



## THE NERC MARINE CENTRES' STRATEGIC RESEARCH PROGRAMME 2007-2012

# National Facility 2: Permanent Service for Mean Sea Level (PSMSL)

Direct measurements of sea level by tide gauges are the only reliable means of monitoring decadal sea level change and long term sea level rise. They are also needed to calibrate satellite altimetry. Working under international auspices, PSMSL collates information from ~2000 tide gauges worldwide, delivering quality-controlled sea level information to other parts of Oceans 2025 and a global community of researchers and research-users.

PSMSL is hosted by the Proudman Oceanographic Laboratory and led by Lesley Rickards, [ljr@bodc.ac.uk](mailto:ljr@bodc.ac.uk)

- Main activities:
- Data acquisition from tide gauge authorities
  - Construction of Mean Sea Level data set
  - Data analysis and quality control
  - Data dissemination to users

The text that follows is based on that submitted to NERC. For details on science Themes and other National Facilities, see [www.oceans2025.org](http://www.oceans2025.org). This information is made public by the Oceans 2025 Directors to facilitate engagement of the wider community in the programme; permission is required for other uses. This text does not include information on resource requirements, and is limited to fully- or partly-funded activities within the Oceans 2025 programme. Since not all the programme is fully-funded, there may be changes to some objectives and deliverables (to be identified in the Implementation Plan).

## National Facility 2: Permanent Service for Mean Sea Level

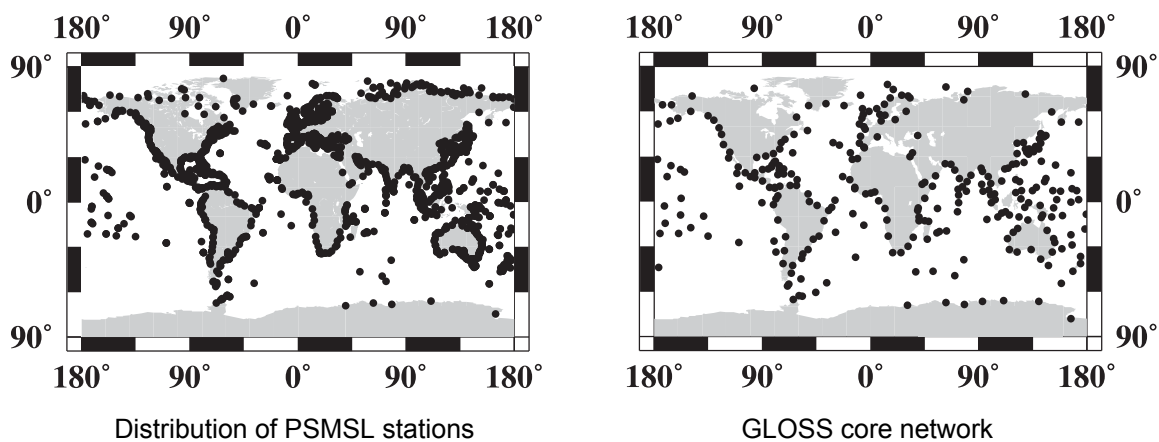
### Strategic context

Sea level data are used across a wide range of research spanning climate change (sea level rise), oceanography (ocean currents, tides, surges), geodesy (national datums), geophysics and geology (coastal land movements). The Permanent Service for Mean Sea Level (PSMSL) is the global data bank for long term sea level change information from tide gauges, and its data set is used by a large community of sea level scientists. Its time series of monthly and annual mean sea level (MSL) information from ~ 2000 gauge sites are employed in all studies which contribute to the Intergovernmental Panel on Climate Change (IPCC) assessments of recent sea level changes. The IPCC Third Assessment Report concluded that sea level rose by 10-20 cm during the past 100 years, and suggested a rise of ~50 cm in the next century, with significant coastal impacts.

There is a continuing national and international need to monitor such changes, and to understand them and their impacts. Analyses of PSMSL data inform studies of impacts of climate change on both national and international levels (e.g. UK Climate Impacts Programme, UKCIP, UK Foresight Flood and Coastal Defence Review, IPCC Working Group II).

The PSMSL has been hosted at the Proudman Oceanographic Laboratory (POL) since 1933 under the auspices of the International Council for Science (ICSU) and is a member of the Federation of Astronomical and Geophysical Data Analysis Services (FAGS). Of the 12 'Geophysical Permanent Service' members of FAGS, the PSMSL is the only one hosted by the UK. For the last decade, PSMSL has led the Global Sea Level Observing System (GLOSS) of the Joint Technical Commission for Oceanography and Marine Meteorology (JCOMM) of the Intergovernmental Oceanographic Commission (IOC) and the World Meteorological Organization (WMO). GLOSS was the first operational component of the Global Ocean Observing System (GOOS), and one of its main aims is to improve the quality and quantity of data supplied to the PSMSL.

GLOSS is structured around a global core network of around 300 tide gauges with two data streams. 'Fast' (real time and similar) data go to the GLOSS Fast Centre at the University of Hawaii Sea Level Center. The 'delayed mode' (DM) data set is managed by the British Oceanographic Data Centre (BODC), and provides the fully quality-controlled sea level information required both for scientific research and for archive alongside the PSMSL monthly and annual means. BODC is also charged with DM quality control of global sets of gauges (similar to although not exactly the same as the GLOSS set) for the Climate Variability and Predictability Programme (CLIVAR) of the World Climate Research Programme (WCRP) and the Global Climate Observing System (GCOS).



### Ongoing scientific need for tide gauge data

Whilst satellite altimetry of TOPEX/Poseidon (T/P) standard is capable of providing global sea-level coverage, tide gauges will remain essential for the measurement of sea level in the foreseeable

future because: a) they have detailed spatial coverage in coastal waters (inaccessible by satellite altimetry); b) they are necessary calibration tools for altimetry; and c) they provide crucial temporal resolution in sampling (altimeters give good spatial but poor time coverage). Moreover, tide gauges are the only source of accurate data concerning sea level changes over a period more than a decade. The PSMSL data base includes sea level time-series more than two centuries long, providing a unique perspective on the trends and accelerations of global sea level.

Actions to enhance the global sea level data set are being developed in close liaison with international programmes such as GLOSS, GCOS and CLIVAR. In parallel with sea level monitoring, there is also need to improve the monitoring of vertical land movements at tide gauge sites, and the PSMSL works closely with the International GNSS Service (IGS) and the Global Geodetic Observing System (GGOS) in this area. GLOSS gauges equipped with GPS receivers have been shown to provide the best system for ongoing calibration of satellite radar altimetry. There are therefore clear inter-dependent links in requirements for MSL information, quality controlled higher frequency tide gauge data, geodetic information and satellite altimetry. The challenge is to combine all components into one system for global sea and land level monitoring.

Since 26 December 2004, the world has been more aware of the destructive power of tsunamis. Prior to this event there were few links between the sea level and tsunami research communities. However, the past year has seen remarkable progress into multiple use of future equipment with all new tide gauges installed for GLOSS now capable of recording tsunamis, seiches and other high frequency motions, and even coastal waves. Data banks such as the PSMSL are therefore necessarily extending their interests and responsibilities to several aspects of the sea level spectrum.

### **Overall aims**

The main strategic aims of PSMSL in 2007-12 are to:

1. Acquire a high quality data set of monthly and annual MSL data from as representative a global set of sea level stations as possible. This will be achieved by maintaining communication with almost 200 tide gauge authorities worldwide.
2. Construct a quality-controlled DM data set of hourly (or similar) sea levels primarily from stations in the GLOSS core network.
3. Analyse large parts of the data set, to complement the sea level science undertaken elsewhere (notably in Themes 1 and 3 of Oceans 2025), and to provide high level data quality control (with particular attention to IPCC timescales).
4. Provide users with the MSL data set via the web, together with ancillary information.
5. Develop training information, and organize training courses, for operators of tide gauges and users of their data sets.
6. Respond to requests for information from national tide gauge agencies, decision makers (local councils, Parliamentary enquiries), the media and general public.

Aims 4-6 emphasise that PSMSL is more than data bank, providing services and advice to the international sea level community. Several of these functions draw on expertise elsewhere in-house, such as the technical knowledge of the POL Ocean Engineering and Technology Group.

The PSMSL and GLOSS data banking activities were graded  $\alpha 5$  (the highest possible) in the NERC Science Management Audit of POL and BODC in 2004. The activities have worked well alongside each other for some years. However, it is clear that now is the optimum time for their combination. In addition to internal benefits (software development, data bank maintenance, metadata gathering etc.), it will be clear to all users that the combined PSMSL is the global repository for not only the long term monthly and annual mean sea levels, but also the higher frequency DM data from the global strategic sets of stations.

## PSMSL management

The combined PSMSL and GLOSS activities will be managed as a joint POL and BODC activity. BODC will provide expertise in the data management, while POL staff will be primarily responsible for scientific-standard quality control, product generation, scientific analysis and relationships with the international scientific community. It is anticipated that all staff will be engaged in all activities at some level.

The appointment of a PSMSL Director by FAGS (historically usually the POL Director) is on condition that the host laboratory has the width of expertise to provide a comprehensive service to the community. The Director must therefore be active in sea level science research or data management. The work of the Service is underpinned by staff with specific responsibility to maintain contact with the many tide gauge authorities worldwide. In addition, contributions by other members of POL and BODC staff are required to provide the necessary breadth of expertise.

The PSMSL reports formally to FAGS through the International Association for the Physical Sciences of the Oceans (IAPSO) Commission on MSL and Tides (President, Dr Philip Woodworth, POL) which FAGS recognises as the expert supervising body. Reports are provided every year, every two years to the conferences of IAPSO and IAG (International Association of Geodesy) and every four years to the International Union of Geodesy and Geophysics (IUGG). All recent reports are on the web. In addition, the PSMSL has an Advisory Group of international scientists active in the field (see PSMSL website [www.pol.ac.uk/psmsl](http://www.pol.ac.uk/psmsl) for present membership).

## Links with other parts of Oceans 2025

The main links between this proposal and other parts of Oceans 2025 are summarized below:

Theme 1	Sea level responses to climate change
Theme 3	Information on extreme sea levels from storm surges and tsunamis, studied using GLOSS DM data
Theme 10	SO 7: UK measurements at South Atlantic and Antarctic stations which provide national contributions to the international GLOSS programme.
NF1: BODC	Close coordination on data management; particularly strong links re GLOSS

## Collaborations and stakeholders

In addition to the UK collaborations primarily via Oceans 2025, the PSMSL works directly with sea level scientists around the world, acquiring those links through its contacts with governments, funding agencies and other bodies. Such collaborations include the organization of scientific study groups and training courses, in addition to joint studies of the sea level data set.

The main PSMSL stakeholder is considered to be the international sea level community, which makes use of the sea level information contributed by contributing agencies to the PSMSL, quality controlled by the PSMSL, and redistributed freely to scientists. An important section of this community consists of scientists interested in climate change, sea level rise and its impacts (e.g. IPCC). Research into ocean circulation variability, geology (vertical land movements) and geodesy is also supported by the data set. Many government departments and agencies are also PSMSL stakeholders, in that they use PSMSL data and related analyses (eg from IPCC) as the evidence - base for recommendations on coastal engineering, land use and other developments. For example, Defra supported a scientific meeting held at the Royal Society in February 2004 on sea level rise and related issues.

## Key deliverables

- An enhanced data set of monthly and annual MSL values (currently approximately 50,000 station-years from 2000 stations worldwide).
- A quality controlled data set of hourly (or similar) sea levels from stations in the GLOSS Core Network.

- Training information and advice to users of tide gauge equipment and of the PSMSL data set.

The main emphasis is on provision and analysis of high quality sea level data sets. However, PSMSL will also meet the need of the international sea level community for a range of derived-products; e.g. annual summaries of MSL and percentile anomalies, extremes etc. throughout the Atlantic. Such products will be developed by PSMSL through its involvement in GLOSS.

### Co-funding

PSMSL receives small amounts from FAGS (~ US\$ 5k pa for last 5 years) and IOC (~ US\$ 15k pa for last 5 years) in recognition of its international importance. However, in common with general FAGS practice, the service is funded primarily by the national host. PSMSL does not charge scientists for its services, nor does it purchase data from national authorities. PSMSL is the only FAGS Service based in the UK.

### Recent PSMSL publications

- Church JA, Gregory JM, Huybrechts P, Kuhn M, Lambeck K, Nhuan MT, Qin D & Woodworth PL (2001) Changes in sea level. In, *Climate Change 2001: The Scientific Basis*. Contribution of WG 1 to the 3rd Assessment Report of the Intergovernmental Panel on Climate Change. (eds. JT Houghton, Y Ding, DJ Griggs, M Noguer, P van der Linden, X Dai, K Maskell & CA Johnson). CUP Cambridge, 881pp.
- Mitchum GT, Cheney R, Fu L-L, Le Provost C, Menard Y & Woodworth P (2001) The future of sea surface height observations. p120-36 In: *Observing the Oceans in the 21st Century*, C Koblinsky & NR Smith (eds), Bureau of Meteorology, Melbourne, Australia. 604pp.
- Woodworth PL, Le Provost C, Rickards LJ, Mitchum GT & Merrifield M (2002) A review of sea-level research from tide gauges during the World Ocean Circulation Experiment. *Oceanogr & Mar Biol: Ann Rev*, 40, 1-35.
- Woodworth PL & Player R (2003) The Permanent Service for Mean Sea Level: an update to the 21st century. *J Coastal Res*, 19, 287-95
- Woodworth PL, Aarup T, Merrifield M, Mitchum GT & Le Provost C (2003) Measuring progress of the Global Sea Level Observing System. *EOS, Trans American Geophys Union*, 84(50), 16 Dec 2003, 565, 10.1029/2003EO500009.
- Woodworth PL, Gregory JM & Nicholls RJ (2004) Long term sea level changes and their impacts. p.715-53 (chapter 18) in *The Sea*, Vol 13, ed AR Robinson & KH Brink. Harvard University Press.

### Acronyms

BODC	British Oceanographic Data Centre	IAPSO	International Association for the Physical Sciences of the Oceans
CLIVAR	Climate Variability and Predictability Programme (WCRP)	ICSU	International Council for Science
Defra	Department for Environment, Food and Rural Affairs	IGS	International GNSS Service
DM	Delayed mode	IOC	Intergovernmental Oceanographic Commission
FAGS	Federation of Astronomical and Geophysical Data Analysis Services	IPCC	Intergovernmental Panel on Climate Change
FTE	Full Time Equivalent	IUGG	International Union of Geodesy and Geophysics
GCOS	Global Climate Observing System	JCOMM	Joint Technical Commission on Oceanography and Marine Meteorology
GGOS	Global Geodetic Observing System	MSL	Mean Sea Level
GLOSS	Global Sea Level Observing System	NERC	Natural Environment Research Council
GNSS	Global Navigation Satellite System	POL	Proudman Oceanographic Laboratory
GOOS	Global Ocean Observing System	UKCIP	UK Climate Impacts Programme
GPS	Global Positioning System	T/P	TOPEX/Poseidon
IAG	International Association of Geodesy	WMO	World Meteorological Organization