Satellite observations for detecting and tracking changes in atmospheric composition

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Today, satellite remote sensing of lower atmospheric composition provides global observations for critical constituents including tropospheric ozone, tropospheric NO2, CO, HCHO, SO2, and aerosol properties. 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]. NOAA's 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 NASA's 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 4-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 paper, we highlight the use of satellite data to constrain biomass burning emissions, to assess 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.

Biomass Burning Emissions from Satellites

Biomass burning (prescribed and natural fires) releases trace gases (e.g. carbon monoxide, oxides of nitrogen (NOx), methane, carbon dioxide), and aerosols into the atmosphere. Hourly emissions of trace gases and aerosols (tons/hr) from fires can be estimated from the US 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 NOx emissions derived from GOES observations during July 2008 forest fires in California. Nearly 1.3 million acres of forest burned in June and July 2008. On certain days in July 2008, total NOx 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.

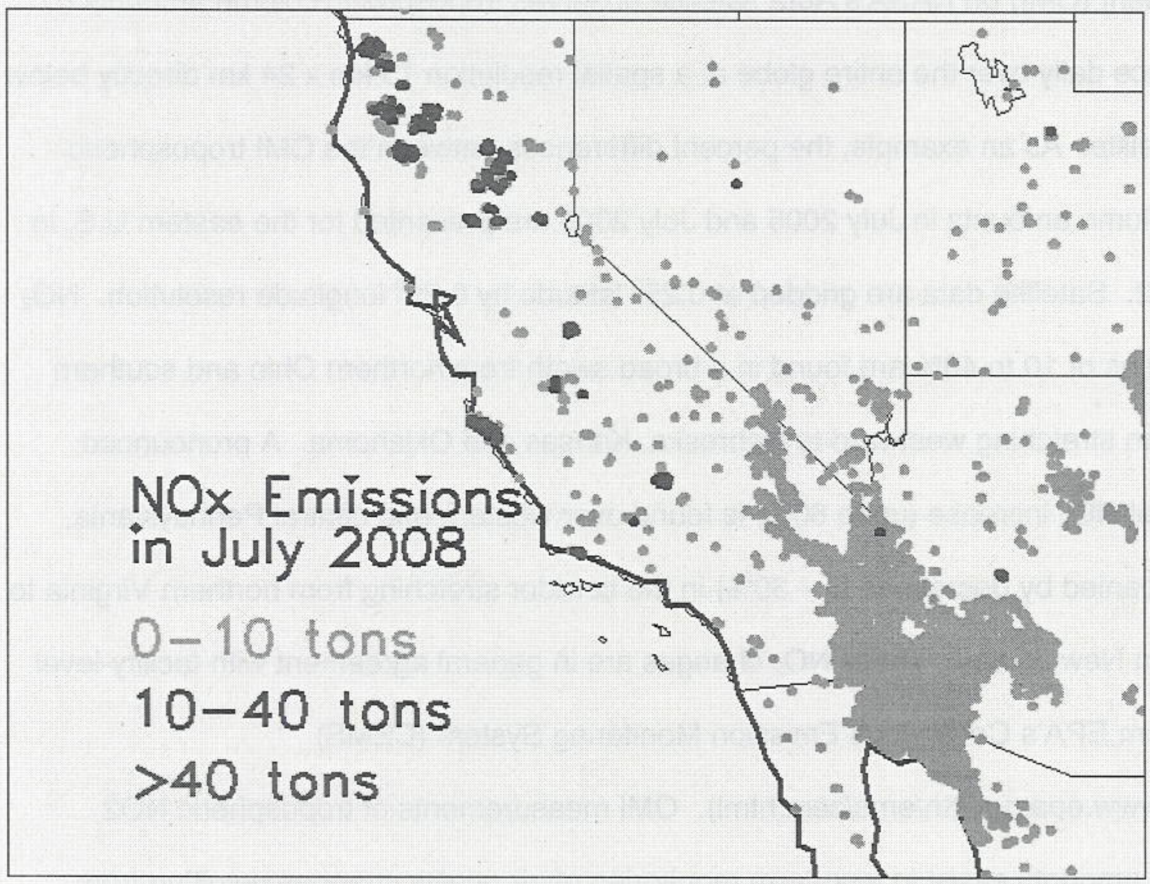

Figure 1. Fire NOx emissions estimated from Geostationary Operational Environmental Satellite are delivered in near real-time.

Assessing NO2 reductions from Satellite Data

US 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% 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) (http://www.epa.gov/ttn/emc/cem.html). OMI measurements of tropospheric NO2 column amounts assist in long-term monitoring of air quality changes resulting from emission regulation programs.

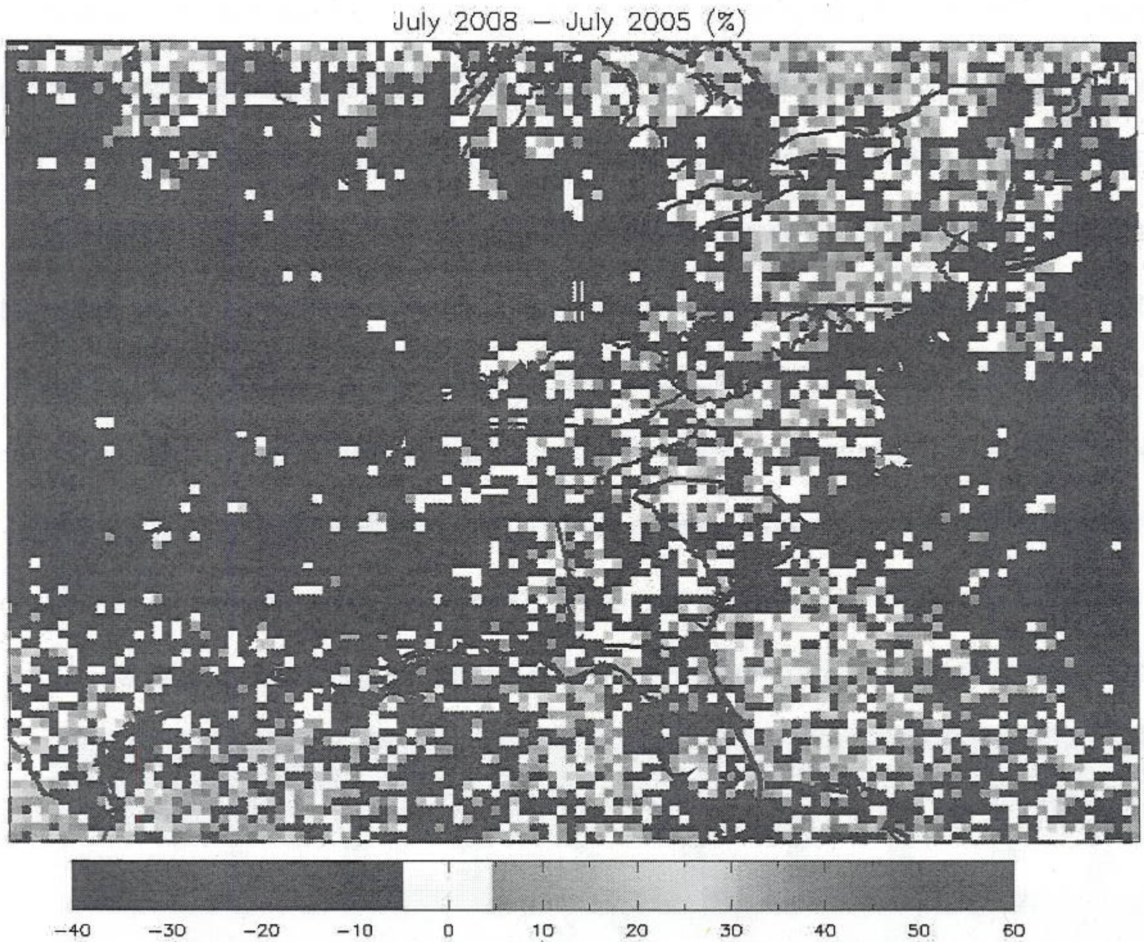

Figure 2. Percentage difference (July 2008 minus July 2005) in satellite-derived tropospheric NO_2 column amounts. Satellite data provide measurements that can be compared over large domains, suitable for trends analysis.

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 onboard the NASA Aura satellite provides some vertical information on ozone and carbon monoxide concentrations in the troposphere[8]. TES complements 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.

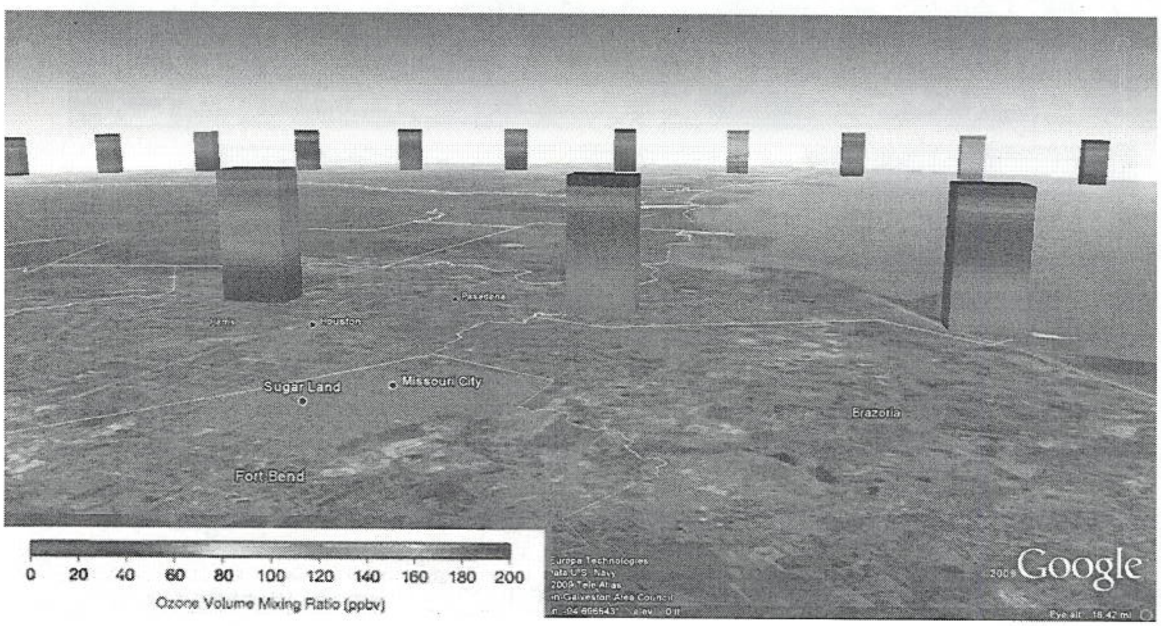

Figure 3: Visualization of satellite ozone profiles using Google Earth for the Houston area in July 2008. Colors indicate ozone concentration (red indicates high amounts of ozone). Satellite data can identify pollutants aloft, and support analyses for the SIP planning process.

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 O_3, 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.

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