Ocean Climate Observation Program
FY 2008 Progress Report

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Project Initiation Year: 2000

Project Summary:

NOAA's Ocean Climate Observation program is the core of the ocean sub-capability of NOAA's Climate Observations and Monitoring Program. The Ocean Climate Observation program also constitutes the backbone of the Global Component of the U.S. Integrated Ocean Observing System (IOOS). IOOS is the U.S. contribution to the international Global Ocean Observing System (GOOS), which is the ocean baseline of the Global Earth Observation System of Systems (GEOSS).

In 2003 the Project Office for Climate Observation (OCO) was established under the auspices of the Climate Program Office (CPO) to manage the Ocean Climate Observation program. It is the job of OCO to advance its multi-year *Program Plan for Building a Sustained Ocean Observing System for Climate*, which is updated annually. The intended outcome is a sustained global system of complementary *in situ*, satellite, data, and modeling subsystems adequate to accurately document the state of the ocean and to force climate models. The observing system is being put in place to meet climate requirements but it also supports weather prediction, global and coastal ocean prediction, marine hazard warning systems (e.g., tsunami warning), transportation, marine environment and ecosystem monitoring, and naval applications. Many non-climate users also depend on the baseline composite system that is nominally referred to as the Sustained Ocean Observing System for Climate.

The Sustained Ocean Observing System for Climate is a composite system-of-systems comprised of ten complementary sub-systems or networks (illustrated in Figure 1). The networks are managed by 22 distributed centers of expertise at NOAA laboratories, centers, joint institutes, universities and business partners. The "System" is centrally managed at the Office of Climate Observation. Specifically, OCO's tasks are to:

- Monitor the status of the globally distributed networks; report system statistics and metrics routinely and on demand;
- Evaluate the effectiveness of the system; take action to implement improvements through directed funding;
- Advance the multi-year program plan; evolve the *in situ* networks through directed funding;
- Focus intra-agency, interagency, and international coordination;
- Organize external review and user feedback; and
- Produce annual reports on the state of the ocean and the adequacy of the observing system for climate.

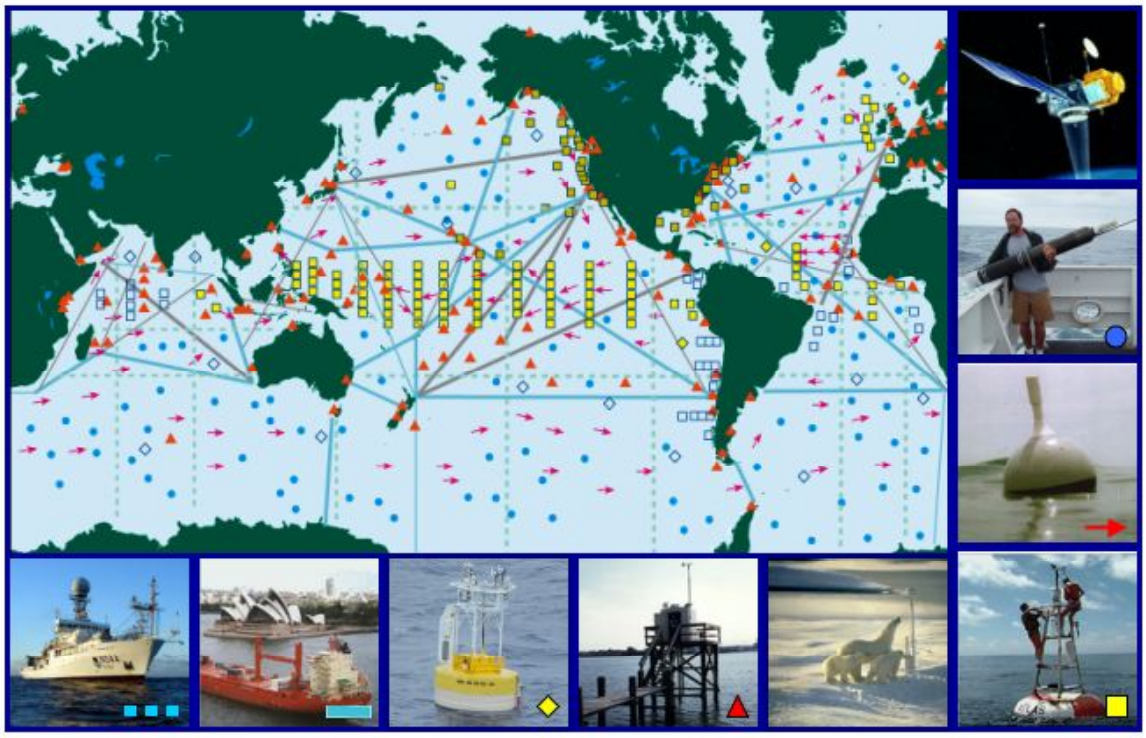

Figure 1. The Networks that make up the Sustained Ocean Observing System for Climate are (from lower left to upper right): Dedicated Ships, Ships of Opportunity, Ocean Reference Stations, Tide Gauge Stations, Arctic Observing Systems, Tropical Moored Buoys, Surface Drifting Buoys, Argo Profiling Floats, and Continuous Satellite Missions for sea surface temperature, sea surface height, surface vector winds, ocean color, and sea ice. Not illustrated are the Data & Assimilation Subsystems and Analysis Products.

The 22 distributed centers of expertise that are implementing NOAA's contributions to the system are at AOML, PMEL, ESRL, GFDL, JIMAR (University of Hawaii), JIMO (Scripps Institution of Oceanography), CICOR (Woods Hole Oceanographic Institution), JISAO (University of Washington), CIMAS (University of Miami), CICAR (Columbia University), CIFAR (University of Alaska), NCDC, NODC, NGDC, CO-OPS, OMAO, NDBC, NCEP, FSU (Florida State University), LSA, CLS America, and OCO. The contributions of these centers are summarized by the project managers in their individual reports, which are published each year in OCO's *Annual Report on the Ocean Observing System for Climate.*

Across the United States there are 46 Federal employees, and 81 non-Federal employees working to implement NOAA's contribution to the global ocean observing system. Within the OCO project office there are seven Federal employees, and two non-Federal employees.

Partnerships are central: A global observing system by definition crosses international boundaries, with potential for both benefits and responsibilities to be shared by many nations. All of the Ocean Climate Observation program contributions to global

observation are managed internationally in cooperation with the Joint WMO/IOC Technical Commission for Oceanography and Marine Meteorology (JCOMM). The Ocean Climate Observation program sponsors nearly half of the observing system platforms in the global ocean, and provides approximately half of the funding needed to support JCOMM's technical infrastructure. OCO employees provide international leadership through active service in the JCOMM Management Committee, Expert Teams, and the Implementation Panels, and have held the office of JCOMM Observations Program Area Coordinator since 2002.

OCO also works cooperatively with other U.S. agencies, especially the National Science Foundation (NSF). The ongoing NSF-NOAA cooperative project for CLIVAR-ocean carbon surveys has proved to be an interagency-international-interdisciplinary success. NSF has initiated the Ocean Observatories Initiative (OOI), which will provide significant infrastructure in support of ocean climate observation; OCO is committed to working with NSF to jointly maintain climate reference stations at the OOI global ocean observatory sites.

Mission and Requirements: The mission of the OCO is to build and sustain a global climate observing system that will respond to the long term observational requirements of the operational forecast centers, international research programs, and major scientific assessments. The focus is on building the *in situ* ocean component. The top-level requirements are to:

- Document long term trends in sea level change;
- Document ocean carbon sources and sinks;
- Document the ocean's storage and global transport of heat and fresh water; and
- Document ocean-atmosphere exchange of heat and fresh water.

Deliverables: The ocean climate observing system must have the capability to deliver continuous instrumental records and analyses accurately documenting:

- Sea level to identify changes resulting from climate variability;
- Ocean carbon content every ten years and the air-sea exchange seasonally;
- Sea surface temperature and surface currents to identify significant patterns of climate variability;
- Sea surface pressure and air-sea exchanges of heat, momentum, and fresh water to identity changes in forcing function driving ocean conditions and atmospheric conditions;
- Ocean heat and fresh water content and transports to: 1) identify changes in the global water cycle; 2) identify changed in thermohaline circulation and monitor for indications of possible abrupt climate change; and 3) identify where anomalies enter the ocean, how they move and are transformed, and where they re-emerge to interact with the atmosphere; and
- Sea ice thickness and concentrations to identify changes resulting from, and contributing to, climate variability and change.

Present ocean observations are not adequate to deliver these products with confidence. The fundamental deficiency is lack of global coverage by the *in situ* networks. Present international efforts constitute only about 60% of what is needed. The *Second Report on*

the Adequacy of the Global Observing System for Climate in Support of the UNFCCC concludes that "the ocean networks lack global coverage and commitment to sustained operations…Without urgent action to address these findings, the Parties will lack the information necessary to effectively plan for and manage their response to climate change."

In response to the Second Adequacy Report, international GCOS produced the *Implementation Plan for the Global Observing System for Climate in support of the UNFCCC* (GCOS-92). GCOS-92 was published in October 2004. It has been endorsed by the UNFCCC and by the Group on Earth Observation (GEO). In particular:

1. The UNFCCC, Decision CP.10, "Encourages Parties to strengthen their efforts to address the priorities identified in the [GCOS] implementation plan, and to implement the priority elements …"
2. The *Global Earth Observation System of Systems (GEOSS) 10-Year Implementation Plan Reference Document* targets include: "Support implementation of actions called for in GCOS-92."

OCO's *Program Plan for Building a Sustained Ocean Observing System for Climate* is in complete accord with GCOS-92 and provides the framework for NOAA contributions to the international effort. In particular 21 of the specific actions listed in the GCOS-92 ocean chapter (pages 56-84) are being acted upon by the OCO program in cooperation with the implementation panels affiliated with JCOMM. These specific GCOS-92 actions provide the roadmap to guide annual work plans. GCOS-92 is accessible via link from the OCO web site: www.oco.noaa.gov -- click on "Reports & Products." The work supported by OCO is directed toward implementation of this international plan and the projects are being implemented in accordance with the GCOS Ten Climate Monitoring Principles. The OCO-supported projects contributed 48% of the total international effort in 2008.

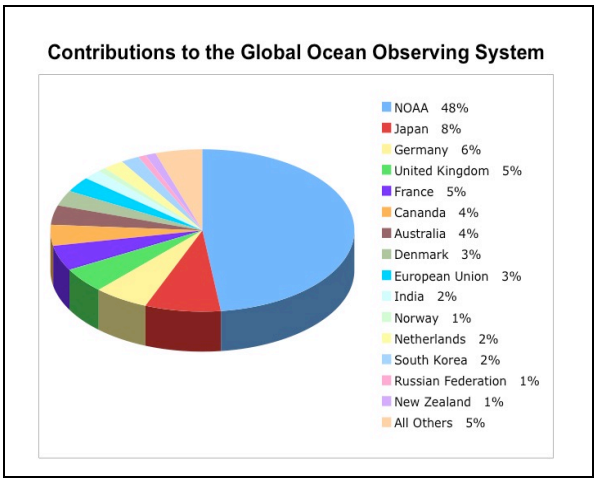

Figure 2: Relative contributions to the Global Ocean Observing System.

FY 2008 Accomplishments:

FY 2008 accomplishments are detailed in the individual Project Manager reports. Some highlights include:

- The international global ocean climate observing system overall advanced from 59% complete in 2007 to 60% complete in 2008. The annual reports of the Project Managers detail the specific advancements of the individual networks. Some highlights for 2008 included:
    - The Global Drifting Buoy array was maintained at its design strength of 1250 data buoys in service for the fourth continuous year since 2005, which enabled NOAA to meet its GPRA Performance Measure for reducing the error in global measurement of sea surface temperature.
    - The Argo profiling float array was maintained at its design strength of 3000 floats in sustained service for the second continuous year since 2007.
    - RAMA, the tropical moored buoy array in the Indian Ocean, progressed from 8 to 14 stations in operation.
    - Transition of the Indonesian Through Flow ocean reference station from NSF to NOAA funding was completed.
    - Transition of the Weddell Sea ocean reference station from CVP to OCO funding was initiated (to be completed in 2009).
    - Two NOAA-NSF CLIVAR/Carbon survey lines were completed, one aboard the NOAA RH Brown and the other aboard UNOLS.

- The Ocean Climate Observation program made the following contributions to the GCOS initial implementation targets for sustained global ocean observing system operations (as modified by JCOMM):
    - Tide gauge stations: 16% (the 2008 total international effort was estimated to 62%)
    - Surface Drifting Buoys: 49% (the 2008 total international effort was estimated to be 79%)
    - Tropical Moored Buoys: 64% (the 2008 total international effort was estimated to be 79%)
    - Ships of Opportunity: 24% (the 2008 total international effort was estimated to be 67%)
    - Argo Profiling Floats: 58% (the 2008 total international effort was at 100%)
    - Ocean Reference Stations: 14% (the 2008 total international effort was estimated to be 36%)
    - Ocean Carbon Networks: 25% (the 2008 total international effort was estimated to 43%)

- In addition to planned dedicated ship support, three research vessels were chartered to conduct annual climate observing system maintenance operations that were unexpectedly cancelled by the NOAA Ship RH Brown, which was recalled from field operations mid-season for emergency repairs due to mechanical and other problems:

- R/V Oceanus (WHOI): 15 days in support of the NTAS/MOVE ocean reference stations.
- R/V Cape Hatteras (Duke U): 10 days in support of the Western Boundary Time Series ocean reference station.
- R/V Antea (France, IRD): 33 days in support of the PIRATA North East Extension moored array.

- Woods Hole Oceanographic Institution released a global analysis of ocean evaporation from 1958 to 2006 at 1-degree resolution. This product, derived from blended satellite and in-situ ocean observations, is the first observationally-derived global dataset showing evaporation of water from the ocean, which is critical for addressing the issue of whether or to what extent the global hydrological cycle is intensifying as a consequence of climate change.

- The OceanSITES Global Data Assembly Center (GDAC) was established at NDBC for collection and distribution of a global set of Ocean Reference Station data and platform metadata.

- Two new daily 1/4° SST analyses were developed at NCDC: the AVHRR-only daily optimum interpolation (OI) from January 1985 to present and the AMSR+AVHRR daily OI from June 2002 to present. Both analyses use in situ data and use a satellite bias correction.

- CPC Extended the GODAS Monthly State of the Ocean briefing to include analyses of:
  1. Real time heat budget analysis for ENSO
  2. Estimation of Atlantic MOC with GODAS
  3. Validation of heat content variability in GODAS

- Twenty-one hurricane drifters were deployed in the paths of hurricanes Gustav and Ike in the Gulf of Mexico by the 53rd Air Force Reserve Squadron "Hurricane Hunters". The drifters measured winds, air pressure, surface temperatures and subsurface temperatures to a depth of 150m providing data for hurricane research and real-time data to NOAA's National Hurricane Center.

- Continuous measurements of pCO_2 were made at 8 ocean moorings to elucidate the magnitude and causes of temporal variability of ocean surface carbon uptake. Underway pCO2 measurements continued on board 12 ships to map the spatial variability of ocean surface carbon uptake. A key accomplishment in FY 2008 was the submission for publication of the OCO-sponsored Takahashi climatology of global ocean pCO_2, assembled from over 3 million measurements made internationally over a period of three decades.

- The NOAA-NSF CLIVAR/Carbon survey conducted two open-ocean transects making full-depth measurements of carbon, tracers, oxygen, nutrients, and physical oceanographic parameters. This international project conducts the only

routine measurements sample below the depth of the ARGO array. Recent findings contribute to ongoing analyses of anthropogenic carbon uptake in the global oceans, and demonstrate warming of abyssal waters.

- OCO and GCC jointly funded work at PMEL and AOML to derive improved methodologies for retrieval of air-sea CO_2 fluxes from space-based measurements of sea surface temperature, winds, ocean color, and potentially other observables. The project draws upon in-situ measurements of pCO_2 made from ships of opportunity and from moorings, which are used to develop and calibrate regionally and seasonally dependent algorithms.

- OCO began cost-sharing with Office of the Oceanographer of the Navy for the maintenance of the GODAE server at Monterey, and worked in cooperation with the IOOS Program office to draft a NOAA-Navy MOU for long-term support of the GODAE server.

- A joint OCO-IOOS project was initiated to expand the Observing System Monitoring Center (web-based system management tool) to include U.S. regional observing systems as well and the international global system.

- A letter of intention was sent to the NSF Ocean Observatories Initiative for cooperative implementation of Ocean Station PAPA (northeast Pacific) as a joint ocean observatory and climate reference station.

- OCO submitted a NOAA report to the House of Representatives Committee on Appropriations on "Implementing the Sustained Global Ocean Observing System for Climate."

- The Sixth Annual System Review was held 3-5 September 2008 in Silver Spring and brought together 109 project managers, data users, advisors, and program managers both from NOAA and from other partner institutions to discuss the observing system's capability to deliver climate information about:
    - Rising Sea Level and the Ocean's Storage of Heat;
    - Ocean Circulation and Global Transport of Heat and Fresh Water;
    - Ocean Biogeochemistry;
    - The Ocean's Influence on Variability in Seasonal Temperatures, Precipitation, Sea Ice, and Extreme Events; and
    - User Requirements and Applications
- The Annual Review also served as a springboard to begin the year-long community-wide preparations for the international OceanObs'09 symposium, which will be held September 2009 in Venice.

Program Funding Summary

Ocean Climate Observation Funding History							
Network			$ K				
Expenditures	**FY 02**	**FY 03**	**FY 04**	**FY 05**	**FY 06**	**FY07**	**FY08**
Ocean Climate Observation Systems							
Tide Gauge Stations	670	710	970	1196	1177	1196	1196
Drifting Buoys	1699	2077	2769	3130	3427	3130	3169
Tropical Moored Buoys	3175	3175	3625	4360	3094	3329	2850
Ships of Opportunity	1960	1903	2487	2907	2776	2804	2678
Argo Profiling Floats	6749	9459	9835	9218	9108	9152	9201
Ocean Reference Stations	1712	2082	2998	2995	3958	5071	5747
Ocean Carbon Networks	1478	2204	2875	3521	3482	3181	3177
Arctic Observing System	1937	4659	3988	5325	5237	4031	4096
Dedicated Ship Time	0	626	523	92	542	378	1801
Data & Assimilation Subsystems	1286	1323	1487	1418	1331	1036	1229
CLS Argos Data Processing	813	480	1525	1408	823	1143	1590
Product Deliver, Analysis/Reanalysis	578	638	896	1982	2048	2572	2697
Institutional Infrastructure	1126	1175	1791	1878	1084	1591	1371
Total	**23183**	**30511**	**35769**	**39430**	**38087**	**38614**	**40802**
					38087	38614	40802
Program Income							
Ocean Observation					17657	18490	20741
Sustained Ocean Observations					5334	5389	5755
Argo					9758	9758	9758
Arctic					4927	3694	3995
Other					411	1283	553
Total					**38087**	**38614**	**40802**

Figure 4: System Funding Record

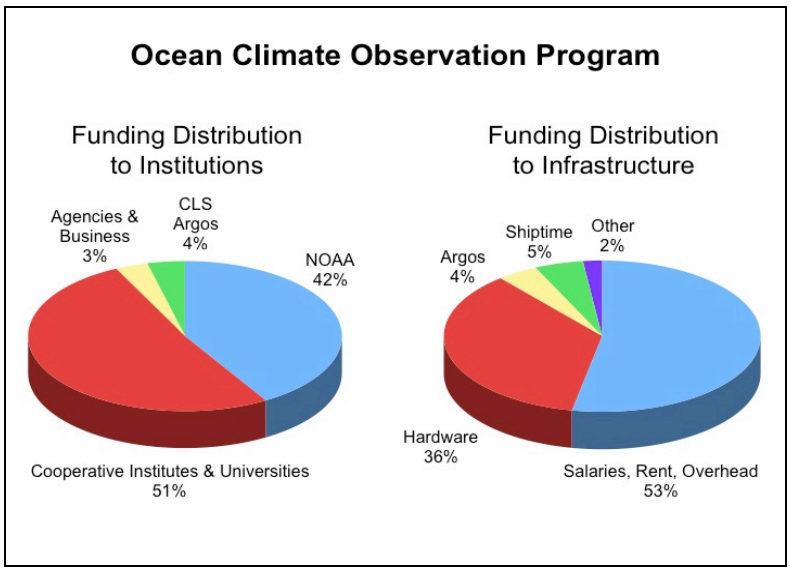

Figure 5: Program funding distribution.