TOOLS AND DATA SERVICES FROM THE NASA EARTH SATELLITE OBSERVATIONS FOR CLIMATE APPLICATIONS

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ABSTRACT

Climate science and applications require access to vast amounts of archived high quality data, software tools and services for data manipulation and information extraction. These on the other hand require gaining detailed understanding of the data’s internal structure and physical implementation to data reduction, combination and data product production. This time-consuming task must be undertaken before the core investigation can begin and is an especially difficult challenge when science objectives require users to deal with large multi-sensor data sets of different formats, structures, and resolutions.

In order to address these issues the Goddard Space Flight Center (GSFC) Earth Sciences (GES), Data and Information Service Center (DISC) Distributed Active Archive Center (DAAC) has made great progress in facilitating science and applications research by developing innovative tools and data services applied to the Earth sciences atmospheric and climate data. The GES/DISC/DAAC has successfully implemented and maintained a long term climate satellite data archive and developed tools and services to a variety of atmospheric science missions including AIRS, AVHRR, MODIS, SeaWiFS, SORCE, TOMS, TOVS, TRMM, and UARS and Aura instruments providing researchers with excellent opportunities to acquire accurate and continuous atmospheric measurements.

Since the number of climate science products from these various missions is steadily increasing as a result of more sophisticated sensors and new science algorithms, the main challenge for data centers like the GES/DISC/DAAC is to guide users through the variety of data sets and products, provide tools to visualize and reduce the volume of the data and secure uninterrupted and reliable access to data and related products. This presentation will describe the effort at the GES/DISC/DAAC to build a bridge between multi-sensor data and the effective scientific use of the data, with an emphasis on the heritage satellite observations and science products for climate applications. The intent is to inform users of the existence of this large collection of data and products; suggest starting points for cross-platform science projects and data mining activities and provide data services and tools information. More information about the GES/DISC/DAAC satellite data and products, tools, and services can be found at http://daac.gsfc.nasa.gov.
What is the GES DISC

A virtual data portal that provides convenient access to Atmospheric, Oceanic and Land datasets and value added products from various current NASA missions and instruments as well as heritage datasets.

It also provided a variety of services that allow users to analyze and visualize gridded data interactively online without having to download any data.

Purpose

Description of the GES DISC data/products access, distribution and services capabilities for supporting the Science and Applications Programs.

Science Focus Areas
- Climate Variability
- Weather
- Carbon Cycle
- Earth Surface
- Atmosphere Composition
- Water and Energy Cycle

National Applications
- Air Quality
- Agriculture
- Energy Efficiency
- Coastal Management
- Aviation Safety
- Community Growth
- Disaster Management
- Invasive Species
- Energy Management
- Public Health
- Homeland Security
- Water Management

http://disc.gsfc.nasa.gov/
Missions/Instruments at the GES DISC

- Coastal Zone Color Scanner (CZCS) 1993
- Advanced Very High Resolution Radiometer (AVHRR) 1994
- Total Ozone Mapping Spectrometer (TOMS) 1994
- Data Assimilation Office (DAO) 1994
- Coastal Zone Color Scanner (CZCS) 1995
- Upper Atmosphere Research Satellite (UARS) 1995
- TIROS Operational Vertical Sounder (TOVS) 1997
- Sea-viewing Wide Field of view Sensor (SeaWiFS) 1997
- Tropical Rainbow Measuring Mission (TRMM) 1998
- MODIS - Moderate Resolution Imaging Spectroradiometer 2001
- Aerosol Monitoring (GLORY) 2007
- Global measurement of Soil Moisture Content and Freeze/Thaw (HYDROS) 2009
- Global Precipitation Measurement (GPM) 2010

Limited Use of Satellite Remote Sensing Data

User’s Limitations

- Low general awareness
- Lack of knowledge of the technology - lack of expertise
- Lack of field studies for validation
- Strict disciplinary boundaries
- Lack of opportunities for cooperation
- Lack of software interoperability
- Lack of user friendly systems
- Different data formats from different providers
- Take long time to obtain the data

Institutional Limitations

- Poor infrastructure for processing satellite data
- High cost of some satellite data products and systems
- Data and products have been developed by and to serve the needs of Earth Science scientists: closed loop
- Scarcity of human resources
- No or very few data services
- Currently most data institutions provide data in archive forms

GES DISC Focus on User’s Requirements

Scientists

- Access to data service functions
  - Reformatting capabilities
  - Spatial/temporal parameters coordinate-based subsetting
  - Accessible re-sampling
  - Re-projection and geo-rectification
- User friendly systems to search and find data, maps and services
- Easy access to multi-dimensional, multi-temporal data services
- Access to multiple data sources provided by different data servers
- Access to data in ready-for-analysis form

General Public

- High resolution data
- Both raw and processed data products
- Rapid access to the latest data
- Lots of data
- Detailed documentation
- Data analysis support
- Expert assistance with preparing or analyzing data

GES DISC Focus on User’s Needs

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GES-DISC Data Search and Order

GES DAAC Data Search and Order by Earth Science Data Type (ESDT)

- Archived Data Sets (search and order system)
  - Full collections of all GES DISC data holdings, by instrument /mission, available for delivery by electronic and hard media.
- Online Data Sets (data pool)
  - Limited collections of the most popular products at the GES DISC, available for instant download using FTP or a Browser.
- Earth Observing System Data Gateway
- Global Change Master Directory

GES DISC Data Search and Order by Earth Science Data Type (ESDT)

External Data Search

- Earth Observing System Data Gateway
- Global Change Master Directory

AMESU-A Daily Summary Browse for 2002/09/01 Ascending (Day)
GES DISC Archived Data Sets

<table>
<thead>
<tr>
<th>Data Set</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>AIRS</td>
<td>Vertical profiles of temperature, humidity and geopotential height from AIRS daily global product.</td>
</tr>
<tr>
<td>MODIS</td>
<td>MODIS Terra and Aqua global monthly chlorophyll and other ocean data from MODIS.</td>
</tr>
<tr>
<td>SeaWiFS</td>
<td>SeaWiFS data analysis system. Comprehensive image analysis package for the processing, display, analysis, and quality control of ocean color data.</td>
</tr>
<tr>
<td>MODIS</td>
<td>MODIS Terra and Aqua data.</td>
</tr>
<tr>
<td>TOMS</td>
<td>Visualization and analysis of the Earth Probe and Nimbus-7 TOMS Daily Global Products and Aura OMI.</td>
</tr>
<tr>
<td>AIRS</td>
<td>AIRS Global Temperature, Humidity and Geopotential Height from AIRS Global Product.</td>
</tr>
<tr>
<td>HALOE</td>
<td>Convenient access to atmospheric profiles of trace gases.</td>
</tr>
</tbody>
</table>

GES-DISC Data Access Tools

**SeaDAS**
- SeaWiFS Data Analysis System. Comprehensive image analysis package for the processing, display, analysis, and quality control of ocean color data.

**HDFLook**
- Multifunctional data processing and visualization tool for MODIS and AIRS L1B data.

**WebWinds**
- Read and georeference MODIS Level 3 data and display it as a false color image over a digital elevation model on a globe or plane.

GES-DISC Interactive Online Visualization and Analysis Infrastructure

**Giovanni**
- Access to data from multiple remote sites as well as local sites;
- Server-side temporal and spatial subsampling;
- Server-side processing;
- Support for multiple data formats including Hierarchical Data Format (HDF), HDF-EOS, network Common Data Form (netCDF), Glided Binary (GRIB), and binary;
- Support for multiple plot types including area, time, Hovmoeller, and image animation;
- Support for outputting data in ASCII format.

**Giovanni Goals**

**GES-DISC Interactive Online Visualization and Analysis Infrastructure**

<table>
<thead>
<tr>
<th>Audience</th>
<th>Modelers, global and regional trends researchers, teachers, students</th>
</tr>
</thead>
<tbody>
<tr>
<td>Purpose</td>
<td>Allow access to information on atmosphere and ocean state from around the world with a few mouse clicks.</td>
</tr>
<tr>
<td></td>
<td>Make gridded remote sensing and model data available in format that anyone can learn to use within minutes and put to work productively for research or applications</td>
</tr>
</tbody>
</table>

**Giovanni Family**

- **MOVAS** - intercomparison analyses between aerosol-related parameters of MODIS (Terra and Aqua) and the Goddard Chemistry Aerosol Radiative and Transport (GOCART) model.
- **TOVAS** - TRMM Online Visualization and Analysis System, based primarily on data from the Tropical Rainfall Measuring Mission.
- **The Ocean Color Giovanni** - access to SeaWiFS and MODIS Aqua global monthly chlorophyll and other ocean data from the start of missions. Supports the Ocean-Color Time-Series funded by the NASA.
- **TOMS Giovanni** - visualization and analysis of the Earth Probe and Nimbus-7 TOMS Daily Global Products and Aura OMI.
- **AIRS Giovanni** - vertical profiles of temperature, humidity and geopotential height from AIRS daily global product.
- **UARS/HALOE Giovanni** - convenient access to atmospheric profiles of trace gases.
TRMM Online Visualization and Analysis System

http://lake.nasa.gov/tovas/

MODIS Online Visualization and Analysis System

http://giovanni.gsfc.nasa.gov/giovanni

MODIS - Terra/Aqua Atmosphere Monthly Global Product

Goddard Chemistry Aerosol Radiation and Transport (GOCART) Model Products

MODIS-Terra/Aqua/GOCART Multi-parameter Intercomparison System

Aerosol Optical Thickness at 0.55 Micron
Aerosol Fine Mode Fraction
Fine Mode Aerosol Optical Thickness (Ocean)
Cirrus Fraction NIR Method - Cirrus Reflectance
Cloud Fraction Daytime IR Method
Cloud Effective Radius Combined Phase - Ice Phase - Water Phase
Cloud Optical Thickness Combined Phase - Ice Phase - Water Phase
Cloud Top Pressure - Temperature
Water Vapor Clear Sky - Above Cloud - NIR Method
Water Vapor Column IR Method

Giovanni Application

 Hurricane Katrina

Time required to create these plots online: 2 minutes

TOVAS Spatial/Temporal Resolutions and Coverage

<table>
<thead>
<tr>
<th>Products</th>
<th>Spatial Res.</th>
<th>Temporal Res.</th>
<th>Coverage</th>
<th>Duration</th>
</tr>
</thead>
<tbody>
<tr>
<td>Experiment TRMM Real-Time Multi-Satellite Precipitation Analysis</td>
<td>0.25°x0.25°</td>
<td>3-hourly</td>
<td>global</td>
<td>2002-02-present</td>
</tr>
<tr>
<td>TRMM and Others GPI Rainfall Estimate</td>
<td>0.25°x0.25°</td>
<td>3-hourly</td>
<td>50°S-50°N</td>
<td>1998-01-present</td>
</tr>
<tr>
<td>TRMM and Others Data Sources Rainfall Estimate</td>
<td>0.25°x0.25°</td>
<td>monthly</td>
<td>50°S-50°N</td>
<td>1998-01-present</td>
</tr>
<tr>
<td>TRMM Microwave Imager (TRMM) rain, latent heat, cloud liquid water profiles</td>
<td>0.5°x0.5°</td>
<td>monthly</td>
<td>40°S-40°N</td>
<td>1998-01-present</td>
</tr>
<tr>
<td>TRMM and Others GPI Rainfall Estimate</td>
<td>1.0°x1.0°</td>
<td>monthly</td>
<td>40°S-60°N</td>
<td>1998-01-2004/03</td>
</tr>
<tr>
<td>TRMM and Others Data Sources Rainfall Estimate</td>
<td>1.0°x1.0°</td>
<td>monthly</td>
<td>40°S-60°N</td>
<td>1998-01-2004/03</td>
</tr>
<tr>
<td>Willmott and Matsuura Global Precipitation</td>
<td>0.5°x0.5°</td>
<td>monthly</td>
<td>global land</td>
<td>1998-01-2004/03</td>
</tr>
<tr>
<td>Global Precipitation</td>
<td>1.0°x1.0°</td>
<td>monthly</td>
<td>global land</td>
<td>1998-01-2004/03</td>
</tr>
</tbody>
</table>

Inter-comparison of TRMM (1B43 V5) and Willmott Precipitation Baseline Products

Rainfall Anomaly Analysis of TRMM Monthly Rainfall Precipitation

3-H TRMM and Other Satellite Rainfall Online Visualization and Analysis

http://lake.nasa.gov/tovas/

2003 Monthly Rainfall Accumulation (mm)

Time required to create these plots online: 6 minutes
Giovanni Application: MODIS-Terra/Aqua/GOCART
Multi-parameter Intercomparison System

Giovanni On-line Product Examples

Giovanni Application
TEN MINUTES study of the effects of heavy spring rains on the Mid-Atlantic Coast in 2003

Near-line Archive Data Mining (NADM)
Data Mining at the GES -DISC

- How to handle too much data?
  - As data volumes get larger, the proportion of data that can be distributed to users decreases.
  - User communities express concern about the ability to manage the data explosion on their end.

- Allow users to run their own data mining algorithm codes in the data provider server
- Migrate data mining and mining preparation activities into the data center

GSFC DAAC Dataset via OPeNDAP - (DODS)
Open Source Project for a Network Data Access Protocol

- Global coverage from visible, infrared, and microwave sensors.
- MODIS Aqua/Terra Products: land, ocean and atmosphere in 36 spectral bands (0.4 - 14.3 µm).
- Climatology Interdisciplinary Data Collection (CIDC): over 70 parameters.
- 16 years of Microwave Sounding Unit (MSU) Deep Layer Temperatures and Ocean Precipitation Data.
- Data Assimilation Products: data from the Goddard Earth Assimilation System Data Assimilation System (SEOS-DAS).
- SeaWiFS Data Products: Global and regional ocean color data
- EOS Aqua/Terra satellite broadcasts data via X-band to the ground.
- Total Ozone Mapping Spectrometer (TOMS): Daily Gridded Data
- Global Ozone Monitoring Experiment (GOME) Daily Gridded Ozone Data (Globally Interpolated), Global column ozone data.
- Tropical Rain Measurement Mission (TRMM) Gridded Rainfall Data

Migrate data mining and mining preparation activities into the data center
GES DISC and Applications
Integrating NASA Earth Science Data into Global Agricultural Decision Support Systems

Develop agriculture-oriented land products and hydrologic products based on TRMM, MODIS and other satellites.

Generate MODIS 250-m, 10-day composite surface reflectance product.

Develop Agricultural Information System (AIS) based on existing TRMM Online Visualization and Analysis System.

Integrate ESE products into USDA/FAS and UN/WFP Decision Support System.

Collaboration with the Pan-American Health Organization - PAHO

GES DISC International Collaboration

- Interaction with the international user community and data center of satellite data and products to share data and required metadata.
- Sharing of information about data quality and standards.

Suggestions
- Develop new or revise international collaboration between operational space agencies and data centers.
- Preparation and submission of joint proposals.
- Exchange of scientists among institutions.
- More time dedicated to data and products delivery, management and archiving during conferences and workshops.
- Motivate multi-disciplinary dialogues and interaction.

CONCLUSION

The GES DISC mission is to maximize the use, usefulness, and usability of NASA's Earth science data for science research and applications.

Make remote sensing data, derived products, tools and services more easily accessible and useful to a broader user community.

http://disc.gsfc.nasa.gov/

The Bridge Between Data and Science