Earth Science Informatics - Overview

H. K. Ramapriyan
Science Systems and Applications, Inc.
&
NASA Goddard Space Flight Center
USA

Hampapuram.Ramapriyan@ssaihq.com

September 28, 2017  IEEE GRSS Distinguished Lecture, Melbourne, FL
Topics

- Informatics
- Earth Science Informatics (ESI)
- IEEE GRSS
- ESI Technical Committee
- Major “players” in the world
- NASA’s involvement – Earth Observing System Data and Information System (EOSDIS)
- Conclusion
NASA’s Earth Science Data Systems

“Advance understanding of Earth and develop technologies to improve the quality of life on our home planet.” -- 2014 NASA Strategic Plan

NASA’s Earth Science Data Systems Program directly supports this strategic goal by providing end-to-end capabilities to deliver data and information products to users.

NASA’s Earth Science Data and Information Policy promotes usage of data by the community:

- In effect since 1990
- No period of exclusive access - Data are available after initial checkout
- Data available at no cost to all users on a non-discriminatory basis except where agreed upon with international partners
Core Capabilities and Competed Programs

■ Core Capabilities
  ➢ Basic operational capabilities to process, archive, manage and distribute data from NASA missions
    ❖ Earth Observing System Data and Information System (EOSDIS)

■ Competitive Programs
  ➢ Peer-review-selected projects
  ➢ New data products – Making Earth System Data Records for Use in Research Environments (MEaSUREs)
  ➢ Research in Earth Science Informatics to feed into the evolution of the core components
    ❖ Applied Information Systems Technology (AIST)
    ❖ Advancing Collaborative Connections for Earth System Science (ACCESS)

■ Core and Competitive Programs collaborate through Earth Science Data System Working Groups (ESDSWG)
Earth Observing System Data and Information System (EOSDIS)

- Development and operation by Earth Science Data and Information System (ESDIS) Project – NASA Goddard Space Flight Center
- Operating since August 1994
- Provides end-to-end capabilities for managing NASA’s Earth science data.
  - Science Operations
    - Science data processing
    - Data management
    - Interoperable distributed data archives
    - On-line data access services
    - Earth science discipline-oriented user services
  - Network Data Transport to distributed system elements
Earth Observing System Data and Information System (EOSDIS)

- **Data downlink**
- **Capture and clean**
- **Subset**
- **Archive**
- **Process**
- **Distribute**

**Users**
- Research
- Applications
- Education
> 11,000 data types (collections)

- **Land**
  - Cover & Usage
  - Surface temperature
  - Soil moisture
  - Surface topography
- **Atmosphere**
  - Winds & Precipitation
  - Aerosols & Clouds
  - Temperature & Humidity
  - Solar radiation
- **Ocean**
  - Surface temperature
  - Surface wind fields & Heat flux
  - Surface topography
  - Ocean color
- **Cryosphere**
  - Sea/Land Ice & Snow Cover

- **Human Dimensions**
  - Population & Land Use
  - Human & Environmental Health
  - Ecosystems

Credit: NASA Science Mission Directorate
Net Primary Productivity is the amount of carbon absorbed by plants minus carbon released by plants, measured in grams of carbon per square meter per day. Image shows the averages over October 2016, globally. Credits - Image made by Reto Stockli, NASA's Earth Observatory Team, using data provided by the MODIS Land Science Team. (http://neo.sci.gsfc.nasa.gov/servlet/RenderData?si=1709924&cs=rgb&format=JPEG&width=720&height=360)
At the top of the atmosphere (TOA), incoming and outgoing radiation determine Earth’s average temperature. This image shows averaged net downward TOA radiation from the Clouds and Earth’s Radiant Energy System (CERES) instrument from 2001 to 2010. The Southern Hemisphere receives more net radiation than the Northern Hemisphere. (Courtesy D. Frierson et al., 2013, Nature Geoscience) – accessed through https://earthdata.nasa.gov/user-resources/sensing-our-planet/rooting-out-rainfall
Aerosol particle sizes – red = small (man made); green = large (natural); yellow = mixed. Map based on data from MODIS instrument on NASA’s Terra satellite. 
This image of Aquarius sea surface salinity (SSS) measurements averaged for 2012 shows a global color scale of salinity intensity. Warm colors mark stronger salinity values. Values are shown in a range between 30 grams per kilogram (purple) and 40 grams per kilogram (red). (Courtesy N. Kuring/NASA) – accessed through https://earthdata.nasa.gov/user-resources/sensing-our-planet/salt-of-the-sea.
Distributed Active Archive Centers (DAACs)

- **Alaska Satellite Facility DAAC**
  - SAR Products, Sea Ice, Polar Processes, Geophysics

- **Land Processes DAAC**
  - Land Cover, Surface Reflectance, Radiance, Temperature, Topography, Vegetation Indices

- **National Snow and Ice Data Center DAAC**
  - Frozen Ground, Glaciers, Ice Sheets, Sea Ice, Snow, Soil Moisture

- **Physical Oceanography DAAC**
  - Gravity, Sea Surface Temperature, Ocean Winds, Topography, Circulation & Currents

- **Goddard Earth Sciences Data and Information Services Center**
  - Global Precipitation, Solar Irradiance, Atmospheric Composition and Dynamics, Global Modeling

- **Socioeconomic Data and Applications Center**
  - Human Interactions, Land Use, Environmental Sustainability, Geospatial Data

- **Ocean Biology DAAC**
  - Ocean Biology, Sea Surface Temperature

- **Crustal Dynamics Data Information System**
  - Space Geodesy, Solid Earth

- **Global Hydrology Resource Center DAAC**
  - Hazardous Weather, Lightning, Tropical Cyclones and Storm-induced Hazards

- **LaRC Atmospheric Science Data Center**
  - Radiation Budget, Clouds, Aerosols, Tropospheric Chemistry

- **Oak Ridge National Laboratory DAAC**
  - Biogeochemical Dynamics, Ecological Data, Environmental Processes

- **Level 1 and Atmosphere Archive and Distribution System (LAADS)**
  - MODIS Level-1 and Atmosphere Data Products
SIPSs perform forward processing of standard products, and reprocess data to incorporate algorithm improvements.
Large & Growing Archive & Distribution Volumes

Diagram showing the growth in Archive Volume and Distributed Volume from 2000 to 2016, with a logarithmic scale on the y-axis for Petabytes and a linear scale on the x-axis for Fiscal Year.

- Cumulative Archive Volume
- Volume Distributed
- Cumulative Archive Volume
EOSDIS Product files Delivered: FY2000 thru FY2016

NOTE: FY = Fiscal Year; FY 2016 is Oct. 1, 2015 to Sept. 30, 2016
- Land and Atmosphere Near real-time Capability for EOS (LANCE)

- Coherent Web Interface: [http://earthdata.nasa.gov](http://earthdata.nasa.gov) is operational
  - Provides a unified view of NASA Earth science data system resources
  - Consolidates 14 web sites, and provides links to various ways to access data and to related external sites

- User Registration System & earthdata login – uniform approach to registration across and access to EOSDIS components
Recent and On-Going Developments (2 of 2)

- Global Imagery Browse Services (GIBS)
  - Standards-based, full resolution, interactive browse capability
  - Accessible from http://earthdata.nasa.gov wiki

- Unified Metadata Model and Common Metadata Repository

- Big Earth Data Initiative (BEDI)

- Preservation Content Specification

- Digital Object Identifiers
  - ESDIS Project is a registration authority (prefix 10.5067)
  - DOI’s assigned to > 50% of datasets
• Building on existing EOSDIS elements provides data from AIRS, AMSR, MISR, MLS, MODIS, OMI, and VIIRS instruments in near real-time (< 3 hours from observation)

• Utilizes software for Standard Science Products, but relaxes requirements for ancillary data inputs

• High operational availability

• Applications of LANCE data include:
  – Numerical weather & climate prediction/forecasting
  – Monitoring of Natural Hazards
  – Disaster Relief
  – Agriculture
  – Air quality

See: https://earthdata.nasa.gov/earth-observation-data/near-real-time/about-lance
Over the four weeks indicated above, >98% of near real-time data requests were satisfied within 3 hours.
EOSDIS Evolution: Earthdata Website

What is the Earthdata Website?
- Sustainable, evolvable, and reliable Website representing community needs for NASA Earth science data and information.
- Supports collaboration within and between organizations, and for development and integration of new applications.
- Coherent and comprehensive Web presence of the Earth Science Data Systems Program.
- See Earthdata at https://earthdata.nasa.gov/.

Benefits of the Earthdata Website:
- Better represents EOSDIS programmatic investments and capabilities.
- Presents data centers clearly as elements within a larger system of systems.
- Facilitates multidisciplinary research and data integration.
- Quickly responds to emerging technologies.
- Provides a platform for demonstration of interoperability throughout all of our systems.
EOSDIS Evolution: Worldview and Global Browse Imagery Services

**GIBS / Worldview Goal:**
To transform how users interact with and discover NASA Earth data; **make it visual**

**Approach:**
- The Global Imagery Browse Services (GIBS) provide open access to full resolution imagery derived from NASA products to any mapping client and script
  
  https://earthdata.nasa.gov/gibs

- Worldview is an open source, **browser-based client** to interactively explore GIBS (and SEDAC) imagery and download the underlying data
  
  https://worldview.earthdata.nasa.gov
Global Image Browse Service (GIBS)

- Goal: “Parameter Visualizations” for all EOSDIS Imagery; ~400 products available now
- Standardized access via OGC WMTS / TWMS / WMS / KML
- Source code for the GIBS OnEarth server and sample code available at the GIBS GitHub site
- Repository of pre-prepared, hierarchically stored imagery to maximize performance for “full-resolution” browse
- Clients can be built to use and display images in GIBS – WorldView is an example
Worldview: Reference Client for GIBS

http://earthdata.nasa.gov/worldview
http://earthdata.nasa.nasa.gov/gibs
Data Tools

- **Search and Order Tools** (45)
- **Data Handling** (Read/Ingest, Format Conversion, Data Manipulation) (31)
- **Subsetting and Filtering Tools** (Temporal, Spatial, Parameter, Channel) (34)
- **Geolocation, Reprojection, and Mapping Tools** (28)
- **Data Visualization & Analysis Tools** (31)
Preserving NASA Earth Science Data

- Bits
- Understandability
- Discoverability & Accessibility
- Usability
- Readability
- Reproducibility of Results

PRESERVE
Categories of Content to be Preserved

NASA’s Preservation Content Specification for Earth Science Data

1. **Preflight/Pre-Operations**: Instrument/Sensor characteristics including pre-flight/pre-operations performance measurements; calibration method; radiometric and spectral response; noise characteristics; detector offsets

2. **Science Data Products**: Raw instrument data, Level 0 through Level 4 data products and associated metadata

3. **Science Data Product Documentation**: Structure and format with definitions of all parameters and metadata fields; algorithm theoretical basis; processing history and product version history; quality assessment information

4. **Mission Data Calibration**: Instrument/sensor calibration method (in operation) and data; calibration software used to generate lookup tables; instrument and platform events and maneuvers

5. **Science Data Product Software**: Product generation software and software documentation

6. **Science Data Product Algorithm Input**: Any ancillary data or other data sets used in generation or calibration of the data or derived product; ancillary data description and documentation

7. **Science Data Product Validation**: Records, publications and data sets

8. **Science Data Software Tools**: product access (reader) tools.
Sources of Content

Science Data Product Documentation

Instrument Teams / PI’s

Science Data Product Software

Science Data Product Algorithm Input

Ancillary data sources (e.g., NOAA)

Instrument Developer/ Manufacturer

Preflight/ Pre-Operations

Data gathering project (e.g., flight project)

Mission logs

Mission Operations

Level 0 Data

Calibration Team

Mission Data Calibration

Science Data Software Tools

DAACs

Science Data Products

Science Data Product Generation Support Teams (SIPSs)

Preflight/Pre-Operations
Lessons learned and information technology advances coupled with advice/comments from community supports a continuously evolving data system with growing capabilities.

- **Discipline/mission specific data systems**
- **Community-specific standards only**
- **Data inter-use proved cumbersome**
- **Offline media**

### <1990
- Improved access to heritage data
- Cross-system search and order access via data interoperability model
- Common distribution format (HDF); other formats also supported
- Higher density offline media

### Mid-1990s
- Support for high data volume & near-line media
- Integrated core plus coupled elements
- Common data model
- Expanded software tools and services
- Options to support or interoperate with external data sources

### Late 90s +
- Coexistence of heterogeneous, distributed data providers / information partners
- Minimal set of core standards; support for community-specific standards
- Coordinate websites (earthdata.nasa.gov)
- Preservation – content specifications
- Reusable software
- Service Oriented Architecture
- On-line archives and cross-system service invocation
- Near Real-Time access

### 2000s
- Federated active archives; loosely coupled
- User Needs driven software development
- Common Metadata Repository with a Unified Metadata Model
- Enable user registration to provide persistence and seamless access
- Collaboratively developed data analytics software
- Open Source software and use of GitHub
- Use of commercial cloud resources
- Easy access Browse imagery
- Ease of innovation and technology infusion

### 2010s +
Earth Science Data System Working Groups

- Focus on exploration and development of recommendations derived from pertinent community insights
- Organized around key technology and information system issues
- Members from NASA-funded core and competed data system activities

Earth Science Information Partners (ESIP)

- Established by NASA in 1998 – now sponsored by NASA, NOAA and USGS
- > 120 members – government agencies, universities, commercial entities
Examples of ESIP and NASA ESDSWG Activities

ESIP Collaboration Areas
- Data Management Training
- Semantic Technologies
- Usability
  - Cloud Computing
  - Documentation
  - Information Quality
  - Discovery
  - Web Services
  - Earth Science Data Analytics
  - VR/AR for Science
  - Earth Sciences Pre-Prints
  - Data Stewardship

Observe
- Process
- Archive
- Discover
- Access
- Analyze/Visualize

NASA ESDS Working Groups
- Cloud Computing
- Data Intensive Architectures
- Time Series
- Map Projections
- Data Quality
- Airborne Data & Metadata
- Search Relevance
- Dataset Interoperability
- Geospatial Web Services
- Data Recipes
- Visualization
- Users Forum
- Digital Object Identifiers & Citations
- Provenance
- Preservation Practices
Conclusion

- Earth Science Informatics is a rapidly developing discipline
- Many organizations around the world are actively pursuing ESI R & D
- Considerable commonality of interests among these organizations
- IEEE GRSS ESI TC, ESIP Federation, Research Data Alliance (RDA) are examples of groups promoting collaboration