Committee on Resources

Witness Testimony

Testimony of
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Wildlife, and Oceans
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Mr. Chairman and members of the Committee, I would like to thank you for this opportunity to testify on the Administration s Fiscal Year 1997 budget recommendations for the oceanography programs of the National Science Foundation.

Let me begin by emphasizing that oceanography, by nature, is a field science. All of the programs and projects that I am about to describe hinge upon the use of the world-class fleet of ocean research vessels operated by the University-National Ocean Laboratory System (UNOLS). Consistent with recent years, approximately one-fourth of the total FY 1997 budget request will go toward ship support of NSF-funded research projects.

The activities of our Ocean Sciences Division are sufficiently diverse, that to cover them all in the short time available would require that we present nothing but a tedious list of program names and activities. An overview of all the programs, special initiatives, and facilities that we support is provided in Appendix One of the written testimony that we have submitted. Appendix Two contains our 1997 budget information. Here we would rather use the available time to highlight several areas in which we anticipate growth under the FY 1997 budget request. These examples are too few in number to represent satisfactorily all aspects of ocean sciences research, but we hope they are sufficient to convey to you the richness and diversity of a field that we believe is especially important to the health and wealth of our nation.

The History of Global Climate Change

As we strive to understand and predict the changes in climate of our planet it is essential to look back in history -- tens, hundreds, and thousands of years -- and determine the nature of the climate changes that have occurred in the past. It is important to have answers to questions like: How often does earth experience significant changes in its climate patterns? How rapidly do these changes occur? What are the causes of these changes, and what are their consequences? The world s oceans hold unique answers to some of these questions because on the ocean floor, in the skeletal remains of past marine life that constitute the seafloor sediments, lies a high-resolution record of many important characteristics of past climate.

To study the record contained in these sediments, the Ocean Sciences Division at the National Science Foundation (NSF) supports a unique facility, the 471-foot drill ship JOIDES Resolution, operated by the international Ocean Drilling Program (ODP), and funded by NSF in cooperation with six international partners representing 17 nations.

The ODP provides a unique capability to study ancient ocean and climate history. The Advanced Piston Corer (APC) on JOIDES Resolution allows collection of undisturbed sediments 200 meters or more beneath the seafloor. When used in regions of rapid sediment deposition, such records allow the exceptionally precise documentation of climatic and oceanographic properties over tens of thousands of years.

Just a few months ago, exciting new results were published from a drill site in the Santa Barbara Basin that produced a sedimentary record that covered a time period from the present back to 160,000 years ago. This is 150,000 years longer than any previous record from the basin recovered by conventional piston coring. Analyses of this sedimentary record showed that changes in past oxygen levels in the bottom water of the basin, (as recorded by the sediments) matched in

extraordinary detail short-lived climatic excursions in the Greenland ice sheet (as determined by drilling the ice) more than one-fourth of the way around the world. Understanding the detailed linkages between climatic and oceanographic events widely distributed around the earth is a key objective of NSF-supported investigations of the earth-ocean-atmosphere system. Such "tele-connections" provide important clues to help understand the complex relationships between the oceans and rapid climate change.

In the last two years, work in the deep sea has shown that, within the span of a human lifetime (as little as 50 years), changes in air temperatures at the poles can be linked to massive melting of glaciers. The glacial melting produces armadas of icebergs that in turn produce changes in ocean circulation and biotic productivity patterns. These changes propagate quickly throughout the world ocean affecting, for instance, coastal climates and environments and offshore fisheries. Documentation of such rapid changes has so far been made for periods of colder climate than exists today. Paleoceanographers (oceanographers who study the characteristics of the worlds oceans in the past) are now searching for evidence of equally rapid changes during the last few thousand years of human history which have been characterized by more temperate climates. The discovery of these rapid changes on a global scale has important implications for climatic research, including research that analyzes the possible impacts of climate change on people.

In addition to investigation of the detailed links between temperate latitude climate and changes in the polar regions, the sedimentary record recently collected from the Santa Barbara Basin provides a unique opportunity to investigate another of the classic "teleconnections" of the climate system, the variations in the El Nino-Southern Oscillation (ENSO). Operating on a much more rapid time scale than glacial climatic change, the ENSO system links oceanographic changes in the western equatorial Pacific directly to pronounced climate and weather patterns in North and South America as well as climatic properties as widespread as Indian Ocean monsoon conditions and African droughts.

The sediments in the Santa Barbara Basin accumulated extremely rapidly -- one inch every 20 years. When cores are studied, annual depositional markers are clearly visible as dark and light bands in the sediments. When combined with precise dates from radioisotopic analysis, these markers make it possible to unravel many hundreds of years of the complex history of this subdecadal climatic signal.

Without the 471-foot drill ship JOIDES Resolution, these studies would not have been possible. It is a unique facility -- no other vessel in the world is capable of drilling to such great depths almost anywhere in the world s oceans. Scientists that use this drilling vessel study a wide range of problems in the marine geosciences -- not just climate change issues as has just been described. Results from other investigations have recently produced new understanding that is important to the unraveling of the mechanics of faults that generate earthquakes.

Faults, Fluids, and Earthquakes

The paradigms of sea-floor spreading and plate tectonics have taught us that as the continents move around on the earth s surface, old ocean floor gets forced back down inside the earth. It is this process of transport of old ocean floor into the earth s interior that is the root cause of earthquake activity in Alaska, the northwestern U.S., Japan, and South America. The ocean floor carries in its uppermost layers large volumes of water. We are learning that this water plays an important role in lubricating the faults, movement along which are the sources of earthquakes.

Fluids return to the ocean from marine sediments at active continental margins, like those off the northwestern U.S. and Alaska, by tectonic compaction and chemical alteration of subducted and mechanically offscraped material. Although it has long been recognized that high fluid pressures facilitate faulting, it is only recently that scientists have been able to document the actual fluid pathways. Studies by the international Ocean Drilling Program along a number of active margins distributed around the globe indicate that fluids move principally through conduits associated with faults. Anomalies in pore water chemistry of drill cores have demonstrated that fluids can migrate laterally and vertically over tens of kilometers from their source. Fluid flow rates measured at numerous local fluid venting sites, are 2 to 6 orders of magnitude larger than the best estimates available a few years ago.

One particularly good example of an ODP investigation of fluid flow at an active continental margin comes from Barbados, where concentrated study has taken place over the past 5 years. The effort has included subsurface imaging of unparalleled resolution (using 3-dimensional seismic reflection techniques) prior to drilling which provides a view

of lateral variation on the buried, subducting fault surface. Ocean Drilling Program sites at selected locations within this detailed grid have confirmed that fluid pressure on this fault surface varies laterally, and studies of the sediments and their fluid and chemical properties are underway to examine these relationships. A particularly important dimension of the fluid flow equation is time variation of flow -- large changes in flow rates signal changing physical conditions prior to earthquakes. Learning how to make such measurements has proven to be a substantial technical challenge, but now a reliable system is available that can be installed as a seal on an ocean floor borehole. This technology allows continuous measurements to be made of the flow properties and chemical variations in the sediments of the fault zone. Installed and sealed by the ODP vessel JOIDES Resolution, two sites in Barbados were revisited for experiments last January in a collaborative experiment by French and American researchers using the French submersible Nautile.

Understanding the processes governing fluid flow and fluid chemistry in the seismically active margins of the oceans provides the necessary framework for deriving relationships between faulting and physical properties, which is key to understanding the causes and properties of earthquakes, submarine landslides, and the biological and mineralization processes which occur in this common continental margin environment.

From earthquakes, let us move to a very different field of research in the fields of Biological and Physical Oceanography.

Understanding Fluctuations in Commercial Fish Stocks

Coastal economies are extremely vulnerable to large fluctuations in commercial fish stocks. The unpredictable "boom and bust" cycles that occur, both domestically and globally, can devastate local fishing industries. In attempting to avoid an economic "bust", management efforts are generally directed toward controlling various aspects of the harvesting process. However, the causes of a collapse may in part be attributed to ocean processes unrelated to excess fishing.

Intense fishing pressure is an industrial age phenomenon, but major fluctuations of important fish stocks such as Cod have been recorded as long as historical records have been kept (sometimes going back hundreds of years), and from analyses of fish scales in sediments, up to 2,000 years in the case of the Pacific Sardine. So it is clear that fish population size is strongly affected by natural environmental variability on scales from seasons to decades and beyond. It is likely that a fish stock already under severe pressure is much more vulnerable to even small departures from the environmental norm.

Global Ocean Ecosystems (GLOBEC), a joint NSF/NOAA program, is now conducting extensive field programs to study the complex natural drivers of fish population growth and mortality by evaluating the entire ecosystem; this includes the reproductive strategies of the fish themselves, their food supply and predators, and the changing patterns of ocean circulation and climate.

The first focus of the U.S. GLOBEC program is in the George s Bank region of the U.S. northeastern coast. Extensive field programs designed to obtain the data required to understand the physical and biological factors which control the production and growth of young fish before they are captured. Rather than ignore the fishermen, who have a vast practical knowledge of the fishery which is hard to incorporate into formal scientific approaches, GLOBEC scientists are actively involving them in collaborative workshops and planning to encourage them in becoming part of the scientific observation network. Eventually, this approach may help to reduce the distrust of science by the industry and help move the community to a time when optimistically, both scientists and fishermen can agree on recommendations for optimal management of the resources.

Already the results of the 1995 field season on George s Bank are yielding important new insights into the factors that control the survival of larvae and hence the production rates of juvenile fish. It is important to understand that most fish produce thousands or even millions of offspring per adult in each breeding cycle. The vast majority of these offspring perish due to predation, harsh environmental conditions, and starvation. If one percent of a million eggs spawned by a single female survive to adulthood, the adult population would increase five-thousand fold! It is therefore of critical importance to identify the predators that feed on the fish larvae and understand the physical

controls that determine their distribution and population. As a direct result of the GLOBEC program an important new predator has been identified on George s Bank, the hydroid, that apparently can survive in the water column, although the process by which these bottom-dwelling organisms rise from the seafloor into the water column is as yet unknown. Direct observations of the consumption of fish larvae by hydroids have been made, thus providing one more piece to the complex puzzle of understanding the controls on fish populations in this region.

The program is now expanding rapidly to include components based in countries across the North Atlantic, including Iceland, Scandinavia and the United Kingdom This is extremely important because fish populations like cod and haddock range across the entire North Atlantic and adjacent seas. Populations within the U.S. George s Bank region may well be influenced by Atlantic basin-wide phenomena, such as changes in physical circulation patterns, possibly leading to local changes in temperature, salinity or food supply for the survival and growth of newly hatched fish. The Cod is already at the southern limit of its range on George s Bank imposed by its desire for colder waters, and even slight increases in temperature brought about by climatic change could eliminate this once important resource from this region.

U.S. science cannot possibly support all the research, ship operations, data analysis and modeling required on the scale of the North Atlantic, but equally importantly, unless the effort is mounted on this ocean basin scale, it will be impossible to understand causes of fish population changes locally for any of the interested countries. Effective international cooperation, effective sharing of resources are the keys to achieving GLOBEC s ambitious goals within the practical constraints of available funds.

In 1997, the GLOBEC program plans to expand with similar studies in the north Pacific Ocean.

Ocean Floor Observatories

As you can see, many of the research topics in the ocean sciences are concerned with the study of change -- changes in climate, changes in fish stocks, changes in fluid flow in the crust -- but all these changes that I have described to you so far are, at least on human time scales, relatively slow -- they take years to tens of years to occur. But such is not the case for all natural processes occurring within the oceans. As has been reported recently in the popular press, three weeks ago there was a major seismic disturbance beneath the ocean floor 95 miles off the coast of Oregon. Rapid investigation of this disturbance by our colleagues at NOAA has confirmed that the seismic activity is related to catastrophic venting of hot water into the deep ocean from beneath the ocean floor. The source of the heat is volcanic activity. Next week, the Oregon State University research vessel, WECOMA, is setting sail with a group of NSF-supported investigators on board to carry out further studies of this exciting event. We are proud of the fact that in just two weeks we have been able to assemble a scientific team, arrange for the availability of a research vessel and provide the necessary funds to get a group of investigators on site to continue physical, chemical, and biological studies of this region to understand the causes and consequences of this event.

In fact, we do not believe that such catastrosphic events are rare -- we believe they could be quite common. It is simply that we do not know about them because we have no way of making observations on the deep ocean floor for very long periods of time (i.e. for many years). This reflects an omission in our capabilities that we are working hard to correct. Scientists at the University of Hawaii are working on designing and installing the Hawaii Undersea Geo-Observatory (HUGO). HUGO integrates marine fiber optic cable and submersible technologies to provide a permanent unmanned laboratory on the ocean floor at the summit of Loihi seamount. Loihi, an active submarine volcano, is located approximately 35 km southeast of the Island of Hawaii. Its shallow summit (about 1000 meters below sea level), exciting geology, earthquakes, frequent volcanic activity, and proximity to land make it an ideal site to install a permanent geo-laboratory, and begin real-time monitoring of processes occurring at the ocean floor. The proposed modular observatory has the potential to house more than 100 experiments from every oceanographic discipline, supplying experiments with electrical power, command capability, and continuous data transmission to shore. With the planned system and future expansions, scientists will be able to study submarine volcanic, biological, and oceanographic processes continuously for at least ten years. Experimenters will be able to interrogate their sensors via telephone from their home offices. HUGO data will be used by the U.S. Geological Survey Hawaiian Volcano Observatory in their studies of Hawaiian volcanoes, and by the Pacific Tsunami Warning Center in characterization of tsunamis from distant earthquakes. In addition, HUGO earthquake and acoustic data will be made available to local

schools for teaching and projects, and subsets will be presented on the INTERNET.

A similar shallow water seafloor observatory (LEO-15) is being installed off the New Jersey coast by Rutgers University. It will provide scientists with continuous long-term measurements of ocean features in the highly dynamic coastal zone. Having access to a variety of measurements from active locations on the seafloor will help scientists study and better understand the natural processes at work in the oceans leading to an improved ability to predict events that may impact human activity and economies ashore.

The seafloor fiber-optic cable at both the Hawaii and New Jersey sites was donated by industry (AT&T). The engineering design, implementation and installation of these developmental observatories has been cosponsored by NSF, NOAA, and the respective states. Once experience has been gained from these two prototype installations, expanded use of seafloor observatories is anticipated. These early development efforts constitute excellent examples of the success of partnerships with industry, the states and with colleagues at other federal agencies.

Conclusion

The improved understanding of such phenomena as long-term climate change, the nature of earthquake activity, and fluctuations in commercial fish stock resulting from the types of projects that I have just described, potentially has enormous economic and societal implications. While opportunities for exciting research such as this abound, it is clear that as all Federal agencies face budgetary pressures in FY 1997 and beyond, we will need to find ways to produce the best science possible while maximizing the return on investment of the federal research dollar. With this in mind, NSF will continue to pursue successful partnerships with the academic research community, the private sector, other federal agencies, and players in the international arena.

Thank you, Mr. Chairman. I will be happy to answer any questions you may have.

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APPENDIX 1 Programs, Initiatives and Facilities Supported byNSF s Division of Ocean Sciences The Core Programs Marine Geology and Geophysics supports research on all aspects of geology and geophysics of the ocean basins and margins, as well as the Great Lakes. Chemical Oceanography supports research on the composition and chemical properties of seawater and the chemical processes related to the biology and geology of the marine environment. Biological Oceanography supports studies of relationships among marine organisms as well as interactions of these organisms with their geochemical and physical environment. Physical Oceanography supports research to better understand physical oceanographic phenomena and their interactions on scales from global to molecular. Ocean Technology and Interdisciplinary Coordination supports a wide range of multidisciplinary activities that broadly seek to develop, transfer, or apply instrumentation and technologies that will benefit research programs supported by NSF and enhance the conduct of basic ocean sciences research. The Special Initiatives Ocean Drilling Program (ODP) collects and analyzes deep-sea cores from around the world to help reconstruct the paleoceanographic record of past climatic and oceanic conditions. Ridge Interdisciplinary Global Experiments (RIDGE) integrates observational, experimental and theoretical studies to determine the primary processes that have shaped the evolution of our planet, and the long-term temporal variations that may have modified the past climate of the earth. World Ocean Circulation Experiment (WOCE) conducts research on the surface and subsurface circulation of the global ocean. U.S. Joint Global Ocean Flux Study (JGOFS) investigates the role of marine organisms and chemistry in modulating global climate change. Global Ocean Ecosystems Dynamics (GLOBEC) elucidates how changing climate alters the physical environment of the ocean and how this, in turn, affects marine animals, especially zooplankton and fish. Coastal Ocean Processes (CoOP) studies the complex relationships between transport processes, geochemistry and ecology in regions of the U.S. west coast and Great Lakes. Earth System History (ESH) studies the paleoceanographic record to address numerous research themes including ocean geochemical and climate change and climate sensitivity and variability. Land-Margin Ecosystems Research (LMER) coordinates interdisciplinary research on estuaries, coastal wetlands and reefs, the tidal portions of rivers, and other areas. Environmental Geochemistry and Biogeochemistry (EGB) enhances fundamental, interdisciplinary research on chemical processes that determine the behavior and distribution of inorganic and organic materials in environments near the Earth s surface. Arctic System Science (ARCSS) supports paleoenvironmental multidisciplinary studies to address the physical, chemical, biological, and social process of the Arctic system. The Academic Research Fleet The U.S. academic fleet is operated by state and private institutions under

the auspices of the University-National Oceanographic Laboratory System (UNOLS). UNOLS was formed in 1971 as an association of ocean science research institutions that operate and use the national academic research fleet. UNOLS is a partnership of 54 academic institutions and five federal agencies (NSF, ONR, NOAA, USGS, USCG). Within UNOLS there are 19 ship operating institutions. The fleet consists of 27 vessels ranging in size from 69 to 279 feet. Funding is provided, on a daily use basis, by the various federal agencies, including NSF, ONR, NRL, NOAA, DOE, USGS and MMS. The National Science Foundation is currently the major user of the fleet providing 70% of the operational funds. The fleet is geographically positioned along the U.S. coast. One ship is located in Hawaii, one in Alaska and one in the Great Lakes. Three ships are located in the Gulf of Mexico area, 13 along the East coast and 8 are stationed on the West coast. APPENDIX 2 FY 1997 Budget Submission for NSF s Division of Ocean Sciences [Excerpted from the FY 1997 Budget Submission] The FY 1997 Budget Request for the Ocean Sciences Subactivity (OCE) is $204.87 million, an increase of $14.30 million, or 7.5 percent, over the FY 1996 Estimate of $190.57 million. (Millions of Dollars) The Ocean Sciences Subactivity supports research to improve understanding of both coastal seas and deep ocean basins, including the sea floor, and the facilities required to gain access to these environments. The FY 1997 Budget Request includes: " $110.18 million for Ocean Sciences Research Support, which includes programs in physical oceanography, chemical oceanography, marine geology and geophysics, biological oceanography, oceanographic technology, and interdisciplinary studies. Research studies focus on factors controlling physical, chemical, geological and biological processes in the oceans and at its boundaries, including coral reefs and other important living resources. Projects range from individual investigator work to multi-investigator contributions and international programs that use substantial amounts of ship and facility time. An increase of $7.16 million in FY 1997 will provide support for the interdisciplinary Coastal Ocean Processes Program, which seeks to understand the complex relationships between transport processes, geochemistry and ecology in regions of the U.S. west coast and Great Lakes; the Global Ocean Ecosystems Dynamics program to understand the role of ocean climate and chemistry on ecosystem variability and living resources; the Earth System History program to understand the implications of past and future changes in the global environment; and for increased core support to investigator-initiated basic research. " $53.65 million for Oceanographic Centers and Facilities, which includes ship operations, instrumentation and technical services, and oceanographic facilities and coordination activities that serve as platforms for research projects funded by the Ocean Sciences Subactivity and other NSF research programs. The programs provide support for research ships and specialized shared-use facilities and equipment operated by U.S. academic oceanographic institutions including marine technicians support, instrumentation and equipment acquisition, and construction or refitting of research ships as required. Programs also support submersible and remotely operated vehicles and the national accelerator mass spectrometry center for radiocarbon analyses. Over $4 million of the $5.95 million increase will be allocated for an NSF-wide instrumentation program. The remainder will support continued ship and submersible operations, maintenance, and technical support, as well as instrumentation improvements and coordination functions. " $41.04 million for the Ocean Drilling Program, a multinational program of basic scientific research in the oceans which uses drilling and data from drill holes to improve fundamental understanding of the role of physical, chemical and biological processes in the geological history, structure and evolution of the oceanic portion of the earth's crust. Operational support for this activity is shared by six international partners, comprising 18 other countries. An increase of $1.19 million in FY 1997 will maintain the current level of effort for the program as operating costs increase. Research will focus on the eastern Caribbean Sea and the north and south Atlantic Oceans. Specific topics include investigation of structural and fluid properties at a subducting margin where tectonic plates are converging; high resolution analysis of historical changes in coastal ocean circulation; detailed study of sea level change on the continental shelf and slope; and examination of the transition between continental and ocean crust. The FY 1997 Budget Request for the Ocean Sciences Subactivity (OCE) is $204.87 million, an increase of $14.30 million, or 7.5 percent, over the FY 1996 Estimate of $190.57 million. (Millions of Dollars) The Ocean Sciences Subactivity supports research to improve understanding of both coastal seas and deep ocean basins, including the sea floor, and the facilities required to gain access to these environments. 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role of ocean climate and chemistry on ecosystem variability and living resources; the Earth System History program to understand the implications of past and future changes in the global environment; and for increased core support to investigator-initiated basic research. $53.65 million for Oceanographic Centers and Facilities, which includes ship operations, instrumentation and technical services, and oceanographic facilities and coordination activities that serve as platforms for research projects funded by the Ocean Sciences Subactivity and other NSF research programs. The programs provide support for research ships and specialized shared-use facilities and equipment operated by U.S. academic oceanographic institutions including marine technicians support, instrumentation and equipment acquisition, and construction or refitting of research ships as required. Programs also support submersible and remotely operated vehicles and the national accelerator mass spectrometry center for radiocarbon analyses. Over $4 million of the $5.95 million increase will be allocated for an NSF-wide instrumentation program. The remainder will support continued ship and submersible operations, maintenance, and technical support, as well as instrumentation improvements and coordination functions. " $41.04 million for the Ocean Drilling Program, a multinational program of basic scientific research in the oceans which uses drilling and data from drill holes to improve fundamental understanding of the role of physical, chemical and biological processes in the geological history, structure and evolution of the oceanic portion of the earth's crust. Operational support for this activity is shared by six international partners, comprising 18 other countries. An increase of $1.19 million in FY 1997 will maintain the current level of effort for the program as operating costs increase. Research will focus on the eastern Caribbean Sea and the north and south Atlantic Oceans. Specific topics include investigation of structural and fluid properties at a subducting margin where tectonic plates are converging; high resolution analysis of historical changes in coastal ocean circulation; detailed study of sea level change on the continental shelf and slope; and examination of the transition between continental and ocean crust. .