Giovanni: A System for Rapid Access, Visualization and Analysis of Earth Science Data Online

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Summary:

Collecting data and understanding data structures are traditionally the first steps that a user must take, before the core investigation can begin. This is a time-consuming and challenging task, especially when science objectives require users to deal with large multi-sensor data that are usually in different formats and internal structures. The Goddard Earth Sciences Data and Information Services Center (GES DISC) has created the GES DISC Interactive Online Visualization and ANalysis Infrastructure, "Giovanni," to enable Web-based visualization and analysis of satellite remotely sensed meteorological, oceanographic, and hydrologic data sets, without users having to download data. The current operational Giovanni system contains eight different interfaces that provide the capability to process a number of important satellite measurements. Depending on the input data structure, the system provides different simple statistical analysis and creates many useful plot type images or ASCII output. Giovanni handles data with different temporal and spatial resolutions and, thus, enables both regional and global long-term climate research and short-term special events investigation, as well as data validations and assessments. Because of its simplicity of usage, Giovanni is powerful and versatile, able to assist a wide range of users, from the discipline scientists conducting preliminary research in various fields, to students in the classroom learning about weather, climate, and other natural phenomena.

Architecture of Giovanni:

From the user's perspective, Giovanni is a simple Web application. Giovanni consists of HTML templates, CGI scripts written in Perl and the back-end engine, Grid Analysis and Display System (GrADS) (Fig. 1). Data are stored on the server machine or on one or more remote machines accessing via GrADS Data Server (GDS). GrADS supports a variety of data formats such as binary, GRIB, netCDF, HDF, HDF-EOS, and station data format. When GrADS is combined with Open-source Project for a Network Data Access Protocol (OPeNDAP), 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.

Features of Giovanni:

The principal 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, visualize, analysis, and then generate quality images or ASCII data. The current features of Giovanni include:

- Access to data from multiple remote sites as well as local sites.
- Server-side temporal and spatial subsetting.
- Server-side data processing.
- No data downloading and preprocessing on client machine
- Support for multiple data formats including Hierarchical Data Format (HDF), HDF-EOS, network Common Data Form (netCDF), GRIdded Binary (GRIB), binary, and station data format.

- Support for multiple plot types including area, time, Hovmoller, and image animation (Table 1).
- Support for outputting data in ASCII format in multiple resolutions.
- Parameter inter-comparisons with functions, such as difference, scatter plot, and correlation coefficient (Table 2).
- Easily configurable to support customized portals for measurements-based projects or disciplines.
- Currently runs on Linux, SGI, and Sun platforms.

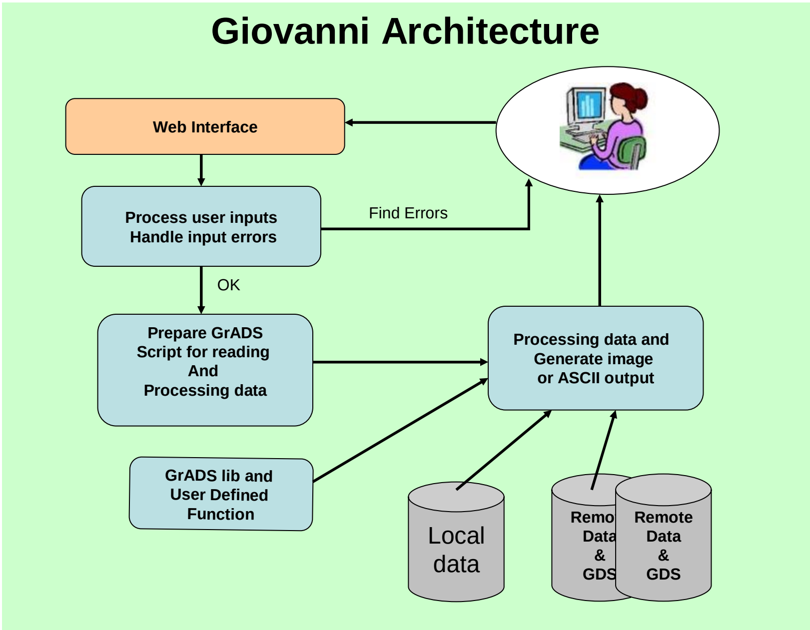


Fig.1 Giovanni Architecture Diagram

Table 1 Standard output types in current 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 or latitude-time plot
Animations	Animations available for area plots
Vertical Profile	Parameter variation with height or pressure (only for data with vertical structure)
Vertical Cross Section	Longitude-height or latitude height plot (only for data with vertical structure)
ASCII Output	ASCII output, available for all plot types, suitable for feeding GIS or other applications

Table 2 Inter-comparisons output type in current Giovanni

Output Type	Description
Area plot of time averaged parameters	Time-averaged color data plot for selected parameters and spatial area (over-plotted)
Area plot of time averaged difference	time-averaged difference for selected parameters and spatial area
Time plot of area averaged parameters	X-Y data plot, where X denotes time and Y the data averaged over the selected spatial area or at a single grid point for multiple parameters
Time Plot of area averaged difference	X-Y data plot, where X denotes time and Y the difference of selected parameters averaged over the selected spatial area or at a single grid point
Scatter plot of parameters in selected area and time period	Scatter plot of all values of the two parameters for a selected area and time range, with a linear least squares fitting line
Scatter plot of area averaged parameters	Scatter plot of parameter values either averaged over a selected spatial area or at a single grid point within a given time range, with a linear least squares fitting line
Temporal correlation map	Displays a geographical view of correlation coefficient of a pair of selected parameters
Temporal correlation of area averaged parameters	Displays a single value of the correlation coefficient of a pair of selected parameters

Current Giovanni Interfaces:

Giovanni interfaces (http://giovanni.gsfc.nasa.gov) were constructed based on scientific needs. Eight Giovanni interfaces are now operational for many different atmospheric and oceanic parameters from a number of satellite instruments:

1. TRMM Online Visualization and Analysis System (TOVAS)

TOVAS is an easy and quick tool to access, visualize, and analysis the TRMM gridded rainfall products and other precipitation data. It is applicable to variety of research and applications, such as climate study and monitoring, weather events study and monitoring, agricultural crop monitoring, rainfall algorithm study, and data products comparison. Currently, there are eight precipitation products available through the TOVAS, of which six are TRMM products and two are monthly precipitation products produced, respectively, by Cort J. Willmott and Kenji Matsuura from the Center for Climatic Research, Department of Geography at University of Delaware; and by the Global Precipitation Climatology Center.

2. Agricultural Online Visualization and Analysis System

This is an interface that allow users to visualize and analyze global TRMM 3-hourly , daily, 10-day, and monthly rainfall; near real-time (experimental quality) TRMM 3-hourly, daily, and 10-day rainfall; as well as monthly climatology and anomaly rainfall. The spatial resolution of monthly climatology and anomaly data is 1.0°x1.0° and all other data are 0.25°x0.25°. This interface is designed to support NASA's Agricultural Efficiency Program for improving agricultural competitiveness through a better understanding of weather and climate.

3. Ocean Color Time-Series Online Visualization and Analysis

The Ocean Giovanni interface is supported by the Ocean Color Time-Series project (NASA REASoN CAN, Dr. Watson Gregg, PI), which currently enables the basic statistical analysis and visualization of global monthly SeaWiFS and MODIS Aqua standard mapped image products processed by the Ocean Biology Processing Group (OBPG). The spatial resolution of the data is 9km at the equator. Functions for performing climatology and anomaly analysis of SeaWiFS data as well as inter-comparisons between SeaWiFS and MODIS Aqua are available. In the future, merged (multiple missions) data products will be added.

4. MODIS Online Visualization and Analysis System (MOVAS)

MOVAS is designed to support NASA aerosol and cloud fraction research studies (sponsored by Dr. Yoram Kaufman). The monthly global aerosol and cloud fraction data of resolution 1.0°x1.0° at the equator from MODIS-Terra, MODIS-Aqua, and GOCART model are currently available in MOVAS. The inter-comparisons of parameters between sensor to sensor or sensor to model are also available. MOVAS provides a function to download parameter and spatial subsets of daily Level 3 data on-the-fly.

5. AIRS Online Visualization and Analysis System:

The AIRS Giovanni is designed for visualization and analysis of the AIRS daily global 1.0°x1.0° products, such as temperature, water vapor, humidity, geopotential height and ozone. The data has vertical structures. The vertical profile of a parameter for a selected area can be compared with in-situ sounding data.

6. TOMS & OMI Online Visualization and Analysis System

This interface is designed for visualization and analysis of the daily global 1.0°x1.25° upper atmospheric chemistry products from TOMS (Earth Probe and Nimbus-7) and TOMS-like (Aura OMI), such as column amount ozone, and UV aerosol index.

7. Aura MLS Online Visualization and Analysis System

This interface is designed to display daily vertical profiles of atmospheric chemistry products from Aura MLS. The vertical resolution of these data is about 3 km, and the spatial coverage is near-global (-82 to +82 latitude), with each profile spaced 1.5° (about 165 km) along the orbit track. The measurements include Ozone, Water Vapor, Carbon Monoxide, Nitrous Oxide, Nitric Acid, etc.

8. UARS HALOE Online Visualization and Analysis System

This interface is designed to visualize daily vertical profiles of atmospheric chemistry products from UARS HALOE. Users can generate Pressure (or Altitude) vs Parameter plots or ASCII Output for UARS/HALOE Sunrise and Sunset events. The data include 12 measurements, such as Ozone, Nitrogen Dioxide, Nitric Oxide, Hydrogen Chloride, etc.

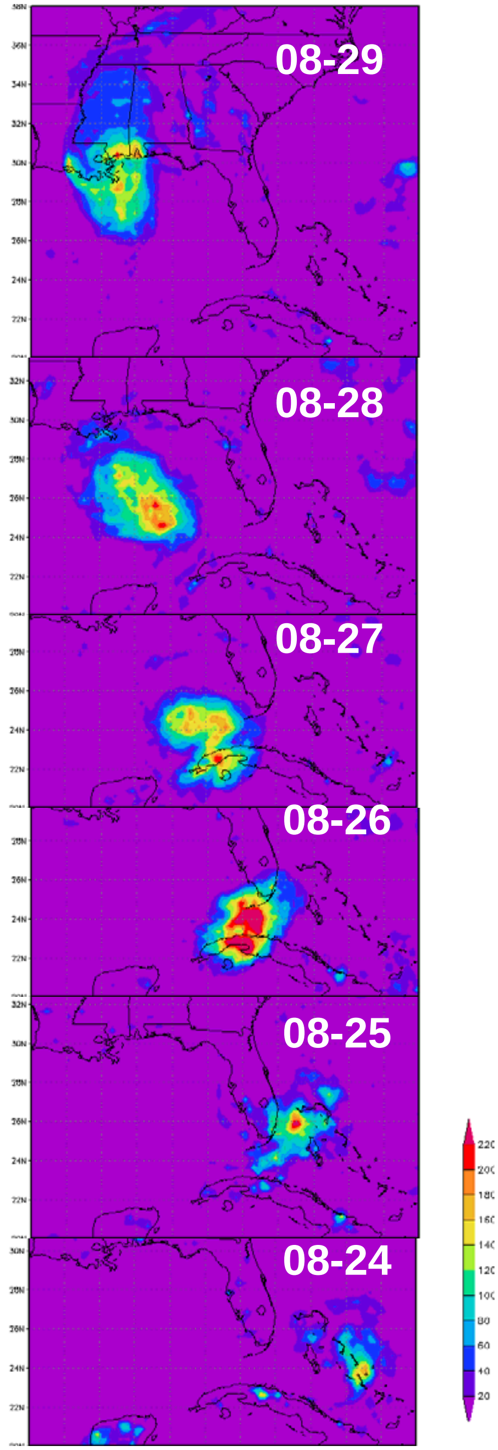


Fig. 2 TRMM observed daily precipitation of August 24-29, during Hurricane Katrina.

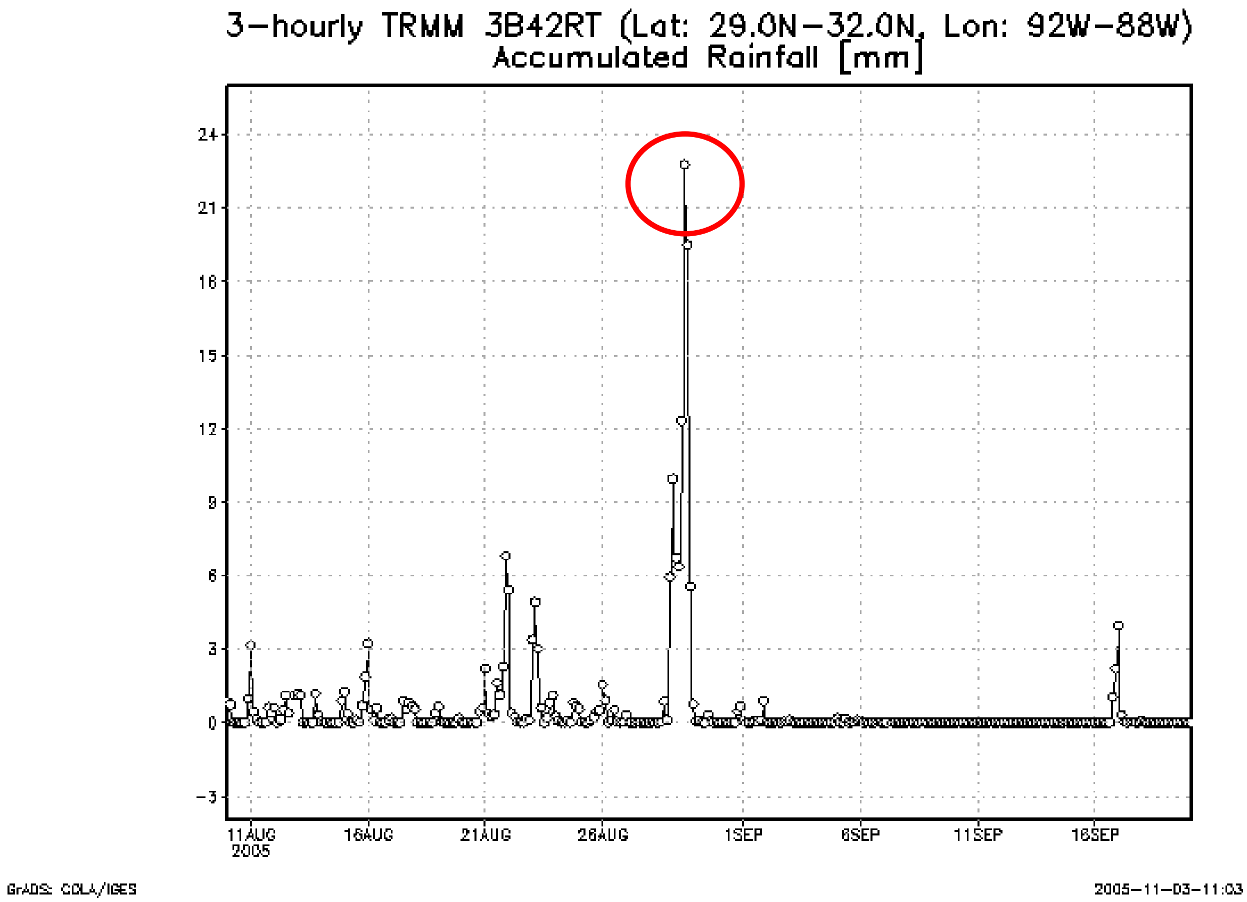


Fig.3 3-hourly cumulated precipitation of August 10 to September 20 over Gulf coastal area where Hurricane Katrina landed on August 29

Sample Uses of Giovanni:

1. Precipitations during Hurricane Katrina

It is easy to use Giovanni to create a series of images of an event of an interested area. Fig. 2 shows daily precipitation amount over Gulf and coast areas from August 24 to 30, 2005 observed by TRMM. The figures indicated the daily path of Hurricane Katrina, which landed at Gulf Coast areas of Louisiana, Mississippi and Alabama on August 29 and caused dramatic damage of this area and over a thousand people lost life. The 3-hourly cumulated precipitation was as high as 23mm over the landing area (Fig. 3) on August 29. These images were generated by using TRMM Online Visualization and Analysis System (TOVAS) and Agricultural Online Visualization and Analysis System.

2. Seasonal Variation of Chlorophyll at Luzon Strait

Recent observation studies (Nitani, 1972; Centurioni and Niiler, 2004) have indicated that the sea surface water flows into South China Sea through the Luzon Strait during northern autumn and winter seasons (October to January) when the winds are dominated by the northeast monsoon. This flow is described as a westward branch of the Kuroshio. We have created climatology monthly chlorophyll *a* concentration at Luzon Strait and South China Sea by using Ocean Giovanni (Fig. 4). It is clearly that the chlorophyll *a* concentration increases during autumn near Luzon coast area

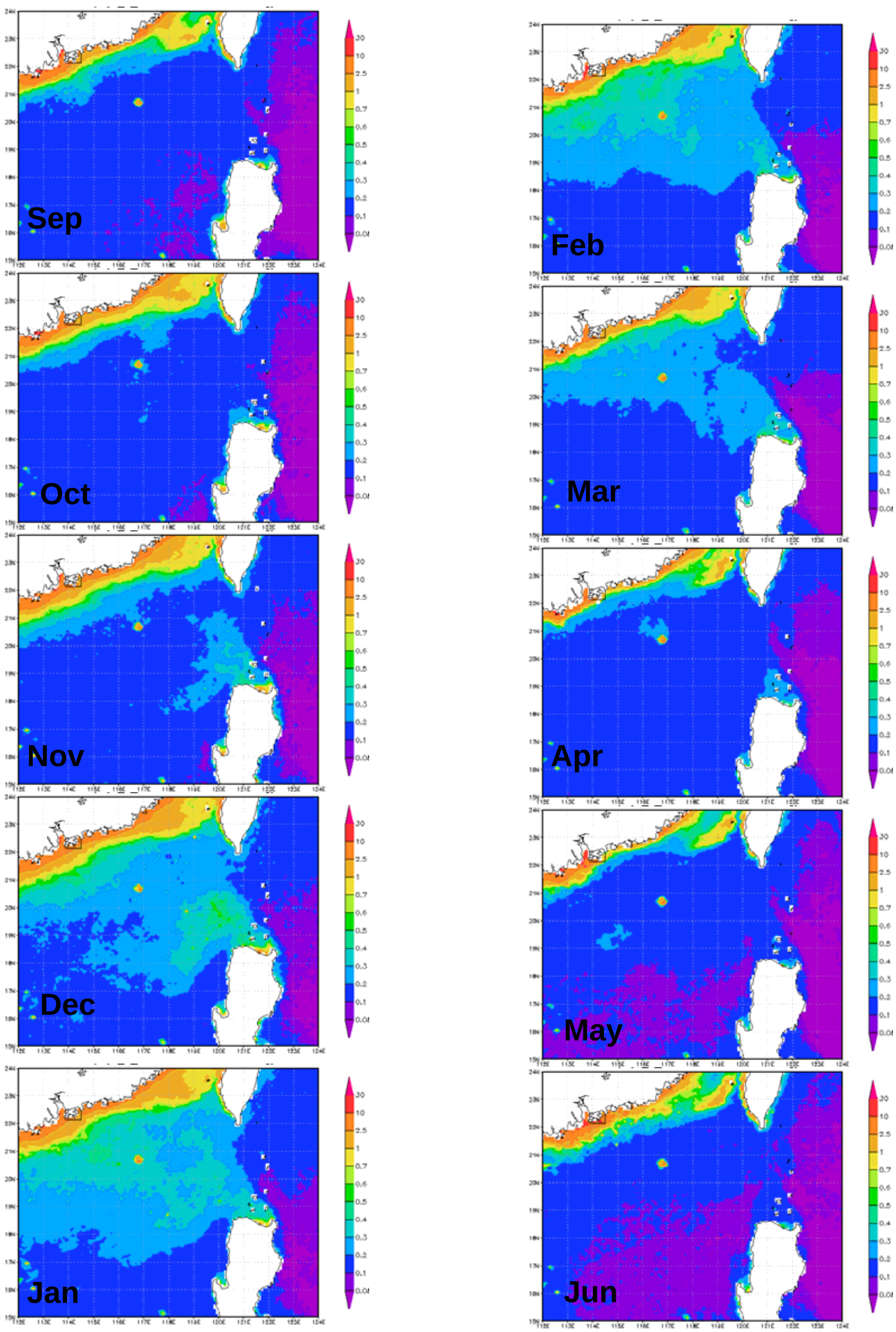


Fig. 4 SeaWiFS Monthly climatology Chlorophyll *a* concentration at Luzon Strait and South China Sea

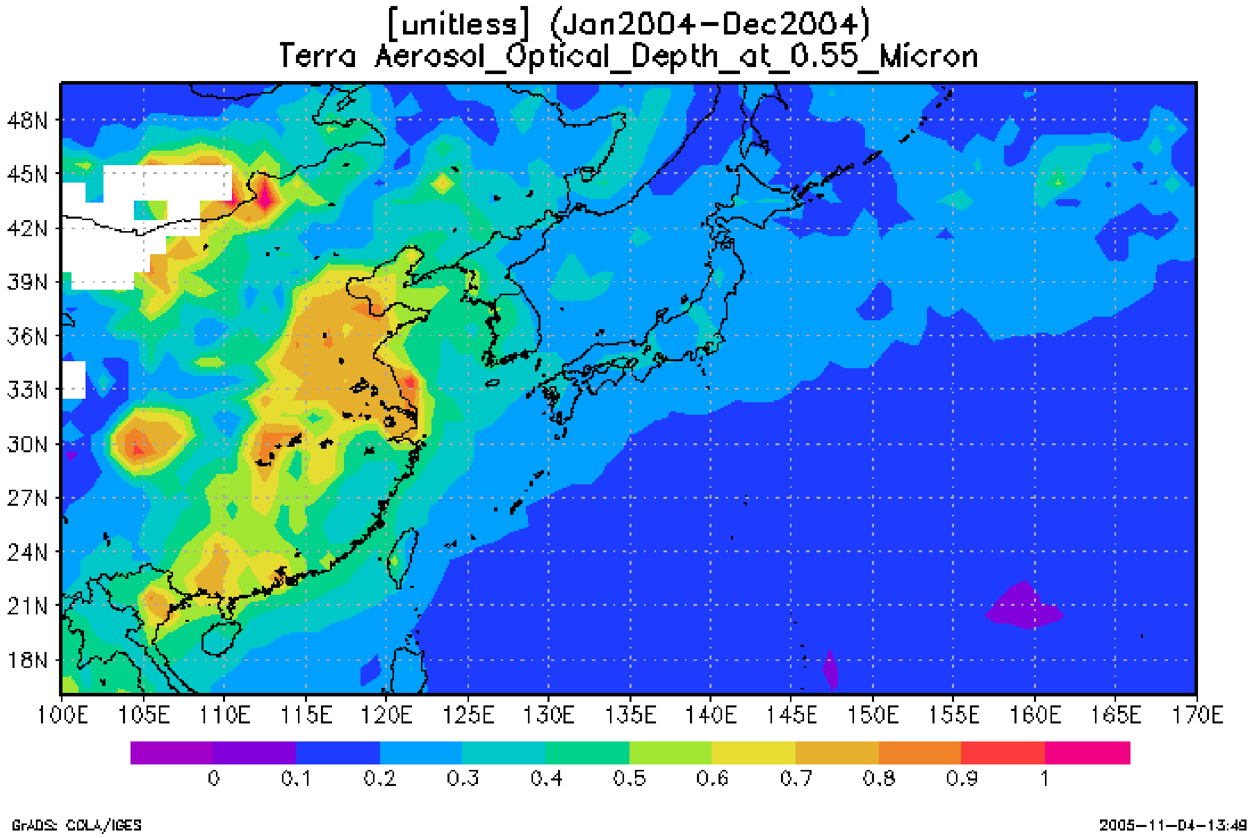
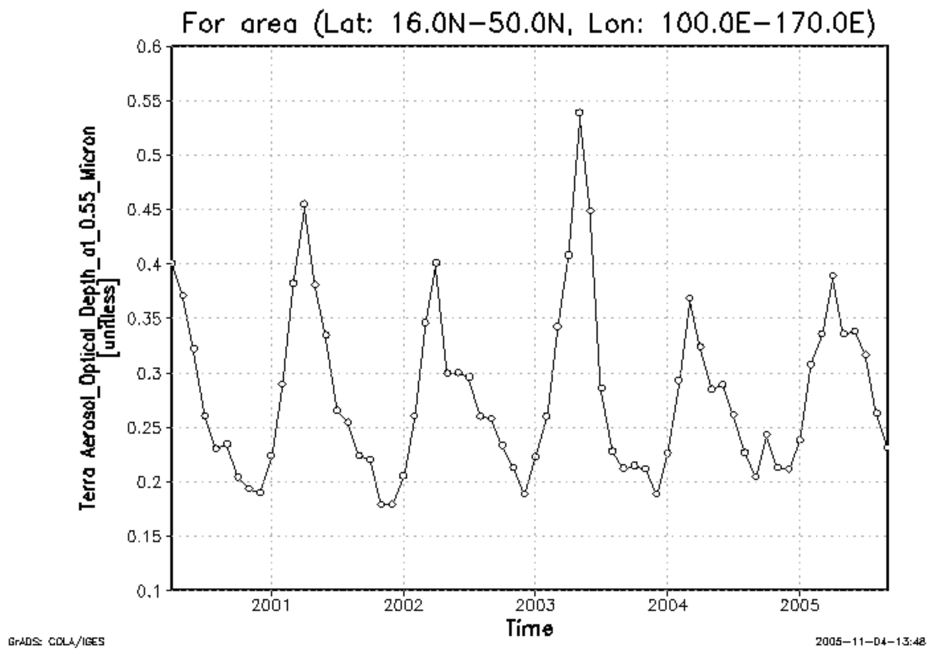


Fig. 5 Averaged aerosol optical depth at 0.55 micron of 2004 over east Asia and west Pacific from MODIS Terra



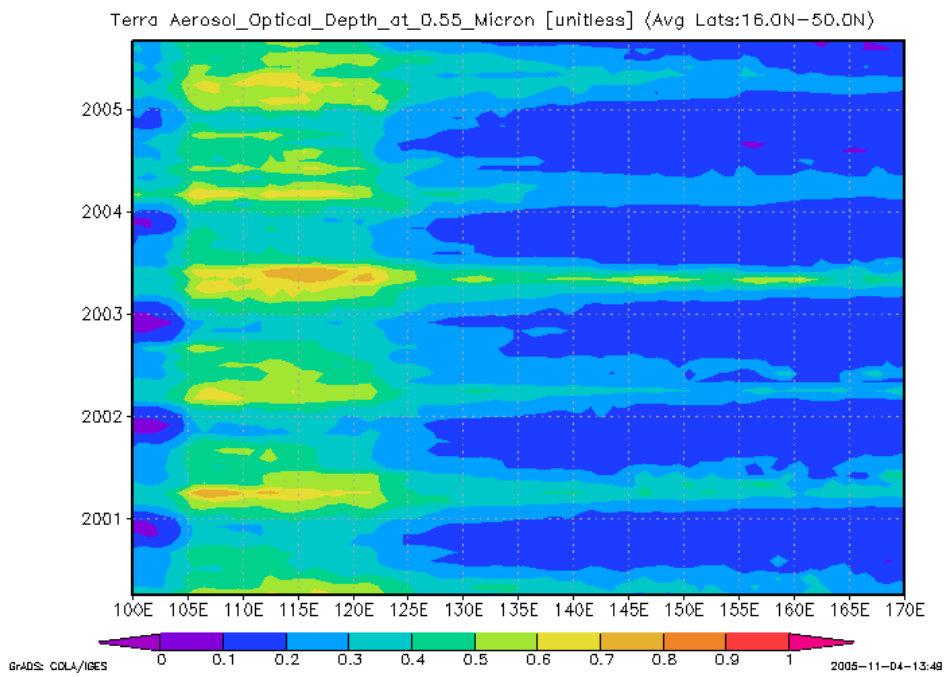


Fig. 6 Aerosol optical depth at 0.55 micron for April 2000 to September 2005 from MODIS Terra: area averaged time series (top panel) and time-longitude plot (lower panel)

and travels toward northeast South China Sea during winter and early spring. This seasonal variation of chlorophyll *a* concentration may be associated with seasonal monsoon variation and the water flow at Luzon Strait region. The upwelling of the water associated with wind changes brings nutrients to the surface that may help growing of phytoplankton.

3. Interannual Variation of Aerosols over East Asia and Western Pacific

The importance of aerosols and cloud forcing to climate change has been investigated by many scientists in last several decades (Chou, et al, 1984; Kaufman, et al 2002; Lau, 2005). East Asia and Western Pacific is a most interested region where the aerosol is heavy and the number of aerosol types is large. Optical thickness of aerosols and cloud fraction products are available from MODIS. MOVAS allows a user to browse the basic features of aerosols and cloud fraction easily from the Level 3 monthly MODIS Terra, MODIS Aqua, and GOCART model, as well as to make inter-comparisons between Terra, Aqua, and GOCART model. Fig. 5 shows the averaged MODIS Terra aerosol optical thickness at 0.55 micron for year 2004 at East China and Western Pacific. The aerosol is largest over northeast central China at 115^{o}E, 36^{o}N and gradually reduced eastward over Northern Pacific. We have created the longitude-time Hovmoller diagram and time-series for the same region to see the interannual variations of aerosols observed from MODIS Terra (Fig. 6). In general, the area averaged aerosol is lowest (~ 0.2) in November or October and highest in April or March (~0.4). The aerosol drops quickly from spring to summer and keeps relative stable during the summer. The aerosol amount varies from year to year. It is shown that 2003 spring has higher aerosol amount and the following year, 2004, has lower amount.

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Giovanni URL: **http://giovanni.gsfc.nasa.gov/**