Abstract Title

Exploring NASA and ESA atmospheric data using GIOVANNI, the online Visualization and Analysis Tool

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GIOVANNI (http://giovanni.gsfc.nasa.gov) is the NASA Goddard Earth Sciences Web-based exploration tool that provides rapid data visualizations and analyses of multi-sensor Earth science data. We describe our first attempt to add ESA ENVISAT data to the currently supported NASA Terra, Aqua and Aura Data Exploration, Visualization and Analysis. We also describe recent additions to GIOVANNI functionalities, e.g., the aerosol instance of Giovanni (MOVAS), intercomparison options in MODIS (Terra and Aqua) and AIRS (Aqua) instances.

EXPLORING NASA AND ESA ATMOSPHERIC DATA USING GIOVANNI, THE ONLINE VISUALIZATION AND ANALYSIS TOOL

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ABSTRACT

Giovanni, the NASA Goddard online visualization and analysis tool (http://giovanni.gsfc.nasa.gov) allows users explore various atmospheric phenomena without learning remote sensing data formats and downloading voluminous data. Using NASA MODIS (Terra and Aqua) and ESA MERIS (ENVISAT) aerosol data as an example, we demonstrate Giovanni usage for online multi-sensor remote sensing data comparison and analysis.

1. GIOVANNI

Giovanni [1], the Goddard Interactive Online Visualization ANd aNalysis Infrastructure, http://giovanni.gsfc.nasa.gov offers a user friendly web-based environment to explore interactively various remote sensing atmospheric data. With a few mouse clicks, the user can easily obtain remote sensing or model information from around the globe, without the overhead of first having to download the data and understand complicated data formats before initiating the intended analysis. Access is provided through a common Web browser, so the user does not need special applications beyond what is available on a typical personal computer.

From a web page the user is able to select the spatial area "box" for the desired region via a Java image map applet or manually enter the coordinates defining the bounding box. The user also selects the temporal range for the data, one or more parameters from this data set, and the desired output type (ASCII or one of several plot types). For the plot selections, several color options are also available. The user is then able to refine this analysis and download the results. ASCII output is useful for GIS or other user applications, and the plots generated can be extracted into the user's final report or paper. For more detailed analysis, links to the data are available so the user can download the entire data set for further local analysis. Depending on the choice of parameters, the majority of users will see the online results in a matter of seconds while online manipulation of larger amounts of data (either spatially or temporally) may take several minutes. Even in this more extreme case, the time from the inception of an analysis idea to actually seeing the results is drastically reduced and the most tedious aspects of the analysis are issues that the user bypasses in their entirety!

2. AEROSOL DATA IN GIOVANNI

Historically, the MODIS aerosol data online analysis was implemented in MOVAS, the pre-Giovanni version of the online visualization and analysis system. The MODIS Online Visualization and Analysis System (MOVAS), operational instance available through Giovanni since September 2003, allows scientists, applications researchers, educators, and students to easily access, visualize and analyze MODIS Level-3 atmospheric daily and monthly products helping them for example to understand seasonal-to-inter-annual variation of atmospheric parameters ranging from aerosol to clouds. MOVAS can provide information at every single point and in any rectangular area within the data domain.

MOVAS as a Giovanni instance includes advanced features with capabilities for performing intercomparison analyses between parameters extracted from MODIS sensors onboard two different satellites Terra and Aqua, as well as those from the Goddard Chemistry Aerosol Radiation and Transport (GOCART) model. It now contains daily and monthly Level 3 1° x 1° aerosol data from Terra and Aqua MODIS [2] (Collections 4 and 5), monthly Terra MISR data (a combination of the latest available collections), along with the GOCART model data [3].

Recently, an effort has started to incorporate fusion of aerosol data measured by different sensors into Giovanni [4]. The initial implementation involves Terra and Aqua MODIS Aerosol Optical Thickness (AOT) daily data. The next dataset to be added is MISR AOT.

3. ENVISAT MERIS AEROSOLS IN GIOVANNI

As proof of concept, the publicly available MERIS Aerosol Optical Thickness at 550 nm monthly Level 3 products (http://envisat.esa.int/level3/meris/) were integrated into Giovanni for intercomparison with MODIS data.

Caveats: These MERIS Level 3 products are the so-called demonstration products, and they are not considered fully operational. The land aerosol is retrieved at 443 nm, the ocean aerosol is retrieved at 865 nm. The AOT at 550 nm is a merged product and it is still to be validated. We clearly understand that, in addition to calibration, retrieval algorithm, and aerosol model differences, some of the differences can be attributed to different statistical methods of spatial and temporal aggregation in deriving the standard products, and also to sampling biases between sensors. Also, it is important to mention that MERIS was designed to measure ocean properties, so MERIS atmospheric products (being basically marine products) are biased toward clear skies, i.e., high optical thickness pixels are most likely rejected (authors thank Omar Torres of University of Maryland/NASA GSFC for pointing to this fact).

These MERIS data were downloaded, reprojected to a lat-lon projection and regridded to 1 x 1 deg, to comply with other existing in Giovanni AOT products from Terra and Aqua MODIS and Terra MISR. These preprocessed data were then integrated into a special Giovanni instance based on the new version 3 of Giovanni architecture (more details in Section 6).

In the present paper we used the above MERIS data to demonstrate how Giovanni can help easily explore MERIS data and compare with other sensor data. The results in this paper should be treated with caution as a more careful usage of quality information is needed to produce the scientifically accurate results. Note that this important preliminary exploration and assessment of differences between various sensor measurements can be easily done within Giovanni without downloading any data - these graphs were generated within seconds.

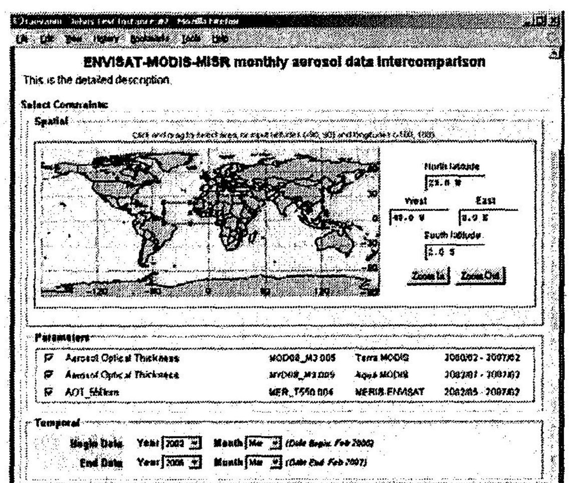

Figure 1. Main page of the ENVISAT Giovanni prototype instance

In Fig. 1 we show how the main page of the prototype Giovanni instance does look. Users can select one or more aerosol parameters from MERIS, Terra MODIS or Aqua MODIS, then select an area of interest, and the time period of interest. Currently available services include lat-lon maps (averaged over time), time-series, and scatter plots with linear fit.

The preliminary zonal time-series are shown on Fig. 2. It is interesting to see that the global MERIS AOT is consistently higher than MODIS data.

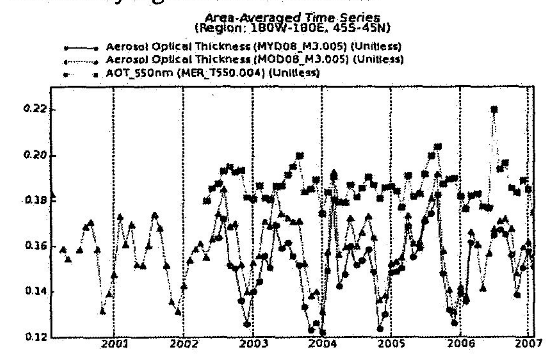

Figure 4. Maps of Terra and Aqua MODIS (Col. 5), and MERIS AOT for March 2004(550nm) (within ±45° latitude)

4. CASE STUDY: HIGH AEROSOL EVENTS WEST OF AFRICA, MARCH 2004

We computed time-series of AOT for the area to the west of Sahara and Sahel. Usually, in early spring there are dust storms in that area that can be easily seen in Fig. 3. MERIS does not report high AOT values while being quite consistent with MODIS sensors at other times over the same area.

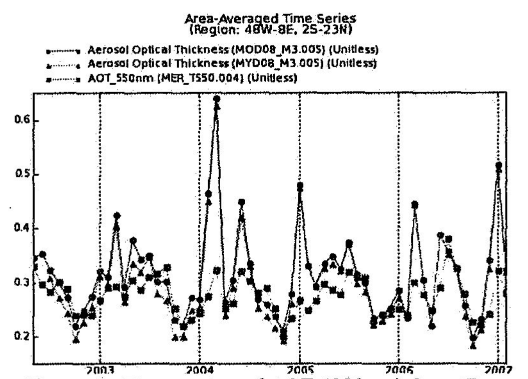

Figure 3. Time-series of AOT (550nm) from Terra and Aqua MODIS, and MERIS

A typical Giovanni scenario is, after identifying interesting events in time-series, to check the corresponding maps. In Fig. 4, we present three AOT lat-lon maps, from Terra MODIS, Aqua MODIS, and

MERIS for March 2004. Areas of high AOT values can be seen in MODIS maps, while MERIS seems to underestimate AOT. This might be attributed to the already mentioned MERIS bias towards ocean measurements. Currently, only monthly data MERIS data have been incorporated into Giovanni. In order to study temporal development of high AOT events, daily or 8-day data are more appropriate.

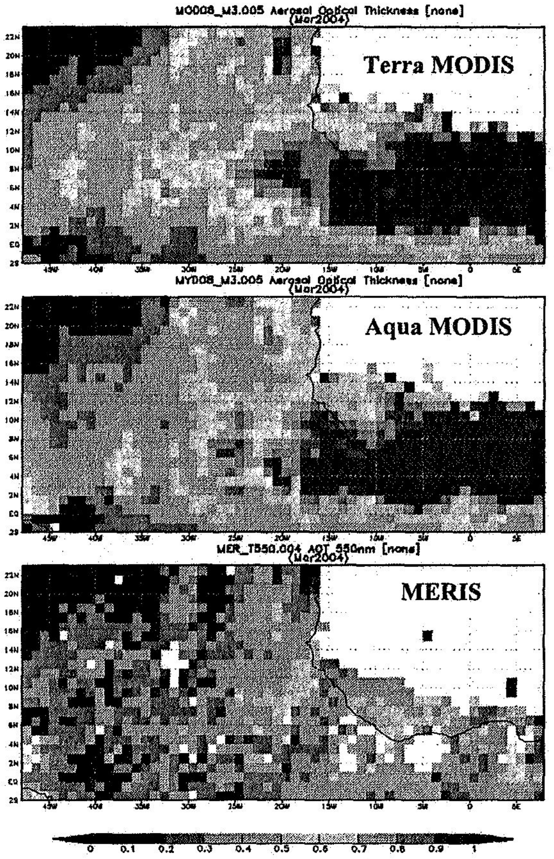

Figure 4. Maps of Terra and Aqua MODIS (Col 5), and MERIS AOT for March 2004.

Giovanni also allows doing quick regression analysis. As can be seen from Fig. 5, for the March 2004 high aerosol event west of Sahara and Sahel, the scatter plot linear fit gives a slope of 0.24 for MERIS vs. Aqua MODIS (Col. 5) AOT. A similar regression for the area but for November 2004 low aerosol loading period gives a slope close to 0.93. This is another indication of some kind of effective threshold on optical thickness imposed by MERIS algorithms.

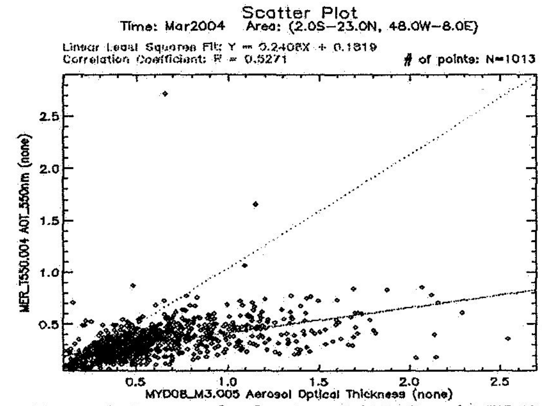

Figure 5. Scatter plot for Aqua MODIS and MERIS AOT for March 2004 high aerosol event west of Africa

Another way to study the spatio-temporal spread and development of large events is to use Hovmöller diagrams. Figs. 6 and 7 with Hovmöller time-longitude and time-latitude plots clearly demonstrate how Giovanni can help to identify location and spread of the major dust events using (Terra) MODIS data. The MERIS data show similar structure on the time-latitude plot, but seem to miss it in the time-longitude plot.

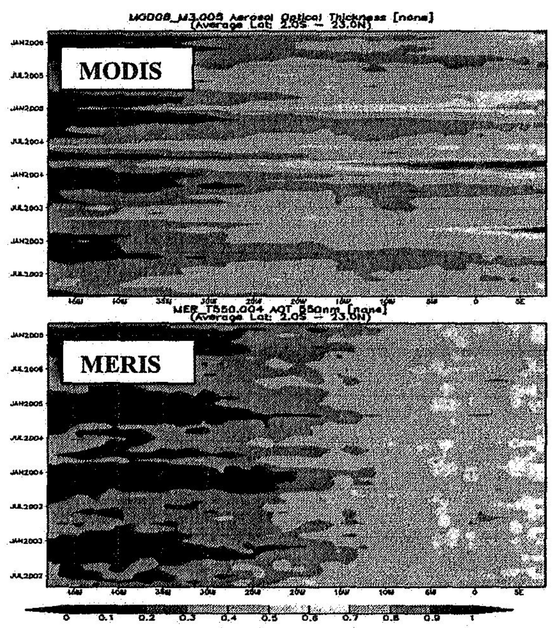

Figure 6. Terra MODIS and MERIS time-longitude Hovmöller plots for the same area

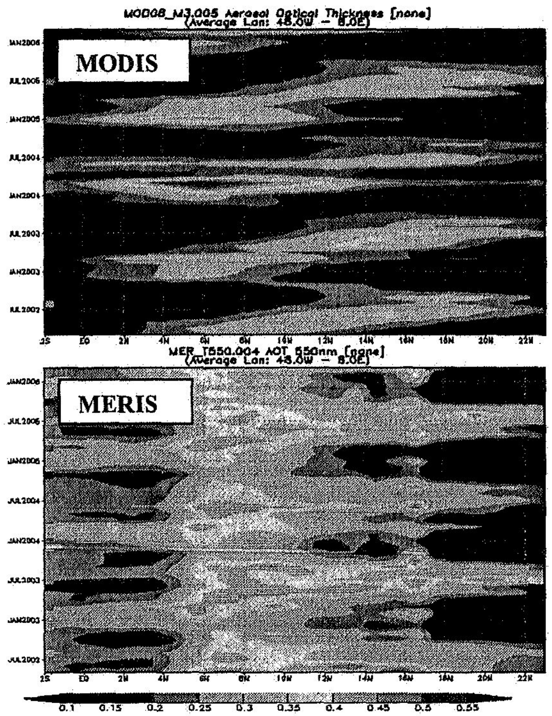

Figure 7. Terra MODIS and MERIS time-latitude Hovmöller plots for the same area

5. OTHER GIOVANNI INSTANCES

There are various Giovanni instances dedicated to atmospheric studies. They feature:

- TRMM rainfall products, near-real-time 3-hourly, Multi-Satellite Precipitation Analysis, and rainfall ground observation data
- Aura MLS daily near-global profile data
- Aura OMI Level 2G derived and TOMS-like daily global data
- TOMS daily global data from Earth Probe and Nimbus-7
- Agriculture-oriented TRMM and other derived precipitation data
- Aqua AIRS daily and monthly global maps and profile data
- UARS HALOE atmospheric profiles
- A-Train Data Depot data from CloudSat, collocated Aqua MODIS profiles, MLS, AIRS profiles, and, in the near future, CALIPSO.

6. NEW GIOVANNI ACHITECTURE

In 2007, all the old Giovanni instances and all new instances will implemented in the next generation Giovanni 3 architecture. It is still in active development, but already it has major enhancements over the current Giovanni 2. These are shown below.

No More Session Time-Outs: Giovanni 3 architecture is inherently asynchronous as opposed to Giovanni 2 which is synchronous. This means that processing can extend beyond a single HTTP session. This means that Giovanni 3 can allow users to do analysis and visualizations over much longer time periods and with higher resolution data than they could before. For normal Giovanni activities, the response is still quick. But if a request does require more time, users will be provided with a RSS feed to monitor the request status.

Saved User Preferences: In addition to providing users with new preferences, Giovanni 3 allows users to save these preferences to their local machine so that they can be reused the next time.

New, Cleaner Interface: Giovanni 3 instances sport new and cleaner interfaces that nonetheless retain the simplicity and intuitiveness of the older Giovanni 2 interfaces.

New Visualizations: Giovanni 3 plans to support all the visualizations of Giovanni 2, but in addition, Giovanni 3 can support more sophisticated visualizations such as the along track vertical "curtain" plots available in the A-Train Giovanni.

More Level 2 Data: Giovanni 3 has better support for handling Level 2 (non-gridded) data. Expect to see more Level 2 data as we add more data to Giovanni.

Data Lineage: An important aspect of any online data analysis and visualization tool is data lineage. Through Giovanni's data lineage feature, one can drill down into the data transformations performed, to know exactly how a plot was made. Each transformation and visualization is accompanied by detailed information on the algorithm used as well as on any limitations or caveats.

Product Download: Giovanni 3 allows downloading intermediate files via the download feature. An intermediate data file in HDF4 format is produced after each transformation and is available for download. Thus, for a time series plot, one can download the data just after it was fetched from the source or after they were area-averaged or after any regridding or just before the data were prepare for rendering a plot. If not HDF4, users can download the data in ASCII instead. Other formats will be available later as well.

Web Services Based: Giovanni 3 is based on a services-oriented architecture (SOA). This means that Giovanni services (such as regridding, averaging, image rendering) can be offered as a standard SOAP Web Services. We will be providing this feature in the near future.

Performance: Giovanni 3 architecture takes advantage of caching by saving intermediate results. For example, if a user wants to make some changes to a resulting plot (e.g. changing the color palette), Giovanni doesn't start all over again. It uses the data it fetched before and merely modifies the image rendering. For big requests (such as time series over a five years of daily data), Giovanni 3 is very fast.

While Giovanni 3 evolves, we continue to maintain our current Giovanni 2 instances.

7. CONCLUSION

The preliminary results of including ENVISAT MERIS data into NASA Giovanni system are very encouraging from the perspective of creating an online environment for multi-sensor aerosol data intercomparison. Adding other ESA products in a more consistent automatic manner will allow researchers from different countries fully utilize vast treasures of NASA and ESA remote sensing data.

8. ACKNOWLEDGMENTS

Giovanni success would be impossible without great efforts by the Giovanni team, scientists and engineers, at the NASA GES DISC (Goddard Earth Sciences Data and Information Services Center). The work has been supported in part by various NASA NRAs and the NASA GES DISC. Level 3 MERIS data are provided by the European Space Agency.

9. REFERENCES

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