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.

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Tools and Data Services from the NASA Earth Satellite Observations for Climate Applications

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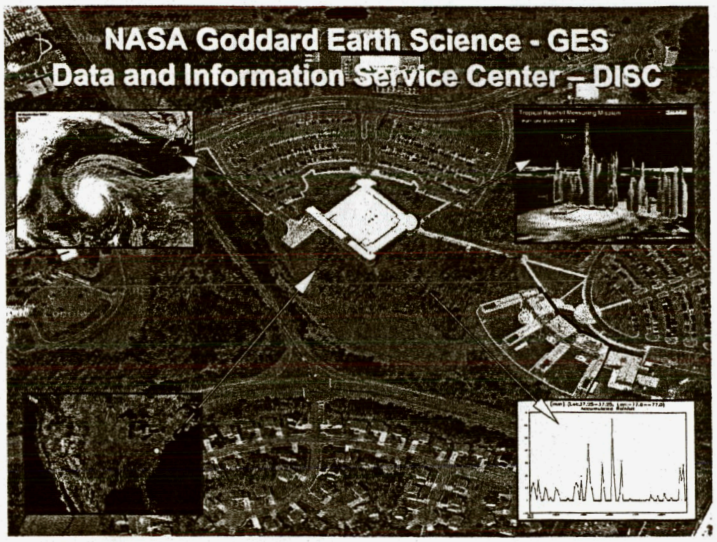
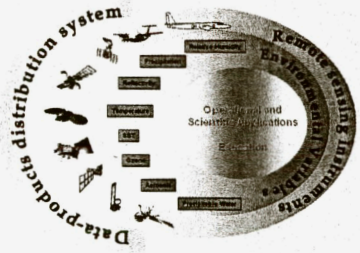
George Mason University - GMU



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

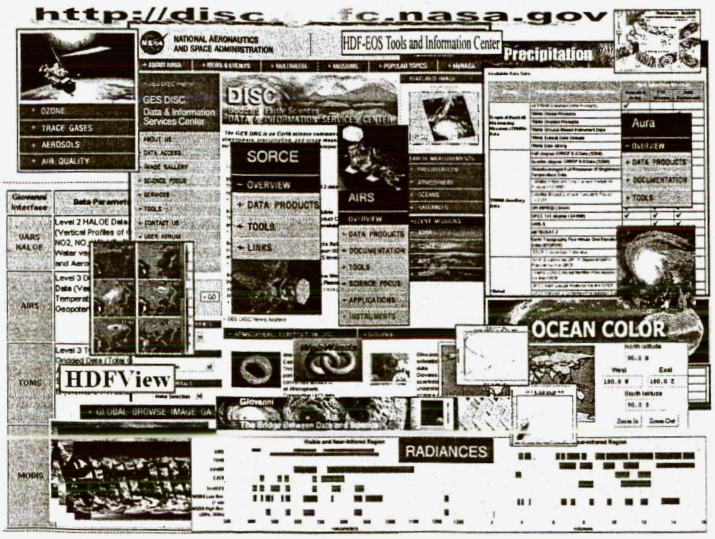
Description of the GES DISC data/products access, distribution and services capabilities for supporting the Science and Applications Programs.

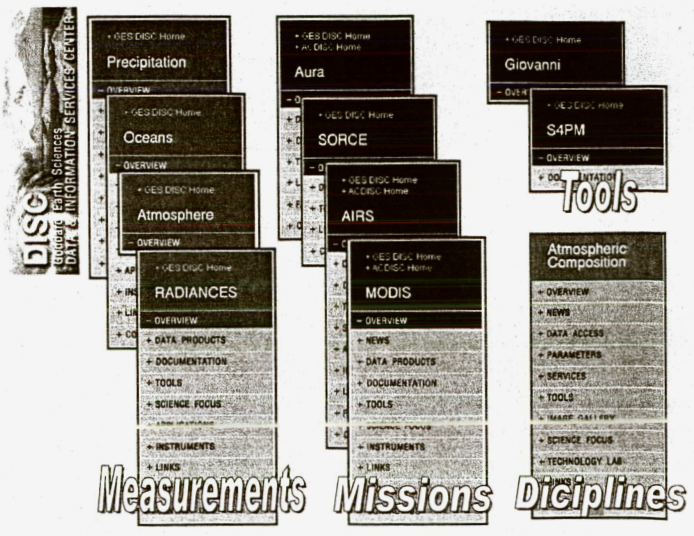
Science Focus Areas

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

National Applications

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





Missions/Instruments at the GES DISC

- **1993 - CZCS** - Coastal Zone Color Scanner
- **1994 - AVHRR** - Advanced Very High Resolution Radiometer
- **1994 - TOMS** - Total Ozone Mapping Spectrometer
- **1994 - UARS** - Upper Atmosphere Research Satellite
- **1994 - DAO** - Data Assimilation Office
- **1995 - TOVS** - TIROS Operational Vertical Sounder
- **1997 - SeaWiFS** - Sea-viewing Wide Field of view Sensor
- **1997 - TRMM** - Tropical Rainfall Measuring Mission
- **1999 - Terra** - **MODIS** - Moderate Resolution Imaging Spectroradiometer
- **2001 - Aqua** - **MODIS**
  - **AIRS** - Atmospheric Infrared Sounder
- **2003 - SORCE** - Solar Radiation & Climate Experiment
- **2004 - Aura** - **MLS** - Microwave Limb Sounder
  - **HIRDLS** - High Resolution Dynamics Limb Sounder
  - **OMI** - Ozone Monitoring Instrument
- **2007 - GLORY** - Aerosol Monitoring
- **2009 – HYDROS** - Global measurement of Soil Moisture Content and Freeze/Thaw
- **2010 - GPM** - Global Precipitation Measurement

GES DISC Focus on User's Requirements

Scientists	General Public
High resolution data	*Small amounts of highly derived products (maps, plots, animations, etc.)*
Both raw and processed data products	*Current and historic data sets*
Rapid access to the latest data	*Easy to understand documentation*
Lots of data	*Web access*
Detailed documentation	*GIS based*
Data analysis support	*Free data/products*
Expert assistance with preparing or analyzing data	*24/7 assistance*

Limited Use of Satellite Remote Sensing Data

User's Limitations	Institutional Limitations
Low general awareness	*Poor infrastructure for processing satellite data*
Lack of knowledge of the technology – lack of expertise	*High cost of some satellite data products and systems*
Lack of field studies for validation	*Data and products have been developed by and to serve the needs of Earth Science scientists: closed loop*
Strict disciplinary boundaries	*Scarcity of human resources*
Lack of opportunities for cooperation	*No or very few data services*
Lack of software interoperability	*Currently most data institutions provide data in archive forms*
Lack of user friendly systems	
Different data formats from different providers	
Take long time to obtain the data	

GES DISC Focus on User's Needs

- *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*

GES-DISC Data Search and Order

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

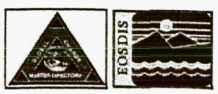
Search for data products by Earth Science data type (use of short names). Example: MOD04_L2: L2 MODIS aerosol product.

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)

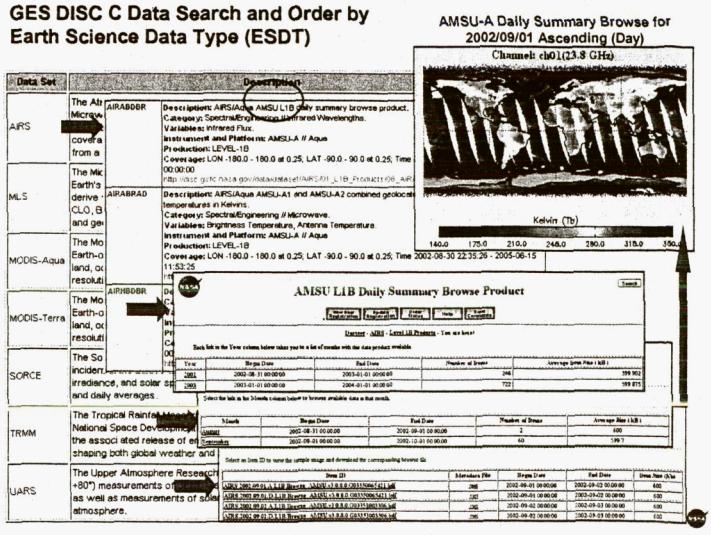
Limited collections of the most popular products at the GES DISC, available for instant download using FTP or a Browser.



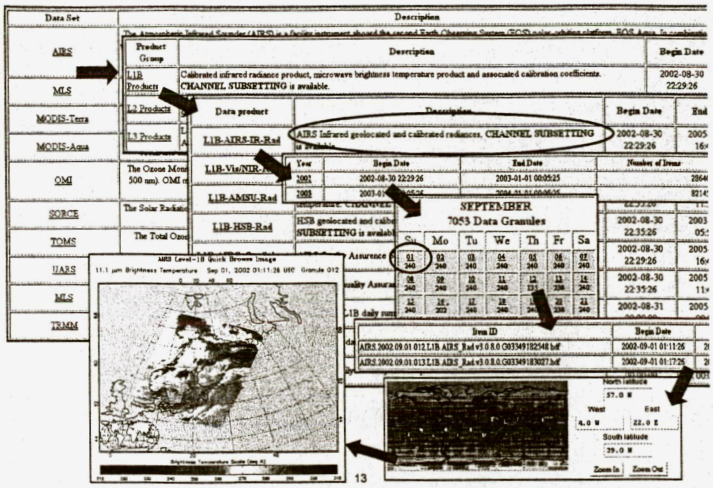
External Data Search

Earth Observing System Data Gateway
Global Change Master Directory

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



GES DISC Archived Data Sets



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.

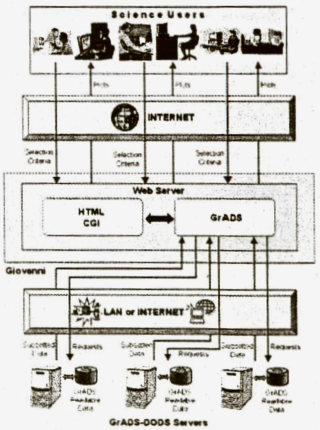
WebWinds

Read and georeference MODIS Level 1-3 data and display it as a false color image over a digital elevation map on a globe or plane.

GES-DISC Interactive Online Visualization and Analysis Infrastructure

Transfer the computation burden from the client to the server

GES-DISC Interactive Online Visualization and Analysis Infrastructure – **G i o v a n n i**



Main Features:

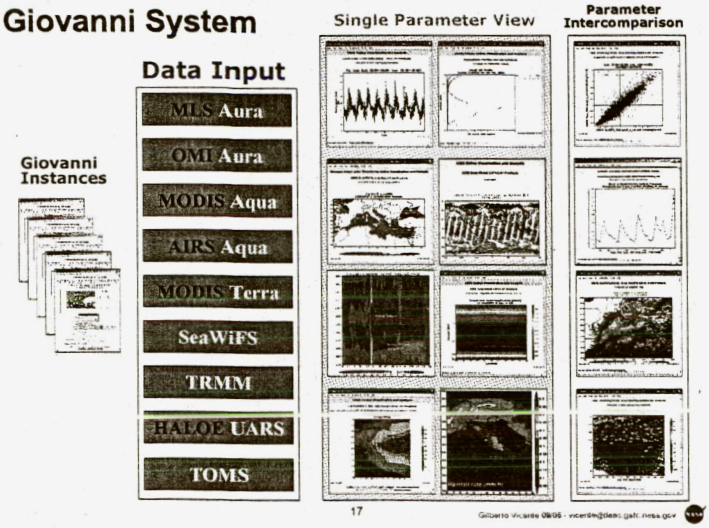
- ***Access to data from multiple remote sites as well as local sites;***
- ***Server-side temporal and spatial subsetting;***
- ***Server-side processing;***
- ***Support for multiple data formats including Hierarchical Data Format (HDF), HDF-EOS, network Common Data Form (netCDF), GRIdded Binary (GRIB),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

Giovanni Goals

GES-DISC Interactive Online Visualization and Analysis Infrastructure

Audience	**Modelers, global and regional trends researchers, teachers, students**
Purpose	**Allow access to information on atmosphere and ocean state from around the world with a few mouse clicks.**
	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

Giovanni System

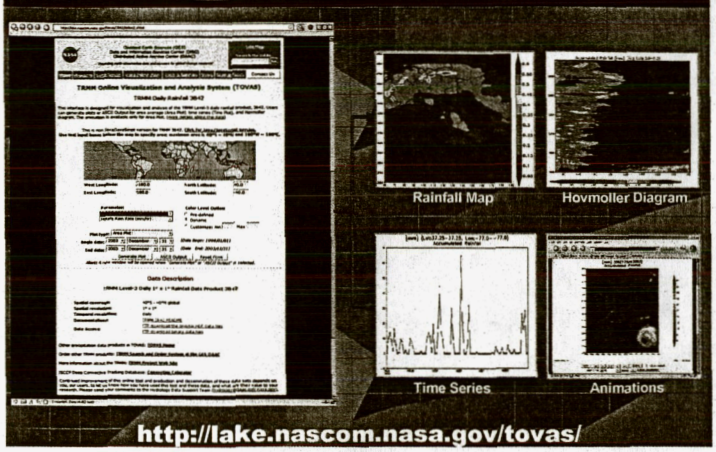


Giovanni Family

- **MOVAS -** intercomparison analyses between aerosol-related parameters of **MODIS** (Terra and Aqua) and the Goddard Chemistry Aerosol Radiation 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

TOVAS

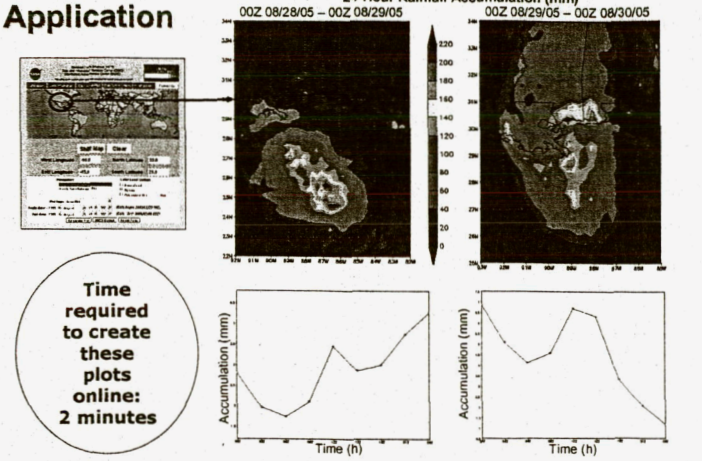


http://lake.nascom.nasa.gov/tovas/

Giovanni Application

Hurricane Katrina

24-Hour Rainfall Accumulation (mm)



Time required to create these plots online: 2 minutes

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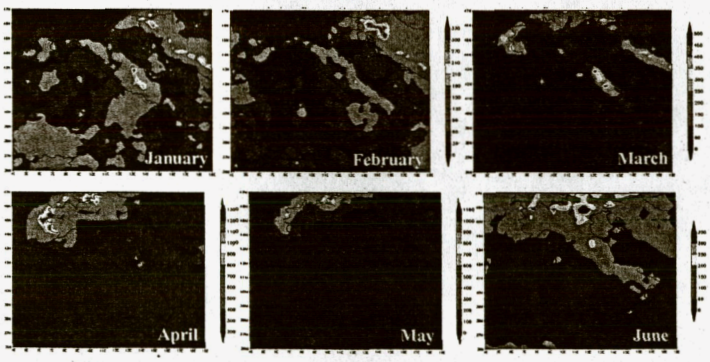
3-H TRMM and Other Satellite Rainfall Online Visualization and Analysis

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

2003 Monthly Rainfall Accumulation (mm)



Time required to create these plots online: 6 minutes

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TOVAS Spatial/Temporal Resolutions and Coverage

Products	Spatial Res. Vertical Res.	Temporal Res.	Coverage	Duration
Experimental TRMM Real-Time Multi-Satellite Precipitation Analysis	0.25°x0.25°	3-hourly	global 60°S-60°N	2002/02 - present
TRMM and Others GPI Rainfall Estimate	0.25°x0.25°	3-hourly	global 50°S-50°N	1998/01 - present
TRMM and Others Data Sources Rainfall Estimate	0.25°x0.25°	monthly	global 50°S-50°N	1998/01 - present
TRMM Microwave Imager (TMI) rain, latent heat, cloud liquid water profiles	0.5°x0.5° 14 vertical layers	monthly	global 40°S-40°N	1998/01 - present
TRMM and Others GPI Rainfall Estimate	1.0°x1.0°	monthly	global 40°S-40°N	1998/01-2004/03
TRMM and Others Data Sources Rainfall Estimate	1.0°x1.0°	monthly	global 40°S-40°N	1959/01-1999/12
Willmott and Matsuura Global Precipitation	0.5°x0.5°	monthly	global land	1998/01-2004/03
Global Precipitation	1.0°x1.0°	monthly	global land	1998/01-2004/03
Inter-comparison of TRMM (3B43 V5) and Willmott Precipitation Baseline Products				
Rainfall Anomaly Analysis of TRMM Monthly Rainfall Product				

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MODIS Online Visualization and Analysis System

MOVAS

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

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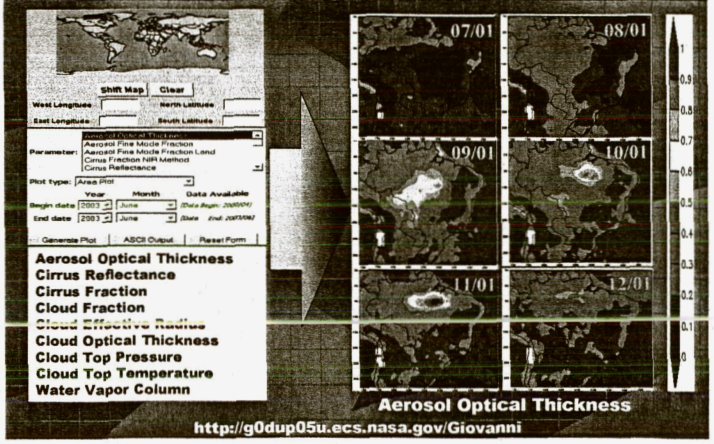
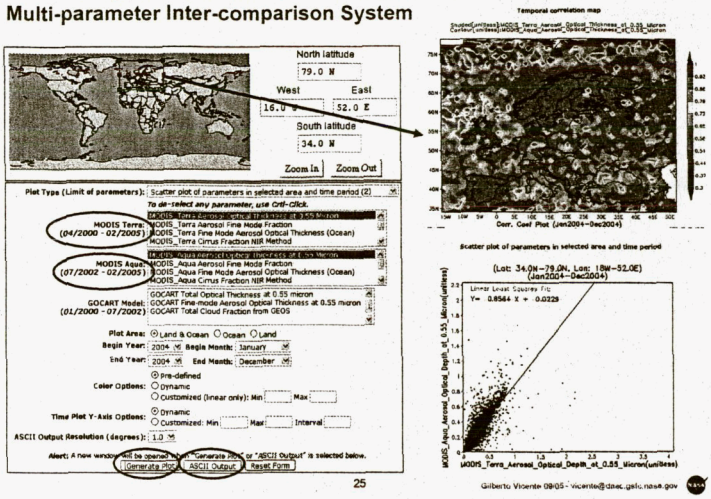
MODIS Online Visualization and Analysis System

MOVAS



http://g0dup05u.ecs.nasa.gov/Giovanni

Giovanni Application: MODIS-Terra/Aqua/GOCART Multi-parameter Inter-comparison System



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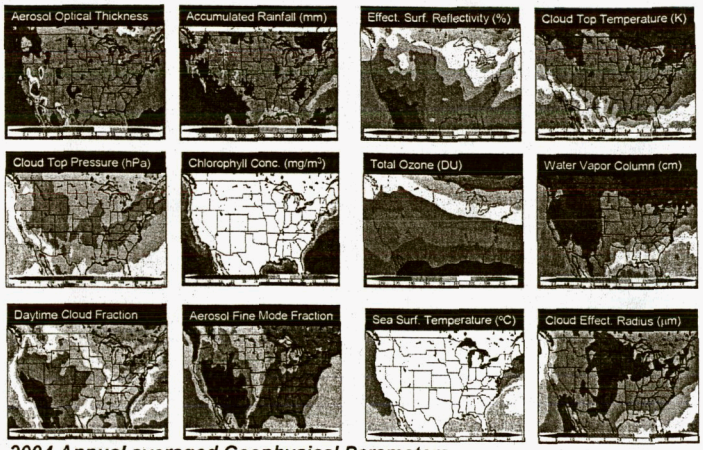
Giovanni On-line Product Examples



2004 Annual averaged Geophysical Parameters

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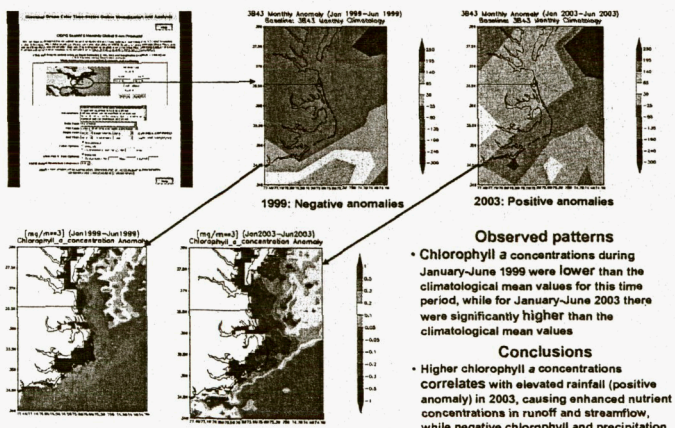
Giovanni Application

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



Observed patterns

- Chlorophyll *a* concentrations during January-June 1999 were lower than the climatological mean values for this time period, while for January-June 2003 there were significantly higher than the climatological mean values

Conclusions

- Higher chlorophyll *a* concentrations correlates with elevated rainfall (positive anomaly) in 2003, causing enhanced nutrient concentrations in runoff and streamflow, while negative chlorophyll and precipitation anomalies observed in 1999

Generate and compare climatological anomalies

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

AIRS	*Global coverage from visible, infrared, and microwave sensors.*		*MODIS Aqua/Terra Products: land, ocean and atmosphere in 36 spectral bands (0.4 - 14.5 μm).*
CIDC	*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 (GEOS-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*

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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

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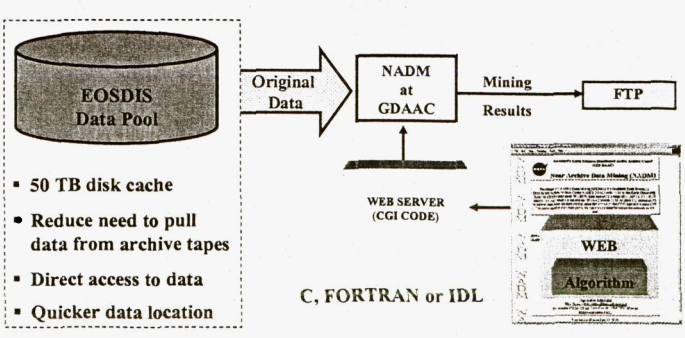

- 50 TB disk cache
- Reduce need to pull data from archive tapes
- Direct access to data
- Quicker data location

- Give users the capability to upload, test their algorithm and mine data from the GES-DAAC online cache
- Decrease download time by applying algorithm closer to data

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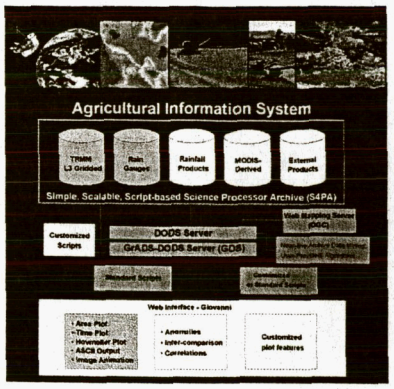
GES DISC and Applications

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.

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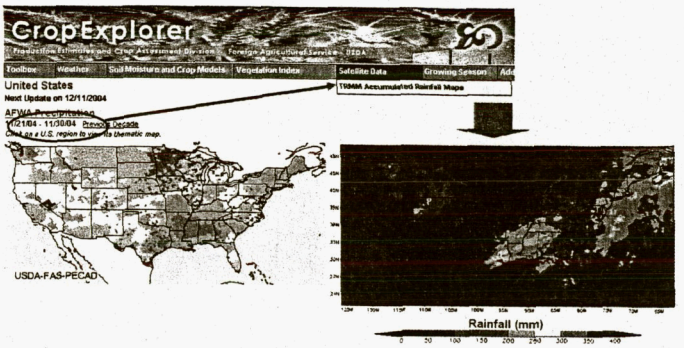
Giovanni Application



Linking the USDA Crop Explorer decision support system to the GES DISC's TRMM Online Visualization and Analysis System (TOVAS)

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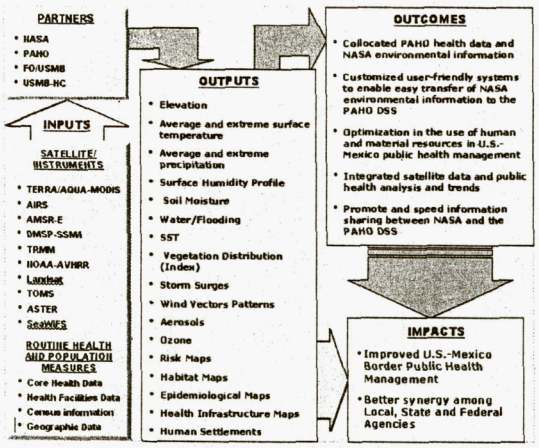
Building Relationships



Collaboration with the Pan-American Health Organization - PAHO

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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.*

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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