Wildfires and Climate Change

AOSC 680

Ross Salawitch

Class Web Sites:
http://www2.atmos.umd.edu/~rjs/class/fall2024
https://umd.instructure.com/courses/1367293

NBC NEWS

One year since Australia's devastating wildfires, anger grows at climate change 'inaction'

A kangaroo rushes past a burning house in Lake Conjola, Australia, on Dec. 31, 2019.

Matthew Abbott / The New York Times via Redux Pictures

https://www.nbcnews.com/science/environment/one-year-australia-s-devastating-wildfires-anger-grows-climate-change-n1256714

Lecture 22

19 November 2024

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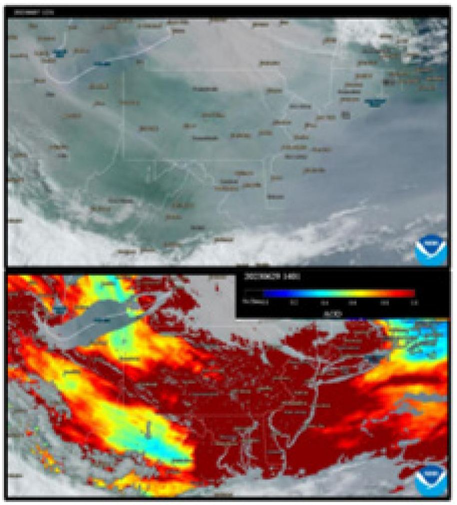
Wildfires and Local Air Quality

State of Maryland
Exceptional Event Demonstration and Analysis
of the June 2023 Quebec Canada Wildfires and their
Impact on Maryland's Ozone Air Quality on
June 7, 2023



ARA / Ambient Air Monitoring Program
Maryland Department of the Environment
1800 Washington Blvd., Suite 730
Baltimore, MD 21230-1720

December 2023

1. Overview

1.1. Introduction

Hundreds of wildfires were ignited by lightning across wildland areas of Quebec on June 1, 2023. Well over 100 fires were still burning across the province on June 4, with over 430 separate fires reported across the province by June 7[1]. Strong and persistent winds behind the system responsible for igniting the fires permitted numerous fires to grow to enormous sizes and spread uncontrolled. Two conglomerate areas of fires established over southwestern and northern Quebec, both of which burned out of control throughout the month of June. In the weeks preceding the event which impacted Maryland on June7, nearly 1 million acres of land, or roughly the size of Rhode Island, burned across Quebec. Between June 5 and June 8, waves of smoke were transported directly towards the Northeast and Mid-Atlantic United States (U.S.) on northerly winds. Diurnal cycling of the fires would cause an increase in emissions during the day, with decreases at night. In aggregate with northerly flow, the scenario resulted in literal "walls" of smoke visible on satellite, and several pulses of smoke of increasing severity striking between Maryland and New York. The wildfire smoke[2] produced record setting fine particle concentrations and a noticeable increase in ozone in the Mid-Atlantic and triggered air quality alerts throughout the region. Ozone concentrations exceeded the 2015 70 ppb National Ambient Air Quality Standard (NAAQS)[3] on June 7, 2023, across the southern tier of Maryland, but with widespread ozone pushing towards the exceedance threshold, including a 69 ppb concentration at Essex, Maryland (Figure 1). Exceedances and widespread elevated ozone occurred despite weather conditions unfavorable for ozone, with high temperatures reaching only 81°F, and weak direct sunlight due to smoke attenuation. In Maryland, the maximum daily 8-hour average ozone (MD8AO) concentration reached a peak of 76 ppb with three Maryland ozone monitors exceeding the 70 ppb standard due to the influences of the Quebec wildfire smoke. Those monitors that exceeded the 70 ppb standard are highlighted in Table 1, along with Essex which peaked at 69 ppb, which will affect future design values for that site. Of the three Maryland sites with MD8AO concentrations above 70 ppb on June 7, all were among the four-highest 8-hour ozone observations at those sites during the 2023 season, with the Essex 69 ppb ranking ninth.

[1] https://www.google.com/url?q=https://edition.cnn.com/us/live-news/us-air-quality-canadian-wildfires-06-07-23/h_e1a588e47fc6d9c8ef1388399da56194&sa=D&source=docs&ust=1699824967531320&usg=AOvVaw1RBnIXG6jI1Mn2oVXSVFf9
[2] Smoke from biomass burning contains volatile organic compounds (VOCs) and nitrogen oxides (NO_x), which react to form ozone.
[3] 42 U.S.C. 7401 et seq,

https://mde.maryland.gov/programs/air/AirQualityMonitoring/Documents/ExceptionalEvents/MDE_Ozone_EE_Demo_2023_June_7.pdf

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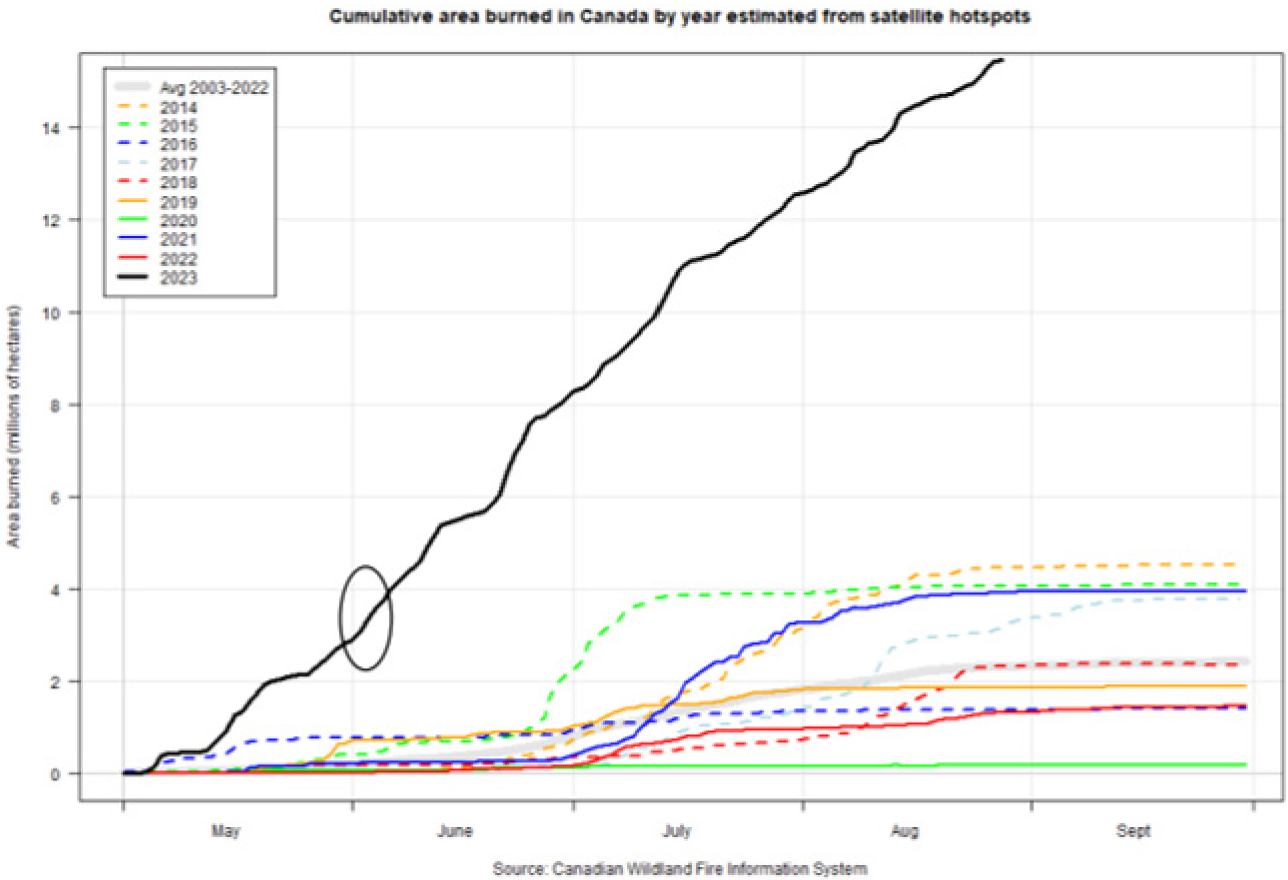

Figure 8. Accumulated hectares burned reported by Canadian Wildland Fire Information System (CWFIS) by day over the last 10 years. Burn area is estimated by satellite. By June 8, 2023 the cumulative burn area across Canada was approximately the size of the entire state of Maryland, with increased emissions during that time period. Area circled highlights the early June period of intense burning across Quebec. Burning across Canada in 2023 is unprecedented compared to any recent year. Source: https://cwfis.cfs.nrcan.gc.ca/downloads/hotspots/burnarea_chart_10yr.png

https://mde.maryland.gov/programs/air/AirQualityMonitoring/Documents/ExceptionalEvents/MDE_Ozone_EE_Demo_2023_June_7.pdf

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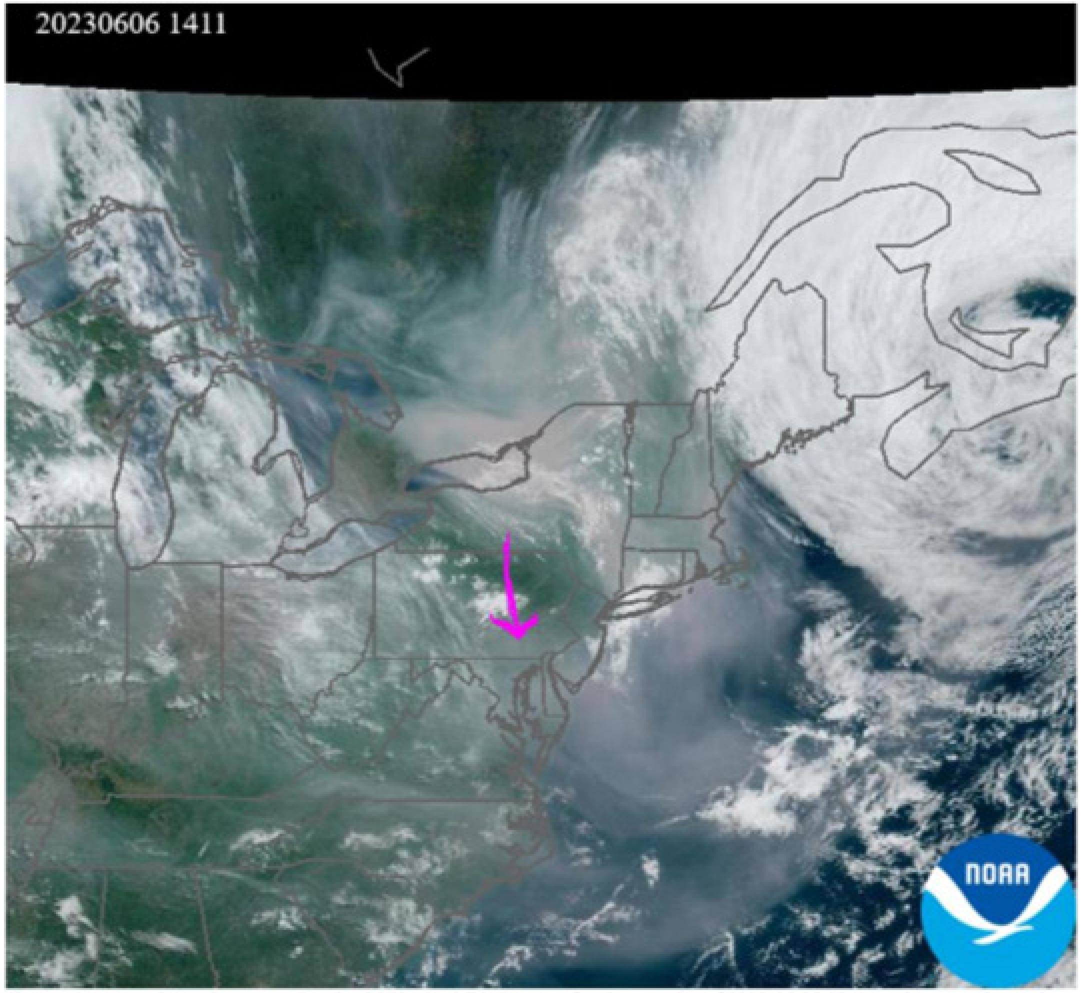

Figure 10c. Aerosol Watch Image using the GOES ABI visible imagery for the morning of 2023-06-06. The purple arrow shows the movement of the wave of smoke impacting Maryland on June 7, the brownish area over Lake Ontario. Images can be viewed online:
https://www.star.nesdis.noaa.gov/smcd/spb/aq/AerosolWatch/?product_date=20230606&zoom=6&lat0=41.801248853664305&lon0=-79.82397460937506&layers=134217729&region=conus&start_time=1141&end_time=1801

https://mde.maryland.gov/programs/air/AirQualityMonitoring/Documents/ExceptionalEvents/MDE_Ozone_EE_Demo_2023_June_7.pdf

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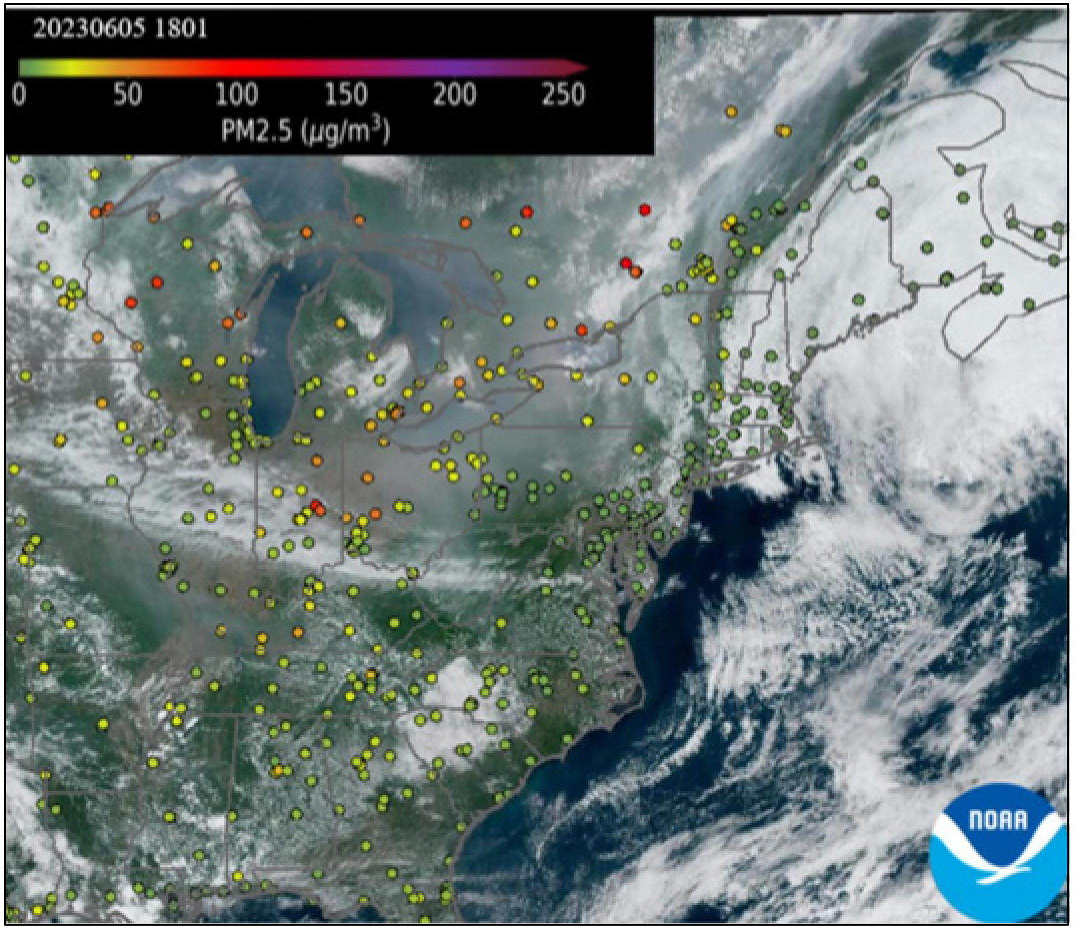

Figure 15. GOES-16 visible imagery at 1801 UTC (2 p.m. EDT) on June 5, 2023, overlaid with hourly $PM_{2.5}$ concentrations (circles) colored by magnitude. Redder colors indicate higher $PM_{2.5}$ concentrations.

https://mde.maryland.gov/programs/air/AirQualityMonitoring/Documents/ExceptionalEvents/MDE_Ozone_EE_Demo_2023_June_7.pdf

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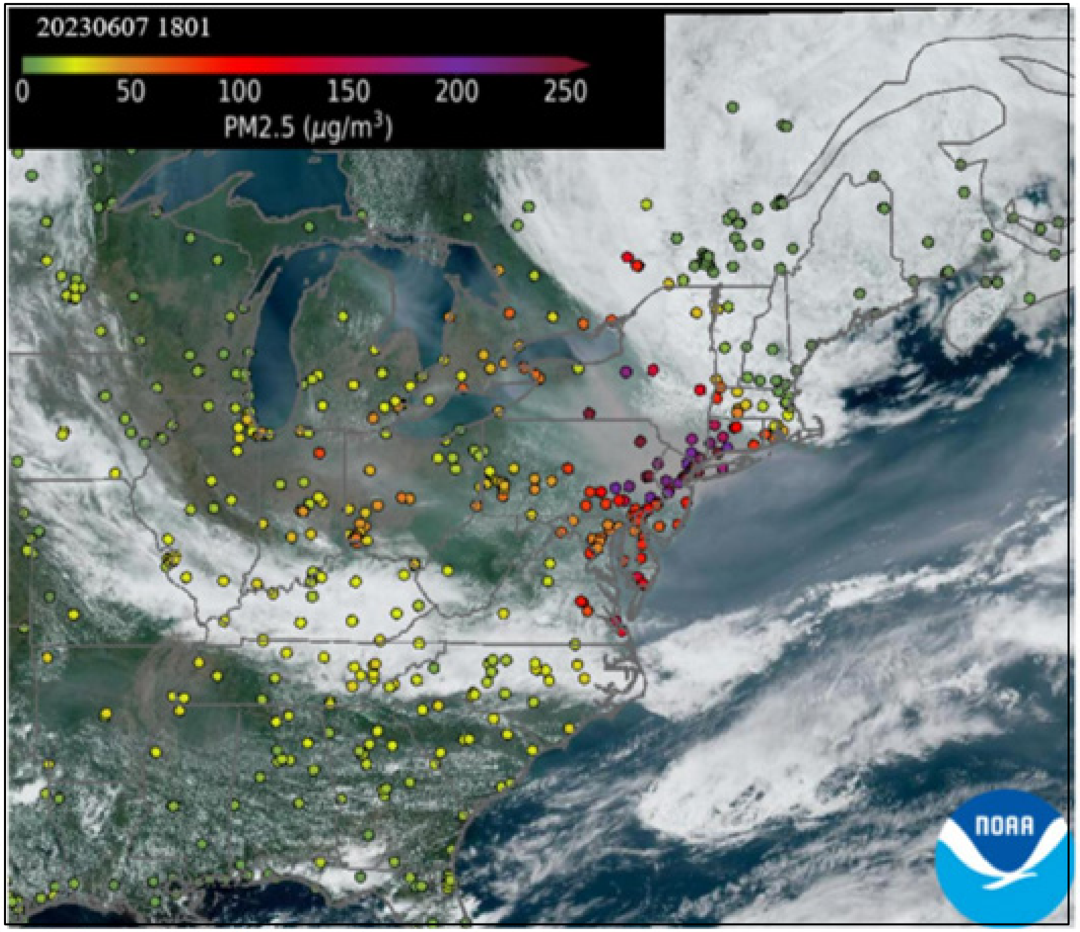

Figure 17. As in Figure 15 except for June 7, 2023.

https://mde.maryland.gov/programs/air/AirQualityMonitoring/Documents/ExceptionalEvents/MDE_Ozone_EE_Demo_2023_June_7.pdf

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Wildfires and Local Air Quality

3.5.2. Particles

$PM_{2.5}$ can be both a primary pollutant and a resultant secondary pollutant of wildfire emissions downstream, as photochemistry within the plume converts certain species to aerosols. The entire MDE network showed a correlated increase in $PM_{2.5}$ 24-hour averages from June 6-9, which aligned with the onset of the smoke plume in Maryland (Figure 27). An additional episode of smoke is visible on June 29-30. No other period of the month exhibited such a large, coherent increase across the entire Maryland network. The early June event possessed the highest particle observations of the month. The fine particle observations therefore provided additional evidence that along with ozone and ozone precursors, fine particles were transported within the smoke-affected airmass and were a distinct indicator of wildfire emissions.

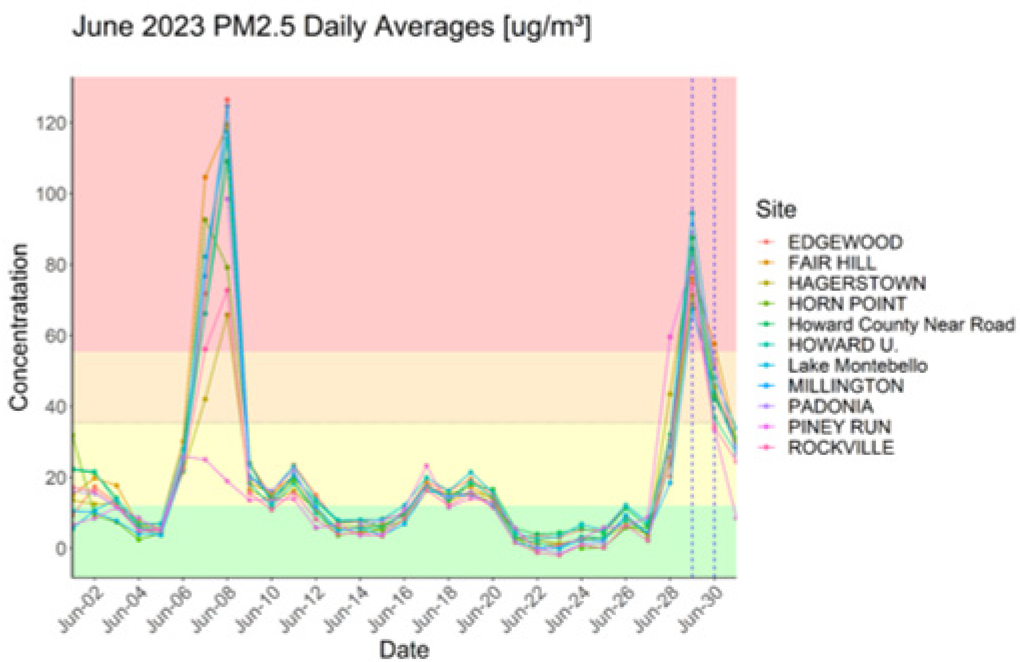

Figure 27. Daily averaged fine particle ($PM_{2.5}$) concentrations for all sites available in Maryland for the month of June, 2023. June 7-8 had the highest daily average concentrations for the month of June, and possibly in the entire historical record of MDE. The two vertical lines highlight the second event at the end of the month. Colored backgrounds are AQI colors.

https://mde.maryland.gov/programs/air/AirQualityMonitoring/Documents/ExceptionalEvents/MDE_Ozone_EE_Demo_2023_June_7.pdf

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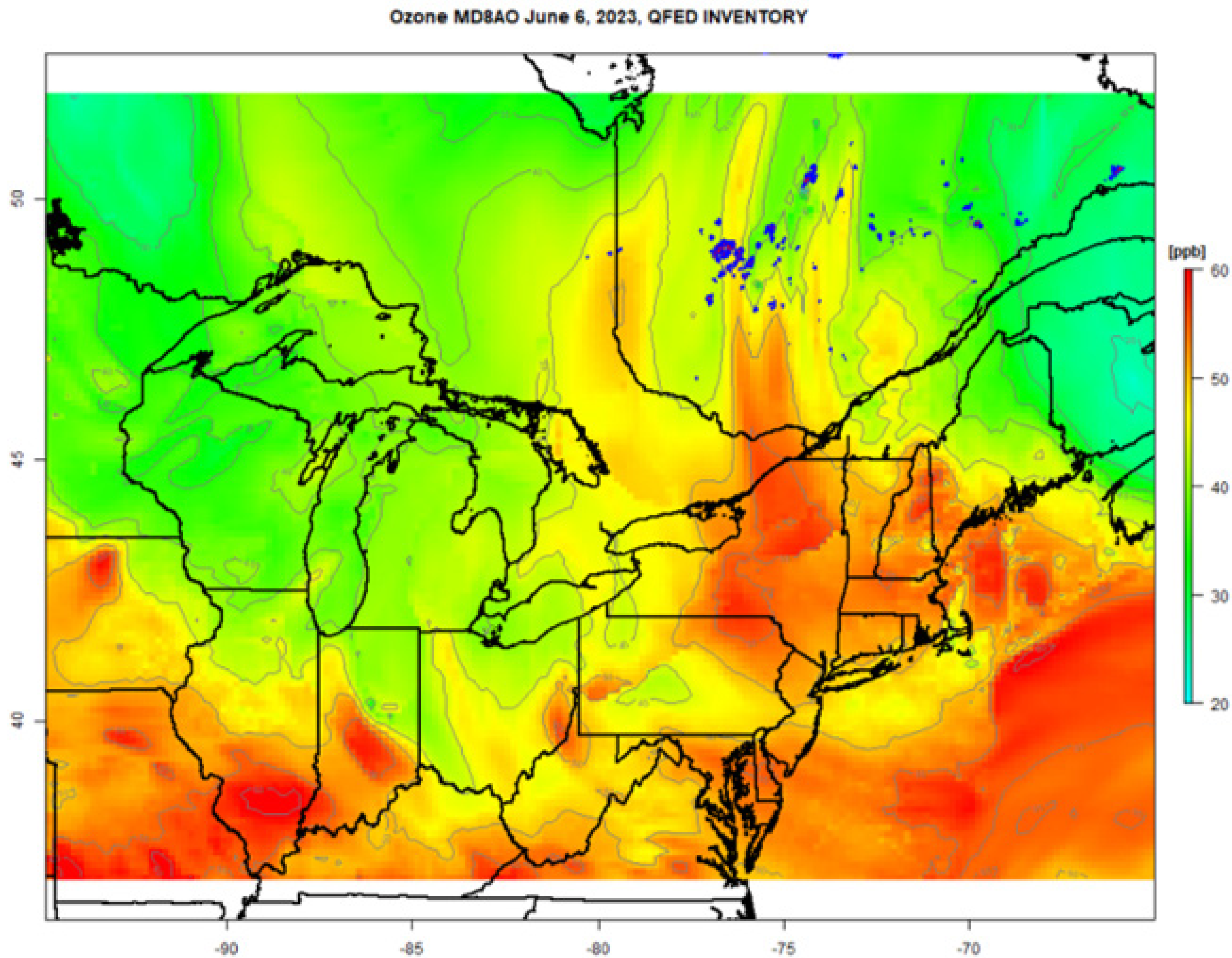

Figure 30. Plumes of ozone (colored fill and contours) streaming south from the fire locations (blue areas) in Quebec on June 6 using the CMAQ modeling done at University of Maryland College Park, with the QFED emissions inventory.

https://mde.maryland.gov/programs/air/AirQualityMonitoring/Documents/ExceptionalEvents/MDE_Ozone_EE_Demo_2023_June_7.pdf

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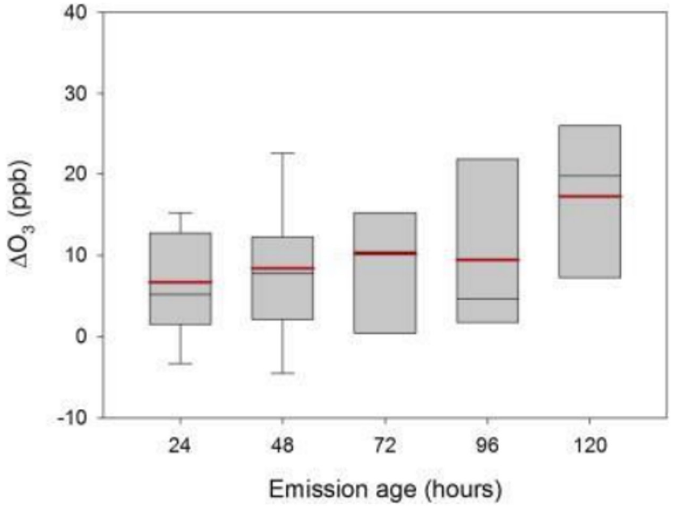

Figure 11. Ozone enhancement with smoke plume age (Putero et al. (2014), Figure 7).

Table 1. Maximum Daily 8-hour average ozone (MD8AO) concentrations and ranks on June 7, 2023, for all Maryland sites. Maryland sites are listed using the common site name and Air Quality System (AQS) identification number (AQSID). MD8AO concentrations in ppb are shown with that day's rank in the 2023 ozone season in parentheses. A rank of (1) indicates the MD8AO was the highest recorded at that site in the 2023 season. The final columns indicate the current fourth high and estimated design value with no exclusion of any data. 2023 data are not final as of this writing, and therefore all DVs are estimated. Monitors exceeding 70 ppb during the event are highlighted according to AQI, as is Essex at 69 ppb due to the effect on attainment status.

Site Name	AQSID	MD8AO, ppb (rank)	2023	
		7-Jun	Fourth High (ppb)	EST DV (ppb)
Essex	24-005-3001	69 (9)	75	73
Calvert	24-009-0011	69 (2)	66	62
S. Maryland	24-017-0010	75 (2)	69	65
Rockville	24-031-3001	62 (13)	68	63
PG Equestrian Ctr	24-033-8003	69 (7)	73	65
S. Carroll	24-013-0001	63 (20)	71	67
Horn Point	24-019-0004	76 (1)	71	66
Beltsville CASTNET	24-033-9991	65 (13)	72	67
Blackwater CASTNET	24-019-9991	71 (2)	68	64

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Wildfires and Stratospheric Chemistry & Dynamics

Geophysical Research Letters

Research Letter | Open Access

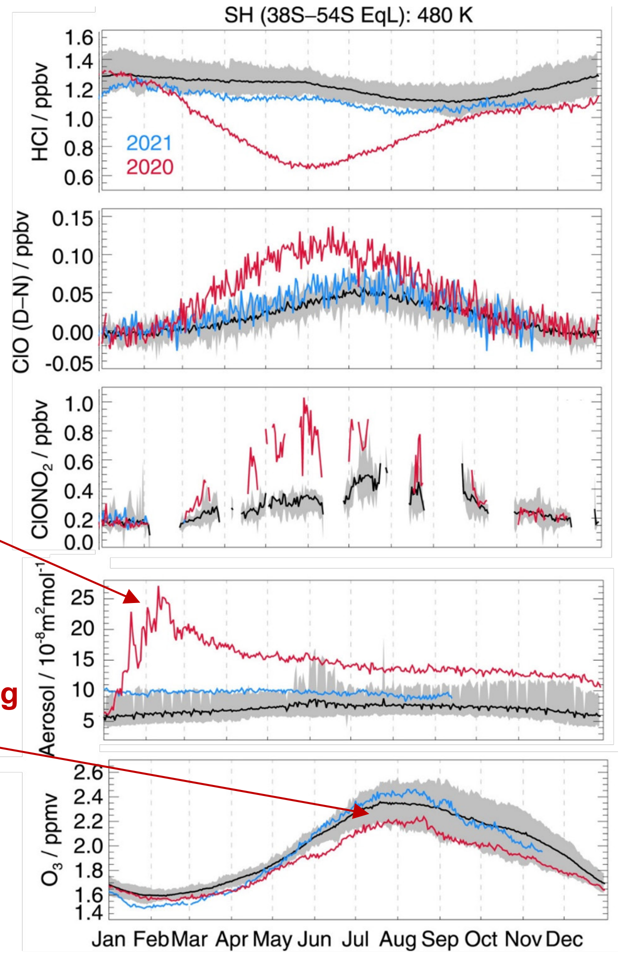
Prolonged and Pervasive Perturbations in the Composition of the Southern Hemisphere Midlatitude Lower Stratosphere From the Australian New Year's Fires

M. L. Santee, A. Lambert, G. L. Manney, N. J. Livesey, L. Froidevaux, J. L. Neu, M. J. Schwartz, L. F. Millán, F. Werner, W. G. Read, M. Park, R. A. Fuller, B. M. Ward

First published: 28 January 2022 | https://doi.org/10.1029/2021GL096270 | Citations: 22

Perturbation to stratospheric aerosols from the Australian Wildfires

Stratospheric ozone reduction following the Australian Wildfires



https://agupubs.onlinelibrary.wiley.com/doi/10.1029/2021GL096270

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Wildfires and Stratospheric Chemistry & Dynamics

ATMOSPHERIC CHEMISTRY

Australian wildfires depleted the ozone layer

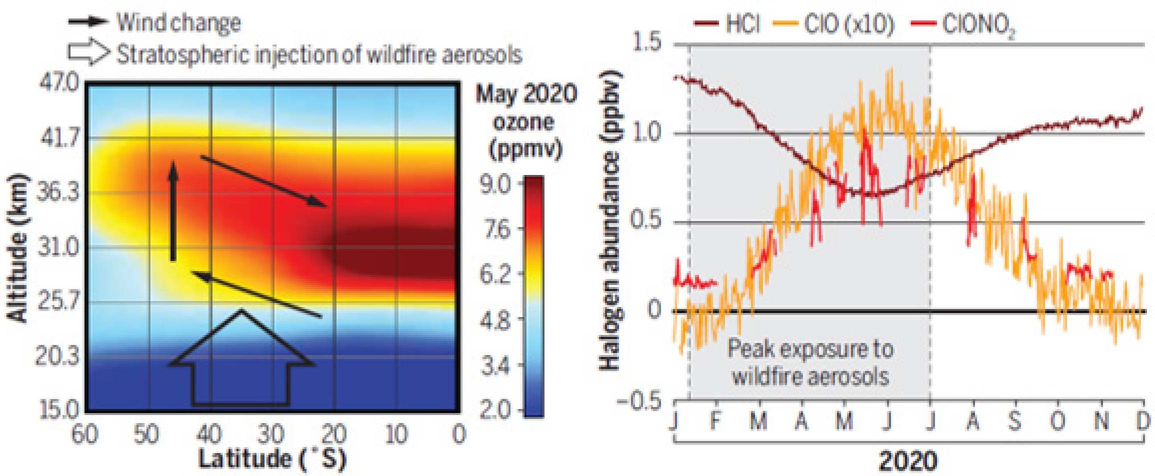
Various mechanisms initiated by wildfires thinned the stratospheric ozone layer

By Ross J. Salawitch[1,2,3] and Laura A. McBride[1,2,4]

Stratospheric ozone was reduced due to a combination of chemistry and dynamics

Response of stratospheric ozone to wildfire aerosols

The thickness of the stratospheric ozone layer in 2020 at Southern Hemisphere mid-latitudes could have been reduced because of changes in wind patterns and by chemical loss reactions involving chlorine monoxide (ClO). The cross section of atmospheric ozone (left) shows changes in stratospheric winds that may have been initiated by the absorption of sunlight by aerosols injected into the lower stratosphere by the Australian wildfires. The chemical process responsible for the observed changes in hydrochloric acid (HCl), chlorine nitrate ($ClONO_2$), and ClO (right) in the lower stratosphere after exposure of air to wildfire aerosols is important for ozone and is not currently understood.



The latitude/altitude cross section of ozone is from the US NASA Microwave Limb Sounder (MLS) instrument, and the time series show data acquired by the MLS (HCl and daytime minus nighttime ClO) and by the Canadian Space Agency's Atmospheric Chemistry Experiment–Fourier Transform Spectrometer instrument ($ClONO_2$) (*12*). ppbv, parts per billion by volume; ppmv, parts per million by volume.

https://www.science.org/doi/full/10.1126/science.add2056

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Wildfires and Stratospheric Chemistry & Dynamics

Reduction of stratospheric HCl, and increase in stratospheric ClO, due to solubility and subsequent reaction on organic aerosols injected into the stratosphere by Australian wildfires Solomon *et al*., *Nature*, 2023. Community still believes ozone reduction was due to a combination of chemical and dynamical effects.

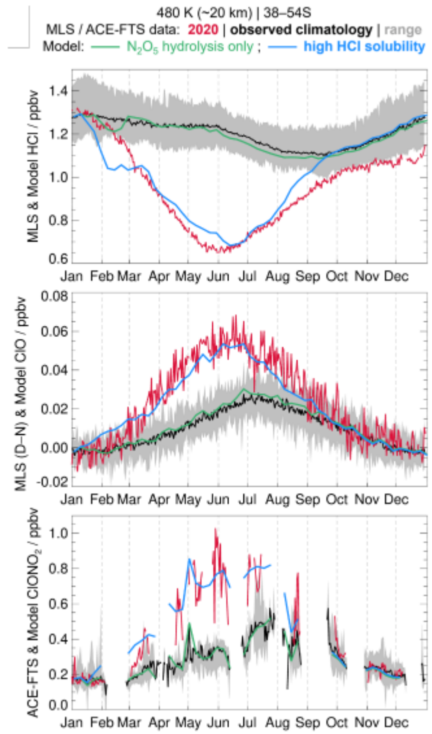

Figure 6. Daily (day and night) averaged mixing ratios of HCl, ClO, and $ClONO_2$ measured in 2020 (red), as well as the climatological mean (black) and range (grey) over 2005–2019 obtained by MLS (HCl and ClO) and ACE-FTS ($ClONO_2$) at the 480 K potential temperature level between 38°S and 54°S. For ClO, the 24-hour-averaged values are approximated as half of the day-night differences to reduce measurement biases (and assuming zero ClO at night). Also shown are hybrid modeled/measured quantities computed by adding model-calculated daily averaged anomalies in the three chlorine species to the respective observed climatological means from MLS and ACE-FTS. For the green lines, the anomalies are taken from a simulation using only N_2O_5 hydrolysis on the aerosols; for the blue lines, they are taken from a simulation that includes enhanced solubility of HCl on organic aerosols and subsequent heterogeneous reactions of HCl. Adapted from Santee *et al.* (2022) and Solomon *et al.* (2023).

Salawitch *et al*., *BAMS*, under review, as of 4 Nov 2024

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