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SUPPORTING EARTH SCIENCE EDUCATION WITH ONLINE VISUALIZATION AND ANALYSIS INFORMATION SYSTEMS

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1. INTRODUCTION

To encourage undergraduate students, especially those underrepresented minority students, to consider academic, operational or research careers in geosciences, it is necessary to let them participate in earth science education and applications as early/frequently as possible and expose to hands-on projects. However, existing issues in data accessing, such as, data format, data volume, etc. are major hurdles for conducting these activities. The NASA Goddard Earth Sciences Data and Information Services Center (GES DISC) has taken a major step towards meeting these challenges by developing an infrastructure that supports a Web interface that allows users to perform interactive analysis online without downloading any data. The underlying infrastructure that integrates all the components is called GES-DISC Interactive Online Visualization and Analysis Infrastructure or "Giovanni." With a web browser and few mouse clicks, an individual can easily obtain global earth science information. At present, Giovanni includes these global products: 3-hourly, daily and monthly precipitation, MODIS monthly atmospheric products and a SeaWiFS monthly product. Basic functionalities include: area plots, time series, Hovmoller diagrams, and animation, for students to understand variations across different temporal and spatial scales and evolution (e.g. via animation). Near-real-time products, such as, precipitation, can be used for classroom projects to monitor flood conditions around the world.

2. GIOVANNI ARCHITECTURE

The principle design goal for Giovanni was to provide a quick and simple interactive means for science data users to study various phenomena by trying various combinations of parameters measured by different instruments, arrive at a conclusion, and then generate graphs suitable for a publication. Alternatively, Giovanni would provide a means to ask relevant what-if questions and get back answers that would stimulate further investigations. This would all be done without having to download and preprocess large amounts of data. A secondary design goal was for Giovanni to be easily configurable, extensible, and portable. The GES DISC currently runs Giovanni on Linux, SGI, and Sun platforms.

Another goal of Giovanni was to off-load as much as possible the data processing workload onto the machines hosting the data and to reduce data transfers to a minimum.

Given the enormous amount of data at the GES DISC Distributed Active Archive Center (DAAC) in HDF, it was a requirement was that Giovanni support HDF, HDFEOS, as well as binary.

Finally, Giovanni needed to be flexible, adaptable, and easy to set up quickly for measurement-based projects at the GES DISC.

Giovanni consists of HTML and CGI scripts written in Perl, Grid Analysis and Display System (GrADS) scripts, and one or more GrADS-DODS (Distributed Oceanographic Data System) Servers (GDS) running on remote machines that have GrADS readable data. In addition, there is an image map Java applet through which a user can select a bounding box area to process. The data flow is illustrated in Fig. 1.

GrADS was chosen for its widespread use for providing easy access, manipulation, and visualization of Earth science data. It supports a variety of data formats such as binary, GRIB, NetCDF, HDF, and HDFEOS. When combined with DODS, as in GDS, the result is a secure data server that provides subsetting and analysis across the network or even the Internet. The ability of GDS to subset data on the server drastically reduces the amount of data that need to be transferred across the network and improves overall performance. GDS provides spatial or temporal subsetting of data while applying any of a number of analysis operations including basic math function, averages, smoothing, correlation, and regression. An equally important feature is the ability to run GrADS data transformations on the server.

Via the Giovanni Web interface (Fig. 2), the user selects one or more data sets, the spatial area, the temporal extent, and the type of output. Supported output types

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are listed in Table 1. The selection criteria are passed to the CGI scripts for processing.

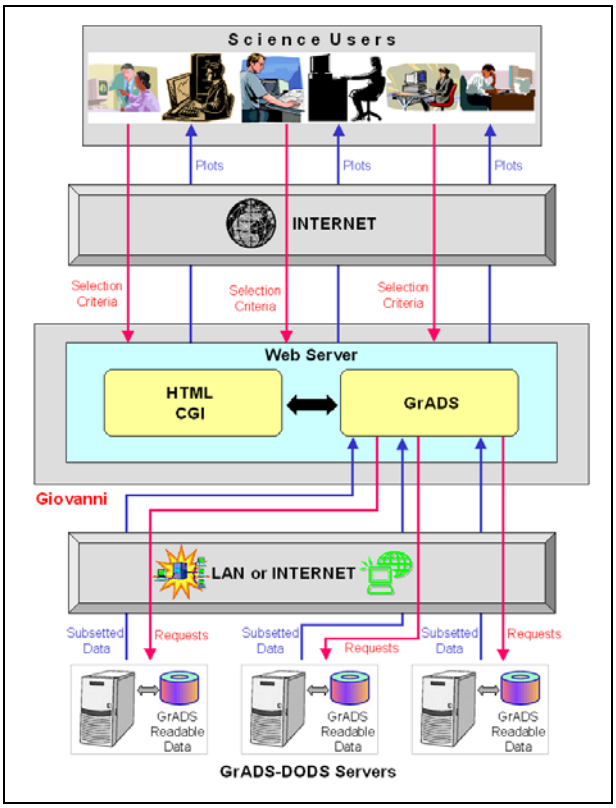

Figure 1. GIOVANNI system diagram.

Table 1. Functions supported by GIOVANNI.

Output Type	Description
Area Plot	Area plot averaged or accumulated over any available data period within any rectangular area
Time Plot	Time series averaged over any rectangular area
Hovmoller Plots	Longitude-time and latitude-time plots
Animations	Animations available for area plots
ASCII Output	ASCII output available for all plot types, suitable feeding GIS or other applications

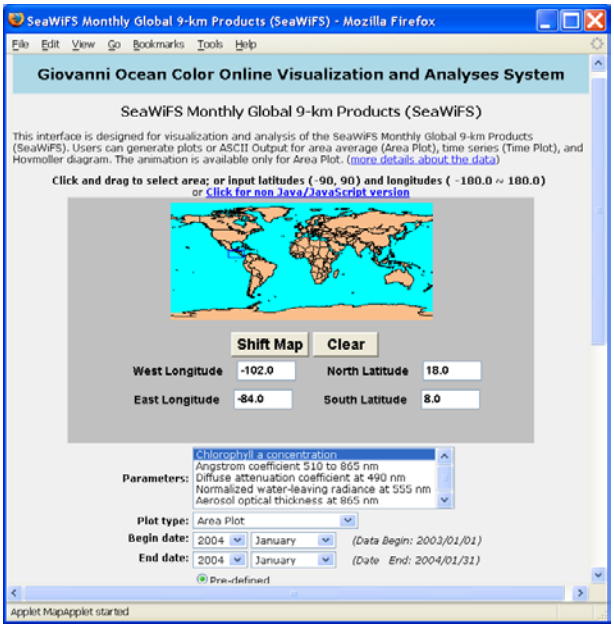

Figure 2. Example web interface of Giovanni for SeaWiFS Monthly Global 9-km Chlorophyll.

3. CURRENT IMPLEMEENTATIONS

At the GES DISC, several instances of Giovanni are currently supporting our data users. Access to these Giovanni instances is available from the GES DISC Web page at: http://disc.gsfc.nasa.gov/ or in the information section of this article.

TOVAS

Precipitation is an important atmospheric variable in our daily life. Each year, floods and droughts happen around the world, causing heavy property damage and human casualties. Traditionally rain gauge measured precipitation is the main source for weather forecast and research. However, satellite remote sensing has increasingly become important in providing precipitation information over vastly undersampled oceans and continents. In particular, the Tropical Rainfall Measuring Mission (TRMM) is a joint U.S.-Japan satellite mission to monitor tropical and subtropical (40° S - 40° N) precipitation and to estimate its associated latent heating (Special Issue on TRMM, 2000). The TRMM satellite provides the first detailed and comprehensive dataset on the four dimensional distribution of rainfall and latent heating over vastly undersampled tropical and subtropical oceans and continents. The TRMM satellite was launched on November 27, 1997. TRMM data products are archived at and distributed by the GES DISC.

TOVAS is the TRMM Online Visualization and Analysis System (TOVAS), based primarily on data from TRMM (Liu et al. 2002a, 2002b, and 2002c; Liu et al. 2002). TOVAS has been operational since March 2001

providing Giovanni analysis tools to users of: Three hourly TRMM and Other Satellite Rainfall (3B42RT) for Jan 2002-present, TRMM Level-3 Daily Rainfall (3B42) for Jan 1998-present, TRMM Level-3 Monthly Rainfall (3B43) for Jan 1998-present, Willmott and Matsuura Global Precipitation (Willmott and Matsuura, 1995) for Jan 1950-Dec 1999, Global Precipitation Climatology Center (GPCC) Monthly Global Precipitation for Jan 1986-present.

TOVAS is a powerful tool that allows users to fully explore data. TOVAS makes TRMM and other gridded precipitation data available in a format that anyone can learn to use within minutes and put to work productively in research or applications. With few mouse clicks, one can easily obtain precipitation information around the world (e.g., Fig. 3 and Fig. 4). Recent applications of TOVAS include:

- Study of coastal urban heat island effect on rainfall.
- Additional rainfall information to supplement ground stations in Sri Lanka.
- Phenology study in Africa and North America.
- Crop yield estimates and flood watch in Africa and Asia.
- Rainfall information for a development project in Afghanistan.
- Fire monitoring activities in Africa.
- Data for hydrological modeling in Africa.
- Range prediction of American butterflies.
- Intercomparison with other products in North America.
- Monitoring rain events in the Balkans.
- Investigation of the 1997-1998 El Nino/La Nina event.
- Investigation of insect activities in the US.

MOVAS

The MODIS (Moderate Resolution Imaging Spectroradiometer) Online Visualization and Analysis System (MOVAS) has been operational since September 2003 providing Giovanni analysis tools to users of the MODIS Terra atmospheres monthly global product (MOD08_M3). Data are available from April 2000 to the present.

MOVAS allows scientists and researchers to easily access, visualize and analyze MODIS Level-3 atmospheric monthly products, thus helping them to understand seasonal-to-interannual variation of atmospheric parameters ranging from aerosol to water vapor. MOVAS can provide information at every single point and in any rectangle area within the data domain, which allows researchers to conduct nearly unlimited investigations. The ASCII output option allows users to do their own customized analyses or applications, such as, GIS.

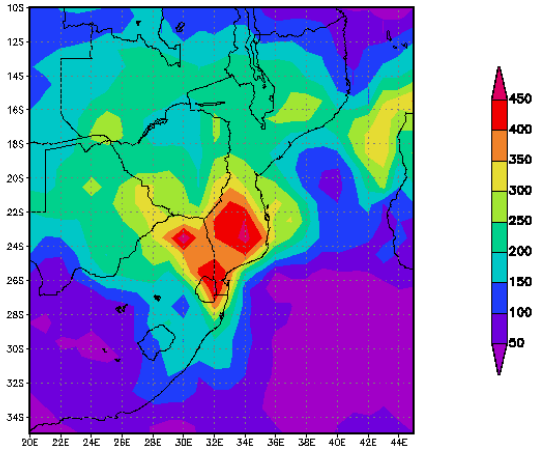

Figure 3. Regional accumulated rainfall for February, 2000. Parts of Mozambique received rainfall of over 300 mm in one day. Over 300 people died and 2 million had been displaced or affected.

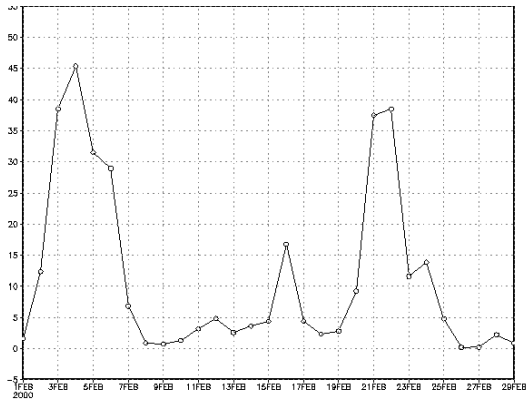

Figure 4. Time series of daily rainfall total (TRMM 3B42) for the southern part of Mozambique. Two major rain events appear in this plot.

OOVAS

The Ocean Color Online Visualization and Analysis System (OOVAS) recently became available operationally (Fig. 5). It provides users access to SeaWiFS and MODIS Aqua global monthly chlorophyll data for all data from the start of mission. It has been developed to support the Ocean-Color Time-Series funded by the REASoN CAN. The goals of this project are to develop and maintain a consistent multi-decadal time series of ocean color data, and to develop and maintain simplified user access and support for the time series that spans missions. Giovanni serves these goals perfectly as it allows access long time-series information without downloading data.

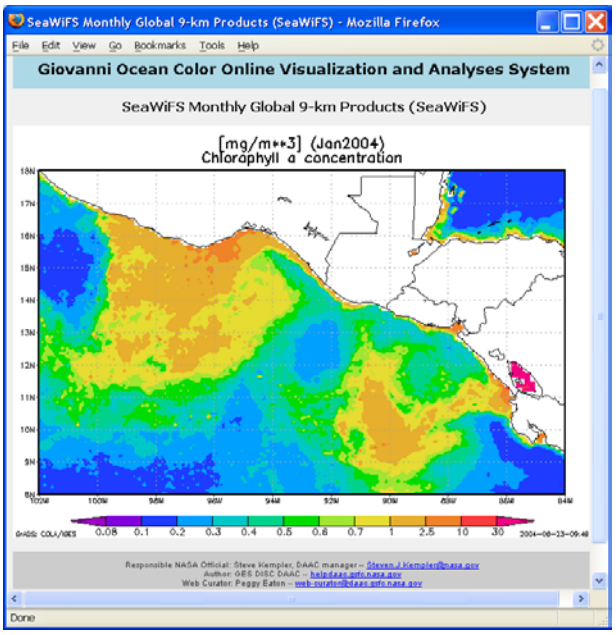

Figure 5. Area plot for the monthly 9-km SeaWFS chlorophyll product. It shows increased productivity corresponding to the Tehuano (south of Mexico) and Papagayo (west of Nicaragua) wind jets in Central America region.

4. FUTURE DIRECTIONS

In the near-term, Giovanni will add support for doing correlations among parameters. An important future direction for Giovanni to take is full support of Geographic Information System (GIS) and output formats suitable for GIS, for example GeoTIFF. Giovanni also needs to better support multi-instrument analyses with smart handling of multiply defined grids. Other directions include the ability to represent errors due to missing data and data quality in meaningful ways.

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Special Issue on the Tropical Rainfall Measuring Mission (TRMM), combined publication of the December 2000 Journal of Climate and Part 1 of the December 2000 *Journal of Applied Meteorology*, American Meteorological Society, Boston, MA.

Willmott, C. J. and K. Matsuura, 1995: Smart Interpolation of Annually Averaged Air Temperature in the United States. *Journal of Applied Meteorology*, 34, 2577-2586.

INFORMATION:

TRMM Online Visualization and Analysis System (TOVAS):
http://lake.nascom.nasa.gov/tovas

MODIS Online Visualization and Analysis System (MOVAS):
http://lake.nascom.nasa.gov/movas

Ocean Color Online Visualization and Analysis System (OOVAS):
http://reason.gsfc.nasa.gov/Giovanni/

Online analysis tools for TRMM rainfall products, NDVI, TOMS aerosols and Willmott climate data:
http://esip.gmu.edu/esip/ES_gridded_online_analysis_gmu.html

Data in higher temporal and spatial resolutions:
http://eosdata.gsfc.nasa.gov/data/

All TRMM standard data can be searched and ordered via:
http://lake.nascom.nasa.gov/data/dataset/TRMM

For further details about TRMM, visit:
http://trmm.gsfc.nasa.gov

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