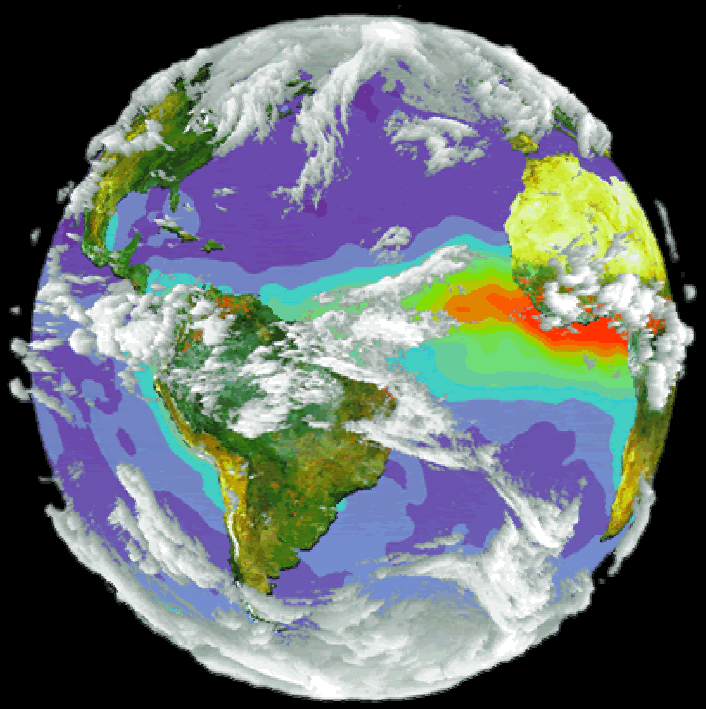
Science for Society



March 13, 2003

v. 3.5 March 2003

"Accelerating the realization of economic and societal benefits from Earth science, information, and technology …"

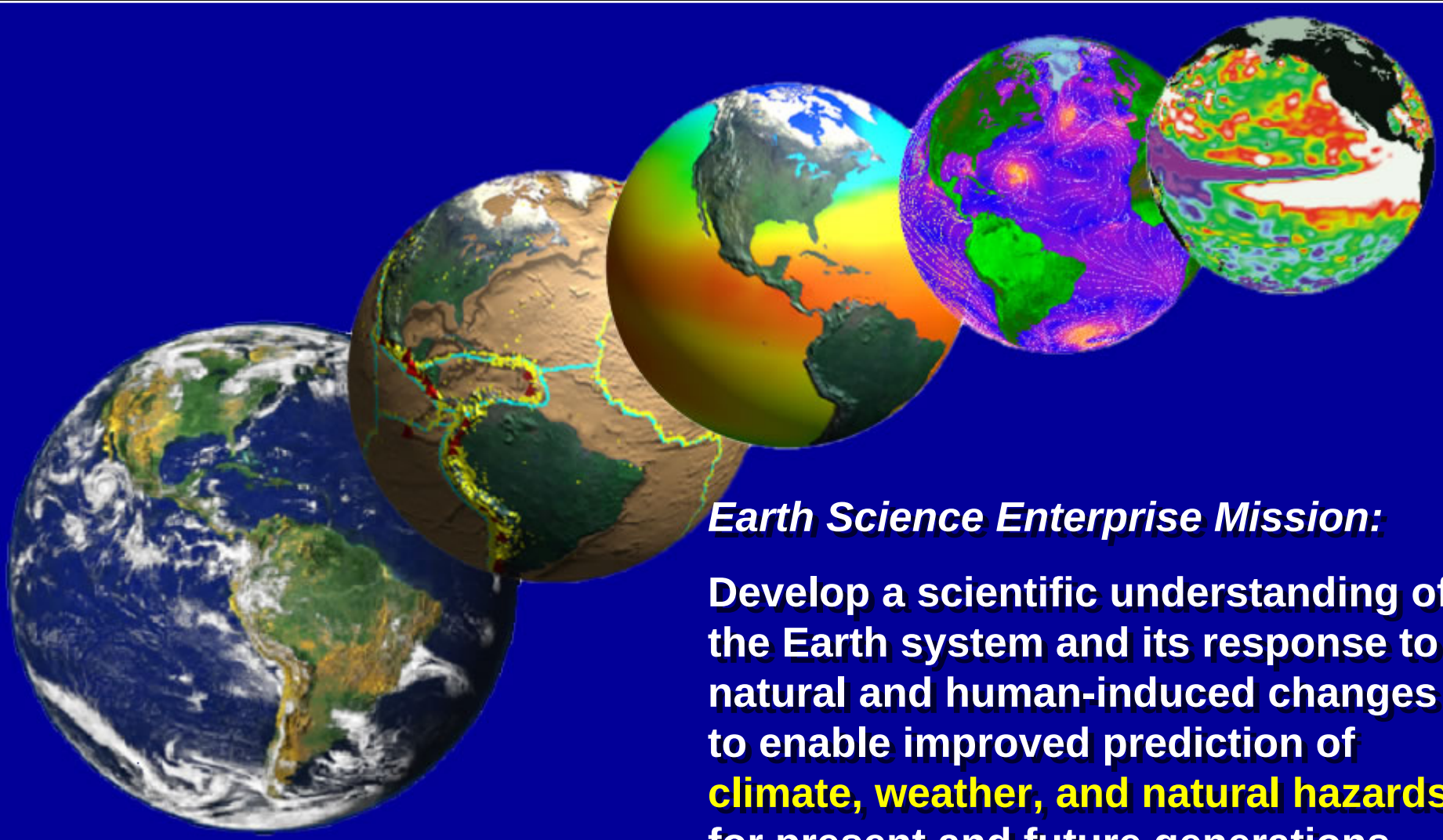
The NASA Vision

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.

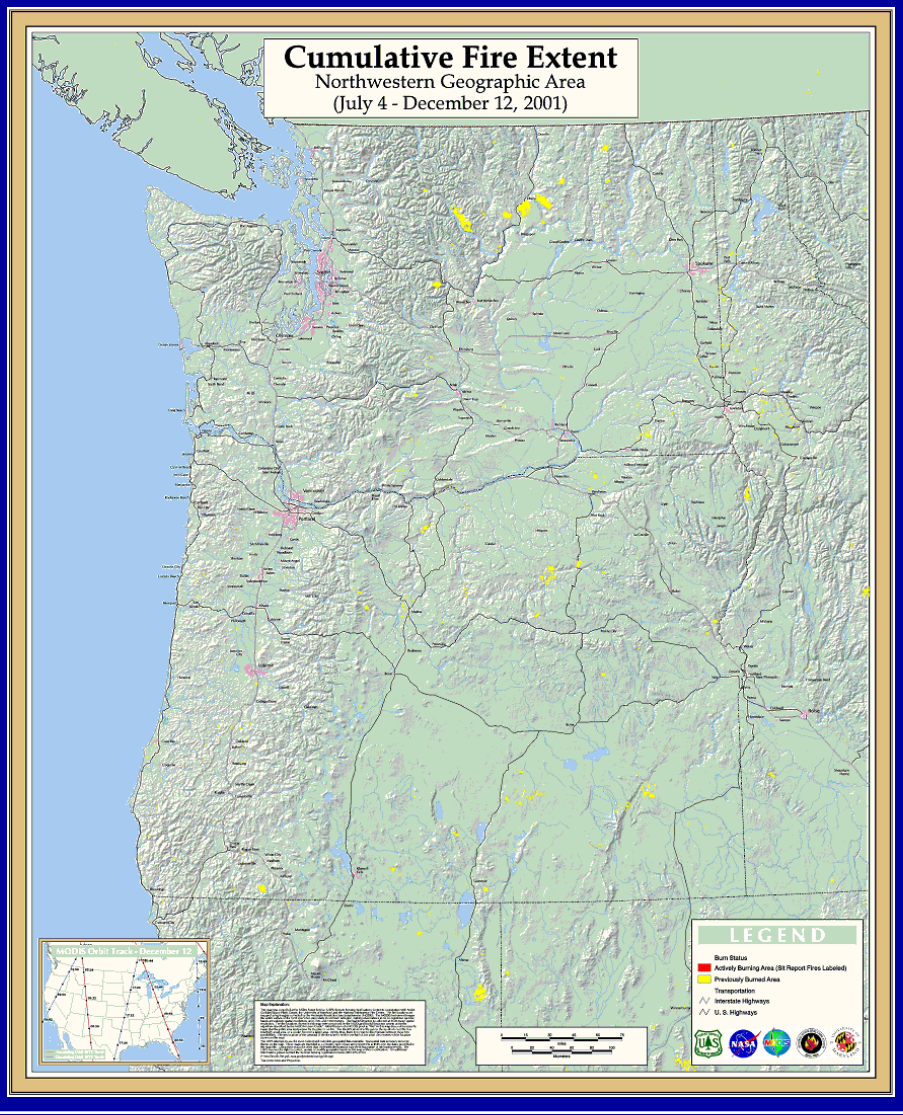
“Understand And Protect Our Home Planet”



Earth Science 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

Managing Wildfires

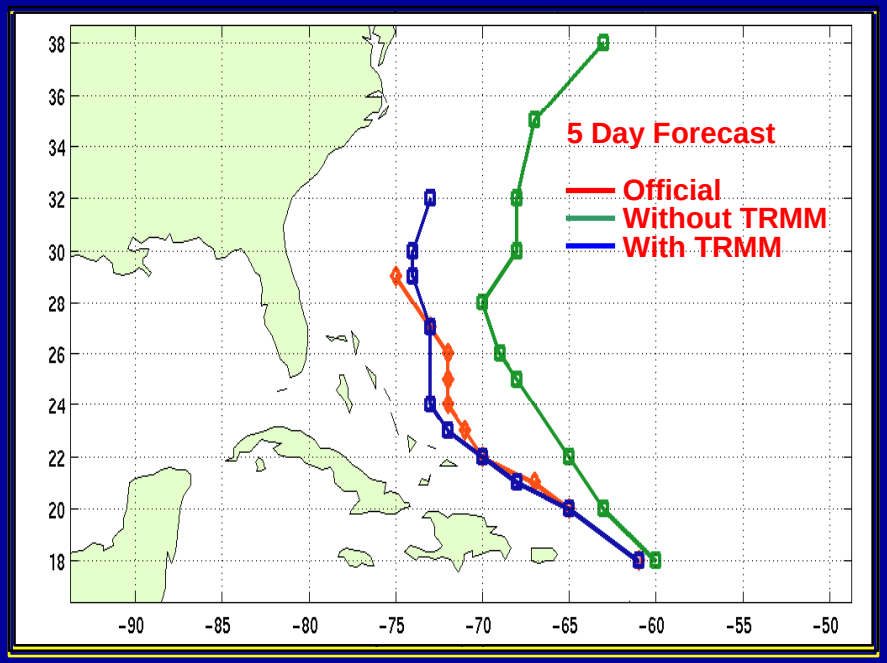


The U.S. Forest Service has established two direct broadcast receiving installations to acquire Terra satellite data, and enable daily, near real-time distribution and decision making on allocation of firefighting assets.

Improving Hurricane Track Forecasts

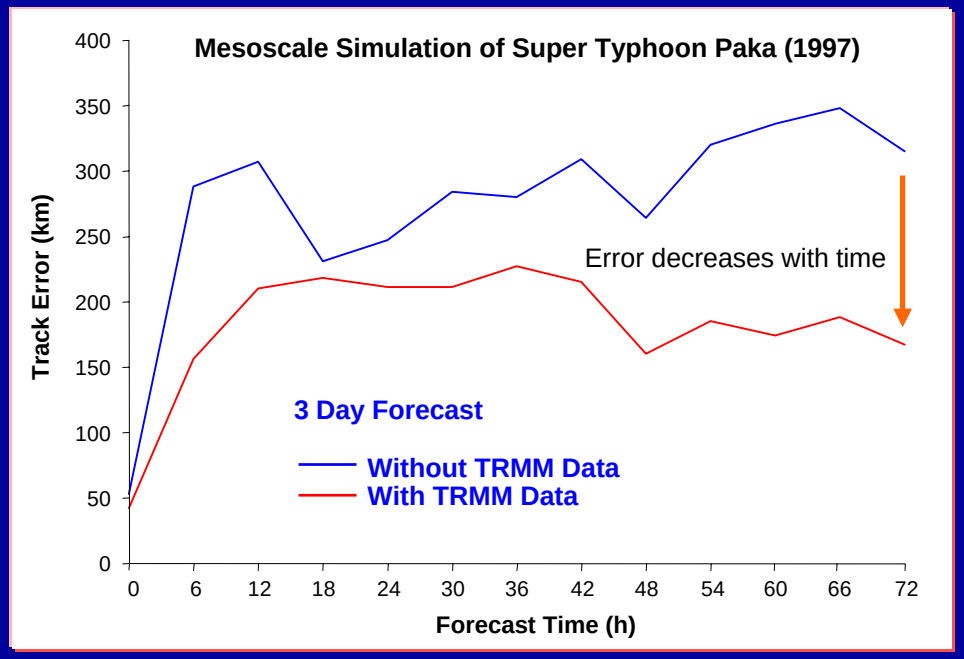
Assimilation of TRMM rainfall location, intensity, and vertical structure into hurricane forecast models leads to improvements in forecasts of future position

Hurricane Bonnie, Atlantic, Aug 1998



Dr. A. Hou, NASA DAO

Hurricane Visualization with TRMM data



Dr. X. Pu, NASA GSFC

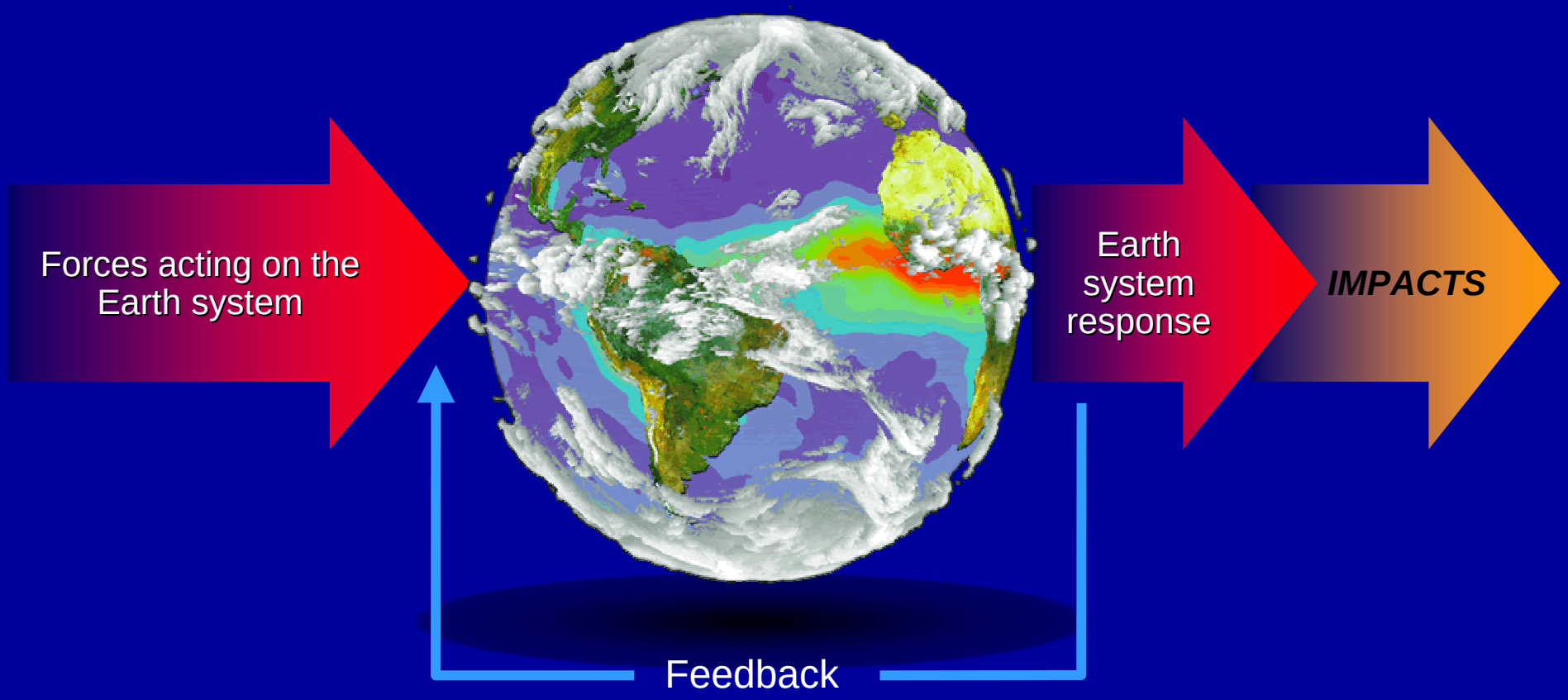
Reduced track errors can save money ($600K - $1M per mile of coast evacuated) and save lives by more precise prediction of eye location at landfall

Statement of Purpose

- **NASA Earth Science Enterprise Applications**
- **conducts research and development of aerospace science and technology**
  - **to increase knowledge of the Earth system**
  - **to improve decision support tools to serve society**

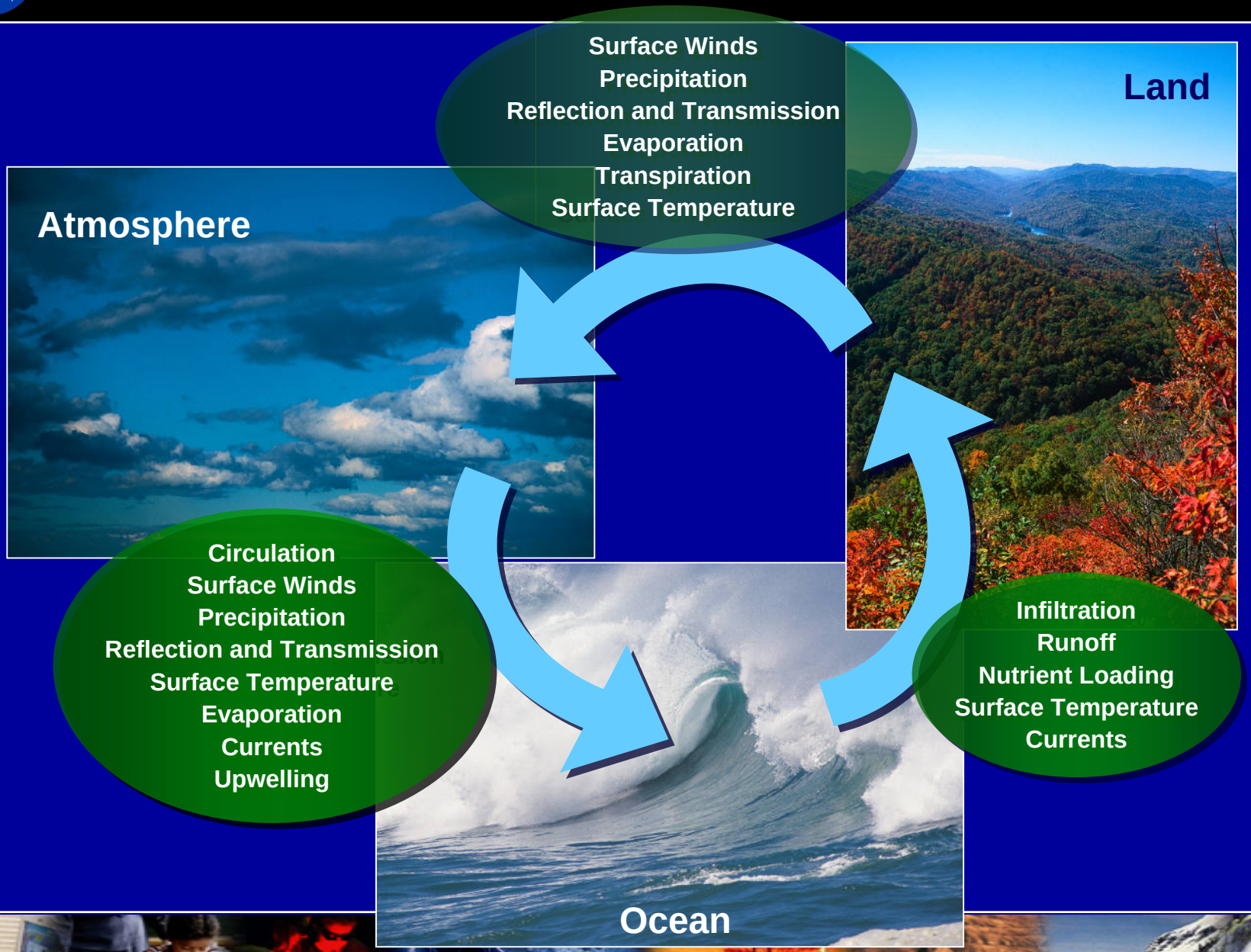
NASA conducts systems engineering and scientific research to serve Earth system science solutions focused on national priorities -- including economic security and homeland security.

Studying Earth as a Dynamic System



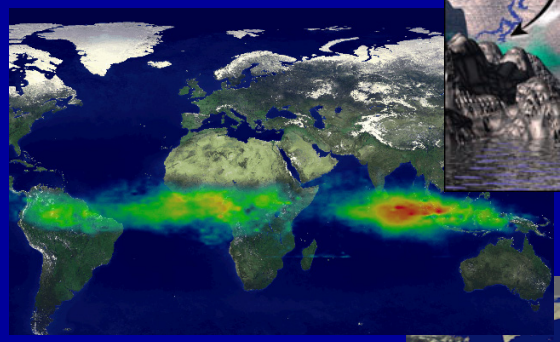
Of the total forcing of the climate system, 40% is due to the direct effect of greenhouse gases and aerosols and 60% is from feedback effects, such as increasing concentrations of water vapor as temperature rises.

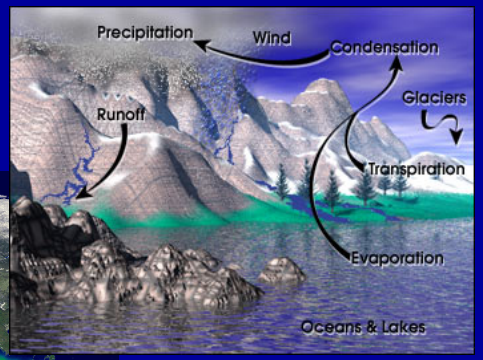
Studying Earth as a Complex System

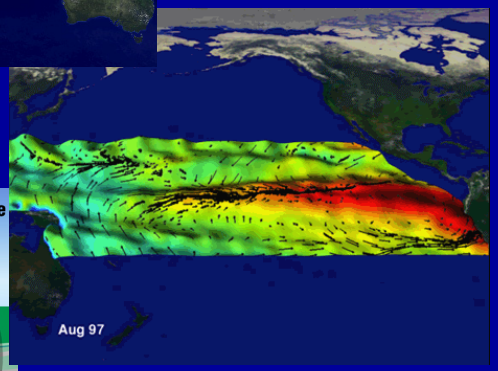


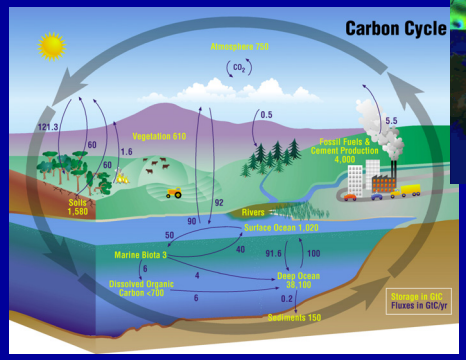
Earth Science Research Areas

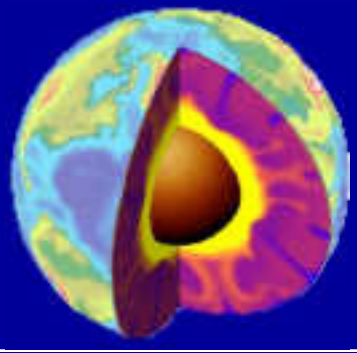
- **Climate Variability**
- **Atmospheric Composition**
- **Ecosystems & Carbon Cycle**
- **Water & Energy Cycle**
- **Weather Research**
- **Solid Earth Science**





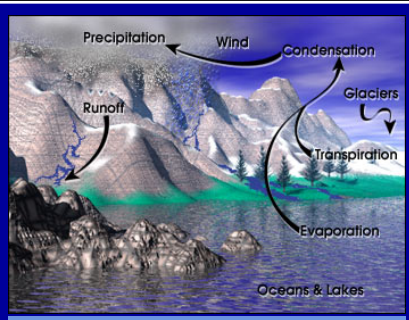


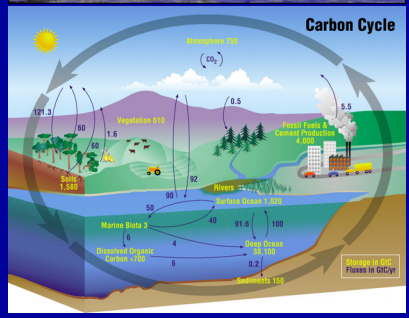


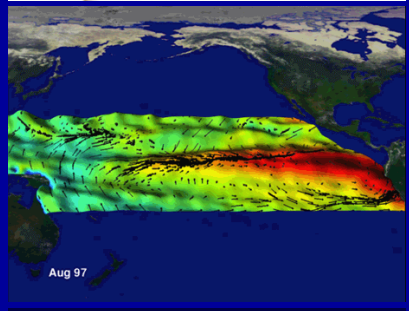


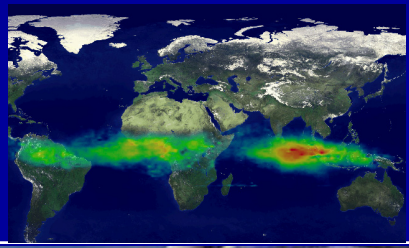
Researching Science Questions

- **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 to the Earth system?**

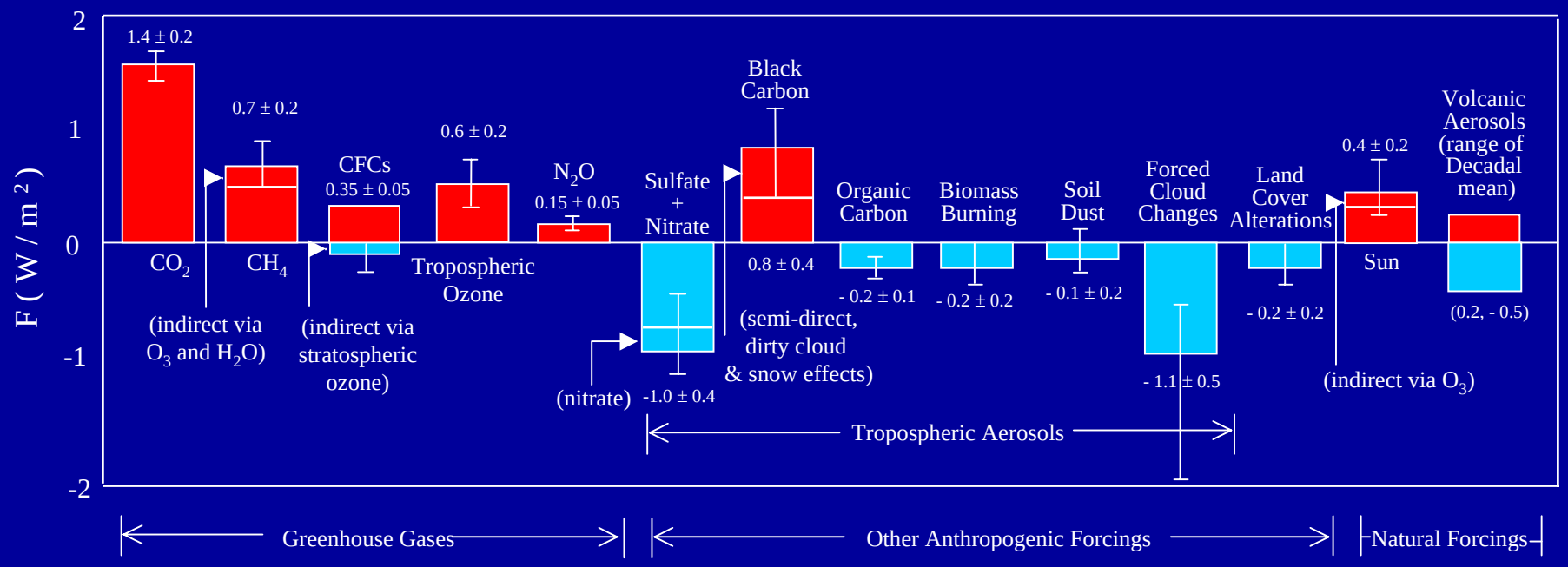








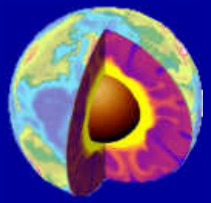
Enabling Reduction in Uncertainties



NASA research and satellite observations enable the global characterization of factors forcing the climate system and their relative strengths.

Land Cover Changes

Motion of the Earth's Interior

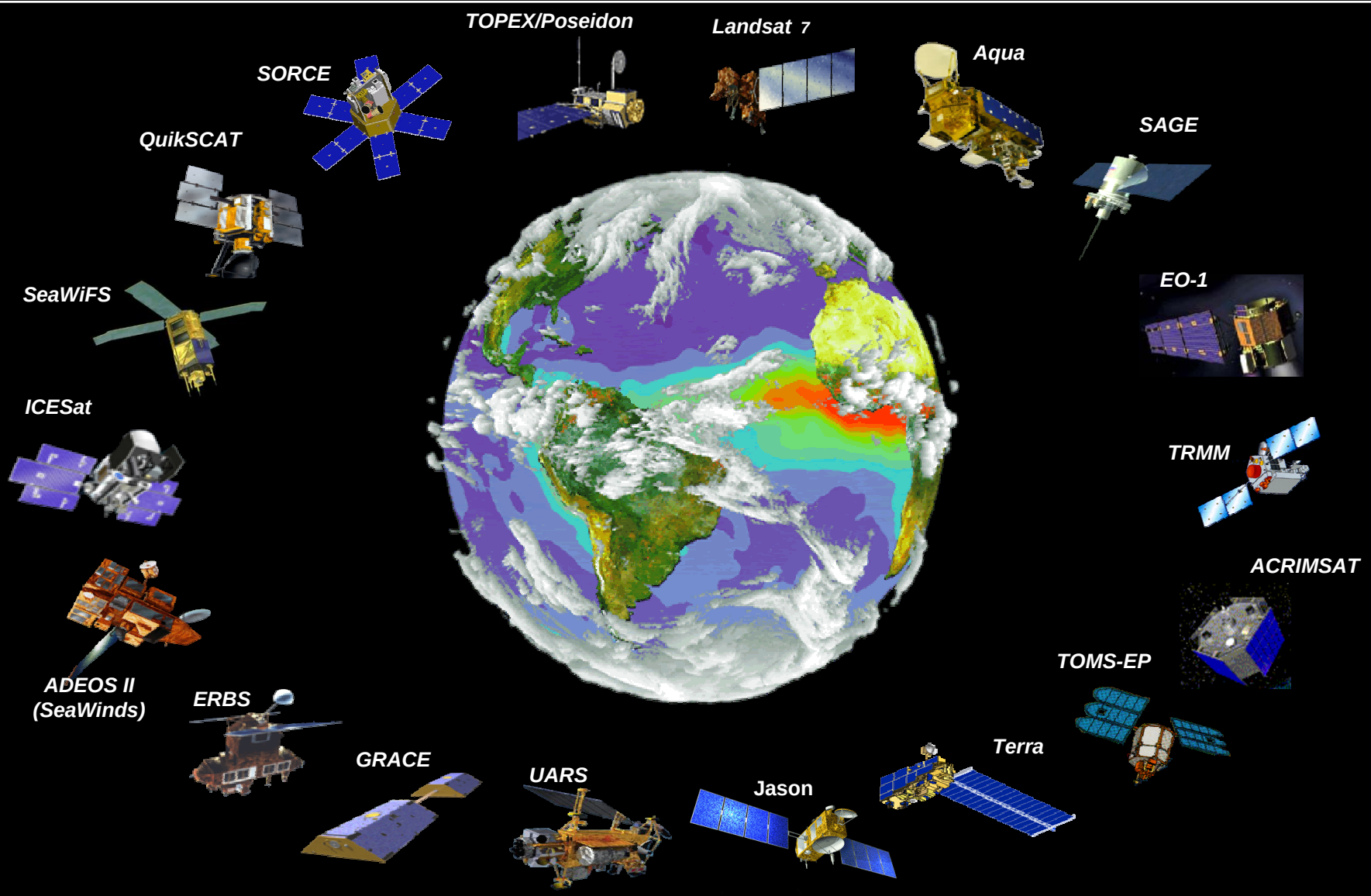


Measurement Requirements for NASA Earth Science Research Strategy

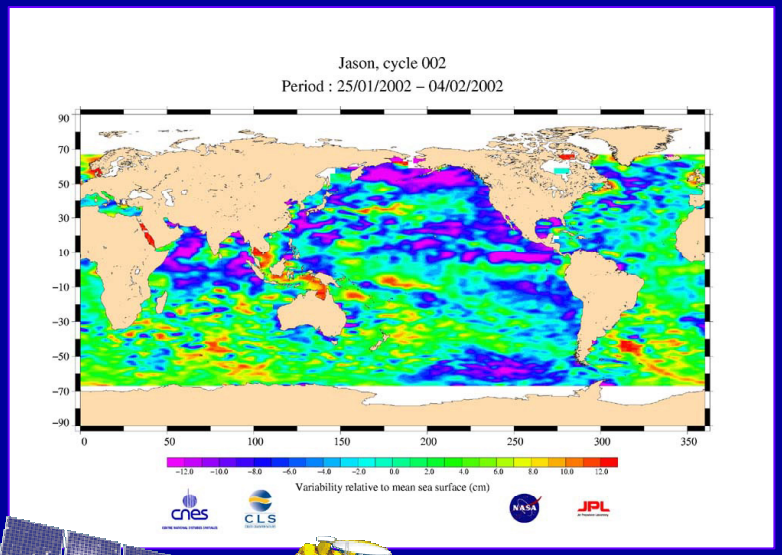
Variability	Forcing	Response	Consequence	Prediction
Precipitation, evaporation & cycling of water changing?	Atmospheric constituents & solar radiation on climate?	Clouds & surface hydrological processes on climate?	Weather variation related to climate variation?	Weather forecasting improvement?
Global ocean circulation varying?	Changes in land cover & land use?	Ecosystem responses & affects on global carbon cycle?	Consequences in land cover & land use?	Transient climate variations?
Global ecosystems changing?	Surface transformation?	Changes in global ocean circulation?	Coastal region change?	Trends in long-term climate?
Stratospheric ozone changing?		Stratospheric trace constituent responses?		Future atmospheric chemical impacts?
Ice cover mass changing?		Sea level affected by climate change?		Future concentrations of carbon dioxide and methane?
Motions of Earth & interior processes?		Pollution effects?		

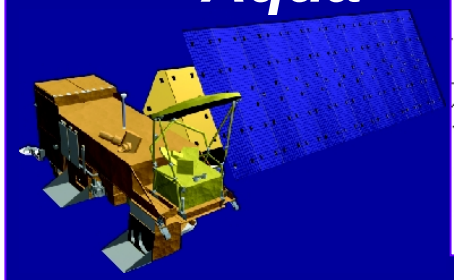
- Requires both systematic & exploratory satellites
- Requires systematic satellite observations
- Requires exploratory satellite observations
- Requires pre-operational and/or systematic/expl
- Use available/new observations in better models

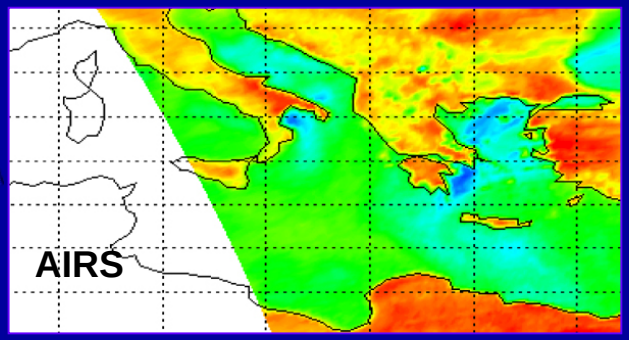
Providing Global Measurements

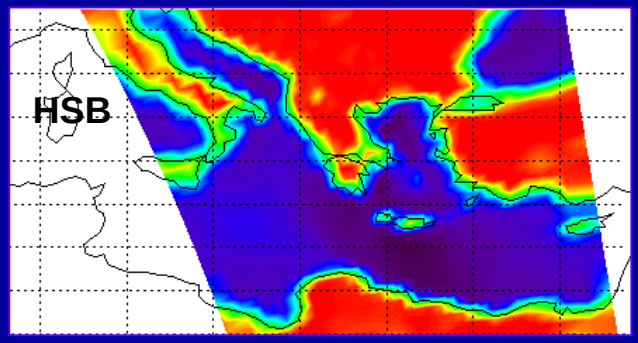


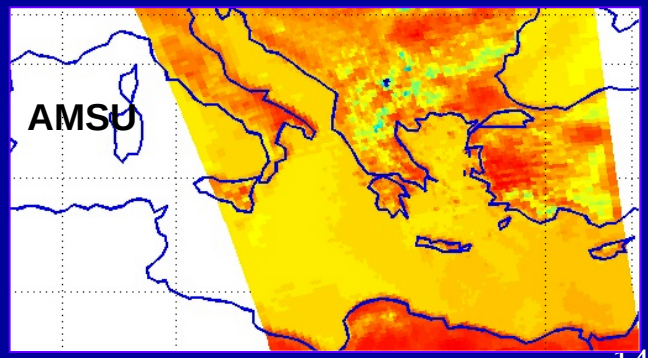
Results: New Data & Understanding

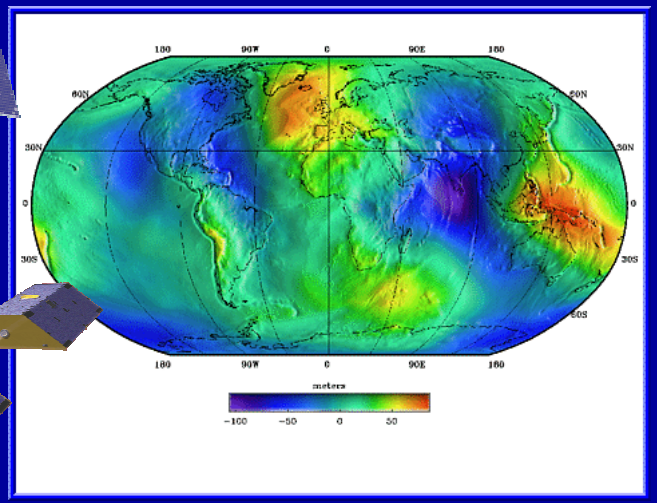


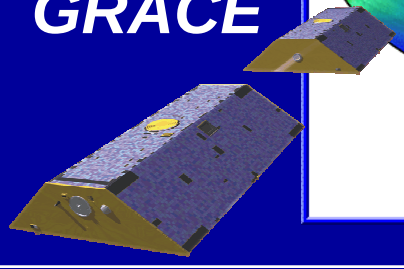




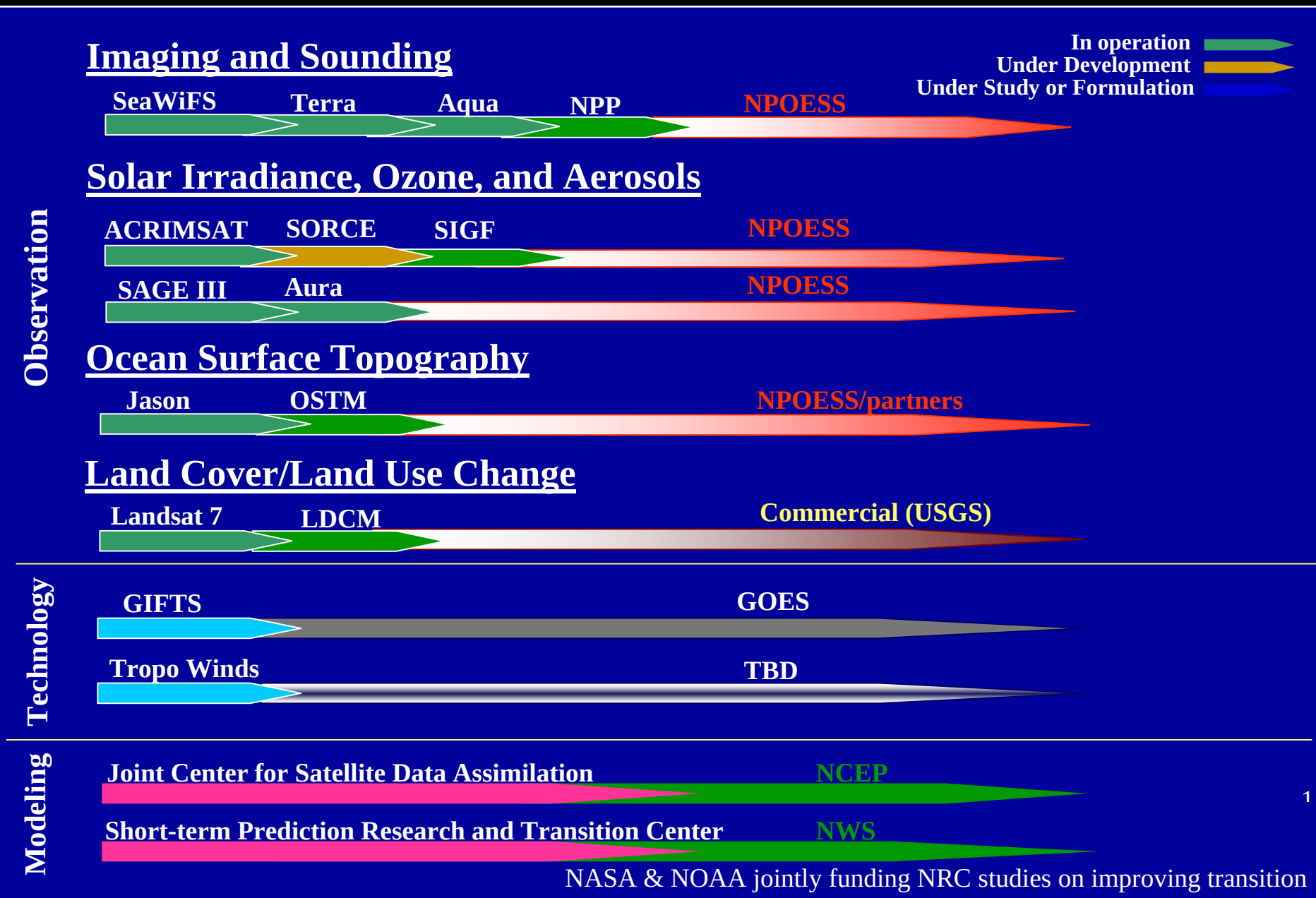






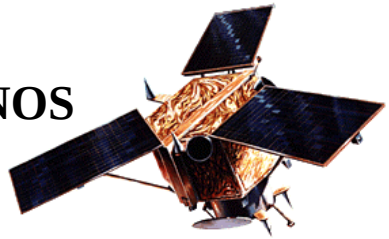


Transitioning from Research to Operations



NASA & NOAA jointly funding NRC studies on improving transition

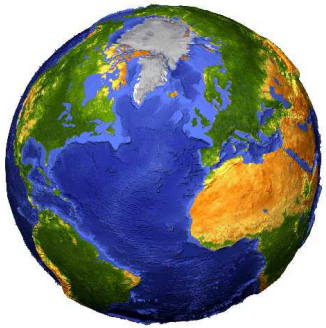
Private Sector Remote Sensing Systems

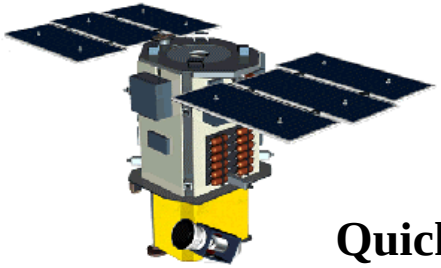


IKONOS

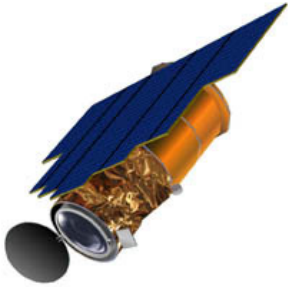
SPIN-2

SPOT 4, 5

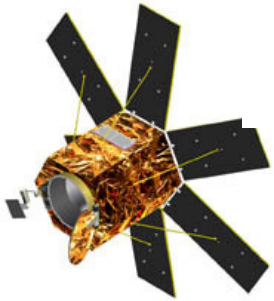




QuickBird



OrbView-3



EROS A1

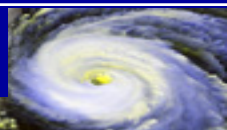
Airborne Remote Sensing Systems

- **Positive Systems ADAR**
- **ESSI Probe**
- **WEI LaserMap**
- **Daedalus TMS**
- **ITRES CASI**
- **TerraSystems DMSV**
- **Intermap STAR-3*i***
- **EarthData Lidar**
- **Emerge MSI**
- **Eaglescan Lidar**
- **Calgis GEOSAR**
- **ERIM Air Lidar**

NASA/NOAA Prediction Goals

	Today	Goals for 2010
Weather	3-Day forecast at 93% accuracy* 7 Day forecast at 62% accuracy* 3 day rainfall forecast not achievable Hurricane landfall +/-400Km at 2-3 days Air quality day by day	5-Day forecast at >90% accuracy* 7-10 Day forecast at 75% accuracy* 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.*



Beyond Scientific Exploration...Serving Society

Global Change

IPCC CCSPO

NRC NCCTPO

UNFCCC WMO

Advanced Weather Prediction

NRC NOAA DOD

Natural Hazards

Natural Hazards Center

NRC Roundtable

SESWG ...

Earth Science Enterprise

Mission: Focus on weather, climate, and natural hazards

Science

Applications

Education

Technology & Missions

Earth System Knowledge

Operational Imperatives

Federal Local

State Tribal

International

Private Sector

Earth Science Education

K-16 & Beyond

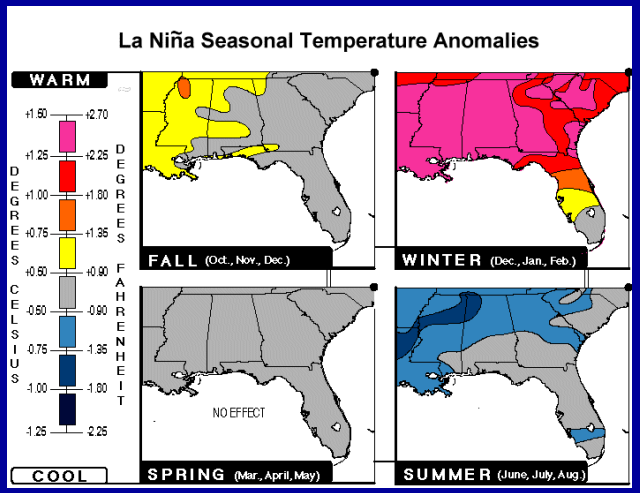
Applications of National Priority

- Weather and climate for **Agricultural Efficiency**
- Sequestration capacity monitoring for **Carbon Management**
- Biological **Invasive Species Management**
- **Water Management** and conservation
- Weather and natural hazards for **Air Quality** management
- Weather and climate for **Energy Forecasting**
- Weather and natural hazards for **Aviation Safety**
- Weather, climate, and natural hazards - **Community Growth**
- Early warning for **Homeland Security**
- Early warning for **Public Health**
- Community preparedness for **Disaster Management**
- Environmental indicators for **Coastal Management**

To Realize Socioeconomic Value

Weather & Energy

- The annual cost of electricity could decrease by at least $1B if the accuracy of 30 hour weather forecasts improved 1 degree Fahrenheit.

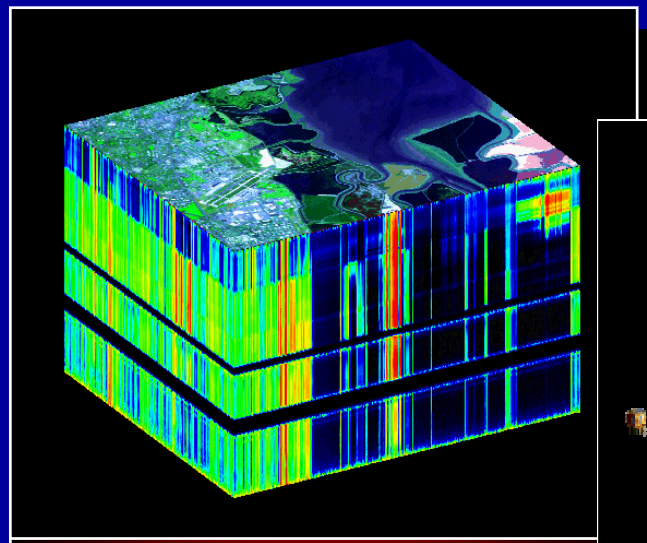


Earth Science & Aviation

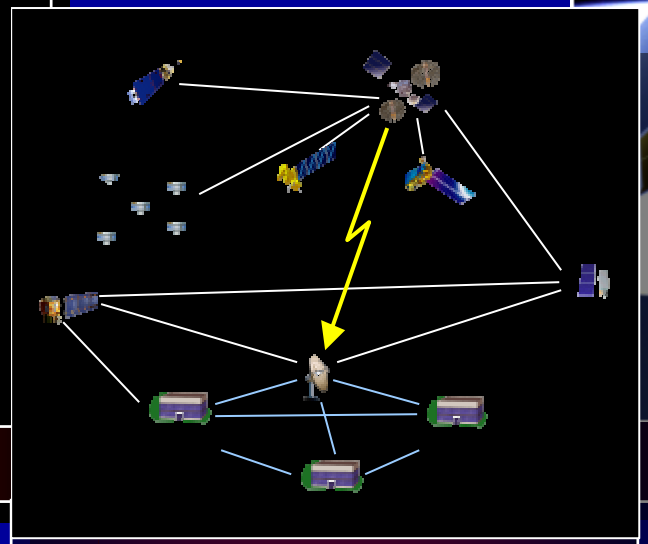
- The projected annual savings of operating aircraft using advanced Synthetic Vision Systems at just 10 airports in the U.S. in one year is over $2B.

Technology Emphasis Areas

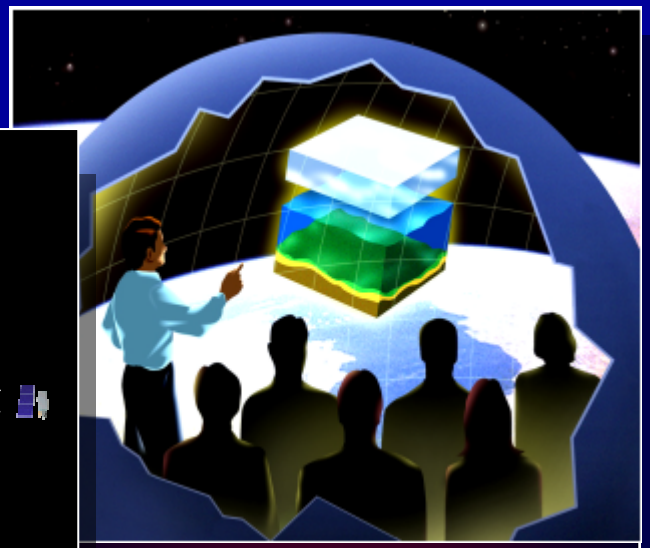
Earth System Science in the future will leverage three ongoing technology revolutions:



Earth Observations



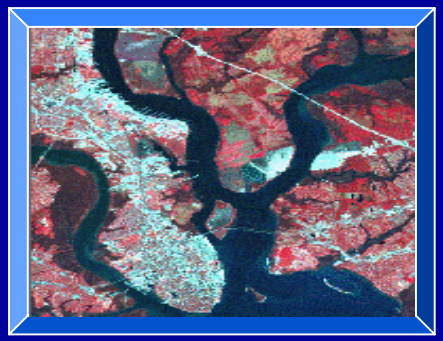
Communications



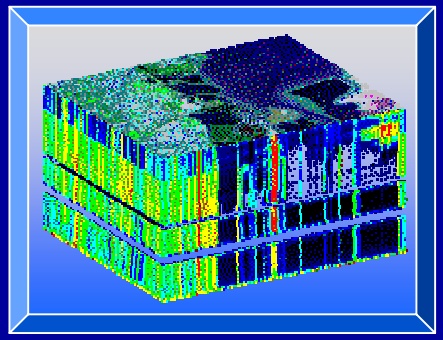
Computing

...To enable timely and affordable delivery of Earth Science data and information to users

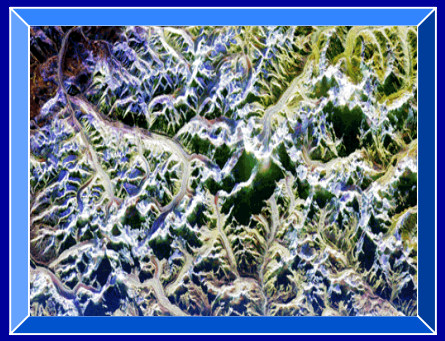
Using Remote Sensing Technologies



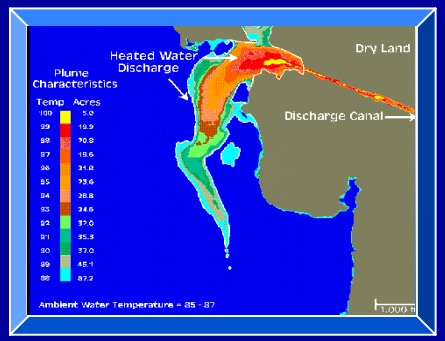
Multispectral



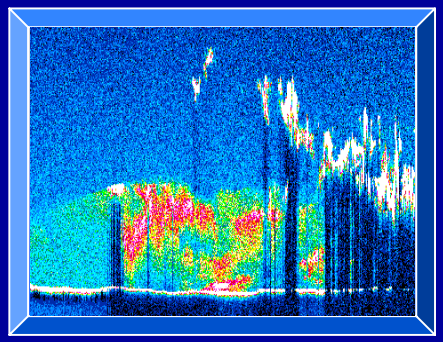
Hyperspectral



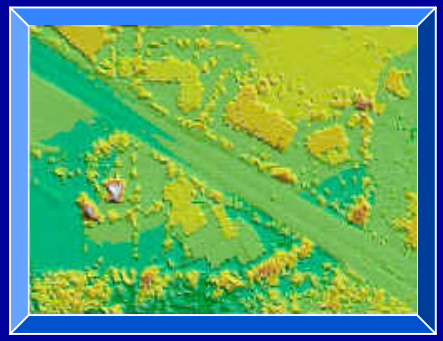
RADAR / SAR



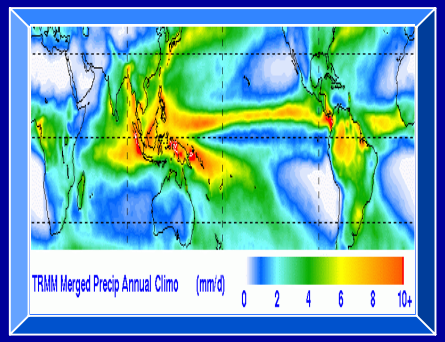
Thermal



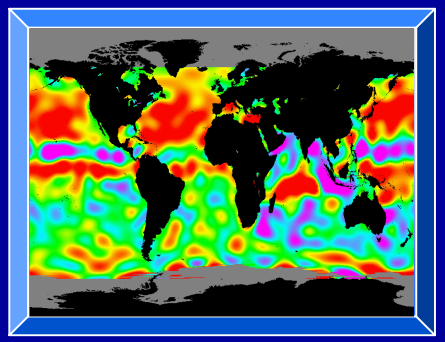
Atmospheric LIDAR



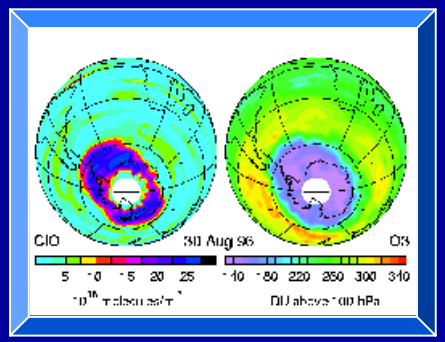
Surface LIDAR



Passive Microwave

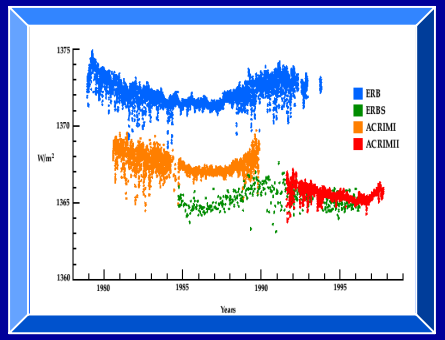


RADAR Altimetry

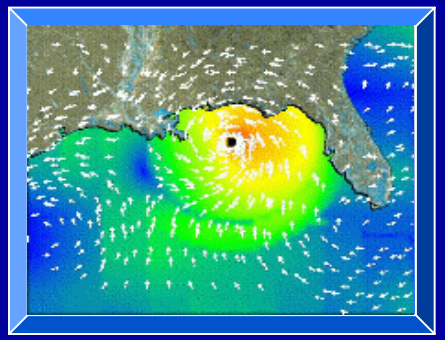


Limb Sounding

Microwave Ranging

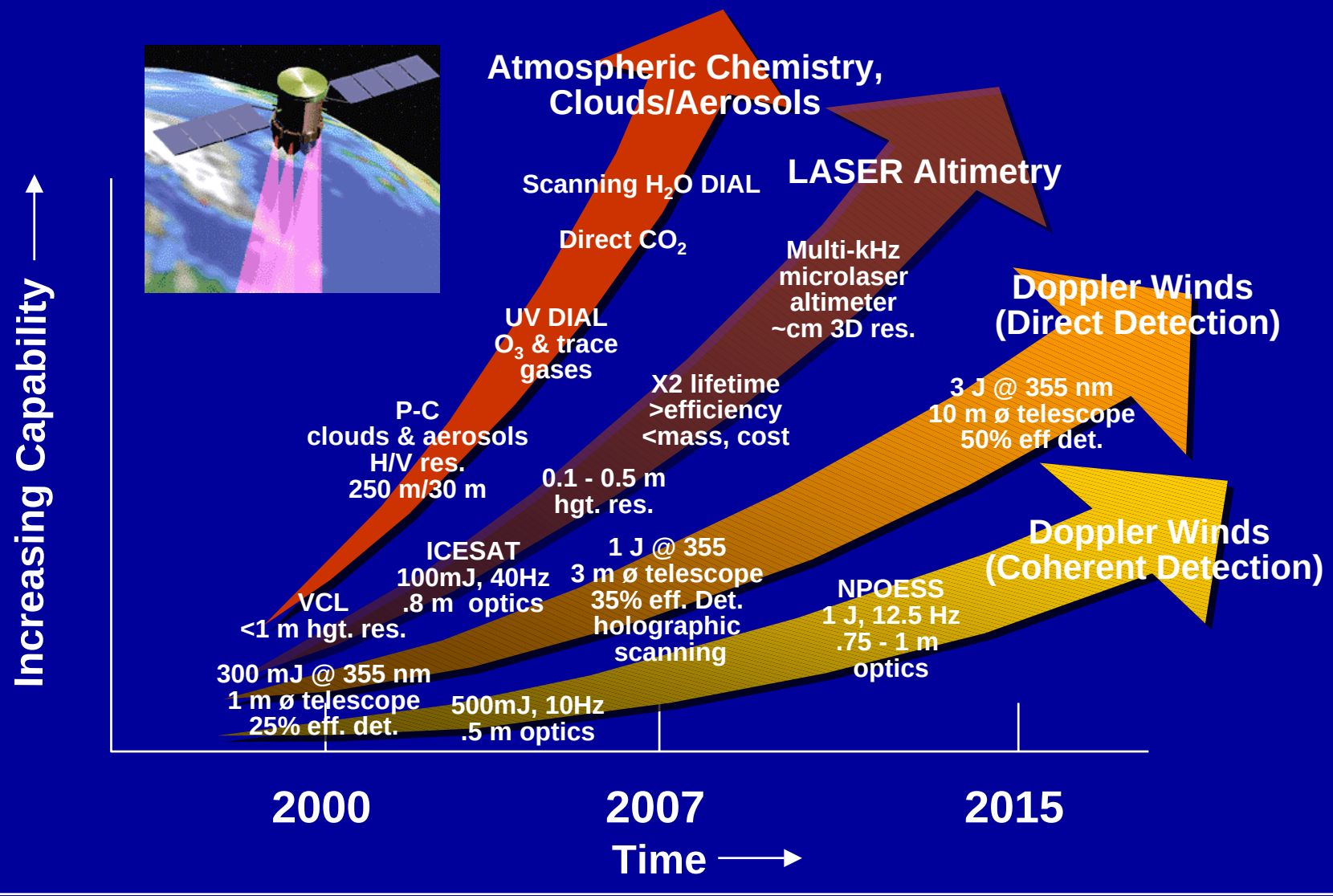


Irradiance/Photometry



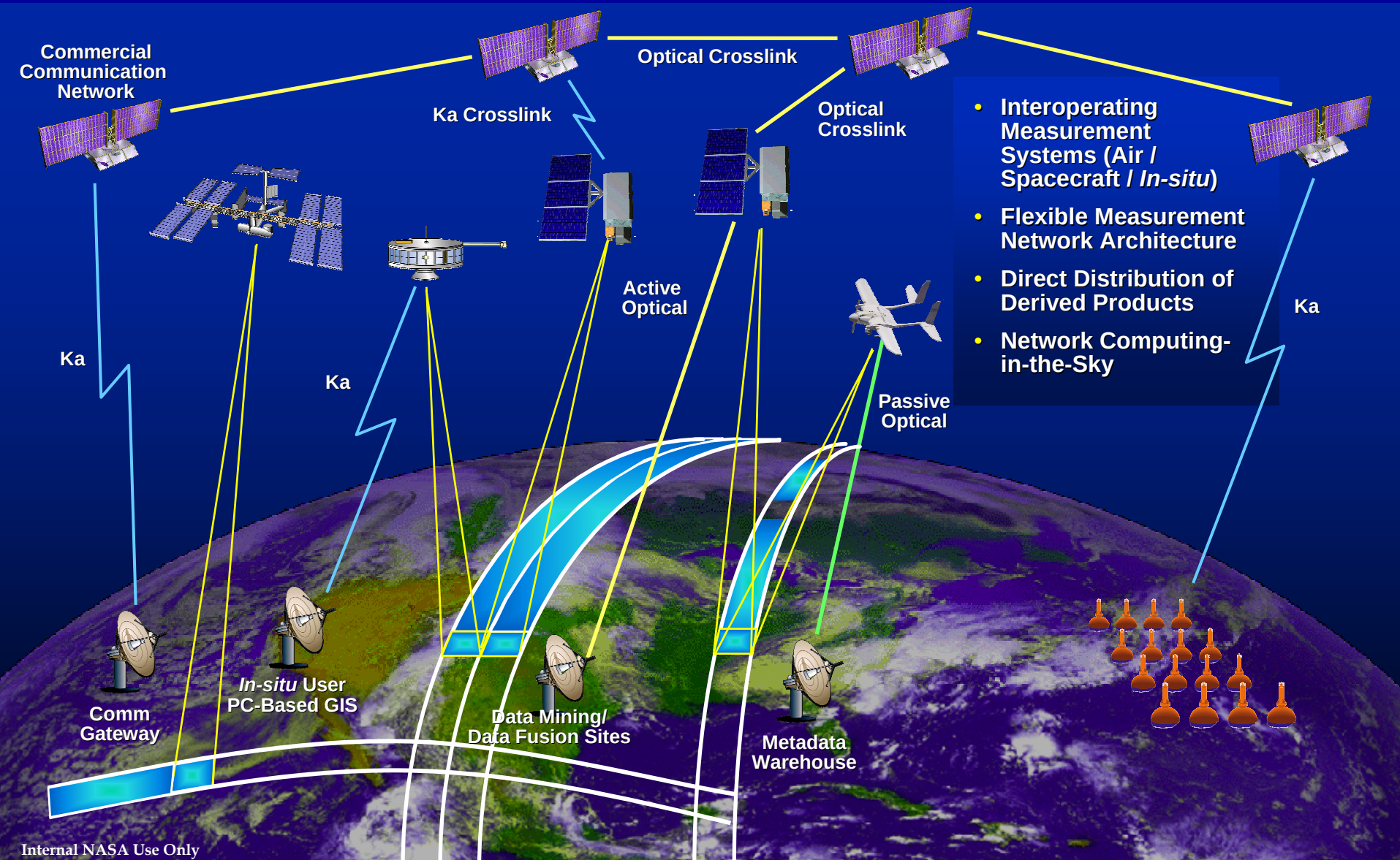
Scatterometry

Technology Development Roadmap



Reconfigurable Communications

Distributed Information-System-in-the-Sky

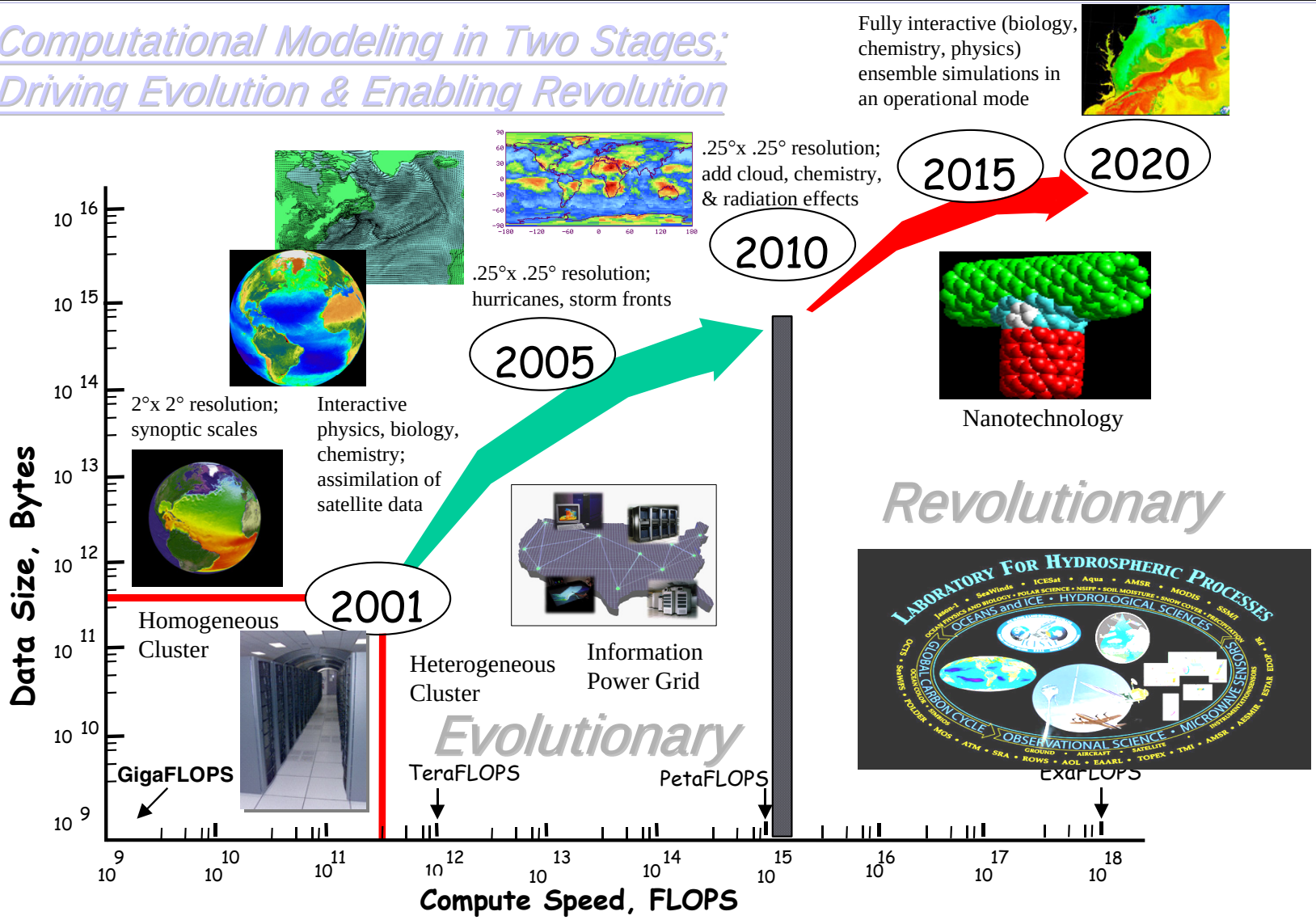


- Interoperating Measurement Systems (Air / Spacecraft / *In-situ*)
- Flexible Measurement Network Architecture
- Direct Distribution of Derived Products
- Network Computing-in-the-Sky

Internal NASA Use Only

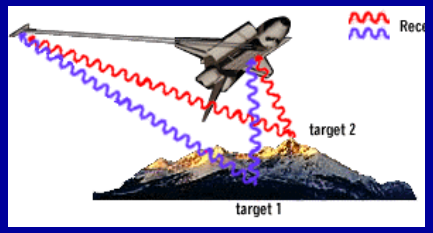
Computational Climate Modeling

Computational Modeling in Two Stages; Driving Evolution & Enabling Revolution



Real Demonstrated Performance doing useful Science

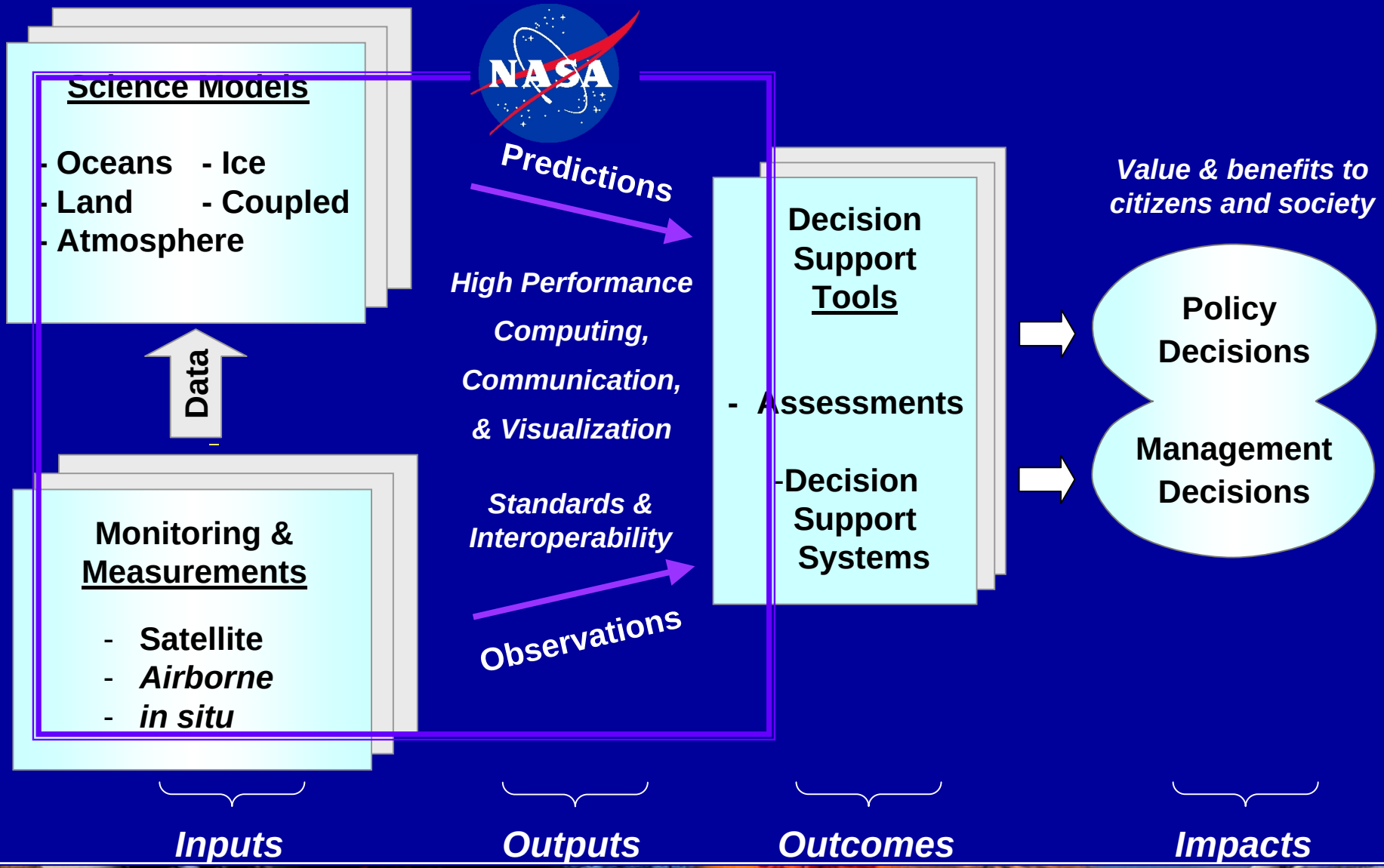
SRTM Digital Elevation



Fly-by of San Francisco Bay area generated using Landsat and SRTM data.

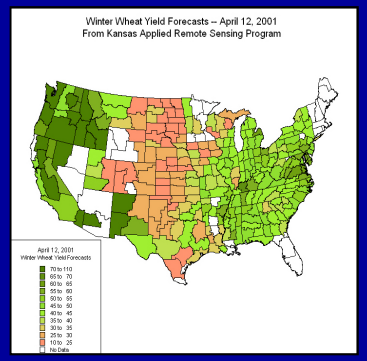
The Shuttle Radar Topography Mission (SRTM) gathered data over 80% of the globe in February 2000. Digital Elevation Models at 90 m resolution will be complete in 2003.

Solutions: Science to Decision Support



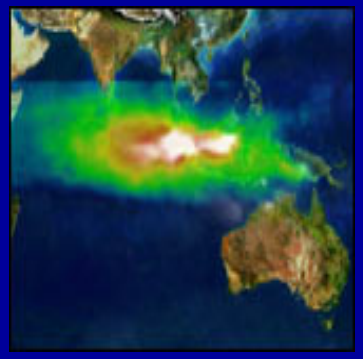
Decision Support Systems

Agricultural:
Foreign Agriculture Forecast

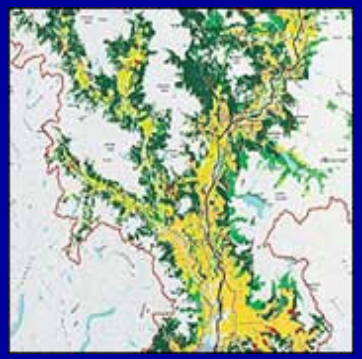


CCCSTI:
Carbon Management System

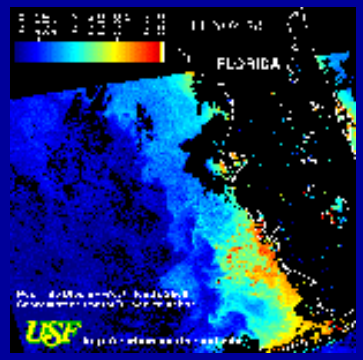
Invasive Species:
Prediction Center



Air Quality:
Community Air Quality



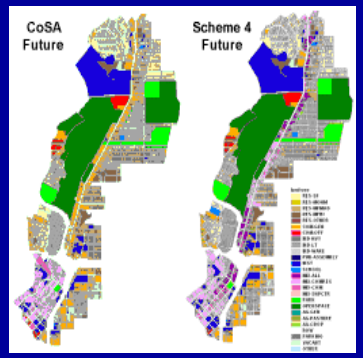
Water Management:
AWARDS, RiverWare



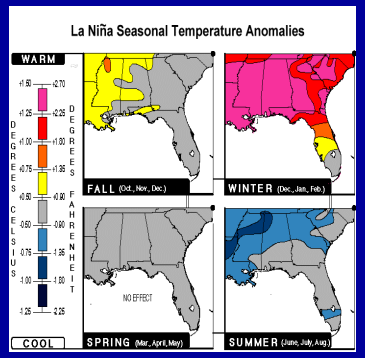
Coastal Management:
Harmful Algal Bloom Forecast

Decision Support Systems

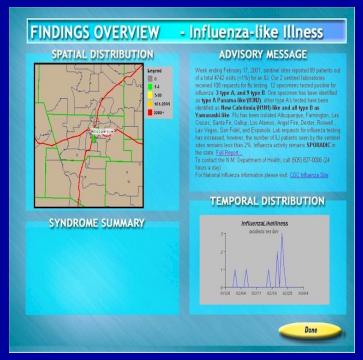
Aviation Safety:
National Airspace System



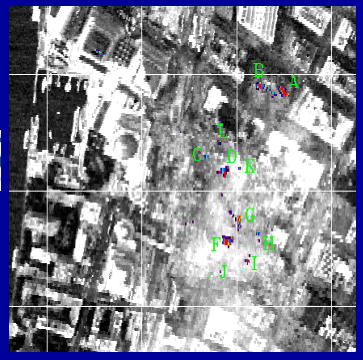
Community Growth:
Urban Dynamics System



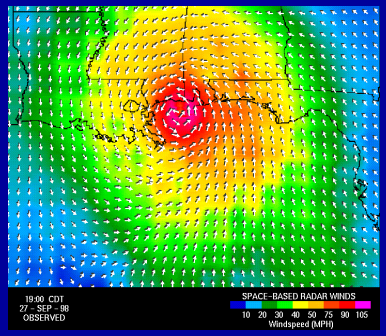
Energy Forecasting:
Renewable Energy System



Public Health:
Risk Assessment System



Homeland Security:
Situation Center



Disaster Preparedness:
HAZUS Risk Prediction

Earth Science Laboratories

GISS

JCSDA

Laboratory for Terrestrial Physics

Laboratory For Hydrospheric Processes

NASA Goddard Space Flight Center
LABORATORY FOR ATMOSPHERES

GHCC

SPoRT

GFDL
Geophysical Fluid Dynamics Laboratory
Princeton, NJ

National Centers for Environmental Prediction

ARL

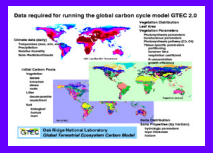
Office of Research and Applications

Data Assimilation Office

NCAR

Earth System Models

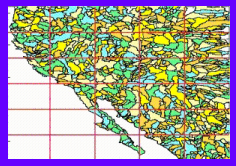
LAND



GTEC
Terrestrial Ecosystem Carbon

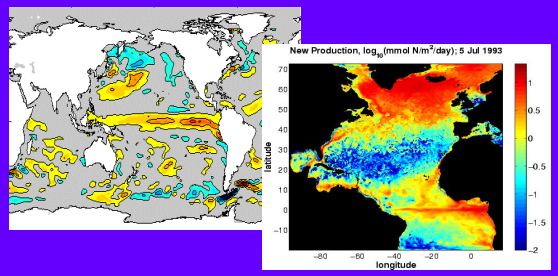
Mosaic	*Energy, water fluxes*
CENTURY	*Land change/carbon*
VolQuake	*Seismicity*
HSPF	*Nutrient transport*
ANIMO	*Soil nitrogen cycle*
PRMS	*Precipitation run-off*
MAESTRO	*Canopy biomass*

Catchment LSM
Soil Moisture Transport



OCEANS/ICE

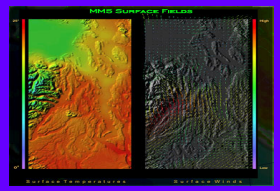
ROMS	*Regional circulation*
MOM3	*Multi-scale ocean*
CSIM4	*Sea Ice*
NWW3	*Global/regional waves*
BOM	*Coastal & shelf seas*
GOTM	*Turbulence & mixing*



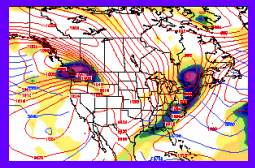
Poseidon, HYCOM
Ocean GCM

ATMOSPHERE

MM5
Mesoscale Meteorology



CAM/CCM	*Global climate*
GISS GCM	*Climate change*
BEIS	*Biogenic emissions*
MSISE	*Density, temperature*
VAFTAD	*Volcanic ash*
PRECIS	*Regional climate*

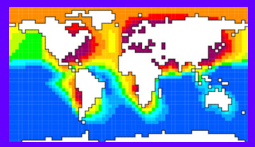


Aries/GEOS
Atmos. GCM

COUPLED MODELS

COUPMODEL
Soil-Plant-Atmosphere

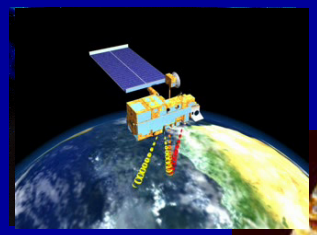
LOIS	*Land-Ocean*
HadCM3	*Ocean-Atmosphere*
COLA	*Atmosphere-Land/Biosphere*
ZEUS, CCSM	*Land-Ocean-Ice-Atmosphere*



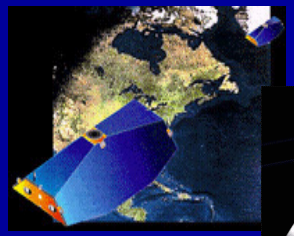
AOM
Atmosphere-Ocean

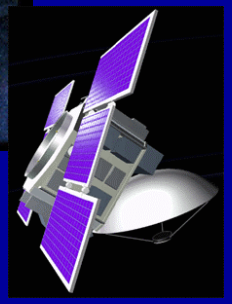
ESE Measurement Missions

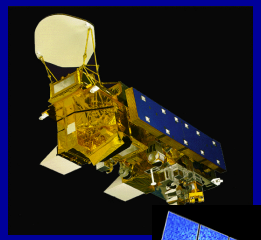
Spaceborne Measurement Systems


Terra

SeaWinds

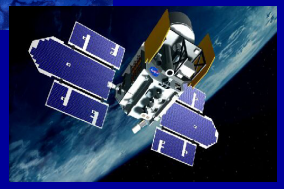

GRACE


CloudSAT


Aqua

Jason-1

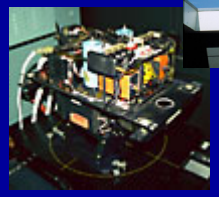
Aura


ICEsat

Airborne & *In Situ* Measurement Systems

AVIRIS

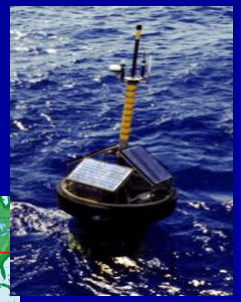
MAMS


MASTER

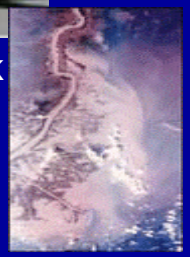
AERONET

Proteus

GTE/TRACE-P

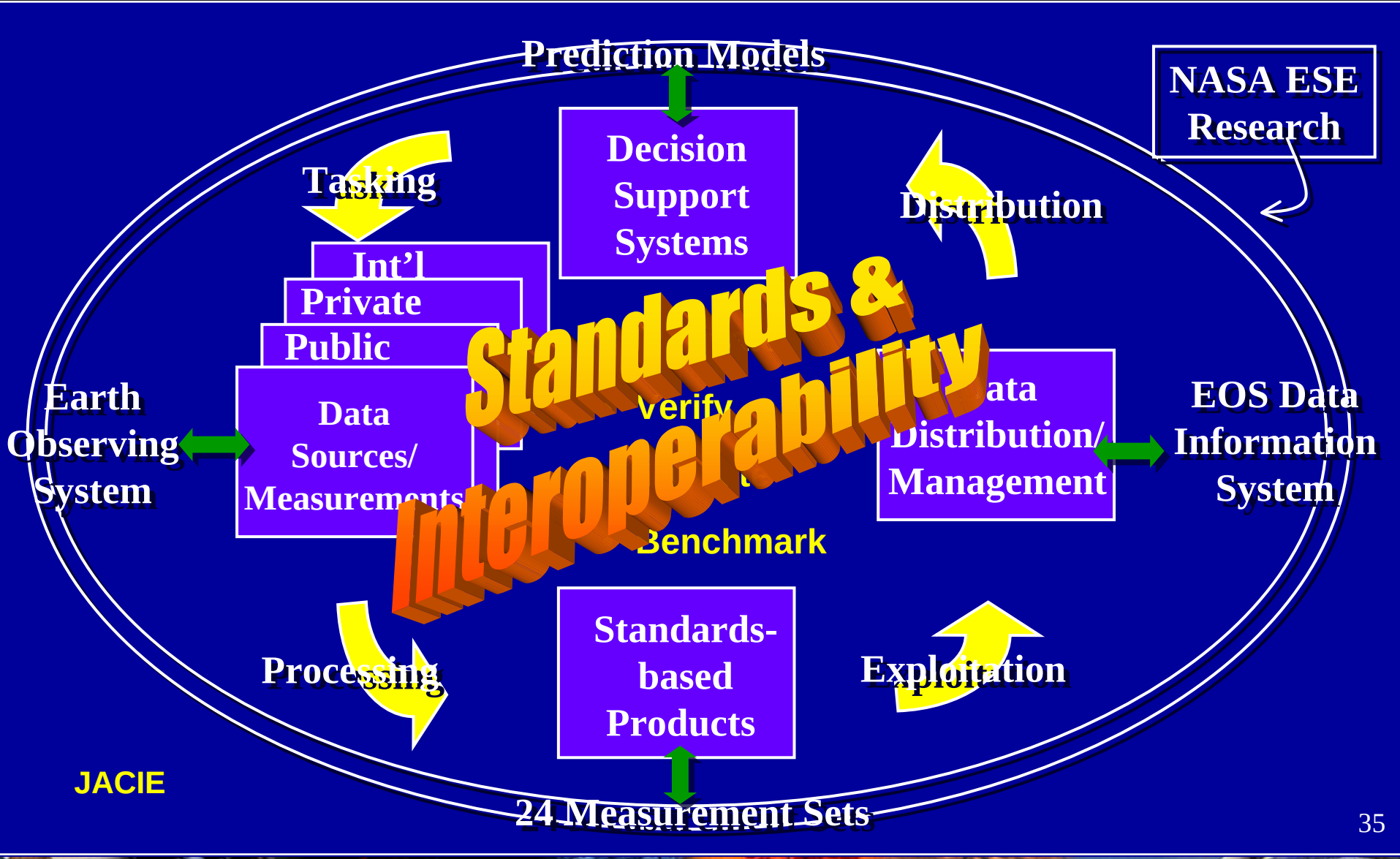

MOBY

STARLink


AOCI

NASA Earth Science Centers

Systems Framework

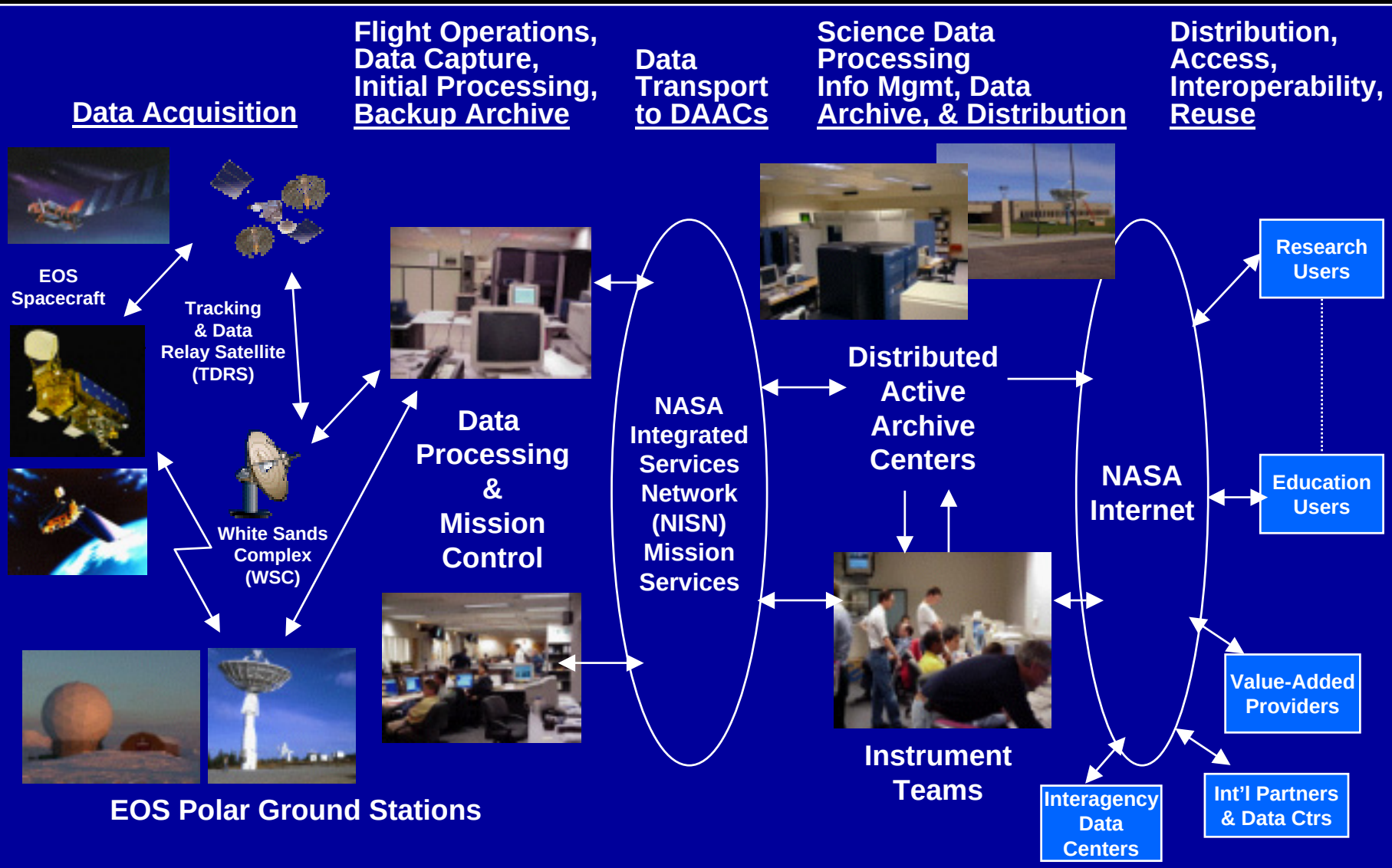


Launching GRACE to Create Improved Geoid

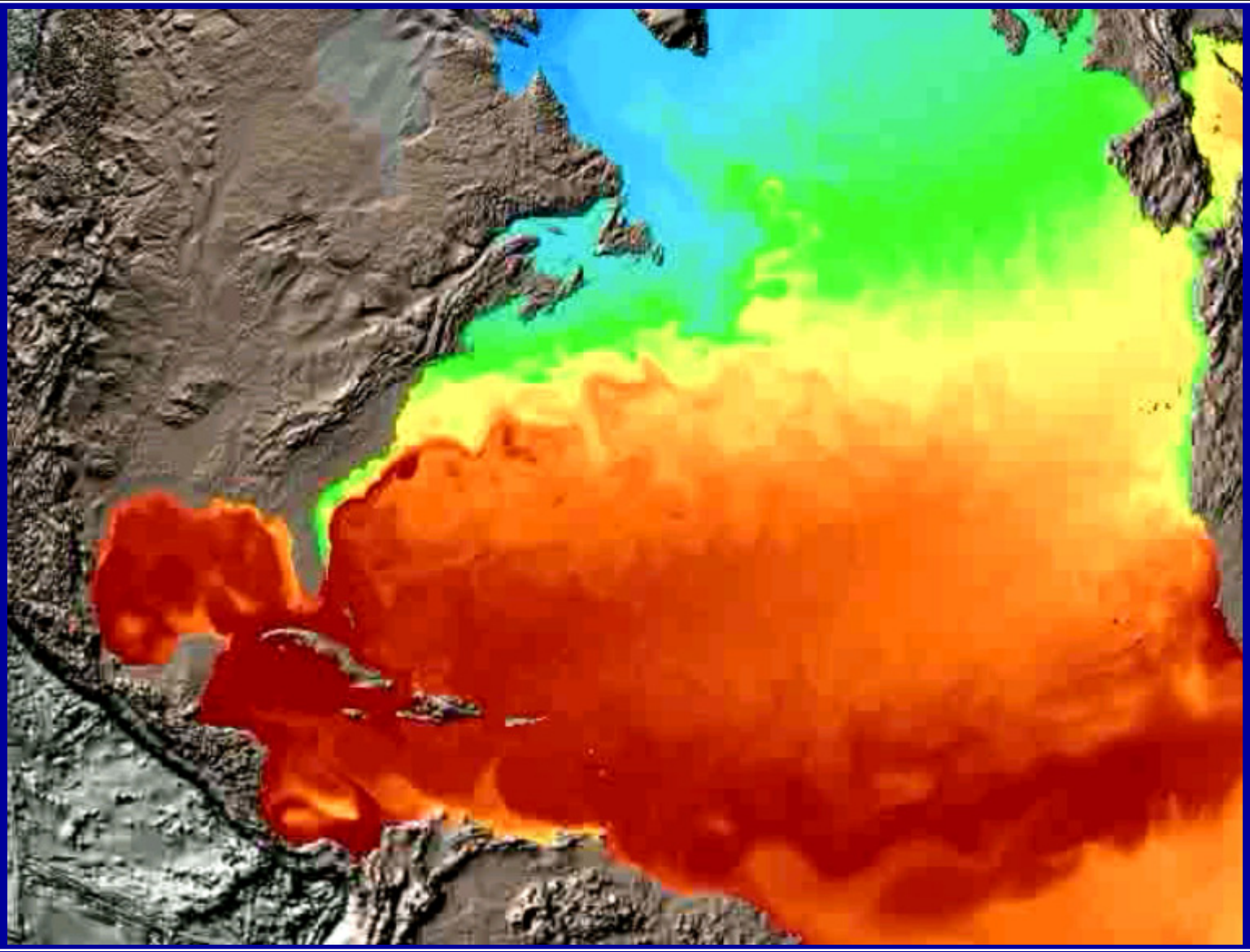
- **Launched in March, the twin GRACE spacecraft are mapping the Earth's gravity field and its variations with unprecedented precision.**
- **GRACE is mapping the variation in the Earth's mass due to mountains, valleys, oceans, and caverns. It provides information on subtle gravity changes due to changes in the ocean, runoff and ground water storage on land, and mass exchange between ice sheets, glaciers and the oceans.**

Operating Satellites on Orbit

Data Archiving and Distribution



Modeling Ocean Circulation



Extending Science & Technology to Society

Petabytes 10^{15}

Multi-platform, multi-parameter, high spatial and temporal resolution, remote & *in-situ* sensing

Calibration, Transformation To Characterized Geophysical Parameters

Terabytes 10^{12}

Interaction Between Modeling/Forecasting and Observation Systems

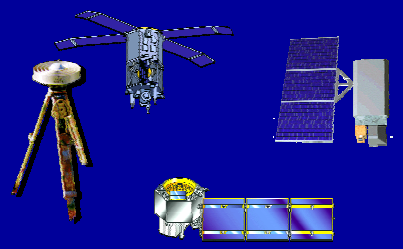
Gigabytes 10^{9}

Interactive Dissemination

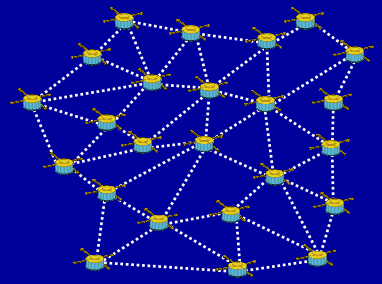
Predictions

Megabytes 10^{6}

Advanced Sensors

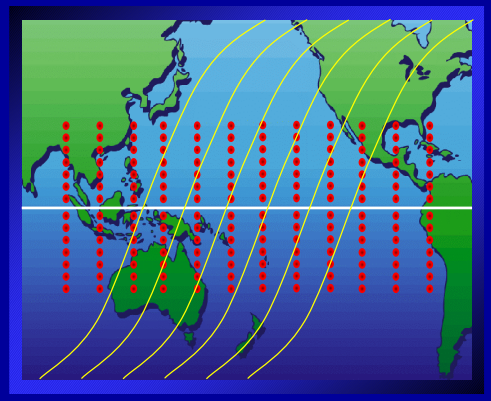


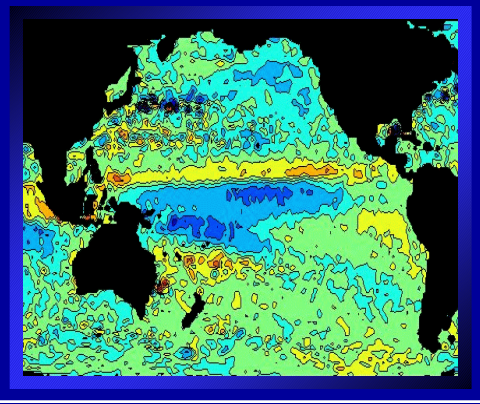
Data Processing & Analysis

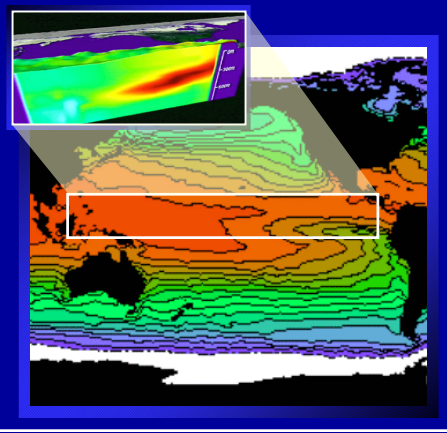


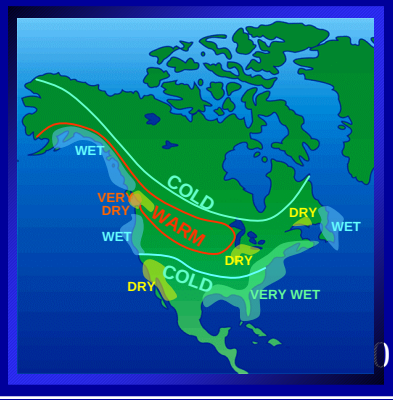
Information Synthesis

Access to Knowledge









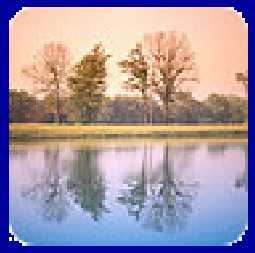
Applications of National Priority

Carbon Management

Public Health

Energy Forecasting

Aviation Safety



Water Management

Homeland Security

Coastal Management

Disaster Preparedness

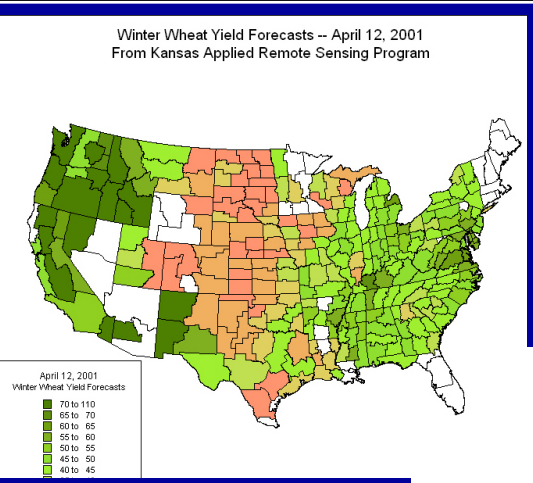
Agricultural Efficiency

Invasive Species

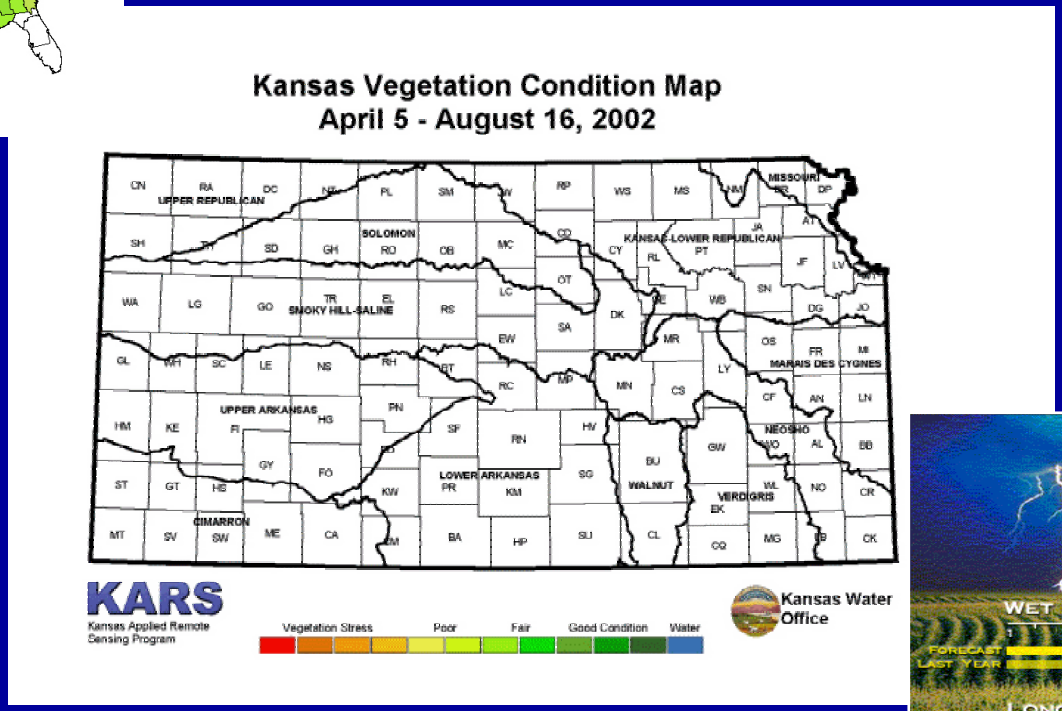
Community Growth

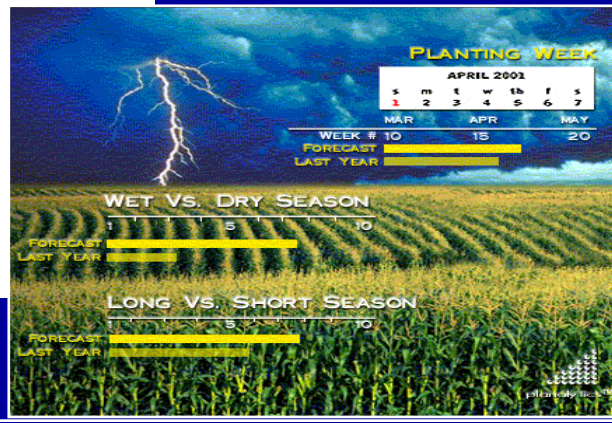
Air Quality

Agriculture: Improving Efficiency



An applications research project with the University of Kansas has led to a new business in crop yield forecasting





Earth Science for Agricultural Efficiency

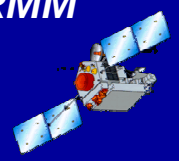
NASA → USDA

Research → Operations

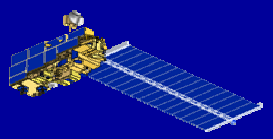
	2002-2003	2004-2005	2006-2007	2008-2010
SCIENCE	Snow and Soil Moisture Sensing Validation Experiments	Data Assimilation Of Multi-Satellite Observations	Weather Forecasting Modeling & Climate Prediction Modeling	Improved Meteorology & Water Cycle

MONITORING & MISSIONS

TRMM

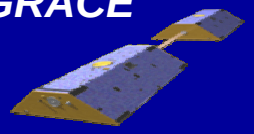


Terra

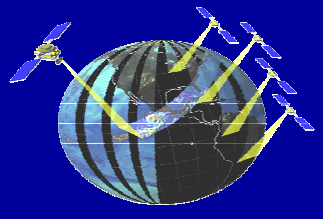


Aqua

GRACE



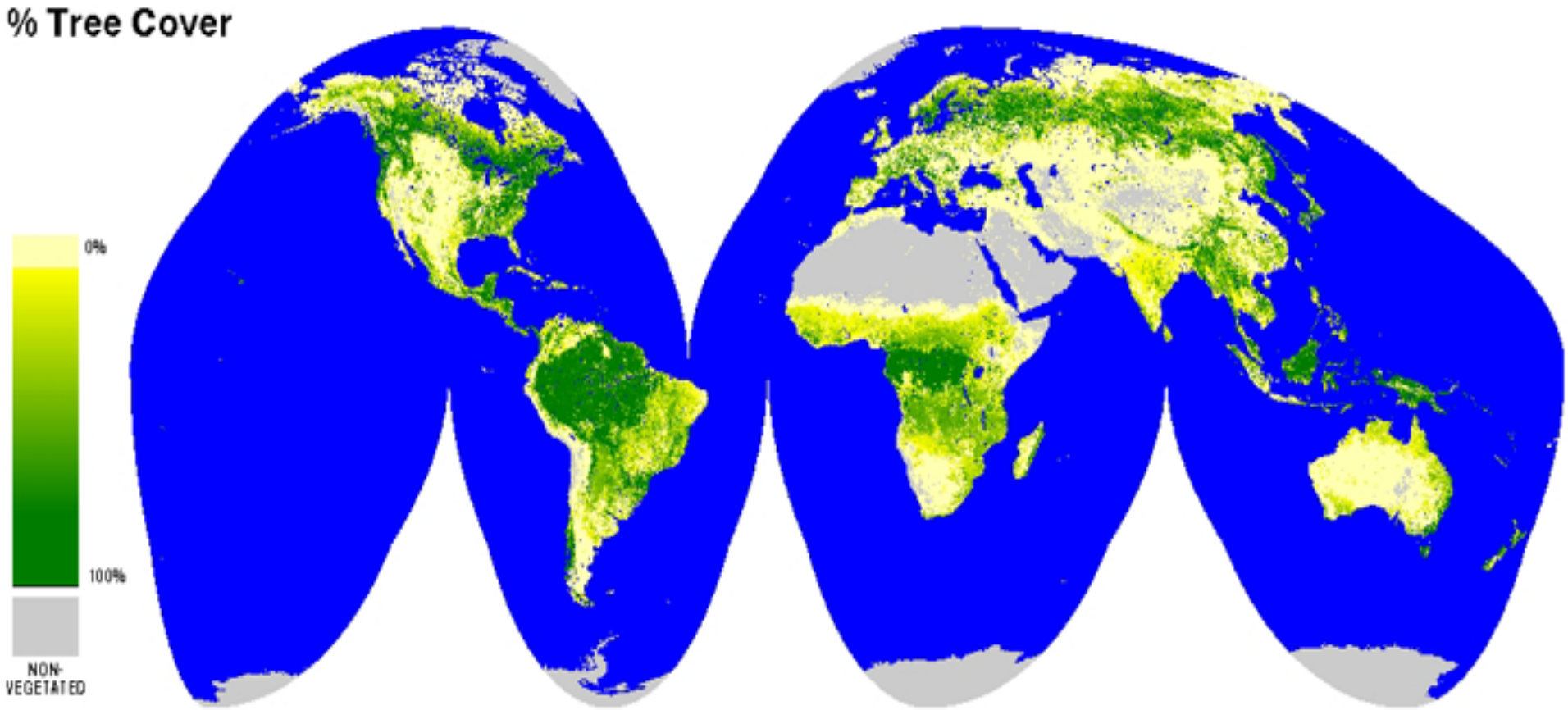
GPM



Evaluation → Validation & Verification → Benchmarking

DECISION SUPPORT TOOLS	Soil Moisture Products	Precipitation Forecasts	Seasonal Predictions	New Services & Technologies	FAS Forecast DSS

Carbon Management: Sequestration



A prototype data set estimating percent tree cover from 10 to 80 percent based on satellite data acquired by the Advanced Very High Resolution Radiometer in 1992-95. Percent tree cover is likely to be underestimated in areas with significant cloud cover throughout the year. The spatial resolution of 1km precludes the detection of finer forest fragments. Future satellites with higher spatial resolution will improve detection of forest patches as well as areas undergoing land cover change. Note that this is an equal area map projection and hence tree cover in high latitudes appears less extensive than in conventional maps.

Global Percentage Tree Cover Product derived from AVHRR data

John Townshend / Ruth Defries, University of Maryland

Carbon Management:
Toward a Carbon Management Regime

Date: 6/14/2002

Carbon Management DSS:
Land Sequestration Capacity
Ocean Sequestration Capacity

Primary Partners:

USDA EPA NOAA USGS *science for a changing world*

Socioeconomic Impact

Global Atmospheric CO_2 → **Field-level assessment of carbon storage and atmospheric flux**

Second-generation global land cover and change products → **Capability to assess and predict sink duration (i.e.. credit longevity) for different land uses**

Soil Surface Moisture Measurement* → **Enables modeling of soil carbon storage as a function of soil fertility and vegetative processes**

Forest height & canopy volume sampled globally. First global land cover change data product → **Capability for volumetric assessment of above ground carbon sinks (3-D vs former 2-D capability) Potential to reduce frequency of costly *in situ* measurements**

N. American Carbon Program and related international results incorporated into models (w/ C data assimilation). → **Regional monitoring of carbon storage in biomass and soils**
Regional assessment of candidates for carbon sequestration projects

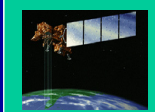
Exploratory studies to extract atmospheric CO_2 from existing satellite sensors; coupled atmospheric-terrestrial model → **Assessment of carbon sink strength at continental scale**
Capability to discriminate between land and atmospheric carbon fluxes

EOS & global land cover observations; Carbon data model assimilation → **Baseline information and dynamics of terrestrial carbon sources and sinks**

Current trajectory:
Steady improvement in model coupling, process characterization, assessment of carbon sources and sinks

An operational decision support system for quantification and verification of terrestrial and oceanic carbon sequestration

USDA **Prototype Carbon DSS**


Landsat 7

Terra

Aqua

NPP/VIIRS

**VCL

LDCM

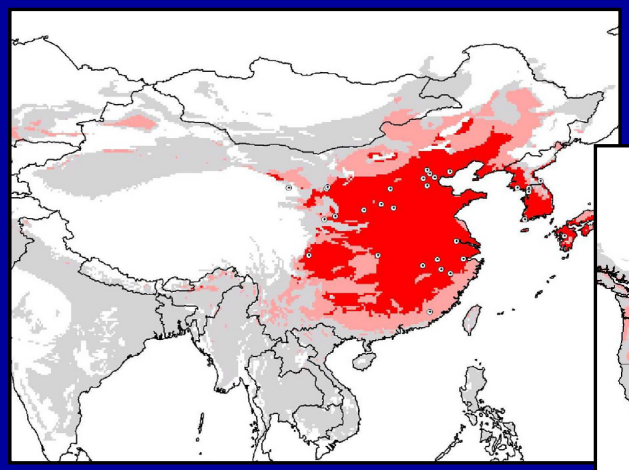
NPOESS

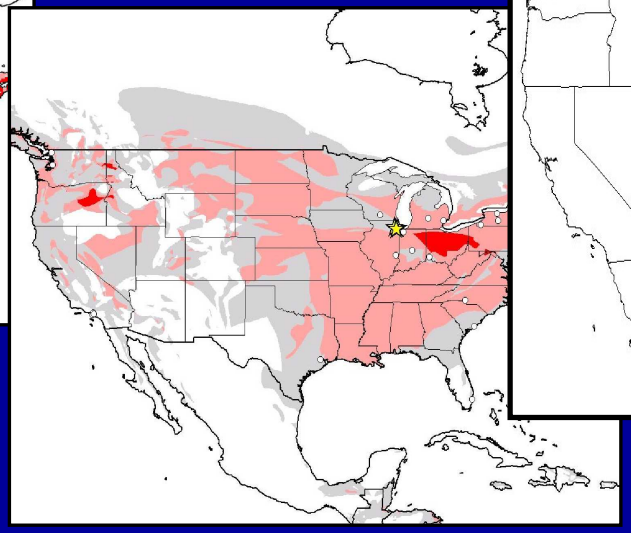
*Pre-formulation
**In review

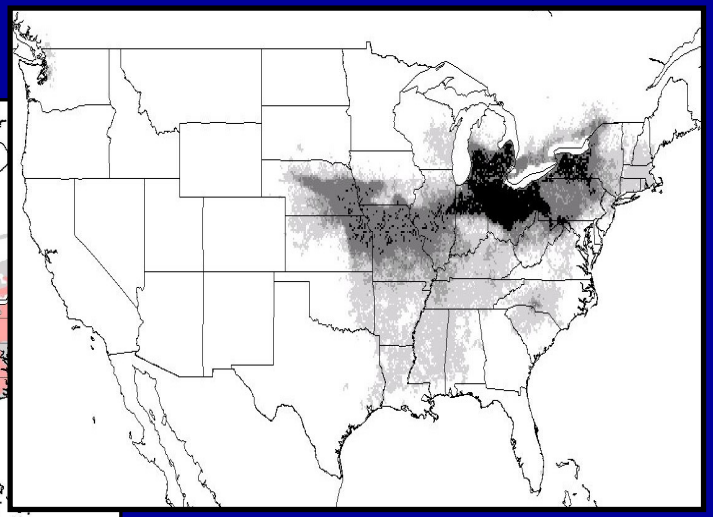
2000 2002 2004 2006 2008 2010 2012

Invasive Species: Asian Long-Horn Beetle

- **Infestations discovered in Asian import warehouses**
- **Models of climate and habitat control in Asia**
- **Model climate-based potential North American spread**
- **Forecast narrowed based on potential habitat**







Invasive Species: Forecasting and Management of Invasive Species

Date: 6/14/2002

Primary Partners:

USGS science for a changing world | USDA | NOAA

Center for Biological Invasions: Regional, National, Int'l measurements & predictions

Global atmospheric CO_2 → **Capability to link biotic potential & diversity to carbon storage & flux**

Second generation global land cover & change products → **Capability to assess & predict patterns of species invasion & biodiversity for different land uses**

Soil surface moisture measurements* → **Enables modeling of invasive species spread as a function of soil fertility & vegetative processes**

Forest height & canopy volume sampled globally. First global land cover change data product → **Capability for assessment of complex structural habitats (3-D vs former 2-D capability)**
Capability for terrestrial & aquatic prediction

N. American Carbon Program & related international results incorporated into models (w/ C, climate, & ecosystem data assimilation. → **Continental assessments of native & exotic plant diversity**
Probable locations of rare habitats & potential areas for future invasion

Exploratory studies to map biological resources using existing satellite sensors; coupled atmospheric-terrestrial models → **Regional assessments of native & exotic plant diversity**
Capability to discriminate between potential "hot spots" of native & exotic plant diversity

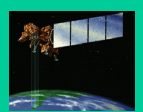
EOS & global land cover observations; Carbon & climate model assimilation → **Baseline information & dynamics of major terrestrial types of invasive species**

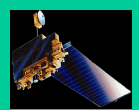
Socioeconomic Impact

Current Trajectory

Steady improvement in model coupling & enhanced functional, structural, spatial, & temporal environmental measurements

Center for Biological Invasions: Local measurements


Landsat 7


Terra

Aqua

NPP/VIIRS

**VCL

LDCM

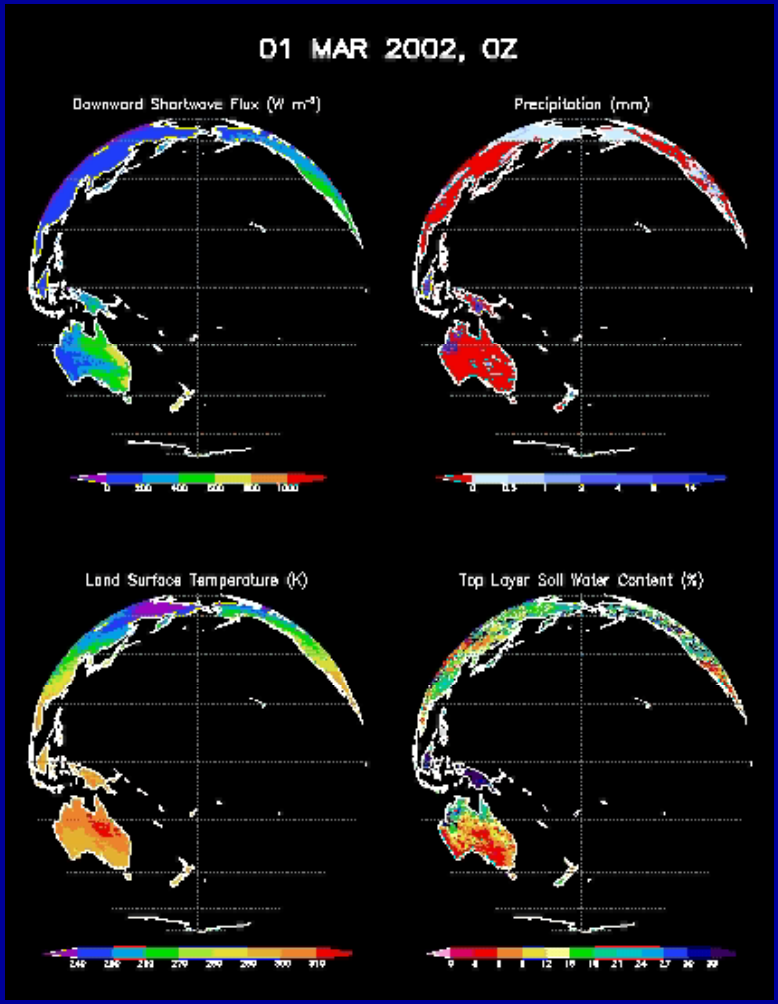
NPOESS

*Pre-formulation
**In review

2000 2002 2004 2006 2008 2010 2012

An operational National Invasive Species Forecasting System for early detection & monitoring of biological invasions.

Water Quantity: Management



Global energy & water budgets derived from NASA ESE observations.

Variation in global snow cover for 2001 derived from NASA ESE observations

Water Management and Conservation:

Assessments and forecasts of water supplies

Date: 6/14/2002

AWARDS (c. 2012)
Three forecasts of precipitations and daily crop water use towards reduction of real-irrigation. Seasonal forecasts for optimum vegetation selection and improved water use efficiency

Primary Partners:

USGS science for a changing world
Bureau of Reclamation
USDA
EPA

Second generation data from missions and prediction and assessment models

Improved capability in DSS resulting from the data, predictions, information products and new science knowledge

Incorporation of NASA's SPoRT project's short-term weather forecasts

Improved capability of DSS to modify advice based on short term predictions (<12 hours) of nominal and severe weather events.

Seasonal Forecasts from NASA's Seasonal to Interannual Project (NSIPP)

Improved water supply and water use potential for a given area for the DSS to result in improved crop selection .

GRACE & AMSR, combined with GLDAS & LIS projects

Improved assessments of surface and sub-surface water storage and transport.

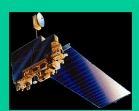
Deployment of Land Data Assimilation Systems (LDAS) and Vegetation Data Sets (from MODIS)

Additional information on current precipitation and potential crop water use statistics. Better knowledge of current crop existence (higher accuracy)

AWARDS (c. 2002)
Agricultural Water Resources and Decision Support, limited to real-time rainfall and daily crop water use estimates

Current trajectory:
Steady improvement in water quality and quantity assessments

Landsat 7

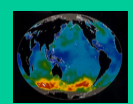

Terra

Aqua

GRACE

**VCL

LDCM


*GPM

NPOESS

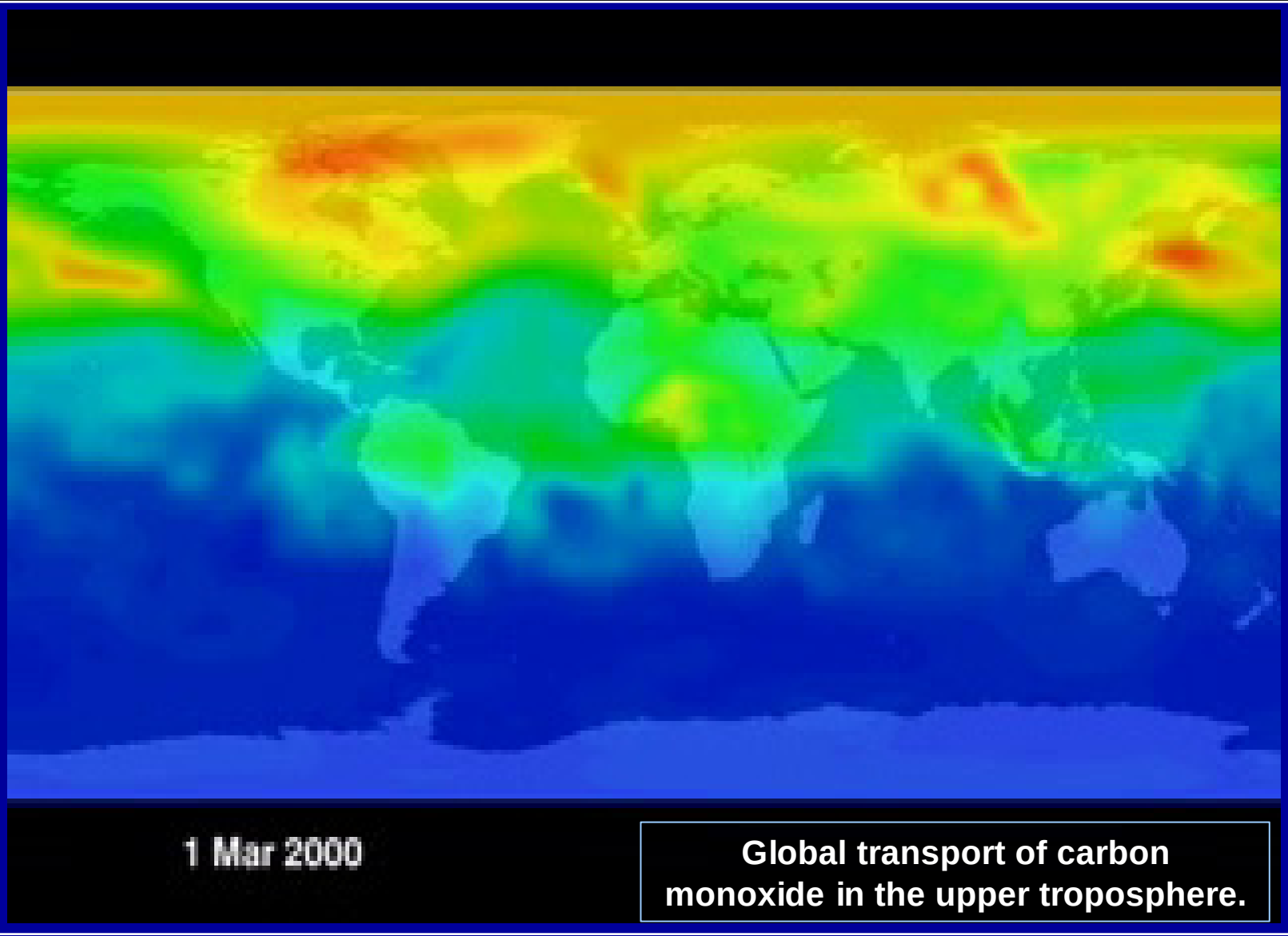
*In formulation
**In review

An integrated decision support system assimilating models and measurements of water transport and storage.

Socioeconomic Impact

2000 2002 2004 2006 2008 2010 2012

Air Quality: Pollution Transport



Global transport of carbon monoxide in the upper troposphere.

Air Quality Management:
Clean Air Standards and Air Quality Forecasts

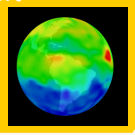
Earth System Modeling Framework Forecasts (c. 2012):
- Robust emissions control planning
- Routine warnings of pollution events
- 3-day air quality forecasts

Socioeconomic Impact

Prevent 1,000s of premature deaths/year
Mitigate $5-10 B reduced crop yields

Primary Partners:

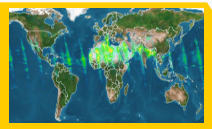
- Day/night chemistry/transport
- Trace gas measurements
- Boundary layer resolution



Outcomes: Improved pollution forecasts. Improved national emissions control planning/mitigation.

Impacts: Mitigate major illnesses and deaths from air pollution episodes.

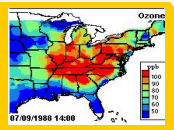
AURA - TES
- Global/regional/local distribution of ozone
- Tropospheric mixing & B.L. interaction



Outcomes: Source & destination of long-range dust & pollutants. Route airplanes. Issue health alerts and NAAQS waivers.

Impacts: Mitigate wear on airplanes and engines. Improve crop estimates for international markets.

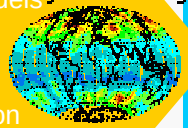
AURA - OMI
- Ozone profiles/transport
- Build on TOMS & GOME
- Aerosol & trace gas characteristics



Outcomes: Assess development policies to achieve or maintain compliance. Improve forecasts of PM and pollution episodes Warnings to hospitals & farmers.

Impacts: Mitigate lung related diseases (asthma, bronchitis, pneumonia). Improve visibility. Benefit crop health & yields.

- Coupled chemistry-aerosol models
- Optical depth data
- Continental inflow/outflow
- Robust satellite data assimilation



Outcomes: Quantify contributions of physical & chemical processes to pollutant concentrations. Improve forecasts of ozone and regional transport.

Impacts: Accurate, timely forecasts & warnings reduce impaired lung function and use of medications. Reduce hospital admissions and lost work/school days.

- Validations
- Ozone residuals
- Better boundary conditions

Outcomes: Assess effects of emission control options. Evaluate development options and emission strategies to set policies and State Implementation Plans (SIP).

Impacts: Achievable SIPs permit air quality compliance which reduce development restrictions and improve economic development opportunities within States and Regions.

Current trajectory:
Steady improvement in chemistry-transport models and pollution episode warnings.

CMAQ Forecasts (c. 2002):
State/regional planning.
Same-day air quality predictions.

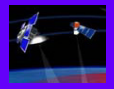
TOMS

GTE

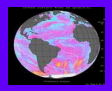
Aqua

AERONET

Aura


CloudSAT

CALIPSO


* Total Column

*NPOESS

* Pre-formulation

2000 2002 2004 2006 2008 2010 2012

Improved capabilities to air quality management tools to assess, plan and implement emissions control strategies & improve air quality forecasts.

Air Quality: Scenario Assessment

MODELS

Chemical/Transport Models

GISS2100

Coupled chemistry-aerosols

Long-range transport

Troposphere/B.Layer Dynamics

Data

MEASUREMENTS

Aqua	Aura
Terra	SAGE III
TOMS	UARS
CALIPSO	SeaWiFS
QuikSCAT	TRMM
SeaWinds	GOES
GOES	EO-1
CloudSAT	Aircraft

Information Products, Predictions, and Data from NASA ESE Missions and Models:

- Trace gas concentrations
- Emissions inventories
- Boundary conditions for multi-scale models
- Fluxes of moisture & heat
- Fields of temperature & pressure
- Precipitation/rain rates
- Radiative characteristics

DECISION SUPPORT

CMAQ/Models-3 for SIP Development

Analysis:
- Assess emissions control strategies & alternatives
- Forecast long-range transport of dust/pollutants
- Prepare source emissions estimates
- Assess compliance

Management Decisions:
- Develop achievable SIPs
- Determine emission control strategy/policies
- Waivers to air standards
- Route aircraft around dust
- Warnings to farmers to mitigate impacts on crops
- Public health alerts

Additional factors:
- Notices where pollutants not expected to occur

VALUE & BENEFITS

- Improve public health
- Reduce lung-related diseases & premature death
- Reduce hospital admissions & use of medicines
- Reduce lost workdays and schooldays
- Improve visibility and reduce haze for tourism
- Improve resiliency of crops; increase yields
- Increase confidence in government
- Improve crop estimates for international markets

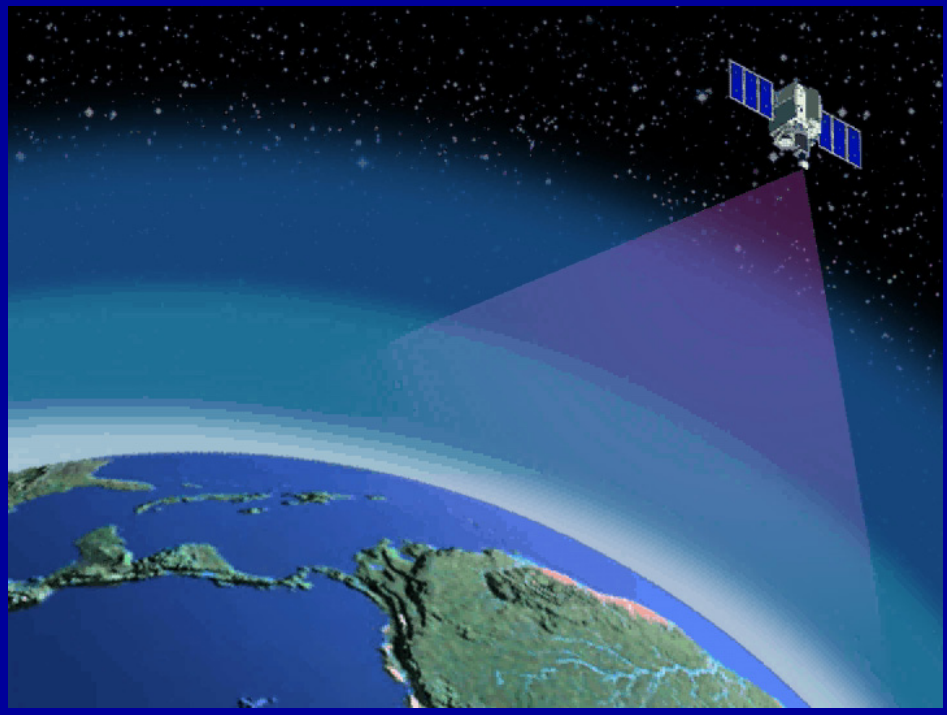
Earth Science for Aviation

- **Digital Atmospheric Data**
- **Digital Terrain Data**

Aviation: Improving Observations

180 Balloon Stations observe twice daily

GIFTS: 1km x 4km 100,000 obs/minute



High-resolution observations are required to accurately locate hazardous weather for aviation

Aviation Safety
Weather Forecasting for Cockpit Visualization

Socioeconomic Impact

$2B/year

Partners:

State 2-**WX Visualization Systems**: Fully integrated **SVS, WARP & ITWS** in-cockpit graphical WX displays featuring real-time weather information with global coverage

State 2- **WX Sensors/Data Sources: AIRS, CrIS & GIFTS** fully integrated into **NEXRAD & TDWR** systems; prepared for seamless integration of **ABS** (GOES-R)

EOS, NPP, NPOESS & GOES-R

NAS-wide Data Link WX Products provide severe weather location and movement data to controllers and aircrews to promote common situational awareness

GIFTS – Geosynchronous Fourier Transform Spectrometer Turbulence & Weather Prediction Modeling

Geostationary satellite technology improvements will vastly improve remote measurement of altitude-resolved vector winds and temperatures, allowing for efficient flight planning, operations and traffic management.

Aqua and NPP fly the AIRS and CrIS sensors (Atmospheric Infrared Sounder and Crosstrack Infrared Sounder)

High spectral (vertical), horizontal and temporal resolution satellite measurements will render precise numerical weather forecasts and extremely high-resolution wind fields based on the tracking of atmospheric water vapor

NAST (I) Atmospheric Sounder Testbed Infrared (Proteus) Experiments

Airborne validation of NPOESS instruments provides DSS product development teams with experience at integrating hyperspectral data and information in preparation for subsequent GIFTS and GOES-R missions

Advanced Satellite Applications Products (ASAP) Program

Integration of existing GOES imagery and sounding data into AWRP products improve Terminal Convective WX product and Integrated Turbulence Forecast

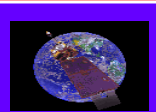
State 1-**WX Visualization Systems**: Discrete, Stand-alone weather products, with little satellite sounding data or imagery

State 1-**WX Sensors/Data Sources:** Ground Doppler Radar, 2x daily balloon readings yield 6 to 12-hour forecasts; poor oceanic coverage

Current trajectory:

Steady improvement in fielding and integration of hyperspectral LEO and GEO satellite data into NWS aviation weather products and AWRP visualization systems, resulting in fully integrated, real-time global aviation WX coverage

Enhanced Aviation Weather DSS and synthetic vision systems that reduce the aviation fatal accident rate by a factor of 10 by 2022



GOES-L,-M

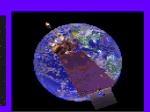
Proteus

Aqua

NPP/VIIRS

GIFTS

***NPOESS**



GOES-R

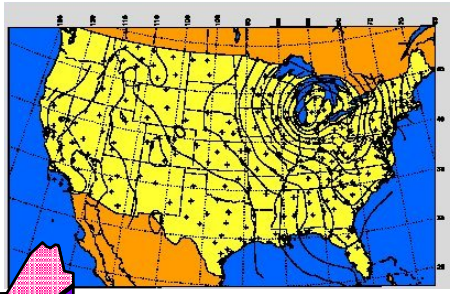
***Pre-formulation**

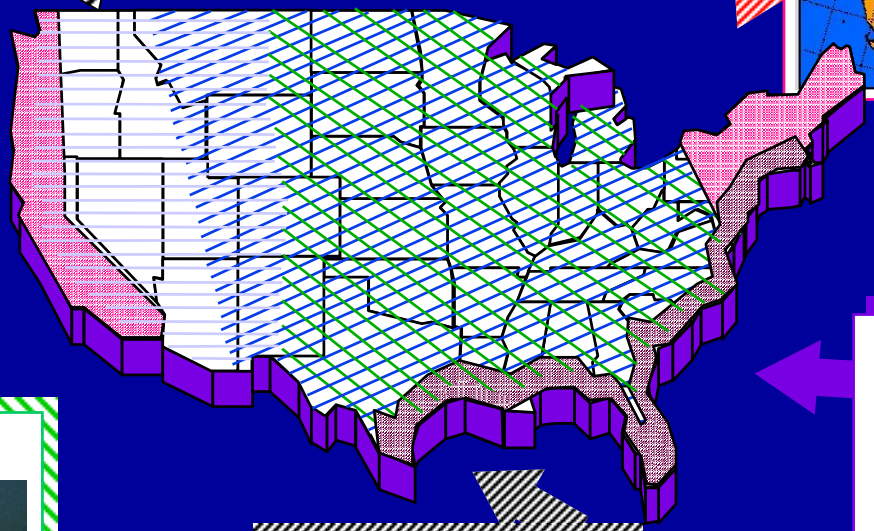
2000 2002 2004 2006 2008 2010 2012

Earth Science for Disaster Management

Thunderstorms and Hail

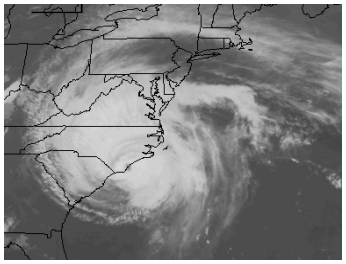
Extratropical Cyclones



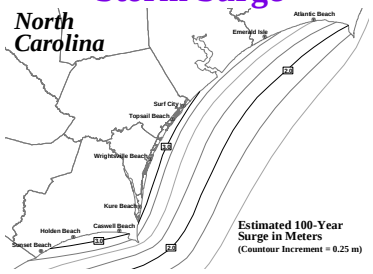


Tornadoes

Hurricanes

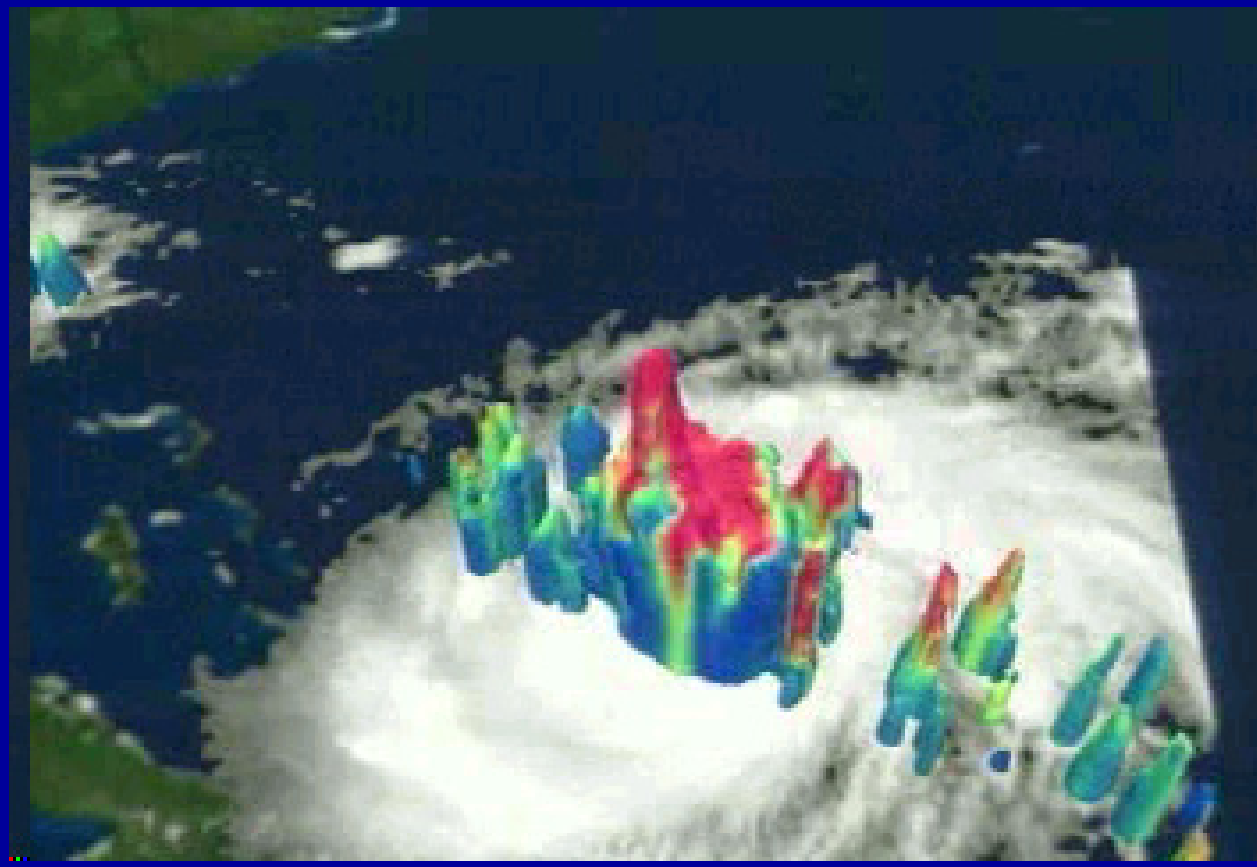


Storm Surge



Disasters: Hurricane Prediction

- **Using QuikSCAT data, forecasters can now predict hazardous weather events over the oceans as much as 12 hours earlier.**
- **Researchers are developing methods that can detect potential tropical cyclones more than 40 hours earlier than with traditional methods.**
- **TRMM is providing 3 dimensional maps of precipitation structure.**



Disaster Management:
HAZUS - Risk Assessment and Loss Estimation

Date: 6/14/2002

HAZUS:
Earthquakes
Hurricanes
Flooding
Tornadoes

Primary Partners:

Transfer of advanced event-modeling capabilities using next-generation hardware, software, and communications

Outcomes: Improvement of FEMA capabilities across all hazards and phases

Impacts: Reduce losses acro all disasters

Provision of real-time weather products for FEMA response applications

Outcomes: Improvement of FEMA response capabilities

Impacts: Reduce losses across all weather-driven disasters

Provision of EOS standard products with minimal time delay for FEMA response applications

Outcomes: Improvement of the HAZUS High Winds Module Final Version

Impacts: Reduce losses related to hurricane and high wind disasters.

Landsat 7 data for characterization of Forest species type, canopy structure, biomass, and tree height, width, and crown

Outcomes: Improvement of the HAZUS High Winds Module

Impacts: Reduce losses related to hurricane and high wind disasters.

FEMA-37 Floodplain Mapping Standard

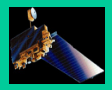
Outcomes: Improvement of all US Floodplain Maps feeding the HAZUS Flood Module

Impacts: Reduce losses related to flood disasters.

HAZUS:
Earthquakes

Socioeconomic Impact

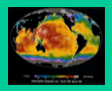
SeaWiFS

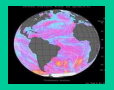

Terra

Jason-1

Aqua

SeaWinds


OcnTopo


* OSWinds

NPOESS

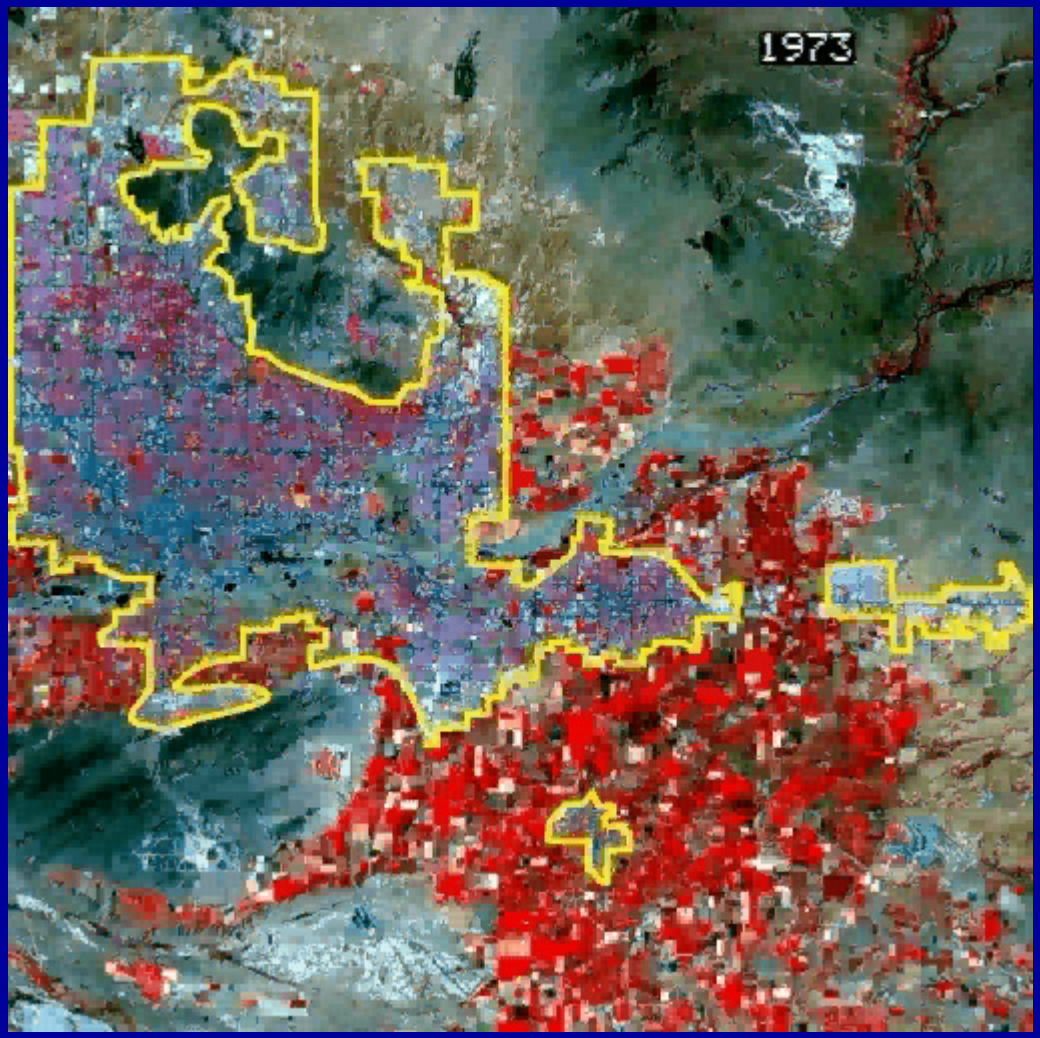
* Pre-formulation

2000 **2002** **2004** **2006** **2008** **2010** **2020**

An operational decision support system for quantification and verification of solutions for natural hazard predictions.

Community Growth: Urban Dynamics

- Transportation Infrastructure
- Urban Growth Planning
- Conservation & Preservation
- Human Impacts on the Land
- Infrastructure and Utilities



Phoenix, AZ

URBAN HEAT ISLAND:
Assessment, forecasting and mitigation

Improved Community Sustainability

Create stronger links to public health:
- Respiratory health alerts
- Real time air quality forecasting

Outcomes:
More timely public information on air quality-related health dangers

Improve biogenic emissions models:
- Utilize higher-resolution landcover data
- Improve treatment of surface properties (albedo, moisture)

Outcomes:
Improved biogenic emissions, particularly in urban areas with complex surfaces

Improve spatial resolution of models:
- Atmospheric models
- Emissions and photochemical models

Outcomes:
More accurate and more highly-resolved temperature and air quality forecasts

Implement anthropogenic urban heating in mesoscale atmospheric models:
- Transportation sources
- Building sources

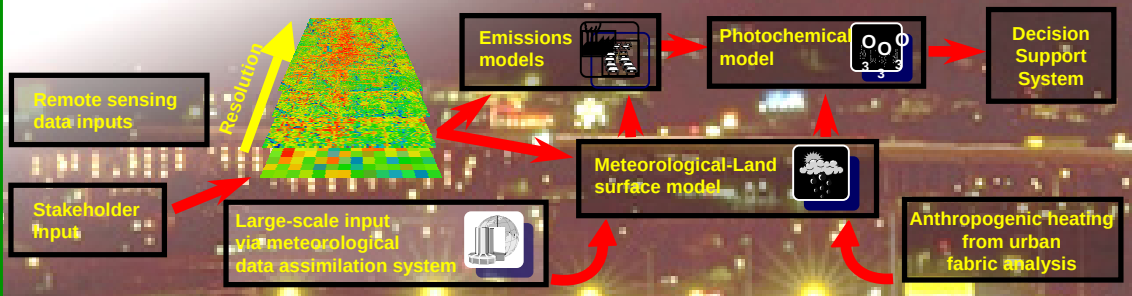
Outcomes:
More accurate simulation of urban air temperatures and consequently air quality

Increase stakeholder input into developing solutions for UHI and air quality problems:
- Develop and refine UHI mitigation strategies
- Conduct urban 'fabric analysis'

Outcomes:
More realistic assumptions about potential mitigation strategies, better understanding of the role of urban composition in the UHI effect

Improve utilization of currently available data:
- Land surface characterization
- Surface albedo
- Surface temperature, emissivity

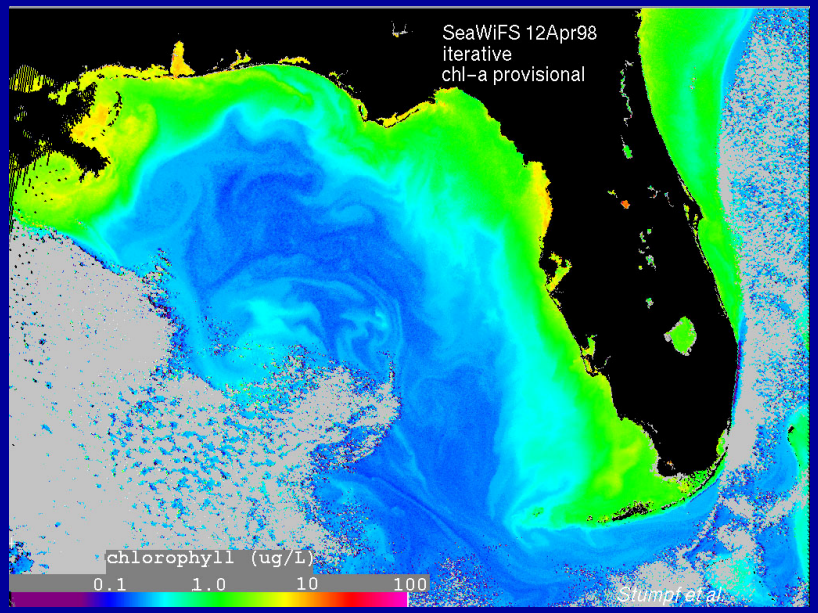
Outcomes:
Improved local atmospheric forecasts; improved estimates of emissions and ozone production



2002 2004 2006 2008 2010 2012

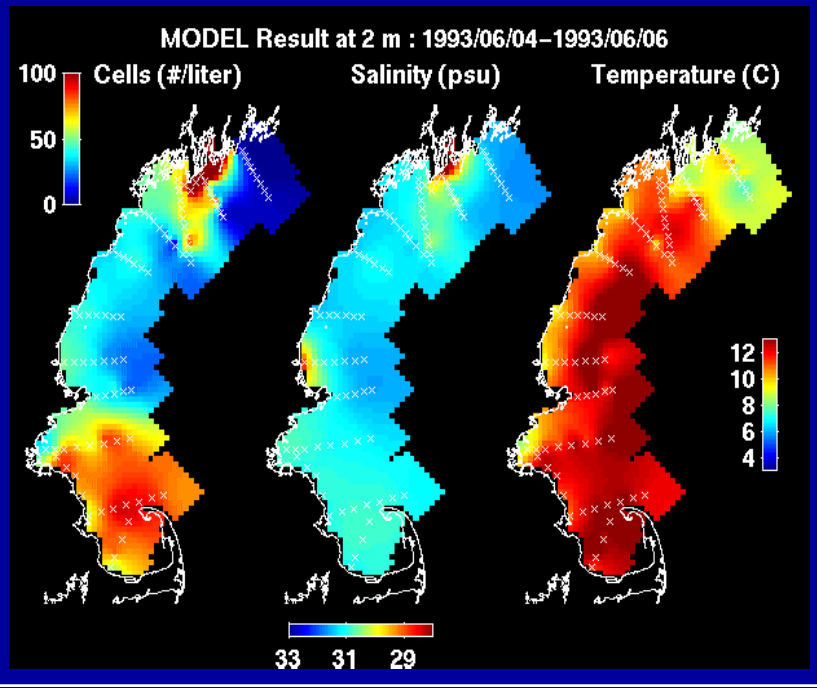
Operational Decision Support System for enhanced community development, habitability, and sustainability

Coastal Management: Predicting Algal Blooms



Current Capacity:

Respond to bloom detection with bio-physical models using satellite data and *in situ* sampling to forecast trajectories and impacts



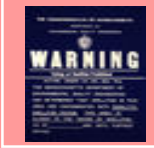
Future Capacity:

Prediction of bloom onset

Coastal Management:
Harmful Algal Blooms (HAB) & Hypoxia

Date: 6/14/2002

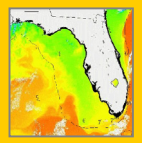
HAB/Hypoxia Forecasts (c. 2012)



- X-Y day warning
- X% initiation
- Y% landfall +/- X km
- X% dissipation

Primary Partners:

- Day/night S.S.Temp
- 3-D coastal circulation models incorporating biological data



Outcomes: 3-4 day warning of landfall. Routine detection. False negatives less than X%.

Impacts: Raise quotas for shellfish harvesting prior to HAB onset.

- Sea surface winds*
- HAB/phytoplankton speciation

Outcomes: Routine identification of particular HAB species. Improved estimates of toxin severity 2-3 day landfall warning.

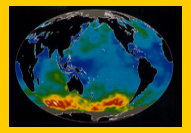
Impacts: Improve design and location of aquaculture facilities.

- Bio-optical sensors
- Improved coastal circulation models

Outcomes: Predictions of HAB transport, direction, and demise along coasts. Improved estimates of landfall area

Impacts: Warnings to fisheries and aquaculture facilities. Reduce impacts to non-target areas.

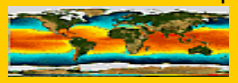
- Improved 2-D ocean circulation models
- Rain rates & salinity
- Sea surface height



Outcomes: 1-2 day warning of general landfall. Improved estimates of HAB demise. Warnings to close beaches.

Impacts: Reduce public exposure to toxins. Reduce hospital admissions and lost work/school days.

- Ocean color for chlorophyll *a*



- Sea surface temperatures

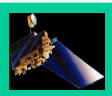
Outcomes: 0-1 day warning of landfall. Better understanding of HAB speciation. Improved estimates of initiation.

Impacts: Reduce economic impacts as possible. Build public confidence in forecasting systems.

HAB/Hypoxia Forecasts (c. 2002)

Current trajectory: Steady improvement in circulation models, HAB transport, and warning times.

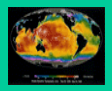
SeaWiFS

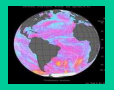

Terra

Jason-1

Aqua

SeaWinds


OcnTopo


* OSWinds

NPOESS

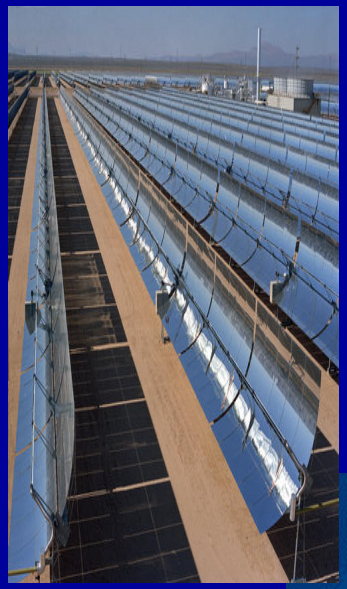
* Pre-formulation

Socioeconomic Impact

2000 2002 2004 2006 2008 2010 2012

Improved capabilities to decision support systems to forecast HAB initiation, transport, toxic severity, landfall and demise.

Surface Solar Energy Project



Objective

To synthesize and convert scientific data to renewable energy industry standards

History

- NASA Surface Radiation Budget Project develops surface solar insolation data set for solar cooking w/ DOE/NREL
- February 1998, “Development of Surface Solar Energy Data Sets for Commercial Applications for Placement of Solar Power Facilities” proposal funded by NASA
- Meteorological data added (surface temperature, moisture and winds)

Surface Energy Analysis & Forecasts

Date: 6/14/2002

Global long-term time series of industrial parameters; forecasted weather products for short-term (1–5 day), mid-term (10–90 day) and long-term (1–2 year).

Primary Partners:

NREL

NOAA

USDA

Socioeconomic Impact

Global Temperature/Moisture information assimilated into forecast and analysis models (GIFTS); improved mid/long-forecasts

DSS improved with short/midterm forecasts; 1st long-term forecasts

Cloud Vertical Profile Statistics (CloudSAT); Global aerosol distributions (CALIPSO)

DSS improved with parameter accuracy in time series & short-term forecasts; 1st mid-term forecasts.

Improved precipitation products (TRMM, AMSR, SSM/I); Analysis of global precipitation and energy fields; Forecasted parameters (NOAA)

DSS improved with addition of precipitation (biomass-fuel support); 1st short-term forecast of industrial parameters

Cloud, aerosol, energy data (Terra/Aqua) to improve/extend time series and evaluate/improve model forecasts; improved reanalysis (GSFC DAO)

DSS improved due to increased accuracy of energy (solar and infrared) and meteorological (temp. humidity, winds, clouds) parameters

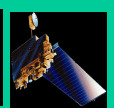
Increased resolution and extended time series (SRB and SSE)

DSS improved with 1st 12-year time series data set of industrial parameters with worldwide coverage at 1° x 1° resolution

Surface site climatological mean input data, coarse resolution global data; little weather forecast data

Incremental improvement in weather and climate forecasts from 1-2 day to 1-2 year predictions.

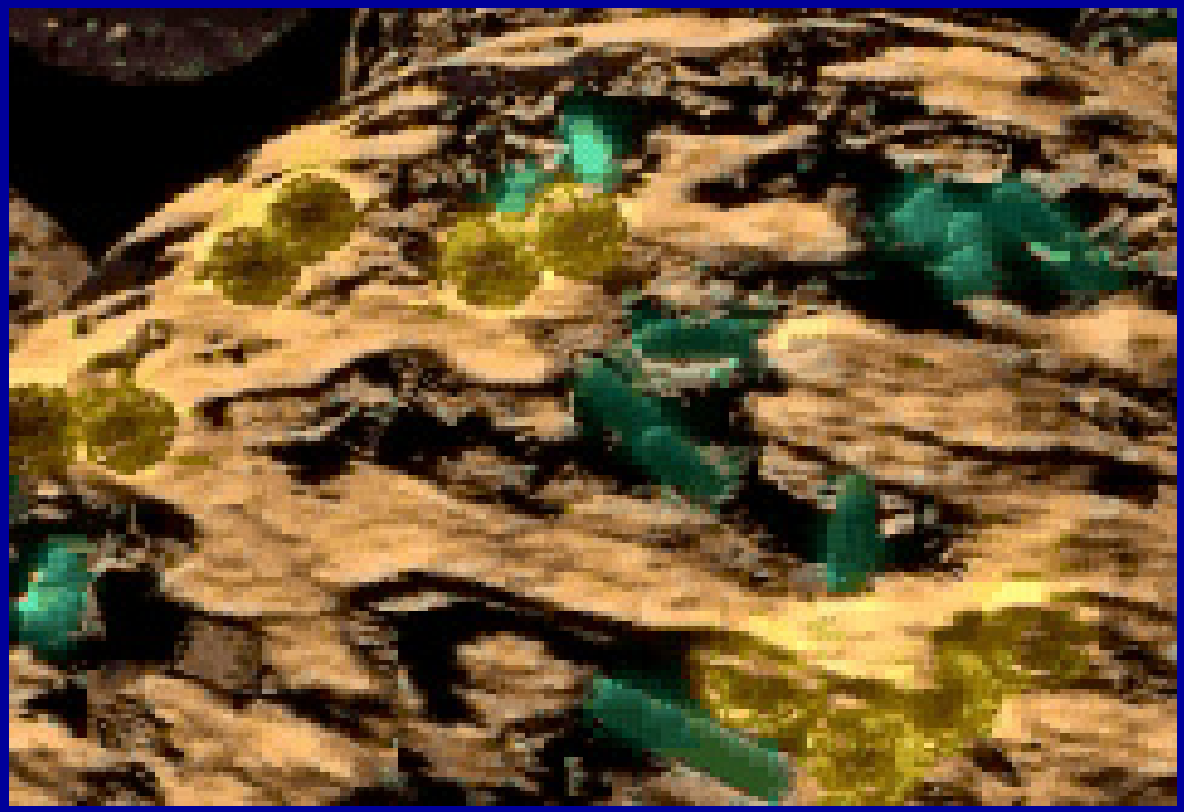
By 2012: Optimization of systems for the development of:
- **renewable energy systems (including integration into power grid),**
- **energy-efficient buildings (construction, renovation, operations),**
- **biomass crop selection and maintenance strategies, and**
- **electric power load and supply assessments**



TRMM Terra Aqua CloudSAT/CALIPSO GIFTS LDCM NPOESS

2000 2002 2004 2006 2008 2010 2012

Public Health: Intercontinental Transport



Visualization depicting transport of microbes attached to dust particles by transoceanic winds from Africa to North America.

Public Health: Infectious disease surveillance systems

Date: 6/14/2002

Primary Partners:

Data standards, compression algorithms, transmission protocols support sustained integration of geospatial and public health surveillance system data

Public health surveillance systems able to track weather-climate-environmental factors to predict disease outbreaks

Automated disease-specific surveillance enhanced with operational measurements and proven algorithms using weather/climate/environment predictive capacity

High speed computation and technologies developed for integration, analysis, and visualization of weather/climate/ environmental data, correlation with adverse public health events.

Weather/climate/environment algorithms supporting disease prediction models are verified, validated, and benchmarked.

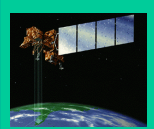
Remote sensors yield information on: vegetation/crop type, vegetation green-up, ecotones, deforestation, forest patches, flooded forests, general flooding, permanent water, wetlands, soil moisture, canals, human settlements, urban features, ocean color, sea surface temperature, sea surface height.

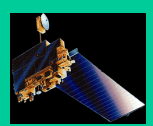
Weather/climate/environment-disease relationships discovered, verified, validated and benchmarked for assimilation into operational models (I.e. RSVP)

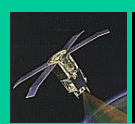
This roadmap depicts improvements in surveillance of disease potential coupling environment/disease relationships with development of predictive models. More rapid improvements will occur with integration of geospatial data into existing surveillance systems.

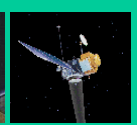
Current disease surveillance approaches lack complete information on weather/climate/environmental factors.

Enhanced public health surveillance systems
-- Weather/climate/environment factors accounted for in disease models.
-- More accurate and precise disease predictions: warning time increased proportionally


Landsat

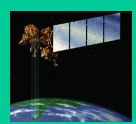

Terra


SeaWiFS


TOPEX

NOAA-POES

Aqua

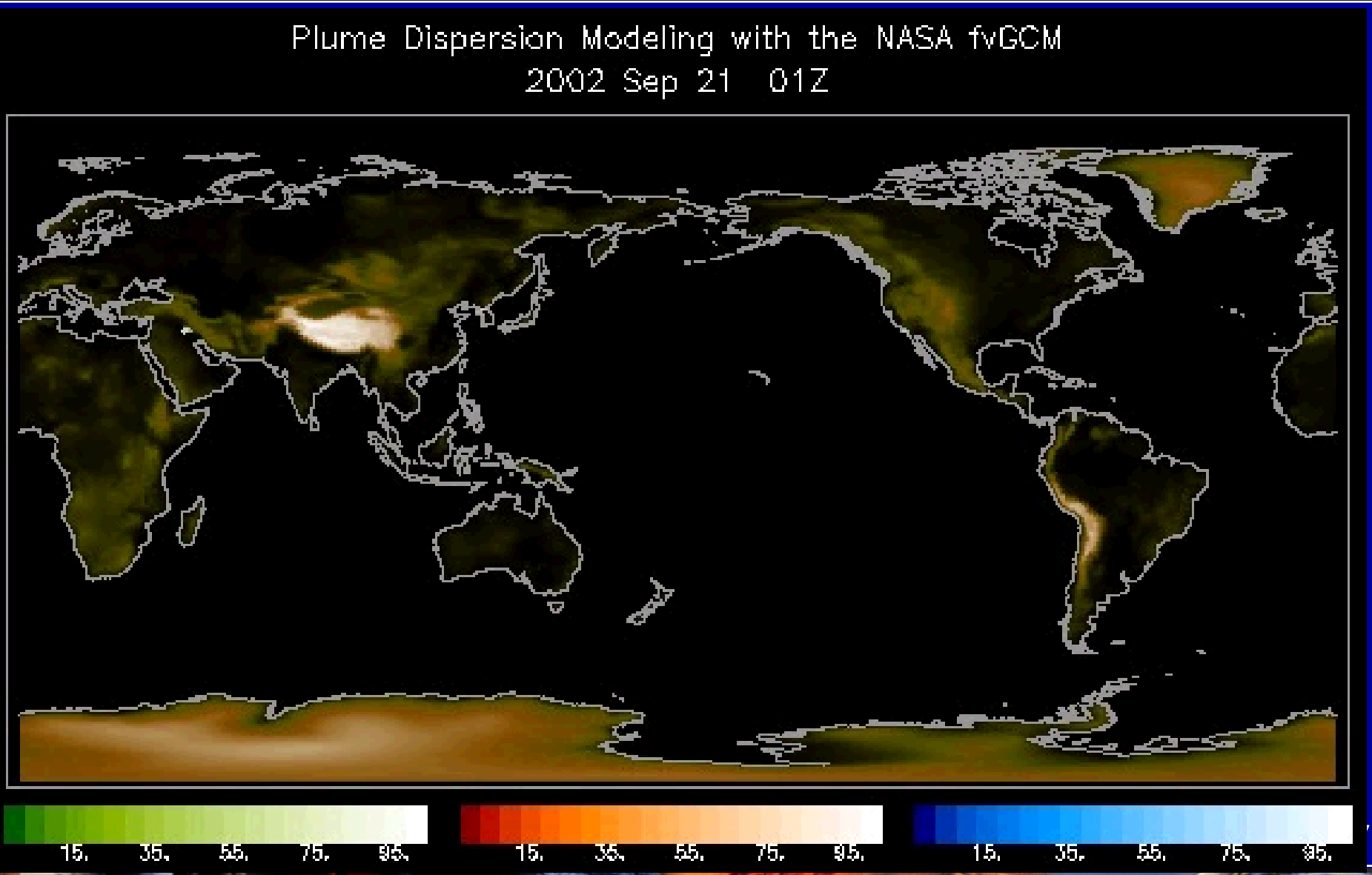

LDCM

NPOESS

2000 **2002** **2004** **2006** **2008** **2010** **2012**

Socioeconomic Impact

Homeland Security: Model of Plume Dispersion from Three Separate Nuclear Blasts



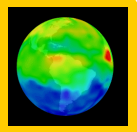
Homeland Security: DHS Situation Center Preparation, Warning & Response

Date: 6/14/2002

OHS Situation Center (c. 2012):
- Prepared with integrated data streams
- Information for warnings & alerts
- Rapid data to support responders and officials with info & analysis

Primary Partners:

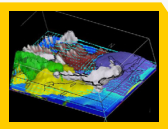
- Day/night air monitoring
- Trace gas measurements
- Improved circulation models



Outcomes: Streamline tasking for priority threats and flow of information.

Impacts: Reduce major illnesses and deaths from events.

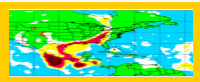
- Long-range deposition
- Bio-optical detection sensors and buoys
- Plume transport visualizations



Outcomes: Rapid identification of air/water biological agents. Trace sources & destinations Issue health alerts.

Impacts: Manage public reaction, fear, and over-reaction.

- Plume chemistry and speciation
- Robust satellite data assimilation
- Aerosol & trace gas characteristics



Outcomes: Improved information for first responders and recovery efforts. Warnings to food handlers & water treatment plants.

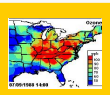
Impacts: Reduce exposure to first responders. Minimize extent of economic impacts.

- Plume advection/deposition
- UAV monitoring and rapid response communications links
- Visualization techniques

Outcomes: Identify downstream exposure to airborne/waterborne contaminants. Increase warning time to people/officials .

Impacts: Reduce health effects and exposure to livestock. Reduce hospital admissions and lost productivity.

- Simulation planning
- Database of sensors
- Sensor validations/verifications



Outcomes: Scenario coordination and planning for organized response. Appropriate sensors to match threat.

Impacts: Minimize subsequent exposure to populations and secondary effects.

OHS Situation Center (c. 2002):
Early formation stage.

Current trajectory: Improvements in plume modeling, sensor capabilities, and visualizations.

QuikSCAT | UAVs | Aqua | GRACE | AERONET | Aura | CloudSAT | MOBY | GIFTS | NPOESS | * Pre-formulation

2000 | 2002 | 2004 | 2006 | 2008 | 2010 | 2012

Socioeconomic Impact

Improved capabilities to homeland security officials to prepare, warn, and respond to homeland threats, especially air and water exposure.

Sharing a Vision of the Future

Stakeholder Communities

Public Sector

Private Sector

Policy Sector

ESE Applications Program

Expand and accelerate the realization of economic and societal benefits from Earth science, information, and technology.

Aerospace Sector

International Sector

Education Sector

Academic Sector

Science Sector

Public Sector Partners

USDA

USGS
science for a changing world

NOAA

Federal Aviation Administration

Federal Emergency Management Agency

Department of Energy

Department of the Air Force

National Imagery and Mapping Agency

U.S. Department of Transportation

EPA

Forest Service

National Institutes of Health

CDC
SAFER • HEALTHIER • PEOPLE

NSF

U.S. Department of the Interior
Bureau of Land Management

Mississippi Space Commerce Initiative

Federal Geographic Data Committee

MEMA

NSGIC

ASA

Research Sector Partners

ESAR
SDSU
UNIVERSITY OF WISCONSIN MADISON
UNIVERSITY OF FLORIDA
THE UNIVERSITY OF TEXAS AT AUSTIN
UTAH STATE UNIVERSITY 1888
ARSC ArcticRegionSupercomputingCenter
University of Hawaii
UCSB REMOTE SENSING RESEARCH UNIT RSRU
OleMiss
THE UNIVERSITY OF ARIZONA
The University of New Mexico
UAF UNIVERSITY OF ALASKA FAIRBANKS
MONTANA STATE UNIVERSITY BOZEMAN
UNIVERSITY OF SOUTH CAROLINA
MISSISSIPPI STATE UNIVERSITY
UNIVERSITY OF MARYLAND
JACKSON STATE UNIVERSITY MISSISSIPPI
UMAC
University of Maine
R • S • T • C
NCGIA
JPL
MITRE www.mitre.org
GLOBAL HYDROLOGY & CLIMATE CENTER GHCC

Private Sector Partners

Ocean Imaging
ERDAS INCORPORATED
PIXSELL
ESRI Technology
Applied Analysis Spectral Analytical Process
WAGGONER ENGINEERING INC.
STIA
EnviSense
DATASTAR Inc.
Kodak
STRO VISION
esa
GeoTek MANAGEMENT SERVICES COMPANY
BGRG Berkeley Geo-Research Group
BECHTEL
Litton TASC
PACIFIC MERIDIAN RESOURCES
i3 -- information integration & imaging
Raytheon
WORLD WINDS
Chevron
MAPPS
Ball
AATA INTERNATIONAL, INC.
EIGYS
ESSI
SII SPECTRAL INTERNATIONAL INC.
VEXCEL Image Information Engineering
ORBIMAGE GLOBAL IMAGING INFORMATION
MAPTECH
TSC Welcome Technology Service Corporation
ASTROVISION
HJW IMAGING THE EARTH
Community Coffee
FALCON INFORMATION TECHNOLOGIES
BOEING
OKSI OPTO-KNOWLEDGE SYSTEMS, INC.
CROPIX
GDE Systems Inc
ERIM International, Inc.
CDRC INC
DIGITALGLOBE
RESOURCE21
EARTHSAT
EARTHDATA
SPACE IMAGING
MTL Systems, Inc.
ADVANCED RESOURCES INTERNATIONAL
LOCKHEED MARTIN
Applied Analysis Inc.
BellSouth Services
POSITIVE SYSTEMS
4 NBC
ADDAX CORPORATION
INTERMAP

Socioeconomic Benefits

National Applications	Estimated Economic Benefits	Citation
Energy Forecasting	**$9.58 B / yr** Estimated annual benefit from implementation of the POWER Project (Biomass Energy Industry and Energy Resource Planning Phases only; average for 2002-2017)	LARC Report: *An Estimate of NASA/ESE/POWER Program Benefits to the U.S. From 2002 through 2017*, June 3, 2002.
Carbon Management	**$150B / yr** Cost savings by soil sequestration for meeting the WRE Carbon 550 Emissions constraint as determined by the MiniCAM model	*Carbon Sequestration in Soils: Science, Monitoring and Beyond*; St. Michaels Workshop, Dec 1998
Agricultural Efficiency	**$300M / yr** Projected annual benefit from improved crop prediction based upon better climate forecasting	*NOAA Strategic Plan*: *A Vision for 2005*; September 1998

Socioeconomic Benefits

Air Quality Management	**350,000** fewer cases of aggravated asthma & **5,000** fewer premature deaths **1 million** fewer cases of reduced lung function in children **$500 million** estimated from ozone reductions…EPA estimate of annual benefit from adopting new NAAQS standards	EPA Fact Sheet, June 25, 1997 EPA Fact Sheet, July 17, 1997 US EPA, National Air Quality and Emissions Trends Report, March 2001
Disaster Management	**$240M / yr** Reduction in losses/yr to the Property and Claims industry through adoption of geospatial technologies estimate $100M per typical hurricane if 24 hour evacuation predictions could be improved to 300 miles of coastline	Insurance Services Office (ISO), 2002. *Weather Impacts, Forecasts and Policy,* March 2002 BAMS
Public Health	**$200M / yr** Amount that could be reduced to contribute to managing risks for asthma.	Johns Hopkins School of Public Health, May 2000

Socioeconomic Benefits

Coastal Management	Reduce economic impacts from harmful algal blooms (HABs) affecting 1) public health 2) commercial fishery 3) recreation and tourism 4) monitoring and management costs	WHOA Technical Report 1999
Invasive Species	**$140 to $408M / yr** Estimated aggregated benefit of reduced environmental damage, reduced crop yield losses and decreased use of herbicides	Office of Technology Assessment (OTA). Report OTA-F-565, 1993.
Water Conservation/ Management	**$11B / yr** Approximation of partial benefits of current water quality levels as compared to what they would have been w/o water pollution control programs	Application Profile (U.S. EPA)

Socioeconomic Benefits

Aviation Safety	**$1.66 B / yr** Average annual savings combined from using synthetic vision system (SVS) to improve airport capacity and delay efficiencies at 10 U.S. airports	NASA Langley Research Center, July 2000
Community Growth	**>$1M / yr per city** More efficient decision making for planning offices saved one city planning office (Scottsdale, AZ) millions of dollars/yr	GIS World November 1997

Enriching Earth Science Education

- **Provide the Nation with life-long learning opportunities about climate change research, weather prediction, and solid Earth and natural hazards**
- **Partner with educators to build human capacity to create effective decision support tools**

Improving public awareness, appreciation and understanding of Earth system science and encouraging pursuit of careers in science and technology using NASA-unique content and resources

Inspiring the Next Generation of Explorers

- **Using the Earth System Science concept to contribute to the way Earth science is taught**
- **Influencing each stage of the education pipeline**
  - **Teacher-reviewed curriculum materials for K-12**
  - **Earth System Science Education curricula**
  - **Sponsoring 150 graduate student fellowships directly**
  - **Sponsoring 40 early career and education grants**
- **Working with 25 museums to integrate NASA Earth science results into evolving exhibits**
  - **Smithsonian Forces of Change Exhibit on El Nino**
- **Partnering with the National Park Service, the Girl Scouts, Earth & Sky Radio, and others to increase public literacy in Earth science**

“Putting Earth Science Data To Use”

- **Focus on solutions for national priority applications**
- **Leverage performance & funding with federal partners**
- **Employ a systems approach**
  - **Missions ->Models -> Decision Support Systems**
- **Benchmark solutions with partner agencies**
- **Connect global monitoring and predictions for local benefits**
- **Realize the benefits and capacity of Earth science laboratories and remote sensing missions through integrated system solutions**

Integrated Virtual Earth System: Delivery of Science & Solutions

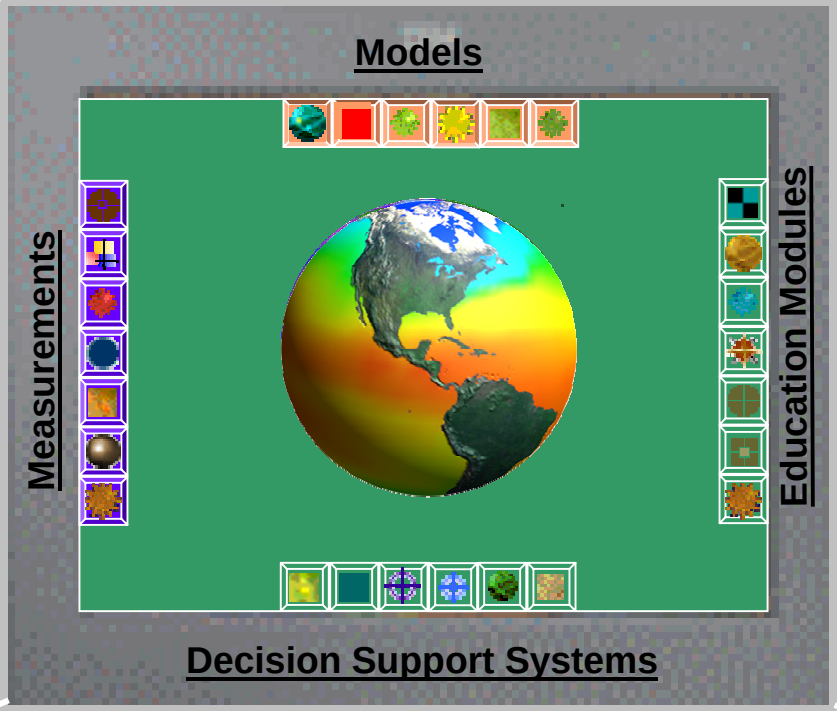
Science Algorithms

Satellite, suborbital & *in situ* observations

Data Handling Systems

EOSDIS
DAAC
ESIP
SEEDS
. . .

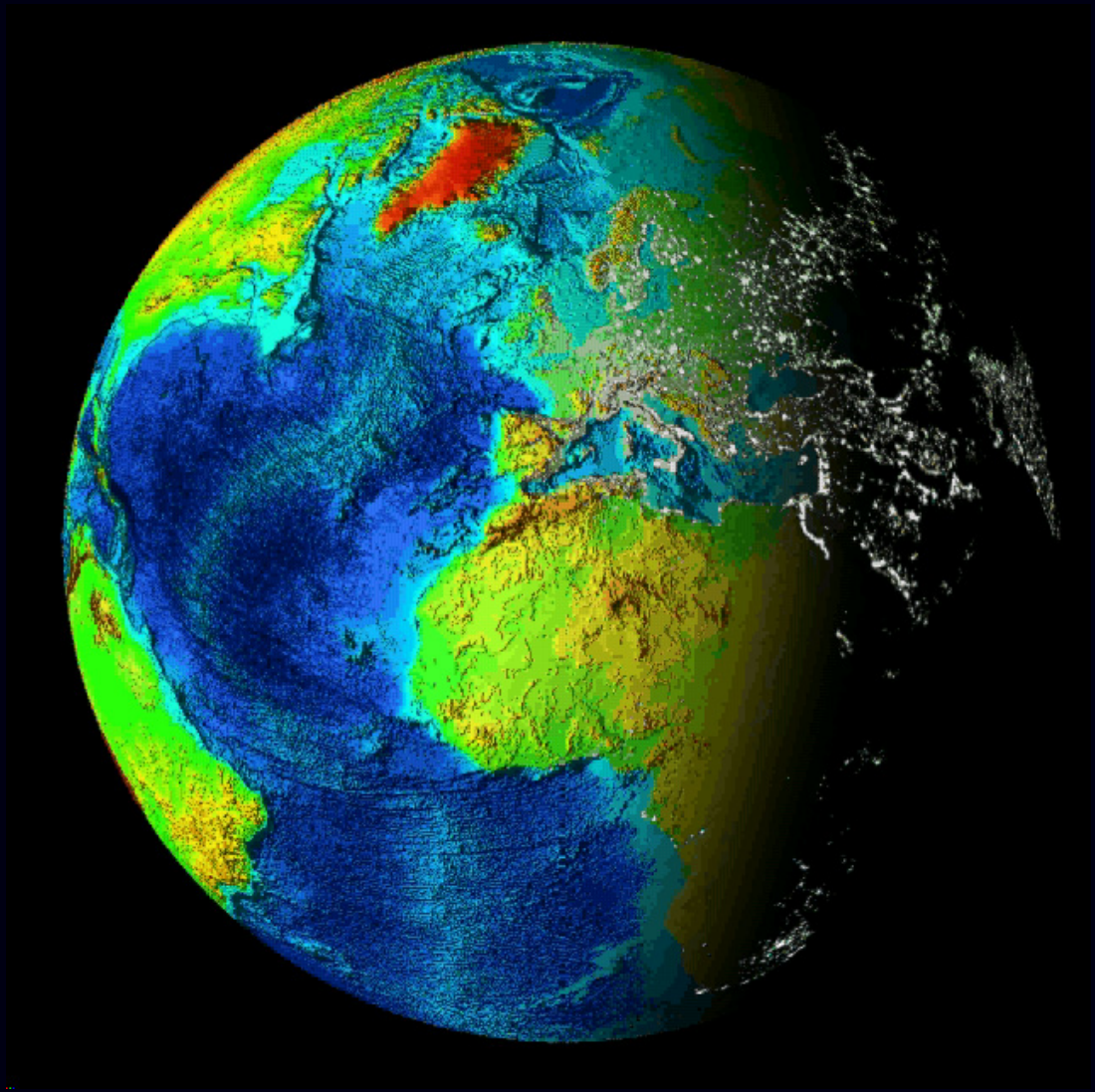
Land, Oceans, Ice, Atmosphere Models



ESSEA
ESSA21
Windows to..
WDET
. . .

Education Products

FAS, CMAQ, HAZUS, EHTN, RiverWare…

Predictions and Observations

Enabling Solutions for Society