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Global Sea Level Observing System (GLOSS) Implementation Plan

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Contents

Summary

The Global Sea Level Observing System (GLOSS) is based on an international network of sea level measuring stations, co-ordinated by IOC. It provides high quality standardized data from which valuable sea level data products are produced for international and regional research programmes as well as for national practical applications.

Global measurements of sea level are necessary to monitor possible dramatic increases due to global warming. Coastal sea level measurements are vital for hydrographic surveys and can also give indications of ocean circulation patterns and climate variability.

The elements of GLOSS are:
(i) the global network of permanent sea level stations for obtaining standardized sea level observations; this forms the primary framework to which regional and national sea level networks can be related;
(ii) data collection for international exchange with unified formats and procedures which may include near-real-time data collection;
(iii) data analysis and product preparation required for scientific and/or practical applications;
(iv) assistance and training for establishing and maintaining sea level stations as part of GLOSS and improving national sea level networks;
(v) a selected set of GLOSS tide gauge bench marks shall be accurately connected to a global geodetic reference system (i.e. the conventional terrestrial reference frame, established by the International Earth Rotation Service (IERS)).

1. GLOSS OBJECTIVE

The plan is to establish by 1990 an operational global network of permanent sea level stations reporting monthly mean averages to the Permanent Service for Mean Sea Level (PSMSL). This network will be the framework for other regional and scientific programmes such as the Tropical Ocean and Global Atmosphere (TOGA) programme and the World Ocean Circulation Experiment (WOCE). As programmes are developed and implemented, certain GLOSS stations will be upgraded to near-real-time transmission of data to be used by national and regional centres for analysis and prediction of oceanographic and atmospheric phenomena.

The major requirements for GLOSS stations are:
(i) sampling of sea level, averaged over a few minutes (to avoid aliasing), at intervals of 15 minutes, is recommended; but in all circumstances the minimum sampling interval should be one hour;
(ii) gauge timing should be compatible with level accuracy, which means an accuracy of 1 minute;
(iii) tide gauges which must measure sea level relative to a fixed and permanent local gauge Bench Mark. This should be connected to a number of Auxiliary Marks to guard against its movement or destruction. Connections between the Bench Mark and the gauge zero should be made to an accuracy of a few millimetres every six months;
(iv) the readings of individual sea levels should be made with a target accuracy of 10 mm;
(v) gauges should be equipped for averaging and rapid sampling; they should also be equipped for automatic data transmission to data centres in addition to the sea level recording on site;
(vi) sea level measurements should be accompanied by observations of atmospheric pressure, and also winds and other environmental parameters, which are of direct relevance to the sea level data analysis.

As data products are made available and analysed, the correlation of mean sea level to climatic phenomena will become clearer, as will the application for forecasting. This along with advancement of technology should result in the eventual upgrade of all stations to near-real-time delivery of data.

2. OPERATION

Member States of IOC agreeing to participate in GLOSS are required to:
(i) have all operating GLOSS stations reporting monthly mean sea level data values to the Permanent Service for Mean Sea Level (PSMSL) within one year of acquisition;
(ii) make hourly values of sea level data available for international exchange;
(iii) upgrade existing stations which are below GLOSS standards; (iv) install new stations in consultation with the IOC Group of Experts on GLOSS;
(v) give the highest priority to the implementation of those stations in GLOSS which are required for international programmes, for example TOGA and WOCE;
(vi) provide assistance to other member states on a bilateral and multilateral basis. Assistance may also be provided by Member States through the IOC Voluntary Co-operation Programme thus enabling other Member States to participate in GLOSS.

The GLOSS Implementation Plan indicates the stations that will constitute the GLOSS network. Member States responsible for these stations have been requested, and in majority of the cases have already made a commitment, to establish fully qualified GLOSS stations. They have also expressed their commitment towards eventually establishing fully qualified GLOSS stations, where they do not already exist, and to ensure that their operation and functioning are in accordance with the provisions of the Plan.

The IOC through the Group of Experts on GLOSS and the Secretariat ensures regular review of the GLOSS development, implementation and co-ordination with other international programmes.

This GLOSS Implementation Plan was approved by the Intergovernmental Oceanographic Commission at the Fifteenth Session of its Assembly by Resolution XV-8.

Résumé

Le Système mondial d'observation du niveau de la mer repose sur un réseau international de stations marégraphiques dont la COI assure la coordination. Il fournit des données normalisées de qualité à partir desquelles sont élaborés des produits utiles pour les programmes de recherche internationaux et régionaux, de même que pour les applications pratiques à l'échelle nationale.

Il est indispensable de procéder dans le monde entier à des mesures du niveau de la mer pour déceler de possibles élévations spectaculaires dues à un réchauffement de la planète. Le long du littoral, ces mesures sont cruciales pour les levés hydrographiques et peuvent également donner des indications sur la circulation océanique et la variabilité du climat.

Les activités et composantes du GLOSS sont les suivantes :
(i) le réseau international de stations marégraphiques permanentes qui permet de procéder à des observations normalisées du niveau de la mer ; il constitue une ossature centrale à laquelle peuvent se rattacher les réseaux nationaux et régionaux ;
(ii) la collecte de données en vue de leur échange international en utilisant des formats et des procédures unifiés, y compris éventuellement la collecte de données en temps quasi réel ;
(iii) l'analyse des données et l'élaboration des produits nécessaires aux applications scientifiques et/ou pratiques ;
(iv) une assistance et une formation pour la création et l'exploitation de stations marégraphiques dans le cadre du GLOSS et pour l'amélioration des réseaux nationaux ;
(v) des repères marégraphiques sélectionnés pour le GLOSS, qui seront reliés d'une manière précise à un système mondial de référence géodésique (par exemple, le cadre de référence terrestre conventionel établi par le International Earth Rotation Service (Service international de la rotation de la terre – IERS).

1. OBJECTIF DU GLOSS

On compte mettre en place d'ici à 1990 un réseau mondial opérationel de stations permanentes d'observation du niveau de la mer transmettant des moyennes mensuelles au Service permanent du niveau moyen des mers (PSMSL). Ce réseau fournira un cadre à d'autres programmes régionaux et scientifiques, tels que celui sur les océans tropicaux et l'atmosphère globale (TOGA) et l'Expérience sur la circulation océanique mondiale (WOCE). Au fur et à mesure de l'élaboration et de la mise en œuvre des programmes, certaines stations du GLOSS seront modernisées de manière à assurer la transmission en temps quasi réel des données que les centres nationaux et régionaux utiliseront pour analyser et prédire les phénomènes océanographiques et atmosphériques.

Les stations GLOSS doivent répondre aux principaux impératifs suivants :
(i) un échantillonnage du niveau de la mer moyenné sur quelques minutes (afin d'éviter des distorsions) de repliement est recommandé à des intervalles de 15 minutes étant entendu que cet intervalle ne devrait en aucun cas excéder une heure ;
(ii) le minutage des jauges doit être compatible avec le niveau de précision, ce qui implique une précision d'une minute ;
(iii) les marégraphes doivent fournir des mesures du niveau de la mer rapportées à un repère local permanent et fixe qui est relié à un certain nombre de repères auxiliaires de manière à se prémunir contre les risques de déplacement ou de destruction. La correspondance entre le repère et le zéro du marégraphe doit être vérifiée tous les six mois, la précision devant être de quelques millimètres ;
(iv) les relevés des différents niveaux de la mer doivent tendre vers une précision de 10 mm ;
(v) les marégraphes doivent être dotés de dispositifs permettant d'assurer un moyennage et un échantillonnage rapide ainsi que la transmission automatique des données à des centres en plus de l'enregistrement du niveau de la mer *in situ* ;
(vi) les mesures du niveau de la mer doivent s'accompagner d'observations de la pression atmosphérique, des vents et d'autres paramètres environnementaux ayant un intérêt pour l'analyse des données relatives au niveau de la mer.

A mesure que les produits seront obtenus et analysés, la corrélation entre le niveau moyen de la mer et les phénomènes climatiques ainsi que ses applications à la prévision deviendront plus claires. Cette évolution, jointe aux progrès de la technologie, devrait déboucher à terme sur la modernisation de toutes les stations en vue d'atteindre l'objectif d'une fourniture des données en temps quasi réel.

2. FONCTIONNEMENT

Les États membres de la COI acceptant de participer au GLOSS sont invités :
(i) à faire en sorte que toutes leurs stations GLOSS en service fournissent des valeurs moyennes mensuelles du niveau de la mer au Service permanent du niveau moyen des mers (PSMSL) dans l'année qui suit leur acquisition ;

(ii) à fournir, en vue d'échanges internationaux, des valeurs horaires du niveau de la mer;
(iii) à moderniser les stations existantes qui ne sont pas conformes aux normes du GLOSS;
(iv) à mettre en place de nouvelles stations en consultation avec le Groupe d'experts de la COI sur le GLOSS;
(v) à accorder la plus haute priorité à la mise en exploitation, dans le cadre du GLOSS, des stations indispensables à l'exécution de programmes internationaux tels que TOGA et WOCE;
(vi) à fournir à d'autres Etats membres une assistance bilatérale et multilatérale et/ou par le truchement du Programme d'assistance volontaire de la COI afin de leur permettre de participer au GLOSS.

Le Plan de mise en œuvre du GLOSS donne la liste des stations qui constitueront le réseau. Les États membres, qui ont la responsabilité de ces stations ont été invités – et pour la plupart se sont déjà engagés – à mettre en place à terme des stations du GLOSS remplissant toutes les conditions voulues et à en assurer l'exploitation et le fonctionnement conformément aux dispositions du Plan.

Par l'intermédiaire du Groupe d'experts sur le GLOSS et de son Secrétariat, la COI suit régulièrement l'évolution et la mise en œuvre du GLOSS et sa coordination avec d'autres programmes internationaux.

Le Plan de mise en œuvre du GLOSS a été approuvé par la Commission océanographique intergouvernementale lors de la quinzième session de son Assemblée par la Résolution XV-8.

Resumen

El Sistema Mundial de Observación del Nivel del Mar (GLOSS) consiste en una red internacional de estaciones de medición del nivel del mar coordinada por la Comisión Oceanográfica Internacional (COI). Proporciona datos normalizados de elevada calidad a partir de los cuales se elaboran valiosos productos de datos sobre el nivel del mar que se utilizan en programas de investigación internacionales y regionales, así como para aplicaciones prácticas en los distintos países.

Es preciso realizar mediciones mundiales del nivel del mar para poder detectar cualquier posible aumento excepcional ocasionado por el recalentamiento de la tierra. Las mediciones del nivel del mar litoral son imprescindibles para llevar a cabo estudios hidrográficos y pueden proporcionar asimismo indicaciones sobre las pautas de circulación del océano y la variabilidad del clima.

El GLOSS se compone de los siguients elementos:
(i) la red mundial de estaciones permanentes de medición del nivel del mar, dedicadas a realizar observaciones normalizadas del nivel del mar; esta red constituye el marco fundamental con el que pueden conectar las redes regionales y nacionales;
(ii) el acopio de datos que se intercambian internacionalmente, en formatos y mediante procedimientos unificados, que puede comprender el acopio de datos en tiempo real aproximado;
(iii) el análisis de los datos y la elaboración de los productos necesarios para las aplicaciones científicas y/o prácticas;
(iv) la asistencia y formación para la creación y mantenimiento de estaciones de medición del nivel del mar que formen parte del GLOSS, así como para mejorar las redes nacionales;
(v) se conectará con precisión un conjunto escogido de cotas de referencia para mareógrafos del GLOSS a un sistema mundial de referencia geodésica (esto es, el marco de referencia terrestre convencional fijado por el Servicio Internacional de Estudio de la Rotación de la Tierra. (IERS)).

1. OBJETIVO DEL GLOSS

Está previsto que antes de 1990 funcione una red mundial de estaciones permanentes de medición del nivel del mar que comuniquen mensualmente los promedios de dicho nivel al Servicio Permanente del Nivel Medio del Mar (PSMSL). Esta red servirá de estructura a otros programas regionales y científicos como el relativo a los Océanos Tropicales y la Atmósfera Mundial (TOGA) y el Experimento Mundial sobre la Circulación del Océano (WOCE). Conforme se desarrollen y ejecuten los programas, se modernizarán algunas estaciones del GLOSS a fin de que los centros nacionales y regionales utilicen la transmisión de datos en tiempo real aproximado para efectuar análisis y predicciones de los fenómenos oceanográficos y atmosféricos.

Las estaciones del GLOSS deberán cumplir las siguientes condiciones mínimas:
(i) se recomienda promediar el muestreo del nivel del mar durante varios minutos (para evitar la aparición de alias, esto es, señales espúreas), a intervalos de 15 minutos, pero, en todo caso, el intervalo mínimo entre cada toma de muestras deberá ser de una hora;
(ii) la sincronización de los mareógrafos deberá ser compatible con la exactitutd de la medición de los niveles, esto es, un margen de un minuto;
(iii) los mareógrafos deben medir la relación del nivel del mar con una cota de referencia local fija y permanente, conectada a diversas cotas auxiliares para evitar su desplazamiento o destrucción. Las conexiones entre la cota de referencia y el nivel cero del mareógrafo deberán ajustarse cada seis meses, con un margen de precisión de pocos milímetros;
(iv) las lecturas de los distintos niveles del mar deberán efectuarse con un margen máximo de diez milímetros de diferencia con el objetivo;
(v) los mareógrafos deberán poder efectuar los promedios y muestreos con rapidez, asimismo, deberán poder transmitir automáticamente los datos a los centros de datos, además de registrar el nivel del lugar en que están situados;
(vi) las mediciones del nivel del mar deberán conjugarse con observaciones de la presión atmosférica, así como de los vientos y demás parámetros ambientales, que son de pertinencia directa para el análisis de los datos relativos al nivel del mar.

Conforme se disponga de los datos y éstos sean analizados, irá resultando más clara la correlación entre el nivel medio del mar y los fenómenos climáticos y su aplicación para formular previsiones. Esta circunstancia, junto con los progresos de la tecnología, hará que a la larga todas las estaciones se modernicen para poder transmitir datos en tiempo real aproximado.

2. FUNCIONAMIENTO

Los Estados Miembros de la COI que convengan en participar en el GLOSS deberán:
(i) conseguir que todas las estaciones del GLOSS en funcionamiento transmitan los valores de los datos men-

suales sobre el nivel medio del mar al Servicio Permanente del Nivel Medio del Mar (PSMSL), a más tardar al año de su obtención;
(ii) poner los datos sobre los valores horarios del nivel del mar a disposición de los interesados en el intercambio internacional;
(iii) modernizar las estaciones que no cumplan los requisitos fijados para participar en el GLOSS;
(iv) instalar nuevas estaciones, en consulta con el Grupo de Expertos sobre el GLOSS de la COI;
(v) asignar máxima prioridad a las estaciones de ejecución del GLOSS necesarias para llevar a cabo los programas internacionales, como TOGA y WOCE;
(vi) prestar ayuda a los restantes Estados Miembros, de carácter bilateral y multilateral, así como por conducto del Programa de Cooperación Voluntaria de la COI, para que puedan participar en el GLOSS.

En el Plan de Ejecución del GLOSS se indican las estaciones que formarán la red del GLOSS. Se ha pedido a los Estados Miembros encargados de esas estaciones —que en su mayoría han demostrado buena disposición— que establezcan estaciones del GLOSS plenamente equipadas o que se comprometan a establecer, en su momento, estaciones de tales características, y que velen por su funcionamiento conforme a lo dispuesto en el Plan.

Por conducto del Grupo de Expertos sobre el GLOSS y la Secretaría, la COI supervisa periódicament la evolución y ejecución del GLOSS, así como su coordinación con otros programas internacionales.

Este Plan de Ejecución del GLOSS ha sido aprobado por la Comisión Oceanográfica Intergubernamental durante la 15a reunión de su Asamblea por Resolución XV-8.

Краткий план реализации

Глобальная система наблюдений за уровнем моря основана на международной сети станций по измерению уровня моря, координируемых МОК. Она предоставляет высококачественные стандартизированные данные, на основе которых подготавливаются ценные данные об уровне моря для международных и региональных научно-исследовательских программ, а также для применения на национальном уровне.

Глобальные измерения уровня моря необходимы для наблюдения за возможными резкими изменениями в результате глобального потепления. Прибрежные измерения уровня моря играют решающую роль для гидрографических обзоров и могут использоваться также для характеристики структуры циркуляции океана и изменчивости климата.

Элементами ГЛОСС являются:
(i) глобальная сеть постоянных станций наблюдения за уровнем моря для получения стандартизированных наблюдений за уровнем моря; она составляет первоочередную основу, к которой могут быть подключены региональные и национальные сети наблюдения за уровнем моря;
(ii) сбор данных для международного обмена с унифицированными форматами и процедурами, которые могут включать сбор данных в масштабе времени, приближающемся к реальному;
(iii) анализ данных и подготовка продукции, необходимой для использования в научных или практических целях;
(iv) оказание помощи и подготовка кадров для создания и обслуживания станций наблюдения за уровнем моря в качестве части ГЛОСС и совершенствование национальных сетей наблюдения за уровнем моря;
(v) отдельный набор отметок уровня мареографов ГЛОСС необходимо четко согласовать с глобальной геодезической справочной системой (например, обычной наземной справочной основой, определенной Международной службой наблюдения за вращением Земли (ИЕРС).

1. ЦЕЛЬ ГЛОСС

План заключается в том, чтобы к 1990 г. создать оперативную глобальную сеть постоянных станций наблюдения за уровнем моря, сообщающих среднемесячные данные в Постоянную службу среднего уровня моря (ПСМСЛ). Эта сеть будет обеспечивать структуру для других региональных и научных программ, таких, как изучение тропических зон океана и глобальной атмосферы (ТОГА) и эксперимент по изучению циркуляции Мирового океана (ВОСЕ). По мере разработки и осуществления программ будет повышаться уровень некоторых станций ГЛОСС с тем, чтобы обеспечить передачу данных в масштабах времени, близких к реальному, с целью использования национальными и региональными центрами для анализа и прогнозирования океанографических и атмосферных явлений.

Основными требованиями к станциям ГЛОСС являются:
(i) рекомендуется выборка показателей уровня моря, усредненных в течение нескольких минут (с целью избежания альтернативной метки) через интервалы в 15 минут, однако во всех случаях минимальный интервал выборки должен составлять один час;
(ii) регулирование времени мареографа должно совпадать с точностью уровня, что означает точность в одну минуту;
(iii) мареографы должны производить замер соотношения уровня моря с фиксированным и постоянным репером, который связан с целым рядом вспомогательных реперов, с тем чтобы предохранить его от перемещения или уничтожения. Соответствие между реперами и нулевым мареографом должно устанавливаться каждые шесть месяцев с точностью до нескольких миллиметров;
(iv) показания отдельных уровней моря должны сниматься с целевой точностью в 10 миллиметров;
(v) мареографы должны быть оборудованы для усреднения и быстрой съемки показателей; они должны быть оборудованы также для автоматической передачи данных в центры данных в дополнение к записи уровня на месте;
(vi) изменения уровня моря должны сопровождаться наблюдениями за атмосферным давлением, а также ветрами и другими экологическими параметрами, которые непосредственно относятся к анализу данных уровня моря.

После получения анализа данных становится более четкой связь уровня открытого моря с климатическими явлениями и появляется возможность их применения для прогнозирования. Все это наряду с развитием технологии должно привести к возможному повышению уровня всех станций, которые будут предоставлять данные в масштабе времени, близком к реальному.

2. ДЕЯТЕЛЬНОСТЬ

Ряд государств - членов МОК согласен принимать участие в ГЛОСС. Требуется:

(i) чтобы все действующие станции ГЛОСС на ежемесячной основе сообщали показатели данных о среднем уровне моря Постоянной службе среднего уровня моря (ПСМСЛ) в течение одного года действия;
(ii) на ежечасной основе предоставлять показатели данных об уровне моря, имеющихся для международного обмена;
(iii) повысить уровень существующих станций, параметры которых ниже стандартов ГЛОСС;
(iv) в консультации с группой экспертов МОК по ГЛОСС создать новые станции;
(v) уделить самый высокий приоритет тем станциям в системе ГЛОСС, которые необходимы для международных программ, таким, как ТОГА и ВОСЕ;
(vi) обеспечить помощь другим государствам-членам на двусторонней или многосторонней основе и/или через программу МОК добровольного сотрудничества, чтобы позволить им принять участие в ГЛОСС.

План выполнения ГЛОСС содержит указания относительно станций, которые будут составлять сеть ГЛОСС. Государствам-членам, ответственным за эти станции, была обращена просьба взять на себя обязательства, и в большинстве случаев они уже сделали это, а именно создать полностью укомплектованные станции ГЛОСС, обеспечить их деятельность и функционирование в соответствии с положениями Плана.

МОК через Группу экспертов по ГЛОСС и Секретариат обеспечивают регулярный обзор хода развития ГЛОСС, выполнения и координации с другими международными программами.

Этот План выполнения ГЛОСС был одобрен Межправительственной Океанографической Комиссией на пятнадцатой сессии ее Ассамблеи резолюцией XV-8.

1. Introduction

The Global Sea Level Observing System is based on an international network of sea level measuring stations co-ordinated by the IOC. It provides high quality standardized data from which valuable sea level products are produced for international and regional research programmes as well as for practical applications on a national level.

The System is known as GLOSS because it measures the Global Level of the Sea Surface, a smooth level after averaging out waves, tides and short-period meteorological events.

The Global Sea Level Observing System has to serve many purposes. It has to cover the entire spectrum in time and space from short-lived tsunami to the changes related to tectonic processes. Characteristics of the network must include permanence, high vertical precision and stability, and the flexibility to develop as the requirements evolve.

A Global network of some 300 sea level gauges has been proposed which is capable of providing valuable data for both practical and scientific applications. Subsequent scientific developments will allow a more appropriate gauge distribution. Therefore continued review is incorporated in the programme. Many of these gauges are already operating, but many need upgrading in terms of levelling, accuracy, documentation, telemetry and time taken before the data become available. About 100 new sites are proposed, many on ocean islands which are best placed for ocean monitoring. In a few cases, especially in polar regions, implementation will pose formidable problems for present technology, but even here there are sites where suitable measurements can be made.

The initial proposal for a Global Sea Level Network was prepared by Prof. K. Wyrtki (University of Hawaii, USA) and Dr. D. Pugh (Natural Environment Research Council, UK)[2] (list of References in Annex I) at the request of the Secretary of IOC and it was considered by the IOC Programme Group on Ocean Processes and Climate at its First Session (Paris, 6-8 March 1985) and by the Thirteenth Session of the IOC Assembly (Paris, 12-28 March 1985).

Upon the Recommendation of the First Session of the IOC Programme Group on Ocean Processes and Climate, the IOC Assembly at its Thirteenth Session by Resolution XIII-7[1] decided to adopt it as a basis for an extension of the existing sea level network, under the auspices of IOC, and urged Member States to participate in the Implementation of the Global Sea Level Observing System.

The first draft GLOSS Implementation Plan was prepared in 1986 with the assistance of the IOC Task Team of Experts on GLOSS. The draft GLOSS Implementation Plan (Doc. IOC/INF-663)[23] was approved in principle by the IOC Executive Council at its Nineteenth Session by Resolution ECXIX.6. This was circulated to IOC Member States with the request to confirm their participation in GLOSS and to provide information on their sea level stations to be included in the GLOSS network. On the basis of the information received from Member States, the revised GLOSS Implementation Plan was prepared as document IOC/INF-663 rev.[32] and circulated in November 1986 for further updating. The development and application of GLOSS and its regional components was further considered at the Second Session of the IOC Programme Group on Ocean Processes and Climate (March 1987) and the Fourteenth Session of the IOC Assembly (March 1987), as well as the sessions of the IOC regional bodies (IOCARIBE, IOCEA, IOCINCWIO, IOCSOC, WESTPAC), WMO-IOC Intergovernmental TOGA Board (November 1987) and meetings of the SSG for WOCE.[26, 11, 12, 13, 14, 25]

The Second Session of the IOC Task Team of Experts on GLOSS, which met in October 1987 (Honolulu, USA), reviewed and updated the GLOSS Implementation Plan.[32, 33]

The present GLOSS Implementation Plan has been prepared based on the advice of the Task Team on GLOSS and the IOC Group of Experts on GLOSS and information provided by Member States up to June 1988. It supersedes all previous versions of the Draft GLOSS Implementation Plan issued by IOC in the form of information documents.

The following experts have assisted in preparation of the GLOSS Implementation Plan since 1985:

D.T. Pugh (UK), K. Wyrtki (USA), G. Homes (Australia), M.A. de Carvalho Oliveira (Brazil), C. Le Provost (France), S.R. Shetye (India), A. Snella (USA), P.A. Pirazzoli (IGCP-200), A. Bolduc (Canada), W.E. Carter (USA), Y. Dequan (People's Republic of China), C.S. Joshi (India), G.W. Lennon (Australia), G.A. Maul (USA), S. Ragoonaden (Mauritius), W. Scherer (USA), J.-M. Verstraete (France), A. Tolkachev (IOC), L.J. Rickards (UK).

2. Gloss Objective and Elements

2.1 The objective is to establish by 1990 an operational global network of permanent sea level stations reporting monthly mean averages to the Permanent Service for Mean Sea Level (PSMSL). This network will be the framework for the sea level components of regional and scientific programmes such as the Tropical Ocean and Global Atmosphere (TOGA) programme and the World Ocean Circulation Experiment (WOCE). As programmes are developed and implemented, certain GLOSS stations will be upgraded to near-real-time transmission of data to be used by national and regional centres for analysis and prediction of oceanographic and atmospheric phenomena.

As data products are made available and analyzed, the correlation of mean sea level to climatic phenomena will become clearer. This, along with advancement of technology, should result in the eventual upgrade of all stations to near-real-time delivery of data.

2.2 The elements of GLOSS are:

(i) the global network of permanent sea level stations for obtaining standardized sea level observations; this forms the primary framework to which regional and national sea level networks may be related;

(ii) data collection for international exchange with unified procedures which may include near-real-time data collection;

(iii) data analysis and product preparation required for scientific and/or practical applications;

(iv) assistance and training for establishing and maintaining sea level stations as part of GLOSS and improving national sea level networks;

(v) a selected set of GLOSS tide gauge bench marks shall be accurately connected to a global geodetic reference system (i.e. the conventional terrestrial reference frame, established by the International Earth Rotation Service (IERS)).

3. Application for Scientific and Practical Purposes

The data provided by the GLOSS network are needed as basic information to answer a wide range of scientific questions as well as for many practical applications.

In the absence of currents, density differences and atmospheric influences, the sea level would coincide with the geodetic surface known as the geoid (Figure 1). This geoid is not a simple geometric surface because of local and large scale anomalous mass distribution within the earth. After eliminating the waves and tides, the remaining mean sea level surface deviates from the geoid by amounts which seldom exceed 1 metre. The differences are related to ocean circulation, density fields, and to the influence of atmospheric pressure and winds.

The significance of the sea level topography for studies of the poleward heat transport and the role of the ocean in climate variability is apparent. Sea-surface topography and circulation are linked by geostrophy, which represents a balance between the Coriolis force and the pressure gradient perpendicular to the flow. At the sea-surface the pressure gradient is given by the slope of the sea level, and procedures have been developed to monitor the variations of geostrophic flow from sea level differences, particularly in the one-dimensional case of narrow passages or straits or for simple ocean currents. Interpretation of sea level variations in terms of regional ocean dynamics are also now becoming routine (for example, Sea level variations: monitoring the breath of the Pacific by K. Wyrtki).[117] Traditionally, oceanographers determine the topography of the sea-surface from the observed distribution of density, but only in relation to a more or less arbitrarily selected reference surface, the so-called level of no motion. Techniques for synoptically determining the internal ocean density distribution in sufficient detail to resolve monthly or even interannual variations are unlikely ever to become cost effective. However, a combination of mean-density fields coupled with measured fluctuations of sea-surface topography and other remote-sensing techniques, such as acoustic tomography, may provide a workable monitoring system for ocean circulation. Examples of changes in the intensity of this circulation, for ocean gyres and for major boundary currents, with time scales of several years, have been well documented. The important annual cycle, which involves major variations of heat transport and heat content also belong in this spectral range. In addition to the circulation and heat-transfer monitoring potential, sea level is also indirectly related to the ocean heat storage through the expansion which results from changes of mean temperature. These may be local adjustments to changes in the thermocline levels or net warming of the global oceans over many years.

Sea level changes over the hundred-year time scale are related to crustal movements, to changes in the geoid, to changes in ice and water volumes, as well as to the mean warming and expansion of the ocean. To measure these changes, as well as the long-term variations of ocean circulation, a high degree of stability of the reference datum is an important requirement. The separation of the several contributions to long-term sea level changes will require information from other geo-scientific disciplines and technologies, for example the measurement of recent vertical crustal movements and their relationship to larger geological trends.

Since sea level records are continuous in time, and several series extending over many decades already exist, they are most suitable for general ocean monitoring. If measurement sites are properly selected, the measured levels can be more representative of the regional oceanography than other more variable parameters, such as coastal temperature and salinity. Also, the technology and local resources required for a long-term monitoring programme are very modest when compared with the cost of other monitoring systems, such as specialized research ships. Such measurements represent a minimum but extremely valuable oceanographic commitment from countries which do not yet have the resources available for major monitoring and research programmes.

Sea levels also have many practical applications for operational and engineering design activities. The analysis of tides, one of the more traditional aspects of sea level observations as a basis for navigation, will continue as an important practical consideration in addition to the intrinsic scientific interest. Meteorologically induced storm surges are also part of the sea level record, and a long-term monitoring programme will provide essential statistics for the calculation of return periods for extreme events, a necessary first stage in the design of local coastal defence systems. On an operational basis, sea levels are needed as input to flood-warning procedures. On an ocean-wide scale, tsunami traverse entire ocean basins, and a global observation system is necessary for their detection and the issue of timely warnings. Many new techniques for the estimation of flooding probabilities have been developed in recent years, but the basic requirement is for several years of good quality sea level data.

In addition to these identified and immediate practical advantages which are afforded by a global network of sea level stations, the longer-term benefits which result from new scientific insights, discoveries of ocean/atmosphere interaction and their consequences for forecasting climatic changes and changes in coastal environment must be

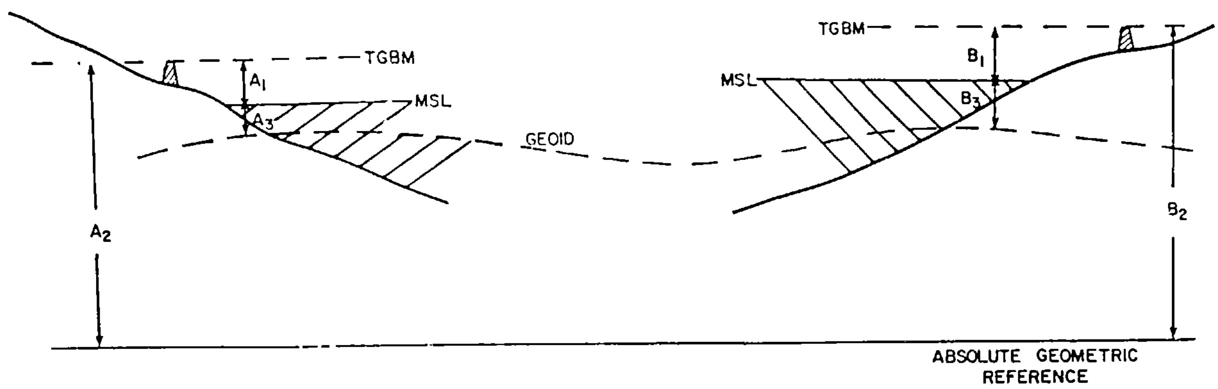

Figure 1. Mean sea level (MSL) at a particular site is related to the Tide Gauge Bench Mark. A variation in this distance (A1) may be due to vertical changes of land level or sea level. Measurement of the displacement of the TGBM from an absolute reference (A2) will allow sea level changes to be identified. When the geoid is accurately known, the differences in absolute sea levels (A3-B3) can be related to ocean currents.

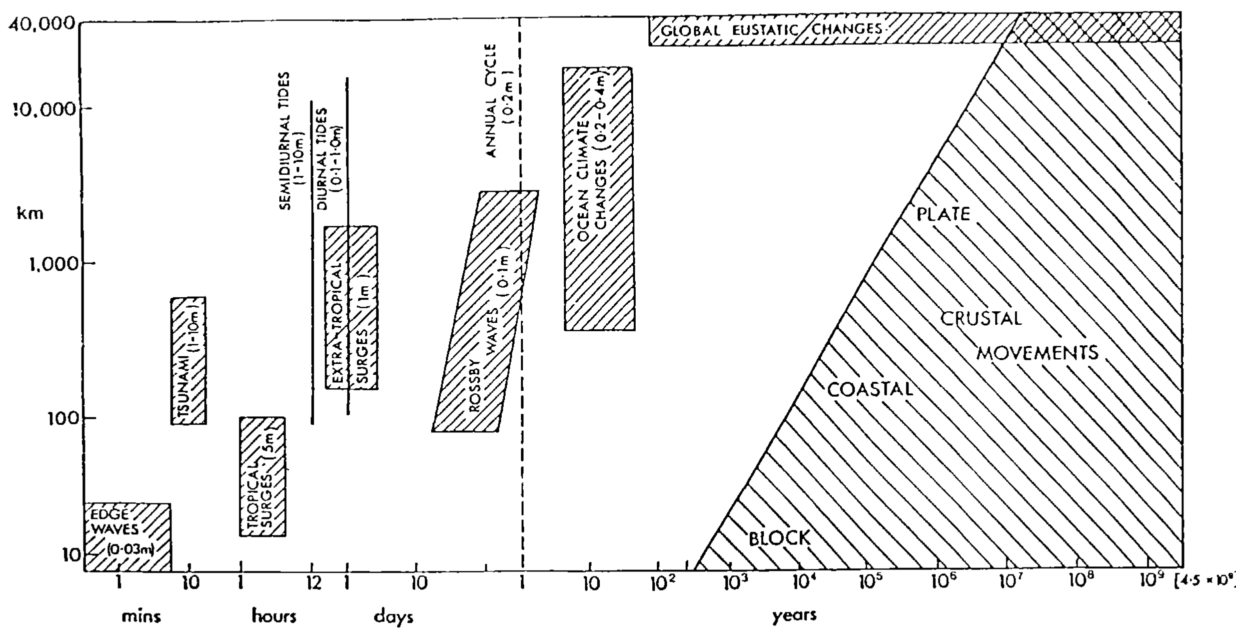

Figure 2. Space-time relationship of sea-level variations (by D.T. Pugh).

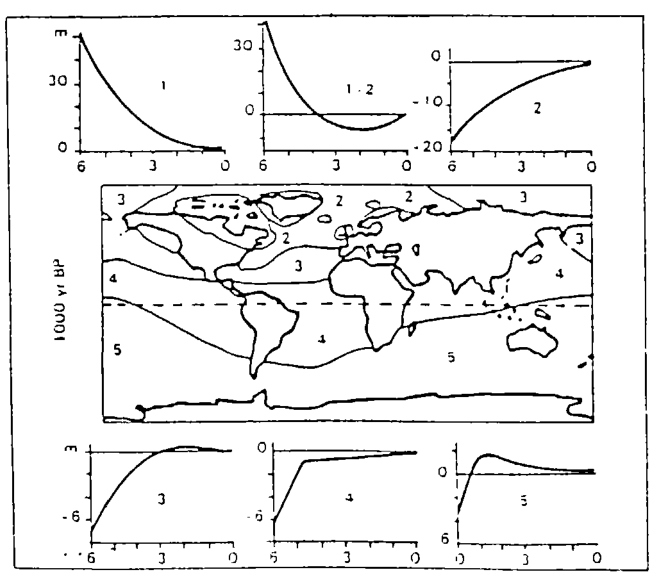

Figure 3.

Centre: Distribution of the five zones of the ocean surface resulting from the last deglaciation, as distinguished by sea level variation curves of different types.

Above and below: Typical form of these curves over the past few thousand years, according to the mathematical model by Clark, Farrell and Peltier.[88]

emphasized. In the foreseeable future, satellites with altimeters will provide a two-dimensional picture of sea-surface topography, for which the sea level network will provide the ground truth and calibration. However, only ground-based gauges are capable of determining very slow and small changes of the mean sea level.

3.1 LONG-TERM CLIMATE STUDIES AND STUDY OF RECENT VERTICAL CRUSTAL MOVEMENTS

Sea level variations result from the integrated effect of a variety of physical processes spanning a broad range of spatial and temporal scales (Figure 2). The longer-term changes of global mean level are attributed to global scale processes, which are related to:
(i) changes in ocean volume through modifications to the water mass and balance over the surface of the Earth, arising from large-scale ice formation/melting and alterations in underground water storage; and
(ii) time-varying deformation of the Earth's crust via changes in glacial loading, plate tectonics, volcanism and sedimentation.

The Second World Climate Conference held in Geneva, 29 October-7 November 1990, made the following conclusion: "Emissions resulting from human activities are substantially increasing atmospheric concentration of the greenhouse gases. These increases will enhance the natural greenhouse effect, resulting on average in an additional warming of the Earth's surface. The Conference agreed that this and other scientific conclusions set out by the UNEP-WMO Intergovernmental Panel on Climate Change reflect the international consensus of scientific understanding of climate change. Without actions to reduce emissions, global warming is predicted to reach 2° to 5° C over the next century, a rate of change unprecedented in the past 10,000 years. The warming is expected to be accompanied by a sea level rise of 65 cm±35 cm by the end of the next century. There remain uncertainties in predictions, particularly in regard to the timing, magnitude and regional patterns of climate change." The Conference emphasized the need to create a Global Climate Observing System, to be based on the WWW and a global ocean observing system (GOOS) to meet the needs for climate system monitoring, climate change detection and response monitoring and other objectives.

Within the International Geological Correlation Programme (IGCP), co-sponsored by IUGS and Unesco, a special project was established to identify and quantify processes of sea level change to provide a basis for predicting near future changes for application to a variety of coastal problems, with particular reference to densely populated low-lying coastal areas. This project is known as Late Quaternary Sea Level Changes: Measurement, Correlation and Future Applications (IGCP-200).[88]

The IGCP-200 promoted the exchange of information on research and scientific publications related to the study of sea level changes. A "Directory of Sea Level Research was issued in 1984 and a Supplement was issued in 1986.

A study undertaken by a working party of IAPSO on Changes in relative mean sea level (under the direction of the IAPSO Advisory Committee on Tides and Mean Sea Level,[68] noted that in any interpretation of secular changes in RSL (mean sea level relative to land), although the prime interest is in very low frequency phenomena, it is necessary to study the local responses of sea level at much higher frequencies.

The Group pointed out that specific tide-gauge locations for monitoring secular changes in global sea level must be decided by national authorities with the ability to maintain them, but emphasized the following:
i) Allowance should be made for tectonic changes through both direct spacegeodetic measurements (e.g. VLBI, GPS, DORIS) and geodynamic modelling.
(ii) The oceanographic influences on the RSL at each station should be examined through theoretical and empirical modelling. There are clearly some advantages to co-locating these tide-gauge positions with those required for the WOCE-TOGA programmes.
(iii) The importance of historical sea level data should be respected. Other things being equal, VLBI measurements should be made at tide-gauge locations which can provide the longest historical records. Lower priority may perhaps be given to stations in areas of substantial glacial rebound.
(iv) It seems particularly desirable to establish new (or upgraded) sea-level stations at all proposed VLBI/GPS nodes, and similarly to establish some new VLBI/GPS nodes at sites of long existing tidal stations.

This work is being continued. Also under the auspices of IAPSO, a new ad hoc Committee is investigating the geophysical, including oceanographic, benefits of fixing tide gauge benchmarks in an absolute global reference system, the technical feasibility and possible strategy for such developments.

The General Assembly of the International Union of Geodesy and Geophysics (IUGG) at its XIXth Session (1987) noting that variations of sea level are of great importance when monitoring ocean circulation and flow through straits as well as climatic change over a timescale of tens of years, and that such monitored variations are useful when calibrating satellite altimetry, recommended that all national authorities make maximum effort to install new tide gauges and to maintain, renew and recalibrate existing ones to modern scientific precision. This should be done at as many oceanic sites as possible, especially at those spanning straits and major jet flows, and it also recommended that such sites should regularly measure atmospheric pressure and precise absolute geodetic position, with telemetry of all the data to collecting centres, such as Permanent Service for Mean Sea Level (PSMSL).

3.2 REQUIREMENTS OF THE WCRP: TOGA AND WOCE

3.2.1 World Climate Research Programme (WCRP)

The World Climate Research Programme (WCRP) is a joint undertaking of the International Council of Scientific Unions (ICSU) and the World Meteorological Organization (WMO). The scientific guidance for the conduct of the WCRP is provided by a Joint ICSU-WMO Scientific Committee (JSC). Oceanographic components of the WCRP, are developed by the Joint SCOR-IOC Committee on Climate Changes and the Ocean (CCCO). Intergovernmental co-ordination of oceanographic aspects of the WCRP implementation, through TOGA and WOCE in particular, is organized by WMO and IOC.

The Scientific Plan for the World Climate Research Programme[3] emphasizes that an especially large observational effort is required for the oceans because the descriptions of large scale dynamic events in the oceanic circulations are not yet based on synoptic observations with appropriate time and space resolution.

In the First Implementation Plan for the World Climate Research Programme (1985)[4] particular emphasis is given to a Sea Level Observing System. The following WCRP requirements for sea level data are outlined in the Implementation Plan:

(i) establishment of about 100 additional conventional tide-gauges as proposed in the IOC Plan for the Global Sea Level Observing System.

The TOGA programme priorities are for stations located in the near-equatorial region. The WOCE priorities are for a relatively thin global network of about 60 stations distributed over the world ocean, with emphasis on major straits and passages, and also areas where the tidal harmonics are not yet precisely determined.

(ii) Arrangements for high-precision levelling of tide-gauge benchmarks to a universal reference geodetic surface or datum, for validation of satellite altimetric data. The levelling should be repeated at least twice during the WOCE field observation period, at selected sea level stations.

(iii) Exchange of sea level data in accordance with internationally agreed procedures (IGOSS) and/or the provision of automatic transmission equipment for relay via satellite data collection systems.

(iv) Support to the operation of the TOGA Sea Level Data Centre for the duration of the TOGA Project (1985-1995).

3.2.2 Tropical Oceans and Global Atmosphere (TOGA) Programme

The Tropical Oceans and Global Atmosphere (TOGA) Programme is one of the key projects within the framework of the World Climate Research Programme. The TOGA programme began in January 1985 and extends over a ten-year period.

The scientific strategy of the TOGA programme has been planned by the TOGA Scientific Steering Group (SSG). This is established as a joint body of the JSC for WCRP and the SCOR-IOC CCCO. The Scientific Plan for the TOGA Programme[5] defines the following objectives:

(i) to gain a description of the tropical oceans and the global atmosphere as a time dependent system, in order to determine the extent to which this system is predictable on time scales of months to years, and to understand the mechanisms and processes underlying its predictability;

(ii) to study the feasibility of modelling the coupled ocean-atmosphere system for the purpose of predicting its variations on time scales of months to years;

(iii) to provide the scientific background for designing an observing and data transmission system for operational prediction if this capability is demonstrated by coupled ocean-atmosphere models.

The observational components of the TOGA programme to achieve these objectives include maintenance and expansion of the existing island-based and coastal tide gauge network in tropical zones of the World Ocean within the framework of the Global Sea Level Observing System (GLOSS) of the IOC and the establishment of a Tropical Sea Level Centre to produce maps of monthly mean sea level anomalies. Details regarding the sea level component of the TOGA programme are included in the TOGA Implementation Plan.[6] In fact, the designation of stations for GLOSS was undertaken with the TOGA requirements in mind and in co-operation with the three CCCO Tropical Ocean Climate Studies Panels. Sea level measurements at various islands and coastal stations are required during the TOGA programme to describe the low frequency fluctuations of the tropical oceans. Sea level integrates effects which occur at different levels in the water column, and since it can be measured hourly, there is no aliasing of high into low frequency fluctuations. The response to low frequency atmospheric forcing is often clearly shown in the sea level data near the Equator, and it has been used extensively in ocean model verification studies. Sea level is a measure of heat content, and can be used as an indicator of thermocline depth. In addition, when sea level anomalies are interpreted as deviations from the mean dynamic height field, sea level differences between pairs of gauges poleward of 2° North or South can be used to estimate the geostrophic component of the surface flow. The horizontal resolution attainable is dictated by the available sites; time resolution is one day; and the required accuracy is 2 cm.

All sea level stations between 30° N and 30° S identified as a part of GLOSS will also serve as TOGA sea level stations. The first priority for installing the sea level stations for TOGA purposes is for those located in the near-equatorial region, and the second priority is for those in the tropical belt. Satellite telemetry will be introduced in scientifically strategic areas during the ten-year TOGA observational period.

The TOGA Scientific and Implementation Plans[5, 6] include maps showing locations of sea level stations required for TOGA, and these are closely related to GLOSS.

3.2.3 The World Ocean Circulation Experiment (WOCE)

The World Ocean Circulation Experiment (WOCE) is a major component of the World Climate Research Programme. It is considered as the principal activity within Stream 3 of the WCRP. To plan and organize the experiment the Joint JSC/CCCO Scientific Steering Group for WOCE has been established. The Scientific Steering Group (SSG)) for WOCE with the assistance of the International WOCE Planning Office Wormley, UK) has prepared the Scientific Plan of the World Ocean Circulation Experiment[9] and WOCE Implementation Plan.[35]

WOCE has two major goals:

Goal 1. To develop models useful for predicting climate changes and to collect the data necessary to test them.

Goal 2. To determine the representativeness of the specific WOCE data sets for the long-term behavior of the ocean, and to find methods for determining long-term changes in the ocean circulation.

3.2.3.1 WOCE Applications

The first basic goal of WOCE requires sea level measurements for two major purposes: (i) calibration of altimetric satellite missions and (ii) geostrophic computations of specific currents, for example, through straits. Sea level will also serve as a check on the validity of numerical model outputs.

The second basic goal of WOCE, determining the representativeness of the specific WOCE data set for the long term behaviour of the ocean, will be addressed by comparing sea level measurements made during WOCE with those held by PSMSL, many of which date from the 19th century. These earlier records of sea level can also serve as a check on the output when the models developed during WOCE are run for previous decades. In addition, because possible enhanced rates of sea level rise are difficult to isolate against the background of interannual oceanographic variability at each site, the understanding of ocean dynamics developed through WOCE will allow these relatively short-term changes of sea level to be identified and removed before calculating long-term trends;

In general, hourly, or more frequent observations are required. For locations at mid and high-latitudes, tide gauge measurements must be supplemented with sea level atmospheric pressure data. It is highly desirable that multiple tide gauge sensors are used to check the outputs and to cover for instrument failures;

3.2.3.2 Detailed Requirements

Altimetric calibration

Sea level measurements are needed to reduce time variable, random errors in altimetric satellite orbits and for absolute (time average) altimetric calibration (and for relating one satellite's data to that of a non-contemporaneous satellite).

Reduction of random orbital errors

WOCE needs data from a selected subset of GLOSS with a 2-month delay for immediate analysis; In addition all hourly sea level data simultaneous with the satellite missions are ultimately potentially useful; For this reason a more extensive subset, collected and checked with 12 to 18 months after the measurements is planned.

Absolute calibration

Tide gauges can be used for substantially reducing the errors in altimeter measurements of sea level in geocentric co-ordinates (absolute measurement of sea level). For example, ten tide gauges sited along the subsatellite track traced out by Topex/Poseidon ephemeris error to a few centimetres, provided the geocentric position of the stations are known in geocentric co-ordinates with comparable accuracy. The co-ordinates can be obtained by differential GPS measurements relative to the nearest VLBI station in conjunction with satellite laser ranging, or by other techniques such as DORIS, PRARE.

Monitoring geostrophic gradients, straits and pairs

Long-term records of sea level differences across currents, either between islands, or across straits, allow monitoring of flow variations. Daily mean sea levels would be adequate for monitoring purposes, but it is recommended that hourly values are obtained during WOCE because these would allow:

(i) non-linear local oceanographic distortions to be seen as higher tidal harmonics;

(ii) continual checks on the gauge performance and identification of potential errors such as datum shifts.

Particular attention should be given to the high latitude Southern Ocean stations which pose special problems because of the ice conditions and the infrequent visits to many of the proposed sites. Support should be given to technology developments necessary to make these measurements possible. Some pairs of stations would be desirable for the study of the zonal wave number of the Antarctic Circumpolar Current variability.

3.2.3.3. Implementation

These requirements identify two related types of sea level data collection and analysis:

(i) data collected and generally available for altimetry within two months, with an accuracy of 3-5 cm. Gauges in this network will probably transmit data by satellite in near-real-time to their national authorities. Hourly values are acceptable, but 6-minute samples are preferred;

(ii) a widely based global network comprising as many of the GLOSS stations as can be activated and maintained, with particular emphasis on those stations mentioned above. Hourly data to be available within 18 months of collection, accurate to 1-2 cm with full datum control and careful checking for inconsistencies and potential errors.

The Scientific Steering Group for WOCE[36] agreed that a set of some 65-70 gauges constitute the WOCE array that are needed for:

(i) support for altimetry with high frequency (> 1 cycle/hr), high precision;

(ii) time series for estimate of transport variation through straits.

Two WOCE Sea Level Data Assembly Centres (DACs) were established at the University of Hawaii (USA) and at the Proudman Oceanographic Laboratory, Bidston (UK).

The SSG/WOCE confirmed that for WOCE, sea level data are needed on six-minute intervals together with adequate air pressure corrections. For some gauges this may involve additional liaison with national authorities and arrangements where possible for bench marks to be established and regujlarly checked, VLBI or other geocentric levelling and similar details.

The WOCE Sea Level Network and its list of stations are shown in Annex X.

3.3 NATIONAL AND REGIONAL BENEFITS

Sea levels also have many practical applications for operational and engineering design activities[53, 55, 56, 63, 77, 85, 89] and are important for the following national applications:
(i) for ship movement operation in harbour and seaports;
(ii) for flood forecasting and control;
(iii) for storm surge warning;
(iv) for defining datums for hydrographic charting and topographic mapping;
(v) for coastal zone management, and control of coastal zone erosion, and sedimentation;
(vi) for engineering applications related to sea-ports design and operation maintenance;
(vii) for tsunami warning;
(viii) for prediction of tides, and preparation of tide-tables;
(ix) for determination of coastal and territorial sea boundaries, in connection with the ownership of land and marine mineral resources exploitation;
(x) for determination of coastal sea circulation;
(xi) for development and verification of ocean models, required to determine currents and pollutants transport;
(xii) for earthquake prediction;
(xiii) for investigation of potential salt water intrusion;
(xiv) for defining geodetic height datums;
(xv) for designing of reclamation scheme, and construction of dumps;
(xvi) for prediction of upwelling (in tropical zone) and fishing operations.

The importance of sea level measurements for regional scientific and practical applications has been emphasized within the various regional oceanographic programmes co-ordinated by IOC.

Within the Central Indian Ocean region (IOCINDIO) the need for sea level measurements was mentioned for regional co-operative research projects, dealing with the study of coastal water dynamics, water mass movements and storm-surge prediction for the marginal seas of the Northern Indian Ocean.

The proposed network of sea level stations in the Indian Ocean, as a part of GLOSS, is appropriate for the monitoring of specific processes, such as the annual development of a western boundary current, the equatorial dynamics, the exchange of water between the Indian and Pacific oceans through the Indonesian Archipelago, and the strength of parts of the Antarctic circulation (Annex IV).

It was also proposed to install, upgrade and maintain tide-gauges in the Southern Ocean to improve our understanding of the tidal regime in this ocean. Sea level measurements could also be of use in assessing the variability of circulation in the Antarctic Circumpolar Current where the barotropic component is thought to be large[13] (Annex IV).

In the Caribbean Sea and adjacent regions a system of co-located sea level/weather stations is considered crucial for the understanding of surface currents. This falls within the proposed regional study of the circulation of the entire Caribbean Sea and adjacent regions, which is required for understanding the effect of the circulation on pollution transport, on coastal dynamics, and on mesoscale features that contribute to the ocean's influence on weather and climate. [11]

In the North Sea, a Storm-Surge Warning System has been developed to warn of impending coastal flooding.

The IOC Tsunami warning system in the Pacific combines selected sea level gauges from several countries into an ocean-wide network for the dedicated purpose of detecting tsunami[10, 34] (Annex IV).

In the Pacific Ocean many sea level stations since 1984 provide data to a specialized Oceanographic Data Centre in Honolulu within the framework of the IGOSS Sea Level Pilot Project (ISLPP). The data are used for the preparation and wide distribution of monthly mean sea level anomaly charts[7, 8] (Annex IV).

The need for establishment of regional networks of sea level stations required for research and for practical applications was also indicated for the Red Sea and the Gulf of Aden, the North and Central Western Indian Ocean [14] (Annex IV) and in the Mediterranean as part of the programme on the Physical Oceanography of the Eastern Mediterranean (POEM).[22].

4. Global Sea Level Observing System

The Proposed Network for the Global Sea Level Observing System, to meet the identified practical and scientific requirements, is shown in Figure 4.

4.1 GLOSS NETWORK

Physically, the network is constrained to land-based stations along continental coasts and at oceanic islands; this necessary but imperfect distribution defines a minimum length scale to the resolution. Scientific analyses of existing and projected data will allow some clarification of the appropriateness of these locations for a monitoring systems. Present knowledge of ocean behaviour indicates that there are several length and time scales over which sea level changes are significant. In general, the long-period changes have the largest spatial scales. For example, the increase of sea level due to changes in ocean volume is a global phenomenon; similarly, the annual cycle of sea level has an hemispheric scale. Phenomena such as El Niño have an event duration of 1-2 years and a basin-wide scale. Interannual variations of sea level over periods from three months to a few years have typical length scales of 1,000 km or greater. At shorter time scales, storm-surge events have periods from days to hours and correspondingly shorter length scales, of order 100 km. Conversely, some processes of vertical crustal movement may have very long time scales, but they may have a spatial coherence which extends over a few tens of kilometres or less.

By concept and design a global network of sea level stations must be primarily concerned with the resolution of large-scale, long-term phenomena. This coarse resolution must be refined in certain areas such as straits or in the vicinity of western boundary currents, which are critical for the behaviour of the oceans as a whole. Individual gauges on the network will also be needed for local studies.

In making this proposal, the following criteria were adopted, with the clear understanding that there would be logistic constraints and that subsequent scientific development would permit a more appropriate monitoring network as the project proceeds:

(i) a gauge has been allocated to each ocean island or group of ocean islands, at intervals not closer than 500 km;

(ii) gauges are located along continental coasts at intervals general not less than 1,000 km; preference is given to nearshore islands to maximize the exposure to the open ocean;

(iii) in special cases, such as a strait that connects large parts of the oceans, the network density has been increased, so that a minimum of one gauge on either side of the strait is proposed;

(iv) priority is given to well established gauges, and gauges which have a long history of previous operation since these can give valuable information on trends.

4.2 MEASUREMENT TECHNIQUES AND REQUIREMENTS

The measuring system at each station will consist of a transducer which senses some physical parameter clearly related to the sea-surface level, and a system for local recording of the data. Automatic transmission or the data in near-real-time to national and international centres should be a feature of the final network. It is important that the operation of the individual measuring systems include procedures for regularly checking the quality and datum stability of the readings.

There are two basic parameters which may be monitored, the surface level itself or the pressure at some fixed point on the sea bed. There are scientific and instrumental advantages of each method. Traditionally, the sea-surface has been measured by means of a float arrangement mounted above a well which damps out short-period wave motions (Figure 5). This procedure is simple, well proven and has no inherent drift. However, there are problems of non-linear responses of stilling wells to waves and currents (Bernoulli effect), which can produce errors in the measurement of the water level. Alternative methods for sensing the sea-surface include acoustic and electromagnetic time-of-flight gauges: these avoid the problems associated with moving floats and wires, but will still be subject to errors if mounted over stilling wells. Despite these reservations, the stilling well arrangement, if properly designed, remains a robust and reliable system for many applications.

An alternative is to measure nearshore sea-bed pressure and to convert this to sea level by means of the hydrostatic relationship between pressure, water density and gravitational acceleration (Figure 6). Sea-bed pressure includes the atmospheric pressure, which must be corrected for, either by separate measurement or by means of differential transducer vented to the atmosphere, as in some bubbler gauges. Unlike surface sensing gauges, which require a vertical structure such as a jetty for mounting, pressure systems may be with the recorder on the sea-bed, or connected by a pressure or electric cable to a recorder ashore. With pressure systems, care is necessary to ensure that the datum level remains constant, and sea-water density variations must be monitored at suitable intervals for the best accuracy.

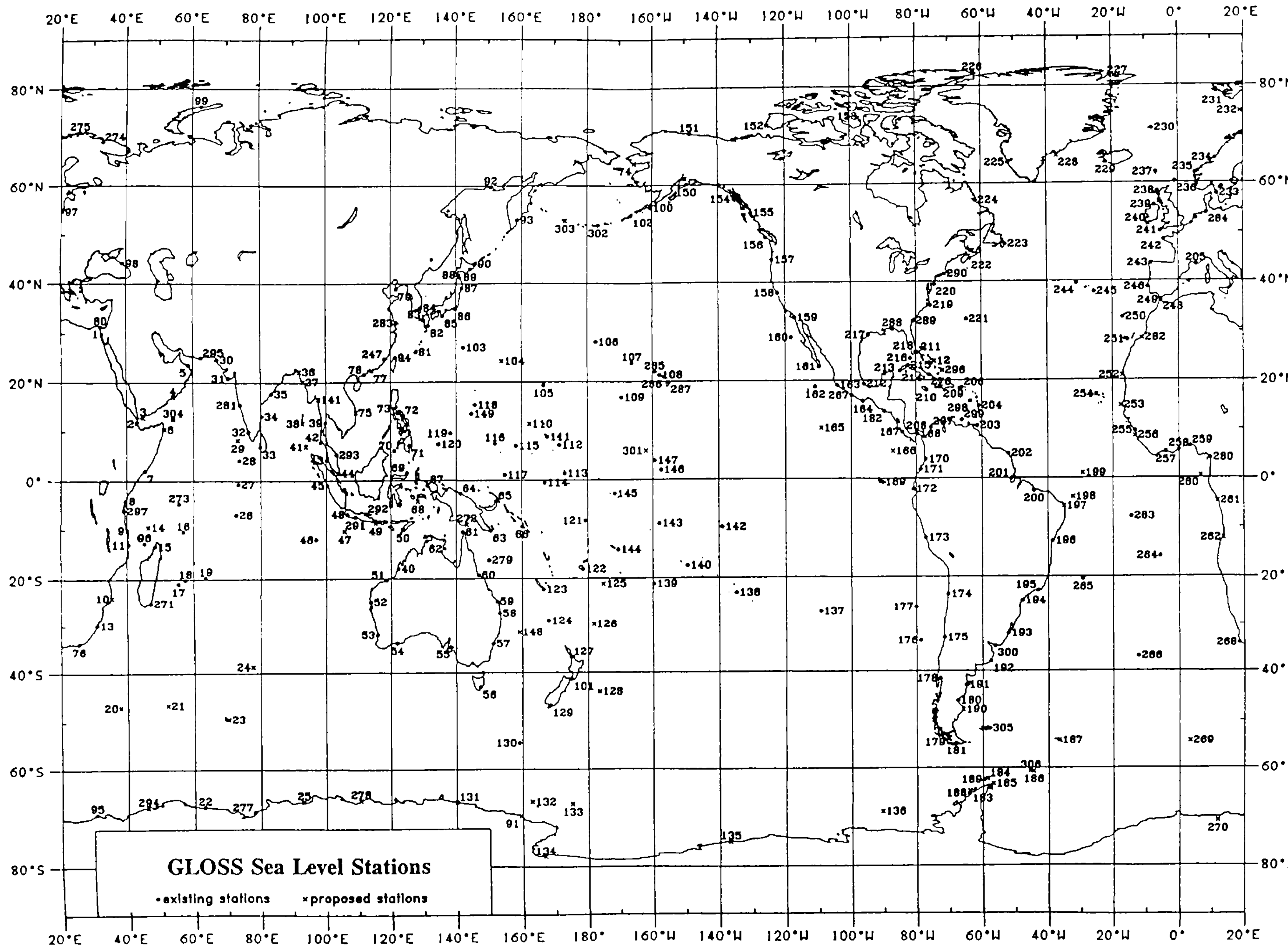

Figure 4. Global Sea-Level Observing System Status December 1988

MAP OF GLOSS SEA-LEVEL STATIONS

KEY TO GLOSS SEA LEVEL STATIONS

1 Suez
2 Djibouti
3 Aden
4 Salalah
5 Muscat
6 Hafun
7 Mogadishu
8 Mombasa
9 Mtwara
10 Inhambane
11 Pemba
12 San Salvador
13 Durban
14 Aldabra
15 Nosy-Be
16 Agalega Is.
17 Pointe des Galets
18 P. Louis
19 Rodrigues
20 Marion Is.
21 Crozet Is.
22 Mawson
23 Kerguelen Is.
24 St. Paul
25 Mirny
26 Diego Garcia
27 Gan
28 Male
29 Minicoy
30 Karachi
31 Veraval
32 Cochin
33 Colombo
34 Madras
35 Vishakhapatnam
36 Chittagong
37 Akyab
38 Port Blair
39 Ko Lak
40 Broome
41 Nicobar
42 Ko Taphao Noi
43 Pengkalam
44 Singapore
45 Padang
46 Cocos Is.
47 Christmas Is.
48 Pelabuhan Ratu
49 Benoa
50 Kupang
51 P. Hedland
52 Carnarvon
53 Fremantle
54 Esperance
55 P. Adelaide
56 Hobart
57 Sydney
58 Brisbane
59 Bundaberg
60 Townsville
61 Booby Is.
62 Darwin
63 Alotau
64 Vanimo
65 Rabaul
66 Honiara
67 Sorong
68 Ambon
69 Manado
70 Jolo
71 Davao
72 Legaspi
73 Manila
74 Nome
75 Qui Nhon
76 Port Elizabeth
77 Quarry Bay
78 Zhapo
79 Dalian
80 Port Said
81 Naha
82 Aburatsu
83 Nagasaki
84 Pusan
85 Kushimoto
86 Mera
87 Ofunato
88 Hakodate
89 Kushiro
90 Yuzno-Kurilsk
91 Leningradskay
92 Nagaevo
93 Petrapavlovsk
94 Kanmen
95 Syowa
96 Dzaoudzi
97 Kaliningrad
98 Tuapse
99 Russkaya Gavan
100 Sand Point
101 Wellington
102 Unalaska
103 Chichijima
104 Minamitorishima
105 Wake Is.
106 Midway Is.
107 French Frigate
108 Honolulu
109 Johnston Is.
110 Eniwetok
111 Kwajalein Is.
112 Majuro
113 Tarawa
114 Nauru Is.
115 Ponape
116 Truk
117 Kapingamarangi
118 Saipan
119 Yap Is.
120 Malakal
121 Funafuti
122 Suva
123 Noumea
124 Norfolk Is.
125 Tongatapu
126 Kermadec
127 Waitemata
128 Chatham Is.
129 Bluff
130 Macquarie Is.
131 Dumont d'Urville
132 Balleny
133 Scott Is.
134 Mc Murdo
135 Russkaya
136 Peter Is.
137 Pascua Is.
138 Rikitea
139 Rarotonga
140 Papeete
141 Moulmein
142 Nuku Hiva
143 Penrhyn
144 Pago Pago
145 Kanton Is.
146 Christmas
147 Fanning
148 Lord Howe Is.
149 Guam Is.
150 Seward
151 Prudhœ Bay
152 Sachs
153 Resolute
154 Sitka
155 Rupert
156 Tofino
157 S. Beach
158 San Francisco
159 Scripps Pier
160 Guadalupe Is.
161 San Lucas
162 Socorro
163 Manzaillo
164 Puerto Angel
165 Clipperton
166 Coco Is.
167 Quepos
168 Balboa
169 Baltra
170 Buenaventura
171 Tumaco
172 La Libertad
173 Callao
174 Antofagasta

175 Valparaiso
176 Juan Fernandez
177 San Felix
178 Puerto Montt
179 Punta Arenas
180 Puerto Williams
181 Ushuaia
182 Acajutla
183 Palmer
184 Jubany
185 Esperanza
186 Bahia Scotia
187 S. Georgia
188 Faraday
189 Base Antarctica
190 Puerto Deseado
191 Puerto Madryn
192 Mar del Plata
193 Rio Grande
194 Cananeia
195 Rio de Janeiro
196 Itaparica
197 Porto de Natal
198 Fernando de Noronha
199 St Peter/St Paul
200 Porto de Itaqui
201 Porto de Santana
202 Cayenne
203 Port-of-Spain
204 Le Robert
205 Marseille
206 San Juan
207 Cartagena
208 Coco Solo
209 Les Cayes
210 Port Royal
211 Bimini
212 Veracruz
213 Progreso
214 Cabo San Antonio
215 Siboney
216 Key West
217 Galveston
218 Miami
219 Cape Hatteras
220 Ventnor
221 Bermuda
222 Halifax
223 St Johns
224 Nain
225 Gothaab
226 Alert
227 Nord
228 Angmagssalik
229 Reykjavik
230 Jan Mayen
231 Spitsbergen
232 Bear Is.
233 Goteborg
234 Rorvik
235 Maloy
236 Lerwick
237 Torshavn
238 Stornoway
239 Malin Head
240 Castletownsend
241 Newlyn
242 Brest
243 La Coruna
244 Flores
245 Ponta Delgada
246 Cascais
247 Xiamen
248 Gibraltar
249 Ceuta
250 Funchal
251 Las Palmas
252 Nouadhibou
253 Dakar
254 P. Grande
255 Conakry
256 Aberdeen Point
257 Abidjan
258 Tema
259 Lagos
260 Sao Tome
261 Pointe Noire
262 Luanda Lobito
263 Ascension
264 St. Helena
265 Ilha da Trindade
266 Tristan da Cunha
267 Acapulco
268 Simonstown
269 Bouvet
270 Novolazarevskaya
271 Fort Dauphin
272 Daru
273 Port Victoria
274 Murmansk
275 Honningsvag
276 Gibara
277 Davis
278 Casey
279 Willis
280 Douala
281 Marmagao
282 Tan Tan
283 Lusi
284 Cuxhaven
285 Nawiliwili
286 Kahului
287 Hilo
288 Pensacola
289 Ft. Pulaski
290 Newport
291 Cilacap
292 Surabaya
293 Cendering/Kula
294 Molodezhnaya
295 Gwadar
296 North Caicos
297 Zanzibar
298 Aves Is.
299 La Orchila
300 Montevideo
301 Palmyra
302 Adak
303 Massacre Bay
304 Socotra Is.
305 Falkland Is/
Malvinas Is.
306 South Orkney Is.
307 Won San

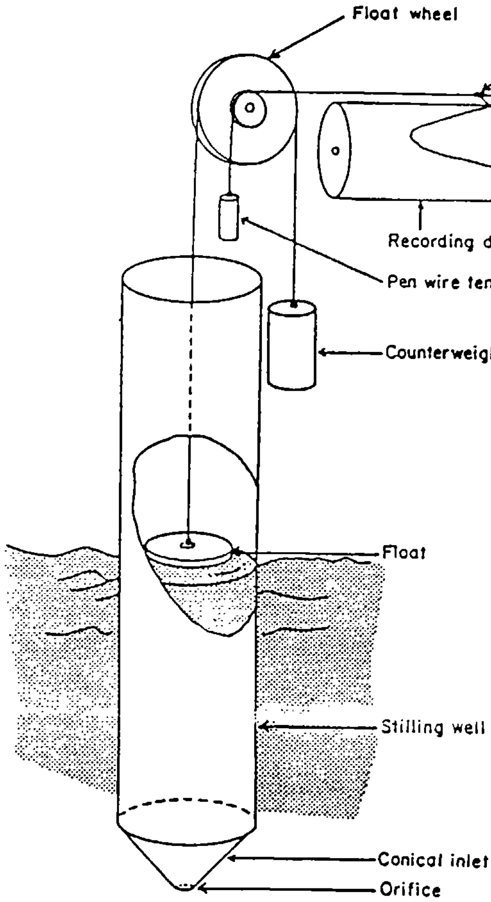

Figure 5. Basic Tide Gauge (from Manual on Sea-Level Measurement and Interpretation.[16]

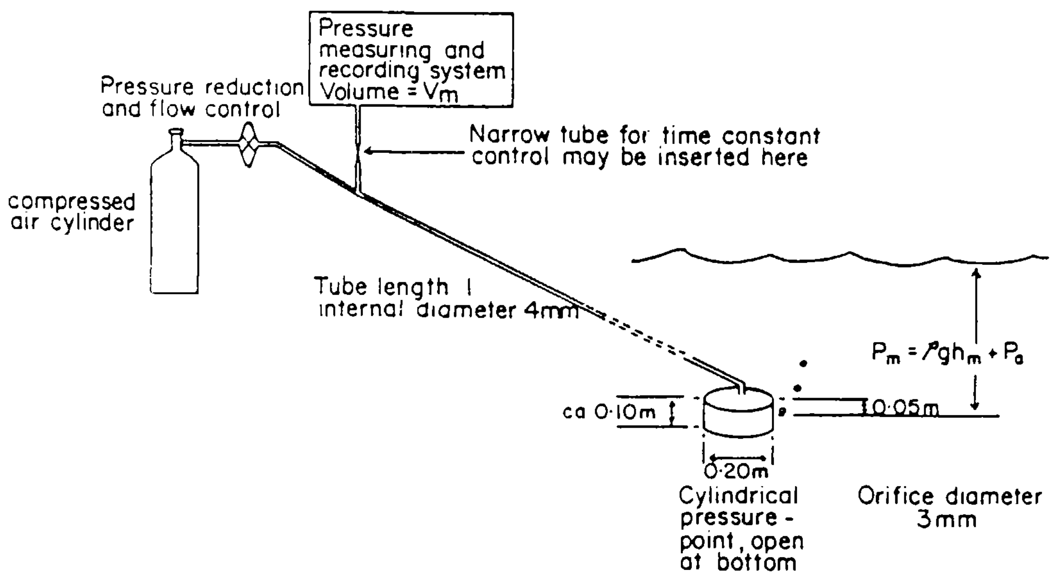

Figure 6. Basic Pneumatic Bubbling System (from Manual on Sea-Level Measurement and Interpretation.[16]

Automatic monitoring systems also afford the possibility of recording and transmitting data on atmospheric pressure, winds and other environmental parameters, which are of direct relevance to the sea level data analysis. Atmospheric pressure data are particularly important, especially at higher latitudes.

The measured sea levels are usually recorded either continuously on a chart, or in digital form at discrete intervals on punched or magnetic tape. Charts are useful for immediate local operations, but as part of a network, each gauge should have data recorded automatically in computerformat. Sampling of sea level averaged over a few minutes (to avoid aliasing), at intervals of 15 minutes, is recommended, but in all circumstances the minimum sampling interval should be one hour. Gauge timing should be compatible with level accuracy, which means an accuracy of plus or minus 1 minute.

All gauges must measure sea levels relative to a fixed and permanent local tide gauge Bench Mark, which is connected to a number of Auxiliary Bench Marks. These guard against the movement or destruction of the main tide gauge bench mark (Figure 7). Connections between the Bench Mark and the gauge zero should be made to an accuracy of a few millimetres every six months. The readings of individual sea levels should be made with a target accuracy of 10 mm. Although initially the network must accept present-day instrument performance, as the technology develops and the resources become available, gauges should be equipped for averaging and rapid sampling; they should also be equipped for automatic data transmission to data centres in addition to the local recording.

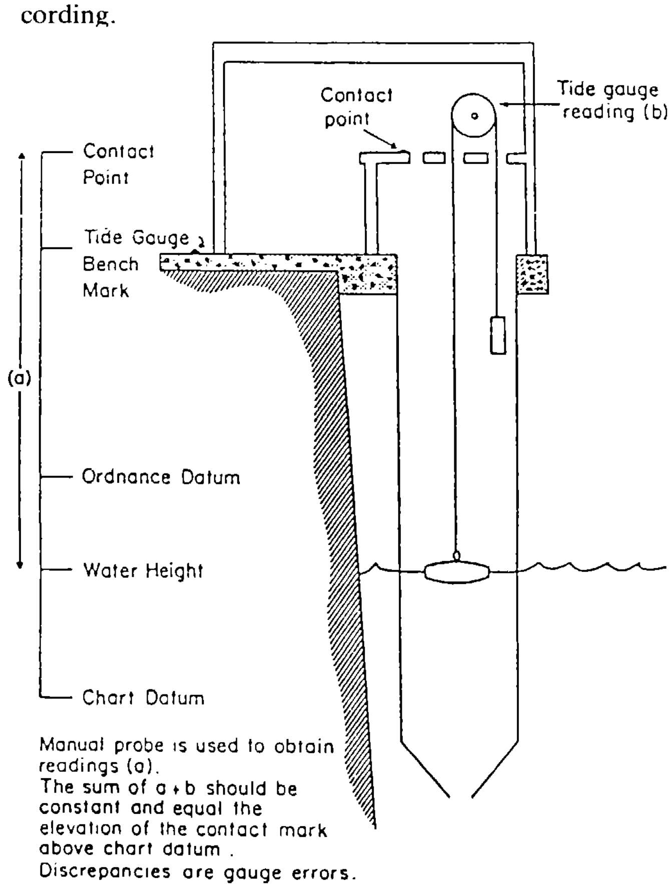

Figure 7. Float Gauge Datum Check (from Manual on Sea-Level Measurement and Interpretation.[17]

Another fundamental development is the ability to connect all network Gauge Bench Marks into a Global Vertical Datum System, which will eventually allow the vertical crustal movements to be distinguished from sea level trends. Similarly, it may eventually be possible to relate all the Bench Marks to a reference geoid, which would enable oceanographers to compute absolute pressure gradients between stations, and to relate these to permanent currents.[38, 40, 41]

The data recorded at the station will contain errors of many kinds. They will require checking by the local or national authority for calibration and timing adjustment, for datum control, and for the removal of obvious instrumental malfunctions. This should be done with the minimum possible delay. This applies for all stations, as this allows problems with the system to be identified and corrected without further loss of data. The daily and monthly mean values should be computed for scientific use according to established methods.

In order to unify procedures for sea level measurements and analysis and to assist those Member States who wish to install or reactivate their sea level stations, a Manual on Sea Level Measurement and Interpretation has been prepared and issued by the IOC in 1985.[16]

The monthly mean values are to be submitted to the Permanent Service for Mean Sea Level and the hourly and daily mean values should be made available for scientific analysis as required.

As automatic transmission from the gauges becomes standard there will be discrepancies between the raw values received by operational centres and the final corrected values issued by the international centres. It is necessary to make a clear distinction between the data transmitted in real-time which will be of inferior quality, but quite adequate for operational purposes, and the final data presented through PSMSL, which requires careful editing and well documented datum control. The IOC can help in the co-ordination of data flow using its existing mechanisms (i.e. IGOSS and IODE).

Annex V contains a list of suppliers of tide gauge equipment.

Technologies for sea level measurements continue to evolve. For example, USA (NOAA) has recently begun to operate new gauges of acoustic type.[40]

It is called Next Generation Water Level Measurement System (NGWLMS), which is designed to meet requirements for long-term monitoring of absolute sea-level. A single measurement from the NGWLMS represents about an order of magnitude improvement over the existing measurement type, i.e. the single measurement will be good to the +/- 1 cm level with most of the systematic error effects either removed or greatly reduced[38] (Figure 8).

Data from several sensors will be stored at a data collection platform and communicated to data analysis centre through the Geostationary Operational Environmental Satellite (GOES) with telephone as a back-up. It will also allow line-of-sight radio communication for local applications. Figure 8 illustrates the NGWLMS communication options.

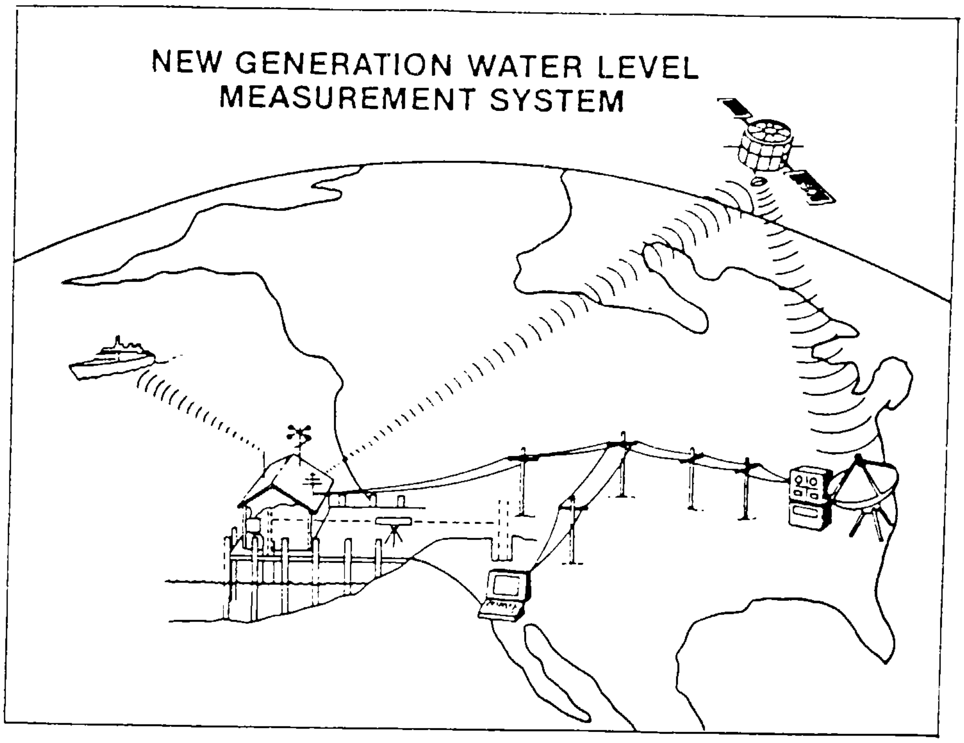

Figure 8. Several different communications options from the new water level system are shown (by D.C. Beaumariage and W.D. Scherer).[38]

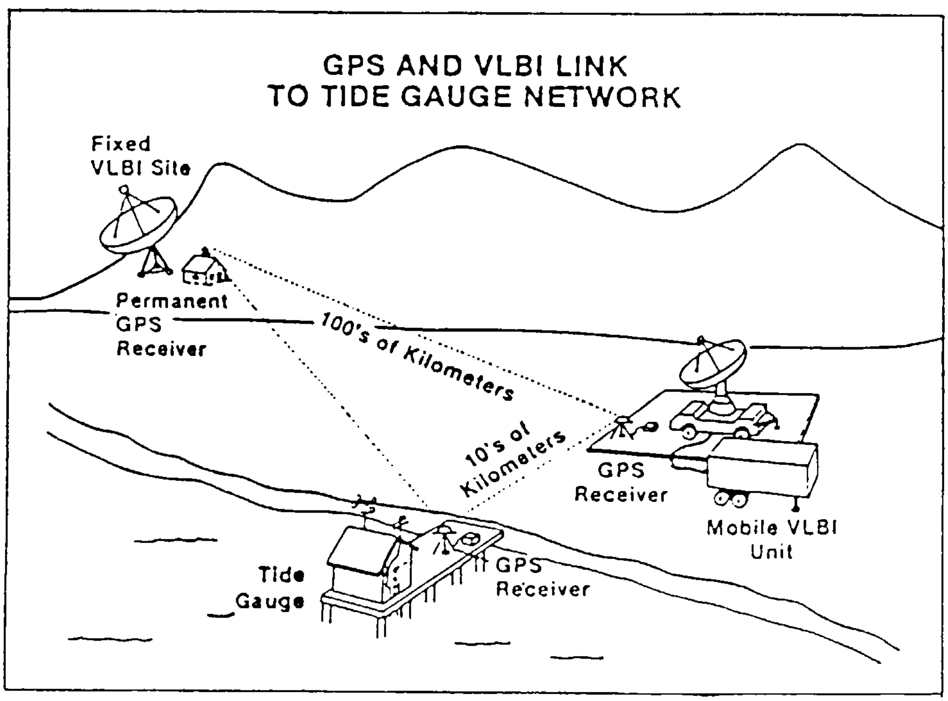

Figure 9. Absolute measurements of global sea level could be obtained by linking NGWLS with GPS and VLBI systems (by D.C. Beaumariage and W.D. Scherer).[38]

4.3 ABSOLUTE SEA LEVEL NETWORK

The presently employed technology for sea level measurements is inadequate for applications to determine long-term trends in absolute sea level needed to understand long-term climate changes as well as tectonic movements.

Tide gauges measure only the relative motion between the sea-surface and the land, and since land can rise and subside, the problems of relative motion must be solved by more sophisticated technology if sea level data are to be properly interpreted and used. The development of new geodetic techniques based on Very Long Baseline Interferometry (VLBI), the Global Positioning System (GPS) and absolute gravity measurements has created the opportunity to link a network of tide gauges to a highly accurate global reference system. By distinguishing sea level changes from land rise or subsidence, this global reference system will ultimately provide the first measure of absolute as opposed to relative sea level change[38] (Figure 9).

Sea level station positions and measured sea-surface positions will be determined in the global VLBI/GPS reference system suitably connected to geocentric coordinates, with an accuracy of about 1 cm, and time series of the absolute motions of the tidal bench marks (land reference points) will be determined, after a sufficient length of time, to better than 1 mm per year.

Within the GLOSS network about 100 absolute sea level stations would be required preferably on open coasts, which are more representative of open-ocean conditions. All tide gauges that are to be used to monitor global sea level must be connected to a local levelling network which is properly constructed and regularly resurveyed (annually if possible). The levelling network should have a minimum of 6 to 10 bench marks and extend over a sufficient area to minimize the chances of destruction by local engineering projects or natural causes. At least one of the marks should be located at a site suitable for GPS observations (i.e. the horizon should be free of obstructions above 10 to 15 degrees elevation). When possible tide gauges should be organized into regional networks, and GPS surveys should be conducted to determine their relative positions with an accuracy of 1 cm or better. These regional networks should be connected to the global VLBI reference frame.

4.4 GLOSS SEA LEVEL STATIONS

The list of GLOSS sea level stations based on the above-mentioned criteria and information provided by participating Member States is shown on the following pages (Table 1).

4.5 OTHER PROGRAMMES WITH SEA LEVEL COMPONENTS

As it was emphasized earlier the GLOSS will serve many scientific and practical purposes. It will be required for global-scale programmes, such as TOGA and WOCE, as well as in support of research programmes to be developed within the regional activities of IOC. These regional activities combine on a rational basis practical items of national interest and joint efforts of the countries of the region in implementing their research and service oriented programmes, in order to use most efficiently and rationally marine resources and improve coastal zone management. It is therefore, considered important that the development of regional networks and Global Network be complementary and that the existing IOC regional subsidiary bodies considers the development of regional projects, by designing and developing regional sea level projects. The IOC Assembly at its Fourteenth Session (1987) pointed out that IOC regional bodies are a proper framework to assist in implementation of GLOSS in their respective regions (see Annex V).

Atlantic Ocean
– The IOC Sub-commission for the Caribbean and Adjacent Regions (IOCARIBE)
– The IOC Regional Committee for the Central Eastern Atlantic (IOCEA)

Indian Ocean
– IOC Regional Committee for the North and Central Western Indian Ocean (IOCINCWIO)
– IOC Regional Committee for the Central Indian Ocean (IOCINDIO)

Pacific Ocean
– IOC Sub-Commission for the Western Pacific (WESTPAC)
– Joint IOC-WMO-CPPS Working Group on the Investigations of El Niño

Southern Ocean
IOC Regional Committee for the Southern Oceans (IOCSOC)

Table 1. List of GLOSS Sea-Level Stations

NN	STATION	COUNTRY/ TERRITORY	CO-ORDINATES	TYPE OF TIDE-GAUGE	O	PERIOD OF OBSERVATION FROM - TO	EXISTING STATION ***	Q **	C *	PARTICIPATION IN OTHER INTERNATIONAL ACTIVITIES (PSMSL, TOGA, ISLPP, ITSU)
262	Lobito	Angola	12-20S 13-34E		A		0			TOGA
186	Bahia Scotia	Argentina	60-44S 044-39W		S		0	Q	C	
190	Puerto Deseado	Argentina	47-45S 065-55W	Float	A	1970-1984	0	Q	C	
185	Esperanza	Argentina	63-18S 56-55W	Float	S	1959-1978	0	Q	C	
184	Jubany	Argentina	62-14S 058-40W		S		0	Q	C	
192	Mar del Plata	Argentina	38-03S 057-33W	Float	A	1954	+	Q	C	
191	Puerto Madryn	Argentina	42-46S 065-02W	Float	A	1945	+	Q	C	
181	Ushuaia	Argentina	54-49S 068-13W	Float	A	1953	+	Q	C	
61	Booby Is.	Australia	10-36S 141-55E	Float	I	1971	+	Q	C	
57	Botany Bay (Sydney)	Australia	33-59S 151-13E	Float	P	1981	+	Q	C	ISLPP
58	Brisbane (West Inner Bar)	Australia	27-22S 153-10E	Bubbler	P	1982	+	Q	C	
40	Broome	Australia	18-00S 122-13E	Float	I	1982	+	Q	C	
59	Bundaberg	Australia	24-46S 152-23E	Float	P	1979	+	Q	C	ISLPP
52	Carnarvon	Australia	24-54S 113-39E	Float	I	1977	+	Q	C	
278	Casey	Australia	66-17S 110-32E		S		0	Q	C	
47	Christmas Is.	Australia	10-25S 105-40E	Float	I	1985	+	Q	C	TOGA
46	Cocos Is. (Keeling)	Australia	12-07S 96-53E	Float	I	1985	+	Q	C	TOGA
62	Darwin	Australia	12-28S 130-51E	Float	I	1981	+	Q	C	
277	Davis	Australia	68-35S 77-58E	Pressure	S		0	Q	C	
54	Esperance	Australia	33-52S 121-54E	Float	S	1965	+	Q	C	
53	Fremantle	Australia	32-03S 115-43E	Float	I	1967	+	Q	C	
56	Hobart	Australia	42-53S 147-20E	Float	S	1960	+	Q	C	
148	Lord Howe Is.	Australia	31-31S 159-04E	Float	P	1986	0	Q	C	TOGA
130	Macquarie Is.	Australia	54-30S 158-56E	Pressure	S		0	Q	C	
22	Mawson	Australia	67-36S 62-52E	Pressure	S		0	Q	C	
124	Norfolk Is.	Australia	29-04S 167-57E	Float	P	1985	+	Q	C	TOGA
55	Port Adelaide (Outer HB)	Australia	34-47S 138-28E	Float	S	1982	+	Q	C	
51	Port Hedland	Australia	20-19S 118-34E	Float	I	1969	+	Q	C	
60	Townsville	Australia	19-16S 146-50E	Float	P	1948	+	Q	C	ISLPP
279	Willis Is.	Australia	16-19S 149-59E	Pressure	P		0	Q	C	TOGA
211	Bimini	Bahamas	25-45N 079-10W		A		0			TOGA
12	San Salvador	Bahamas	24-00N 074-30W		A		0			
36	Chittagong	Bangladesh	22-15N 091-50E		I	1961-1968	0			
120	Malakal	Belau	07-20N 134-28E	Float	P	1974-1990	+	Q	C	ISLPP, TOGA
194	Cananeia	Brazil	25-01S 047-55W	Float	A	1984	+	Q	C	TOGA
198	Fernando de Noronha	Brazil	03-52S 032-25W	Float	A	1972-1985	0	Q	C	TOGA
196	Itaparica	Brazil	12-52S 038-41W	Float	A	1985	+	Q	C	TOGA
200	Porto de Itaqui	Brazil	02-34S 044-22W	Float	A	1985	+	Q	C	TOGA
197	Porto de Natal	Brazil	05-46S 035-12W		A		0	Q	C	TOGA
195	Porto de Rio de Janeiro	Brazil	22-52S 043-08W	Float	A	1984	+	Q	C	
193	Porto de Rio Grande	Brazil	32-06S 052-11W	Float	A	1983	+	Q	C	
201	Porto de Santana	Brazil	00-03S 051-10W	Float	A	1970	+	Q	C	TOGA
199	Penedo Sao Pedro e Sao Paulo	Brazil	01-00N 029-23W	Pressure	A		+			TOGA
265	Ilha da Trindade	Brazil	20-30S 029-18W	Float	A	1974	+	Q	C	
197	Porto de Natal	Brazil	05-46S 035-12W		A		0	Q	C	TOGA

Ocean: P - Pacific; I - Indian; A - Atlantic; S - Southern; Ar - Arctic; M - Mediterranean Sea; RS - Red Sea

* C - the station committed to GLOSS

** Q - questionnaire has been received

*** + station exist; 0 station does not exist

NN	STATION	COUNTRY/ TERRITORY	CO-ORDINATES	TYPE OF TIDE-GAUGE	O	PERIOD OF OBSERVATION FROM - TO	EXISTING STATION ***	Q **	C *	PARTICIPATION IN OTHER INTERNATIONAL ACTIVITIES (PSMSL,TOGA, ISLPP, ITSU)
280	Douala	Cameroon	04-03N 009-41E	Float	A	1985	+	Q	C	TOGA
226	Alert	Canada	82-30N 062-20W		Ar	1961-1984	O	Q	C	
222	Halifax	Canada	44-40N 063-35W	Float	A	1919-1986	+	Q	C	PSMSL
224	Nain	Canada	56-32N 061-41W	Float	A	1963-1986	+	Q	C	PSMSL
155	Prince Rupert	Canada	54-19N 130-19W	Float	P	1909-1986	+	Q	C	ISLPP
153	Little Cornwallis Island	Canada	75-23N 096-57W	Bubbler	Ar	1957-1984	O	Q	C	
152	Sach Harbour	Canada	71-58N 125-15W		Ar	1971-1984	O	Q	C	
223	St John's Nfld	Canada	47-34N 052-42W	Float	A	1957-1986	+	Q	C	PSMSL
156	Tofino	Canada	49-09N 125-55W	Float	P	1910-1986	+	Q	C	ISLPP
254	Porto Grande	Cape Verde	16-52N 024-59W		A	1947-1950	O		C	TOGA
174	Antofagasta	Chile	23-39S 070-25W	Bubbler	P	1945	+	Q	C	ISLPP, TOGA
137	Isla da Pascua	Chile	27-09S 109-27W	Bubbler + Sat	P	1957	+	Q	C	TOGA
176	Juan Fernandez	Chile	33-37S 078-50W	Bubbler	P	1957	+	Q	C	TOGA
178	Puerto Montt	Chile	41-29S 072-58W	Bubbler	P	1945	+	Q	C	
180	Puerto Williams	Chile	45-56S 067-37W	Float	P	1964	+	Q	C	
179	Punta Arenas	Chile	53-10S 070-54W	Bubbler	P	1944	+	Q	C	
175	Valparaiso	Chile	33-02S 071-38W	Bubbler + Sat	P	1944	+	Q	C	ISLPP, TOGA
177	San Felix	Chile	26-17S 080-07W	Bubbler + Sat	P	1984-1986	+	Q	C	TOGA
189	Capitan Prat	Chile	62-29S 059-38W	Bubbler	S	1983-1986	O	Q	C	
79	Dalian	China	38-52N 121-41E		P	1975-1987	+	Q	C	TOGA, ISLPP, ITSU
78	Zhapo	China	21-35N 111-49E		P	1975-1987	+	Q	C	TOGA, ISLPP, ITSU
283	Lusi	China	32-08N 121-37E		P	1959	+	Q	C	ISLPP, ITSU
247	Xiamen	China	24-27N 118-04E		P	1954	+	Q	C	TOGA, ISLPP, ITSU
94	Kanmen	China	25-05N 121-17E		P	1960-1987	+	Q	C	ISLPP, ITSU
170	Buenaventura	Colombia	03-53N 077-06W	Float	P	1942	+	Q	C	ISLPP
171	Tumaco	Colombia	01-50N 078-44W	Float	P	1953	+	Q	C	ISLPP
207	Cartagena	Colombia	10-24N 075-33W	Float	A	1949-1984	+	Q	C	PSMSL
261	Pointe-Noire	Congo	04-47S 011-50E	Float	A	1959	+			TOGA
143	Penrhyn	Cook Isl.	09-01S 158-04W	Float + Sat	P	1977	+	Q	C	TOGA
139	Rarotonga	Cook Isl.	21-12S 159-46W	Float + Sat	P	1977	+	Q	C	TOGA
167	Quepos	Costa Rica	09-24N 084-10W	Float	P	1957-1985	+			TOGA
166	Isla del Coco	Costa Rica	05-33N 087-04W		P		O			TOGA
257	Abidjan	Cote d'Ivoire	05-15N 004-00W		A	1971	+		C	
276	Gibara	Cuba	21-07N 076-07W	Float	A	1970	+	Q	C	TOGA
214	Cabo San Antonio	Cuba	21-54N 84-54W	Float	A	1971	+	Q	C	TOGA
215	Siboney	Cuba	23-05N 82-28W	Float	A	1986	+	Q	C	TOGA
307	Won San	Dem. People's Rep. of Korea	39-10N 127-26E	Float	P	1954-	+	Q	C	TOGA
225	Godthaab/Nuuk, Greenland	Denmark	64-10N 51-44W	Float	A	1950-1986	+	Q	C	
228	Angmagssalik, Greenland	Denmark	65-30N 37-00W		A		O	Q	C	
227	Nord, Greenland	Denmark	81-40N 18-00W		A		O		C	
237	Torshavn, Faroe Is.	Denmark	62-00N 006-46W	Float	A	1901-1907, 1957-1986	+	Q	C	
2	Djibouti	Djibouti	11-36N 043-09E		I	1970-1972				TOGA
172	La Libertad	Ecuador	02-12S 080-54W	Float + Sat	P	1969-1990	+	Q	C	ISLPP, TOGA

NN	STATION	COUNTRY/ TERRITORY	CO-ORDINATES	TYPE OF TIDE-GAUGE	O	PERIOD OF OBSERVATION FROM - TO	EXISTING STATION ***	Q **	C *	PARTICIPATION IN OTHER INTERNATIONAL ACTIVITIES (PSMSL,TOGA, ISLPP, ITSU)
169	Santa Cruz	Ecuador	00-45S 090-17W	Float + Pressure + Sat	P	1968-1985	+	Q	C	ISLPP, TOGA
1	Suez (Port Taufig)	Egypt	29-55N 032-33E	Float	M	1900				TOGA
80	Port Said	Egypt	31-15N 032-18E	Float	RS	1923-1946	o			
117	Kapingamarangi, Carolines	Fed Micronesia	01-06N 154-47E	Float + Sat	P	1978	+	Q	C	ISLPP, TOGA
115	Ponape, Carolines	Fed Micronesia	06-59N 158-14E	Float + Sat	P	1974	+	Q	C	ISLPP, TOGA
116	Truk Atoll, Carolines	Fed Micronesia	07-27N 151-51E	Float	P	1974	+	Q	C	ISLPP, TOGA
119	Yap, Carolines	Fed Micronesia	09-31N 138-08E	Float	P	1974	+	Q	C	ISLPP, TOGA
122	Suva	Fiji	18-08S 178-26E	Float	P	1975	+	Q	C	ISLPP, TOGA
242	Brest	France	48-23N 004-30W	Float	A	1807	+	Q	C	
165	Clipperton	France	10-17N 109-13W		P		o			TOGA
21	Crozet Is.	France	46-25S 051-52E		I		o			
131	Dumont d'Urville	France	66-40S 140-01E		S		o			
23	Kerguelen Is.	France	49-21S 070-12E		I		o			
204	Le Robert, (Martinique)	France	14-42N 060-55W	Float	A	1972-1984	+	Q	C	TOGA
205	Marseille	France	43-18N 05-21E	Float	M	1885	+	Q	C	
123	Nouméa (Nouvelle Caledonie)	France	22-18S 166-26E	Float + Pressure + Sat	P	1967	+	Q	C	ISLPP, TOGA
142	Nuku Hiva, Marquesas Is.	France	08-56S 140-05W	Float	P	1985	+	Q	C	TOGA
140	Papeete (Tahiti) *	France	17-32S 149-34W	Float,Pressure	P	1957	+	Q	C	ISLPP, TOGA
17	Pointe des Galets (Rèunion)	France	20-55S 055-18E	Float	I	1974	+	Q	C	TOGA
138	Rikitea, Gambier	France	23-08S 134-57W	Float	P	1975	+	Q	C	ISLPP, TOGA
24	Saint Paul Is.	France	38-43S 077-35E		I		o			
96	Dzaoudzi (Mayotte)	France	12-47S 045-15E	Float	I	1981	+	Q	C	
202	Cayenne	France	05-00N 052-00W	Float	A	1977	+			TOGA
284	Cuxhaven	Germany, Fed. Republic of	53-52N 008-43E	Float	A	1843/extreme values 1918/hourly	+	Q	C	
258	Tema	Ghana	05-37N 00-00W	Float	A		+	Q	C	TOGA
255	Conakry	Guinea	09-30N 13-15W		A		+			TOGA
209	Port-au-Prince/ Les Cayes	Haiti	18-34N 072-21W		A	1949-1961	o			TOGA, PSMSL
77	Quarry Bay	Hong Kong	22-18N 114-13E	Float	P	1962	+	Q	C	
229	Reykjavik	Iceland	64-09N 21-56W	Float	A	1957-1986	o	Q	C	
32	Cochin	India	09-58N 076-16E	Float	I	1886-1891, 1955	+	Q	C	TOGA
41	Nicobar	India	07-00N 093-50E		I		o			TOGA
34	Madras	India	13-06N 080-18E	Float	I	1886-1889, 1894-1933, 1952	+	Q	C	TOGA
281	Marmagao	India	15-25N 073-48E	Float	I	1884-1888 1969-1990	+			TOGA
29	Minicoy	India	08-17N 073-03E	Float	I	1891-1895, 1963-1977	o	Q	C	TOGA

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* Another tide gauge has been established in Papeete by the University of Hawaii

NN	STATION	COUNTRY/ TERRITORY	CO-ORDINATES	TYPE OF TIDE-GAUGE	O	PERIOD OF OBSERVATION FROM - TO	EXISTING STATION ***	Q **	C *	PARTICIPATION IN OTHER INTERNATIONAL ACTIVITIES (PSMSL,TOGA, ISLPP, ITSU)
						1976				
38	Port Blair	India	11-41N 092-46E	Float	I	1952-1964				TOGA
31	Veraval	India	20-54N 70-22E	Float	I	1955-1968,	+	Q	C	TOGA
35	Vishakhapatnam	India	17-41N 083-17E	Float	I	1879-1884	+	Q	C	TOGA
						1937				
68	Ambon	Indonesia	04-20S 128-12E		P	1929-1931	O	Q	C	
49	Benoa	Indonesia	08-46S 115-13E	Float	I	1980	O			
291	Cilacap	Indonesia	07-34S 108-59E	Float	I	1980	+	Q	C	
50	Kupang	Indonesia	10-10S 123-35E		I		O			TOGA
69	Manado (Bitung)	Indonesia	01-27N 125-12E	Float	P	1985-1990,	+			TOGA
45	Padang (Telu Bayuk)	Indonesia	00-58S 100-20E	Float	I	1985	+			TOGA
48	Pelabuhan Ratu	Indonesia	07-00S 106-30E	Float	I	1985	+			
67	Sorong	Indonesia	00-53S 131-15E		I		O			
292	Surabaya	Indonesia	06-55S 112-14E	Float	P	1980	+	Q	C	
239	Malin Head	Ireland	55-22N 007-20W	Float	A	1958	+	Q	C	
240	Castletownsend	Ireland	51-32N 009-11W		A					
210	Port Royal,Kingston	Jamaica	17-56N 076-51W		A	1954-1973	+	Q	C	TOGA, PSMSL
82	Aburatsu	Japan	31-34N 131-25E	Float	P	1929	+	Q	C	ISLPP
103	Chichijima	Japan	27-05N 142-11E	Float	P	1975	+	Q	C	
88	Hakodate	Japan	41-47N 140-44E	Float	P	1955	+	Q	C	ISLPP
85	Kushimoto	Japan	33-28N 135-47E	Float	P	1951	+	Q	C	ISLPP
89	Kushiro	Japan	42-58N 144-23E	Float	P	1949	+	Q	C	ISLPP
86	Mera	Japan	34-55N 139-50E	Float	P	1930	+	Q	C	ISLPP
104	Minamitorishima	Japan	24-18N 153-58E		P	1963-1971	O	Q	C	TOGA
83	Nagasaki	Japan	32-44N 129-52E	Float	P	1961	+	Q	C	
81	Naha	Japan	26-13N 127-40E	Float	P	1966	+	Q	C	ISLPP
95	Syowa	Japan	69-00S 030-35E	Pressure	S	1976	+			
87	Ofunato	Japan	39-01N 141-45E	Float	P	1963	+	Q	C	ISLPP
8	Mombasa	Kenya	04-03S 039-40E	Float	I	1986	+			TOGA
145	Kanton, Phoenix Is.	Kiribati	02-48S 171-43W	Float + Sat	P	1975	+	Q	C	TOGA
146	Christmas, Line Is.	Kiribati	01-59N 157-28W	Float + Sat	P	1974	+	Q	C	ISLPP, TOGA
147	Fanning, Line Is.	Kiribati	03-54N 159-23W	Float	P	1975	+	Q	C	TOGA
113	Tarawa, Gilbert Is.	Kiribati	01-22N 172-56E	Float + Sat	P	1982	+	Q	C	ISLPP, TOGA
271	Fort Dauphin	Madagascar	25-01S 47-00E	Float	I					TOGA
15	Nosy-Be	Madagascar	13-24S 048-17E	Float	I	1958-1972,	+			TOGA
						1985				
43	Lumut	Malaysia	04-14N 100-11E	Float	I	1985	+	Q	C	TOGA
293	Cendering	Malaysia	05-16N 103-11E	Float	P	1985	+	Q	C	TOGA
27	Gan	Maldives	00-42S 073-10E	Float	I	1987	+			TOGA
28	Male	Maldives	04-10N 073-30E	Float	I	1987	O			TOGA
112	Majuro	Marshall Is.	07-06N 171-22E	Float + Sat	P	1975	+	Q	C	ISLPP, TOGA
110	Eniwetok	Marshall Is.	11-26N 162-23E	Float	P	1974-1979	O			
252	Nouadhibou	Mauritania	20-54N 017-01W		A	1981	O		C	TOGA
16	Agalega Is.	Mauritius	10-26S 056-45E	Pressure	I	1988	+	Q	C	TOGA
18	Port Louis Harbour	Mauritius	20-09S 057-28E	Float	I	1987	+	Q	C	TOGA
19	Rodrigues, Port Mathurin	Mauritius	19-41S 063-25E	Float	I	1987	+	Q	C	TOGA
161	Cabo San Lucas	Mexico	22-53N 109-54W	Float	P	1974	+	Q	C	TOGA, ISLPP
160	Isla Guadalupe	Mexico	28-53N 118-18W	Float	P	1977-1985	+	Q	C	TOGA
163	Manzanillo, Col.	Mexico	19-03N 104-20W	Float	P	1954-1982	+	Q	C	TOGA, ISLPP
213	Progreso, Yuc.	Mexico	21-18N 089-40W	Float	A	1952-1984	+	Q	C	ISLPP, TOGA, PSMSL
267	Acapulco, Gro.	Mexico	16-50N 099-55W	Float	P	1952-1986	+	Q	C	ISLPP, PSMSL

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162	Socorro Is.	Mexico	18-14N 111-03W	Bubbler + Sat	P	1975-1978, 1987	+	Q	C	TOGA
164	Puerto Angel	Mexico	15-39N 096-30W	Float	P	1961-1986	O	Q	C	
212	Veracruz, Ver.	Mexico	19-11N 96-07W	Float	A	1953-1985	+	Q	C	TOGA, PSMSL
282	Tan Tan	Morocco	28-30N 011-03W		A	1957-1959	O	Q	C	
11	Pemba	Mozambique	12-58S 40-29E	Float	I	1981	+			TOGA
10	Inhambane	Mozambique	23-55S 35-30E		I		+			
37	Akyab	Myanmar, Union of	20-09N 092-54E		I	1937-1942	O			
141	Moulmein	Myanmar, Union of	16-29N 097-37E		I	1954-1964				
114	Nauru	Nauru	00-32S 166-54E	Float + Sat	P	1976	+	Q	C	ISLPP, TOGA
127	Auckland-Waitemata Harbour	New Zealand	36-51S 174-46E	Float	P	1900	+	Q	C	ISLPP, TOGA
132	Balleny Is.	New Zealand	66-35S 162-50E		S		O			
129	Bluff Harbour	New Zealand	46-36S 168-21E	Float	P	1920	+	Q	C	
128	Chatham Is.	New Zealand	43-50S 176-30W		P		O			
126	Kermadec Is.	New Zealand	29-50S 178-15W		P		O			TOGA
133	Scott Is.	New Zealand	67-00S 175-00E		S		O			
101	Wellington Harbour	New Zealand	41-17S 174-47E	Float	P	1944-1986	+	Q	C	ISLPP
259	Lagos	Nigeria	06-25N 03-27E		A		+	Q	C	TOGA
118	Saipan	N. Mariana Is.	15-14N 145-44E	Float	P	1978	+	Q	C	TOGA
232	Bjornoya (Bear Is.)	Norway	74-30N 019-00E		A					
269	Bouveteya (Bouvet Is.)	Norway	54-22S 03-22E		A					
234	Rorvik	Norway	64-52N 011-15E	Float	A	1970	+	Q	C	
275	Honningsvag	Norway	70-59N 025-59E	Float	A	1970	+	Q	C	
136	Peter Is.	Norway	68-47S 090-35W		S		O			
230	Jan Mayen Is.	Norway	71-00N 008-00W		A		+			
235	Maloy	Norway	61-56N 005-07E	Float	A	1945	+	Q	C	
5	Muscat(Qaboos Port)	Oman	23-37N 058-35E	Float	I	1987	+			TOGA
4	Salalah	Oman	17-00N 054-00E		I					TOGA
30	Karachi, Manoro Is.	Pakistan	24-48N 066-58E	Float	I	1916, 1921 1936-1949,	+	Q	C	
295	Gwadar	Pakistan	25-07N 062-20E	Float	I	1986	+	Q	C	
168	Balboa	Panama	08-58N 79-36W		P	1909-1985	+			
208	Coco Solo	Panama	09-22N 079-53W		A					
63	Alotau	Papua New Guinea	10-21S 150-29E	Float	P	1984	+			operated by CSIRO, Australia TOGA
64	Vanimo	Papua New Guinea	02-41S 141-19E		P		+			
272	Daru	Papua New Guinea	09-04S 143-12E		P		O			TOGA
65	Rabaul	Papua New Guinea	04-12S 152-11E	Float + Sat	P	1974	+	Q	C	ISLPP, TOGA
173	Callao	Peru	12-03S 077-09W	Float + Sat	P	1942-1990	+		C	TOGA, Tsunami ISLPP
71	Davao, Davao Gulf	Philippines	07-05N 125-38E	Float	P	1951	+	Q	C	TOGA
70	Jolo, Sulu	Philippines	06-04N 121-00E	Float	P	1951	+	Q	C	TOGA

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72	Legaspi, Albay	Philippines	13-09N 123-45E	Float	P	1951	+	Q	C	TOGA
73	Manila, S. Harbor	Philippines	14-35N 120-50E	Float	P	1951	+	Q	C	TOGA
246	Cascais	Portugal	38-41N 009-25W	Float	A		+	Q	C	
250	Funchal (Madeira)	Portugal	32-38N 16-54W	Float	A		+	Q	C	
245	Ponta Delgada, (Azores)	Portugal	37-44N 025-40W	Float	A		+	Q	C	
244	Flores (Azores)	Portugal	39-27N 031-07W	Float	A		+	Q	C	
206	San Juan	Puerto Rico/USA	18-27N 066-05W		A	1962-1974	+			TOGA
84	Pusan	Rep. of Korea	35-06N 129-02E	Float	P	1960				
182	Acajutla	El Salvador	13-35N 089-50W		P	1962-1985	+			
260	Sao Tome	Sao Tome and Principe	00-25N 06-30E		A		O			TOGA
253	Dakar	Senegal	14-38N 17-27W		A	1957-1966				TOGA
14	Aldabra	Seychelles	09-30S 046-20E		I		O			TOGA
273	Port Victoria, Hodoul Is.	Seychelles	04-40S 055-28E	Float	I		+			TOGA
256	Aberdeen Point	Sierra Leone	08-30N 13-14W	Float	A		O	Q	C	TOGA
44	Keppel Harbour	Singapore	01-28N 103-50E	Float	I		+			TOGA
66	Honiara	Solomons	09-26S 159-57E	Float + Sat	P	1974	+	Q	C	TOGA
7	Mogadishu	Somalia	02-01N 045-20E	Float	I		O			TOGA
6	Hafun	Somalia	10-27N 051-15E		I		O			TOGA
13	Durban	(PSMSL)	29-53S 031-00E		I	1926-1982	+			
20	Marion Is.	(PSMSL)	46-53S 037-52E		I		O			
76	Port Elizabeth	(PSMSL)	34-00S 025-30E		I					
268	Simonstown	(PSMSL)	34-11S 018-26E		A	1957-1981	+			
249	Ceuta	Spain	35-54N 005-19W	Float	A	1944-1987	+	Q	C	
243	La Coruna	Spain	43-32N 008-24W	Float	A	1943-1987	+	Q	C	
251	Las Palmas, Canary Is.	Spain	28-08N 015-25W	Float	A	1949-1956, 1969-1987	+	Q	C	TOGA
33	Port of Colombo	Sri Lanka	06-56N 079-51E	Float	I	1934-1957	+			
233	Goteborg-Torshamman	Sweden	57-41N 011-48E	Float	A	1967-1986	+	Q	C	
9	Mtwara	Tanzania	10-08S 040-07E		I		O	Q	C	TOGA
297	Zanzibar	Tanzania	06-09S 039-11E	Float	I	1984	+	Q	C	
42	Ko Taphao Noi	Thailand	07-50N 098-26E	Float	I	1973	+	Q	C	
39	Ko Lak	Thailand	11-47N 099-49E	Float	P	1973	+	Q	C	
125	Tongatapu	Tonga	21-10S 175-15W		P					TOGA
203	Port of Spain	Trinidad and Tobago	10-35N 061-30W	Float & Bubbler	A	1982	+	Q	C	
121	Funafuti, Ellice Is.	Tuvalu	08-32S 179-13E	Float + Sat	P	1977	+	Q	C	ISLPP, TOGA
248	Gibraltar	U.K.	36-08N 005-21W	Float	A/M	1961	+	Q	C	PSMSL

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263	Ascension	U.K.	07-55S 014-25W	Pressure	A	1983	+	Q	C	TOGA
221	Bermuda	U.K.	32-22N 64-42W	Float	A	1932-1979	+	Q	C	TOGA, PSMSL
	St. Georges Is.									
26	Diego Garcia	U.K.	07-00S 072-30E		I	1959-1964,	+			TOGA (opera-
						1986				ted by USA)
236	Lerwick	U.K.	60-09N 001-08W	Float/Bubbler	A	1957-1989	+	Q	C	PSMSL
241	Newlyn	U.K.	50-06N 005-33W	(1) Float	A	1915-1984(1)	+	Q	C	
				(2) Bubbler		1985 (2)				
187	South Georgia	U.K.	54-15S 036-45W		A	1957-1959	O			
296	North Caicos	U.K.	22-00N 072-00W		A		O			
188	Faraday	U.K.	65-15S 064-16W		S					
264	St. Helena	U.K.	15-58S 005-42W	Pressure	A	1986	+	Q	C	TOGA
238	Stornoway	U.K.	58-12N 006-23W	(1) Float/	A	1928-1982,	+	Q	C	
				Pressure						
				(2) Bubbler		1985				
266	Tristan da Cunha	U.K.	37-03S 12-18W	Pressure	A	1986	+	Q	C	
305	Falkland Is.	U.K.	51-45S 057-56W		S	1988-	+			
	(Malvinas)									
	South Orkney Is.	U.K.	60-42S 045-36W		S		O			
220	Ventnor, N.J.	U.S.A.	39-20N 74-29W	Float	A	1911-1985	+	Q	C	
	(Atlantic City)									
219	Cape Hatteras N.C.	U.S.A.	35-13N 75-38W	Float	A	1973	+	Q	C	
107	French Frigate	U.S.A.	23-52N 166-17W	Float + Sat	P	1975	+	Q	C	ISLPP, TOGA
	Shoal H.									
217	Galveston, TX	U.S.A.	29-17N 94-47W	Float	A	1957-1986	+	Q	C	
149	Guam, Marianas	U.S.A.	13-26N 144-39E	Float	P	1948	+	Q	C	
108	Honolulu, HI	U.S.A.	21-18N 157-52W	Float	P	1905	+	Q	C	ISLPP, TOGA
109	Johnston Island	U.S.A.	16-44N 169-32W	Float	P	1950	+	Q	C	ISLPP, TOGA
216	Key West, FL	U.S.A.	24-33N 81-48W	Float	A	1926-1979	+	Q	C	PSMSL
111	Kwajalein Island	U.S.A.	08-44N 167-44E	Float	P	1946	+	Q	C	TOGA
	Marshall Is.									
218	Miami (Haulover	U.S.A.	25-46N 80-08W	Float	A	1981	+	Q	C	PSMSL
	Pier)									
134	Mc Murdo	U.S.A.	77-51S 166-40E		S		O			
106	Midway Island	U.S.A.	28-13N 177-22W	Float	P	1947	+	Q	C	TOGA, ISLPP
144	Pago Pago, Samoa	U.S.A.	14-17S 170-41W	Float	P	1948	+	Q	C	TOGA
158	San Francisco, CA	U.S.A.	37-48N 122-28W	Float	P	1854	+	Q	C	ISLPP
154	Sitka, AK	U.S.A.	57-03N 135-20W	Float	P	1938	+	Q	C	ISLPP
157	South Beach, OR	U.S.A.	44-38N 124-03W	Float	P	1962	+	Q	C	ISLPP
285	Nawiliwili, HI	U.S.A.	21-57N 159-22W	Float	P	1955	+	Q	C	
102	Unalaska, AK	U.S.A.	53-53N 166-32W	Float	P	1955	+	Q	C	ISLPP
105	Wake Island	U.S.A.	19-17N 166-37E	Float	P	1950	+	Q	C	ISLPP, TOGA
286	Kahului, HI	U.S.A.	20-54N 156-28W	Float	P	1951	+	Q	C	
287	Hilo, HI	U.S.A.	19-44N 155-04W	Float	P	1946	+	Q	C	
288	Pensacola, FL	U.S.A.	30-24N 87-13W	Float	A	1923-1980	+	Q	C	PSMSL
100	Sand Point, AK	U.S.A.	55-20N 160-30W	Float	P		+	Q	C	
150	Seward, AK	U.S.A.	60-07N 149-26W	Float	P	1923-1986	+	Q	C	
159	Scripps Pier, CA	U.S.A.	32-52N 117-16W	Float	P	1924-1986	+	Q	C	
289	Ft. Pulaski, GA	U.S.A.	32-02N 080-54W	Float	A	1935-1986	+	Q	C	
183	Palmer (Antarct.)	U.S.A.	64-46S 064-03W		S		O			
116	Truk Atoll,	U.S.A.	07-27N 151-51E	Float	P	1953	+	Q	C	ISLPP
	Carolines	(Fed Micronesia)								
151	Prudhoe Bay, AK	U.S.A.	70-23N 148-30W	Float	Ar	1976	+	Q	C	
290	Newport, RI	U.S.A.	41-30N 71-20W	Float	A	1930-1980	+	Q	C	
301	Palmyra	U.S.A.	05-52N 162-06W		P	1949-1981	O			
302	Adak	U.S.A.	51-52N 176-38W	Float	P	1943-1986	+	Q	C	ISLPP
303	Massacre Bay,	U.S.A.	52-50N 173-12E		P	1943-1972	O			
	Attu Is.									
74	Nome	U.S.A.	64-30N 165-30W		P		O			

NN	STATION	COUNTRY/ TERRITORY	CO-ORDINATES		TYPE OF TIDE-GAUGE	O	PERIOD OF OBSERVATION FROM - TO	EXISTING STATION ***	Q **	C *	IN OTHER INTERNATIONAL ACTIVITIES (PSMSL,TOGA, ISLPP, ITSU)
231	Barentsburg, Spitsbergen	U.S.S.R.	78-04N	14-15E		Ar	1948-1982	+	Q	C	
270	Novolazarevskaya	U.S.S.R.	70-46S	011-50E		S					
25	Mirny	U.S.S.R.	66-33S	093-01E		S					
294	Molodezhnaya	U.S.S.R.	67-40S	045-50E		S					
274	Murmansk	U.S.S.R.	68-58N	033-03E	Float	A	1959-1982	+	Q	C	
97	Kaliningrad	U.S.S.R.	54-42N	020-29E	Float	A	1959	+	Q	C	
98	Tuapse	U.S.S.R.	44-06N	039-04E	Float	A	1959	+	Q	C	
92	Nagaevo Bay	U.S.S.R.	59-44N	150-42E	Float	P	1959	+	Q	C	
93	Petropavlovsk-Kamchatsky	U.S.S.R.	52-59N	158-39E	Float	P	1959	+	Q	C	ISLPP
91	Leningradskay	U.S.S.R.	69-30S	159-23E		S					
135	Russkaya	U.S.S.R.	74-46S	136-51W		S					
99	Russkaya Gavan	U.S.S.R.	76-14N	62-35E		A	1959	+	Q	C	
90	Yuzno Kurilsk	U.S.S.R.	44-01N	145-52E		P	1959	+	Q	C	ISLPP
300	Montevideo	Uruguay	34-54S	056-15W	Float	A		+	Q	C	
298	Aves Is.	Venezuela	15-39N	063-35W	Float	A	1987	+	Q	C	
299	La Orchila	Venezuela	11-48N	066-08W		A	1987	+	Q	C	
75	Qui Nhon	Vietnam	13-46N	109-13E	Float	P	1987	O	Q	C	TOGA
3	Aden	P.D.R. Yemen	12-47N	044-59E		I	1879-1969	O			TOGA
306	Socotra Is.	P.D.R. Yemen	12-30N	054-00E		I		O			TOGA

Ocean: P - Pacific; I - Indian; A - Atlantic; S - Southern; Ar - Arctic; M - Mediterranean Sea; RS - Red Sea

* C - the station committed to GLOSS

** Q - questionnaire has been received

*** + station exist; O station does not exist

Type of tide gauge is given as either float, bubbler or pressure. Where satellite transmission facilities are available this is indicated by '+ Sat' in the Type of Tide Gauge column.

5. Sea Level Data Collection and Exchange

5.1 GENERAL SCHEME FOR DATA COLLECTION AND EXCHANGE

One of the major functions of GLOSS is to provide sea level data in a unified format and using agreed procedures for international exchange through existing IODE and IGOSS mechanisms. Therefore these activities should be co-ordinated with the IOC Committee on International Oceanographic Data and Information Exchange (IODE) and the Joint IOC-WMO Committee on Integrated Global Ocean Services Systems (IGOSS) as well as with the relevant international bodies dealing with planning and co-ordination of the TOGA and WOCE Programmes (SCOR-IOC CCCO, WMO-IOC Intergovernmental TOGA Board, IOC-WMO Intergovernmental WOCE Panel).

The flow of sea level data from the GLOSS network includes the following major streams:

(i) Submission of monthly mean sea level values to the Permanent Service for Mean Sea Level (PSMSL); hourly and monthly mean values should be made available by national authorities as required for scientific analysis. Recommendations for submission of data to PSMSL and the format for submission of monthly and annual sea level data to PSMSL are shown in Annex VII.

(ii) Submission of sea level data on real or near-real-time basis to specialized International Sea Level Data Analysis Centres, established within the framework of international research and monitoring programmes:

a) TOGA Sea Level Centre (Global Tropical zone to 30° latitude) (Format and Procedures for sea level data submission are shown in Annex VIII).

b) Specialized Oceanographic Centre for the IGOSS Sea Level Programme in the Pacific Ocean (Format and Procedures for sea level data submission are shown in Annex-VIII).

c) Specialized Oceanographic Centre for the IGOSS Sea Level Pilot Project in the North and Tropical Atlantic.

d) WOCE Sea Level Data Assembly Centres (DACs).

e) Submission of data to RNODC's for sea level data, which can be established in support of projects or specific regional sea level activities (as for example MEDALPEX and POEM, see Annex IV).

(iii) Final submission of sea level data from the GLOSS network and specialized sea level analysis centres and their archiving in the World Data Centres (Oceanography).

(iv) Dissemination of sea level data and products by specialized sea level data centres to the participating countries, other international centres and scientists.

(v) Regular monitoring of GLOSS sea level data flow and preparation of inventories of sea level data.

Attention must be given to the quality control of sea level data, and data exchanged through the above procedures should be accompanied by necessary documentation so that users can evaluate its reliability. The timeliness of data submission is also very important. Near-real-time and non-real-time data flow are shown separately in the diagram (Figure 10).

This diagram describes the principle flow of GLOSS sea level data, showing relationship between various national and international centres. More specific descriptions of data flow and data collection/exchange procedures are developed for individual research projects, as shown, for example in the Implementation Plan for TOGA.

5.2 FORMATS FOR DATA EXCHANGE

The participants of GLOSS should use unified formats for data collection, exchange and archiving. Recommended formats for sea level data submission to PSMSL, SOC for ISLPP and TOGA Sea Level Centre are shown in Annexes VII and VIII.

The Committee for IODE has developed and approved the IOC General Magnetic tape format for the International Exchange of Oceanographic Data (GF3). Furthermore, a Standard GF3 Subset for Mean Sea Level (PSMSL) has been developed and approved. It is the format in which the PSMSL and WDCs (Oceanography) prefer to receive and transmit monthly mean sea level data (Annex VII).

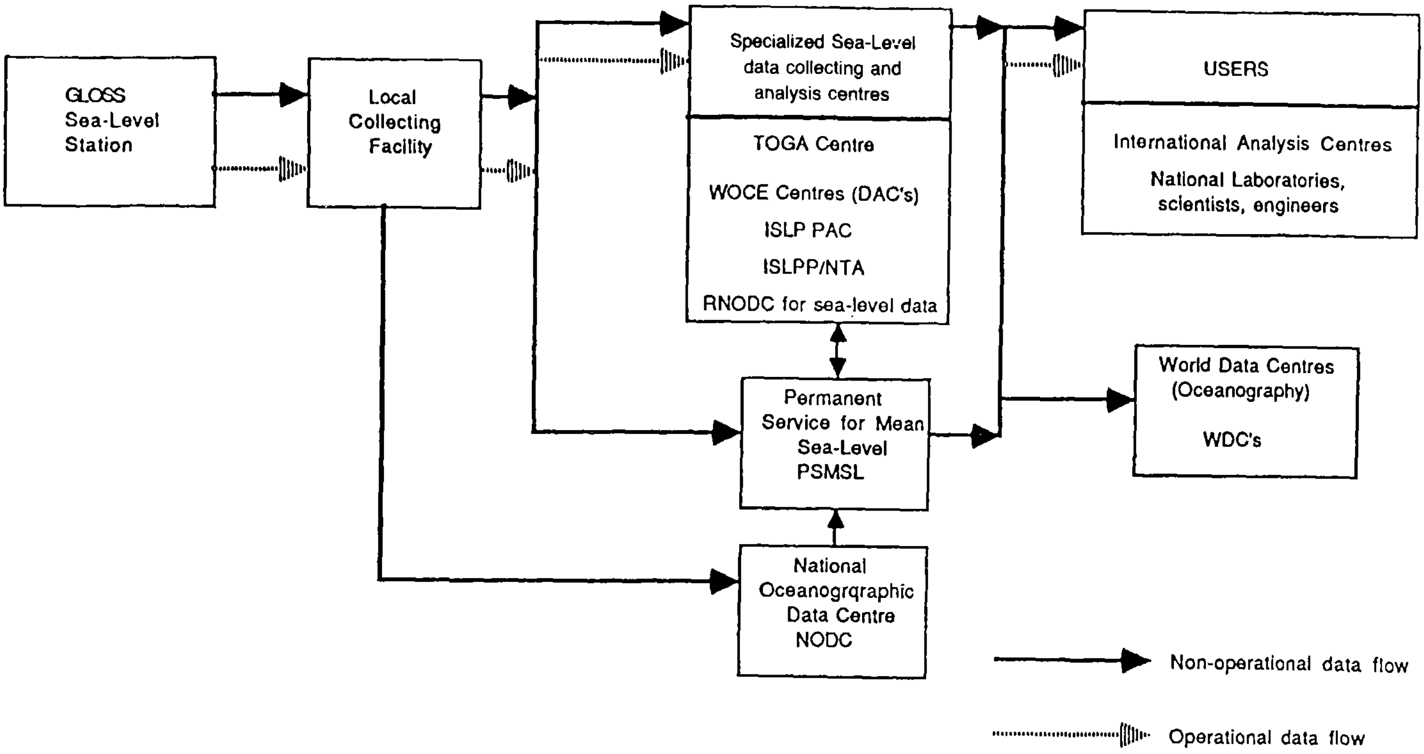

Figure 10. Flow of GLOSS Sea-Level Data.

6. Sea Level Products Preparation and Dissemination

One of the primary functions of GLOSS is to organize the preparation of various sea level products: in the form of data extracts, data summaries, data catalogues, sea level charts and other forms of data analysis required for various international programmes and studies and wide distribution to Member States, research centres and individual scientists.

There are several international centres involved in sea level data collection and dissemination, and in the preparation of sea level products.

6.1 THE PERMANENT SERVICE FOR MEAN SEA LEVEL

The Permanent Service for Mean Sea Level (PSMSL) was established in 1933 at Bidston Observatory, Merseyside, UK. It is a member of the Federation of Astronomical and Geophysical Services (FAGS) of the International Council of Scientific Unions (ICSU). Under the aegis of the International Association for the Physical Sciences of the Ocean (IAPSO), the PSMSL is charged with the collection, dissemination and analysis of mean sea level data. The activities of PSMSL are supported through FAGS and through the Intergovernmental Oceanographic Commission (IOC), and by the United Kingdom Natural Environment Research Council (NERC). PSMSL still operates at Bidston Observatory, hosted by the NERC Proudman Oceanographic Laboratory.

Monthly and annual mean values of sea level are sent to PSMSL by national authorities, together with details of gauge location, missing days, and a definition of the datum to which the measurements are referred. Received data are checked for consistency. If possible, values are reduced to Revised Local Reference (RLR); this involves the identification of a stable, permanent bench mark close to the tide-gauge and the reduction of all data to a single datum level which is referred to this benchmark. This ensures continuity with subsequent data. The computer data bank at present holds series from over 1,000 stations. There are 518 stations for which the PSMSL has at least 20 years of data, and 115 stations have data from before 1900. The most recent year for which PSMSL holds data from GLOSS stations is shown in Table 2.

Data and other information are available free of charge to the scientific community. Updated listings can be sent, and data are available on magnetic tape in the GF3 approved format. A catalogue of all data held by PSMSL was published in 1987, and is available on request.[28]

PSMSL also provides information and advice to organizations interested in measuring sea level. Details of different types of tide-gauges and suitable locations can be given, and advice on data reduction and filtering methods is available.

PSMSL sometimes acts as a sea level data co-ordinator for special international projects such as the 1981-1982 Mediterranean Experiment MEDALPEX.[127]

Analyses produced from the mean sea level data bank include statistics of local and global trends, seasonal variations and low frequency variations. They also include the identification of anomalously high or low levels which may occur in particular areas. The aim is to produce summaries which may be used for direct comparison with data from other scientific studies, such as climatology and earthquake prediction.

6.2 TOGA SEA LEVEL CENTRE

The Tropical Ocean - Global Atmosphere programme (TOGA) has established a TOGA Sea Level Centre at the University of Hawaii. The purpose of the centre is to collect all sea level data in the TOGA area between 30° N and 30° S during the ten years of the TOGA project, 1985 to 1995, and make them available for research. The TOGA Sea Level Centre will also obtain and archive past sea level data for the same region, as long as they are made available from the originators. The importance of sea level data has been enhanced by the need for calibration of satellite altimeters like GEOSAT and for the TOPEX mission planned for WOCE. The creation of GLOSS and the requirements of CCCO for climate monitoring have placed additional emphasis on the value of sea level information. The TOGA Sea Level Centre is funded by NOAA through the U.S. TOGA Office. It co-operates closely with NODCs and the World Data Centres.

The scientific requirements of TOGA specify the need for daily mean sea-level values at all observing stations. Because scientific study of sea-level demands different types of filtering of the original data, the need for daily mean sea level requires the acquisition of hourly or more frequent original data. After acquisition the sea level data are subjected to a stringent quality control before they are filtered and archived.

Data acquisition during the first year of operation of the Sea Level Centre has been concentrated on the Pacific Ocean, where an extensive sea level network exists, and where most of the ongoing TOGA research is concentrated. During the second year acquisition has been expanded to the Indian Ocean, where a new sea level network is being established for TOGA. In the following years data from the Atlantic Ocean will also be included into the archive.

Data are being made available to scientific investigators in two different modes. Some sea level stations, presently 26, transmit their data by satellite. Data from these stations are available within about four weeks, although they may be subject to later correction to absolute levels.

The TOGA Sea Level Centre also handles the preparation of the monthly synoptic sea level maps for the IGOSS Sea Level Programme (ISLP). As part of this project monthly mean sea level data from 78 stations in the Pacific are also available within one month.

The incoming sea level data are usually received, quality controlled and filtered in batches of one year. The Sea Level Centre maintains archives of high frequency, hourly, daily and monthly sea level values on magnetic tapes. These data sets are available on request, and 34 such requests from various agencies and scientists have been filed during 1987.

6.3 WOCE SEA LEVEL CENTRES

The flow of sea level data for the WOCE Project will include hourly (or more frequent) transmissions of tide-gauge measurements on a real-time basis, using satellite data collection links or other appropriate communications, to one or more specialized WOCE Sea Level Data Centres for global analysis and merging with satellite altimetry data and computing the state of the world ocean circulation and the production of further derived products. The activities of the WOCE sea level centres are described in the WOCE Implementation Plan prepared by the Scientific Steering Group for WOCE which was published in the second half of 1988.[128]

6.4 SPECIALIZED OCEANOGRAPHIC CENTRE (SOC) FOR IGOSS SEA LEVEL PROGRAMME IN THE PACIFIC

A Specialized Oceanographic Centre (SOC) for the IGOSS Sea Level Pilot Project (ISLPP) was established in March 1984 at the University of Hawaii under the direction of Prof. Klaus Wyrtki by joint action of the Intergovernmental Oceanographic Commission (IOC) and the World Meteorological Organization (WMO). The government of the United States has funded the centre for its intended operational period of five years. The IGOSS Sea Level Pilot Project is co-located with the sea level centre for the Tropical Ocean Global Atmosphere project (TOGA).

The purpose of the IGOSS Sea Level Pilot Project is to make monthly mean sea level data available to users in a timely fashion and to generate products which are valuable for scientific analysis of climate related ocean processes.

As of July 1987 the number of participating countries has increased to 30 and a total of 78 stations participate in the project. The monthly maps are published about 28 days after the end of each month. They are distributed to a mailing list of about 140 users, and the national contacts of several participating countries distribute them further. The maps are also reproduced in the monthly bulletin of the Climate Analysis Centre of NOAA and in the monthly bulletin of the World Climate Programme published by WMO.

The SOC also prepares at quarterly intervals an index of upper layer volume for the equatorial Pacific Ocean, which is used as an indicator for the development of El Niño and is reproduced in the Climate Analysis Bulletin of NOAA. It is also intended to produce indices of the strength of equatorial currents in the Pacific on the basis of sea level differences between selected stations.

The data from the 78 sea level stations participating in ISLPP are available for the years 1974 to 1986 on magnetic tape to interested parties. They are also part of the data archive of the TOGA Sea Level Centre. Samples of the products issued by the SOC for ISLPP are shown in Annex VIII Recommendations for sea level submission.

The IOC-WMO Committee for IGOSS at its fifth session (November 1988) recommended that the Pilot Project became a permanent operational programme of IGOSS under the title IGOSS Sea-Level Programme in the Pacific (ISLP/PAC).

6.5 SPECIALIZED OCEANOGRAPHIC CENTRE FOR THE IGOSS SEA LEVEL PILOT PROJECT IN THE NORTH AND TROPICAL ATLANTIC (ISLPP/NTA)

In 1988, the IOC Executive Council approved the proposal to launch the IGOSS Sea Level Pilot Project for the North and Tropical Atlantic in order to collect monthly mean sea level data from sea level stations of the North and Tropical Atlantic (to 30° S) and to produce a monthly sea level maps for this area. The Marine Environmental Data Service (MEDS) of Canada will act as SOC for the ISLPP in the North and Tropical Atlantic.[27, 33, 91]

The basic component of ISLPP/NTA will be the receiving, processing and quality control of the monthly mean sea level data from existing and future permanent gauging stations of Member States of the North and Tropical Atlantic Ocean Basin. The area covered extends from 65° N to 30° S, to include the TOGA area, and from 100° W to 20° E. In the beginning the project will involve the participation of 24 different Member States located around the North and Tropical Atlantic Ocean Basin.

The basic parameter required is the monthly mean sea level recorded at various tide stations in the North and Tropical Atlantic Ocean Basin. As there are many ways to compute such a parameter, Member States will be requested to indicate which of the following methods has been used to determine the data set from each gauging station.

(i) Arithmetic mean of hourly values.
(ii) Low pass numerical filter of hourly values.
(iii) Arithmetic mean of paired high and low tidal levels.

The time periods to calculate the mean will be the regular calendar months. At the end of each month, the participating Member States will send to MEDS the computed monthly mean sea level and the number of values used to compute that mean for each station under the responsibility of that country. The number of values to compute the mean is required only to provide an indication of its reliability. The station and month identification are required together with the mean sea level values.

The following is an illustration of the suggested table that can be used for the data to be sent to the ISLPP/NTA Data Centre (MEDS). The month and year are indicated at the top of the form. The station identification includes the GLOSS number (NN), the station name and the name of the responsible country for that station. Following the identification information are the monthly mean values for that station month and the number of values used to compute the monthly mean. In the sample shown below the monthly mean has been computed from the hourly values.

Mean Sea Level Data for January 1989

NN = 222 Station is Halifax Country is Canada
Monthly mean = 1.13 number of values = 744
NN = 223 Station is Sr. John's Country is Canada
Monthly mean = 1.15 number of values = 744

The IOC-WMO Committee for IGOSS at its fifth session recommended to initiate this Pilot Project in 1989.

6.6 INTERNATIONAL HYDROGRAPHIC ORGANIZATION

Many of the Hydrographic Authorities of the 54 Member States of IHO are actively concerned with the observation of tidal levels, both for the application of tidal height to reduce sounding measurements to Chart Datum, and for prediction of tidal heights for the information of mariners using nautical charts.

Much of the information acquired has been analyzed and is stored in the IHO Tidal Data Constituent Bank. The data is available from this bank in accordance with agreed procedures, and the bank is regularly updated as new constituents become available. In some cases, the Hydrographic authorities are the national focal point for tidal matters.[53, 54, 60, 65, 69, 102, 103]

Table 2. Most Recent Year of Sea-Level Data submitted to PSMSL from GLOSS Stations (prepared by PSMSL, 1990)

COLUMN 1 = GLOSS NUMBER
COLUMN 2 = STATION NAME
COLUMN 3 = RESPONSIBLE COUNTRY
COLUMN 4 = COMMITTED TO GLOSS FLAG
COLUMN 5/6 = PSMSL COUNTRY/STATION CODE
COLUMN 7 = LATEST DATA IN PSMSL DATABASE

262	LOBITO	ANGOLA			
185	BAHIA ESPERANZA	ARGENTINA	C	A /001	1978
186	BAHIA SCOTIA	ARGENTINA	C		
184	JUBANY	ARGENTINA	C		
192	MAR DEL PLATA	ARGENTINA	C	860/111	1946
190	PUERTO DESEADO	ARGENTINA	C	860/011	1937
191	PUERTO MADRYN	ARGENTINA	C	860/031	1984
181	USHUAIA	ARGENTINA	C	860/001	1969
61	BOOBY IS.	AUSTRALIA	C	680/025	1980
57	BOTANY BAY, SYDNEY	AUSTRALIA	C	680/141	1989
58	BRISBANE	AUSTRALIA	C	680/078	1984
40	BROOME	AUSTRALIA	C	680/486	1983
59	BUNDABERG	AUSTRALIA	C	680/073	1985
52	CARNARVON	AUSTRALIA	C	680/476	1984
278	CASEY	AUSTRALIA	C		
47	CHRISTMAS IS.	AUSTRALIA	C	563/001	1966
46	COCOS IS.(KEELING)	AUSTRALIA	C	680/501	1969
62	DARWIN	AUSTRALIA	C	680/011	1984
277	DAVIS	AUSTRALIA	C		
54	ESPERANCE	AUSTRALIA	C	680/446	1985
53	FREMANTLE	AUSTRALIA	C	680/471	1985
56	HOBART	AUSTRALIA	C	680/201	1985
148	LORD HOWE IS.	AUSTRALIA	C	680/121	1970
130	MACQUARIE IS.	AUSTRALIA	C	680/208	1974
22	MAWSON	AUSTRALIA	C		
124	NORFOLK IS.	AUSTRALIA	C	680/091	1965
55	PORT ADELAIDE	AUSTRALIA	C	680/311	1985
51	PORT HEDLAND	AUSTRALIA	C	680/481	1985
60	TOWNSVILLE	AUSTRALIA	C	680/052	1960
279	WILLIS IS.	AUSTRALIA	C	680/039	1981
211	BIMINI	BAHAMAS			
12	SAN SALVADOR	BAHAMAS			
36	CHITTAGONG	BANGLADESH		510/025	1968
120	MALAKAL	BELAU	C	710/021	1987
194	CANANEIA	BRAZIL	C	874/051	1986
198	FERNANDA DE NORONHA	BRAZIL	C	874/141	1972
196	ITAPARICA	BRAZIL	C		
200	PORTO DE ITAQUI	BRAZIL	C		
197	PORTO DE NATAL	BRAZIL	C		
193	PORTO DE RIO GRANDE	BRAZIL	C	860/004	1976
201	PORTO DE SANTANA	BRAZIL	C	874/171	1984
195	RIO DE JANEIRO	BRAZIL	C	874/091	1968
199	ST. PETER & ST. PAUL ROCKS	BRAZIL			
265	TRINIDADE IS.	BRAZIL	C	874/101	1975
37	AKYAB	BURMA		530/001	1942
141	MOULMEIN	BURMA		530/021	1964
280	DOUALA	CAMEROON			
226	ALERT	CANADA	C	970/162	1977
222	HALIFAX	CANADA	C	970/011	1984
153	LITTLE CORNWALLIS IS.	CANADA	C	970/151	1977
224	NAIN	CANADA	C	970/134	1983
155	PRINCE RUPERT	CANADA	C	822/001	1984
152	SACHS HARBOUR	CANADA	C	970/203	1982
223	ST. JOHNS, NEWFLND.	CANADA	C	970/121	1984

156	TOFINO	CANADA	C 822/116	1984
254	PORTO GRANDE (ST. VICENTE)	CAPE VERDE	C 380/001	1950
174	ANTOFAGASTA	CHILE	C 850/012	1987
189	BASE ANTARCTICA (CAPT. PRAT)	CHILE	C	
176	JUAN FERNANDEZ IS.	CHILE	C 850/037	1984
137	PASCUA IS.	CHILE	C 810/002	1984
178	PUERTO MONTT	CHILE	C 850/051	1970
180	PUERTO WILLIAMS	CHILE	C 850/081	1970
179	PUNTA ARENAS	CHILE	C 850/061	1970
177	SAN FELIX IS.	CHILE	C	
175	VALPARISO	CHILE	C 850/032	1987
79	DALIAN	CHINA	C 610/044	1979
94	KANMEN	CHINA	C 610/016	1989
283	LUSI	CHINA	C 610/032	1989
247	XIAMEN	CHINA	C 610/005	1989
78	ZHAPO	CHINA	C 610/002	1989
170	BUENAVENTURA	COLOMBIA	C 842/011	1988
207	CARTAGENA	COLOMBIA	C 902/021	1988
171	TUMACO	COLOMBIA	C 842/021	1988
261	POINTE NOIRE	CONGO	424/021	1979
143	PENRHYN	COOK ISLANDS	C 775/001	1986
139	RAROTONGA	COOK ISLANDS	C 785/001	1987
166	I. DEL COCO	COSTA RICA		
167	QUEPOS	COSTA RICA	836/011	1969
257	ABIDJAN	COTE D'IVOIRE	C 405/001	1976
214	CABO SAN ANTONIO	CUBA	C 930/071	1986
276	GIBARA	CUBA	C 930/031	1986
215	SIBONEY	CUBA	C 930/016	1987
228	ANGMAGSSALIK, GREENLAND	DENMARK	C	
225	GODTHAB/NUUK, GREENLAND	DENMARK	C 980/031	1986
227	NORD, GREENLAND	DENMARK	C	
237	THORSHAVN, FAEROES	DENMARK	C 015/011	1986
2	DJIBOUTI	DJIBOUTI	475/001	1972
169	BALTRA, GALAPAGOS IS.	ECUADOR	C 845/034	1987
172	LA LIBERTAD	ECUADOR	C 845/012	1989
80	PORT SAID	EGYPT	330/001	1946
1	SUEZ	EGYPT	330/041	1986
182	ACAJUTLA	EL SALVADOR		
117	KAPINGAMARANGI, CAROLINE IS.	FED.MICRONESIA	C 710/026	1987
115	PONAPE, CAROLINE IS.	FED.MICRONESIA	C 710/031	1987
116	TRUK, CAROLINE IS.	FED.MICRONESIA	C 710/001	1988
119	YAP, CAROLINE IS.	FED.MICRONESIA	C 710/011	1987
284	CUXHAVEN	FED.REP.GERMANY	C 140/011	1986
122	SUVA	FIJI	C 742/012	1987
242	BREST	FRANCE	C 190/091	1987
202	CAYENNE, FRENCH GUIANA	FRANCE		
165	CLIPPERTON IS.	FRANCE		
21	CROZET IS.	FRANCE		
131	DUMONT D'URVILLE	FRANCE		
96	DZAOUDZI (MAYOTTE)	FRANCE	C	
23	KERGUELEN IS.	FRANCE		
204	LE ROBERT, MARTINIQUE	FRANCE	C 912/001	1984
205	MARSEILLE	FRANCE	C 230/051	1989
140	MATAVAI, TAHITI	FRANCE	C 780/011	1987
123	NOUMEA, NEW CALEDONIA	FRANCE	C 740/011	1987
142	NUKU HIVA, MARQUESAS IS.	FRANCE	C 805/011	1986
17	PTE DES GALETS, REUNION IS.	FRANCE	C 451/001	1985
138	RIKITEA, GAMBIER IS.	FRANCE	C 808/001	1987
24	ST. PAUL IS.	FRANCE		
258	TEMA	GHANA	C 410/016	1982
255	CONAKRY	GUINEA		
209	PORT-AU-PRINCE/LES GAYES	HAITI	934/011	1961
77	QUARRY BAY	HONG KONG	C 611/010	1988
229	REYKJAVIK	ICELAND	C 010/001	1986

32	COCHIN	INDIA	C 500/081	1986
34	MADRAS	INDIA	C 500/091	1986
281	MARMAGAO	INDIA	500/065	1980
29	MINICOY, LACCADIVE IS.	INDIA	C 455/011	1977
41	NICOBAR	INDIA		
38	PORT BLAIR, ANDAMAN IS.	INDIA	540/001	1964
31	VERAVAL	INDIA	C 500/021	1983
35	VISHAKHAPATNAM	INDIA	C 500/101	1986
68	AMBON	INDONESIA	C 590/001	1931
49	BENOA	INDONESIA		
291	CILACAP	INDONESIA	C 560/121	1931
50	KUPANG,TIMOR	INDONESIA		
69	MANADO (BITUNG)	INDONESIA	580/012	1988
45	PADANG (TELU BAYUK)	INDONESIA	560/031	1931
48	PELABUHAN RATU	INDONESIA	560/111	1931
67	SORONG	INDONESIA		
292	SURABAYA	INDONESIA	C 560/161	1931
240	CASTLETOWNSEND	IRELAND		
239	MALIN HEAD	IRELAND	C 175/011	1988
210	PORT ROYAL, KINGSTON	JAMAICA	C 932/011	1969
82	ABURATSU	JAPAN	C 645/021	1988
103	CHICHIJIMA	JAPAN	C 648/001	1988
88	HAKODATE	JAPAN	C 641/031	1988
85	KUSHIMOTO	JAPAN	C 642/141	1988
89	KUSHIRO	JAPAN	C 641/022	1988
86	MERA	JAPAN	C 642/061	1988
104	MINAMI-TORI-SHIMA	JAPAN	C	
83	NAGASAKI	JAPAN	C 645/064	1988
81	NAHA	JAPAN	C 646/024	1988
87	OFUNATO	JAPAN	C 642/022	1988
95	SYOWA	JAPAN		
8	MOMBASA	KENYA	470/001	1987
145	CANTON IS. PHOENIX IS.	KIRIBATI	C 750/012	1987
146	CHRISTMAS IS. LINE IS.	KIRIBATI	C 770/022	1987
147	FANNING IS. LINE IS.	KIRIBATI	C 770/012	1987
113	TARAWA, GILBERT IS.	KIRIBATI	C 730/007	1987
84	PUSAN	KOREA	620/046	1989
271	FORT DAUPHIN (TAOLANARO)	MADAGASCAR		
15	NOSY-BE	MADAGASCAR	440/002	1989
293	CENDERING/KUALA TERENGGANU	MALAYSIA	C 550/017	1986
43	PENGKALAN/TLDM/LUMUT	MALAYSIA	C 550/005	1986
27	GAN	MALDIVES	454/001	1963
28	MALE	MALDIVES		
110	ENIWETOK	MARSHALL IS.	720/001	1972
112	MAJURO	MARSHALL IS.	C 720/016	1987
252	NOUADHIBOU (CAP BLANC)	MAURITANIA	C	
16	AGALEGA	MAURITIUS	C	
18	PORT LOUIS	MAURITIUS	C 450/011	1989
19	RODRIGUES, PORT MATHURIN	MAURITIUS	C	
267	ACAPULCO, GRO.	MEXICO	C 830/081	1988
161	CABO SAN LUCAS	MEXICO	C 830/020	1981
160	ISLA GUADALUPE	MEXICO	C 830/012	1981
163	MANZANILLO,COL.	MEXICO	C 830/071	1982
213	PROGRESO, YUC.	MEXICO	C 920/001	1985
164	PUERTO ANGEL	MEXICO	C 830/086	1986
162	SOCORRO IS.	MEXICO	C 830/061	1959
212	VERACRUZ, VER.	MEXICO	C 920/041	1985
282	TAN TAN	MOROCCO	C	
10	INHAMBANE	MOZAMBIQUE		
11	PEMBA	MOZAMBIQUE		
118	SAIPAN	N.MARIANA IS.	C 700/011	1987
114	NAURU, GILBERT IS.	NAURU	C 715/001	1987
127	AUCKLAND-WAITEMATA HBR.	NEW ZEALAND	C 690/001	1989
132	BALLENY IS.	NEW ZEALAND		

129	BLUFF HBR.	NEW ZEALAND	C 690/041	1989
128	CHATHAM IS.	NEW ZEALAND		
126	KERMADEC IS. (RAOUL)	NEW ZEALAND		
133	SCOTT IS.	NEW ZEALAND		
101	WELLINGTON	NEW ZEALAND	C 690/011	1989
259	LAGOS	NIGERIA	C 420/003	1941
232	BJORNOYA (BEAR ISLAND)	NORWAY		
269	BOUVETEYA (BOUVET IS.)	NORWAY		
275	HONNINGSVAG	NORWAY	C 040/015	1989
230	JAN MAYEN IS.	NORWAY	012/001	1983
235	MALOY	NORWAY	C 040/211	1989
136	PETER IS.	NORWAY		
234	RORVIK	NORWAY	C 040/136	1989
5	MUSCAT (QABOOS PORT)	OMAN		
4	SALALAH	OMAN		
3	ADEN	P.D.R. YEMEN	485/001	1969
304	SOCOTRA IS.	P.D.R. YEMEN		
295	GWADAR	PAKISTAN	C	
30	KARACHI, MANORO IS.	PAKISTAN	C 490/021	1985
168	BALBOA	PANAMA	840/012	1985
208	COCO SOLO	PANAMA		
63	ALOTAU	PAPUA NEW GUINEA	670/006	1985
272	DARU	PAPUA NEW GUINEA		
65	RABAUL	PAPUA NEW GUINEA	C 670/021	1987
64	VANIMO	PAPUA NEW GUINEA		
173	CALLAO	PERU	C 848/032	1988
71	DAVAO	PHILLIPINES	C 660/121	1989
70	JOLO	PHILLIPINES	C 660/141	1989
72	LEGASPI	PHILLIPINES	C 660/021	1989
73	MANILA	PHILLIPINES	C 660/011	1989
246	CASCAIS	PORTUGAL	C 210/021	1987
244	FLORES, AZORES	PORTUGAL	C 360/041	1989
250	FUNCHAL, MADEIRA	PORTUGAL	C 365/001	1986
245	PONTA DELGADO, AZORES	PORTUGAL	C 360/001	1986
206	SAN JUAN	PUERTO RICO/USA	938/021	1988
260	SAO TOME	SAO TOME/PRINCIPE		
253	DAKAR	SENEGAL	390/001	1966
14	ALDABRA	SEYCHELLES	441/001	1977
273	PORT VICTORIA, HODOUL IS.	SEYCHELLES	442/001	1979
256	ABERDEEN POINT	SIERRA LEONE	C	
44	SINGAPORE	SINGAPORE	555/051	1988
66	HONIARA	SOLOMON IS.	C 734/002	1987
6	HAFUN (DANTE)	SOMALIA		
7	MOGADISHU	SOMALIA		
13	DURBAN	SOUTH AFRICA	430/091	1988
20	MARION IS.	SOUTH AFRICA		
76	PORT ELIZABETH	SOUTH AFRICA	430/088	1988
268	SIMONSTOWN	SOUTH AFRICA	430/061	1988
249	CEUTA (SPANISH N. AFRICA)	SPAIN	C 340/001	1964
243	LA CORUNA	SPAIN	C 200/030	1987
251	LAS PALMAS, CANARY IS.	SPAIN	C	
33	COLOMBO	SRI LANKA	520/001	1979
233	GOTEBORG	SWEDEN	C 050/032	1986
9	MTWARA	TANZANIA	C 460/001	1962
297	ZANZIBAR	TANZANIA	C 460/016	1989
39	KO LAK	THAILAND	C 600/021	1987
42	KO TAPHAO NOI	THAILAND	C 600/001	1986
125	TONGATAPU	TONGA		
203	PORT OF SPAIN	TRINIDAD AND TOBAGO	C 890/001	1988
121	FUNAFUTI, ELLICE IS.	TUVALA	C 732/011	1986
263	ASCENSION	UK	C	
221	BERMUDA, ST.GEORGES IS.	UK	C 950/011	1988
26	DIEGO-GARCIA IS.	UK	453/001	1964
266	EDINBURGH(TRISTAN DA CUNHA)	UK	C	

188	FARADAY (ANTARCTICA)	UK	A /003	1983
248	GIBRALTAR	UK	215/001	1988
236	LERWICK	UK	C 170/001	1988
241	NEWLYN	UK	C 170/161	1988
296	NORTH CAICOS	UK		
306	SIGNY, SOUTH ORKNEY ILS.	UK		
187	SOUTH GEORGIA (S.ATLANTIC)	UK		
264	ST. HELENA	UK	C	
305	STANLEY, FALKLAND IS.	UK		
238	STORNOWAY	UK	C 170/251	1988
300	MONTEVIDEO	URUGUAY	C 870/011	1971
302	ADAK, ALEUTIAN IS.	USA	C 821/003	1988
149	APRA HARBOUR,GUAM,MARIANAS	USA	C 700/001	1988
219	CAPE HATTERAS, N.C.	USA	C 960/063	1988
289	FORT PULASKI, GA.	USA	C 960/031	1988
107	FRENCH FRIGATE SHOALS, H.IS.	USA	C 760/016	1986
217	GALVESTON	USA	C 940/007	1988
287	HILO, HAWAII, HAW.IS.	USA	C 760/061	1988
108	HONOLULU, HAWAIIAN IS.	USA	C 760/031	1988
109	JOHNSTON IS. HAWAIIAN IS.	USA	C 760/011	1988
286	KAHULUI HARBOR,MAUI, HAW.IS.	USA	C 760/051	1988
216	KEY WEST	USA	C 940/071	1988
111	KWAJALEIN, MARSHALL IS.	USA	C 720/011	1988
303	MASSACRE BAY,ATTU IS.,ALASKA	USA	820/001	1966
134	MCMURDO (ANTARCTICA)	USA	A /061	1985
218	MIAMI (HAULOVER PIER)	USA	C 960/002	1988
106	MIDWAY IS. HAWAIIAN IS.	USA	C 760/001	1988
285	NAWILIWILI, KAUAI, HAW.IS.	USA	C 760/021	1988
290	NEWPORT, RI.	USA	C 960/161	1988
74	NOME	USA		
144	PAGO PAGO, AMERICAN SAMOA	USA	C 745/001	1988
183	PALMER (ANTARCTICA)	USA		
301	PALMYRA IS., LINE IS.	USA	770/001	1957
288	PENSACOLA, FLORIDA	USA	C 940/041	1988
151	PRUDHOE BAY, ALASKA	USA	C	
159	SAN DIEGO	USA	C 823/071	1988
158	SAN FRANCISCO	USA	C 823/031	1988
100	SAND POINT, ALASKA	USA	C 821/006	1988
150	SEWARD, ALASKA	USA	C 821/017	1988
154	SITKA, ALASKA	USA	C 821/031	1988
157	SOUTH BEACH,OREGON	USA	C 823/016	1984
102	UNALASKA, ALEUTIAN IS.	USA	C 820/021	1988
220	VENTNOR (ATLANTIC CITY),N.J.	USA	C 960/092	1988
105	WAKE IS. MARSHALL IS.	USA	C 720/021	1988
231	BARENTSBURG (SPITSBERGEN)	USSR	C 025/001	1989
97	KALININGRAD	USSR	C 080/181	1986
91	LENINGRADSKAY (ANTARCTICA)	USSR		
25	MIRNY (ANTARCTICA)	USSR		
294	MOLODEZHNAYA (ANTARCTICA)	USSR		
274	MURMANSK	USSR	C 030/018	1989
92	NAGAEVO BAY	USSR	C 630/011	1989
270	NOVOLAZAREVSKAYA (ANTARCTIC)	USSR		
93	PETROPAVLOVSK-KAMCHATSKY	USSR	C 630/021	1989
98	PORT TUAPSE, BLACK SEA	USSR	C 300/001	1989
135	RUSSKAYA	USSR		
99	RUSSKAYA GAVAN	USSR	C 030/001	1989
90	YUZHNO KURILSK	USSR	C 630/001	1989
298	AVES IS.	VENEZUELA	C	
299	LA ORCHILA	VENEZUELA	C	
75	QUI NHON	VIETNAM	C	

7. Development Components

In discussing the Global Sea Level Observing System the IOC emphasized that it would require a strong TEMA component (TEMA is a Joint-Unesco-IOC activity dealing with Training, Education and Mutual Assistance in the field of ocean sciences). The IOC urged Member States to assist developing countries through TEMA and/or bilateral and multilateral assistance mechanisms, to enable them to participate actively in GLOSS.

TEMA activities related to GLOSS include:
(i) provision of instruments and their spare parts;
(ii) assistance in selection of sites for GLOSS stations;
(iii) assistance in installation of tide gauges;
iv) assistance in training of technicians and sea level specialists;
(v) support for attendance at international seminars and meetings;
(vi) provision of documents related to GLOSS.

This assistance can be provided in 2 different ways:
(i) allocations to GLOSS from voluntary contributions to the IOC Trust Fund in accordance with Rule of Procedure No. 55;[18]
(ii) through the IOC Voluntary Co-operation Programme (IOC-VCP).[19]

The co-ordination of those activities will be undertaken by the IOC Secretariat, under TEMA activities, in co-operation with the Unesco Division of Marine Sciences.

Since 1985 several countries have already provided such assistance through IOC or on bilateral/multilateral basis:
(i) the United States of America has assisted in the installation of about 20 tide gauges in the Pacific and Indian Oceans;
(ii) the United Kingdom has organized sea level training courses at Bidston Observatory annually since 1983 with the support of IOC;
(iii) the People's Republic of China organized a sea level training course in 1984, and has offered 2 tide gauges for developing countries;
(iv) Portugal is assisting Cape Verde, Saõ Tome and Principe and Mozambique in setting up their GLOSS stations;
(v) France organized in 1990 a sea level training course for French speaking countries;
(vi) Sweden has offered 10 tide gauges for developing countries;
(vii) Australia is assisting the Philippines, Malaysia, Indonesia, Singapore and Thailand in setting up sea level stations;
(viii) the Federal Republic of Germany has employed a consultant to assist in the installation and repair of tide gauges.

Such assistance is needed for many Member States especially in the IOCEA and IOCARIBE regions. Sea level training courses need to be continued, for at least the next 5 years, for English, French and Spanish speaking countries, in order to ensure proper functioning of the GLOSS stations.

Member States addressing requests for assistance in setting up GLOSS stations should give as many details as possible regarding the type of tide gauge required, detailed description of the installation site, the construction of a stilling well and recording equipment shelter, and the type of training required.

The responsibility of the recipient country includes maintenance of the GLOSS tide gauge(s), submission of sea level data for international exchange, provision of support for a foreign consultant/expert dealing with the installation of a tide gauge. This includes local transport, assisting with customs procedures for importing tide gauges, the name and address of the national agency and person responsible for local arrangements and other financial and material support to establish or reactivate a GLOSS sea level station.

Requests for assistance for the training of specialists/technicians in sea level measurements and interpretation should be accompanied by a Curriculum Vitae of the proposed candidate and a statement of the type of training required and language used by the trainee.

Upon receipt of the request with the above details, the IOC will then address this request to the potential donor countries.

At the request of the IOC, a Manual on Sea Level Measurement and Interpretation has been prepared by the Institute of Oceanographic Sciences of the United Kingdom. It is published in English, French, Russian and Spanish. Translation of this Manual into other languages is highly desirable in order to unify the procedures for sea level measurements.[16] Portugal arranged its translation into Portuguese language.

8. International Co-ordination and Management Mechanism

Operation of GLOSS as an international system requires an appropriate international mechanism (see Annex IX).

8.1 NATIONAL AND INTERNATIONAL CONTACT POINTS FOR GLOSS

The system of National Contact Point is a basic element of the international co-ordinating mechanism. The National Contact Point is designated by Member States and notified to the Secretariat in order to promote the implementation of GLOSS at a national level and to effect liaison with the IOC on all matters related to GLOSS.

The specific responsibilities of the National GLOSS Contacts are to:
(i) promote implementation of GLOSS at national level;
(ii) liaise with IOC and the PSMSL on all matters related to GLOSS;
(iii) act as contact points for data requests, i.e. to link between requests for data and data products in the country;
(iv) liaise with national sea-level scientists, promote GLOSS and be aware of sea-level studies.

Regional contact points for GLOSS can be designated for liaison with the IOC Secretariat and the IOC Group on GLOSS if a regional sea level project relevant to GLOSS is established.

Regional GLOSS Co-ordinator: the Regional Co-ordinator should be active in sea-level studies and the Group of Experts on GLOSS should give advice to IOC Regional subsidiary bodies on suitable candidates. Continuing close collaboration must be maintained between the Group of Experts and the Regional bodies.

The specific responsibilities of GLOSS Regional Co-ordinators are:
(i) to liaise with PSMSL, national GLOSS Contacts and Technical Secretary;
(ii) to encourage the adoption of international standards for data within the region;
(iii) to organize yearly meetings of national GLOSS contacts;
(iv) to make regional member countries aware of the usefulness of GLOSS;
(v) to assist the GLOSS Technical Secretary in identifying national GLOSS contacts;
(vi) to maintain a correspondence file for the Region.

A GLOSS Technical Secretary, with the primary role as GLOSS Co-ordinator is located in the IOC Secretariat, at least for the initiation/implementation stage, with two-way communication with national and regional GLOSS management, and other international organizations such as IAPSO, UNEP.

The specific responsibilities of the GLOSS Technical Secretary would be to:
(i) make sure nationally-committed GLOSS gauges are operational;
(ii) service needs of Group of Experts on GLOSS;
(iii) manage IOC budget for GLOSS;
(iv) act as broker for aid, organize consultant visits, donor/recipient equipment;
(v) oversee publication and distribution of any GLOSS publications.

The List of National and International Contact Points for GLOSS is shown in Annex III.

8.2 THE IOC GROUP OF EXPERTS ON GLOSS

The GLOSS Implementation Plan will need regular updating and proper co-ordination with other international research and service oriented programmes.

Initially these functions were being carried out by the IOC Task Team on GLOSS. In 1988 the IOC Executive Council[27] decided to establish an IOC Group of Experts on GLOSS as a subsidiary body of the IOC Committee on Ocean Processes and Climate with the following Terms of Reference:

The Group of Experts shall:
(i) advise the Committee on Ocean Processes and Climate on the implementation of the GLOSS system, at global and regional levels, based on sea level networks and related data flow and products;
(ii) update the GLOSS Implementation Plan at least every two years and formulate recommendations thereon to the IOC governing bodies;
(iii) ensure proper liaison with other international research programmes (such as TOGA, WOCE) and monitoring activities, with relevant bodies of IOC (Committee for IODE, Joint IOC-WMO Committee for IGOSS, regional subsidiary bodies of the Commission, International Co-ordination Group for ITSU, Joint SCOR-IOC CCCO), and, other international organizations concerned, such as IHO, UNEP and the IUGG, as appropriate;
(iv) provide advice on the development of TEMA components of GLOSS, regarding training of specialists, provision of instruments, their installation and maintenance, and data evaluation and interpretation;
(v) advise the Committee on Ocean Processes and Climate on the gradual integration of GLOSS into a possible future global ocean observing system;
(vi) report periodically to the IOC Committee on Ocean Processes and Climate.

9. Action Plan

Member States of IOC agreeing to participate in GLOSS are required to:
(i) have all operating GLOSS stations reporting monthly mean sea level data values to the Permanent Service for Mean Sea Level (PSMSL) within one year of acquisition;
(ii) make hourly values of sea level data available for international exchange;
(iii) upgrade existing stations which are below GLOSS standards;
(iv) install new stations in consultation with the IOC Group of Experts on GLOSS;
(v) give the highest priority to the implementation of those stations in GLOSS which are required for international programmes, for example TOGA and WOCE, and to provide sea level data to the TOGA/WOCE Sea Level Centres in accordance with the requirements of those programmes;
(vi) provide assistance to other member states on a bilateral and multilateral basis. Assistance may also be provided by Member States through the IOC Voluntary Co-operation Programme thus enabling other Member States to participate in GLOSS;
(vii) keep the IOC Secretariat informed on all changes with regard to the state of GLOSS stations, data submission and National and International GLOSS Contacts.

The GLOSS Implementation Plan indicates the stations that will constitute the GLOSS network. Member States responsible for these stations have been requested, and in majority of the cases have already made a commitment, to establish fully qualified GLOSS stations. They have also expressed their commitment towards eventually establishing fully qualified GLOSS stations, where they do not already exist, and to ensure that their operation and functioning are in accordance with the provisions of the Plan.

The IOC through the Group of Experts on GLOSS and the Secretariat ensures regular review of the GLOSS development, implementation and co-ordination with other international programmes.

The IOC regional bodies are requested when developing regional sea level networks required for regional scientific and practical applications, to take into account the GLOSS requirements and to provide proper co-ordination with GLOSS development.

Member States having necessary logistic support are encouraged to establish and maintain GLOSS stations in Antarctica. The publication Report of the Workshop on Sea Level Measurements in Hostile Conditions[122] provides relevant advice on suitable methods and technology for sea level measurements in hostile conditions.

The IOC Committee for IODE and the Joint IOC-WMO Committee for IGOSS are requested to assist in developing proper data management schemes and formats for GLOSS data collection, exchange and archiving.

The IOC Secretariat will prepare and distribute to national GLOSS contacts and others on a regular basis, an information bulletin on GLOSS development (GLOSS Newsletter). The GLOSS Handbook will be also prepared and regularly updated, as a comprehensive data base of information about the GLOSS stations.

Annex I

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Annex II

Intergovernmental Oceanographic Commission Questionnaire on Participation in the Global Sea-Level Observing System*

Country .... Date ....

Ocean/Sea ....

1. Global Sea-Level Station ....
   1.1 Name of the location ....
   1.2 Geographical Co-ordinates: Lat ....
   Long ....
2. Participation in GLOSS yes no
   ** 2.1 ....
   *** 2.2 ....
3. State of tide-gauge
   3.1 Existing/in operation yes no
   3.2 Need assistance yes no
   3.3 Need new technology yes no
4. Type of gauge ....
5. Period of observation (from) .... (to) ....
6. Method of data reduction:
   6.1 tabulated from analogous charts ....
   6.2 automatic digitization from analogous charts ....
   6.3 direct computer entry and editing ....
7. Data available:
   7.1 hourly yes .... no ....
   7.2 daily yes .... no ....
   7.3 monthly yes .... no ....
   7.4 computer compatible yes .... no ....
   (i.e. computer punched cards or magnetic tapes)
8. Means of data transmission (mail, cable, telex, radio, etc.) ....
9. Interest in receiving sea-level data from other countries or PSMSL ....
   9.1 Indicate the oceanic areas of interest: ....
10. National Contact Point and/or National Responsible Agency (name, address): ....

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* To be filled for each sea-level station.
Please attach a map, showing location of the station.

** 2.1 Possibility to provide data on real or near-real-time basis.

*** 2.2 Participation in other international programmes (TOGA, WOCE, ISLPP, Tsunami Warning System, etc.) please indicate.

Annex III

List of National and International Contact Points for GLOSS

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UNION OF SOVIET SOCIALIST REPUBLICS	Mr. B. Himich USSR State Committee for Hydrometeorology 12 P. Morozov Street MOSCOW 123376 Tlx: 411117 RUMS SU
	Director, All-Union Research Institute of Hydrometeorological Information - World Data Centre 6 Korolev Street OBNINSK, KALUZHSKAYA OBLAST 249020 Tlx: 412633 INFOR SU
	Arctic and Antarctic Research Institute 38 Bering Street LENINGRAD 199226 Tel: 352-03-19 Tlx: 121423 NILAS SU FAX: (812) 352.26.88
	Dr. P. Agafonov Secretary Oceanographic Committee of the Soviet Union 11 Gorky Street MOSCOW 103009 Tel: 229.25.72 Tlx: 411241 SU Tlg: MOSCOW OCEAN
UNITED KINGDOM OF GREAT BRITAIN & NORTHERN IRELAND	Mr. G.A. Alcock Proudman Oceanographic Laboratory Bidston Observatory Birkenhead, MERSEYSIDE L43 7RA Tel: 051 653 86 33 Tlx: 628591 OCEAN G Fax: 051 653 62 69
	Dr. David T. Pugh Institute of Oceanographic Sciences Brook Road WORMLEY Godalming, SURREY GU8 5UB Tel: (428) 79 41 41 Tlx: 858833 OCEANS G Tlm: D.PUGH FAX: (428) 79 30 66
UNITED STATES OF AMERICA	Prof. Klaus Wyrtki University of Hawaii at Manoa Department of Oceanography 1000 Pope Road MSB 307 HONOLULU, HAWAII 96822 Tel: (808) 948.76.33 Tlx: 650 2478678 Tlm: K.WYRTKI
	Dr. Bruce C. Douglas Chief, Geodetic Research and Development Laboratory NOAA/National Ocean Service Room 424 11400 Rockville Pike ROCKVILLE, MD 20852 USA Tel: (301) 320.31.45 Fax: 301.468.57.14 Tlm: NOAA.GEOSAT

COUNTRY/TERRITORY	CONTACT POINT
URUGUAY	Jorge di Lorenzi Servicio de Oceanografia, Hidrografia, Meteorlogia de la Armada Capurro 980 MONTEVIDEO
VENEZUELA	Instituto Oceanografico de Venezuela Universidad de Oriente Apartado de Correos 245 CUMANA Tlx: 93152 UDONS VE Capitan Jesus E. Moretti-Russian Direccion de Hidrografia y Navigacion Apartado Postal 6745 CARACAS
VIET NAM	Mr. Dang Ngoc Thann Centre National de Recherches Scientifiques du Viet Nam HO CHI MINH CITY Hydrometeorological Service No. 4 Dang Thai Than St. HANOI Département Général de la Météorologie Tong cue Khi tuong Thuy van HANOI
YEMEN, REPUBLIC OF	Mr. A. Hammadi Director Marine Science and Resources Research Centre Ministry of Fish Wealth P.O. Box 1242 ADEN
YUGOSLAVIA	Institute of Oceanography and Fisheries P.O. Box 114 58001 SPLIT

INTERNATIONAL CONTACTS

Permanent Service for Mean Sea Level (PSMSL) Director, PSMSL	Dr. P. Woodworth Bidston Observatory Birkenhead, MERSEYSIDE L43 7RA United Kingdom Tel: 051-6538633 Tlx: 628591 OCEAN G Tlm: PSMSL.POL
WOCE Sea Level Data Assembly Center(DAC)	Dr. M. Jones Director, British Oceanographic Data Center Bidston Observatory Birkenhead, MERSEYSIDE L43 7RA United Kingdom Tel: 0516538633 Tlx: 628591 OCEAN G Tlm: BODC.UK Fax: 0516536269
Specialized Oceanographic Center for the IGOSS Sea-Level Programme in the Pacific	Prof. K. Wyrtki Director University of Hawaii 1000 Pope Road Honolulu, HAWAII 96822 United States of America Tel: (808) 948 76.33 Tlx: 650-2478678 Tlm: K.WYRTKI
TOGA Sea Level Center	Prof. K. Wyrtki Director (same address as above)
WOCE Sea Level Data Assembly Center	Prof. K. Wyrtki (DAC) (same address as above)
Specialized Oceanographic Center for the IGOSS Sea-Level Pilot Project in the North and Tropical Atlantic	Dr. A. Bolduc MEDS Department of Fisheries & Oceans 200 Kent Street Ottawa, ONTARIO K1A OE6 Canada Tel: 613-990.02.97 Tlx: 534228 Tlm: A.BOLDUC Fax: 6139906050
International Hydrographic Organization	IHO 7, avenue Président J.F. Kennedy B.P. 445 MC 98011 Monaco Cedex Principauté de Monaco Tel: (33) 93.50.65.87 Tlx: 479164 MC-INHORG

IGOSS Pilot Project on Altimetric Sea-Surface Topography Data	The Project Manager Dr. Robert E. Cheney Office of Charting and Geodetic Services National Ocean Service, NOAA N/CG1, Room 426A, Rockwall Bldg. Rockville, MD 20852 United States of America Tel: 3014438556 Tlm: NOAA.GEOSAT
IOCARIBE	Dr. George A. Maul NOAA Atlantic Oceanographic and Meteorological Laboratory 4301 Rickenbacker Causeway MIAMI, FL 33149 United States of America
IOCEA	Dr. S. Konate Directeur Centre de Recherches Scientifiques de Conakry-Rogbané B.P. 561 Rogbané, CONAKRY Guinea
IOCINCWIO	Mr. Mika Odido Regional Co-ordinator Kenya Marine and Fisheries Research Institute P.O. Box 81651 MOMBASA Kenya Tel: Mombasa 471366 Tlx: 21115
Intergovernmental Oceanographic Commission (IOC)	Dr. A. Tolkachev Senior Assistant Secretary SC/IOC Unesco 1 rue Miollis 75015 PARIS France Tel: (1) 45.68.39.78 Tlx: 204461F Paris Tlm: IOC.SECRETARIAT Fax: 33 (1) 40 56 93 16

Annex IV

Other Programmes with Sea-Level Components

THE PACIFIC OCEAN

The IOC Tsunami Warning System in the Pacific combines selected sea-level gauges from several countries into an ocean-wide network for the dedicated purpose of detecting tsunamis: once a seismic event is indicated, sea-level stations are interrogated to determine whether a tsunami has been generated, and if so, warnings are issued to areas at risk. Stations in this system are also capable of providing regular sea-level records for other applications if the records are suitably reduced. The Catalogue of tide-gauges in the Pacific[10] provides a list of sources of tidal data which can be used in postevent studies of tsunamis and in other branches of oceanographic study (Figure 1).

IGOSS SEA-LEVEL PROGRAMME IN THE PACIFIC

In 1984, an IGOSS Sea-Level Pilot Project in the Pacific (ISLPP) was launched. The purpose of the ISLPP is to make monthly mean sea-level data available to users in a timely fashion and to generate products which are valuable for scientific analysis of climate related ocean processes. Sea-level data from 78 stations in the Pacific are provided on a regular (monthly) basis to an IGOSS Specialized Oceanographic Centre (SOC) at the University of Hawaii at Manoa. Since 1984, the SOC for ISLPP has produced and widely distributed maps of monthly mean sea-level anomaly charts (Figure 2) and since 1988 maps of sea-level corrected for atmospheric pressure (Figure 3). The SOC also prepares an index of upper layer volume for the equatorial Pacific Ocean at quarterly intervals (Figure 4). The data from the 78 sea-level stations participating in ISLPP are available for the years 1974 to 1986 on magnetic tape to interested parties. They are also part of the data archive of the TOGA Sea-Level Centre.[119, 123]

In 1989, the IOC-WMO Committee at its fifth session recommended that the Pilot Project become a permanent operational programme of IGOSS under the title IGOSS Sea-Level Programme in the Pacific (ISLP/PAC.).

Samples of sea-level products issued by the SOC for ISLP/PAC are shown on the following pages (Figures 2, 3, 4).

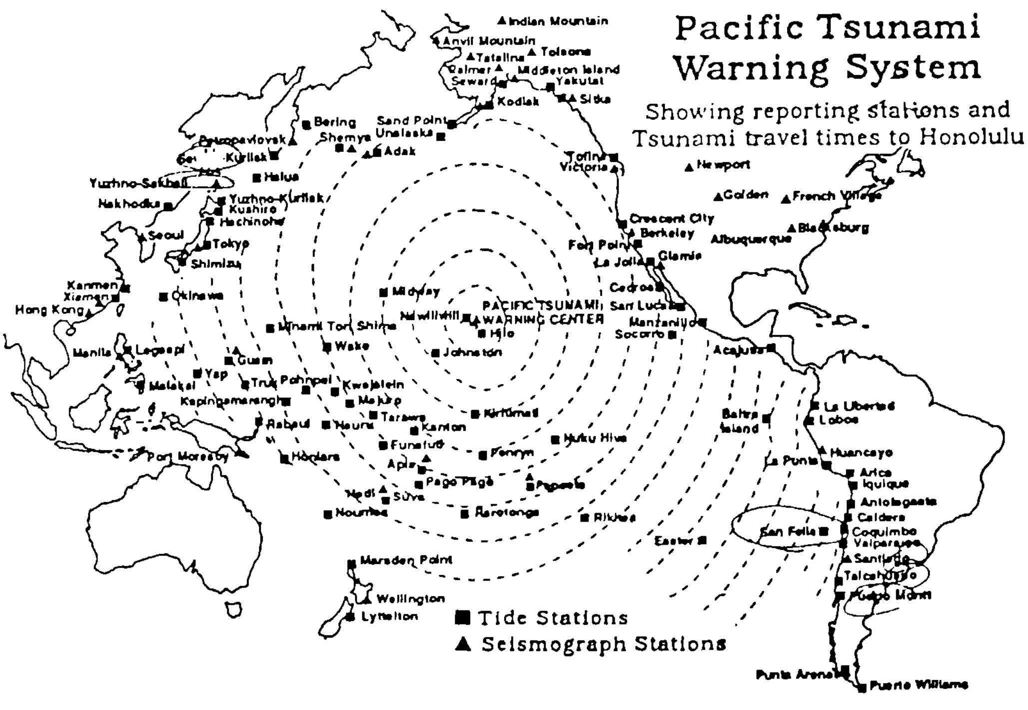


Figure 1. Location of Tsunami Warning System network and the tide network in the Pacific (by N.M. Ridgway).

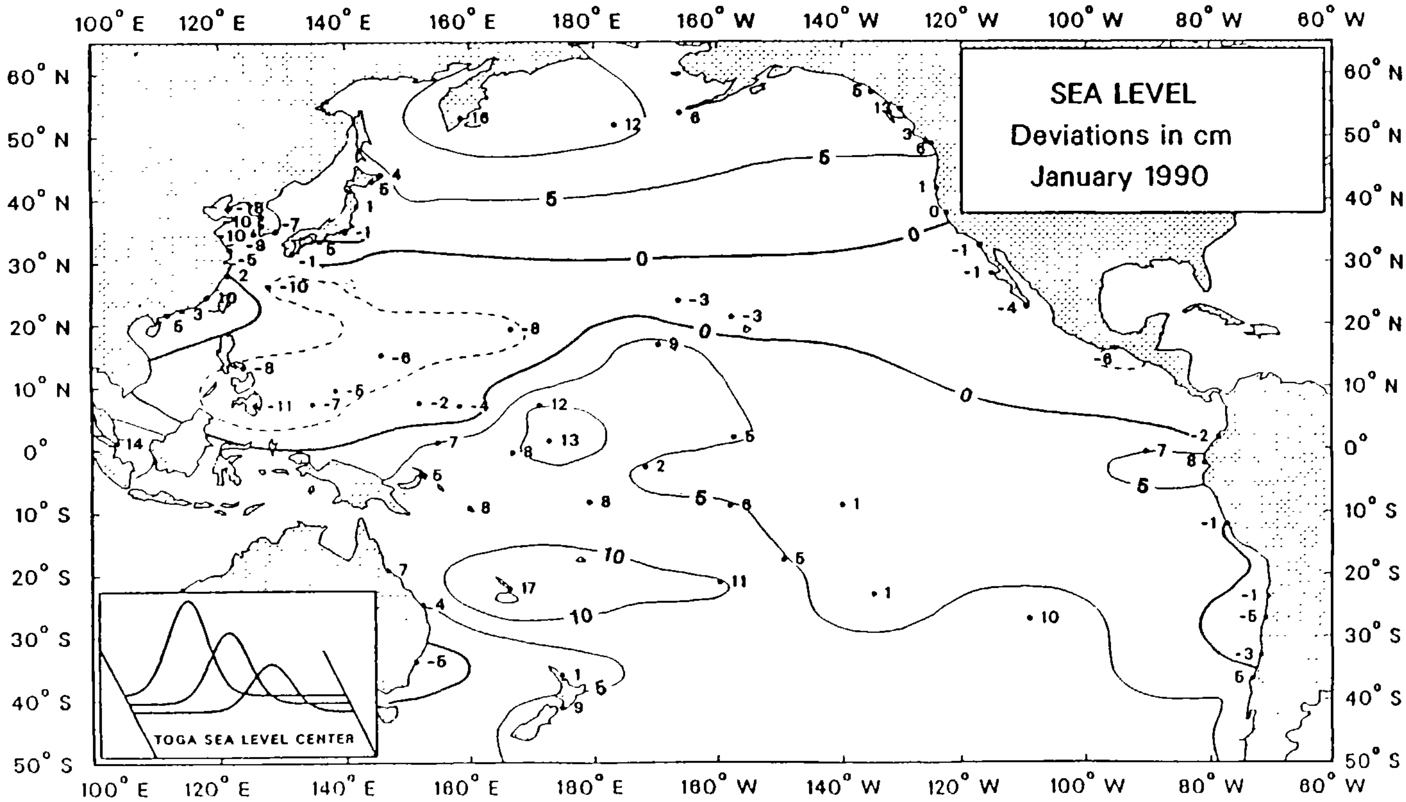


Figure 2. Deviation of sea level from the 1975 to 1986 mean sea level.

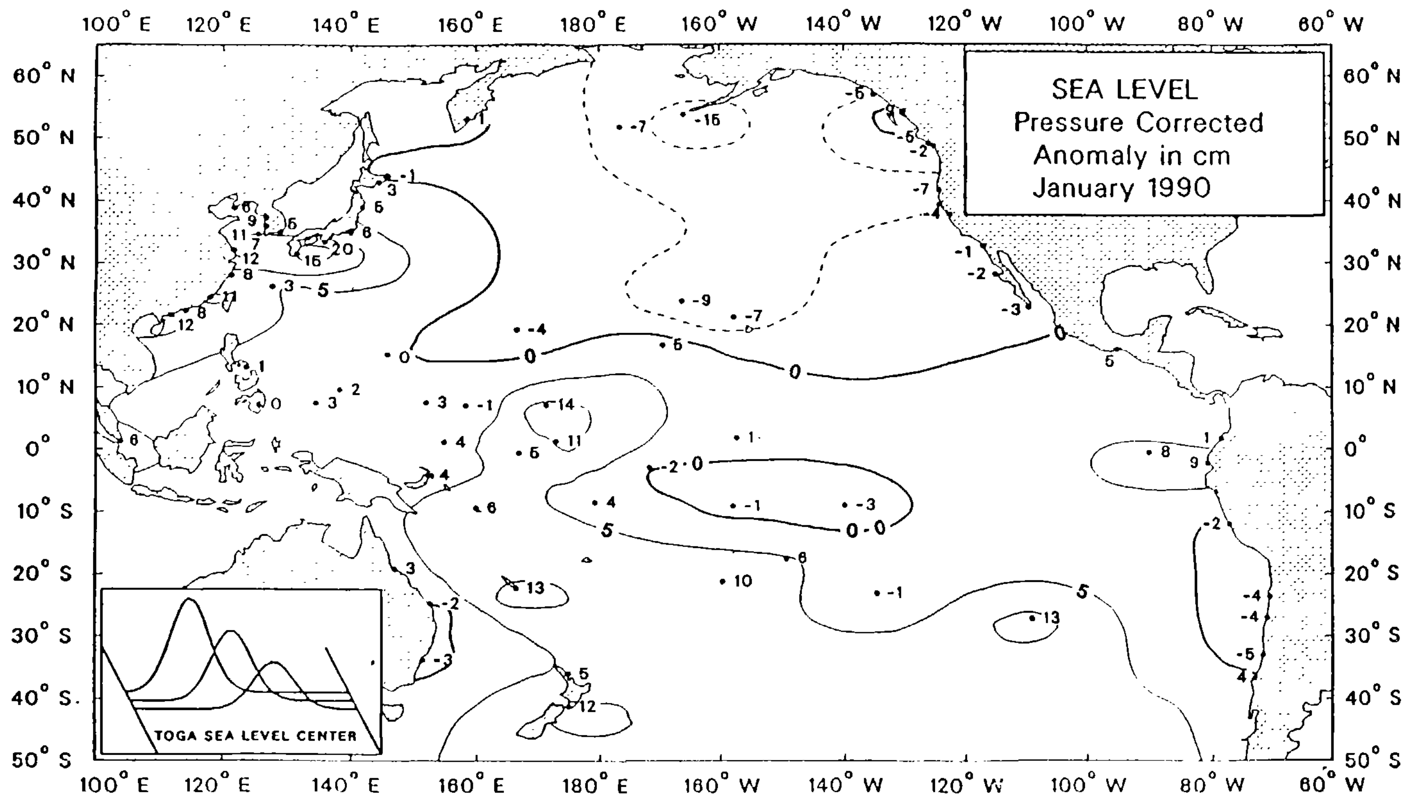


Figure 3. Anomaly of sea level from the 1975 to 1986 mean JANUARY sea level adjusted for atmospheric pressure.

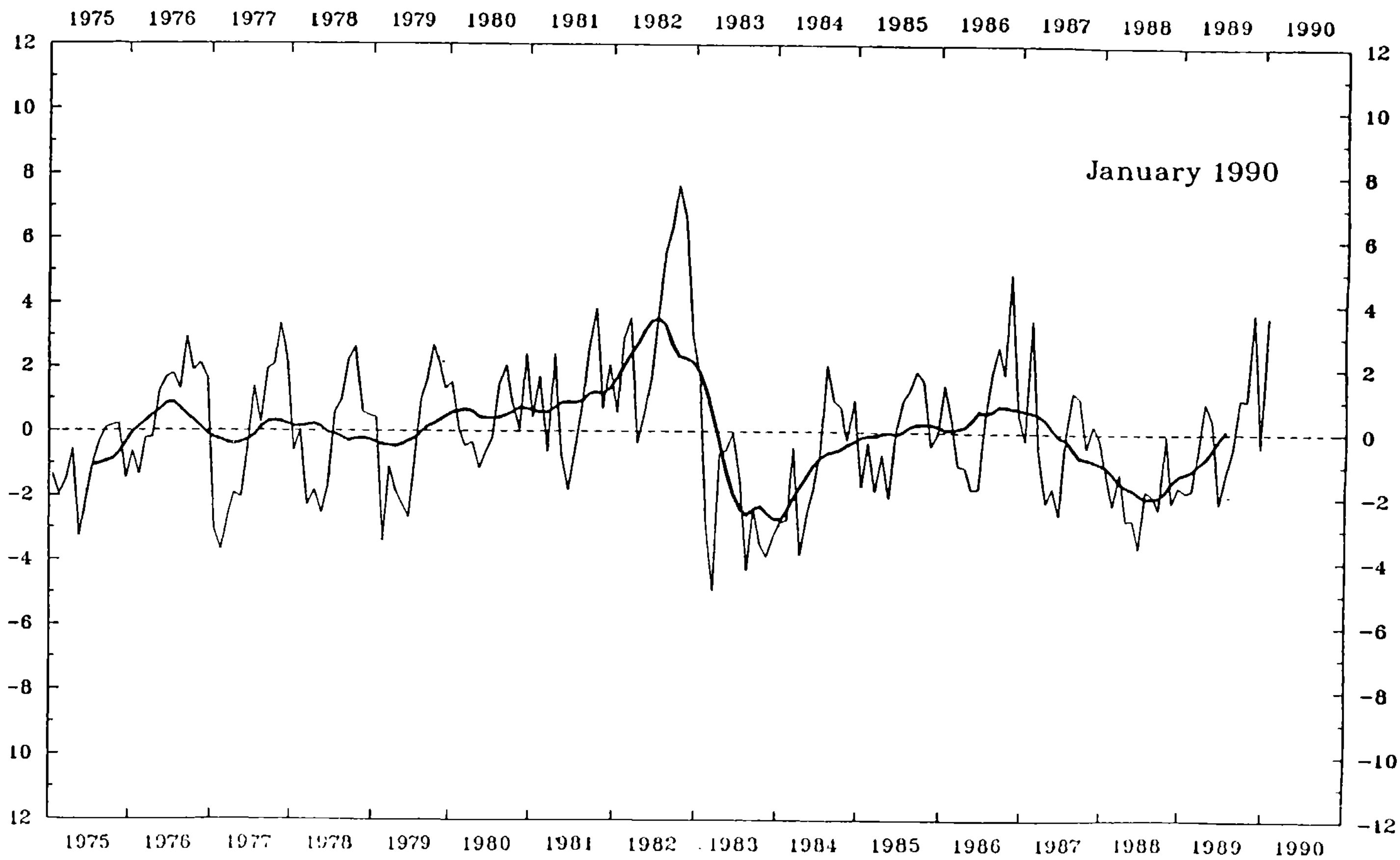


Figure 4. Upper layer volume in the tropical Pacific between 15° N and 15° S in 10^{14} m^3 relative to its mean value of about 70 x 10^{14} m^3. The annual cycle is not removed (see Journal of Geophysical Research, v. 90, p. 7129-7132).

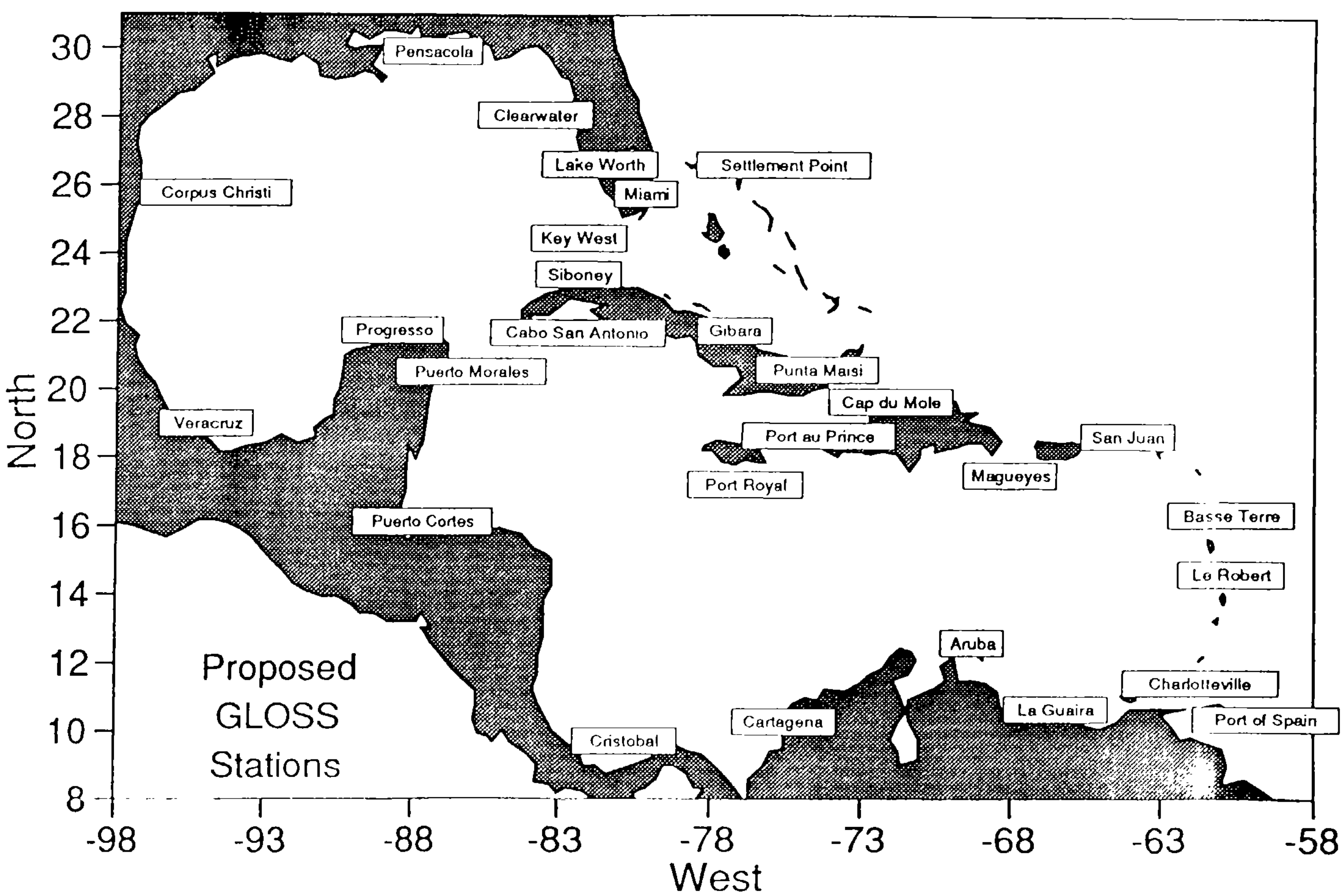


Figure 5. Proposed IOCARIBE Network of Sea-Level stations.

INTEGRATED GLOBAL OCEAN SERVICES SYSTEM (IGOSS)
IGOSS SEA-LEVEL PROGRAMME (ISLP)
SPECIALIZED OCEANOGRAPHIC CENTER (SOC) FOR MEAN SEA-LEVEL IN THE PACIFIC
(Text of Figures 2, 3, 4)

Sea-Level, January 1990

A region of lower than average sea level persists from the Philippines eastward to Wake Island and northward to Naha. Higher than average sea level is found in most of the equatorial and southern Pacific. This region extends from New Guinea to Johnston Island to Easter Island to New Zealand and northern Australia. Maximum deviations are found at Noumea (17 cm) and at Tarawa (13 cm).

Sea level is above average at Singapore and along the southern coast of China. Negative sea level deviations are found along northern China and in the Yellow Sea. Sea level deviations are small along the coast of Japan.

Sea level is higher than average in the northern Pacific from Japan to California. The maximum deviations are found on the Kamchatka peninsula (16 cm) and in the Aleutians (12 cm).

Sea level is slightly below average over most of the coast from Baja California to Chile. Sea level is above average in the Galapagos and at La Libertad. Sea level at most of these stations has risen by about 10 cm since last month.

Anomaly of sea-level corrected for atmospheric pressure, January 1990

The sea level anomalies from the Philippines to Saipan and in the western equatorial Pacific are near normal after correcting for the mean annual cycle. The pattern of pressure-corrected sea level anomalies in the central and southern Pacific is similar to the pattern of sea level deviations with the exception of a region of slightly negative anomalies from Kanton to Nuku Hiva.

Positive anomalies are found at Singapore and along the coast of China. This region is positive pressure-corrected sea level anomalies extends to the Yellow Sea and along the coast of Japan. Negative anomalies are found at Hawaii and in the Aleutians. Atmospheric pressure anomalies are significant at these stations.

Sea level anomalies are predominantly negative from Alaska to Baja California. Positive anomalies are found from Mexico to La Libertad and in the Galapagos. The pressure-corrected anomalies are negative along the coast of Chile with the exception of Talcahuano.

Data to this map were contributed by: Australia, Belau, Canada, Chile, Colombia, Cook Islands, Ecuador, Federated States of Micronesia, French Polynesia, Hong Kong, Japan, Kiribati, Korea, Marshall Islands, Mexico, Nauru, New Caledonia, New Zealand, Northern Mariana Islands, Papua New Guinea, People's Republic of China, Peru, Philippines, Singapore, Solomon Islands, Tuvalu, Union of Soviet Socialist Republics, and United States of America.

72 stations reported monthly mean sea-level.

Dr. Klaus Wyrtki and Dr. Gary T. Mitchum
Department of Oceanography
University of Hawaii at Manoa
1000 Pope Road MSB 307
Honolulu, Hawaii 96822
USA

THE INDIAN OCEAN

The proposal for the establishment of a tide-gauge network in the Indian Ocean as a part of the Global Network was considered by the IOC-Unesco Workshop on Regional Co-operation in Marine Science in the Central Indian Ocean and Adjacent Seas and Gulfs (Colombo, Sri Lanka, 8-13 July 1985).

The IOC Regional Committee for the Co-operative Investigation in the North and Central Western Indian Ocean (IOCINCWIO), at its Second Session (Arusha, Tanzania, 7-11 December 1987), adopted the proposal for the implementation of the regional component of GLOSS, urged its Member States to participate fully in GLOSS and agreed to establish an IOCINCWIO Regional Co-ordinator for GLOSS.[14]

THE ATLANTIC OCEAN

The IOC Regional Committee for the Central Eastern Atlantic at its First Session (Praia, Cape Verde, 19-23 January 1987) adopted the regional component of GLOSS, urged Member States of the region to participate actively in its implementation and recommended the establishment of a Task Team on the IOCEA regional component of GLOSS.[12] The establishment of the network of sea-level stations in the Caribbean Sea and Adjacent regions was discussed at the IOCARIBE Workshop on Physical Oceanography and Climate (1986) and at the Second Session of the IOC Sub-Commission for the Caribbean and Adjacent Regions (Havana, Cuba, 8-13 December 1986).[11] A proposed IOCARIBE network of sea-level stations is shown in Figure 5.

The IOC Executive Council at its Twenty-first Session (Paris, 7-15 March 1988) approved the IGOSS Sea-Level Pilot Project for the North and Tropical Atlantic (ISLPP/NTA) (30° S). The ISLPP/NTA Project will undertake to acquire on a monthly basis the monthly mean sea level data from GLOSS sea level stations located around and in the North and Tropical Atlantic Basin in order to obtain a monthly synoptic data set of mean sea levels from which monthly Mean Sea Level Charts will be produced and disseminated. The mean sea level data will be received, processed and quality controlled at the ISLPP/NTA Data Centre (Marine Environmental Data Service, Ottawa), the Canadian National Oceanographic Data Centre. The description of the Project is given in Annex VII of the Summary Report of the Fifth Session of the Joint IOC-WMO Committee for IGOSS.[37]

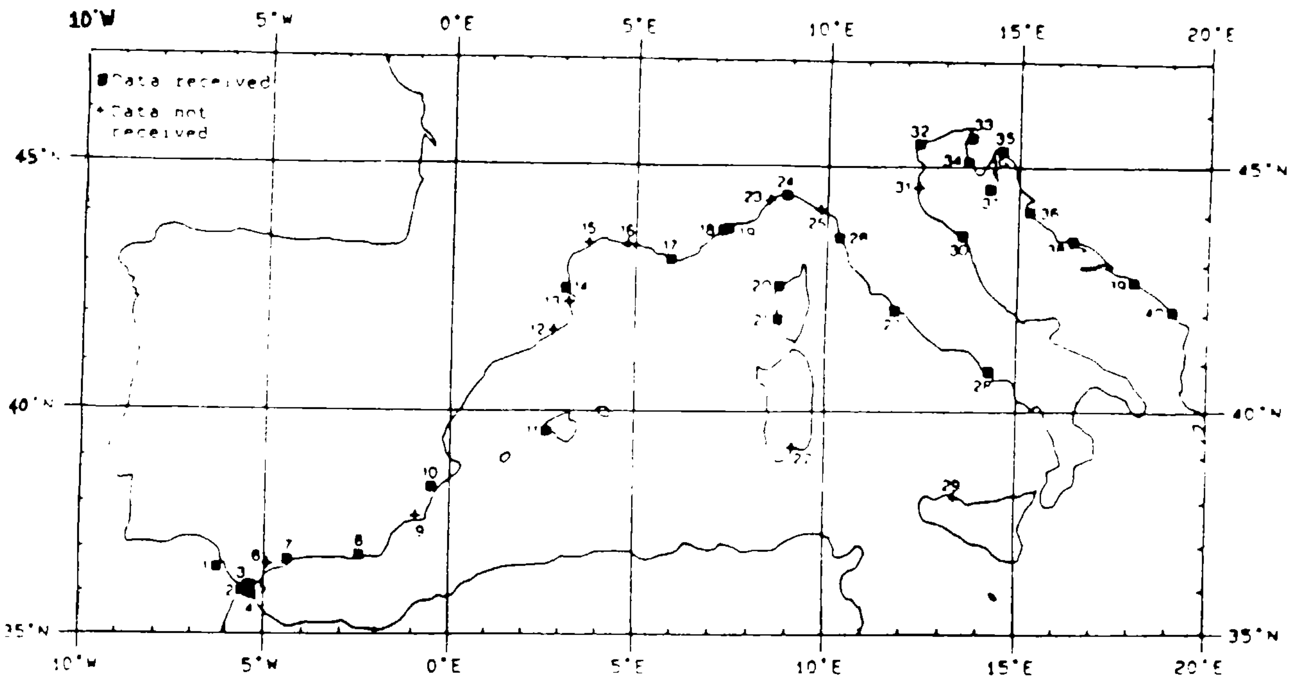


Figure 6. MEDALPEX Sea-Level Sites.

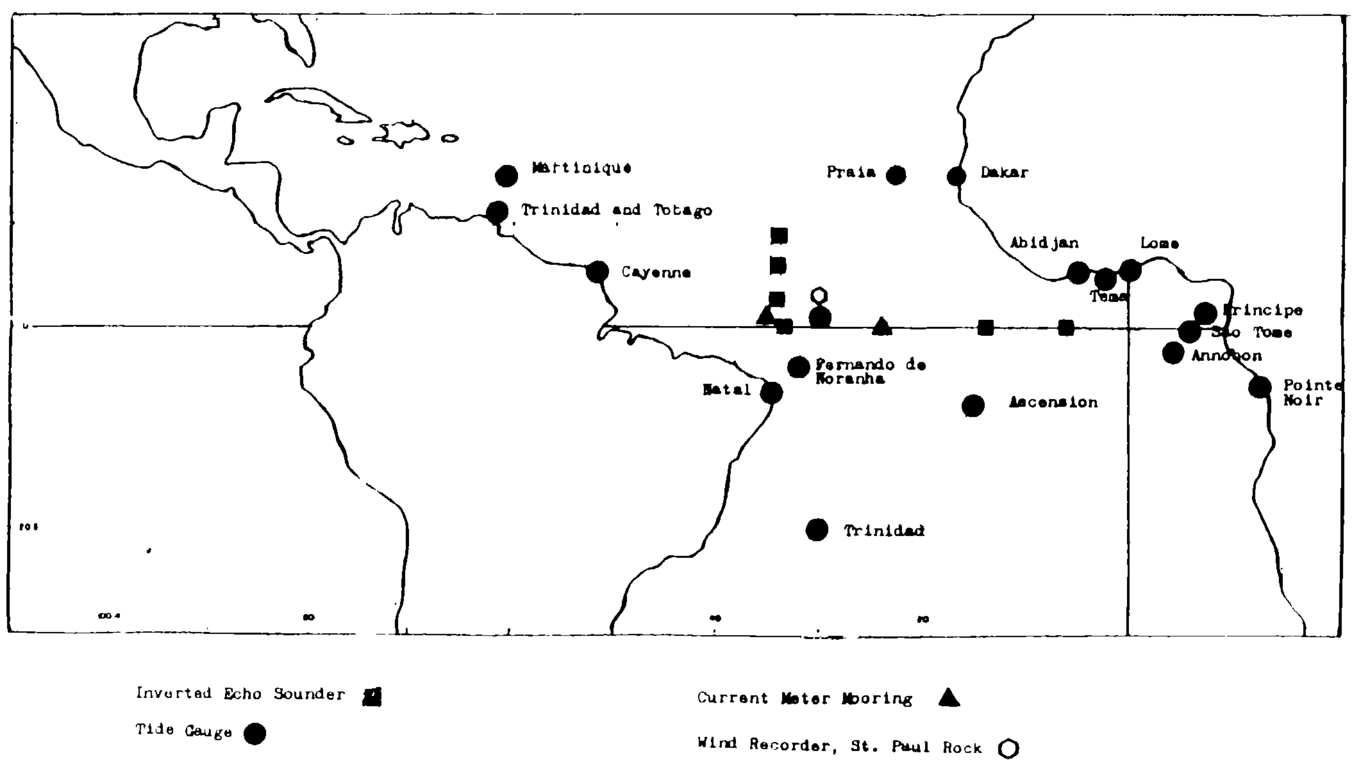


Figure 7. Tropical Atlantic Time Series Measurements.

The United Kingdom National Oceanographic Data Centre on behalf of PSMSL, fulfilled the role of the Responsible National Oceanographic Data Centre for the MEDALPEX Sea-Level Data Set and prepared the complete sea-level data set for sea-level sites (Figure 6) the Northern part of the Western Mediterranean Sea. The set of data on the magnetic tape may be obtained from WDCA and WDCB (Oceanography) and MIAS (Bidston, UK).[127]

In the Tropical Atlantic, ORSTOM (France) since 1982 undertakes studies of seasonal and interannual sea-level changes initiated within the framework of FOCAL/SEQUAL programme (1982-1984) and continued after 1984 in support of TOGA programme with the use of network of pressure type tide gauges (Figure 7).[114]

THE SOUTHERN OCEAN

The proposals for the establishment of the sea-level observation network in the Southern Ocean were made by the IOC Regional Committee for the Southern Ocean at its Fourth Session (1983), by SCOR WG-74 (1985) and the IOC Regional Committee for SOC at its Fifth Session (Paris, 9-12 June 1987).[13]

The problem of sea-level measurements in such hostile conditions as Antarctica was discussed at the Ad hoc meeting of the Group of Experts on Sea-Level Measurements in Hostile Conditions within the framework of GLOSS and WOCE (Bidston Observatory, Birkenhead, UK, 28-31 March 1988).[122]

The principle conclusions of the meeting were:
(i) technology exists and is affordable to make sea level measurements in hostile regions;
(ii) technology and techniques must be site specific;
(iii) bench mark connections are mandatory at the applicable stateoftheart;
(iv) atmospheric pressure measurements are mandatory at the applicable state-of-the-art;
(v) real time transmission is required to ensure proper operation and early availability of the data to the user community;
(vi) since the availability of global reference systems has increased (VLBI/GPS), local reference systems can be tied into the global systems to improve the quality of the sea level measurements;
(vii) bench marks themselves have to meet technical requirements for the site in view of permafrost disturbances and other local hazards.

IGOSS PILOT PROJECT ON ALTIMETRIC SEA-SURFACE TOPOGRAPHY DATA

The Joint IOC-WMO Committee for IGOSS, at its Fifth session (Paris, 14-23 November 1988), adopted the proposal of the USA to initiate an IGOSS Pilot Project on Altimetric Sea-Surface Topography Data in order to evaluate the fidelity of sea-level changes derived from satellite altimeter measurements.[37]

Products available will be maps depicting monthly departures of sea level from a long-term mean sea level, derived by analysis of satellite altimetry measurements. These maps will cover the Atlantic, Pacific and Indian Oceans from 30° S to 30° N.

Description

Launched in 1985, the U.S. Navy's Geodetic Satellite (GEOSAT) has become the most successful satellite mission ever flown for oceanography. Approximately 500,000 observations of sea level, wind speed and wave height are collected each day over the global oceans. Under agreement with the U.S. Navy, the National Ocean Service of NOAA produces the GEOSAT Geophysical Data Records (GDRs) in Rockville by combining the raw measurements with a precise orbit, a tide model, and radar path length corrections for delays due to troposphere and ionosphere. GDR's are distributed to the public by NOAA each month and reach the user within 2-3 months of acquisition, remarkably fast turnaround for a global satellite data set. Nearly 40 institutions around the world have purchased subscriptions to the NOAA GEOSAT data, and it is anticipated that the mission will continue for several more years, perhaps into the 1990's.

In addition to processing the data for public distribution, NOAA is analyzing the GEOSAT data to observe global sea level variability. These data have already been shown to be of enormous value in the study of ocean dynamics, particularly in the tropical oceans. At NOAA, the GEOSAT data are being used to measure sea level change as a function of time, in much the same way that island tide gauge data are used (Figure 8). During the recent 1986-87 El Niño event, NOAA was able to monitor sea level changes throughout the tropical Pacific in near-real time, the first time this had been accomplished. An operational sea level bulletin for the tropical Pacific, Atlantic, and Indian Oceans is now produced on a monthly basis and distributed to users worldwide through NOAA's Climate Diagnostics Bulletin.

Products

GEOSAT sea level time series are generated on a uniform grid, 2 degrees longitude by 1 degree latitude. For mapping purposes, data are expressed in terms of anomalies from a common 1-year mean. In the Pacific, the 1-year period (April 1985-86) is used as a reference, whereas in the Indian and Atlantic Oceans, anomalies are expressed relative to the 1-year period (August 1987-88). The maps are computed each month and are available for distribution by the ninth day of the following month. Product example is shown under Figure 9.

Data Tapes

The GEOSAT Geophysical Data Records are archived and disseminated by three U.S. data centres. GEOSAT data are managed by the National Oceanographic Data Centre; the land/ice data are managed jointly by the National Geophysical Data Centre and the National Snow and Ice Data Centre. To encourage multidisciplinary use of the data, the centres provide data services,

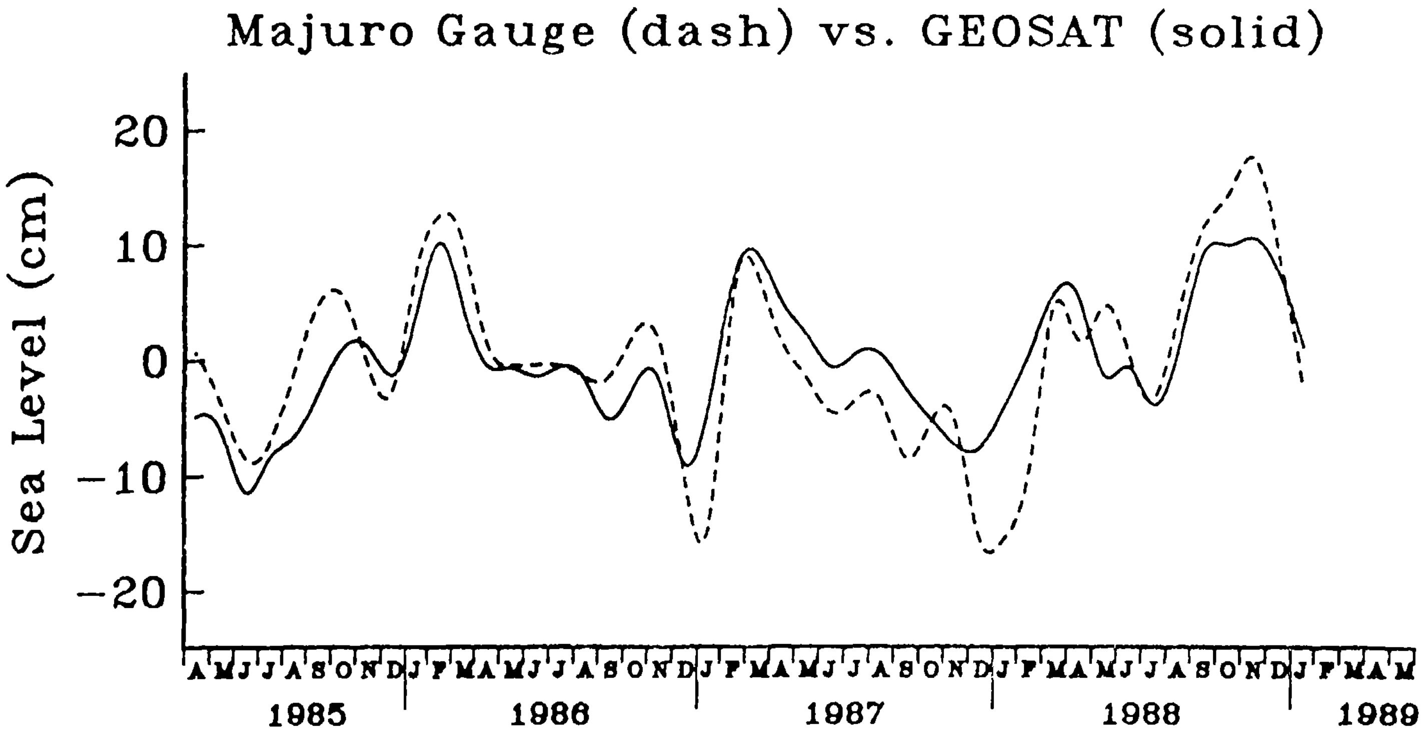


Figure 8. Sea level at Majuro, an island in the western tropical Pacific (7.1° N, 171.4° E). Solid line is GEOSAT altimeter time series: a continuous, 4-year solution constructed from GEOSAT altimeter data in an 8 x 1 degree (longitude x latitude) region centered on Majuro. Monthly mean values from the Majuro tide gauge (from maps prepared by K. Wyrtki, Univ. Hawaii) are indicated by the dashed line. Agreement between these independent measures of sea level is 4.5 cm rms with a correlation of 0.8. Discrepancies between the two records, occasionally as large as 10 cm, are probably due to a combination of altimeter error (improperly modelled water vapor, satellite orbit uncertainty) and local tide gauge effects not reflected in the open ocean.

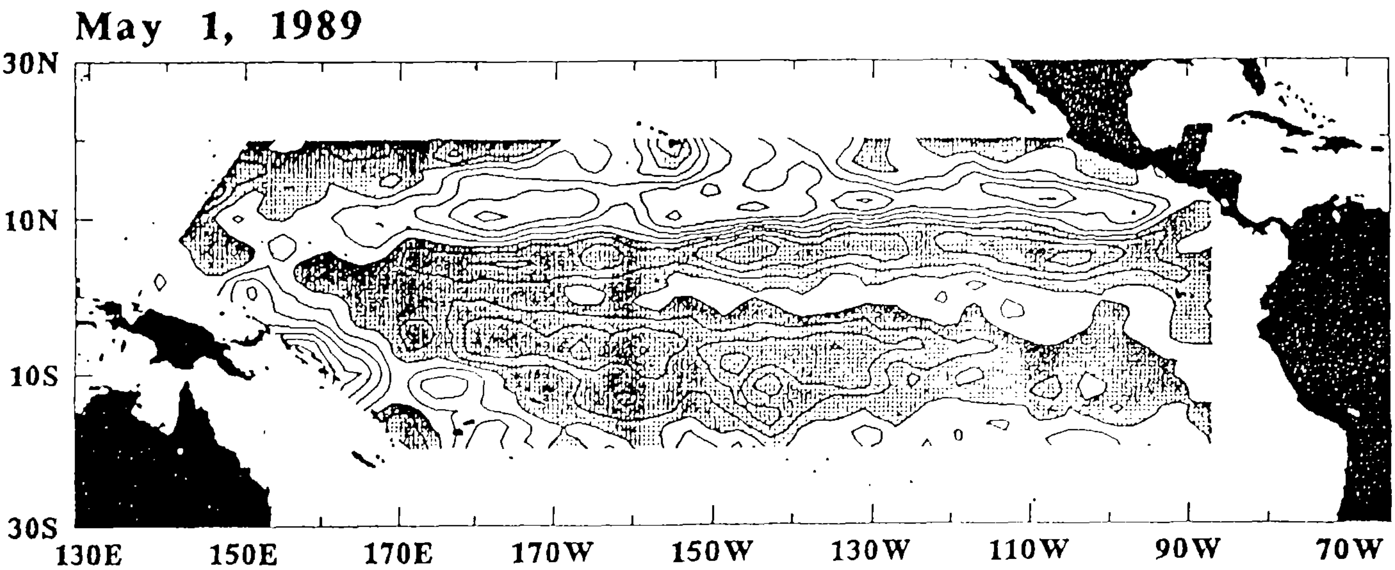


Figure 9. Sea level anomaly based on GEOSAT altimetry using the method of collinear differences. The map is constructed from approximately 2400 time series in 2 x 1 degree (longitude x latitude) areas. Anomalies represent departures from a 1-year mean, April 1985-86. Contour interval is 4 cm, negative values shaded.

including subscriptions to the monthly data tapes, to researchers. Potential GEOSAT data users may contact the centre appropriate to their primary area of interest:

Ocean Applications
National Oceanographic Data Centre, NOAA
1825 Connecticut Avenue N.W.
Washington, DC 20235

Land and Seafloor Applications
National Geophysical Data Centre, NOAA
325 Broadway, Dept. 445
Boulder, CO 80303

Snow and Ice Applications
National Snow and Ice Data Centre, CIRES
Campus Box 449, University of Colorado
Boulder, CO 80303

Project Management

This project will be managed by NOAA's National Ocean Service. The Project Manager is:

Dr. Robert E. Cheney
Office of Charting and Geodetic Services
National Ocean Service, NOAA
N/CG1, Room 426A, Rockwall Bldg.
Rockville, Maryland 20852
USA
Tel: 3014438556
Tlm: NOAA.GEOSAT

GEOSAT ALTIMETER PACIFIC OCEAN SEA LEVEL ANALYSIS

Robert Cheney and Laury Miller, N/CG112
NOAA/NOS, Rockville, MD 20852
(Description of Figure 9.)

The negative anomaly band north of the equator has been a persistent feature since January, but during this time has gradually moved southward from 9° N to its present location of approximately 4° N. The positive band along 12° N has been well-established only since March. Weak positive anomalies are found along the equator while most of the region south of the equator is negative. Large positive values (up to 24 cm) are found east of New Guinea. Overall, the structure in May 1989 is remarkably similar to that observed by GEOSAT in May 1985, suggesting that normal conditions (with respect to El Niño/anti El Niño) have returned to the tropical Pacific.

Annex V

List of Suppliers of Tide Gauge Equipment

1. A. OTT GmbH
   Jagerstrasse 4-12
   Postfach 2120
   D-8960 KEMPTEN
   F.R.G.

2. MUNRO SESTREL LTD.
   Loxford Road
   Barking
   ESSEX IG11 8PE
   U.K.

3. KENT INSTRUMENTS
   Biscot Road
   Luton
   BEDFORDSHIRE LU3 1AL
   U.K.

4. BEACON WORKS
   77 High Street
   BRENTFORD TW8 OAB
   U.K.

5. AANDERAA INSTRUMENTS
   Fanaveien 13
   P.O. Box 160
   N-5051 BERGEN
   Norway

6. NEYRTEC
   B.P. 75 Centre de Tri
   38041 GRENOBLE CEDEX
   France

7. SUBER
   Sainte-Anne-du-Porzic
   29200 BREST
   France

8. AGA NAVIGATION AIDS
   S-181 8-LIDINGO
   Sweden

9. INSTRUMENTEN FABRIEK VAN ESSEN
   DELFT
   The Netherlands

10. ACCO, BRISTOL DIVISION
    40 Briston Avenue
    WATERBURY, CT 06720
    U.S.A.

11. ALSTHOM ATLANTIC INC.
    NEYTEC DIVISION
    50 Rockefeller Plaza
    NEW YORK, NY
    U.S.A.

12. APPLIED MICROSYSTEMS, LTD.
    769 Lily Avenue
    VICTORIA, British Columbia
    Canada

13. BARTEX INCORPORATE
    613E Bayview Hillsmore
    ANNAPOLIS, MD 21403
    U.S.A.

14. BETHOS, INC.
    Edgerton Drive
    FALMOUTH, MA 02556
    U.S.A.

15. FISHER AND PORTER
    WARMINSTER, PA 18974
    U.S.A.

16. GENERAL OCEANICS, INC.
    5535 NW Seventh Avenue
    MIAMI, FL 33127
    U.S.A.

17. GEORGE KELK LIMITED
    48 Lesmil Road
    DON MILLS, Ontario
    Canada

18. GRUNDY'S ENVIRONMENTAL SYSTEMS
    3939 Ruffin Road
    SAN DIEGO, CA 92138
    U.S.A.

19. INTER OCEAN SYSTEMS, INC.
    3540 Aero Court
    SAN DIEGO, CA 92123
    U.S.A.

20. LEEUPOLD AND STEVENS, INC.
    P.O. Box 688
    BEAVERTON, OR 97005
    U.S.A.

21. MAGANAVOX, ELECTRONIC SYSTEMS
    1311 Production Road
    FORT WAYNE, IN 46808
    U.S.A.

22. METERCRAFT CORPORATION
    7305 Pulaski Highway
    BALTIMORE, MD 21237
    U.S.A.

23. METRITAPE, INC.
    33 Bradford Street
    MIDDLETOWN, RI 02840
    U.S.A.

24. MILLTRONICS, INC.
    2409 Avenue J., Suite D
    ARLINGTON, TX 76011
    U.S.A.

25. NEIL BROWN INSTRUMENTS, INC.
    P.O. Box 498
    1140 RTE. 28A
    CAUAMET, MA 02534
    U.S.A.

26. OCEAN DATA EQUIPMENT
    5 John Clarke Road
    MIDDLETOWN, RI 02840
    U.S.A.

27. PROGRESS ELECTRONIC CO. OF OREGON
    5160 N. Oagoon Avenue
    Swan Island Industrial Park
    PORTLAND, OR 97217
    U.S.A.

28. RAYTHEON OCEAN SYSTEMS CO.
    10 Risho Avenue
    EAST PROVIDENCE, RI 02914
    U.S.A.

29. SEA AND METEOROLOGY, INC.
    630 Oak Street
    HERDON, VA 22070
    U.S.A.

30. SEA DATA CORPORATION
    153 California Street
    NEWTON, MA 02158
    U.S.A.

31. THE SUTTON CORPORATION
    2190 Fox Mill Road
    HERDON, VA 22071
    U.S.A.

Annex VI

Standard GF3 Subset for Mean Sea-Level (PSMSL)

(Approved by the Committee on IODE Group of Experts on Format Development - June 1983)

1. STANDARD SUBSET

1.1 This subset represents the output format in which the Permanent Service for Mean Sea-Level is prepared to make available copies of its Revised Local Reference (RLR) global bank of mean sea-level data.
1.2 The data are organized into a single multi-series data file as illustrated in section 3.
1.3 Each series contains time sequenced mean sea-level data for a single fixed location. Two types of data are held for each series, monthly means and annual means.
1.4 The annual means are held in data cycles placed in the user formatted area of the series header record, as defined by the definition record given in section 4.1. Each data cycle contains values for the parameters year, annual mean sea-level, and a quality code. The quality code (FFFF7AAN) makes use of just one of the entries in GF3 Code Table 6 (validation flag) viz:
Q - Questionable Value which is taken to mean that the annual mean is affected by missing or interpolated data otherwise it is left blank. If no annual mean was calculated, the mean sea-level is set to its null value (i.e. 9's).
1.5 A single series header record can contain up to 114 annual means. If more than 114 annual means are available, series header byte 397 is set to '1' and the annual means are continued on a second series header record (immediately following the first) with bytes 1-400 set identical to that in the first series header record (except of course for bytes 2, 377-386 and 397).
1.6 The monthly means are held in data cycle records formatted according to the definition record given in section 4.2. Each data cycle contains values for the parameters year, month, monthly mean sea-level, and a two digit quality flag (FFFF6XXN) whose contents specify the number of days of data missing in the raw data from which the monthly mean was calculated. Each data cycle record allows for up to 138 monthly means—further data cycles may be continued on succeeding data cycle records.
1.7 Null values are not specified for the parameters YEAR in the series header record and YEAR and MNTH in the data cycle record. In this subset these fields are mandatory.

2. USER OPTIONS

None—this subset is used as a fixed output format for PSMSL—The Permanent Service for Mean Sea-Level.

3. TAPE STRUCTURE

Test File	Test Records
	EOF
Tape Header File	Tape Header Record Plain Language Record(s) Series Header Definition Record Data Cycle Definition Record
	EOF
	File Header Record Plain Language Record(s) Series Header Record(s) Plain Language Record(s) Data Cycle Records . . . Plain Language Record(s) Series Header Record(s) Data Cycle Records . . . etc. . . .
	EOF
Tape Terminator File	File Header Record (dummy entries) End of Tape Record
	EOF
	EOF

Footnote: For a complete description of the GF3 format, please refer to IOC Manuals and Guides No. 17.[126]

4. DEFINITION

4.1 Series Header Definition Record

```
         1         2         3         4         5         6         7         8
12345678901234567890123456789012345678901234567890123456789012345678901234567890

34  0  3P         (19(2X,6(I4,I5,A1,3X)))                                    001
3                                                                            002
3                                                                            003
3 YEAR7ZTN    YEAR                       I   4          1         0          004
3 SLEV7XXD    SEA LEVEL (ANNUAL MEAN) (M)I   5 95   0.001         0          005
3 FFFF7XXN    QUALITY FLAG FOR SEA LEVEL A   1                               006
3                                                                            007
3                                                                            008
3                                                                            009
3                                                                            010
3                                                                            011
3                                                                            012
3                                                                            013
3                                                                            014
3                                                                            015
3                                                                            016
3                                                                            017
3                                                                            018
3                                                                            019
3                                                                            020
3                                                                            021
3                                                                            022
3                                                                            023
3                                                                            024
```

4.2 Data Cycle Definition Record

```
         1         2         3         4         5         6         7         8
12345678901234567890123456789012345678901234567890123456789012345678901234567890

45  0  4I         (60X,                                                      001
4                 23(2X,6(I4,I2,I5,I2)))                                     002
4                                                                            003
4 YEAR7ZTN    YEAR                       I   4          1         0          004
4 MNTH7ZTN    MONTH                      I   2          1         0          005
4 SLEV7XXD    SEA LEVEL(MONTHLY MEAN) (M)I   5 95   0.001         0          006
4 FFFF6XXN    FLAG FOR MISSING DAYS      I   2 92       1         0          007
4                                                                            008
4                                                                            009
4                                                                            010
4                                                                            011
4                                                                            012
4                                                                            013
4                                                                            014
4                                                                            015
4                                                                            016
4                                                                            017
4                                                                            018
4                                                                            019
4                                                                            020
4                                                                            021
4                                                                            022
4                                                                            023
4                                                                            024
```

5. ANNOTATED LISTING OF SAMPLE SERIES HEADER RECORD FORMATTED ACCORDING TO THE DEFINITION GIVEN IN 4.1

```
         1         2         3         4         5         6         7         8
12345678901234567890123456789012345678901234567890123456789012345678901234567890

67PSMSL    469   ICELAND                                 8211191700  RLR/010/001 001
617                  REYKJAVIK                                                  002
6                                                                               003
6195601          198112         64 900N 215600W    999999      0999999    0    0004
6999999999999999999999999999999     A                        1      26         0005
   195699999     1957 6995    1958 6948     1959 7020     1960 6990     1961 7010
   1962 6967     1963 6964    1964 7086     1965 7051     1966 6985     1967 7025
   1968 6980     1969 6984    1970 6983     1971 7008     1972 7081     1973 7016
   1974 7056     1975 6999    1976 7073Q    1977 7030     197899999     1979 7074
   1980 7013     1981 7014
```

No. of data cycles in record (26)

Fixed format part of record (lines 001–0005)

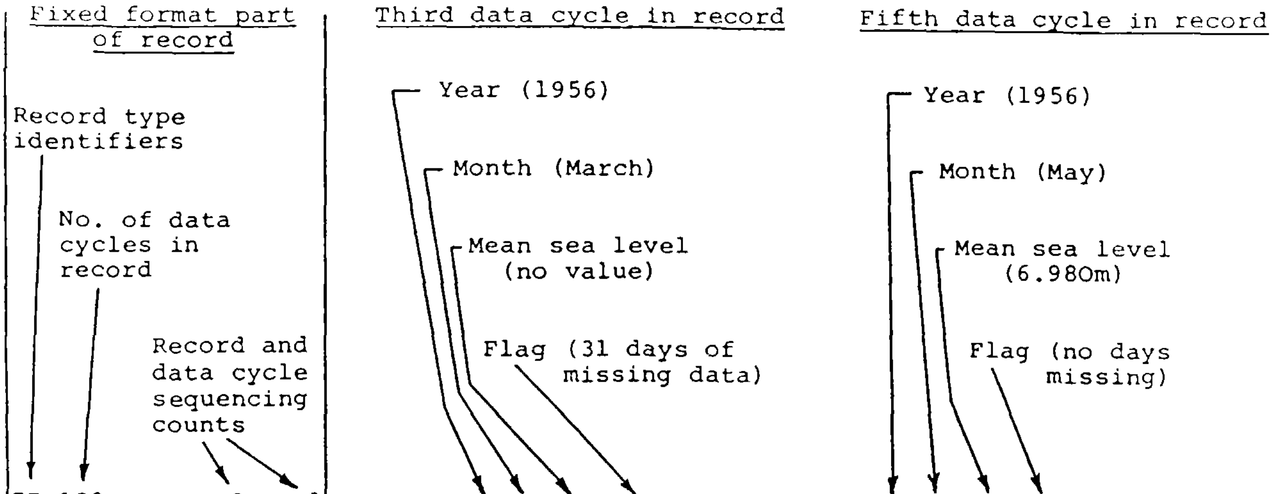
21st data cycle in record (1976 7073Q)

Flag (mean value affected by missing or interpolated data)

Annual mean sea level (7.073m)

Year (1976)

5.1 Annotated Listing of Sample Series Header Record Formatted According to the Definition Given in 4.2




```
77 138            0  1
    1956 199999311956 299999291956 399999311956 499999301956  5 6980  1956 6 6840
    1956 7 6890  1956 8 6830  1956 9 6830  195610 6980  195611 7040  195612 7140
    1957 1 7150  1957 2 7050  1957 3 7010  1957 4 6940  1957 5 6980  1957 6 6940
    1957 7 6950  1957 8 6880  1957 9 6890  195710 7100  195711 7000  195712 7060
    1958 1 7020  1958 2 6840  1958 3 6840  1958 4 6860  1958 5 6790  1958 6 6860
    1958 7 6900  1958 8 6980  1958 9 7030  195810 7060  195811 7110  195812 7080
    1959 1 6910  1959 2 7030  1959 3 7090  1959 4 6940  1959 5 6890  1959 6 6970
    1959 7 7030  1959 8 6950  1959 9 7010  195910 7140  195911 7100  195912 7180
    1960 1 7000  1960 2 6920  1960 3 6750  1960 4 6930  1960 5 6920  1960 6 7000
    1960 7 7010  1960 8 6930  1960 9 7060  196010 7020  196011 7190  196012 7150
    1961 1 7060  1961 2 7110  1961 3 7050  1961 4 6980  1961 5 6940  1961 6 7070
    1961 7 6950  1961 8 7020  1961 9 7140  196110 6930  196111 6890  196112 7010
    1962 1 7140  1962 2 6970  1962 3 6800  1962 4 6820  1962 5 6850  1962 6 6950
    1962 7 6930  1962 8 7030  1962 9 7050  196210 7080  196211 7020  196212 6970
    1963 1 6800  1963 2 6950  1963 3 7110  1963 4 6930  1963 5 6760  1963 6 6610
    1963 7 6990  1963 8 7000  1963 9 7050  196310 7160  196311 7130  196312 7060
    1964 1 7130  1964 2 7070  1964 3 7080  1964 4 6990  1964 5 7060  1964 6 7070
    1964 7 7110  1964 8 7010  1964 9 7130  196410 7130  196411 7150  196412 7090
    1965 1 7100  1965 2 6830  1965 3 6940  1965 4 7000  1965 5 7000  1965 6 7160
    1965 7 7020  1965 8 7080  1965 9 7110  196510 7160  196511 7040  196512 7160
    1966 1 7030  1966 2 7050  1966 3 6910  1966 4 6920  1966 5 6930  1966 6 7000
    1966 7 6930  1966 8 6760  1966 9 7140  196610 7050  196611 7030  196612 7080
    1967 1 6990  1967 2 7110  1967 3 7010  1967 4 6900  1967 5 6930  1967 6 7010

         1         2         3         4         5         6         7         8
12345678901234567890123456789012345678901234567890123456789012345678901234567890
```

Annex VII

Recommendations for Contributing Data to the Permanent Service for Mean Sea-Level

1. GENERAL

The Permanent Service is grateful to all the organizations supplying mean sea-level data and does not seek to impose unnecessary conditions upon these contributors. Nevertheless a minimum of quality control must be exercised by the Service if the data bank is to be an authoritative reference. To this end the Service requests the following information for each set of monthly and annual values supplied:
(i) unit (feet, metres, etc.);
(ii) statement of the datum to which the values refer;
(iii) statement of the measured depth of that datum below the primary TGBM;
(iv) an indication of incomplete or deduced data (see paragraph 2);
(v) number of observations per day used to calculate the monthly means;
(vi) any information of changes in data, bench marks or relevant procedures since the previous batch of data.

Although data will be accepted in any format, mean heights should preferably be in the metric system to the nearest millimetre, and the datum to which the means refer should preferably be the tide gauge zero.

2. TREATMENT OF INCOMPLETE RECORDS

One of the most important things for users of the mean sea—level data bank to know is the accuracy of the published figures. Details of the treatment of gaps in the tidal record are of particular interest.

Therefore the Service makes the following recommendations:
(i) small gaps in observed tidal records should be interpolated, if possible, before computing monthly and annual means;
(ii) the interpolation should be performed at an early stage in the processing. One principle to adopt is that of a comparison with the complete records from a nearby station. However we would stress that predicted values are not suitable for interpolation;
(iii) in cases where interpolation is impossible the monthly mean should be compiled from the incomplete data. Where more than 15 days are missing from a month a mean value should not be computed;
(iv) when sending mean values to the Service, authorities are requested to indicate if interpolation has been effected or the exact number of missing days of data. These details should be sent as suffixes after each monthly mean and shown in brackets: e.g. 2487(9) would mean 9 daily mean values were missing and not interpolated when computing the mean of 2487 mm. 913 (xx) would mean missing data were interpolated to provide the average of 913 mm;
(v) if there are 11 or 12 monthly mean values available then an annual mean should be calculated. If the annual mean is computed by averaging the monthly means, the monthly means must first be weighted. The weight for each month should be the number of days for which readings were available.

3. COMPUTATION OF MONTHLY AND ANNUAL MEAN VALUES

The PSMSL draws to the attention of data contributors a publication entitled 'Manual on Sea-Level Measurements and Interpretation'. This was published in 1985 by the Intergovernmental Oceanographic Commission. Additionally PSMSL will be pleased to assist with advice on methods of data processing and determining mean values.

4. PRESERVATION OF ORIGINAL DATA

Contributors are urged to preserve the original sea level data in some permanent form. The information contained in such basic time series is of great value in many scientific studies and should not be lost to posterity.

FORMAT FOR SUBMISSION OF MONTHLY AND ANNUAL SEA-LEVEL DATA TO THE PERMANENT SERVICE FOR MEAN SEA-LEVEL (PSMSL)

Country ....

Station .... GLOSS number ....

Co-ordinates: .... latitude .... longitude ....

Year ....

Month	Values	Number of days for which no data is available	XX if interpolation used
I			
II			
III			
IV			
V			
VI			
VII			
VIII			
IX			
X			
XI			
XII			
Annual			

Units used: ....

Datum of observations: ....

Reference Bench Mark (by name or number): ....

Distance between datum and Bench Mark: ....

Details of any changes in this distance which have occurred during the year ....

No. of observations per day used to calculate mean: ....

Name: ....

Authority and address: ....

....

....

Date: ....

Annex VIII

Recommendations for Sea-Level Data Submission to the SOC for ISLP PAC. and TOGA Sea-Level Centre

Recommendations for Submission of Sea-Level Data to the SOC/ISLP

No rigid format has been defined for ISLP monthly mean data that are received at the Centre. These data are collected, in near-real-time, via cable, telex, letter, telephone and satellite. The only requirements are that the co-operating agency clearly identify the data with the correct date and station and that they be consistent with their levelling and units.

Recommendations for Submission of Sea-Level Data to TOGA Sea-Level Centre

Data sent to the TOGA Sea-Level Centre comes in one of the four following categories:

(i) Original analog records from gauges—the records should be clearly marked with the station name and date-time-group (DTG), and that levelling information concerning the gauges be supplied on a routine basis.

(ii) Listing of manually reduced data—the listings should be clearly marked with the station name and date-time-group (DTG), that levelling information concerning the gauges be supplied on a routine basis, and that the stations be consistent in units.

(iii) Hourly values on magnetic tape—the data should be written on 1/2 inch, 1600 or 6250 BPI, ASCII, no-label tapes in card images with the first data record preceded by header record and the beginning of every year of data preceded by a header record.

The header record format reserves the first eleven spaces for station identification, the next four spaces for the year, the next two spaces for the month, and the next two spaces for the day of the first data record. The rest of the record is filled with information in a free format, such as latitude, longitude, timezone, etc., i.e.
O1PONAPE 1983 12 1 Lat06 59.4N Long158 13.8E TimezoneGMT

The data record format reserves the first eleven spaces for station identification, the next four spaces for the year, the next two spaces for the month, the next two for the day or the data record, and the next space to indicate if the record is the first 12 hours of the second 12 hours for that day. The next 60 spaces contain the hourly data in groups of five spaces per observation, 12 per record. The data are assumed to be in units of millimeters. If time averaged, the averages are centered on the hour, with the time of the first hour OOOOZ and the last hour 23OOZ. Missing data is flagged by four nines (9999), and each month must be completely filled with either data or missing data flags, i.e.

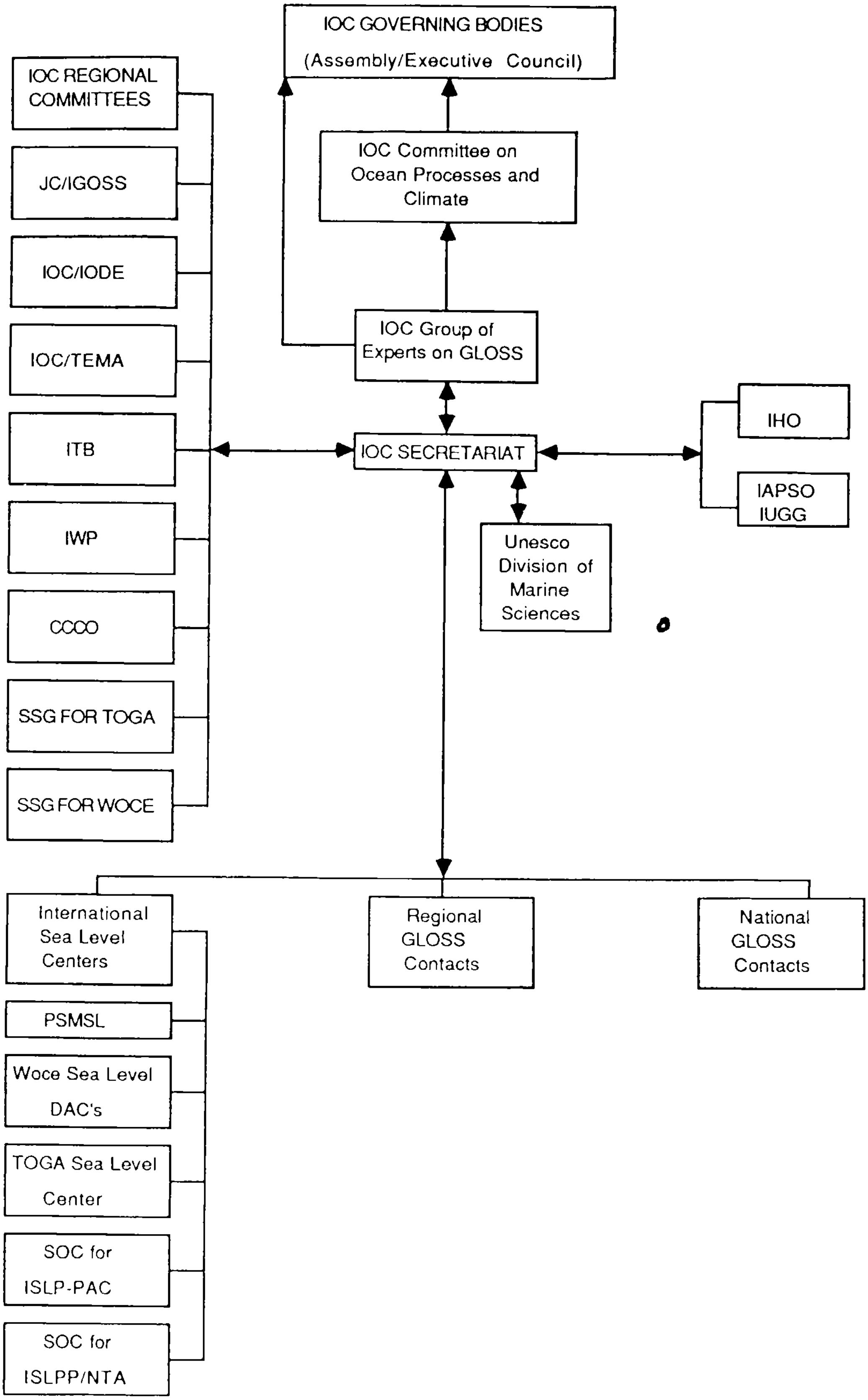
(iv) Data directly from satellite transmitting stations—the agencies or investigators who wish the TOGA Sea-Level Centre to receive their satellite transmitted data should work directly with centre personnel when developing the programmes for their platforms.

```
STATION
ID       YEAR
 :        :    MONTH
 :        :   :  DAY
 :        :   :  :  INDICATOR FOR 1ST OR 2ND HALF OF THE DAY
 :        :   :  :  :
 :        :   :  :  :
 :-----------------------DATA-MM---------------------------
 :--------:---:--:--:--:---:----:----:----:----:----:----:----:----:----:----:----:----:

O1PONAPE 1983 12 11  1010 1090 1152 1128 1048  916  776  654  566  479  462  547
O1PONAPE 1983 12 12   693  846  954  958  989  770 9999 9999 9999 9999 9999 9999
O1PONAPE 1983 12 21   811 1037 1212 1288 1256 1111  907  727  578  439  371  408
```

Annex IX

Mechanism for Co-ordination of the GLOSS Implementation



Annex X

WOCE Sea-Level Network

ATLANTIC

Bermuda	S
Porto Grande	S
Dakar	S, D
Tristan da Cunha	S, D
St. Helena	S, D
Ascension	S
So. Georgia	
Simonstown	
So. Orkney	S, D - Signy
Faraday	
Vestkapp	
Duck	S
Lake Worth	S
Settlement Pt.	S
Gd. Cayman	
Puerto Rico	S
St. Croix	S
Diego Ramirez	
St. Peter & Paul Rocks	
Fernando de Noronha	S

INDIAN

Cocos	
Reunion	D
Christmas	
Diego Garcia	(D)
Mombasa	
Port Louis	
Port Victoria	
Male	
Heard	
Port Elizabeth	
Durban	
Amsterdam	D
Kerguelen	D
Marion	D
Syowa	(V)

PACIFIC

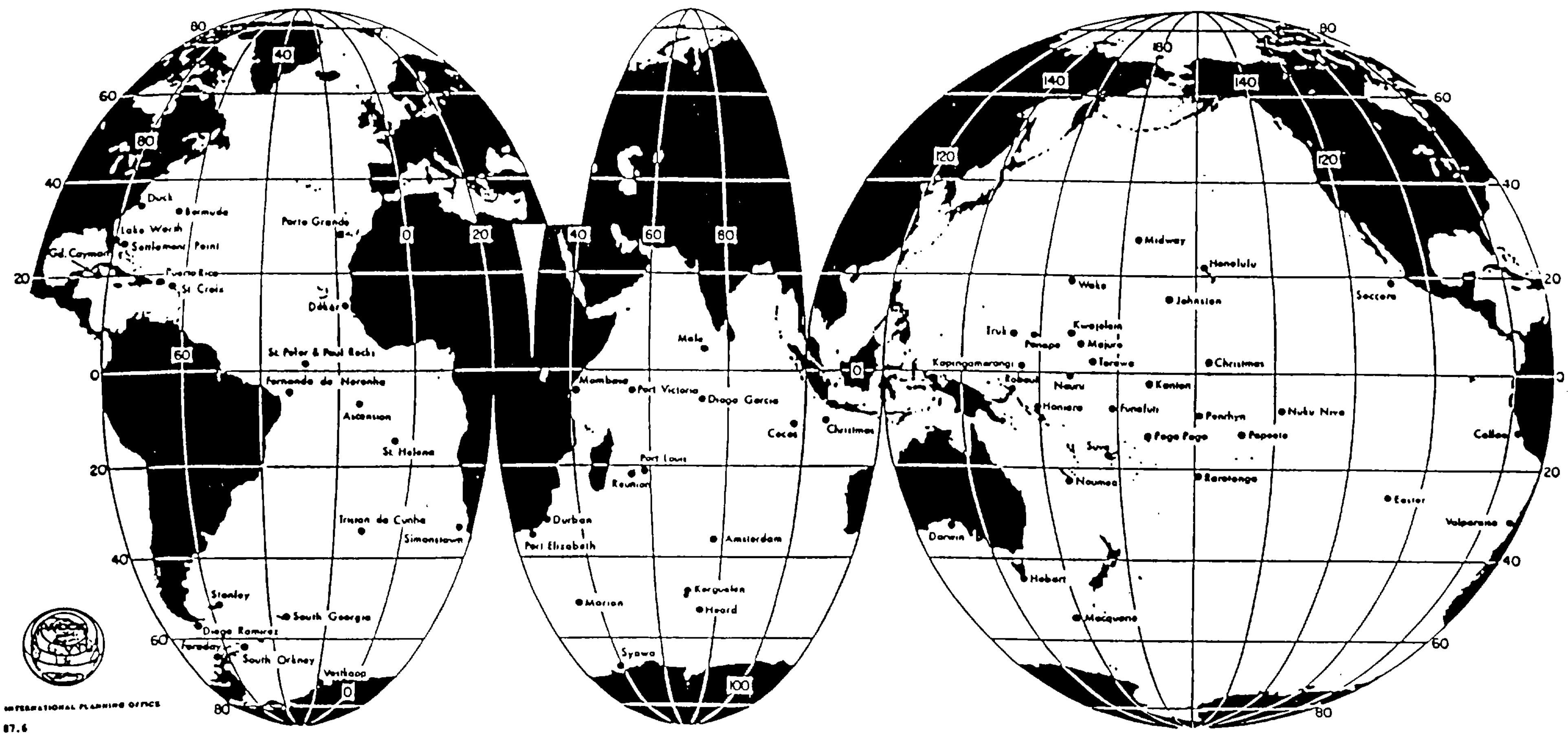
Hobart	S, V
Macquarie	
Darwin	
Christmas	S
Ponape	S
Tarawa	S
Majuro	S
Nauru	S
Rabaul	S
Honiara	S
Rarotonga	S
Callao	S
Kapingamarangi	S
Johnston	S
Valparaiso	S
Kanton	S
Easter	S, D
Nuku Niva	S
Penrhyn	S
Wake	S
Funafuti	S
Noumea	S, D
Socorro	D
Suva	S
Kwajalein	S, V, (D)
Honolulu	S, D - Maui, V - Kauai
Truk	S
Pago Pago	
Midway	S
Papeete	

Key

S Satellite Transmission
D Doris
V VLBI
( ) Planned

Ref: WOCE Data Management Committee. Report of the 2nd Meeting DMC-2. Institut fur Meereskunde, Hamburg, FRG, 6-8 November 1989.

WOCE Sea-Level Network



INTERNATIONAL PLANNING OFFICE
87.6