GOOS Update: Implementation Progress

Now Operational Global Ocean Observing System Leading to Instrument Earth's Surface Extends Deeper into Understanding Of Oceans, Coastal Zones; Multiple Contributors & Users

By Dr. Colin Summerhayes
Director, GOOS Project Office
Intergovernmental Oceanographic Commission, UNESCO
Paris cedex 15, France

The coordinated international Global Ocean Observing System (GOOS) describes the present state of the sea, its contents and forecasts of these for as far ahead as possible, underpinning climate-change forecasts. The system enables conversion of research into operational tools. Its products are useful to a wide range of users. Detailed descriptions of GOOS (*Sea Technology*, August 1997) and its many components are available at the web site http://ioc.unesco.org/goos.

The model for GOOS is the highly successful World Weather Watch (WWW) of the World Meteorological Organization (WMO), which underpins all weather forecasting—GOOS adds to the successes of the WWW. As a tool for satisfying information needs of a wide user community. GOOS may be used for example to improve the ability of individual countries to meet their obligations under regional conventions, and to help fishery bodies implement an ecosystem-based approach to fisheries management. Typical GOOS products include: forecasts of change in water level; positions and strengths of currents; occurrence of unusually high waves; extent of sea ice; rainfall predictions in dry areas; length and coldness of winters; incidence of harmful algal blooms; vulnerability of fish stocks and farms; and forecasts of the likelihood of disease outbreaks. Consequently, benefits include improvements in: forecasts of wind, waves, sea-ice; warnings of storms, high waves and surges; climate forecasts; offshore facility designs and operations; ship routing and marine recreation; rain and temperature forecasts for agriculture, energy, and water industries; management of ports and harbors, fisheries and aquaculture; detection of poor water quality; and preparation for epidemics (e.g. malaria).

As part of the Global Climate Observing System (GCOS), GOOS now contributes to meeting the monitoring requirements of the UN Framework Convention on Climate Change. Strong links are developing between regional GOOS bodies and UNEP's Regional Seas Programme, for which GOOS is seen as a tool. Links with this program have been strengthened particularly in Northeast Asia, the Caribbean, and the Mediterranean. For examples of products, see the GOOS Data Products and Services Bulletin at http://ioc.unesco.org/gpsbulletin/.

Via a series of planning meetings, GOOS was implemented in initial form in 1998. It is being progressively implemented through projects and programs involving ships, buoys (both fixed and drifting), subsurface floats, tide-gauges, and satellites, which are leading towards the instrumentation of the surface of the planet. Its implementation occurs at several levels: first, through large-scale international programs, including experiments and pilot projects that demonstrate the value of particular activities; second, through regional programs where neighboring nations have agreed to work together on, and exchange information about, a common water body, like the Baltic; and third, at the national level, where individual countries are contributing parts of their national observing systems to GOOS.

GOOS was first called for by groups of countries at the end of the 1980s. Given that intergovernmental collaboration is essential for the development and management of such an ambitious project, GOOS is sponsored by a collection of UN agencies (the IOC of UNESCO, the World Meteorological Organization (WMO), and the United Nations Environment Programme (UNEP), with help from the Food and Agriculture Organization (FAO)) together with the International Council of Science (ICSU). IOC is the lead agency, and takes advice on GOOS through the Intergovernmental Committee for GOOS (Policy) and the GOOS Steering Committee (Science).

The main GOOS objectives are: determining users' requirements and specifying the data needed to meet them; developing and implementing strategies for gathering and exchanging those data; developing products based on those data, and encouraging their use; enabling developing countries to benefit from and contribute to GOOS; spreading standards and best practice; and coordinating with other systems of global observation.

The main GOOS activities, primarily carried out by national agencies working to a common plan, are: data collecting; data and information management; data analysis; preparation and dissemination of products; numerical modeling and forecasting; training, technical assistance and technology transfer; and enabling research.

The focus is on "operational" observations—observations that are: systematic; routine; sustained for the long

term; relevant to user's needs; high quality; cost-effective; and available in a timely manner. While many GOOS observations are made by agencies on operational budgets, many are also made using research budgets. In effect this makes GOOS a quasi-operational system. The fact is that regardless of what budget is used to make the observations, they are useful for operational purposes.

GOOS is being developed through five phases of implementation: designing and planning; incorporating existing observing systems; operational demonstrations and pilot projects; gradual operational implementation to full-scale (planned by 2010) followed by review, assessment and improvement.

GOOS Design

Over the past two years, the approach to the GOOS design was simplified and streamlined. It now centers on an open-ocean GOOS theme, devoted mainly to weather and climate forecasting and services and related issues, and a coastal GOOS theme with a much higher density of observations that addresses a wider variety of issues including pollution and living marine resources. The details of the design will vary from one area to another, depending on local concerns.

The Ocean Observations Panel for Climate (OOPC) is designing the open ocean theme. Its tasks are:

• To monitor, describe, and understand the physical and biogeochemical processes that determine ocean circulation and its effects on the carbon cycle and climate variability

• To provide the information needed for ocean and climate prediction, including marine forecasting.

The published open ocean GOOS design includes measurements of: sea-surface temperature; sea-surface salinity; surface wind; heat flux and precipitation; sea-surface height; sea ice; dissolved carbon dioxide; and upper ocean temperature and salinity.

Coastal GOOS

The Coastal Ocean Observations Panel (COOP) is responsible for the design of the coastal theme. COOP was formed in October 2000 by merging the advisory panels for Coastal GOOS, Health of the Ocean (HOTO), and Living Marine Resources (LMR). Those panels had completed their work by drafting design plans for publication on the GOOS web site. COOP will integrate the three design plans into a single comprehensive design plan for coastal seas for publication by the end of 2002.

COOP's primary focus is on:

• Preserving healthy coastal environments (habitat loss, nutrient enrichment, algal blooms and pollution)

• Promoting sustainable use of marine resources (ecosystem-based management; aquaculture)

• Mitigating coastal hazards (storm surges; tropical storm damage; coastal erosion; sea-level rise)

• Ensuring safe and efficient marine operations (navigation; spills; ballast water).

The COOP observational design will focus on six elements: beach and near-shore zone observations; tide gauges (for sea level and other measurements); fixed and drifting platforms and buoys; ships (including ferries); remote sensing from space and aircraft; and remote sensing from land (HF radar).

JCOMM Aids Implementation

GOOS implementation will depend to a fair extent on the success of the new Joint WMO/IOC Technical Commission for Oceanography and Marine Meteorology (JCOMM). The structure and functions of JCOMM were finalised at its first meeting, held in Iceland in June 2001. JCOMM will provide the essential infrastructure for implementing much of the GOOS design. It will respond to GOOS requirements, through program areas for observations, data, services and capacity building. It will: develop the observing networks, implement data management systems, deliver products and services and provide capacity building for developing countries. Current JCOMM activities are focused on contributions to maritime safety, oil pollution response, sea-ice forecasts, wave and surge advisories, and the provision of a wide range of oceanographic and meteorological information (see the JCOMM Portal at http://ioc.unesco.org/jcomm/).

To a large extent GOOS is being implemented via JCOMM through a set of pre-existing ocean observing subsystems and pilot projects. There are 5,000 voluntary observing ships making meteorological measurements; 120 vessels observing subsurface temperature and salinity; 1,400 surface drifters observing meteorology and surface ocean characteristics; several hundred buoys making meteorological and oceanographic measurements (like those observing El Nino events in the Equatorial Pacific); some 300 tide gauge stations wordwide; the fast developing network of Argo profiling floats (see below); sea ice measurements; and a multitude of measurements of the ocean surface from satellites. In addition, ocean plankton measurements are made routinely by a continuous plankton recorder program. Coral reefs are monitored through the Global Coral Reef Monitoring Network.

GOOS will grow on this nucleus by including new observing subsystems and pilot projects, and adopting national observing systems or subsystems whose incorporation is now under consideration.

Data, Information Management

GOOS data and information management (DIM), following a published GOOS DIM plan, continues the development of a one-stop-shop for metadata relating to the observing systems—the Global Observing Systems Information Centre (GOSIC) at the University of Delaware (http://www.gos.udel.edu./). GOSIC provides: a metadata window into GOOS data; access to a distributed directory of climate data and information; information on observing system programs, plans, data centers, sources and experts; documentation on observing system data networks; a bulletin board to facilitate communication about data plans; dissemination of information about standards etc.

Pilot Projects

The major GOOS pilot project is the Global Ocean Data Assimilation Experiment (GODAE). It aims to provide a practical demonstration of real-time, global ocean data assimilation for operational oceanography. Its main goals are to:

• Apply state-of-the-art ocean models and assimilation methods for: short-range open-ocean forecasts; boundary conditions for coastal forecasts; and initial conditions for climate forecast models

• Provide global ocean analyses and re-analyses to improve: understanding of the oceans; assessments of the predictability of ocean systems; and the design and effectiveness of GOOS.

Plans (strategic and implementation) have been published for GODAE (http://www.bom.gov.au/bmrc/ocean/

GODAE/), which is managed through the Bureau of Meteorology (Melbourne, Australia). The main development of GODAE will be in 2003-2005. It will be followed by a transition phase (2006-2007) to accommodate its transition to operational support. A GODAE High-Resolution Sea-Surface Temperature (SST) Pilot Project is underway to develop high-resolution SST data sets and products using all available remote and *in situ* measurements and scientifically defensible definitions of SST. The establishment of the GODAE Server, operated by the U.S. Navy (Monterey, California), is the most significant recent development in taking GODAE forward. This site will provide access to all GODAE data (either directly or via distributed access) as well as providing a range of products. A similar facility is being established in France.

The Argo Pilot Project to seed the ocean with 3,000 profiling floats to collect upper-ocean temperature and salinity data will make a significant contribution to the success of GODAE. Around 900 floats are already funded and some 2,500 floats are proposed over the next three years, making it likely that the 3,000 target will be reached during the period 2003-2005. Argo information is available from the Argo Information Centre (Toulouse, France) (http://argo.jcommops.org/). Several countries are funding floats and sharing the costs of running the center.

Another important GOOS pilot project is the Brazil-led Pilot Research moored Array (PIRATA) in the Tropical Atlantic through which moored buoys collect ocean and atmospheric data useful for climate forecasts in South America and Africa (Sea Technology, October 1999).

Regional Implementation

GOOS is also being implemented by a fast developing group of regional GOOS bodies, namely: Europe—EuroGOOS with its Northwest Shelf Operational Oceanographic System (NOOS) and its Baltic Operational Oceanographic System (BOOS); the Black Sea (Black Sea GOOS); the Mediterranean (MedGOOS); Africa (GOOS-AFRICA); the Caribbean (IOCARIBE-GOOS); the Northeast Asian Region (NEAR-GOOS); Southeast Asia (SEAGOOS, including the Southeast Asia Centre for Marine and Atmospheric Prediction-SEA-CAMP); the Pacific islands (PacificGOOS); and the Indian Ocean (IO-GOOS, including the Western Indian Ocean Marine Applications Project (WIOMAP).

These GOOS bodies promote regional implementation, develop networks and pilot/demonstrator projects, adapt existing observing systems and integrate them into a common system, survey users to determine needs, increase awareness and foster support and build capacity.

EuroGOOS (*Sea Technology*, August 1998) is beginning to work towards implementing operational ecosystems models and forecasts to assist fisheries and environmental managers, in conjunction with the International Council for the Exploration of the Sea (ICES), the Helsinki Commission (HELCOM), and the Oslo-Paris Commission (OSPAR). The proceedings of the Second EuroGOOS Conference were published mid-2002, and the Third EuroGOOS Conference is scheduled for Athens on December 3-5, 2002. NEAR-GOOS has embarked on a strategic planning effort that should ultimately lead to the inclusion of chemical and biological parameters, as well as to operational forecasting.

MedGOOS and Black Sea GOOS were recently awarded substantial funding by the European Commission to develop observing networks. Other proposals await funding (e.g. for WIOMAP, SEACAMP and GOOS-AFRICA).

To encourage GOOS developments in the Indian Ocean and the South Atlantic dedicated regional GOOS program offices have been opened in Perth, Australia and Rio de Janeiro, Brazil.

Continued implementation of GOOS at the national level is essential to facilitate GOOS development. Many coastal countries are planning or collecting their own coastal seas observations following GOOS principles, often working through national GOOS co-coordinating committees involving many stakeholders.

IGOS

Both GOOS and the IOC, along with other organizations and the major space agencies, are members of the Partnership for an Integrated Global Observing Strategy (IGOS-P)(http://ioc.unesco.org/igospartners/). The partnership recognizes that no one country or agency can do all that is required to observe the Earth as a whole, and that to do so efficiently and effectively we need coherence and synergy between bodies observing at global scale. The partnership aims to enable more cost-effective and timely observations by: linking all observing systems together; integrating *in situ* and space-based measurements; taking a thematic approach (e.g. focusing on discrete parts of the Earth system); adapting existing strategies to this end; and developing appropriate new plans.

In January 2001 the IGOS Partners published the Ocean Theme document (http://ioc.unesco.org/igospartners/IGOS-Oceans-Final-0101.pdf) indicating the capabilities of and developments needed in space-based measurements to make GOOS work. The Ocean Theme sets out the challenges particularly for the space agencies. Among the main operational needs are: precision ocean topography (Jason-1); ocean vector winds (QuikScat); ocean color (SeaWifs); routine and meaningful SST (for example from meteorological satellites) and sea-ice measurements from passive microwave systems. Among the research needs are: a salinity sensor (offered by SMOS); the precision gravity field: (offered by GRACE/GOCE); sea-state measurements from SAR; improved ocean color algorithms; and measures of sea-ice thickness.

The IGOS Partners are developing an Integrated Global Carbon Observing Theme, which will include an ocean observing system for carbon.

Capacity Building

A "strategy and an action" plan have been developed to guide efforts of developing countries to build their capacity to participate in, benefit from, and contribute to GOOS. One key requirement is to clearly enunciate benefits, so as to persuade developing country governments of the value of investing in GOOS, and to persuade donor agencies to be generous.

To assist GOOS developments and build capacity, several of the world's major oceanographic institutions and agencies have joined forces to form the Partnership for Observations of the Global Ocean (POGO)(http://www.oceanpartners.org). POGO recognizes that the major institutions are both major users and major suppliers in the GOOS context. POGO has developed a fellowship program for capacity building.

Next Steps

We plan to publish the Coastal GOOS designs, and a related Handbook; flesh out implementation plans; integrate existing systems; entrain national observing systems; work with the space agencies to ensure follow-on space programs; establish new pilot projects to demonstrate GOOS concepts; promote pre-operational R&D to bring new observing capabilities on line; develop new technologies (sensors) to measure new properties; facilitate data and information flow; promote the development and expansion of services; and build capacity. /st/

(photo) Dr. Colin Summerhayes**,** *Director, GOOS Project Office, formerly was director of the U.K.'s Institute of Oceanographic Sciences Deaco Laboratories (IOSDL) where he had also been deputy director.*

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Figures 1 . . argo_float_array.tif . . .1.5 col/13 pica

Argo profiling floats some time after initial deployment on a 300 kilometer grid

pattern (courtesy GODAE Office, Melbourne).

Data collection network for the El Nino-Southern Oscillation (ENSO) forecasting system (Courtesy of U.S. National Oceanic & Atmospheric Administration).

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