Monitoring of Air Quality from the Aura and other A-Train Satellites

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Overview

NASA EOS satellites Aqua, Aura and CALIPSO that are part of the **A**-Train constellation (**A**fter-noon around 1:30 p.m equator crossing satellites) have been routinely providing almost simultaneous global measurements of Aerosols and many Atmospheric Pollutants such as O_3, CO, NO_2, SO_2, and HCHO. These measurements provide information on the vertical and spatial distribution of atmospheric pollutants, and their transport to far distances across the oceans and continents. This presentation provides some examples of how A-Train data can be useful in monitoring air quality, identifying sources and sinks of pollution, and understanding seasonal variations and underlying photochemical and meteorological processes involved.

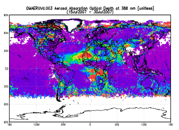
For this presentation we use Air Quality instance in Giovanni (web-based data analysis tool developed at the GES DISC http://giovanni.gsfc.nasa.gov/). The A-Train instance, also available in Giovanni, allows extraction of collocated air quality and atmospheric dynamics data from different A-Train sensors along the CALIPSO track which facilitates the simultaneous visualizations and correlation of different multi-satellite air quality and other ancillary atmospheric data.

Aerosols Monitoring from Aura, Aqua & CALIPSO

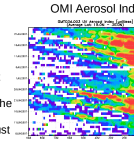
Aerosol Index and Aerosol Optical Depth data from the NASA TOMS missions have been used for aerosol monitoring over the last three decades, and now data from A-Train sensors Aqua-MODIS, Aura OMI and CALIPSO-CALIOP have continued the task of global monitoring of aerosol sources and sinks. Aura HIRDLS provides vertical aerosol extinction profiles. The Aqua AIRS team is also in the process of developing an operational dust aerosol retrieval algorithm (thermal brightness temperature based) which will provide both day and night dust monitoring capability. CALIPSO provides detailed information on the aerosol particle characteristics, in addition to aerosol height. MISR flown on Terra (not part of A-Train; 10:30 am equator crossing time) has also been providing global aerosol information.

Long-Range Transport of Smoke and Dust Aerosols

OMI Absorption Optical Depth



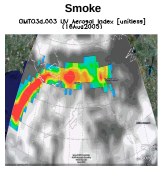
OMI Aerosol Index



On the left, the global map of OMI Absorption Optical Depth (July 2007), shows North African dust traveling westward over the Atlantic Ocean and reaching Mexico and North America. It also shows smoke plumes from the biomass burning from central Africa. The Aerosol Index map on the right shows westward transport of North African dust plumes with time.

OMI can see UV absorbing Aerosols (dust & smoke) over clouds

Smoke

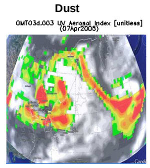


Asian dust plumes usually start in March and many build up over Taklamakan and Gobi deserts and move eastwards, travel over the Pacific and reach the west coast of America. On the right, the map of OMI Aerosol Index of April 7, 2005 shows dust plume over East China, Korea and Japan.

Plumes of smoke from a Canadian Boreal Forest Fire for August 16, 2005 is shown on the left.

These Aerosol index maps have been overlaid on OMI retrieved Cloud Cover to show that OMI can detect aerosols even over clouds.

Dust

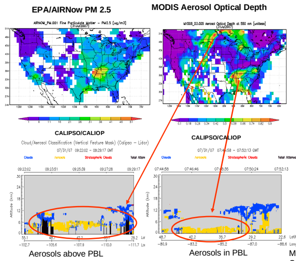


[Aura/OMI Near-UV Aerosol Retrieval Algorithm P.I is Omar Torres and OMI instrument PI is KNMI (Netherland) scientist Pieternel Levelt]

Satellite Aerosol Optical Depth Observations as a Proxy for Surface PM2.5 Estimates?

Measurements of fine aerosol particles are routinely made by EPA surface based networks 'AIRNow'. The particulate matter of radius less than 2.5 micron (PM2.5) has been found to be unhealthy as it affects the lungs. The question: can we estimate surface PM2.5 from satellite data?. Atmospheric scientists are working on this problem. GES DISC developed Giovanni interface for Air Quality, provides access to AIRNow daily observations of PM2.5 in addition to satellite based aerosol measurements. This gives the opportunity of data validations, algorithm enhancements and correlative analysis. Below is a case study over the US which uses MODIS and CALIPSO data from July 31, 2007.

EPA/AIRNow PM 2.5 | MODIS Aerosol Optical Depth



Aerosols above PBL | Aerosols in PBL

CALIPSO/CALIOP Vertical Feature Mask

CALIPSO provides Aerosol Plume Height Information

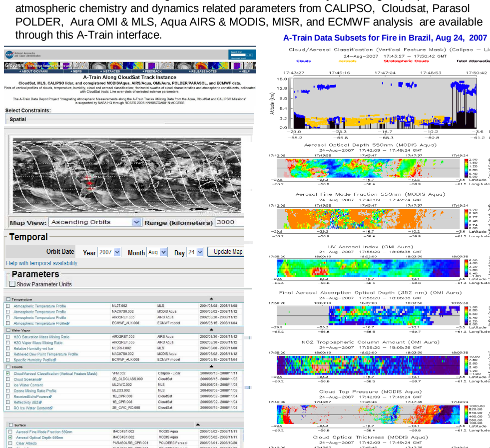
The maps of PM2.5, MODIS Aerosol optical depth, and CALIOP vertical feature masks shown on the left reveal thick aerosols plumes over most of the US. The CALIOP overpass shows that for Canada and the North-central US, the plume is above the boundary layer, and for the Southeast US, the aerosol layer is closer to the surface. We notice that PM2.5 is well correlated with satellite observations when the aerosol plume is near the boundary layer (see high PM2.5 and high MODIS aerosol optical depth over Tennessee and most of Southeast US), as expected, compared to when it is above the boundary layer.

MODIS Aerosol Algorithm PI are L. Remer and D. Tanre
CALIPSO/CALIOP Principal Investigator is D. Winker

Correlative Studies using A-Train Collocated Data

The A-Train instance in Giovanni allows collocation of air quality data along the CALIPSO track that facilitates the simultaneous visualizations of different multi-satellite air quality parameters. Data can be used for the validation of algorithms and the correlative analysis among major pollutants. Many atmospheric chemistry and dynamics related parameters from CALIPSO, Cloudsat, Parasol POLDER, Aura OMI & MLS, Aqua AIRS & MODIS, MISR, and ECMWF analysis are available through this A-Train interface.

A-Train Data Subsets for Fire in Brazil, Aug 24, 2007

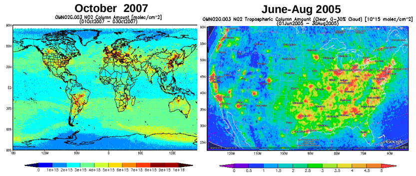


*** User can Download images, source data products and data products derived** from Giovanni subsetting processing stages. For simplicity purposes, only the initial retrieval and final rendering phases are currently accessible for downloading. Supported download formats are HDF, NetCDF(NCD), ASCII, and KMZ. To download multiple files at once, select the desired files (from any section) by clicking on their associated checkboxes, and then click 'Download in Batch'.

Multi-sensor based, global & regional data analysis capabilities (Time series, scatter plots, correlation maps, anomalies, hovmoller plots etc) are available from the Sensor or Theme based Giovanni interfaces, see http://giovanni.gsfc.nasa.gov

Aura OMI Detects NO2 Pollution Sources

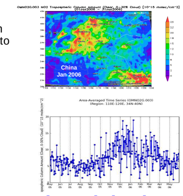
October 2007 | **June-Aug 2005**



Nitrogen Dioxide's main sources are anthropogenic (fossil fuel and bio-fuel), biomass burning, soil emissions and lightning. The seasonal variability is used to identify the dominant source of NO_2 emissions.

The lifetime of NO_2 from anthropogenic emissions near the surface is very short (approximately 24 hours), and is typically not transported far from its sources. Its distribution identifies mainly pollution source regions. NO2 is the main surface ozone precursor.

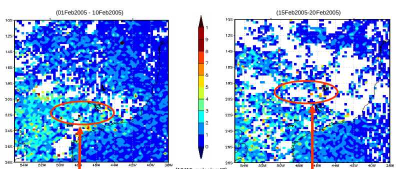
Recent studies indicate significant growth in tropospheric NO_2 over East China (up to 30% per year), especially over its major cities as a result of increasing fuel consumption. Aura OMI is able to detect the weekly cycle of traffic induced NO_2 pollution, as well pollution from industrial sites. Because of increased use of coal burning during winter, the time series of NO_2 over highly industrialized and populated cities in China show a strong seasonal cycle with maxima in winter.



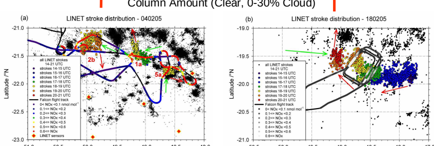
OMI Observes NO2 During Lightning

(Case Study: Brazil, Feb. 2005)

Lightning is a significant source of NOx (NO and NO_2) in the middle and upper troposphere where NO_2 is longer-lived. NOx emissions from lightning (LNOx) are not only ozone precursors, but they also produce HNO_3 which is eventually deposited to the surface by dry or wet deposition (Pickering et al.,2004; 2007). To examine whether OMI was able to detect LNOx during the Brazilian Lightning activity event of February 2005, we used Giovanni. A field campaign, Tropical Convection, Cirrus and Nitrogen Oxides (TROCCINOX), was also organized in Feb 2005 for the LNOx study. Giovanni based maps of OMI NO_2 product (Level-2G) are shown below. During thunder activity clouds are dense and OMI could only see the NO_2 only through some holes in the clouds.



OMN02G.003 NO2 Tropospheric Column Amount (Clear, 0-30% Cloud)

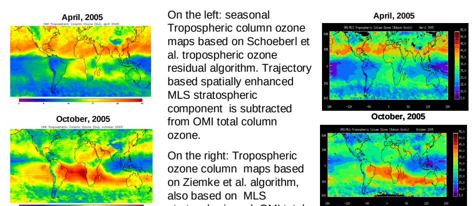


Lightning strokes from LINET, the Lightning Location Network (source: Huntrieser, et al., Atm. Chem Phys, 2008)

OMI NO2 retrieval Algorithm PI are James Gleason and Pepijn Veefkind

Monitoring of Tropospheric Column Ozone

Ozone in the troposphere, particularly near the surface, is harmful to humans and the Earth's ecosystems. Ozone in the troposphere is produced by photochemical oxidation of carbon monoxide (CO) and volatile organic compounds (VOCs) in the presence of nitrogen oxides. Depending on meterological conditions, it also gets transported over long distances. OMI, HIRDLS, MLS, TES on Aura and AIRS on Aqua provide column amount and vertical distribution of ozone. OMI Tropospheric column ozone is produced (research product) by a number of OMI scientists (Schoeberl et al., 2007; Ziemke et al., 2006, Liu & Bhartia., 2008).



On the left: seasonal Tropospheric column ozone maps based on Schoeberl et al. tropospheric ozone residual algorithm. Trajectory based spatially enhanced MLS stratospheric component is subtracted from OMI total column ozone.

On the right: Tropospheric ozone column maps based on Ziemke et al. algorithm, also based on MLS stratospheric and OMI total column ozone.

Tropo O3 data courtesy : Mark Schoeberl | Image courtesy: Jerry Ziemke

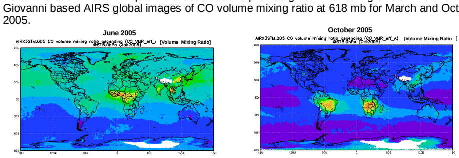
These maps show enhancement in northern mid-latitudes in late spring (March- August). During the months of intense biomass burning (Sept-Nov), enhanced O3 is found over the Amazon and surrounding region. The lowest values occur during winter (Dec-Feb).

Carbon Monoxide A Tracer of Polluted Air Masses

Atmospheric carbon monoxide is produced as result of incomplete combustions of fossil fuel, biofuel, biomass burning, and oxidation of methane and VOCs. In urban areas it is a good tracer of mobile source emissions. Its average lifetime in the atmosphere is on the order of a month which makes it useful for tracking air masses and pollution sources and sinks.

Aura TES and MLS and Aqua AIRS observations provide global monitoring of CO. We show here Giovanni based AIRS global images of CO volume mixing ratio at 618 mb for March and October 2005.

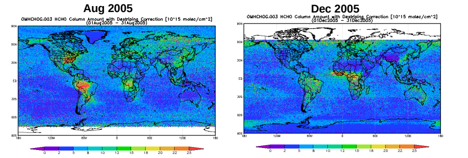
June 2005 | **October 2005**



In general, in spring, CO produced from fires burning in equatorial Africa is carried across the Atlantic Ocean and to the Pacific Ocean by equatorial easterly winds. In October-November westerly winds play a major role in taking CO plumes from Amazonia and Western Africa fires to Australia and New Zealand. (The P.I for the AIRS CO product is Wallace McMillan, AIRS Science Team)

HCHO & VOCs Monitoring from Space

Aug 2005 | **Dec 2005**



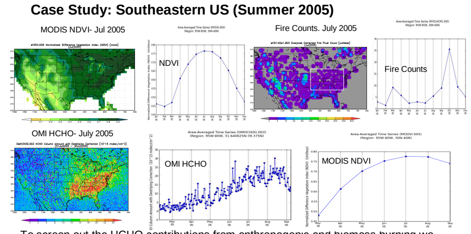
OMI HCHO maps, shown above for August and December 2005, identify the regions of high HCHO. These regions show strong seasonal variations depending on the HCHO sources (e.g natural biogenic, biomass burning, anthropogenic and combinations)

OMI HCHO as a Proxy for Biogenic VOCs?

Volatile Organic Compounds (VOCs) are important precursors of tropospheric trace gases. Formaldehyde (HCHO) is an intermediate product of VOCs oxidation, which makes HCHO a good indicator of the amount of VOCs present. HCHO distribution retrieved from space is expected to provide useful information on isoprene emissions, a major component of total VOCs (see Millet et al 2006 & 2008; Chance et al, 2007). More than 90 percent of global isoprene comes from plants, in particular the broad leaf trees and deciduous forests. Ground based studies (Guenther, 1995, Lathiere, et al 2005) have shown that isoprene emission is a function of Biomass, Leaf Area Index (LAI), Temperature and Photosynthetically Active Radiation (PAR).

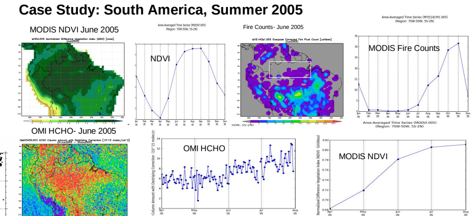
Here, we explore this correlation using Giovanni (http://giovanni.gsfc.nasa.gov/), which has direct access to atmospheric composition, radiation and key land parameters including fire counts, Normalized Vegetation Index (NDVI), Surface Temperature and Precipitation. For data exploration we selected the Southeastern US and Northern Brazil, where plant categories are in accordance to major isoprene contributors.

Case Study: Southeastern US (Summer 2005)



To screen out the HCHO contributions from anthropogenic and biomass burning we selected a small region (white box) based on seasonal variations of NDVI and fire counts from MODIS (see top panel) The figures above on second row show HCHO and NDVI variation for the time interval when biomass burning activity is negligible. The correlation between vegetation index (proxy of isoprene emission) and HCHO is very promising.

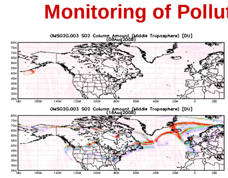
Case Study: South America, Summer 2005



Above graphs also show seasonal variation of NDVI and fire counts from MODIS, but for Northern Brazil. The figures above on second row show HCHO and NDVI variation for the time interval free from biomass burning emissions. Correlation between HCHO and NDVI confirms that satellite retrieved formaldehyde in the selected region (white box) is mainly produced in summer due to oxidation of isoprene emitted from plants.
(Also see Bryan Duncan et al. presentations at this Aura meeting related to Variations in HCHO associated with drought in the SE; and 'HCHO as a proxy for reactive VOCs' presentation by Millet et al)

[OMI HCHO retrieval Algorithm Principal Investigators are Kelly Chance and Tom Kruosu]

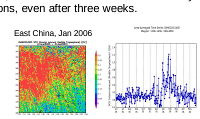
Monitoring of Pollution & Volcanic SO2



Aura OMI provides UV based monitoring of background SO_2 and can track pollution plumes on a daily basis, in addition to tracking volcanic SO_2 plumes.

The images on the left are SO_2 maps from the August 7, 2008 Kasatochi eruption. In ten days the plume covered most of the globe, and its traces were detected in many regions, even after three weeks.

East China, Jan 2006

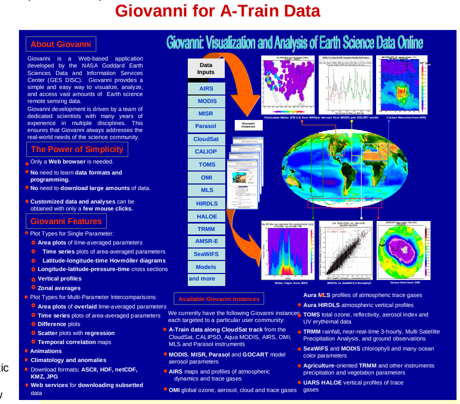


On the right is the map and time series of background SO_2 over Eastern China. SO_2 emissions over Eastern China are maximum in winter since 70% of China's energy is derived from industrial power plants and burning coal. This is the only country where SO2 emissions are increasing each year

[OMI SO2 retrieval algorithm PI are N. Krotkov, K.Yang, S. Carn and A. Krueger]

Aqua AIRS team is also in the process of developing a thermal bands based operational algorithm for volcanic SO2 monitoring (also applicable to night time monitoring). Aura MLS provides SO2 profiles based on microwave emissions.

Giovanni for A-Train Data



http://giovanni.gsfc.nasa.gov/

Get Atmospheric Data from the GES DISC
http://disc.gsfc.nasa.gov/

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