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The Global Sea Level Observing System

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Introduction

THE subject of long term changes in global sea level due to climate change receives a lot of publicity because of the potential impacts on the environmental, economic and social infrastructure at the coast. According to the recent Intergovernmental Panel on Climate Change (IPCC) Third Assessment Report, global sea level increased within the range 10-20 cm during the last century, and could increase within the range 9-88 cm during the next, with a central estimated value of 48 cm. It is important to realise that many of the longest records of sea level at our disposal did not originate from 'scientific' studies, but were the by-product of measurements made for other purposes, notably harbour operations and navigation. Many of the great ports of the world have long sea level records stemming from the 19th century if not before: Amsterdam, Liverpool, New York, San Francisco, Bombay and Sydney are just a few examples. These records are now of great importance to sea level change studies.

The GLOSS Programme

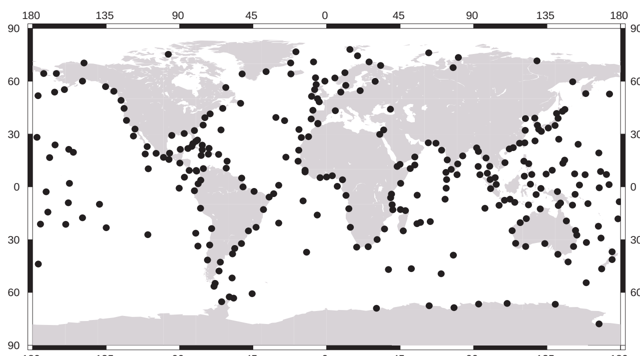
In the 1980s, the Intergovernmental Oceanographic Commission (IOC) initiated a programme called the Global Sea Level Observing System (GLOSS). While many countries had donated (and continue to donate) their sea level data on a regular basis to the global sea level data bank (called the Permanent Service for Mean Sea Level, PSMSL), GLOSS was established to develop the worldwide network of tide gauges on a more professional basis with, as far as possible, common high standards for hardware and data transmission, and, consequently, common high standards for the resulting data sets. This development was analogous to the construction many years ago of coordinated global networks for meteorology with data shared between all participating national agencies.

GLOSS has now reached a level of development which can to some extent be considered a plateau. The GLOSS Core Network of approximately 280 stations around the world (Figure 1) is approximately two-thirds in place. However, there are important gaps in some regions, the most obvious being those for which access is difficult such as Antarctica. In addition, there are extensive parts of Africa, South America and Asia where help is required to complete the network. That is why we need once again the help of organisations such as the Association of Ports and Harbours, together with related national agencies such as Hydrographic Offices, if the network is to develop further.

It is important to realise that sea level data are not required simply for long term Mean Sea Level change studies. Sea level data have many applications in what is sometimes called 'operational oceanography'. For example, GLOSS has established a 'Fast Centre' at the University of Hawaii through which we are attempting to establish a route for the transmission of data from gauges to international data banks within a few days. These data can then be used by oceanographers, together with data from satellites (Figure 2), within ocean numerical models in order to predict 'ocean weather' in analogous fashion to the use of air pressure and wind data within operational weather forecasts.

Sea level data also have a wide range of regional, national and local (e.g. port) applications. That is why the GLOSS programme has worked to effectively densify the Core Network in certain regions. For example, there are sub-programmes in the Pacific,

Fig 1. GLOSS Core Network defined by GLOSS97



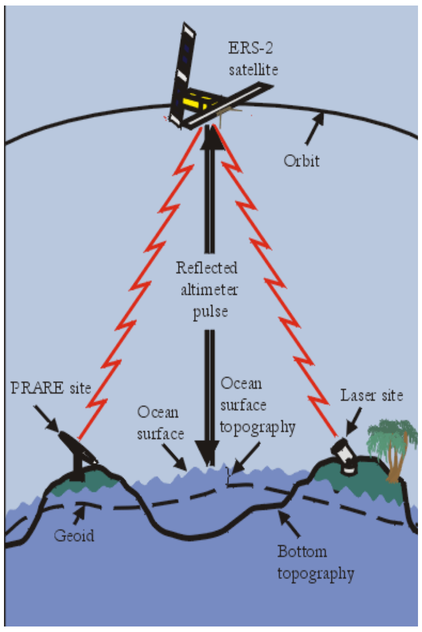


Fig 2. Schematic Showing the complementarity between measurements of sea level from space (the ERS-2 satellite rader altimeter in this case) and from tide gauges

Caribbean and Mediterranean which have a greater number of gauges than the average of the Core Network because of their particular oceanographic requirements. At the national levels, many countries have networks for flood warning from storm surges and share those data at a regional level with their neighbours. And, of course, at the local level nearly all ports have some kind of system in place to measure sea level for their own operations. Such a system may range from a modern digital sea-level recorder which displays the measurements in real-time and records the observations on a computer, to a traditional analogue system that records observations on a paper chart from which it is possible to digitise the observations if required.

A purpose of this article is to ask for the help of the Association in ensuring that, whenever gauges are installed, consideration is giving to the potential multiple usage of the data. That may mean that hardware installed might be more expensive than the port was considering initially. However, the same data should then be exploitable by a wider range of users, which should lead to cost savings and efficiency gains overall. The same gauge data might then be used in real-time for:

- The provision of operational sea level data to ships entering or leaving harbour
- The delivery of data to storm surge and tsunami warning systems
- The management of sluices and barrages

In addition, the same data can be used in delayed mode for:

- The determination of tidal constituents for application to tidal prediction
- The computation of 'extreme levels' (the probabilities of exceeding given levels in terms of 'return period') for input to coastal engineering design including work on sea defences and port development
- The wide range of scientific studies including those of long-term changes of Mean Sea Level and the statistics of extremes for insurance purposes.

All of these applications interact to some extent. For example, a global sea level rise will impact the growing population in the coastal zone, with the most serious impacts including increased coastal erosion, restriction of run-off, salinisation of estuaries, and increased risk of coastal flooding. At present, this is mostly a 'scientific' study. However, it will clearly have very practical application as time progresses. A second example concerns the rapid development of models of the ocean (temperature, salinity, currents, water quality etc.) which assimilate sea level measurements along with other parameters to provide the most reliable forecasts. These modelling products may in a few years become standard operational tools with, for example, currents made available to vessel traffic service centres and as navigational overlays on electronic chart systems.

It is clear that we have to monitor sea level changes in order to provide the necessary real-time information for operational purposes, and also to derive the long-term scientific insight by which we may understand better how the ocean works, and thereby make predictions on different time scales. That is what the GLOSS programme is trying to do.

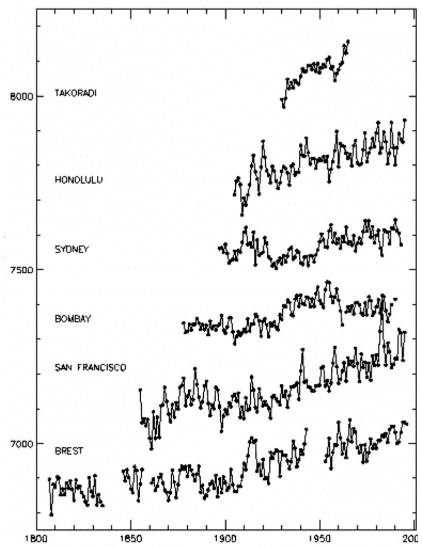


Fig 3. Long sea level records from each continent: Takoradi, Ghana (Africa), Honolulu (Pacific), Sydney (Australia), Bombay (India), San Francisco (USA) and Brest (France). Each record has been offset vertically for presentation purposes. Observed trends for the twentieth century are 3.1, 1.5, 0.8, 0.9, 2.0 and 1.3 mm/year respectively. The effect of postglacial rebound as simulated by the Peltier ICE-3G model is less than or of the order 0.5 mm/year at each site. Trends for the next century are estimated by the IPCC to be several times larger.

Requests to Ports and Harbours

There are several ways in which ports and harbours and other national agencies can contribute to the enhancement of the GLOSS Core Network and its sub-networks.

Upgrade and Renovation of Tide Gauges -

As mentioned above, sea level measurements in ports and harbours are often required by a wide range of users. The different applications imply different standards: real-time operations such as ship movements demand accuracies of around 0.1 m whereas long-term monitoring of sea level trends (Figure 3) calls for accuracies of order 0.01 m or better. However, in practice there are advantages in making all observations to the highest standards so that the data are available for all applications. The difference in cost between a high quality sea level gauge and a lower quality one is small. Many harbour agencies will in the coming years upgrade and renew their tide gauges. Therefore, we would encourage harbours to aim if possible for replacement by high quality gauges. Advice on types of tide gauge technology is available from the PSMSL Training web page mentioned in the Table.

Data submission -

Each country will have 'GLOSS Contacts' who are people nominated by their Governments to keep in touch with the GLOSS programme (and especially with the GLOSS Technical Secretary at IOC), deliver status reports on their national sea level recording to IOC, and aid the flow of data to international data centres. Consequently, good communication should exist between the Contacts and the people responsible for the gauges in the ports. Data submission to the international data banks such as the PSMSL has always been of great importance in delayed-mode, and near real-time delivery of data for local operational purposes and for delivery to the GLOSS Fast Centre is becoming increasingly more important. Consequently, there are increasing demands on GLOSS Contacts to communicate effectively. The help of port authorities is requested to make national dialogues work as efficiently as possible, so that international communications between Contacts, IOC and data banks can in turn be improved further.

Historical Sea Level Data – Data Archaeology

GLOSS has a particular interest in the continuation of sea level recording at sites with very long historical records whether those sites are formally in the GLOSS Core Network or not. Historical tide gauge data are usually in the form of paper charts and tabulations, and their conversion to modern computer-accessible media is called 'data archaeology'. These data sets are of potential great value to the sea level community in a range of applications, of which the most obvious is the extension of existing sea level time series as far back as possible in order to understand more completely the timescales of sea level change. Information about the extent of historical records is currently being collected by the GLOSS programme, and port authorities are asked to inform GLOSS if they have archives of such information in their organisations. Information may be sent to the GLOSS Technical Secretary in IOC.

Summary

GLOSS operates in the framework of the United Nations (i) to promote the establishment of networks of well-maintained tide gauges, (ii) to facilitate the exchange of sea level data, and (iii) to provide technical and scientific advice on sea level to both governmental and non-governmental bodies. In order to achieve these objectives, GLOSS must work with all other relevant organisations, of which the Association of Ports and Harbours is one example. To summarise the above short note, GLOSS hopes for the continued active participation by ports and harbours to:

- Upgrade as far as possible to high quality tide gauges when renovating national tide gauge networks or individual gauges
- Improve data delivery for GLOSS gauges and
- Help in the identification of historical sea-level data sets

Additional Information on GLOSS and Related Organisations

Global Sea Level Observing System (GLOSS)

Contact:
Intergovernmental Oceanographic Commission (IOC)
UNESCO
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Fax: +33 (0) 145 685812
http://www.pol.ac.uk/psmsl/programmes/gloss.info.html
Email: t.aarup@unesco.org

For more information on GLOSS download a copy of its Implementation Plan via the above web page or contact Dr. Thorkild Aarup via the above email. The same web page also provides a link to various other related reports and data sets concerning GLOSS.

Permanent Service for Mean Sea Level (PSMSL)

http://www.pol.ac.uk/psmsl/
Email: psmsl@pol.ac.uk

The PSMSL is the global data bank for long term sea level change information. Its data bank consists of approximately 50000 station-years of monthly and annual means of sea level. The PSMSL also functions as the long term GLOSS International Archiving Centre. The PSMSL also provides a range of information on its Training Web Page (Information, Reports, Manuals, Tidal analysis software etc.) accessed via the above address.

University of Hawaii Sea Level Center (UHSLC)

http://www.soest.hawaii.edu/UHSLC/
Email: markm@soest.hawaii.edu

The UHSLC hosts the Joint Archive for Sea Level and maintains a Research Quality Data Set of hourly, daily and monthly values of sea level for several hundred stations primarily but not exclusively in the Pacific. The UHSLC is now the nominated GLOSS Fast Centre for the collection and transmission of near-real time data.

Other Sea Level Programmes and Data Sets

See http://www.pol.ac.uk/psmsl/programmes/