Earth Science Enterprise (ESE)

Mission

The mission of NASA's Earth Science Enterprise (ESE) is to develop a scientific understanding of the Earth system and its response to natural and human-induced changes to enable improved prediction of climate, weather, and natural hazards for present and future generations. NASA brings to this endeavor the vantage point of space, allowing global views of Earth system change. NASA is a provider of objective scientific information, via observation, research, modeling, and applications demonstration, for use by decision-makers in both the public and private sectors. NASA has been studying the Earth from space from its beginnings as an agency. These efforts have led to our current activity of deploying the first series of Earth Observing System satellites that will concurrently observe the major interactions of the land, oceans, atmosphere, ice, and life that comprise the Earth system.

We know that natural and human-induced changes are acting on the Earth system. Natural forces include variation in the Sun's energy output, and volcanic eruptions, which spew dust into the atmosphere and scatter incoming sunlight. Human forces include deforestation, carbon emission from burning of fossil fuels, methane and soil dust production from agriculture, and ozone depletion by various industrial chemicals. Internal climate factors such as atmospheric water vapor and clouds also introduce feedbacks that serve to either dampen or enhance the strength of climate forcing. We also know the climate system exhibits considerable variability in time and space, i.e., both short and long term changes and regionally specific impacts.

NASA introduced the concept of Earth System Science. Researchers have constructed computer models to simulate the Earth system, and to explore the possible outcomes of potential changes they introduce in the models. This way of looking at the Earth as a system is a powerful means of understanding changes we see around us. That has two implications for Earth Science. First, we need to ***characterize*** (that is, identify and measure) the forces acting on the Earth system and its responses. Second, we have to peer inside the system to ***understand*** the source of internal variability: the complex interplay among components that comprise the system.

Earth system changes are global phenomena. Yet the system comprises many micro-scale processes, and the most significant manifestations are regional. Thus, studying such changes requires a global view at regionally discerning resolutions. This is where NASA comes in, bringing the unique capability to study planet Earth from the vantage point of space. By combining observations, research and modeling, we create a capability to ***predict*** Earth system change to help our partners produce better forecasts of change.

To ***characterize*** the forces acting on the Earth system and its responses, ***understand*** the source of internal variability and ***predict*** Earth system change, NASA must observe the Earth, conduct research and analysis of the data, model the data and synthesize the information into new knowledge. Where we are on this knowledge "life cycle" determines the strategy for our investment decisions.

Implementation Strategy

The ESE is pursuing a targeted research program, focused on a set of specific science questions that can be addressed effectively with NASA's capabilities. ESE formulates comprehensive research strategies that can lead to definitive scientific answers and to effective applications for the nation.

The key Earth Science research topics sponsored by NASA fall largely into three categories: forcings, responses, and the processes that link the two and provide feedback mechanisms. This conceptual approach applies in essence to all research areas of NASA's Earth Science program, although it is particularly relevant to the problem of climate change, a major Earth Science-related challenge facing our nation and the rest of the world. The ESE has articulated an overarching question and a set of strategic science questions which its observational programs, research and analysis, modeling, and advanced technology activities are directed at answering.

How is the Earth system changing, and what are the consequences for life on Earth?

How is the global Earth system changing?

What are the primary causes of change in the Earth system?

How does the Earth system respond to natural and human-induced changes?

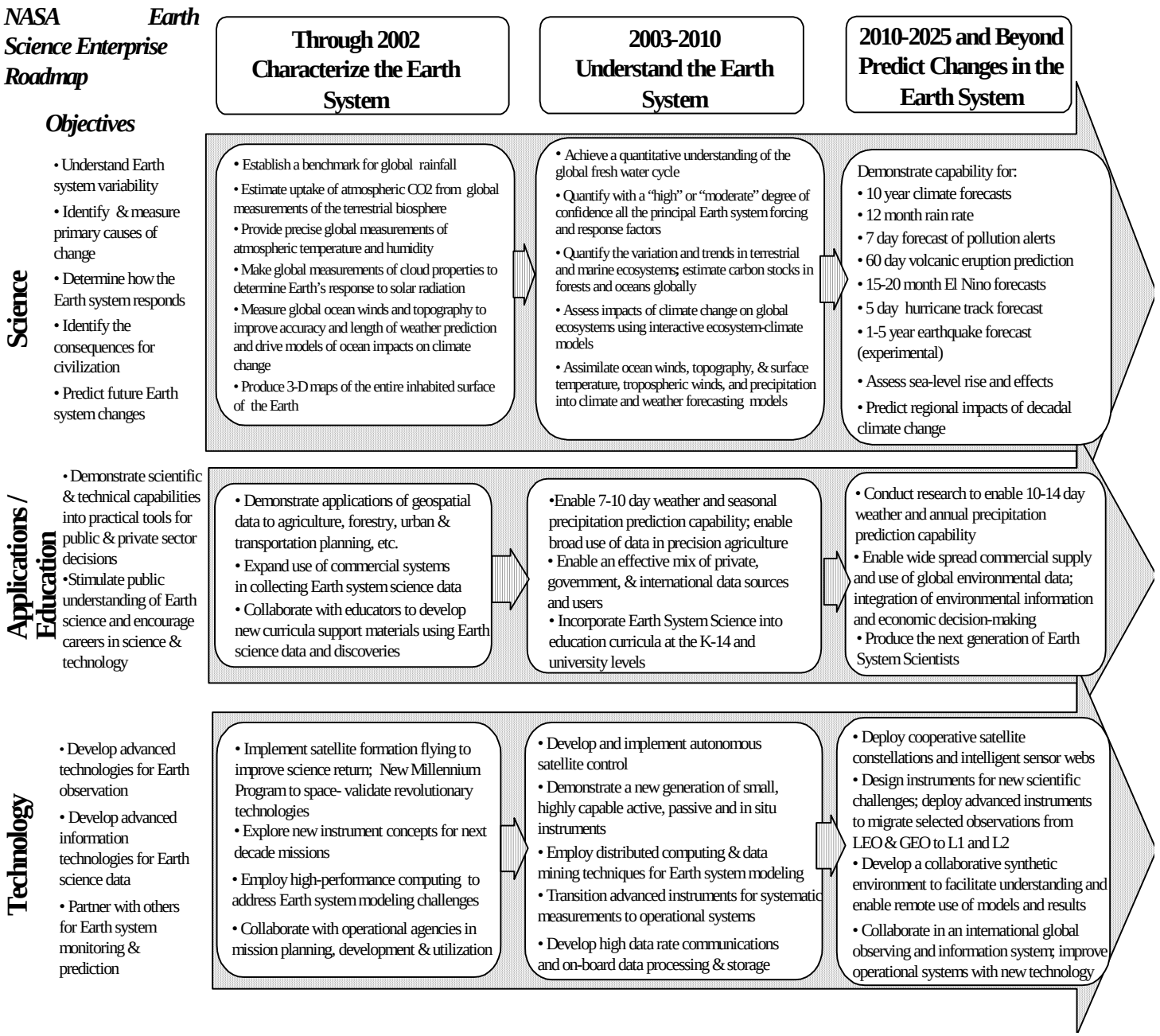
What are the consequences of changes in the Earth system for human civilization?

How can we predict future changes in the Earth system?

In this and subsequent Performance Plans, NASA's annual results in Earth Science will be measured in terms of progress made toward answering these questions. Accordingly, the assessment of performance against the first strategic goal is structured in the form of key questions whose answers are provided by the ongoing mission of NASA's Earth Science program. While these questions will be answered over a period greater than a single year, the general nature of activities in FY02 focuses on completion of the first EOS series and characterization of the forces acting on the Earth system and its responses.

Earth Science is science in the national interest. NASA is pleased to play a leadership role in exploring and understanding our home, Earth. This ESE Performance Plan describes our planned accomplishments toward this great endeavor in Fiscal Year 2002. These planned accomplishments, while important and useful in their own right, are essential stepping stones on the path to answering ESE's science questions over the next decade.

Figure 1. Strategic Roadmap for the Earth Science Enterprise



Resource Requirements

(NOA, dollars in millions)

	FY1999	FY 2000	FY 2001	FY 2002
$ M	1413.8	1443.4	1484.6	1278.0
Civil Service FTE	1,365	1,907	1,750	1,679

Performance Measures

Enterprise Mission: Develop a scientific understanding of the Earth system and its response to natural and human-induced changes to enable improved prediction of climate, weather, and natural hazards for present and future generations.

NASA's ESE is dedicated to understanding the total Earth system and the effects of natural and human-induced changes on the global environment. The vantage point of space provides information about Earth's land, atmosphere, ice, oceans and biota that is obtainable in no other way. Programs of the ESE study the interactions among these components to advance the new discipline of Earth System Science. Our research results contribute to the development of sound environmental policy and economic investment decisions.

NASA's ESE also develops innovative technologies and applications of remote sensing for solving practical societal problems in agriculture and food production, natural hazard mitigation, water resources, regional planning, and national resource management in partnership with other Federal agencies, with industry, and with state and local governments. Earth Science discoveries are shared with the public to enhance science, mathematics, and technology education and increase the scientific and technological literacy of all Americans. ESE combines the excitement of scientific discovery with the reward of practical contribution to the sustainability of planet Earth.

Strategic Goal (I): Observe, understand, and model the Earth system to learn how it is changing, and the consequences for life on Earth.

NASA's Earth observing and research program elements are the principal means by which global-scale questions about our home planet are posed and answered. These elements identify the variability in the Earth system, the forces responsible for change, the responses of the Earth system to changes, and the consequences and predictability of future change. Nations and industries make billions of dollars worth of investment decisions yearly that will be better informed by the information and understanding we provide.

Objective (IA): Discern and describe how the Earth is changing.

Annual Performance Goal 2Y1: Increase understanding of global precipitation, evaporation and how the cycling of water through the Earth system is changing by meeting at least 3 of 4 performance indicators.

It is important to establish a baseline for determining the existence or absence of significant trends in the water cycle, and the extent to which observed changes match predictions. Acceleration of the global water cycle could result in intensification and/or redistribution of rainfall patterns, severe storm frequency, droughts and glacial melting. Understanding of the water cycle enables prediction of freshwater availability.

- Combine analysis of global water vapor, precipitation and wind data sets to decipher variations (and possible trends) in the cycling of water through the atmosphere and their relation to Sea Surface Temperature changes.

- Analyze data from polar and geostationary satellites in a consistent fashion over at least two decades to evaluate whether the detectable moisture fluxes are increasing beyond the expected ranges of natural variability.

- Determine the time and spatial variability of the occurrence of strong convection regions, precipitation events, and areas of drought to assess whether or not there are discernable global changes in the distribution of moisture availability useful to food and fiber production and management of fresh water resources.

- Establish passive and active rainfall retrievals of zonal means to establish a calibration point for long-term data records of the World Climate Research Program, Global Precipitation Climatology Project (GPCP).

Annual Performance Goal 2Y2: Increase understanding of global ocean circulation and how it varies on interannual, decadal, and longer time scales by meeting 2 of 2 performance indicators.

Establishing the basis for variations in the temperature and circulation of the upper ocean can be used to help assess any changes that may be affecting the Earth's weather and climate, including El Niño phenomena.

- Routine (every ten days) analysis from a data-assimilating global ocean model, using NASA satellite observations, will be used to evaluate ocean circulation changes. [http://www.ecco.ucsd.edu/]

- Sponsor research and satellite data analysis to develop and publish the trends in the duration and dynamics of the sea ice season for the Arctic and Antarctic polar sea ice covers for the period 1979-1999.

Annual Performance Goal 2Y3: Increase understanding of global ecosystems change by meeting at least 3 of 4 performance indicators.

The activity establishes the basis for short-term, seasonal and inter-annual variability of ecosystems and provides a baseline against which to evaluate future change. Measurements of seasonal, annual and inter-annual changes in ecosystems are used to estimate productivity in agriculture, forestry, fisheries and Earth's unmanaged lands and oceans.

- Merge Moderate-Resolution Imaging Spectroradiometer (MODIS) instrument and Sea-viewing Wide Field-of-view Sensor (SeaWiFS) data to increase the global ocean color data coverage by 25% from a baseline of 17% per day.

- Test our ability to discriminate phytoplankton from other constituents in coastal waters using observations of phytoplankton fluorescence observations acquired by MODIS.

- Release first comprehensive validation of MODIS land data products using results from the South African Fire-Atmospheric Research Initiative (SAFARI 2000) field campaign and related field validation programs.

- Establish a quantitative relationship between vegetation indices time series derived from Advanced Very High-Resolution Radiometer (AVHRR) and MODIS to ensure long-term continuity and comparability of time series.

Annual Performance Goal 2Y4: Increase understanding of stratospheric ozone changes, as the abundance of ozone-destroying chemicals decreases and new substitutes increases by meeting 2 of 2 performance indicators.

Reduction in atmospheric ozone amounts leads to an increased flux of ultraviolet radiation at the Earth's surface, with harmful effects on plant and animal life including human health.

- Provide continuity of calibrated data sets for determining long term trends in the total column and profile abundances of stratospheric ozone with sufficient precision to enable the later assessment of expected ozone recovery.

- Characterize the inter-annual variability and possible long-term evolution of stratospheric aerosol characteristics and profile abundances to assist in the interpretation of observed ozone changes and Chemistry-climate interactions. This requires a combination of consistently processed data records from ground-based, airborne, balloon-borne, and space-based measurements.

Annual Performance Goal 2Y5: Increase understanding of change occurring in the mass of the Earth's ice cover by meeting at least 3 of 4 performance indicators.

Sea level is estimated to have been rising by about 2 mm/year over the last century. Possible contributions to this change include thermal expansion of the oceans and the loss of ice from glaciers and the large ice sheets. Of these, the large ice sheets present the greatest uncertainty in terms of their contribution to sea level rise and also represent the greatest potential threat to

the coastal ecosystems and infrastructure. It is therefore important to establish whether polar regions are in the process of losing mass and contributing to the current observed sea level rise.

- Submit for publication the first Greenland ice sheet accumulation rate and its inter-annual variability maps for the period 1975-98.

- Provide the first record of changes and variability in extent of Greenland ice sheet surface melt over the 21 years, 1979-1999, and submit for publication.

- Produce the first map of Antarctic ice sheet margin change, 1997-2000, covering key regions of the Antarctic coastline and submit this for publication.

- Define parameters for separating post-glacial rebound from ice mass changes based on Gravity Recovery And Climate Experiment (GRACE) and Ice, Clouds, and Land Elevation Satellite (ICESat) observations.

Annual Performance Goal 2Y6: Increase understanding of the motions of the Earth, the Earth's interior, and what information can be inferred about the Earth's internal processes by meeting at least 3 of 4 performance indicators.

Motions of the Earth's Interior are the forcings which drive earthquakes, volcanoes and build our mountains and valleys. Knowledge, which has been building over the past decades, has led to a quantum leap in our understanding of how our planet has evolved. Through this new knowledge has come a better understanding of natural hazards and natural resource assessment. Technological by-products include better navigation (including civilian Global Positioning System (GPS)), the tracking of ocean height variability and the attendant visualization of EL Nino and related phenomena to name just a few of many applications.

- Produce first estimate of the secular (Long-Term) change of the Earth's magnetic field from continuous satellite measurements of the geomagnetic field. Estimate the long-term variation to 3 nano Tesla/yr or better which is equivalent to a change of 1 part in 20,000.

- Complete the evaluation of the Continuous Observations of the Rotation of the Earth (CORE) concept to demonstrate a nearly 300% improvement in Earth rotation precision using the new Mark IV correlator technology and an international consortium of Very Long Baseline Interferometry (VLBI) observatories.

- Complete Solar Laser Ranging 2000 (SLR2000) prototype development and begin evaluation of the performance of new SLR2000 automated satellite ranging station.

- Evaluate the ability of the real-time precision GPS positioning software to produce better than 40 cm global real-time positioning using NASA's Global GPS Network.

- Complete preliminary algorithms for mass flux estimation from temporal gravity field observations in preparation for the GRACE mission.

Objective (IB): Identify and measure the primary causes of change in the Earth system.

Annual Performance Goal 2Y7: Increase understanding of trends in atmospheric constituents and solar radiation and the role they play in driving global climate by meeting at least 3 of 4 performance indicators.

Solar radiation is the primary external force acting on Earth's climate. Atmospheric constituents, clouds and aerosols drive the climate system; changes in their concentration/distribution will contribute to climate change through a variety of processes.

- Provide continuity of 22 years of concentration measurements (and associated standards development) of anthropogenic and naturally occurring halogen-containing chemicals and other chemically active greenhouse gases to provide for an understanding of future changes in ozone and climate forcing.

- Use data assimilation techniques to combine Carbon Monoxide and Methane measurements from Measurements of Pollution in the Troposphere (MOPITT) with chemical transport models of the atmosphere to help characterize interannual differences in global emissions.

- Provide first comprehensive multi-instrument/multi-angle integrated data set for study of sources/sinks and distribution of tropospheric aerosols over land based on data from Total Ozone Mapping Spectrometer (TOMS), MODIS, and Multi-angle Imaging Spectroradiometer (MISR) instruments.

- Reduce the uncertainty in the retrievals of upper troposphere / lower stratosphere water vapor (from microwave soundings) by 10 – 30% through improved laboratory spectroscopic measurements of the water vapor continuum.

Annual Performance Goal 2Y8: Increase understanding about the changes in global land cover and land use and their causes by meeting at least 2 of 3 performance indicators.

Change in land cover and land use is the dominant present-day forcing of change in terrestrial and coastal ecosystems and constitutes our largest uncertainty in the global carbon budget. Understanding the human and biophysical factors that cause land cover and land use change will be essential for assessing consequences for food production, natural resources availability, and resource management as well as for predicting future global changes.

- Publish the first set of regional land cover and land use change case studies and a synthesis of their results.

- Characterize the role of land cover changes associated with natural fires in determining the carbon balance of ecosystems in at least two major regions of the boreal forests, quantify their impact on the global carbon budget, and submit the results for publication.

- Characterize the role of deforestation in the carbon balance of ecosystems of the Amazonian tropical forest, quantify the impact on the global carbon budget, and submit the results for publication.

Annual Performance Goal 2Y9: Increase understanding of the Earth's surface and how it is transformed and how such information can be used to predict future changes by meeting at least 4 of 5 performance indicators.

This effort is leading to a better understanding of natural events/processes that transform or change the topographic surface of the Earth, and the impact of such changes on human activities. Progress toward answering this question will lead to a better understanding of the risk of natural hazards and societies vulnerability to natural disasters. By products of these activities include better topographic maps of the Earth surface. These are important to many endeavors such as airplane landing and routing, watershed assessment, and roadway planning. Risk assessment for natural hazards such as flooding, earthquakes, landslides and volcanoes is becoming increasingly important as societal resources are developed and concentrated in vulnerable areas.

- Begin 5-yr assessment of utility of completed Southern California Integrated GPS Network in understanding tectonic activities.

- Perform a new integrated earthquake risk assessment of the Los Angeles basin based on continued measurement of accumulated strain in the southern California region.

- Continue providing the Digital Elevation Models (DEM) of the Earth for scientific studies and practical applications.

- Evaluate the utility of single frequency GPS array technology for assessing volcanic deformation processes.

- Characterize and model topographic evolution processes in at least two major tectonically active regions of the world and publish results.

Objective (IC): Determine how the Earth system responds to natural and human-induced changes.

Annual Performance Goal 2Y10: Increase understanding of the effects of clouds and surface hydrologic processes on climate change by meeting at least 4 of 5 performance indicators.

It is important to establish a basis for determining the vertical distribution and optical properties of cloud particles to provide measurement-based estimates of atmospheric heating rather than relying on climatological statistics or models. Clouds are the most important factor that controls the Earth's radiation balance, which, along with evaporation and condensation of atmospheric and surface water, drives the major weather systems. Thus, determining the vertical distribution and optical properties of cloud particles will ultimately lead to better climate predictions. Soil moisture is an important land surface state variable, currently unmeasured at large spatial scales, that also affects weather and climate.

- Continue assembling and processing of satellite data needed for the multi-decadal global cloud Climatology being developed under the International Satellite Cloud Climatology Project (ISCCP). Reduce uncertainty (3-7% in monthly mean) in the current ISCCP dataset of globally observed cloud characteristics, particularly in the polar regions, by comparing it with new satellite datasets that provide new constraints on the derived quantities and with in situ ground-based and airborne measurements.

- Initiate development of the Cirrus Regional Study of Tropical Anvils and Layers (CRYSTAL) field study to determine the upper tropospheric distribution of ice particles and water vapor and associated radiation fluxes on storms and cloud systems, and on cloud generation, regeneration and dissipation mechanisms and their representation in both regional-scale and global climate models.

- Improve the determinations of radiation forcings and feedbacks, and thereby increase accuracy in our knowledge of heating and cooling of the Earth's surface and atmosphere. Continue the analysis of global measurements of the radiative properties of clouds and aerosol particles being made by MISR and Clouds and the Earth's Radiant Energy System (CERES) instruments on the Terra and Aqua spacecraft.

- Demonstrate over a variety of landscapes the capability to measure and diagnose soil moisture from airborne platforms, in preparation for a space-flight trial of soil moisture remote sensing.

- Improve the understanding and modeling of the aerosol radiative forcing of climate and its anthropogenic component (reduce current uncertainties of 0.1 to 0.05 in the aerosol column optical thickness and 1 to 0.4 in the Angstrom coefficient). Develop and validate aerosol retrieval and cloud screening algorithms, and processing of satellite data and transport model evaluations for a 20-year Climatology of aerosol optical thickness and particle size.

Annual Performance Goal 2Y11: Increase understanding of how ecosystems respond to and affect global environmental change and affect the global carbon cycle by meeting at least 4 of 5 performance indicators.

Today, Earth's ecosystems are experiencing multiple, interacting, changing environmental conditions, and it will be vitally important to understand the implications of their responses, including some that may surprise us, for sustained agriculture, forestry, and fisheries, and for the continued provision of ecosystem goods and services that are valuable to human societies. We also need to know how their responses provide feedback to the atmosphere through fluxes of water, energy, and trace gases. Most importantly, we must develop understanding of the past, present, and future role of ecosystems as sources and sinks of carbon and in regulating the global carbon cycle.

- Demonstrate the feasibility of using remote sensing imagery to identify functional groups of phytoplankton in the ocean.

- Develop a relationship between oceanic primary productivity and export of carbon to the deep-sea based on remote sensing observations and ocean biology models.

- Conduct airborne remote sensing campaign in Amazonia to evaluate measurement approaches for vegetation recovery and biomass change following forest clearing and impact of this secondary growth on removal of water from the atmosphere.

- Assemble and publish the first comprehensive regional analysis of the linkages between land-atmosphere interaction processes and the relationship between trace gas and aerosol emissions and the consequences of their deposition to the functioning of the ecosystems of southern Africa.

- Conduct diagnostic analysis of results from new carbon cycling models that improve the treatment of land use and land management and incorporate the effects of nutrient deposition as well as climate change, carbon dioxide enrichment, and land cover change to assess interrelation among these multiple factors affecting these ecosystems.

Annual Performance Goal 2Y12: Increase understanding of how climate variations induce changes in the global ocean circulation by meeting at least 4 of 6 performance indicators.

Ocean circulation patterns strongly influence regional climates, yet these are known to have exhibited variability. For example, circulation associated with the north Atlantic "conveyor" belt, including the Gulf Stream, provides for the relatively mild climate of northern Europe. Changes in such large-scale ocean circulation could significantly impact the habitability of this region.

- Diagnostic analysis of seasonal and interannual variability induced in the interior ocean based on forcing of an ocean model with three years of high resolution ocean winds (Ocean Surface Vector Winds Science Team).

- Near decade-long sea surface topography time series will be assimilated into high resolution Pacific Ocean model to elucidate the mechanisms of the Pacific Decadal Oscillation and its impact on seasonal/decadal climate variations.

- From Ocean Topography Experiment (TOPEX) time series, in situ observations of the World Ocean Data Assimilation Experiment, and assimilation of these data into ocean models, ascertain whether detectable changes in the deep ocean have occurred over the last decade.

- Submit for publication the first estimate of the inter-annual variability of Arctic Ocean seasonal ice production and heat and brine flux, from three years of Canadian Radar Satellite (RADARSAT) observations.

- Complete a preliminary review of how data assimilation techniques are currently being used to improve knowledge of the polar oceans (in particular the Arctic), through convening a workshop. Provide recommendations that outline the way forward for future application of data assimilation techniques for polar oceans research in NASA's ESE.

- Submit for publication twenty years of “Fram Strait” sea ice flux from RADARSAT and passive microwave ice motion. Sea ice flux through the Fram Strait represents export of fresh water from the Arctic Ocean, which in turn influences deep ocean circulation and climate variations.

Annual Performance Goal 2Y13: Increase understanding of stratospheric trace constituents and how they respond to change in climate and atmospheric composition by meeting 2 of 2 performance indicators.

Stratospheric composition, most importantly amounts of ultraviolet (UV)-absorbing ozone, respond to concentrations of chemically active trace gases and underlying meteorological conditions, such as temperature and wind distributions. Changing atmospheric conditions associated with global chemical change (and associated global warming) have the potential to affect the stratosphere, which can in turn affect fluxes of biologically-damaging UV radiation at the Earth's surface.

- Assess the possible impact of the increased abundances of greenhouse gases on the future evolution of Northern Hemisphere high latitude ozone concentration. Based on data from the Sage Ozone Loss and Validation Experiment (SOLVE) experiment.

- Document and submit for publication the respective variability of temperatures, ozone concentrations, and water vapor in and above the tropopause region and assess the interconnectedness of these changes through retrospective modeling and data analysis.

Annual Performance Goal 2Y14: Increase understanding of global sea level and how it is affected by climate change by meeting at least 2 of 3 performance indicators.

The polar ice sheets are a repository for about 75% of the Earth's fresh water and a reduction in their combined mass of just 1% would increase sea level by about 90 cm. Of the order of 100 million people would be at direct risk from a sea level rise of this magnitude (Intergovernmental Panel on Climate Change (IPCC), 1995) and many more would be indirectly affected through economic and other impacts. It is therefore important to establish whether the ice sheets have the potential, under climate change scenarios, to exhibit major changes in mass balance and if so, what the expected time-scale for such changes would be.

- Map the surface velocities at their outlets of at least 10 major outlet glaciers draining West Antarctica and at least 10 outlet glaciers draining East Antarctica and determine the positions where these glaciers start to float with a precision of 100 m. Submit these maps for publication.

- Compare new estimates of ice discharge of 20 or more Antarctic glaciers with interior mass accumulation to provide the first estimates of mass balance for their grounded ice catchments. Submit these estimates for publication.

- Establish a methodology for refining ice stream models based on radar sounding, surface velocity and surface topographic observations. Generate a technical report for peer review.

Annual Performance Goal 2Y15: Increase understanding of the effects of regional pollution on the global atmosphere, and the effects of global chemical and climate changes on regional air quality by meeting at least 4 of 5 performance indicators.

There is significant evidence that pollutant gases can be transported over very long distances (e.g., across the Pacific or Atlantic oceans). The global effects of atmospheric pollution (on agriculture, materials, human health, etc.) are poorly known due to inexact characterization of tropospheric transport, physics, and chemistry.

- Continue and extend the three year data record in order to build climatology of the high resolution vertical distribution of ozone in the tropics to improve the retrievals of tropospheric ozone concentrations based on the residual products from space-based observations.

- Archive and analyze data from the Transport of Chemical Evolution over the Pacific (TRACE-P) airborne mission and associated data sets to characterize the atmospheric plume from East Asia and to assess its contribution to regional and global atmospheric chemical composition.

- Estimate the tropospheric distributions of Hydroxyl (OH) and examine the consistency between inverse and assimilation models in determining global OH fields using multiple data sets; document via submission of one or more publications to peer-reviewed literature.

- Simulate changes in atmospheric composition projected over the 21st century with a coupled aerosol-chemistry-climate general circulation model including projected changes in anthropogenic emissions. This model, which will include first-time parameterization of tropospheric aerosol chemistry, will help to diagnose the climatic consequences of these emissions and the associated feedbacks on atmospheric composition.

- Estimates of the stratospheric contribution to tropospheric ozone will be made through chemical transport and Lagrangian transport models. The stratosphere-troposphere exchange included in these model calculations will be examined for its sensitivity to global warming.

Objective (ID): Identify the consequences of change in the Earth system for human civilization.

Annual Performance Goal 2Y16: Increase understanding of variations in local weather, precipitation and water resources and how they relate to global climate variation by meeting 2 of 2 performance indicators.

This activity establishes a basis for determining what changes will be induced by climate trends in the frequency, strength, and path of weather systems, which produce clouds and rain and replenish fresh water supplies.

- Characterize the interannual variations of deep tropical convection utilizing existing and new satellite-based datasets to understand relations between large-scale surface and atmospheric forcing and tropical forcing and submit results for publication.

- Demonstrate impact of assimilation of Tropical Rainfall Measuring Mission (TRMM) rainfall data on forecasting track and intensity of tropical storms by showing improvement in near real-time hurricane and typhoon forecasts in a variety of cases/conditions.

Annual Performance Goal 2Y17: Increase understanding of the consequence of land cover and land use change for the sustainability of ecosystems and economic productivity by meeting at least 2 of 3 performance indicators.

Today, land cover and land use changes are primarily due to human activities, and are most prevalent where human populations are large; thus the consequences of land cover and land use change impact our daily lives and the potential sustainability of food production, natural resource use, and environmental quality. Consequences of concern include changes in carbon sources and sinks; the loss of biodiversity; inputs of sediments, nutrients, and pollutants to coastal regions; land degradation, and increased risks to human health.

- Release a document describing the first set of regional land cover and land use change case studies and providing a synthesis of their results.

- Develop models incorporating the biophysical, socio-economic, institutional, and demographic determinants of land use and land cover change in Amazonia.

- Enable the scientific interchange of data, methods, and results through the operation of regional networks of scientists in four major regions of the world.

Annual Performance Goal 2Y18: Increase understanding of the consequences of climate and sea level changes and increased human activities on coastal regions by meeting 2 of 2 performance indicators.

The consequences of global environmental change are often seen in the coastal zone. Human populations are concentrated near coastlines, and there are severe impacts on coastal communities from pollution, excess nutrients, storm-surge and sea-level rise. It will be important to understand the relative contributions of each of these factors to the overall changes in coastal regions, and especially, their effect on the resident human communities.

- Increase the coverage of space-based maps of coral reef distribution by 25% beyond current estimates using remotely sensed imagery.

- Develop an improved algorithm for retrievals of ocean color information from remotely sensed observations of turbid coastal systems (i.e. Case 2 water).

Objective (IE): Enable the prediction of future changes in the Earth system.

Annual Performance Goal 2Y19: Increase understanding of the extent that weather forecast duration and reliability can be improved by new space-based observations, data assimilation and modeling by meeting at least 2 of 3 performance indicators.

This activity contributes to improving the accuracy of short-term weather predictions and increasing the period of validity of long-range forecasts which are used by government, business, and individuals to protect lives and property and make investment decisions.

- Determine tropical mean convection structure (fraction of convective vs. stratiform rainfall) for the first time using TRMM's first three years of data and submit results for publication.

- Define the quantitative requirements for new operational sensors, including space-based tropospheric winds through participation in inter-agency Observing System Simulation Experiments (OSSE).

- Develop new analysis methods that integrate global observations from the complete suite of satellite (and conventional) weather measurements into a single, self-consistent analysis of water-related phenomena (diabatic heating by radiation and precipitation, water vapor and clouds, inference of water and energy fluxes and transports). This development provides for developing requirements for new satellite sensors and new data assimilation techniques.

Annual Performance Goal 2Y20: Increase understanding of the extent that transient climate variations can be understood and predicted by meeting at least 4 of 5 performance indicators.

This activity contributes to the ability to predict global and regional climate on seasonal-to-interannual time scales with sufficient accuracy for concerned socioeconomic interests to estimate the likely impact of climate variations, such as those associated with El Nino/La Nina, and to issue warnings and make appropriate contingency plans. NASA will endeavor to transition the results of this research to those public agencies that have operational planning and warning responsibilities and will also make the results available to concerned interests in the private sector.

- Document in the peer-reviewed literature the quantified impact of satellite altimeter observations on improving 12-month El Nino forecasts with a state-of-the-art coupled ocean-atmosphere-land model by comparing model predictions initialized with in-situ data and both with and without satellite altimeter data.

- Contribute to national seasonal forecasts by delivering ensembles of forecast products (e.g., surface temperature, precipitation, upper level winds) to Operational agencies (e.g., National Center for Environmental Prediction (NCEP), International Research Institute (IRI)). Forecasts with and without the use of satellite-based data will be used to document the impact of such remotely sensed data on forecast quality.

- Estimate and document potential predictability, based on multi-year reanalysis data and modeling, of regional climate variability in order to evaluate the relative contributions of seasonal-to-interannual and decadal climate variability on

specific regions, with a focus on occurrence of major floods and droughts in North America and the Asian-Australian monsoon regions.

- Develop, implement, and document advanced cloud radiation and moist physics schemes in NASA climate models, and validate them against remotely-sensed radiation data, in order to improve overall skill of climate model simulations of the global energy and water cycles.

- Use multi-year satellite observations of lightning to assess the relationship of strong convection to interannual climate variations (e.g., El Nino and La Nina), and use as proxy data to assist in evaluating model representation of convective precipitation. Document results.

Annual Performance Goal 2Y21: Increase understanding of the extent that long-term climate trends can be assessed or predicted by meeting at least 4 of 5 performance indicators.

This activity will provide information needed to determine policies for possible mitigation of, or adaptation to, climate change. Specifically, it will provide information on the causes of recent and current climate changes and the expected magnitude and causes of future climate trends including the nature of regional climate changes. An integral part of this research is an assessment of the reliability of climate predictions and how alternative assumptions and policies affect them.

- Monitor global tropospheric and stratospheric temperatures, to validate climate model simulations, and to improve understanding of the relationship between surface and upper-air temperatures in a changing climate system. Document results.

- Quantify and document the likely contributions of different climate forcings (greenhouse gases, ozone, water vapor, solar irradiance) to observed long-term trends of the Arctic Oscillation. The Arctic Oscillation has practical significance as it affects the geographical patterns of climate variability and change in the troposphere.

- Quantify and document the degree to which the stratosphere and mesosphere need to be incorporated and resolved in climate models to realistically simulate interannual and decadal climate variability and change in the troposphere.

- Quantify and document the role of different forcings (greenhouse gases, ozone, water vapor, solar irradiance, stratospheric and tropospheric aerosols) and unforced (chaotic) variability in determining the evolution of global climate over the past 50 years, to develop confidence in quantitative model predictions of future climate change.

- Make quantitative comparisons of the ability of alternative ocean modeling treatments to simulate climate variability and change on interannual to century time scales. Document results.

Annual Performance Goal 2Y22: Increase understanding of the extent that future atmospheric chemical impacts on ozone and climate can be predicted by meeting at least 2 of 3 performance indicators.

A sound scientific basis is essential for informed decision making at the national and international level on environmental issues that underlie human health and well being and the health of the numerous ecosystems. Only through the integration of science and policy, as occurred effectively through the assessment process (for example the various assessment panels associated with the Montreal Protocol), can the sustainable development of our Nation be insured.

- Analyze the measured trends in atmospheric trace gas concentrations and compare with those estimated from industrial production and emission data. Analysis will be used to assess the completeness of our understanding of the atmospheric persistence and degradation of industrial chemicals as well as to examine the efficiency of current regulatory agreements and international reporting on the production and emissions of regulated chemicals.

- Conduct laboratory studies designed to assess the atmospheric fate of new industrial chemicals by characterizing the key photochemical processes responsible for their atmospheric breakdown.

- Continue the implementation of the Global Modeling Initiative (GMI) to provide metrics, benchmarks and controlled numerical experiments for model and algorithm simulations performance, which will allow the development of standards of model behavior for participation in assessment exercises.

Strategic Goal (II): Expand and accelerate the realization of economic and societal benefits from Earth science, information & technology.

Scientific data must be transformed into information products useful to non-scientists in order for the economy and society to realize the full benefit of it. Our applications and education programs are designed to achieve this end through partnerships between NASA and professional information product providers and educators. The accomplishment of the identified performance indicators will enable the user community to accomplish their day-to-day decision-making in a more effective manner resulting in either cost savings, improved timeliness or quality, or to accomplish tasks that were not previously possible with conventional means. The accomplishment of the performance indicators will enable the U.S. taxpayer to reap the potential socio-economic benefits of NASA's investment in Earth science and technology.

Objective (IIA): Demonstrate scientific and technical capabilities to enable the development of practical tools for public and private-sector decision makers.

Annual Performance Goal 2Y23: Provide regional decision-makers with scientific and applications products and tools.

Increased application of and access to ESE's science and technology results will enable the Nation to reap significant benefits in the areas of community growth and infrastructure, disaster management, environmental assessment, and resource

management. The performance indicators are aimed at measuring: (a) the identification of the most significant needs in the federal, state, local and tribal government community that can benefit from these results; (b) the development of new and advanced applications and related methods and practices in cooperation with the user community; and (c) the distribution of these results to the broader user population. The accomplishment of the identified target indicators and related application activities will enable the user community to accomplish their day-to-day decision-making in a more effective and efficient manner resulting in either cost savings, improved timeliness or quality, or in an ability to accomplish tasks that were not previously possible with conventional means. The accomplishment of the performance indicators will enable the U.S. taxpayer to reap the potential socio-economic benefits of NASA's investment in Earth science and technology.

- Conduct Program Planning and Analysis activities that result in the identification of five potential demonstration projects where user needs match NASA ESE science and technology capabilities.

- Develop two new joint demonstration projects with the user community.

Objective (IIB): Stimulate public interest in and understanding of Earth system science and encourage young scholars to consider careers in science and technology.

Annual Performance Goal 2Y24: Share NASA's discoveries in Earth science with the public to enhance understanding of science and technology.

Increased public awareness and understanding of how the Earth functions as a system and increased literacy in Earth science and technology will result in quality teaching and learning about the Earth and its environment, and build capacity for productive use of Earth science information in resolving everyday practical problems. Success will equate to meeting 3 of 4 performance indicators.

- Release at least 50 "stories" per year that cover scientific discoveries, practical benefits or new technologies.

- Sponsor assistance to at least 2 leading undergraduate institutions to develop courses that enable pre-service science educators to become proficient in Earth system science.

- Continue to train a pool of highly qualified scientists and educators in Earth science and remote sensing by sponsoring approximately 140 fellowships (50 of which are new) and a total of 30 New Investigator Program awards.

- Work with at least one professional society to develop content standards for professional practice of Earth remote sensing.

Strategic Goal (III): Develop and adopt advanced technologies to enable mission success and serve national priorities.

New and less costly remote sensing capabilities are made possible by targeted investment in advanced technologies. These technologies will make possible the next generation of weather, climate and Earth systems monitoring satellites. They will leverage advances in information technologies to make vast quantities of Earth science data useful and accessible to scientists, practitioners, and the public.

Objective (IIIA): Develop advanced technologies to reduce the cost and expand the capability for scientific Earth observation.

Annual Performance Goal 2Y25: Successfully develop and infuse technologies that will enable future science measurements, and/or improve performance and reduce the cost of existing measurements. Increase the readiness of technologies under development, advancing them to a maturity level where they can be infused into new missions with shorter development cycles.

New technology enables measurements that have never been previously made. Often, these measurements enable the early warnings to the public of natural hazards (ozone, chemical or particulate threats) or life threatening weather conditions and allow study of Earth from new vantagepoint of space. Alternatively, many new technologies reduce the cost of existing measurements while improving their quality. Predictive information can be generated for the public with more reliability, at lower cost and in delivery of resulting information in a shorter period.

- Annually advance 25% of funded technology developments one Technology Readiness Level (TRL)
- Mature 2-3 technologies to the point where they can be demonstrated in space or in an operational environment.
- Enable one new science measurement capability or significantly improve performance of an existing one.

Objective (IIIB): Develop advanced information technologies for processing, archiving, accessing, visualizing, and communicating Earth science data.

High-end computational modeling capabilities will enable in-depth analysis and simulation of earth system processes. This analysis will lead to higher quality, more refined characterization of the Earth system and longer-range predictions of natural hazards or life threatening weather conditions.

Annual Performance Goal 2Y26: Develop hardware/software tools to demonstrate high-end computational modeling to further our understanding and ability to predict the dynamic interaction of physical, chemical and biological processes affecting the earth.

- Successfully establish networked high performance computer testbed for Earth science modeling challenges.

- Finalize Earth science multidisciplinary, integrated Modeling Framework requirements by holding successful system design review.

Annual Performance Goal 2Y27: Develop baseline suite of multidisciplinary models and computational tools leading to scalable global climate simulations.

- Attain a three time improvement over negotiated baseline for three to eight Earth Science modeling codes transferred to the high performance computer testbed.

- Successfully demonstrate up to three Earth science modeling codes interoperating on a functioning Modeling Framework prototype.

Objective (IIIC): Partner with other agencies to develop and implement better methods for using remotely sensed observations in Earth system monitoring and prediction.

Lowering overall costs to the government, collaboration permits NASA to utilize other agencies' skills and resources, precluding inefficient duplication of missions and research efforts.

Annual Performance Goal 2Y28: Collaborate with other Federal and international agencies in developing and implementing better methods for using remotely sensed observations.

- Continue to take advantage of collaborative relations with U.S. Geological Survey (USGS), U.S. Department of Agriculture (USDA) and Environmental Protection Agency (EPA) to promote the use of remotely sensed data and information to accomplish U.S. strategic scientific, environmental and economic objectives.

- Demonstrate enhanced interoperability and interconnectivity of international remote sensing information systems and services through NASA's participation in the Committee on Earth Observation Satellites (CEOS) Working Group on Information Systems and Services.

- Demonstrate enhanced mission coordination and complementarity of remote sensing data through NASA's participation in the CEOS Working Group on Calibration and Validation.

- Demonstrate the establishment of an agreed international approach to an integrated global observing strategy for the oceans and the terrestrial carbon cycle through participation in the Integrated Global Observing Strategy - Partners (IGOS-P).

Enterprise-Wide Activities that enable achievement of Earth Science strategic goals.

Annual Performance Goal 2Y29: Successfully develop, have ready for launch, and operate instruments on at least two spacecraft to enable Earth Science research and applications goals and objectives.

- Successfully develop and have ready for launch at least two spacecraft.
- At least 90% of the total on-orbit instrument complement will be operational during their design lifetime.

Annual Performance Goal 2Y30: Successfully disseminate Earth Science data to enable our science research and applications goals and objectives. Success will equate to meeting 4 of 5 performance indicators.

- Make available data on seasonal or climate prediction, and land surface changes to users within 5 days of their acquisition.
- Increase by 50% the volume of data acquired and archived by NASA for its research programs compared to FY01.
- Increase the number of distinct NASA Earth Observing System Data and Information System (EOSDIS) customers by 20% compared to FY01.
- Increase scientific and applications data products delivered from the Earth Observing System (EOS) Distributed Active Archive Centers (DAACs) by 10% compared to FY01.
- User satisfaction: increase the number of favorable comments from DAAC and Earth Science Information Partner (ESIP) users as recorded in the customer contact logs over FY01; decrease total percentage of order errors by 5% over FY01.

Annual Performance Goal 2Y31: Safely operate airborne platforms to gather remote and *in situ* earth science data for process and calibration/validation studies.

- Support and execute seasonally dependent coordinated research field campaigns within one-week of target departure with the aid of airborne and sub-orbital platforms, as scheduled at the beginning of the fiscal year.

Verification and Validation

While performance indicators are noted in order to demonstrate significant scientific progress toward the annual performance goal, the ESE will also rely on external expert review. The Earth Science Advisory Committee of the NASA Advisory Council will conduct an annual assessment of the ESE's near-term science objectives. It will provide a qualitative progress measurement (Green, Yellow,

or Red). "Green" will indicate that the objective was met; "Yellow" will indicate a concern that an objective was not fully accomplished; and "Red" will indicate that events occurred that prevented or severely impaired the accomplishment of the objective. The assessment will include commentary to clarify and supplement the qualitative measures.

Earth System Science and Applications Advisory Committee (ESSAAC) is a committee of the NASA Advisory Council under the Federal Advisory Committee Act, and comprises outside scientific and technical experts from academia, industry and other government agencies. ESSAAC meets at least twice a year to review plans and progress in the ESE. After the end of each fiscal year, the ESE will provide to ESSAAC a self-assessment in each of the relevant objectives, highlighting performance against the metrics in the Performance Plan for that year. ESSAAC will deliberate internally and render its own assessment, which may confirm or modify ESE's self-assessment. ESSAAC's assessment will be reported in the Performance Report for that year. This process will be repeated annually.

The ESE will regularly review performance objectives as part of an existing monthly review process. Tracking current performance on a monthly basis for each specific FY02 annual performance goal enables the ESE to institute measures to ensure improvement and progress toward meeting its strategic goals.

Multi-year Performance Trend
Earth Science Enterprise

***New objectives have been developed for FY 2002. The targets can be mapped to the following new objectives:**

Objective (1A): Discern and describe how the Earth is changing.
Objective (1B): Identify and measure the primary causes of change in the Earth system.
Objective (1C): Determine how the Earth system responds to natural and human-induced changes
Objective (1D): Identify the consequences of change in the Earth system for human civilization.
Objective (IE): Enable the prediction of future changes in the Earth system.

FY 99-01 Strategic Objective: Understand the causes and consequences of land-cover/land-use change

	FY 1999	FY 2000	FY 2001	FY 2002
Annual Performance Goal and APG #	Collect near-daily measurements of ocean color (index of ocean productivity from which calculations of ocean update of carbon are made). (Y3). Refresh the global archive of 30m land imagery from Landsat 7, two to three times per year. A single global archive has not been constructed since late 1970's. This will include a 15m panchromatic band (Y1).	SIMBIOS will merge MODIS ocean color data into the global ocean color time series, which began with Ocean Color Temperature Sensor (OCTS) and SeaWiFS. Use time series to understand and predict response of the marine ecosystem to climate change. Make data set available via the Goddard DAAC (0Y4). Continue the ocean color time series with 60% global coverage every 4 days (0Y3). Continue the development of a global land-cover/use change data set based on Landsat and EOS instrument, at seasonal refresh rate (0Y1).	Increase understanding of the dynamics of the global carbon cycle by developing, analyzing and documenting multi-year data sets and meeting at least 3 of 4 performance indicators in this research area (1Y3). Explain the dynamics of global carbon cycle by building improved models and prediction capabilities and meeting 2 of 2 performance indicators in this research area (1Y4).	Increase understanding of global ecosystems change by meeting at least 3 of 4 performance indicators (2Y3). Increase understanding about the changes in global land cover and land use and their causes by meeting at least 2 of 3 performance indicators (2Y8). Increase understanding of how ecosystems respond to and affect global environmental change and affect the global carbon cycle by meeting at least 4 of 5 performance indicators (2Y11).
Assessment	Y3 and Y1 were yellow	0Y4 was yellow. 0Y3 and 0Y1 were green.	TBD	TBD

FY 99-01 Strategic Objective: Understand the causes and consequences of land-cover/land-use change (continued)

	FY 1999	FY 2000	FY 2001	FY 2002
Annual Performance Goal and APG #	Collect near-daily global measurements of the terrestrial biosphere (index of terrestrial photosynthetic processes from which calculations of carbon uptake are made) from instruments on TERRA (Y2).	Continue to collect near-daily global measurements of the terrestrial biosphere (index of terrestrial photosynthetic processes from which calculations of carbon uptake are made) from instruments on TERRA (0Y2). Produce near-real-time fire monitoring and impact assessment based on Landsat and EOS inventory and process monitoring to provide an observational foundation for monitoring change in ecosystem productivity and disturbance. Post near-real-time assessments on a web site for quick access by researchers and regional authorities (0Y7).		Increase understanding of the consequence of land cover and land use change for the sustainability of ecosystems and economic productivity by meeting at least 2 of 3 performance indicators (2Y17). Increase understanding of the consequences of climate and sea level changes and increased human activities on coastal regions by meeting 2 of 2 performance indicators (2Y18).
Assessment	Yellow	0Y2 was green. 0Y7 was green		TBD

***New objectives have been developed for FY 2002. The targets can be mapped to the following new objectives:**

Objective (1A): Discern and describe how the Earth is changing.
Objective (1B): Identify and measure the primary causes of change in the Earth system.
Objective (1C): Determine how the Earth system responds to natural and human-induced changes
Objective (1D): Identify the consequences of change in the Earth system for human civilization.
Objective (IE): Enable the prediction of future changes in the Earth system.

FY 99-01 Strategic Objective: Predict seasonal-to-interannual climate variations

	FY 1999	FY 2000	FY 2001	FY 2002
Annual Performance Goal and APG #	TRMM will begin the second of a 3-year sequence of instantaneous measurements of rainfall rates and monthly accumulations in the global tropics. This will be the first measurement of global tropical rainfall. Current uncertainty is 50 percent. TRMM data will reduce uncertainty to 10 percent. (Y4). QuikScat to provide 25km resolution wind speed & direction measurements over at least 90% of the ice-free oceans every two days. Resolution increases by a factor of two, and a 15% increase of coverage over previous measurement (Y5).	Establish a benchmark for global and regional rainfall measurements by combining TRMM measurements with measurements from other sources. Create maps of the diurnal cycle of precipitation for the first time. Combine the existing ten-year data set with TRMM measurements to validate climate models and demonstrate the impact of rainfall on short-term weather forecasting. Distribute through the Goddard DAAC for ease of access to science and operational users (0Y9).	Increase understanding of the dynamics of global water cycle by developing, analyzing, and documenting multi-year data sets and meeting 2 of 2 performance indicators in this research area. (1Y5). Explain the dynamics of global water cycle by building improved models and prediction capabilities and meeting at least 2 of 3 performance indicators in this research area (1Y6).	Increase understanding of global precipitation, evaporation and how the cycling of water is changing by meeting at least 3 of 4 performance indicators (2Y1). Increase understanding of global ocean circulation and how it varies on interannual, decadal, and longer time scales by meeting 2 of 2 performance indicators (2Y2). Increase understanding of how climate variations induce changes in the global ocean circulation by meeting at least 4 of 6 performance indicators (2Y12)
Assessment		Green	TBD	TBD

FY 99-01 Strategic Objective: Predict seasonal-to-interannual climate variations (continued)

	FY 1999	FY 2000	FY 2001	FY 2002
Annual Performance Goal and APG #		Develop/improve methods to couple state-of-the-art land surface and sea ice models to a global coupled ocean-atmosphere model and use to predict regional climactic consequences of El Nino or La Nina occurrence in the tropical Pacific. Results of research will be published in the open literature and provided to NOAA's National Climate Prediction Center and the U.S. Navy's Fleet Numeric Prediction Center. Ultimate goal: develop a capability to significantly improve the prediction for seasonal-to-interannual climate variations and their regional climate consequences. The main focus is on North America (0Y10).		Increase understanding of variations in local weather, precipitation and water resources and how they relate to global climate variation by meeting 2 of 2 performance indicators (2Y16) Increase understanding of the extent that weather forecast duration and reliability can be improved by new space-based observations, data assimilation and modeling by meeting at least 2 of 3 performance indicators (2Y19). Increase understanding of the extent that transient climate variations can be understood and predicted by meeting at least 4 of 5 performance indicators (2Y20).
Assessment		Green		TBD

FY 99-01 Strategic Objective: Predict seasonal-to-interannual climate variations (continued)

	FY 1999	FY 2000	FY 2001	FY 2002
Annual Performance Goal and APG #		Measure production and radiative properties of aerosols produced by biomass burning in Africa based on SAFARI 2000 (field experiment) and EOS instruments. Includes extensive international participation. This burning is estimated to contribute one-half of global atmospheric aerosols (0Y11). Launch the NASA-CNES Jason-1 mission. This follow-on to TOPEX/ Poseidon is to achieve a factor-of-four improvement in accuracy in measuring ocean basin-scale sea-level variability. This is 1 order of magnitude better than that specified for TOPEX/Poseidon. (0Y12). Generate the first basin-scale high-resolution estimate of the state of the Pacific Ocean as part of the international Global Ocean Data Assimilation Experiment (GODAE) (0Y47).		
Assessment		0Y11 was green. 0Y12 was yellow 0Y47 was green.		

***New objectives have been developed for FY 2002. The targets can be mapped to the following new objectives:**

Objective (1A): Discern and describe how the Earth is changing.
Objective (1B): Identify and measure the primary causes of change in the Earth system.
Objective (1C): Determine how the Earth system responds to natural and human-induced changes
Objective (1D): Identify the consequences of change in the Earth system for human civilization.
Objective (IE): Enable the prediction of future changes in the Earth system.

FY 99-01 Strategic Objective: Identify natural hazards, processes, and mitigation strategies

	FY 1999	FY 2000	FY 2001	FY 2002
Annual Performance Goal and APG #	The Enterprise will provide the technology and instruments to create the first digital topographic map of 8o percent of Earth's land surface, everything between 60°N and 56°S. SRTM will be ready to launch in September 1999. (Y6). Use GPS array in southern California to monitor crustal deformation on a daily basis with centimeter precision; initiate installation of the next 100 stations. Data will be archived at JPL and run in models, with results given to the California Seismic Safety Commission and FEMA. (Y7).	Use Southern California Global Positioning System (GPS) array data to understand the connection between seismic risk and crustal strain leading to Earthquakes (0Y37). Develop models to use time-varying gravity observations for the first time in space (0Y38). Demonstrate the utility of spaceborne data for floodplain mapping with the Federal Emergency Management Agency (0Y39). Develop an automatic volcano cloud/ash detection algorithm employing EOS data sets for use by the Federal Aviation Administration (0Y40).	Increase understanding of the dynamics of the Earth's interior and crust by developing, analyzing, and documenting multi-year data sets and meeting 2 of 2 performance indicators in this research area (1Y11). Explain the dynamics of the Earth's interior and crust by building improved models and prediction capabilities and meeting 2 of 2 performance indicators in this research area (1Y12).	Increase understanding of the motions of the Earth, the Earth's interior, and what information can be inferred about the Earth's internal processes by meeting at least 3 of 4 performance indicators (2Y6). Increase understanding of the Earth's surface and how it is transformed and how such information can be used to predict future changes by meeting at least 4 of 5 performance indicators (2Y9).
Assessment	Green	Green	TBD	TBD

FY 99-01 Strategic Objective: Identify natural hazards, processes, and mitigation strategies (continued)

	FY 1999	FY 2000	FY 2001	FY 2002
Annual Performance Goal and APG #	Use GPS data to test improved algorithms for sounding the atmosphere with the occulted GPS signal. Data will be archived at JPL and results published in science literature. (Y8).			
Assessment	Green			

***New objectives have been developed for FY 2002. The targets can be mapped to the following new objectives:**

Objective (1A): Discern and describe how the Earth is changing.
Objective (1B): Identify and measure the primary causes of change in the Earth system.
Objective (1C): Determine how the Earth system responds to natural and human-induced changes
Objective (1D): Identify the consequences of change in the Earth system for human civilization.
Objective (IE): Enable the prediction of future changes in the Earth system.

FY 99-01 Strategic Objective: Detect long-term climate change, causes, and impacts

	FY 1999	FY 2000	FY 2001	FY 2002
Annual Performance Goal and APG #	MODIS, MISR, ASTER, CERES (TERRA instruments) will begin to conduct daily observations of cloud properties such as extent, height, optical thickness and particle size. Data will be distributed through the Goddard DAAC (Y9). TERRA will map aerosol formation, distribution and sinks over the land and oceans (Y10). The TERRA instrument will achieve a 40-percent reduction in the uncertainty in Earth's radiation balance (that is improved angular models leading to an estimated error reduction in regional-scale monthly average net radiation of about 50 percent. (Y11).	Complete the collection of satellite data needed for the 17-year cloud climatology being developed under the International Satellite Cloud Climatology Project. Data will be used to improve the understanding and modeling of role of clouds in climate. Data will be available in the Goddard DAAC (0Y13). Continue the development of the global aerosol climatology data set and analysis of this climatology in climate models. Data will be available in the Goddard DAAC (0Y14). Provide for the continuation of the long-term, precise measurement of the total solar irradiance with the launch of EOS ACRIM (0Y15).	Increase understanding of the dynamics of long term climate variability by developing, analyzing, and documenting multi-year data sets and meeting at least 2 of 3 performance indicators in this research area (1Y7). Explain the dynamics of long term climate variability by building improved models and prediction capabilities and meeting at least 3 of 4 performance indicators in this research (1Y8).	Increase understanding of change occurring in the mass of the Earth's ice cover by meeting at least 3 of 4 performance indicators (2Y5). Increase understanding of the effects of clouds and surface hydrologic processes on climate change by meeting at least 4 of 5 performance indicators (2Y10). Increase understanding of global sea level and how it is affected by climate change by meeting at least 2 of 3 performance indicators (2Y14). Increase understanding of the extent that long-term climate trends can be assessed or predicted by meeting at least 4 of 5 performance indicators (2Y21).
Assessment	Yellow	All were green	TBD	TBD

FY 99-01 Strategic Objective: Detect long-term climate change, causes, and impacts (continued)

	FY 1999	FY 2000	FY 2001	FY 2002
Annual Performance Goal and APG #		Acquire, through a Radarsat repeat of Antarctic Mapping Mission conducted in Sept.-Oct. 1997, a second set of high-resolution radar data over all of Antarctica for comparison with baseline data set acquired in 1997, to identify changes on the ice sheet (0Y16). Publish the first detailed estimates of thickening/thinning rates for all major ice drainage basins of Greenland ice sheet derived from repeated airborne laser-altimetry surveys. Measures represent the baseline data set to compare with early GLAS data (July 2001 launch) (OY17). Initiate a program of airborne mapping of layers within the Greenland ice sheet to decipher the impact of past climate variation of polar regions (0Y18).		
Assessment		All were green		

FY 99-01 Strategic Objective: Detect long-term climate change, causes, and impacts (continued)

	FY 1999	FY 2000	FY 2001	FY 2002
Annual Performance Goal and APG #		Develop a remote-sensing instrument/technique for ocean surface salinity measurements from aircraft. Goal: to improve measurement accuracy to ` order of magnitude better than available in FY98. The ultimate goal is the capability to globally measure sea surface salinity from space (0Y19). Continue to improve the design and sophistication of a global climate system model, including use of higher resolution, to make it a state-of-the-art climate system model for projecting the climatic consequences at the regional level. Improvement will be manifested in increased resolution from added computing power and better numerical representations (0Y20).		
Assessment		0Y19 and 0Y20 were green		

***New objectives have been developed for FY 2002. The targets can be mapped to the following new objectives:**

Objective (1A): Discern and describe how the Earth is changing.
Objective (1B): Identify and measure the primary causes of change in the Earth system.
Objective (1C): Determine how the Earth system responds to natural and human-induced changes
Objective (1D): Identify the consequences of change in the Earth system for human civilization.
Objective (IE): Enable the prediction of future changes in the Earth system.

FY 99-01 Strategic Objective: Understand the causes of variation in atmospheric ozone concentration and distribution

	FY 1999	FY 2000	FY 2001	FY 2002
Annual Performance Goal and APG #	TOMS data will be used for new retrieval methods to collect and analyze three new data products, including surface ultraviolet, tropospheric aerosols, and tropospheric columns. With SBUV/2 data, TOMS will make a continuous 20-year data set for total ozone-measuring effectiveness of Montreal Protocol. New and extended data products will be made available on TOMS web site. (Y12). Complete initiation of the full Southern Hemisphere Additional Ozonesonde network to obtain the first-ever climatology of upper tropospheric ozone in the tropics (Y14).	Implement the SAGE III Ozone Loss and Validation Experiments. Measurements will be made from October 1999 to March 2000 in the Arctic/high-latitude region from the NASA DC-8, ER-2, and balloon platforms. Will acquire correlative data to validate SAGE III data and assess high-latitude ozone loss (0Y22). (Green) Complete the analysis and publication of the PEM-Tropics-B field experiment (0Y23). (Green) Complete the Troposphere Chemistry aircraft instrument size and weight reductions (by ~40%) initiative (0Y24). (Green)	Increase understanding of the dynamics of atmospheric composition by developing, analyzing, and documenting multi-year data sets and meeting at least 4 of 5 performance indicators in this research area (1Y9). Explain the dynamics of atmospheric chemistry by building improved models and prediction capabilities and meeting at least 2 of 3 performance indicators in this research area (1Y10).	Increase understanding of stratospheric ozone changes, as the abundance of ozone-destroying chemicals decreases and new substitutes increases by meeting 2 of 2 performance indicators (2Y4). Increase understanding of trends in atmospheric constituents and solar radiation and the role they play in driving global climate by meeting at least 3 of 4 performance indicators (2Y7). Increase understanding of stratospheric trace constituents and how respond to change in climate and atmospheric composition by meeting 2 of 2 performance indicators (2Y13).
Assessment	Yellow due to Russian implementation delay	All were green.	TBD	TBD

FY 99-01 Strategic Objective: Understand the causes of variation in atmospheric ozone concentration and distribution (cntinued)

	FY 1999	FY 2000	FY 2001	FY 2002
Annual Performance Goal and APG #	With data from other atmospheric ozone programs, continue the detailed multi-aircraft study of troposphere chemistry over the tropical Pacific Ocean, especially the contribution of long-range transport of air from South America and Africa to unpolluted areas. Complete the field measurements phase of PEM-Tropics-B (rainy season) with an improved payload that has resulted from an initiative to develop a smaller, lighter payload with equal or better performance than PEM-Tropics-A (dry season). Results will be fully analyzed and published. (Y15).	Complete the planning for major new 2001 airborne/unmanned aerospace vehicle mission that will use a smaller Troposphere Chemistry aircraft instrument (0Y25).		Increase understanding of the effects of regional pollution on the global atmosphere, and the effects of global chemical and climate changes on regional air quality by meeting at least 4 of 5 performance indicators (2Y15). Increase understanding of the extent that future atmospheric chemical impacts on ozone and climate can be predicted by meeting at least 2 of 3 performance indicators (2Y22).
Assessment	Yellow due to Russian implementation delay	Green		TBD

FY 99-01 Strategic Objective: Understand the causes of variation in atmospheric ozone concentration and distribution (continued)

	FY 1999	FY 2000	FY 2001	FY 2002
Annual Performance Goal and APG #	Use SAGE III to improve the collection and analysis of measurements provided by SAGE II, and add: nitrogen trioxide and chlorine dioxide measures; additional wavelength sampling to directly measure and retrieve aerosols throughout the troposphere; and, higher spectral resolution (Y13). With data from other atmospheric ozone programs, measure surface levels of chlorine- and bromine-containing chemical compounds addressed in the Montreal Protocol to document decreasing concentrations of regulated compounds and increasing concentrations of replacement compounds. Analyses will be provided to researchers supporting the WMO assessment process. (Y16).			
Assessment	Yellow due to Russian implementation delay			

FY 2002 Enterprise-Wide Supporting Activities/FY 99-01 Objective: Successfully launch spacecraft

	FY 1999	FY 2000	FY 2001	FY 2002
APG #	The Enterprise will successfully launch three spacecraft within 10% of budget on average (Y35).	Launch three spacecraft and deliver two instruments for international launches within 10% of budget on average (0Y36).	Successfully develop, have ready for launch, and operate instruments on a least two spacecraft within 10 percent of their schedules and budget to enable Earth Science research and applications goals and objectives (1Y1).	Successfully develop, have ready for launch, and operate instruments on at least two spacecraft to enable Earth Science research and applications goals and objectives (2Y29).
Assessment	Yellow	Green	TBD	TBD

FY 2002 Enterprise-Wide Supporting Activities/FY 99-01 Objective: Implement open, distributed, and responsive data system architectures

	FY 1999	FY 2000	FY 2001	FY 2002
APG #	Make available data on prediction, land surface, and climate to users within 5 days (Y17). Increase the volume of data archived by 10% compared to FY97 (target = 139 terabytes). Goddard has been collecting trend data since FY94. (Y18). Increase the number of distinct customers by 20% compared to FY97 (target = 839,000). Goddard has been collecting trend data since FY94 (Y19). Increase products delivered from the DAACs by 10% compared to FY97 (target = 3.8 million). Goddard has been collecting trend data since FY94 (Y20).	EOSDIS make available data on prediction, land surface, and climate to users within five days (0Y26). EOSDIS will double the volume of data archived compared to FY98 (0Y27). EOSDIS will increase the number of distinct customers by 20% compared to FY98 (0Y28). EOSDIS will increase products delivered from the DAACs by 10% compared to FY98 (0Y29).	Successfully disseminate Earth Science data to enable our science research and applications goals and objectives by meeting all performance indicators in this research area (1Y2).	Successfully disseminate Earth Science data to enable our science research and applications goals and objectives. Success will equate to meeting 4 of 5 performance indicators (2Y30). Safely operate airborne platforms to gather remote and in situ earth science data for process and calibration/validation studies (2Y31).
Assessment	Blue	All were blue.	TBD	TBD

Objective: Stimulate public interest in and understanding of Earth system science and courage young scholars to consider careers in science and technology/FY 99-01 Objective: Increase public understanding of Earth system science through education and outreach.

	FY 1999	FY 2000	FY 2001	FY 2002
Annual Performance Goal and APG #	Award 50 new graduate student research grants and 20 early career postdoctoral fellowships in Earth Science. (Y21). Conduct over 300 teacher workshops to train teachers in use of Earth Science Enterprise education products (Y22). Increase number of schools participating in GLOBE from to 8,000, from 5,900 in FY98, a 35-percent increase; increase participating countries from 70 in FY98 to 72 (Y23).	Award 50 new graduate student research grants and 20 early career fellowships in Earth Science (0Y30). Conduct at least 300 workshops to train teachers in use of ESE education products (0Y31). Increase number of schools participating in GLOBE to 10,500, a 30% increase over FY99; increase participating countries to 77 (from 72). (0Y32).	Increase public understanding of Earth system science through formal and informal education by meeting at least 3 of 4 performance targets in this area (1Y18).	Share NASA's discoveries in Earth science with the public to enhance understanding of science and technology (2Y24).
Assessment	Green	0Y30 was green. 0Y31 was blue. 0Y32 was yellow.	TBD	TBD

Objective: Develop advanced technologies to reduce the cost and expand the capability for scientific Earth observation/FY 99-01 Objective: Develop and transfer advanced remote-sensing technologies.

	FY 1999	FY 2000	FY 2001	FY 2002
Annual Performance Goal and APG #	Annually advance at least 25% of funded instrument technology developments one TRL (Y30). Demonstrate a new capability to double the calibration quality for moderate-resolution land imagery. (Y28). Annually transfer at least one technology development to a commercial entity for operational use (Y29).	Advance at least 25% of funded instrument technology development one TRL to enable future science missions and reduce their total cost (0Y35). Achieve a 50% reduction in mass for future land imaging instruments (0Y33). Transfer at least one technology development to a commercial entity for operational use (0Y34).	Achieve success with timely development and infusion of technologies. Enable future science missions by increasing technology readiness for mission concepts to reduce their total cost. Do this by meeting at least 3 of 4 performance indicators for this advanced technology area (1Y13).	Successfully develop and infuse technologies that will enable future science measurements, and/or improve performance and reduce the cost of existing measurements. Increase the readiness of technologies under development, advancing them to a maturity level where they can be infused into new missions with shorter development cycles (2Y25).
Assessment	Green	0Y35 was blue 0Y33 and 0Y34 were green	TBD	TBD

Objective: Develop advanced information systems for processing, archiving, accessing, visualizing, and communicating Earth science data.

	FY 1999	FY 2000	FY 2001	FY 2002
Annual Performance Goal and APG #				Develop hardware/software tools to demonstrate high-end computational modeling to further our understanding and ability to predict the dynamic interaction of physical, chemical and biological processes affecting the earth (2Y26). Develop baseline suite of multidisciplinary models and computational tools leading to scalable global climate simulations. (2Y27)
Assessment				TBD

Objective: Demonstrate scientific and technical capabilities to enable the development of practical tools for public and private-sector decision makers/FY 99-01 Strategic Objective: Extend the use of Earth Science research for regional, state, and local applications

	FY 1999	FY 2000	FY 2001	FY 2002
Annual Performance Goal and APG #	Establish at least five Regional Earth Science Applications Centers (RESACs) (Y31). Complete solicitation for seven co-operative agreements with State and local governments in areas of land use planning, land capability analysis, critical areas management, and water resource management (Y33). Establish at least eight new projects, with USDA, in the areas of vegetation mapping and monitoring, risk and damage assessment, resources management and precision agriculture (Y32).	At least one of seven Regional Earth Science Applications Center (RESAC) becomes self-sustaining. Continue funding for the remaining centers (0Y41). Develop two new validated commercial information products as a result of verification and validation partnerships with industry (0Y46). Implement at least five joint applications research projects/partnerships with State and local governments in remote – sensing applications (0Y43).	Provide regional decision-makers with scientific and applications products/tools by meeting at least 7 of 8 performance indicators for this applications research area (1Y14). Improve access to and understanding of remotely sensed data and processing technology by meeting 3 of 3 performance indicators in this area (1Y15).	Provide regional decision-makers with scientific and applications products and tools (2Y23).
Assessment	Blue	0Y41 was yellow 0Y46 and 0Y43 were green	TBD	TBD

Objective: Partner with other agencies to develop and implement better methods for using remotely sensed observations in Earth system monitoring and prediction/FY 99-01 Strategic Objective: Extend the use of Earth Science research for regional, state, and local applications.

	FY 1999	FY 2000	FY 2001	FY 2002
Annual Performance Goal and APG #				Collaborate with other Federal and international agencies in developing and implementing better methods for using remotely sensed observations (2Y28)
Assessment				TBD

FY 99-01 Objective: Support the development of a robust commercial remote sensing industry

	FY 1999	FY 2000	FY 2001	FY 2002
Annual Performance Goal and APG #	Establish at least 75 commercial partnerships in "value-added" remote sensing product development; an increase from 37 over FY97 (Y34).	Focus EOCAP joint commercial applications research to develop 20 new market commercial products (e.g., oil spill containment software by EarthSat and map sheets products by ERDAS, Inc.). (0Y44). Provide three commercial sources of science data (from the data buy) for global change research and applications (0Y45). Develop two new validated commercial information products as a result of verification and validation partnerships with industry (0Y46).	Stimulate the development of a robust commercial remote sensing industry by meeting at least 4 of 5 performance indicators in this area (1Y16). Increase efficiencies in food and fiber production with the aid of remote sensing by meeting the performance indicator in this area (1Y17).	
Assessment	Blue	0Y44 was yellow 0Y45 and 0Y46 were green	TBD	

FY 99-01 Strategic Objective: Make major scientific contributions to national and international environmental assessments

	FY 1999	FY 2000	FY 2001	FY 2002
Annual Performance Goal and APG #	Make significant contribution to World Meteorological Organization (WMO) Ozone Assessment by providing a lead chapter author and most of the global-scale data (Y26). Contribute model results of climate affects of measured aircraft emissions and provide report to IPCC assessment report (Y24). Make significant contributions to US. Regional/national assessments in partnership with U.S. Global Change Research Program agencies (Y25). Provide lead chapter author and most of the global-scale data and contributing researchers to the IPCC Assessment Report, sponsored by the United Nations Environment Programme and WMO (Y27).	Sponsor two regional national assessment studies of environmental variations and natural resources vulnerability (0Y48). (Green) Complete the contribution to the First National Assessment of the Potential Consequences of Climate Variability and Change: provide climate scenario information, support the national synthesis, conduct several regional U.S. analyses, and provide supporting research for sector analyses. Provide information to the U.S. National Assessment Coordination Office. (0Y5). (Green)	Note: incorporated into science objectives in FY01 and beyond	
Assessment	Green	Green		

FY 99-01 Strategic Objective: Make major scientific contributions to national and international environmental assessments (continued)

	FY 1999	FY 2000	FY 2001	FY 2002
Annual Performance Goal and APG #		Conduct the first regional international assessment in South Africa: quantify the effects of climate variability and management practices on the environment, publish in open literature, and provide analyses to IPCC for their 2000 assessment. (0Y6). Provide the first global, regional and country-by country forest cover inventory in support of national and international needs research, operational and policy communities. Publish and provide to IPCC and the International Geosphere-Biosphere Programme for their 2000 assessment report (0Y8).		
Assessment		0Y6 was yellow. 0Y8 was green.		

Earth Science Enterprise FY 2002	Budget Category	Earth Observing System	Earth Explorers	Operations	Research and Technology	Investments
2Y1: Increase understanding of global precipitation, evaporation and how the cycling of water is changing by meeting at least 3 of 4 performance indicators.		X		X	X	
2Y2: Increase understanding of global ocean circulation and how it varies on interannual, decadal, and longer time scales by meeting 2 of 2 performance indicators.				X	X	
2Y3: Increase understanding of global ecosystems change by meeting at least 3 of 4 performance indicators		X			X	
2Y4: Increase understanding of stratospheric ozone changes, as the abundance of ozone-destroying chemicals decreases and new substitutes increases by meeting 2 of 2 performance indicators.		X		X	X	
2Y5: Increase understanding of change occurring in the mass of the Earth's ice cover by meeting at least 3 of 4 performance indicators.		X	X		X	
2Y6: Increase understanding of the motions of the Earth, the Earth's interior, and what information can be inferred about the Earth's internal processes by meeting at least 4 of 5 performance indicators.			X		X	
2Y7: Increase understanding of trends in atmospheric constituents and solar radiation and the role they play in driving global climate by meeting at least 3 of 4 performance indicators.		X			X	
2Y8: Increase understanding about the changes in global land cover and land use and their causes by meeting at least 2 of 3 performance indicators.		X			X	
2Y9: Increase understanding of the Earth's surface and how it is transformed and how such information can be used to predict future changes by meeting at least 4 of 5 performance indicators.		X	X		X	

Earth Science Enterprise FY 2002	Budget Category	Earth Observing System	Earth Explorers	Operations	Research and Technology	Investments
2Y10: Increase understanding of the effects of clouds and surface hydrologic processes on climate change by meeting at least 4 of 5 performance indicators.		X			X	
2Y11: Increase understanding of how ecosystems respond to and affect global environmental change and affect the global carbon cycle by meeting at least 4 of 5 performance indicators.		X		X	X	
2Y12: Increase understanding of how climate variations induce changes in the global ocean circulation by meeting at least 4 of 6 performance indicators.		X			X	
2Y13: Increase understanding of stratospheric trace constituents and how they respond to change in climate and atmospheric composition by meeting 2 of 2 performance indicators.				X	X	
2Y14: Increase understanding of global sea level and how it is affected by climate change by meeting at least 2 of 3 performance indicators.					X	
2Y15: Increase understanding of the effects of regional pollution on the global atmosphere, and the effects of global chemical and climate changes on regional air quality by meeting at least 4 of 5 performance indicators.		X		X	X	
2Y16: Increase understanding of variations in local weather, precipitation and water resources and how they relate to global climate variation by meeting 2 of 2 performance indicators.		X		X	X	
2Y17: Increase understanding of the consequence of land cover and land use change for the sustainability of ecosystems and economic productivity by meeting at least 2 of 3 performance indicators.		X			X	

Earth Science Enterprise FY 2002	Budget Category	Earth Observing System	Earth Explorers	Operations	Research and Technology	Investments
2Y18: Increase understanding of the consequences of climate and sea level changes and increased human activities on coastal regions by meeting 2 of 2 performance indicators.		X			X	
2Y19: Increase understanding of the extent that weather forecast duration and reliability can be improved by new space-based observations, data assimilation and modeling by meeting at least 2 of 3 performance indicators.				X	X	
2Y20: Increase understanding of the extent that transient climate variations can be understood and predicted by meeting at least 4 of 5 performance indicators.		X		X	X	
2Y21: Increase understanding of the extent that long-term climate trends can be assessed or predicted by meeting at least 4 of 5 performance indicators.					X	
2Y22: Increase understanding of the extent that future atmospheric chemical impacts on ozone and climate can be predicted by meeting at least 2 of 3 performance indicators.					X	
2Y23: Provide regional decision-makers with scientific and applications products and tools.					X	
2Y24: Share NASA's discoveries in Earth science with the public to enhance understanding of science and technology.					X	
2Y25: Successfully develop and infuse technologies that will enable future science measurements, and/or improve performance and reduce the cost of existing measurements. Increase the readiness of technologies under development, advancing them to a maturity level where they can be infused into new missions with shorter development cycles.					X	

Earth Science Enterprise FY 2002	Budget Category	Earth Observing System	Earth Explorers	Operations	Research and Technology	Investments
2Y26: Develop hardware/software tools to demonstrate high-end computational modeling to further our understanding and ability to predict the dynamic interaction of physical, chemical and biological processes affecting the earth.					X	
2Y27: Develop baseline suite of multidisciplinary models and computational tools leading to scalable global climate simulations by meeting at least 2 of 3 performance indicators.					X	
2Y28: Collaborate with other Federal and international agencies in developing and implementing better methods for using remotely sensed observations.					X	
2Y29: Successfully develop, have ready for launch, and operate instruments on at least two spacecraft to enable Earth Science research and applications goals and objectives.		X	X		X	
2Y30: Successfully disseminate Earth Science data to enable our science research and applications goals and objectives. Success will equate to meeting 4 of 5 performance indicators.		X			X	
2Y31: Safely operate airborne platforms to gather remote and in situ earth science data for process and calibration/validation studies.					X	