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IOC CONTRIBUTIONS TO INTERNATIONAL, INTERDISCIPLINARY OPEN DATA SHARING

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INTRODUCTION

Over the last 50 years, the Intergovernmental Oceanographic Commission (IOC) has had a profound influence upon the willingness of United Nations Member States to share and provide access to their international and interdisciplinary oceanographic data. (For an early history and review of IOC achievements, see Roll, 1979.) Ocean science over the last half century has been transformed from a predominately modular, single-disciplinary, and individualistic science into a national and multinational interdisciplinary enterprise (Briscoe, 2008; Powell, 2008). The transformation began slowly, but as computing power increased, the pace accelerated, and along with these alterations came shifts in cultural practices regarding the sharing of data.

The transformation of ocean science to a multidisciplinary national and international enterprise was abetted by the new availability of a multiplicity of data sources, thanks, in no small part, to IOC. Remotely operated vehicles and autonomous underwater vehicles, floats, and gliders now complement observations from ships, moorings, satellites, and manned submersibles (D'Asaro et al., 2008). Both at sea and in shore-based laboratories, biogeochemical and genetic tools and techniques have changed the nature of the experimental side of the science. High-resolution coupled physical, biogeochemical, and biological models are now used to hindcast with existing data sets and are setting the stage for the forecasting needed to assist in anticipating climate change and the future management of our planet (Rothstein, 2006).

To encourage data openness (defined here as broad accessibility to data provided by Member States to all others), IOC has had to face two very real challenges: rapid computer technology advancement and established national data cultures. Although IOC is not in the technology development business per se, the widely varying state of technological readiness among Member States (see Figure 1) dictated the limits of what could be done as opposed to what could be imagined. Nevertheless, as technology evolved, IOC operated at the forefront of this evolution, doing what it does best—convincing participants to share their data for the common good.

The IOC oceanographic data exchange policy (stated in 1999 as the 11th resolution of the 20th session of the IOC Assembly) subsumes the idea that data collected in the field have an intrinsic value that cannot be replaced. The time-worn saying "you cannot step into the same stream twice" especially applies here, considering the time, energy, and money required to make sea-going measurements. In truth, one only gets out of a model what one puts into it. However, you never know what you are going to find any time you expose a sensor to the environment. Therefore, any actual measurement made must be protected (along with all of the attendant metadata: where/when was the measurement made, what method was used, who made the measurement, what are its error bounds, and other information).

Although "technology" is a familiar term, the concept of "data culture" is one that has received little attention. Data extracted from nature are much like ore removed from the earth—problematical to obtain and as yet unproven in worth. Later, through the processes of refining, purifying, and alloying, data, like ores, become more valuable. Convincing Member States to share and pool their data has required (and still requires to this day) a culture shift in the concepts of data value and the meaning of the common good. In this article we explore the history of some of the obstacles faced, and present examples of solutions and benefits provided by IOC efforts to promulgate an international, interdisciplinary pooling of hard-won data wrested from the ocean.

HISTORY

IOC's accomplishments over the past 50 years are numerous, and the notion that we could summarize the influence these accomplishments have had on data openness in a few pages here is overly optimistic. However, we review the five decades of IOC's history from the early years (1960–1969), through the middle years, to the latest decade (2000–present), highlighting key accomplishments of IOC and its chief arm, the International Ocean Data and Information Exchange (IODE). During each period, we focus on how IOC, standing at the intersection of technological advances and cultural shifts, brought about changes in the way the

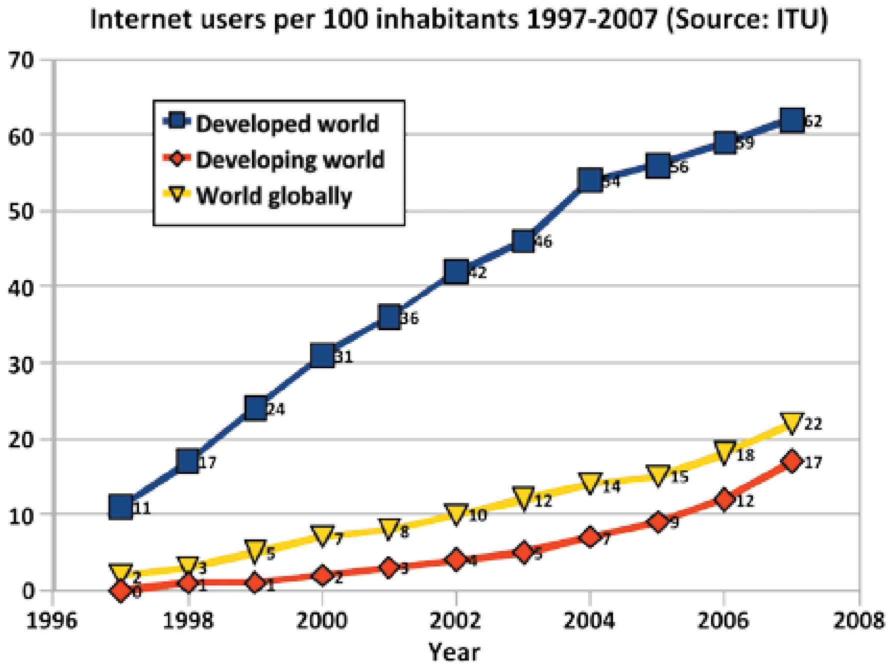

Figure 1. A plot showing the rise in access to the World Wide Web. The disparity between the developed and developing world is immediately apparent. That IOC makes allowances for this discrepancy is one of the strengths of its approach. Here, access to the WWW is being used as a proxy for access to technology. *Source: http://www.itu.int/ITU-D/ict/statistics/ict/graphs/internet.jpg*

oceanographic community in particular, and the scientific world in general, shared data. Finally, we speculate about IOC's potential future role in data sharing (Figure 2).

1960–1969: Things Get Organized

In the beginning, data exchange was an important reason for IOC's creation. There were other reasons, including international cooperation and coordination, capacity building, and sustainable management of the marine environment. But, during the Cold War of the 1960s, exchange of ocean data was highly controlled, and it needed a forum for agreements to be made. In a time when data were printed on paper, carrying them through airport customs without declaration was not an option[1]. This world was strange to many of us; integrated circuits had just been invented, allowing the introduction of the IBM 360 "mainframes" and the DEC PDP-8 "mini-computer"—which filled only a fraction of a large room. There were no calculators (the slide rule was king) and Microsoft's Bill Gates was still in high school. When it came to data exchange, much could be imagined, but little (even for the "developed countries") could actually be accomplished.

First, IOC had to be created, and this was accomplished by a recommendation from the Intergovernmental Conference on Oceanographic Research held in Copenhagen in July 1960 (see IOC timeline at: http://portal.unesco.org/science/en/ev.php-URL_ID=8463&URL_DO=DO_TOPIC&URL_SECTION=201.html). In effect, this recommendation not only established the need for an organization such as IOC, but made IOC an arm of UNESCO. Then, by Resolution 2.31 at the 11th session of the UNESCO General Conference in November 1960, IOC was made a reality. IOC's mission statement (IOC, 2000) reads:

> *To promote international cooperation and to coordinate programmes in research, services, and capacity building, in order to learn more about the nature and resources of the ocean and coastal areas and to apply that knowledge for the improvement of management, sustainable development and protection of the marine environment and the decision-making process of its Member States.*

It followed, then, that IOC needed "arms" of its own to pursue these goals, especially when it came to the issue of data. In October 1961, IOC's working group on Data and information Exchange (IOCDE) was established at the 1st session of the IOC Assembly held in Paris (headquarters). This working group was the forerunner of the organization known today as the International Oceanographic Data and Information Exchange (IODE). Its purpose was to enrich scientific marine research, exploitation, and development. IODE was to accomplish these goals by ensuring

[1] The first floppy disks (eight inches, 80 KB) were invented in 1969, but they were not marketed until 1971. Historical information provided here about computer technology is drawn from A Brief History of Computing: Complete Timeline by Stephen White, available online at: http://trillian.randomstuff.org.uk/~stephen/history/timeline.html.

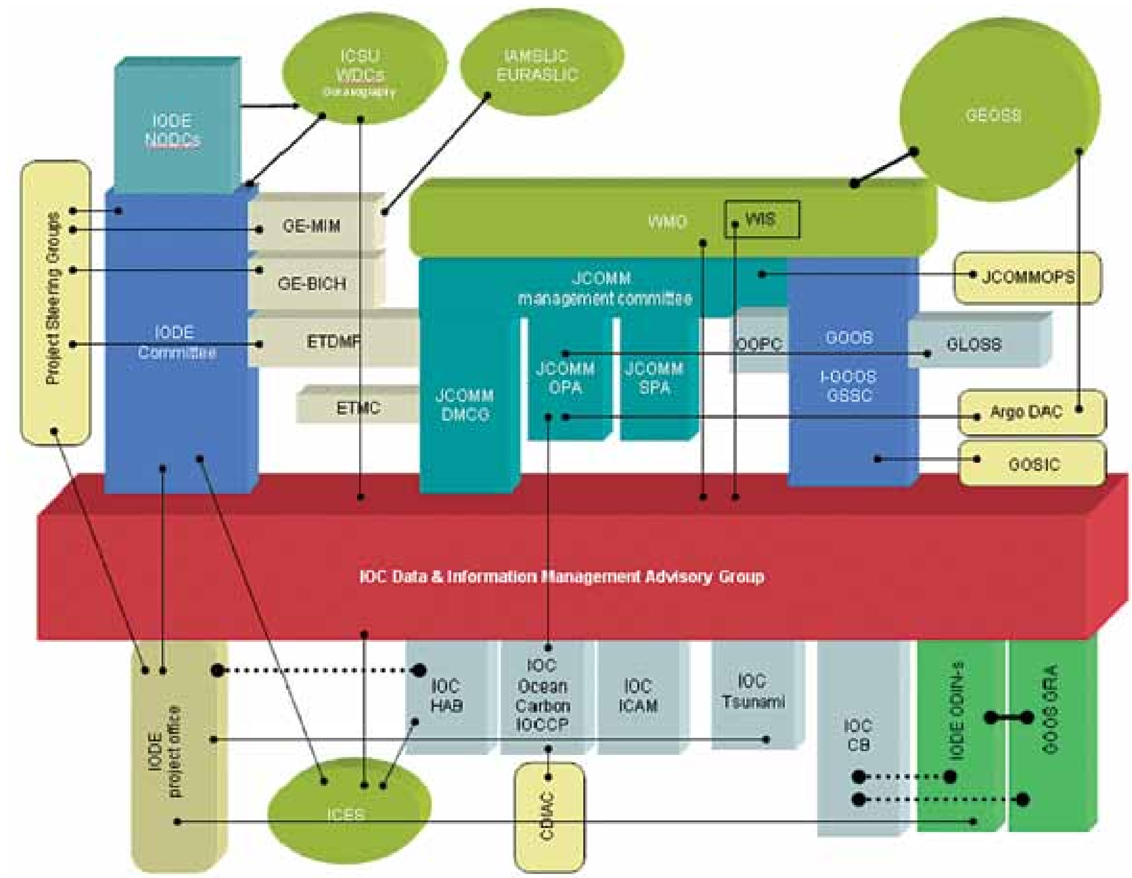

Figure 2. Schematic of the flow of data and information in the IOC data and information management plan (IOC, 2007). Since publication, this figure has been amended to include the Ocean Biogeographic Information System (OBIS) as part of the International Oceanographic Data and Information Exchange (IODE) community.

oceanographic data and information could be exchanged between Member States. This exchange involved not only supplying data (i.e., numbers) but also information products (i.e., knowledge), even if the Member States were suspicious of the new technology or just reluctant to part with their hard-won data. IODE to this day is one of the programs that still requires intergovernmental agreements and decision making, so participants at the meetings are officially designated representatives of their governments.

These accomplishments might be thought sufficient for one decade, but as is often the case, beginnings are a time of ambition and foresight. In 1967, Ambassador Arvid Pardo of Malta made an impassioned speech to the 22nd session of the United Nations General Assembly (UNGA) that laid the foundation for negotiations on a new Law of the Sea. Preparing for and then making the United Nations Conventions on the Law of the Sea (UNCLOS) succeed would be prominent in IOC agendas through the next two decades. In December 1968, UNGA adopted long-term plans for the International Decade of Ocean Exploration (IDOE), and the data and knowledge flowing from that would become a dominant fixture in IODE during the 1970s and beyond. At the 6th session of the IOC

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Assembly (1969), a general plan was mapped out for the Integrated Global Ocean Station System (IGOSS) to permit collecting and exchanging oceanographic data jointly with the World Meteorological Organization (WMO). With no Internet, not even TCP/IP, that was ambitious indeed.

The name of IGOSS was changed more than a decade later. As the many ocean weather stations, which were the basic data providers to IGOSS, began to close and data were starting to come in from vessels of opportunity, the meaning of the "S" changed from "stations" to "services." Thus, the later name, Integrated Global Ocean Services System, was adopted.

1970–1979: Data Are "Published"

Computer technology underwent a growth spurt in the 1970s. This decade saw the first RAM chip, microprocessor, and calculator. The UNIX operating system was developed, as was the VAX computer and the concept of virtual memory. The US Department of Defense was experimenting with networks (ARPANET), Microsoft was incorporated, and that greatest of all computer technology equalizers, the personal computer (PC) was born. Prior to this time, data exchange was carried out by mailing 7- or 9-track magnetic tape reels. When floppy disks arrived, it was possible to carry reams of data (if printed out) in a rather large coat pocket. Some dreams became possible, at least for the wealthier nations. Still, things were missing. There was no DOS (or Windows), floppies were really floppy (not durable), and there was no Macintosh. There was no Internet, no World Wide Web, and most hard drives were considerably smaller than one gigabyte.

But, if the 1960s were the organizing decade, the 1970s were the years IOC started publishing data reports and optimizing mechanisms for international cooperation in the collection and distribution of marine data. In 1971 at the 7th session of the IOC Assembly, the Report of Observations/Samples Collected by Oceanographic Programs (ROSCOP) forms were adopted as de rigueur for all oceanographic research cruises. Every oceanographer has had the experience of filling out the ROSCOP forms as the ship deadheads back to port at the end of a cruise. At the same Assembly, IGOSS was organized into three phases so that by 1975 it would be fully operational. And, in 1975, the 9th session of the IOC Assembly launched the First Global Atmosphere Research Program (GARP) Global Experiment (FGGE), a drifting buoy system that provided meteorologists and oceanographers the opportunity to study the ocean/atmosphere as a single, integrated fluid system. A year later, IOC, WMO, and CPPS (Permanent Commission for the South Pacific) started their El Niño research program. At the 11th session of the IOC Assembly (1979), it was decided to co-sponsor an IOC-Scientific Committee on Oceanic Research (SCOR) Committee on Climate Change and the Ocean (CCCO) to provide scientific advice on oceanographic aspects of the World Climate Programme (WCP, a WMO project).

A multidisciplinary Marine Environmental Data and Information referral system had been adopted at the 8th session of the IOC Assembly (1973). It is of particular interest that this was one of the earliest metadata systems to be put into practice; the Ethernet was invented the same year, although its adoption as the de facto way to interconnect computers on a local area network was still decades away. At the same Assembly session, a joint IOC/IHO (International Hydrographic Organization) committee was formed to provide guidance to the General Bathymetric Chart of the Oceans (GEBCO) project. The IOC/IHO GEBCO project has as one of its goals to "encourage and facilitate scientific cooperation leading to the exchange and preservation of bathymetric data and associated metadata." GEBCO is one of the longest-running ocean data collection efforts, extending back to its creation in 1903 by Prince Albert I of Monaco and like-minded geographers and oceanographers. In 1977, IOC oversaw the preparation of a timely report on the present, planned, and potential uses of satellite and other remotely sensed marine data (IOC, 1992) at a time when TIROS-N (the first satellite to carry the Advanced Very High Resolution Radiometer), NIMBUS-7 (Coastal Zone Color Scanner debut), and Seasat (the first spaceborne synthetic aperture radar, scanning multichannel microwave radiometer, and altimeter) were all a year away from launch (Kramer, 2002).

With all the previous "organizing" and "launching," data started becoming available. The 10th IOC Assembly session established the FGGE data processing center in Germany and a "delayed mode" data center in the United States. This was the first time large amounts of surface drifter data were distributed on the global telecommunication system (GTS) of the day. This example of early data distribution, directly from a research program, was done in a near-real-time fashion, sharing sea surface temperature (SST) and SST anomalies every five days (Keeley and Taylor, 1982). The same year, the first volumes of the International Cooperative Investigations of the Tropical Atlantic oceanographic atlases of physical, chemical, and biological oceanographic data became available. Also hitting the streets at this time was the Indian Ocean Expedition phytoplankton production atlas. IOC also made plans to put together three volumes of the GARP Atlantic Tropical Experiment Oceanographic Atlas.

The 1970s saw a lot of preparation for the exact interpretation of certain Parts and Articles of UNCLOS, in particular Parts XIII (Marine Scientific Research), XIV (Transfer of Marine Technology), and Section 76 (definition of the continental shelf). Thus, practical means were needed to ensure that the rights and concerns of all Member States were respected without UNCLOS becoming a closed door instead of the open window it was intended to be in providing for the collection of data the world over. In particular, the national Exclusive Economic Zones (EEZs) established by UNCLOS (Figure 3) for coastal states would become flash points in the next decade.

1980–1989: UNCLOS Impact Is Felt

Computer technology during the 1980s began to look like it does today. DOS and Windows appeared, but not at the same time and not without their problems (Windows 3.0 would have to wait for the next decade). Nevertheless, the personal computer was now placed on the desktop, for those who had the wherewithal, with enough computational power that anyone could have a personal data center; processor clock speeds ramped up from around 4 to 33 MHz, RAM jumped from 1 MB in 1980 to 128 MB by the end of the decade, and disk storage space exploded from 140 KB on 5¼-inch floppies to 2 GB partitions on hard drives. The page layout language Postscript and laser printers appeared, CD–ROMs were marketed, and Apple's Macintosh became available, turning anyone's office into a publishing house with just the addition of relatively small and increasingly affordable machines. Near the beginning of the 1980s, ARPANET was combined with TCP/IP and the Internet was born, global exchanges of e-mail became widespread, and, later in the same decade, the Internet and Hypertext were combined to create the World Wide Web (WWW). All of the major pieces were now on the board and humankind stood at a critical crossroad that would determine access to data. What was needed was guidance.

During the 1980s, technology advanced to the point that IOC could give attention to another part of its mandate, capacity building. In 1982

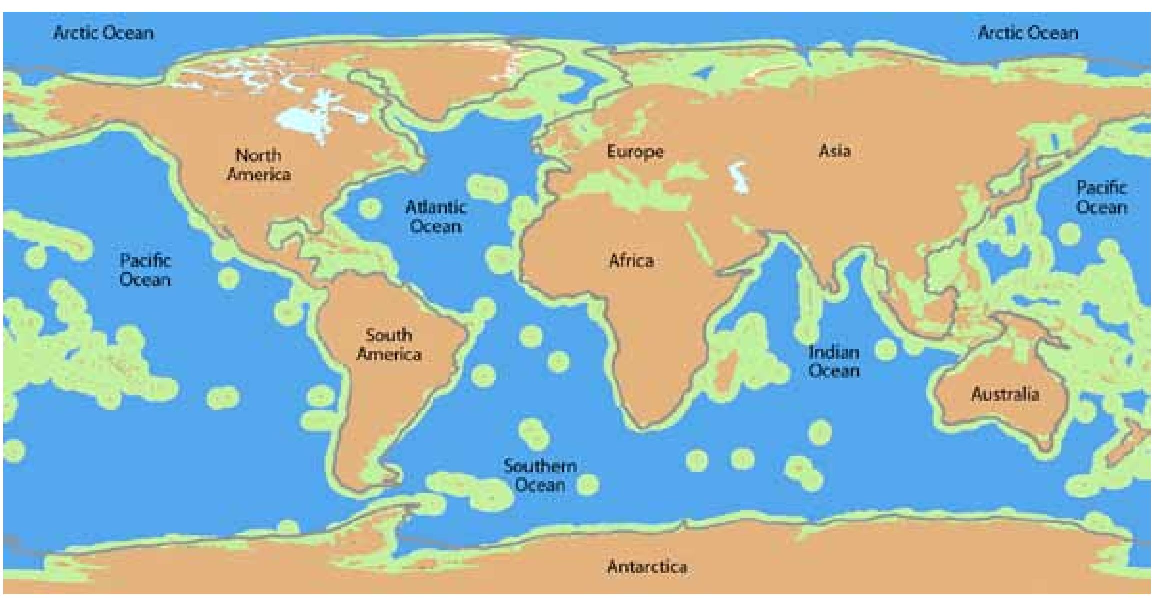

Figure 3. A map of the world's Exclusive Economic Zones (EEZs). Although there is plenty of open ocean, it is impossible for a launching nation to prevent free-floating sensors from being carried into another country's EEZ by capricious ocean currents. Green is an approximate indication of the 200-nautical-mile limit, and the gray line represents the continental shelf break. *Modified from an official work published by the Government of Canada from http://www.dfo-mpo.gc.ca/international/dip-rfmo-eng.htm. This graphic is not produced in affiliation with, or with the endorsement of, the Government of Canada.*

at the 12th Assembly session, IOC adopted the document *Marine Science and Ocean Services for Development: UNESCO/IOC Comprehensive Plan for a Major Assistance Programme to Enhance the Marine Science Capabilities of Developing Countries*, which established an avenue for IOC to engage in outreach activities to lift the capabilities of all Member States to the same level.

Following this document's adoption, in 1985, UNESCO/IOC formulated the Comprehensive Capacity Development Plan for Major Assistance Programme with the purpose of enhancing the marine science capabilities specifically of developing countries. At the 12th Assembly session, IOC instructed CCCO to design a comprehensive set of large-scale experiments for monitoring the ocean with the purpose of meeting World Climate Research Programme objectives. IOC also recommended the General Format (GF3) be used for the exchange of oceanographic data at a time when the media with the greatest data density for such exchanges were 9-track tapes (up to 140 MB per 2400 foot reel). The GF3 format was supported by a comprehensive software package, GF3-Proc, prepared by IOC and made freely available to all organizations and laboratories involved in the international collection, management, or exchange of oceanographic and other Earth sciences data.

More accomplishments in getting data out to the scientific community and the public followed at the 13th IOC Assembly session with the printing, publication, and distribution by the Soviet Union of the *International Bathymetric Chart of the Mediterranean (IBCM)* in 1985. At that Assembly, Mexico offered to take an active role in the preparation of bathymetric charts for the Caribbean and Central American coastal Pacific. This Assembly also brought the development of an implementation plan for IGOSS to accelerate the appropriate global mechanisms for timely collection and exchange of standard oceanic and related meteorological data. At this IOC session, the Global Sea Level Observing System (GLOSS) was established under IOC's direction and oversight. IODE's role was expanded to include Marine Information Management.

"IOC'S GREATEST CONTRIBUTION TO DATA OPENNESS HAS BEEN IN THE FORESIGHT OF THE MANY PARTICIPANTS IN ALLOWING EACH MEMBER STATE TO CONTRIBUTE AS THEIR ABILITIES ALLOWED, ALL THE WHILE HELPING THEM TO MEET THEIR GOALS AND ADD TO THEIR CAPACITY."

Following on the heels of these accomplishments were the Tropical Ocean and Global Atmosphere (TOGA) program in 1986, the World Ocean Circulation Experiment (WOCE) in 1987, and the Joint Global Ocean Flux Study (JGOFS) in 1988. All of these activities were global in nature, involved many nations, and collected (*for distribution*) lots of data. The TOGA program was a joint IOC/WMO project, with the international planning office located in the United States (it continues to this day). WOCE would go on to plan a joint IOC/WMO and ICSU[2]/SCOR international scientific convention in Paris in 1988. Its planning office would be in the United Kingdom, with data assembly centers (DACs) scattered around the world. (Some, but not all, DACs were collocated with national data centers that were members of IODE.) Plans to monitor and predict the El Niño phenomena in the Southeast Pacific were formulated at this point. In 1987, IOC joined ICSU's SCOR to help develop and implement the marine components of the International Geosphere-Biosphere Programme (IGBP). A year later, the SCOR-initiated JGOFS became part of IGBP, which provided JGOFS with an intergovernmental mechanism for executing plans for five regional process studies around the world. JGOFS would have its International Project Office at the University of Bergen, Norway (closed in 2003), and the US planning and data management office was based in Woods Hole, MA, USA (Glover et al., 2006).

At the 14th session of the IOC Assembly (1987), the structure of the working committee (IODE) was

[2] International Council of Scientific Unions (now known as the International Council of Science but with the same acronym)

modified, and its name was changed to the Technical Committee on International Oceanographic Data and Information Exchange, although it continues to use IODE as its acronym. Later, at the 15th session of the IOC Assembly (1989), the idea of a TOGA Coupled Ocean–Atmosphere Response Experiment was endorsed as an indispensable part of TOGA. The Global Ocean Observing System (GOOS) concept was developed jointly with WMO during this period toward providing an important piece in the study of the connection between the ocean and atmosphere for global climate studies.

The 1980s brought about the Law of the Sea and the establishment of national EEZs, instituted by the Third United Nations Convention on the Law of the Sea in 1982, which also affected data exchange practices and politics. The signing of UNCLOS by Members States established a legal framework for ensuring international maritime communications, peaceful use of the seas, and exploitation of marine resources without unfair advantage. It further protected the rights of the Member States to investigate and preserve the marine environment and conserve the biological standing stock.

In the late 1980s, the Global Temperature Salinity Pilot (later changed to Profile) Project began under joint sponsorship of IODE and IGOSS, and continues to the present. A number of countries became involved, contributing data and other resources to what was deemed the "Continuously Managed Database (CMD)." Global ocean profile data circulating on GTS was captured by the Canadian data center, using new software to check data quality and duplications, and files were sent through Internet connections three times a week to the US National Ocean Data Center (NODC), which operated CMD. The concept was to provide as complete a data set as possible to a user at any time from days to years after collection. As delayed-mode data were received, they would replace the typically lower resolution and lower quality real-time data. This project also introduced a standard for quality control of ocean profile data. Both the ideas embodied in CMD and the quality-control procedures strongly influenced later developments in this decade and beyond.

1990–1999: IOC Embraces Global Programs

Computer technology assumed a more incremental development trajectory in the nineties, and true multitasking was added to operating systems. LINUX was developed and USB support released. Now it was the time for IOC (and others) to put that technology to work.

Many of the global programs planned at the end of the 1980s were relevant to the study of Earth's variable climate system, with the attendant concerns as to what programs IOC should initiate to study humankind's contributions to that variability. The 1990s began with the Second World Climate Conference (WCC2) held in Geneva in October 1990. Here, the international cooperation necessary to support WCP was underlined, and in order to meet these global goals, the creation of GOOS was requested. GOOS later became the oceanographic component of the Global Climate Observing System (GCOS). Implementation of GOOS by IOC Member States would be accomplished by government agencies, navies, and oceanographic research institutions organized along thematic and regional alliances in complete cooperation with each other. In 1991, agreements were signed between WMO, ICSU, and the United Nations Environment Programme (UNEP) to ensure the cooperation necessary in organizing GCOS.

Late in 1990, the United Nations General Assembly created an Intergovernmental Negotiating Committee to review the details of a United Nations Framework Convention on Climate Change (UNFCCC) that would establish the need for stabilizing greenhouse gas concentrations in the atmosphere. UNFCCC itself would be penned at the "Earth Summit" in Rio de Janeiro in 1992; although it was a legally nonbinding document (it set no limits for greenhouse gas emissions), it would later be updated by the Kyoto Protocol.

At the 16th session of the IOC Assembly (1991), arrangements were made to coordinate with the Committee on Earth Observations Satellites and national space agencies. At the same Assembly, IOC chose to co-sponsor WCP, in particular the World Climate Research Programme (WRCP) with ICSU. This arrangement would be finalized in 1992. IOC further decided to provide a GOOS support office within the IOC Secretariat to develop GOOS. At the 17th session of the IOC Assembly, the Intergovernmental Committee for Global Ocean Observing System (I–GOOS) met for the first time. The Training, Education, and Mutual Assistance (TEMA) operational fund was also established at this Assembly to attempt to guarantee adequate support for the

TEMA program in the years ahead.

At this same 17th Assembly, the IODE Global Oceanographic Data Archaeology and Rescue (GODAR) project was initialized (Levitus et al., 2005). GODAR, still underway, has recovered millions of profiles of temperature, salinity, oxygen, and nutrients that were at risk of loss due to media decay (either paper or fading electronic media). All of these data have been made available internationally, without restriction, on DVD and online (http://www.nodc.noaa.gov) as part of the World Ocean Database (WOD) series. WOD is a global collection of ocean profile data at both observed and standard levels in one common format with accompanying metadata (Figure 4). Boyer et al. (2009) describe the latest version, WOD09. The importance of such a database to the scientific community cannot be underestimated. For example, Levitus (1982) published the first global analyses of objectively analyzed fields of temperature, salinity, and oxygen on a one-degree grid at standard depth levels. This work has been cited approximately 2600 times, and its successors, known as the World Ocean Atlas series, have similarly been cited a large number of times. These atlases were made possible by the sharing of data among IOC Member States through the IOC/IODE mechanism, recognizing that no one country can observe the entire world ocean due to a variety of resource limitations.

As the 1990s came to a close, the 20th IOC Assembly began planning to implement the Global Ocean Data Assimilation Experiment (GODAE). This experiment was conceived to help provide short-term ocean forecasting, boundary conditions to coastal ocean forecasting, and seasonal to interannual atmospheric forecasting (for more information on GODAE, see *Oceanography* 22(3), September 2009, at http://tos.org/oceanography/issues/issue_archive/22_3.html). However, GODAE has also been useful for comparisons of global open-ocean models with data, input into recent global ocean acidification studies (Xu et al., 2010), and long-term ocean–atmosphere climate model integrations. The Argo program (Roemmich et al., 2009) was accepted by IOC at this Assembly as an important contribution to GCOS and GOOS, and was further considered by IOC as a major contribution to WCR's Climate Variability and Prediction (CLIVAR) program. All of this was set down in IOC Resolution XX-6. This Assembly also formed a Group of Experts for the Oceanographic Data Exchange Policy, whose chief task was to reaffirm IOC policies and principles pertaining to free and open access to and exchange of marine data. By 1999, the groundwork was being laid for formation of the IOC/WMO Joint Technical Commission for Oceanography and Marine Meteorology (JCOMM), an intergovernmental organization dedicated to unifying the activities IOC and WMO had in common. JCOMM went on to provide coordination, regulation, and management, as well as data management services among its international oceanographic and meteorological members. Today, it provides an important nexus of expertise

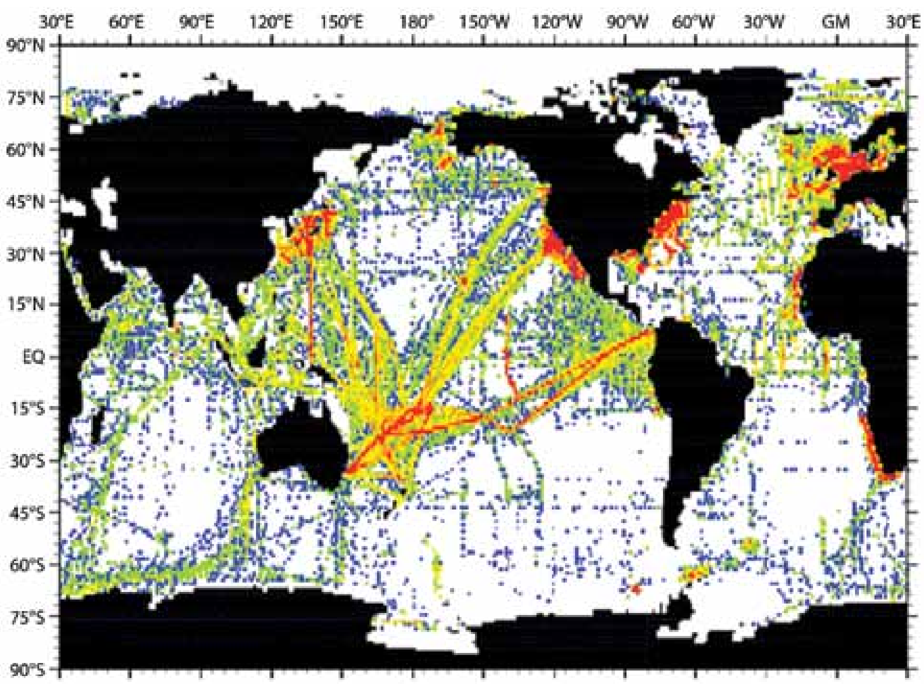

Figure 4. Distribution of chlorophyll profile data recovered by the Global Oceanographic Data Archaeology and Rescue (GODAR) project and surface-only chlorophyll data (Levitus et al., 2005). A red dot indicates a one-degree square containing 41 or more surface chlorophyll observations, orange indicates 21–40, yellow 6–20, and green 2–5. Blue indicates a one-degree square containing one observation. Note the relative absence of data in the central Indian Ocean, the eastern South Pacific Ocean, and the South Atlantic Ocean. *Data courtesy of the French Ship-of Opportunity program*

and expedition for international issues of the day as they pertain to GOOS, GCOS, and follow-on activities of GODAE.

Throughout the 1990s, issues of UNCLOS interpretation and implementation arose. In 1995, at the 18th session of the IOC Assembly, an intersessional working group (WG) was formed to examine the relationship between IOC and UNCLOS, and to review all articles of UNCLOS that influence IOC operations either explicitly or implicitly. In 1997, the 19th session of the IOC Assembly created a largely unstructured Advisory Body of Experts (ABE) on the Law of the Sea (LOS). The main ABE–LOS responsibility is to provide advice to IOC on matters pertaining to the implementation of proposals and recommendations that have arisen or will arise from the IOC WG attempting to formulate IOC's role in UNCLOS.

Technology not only evolves and improves, it also spreads. As time went on, it became more feasible (mostly, affordable) for developing nations to integrate into the global Internet. By the end of the 1990s, it was possible to propose, review, and accept the concept of Ocean Data and Information Networks (ODIN) as an IODE mechanism for providing national and regional structure for data exchange services and products. The first of these was ODINAFRICA, accepted at the 20th session of the IOC Assembly.

2000–2010: IOC Promotes Intergovernmental Cooperation At Sea

In the first decade of the twenty-first century, there has been a need for even greater intergovernmental cooperation at sea, and IOC has tried to broker a best effort from each of its Member States, given the heterogeneous nature of their capabilities. In 2001, the Argo Information Center (AIC) was established in Toulouse, France. One of AIC's purposes is to track Argo floats in order to alert coastal Member States of their arrival in EEZs (Figure 5). This center was the culmination of nearly 10 years of debate among the Member States as to what comprises "the right to conduct" peaceful marine scientific research in light of the "sovereignty" and "jurisdiction" of coastal states, all terms used in UNCLOS. The Argo program, with the near unpredictability of when and where the floats would be collecting data, tested the wisdom of having the right to conduct peaceful marine research and having exclusive sovereignty of nearby oceanic regions (EEZs).

At the 21st session of the IOC

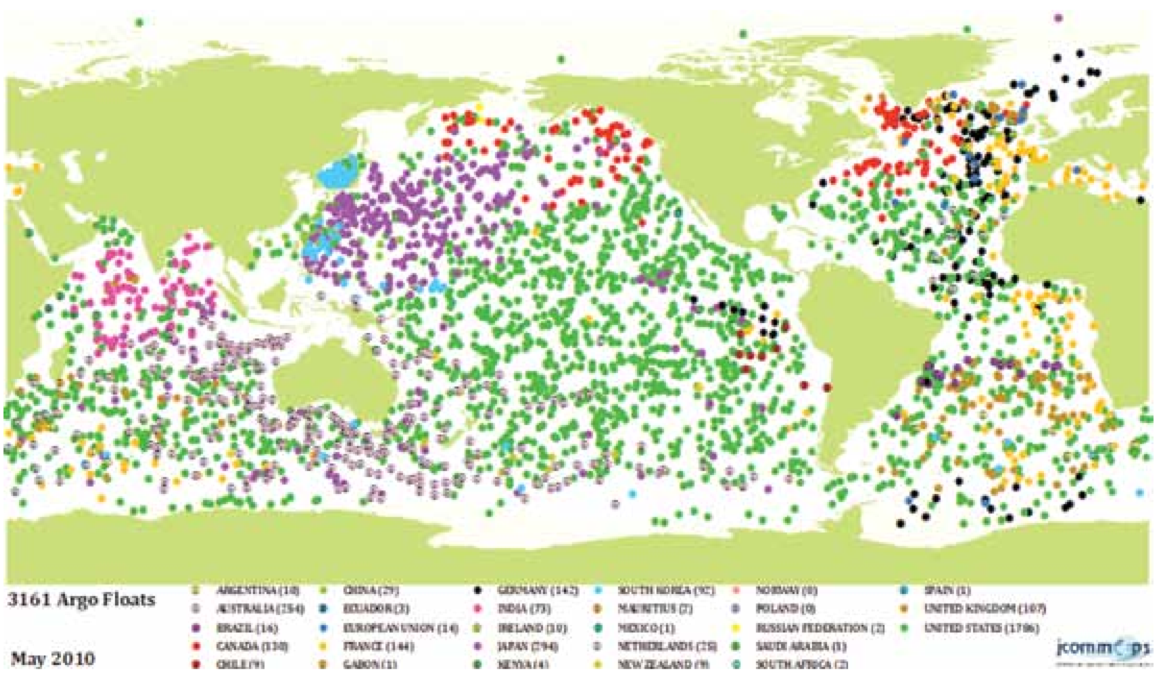

Figure 5. Distribution of Argo floats (as of May 31, 2010) in the world's ocean. Today, over 3000 Argo floats have been released (given an average lifetime of 3.75 years, approximately 800 floats must be released each year to sustain the desired standing stock of 3000 active floats). *Source: http://wo.jcommops.org/cgi-bin/WebObjects/Argo.woa/1/wo*

Assembly (2001), the World Ocean Database project and the Global Ocean Surface Underway Data projects were established and pilot projects were planned. The World Ocean Database project has the goals of increasing the exchange of data gathered in recent times and the development of regional atlases. NODC has already published several such atlases as part of its International Atlas and Information series (http://www.nodc.noaa.gov). At the next session of the IOC Assembly (the 22nd, 2003), the IOC Oceanographic Data Exchange Policy was accepted by the Assembly; it states that access to all oceanographic data collected under IOC patronage is to be timely, free, and unrestricted, and include associated metadata and all derivative products. This policy is based on a number of previous data policy statements made under various IOC/ICSU joint programs. Regional ODIN networks were also developed by the 22nd Assembly, in particular for Africa (ODINAFRICA) and for the Caribbean and South America (ODINCARSA), along with their associated teacher training and educational outreach activities. That summer, at the First Earth Observation Summit (EOS-10) held in Washington, DC, the 10-year Global Earth Observing System of Systems (GEOSS) implementation plan was created. The plan envisioned a sustained GEOSS based on existing observing systems.

IOC has sponsored activities on ocean carbon science and observations since the early 1980s, with the terms of reference for the "CO_2 Panel" evolving each decade to focus on such issues as certified reference materials, developing a global observing strategy, or integrating ocean carbon data and information with the atmospheric and terrestrial domains. At the 23rd session of the IOC Assembly (2005), the IOC-SCOR Ocean CO_2 Advisory Panel was officially renamed the International Ocean Carbon Coordination Project (IOCCP) with an emphasis on assisting research programs with international data compilation and synthesis activities. The Surface Ocean CO_2 Atlas (SOCAT) Project, co-sponsored by the Integrated Marine Biogeochemistry and Ecosystem Research project and the Surface Ocean Lower Atmosphere Study, is working to establish a standard global surface carbon dioxide dataset that brings together all publicly available data in a common format. This compilation currently offers in a common format approximately 7.5 million measurements of various carbon parameters collected by more than 10 countries during 2100 cruises made from 1968 to 2007. It is a first level quality-controlled data set. Also at this assembly, an implementation plan for the IOC strategy for capacity building was developed and accepted. These plans for capacity building had been around since the 1980s, but finding an implementation plan to make them a reality was a while in coming. Lastly, an International Coordination Group was formed to plan out an Indian Ocean Tsunami Warning System.

> "WITH STRONG SUPPORT OF UNESCO AND IOC BY VARIOUS NATIONS, THE OCEANOGRAPHIC COMMUNITY CAN PLAY ITS PART IN A LARGER INTERNATIONAL INFORMATION WAREHOUSE OF EARTH DATA."

At its 24th session in 2007, the IOC Assembly adopted the Ocean Data Portal Project. This IODE program aspires to provide seamless access to all oceanographic data held in its network. Further, members of ABE-LOS were strongly encouraged to put aside national politics and continue their efforts to refine the legal framework IOC relies upon to ensure that oceanographic data collected under IOC auspices meet UNCLOS requirements, especially under Part XIII (Marine Scientific Research). Eventually, at the 25th session of the IOC Assembly in 2009, guidelines to implement Resolution XX–6 (Accepting the Argo Project) were promulgated, allowing for autonomous profiling floats on the high seas as an important contribution to GOOS, GCOS, and CLIVAR. Keep in mind the 20th (XX) session of the IOC Assembly took place in 1999, and for 10 years, dedicated men and women gave endless hours of their time to resolve every perceived inconsistency in UNCLOS wording to make sure that culture and technology were finally reconciled. The 25th session also adopted a resolution to accept the Ocean

Biogeographic Information System (OBIS), an IOC activity within IODE; the process to ensure a smooth transition of OBIS into IOC is underway.

BENEFITS

The benefits to the global ocean commons of active and effective IOC data management and data exchange can be summarized as:

- Provision of quality-controlled and properly archived data of many variables measured with documented current scientific methods, standards, and formats
- Timely distributions of data (observations) and model output (computa), as well as attendant metadata and derived products
- Easy discovery of and access to critical data, derived products, and forecasts
- Elimination of major barriers to efficient use and re-use of data; this ongoing struggle will require continuous chipping away at the data sharing cultures that still block an open data-access world today

No one back in the 1960s could have predicted the path technology and data culture would share. IOC's greatest contribution to data openness has been in the foresight of the many participants in allowing each Member State to contribute as their abilities allowed, all the while helping them to meet their goals and add to their capacity.

CONCLUSION

The future holds large promise as the oceanographic community stands on the threshold of a truly global view of the ocean. Yet, even larger challenges exist. It is ironic that the rapid development of technology, which has made so much possible over the last 50 years, is now threatening to "balkanize" the World Wide Web into Nation-Wide Webs. Today's technology has given nations the ability to assert their claim to ownership of outgoing information and to censor incoming data. Once again, data culture becomes paramount, and we can all count on IOC to continue to guide, promote, and provide for Member States as each contributes according to its abilities. With strong support of UNESCO and IOC by various nations, the oceanographic community can play its part in a larger international information warehouse of Earth data.

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