

## Permanent Service for Mean Sea Level (PSMSL)

<http://www.pol.ac.uk/psmsl>

*Director: Lesley J. Rickards (UK)*

### Overview

The Permanent Service for Mean Sea Level (PSMSL) is based at the 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 in 2008 PSMSL celebrated its 75th anniversary. To mark this milestone PSMSL organised two major symposia. The first was a session “Observations and Causes of Sea Level Change: A Session to Mark the 75th Anniversary of the Permanent Service for Mean Sea Level (PSMSL)” at the EGU 2008 General Assembly in Vienna in April, which attracted a large number of papers and posters, and the second at the British Association Science Festival in September. This latter meeting entitled “Liverpool, Home of Sea Level Science: Sea Level Rise and Climate Change” with distinguished speakers from the UK and abroad, was held in Liverpool, designated the European Capital of Culture for 2008. PSMSL also partially sponsored The Geological Society of London’s William Smith meeting “Observations and Causes of Sea-Level Changes on Millennial to Decadal Timescales”.

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 during 2007 and 2008 over 4000 station-years of data were entered into the PSMSL database, increasing the total PSMSL data holdings to over 57000 station-years. Although data receipts were a little below average in 2007, 2008 saw a large increase compared to the norm of recent 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 750 site years of high-frequency delayed-mode were received during the period June 2007 to April 2009.

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. In 2006 the PSMSL and POL took a major interest 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.

Subsequently, in December 2007, Dr. Philip Woodworth attended a ceremony at Inmarsat headquarters in London which included the signing of an agreement between the Intergovernmental Oceanographic Commission (IOC) and Inmarsat for the use of the BGAN system in the Indian Ocean Tsunami Warning System (IOTWS). BGAN allows return of real-time data from almost anywhere on earth and thus has the potential to improve the speed of tsunami warnings and to save lives. The value of this has been recognised with two awards: the prestigious Denny Medal from the Institute of Marine Engineering, Science and Technology (IMarEst) and a “Highly Commended” award from the UK Institution of Engineering and Technology, Innovation Awards 2009 (North West).

## Activities

### 1. Introduction

The Permanent Service for Mean Sea Level (PSMSL) is based at the 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 re-organizing 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 has been formed, with Dr. Philip Woodworth, the previous PSMSL Director and FAGS Secretary, as a member. Dr. Lesley Rickards will be a member of the newly formed World Data System Scientific Committee. However, as far as PSMSL is concerned, there should be little change in function.

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, the PSMSL organised two major symposia. The first was a session “Observations and Causes of Sea Level Change: A Session to Mark the 75th Anniversary of the Permanent Service for Mean Sea Level (PSMSL)” at the EGU 2008 conference in Vienna in April, which attracted a large number of papers and posters, and the second at the British Association Science Festival in September. This latter meeting entitled “Liverpool, Home of Sea Level Science: Sea Level Rise and Climate Change” with distinguished speakers from the UK and abroad, was held in Liverpool, designated the European Capital of Culture for 2008. In addition, PSMSL partially sponsored The Geological Society of London’s William Smith meeting “Observations and Causes of Sea-Level Changes on Millennial to Decadal Time-scales”.

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 (the parent body of POL); 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 (both at Liverpool and both delayed-mode, although technically one within POL and one within BODC). The proposal was graded as 'alpha-5', the highest possible, which provided a clear way forward.

### 3. PSMSL Data Receipts for 2007 and 2008

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 during 2007 and 2008 over 4000 station-years of data were entered into the PSMSL database, increasing the total PSMSL data holdings to over 57000 station-years. Although data receipts were a little below average in 2007, 2008 saw a large increase compared to the norm of recent years. Most data originated from Europe and North America. However, large data sets were also obtained from Asia, Australasia and southern Africa (see Figures 1a and 1b). Major gaps in data receipts persist in other parts of Africa which are receiving special attention through ODINAFRICA (see section 4.4 below).

The figures 2 (a) and (b) below show (a) the all of the stations that have contributed to the PSMSL and (b) the year of the most recent data received from each site.

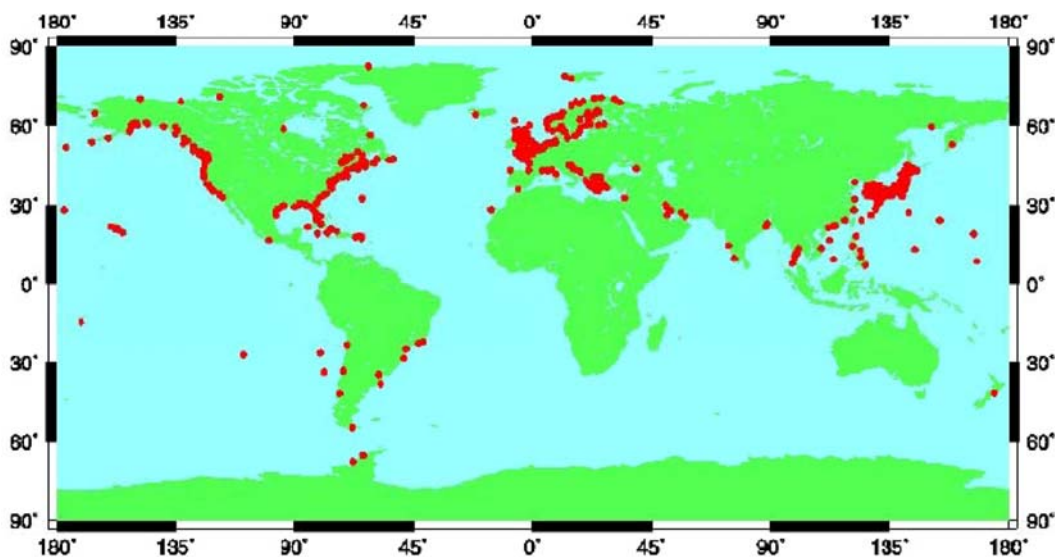


Figure 1a: New PSMSL data for 2007

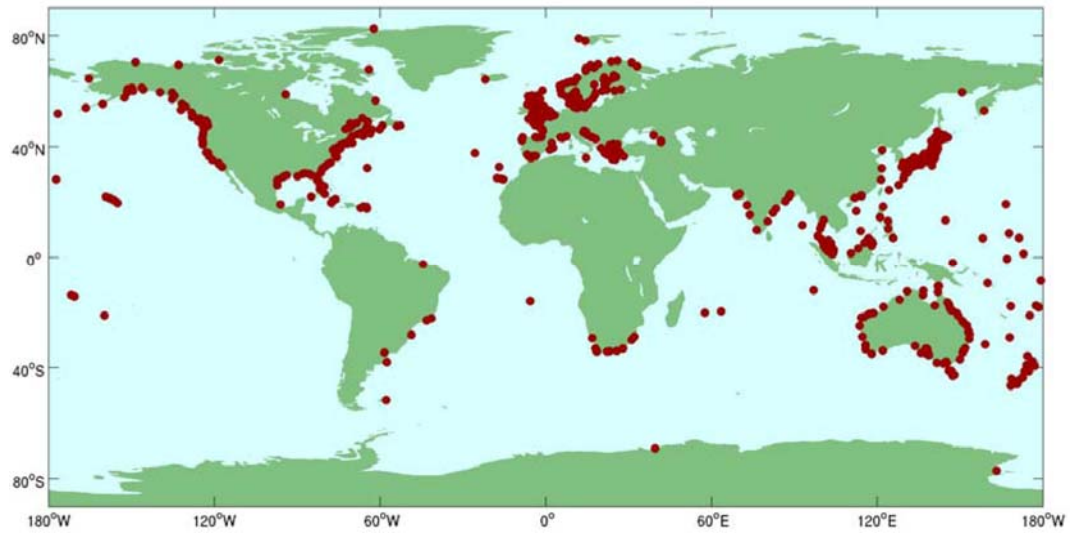


Figure 1b: New PSMSL data for 2008

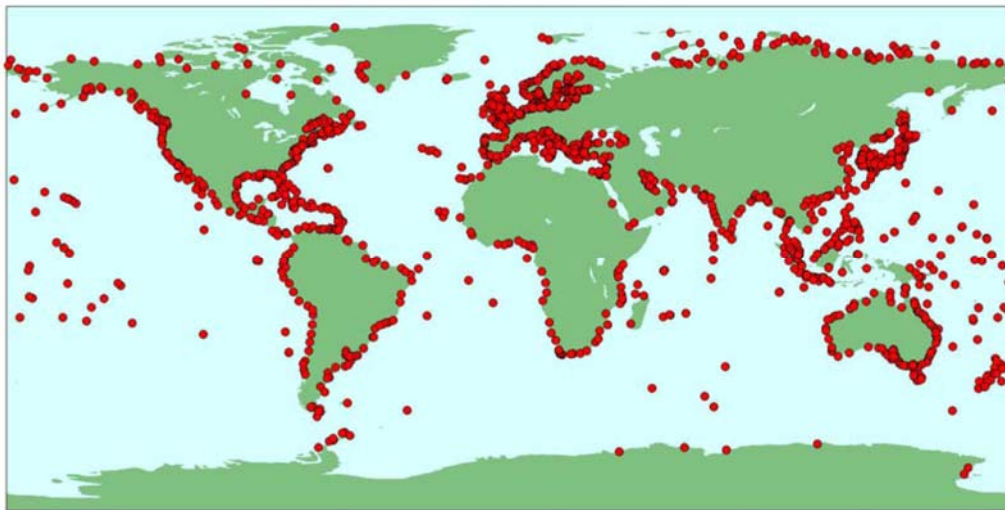


Figure 2a: Stations providing data to PSMSL

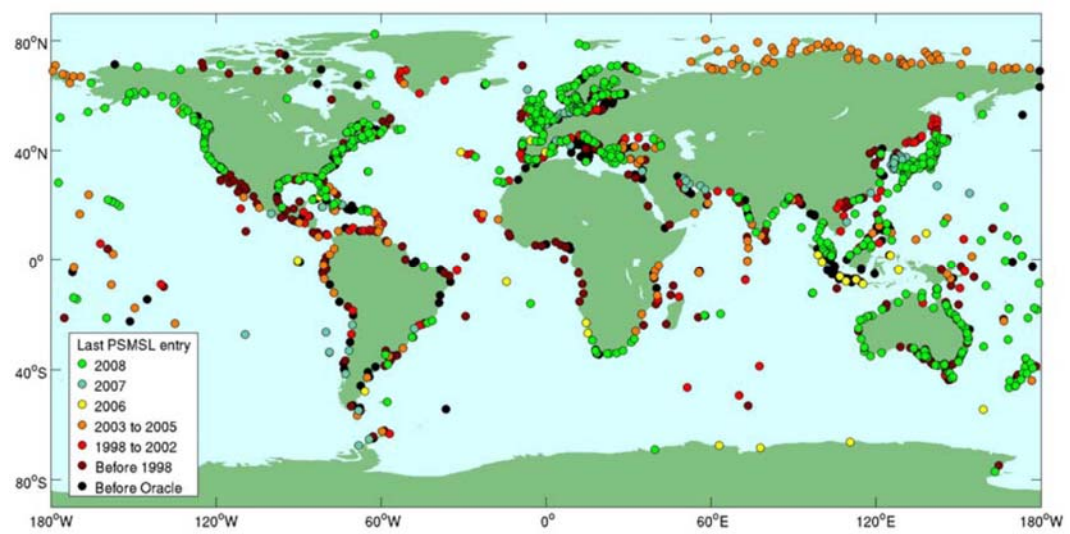


Figure 2b: Year of most recent data received by PSMSL

#### 4. Delayed Mode High Frequency (DM HF) Data Receipts for 2007-2009

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 750 site years of high-frequency delayed-mode were received during the period June 2007- April 2009, adding to the 5000 site years already held.

Once again data have been received from important data sparse regions. Six gauges that form part of the ODINAFRICA network have supplied over a year's worth of quality controlled data. 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, and 2008 been the latest year supplied.

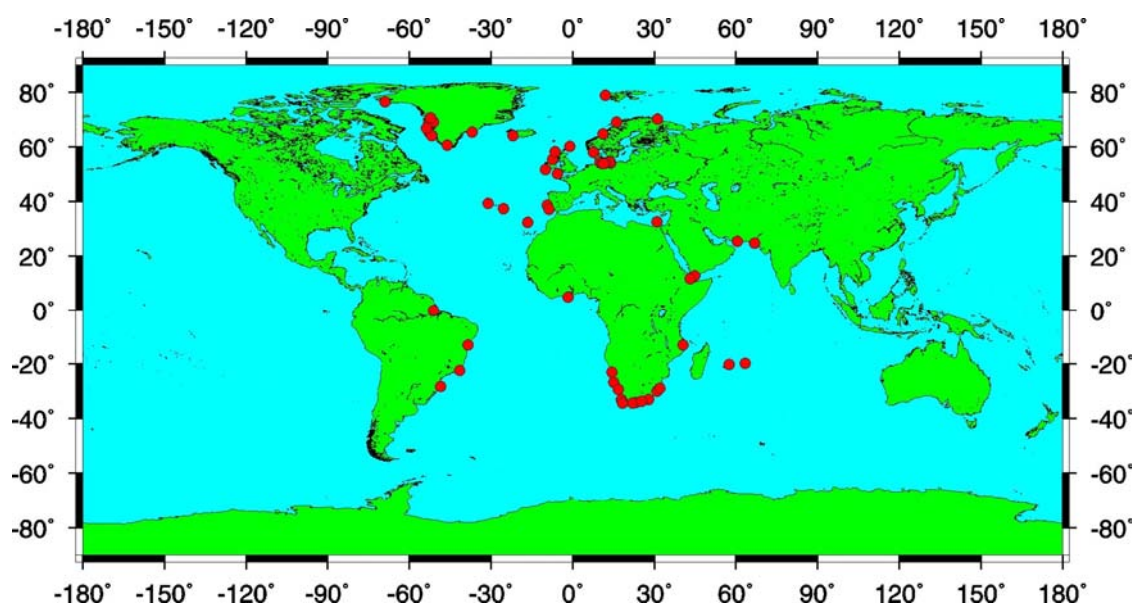


Figure 3: New DM HF Data received from mid-2007 to mid-2009

#### 5. GLOSS Activities

##### 5.1 New GLOSS and PSMSL Web Sites

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 GLOS 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.

The current PSMSL web site ([www.pol.ac.uk/psmsl](http://www.pol.ac.uk/psmsl)) was launched in 2007 with a revised home page and the addition of a section with commentaries on the interpretation of long sea level records. Plans are now underway for a completely redesigned PSMSL web-site a new structure and simpler navigation with improved data delivery.

### ***5.2 GLOSS Status from a PSMSL Viewpoint (October 2008)***

For a number of years, the PSMSL has provided an annual summary of the status of the GLOSS Core Network (GCN) from its viewpoint. A review of its status as of October 2008 can be found at the above GLOSS web-site. 2007 showed a modestly improvement compared to that a year ago, but 2008 showed a decrease in the Category 1 stations which needs to be addressed. 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.

### ***5.3 GLOSS Training Courses and IOC Indian Ocean Tsunami Warning System (IOTWS) 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 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.

### ***5.4 New GLOSS and ODINAFRICA Tide Gauges***

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. Currently eleven tide gauges have been installed in Africa and the Indian Ocean. These are: Aden (Yemen), Chabahar (Iran), Djibouti (Djibouti), Karachi (Pakistan), Inhambane (Mozambique), Lagos (Nigeria), Nouakchott (Mauritania), Pemba (Mozambique), Pointe Noire (Republic of Congo), Port Sonara (Cameroon) and Takoradi (Ghana). Eight 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. PSMSL is moving towards devising effective methods for maintenance and assurance of data flow from the newly installed sites. A new data logger and replacement batteries have been dispatched and should resolve the problems at the two sites. Delayed-mode quality controlled 15 minute data with documentation are available for download from the GLOSS web-site from Aden, Chabahar, Djibouti, Karachi, Pemba and Takoradi. Inhambane and Nouakchott will be added soon.

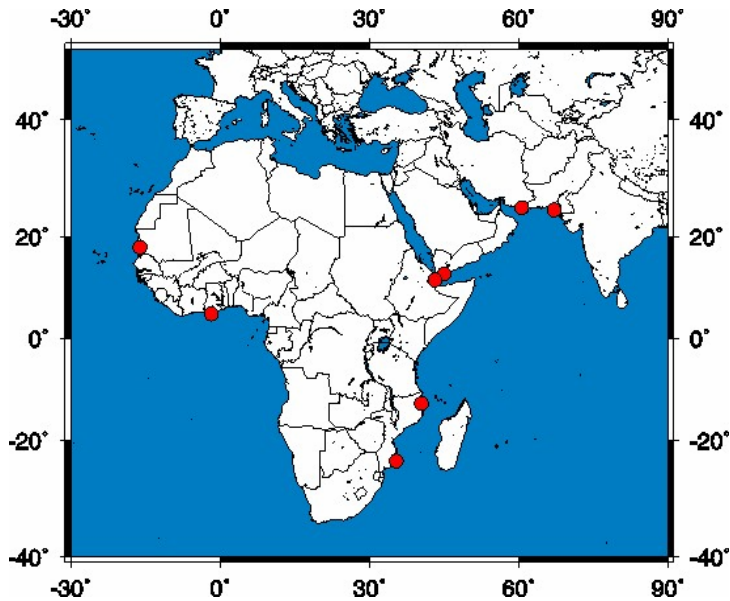


Figure 4: African and Indian Ocean tide gauges on the GLOSS web-site

## 6. BGAN Satellite Transmission

The PSMSL and POL 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 POL 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.

Over the last few years the PSMSL and POL have taken a major interest 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. Work carried out has been described in the sections above. 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.

The usefulness of this has been recognised as four PSMSL and POL scientists (Simon Holgate, Peter Foden, Jeff Pugh and Philip Woodworth) were awarded the prestigious Denny Medal from the Institute of Marine Engineering, Science and Technology (IMarEst) for their paper entitled 'Real time sea level data transmission from tide gauges for tsunami monitoring and long term sea level rise observations' published in the Journal of Operational Oceanography Volume 1 Number 1. In addition, they have also received a "Highly Commended" award at the UK Institution of Engineering and Technology, Innovation Awards 2009 - North West for their tsunami monitoring system, enabling the return of real-time data from almost anywhere on earth.



Figure 5: POL scientists receive their commendation. From the left: Clive Deadman of United Utilities and Denise Massey of EA Technology; Philip Woodworth, Simon Holgate, Jeff Pugh and Peter Foden from POL and Malcolm Sarsted of Unilever (chair of judging panel).

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

### **7.1 *Tsunami Projects***

PSMSL staff are contributing to UK-organized 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, studies of optimum networks and hardware and modelling of tsunami propagation. PSMSL also contributed to the IOC Global Meeting of the Inter-governmental Coordination Groups for Tsunami Warning Systems held in Paris in March 2009.

### **7.2 *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.

## **8. 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.



## **9. Visitors to the PSMSL 2007 - 2008**

Visitors welcomed to the PSMSL in 2007 and 2008 included David Dixon (Plymouth, UK), Dr. Hans von Storch (GKSS, Germany), Dr. Rolf Weisse (GKSS, Germany), Dr. Thorkild Aarup (IOC), Dr. Rui Manuel da Silva Fernandez (Portugal), Drs. Norman Teferle and Richard Bingley (University of Nottingham, UK), Sir David Wallace (Isaac Newton Institute, Cambridge, UK), Prof. Afranio Rubens de Mesquita (University of Sao Paulo, Brazil), Prof. Roland Gehrels (Plymouth University, UK), Drs. Marta Marcos and Mikis Tsimplis (National Oceanography Centre, Southampton, UK), Drs. Carl Wainman and Sanette Gildenhuis (Institute for Maritime Technology, South Africa), Dr. Siobhan O'Farrell (Bureau of Meteorology, Australia), representatives of the Miros tide gauge company, Mikhail Karpytchev, Mélanie Becker, Thomas Gouriou and Nicholas Poivreau (University of La Rochelle, France), Graham Alcock (New Zealand), Dr. David Pugh (UK), Dr. Matt King (Newcastle University, UK), Alexander Rabinovich (NOAA, USA), Anton Felder (OTT Germany), Prof. Gary Mitchum (University of South Florida), Dr. Per Knudson (DTU Space, Denmark) and Prof. Richard Peltier (University of Toronto, Canada).

## **10. Summary**

It can be seen that the last two 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. Particular thanks as usual go to PSMSL staff and to colleagues at the Proudman Oceanographic Laboratory and British Oceanographic Data Centre who contribute part of their time to PSMSL activities.