PSMSL Report for GE/GLOSS-XII

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1. Introduction

This report reviews briefly the work of the Permanent Service for Mean Sea Level (PSMSL) during 2009-2011. In this period, the PSMSL has continued with its main duty, of banking monthly mean sea level data from tide gauges for the scientific community. In addition, it has taken a major role in the development of the Global Sea Level Observing System (GLOSS), provided training and support for tide gauge operators and the community at large, and has contributed to important international working groups and conferences on climate change and geophysics.

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 Prof. 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 is applying to become a member of that new System in 2011.

PSMSL has continued to provide strong support to the Global Sea Level Observing System (GLOSS) and to 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 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.

2. Staffing and funding

Lesley Rickards continues as the Director of the PSMSL. The main PSMSL scientific staff concerned with the collection and analysis of monthly MSL data are Philip Woodworth, Simon Holgate, Svetlana Jevrejeva and Mark Tamisiea. Kathy Gordon continues to be responsible for management of the mean sea level data set and Andrew Matthews has worked on re-structuring the database, improving data delivery and provision of new tools to aid data input, quality control and reporting.

Alongside the monthly MSL collection, the PSMSL together with British Oceanographic Data Centre (BODC), is responsible for an archive of delayed-mode higher- frequency sea level data from the GLOSS network. This activity has so far included Elizabeth Bradshaw and other colleagues in the 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 2009 to 2011

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 2009 and 2011 over 6250 station-years of data were entered into the PSMSL database, increasing the total PSMSL data holdings to approximately 60700 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 6.4 below), where data are beginning to flow.

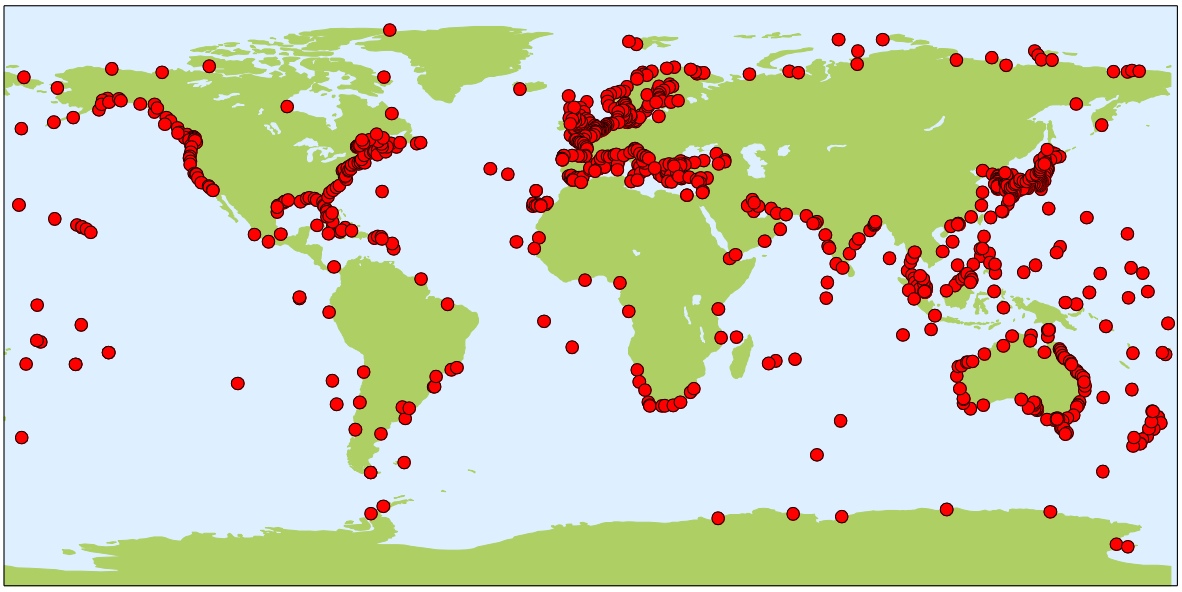

Figure 1: New PSMSL data received between 2009 and 2011

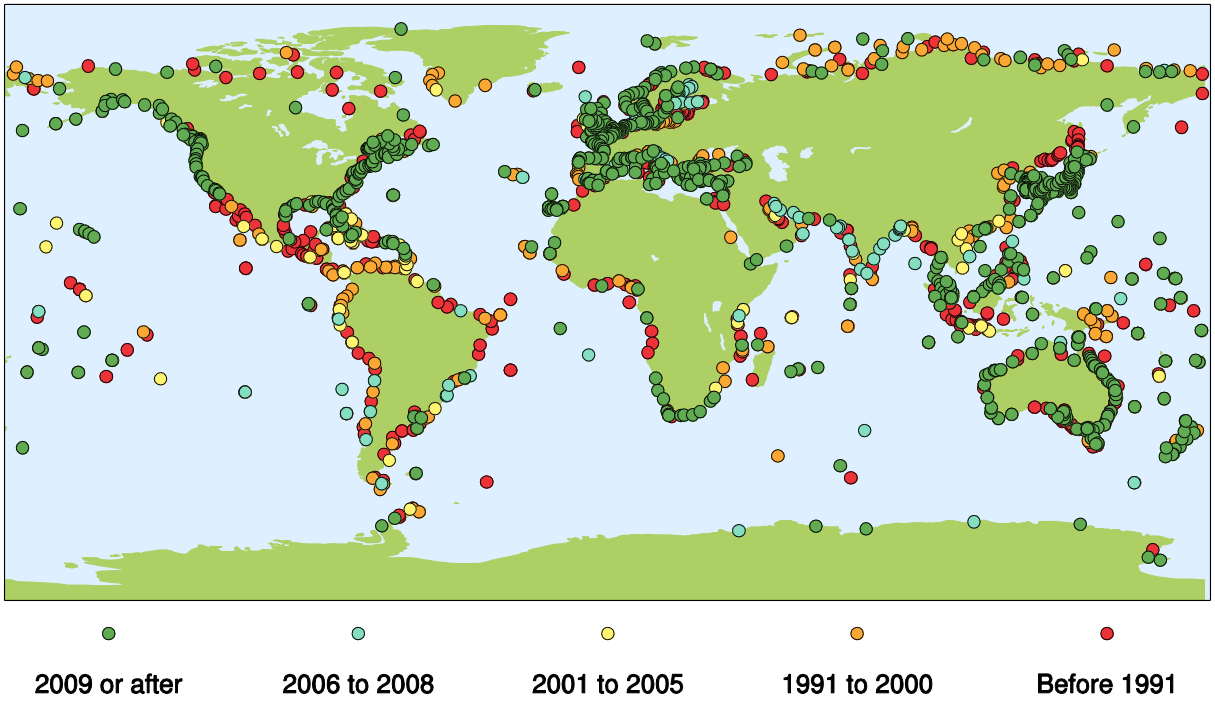

Figure 2: Year of most recent data received by PSMSL

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).

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).

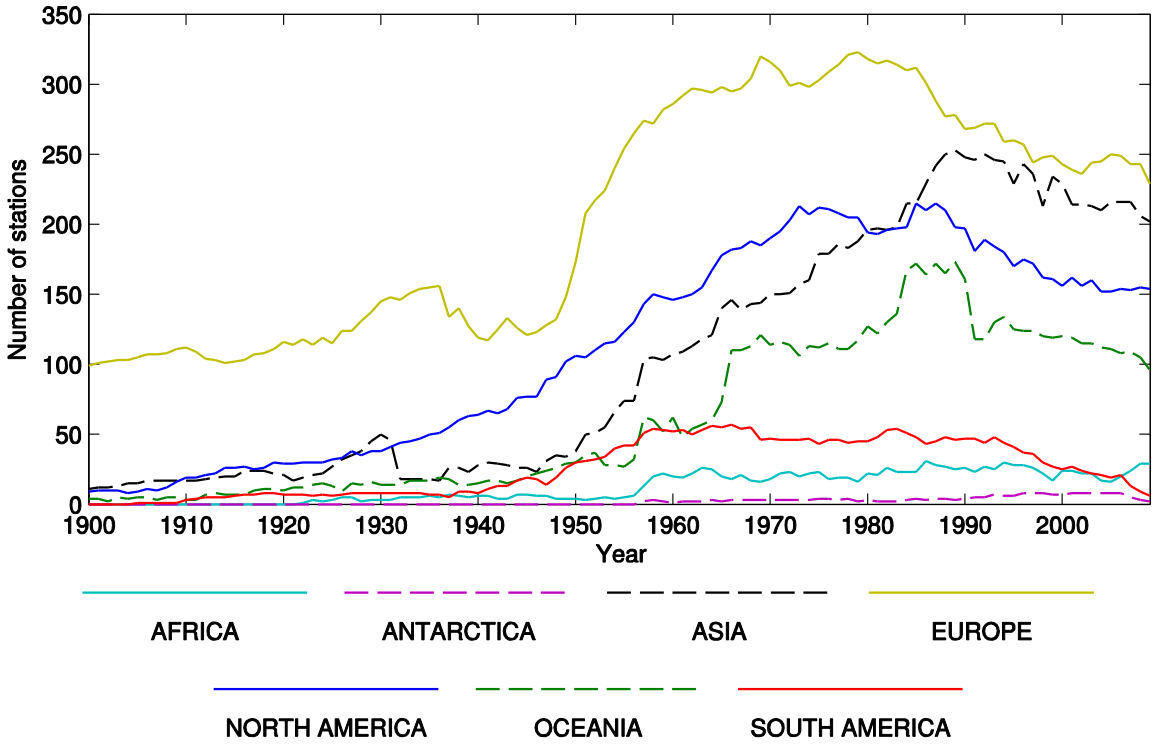

Figure 3: Regional distribution of data held by the PSMSL

4. New PSMSL web-site

The entire PSMSL data set is available from the new website: www.psmsl.org, which was launched on 1st 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. Two new products recently launched allow the user to explore changes to sea level as observed by tide gauges. The anomalies map demonstrates how sea level varies from year to year when compared the long-term average at that site, calculated over the period from 1960 to 1990. Moving the slider along the time line shows how sea level can vary by over 20 cm from year to year at some locations.

On loading the page the background trend at each tide gauge is not removed. Thus, a majority of the early years are dominated by blue colours showing negative anomalies and the later years by red colours showing positive anomalies as the average global sea level rises. There are notable exceptions to this pattern, however. For example, the land surrounding the Gulf of Bothnia is uplifting as the earth continues to recover from the collapse of the large ice sheets that covered

the region during the last ice age. This causes sea level measured by tide gauges to decrease. Thus, the anomalies in that region go from red to blue over the time span of the data. The background trend can be removed at each site.

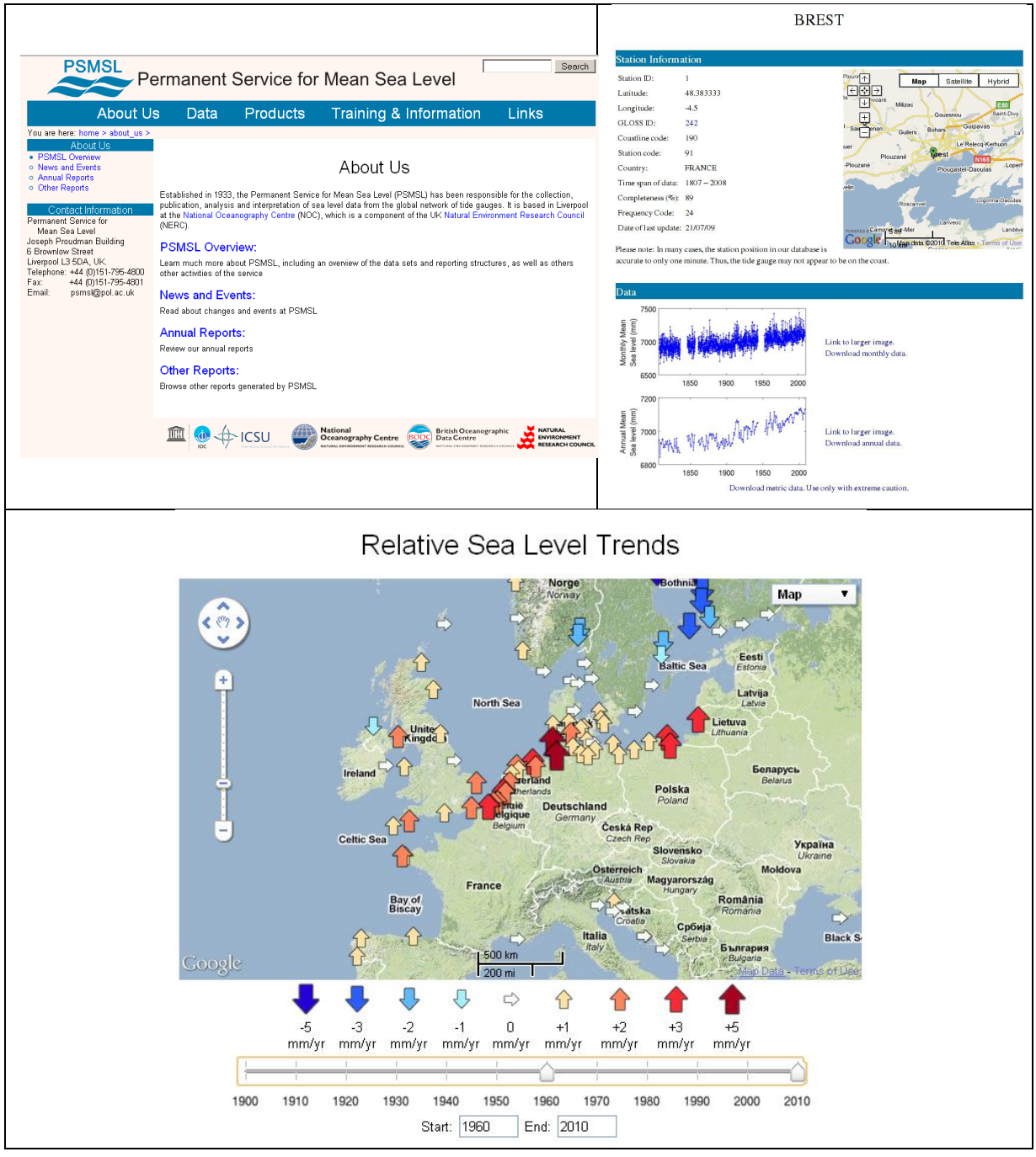

Figure 4: New PSMSL web-site: Home page (top left), individual station page (top right) and relative sea level trend explorer (bottom).

The second tool explores the trends in relative sea level from the tide gauge data at the PSMSL. One can examine the trends over different periods of time by sliding the start and end markers.

One interesting aspect to note is the geographic sampling of the data. By choosing the entire time span, 1900-2010, the lack of data covering this period in the Southern Hemisphere and western Pacific can be observed. More data are available if the start date is moved up to 1950, but unfortunately there is still a lack of geographic coverage in the Southern Hemisphere.

5. Delayed Mode High Frequency (DM HF) Data Receipts for 2009 - 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 289 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 800 site years of high-frequency delayed-mode were received during the period 2009 - 2011, adding to the 5500 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. Data have been 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.

6. GLOSS Activities

6.1 GLOSS Web Site

The GLOSS web pages (www.gloss-sealevel.org) have been updated as required. The GLOSS Station Handbook has also been revised and is being updated to reflect the new definition of the GLOSS Core Network. New material has been added to the GLOSS web pages including training material, national reports from the last GLOSS Group of Experts meeting (GE-GLOSS-XI), national reports from training courses, and other relevant reports received by the GLOSS Technical Secretary. New quality controlled data from ODINAfrica and the Indian Ocean tide gauges have been added periodically to the dedicated Africa and Western Indian Ocean sea level data page. Links to data from all of the GLOSS data streams are also available. Future developments include improving the access to data from the GLOSS data streams and in particular improved online access to the GLOSS Core Network delayed-mode high frequency data set archived at BODC. The web-site continues to be maintained by the PSMSL and BODC on behalf of GLOSS.

6.2 GLOSS Status from a PSMSL Viewpoint (November 2011)

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 were category 1 at the end of 2010, 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. The map below (Figure 5) shows the current status as of 4 November 2011, which is similar to the 2010 status. However, as further data sets are expected in November and December, this will be updated at the end of the year and then posted on the web-site together with a summary of the status.

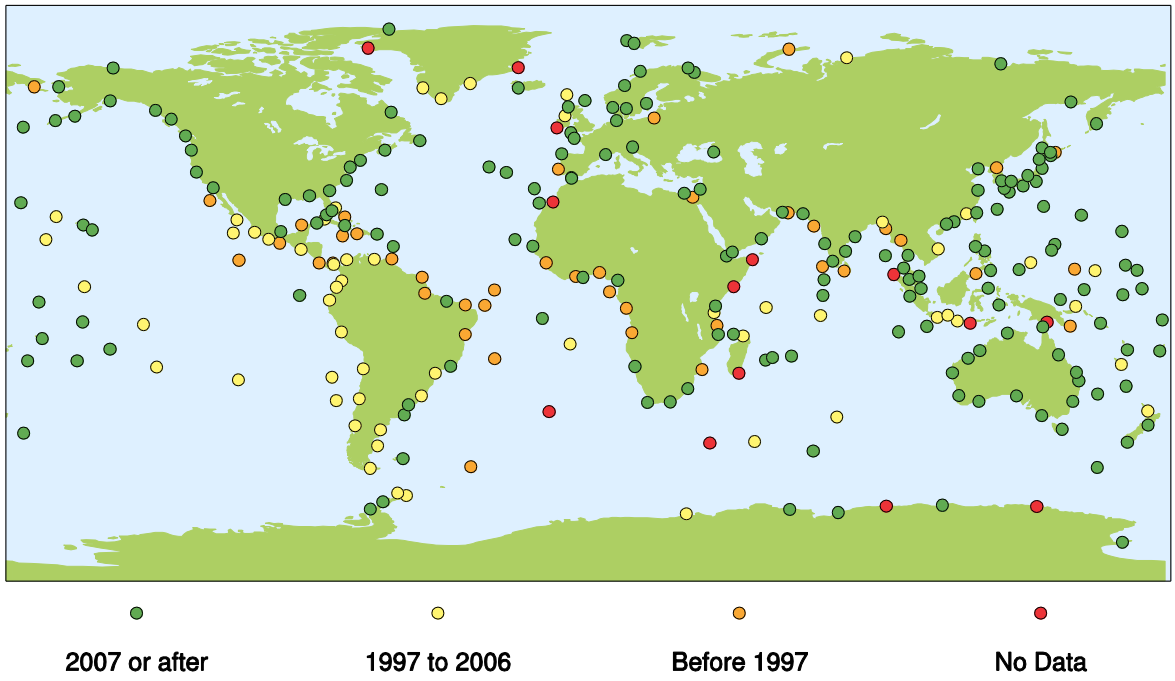

Figure 5: Status of the GLOSS Core Network from a PSMSL perspective

6.3 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; many organised by PSMSL in collaboration with IOC and GLOSS. More recently, PSMSL has organised a number of short training courses at PSMSL/NOC under the IOC Indian Ocean Tsunami Warning System (IOTWS) and Europe Africa Marine Earth Observation Network (EAMNet) Fellowship programmes. Most recently (summer 2011) PSMSL has hosted visitors from Kenya (Joseph Amollo, Kenya Meteorological Office) and Nigeria (Adesina Adegbie, Nigerian Institute for Oceanography and Marine Research).

6.4 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 the efforts of programmes such as ODINAfrica have increased the number of available stations to pre-2000 levels as shown in Figure 6.

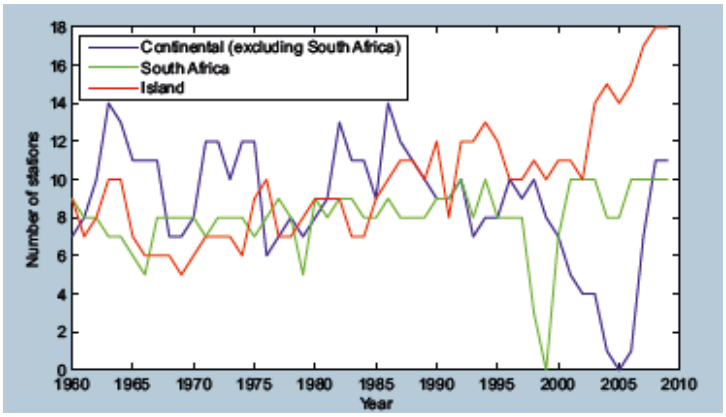

Figure 6: African stations available in the PSMSL data set, and their availability over the past fifty years

The PSMSL has been closely involved in the delivery of sea level hardware and technical support 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). Most of these gauges are currently providing data to the real-time Sea Level Station Monitoring Facility (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.

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 (Figure 7) 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. 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	**425**
Citations	633	1029	500	329	846	676	610	339	445	63	9	**5541**

Table 1: PSMSL related papers and citations

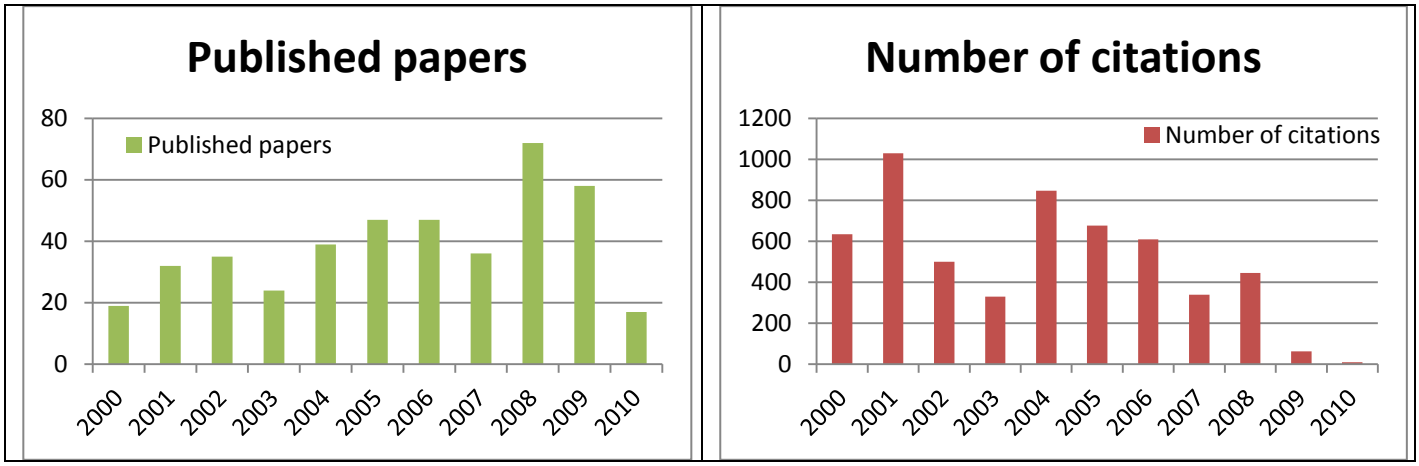

Figure 7: PSMSL related papers and citations

[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, the Global Geodetic Observing System (GGOS), the European Geophysical Union (EGU, convening sea level sessions) and other meetings and workshops. 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. Prof. Philip Woodworth was a lead author on the sea level chapter of the 3rd Assessment Report and a contributing author to the 4th Assessment Report. In addition, papers by PSMSL staff were cited in the 4th 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 5th 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. Those reports directly relevant to PSMSL, containing the first published compilations of monthly and annual mean sea level data, are available from the PSMSL web-site (www.psmsl.org/about_us/other_reports/iapso.php).

The former Director of the PSMSL, Prof. 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 was awarded the Member of the Order of the British Empire (MBE) "For

service to Science" in the 2011 New Year's Honours list. Lesley Rickards and Philip Woodworth were amongst 43 recipients of 50th Anniversary Commemorative Medals from the IOC on 22 June 2011. Medals were awarded, as part of the IOC 50th Anniversary celebrations, to those deemed to have made a substantial contribution to the work of IOC. In its citation, IOC says that recipients "...are decorated for their exemplary dedication to the IOC, for their devotion to the IOC mission and for their continuing support to IOC activities." In addition, Lesley Rickards was appointed a Fellow of the International Association of Geodesy (IAG) at the IAG General Assembly in July 2011.

During the IUGG meeting in Melbourne (28 June-7 July 2011), the IAPSO Commission on Mean Sea Level and Tides (CMSLT) elected new officers. Gary Mitchum of the University of South Florida is the new president, and Simon Holgate of the PSMSL and National Oceanography Centre PSMSL is the new vice-president.

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. Dr Simon Holgate, Mr Peter Foden, Mr Jeff Pugh and Prof. Philip Woodworth were awarded the Denny medal (awarded by the Institute of Marine Engineering Science and Technology, IMarEST) for this work which was also 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 three 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 PSMSL regularly convenes a sea level session at the EGU. 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.