GEOSCIENCES

GEOSCIENCES $728,500,000

The FY 2005 Budget Request for the Geosciences Activity (GEO) is $728.50 million, an increase of $15.40 million, or 2.2 percent, over the FY 2004 Estimate of $713.10 million.

Geosciences Funding
(Dollars in Millions)

	FY 2003 Actual	FY 2004 Estimate	FY 2005 Request	Change over FY 2004 Amount	Percent
Atmospheric Sciences	231.29	238.78	243.63	4.85	2.0%
Earth Sciences	147.32	151.58	155.61	4.03	2.7%
Ocean Sciences	313.23	322.74	329.26	6.52	2.0%
Total, GEO	$691.84	$713.10	$728.50	$15.40	2.2%

Totals may not add due to rounding.

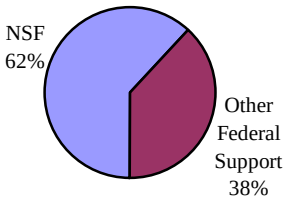
The mission of the Geosciences Activity (GEO) is to support the research, infrastructure, and education in the atmospheric, earth, and ocean sciences needed to advance our understanding of the integrated Earth system. Breakthroughs in observation techniques, modeling, and understanding complex Earth systems are coming just at the time when society is in critical need of sound scientific advice on how to mitigate or adapt to changes in the habitability of the planet. The geosciences stand poised to make tremendous contributions to improve the quality of life by providing useful information to decision makers about the key planetary processes, their complex interactions, and where possible, their future implications.

RELEVANCE

The Geosciences Activity supports basic research that contributes to a better understanding of the many processes that affect global environment such as the role of the atmosphere and oceans in climate, the genesis of earthquakes, and the effects of increased concentrations of greenhouse gasses in the atmosphere. Support is provided for interdisciplinary studies in climate and hydrologic systems, biogeochemical dynamics, ecological systems and dynamics, solid earth processes, and solar influences on the Earth system. Associated with these studies is the need for databases and cyberinfrastructure to provide the scientific community with the resources to assemble and utilize data and information efficiently and effectively.

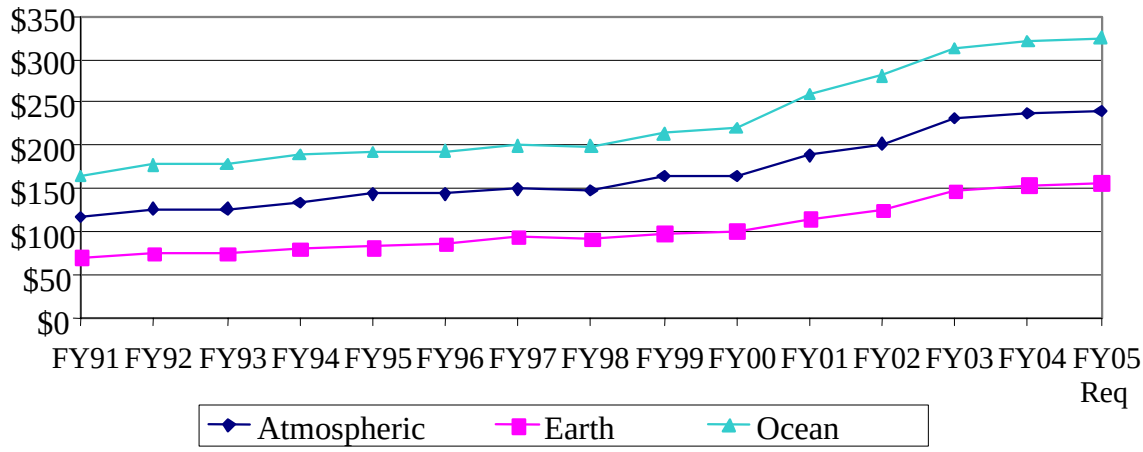
GEO is the principal source of federal funding for university-based basic research in the geosciences, providing about 62 percent of the total federal support in these areas. Within the atmospheric sciences, GEO provides about 47 percent of federal support for university-based basic research; within geological sciences, about 72 percent; and within oceanography, about 67 percent. GEO plays a critical role in addressing the nation's need to understand, predict and respond to environmental events and changes, and helping determine the best use of Earth's resources. Fundamental research in the geosciences advances scientific knowledge of Earth's environment, including resources such as

Federal Support for Basic Research in Geosciences at Academic Institutions



water, energy, minerals, and biological diversity. GEO-supported activities also advance our ability to predict natural phenomena of economic and human significance, such as weather, climate change, earthquakes, fish-stock fluctuations, and disruptive events in the solar-terrestrial environment.

GEO Subactivity Funding
(Dollars in Millions)



STRATEGIC GOALS

GEO invests in four strategic goals:

- People: Improvement of the quality of geoscience education and training and enhancing diversity in all the fields of geoscience. GEO will advance education and training for current geoscientists, increase the diversity of the geoscience community, facilitate education and training for future generations of geoscientists, and enhance public knowledge about the integrated components of the Earth system.

- Ideas: Advancement of knowledge about the Earth system, including both maintaining adequate base support across all geoscience fields and identifying opportunities where more focused support can play a catalytic role in advancing scientific progress.

- Tools: Enhancement of the infrastructure for the conduct of geoscience research. GEO will identify and make investments in instrumentation and facilities, including ships, aircraft, computers, radars, seismometers, and data management systems needed to do world-class research.

- Organizational Excellence: Provision of administrative activities necessary to enable GEO to achieve its mission and goals. These investments include support for Intergovernmental Personnel Act appointments and for contractors performing administrative functions.

Funding by Strategic Goal: Summary
(Dollars in Millions)

	FY 2003 Actual	FY 2004 Estimate	FY 2005 Request	Change over FY 2004 Amount	Change over FY 2004 Percent
People	30.76	32.43	33.39	0.96	3.0%
Ideas	412.88	405.21	409.99	4.78	1.2%
Tools	243.38	270.16	279.69	9.53	3.5%
OE	4.82	5.30	5.43	0.13	2.5%
Total, GEO	$691.84	$713.10	$728.50	$15.40	2.2%

PEOPLE (+$960,000 million, for a total of $33.39 million)

GEO People Investments
(Dollars in Millions)

	FY 2003 Actual	FY 2004 Estimate	FY 2005 Request	Change over FY 2004 Amount	Change over FY 2004 Percent
Individuals	20.34	21.31	21.91	0.60	2.8%
Institutions	2.83	3.14	3.50	0.36	11.5%
Collaborations	7.59	7.98	7.98	0.00	0.0%
Total, GEO	$30.76	$32.43	$33.39	$0.96	3.0%

INDIVIDUALS

- $3.42 million, level with the FY 2004 Estimate, to support the Integrative Graduate Education and Research Traineeship (IGERT) program, which reflects an emphasis on multidisciplinary training in all areas of NSF-supported research.
- $6.23 million to support the CAREER program, which supports integrative research and education activities undertaken by early-career scientists.
- $4.60 million, an increase of $600,000 over FY 2004, to support the Opportunities to Enhance Diversity in the Geosciences (OEDG) program, which seeks to increase the participation in geosciences education and research by students from groups historically underrepresented in the geosciences. A secondary goal of the program is to strengthen the understanding of the geosciences and their contribution to modern society by a broad and diverse segment of the population.
- $2.60 million to support the Geoscience Education and the Global Learning and Observations to Benefit the Environment programs.

INSTITUTIONS

- $3.50 million, unchanged from FY 2004, to support the Foundation-wide ADVANCE program to increase the representation and advancement of women in academic science and engineering careers.

COLLABORATIONS

- $2.60 million, unchanged from the FY 2004 Estimate, to maintain the Centers for Ocean Science Education Excellence initiated in FY 2002. These centers foster the integration of ocean research into high quality educational materials, allow ocean researchers to gain a better understanding of

educational organizations and pedagogy, provide educators with an enhanced capacity to understand and deliver high-quality educational programs in the ocean sciences, and provide material to the public that will promote a deeper understanding of the ocean and its influence on each person's quality of life and our national prosperity.

IDEAS (+$4.78 million for a total of $409.99 million)

GEO Ideas Investments
(Dollars in Millions)

	FY 2003 Actual	FY 2004 Estimate	FY 2005 Request	Change over FY 2004 Amount	Percent
Fundamental Science and Engineering	399.66	391.24	396.22	4.98	1.3%
Centers Programs	13.22	13.97	13.77	-0.20	-1.4%
Total, GEO Ideas	$412.88	$405.21	$409.99	$4.78	1.2%

FUNDAMENTAL SCIENCE AND ENGINEERING

Support for ideas, spanning the geosciences and encompassing a wide range of topics, totals $396.22 million in FY 2005, an increase of $4.98 million from the FY 2004 Estimate of $391.24 million. Projects in the Atmospheric Sciences Subactivity improve the understanding and prediction of climate, weather, space weather, and the global environmental system. Earth Sciences Subactivity research advances knowledge of the structure, composition, and history of the solid Earth and of the geological and hydrological processes that modify Earth. Projects in the Ocean Sciences Subactivity improve knowledge of the global climate system, coastal environments, the character of the ocean floor, as well as processes that control the chemical composition, motion, and biological production of ocean waters.

GEO will continue to participate in the Climate Change Research Initiative (CCRI), with an FY 2005 investment of $20.0 million, level with FY 2004. Emphasis in FY 2005 will continue to be placed on understanding the Earth's carbon cycle and advancing our ability to model dynamic multivariate systems. In addition, GEO will continue to support key research activities of the U.S. Climate Change Research Program.

In FY 2005, GEO will emphasize research on the key physical, chemical and geologic cycles within the Earth system, the characteristics and dynamics of which are of paramount importance to science and society. These activities will be complementary to, and well coordinated with, the biologically oriented studies of Earth cycles that will be carried out within the context of the Foundation-wide Biocomplexity in the Environment priority area. Areas of emphasis include:

- Studies of abrupt and rapid climate change through interdisciplinary studies of ocean circulation combined with those of paleoclimate records to document the frequency, temporal resolution, and spatial extent of past rapid climate change;
- Continued examination of biogeochemical cycles including emphasis on understanding the sources, sinks and processes which control the atmospheric abundance and distribution of carbon and water;
- Continuation of the Oceans and Human Health Initiative in partnership with the National Institutes of Health to understand the linkages between oceans and human health, including water-borne diseases, harmful algal blooms and marine pharmaceuticals;

- Multidisciplinary studies of the processes that govern water quantity and quality, the character and dynamics of the Earth's surface, and the interactive processes at the intersection of the geosphere and biosphere;
- Improving understanding of natural hazards such as floods, earthquakes, volcanic eruptions, hurricanes, and solar storms; and
- Research projects and field programs focused on understanding dynamics of the ocean mantle and its effect on the structure and evolution of the lithosphere, and on the dynamics of the atmosphere and atmospheric coupling.

CENTERS PROGRAMS

GEO-supported centers include Science and Technology Centers (STCs) and Long Term Ecological Research (LTER) sites.

GEO Centers
(Dollars in Millions)

	FY 2003 Actual	FY 2004 Estimate	FY 2005 Request	Change over FY 2004 Amount	Change over FY 2004 Percent
Science and Technology Centers	11.56	10.77	10.57	-0.20	-1.9%
Long Term Ecological Research Sites	1.66	3.20	3.20	0.00	0.0%
Total, GEO	$13.22	$13.97	$13.77	-0.20	-1.4%

In FY 2005, GEO will support three Science and Technology Centers:

The scientific foci of the Science and Technology Center on the Sustainability of Semi-Arid Hydrology and Riparian Areas (SAHRA) are: 1) spatial and temporal properties of hydrologic variables; 2) processes controlling water and chemical balances in catchments; 3) functioning of riparian systems; and 4) integrated modeling of catchment-scale processes. Educational initiatives contribute to sustainability by bringing water resources issues to the forefront of K-16 science education and by promoting hydrologic literacy among the public.

The National Center for Earth-surface Dynamics (NCED) is a Science and Technology Center focused on understanding the processes that shape the Earth's surface, and on communicating that understanding to a broad range of stakeholders. NCED's work supports a large, community-based effort to develop a suite of quantitative models of the Earth's surface: a Community Sediment Model (CSM). Results of the NCED-CSM collaboration will help solve pressing societal problems through both short-term prediction of surface response to natural and anthropogenic change and long-term interpretation of how past conditions are recorded in landscapes and sedimentary strata. NCED education and knowledge transfer programs include exhibits and educational programs at the Science Museum of Minnesota, internships and programs for students from tribal colleges and other underrepresented populations, and research opportunities for participants from outside core NCED institutions.

The Center for Integrated Space Weather Modeling (CISM) focuses its activities around building a comprehensive, physics-based, numerical simulation model that describes the space environment from the Sun to the Earth. In the course of developing this model, CISM will achieve three complementary goals: 1) better understanding of the complex, closely coupled Sun-Earth system; 2) transition of the results of space weather research into robust and operationally useful forecasting tools; and 3) improved public awareness of space weather and its effects. Model development activities will lead to new techniques for model coupling, data assimilation, and visualization. Knowledge transfer will be performed through partnerships with operational support personnel at the National Oceanic and Atmospheric Administration

(NOAA) and the Department of Defense. Education and public outreach activities will be integrated with the CISM research program, and will concentrate on creating and preparing a diverse pool of qualified scientists to face space weather challenges of the future.

Long Term Ecological Research sites support projects requiring long periods of study; the sustained nature of studies allows scientifically sound evaluations of major environmental phenomena. The LTERs represent many disciplines that enhance understanding of general ecological phenomena that occur over long temporal and broad spatial scales, provide information for the identification and solution of environmental problems, and enable interdisciplinary collaborative activities.

TOOLS (+ $9.53 million, for a total of $279.69 million)

The GEO Activity supports user facilities necessary for the conduct of research in the geosciences. These include large national user facilities such as the National Center for Atmospheric Research (NCAR) and the U.S. academic research fleet, and smaller facilities in the atmospheric, earth, and ocean sciences.

GEO Investments in Tools
(Dollars in Millions)

	FY 2003 Actual	FY 2004 Estimate	FY 2005 Request	Change over FY 2004 Amount	Change over FY 2004 Percent
FACILITIES:					
Academic Research Fleet/Ship Operations	65.20	76.50	83.20	6.70	8.8%
Advanced Modular Incoherent Scatter Radar	14.00	11.00	12.30	1.30	11.8%
EarthScope Operations	0.40	1.70	3.45	1.75	N/A
Incorporated Research Institutions for Seismology	13.20	13.00	13.00	0.00	0.0%
Integrated Ocean Drilling Program		35.60	31.60	-4.00	-11.2%
Ocean Drilling Program Operations	30.00	1.90	4.00	2.10	110.5%
Other GEO Facilities[1]	22.17	28.00	24.50	-3.50	-12.5%
Subtotal	144.97	167.70	172.05	4.35	2.6%
INFRASTRUCTURE & INSTRUMENTATION:					
Digital Library	4.20	4.91	4.91	0.00	0.0%
Research Resources	13.41	13.75	17.58	3.83	27.9%
Subtotal	17.61	18.66	22.49	3.83	20.5%
FEDERALLY FUNDED RESEARCH & DEVELOPMENT CENTERS:					
NAIC	1.80	1.80	1.90	0.10	5.6%
NCAR	79.00	82.00	83.25	1.25	1.5%
Subtotal	80.80	83.80	85.15	1.35	1.6%
Total, Tools Support	$243.38	$270.16	$279.69	$9.53	3.5%

[1]Other GEO facilities include multi-user accelerator-based mass spectrometers, synchrotron beamlines, radar facilities to study weather and the upper atmosphere (including the National Astronomy and Ionosphere Center), facilities to support the scientific use of the Global Positioning System, and activities related to the Integrated Ocean Drilling program.

FACILITIES

NSF support provides for ongoing operations and maintenance, including upgrades to existing facilities as well as regularly scheduled repairs. FY 2005 plans include:

- $83.20 million, an increase of $6.70 million, or 8.8 percent, over the FY 2004 Estimate of $76.50 million, for the continued operation and renewal of the U.S. Academic Research Fleet. Approximately 325 projects with about 2,500 scientists and students will use the fleet's 27 ships. The projects range from individual investigator studies of coastal waters to integrated multi-investigator studies of global ocean processes. NSF-funded researchers are the primary users of the ships, accounting for about 65 percent of their total use. NSF ship operation funds support the costs associated with the use of the fleet by these researchers. Also included are funds to continue acquisition of a new deep submergence capability to replace the pioneering submersible ALVIN, and anticipated acquisition of a seismic research vessel to replace the aging R/V *Maurice Ewing* which is in need of a significant refit. These new investments will open significant expanses of the deepest ocean to exploration, and bring greatly enhanced capability to map structures under the sea floor to U.S. researchers.
- $12.30 million, an increase of $1.30 million, or 11.8 percent, over the FY 2004 Estimate of $11.0 million, to continue construction of the Advanced Modular Incoherent Scatter Radar (AMISR). Begun in FY 2003, the AMISR represents a significant augmentation of our ability to study phenomena in the upper atmosphere. Using state of the art technology, AMISR sets a new world standard in upper atmospheric research facilities, and its unique design features allow the radar to be disassembled and moved as scientific needs dictate. In FY 2005, the first of three "faces" of AMISR is scheduled to be completed and begin preliminary operation in Alaska.
- $3.45 million, an increase of $1.75 million, will continue preliminary operation of the EarthScope facility. EarthScope, which has received construction funding through the Major Research Equipment and Facilities Construction (MREFC) Account, is a distributed, multi-purpose geophysical instrument array that will make major advances in our knowledge and understanding of the structure and dynamics of the North American continent.
- $13.0 million, unchanged from the FY 2004 Estimate, to continue support for the Incorporated Research Institutions for Seismology (IRIS). IRIS facilities provide rapid analysis of earthquakes, aid in monitoring nuclear proliferation, and permit imaging of the internal physical structure of Earth.
- $31.60 million, a decrease of $4.0 million, or 11.2 percent, below the FY 2004 Estimate of $35.60 million, to continue support of the Integrated Ocean Drilling Program (IODP) initiated in FY 2004 following the conclusion of the successful Ocean Drilling Program. Support in FY 2005 will enable the continued operation of an interim drillship pending the lease and outfitting of a more robust scientific platform utilizing funds from the MREFC Account. Additional information on IODP is contained in the Tools chapter.
- $4.0 million, an increase of $2.10 million over the FY 2004 Estimate, to support core storage and data distribution infrastructure associated with the Ocean Drilling Program (ODP). In 2003, the *JOIDES Resolution* completed its contracted drilling operations for the ODP.
- $24.50 million, a decrease of $3.50 million, or 12.5 percent, below the FY 2004 Estimate of $23.0 million, for Other Geosciences Facilities, which includes facilities to support the use of the Global Positioning System for scientific research, multi-user analytical facilities such as accelerator-based mass spectrometers, synchrotron beamlines, and operation, upgrade, development, and construction of radar facilities to study precipitation and upper atmospheric phenomena.

<u>INFRASTRUCTURE AND INSTRUMENTATION</u>

- $4.91 million, equal to FY 2004, will enable continued operation of the Digital Library for Earth System Education (DLESE). DLESE provides access to high-quality collections of educational resources; data sets and imagery, including the tools and interfaces that enable their effective use in educational settings; support services to help educators and learners effectively create, use, and share educational resources; and communication networks to facilitate interactions and collaborations across all dimensions of Earth system education.

- Included within the $17.58 million for Research Resources is support for significant infrastructure investments and upgrades not associated with specific facilities, as well as investment in some aspects of cyberinfrastructure.

FEDERALLY-FUNDED RESEARCH AND DEVELOPMENT CENTERS (FFRDCs)

- $83.25 million, an increase of $1.25 million, or 1.6 percent, over the FY 2004 Estimate of $82.0 million, for the operation and maintenance of observational and computer facilities at the National Center for Atmospheric Research. NCAR is a world-renowned center for atmospheric research that makes facilities available – including supercomputers, instrumented research aircraft and ground-based portable observing systems – to scientists at universities, NCAR, and elsewhere. FY 2005 sees the initial operation of the new HIAPER facility, constructed utilizing funds from the MREFC Account, at a level of $300,000. In FY 2005 NCAR will focus on: research on Earth's natural cycles, including climate system modeling and the operation of the computation facilities for the Climate Simulation Laboratory; projects within the U.S. Weather Research Program (USWRP) and the National Space Weather Program (NSWP), which aim to achieve a better understanding and improved predictive capability of costly and disruptive storms on Earth and in space; and continued development of observational and computational capabilities.

ORGANIZATIONAL EXCELLENCE (+$130,000, for a total of $5.43 million)

Organizational Excellence provides support for Intergovernmental Personnel Act appointments, IPA's travel and the administrative contracts necessary to conduct the level of program activity at the Request Level. Requested funding for FY 2005 is $5.43 million.

PRIORITY AREAS

In FY 2005, GEO will support research and education efforts related to broad, Foundation-wide priority areas in Biocomplexity in the Environment, Nanoscale Science and Engineering, Mathematical Sciences, and Human and Social Dynamics.

GEO Investments in Priority Areas
(Dollars in Millions)

	FY 2003 Actual	FY 2004 Estimate	FY 2005 Request	Change over FY 2004 Amount	Change over FY 2004 Percent
Biocomplexity in the Environment	23.00	37.22	37.22	0.00	0.0%
Nanoscale Science and Engineering	7.53	7.94	7.94	0.00	0.0%
Mathematical Sciences	4.57	7.07	7.07	0.00	0.0%
Human and Social Dynamics	N/A	1.35	1.35	0.00	0.0%

Biocomplexity in the Environment: In FY 2005, GEO will provide $37.22 million, level with the FY 2004 Estimate, to support the NSF-wide Biocomplexity competition and a set of coordinated activities in environmental science, engineering and education that advance scientific knowledge about the connection between the living and non-living Earth system. These funds will enable the continuation of four interdisciplinary activities:

- Planetary Ecology focuses on understanding the Earth's marine and terrestrial ecosystems and their evolution, and the interaction of the biosphere with earth system processes. GEO will support research focused on microbial habitats in the terrestrial and submarine deep subsurface to study processes including: biologically controlled mineralization, the production of gas hydrates, microbiological controls on seawater chemistry and productivity, and soil and rhizosphere processes. Included is $4.0 million to study the Ecology of Infectious Diseases;
- Planetary Metabolism aims to understand the links and feedbacks among the Earth's physical, chemical, geological, and biological, as well as social, systems; how they have evolved; and how they affect the planet's biosphere and geosphere;
- Planetary Energetics and Dynamics attempts to understand the links between physical and biochemical processes by focusing on energy exchange. This includes an effort to understand, mitigate and predict natural hazards – for example, hurricane genesis and storm tracking, earthquake nucleation, and energetic processes in the upper atmosphere; and
- Earth Observatories will make sustained time-series observations to understand the temporal evolution of environmental systems that are central to the study of biocomplexity in the environment.

Nanoscale Science and Engineering: In FY 2005, GEO will support Nanoscale Science and Engineering at a level of $7.94 million, unchanged from the FY 2004 Estimate, for activities that focus on:

- Development and application of chemical and biological sensor technology for making rapid, high-precision observations at submicroscopic spatial and volumetric scales;
- Support for crosscutting studies aimed at understanding the distributions and behavior of nanoscale structures throughout the Earth, atmosphere, and oceans; and
- Development of heavily instrumented interdisciplinary Earth System Observatories that facilitate our understanding of nanoscale geoscience processes, including platforms to detect and characterize nanoscale particles and their interactions throughout the atmosphere and oceans.

Mathematical Sciences: In FY 2005, GEO will support multidisciplinary research involving the partnering of mathematicians and geoscientists to investigate topics spanning the earth, atmospheric, and ocean sciences at a level of $7.07 million, unchanged from the FY 2004 Estimate.

Human and Social Dynamics: In FY 2005, GEO will participate in the Human and Social Dynamics priority area at a level of $1.35 million to engage the social science community in understanding and predicting behavior in response to extreme events (earthquakes, hurricanes, tornados, solar disruptions, etc.) and other natural processes affecting society.

QUALITY

GEO maximizes the quality of the R&D it supports through the use of a competitive, merit-based review process. The share of basic and applied research funds that were allocated to projects that undergo merit review was 77 percent in FY 2003, the last year for which complete data exist. OMB's definition of competitive, merit-based review does not include Federally Funded Research and Development Centers, therefore support for the National Center for Atmospheric Research, although regularly merit-reviewed, is not considered as funding that undergoes competitive, merit-based review for this calculation.

To ensure the highest quality in processing and recommending proposals for awards, GEO convenes Committees of Visitors, composed of qualified external evaluators, to review each program every three years. These experts assess the integrity and efficiency of the processes for proposal review and provide a retrospective assessment of the quality of results of NSF's investments.

The Directorate also receives advice from the Advisory Committee for Geosciences (AC/GEO) on such issues as: the mission, programs, and goals that can best serve the scientific community; how GEO can promote quality graduate and undergraduate education in the geosciences; and priority investment areas in geoscience research. The AC/GEO meets twice a year and members represent a cross section of the geosciences, with representatives from many different sub-disciplines within the field; a cross section of institutions including industry; broad geographic representation; and balanced representation of women and under-represented minorities.

PERFORMANCE

Recent Research Highlights

Understanding Complex Coastlines

Our understanding of shallow water waves and currents, and their effects on beach erosion and the dispersal of pollutants, is based on studies of long, straight coastlines onshore of simple continental-shelf and nearshore bathymetry. However, most of the world's coastlines are complex, having features such as shoals, islands, and submarine canyons, which can have dramatic effects on nearshore waves and currents. To gain a better understanding of the underlying physical processes and to help engineers and planners mitigate the effects of wave and current action, scientists from several institutions are monitoring and modeling waves, currents, and morphological changes to the beach near two steep submarine canyons on the southern California coast during the Nearshore Canyon Experiment. Scientists will test models and investigate coastal processes using observations from an instrument array that includes 6 wave buoys, more than 50 wave gages and current meters, 10 drifters, shore-based video cameras and radars, acoustic sediment sensors, and aircraft overflights.

Geochemical Evidence of the Earliest Conditions on Earth

The refractory mineral zircon forms a robust time capsule from the earliest Earth. Older than the oldest known rocks (4.0 billion years), tiny grains of zircon from Western Australia have been analyzed by ion microprobe/secondary ion mass-spectrometer, revealing new insight into Earth's early history. The discovery of a crystal that formed 4.4 billion years ago, less than 160 million years after the formation of Earth and the Moon, causes researchers to question the conventional view that Earth was covered by oceans of magma at this time. New results suggest the formation of crust, a cool early Earth, and even liquid water oceans much earlier than previously thought. Now researchers are searching for more ancient zircons and hoping to find fragments of rock preserved from this time. Possibly, evidence exists to answer another much-debated question: when did life first exist on Earth? And, if life evolved as early as 4.4 billion years ago, would it have survived late heavy meteorite bombardment?

Upward Lightning

On average, about 100 lightning discharges occur every second in approximately 2000 thunderstorms that are active globally at any given time. While the average person has likely witnessed these "ground-to-cloud" discharges, airline pilots had reported seeing "upward lightning" for some time. It wasn't until the 1990s that these phenomena were finally documented and studied. Scientists have now shown that lightning discharges at cloud altitudes (<10 km) affect the high altitude (>40 km) upper atmosphere either

via the release of intense electromagnetic pulses and/or the production of intense quasistatic electric fields. A spectacular manifestation of these intense fields is the so-called "sprites," large, luminous discharges in the altitude range of ~40 km to 90 km, which are produced by the heating of ambient electrons for a few to tens of milliseconds following intense lightning flashes. The so-called "elves" are optical flashes that last for a much shorter (<1 ms) time than sprites, and are typically limited to 80-95 km altitudes with much larger (up to 600 km) lateral extent, being produced by the heating, ionization, and optical emissions due to the electromagnetic pulses radiated by both positive and negative lightning discharges. These newly discovered phenomena indicate strong electrical coupling between upper atmospheric regions, the global significance of which must now be evaluated so that existing models of upper atmospheric dynamics can be properly modified to account for such coupling.

Other Performance Indicators

The tables below show the number of people benefiting from GEO funding, and trends in growth of award size, duration and number of awards.

Number of People Involved in GEO Activities

	FY 2003 Estimate	FY 2004 Estimate	FY 2005 Estimate
Senior Researchers	3,816	3,900	3,900
Other Professionals	2,627	2,700	2,700
Postdoctorates	598	600	600
Graduate Students	2,139	2,200	2,200
Undergraduate Students	1,209	1,200	1,200
Total Number of People	10,389	10,600	10,600

GEO Funding Profile

	FY 2003 Actual	FY 2004 Estimate	FY 2005 Request
Statistics for Competitive Awards:			
Number	1,515	1,500	1,500
Funding Rate	36%	35%	34%
Statistics for Research Grants:			
Number of Research Grants	839	800	800
Funding Rate	33%	32%	31%
Median Annualized Award Size	$82,264	$83,100	$83,100
Average Annualized Award Size	$146,467	$147,900	$147,900
Average Award Duration, in years	2.9	3.0	3.0

ATMOSPHERIC SCIENCES $243,630,000

The FY 2005 Budget Request for the Atmospheric Sciences Subactivity is $243.63 million, an increase of $4.85 million, or 2.0 percent above the FY 2004 Estimate of $238.78 million.

Atmospheric Sciences Funding

	FY 2003 Actual	FY 2004 Estimate	FY 2005 Request	Change from FY 2004 Amount	Change from FY 2004 Percent
Atmospheric Sciences Research Support	147.94	156.78	160.13	3.35	2.1%
National Center for Atmospheric Research	83.35	82.00	83.50	1.50	1.8%
Total, ATM	$231.29	$238.78	$243.63	$4.85	2.0%

Totals may not add due to rounding.

Research and education activities in the Atmospheric Sciences Subactivity (ATM) further our understanding of weather, climate, and the solar-terrestrial system by expanding the fundamental knowledge of the composition and dynamics of Earth's atmosphere and geospace environment. About 40 percent of the funds for ATM support the operation and maintenance of large, complex facilities required for research in the atmospheric and solar-terrestrial sciences. These facilities are shared by the atmospheric science community for fundamental research by individuals and groups of investigators participating in national and international scientific field programs and experiments. The year 2005 will see the commissioning and transfer to full operational status of NSF's High-Performance Instrumented Airborne Platform for Environmental Research (HIAPER). The HIAPER project is the modification and instrumentation of a multidisciplinary high altitude research aircraft capable of conducting science from near the Earth's surface to an altitude of 50,000 feet with an extensive scientific payload and a flight range in excess of 6,000 nautical miles that will enable investigators to perform critical atmospheric and earth system science research.

The "Rain in Cumulus over the Ocean" (RICO) experiment, a study of trade wind cumulus clouds, will be conducted from November 2004 through January 2005. It will focus on understanding the formation of rain in warm clouds. The experiment involves investigators from more than 15 universities and other laboratories as well as participants and facilities from France and England. The RICO investigators will attempt to resolve a central and long-standing problem in cloud physics: theoretical and model calculations predict that rain should form in warm clouds more slowly and in smaller amounts than is actually observed. Because precipitation is such an important feature of weather and climate, this weakness in our ability to predict rain formation affects weather and climate models in fundamental ways. The experiment is designed to test a number of hypotheses that address this discrepancy and also to collect a benchmark set of observations that can be used to improve representations of precipitation formation in models. This study also will provide new understanding of the important influences of trade wind cumulus clouds on larger-scale budgets of radiant energy and moisture in the global climate system.

In recent research, the Bow-echo and Mesoscale Convective Vortex Experiment (BAMEX) was conducted over a seven-week period in the spring of 2003 over a large region of the Midwest. The goal of BAMEX is to study the life cycle of mesoscale convective systems (MCS) with an emphasis on the causes of locally damaging straight line winds and a phenomenon known as a mesoscale convective vortex (MCV). The MCV is of special interest since it can persist well after the demise of the parent MCS and often serves as the initiator of a new round of severe storms many hours after all previous storms have dissipated. This implies a degree of predictability of severe weather that is not currently obtainable. The field phase of the BAMEX required an unprecedented coordination of multiple aircraft and ground based observational systems over a very large area of the Midwest including the Great Plains,

Mississippi and Ohio Valleys. Additionally, the newly developed Weather Research and Forecast (WRF) model was used for the first time in a forecast mode to aid in planning the daily field operations.

In upper atmospheric and near-Earth space research, there has been increasing body of evidence that indicates that the voltage that is applied across the earth's polar cap by the solar wind is limited by some, as yet unexplained, mechanism. Despite the fact that the solar wind driver can become very large, the polar cap voltage drop never gets much larger than 200 kilovolts. In a recent study, evidence presented shows that the limitation must be related to a limitation on the amount of electric current that can flow along magnetic field lines at very high latitudes. State of the art computer simulations show that during conditions of a strong solar wind driver, a dimple is formed at the magnetopause resulting in a region of stagnation in the flow. This limits the rate of magnetic reconnection and thus limits the amount of field-aligned current that can flow into the polar cap. This new result eliminates several old theories of the cause of the polar cap potential saturation.

The FY 2005 Budget Request includes $160.13 million for Atmospheric Sciences Research Support, which provides funding for individual and group research projects in physical meteorology, large-scale dynamic meteorology, experimental meteorology, climate dynamics, atmospheric chemistry, aeronomy, magnetospheric physics and solar-terrestrial relations. Research studies develop the scientific basis for understanding the dynamic and physical behavior of climate and weather on all scales, the natural global chemical cycles of gases and particles in Earth's atmosphere, the composition, energetics, and particularly the dynamics of the coupled upper atmospheric system, and the sun as it relates to Earth's upper atmosphere and space environment. Support is also provided for lower atmospheric facilities at several universities and for upper atmospheric observatories in Massachusetts, Puerto Rico, Greenland and Peru that are operated by U.S. universities and research institutions. Also included is support for Unidata, a national program to help universities use computing technology and atmospheric data for teaching and research. Highlights for FY 2005 include:

- Development of improved computer systems and numerical models, smart instrumentation, and collaboratories which will allow new discoveries, greater access to atmospheric data, and improved understanding of the atmospheric environment;
- Support for new environmental modeling that employ data assimilation and innovative mathematic and statistical techniques to improve predictions of fundamental atmospheric and Earth system processes;
- Continued construction and initial partial deployment of the Advanced Modular Incoherent Scatter Radar (AMISR), a next-generation upper atmospheric observational system to further our understanding of space weather and, thereby, to help to mitigate society's vulnerability to space storms.

FY 2005 support for the National Center for Atmospheric Research (NCAR) totals $83.50 million. During FY 2005 NCAR will focus on:

- Research in the atmospheric and related sciences, including climate system modeling and the operation of the computation facilities for the Climate Simulation Laboratory;
- The U.S. Weather Research Program and the National Space Weather Program, which aim to achieve a better understanding and improved predictive capability of costly and disruptive storms on Earth and in space; and
- Continued support and development of new and improved observational and computational capabilities.

EARTH SCIENCES $155,610,000

The FY 2005 Budget Request for the Earth Sciences Subactivity is $155.61 million, an increase of $4.03 million, or 2.7 percent, over the FY 2004 Estimate of $151.58 million.

Earth Sciences Funding
(Dollars in Millions)

	FY 2003 Actual	FY 2004 Estimate	FY 2005 Request	Change from FY 2004 Amount	Change from FY 2004 Percent
Earth Sciences Project Support	115.38	119.58	122.61	3.03	2.6%
Instrumentation and Facilities	31.94	32.00	33.00	1.00	3.1%
Total, EAR	$147.32	$151.58	$155.61	$4.03	2.7%

Totals may not add due to rounding.

The Earth Sciences Subactivity (EAR) supports research and education activities that improve our understanding of processes that govern the behavior and characteristics of the Earth's surface environment and determine its internal structure, composition and dynamics. EAR funding supports theoretical, computational, laboratory and field studies, and state-of-the-art scientific infrastructure needs. New understanding gained from such studies provides the scientific basis for 1) predicting natural hazards such as earthquakes, volcanic eruptions, floods and droughts, and the mitigation of their impacts; 2) discovery and management of mineral, energy, and water resources; and 3) environmentally sound decision-making. EAR projects are often partnered with and complementary to focused efforts by other federal and state agencies. EAR support is crucial in advancing research and education in the Earth Sciences.

Construction of the new EarthScope facility began with funding from NSF's Major Research Equipment and Facility Construction (MREFC) Account in FY 2003. EarthScope is a distributed, multi-purpose geophysical instrument array for the exploration of fundamental processes that shape the structure and influence the deformation of continents. Research and operation support from Earth Sciences Project Support will enable scientists utilizing EarthScope to enhance understanding of earthquakes and seismic hazards, magmatic systems and volcanic hazards, regional tectonics, continental structure and evolution, and fluids in the crust. Partners in EarthScope include the U.S. Geological Survey (USGS), the National Aeronautics and Space Administration (NASA), the Department of Energy (DOE), and the International Continental Scientific Drilling Programme (ICDP). Additional project partners may include state and local governments, Canadian, and Mexican agencies. Geotechnical and engineering firms will use data and models enabled by EarthScope, and instrumentation firms will collaborate on development for state-of-the-art seismic systems, down-hole instrumentation, and high-precision Global Positioning Systems (GPS) antenna designs.

EarthScope's broader impacts will be felt through applications in hazard assessment and resource management, and through the EarthScope education and outreach program. While EarthScope is a national program, it will be installed and operated at a local level through interactions with hundreds of U.S. universities, schools and other organizations. EarthScope will be a tool for communicating scientific understanding, and perhaps as importantly, the nature of the scientific method. As EarthScope observatories are installed across the U.S., students and the public will consider scientific questions, and the role their region plays in the North American continent. The broad participation necessary for EarthScope to operate will provide pathways for underrepresented groups, especially in rural areas, to participate directly in a national scientific experiment.

The FY 2005 Budget Request includes $122.61 million for Earth Sciences Project Support to provide funds for three main activities. The first is support for individuals and groups of scientists whose research provides the foundation of excellence and capability across all disciplines of the Earth Sciences. Supported programs include disciplinary studies in geology, paleobiology, geophysics, geochemistry, and the hydrologic sciences. The second is support for interdisciplinary research to help understand the parameters and processes that govern the behavior of complex global systems and gain insight into the character and behavior of the Earth's environment. This funding will enable continued support for U.S. scientists and engineers to participate in coordinated national and international research activities as well as an increased emphasis on natural hazards, the water sciences and collaborative multidisciplinary studies to understand the Earth as a functioning dynamic system. The third is the integration of research, education and public awareness through the support of outreach projects, digital libraries and other human resources activities within the geosciences. Priorities for FY 2005 include support for:

- Multidisciplinary studies of the hydrological and biogeochemical cycles, processes that govern water quantity and quality, the character and dynamics of the Earth's surface, and the interactive processes at the intersection of the geosphere and biosphere;
- Improving understanding of natural hazards such as floods, earthquakes and volcanic eruptions;
- Implementation of the EarthScope geophysical and geodetic observational capabilities in order to better understand the physics of earthquakes and the structure, dynamics and evolution of the North American continent;
- Expanding capabilities for computationally challenging planetary research such as dynamic modeling of Earth system processes, managing very large data sets, and integrating and synthesizing data between disciplines while meeting interagency information technology goals;
- Enabling national and international continental scientific drilling focusing on the mechanics of earthquake initiation, and the detailed mechanisms that control eruptive volcanism.

Support for the Instrumentation and Facilities program and infrastructure activities totals $33.0 million. This supports shared research facilities such as Incorporated Research Institutions for Seismology (IRIS) for seismological research, the University Navstar Consortium (UNAVCO, Inc.) for precision geodetic measurements using Global Positioning Systems (GPS), accelerator-based mass spectrometers, ion-beam microprobes, and synchrotron beam lines. The program also funds the research and educational needs for instrumentation and computational infrastructure at universities and colleges throughout the nation. Priorities for FY 2005 include support for:

- Through the EarthScope facilities, enhancement of seismic, geodetic and other geophysical observational platforms on the North American continent to obtain unprecedented resolution imaging of Earth structures underneath the continent and improved understanding of earthquakes, volcanic eruptions and related active tectonic processes;
- Development and deployment of ultra-high pressure technology enabling laboratory investigations of Earth and other planetary bodies under extreme conditions existing in deep planetary interiors;
- The IRIS facility, for enhancement of operation and deployment of the Global Seismic Network for deep earth research and monitoring associated with nuclear nonproliferation and verification, continue making available portable seismic arrays to facilitate focused geophysical research, and to sustain the Data Management System which makes available data on seismic events to researchers world-wide; and
- Development of a dedicated InSAR (Interferometric Synthetic Aperture Radar) satellite mission, carried out jointly with partner agencies (NASA, USGS), to provide spatially continuous strain measurements over wide geographic areas.

OCEAN SCIENCES $329,260,000

The FY 2005 Budget Request for the Ocean Sciences Subactivity is $329.26 million, an increase of $6.52 million, or 2.0 percent over the FY 2004 Estimate of $322.74 million.

Ocean Sciences Funding
(Dollars in Millions)

	FY 2003 Actual	FY 2004 Estimate	FY 2005 Request	Change from FY 2004 Amount	Change from FY 2004 Percent
Oceans Section	117.98	120.45	120.45	0.00	0.0%
Integrative Programs Section	110.26	118.08	120.24	2.16	1.8%
Marine Geosciences Section	84.98	84.21	88.57	4.36	5.2%
Total, OCE	$313.23	$322.74	$329.26	$6.52	2.0%

Totals may not add due to rounding.

The Ocean Sciences Subactivity (OCE) supports research and education to improve understanding of the physical, chemical and biological processes that characterize both coastal seas and deep ocean basins, and the geological and geophysical processes that shape the continental shelves and deep sea floor. Support is also provided for the facilities required to gain access to the ocean, including research vessels, manned deep diving submersibles and a wide range of technologically advanced observational instrumentation. Ocean science is a highly interdisciplinary research endeavor that is fundamental to the understanding of the Earth's climate, to resource and hazard assessment, and to the health of the ocean's complex and diverse ecological systems.

Recent observations from new instruments and techniques employed to study internal tides off Hawaii show that ocean tides do much more than cause the slow rise and fall of sea level. These recent studies show that internal tides flowing over undersea ridges are an important source of deep ocean mixing. The new results show that ocean mixing associated with internal tides flowing over the Hawaiian Ridge was 10 times greater than in normal open ocean areas. Ocean mixing is of fundamental importance to the distribution of heat around the globe and is thus one of the important natural controls of the Earth's climate. The new results could lead to new theories of ocean mixing and thus to better understanding of ocean circulation and its role in affecting global climate.

The FY 2005 Request includes $120.45 million for Oceans Section research support. Studies span a wide range of research topics involving processes occurring within the water column from the air/sea interface to the ocean floor. Research problems increasingly require focused, collaborative, and coordinated programs of observation and interpretation that are often interdisciplinary. Projects range from individual investigator laboratory-based work to multi-investigator collaborations and international programs that require substantial amounts of ship-time and other facility resources. Priorities for FY 2005 include support for:

- A Project Office to coordinate new activities related to ocean observations and the planning for ocean observatories;
- Continuation of the Oceans and Human Health Initiative (with NIEHS) to understand the linkages between oceans and human health, including vector & water-borne diseases, harmful algal blooms and marine pharmaceuticals;

- Studies of marine biocomplexity, particularly marine ecosystems at all levels of organization from functional genomics of marine organisms at the molecular level to open ocean non-linear processes;
- Continued development of capabilities for data assimilation and modeling for ocean circulation and biogeochemical flux studies, resulting from a growing history of sustained time-series observations;
- Interdisciplinary collaborations between mathematicians, statisticians and geoscientists to develop new approaches to solve problems and provide new insights in quantitative oceanography;
- Research to identify, understand, and quantify the processes controlling carbon cycling in the oceans; and
- Enhanced long-term process studies of deep ocean and coastal systems using sustained time-series observations, and development of new technology for ocean and seafloor observation systems.

The Integrative Programs Section totals $120.24 million, an increase of $2.16 over FY 2004, and coordinates critical functions integral to the Ocean Sciences Subactivity. They include education and diversity programs, ship operations, upgrades, construction, instrumentation, technical services, and oceanographic facilities, new technology development, ocean observatories and observation systems, the National Oceanographic Partnership Program (NOPP) and its emerging OCEANS.US coordination office. Priorities for FY 2005 include:

- Replacement and enhancement of deep submergence capabilities using the results of an National Research Council study to guide plans for replacing the 38-year old submersible ALVIN;
- Development of concept designs for new Regional Class vessels as part of the Federal Oceanographic Facilities Committee's (FOFC) plan for renewal of the academic fleet;
- Operation of the academic research fleet to ensure that required ship time and capabilities are provided to satisfy merit reviewed research project requirements for NSF-sponsored studies;
- Enhancement of technical and shared-use instrumentation for projects to sea-going scientists;
- Continued maintenance and ship-improvement programs and increased support for quality improvement activities in operations and technical services programs; and
- Technology development, particularly for smart environmental sensors and the design of infrastructure to support seafloor observatories.

The Marine Geosciences Section totals $88.57 million, an increase of $4.36 million over FY 2004, and supports research to improve fundamental understanding of the composition, structure and evolution of the oceanic crust and continental margins; the record of global environmental and biologic change; and geochemical cycling produced by plate tectonic processes and fluid flow in sedimentary and crustal rock. This includes support for core research in marine geology, geochemistry and geophysics; coordinated community initiatives focused on thematic priorities in planetary dynamics and earth system cycles; and U.S. co-management (with Japan) and participation in the new Integrated Ocean Drilling Program (IODP). Priorities for FY 2005 include support for:

- Research projects and field programs focused on understanding dynamics of the ocean mantle and its effect on the structure and evolution of the lithosphere,
- Increased use of observatory instrumentation and experiments at integrated ridge crest study sites to evaluate biological and hydrothermal dynamics and their roles in planetary metabolism and ecology,
- Integrated observational, laboratory and theoretical studies of continental rifting process in coordination with the Earth Sciences subactivity, and
- Coordinated geologic, geochemical, geophysical and drilling studies of fluid flow in ocean crust and continental margin sediments.