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A REPORT ON THE STATUS OF THE GLOSS PROGRAMME AND A PROPOSAL FOR TAKING THE PROGRAMME FORWARD

The Global Sea Level Observing System (GLOSS) has the aim of establishing a Core Network of approximately 300 sea level stations around the world, together with related regional networks, and functional networks for satellite radar altimeter calibration and the monitoring of ocean circulation and long-term sea level trends. This document provides a status report on these activities, measured primarily in terms of data delivered to data centres. The main 'delayed mode' and 'fast' data streams are seen to be operational at approximately the one half and one third level respectively, and the relatively new 'fast' stream is making particularly encouraging progress. However, if significant further progress is to be made, then a more coordinated approach led by IOC is required, and this report includes a proposal for some upgrades and acquisitions of tide gauge equipment to close the observation gaps in the Core Network. The proposed network upgrade should improve the operational status of GLOSS measured by the delayed mode streams by at least 30%, and should approximately double the effective number of sites available in 'fast' mode. It will contribute to the international GLOSS programme from both the 'oceanography and climate' and 'coastal' perspectives'. It has the potential for broadening the ownership of GLOSS itself and of many of the projects within the Global Ocean Observing System (GOOS) which GLOSS contributes to.

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EXECUTIVE SUMMARY

For over a decade, the GLOSS programme has had the aim of establishing a Core Network of approximately 300 stations around the world, together with related regional networks, and functional networks for altimeter calibration (ALT), ocean circulation (OC) and long term trends (LTT). The networks serve scientific research in oceanography and climate change, and provide a 'global baseline' for a range of coastal studies. They form part of the JCOMM observation networks and their sea level data complement those from satellite altimetry and data from other observing systems (Argo, VOS, DBCP etc.).

This document provides a status report on these activities, measured primarily in terms of data delivered to data centres. GLOSS has four main data streams: (1) Mean Sea Level (MSL) data to the Permanent Service for Mean Sea Level (PSMSL), (2) Delayed mode higher frequency data to the University of Hawaii Sea Level Center (UHSLC) or PSMSL (GLOSS Archiving Centres); (3) Fast higher frequency data to UHSLC (GLOSS Fast Centre); (4) GPS data to the TIGA (TIde GAuge) data centre of the International GPS Service. Streams (1-3) are seen to be operational at approximately the one half, one half and one third level respectively, with an increasing number of GPS receivers being installed for stream (4). Although developments are encouraging, they have taken place slowly and, in particular, the delivery of 'fast' data needs to be accelerated for use alongside altimetry in a number of deep ocean (e.g. Global Ocean Data Assimilation Experiment - GODAE) and coastal (e.g. coastal GOOS) operational schemes.

If one studies the report in detail, it is clear that many countries have made major efforts towards GLOSS developments in recent years, while others have not. The latter have under-performed so far for different reasons; of course, we ask that all countries now take action to fulfil commitments to GLOSS in accordance with the Implementation Plan 1997 as endorsed by Member States at previous Assemblies.

However, in our opinion, if significant further progress is to be made, a more coordinated approach led by IOC is also required. Therefore, this report contains a proposal for major investment in:

- 92 new high quality gauges to be installed worldwide (but with some concentration in the southern hemisphere) to complete the GLOSS Core Network (GCN), ALT and OC sets as far as possible. These gauges will all be capable of near real-time ('fast') reporting.
- 30 station upgrades and conversions to real-time reporting.
- Approximately 20 GPS receivers for enhancement to the ALT and OC sets, and to the LTT set in the southern hemisphere.
- Personnel to ensure project management, station maintenance, data transmission and quality control.
- Training courses and materials.
- Web development for global data distribution, much of it in near real-time.

The programme will be overseen from IOC with scientific direction from the GLOSS Group of Experts, OOPC, COOP and other bodies. The PSMSL and UHSLC will play leading roles in its implementation.

The total funding requested amounts to almost US$ 3.5M of which one half are one-off capital and installation costs and one half are annual costs over 3 years.

Unlike many of the other observing systems (ship-based sampling, or ship/air deployed systems), GLOSS is a programme which depends on the active participation of a very large number of Member States, including many developing countries. In that respect, GLOSS has posed a big challenge which has so far been met in some cases and failed completely in others.

The proposed programme should improve the operational status of GLOSS measured by the ‘delayed mode’ streams by at least 30%, and should approximately double the effective number of sites available in ‘fast’ mode. It will contribute to the international GLOSS programme from both the ‘oceanography and climate’ and ‘coastal’ perspectives’. Therefore, it has the potential for broadening the ownership of GLOSS itself and of many of the projects within GOOS which GLOSS contributes to.

1. INTRODUCTION

Sea level is a fundamental parameter in the sciences of oceanography, geophysics and climate change. Changes in observed sea level occur across a wide spectrum from seconds and minutes (wind waves, earthquakes, tsunami), hours to days (tides, storm surges), years (seasonal cycles, El Niño), through to long term changes due to climate change and the slow vertical land movements which are still occurring following the last ice age. Knowledge of sea level gradients is essential for understanding the ocean circulation. Sea level data are of great practical importance to coastal populations in applications such as flood defence and navigation.

The case for monitoring, and understanding, sea level changes need not be made in great detail here again. The literature is replete with prestigious reports on the subject and the reader will undoubtedly be aware of the arguments. However, if we must pick one, consider the Intergovernmental Panel on Climate Change (IPCC) Third Assessment Report. It concluded that global sea level increased at an average rate of 1-2 mm/year during the past 100 years, with some evidence for a small acceleration in the rate of sea level rise between the 19th and 20th centuries. It also concluded that the rate of rise of sea level could increase significantly during the 21st century, tripling or more the rates observed during the past 100 years. Such a rise (of the order of 50 cm) would have major impacts on all coastlines in all countries, rich or poor. This potential rise needs quantifying more much accurately, and part of that objective can be achieved by measuring present day rates of change of sea level and of sea level gradients.

Scientific and practical applications interact in many ways. For example, knowledge of long term sea level rise will need to be input into the engineering design of coastal structures, many of which will have a lifetime of many decades or a century. Insight into the rate of sea level rise may also help in the understanding of complex coastal processes, such as sedimentation and erosion, which may result in high costs. A second example concerns ‘fast’ sea level data assimilation into numerical models (e.g. storm surge, GODAE). Understanding of the correct physics in such models is clearly a ‘scientific’ pursuit. However, once processes are understood, and necessary data are made available, their use is ‘practical’. In all of these scientific and practical applications, the reliable exchange of high-quality data, nationally, regionally and even globally, can improve our ability to predict change on a range of time-scales. This exchange of data and operational experience, within a global programme but with local applications, is something which GLOSS and GOOS actively support and encourage.

If the case for sea level monitoring on a global basis has been made, then it remains only to decide how best to do it and find the necessary resources. In particular, we need to consider the slightly different requirements of global sea level monitoring and ocean circulation change, which are primarily ‘deep ocean’ topics, and those which relate more to coastal seas and to the coasts themselves. The Global Sea Level Observing System (GLOSS) was initiated by IOC with the aims of contributing to both of these areas of interest.

2. BACKGROUND TO GLOSS

GLOSS was conceived in the mid-1980s as a network of tide gauges (sea level stations) around the world, providing the key data needed for international sea level programmes related to oceanography, geophysics and climate change. In particular, the network would improve the quality and quantity of monthly mean sea level (MSL) data provided by countries to the Permanent Service for Mean Sea Level (PSMSL) which had received data from countries for many years but on a rather *ad hoc* and voluntary basis. The network was also envisaged as providing a 'global baseline' around which more dense regional and national networks would be constructed for local and practical purposes. The GLOSS Core Network (GCN), as it came to be known, would be operated with high quality gauges and to common standards, and each country would contribute to the collaborative international programme out of national funds with coordination from IOC. Even though GLOSS is now formally a JCOMM activity, rather than a purely IOC one, the ethos of its organisation remains the same.

By the mid-1990s several things were becoming clear. Firstly, while many gauges were being installed worldwide, particularly for the World Ocean Circulation Experiment (WOCE), some countries were unwilling to provide funds to implement their parts of the GCN, in spite of national commitments made at IOC Assemblies and in spite of their tide gauge specialists having attended one or more of the 20 international GLOSS training courses held since 1983. Secondly, major technological developments had taken place, especially in satellite radar altimetry and GPS, which meant that the need for the GLOSS *in situ* network had to be reconsidered. This was accomplished by means of the GLOSS Implementation Plan 1997, which was approved by the IOC Assembly the same year (download from http://www.pol.ac.uk/psmsl/training/gloss.pub.html).

Although six years have passed since that Plan was constructed, its requirements remain valid. The Plan (and small modifications made at regular GLOSS Experts meetings) demanded:

- The establishment of a newly defined GCN of approximately 300 stations, meeting the 'global baseline' objective of the original GLOSS proposal.
- The establishment of a smaller, specialist network (perhaps a subset of the GCN) for the purpose of ongoing calibration of satellite altimeter data. By this time, even the most enthusiastic of altimeter data users had realised that their data sets can contain long term drifts and biases. This subset network was called GLOSS-ALT.
- The establishment of a modest number of gauges at locations essential for the monitoring of the ocean circulation via sea level changes, but where altimetry is not ideal. This includes at straits, high latitudes and western boundary current locations. This subset was called GLOSS-OC.
- The recognition by agencies of the vital importance of the continuation of long sea level records for climate change monitoring purposes (e.g. within the scientific reviews of the IPCC). 'Long' might mean 40 years or longer in Europe, N America etc. but less in the southern hemisphere. This set of several 100 gauges was grouped within the GLOSS-LTT heading and was not a GCN subset.
- The installation of GPS receivers (and possibly other forms of geodetic monitoring such as DORIS and Absolute Gravity) at sites within most of the ALT and LTT sets, and ideally OC also, to enable vertical land movements in the gauge records to be removed.
- The delivery of MSL data from all GLOSS sites to the PSMSL by July in the calendar year following the data-year.
- The delivery of higher frequency data (i.e. raw data, typically hourly values) in 'delayed mode' form to GLOSS Centres (in practice either the PSMSL again or

University of Hawaii Sea Level Center, UHSLC) with a maximum delay of 6 months. The Plan stated that this requirement could also be met by agencies provide these data on a publicly-available web site in their own organisation from where the GLOSS Centres could download the data.

It was anticipated that the last point would be an issue in some countries from the perspectives of national security or cost-recovery, and so it has proved as will be seen below. However, the 1997 Plan stressed that higher frequency data were required by the programme for very good reasons: (i) to provide the possibility for essential quality control checking of the monthly and annual MSL values to common, modern standards; (ii) to provide access to the higher frequency section of the sea level variability spectrum, thereby aiding interpretation of interesting signals which may be less evident in the monthly means; and (iii) to enable long term archiving of irreplaceable GLOSS data sets.

The major development which has arisen since the 1997 Plan was constructed has been the recognition of the need for ‘fast’ (near-real time) data sets in addition to the ‘delayed mode’ MSL and higher-frequency sets described above. In this context, ‘fast’ means data to be provided within several days to one week, enabling assimilation of data into the new generation of ocean models (e.g. GODAE models) and for rapid use in altimeter calibration. In 1999, GLOSS established the GLOSS Fast Centre at UHSLC as a logical evolution of UH’s previous WOCE fast role, and in a series of circular letters during 1999-2003 has encouraged countries to engage in this data stream. It is realised that ‘fast’ data imply expenditure in both upgrades to gauge hardware and data transmission methods and in staff resources. However, it is considered that, as many GLOSS gauges are relatively old, such upgrades would soon be required anyway.

With regard to the operation of GPS receivers at tide gauge sites, in 1997 the PSMSL, GLOSS and the International GPS Service hosted an important meeting at which the state of the art of GPS at gauges was reviewed and a joint working group (now called Continuous GPS at gauges, CGPS@TG) was established. The IGS has since initiated a Tide Gauge GPS project (TIGA), which held its first meeting alongside the 7th meeting of the GLOSS Experts, which aims to collect data from as many gauge sites as possible and to learn how measurement errors in the determination of rates of vertical land movements can be reduced. (Several other national and international projects with this theme are also underway.). Therefore, following the GE-7 meeting, countries with GPS receivers at gauge sites have been requested by GLOSS to contribute their data to the TIGA Centre at GFZ, Potsdam.

To summarise data flows, there are currently 4 main data streams within GLOSS:

(1) MSL data to the PSMSL

(2) Delayed mode higher frequency data to UHSLC or PSMSL (GLOSS Archiving Centres)

(3) Fast higher frequency data to UHSLC (GLOSS Fast Centre)

(4) GPS data to the TIGA (IGS) data centre.

It is important to stress that data exchange can be two-way, and that countries can benefit significantly from participation in the programme. GLOSS is keen that each contributing country makes maximum use of its own data, which has added value by being shared, if only from the ‘buddy checking’ quality control of data from nearby sites. Scientists in one country benefit from access to data from all other countries. In addition, GLOSS data centres can help with the provision of local practical products based on the contributors' data.

Finally, we may mention the development of regional GLOSS networks, which provide important components of the GCN and serve to densify it locally. A re-inspection of the 1997 Plan reminds us that many of the developments in GLOSS at that time were taking place on a regional basis, especially within the tropical Pacific (the then TOGA/WOCE network) and in the Caribbean (IOCARIBE activities). This pattern has continued into recent years with most development occurring on a regional basis in Europe (EOSS followed by ESEAS), Mediterranean (MedGLOSS), Central America (RONMAC and CPACC), and with initiatives for Africa and S.E. Asia. Regional development would appear to offer one successful model for building future global GLOSS capacity, providing a large enough scope for scientific and practical justification for funding.

3. GLOSS STATUS

In this section, we review the status of the four GLOSS data streams insofar as they apply to the GCN. Our aim is to show which countries are doing good and bad jobs in contributing to the programme, and to identify reasons for deficiencies. Of course, the Core Network does not include all sites which have tide gauges or which have nearby GPS receivers. Therefore, a country could have gauges and receivers which do not happen to be located at designated GCN sites. However, the GCN list does serve to provide one overview of the status of recording globally which we believe to be fairly realistic.

(1) Status of MSL Data (PSMSL)

With regard to stream (1), GCN status has been reviewed every year by the PSMSL since 1989 (http://www.pol.ac.uk/psmsl/programmes/gloss.info.html). Status is defined in terms of the current year Y within 4 categories:

Category 1: Latest data Y-4 or later (i.e. 'operational')

Category 2: Latest data Y-14 to Y-5 (i.e. 'probably operational')

Category 3: Latest data before Y-14 (i.e. 'historical data only')

Category 4: No data at all

It is interesting to note that back in 1989, only about a third of the GCN was Category 1. The proportion grew through the 1990s thanks to WOCE and other activities until it peaked around two-thirds in 1996, and has since shrunk a little. As of October 2002, 168 of the 290 GCN stations were Category 1 (Table 1 and Figure 1). The GCN itself has been redefined from time to time, following discussions at GLOSS Experts meetings, but we do not believe that such adjustments bias the status statistics significantly.

Table 1. Number of GLOSS Core Network Stations in Each 'Responsible Country' and for Each Category 1-4 based on MSL Data Available from PSMSL (Totals 1-4: 168, 69, 28, 25). Category 1: Latest data 1998 or later (i.e. 'operational'); Category 2: Latest data 1988 to 1997 (i.e. 'probably operational'); Category 3: Latest data before 1988 (i.e. 'historical data only'); Category 4: No data at all.

Country	Cat 1	Cat 2	Cat 3	Cat 4	Country	Cat 1	Cat 2	Cat 3	Cat 4
ANGOLA	0	0	1	0	MALDIVES	2	0	0	0
ARGENTINA	3	2	0	0	MARSHALL IS.	2	0	0	0
AUSTRALIA	21	1	0	0	MAURITIUS	2	0	0	0
BAHAMAS	1	1	0	0	MEXICO	2	4	2	0
BANGLADESH	1	0	0	0	MOROCCO	0	0	0	1
BELAU	1	0	0	0	MOZAMBIQUE	1	1	0	0
BRAZIL	1	2	4	3	MYANMAR	0	0	2	0
CANADA	4	2	0	0	NAMIBIA	1	0	0	0
CAPE VERDE IS.	1	0	0	0	NAURU	1	0	0	0
CHILE	4	4	0	0	NEW ZEALAND	1	2	0	2
CHINA, PEOPLE'S REP.	0	5	0	0	NIGERIA	0	1	0	0
COLOMBIA	3	0	0	0	NORTH MARIANA IS.	1	0	0	0
CONGO	0	1	0	0	NORWAY	6	0	1	1
COOK ISLANDS	2	0	0	0	OMAN	1	0	0	0
COSTA RICA	0	1	0	0	PAKISTAN	0	1	0	1
COTE D'IVOIRE	0	1	0	0	PANAMA	0	2	0	0
CUBA	3	0	0	0	PAPUA NEW GUINEA	0	2	0	2
DENMARK	3	0	0	0	PERU	0	1	0	0
DJIBOUTI	0	0	1	0	PHILIPPINES	0	4	0	0
ECUADOR	2	0	0	0	PORTUGAL	1	3	0	0
EGYPT	0	0	1	0	PUERTO RICO/USA	1	0	0	0
EL SALVADOR	0	1	0	0	RUSSIA	6	4	1	3
FED. MICRONESIA	3	1	0	0	SAO TOME/PRINCIPE	0	1	0	0
FIJI	1	0	0	0	SENEGAL	1	0	0	0
FRANCE	6	3	2	1	SEYCHELLES	1	0	0	0
FRENCH GUIANA	0	1	0	0	SIERRA LEONE	0	0	0	1
FRENCH POLYNESIA	2	0	0	0	SINGAPORE	1	0	0	0
GERMANY	1	0	0	0	SOLOMON IS.	1	0	0	0
GHANA	0	0	1	0	SOMALIA	0	0	0	2
GUINEA	0	1	0	0	SOUTH AFRICA	0	3	0	1
HAITI	0	0	1	0	SPAIN	3	0	0	0
HONG KONG	1	0	0	0	SRI LANKA	0	1	0	0
ICELAND	1	0	0	0	SWEDEN	1	0	0	0
INDIA	1	3	3	1	TANZANIA	1	0	1	0
INDONESIA	0	4	2	2	THAILAND	2	0	0	0
IRELAND	1	0	1	0	TONGA	1	0	0	0
ISRAEL	1	0	0	0	TRINIDAD AND TOBAGO	0	1	0	0
JAMAICA	0	0	1	0	TUVALU	1	0	0	0
JAPAN	15	0	0	0	U.K.	10	0	1	3
KENYA	1	0	0	0	U.S.A.	25	1	1	0
KIRIBATI	3	0	0	0	URUGUAY	0	1	0	0
KOREA, P.D.R.	0	1	0	0	VENEZUELA	0	1	0	0
KOREA, REPUBLIC OF	1	0	0	0	VIET NAM	1	0	0	0
MADAGASCAR	1	0	0	1	YEMEN, P.D.R.	0	0	1	0
MALAYSIA	2	0	0	0					

GLOSS status within the PSMSL dataset. October 2002

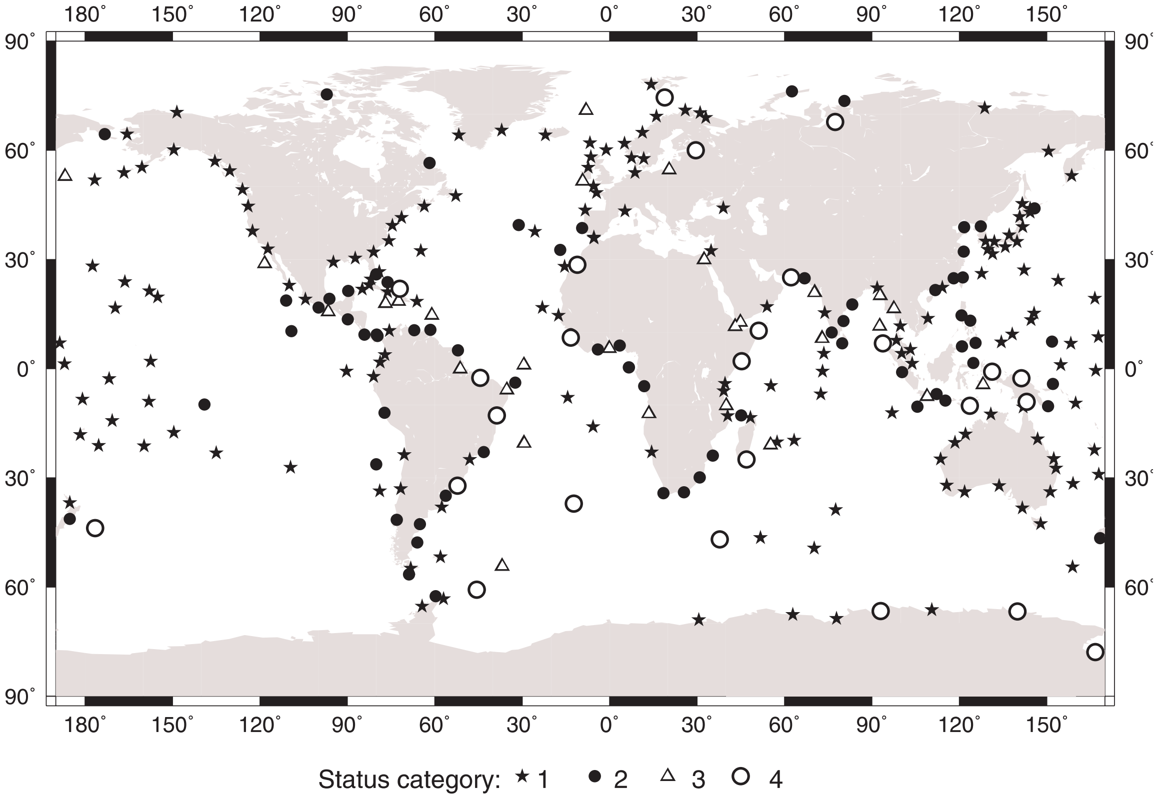

Figure 1. GLOSS status summary as of October 2002**.** For explanation of the status categories please see Table 1.

(2) Delayed Mode Hourly Data

A further table can be produced showing GCN status in terms of data stream (2), the delivery of raw data (typically hourly values) to one of the GLOSS Centres, which, in practice, means to UHSLC and/or to PSMSL (with BODC). Table 2 provides such statistics using the same 4 Categories in terms of the latest year of data available at one or other of the two centres. The statistics are comparable to, if slightly worse than, those for stream (1) for PSMSL data, partially reflecting the fact that some agencies are less willing to exchange hourly data than MSL information.

Table 2. Number of GLOSS Core Network Stations in Each 'Responsible Country' for Each Category 1-4 based on Delayed-Mode Higher-Freq. Data (Totals 1-4: 146, 56, 16, 72). Category 1: Latest data 1998 or later (i.e. 'operational'); Category 2: Latest data 1988 to 1997 (i.e. 'probably operational'); Category 3: Latest data before 1988 (i.e. 'historical data only'); Category 4: No data at all.

Country	Cat 1	Cat 2	Cat 3	Cat 4	Country	Cat 1	Cat 2	Cat 3	Cat 4
ANGOLA	0	0	1	0	MALDIVES	2	0	0	0
ARGENTINA	2	1	0	2	MARSHALL IS.	2	0	0	0
AUSTRALIA	18	2	0	2	MAURITIUS	2	0	0	0
BAHAMAS	1	1	0	0	MEXICO	2	2	3	1
BANGLADESH	1	0	0	0	MOROCCO	0	0	0	1
BELAU	1	0	0	0	MOZAMBIQUE	0	0	1	1
BRAZIL	1	1	4	4	MYANMAR	0	1	0	1
CANADA	4	1	0	1	NAMIBIA	1	0	0	0
CAPE VERDE IS.	1	0	0	0	NAURU	1	0	0	0
CHILE	4	2	0	2	NEW ZEALAND	0	3	0	2
CHINA, PEOPLE'S REP.	1	4	0	0	NIGERIA	0	1	0	0
COLOMBIA	3	0	0	0	NORTH MARIANA IS.	1	0	0	0
CONGO	0	1	0	0	NORWAY	0	0	0	8
COOK ISLANDS	2	0	0	0	OMAN	1	0	0	0
COSTA RICA	0	1	0	0	PAKISTAN	0	1	1	0
COTE D'IVOIRE	0	1	0	0	PANAMA	0	2	0	0
CUBA	0	2	0	1	PAPUA NEW GUINEA	0	2	0	2
DENMARK	3	0	0	0	PERU	0	1	0	0
DJIBOUTI	0	0	0	1	PHILIPPINES	0	4	0	0
ECUADOR	2	0	0	0	PORTUGAL	2	2	0	0
EGYPT	0	0	0	1	PUERTO RICO/USA	1	0	0	0
EL SALVADOR	1	0	0	0	RUSSIA	0	1	0 13	
FED. MICRONESIA	3	1	0	0	SAO TOME/PRINCIPE	0	1	0	0
FIJI	1	0	0	0	SENEGAL	1	0	0	0
FRANCE	4	4	2	2	SEYCHELLES	1	0	0	0
FRENCH GUIANA	0	0	0	1	SIERRA LEONE	0	0	0	1
FRENCH POLYNESIA	2	0	0	0	SINGAPORE	1	0	0	0
GERMANY	1	0	0	0	SOLOMON IS.	1	0	0	0
GHANA	0	0	0	1	SOMALIA	0	0	0	2
GUINEA	0	1	0	0	SOUTH AFRICA	2	1	0	1
HAITI	0	0	0	1	SPAIN	1	2	0	0
HONG KONG	1	0	0	0	SRI LANKA	0	1	0	0
ICELAND	1	0	0	0	SWEDEN	0	0	0	1
INDIA	0	0	0	8	TANZANIA	1	0	0	1
INDONESIA	0	4	0	4	THAILAND	2	0	0	0
IRELAND	1	0	1	0	TONGA	1	0	0	0
ISRAEL	1	0	0	0	TRINIDAD AND TOBAGO	0	1	0	0
JAMAICA	0	0	1	0	TUVALU	1	0	0	0
JAPAN	14	1	0	0	U.K.	12	1	0	1
KENYA	1	0	0	0	U.S.A.	26	0	1	0
KIRIBATI	3	0	0	0	URUGUAY	0	0	0	1
KOREA, P.D.R.	0	0	0	1	VENEZUELA	0	1	0	0
KOREA, REPUBLIC OF	0	0	0	1	VIET NAM	0	0	0	1
MADAGASCAR	1	0	0	1	YEMEN, P.D.R.	0	0	1	0
MALAYSIA	2	0	0	0					

(3) Fast Mode Data

Table 3 gives the corresponding statistics for the 'fast' stream (3) from the GLOSS (and CLIVAR) Fast Centre at UH with 'fast' in this context meaning within 1 or 1.5 months as for WOCE 'fast' data. As the GLOSS Fast Centre was established only in 1999, the data fall essentially into 2 columns (Categories 1 and 4) with 111 in Category 1. The GLOSS Fast Centre also presently receives 'fast' data from 28 sites which are not in the GCN.

Table 3. Number of GLOSS Core Network Stations in Each 'Responsible Country' for Each Category 1-4 based on Available Fast Data (Totals 1-4: 111, 3, 0, 176). Category 1: Latest data 1998 or later (i.e. 'operational'); Category 2: Latest data 1988 to 1997 (i.e. 'probably operational'); Category 3: Latest data before 1988 (i.e. 'historical data only'); Category 4: No data at all. Please note: This table does not include as 'Category 1 Countries' those countries which make data available in 'fast' mode but for which mechanisms have not yet been established to transfer data to the GLOSS Fast Centre. These countries include Israel and Hong Kong which display 'fast' values on their own web sites.

Country	Cat 1	Cat 2	Cat 3	Cat 4	Country	Cat 1	Cat 2	Cat 3	Cat 4
ANGOLA	0	0	0	1	MALDIVES	2	0	0	0
ARGENTINA	2	0	0	3	MARSHALL IS.	2	0	0	0
AUSTRALIA	7	0	0	15	MAURITIUS	2	0	0	0
BAHAMAS	1	0	0	1	MEXICO	2	1	0	5
BANGLADESH	0	0	0	1	MOROCCO	0	0	0	1
BELAU	1	0	0	0	MOZAMBIQUE	0	0	0	2
BRAZIL	0	0	0	10	MYANMAR	0	0	0	2
CANADA	3	0	0	3	NAMIBIA	0	0	0	1
CAPE VERDE IS.	1	0	0	0	NAURU	1	0	0	0
CHILE	4	1	0	3	NEW ZEALAND	1	0	0	4
CHINA, PEOPLE'S REP.	0	0	0	5	NIGERIA	0	0	0	1
COLOMBIA	0	0	0	3	NORTH MARIANA IS.	1	0	0	0
CONGO	0	0	0	1	NORWAY	0	0	0	8
COOK ISLANDS	2	0	0	0	OMAN	1	0	0	0
COSTA RICA	0	1	0	0	PAKISTAN	0	0	0	2
COTE D'IVOIRE	0	0	0	1	PANAMA	2	0	0	0
CUBA	0	0	0	3	PAPUA NEW GUINEA	1	0	0	3
DENMARK	0	0	0	3	PERU	1	0	0	0
DJIBOUTI	0	0	0	1	PHILIPPINES	0	0	0	4
ECUADOR	2	0	0	0	PORTUGAL	1	0	0	3
EGYPT	0	0	0	1	PUERTO RICO/USA	1	0	0	0
EL SALVADOR	0	0	0	1	RUSSIA	0	0	0	14
FED. MICRONESIA	3	0	0	1	SAO TOME/PRINCIPE	1	0	0	0
FIJI	1	0	0	0	SENEGAL	1	0	0	0
FRANCE	5	0	0	7	SEYCHELLES	1	0	0	0
FRENCH GUIANA	0	0	0	1	SIERRA LEONE	0	0	0	1
FRENCH POLYNESIA	2	0	0	0	SINGAPORE	1	0	0	0
GERMANY	0	0	0	1	SOLOMON IS.	1	0	0	0
GHANA	0	0	0	1	SOMALIA	0	0	0	2
GUINEA	0	0	0	1	SOUTH AFRICA	1	0	0	3
HAITI	0	0	0	1	SPAIN	0	0	0	3
HONG KONG	0	0	0	1	SRI LANKA	0	0	0	1
ICELAND	0	0	0	1	SWEDEN	0	0	0	1
INDIA	0	0	0	8	TANZANIA	1	0	0	1
INDONESIA	0	0	0	8	THAILAND	0	0	0	2
IRELAND	0	0	0	2	TONGA	1	0	0	0
ISRAEL	0	0	0	1	TRINIDAD AND TOBAGO	0	0	0	1
JAMAICA	0	0	0	1	TUVALU	1	0	0	0
JAPAN	14	0	0	1	U.K.	8	0	0	6
KENYA	1	0	0	0	U.S.A.	24	0	0	3
KIRIBATI	3	0	0	0	URUGUAY	0	0	0	1
KOREA, P.D.R.	0	0	0	1	VENEZUELA	0	0	0	1
KOREA, R.o	0	0	0	1	VIET NAM	0	0	0	1
MADAGASCAR	0	0	0	2	YEMEN, P.D.R.	0	0	0	1
MALAYSIA	0	0	0	2					

However, it is clear that this older WOCE definition of 'fast' will not be 'fast enough' in the future for use in applications such as GODAE or operational coastal modelling. Figure 2 shows the 73 sites of the GCN for which data are received at the GLOSS Fast Centre as of April 2003, either in near real-time (within a few hours) or with a small delay of up to one week, which is still an acceptable lag for deep ocean modelling. A further 24 non-GCN sites are also regularly delivering data to UH in this 'faster' mode.

Even though this situation is encouraging (and the reasonable global coverage of Figure 2 is particularly encouraging), we would like as many GLOSS sites as possible which contribute to the 'delayed mode' streams to also contribute to the 'fast' streams. That implies major improvements by means of upgrades to gauge hardware and data acquisition methods.

GLOSS Real Time Stations (April 2003)

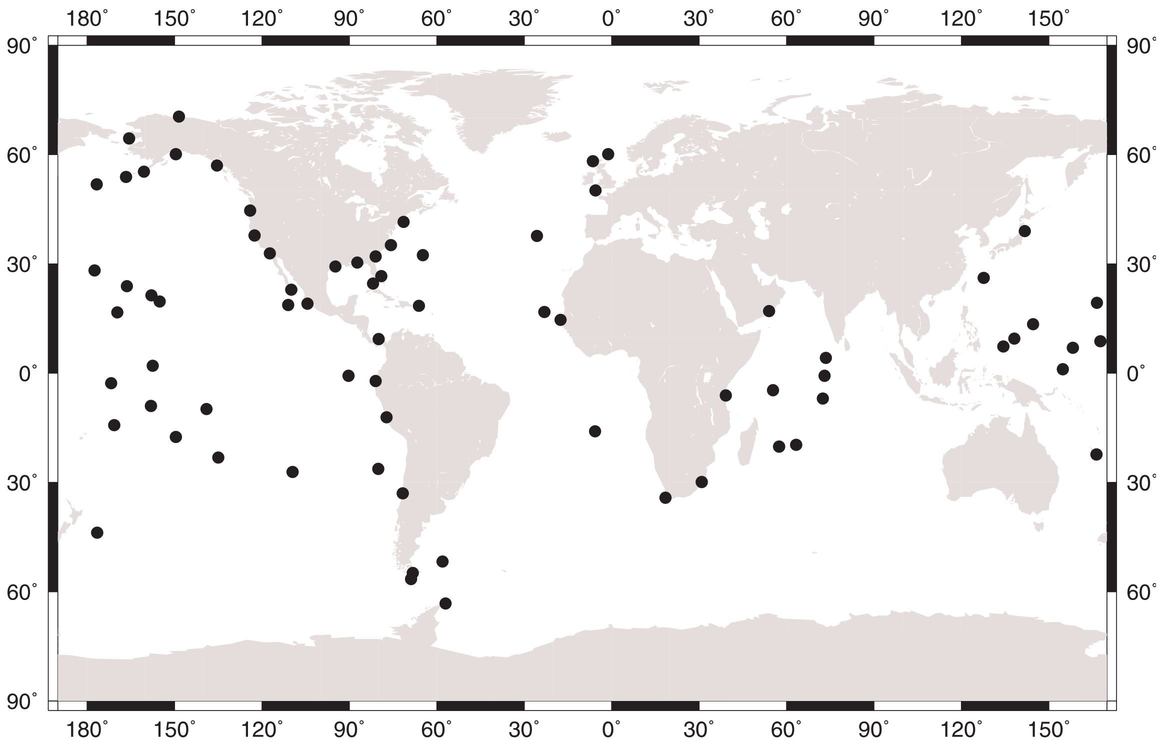

Figure 2. GLOSS Real Time Stations (April 2003)

GLOSS Handbook Status Survey

As a slight digression, a survey of GCN status, to contrast to the status inferred from the statistics of streams (1-3), is provided by questionnaire replies to Dr. Lesley Rickards, editor of the 'GLOSS Handbook'. These questionnaires are usually conducted following GE meetings and the last was undertaken in June 2001 following GE7. Only 34 of the GCN stations were claimed by their owners to have no working tide gauge at all, which implies that approximately 250 were 'operational' at some level compared to the lower numbers in each Category 1 of streams 1-3.

The differences can be accounted for in several ways. At some sites, environmental conditions mean that gauges capable of delivering true sea level data cannot be operated, and so sea level data cannot be provided to the centres, but the stations are equipped with pressure transducers which can supply useful sub-surface pressure data for oceanographic studies. Examples of such sites include Tristan da Cunha and Signy. Nevertheless, most of the difference comes from stations having some kind of 'operational' gauge, but either the gauges are unreliable somehow, or the data from the gauges are not getting through to national data centres, or the national centres do not communicate well with PSMSL and UHSLC. Examples include 9 of the 10 Brazil GLOSS stations and all 8 stations in Indonesia. Table 4 lists the 29 GCN sites from the 2001 survey claimed to be 'completely non-operational' (i.e. 34 less 5 subsequently dropped in the 2002 redefinition of the GCN, and note, with reference to the discussion below, that 12 are located in Africa). For these reasons, we believe that the PSMSL and 'delayed mode' hourly statistics on one hand, and the Rickards survey on the other, provide the most pessimistic and optimistic bounds respectively on overall GCN status.

Table 4. GCN Non-Operational Sites from GLOSS Handbook Survey in 2001

GLOSS Code	Station	Responsible Country
1	SUEZ	EGYPT
2	DJIBOUTI	DJIBOUTI
3	ADEN	YEMEN,P.D.R.
6	HAFUN (DANTE)	SOMALIA
7	MOGADISHU	SOMALIA
9	MTWARA	TANZANIA
20	MARION IS.	SOUTH AFRICA
25	MIRNY (ANTARCTICA)	RUSSIA
29	MINICOY, LACCADIVE IS.	INDIA
37	AKYAB	MYANMAR
41	NICOBAR	INDIA
64	VANIMO	PAPUA NEW GUINEA
67	SORONG	INDONESIA
134	SCOTT BASE	NEW ZEALAND
141	MOULMEIN	MYANMAR
165	CLIPPERTON IS.	FRANCE
199	ST. PETER & ST. PAUL ROCKS	BRAZIL
209	PORT-AU-PRINCE/LES GAYES	HAITI
224	NAIN	CANADA
232	BJORNOYA (BEAR ISLAND)	NORWAY
240	CASTLETOWNSEND	IRELAND
256	ABERDEEN POINT	SIERRA LEONE
257	ABIDJAN	COTE D'IVOIRE
258	TEMA	GHANA
261	POINTE NOIRE	CONGO
262	LOBITO	ANGOLA
272	DARU	PAPUA NEW GUINEA
282	TAN TAN	MOROCCO
303	MASSACRE BAY,ATTU IS.,ALASKA	U.S.A.

Summary of Tide Gauge Data Flow

In summary, Tables 1-3 demonstrate that some countries contribute in a major way to all streams (1-3) (e.g. Australia, Japan, UK, USA). However, the overall situation is more complex. For example, India and Russia contribute several Category 1 stations to stream (1) but not to streams (2-3), while Spain contributes to Category 1 streams (1-2) but not (3). Similar examples can be seen for a number of other countries. Some of these anomalies occur through constraints on data delivery because of cost recovery issues and insufficient administrative priority given to international programmes (e.g. in New Zealand).

(4) GPS Receivers

In the last decade, major developments have taken place in the accuracy and ease-of-use of GPS equipment. This equipment is used for two main purposes: to locate tide gauge measurements into the same geocentric reference frame as altimeter data for altimeter calibration purposes and for the production of combined mean sea surface products; and the measurement of changes in vertical land movements (VLMs) in order to convert the 'relative' sea level measurements of tide gauges (i.e. relative to the land upon which the gauges are located) to 'geocentric' sea level measurements (i.e. relative to the centre of the Earth).

In addition to GPS, there have been advances in the absolute gravity technique. This has been recognised by the GLOSS working groups as an important secondary method, but its cost makes its wide-scale use impractical at present. The French DORIS system is more complementary to GPS, but worldwide commercial and scientific investment in DORIS is considerably less than in GPS, and, in the next few years, the European Galileo system will in effect extend the widespread use of GPS.

As GPS and the other techniques are only starting to provide time series of VLMs which can be combined with tide gauge data, scientists have so far used geodynamic models of Glacial Isostatic Adjustment (GIA) to estimate VLMs. GIA is the only geological process for which a global model can be made, but it is clear that at any one location, other processes (e.g. local subsidence), which can be much larger than GIA locally, can also contribute to observed VLM. Only by measuring VLMs directly can we adequately assess them. Where their time series prove to be monotonic, then their rates can probably be used with confidence to correct historical gauge data.

In principle, GPS (and DORIS if available) data are needed for most (but not necessarily all) stations in the GLOSS-ALT activity. GPS data are also needed for -OC and -LTT. However, they are not necessary for all GCN sites, if the main applications for gauges in a region do not require it. For example, GPS is not required at gauges used primarily for storm surge monitoring. The GPS equipment used must of the highest (geodetic) quality and accompanied by high quality antenna, monumentation etc.

Table 5 provides a list of ‘responsible countries’ (in the sense of Tables 1-4) which have GPS receivers near to or at GCN gauges, based on regularly updated lists of such information provided to GLOSS by Dr Guy Wöppelmann. This list includes receivers installed specially for GLOSS and those installed as part of the IGS network. (We omit discussion here of whether receivers should be located ‘on’ or ‘off’ the gauges.) As of September 2002, CGPS equipment was installed, or is soon to be installed, at 55 GCN sites (Figure 3), and a further 20 or so are installed at non-GCN gauges. In view of the cost of GPS receivers (approximately twice the cost of a gauge), this seems to us to be a reasonable proportion overall, and, given that the cost of receivers is falling, one might expect the proportion to increase in future without special action. Approximately 20 gauges have DORIS nearby.

In the proposal of Section 5, we have requested funding for 20 GPS receivers to be used primarily to satisfy remaining ALT and OC needs. (This would make the number of open ocean gauges with GPS similar to the requirement of 69 quoted in some OOPC documents. It is not clear on where the statement of 69 came from, but the exact number is not critical.) In addition, we suggest installation of several receivers in regions such as Africa, where there has been relatively little experience with the technique so far. The latter might include the relatively few southern hemisphere sites with long tide gauge records for LTT.

Table 5. Number of GPS and DORIS Stations Near to GCN Gauges.

GPS Receivers Near to Gauges			
Country	**Number**	**Country**	**Number**
ARGENTINA	1 (planned)	JAPAN	2
AUSTRALIA	6	MALDIVES	1
BAHAMAS	1	MEXICO	1
BRAZIL	1	NEW ZEALAND	3
CANADA	2 (1 planned)	NORWAY	3
CAPE VERDE	1 (planned)	PHILIPPINES	1
CHILE	2	RUSSIA	1
COLOMBIA	1	SEYCHELLES	1
DENMARK	1	S.AFRICA	1
ECUADOR	2 (planned)	SPAIN	2
FIJI	1	TUVALU	1 (planned)
FRANCE	6	UK	5
ICELAND	1	USA	8

DORIS Beacons Near to Gauges				
DORIS Name	**Longitude**	**Latitude**	**Country**	**GLOSS id**
ASCENSION	-14.33	-7.92	UK	263
CHATHAM Is.	-176.57	-43.96	NEW ZEALAND	128
COLOMBO	79.87	6.89	SRI LANKA	033
EASTER Is.	-109.38	-27.15	CHILI	137
KERGUELEN	70.26	-49.35	FRANCE	023
MAHE	55.53	-4.68	SEYCHELLES	273
MARION ISLAND	37.86	-46.88	SOUTH AFRICA	020
NOUMEA	166.41	-22.27	FR. CALEDONIA	123
PAPEETE	-149.61	-17.58	FR. POLYNESIA	140
PONTA DELGADA	-25.66	37.75	PORTUGAL (AZORES)	245
PORT MORESBY	146.18	-9.43	PAPUA NEW GUINEA	---
REYKJAVIK	-21.99	64.15	ICELAND	229
SAINTE-HELENE	-5.67	-15.94	UK	264
SAL	-22.98	16.78	CAPE VERDE	329
SOCORRO	-110.95	18.73	MEXICO	162
ST. JOHN'S	-52.68	47.40	CANADA	223
SYOWA	39.58	-69.01	JAPAN (ANTARCTICA)	095
TERRE ADELIE	140.00	-66.67	FRANCE (ANTARCTICA)	131
THULE	-68.83	76.54	DENMARK (GREENLAND)	---
TRISTAN DA CUNHA	-12.31	-37.07	UK	266

GLOSS Core Network Stations with GPS (September 2002)

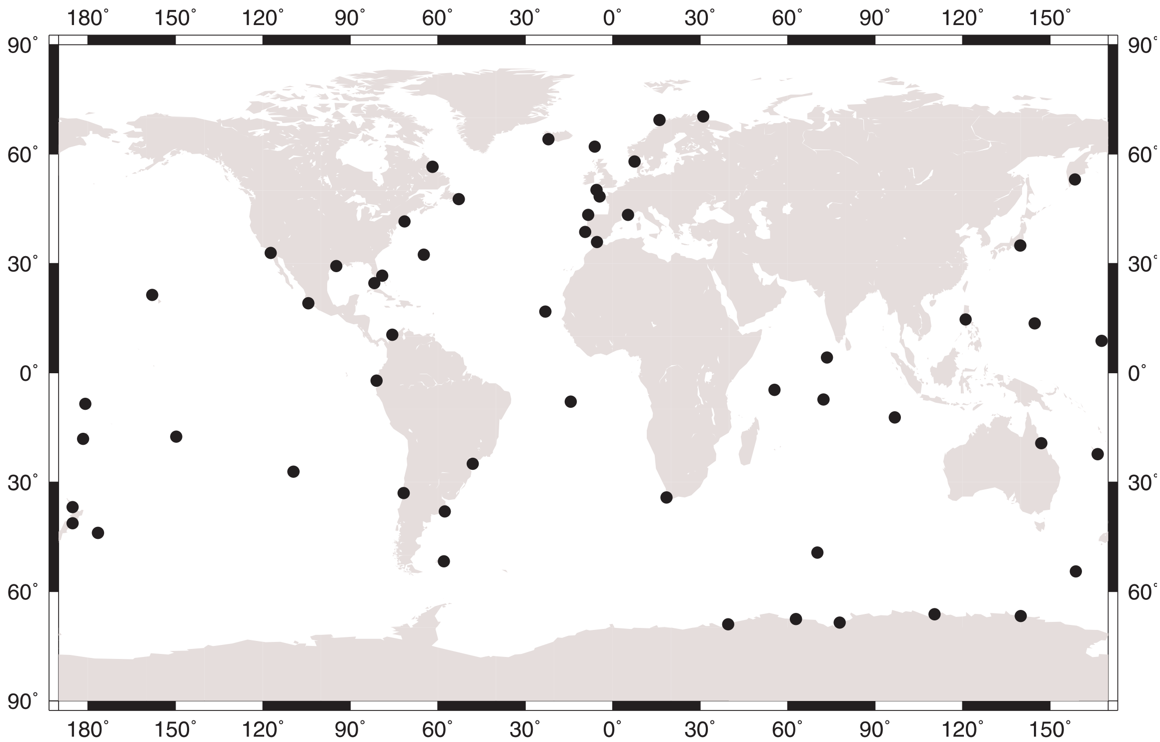

Figure 3. GLOSS Core Network Stations with GPS (September 2002).

We do not recommend the inclusion in this proposal of funds for receivers for most of the LTT sites, which are located primarily in the northern hemisphere. The determination of VLMs for LTT constitutes the most demanding use of GPS data, and is being actively addressed in research and operational mode by a number of European, US and Japanese groups (e.g. the European ESEAS activity is currently installing 14 receivers at gauges.). It is also being addressed within the TIGA project. In our opinion, VLM determination by GPS has not yet achieved the (sub-cm and bias-free) accuracy that would justify the inclusion in the proposal section of this present report of a further large number of GPS receivers for LTT, although it is possible that TIGA may advance that situation within a short period. However, it is important to stress again that projects like TIGA will never succeed in improving accuracies if the best quality GPS equipment has not been installed in the first place.

4. UPDATES ON GLOSS-OC, -ALT AND -LTT

GLOSS-OC Update

While it is clear that satellite altimetry is the main technique for monitoring the global ocean circulation, there are several aspects in which tide gauges can play major roles. In the 1997 GLOSS Plan, a partial list of gauges for ocean circulation monitoring was constructed, based on three criteria:

(i) across narrow straits, where pairs of gauges not only provide superior temporal sampling but are located typically in constricted coastal areas not suitable for cross-strait altimetric measurements. Examples include Straits of Gibraltar, Indonesian Through-Flow straits, and the various Caribbean and Florida straits;

(ii) across wider ‘straits’ and ‘choke points’, and across basin-sections through which measurements of transport variability are of particular interest, each of which can be monitored more efficiently with pairs of gauges. Examples are the choke points of the Antarctic Circumpolar Current (Drake Passage, South Africa - Antarctica, Amsterdam - Kerguelen-Heard Island, Australia - Antarctica) which have been studied in detail during WOCE. Sections spanning other major current systems such as the Gulf Stream, Kuroshio and NE and NW Atlantic straits are also important, while there will be continued interest in monitoring aspects of Tropical Pacific circulation with sets of gauges.

(iii) along polar coastlines, especially that of Antarctica. In the Southern Ocean, winter ice coverage to approximately 60º S precludes all-year altimetry, but sea levels along the Antarctic coast are a potential index of ACC transport.

The use of gauges for ocean circulation monitoring has been discussed at several workshops since 1997, and an updated OC list of 68 stations based on criteria (i-iii) is shown somewhat schematically in Annex I and Figure 4. At GE7, this new list was thought likely to form the basis of requests from IOC for VERY ‘fast’ data (within typically 2 days) into the GLOSS Fast Centre for assimilation into numerical models.

GLOSS OC Stations (Somewhat Schematic)

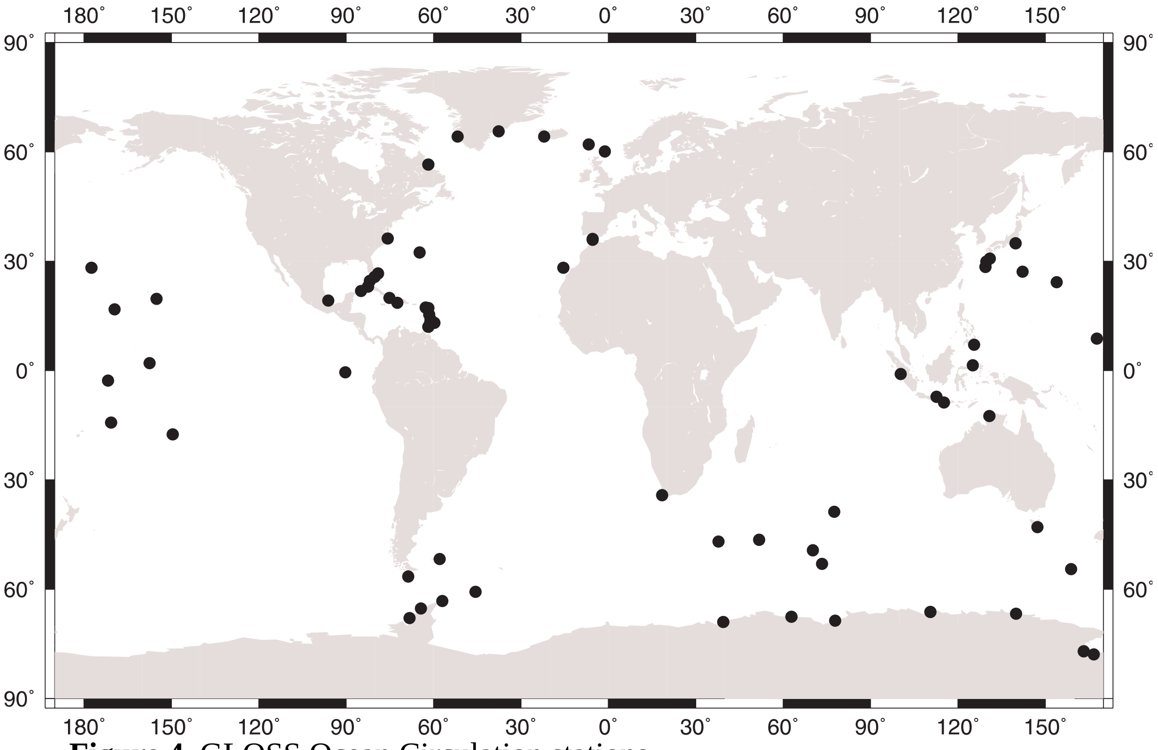

Figure 4. GLOSS Ocean Circulation stations

The majority of gauges in this list are either installed already or, in the case of Antarctic sites, the limitations to installation are primarily associated with the difficulties of operation and access rather than funding. So far as we know, no pairs or networks of GPS receivers have ever been installed to date explicitly for OC-related purposes, although Figure

3 shows that some do exist via installations for other purposes. Consequently, we suggest that approximately a further 6 be installed, chosen optimally to complement ALT and GCN if possible, to test the feasibility of measuring differential VLMs in addition to sea level differences across straits.

Also regarding ocean circulation, it is important to realise that, if there are gaps in altimeter operations, then the global network (i.e. the GCN plus as many other sites as possible) will be required to provide information on large scale ocean variability. Studies of variability in the pre-TOPEX/POSEIDON era using gauge data alone, but with insight obtained from altimetry and ocean models, have demonstrated that the GCN can provide such functionality (e.g. Chambers et al., JGR, 2002).

GLOSS-ALT Update

In the 1997 GLOSS Plan, 30 relatively open ocean GLOSS-ALT sites were selected, grouped into latitudinal sets, based on the work of Gary Mitchum at that time. However, this is now outdated and several groups of authors (including Mitchum) have shown that it is possible to exploit the existing network of both island and some continental gauges, as long as they are equipped as far as possible with GPS (and DORIS) receivers to adjust for vertical land movements. Work on the latter aspect has taken, and is taking, place within the CGPS@TG group and TIGA.

Therefore, we can consider the ALT issue to be largely solved, with different definitions of the 'GLOSS-ALT' subset used by different authors. There is a need to ensure the further tide gauge and GPS instrumentation of as many islands as possible, and the gauge data should certainly be transmitted through the 'fast' stream. A small number (perhaps 5) such additional island sites are suggested in this proposal. Possibilities in the Pacific include Christmas and Galapagos and with lower priority Midway and Johnston; in the Indian Ocean Port Louis, Mauritius and Seychelles; in the Atlantic, Azores and a Brazil location. The large arrays of GPS receivers in Europe, N America, Japan, Australia and other countries means that there are probably already sufficient continental sites, and will almost certainly be in the next few years.

The above remarks apply to what has sometimes been called 'relative' calibrations (Woodworth et al., 2003). 'Absolute' calibrations are undertaken at dedicated altimeter calibration sites such as Harvest and Ajaccio, Corsica and form special cases. However, the 'relative' and 'absolute' aspects are rapidly becoming blurred (e.g. Dong et al., 2002 Marine Geodesy).

GLOSS-LTT Update

The arguments for maintaining gauges with long records, and establishing new sites in the southern hemisphere where there are few long records, remains the same as in the 1997 Plan. In addition, the LTT list included in the Plan remains essentially the same. Many of these sites need to be equipped with CGPS equipment, and visited regularly if possible by absolute gravity devices. However, in countries where there are many long records, it may not be necessary for all sites to be so equipped; there is a scientific assessment to be made.

The GLOSS-OC and LTT requirements are consistent with those stated in the CLIVAR Initial Implementation Plan (Section 4.2.2) although at the time of writing CLIVAR sea level requirements are still being assessed, see http://www.clivar.org/publications/other_pubs/iplan/iip/contents.htm.

Overlap with CLIVAR, GOOS-OOPC, GOOS-COOP, GTOS, IHO and IALA

As stated above, CLIVAR sea level requirements are still being addressed. However, CLIVAR is represented in the GLOSS Science Sub-Group, and has mandated the former WOCE sea level centres (UHSLC and BODC/PSMSL) to be viewed as formal CLIVAR fast and delayed mode centres respectively for an initial period of three years.

The OOPC Chair (Dr. Ed. Harrison) has reiterated that OOPC is eager to advance sustained climate observations however possible. It is doing so within the framework of the consensus recommendations of the international climate community, such as those of the sea level community described in this report. Furthermore it is noted that the Second Report on the Adequacy of the Global Observing Systems for Climate (http://193.135.216.2/web/gcos/gcoshome.html) highlights the need for sea level measurements for several purposes and calls for an enhancement and extension of the global baseline and regional sea-level networks for climate change detection and assessment of impacts.

In the Integrated, Strategic Design Plan for the Coastal Ocean Observations Module of the Global Ocean Observing System (http://ioc.unesco.org/goos/docs/GOOS_125_COOP_Plan.pdf) it is clearly stated that the GLOSS system provides the sea level data for the global coastal module of GOOS. The Strategic Plan also recognizes that there are other local tide gauges operated by national agencies which can provide additional data within the structure of GOOS Regional Alliances. The GLOSS sites may in some cases also provide a platform to measure additional 'common variables' foreseen in the global coastal network of the coastal module of GOOS.

The coastal panel of the Global Terrestrial Observing System (GTOS) has identified sea-level rise as a key coastal issue requiring terrestrial observation. The topic of sea level changes and their impacts on coastal development have been discussed at recent meetings. Such interests from an 'impacts' perspective are consistent with GLOSS LTT scientific objectives.

Discussions have recently taken place between IOC, IHO and IALA towards development of sea level monitoring systems which can benefit all three agencies, including the holding of a joint technical workshop in October 2003. The essential global baseline role of the GCN has recently been endorsed by informal contacts; the GLOSS Group of Experts and the IHO Tidal Committee have formally agreed to exchange representatives.

5. PROPOSAL FOR TAKING GLOSS FORWARD

A first question in considering the future of GLOSS is whether we wish to persevere with the concept of the GCN and related functional (ALT, OC, LTT) and regional networks as proposed in the 1997 Plan. In the opinion of the GLOSS Experts and the Scientific Sub-Group

(Chair Dr. Gary Mitchum), this network model would indeed provide the 'global baseline' for both ocean/climate and coastal studies, if fully implemented, and, of course, subject to regular revision.

It is clear that progress cannot be made rapidly in the development of the GLOSS Core and related Networks without either significant, simultaneous investment over the next few years by a number of countries which have not invested so far, or a more coordinated approach led by IOC. From our experience of the programme during the last decade, we have little expectation that the former will happen. Therefore, this section considers a proposal for the latter, based on the information presented in the Tables and Annex II and with an assumption that funds can be sought from several sources.

We give in Annex III an assessment of where new and re-equipped gauge sites ('re-equipped' will usually amount to 'new' in most cases) and upgraded sites (e.g. float gauge equipped with real-time capability) are required in each country, and we assign a priority and risk assessment. The latter has been based on perceptions of difficulty of installation, maintenance and durability and of the availability of good contacts. The assessment is obviously an ongoing exercise, with details subject to change as more is learned of the practicalities of installations in each country.

We have not included countries for which we believe all possible is being done from national or international resources, or if we believe that new funding would not necessarily bring improvements (e.g. if there are practical reasons why recording is impossible). These countries include Angola, Australia, Bahamas, Belau, Canada, Cape Verde, Chile, Colombia, Cook Is, Cost Rica, Cuba, Denmark, El Salvador, Fed. Micronesia, Fiji, France, Germany, Guinea, Haiti, Hong Kong, Israel, Jamaica, Japan, Kiribati, South Korea, Nauru, New Zealand, North Mariana Is, Norway, Oman, Panama, Papua New Guinea, Puerto Rico, Sao Tome, Senegal, Singapore, Solomon Is, South Africa, Spain, Sweden, Tonga, Trinidad and Tobago, Tuvalu, UK, USA. We have also omitted countries with which we have had next to no contact in recent years in spite of many efforts. These countries include Myanmar, North Korea, Philippines, Sierra Leone, Somalia, Uruguay.

For each country listed, we mention all GCN sites together with a small number of others if appropriate; reasons for the latter are given. GCN gauges which are known to be modern (or soon will be) and should be working to required standards are shown in italics; these obviously do not form part of our funding proposal. GCN sites shown for new gauges need not be definite choices if, following local advice, nearby alternatives are available; the implicit change of the GCN would need to be approved by the GLOSS Experts. The reason for priority selection in some cases is also shown; this is sometimes a qualitative assessment and comments based on local knowledge are welcomed. In countries where there are several new sites are required, priorities are given.

It can be seen that a total of 92 new stations are required, of which 50 are priority ≥ 3 and 10 are spare stations. 10 stations will be upgraded in Indonesia and 20 central American gauges will modernised and converted to real time data delivery.

Estimated Costs (units US K$)

One-Off Costs Spread Over 3 Years

Hardware for 92 new stations assuming 5K per gauge	460	
Installation costs for 92 stations assuming 6K per gauge	552	
Upgrade costs for 10 Indonesian stations assuming 10K each	100	
Real time upgrade costs for 20 central American stations 5K each	100	
Operation/Training packs preparation	30	
Hardware for 20 GPS stations at 15K each	300	
Installation costs for 20 GPS stations at 7.5K each	150	
Total One-Off Costs	1692	

Annual Costs

Scientific Coordinator costs (half post contracted)	25*2	see (d,e) below
Project Manager costs (half post IOC or contracted)	25*2	
Salary for Lead Technician Region I (centred on Africa)	50*2	
Salary for Lead Technician Region II (centred on SE Asia)	50*2	
Salary for 2nd Technician I (half post)	25*2	
Salary for 2nd Technician II (half post)	25*2	
Lab overhead costs Technicians I	10*2	
Lab overhead costs Technicians II	10	
Travel costs for scientific coordinator	10	
Travel costs for project manager	10	
Travel costs for Technicians I	30	
Travel costs for Technicians II	30	
Travel costs for Regional Coordinator I	10	
Travel costs for Regional Coordinator II	10	
Data transmission costs	10	
Data processing costs	-	see (h) below
Training courses (2 courses/year at 25K each)	50	see (i) below
Web development	20	see (j) below
Total Annual Costs per Year	600	

Total Costs over 3 years	1692+3*600	3492

Assumptions:

(1) Countries will appoint and fund a responsible local contact for each gauge site, preferably from an agency already experienced in tide gauge measurements, who will have a long term personal commitment to gauge operations.

(2) The contact will identify a suitable gauge location and be responsible for all local arrangements including: installation of a suitable nearby 'tide gauge hut', site access and security, liaison with network technicians for installation and maintenance, undertaking of simple regular maintenance duties, installation of local benchmark network etc.

(3) Countries will be responsible for telephone installation and usage costs, and all other local costs.

(4) Countries will be responsible for all subsequent gauge refurbishment costs after gauge equipment guarantee period has passed.

(5) Countries will undertake that the local contact (or colleagues) will conduct regular gauge checks and geodetic levellings to benchmarks according to GLOSS standards.

(6) Countries will be responsible for the dissemination of local, regional and global products to the relevant organisations in their country.

(7) Countries will not place conditions on the transfer of data to GLOSS data centres and the use of the data by the international community. Note the Resolution on IOC Oceanographic Data Exchange Policy to the 2003 Assembly: "there should be timely, free and unrestricted access to all data, associated metadata and products generated under the auspices of IOC programmes". Countries which cannot commit to this will not be included in this project.

(8) The Project Manager at IOC will oversee the purchase of the gauge equipment in consultation with a sub-group of the GLOSS Experts and with the two Lead Technicians, and will be responsible for its allocation to countries according to priorities reviewed regularly by the GLOSS Group of Experts.

(9) IOC will oversee the appointment of two Regional Coordinators who will be responsible for assessing the network operational status and data quality and for liasing with technicians and data centres. It is envisaged that they will have science backgrounds and be funded by a country from the region. They will receive travel costs from the project.

(10) IOC will oversee the appointment of four network technicians (two full time lead and two half time secondary) who will be responsible for installation of gauges purchased as part of this proposal and for network continuity. Discussions with Proudman Oceanographic Laboratory (for PSMSL) and University of Hawaii have confirmed that at least one of these technicians could be based at each of these organisations if funding was available. The half time posts are required in particular for the first years of the project, and may be short term appointments. Two technicians will be required for most installation and maintenance visits if health and safety rules are to be followed.

Explanations:

(a) A three year programme has been assumed on the basis that the maximum number of new sites which can be installed by each team is one per month, or 24 total per year. If equipment can be standardised as far as possible, this target will have a better chance of being met or exceeded. However, the target is an ambitious one. A longer installation programme would not be satisfactory for GODAE and GOOS.

(b) The cost of gauges is based on a current choice of gauge technology of radar or high-quality acoustic, although pressure gauges may be used in some cases. The choice will be guided by discussion at a GLOSS technical workshop in October 2003.

(c) The costs make no allowance for ancillary data channels e.g. met data which are assumed can be provided from nearby met stations.

(d) We assume that a Scientific Coordinator can be identified by the GLOSS Group of Experts who will undertake scientific oversight of the project on a half time basis and work closely with the Project Manager. The overall 'ownership' of the project will of course remain with the GLOSS Group.

(e) The '*2' alongside salary costs allows for typical overhead costs in most organisations.
(f) Lab overhead costs are for toolboxes, spare parts etc. which the technicians will require.

(g) Data transmission costs are for phone calls (or similar costs via satellite systems) to the gauges from data centres, especially for access to data in 'fast mode'.

(h) Data processing costs have been set to zero as POL/PSMSL and UH have confirmed that these costs can be covered within their existing national commitments to the GLOSS programme. These specific 'In Kind Contributions' amount to approximately 100K per year each.

(i) Training course costs are estimated from the cost of similar courses in recent years. They allow for typically 10 attendees at a 2 week course. (POL/PSMSL and UH have confirmed that they would be willing to host regular courses with the staff time of lecturers provided freely as national contributions to GLOSS. Courses in other countries will also be desirable.)

(j) Web development will be spread across participating organisations with the aim of making all GLOSS products as easy to use as possible. They will take place in consultation with IODE.

Special Comments on Africa:

It can be seen that major investment is proposed in Africa, which contains the longest expanse of coastline in the world without adequate sea level monitoring. Two scientific topics are of great concern to Africa and receive a great deal of publicity. The first relates to investigations of ENSO, which causes large sea level changes in the Indian (as well as the Pacific) Ocean and which is related to fluctuations in regional weather patterns. Climate fluctuations related to the Indian Ocean Dipole and other indices have also been linked to African land and coastal changes. The second concerns long-term changes in global sea level as discussed in the IPCC reviews. These changes, both interannual and long term, have potential social, economic and environmental consequences for coastal zones. We note that by 2010 Africa will contain a coastal 'mega-city' in Lagos, Nigeria and many smaller coastal cities.

As well as contributing to the scientific global monitoring programmes, Africa has needs for practical applications of sea level information include coastal engineering, in which sea level data are needed as instantaneous levels, as well as statistics of extreme levels over long periods. Measurements with real-time data transmission are needed for ship movements in harbours and ports, for issuing flood warnings, and for the operation of sluices and barrages. Over a longer period, data are needed for tidal analysis and prediction, for control of siltation and erosion (particularly important in West Africa), for the protection of coral reefs (important in East Africa), for inputs to models to estimate the paths of pollutants and to forecast water quality, and for the design of reclamation schemes and the construction of disposal sites. In addition, they have application to studies of upwelling (e.g. Moroccan and Namibian coasts) and fisheries throughout tropical areas. All these topics form part of the GOOS Coastal Module.

The donation of second-hand equipment from Europe to Africa has been tried several times within GLOSS and has not been successful and we do not consider this to be a practical option for the future. We consider that a network with new equipment is required, and the African part of the present proposal for taking GLOSS forwards differs only in details from the suggestions of the GLOSS Africa 2002 proposal submitted to the African Partnership Conference in Johannesburg.

6. CONCLUSIONS

GLOSS's character has always been different to that of the other observation programmes which make up GOOS. In some ways it is a simpler programme than others, in that most of the arguments for sea level measurements are well understood, most of the technology is well established (gauges have existed for several centuries) and is relatively inexpensive (for many countries at least). Where it fails is either because appropriate national contacts do not exist, or have insufficient technical expertise, or have positions which carry insufficient authority to organise others to conduct the work, or (even in some developed countries) have little interest outside their immediate, national responsibilities. In some countries, there are national security and cost recovery concerns which inhibit data exchange.

GLOSS has also attempted to be two programmes at once (the ‘climate’ and ‘coastal’ halves) and for many years that balance may have tilted more to the former because of the need for data in programmes such as WOCE. However, with the articulation of GOOS coastal requirements that balance may be being restored: Patricio Bernal in his opening remarks to the 6th Session of the Intergovernmental Committee for GOOS (Paris, 10-14 March 2003) focussed on the need to upgrade the GLOSS network and he stressed that such a project could “broaden the ownership of GOOS among coastal states" and thereby help GOOS to succeed.

The proposal included within this status report attempts to fill some of the deficiencies some countries have in contributing to the international GLOSS programme, from both the ‘oceanography and climate’ and ‘coastal’ perspectives. It will provide equipment, install it and supervise its maintenance, provide training to make use of data locally, and thereby convince countries of the value of ongoing measurements. It should improve the operational status of GLOSS measured by the ‘delayed mode’ streams by at least 30%, and should approximately double the effective number of sites available in ‘fast’ mode. As a result, the international community will gain access to information from a wider, ‘kick-started’ network than would be possible by waiting for GLOSS to evolve as originally intended.

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ANNEX I

GLOSS-OC Update

It can be seen that almost all of this GLOSS-OC list consists of GCN sites, although a few others are suggested. Possible sites are shown by [GCN no.], or [PSMSL code] if not GCN.

Mediterranean Inflow: Gibraltar [248] (or nearby Spanish gauges) - Ceuta [249]

Florida Current: On west side, Lake Worth was suggested in the 1997 Plan but that does not seem to be working (last PSMSL data 1988). Replaced with Virginia Key [PSMSL 960/008]. On east side, Settlement Point [211]

Gulf Stream: Duck [219] - Bermuda [221]

Gulf Stream return section: Bermuda [221] - Tenerife [Las Palmas, 219]

Kuroshio: Mera [86] - Chichijima [103] - Minamitorishima [104]

also Tokara Strait: Naze [PSMSL 646/001] - Nakanoshima [PSMSL 646/011] - and Nishinoomote [PSMSL 645/031]

NE Atlantic: Angmagssalik [228] - Reykjavik [229] - Torshavn [237] - Lerwick [236]

NW Atlantic: Nain [224] - Gothåb [225]

Caribbean Straits: Florida St. Key West [216] - Siboney [215]; Yucatan Channel Cabo San Antonio [214] - Veracruz [212]; Windward Passage Guantanamo Bay [PSMSL 930/052] - Port au Prince, Haiti [209] (both not working); Mona Passage (nothing working)

Lesser Antilles: good CPACC array from Antigua, St.Kitts, Dominica, St. Lucia, St.Vincent, Grenada, Barbados (N.B. Martinque [204] or Guadalope may not be needed)

ACC 'Drake Passage/Scotia Sea choke points': North side Diego Ramirez [180], Stanley [305], South side Signy [306], Faraday/Vernadsky [188], Esperanza [185], Rothera [-]. Several sites on the south side of the Passage allows for data gaps.

ACC African choke point: Simons Bay [268] - Marion [20] - Syowa [95]

ACC Indian Ocean choke point: Amsterdam/St.Paul [24] - Kerguelen [23] - Heard [-] - Crozet [21]

ACC Australian choke point: Spring Bay [56] or Hobart [PSMSL 680/201] - Macquarie [130] - Dumont d'Urville [131]

Indonesian through flow: Davao [71] - Darwin [62] were used by Wyrtki, (1987). Padang, Benoa, Surabaya, Bitung are the only sites in Indonesia itself with recent data; they may not be optimal for through-flow studies. This needs further work.

Pacific volume stations. (see Section 8.3.2 of 1997 Plan, this is now somewhat historical): Midway [106], Hilo [287], Johnston [109], Kwajalein [111], Christmas [146], Kanton [145], Pago Pago [144], Papeete [140]

Pacific equatorial gradients: Christmas [146] - Baltra [169]

Antarctic sites (Rothera, Faraday/Vernadsky, Esperanza, Signy, Syowa, Mawson, Davis, Casey, Dumont d'Urville, Cape Roberts, Scott) As many Antarctic sites as possible are needed to allow for data gaps. Rothera for Faraday/Vernadsky, McMurdo for Scott etc. (It is not reasonable to expect as rapid data flow from these sites as for others).

ANNEX II

BRIEF COMMENTS ON GLOSS STATUS IN EACH COUNTRY

This Annex provides a set of brief remarks on the status of recording in each country. We hope that together they may reflect the status of GLOSS overall. Please forgive any omissions or mistakes. The PSMSL web site contains a set of 'country reports' which provide further information on a number of countries.

North America

USA and **Canada –** well funded networks with data readily made available.

Mexico – has three tide gauge networks which are taking encouraging steps to coordinate activities, process back data and install new sites. The largest network is operated by the Mexican Navy and consists of 25 Aanderaa pressure gauges of which only 5 report in real time. 8 new stations are planned, including Socorro Is. Formal correspondence between IOC and Navy is underway to request data for GLOSS. The two other networks operated by research and university organisations (CICESE and UNAM) have considerable chart archives requiring extensive data archaeology.

Cuba – the three main gauges with medium-length MSL records will deliver real time data via the web shortly. An additional gauge is planned at the eastern end of Cuba replacing Guantanamo Bay (US).

Martinique – SHOM (France) plans to equip Fort de France, replacing Le Robert, within one year.

Other **Caribbean countries** and **Central American States** – significant investment in gauge hardware in recent years through CPACC and RONMAC (see http://www.pol.ac.uk/psmsl/programmes) but there has been little data flow into data centres.

An impression of the Caribbean and central American region from Mexico to Venezuela suggests that adequate gauge hardware exists in many cases but that investment is needed for real time reporting which can be relatively easily implemented. (Why real-time is not already working for CPACC/RONMAC is not clear.) Institutional organisational difficulties have also been flagged. Expertise and scientific demand exist in the region, as demonstrated by RONMAC sea level training courses.

South America

Chile – has a modern gauge network with data sent routinely to GLOSS centres. SHOA in Valparaiso hosted a GLOSS training course in 2003 with attendees from most South American countries and has offered to serve as a focus for GLOSS activities in the region.

Peru – has an older gauge network with the need for modernisation identified. Nevertheless real-time data are available on the web.

Ecuador – also has an older small network of float gauges but with real time data. Baltra and Santa Cruz are operated with UH assistance.

Colombia – has float gauges without real time capability.

Panama – MSL data were provided for many years by the Panama Canal Commission (PCC) but have fallen behind. A new Commission for Oceanography and Hydrography, which includes the PCC and 3 other agencies, is now responsible for sea level data. In addition to Coco Solo (Cristobal) and Balboa at the ends of the Canal, there are 2 other gauges on the Pacific and 1 on the Atlantic side of Panama. All are float gauges with chart recorders and with need for modernisation.

Argentina – has a long established network and has undertaken upgrades recently in collaboration with NOAA. Argentina has hosted GLOSS training courses.

Falklands (Malvinas) – POL operates a gauge at Port Stanley which provides ‘fast’ data.

Uruguay – data used to be provided routinely from Montevideo. But contact appears to have ceased.

Brazil – has a long history of involvement in GLOSS. For example, two training courses have been held at the University of Sao Paulo, and there has been a recent special GLOSS mission to DHN. Brazil has a long coastline with an old (mostly DHN) network requiring modernisation, a network established by the Brazil Space Agency (INPE) in NE Brazil in the 1990s which is now defunct, and a small operational USP network of 2 sites, one of which is in GCN. Brazilian colleagues definitely recognise their need to contribute more strongly to GLOSS and a proposal for a GLOSS-Brazil network is near completion which involves extensive national and international collaboration. A draft version of the report identifies 12 potential GLOSS sites (9 principal, 3 secondary) of which approximately half are active, if not to modern standards, and half require installation; some GCN redefinition may be required. Technical developments are taking place (e.g. Digilevel device). A major problem is concerned with the plethora of organisations (Navy, universities, space agency, port authorities, survey organisations etc.) which are involved.

Venezuela – contact has not been good so far with the government agency which operates the gauges (IGN), a situation rectified somewhat by discussions at the Chile 2003 GLOSS training course. Main contact in Venezuela has been via the Universidad de Oriente but movements of personnel mean that will no longer be possible. 7 gauges exist along the Venezuelan coast, some with long records, all of which have potentiometer readout from float systems. Investment is taking place in new data loggers but none report so far in real time.

Most **other NE S.America countries –** links are poor except for Trinidad & Tobago which hosts the CPACC data centre and operates a modern CPACC gauge. SHOM (France) plans to replace a gauge at Cayenne, French Guiana with a new station at Ile du Salut some distance away within 18 months.

Antarctica

The operation of gauges in Antarctica is a specialised activity in which the UK, Japan, Australia, France and New Zealand in particular have excelled. While extensions to the present network are to be welcomed, they are not addressable in our opinion from a single technical perspective as practical solutions to operations in this difficult area have to be decided at each station individually. Certainly, GLOSS and international organisations such as SCAR encourage countries presently engaged in recording to continue to enhance the Antarctic network (cf. Hughes et al., 2003, GRL).

Australasia and Oceania

Extensive networks exist throughout Australia, New Zealand and the western Pacific, see the web sites of PSMSL, UHSLC and Australian National Tidal Facility for detailed information. SHOM (France) is currently installing a new gauge at Noumea, French Caledonia.

New Zealand – contains an extensive network of approximately 20 bubbler gauges owned by NIWA (National Institute of Water and Atmospheric Research). Data from older gauges in ports and harbours are now managed through LINZ (Land Information New Zealand). While some hourly values are made available to GLOSS from the NIWA network, some in real time, and while some MSL information is made available to PSMSL as a product of scientific research of the University of Otago, there seems to be a general reluctance to undertake international data exchange, partly from administrative lack of resources and partly from cost recovery issues. These matters have been explored in a number of high level communications in recent years without satisfactory resolution.

Asia

A GLOSS presentation to the GCOS regional workshop (Singapore, September 2002) summarised the status of GLOSS in each country as follows.

India – MSL data (GLOSS and non-GLOSS) have been delivered to PSMSL for many years but are usually several years behind. No hourly data have ever been provided.

Bangladesh – major investments are needed in a difficult estuary environment. Recently a number of gauges are known to have been installed but not at the nominated GLOSS sites (needs further information).

Myanmar – first recent contact for many years was made by IOC with Myanmar authorities in 2002. In that exchange of letters, older data were received. No recent data.
Thailand – MSL are data delivered promptly by the Royal Thai Navy to PSMSL, but tide gauges are old and need upgrading.

Malaysia – has excellent tide gauge and GPS networks. Data are provided efficiently. Malaysia is hosting a GLOSS training course in 2003.

Singapore – has a good gauge network.

Vietnam – new gauges for flood warning have recently been installed.

PR China – MSL data are delivered regularly if a bit behind. We believe that most gauges are old. More gauges are known to exist than provide data to international data banks.

Hong Kong China – a long standing history of data provision from HK Observatory. MSL data are provided regularly and real time data are on web.

Japan – excellent networks of gauges and GPS of several agencies.

S. Korea – good gauges. MSL data behind to PSMSL.

N. Korea – contacts with GLOSS have lapsed. The UNESCO Participation Programme has provided funds to N. Korea to purchase one or more tide gauges which supposedly supply data to the tsunami warning programme. However, to date no data or news have been received by either that programme or GLOSS.

Russia – good formal contacts. Several gauges were destroyed by tsunami several years ago. They were anyway old float gauges and there is a need for modernisation.

Philippines – long standing contacts of PSMSL and UHSLC with National Mapping & Resources Information Authority have lapsed.

Indonesia – has a large gauge network (approximately 50 sites), many modern although based on float gauge technology. Most no longer work due to funding problems, and we understand that even recently installed systems have deteriorated significantly through siltation etc. A letter has recently been sent from GLOSS to BAKOSURTANAL to explore data exchange formalities and other needs, and we understand that BAKOSURTANAL has asked the Norwegian authorities to consider funding upgrades to the gauges they installed in the late 1990s. Difficulties associated with mains power, telephone connections and site access are not to be underestimated, but this is such an important region for climate studies that action is needed.

Middle East

Pakistan – Hydrographic Office and National Institute of Oceanography have enthusiastic people in regular contact with PSMSL but funds are required for the modernization of 2 GCN sites.

Iran – has been the leader of a long standing proposal for a Gulf GLOSS sub-network. Some types of gauges exist but there are no data in data banks.

Saudi Arabia – tide gauges have historically been installed for oil industry operations by ARAMCO on Gulf coast, and for needs of navigation etc. on Red Sea. Some historical data exist in data banks but all Red Sea gauges installed in the 1990s are known to be non-operational now.

Yemen – Aden has one of the longest sea level records in the world which ceased in 1969. A gauges has recently been purchased and should be capable of being operated at the same site, but no definite news.

N.B. IOC and PERSGA proposed an expert mission to Red Sea countries in 2002 and identified a suitable consultant. However, the mission did not take place for several reasons. It would be appropriate to reconsider it as soon as possible.

Africa

The following information is based on that in a status report on GLOSS in Africa contributed to the GOOS-AFRICA Meeting 2001 in Nairobi. Some of the information has been updated by Dr. Charles Magori.

Egypt – has a history of extended tide gauge recording at Alexandria and at locations connected with the Suez Canal. Plans are underway by the Survey Research Institute for a new gauge at Alexandria and possibly another location. One scientist has attended GLOSS courses at POL (1997) and Jeddah (2000).

Algeria – one person from military management attended POL (1997) course. Gauges are thought to be operated by the Hydrographic Service at Oran, Algiers and Jijel but no data available.

Morocco – two gauges are operated by the Direction de l'Equipment. However, they require upgrades. We understand that plans exist for gauges at Rabat on the Atlantic coast and at another location in collaboration with the French Navy. Installation of a planned MedGLOSS gauge at Nador on the Mediterranean coast by a group from Israel was abandoned due to the political situation. One scientist attended the POL (1997) course and a scientist from the Direction has been accepted to join the GLOSS Group of Experts.

Mauritania – a GLOSS Core Network gauge was suggested at Nouadhibou (Cap Blanc) for many years, and the site was visited by a consultant from Germany on behalf of IOC around 1986. Since then no developments.

Cape Verde Is. – a Next Generation Water Level Monitoring System (NGWLMS) gauge (a US acoustic gauge) was installed in the mid-1990s at Palmeira with direct data transmission to NOAA in Washington. The last data available is from 1996. NOAA withdrew from installing and maintaining gauges outside of the US around 1998 but left the gauges and other equipment in place in most cases but without maintenance. The station was moved to Sal Island in March 2000 to be near the Met Office (INMG) with GPS nearby and data processed by the University of Hawaii. Recently, we heard from Jose Manual Moreno (INMG, Cape Verde) that the gauge was not working but he was trying to solve the problem. One scientist from Cape Verde attended the 6th GLOSS Group of Experts (GE6) Session in 1999. However, contact with him has since been lost.

Senegal – a NGWLMS was also installed in Dakar in the mid-1990s and is still operating, with the same maintenance concerns as for Palmeira. Local scientists do not maintain it or have direct access to the data. An IRD (France) pressure gauge was also located in Dakar but IRD no longer considers it owns it. One specialist attended the Cape Town GLOSS training course in 1998. One scientist attended the GE6 Session.

Côte d'Ivoire – data exist from Abidjan and Port San Pedro although very little is in databanks. The Laboratoire d'Océanographie et de Géophysique Spatiale (LEGOS) group in Toulouse has an agreement with Dr. Angora Aman to digitise charts from the locally-operated and currently operational Port San Pedro gauge and provide software support. One specialist attended the Cape Town GLOSS training course in 1998. Dr. Angora Aman is also the nominated GLOSS Regional Contact for French-speaking West African countries.

Ghana – has some of the longest tide gauge records in Africa (e.g. Takoradi in the west of Ghana). Tema (the port of Accra in east Ghana) is a GLOSS Core Network site. Gauges installed at both places by German consultant around 1986 were not successful. Recently, India has agreed to provide 2 gauges for Tema and Takoradi. One scientist attended the Cape Town GLOSS training course in 1998. Gauges along the Côte d'Ivoire and Ghana coasts would be of potential value for upwelling studies.

Atlantic Islands – the UK (POL) operates gauges at Ascension and St. Helena. Which provide data in ‘fast’ mode. A replacement gauge is planned for Tristan da Cunha which is presently out of service.

São Tome – historical data are available from TOGA studies in the 1980s. More recently, the LEGOS group in Toulouse receives real time data from São Tome. The station has a bottom pressure gauge and a barometer and is owned and maintained by IRD. Data have been sent since 1999 for validation to UHSLC.

Nigeria – a number of scientists from Nigeria have attended GLOSS meetings and training courses. Most recently, Dr. Adeleke Adekoya attended the Cape Town 1998 course and the GE6 1999 Session and he is the nominated GLOSS Regional Contact for English-speaking West Africa. Two gauges existed at Lagos until 2000 when both were destroyed by a storm. One was a NGWLMS acoustic gauge (see above) and the other was a float gauge. Plans are in progress to investigate possible replacement (a pressure gauge has been suggested).

Congo – a gauge at Pointe Noire has been suggested by French groups. Pointe Noire has the longest existing data set from this part of the coast (data for 1955-88). IRD has asked LEGOS for advice if they should install a gauge there and LEGOS is conducting a study, the results of which are expected shortly. It is anticipated that the report will request IRD to install a permanent station there. In addition to global aspects, the gauge may be of local use for upwelling studies, although may be affected by Congo river runoff.

Angola – no significant history of recording. We understand that the Benguela Current Large Marine Ecosystem (LME) programme plans to acquire 9 gauges for the region, of which 3 each will go to Angola, Namibia and South Africa, and that a GLOSS training course has been requested.

Namibia – prior to 1999 gauges at Walvis Bay and Luderitz were operated by the South African Hydrographic Office. However, they were since transferred to the Namibian Ministry of Agriculture and then to NAMPORT with plans for modernisation. GLOSS is in good contact with NAMPORT. One scientist attended the Cape Town 1998 training course. (See also Angola for LME plans.)

South Africa – contains a number of gauges with records staring in the mid-1950s. However, only a partially-successful upgrade programme from float to acoustic gauges in the 1990s led to an interruption in the supply of good quality data. Several scientists attended the 1998 training course at the University of Cape Town, from which Prof. Geoff Brundrit is South African GLOSS Contact and Regional Contact for Southern Africa. South Africa is currently upgrading parts of its network using radar gauges. (See also Angola for LME plans.)

Mozambique – some data have come from Mozambique in recent years although quality is a major issue. One scientist attended the 1998 Cape Town GLOSS training course.

Madagascar – recent data exist from Nosy Be.

Tanzania – recent data exist from Zanzibar. One scientist attended the 1998 Cape Town training course.

Kenya – recent data exist from Lamu and Mombasa. A number of scientists from Kenya have attended GLOSS Experts meetings and training courses (most recently GE6 1999 and Cape Town 1998 respectively) and Dr. Charles Magori from Kenya is the GLOSS Regional Coordinator for East Africa.

Djibouti – at the Jeddah GLOSS course in 2000 the gauge at Djibouti was claimed to be operational but no recent data flows to data banks as problems with hardware. An effective gauge there would be an ideal complement to Aden (Yemen) which is installing new gauges. One specialist attended the Jeddah GLOSS training course in 2000.

Sudan – last data are from 1994 when Port Sudan gauge expired. Plans are in place for new systems. One specialist attended the Jeddah GLOSS training course in 2000.

Indian Ocean Islands – Mauritius has recent data from Port Louis and Rodrigues. Seychelles has recent data from Pt. La Rue. However, both Mauritius and Seychelles gauges are old technology systems. Mauritius scientists have attended several GLOSS training courses. SHOM (France) plans to renew the presently non-operational Pointe des Galets station at La Reunion within 2 years.

Europe

We do not list each country although several gaps in the GLOSS Core Network (GCN) are mentioned below. Gauges have been operated in Europe for centuries, which is part of the problem as there is a continent-wide need for gauge modernisation, coordination of data processing and dissemination methods, and expansion of the presently sparse European Mediterranean network to North Africa. Some of this modernisation is currently taking place within the EU-funded European Sea Level Service (ESEAS) activity and the IOC/CIESM MedGLOSS programme. Most countries are now providing data freely, usually via the web. Particular countries which might be named include:

Ireland – a site on the west coast of Ireland has long been identified for the GCN (Castletownsend) which is one of the most open-ocean locations in Europe. Irish authorities have expressed interest in GLOSS and European tide gauge networks several times through the years but no developments have happened.

Portugal – upgrades to Cascais are needed. It is now out of action but has one of the longest records in the world. A backup to Ponta Delgarda in the Azores for satellite altimeter calibration (amongst other things) would also be desirable.

Arctic

The operation of gauges in the Arctic is, as in Antarctica, an exercise in the possible rather than the desirable. For a fairly recent review, see "IOC. 2000. (ed. H-P. Plag) Arctic tide gauges: a status report. IOC/INF-1147", available via
http://ioc.unesco.org/iocweb/iocpub/iocdoc/i1147.doc

Russian Arctic – back MSL data from a large number of sites have recently been made available. However, we believe that many sites are now not operational.

Greenland – half of the Danish gauges in Greenland have been recently abandoned. Remaining GCN sites are at Angmagssalik and Nuuk (Gothåb).

Canadian Arctic – many Canadian Arctic gauges were removed during the 1990s. The Little Cornwallis Is. Stations is now closed with no plans to reopen. Nain was reactivated last summer but was hit by a storm and needs new installation. Stations presently active in the Arctic include Alert (since July 2002 in its new form) and Holman Is. (since August 2002). There are plans to reactivate Tuktoyaktuk and to have a new station at Pond Inlet. All Arctic stations are tied to GPS for work with the TIGA project.

ANNEX III

GAUGES REQUIRED IN EACH COUNTRY

The table below provides an assessment of where new and re-equipped gauge sites ('re-equipped' will usually amount to 'new' in most cases) and upgraded sites (e.g. float gauge equipped with real-time capability) are required in each country. For each country listed, we mention all GCN sites together with a small number of others if appropriate; reasons for the latter are given. GCN gauges which are known to be modern (or soon will be) and should be working to required standards are shown in italics; these obviously do not form part of the funding proposal. GCN sites shown for new gauges need not be definite choices if, following local advice, nearby alternatives are available. The reason for priority selection in some cases is also shown; this is sometimes a qualitative assessment and comments based on local knowledge are welcomed. Column 5 lists for each country the total number of new tide gauges needed and of this, the total number of new tide gauges needed with priority ≥3.

Country	**Station**	**Priority (1-5 high)**	**Risk (1-5 high)**	**Totals: All,High priority**	**Comments**
		North America			
Mexico	Cabo San Lucas (Pac)	4	2		
	Acapulco	2	2		
	Is. Guadalupe	2	2		
	Manzanillo	4	2		
	Puerto Angel	2	2		
	Socorro Is.	2	2		
	Progreso (Carib)	4	2		
	Veracruz	4	2	8,4	Note that this allocation was made on the basis of information available from data receipts, but the Mexican Navy is known to have a large, technically-adequate network the data from which could possibly be made available to GLOSS, see Annex II. At a minimum, 2 good sites are required on each coast for GLOSS.
		South America			
Ecuador	Baltra	4	2		
	La Libertad	2	2	2,1	
Peru	Callao	3	2	1,1	
Argentina	*Bahia Esperanza*				
	Mar del Plata				
	Ushuaia				
	Puerto Madryn	4	2		
	Puerto Deseado	4	2	2,2	
Brazil	*Cananeia*				
	F de Noronha Is.	4	3		
	Itaparica	2	2		
	Ponta de Madeira	2	2		No PSMSL data
	Porto de Natal	2	2		Little PSMSL data
	Porto de Rio Grande	2	2		No PSMSL data
	Porto de Santana	2	2		No PSMSL data
	Rio de Janeiro	4	2		
	St.Peter and Paul Rocks	4	5		
	Trinidade Is.	4	4	9,6	See Annex II. Several stations are required along the long Brazil coast and a new selection of GCN sites may be required. Island sites may be difficult to operate.
		Asia			
India	*Cochin*				
	Madras				
	Marmagoa				

Country	**Station**	**Priority (1-5 high)**	**Risk (1-5 high)**	**Totals: All,High priority**	**Comments**
	Vishakhapatnam				
	Mumbai (Bombay)	4	3		Not in GCN at present but very long record, preferred over Veraval/Porbandar. Veraval in GCN has stopped working and suggested replacement is Porbandar.
	Veraval	1	3		Veraval in GCN has stopped working and replacement suggested by NIO is Porbandar.
	Port Blair, Andaman Is.	2	4		
	Minicoy, Laccadive Is.	2	4		
	Nicobar, Nicobar Is.	2	4	5,1	India has a programme of upgrades to long-maintained float gauges which could be very cost effective. The first 4 are shown as already operational for this reason, to be confirmed. The 3 island sites could be difficult to maintain.
Sri Lanka	Colombo	1	1	1,1	
Thailand	Ko Lak	3	2		
	Ko Taphao Noi	3	2	2,2	Good local contacts. Gauge exists but old technology. One gauge shown for each coast.
Bangladesh	Chittagong	4	3	1,1	Populated delta for which reliable data need for range of sea level studies.
PR China	Dalian	4	2		
	Lusi	2	2		
	Kanmen	4	2		
	Xiamen	2	2		
	Zhapo	2	2	5,2	The 5 stations are shown N to S. Zhapo is almost same latitude as Hong Kong.
Russia	Barentsburg (Svalbard)	1	4		
	Russkaya Gavan (Arctic)	3	3		
	Murmansk	3	3		
	Nakhodka	1	3		
	Dikson	3	3		
	Tiksi	3	3		
	Yuzhno Kurilsk (Pac)	3	3		
	Nagaevo Bay	3	3		
	Petropavlovsk	3	3		
	Providenya	1	3		
	Port Tuapse (Black Sea)				
	Kaliningrad (Baltic)				
	Kronshadt				Very long historical record.
	Mirny (Antarctic)			14,7	Not relevant – see notes. Priorities have been allocated on basis of record length. more information is needed to assess present status and requirements.
Indonesia					10 Upgrades to relatively new stations to be selected.
		Middle East			
Pakistan	Karachi	4	3		Long existing record although site now being changed.
	Gwadar	2	4	2,2	Only scrappy data exist so far.
Iran		2	2	2,0	To be selected, not in GCN at present, to start Gulf network.
Yemen	Aden	4	4	1,1	Very long historical record.
		Africa			
Egypt	Alexandria	3	4	1,1	Not in GCN but long record from a subsiding delta area requiring data for impacts studies. gauges exist but are old and bureaucracy precludes data transfer.
Morocco	Tan Tan (Atl coast)	3	2	1,1	Or similar station, for upwelling

Country	**Station**	**Priority (1-5 high)**	**Risk (1-5 high)**	**Totals: All,High priority**	**Comments**
					and eastern boundary current studies.
Gambia	Banjul	4	2	1,0	Not GCN but recommended by GLOSS Africa 2002. Sensible backup to Dakar.
Senegal	*Dakar*				Suggested for new gauge in GLOSS Africa 2002 proposal but modern acoustic gauge exists (?).
Guinea Bissau	Conakry	1	4	1,0	Not GCN, suggested GLOSS Africa 2002 proposal.
Cote D'Ivoire	Abidjan	3	3	1,1	Existing short record and enthusiastic local people. Recommended also by GLOSS Africa 2002 proposal.
Ghana	Tema	3	2		
	Takoradi	4	2	2,2	Pressure gauges have been promised for some time by NIO, India but at present have not yet been installed. Takoradi has the longest record in Africa. Important for upwelling, coastal studies. Good local contacts. Recommended also by GLOSS Africa 2002 proposal.
Nigeria	Lagos	3	2	1,1	Medium length, scrappy historical record. Data needed for nearby 'mega-city'. Good local contacts at NIOMR.
Equ. Guinea	Malabo	1	4	1,0	Not GCN. Recommended by GLOSS Africa proposal. Little historical data.
Congo	Pointe Noire	2	4	1,0	Proposed by IRD, France gauge mentioned in ANNEX IV not materialised at present. Sea level affected materially by river outflow needs study. Recommended also by GLOSS Africa 2002 proposal.
Namibia	*Walvis Bay*				
	Luderitz	3	2	1,1	Not in GCN. At least one good gauge at WB or Luderitz required for upwelling coast. Discussion needed.
Mozambique	Inhambane	3	2		
	Pemba	3	2	2,2	Good local contacts with some experience of sea level data, although scrappy historical records. GLOSS Africa 2002 proposal suggested also Chinde (not GCN and little historical data).
Madagascar	Morondava	2	5	1,0	Not in GCN. This site was suggested in GLOSS Africa 2002 proposal. Contacts with Madagascar in recent years have been poor.
Tanzania	Zanzibar	4	1		Good local contacts. Operational gauge exists but needs updating.
	Mtwara	1	4	2,1	Old data exist. In far south of Tanzania, nothing known of site. Suggested also in GLOSS Africa 2002 proposal.
Kenya	Mombasa	4	1	1,1	Good local contacts. Operational gauge exists but needs updating. GLOSS Africa2002 proposal suggested also Shimoni (not GCN) but that has little historical record. Resources better into an established site.

Country	**Station**	**Priority (1-5 high)**	**Risk (1-5 high)**	**Totals: All,High priority**	**Comments**
Djibouti	Djibouti	2	5	1,0	Few recent contacts. Would complement Aden for Red Sea studies, otherwise high risk.
Sudan	Port Sudan	3	3	1,1	Not in GCN at present, but a medium length record and local contacts exist through PERSGA. Would form centre of Red Sea network.
Mauritius	Port Louis	4	1		
	Rodrigues	4	1	2,2	Good local contacts. Operational gauges exist but need updating. GLOSS Africa 2002 proposal suggested also Agalega (not GCN) but that has little historical record and would be instrumentally difficult. Resources better into an established site.
Seychelles	Pt. de la Rue	3	2	1,1	Operational gauge exists but needs updating. GLOSS Africa2002 proposal suggested also Aldabra (not GCN) but that has little historical record and would be instrumentally difficult. Resources better into an established site.
Comoros	Moroni	1	4	1,0	Not GCN. Suggested in GLOSS Africa 2002 proposal. Little historical record.
		Europe			
Ireland	*Malin Head*	4	1	1,1	At present not operational but a replacement gauge is planned by Irish Ordnance Survey which we assume will occur.
	Castletownsend				Short historical record. Rocky coast may require special installation.
Portugal	*Ponta Delgardo, Azores* Cascais	5	2		One of the longest records in Europe, old gauge recently removed through marina construction.
	Flores	3	2		Backup for operational Ponta Delgardo, Azores for –ALT. other end of Azores arc.
	Funchal, Madeira	3	2	3,3	Medium length historical record.

<u>Totals</u>

Total new	82 (of which 50 have priority ≥3)
Spare new stations	10 making 92 total new
Indonesia upgrades	10
Central American real-time upgrades	20

ANNEX IV

LIST OF ACRONYMS

ALT	Altimeter calibration station network (in GLOSS)
BODC	British Oceanographic Data Centre
CGPS@TG	Continuous GPS at Tide Gauges (IGS/PSMSL working group)
CIESM	International Commission for the Scientific Exploration of the Mediterranean Sea
CLIVAR	Climate Variability and Predictability (
COOP	Coastal Ocean Observations Panel
CPACC	Caribbean Planning for Adaptation to Climate Change
DBCP	Data Buoy Cooperation Panel
DHN	Diretoria de Hidrografia e Navegacao (Brazil)
DORIS	Doppler Orbitography and Radio positioning Integrated by Satellites
ENSO	El Niño Southern Oscillation
EOSS	European Sea Level Observing System (superseded by ESEAS)
ESEAS	European Sea-Level Service
EU	European Union
GCN	GLOSS Core Network
GE	Group of Experts (of GLOSS)
GFZ	Geo Forschungs Zentrum, Potsdam, Germany
GIA	Glacial Isostatic Adjustment
GLOSS	Global Sea Level Observing System
GODAE	Global Ocean Data Assimilation Experiment
GOOS	Global Ocean Observing System
GTOS	Global Terrestrial Observing System
GPS	Global Positioning System
IALA	International Association of Marine Aids to Navigation and Lighthouse Authorities
IGS	International GPS Service for Geodynamics
IHO	International Hydrographic Organization
IOC	Intergovernmental Oceanographic Commission (of UNESCO)
IPCC	Intergovernmental Panel on Climate Change
IRD	Institut de recherche pour le développement (France)
JCOMM	WMO-IOC Joint Technical Commission on Oceanography and Marine Meteorology
LME	Large Marine Ecosystem
LTT	Long Term Trends
MEDGLOSS	Mediterranean Programme for the Global Sea-Level Observing System (of IOC and CIESM)
MSL	Mean Sea Level
NOAA	National Ocean and Atmosphere Administration (USA)
OC	Ocean Circulation station network (in GLOSS)
OOPC	Ocean Observations Panel for Climate
PERSGA	Regional Organization for the Conservation of the Environment of the Red Sea &Gulf of Aden
POL	Proudman Oceanography Laboratory (UK)
PSMSL	Permanent Service for Mean Sea-Level

RONMAC	Red de Observacion del Nivel del Mar para America Central
SCAR	Scientific Committee on Antarctic Research
TIGA	Tide Gauge and GPS Benchmark Monitoring Project (of IGS)
TOGA	Tropical Ocean Global Atmosphere Programme
TOPEX	Ocean Topography Experiment
UHSLC	University of Hawaii Sea Level Center
UNESCO	United Nations Educational, Scientific and Cultural Organization
USP	University of Sao Paulo, Brazil
VLM	Vertical Land Movement
VOS	Voluntary Observing Ship
WMO	World Meteorological Organization
WOCE	World Ocean Circulation Experiment

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INTERGOVERNMENTAL OCEANOGRAPHIC COMMISSION
(of UNESCO)

A REPORT ON THE STATUS OF THE GLOSS PROGRAMME AND A PROPOSAL FOR TAKING THE PROGRAMME FORWARD

CORRIGENDUM

(SC-2003/WS/21 corr.)

GLOSS status within the PSMSL dataset. October 2002

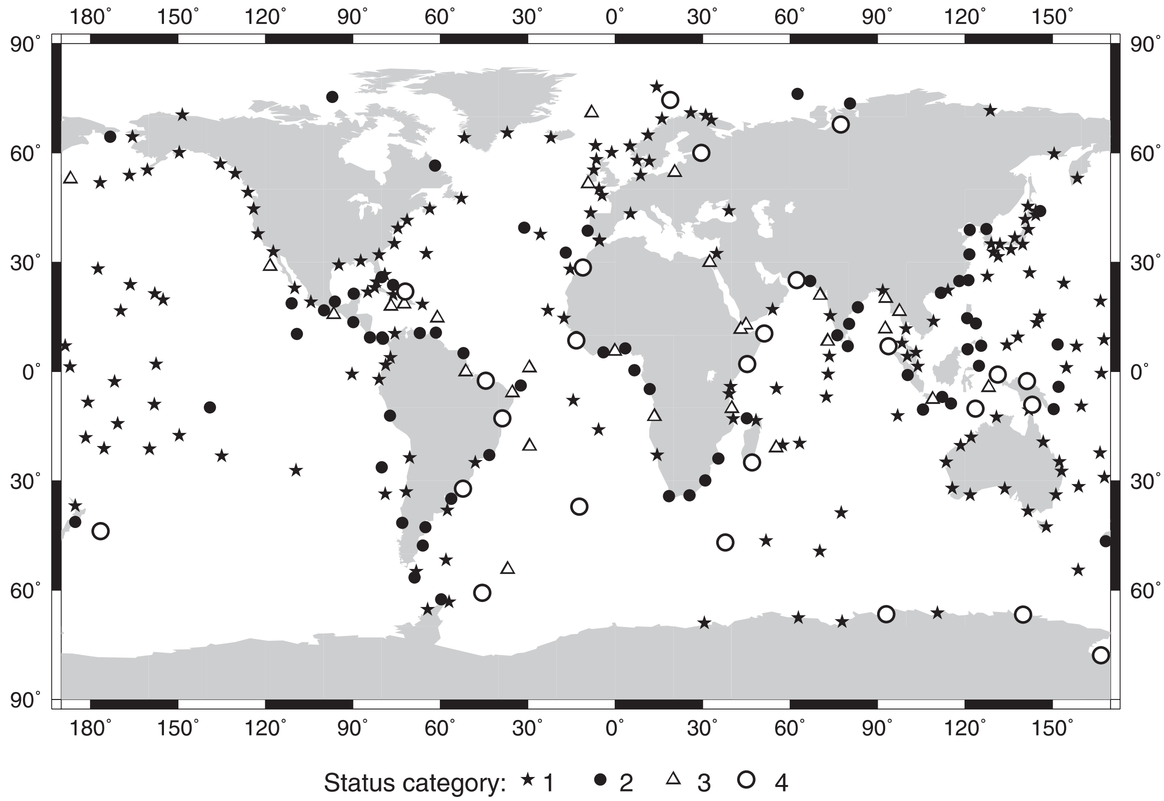

Figure 1. GLOSS status October 2002. For explanation of the status categories please see Table 1.

GLOSS Real Time Stations (April 2003)

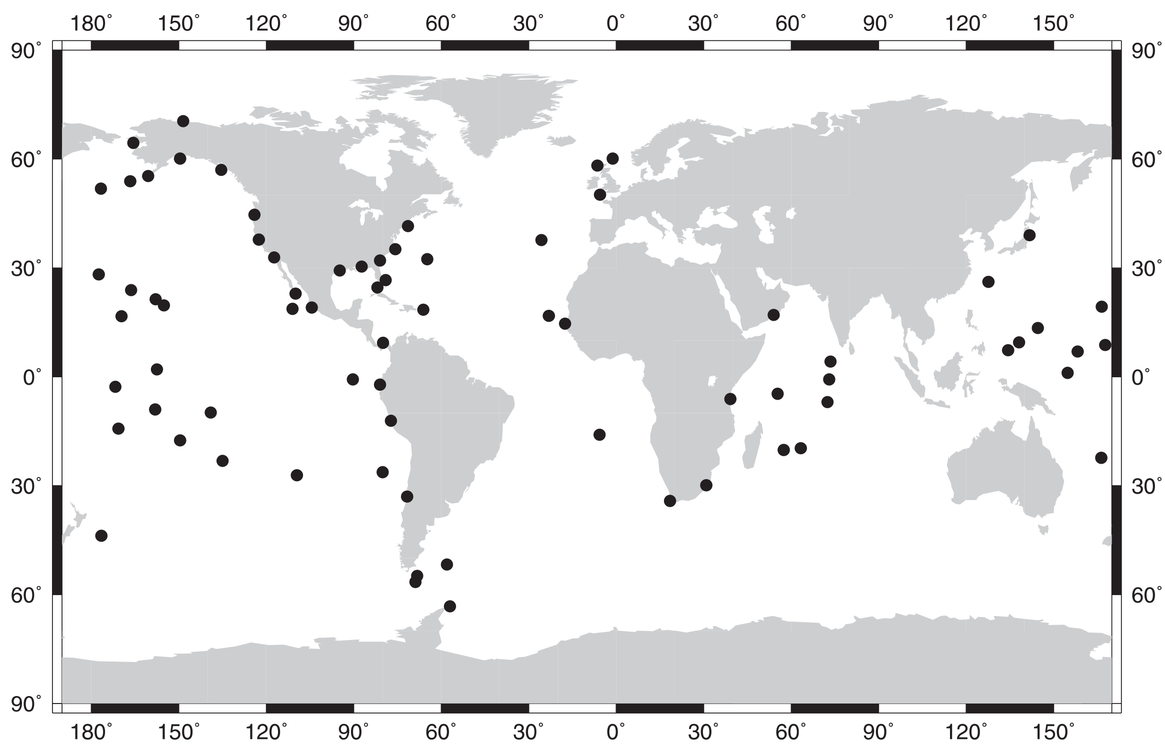

Figure 2. GLOSS real time stations (April 2003).

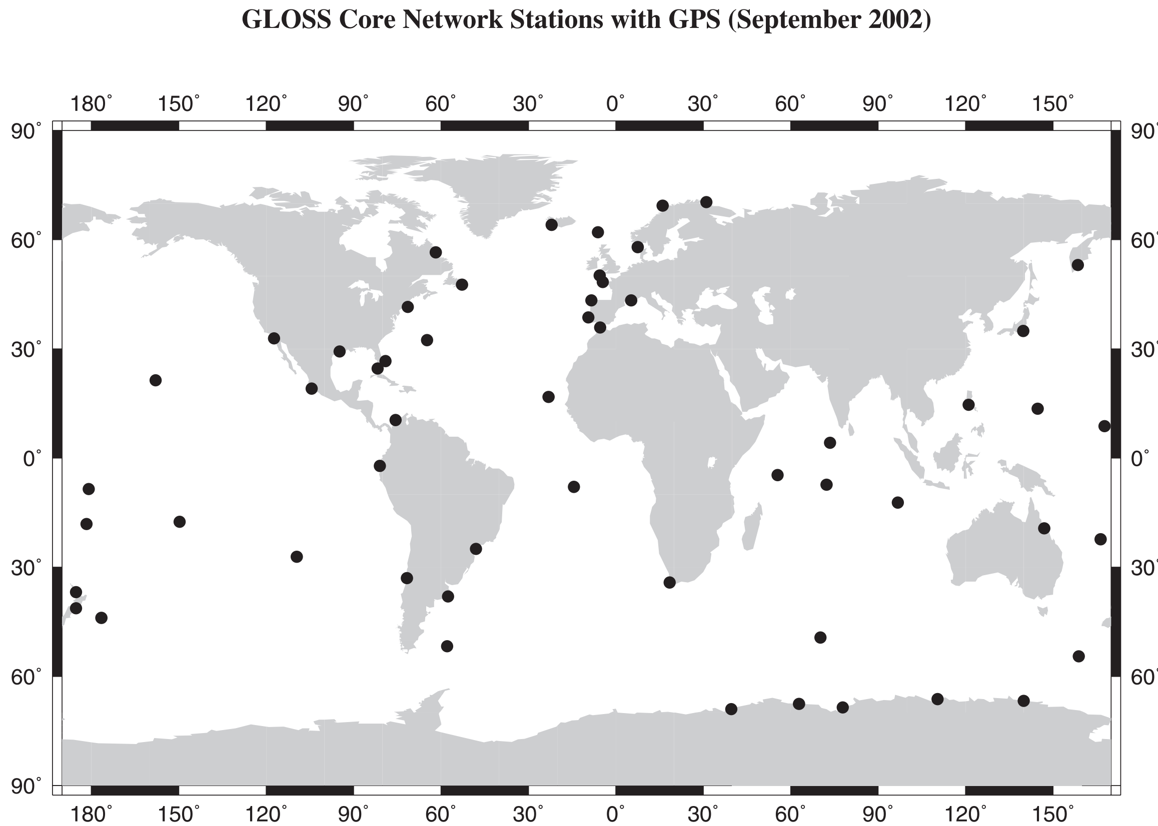

Figure 3. GLOSS Core Network Stations with GPS (September 2002).

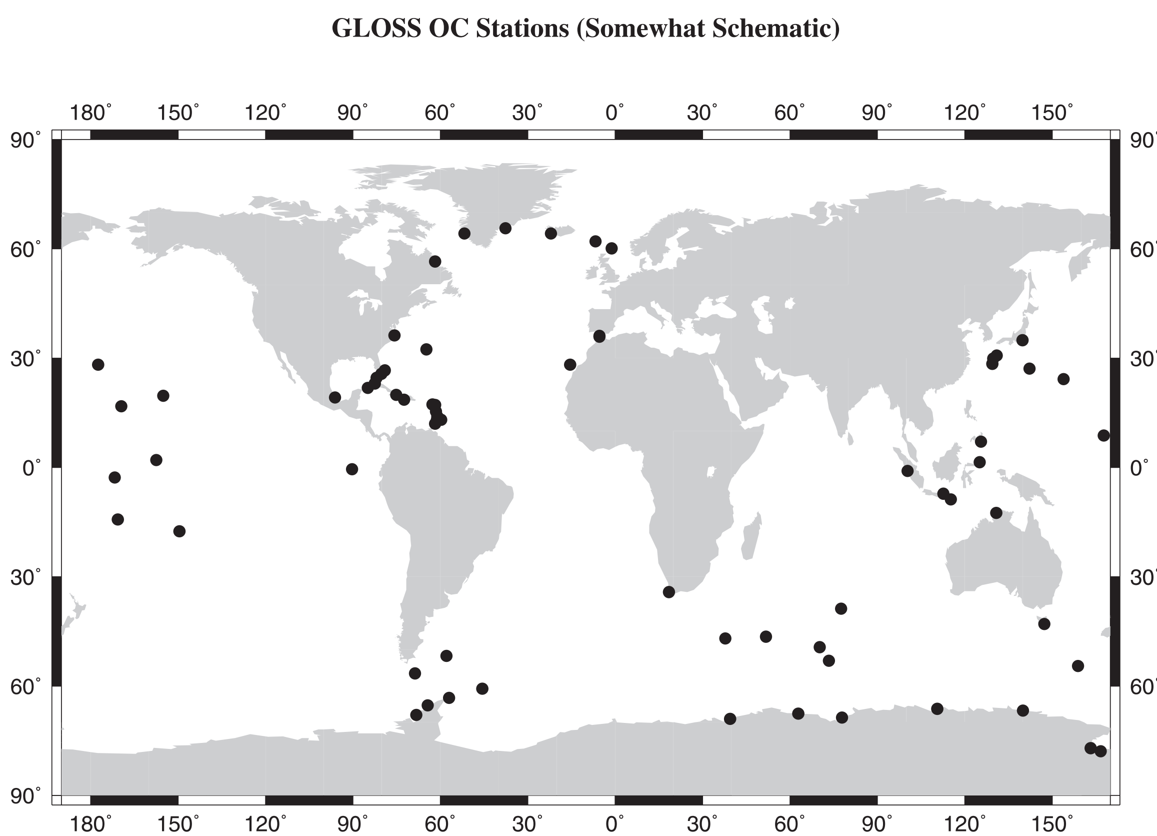

Figure 4. GLOSS Ocean Circulation stations.