NASA GES DISC On-line Visualization and Analysis System for Gridded Remote Sensing Data

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Abstract – The NASA Goddard Earth Sciences Data and Information Services Center (GES DISC) has developed an infrastructure with a Web interface that allows users to perform interactive analysis online without learning different formats and downloading any data, the GES-DISC Interactive Online Visualization and Analysis Infrastructure or "Giovanni." We describe several operational Giovanni instances to serve TRMM users, Aerosol scientists, Ocean Color and Agriculture applications users. We also illustrate usability of Giovanni by providing several examples of analysis of atmosphere over Saint Petersburg area.

Keywords: remote sensing, visualization, statistical analysis, interoperability, multi-sensor, data tools, value-added services

1. INTRODUCTION

The ability to use data stored in the current NASA Earth Observing System (EOS) archives for studying regional or global phenomena is highly dependent on having a detailed understanding of the data's internal structure and physical implementation. Gaining this understanding and applying it to data reduction is a time-consuming task that must be undertaken before the core investigation can begin. This is an especially difficult challenge when science objectives require users to deal with large multi-sensor data sets that are usually of different formats, structures, and resolutions. The NASA Goddard Earth Sciences Data and Information Services Center (GES DISC) has taken a major step towards meeting this challenge by developing an infrastructure with a Web interface that allows users to perform interactive analysis online without downloading any data, the GES-DISC Interactive Online Visualization and Analysis Infrastructure or "Giovanni." Giovanni provides interactive, online, analysis tools for data users to facilitate their research. There have been several instances of this interface created to serve TRMM users, Aerosol scientists, Ocean Color, and Atmospheric Composition data users.

2. GIOVANNI GOALS

Answering to Earth Observing System (EOS) data accessibility issues (voluminous data products – 1.75 PetaByte of data just in the GES DISC archive, large data granules – up to 1 GB, limited throughput of tape-based archive, complicated data formats), the GES DISC has developed the GES-DISC Interactive Online Visualization and Analysis Infrastructure (Giovanni), the underlying infrastructure for a family of Web interfaces for online data analysis. It is very useful to and popular by modelers, global and regional trends researchers, teachers, students, etc.
Giovanni makes gridded data available in a format that anyone can learn to use within minutes and put to work productively for research or applications.

With Giovanni and a few mouse clicks, one can easily obtain various remote sensing and model information from around the world. Users can explore and analyze gridded data interactively online without having to download any data. There is no need anymore to learn different complicated data formats, to retrieve and process data. Everything is done via a regular Web browser and intuitive user-friendly interfaces customized for various disciplines.

Goals of Giovanni:

- Study various phenomena interactively:
- Ask what-if questions and get back answers to stimulate further investigations;
- Try various combinations of parameters measured by different instruments;
- Arrive at a conclusion;
- Generate graphs suitable for a publication. Caution: Giovanni is an exploration tool, so users should be aware of data preparation issues and all the caveats of statistical analysis.

3. GIOVANNI USER INTERFACE

From the user's perspective, Giovanni is a simple Web application. The main Web page contains a title, a brief description of the site, and a descriptive list of one or more Giovanni deployments available. The elements on this initial Web page are defined in the Giovanni global configuration file. A user can select either the Java or non-Java version.
The resulting Web page is one that allows the user to select the spatial area via the Java image map applet or, if the non-Java version was selected, manually by entering in coordinates defining a bounding box. The user also selects the temporal range of the data, one or more parameters from this data set, and the output type (ASCII or one of several plot types). For plots, several color options are also available.
Once the Giovanni Web page options are selected, the user has the option of generating a plot or outputting the results to an ASCII file that can be downloaded. ASCII output is useful for GIS or other user applications. If plotting is selected, another Web browser window is opened within which the plot is displayed. Links to the data are provided so the user can download the entire data set. Depending upon the parameters selected, the vast majority of users will see the results in a matter of seconds. For users who choose large amounts of data either spatially or temporally, the results may take several minutes.

4. GIOVANNI FEATURES

The first generation of the GES DISC online tools supports gridded data only. The user selects geophysical parameters, area of interest, time period; and the system generates an output on screen in a matter of seconds. The currently available output options are:

- Area plot averaged or accumulated over any available data period for any rectangular area;

- Time plot time series averaged over any rectangular area; Hovmoller plots image view of any longitude-time and latitude-time cross sections;
- ASCII output for all plot types;
- Image animation for area plot.

Another analysis suite deals with parameter intercomparison: scatter plots, temporal correlation maps, etc. This allow user to focus on data content (i.e. science parameters) and eliminate the need for expensive learning, development and processing tasks that are redundantly incurred by an archive's user community.

5. GIOVANNI ARCHITECTURE

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

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 HDF-EOS. 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.

Giovanni is easily configurable to support customized portals for measurements-based projects or disciplines.

Going beyond basics, Giovanni provides parameter intercomparison:

- Area plot of time averaged parameters - geographical intercomparison between two parameters.
- Time plot of area averaged parameters - an X-Y time series plot for several parameters.
- Scatter plot of parameters in selected area and time period - relationship between two parameters geographically.
- Scatter plot of area averaged parameters - regional (i.e., spatially averaged) relationship between two parameters.
- Temporal correlation map - relationship between two parameters at each grid point in the selected spatial area.
- Temporal correlation of area averaged parameters - a single value of the correlation coefficient of a pair of selected parameters.
- A single file ASCII output with all selected parameters in a format suitable for importing spreadsheets and other programs for off-line analysis.

6. GIOVANNI INSTANCES

At the GES DISC, several instances of Giovanni are currently supporting our data users:
http://disc.gsfc.nasa.gov/techlab/giovanni/index.shtml

6.1 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 rectangular area within the data domain, which allows researchers to conduct nearly unlimited investigations.

MOVAS is a Giovanni instance with the most advanced features - designed for performing intercomparison analyses between parameters extracted from data from MODIS instruments onboard Terra and Aqua satellites, and those from the Goddard Chemistry Aerosol Radiation and Transport (GOCART) model. Current instance works with Monthly Global Products. Users can generate plots or ASCII Output for displaying the calculation results.

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

6.2 TOVAS

TOVAS is the TRMM Online Visualization and Analysis System (TOVAS), based primarily on data from the Tropical Rainfall Measuring Mission (TRMM). TOVAS has been operational since March 2001 providing Giovanni analysis tools to users of (1) three hourly TRMM and Other Satellite Rainfall (3B42RT) for Jan 2002-present; (2) TRMM Level-3 Daily Rainfall (3B42) for Jan 1998-present; (3) TRMM Level-3 Monthly Rainfall (3B43) for Jan 1998-present; (4) Willmott and Matsuura Global Precipitation for Jan 1950-Dec 1999; and (5) Global Precipitation Climatology Center (GPCC) Monthly Global Precipitation for Jan 1986-present.

Like MOVAS, TOVAS is another 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.

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.
- Range prediction of American butterflies.
- Intercomparison with other products in North America.
- Monitoring rain events in the Balkans.
- Investigation of the 1997-1998 El Niño/La Niña event.
- Investigation of insect activities in the US.

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

6.3 Ocean-color

The Ocean Color Online Giovanni provides users access to SeaWiFS and MODIS Aqua global monthly chlorophyll data from

the start of missions. It has been developed to support the Ocean-Color Time-Series funded by the NASA. 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 to long time-series information without downloading data. It has already helped to find interesting phenomena in Northern Red Sea by doing all the analysis on-line (Acker, 2005)

http://reason.gsfc.nasa.gov/Giovanni

6.4 Atmospheric Composition

This is the most recent instance that has started with TOMS. This interface is designed for visualization and analysis of the Earth Probe and Nimbus-7 TOMS Daily Global 1.0°x1.25° Products. The Nimbus-7 TOMS data set covers the data period from November 1, 1978 to May 6, 1993. The EP-TOMS data set covers the data period from July 25, 1996 to the Present. This is the only Giovanni utilizing daily data, and also providing polar and Robinson projection for the output options.

In late spring – early summer of 2005, data from HALOE and AIRS, and later, from Aura instruments (OMI and MLS) will be added to this instance.

http://reason.gsfc.nasa.gov/Giovanni_toms

7. EXAMPLES OF GIOVANNI USAGE OVER SAINT-PETERSBURG

To demonstrate usability of Giovanni in analyzing environment over Saint-Petersburg, the place of the current symposium, we provide several snapshots from various Giovanni instances.

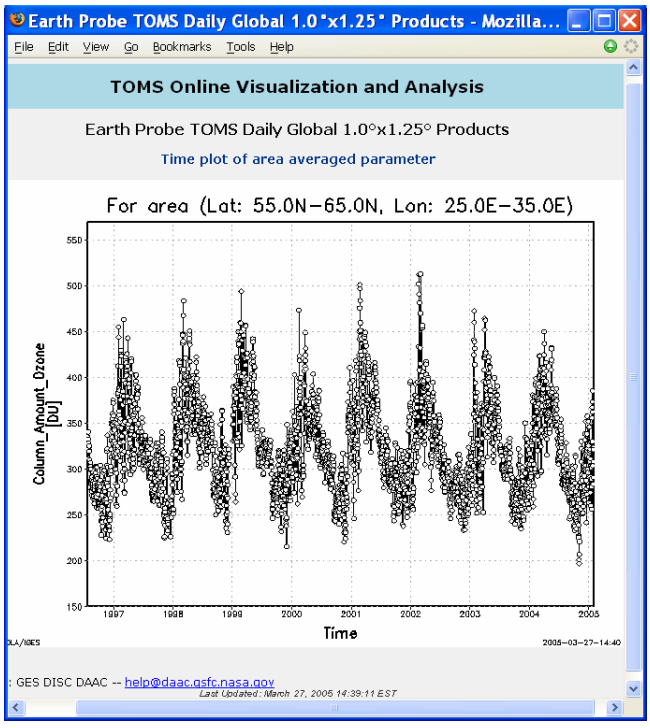

Figure 1. Ozone total column time-series over Saint-Petersburg measured by EP-TOMS.

As it can be seen from Fig 1, the highest concentrations of ozone are measured in early spring every year.

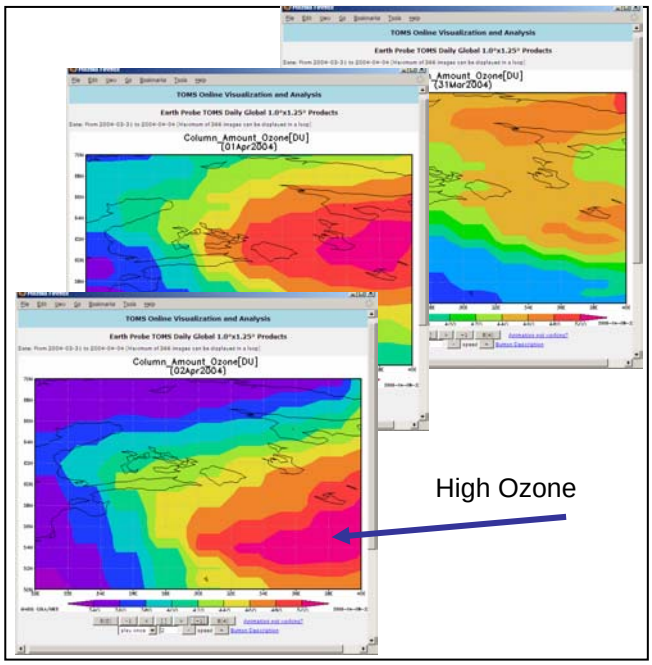

Figure 2. Ozone area maps for 31 March (upper right image) to 2 April, 2004

From Fig 2, one can see the highest ozone concentration over Saint-Petersburg (and even higher over Ladoga) on 1 April.

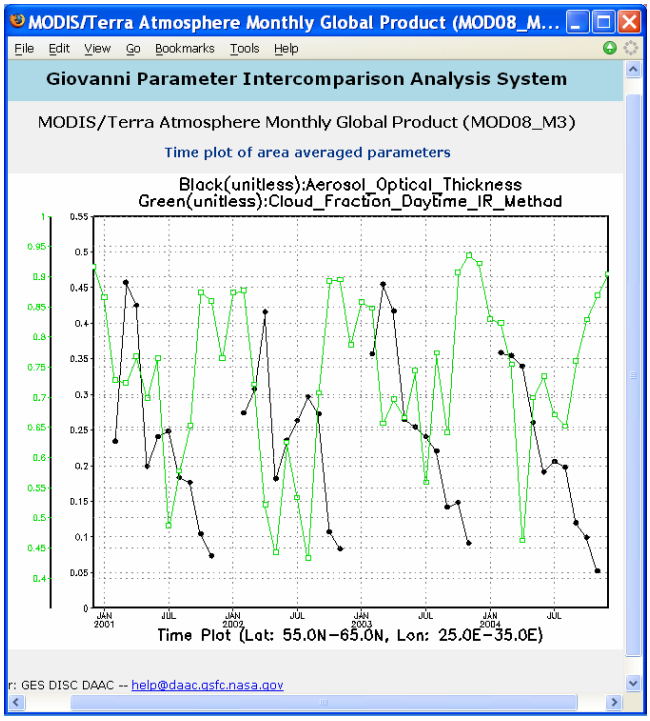

Figure 3. Time-series of Aerosol Optical Thickness and Cloud Fraction over Saint-Petersburg measured by MODIS Terra.

Figure 3 shows increased level of aerosols in early spring, and significant cloudiness in winter. The latter even prevented MODIS from measuring aerosols in mid winter for 2002 – 2004.

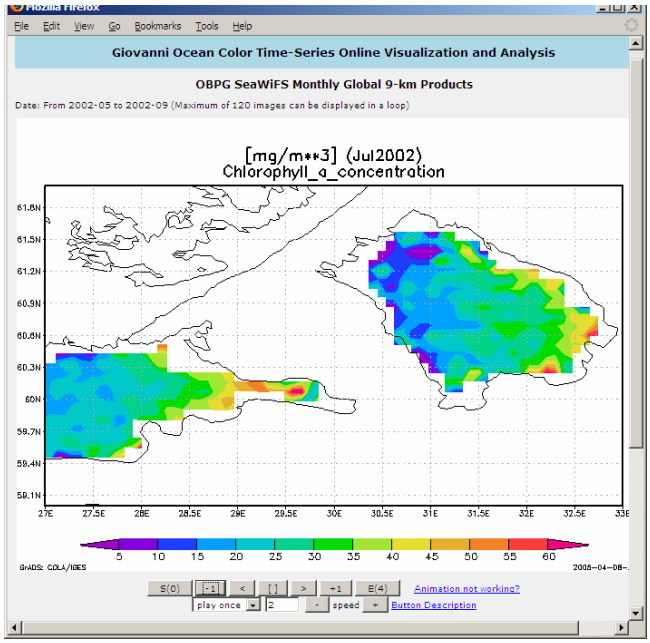

Figure 4. Chl a in Baltic Sea and Lake Ladoga for July 2002 measured by SeaWiFS.

8. FUTURE PLANS

In the future, the following features will be added to Giovanni:

- Vertical profile presentation – 2D slices through 3D data
- Enhanced parameter intercomparison.
- Full support of output formats suitable for Geographic Information Systems (GIS), for example GeoTIFF.
- Lagged temporal correlations,
- Better support for multi- instrument analyses with smart handling of multiple grids.
- Errors representation due to missing data and data quality in meaningful ways.

Data from AIRS, OMI, MLS, along with various model data, will be added to existing Giovanni instances.

9. CONCLUSIONS

For the future projects, it is cost-effective to utilize the existing data management and processing infrastructure at the GES DISC that supports a wide spectrum of options, from simple data support to sophisticated online analysis tools

10. REFERENCES

10.1 References from Journals

J.G. Acker, L.W. Harding, **G. Leptoukh**, T. Zhu, S. Shen, "Remotely-sensed chl a at the Chesapeake Bay mouth is correlated with annual freshwater flow to Chesapeake Bay," Geophysical Research Letters, vol **32**, L05601, February 2005

10.2 Acknowledgements

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