The Sensitivity of Surface Ozone Formation as Inferred from OMI Formaldehyde and Nitrogen Dioxide Tropospheric Column Data

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Abstract

We investigated variations in the sensitivity of surface ozone formation in summer to precursor species concentrations of volatile organic compounds (VOCs) and nitrogen oxides (NOx) as inferred from the ratio of tropospheric columns of formaldehyde (HCHO) and nitrogen dioxide from the Aura Ozone Monitoring Instrument (OMI). The data indicate that ozone formation became more sensitive to NOx over most of the U.S. from 2005 to 2007 because of substantial decreases in emissions from stationary sources, and more sensitive to NOx with increasing temperature, in part because emissions of highly reactive, biogenic isoprene increase with temperature, thus increasing the total VOC reactivity. Based on our interpretation of the data, current strategies implemented to reduce unhealth levels of surface ozone should focus on reducing NOx emissions, even in cities which have historically benefited from reductions in both NOx and VOC emissions (e.g., Los Angeles, New York City).

HCHO/NOx: Variability from Variations in NOx

The figure shows the monthly-average HCHO/NOx for the southwestern, Midwestern, and northeastern U.S for August 2006. Many urban areas (e.g., Los Angeles, Chicago, and New York City) have downtown ratios less than 1, indicating that the instantaneous ozone production rate is limited by the concentration of VOCs there.

HCHO/NOx: Air Quality Indicator

An air quality indicator indicates which ozone precursor species, volatile organic compounds (VOCs) or nitrogen oxides (NOx), limit the instantaneous rate of ozone production. Sillman [1995] (Sillman, S. The use of NOx, HCHO, and NO2 as indicators for O3 and PM2.5 sensitivity in urban locations. J. Geophys. Res. 100, 14757-14768, 1995) pioneered the use of ratios of in situ data (e.g., H2O/NOx) to provide guidance on the development of emission control strategies with the intent to reduce unhealth levels of surface ozone. Martin et al. [2004] (Martin, R. A., F. Farre, and A. Van Donkelaar. Space-based diagnosis of surface ozone sensitivity to anthropogenic emissions. Geophys. Res. Lett. 31, L06120, doi:10.1029/2004GL019416, 2004) applied this concept to the ratio of the tropospheric columns of HCHO and NOx from the GOME instrument. Here we use the same ratio from the OMI, which has a three horizontal resolution than GOME.

HCHO/NOx: Range of Ratios

The figure shows that there was a considerable range of monthly ratios during summer from 2005-2007 (i.e., 9 months to all). The minimum monthly HCHO/NOx is shown in the left column and the maximum is shown in the right column.

While there were no clear trends in HCHO during the summers of 2005-2007, there was significant variation, mainly associated with the temperature dependence of emissions of biogenic isoprene. This implies that cities, which have isoprene contributing significantly to their total VOC reactivities, become more NOx-limited during heat waves; this is important as high ozone episodes are more frequent during heatwaves than in cooler periods. This effect is most clearly seen in cities with high biogenic emissions (e.g., Atlanta and NYC).