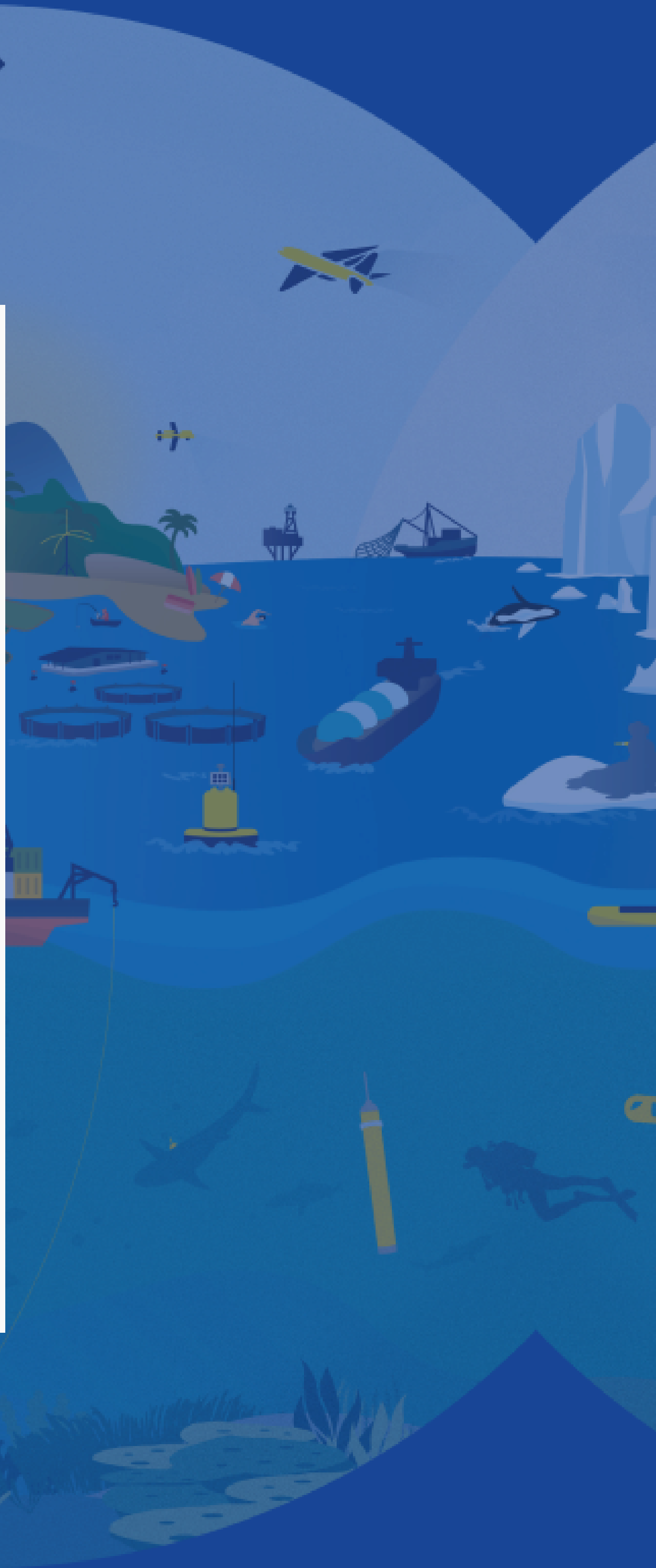
MEETING REPORT

Global Ocean Observing System



Eighteenth session of the IOC Group of Experts on the Global Sea Level Observing System (GLOSS)

Final Report

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ABSTRACT

This report presents a summary of the topics discussed at the Eighteenth Session of the Group of Experts for the Global Sea Level Observing System (GLOSS-GE). The Group of Experts evaluated the status of the GLOSS network and programmatic activities since the last meeting of the group in 2022 (GE-GLOSS-XVII) and discussed future developments, including the updating of the GLOSS Implementation Plan, 2012.

The Group reviewed reports of the GLOSS Data Centres and established new Working Groups and Task Teams. It tasked the GLOSS-GE Steering Committee to develop a new Implementation Plan.

Several regional and national reports were presented and reviewed. Finally, the Group reviewed present links between GLOSS and other relevant programmes and identified its own intersessional activities for 2025–2027.

Since its inception in 1988, GLOSS has provided oversight and coordination for the global and regional sea level network in support of scientific research and early warning systems. This also includes the study of vertical ground motion near tide gauges through baseline monitoring and continuous GNSS measurements.

***Note**: this report is published in electronic copy only and is available on UNESDOC, the documents database of UNESCO (http://unesdoc.unesco.org)*

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1. Executive Summary / Resumen Ejecutivo / Résumé exécutif

The Eighteenth Meeting of the Group of Experts on the Global Sea Level Observing System (GLOSS-GE) was held at the Radisson Panama Canal Hotel in Panama from March 11 to 14, 2025, with the support of the Panama Canal Authority and the Panama Maritime Authority.

More than 40 in-person experts and approximately 15 online participants from 30 Member States attended the meeting (Argentina, Belgium, Chile, Colombia, Costa Rica, Cuba, Denmark, Dominican Republic, Ecuador, Egypt, France, Germany, Guatemala, India, Ireland, Japan, Mauritius, Morocco, Nicaragua, Norway, Panama, Peru, Qatar, the Russian Federation, South Korea, Spain, the United Kingdom, the United States, Uruguay and Venezuela). Most of these countries representatives presented their national activities, including relevant updates and challenges of sea level measurements and applications in their countries.

The Group approved the continuation or establishment of three thematic Working Groups (WG) to support GLOSS strategic objectives: WG on Sea Level Data Archaeology; a WG on Sensor performance and emerging technologies and a WG on Quality Control, Data Processing and Data Management.

The Group reviewed the status of GLOSS manuals and best practices and identified new topics to be addressed such as tidal analysis or levelling.

The Group also reviewed updates by the GLOSS Data Centers including the University of Hawaii Sea Level Center (UHSLC), the IOC Sea Level Station Monitoring Facility (SLSMF) hosted by the Flanders Marine Institute (VLIZ), the Permanent Service for Mean Sea Level (PSMSL) hosted by the UK's National Oceanography Centre (NOC) and the Système d'Observation du Niveau des Eaux Littorales (SONEL) hosted by University of La Rochelle, France. .

The Group further reviewed existing links between GLOSS and other relevant programmes **and identified** its intersessional activities for 2025–2027, including the urgent need for a new implementation plan and a review of the GLOSS Terms of Reference.

The Group elected Dr (Ms) Begoña Pérez Gómez (Spain) as the new chair of GLOSS-GE.

Resumen Ejecutivo

La decimoctava reunión del Grupo de Expertos sobre el Sistema Global de Observación del Nivel del Mar (GLOSS-GE) se celebró en el Hotel Radisson Panama Canal, en Panamá, del 11 al 14 de marzo de 2025, con el apoyo de la Autoridad del Canal de Panamá y la Autoridad Marítima de Panamá.

Más de 40 expertos presenciales y aproximadamente 15 participantes en línea de 30 Estados Miembros asistieron a la reunión (Argentina, Bélgica, Chile, Colombia, Costa Rica, Cuba, Dinamarca, República Dominicana, Ecuador, Egipto, Francia, Alemania, Guatemala, India, Irlanda, Japón, Mauricio, Marruecos, Nicaragua, Noruega, Panamá, Perú, Qatar, la Federación de Rusia, Corea del Sur, España, el Reino Unido, los Estados Unidos, Uruguay y Venezuela). La mayoría de los representantes de estos países presentaron sus actividades nacionales, incluidas actualizaciones relevantes y desafíos en la medición del nivel del mar y sus aplicaciones en sus respectivos países.

El Grupo aprobó la continuación o el establecimiento de tres Grupos de Trabajo (GT) temáticos para apoyar los objetivos estratégicos de GLOSS: un GT sobre Arqueología de Datos del Nivel del Mar; un GT sobre rendimiento de sensores y tecnologías emergentes; y un GT sobre Control de Calidad, Procesamiento y Gestión de Datos.

El Grupo revisó el estado de los manuales y buenas prácticas de GLOSS **e identificó** nuevos temas a abordar, como el análisis de mareas o la nivelación.

El Grupo también revisó las actualizaciones de los Centros de Datos de GLOSS, incluidos el University of Hawaii Sea Level Center (UHSLC), la instalación IOC Sea Level Station Monitoring Facility (SLSMF) alojada por el Instituto Marino de Flandes (VLIZ), el Permanent Service for Mean Sea Level (PSMSL) alojado por el National Oceanography Centre (NOC) del Reino Unido, y el Sistema de Observación del Nivel de las Aguas Litorales (SONEL) alojado por la Universidad de La Rochelle, Francia.

El Grupo examinó además los vínculos existentes entre GLOSS y otros programas pertinentes, **e identificó** sus actividades intersesionales para 2025–2027, incluida la necesidad urgente de un nuevo plan de implementación y una revisión de los Términos de Referencia de GLOSS.

El Grupo eligió a la Dra. (Sra.) Begoña Pérez Gómez (España) como nueva presidenta del GLOSS-GE.
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Résumé exécutif

La dix-huitième réunion du Groupe d’Experts sur le Système Mondial d’Observation du Niveau de la Mer (GLOSS-GE) s’est tenue à l’hôtel Radisson Panama Canal, au Panama, du 11 au 14 mars 2025, avec le soutien de l’Autorité du Canal de Panama et de l’Autorité Maritime du Panama.

Plus de 40 experts présents sur site et environ 15 participants en ligne provenant de 30 États membres ont assisté à la réunion (Argentine, Belgique, Chili, Colombie, Costa Rica, Cuba, Danemark, République dominicaine, Équateur, Égypte, France, Allemagne, Guatemala, Inde, Irlande, Japon, Maurice, Maroc, Nicaragua, Norvège, Panama, Pérou, Qatar, Fédération de Russie, Corée du Sud, Espagne, Royaume-Uni, États-Unis, Uruguay et Venezuela). La plupart des représentants de ces pays ont présenté leurs activités nationales, y compris les mises à jour pertinentes et les défis liés aux mesures du niveau de la mer et à leurs applications dans leurs pays.

Le Groupe a approuvé la poursuite ou la création de trois groupes de travail thématiques (GT) afin de soutenir les objectifs stratégiques de GLOSS : un GT sur l’archéologie des données du niveau de la mer ; un GT sur la performance des capteurs et les technologies émergentes ; et un GT sur le contrôle qualité, le traitement des données et la gestion des données.

Le Groupe a examiné l’état des manuels et des bonnes pratiques GLOSS et **a identifié** de nouveaux sujets à aborder, tels que l’analyse des marées ou le nivellement.

Le Groupe a également examiné les mises à jour fournies par les Centres de Données GLOSS, notamment le University of Hawaii Sea Level Center (UHSLC), le IOC Sea Level Station Monitoring Facility (SLSMF) hébergé par l’Institut Marin de Flandre (VLIZ), le Permanent Service for Mean Sea Level (PSMSL) hébergé par le National Oceanography Centre (NOC) du Royaume-Uni, et le Système d’Observation du Niveau des Eaux Littorales (SONEL) hébergé par l’Université de La Rochelle, en France.

Le Groupe a également examiné les liens existants entre GLOSS et d’autres programmes pertinents **et a identifié** ses activités intersessions pour 2025–2027, y compris la nécessité urgente d’un nouveau plan de mise en œuvre et d’une révision des Termes de Référence de GLOSS.

Le Groupe a élu la Dr (Mme) Begoña Pérez Gómez (Espagne) comme nouvelle présidente du GLOSS-GE.

1. ORGANIZATION OF THE SESSION

1.1 OPENING OF THE SESSION

1. The Eigthteen session of the Global Sea Level Observing System Group of Experts (GLOSS-GE) was opened by Eng. (Mr.) Arnulfo Sanchez, Chief of Environment Division, Panama Maritime Authority. He emphasized the importance of sea level monitoring for operational maritime activities as well as for long term studies on sea level variability and maritime planning. He welcomed all participants on behalf of the Government of Panama and declared the session open.

2. The Chairperson, Dr Gary Mitchum sent a video-recorded message expressesing gratitude to Panama for hosting the meeting and apologized for not attending due to last-minute unforeseen circumstances. He noted that a key agenda item is the election of the new GLOSS chair. Dr Mitchum informed that only one nomination was received—from Spain's Dr Begoña Pérez Gómez, a seasoned expert in tide gauges and sea level. Dr Mitchum strongly endorsed her candidature and handed over the floor over to her, wishing everyone a successful and enjoyable meeting.

3. The meeting began therefore with the election by acclamation of Dr (Ms) Begoña Pérez Gómez (Spain) as the new chair of GLOSS-GE for a 2-year renewable term, as per IOC Rules of Procedure. After her acceptance speech highlighting the importance of sea level monitoring and thanking previous chair Dr Gary Mitchum, the meeting continued with a round of introductions from the 55 participants (40 on-site and 15 online), representing various oceanographic institutions and national tide gauge networks from around the world.

1.2 PRACTICAL ARRANGEMENTS

4. The Technical Secretary, Mr Bernardo Aliaga Rossel, provided an overview of logistic details for the meeting. The meeting included a visit to the Panama Canal Visitor Center at the Atlantic entrance. All documents and presentations delivered at this meeting are available from the following website: https://oceanexpert.org/event/4663 .

1.3 ADOPTION OF THE AGENDA AND TIMETABLE

5. The agenda was adopted as given in Annex I, available also as Annex I of Circular Letter 3022.

2. REVIEW OF PROGRESS ON ACTIONS FROM GE-XVII

2.1 REVIEW OF GLOSS MANUALS

6. The group discussed the review of GLOSS manuals and best practices.

7. Andrew Matthews (PSMSL) presented the history of GLOSS manuals from the 1980s to the most recent 2016 version covering radar sensors (*Manual on Sea-level Measurements and Interpretation, Volume V: Radar Gauges*. IOC Manuals and Guides No.14, vol. V) and quality control (*Quality Control of in situ Sea Level Observations: A Review and Progress towards Automated Quality Control*, Vol. 1. IOC Manuals and Guides No.83).

The group identified several needs in terms of manuals and best practices: updating manuals for new technologies like Artificial Intelligence (AI) in quality control, addressing data archaeology processes, handling ancillary meteorological measurements at tide gauges (Li Wenshan, China), and potentially developing unified software tools for data processing (Julio Castro, Chile). Fernando Oreiro (Argentina) suggested creating a common software repository, while Phil Thompson (University of Hawai Sea Level Center, UHSLC) noted that meteorological best practices should be left to WMO. Professor Hamouda (Egypt) emphasized the need for standardized equipment documentation and evaluation of existing infrastructure, particularly in developing countries. The group also discussed the need for guidelines on data management and distribution, including improved communication with national providers regarding the procedures being followed by GLOSS data portals. There was a general agreement on the need to identify and propose new manuals to be developed, and include reference to all existing ones in the new implementation plan. A separate working group was proposed to address quality control and data processing. The conversation ended with an update on the work on IOC best practices that has been under development.

8. **The group agreed** to address these needs in different working groups, maintaining the existing Data Archaeology Working Group, and forming two additional working groups: one on sensors performance and emerging technologies (including GNSS-IR), and another on quality control, data processing and data management.

2.2 IAPSO CMSLT BEST PRACTICES

9. Mr Andrew Matthews (PSMSL) updated the group with a presentation on IAPSO's initiative to create best practice guidelines for tidal analysis,. He noted that a meeting funded by IAPSO was held in late 2023 when the group produced initial documentation including recommended constituent sets for different data lengths and a list of available software packages. The document covers practical challenges such as overfitting, analyzing shallow estuaries, and dealing with nodal cycles. The group seeks additional contributions on topics including satellite data analysis, non-classic. Marta Marcos (Spain) pointed to the need to consider non-stationary tidal analsyis in rivers. The group seeks additional contributions on topics including satellite data analysis, non-classical analysis techniques, AI methods, and examples of challenging tidal records to analyze. GLOSS GE members are invited to send their contributions and examples by e-mail (antt@noc.ac.uk). When completed, the guidelines will be submitted to the International Oceanographic Commission's best practice system (https://www.oceanbestpractices.org/).

2.3 DATA ARCHEOLOGY

10. Mr Laurent Testut (France) presented on the The GLOSS Data Archaeology Working Group (DAWG) which was officially created in November 2022 during GLOSS XVII in Paris. Its mission is to rescue and preserve historical sea level data, including digitizing old tidal charts and ledgers. Mr Testut presented the group's activities, which began with a kickoff online meeting held in July 2024 with 16 participants from Australia, France, Italy, Netherlands, Norway, Spain, Sweden, UK, USA. The DAWG is open to anyone interested in contributing. The group aims to establish country contacts, document best practices, and create an inventory of historical data. A specific section for this working group was created on the GLOSS website. Key challenges discussed include data quality assessment, standardization of vertical leveling references, and proper handling of metadata. Oda Ravndal (Norway) mentioned the difficulty in gathering relevant metadata and compiling the historical information of the station. Elizabeth Bradshaw (UK, PSMSL) mentioned existing resources through Copernicus and PSMSL for data rescue projects. Immediate action items include to establishing a comprehensive contact list of interested parties by country, with IOC's help in reaching out to Member States not currently participating, setting up a website to host rescued data, and dedicating further efforts to countries in South America.

3. REPORT OF GLOSS DATA CENTERS

11. Mr Phil Thompson, director of the UHSLC and associate professor in the Department of Oceanography, presented on the UHSLC Data Management and updates. He noted that the center maintains two main data streams: research quality data (JASL) with one-year

latency and Quality Control (QC) including vertical stability, timing, and station metadata, contributing to PSMSL and GESLA-3 (97 of 114 countries), and fast delivery data with one-month latency, QC focused on outlier detection and primarily for the GLOSS Core Network. A JASL Archive Update (as of Dec 2024 the JASL Archive Metadata format changed from dmt to machine-readable yaml) contains a total of 19,405 station-years from 691 series, with a GLOSS subset of 10,880 station-years from 254 sites.

12. UHSLC is working on modernizing their database infrastructure by migrating from ASCII to PostgreSQL (with TimescaleDB), which supports complex metadata and time series relationships. The center has added 928 station years from 157 different series since 2020, with recent updates focusing on stations in Australia, Japan, Malaysia and USA. They are developing new tools for station monitoring and working to improve data access through ERDDAP servers. Mr Thompson presentation also highlighted increasing usage of their data, demonstrated by growing citation metrics.

Ms Chanmi Kim and Mr Andrew Matthews (PSMSL) updated the group with a presentation on the PSMSL which is the global data center for long-term mean sea level data, active since 1933. Hosted by the UK's National Oceanography Centre (NOC) and supported by the British Oceanographic Data Centre (BODC), PSMSL is a key contributor to GLOSS, IAG, IAPSO, and GCOS. Mr Matthews noted that PSMSL continues to acquire, quality control, and distribute mean sea level data, with gaps remaining in the Arctic, Antarctica, Africa, and South America, especially for long-term records. From 2018–2022, PSMSL data was cited in 451 papers across 182 journals, including Nature and Geophysical Research Letters.

PSMSL hosts a growing repository of Global Navigation Satellite System – Interferometric Reflectometry (GNSS-IR) sea level data (now ~350 sites), with a dedicated portal: https://psmsl.org/data/gnssir/ that includes Python notebooks and metadata for programmatic access. BODC has modernized quality control software for UK tide gauge data, developed ERDDAP dashboards for real-time coastal flood monitoring and is working with PSMSL to align metadata with the upcoming GLOSS ERDDAP server.

Mr Matthews shared the initiative on Data Rescue & Citizen Science which obtained Quality-controlled historical data (1853–1903) from Liverpool Bay via Zooniverse volunteers and was used to validate a 1902 storm surge reanalysis.

He reported that future plans of PSMSL include: finalize ERDDAP data delivery for PSMSL and BODC, improve metadata lineage and use of permanent identifiers, expand GNSS-IR applications (e.g., near real-time, wave height) and continue historical data recovery efforts.

Mr Bart Vanhoorne and Mr Stijn Vermaere (Flanders Marine Institute VLIZ) presented on the IOC Sea Level Station Monitoring Facility (SLSMF) operated for IOC as part of the GLOSS program. They noted that the SLSMF collects real-time sea level data from 1,257 stations operated by 179 institutes worldwide. The SLSMF collects data via GTS, FTP, HTTP, and BGAN; data is parsed and inserted into a central VLIZ database every minute. SLSMF delivers real-time operational status, raw data stream visualization, metadata management, Web services and APIs as well as a Sea Level Station Catalogue (SSC). The system includes several new features: automated quality control of data, a new API with expanded functionality to be released on March 21st, 2025, and integration of DART buoy data for tsunami detection. Key developments include a daily quality control dataset that flags potentially problematic data, though this may filter out legitimate extreme events like tsunamis. The facility is working on metadata versioning, infrastructure updates, and a unified station page oriented around catalog identifiers. Discussion highlighted challenges around data transmission methods, gap management, sensor offset handling and lack of datum information in the VLIZ portal. Venkat

Shesu Reddem, India, pointed to the convenience of implementing automatic scripts to fill gaps due to transmission failure.

Mr Guy Wöppelmann (University of La Rochelle, France) presented a report of the Système d'Observation du Niveau des Eaux Littorales (SONEL). SONEL is the GLOSS Data Assembly Centre for GNSS@Tide Gauges (TG). It collects, processes, and distributes GNSS data co-located with tide gauges to monitor Vertical Land Motion (VLM) and improve Absolute Sea Level (ASL) measurements. Mr Wöppelmann provided an overview of GNSS (Global Navigation Satellite System) stations and their relationship with tide gauges in the GLOSS network. He explained that while there are over 1,300 stations from 150 agencies across 60 countries, only 15% of the GLOSS Core Network (GCN) stations are strictly co-located with GNSS antennas, though 60% have stations within 15 kilometers. Mr Wöppelmann emphasized that distance between GNSS antennas and tide gauges is a crucial factor, as local vertical motion may not be uniform over short distances. Distance is a poor proxy for VLM simmilarity—because local conditions (e.g., pier stability) can cause significant variation even within 100 m. He recommended agencies to install their own GNSS stations at tide gauges rather than relying on distant ones. Glenn Nolan (Ireland) asked about the minimum timeseries length required for GNSS to be included in the data processing chain to obtain reliable VLM estimations. Mr Wöppelmann replied that, in principle, at least 3.5 years are required in many studies (10-12 years and more in areas where complex non-linear hydrological effects occur, such as in the tropical areas).

SONEL provides open access to standard GNSS data and derived products (e.g., velocities) from groups that follow IGS reanalysis standards for geophysical modeling and corrections and supports GNSS-Reflectometry (GNSS-R) applications (e.g., the new PSMSL dataset) and repository or investigations on future tide gauge technologies. Mr Wöppelmann concluded by discussing future plans, including developing a new web portal, expanding data server capacity, and updating GNSS products more frequently (once per year or every six months) through the Copernicus Marine Service.

During this session, the group raised questions about the need to develop standardized methods for gathering metadata from national providers, to provide easier and more streamlined ways to download data, and to harmonize data processing (highlighting differences sometimes encountered between products obtained by GLOSS data portals and those obtained at national level).

New stations offered to be shared with GLOSS data portals: Krisna Bucha (Mauritius) offered 4 new stations, Araely Reyes (Guatemala) offered one station, and José Méndez (Venezuela) offered participation in GLOSS program.

4. STATUS OF GLOSS CORE NETWORK (GCN)

13. Mr Andrew Matthews (PSMSL) updated the group with a presentation showing the status of GLOSS Core Network (GCN) stations across different data centers. The GCN was initially defined in 1990 with 307 sites. It has been periodically updated, with the latest additions made in 2019. The GCN was envisioned as an aspirational backbone network that sets standards for sea level observations, around which regional and national networks can build, highlighting global coverage needs. Its composition is therefore expected to remain relatively stable over time. The network currently has 294 sites, with 107 sites providing data to all streams and 84 having GNSS data. The latest list of GCN stations is available from the GLOSS Implementation Plan 2012, plus 4 sites on Pacific islands added at the Sixthteen session of the GLOSS-GE (GE XVI), Busan, Korea, 2019. The status of the network is monitored via PSMSL.org. The analysis focuses on whether a site is installed and providing

data to any data center, not necessarily in real-time. The last date of data submission to each center is used to assess activity. A best guess based on data since 2018 is as follows:

- No installation ever: 6 sites
- No current installation: 52 sites
- Not quality controlled: 34 sites (only in VLIZ / UHSLC Fast)
- Not datum controlled: 8 sites (in PSMSL, but not RLR)
- Missing from one or more data centres: 87 sites
- Working: 107 sites (84 have GNSS too)

14. The group then discussed next steps for the GCN based on Mr Matthews' presentation. Key action items include data centers double-checking their information to understand why some stations are not being updated, and potentially redefining network requirements as part of the next Implementation Plan. The group clarified that while the GCN is a fixed set of stations defined in the implementation plan, any station contributing to GLOSS Data Centers can be considered a GLOSS station.

5. NATIONAL SEA LEVEL ACTIVITIES - PRESENTATION OF A SELECT SET OF NATIONAL REPORTS

15. Written national reports were delivered by Argentina, Australia, Chile, Cuba, Denmark Ecuador, Egypt, France, Germany, India, Japan, Kenya, Morocco, Norway, Panama, Peru, Russian Federation, Spain, Sweeden, United Kindom and United States. Powerpoint presentations were delivered by Argentina, Chile, China, Denmark, Dominican Republic, Egypt, France, Germany, India, Ireland, Japan, Morocco, Norway, Russian Federation, Spain, Sweeden and United Kingdom.

16. China reports 70 tide stations with 6 GLOSS core stations, showing accelerated sea level rise along their coast. Denmark operates 80 tide gauges with 8 co-located GNSS stations, while in Greenland is testing GNSS reflectometry as an alternative to traditional tide gauges due to challenges with sea ice. Egypt emphasizes urgent concerns about sea level rise impacts on the Nile Delta, reporting a 5cm per year increase over the last decade. Germany maintains about 160 stations along the North Sea coast and has discovered historical tide gauge data from the 1940s from various European countries. Ireland operates 19 active tide gauge stations with real-time data sharing capabilities, including three GLOSS stations, and has recently experienced significant storm surges, particularly during Storm Aeon in January 2025.

17. Japan Meteorological Agency manages 70 tide gauge stations and uses radio wave type tsunami meters, with data collected through a satellite system shared with 5-minute latency. Morocco monitors sea levels through two bodies (Meteorological Agency and Harbors Authority) and recently recorded storm surges in Casablanca and tsunami effects from the 2023 Turkey-Syria 7.8-magnitude earthquake, which occurred on February 6, 2023. The Norwegian Mapping Authority operates 30 tide gauge stations including 5 GLOSS stations, has installed 4 new radar gauge stations since the last meeting, and is conducting a comparative study of different sensor types. Russia reports maintaining 180 active tide gauge stations across 13 seas through Roshydromet's regional centers.

18. Spain's sea level monitoring networks are operated by different institutions at national and regional level (Puertos del Estado, National Research Council-CSIC (IEO RONIMAR and

VENOM networks), National Geographic Institute (IGN), Spanish Hydrographic Office (IHM), Balearic Islands Coastal Observing and Forecasting System (SOCIB) and AZTI (Vasque Country). At least 87 active tide gauges have been installed by these different stakeholders for different purposes. Puertos del Estado operates a network since 1992, which includes now 41 stations with radar sensors, measuring sea level, waves, and atmospheric data, and 10 stations co-located with GNSS receivers. The IEO runs 11 stations with data since 1943, including the 3 GLOSS GCN stations in the country (Coruña, Las Palmas and Ceuta) while the IGN operates 17 stations including the country's oldest tide gauge in Alicante. IHM has recently deployed new low-cost sensors in small ports, and there are ongoing efforts across institutions (Puertos del Estado and IGN) to assess VLM and relative sea level rise through GNSS co-location and leveling campaigns. Puertos del Estado is now designing an experiment for testing novel techniques and new low-cost sensors in at least three different ports with different sea level variability conditions, including the low-cost station including a co-located low-cost GNSS sensor being deployed by IHM. Most of these data are contributing to GLOSS data portals.

19. The Swedish Sea level network consists of 60 stations delivering one-minute data. The network features real-time quality control, open API access, and radar gauge sensors protected by wells due to ice conditions. The longest time series dates back to 1774 in Stockholm, 93% of which are digitized. Recent upgrades funded by the EU included sensor duplication and leveling to the Baltic Sea datum 2000. The data shows land uplift of approximately 0.5cm per year in Stockholm, with sea level rise accelerating since the 1980s to about 3mm per year. The network shares data openly through various services including Copernicus and EMODnet. Future developments include implementing S-100 standards to integrate sea level and current information with navigation systems through the Baltic+ SEAL (Sea Level) Project.

6. GLOSS UNIFIED DATA ACCESS AND STATUS REPORTING

20. Mr Phil Thompson, director of the UHSLC and associate professor in the Department of Oceanography offered a presentation outlining efforts to modernize and simplify access to GLOSS data.

21. The motivation for this initiative is that the current GLOSS data system is confusing and outdated. Users struggle to identify the right dataset for their needs and locate where the data is hosted. Considering this, the GLOSS Data Centers are looking into how to improve data accessibility.

22. Goals and next steps are to reorganize and reclassify data, to unify metadata and use controlled, standardized language, replace vague terms like “delayed mode” with clear quality levels, ensure unique time series across all data streams, link data resolution and QC levels to specific applications and communicate this to users, and to create a Unified Data Portal.

23. The Unified Data Portal will use linked ERDDAP servers at each data center as the back-end. It will develop a centralized front-end (led by VLIZ), allow integration into existing websites (e.g., NOC) and make the data center hosting invisible to the end user.

24. **The group agreed** to have a regular brief report on the status of the ongoing work on the Unified Data Portal.

7. UN DECADE OF OCEAN SCIENCE FOR SUSTAINABLE DEVELOPMENT

25. Mr Bernardo Aliaga, Technical Secretary of GLOSS, presented an update on the UN Ocean Decade initiative (2021-2030), explaining that while it does not provide direct funding, it offers endorsements that can help secure national funding. Mr Glenn Noland (Ireland) suggested submitting the Unified Data Portal as a potential Ocean Decade project.

8. GLOSS IMPLEMENTATION PLAN

26. This item was briefly introduced by Chair Begoña Pérez Gómez. She recalled that at the GLOSS-XVII session (2022) the Group of Experts had agreed to request the previous Chair to continue the update of the GLOSS Implementation Plan (2012) with the aim to submit a first draft to the Steering Committee at its next meeting. This was not possible due to unforeseen circumstances and therefore the Steering Committee proposes to allow more time for the drafting and complete an initial draft for an online review of GLOSS-GE within 2025.

27. **The Group agreed** to task the Steering Committee to complete a first draft of the new Implementation Plan to be distributed by the secretariat to GLOSS Focal Points for comments.

28. **The Group agreed** to review and update GLOSS-GE Terms of Reference given the dissolution of JCOMM.

9. LINKAGES BETWEEN GLOSS AND OTHER PROGRAMMES AND BODIES

9.1 TWCWG

29. Mr Chris Jones from the UK Hydrographic Office presented an overview of the International Hydrographic Organization (IHO) Tides, Water Levels and Surface Currents Working Group (TWCWG). He described the role, structure, and current initiatives of the IHO and its TWCWG, with a focus on collaboration with GLOSS and the development of standards for tides, water levels, and currents. He reported that IHO is an intergovernmental organization promoting uniform hydrographic practices and nautical charting, that was established in 1921 and is composed of 100 Member States. IHO coordinates hydrographic offices globally and develops standards and best practices.

30. TWCWG focuses on technical coordination related to tides, water levels, currents and vertical datums, with significant overlap with GLOSS activities. Key initiatives include developing standards for electronic navigation products (S-104 for water levels and S-111 for surface currents), maintaining a standard constituent list, and working on vertical reference frames. Mr Jones emphasized the importance of collaboration between TWCWG and GLOSS to avoid duplication of efforts, particularly in areas like metadata standards and mean sea level monitoring. GLOSS is represented in TWCWG.

9.2 OCG

31. Ms Emma Heslop from the Global Ocean Observing System (GOOS) presented an overview of the Observation Coordination Group (OCG) and its work with GLOSS, considered a fundamental part of GOOS. She explained that OCG works across GOOS networks to develop frameworks, strengthen implementation, and set standards, with current focus areas including data management, requirements gathering, and network health metrics. Ms Heslop highlighted ongoing initiatives including work on ERDDAP federation across data centers, the cross-network data implementation strategy, and collaboration with IODE on data infrastructure. The group discussed future priorities of GOOS regarding GLOSS, including having GLOSS visible in GOOS visualization tools, enhance communication by jointly delivering strong and consistent messages, improving metadata standards, and sharing unique IDs, and strengthening regional collaboration through GOOS Regional Alliances (GRAs), particularly for developing regions. The next OCG-16 meeting in Brest (7 – 10 Apr 2025) will provide an opportunity to advance these initiatives with GLOSS representatives in attendance. Chair Begoña Pérez Gómez informed the Group that Ms Elizabeth Bradshaw (PSMSL, UK) has joined the OCG Task Team on Data Management on behalf of GLOSS.

9.3 TSUNAMI

32. Mr Bernardo Aliaga, Head Tsunami Resilience Section of IOC presented the historical development of the IOC's tsunami program, which began with initial developments by the United States in 1948 and expanded significantly after the 2004 Indian Ocean tsunami when systems were established in the Caribbean, Mediterranean and northeastern Atlantic regions and Indian Ocean. The current system includes 12 Tsunami Service Providers (TSPs) worldwide, though challenges remain as demonstrated by incidents in Chile (2010), Indonesia (2018), and Tonga (2022). He indicated that while GLOSS initially focused on the establishment of a high-quality, well-designed in situ sea level observing network to support a broad research and operational user base, including oceanographic and climate research communities, it began supporting tsunami warning systems in 2012, with the University of Hawaii Sea Level Center and VLIZ playing key roles in establishing sea level monitoring networks and real-time reporting facilities. Mr Aliaga noted that the current challenge for the tsunami programme is to detect tsunamis within 10 minutes of generation.

9.4 PUERTO RICO SEISMIC NETWORK

33. Mr Victor Huerfano, Puerto Rico Seismic Network (PRSN) presented their monitoring system, which includes 30 tide gauges, tsunami cameras, and 145 accelerometers, with the capability to provide alerts within 5 minutes as required by law. Mr Huerfano also highlighted Puerto Rico's leadership in the Tsunami Ready program with 47 recognized communities and described their historical experience with tsunamis, including a devastating 7.3 magnitude earthquake and 6-meter tsunami a century ago.

10. INTERSESSIONAL ACTIONS FOR GLOSS-GE 2025–2026

34. The discussion about the intersessional actions for the GLOSS-GE, was organised on three break-out working groups:

- Data Archeology (led by Laurent Testut)
- Sensor performance and emerging technologies including GNSS-IR /Reflectometry (led by Phil Thompson and Guy Wöppelmann)
- Quality Control and Data Processing (led by Begoña Pérez Gómez)

35. <u>Data Archaeology</u>

36. Mr Laurent Testut reported on the results fo this WG which purpose is to focus on historical sea level data with the following objectives:

- Identify and catalogue existing historical sea level data.
- Develop and promote best practices for data archaeology.
- Facilitate tools and methodologies for data recovery and digitization.
- Encourage international cooperation in digitization efforts.
- Support funding initiatives for data archaeology.

- Integrate digitized data into GLOSS public repositories.

37. **The Group agreed to** the proposed Actions:

- Establish a regionally balanced Working Group.
- Seek IOC support to engage participants from underrepresented regions (India, Russia, South America, Africa, Asia).
- Appoint a lead and co-lead for the Group.
- Finalize the Terms of Reference for the Working Group.
- Clarify any formal procedures for WG creation.

38. Mr Testut note the following expected deliverables:

- A comprehensive inventory of historical sea level data.
- A best practices guide for data archaeology.
- A technical report on tools and workflows.
- A report to GLOSS-GE.
- A repository of publications and outreach materials on the GLOSS website.
- A directory of relevant contacts.
- Contributions to data rescue proposal development.

39. The Secretariat clarified that Working Groups terms of reference and membership should be renewed at each GLOSS-GE sessions, with chairs serving two-year terms renewable once.

40. Sensor Performance and emerging technologies, including GNSS-IR

41. Mr Phil Thompson and Guy Wöppelmann reported that this intra-session WG gathered ~20 participants. The session started with the use of GNSS-IR (and extended to the broader issue of sensor performance evaluation for sea level monitoring. A quick survey revealed limited direct experience with GNSS-IR, highlighting the need to bring in external expertise.

42. GNSS-IR is increasingly recognized as a valuable complementary technique to traditional tide gauges in sea level monitoring. Its strength lies in its ability to operate effectively in locations where conventional methods may be impractical or unavailable, offering a flexible alternative for expanding observational coverage.

43. While GNSS-IR is not yet positioned to replace traditional tide gauges, it provides unique insights into sea level variations, particularly in challenging environments. The participants have identified two major approaches of processing GNSS-IR data: spectral methods (e.g. using Lomb-Scargle Periodogram), as employed by the PSMSL, and the inverse methods (e.g. least squares/Kalman filtering method). Together, these approaches underscore GNSS-IR's potential to enhance sea level monitoring networks, especially when integrated thoughtfully alongside established techniques.

44. **The Group agreed** on the following actions

- Establish an overarching permanent WG on Instrumentation and Technology similar to the OST/ST in satellite altimetry or a more classic WG on Sensor performance and emerging technologies, including Task Forces or subgroups on GNSS-IR and best practices for assessing sensor performance.
- Create subgroups on:
  - GNSS-IR
  - Low-cost sensors
  - Sensor comparison best practices
- Draft a proposal for WG structure (Terms of Reference) and circulate it within the Steering Committee.
- Encourage participation
- Explore low-cost GNSS alternatives, such as mobile-based solutions.

Quality Control, Data Processing, and Data Management

45. Ms Begoña Begoña Pérez Gómez reported that participants from various countries expressed a shared commitment to improving sea level data quality and management, highlighting several key priorities. Foremost among these was the need for standardization, with calls for clear methodologies, detailed checklists, and a unified data processing chain to ensure consistency across institutions. The importance of QC was also emphasized, with participants advocating for both automatic and manual approaches that are traceable and reproducible.

46. Another critical area was Metadata, where contributors stressed the necessity of embedding QC Metadata and thorough documentation at every stage of data handling. However, capacity gaps were noted, as some countries lack the manpower or technical resources to perform regular QC and data processing. To address this, there were suggestions to enhance performance monitoring, including tracking data completeness, update frequency, and other network metrics. Finally, participants underscored the value of knowledge sharing, calling for improved communication and collaboration across countries to exchange QC practices and tools more effectively.

47. Considering the current landscape and challenges including available resources from IOC-UNESCO and NOAA and contributions from national institutions, data centers, and international programs, as well as the need for continuous improvement, testing and implementing AI techniques, and regular updates to practices:

48. **The Group recommended** to:

- Establish a permanent Working Group within GLOSS focused on QC, processing, and data management.
- Create Subgroups for specific topics (e.g., metadata, algorithms, unified processing).
- Invite External Experts to contribute at national/regional levels.

- Improve Communication between national providers and data centers.
- Conduct Regular Surveys to assess national capabilities and data processing status.
- Ensure QC Metadata is part of the required metadata for each time series.
- Develop Network Performance Metrics and display them on the GLOSS website.
- Advance towards a Unified Processing Chain to support a single GLOSS data access point.

49. For the immediate period **the Group agreed** to:

- Define terms of reference and membership of a WG on Quality Control, Data Processing, and Data Management
- Review and update existing manuals and public code.
- Compile challenging time series for AI training.
- Provide standardized, open-access code for computing monthly mean sea levels.
- Conduct benchmark tests to evaluate different QC and processing standards.

The team considered the idea of having a workshop focused on a specific topic of importance for GLOSS, potentially on instrumentation and technology. They also discussed the possibility of having the next GLOSS-GE sessions meeting back-to-back with a scientific workshop.

11. GLOSS CHAIR ELECTION

50. **The Group elected** by acclamation of Dr (Ms) Begoña Pérez Gómez (Spain) as the new chair of GLOSS-GE for a 2-year renewable term, as per IOC Rules of Procedure.

12. ANY OTHER BUSINESS

51. No other subjects were discussed.

13. DATE AND PLACE OF THE NEXT SESSION

52. The Group discussed dates and venue for the next meeting of the group of experts. La Rochelle, France and Lima, Peru were proposed as potential locations for GLOSS-GE-XIX, in 2027.

53. . **The Group agreed to meet** in March or April 2027, if possible back-to-back with the IHO meeting, avoiding the week of the 4th to 9th of April, **and requested** the Steering Commmitee and the Secretariat to discuss with France and Peru on the venue and specific dates,

14. CLOSURE

54. The group expressed gratitude to the local hosts in Panama for the successful meeting. The translators were also praised for their work. Mr Jorge Rodrigues (Panama GLOSS

National Focal Point) expressed his appreciation for the meeting held in Panama and his commitment to the cause of monitoring sea levels. The meeting ended with a sense of accomplishment and anticipation for future collaborations.

55. The meeting closed at 12:00 local time on 14 March 2025.

ANNEX I

AGENDA

1. ORGANIZATION OF THE SESSION
    1.1. OPENING OF THE SESSION
    1.2. PRACTICAL ARRANGEMENTS
    1.3. ADOPTION OF THE AGENDA AND TIMETABLE
2. REVIEW OF PROGRESS ON ACTIONS FROM GE-XVII
    2.1. REVIEW OF GLOSS MANUALS
    2.2. IAPSO CMSLT BEST PRACTICES
    2.3. DATA ARCHEOLOGY
3. REPORT OF GLOSS DATA CENTERS
4. STATUS OF GLOSS CORE NETWORK
5. NATIONAL SEA LEVEL ACTIVITIES - PRESENTATION OF A SELECT SET OF NATIONAL REPORTS
6. GLOSS DATA ACCESS AND STATUS REPORTING
7. UN OCEAN DECADE
8. GLOSS IMPLEMENTATION PLAN
9. LINKAGES BETWEEN GLOSS AND OTHER PROGRAMMES AND BODIES
    9.1. TWCWG
    9.2. OCG
    9.3. TSUNAMI
    9.4. PUERTO RICO SEISMIC NETWORK
10. INTERSESSIONAL ACTIONS FOR GLOSS-GE 2025–2026
11. GLOSS CHAIR ELECTION
12. ANY OTHER BUSINESS
13. DATE AND PLACE OF THE NEXT SESSION
14. CLOSURE

ANNEX II

DECISIONS, ACTIONS AND RECOMMENDATIONS

The Eighteenth Session of the Group of Experts for the Global Sea Level Observing System (GLOSS-GE) meeting was hosted in Panama from March 11 to 14, 2025

The Group agreed to review and update GLOSS-GE Terms of Reference given the dissolution of JCOMM.

The Group agreed to task the Steering Committee to complete a first draft of the new Implementation Plan to be distributed by the secretariat to GLOSS focal points for comments.

The Group agreed to have a regular brief report on the status of the ongoing work on the Unified Data Portal and new front-end visualization tool.

The Group agreed to establish three Working Groups with specific recommendations and actions regarding the development of new best practices for different key areas of interest:

- **Working Group on Sea Level Data Archaeology**
- **Working Group on on Quality Control, Data Processing, and Data Management**
- **Working Group onSensor performance and emerging technologies, including GNSS-IR (Global Navigation Satellite System – Interferometric Reflectometry()**

The Group instructed the Steering Committee to develop Terms of Reference for the above Working Groups **and requested** the Secretariat to invite Member States to appoint experts to these Working Groups through the GLOSS-GE.

The Group recommended exploring and compiling ideas from the sea level community to seek endorsement of a UN Ocean Decade program.

The group expressed its appreciation to the Government of Panama for hosting the GLOSS-GE-XVIII session.

The Group agreed to meet in March or April 2027, if possible back-to-back with the IHO meeting, avoiding the week of the 4th to 9th of April, and requested the Steering Commmitee and the Secretariat to discuss with France and Peru on the venue and specific dates,

The Group elected by acclamation of Dr (Ms) Begoña Pérez Gómez (Spain) as the new chair of GLOSS-GE for a 2-year renewable term.

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ANNEX III

Eighteenth Session of the Group of Experts for the Global Sea Level Observing System (GLOSS-GE XVIII)

11-14 March 2025

ANNEX VI

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ANNEX IV

LIST OF ACRONYMS

ASL	Absolute Sea Level
BODC	British Oceanographic Data Centre (UK)
CMSLT	Commission on Mean Sea Level and Tides (IAPSO)
EMODnet	European Marine Observation and Data Network
GCN	GLOSS Core Network
GCOS	Global Climate Observing System (WMO–ICSU–IOC–UNEP)
GE	Group of Experts
GGOS	Global Geodetic Observing System (IAG)
GLOSS	Global Sea Level Observing System
GNSS	Global Navigation Satellite System
GOOS	Global Ocean Observing System (WMO–ICSU–IOC–UNEP)
GPS	Global Positioning System
GNSS	Global Navigation Satellite System
GNSS-R	GNSS-Reflectometry
GNSS-IR	Global Navigation Satellite System – Interferometric Reflectometry
IAG	International Association of Geodesy
IAPSO	International Association for the Physical Sciences of the Oceans
IHO	International Hydrographic Organization
IOC	Intergovernmental Oceanographic Commission (UNESCO)
JCOMM	Joint Commission for Oceanography and Marine Meteorology (WMO–IOC)
JCOMMOPS	JCOMM Observations Programme Support Centre
JMA	Japan Meteorological Agency
NOC	National Oceanography Centre (UK)
OCG	Observation Coordination Group
PRSN	Puerto Rico Seismic Network
PSMSL	Permanent Service for Mean Sea Level (UK)
QC	Quality Control
SHOM	Service Hydrographique et Océanographique de la Marine (France)
SSC	Sea Level Station Catalogue
SLSMF	Sea Level Station Monitoring Facility
SONEL	Système d'Observation du Niveau des Eaux Littorales (France)
TWCWG	Tides, Water Levels and Surface Currents Working Group (IHO)
UHSLC	University of Hawaii Sea Level Center
UNESCO	United Nations Educational, Scientific and Cultural Organization
VLIZ	Vlaams Instituut voor de Zee/Flanders Marine Institute (Belgium)
VLM	Vertical Land Motion
WG	Working Group
WMO	World Meteorological Organization

GOOS
Global Ocean Observing System

IN SITU MATURE GLOBAL OCEAN OBSERVING NETWORKS

Ship Based Meteorological
Ship Observations Team (SOT)

Ship Based Oceanographic
Ships Of Opportunity Programme (SOOP)

Ship Based Aerological
Automated Shipboard Aerological Programme (ASAP)

Repeated Transects
Global Ocean Ship-Based Hydrographic Investigations Programme (GO-SHIP)

Sea Level Gauges
Global Sea Level Observing System (GLOSS)

Moored reference stations
OceanSITES

Moored Buoys
Data Buoy Cooperation Panel (DBCP)

Tsunami Buoys
Data Buoy Cooperation Panel (DBCP)

High Frequency Radars
The Global High Frequency Radar Network

Drifting Buoys
Data Buoy Cooperation Panel (DBCP)

Profiling Floats
Argo

Gliders
OceanGliders

Animal Borne Sensors
Animal-Borne Ocean Sensors (AniBOS)

IN SITU EMERGING GLOBAL OCEAN OBSERVING NETWORKS

Fishing Vessels
Fishing Vessel Ocean Observing Network (FVON)

SMART Subsea Cables
Science Monitoring And Reliable Telecommunications (SMART) Subsea Cables

Surface CO_2 Observing Platforms
Surface Ocean CO_2 Observing Network (SOCONET)

Uncrewed Surface Vehicles
Surface UNcrewed Fleet (SUN Fleet)

The Global Ocean Observing System (GOOS)

GLOSS is one of the observing networks contributing to the Global Ocean Observing System (GOOS) – a programme led by the Intergovernmental Oceanographic Commission (IOC) of UNESCO, and co-sponsored by the World Meteorological Organization (WMO), UN Environmental Programme (UNEP) and the International Science Council (ISC).

GOOS provides leadership and coordination for a global system of sustained ocean observations, based on a set of Essential Ocean Variables. It is the foundation for data-driven solutions for weather and extreme event forecasting, climate adaptation, coastal and maritime risk responses, biodiversity stewardship, and sustainable ocean economies. Through a globally integrated infrastructure of ocean observing networks, national and regional observing initiatives, and with the guidance of its expert panels, GOOS ensures the delivery of essential ocean information that supports ecosystems, economies, and communities worldwide.

GOOS *in situ* mature ocean observing networks

The GOOS *in situ* mature observing networks provide long-term, global, high-quality, observations of Essential Ocean Variables – the minimum set of measurements that are needed to assess ocean state and variability for important global ocean phenomena, and to provide essential data for applications that support societal benefit. The real-time visualizations of all mature GOOS network platforms and their metadata can be accessed through OceanOPS – the operational coordination and monitoring centre of GOOS.

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