Permanent Service for Mean Sea Level (PSMSL)

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PSMSL website - https://psmsl.org/

1 Activities during the reporting period 2023-2025

1.1 Introduction

For over 200 years, we have been observing the height of the ocean using tide gauges. Perhaps more accurately called water level sensors, as they can be used in areas where there is little or no tide, they can be used to monitor variations in heights across a wide range of timescales, from high frequency waves, storm surges and tides, to long term changes in ocean currents, changes due to the expansion of warming water, and the melting of glaciers and ice caps.

The Permanent Service for Mean Sea Level (PSMSL) is GGOS's data centre for monthly mean sea level information, but our origins go back to the IUGG General Assembly held in Lisbon in 1933, when our first director, Joseph Proudman, was tasked with collating and publishing mean sea level data from sites around the world. Today we remain a permanent service of two of IUGG's constituent unions, for Geodesy and Oceanography, and a data centre for the Intergovernmental Oceanographic Commission's Global Sea Level Observing System (GLOSS).

The PSMSL is based at the Liverpool site of the UK's National Oceanography Centre (NOC) who have committed to supporting its operations in the long term. The NOC is an independent self-governing organisation – a charitable company limited by guarantee, which is funded by UK Research and Innovation to work on National Capability programmes.

1.2 MSL data received

The fundamental purpose of the PSMSL is to acquire, quality control, and make available mean sea level data. The PSMSL MSL dataset has continued to grow from 2020 to 2024.

Some sites have not contributed data for over 20 years, and it may be that these stations have ceased to function. One concern is that many of these older stations are in the Arctic and Antarctic and are key gaps in the dataset. There are no datum-controlled records at PSMSL longer than 100 years for the Arctic, Africa, South America or Antarctica.
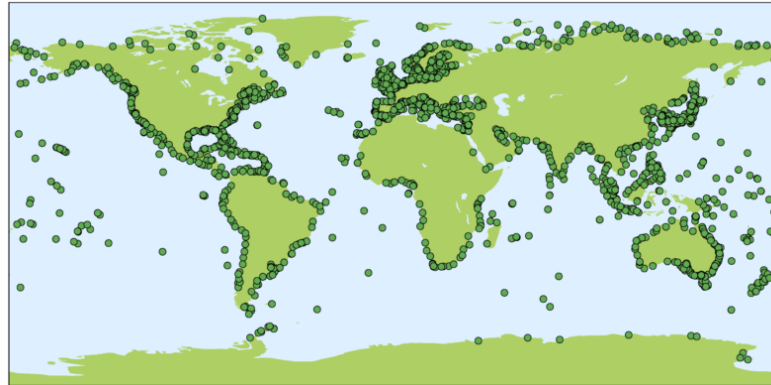
Fig. 1. All stations in the PSMSL databank

Year	2020	2021	2022	2023	2024
No. of stations	790	636	688	693	730
Station years	1361	1099	1325	1350	1796

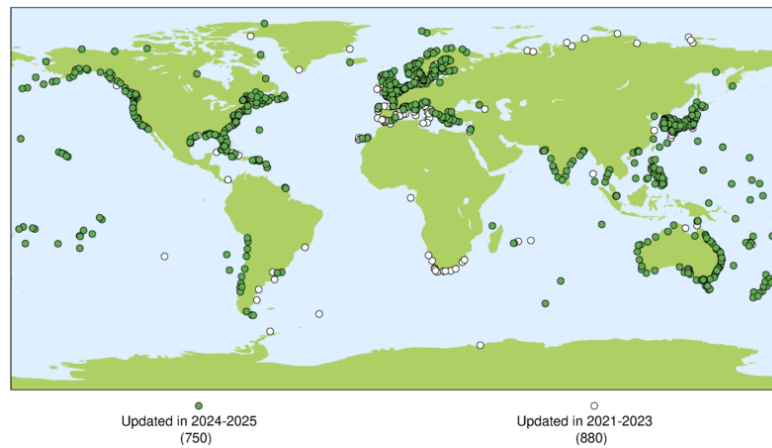**Fig. 2.** Data added to the PSMSL databank

Fig. 3. Stations updated in since 2021

There has been a continued downward trend in number of stations provided to the PSMSL. We are aware that some stations continue to operate in near real time, but data are not being quality controlled and mean sea level data are not being calculated. We hope that the continued development of automatic quality control software may help reverse this trend.

1.3   Projects

Global Navigation Satellite Systems - Interferometric Reflectometry (GNSS-IR) data processing and delivery

The PSMSL continues to host a repository of sea level data extracted from GNSS receivers using interferometric reflectometry (GNSS-IR). Over the past two years, we have expanded the portal from ~250 sites to nearly 350. We have continued to improve the metadata delivered with our GNSS-IR data (https://psmsl.org/data/gnssir/), including adding metadata files that can be used for bulk processing and Jupyter notebooks showing worked examples of using the data, explaining the file format and how we calculate daily means.
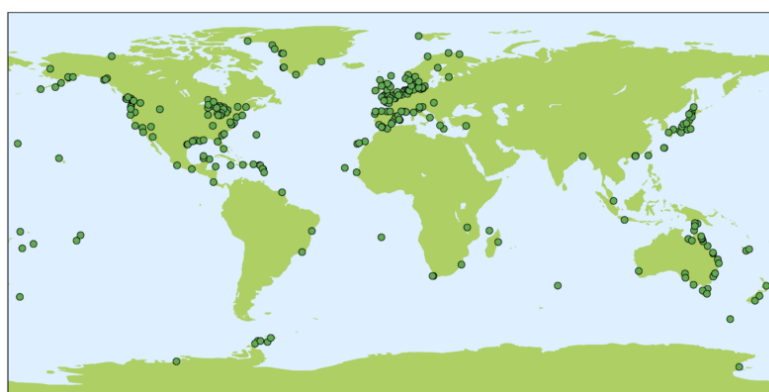

Fig. 4. GNSS-IR sea level records available from PSMSL
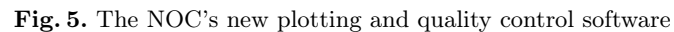
Copernicus Marine Service

We distributed a questionnaire to sea level data providers to support the development of the Copernicus Sea Level REProcessed product and a Global Ocean Observing System (GOOS) project on global network data flow. The aim was to clearly map out the data and metadata flows, for both real-time and delayed mode data, across all the ocean observation global networks.

This was to enable those outside the networks to better understand how data flows into global data management systems, enable us to identify gaps and areas where we can potentially improve or better support data and metadata flow or access, and to ensure data suppliers are properly credited.

The PSMSL staff were involved in updating and quality controlling the latest Copernicus Marine reprocessed sea level data product, released in November 2024. As part of this release, we improved the lineage metadata, following DataCite Metadata schema principles to better credit those involved with collecting, managing and distributing the data.

Updated plotting software and improvement of tidal analysis

The main sea level plotting and quality control package used at the NOC had become difficult to maintain due to its age and complexity. With help from the PSMSL scientists, developers

at the NOC modernized the package using common libraries and best practices. The software is now being used to quality control sea level data from the UK's national tide gauge network and after further testing will be used for other international sites.

Fig. 5. The NOC's new plotting and quality control software

Reorganisation of PSMSL archives

In 2024, NOC refurbished its Liverpool office, prompting the relocation of PSMSL's paper archives. We used this opportunity to review, reorganise and catalogue our paper records.

Refurbishment of the Doodson-Légé tidal prediction machine

The Liverpool site of the NOC still hosts two analogue tidal prediction machines, on loan from National Museums Liverpool. In July 2024, one of the museum's metals conservators visited to carry out routine maintenance on the newer Doodson-Légé machine.

In the 1950s, these machines were operated by a team of assistants known as "computers". As these computers retired, the knowledge of how to program these machines has been handed down, but we were at risk of losing this expertise, as only a few members of staff had previously carried out the task. We took the opportunity to train four more "computers" and document the process in order to properly preserve this important part of our history.

Fig. 6. A selection of mareograms from Australia contained in the PSMSL archives

Fig. 7. The Doodson-Légé Machine

1.4   Meetings attended

Andy Matthews attended the GGOS Bureau and Working Group meeting in July 2023 and gave a presentation on the activities of the PSMSL.

Andy Matthews virtually attend the GGOS days meeting in September 2023 and gave the service report presentation for the PSMSL https://www.youtube.com/watch?v=R1wXtK48Ylw.

Elizabeth Bradshaw virtually attended the World Data System's Members' Forum in October 2023 and gave a presentation on the highlights and challenges for the PSMSL - https://vimeo.com/882657357.

Chris Banks, a satellite oceanographer at the NOC, presented a poster on behalf of the PSMSL and gave a talk on "A new dataset of relative sea level measurements created using Global Navigation Satellite System (GNSS) receivers" at the Ocean Surface Topography Science Team (OSTST) in November 2023.

The EuroGOOS (European Global Ocean Observing System) Tide Gauge Task Team Annual Meeting was held in November 2023 at the NOC in Liverpool and Elizabeth Bradshaw, Chanmi Kim and Andy Matthews attended. Elizabeth gave a number of presentations on data flow and metadata, as well as the activities of the Tide Gauge Task Team.

At the European Geosciences Union (EGU) General Assembly in April 2024 Chanmi Kim presented a poster titled "Linking the Permanent Service for Mean Sea Level's (PSMSL) global mean sea level dataset to the ellipsoid" (https://doi.org/10.5194/egusphere-egu24-9936) in the session on Understanding sea level changes: global to local, from past to future.

Lesley Rickards, former director of the PSMSL, attend the International Conference on Marine Data and Information Systems in May 2024 on our behalf. Lesley presented the poster "Next steps in creating FAIR sea level data" in the session on technical developments for marine information and data management -https://share.ifremer.fr/share/s/PV_4MDQyQW2X2tdxl6mw3Q.

Elizabeth Bradshaw, Chanmi Kim and Andy Matthews virtually attended the GGOS days meeting in October 2024 and Elizabeth presented the PSMSL service report - https://www.youtube.com/watch?v=GtWph9wEgnQ.

Chanmi Kim and Andy Matthews attended the GLOSS Group of Experts meeting in March 2025 and presented on the activities of the PSMSL and on the GNSS-IR dataset - https://goosocean.org/document/35780.

Elizabeth Bradshaw attended the Global Ocean Observing System (GOOS) Observations Coordination Group OCG-16 in April 2025 and provided input on metadata and sea level network data flow discussions.

Chanmi Kim presented a poster titled "The Permanent Service for Mean Sea Level's (PSMSL) global mean sea level dataset" (https://doi.org/10.5194/egusphere-egu25-11494) at the EGU General Assembly in April 2025, in the session on Tides and Surges: Dynamics, Impacts and Long-term Changes.

1.5   Training and visitors

IAPSO workshop

In November 2023 we held a two-day workshop, organised under the International Association for the Physical Sciences of the Oceans best practice study group on tidal analysis. The aim of the meeting was to produce a guidance document on best practice to follow when carrying out tidal analyses.

Staff from the PSMSL internal advisory group also delivered training in:

- Sea level monitoring and science to remote sensing PhD students in the UK (January 2023)
- Tidal analysis and sea level variability to Madagascan stakeholders (January 2024)
- Visiting Anguilla to support their project to obtain tsunami ready accreditation from the IOC, including sessions on tide gauge maintenance and sea level science (March 2024)

1.6   Staff and advisory group

The core PSMSL team is:

- Elizabeth Bradshaw, Head of the PSMSL

- Andrew Matthews, Technical lead, PSMSL
- Chanmi Kim, PSMSL data manager

We are supported by other members of NOC staff, who provide expertise and guidance in a variety of areas, occasionally represent PSMSL at conferences, and aid us in our remit to provide training and support to operators of tide gauges and users of data.

The PSMSL has an internal advisory group made up of the following NOC staff:

- Angela Hibbert, capacity building
- Chris Hughes, scientific advisor
- Svetlana Jevrejeva, projections, impact and adaptation
- Joanne Williams, surges, extremes and tides
- Simon Williams, GNSS and VLM
- Chris Wilson, ocean circulation and modelling
- Philip Woodworth, scientific advisor and former director
- Lesley Rickards, former director

1.7   Summary

2023 to 2025 have been typically busy years for the PSMSL, with data acquisitions higher than in previous years. We've also continued to develop the GNSS-IR portal with an aim to making it a sustainable product in the long term. We've been busy working with the sea level and wider scientific communities on a diverse range of projects and committees.

Tilo Schöne, who led the IGS Tide Gauge (TIGA) Working Group stepped down at the end of 2023. The TIGA working group has been instrumental in improving the connection between sea level measurements and vertical land movements and we wish to thank Tilo Schöne for his invaluable work.

Per Knudsen (DTU SPACE, Denmark) has agreed to act as an IAG representative to PSMSL for 2023-2027.

We expect 2025-2027 to be just as busy and some of our future objectives are:

- A new project to update and improve PSMSL website and data delivery, including finalising the delivery of data through ERDDAP servers
- Improving PSMSL metadata, particularly lineage metadata, so our data suppliers are properly credited
- Continuing the investigation of the use of permanent identifiers to improve tide gauge metadata
- Further developing the use of GNSS-IR, in particular near real time delivery and significant wave height data
- Continuing to explore methods of recovering historical sea level data, including Citizen Science.

1.8   Selected publications

PSMSL staff contributed to the white paper on the definition of Essential Geodetic Variables (EGVs): Gruber, T.; Angermann, D.; Sánchez L. (2025), Definition of Essential Geodetic Variables (EGV): Contribution of Geodesy to Earth Observation, White Paper, Global Geodetic Observing System (GGOS) https://doi.org/10.5281/zenodo.14619439.

Over the past two years, PSMSL staff have been involved in the production of the publications given below.

References

[1] Lin-Ye, Jue, et al. (2023) Delayed-mode reprocessing of in situ sea level data for the Copernicus Marine Service. Ocean Science 19.6: 1743-1751.

[2] Kendon, Mike, et al. (2023) State of the UK climate 2022. International journal of climatology 43: 1-83.

[3] Kendon, Mike, et al. (2024) State of the UK Climate 2023. International Journal of Climatology 44: 1-117.

[4] Thompson, Philip R., et al. (2025) Reply to timing errors in global sea level observations (Pan et al., 2025). Ocean Dynamics 75.2: 1-6.

Acronyms

EGU	European Geosciences Union
EuroGOOS	European Global Ocean Observing System
GGOS	Global Geodetic Observing System
GLOSS	Global Sea Level Observing System
GNSS-IR	Global Navigation Satellite Systems Interferometric Reflectometry
GOOS	Global Ocean Observing System
IAG	International Association of Geodesy
IAPSO	International Association for Physical Sciences of the Oceans
IGS	International GNSS Service
IOC	Intergovernmental Oceanographic Commission
IUGG	International Union of Geodesy and Geophysics
MSL	Mean Sea Level
NOC	National Oceanography Centre
OCG	Observations Coordination Group
PSMSL	Permanent Service for Mean Sea Level