Weekly cycles of NO_x and O_3 concentrations as a function of land use type and O_3 production sensitivity

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Goals: Understanding observed and modeled weekly cycles of ground-level O_3

▪Photochemical ozone production in the lower troposphere is dependent upon chemical environment, which is heavily influenced by the ratio of VOCs to NO_x emissions. Thus, weekly variations of surface O_3 concentrations need to be investigated to understand the controlling effects of the key precursors on the O_3 concentrations.

▪Previous studies have focused on weekly O_3 variations over several metropolitan areas and their neighboring regions, such as New Jersey, Southern California, Los Angeles, Atlanta, Chicago, Denver, NYC, Chicago, Dallas, Houston, Phoenix, and Washington, DC, and Baltimore (e.g., Lebron, 1967; Cleveland et al., 1974; Elkus and Wilson, 1977; Vukovich, 2000; Marr and Harley, 2002; Fujita et al., 2003; Qin et al., 2004; Blanchard and Tanenbaum, 2006; Shutters and Balling Jr., 2006; Blanchard et al., 2008; Yarwood et al., 2008). These studies highlights the weekend effect over urban areas where higher ground-level O_3 concentrations occur during weekends rather than weekdays.

▪Estimating a photochemical indicator, which is obtained by the ratio of VOCs to NO_x emissions, is crucial to understand about photochemical O_3 production because the production is strongly affected by photochemical environment. Sillman et al. (1990) and Sillman (1999) introduced a photochemical indicator that uses ratios of chemical species to represent O_3-NO_x-VOC sensitivity for a particular geographical area. Recently, Martin et al. (2004) and Duncan et al. (2010) utilized the ratio of satellite HCHO to NO_2 column density from GOME and OMI as a photochemical indicator.

Approaches: the Community Multiscale Air Quality (CMAQ) model version 4.7.1 and satellite resources

1. Model Setup and Method

▪Time period: August 2009 (the greatest O_3 biases from NOAA National Air Quality Forecasting Capability (NAQFC) were shown during 2007 through 2009)
▪Version : CMAQ4.7.1 (12km with 22 vertical layers to 100 hPa)
▪To investigate the difference of weekly cycles of surface NO_x and O_3 concentrations at EPA's AQS stations over geographical regions and chemical regions, we divided 12km CMAQ model grids covering the whole CONUS into two different types of satellite-derived classifications: The AVHRR-derived USGS LULC regions (i.e., urban, forest, and other region) and GOME-2 derived and CMAQ-derived chemical regimes (i.e., NO_x-saturated, NO_x-sensitive, and mixed regime).

2. Measurements

2.1 Satellite measurement

▪Satellite NO_2 and HCHO column density: from GOME-2 sensor on EUMETSAT MetOp-A satellite
▪GOME-2 NO_2 and HCHO column products (http://www.temis.nl/airpollution)
▪1km AVHRR USGS LULC data are from Global Land Characteristics Data Base version 2.0 (http://edc2.usgs.gov/glcc/globdoc2_0.php).

2.2 In-situ ground measurement

▪Hourly O_3 data: 1100 US EPA's AQS stations
▪Hourly NO_x data: 265 US EPA's AQS stations

Results:

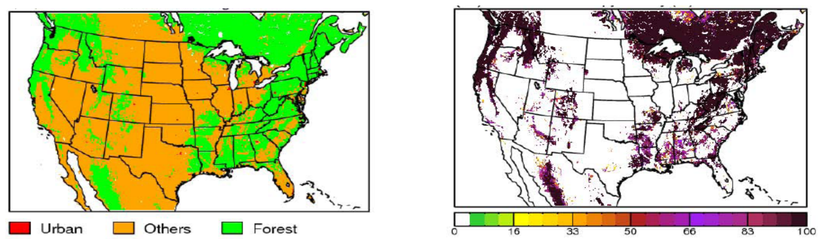

Fig1. AVHRR USGS LULC geographical regions (red: urban region including USGS LULC type 1, green: forest region including USGS LULC types 11-15, and orange: other region including all the rest except urban region, forest region, and water bodies (left panel) and canopy density mapped into 12km CMAQ model grids (right panel).

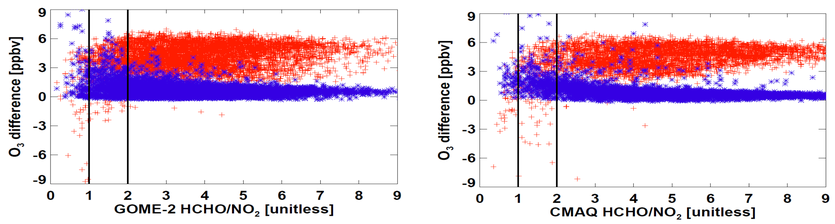

Fig2. Surface O_3 differences between baseline CMAQ and CMAQ with 30% NOx (red colored) or VOC emissions (blue colored) reduction as a function of GOME-2 HCHO to NO_2 column density (left panel) and CMAQ HCHO to NO_2 column density (right panel). The ozone differences are estimated by daytime (1-5PM, local time) during August 2009.

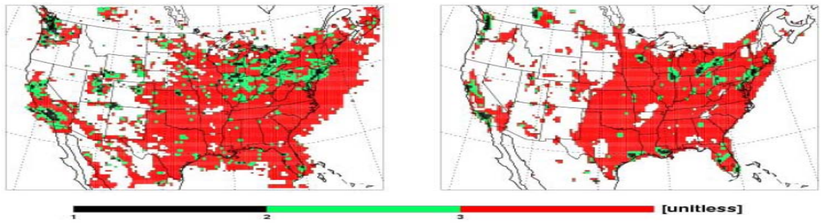

Fig.3 GOME-2 derived and CMAQ-derived chemical regimes using two transitions (1 and 2, see Fig. 2) using the ratio of GOME-2 HCHO to NO_2 column density (left panel) and CMAQ HCHO to NO_2 column density (right panel). The black represents category 1 region (HCHO/NO_2 <1, a NO_x-saturated regime), green represents category 2 (1<HCHO/NO_2<2, a mixed regime) and red represents category 3 region (HCHO/NO_2 >2, a NO_x-sensitive regime).

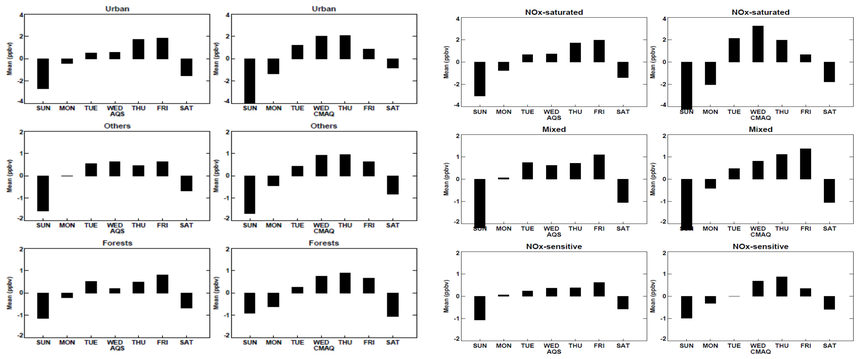

Fig.4 Weekly anomalies of AQS-obseved and CMAQ-simulated ground-level NO_x concentrations at EPA's AQS stations over AVHRR-derived geographical regions (left two columns) and GOME-2 derived chemical regimes (right two columns) for August 2009. For the consistency, only daytime (1-5PM, local time) NO_x concentrations are used and some data are filtered out during August 17-19, 2009 when a tropical storm, Ana strongly affects air quality over the eastern US.

Results con.:

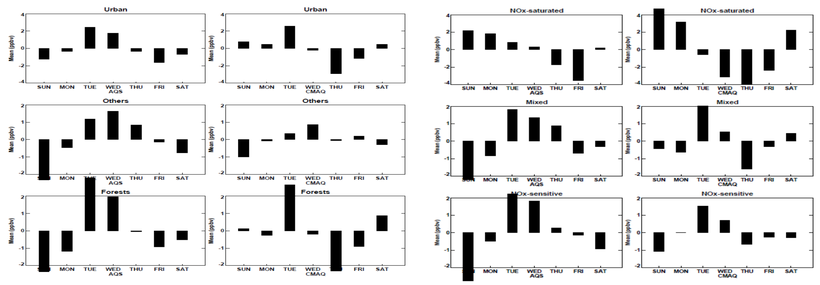

Fig 5. Same as in Fig. 4, but for ground-level O_3 concentrations.

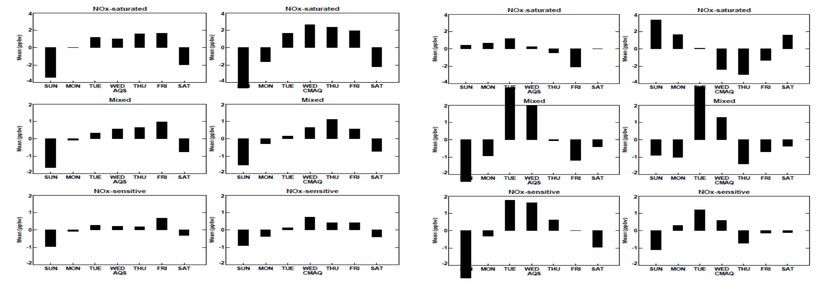

Fig 6. Weekly anomalies of AQS-observed and CMAQ-simulated ground-level NO_x at EPA's AQS NO_x stations (left two columns) and O_3 concentrations at EPA's AQS O_3 stations (right two columns) over CMAQ-derived chemical regimes for August 2009.

Conclusions:

Simulation results from the Community Multiscale Air Quality (CMAQ) model version 4.7.1 over the Conterminous United States (CONUS) for August 2009 are analyzed to evaluate how satellite-derived O_3 sensitivity regimes capture weekly cycles of the U.S. EPA's Air Quality System (AQS) observed ground-level concentrations of ozone (O_3). The AQS stations are classified according to a geographical-based land use designation or a O_3-NO_x-VOC chemical sensitivity regime. The geographical land use designations are derived from the Advanced Very High Resolution Radiometer (AVHRR) global land cover characteristic data representing three features: urban, forest, and other. The O_3 chemical regimes (NO_x-saturated, mixed, and NO_x-sensitive) are inferred from low to high values of photochemical indicators based on the ratio of HCHO to NO_2 column density from the Global Ozone Monitoring Experiment 2 (GOME-2) and CMAQ. Both AQS-observed weekly cycles of NO_x at measurement sites over AVHRR geographical regions and GOME-2 sensitivity regimes show high NO_x on weekday and low NO_x on weekend. However, AQS-observed O_3 weekly cycle at the sites over GOME-2 NO_x-saturated regime is noticeably different from that over AVHRR urban region. Whereas weekend high O_3 anomaly is clearly shown at sites over GOME-2 NO_x-saturated regime in both AQS and CMAQ, the weekend effect is not captured at other sites over AVHRR urban region. It was also found that the weekend effect from AQS is more clearly shown at the sites over GOME-2 NO_x-saturated regime than other sites over CMAQ NO_x-saturated regime. This study suggests that chemical classification into GOME-2 chemical regime stations gives a more detailed picture for weekly O_3 cycles than CMAQ chemical or AVHRR geographical classification.

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