The Development of Global Operational Oceanography: IGOSS the Foundation

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Abstract

Several scientists and scientific groups have provided definitions of Operational Oceanography. In most of these cases all suggest that the concept includes the systematic observation of the ocean, and the use of the data in scientifically derived applications, such that timely information is made available to decision makers. Operational Oceanography is often drawn as a parallel to Operational Meteorology in general and more specifically Meteorological Services. In the early 1960's, the establishment of the World Weather Watch, as well as other activities and events led groups of visionary ocean scientists to begin a process that could lead to a global system of ocean observations and services. The realization of these visions is now best represented by the relatively new Global Ocean Observing System (GOOS) and its implementation body the Joint WMO/IOC Technical Commission for Oceanography and Marine Meteorology (JCOMM). The foundation for GOOS and JCOMM has resulted largely from the activities established through the Integrated Global Ocean Station (Services) System (IGOSS) under the joint responsibility of the IOC and WMO. This paper reports on the global infrastructure of data buoys, ships of opportunity, real time tide monitoring, radio frequency allocation, data code forms and exchange, observing standards and practices, and atmosphere-ocean integration processes that have been established within the framework of IGOSS over the last half century, and that have been important to the development of Operational Oceanography.

INTRODUCTION

Mathew Fontaine Maury easily could be considered the father of operational meteorology and oceanography. His desire and leadership focused, to a large degree, on the acquisition and processing of oceanographic data for application into timely useful information for the public and, more specifically, mariners. As a result, it is highly appropriate to discuss the development of operational oceanography at this 150th anniversary of the "Brussels Conference" which he convened.

Several Scientists and scientific groups have provided definitions for the term "Operational Oceanography". Most agree that it is the systematic observation of oceanographic data and the timely application of that data for use by the public and other users, including the science community. The IGOSS concept fits this description and is considered to be the initial international program activity that was developed to provide systematic oceanic observations and

services. The IGOSS plan and program states: "The primary purpose of IGOSS is to promote international operational exchange of ocean observations…". In addition, WMO EC-XX (1968) stated, **" IGOSS was not merely a system of observing stations, but that it was a complete operational system conceived as the mirror image of the World Weather Watch.**

Other IOC and WMO program initiatives, such as the "International Coordination Group for the Tsunami Warning System in the Pacific," and the "Maritime Meteorological Services" also can be considered operational marine programs. The establishment of IGOSS came at a time when the science of oceanography was beginning to undergo a major change. The classical research of gathering observations and data from oceanographic expeditions and cruises was giving way to additional technology that could be easily telecommunicated and recorded in forms that could be processed automatically either in analog or digital forms. Quality observations were also being made from unmanned platforms both at sea (Data Buoys) and from space (Satellites). This technology and research culture change were not only providing a higher quantity and better quality observations, but also data that could be processed and analyzed more accurately and quickly.

The recent establishment and development of the Global Ocean Observing System (GOOS) now has become what was largely envisioned by the early pioneers involved in the planning for IGOSS. In fact, **the foundation upon which the GOOS has evolved was put in place by the IGOSS planning and implementation.** This paper will take a look at this early evolution, particularly the establishment of mechanisms and institutions that have been useful in providing infrastructure for the formation of the GOOS.

The evolution of international operational oceanography has been influenced and supported by many factors. Most of these factors, while interrelated, can be largely discussed within the growth and enhancement of technology, increased understanding from science, and the practice of public and political decision-making. The confluence of factors within these three categories has largely determined the growth of operational oceanography and more specifically **the IGOSS evolution into GOOS.**

MOTIVATION FOR IGOSS

The Integrated Global Ocean Station System (IGOSS) was established by the Fifth session of the IOC assembly in 1967. It was further adopted as a joint program by the WMO at its Executive committee session in 1968 (EC-XX). The motivation to create IGOSS came from many different sources, but primarily from those representing the Member States of IOC. However; the Members of WMO did recognize the eventual need to expand below the sea surface and beyond the typical terrestrial based environment. While still participating as a full partner, WMO informally agreed that the IOC take a leadership role in developing IGOSS.

In establishing IGOSS, the IOC created a standing Working Committee to provide technical guidance for program development. While in WMO an Executive Panel of Experts on Meteorological Aspects of Ocean Affairs was established to provide technical guidance and advice

for IGOSS and other ocean related matters. It was agreed that both the Working Committee and EC panel would meet separately for one or two days, then meet in joint session for week or more. This somewhat awkward arrangement of two "program management" bodies was due to the different operating and procedural regulations of the WMO and IOC. Many pioneers involved in the early planning also felt that a significant amount of distrust and skepticism existed between those representing the two bodies. After the "comfort level" was increased in both IOC and WMO and through the good relationships that developed between the respective secretariat program officers, a single Joint IOC-WMO Working Committee was created in 1977.

In the mid 1960's, following a motivating speech by President John F Kennedy to the UN General Assembly on the, "Peaceful Uses of Outer Space", the WMO and the International Council of Scientific Unions (ICSU) developed the World Weather Watch and the Global Atmospheric Research Program (GARP). Several Members of WMO recognized that at some point in the next decade, a set of comparable efforts dealing with the ocean would be required. Further, the WMO had already jointed with the IOC to establish a standardized observation program for the Ocean Station Vessels and to oversee jointly the allocation and management of a new set of radio frequency spectra for use in telecommunications of ocean and atmospheric data.

To enhance understanding of why IGOSS evolved in 1967, it is important to reflect on many of the early actions and considerations taken by IOC in the early 1960s. The IOC was established in 1960 by the Eleventh General Conference of UNESCO in large part as a result of several new UN resolutions on the oceans and an International Conference on Ocean Research which provided much of the background for initiatives developed within the newly formed IOC. The IOC developed a generalized "blueprint" for most of its activity as well as an overall guidance in Oceanography for the UN system, through the Long-term and Expanded Programmes of Ocean Research (LEPOR).

The FAO and ICES, like WMO, were closely associated organizations of IOC. Their participation in IOC bodies was active and often considered quite supportive. This was particularly true with respect to the establishment of IGOSS where both FAO and ICES had at one time or another actively considered setting up their own operational oceanographic systems. Some of the important early advice on developing IGOSS came from the Advisory Committee on Marine Resources Research (ACMRR). ACMRR, an advisory body to the IOC, was supported under the framework of the FAO. In addition to international activities, there was significant national interest form Member States of IOC to create IGOSS and to expand already existing national and bilateral related activities. A limited aspect of IGOSS, specifically related to the real-time exchange of bathythermograph data, was already in operation in the early 1960s through the auspices of NATO. One major supporting interest came from the USA's study from the National Marine Resources and Engineering Commission (i.e. "Stratton Commission) that was completing its work at the time of IGOSS creation. Their final report strongly recommended a national marine environmental prediction capability as part of a global program. The USSR also provided strong support of the IGOSS concept in order to aid in their global study of ocean variability, particularly through co-operative investigations.

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A NEW PHASE FOR OCEANOGRAPHY

The first session of the IOC (October, 1961) already recognized the vital role for "real-time" reporting of ocean data, as well as the decreasing availability of communications spectrum, and as a result established a working group of experts on radio communications. The Working Group was to study the requirements for oceanographic radio communications for use at the next study session of the Aeronautical Radio Conference. IOC-I (1961) also considered the summary report from the International Conference on Ocean Research (Paris, 1960) and created a working group, with WMO, "to study the existing network of fixed stations and the needs of extending it." The Commission recognized the increasing importance of fixed stations for taking observations as a part of "modern" oceanography particularly for understanding variability. The report of the Ocean Research Conference noted the use of fixed stations is indispensable for the solution of several types of oceanographic problems. The Confernce pointed out that, "series of data from fixed points closely spaced in time, make possible the study of time variations in oceanographic parameters. Some of these parameters vary importantly with frequencies of a few minutes, other with frequencies of days, months or years. Further, a network of fixed stations at suitable locations provided sets of truly synoptic observations which can be employed to monitor changes in the ocean circulation and distribution of properties, and thus contribute to the solution of problems of forecasting." As a matter of organization, the IOC session specified that fixed stations now in use or expected in near future included; Coastal and island stations, ocean station vessels (including weather ships); unmanned anchored buoys, and manned anchored platforms.

The Working Group on Fixed Oceanographic Stations held its first session in August of 1962 and the summary report of the meeting was presented to the second session of the IOC (September, 1962). Desmond Scott (UK), rapporteur, indicated that the working group recommended that the Commission change the name of the group to "Fixed Oceanographic Stations" so as to avoid confusion with the terminology "fixed stations" used for shore-based radio communications. At the request of the Working Group, the Secretary of the Commission was requested to inquire from Member States the list of the fixed oceanographic observing stations they maintain and operate. The term "fixed oceanographic stations" was defined as, "stations at which observations are taken continuously and periodically for periods of one year or more." The Working Group in their report clearly indicated the information received from Member States and the subsequent analyses would be used jointly by WMO and IOC "to plan" for an ocean-wide network of "synoptic" stations. It was also agreed to encourage an "increase in the number of ocean weather ships." This plan for expansion was also recommended by the WMO EC Working Group on Worldwide network of Meteorological Stations. The Commission agreed that the IOC would cooperate with WMO to define ways and means that weather ships could be employed to give maximum benefit to both meteorology and oceanography.

IOC-II (1962) recognized that before a decision could be reached on such a network, agreement should be reached on (1) the "properties" to be observed regionally and globally, (2) whether data should be collected without a specific programme "in mind" and be stored in data centers for future use, and (3) whether observations should be collected for the solution of particular problems. The summary report of the Commission session and its resolution annex (IOC-II Resolution 17, Annex 5) specified the minimum observation requirements desired for manned

ocean stations. These requirements clearly included atmosphere, surface, and sub-surface measurements and signified a vision for an integrated meteorological-oceanographic observing system. The Commission, sensing the need to push the technology encouraged the use of new technology (e.g. the Electronic BT should replace the mechanical BT). In addition, the issue of navigational fixing of ocean weather ships was discussed and found "unsatisfactory" for deriving ocean currents and suggested technological improvements to include V.L.F. long range fixing (e.g. Omega) and the use of acoustic bottom beacons and marker buoys. The Commission's annex report stated that "there is an urgent need by various organizations, for synoptic hydrographic information which can only be met if data are transmitted by radio on a daily schedule." Relative to establishing a network, It should be pointed out that the Commission also was seeking, as a part of UNESCO and with IMCO (now IMO), the Legal Status of Manned and Unmanned Observing Buoys in order to protect stations and assure the safety of shipping from navigational hazards. In addressing the problem of data intercomparison, the Commission suggested that where possible, different instruments and techniques be used at fixed oceanographic stations.

In addition to the discussion on "Fixed Oceanographic Stations", IOC-II (1962) at the request of the USSR, USA and ICES specifically discussed the "recent development of synoptic oceanography". There was recognition that data of sea surface temperature and other synoptic oceanographic factors are used by some countries for the prediction of fisheries conditions as well as for meteorological forecasts. It was pointed out that, "although speedy collection of these synoptic data and distribution by means of facsimile broadcasting…are developed on national or regional bases, there is no well-organized system for communication regarding these data."

The Working Group on Communications also held their first meeting in August 1962 so as to provide a report to IOC-II (1962). Dr. James Snodgrass (USA) was elected chair and Dr. Ron Wilson (Canada) as rapporteur. The meeting had one major item to discuss, "that provisions be initiated that will ultimately lead to the international allocation of certain portions of the radio spectrum for the exclusive use of oceanographic and meteorological research and survey." It was agreed by the Commission that an overall system engineering approach should be made to support the "oceanographic and meteorological communication problem." The Group did recognize that international allocations (of frequency spectra) will require much time and "will, in fact, probably be difficult," such that the IOC and WMO should establish a coordinated plan for the use of the required radio frequencies and that Member State telecommunication authorities should be urged to initiate action with the ITU. The Working Group on Communications clearly envisioned an integrated observing system and stated, "As the world-wide use of fixed oceanographic stations increases they will become important as platforms for the simultaneous acquisition of meteorological and oceanographic data. It will be one of the tasks of this Working Group (communications) to aid in avoiding unnecessary duplication of communication facilities."

Besides the considerable discussion regarding ocean observations and communications, IOC-II (1962) also began the initial establishment of a related activity in "operational oceanography" by recommending the collaboration of Member States and other international bodies with the USA to operate seismic and tidal facilities as a part of a basin wide programme that would eventually become the Tsunami Warning System for the Pacific Ocean.

By the time of the third session of the commission in 1964 (IOC-III) the Secretary of the IOC had analyzed the reports from Member States and had prepared a booklet entitled, "Fixed Oceanographic Stations of the World, 1963." In addition to the booklet, two world maps were prepared that graphically depicted the information. The Commission also established an *ad hoc* Working Group on Fixed Oceanographic Stations under the chairmanship of Dr. Art Maxwell (USA). The Group was to discuss the problems of: (1) developing an ocean-wide network of fixed oceanographic stations; (2) legal aspects of fixed oceanographic stations; and (3) marking of buoys. IOC-III specifically stated, " it was the general opinion that the efforts of the IOC and WMO should be united to achieve meaningful results.

IOC-III (1964), similar to its previous two sessions, clearly expressed its vision by requesting the IOC and WMO secretariats to begin discussions "with a view to forming a combined Working Group from the two organizations to prepare a proposed World Network of Oceanographic Stations, taking into account the existing network and also the proposed co-operative programmes of the Commission." On a related point, discussions by the Commission focused on the increased role of IOC in international ocean data exchange by collaborating with the ICSU/SCOR activity regarding ocean data centers. In particular, SCOR agreed that the IOC should prepare the Guide relating to oceanographic data exchange. It should be pointed out that this greater role by IOC was in recognition of the increased importance of Declared National Programmes and the expectation of increased data exchange by new mechanisms (e.g. in real time by radio communications).

The fourth session of the Commission was held in November of 1965 (IOC-IV) and resulted in the establishment, with participation of WMO, of a Working Group on Ocean-Atmosphere Interaction. The suggestion for such an activity came from the WMO Commission for Maritime Meteorology and a joint ICSU/IUGG committee of IAMAP and IAPO. Additional motivation for such a Working Group was also provided by the ICES and FAO in order to improve effective exploitation of marine food resources. The Working Group was specifically requested "to consider the operational aspects and opportunities for intergovernmental action in this field. The Commission was reacting to the increased understanding in air-sea interaction as a fundamental basis for long-range prediction of weather and of ocean surface conditions and circulation. Prior to IOC-V, the WMO had convened its Fifth Meteorological Congress (Cg-V) 1967) where the initiation of the World Weather Watch (WWW) was adopted and the early suggestion that a counterpart activity would be needed for the world oceans. During this timeframe several Members of WMO had speculated on the eventual creation of not only a WWW, but also a World Ocean Watch both contributing to a World Environmental Watch. In this regard it is understandable that IGOSS would be an important element in such a concept.

The issue of allocating radio frequency spectra was on a fast track in order to impact on the World Administrative Radio Conference in 1967 and all the necessary preparatory sessions that would be convened from 1965 onwards. As a result, an extraordinary meeting of the WG on Communications developed "interim solutions to address the requirement for frequencies." IOC-IV (1965) approved the interim solution so that it could be presented to the Extraordinary Aeronautical Radio Conference where parts of frequency spectra in the mobile part of the band

were being sought. At the request of communication experts, the Commission changed the name of the WG on Fixed Oceanographic Station to the Working Group on Ocean Data Stations.

During a second meeting of the WG on Ocean Data Stations (1966) the link between operational oceanography and the World Data Center concept, including international ocean data exchange, began to take shape with the responsibility for maintaining the information on ocean data stations resting with the World Data Centers "A" and "B" as well as ICES and the Kuroshio Data Center. The WG also pointed out that telecommunication codes should be improved in order to increase the quality and quantity of oceanographic information. It recommended that the WMO through its Commission on Synoptic Meteorology may wish to look at the automatic station code, and the ship reporting code as well as possible new codes needed to meet oceanographic requirements.

In a further suggestion of operational oceanography, the WG did recognize that "one of the most important uses to which data from Ocean Data Stations are put, is the preparation of synoptic oceanographic charts." The WG pointed out that the Ocean Station Vessels and Weather Ships are some of the most important long-term ocean data collecting facilities and some concern was expressed at the possible discontinuance of these stations in the North Atlantic. Further, the WG recommended that the IOC WG on Data Exchange include measurements of temperature, conductivity and pressure by electrical techniques from automatic stations in the "Manual on International Oceanographic Data Exchange" under the category of standard data. The WG also discussed the new National Data Buoy Project underway in the USA and its contribution to ocean data station networks and as a possible replacement to Ocean Station Vessels. Also, in order for the data buoys to operate effectively, the radio communication frequency spectra being sought from the WARC, would be necessary.

The WG on Ocean Data Stations specifically recognized that "it is economically undesirable to set up separate large-scale networks for the collection of meteorological and oceanographic data." As a result, it recommended most strongly that all methods of arranging joint meetings between relevant IOC and WMO groups be thoroughly investigated." In this regard, it was suggested that joint planning be used with respect to data collecting platforms at sea, communication channels, and dissemination of information. The WG also was aware that the differing constitutions of WMO and the IOC provided some limitations on joint meetings and suggested that both bodies jointly seek out ways to solve procedural problems. In another indication of the vision of a joint operational program, the WG provided a framework for basic measurements from "synoptic stations" in support of both oceanic and atmospheric science. The measurement specifications ranged from temperature and salinity at depth to common atmospheric variables of temperature, pressure, wind velocity, as well as solar radiation. Further insight of the "operational vision" the WG was demonstrated by its notation that "the production of synoptic charts requires essentially a continuous flow of data from ocean data stations. " Using this rationale, the WG highlighted the need for a family of high frequency radio spectra so as to provide 24-hour communications. The WG then recommended the establishment of a "Joint (IOC-WMO) Panel of Experts on Co-ordination of Requirements for a Network of Ocean Data Stations".

IGOSS ESTABLISHED

By 1967 the confluence of many events within IOC suggested a more integrated and streamlined program structure. Recognizing this, the Fifth Session (1967) of the IOC (IOC-V) decided to integrate more closely many of its activities and, as a result, created the Integrated Global Ocean Station System (IGOSS). During the opening of IOC-V the Secretary-General of the WMO, D.A. Davies, pointed out "the influence of the oceans upon the atmospheric processes is so significant as to make a study of certain aspects of oceanography essential to a full study of meteorology." He also stated that, "it is in fact difficult to draw a line of demarcation between the two sciences. The two sciences not only have much scientific ground in common but they are basically the same kind of science, and the problems to be solved are in may respects of a similar character." He also took the opportunity to describe the newly created World Weather Watch (WWW) for the session. Based on the implementation of new technologies and better understanding of the atmosphere from the GARP, the WWW would change the existing world meteorological system. In this respect he did suggest that the WWW would contain the same "main elements of a similar world scientific programme for oceanography." Specifically such a program should "(1) First observe; (2) then process the observed data; (3) then exchange the processed and unprocessed data; (4) use the information for research; and (5) ensure adequate trained manpower."

During IOC-V (1967) the Secretary outlined the necessity "to co-ordinate the work of the Commission's Working Groups on Oceanographic Data Exchange, Ocean Data Stations, Communications, Variability, and Ocean-Atmosphere Interaction, with a view to preparing the ground for the eventual establishment of a system of synoptic oceanographic observations in the ocean." It is quite interesting to note that IOC-V made the following statement regarding IGOSS: "the implication of the 'Integrated' in the chosen name of the system to be established (i.e. IGOSS) should be interpreted as meaning that such a system would eventually co-ordinate all regional activities pursuing the same purpose as IGOSS." The statement was in response to a request by ICES and its desire to make sure a synoptic ocean system would be established in the ICES area of interest (i.e. North Atlantic). In discussing the report of the WMO/IOC Panel of experts on Co-ordination of Requirements, The Commission also stated that the creation of an integrated global ocean data system provided an integration of meteorology and oceanography that must serve all Member States. Many IOC and WMO discussions related to IGOSS inferred various meanings for the term integrated in its title. In this regard, Dr. F. Webster, Chair of the Scientific Advisory Board of the IOC, in 1977 stated, " The terms chosen by the IOC nearly a decade ago, tells something about what is intended by this system, but the same terms also can mislead. …The initial sense of the term 'integrated' implied integrating observations, data transmission, and data processing methods for oceanic and atmospheric needs. Integrated might also mean combining individual national programs of ocean services to form an international program having more global effectiveness. Finally, the various phases of the system: collecting the data, processing it, and distributing both the data and products derived from it, could be integrated into a system with a common objective and purpose.

In 1981 the Integrated Global Ocean Station System was changed to the Integrated Global Ocean Services System; however, it should be pointed out that the name of the programme was the subject of many discussions even before its establishment. In 1967 the IOC Working Group on Ocean-Atmosphere Interaction discussed a proposal for a Synoptic Oceanographic Service and

suggested that "the title 'A Synoptic Ocean Data System' may be a better designation for a coordinated approach" and that "the use of the word 'service' may be understood as excluding research requirements which clearly was not the intention of the proposal in question."

During the IOC-V (1967) session, the Chairman of the WG on communications indicated that the proposed availability of radio frequencies in support of oceanography would greatly facilitate the eventual development of synoptic oceanographic systems and that further aspects of this issue should be considered within the context of the newly created IGOSS. The observer from the ITU attending IOC-V then confirmed that the designation of frequencies for oceanography had been approved by the WARC and that the WMO and IOC in consultation with the Intergovernmental Frequency Resource Board (IFRB) should become responsible for the development and maintenance of a frequency utilization plan. During the discussion on co-operative studies of variability in the ocean, the Chair of the WG (Dr. Warren Wooster) indicated that much of the future work of the Group could eventually merge into the development of synoptic systems such as IGOSS. However, the Commission decided also to establish an "IOC Group of Experts on Oceanic Variability,"

The specific IOC resolution creating IGOSS (Resolution V-20) recognized the activities of the World Weather Watch and that the WMO Congress had stressed the need for closer co-operation with IOC. The resolution created a permanent Working Committee for an Integrated Global Ocean Station System that will work "jointly with the WMO. The Resolution contained 5 sub-sections (resolution V-20 A through E) which addressed (A) the close collaboration between IGOSS and Oceanographic Data Exchange; (B) the relationship between IGOSS and a joint IOC/WMO Group of Experts on Radio Communications; (C) the relationship with a Joint (WMO/IOC) Working Group on Ocean-Atmosphere Interaction; (D) the relationship with an IOC Group of Experts in the field of Ocean Variability, particularly with respect to "monitoring, measuring and understanding ocean variability"; and (E) invited the WMO to participate in any additional study regarding the Legal Status of Ocean Data Stations. The Resolution called for a membership of no more than 12 Member States, the Chairs of Expert Groups, and representatives and observers of interested organizations.

The fifth Meteorological Congress (Cg-V) (1967) in adopting the World Weather Watch, also decided, "that the WMO shall endeavor to participate in all meteorological and related aspects of international marine scientific activities." In 1968, following the guidance from its Congress, the WMO (EC-XX) established an EC panel on Meteorological Aspects of Ocean Affairs (EC/MAOA) to provide technical advice on ocean and marine actives for the organization and more specifically to work jointly with the IOC Working Committee for an IGOSS. The following year EC-XXI (1969) adopted a resolution relating IGOSS and the WWW and specifically endorsing, "the principles regarding the integrated planning of IGOSS with the World Weather Watch…" Six years later the 7th Meteorological Congress (1975) (Cg-VII-Resolution 19) recognized, "IGOSS as a joint IOC/WMO undertaking to be planned in conjunction with the WWW and the Marine Meteorological Services System, in support of operational maritime activities and research programmes dealing with the marine environment such as GARP and co-operative scientific investigations concerned with ocean-atmosphere interaction processes."

APRROVAL OF THE IGOSS PLAN AND IMPLEMENTATION PROGRAM

The first session of the Working Committee for IGOSS was in April 1968, under the chairmanship of Dr. J. P. Tully (Canada). Representatives of the WMO participated in the session as the EC/MAOA was as yet formally established. During this session much of the discussion was concerned with the definition of the objectives of IGOSS and how it should evolve. It was agreed that, "initially, IGOSS should be limited to those ocean observations which are, or can be, readily made, which can be coded, and for which there is an immediate requirement." It was further agreed to develop an initial first phase plan for IGOSS within one year's time. Following the creation of IGOSS, the secretariat function was part time and carried out by Dr. A. Y. Takenouti, a seconded WMO science officer to the IOC. In November of 1968, Mr. R. Junghans reported to the IOC Secretariat to become the first full time IOC Assistant Secretary specifically tasked with Ocean Services in general and more specifically the development of IGOSS.

In February of 1969 EC/MAOA had a short organizational meeting and elected Mr. P. Meade (UK) as chair of the Panel. The panel meeting was immediately followed by the First Joint Meeting with WC/IGOSS chaired by Dr. J.P. Tully (Canada). Much of the discussion in the Joint Session considered operating procedures and the development of the plan. The Joint Session agreed to the outline of a plan and provided considerable detailed guidance to the Secretariats so that the plan could be made available later that year. The actual drafting of the IGOSS plan and program was accomplished by F. Keyte (Canada), M. Menache (France) and B. Thompson (USA). The "General Plan and Implementation Programme of IGOSS for Phase I," was approved in September 1969, by the Sixth Session of the IOC (Resolution VI-7). Approval by WMO came from its President in 1969 and later confirmed by the twenty-second session of the EC (Resolution 13) in the spring of 1970.

START OF IGOSS OPERATIONS

The major elements of IGOSS included: Observations; Telecommunications; Data Processing (including product and service preparation); and Data Storage and Retrieval. One of the objectives of the IGOSS Phase I plan was to integrate as quickly as possible ongoing national capabilities into a global system. As a result, it was important to establish an approved code form that be used to exchange data in near real time (Both WMO and IOC agreed that real time could extend out to thirty days if necessary). The initial plan called for the IGOSS Telecommunications Arrangements to use the WWW Global Telecommunication System (GTS). Under these arrangements, it was then necessary to get approval of the WMO Members for a new code form. Many North Atlantic nations had already adopted a BATHY code which provided an accelerated start for this aspect of the program. By 1972 there was agreement for the distribution of BATHY and TESAC over the GTS on a test (pilot) basis which became fully operational by 1975. Initially the exchange provided over 1000 BATHY messages per month and continued to grow. Later in IGOSS additional arrangements were added to cover operationally TRACKOB, BUOY, and changes to the SHIP codes.

Besides building on the integration of existing national capabilities, several expert groups were established by recommendation from the third joint session of the WC/IGOSS and EC/MAOA to help design and plan for IGOSS beyond Phase I. The Joint IOC-WMO Planning Group for IGOSS (IPLAN) was tasked with the overall guidance for future plans. The Joint IOC-WMO Group of Experts on IGOSS Technical Systems Design and Development and Services Requirements (ITECH) was tasked to provide guidance on the operational systems and services for IGOSS. The IOC Group of Experts on Ocean Research as it relates to IGOSS (IRES) was to provide guidance to the WC/IGOSS based on ocean research, particularly those activities of the Commission.

Because of the operational aspects, one of the unique features of the IGOSS concept to IOC was the need to establish technical regulations and practices. In contrast, this was one of the major activities of the WMO where manuals (technical regulations) had been established for the WWW and the applications programs. In addition, an overall WMO guide for observing practices had been established and used by all aspects of meteorology. By 1975, two guides and one manual had been adopted for use by IGOSS. These included: The Manual on IGOSS Data Archiving and Exchange; The Guide to Operational Procedures for the Collection and Exchange of Oceanographic Data; and The Guide to Oceanographic and Marine Meteorological Instruments and Observing Practices.

In the first few years the quantity of ocean data exchanged grew at a steady rate as the IGOSS concept gained acceptance and began to mature. One significant outcome from the start of real time ocean data exchange was the closer relationships that developed between national meteorological and oceanographic authorities. One of the expected growth areas in IGOSS was the potential expansion of Ocean Station Vessels and Weather Ships; however, this did not occur. In fact, these platforms, with their "rich" long time series of ocean and meteorological data, were undergoing a major decommissioning and being phased out of service, because of the high costs that were incurred. This demise was aggravated to some degree by the newly emerging satellite agencies that suggested the same observations would be available from space at much less cost. Unfortunately this appeared to be welcome information for most of the Western Governments that were seeking limited or no-growth in "discretionary" spending. It should be noted that eventually, through enhanced instrumentation and data assimilation techniques, satellites did begin to provide a significant amount of global data needed by ocean and atmosphere numerical models. These data included, high-resolution information on sea surface topography, ocean color, surface stress parameters, and precipitation at sea. However; there was a several decade gap between the satellite capability and the lost of the ocean stations.

THE IGOSS EXPERIENCE AND LEGACY

For the next 30 years IGOSS would provide the major test bed for the evolution of most of what now is considered international operational oceanography including the definition used as a part of the GOOS. IGOSS accomplishments and its failures have been an important factor in the development of the Global Ocean Observing System (GOOS) and the management concept used by the IOC-WMO Joint Technical Commission on Oceanography and Marine Meteorology (JCOMM).

The IGOSS evolution into GOOS and JCOMM has been a success; however, the initial planning and implementation of IGOSS did provide a major challenge to the very diverse cultures of IOC and WMO. In fact, during several early joint planning sessions for IGOSS, debate and discussion nearly collapsed. The early phases of the IGOSS concept experienced some limitation to growth based on confusion, skepticism, and misunderstanding within both IOC and WMO. This was most visible in the very difficult discussions held within the joint IOC/WMO expert groups and planning bodies as well as the joint sessions of the WC/IGOSS and EC/MAOA. One issue informally expressed on many occasions concerned the potential drain on resources within WMO that would have come at the expense of more terrestrial based programs. This led to perceptions that WMO was less than supportive to a fast developing IGOSS. Several in WMO expressed frustration that the pace was too rapid, and approval of effective operational technical regulations could not be attained without a full discussion on impacts and appropriate testing. In addition, many ocean scientists assumed from the title and it's heritage, that IGOSS was largely a program to establish, maintain, and expand fixed observing stations in the global oceans by establishing additional Ocean Station Vessels and Moored Data Buoy locations. As a result, there was a fear that such an activity would drain much of the funding available for ocean research. An interesting dialogue (debate) on this issue took place in the form of a paper by H. Stommel in Science Magazine (25 June 1970; Vol. 168; No. 3939), and a reply to the editor by W. Wooster.

The rate of growth of the IGOSS concept was largely limited by both the state of the science, and equally importantly the evolution of technology needed to observe, communicate, and analyze. On the other hand, the IGOSS did benefit from its close association with the WWW where it shared many of the facilities, particularly telecommunications. In addition, the 1960/70 era was start of coordinated global environmental science including the large field experiments of the GARP and the International Decade of Ocean Exploration (IDOE) as well as increased interest in the monitoring of global environmental quality.

Within the development of international operational oceanography, IGOSS has provided considerable infrastructure for testing new activities and concepts in the form of pilot projects. One of the major pilot projects involved Marine Pollution Monitoring which was found to be of limited use in terms of global application; however a cursory evaluation did suggest some value with respect to distribution of certain hydrocarbon products and tar balls. Both ICES and FAO strongly supported the IGOSS concept in hopes that enhanced ocean observations and services could significantly improve the efficiency of commercial fishing and aid in better understanding the links between the physical and biological properties of the ocean.

The IGOSS could be considered a test bed that provided information which permitted an evolution of management structure going from the joint sessions of WC/IGOSS and WMO EC/MAOA to an IOC-WMO Joint Working Committee for IGOSS and eventually to the WMO-IOC Joint Technical Commission on Oceanography and Marine Meteorology (JCOMM). Along the way, these evolutionary management bodies produced Five IGOSS Plan and Implementation Programmes spanning from 1970 to 2003. In a discussion with people who have devoted large amounts of their professional life to the early development of the IGOSS concept (see Annex A) there was a general agreement that an evolution took place in WMO and IOC moving from limited support, but skepticism to enthusiasm with a high priority for succeeding. As IGOSS was in the process of "passing" the torch to JCOMM and GOOS, it became clear that the secretariat program staff, the

Executive Offices of the secretariat, and the Presiding Officers of both WMO and IOC became increasingly intent to move jointly in bringing operational oceanography into the twenty first century.

Both WMO and IOC had considered the IGOSS as the major mechanism for joint operational activities of the two bodies. In many cases IGOSS was a catalyst that influenced, as well as directly and indirectly spun-off, other organizations and programs important to operational oceanography. These include the Data Buoy Cooperative Panel, Ships of Opportunity program, IGOSS Sea Level Programs (i.e. Pacific, and the North and Tropical Atlantic), IGOSS Pilot Project on Altimetric Sea-surface Topography data (IPAST), IGOSS Sub-surface Thermal Programme (ISTP), IGOSS/IODE Global Temperature-Salinity Project, special ad hoc groups to support GARP field programs (i.e. GATE, FGGE, MONEX, etc.).

The evolution of the management and structure of IGOSS can be described in terms of the growth of the science and technology. The evolution included the observing of the ocean by simple Bathythermographs and classic "Hydro-Nansen" casts; to expendable BTs and CDTs; to Satellite tracked drifting buoys; to automated ship observations; to large moored automatic buoy arrays with surface and subsurface sensors and satellite altimetry, ocean color, and microwave spectrometry; to a global array of sub-surface floats (ARGO). Similarly, communication technology over the 30 years evolved from high and very high frequency radio, to Satellite data communication platforms, to global and regional satellite position fixing (Service Argos), to Global Positioning Systems and to a broad banded world internet. Related to this technology growth, has been an evolution from analog telecommunication codes, to binary code forms, and on to other digital codes. Scientific understanding and processing technology has also evolved from hand drawn subjective analysis based on historical analyses and classic water-mass concepts, to simple numerical one dimensional models using analog processing and computers with processing speeds in the kilohertz range and on to sophisticated data assimilation schemes and multi-vector processing at more than tera-flop speed allowing dynamically coupled ocean-atmosphere general circulation models and near real-time satellite processing.

It was this evolution that both bounded and stimulated the infrastructure of the IGOSS concept to grow into the JCOMM/GOOS concept of Operational Oceanography.

In preparing this paper, I would like to acknowledge the support of the WMO, IOC, and a Group of reviewers that were involved in most of the international leadership positions responsible for the early evolution and development of the Integrated Global Ocean Service (originally Station) System (IGOSS). In particular, I would like to thank Dr. Neil Campbell, Dr. Geoff Holland, Dr. Ferris Webster, Mr. Bob Junghans, Mr. Burt Thompson, Mr. Mitchell Shank, Dr. Richard Hallgren, Dr. Colin Summerhayes, Mr. Yves Treglos, and Dr. Peter Dexter.

ANNEX A

Acronyms

ARGO	**Temperature/Salinity profiling floats (See Jason in Greek Mythology)**
BATHY	**Report of Bathythermal observation (WMO Code FM63-IX)**
BT	**Bathythermograph**
Cg	**Designation for WMO Congress**
CTD	**Conductivity-Temperature-Depth probe**
DBCP	**Data Buoy Co-operation Panel**
EC-IOC	**Executive Council**
EC-WMO	**Executive Committee**
FAO	**Food and Agriculture Organization**
FGGE	**First GARP Global Experiment**
GARP	**Global Atmospheric Research Program**
GATE	**GARP Atlantic Tropical Experiment**
GLOSS	**Global Sea-Level Observing System**
GOOS	**Global Ocean Observing System**
GTSPP	**Global Temperature and Salinity Profile Project**
IAMAP	**International Association of Meteorology and Atmospheric Physics**
IAPO	**International Association of Physics in the Ocean**
ICES	**International Council for the Exploration of the Sea**
ICSU	**International Council for Science (of Scientific Unions)**
IFRB	**International Frequency Resource Board**
IGOSS	**Integrated Global Ocean Services (Station) System**
IMCO	**International Maritime Consultative Organization**
IMO	**International Maritime Organization (From 1988)**
IMO	**International Meteorological Organization (until 1950)**
IOC	**Intergovernmental Oceanographic Commission**
IODE	**International Oceanographic Data and Information Exchange**
IPLAN	**Joint IOC-WMO Planning Group for IGOSS**
ISLP-Pac	**IGOSS Sea-Level Programme in the Pacific**
ISLPPNTA	**IGOSS Sea-Level Pilot Project In the North and Tropical Atlantic**
IRES	**IOC Group of Experts on Research as it relates to IGOSS**
ISTP	**IGOSS Sub-surface Thermal Programme**
ITA	**IGOSS Telecommunication Arrangements**
ITECH	**Joint IOC-WMO Group of Experts on IGOSS Technical System Design and Development and Service Requirements**
ITU	**International Telecommunications Union**
IUGG	**International Union for Geology and Geophysics**
JCOMM	**IOC-WMO Joint Technical Commission on Oceanography and Marine Meteorology**
LEPOR	**Long-term and Expanded Programme for Ocean Research**

MAOA	**WMO EC Panel on Meteorological Aspects of Ocean Affairs**
MONEX	**Monsoons Experiment**
SCOR	**Scientific Committee on Oceanic Research**
TESAC	**Temperature Salinity and Currents Report from a Sea Station (WMO code FM64-IX)**
TRACKOB	**Report of Marine Surface Observations along a Ship Track (WMO code FM 62-VIII Ext.)**
UN	**United Nations**
UNESCO	**United Nations Educational, Scientific, and Cultural Organization**
WARC	**World Administrative Radio Conference**
WC	**Working Committee**
WG	**Working Group**
WMO	**World Meteorological Organization**
WWW	**World Weather Watch**

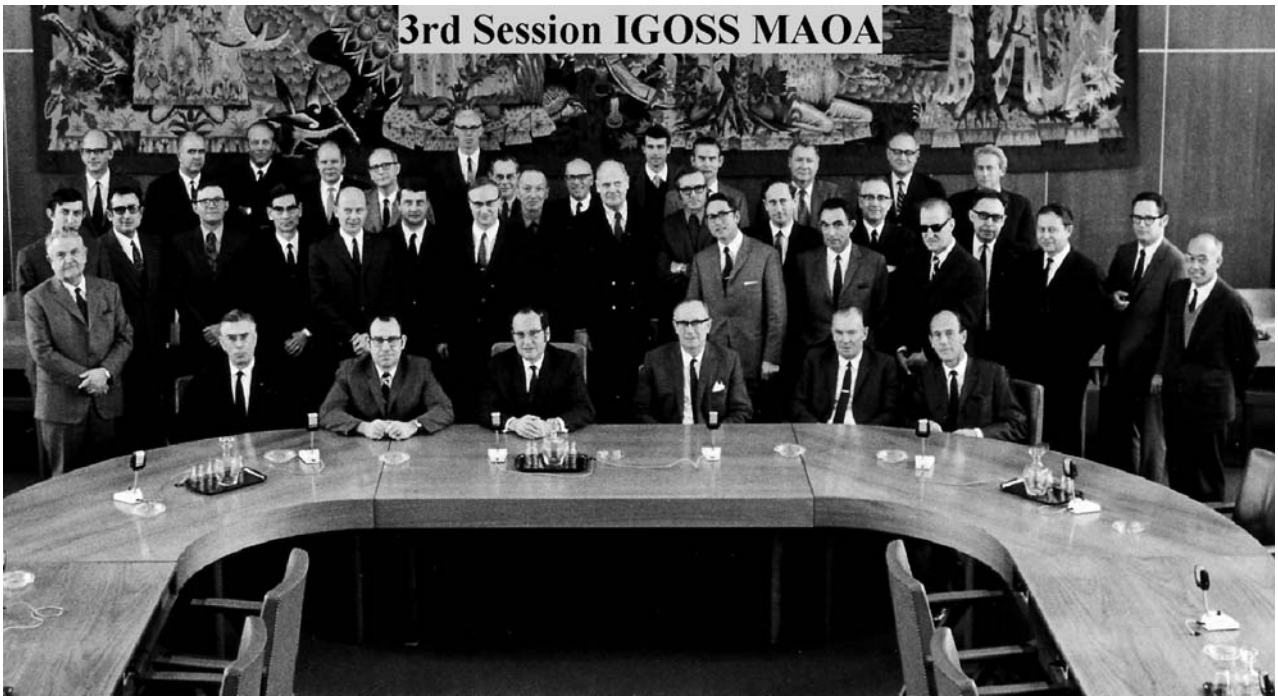
Annex B

"The Early Pioneers of IGOSS"*

*** The pioneers (Pre IGOSS and the first five years) have been selected from participants in 2 or more IGOSS sessions or Expert meetings, Experts that were involved in establishing IGOSS, and Secretariat.**

Campbell, N.J. (Canada) - Chair WC, Chair IOC
Charnock, H (UK) - Chair Expert Group
Davydov, G.M. (USSR) - WC delegate; Expert
Dellamula, F. (ITU- IFRB) - IGOSS rep
Dorrestein, R. (Netherlands) - WC delegate; Expert
Eggvin, J. (Norway) - WC delegate; Expert
Federov, K.N. (IOC-USSR) - Secretary IOC
Hallgren, R. (USA) - WC delegate
Hamon, B. (Australia) – Expert
Hanzawa, (IOC-Japan) – Secretariat
Hill, H.W. (UK) - WC delegate
Hodgeman, J. (USA) - WC delegate, Expert
Holland, G. (Canada) - Chair WC, Chair IOC
Junghans, R (USA) - Chair WC; Secretariat
Landis, R (USA) - WC delegate; Secretariat
Mann, C.R. (Canada) – Expert
McLeod, K.T. (Canada) – Expert
Meade, P. (UK) - First Chair EC panel
Morales, C. (IOC-Sweden) – Secretariat
Nasmyth, P. (Canada) - Chair Expert Group
Ohwada, M. (IOC-Japan) – Secretariat
Rama Sastry, P.A. (India) - MAOA delegate
Roll, H.U. (FRG) - Chair Expert Group
Romer, J. (France) - Chair Expert Group, MAOA delegate
Rybnikoff, A (USSR – Expert
Scott, D.P.D. (UK) - Chair Expert Group; Secretary IOC
Shank, M.K. (USA) - WC delegate
Smed, J. (ICES) - IGOSS rep
Smirnov, N.A. (USSR) - WC delegate, Expert
Snodgrass, J. (USA) - Chair Expert Groups

Stewart, H. (USA) - WC delegate; Expert
Swallow, J. (UK) – Expert
Takenouti, A.Y. (IOC-Japan) – Secretariat
Thompson, B.J. (USA) - Secretariat; WC delegate
Tolkachev, A. (IOC-USSR) – Secretariat
Tomczak, G (FAO) - IGOSS rep
Treglos, Y. (France) - Chair WC; Secretariat
Tully, J. (Canada_ - First Chair WC
Van Hamme, J.L. (Belgium) - WC delegate
Veranemen, N. (WMO-Belgium) – Secretariat
Verploegh, G. (WMO-Netherlands) – Secretariat
Walden, H. (FRG) - WC delegate
Webster, F. (USA) –Chair Expert Groups
Weiss, G. (WMO-Austria) – Secretariat
Wilson, R. (Canada) - Chair Expert Group
Wooster, W. (USA) - Chair Expert Group



IIIrd Joint Session of IOC Working Committee and WMO EC Panel MAOA (1970)

2nd row standing: Dorrestein (Netherlands), Smirnov (USSR), Tomczak (FAO), (USSR Interpreter), Godson (Canada), McLeod (Canada), Holland (Canada), Dinsmore (USA), Roche (USA), Mull (USA), Holland (Norway).
1st row standing: Schwitzer (Fed Rep Germany), Shank (USA), Ataide (Portugal), Webster (USA), Masuzawa (Japan), Walden (Fed Rep Germany), Shulze (Fed Rep Germany), Van Hamme (Belgium), Charnock (UK), Saila (IOC/FAO), Cartwright (USA), Eaton (WMO), Thompson (USA), Verploegh (WMO), Hill (UK), Vitureau (France), Tournier (France), Romer (France), Smed (ICES), Ferrowski (IAEA), Shykind (USA), Quintos (IFRB),
Seated: Snodgrass (USA), Junghans (IOC), Campbell (Canada), Meade (UK), Tierney (WMO), Veranneman (WMO).