NASA’s Earth Observing System Data and Information System - EOSDIS

Presented at
George Mason University

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- Any opinions expressed here are those of the author and do not necessarily imply official NASA policy.
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Global Climate Change – IPCC Report

  – “Warming of the climate system is unequivocal, as is now evident from observations of increases in global average air and ocean temperatures, widespread melting of snow and ice and rising global average sea level.”
  – “Observational evidence from all continents and most oceans shows that many natural systems are being affected by regional climate changes, particularly temperature increases.”
  – “There is medium confidence that other effects of regional climate change on natural and human environments are emerging, although many are difficult to discern due to adaptation and non-climatic drivers.”

• Accurate, long-term, consistent, global observations, modeling and analysis are key to understanding the Earth system, predicting its behavior and supporting policies beneficial to society
NASA’s Earth Science Data Systems

• NASA Strategic Plan (2011) – Strategic Goal #2: Expand scientific understanding of the Earth and the universe in which we live.
  – 2.1 Advance Earth system science to meet the challenges of climate and environmental change.

• NASA’s Earth Science Data Systems directly support this objective by providing end-to-end capabilities to deliver data and information products to users
24 EOS Measurements
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Earthquake and Tsunami near Sendai, Japan – 2:46 p.m. local time, March 11, 2011

This pair of images, acquired on March 12, 2011, by the Multi-angle Imaging SpectroRadiometer (MISR) instrument aboard NASA’s Terra spacecraft, shows a large smoke plume that appears to be associated either with the Shiogama incident or the Sendai port fires. The presence of clouds makes it difficult to pinpoint the exact origin. The data were obtained at a local time of about 10:30 a.m. - http://earthobservatory.nasa.gov/; Image Credit: NASA/GSFC/LaRC/JPL, MISR Team
Post-Tsunami image, taken on March 13, 2011, provides a clear view of tsunami flooding along the coastline. Water, black and dark blue in these false-color images, still covers the ground as much as five kilometers (three miles) from the coast. [http://earthobservatory.nasa.gov/](http://earthobservatory.nasa.gov/). Image Credit: the MODIS Rapid Response Team at NASA GSFC; Instrument: Aqua MODIS
Fires in Southeastern Australia

Red boxes outline the locations of several fires burning in southeastern Australia on March 7, 2011. The fires are burning primarily in the dark green forest-covered Australian Alps in Victoria. Though the smoke pouring from the fires makes them appear to be large wildfires, most are controlled burns. The Moderate Resolution Imaging Spectroradiometer (MODIS) on NASA's Aqua satellite acquired this true-color image early in the afternoon on March 7 – [http://earthobservatory.nasa.gov/](http://earthobservatory.nasa.gov/). Image Credit: Jeff Schmaltz, MODIS Rapid Response Team at NASA GSFC.
Hurricane Bertha – July 9, 2008

Image captured by the Moderate Resolution Imaging Spectroradiometer (MODIS) on NASA’s Terra satellite.
Image from [http://earthobservatory.nasa.gov/](http://earthobservatory.nasa.gov/).
NASA image created by Jesse Allen, using data provided courtesy of MODIS Rapid Response Team.
Floods in Iowa – June 2008

ASTER is a Japanese instrument on NASA’s Terra satellite.
Images from http://earthobservatory.nasa.gov/.
NASA image created by Jesse Allen, using data provided courtesy of NASA/GSFC/METI/ERSDAC/JAROS, and U.S./Japan ASTER Science Team.
Global Fire Map (June 29 – July 8, 2008)


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Core and Community Capabilities - Definition

- ‘Core’ data system elements reflect NASA’s responsibility for managing Earth science satellite mission data characterized by the continuity of research, access, and usability.

- The core comprises all the hardware, software, physical infrastructure, and intellectual capital NASA recognizes as necessary for performing its tasks in Earth science data system management.

- ‘Community’ elements are those pieces or capabilities developed and deployed largely outside the NASA core elements and are characterized by their ‘evolvability’ and innovation.
Earth Science Data Systems Context

Data Acquisition
- Tracking & Data Relay Satellite (TDRS)
- Ground Stations
- Polar Ground Stations

Flight Ops Data Capture, Initial Processing, Backup Archive
- Data Processing & Mission Control

Data Transport
- NASA Integrated Services Network (NISN) Mission Services

Science Data Processing, Data Mgmt., Interoperable Data Archive & Distribution
- EOSDIS Data Centers*
- ECHO*
- ACCESS
- REASONs/MEaSUREs
- Science Teams (SIPS)*
- Measurement Teams

Distribution and Data Access,
- Research
- Education
- Value-Added Providers
- Interagency Data Centers
- Earth System Models
- International Partners
- Decision Support Systems

Technology Infusion
(IT Currency, Standards, Reuse, Interoperability)

*EOSDIS Elements
EOSDIS: A Core Capability

- NASA's Earth Observing System Data and Information System (EOSDIS) is a petabyte-scale archive of environmental data that supports global climate change research.

- EOSDIS provides for
  - Data ingest
  - Data processing
  - Data distribution
  - Archive management
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EOSDIS Key Metrics

** EOSDIS Metrics (Oct 1, 09 to Sept 30, 10) **

- Unique Data Products: > 4,200
- Distinct Users of EOSDIS Data and Services: > 1.1 M
- Web Site Visits of 1 Minute or more: > 1.1 M
- Average Daily Archive Growth: 2.9 TB/day
- Total Archive Volume: 4.6 PB
- End User Distribution Products: > 412 M
- End User Average Daily Distribution Volume: 9.9 TB/day

** ESDIS Project Supports **

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** EOSDIS Products Delivered (Millions) **
EOSDIS Data Distribution In FY2010

Number of Products Distributed in FY10 (Millions)

- US EDU, 109, 27%
- US COM, 22, 5%
- US GOV, 91, 23%
- EU, 58, 15%
- Canada, 4, 1%
- Japan, 22, 6%
- US ORG, 1, 0%
- US Other, 19, 5%
- Unresolved, 5, 1%

Number of Distinct Data Users in FY2010

- US Other, Unresolved, 17,006, 4%
- US ORG, 1,684, 0%
- US EDU, 23,830, 5%
- US GOV, 10,329, 2%
- EU, 78,499, 16%
- China, 118,822, 25%
- Japan, 6,905, 2%
- Other non-US, 107,854, 22%
- Canada, 14,538, 3%
Impact of EOSDIS - Earth Science Research
Impact of EOSDIS - Scientific Productivity

Publications resulting from EOS Terra (12/99 launch) instruments and data
Publications resulting from EOS Aqua (05/02 launch) instruments and data

• Publications and citations shown here are a good indicator of scientific growth resulting from NASA's Terra and Aqua missions
• Pre-launch publications and citations are significant, but dramatic growth seen post-launch
• NASA's EOSDIS, through its well-established data management practices:
  • Produces and stores data and metadata in formats compliant with well-documented standards
  • Provides data, metadata and software tools promptly to a broad scientific community
• Data management is a key element in supporting scientific growth

Impact of EOSDIS/Applications

Pyrocumulus clouds & smoke - Station Fire 2009

Flooding – North Dakota 2010

Snow - East Coast 2010

Carbon monoxide emissions - Station Fire 2009

Gridded Population Density

Composite 2007&2009

Earthquake - Haiti 2010

Cyclone and Flooding – Myanmar 2008
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ASF DAAC
(Alaska Satellite Facility DAAC)

• Located: University of Alaska, Fairbanks, AK
• Cryosphere, Solid Earth, Land Use/Land Cover, Natural Hazards, Oceans
• Archive size (approx): 391 TB
• Ingest rate (approx): 73 GB/Day
• Distributes (approx): 54 GB/Day

Synthetic Aperture Radar Imagery of the Bering Sea from Radarsat-1 taken near real-time for USCG Healy.
COOlS
(Crustal Dynamics Data Information System)

- Located: NASA GSFC, Greenbelt, MD
- Solid Earth - Space Geodesy
- Archive size (approx): 4 TB
- Ingest rate (approx): 2.0 GB/Day
- Distributes (approx): 50 GB/Day

The global space geodesy network today includes 385 GNSS receivers, 35 laser ranging sites, 42 VLBI stations, and 55 DORIS sites and provides the means of determining an accurate and global Terrestrial Reference Frame. The CDDIS provides data from these sites and higher-level data products derived from the data to support a wide range of Earth science research.

- Specialized data center responsible for the archive of space geodesy data sets: GNSS, laser ranging (SLR), VLBI, DORIS and products derived from these data (station positions and velocity for the terrestrial reference frame, Earth orientation parameters, precise satellite ephemerides, total electron content maps, troposphere parameters, etc.)
- Supports geodetic (e.g., LAGEOS, Etalon, etc.) and multi-disciplinary missions (e.g., LRO, GRACE, CHAMP, ERS, Envisat, SPOT, Jason, ALOS, etc.)
- Extensive international partnerships with the International Association of Geodesy (IAG) and serves as a primary data center for IAG geometric services
- Access provided through anonymous ftp
  http://cddis.gsfc.nasa.gov/
GES DISC
(GSFC Earth Sciences Data and Information Services Center)

- Located: GSFC, Greenbelt, MD
- Atmospheric Dynamics, Hydrology, Atmospheric Composition, Atmospheric Modeling, Multi-Sensor data management
- Archive size (approx): 250 TB
- Ingest rate (approx): 466 GB/Day
- Distributes (approx): 436 GB/Day

Global data products, such as from AIRS, Modeled data, such as from GOCART, and vertical measurements, such as from A-Train's Cloudsat, can be user-selected, subsetted, displayed, and accessed using GIOVANNI
Global Hydrology Resource Center

- Located: Marshall Space Flight Center, Huntsville, AL
- Atmospheric Science, Water and Energy Cycle, Weather
- Archive size (approx): 5 TB
- Ingest rate (approx): 5 GB/Day
- Distributes (approx): 34 GB/Day

- Lightning Imaging Sensor SCF: national lightning data center for the TRMM Lightning Imaging Sensor and validation networks

- Field campaigns: Web-based collaboration for science before, during, and after experiments. Data acquisition, integration, archive and distribution:

- DISCOVER: Highly accurate long-term (decadal+) climate and ocean data sets from multiple instruments on multiple platforms
  - Interoperability technologies for improved data access and usability

- http://ghrc.msfc.nasa.gov
Level 1 and Atmosphere Archive and Distribution System (LAADS, a MODIS Adaptive Processing System)

- Located: Goddard Space Flight Center
- MODIS Level 1 and atmosphere products
- Archive size (approx): 600 TB
- Ingest rate (approx): 100 GB/Day
- Distributes (approx): 5 TB/Day

- Provide access to MODIS Level 1 and Atmosphere products

- Subsetting, sub-sampling, mosaicing, masking, reprojection and format conversion options enable users to transform MODIS standard products

- http://ladsweb.nascom.nasa.gov/
Land Processes DAAC (LPDAAC)

- **Location:** Earth Resources Observation and Science (EROS) Center, Sioux Falls, SD

- **Role:** Process, archive, and distribute land-related data collected by EOS sensors, thereby promoting the inter-disciplinary study and understanding of the integrated Earth system (Climate Variability and Change, Carbon Cycle and Ecosystems, and Solid Earth and Natural Hazards)

- **Products:**
  - ASTER: 1 archived, 20 on-demand
  - MODIS: 60+ archived Land Products

- **Key Metrics:**
  - Archive: ~1,450 TB
  - Ingest: ~600 GB/Day
  - Distribution: ~1,200 GB/Day

National Snow & Ice Data Center DAAC (NSIDC DAAC)

• Located: University of Colorado, Boulder, CO

• Snow and Sea Ice Extent, Ice Dynamics, Icesheet topography, Glacier Changes and Hydrology

• Increasingly Active Snow and Ice Data Distribution and Services from MODIS, ICESat, AMSR-E, SSM/I, SMMR and other sensors and data sources.

• Archive size (approx): 146 TB ^

• Ingest rate (approx): 50 GB/Day ^

• Distributes (approx): 135 GB/Day ^
NASA Ocean Biology Processing Group

- Located: Goddard Space Flight Center
- Total Archive size: 313 TB
- Distribution (> 2/04): 24 million files

MODIS support is implemented within the framework and facilities of the current NASA Ocean Data Processing System (ODPS) which has been successfully supporting operational, satellite-based remote-sensing missions since 1996, and its capabilities continue to evolve and expand to meet the demands and challenges of future missions.

MISSIONS SUPPORTED
- SeaWiFS: 1997 - active
- MODIS (Terra and Aqua): 2000 - present
- CZCS / Nimbus-7: 1978 - 1986
- Glory data system prototype: 2009 launch
- Aquarius / SAC-D: 2010 launch
- VIIRS / NPP: 2010 launch
- Community Processing & Analysis Software SeaDAS (1991- present)

Consolidated data access, information services and community feedback

oceancolor.gsfc.nasa.gov
Oak Ridge National Laboratory DAAC
( ORNL DAAC)

• Located: Oak Ridge, TN
• Biogeochemistry, Terrestrial Ecology, Land Validation, Carbon/Energy Cycles
• Archive size (approx): 1.08 TB
• Ingest rate (approx): 78 GB/year
• Distributes (approx): 1.4 TB/year

• Archive for field campaigns (ongoing): Large-scale Biosphere Atmosphere Experiment in Amazonia
• Support for Validation of Remote Sensing Products: providing ground-based measurements (FLUXNET);
Development of tools to aid in validation (MODIS subsets for field sites, collaboration with NOAA / NCDC)
• Archive for regional and global data for land surface models: Global fire emissions data; ISLSCP II archive; model source code archive; Tools for visualizing Spatial data (WebGIS)
• www.daac.ornl.gov
PODAAC (Physical Oceanography DAAC)

- Located: JPL, Pasadena, CA
- Physical Oceanography, Sea Surface Temperature, Sea Level Height, Seasonal Climate, Ocean Vector Winds
- Archive size (approx): 45 TB
- Ingest rate (approx): 43 GB/Day
- Distributes (approx) 465 GB/Day

Erin Aug. 15, 2007 - Global High-Resolution Sea Surface Temperature (GHRSSST)/Operational Sea Surface Temperature and Sea Ice Analysis (OSTIA)
Socioeconomic Data and Applications Center (SEDAC DAAC)

- Located: Columbia University, NY
- Population, urbanization, land use, conservation, hazard vulnerability, environmental health, GHG emissions, poverty, food security, sustainability, environmental treaties, climate impacts
- Archive size (approx): 452 GB
- Ingest rate (approx): 0.4 GB/day
- Distributes (approx): 0.4 GB/Day

- Active support for GEOSS development through access to data, metadata, and map client via open standards, including contributions to Architecture Implementation Pilot, GEOSS clearinghouse and portal candidates, and GEO data sharing guidelines
- Host for IPCC Socioeconomic Data Distribution Centre and active in recent IPCC meetings on regional climate vulnerability and development of new scenarios
- High profile citations and data usage in 2008 World Development Report, recent UN reports, IPCC FAR, NRC studies, Science, National Geographic atlases, online media

Screen shot from OGC videos for GEO-IV Plenary
Science Investigator-led Processing Systems (SIPSS)

- MODAPS – Moderate Resolution Imaging Spectroradiometer (MODIS) Adaptive Processing System
  - Product Generation
  - Archive and Distribution
- OBPG - Ocean Biology Processing Group
- AMSR-E SIPS - Advanced Microwave Scanning Radiometer for EOS SIPS
- ICESat SIPS - Ice, Clouds, and Land Elevation Satellite SIPS
- MOPITT SIPS - Measurement of Pollution in the Troposphere SIPS
- HIRDLS SIPS - High-Resolution Dynamics Limb Sounder SIPS
- MLS SIPS - Microwave Limb Sounder SIPS
- OMI SIPS - Ozone Monitoring Instrument SIPS
- TES SIPS - Tropospheric Emission Spectrometer SIPS
MODAPPS – Product Generation

• Location: GSFC, Greenbelt, MD
• MODIS - Level 1, Land and Atmosphere products
• Science Team Size: 50
• No. of Products: 51
• Daily Ingest: 0.1TB
• Daily Output: 0.5TB (current day) to 2.2TB (reprocessing)
• Products Archived at: LP DAAC, NSIDC and LAADS

Land Surface Reflectance with dynamic aerosol model improves correction for aerosol

Burned areas over the 2003 dry season in Australia (March-November) from the new MODIS burned area product
AMSRS E SIPS

• Location: MSFC, Huntsville, Alabama

• Science Disciplines: standard products for the global hydrologic cycle

• Science Team Size: ~70

• No. of Products: 15
  ➢ rainfall, sea ice, sea surface temperatures, water vapor, cloud water, soil moisture, snow

• Ingest rate: ~2.5 GB/Day

• Output Rate: ~3.5 GB/Day

• Products Archived at: NSIDC DAAC

89H GHz Brightness Temperatures Imagery Descending Passes for 2007-08-08
I-SIPS (ICESat SIPS) -
Geoscience Laser Altimeter System (GLAS)

• Location: GSFC, Greenbelt, Maryland
• Science Team Size: 23
• No. of Products: 15
• Ingest rate (approx): 5 GB/Day
• Output Rate (approx): 18 GB/Day
• Products Archived at: NSIDC
Measurements of Pollution in the Troposphere (MOPITT) SIPS

- Location: National Center for Atmospheric Research (NCAR), Boulder, CO
- Atmospheric chemistry, pollution transport
- Science Team Size: 7
- No. of Products: 5
- Ingest rate (approx): 400 MB/Day
- Output Rate (approx): 230 MB/Day
- Products Archived at: LaRC DAAC

High Resolution Dynamics Limb Sounder (HIRDLS) SIPS

- Location: University of Colorado/NCAR, Boulder, CO
- HIRDLS studies small scale dynamics and transports (stratosphere-troposphere exchange, UTLS chemistry, aerosol, cirrus and PSC distributions, gravity waves)
- Science Team Size: 17 FTE
- No. of Products: 4 to date (temperature, ozone, nitric acid, cloud top pressure)
- Ingest rate (approx): 2.5 GB/Day
- Output rate (approx): When in routine production, HIRDLS expects to deliver about 800 MB/Day
- Products Archived at: GES DISC

HIRDLS uniquely observes small scale gravity waves, permitting assessment of gravity wave forcing in stratospheric circulation.
Microwave Limb Sounder (MLS) SIPS

- Location: JPL and Raytheon, Pasadena, CA
- Science Discipline: Atmospheric Chemistry
- Science Team Size: 18
- No. of Products: 25 products/Day
- Ingest rate (approx): 1 GB/Day
- Output Rate (approx): 5 GB/Day
- Products Archived at: GES-DISC
Ozone Measuring Instrument (OMI) SIPS

- Location: NASA GSFC, Greenbelt, MD
- Science Discipline: Atmospheric Chemistry
- Science Team Size: 20
- No. of Products: 16 Standard Products
- Ingest rate (approx): 11 GB/day
- Output Rate (approx): 30.5 GB/day
- Products Archived at: GES DAAC
Tropospheric Emission Spectrometer (TES) SIPS

- Location: JPL, Pasadena, CA
- Science Discipline: Atmospheric Chemistry
- Science Team Size: 15
- No. of Products: (January 4, 2008)
  - 497 R10 Global Survey products
  - 1070 R10 Special Observation products
- Ingest rate (approx): 6 GB/day
- Output Rate (approx): 5 GB/day
- Products Archived at: Atmospheric Science Data Center (ASDC) DAAC

TES Step and Stare Transects showing concentrations of atmospheric pollutants ozone ($O_3$) and carbon monoxide (CO).
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EOSDIS Near Real-time support

LANCE (Land, Atmosphere Near-real-time Capability for EOS)

- Building on existing EOSDIS elements, provides data from MODIS, OMI, AIRS, MLS, and AMSR-E instruments in near real-time (< 3 hours from observation)
- Utilizes standard science product generation software, but relaxes requirements for ancillary data inputs
- High operational availability
- 92 products available across MODIS, AIRS, AMSER-E, OMI, and MLS
- Applications of LANCE data include:
  - Numerical weather & climate prediction/forecasting
  - Monitoring of Natural Hazards
  - Disaster Relief
  - Agriculture
  - Air quality
  - Homeland Security
- Over 150 users accessing data from LANCE on a regular basis
The Eyjafjallajökull (Iceland) 2010 eruption was unusual because effusive eruptions typically emit limited ash that falls locally. Here, glacial melt produced much phreatic fine ash that drifted at relatively low altitudes.
LANCE Enabling Weather Forecasters
SPoRT: Short-term Prediction Research and Transition Center

Products used to improve situational awareness of weather events, and short term weather forecasts
- off shore weather processes
- improved forecasts of clouds, fog, precipitation, and temperature in coastal regions

AMSR-E Rain Rate

AIRS profiles improve model initial conditions in data void regions producing improved analyses and forecasts
Near Real Time Data from LANCE has been integrated into the GLAM (Global Agricultural Monitoring) system which enables timely monitoring of agricultural areas by USDA crop analysts. LANCE products are used until the MODIS Science Products are released.
Atmospheric Science Data Center
(Langley DAAC)

- Located: NASA Langley Research Center, VA
- Radiation Budget, Aerosols, Clouds, Tropospheric Chemistry
- Archive size (approx): 2,081 TB
- Ingest rate (approx): 329 GB/Day
- Distributes (approx): 754 GB/Day

MISR distinguishes clouds from smoke and determines aerosol optical depth as a measure of air quality for Yukon fires on June 30, 2004

(Image Credit: NASA/GSFC/LaRC/JPL, MISR Team)
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Data Access

• NASA’s Earth Science Data Systems provide end-to-end capabilities to deliver data and information products to users using an "open data policy"
  – Data available to all users with no period of exclusive access
  – Users obtain most of the data at no charge
  – Distributed, heterogeneous system – a "virtual data system" or "System of Systems"

• Several data access mechanisms are provided
  – "One-Stop Shopping" through EOS Clearing House (ECHO) and Warehouse Inventory Search Tool (WIST)
  – Data Center-unique software clients

• Most of data in EOSDIS are available on-line (disks)
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Evolution

• "Research archive" maintenance implies continuing evolution
  - keep up with technologies – hardware upgrades, data migration, upgrade of software and tools to “keep up with the times”
    - For example, all data were initially stored on near-line robotic archives; now they are on-line (RAID)
    - Data distribution was both on media and on-line; now it is only on-line (with very rare exceptions)
  - Data from community data system projects and from new missions are accommodated within the functioning infrastructure, e.g.,
    - Preparing for Decadal Survey Missions
    - Archiving and distribution of products from MEaSUREs Projects
Evolution of Data System Features

Lessons learned and information technology advances coupled with advice/comments from community supports a continuously evolving data system with growing capabilities.
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<th>Vision 2015 Goals*</th>
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<td>Archive Management</td>
<td>- NASA will ensure safe stewardship of the data through its lifetime.</td>
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<td>- The EOS archive holdings are regularly peer reviewed for scientific merit.</td>
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<td>EOS Data Interoperability</td>
<td>- Multiple data and metadata streams can be seamlessly combined.</td>
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<td>- Research and value added communities use EOS data interoperably with other relevant data and systems.</td>
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<td>- Processing and data are mobile.</td>
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<td>Future Data Access and Processing</td>
<td>- Data access latency is no longer an impediment.</td>
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<td>- Physical location of data storage is irrelevant.</td>
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<td>- Finding data is based on common search engines.</td>
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<td>- Services invoked by machine-machine interfaces.</td>
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<td>- Custom processing provides only the data needed, the way needed.</td>
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<td>Data Pedigree</td>
<td>- Mechanisms to collect and preserve the pedigree of derived data products are readily available.</td>
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<td>Cost Control</td>
<td>- Data systems evolve into components that allow a fine-grained control over cost drivers.</td>
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<tr>
<td>User Community Support</td>
<td>- Expert knowledge is readily accessible to enable researchers to understand and use the data.</td>
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<td>- Community feedback directly to those responsible for a given system element.</td>
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<td>IT Currency</td>
<td>- Access to all EOS data through services at least as rich as any contemporary science information system.</td>
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*Developed by EOSDIS Elements Evolution Study Team - 2005*