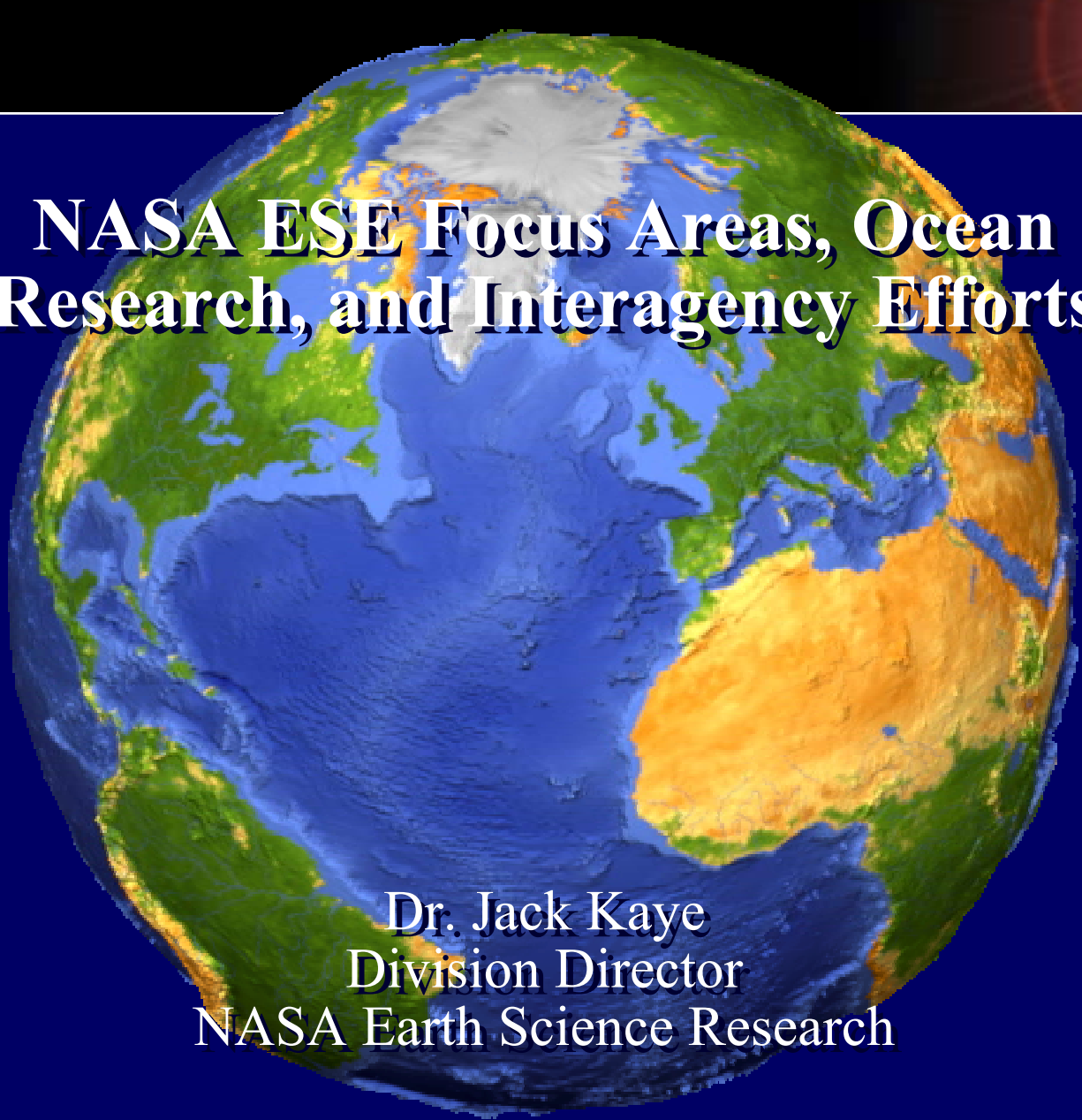
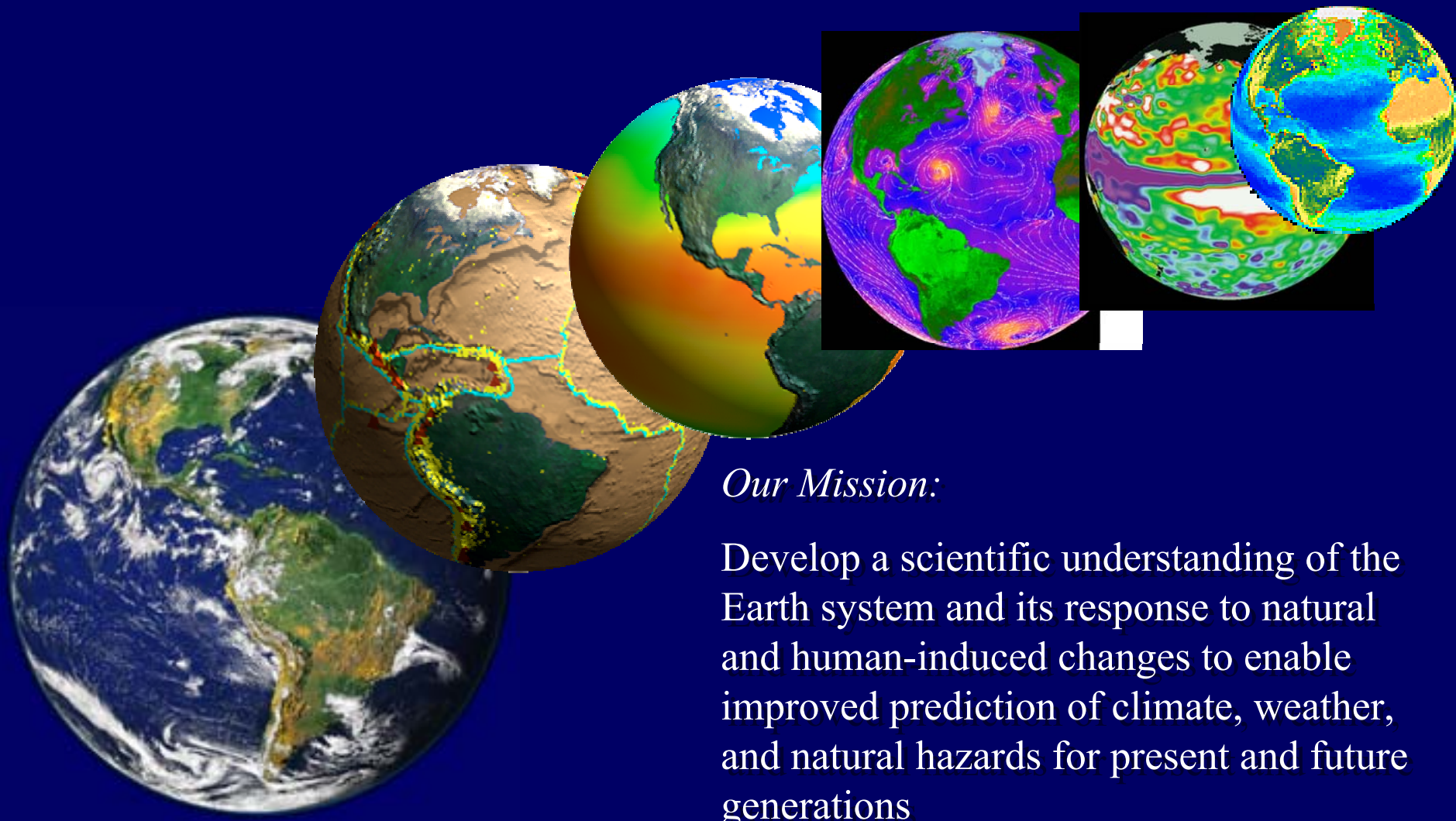


NASA ESE Focus Areas, Ocean Research, and Interagency Efforts

Dr. Jack Kaye
Division Director
NASA Earth Science Research


The NASA Vision
To improve life here,
To extend life to there,
To find life beyond.
The NASA Mission
To understand and protect our home planet,
To explore the universe and search for life,
To inspire the next generation of explorers
... as only NASA can.

Earth Science Enterprise



Our Mission:

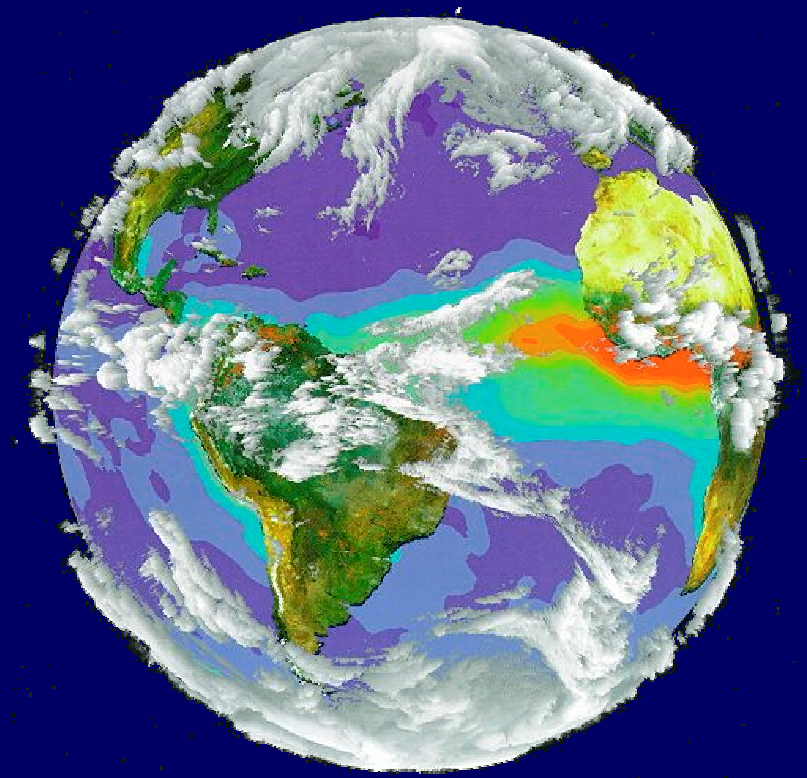
Develop a scientific understanding of the Earth system and its response to natural and human-induced changes to enable improved prediction of climate, weather, and natural hazards for present and future generations

ESE Overview: What NASA's ESE Does . . .

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

GOALS

1. Observe, understand, and model the Earth system to learn how it is changing, and the consequences for life on Earth
2. Expand and accelerate the realization of economic and societal benefits from Earth science, information, and technology
3. Develop and adopt advanced technologies to enable mission success and serve national priorities

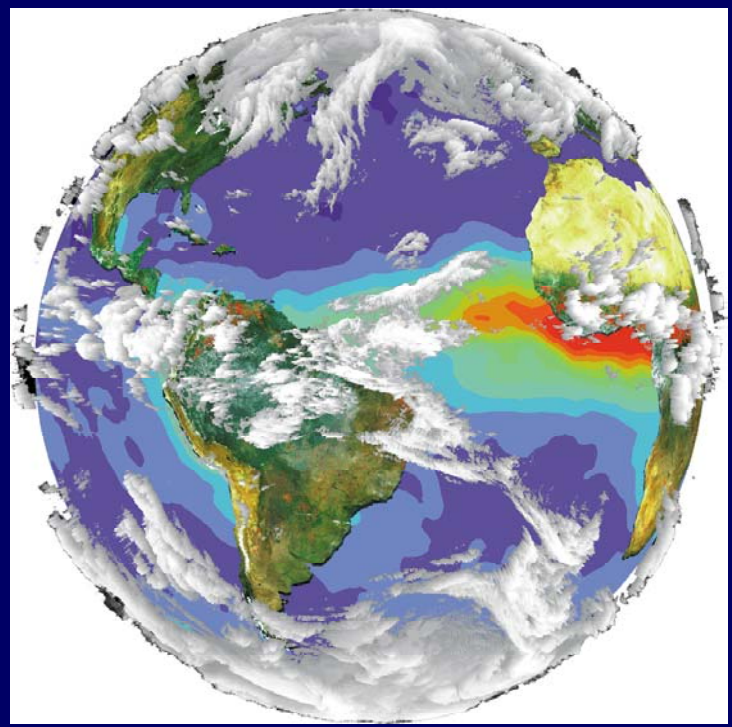


We provide objective, scientific information for decision-makers

ESE Overview

Within and Among Time Scales, A Complex Set of Forces and Feedbacks Result in a Wide Range of Responses and Impacts

Forces Acting on the Earth System

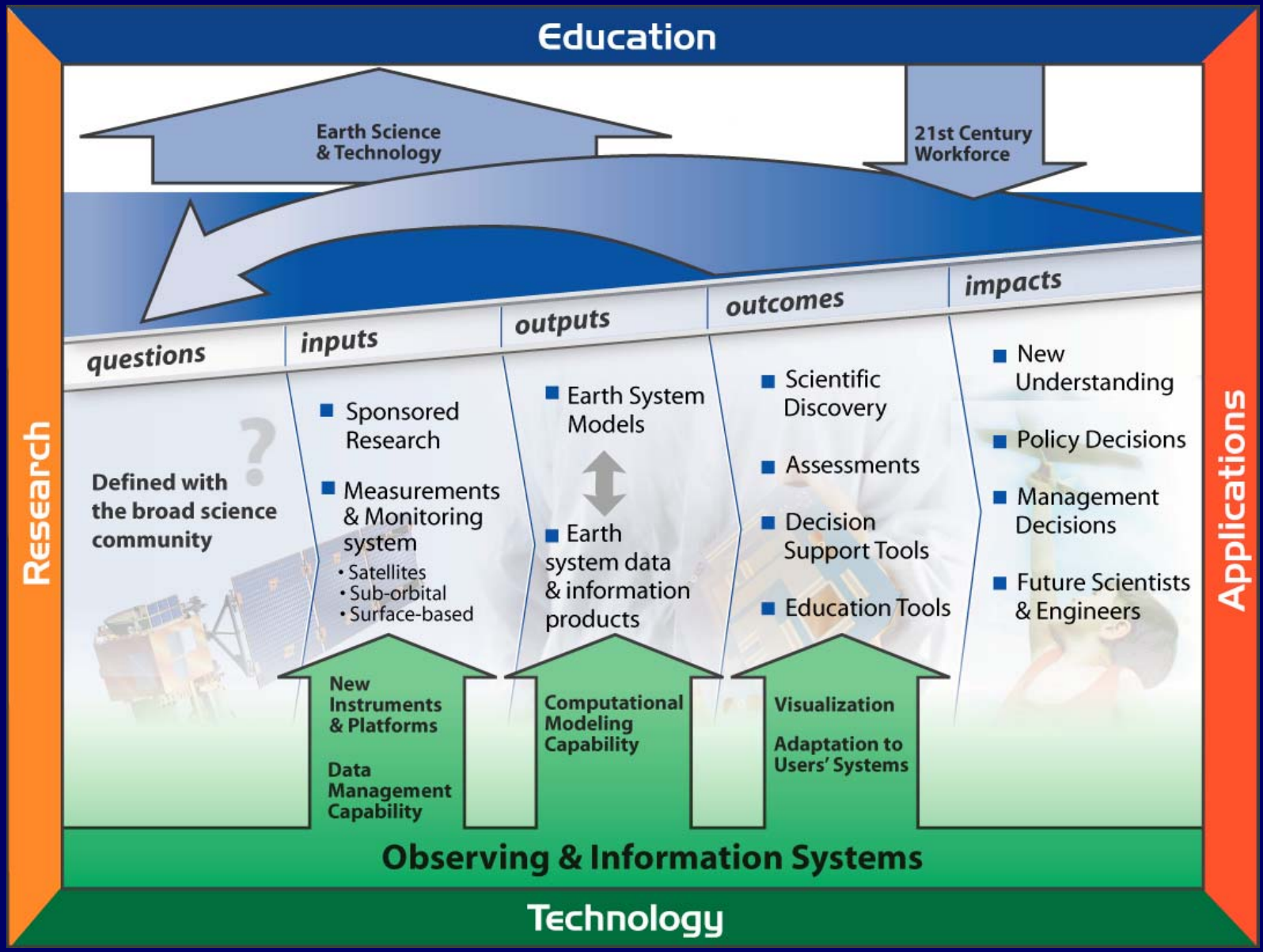


Earth System Response

Consequences

Feedback

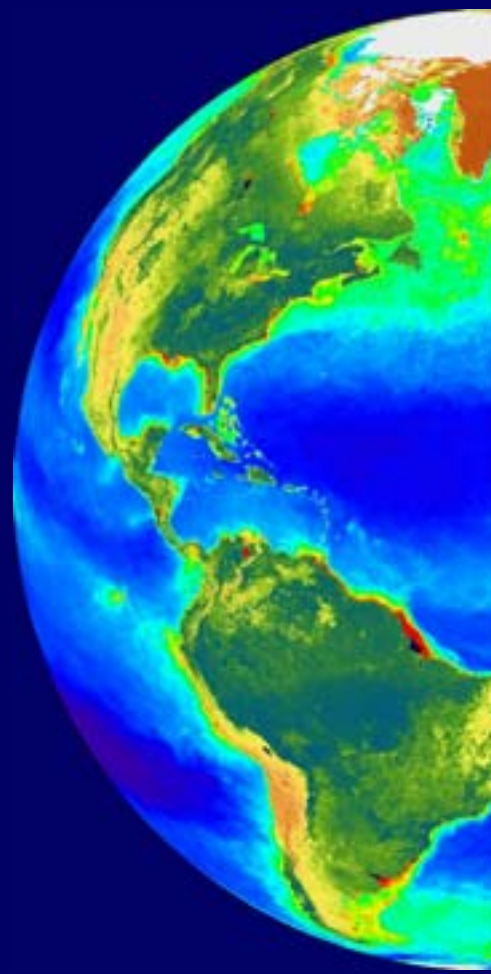
ESE Research is Part of an End-to-End Program of Science for Society



ESE Research Summary Questions

How is the Earth Changing and What Are the Consequences for Life on Earth?

- How is the global Earth system *changing*?
- What are the primary *forcings* of 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 well can we *predict* future changes in the Earth system?



Science Questions and Focus Areas

Variability	Forcing	Response	Consequence	Prediction
Precipitation, evaporation & cycling of water changing?	Atmospheric constituents & solar radiation on climate?	Clouds & surface hydrological processes on climate?	Weather variation related to climate variation?	Weather forecasting improvement?
Global ocean circulation varying?	Changes in land cover & land use?	Ecosystems, land cover & biogeochemical cycles?	Consequences of land cover & land use change?	Improve prediction of climate variability & change?
Global ecosystems changing?	Motions of the Earth & Earth's interior?	Changes in global ocean circulation?	Coastal region impacts?	Ozone, climate & air quality impacts of atmospheric composition?
Atmospheric composition changing?		Atmospheric trace constituents responses?	Regional air quality impacts?	Carbon cycle & ecosystem change?
Ice cover mass changing?		Sea level affected by Earth system change?		Change in water cycle dynamics?
Earth surface transformation?				Predict & mitigate natural hazards from Earth surface change?

Climate Variability and Change
Carbon Cycle and Ecosystems
Water and Energy Cycle
Atmospheric Composition
Weather
Earth Surface and Interior

ESE Research Focus Areas

- Build Program around 6 interdisciplinary focus areas
  - Carbon cycle/biogeochemical cycles, and ecosystems
  - Global water and energy cycle
  - Weather
  - Atmospheric Composition
  - Climate Variability and Change
  - Earth Structure and Interior

- Approaches and milestones are outlined in the ESE Roadmaps
  - *http://earth.nasa.gov/roadmaps/*

The Roadmapping Challenge

- Need to be able to demonstrate goal at end of reasonable time interval (e.g., decade)
  - Scientific knowledge
  - Societally relevant products and their impacts
- Need to demonstrate connection between where we are now and where we expect to be
- Need to show that different components of ESE research are integrated into uniform whole
- Need to demonstrate availability of intermediate milestones (focusing on "outcomes" and not "outputs")
- Need to show interconnectedness of research activities (no "stovepipies")
- Need to give sense of relationship of NASA activities to those of our partners

Roadmap Organizing Principles

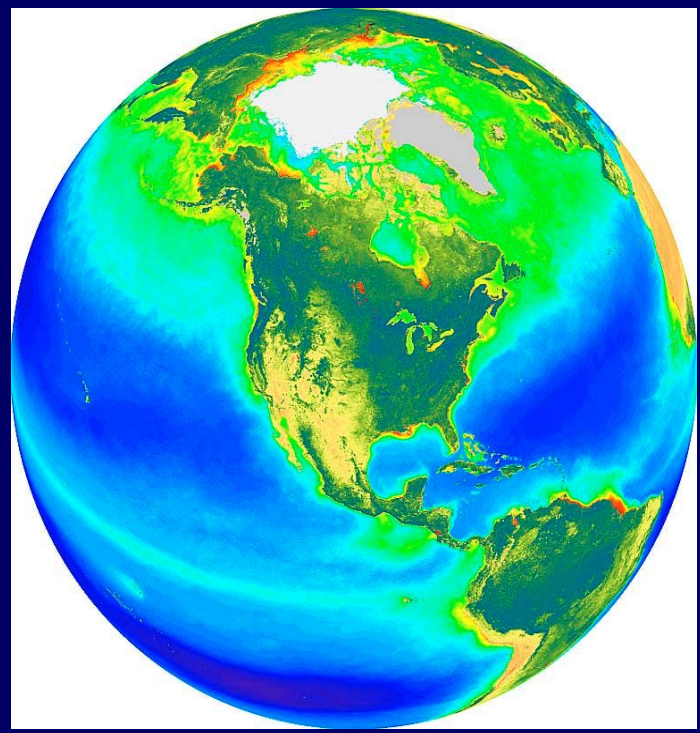
- Start showing sense of where we are and give vision of where we intend to be
- Indicate “base” of activities that supports other activities, esp. systematic measurements and partner-supplied information
- Provide sense of improved knowledge based on continuing research based on current information and capability
- Show inputs and corresponding outcomes based on current investments for present and near-term inputs
- Indicate longer lead term items that require technology development
- Provide some sense of what’s likely to be doable within present program and what is not

Roadmap Example: Carbon and Ecosys.

Knowledge of the interactions of global biogeochemical cycles and terrestrial and marine ecosystems with global environmental change and their implications for the Earth's climate, productivity, and natural resources is needed ***to understand and protect our home planet.***

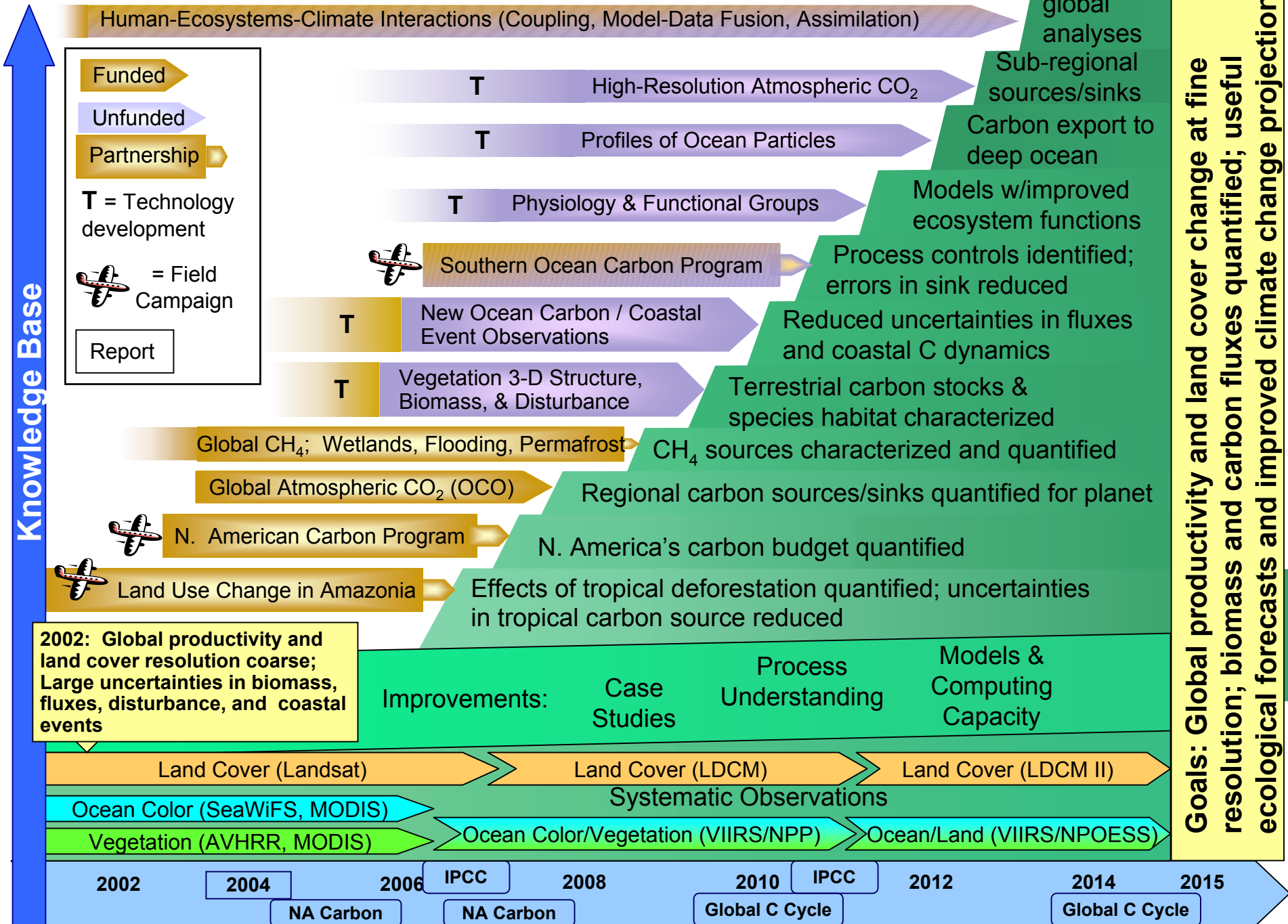
Important Concerns:

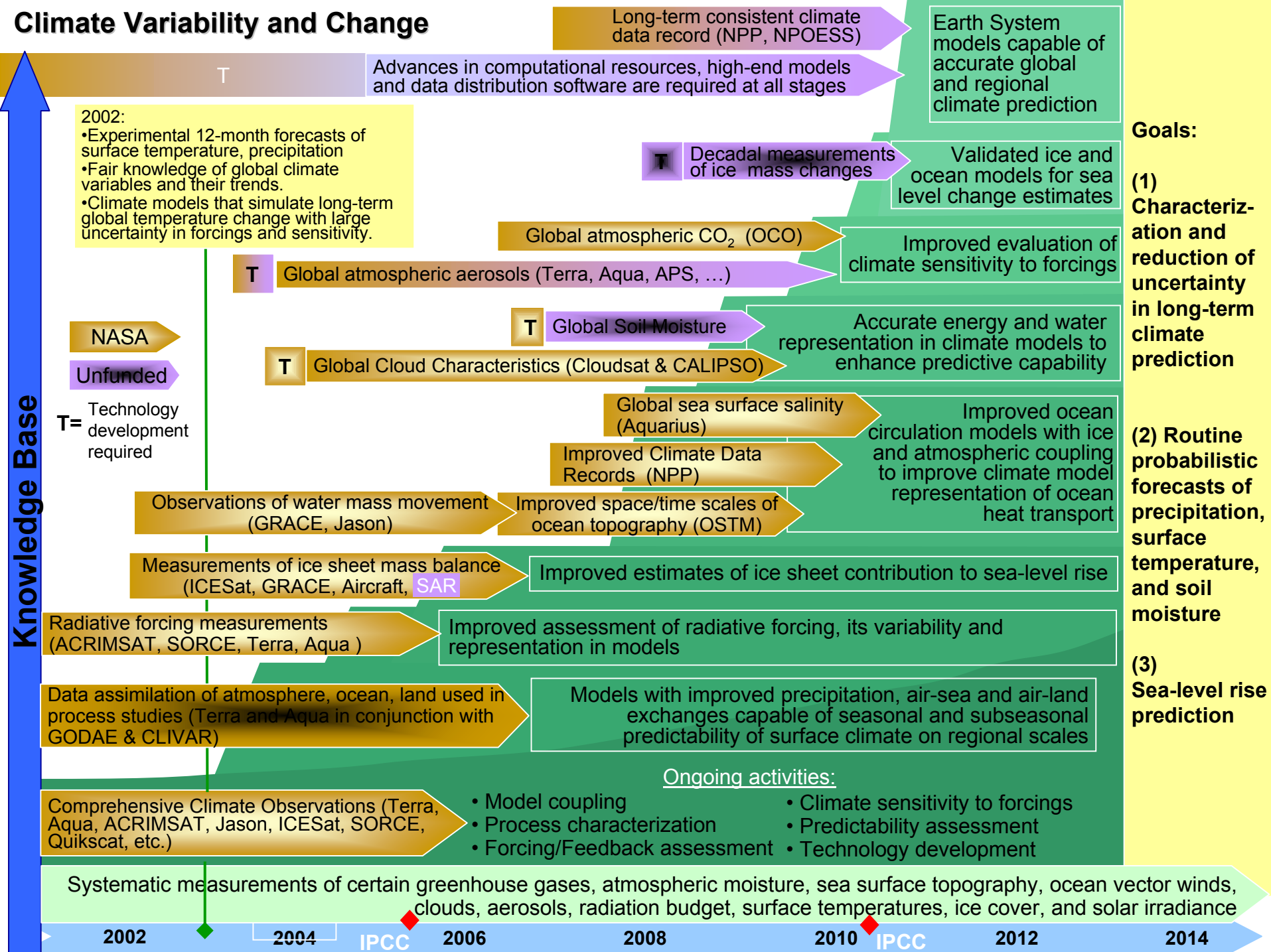
- **Potential greenhouse warming (CO_2, CH_4) and ecosystem interactions with climate**
- **Carbon management (e.g., capacity of plants, soils, and the ocean to sequester carbon)**
- **Productivity of ecosystems (food, fiber, fuel)**
- **Ecosystem health and the sustainability of ecosystem goods and services**
- **Biodiversity and invasive species**



NASA provides the global perspective and unique combination of interdisciplinary science, state-of-the-art Earth system modeling, and diverse synoptic observations needed to document, understand, and project carbon cycle dynamics and changes in terrestrial and marine ecosystems and land cover.

Carbon Cycle and Ecosystems




Climate Variability and Change
Long-term consistent climate data record (NPP, NPOESS)
Earth System models capable of accurate global and regional climate prediction
T
Advances in computational resources, high-end models and data distribution software are required at all stages
2002:
•Experimental 12-month forecasts of surface temperature, precipitation
•Fair knowledge of global climate variables and their trends.
•Climate models that simulate long-term global temperature change with large uncertainty in forcings and sensitivity.
T
Decadal measurements of ice mass changes
Validated ice and ocean models for sea level change estimates
Global atmospheric CO_2 (OCO)
Improved evaluation of climate sensitivity to forcings
T
Global atmospheric aerosols (Terra, Aqua, APS, …)
NASA
Unfunded
T= Technology development required
T
Global Soil Moisture
Accurate energy and water representation in climate models to enhance predictive capability
T
Global Cloud Characteristics (Cloudsat & CALIPSO)
Global sea surface salinity (Aquarius)
Improved ocean circulation models with ice and atmospheric coupling to improve climate model representation of ocean heat transport
Improved Climate Data Records (NPP)
Observations of water mass movement (GRACE, Jason)
Improved space/time scales of ocean topography (OSTM)
Measurements of ice sheet mass balance (ICESat, GRACE, Aircraft, SAR
Improved estimates of ice sheet contribution to sea-level rise
Radiative forcing measurements (ACRIMSAT, SORCE, Terra, Aqua)
Improved assessment of radiative forcing, its variability and representation in models
Data assimilation of atmosphere, ocean, land used in process studies (Terra and Aqua in conjunction with GODAE & CLIVAR)
Models with improved precipitation, air-sea and air-land exchanges capable of seasonal and subseasonal predictability of surface climate on regional scales
Ongoing activities:
Comprehensive Climate Observations (Terra, Aqua, ACRIMSAT, Jason, ICESat, SORCE, Quikscat, etc.)
• Model coupling
• Process characterization
• Forcing/Feedback assessment
• Climate sensitivity to forcings
• Predictability assessment
• Technology development
Systematic measurements of certain greenhouse gases, atmospheric moisture, sea surface topography, ocean vector winds, clouds, aerosols, radiation budget, surface temperatures, ice cover, and solar irradiance
Knowledge Base
2002
2004
IPCC
2006
2008
2010
IPCC
2012
2014
Goals:
(1) Characterization and reduction of uncertainty in long-term climate prediction
(2) Routine probabilistic forecasts of precipitation, surface temperature, and soil moisture
(3) Sea-level rise prediction

Organizing Earth System Science Research

- Earth system is sufficiently complex that implementing program requires it be "taken apart" to be "put back together"
  - No unique way to do this
- Earth system is sufficiently interlinked that no way of taking it apart doesn't separate tightly linked processes
  - Need to assure interdisciplinary science is addressed
- Organizing structure can take advantage of unique elements of Earth system
  - Presence of life
  - Presence of water in multiple interacting phases
  - Oxidizing atmosphere
  - Surface made up of water and land

Earth Science Applications Program

Program Purpose

Program to help NASA facilitate transfer and use of Earth science results by partners

Support transition of research to operations

Buttress arguments for need for continuous / increased Earth science observations and models

research ↔ operations

Focus & Scope

Extend Earth science results to partners' Decision Support Systems (DSS)

- National/regional level

- DSSs owned and operated by partners

- Funds to develop prototype products (observations, model outputs) to enable integration in DSSs

- Not applied science

Coastal Application

Topics / DSS:

HAB (NOAA, NRL)
HAB Bulletin/Mapping

Coral Reefs (NOAA)
CREWS, ReefBase

Oil Spills (NOAA, USCG)
GNOME

Fisheries (NOAA)

Solicitation: Spring 2004

Contacts:

Lawrence Friedl,
202-358-1599
Callie Hall, 228-688-2360

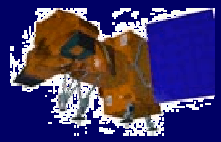
Recent Milestones

- Enhance the science base:
  - **Coral reef health from spectral analyses and remote sensing**
  - **Sea grass assessment and productivity from remote sensing**
  - **Ocean signatures of harmful algal blooms**
  - **Ultraviolet aerosol measurements of iron-containing mineral dust**
  - **First global maps of marine and terrestrial biosphere**
  - **The role of the Antarctic Ocean in absorbing atmospheric carbon dioxide**
  - **First support of biodiversity (coral reefs, ecological modeling) in Interdisciplinary Science NRA**
- Enhance observing & monitoring systems:
  - **Together with partners launched five space observation missions: SAGE III, Jason-1, GRACE, Aqua and POES (NOAA-M) in FY02, and 3 so far in FY03 (SeaWinds/ADEOS-II, ICESat, SORCE)**
  - **Conducted CRYSTAL-FACE campaign (FY02), SOLVE II (FY03), Precipitation validation mission (Japan, FY03), Chilean sea ice observations, Cold Land Processes and Soil Moisture Field Experiments**
- Improve decision support tools:
  - **QuikSCAT data being employed in operational weather forecasts**
  - **TRMM data being employed by NOAA for seasonal climate prediction**
- Enhance exploratory research:
  - **Selected / matured 38 new instrument concepts for future observing techniques**
  - **Initiated partnership with NSF, NOAA, DOE, and 15 universities to develop a common modeling framework**

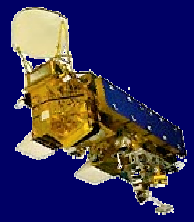
Multiple Satellite Observations Provide New Global Perspectives

The Earth Observing System - - systematic measurement of interactions among land, oceans, atmosphere, ice & life

Exploratory missions to probe key Earth system processes globally for the first time



Landsat



Aqua

TRMM

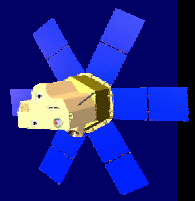
GRACE

Jason

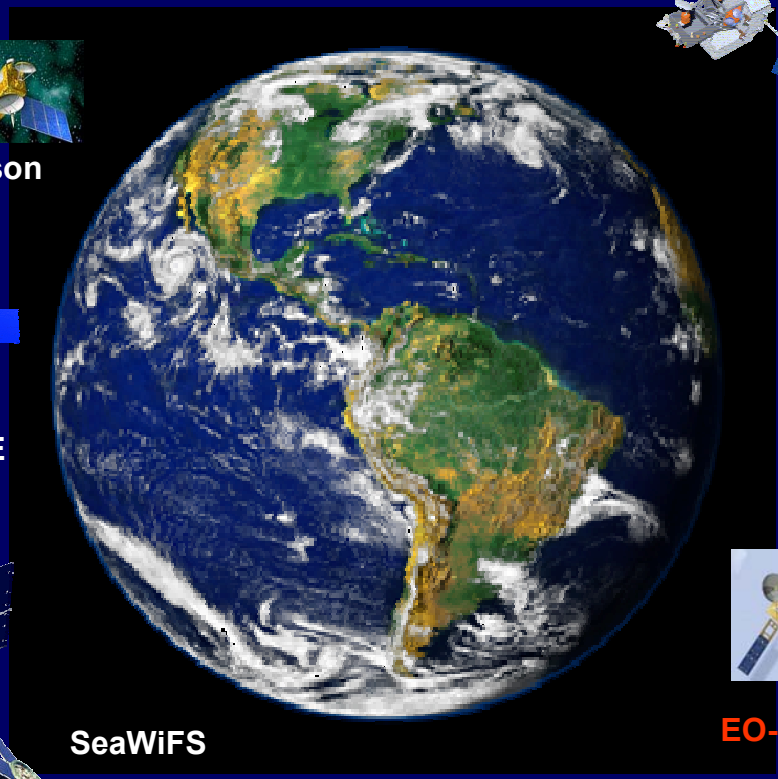
Terra

CALIPSO

Cloudsat

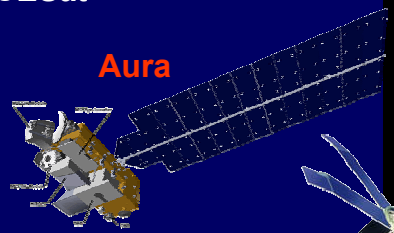


SORCE

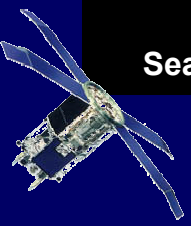


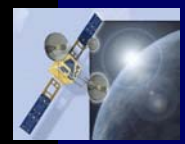
SeaWiFS

ICESat



Aura





EO-3: GIFTS

EO-1: ALI & Hyperion

Launched

In Development

Operational precursor / Technology demos

ESE Research Solicitations

- Selected in 2003/2004
  - New Investigator Program in Earth Science
  - Solid Earth and Natural Hazards Research and Applications
  - Earth System Science Fellowship
  - Advanced Component Technology (ACT) Program
  - Atmospheric Chemistry Modeling and Analysis Program (ACMAP)
  - Instrument Incubator Program
  - Advanced Information Systems Technology (AIST) Program
  - Earth Science REASoN - Research, Education and Applications Solutions Network
  - Radiation Science Program
  - Research Opportunities for Precipitation Measurement Missions
  - NPP Science Team
  - Interdisciplinary Science Earth System Science Investigations using EOS Data

- Solicitations Closed, Under Review
  - Carbon Cycle Science
- Open Solicitations [due date]
  - Oceans and Ice [4 May 2004]

* Get announcements at http://research.hq.nasa.gov/code_y

Upcoming Research Opportunities

- Science NRAs
  - Water & Energy Cycle
  - Modeling & Analysis
- Applications & Education
  - Integrated Systems Solutions
  - Solutions Networks
  - Earth Science Explorers (K-16 & informal)
  - Graduate Student Fellowships
  - Earth Science Outreach
- Missions & Technology
  - Announcements of Opportunity in two mission classes
  - Instrument Incubator
  - Earth System Science Pathfinder

A Vision of the Future:
Enabling Earth System Prediction

	TODAY	Goals for 2010
Weather	3-Day forecast at 93%* 7 Day forecast at 62%* 3 day rainfall forecast not achievable Hurricane landfall +/-400Km at 2-3 days Air quality day by day	5-Day forecast at >90%* 7-10 Day forecast at 75%* 3 day rainfall forecast routine Hurricane landfall +/-100Km at 2-3 days Air quality forecast at 2 days
Climate	6-12 month seasonal prediction experimental; achieved an understanding of El Nino mechanics Decadal climate prediction with coarse models and significant uncertainties in forcing and response factors	6-12 month seasonal prediction routine; 12-24 months experimental 10 year climate forecasts experimental; moderate to high confidence in forcing & response factors
Natural Hazards	Demonstrate centimeter-level measurement of land deformation Accurate characterization of long-term tectonic motions, but no short-term earthquake forecast capability Accurate characterization of volcanic activity, but no long-term prediction accuracy	Continuous monitoring of surface deformation in vulnerable regions with millimeter accuracy Improved temporal dimension of earthquake & volcanic eruption forecasts Improve post-eruption hazard assessment

** Accuracy refers to sea level pressure forecasts over Northern Hemisphere during winter.*

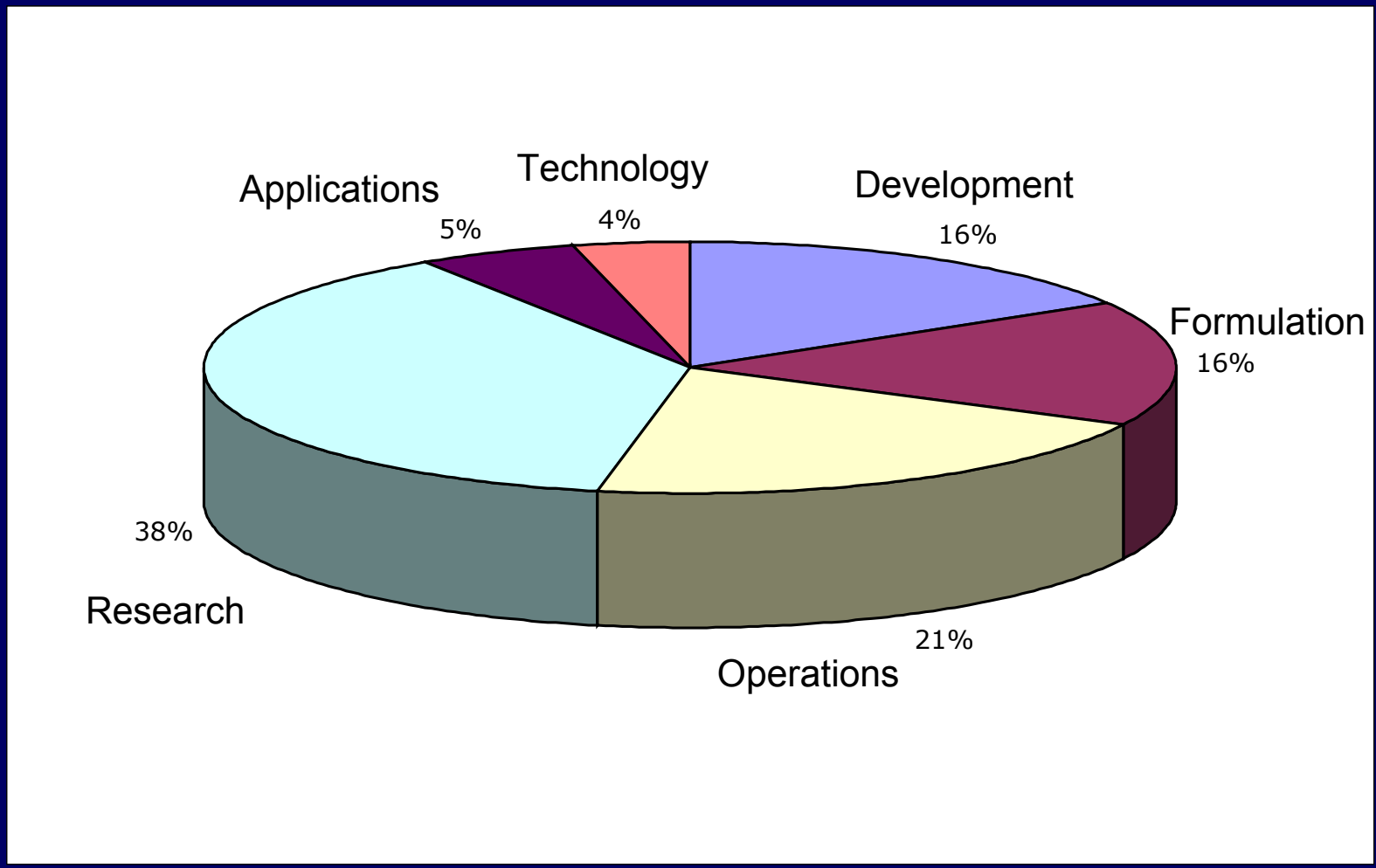
Earth Science FY05 Budget

The President's budget request for FY05 includes:

- **$99 million for the Climate Change Research Initiative, making NASA the largest contributor to the interagency Climate Change Science Program (CCSP)**
- **$141 million for development of the NPOESS Preparatory Project (NPP), 36% above FY04. NPP in full implementation**
- **$42 million to maintain critical work on Landsat continuity**
- **$560 million for research, data analysis and modeling, 7% above FY04, allowing research on data from 80 sensors on 18 operating satellites**
- **$240 million for missions in formulation, a 37% increase from FY 2004, including such missions as Orbiting Carbon Observatory, Aquarius, Hydros, and Glory**

$ In Millions	FY 2004	FY 2005	FY 2006	FY 2007	FY 2008	FY 2009
Earth Science	**1,613**	**1,485**	**1,390**	**1,368**	**1,343**	**1,474**
Earth System Science	1,522	1,409	1,313	1,290	1,266	1,397
Earth Science Applications	91	77	77	77	77	77

ESE Investment Portfolio



Summary

- NASA is well integrated into the interagency CCSP and fills a specific research niche by providing space-based observations of climate change and key deliverables for goals in the Strategic Plan's Synthesis and Assessment Reports
- NASA's ESE research program is designed to answer key scientific questions on variability, forcing, response, consequences, and prediction for the Earth system
- NASA research will answer specific questions regarding climate change posed by the Administration