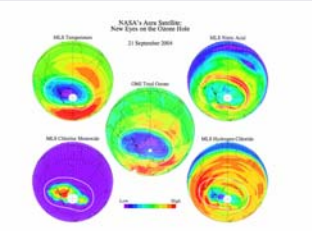
Introduction

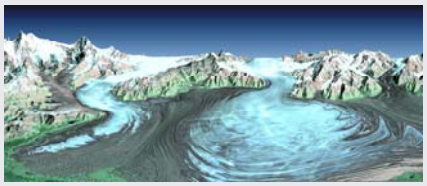
- Earth Science Objectives
- Earth Science Mission and Technology Requirements
- Current Earth Science Missions at NASA
- Current Earth Science Technologies
- Earth Science Mission Priorities
- Technology Approaches
- Future Mission Concepts

2

Earth Science Questions

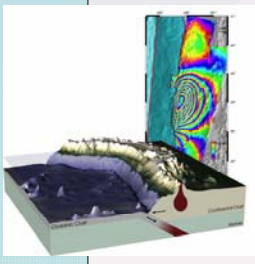
How is Earth changing?

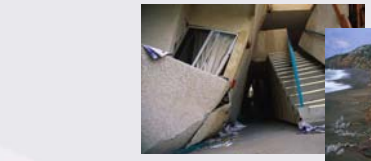


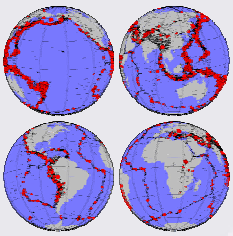


Science Questions:

- What changes are taking place in atmosphere-ocean circulation?
- How is land cover and land use changing?
- What changes are taking place in the water and energy cycle?
- How is atmospheric composition changing?
- How does solar radiation vary?
- How will all of these changes affect climate?

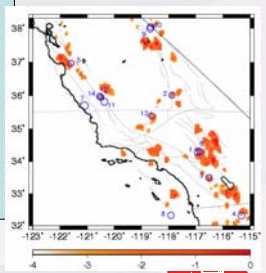






Science Questions:

- What are the local impacts of climate change?
- Can the Earth supply enough fresh water?
- Will air quality continue to support a healthy environment?
- Will the future environment allow us to produce enough food?
- Can earthquakes and volcanic eruptions be predicted?
- What is man's overall impact on life on Earth?



Significant NASA Contributions to Earth Exploration and Earth Science

What have we observed from space.

- The extent of the ozone hole and its cause
- The transport of air pollution between countries and continents
- Increasing rates of glacial and sea ice retreat
- Land cover and use change due to urbanization, deforestation, and other causes
- Changing weather patterns due to pollution and land conversion
- The interaction between earthquake faults
- The wide-scale effects of El Nino on weather
- The tracking and development of hurricanes, typhoons, severe storms, and other weather events

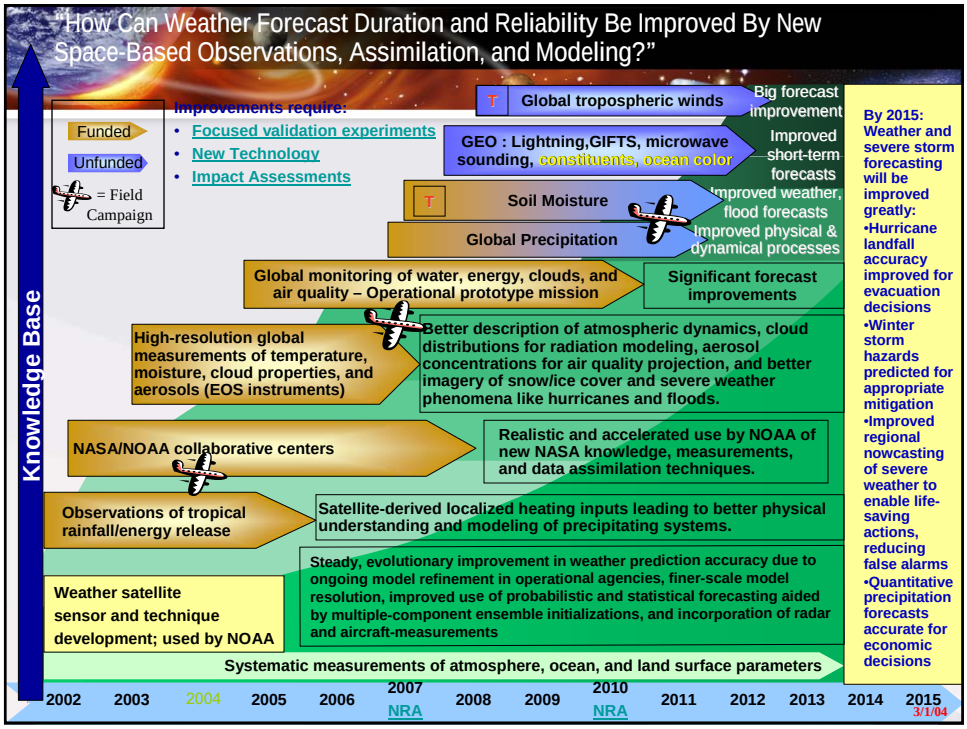
And more…

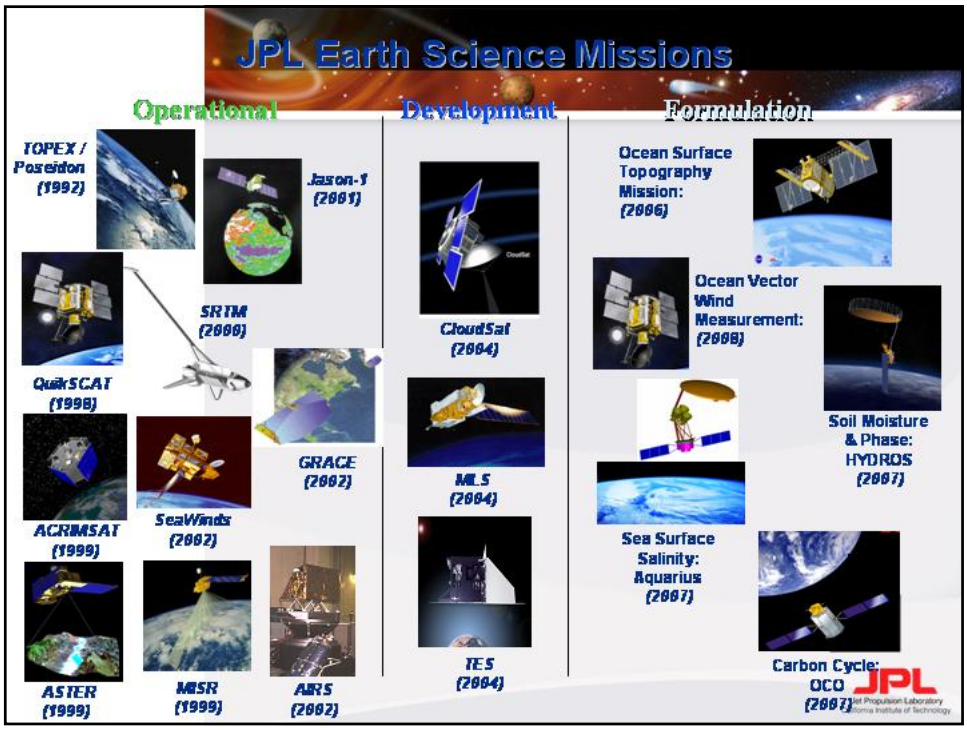
What are we exploring next.

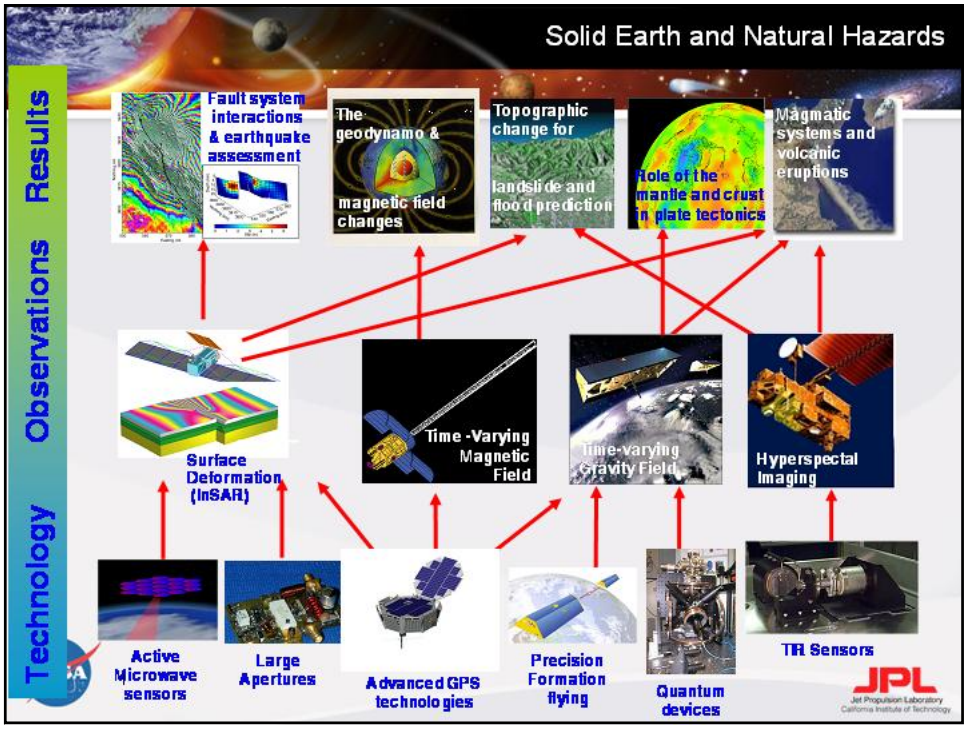
- The recovery of the ozone layer
- The impact of global pollution transport on regional air quality
- The quantity and quality of fresh water resources
- The future sea level rise and coastal flooding
- Identifying precursors for earthquakes and volcanic eruptions
- Identifying human impact on life on the land and in the ocean
- Improving weather forecasts, severe weather event warnings, and regional climate change predictions

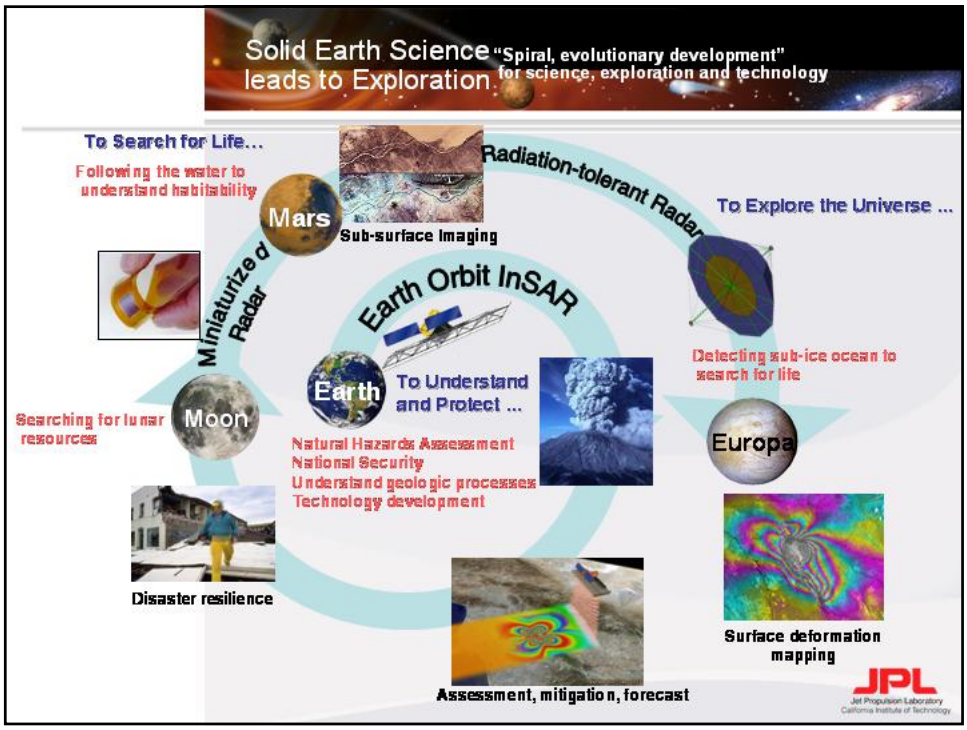
And more…

EOS Measurements


"How Can Weather Forecast Duration and Reliability Be Improved By New Space-Based Observations, Assimilation, and Modeling?"
Knowledge Base
Funded
Unfunded
= Field Campaign
Improvements require:
• Focused validation experiments
• New Technology
• Impact Assessments
T Global tropospheric winds
Big forecast improvement
GEO : Lightning,GIFTS, microwave sounding, constituents, ocean color
Improved short-term forecasts
T Soil Moisture
Global Precipitation
Improved weather, flood forecasts
Improved physical & dynamical processes
Global monitoring of water, energy, clouds, and air quality – Operational prototype mission
Significant forecast improvements
High-resolution global measurements of temperature, moisture, cloud properties, and aerosols (EOS instruments)
Better description of atmospheric dynamics, cloud distributions for radiation modeling, aerosol concentrations for air quality projection, and better imagery of snow/ice cover and severe weather phenomena like hurricanes and floods.
NASA/NOAA collaborative centers
Realistic and accelerated use by NOAA of new NASA knowledge, measurements, and data assimilation techniques.
Observations of tropical rainfall/energy release
Satellite-derived localized heating inputs leading to better physical understanding and modeling of precipitating systems.
Steady, evolutionary improvement in weather prediction accuracy due to ongoing model refinement in operational agencies, finer-scale model resolution, improved use of probabilistic and statistical forecasting aided by multiple-component ensemble initializations, and incorporation of radar and aircraft-measurements
Weather satellite sensor and technique development; used by NOAA
Systematic measurements of atmosphere, ocean, and land surface parameters
By 2015: Weather and severe storm forecasting will be improved greatly:
•Hurricane landfall accuracy improved for evacuation decisions
•Winter storm hazards predicted for appropriate mitigation
•Improved regional nowcasting of severe weather to enable life-saving actions, reducing false alarms
•Quantitative precipitation forecasts accurate for economic decisions
2002 2003 2004 2005 2006 2007 NRA 2008 2009 2010 NRA 2011 2012 2013 2014 2015
3/1/04


JPL Earth Science Missions
Operational
Development
Formulation
TOPEX / Poseidon (1992)
Jason-1 (2001)
SRTM (2000)
QuikSCAT (1998)
GRACE (2002)
ACRIMSAT (1999)
SeaWinds (2002)
ASTER (1999)
MISR (1999)
AIRS (2002)
CloudSat (2004)
MLS (2004)
TES (2004)
Ocean Surface Topography Mission: (2006)
Ocean Vector Wind Measurement: (2008)
Soil Moisture & Phase: HYDROS (2007)
Sea Surface Salinity: Aquarius (2007)
Carbon Cycle: OCO (2007)
JPL


Solid Earth and Natural Hazards
Results
Observations
Technology
Fault system interactions & earthquake assessment
The geodynamo & magnetic field changes
Topographic change for landslide and flood prediction
Role of the mantle and crust in plate tectonics
Magmatic systems and volcanic eruptions
Surface Deformation (InSAR)
Time -Varying Magnetic Field
Time-varying Gravity Field
Hyperspectal Imaging
Active Microwave sensors
Large Apertures
Advanced GPS technologies
Precision Formation flying
Quantum devices
TIR Sensors
JPL
Jet Propulsion Laboratory
California Institute of Technology


Solid Earth Science leads to Exploration
"Spiral, evolutionary development" for science, exploration and technology
To Search for Life...
Following the water to understand habitability
Mars
Sub-surface Imaging
Radiation-tolerant Radar
To Explore the Universe ...
Miniaturized Radar
Earth Orbit InSAR
Earth
To Understand and Protect ...
Natural Hazards Assessment
National Security
Understand geologic processes
Technology development
Detecting sub-ice ocean to search for life
Searching for lunar resources
Moon
Europa
Disaster resilience
Surface deformation mapping
Assessment, mitigation, forecast
JPL
Jet Propulsion Laboratory
California Institute of Technology

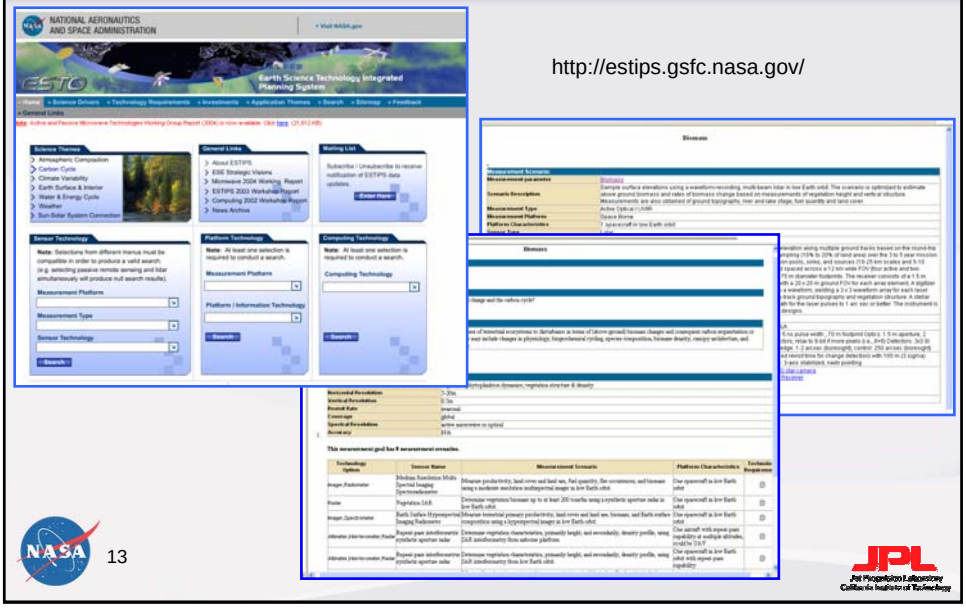
Earth Science Mission Priorities (preliminary)

NPOESS Preparatory Project (2009) Strategic mission - Systematic measurement	Required for continuity of several key climate measurements between EOS and NPOESS
Landsat Data Continuity Mission (2010) Strategic mission - Systematic measurement	Required for continuity of long-term global land cover change data; plan for post-LDCM acquisition operational agency in work
Ocean Surface Topography Mission (2008) Strategic mission - Systematic measurement	Required for continuity ocean altimetry; planned as part of a transition to operational agencies
Glory (2008) Strategic - Initializes a systematic measurement	Addresses high priority objective of the US Climate Change Science Program
Orbiting Carbon Observatory (2008) Competed mission - Earth System Science Pathfinder	First global measurement of CO2 from space
Aquarius (2009) Competed mission - Earth System Science Pathfinder	First global measurement of sea surface salinity from space
Global Precipitation Measurement (2012) Initializes a systematic measurement	Extend spatial coverage to global and temporal coverage to every 3 hours with constellation
Earth System Science Pathfinder – TBD (2014) Competed mission - 2008 solicitation for 2014 launch; subsequent TBD	*Could address one of the future representative mission elements below; focus and relative priority to be determined using decadal survey*

Future Missions (preliminary)

Future Representative Mission Elements *(unprioritized):* • Changes in Earth's Ice Cover • Global Ocean Carbon, Ecosystems & Coastal Processes • Global Soil Moisture • Global Wind Observing Sounder • Multi-spectral Atmospheric Composition • Sea Surface & Terrestrial Water Levels • Vegetation 3-D Structure, Biomass, Disturbance • Wide-swath All-weather Geodetic Imaging	*Mission concept definitions and priorities to be determined after the NRC decadal survey is available. Mission concept studies will likely result in integrating more than one of these elements into a single mission based on common or compatible technologies and observing techniques.*

Tech Requirements



http://estips.gsfc.nasa.gov/

Weather Prediction Knowledge Requirement

Science Requirements | Technology Options | Top Level Requirements

Weather Prediction Knowledge Requirement

Tropospheric Winds

- Hybrid Doppler Wind Lidar **IR to UV Bands**
- Direct Detection Doppler Wind Lidar **UV/NIR Band**
- Coherent Doppler Wind Lidar **IR Band**

→ **High Power/Efficiency Laser Transmitters**
→ **Lightweight, Large Aperture, Diffraction Limited Optics**
→ **Precise Optical Alignment & Pointing Accuracy Technology**
→ **Efficient Dissipation of 2kW heat in orbit**

Soil Moisture

- Very Large Real Aperture Mesh Antenna Radiometer **L Band**
- Synthetic Thinned Aperture Radiometer (STAR) **L Band**
- **UHF/VHF** SAR

→ **Large, Lightweight Deployable Antenna Structures & Reflectors**
→ **Low Mass Booms & Trusses**
→ **High Power/Efficiency T/R Technologies**
→ **Technologies for Control & Stability of Large Rotating Antennas in Space**

Potential Missions/Implementation

Focus Areas	Potential Element / Measurements	Implementation Approach
Atmospheric Composition	Sentinel multispectral atmospheric composition	GEO or L1 spectrometers UV/vis, near-IR, thermal IR
	Next Generation Aerosol Measurements	Multi-angle multi-spectral imaging polarimeter + High sensitivity backscatter lidar
	Atmospheric Composition for Climate and Transport	Advanced microwave sounder mid-earth orbit
	Systematic Upper Trop/lower Strat Composition	Micro-FTS Solar Occultation
Carbon Cycle and Ecosystems	Vegetation 3-D Structure, Biomass & Disturbance	In priority order: 1) Profiling lidar; 2) P-band SAR; 3) InSAR? **Optimal: Combination of 1 and 2 or 3**
	Global Ocean Carbon, Ecosystems, and Coastal Processes	LEO spectrometer and aerosol instrument; 20 aggregate bands in 350-1400 nm region with 5nm resolution from UV to 800nm (longer wavebands for atmospheric correction); 1km spatial resolution; SNR greater than 1000 for UV and visible aggregated bands, greater than 500 in near infrared
	Physiology & Functional Groups	Polar-orbiting imaging spectrometer(s) (~340-2500 nm) -- with aerosol lidar for atmospheric correction. over ocean

Potential Missions/Implementation

Focus Areas	Potential Element / Measurements	Implementation Approach
Climate Variability and Change	Sea surface and terrestrial water levels	Radar altimeter/ wide swath/ delayed Doppler
	ICESat Follow-on (Detailed Ice elevation, ice sheet mass)	
	Next Generation Ocean Surface Winds	Advanced scatterometer
Earth Surface and Interior	Wide Swath All Weather Geodetic Imaging	L-Band InSAR
	Land Surface Imaging	Spectrometers UV/vis, near-IR, thermal IR
	Advanced Gravity Measurements	GRACE-like satellite pairs, gradiometer constellation
	Geodetic Observing System	SLR/VLBI/GNSS ground networks
	Ionospheric Dynamics and Atmospheric Surface Pressure	GNSS Remote Sensing/Magnetometry
Water and Energy Cycle	Global Soil Moisture	Active & Passive L-band (microwave) remote sensing system
	Surface Water Runoff	Dual Ka-band SARs
	Measurement of Snow and its Water Equivalent	Active Ku-band SAR + passive microwave radiometer (K or Ka band)
	Changes in Groundwater Storage	Constellation of GRACE satellite pairs

Potential Missions/Implementation

Focus Areas	Potential Element / Measurements	Implementation Approach
Weather	Global Wind Observing Sounder	Hybrid (coherent and direct detection) Doppler wind lidar
	Geostationary Synthetic Thinned Aperture Radiometer	Synthetic aperture microwave radiometer
	Active Temperature and Humidity Sounder	Combination active (i.e., lidar) and passive IR sounder
	Geostationary Precipitation Radar	Precipitation radar
Crosscutting	Advanced Remote-sensing Imaging Emission Spectrometer	Hyperspectral, high horizontal resolution IR and visible grating spectrometer imager sounder

Summary

- How can technology enable new missions within the current cost constraints?
  - Innovation
    - Large Aperture, Gigapixel FPA, Laser (1/2 um), On board computing, Miniaturization
  - Technology infusion & validation
    - Airborne and UAV demo, simulation
  - Simulation and Model
    - OSSE, validation & verification, data assimilation
  - Application/Decision support systems
    - 3 hr requirements for weather
- Opportunities
  - NASA Roses IIP, ACT, and AIST
    - $500K to $1M per year for 3 years
  - Collaboration and partnerships
    - NASA , Academia, Industries
    - Foreign spacecraft