Program Plan
For
Building a Sustained Ocean Observing System for Climate

Updated: March 2004

Overall Summary

The Climate Change Science Program (CCSP) has identified the critical need for the federal government to begin delivering regular reports documenting the present state of the climate system components. Yet an observing system does not presently exist that is capable of accurately documenting climate variability and change in the Earth's oceans, atmosphere, cryosphere, and land surface. Through this program plan NOAA will develop the infrastructure necessary to build, with national and international partners, the ocean component of a global climate observing system and to deliver regular reports on the ocean's contribution to the state of the climate and on the adequacy of the observing system.

1.0 Base Program

1.1 Key activities currently carried out by NOAA for this strategy area: Over the past decade NOAA has worked with national and international partners to begin building a sustained global ocean system for climate, focusing first on the tropical Pacific, expanding to the Atlantic, and promoting future research in the Indian Ocean. It is now well understood that documenting and forecasting climate will require continuous measurements from space along with the instrumenting of the entire global ocean. The present international effort is about 45% of what will ultimately be needed for the global system. NOAA presently maintains approximately 60% of the *in situ* networks and 30% of the space components and is committed to the goal of providing at least 50% of the composite system over the long term.

The existing foundation is comprised of eleven complementary *in situ*, space based, data and assimilation subsystems: 1) Global Tide Gauge Network; 2) Global Surface Drifting Buoy Array; 3) Global Ships of Opportunity Network; 4) Tropical Moored Buoy Network; 5) Argo Profiling Float Array; 6) Ocean Reference Stations; 7) Coastal Moorings; 8) Ocean Carbon Monitoring Network; 9) Dedicated Ship Operations; 10) Satellites for Sea Surface Temperature, Sea Surface Height, Surface Vector Winds, and Ocean Color; 11) Data and Assimilation Systems and their products? (the Global Ocean Data Assimilation Experiment – GODAE). The system design is illustrated in Figure 1. This is an international effort. NOAA's plan includes a twelfth element – 12) System Management and Product Delivery – to focus program resources on answering the nation's highest priority policy- and economically-relevant questions. In addition, complementary atmospheric observations and analyses, including precipitation and radiation, as well as a global analysis of winds using satellite and surface data help complete the system.

The plan is being advanced via matrix management within the NOAA Climate Program. Implementation of the in situ networks is through distributed centers of expertise at the NOAA Research laboratories, the National Ocean Service Center for Operational Oceanographic Products and Services, the National Data Buoy Center, and the university laboratories that have developed the instruments and techniques. The space components are centered in the National Environmental Satellite, Data and Information Service; the space components are being advanced via other NOAA program planning; they are noted here because of their central role in global observation but they are not detailed in this plan. The focal point for developing global ocean data assimilation capabilities will be the Geophysical Fluid Dynamics Laboratory in partnership with the National Centers for Environmental Prediction and university-based applied research centers. The system management functions are focused in the Office of Global Programs.

1.2 Matrix document showing key activities and current status: Illustrated in Figure 2 and detailed below in Section 6.

1.3 Current out-year performance measures based on current funding levels: The performance measures are given in Section 5. At current funding levels the out-year accomplishments will be frozen at the deliverables indicated for FY05.

1.4 Current budget for each of the major activities (FY 2004):

Tide Gauge Network	$1.7 M
Drifting Buoy Array	$2.8 M
Tropical Moored Buoy Network	$4.2 M
Ships-of-Opportunity Network	$4.1 M
Argo Array of Profiling Floats	$10.9 M
Ocean Reference Stations	$3.8 M
Ocean Carbon Monitoring	$2.9 M
Integrated Arctic Observing System	$2.6 M
Dedicated Ship Time	$10.7 M
Data and Assimilation Subsystems	$4.6 M
Management and Product Delivery	$2.4 M
	$50.7 M

2.0 Statement of Need

The *Second Report on the Adequacy of the Global Observing System for Climate in Support of the UNFCCC* concludes "there has been progress and improvement in the implementation of global climate observing systems since the first report, especially in the use of satellite information and in the provision of some ocean observations. At the same time, the Report notes that the global terrestrial networks remain to be fully implemented; the ocean networks lack global coverage and commitment to sustained operations; and the atmospheric networks are not operating with the required global coverage and quality. The Report concludes, in agreement with the IPCC, that there remain serious deficiencies in the ability of the current global observing systems for climate to meet the observational needs of the UNFCCC. …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."

The Report goes on to note "new technology developed and proven by the ocean climate programs of the 1990s has allowed the ocean community to design and commence implementation of an initial ocean climate observing system that is well focused on the UNFCCC needs. The first priority is the full implementation of this system together with its associated data, analysis and product capabilities."

This program plan is founded on the international design noted in the Report; it is illustrated in Figure 1. Other requirement drivers include the CCSP Strategic Plan expressing need for "complete global coverage of the oceans with moored, drifting, and ship-based networks," and the OCEAN.US *Implementation of the Initial U.S. IOOS* specifying "the highest priority for the global component of the IOOS is sustained, global coverage." NOAA's contribution to the commencement of global implementation is represented in the current program budget and the progress to date is illustrated in Figure 2. Implementation of this program plan will demonstrate to the world community that the United States is intent on taking immediate action to address the Report findings, is willing to play a leadership role in achieving global coverage of the ocean networks, and is committed to sustained operations.

2.1 Program Office requirements to be met: The NOAA Office of Global Programs is organized around four strategic objectives: 1) Development of an Earth System Model for climate change projections at GFDL; 2) Improvement of NWS operational seasonal to international climate forecasts; 3) Development of the in situ ocean component of the global climate observing system; and 4) Development of decision support tools. This plan describes the program for meeting the third objective.

2.2 Input from NOAA leadership, internal councils, and crosscut teams related to this strategy: VADM Lautenbacher has announced as one of his top priorities the building of a global climate observing system, particularly the ocean component. The NOAA Council on Long Term Climate Monitoring (CLTCM) has prioritized elements of ocean observation for their feasibility, impact and timeliness for reducing uncertainty in the role of the ocean in climate variability and change. A cross-cut team has been established in response to the recommendations of the NOAA Performance Review for developing an observing system architecture that will a) determine the adequacy of the state of the system today and in the future; b) address utilization of the data and archival; and c) consider other systems as well. This program plan is directed toward achieving VADM Lautenbacher's vision, the priorities of the CLTCM, and the three aspects of the observing system architecture for ocean climate.

2.3 External constituent input related to the strategy area: In 2001 the U.S. GOOS Steering Committee conducted a formal review of the 2001 version of this program plan. The review panel included international representatives of the IOC, IGOS, CLIVAR, WOCE, OOPC, GODAE, and JCOMM as well as partner agencies within the United States – NASA and NAVOCEANO. The seven summary recommendations of the review are paraphrased below.

1. Strong overall support for the plan. U.S. GOOS urged NOAA to implement the plan with the following additional recommendations:
2. The need for a management plan – An effort of the proposed magnitude must be integrated, organized, and managed as a system in order to be effective. The management plan should define an orderly decision making process with management accountability that is understood by other agencies and by customers. A single NOAA point of responsibility and authority is very desirable. Sections 7.0–7.7 achieve this recommendation.
3. The need for a data and information management budget. Section 6.11 achieves this recommendation.
4. The need for improved ocean products – evaluation and delivery. Section 7.6 achieves this recommendation.
5. The need for transition to operations of precision altimetry. Section 6.10 achieves this recommendation.
6. The need for ocean carbon monitoring to be better defined. Section 6.8 achieves this recommendation.
7. The need to deal with dedicated ship time issues. Section 6.9 has been revised to achieve this recommendation.

2.4 Relevant Congressional input or guidance related to the strategy area: The FY03 Senate Committee on Appropriations Report "reaffirms its support for the establishment of an integrated, interagency ocean and coastal observing system … and requests the submission of a plan to implement such a system." The National Oceanographic Partnership Program's Ocean.US office is responding to this Congressional request on behalf of the contributing agencies. The climate system detailed below forms the nucleus of the global component of the U.S. Integrated Ocean Observing System.

2.5 Known impediments (legal, fiscal, policy) towards achieving performance targets and objectives: None.

3.0 Program Initiative

3.1 Overall strategy for addressing deficiencies outlined in the Statement of Need Section. The strategic approach underlying this program plan is as follows:

- Build the long-term ocean component of the observing system in the context of a comprehensive, multi-year, climate services initiative. Improved marine and coastal forecast services will be immediate byproducts.

- Set a 2000-2010 timeline for phased implementation.
- Establish accountability by defining specific objectives and performance measures.
- Define an "initial observing system design" that will accomplish the objectives and performance measures. Identify annual milestones to complete the initial system over the ten-year time line. Emphasize that the initial design is our best guess at this time – it must be evolutionary as knowledge and technology advance.
- State the obvious – a global observing system cannot be built with existing budgets. Estimate the annual funding needed to achieve the identified milestones. Estimate that NOAA will implement about 50% of the global system.
- Work with national and international partners to achieve 100%.

Although NOAA's marine and coastal services and the mission services of the other agencies and nations will benefit from this plan, and are considered throughout, accomplishing NOAA's climate mission is the fundamental driver. The scientific foundations come from the Climate Variability and Predictability Program (CLIVAR), the Carbon Cycle Science Program, and the Global Water Cycle Program. It is not the intent of the plan to provide all of the observations needed by these programs but to provide a baseline observing system, to be sustained over the long term, that can be built upon where needed to answer specific questions. This baseline system looks for efficiencies to be gained by utilizing common platforms/sites/data infrastructure for several objectives in parallel, and seeks to foster a system approach to effective international organization of complementary in situ, satellite, data, and modeling components of climate observation.

Priorities for implementation are now in place based on the concept of extending the building blocks that have already been put in place, and on the international plan drafted by over 300 scientists from 26 nations that met in Saint Raphael, France, October 1999, at the OCEANOBS 99 Conference for design of *The Ocean Observing System for Climate.* Again, this NOAA plan does not seek to implement all aspects of the Saint-Raphael system, but only those base-line components needed to meet the design objectives (see Section 4.2), and those for which NOAA should expect to have primary mission responsibility in the United States.

3.1.1 NOAA context*:* This plan supports NOAA's strategic goal to monitor and observe: "NOAA will invest in needed climate quality observations and encourage other national and international investments to provide a comprehensive observing system in support of climate assessments and forecasts." The plan details how NOAA will achieve one element of that strategic goal – implementation of the sustained in situ ocean component of the climate observing system.

3.1.2 Interagency context: The observational objectives of NOAA's climate program and those of the CCSP are essentially identical and the ocean observing system architecture detailed below will be implemented by NOAA within the framework of, and as an element of, the CCSP. At the same time the observing system must be advanced in support of climate services, it must also be advanced in response to a national demand for the ocean agencies to coordinate implementation of an U.S. contribution to the global ocean observing system. It is recognized that an effective global ocean observing system can be achieved only through continuing interaction among all national (and international) partners. In this context, NOAA will provide a significant contribution to the global component of the Integrated Ocean Observing System. Implementation will be coordinated with the National Oceanographic Partnership Program agencies, just as all of NOAA's climate observation and research activities have been coordinated through the U.S. Global Change Research Program for the past decade.

3.1.3 International context: The observational component of climate services has by far the greatest opportunity and necessity for international collaboration. A global observing system by definition crosses international boundaries and the potential exists for both benefits and responsibilities to be shared by many nations. The system described below is based on the international design of, and is an U.S. contribution to, *The Ocean Observing System for Climate* (Saint-Raphael, France, 1999). The observing system projects that make up the climate component have been developed, and will continued to be evolved, organized and managed, in cooperation with the international implementation panels of the Joint IOC/WMO Technical Commission for Oceanography and Marine Meteorology (JCOMM), and with scientific guidance from the GCOS/GOOS/WCRP Ocean Observations Panel for Climate (OOPC).

3.2 Proposed out-year performance targets: See Sections 5.0-5.4.

3.3 Discussion of individual investments necessary to address shortfalls: Given in Sections 6.0-7.7.

3.4 ROM cost and schedule for each investment: Details given in Table 2. Summary:

	FY03	FY04	FY05	FY06	FY07	FY08	FY09	FY10
System annual operating cost ($ M)	35.2	41.2	59.2	98.1	125.7	139.3	142.6	144.5

4.0 Program Goal and Objectives

4.1 Goal

The goal of this plan is to build and sustain the ocean component of 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.

4.2 Objectives

The ocean is the memory of the climate system and is second only to the sun in effecting variability in the seasons and long-term climate change. It is estimated that the ocean stores 1000 times more heat than the atmosphere, and 50 times more carbon. Eighty percent of the precipitation that waters our Earth comes directly from the ocean. Changing sea level is one of the most immediate impacts of climate change. Additionally, the key to possible abrupt climate change may lie in deep ocean circulation.

Accordingly, the objectives of the sustained ocean observing system for climate are to:

1) Document long-term trends in sea level change;
2) Document ocean carbon sources and sinks;
3) Document heat uptake, transport, and release by the ocean; and
4) Document the air-sea exchange of water and the ocean's overturning circulation.

This implementation plan will provide a composite global ocean observing system of complementary networks that includes: 1) deployment and maintenance of observational platforms and sensors; 2) data delivery and management; and 3) routine delivery of ocean analyses. This end-to-end ocean system will provide the critical "up-front" information needed for climate forecasting, research, and assessments – continuous, long term, climate quality, global data sets and a suite of routinely delivered ocean analyses. At the same time, the system will provide real-time data to serve the needs of NOAA's marine and coastal forecast missions and the needs of the other agencies in accomplishing their missions.

5.0 Performance Measures

In order to achieve the four objectives, the system must accurately measure: 1) sea level to identify changes resulting from climate variability; 2) ocean carbon content every ten years and the air-sea exchange seasonally; 3) sea surface temperature and surface circulation to identify significant patterns of climate variability; 4) sea surface pressure and air-sea exchanges of heat, momentum, and fresh water to identify changes in forcing functions driving ocean conditions and atmospheric conditions; 5) ocean heat and fresh water content and transports to identify where anomalies enter the ocean, how they move and are transformed, and where they re-emerge to interacting with the atmosphere; 6) identify the essential aspects of thermohaline circulation as well as the subsurface expressions of the patterns of climate variability; and 7) sea ice thickness and concentrations.

The sampling requirements for these parameters have been documented by international GOOS and GCOS. Table 1 lists the requirements as presented at the OCEANOBS 99 Conference in Saint-Raphael, France. It represents the best estimates of the international community at this time.

The Proceedings of OCEANOBS 99 and the final report from the conference, *Observing the Ocean in the 21st Century*, outline implementation strategies for achieving these sampling requirements. Additionally, for documenting sea level variability and change, the implementation strategy is further defined in the *International Sea Level Workshop Report*, 1998; and for documenting ocean carbon sources and sinks the implementation strategy is defined in the *Large Scale CO_2 Observing Plan: In Situ Oceans and Atmosphere (LSCOP)*, 2002. The latter plan is for the United States only at this time, but was developed by U.S. scientists working in collaboration with international partners. The international community met in Paris, January 2003, to advance international implementation of the ocean carbon monitoring system and the United States contribution will be updated as the international plan is formulated. These foundation documents are available from the NOAA Office of Global Programs and are listed in Appendix A.

Based on the requirements in Table 1 and the implementation strategies defined in the foundation documents listed in Appendix A, the system's effectiveness in meeting the objectives will be gauged by the performance metrics listed below. Detailed metrics are given for each objective in sections 5.1-5.4. Those detailed metrics will lead to a system that can be summarized in three overarching measures of success:

Performance Measure 1: Reduce the uncertainty in projections of sea level rise during the 21st century.

Metric: Range between credible estimates of sea level rise (centimeters):

2002	2003	2004	2005	2006	2007	2008	2009	2010
80 cm	80 cm	70 cm	60 cm	50 cm	40 cm	30 cm	25 cm	25 cm

Performance Measure 2: Reduce the uncertainty in estimates of the increase in carbon inventory in the global ocean.

Metric: Uncertainty in estimates of anthropogenic changer per decade (Gigatons):

2002	2003	2004	2005	2006	2007	2008	2009	2010
10 Gt	10 Gt	10 Gt	8 Gt	8 Gt	7 Gt	6 Gt	4 Gt	4 Gt

Performance Measure 3: Reduce the error in global measurement of sea surface temperature.

Metric: Potential satellite bias error (degrees Celsius):

2002	2003	2004	2005	2006	2007	2008	2009	2010
0.7 C	0.7 C	0.6 C	0.5 C	0.4 C	0.3 C	0.2 C	0.2 C	0.2 C

5.1 Document long-term trends in sea level change.

Performance Measure 4: Complete the installation of real-time, remote reporting tide gauges and co-located permanent GPS receivers at the international GLOSS subset of 62 stations for Long Term Trends and subset of 30 stations for altimeter drift calibration.

Performance Measure 5: Establish the permanent infrastructure necessary to process and analyze the tide gauge and GPS data and deliver routine annual sea level change reports.

Metrics:

- For 62 climate reference stations worldwide, routinely deliver an annual report of the variations in relative annual mean sea level for the entire length of the instrumental record, and the monthly mean sea level trend for the past 100 years with 95% confidence interval.
- Routinely deliver an annual report of global absolute sea level change to an accuracy of 1 mm per year.

5.2 Document ocean carbon sources and sinks.

Performance Measure 6: Complete the Northern Hemisphere ocean observing system to assist in determining carbon dioxide sources and sinks over the coterminous United States in partnership with the atmospheric observing system.

Performance Measure 7: Complete the expansion of the global oceanic observing system to inventory global scale oceanic uptake of excess carbon dioxide in partnership with the atmospheric observing system.

Metrics:

- Report interhemispheric gradients of CO_2 constrained to 1 ppm on seasonal time scales.
- Improve measurements of North Atlantic and North Pacific Ocean basin carbon dioxide fluxes to within ±0.2 Pg/C per year.
- Reduce uncertainty on regional estimates of carbon sources and sinks on a global basis to ±50%.
- Report the change in ocean carbon inventory over the last decade constrained to 2 Pg/C per year.
- Provide publicly available, routine changes in inventory of carbon, heat, and salinity in the ocean basins on a decadal time frame to assess the effect of global change and feedbacks on the ocean

5.3 Document the ocean's storage and global transport of heat and fresh water.

Performance Measure 8: For the global ocean, complete the ocean observing system needed to measure the global variations in sea surface temperature, surface and 2000 m circulation, total heat content of the ocean, and the transport of heat across and between all ocean basins.

Performance Measure 9: Design, deploy, and implement instrument and analysis systems to provide long term integrated measures of the global thermohaline circulation and deliver yearly estimates of the state of the thermohaline circulation - intensity, properties, freshwater transport.

Metrics:

- At ocean reference stations, deliver routine annual analyses of variability in average temperature at 0-1000 m depth to 0.1°C, and seasonal average temperature change to 0.1°C per three months.

- Deliver analyses of the seasonal means of the surface and 2000 m ocean velocity fields on appropriate spatial resolutions that capture the major features of the overturning circulation for all the core climate variability regions (the global tropics, Pacific Decadal Oscillation, North Atlantic Oscillation, high latitude water mass formation regions both northern and southern hemispheres).
- Deliver analyses of monthly mean sea surface temperature anomaly at 500 km resolution to 0.2°C accuracy, average temperature at 0-1000 m depth to 0.5°C accuracy, and annual average temperature change to 0.5°C per year.
- For the sinking regions of the north Atlantic and southern hemisphere, deliver yearly estimates of the annual average temperature and salinity of the intermediate, deep, and bottom waters to 0.03°C and 0.03PSU.
- Across zonal sections in the Atlantic at 24°N, 47°N, and globally at 35°S, deliver estimates of the average annual meridional heat transport from surface to bottom at 0.3PWatt accuracy.

5.3 Document the air-sea exchange of heat and fresh water.

Performance Measure 10: For the global tropical ocean belt, complete the upper ocean and surface meteorology observing system needed to measure the ocean-atmosphere exchange of heat.

Performance Measure 11: For the global ocean, complete the oceanographic, surface meteorology, and analysis system needed to measure variability in the ocean-atmosphere exchange of fresh water, i.e., precipitation and evaporation.

Metrics:

- For the global ocean, deliver analyses of weekly mean sea surface temperature at 500 km resolution to 0.2°C accuracy
- At ocean reference stations, deliver routine annual analyses of variability in ocean-atmosphere flux to 10 W/m^2.
- For the global ocean deliver weekly analysis of precipitation and evaporation at 500 km resolution to 5 cm per month accuracy.

6.0 Milestones

In order to achieve the Performance Measures, the integrated ocean observing system will be completed according to the following schedule. The schedule is based on the initial design and projections of adequate funding. The milestones will be updated annually to reflect evolution of the design as knowledge and technology advance, and to reflect the realities of funding availability.

	FY02	FY03	FY04	FY05	FY06	FY07	FY08	FY09	FY10
System % Complete:	40	45	48	55	77	88	94	99	100

Although individual network priorities are described below, they must all go forward together as a system. For example, the global Argo array of profiling floats is a primary tool for documenting ocean heat content; yet deployment of the floats in the far corners of the ocean cannot be achieved without the ships-of-opportunity and dedicated ship time elements; and the Argo array cannot do its work without global over-flight by continued precision altimeter space missions; while the measurements taken by all networks will be rendered effective only through the data and assimilation subsystems.

The following sections indicate network improvements that work toward building the observing system as a whole. The ocean observing system is a composite of complementary networks, each one contributing its unique strengths; most serve multiple purposes. One of the primary goals of NOAA's Office of Climate Observation is to look for efficiencies to be gained by utilizing common platforms/sites/data infrastructure for several objectives in parallel. For these reasons it is difficult to assign the network components specifically to the climate service product lines on a one-to-one basis. In general, however, the network tasks described below will contribute to the deliverables as follows:

1) Document long-term trends in sea level change:
- Tide Gauge Network
- Satellites
- Data and Assimilation Subsystems

2) Document ocean carbon sources and sinks:
- Drifting Buoy Array
- Tropical Moored Buoy Network
- Ships of Opportunity
- Argo Array
- Ocean Reference Stations
- Ocean Carbon Measurements
- Coastal Moorings
- Dedicated Ship Time
- Data and Assimilation Subsystems

3) Document heat uptake, transport, and release by the ocean:
- Tide Gauge Network
- Drifting Buoy Array
- Tropical Moored Buoy Network
- Ships of Opportunity
- Argo Array

- Ocean Reference Stations
- Coastal Moorings
- Dedicated Ship Time
- Satellites
- Data and Assimilation Subsystems

4) Document the air-sea exchange of water and the ocean's overturning circulation:
- Drifting Buoy Array
- Tropical Moored Buoy Network
- Ships of Opportunity
- Argo Array
- Ocean Reference Stations
- Coastal Moorings
- Dedicated Ship Time
- Satellites
- Data and Assimilation Subsystems

Priorities and milestones for the individual networks follow. For each network the several priority tasks are listed in tabular form. The bottom lines of the tables give the representative milestones that are shown graphically in Figure 2; representative milestones are used to simplify the graphic depiction of the phased implementation plan illustrated by Figure 2. Relative emphases in completing the several components of the observing system will depend on the relative priorities assigned to the network tasks in the context of the overall requirements of climate services.

6.1 Tide Gauge Network: Tide gauges are necessary for accurately measuring long-term trends in sea level change and for calibration and validation of the measurements from satellite altimeters, which are assimilated into global climate models for predicting climate variability. Many tide stations need to be upgraded with modern technology. Permanent GPS receivers will be installed at a selected subset of stations, leading to a geocentrically located subset expansion from the present 37 GPS sites to 86 sites globally by 2006. In cooperation with international partners NOAA will maintain a global climate network of 199 tide gauges stations, including the subset noted above, for validation of satellite retrievals, validation of climate model results, and documentation of seasonal to centennial variability in the El Nino Southern Oscillation, Indian Ocean and Asian-Australian monsoons, tropical Atlantic variability, North Atlantic Oscillation, North Pacific variability, high latitude circulation, western boundary currents, and circulation through narrow straits and chokepoints. This task will contribute to climate services by providing the long term records needed to 1) document sea level change: 2) document heat uptake, transport, and release by the ocean (sea surface height contributes to the measurement of ocean heat content); and 3) documents the ocean's overturning circulation (gradients of sea surface height across straights and choke-points are used to calculate large-scale ocean currents).

		NOAA Contributions								International Goal
		FY03	FY04	FY05	FY06	FY07	FY08	FY09	FY10	
Operational stations		57	63	63	63	63	63	63	63	107?
Research stations		6	0	0	0	0	0	0	0	0
Station upgrades		0	4	10	16	26	32	32	32	199
GPS installation	5	10	14	20	40	40	40	40	86	
GPS data processing				X	X	X	X	X	X	X
Technology development					X	X	X	X	X	X
International GPS/DORIS		43	55	75	86	86	86	86	86	86

6.2 Drifting Buoy Array: Data sparse regions of the global ocean are a major source of uncertainty in the seasonal forecasts and are also a major uncertainty in the detection of long-term trends in global sea surface temperature, which in turn is an indicator of global change. Data gaps must be filled by surface drifting buoys to reduce these sources of error to acceptable limits. NOAA, together with international partners, will extend the global SST/velocity drifting buoy array to data sparse regions, increasing from 787 to 1250 buoys by 2005, while adding wind, pressure, and precipitation measurement capabilities to serve short term forecasting as well as climate research, seasonal forecasting, and assessment of long term trends. This task will support climate services by providing measurements needed to 1) document heat uptake, transport, and release by the ocean; 2) document ocean carbon sources and sinks (sea surface temperature affects the rate of transfer of CO_2 between the ocean and atmosphere; 3) document the air-sea exchange of water and the ocean's overturning circulation, and 4) document sea level change by providing the sea surface atmospheric pressure measurements that are essential for calculating sea surface height from satellite altimeter measurements.

		NOAA Contributions								International Goal
		FY03	FY04	FY05	FY06	FY07	FY08	FY09	FY10	
Operational buoys		420	670	1040	1040	1040	1040	1040	1040	1250
Research buoys		200	200	0	0	0	0	0	0	0
Add met sensors		40	40	500	670	670	670	670	670	1250
Technology development				X	X	X	X	X	X	X
International array size	787	1050	1250	1250	1250	1250	1250	1250	1250	

6.3 Tropical Moored Buoy Network: Most of the heat from the sun enters the ocean in the tropical/sub-tropical belt. The advanced understanding of the role of the tropics in forcing mid-latitude weather and climate was learned primarily through the observations of the tropical moored buoy array (TAO/TRITON) in the Pacific. A similar pilot array in the Atlantic basin (PIRATA) now offers the potential of even better understanding, improved forecasts, and improved ability to discern the causes of longer-term changes in the Oceans. In addition to monitoring the air-sea exchange of heat, the moored buoys provide platforms for supporting instrumentation to measure carbon dioxide and rainfall in the tropics. The global tropical moored buoy network will be expanded from 79 to 112 stations by 2009 and will ultimately span all three oceans - Pacific, Atlantic, and Indian Ocean. This task will support climate services by providing both ocean and atmospheric observations to 1) document heat uptake, transport, and release by the ocean; 2) document carbon sources and sinks; and 3) document the air-sea exchange of fresh water.

	NOAA Contributions								International Goal
	FY03	FY04	FY05	FY06	FY07	FY08	FY09	FY10	
Operational buoys	55	65	65	65	65	65	65	65	79
Research buoys	10	0	0	0	0	0	0	0	0
Indian Ocean expansion		3	6	15	15	15	15	30	
Atlantic Ocean expansion			2	2	5	5	5	5	9
Add salinity sensors	10	10	60	65	65	65	65	65	99
Add flux capability to buoys			5	5	5	5	5	5	8
Technology development			X	X	X	X	X	X	X
International network size	79	79	82	85	89	100	112	112	112

6.4 Ships of Opportunity: The global atmospheric and oceanic data from Ships of Opportunity (SOOP) have been the foundation for understanding long-term changes in marine climate and are essential input to climate and weather forecast models. Improved instrument accuracy, automated reporting, and improved information about how the observations were taken will greatly enhance the quality of these data, reducing both systematic and random errors. NOAA will improve meteorological measurement capabilities on the global SOOP fleet for improved marine weather and climate forecasting in general, and will concentrate on a specific subset of high accuracy SOOP lines to be frequently repeated and sampled at high resolution for systematic upper ocean and atmospheric measurement. This climate-specific subset will build from 26 lines presently occupied to a designed global network of 41 lines by 2007 and will provide measurements of the upper ocean thermal structure, sea surface temperature and chemistry, and surface meteorology of high accuracy. Additionally, the SOOP fleet is the primary vehicle for deployment of the drifting arrays. This task will support climate services by providing ocean and atmosphere measurements needed to 1) document heat uptake, transport, and release by the ocean; and 2) document ocean carbon sources and sinks (carbon sampling instrumentation is detailed under a separate task below); and 3) document the air-sea exchange of water and the ocean's overturning circulation.

	NOAA Contributions								International Goal
	FY03	FY04	FY05	FY06	FY07	FY08	FY09	FY10	
Operational HRX lines	2	15	21	21	21	21	21	21	26
Research HRX lines	6	0	0	0	0	0	0	0	0

Frequently repeated lines	4	5	8	8	8	8	8	8	22
Add flux/salinity HRX	2	2	7	12	15	15	15	15	26
Auto-met package, VOSClim	0	0	40	100	200	200	200	200	200
Technology development				X	X	X	X	X	X
International lines	26	29	30	36	45	45	45	45	45

6.5 Argo array of profiling floats: The heat content of the upper 2000 meters of the world's oceans, and the transfer of that heat to and from the atmosphere, are variables central to the climate system. The Argo array of profiling floats is designed to provide essential broad-scale, basin-wide monitoring of the upper ocean heat content. Three thousand floats will be deployed worldwide by 2005. The U.S. contribution is approximately one-half of this international project. Glider technology will replace standard drifting Argo floats in the boundary currents and targeted deep circulation regions. This task will support climate services by providing measurements needed to 1) document heat uptake, transport, and release by the ocean; and 2) document the air-sea exchange of water and the ocean's overturning circulation.

		NOAA Contributions								International Goal
		FY03	FY04	FY05	FY06	FY07	FY08	FY09	FY10	
Operational Argo floats	320	1000	1500	1485	1485	1385	1385	1385	2800	
Research Argo floats		15	0	0	0	0	0	0	0	0
Operational gliders		0	0	0	0	0	100	100	100	200
Research gliders		3	3	10	20	50	0	0	0	0
Technology development					X	X	X	X	X	X
International array size	1000	2000	3000	3000	3000	3000	3000	3000	3000	

6.6 Ocean Reference Stations:

6.6.1 Subtask 1: NOAA, together with international partners, will implement a global network of ocean reference station moorings, expanding from the present six pilot stations to a permanent network of 21 (plus 8 within the tropical moored buoy network) by 2008. NSF's Ocean Observatories Initiative will provide a major piece of the infrastructure needed for this network, establishing high-capability re-locatable moored buoys in remote ocean locations. NOAA will maintain climate instrumentation aboard the NSF-supplied platforms.

6.6.2 Subtask 2: Monitoring the transport within the ocean is a central element of documenting the overturning circulation of fresh water and heat and carbon uptake and release; heat and carbon generally are released to the atmosphere in regions of the ocean far distant from where they enter. Long-term monitoring of key choke points, such as the Indonesian through-flow, and of boundary currents along the continents, such as the Gulf Stream, must be established to measure the primary routes of ocean heat, carbon, and fresh water transport.

6.6.3 Subtask 3: Monitoring thermohaline circulation is a central element of documenting the ocean's overturning circulation and a critical need for helping scientists understand the role of the ocean in abrupt climate change. It is essential that the ocean observing system maintain watch at a few control points at critical locations. Key monitoring sites have been identified by an international team of scientists for deployment of long-term subsurface moored arrays and repeated temperature, salinity, and chemical tracer surveys from research vessels. NOAA will focus with Canadian partners on monitoring the Labrador Sea and upstream locations in Davis Strait and the Canadian Arctic Archipelago, while European partners will focus on the eastern north Atlantic. One exception to this is that NOAA will maintain the Greenland-Iceland-Norwegian (GIN) Seas times-series that was started in 1991. Additionally, to estimate the effect of Antarctic zone water on the global thermohaline circulation, NOAA will maintain time series moorings and repeat sections in the northwestern Weddell Sea, and will establish time series measurements in the Ross Sea. These locations are important to examine the variability of water mass transformation processes as they relate to climate variability in the Southern Ocean.

6.6.4 Summary: These three subtasks will support climate services by providing ocean and atmosphere measurements needed to 1) document heat uptake, transport, and release by the ocean; 2) document ocean carbon sources and sinks (carbon sampling instrumentation is detailed under a separate task below; and 3) document the air-sea exchange of water and the ocean's overturning circulation.

	NOAA Contributions								International Goal
	FY03	FY04	FY05	FY06	FY07	FY08	FY09	FY10	
Operational flux moorings	1	2	6	7	9	9	9	9	29
Research flux moorings 1	0	0	0	0	0	0	0	0	
Operational full depth stations	0	0	3	5	10	10	10	10	42
Research full depth stations	1	1	0	0	0	0	0	0	0
Operational transport stations	0	0	2	4	4	5	5	5	10
Research transport stations	2	0	0	0	0	0	0	0	0
Pacific Raingauge (PACRAIN)	0	28	28	28	28	28	28	28	28
Research rain gauge network	28	0	0	0	0	0	0	0	0
Operational GIN time series	0	1	1	1	1	1	1	1	1
Research GIN time series	1	0	0	0	0	0	0	0	0
Sinking regions, operational	0	2	2	4	4	4	4	4	5
Sinking regions, research	1	1	0	0	0	0	0	0	0
S. Hemisphere sections	0	0	0	2	3	3	3	3	3
Technology development				X	X	X	X	X	X
International flux array 6	7	10	14	16	29	29	29	29	

6.7 Coastal Moorings: Improved near shore measurements from moored buoys are critical to coastal forecasting as well as to linking the deep ocean to regional impacts of climate variability. The boundary currents along continental coastlines are major movers of the ocean's heat and fresh water (e.g., the Gulf Stream). Furthermore, the coastal regions are critical to the study of the role of the ocean in the intensification of storms, which are key to the global atmospheric transport of heat, momentum and water, and are a significant impact of climate on society. Coastal arrays are maintained by many nations making this a "global" network of "coastal" stations. A climate subset of NOAA's existing network will be improved by augmenting and upgrading the instrument suite to provide measurements of the upper ocean as well as the sea surface and surface meteorology. Ten of these moorings will serve as platforms-of-opportunity for the addition of carbon sampling instrumentation. This task will support climate services by providing ocean and atmosphere measurements needed to 1) document heat uptake, transport, and release by the ocean; 2) document ocean carbon sources and sinks (carbon sampling instrumentation is detailed under a separate task below); and 3) document the air-sea exchange of water.

	NOAA Contributions								International Goal
	FY03	FY04	FY05	FY06	FY07	FY08	FY09	FY10	
Upgrade w/climate sensors	0	0	20	65	65	65	65	65	105
Technology development				X	X	X	X	X	X
International coastal network	0	0	20	85	95	105	105	105	105

6.8 Ocean Carbon: Understanding the global carbon cycle and the accurate measurement of the regional sources and sinks of carbon are of critical importance to international policy decision making as well as to forecasting long term trends in climate. Projections of long-term global climate change are closely linked to assumptions about feedback effects between the atmosphere, the land, and the ocean. To understand how carbon is cycled through the global climate system, ocean measurements are critical. NOAA will add autonomous carbon dioxide sampling to the moored arrays and the VOS fleet to analyze the seasonal variability in carbon exchange between the ocean and atmosphere, and in cooperation with NSF will implement a program of systematic global ocean surveys that will provide a complete carbon inventory once every ten years. This task is coordinated with the Global Carbon Cycle Science program, is dependent on implementation of the ship lines and moored and drifting arrays, and will support climate services by providing measurements to document ocean carbon sources and sinks.

	NOAA Contributions								International Goal
	FY03	FY04	FY05	FY06	FY07	FY08	FY09	FY10	
Inventory lines per decade	6	6	11	11	11	11	11	11	25
Time series moorings	2	2	4	6	6	6	6	6	12

Coastal flux moorings	0	0	0	11	11	11	11	11	29
Flux on ships of opportunity	4	7	12	12	12	12	12	12	21
Research flux on moorings	2	0	0	0	0	0	0	0	0
Trans rsch flux moorings to ops	0	2	2	2	2	2	2	2	2
Technology development			X	X	X	X	X	X	X
International flux array 14	17	28	38	48	62	62	62	62	

6.9 Integrated Arctic Observing System: To understand the role of the Arctic on global environmental change, the amount of uncertainty in the causes and trajectories of global climate change needs to be reduced. Given the sensitivity of the Arctic environment to climate variability and change, it is in this region that early indications of the future progression of climate change are likely to be first detected.

<u>Ocean Climate Observations in the Arctic Ocean and Northern High Latitude Seas</u> – A program of sustained observations of this area is being conducted through dedicated and shared ship-based cruises and permanent oceanographic moorings, supplemented by acquisition and analysis of historical data sets. The long-term goal is to detect climate-driven physical and ecological change, especially due to changes in sea ice extent and duration, and in ocean density and circulation that together may lead to changes in ocean heat transport, productivity, and food web structure. International collaboration is essential for completing this program, especially with Russia and Canada. In FY2003, one new mooring was deployed in the Northern Bering Sea, a research cruise was conducted to the Chukchi Sea in collaboration with China, planning was initiated for a future Chukchi Sea cruise in collaboration with Russia, sea-glider deployments were initiated in the Labrador Sea, joint US-Canada observations were conducted in Barrow Strait, and efforts begun to discover, obtain and manage historical data sets.

<u>Arctic Sea Ice Observations</u> – Ice-tethered buoys and bottom-mounted moorings are deployed to monitor the drift of Arctic sea ice and to determine its thickness. The long-term goal is to provide an accurate record of changes in sea ice thickness that, together with satellite observations of sea ice extent, can provide an estimate of changes in sea ice volume. This information is critical for improvement of global climate models and development of a regional Arctic climate model. Several ice buoys and two ice thickness stations were deployed in summer 2003.

This task will support climate services by providing ocean and ice measurements needed to document heat uptake, transport, and release by the ocean.

	NOAA Contributions								International Goal
	FY03	FY04	FY05	FY06	FY07	FY08	FY09	FY10	
Arctic pathway moorings	0	0	1	2	4	6	8	8	12
Arctic Ocean moorings	0	0	1	2	4	6	7	7	8

ASOF gateway mooring sets	0.5	0.5	1	1	1	1	2	2	5
Automated drifting stations	0	0	1	2	2	2	2	3	3
Ice buoys	10	10	11	20	20	20	20	20	40
Hydrographic stations	0	0	1	4	6	8	9	10	16
Bering Sea moorings	1	1	1	2	4	6	6	6	6
Western boundary sections	0	0	1	1	1	1	1	1	1
Western boundary moorings	0	0	2	2	4	4	4	4	4
Ice buoys and moored stations	10	11	13	23	25	33	43	51	51

6.10 Dedicated Ship Time:

6.10.1 Subtask 1: Climate Ship time within the UNOLS research fleet for deployment of the moored and drifting arrays, and for deep ocean surveys is an essential component of this initiative. The deep ocean cannot be reached by SOOP and Argo; yet quantification of the carbon and heat content of the entire ocean column is needed to solve the climate equations. In addition to providing the survey and deployment platforms for the autonomous arrays, the research fleet will maintain sensor suites on a small core of vessels as the highest quality calibration points for validation of the other system measurements. Annual requirements for ship time are 54 days in addition to the Ka'imimoana for TAO/TRITON maintenance, 74 days for the carbon inventory, 34 days for PIRATA in addition to the French/Brazilian support (see Subtask 2), 47 days for ocean reference stations growing to 120 days, 60 days for deployment of the drifting arrays in remote regions, and 46 days for thermohaline circulation monitoring growing to 172 days.

6.10.2 Subtask 2: The PIRATA array has been maintained by French research vessels, once per year in the east, and the Brazilian navy once per year on the western side of the Atlantic. Two maintenance visits per year to each mooring are necessary to maintain adequate operational data flow, as has been demonstrated in the Pacific with the TAO/TRITON array. The PIRATA consortium (Brazil, France, U.S.A.) has proposed a plan to establish an international ship base in Natal, Brazil, and operate cooperatively a new ship dedicated to Atlantic climate operations. The consortium has proposed that NOAA and French partners cooperate to acquire a new ship, and build the capacity in Brazil to support long-term climate operations. The new ship would support Argo and drifter deployments as well as PIRATA maintenance. The U.S. homeport for the ship, and support base for north Atlantic operations, would be Charleston, SC; Natal would support operations in the tropical and south Atlantic. This is a new concept in international collaboration and capacity building. In 2003, NOAA began feasibility study together with French and Brazilian partners to identify the best long-term solution to this issue. In the mean time, NOAA will begin supplementing the once-per-year French and Brazilian maintenance cruises with a second maintenance cruise using UNOLS or other charter operations (see Subtask 1).

6.10.3 Summary: This task will support climate services by providing multi-use platforms for the ocean and atmosphere measurements needed to 1) document heat uptake, transport, and release by the ocean; 2) document ocean carbon sources and sinks; and 3) document the air-sea exchange of water and the ocean's overturning circulation.

Ship days at sea	NOAA Contributions								International Goal
	FY03	FY04	FY05	FY06	FY07	FY08	FY09	FY10	
Ka'imimoana	276	276	276	276	276	276	276	276	276
TAO/TRITON additional	54	54	54	54	54	54	54	54	90
PIRATA	0	0	34	34	34	34	34	34	124
Carbon survey	74	74	74	74	74	74	74	74	240
Coastal flux maps	0	0	0	36	40	40	40	40	240
Reference Stations	47	47	47	60	102	120	120	120	480
Deployment of drifting arrays	0	0	0	60	60	60	60	60	100
Thermohaline circulation	46	46	46	46	90	172	172	172	340
Arctic hydrographic sections	0	0	0	60	60	60	60	60	120
NOAA total	497	497	531	700	790	890	890	890	
International fleet	550	610	750	900	1200	1620	1620	1620	1620

6.11 Satellites:

The initial ocean observing system for climate depends on space based global measurements of 1) sea surface temperature, 2) sea surface height, 3) surface vector winds, and 4) ocean color. These satellite contributions are detailed in other NOAA program plans.

6.11.1 Sea surface temperature: Satellite measurements of sea surface temperature are included in NOAA's operational satellite program and the NPOESS program. Satellite data provide high-resolution sea surface temperature data. Both infrared and microwave satellite data are important. Microwave sea surface temperature data have a significant coverage advantage over infrared sea surface temperature data, because microwave data can be retrieved in cloud-covered regions while infrared cannot. However, microwave sea surface temperatures are at a much lower spatial resolution than infrared. In addition microwave sea surface temperatures cannot be obtained within roughly 50 km of land. A combination of both infrared and microwave data are needed because they have different coverage and error properties. Drifting buoy and other *in situ* data are critically important in providing calibration and validation in satellite data as well as providing bias correction of these data. Satellite biases can occur from obit changes, satellite instrument changes and changes in physical assumptions on the physics of the atmosphere (e.g., through the addition of volcanic aerosols). Thus, drifting buoy and other *in situ* data are needed to correct for any of these changes.

6.11.2 Sea surface height: The value of spaced-based altimeter measurements of sea surface height has now been clearly demonstrated by the TOPEX/Poseidon and Jason missions. Changes in sea level during major El Nino events can now be discerned at high resolution and provide realistic model initializations for seasonal climate forecasting. The same data, when calibrated with island tide gauge observations, are also able to monitor the rate of global sea level change with an accuracy of 1 mm per year. The planned NPOESS altimeter will be adequate for shorter term forecasting, but the NPOESS altimeter will not fly in the same orbit as TOPEX/Poseidon and Jason; and for monitoring long-term sea level change, continuation of precision altimeter missions in the TOPEX/Poseidon/Jason orbit is necessary. Jason follow-on altimeter missions (Ocean Surface Topography Mission, OSTM) are necessary to continue the long-term sea level record. NASA and CNES have asked NOAA and EUMETSAT to transition the Jason-class altimeter from research to operations beginning with the OSTM. In FY2006, NOAA will assume primary U.S. responsibility for continuing this international effort. This task will contribute to climate services by providing the long term records needed to 1) document sea level change; 2) document heat uptake, transport, and release by the ocean; and 3) document the ocean's overturning circulation (sea surface height contributes to the measurement of ocean heat and fresh water content and their transport).

6.11.3 Surface vector winds and ocean color: The best methods of sustaining satellite measurement of surface vector winds and ocean color are still a research and development question; over the next five years NOAA, NASA, and NPOESS will weigh the alternatives and determine the long term strategy for maintenance of these elements.

6.12 Data and Assimilation Subsystems:

6.12.1 Subtask 1 – Long Term Stewardship: The value of the observations does not end with their initial use in detecting and forecasting climate variability. The data must be retained and made available for retrospective analyses to understand long-term climate change, and for designing observing system operations and improvements. NOAA's long history and unique expertise in environmental data management will be applied to the ocean observing system. NOAA also will include the vast holdings of historical ocean observations within the context of the integrated environmental data access and archive system. Support will also be provided for a World Ocean Database to incorporate modern data into an integrated profile system.

6.12.2 Subtask 2 – Data Management and Communications: A robust and scalable data management infrastructure is essential to the vision of a sustained ocean observing system. NOAA's ocean climate data element will contribute a global component to the Data Management and Communications System (DMAC) of the U.S. Integrated Ocean Observing System (IOOS) that is being implemented by the National Oceanographic Partnership Program agencies. The DMAC plan integrates data transport, quality control, data assembly, limited product generation, metadata management, data archeology, data archival, data discovery, and administration functions. Uniform access to data will be addressed through the concept of "middleware" connectivity – a common set of standards and protocols that connects all data sources to data users. The middleware approach shields end users from many of the traditional barriers that have been associated with climate data access, including file formats, the distributed location of data, and the large size of some data sets. The preliminary design has been developed by the National Virtual Ocean Data System (NVODS) project.

The nature of IOOS requires the DMAC to be very highly distributed, supporting both large and small data providers at Federal, regional, state, municipal and academic levels. Data assembly centers will be built into the design to add fault-tolerance and increase ease of use. The GODAE server at Navy's Fleet Numerical Modeling Operations Center (FNMOC) in Monterey will provide robust, operational access to aggregated and quality-controlled real-time data streams and will be a primary assembly center for NOAA's real-time global measurements. Delayed-mode data sources will be distributed across many institutions including the Asia-Pacific Research Data Center (APDRC) (part of the International Pacific Research Center (IPRC) at the University of Hawaii) and the NOAA Data Centers. The APDRC will provide data assembly services for delayed-mode observations in a cooperative partnership with the GODAE Server.

The Data Management and Communications component of NOAA's ocean climate observing system must also deliver the information products needed by NOAA scientists and managers for decision support. The products must provide the information needed to monitor the month-by-month effectiveness of the observing system and to diagnose problems. The products should include intelligible scientific graphics and human-readable numeric tables that provide an overview of the integrated system, selectively merging the data from all relevant measurement streams. These information products will be a component of NOAA's contribution to IOOS.

6.12.3 Subtask 3 – Four dimensional data assimilation including GODAE: For climate forecasting, the combined fields from many different networks are used as initial conditions to begin the forecast. These combined fields, or analyses, are also used to document what the ocean and atmosphere are doing at present and what they did in the past, thus providing a record of the changing climate. By routinely comparing models and data, shortcomings in the observing system can be identified and both the models and forecasts can be improved. To utilize effectively the ocean observations, NOAA will expand the current ocean analyses (presently focused on the tropical Pacific) to the global domain and will develop and implement improved assimilation subsystems that can more effectively use the new data types that are being collected. The principal vehicle for developing this capability, involving both national and international communities and producing a variety of marine products in addition to the use of these observations in forecast systems, will be the Global Ocean Data Assimilation Experiment (GODAE). The global data and ocean product delivery will be operationalized as a contribution to, and continue as a follow-on to, GODAE through the interagency/international server infrastructure being implemented by GODAE for real-time at FNMOC and for delayed mode at the IPRC; NOAA will provide the primary U.S. support to sustain the IPRC server infrastructure over the long term (in cooperation with Japan). In addition to improving initializations for seasonal forecasting at NCEP, NOAA will implement sustained ocean data assimilation activities at GFDL to enable experimental decadal forecasts, provide ocean initial conditions for IPCC type scenarios, monitor ocean heat uptake, monitor the thermohaline circulation for abrupt changes, and develop a capability for monitoring changes in oceanic carbon sources and sinks.

6.12.4 Summary: This task will support climate services by providing the integrating data, synthesis, and analysis infrastructure for the ocean and atmosphere measurements, both *in situ* and space based, needed to: 1) document long-term trends in sea level change; 2) document heat uptake, transport, and release by the ocean; 3) document ocean carbon sources and sinks; and 3) document the air-sea exchange of water and the ocean's overturning circulation.

	NOAA Contributions								International Goal
	FY03	FY04	FY05	FY06	FY07	FY08	FY09	FY10	
Data set development	X	X	X	X	X	X	X	X	X
World Ocean Database				X	X	X	X	X	X
Standards and protocols			X	X	X	X	X	X	
Systems interoperability X	X	X	X	X	X	X	X	X	
Automated monitoring tools	X	X	X	X	X	X	X	X	X
IPRC server	X	X	X	X	X	X	X	X	X
GODAE pilot activities (JIMO)	X	X	X	X	X	X	X	X	X
Operationalize GODAE pilot		X	X	X	X	X	X	X	X
Global initialization for S-I	X	X	X	X	X	X	X	X	X
Experimental decadal forecast		X	X	X	X	X	X	X	X
Conditions for IPCC scenarios		X	X	X	X	X	X	X	X
Monitor ocean heat uptake		X	X	X	X	X	X	X	X
Monitor thermohaline circulation			X	X	X	X	X	X	
Monitor carbon sources and sinks	X	X	X	X	X	X	X	X	X
Argos data processing – Drifting Buoy arrays	X	X	X	X	X	X	X	X	X
Argos data processing – Tropical Moored Buoy network	X	X	X	X	X	X	X	X	X
Argos data processing – Ocean Ref stations	X	X	X	X	X	X	X	X	X

7.0 Management Plan – System organization and product delivery

A global effort of the proposed magnitude must be integrated, organized, and managed as a system in order to be effective. Matrix management is NOAA's corporate business practice and standard protocol. This management plan will follow that protocol by capitalizing on the capabilities that presently exist across the agency while building toward the vision of a single composite system.

Implementation of the individual *in situ* networks will continue to be through distributed centers of expertise at the NOAA Research laboratories, the National Ocean Service Center for Operational Oceanographic Products and Services, the National Data Buoy Center, and the university laboratories that have developed the instruments and techniques. The space components and data management will be centered in the National Environmental Satellite Data and Information Service. The focal point for developing global ocean data assimilation capabilities will be the Geophysical Fluid Dynamics Laboratory in partnership with the National Centers for Environmental Prediction and university-based applied research centers.

To weld the distributed efforts together into the single vision, NOAA has established a project Office of Climate Observation (OCO) under the auspices of the NOAA Climate Program. Organizationally the project office is located within the Office of Global Programs (OGP). OGP embodies a global perspective and is experienced in matrix management. One of OGP's four strategic objectives is "development of the *in situ* ocean component of the global climate observing system." Additionally, for the climate observing system institutional mechanisms must be put in place to ensure continuous and close involvement of the research community. Research, operations, and management are inseparable for climate observation and OGP will hard-wire that relationship.

The Director of OGP utilizing the OCO is charged with advancing NOAA's multi-year program plan for *Building a Sustained Ocean Observing System for Climate*. The OCO is a hybrid combining the functions of a traditional program office with the functions of a center for system monitoring, evaluation, integration, and action. The individual network managers will continue to monitor and evaluate the performance of their individual networks, while the OCO will build the capability to monitor and evaluate the performance of the system as a whole, and take action to evolve the *in situ* networks for overall effectiveness and efficiency in meeting climate observation objectives.

The OCO is the management focus for the distributed ocean network operations and, utilizing the NOAA Observing System Architecture, establishes and maintains operational linkages between the networks and NOAA's other *in situ* and satellite elements and the data and modeling activities that are essential components of climate observation. The office provides a central point of contact within NOAA for coordination with the other agencies and nations involved in observing system implementation. The office receives and acts on feedback from the observing system customers - the operational forecast centers, international research programs, and major scientific assessments - and acts on their observational requirements in accordance with the NOAA Requirements-Based Management Process.

7.1 Subtask 1 – System Monitoring: The OCO monitors the status of the globally distributed networks to anticipate gaps and overlaps in their combined capabilities. Real-time reports from all platforms are being centralized so that up-to-date status can be displayed at all times. The office is working to report system statistics and metrics, routinely and on demand.

7.2 Subtask 2 – Evaluation: Expert teams of scientists both internal and external to NOAA will be established to continually evaluate the effectiveness of the networks in meeting the performance measures and the adequacy of the deliverables in meeting the system objectives. The expert teams will evaluate analysis/synthesis products, recommend product improvements, recommend where additional sampling is needed or redundancies are not needed, recommend better utilization of existing and new *in situ* and satellite data, and assess the impacts of proposed changes to the system. Figure 3 shows the draft framework for expert teams for the ocean component of the system. Three teams are at least partially established…the Air-Sea Exchange of Heat And Water "goal" team under the direction of Dick Reynolds (NCDC); the Carbon Sources and Sinks "goal" team under the direction of Richard Feely, Rik Wanninkhof, and others; and the Seasonal Forecasting "mission" team under the direction of ODASI.

7.3 Subtask 3 – Action: System monitoring and evaluation will be useless unless there is responsive action taken to build the system, fix problems, and improve sampling strategies. Decisions must be made to implement the best solutions to conflicting requirements (multiple partners and customers have differing missions and will inevitably have differing requirements), to re-deploy existing resources to best improve the system, to select the highest priorities for system extensions and funding of new ideas, and to agree on quid pro quo with interagency and international partners. The OCO is charged with advancing NOAA's multi-year program plan and with evolving the system for maximum effectiveness and efficiency along the way.

7.4 Subtask 4 – Intra-agency, Interagency, and International Coordination: National and international coordination is essential to success in building the global ocean observing system for climate. The OCO is charged with building the infrastructure necessary to organize NOAA's ocean observing efforts along three axes – 1) climate services, 2) the U.S. Integrated Ocean Observing System, and 3) international implementation.

1) For climate services the ocean observations must be available to be combined with data from the atmospheric networks, land surface networks, and cryosphere networks. The requirements from the three user communities – the forecast centers, research programs, and scientific assessments – must be received and synthesized into common requirements or prioritized if they do not resolve readily.

2) For the U.S. Integrated Ocean Observing System, NOAA's climate system will make a significant contribution to the global component where like data from the various platforms, *in situ* and space-based, must be combined to form complete fields (e.g., sea surface temperature from ships, drifting and moored buoys, and satellites). NOAA's efforts must be combined with the efforts of the other NOPP agencies into a seamless system.

3) For international implementation NOAA must work with the implementation panels of the Joint IOC/WMO Commission for Oceanography and Marine Meteorology (JCOMM) to ensure that consistent standards and formats are used by all participating nations so that data

can be easily shared and that consistent quality can be expected from all platforms regardless of their national origin.

In addition to dedicated infrastructure needed for NOAA to operate an office for climate observation, dedicated infrastructure is also needed for operation of the interagency and intergovernmental planning and implementation coordination organizations. These interagency/international organizations rely on funding from the member agencies for their support. NOAA has historically provided a significant portion of the funding needed to maintain the existing international secretariats, science and implementation panels, and capacity building efforts of GOOS, GCOS, and the JCOMM. This funding support has been ad hock and in general from the research programs. As a central component of sustaining the long-term, operational global climate observing system, support for the national/international coordination/implementation infrastructure will be institutionalized via the OCO.

7.5 Subtask 5 – Annual Report on the Ocean's Role in Climate: The organizing framework to bring the multiple elements of the composite ocean observing system together is the routine delivery of an *Annual Report on the State of the Ocean and the Ocean Observing System for Climate.* The National Climate Change Science Program strategic plan has identified the critical need for regular reports documenting the present state of the climate system components. NOAA's Office of Climate Observation will lead the national effort to develop this reporting for the ocean component. The theme of the report is the CCSP overarching question for guiding climate observations and monitoring- "What is the current state of the climate, how does it compare with the past, and how can observations be improved to better initialize and validate models for prediction or long term projections?"

The annual report synthesizes satellite and *in situ* observations integrated with models and provides the products to decision makers, the science community, and the public. This reporting framework also establishes a formal mechanism for implementing a "user-driven" observing system and for reporting on the system's performance in meeting the requirements of the operational forecast centers, international research programs, and major scientific assessments. Stakeholders are invited to provide formal recommendations for system improvement and evolution as part of the annual report process.

The annual report contains four chapters:

1) This chapter describes The Role of the Ocean in Climate and includes a description of ENSO, SST, sea ice, and sea level, and the various demands on the system incorporating seasonal, interannual, decadal, and climate change time scales. This chapter sets the context for the report and outlines common themes, including the significance of the global ocean observing system and the demands on the system.

2) The second chapter documents the State of the Ocean. The target audience is decision makers and non-scientists. This chapter will be written by the experts in the field and will be an

annually updated climatology of the ocean, placed in historical context, with discussion of the present uncertainties and with pointers to products of greater detail and climate applications.

3) The third chapter documents the State of the Observing System. The target audience is NOAA management. This chapter has two sections:

a) System Progress in meeting milestones is documented by the network managers for their projects and by the OCO for the system in total. Annual statistics and status are given.
b) In the future, overall System Performance will be evaluated by the expert teams and by the users of ocean observations (the operational forecast centers, research programs, and scientific assessments). The stakeholders will be invited annually to give formal feedback to the observing system management and recommend improvements needed in the observations for delivery of climate services.

4) Chapter four recaps the State of the Science. The target audience is scientists. The final chapter of the report contains a bibliography of refereed publications from scientific journals treating the global observation of ocean heat, carbon, fresh water, and sea level change. Each year a selected number of reprints of particularly relevant scientific papers and/or abstracts will be published with the report.

7.6 Subtask 6 – External Review: The execution of this plan will be subject to normal management review in accordance with NOAA's Requirements-Based Management Process. Additionally, for specific programmatic advice and guidance, the Climate Observing System Council (COSC) has been established to review the program's contribution to the international Global Climate Observing System and to recommend effective ways for the program to respond to the long-term observational needs of the operational forecast centers, international research programs, and major scientific assessments. The Council is comprised of members both internal and external to NOAA who individually offer their expert advice; the Council is not expected to develop consensus opinions. The term of membership is two years with a renewal option for two additional terms. The Council meets at least annually to:

- Advise the OCO on priorities for sustaining and enhancing components of the global climate observing system.
- Review the accomplishments and future plans of specific program activities.
- Recommend realignment of activities, or entirely new activities, within the program as appropriate to satisfy the evolving requirements for climate observation.
- Bring to the OCO a broad view on national and international climate research and operational activities and their implications.
- Provide coordinating linkages with national and international programs requiring and/or contributing to the implementation of the global climate observing system.
- Advise the OCO on the balance of activities within the program in the context of NOAA's overarching climate service requirements, of other national and international requirements, and of other national and international contributions to the global climate observing system.

7.7 System management and product delivery milestones:

	NOAA Contributions								International Goal
	FY03	FY04	FY05	FY06	FY07	FY08	FY09	FY10	
System Monitoring	X	X	X	X	X	X	X	X	X
System Evaluation:									
Seasonal forecasting		X	X	X	X	X	X		X
Decadal forecasting		X	X	X	X	X	X	X	X
Climate change				X	X	X	X	X	X
Sea level change		X	X	X	X	X	X	X	X
Carbon sources and sinks									X
Air-sea exchange,heat/water		X	X	X	X	X	X	X	X
Heat storage/thermohaline circulation		X	X	X	X	X	X	X	X
SST	X	X	X	X	X	X	X	X	X
Sea Ice		X	X	X	X	X	X	X	X
Interagency/International panels	X	X	X	X	X	X	X	X	
International capacity building				X	X	X	X	X	X
Transition SST eval res to ops	X	X	X	X	X	X	X	X	X
Mgmt – wkshps & science mtgs		X	X	X	X	X	X	X	X
Mgmt – administration & finance		X	X	X	X	X	X	X	X
Mmgt ops funded from research	X	X	X	X	X	X	X	X	X
Annual Report		X	X	X	X	X	X	X	X
External review			X	X	X	X	X	X	

Table 2. Tabulated Observational Data Requirements for GOOS/GCOS (from GOOS, 1999).

A summary of the sampling requirements for the global ocean, based largely on OOSDP (1995), but with revisions as appropriate. These are a statement of the required measurement network characteristics, not the characteristics of the derived field. The field estimates must factor in geophysical noise and unsampled signal. Some projections (largely unverified) have been included for GODAE.

Sampling Requirements for the Global Ocean							
Code	**Application**	**Variable**	**Hor. Res.**	**Vert. Res.**	**Time Res.**	**#samples**	**Accuracy**
A	NWP, climate, mesoscale ocean	Remote SST	10 km	-	6 hours	1	0.1-0.3°C
B	Bias correction, trends	*In situ* SST	500 km	-	1 week	25	0.2-0.5°C
C	Climate variability	Sea surface salinity	200 km	-	10 day	1	0.1
D	Climate prediction and variability	Surface wind	2°	-	1-2 day	1-4	0.5-1 m/s in components
E	Mesoscale, coastal	Surface wind	50 km	-	1 day	1	1-2 m/s
F	Climate	Heat flux	2° x 5°	-	month	50	Net: 10 W/m^2
G	Climate	Precip.	2° x 5°	-	daily	Several	5 cm/month
H	Climate change trends	Sea level	30-50 gauges + GPS with altimetry, or several 100 gauges + GPS	-	monthly means		1 cm, giving 0.1 mm/yr accuracy trends over 1-2 decades
I	Climate variability	Sea level anomalies	100-200 km	-	10-30 days	~ 10	2 cm
J	Mesoscale variability	Sea level anomalies	25-50 km	-	2 days	1	2-4 cm
K	Climate, short-range prediction	sea ice extent, concentration	~ 30 km	-	1 day	1	10-30 km 2-5%
L	Climate, short-range prediction	sea ice velocity	~ 200 km	-	Daily	1	~ cm/s
M	Climate	sea ice volume, thickness	500 km	-	monthly	1	~ 30 cm
N	Climate	surface pCO_2	25-100 km	-	daily	1	0.2-0.3 µatm
O	ENSO prediction	T(z)	1.5° x 15°	15 m over 500 m	5 days	4	0.2°C
P	Climate variability	T(z)	1.5° x 5°	~ 5 vertical modes	1 month	1	0.2°C
Q	Mesoscale ocean	T(z)	50 km	~ 5 modes	10 days	1	0.2°C
R	Climate	S(z)	large-scale	~ 30 m	monthly	1	0.01
S	Climate, short-range prediction	U(surface)	600 km	-	month	1	2 cm/s
T	Climate model valid.	U(z)	a few places	30 m	monthly means	30	2 cm/s

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Table 1. From *The Action Plan for GOOS/GCOS and Sustained Observation for CLIVAR* by Needler et al. -- *OCEANOBS 99*

Appendix A

Foundation Documents

Observing the Oceans in the 21st Century, edited by Chester J. Koblinsky and Neville R. Smith, 2001, GODAE Project Office, Bureau of Meteorology, Melbourne, Australia, ISBN 0642 70618 2.

OCEANOBS 99, proceedings of the International Conference on the Ocean Observing System for Climate, GCOS/GOOS/WCRP Ocean Observations Panel for Climate and the CLIVAR Upper Ocean Panel, Saint-Raphael, France, October 1999.

International Sea Level Workshop Report, GCOS/GOOS/WCRP Ocean Observations Panel for Climate and the CLIVAR Upper Ocean Panel, April 1998, GCOS #43, GOOS #55, ICPO #16.

A Large Scale CO_2 Observing Plan: In Situ Oceans and Atmosphere (LSCOP), a contribution to the implementation of the U.S. Carbon Cycle Science Plan by the *In situ* Large-Scale CO_2 Observations Working Group, April 2002.

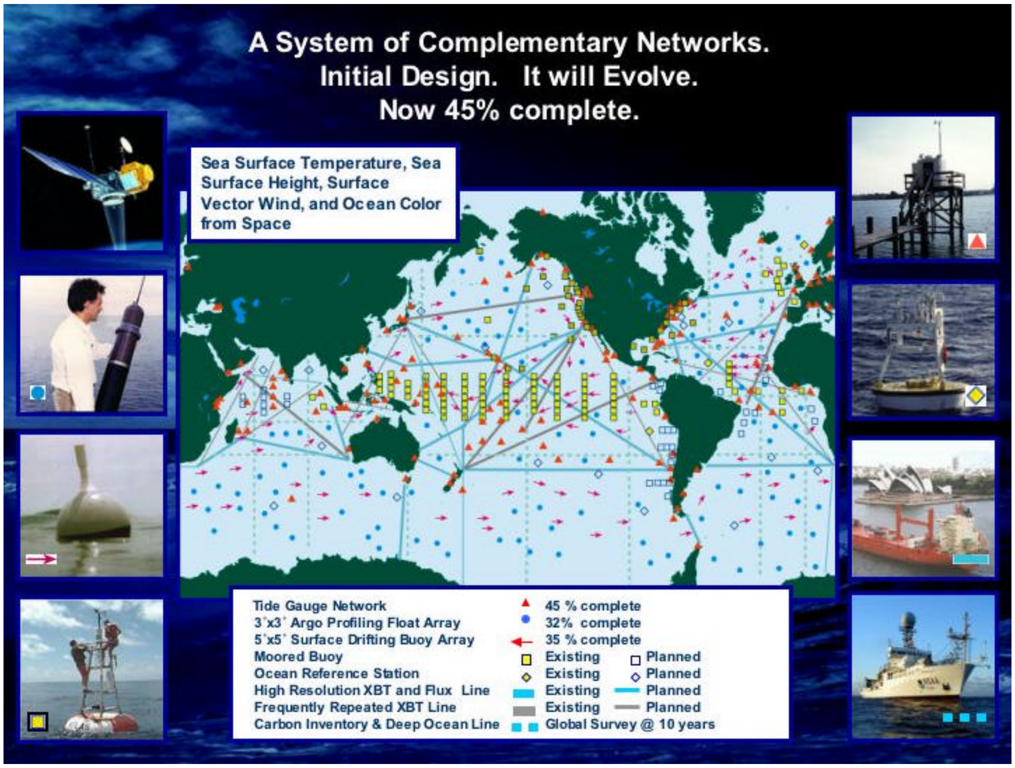

Figure 1

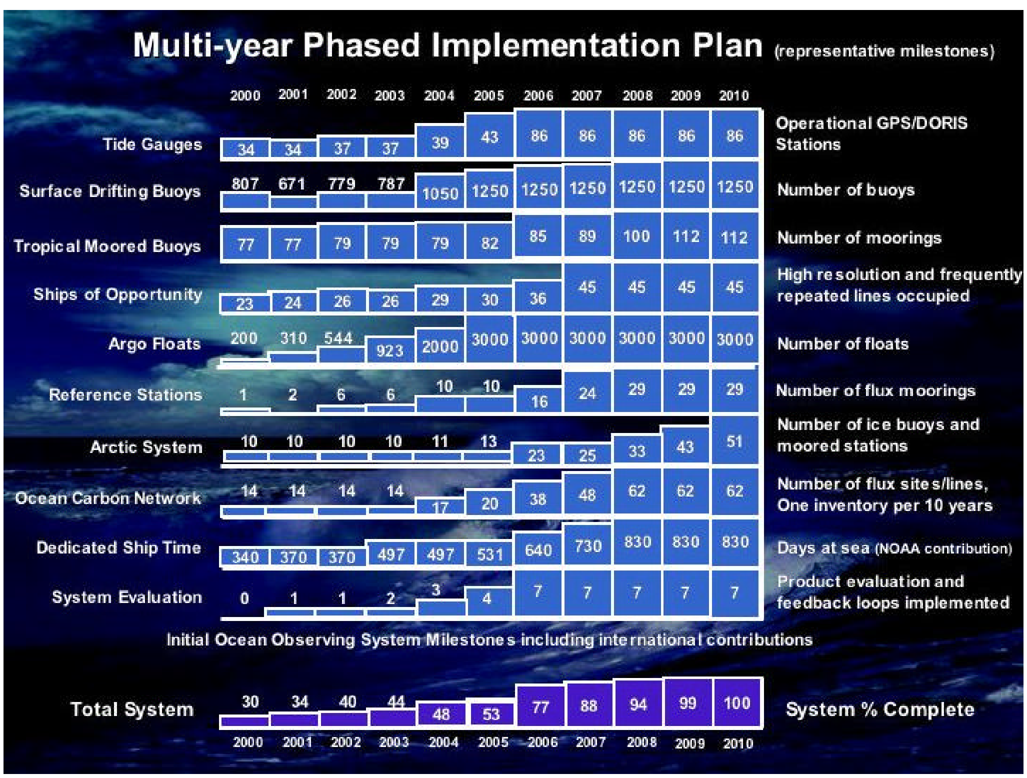

Figure 2

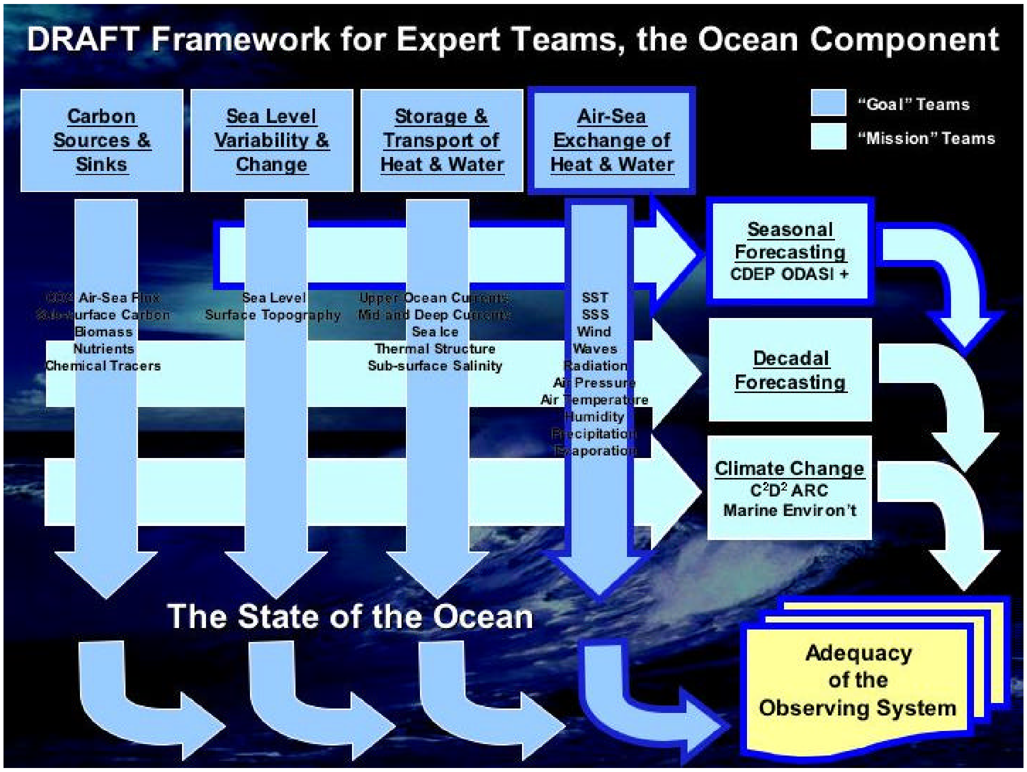

Figure 3

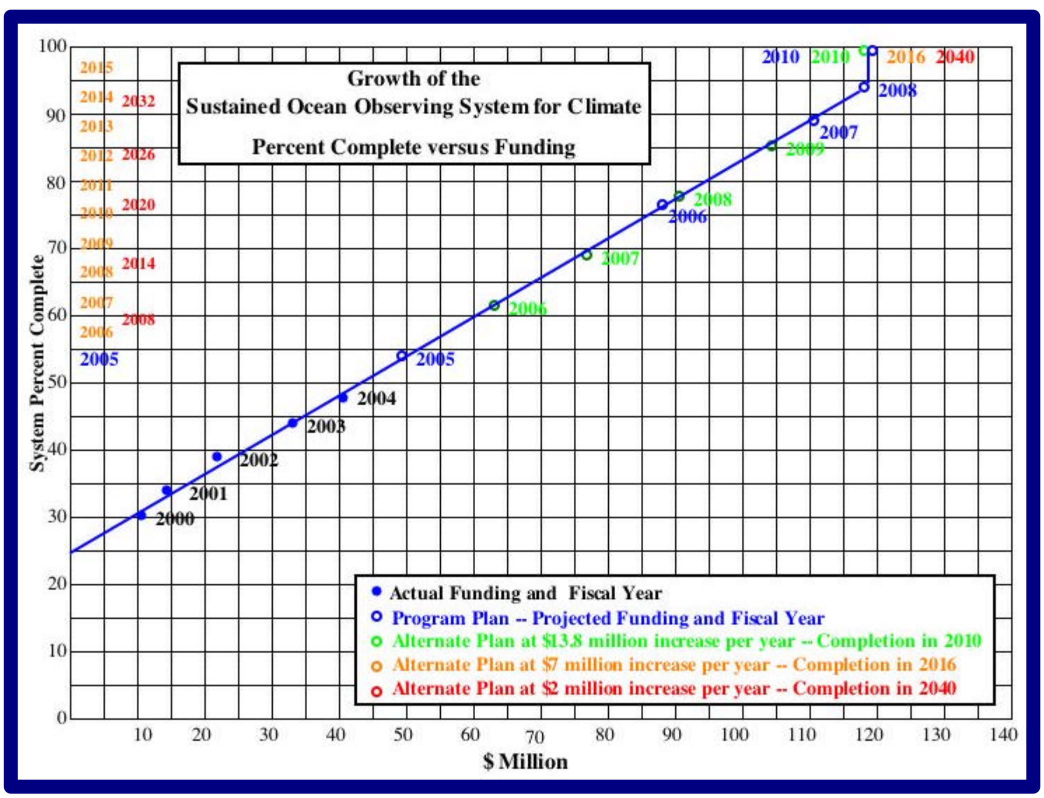

Figure 4