# Satellite Observations

## for Detecting and Tracking Changes in Atmospheric Composition

Today, satellite remote sensing of lower atmospheric composition provides global observations for critical constituents including tropospheric ozone, tropospheric nitrogen dioxide ($NO_2$), carbon monoxide (CO), formaldehyde (HCHO), sulfur dioxide ($SO_2$), and aerosol properties.

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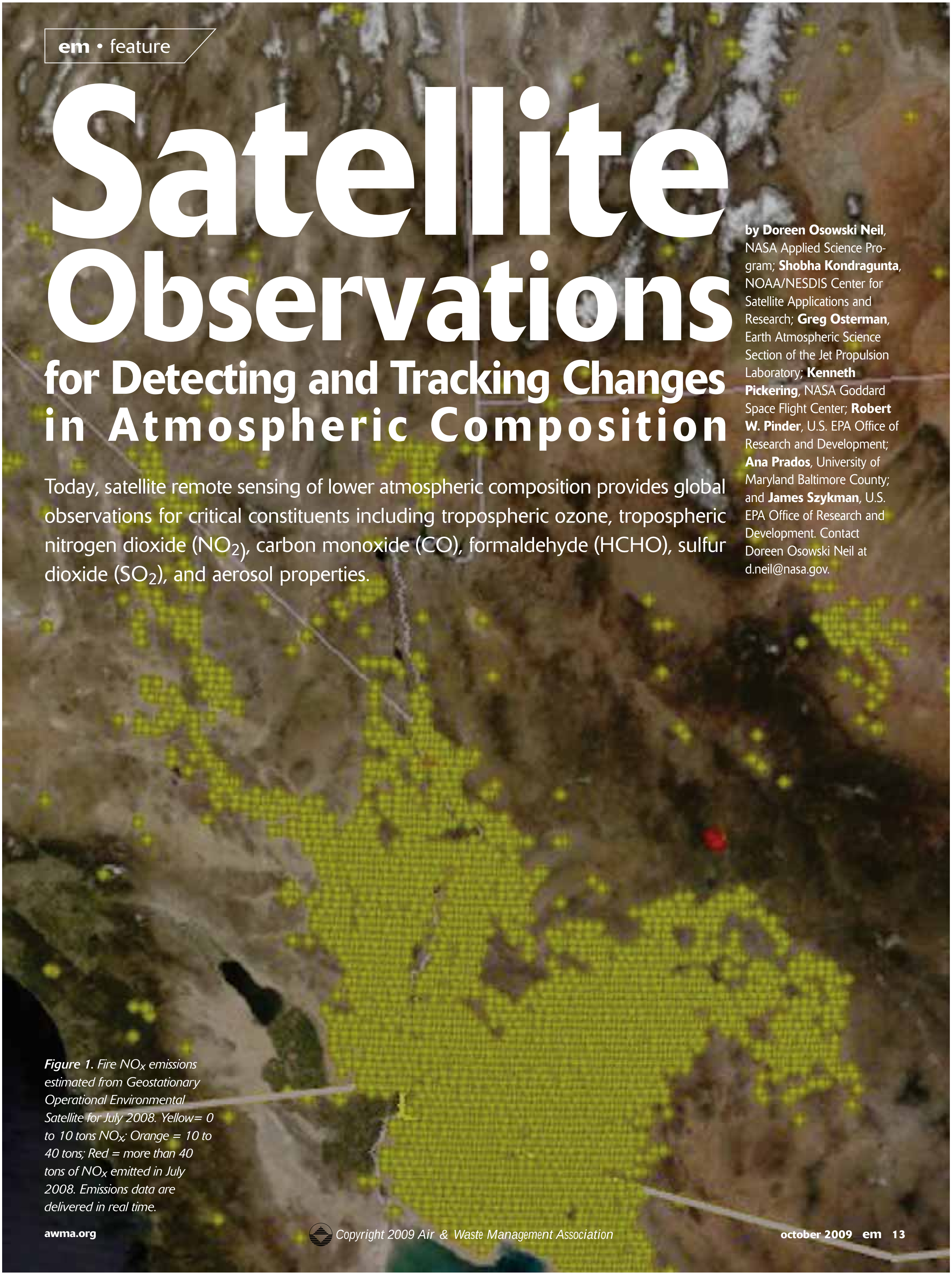
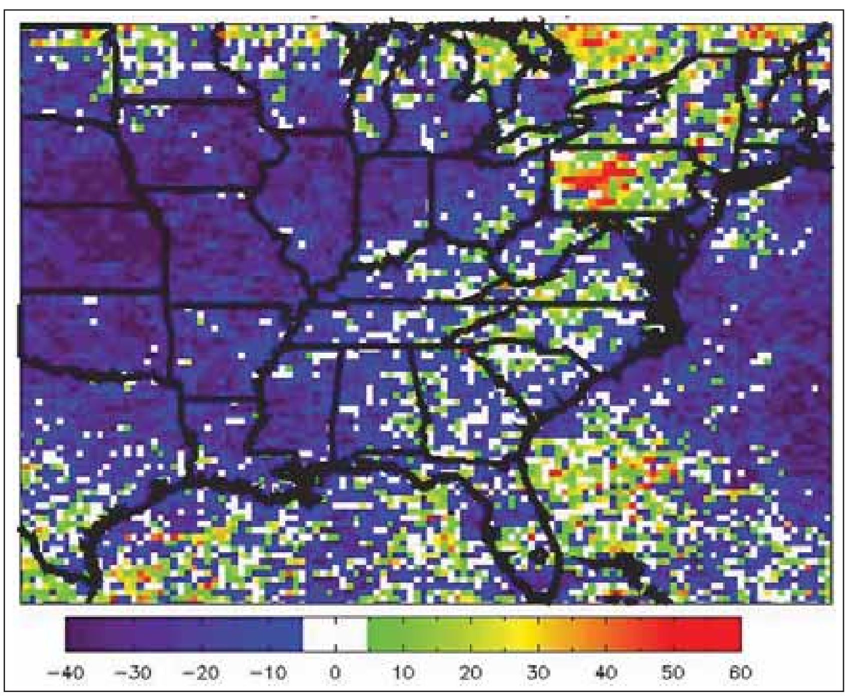


***Figure 1.*** *Fire $NO_X$ emissions estimated from Geostationary Operational Environmental Satellite for July 2008. Yellow= 0 to 10 tons $NO_X$; Orange = 10 to 40 tons; Red = more than 40 tons of $NO_X$ emitted in July 2008. Emissions data are delivered in real time.*

The satellite observations provide constraints on detailed atmospheric modeling, including emissions inventories, indications of transport, harmonized data over vast areas suitable for trends analysis, and a link between spatial scales ranging from local to global, and temporal scales from diurnal to interannual.[1] The National Oceanic and Atmospheric Administration's (NOAA) long-term commitments help provide these observations in cooperation with international meteorological organizations. NASA's long-term commitments will advance scientifically important observations as part of its Earth Science Program, and will assist the transition of the science measurements to applied analyses through the Applied Science Program. Both NASA and NOAA have begun to provide near real-time data and tools to visualize and analyze satellite data,[2] while maintaining data quality, validation, and standards. Consequently, decision-makers can expect satellite data services to support air quality decision making now and in the future.

The international scientific community's Integrated Global Atmosphere Chemistry Observation System Report[3] outlined a plan for ground-based, airborne and satellite measurements and models to integrate the observations into a four-dimensional representation of the atmosphere (space and time) to support assessment and policy information needs. This plan is being carried out under the Global Earth Observation System of Systems (GEOSS). Demonstrations of such an integrated capability[4] provide new understanding of the changing atmosphere and link policy decisions to benefits for society. In this article, we highlight the use of satellite data to constrain biomass burning emissions, to assess oxides of nitrogen ($NO_x$) emission reductions, and to contribute to state implementation plans, as examples of the use of satellite observations for detecting and tracking changes in atmospheric composition.

*Figure 2.* *Percentage difference (July 2008 minus July 2005) in satellite-derived tropospheric $NO_2$ column amounts. Satellite data provide measurements that can be compared over large domains, suitable for trends analysis.*




## Biomass Burning Emissions from Satellites

Biomass burning (prescribed and natural fires) releases trace gases (e.g. CO, $NO_x$, methane, carbon dioxide ($CO_2$)), and aerosols into the atmosphere. Hourly emissions of trace gases and aerosols (tons/hr) from fires can be estimated from the U.S. Geostationary Operational Environmental Satellites (GOES) biomass burning emissions algorithm.[5] Emissions products are distributed in near real-time to federal, state, and local air quality managers. Figure 1 displays $NO_x$ emissions derived from GOES observations during July 2008 forest fires in California where nearly 1.3 million acres of forest burned. On certain days in July 2008, total $NO_x$ emissions from fires in northern California were as high as 325 tons/hr, compared to anthropogenic emissions which are generally below 10 tons/hr in regions where these fires occurred.

## Assessing $NO_2$ Reductions from Satellite Data

U.S. Environmental Protection Agency (EPA) regulations aimed at reducing $NO_x$ emissions include the $NO_x$ Budget Trading Program for power plants and the Tier 2 Tailpipe Standard for vehicles. Surface measurements to track the resulting changes in $NO_x$ concentrations are not sufficient because of interferences in the measurement of $NO_2$, inability of ground-based observations to reveal the transport of $NO_x$ aloft, and gaps in the surface measurement networks. Satellite measurements complement the surface network, especially in areas with few monitoring stations, and can be used to assess trends.[6] The Ozone Monitoring Instrument (OMI) on NASA's Aura satellite observes tropospheric column amounts of $NO_2$ once daily over the entire globe at a spatial resolution 13 km x 24 km directly below the satellite. As an example, the percent differences between the OMI tropospheric $NO_2$ column amounts in July 2005 and July 2008 are presented for the eastern U.S. in Figure 2. Satellite data are gridded at 0.25° latitude by 0.25° longitude resolution. $NO_2$ decreases of 10 to 40 percent are found in a broad swath from northern Ohio and southern Michigan stretching westward to Nebraska, Kansas, and Oklahoma. A pronounced region of $NO_2$ increase (up to 60%) is found over western and central

Pennsylvania, accompanied by decreases (5 – 30%) in the corridor stretching from northern Virginia to northern New Jersey. These $NO_2$ changes are in general agreement with facility-level data from EPA's Continuous Emission Monitoring System (CEMS) (www.epa.gov/ttn/emc/cem.html) and with the EPA $NO_x$ Budget Trading Program 2008 Progress Report (www.epa.gov/airmarkets/progress/NBP_1.html). OMI measurements of tropospheric $NO_2$ column amounts assist in long-term monitoring of air quality changes resulting from emission regulation programs.

## Use of Satellite Data in State Implementation Planning

State Implementation Plans (SIPs) provide detailed emissions control programs to improve the state's air quality. SIP development frequently uses air quality models and field observations to understand the current situation and to develop scenarios for regulatory plans. In the Houston area, the Texas Commission on Environmental Quality (TCEQ) used satellite data in the 2006 SIP process[7] by assimilating satellite data into global chemical models, and by using satellite data for evaluation of regional air quality models. The Tropospheric Emission Spectrometer (TES) instrument on board the NASA Aura satellite provides some vertical information on ozone and carbon monoxide concentrations in the troposphere.[8] TES compliments the existing surface data by providing information above the ground-based monitors, and is particularly useful in regions where there are no surface monitors (rural areas, over water). Figure 3 illustrates a Google Earth representation of satellite ozone data over the Houston area in July 2008. Coarse profiles obtained every 45 km along an orbit track are displayed as layers of ozone from low concentration (blue) to high (red). In addition to chemical constituents, other satellite data sets (temperature, water vapor, sea surface temperature, and winds) are being used to improve modeled meteorological fields, a foundation for improved air quality model simulations.

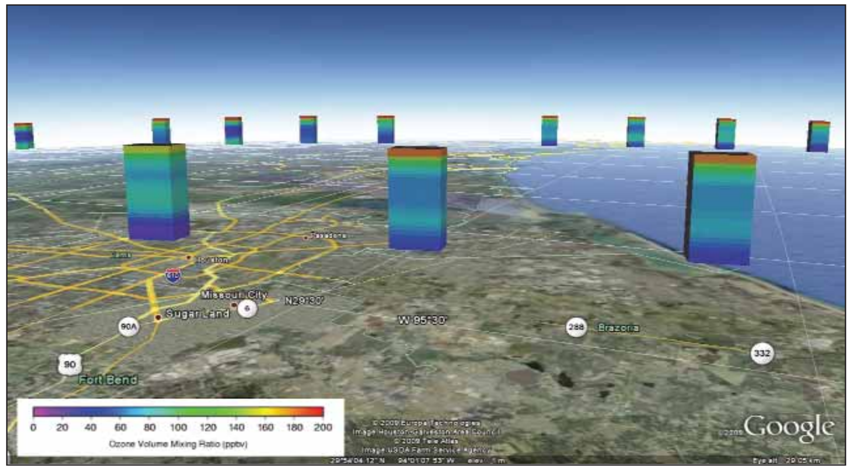



*Figure 3. Visualization of satellite ozone profiles using Google Earth for the Houston area in July 2008. Colors indicate ozone concentration (red indicates high amounts of ozone). Satellite data can identify pollutants aloft, and support analyses for the SIP planning process.*

## Satellite Air Quality Products in the Future

Satellite data product algorithms can continue to be improved throughout the life of space-borne instruments. Increased collaboration between air quality professionals and the satellite data community can lead to rapid advancement in data products for air quality management, and can support evaluation and improvement of modeled physical and chemical mechanisms. NASA is planning its next-generation satellite instruments (launch estimated after 2016) as directed in a National Research Council[9] report. These instruments provide hourly observations of ozone, CO, $NO_2$, $SO_2$, HCHO, and aerosol at 5-10 km horizontal spatial resolution. NOAA's GOES-R satellite will continue the delivery of advanced aerosol and fire products for use by air quality professionals with its launch in 2014. **em**

## References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