Analyzing the Impact of Canadian Wildfires on Air Quality in the U.S. Mid-Atlantic: with data and tools from NASA's Atmospheric Sciences Data Center

ATMOSPHERIC SCIENCE DATA CENTER

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Introduction

Wildfires pose a growing concern in North America due to their harmful impacts on air quality and public health, with increased wildfire activity in recent years leading to widespread smoke plumes that can transcend borders. The exposure of New York City (NYC), the most populous city in North America, to Canadian wildfire smoke highlights the substantial implications for public health and urban environments. To better understand the impact of Canadian wildfires on air quality in NYC, satellite data from the NASA Atmospheric Science Data Center (ASDC) at Langley Research Center, along with ground-based measurements and atmospheric modeling results, are analyzed.

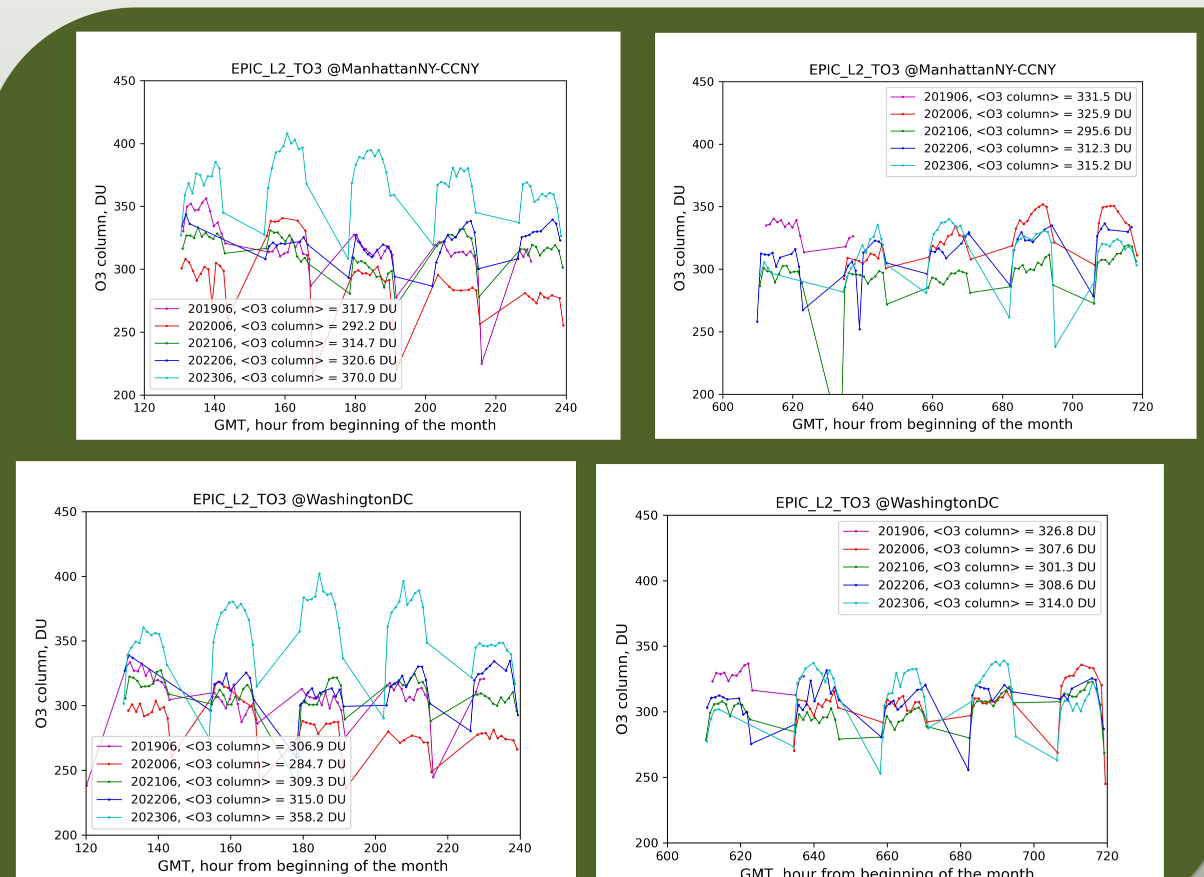
NASA's Atmospheric Science Data Center (ASDC) is in the Science Directorate located at NASA'S Langley Research Center in Hampton, Virginia. The Science Directorate's Climate Science Branch, Atmospheric Composition Branch, and Chemistry and Dynamics Branch work with ASDC to study changes in the Earth and its atmosphere. ASDC projects focus on the Earth science disciplines: Radiation Budget, Clouds, Aerosols, and Tropospheric Composition. All the products chosen for this analysis are products hosted by ASDC and available for users to obtain via our services [1].

Deep Space Climate Observatory (DSCOVR): Shift in total O3 column during extreme air pollution

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. This reaction happens when pollutants emitted by cars, power plants, industrial boilers, refineries, chemical plants, and other sources chemically react in sunlight [2]. 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.

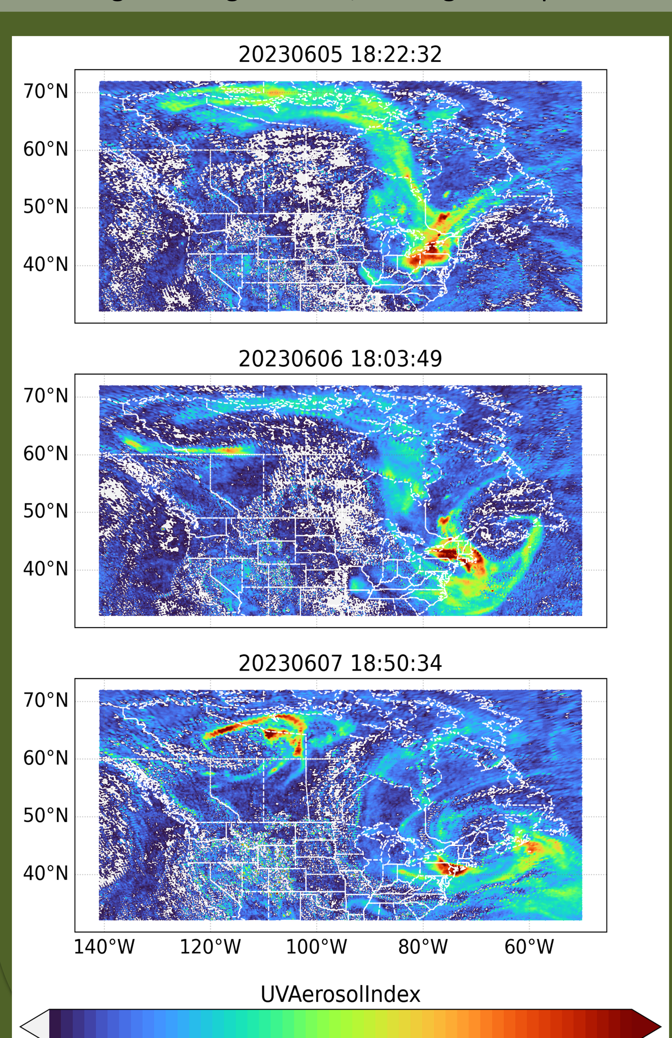
The reflectance spectra measured by the Earth Polychromatic Imaging Camera (EPIC) instrument aboard the DSCOVR spacecraft are compared with a set of radiative transfer-derived lookup tables for the EPIC filter transmission functions and a wide range of ozone values to retrieve ozone with a maximum resolution of 18 km at the sub-satellite point [3]. EPIC provides total column ozone in level 2 (L2) and level 4 (L4) products.

The figures below show the variation of total O_3 (TO3) column, using the EPIC ozone L2 product [4], that can be attributed to air pollution. U.S. north-east cities also show a noticeable increase in the total column, ~50 Dobson units (DU), on June 6 – 10, 2023 (hours 120 through 240 from beginning of June) when the plume from Canadian wildfires covered the area comparable with previous years, while this year shows usual behavior at the end of the month, hours 600 through 720.

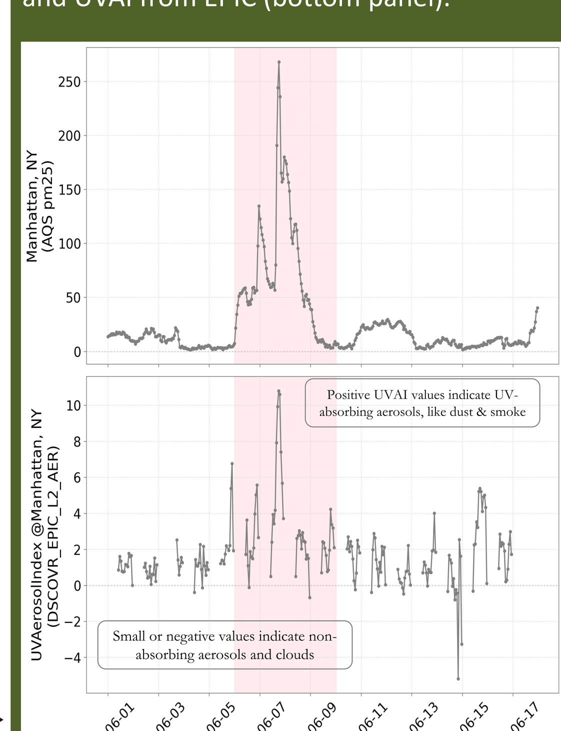


DSCOVR: UV Aerosol Index (UVAI)

The figures below highlight UVAI from EPIC L2 aerosol data [5]. This product can reveal massive smoke black carbon plumes from fires because it measures radiances at 340 and 388 nm wavelengths, which are sensitive to scattering and absorbing aerosols. Elevated UVAI is indicative of greater concentration of black carbon aerosols, and such aerosols can be responsible for increasing the concentration of surface air pollutants. When we breathe in air pollutants, they can enter our bloodstream and contribute to coughing or itchy eyes and cause or worsen many breathing and lung diseases, leading to hospitalizations, cancer, or even premature death.

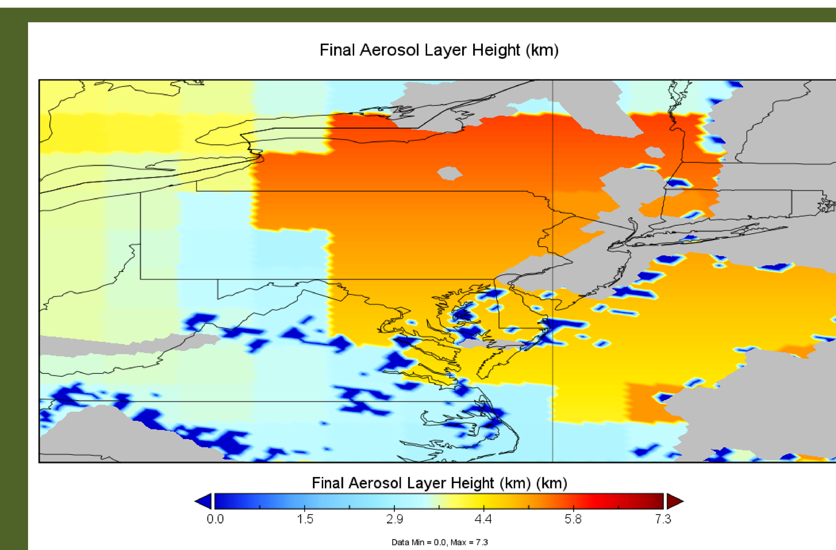


In the maps to the left, one can see the general movement of aerosols across three days. The timing of the peak in UVAI at Manhattan, NY can be assessed by the timeseries graphic below, which shows ground station particulate estimates from the EPA Air Quality System (AQS; top panel) [6] and UVAI from EPIC (bottom panel).



DSCOVR: Aerosol Layer Height

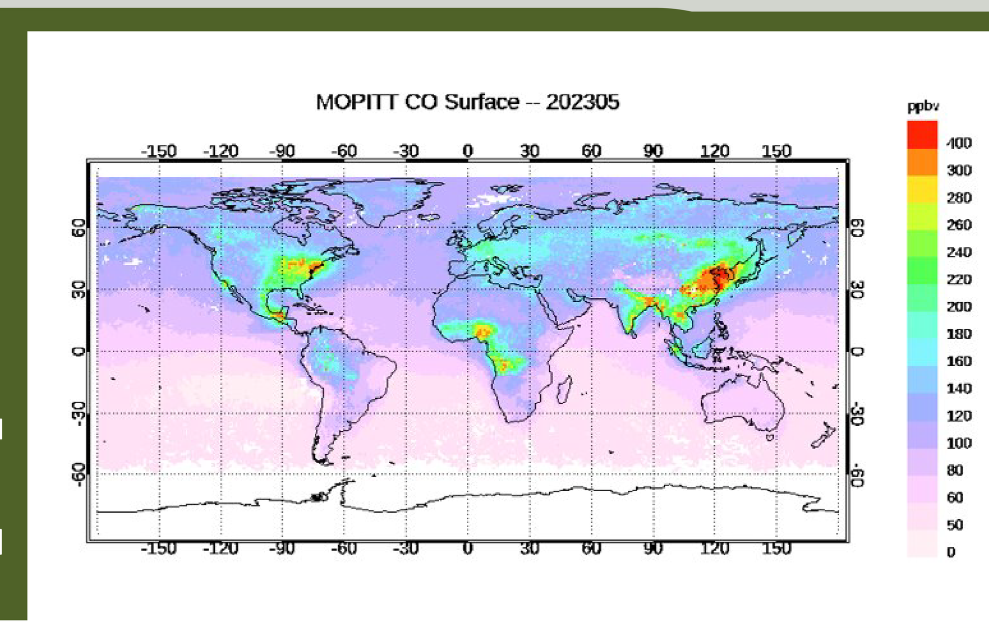
The figure below shows Aerosol Layer Height data [5], which estimates the height of aerosol layers over the ocean using EPIC's channels in the Oxygen-A and B bands. On June 5th, 2023, 20:33:27 UTC, the height of aerosol layers increased from ~2.9 km in light blue over Canada to ~5.8 km in orange over the US.

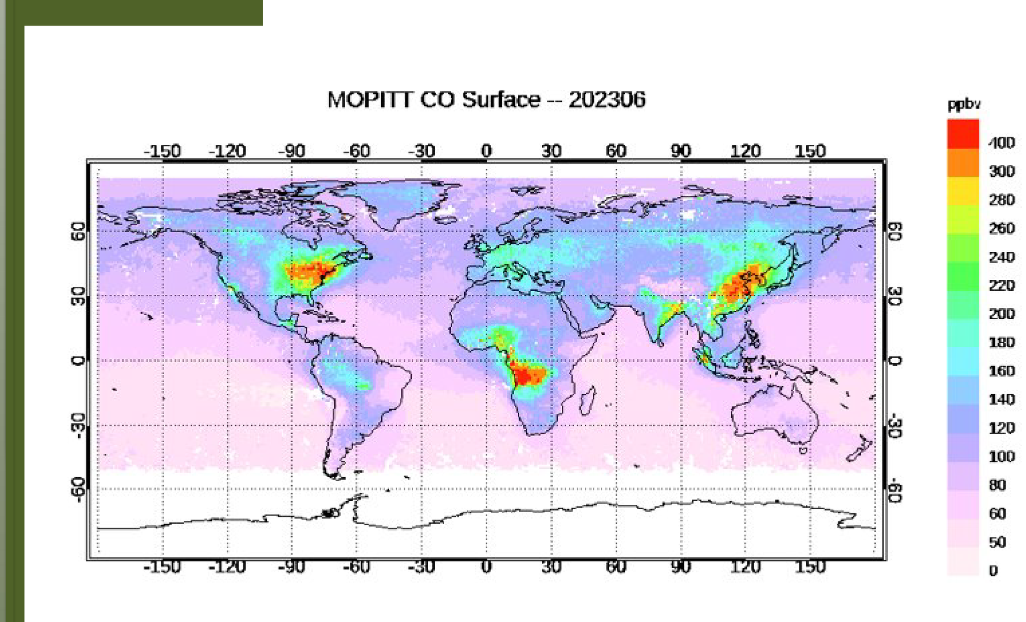


Measurement of Pollution in the Troposphere (MOPITT): Carbon Monoxide

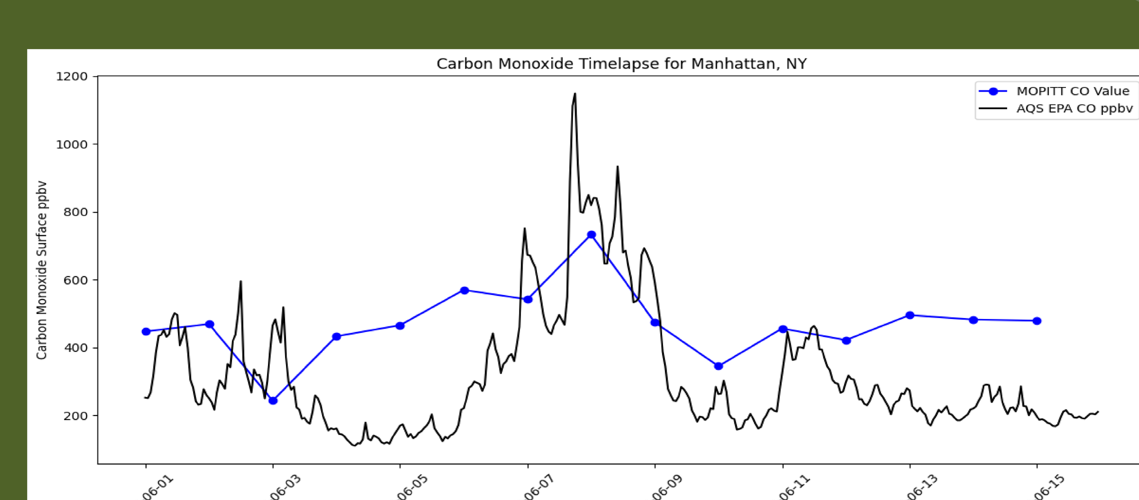
MOPITT is a NASA satellite instrument used to measure carbon monoxide (CO) levels in the Earth's atmosphere, and it operates as part of NASA's Terra satellite. MOPITT uses gas correlation radiometry to measure the concentration of carbon monoxide in Earth's lower atmosphere. It provides valuable data for monitoring air quality, understanding atmospheric pollution, and studying the sources and transport of carbon monoxide in the troposphere [7]. These measurements are pivotal for criterion assessment, given carbon monoxide's impact on both air quality and Earth's carbon cycle. The two maps presented below illustrate the monthly average global surface carbon monoxide levels, comparing the period before the Canadian wildfires in May to the period after the wildfires in June.

The surface concentration of carbon monoxide (CO) exhibited a notable rise across North America from May to June. In contrast, CO levels remained consistent over Asia during the same period.[8]





The figure below shows a timelapse created by analyzing surface CO concentration data over Manhattan, NY, obtained from the EPA AQS [6] and MOPITT sources. It reveals a significant spike in carbon monoxide levels. The data clearly indicate a maximum increase in carbon monoxide concentration occurred on June 8th, 2023.

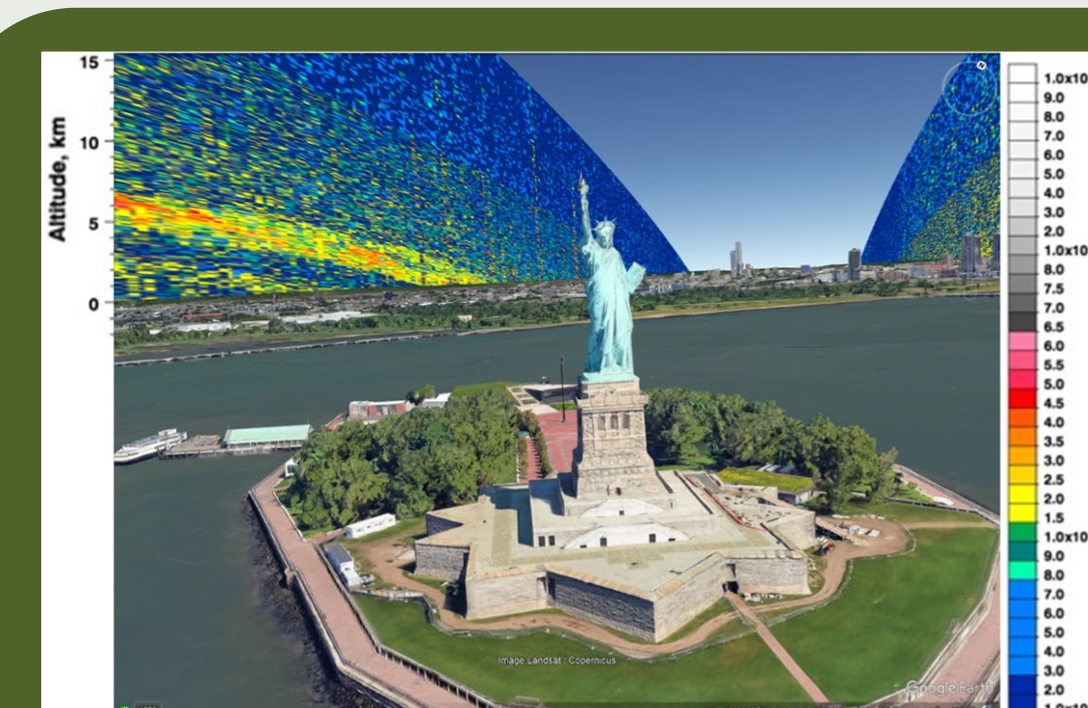


Cloud-Aerosol Lidar and Infrared Pathfinder Satellite Observations (CALIPSO): Determining the smoke plume thickness

CALIPSO is a joint NASA and CNES (Centre National d'Etudes Spatiales) satellite mission launched on April 28, 2006. CALIPSO is part of the A-Train constellation of satellites, which are a group of Earth-observing satellites that follow each other in close proximity, allowing for comprehensive and coordinated observations of Earth's atmosphere and surface.

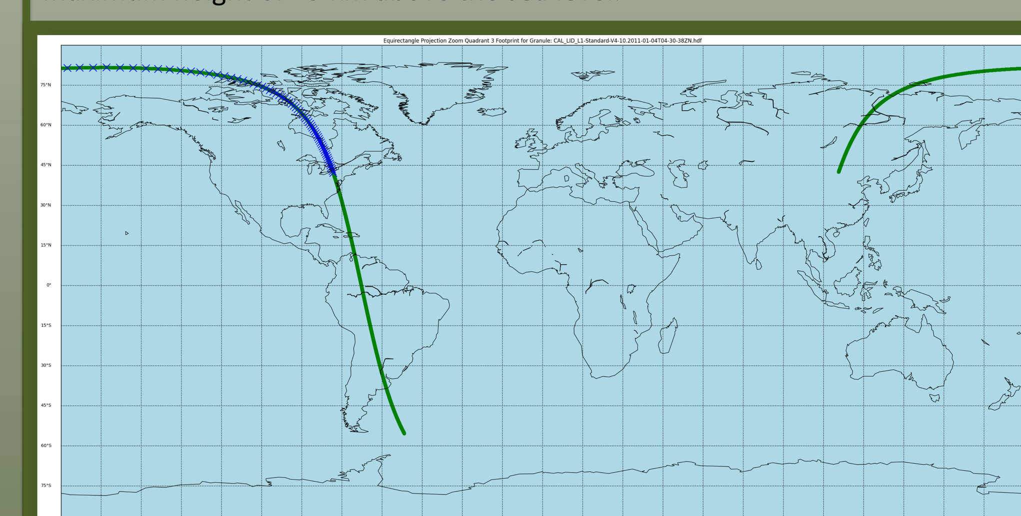
The primary instrument on CALIPSO is a LIDAR (Light Detection and Ranging) system, which uses laser pulses to measure the altitude and properties of clouds and aerosols (tiny particles suspended in the atmosphere). CALIPSO's observations are crucial for studying the Earth's climate and improving our understanding of how clouds and aerosols influence the planet's energy balance.

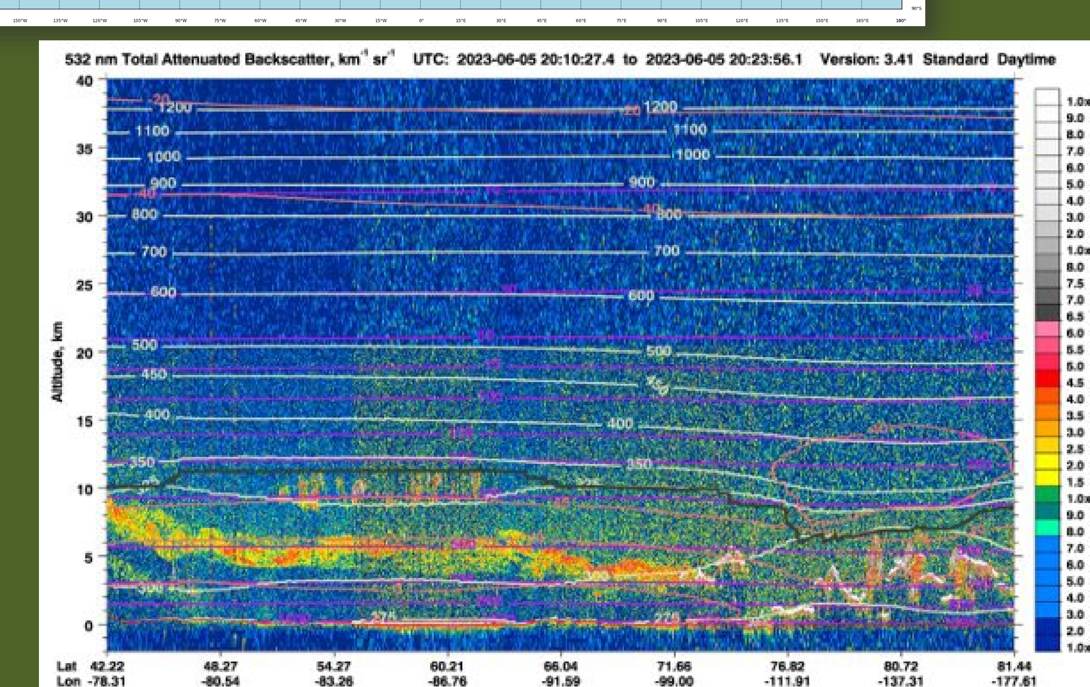
We use CALIPSO LIDAR 532 nm Total Attenuated Backscatter data [9,10] to determine the smoke plume thickness. CALIPSO is a low Earth orbit (LEO) satellite-based instrument that provides a detailed 2D profile of smoke and clouds in the atmosphere. Unfortunately, the CALIPSO mission concluded on August 1st, 2023, due to propellant depletion. The images below illustrate a CALIPSO profile portraying the Canadian wildfire smoke (that affected NYC) on June 5th at 20:10:27 UTC. Note that the CALIPSO vertical profile in the background of the Statue of Liberty is 5X the true altitude for visualization purposes.



The green line in the map below shows an entire orbit of the CALIPSO LIDAR, and the blue 'x's indicate positions for which data are represented in the cross-section of the lower panel. Notice how observations crossed the Canadian wildfires along the wind direction to the south-east.

The second figure shows the 532 nm Total Attenuated Backscatter from 20:10 to 20:23 UTC on 2023-06-05. Blue represents the minimum and white represents the maximum backscatter values. Yellow to red colors represent the distribution of aerosols in the atmosphere from wildfires based on the CALIPSO LIDAR measurements. The average smoke plume thickness is ~3 km. The bottom of the wildfires' plumes was recorded at an altitude of ~4 km, while reaching a maximum height of ~9 km above the sea level.

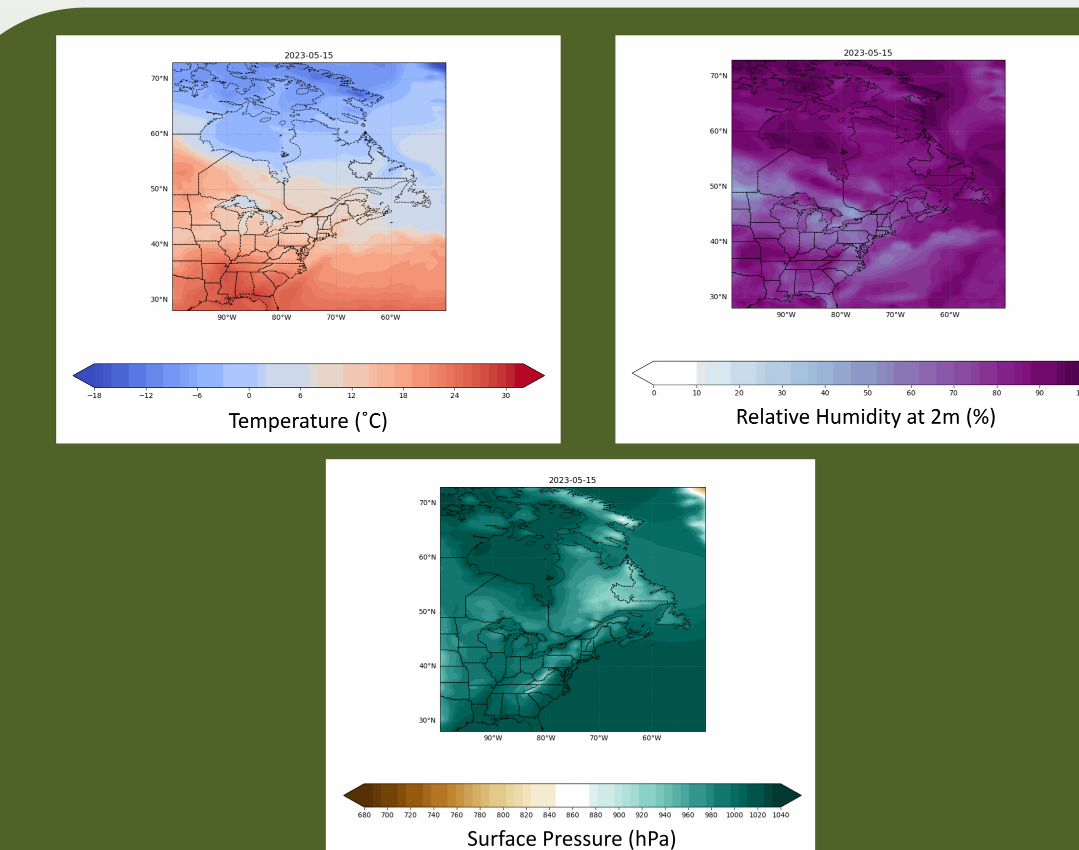




The Prediction of Worldwide Energy Resources (POWER): Viewing temperature, pressure and relative humidity

The POWER Project provides solar and meteorological data sets from NASA research for support of renewable energy, building energy efficiency and agricultural needs. The data obtained through the POWER web services is made possible with collaboration from the Atmospheric Science Data Center (ASDC). Via the POWER Knowledgebase binder — a code repository — a user can obtain all available POWER data via the POWER Zarr Datastore and run any of the provided codes to analyze and visualize the data [11].

For our analysis, we wanted to obtain *temperature* and *pressure* data for the days the Canadian wildfires affected New York City. Temperature and pressure influence the buoyancy of smoke plumes. Warmer air is generally less dense and tends to rise, carrying the smoke with it. The temperature gradient and pressure differences in the atmosphere determine how high the plume rises and how it disperses horizontally. Temperature and pressure also affect the dispersion and dilution of pollutants within the atmosphere. Changes in these parameters can influence how smoke plumes interact with the surrounding air, potentially impacting air quality in different regions. Understanding these interactions help in assessing the health and environmental risks associated with wildfires.



Where to go for data?

Data can be discovered and retrieved via the *Earthdata Search* client and the *Worldview* browser interface. Questions can be asked of NASA subject matter experts directly via the Earthdata Forum.

EARTHDATA Search
WORLDVIEW
EARTHDATA Forum

What data are upcoming?

The Tropospheric Emissions: Monitoring of POllution (TEMPO) instrument level-2/3 data will be released in April 2024. It will provide additional measurements of air pollutants and aerosols.

REFERENCES

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