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ANALYZING METEOROLOGICAL AND CHEMICAL CONDITIONS FOR TWO HIGH OZONE EVENTS OVER THE NEW YORK CITY AND LONG ISLAND REGION

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ABSTRACT

This study investigated ozone (O_3) formation conditions during two high O_3 events in July of 2018 over the New York City metropolitan and Long Island area using surface meteorological observations, surface concentration measurements of O_3, NO_2, CO and $PM_{2.5}$, and tropospheric column CO, HCHO, NO_2 from TROPOMI satellite measurements. We found that both events are associated with high temperature with maximum temperature above 31 ˚C. However, TROPOMI data showed high tropospheric column CO and HCHO, low NO_2 and large HCHO/NO_2 ratios over the study area in Event 1; while the opposite is seen in Event 2, with lower CO and HCHO, higher NO_2 and lower HCHO/NO_2 ratios over the study area. Precursor conditions which formed the high O_3 differed. For Event 1, it was the fire-induced smoke (VOCs) that contributed to the high spike of ground-level O_3, and most of the study area was a NOx-limited or a transitional regime. For Event 2, it was more like a normal high NO_2 event, which resulted in a more widespread VOC-limited regime.

Index Terms — Surface O_3 concentration, Temperature, TROPOMI, NOx and VOCs, tropospheric column CO, HCHO and NO_2

1. INTRODUCTION

Surface ozone (O_3) is a secondary air pollutant produced during the atmospheric photochemical oxidation of emitted volatile organic compounds (VOCs) in the presence of sunlight and nitrogen oxides (NOx) [1]. Nitrogen oxides and VOCs play important roles in tropospheric chemistry, participating in O_3 and aerosol production [2]. Temperature directly influences O_3 production by accelerating the rates of chemical reactions and increasing the emissions of VOCs. In the absence of total VOCs information, one can use the formaldehyde (HCHO) concentration as a proxy for VOCs [3].

The NO_2 and HCHO column amount in the atmosphere can be measured using satellite-based instruments. The previous studies showed that HCHO and NO_2 from the Ozone Monitoring Instrument (OMI) satellite serve as appropriate indicators for in situ observations of total reactive nitrogen and VOCs [4][5][6]. A tropospheric HCHO/NO_2 ratio <1 suggests that O_3 formation is more influenced by changes in VOCs concentrations (i.e., VOC-limited conditions), whereas HCHO/NO_2 ratio > 2 represents NOx-limited conditions. The ratio between 1 and 2 indicates a transitional condition (regime) where both NOx and VOC reductions may decrease O_3 formation [4][7].

The TROPOspheric Monitoring Instrument (TROPOMI), launched on 13 October 2017, aboard the Sentinel-5 precursor satellite, measures reflected sunlight in the ultraviolet, visible, near-infrared, and shortwave infrared spectral range to track several atmospheric pollutants. It is expected to revolutionize the way we monitor air pollution from space because of its unprecedented spatial resolution (3.5 km x 7 km at the beginning of the mission and 3.5 km x 5.5 km since 6 August 2019) [2].

In this study, we present an observation-based analysis of two high O_3 events that happened in July 2018 in the New York City (NYC) metropolitan and Long Island region and their meteorological and chemical conditions to understand the high O_3 formation over this area.

2. DATA AND METHODS

The study focused over the NYC and Long Island region. NY State has 11 surface stations in this region that measure hourly O_3 concentration regularly. There were two high O_3

events in early July, 2018. Event 1 was from June 30 to July 2, and Event 2 was from July 9 to 10. A high O_3 event is defined as period with several surface stations over the study region with maximum daily 8-hour average O_3 concentrations exceeding the U.S. National Ambient Air Quality Standards (NAAQS) of 70 ppb. The meteorological variables, i.e., 2m temperature, relative humidity and wind speed and direction, were analyzed from three Automated Surface Observing System (ASOS) stations: LaGuardia Airport (LGA), White Plain-Westchester County Airport (HPN) and Farmingdale Republic Airport (FRG), to represent the meteorological conditions over the study region.

In addition to O_3, concentrations of CO, NO_2 and $PM_{2.5}$ from the New York State Department of Environmental Conservation (NYSDEC) Queens College Photochemical Assessment Monitoring Stations (PAMS) site were analyzed.

TROPOMI is designed to retrieve the concentrations of several atmospheric constituents including O_3, NO_2, CO, HCHO, CH_4 and aerosol properties. Due to its high spatial resolution, TROPOMI observations are suitable to monitoring polluting emission sources at the city level [2]. The TROPOMI satellite orbit passes the equator at 1:30pm local solar time. The tropospheric column CO, HCHO, NO_2 and the HCHO/NO_2 ratios from TROPOMI were compared between the two high O_3 events to understand the O_3 formation conditions.

3. RESULTS AND MAJOR FINDINGS

For most of the high O_3 days, the temperatures [Figure 1(a)] were very high with maximum values above 31 ˚C and the relative humidity values were low, which indicated a clear sunny day. Winds were predominantly from the southwest, indicative of transport of O_3 precursors from Maryland, Pennsylvania, New Jersey up to the study area. These upwind emissions added to the local emissions, which were also contributing to O_3 locally.

The Queens College onsite measurements of surface O_3, NO_2, $PM_{2.5}$ and CO [Figure 1 (b)] showed very high hourly O_3 values during the two events and there were high CO concentrations during early morning hours during the high O_3 events, especially in Event 1. The $PM_{2.5}$ value was also high in Event 1.

TROPOMI data can provide the spatial patterns and details of air pollution over this region. On July 1st and 2nd, the tropospheric column NO_2 values [Figure 2(c)] are low over the study region. A small area with high NO_2 reaching to $1.4x10^{16}$ mol/cm^2 is centered at the inner city. All the other areas have NO_2 lower than $6.0x10^{15}$ mol/cm^2. On July 9th and 10th, higher NO_2 [Figure 3(c)] with a west-east orientation covered the city area and half of Long Island. The relatively high NO_2 along the Interstate 95 corridor is evident on both events. The column CO and HCHO display the opposite patterns, with high values in Event 1 [Figure 2 (a) (b)] and low values in Event 2 [Figure 3 (a) (b)].

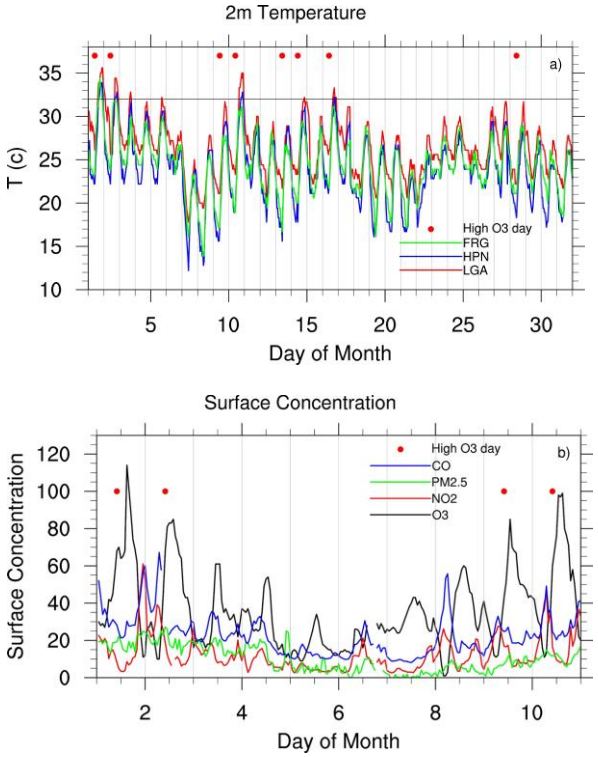

Figure 1. The diurnal variation of (a) 2m temperature at three different ASOS stations in the NYC and Long Island region, (b) surface concentrations of O_3, NO_2, $PM_{2.5}$ and CO measured from the Queens College site in July 2018. The red dot indicates a high O_3 event day on which there are at least one station over the NYC and Long Island region with maximum daily 8-hour average O_3 concentrations exceeding the U.S. National Ambient Air Quality Standards (NAAQS) of 70 ppb. The unit is ppb for O_3 and NO_2, μg/m^{3}LC for $PM_{2.5}$ and ppb/10 for CO.

Several studies [8] [9] found that distant wildfires can raise ground-level O_3 concentrations to unhealthy levels even at large distances from the fire sites. The column HCHO (proxy for high VOCs), surface level CO and $PM_{2.5}$ from Queens College and the NOAA HRRR-Smoke model (https://rapidrefresh.noaa.gov/hrrr/HRRRsmoke/) indicated smoke over this region contributed to degraded air quality during Event 1.

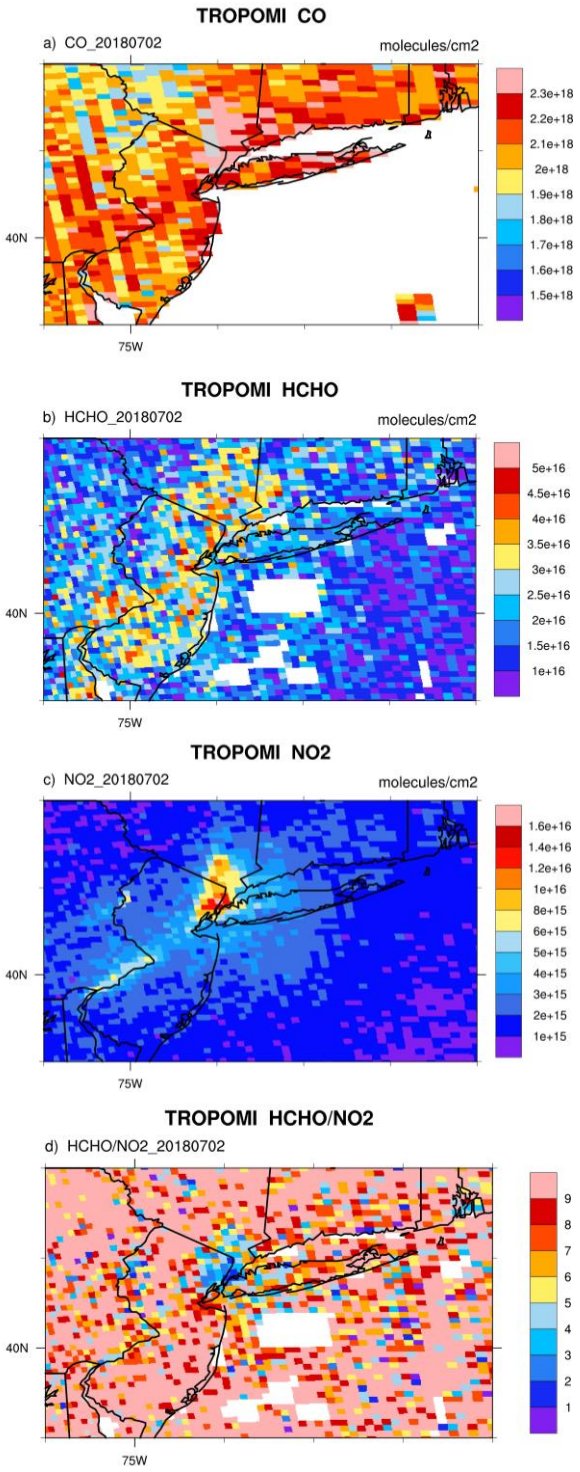

Figure 2. The tropospheric (a) CO columns, (b) HCHO columns, (c) NO_2 columns, and (d) HCHO/NO_2 ratios from TROPOMI measurements on July 2nd, 2018.

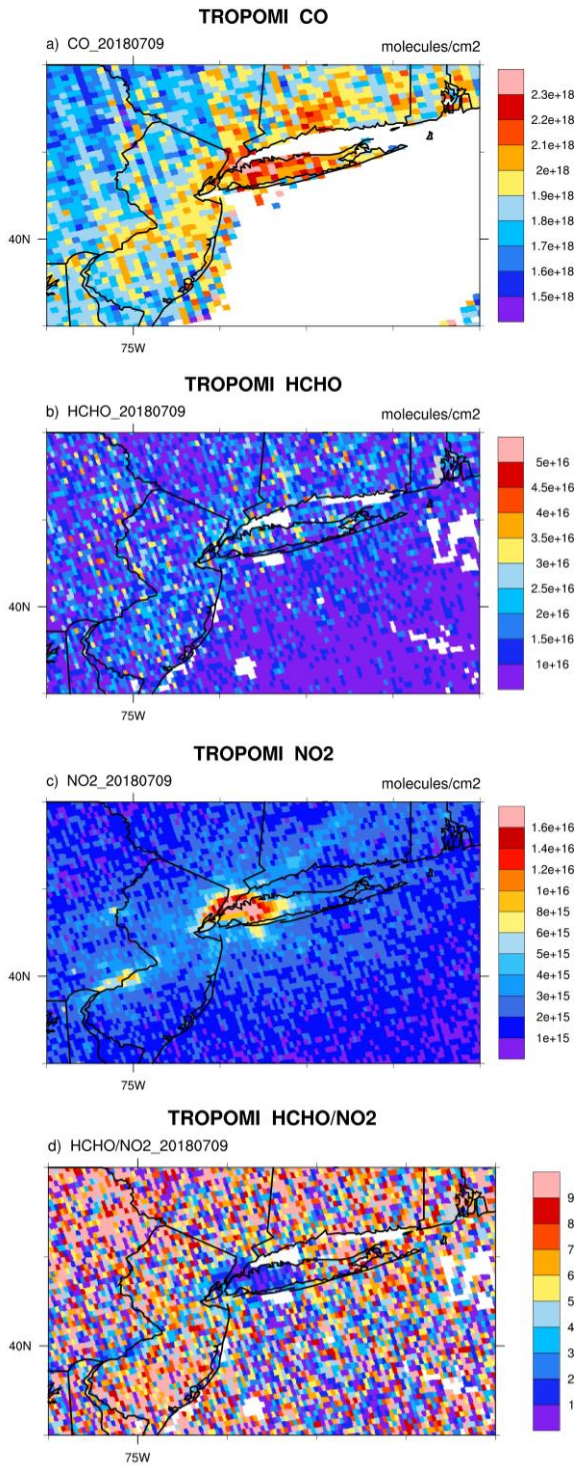

Figure 3. Same as Figure 2 but from the TROPOMI measurements on July 9th, 2018.

Based on TROPOMI data, a previous study (Xiaomeng Jin, personal communication) suggested that O_3 formation decreases with decreasing VOCs at HCHO/NO_2 ratios <2 and NOx at ratios >4; both NOx and VOCs reductions may decrease O_3 formation for ratios between 2 and 4.

The $HCHO/NO_2$ ratios in Event 1 [Figure 2 (d)] in this study are between 2 and 5 in the core urban area and larger than 5 for most surrounding areas. There are very limited areas that showed the ratios smaller than 2. This means that during this episode Long Island was generally a NOx-limited regime while the core of NYC was mostly a transitional regime.

In Event 2 [Figure 3 (d)], there is a relatively large area covering the NYC and half of the Long Island with ratios smaller 2. Clearly, the study region was more VOC-limited during this high O_3 event.

This study showed the possibility to use the TROPOMI data to distinguish the daily variability of O_3 chemistry. The $HCHO/NO_2$ ratio is a good indicator to determine the sensitivity of surface O_3 to precursors. The O_3 formation could be sensitive to VOCs, NOx or both during a high O_3 event in the NYC and Long Island region. A good understanding of the O_3 formation conditions will help us to accurately identify control strategies to achieve the air quality goals for NY State.

The O_3 formation for a given location varies throughout the day and from day to day because of changes in meteorological conditions and precursor emissions [4][10][11]. The sensitivity of O_3 to precursors at morning times for these two events is unknown due to the TROPOMI afternoon overpass, and a lack of hourly measurements of HCHO or other VOCs. A geo-stationary satellite will benefit us for monitoring air quality and understanding the O_3 diurnal formation and change. Currently, NY is not requesting EPA to make an exceptional event determination for any ozone exceedances measured. While our analysis concluded that the smoke may have contributed to the measured ozone concentrations, we could not quantify that contribution.

4. REFERENCES

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6. ACKNOWLEDGMENTS

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7. DISCLOSURE STATEMENT

This scientific results and conclusions, as well as any views or opinions expressed herein, are those of the authors and do not necessarily reflect the views of New York State Department of Environmental Conservation.