P1.6 AEROSOL INDEX FROM TOMS AND OMI MEASUREMENTS

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1. INTRODUCTION

Smoke from biomass burning, and dust particles from desert storms are among the main atmospheric constituents that affect the air quality and the Earth's climate system. Monitoring of these atmospheric constituents is only possible through satellite measurements because ground based measurements are very limited in space and time and these constituents get transported over long distance from their source region. For more than two decades, Total Ozone Mapping Spectrometer (TOMS) instruments (McPeters et al, 1996) have been providing useful global data on the long-range transport of smoke and dust plumes. TOMS measures back scattered radiances in the near Ultra-Violet (UV) region of the spectrum and from these measurements, the TOMS ozone retrieval algorithm computes an absorbing Aerosol Index (AI), which is a qualitative measure of the presence of UV absorbing aerosols such as mineral dust and smoke.

At the present time, the long-term data record of the aerosol information from the TOMS instrument is continued by the Ozone Monitoring Instrument (OMI) flown on the EOS Aura spacecraft (launched July 2004). The key objectives (Levelt, et al., 2000) of the OMI measurements (Ahmad et al., 2003) include monitoring of aerosols and smokes from biomass burning, SO_2 from volcanic eruptions, and key tropospheric pollutants and surface UV radiation that are threat to the human health. Because of better measurement accuracy and better spatial resolution (13x24 km) OMI provides better estimates of atmospheric pollutants and their transport through the Earth's atmosphere.

In spite of the fact that the Aerosol Index is a qualitative indicator of the presence of the absorbing aerosols, many scientists have used it in variety of applications with the encouraging results. For example, AI has been used in identifying the sources of air pollution over the globe, understanding the transport of air pollution across the oceans and continents, air quality forecast models, and radiation energy balance, and climate forcing studies.

The AI data from TOMS and OMI instruments are available free from the NASA Goddard Earth Sciences Data Information Services Center (GES DISC) (http://acdisc.gsfc.nasa.gov/). GES DISC also provides a web based on line data visualization and data mining capabilities (called 'Giovanni') for the easy data access and data exploration. This presentation highlights the unique characteristics of the AI products, and also shows some of Giovanni based 2D color maps, Hovmoller and time-series plots showing spatial and temporal distribution of dust and smoke over the land and the ocean.

2. ABSORBING AEROSOL INDEX

The absorbing aerosol index (AI) from the current Earth Probe TOMS is defined as the difference between the measured (includes aerosols effects) spectral contrast of the 360 and 331 nm wavelength radiances and the contrast calculated from the radiative transfer theory for a pure molecular (Rayleigh particles) atmosphere.

In the current version-8 Nimbus-7 TOMS (1979-1993) and Earth Probe TOMS (1996- present) and version-2 Aura OMI (2004-present) algorithms, it is mathematically defined as:

$$AI = 100 \{ \log_{10}[(I_{360}/I_{331})_{meas}] - \log_{10}[(I_{360}/I_{331})_{calc}] \}$$

Since $I_{360\,calc}$ calculation uses reflectivity derived from the 331 nm measurements, the Aerosol Index definition essentially simplifies to:

$$AI = 100 \log_{10} (I_{360\_meas}/I_{360\_calc})$$

The Aerosol Index detects dust, smoke and volcanic ash over all terrestrial surfaces including deserts and snow-ice covered surfaces. These aerosol types are also detected intermingled with clouds and above cloud decks.

The AI can differentiate very well between absorbing and non absorbing aerosols, because it provides a measure of absorption of UV radiation by smoke and desert dust. AI positive values are associated with UV-absorbing aerosols, mainly mineral dust, smoke and volcanic aerosols. However, negative values are associated with non-absorbing aerosols (for example, sulfate and sea-salt particles) from both natural and anthropogenic sources (Torres et al, 1998). Near zero values indicate cloud presence. In interpreting the results care has to be taken that some surface effects, such as sea-glint and ocean color, can also enhance the AI.

3. APPLICATIONS

The TOMS Aerosol Index though initially computed for the correction of aerosol induced errors in the retrieval of total ozone (Torres and Bhartia, 1999), it has been extensively used in a variety of other applications.

In particular, NASA and other scientists have used AI in:

-Mapping and analyzing the global distribution of UV-absorbing aerosols (*Herman et al.*, 1997),

-studying the aerosol properties (*Torres et al.*, 1998, 2001)

-estimating UV reduction at the earth's surface (Herman et al. 1999; Krotkov et al. 1998),

- estimating the radiative forcing effects of mineral aerosols and the smoke layer above the cloud deck, in conjunction with Earth Radiation Budget Experiment (ERBE) data (Hsu et al. 2000).

- studying the interannual variability of soil dust aerosols in conjunction with Advanced Very High Resolution Radiometer (AVHRR) data (Cakmur et al. 2001)

-environmental characterization of soil dust sources (Prospero et al. 2002)

-monitoring of health hazard microorganisms transported by African dust across the Atlantic Ocean) and identifying microbes and pollutants in the African soil dust (Prospero, 2004)

-monitoring of the ecosystems, for example the decline of coral reefs caused by the dust from Saharan desert dumping into the North Atlantic Ocean(Shinn, et al.,2000)

- identifying the dust aerosol induced biases in retrieved sea surface temperature and devising a correction based on the relationship between errors in AVHRR-derived SST and the TOMS AI. (Diaz et al. 2001)

- initializing forecasting model of dust aerosol (*Alpert et al.*, 2002)

- developing a global dust source function for aerosol transport model (*Ginoux et al.*, 2001), and validating dust distribution at the regional and global scale.

- monitoring of transport of biomass burning emissions deeply injected into the lower stratosphere, followed by the phenomenon of pyro-cumulonimbus 'eruptions' (Fromm et al, 2005).

Although the AI is a very useful qualitative indicator of aerosol presence, an actual inversion procedure is needed to interpret the measured radiance departures from a Rayleigh atmosphere model, in terms of traditional aerosol parameters such as optical depth, τ, and single scattering albedo, ω_0 (Torres et al. 1998).

4. AEROSOL INDEX AND AIR QUALITY FORECAST

Aerosol index is used directly or indirectly in developing some regional forecast systems. We provide here two examples:

-**DUST Forecast System for Mediterranean Israeli Dust Experiment (MEIDEX)**

A regional dust prediction and forecasting system has been developed at Tel Aviv University (TAU). It is based on the weather and dust predicting Eta model. The dust abundance is initialized by using daily TOMS aerosol index data (Alpert et al., 2002). The system allows daily dust prediction at least 24 hours ahead of time.

(http://geophysics.tau.ac.il/meidex/Forecast/forecast.htm)

-**Smoke Regional Forecast System for South America:** PM2.5 emissions (the fine aerosol particles of radius less than 2.5 microns) are unhealthy to human and have been reaching North America. Sources of PM2.5 include emissions from any type of combustion, primarily motor vehicles, power plants, industrial processes and forest fires. n a regional study over South America, scientists have used TOMS Aerosol Index for the validation of PM 2.5 column amount computed from the RAMS (Regional Atmospheric Modeling System of Colorado State University prediction system) coupled with an emission model. Comparisons are shown here (Fig. 1) for Aug 24, 1999 smoke plume (following the anticyclone circulation) over the Atlantic Ocean

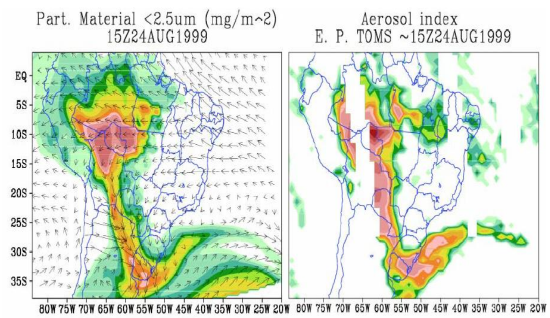


Fig.1 PM2.5 forecast and TOMS Aerosol index over Chile, South America (source: S. R. Freitas et al.,http://www.fire.unifreiburg.de/vfe/vfe_southamerica.htm)

PM2.5 Particles are small enough to be breathed deeply into the lungs and pose a potential health risk. The U. S. Environmental Protection Agency in cooperation with the National Weather Service is in the process of developing a National Air Quality Forecasting to provide timely forecasts of ozone, particulate matter, and other pollutants to prevent or reduce adverse effects of these hazards. NOAA is committed to provide PM2.5 forecast for the nation within the coming years. Testing of PM 2.5 forecast is in progress using Community Multi-scale Air Quality Modeling System (http://www.epa.gov/asmdnerl/cmaq.html)

5. GIOVANNI DATA ANALYSIS TOOL

The NASA Goddard Earth Sciences Data and Information Services Center (GES DISC) has developed a tool called ‘Giovanni’. The Giovanni (GES-DISC Interactive On-line Visualization & Analysis Infrastructure) is a Web based interface for data exploration, visualization and analysis (http://acdisc.gsfc.nasa.gov/). It has been developed to provide an easy access to the long-term atmospheric composition datasets residing at the GES DISC virtual Atmospheric Composition Data and Information Services Center (ACDISC). Some key atmospheric composition datasets residing at the GES DISC available through ACDISC (Leptoukh et al., 2005), are from Aura MLS OMI, HIRDLS; UARS HALOE, MLS, CLAES, ISAMS; MODIS and AIRS; LIMS, TOMS, SBUV, BUV, SSBUV, ATMOS, and GOME.

Giovanni facilitates science data usage by providing data exploration capabilities (Figure 2) based on user requested criteria. There is no need to learn data formats, everything is done via a web browser. User can save the images generated during the data exploration session and download the subsetted data in ASCII (option of download of data in original format is also available).

Several plot type options are available depending on the mission and the parameters selected. For example for almost all gridded products (including TOMS and OMI TOMS-like gridded product) the available plot types are: 2D maps for spatial distribution, maps of latitudinal or longitudinal distribution as a function of time also referred as Hovmoller plots, time-series along with simple statistics, animations, meridional and zonal averages.

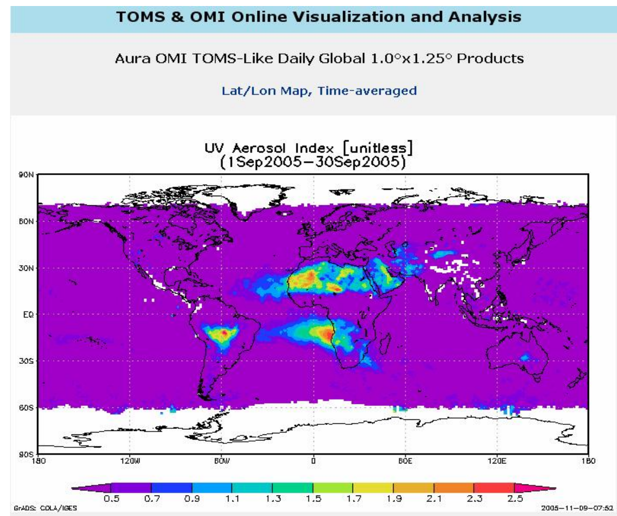


Fig 2a - Global distribution of Dust and smoke (OMI Aerosol index averaged for September 2005)

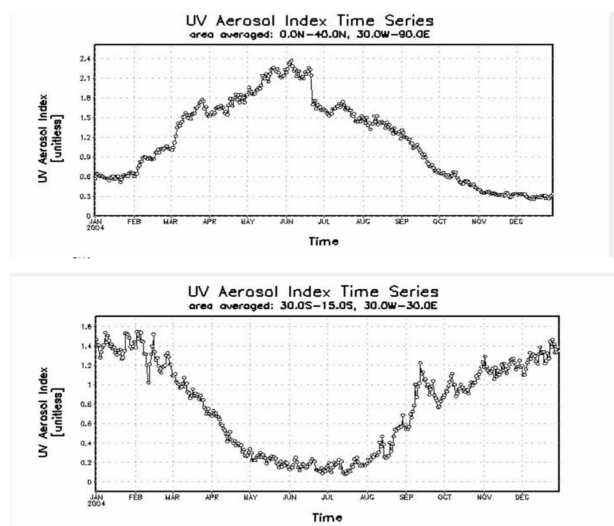
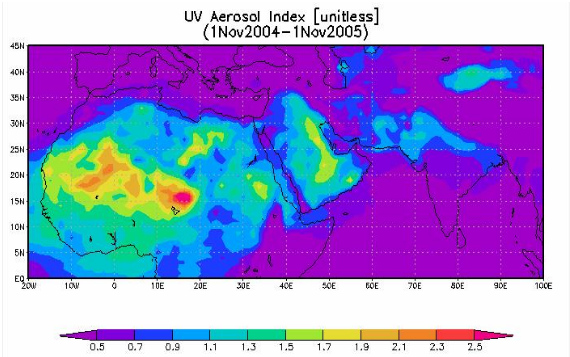


Fig 2b Time Series plots for Dust over North Africa (top) and Smoke over South Africa (bottom)



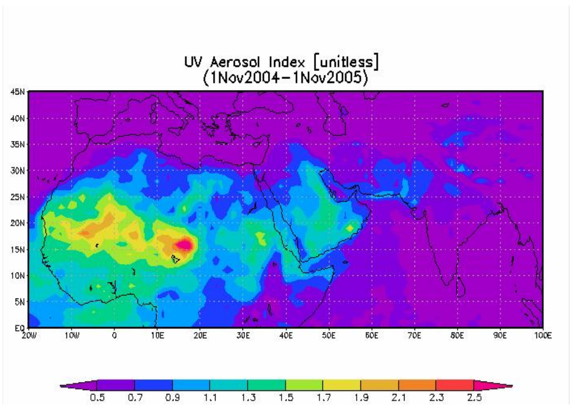


Fig. 2c – Maps EOS of Aura-OMI (top) and EP-TOMS (bottom) aerosol index, for the 'Dust-belt' averaged over one year (Nov 2004 to Nov 2005).

For MODIS Aerosol, cloud, and water vapor multi satellite parameter comparisons (including the aerosol parameters from GOCART model), scatter plots, correlation maps, maps of differences for the parameters from two different sources are also provided.

For Aqua AIRS, Aura MLS and UARS HALOE data, the Giovanni provides browsing capabilities of vertical profiles of several trace gases, temperature and geopotential height.

Giovanni for the OMI L2G products has also been developed. It uses OMI L2G daily data product that is produced by OMI science team. It is a special product which has been created by taking data from fifteen Level-2 data files (corresponding to15 orbits) and binning it into 0.25 x 0.25 degree global grids. All the information related to data points (that fall in the small grid) are saved without averaging. The L2G Giovanni interface provides the capability for the user to be able to display, average and create OMI gridded global/regional products on-line at the coarser resolution. The filtering of data (based on quality flags) is also provided. This allows data subsetting with the option of ASCII output. Currently, OMI L2G Giovanni is in test mode, it will be released soon to the public.

Giovanni provides tremendous capability of exploring the TOMS, OMI and MODIS aerosol data for monitoring sources and sinks of smoke and dust and its transport. MODIS Giovanni also provides data on fine mode fraction of aerosols and Fire counts for the correlative studies. (http://acdisc.gsfc.nasa.gov/services.shtml)

6. DATA AVAILABILITY

For the air quality monitoring, validation and testing of air quality forecast models, aerosol products from TOMS, OMI and MODIS are available from NASA GES DISC (http://acdisc.gsfc.nasa.gov/data_access.shtml). TOMS and OMI aerosol index, aerosols optical thickness and images are also available from TOMS Mission site (http://toms.gsfc.nasa.gov/). TOMS Version 8 Level-3 data are also available on DVD-ROM.

7. SUMMARY

Absorbing Aerosol index is a qualitative parameter however it does excellent job in classifying UV absorbing and non absorbing aerosols. It has been used extensively not only in the monitoring of the dust from storms and the smoke from biomass burning but also in the correction of several algorithms for the aerosol contamination and in the validation of transport and forecast models. A long-term data record (over 25 years) of AI from TOMS and data from Aura OMI is available from GES DISC and TOMS mission sites. GES DISC also provides an on-line web based data analysis capability called Giovanni, which provides convenient access to long-term data set for data exploration and tracking temporal patterns of air pollutants.

8. ACKNOWLEDGMENT

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