

## Permanent Service for Mean Sea Level (PSMSL)

<http://www.psmsl.org>

*Director: Lesley J. Rickards (UK)*

### Overview

The Permanent Service for Mean Sea Level (PSMSL) is based at the National Oceanography Centre (NOC, formerly Proudman Oceanographic Laboratory (POL)) on the campus of Liverpool University in the UK. For many years it has been a member of the Federation of Astronomical and Geophysical Data Analysis Services (FAGS) and operates under the auspices of the International Council for Science (ICSU).

The PSMSL was established in 1933 by Joseph Proudman who became its first Secretary. Thus 2008 marked the 75th anniversary of the founding of PSMSL. To celebrate this milestone, PSMSL organised or co-organised three meetings: gathering experts to discuss continuing research into sea level during a special Interdivision Session at the European Geophysical Union General Assembly, co-sponsoring the Geological Society's William Smith Meeting, "Observations and Causes of Sea-Level Changes on Millennial to Decadal Timescales" and organizing "Liverpool, Home of Sea Level Science: Sea Level Rise and Climate Change", a one-day session at the British Association Festival of Science in Liverpool.

The primary aim of the PSMSL is providing the global data bank for long term sea level information from tide gauges. PSMSL has continued to increase its efforts in this regard and over the last 4 years over 7000 station-years of data were entered into the PSMSL database, increasing the total PSMSL data holdings to over 60000 station-years. In addition, the PSMSL, together with the British Oceanographic Data Centre (BODC), are responsible for the archive of delayed-mode higher-frequency sea level data (e.g. hourly values and higher frequency) from the Global Sea Level Observing System (GLOSS) core network. Approximately 1400 site years of high-frequency delayed-mode were received during the period June 2007 to April 2011.

The entire PSMSL data set is available from the new website: [www.psmsl.org](http://www.psmsl.org), which was launched on 1<sup>st</sup> April 2010. The redevelopment of the website, along with a redesign of the underlying PSMSL database, aims to facilitate the ease of accessing and exploring the data held by PSMSL. In addition the GLOSS web pages ([www.gloss-sealevel.org](http://www.gloss-sealevel.org)) have been completely modernised and updated.

The PSMSL has been closely involved in the development of a sea level network in Africa (through the Ocean Data and Information Network for Africa – ODINAfrica - project). This has included delivery of sea level hardware for a number of stations in Africa and the western Indian Ocean. Currently eleven tide gauges have been installed in Africa and the Indian Ocean with the real-time data transmitted to the IOC Sea Level Station Monitoring Facility ([www.ioc-sealevelmonitoring.org](http://www.ioc-sealevelmonitoring.org)), and the delayed-mode quality controlled 15 minute data with documentation are available for download from the Africa and Western Indian Ocean Sea Level Data section of the GLOSS web-site.

The PSMSL and NOC have investigated the use of the Inmarsat BGAN (Broadband Global Area Network) system for real-time transmission of tide gauge data from remote stations, and

especially for data of interest for tsunami warning. BGAN has the potential to improve the speed of tsunami warnings, and therefore to save lives.

PSMSL staff have continued to be active in a variety of international meetings, working groups, conferences and workshops including IOC GE-GLOSS and IOC Coordination Groups for tsunami warning systems, IPCC, GGOS, WCRP, and EGU over the last 4 years. In addition, they have answered many enquires relating to sea level and have appeared on radio and television discussing aspects of sea level change. Short training courses have been run at PSMSL, in cooperation with NOC, for technicians and visitors taking part in the IOC Indian Ocean Tsunami Warning System (IOTWS) fellowship scheme. The former Director of the PSMSL, Dr Philip Woodworth was awarded the EGU Vening Meinesz medal for distinguished research in geodesy in 2010, in part for his contribution to PSMSL.

## Activities

### 1. Introduction

The Permanent Service for Mean Sea Level (PSMSL) is based at the National Oceanography Centre (formerly Proudman Oceanographic Laboratory (POL)) on the campus of Liverpool University in the UK. For many years it has been a member of the Federation of Astronomical and Geophysical Data Analysis Services (FAGS) and operates under the auspices of the International Council for Science (ICSU).

As a result of the Priority Area Assessment on Data and Information in 2004, ICSU is reorganizing FAGS and the World Data Centre System. This takes into account the recommendations of the *ad hoc* Strategic Committee on Scientific Information and Data which were approved by the ICSU General Assembly in October 2008. An ICSU World Data System will be established and to smooth the way a FAGS-WDC Transition Team was formed, with Dr. Philip Woodworth, the previous PSMSL Director and FAGS Secretary, as a member. Dr. Lesley Rickards is a member of the more recently formed World Data System Scientific Committee. Methods of accreditation to the WDS have been established and the PSMSL will apply to become a member of that new System in 2011.

The PSMSL was established in 1933 by Joseph Proudman who became its first Secretary. Thus 2008 marked the 75th anniversary of the founding of PSMSL. To celebrate this milestone, PSMSL organised or co-organised three meetings: gathering experts to discuss continuing research into sea level during a special Interdivision Session at the European Geophysical Union General Assembly, co-sponsoring the Geological Society's William Smith Meeting, "Observations and Causes of Sea-Level Changes on Millennial to Decadal Timescales" and organizing "Liverpool, Home of Sea Level Science: Sea Level Rise and Climate Change", a one-day session at the British Association Festival of Science in Liverpool.

PSMSL has continued to provide strong support to the Global Sea Level Observing System (GLOSS) and to related projects such as the Ocean Data and Information Network for Africa (ODINAfrica). It has provided advice and assistance to a large number of people with interests in sea level science, thereby fulfilling its overall obligations as a FAGS Service. Finally, and most importantly, it has redoubled its efforts in its primary aim of providing the global data bank for long term sea level information from tide gauges.

In September 2008, the PSMSL Advisory Board met in Liverpool. Members of PSMSL staff provided an overview of current and planned activities including restructuring of the database to bring it up to modern standards, a new web-site, and development of a wider range of scientific and practical products.

## **2. Staffing and funding**

In April 2007, there was a change of PSMSL Director from Dr. Philip Woodworth to Dr. Lesley Rickards. Dr. Rickards has been responsible for the GLOSS Delayed-mode Sea Level data bank and until recently was chair of the International Oceanographic Data and Information Exchange (IODE) programme of the IOC. Dr Woodworth remains closely involved with PSMSL and together with Drs. Simon Holgate and Svetlana Jevrejeva, makes up the main PSMSL scientific staff concerned with the collection and analysis of monthly mean sea level data. In the same month, Dr Mark Tamisiea joined the PSMSL. He contributes primarily to links between PSMSL and geodetic and geophysical programmes (e.g. GGOS), to the provision of geophysical information in PSMSL web pages, and to analysis of sea level data which requires geophysical insight. Mrs. Kathy Gordon continues to be responsible for management of the mean sea level data set. In February 2008, Dr Andrew Matthews joined the PSMSL staff. He is contributing to clearing the backlog of GLOSS delayed-mode high frequency data, re-structuring the database and improving data delivery and provision of new tools to aid data input, quality control and reporting.

Alongside the monthly mean sea level data collection, the PSMSL, together with BODC, is responsible for an archive of delayed-mode higher-frequency sea level data from the GLOSS network. This activity has so far included Miss Elizabeth Bradshaw and other colleagues in the British Oceanographic Data Centre (BODC).

Funding continues to be provided by the UK Natural Environment Research Council (NERC, the parent body of NOC); this has seen a modest expansion for the current five year period. A major aspect of that application was the merger as far as possible of the PSMSL and GLOSS delayed-mode activities. The proposal was graded as “alpha-5”, the highest possible, which provided a clear way forward. During 2010 a document was prepared by PSMSL for NERC as part of its review of National Capability to aid future funding decisions. The document highlights PSMSL’s unique role and the synergy generated by its co-location with NOC.

## **3. PSMSL Data Receipts for the period 2007 to 2010**

The primary aim of the PSMSL is providing the global data bank for long term sea level information from tide gauges. Data are carefully quality controlled. Where possible, data for each station are reduced to a common datum, known as the Revised Local Reference (RLR), which ensures they are suitable for use in research quality time series analysis.

PSMSL has continued to increase its efforts in this regard and between 2007 and 2010 over 7000 station-years of data were entered into the PSMSL database, increasing the total PSMSL data holdings to approximately 60000 station-years of monthly and annual mean sea level from about 2050 stations, supplied by 200 authorities worldwide. Most data originated from Europe and North America, including the Arctic. However, large data sets were also obtained from Asia, Australasia and southern Africa (see Figures 1 and 2). Major gaps in data receipts persist in other parts of Africa which are receiving special attention through ODINAfrica (see section 4.4 below), where data are beginning to flow.

Revised monthly sea level data for 18 tide gauge stations in Russian Arctic were downloaded from the Arctic and Antarctic Research Institute (Russia) website, covering the period 1950 to 1990. These new time series from the official data authority have replaced the existing records. Additional data from 1991 to 2009 have also been added to the PSMSL data set.

In addition, PSMSL has received historical monthly mean sea level data for four new locations in Russian Arctic. Some of these records span more than 50 years, including Polyarniy (1906-1990), the earliest observation in the Arctic region. The three other stations are Burgino, Mys Pikshueva, and Teriberka. PSMSL is grateful to project team of the International Polar Year project “Long-term Sea Level Variability in the Nordic Seas (LEVANS)” for providing the data to PSMSL. This project ran from 2007-2009 and was funded by the Research Council of Norway and included the Norwegian Polar Institute and the Arctic and Antarctic Research Institute (Russia).

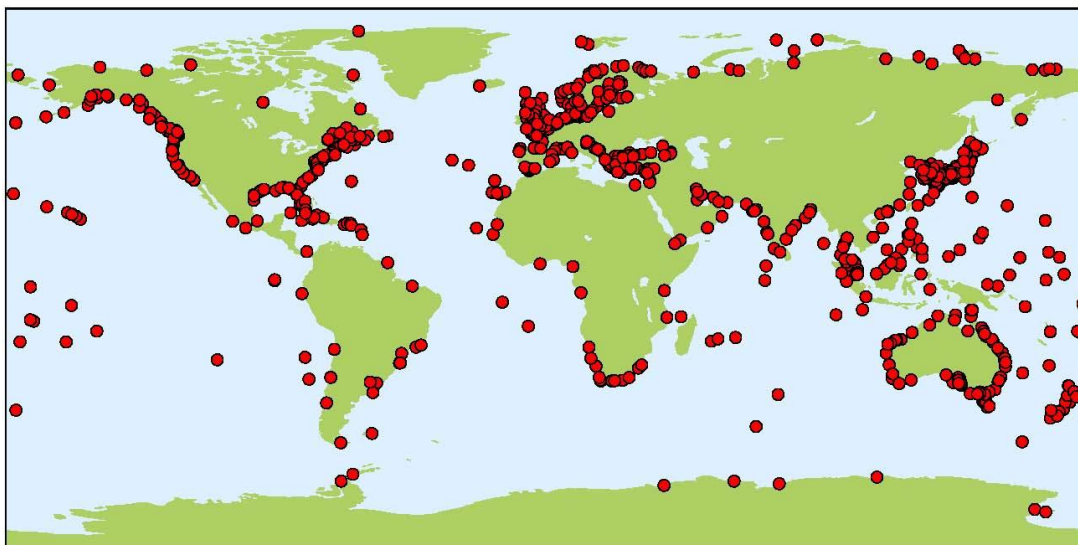


Figure 1: New PSMSL data received between 2007 and 2010

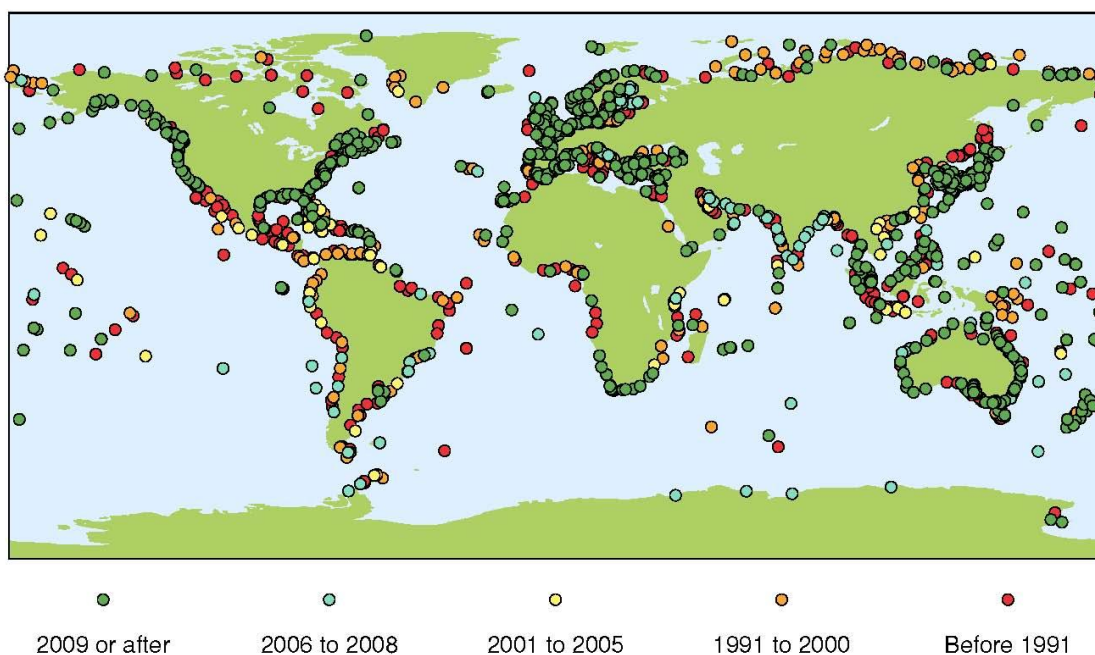


Figure 2: Year of most recent data received by PSMSL

Although data have been contributed from across the globe, large gaps in the network still exist in Africa, Asia and South America, especially for long time series (e.g. over 50 years). Consequently, the Southern Hemisphere is heavily under represented. Series of over one hundred years in length are found almost exclusively in Europe and North America.

Africa is particularly poorly represented, with only two continental time series over 50 years long. In the past thirty years, there has been a gradual decline in the number of stations providing data to the PSMSL. All regions have seen a decline in contributions, but the decrease has been particularly apparent in South America (see the red line in Figure 3).

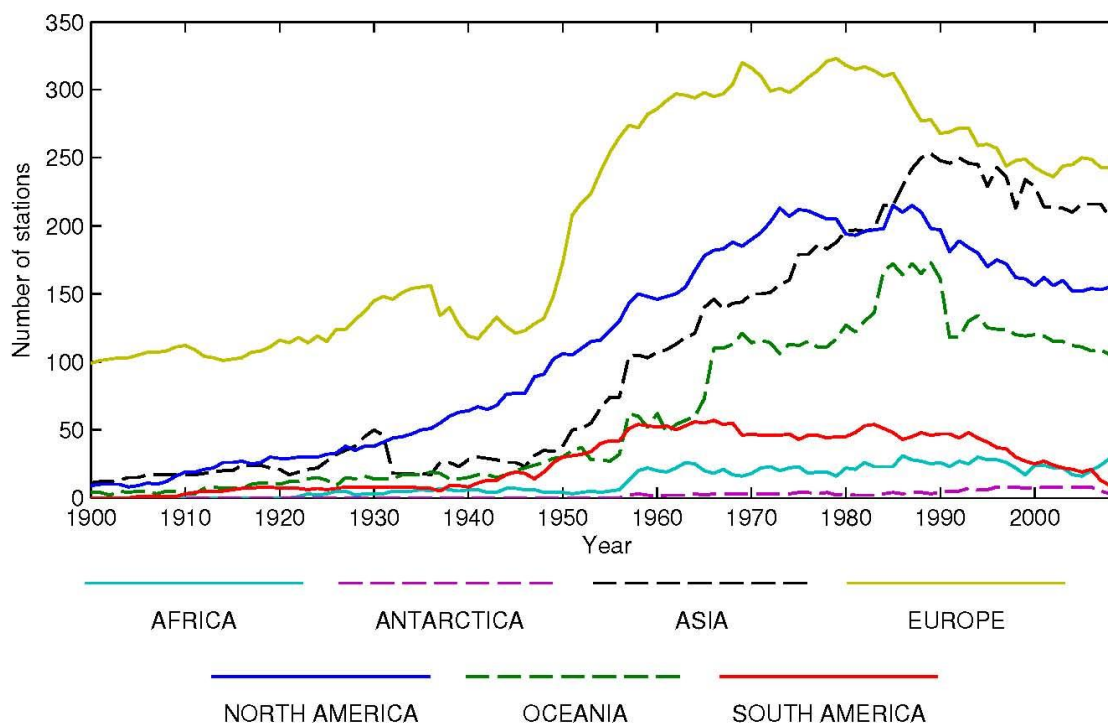


Figure 3: Regional distribution of data held by the PSMSL

#### 4. New PSMSL web-site

The entire PSMSL data set is available from the new website: [www.psmsl.org](http://www.psmsl.org), which was launched on 1<sup>st</sup> April 2010. The redevelopment of the website, along with a redesign of the underlying PSMSL database, aims to facilitate the ease of accessing and exploring the data held by PSMSL.

Each station now has its own dedicated web page, displaying metadata, documentation, a location map and data plots, as well as links to obtain the station time series. The data files on the website are updated every Wednesday morning, allowing users prompt access to the latest PSMSL data.

The PSMSL is also developing interactive products to allow website users to explore the PSMSL data set more easily. The website currently includes a KML file that allows the RLR catalogue to be imported into Google Earth.

New products soon to be launched will allow the user to explore the PSMSL data set interactively. The first wave of these will allow the user to examine sea level trends.



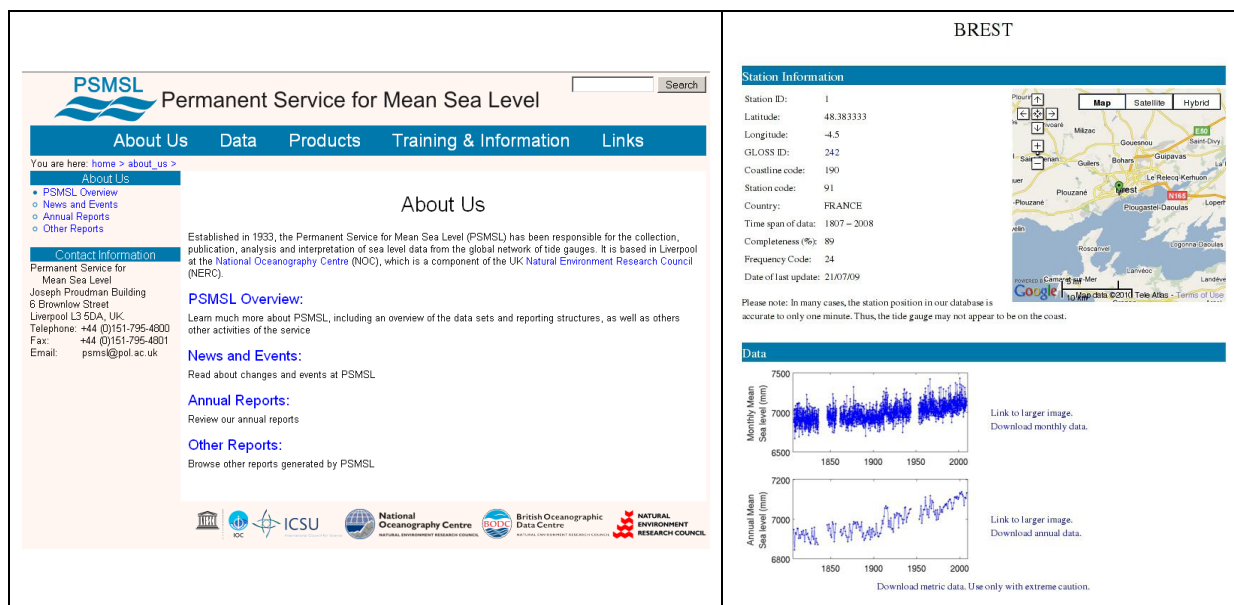


Figure 4: New PSMSL web-site: Home page (left) and individual station page (right)

### 3. Delayed Mode High Frequency (DM HF) Data Receipts for June 2007 - April 2011

The PSMSL and BODC are responsible for the archive of delayed-mode higher-frequency sea level data (e.g. hourly values and higher frequency) from the GLOSS core network of 290 stations. This activity builds on the earlier work carried out as the Delayed-mode Sea Level Data Assembly Centre (DAC) for the World Ocean Circulation Experiment (WOCE). Following the successful completion of WOCE, the Delayed-mode Sea Level DAC was designated a GLOSS Archive Centre. Approximately 1400 site years of high-frequency delayed-mode were received during the period June 2007- April 2011, adding to the 5000 site years already held.

Once again data have been received from some important data sparse regions. The data from ODINAfrica gauges described below are being added to the data set. The Polar Regions are also an area of interest where there are few tide gauges. There has been data submitted from the new gauge at Thule, in Greenland, as well as more recent data from other more established Greenland gauges.

There has been a complete revision of the historic South African tide gauge dataset, with some sites having over 45 years worth of data. There was also a submission of more recent data from the region. Portugal also submitted long time series, with the GLOSS station of Funchal (Madeira) having nearly 50 years worth of data. Further updates have been received from Australia, Canada, Japan, UK and USA.

## 4. GLOSS Activities

### 4.1 New GLOSS Web Site

The GLOSS web pages ([www.gloss-sealevel.org](http://www.gloss-sealevel.org)) have been completely modernised and updated. The GLOSS Station Handbook has also been revised and updated and has been merged with the GLOSS web-site. New material has been added to the GLOSS web pages including training material and national reports from the GLOSS Group of Experts meetings (GE-GLOSS-X and GE-GLOSS-XI). Much of the information text has been reviewed and revised. A new page providing quality controlled data from ODINAfrica and the Indian

Ocean has been added. The web-site continues to be maintained by the PSMSL and BODC on behalf of GLOSS.

#### ***4.2 GLOSS Status from a PSMSL Viewpoint (December 2010)***

For a number of years, the PSMSL has provided an annual summary of the status of the GLOSS Core Network (GCN) from its viewpoint. During 2010 the latest revision of the GLOSS Core Network has been agreed with 289 stations included. Twenty-two new stations have been added and 23 removed. As the new stations are operational and providing data, this has improved the status of the network (65% of the stations are category 1, having reported their data from 2006 or more recently to PSMSL). However, although improvements to the network, some following on from the considerable investments being put into sea level recording in Africa and in the Indian Ocean following the Sumatra tsunami, will feed through to status improvement in the coming years, further work is still required to develop the network further in order that all stations can be Category 1. A review of its status as of December 2010 can be found at the above GLOSS web-site.

#### ***4.3 GLOSS Training Courses and IOC Indian Ocean Tsunami Warning System fellowships***

GLOSS training courses have been held in many countries since the mid-1980s. In May 2007 PSMSL organised a short training course at POL for technicians from Egypt, Germany and Iran which was most useful preparation for the recent tide gauge installations.

In 2007 PSMSL also hosted two visitors under the IOC Indian Ocean Tsunami Warning System (IOTWS) fellowship scheme. These were Dr. E.M.S. Wijeratne from the National Aquatic Resources Research and Development Agency (NARA) in Sri Lanka and Mr. D. Sundar from the National Institute of Oceanography in India. This was followed in 2008 by a further three visitors under the same Fellowship scheme: Mr Naimatullah Sohoo from the National Institute of Oceanography, Pakistan, Dr Parluhutan Manurung from National Coordinating Agency for Surveys and Mapping (BAKOSURTANAL), Indonesia and Mr Rene Ibara from Pointe Noire, Republic of Congo.

#### ***4.4 New GLOSS and ODINAfrica Tide Gauges***

Improvements have been made to the African network in the past ten years. Between 1960 and 2000, there were roughly equal numbers of stations from the islands around Africa, stations in South Africa, and stations from other countries around the African coastline. Most of the improvement in the African network in the past ten years has been due to an increase in the number of island stations. The number of continental stations dropped sharply in the early 2000s, but efforts of programmes such as ODINAfrica have increased the number of available stations to pre-2000 levels.

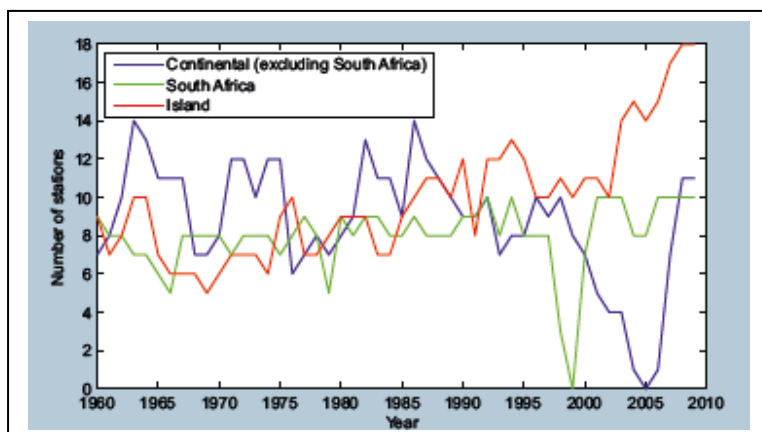


Figure 5: African stations available in the PSMSL data set, and their availability over the past fifty years

The PSMSL has been closely involved in the delivery of sea level hardware for a number of stations in Africa and the western Indian Ocean, particularly in the frame of the ODINAfrica project. Currently eleven tide gauges have been installed in Africa and the Indian Ocean. These are: Aden (Yemen), Alexandria (Egypt), Chabahar (Iran), Djibouti (Djibouti), Inhambane (Mozambique), Karachi (Pakistan), Nouakchott (Mauritania), Pemba (Mozambique), Pointe Noire (Republic of Congo), Port Sonara (Cameroon) and Takoradi (Ghana). All of these gauges are currently providing data to the real-time Sea Level Station Monitoring Facility ([www.ioc-sealevelmonitoring.org](http://www.ioc-sealevelmonitoring.org)) operated by the Flanders Marine Institute (VLIZ), Belgium, and delayed-mode quality controlled 15 minute data with documentation are available for download from the Africa and Western Indian Ocean Sea Level Data section of the GLOSS web-site. PSMSL is moving towards devising effective methods for maintenance and assurance of data flow from the newly installed sites.

## **5. BGAN Satellite Transmission**

The PSMSL and NOC, Liverpool, took a major interest in 2006 in the use of the Inmarsat BGAN (Broadband Global Area Network) system for real-time transmission of tide gauge data from remote stations, and especially for data of interest for tsunami warning. This telemetry enables always-on broadband internet connections to tide gauges, providing higher bandwidth and reduced latency in data transfer than available at present by systems such as Meteosat. Inmarsat have been very helpful in providing test equipment.

In December 2007, Dr. Philip Woodworth attended a ceremony at Inmarsat headquarters in London which included the signing of an agreement between IOC and Inmarsat for the use of the Inmarsat BGAN system in the IOTWS. The use of BGAN in this way had been suggested by PSMSL and other NOC, Liverpool, staff (notably Dr. Simon Holgate, Mr. Peter Foden and Mr. Jeff Pugh) and subsequently demonstrated in a series of tests. BGAN has the potential to improve the speed of tsunami warnings, and therefore to save lives.

## **6. European and other international projects**

### ***6.1 Tsunami Projects***

PSMSL staff contributed to UK-organised tsunami warning activities (e.g. for the UK Defra ministry), European Union ones (TRANSFER) and those coordinated under the auspices of the IOC (e.g. Indian Ocean (IOTWS) and North East Atlantic and Mediterranean (NEAMTWS) Tsunami Warning Systems). These activities have included leading a survey of European sea level infrastructure leading to a report that includes the technical requirements for detecting tsunamis, studies of optimum networks and hardware and modelling of tsunami propagation. PSMSL also contributed to the IOC Global Meeting of the Intergovernmental Coordination Groups for Tsunami Warning Systems held in Paris in March 2009.

### ***6.2 European Projects***

The PSMSL took the lead, with the Danish Meteorological Institute (DMI), in initiating a web page for real time sea level data from the European Atlantic coastline ([www.sleac.org](http://www.sleac.org)). In addition, it took part in an IOC study group on access to real time data from across Europe. The PSMSL continues to provide input to the European Sea Level Service (ESEAS) through its Governing Board and has also contributed proposals to the Chair of the ESEAS Governing Board through which the delivery of delayed mode sea level data from the region can be placed on a more reliable basis. Subsequently funding has been secured and an ESEAS Data Portal developed which is currently undergoing testing.



## 7. Publications

The PSMSL has a responsibility to not only collect and redistribute sea level information, but also to analyse data and publish scientific results. The main papers published each year are listed in PSMSL Annual Reports.

In order to assess the usage of PSMSL and its data, a search has been carried out for the number of occurrences of PSMSL in the scientific literature since the year 2000. The histograms below illustrate (i) the number of "papers" published in each year and (ii) the number of citations for papers that were published in a given year (i.e. not the number of citations per year). Of the 504 references to PSMSL since 2000, there are 425 that count as books or papers which have, in total, been cited 5481 times between them. This is equivalent to an h-factor of 35. It is also worth noting that in the IPCC Fourth Assessment Report, references for Chapter 5, Observations: Oceanic Climate Change and Sea Level, includes 28 references which use the PSMSL dataset.

Year	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	Totals
Papers	19	31	35	24	39	47	47	36	72	58	17	<b>425</b>
Citations	633	1029	500	329	846	676	610	339	445	63	9	<b>5541</b>

Table 1: PSMSL related papers and citations

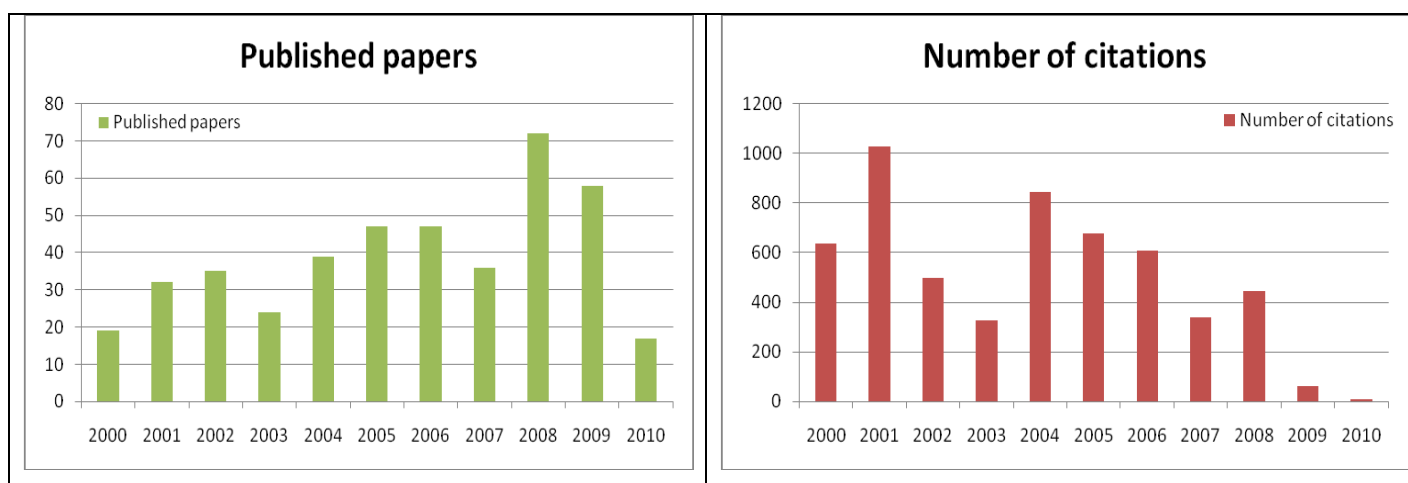


Figure 6: PSMSL related papers and citations

Note: "Number of citations" shown for a given year are the citations of papers published in that year, not the year that the citing paper was published. This is not the true citation profile through time.

## 8. PSMSL-Related Scientific Meetings, Activities and Events

PSMSL staff have continued to be active in GE-GLOSS meetings and workshops and GGOS meetings over the last 4 years, co-convended sea level sessions at the EGU and contributed to IOC coordination groups tsunami warning system meetings. In addition, PSMSL staff attended an international meeting in February 2011 organised by the World Climate Research Programme focusing on regional rather than global sea level variability.

PSMSL contributes to the IPCC not only through the provision of data but also with direct scientific input. Dr Philip Woodworth was a lead author on the sea level chapter of the 3<sup>rd</sup> Assessment Report and a contributing author to the 4<sup>th</sup> Assessment Report. In addition, papers by PSMSL staff were cited in the 4<sup>th</sup> Assessment Report. PSMSL staff contributed to the IPCC meeting on sea level and cryosphere held in Malaysia in 2010 and Dr Svetlana

Jevrejeva will be a lead author on the 5<sup>th</sup> Assessment Report, with other PSMSL staff also contributing.

PSMSL undertook the task of electronically scanning and converting to pdf form the historical IAPO and IAPSO reports that are in the NOC Liverpool library. This covers all of the reports from 1 to 35, with the exception of number 21. This work is now complete and the pdf files have been passed to Professor Rodhe, Secretary General, IAPSO.

The former Director of the PSMSL, Dr Philip Woodworth was awarded the EGU Vening Meinesz medal for distinguished research in geodesy in 2010, in part for his contribution to PSMSL. He was also awarded the Member of the Order of the British Empire (MBE) "For service to Science" in the 2011 New Year's Honours list. PSMSL staff have worked alongside engineers and technologists at NOC undertaking real-time telemetry which has been adopted by the IOC as the basis for the Indian Ocean Tsunami Monitoring System IOTWS: this work has received the Denny medal (awarded by the Institute of Marine Engineering Science and Technology, IMarEST) and was highly commended by the Institution of Engineering and Technology (IET) and the North West Regional Development Agency (NWRDA) in their North-West Innovation Awards of 2009.

## **9. Summary**

It can be seen that the last four years have been a further active period with regard to important workshops and conferences, and a busy one with regard to data acquisition and analysis. The functions provided by the PSMSL are in as much demand as ever, and several successful events were organised to celebrate the 75th anniversary of the Service in 2008. The PSMSL database has been restructured, new software tools developed, and a new web-site launched with improved data dissemination. Particular thanks as usual go to PSMSL staff and to colleagues at the National Oceanography Centre and British Oceanographic Data Centre who contribute part of their time to PSMSL activities.