Space Exploration Vision for the 21st century

Presentation to: Great Midwestern Space Grant Region Biennial Meeting

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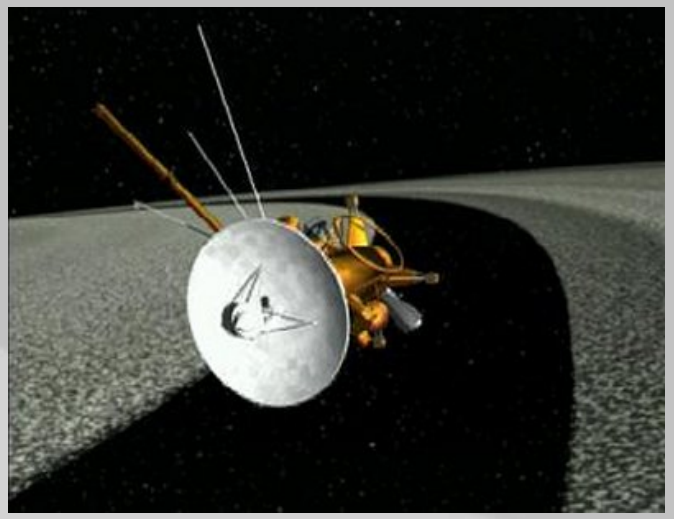
Applied Sciences Program
NASA Science Mission Directorate


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.

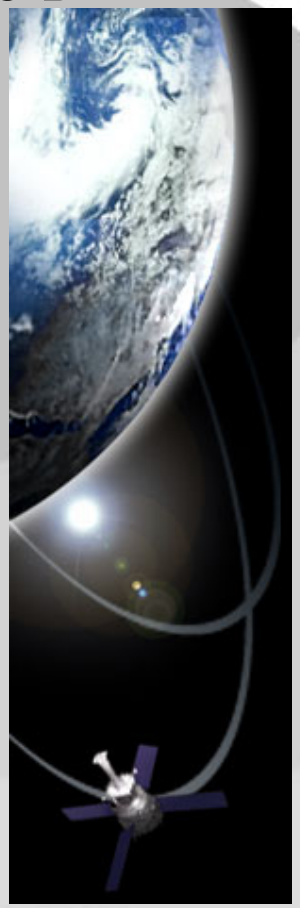
First Wave of Great Observatories and the next wave of Planetary Explorers are in Space

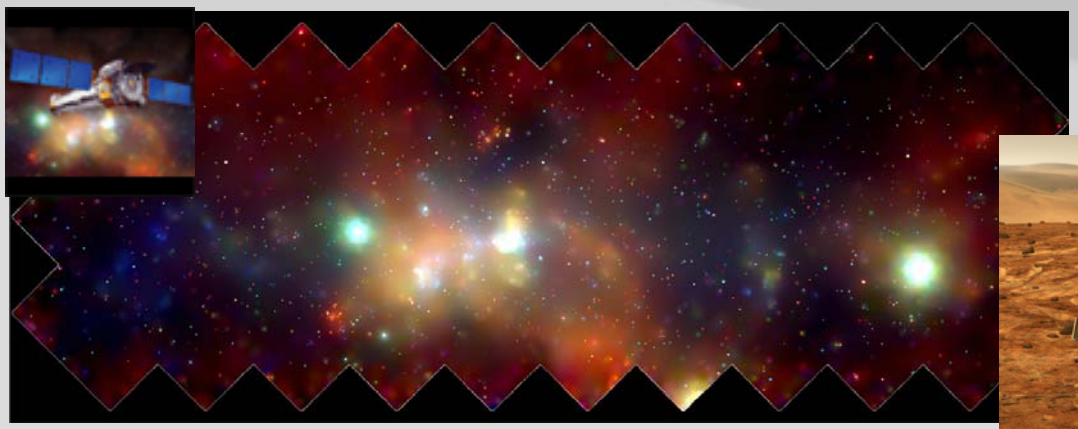


Cassini

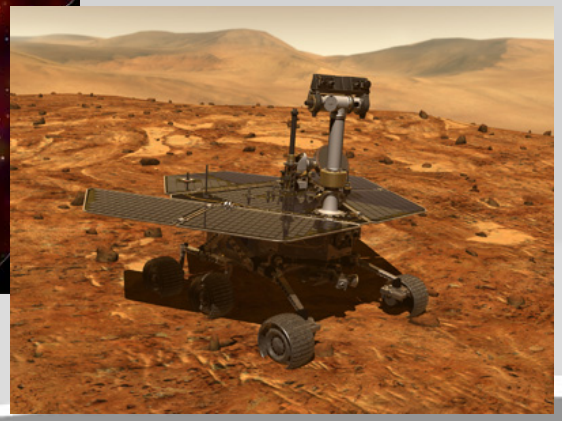
Hubble

Gravity Probe-B

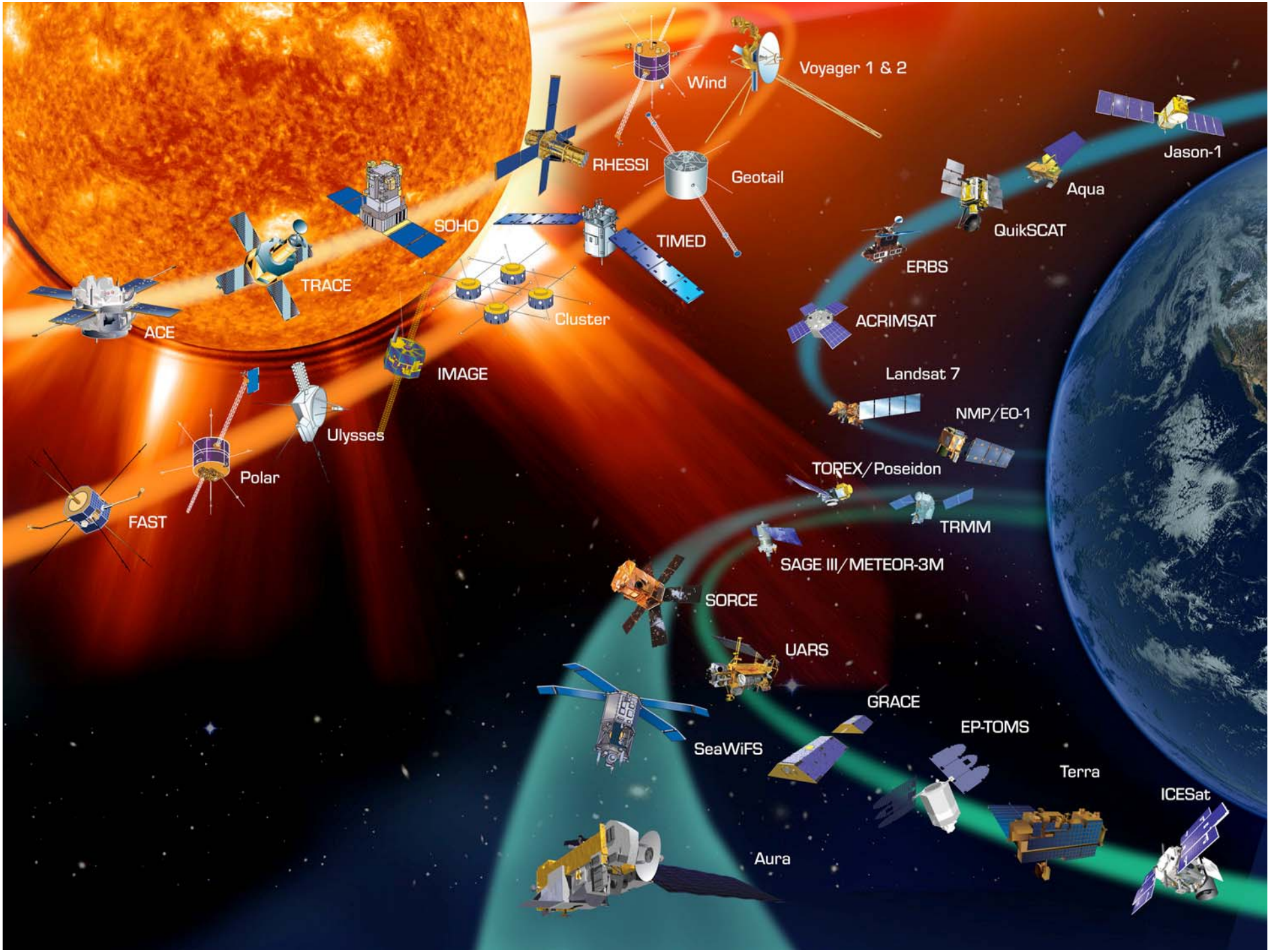




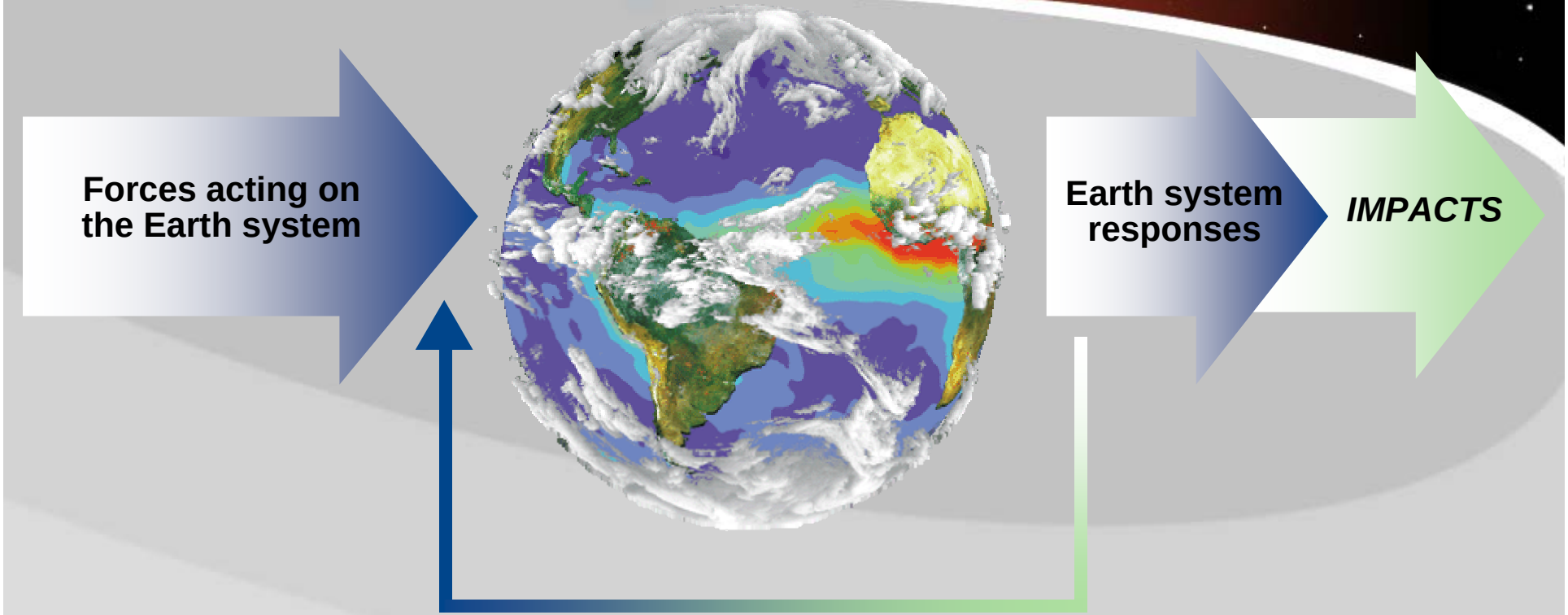
Chandra



Mars Rovers


Voyager 1 & 2
Wind
RHESSI
Geotail
SOHO
TIMED
TRACE
ACE
Cluster
IMAGE
Ulysses
Polar
FAST
Jason-1
Aqua
QuikSCAT
ERBS
ACRIMSAT
Landsat 7
NMP/EO-1
TOREX/Poseidon
TRMM
SAGE III/METEOR-3M
SORCE
UARS
GRACE
EP-TOMS
SeaWiFS
Terra
ICESat
Aura

Planet Earth - a Dynamic System



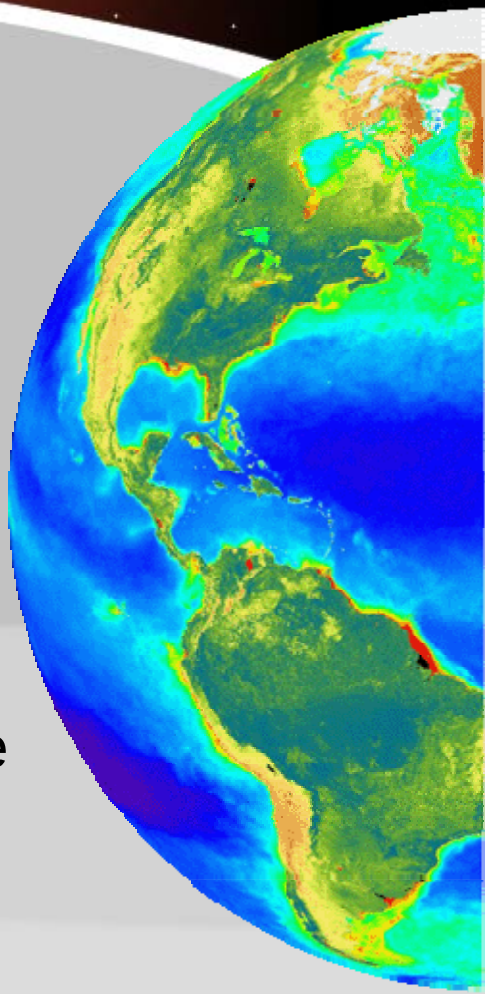
Feedbacks

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.

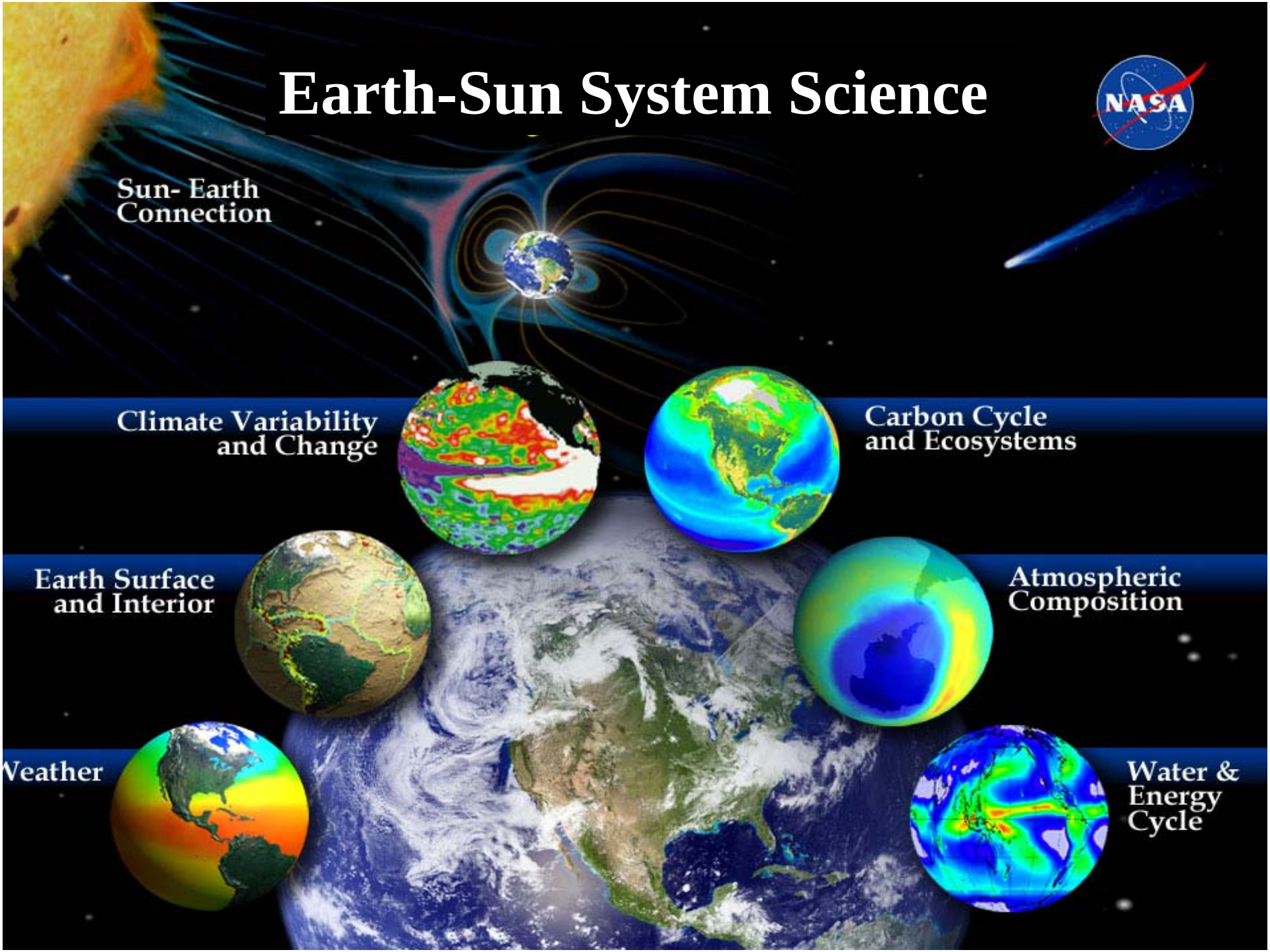
Science Questions Focusing NASA Research for Earth System Science

How is the Earth changing and what are the consequences of life on Earth?

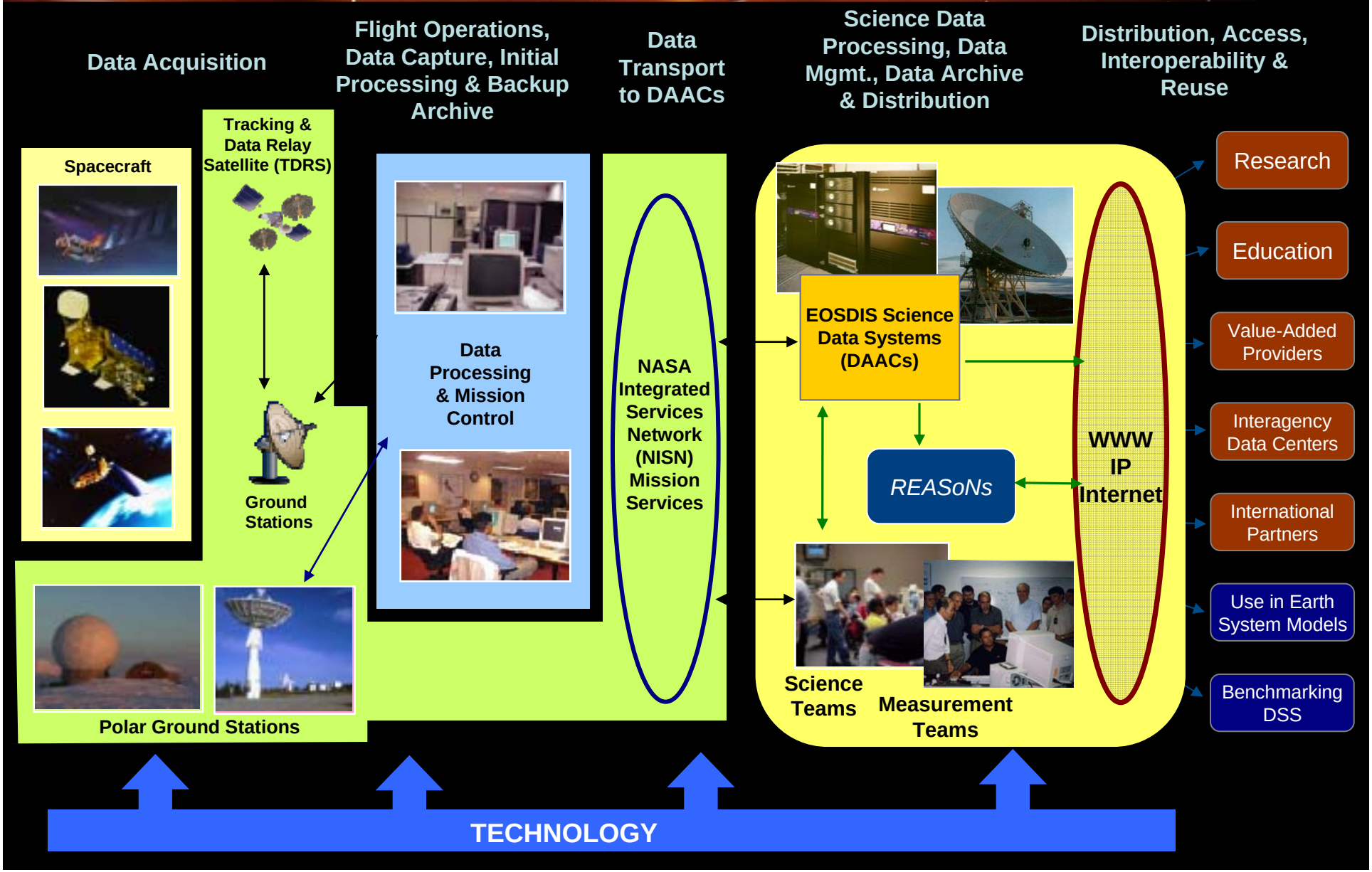
- How is the global Earth system ***changing***?
- What are the primary **forcings** of the Earth system?
- How does the Earth system ***respond*** to natural and human-induced changes?
- What are the ***consequences*** of changes in the Earth system for human civilization?
- How well can we ***predict*** future changes in the Earth system?



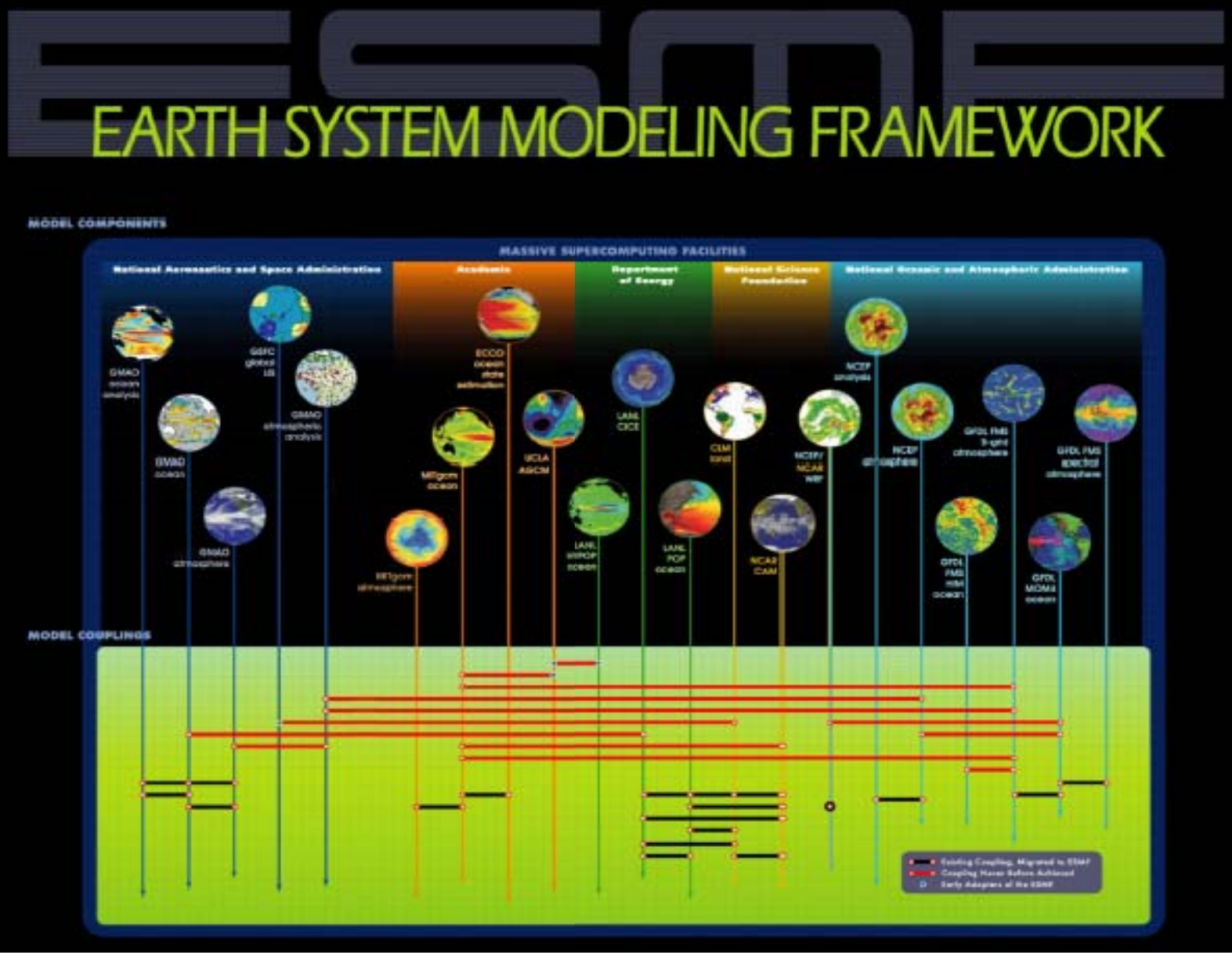
Earth-Sun System Science



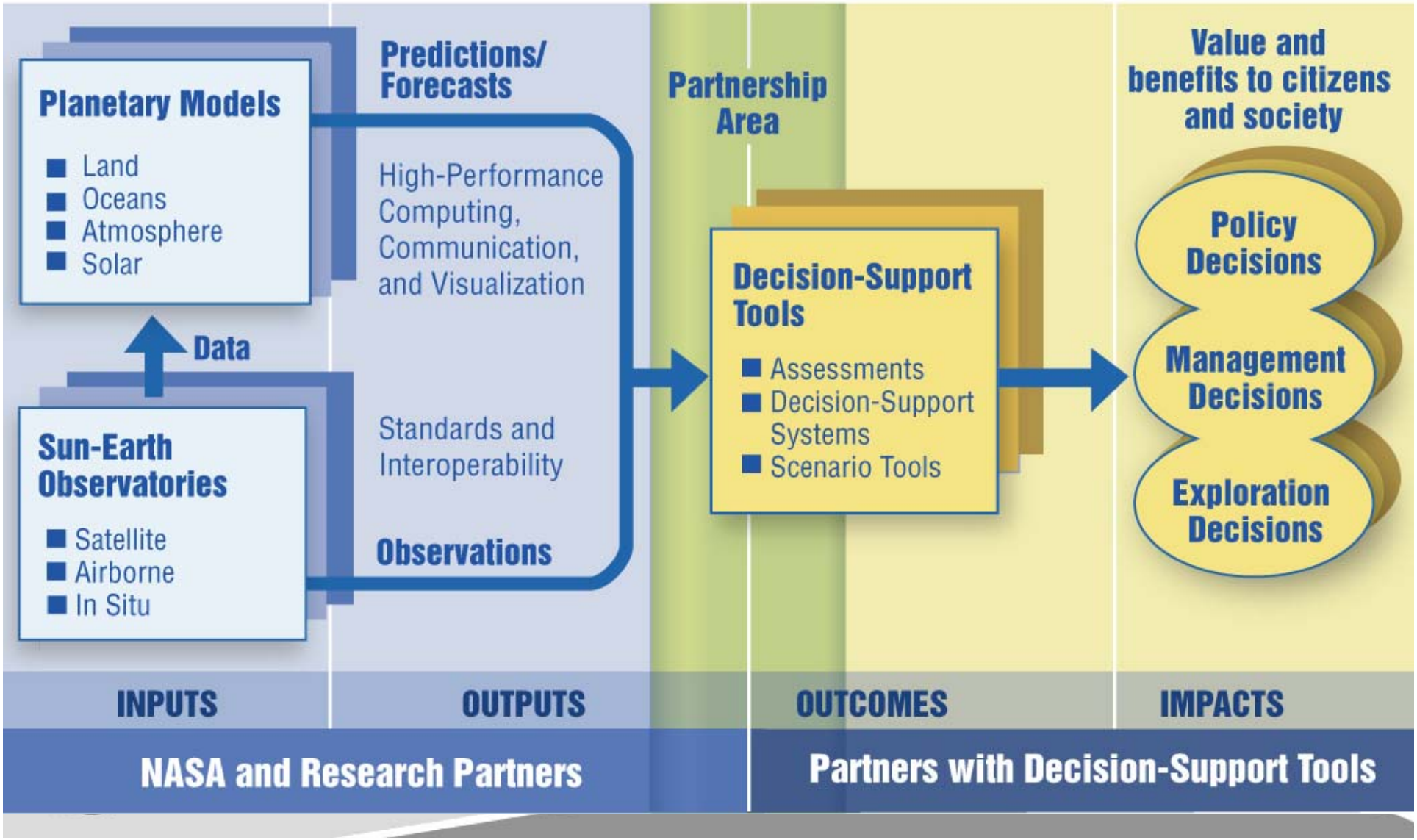
Data Acquisition to Data Access



Earth System Models



Integrating Knowledge, Capacity and Systems into Solutions



Applications of National Priority

Agricultural Efficiency

Air Quality

Aviation

Carbon Management

Coastal Management

Disaster Management

Ecological Forecasting

Energy Management

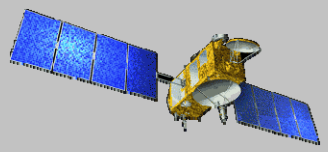
Homeland Security

Invasive Species

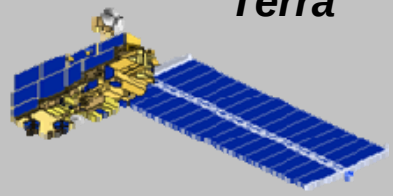
Public Health

Water Management

Agriculture Efficiency



Jason



Terra

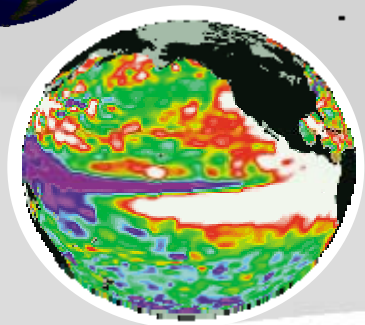
Tasking

EDOS: Mission Control

Downlink

Exploitation

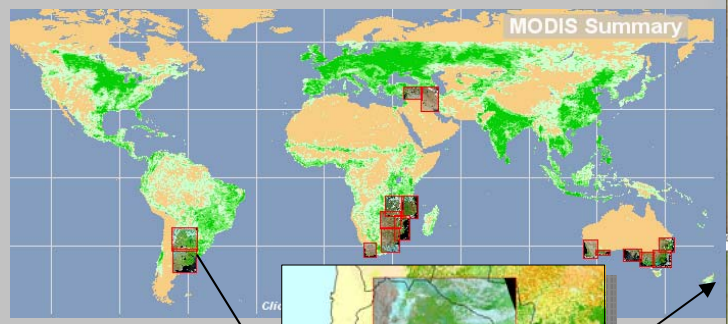
EOSDIS & DAACs

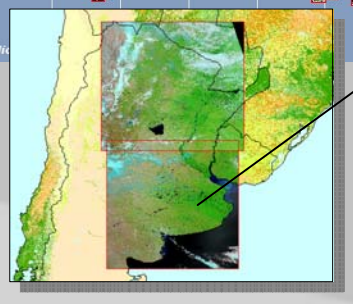


Societal Benefits

CADRE:
USDA Decision Support System for Global Crop Production Assessments

NASA Research Results benchmarks for improving Agriculture Efficiency





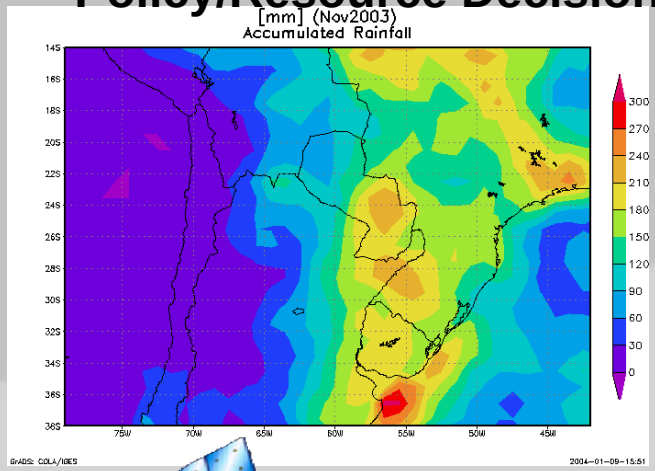
MODIS Rapid Response products provide timely looks at crop condition

EOS products

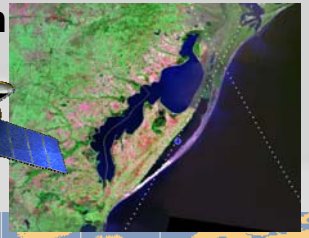
Productivity modeling (FAS)

WAOB Estimates

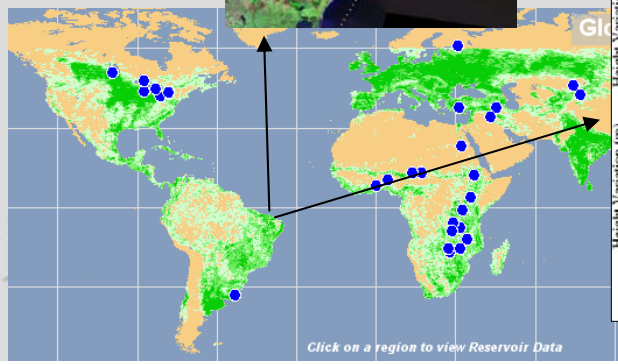
Policy/Resource Decisions

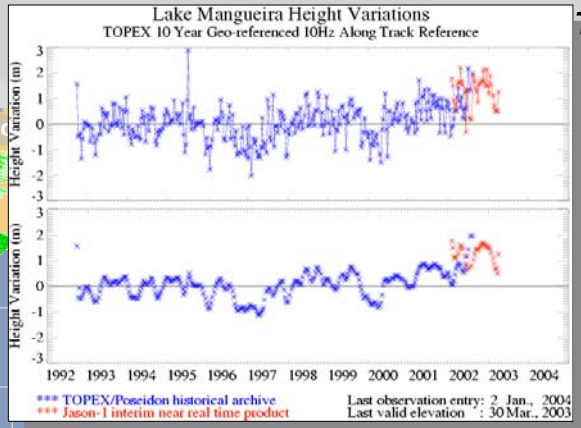


Jason

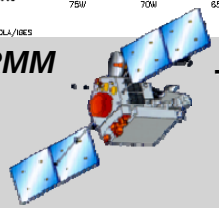


TOPEX and JASON-1 products provide lake level data in critical irrigated areas





TRMM



TRMM products provide better data on available water

Change Detection: Landsat and MODIS

Landsat 7

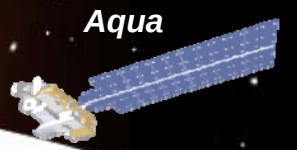
Landsat

August, 1993

August, 2002

Terra

Aqua

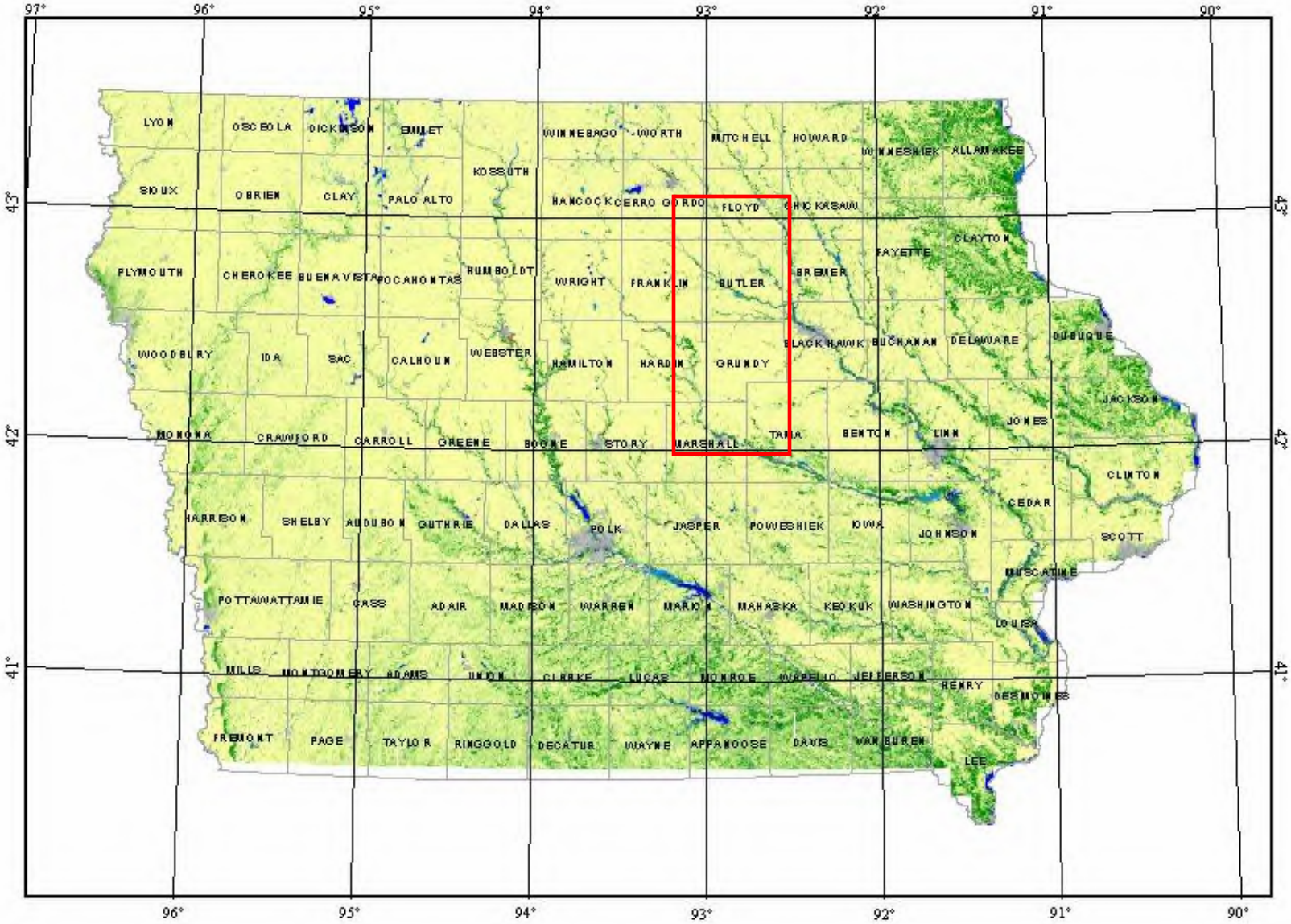


MODIS

April, 2003

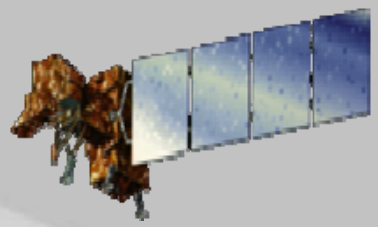
August, 2003

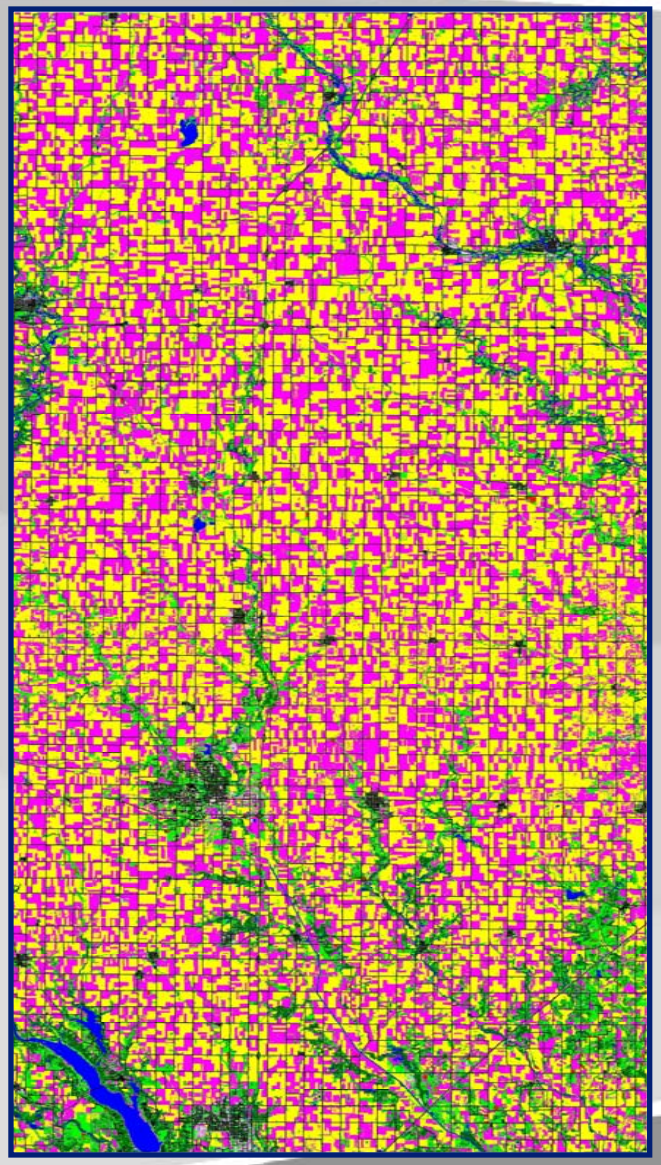
2002 Yield Study in Central Iowa



Classification of Landsat Imagery for SMEX02 Study Site

Landsat 7





Legends

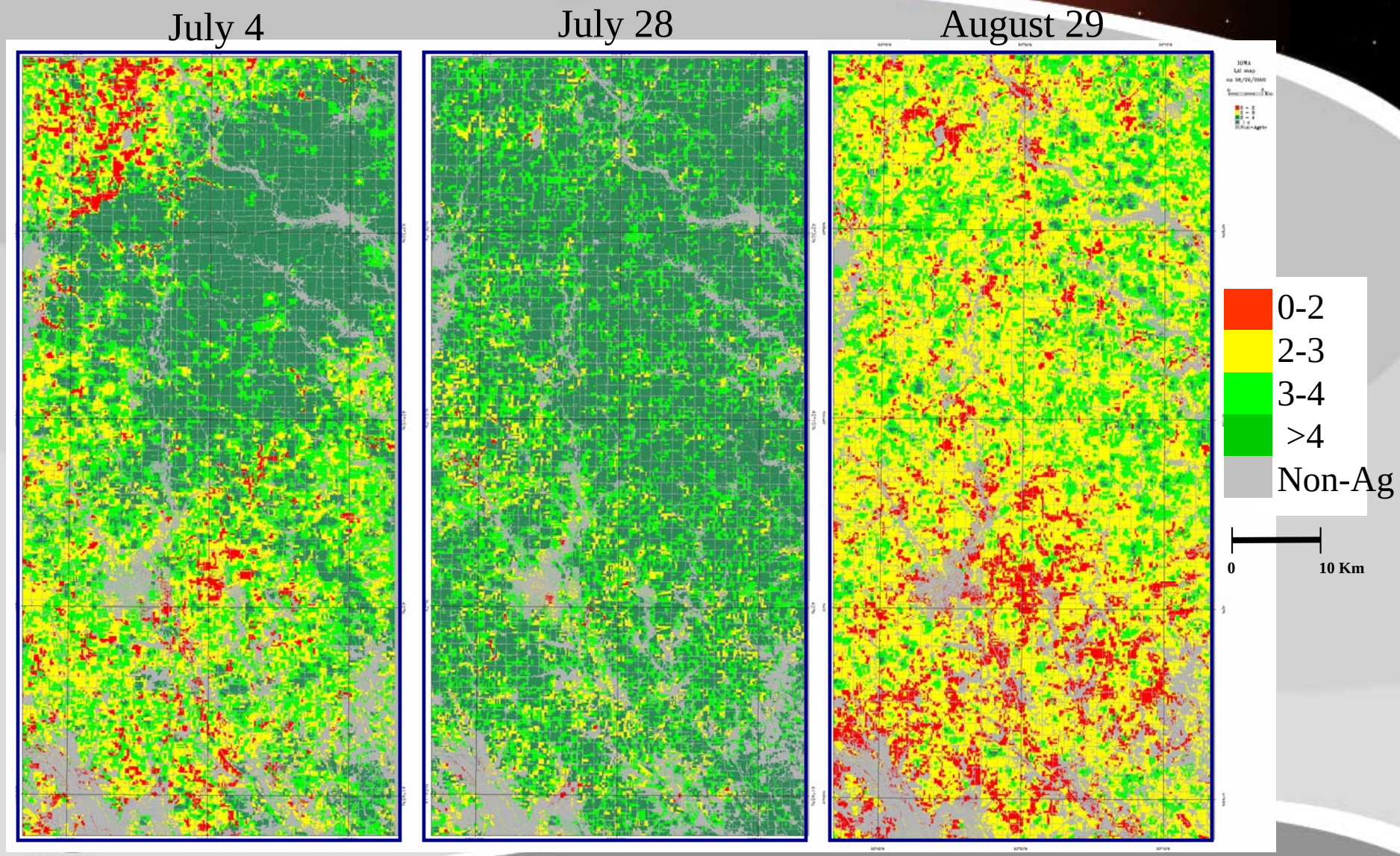
Class Names

- Alfalfa
- Corn
- Grass
- Soybean
- Tree
- Urban
- Water
- Roads

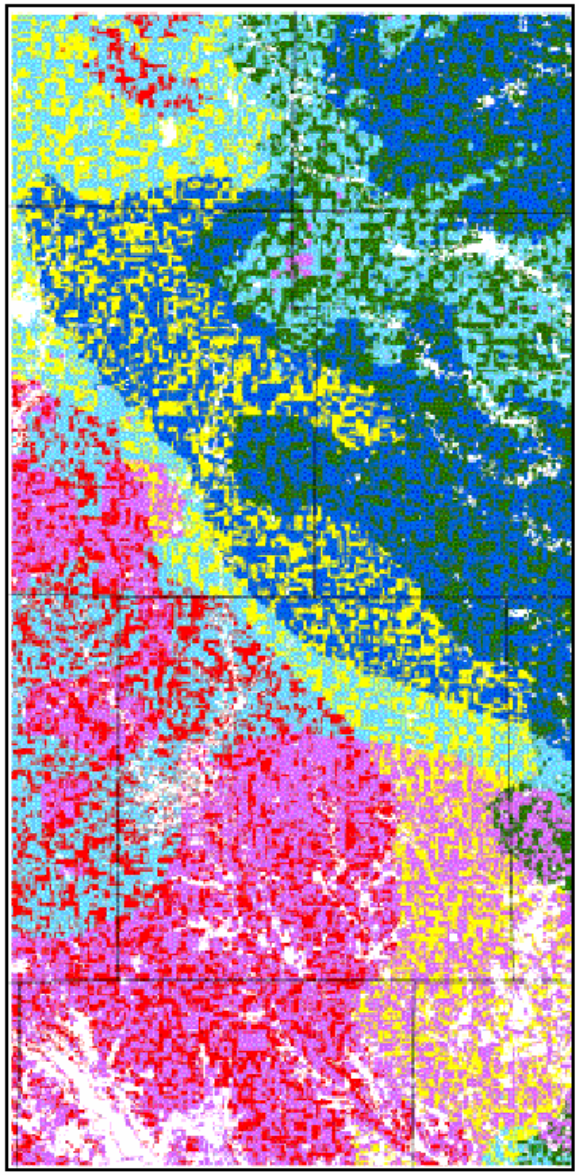
Scale

10 0 10 20 30 40 Kilometers

LAI simulation (250m) for Corn & Soybean



Corn and Soybean Crop Yields, 2002



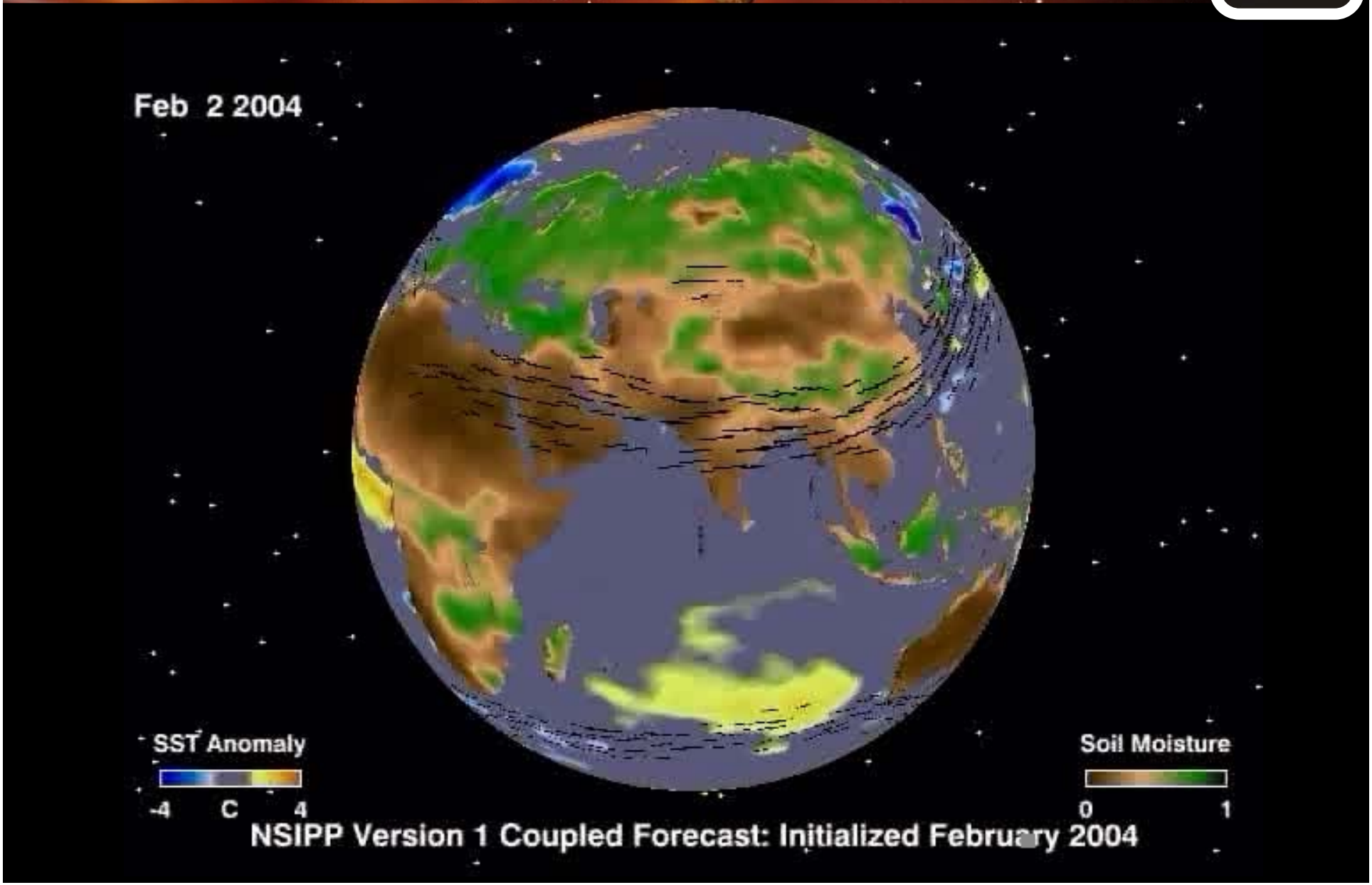
Corn (T/ Ha)

- 8.65 – 11.45
- 11.45 –11.86
- 11.86 –12.39

Soybean (T/ Ha)

- 2.85 – 3.43
- 3.43 – 3.56
- 3.56 – 3.76

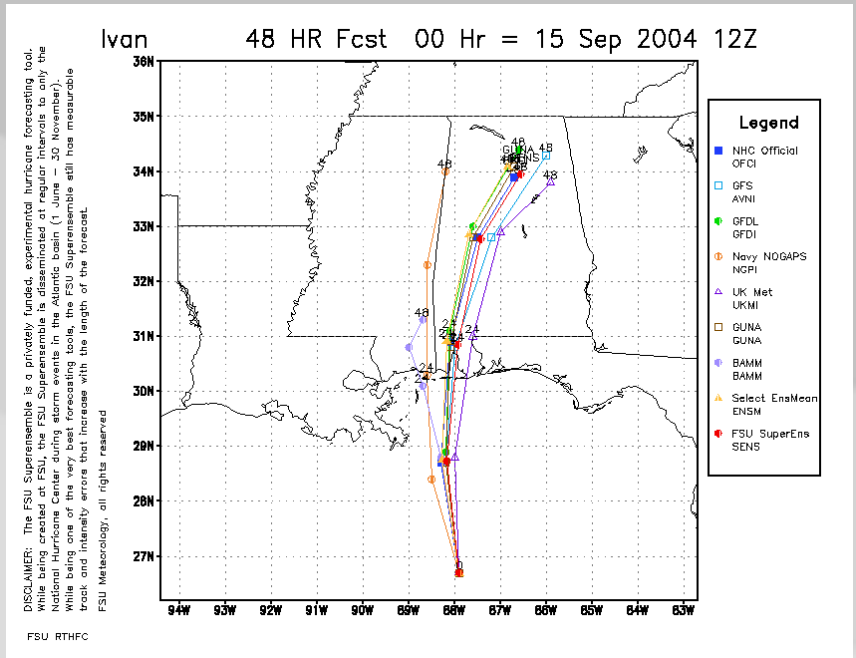
12 Month Coupled Climate Forecast



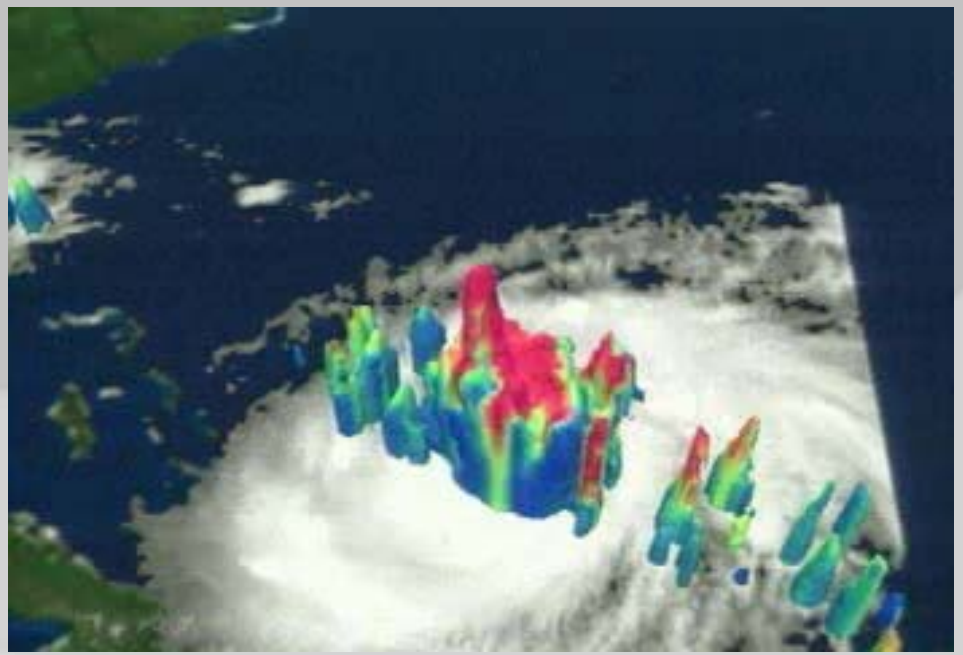
Using Earth Observation Data to Model Hurricanes

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

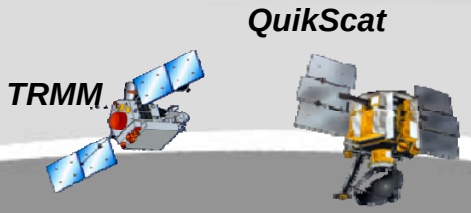
Hurricane Ivan Forecast, September 2005



Hurricane Visualization with TRMM data

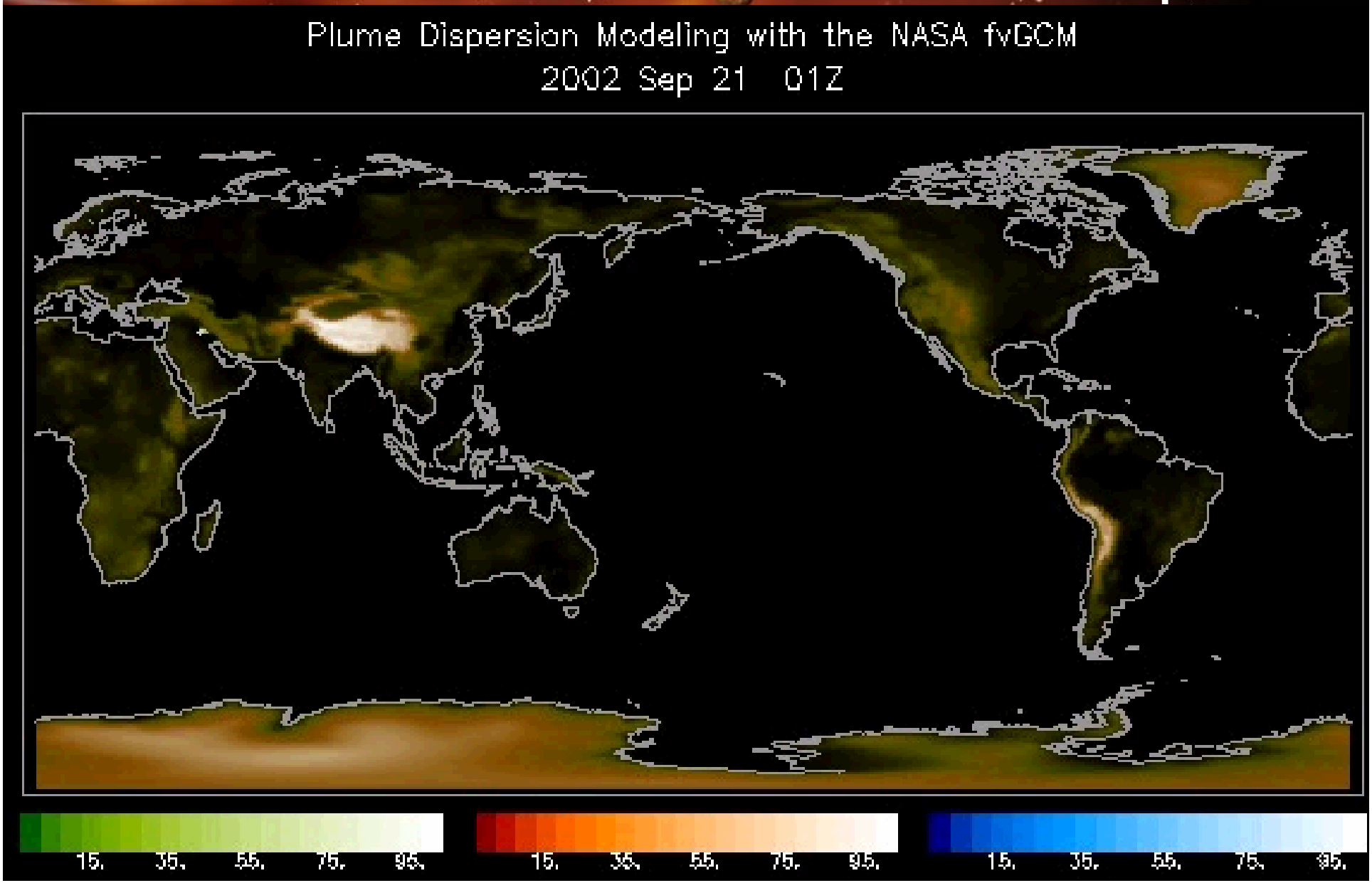


Reduced track errors can save money ($600K - $1M per mile of coast evacuated) and save lives by more precise prediction of eye location at landfall



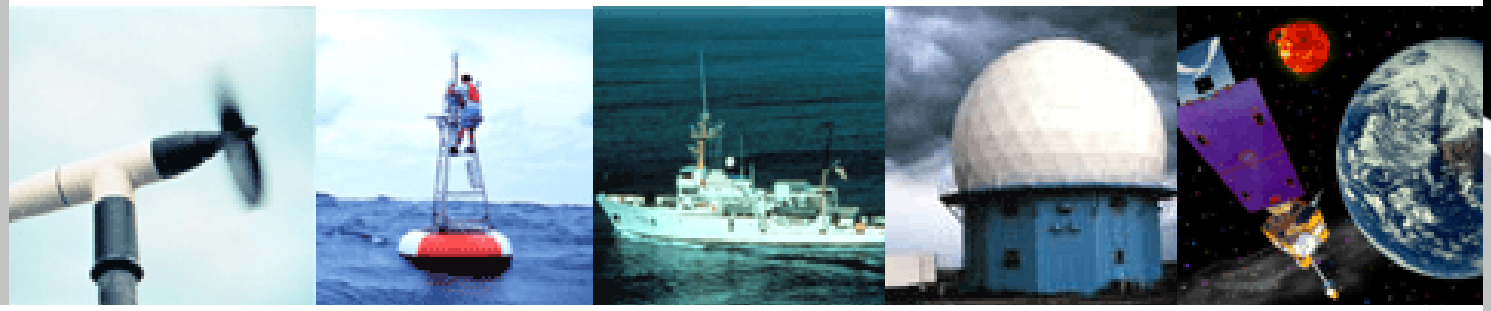
Homeland Security

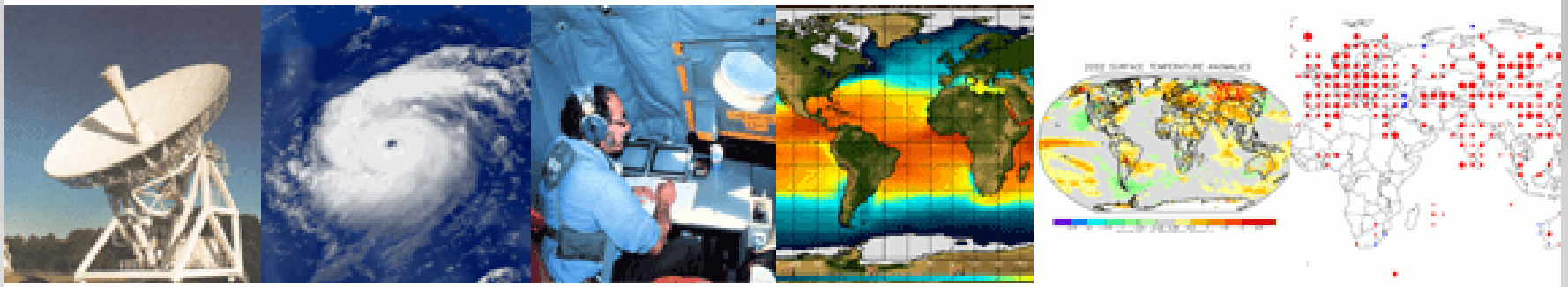
Plume Dispersion

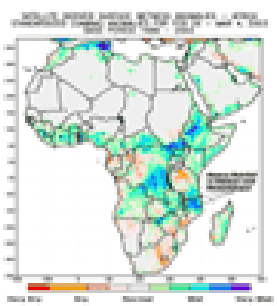


Global Earth Observations for Society

Global Earth Observing System of Systems

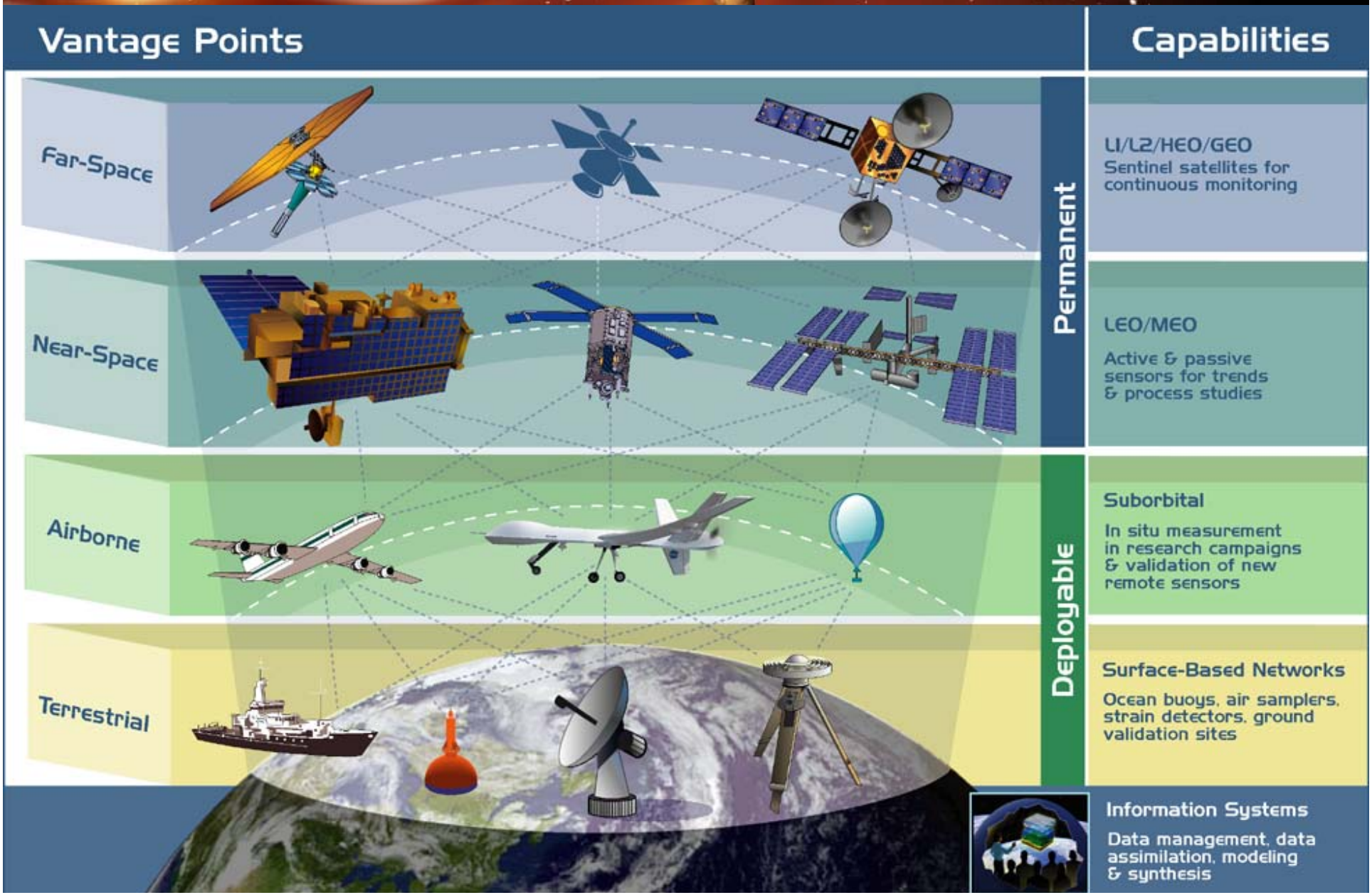






From Observations to Users to Benefits

Global System for Earth Observation Integrating Orbital, Suborbital and In Situ Components



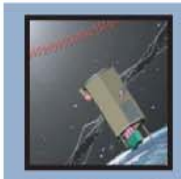
Next Generation Missions

Candidate Future Missions
In Formulation/Preformulation

NPOESS Preparatory Project

Global Precipitation Measurement

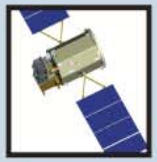
Synthetic Aperture Radar



Orbiting Carbon Observatory

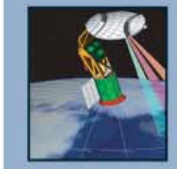
Blue Horizons

Landsat Data Continuity Mission



Aerosol Polarimeter Sensor

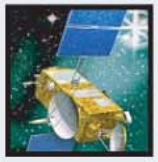
Chemistry/Climate Mission



Aquarius

Restless Planet

Aiolos



Ocean Surface Topography Mission

Cryosphere Monitoring Mission

Hydros

•
•
•

Next generation systematic measurement missions to extend/enhance the record of science-quality global change data

Exploratory

Expeditionary research missions for new vantage points & sensor types

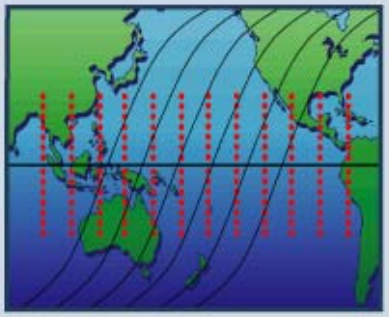
Turning Observations into Knowledge Products

Downlink Speed

Petabytes 10^{15}

Multi-platform, multiparameter, high spatial and temporal resolution, remote & in-situ sensing

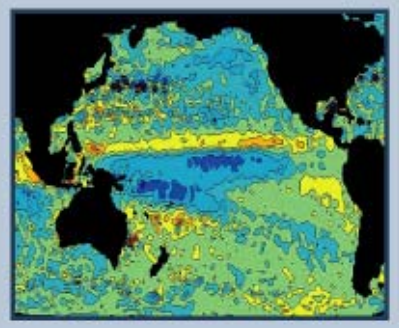
Advanced Sensors



Terabytes 10^{12}

Calibration, Transformation To Characterized Geo-physical Parameters

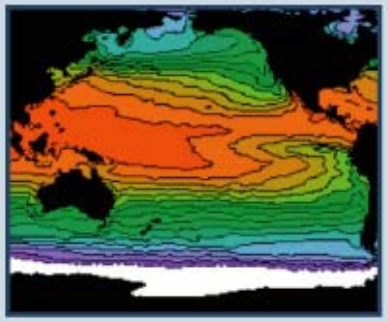
Data Processing & Analysis



Gigabytes 10^{9}

Interaction Between Modeling/Forecasting and Observation Systems

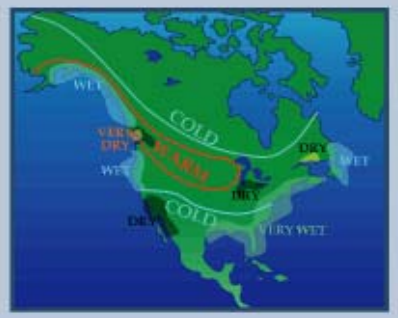
Information Synthesis



Megabytes 10^{6}

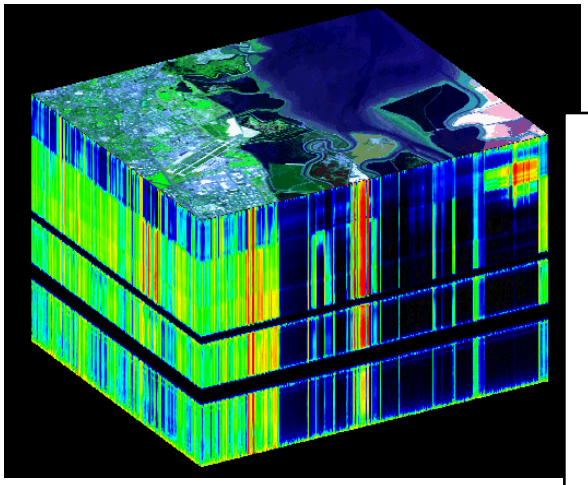
Interactive Dissemination and Predictions

Access to Knowledge

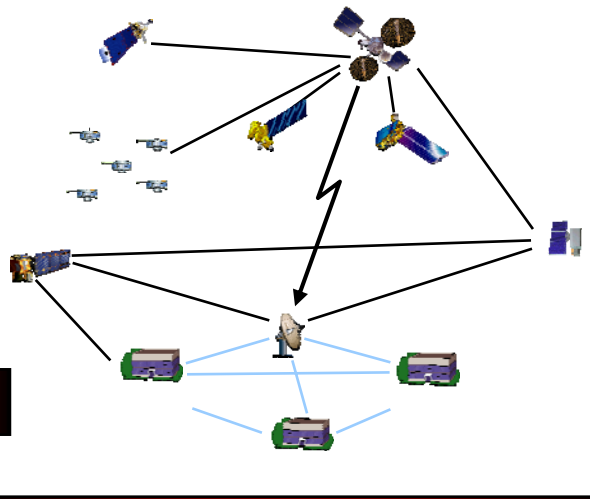


Technologies of the Future

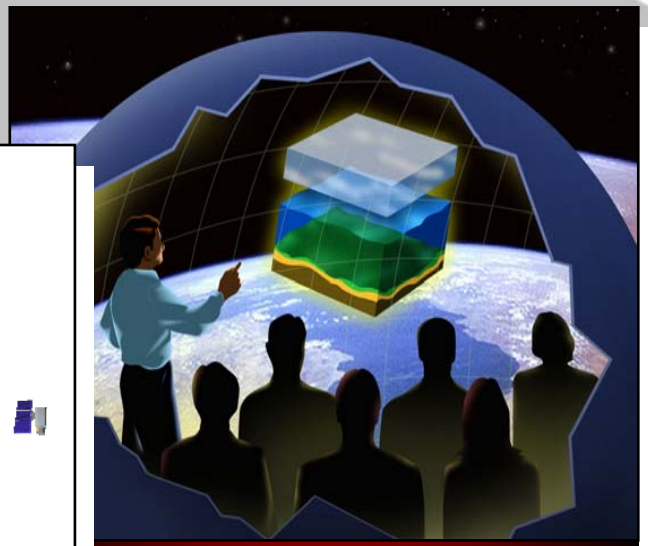
Connecting Geospatial, Communications and Computing Infrastructure



Remote Sensing



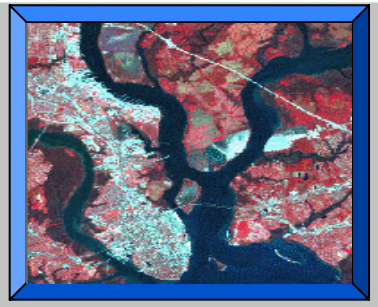
Communications



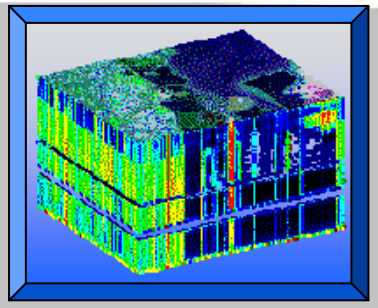
Computing

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

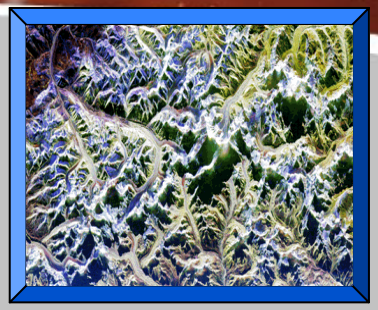
Remote Sensing Technologies



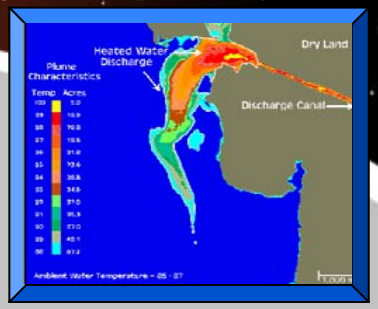
Multispectral



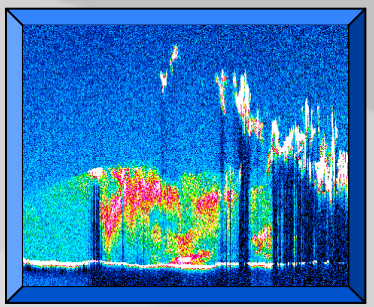
Hyperspectral



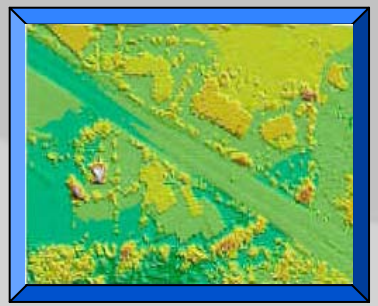
RADAR / SAR



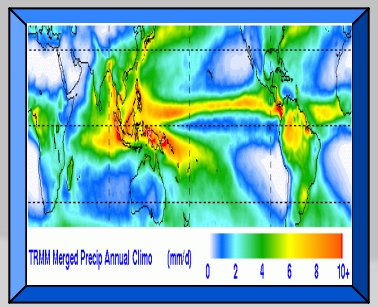
Thermal



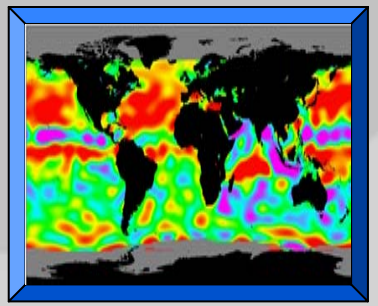
Atmospheric LIDAR



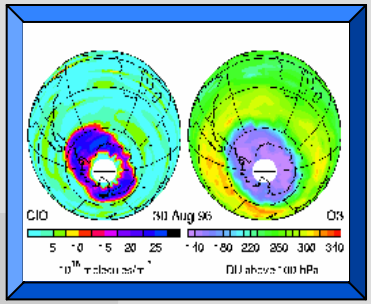
Surface LIDAR



Passive Microwave

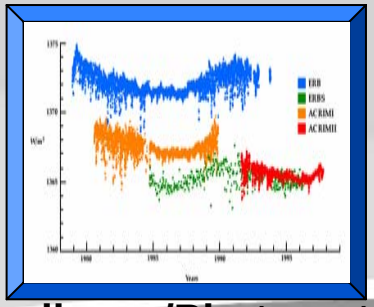


RADAR Altimetry

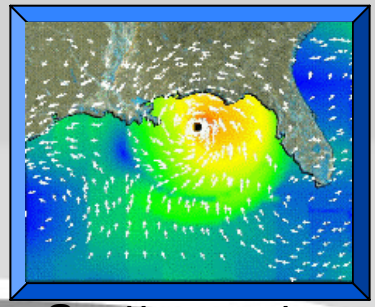


Limb Sounding

Microwave Ranging



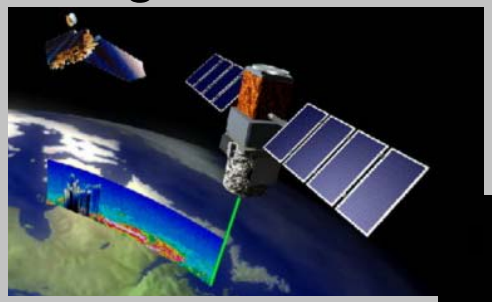
Irradiance/Photometry

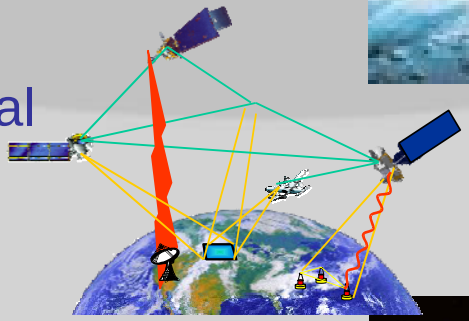


Scatterometry

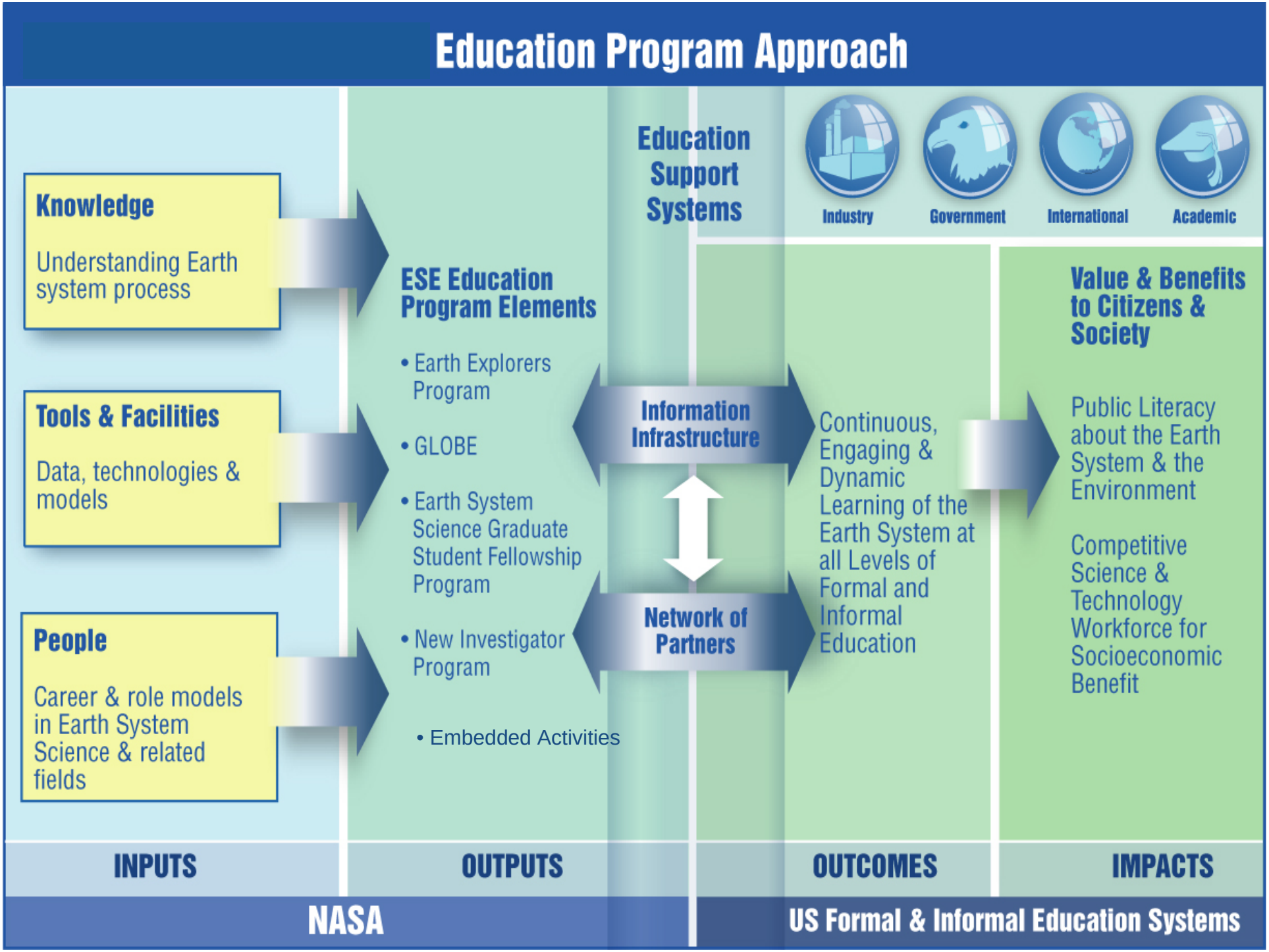
Future Enabling Technologies

- **Information Synthesis: Distributed, Reconfigurable, Autonomous**
- **Access to Knowledge: On-orbit Processing, Immersive Environments**
  - Laser/Lidar technology to enable Earth system science measurements
  - Large Deployables to enable future weather/ climate / natural hazards measurements
  - Intelligent Distributed Systems using optical communication, on-board reprogrammable processors, autonomous network control, data compression, high density storage
  - Information Knowledge Capture through 3-D Visualization, holographic memory and seamlessly linked models.



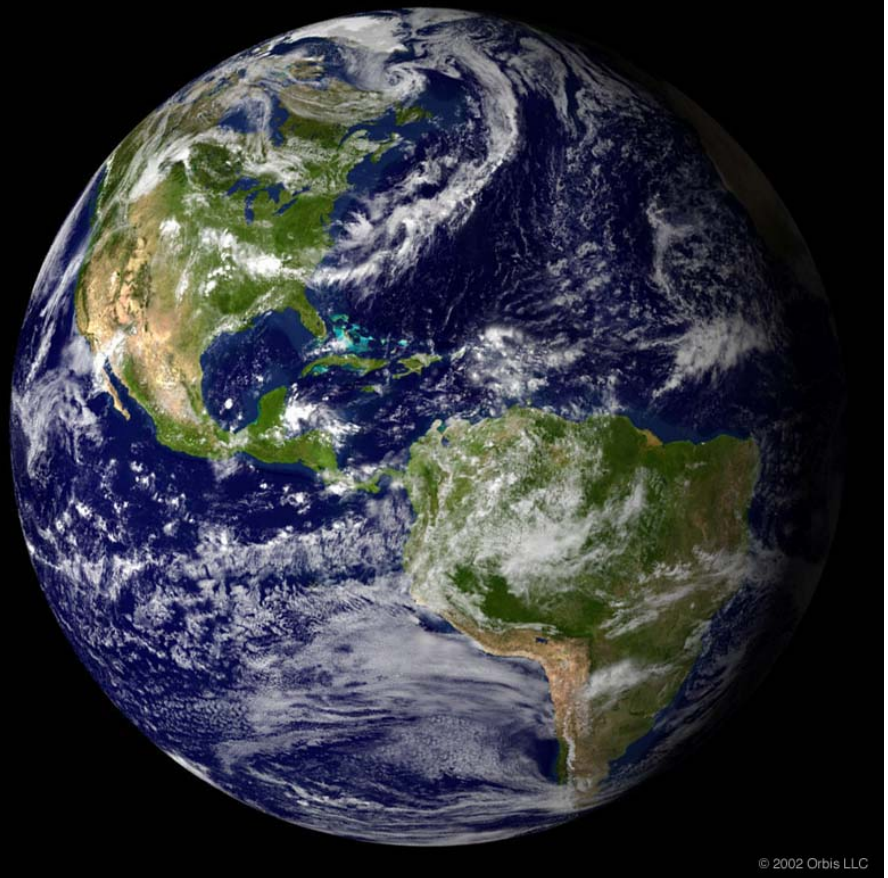


Inspiring the Next Generation of Earth Explorers

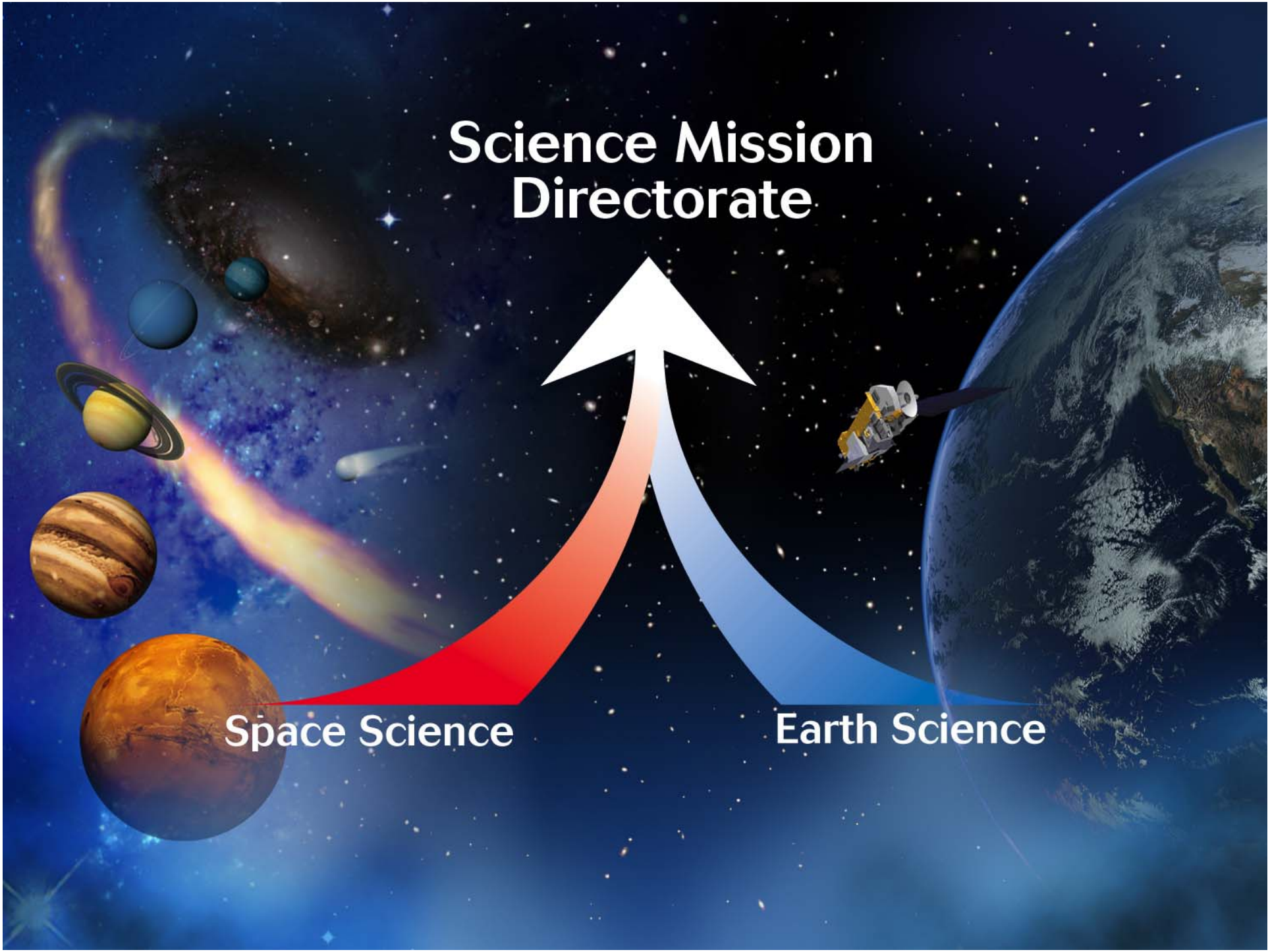

Education Program Approach
Knowledge
Understanding Earth system process
Tools & Facilities
Data, technologies & models
People
Career & role models in Earth System Science & related fields
ESE Education Program Elements
• Earth Explorers Program
• GLOBE
• Earth System Science Graduate Student Fellowship Program
• New Investigator Program
• Embedded Activities
Education Support Systems
Information Infrastructure
Network of Partners
Industry
Government
International
Academic
Continuous, Engaging & Dynamic Learning of the Earth System at all Levels of Formal and Informal Education
Value & Benefits to Citizens & Society
Public Literacy about the Earth System & the Environment
Competitive Science & Technology Workforce for Socioeconomic Benefit
INPUTS
OUTPUTS
OUTCOMES
IMPACTS
NASA
US Formal & Informal Education Systems

Challenges Ahead

- Characterizing, understanding & predicting the interactions among Earth's continents, oceans, atmosphere, ice, and life
- Evolution of a comprehensive, coordinated and sustained Earth observation system
- Forging the partnerships required to sustain the system and its uses for scientific exploration and practical applications
- Applying the knowledge, capacity and systems from Earth System Science to Exploration
- Training the next generation of scientists, engineers, and decision-makers



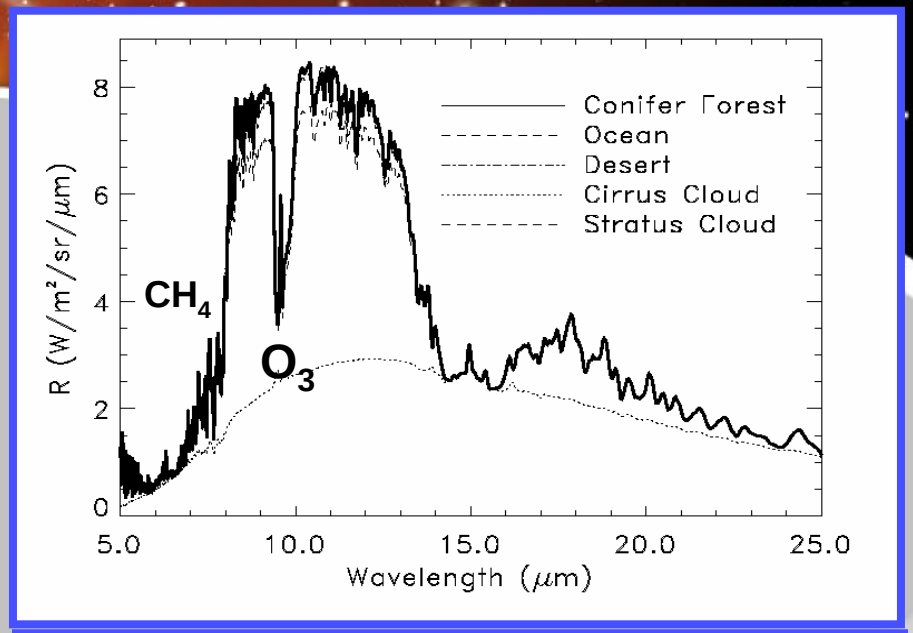
From Terra satellite imagery rendered by Orbis LLC/Eric Morris

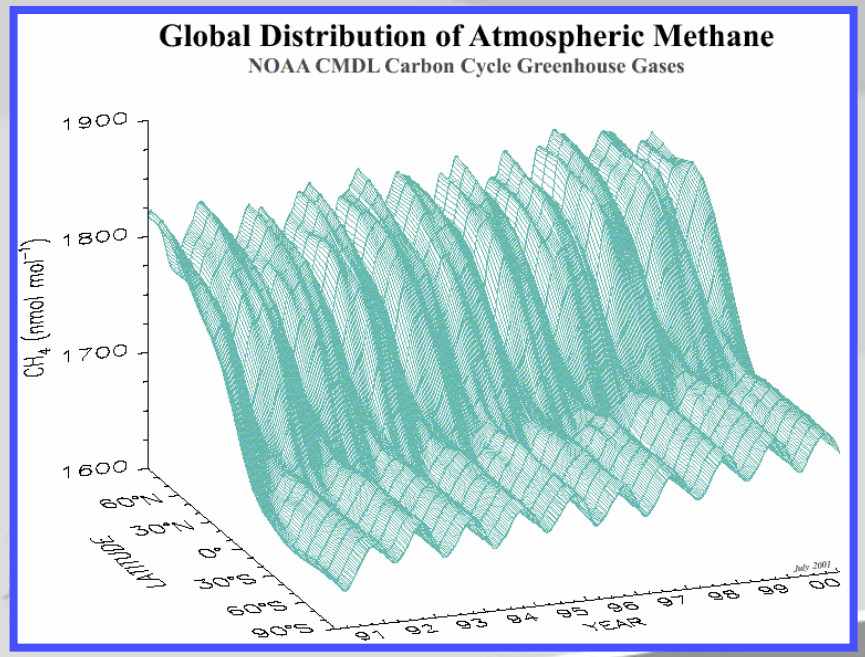

Science Mission Directorate
Space Science
Earth Science

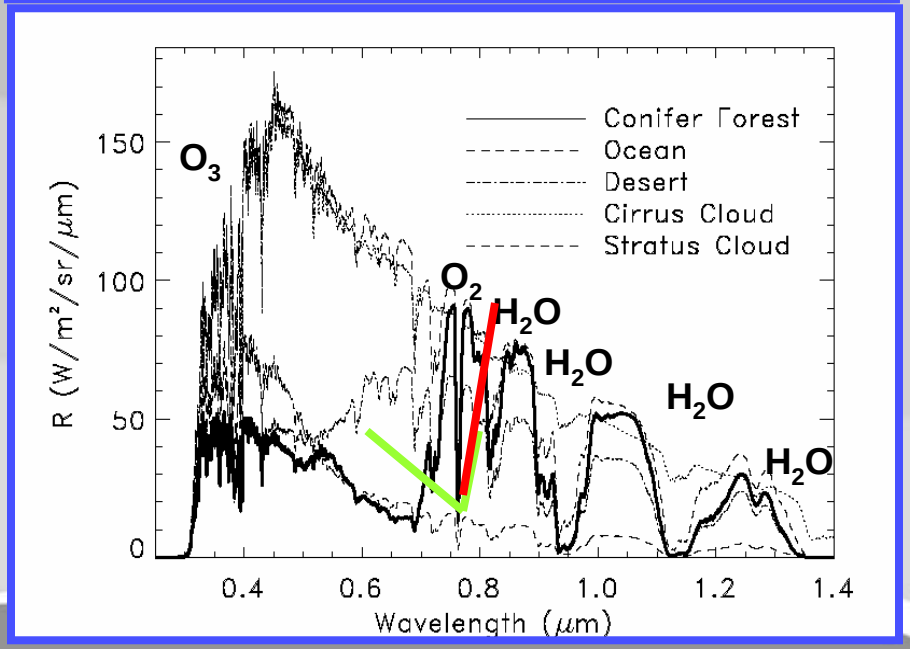
Space-based System of Systems

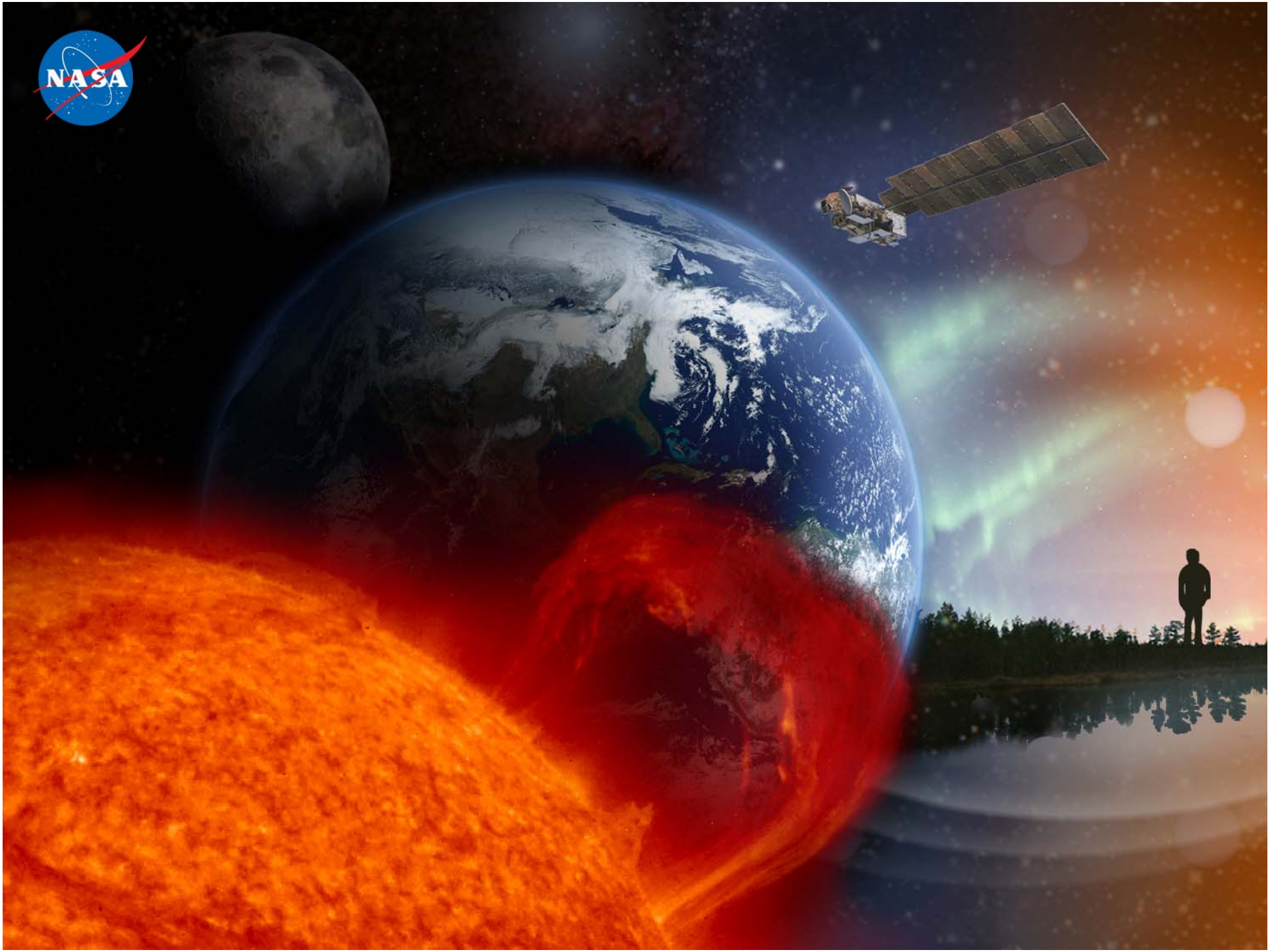
Exploring for Signatures Of Life

- **Astronomical Biosignatures** are detected by photometric, spectral and temporal features that indicate life
- **The Mid-IR**
  - O_3 (sensitive indicator of O_2), CH_4 and N_2O (H_2O - habitability)
- **The visible (and NIR)**
  - O_2 (direct detection), O_3(UV), CH_4, chlorophyll and red-edge, H_2O








NASA