear Sciences) and LINZ (Land Information New Zealand - which hosts the New Zealand Hydrographic Office):

- 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, member of the IHO SWPHC; 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 at rotating locations in Wellington (NIWA, GNS Science, LINZ). Records of the agendas and minutes of the TMC meetings are kept at NIWA. These TMC meetings aim:

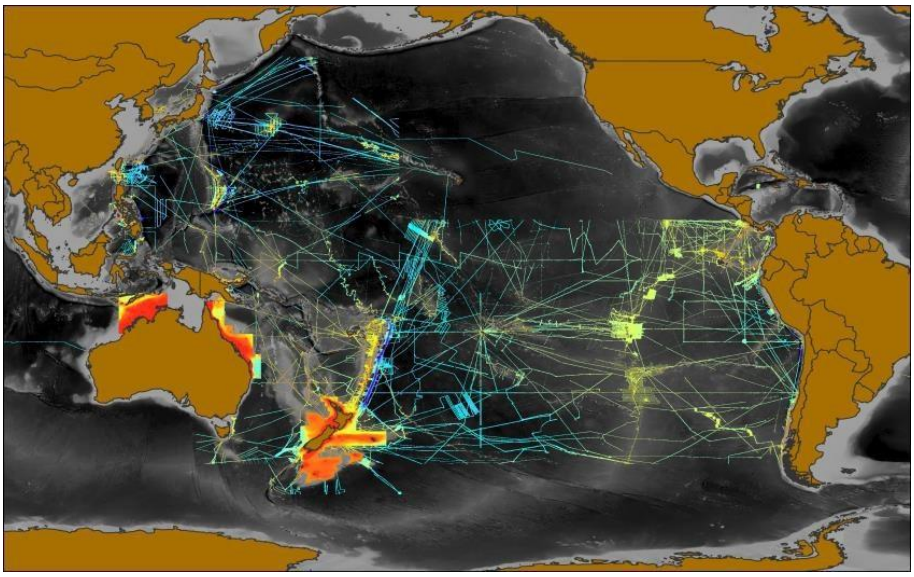
- to follow up on the progress of the SaWPaC technical and administrative work,
- to provide updates on participation in meetings/conferences aiming to promote Seabed 2030 and seek bathymetric data,
- to identify actions for the upcoming month.

Short-term interns at SaWPaC (Year 3)

- Mr. Hugo Chonavel, ENSTA Bretagne; June - August 2019.
- Lt. Mohammad Rafeq bin Paimin, Royal Malaysian Navy; August 2019.
- Dr. Maria Kottermair, University of Guam; January 2020.
- Marjorie David, ENSTA Bretagne; scheduled for June -August 2020 (due to the Covid-19 pandemic, it is unlikely that Marjorie will intern at SaWPac)

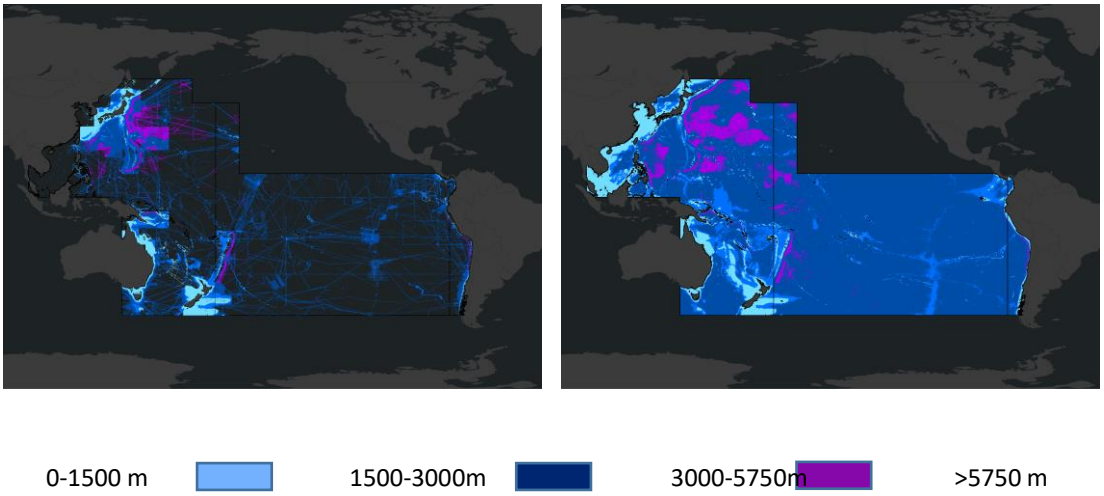
Regional Mapping progress

SaWPaC 2019 delivery integrated into the GEBCO_2020 release covers ca. 23.8 % of the GEBCO_2020 cells (15 arc sec grid cell size) for the SaWPaC regional extent.



SaWPaC delivery 2019 - bathymetric data layer, 15 arc sec sparse grid- overlain on the GEBCO_2019 gridded bathymetry.

SaWPaC uses the NIWA ArcGIS infrastructure to maintain a bathymetric database, which references source data (processed multibeam soundings and regional compilations) stored in native resolution (as received from the data holders) and allows gridding using different cell size. This will be used to create the target depth-banded Seabed 2030 grid.



SaWPaC delivery 2019 (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 visualize the data delivered in 2019 and current bathymetric data holdings, SaWPaC is developing apps

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 32st GEBCO SCUFN Plenary Session, Kuala Lumpur, Malaysia on 5-9th August 2019; the 7th Steering Committee of the East Asia Hydrographic Commission in Tokyo, Japan in 3-7th February 2020 and at the 13th meeting of the south West Pacific Hydrographic Commission in Wollongong, Australia 12-14th February 2020.

Conference/workshop presentations

Mackay, K. (2019) The Nippon Foundation – GEBCO Seabed 2030. 32nd GEBCO SCUFN Plenary Session, Kuala Lumpur, on 5-9th August 2019.

Mackay, K., Lamarche, G. and Bazhenova, E. (2019) Progress towards 100% of the World Ocean floor mapped by 2030. The Nippon Foundation-GEBCO Seabed 2030 Project. Australian Marine Sciences Association Conference, Fremantle, Australia, July 7-11, 2019.

Greenland, A. (2019) National Report by New Zealand. South-West Pacific Hydrographic Commission (SWPHC) 16th Meeting, Wollongong, Australia 12-14th February 2020.

Pallentin, A. Mackay, K., and Bazhenova, E. (2019) 100% of the World Ocean floor mapped by 2030. The Nippon Foundation-GEBCO Seabed 2030 Project. Pacific Islands Remote Sensing and GIS Conference, Suva, Fiji, December 7, 2019.

Steinmetz, T., Bazhenova, E. (2019) Using the ESRI Bathymetry Information System in Seabed 2030.
NZ ESRI User Group Conference, Auckland, 10th August 2019.

Mackay, K., Bazhenova, E, and Greenland, A. (2020) The Nippon Foundation – GEBCO Seabed 2030 project. LINZ seminar for the World Hydrography Day, Wellington, NZ, June 22, 2020.

Mackay, K., Bazhenova, E. (2020) Progress towards 100% of the World Ocean floor mapped by 2030. The Nippon Foundation-GEBCO Seabed 2030 Project. Australian Marine Sciences Association Seminar, June 25, 2020.

Report of status of regional mapping committee

The second Regional Mapping Committee Meeting will be held by SaWPaC as a virtual meeting, on June 23-24, 2019.

The following materials are available from this meeting:

- First Circular

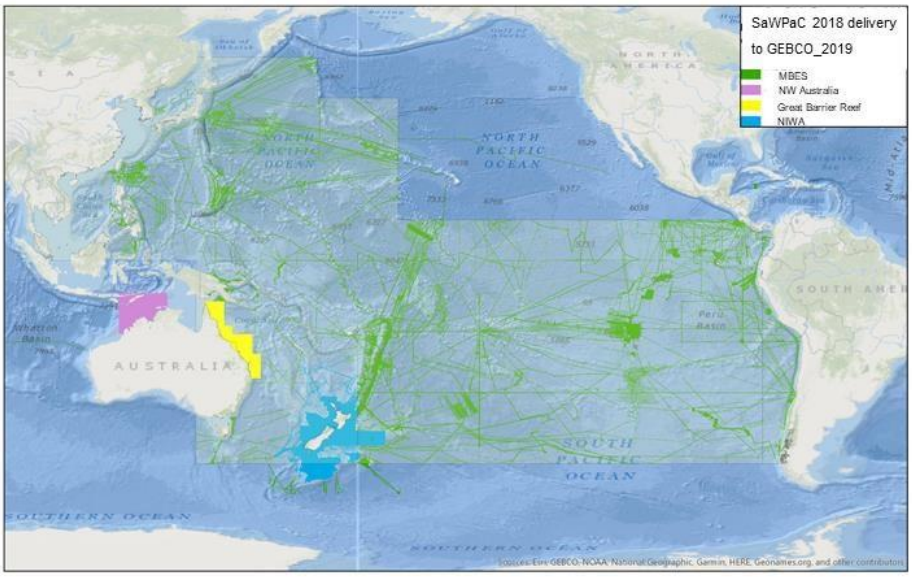
The objectives of this meeting were to:

- 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.

Currently, about fifty delegates from 12 countries from the Pacific region have registered their interest in participating in the meeting.

Major data and grid contributions

During Year 3, the SaWPaC regional inventory of bathymetric data was updated.



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
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.
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 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** Included into GEBCO_2014 and GEBCO_2019 releases
Lamont-Doherty Earth Observatory (LDEO), Columbia University	**GMRT v.3.5** (February 2018) https://www.gmrt.org/about/index.php 15arc-sec (~500m) grid
Land Information New Zealand (LINZ)	**Multibeam data used to compile New Zealand navigation charts, ENC data**

Marine Geoscience Data System (MGDS)	**Gridded multibeam data** from 6 cruises
National Institute of Water and Atmospheric Research (NIWA)	**New Zealand bathymetry compilation - 250m** https://www.niwa.co.nz/our-science/oceans/bathymetry The compilation contains separate TIDs: multibeam, singlebeam, ENC soundings, chart contours, pre-generated grid.
NOAA NCEI Multibeam Bathymetry Database	**Gridded multibeam data** from 34 cruises
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 singlebeam data) contributed through the GDACC**
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

Multibeam Survey Data

Source	Description and Reference
Alfred Wegener Institute for Polar and Marine	6 Cruises of multibeam data in the South and West Pacific Ocean

Research (AWI)	
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
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	Singlebeam (and some multibeam) data collected by fishing vessels in the Pacific Ocean

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

Activities at the Atlantic/Indian Oceans Regional Center (AIORC) has continued to focus on data assembly, the gathering and assembly of information about existing embargoed data, and stakeholder engagement. A major achievement over the past year was to adopt the use of the ESRI BIS approach for assembling regional data products. This approach is used by other RDACCs and facilitates the integration of raster datasets with full comprehensive metadata and is a much more efficient approach for assembling components. We also migrated remaining data that had previously been added to the compilation by the GDACC to the AIORC for integration into the regional product at the RDACC. 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. In addition, the gridding approach developed by GMRT was adapted for use by the AIORC and we are actively working to more efficiently leverage these tools as a means of accelerating multibeam data integration for the Atlantic and Indian Oceans, which could also be extended to other regions.

Significant effort was dedicated to stakeholder engagement at national, regional and global scale. Highlights of regional engagement are described in detail below, and highlights of global engagement include Ferrini's effort in planning and executing the Vision to Action event in London in October 2019, as well as planning for the World Ocean Summit, which was unfortunately cancelled due to the COVID-19 pandemic. Ferrini has also played a leading role in developing a data submission web form for GEBCO/Seabed 2030 and is a member of the Communications group.

Over the past year, the AIORC staff included Nippon Foundation-GEBCO Alumnus Tinah Martin, Dr. Frank Nitsche, Ms. Claudia Giulivi, and Mr John Morton, with administrative support provided by Ms Sara Robinson and IT support from Mr Ed Bohl and Mr Eric Malikowski. For the summer of 2019, the Center welcomed 4 undergraduate students to assist with data processing: Hayley Drennon (College of Charleston) and Jesse Jenkins (Vassar College) both returned for a second summer working with the center, and Mikayla Drost, and Treyson Gillespie both from the College of Charleston. These students contributed to data preparation and assembly as well as the development of outreach materials. Two of these students (Drost & Drennon) presented the results of their work at the fall AGU meeting, and one (Drost) was awarded the Outstanding Student Presentation Award. Due to the COVID-19 pandemic, we were unable to hire students to work with us at LDEO during summer 2020 as in past years. We were able to get Hayley Drennon into a remote working arrangement (for her third year with us!), as well as a couple of other colleagues who will assist with data preparation and new approaches for automating quality control as data are assimilated.

Regional Mapping progress

Stakeholder Engagement

- Ocean Obs'19 - Honolulu, Hawaii, Sept 2019
    - Ocean Obs is a decadal meeting with IOC-level impact that gathers the international community of ocean observation experts together to set goals and priorities for the coming decade. Several plenary presentations were given that highlighted Seabed 2030 including by David Millar (Fugro), Larry Mayer (UNH-CCOM), and Vicki Ferrini (LDEO). The Seabed 2030 Exhibit Booth at Ocean Ob's 19 was coordinated by the AIORC and was intended to increase the visibility of the seabed mapping and the need for new data acquisition as part of ocean observing. In addition to new contacts who are both data providers and data consumers, a key outcome of the meeting was the recognition of the seafloor in the conference statement which will help to increase awareness of mapping in the coming decade.
- Lakebed 2030, Taverse City, Michigan, Oct 2019
    - Vicki Ferrini was an invited Key Note speaker at Lakebed 2030 Conference - a project inspired by Seabed 2030 to map the Great Lakes by 2030. Was an opportunity to engage with stakeholders regarding common strategies and approaches for reaching our collective goals. Participants included government, academic, and industry reps from the US and Canada. A special issue of Marine Technology Society (MTS) will be released soon that will include a short commentary based on presentation given.
- Global Ocean Science Education (GOSE) workshop - Reston, VA, Nov 2019

- Vicki Ferrini was a member of the Executive Planning Committee for this workshop which was a collaboration with the Atlantic Ocean Research Alliance (AORA) Ocean Literacy Working Group, the Seabed 2030 AIORC, and was facilitated by the international Consortium for Ocean Science Exploration and Engagement (COSEE) and the College of Exploration (CoE). Ferrini gave a Seabed 2030 presentation at the workshop and made many important connections within the Atlantic Ocean stakeholder community. The report from the meeting is available online at: http://www.coexploration.org/gose/

- Tinah Martin participated in the Early Career session for the GOSE Workshop held at the American Society of Civil Engineers (ASCE) in Washington DC where she shared her perspective and experience in Ocean Science. The 3 days sessions were strategic as the main output of the workshop was oriented to tailor the UN Decade for Ocean Science strategy for the Atlantic Ocean Region. Participants of the Early-career session shared what is the main barrier faced by Ocean Observer in their fields of work, specifically in the region they are working. Related to Seabed mapping, it was shared that accessing to bathymetric data and enabling the pipeline for sharing these data is still the core challenge. Furthermore, engaging the community in seafloor mapping and connecting Ocean Science communities are steps that are necessary to improve understanding of Ocean Science at a global scale. The presentation is available here

- Fall AGU Meeting - San Francisco, CA, Dec 2019

  - Ferrini co-convened a conference session dedicated to ocean mapping that built upon the themes of the OceanObs'19 meeting - "Beyond Hydrography". The session was very well attended and was written up by AGU in their periodical Eos: https://eos.org/articles/momentum-grows-for-mapping-the-seafloor

  - Summer students from the AIORC - Hayley Drennon and Mikayla Drost presented posters highlighting their work at LDEO as part of the AIORC. Mikayla was awarded a 2019 Outstanding Student Presentation Award.

  - The Seabed 2030 Exhibit Booth at AGU was coordinated by the AIORC. set to allow ocean science fellows and enthusiasts attending the meeting to understand better what is the Nippon Foundation GEBCO Seabed 2030 Project.

  - Invited presentations at the ESRI Exhibit Booth about International Efforts to map the seafloor. Story Map here: https://storymaps.arcgis.com/stories/a0122ef457dd435294e44a2a83dfbd7e

- Atlantic Seabed Mapping International Working Group (ASMIWG) - Brussels, Feb 2020

  - Provided presentation material for this meeting which was attended by Larry Mayer and David Millar.

- Ocean Sciences 2020 - San Diego, CA, Feb 2020

  - Ferrini participated in an OceanObs Research Coordination Network meeting as a follow-up to the OceanObs'19 conference. Advocated for acquisition and sharing of bathymetry data as well as integration of data resources describing the seabed to be more integrated with the ocean observation community.

- Ferrini was an invited panellist at a town hall meeting about the UN Decade of Ocean Science for Sustainable Development - promoting the Seabed 2030 Project as well as seabed mapping and data sharing in general.

- Florida Coastal Mapping Program - Virtual, March 2020

  - Ferrini gave invited (virtual) presentations in March 2020 to exchange ideas and approaches used in this regional mapping project.

GEBCO-NF Alumni Engagement

- Alumni Hosted for RDACC Visit at AIORC - As in past years, the group at LDEO hosted Nippon Foundation - GEBCO Training Program students for lab visits. These visits serve as an important opportunity to strengthen relationships with the Alumni, and to develop strategies for data sharing, while teaching the students about Seabed 2030, GMRT, and other marine geoscience data management efforts underway at LDEO.

  - August 2019: Keshav Sauba (Mauritius) - spent 1 week visiting the AIORC and worked with our team on data assembly for Seabed 2030.

  - September 2019: Mekayla Dale (Northern Ireland) - spent 2 weeks visiting the AIORC and worked with our team on data assembly for Seabed 2030.

- 2nd Conference on Fisheries and Coastal Environment, (Ghana 18-21 August 2019) - Mapping the ocean to support policy making and sustainable ocean management - a local, regional and global call for collaboration and coordination to build a complete bathymetric map", a poster co-authored by several NF-GEBCO Training Program Alumni at the 2nd Conference on Fisheries and Coastal Environment was presented by Eunice Nuerkie Ofoli-Anum (Yr9 Ghana) at the CFCE19 as part of outreach activities in the Atlantic Ocean Region. Eunice's intervention focused on how the networks of people working to map our oceans are going to be important as we collate and archive data to help us better understand our oceans and support the implementation of a Blue Economy and policy making to achieve Sustainable Development Goals. This participation of Seabed mapping in the CFC19 captured the attention of the audience and raise their awareness towards the importance of understanding the link between seabed mapping and achieving sustainable fisheries goals. The poster is accessible here.

- Alumni-led presentation at AGU Fall Meeting (December 9 – 13 2019) - The “Perspectives on the Use of Ocean Mapping Data in the Atlantic and Indian Oceans” at the AGU 19 Fall Meeting aimed to promote how bathymetry data are used in different fields, taking example from the Atlantic and Indian Ocean Region. Co-authored by several Alumni of the GEBCO NF- Training Program (Tinah Martin, Yr13, Madagascar ; Muhammad Bashir Yr2 Pakistan; Aileen Bohan Yr14 Ireland; Mohammad ZR Chowdhury Yr8 Bangladesh; Cecilia Zuleiman Cortina Guzman Yr14 Mexico; Mekayla Dale Yr15 Northern Ireland; Mohamed Elsaied Abou-Mahmoud Yr13; Djoko Hartoyo Yr2 Indonesia; Athur Yordan Herwindya Yr6 Indonesia ; Xinh Le Sy Yr9 VietNam; Vasudev P. Mahale Yr3 India; Mohammad Muslem Uddin Yr7 Bangladesh; Victoria Obura Yr15 Kenya; Eunice Nuerkie Ofoli-Anum Yr Ghana; Walter Reynoso Peralta Yr Argentina; Jaya A Roperez Yr11 Philippines; Indra Budi Prasetyawan Yr11 Indonesia; Hemanaden Runghen Yr10 Mauritius; Bernice Mahabier Yr6 Suriname; Seeboruth Shailesh Sattiabaruth Yr13 Mauritius; Shereen Sharma Yr1 Fiji/Australia; Rochelle Anne Wigley Yr4 South Africa / USA; Nilton Sanchez Yr10Espinosa Ecuador), the presentation highlights some use cases for bathymetry data from the perspective of the

diverse network of stakeholders. With this initiative, common needs across the region are revealed and will help in order to prioritize future collaborative efforts to map the gaps in bathymetric data coverage. From this first initiative, few authors started to share data sets to be included in the GEBCO 2020. The slides from the presentation are available here.

- UN Decade of Ocean Science for Sustainable Development Workshop for African and Adjacent countries (Kenya January 27 - 29 2020) - The UN Decade of Ocean Science for Sustainable Development Workshop for African and Adjacent countries was held in Nairobi Kenya from 27 to 29 January 2020. This event provided a forum to gather ocean leaders/champions/key stakeholders to further discuss and prioritize the issues identified at the First Global Planning Meeting. Plenary and working groups will facilitate regional, interdisciplinary discussions across sectors (such as ocean science and technology; ocean policy and sustainable development; business and industry; NGOs and civil society; donors and foundations) to identify concrete deliverables and partnerships to meet the Decade's six societal objectives. The Nippon Foundation - GEBCO Seabed 2030 Project and mapping the world ocean, in general, is a key component for the meeting as its goal aligned with the SDG's and the overall UN Decade for Ocean Science's mission. Two NF GEBCO Training Program Alumni attended the event, (Mohammad Muslem Uddin Yr7, Bangladesh; Victoria Obura Yr15, Kenya). Victoria represented the AIORC at the workshop and contribute to the discussions and designing of the strategy related to the Decade's six societal objectives.

- The WIOMSA Magazine - People & the environment - Issue #9 (December 2020) - Tinah Martin's story was featured in the People & Environment Issue #9, one of the two special editions of the WIOMSA Magazine that focused on the inspiring stories of women who are making a difference in coastal and marine resource management. The magazine issue is accessible here.

Regional IHO/IOC Engagement

- IHO/IOC - GEBCO Subcommittee and Guiding Committee Meetings & GEBCO Symposium, November 2019.
    - Vicki Ferrini, Frank Nitsche and Tinah Martin attended the GEBCO meetings in New Hampshire. They coordinated a Seabed 2030 booth at the symposium and presented results of regional activity at the SCRUM meeting and during the Symposium. Frank also attended the Regional Mapping Committee meeting for the Arctic and Antarctic.

- IHO: MACHC - December 2019
    - Ferrini has been working closely with the Chair of the MACHC to develop the resources needed to facilitate coordination within the RHC. This includes contributing to the MACHC website (https://www.iho-machc.org/seabed2030.html) and developing a map interface. A custom Story Map was also assembled for the 2019 MACHC meeting that was held in the Dominican Republic, which was attended by Ferrini. https://storymaps.arcgis.com/stories/2ab16d9058164f7ea6d32da7f13885c7
    - An Alumnus from the region (Ms Cecilia Zuleiman Cortina Guzman, Yr 14, Mexico) has graciously agreed to be the Seabed 2030 Liaison for the MACHC and will be working closely with the MACHC Chair and the AIORC to facilitate communication and coordination.

- IHO: SWAtHC - March 2020
    - Ferrini worked closely with GGC member Obino (Brazil) who is part of the SWatHC. A Story Map was presented for this meeting in collaboration with Obino, who presented it at the meeting. https://storymaps.arcgis.com/stories/3dec7016de894ee9872e6d507b6a32ae
- IOC: International Indian Ocean Experiment - March 2020 **cancelled
    - Kim Picard of Geoscience Australia was going to attend this meeting on behalf of the AIORC. An abstract was submitted in collaboration with Alumnus Vasudev Mahale and Tinah Martin and Vicki Ferrini.
- IOC: UN Decade of Ocean Science for Sustainable Development 2021-2030: African and Adjacent Countries Regional Workshop (Kenya January 27 - 29 2020)
    - Details above under Alumni Engagement
- IOC: UN Decade of Ocean Science for Sustainable Development 2021-2030: Western Tropical Atlantic Regional Workshop (Virtual Meeting) 28-29 April, 2020
    - Vicki Ferrini and Tinah Martin both participated virtually, along with several colleagues from the MACHC

Regional Mapping Committee Meetings

No in-person RMC meeting has yet been held since the second one that was held in April 2020. We are currently pursuing options to gather stakeholders for a virtual meeting. We intend to target new stakeholders in the South Atlantic and Indian Oceans.

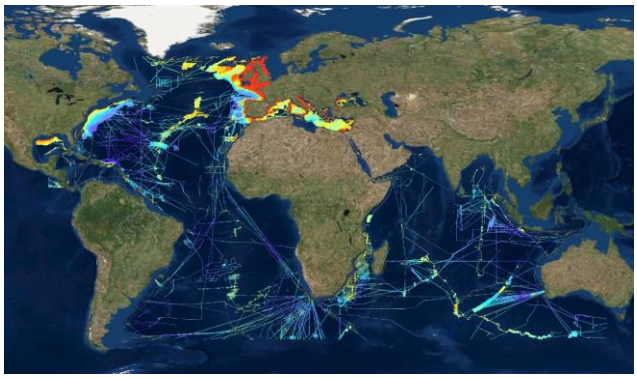
Major data and grid contributions

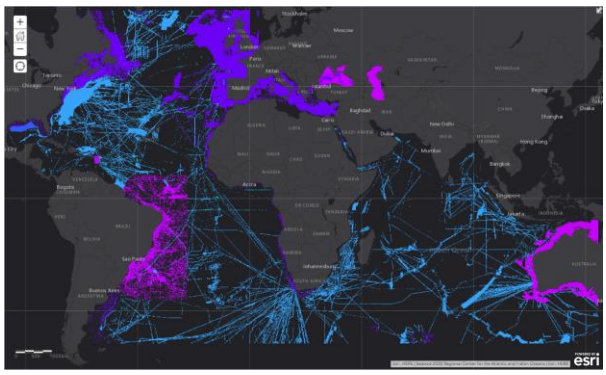
- **GMRT v3.7**
    - Includes > 1,100 cruises of processed multibeam data globally, covering > 9% of the world ocean.
- **Canadian Hydrographic Service- Non-Navigational (NONNA-100) Bathymetric Data**
    - All currently validated, digital bathymetric sources acquired by CHS, combined at a resolution of approximately 100 metres. Contains information licensed under the Open Government License – Canada.
- **Olex - Crowd source bathymetry data**
    - These data are primarily single beam soundings collected by fishing vessels using the Olex acquisition system.
- **Directorate of Navigation and Hydrography Brazil**
    - 1km resolution DTM of Brazilian Margin

- Data in support of naming seafloor features (SCUFN 32), in the South Atlantic Ocean.

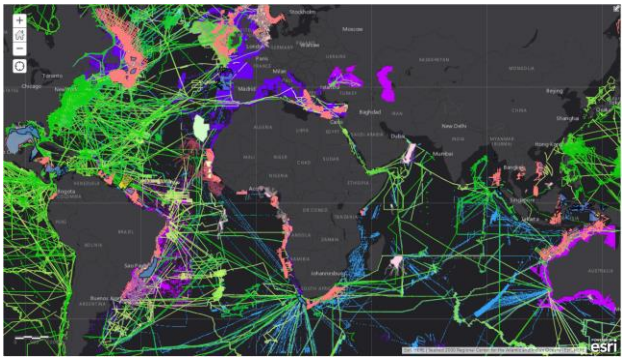
- **XPRIZE**
  - Data resulting from the Shell Ocean Discovery XPRIZE Competition near Puerto Rico and Greece

- **Hydrographic Service for the Navy, Ministry of the Defence of Argentina -** Bathymetric grids based on data acquired during cruises:
  - ARG-MD_2007 (2007)
  - HES-2008-COOPERACION (2008)
  - HE-2016 (2016)
  - the recovery of the A.R.A SAN JUAN submarine (2017)





Left: Data assembled by the Atlantic/Indian RDACC that was included in the GEBCO 2019 Product (represented as depth) compared with (right) the extent of data assembled for the GEBCO 2020 Product (represented by TID).



Map showing the combined publicly available data, some of which has been integrated into the 2020 GEBCO product, as well as currently embargoed data from two industry sources (Fugro and PGS) as well as data that exists for UNCLOS. We hope to gain access to these, and other data, in the coming year.

Financial report

Given the COVID-19 pandemic, travel plans have been drastically changed. We are working to ensure that this does not impact the project be focusing on virtual techniques. We anticipate another potential gap between the end of this year's annual funding cycle and the beginning of the next and have therefore requested a no-cost-extension on Yr 3 funds to carry us until the end of August 2020. We anticipate that we will have spent our entire year 3 budget by the end of August 2020.

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 SU team worked on identifying and processing new bathymetric data sets from the Arctic region as well as re-visiting data that previously had been incorporated at lower resolutions. In addition, new and faster gridding methods and approaches to calculate statistics of mapped seafloor area were developed by the SU team. The latter were implemented to calculate the area that is constrained by bathymetric data in the GEBCO 2020 grid, considering the Seabed 2030 depth-variable resolution scheme. In total, the bathymetric database of the Arctic Ocean region contains >550 datasets of which several, in turn, consist of compilations of many bathymetric cruises, e.g. the NONNA-100 (Non-Navigational) grid provided by the Canadian Hydrographic Service. A new International Bathymetric Chart of the Arctic Ocean (IBCAO) polar stereographic grid was completed at a resolution of 200 x 200 m and released separately to the GEBCO 2020 global grid during Year 3. The IBCAO Ver. 4.0 polar stereographic grid complements the GEBCO 2020 geographic grid, as the latter is highly distorted at high latitudes and therefore does not serve the needs for polar scientists and mapmakers. IBCAO Ver. 4.0 is constrained by individual depth soundings covering three times more area of the Arctic Ocean than Ver. 3.0 previously released 2012 (~19.8 % versus 6.7 %). Modern multibeam bathymetry comprises ~14.3 % in Ver. 4.0 compared to ~5.4 % in Ver. 3.0. Along with the release of IBCAO Ver 4.0 a descriptive scientific paper was published in the Nature *Scientific Data*.

Center Staff

Department of Geological Sciences, Stockholm University

- Ms Caroline Bringensparr, data manager and data analyst
- Dr. Carlos Castro, data manager and data analyst
- Mr. Rezwann Mohammad, developer and data manager
- Mr. Björn Eriksson, IT support

North Pacific:

This past year the UNH team identified and processed **119 multibeam** sonar data sets that were incorporated into the GEBCO 2020 grid, bringing the total number of new (since 2019) data sets to **146**. Since the publication of the GEBCO 2020 grid, the UNH team continued to work on identifying additional cruises to incorporate into the upcoming North Pacific compilation for 2021. This work has, to date, identified and acquired **131** raw multibeam datasets within the RDACC polygon that were not included in previous releases of GMRT or GEBCO. The data not yet incorporated into the grid represents 1.9 terabytes that were downloaded from NCEI and stored on CCOM servers. These datasets will be processed following the workflow and metadata guidelines established by the SB2030 technical group. In addition to the **131** new raw multibeam data sets identified to date, and additional **732** processed hydrographic datasets not currently incorporated in the GEBCO grid have been identified from NOAA's National Ocean Service. These data sets will be incorporated in 2021 and will greatly improve the GEBCO grid's representation of coastal waters off the west coast of the United States.

Center for Coastal and Ocean Mapping, University of New Hampshire

- Mr Paul Johnson, data manager
- Mr Tomer Ketter, data analyst

Regional Mapping Progress

Arctic Ocean Region

During year 3, the SU team further developed the data processing workflow and gridding algorithms used to compile the Arctic Ocean region on a polar stereographic grid. Figure 1 shows the workflow, from when data are received until they are compiled into a digital bathymetric grid. The gridding routines are currently being moved to operate on Sweden's National Super Computer Centre (https://www.nsc.liu.se/). In this process, components of the algorithms are being re-written to use Python rather than calling upon routines from Generic Mapping Tools (GMT). An internal metadata system has been developed that also conforms to the standard adopted by EMODnet.

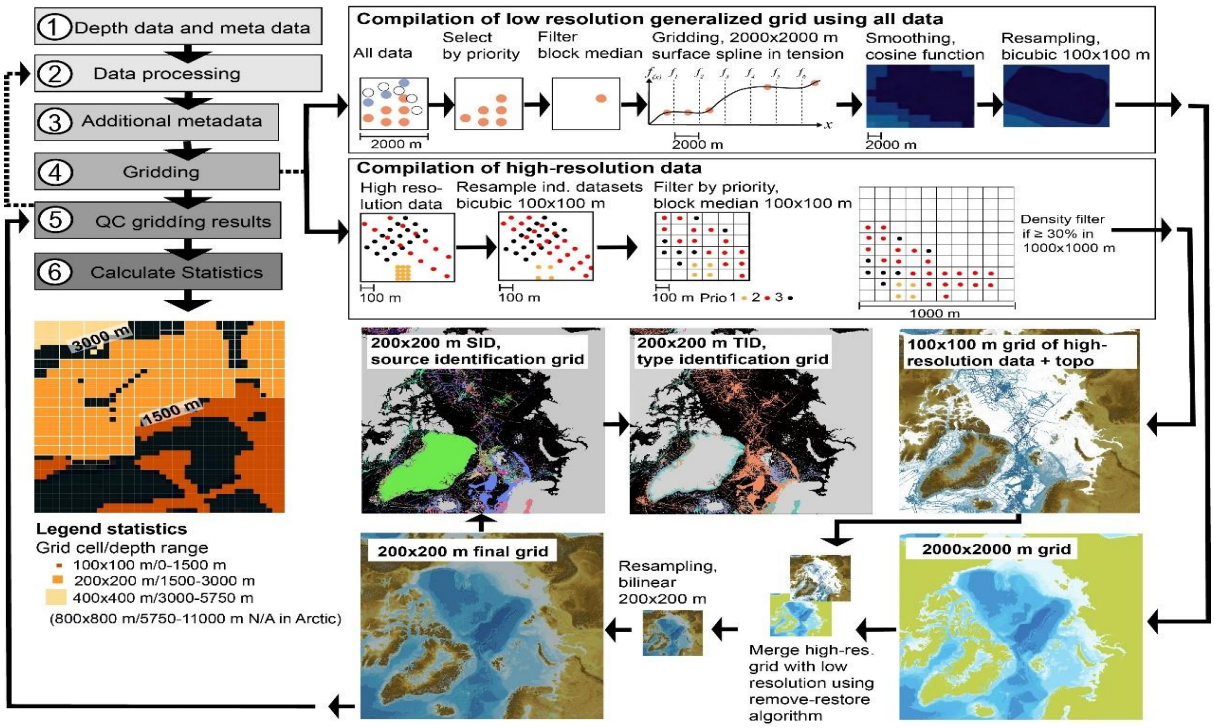


Figure 1: Schematic illustration of the IBCAO DBM compilation work flow. (Figure from the IBCAO Ver. 4.0 article in press in *Scientific Data*).

During Year 3, the work on Version 4.0 of the International Bathymetric Chart of the Arctic Ocean (IBCAO) polar stereographic grid was completed. This grid was converted to geographic latitude longitude spherical coordinates in order to represent the Arctic bathymetry in the GEBCO 2020 global grid. IBCAO Ver. 4.0 was compiled at a resolution of 100 x 100 m, but released to the public through the GEBCO web as a 200 x 200 m polar stereographic grid. It has been described in a release article accepted for publication in the Nature journal *Scientific Data*. The area constrained by soundings in IBCAO Ver. 4.0 amounts to ~19.8 %, which is about three times larger area than in Ver 3.0 released in 2012 (Fig. 2). Modern multibeam bathymetry comprises ~14.3 **%** in Ver. 4.0 compared to ~5.4 % in

Ver. 3.0. Note that the "IBCAO-region" encompasses almost the entire area of the Arctic Regional Center's area of responsibility. The article accepted for publication in *Scientific Data* includes a table of all major data sets (Appendix 1.). To date, the database of the Arctic Ocean region contains **>550** datasets of which several, in turn, consist of compilations of many bathymetric cruises. Since the completion of IBCAO Ver. 4.0, the bathymetric data sets listed in Table 1 have been identified. These will be processed during Year 4.

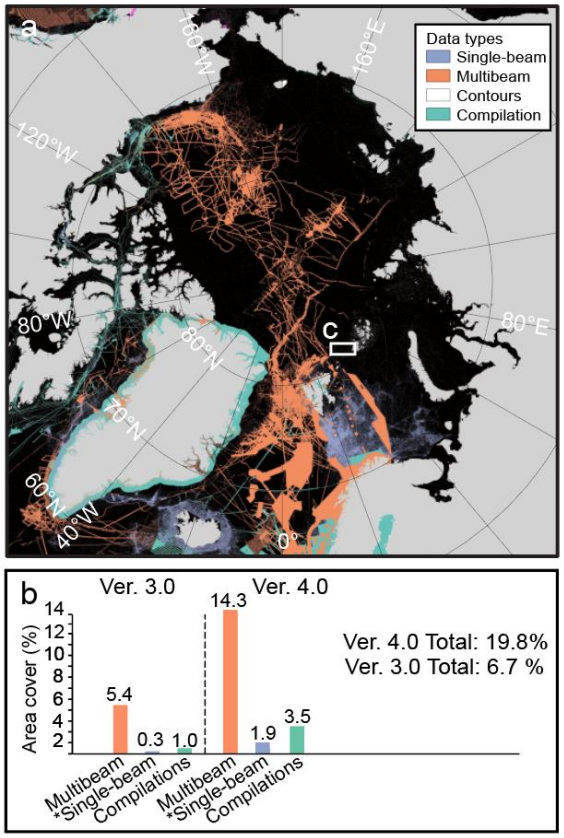


Figure 2: a) Distribution of different categories of depth data in IBCAO Ver. 4.0. The single-beam soundings are barely visible since the map is created at the full resolution of 100x100 m, and a sparse single beam sounding is then only filling one grid cell. **b)** Comparison of data coverage between IBCAO Ver. 4.0 and 3.0.

Table 1: Data identified not included in the IBCAO Ver. 4.0. These data will be processed during Year 4.

Data	Status
Arctic Ocean 2018	MB raw data, needs processing
British Arctic Survey JR99	MB "Raw", needs processing
British Arctic Survey JR106	MB "Raw", needs processing
British Arctic Survey JR127	MB "Raw", needs processing
British Arctic Survey JR132	MB "Raw", needs processing

British Arctic Survey JR133	MB “Raw”, needs processing
British Arctic Survey JR142	MB “Raw”, needs processing
British Arctic Survey JR210	MB “Raw”, needs processing
British Arctic Survey JR302	MB “Raw”, needs processing
British Arctic Survey JR17007	MB “Raw”, needs processing
Danish Navy Christof Pearce	MB raw data, on hold (EIVA format)
NOAA HLY1101 2011	MB raw data, needs processing
NOAA HLY1103 2011	MB raw data, needs processing
NOAA HLY1201 2012	MB raw data, needs processing
NOAA HLY1203 2012	MB raw data, needs processing
NOAA HLY1301 2013	MB raw data, needs processing
NOAA HLY1303 2013	MB raw data, needs processing
NOAA HLY1401 2014	MB raw data, needs processing
NOAA HLY1402 2014	MB raw data, needs processing
NOAA HLY1502 2015	MB raw data, needs processing
NOAA KM0312 2003	MB raw data, needs processing
NOAA SKQ201505S 2015	MB raw data, needs processing
NOAA SKQ201509T 2015	MB raw data, needs processing
NOAA SKQ201511S 2015	MB raw data, needs processing
NOAA TN250 2010	MB raw data, needs processing
PANORAMA 2015	MB Raw Data, on hold

North Pacific Region

This past year, the UNH team evaluated the GIS-based approach to grid assembly and area calculation, in contrast to the Stockholm method which had been used in previous years. This was done to allow the team to compare and contrast the workflows of each approach through each step of the process (e.g., data management, data ingest, grid assembly, source tracking, and area calculation). The GIS approach offers many potential benefits but at this point in time (mostly due to the reliance of the Bathymetric Information System (BIS) on an outdated 32-bit ArcGIS platform), it also has many limitations in handling the potentially very large number of polygons generated by some of our data sets (particularly when they incorporate sparse data). ESRI is aware of these issues and is working on porting the BIS to the 63-bit ArcPro platform. Using the GIS approach the UNH team reprocessed and incorporate all **146** multibeam data sets it currently has in the North Pacific region, into the GEBCO 2020 grid (Fig. 3). These data sets come from three primary sources: data collected by E/V NAUTILUS data in support of the NOAA’s Ocean Exploration Program; data downloaded from the U.S. National Archive at NOAA’s National Center For Environmental Information (Boulder), and; UNH/CCOM data from their Extended Continental Shelf mapping cruises. Additionally, approximately **131** North Pacific data sets that are not in either the GEBCO

grid or GMRT were identified. The quality and relevance of these data is currently being examined for eventual incorporation into the 2021 GEBCO grid.

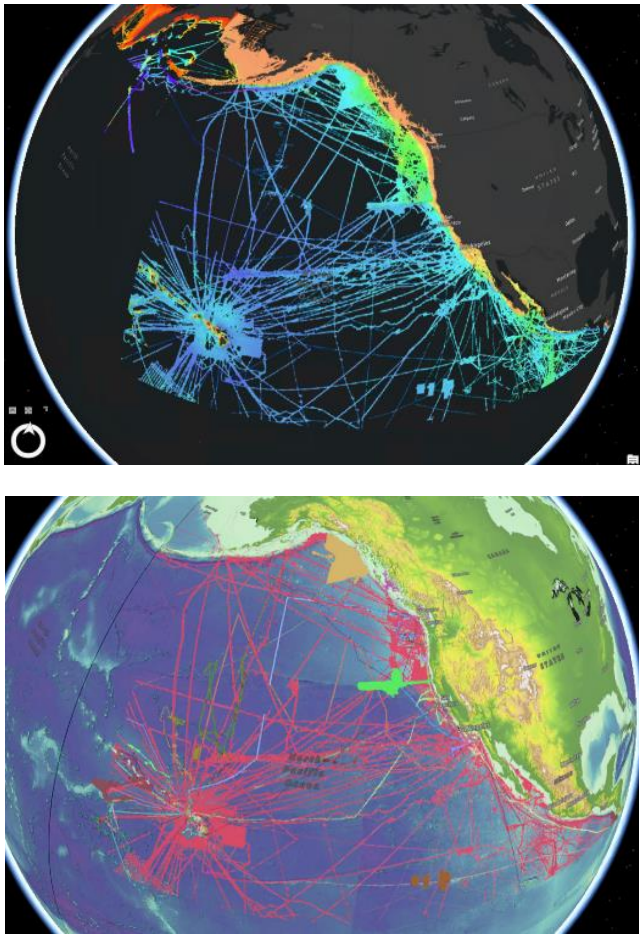


Figure 3: *North Pacific 2020 bathymetric grid (upper) and TID layer overlaid on the GEBCO topo-bathy product (lower).*

Major data and grid contributions

The major the North Pacific compilation data additions to the 2020 grid include:

- **Ocean Exploration Trust:** Multibeam bathymetry from **19** cruises on the E/V NAUTILUS in the North Pacific since 2018 have been compiled into the GEBCO 2020 Grid:

Region	Year	Cruise ID
Shakedown	2018	NA093

Southern California	2018	NA094
Cascadia	2018	NA095
Cascadia Margin	2018	NA096
NE Pacific Seamounts	2018	NA097
Pacific Seamounts	2018	NA099
Loihi Seamount	2018	NA100
Papahanaumokuakea	2018	NA101
Clarion Clipperton	2018	NA102
Monterey Bay National	2018	NA103
Submerged Shorelines of	2018	NA104
Shakedown 2019	2019	NA105
Osborn Bank	2019	NA106
California Mapping	2019	NA107
Gorda Ridge	2019	NA108
Pacific Seamounts	2019	NA109
Kingman-Palmyra, Jarvis	2019	NA110
American Samoa	2019	NA112
Baker, Howland, Johnston	2019	NA114

- **NOAA NCEI multibeam data repository: 74** multibeam datasets from the US academic fleet.
- **OLEX**: Compilation of bathymetry primarily from fishing vessels using the Olex system. More information at: http://www.olex.no
- **Canadian Hydrographic Service** (CHS): a dataset of Non-Navigation hydrographic soundings in XYZ format, downloaded from their website.
- **SHOM** (French Naval Hydrographic and Oceanographic Service): contributed an XYZ dataset (via GDACC).
- **Global Seas LLC** contributed a fully processed multibeam grid in deep water (via GDACC).

Other activities

Hosts for the Fall 2019 GEBCO Sub-Committees Meetings, GEBCO Guiding Committee Meeting, GEBCO Symposium, and the 2nd Annual Arctic, Antarctic, and North Pacific Mapping Meeting

During the fall of 2019, with extraordinary help from the Center for Coastal and Ocean Mapping's administrative staff, the UNH team hosted seven days of meetings related to either GEBCO activities or Seabed 2030 activities. These meetings included a meeting of the GEBCO Guiding Committee and meetings of the GEBCO Sub-Committees (TSCOM, SCRUM, and SCOPE) attended by 87 people, a one-day GEBCO Symposium attended by 136 people, and 2 days for the 2nd annual meeting of the Arctic, Antarctic, and North Pacific Mapping effort which was attended by 34 people. This last meeting allowed the leads of the 2 regional Centers (Arctic/North Pacific and the Antarctic), along with their technical staffs to meet with industry partners, data contributors, and governmental groups and have detailed discussions about mapping in the polar regions. This meeting also let the Centers talk about their workflows, including data identification, data management, gridding, and data visualization.

Figure 4. GEBCO Symposium held in Portsmouth N.H. attracted almost 140 people. The Symposium was held along with meetings of the GEBCO Guiding Committee, TSCOM, SCRUM and SCOPE meetings, and a meeting of the Arctic/North Pacific and Antarctic Regional Data Centers.

On-line technical workshop on gridding bathymetric data, May 4-5

A technical workshop was organized by the SU and UNH team to discuss approaches to gridding heterogeneous bathymetric data. It also included technical details on the method developed by the SU team to calculate statistics of data coverage. Between 35 and 40 participants attended the

workshop, which consisted of presentations followed by discussions. Some industry partners attended and gave presentations, e.g. Amazon, ESRI, Kongsberg.

Online Interactive Arctic Mapping Prioritization Tool

A request came out of the fall 2019 Arctic, Antarctic, and North Pacific Regional Data Centers meeting for the development of a web-based tool that would allow users to interactively draw mapping priority polygons or point locations on top of all available bathymetric data. The idea was to provide members of the community with the ability to easily highlight areas in greatest need for mapping and share that information in a single widely available location. To address this, the UNH team developed a tool served from the University of New Hampshire GIS portal that allows users to interactively draw and document mapping priority zones over the IBCAO Version 4 bathymetry (Figure 5). This web application uses an online database to store the spatial locations for the polygons and points, a designation of the level of priority, the name of the requestor or agency, and any comments that the user wishes to enter. The UNH team has also developed a series of alternative Graphical User interfaces for this app to test the ease the access to the data and the user's ability to draw and annotate the priority areas on the map.

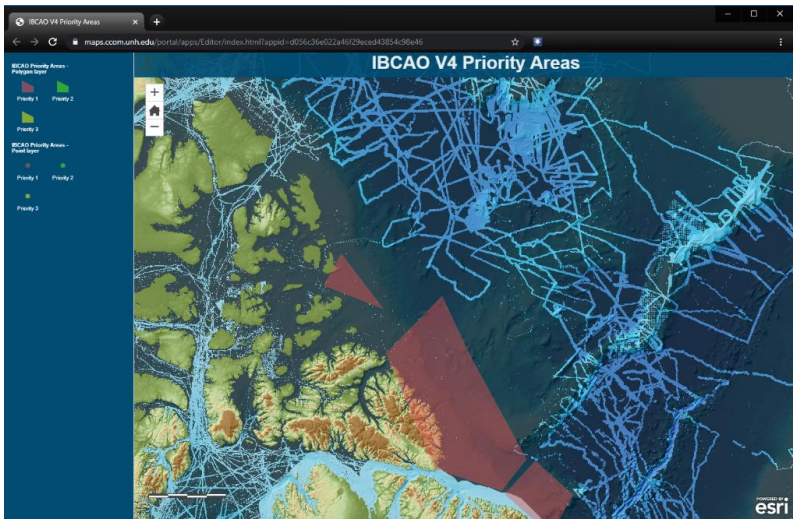


Figure 5: Screen shot from the Arctic prioritization web application hosted on the UNH GIS portal. This app allows user to create polygons and points indicating mapping priority areas on top of the IBCAO grid.

Online Interactive GEBCO Grid Quality Assessment Tool

During the Spring of 2020, the UNH team developed two interactive web applications that allowed each of the Seabed 2030 RDACCs and the Global Center to visualize and comment on the draft releases of the GEBCO 2020 bathymetry grid. This interface displayed the draft version of the

bathymetry grid as a multi-directional hillshade (shaded relief) illuminated bathymetry with an optional overlay of a TID layer and a comments layer. Within this interface (Figure 6), the Seabed 2030 community could draw polygons and shapes with embedded metadata documenting the reviewer/agency name, the type of data issue, and any comments. Each of the metadata fields is logged within a database on the UNH GIS server, which in turn can be exported to shapefiles at the request of any of the RDACCs or the Global Center.

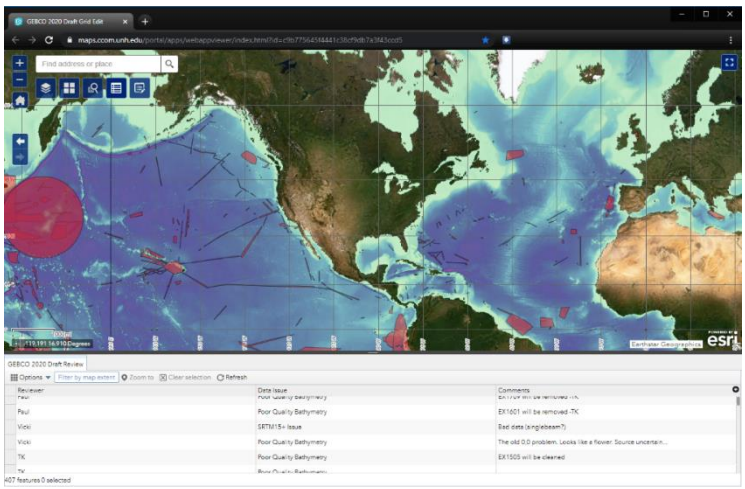


Figure 6: Screen shot from the web application hosted on the UNH GIS portal, showing a preliminary GEBCO 2020 bathymetry grid with graphical annotations marking areas to review.

Online Interactive Visualization Tools

The GEBCO 2019 bathymetry grid can be difficult to work with and to visualize due to its large size, 86,400 x 43,200 grid nodes. This was especially apparent when trying to incorporate it into online dynamically drawn web applications that do not use pre-rendered tiles to visualize the data. While tile sets allow for more rapid online distribution, they do not allow for features that are calculated in real time (e.g., dynamically adjusted by depth range colour palettes, dynamically calculated multi-directional hillshades, and interactive depth queries). To overcome the limitation of working with a tiled dataset, the UNH team optimized the grid for integration into their online GIS portal and were able to produce web applications that allowed the visualization of the full GEBCO 2019 grid as both a traditional "flat" map in a world Mercator projection (Figure 7), and as a fully interactive globe showing the portions of the world's oceans mapped by direct measurement (Figure 8). The GIS services available through the University of New Hampshire's GIS Portal are not limited to just work with the pre-made WebApps that the UNH team has created, but are also available through a standardized REST interface for any user to work with either through their own WebApps or through their desktop GIS applications.

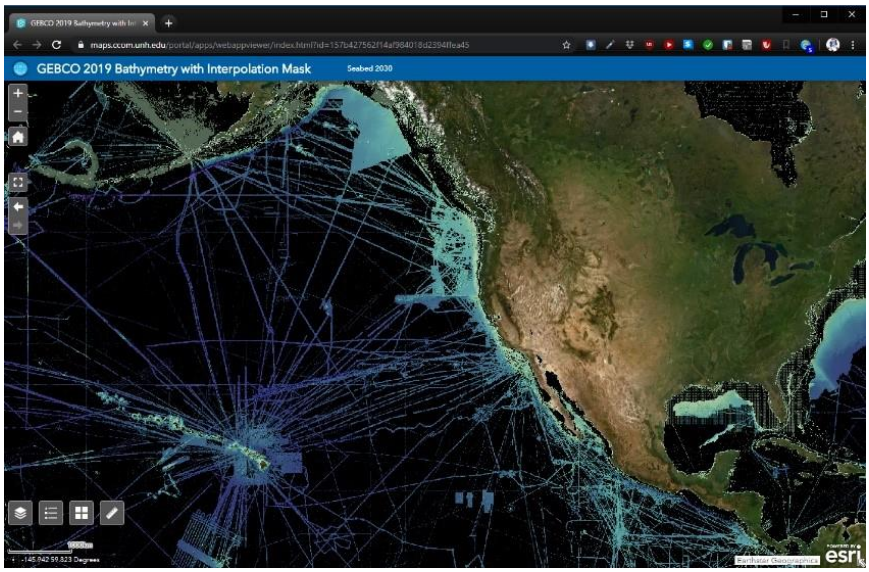


Figure 7: Screen shot from the web application hosted on the UNH GIS portal, showing a visualization of GEBCO 2019 bathymetry grid with a mask allowing the viewing of areas with a direct measurement of the bathymetry. https://maps.ccom.unh.edu/portal/apps/webappviewer/index. html?id=157b427562f14af984018d2394ffea45

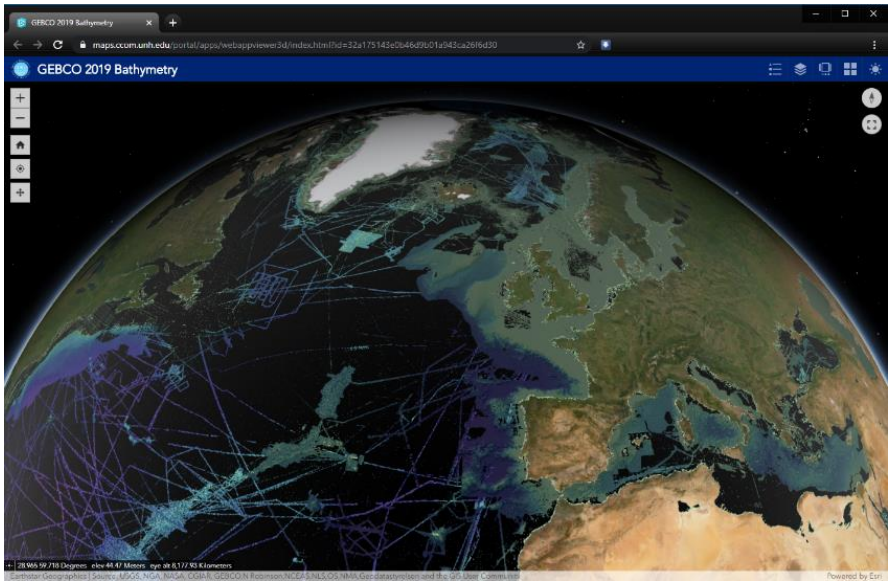


Figure 8: Screen shot from the web application hosted on the UNH GIS portal, showing a 3D global visualization of GEBCO 2019 bathymetry grid with a mask allowing the viewing of areas with a direct measurement of the bathymetry.
https://maps.ccom.unh.edu/portal/apps/webappviewer/index.html?id=157b427562f14af984018d2394ffea45

BathyGlobe

Last year we reported on the BathyGlobe project (started in 2018) being developed for the display of global bathymetric data. One of its goals is to provide support for the Seabed 2030 initiative to heighten awareness of the extent to which the ocean floor has and has not been mapped. The BathyGlobe can be used with a high resolution (4K) touchscreen in order to show high resolution images of the seafloor with load times that appear instantaneous. The current state of the project is shown in Figure 9. A touch on part of the globe selects that region and causes the globe to rotate so that the indicated region is centered and a higher resolution view of the area appears to the upper right. Selecting within the higher resolution view causes a 3D view of that location to appear in the lower right quadrant. Innovations this year include a much faster rendering engine, the inclusion of high-resolution "BAG" data, and much more robust 3D views and geospatial interrogation capabilities.

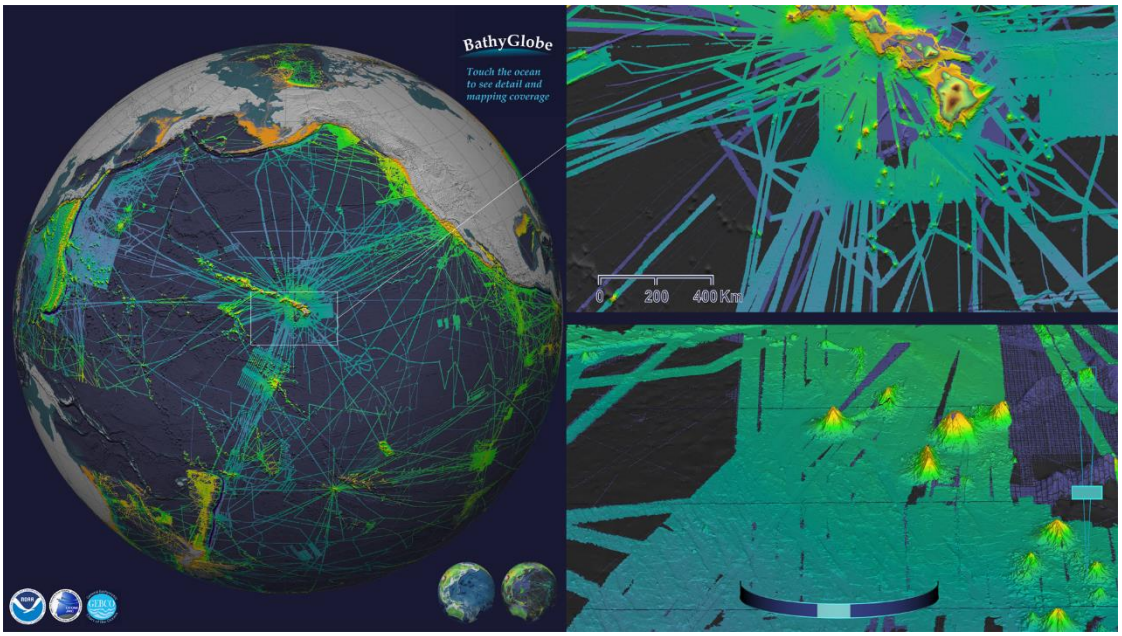


Figure 9. Latest iteration of BathyGlobe display

Global Geographic Grid System (GGGS)

Last year we also reported on the Global Geographic Grid System (GGGS) for visualizing bathymetry. GGGS combines a metagrid hierarchy with a system of compatible data grids. Metagrid nodes define the boundaries of data grids. Data grids are square grids of depth values. Both metagrids and data grids are defined in geographic coordinates to allow broad compatibility with the widest range of geospatial software packages. An important goal of the GGGS is to support the meshing of adjacent tiles with different resolutions so as to create a seamless surface. This is accomplished by ensuring that abutting data grids either match exactly or only differ by powers of two. This was developed to address the needs of the seabed 2030 project and for other applications where a

geographic grid is desirable. A first draft was submitted to the Seabed 2030 Technical Committee in January 2019 and revised version was submitted in April. The system has been discussed at a number of technical group meetings. A manuscript has been submitted for publication and is currently under review in the EGU Journal Geoscientific Instrumentation, Methods and Data Systems.

Mapping the Ocean Frontier Pilot Project

A specific proposal was sent to Nippon Foundation for a pilot project aimed to test the concept of the proposed *Mapping of Ocean Frontiers* program. The pilot was granted by Nippon Foundation and provided a budget separated from the Seabed 2030 project. The aim was to add multibeam operators on Swedish icebreaker *Oden* during transits and when the vessel was chartered by the US National Science Foundation (NSF) for a scientific expedition in the North West Passage, Arctic Canada, as this expedition did not have a multibeam component. In addition, *Oden's* transit routes were adjusted to complement existing bathymetric data, i.e. to fill the gaps. First, a multibeam operator was included during the two transits between Helsingborg, southern Sweden, and Thule, northern Greenland, made in conjunction with the *Ryder 2019 Expedition*. Along these two transits, amounting in total to a length of **9700 km**, multibeam bathymetry were collected continuously and the transit-routes were adjusted to fill gaps between existing sounding data (Fig. 10). On a side note, the *Ryder 2019 Expedition* with icebreaker *Oden*, officially designated by Explorers Club as "Flag Expedition #51, mapped in Nares Strait separating Greenland from Ellesmere Island, southern Lincoln Sea and the previously uncharted Sherard Osborn Fjord in northern Greenland. The *Ryder 2019 Expedition* was carried out between August 5 and Sept 10, Thule-Thule. Despite not being part of the pilot project, all these data were directly provided for use by the Artic Regional Center in the compilation of IBCAO Ver. 4.0. Prior to the *Ryder 2019 Expedition* and following the transit from Helsingborg to Thule, the US National Science Foundation expedition in the North West Passage was carried out. Also, during this expedition, multibeam operators were placed onboard *Oden* through the Mapping of Ocean Frontiers pilot project to ensure high quality data collection. This was facilitated through additional financial support from Center for Coastal and Ocean Mapping, University of New Hampshire, and Stockholm University. A total of **4150 km** of multibeam bathymetry was collected during the North West Passage expedition. Nippon Foundation also requested that a film was to be made about the *Ryder 2019 Expedition* as part of the pilot project, in order to show how mapping in remote areas is carried out, as well as the immense challenges, for the broader audience. This work has begun and will be based on filming made during the expedition and specifically produced computer graphics and interviews.

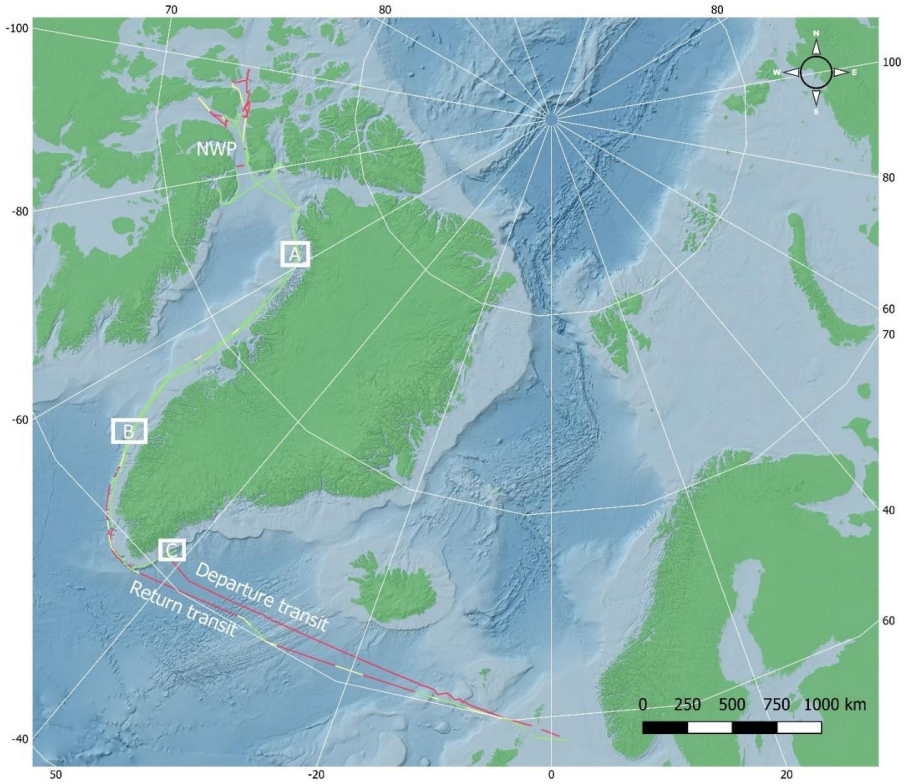


Figure 10: Multibeam bathymetry collected as a part of the Nippon Foundation supported Mapping Ocean Frontiers Pilot Project. The NSF Northwest Passage Project and transit tracks with Swedish icebreaker Oden are shown overlaid on a shaded-relief display of the regional bathymetry. The green, yellow, and red colors along the tracks correspond to good, intermediate, or poor data quality, respectively. NWP: North West Passage. A, B and C refers to areas discussed in a separate report on the collected bathymetry.

Development of method to calculate the mapped area of the World ocean floor considering the Seabed 2030 variable depth-resolution scheme

How much of the World ocean floor that has constraining depth data in the GEBCO grid, considering the Seabed 2030 variable resolution scheme, is the primary metrics that Nippon Foundation requests as a measure of progress. During Year 1, the SU team developed a method to calculate this metric based on GMT routines embedded in Python code. This approach has since been fully automated and included in the workflow of the Arctic and Southern oceans regional centres. During Year 1, the SU team also calculated the global coverage. During Year 3, an approach was developed by the SU Team to regularly calculate the critical statistics automatically, including how much of the seafloor area that has been map in each of the Seabed 2030 regions, in the responsibility areas of the Regional Hydrographic Commissions, and also how much that has been mapped considering different data types, e.g. multibeam, single beam etc. The code was re-written to use Python without GMT routines, as the latter were computer intensive and required a lot of computer time. The code was moved to Sweden's

National Super Computer will during Year 4 be parallelized. The goal is to be able to deliver statistics on a quarterly basis. In order to make the calculations, each centre is required to upload their bathymetric data to a secured space handled by the SU team.

Figure 11 shows the web-report created by the SU team that shows the bathymetric statistics underlying the yet to be released GEBCO 2020 grid.

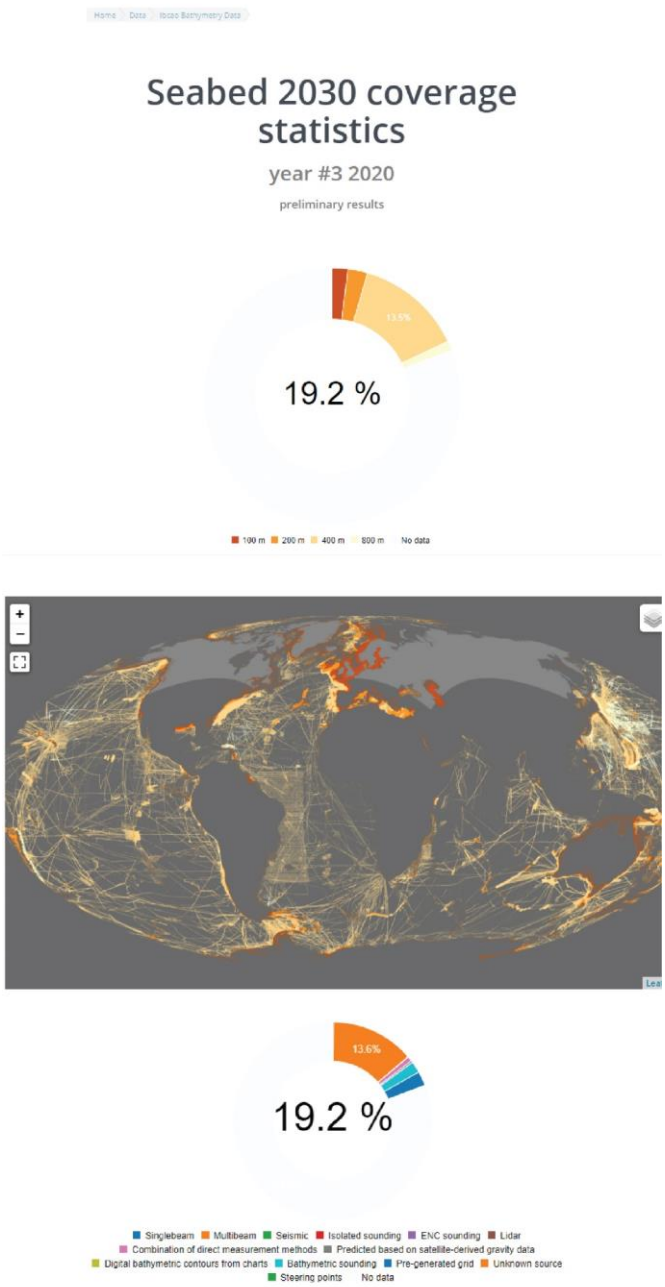


Figure 11: *Web-report created by the SU team that shows the bathymetric statistics underlying the yet to be released GEBCO 2020 grid. Not all metrics that are calculated by the routines developed by the SU team is shown on this web report*.

Major Data and Grid Contributions:

Major sources used in the compilation of IBCAO Ver. 4.0. Published peer-review articles and cruise reports linked to the data sources are listed where available in our metadata records. Bathymetric data that have been contributed without metadata are not listed, although used in the compilation where no other data are available. The table is included in the article describing IBCAO 4.0 accepted for publication in the Nature journal *Scientific Data*.

Alaska Fisheries Science Center of the US National Oceanic and Atmospheric Administration's National Marine Fisheries Service (NOAA Alaskan Fisheries)	**Bathymetry data from the Alaska bathymetry compilations for the Aleutian Islands, central and western Gulf of Alaska and Norton Sound:** https://www.afsc.noaa.gov/RACE/groundfish/Bathymetry/default.htm **Digitized chart soundings, Alaska:** Proofed digitized historical chart soundings from "smooth sheets" covering Alaskan waters [1-4]
Alfred Wegener Institute (AWI)	**81 Cruises of Multibeam data in the Atlantic and Indian Ocean region.** **11 Cruises of multibeam data in the South and West Pacific:** https://www.pangaea.de/ https://www.pangaea.de/expeditions/cr.php/Polarstern https://webapp-srv1a.awi.de/eBathy/datasets2.php
National Institute of Oceanography and Applied Geophysics (OGS), Infrastructures Division; Barcelona University (UB), Department of Stratigraphy, Paleontology and Marine Geosciences (now Department of Earth and Ocean Dynamics); University of Bremen, MARUM – Center for Marine Environmental Sciences;	OGS provided a combined grid of the following datasets **Multibeam bathymetry from EGLACOM cruise with RV OGS-Explora in 2008 to the western Barents Sea margin [5]** **Multibeam bathymetry from SVAIS cruise with RV Hesperides 2007 to the western Barents Sea margin [6]** **Multibeam bathymetry from DEGLABAR cruise with RV OGS-Explora in 2015 to the western Barents Sea margin [7]** **Multibeam bathymetry from EDIPO cruise with RV OGS-Explora in 2015 to the western Barents Sea margin [8]** **Multibeam bathymetry by MARUM from MSM30 (CORIBAR) cruise with RV M.S. Merian in 2013 to the western Barents Sea margin [9]**

University of Tromsø (UiT), The Arctic University of Norway, CAGE, Centre for Arctic Gas Hydrate; Italian Navy,Italian Hydrographic Institute	**Multibeam bathymetry by University of Tromsø from Glacibar cruise with RV Jan Mayen in 2009 to the western Barents Sea margin** [10,11] **Multibeam bathymetry by Italian Hydrographic Institute from High North 17 and 18 cruise with RV Alliance in 2017 and 2018 to the western Barents Sea margin** [12,13]
British Antarctic Survey (BAS), UK NERC Polar Data Centre	**Multibeam data from three cruises of the RRS James Clark Ross:** https://www.bas.ac.uk/ **JR51, 2000, Greenland and Norwegian Seas** [14,15] **JR142, 2006, Svalbard** [14,15] **JR175, 2009, West Greenland** [16] **JR211, 2008, Svalbard** [17]
Canadian Hydrographic Service (CHS)	**Non-Navigational (NONNA-100) Bathymetric Data** (gridded compilation)**:** All currently validated, digital bathymetric sources acquired by CHS, combined at a resolution of approximately 100 meters. Contains information licensed under the Open Government Licence – Canada. https://open.canada.ca/data/en/dataset/d3881c4c-650d-4070-bf9b-1e00aabf0a1d
Capricorn Greenland Exploration A/S	**Single beam bathymetry from two surveys in 2008 and 2009:** No publications available
ConocoPhillips	**Single beam navigation data from Baffin Bay seismic surveys:** No publications available Navigation data from 2D-seismic surveys for exploration of hydrocarbons in Baffin Bay, West Greenland, in 2012, conducted by Polarcus DMCC for ConocoPhillips. Released to and provided through Greenland Institute of Natural Resources for the purpose of preparation for publication in IBCAO/GEBCO.
Digitized depth contours from bathymetric maps	**Contours digitized from six published maps are used in the IBCAO Ver. 4.0 compilation where no other data are available** [18-22]
EMODnet (gridded compilation)	**The EMODnet Digital Bathymetry (DTM) 2018:** A multilayer bathymetric product for Europe's sea basins, based upon more than 9400 bathymetric survey data sets and Composite DTMs gathered from 49 data providers

	from 24 countries [23]
Geological Institute, Russian Academy of Sciences (GIN RAS)	**Multibeam data from four surveys with RV Akademik Nikolaj Strakhov of the Knipovich Ridge** (Updated since IBCAO v3 with higher resolution) [24] http://atlantic.ginras.ru/download/exp/grd/grd_data.html
Geological Survey of Canada (GSC), Canadian Hydrographic Service (CHS)	**Multibeam and single beam bathymetry from CCGS Louis St-Laurent:** ***Single beam*** **LSL2007** [25] **LSL2008** [26] **LSL2009** [27] **LSL2010** [28] **LSSL2011** [29] ***Multibeam*** **LSSL2014** [30] **LSSL2015** [31] **LSSL2016** [32]
Geological Survey of Denmark and Greenland (GEUS)	**Single beam data acquired during seismic exploration surveys of the Greenland continental margin provided by GEUS:** This contribution consists of >30 surveys carried out by various exploration companies for which the moratorium of the single beam bathymetry has expired. https://eng.geus.dk/
Geological Survey of Denmark and Greenland (GEUS), Danish Geodata Agency	**Multibeam bathymetry collected by Fugro for Denmark's extended continental shelf claim:** No publication available
Geological Survey of Denmark and Greenland (GEUS), Stockholm University and Swedish Polar Research Secretariat	**Multibeam bathymetry from Swedish icebreaker Oden acquired during the Lomonosov Ridge off Greenland (LOMROG) Expeditions 2007-2012 and East Greenland Ridge Expeditions (EAGER) 2011:** **LOMROG, 2007, Central Arctic Ocean** [33,34] **LOMROG 2009, Central Arctic Ocean** [35] **LOMROG 2012, Central Arctic Ocean** [36,37] **EAGER 2011, East Greenland Ridge** [38]
Geological Survey of Sweden (SGU)	**Hoburg's shoal survey from 2016/2017** [39]

	https://www.sgu.se/samhallsplanering/hav-och-kust/stod-till-havsplanering-och-forvaltning/projekt-hoburgs-bank/
GEOMAR Helmholtz Centre for Ocean Research Kiel	**Multibeam data from RV Maria S. Merian:** **05/03, 2007, Ilulissat Ice Fjord** [40] https://www.geomar.de/en/centre/
Global Multi-resolution Topography Data Synthesis (GMRT)	**GMRT version 3.5:** A multi-resolutional compilation of edited multibeam sonar data collected by scientists and institutions worldwide, that is reviewed, processed and gridded by the MGDS Team and merged into a single continuously updated compilation of global elevation data, provided at 15 arc sec resolution to GEBCO. https://www.gmrt.org/
Greenland Institute of Natural Resources (GINR)	**Crowd source data and multibeam data provided through Greenland Institute of Natural Resources**: These data include single beam soundings collected by GINR vessels Martek Aps, Kisaq, Greenland Police and Polar Seafood and multibeam bathymetry collected by Sanna in Nuup Kangerlua (Godthaabsfjord), Ameralik and Fyllas Bank of West Greenland in 2018. https://natur.gl/
IceBridge BedMachine Greenland	**IceBridge BedMachine Greenland, Version 3**: Greenland under-ice topography/bathymetry gridded compilation. Gridded resolution is 150x150 m on a Polar Stereographic projection [41] http://nsidc.org/data/IDBMG4
International Hydrographic Organization Data Center for Digital Bathymetry (IHO DCDB)	**Bathymetric Soundings extracted from the data maintained by the International Hydrographic Organization (IHO) Data Center for Digital Bathymetry (DCDB) at the US National Centers for Environmental Information (NCEI):** https://www.ngdc.noaa.gov/iho/
Japan Agency for Marine-Earth Science and Technology (JAMSTEC)	**Multibeam bathymetry collected with Japanese RV Mirai extracted from Data and Sample Research System for Whole Cruise Information in JAMSTEC:** **MR00_K06:** http://www.godac.jamstec.go.jp/darwin/cruise/mirai/MR00-K06/e **MR02_K05:** http://www.godac.jamstec.go.jp/darwin/publication/mirai/mr02-k05/e **MR04_K05:**

	No publication available **MR99_K05:** http://www.godac.jamstec.go.jp/darwin/cruise/mirai/mr99-k05_leg1/e http://www.godac.jamstec.go.jp/darwin/e
Korean Polar Research Institute (KOPRI)	**Multibeam data from Korean RV Araon expeditions:** **ARA02B and ARA03B** [42] **ARA04C:** No publication available https://eng.kopri.re.kr
Maersk	**Single beam navigation data from Baffin Bay seismic surveys:** No publication available **Navigation data from 2D-seismic surveys for exploration of hydrocarbons in Baffin Bay, West Greenland, in 2012, conducted by Polarcus DMCC for Maersk Oil. Released to Greenland Institute of Natural Resources for the purpose of preparation for publication in IBCAO/GEBCO.**
MAREANO; Norwegian Hydrographic Service (NHS)	**Bathymetric model of the Norwegian continental shelf compiled by the MAREANO project:** This gridded bathymetric model (incorporated at a resolution of 50x50 m) has been produced by using high quality hydrographic survey data, primarily multibeam. In ocean areas, the coverage is largely dependent on the surveys organized by the MAREANO program (www.mareano.no/en). The coverage area is extended continuously and the data is updated whenever new hydrographic surveys are finished being processed. https://kartkatalog.geonorge.no/metadata/67a3a191-49cc-45bc-baf0-eaaf7c513549
Nansen Environmental and Remote Sensing Center	**Single beam from RH SABVABAA (Hoovercraft) drifts in the central Arctic Ocean:** **Drifts in 2011 and in 2014/2015** [43]
NASA-Ocean Melting Greenland project, Caltech's Jet Propulsion Laboratory and the University of California Irvine	**Multibeam bathymetry acquired by the Ocean Melting Greenland Project (OMG) 2013-2018 along the coast of Greenland from airborne marine gravity and ship-based observations** [44-53] https://omg.jpl.nasa.gov/portal/
National Geospatial-Intelligence Agency (NGA)	**Single beam data from Melville Bay, Greenland, contributed by NGA:**

	No metadata included on contribution
Lamont-Doherty Earth Observatory, Columbia University, Earth Institute (R/V Marcus G. Langeth expeditions)	**Multibeam bathymetry from R/V Marcus G. Langseth:** **MGL 1112, 2011, Chukchi Sea** [54,55] **MGL 1109, 2011, Gulf of Alaska** [56]
Northeast Greenland Digital Bathymetric Model	**Digital bathymetric model of Northeast Greenland (gridded compilation)** [57]
Norwegian Hydrographic Service (NHS)	**Svalbard bathymetry grid based on multibeam bathymetry:** Released in 2016, this dataset includes modern multibeam data from surveys up until autumn 2015. Data is originally at 10x10 m, but down sampled to 100x100 m during the incorporation. https://www.kartverket.no/
The Norwegian Petroleum Directorate (NPD)	**Multibeam bathymetry collected on behalf of the Norwegian Petroleum Directorate:** **The multibeam mapping was carried out by Gardline Ltd.** https://www.gardline.com/
Norwegian Polar Institute (NPI)	**Svalbard topography grid:** New topographical data of Svalbard with updated glacial fronts from satellite imaging. https://toposvalbard.npolar.no/ http://www.npolar.no/no/
Olex AS, Norway	**Crowd source bathymetry provided by Olex:** These data are primarily single beam soundings collected by fishing vessels using the Olex acquisition system. The data are provided gridded at a resolution of 400x400 m. www.olex.no
Shell	**Single beam navigation data from Baffin Bay seismic surveys:** No publication available Navigation data from 2D-seismic surveys for exploration of hydrocarbons in Baffin Bay, West Greenland, in 2012, conducted by Polarcus DMCC for Royal Dutch Shell. Released

	to Greenland Institute of Natural Resources for the purpose of preparation for publication in IBCAO/GEBCO.
Swedish Polar Research Secretariat and Stockholm University	**Multibeam and single beam data from expeditions with Swedish icebreaker Oden:** The LOMROG and EAGER expeditions are listed separately above. ***Single beam*** **Arctic Ocean 1991, 1996, 2001** [58-60] ***Multibeam*** **AGAVE 2007** [61] **NEGC 2008**, Operated by Statoil A/S, no publication available **SAT 2008, 2009** [62] **SWERUS-C3 2014 Expedition** [63-65] **Petermann 2015 Expedition** [66,67] **Arctic Ocean 2016 Expedition** [32] **Ryder 2019 Expedition** [68] Oden Mapping data: https://oden.geo.su.se/
Stockholm University, University of New Hampshire and Ola Skinnarmo	**Multibeam bathymetry acquired in Melville Bay, west Greenland, during the VEGA-Greenland Expedition 2013, with SY Explorer of Sweden** [69]
TelePost Greenland A/S	**Greenland Connect Nord multibeam bathymetry from south-west Greenland:** No publication available Multibeam survey for offshore and inshore telecommunication cable from Nuuk to Aasiaat. Released to Greenland Institute of Natural Resources for the purpose of preparation for publication in IBCAO/GEBCO.
The University Centre in Svalbard (UNIS)	**Multibeam bathymetry from Svalbard, from seven cruises with RV Helmer Hanssen:** **JM09H** **JM10** [70] **HH11** [71] **HH12** [72] **HH13-NAL** [73] **HH13-SF** [74] **HH14**, No publication available https://www.unis.no/

University of Alaska Fairbanks and its College of Fisheries and Ocean Sciences	**Alaska Region Digital Elevation Model (ARDEM) Version 2.0** [75]
University of Bremen, MARUM - Center for Marine Environmental Sciences	**Multibeam data from western Svalbard region (Vestnesa Ridge) with MARUM RV Heincke** [76] **HE449:** https://www.marum.de/en/Research/RV-HEINCKE-HE449-1-August-22-August-2015-Trondheim-Tromso.html **HE450:** https://www.marum.de/en/Research/RV-HEINCKE-HE450-25-August-8-September-2015-Tromso-Tromso.html https://www.marum.de/en/index.html
University of New Brunswick, Ocean Mapping Group	**Multibeam bathymetry acquired with Canadian CCGS Amundsen:** Multibeam data from expeditions between 2003-2011 and 2013 are provided through the Ocean Mapping Group at University of New Brunswick separately from the NONNA-100 compilation where they also are included. http://www.omg.unb.ca/arctic-mapping/
University of New Hampshire, Center for Coastal and Ocean Mapping/Joint Hydrographic Center	**Multibeam bathymetry from U.S. Law of the Sea cruise to map the foot of the slope and 2500-m isobath of the US Arctic Ocean margin carried Center for Coastal and Ocean Mapping/Joint Hydrographic Center, University of New Hampshire**: https://ccom.unh.edu/theme/law-sea/arctic-ocean **HLY1603** [77] **HLY1202** [78] **HLY1102** [79] **HLY0905** [80] **HLY0805** [81] **HLY0703** [82] **HLY0302** [83,84] **HLY0405** [85] **HLY0503** [86]

	Bathymetry are in addition provided from the following expeditions with USCGC Healy through the Center for Coastal and Ocean Mapping/Joint Hydrographic Center, or retrieved from the IHO-DCDB: HLY0201, HLY0203, HLY0204, HLY0304, HLY0402, HLY0403, HLY0404, HLY0501, HLY0502, HLY0602, HLY0804, HLY0806, HLY0904, HLY1002
United States Geological Survey (USGS); National Geospatial-Intelligence Agency (NGA)	**Global Multi-resolution Terrain Elevation Data 2010 (GMTED2010)** https://www.usgs.gov/land-resources/eros/coastal-changes-and-impacts/gmted2010?qt-science_support_page_related_con=0#qt-science_support_page_related_con
US Navy	**Bathymetry from the Arctic region collected from US Navy nuclear submarines:** ***Single beam*** USS Topeka, 2012 USS New Hampshire, 2011 USS Connecticut, 2011 ***Single beam released in batches with no connection to specific submarine*** 1992-2000; 1985-1992; 1958-1985, 2001-2005 ***Single beam from the SCICEX program 1993-1998, and swath bathymetry from 1999*** SCICEX-93; USS Pargo SCICEX-95; USS Cavalla SCICEX-96; USS Pogy SCICEX-97; USS Archerfish SCICEX-98; USS Hawkbill SCICEX-99; USS Hawkbill (Swath bathymetry acquired with the SCAMP system, see main text) [87,88]
Woods Hole Oceanographic Institution (WHOI)	**Multibeam data from RV Knorr provided through WHOI Data Library and Archives:** **KN166-14, 2002, North Atlantic:** No publication found https://www.whoi.edu/

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Financial Report

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

Global Center

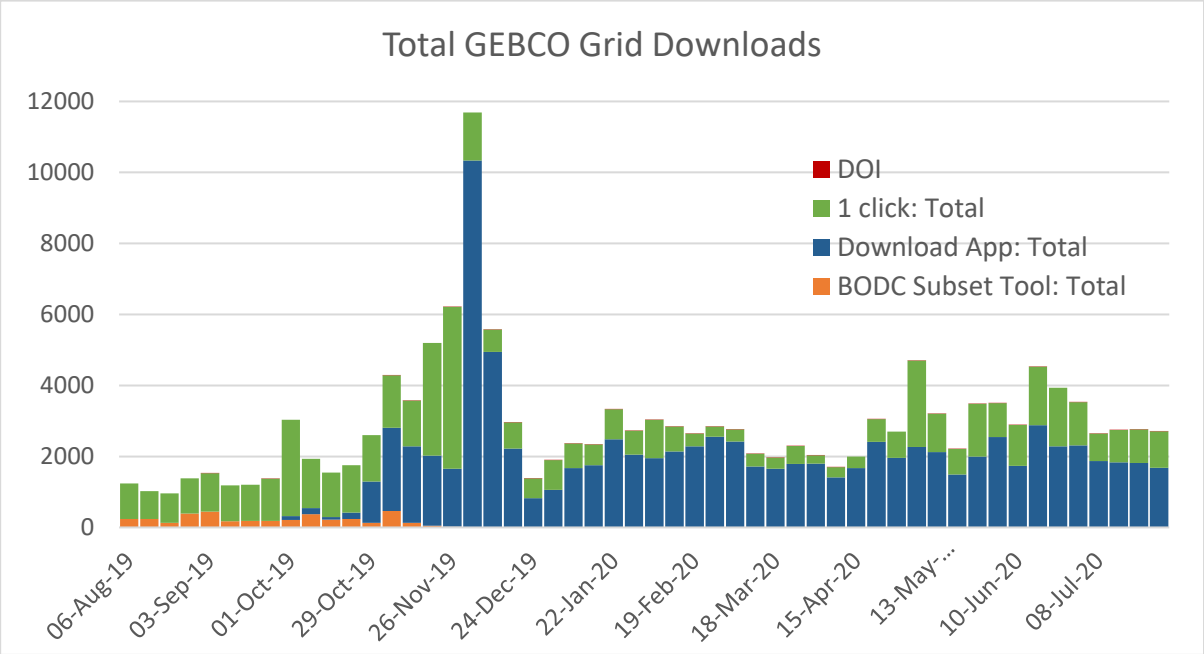
Location: British Oceanographic Data Centre, National Oceanography Centre, United Kingdom.

Center Lead: Helen Snaith.

Summary

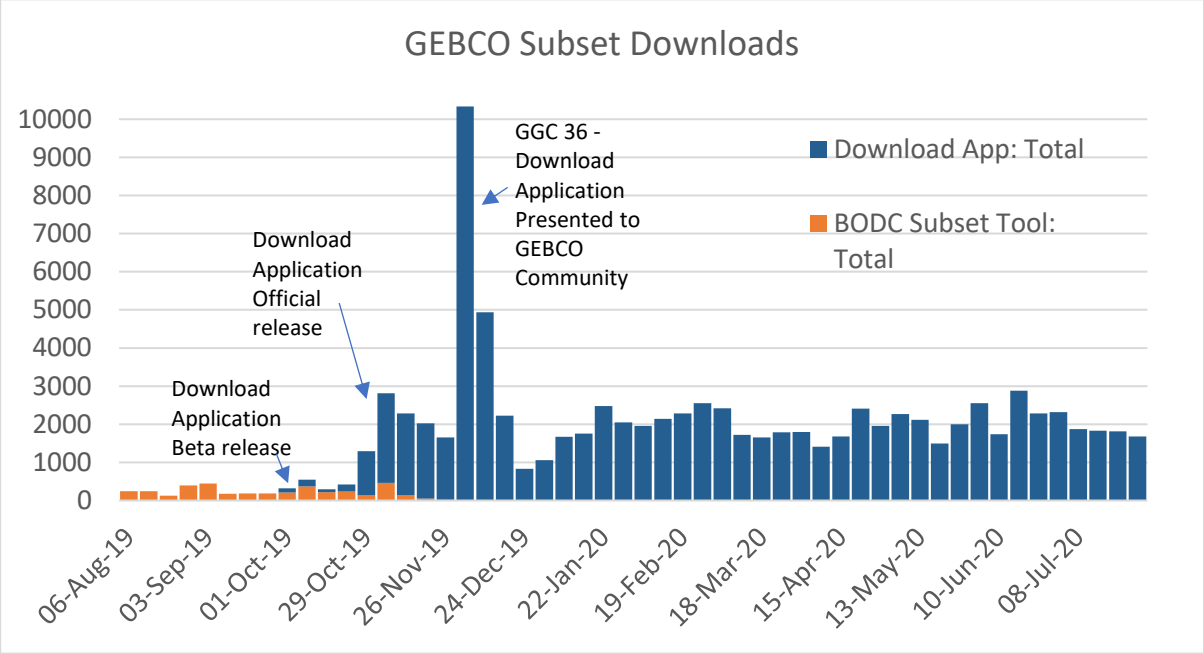
During Year 3 of the project, the Global Center has continued to focus on effective development and delivery of the global gridded products.

The final GEBCO_2020 global bathymetry grid and associated type identifier (TID) grid was released on 30th April 2020, based on the SRTM+ v2 base grid with regional center inputs merged to create the global products. The new dataset was allocated a new doi. The products are now available in a number of different format: 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. A delay of several weeks was caused by the Global Center staff transferring to home working and a necessary period of adjustment, due to the COVID-19 outbreak in March 2020.



Total Downloads of the GEBCO gridded products during Year 3. The number of global (1 click) downloads reduced significantly with introduction of the highly successful download application in November 2019

Introduction of the new data download service has seen a 10-fold increase in the number of subset download requests successfully fulfilled for the project, from an average of 230 (over Apr – Oct 2019) to 2350 (Nov 2019 – Apr 2020) per week.



Downloads through the GEBCO subsetting options: BODC Tool available until end of November 2019, Download Application final release 1 November 2019

The Seabed 2030 website 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

During Year 3, the decision was taken to change the base grid from SRTM v1 to the much enhanced SRTM v2. There were a number of interactions with the SRTM group, led by Prof David Sandwell at Scripps, to investigate alternative versions of the grid that might provide a better base, including investigating use of a 'predicted only' grid, with no high resolution observations integrated into the grid. However, the decision was that the published version of the grid provided the best option to act as a base grid, allowing additional observations, available to SRTM but not incorporated in the regional center datasets, to be represented.

Additional phases of testing and external validation of the global grid were included in the process for this second Seabed2030 release. A draft version of the grid was initially created by the Global Center in December for internal project review. Paul Johnson of CCOM provided an interactive viewer

(https://maps.ccom.unh.edu/portal/apps/webappviewer/index.html?id=c9b775645f4441c38cf9db7a3f43ccd5) that allowed the project technical team to identify and comment on particular issues in the grid to be improved before final grid release. During this initial assessment, it became clear that there were some specific artefacts being generated by the remove-restore method used to integrate the regional center sparse grids. This created an artificial oscillation around the observations. In order to both remove these fringe effects, and also to make it totally clear which grid cells represented actual observations, and which were from the underlying base grid, it was decided to use a simple 'paste' method. As a result, there are more unrealistic 'cliff edge' type effects in the 2020 grid that its predecessor, but these can be clearly identified as edge of survey effects.

A second draft of the release was created in early February and the review service was used to collect input from the technical team and also from the GEBCO Technical Sub Committee (TSCOM) members. This identified some remaining issued addressed in the final release.

Feedback from users of the 2019 NetCDF products indicated that the internally compressed NetCDF format was not generally easily integrated into many GIS applications, and a non-compressed version of the product was made available during the year. To further reduce the data volume transferred, the 2020 product was released using an integer format.

The final GEBCO_2020 global bathymetry grid was released on 30th April 2020, with a unique doi.

Development of the Type Identifier grid

One of the project developments in year 2 was a proposal to release a 'Type Identifier' (TID) grid, rather than a complete Source Identifier, to allow a simple recognition of the type of data used to generate a specific grid cell. During Year 3, in collaboration with GEBCO TSCOM, the exact definitions to be used were modified to allow classification and potential future new types to be added. The 2019 ID grid was re-released using these new classifications. The new classification was also used to generate the GEBCO_2020_TID grid, released along with the GEBCO_2020 grid on 30th April.

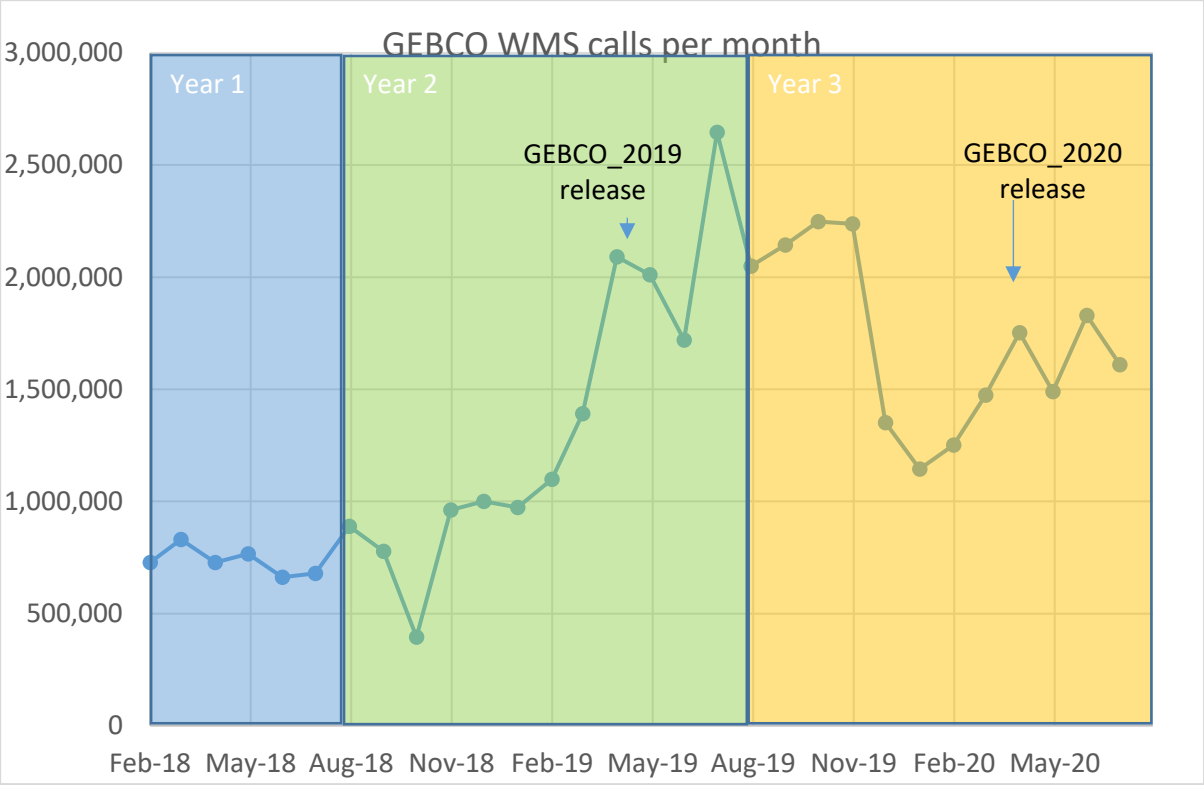
Data Distribution

The key enhancement to delivery of the GEBCO gridded products was the release of the GEBCO download app (download.gebco.net). Significant improvements to the beta version, released at the end of year 2, were made to the application and the service went live as the primary data delivery mechanism in November 2019 ahead of the GEBCO guiding committee meeting. Since the release, there has been a 10-fold increase in the number of download requests successfully fulfilled for the project. The service allows download of user-defined subsets of the current products (bathymetry and TID) in one of 3 formats – NetCDF, GeoTIFF or ESRI ASCII.

In response to user feedback, the global centre has also generated global tiled versions of the bathymetry and TID grids in GeoTIFF and ESRI ASCII format, each available as a single compressed data package. These were generated for the 2019 grid and made available on release for the 2020 grid.

The GEBCO_2019 WMS layer was released during year 3. The decision was taken to retain the existing WMS service and to add additional services for the 2019 application to ensure continuity of service for existing users.

The service has of the order or 2,000.000 'hits' per month.



Number of GEBCO Web Map Service (WMS) calls since the start of the Seabed2030 Project. Note the increased interest and number of hits as we approached the first Seabed2030 release. Figures have remained higher than pre Seabed 2030 levels

Financial report

Seabed 2030 will fund 1.6 FTE of the staff time in year 3 of operation. Additional contribution of at least 0.5FTE is anticipated by the end of the year, provided from central British Oceanographic Data Centre funds for year 3 of operations.

Other activities

Global Center staff 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 accounts and maintain the mailing lists for the project. 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.

We also maintain the internal project communications tools (email accounts, wiki and document repositories). The global centre staff also arrange, facilitate and report on the monthly project and technical team meetings. Support for this activity was provided by the temporary administrative support for the Director, based within BODC, until the end of September 2019. Since March 2020, the new Project Administrator post, also based within BODC, has provided additional support for meeting organisation and reporting.

Center staff have represented the Center, and the project, at a number of national and international meetings, including the OceanObs 2019 conference, September 2019. The head of the global centre was a co-convenor of a session at the World Ocean Council summit on sustainable development in Paris, Nov 2019.

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 allows for the ingest, discovery and access of CSB data.

The DCDB is happy to report the addition of two new bathymetry data managers that started in Fall 2020. Their duties include managing both new and backlogged bathymetry data (ingest, archive, public accessibility). The bathymetry team has also been working on developing a redesign of the entire end-to-end data pipeline that will ultimately allow for a much more flexible inclusion of data. The new pipeline should be in place by 2021. Over the last year, numerous enhancements were also made to the CSB pipeline and IHO DCDB webpage.

The main activities of Year 3 include:

- Crowdsourced bathymetry ingest pipelines were established with FarSounder Inc. and MacGregor Germany. MacGregor supplies Voyage Data Recorders to Carnival Cruise Line ships.
- Completed a significant overhaul of the IHO DCDB website (ngdc.noaa.gov/iho/). The site now describes how to contribute and accesses data much clearer and provides information on the IHO CSB effort and how to become involved.
- At the request of the IHO, the DCDB implemented a geographic filter that will filter out CSB data collected from the waters of all coastal countries that have not approved CSB activity.

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

- Released a modernized and much-improved GEBCO Undersea Feature Names Gazetteer (ngdc.noaa.gov/gazetteer/) in March 2020.

Data submission

The DCDB has archived over 8 TB (482 surveys, 16 sources) of new multibeam bathymetry data since August 2018. This includes:

- 153 surveys from 6 vessels contributed by CSU Monterey Bay Seafloor Mapping Lab
- 25 surveys from 6 vessels contributed by Fugro
- 1 survey from 1 vessel contributed by GEOMAR
- 23 surveys from 5 vessels contributed by Geological Survey of Ireland (GSI)
- 2 surveys from 1 vessel contributed by IFREMER
- 9 surveys from 1 vessel contributed by Institute of Environmental Physics, University Bremen
- 1 survey from 1 vessel contributed by Lamont-Doherty Earth Observatory
- 1 survey from 1 vessel contributed by MARUM
- 5 surveys from 1 vessel contributed by Marine Geoscience Data System (MGDS)
- 2 surveys from 1 vessel contributed by Max Planck Institute for Marine Microbiology, Bremen, Germany
- 31 surveys from 2 vessels contributed by NOAA Chesapeake Bay Office (NCBO)
- 8 surveys from 1 vessel contributed by NOAA Office of Ocean Exploration and Research (OER)
- 37 surveys from 3 vessels contributed by National Oceanic and Atmospheric Administration (NOAA)
- 173 surveys from 11 vessels contributed by the UNOLS Rolling Deck to Repository (R2R)
- 9 surveys from 1 vessel contributed by Swiss Polar Institute
- 2 surveys from 2 vessels contributed by University of South Florida College of Marine Science

Other activities

- As discussed at GGC-35, have begun the effort to draft the new IHO Circular Letter (to update the CL 23/1990) with regard to increasing roles and importance of the IHO DCDB in relation to the increasing ocean mapping, CSB and SB2030 activities. This letter will serve as a reminder to IHO Member States and stakeholders to provide their bathymetric data to the DCDB.

- Wrote letters to several IHO Regional Hydrographic Commissions stressing the importance of providing data to the DCDB (ARHC, MACHC, EAHC, SWPHC)

- As chair, led IHO Crowdsourced Bathymetry Working Group 8 (remotely) in October 2019.

- Georgie Zelenek, IHO DCDB data manager, attended the Seabed 2030 Arctic-Antarctic and North Pacific

Mapping Meeting in November 2019 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, will attend (virtually) the Seabed 2030 South & West Pacific Mapping Meeting in June 2019 and present 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 3 Work Plan is at Appendix 1.

Change to work plan due to reduced capacity

Work Package	Description
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

WP1: Data

Task 1.1. Publish Data Product – GEBCO 2020

D1.1.1 – GEBCO 2020 is published by 31st March 2020

Draft grids provided to technical team by end of December 2019, including use of the enhanced SRTM v2 base grid.

Issues with consistency in use of TID values and 'ripple' effect of remove method identified and work continued with the regional teams to rectify these.

Regional Centres re-submitted final grids by 20 Jan.

Global Centre investigated alternative methods of grid combination - a draft version of 'pasted' grid was produced for technical team review on 17th Jan 2020. This was agreed as the recommended way forward for producing the non-polar regions of the global grid.

Original timescale for 'soft release' of the grid was first week in April. Due to move to home-working as a result of the COVID-19 outbreak, the final stages of grid testing and documentation creation were delayed.

The Global bathymetric grid (GEBCO_2020) and TID (GEBCO_2020_TID) grid were released on 30th April, and made available through one-click download (NetCDF and tiles GeoTIFF), via DOI (NetCDF), and through the download app. Release of the ESRI ASCIIt tiles grids was delayed until 14 May due to an issue with file size.

The release also included:

Documentation - including data use agreement and information of grid generation process.

Data contributors page - providing details of data contributions in current release.

A data errata page to detail any errors notified for the 2019 release that have been corrected in the 2020 release, and any identified errors in the 2020 release yet to be rectified.

The Nippon Foundation requested a short delay in announcing the release of the Grid to allow suitable media coverage that was clear of other competing media coverage. Thus, notwithstanding the “soft release” in April, a media statement announced the “formal release” of the Grid to coincide with World Hydrography Day on 21 June 2020. Using the SU process to calculate statistics, coverage of 19% of ocean floor mapped was achieved. This is based on a multi-resolution computation and represents a healthy increase from the Year 2 figure of 15%.

Task 1.2 Publish Data Product – IBCAO 2019

D1.2.1 – IBCAO 2019 is published by 31st August 2019

The new published IBCAO Ver. 4.0 has been compiled as a part of the Seabed 2030 activities as it forms the Arctic-North Pacific regional centre's contribution to the GEBCO_2020 global grid. IBCAO 4.0 has more than twice the resolution compared to the previous Ver 3.0 released in 2012; the grid-cells size has been enhanced from 500´500 m to 200x200 m. Furthermore, individual depth soundings are now constraining three times more area of the Arctic Ocean (~19.8 % versus 6.7 %). Modern multibeam bathymetry now comprises ~14.3 % in Ver. 4.0 compared to ~5.4 % in Ver. 3.0. Thus, the new IBCAO Ver. 4.0 has substantially more seafloor morphological information that offers new insights into a range of submarine features and processes; for example, the improved portrayal of Greenland fjords better serves predictive modelling of the fate of the Greenland Ice Sheet. A data description article has been submitted to the Nature journal *Scientific Data*, which aims to highlight data sets of high importance.

Task 1.3 Publish Data Products – IBCSO V2 2019

D1.3.1 – IBCSO V2 2019 is published by 30th September 2019

Publication of IBCSO V2 is delayed.

Current status: workflow is established, data homogenisation is completed, data cleaning is ongoing.

Task 1.4 Secure data contributions from different communities

D1.4.1 – Increased data contributions from non-research communities

Whilst it has been a challenging year as a result of COVID impacts, data have been received from non-research sources Fugro, PGS and Caladan Oceanic (Five Deeps). More is anticipated from the *Two Oceans Two Technologies* transits programme. In addition to Crowd Sourced Bathymetry initiatives, there needs to be encouragement for governments to share data (as mentioned in the DCDB report above) and to find mutually acceptable ways of extracting gridded data from embargoed holdings from all sources.

WP2: System and tools

Task 2.1 Define the standards for data and metadata contributions

D2.1.1 – Version 1 of protocols for contributing data are published and used

A web form was designed and created to facilitate the submission of data to the project and is now in operation on our web pages

Task 2.2. Implement agreed process and formats for data contributions

D2.2.1 – Publish a Data Submission Process for external use

Progress has been slow and this work will be carried forward for completion in the early part of Year 4

Task 2.3 Implement agreed process and formats for data exchange between Seabed 2030 Centers

D2.3.1 – Seabed 2030 Centers are exchanging data to agreed process and formats

Agreed processes and formats remain an area for continuous improvement and the Project team will work alongside TSCOM to implement best practice.

Task 2.4 Develop the concept of the next generation GEBCO product

D2.4.1 – Prototype of next gen GEBCO product developed for evaluation by end of Year 3

A prototype tool for visualisation of multi-dimensional grids has been developed at CCOM but this is not deemed a suitable possible data storage / delivery mechanism.

Work on this deliverable will take place the late part of Year 3 and early part of Year 4.

Task 2.5 Enhanced data access and visualisation tools

D2.5.1 – Website provides user tools

The Beta download tool developed in year 2 was provided as a web-based application for testing by the Seabed 2030 technical team in August 2019.

The Beta service was then released publicly, including to the GEBCO Technical Sub-Committee, in September 2019, for external review.

Updates to UI were made in response to the feedback received.

This beta was made live in November 2019, ahead of the GEBCO Guiding committee meeting, and the legacy BODC download tool was retired.

Since the release of the new tool, there has been a 10-fold increase in the number requests for subsets of data (from 200 to 2000 per week).

Incremental improvements to data download tool continue to be made, including:

1 - direct access to the one click downloads from within the download app

2 - addition of precompiled tiles to provide global GeoTIFF and ESRO ASCII format one-click downloads

3 - changes to colour schemes to allow identification of gaps in the TID grid

4 - change to deliver 2020 grid through the download app

Task 2.6 Publish map of gaps and data coverage

D2.6.1 – Website contains interactive map of gaps

Currently investigating how to integrate existing services - primarily those already provided through DCDB - and not duplicate - or miss - any existing information.

Work carried out on developing metadata schema to allow capture of included, existing and planned data in conjunction with Metadata working group of TSCOM.

Test data in schema used for generating visualisation of gaps - in particular for data not yet available to complement visualisation of data already held in DCDB or regional centres.

TID grid visualisation on the download app allows ready determination of areas with no observations in the current grid.

WP3: Technology Innovation

Task 3.1. Establish a Seabed 2030 Technology Innovation strategy

D3.1.1 – A published Seabed 2030 Technology Innovation strategy document

This is work in progress.

Task 3.2 Technology innovation projects in support of Vision to Action 3 initiatives

D3.2.1 – Catalogue of data contributions through Map the Remote Gaps initiative

The *Ryder 2019* pilot project has delivered contributions in this Year. Plans are in place to leverage uncrewed technology, controlled over the horizon, as part of the *Two Oceans Two Technologies* transit activity in the early part of Year 4.

WP4: Map the Gaps

Task 4.1 Implement the Seabed 2030 Funding Strategy

D4.1.1 – increase in Seabed 2030 funding income

There has been effective liaison between the Project Team and members of the GEBCO ad hoc fund-raising group. There are significant costs associated with expanding ocean mapping initiatives to achieving our vision. The Nippon Foundation have noted that they are professionals within this funding field and if any donations were offered, these should come through The Nippon Foundation.

Task 4.2 Progress Mapping the Remote Gaps

D4.2.1 – Catalogue of data contributions through Map the Ryder initiative

The Nippon Foundation support dedicated to the *Mapping of Ocean Frontiers* pilot project helped facilitating continuous multibeam mapping with Swedish icebreaker *Oden* during the two transits between Helsingborg, southern Sweden, and Thule, northern Greenland, made in conjunction with the *Ryder 2019 Expedition*. Along these two transits, amounting in total to a length of 9700 km, multibeam bathymetry were collected continuously and the transit-routes were adjusted to fill gaps between existing sounding data. The *Ryder 2019* Expedition, officially designated by Explorers Club as "Flag Expedition #51, mapped in Nares Strait separating Greenland from Ellesmere Island, southern

Lincoln Sea and the previously uncharted Sherard Osborn Fjord in northern Greenland. The *Ryder 2019 Expedition* was carried out between August 5 and Sept 10, Thule-Thule. Prior to the *Ryder 2019* Expedition and following the transit from Helsingborg to Thule, *Oden* was chartered by the US National Science Foundation for a scientific expedition in the North West Passage, Arctic Canada. Also, during this expedition, multibeam operators were placed onboard *Oden* through the *Mapping of Ocean Frontiers* pilot project to ensure high quality data collection. This was facilitated through additional financial support from Center for Coastal and Ocean Mapping, University of New Hampshire, and Stockholm University. The work on a film about the *Ryder 2019 expedition* has begun and will be based on filming made during the expedition and specifically produced computer graphics and interviews.

Task 4.3 Progress crowdsourcing approach

D4.3.1 – Significant increase in crowd sourced data submissions

The IHO DCDB has archived over 10 GB (~250 million soundings) of crowdsourced bathymetry data from over 220 vessels. In the last year, two new data providers were added to the data pipeline: FarSounder Inc. and MacGregor Germany.

FarSounder designs and manufactures 3D Forward Looking Sonar (3D-FLS) and their clients, which include expeditionary cruise ships and private superyachts, use their system to safely explore exotic and poorly charted or uncharted areas. Program participants are given the option of submitting their singlebeam echosounder bathymetry data they also collect to the DCDB. Three vessels submitted nearly 3 million SBES soundings.

Macgregor Germany manufactures Voyage Data Recorders (VDR), devices that are mandated for effectively all ships on international voyages. By default, this device logs depth-sounding data for IMO mandated shipborne single beam devices. Carnival Cruise Line, a client of MaGregor's, agreed to participate in the IHO CSB initiative and since early 2020, have been contributing data from seven Carnival vessels.

Unfortunately, a large percentage of the data contributed had to be filtered and not made public. This was due to the results of IHO Circular Letter 11/2019, as described in IHO Circular Letter 47/2019, which listed the very few countries (14) that have confirmed the allowance of CSB activity within their waters under national jurisdiction. Until more governments agree to support this effort, the vast majority of contributed data will not be made available to the Seabed 2030 Project.

Task 4.4 Crowdsourcing projects in support of Vision to Action 3 initiatives

D4.4.1 – Catalogue of data contributions through Map the Remote Gaps initiative

Working closely with Jennifer Jencks (Director DCDB & Chair of IHO's CSB Working Group) and Brian Calder (UNH and CSB Working Group member), the Director has been in detailed discussion with organisations who are keen to collaborate with us in deploying data loggers to collect bathymetry in data in data sparse areas and to support us in spreading the Seabed 2030 message and the benefits of IHO CSB. Working around COVID-related supply-chain issues towards the end of Year 3, the Project procured and despatched data loggers. In-country contacts will ensure these are rolled out to a broad cross section of appropriate vessels in due course and, along with potential Alumni support, will assist us in harvesting collected data for submission to DCDB. Thus far we have support from:

- South Africa – National Hydrographic Office & Institute for Maritime Technology.
- Palau – Bureau of Marine Transportation.
- Greenland – Institute of Natural Resources. This is part of a more formal mapping project proposal that spans both the Ocean Frontier Mapping and Crown Sourced Bathymetry initiatives. An element of Year 4 funding has been identified for this. Fuller details are at Appendix 2.

Separately but related there has been engagement with the DARWIN 200 initiative (https://darwin200.com/) that will see a team of scientists embarked on *TS Pelican of London* undertake a 2-year voyage around the world beginning in 2021 that will re-trace Charles Darwin's famous journey whilst undertaking a variety of research projects. A data logger was provided for trials and training purposes during the 2020 UK launch voyage. The global circumnavigation in 2021 will provide an opportunity for some meaningful CSB data gathering whilst also spreading the wider Seabed 2030 message.

Task 4.5 Mapping Ocean Frontiers projects in support of Vision to Action 3 initiatives

D4.5.1 – Catalogue of data contributions through Map the Remote Gaps initiative

In addition to the *Ryder 2019* expedition reported at D4.2.1 above, there has been extensive discussions with The Nippon Foundation on how to should establish a process for, and progress work on, Ocean Frontier Mapping. A sum of $2M, representing, 50% of the XPrize winnings, has been reserved by The Nippon Foundation to assist in further establishing this crucial work and will be available from August 2030 subject to submission of periodic bids for allocation to:

- Fund dedicated mapping days for already scheduled expeditions in remote and poorly mapped ocean areas.

and/or

- Leverage the skills of the alumni from The Nippon Foundation-GEBCO training program to provide experienced echosounder operators will also assist expeditions to ensure that vital mapping data are collected at all times, including during transit

An Ocean Frontier Mapping Committee has been established and its inaugural meeting is scheduled for September 2020. Its remit is to make informed choices for funding eligible missions delivering mapping days in Ocean Frontiers gaps against broad criteria for mission selection. Voting members are the Director (Chair), Project Center Heads and 2 External Advisers: Jyotika Virmani (Schmidt Ocean Institute) and Denis Hains (H2i). More details are at Appendix 3a.

Following new direction on processes from the Nippon Foundation, a short notice bid was submitted in early July to secure the first batch of funding. This focused on a provisional selection of scheduled missions known to us at the time but with the caveat that adjustments would be necessary as research and philanthropic operators readjusted to operational challenges of the COVID era. Details are at Appendices 3b and 3c.

A quick win here is the *Two Oceans Two Technologies* transits programme that aims to leverage ocean mapping from 2 wider marine science programmes: one in the Atlantic and one in the Pacific. Seabed 2030 participation in these missions presents a unique and valuable opportunity for us to leverage new technology; to access new data; and to support the professional development of The GEBCO-Nippon Foundation. The scheduled missions are:

- The European Space Agency (ESA) led Unmanned Trans-Atlantic Survey (UTAS), using the XPrize-winning SEAKIT vehicle, *USV Maxlimer*. The overall mission, funded externally, is to achieve final proof of concept for the USV technology whilst gathering invaluable ocean data. Scheduled for operations in August 2020, Seabed 2030's focus is to use our alumni expertise to remotely operate the USV's multibeam sonar system to gather and process bathymetry.

- Part of the US National Oceanographic Partnership Program (NOPP) funded scientific research mission will see use of a 22m long SAILDRONE unmanned surface vehicle (USV) to gather global ocean data. Seabed 2030's involvement here is to achieve additional dedicated mapping days in the Pacific Ocean, between the west coast of continental USA and Hawaii. This work was scheduled for October 2020 but will occur now in early 2021.

WP5 Management

WP5.1 Operational Management

Task 5.1.1 Secure Year 4 funding

D5.1.1 – Year 4 Work Plan and budget approved.

Based on a draft Work Plan, pending GGC ratification, and budget submission, The Nippon Foundation has allocated the Year 4 Grant. See Appendices 4a, 4b, 4c and 4d.

Task 5.1.2 Year 3 Financial Management

D5.1.2 – Year 3 finance ledger is accurate and Project run to budget.

Work was undertaken to reconcile Year 1 and Year 2 finances. The grants for these years were $1,030,500.00 and $1,255,000.00 respectively giving a combined total of $2,285,500. It was determined that the surplus of unspent funds was $164,989. We are awaiting instructions from The Nippon Foundation as to retention or remittance of these unspent funds. See Appendix 11.

A grant of $2,346,170 was provided for Year 3. Expenditure, used solely for the purpose of carrying out the Project, was $2,309,639. This has resulted in a surplus of unspent funds of $36,531. Discussions are ongoing with The Nippon Foundation on the revised format for the financial report and on audit requirements. See Appendix 12.

Task 5.1.3 Annual Project Reporting to GGC

D5.1.3 – Year 3 Annual Report submitted to GGC.

On track for submission at the next meeting of GGC.

Task 5.1.4 Quarterly Project Reporting to GGC

D5.1.4 – Status reports submitted to GGC

No formal quarterly reports have been submitted.

Task 5.1.5 Project Reporting to Sponsors

D5.1.5 – Sponsors meetings held as required (completed)

Notwithstanding the informal gathering of the Sponsors at the Vision to Action event in October 2019, scheduling a more formal meeting in Year 3 has not been possible. One has been scheduled for the early part of Year 4.

Task 5.1.6 Engage with the GEBCO community

D5.1.6 – Diary of Year 3 engagement demonstrating GEBCO contribution to Seabed 2030

The GEBCO community and Sub-Committees were engaged extensively during Year 3, through the GEBCO Guiding Committee Meeting (GG36) and at several additional points throughout the year. A diary of engagement with the GEBCO community is maintained and stored on the Project's internal Wiki site. Activities undertaken during Year 3 included participation in an online SCRUM meeting and an intersessional GGC meeting, the aim of which was to develop a virtual communication strategy for the COVID-19 era.

Details of GEBCO activities and events have been consolidated those other activities and events at Task D5.3.2 and listed at Appendix 10.

Task 5.1.7 Recruit a Project Administrator.

D5.1.7 – Recruit a Project Administrator (completed)

Following an open recruitment campaign by the National Oceanography Centre in late 2019/early 2020, the full time Project Administrator was in place by March 2020. The incumbent is providing significant support to the Director and the wider Project team.

Task 5.1.8 Convene the Seabed 2030 Strategic Advisory Group

D5.1.8 – Convene the Seabed 2030 Strategic Advisory Group

Creation of the Strategic Advisory Group (SAG) was previously placed on hold due to capacity issues and pending the arrival of the new Director. SAG has now been constituted and its members are:

- Dawn Wright (ESRI)
- Bjorn Jalving (Kongsberg)
- Yulia Zarayskaya (Russian Academy of Science Geological Institute)

- Kilaparti Ramakrishna (Green Climate Fund)
- Denis Hains (H2i)

COVID-19 challenges precluded a meeting in person and other commitments meant that the inaugural meeting of SAG was scheduled for 4 August 2020 with plans in place for quarterly virtual meetings thereafter whilst SAG learn the wider business of Seabed 2030.

Task 5.1.9 Convene the Seabed 2030 Review Panel

D5.1.9 – Convene the Seabed 2030 Review Panel (completed)

The Review Panel was not convened in Year 3.

WP5.2 Strategy

Task 5.2.1 Engage with users of GEBCO products

D5.2.1 – GEBCO product users are active in Seabed 2030

The GEBCO products have had more than 149,221 downloads between August 2019 and July 2020.

Since release of the 2019 grid, user registration is not required, however there is provision of a link for feedback on the data.

During 2019, 80 separate enquiries were dealt with, and during 2020 (to end September) 39. Much of the reduction in enquires has been due to the introduction of the new download tool which has been far more reliable and there has been fewer enquires regarding being unable to access subsets of the data.

Some enquiries relate to users with specific use cases requesting imagery or data in specific formats in support of their projects. As a result of these development is underway for a KML image download option from the download application alongside the Web Map Service that already delivers a range of image formats. Also, interesting use cases are being collated for follow up.

Notwithstanding COVID restrictions, outreach has been satisfactory and there has been engagement of supporters, contributors and users alike across a range of fora and sectors including intergovernmental, governmental, academic and industry including associations and societies.

Following encouragement by The Nippon Foundation, “Use Case” work was commissioned. Named the *Wind in the Sails* study, the first phase of this activity was to conduct:

A Rapid Evidence Review to collate as many reports or plans as possible across the globe that articulate the areas of greatest need in relation to unmapped areas of the seabed. Also, to catalogue any models used to help quantify the values / benefits of such planned exercises. While much of this information will be open source, it has not to date been collated into one single source of truth of global seabed needs.

An Online survey to supplement the open-source Rapid Evidence Review, an online proforma or survey was issued and promoted to the global hydrographic / ocean community, asking for input into what stakeholders feel are the most pressing areas of interest for seabed mapping and why.

Collation and analysis of data. Both data sets combined and interrogated.

The *Wind in the Sails* Phase 1 Report is at Appendix 5. To note Annex D, containing personal information of respondents has been omitted to comply with GDPR legislation.

The output of this work was delivered at Year end and findings are being assessed. However it is worthy of note that:

- There were 366 responses across 65 countries.
- There was overwhelming support and recognition that the world's oceans need to be mapped and praise for The Nippon Foundation-GEBCO-Seabed 2030 initiative.
- There was comprehensive evidence, showing the need for geospatial data across every maritime sector in the marine domain. Demands were of an equal footing across governments, industry and academia/science.
- There is clear evidence that creating an appropriate crowdsourcing tool/map would enable easier data gathering (by non-specialists in ocean mapping).
- Current survey/environmental strategies and initiatives may not be using a coordinated approach.
- Some 27% of respondents have, or will have data to contribute to Seabed 2030. This will be followed up in the next phase of activity.

Task 5.2.2 Solicit external strategic input

D5.2.2 – Strategy of Seabed 2030 is improved by input of 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 is acknowledged as a key global initiative

A majority audience recognises the global importance of the Seabed 2030 project. Strong media coverage, not least around the 2020 Grid release, and the support of a large number of interlocutors has greatly assisted in spreading the message. The Project is seen as a contributor to UN SDG14, supporting UN GGIM and a fundamental geospatial project the output of which support a diverse community across many sectors of society. Also, it complements the UN Decade of Ocean Science (DOS) where it has a key role to play. DOS is already promoting Seabed 2030 as the primary mechanism to achieve a wholly mapped ocean: this is important to achieving Decade goals & objectives including the Scientific Priority of a "comprehensive digital atlas of the ocean".

Task 5.2.4 Build strong partnerships

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

Currently are some 140 organisations that pledge support to Seabed 2030 in some way. Further details are at Appendix 6. Groups are defined these 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.

In the Year 2 Report the Project reported 4 formal MOUs in place with 4 more in progress. At the end of Year 3, some 8 formal MOUs were in place including a Software Sponsorship Agreement (a MOU to all intents). Two further MOUs were at an advanced stage ready for signature in August and September 2020 respectively (Year 3) and a further 4 MOUs are in progress.

WP5.3 Comms and outreach

As detailed under the items below, there has been a significant push on media activity. The external media team, Raitt Orr, has continued to provide strong media and communication support through Year 3. Raitt Orr have worked tirelessly to identify and cultivate effective media opportunities and create high quality media content for Seabed 2030. A Media Strategy has been prepared and is at Appendix 7 – please note that this is sensitive to the Project and not for wider distribution outside the GGC/Seabed 2030 community. The newly established Communications Group has also been proactive across this area; and there has been good external communications coverage whilst also introducing the first e-newsletter, *In-depth* (see Appendix 8). Separately but related the Use Case survey has been a worthwhile channel in raising awareness of Seabed 2030 across a wider of community of organisations and individuals that use geospatial data.

Task 5.3.0 Publish Seabed 2030 Brand Guidelines – the colors and fonts to be used in all material

D5.3.0 – Publish Seabed 2030 Brand Guidelines

Following development work and internal negotiations, the Seabed 2030 logo was launched in June 2020. This has been rolled out across our media work. Separately but related a draft Brand Guidelines document is being prepared for internal circulation before publishing the final version in the early part of Year 4.

Task 5.3.1 Publish media content (news articles, press releases)

D5.3.1 – Catalogue of content

Raitt Orr, the external media team, promote and track media articles that relate to the Seabed 2030 Project. Over the course of Year 3, some 320 articles have been published and are tracked and catalogued at Appendix 9 (also see under D5.3.3.).

Task 5.3.2 Promote Seabed 2030 at external events and meetings

D5.3.2 – Catalogue of events and meetings attended

COVID-19 has provided a challenge for the majority of live meetings planned in the latter half of Year 3. A number of these, including the World Ocean Summit (scheduled for March 2020 in Tokyo), were cancelled or postponed indefinitely. However, following an "operational pause" by many event organisers, there was a shift in emphasis to scheduling virtual meetings. A list of events attended, and presentations made, is at Appendix 10. This also includes details of engagement demonstrating GEBCO contribution to Seabed 2030 (Task D5.1.6).

Task 5.3.3 Promote Seabed 2030 through the website and social media

D5.3.3 – New content is published on website

The existing website, content management tools and hosting arrangements are obsolescent. NOC is undertaking a process to shift its family of websites, of which the Seabed 2030 site is part, to an externally hosted Drupal framework. Work is due to complete in October 2020. In parallel our external Media Team and Vicki Ferrini are working with the NOC team to revamp the look and feel of the Seabed 2030 to make it more contemporary, appealing to a wider audience, and easier to use. Key to this will be generating informative and engaging content for not only the website but also social media channels as part of the wider Seabed 2030 Media Strategy to which the Team are beginning to work (within defined funding limits).

In the meantime, having worked around the challenges of giving the new Project Administrator access to the existing Seabed 2030 website, routine site updates are maintained in anticipation of the new service launch in October 2020.

A Communications Team has been formed from Project Team members and representatives from Raitt Orr (our external media team), GEBCO and The Nippon Foundation. The team's remit is to strengthen links and communications expertise with the international news media that will enable swift and accurate responses to media enquiries and questions, but with the technical knowledge and facts that such requests often require. Raitt Orr actively seek out new opportunities for positive publicity, as well as dealing with all other media enquiries and media releases, both press and broadcast. The Group has overseen the introduction of the Seabed 2030 newsletter, *In Depth*, which has received positive feedback an informative publication for many of those interested in Seabed 2030 work but not close to the day to day running of the Project. The Group has also worked on a number of articles and press releases, not least the one heralding the launch of the GEBCO 2020 Grid on 21 June 2020 (World Hydrography Day) which was rebroadcast extensively around the world in varying forms. This also was the basis for the high-profile article by the BBC and also a piece by Reuters. These are reported in Appendix 9 as part of the 320 media articles referring to Seabed 2030 during the course of Year 3.

Very recently (end of July) a shared photo resource was established to archive suitable images and associated "editorial & use metadata" that will allow a ready supply of suitable images for media requests and our own articles. There has been engagement with the Chair of SCOPE on this and database population is ongoing but more contributions for across our community are needed.

Task 5.3.4 Acknowledge partner contributions

D5.3.4 – Seabed 2030 website

The existing website, content management tools and hosting arrangements are obsolescent. NOC is undertaking a process to shift its family of websites, of which Seabed 2030 is part, to an externally hosted Drupal framework. Work is due to complete in October 2020. In parallel our Media Team and Vicki Ferrini are working with the NOC team to revamp the look and feel of the Seabed 2030 to make it more contemporary, appealing to a wider audience, and easier to use. Key to this will; generating informative and engaging content.

Currently there is have a page highlighting those partner organisations with whom Seabed 2030 has a signed MOU. As part of the wider development work there will be an assessment of how contributions are acknowledged in a way that is fully inclusive regardless of volume or frequency of contribution – on the principle that every contribution is important to the Project.

Task 5.3.5 Hold Seabed 2030 meetings

D5.3.5 – Royal Society event is a success (completed)

The Vision to Action (V2A) event focusing on the future of Seabed 2030 was held at the Royal Society in London in the afternoon of 22 October 2019.

The main event was proceeded by a morning session to bring together a network for technology and innovation in ocean mapping and data processing; and had around 35 attendees from research institutions, industry, government, intergovernmental organisations The Seabed 2030 team and the GEBCO community.

With around 90 people attendees (from the same sectors as above), V2A began with an address by the Japanese Ambassador in the UK and a welcome by the Vice President of the Royal Society. Thereafter the Chairman of the Nippon Foundation, Mr Yohei Sasakawa, in his opening remarks launched the 3 Initiatives for further cooperation to accelerate ocean mapping: Ocean Frontier Mapping, Crowd Sourced Bathymetry and Technical Innovation. A keynote speech was given by the Director of Coast Survey, NOAA that provided context for other speakers from GEBCO, the Seabed 2030 team, the IHO (Secretary General) and IOC (Executive Secretary). The new Director designate, Jamie McMichael-Phillips was introduced and the forum also provides an appropriate environment for signature of a MOU between Seabed 2030 and the Schmidt Ocean Institute.

Despite the challenges around the timing of the event (UK amidst Brexit negotiations), the Media Team worked hard to achieve a good level of interest. In addition, the event sparked further engagement with attendees through the course of Year 3.

WP5.4 Capacity Development

Task 5.4.1 Develop how to involve GEBCO-NF alumni in Seabed 2030

D5.4.1 – Document: A Strategy for GEBCO-NF alumni contribution to Seabed 2030

Seabed 2030 continues to seek opportunities for capacity development and a greater engagement of GEBCO-Nippon Foundation Alumni in the project. Some already work at the Centers, others have undertaken working acquaint visits whilst others have been engaged in data gathering at sea, for example with the Five Deeps mission. In the final month of this funding year, a group of 12 alumni were planning for the Atlantic component of the *Two Oceans Two Technologies* transits, part of our Ocean Frontier Mapping initiative, that began in earnest in August 2020.

There have been extensive discussions between the Director and The Nippon Foundation on the wider engagement of alumni in activities that support Seabed 2030 with the result that funds are available to employ a full time Alumni Coordinator within the Project. The intention is for the postholder to formulate and delivering a comprehensive Alumni Engagement & Development Plan (AEDP) that utilizes the skills

and experience of members of the Alumni to support a wide range of Seabed 2030 activities; whilst also providing individual and collective development opportunities across a broad spectrum of ocean mapping and technological innovation. It is anticipated that the recruitment process will begin in October 2020.