A Comparative Analysis of Air Quality Monitoring by Orbital and Suborbital NASA Missions: A Case Study by ASDC

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Introduction

Stratospheric ozone occurs naturally in the upper atmosphere, forming a protective layer that shields us from the sun's harmful ultraviolet rays. Tropospheric ozone is not emitted directly into the air but is created by chemical reactions between nitrogen oxides (NOx) and volatile organic compounds (VOC). This reaction happens when pollutants emitted by cars, power plants, industrial boilers, refineries, chemical plants, and other sources chemically react in sunlight [1]. Therefore, increased levels of tropospheric ozone indicate the presence of pollutants in the air. While daily anthropogenic activity causes an increase of ground-level ozone, variation of stratospheric ozone changes happens much slower, so that variation of the total ozone column reflects the variation of the tropospheric column due to natural, e.g., wildfires and anthropogenic air pollution. Both total and tropospheric ozone column products are used in this study.

The reflectance spectra measured by the Earth Polychromatic Imaging Camera (EPIC) instrument aboard the Deep Space Climate Observatory (DSCOVR) spacecraft are compared with a set of radiative transfer-derived lookup tables for the EPIC filter transmission functions and a wide range of ozone values to retrieve ozone with a maximum resolution of 18 km at the sub-satellite point [2]. EPIC provides total column ozone in level 2 and level 4 products and tropospheric column ozone in level 4 products. Both EPIC Ozone products [2] are available at the Atmospheric Science Data Center (ASDC) at NASA Langley Research Center [3, 4].

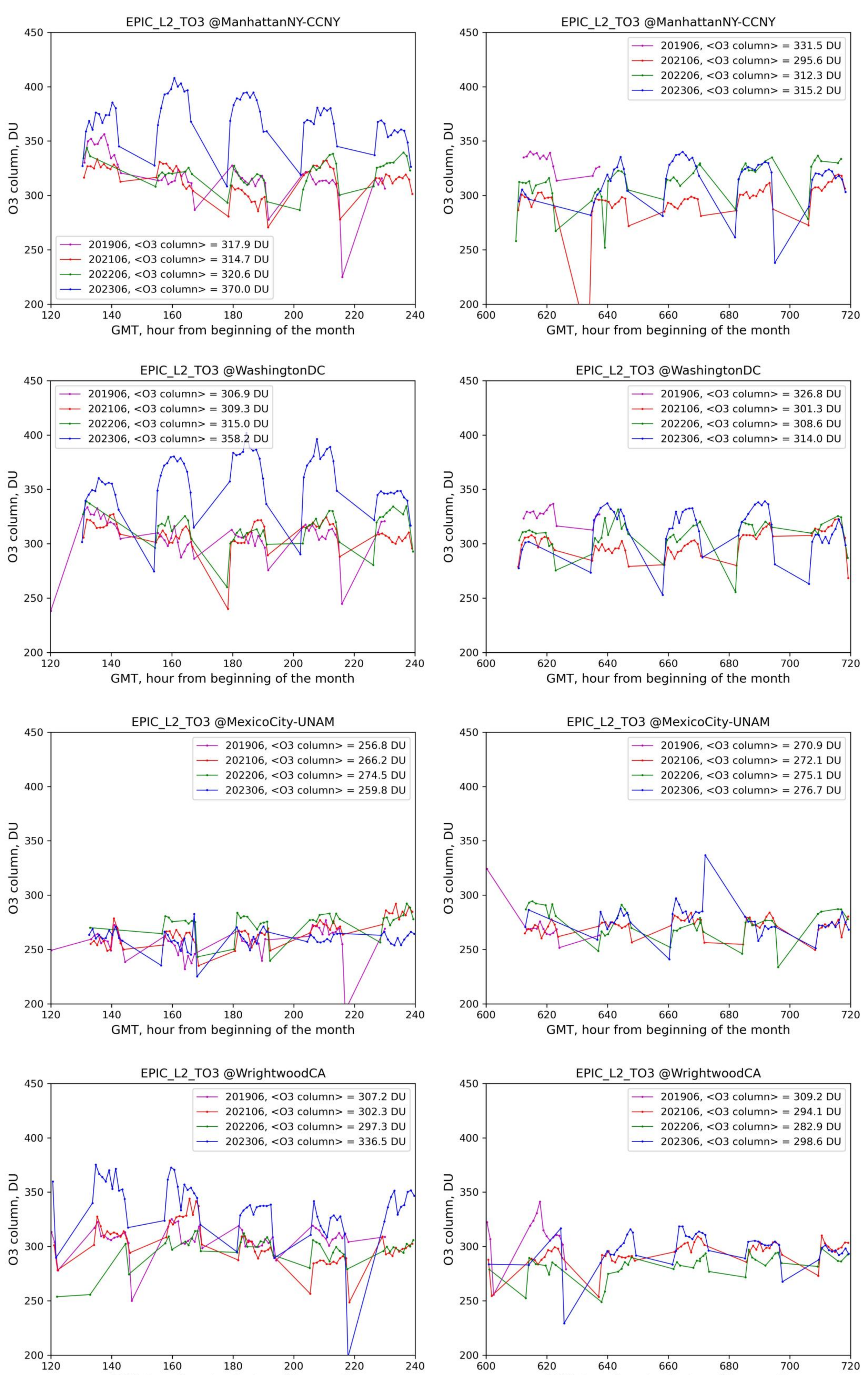
Pandora spectrometer instrument spectroscopy measures columnar amounts of trace gases in the atmosphere. These gases (O_3, NO_2, CH_2O) absorb specific wavelengths of light from the sun in the ultraviolet-visible spectrum [5]. Using the theoretical solar spectrum as a reference, Pandora determines trace gas amounts using differential optical absorption spectroscopy (DOAS). Pandora ozone retrieval is available from the Pandonia Global Network [6]. Pandora data from North American major metropolitan areas, New York, NY, Washington DC, Los Angeles, CA, and Mexico City.

Tropospheric Ozone Lidar Network (TOLNet) was established in 2012 to provide high spatiotemporal observations of tropospheric ozone to (1) better understand physical processes driving the ozone budget in various meteorological and environmental conditions and (2) validate the tropospheric ozone measurements of space-borne missions [7]. TOLNet data are available at ASDC [8].

While EPIC provides global coverage of ozone retrievals several times daily, temporal resolution may miss some features in daily ozone variations. Ground-based sensors such as Pandora spectrometers and TOLNet lidars provide better temporal resolution while missing continuous spatial coverage. The forthcoming ozone retrieval from the TEMPO mission [9] will provide better spatial and temporal coverage of air quality (including ozone) over North America. This study investigates whether EPIC ozone products can detect diurnal air quality variations and compare ozone temporal development with retrieval by ground-based instruments.

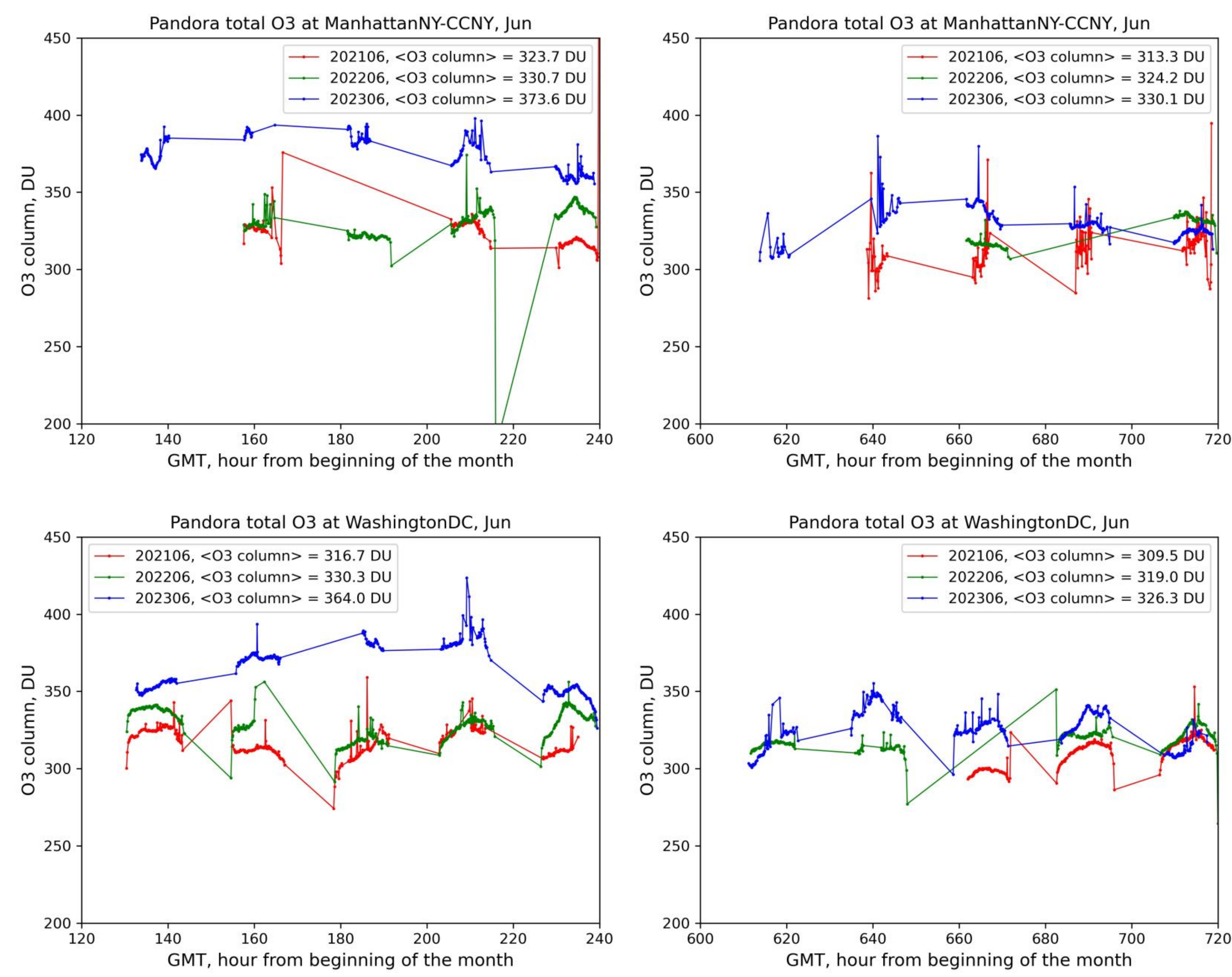
EPIC ozone L2 product: shift in total ozone column during extreme air pollution

The figures below show the daily variation of ozone, using the EPIC ozone L2 product, that can be attributed to air pollution in the major urban areas. US north-east cities also show a noticeable increase in the total column, ~50 Dobson units (DU), on June 6 – 10, 2023 (hours from 120 through 240) when the plume from Canadian wildfires covered the area, while this year shows usual behavior at the end of the month (hours 600 through 720).



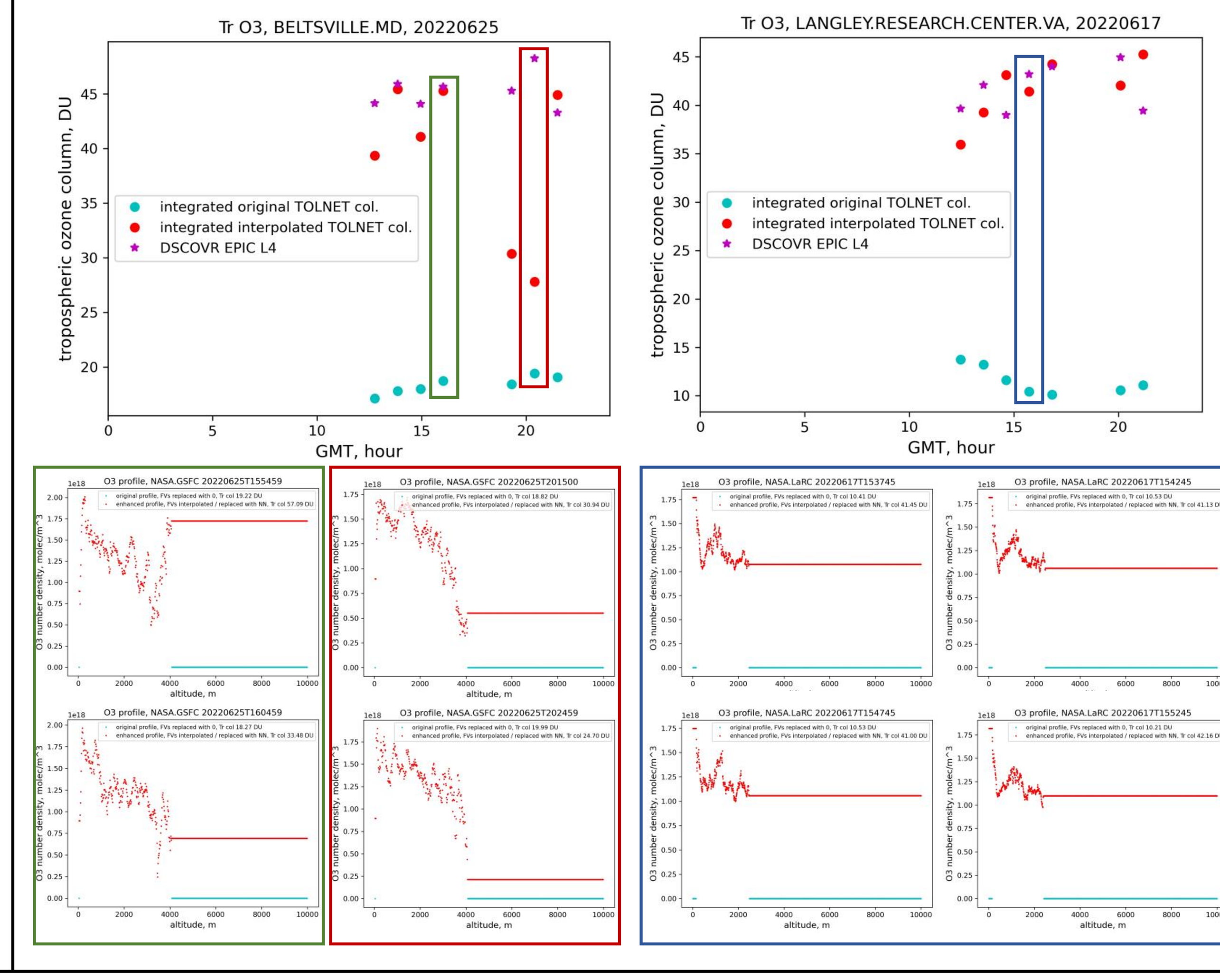
Does Pandora spectrometers support EPIC L2 Ozone increase during wildfires?

The figures below show the exact locations and time series used to analyze the EPIC L2 product. Although temporal development cannot be directly compared between EPIC and Pandora retrievals due to different temporal resolutions of the instruments, Pandora ozone retrievals indicate a similar 5-day average increase in total columns in NYC and Washington DC during the plume overpassing event this year.



EPIC L4 Tropospheric Ozone Column vs TOLNet Ozone lidar retrievals

The figures below show the time series of tropospheric ozone column from EPIC L4 product and ozone column integrated from TOLNet lidar profiles falling into 10-minute intervals around EPIC observation at NASA Centers; GSFC (left, 10-min. registration time) and LaRC (right, 5-min.registration time), with two approaches for handling profile fill panels. Individual lidar profiles contributing to highlighted time points are shown in the bottom panels.



Conclusion

•DSCOVR EPIC total column ozone retrievals can detect significant air pollution events. The retrievals from EPIC L2 and L4 products are in good agreement with Pandora over major metropolitan areas.
•Diurnal cycles were not detected; however, more long-term, weekly cycles may exist. Ozone column variations may also be driven by airmass change.
•Ozone profiles acquired by TOLNet lidars can be used for EPIC data validation, but either a careful selection of profiles covering the entire tropospheric column, or a proper profile gap-filling procedure needs to be performed. An attempt to fill profile gaps presented in the study improves agreement between EPIC and TOLNet tropospheric ozone retrievals.
•Upcoming retrievals from the new TEMPO mission are expected to improve air quality monitoring over North America.
•Monitoring Total Ozone Retrievals from the Deep Space Climate Observatory's (DSCOVR) Earth Polychromatic Imaging Camera (EPIC) can be a valuable tool during wildfire events, but its reliability depends on various factors including background anthropogenic emissions.
•Predicting nighttime ozone concentration from morning ozone retrieval using various statistical methods can be a helpful way forward for this comparative analysis between orbital and suborbital ozone monitoring.
•The 2020 data was excluded due to the COVD-19 lockdown and lack of a diurnal cycle.

References

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Daily total column ozone comparison between EPIC ozone L4 and Pandora L2

The figures below show the time series of total column ozone from EPIC L4 product and Pandora L2 product (rout2p1-8) in 9 consecutive days over major North American metropolitan areas. Unlike the L2 product, the L4 product is on the regular 1° grid, providing users better convenience. The total ozone column from L4 also provides a bridge comparison of the L2 total column to the L2 tropospheric column. The Saturday through Sunday 9-day periods are chosen to check whether weekly cycles exist while individual daily figures do not reveal diurnal patterns.