1. CIOSS Overview
10-11-06

The Cooperative Institute for Oceanographic Satellite Studies (CIOSS) was established in an agreement between the National Oceanic and Atmospheric Administration (NOAA) and Oregon State University (OSU) by a Memorandum of Agreement (MOA), signed on October 2, 2003 by OSU President Edward J. Ray and signed on December 23, 2003 by Under Secretary for Oceans and Atmosphere, U.S. Department of Commerce, VADM Conrad C. Lautenbacher. CIOSS was selected competitively from proposals submitted in response to a Request for Proposals posted in the Federal Register Notice (FRN, May 3, 2002, Volume 67, Number 86). Initial research collaborations are between OSU's College of Oceanic and Atmospheric Sciences (COAS, http://coas.oregonstate.edu/) and the Center for Satellite Applications and Research (STAR, http://www.orbit.nesdis.noaa.gov/star/), formerly the Office of Research and Applications (ORA), within NOAA's National Environmental Satellite, Data, and Information Service (NESDIS, http://www.nesdis.noaa.gov/). As stated in the MOA, the creation of CIOSS recognizes the "mutual, evolving and long-term interest in cooperative research projects and operational programs" involving oceanographic issues, shared by OSU/COAS and NOAA. Further information about CIOSS, including the text of the MOA, the Five-Year Plan, annual and other reports (from workshops, etc.) can be found in the appendices of this briefing book and on its web site at http://cioss.coas.oregonstate.edu/. Information about OSU can be found at http://oregonstate.edu.

The primary purpose of CIOSS is to establish a cooperative (federal-academic) center of excellence for research involving satellite remote sensing of the ocean and the air-sea interface. With the addition of CIOSS, the NESDIS/STAR Cooperative Research Program includes more complete programmatic coverage of remote sensing for both the ocean and the atmosphere, since the other Cooperative Institutes (CIs) within STAR (CIMSS, CIRA, CICS, and CREST) emphasize atmospheric remote sensing. CIOSS' research projects are defined to be of mutual interest to CIOSS/COAS and NOAA. Although research within COAS spans the range between pure (basic) research and applied research, the specification of topics that are of "mutual interest" to COAS/CIOSS and NOAA selects a subset of COAS research topics that are more applied in nature, since NOAA is a mission-oriented agency. The collocation of CIOSS within COAS is ideal, in that COAS research encompasses both the ocean and atmosphere, with traditional strengths in remote sensing, modeling and observational field programs.

The CIOSS mission is to enhance and improve the use of satellite remote sensing for oceanographic research, operational applications and education/outreach. The research needed to do this can be categorized into five areas, which form the five **CIOSS Themes**:

1. **Satellite Sensors and Techniques:** Research on satellite *sensors* and algorithms helps to ensure that the best "level 0" data are collected;
2. **Ocean-Atmosphere Fields and Fluxes:** Conversion of these basic data into higher level *products* is needed to obtain the information needed for research, applications and outreach;
3. **Ocean-Atmosphere Models and Data Assimilation:** Use of these products in *models* of ocean circulation and ecosystems allows a more complete view of the changing 3-D fields in the ocean;

4. **Ocean-Atmosphere Analyses:** *Analyses* of combinations of satellite data, model output and in situ data allows us to test hypotheses and increase our understanding of oceanographic and air-sea processes, which may then lead to improved sensors and models; and
5. **Outreach:** Use of remotely-sensed products in *formal and informal education* at all levels prepares some students for careers in remote sensing (at NOAA or elsewhere), increases the "environmental literacy" in the public and develops an appreciation for science in general, in a very tangible form. *Scientific outreach* also occurs under this heading, consisting of workshops and short courses.

These Themes serve to conceptually organize activities within CIOSS, although some activities address more than one theme and more than one NOAA Strategic Goal. In Figure 1.1, we present an organizational chart for CIOSS, which will be referred to throughout this document. The five Themes are found in the lower half of the chart, above CIOSS Working Groups for the COAST (Coastal Ocean Applications and Science Team) Project, Ocean Vector Winds (OVW), Product Development, and Dynamics/Modeling. These working groups are described later. Under Education and Outreach are our two Formal and Informal Education efforts: SMILE (Science and Math Investigative Learning Experiences and a pilot interactive display at the public wing of the Hatfield Marine Science Center (HMSC) in Newport, Oregon. The chart also shows the NOAA and other Federal partners, Academic Institutions and Public Outreach activities associated with each of the major CIOSS Working Groups and Themes (the uncolored boxes).

CIOSS Organizational Chart

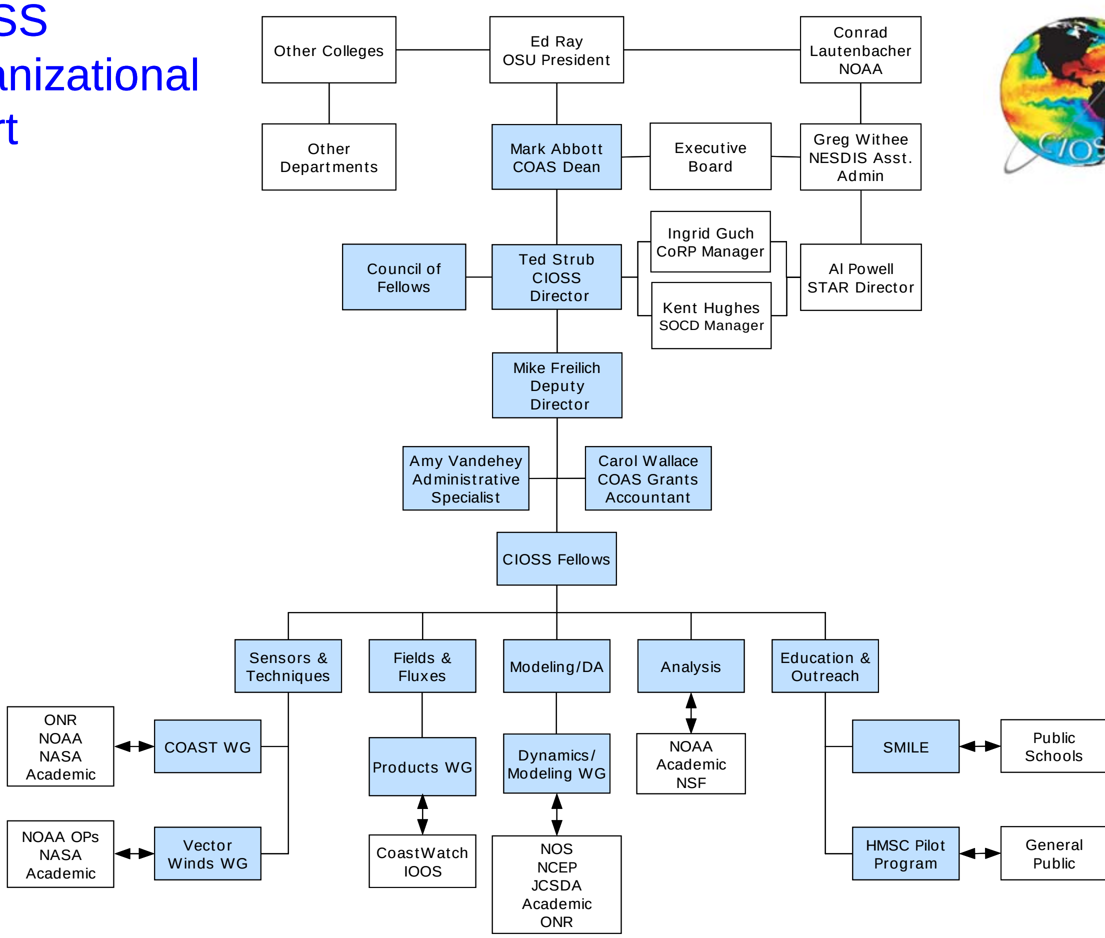

Figure 1.1: CIOSS Organizational Chart.

The major difference between oceanographic applications of satellite data and atmospheric research pursued in the other NESDIS CIs is that water is opaque to most electromagnetic radiation. Thus, with the exception of the visible wavelengths, satellite data directly measure only properties of the surface air-sea interface of the ocean. The visible radiation penetrates the ocean down to 50 m depths for clear water, still providing only a relatively shallow view of the deep (3000-5000m) ocean. Fortunately, most phytoplankton (the target of “ocean color” remote sensing) require sunlight for photosynthesis and live in that upper layer. The limitation of remote sensing to sampling only the ocean’s upper layer is in contrast to the atmospheric soundings made from satellites, where vertical profiles are available. However, this information about the upper ocean is invaluable due to the facts that the observable surface parameters are critical to the understanding of ocean dynamics (physical and biological), and that more traditional observation systems in the ocean (ships, moorings, surface drifters) are extremely limited in their spatial and temporal sampling, while satellites provide basin-scale, repeat coverage over periods of hours to a month. Thus, oceanographic remote sensing over the last several decades has given us a new and much more complete view of its forcing (surface wind stress, radiative fluxes and temperature), dynamic response (geostrophic and Ekman transports, temperatures associated with upwelling and fronts, etc.), phytoplankton distributions and production.

Observation of the ever-changing 3-D structure of the ocean, however, requires the combination of satellite remote sensing with in situ subsurface observations. Within the heavily used coastal ocean, new autonomous under-water gliders and other autonomous vehicles, profiling mooring systems and drifters are becoming available to combine with satellite data and provide an operational capability that has not been possible before now. On the larger scale, coupling of the satellite data sets with a global system of subsurface observations from autonomous profiling floats (the ARGO system) will allow basin-scale oceanography to also enter a truly operational phase. To integrate the satellite and in situ observations, numerical models of ocean circulation and biology are needed to complete the picture, on both the coastal and basin scales. The planned Integrated Ocean Observing System (IOOS) emphasizes all three elements (satellite remote sensing, in situ data collection, and modeling) and CIOSS/COAS has strengths in each of these. Thus, CIOSS has come into existence at a time of great opportunity and has the necessary strengths to help shape the role of satellite remote sensing and modeling in NOAA’s operational oceanographic activities.

Ocean remote sensing can “directly” observe five parameter groups, mostly characterized by the type of sensor: ocean color in the visible wavelengths, ocean vector winds (OVW), sea surface height (SSH), sea surface temperature (SST) and ocean surface roughness (SAR). Expertise within CIOSS/COAS is extensive for the four most useful (and directly interpretable) of these parameter groups (all except surface roughness). Remote sensing in the visible bands (“ocean color”) provides a suite of optical and biological parameters in the ocean’s surface layer, most of which are well established for the open ocean, but still under development for the optically complex coastal waters. CIOSS Fellows have a long history of designing ocean color sensor specifications and developing algorithms, products and applications using visible channels. They are heavily involved in “risk reduction” preparations for the Hyperspectral Environmental Suite for Coastal Waters (HES-CW) on future geostationary satellites (GOES-R) and are experienced in developing instruments and products for polar orbiting satellites (MODIS, SeaWiFS), applicable to the NPOESS VIIRS instrument. CIOSS Fellows have a similar history with design and analysis of OVW and SSH data from active radar instruments (scatterometers and altimeters). They also have recent experience with the passive microwave sensors planned for future OVW measurements. As with ocean color sensors, CIOSS Fellows are participating in individual research and working groups that are designing and evaluating future sensors, algorithms and products for OVW and SSH, representing research that falls under CIOSS Themes 1 and 2. Examples include the development of OVW fields with increased spatial resolution (needed especially in the coastal region) and the use of the high-resolution (10-20Hz) along-track SSH data next to the coast. For SST (infrared and microwave), CIOSS Fellows collaborate with those working at the sensor level, concentrating in CIOSS on improvements and uses of SST products produced by NESDIS (CIOSS Theme 2). An example is the improved spatial resolution of the global SST fields produced by R. Reynolds at the National Climate Data Center (NCDC). Within national programs (such as the U.S. Global Ocean Ecosystem Dynamics Program [GLOBEC]), CIOSS Fellows have also collected and archived SST fields, making the data available to those in the programs (Theme 5).

CIOSS Fellows are also active in the remote sensing of atmosphere, whose effect is oftentimes coupled with the signal from the ocean and needs to be removed for accurate retrievals ("atmospheric correction"). Research in atmospheric radiative transfer in CIOSS is focused on atmospheric aerosol and cloud characteristics, along with an effort to estimate fields of short-wave and long-wave radiative fluxes at the ocean surface (CIOSS Theme 2). The radiative fluxes are part of the surface heat budget of the ocean. The other surface heat fluxes (latent and sensible heat fluxes) are not directly observable from satellites, although attempts to estimate these from satellite data or combinations of satellite and atmospheric model fields are a topic of ongoing research. CIOSS Fellows have carried out some of this research.

Another element of oceanic remote sensing consists of mapping the distribution and type of sea ice and the actual geography of the coastline. While these are not the focus of present CIOSS research, support for such activities has come through CIOSS. Research projects in coastal geography and ice mapping/analysis are carried out by our colleagues in the Geosciences Department at OSU.

Considerations of operational oceanographic systems provide the other major contrast with atmospheric remote sensing at NESDIS Cooperative Institutes,. Whereas the atmospheric CIs have a long history of providing improvements to products for operational meteorological programs in the National Weather Service, operational oceanographic systems are only in the initial stages of planning and development. The planning for IOOS includes both basin-scale and regional coastal systems. The basin-scale *in situ* system consists primarily of autonomous, subsurface profiling (ARGO) floats, along with the tropical moorings in the TAO array. The floats provide profiles of density in the upper 1000-2000 m every 10 days, for analysis and assimilation into basin-scale models. The coastal systems within IOOS are defined by a number of "Regional Associations" (RAs), including three along the U.S. west coast. CIOSS Fellows specializing in *in situ* ocean observations have been leaders in developing the RA located off Oregon and Washington (known as NANOOS - Northwest Association of Networked Ocean Observing Systems) and a separate system (known as PaCOOS - Pacific Coastal Ocean Observing System) that is being developed along the entire west coast by the National Marine Fisheries Service (NMFS). CIOSS Fellows are actively engaged in planning for NANOOS and PaCOOS and are also active in national IOOS leadership. NESDIS is envisioned as the "national backbone" for IOOS remote sensing and CIOSS efforts are helping to define and develop that capability for both coastal and basin scales. At present, the NESDIS CoastWatch program provides a primary outlet for CIOSS improvements in satellite products, especially the CoastWatch node for the West Coast, located in Monterey California. As the IOOS coastal program develops, we expect the CoastWatch program to evolve as the data-delivery and product development component of NESDIS/IOOS. Thus, a natural partnership has developed between CIOSS and CoastWatch, based on their mutual interests in developing improved products from satellite data and making them available to the coastal oceanographic community (CIOSS Themes 2 and 5). Some of the products under development at CIOSS (such as improved wind fields) apply to the global ocean and thus to the basin-scale IOOS program.

An important element of the future coastal and basin-scale IOOS system is the use of oceanographic circulation models to assimilate both remotely sensed and in situ data, in order to produce complete fields of physical and biological variables. The IOOS plans provide for basin-scale models, run by NOAA's National Centers for Environmental Predictions (NCEP), and nested coastal models, run by the National Ocean Service (NOS). Nowcast and (eventually) forecast models will be important for a range of operational activities, especially in the coastal ocean. To help develop the modeling techniques needed in the future, several CIOSS projects focus on coastal and basin-scale modeling and data assimilation. Coastal projects include nested coastal models that assimilate altimeter and coastal radar (surface velocity) data, a pilot coastal ocean forecast system, analysis of Naval Research Laboratory (NRL) model output in the California Current and a regional coupled ocean-atmosphere model in a coastal domain. On the basin-scale, CIOSS Fellows are interacting with NCEP ocean modelers to improve data assimilation and error estimation techniques. CIOSS Fellows have also conducted research on air-sea (SST-wind stress) interactions. These demonstrate the need for atmospheric models to use higher-resolution SST fields as boundary conditions, in order to produce more realistic high-resolution structure in the surface winds. While NESDIS works on generating 1-km global SST retrievals from future satellites, research at CIOSS (under Theme 4) is presently being extended to look at SST effects on winds in and above the atmospheric boundary layer. Thus, both oceanic and atmospheric models (CIOSS Theme 3) are important components of CIOSS research.

CIOSS oceanographic modeling also includes ecosystem components of the coastal ocean, through interactions with the U.S. GLOBEC program. Basic NPZ (nutrient, phytoplankton, zooplankton) modeling, funded separately by GLOBEC, will be incorporated into the CIOSS nested, coastal, data assimilating models, which are also funded partially by GLOBEC. Lagrangian "Individual-based models" of zooplankton are also funded by GLOBEC, through CIOSS. GLOBEC funding comes from the NOS, which also presently houses the NOAA "Oceans and Human Health" (OHH) program. NOS/OHH funds another biological project using ocean color to investigate Harmful Algal Blooms (HABs) off Oregon. The HAB research is led by CIOSS Fellows in COAS and at the University of Oregon.

Outreach at CIOSS (CIOSS Theme 5) includes: Support for graduate students in COAS and the exchange of graduate students with other CIs; the OSU program called Science and Math Investigative Learning Experiences (SMILE); a project to produce an interactive display at the Hatfield Marine Science Center (HMSC) in Newport; and "scientific outreach" to our professional colleagues. CIOSS supports the SMILE program at the high-school level, which consists of weekly, after school club activities and a culminating "High School Challenge Event" each spring. It serves school districts in Oregon that have a high percentage of students in groups that are historically under-represented in high-school graduation and university attendance, particularly in fields involving science and mathematics. With CIOSS support, they have developed club activities and Challenge scenarios involving oceanographic and remote sensing themes. Within a new program in Informal Education at OSU, CIOSS is partially supporting the research of a PhD student, who is developing an interactive display that will highlight CIOSS and COAS oceanographic research in the coastal ocean, using remote and in situ data. The student is using the public wing of HMSC to test presentation techniques. The final display will also reside at HMSC. Outreach to our professional colleagues includes workshops and short courses on advanced topics in remote sensing and modeling. Topics of workshops include ocean color specifications for the future HES-CW, climate data records for ocean color, cal/val for ocean color, operational and research uses of ocean vector winds from scatterometers and passive microwave sensors, and data assimilation in coastal and basin-scale ocean models. Examples of training include presentations at the annual training workshop for coastal weather forecasters and a recent (August 2006) 3-day short course on the use of satellite remote sensing for fisheries applications.

As would be expected for a new CI that is "spinning up," the CIOSS approaches to many aspects of its activities and interactions with NOAA have evolved continuously over its first 3-4 years. The degree of ongoing change has been amplified by the fact that NOAA policy regarding CIs has also been modified considerably during the same period. The present policy states that new CIs will be awarded competitively for an initial 5-year period, followed by a formal review that will determine whether a second, and final, 5-year period will be awarded. The present review is the formal 5-year review of CIOSS. At the end of the second 5-year period, NOAA will determine whether it still needs this type of Cooperative Institute. If so, it will hold an open or partially-limited competition, which will either continue the CI in its present location or start a new CI elsewhere for the same type of activity.

CIOSS is one of the first CIs formed under this policy and there are a number of consequences of the policy that set CIOSS apart from the other NESDIS CIs. One difference is fact that there are no NESDIS (or other NOAA) personnel collocated with CIOSS in COAS at OSU. The degree of uncertainty as to its longevity, created by the present policy, has made NOAA hesitant to consider establishing a "permanent" presence at CIOSS. CIOSS has been able to find other ways to interact with NOAA during its first 3 years and will present ideas for mechanisms to increase that interaction during the review, in lieu of "permanent" local NOAA personnel. We ask the Review Panel to comment on this issue in its recommendations. Other issues that we will raise include support for a full time Deputy Director, support for a dedicated data analyst to help transition research to products for CoastWatch and other NOAA offices, and the establishment of a more formal team for coastal modeling and data assimilation. This modeling and data assimilation activity would be similar, in some aspects, to the COAST activity for GOES-R Risk Reduction. In essence, "risk reduction" is needed for the future modeling systems, as well as future satellite systems. There is some level of synergy between these issues (the lack of local NOAA personnel, the need for more administrative support and the need for a modeling sub-group), which we will discuss during the review. Another new initiative that CIOSS is exploring is the creation of an REU (Research Experiences for Undergraduates) program in CIOSS, designed to attract undergraduates into research that may lead to graduate studies in CIOSS research themes.

In addition to the CIOSS' Research Themes and interactions with NOAA program managers, several developments, external to CIOSS, will continue to shape its evolution during years 5-10. One is the ongoing "re-scoping" and redefinition of the future satellites and sensors in the NPOESS era and beyond. CIOSS personnel are engaged in discussions with NOAA of both the NOAA-NASA response to the re-scoping plans and the future of satellite Climate Data Records (CDRs), which involve evaluation of the abilities of future sensors to provide data records that are consistent with the historical satellite data records. In the near future, we also expect the report from the NRC Decadal Survey to be released, with a further need for responses from the remote sensing community as to how to implement the recommendations in that report. CIOSS has been, and will continue to be, involved in these discussions and plans. At the same time, funding for the planned IOOS system is expected to increase, placing pressure on NOAA to determine how it will form the “national backbone” for remote sensing and modeling in that system. CIOSS research projects have been chosen to provide us with the ability to contribute to the remote sensing and modeling aspects of IOOS (linked through data assimilation methods). We expect these to become even more active over the next five years (and beyond). These factors will emphasize work on CIOSS Themes 1-3: sensors, products and modeling. As suggested above, one mechanism for increasing the modeling activities is to seek funding to support a more formal CIOSS Modeling and Data Assimilation Team. We hope the Review Panel will provide suggestions as to these (or other) future directions for CIOSS.

The annual growth of CIOSS activities is presented graphically below in two ways: Figure 1.2 shows the total funding for each year. Note that the start date for CIOSS is April 1, so 2003 is April 1, 2003 – March 31, 2004. The funding denoted is that received in that funding year, not necessarily that expended during that year. For example, Post-Doc projects were funded in years 1-2, although some Post-Docs did not arrive and begin work until year 3. Figure 1.3 depicts the approximate number of projects and activities funded or begun in each year. For 2006, eleven of the activities are included in the overall COAST project.

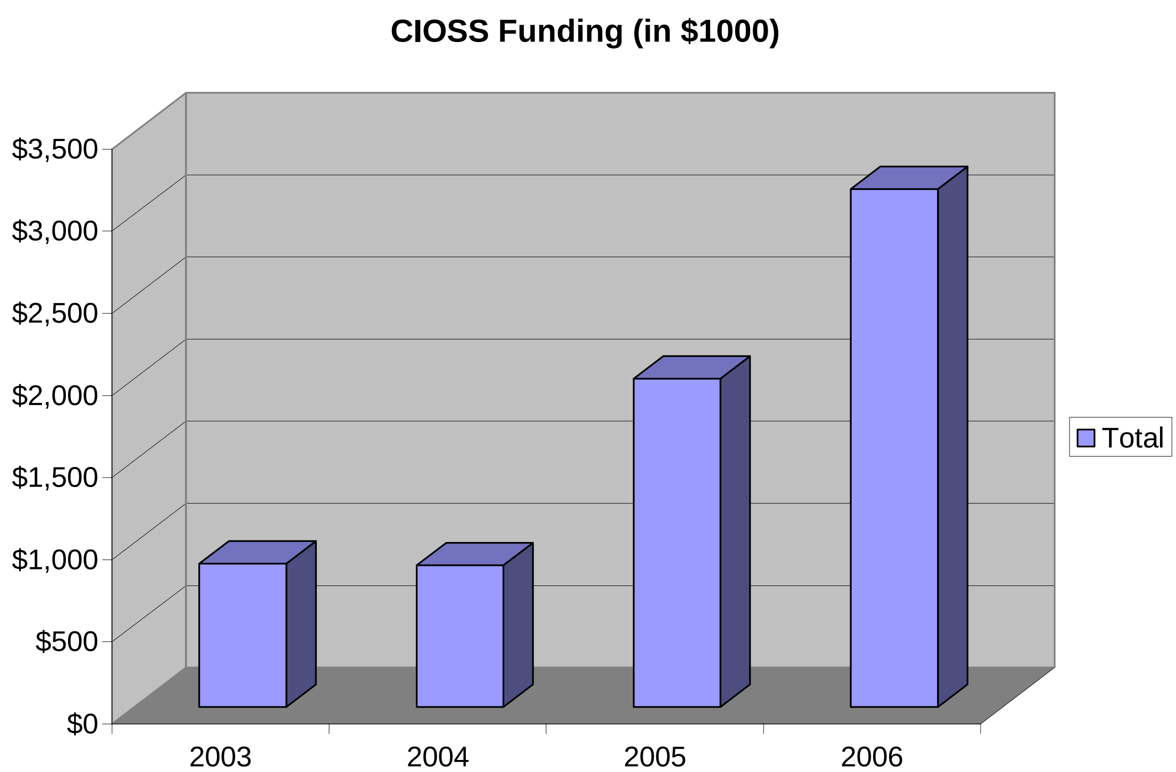

Figure 1.2: CIOSS Funding for the past 4 years.

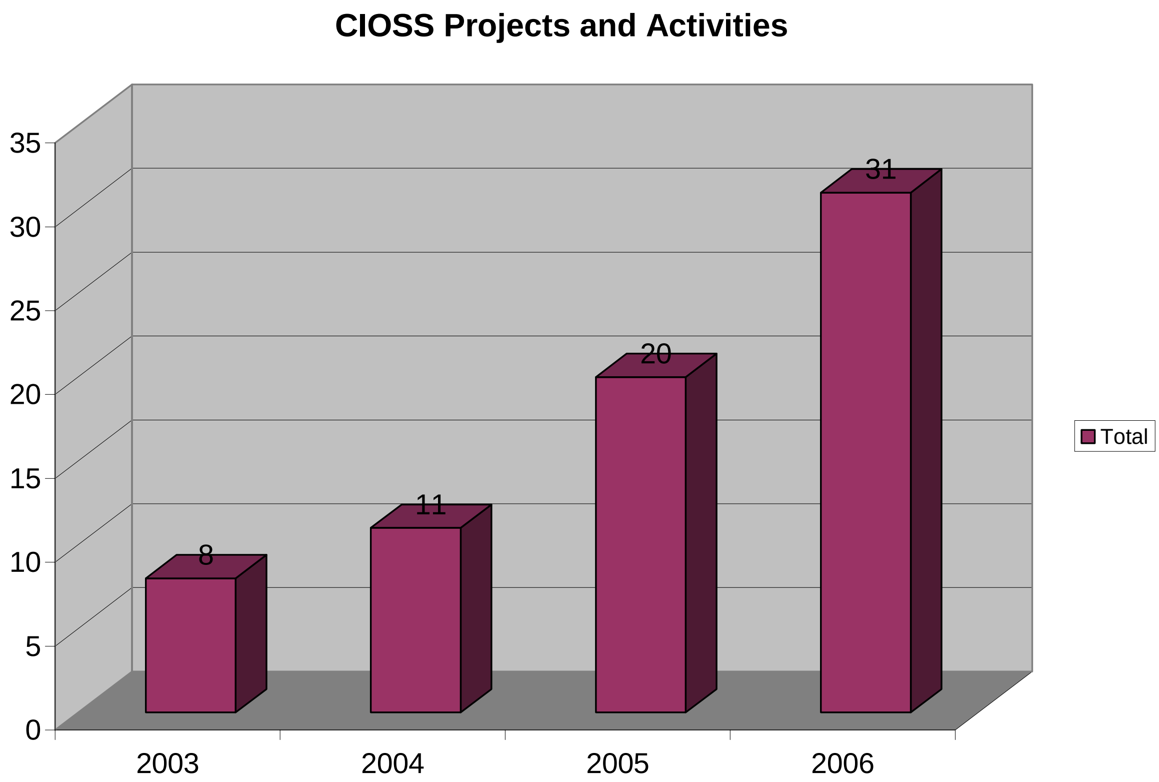

Figure 1.3: CIOSS Projects and Activities for the past 4 years.