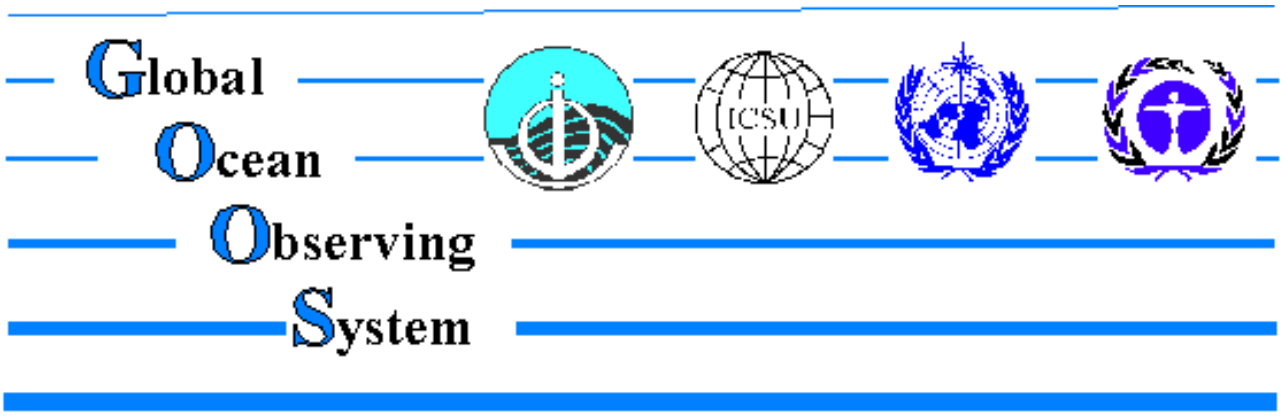

Intergovernmental Oceanographic Commission
Reports of Meetings of Experts and Equivalent Bodies

IOC Group of Experts on the Global Sea Level Observing System (GLOSS)

Seventh Session
Honolulu, USA
26-27 April 2001

GOOS Report No. 116
GCOS Report No. 72

UNESCO

Intergovernmental Oceanographic Commission
Reports of Meetings of Experts and Equivalent Bodies

IOC Group of Experts on the Global Sea Level Observing System (GLOSS)

Seventh Session
Honolulu, USA
26-27 April 2001

GOOS Report No. 116
GCOS Report No. 72

UNESCO 2002

IOC/GE-GLOSS-VII/3
Paris, 18 May 2001
English only

Abstract

This report presents the results of the seventh session of the Global Sea Level Observing System Group of Experts (GLOSS GE7). The GLOSS-GE reviewed the programme and made recommendations on the programme implementation. In connection with the GLOSS GE meeting, four associated scientific workshops were convened; 1) A one day workshop (spanning 23-24 April 2001) in honor of Professor Klaus Wyrtki which addressed sea level and oceanographic topics in the Pacific and Indian Oceans; 2) A one day workshop (spanning 23-24 April 2001) which focused on research activities conducted under the sea level component within the Asia-Pacific Space Geodynamics Programme (http://center.shao.ac.cn/APSG); 3) A working group meeting (also spanning 23-24 April 2001) on IAG Section II GPS-Water Level Measurements; and 4) A workshop (25 April) on the use of GPS for the monitoring of tide gauge benchmarks.

TABLE OF CONTENTS

ANNEXES

1. ORGANIZATION OF THE SESSION

1.1 OPENING OF THE SESSION

Philip Woodworth, Chairman of the Group of Experts (GE) for the Global Sea Level Observing System (GLOSS), opened the session and welcomed all the participants. He emphasized the importance of the meeting which functions as the main source of guidance to the Intergovernmental Oceanographic Commission (IOC) for the GLOSS programme for the next two years. He explained that the GE-GLOSS meetings are primarily 'business meetings' in which representatives of each country are to consider what their needs are in relation to the GLOSS programme, and in turn they are to consider what they could contribute to the programme. To some extent, the session was intended to provide an Asia-Pacific complement to that held two years ago in Toulouse, in which the concentration of interest was focused upon the Atlantic and Indian Oceans and Africa.

In his welcome, he thanked Mark Merrifield and his staff at the University of Hawaii Sea Level Center (UHSLC) for the local arrangements, and the Hawaii Institute of Geophysics and Planetary Physics (HIGP) for hosting this seventh session of the Group of Experts (GE7). Klaus Keil, Director of the HIGP, welcomed the attendees and gave a brief introduction to the activities at HIGP. He expressed his wishes for a productive meeting and generously offered logistic support and assistance during the GE7 meeting. On behalf of the Executive Secretary of the Intergovernmental Oceanographic Commission (IOC), Thorkild Aarup welcomed the participants and expressed his thanks to Mark Merrifield and the local organizing committee for the fine arrangements.

1.2 ADOPTION OF THE AGENDA

Philip Woodworth reviewed the agenda (Annex I) which was approved by the participants. A list of participants is given in Annex II.

1.3 DESIGNATION OF THE RAPPORTEUR

Mark Merrifield and Yvonne Firing were elected Rapporteurs.

2. REVIEW OF GLOSS ACTIVITIES

Philip Woodworth presented the Chairman's Report on GLOSS activities since the sixth session of the Group in Toulouse in 1999 (Annex III). This report refers to actions taken since GE6, a review of various GLOSS-related activities (many of which were discussed in greater detail during GE7) and of recent publications (including the GE6 and Workshop reports from the Toulouse meeting), and a short status report on the GLOSS Core Network.

3. REPORT OF THE 'KLAUS WYRTKI' WORKSHOP (MARK MERRIFIELD)

The hosting of the GE7 meeting in Honolulu provided an opportunity to honor Professor Klaus Wyrtki, an Emeritus Professor at the University of Hawaii and a preeminent researcher in the field of physical oceanography. The Wyrtki workshop was convened by Mark Merrifield, Roger Lukas and Gary Mitchum, and consisted of two half-day sessions of presentations by invited speakers who each touched on some aspect of Professor Wyrtki's career. An overview of Indonesian Throughflow was presented by Arnold Gordon of Lamont Doherty Earth Observatory including a description of recent direct observations of transport and variability. James O'Brien of Florida State University discussed progress in ENSO modelling, highlighting recent findings on coastal instabilities and eddy formation. Philip Woodworth of the Proudman Oceanographic Laboratory, UK and the PSMSL described the evolution of the GLOSS programme and its role in various international oceanographic programmes such as WOCE and CLIVAR. Wolfgang Scherer of the National Tidal Facility, Australia discussed the issue of global sea level rise, emphasizing the importance of long time

series and geodetic monitoring. The issue of sea level rise was further addressed by Christian Le Provost of GRGS, Toulouse in a synthesis of steric height, altimeter, and tide gauge data. His re-evaluation of the Douglas estimate of global sea level rise from tide gauges was a meeting highlight. Four of Professor Wyrtki's former students made presentations on the second day of the meeting. The first was Gary Meyers of CSIRO, Australia who traced Wyrtki's early work on Java upwelling in the Indonesian region to recent developments on the Indian Ocean Dipole and Indonesian Through-flow. Bill Patzert of JPL overviewed the dramatic developments that have taken place with the advent of altimetry, culminating in the depiction of the recent El Niño and La Niña events. Bill Emery of the University of Colorado described recent advances for estimating surface currents from infrared sea surface temperature and satellite altimetry measurements, and applied the method to the East Australian Current region. Roger Lukas of the University of Hawaii presented the state of the art of ocean observing systems with special emphasis on the importance of salinity measurements for describing the state of the ocean. Mark Merrifield of the University of Hawaii presented a description of sea level and current variability local to the Hawaiian Islands. Each speaker described the special role that Professor Wyrtki has played in his or her careers. The meeting ended on a high note with a statement by Professor Wyrtki himself, as well as the awarding to Professor Wyrtki of a Certificate of Appreciation on behalf of GLOSS, and the announcement that a coastal research vessel donated to the University of Hawaii would be christened the RV *Wyrtki* in his honour.

4. REPORTS OF THE APSG SEA LEVEL WORKSHOP AND GPS-WATER LEVEL MEASUREMENTS WORKSHOP (C. K. SHUM, WOLFGANG SCHERER, DOUG MARTIN AND TILO SCHOENE)

There were two Workshops held on the afternoons of 23 April and 24 April 2001. The first was the Asia-Pacific Space Geodynamics (APSG) Programme Sea Level Workshop, organized by C. K. Shum, Wolfgang Scherer and Cheng Huang. The second was the Workshop of the IAG Special Study Group 2.194, GPS-Water Level Measurements, organized by Gerry Mader, Doug Martin and Tilo Schoene.

There were in turn two Sessions within the APSG Workshop, chaired by Wolfgang Scherer of the Australian National Tidal Facility and Nanhua Yu of Shanghai Astronomical Observatory respectively, and held on the afternoons of 23 April and 24 April 2001. A total of ten oral presentations were given for the APSG Workshop. There were also two Sessions within the GPS-Water Level Workshop, chaired by Doug Martin of NOAA-CO-OPS and Tilo Schoene of GFZ respectively, and held on the afternoons of 23 April and 24 April 2001. A total of six oral presentations were given for the GPS-Water Level Workshop. There were a total of seven poster papers associated with the two Workshops on display 23-25 April 2001.

4.1 REPORT ON THE ASIA-PACIFIC SPACE GEODYNAMICS PROGRAMME SEA LEVEL WORKSHOP (ORGANIZERS: C. K. SHUM, WOLFGANG SCHERER AND CHENG HUANG)

Monday Afternoon, 23 April 2001
Chair: Wolfgang Scherer, National Tidal Facility

C. K. Shum of Ohio State University presented the science objectives of the APSG programme Sea Level Working Group, its goals, affiliated programs and projects, prior workshops and its current status. The status of the APSG Sea Level Project Data Center, to be established at the National Tidal Facility (NTF) in Australia with other mirror sites was reported. He presented results on sea level trend determination using satellite altimetry (GEOSAT, ERS-1, ERS-2, T/P and GFO), and tide gauges. Altimeter drift estimates using WOCE and Great Lakes tide gauge were presented. Current estimate of sea level trend using multiple altimetry covering a 15-year time span (1985-2001) is 1.7±0.7 mm/yr. It is anticipated that altimetric data, tide gauge data from PSMSL/WOCE, other in situ sea level measurements not at present in data banks, vertical motion data, etc. will be included in the APSG Data Centre.

Wolfgang Scherer of the NTF presented an update on Phase III of the South Pacific Sea Level and Climate Monitoring Project. In the project, GPS receivers will be collocated with the tide gauges already installed in the South Pacific Island nations. He presented recent results of sea level trends and El Niño signals observed at the island nation tide gauges, and commented that longer time series in some of the sites are needed to provide a reliable sea level trend.

Don Chambers of the University of Texas presented a study on the interannual variations in sea level in the Pacific using reconstructed sea level time series with EOFs from tide gauges and satellite altimetry (GEOSAT and T/P). Results show high coherence of tide gauge and altimetric sea level time series during the same time span, with the sea level time series reconstructed back in time using the tide gauges alone together with the determined EOF information. Chambers also reported on another study of the Indian Ocean dipole [Saji *et al.,* 1999] and the Pacific Ocean dipole, using sea level in addition to sea surface temperatures. It was found that the sea level correlates better between the Indian and Pacific Oceans than does SST.

Xaoli Ding of Hong Kong Polytechnic University presented a talk on sea level changes in Hong Kong and their relationship to ENSO studies. He presented a sea level trend analysis of the 50-year record (1951-2001) for the Hong Kong tide gauge. The limitations include the analysis of land motions using leveling data, as the tide gauges were located in reclamation areas. He then provided a correlation analysis of sea level signals, including seasonal and inter-annual frequencies, with ENSO in the form of the Southern Oscillation Index (SOI), air pressures ('inverse barometer') and air temperatures. Fourier and wavelet analyses were used. It was observed that there is a three-month lead for atmospheric pressure to sea level, and the phase of SOI is two-month lead, and SST has a one-month lead.

Xaoli Ding also presented a talk on atmosphere angular momentum (AAM), length of day (LOD), SOI, and Hong Kong sea level correlations. Correlations have been observed, indicating the seasonal and inter-annual variability of the sea level is correlated with ENSO and with observed earth rotation. A prediction of El Niño was conducted based on these correlations and using statistical techniques.

Richard Coleman of the University of Tasmania at Hobart, Australia presented a talk on the measurement of long term sea level change using historical sea level measurements tied to an historic benchmark at Port Arthur. On 1 July 1841, Thomas Lempriere installed a tidal benchmark on the shores of the Isle of the Dead at Port Arthur in Tasmania. It is believed that it is one of the first such marks placed anywhere in the world for the scientific study of sea level. He also collected several years of sea level data, which were related to the benchmark. An Aquatrak acoustic tide gauge was established at Port Arthur during 1998/99 and became fully operational in August 1999. Using a combination of leveling, GPS buoy and static GPS observations, Coleman and colleagues have established a connection between the 1841-1842 benchmark and the current operational tide gauge. These observations, over the 158-year period, have been used to estimate mean sea level changes in southern Tasmania. The estimated rise of 0.82±0.19 mm/yr has been provisionally corrected for local vertical land movement (primarily post-glacial rebound).

Wolfgang Bosch of the Deutsches Geodätisches Forschungsinstitut (DGFI) presented a study on low frequency sea level variations over seasonal and inter-annual scales in the North Atlantic using satellite altimetry. The paper analyzed eight years of TOPEX/POSEIDON altimeter data in order to identify long periodic anomalous sea level changes in the North Atlantic. Annual oscillations as well as aliased effects from imperfect ocean tide corrections were estimated by harmonic analysis and were subtracted from the sea level heights. Principal Component Analysis and Mortel wavelet analysis of the residuals identified a dominant mode that showed a low frequency variation with duration of approximately seven years. The sea level time series was compared to the North Atlantic Oscillation (NAO) index and the results of comparable analyses of sea surface temperature and sea level pressure. Correlations between these data sets were observed.

Wolfgang Bosch also presented a position paper on the IAG's CSTG Sub-Commission on Multi-Mission Satellite Altimetry, ScoMMSA. His goal is to create a unified multi-mission altimeter database with specific considerations on its organization, functionality, content and structure. The purpose is to initiate a discussion towards an International Altimeter Service, which would use such a system and data base structure to serve users. He provided a detailed description of the design of a prototype system. A discussion followed on the concept and the design of the data service system.

Tuesday Afternoon, 24 April 2001
Chair: Nanhua Yu, Shanghai Astronomical Observatory

Wolfgang Bosch (DGFI) presented results of comparison of altimetric sea level time series and tide gauge registrations. The approach was applied to several tide gauges in the North Atlantic and the correlation between sea level time series and tide gauge registrations was shown. The comparison of combined T/P and ERS-2 sea level with tide gauges in the Caribbean was shown. An example of a poor comparison is Key West, with a correlation of only 0.41; a good example comparison is Magueyes Island with a correlation of 0.85. T/P and ERS-2 show good consistency. The mean rms for comparisons is 5.2 cm, correlations are on average 0.7, with island gauges at 0.8.

Baki Iz of Hong Kong Polytechnic University presented a study towards establishment of a global vertical datum using global VLBI network using tetrahedral deformations using a finite element approach. Results show that station deformation for all configurations (corrected for plate motion) is 10-3 μstrain for the strain tensor components and a few mas for network rigid body rotation. The global vertical datum will be known within 0.5-3 mm, the station height variation within 10-35 mm.

4.2 REPORT ON THE WORKSHOP ON IAG SSG 2.194, GPS-WATER LEVEL MEASUREMENTS (Organizers: Gerry Mader, Doug Martin and Tilo Schoene)

Monday Afternoon, 23 April 2001
Chair: Doug Martin, Center for Operational Oceanographic Products and Services (CO-OPS), NOAA

Doug Martin of the Center for Operational Oceanographic Products and Services (COOPS, NOAA) gave introductory remarks and opened the Workshop. He commented that the Workshop is conducted under IAG's Section II Special Study SSG 2.194, entitled GPS-Water Level Measurements. This is the second Workshop dedicated to SSG 2.194 science. A dozen presentations were made, including poster papers. Doug Martin mentioned that five-six presentations had also been made on this subject in a workshop at the European Geophysical Society (EGS) Symposium in Nice, May 2000.

Tilo Schoene of GeoForschungsZentrum (GFZ), Potsdam in Germany presented an introduction to the Workshop. He showed the geographical distribution of membership of the SSG (http://op.gfz-potsdam.de/altimetry/SSG_buoys). He discussed the pros and cons of current designs of different styles of buoy, including the life-safer, spar, and toroid and other styles of GPS-buoys. A number of technical issues remain for the design of a working buoy for such applications as radar altimeter calibrations, including the automation requirements, hardware design, RTK GPS solution strategy, communication, robustness of buoys and design to withstand rough sea conditions. The objective of the Workshop was to exchange information towards the using of GPS Water level instrument for interdisciplinary applications.

Tilo Schoene also discussed a project at GFZ called SEAL within which GPS buoys are used for calibration of radar altimeters. He described the North Sea site to calibrate multiple radar altimeters. The water depth is only 20 m, and GPS buoy design includes tilt-meter or inclinometer, accelerometer, radar reflector, pressure and temperature sensors, sub-surface conductivity-temperature sensor, batteries, web-cam, and radio HF transmitter. The buoyancy is 2.5 ton. (Doug Martin commented that the NOS buoys weigh 18 tons.). The buoy was tested without instruments in water for 14 days in the North Sea. The goal is to test, integrate and deploy the buoy in September, to be ready for the launch of ENVISAT in October-November 2001.

Tuesday Afternoon, 24 April 2001
Chair: Tilo Schoene, GeoForschungsZentrum, Potsdam

Philip Woodworth of Proudman Oceanographic Laboratory, UK presented a study on absolute calibration of the TOPEX/POSEIDON altimeters using UK coastal gauges and a precise geoid model. UK gauges include seven in the South Atlantic which contribute to the 'relative' altimeter calibrations (e.g., by Mitchum, 1994) and 44 gauges on the UK mainland of which 16 have had their benchmarks collocated using either permanent or campaign GPS measurements. The present study used six gauges and relies on the use of a precise geoid model. He stressed the importance of the consistent treatment of the permanent tide when comparing altimeter and tide gauge (GPS collocated) measurements. The signal of the permanent tide at UK latitudes is around 7 cm. Tide gauge minus altimeter sea level difference is around 4 cm rms. Regional geoid models, EGG97 or EDIN2000, are used. An error budget in terms of RSS is estimated: 2-6 cm for systematic errors and 4-10 cm for quasi-random errors. Results indicated that averaged TOPEX bias is –1.3, median value is 0.6 cm, and POSEIDON bias is –0.5 cm, median value is 0.7 cm. These results are consistent with those from the dedicated Harvest platform calibration site and with results from a study by G. Liebsch *et al.*, who used a method similar to that of Woodworth for gauges on the German Baltic Sea coast, and which was presented in poster form at this Workshop.

Chris Watson of the University of Tasmania at Hobart presented a study on absolute altimeter activities in Bass Strait, Australia, using a GPS-buoy. Wave rider buoys, tide gauge, GPS, and bottom gauges are to be used for the altimeter calibration. Leica receivers and RTK software (GeoGenius) are used, with the baseline around 1.2 km. An improved design includes a battery, three floats, and an operational life of 24-hours. The antenna reference point can be measured with respect to the mean water level to within ±2 mm using an optical leveling technique. A simple exponential filter is used to filter GPS water level fluctuations. Comparison with a tide gauge showed zero mean, and 2 mm rms. Comparisons between two buoys at Port Arthur and the Isle of the Dead, which are 1.2 km apart, gave about 4 mm rms and zero mean. Comparison with geoid models is around the 27 mm level. An altimeter calibration experiment was conducted using baseline solutions of 4 km, 20 km, and 30 km, using TRACK software by Tom Herring. There are differences of several cm between the solutions using the different baselines. Current meters and ADCPs are also available underneath the TOPEX altimeter track. GPS-buoy future research at the University of Tasmania includes refinement of processing methodologies and improved buoy design, including a buoy for Antarctic applications.

Doug Martin presented a talk on the improved NOS GPS buoy design and analysis of the Cape Henry GPS Buoy project. The aims of the Cape Henry GPS Buoy project include the improvement of open ocean boundary conditions at the Chesapeake Bay to support near-real time operations for NOAA's Coastal Ocean Forecast System. Reference GPS stations are located about 18 km from the buoy. The buoy (9x36 buoy type) belongs to the US Coast Guard and weighs 18,000 lbs. Components on the buoy include ultrasonic water level sensor, pressure sensor, GPS receiver and antenna, radio communication device, 6-axis tilt sensor, microprocessor to manage data flow, 12 V batteries, navigation light, solar panels, etc. The power budget was described.

A general discussion followed the presentations. It was noted that there are technical notes on the SSG website: http://op.gfz-potsdam.de/altimetry/SSG_buoys/*Posters* *(23-25 April 2001).*

A number of poster papers were displayed as part of the APSG Sea Level, GPS-Water Level Measurement and CGPS@TG Workshops:

J. Hu, J. Li, X. Dong and J. Ma: Use satellite altimetry technique to monitor the sea level changes;

K. Cheng, C. Shum, Y. Yi, S. Calmant and D. Martin: Absolute radar altimeter calibration using GPS water level measurements;

T. Schoene, C. Reibger, G. Gendt, M. Ge and M. Ramatschi: Continuous monitoring of tide gauge benchmarks with GPS in SEAL project;

G. Liebsch, K. Novotny, R. Diertich, J. J. Wendt and C. Shum: Altimeter calibration in the South Baltic Sea;

M. Martinez-Garcia, J. Martinez-Benjamin and M. Ortiz-Castellon: GPS buoy technology applied to the absolute calibration of space radar altimeters and to the regional mapping the sea surface topography;

P. Bonnefond, P. Exertier and Y. Menard: Radar altimeter calibration using GPS buoy in Corsica;

P. Bonnefond, P. Exertier and Y. Menard: Levelling the sea surface using a GPS catamaran;

W.Bosch, P.Häfele and K.Kaniuth: GPS estimates of vertical crustal movements for sites around the North Atlantic Ocean.

5. REPORT OF THE GPS AT TIDE GAUGES WORKSHOP (MIKE BEVIS)

This one-day technical workshop, which followed the Wyrtki and APSG meetings, and preceded the GE7 meeting, was focused on geodetic positioning of tide gauges using continuous GPS and related space-geodetic measurement systems such as DORIS. The 'CGPS@TG' entity is a joint working group of IAG, PSMSL, IAPSO, GLOSS and the IGS.

Michael Bevis opened the meeting by discussing the challenges of the geodetic agenda. Even though the geodetic community is not yet capable of estimating the absolute vertical velocities of global CGPS networks with sub-mm/yr accuracy, as required by the most pressing oceanographic applications, there can be little doubt that such a capability will eventually be realized, provided that we collect CGPS time series of sufficient length and pay meticulous attention to site selection, monumentation, leveling ties, etc. The technical issues associated with field implementation are being addressed by position papers and case studies published in the CGPS@TG website (www.soest.hawaii.edu/cgps_tg). The processing issues are being addressed by a new IGS pilot project TIGA, chaired by Tilo Schoene (GFZ) that will soon release its call for participation. Bevis encouraged the workshop participants to submit more case studies and position papers to the CGPS@TG website.

Steve Nerem and Gary Mitchum made the case that the biggest source of uncertainty in the sea level rise estimates being derived from satellite altimetry is the lack of knowledge of vertical crustal velocity affecting the tide gauges which are used to calibrate the altimeters.

Wolfgang Scherer announced that NTF and AUSLIG will be installing about 10 CGPS stations at tide gauges in the West Pacific region during the next two or three years. This effort is being coordinated with a similar programme already being executed by the University of Hawaii.

Jim Davis described the use of the BIFROST CGPS network (Scandinavia) to measure the postglacial rebound velocity field. He emphasized the importance of assessing temporal changes in the geoid, as well as absolute vertical velocity of the lithosphere, in understanding the sea level signals recorded by tide gauges.

Ruth Neilan and Tilo Schoene addressed the TIGA pilot project and its place in the overall structure of IGS. Tilo Schoene sought input on the content of the call for participation document. This led to an extensive discussion, which continued the next day during the lunch break of the GE7 meeting. Project TIGA will eventually incorporate several centers of activity. The first of these to be funded is the geodetic component of the German project SEAL. Guy Woppleman indicated that he and others are seeking funds for French participation in TIGA. They hope to establish a data center dedicated to the CGPS@TG agenda that would archive CGPS data and leveling data. It was widely recognized that TIGA needs several independent GPS analysis centers, and it is hoped that other groups will be able to obtain the funding necessary to participate in this effort. Hopefully all of the major scientific GPS processing packages (GIPSY, GAMIT, BERNESE, EPOS, etc.) will be incorporated. Only when several GPS groups are capable of producing essentially similar velocity solutions will the oceanographic community be able to place a great deal of confidence in the utility of these geodetic products.

Jean-Francois Creteaux described a new round of DORIS deployments that will emphasize collocation with tide gauges, and especially tide gauges that are already collocated with CGPS. The importance of properly integrating GPS reference and measurements systems with other space geodetic systems, such as DORIS and SLR, was widely acknowledged.

Trevor Baker made a strong case for making absolute gravity measurements at as many CGPS@TG sites as possible, and described the effort already underway in the UK on both absolute gravity and GPS. He emphasized the present problems in determining accurate vertical velocities by showing the contrasting results for some global CGPS sites obtained by different GPS analysis centres.

Several participants suggested that the original goal of measuring sea and land level changes in a space-geodetic (geometrical) reference frame should be modified to incorporate the motion of the geoid in this same reference frame. The re-emergence of physical (as opposed to geometrical) geodesy, with new satellite missions such as GRACE and CHAMP, makes this tripartite approach viable for the first time. In this context absolute gravimeters take on a key role – they serve as the tide gauges of the gravity field.

6. REPORTS OF THE INTERNATIONAL SEA LEVEL CENTRES, REGIONAL AND INTERNATIONAL ACTIVITIES, AND NATIONAL REPORTS

The following reports were received from international and regional sea level centres and programmes (see Annex IV).

Permanent Service for Mean Sea Level (PSMSL). (This report is not included in Annex IV as the same report was used as for the upcoming IAG Conference in Budapest. That report is available at http://www.pol.ac.uk/psmsl/reports/iag2001.doc).

- University of Hawaii Sea Level Center (UHSLC);
- WOCE Delayed Mode Data Assembly Centre (British Oceanographic Data Centre);
- South Pacific Network (Australian National Tidal Facility);
- Southern Ocean Sea Level Centre (Australian National Tidal Facility);
- Central American Network (COOPS, NOAA);
- Caribbean Network: Planning for Adaptation to Global Climate Change (CPACC).

In addition, recently published regional reports on the Arctic and European networks were made available to the meeting (not included at ANNEX IV. Both reports are dated 2000 and can be obtained via http://www.pol.ac.uk/psmsl/training/gloss.pub.html). Reports requested from the West Africa, Indian Ocean or Mediterranean regional programmes were not received.

The following reports were received from national sea level centres and programmes (see Annex IV).

- Australia (one report on the NTF as an NODC; one on the Australian Baseline Network)
- Bangladesh
- Canada
- Chile
- France
- Indonesia
- Israel
- Japan
- Malaysia
- New Zealand
- People's Republic of China

- Singapore
- Thailand
- United Kingdom
- Vietnam

6.1 MATTERS ARISING FROM SOME OF THE REPORTS

Metamorphosis of the WOCE Fast and Delayed Mode Activities into GLOSS

It will be recalled that at the GE6 meeting in Toulouse, the recognition of the UHSLC as the 'GLOSS Fast Centre', as a continuation of its role as the 'WOCE Fast Centre' and given that the WOCE field programme ended in 1997, was approved. At GE7, Mark Merrifield (Director UHSLC) reported that 127 stations now regularly report to UH in 'fast mode' (within typically a few weeks) and that plans are being laid to extend the activity further.

Christian Le Provost had previously conveyed to the Chairman (Le Provost being unable to attend the GE7 meeting himself) the information that the GODAE data assimilation project, which commences in 2003 for a first period of three years, would wish to acquire a subset of 'fast' data within typically two days of recording for assimilation into the ocean models, and a second subset 'less fast' (perhaps within seven-days) for validation of the modeled sea level information. The former 'very fast' (two-day) set would be largely based around the GLOSS-OC subset identified in the GLOSS Implementation Plan 1997, although Le Provost would undertake to review that subset with Woodworth and convey updates to the GLOSS community. The seven-day subset would represent largely an expansion and expedition of the existing 'GLOSS Fast' activity.

After some discussion, particularly with regard to UH's ability to undertake this role, this activity, which represents a major challenge to GLOSS, was endorsed by the Group and a series of Action Items were identified to bring this development about (Annex VI).

In a separate discussion, Lesley Rickards (BODC) discussed the metamorphosis of the 'WOCE Delayed Mode' activity into a 'GLOSS International Archiving Centre' activity alongside the PSMSL, in line with the requirements of the GLOSS Implementation Plan. In that activity, PSMSL (together with BODC) would add to its role as a data centre for monthly and annual means, and would undertake to collect and archive (but not necessarily to re-quality control) as much of the higher frequency data from the GLOSS Core Network and its extensions as far as possible, primarily by means of links to other international and national data centres. This activity is absolutely necessary for long term data security and to complement the monthly and annual mean archive. These plans were also supported by the Group and provided their own Action Items.

Tidal Constants

Also related to the WOCE/GLOSS collections of hourly (and similar) data, Philip Woodworth informed the Group of developments within the International Hydrographic Organization which had led to the decision to abandon its data bank of tidal constituents in Canada. Savi Narayanan (MEDS) provided further background information.

After some discussion, the decision was made that GLOSS will largely go its own way in this regard. It will process all eventual GLOSS hourly data to derive a GLOSS tidal constants data set using the same (Toulouse) software as used already for pelagic data and for a subset of GLOSS data included on the Halifax WOCE Conference CD-ROM. This software provides error estimates as well the constituents value themselves. In addition, it will investigate the possibility for a databank of tidal constants at MEDS to be updated at regular intervals (i.e., this data set will be under GLOSS and not IHO auspices). However, so as all contact will not be lost with IHO and so that some of the information content of the existing IHO data set can be preserved for the community, a formal letter will be written to IHO to ask for permission to make available to *bona fide* ocean tide modelers the filtered set of 700 IHO constants already available at Toulouse (out of the total of 3000 constants in

the whole data bank). This provision could be made possible through PSMSL or MEDS 'good offices', as agreed by the IHO representative at GE6 (Captain Hans Rohde).

7. DATA ARCHAEOLOGY PROJECTS

During the Sixteenth Session of the IOC Committee on International Oceanographic Data and Information Exchange (IODE), Lisbon, Portugal, 30 October-9 November 2000, Lesley Rickards, representing the GE-GLOSS , reported to the Committee, that the GE-GLOSS had discussed the need for data archaeology of historic sea-level records to extend existing time-series and to gain access to observations which are not in digital form.

Subsequently, a representative of the GE-GLOSS proposed to the IGRC that sea-level data is included in the second phase of the Global Oceanographic Data Archaeology and Rescue Project (GODAR) project.

The rationale of the GODAR sea-level proposal is based on the fact that in many countries there are considerable amounts of historical sea-level data in paper form, such as charts or tabulations. These need to be computerised (i) to provide electronic access (ii) as a backup for data security and (iii) so that they can be subject to modern quality control and data analysis. The data can then be used for the various GLOSS-related activities described in the GLOSS Implementation Plan. The original records (e.g., charts, manuscript tabulations, etc.) would not be destroyed, as they may contain further information which is not captured by the computerised version (for example, charts digitized to hourly values might miss seiche or tsunami information) and also, in some cases, they are historic documents.

The Committee supported the proposal and recommended that the proposed sea-level data archaeology project should be co-ordinated by the GE-GLOSS, with the GODAR Project Leader, Dr. Sidney Levitus, acting as advisor to the project.

The Committee had encouraged all countries to assess their holdings of historical tide gauge data which can potentially be rescued and convey that information to the Permanent Service for Mean Sea Level (PSMSL), which will act as the contact point. Following this, the GE-GLOSS would undertake action to put countries in communication with each other and with sea-level organizations with regard to collaborative data rescue. The GLOSS and other important sites (e.g., those with long records) should be regarded as priority sites. The Committee noted that sea-level data archaeology has begun in several regions already (e.g., Europe, USA and Canada).

The U.S. NOAA, as part of their Atlantic CLIVAR project, has funded a small one-year project to investigate the prospects for sea-level data archaeology in the Atlantic Ocean. The PI of this project is Gary Mitchum at the University of South Florida, and the project is co-ordinated with the archaeology activities of the University of Hawaii Sea Level Center (UHSLC). The aim of this project is simply to assess the prospects in the sense of identifying where significant amounts of data exist that have never entered the international archives, and the area of interest, which was driven by the NOAA Atlantic CLIVAR interests, is the Atlantic coast of the Americas. The outcome of the project will be a report on what data might be recovered with a more substantial investment, and if it were decided to take this next step, this would likely be done with the UHSLC taking the lead. The project report is due at the end of calendar year 2001.

8. GLOSS SCIENCE SUB-GROUP (SSG) DEVELOPMENTS

At the Sixth Meeting of the GLOSS Group of Experts (GE6) in Toulouse, France in May 1999 the decision was made to establish a Scientific Sub-Group (SSG) of the GE-GLOSS as a source of scientific advice, especially for climate, with the sub-group potentially a joint committee with (at present) OOPC, CLIVAR/UOP and IAPSO/CMSLT. The IOC Executive Council approved this action in June 2000, and the group has since been formed, with Dr. Gary Mitchum as Chairman, and with

representatives of each of the main areas of research in GLOSS. The group will advise the GE as appropriate as scientific priorities develop in future.

Gary Mitchum produced a progress report on SSG developments for the GE7 meeting (Annex V).

Since the approval of the formation of the SSG, the GLOSS SSG and GE Chairs have discussed topics that might comprise good initial areas of emphasis for the SSG and a summary of these discussions is given in Annex V, Appendix 2. The GE is invited to comment on these suggestions and to make additional suggestions as well, and may do so by contacting the SSG or GE Chairs.

Progress has also been made on establishing linkages with other relevant bodies. In addition to the linkages provided by the SSG membership (see Annex V, Appendix 1), the SSG Chair has been asked to serve as an *ex officio* member of the recently established CLIVAR Ocean Observations Panel, which has replaced the former CLIVAR Upper Ocean Panel. This body met recently and the SSG Chair prepared input on behalf of GLOSS. That report is included as Annex V, Appendix 3.

9. COASTAL OCEAN OBSERVATIONS PANEL AND GLOSS (KEITH THOMPSON)

Keith Thompson of Dalhousie University, Halifax, Canada, provided an overview of recent developments of the coastal module of GOOS.

Over the past few years design plans for GOOS have been developed in a modular manner by four key science planning modules: Coastal Seas (C-GOOS), Living Marine Resources (LMR), Health of the Ocean (HOTO) and Climate. By late 2000 all four panels had completed their design plans. (The design plans are available at http://ioc.unesco.org/goos/doclist.htm).

With the completion of its work, the "coastal ocean related panels" (C-GOOS, LMR and HOTO) were dissolved. At the same time, under the direction of the GOOS Steering Committee (GSC), the Coastal Ocean Observations Panel (COOP) was formed to formulate a unified, comprehensive design that integrates the design plans for the C-GOOS, LMR and HOTO. The terms of reference for COOP and the list of panel members can be found at:
http://ioc.unesco.org/goos/COOP.htm.
The first session of COOP was held from 15-17 November 2000, San Jose, Costa Rica.

At the first session of COOP the panel drafted an action plan to complete the design phase at its second meeting in June 2001. Following the completion of the design plan the panel will turn its focus to the implementation plan, which is expected to be finished by the end of 2003.

The C-GOOS Design Plan provides the framework for integrating the HOTO and LMR plans into a common framework. Highlights of the plan are as follows:

Design Considerations: The knowledge gained from oceanographic and ecological research is the foundation for coastal GOOS. Four important generalizations will guide the design of the system: (i) most of the changes occurring in coastal ecosystems are local in scale and are globally ubiquitous; (ii) such changes are often local expressions of larger scale changes in coastal drainage basins, airsheds, basin scale oceanic regimes, or some combination there of; (iii) physical processes structure the pelagic environment and are of fundamental importance to changes in the biological and chemical characteristics of coastal ecosystems; and (iv) changes in these characteristics are related through a hierarchy of interactions that can be represented by robust models of ecosystems dynamics (e.g., numerical models of physical processes and coupled physical-biological models). Thus, it is likely that there is a relatively small set of core variables that, if measured with sufficient resolution, for extended periods over large scales, will provide the data and information required to detect and predict changes in coastal ecosystems that benefit a broad spectrum of user groups.

Design Framework: The observing system is conceived as a global network for the measurement and analysis of a common set of key variables that is regionally and locally customized (e.g., more variables, greater resolution, additional products) to address those issues that are of greatest concern to participating countries. The global network is the focus of the C-GOOS design strategy. Linking user needs to measurements to form an end-to-end, user-driven system requires a managed, two-way flow of data and information among three essential subsystems: (i) the observing subsystem (detection); (ii) the communications network and data management subsystem (integration); and (iii) the modelling (prediction) and applications subsystem.

The **observing subsystem** consists of the global infrastructure required to measure the common variables and transmit data to the communications network and data management subsystem. Recommended common variables are surface winds, air pressure and temperature, precipitation, sea level, bathymetry, temperature, salinity, surface currents and waves, turbidity, sediment type dissolved nutrients, phytoplankton pigments, and water clarity. The infrastructure must incorporate the mix of platforms, samplers, and sensors required to measure the common variables with sufficient spatial and temporal resolution to capture important scales of variability in four dimensions. This will require the assimilation of data from remote sensing and in situ measurements involving six interrelated categories of observing elements: (i) coastal observing networks for the near shore (CONNS); (ii) global network of coastal tide gauges (GLOSS); (iii) fixed platforms, moorings and drifters; (iv) ships of opportunity (SOOP) and voluntary observing ships (VOS); (v) remote sensing from satellites and aircraft; and (vi) remote sensing from land-based platforms (e.g., high frequency radar).

Data communications and management link measurements to applications. The objective is to develop a system for both real-time and delayed mode data transmission that allows users to exploit multiple data sets from disparate sources in a timely fashion. A hierarchical system of local, national and supra-national organizations is envisioned to provide data, information, and access to users at each level. Some national and supranational organizations will also become synthesis centers that will provide highly processed products (e.g., assimilating data from remote and in situ sources for numerical model predictions requiring substantial computing power). High priority should be placed on the design and implementation of this subsystem.

Data assimilation and modelling are critical components of the observing system. Real-time data from remote and in situ sensors will be particularly valuable in that data telemetered from these sources can be assimilated to (i) produce more accurate estimates of the distributions of state variables (for both validation and assimilation), (ii) develop, test and validate models, and (iii) initialize and update models for improved forecasts of coastal environmental conditions and, ultimately, changes in measures of ecosystem health and living resources. A variety of modeling approaches (statistical, empirical, theoretical) will be required. The challenge of developing a cost-effective observing system underscores the importance of the interaction between measurements and modelling. Due to the complexity of coastal ecosystems and the cost of observing them, Observation System Simulation Experiments (OSSEs) will become increasing valuable as tool for assessing the efficacy of different sampling schemes and the value of measuring different variables.

Building C-GOOS: C-GOOS will be implemented in step-by-step fashion by selectively incorporating, networking, enhancing, and supplementing existing programs. It is recognized that many of the elements required for a comprehensive, fully integrated, multi-disciplinary observing system are not operational, that much work is needed to develop and determine those products that are most useful, and that capabilities and resources vary enormously among nations. In that context National and Regional GOOS Programmes play a very important role for the implementation. They provide an important means for facilitating the user input required to implement and enhance the core program and for institutionalizing mechanisms for sustainable funding.

In closing Keith Thompson stressed that sea level is one of the core variables identified by C-GOOS and that GLOSS is seen as essential element of the initial observing subsystem. Other variables could in principle be measured at GLOSS stations (e.g., pa, S, T, w) and could be part of CONNS. The C-GOOS Design Plan stressed the importance of strong, ongoing collaboration with GLOSS. As

COOP merges the design plans of C-GOOS, HOTO and LMR it can be anticipated that GLOSS will continue to be a critical element of the initial observing subsystem for the coastal ocean.

10. CAPACITY BUILDING ACTIVITIES

Philip Woodworth summarized capacity building activity developments since the GLOSS GE6 meeting.

Training Courses

The Chairman informed the Group that a GLOSS training course was held at the University of Sao Paulo, Brazil from August 30 – September 25 1999 and organized by Professor Afranio de Mesquita (IOC Training Course Report No. 54; http://ioc.unesco.org/iocweb/iocpub/iocpdf/tc054.pdf). A second course was held at the Meteorology and Environmental Protection Administration (MEPA), Jeddah, Saudi Arabia from April 15-20 2000 organized by Dr. Dirar Nasr. The course was co-sponsored by the Regional Organization for the Conservation of the Environment of the Red Sea & Gulf of Aden (PERSGA) and the Arab League of Education, Culture and Science Organization (ALECSO). (IOC Training Course Report No. 57, http://ioc.unesco.org/iocweb/iocpub/iocpdf/tc057.pdf).

A number of provisional offers for hosting further training courses were noted from (i) Israel Oceanographic and Limnological Research; (ii) the Department of Survey and Mapping of Malaysia; (iii) the Hydrographic Department of the Chilean Navy; and (iv) University of West Indies. In addition, a number of related courses that might be expanded to have more GLOSS content were mentioned. It was left for the GLOSS Technical Secretary to explore these offers further and discuss issues about possible financial support co-sponsorship.

Pat Caldwell informed the Group that a course for countries in the RONMAC (Red de Observacion del Nivel del Mar para America Central) programme would be held in Guatemala during 14-18 May. It would follow standard GLOSS training course procedures with reviews of ocean physics and sea level variations, examples of data processing and applications, and hands-on computer experience.

One related issue concerns the need to establish a pool of potential lecturers for training courses, given that the teaching load in previous courses has tended to fall upon the same people. No names being immediately volunteered by the meeting, this topic was also left to the Chairman and Technical Secretary to explore at a later date.

Fellowships

The Partnership for Observation of the Global Oceans (POGO) and its partners, IOC and the Scientific Committee on Oceanic Research (SCOR), has announced a new Fellowship Programme, designed to promote training and capacity building leading towards a global observation scheme for the oceans. More information about these fellowships is available at www.oceanpartners.org.

Publications

Philip Woodworth informed the Group that the update of the *GLOSS Manual on Sea Level Measurement and Interpretation* (Volume 3) was nearly complete and would be finalized over the next two months. (The draft version of the manual is available at http://www.pol.ac.uk/psmsl/manuals/manual3.doc).

The Chairman's report also listed a number of new books that are extremely useful for capacity building activities. These include a book on sea level changes on various timescales and their impacts edited by Douglas, Kearney and Leatherman, and a book on sea levels measured from space by satellite altimetry edited by Fu and Cazenave. In addition, a book edited by Noye and Grzechnik

has been published containing papers on sea level with an emphasis on changes in the Pacific. Full details of these publications can be found on the PSMSL web pages (www.pol.ac.uk/psmsl/training/books.html)and (www.pol.ac.uk/psmsl/training/gloss.pub.html)

Consultant Visits

One of the recommendations from the training course in Saudi Arabia was to have a technical expert visit the relevant countries in the region to check on the operation of the tide gauges. This expert should provide help and guidance in the installation of new systems in Yemen and in the operation of the system in Sudan.

Data delivery to the PSMSL archive from the GLOSS stations in Brazil is still a problem. The Technical Secretary has written the Head of the DHN (Admiral Leal, who is also an IOC Vice Chairman) and alerted him to the problem. It was suggested that a visit to Brazil by a GLOSS technical expert/software expert could be useful and it was left for the Chairman and Technical Secretary to explore this option further.

Tidal Analysis Software Packages

Philip Woodworth reported that the tidal analysis software TASK-2000 developed at the Proudman Oceanographic Laboratory would be adapted to the WINDOWS environment by Dov Rosen and his colleagues at IOLR in Israel. In addition, he mentioned the production of a Matlab version of the Mike Foreman tidal package (the original version of which is included in the University of Hawaii tidal package). Pat Caldwell added that the University of Hawaii package is now available in Spanish.

11. NEW RESOURCES FOR GLOSS

Regular IOC Secretariat budget funds for GLOSS are extremely limited and tend to be devoted to the costs of meetings, training courses and sea level products (e.g. data and training CD-ROMs). There are virtually no funds for new gauges, geodetic equipment or tide gauge network development. The reasons for this state of affairs are twofold. Firstly, the IOC is funded to facilitate and coordinate international actions, and to raise awareness and capacity, not to implement systems. Secondly, IOC's limited funds arrive via two sources: (i) allocations from UNESCO, which themselves are under heavy pressure, and (ii) additional allocations to the IOC Trust Fund, which provide IOC with its flexibility, but which are earmarked by the donors for some specific purpose, like funding training activities. There are no IOC programmes, including GLOSS that can fund a broad slate of activities, or equipment, without donations from outside. In the case of GLOSS there is a particular need to enhance resources for tide gauges and tide gauge network development (particularly in developing countries) as outlined in the Chairman's report to the GLOSS GE7 (Annex III).

Since the GE6 meeting, the GLOSS Technical Secretary and Chairman have been investigating possibilities for obtaining additional funding for the programme. The Technical Secretary presented is part of these efforts (http://www.pol.ac.uk/psmsl/reports.gloss/ge7/GLOSS_Funding.doc). In addition to the contribution from the United Kingdom (which has provided steady support for GLOSS in recent years), there had been some new pledges of financial support (France, USA, European Space Agency, CNES). Some countries had responded with in-kind offers of used tide gauge equipment, hosting of courses, translation of GLOSS material, etc.

The GE congratulated the Chairman and Technical Secretary on their efforts.

The funding obtained so far does not allow for any acquisition of tide gauges, GPS equipment, installation, etc. Such activities will require funding that typically exceeds what can be achieved from discretionary spending available from IOC focal points and GLOSS focal points.

In their report, the Chairman and Technical Secretary pointed to other sources of funding such as foreign aid agencies, GEF, development banks, EU, etc., which could be explored. (A list of potential donors is listed in the report). Many national bilateral and multilateral foreign aid programmes require that funding requests come from the local recipient country. Establishing local buy-in and getting local GLOSS contacts actively involved is therefore essential. It also requires a dialogue with donors, to bring them on board, and to get them to accept local priorities.

In order to broaden the funding search and to address the above issues surrounding large scale funding from bilateral and multilateral development agencies, it was decided:

- To establish an intersessional working group under GLOSS to develop a strategy/priority for attracting funds for GLOSS capacity building activities in particularly acquisition/upgrade/installation of tide gauge equipment and tide gauge network development. (The strategy/priority need to address money, equipment, stations/countries/regions and particularly how to strengthen local involvement perhaps through development of an information package portfolio).

To further enhance the implementation/upgrade of GLOSS it was also suggested to:

- Enhance the dialogue with scientific and operational oceanographic programmes that can assist with the implementation of GLOSS (Examples: GOOS/COOP; regional GOOS organizations; Large Marine Ecosystems (LME); WMO programmes concerned with climate change, hydrology, storm surges and tropical cyclones; UNEP Regional Seas Programmes). (This activity is partly under way and will be developed further).

- Establish links and recommendations to non-scientific organizations that can assist in implementing GLOSS (International Ports and Harbor Association; IALA, etc.). This is for the following reasons: (i) ports typically have some kind of sea-level measurement in place and many GLOSS gauges are located in harbors – hence there could be a better synergy effect; (ii) many ports are establishing environmental monitoring systems and sea-level observations could be integrated with this activity; (iii) the amount of money that goes into harbor expansion/reconstruction and associated infrastructure is often significant; (iv) foreign aid agencies are also supporting harbor construction expansion/projects.

12. MEETINGS AND ACTIVITIES RELATED TO GLOSS

12.1 JCOMM-1 (PHILIP WOODWORTH)

One of the implementation mechanisms for GOOS will be the WMO-IOC Joint Technical Commission on Oceanography and Marine Meteorology (JCOMM) to which a number of operational observing programmes including GLOSS will report to. For more information on JCOMM please see http://ioc.unesco.org/goos/jcomm.htm and http://www.wmo.ch/web/aom/marprog/index.html. The first meeting of JCOMM will take place in Iceland in June 2001 and the report on GLOSS is available at: http://www.pol.ac.uk/psmsl/reports.gloss/gloss_jcomm1.pdf. It was noted that reporting to JCOMM should also facilitate enhanced linkage with WMO's programmes on Wind Waves and Storm Surges, climate and hydrology.

12.2 IPCC TAR (PHILIP WOODWORTH)

Philip Woodworth reported that the Third Assessment Report (TAR) of the Intergovernmental Panel on Climate Change (IPCC) has been completed with a Chapter 11 on sea level changes led by John Church (CSIRO, Australia) and Jonathan Gregory (Hadley Centre, UK) and with himself as a Lead Author. This process took over two years and chapter meetings were held in Germany, Tanzania,

New Zealand and Canada. Cambridge University Press will publish the IPCC report at the end of June 2001. A Summary for Policymakers can be downloaded via the IPCC web site (http://www.ipcc.ch).

12.3 GLOUP (CHRIS HUGHES)

In July 1999, IAPSO recommended that a database of Global Undersea Pressures (GLOUP) be established under the auspices of the PSMSL. Since then, bottom pressure data from the UK ACCLAIM programme, and from the British Oceanographic Data Centre archives have been checked, documented, and converted to a uniform format. The 279 records compiled so far are now available from http://www.pol.ac.uk/psmslh/gloup/gloup.html as either "high frequency" (HF) or "daily" files. The "high frequency" files contain data at typically 15 minute or hourly intervals, together with tidal analyses and tidal residuals. The tidal analyses are based on a number of tidal components, which varies with the length of the record, and the amplitudes and phases are given in separate files. However, those who are interested in the fine detail of the tidal analyses are encouraged to use the HF data and to perform their own analyses.

The records collected so far are limited to the Atlantic and Indian Ocean sectors, with no data yet from Pacific longitudes (data currently extend from longitude 63^{o}W to 82^{o}E, and from latitude 61.5^{o}S to 63^{o}N). Work is underway to expand the geographical coverage of the database and to update it to include more recent data. The next version of the database will explicitly incorporate the "Pelagic tidal constants" dataset.

12.4 ALTIMETRY (CHRISTIAN LE PROVOST)

JASON-1, the successor of TOPEX/POSEIDON, is a CNES/NASA project, the objective of which is the continuation of high accuracy measurement of mesoscale ocean circulation. The main instrument of JASON-1 is the POSEIDON-2 radar-altimeter. The launch of JASON-1 is scheduled for August 2001.

The proposed JASON-2, scheduled for launch in 2004, appears to be moving ahead although this mission is not yet formally approved. ENVISAT is scheduled to launch in late 2000 or early 2001 and will be in the same orbit as the ERS series. These missions, if all go forward, will carry the T/P and ERS time series until probably 2005 and possibly until 2010, although the latter is likely an overly optimistic estimate. Past that time, starting around 2010, there is an U.S. plan to include an altimeter in the NPOESS series, although these plans are not yet defined in detail. There are technological developments on the horizon that are potentially very exciting. First, as part of the NASA Instrument Incubator Programme, a project has been funded at the Johns Hopkins University's Applied Physics Laboratory to develop a low-power altimeter that is light enough to enable multiple altimeters to be placed into orbit from a single launch vehicle (Raney, 1998). CNES in France is also investigating low cost altimeter missions on micro satellites as part of their ALTIKA project, which will similarly allow multiple altimeter coverage at low cost. Second, an alternative to multiple satellites may be the development at the JPL in the U.S. of a wide swath altimeter that obtains SSH measurements not only at nadir, which is the situation with all present altimeters, but along a swath of order 200 km total width, and it is possible that an experimental version of this swath altimeter might be flown as part of the JASON-2 mission.

The Water Inclination Topography and Technology Experiment (WITTEX), is named in honor of E. Witte, who in 1878 first discovered the geostrophic current equation. WITTEX consists of three co-planar small satellite radar altimeters launched on the same vehicle into a GEOSAT-class orbit. The proposed satellite constellation would support measurement for the first time of both orthogonal components of the ocean’s surface slope, rather than the single component seen by conventional instruments. The satellites are spaced by several kilometers along their orbit; Earth rotation causes their sub-satellite tracks to be laterally separated. Track separation can be readily adjusted by selection and autonomous control of inter-satellite spacing. If the satellite spacing were about 900 km, then the sub-satellite orbit tracks would fall approximately uniformly 53 km apart at the equator. This spacing is nearly optimal for observing oceanic eddy fields and surface energy transport.

The enabling conceptual innovation is the delay-Doppler Radar Altimeter (DDA). Studies have shown that this technique yields more precise measurements than a conventional radar altimeter, yet it requires much less transmitted power. The notional instrument has two frequencies and an onboard water vapor radiometer, similar to TOPEX. The DDA approach combined with recent advances in spacecraft technology leads to substantial miniaturization; the goal is to use a small rocket as the launch vehicle. More information is available at:
http://www.sdl.usu.edu/conferences/smallsat/proceedings/13/tech-vii/ts-vii-7.pdf.

The Global Altimeter Measurements By Leading Europeans (GAMBLE) is a proposal for Thematic Network under the European Union Framework V programme.

The proposal, currently under review, is led by CNES and Satellite Observing Systems (UK). The intention is to build a co-operative network of all major altimeter experts in Europe to ensure that complementarity of proposed altimeter missions is exploited to the full. Satellite altimeter missions approved and under consideration are ENVISAT, JASON, GANDER, ALTIKA and SWIMSAT. Under the GAMBLE proposal a number of themed workshops will take in expert opinion to advise on the specification of new missions, and on the joint processing of data from different missions. For more information please see http://www.satobsys.co.uk.

12.5 GLOSS HANDBOOK UPDATING (Lesley Rickards)

The GLOSS Station Handbook is an information resource containing details on each gauge in the GLOSS Core Network. Dr. Lesley Rickards reported that over the last two years improvements had been made to the GLOSS Handbook. In particular, links to those stations where data were available on-line had been implemented and the layout of the index table had been improved. A version of the Handbook (as of July 2000) had been included on the recently released WOCE Sea Level Data CD-ROM (Version 2). Copies of this CD-ROM are available from UHSLC and BODC.

The contents of the GLOSS Handbook have been reviewed and some improvements made. She was currently in the process of updating the Handbook, and a new version would be available on the Web later in the year. Special efforts were being made to include information relating to other parameters collected at the tide gauge site, details of any historical manuscript or chart data not yet digitised and improved GPS information. In addition, a comparison of benchmark information held in the Handbook with that held by the PSMSL would take place. It was also intended that the Handbook would be expanded to include the Altimeter (ALT) and Ocean Circulation (OC) sites, and a subset of the Long Term Trend (LTT) set which will have Global Positioning System (GPS) receivers. A further request for updated information would soon be sent to national GLOSS contacts, including a request for photographs of the tide gauge sites, benchmarks and other relevant metadata.

The GLOSS Handbook web pages are at: http://www.bodc.ac.uk/services/glosshb/

For people without good web access, Version 2.0 of the WOCE sea level data set is now available on CD-ROM. In addition to the ‘Fast-Delivery’ and ‘Delayed-Mode’ WOCE sea level data sets, the CD-ROM contains tidal constants from the WOCE sea level data set, PSMSL monthly and annual mean sea level data set, and the GLOSS Station Handbook (Version 4.1). Copies are available from PSMSL, BODC or the University of Hawaii Sea Level Center. The Sea Level CD-ROM is a contribution to the WOCE Global Data (Version 2.0) CD-ROM set (15 CDs). Copies of the complete set are available from the US National Oceanographic Data Center, Silver Spring, USA.

In the discussion following the presentation, several topics related to GLOSS Handbook development were mentioned the need for an updated definition of a 'GLOSS Core Network 2001'; the requirement to have the Handbook information include the various ‘fast’ information referred to above; and the need for more metadata information. Several of these suggestions have been incorporated into the meeting Action Items (Annex VI).

13. HARDWARE DEVELOPMENTS

A short discussion took place on new hardware developments. However, no significant new hardware developments were reported (which could influence the completion of the IOC Manual Volume 3 on Sea Level Measurement and Interpretation, for example).

With regard to data transmission, Lee Chapin mentioned that the GOES satellite data transmission will soon offer a higher transmission rate of 1200 baud.

14. SURVEY OF COMPLIANCE WITH GLOSS IMPLEMENTATION PLAN 1997

Dr. Lesley Rickards carried out a survey into how many of the Core Network stations were making their 'hourly' data available to the community (in addition to sending monthly means to the PSMSL), as they are required to do by Chapter 7 of the Implementation Plan. Countries should either make their data available on their own web sites or pass them on to one of the recognized GLOSS centres (e.g., UHSLC, PSMSL/BODC, NTF). In addition, the survey attempted to estimate how many of these hourly-reporting stations were 'real time'.

The conclusions are that over 75 per cent of the Core Network stations now make hourly data available, and that the number of real time sites is continuing to grow - currently 105 sites report data to the GLOSS 'fast-delivery' centre. These are very encouraging developments, although much work remains to be done. Unfortunately some of the problem areas noted in a similar survey carried out at the time of GE-GLOSS 6 (e.g., India, Russia, West Africa) still remain.

15. RESUME OF RECOMMENDATIONS

No formal recommendations were submitted to the Technical Secretary for consideration by the Group, and for transmission to the IOC Assembly and JCOMM meetings. Nevertheless, the Chairman noted that several issues (e.g., the need for visits by consultants' in particular areas) were sufficiently important that he would be sure to raise them in presentations to these important international meetings.

16. ANY OTHER BUSINESS

(i) A discussion took place on the methods by which GLOSS can publicize itself ('outreach'). The Chairman reported that we now have a number of brochures available in different languages, which can be downloaded from the web. However, there was a problem with newsletters. For some years, he had been editing the GLOSS Bulletin on the web but felt that it was now time for someone else to take on the task or for the Bulletin to be abandoned. After some discussion, as no volunteers were forthcoming, it was decided that a final issue of the GLOSS Bulletin will be produced by Woodworth, based in large part on the materials provided to the GE7 meeting. Following that any GLOSS news articles will be posted under a "what's New at Gloss" heading on the GLOSS website. .

Meanwhile, the GE encouraged Professors Afranio de Mesquita and Geoff Brundrit to continue the publication of the Afro-American GLOSS Newsletter on the web. This newsletter was originally to have included articles primarily in Spanish and Portuguese. However, at GE6 the decision was taken to widen its usefulness by including articles in English also. The Chairman suggested that the newsletter may wish to broaden its geographical scope and welcome articles from outside the Afro-America region, as sea level changes are really a global topic.

In addition, the need to publicize GLOSS as widely as possible was recognized. It was suggested that another possible publication target for a GLOSS article would be the GOOS Products and Services Bulletin.

(ii) The Chairman informed about the 'Georisk' projects, one of which is organized under the auspices of IUGG and one under IOC. Vivien Gornitz and David Aubrey, both of whom have interests in the impacts of sea level change, especially for 'megacities', had agreed to represent GLOSS in these activities.

(iii) The Chairman also informed the Group that many GLOSS stations in West Africa are not functioning and there are currently no GLOSS stations between Senegal and South Africa, which are delivering data to the centres. The longest time series for Africa exists for Takoradi (which goes from at least 1929-1992). At the IOC Executive Council meeting in June 2000, the Indian delegation offered to provide Ghana with two replacement gauges, one meteorological station and accompanying computer equipment. The Chairman and Technical Secretary have been exploring this offer in collaboration with the IOCEA chairman and the National Institute of Oceanography, India and installation is expected to take place later this year.

(iv) Finally, the Chairman informed the group about activities in PIRATA. The next regular meeting of the pilot research moored array in the tropical Atlantic project (PIRATA-8) will be held in Paris from 29-31 August 2001. This meeting will be held back to back with the CLIVAR tropical Atlantic variability workshop. The two meetings could be a good opportunity to present GLOSS activities in the region and draw attention to the issues surrounding sea-level observing activities.

17. PLAN OF ACTION

The Chairman presented a draft list of actions (Annex VI) to the Group. This list included actions from the GE6 meeting in 1999 that had not been completed. The Group approved the draft list of actions.

18. DATE AND PLACE OF THE NEXT SESSION

The date and venue for the next GE-GLOSS meeting was left open and would be determined later.

19. CLOSURE

Philip Woodworth thanked the participants for a productive session. Special thanks were given to the hosts of the meeting at the University of Hawaii, to the several workshop organizers earlier in the week, to the GE7 Rapporteurs, to all speakers and poster presenters and authors of special reports. The Chairman closed the session at 14.30 hours on 27 April 2001.

ANNEX I

AGENDA

1. ORGANIZATION OF THE SESSION

1.1 OPENING OF THE SESSION
1.2 ADOPTION OF THE AGENDA
1.3 DESIGNATION OF THE RAPPORTEUR

2. REVIEW OF GLOSS ACTIVITIES

3. REPORT OF THE 'KLAUS WYRTKI' WORKSHOP

4. REPORT OF THE APSG SEA LEVEL WORKSHOP

5. REPORT OF THE GPS AT TIDE GAUGES WORKSHOP

6. REPORTS OF THE INTERNATIONAL SEA LEVEL CENTRES, REGIONAL AND INTERNATIONAL ACTIVITIES, AND NATIONAL REPORTS

6.1 MATTERS ARISING FROM SOME OF THE REPORTS

7. DATA ARCHAEOLOGY PROJECTS

8. GLOSS SCIENCE SUB-GROUP (SSG) DEVELOPMENTS

9. GOOS-COOP (COASTAL OCEAN OBSERVATIONS PANEL) AND GLOSS

10. CAPACITY BUILDING ACTIVITIES

11. NEW RESOURCES FOR GLOSS

12. MEETINGS AND ACTIVITIES RELATED TO GLOSS

12.1 JCOMM-1 ICELAND JUNE 2001
12.2 INTERGOVERNMENTAL PANEL ON CLIMATE CHANGE (IPCC) THIRD ASSESSMENT REPORT (TAR)
12.3 GROUP
12.4 ALTIMETRY DEVELOPMENTS
12.5 GLOSS HANDBOOK UPDATING

13. HARDWARE DEVELOPMENTS

14. SURVEY OF COMPLIANCE WITH GLOSS IMPLEMENTATION PLAN 1997

15. PLAN OF ACTION FOR 2001-2003

16. RESUME OF RECOMMENDATIONS FROM GE7

17. ANY OTHER BUSINESS

18. DATE AND PLACE OF THE NEXT SESSION

19. CLOSURE

ANNEX II

LIST OF PARTICIPANTS

Thorkild **AARUP**
UNESCO/IOC
1, rue Miollis
75732 Paris Cedex 15
FRANCE
Tel: 33 1 45 68 40 19
Fax: 33 1 45 68 58 10
E-mail: t.aarup@unesco.org

Trevor **BAKER**
Proudman Oceanographic Laboratory
Bidston Observatory
Birkenhead, Merseyside
CH43 7RA
UNITED KINGDOM
Tel: 44 151 653 8633
Fax: 44 151 653 6269 (fax)
E-mail: tfb@pol.ac.uk

Wolfgang **BOSCH**
Deutsches Geodätisches Forschungs-Institut
Marstallplatz 8, D-80539
München
GERMANY
Tel: 49 89 23021 115
E-mail: bosch@dgfi.badw.de

Patrick **CALDWELL**
Dept. Oceanography
University of Hawaii
Honolulu, HI 96822
U.S.A
Tel: 808 956 4105
Fax: 808 956 2352
E-mail: caldwell@soest.hawaii.edu

J. Lee **CHAPIN**
Organization of American States
USDE
6763 Circle J Drive
Tallahassee, Florida 32312
U.S.A
Tel: 850 894-6920
Fax: 850 894-6933 (fax)
E-mail: chapin_l@msn.com

Juan C. **FIERRO**
Servicio Hidrografico y Oceanografico de la Armada de Chile
Errazuriz 232 Playa Ancha -Valparaiso
CHILE
Tel: 56 32 266 676
Fax: 56 32 266 542
E-mail: din.costera.oc@shoa.cl

Yvonne L. **FIRING**
Dept. Oceanography
University of Hawaii
Honolulu, HI 96822
U.S.A
Tel: 808 956 6161
Fax: 808 956 2352
E-mail: yfiring@soest.hawaii.edu

Guo **FENGYI**
National Marine Data and Information Service
93 Liuwei Road, Hedong District
Tianjin
CHINA
Tel: 86 22 24010833
Fax: 86 22 24304408
E-mail: div_5@netra.nmdis.gov.cn

John **HANNAH**
School of Surveying
University of Otago
P.O. Box 56
Dunedin
NEW ZEALAND
Tel: 64 3 4799010
Fax: 64 3 4797586
E-mail: johnh@albers.otago.ac.nz

Masakazu **HIGAKI**
Office of Marine Prediction
Japan Meteorological Agency
1-3-4, Otemachi, Chiyoda-ku
Tokyo 100-8122
JAPAN
Tel: 81 3 3212 8359
Fax: 81 3 3211 3047
E-mail: m-higaki@naps.kishou.go.jp

Hasan **JAMIL**
Department of Survey and Mapping, Malaysia
Bangunan Ukur
Jalan Semarak
50578
Kuala Lumpur
MALAYSIA
Tel: 603 2692670
Fax: 603 26934084
E-mail: hasanj@jupem.gov.my

Ronan Le **ROY**
French Hydrographic Service
13, rue du Chatellier
29200 Brest
FRANCE
Tel: 33 02 98 22 15 89
Fax: 33 02 98 22 08 99
E-mail: rleroy@shom.fr

Mark **MERRIFIELD**
Dept. of Oceanography
University of Hawaii
1000 Pope Road, MSB 317
Honolulu, Hawaii 96822
U.S.A
Tel: 1 808 956 6161
Fax: 1 808 956 2352
E-mail: markm@soest.hawaii.edu

Abdul Matin **MONDAL**
Director Hydrography
Dept. of Hydrography
B1WTA, 141-143, Motijueel C/A
Dhaka-1000
BANGLADESH
Tel: 880 2 9553552
Fax: 880 2 9551072
E-mail: biwta@bttb.net

Savi **NARAYANAN**
Marine Environmental Data Service (MEDS)
W083, 12th Floor, 200 Kent Street
Ottawa, Ontario K1A 0E6
CANADA
Tel: 613 990 0265
E-mail: narayanans@dfo-mpo.gc.ca

Lesley **RICKARDS**
British Oceanographic Data Center
Proudman Oceanographic Laboratory
Bidston Observatory
Birkenhead, Merseyside
CH43 7RA
UNITED KINGDOM
Tel: 44 151 653 8633
Fax: 44 151 653 6269 (fax)
E-mail: ljr@bodc.ac.uk

Wolfgang **SCHERER**
National Tidal Facility Australia
Flinders University of South Australia
GPO Box 2100
Adelaide, SA 5001
AUSTRALIA
Tel: 618 201 75 32
Fax: 618 201 75 23
E-mail:
mailwolfgang.scherer@ntt.flinders.edu.au

Fred **STEPHENSON**
Canadian Hydrographic Service
Institute of Ocean Sciences
P.O. Box 6000
Sidney, B.C. V8N 5Y9
CANADA
Tel: 250 363 6349
Fax: 250 363 6323
E-mail:stephensonf@pac.dfo-mpo.gc.ca

Cecep **SUBARYA**
Bakosurtanal
Jl. Raya Jakarta - Bogor Km. 46
Cibinong 16911
INDONESIA
Tel: 62 21 8757329
Fax: 62 21 8752064
E-mail: geodesi@indo.net,id and
csubarya@bakosurtanal.go.id

Witoon **TANTIGUN**
Oceanographic Div.
Hydrographic Dept.
Royal Thai Navy
Bangkok 10600
THAILAND
Tel: 66 2 4754714
Fax: 66 2 4652328
E-mail: witt@navy.mi.th

Keith **THOMPSON**
Dept of Oceanography
Dalhousie University
Halifax, Nova Scotia, B3H 4J1
CANADA
Tel: 902 494 3491
Fax: 902 494 2885
E-mail: keith.thompson@dal.ca

Sidney W. **THURSTON**
NOAA Office of Global Programs, Tokyo
Level 14, Hibiya Central Building
1-2-9 Nishi-Shinbashi Minato-ku
Tokyo, 105-0003
JAPAN
Tel: 813 5532 7249
Fax: 813 5532
E-mail: thurston@ogp.noaa.gov

Michael **TSIMPLIS**
Southampton Oceanography Centre
Empress Docks
Southampton S014 3ZH
UNITED KINGDOM
Tel: 44 23 80596412
Fax: 44 (0) 23 80596204
E-mail: mnt@soc.soton.ac.uk

Nguyen The **TUONG**
Director Marine Hydrometeorological Centre
Nguyen Chi Thanh St.
Hanoi
VIETNAM
Tel: 84 48 343794
Fax: 84 48 350606
E-mail: thetuong@hn.Vnn.Vn

Jens **WENDT** (on behalf of Gunter Liebsch)
Technische Universitat Dresden
Institut fur Planetare Geodasie
01062 Dresden
GERMANY
Tel: 49 351 4634652
Fax: 49 351 4637063
E-mail: liebsch@ipg.geo.tu-dresden.de

Philip **WOODWORTH**
Permanent Service for Mean Sea Level
Proudman Oceanographic Laboratory
Bidston Observatory
Birkenhead, Merseyside
CH43 7RA
UNITED KINDOM
Tel: 44 151 653 8633
Fax: 44 161 653 6269
E-mail: plw@pol.ac.uk

Mohd Yunus Mohd **YUSOFF**
Department of Survey and Mapping, Malaysia
Geodesy Section, Bangunan Ukur, Jalan Semarak
50578 Kuala Lumpur
MALAYSIA
Tel: 603 2692670
Fax: 603 26934084
E-mail: my.my@jupem.gov.my

ANNEX III

CHAIRMAN'S REPORT OF GLOSS ACTIVITIES SINCE THE SIXTH SESSION OF THE GROUP OF EXPERTS

P.L.**WOODWORTH**
Permanent Service for Mean Sea Level,
Proudman Oceanographic Laboratory, Bidston Observatory,
Birkenhead, Merseyside CH43 7RA, U.K.

The sixth session of the GLOSS Group of Experts (GE6) was held in Toulouse, France in May 1999 at the invitation of Dr. C. Le Provost of GRGS/Observatoire Midi Pyrenees. This report is intended to provide a brief summary of some GLOSS-related activities since the GE6 meeting from my point of view. The list of achievements is a good one but much remains to be done. I hope that this summary will serve to stimulate consideration of further GLOSS products and projects (especially its Pacific regional activities) at the seventh session in Hawaii in April 2001.

The format of the week of GE7 at the University of Hawaii was modelled on the successful format of the week of meetings in Toulouse. It will include a scientific workshop entitled 'The Klaus Wyrtki Workshop: Observations and Integrations' concentrating on sea level science in the Pacific and held in honor of Professor Wyrtki, a further workshop concerning sea level aspects of the Asia-Pacific Space Geodynamic Project (APSG), and a workshop on GPS at tide gauges.

POST-TOULOUSE PUBLICATIONS

Minutes of the sixth meeting have been published by IOC (most IOC reports are now available in PDF form as well as on paper) while the report of the workshop on 'Ocean Circulation Science derived from the Atlantic, Indian and Arctic Sea Level Networks' organized by Dr. Gary Mitchum is in press. The week in Toulouse also contained a workshop on 'GPS at Tide Gauge Benchmarks for Long Term Sea Level Change Studies and for Altimeter Calibration' organized by Prof. Mike Bevis. Mike's working group was later confirmed at the IUGG Conference in July 1999 as a joint IAG/IAPSO/IGS/PSMSL/GLOSS activity. A part-list of reports published since GE6 is included Appendix 1 of this note.

ACTIONS LIST

A large number of actions were generated by the GE6 meeting which can be inspected via http://www.pol.ac.uk/psmsl/gb/gb7/ge6actions

As with the list of actions produced following GE5 (the first time such a comprehensive list was produced following a GE meeting), this list has proved to be very useful in providing stimulus to activity in between meetings. Any updates should be provided to the IOC GLOSS Technical Secretary (Dr. Thorkild Aarup) or me. Another list will be produced during GE7.

One of the most important outcomes of GE6 was the decision to establish a Scientific Steering Group (SSG), initially as a sub-group of the Group of Experts but eventually as a joint group with other GLOSS-related programmes (e.g. OOPC, CLIVAR-UOP, IAPSO CMSLT). This group has since been formed, with Dr. Mitchum as Chairman, and with representatives of each of the main areas of research in GLOSS. The group will advise the GE as appropriate as scientific priorities develop in future.

GLOSS STATUS FROM A PSMSL VIEWPOINT (OCTOBER 2000)

For several years, the PSMSL has provided a summary of the status of the GLOSS Core Network (GCN) from its viewpoint which can serve as a reflection of the status of the programme overall. This summary has usually been made in October so as not to bias the statistics because of the seasonal cycle of data receipts. A review of GCN status as of October 2000 can be found at:

http://www.pol.ac.uk/psmsl/programmes/gloss.info.html

In brief, the status of the programme at the present time is near identical to that one year ago. The GCN can be considered approximately two-thirds operational, if one uses data receipts by the PSMSL as a guide to operational status, or somewhat better if one considers several factors discussed in detail in the PSMSL 1999 Annual Report. (This refers to the fact that at some locations, the gauges take the form of simple pressure transducers, which provide useful information for oceanography, if not MSL data for the PSMSL.) However, these status summaries hide major problems in several regions, with expenditure in new tide gauge equipment in a number of countries, and the network improvements which result, balanced against the fact that many GLOSS stations in other countries are being terminated or require major upgrades. In addition, the investments made in gauges for international programmes (notably WOCE) are unlikely to be repeated in future. Consequently, it is possible that GLOSS status, measured in terms of PSMSL receipts, may have reached a plateau.

This pessimism is contradicted to some extent by the stated requirements for investment in regional networks of coastal tide gauges by, for example, the GOOS COOP (Coastal Oceans Observations Panel). Therefore, GLOSS status may receive a boost in the long term from 'coastal', rather than 'climate' or 'oceanographic', applications. Whatever the scientific emphasis, investment in equipment and training is a necessity in many countries.

REGIONAL ACTIVITIES

A number of regional GLOSS activities have taken place in 1999-2000 including the Arctic and Europe (for which Prof. Hans-Peter Plag is to be thanked for taking a major lead), Mediterranean/Black Seas (thanks for Dr. Dov Rosen) and Asia-Pacific (thanks to Prof. C.K. Shum and Dr. Wolfgang Scherer). These and other regional initiatives will be discussed at GE7.

GOOS COASTAL MODULE/COOP

This year has seen the publication of several GOOS documents, which refer to the need for sea level measurements for coastal GOOS applications. At GE6, Dr. Eduardo Marone reviewed the status of (what was then called) C-GOOS and its needs for hardware and training. Joint training was suggested in addition to the possible use of tide gauge data transmission platforms for delivery of other data types. However, the scope for collaboration needs to be more firmly resolved.

GLOSS-ALT

GLOSS-ALT is the name given in the GLOSS Implementation Plan 1997 to the use of a number of tide gauges distributed worldwide, primarily on islands, for on-going altimeter calibration. This topic has been led in particular by Dr. Gary Mitchum with contributions from several other groups. As reported at GE6, the developments in this field, in demonstrating the important symbiosis between altimetry and gauges, are so significant that to a great extent we may call GLOSS-ALT operational. Reports related to this activity by Mitchum and others are to be expected at GE7.

GLOSS HANDBOOK, FAST WOCE/GLOSS AND DELAYED MODE WOCE DATA SETS

Sea level researchers will be familiar with the GLOSS Handbook product available on the web and edited by Dr. Lesley Rickards of the British Oceanographic Data Centre (BODC). The Handbook was updated and extended during 1999 by means of rounds of correspondence with GLOSS Contacts and a survey conducted at the GE6 meeting in May 1999. Lesley has now commenced major updates towards a 2000-01 version. GLOSS Contacts can be expected to be asked to provide information.

The GLOSS Handbook web pages at: http://www.bodc.ac.uk/services/glosshb now provide links to 'Fast-Delivery' and 'Delayed Mode' WOCE high-frequency (typically hourly) data (HFD) sets. It may be recalled that a survey by Lesley at GE6 suggested that HFD were available from approximately 200 of GLOSS Core Network sites from various national and international centres. Not

all of these are available from the GLOSS Handbook pages, but an important start has been made.

For people without good web access, Version 2.0 of the WOCE sea level data set is now available on CD-ROM. In addition to the 'Fast-Delivery' and 'Delayed-Mode' WOCE sea level data sets, the CD-ROM contains tidal constants from the WOCE sea level data set, PSMSL monthly and annual mean sea level data set, and the GLOSS Station Handbook (Version 4.1). Copies are available from PSMSL, BODC or the University of Hawaii Sea Level Center. The Sea Level CD-ROM is a contribution to the WOCE Global Data (Version 2.0) CD-ROM set (15 CDs). Copies of the complete set are available from the US National Oceanographic Data Center, Silver Spring, U.S.A.

It will be recalled that it was agreed at GE6 that the 'Fast WOCE' activity should be expanded as far as possible into a 'Fast GLOSS' activity, for the benefits of a different set of sea level data users, and also as an aid to more efficient data quality control. A report on this development will be presented at GE7.

PROPOSAL FOR A SEA LEVEL DATA ARCHAEOLOGY PROJECT

At the recent IOC International Oceanographic Data and Information Exchange (IODE) XVI Committee meeting several extensions to the Global Ocean Data Archaeology and Rescue (GODAR) project led by Mr. Syd Levitus (Ocean Climate Laboratory, WDC-A) were suggested. Dr. Lesley Rickards represented GLOSS at this meeting and proposed a data archaeology project for historical sea level records with the aim of extending existing time series and gaining access to observations, which are not in digital form. In many countries there are considerable amounts of historical sea level data in paper form such as charts or tabulations. These need to be computerized to provide electronic access, as backup for data security, and so that they can be subject to modern quality control and analysis. The original records would not be destroyed, as they may contain further information which is not captured by the computerised version (for example, charts digitised to hourly values might miss tsunami or seiche information) and also, in some cases, they are historic documents.

The IODE Committee supported the proposal and recommended that the sea level archaeology project should be coordinated by GLOSS, with the GODAR Project Leader acting as advisor to the project. The GLOSS Secretariat will now encourage all countries to assess their holdings of historical tide gauge data which can potentially be rescued. Following on from this, IOC/GLOSS will aim to put countries in touch with each other and with sea level organizations with regard to collaborative data rescue.

IHB TIDAL CONSTANTS DATA SET

At GE6 there was a proposal (suggested by the representative of the IHB) for the PSMSL to act as a source of the complete IHB tidal constants data bank from which bona fide tidal researchers (and no others) would have access. However, this proposal was overtaken by events in 2000, when the IHB decided not to continue with the data bank in Canada. Anyone requiring constants in future will have to apply to national hydrographic offices.

During 2000, correspondence was exchanged between myself, IOC, IHB and the Canadian Hydrographic Office as to whether they would rethink their decision and continue with the data bank as a Canadian contribution to GLOSS. However, that appeal was unsuccessful as confirmed in a letter from the IHB in October. If the community now feels that such a data set is useful, based on GLOSS/WOCE data, then some joint action needs to be taken between the GE and IAPSO/CMSLT.

GPS/TIDE GAUGE SURVEY

A survey has been conducted on behalf of GLOSS and other organizations on the availability of permanent GPS stations near to tide gauges. The survey was undertaken by Dr. Guy Woppelmann of SHOM, France and first results can be found via:
http://sonel.ensg.ign.fr/stations/cgps/cgps_survey.html.

This web page also contains a mechanism by which the community should be able to keep the information up-to-date as a 'living document'. A second survey was conducted in early 2001.

IOC TRAINING COURSES

IOC/GLOSS training courses have been held each year since GE6. A course took place at the University of Sao Paulo, Brazil in September 1999 organized by Prof. Afranio de Mesquita and with Drs. Baker and Vassie from POL as guest lecturers. As with previous courses, the Sao Paulo agenda concerned itself with background sea level science (climate change, oceanography), the need for related geodetic measurements, and 'hands on training sessions' (HOTS). A further course took place during 15-19 April at Jeddah, Saudi Arabia funded by the Programme for the Environment of the Red Sea and Gulf of Aden (PERSGA) and IOC. The local organization was led by Dr. Dirar Nasr of PERSGA and IOC provided support for Mr. David Dixon (Plymouth, U.K.) to provide lectures on background sea level science (climate change, oceanography), the need for related geodetic measurements, and (HOTS) using many training materials from previous courses.

Workshop reports are available for both of these courses. At the time of writing, no new course has been approved for funding by IOC. However, there have been several suggesting for hosting new courses, which will be discussed at GE7.

TRAINING MATERIALS AND TRAINING WEB PAGE

An updated version of the third volume of the IOC Manuals and Guides No.14 on sea level measurement and interpretation has been completed and can be down-loaded from the PSMSL training web page: http://www.pol.ac.uk/psmsl/training/training.html.

This is a typical example of the set of sea-level related information, which we hope such a training page will eventually contain. Suggestions for additions will be discussed at GE7.

Several sets of tidal analysis software continue to be widely distributed and play a major role in improving data quality and timely delivery. The most used is that of Pat Caldwell from the University of Hawaii. The TASK-2000 package from POL was used at recent GLOSS training courses. A further package is available from the Australian NTF.

NEWSLETTERS AND BROCHURES

There have been seven issues of the GLOSS Bulletin on the web, of which the last was produced by the PSMSL in 1999 using contributions from GE6. However, a volunteer is required to take over production of the Bulletin from now on. Several issues of the Afro-American GLOSS News (AAGN) have been produced by the University of Sao Paulo, with recent editions on the web. At GE6, it was suggested that the AAGN be produced in future jointly by the Universities of Sao Paulo and Cape Town, thereby widening the geographical scope of the Newsletter. However, this has not yet happened.

All sea level centres (PSMSL, BODC, UHSLC, NTF) now have good web pages which serve to spread information to the public as well as the science community.

Two page brochures advertising GLOSS are now available in English, Portuguese, Spanish and (soon) French and can be downloaded from the PSMSL training web page.

SEA LEVEL SCIENCE

Numerous papers have been published using GLOSS (and sea level in general) data. However, perhaps one of the most important sets of publications are the reviews of the Intergovernmental Panel on Climate Change (IPCC). The Third Assessment Report (TAR) of the IPCC has continued under development in 1999-2000 with Chapter 11 on sea level changes led by Dr. J. Church (Australia) and Dr. J. Gregory (UK) and with me as a Lead Author. Chapter meetings took place in New Zealand in

February and Canada in July 2000 with final publication of the TAR in January 2001.

Other notable sea level publications during the past two years include a book on the history of tidal research by David Cartwright, and a book on sea level changes edited by Bruce Douglas, Steve Leatherman and M.S. Kearney. A review of global and European regional sea level changes has also been published by David Smith and colleagues.

RELEVANT GLOSS-RELATED MEETINGS

Full meetings of the GLOSS Group of Experts (GGE) take place at approximately two-yearly intervals. However, important GLOSS-related meetings also take place in the intervening periods whenever possible. Several examples are given below.

The University of Birmingham, UK hosted the four-yearly conference of the International Union of Geodesy and Geophysics (IUGG) in July 1999 with GLOSS, and related sea level science, represented strongly in a number of scientific sessions, working groups and business meetings of the various associations (IAPSO and IAG). It was at this Conference that the joint 'Bevis' GPS working group referred to above was established.

In October 1999, the PSMSL and GLOSS and the sea level group of the Asia Pacific Space Geodynamics (APSG) Project were represented at the GPS'99 Conference in Japan. Dr. Trevor Baker presented an overview of the status of GLOSS worldwide and in the region.

In April 2000, an important sea level conference on Climate Change, Climate Variability and Sea Level Rise took place at Rarotonga, Cook Islands organized by the Australian National Tidal Facility and others. A large number of major papers were presented, including those by people closely associated with the GLOSS programme.

In May, I attended the Coordination Meeting of the MedGLOSS programme at Haifa, Israel organized by Dr. Dov Rosen. MedGLOSS is a joint programme of the International Commission for the Scientific Exploration of the Mediterranean Sea (CIESM) and IOC and aims to install and coordinate a network of gauges for the Mediterranean and Black Seas.

In June, I represented GLOSS at the second Transition Planning Meeting of the Joint IOC/WMO Technical Commission for Oceanography and Marine Meteorology (JCOMMTRAN-2), the first having been in St. Petersburg, Russian Federation in 1999 at which GLOSS was represented by Dr. Oleg Zilberstein. This second meeting was charged with construction of the essential documents for the first meeting of JCOMM itself in Iceland in June 2001 at which many of the activities of IOC and the World Meteorological Organization (WMO) will be combined in one framework.

Several important sea level science meetings took place in 2000. In April, I presented an overview of sea level and space gravity science at the Geosciences 2000 conference at Manchester, U.K. In September, I gave a presentation on the monitoring and predicting of long term sea level changes at the Eurocoast 2000 conference in Dubrovnik, Croatia. In November-December, Dr. David Pugh represented GLOSS at a meeting of oceanographic institutes (POGO) in Sao Paulo, Brazil and gave a presentation on sea level and climate changes. Shortly afterwards, he gave a lecture at the MarCUBA conference in Cuba on climate and sea level trends.

TIDE GAUGE HARDWARE PROVISION

Four second hand Ott R20 gauges (chart recorders) were donated to GLOSS by Singapore and eventually two were provided to Romanian authorities as a contribution to MedGLOSS development. The two others remain at POL in a part-serviceable state and could be made available if required.

This exercise resulted from an appeal for useful second hand equipment for GLOSS in

developing countries made in 1999. However, we discovered that it is not a trivial matter for IOC, POL etc. to organize the freighting of such equipment around the world, which is why the appeal has not been repeated so far. Bilateral arrangements between donors and recipients would seem to be more appropriate and direct.

REQUESTS FOR NEW RESOURCES FOR GLOSS

IOC funds for GLOSS are extremely limited and tend to be devoted to the costs of meetings, training courses and sea level products (e.g. data and training CD-ROMs). There are virtually no funds for new gauges or geodetic equipment.

During the past year, I have been working closely with Thorkild to investigate possibilities for obtaining additional funding for the programme, with many letters asking for support having been sent to national and international funding agencies. Results in this area will be reported to the GE7.

PUBLICATIONS AND OUTREACH

Various activities have been made on behalf of PSMSL and GLOSS, which are described in the PSMSL Annual Reports. These include various TV, radio and press interviews, Open Days and presentations to politicians and national delegations. In addition, presentations have been made by Thorkild and I to the IOC-community at Assemblies and Executive Councils.

ACKNOWLDGEMENTS

I would like to extend to Thorkild Aarup my appreciation of his help and advice about GLOSS and other IOC matters during the past two years.

Appendix 1: Summary of GLOSS Workshop and Meeting Reports published since GE6

IOC Group of Experts on the Global Sea Level Observing System (GLOSS) 6th Session. Rep. Meet. Experts Equiv. Bodies IOC; GOOS Report No. 71 No: 152; Year: 1999. http://ioc.unesco.org/iocweb/iocpub/iocpdf/ggegloss06 pdf.

IOC/GLOSS-GOOS Training Workshop on Sea level Measurements, Tidal Analysis, GPS and Gravity Measurements, Satellite Altimetry and Numerical Modelling. Instituto Oceanografico da Universidade de Sao Paolo. Sao Paolo, Brazil. 30 August-25 September 1999. Train. Course Rep. IOC No: 54; Year: 2000 http://ioc.unesco.org/iocweb/iocpub/iocpdf/tc054.pdf.

PERSGA/ALECSO - IOC/GLOSS-GOOS Training Workshop on Sea-level Data Analysis for the Red Sea and Gulf of Aden Region; Jeddah, Kingdom of Saudi Arabia, 15-19 April 2000. Train. Course Rep. IOC No: 57; Year: 2000 http://ioc.unesco.org/iocweb/iocpub/iocpdf/tc057.pdf.

Arctic tide gauges: a status report (Ed. H.P. Plag) IOC/INF-1147; Year: 2000 http://ioc.unesco.org/iocweb/iocpub/iocpdf/i1147.pdf.

Ocean Circulation Science derived from the Atlantic, Indian and Arctic Sea Level Networks (Ed. G. Mitchum) IOC Workshop Report No: 171; Year: 2001 http://ioc.unesco.org/iocweb/iocpub/iocpdf/w171.pdf

MedGLOSS meeting report 15-17 May, 2000 (The report is not yet incorporated in the IOC-library; web-link will be announced)

In addition, the following brochures were added to the web site:

Portuguese version of GLOSS brochure (kindly provided by Dr. Eduardo Marone): http://www.pol.ac.uk/psmsl/brochures/portfront.pdf

Spanish version of GLOSS brochure (kindly provided by Capt. Javier Valladeres and Dr. Hernan Troisi):http://www.pol.ac.uk/psmsl/brochures/glossf8esp.pdf
http://www.pol.ac.uk/psmsl/brochures/glossb8esp.pdf; with French and Chinese versions to follow.

Reports relevant to GPS at tide gauge sites can be obtained from the
CGPS@Tgwebsite:http://www.soest.hawaii.edu/cgps.

ANNEX IV

LIST OF INTERNATIONAL AND REGIONAL SEA LEVEL CENTRE AND PROGRAMME REPORTS

Permanent Service for Mean Sea Level (PSMSL). (see http://www.pol.ac.uk/psmsl/reports/iag2001.doc)

At the time of writing the following reports (see below) are available at the GLOSS GE7 website: http://www.pol.ac.uk/psmsl/ge7/annexes/. (These reports will be included into an intended complete set of country reports to be available from the GLOSS web page http://www.pol.ac.uk/psmsl/programmes/gloss.info.html).

REGIONAL REPORTS

- University of Hawaii Sea Level Center (UHSLC)
- WOCE Delayed Mode Data Assembly Centre (British Oceanographic Data Centre)
- South Pacific Network (Australian National Tidal Facility)
- Southern Ocean Sea Level Centre (Australian National Tidal Facility)
- Central American Network (COOPS, NOAA)
- Caribbean Network: Planning for Adaptation to Global Climate Change (CPACC)

NATIONAL SEA LEVEL CENTRES AND PROGRAMME REPORTS

- Australia (one report on the NTF as an NODC; one on the Australian Baseline Network)
- Bangladesh
- Canada
- Chile
- France
- Indonesia
- Israel
- Japan
- Malaysia
- New Zealand
- People's Republic of China
- Singapore
- Thailand
- United Kingdom
- Vietnam

ANNEX V

REPORT OF THE GLOSS SCIENCE SUB-GROUP (SSG)

Report prepared by Gary T. Mitchum, Chair of the SSG

At the Sixth Meeting of the GLOSS Group of Experts (GE6) in Toulouse, France in May 1999 the decision was made to establish a Scientific Sub-Group (SSG) of the GLOSS GE as a source of scientific advice, especially for climate, with the sub-group potentially a joint committee with (at present) OOPC, CLIVAR/UOP and IAPSO/CMSLT. Since GE6, the Executive Council of the IOC has approved this action in June 2000, and a chairman of the SSG has been identified by the Chairman of the GGE and the initial membership of the SSG has been established (see Appendix 1).

The approved Terms of Reference of the SSG are:

(i) Provide the GLOSS Group of Experts and other interested relevant bodies, *via* the Chairperson of the GGE with general scientific advice on matters pertaining to the implementation of the monitoring of global and regional sea level changes within the GLOSS programme, particularly with regard to climate change;

(ii) Undertake specific studies pertaining to the effective monitoring of global sea level changes on matters requested by the Chairman of the GGE;

(iii) Provide assistance as requested to the Chairman of the GGE in the construction of Science and Implementation Plans for GLOSS;

(iv) Provide, through its scientific membership, links to other relevant bodies concerned with sea level changes including OOPC, CLIVAR/UOP, IAPSO/CMSLT and C-GOOS and report implications to the GGE.

Since the approval of the SSG last summer the Chair of the SSG and Chair of the GGE have discussed topics that might comprise good initial areas of emphasis for the SSG, and a summary of these discussions in given in Appendix II. The GE is invited to comment on these suggestions and to make additional suggestions as well, and may do so by contacting the SSG Chair or the GGE Chair.

Progress has also been made on establishing linkages with other relevant bodies. In addition to the linkages provided by the SSG membership (see Appendix I), the SSG Chair has been asked to serve as an ex officio member of the recently established CLIVAR Ocean Observations Panel, which has replaced the former CLIVAR Upper Ocean Panel. This body met recently and the SSG Chair prepared input on behalf of GLOSS. That report is included here as Appendix III.

Appendix 1: MEMBERS OF THE GLOSS SSG

Gary MITCHUM (Chair)	mitchum@marine.usf.edu
John CHURCH	john.church@marine.csiro.au
Jonathon GREGORY	jmgregory@meto.govt.uk
Chet KOBLINSKY	koblinsky@gsfc.nasa.gov
Keith THOMPSON	keith@phys.ocean.dal.ca
Eduardo MARONE	marone@uol.com.br
Neville SMITH	N.Smith@bom.gov.au
Bruce DOUGLAS	bdouglas@bss2.umd.edu
Kurt LAMBECK	kurt.lambeck@anu.edu.au
Anny CAZENAVE	anny.cazenave@cnes.fr
Mark MERRIFIELD	markm@soest.hawaii.edu
Guy WOPPELMANN	guy@ensg.ign.fr
Tony STURGES	sturges@ocean.fsu.edu
Geoff BRUNDITT	brundrit@physci.uct.ac.za

Gilles REVERDIN Gilles.Reverdin@cnes.fr
Rosemary MORROW morrow@nanook.cst.cnes.fr
Roger FLATHER raf@pol.ac.uk
John de RONDE deronde@rikz.rws.minvenw.nl

***Ex officio* members**

Philip WOODWORTH plw@pol.ac.uk
Thorkild AARUP t.aarup@unesco.org

Appendix 2: SUMMARY OF POSSIBLE TOPICS FOR SSG CONSIDERATION

Five topics were considered as initial possibilities for SSG attention. These topics are:

(i) Review of ocean circulation for GIP update;
(ii) Extreme sea levels;
(iii) Sea level pressure;
(iv) Bottom pressure;
(v) Funding for GLOSS in general.

The following comments reflect discussions between Phil Woodworth (GGE Chair) and the SSG Chair, and represent the current plan of attack. We welcome comments and additions from the GE.

1) Review of ocean circulation for GIP update:

While this is an obvious thing for the SSG to do, it was thought it was not a pressing issue and should wait until the GIP was closer to being in need of the next major revision. It was put as fourth on the list of priorities.

2) Extreme sea levels:

This was considered the most pressing issue, and was placed first on the list of SSG priorities.

It was thought that we could make use of the full expertise of the Group by having modelling and data gathering/analysis activities. In the former, there have been a number of studies wherein barotropic models have been run for certain areas (e.g., the European shelf) forced by historical meteorological datasets or by 'future weather' from a GCM. The areas concerned so far, however, do not make a global. If some of the modellers (Le Provost being the obvious candidate) feel in a position to take this sort of study global that would be a large step forward. It might not do an ideal job in all areas but it would give some basis for computing statistics on changes of risk along the world coastline for a given (e.g., IPCC) sea level change.

Meanwhile, the more traditional sea level types could organize a collection of extreme values (the annual extremes would do but normally now people like to use say the five largest extremes in each year) from as many places as we can. It is likely that 20 years is enough, including datum information of course. There is no intention at the moment to collect extreme information on an ongoing basis; it should be acceptable if the 20 years are from the second half of the 20th century. For places with data in one of the data banks we can obviously compute the extremes ourselves from the hourly data. For places that do not send us the hourly data, they may be willing to send extremes. In some places extremes are noted in preference to the hourly observations or the means (e.g., Venice) or are the only data available (e.g., some parts of Bangladesh).

We are talking in effect of constructing a dataset for extremes along the lines of the International Hydrographic Bureau dataset for tidal constants. One possibility might be to make use of the Regional GLOSS Contacts, who could contact each country in their area, make their own dataset (in the same recommended format), which someone could put together into a global set. Then

any group(s) could analyze this set using modern extreme level statistical methods. This implies involvement by people outside of the SSG list but still within GLOSS as such.

3) Sea level pressure:

This was considered a good topic, and has been discussed at length with the COSTA programme, which considered this need explicitly and suggested using ARGO floats to obtain additional measurements. But this is something that we have talked about in the past, too, so perhaps it is not so timely. This is possibly a rationale for modernizing tide gauge hardware, however, and probably has a link to the long-term funding issue if the data were available to the meteorological agencies in a timely manner. For now, however, this topic was prioritized as third in line.

4) Bottom pressure:

This is a very timely topic given the present interest and a relevant recommendation from the last GE-GLOSS meeting. It may be difficult to do anything really definitive, but it should be easier to at least state the rationale for such observations. We note that the IAPSO CMSLT has nominal oversight on this topic, and we have members in common with that group. We prioritize this as second, but intend a very limited effort at this point in time.

5) Funding for GLOSS in general:

This is certainly an important topic, and hopefully one that the SSG will eventually tackle. It was thought, however, that it would be better for the SSG to start with several science issues before becoming involved in the funding problems. This was therefore placed as lowest on the priority list for now.

Appendix 3: Input for CLIVAR Ocean Observations Panel (COOP) meeting on *Global Sea Surface Height Observations*. Prepared by Gary T. Mitchum, Chair, GLOSS Science Steering Group for the COOP meeting in Hobart, Australia in April 2001.

This report concerns progress toward an integrated sea surface height (SSH) observing system that should serve the needs of CLIVAR as well as any future climate observing programs. There has been excellent progress in this area as part of the GLOSS project, and in the summer of 2000, the International Oceanographic Commission approved the creation of a Science Steering Group for the GLOSS project. This group is explicitly charged with coordination with science programs such as CLIVAR in order to make GLOSS as responsive as possible to the needs of these programs. This report is aimed at informing the COOP group of the recent activities and progress concerning the global SSH observing system, and at soliciting questions that the GLOSS SSG might take up in order to make further progress. We will first report on progress toward an integrated SSH system, and will then report on future improvements that seem likely to occur.

In addition to overseeing the development and maintenance of the global tide gauge network, the GLOSS project, under the direction of Dr. Philip Woodworth, has designated two subsets of gauges for special attention that are of particular interest in the present context. First, the GLOSS-ALT subset is specifically aimed at developing a high quality subset of stations that are most valuable for the calibration and monitoring of satellite altimeter estimates of SSH. Second, the GLOSS-LTT identifies stations with the longest high quality records (typically many decades of observation) that are particularly valuable for studies of low frequency variability in the ocean. Third, although a specific subset of gauges is not identified in this case, the GLOSS programme has taken a leadership role in the development of absolute sea level observations via the combination of tide gauge data with GPS and DORIS measurements of the motion of the land adjacent to the tide gauges. This effort is especially relevant to the problem of maintaining the stability of satellite altimeters, as will be discussed shortly.

As mentioned above, in the summer of 2000, the creation of a Science Steering Group was approved by the IOC and charged with generally advising the GLOSS project and Dr. Woodworth on scientific issues and in particular with interfacing with appropriate science programmes to insure that the GLOSS project can maximize its contribution to these programs. The membership of the GLOSS SSG is included below as Appendix 1. Additional information on the GLOSS project may be found in the most recent version of the GLOSS Implementation Plan, which is available on the web at http://unesdoc.unesco.org/images/0011/001126/112650eo.pdf.

In parallel to the development of the in situ observation system, there has been excellent progress in satellite altimetry during the past decade, particularly via the TOPEX/POSEIDON (T/P) mission of the U.S. and France and the ERS-1 and ERS-2 missions of the European Space Agency. The use of tide gauges as part of the routine calibration and validation of the T/P data has been accepted for some time now, and the global tide gauge network has been shown to be capable of detecting and correcting drift in the altimetric system at the level of 1 mm/yr (e.g., Mitchum, 1998 and 2000). Partly because of the ability to control drifts in the altimetric data to this level, precise estimates of global sea level change rates during the T/P mission have been made (see Nerem and Mitchum, 2000 for a recent review), and with the T/P series now approaching a decade in length, it is likely that these data can be applied to problems involving decadal variability. Finally, the T/P project is also supporting the application of GPS and DORIS measurements of land motion to tide gauge benchmark fixing in order to further improve on the tide gauge determinations of the T/P stability in time. The progress in this area has been described by Mitchum *et al.* (1999), who also describe the plan for the future SSH observing system that is described next.

One of the outcomes of the T/P mission has been a clear understanding of exactly what it required to obtain precise and stable time series of global SSH from satellite altimeters. Precision orbits are necessary, a dual frequency measurement to obtain ionospheric corrections is required, a water vapor radiometer is essential, and the in situ sea level network is necessary to estimate the low frequency drift in the satellite system. In a complex system like a satellite altimeter, drift is inevitable and at present the global tide gauge network provides the best estimates of the altimetric drift. In addition, a variety of sampling studies have been done, and it has been determined (e.g., Le Traon and Dibarboure, 1999; Jacobs *et al.*, 1999) that 2-3 simultaneous altimetric systems are required to obtain reasonable estimates of the ocean mesoscale variability.

Based on these considerations it has been argued (Mitchum *et al*., 1999) that the future SSH system should consist of several parts. First, an altimeter should be maintained in the T/P ground track that is comparable to T/P in precision in order to continue the highly precise time series that we have now begun. Starting again in a different ground track would require new determinations of various error terms, and would essentially mean starting over. Second, 1-2 altimeters in ground tracks selected to optimize the resolution of the oceanic mesoscale should complement the altimeter in the T/P ground track. The oceanic mesoscale is important for low frequency studies because of the interactions with the mean flows. Also, given the operational interest in the mesoscale, it is unlikely that an altimetric system that did not resolve the mesoscale would receive widespread support. It is not necessary, however, that these additional altimeters be of T/P precision, given that the mesoscale signals are of reasonably large amplitude. Third, the *in situ* tide gauge network that is overseen by GLOSS must be maintained and improved in order to continue to provide the drift estimates for the altimetric SSH that makes these time series useful for studies of low frequency variability, and to improve these estimates in the future. At present the largest remaining source of error in the tide gauge determinations of altimetric drift is the land motion at the gauges (Mitchum, 2000), which necessitates the placement of GPS and DORIS receivers at as many tide gauges as possible. In addition to the use of tide gauge data for the calibration of the altimetric heights, tide gauge data are also essential in certain areas where the altimetric data are of limited utility. For example, narrow boundary currents are difficult to resolve with altimetry and tide gauge differences are still required. Also, flows through important “choke points” are still best made with tide gauge measures of SSH.

There are several developments on the horizon that make it very likely that the above requirements can be met. One of the most exciting possibilities is the swath altimeter developed at JPL (Rodriguez *et al*., 2000) that is presently approved for flight on the JASON-2 mission in the T/P

ground track. This technology promises T/P precision, but in a swath nearly 200 km wide rather than in the narrow nadir track presently obtained from satellite altimeters. The net result is that a truly global coverage is possible in 10 days, as opposed to the global set of narrow cuts presently obtained each 10 days. Second, given that multiple altimeters are presently required to obtain the space-time coverage required, two plans are in place that could provide multiple altimeters at low cost to complement the precise measurement in the T/P track. The first of these is the so-called WITTEX (http:// fermi.jhuapl.edu/wittex), which uses an improved altimeter to obtain T/P precision with far less power consumption. The reduced power requirement allows the launch of multiple altimeters with a single launch, resulting in a cost-effective multiple satellite system. The second possibility is the French ALTIKA (Phalippou *et al.*, 2000) that uses a much smaller satellite in a low orbit and in a different frequency band to obtain the necessary mesoscale resolution. Finally, and also in the area of developments presently on the horizon, GPS and DORIS instruments are presently being installed at many gauges for a variety of reasons, and it is likely that this trend will continue. Consequently, the ability of the tide gauge network to provide the stability estimates required for precise studies of low frequency variations should steadily improve with time.

Our experience with T/P and the continuation of this success with JASON and ERS/ENVISAT, along with the development of determinations of altimetric stability from the tide gauge data and the expected improvements to both components of the SSH observing system in the future, bode well for programs such as CLIVAR. With the JASON and ENVISAT altimetric missions continuing, and with the technological improvements presently ready for testing, it is likely that a highly precise global SSH system will remain in place at relatively low cost. The reason for low cost is because the ability to simultaneously observe the mesoscale makes the altimetric missions relevant for operational applications, thus justifying the maintenance of these data streams aside from the needs of the climate programs. In order to be most useful for climate studies, however, the stability of the altimetric data must be maintained to high accuracy. Maintaining and improving the global tide gauge network can provide this accuracy, but this could be problematic. At present nearly all of the funding to maintain the tide gauge network is from national agencies that often do not have the resources to do a thorough job. It would be preferable that a project such as GLOSS have sufficient resources to step in where necessary, and given that these efforts are required to make the SSH system maximally useful for climate work, these costs would be a sensible expenditure for international climate programs such as CLIVAR. This is a small marginal cost that would insure that the existing and future SSH observing systems would fully serve the needs of CLIVAR and future climate-oriented studies.

As a final note, we would point out that the GLOSS SSG is ready and willing to address any issues and questions relating to the global SSH observing system. We would very much appreciate suggestions for topics that we should consider, and we look forward to feedback from the COOP group and others. Please feel free to contact the GLOSS chair, Philip Woodworth, the SSG chair, Gary Mitchum, or any of the SSG members with suggestions. Email addresses for these people are included in Appendix 1.

References:

Jacobs, G., C. Barron, M. Carnes, D. Fox, H. Hurlburt, P. Pistek, R. Rhodes, W. Teague, J. Blaha, R. Crout, O. Smedstadt, K. Whitmer, 1999: Navy Altimeter Data Requirements, Technical Report, Naval Research Laboratory, Stennis Space Center, MS 39529-5004, USA.

Le Traon, P., and G. Dibarboure, 1999: Mesoscale mapping capabilities of multiple-satellite altimeter missions. J. Atmos. and Oceanic Tech., 16, 1208-1223.

Mitchum, G., 1998: Monitoring the stability of satellite altimeters with tide gauges. J. Atmos. and Oceanic Tech., 15, 721-730.

Mitchum, G., 2000: An improved calibration of satellite altimetric heights using tide gauge sea levels with adjustment for land motion. Marine Geodesy, 23, 145-166.

Mitchum, G., R. Cheney, L. Fu, C. Le Provost, Y. Menard, and P. Woodworth, 1999: The future of sea surface height observations, Prodeedings of the OceanObs '99 conference, St. Raphael, France, November 1999.

Nerem. R., and G. Mitchum, 2000: Sea level changes, in Satellite Altimetry and Earth Sciences, L.-L. Fu and A. Cazenave (eds.), Academic Press.

Phalippou, L., E. Caubet, and E. Thouvenot, 2000: Preliminary design of a combined Ka-band altimeter and dual frequency radiometer, Proceedings of the IGARSS2000, Honolulu, Hawaii, USA.

Rodriguez, E., B. Pollard, and J. Martin, 2000: Wide-swath ocean altimetry using radar interferometry, IEEE Trans. On Geoscience and Remote Sensing, In review.

ANNEX VI

GLOSS PLAN OF ACTION 2001-03

FOLLOWING THE REPORT OF THE GE7 MEETING IN HAWAII, APRIL 2001

1. [Various] Complete outstanding GE6 actions (some included explicitly below);

2. [Aarup, Woodworth] Complete first draft of GE7 meeting report, circulate for comments, and present final version to IOC Assembly 2001;

3. [Aarup, Woodworth] Present GLOSS status report to JCOMM meeting 2001;

4. [All] Review data provided to the PSMSL, UHSLC and (if appropriate) Southern Ocean SLC at the Australian NTF and send data updates. Also, send Woodworth the titles etc. of all GLOSS-related reports;

5. [Shum, Scherer] Investigate possible journal publications of papers presented at APSG workshop, possible fall-back option being an IOC workshop report;

6. [Bevis] Expand the CGPS@TG website with further case studies and background information (the proposed 'Bevis IOC Manual' now having been dropped given the existence of this website);

7. [Schoene, Neilan etc.] Initiate TIGA Pilot Project following discussions on the proposed Call during the CGPS@TG workshop;

8. [Rickards, Kilonsky] define a standard format for tide gauge data (hourly values or similar) to be provided to the TIGA data centre'

9. [Woppelmann] update the list of GPS receivers at tide gauge sites at regular intervals;

10. GLOSS Handbook etc:

[Rickards] complete the latest (2001) version of the GHB;

[Rickards, Woodworth] redefine GCN following new round of GLOSS Handbook correspondence, redefine GLOSS-OC following discussions with Le Provost (see also 'Fast Delivery' below);

[Rickards] GHB information to include station histories as far as possible, and also status of 'Fast Delivery' (see below) In addition new Handbook to include photographs, information on site environmental conditions (hard rock etc.) and other metadata;

[Rickards] update the table of Survey of Compliance with the GLOSS Implementation Plan;

11. [Le Provost, Woodworth, Narayanan] process the GLOSS hourly data to derive a GLOSS tidal constants data set using same Toulouse software as used already for pelagic data; investigate possibility for a databank of tidal constants at MEDS (the GLOSS set to be updated at regular intervals). Formal letter to be written to IHO to ask for permission to make available to bona fide ocean tide modellers the filtered set of 700 IHO constants already available at Toulouse (out of the total of 3000 constants in the whole data bank);

12. [Hannah, Woodworth, Aarup] Letter to be sent from GLOSS to LINZ in support of the proposed NZ central data archive and contact point (draft of letter to be composed by Hannah);

13. [Woodworth, Aarup] Letter to be sent to Plag (chairman ESEAS activity) and Rosen (chairman MedGLOSS) requesting that they coordinate their planning, meetings etc. as far as possible to lead to the best coordinated sea level activity for the Mediterranean and Black Seas;

14. [Aarup, Guo Fengyi] Letter to be sent to China with advice from Guo Fengyi requesting information on the 60-odd gauges known to exist along the Chinese coast in addition to those for which data are already made available to the community;

15. [LeRoy, Aarup] letter to be sent to SHOM regarding the 2 gauges to be installed by France in Morocco, one on the Atlantic coast (Rabat) and one in the Mediterranean. Letter to stress the need for GLOSS sites in this area, the fact that MedGLOSS has funded a gauge on the Mediterranean coast (with IOC/CIESM funds) and that the 2 new gauges should be operated to GLOSS standards with data provided to the community;

16. [Aarup] write to DHN, Brazil with regard to the desirability of a software expert visit with regard to more efficient data supply (Pat Caldwell suggested);

17. [Aarup, PERSGA] select a technical expert to conduct a regional survey as recommended by the 2001 GLOSS training course in Saudi Arabia. Need to define initially more clearly the sites to be visited, local contacts etc. Possible experts suggested as from UH, NOS or Lee Chapin;

18. [Manning] Review of Antarctic sea level recording requested to be made available to GLOSS as soon as possible. (SCAR project on "Consolidation of Antarctic tide gauge information" commenced July 2000);

19. [Woodworth *et al.*] to complete paper for Oceanography and Marine Biology on the use of tide gauge during WOCE;

20. Newsletters etc:

[Woodworth] the GLOSS Bulletin to be wound down; last issue may be a meeting report from GE7. A 'What's New in GLOSS' section to be added to GLOSS web pages instead. [Mesquita] to be asked to continue with the Afro-America GLOSS News, with perhaps more articles solicited in English and from European/US etc. groups. [Aarup] to investigate articles in the IOC Products and Services Bulletin, GOOS News, IALA Newsletter etc.

21. Data Archaeology:

[Woodworth, Rickards, Rosen] investigate once again the possibilities for chart digitizing packages.

[Aarup] inform community of the offer from UH to computerise tabulations of sea level data from GLOSS sites where available

[Rickards] to include in GHB questionnaires whether there exists sea level information from GLOSS sites in non-computer form that requires conversion.

22. [Mitchum] solicit further advice on proposed SSG science activities and initiate studies;

23. [Woodworth, Aarup] finalise and publish the 'IOC Manual 3';

24. [Rosen] complete Windowisation of the POL TASK-2000 QC and tidal analysis package;

25. [Aarup, Woodworth] complete arrangements for installations in Ghana of gauges to be provide by India;

26. [Scherer etc.] to conduct intercomparison of different types of acoustic gauges and other types (Note Action Item 25 from GE6 read, Comparative study of new acoustic gauges (Sonar Research or

MORS type) and other technologies by Perez (Spain), Waldron (South Africa), Israel (Rosen), Norway (Plag), France (Woppelmann) and Australia (Scherer);

27. [Le Provost, Aarup?] someone based in France to attend the PIRATA-8 meeting at University of Paris 29-31 August and present a review of GLOSS in the region;

28. [Chapin] Lee to provide Woodworth with the six page report to RONMAC by Gutierrez on Central American gauges. Woodworth to add to GLOSS web.

29. [Woodworth] request David Aubrey and Vivien Gornitz to keep a watching brief on the IUGG and IOC 'Georisk' programmes on behalf of GLOSS and to report to next GE meeting;

30. [Woodworth] request a person to be decided to keep a watching brief on the JCOMM Waves and Surges project (for which an Expert Group will be established, and to report to next GE meeting;

31. [Higaki] provide names of 3 (2-4 anyway) sites on the west coast of Japan for inclusion in the GLOSS Core Network. Criteria should include long records, open ocean conditions as far as possible, good quality data, GPS nearby (or potentially nearby), as little as possible local tectonics (see the GLOSS Implementation Plan for more criteria). Hourly data to be freely available in addition to monthly means to PSMSL;

32. Fast Delivery: (Background to this is a request by the GODAE programme that from 2003 the data from the GLOSS-OC set be made available for assimilation with a timescale of 2 days, with data from as many as possible GLOSS sites for model validation within 7 days. 'Fast' (i.e. usually un-QC'd) data from approximately 127 sites are currently delivered to the GLOSS Fast Centre at UH with a timescale of the order of a month):

[Merrifield] need to develop UH processing capabilities to satisfy above requirements by 2003.

[Woodworth, Le Provost, Thompson] Le Provost and Woodworth to update the definition of the GLOSS-OC set in the Implementation Plan 1997, from which planning can take place. Thompson to advise Le Provost on model-based information sources (this exercise subject no doubt to regular reviews);

[Aarup, Woodworth] when above -OC set determined, inform GLOSS Contacts on requirements for fast data delivery;

33. Delayed Mode Data:

{Woodworth, Rickards] subject to anticipated increase in staffing levels, the WOCE Delayed Mode Data Centre to metamorphose into the GLOSS Delayed Mode and Archiving Centre (as per the Implementation Plan) with hourly data complementing the available PSMSL monthly means as far as possible;

34. [UHSLC, BODC/PSMSL, ANTF] as far as possible replace mention of 'WOCE Centres' by 'GLOSS Centres'. The two WOCE/GLOSS Sea Level Centres and Southern Ocean Sea Level Centre should continue to be developed to serve user needs;

35. Training Courses:

[Rosen] to provide more details of the proposed training course in Israel in autumn 2001. This course originated in response to the request from the IOC Secretary for financial support in training for developing countries on sea level measurements and analysis. Some funds have been raised in Israel for a one-week training course for a small number of participants. A few IOLR staff and perhaps SOI on geodesy, and one-two foreign experts will conduct the training.

[Aarup, Hasan] formal letter to Director General Mapping Malaysia to request the hosting of a course late 2002/early 2003 as discussed at GE7. Imported lecturer support (e.g. from NTF) to be determined;

[Aarup, Fierro, Chapin] letter to head of Hydrographic Department (?) to request the hosting of a course in 2002. RONMAC funds to be investigated;

[Aarup, Chapin] letter to Neville Trots (?) (Univ. of the West Indies) to request the hosting of a course early 2002. CPACC/IMPACT funds for attendees from 12 countries to be investigated;

[All] provide Aarup and Woodworth with names of possible experts who could lecture at the above and other courses.

36. GLOSS Funding:

[Aarup] any future round of letters to agencies asking for contributions to Trust Fund to be better focused and specific;

[Aarup, Chapin] investigate the Interim National Communications funding possibilities;

[Haines, Aarup, Woodworth] investigate potential for JPL Outreach funds from the T/P project in support of training;

[Aarup] arrangements for GOOS capacity building workshop for Africa at which sea level is a major theme (November 2001);

[Aarup] initiate by email the first discussions of the proposed Intersessional Group on Funding for GLOSS (proposed members Aarup, Brundrit, Pugh, Chapin and others). Select chairman?

37. Regional Coordination:

[Shum, Scherer] advise Aarup on best mechanism for regional coordination in the 'APSG region', following this meeting. Can a Coordinator be designated from attendees at GE7? (not necessarily the chairs of the APSG which has a finite duration);

[Woodworth, Aarup etc.] review the functions of other Regional Coordinators once again;

38. [Aarup etc.] Arrangements for GE8 around 2003, preferably at a location not used so far with a suitable accompanying workshop(s). Mini-GE meeting to be organised in the interim if feasible;

39. GLOSS brochures produced at PSMSL in French and Chinese to be added to web, brochures in English, Spanish, Japanese and Portuguese already available;

40. [Brundrit, Aman, Adekoya etc.] Proper implementation of the many actions for West Africa (see item 19 in http://www.pol.ac.uk/psmsl/gb/gb7/ge6actions);

41. [Scherer] Investigation of release of data from the Association of Southeast Asian Nations (ASEAN) to the community (carried forward from GE6);

42. [IOC] Continued support of PSMSL activities with regard to GLOSS development (carried forward from GE6);

43. [Chairman] Circulation of a questionnaire in which GLOSS stations have extra channels for additional C-GOOS parameters, information to be inserted into the GLOSS Handbook (carried forward from GE6);

Such a questionnaire was circulated in 2001 but should be repeated following discussions at GE7. This could also be part of the GHB.

44. GLOSS Data Management Committee to determine ways in which the WOCE/GLOSS Sea Level Centres (UHSLC and BODC) and others can work towards common products and implementation of the Implementation Plan (Rickards/Kilonsky/others). (Carried forward from GE6);

45. [Chairman/IOC] Use of IOC resources for technical consultant(s) for gauge installations or leveling ties, and investigation of possible exchange programme of technical and scientific experts (carried forward from GE6);

46. [Somasundar/Shetye] Implementation of recommendations for continuing the work of the Pilot Phase of the Indian Ocean 'CMAS' activity and of two proposals for sea level networks and storm surge warning systems in the Northern Indian Ocean (carried forward from GE6);

47. [Marone/Thompson/Aarup] Discussions with C-GOOS working panels on deployment of C-GOOS sea level stations joint training with GLOSS etc. (carried forward from GE6);

48. [All] Responsibility for publicizing the aims and achievements of GLOSS whenever possible.

ANNEX VII

LIST OF ACRONYMS

AAGN	African American GLOSS News
AAM	Atmosphere Angular Momentum
ACCLAIM	Antarctic Circumpolar Current Levels from Altimetry and Island Measurements
ADCP	Acoustic Doppler Current profiler
ALECSO	Arab League of Education, Culture and Science Organization
ALTIKA	Ka-band altimeter
APSG	Asia Pacific Space Geodynamics Project
ARGO	Global Array of Profiling Floats
ASEAN	Association of South-East Asian Nations
AUSLIG	Australia's national mapping agency
BIFROST	Baseline Inferences for Fennoscandian Rebound, Sea-level, and Tectonics
BODC	British Oceanographic Data Centre
C-GOOS	Coastal Module of the Global Ocean Observing System
CHAMP	Challenging Minisatellite Payload
CIESM	International Commission for the Scientific Exploration of the Mediterranean Sea
CLIVAR	Climate Variability and Predictability
CMSLT	Commission on Mean Sea Level and Tides
CNES	Centre national d'études spatiales (France)
CONNS	Coastal Observing Networks for Near Shore
COOP	Coastal Ocean Observations Panel
CO-OPS	Center for Operational Oceanographic Products and Services (of NOAA)
COSTA	Climate Observing System for the Tropical Atlantic
CPACC	Caribbean Planning for Adaptation to Climate Change
CSIRO	Commonwealth Scientific and Industrial Research Organization
CSTG	Commission on International Coordination of Space Techniques for Geodesy and Geodynamics
DGFI	Deutsches Geodätisches Forschungsinstitut (Germany)
DHN	Diretoria de Hidrografia e Navegar·o (Brazil)
DORIS	Doppler Orbitography and Radio positioning Integrated by Satellites
EGS	European Geophysical Society
ENSO	El Nino Southern Oscillation
ENVISAT	Environmental Satellite
EOF	Empirical Orthogonal Function
ERS 1-2	European Remote Sensing Satellite 1 - 2
ESA	European Space Agency
ESEAS	European Sea-Level Service
EU	European Union
GAMBLE	Global Altimeter Measurements By Leading Europeans
GCN	Global Core Network
GE	Group of Experts
GEF	Global Environmental Facility
GEOSAT	Geodetic Satellite (USA)
GFO	GEOSTAT Follow-on
GFZ	Geoforschungzentrum
GGE	GLOSS Group of Experts
GLOSS	Global Sea-Level Observing System
GLOUP	Global Undersea Pressure
GODAE	Global Data Assimilation Experiment
GODAR	Global Oceanographic Data Archaeology and Rescue Project
GOES	Geostationary Operational Environmental Satellite
GOOS	Global Ocean Observing System
GPS	Global Positioning System
GRACE	Gravity Recovery and Climate Experiment

GRGS	Groupe de Recherches de Géodésie Spatiale (Grasse/Toulouse)
HIGP	Hawaii Institute of Geophysics and Planetary Physics
HOTO	Health of the Oceans (design panel of GOOS)
HOTS	Hands on Training Session
IAG	International Association of Geodesy
IALA	International Association of Marine Aids to Navigation and Lighthouse Authorities
IAPSO	International Association for the Physical Sciences of the Ocean
IGS	International GPS Service for Geodynamics
IHO	International Hydrographic Organization
IHB	International Hydrographic Bureau
IOC	Intergovernmental Oceanographic Commission (UNESCO)
IODE	International Oceanographic Data and Information Exchange
IORL	Israel Oceanographic and Limnological Research
IPCC	Intergovernmental Panel on Climate Change
IUGG	International Union of Geodesy and Geophysics
JCOMM	WMO-IOC Joint Technical Commission on Oceanography and Marine Meteorology
JPL	Jet Propulsion Laboratory (NASA)
LMR	Living Marine Resource
LOD	Length of Day
LTT	Long Term Trend
MedGLOSS	Mediterranean Programme for the Global Sea-Level Observing System
MEDS	Marine Environmental Data Services
NAO	North Atlantic Oscillation
NASA	National Aeronautics and Space Administration (USA)
NOAA	National Ocean and Atmosphere Administration (USA)
NOS	National Ocean Service (of NOAA)
NPOESS	National Polar-Orbiting Operational Environmental Satellite
NTF	National Tidal Facility (Australia)
OOPC	Ocean Observations Panel for Climate
OSSE	Observation System Simulation Experiment
PERSGA	Regional Organization for the Conservation of the Environment of the Red Sea & Gulf of Aden
PIRATA	Pilot Research Moored Array in the Tropical Atlantic
POGO	Partnership for Observation of the Global Oceans
POL	Proudman Oceanography Laboratory (UK)
PSMSL	Permanent Service for Mean Sea-Level
QC	Quality Control
RONMAC	Red de Observacion del Nivel del Mar para America Central
RTK	Real-Time Kinematic
SCAR	Scientific Committee on Antarctic Research
ScoMMSA	Sub-Commission on Multi-Mission Satellite Altimetry (IAG)
SEAL	Sea Level Change (research project of the Hermann von Helmholtz Association, Germany)
SHOM	Service Hydrographique et Océanographique de la Marine
SLR	Satellite Laser Ranging
SOI	Southern Oscillation Index
SOOP	Ship Of Opportunity Programme
SOSLC	Southern Ocean Sea Level Centre
SSG	Scientific Sub Group
SSH	Sea Surface Height
TAR	Third Assessment Report
TASK	Tidal Analysis Software Kit
TIGA	GPS Tide Gauge Benchmark Monitoring
TOPEX	Ocean Topography Experiment
UOP	Upper Ocean Panel (CLIVAR)
UHSLC	University of Hawaii Sea-Level Centre
UNEP	United Nations Environment Programme

UNESCO	United Nations Educational, Scientific and Cultural Organization
UNFCCC	UN Framework Convention on Climate Change
VLBI	Very Long Baseline Interferometry
VOS	Voluntary Observing Ship
WITTEX	Water Inclination Topography and Technology Experiment
WMO	World Meteorological Organization
WOCE	World Ocean Circulation Experiment