Spatial and temporal variability of ozone and nitrogen dioxide over a major urban estuarine ecosystem

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ABSTRACT:

Spatial and temporal dynamics in trace gas pollutants were examined over a major urban estuarine ecosystem, using a new network of ground-based Pandora spectrometers deployed at strategic locations along the Washington-Baltimore corridor and the Chesapeake Bay. Total column ozone (TCO_3) and nitrogen dioxide ($TCNO_2$) were measured during NASA's DISCOVER-AQ and GeoCAPE-CBODAQ campaigns in July 2011. The Pandora network provided high-resolution information on air-quality variability, local pollution conditions, large-scale meteorological influences, and interdependencies of ozone and its major precursor, NO_2. Measurements were used to compare with air-quality model simulations (CMAQ), evaluate Aura-OMI satellite retrievals, and assess advantages and limitations of space-based observations under a range of conditions. During the campaign, $TCNO_2$ varied by an order of magnitude, both spatially and temporally. Although fairly constant in rural regions, $TCNO_2$ showed clear diurnal and weekly patterns in polluted urban areas caused by changes in near-surface emissions. With a coarse resolution and an overpass at around 13:30 local time, OMI cannot detect this strong variability in NO_2, missing pollution peaks from industrial and rush hour activities. Not as highly variable as NO_2, TCO_3 was mostly affected by large-scale meteorological patterns as observed by OMI. A clear weekly cycle in TCO_3, with minima over the weekend, was due to a combination of weekly weather patterns and changes in near-surface NOx emissions.

** The Giovanni online data system was used in this study to examine ozone (TCO_3) spatial variability over the Eastern U.S from Aura-OMI.*

ACKNOWLEDGEMENTS:

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Introduction

Photochemical smog (NO_x and ozone pollution) remains a serious problem in many coastal cities worldwide, both in industrialized and, particularly, in developing economies where rapid coastal urbanization is presently occurring. High resolution ground-based measurements of trace gases are essential in urban coastal areas to: 1) better understand atmospheric dynamics at higher spatial resolution than is currently available from satellite observations, 2) capture the high temporal variability associated with local pollution patterns and photochemical processes, and 3) make measurements of atmospheric trace gases and pollutants relevant to our understanding of urban and coastal ecosystem dynamics.

Here, we present new, high-resolution, continuous measurements of total column O_3 and NO_2 spatial and temporal variability over the Washington DC / Baltimore metropolitan area and the Chesapeake Bay estuary, using a new network of ground-based Pandora spectrometer systems. The small size and portability of the Pandora instruments allowed deployment at strategic locations within this major urban estuarine system. This in turn allowed us to capture, *for the first time*, short-term and small-scale dynamics in trace gas amounts along this coastal regions, and assess influences of both regional near-surface pollution emissions and larger scale meteorological processes.

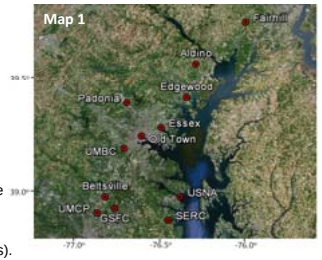
Methods

♦ Measurements were performed during July 2011, as part of two simultaneous field campaigns in the region: the DISCOVER-AQ (Deriving Information on Surface Conditions from Column and Vertically-Resolved Observations Relevant to Air Quality) and the GeoCAPE-CBODAQ (Geostationary Coastal and Air Pollution Events-Chesapeake Bay Oceanographic Campaign with DISCOVER-AQ) field campaigns.

♦ Ground-based measurements of trace gases (O_3 and NO_2) were performed using a network of Pandora spectrometers (Map 1).

♦Pandora measurements were compared to Aura-OMI satellite retrievals (OMNO2-L2OVP and OMI-TOMS $OMTO_3$ V8.5 products).

♦ Ground based and satellite retrievals were compared to model simulations using the Environmental Protection Agency's (EPA) Community Multiscale Air Quality (CMAQ) at a horizontal resolution down to 1.33 km for the entire DISCOVER-AQ field campaign.



Results

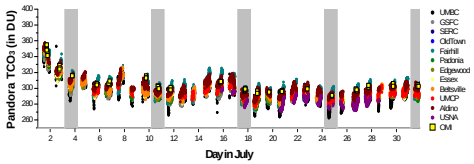


Figure 1: Spatial and temporal variability in TCO_3 as observed by the Pandora network (circles) and Aura-OMI (squares). Sharp gradients in TCO3 by 50 DU at the beginning of the campaign were due to large scale meteorological processes transporting air masses with higher ozone content over the northeastern US coast (see Figure 2). A clear weekly cycle in ozone of about 10 DU and minimum values on Sundays (indicated by the shaded areas) was observed at most sites. Air quality model simulations suggest that this weekly minimum in TCO_3 is partly due to lower NOx emissions over the weekend (see Figure 5).

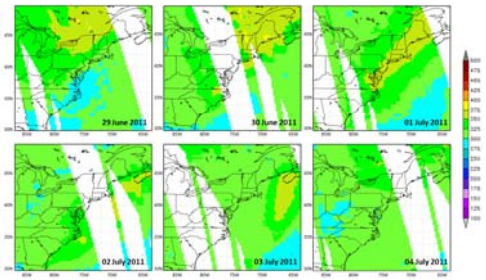


Figure 2. Aura-OMI TCO_3 (DU) over the Eastern U.S. during June 29th and July 4th, 2011.The OMI images reveal the passage of a front moving from North to South and transporting air masses with higher TCO_3, in the range of 350 to 375 DU, over the Washington DC - Chesapeake Bay area on June 30th and July 1st. On July 2nd, TCO_3 over the area dropped to 325-350 DU, decreasing to 300-325 DU on July 3rd and July 4th. These OMI TCO_3 maps (OMI/Aura TOMS-like ozone product) were produced with the Giovanni online data system, developed and maintained by the NASA GES DISC.

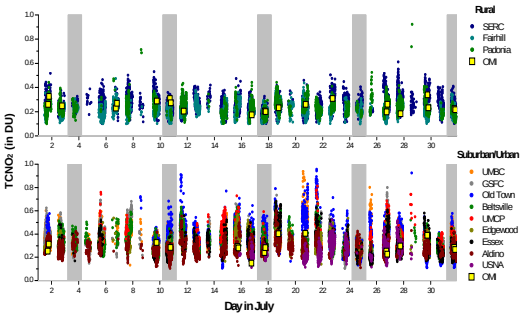


Figure 3: Spatial and temporal variability in TCO_3 (in DU) as observed by the Pandora network (circles) and Aura-OMI (squares). Pandora sites are grouped from rural (upper panel) to suburban (mid panel) and urban (lower panel). Measurements during Sundays are indicated by the shaded area. Although quite constant at rural sites, and typically less than 0.4 DU, total column NO_2 varied by as much as an order of magnitude in areas closer to highly polluted urban centers. In these regions, NO_2 showed a well defined weekly behavior and strong diurnal patterns associated with human activities and rush-hour peaks in near-surface NOx emissions. These observed patterns in NO_2 were consistent with high-resolution air-quality model simulations using CMAQ (see Figure 4 A, B).

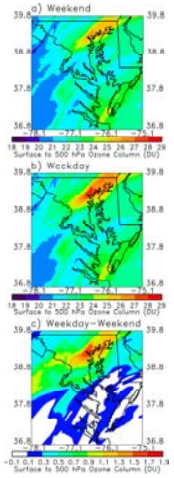


Figure 5. CMAQ simulated surface to 500 hPa ozone column on Sunday, 17 July 2011 at 1800-1900 UTC using: (a) emissions appropriate for each day of the week (i.e., Sunday emissions), and (b) emissions appropriate for Wednesday, 13 July 2011. Differences between the two CMAQ runs are shown in (c), and illustrate the weekday/weekend effect of emissions changes on tropospheric O_3. Decreases in ground-level ozone amounts due to lower NOx emissions over the weekend could be partly responsible for the observed weekly pattern in TCO3 (shown in Figure 1). Weekly weather patterns affecting mainly upper tropospheric and stratospheric ozone amounts were most likely also partly responsible, as the TCO_3 weekly pattern was observed across the whole region, at both rural and urban sites, and it was also detected to a certain degree by OMI (square symbols in Figure 1).

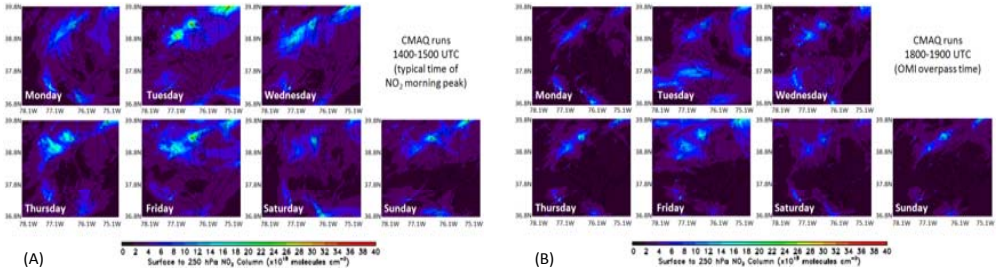


Figure 4. Weekly behavior in NO_2 (surface to 250 hPa) as predicted by CMAQ. Daily averages during 4-31 July 2011 are shown here for: (A) 1400-1500 UTC, when maximum values in $TCNO_2$ typically occur at highly polluted urban sites, associated with morning rush-hour emissions; and (B) 1800-1900 UTC, during OMI overpass time, when spatial and day-to-day variability in $TCNO_2$ are considerably reduced. On a sun-synchronous polar orbit and with an overpass at around 13:30 local time, OMI misses the morning and late afternoon rush-hour peaks in $TCNO_2$ observed over urban areas on most weekdays, providing a satellite image of $TCNO_2$ under relatively low near-surface emission conditions.