# Supplementary Materials

# The Status of Air Quality in the United States during the COVID-19 Pandemic: A Remote Sensing Perspective

## 1.1 Validation of the Tropospheric Column Ozone (TCO)

Here we demonstrate the validity of the TCO product. Each figure is self-explained via a caption that describes the validation results. The analysis below include ozonesonde - TCO (Figure S 1, Figure S 2) and OMI/MLS - TCO (Figure S 3, Figure S 4) cross-evaluations. Both, ozonesondes and OMI/MLS are established products. We also show the OMPS/MERRA2 TCO (in Dobson Units, DU) seasonal climatology global maps derived using data from January 2012 – December 2019.

**OMPS/MERRA2 TCO comparisons with ozonesonde**

Comparisons between collocated ozonesonde and OMPS/MERRA-2 tropospheric column ozone in the tropics and extra-tropics indicate mean differences varying from near zero to at most ~±6 DU, respectively, with standard deviations from a few DU in the tropics to at most ~6-8 DU in mid-high latitudes [Figure S 1].

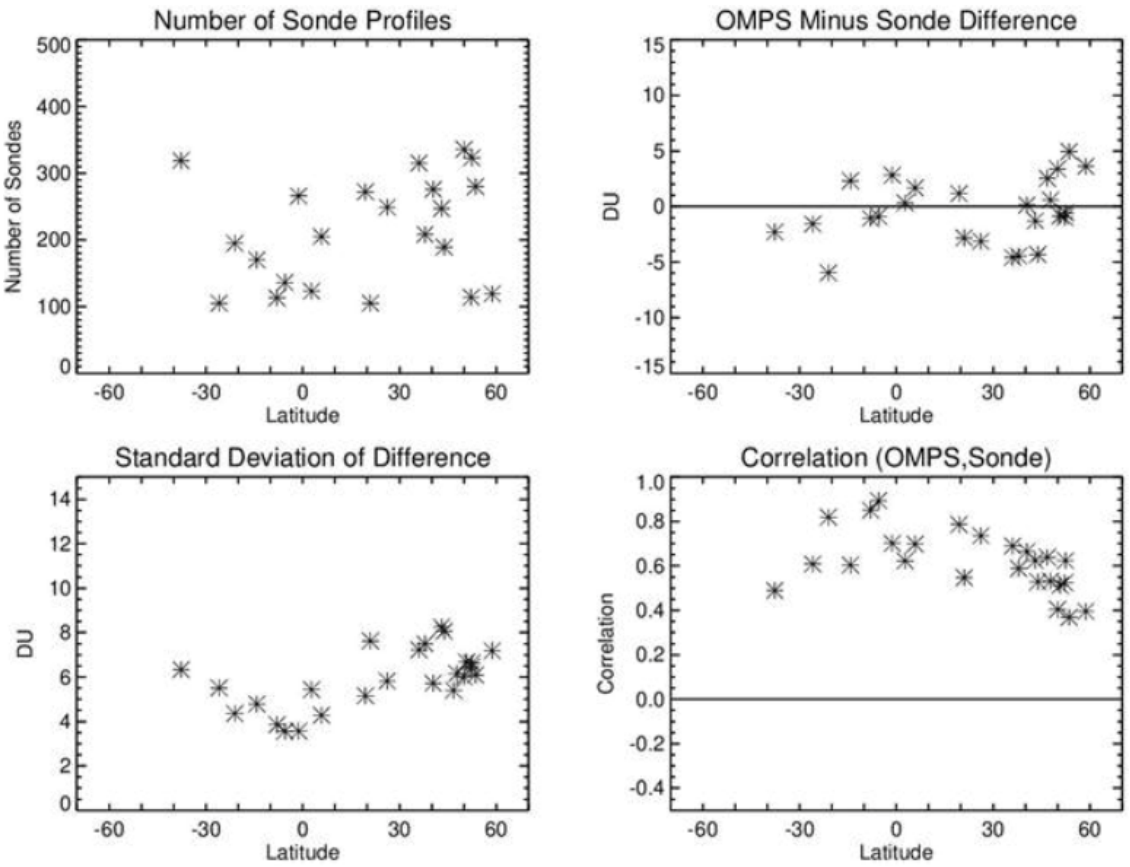


Figure S 1: Statistical analyses of OMPS/MERRA2 TCO based on comparisons with ozonesonde TCO. The analyses were done using co-located daily measurements for years 2013-2017 and plotted versus sonde station latitude. Both OMPS/MERRA2 and ozonesonde TCO use the same tropopause pressure each day to derive the vertically integrated TCO columns. Upper left: Total number of daily matchups. Upper right: Offset differences (DU). Lower left: Standard deviations (DU) of their difference time series. Lower right: Temporal correlation between OMPS/MERRA2 and ozonesonde TCO time series.

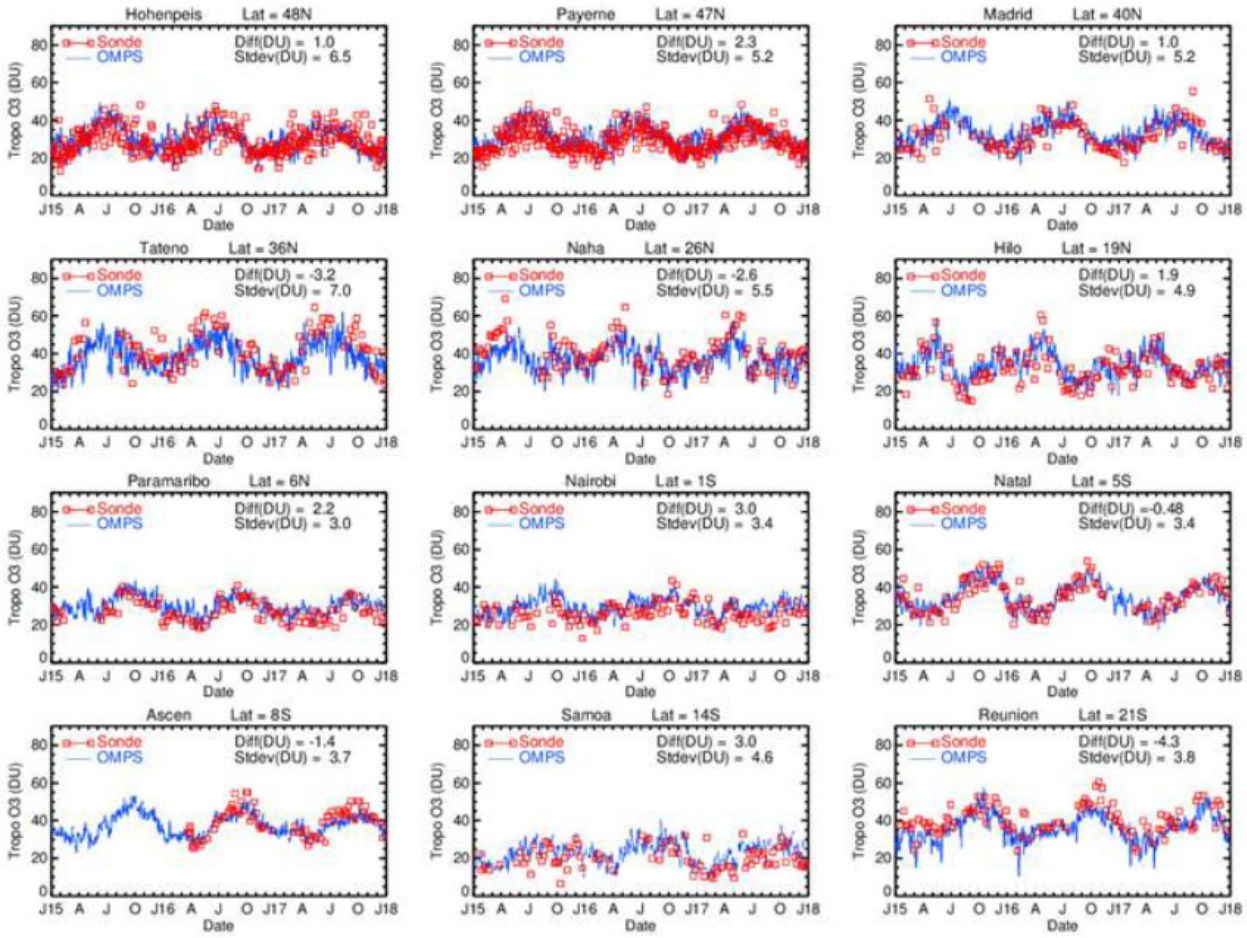


Figure S 2: Selected daily time series comparisons between OMPS/MERRA2 TCO (blue curves) and ozonesonde TCO (red boxes) for several northern hemisphere (NH) and southern hemisphere (SH) sonde station sites for years when there were 2-3 years of mostly continuous weekly ozonesonde measurements. Included in each panel are the OMPS minus sonde offset (in DU) and the standard deviation (in DU) of their difference time series for 2015-2017.

## OMI/MLS and OMPS/MERRA-2 TCO

Comparisons between collocated OMI/MLS and OMPS/MERRA-2 TCO demonstrate small difference standard deviations at only about 2-3 DU at all latitudes. These small standard deviations show that the two TCO products are capturing very similar space-time variability [Figure S 3, Figure S 4]. Mean offsets between OMI/MLS and OMPS/MERRA-2 are small, at most 2-3 DU everywhere except in mid-high latitudes in the SH where average offset is about -5 DU.

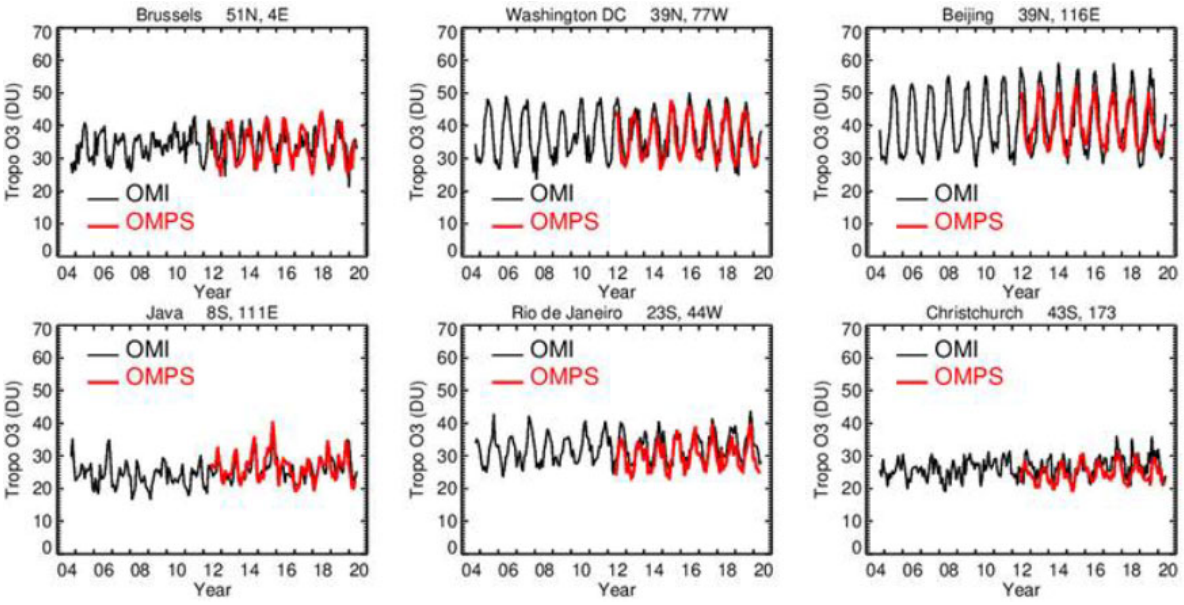


Figure S 3: Selected monthly TCO (in DU) time series comparisons at several city sites (three in NH, three in SH) between OMI/MLS (black curves) and OMPS/MERRA2 (red curves). One site shown is Washington DC (upper middle panel) that is located over the eastern coast of the United States. The OMI/MLS TCO measurements (Ziemke et al., 2006) use a different tropopause pressure definition (WMO 2K/km lapse rate definition) than OMPS/MERRA2 TCO. However, these different tropopause pressure definitions cannot produce more than ~1-2 DU time series differences between monthly OMI/MLS and OMPS/MERRA2 TCO.

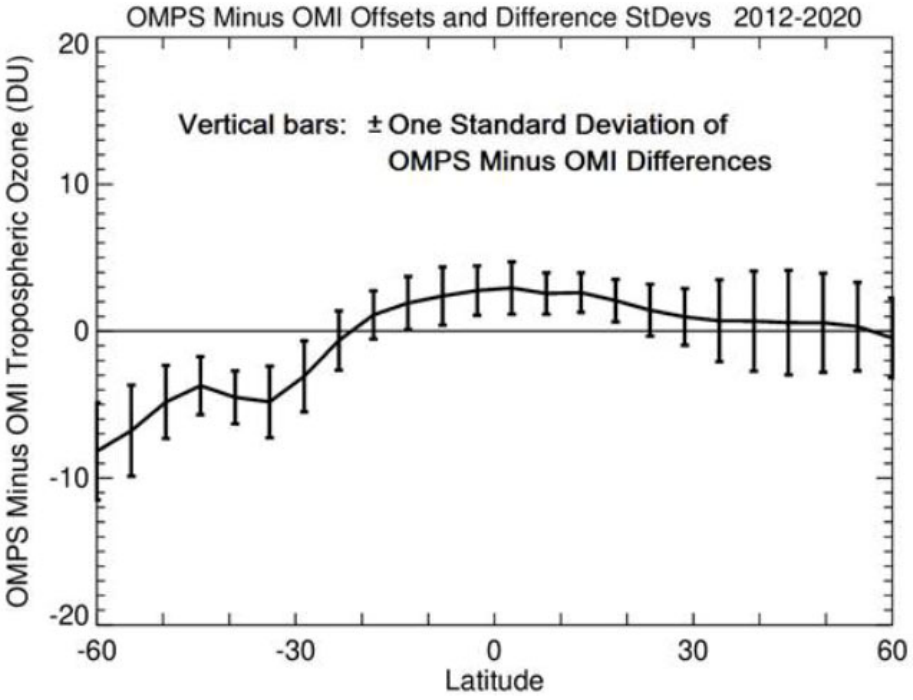


Figure S 4: OMPS/MERRA2 TCO minus OMI/MLS TCO average offsets and calculated ±1 standard deviations of their differences (shown as vertical bars). Data points for this statistical analysis are accrued over both space (longitude) and time (month) in 5-degree latitude bands. Mean offsets are small, at most 2-3 DU everywhere except in mid-high latitudes in the SH where average offset is about -5 DU. The cause for this offset in the SH is not unexpected due to having two different TCO products with very different algorithms and also instrument calibration differences that can have a latitude dependence. The difference standard deviations as shown by the vertical bars are also small at only about 2-3 DU at all latitudes. These small standard deviations show that the two TCO products are capturing very similar space-time variability.

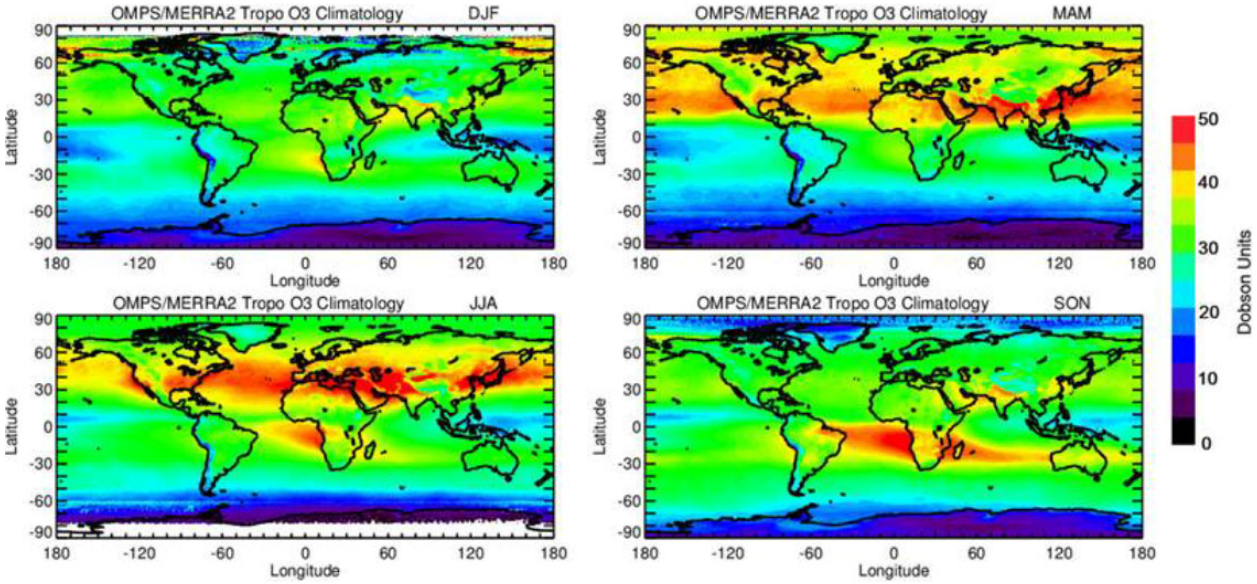


Figure S 5: OMPS/MERRA2 TCO (in DU) seasonal climatology global maps derived using data from January 2012 – December 2019. Seasonal means (indicated) are for December-January-February (DJF), March-April-May (MAM), June-July-August (JJA), and September-October-November (SON).

## Overview of AQ changes (including trends and non-significant data)

The purpose of this figure is to show the pollutants variability before removing the trends, as well as the relative change ((2020-base)/base*100), including non-significant changes.

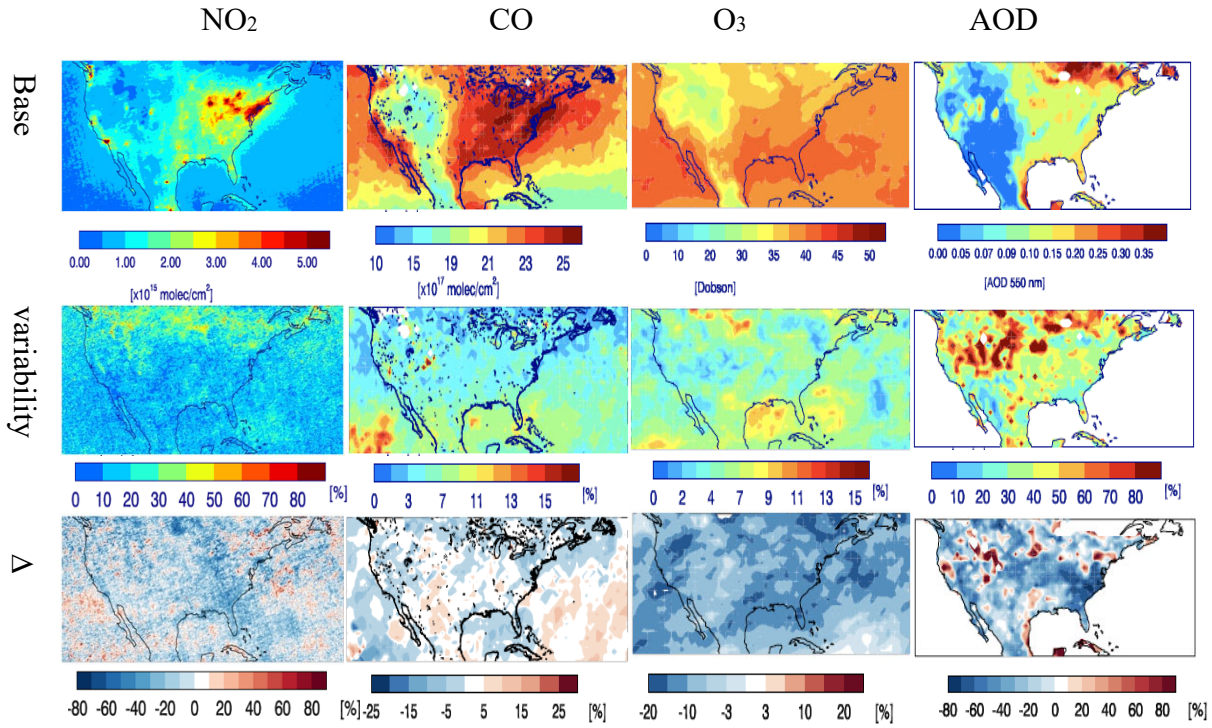


Figure S 6: Top panel: Mean pollutant levels during the base period (Base, 2015-2019); Middle panel: mean annual variability (due to trends and interannual variability) of the base period; Bottom panel: Relative change (Δ) during the lockdown period of the COVID-19 pandemic.

Daily time series of $NO_2$, and $O_3$.

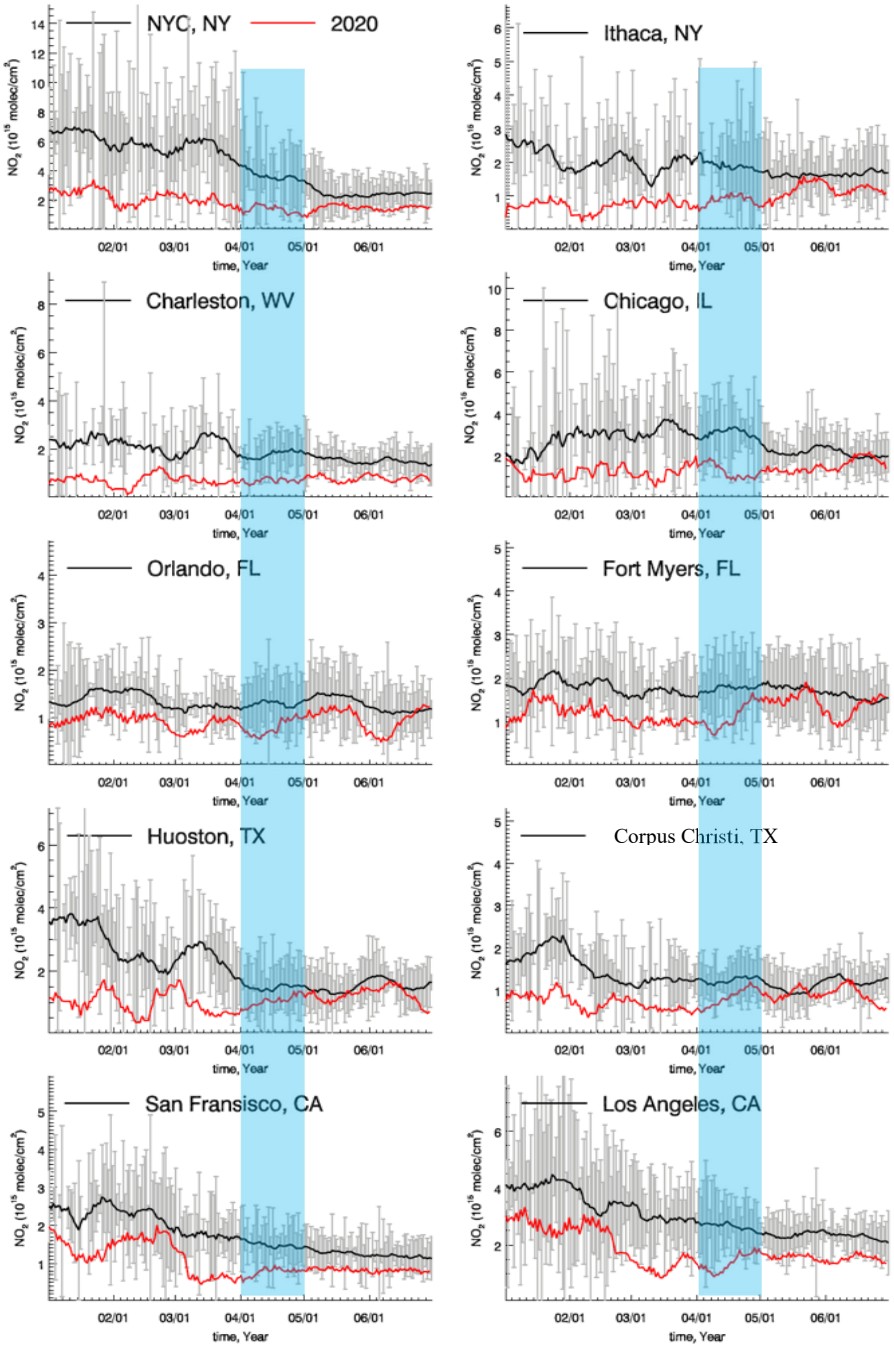


Figure S 7: 15-days running average of $NO_2$ tropospheric column during the base period (solid black line, 2015-2019); mean standard deviation of the base period (error bars); and $NO_2$ tropospheric column during the lockdown period of the COVID-19 pandemic. The time series is an average of a 1º box (lon × lat) from the respective city center and therefore may have been biased with nearby pollution sources.

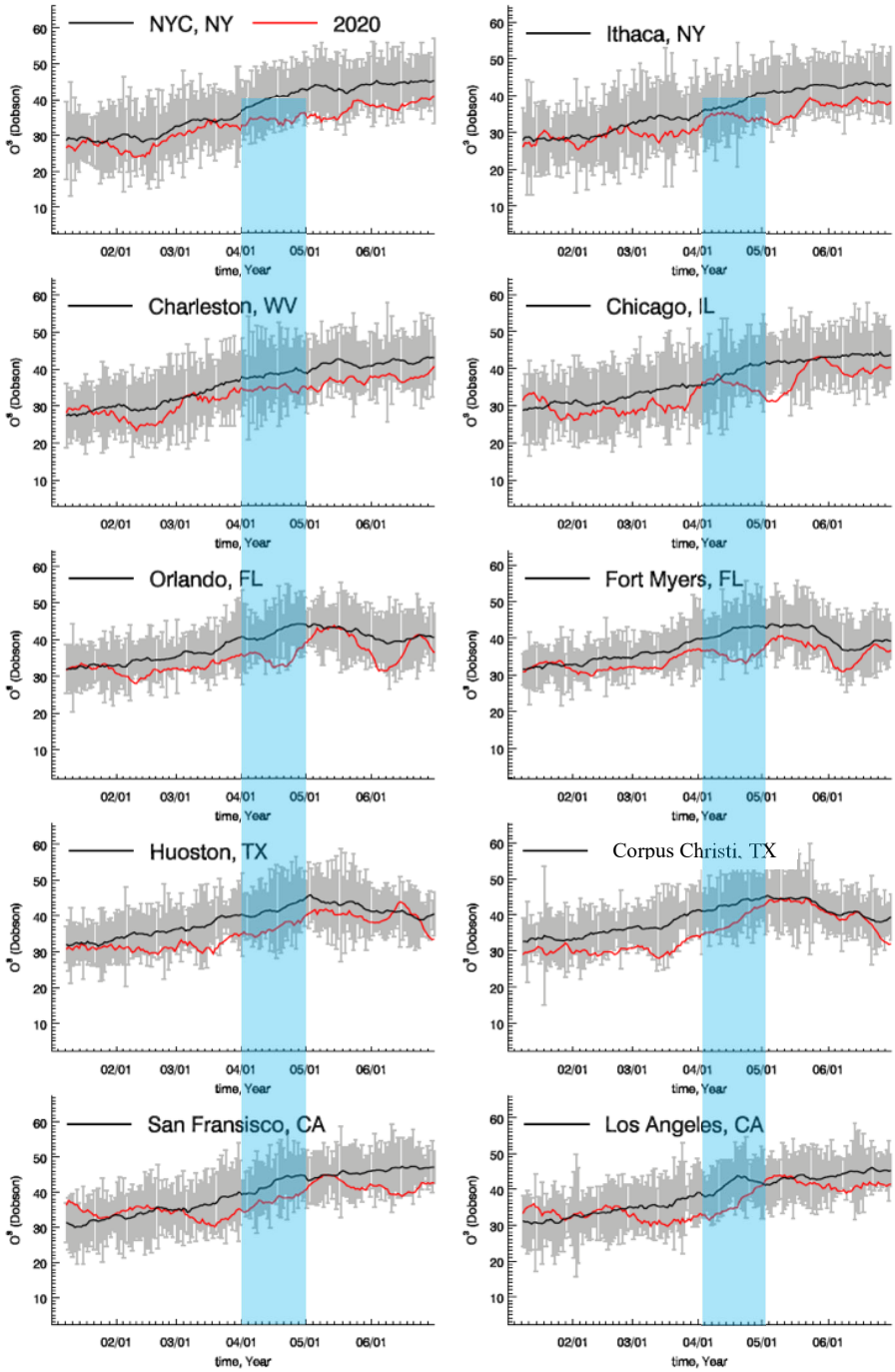


Figure S 8: Same as S 7 but for $O_3$ tropospheric column.

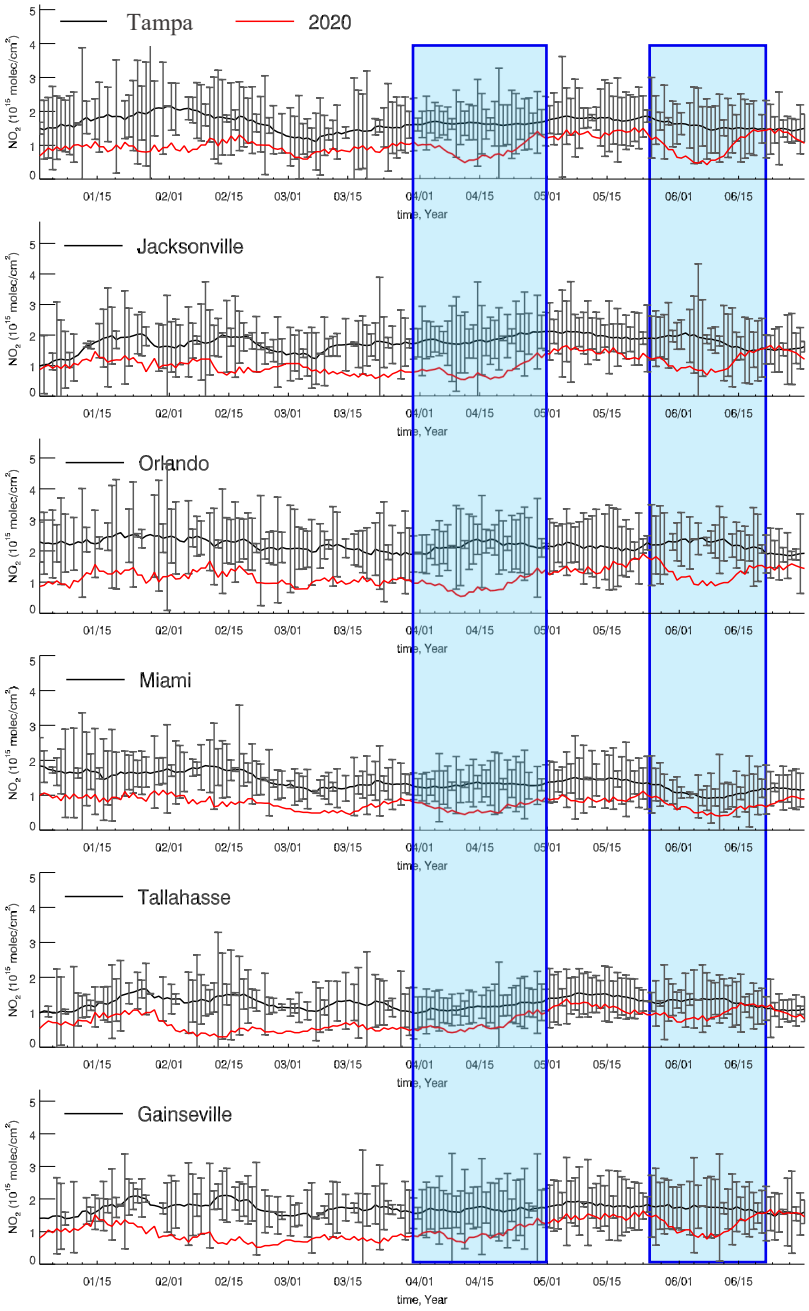


Figure S 9: Mean $NO_2$ during the base (solid black line) period (2015-2019) compared to the 2020 (solid red line).