Appendix B

Exceptional Event Demonstration for the 2023 June and July Canadian Wildfire Impacts on Ozone Concentrations in the Milwaukee Area: Waukesha Cleveland Avenue and University of Wisconsin-Milwaukee UPark

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EXCEPTIONAL EVENT DEMONSTRATION

2023 June and July Canadian Wildfire Impacts on Ozone Concentrations in the Milwaukee Area: Waukesha Cleveland Avenue and University of Wisconsin-Milwaukee UPark

Prepared by the Wisconsin Department of Natural Resources

Publication Date:

Publication Number: AM-656

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Acronyms

AGL	Above ground level
AOD	Aerosol optical depth
CART	Classification and regression tree
CIFFC	Canadian Interagency Forest Fire Centre
CWFIS	Canadian Wildland Fire Information System
DNR	Wisconsin Department of Natural Resources
DV	Design value
EMBER	Expedited Modeling of Burn Events Results
EPA	U.S. Environmental Protection Agency
EE	Exceptional event
GAM	Generalized additive model
GLM	Generalized linear model
ha	Hectares
HMS	Hazard Mapping System
HYSPLIT	Hybrid Single-Particle Lagrangian Integrated Trajectory
LADCO	Lake Michigan Air Directors Consortium
MAIAC	Multi-Angle Implementation of Atmospheric Correction
MDA8	Maximum Daily Eight-hour Average
Milw16	Milwaukee-16th Street
MilwCA	Milwaukee College Avenue
MilwUPark	University of Wisconsin-Milwaukee UPark
MODIS	Moderate Resolution Imaging Spectroradiometer
NAAQS	National Ambient Air Quality Standard
NCW	No Canadian wildfires
NO_2	Nitrogen dioxide

NPL	National Preparedness Level
O_3	Ozone
$PM_{2.5}$	Fine particulate matter
ppb	Parts per billion
SLTs	State, local and tribal agencies
TROPOMI	Tropospheric Monitoring Instrument
UW	University of Washington
WCA	Waukesha Cleveland Avenue
Z	Zulu

Introduction

During the 2023 Canadian wildfire season, over 17 million hectares (ha) of wildland was burned, more than doubling Canada's previous annual record from 1989 and nearly seven-times its annual average of 2.5 million ha.[1] According to the Canadian Interagency Forest Fire Centre (CIFFC), the National Preparedness Level (NPL) reached its highest level of "5" on May 11, 2023, and it remained there until September 7, 2023.[2] The CIFFC states NPL 5 means that "[w]ildland fire activity is significant within one or more jurisdictions. Firefighters and equipment in every jurisdiction in Canada is put to use, and international help has been requested."[3]

Canadian wildland fire data from the CIFFC archives[2] shows that from May 11 until May 31, 2023, total area burned in Canada grew from 506,541 ha to 2,329,461 ha, a growth of over 1.8 million ha, which is over 70% of the country's annual average in a 20-day period. This included the Shelburne County fire, Nova Scotia's largest wildfire in recorded history.[4] In Eastern Canada, more land was burned in southern Quebec from June 1 through June 25 than in the previous 20 years combined.[5] And in the five-day period from July 17 until July 21, nearly 640,000 ha burned in the Provinces of Northwest Territories, British Columbia, Alberta, and Saskatchewan, which is more than the *total* area burned in these Provinces up to July 21 averaged over the previous five years.

The multitude, longevity and scale of the 2023 Canadian wildfires in concert with favorable meteorological conditions led to prolonged periods of near-surface smoke across the eastern half of the United States, with Wisconsin measuring its highest hourly and daily average $PM_{2.5}$ concentrations in recorded history, as well as the highest eight-hour average ozone (O_3) concentration since 2003.

Pursuant to the U.S. Environmental Protection Agency's (EPA) Exceptional Events (EE) Rule, state, local and tribal agencies (SLTs) may request that the EPA exclude data impacted by EEs from the data sets used to make regulatory determinations (e.g., the data set used to calculate a design value (DV)) in instances where the exclusion of the data has regulatory significance.[6]

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[1] https://ciffc.net/situation/2023-10-06
[2] https://ciffc.net/situation/archive/
[3] https://ciffc.net/pdfs/nationalpreparedness-levels.pdf
[4] https://novascotia.ca/natr/forestprotection/wildfire/nova-scotia-wildfires-2023-after-action-report.pdf
[5] https://natural-resources.canada.ca/stories/simply-science/canada-s-record-breaking-wildfires-2023-fiery-wake-call
[6] https://www.epa.gov/sites/default/files/2018-10/documents/exceptional_events_rule_revisions_2060-as02_final.pdf

Table 1 shows 2025 8-hour average O_3 DVs for the Waukesha Cleveland Avenue (WCA) and University of Wisconsin-Milwaukee UPark (MilwUPark) monitors, the dates of four smoke events and resulting MDA8 O_3 concentrations at these monitors and the 2025 8-hour average O_3 DVs after exclusion of the data from July 25, 2023, at the MilwUPark, and June 2, June 19, June 29 and July 25, 2023, at the WCA monitor. Given that the exclusion of these data results in the 2025 DVs at both monitors meeting the 2015 8-hour average O_3 National Ambient Air Quality Standard (NAAQS) of 70 parts per billion (ppb), the Wisconsin Department of Natural Resources (DNR) formally submits the following EE Demonstration.

Table 1: 2025 O_3 DVs for WCA and MilwUPark monitors before and after data exclusion.

Site	AQS ID	Dates for Exclusion	MDA8 O_3	2023-25 O_3 DV Before Exclusion	2023-25 O_3 DV After Exclusion
MilwUPark	55-079-0068	7/25/2023	97 ppb	71 ppb	70 ppb
WCA	55-133-0027	6/2/2023 6/19/2023 6/29/2023 7/25/2023	83 ppb 83 ppb 85 ppb 80 ppb	71 ppb	70 ppb

Narrative Conceptual Model

Discussion of Non-Event O_3 Formation

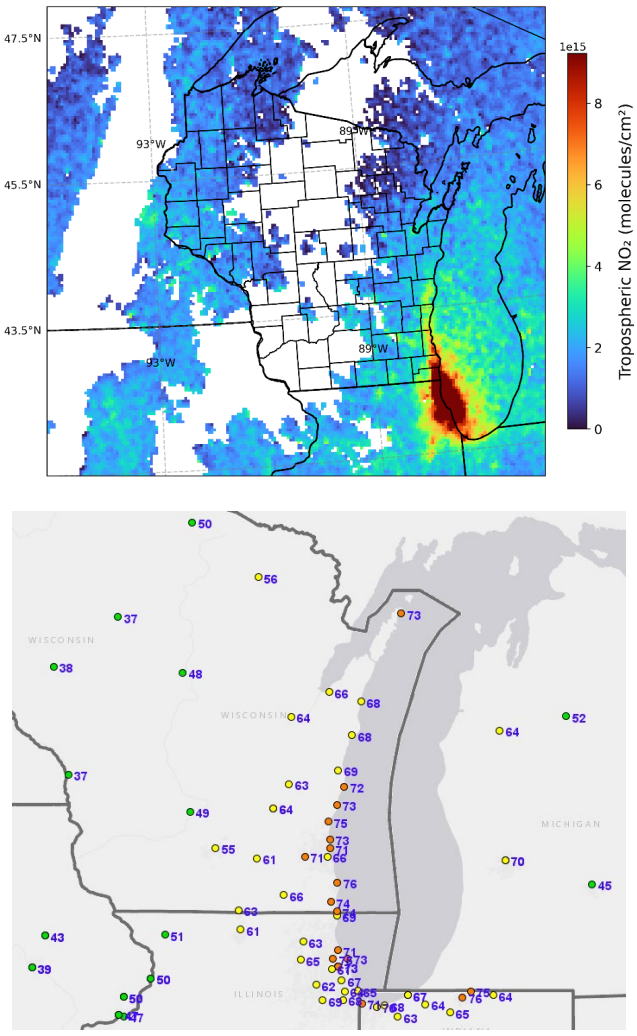
The Lake Michigan area has a long and well documented history of O_3 nonattainment, with Michigan, Indiana, Illinois, and Wisconsin at some point containing nonattainment areas for the 1997, 2008 and 2015 O_3 NAAQS. In February 2023, the Lake Michigan Air Directors Consortium (LADCO) published a report titled *Conceptual Models of* O_3 *Formation in the Great Lakes Region*.[7] For the Wisconsin's Lake Michigan lakeshore, the report notes that LADCO's classification and regression tree (CART) analysis and EPA's generalized linear model (GLM) find that maximum temperature and southerly transport are the most important meteorological features impacting O_3 production. Although southerly synoptic flow is a key component to O_3 production in the Milwaukee area, smaller-scale dynamical features, specifically the lake or land breeze circulation, play a critical role in enhancing O_3 observations close to the lakeshore.

On a typical (non-event) high O_3 day in the Milwaukee area, light southerly winds will transport anthropogenic precursor emissions from the Chicago urban core and heavily industrialized northern Indiana area out over southern Lake Michigan, where they become trapped in a shallow, marine boundary layer. This process may also be aided by a land breeze circulation. After sunrise, photochemistry can begin processing precursor emissions into O_3 and daytime heating initiates the lake breeze circulation. As the shallow marine boundary layer moves inland via the lake breeze circulation, high concentrations of O_3 can be observed, and further anthropogenic precursor emissions can be injected into the circulation. When imbedded within a synoptic flow dominated by southerly transport, a "corkscrew" lake breeze[8] is initiated, traveling north along the Lake Michigan shoreline, even impacting rural areas with minimal precursor emissions such as Door County. In the absence of southerly synoptic transport (e.g., within a stagnant, high pressure air mass), the lake breeze along Lake Michigan's western shore will eventually veer north with time in response to the Coriolis force, evolving into a corkscrew lake breeze.[8] Thus, even on stagnant days with minimal synoptic forcing, Chicago and northern Indiana precursor emissions can be transported north into the Milwaukee area via the lake breeze circulation.

[7] https://www.ladco.org/public-issues/ozone/ozone-science/
[8] https://agupubs.onlinelibrary.wiley.com/doi/full/10.1029/2003RG000124

Figure 1 shows tropospheric nitrogen dioxide (NO_2) from the Tropospheric Monitoring Instrument (TROPOMI[9]; top panel) and Maximum Daily Eight-hour Average (MDA8) O_3 (bottom panel) on September 19, 2024. This non-event day was characterized by synoptic southerly flow and hot temperatures, typical of high O_3 formation in the Milwaukee area. The NO_2 map (overpass around 1 PM local time) shows the Chicago urban core and northern Indiana plumes already leading to significant anomalies along Wisconsin's southern lakeshore. MDA8 O_3 observations show that a corkscrew lake breeze led to exceedance-level impacts as far north as Door County, while inland monitors observed Good to Moderate Air Quality Index values.

Figure 1: (Top) TROPOMI NO2 retrieval on September 19, 2024; (Bottom) AirNow MDA8 O_3 on September 19, 2024.

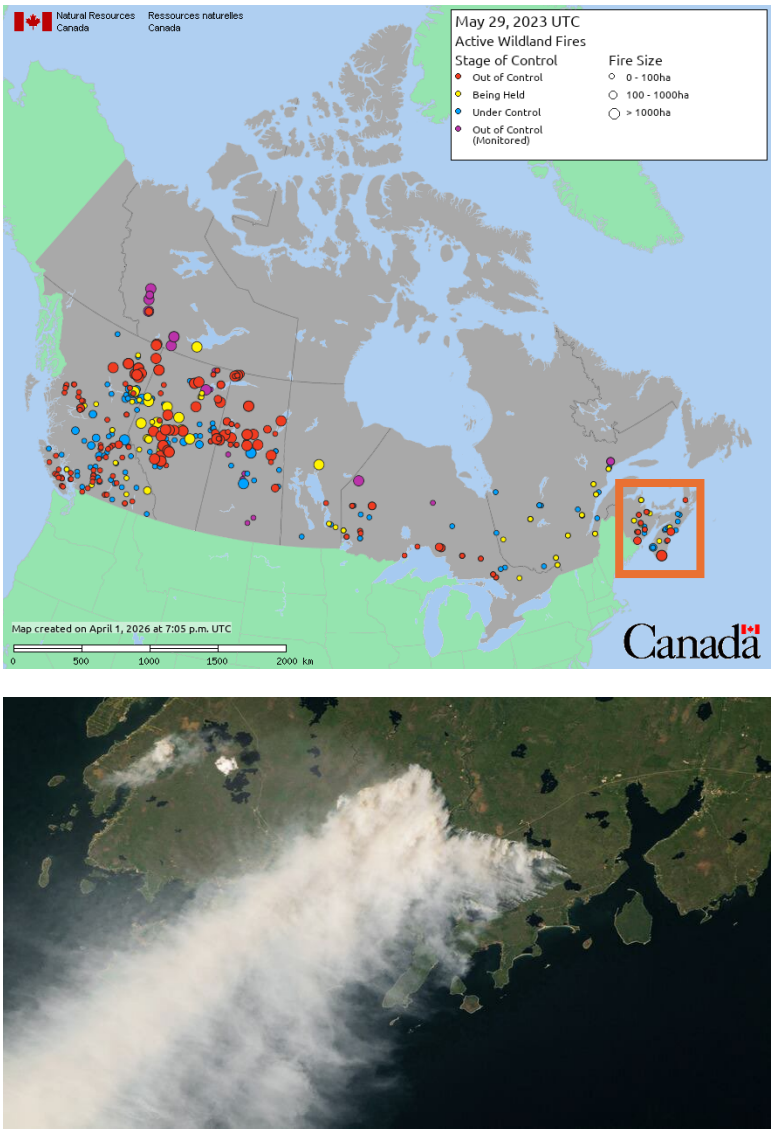


[9] All TROPOMI data was provided by the University of Wisconsin – Madison and has been processed to a 4km grid using the Wisconsin Horizontal Interpolation Program for Satellites. https://sage.nelson.wisc.edu/data-and-models/datasets/satellite-data-for-air-quality/

June 2, 2023

The Canadian Wildland Fire Information System (CWFIS) active wildfire map for May 29 shows multiple out of control wildfire complexes in far eastern Canada, including a large-scale fire (defined as measuring greater than 1000 ha) in southern Nova Scotia (Figure 2). This fire in Shelburne County will go on to become Nova Scotia's largest wildfire on record.[10]

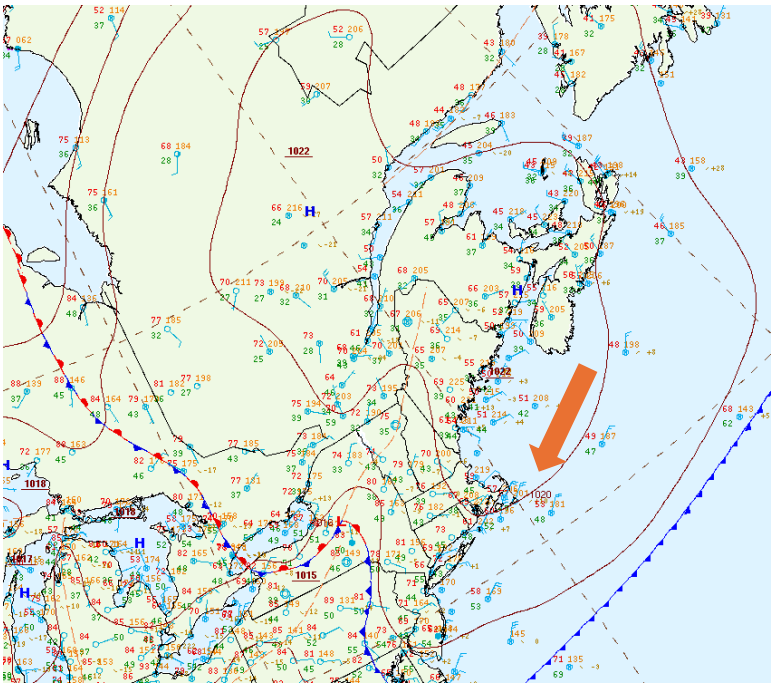
Figure 2: (Top) CWFIS active wildfires on May 29, 2023; (Bottom) Visible satellite imagery of Shelburne County, Nova Scotia wildfire on May 29, 2023.



[10] Residents watch with dread as N.S.'s largest forest fire continues to rage in Shelburne County | CBC News

The 21Z May 29 surface analysis (Figure 3) shows a dominant high pressure air mass over New Brunswick and southern Quebec. Wildfires across the area are injecting smoke into this air mass with clockwise winds beginning to transport smoke to the southwest (orange arrow in Figure 3), which is evident in the satellite photo from May 29 (Figure 2 bottom).

Figure 3: 21Z May 29, 2023, surface map centered over New Brunswick and southern Quebec.



Over the course of the next several days, the high pressure air mass containing the smoke slowly drifted south-southwest before retrograding west-northwest, as is evident in the 500-mb analysis (Figure 4). As this air mass with aging wildfire smoke moved from the Atlantic towards the Great Lakes region, a growing area of anomalous O_3 production engulfed a region from the Ohio River valley to the southern Great Lakes (Figure 5).

Figure 4: 500mb chart from 00Z June 1 (Top), June 2 (Middle) and June 3 (Bottom), 2023.

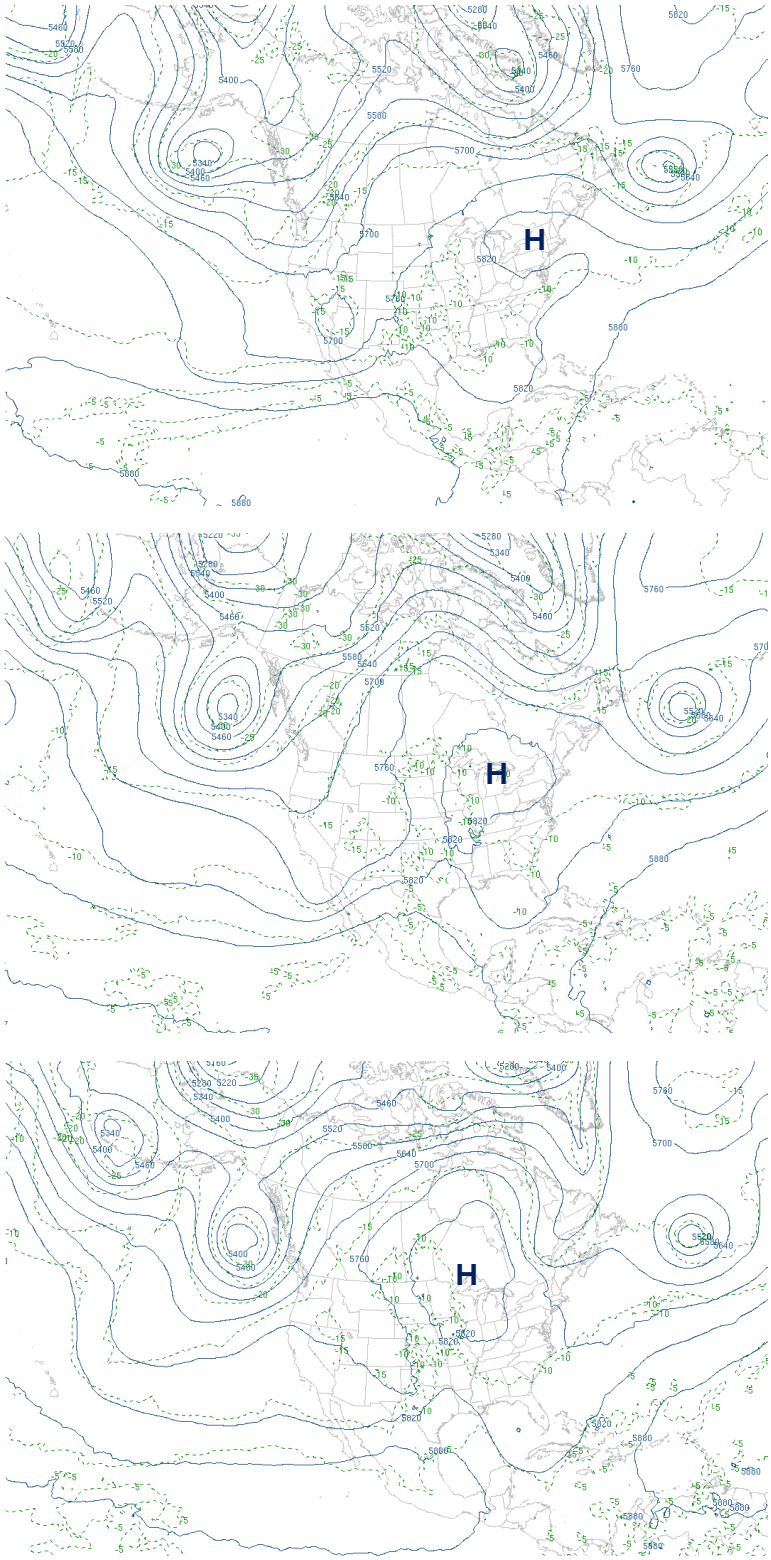
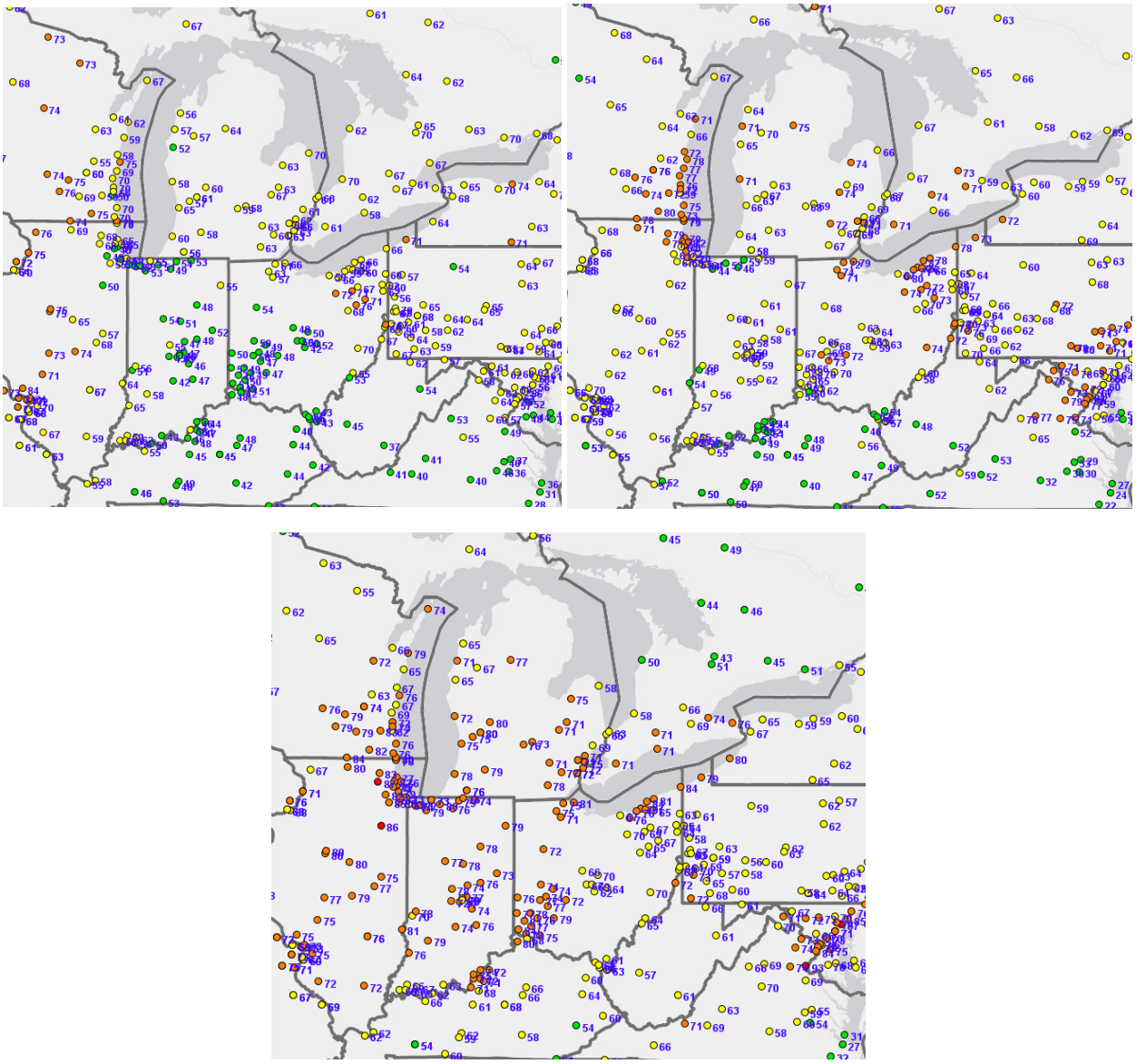
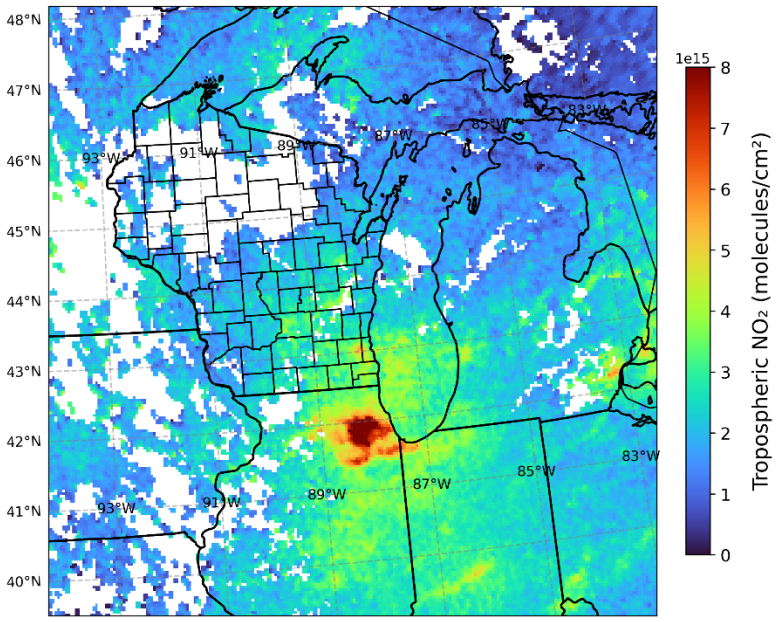


Figure 5: AirNow MDA8 O_3 on May 31 (Top Left), June 1 (Top Right) and June 2 (Bottom), 2023.



The east-northeast synoptic flow on June 2 is not conducive to anomalous O_3 production in the Milwaukee area, as the Chicago and northern Indiana plumes are not transported over Lake Michigan. This is evident in the satellite NO_2 retrieval from June 2 (Figure 6), which depicts these plumes moving inland, away from Lake Michigan. As discussed in the non-event O_3 formation section of this document, as well as within LADCO's Conceptual Models of O_3 Formation in the Great Lakes Region, the injection of these precursor plumes into Lake Michigan's marine boundary layer is crucial in the

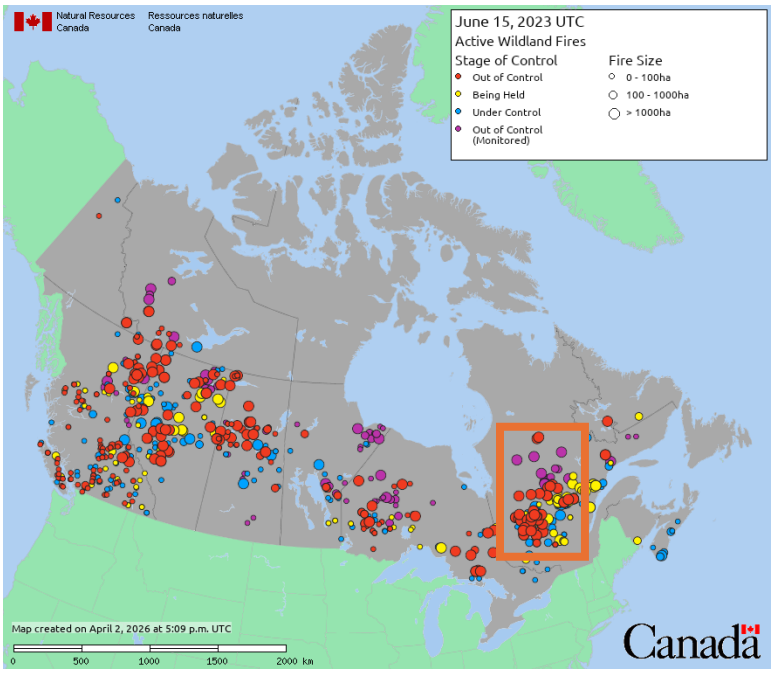
subsequent development of enhanced O_3 concentrations in the Milwaukee area.Figure 6: TROPOMI NO2 retrieval on June 2, 2023.



June 19, 2023

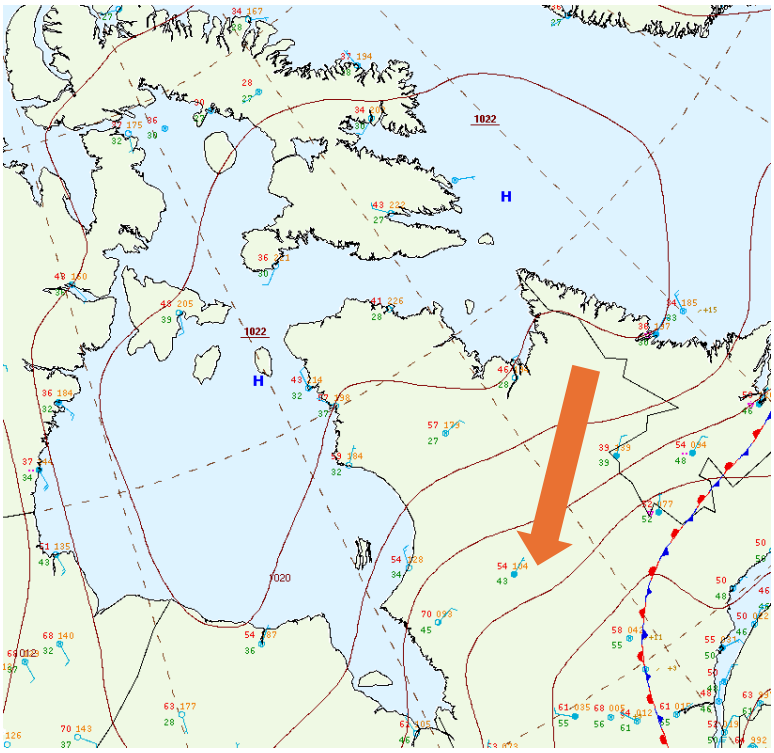
The CWFIS active wildfire map for June 15 shows a multitude of out of control, large-scale wildfire complexes in Quebec Canada (Figure 7), and according to CIFFC archives, nearly 125,000 ha of land was burned in Quebec from June 15 to June 18.

Figure 7: CWFIS active wildfires on June 15, 2023.



The 21Z June 15, 2023, surface analysis shows a dominant high pressure air mass over Hudson Bay and Baffin Island areas (Figure 8). Wildfires across Quebec are injecting smoke into this air mass with clockwise winds beginning to transport smoke to the southwest, indicated by the orange arrow in Figure 8.

Figure 8: 21Z June 15, 2023, surface map centered over Hudson Bay and Baffin Island area.



This high pressure air mass became established over the Great Lakes region on June 17 before slowly drifting east-northeast on June 18-19 as a weak low moved from the Plains into the Ohio River valley (Figure 9). Anomalous O_3 production within the high pressure air mass began to flare up in the Great Lakes region on June 17, spreading on June 18 and culminating in widespread smoke-related O_3 exceedances on June 19 across western Michigan, northern Indiana and Illinois, eastern Iowa and much of Wisconsin (Figure 10).

Figure 9: 21Z Surface maps centered over Great Lakes on June 17 (Top Left), June 18 (Top Right) and June 19 (Bottom), 2023.

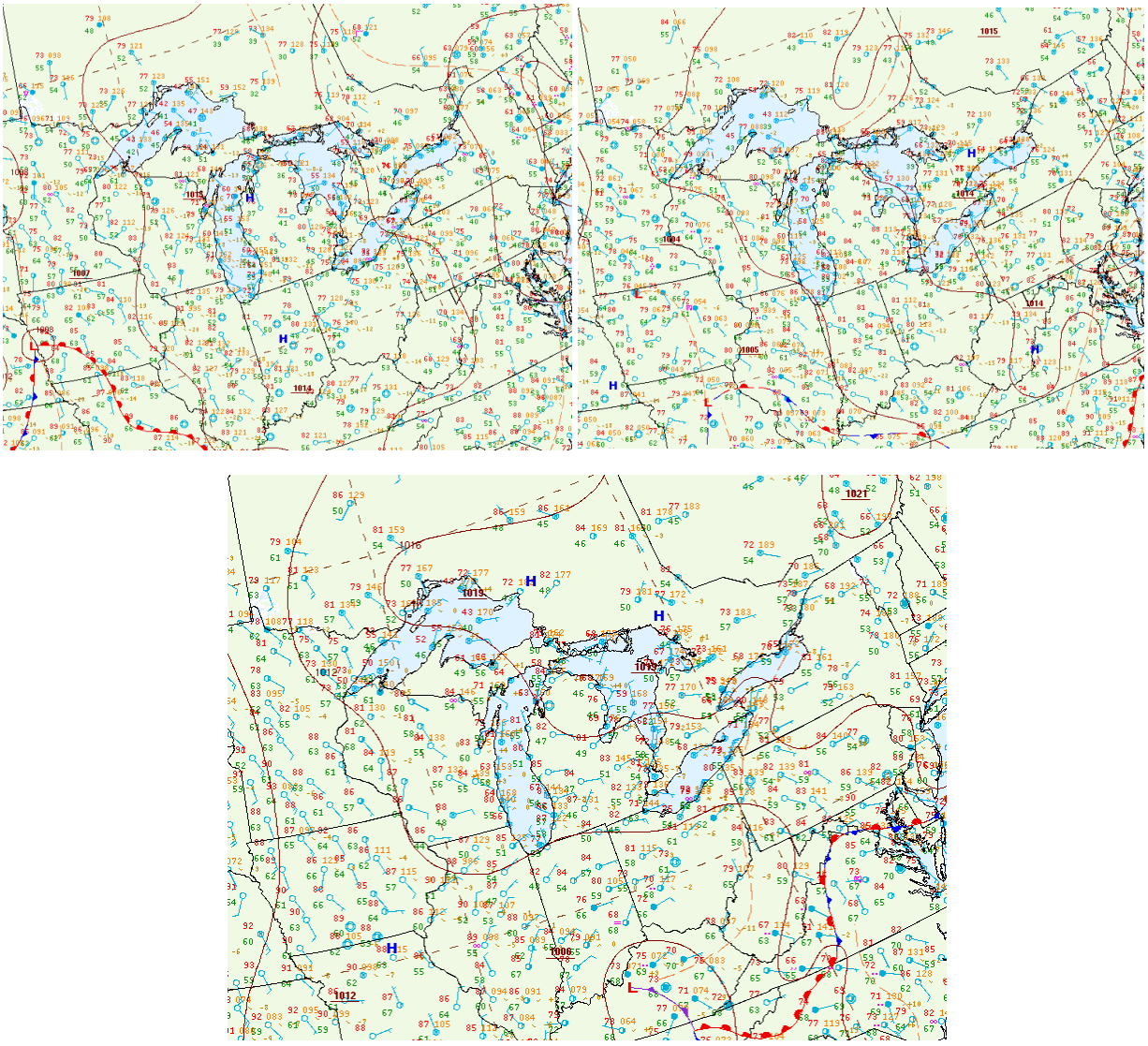
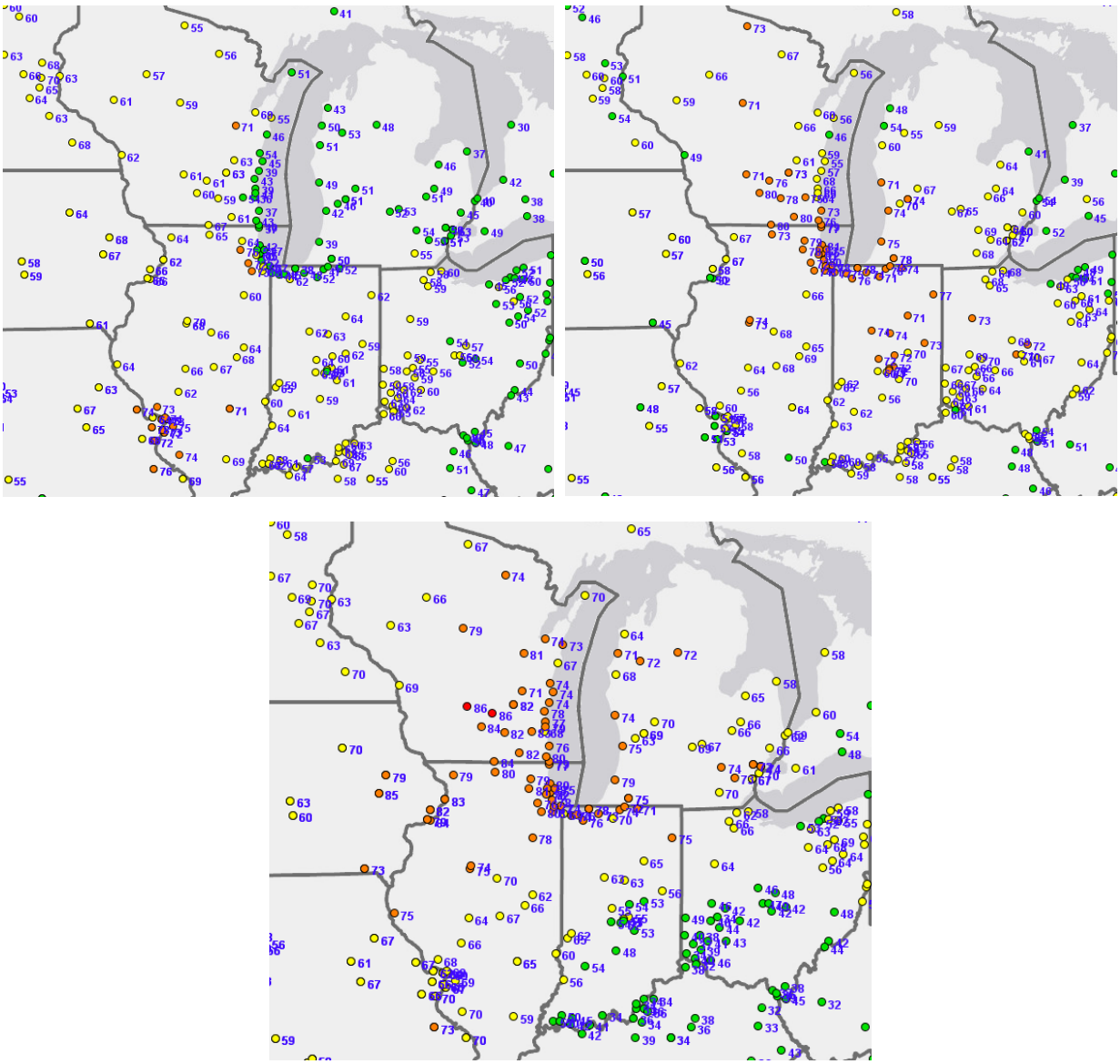
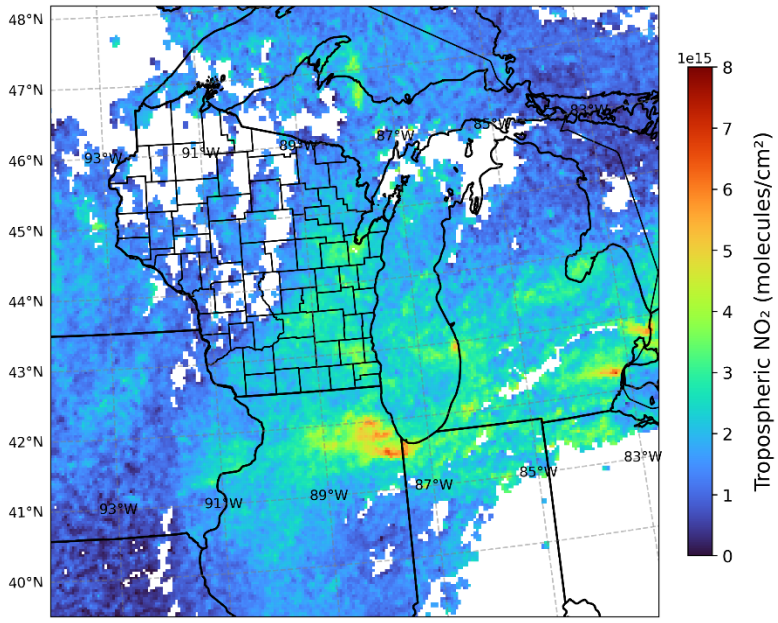


Figure 10: AirNow MDA8 O_3 on June 17 (Top Left), June 18 (Top Right) and June 19 (bottom), 2023.



Notably, this meteorological setup with an east-northeast synoptic flow is not typically conducive to O_3 production in the Milwaukee area, as the Chicago and northern Indiana plumes are not transported over Lake Michigan, as is evident in the satellite NO_2 retrieval from June 19 (Figure 11).

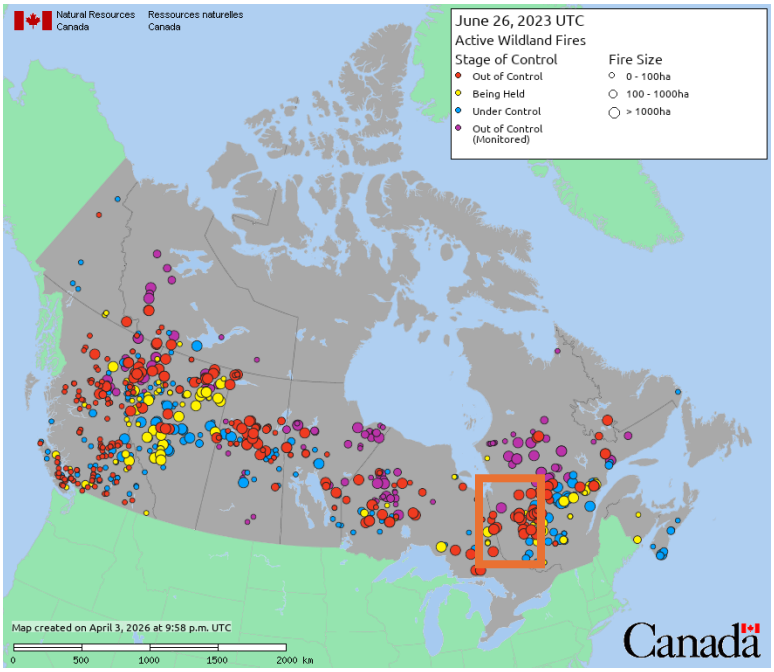
Figure 11: TROPOMI NO2 retrieval on June 19, 2023.

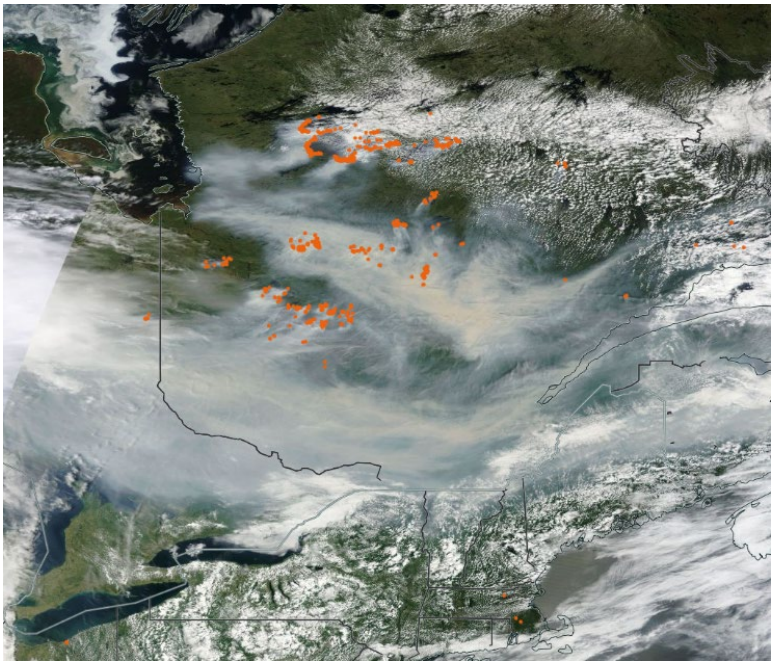


June 29, 2023

The CWFIS active wildfire map for June 26, 2023, shows a multitude of out of control, large-scale wildfire complexes in Quebec (Figure 12 top). June 25 visible satellite with fire and thermal anomalies marked in orange give a sense of the quantity of wildfire complexes and the scale of the dense smoke being produced (Figure 12 bottom).

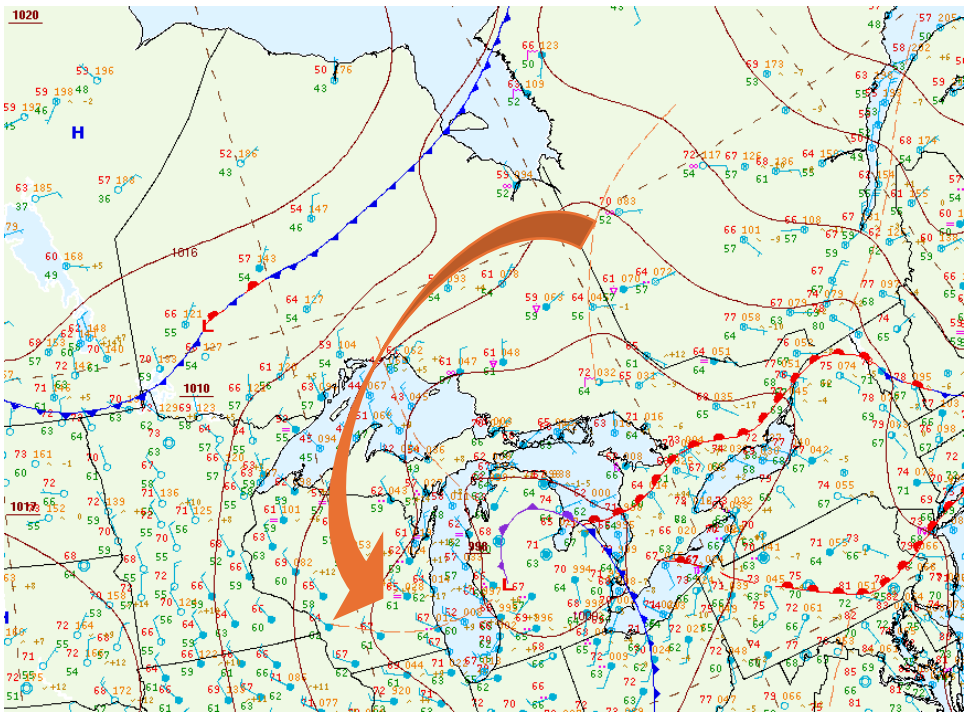
Figure 12: (Top) CWFIS active wildfires on June 26, 2023; (Bottom) Visible satellite imagery of southern Quebec wildfires on June 25, 2023.





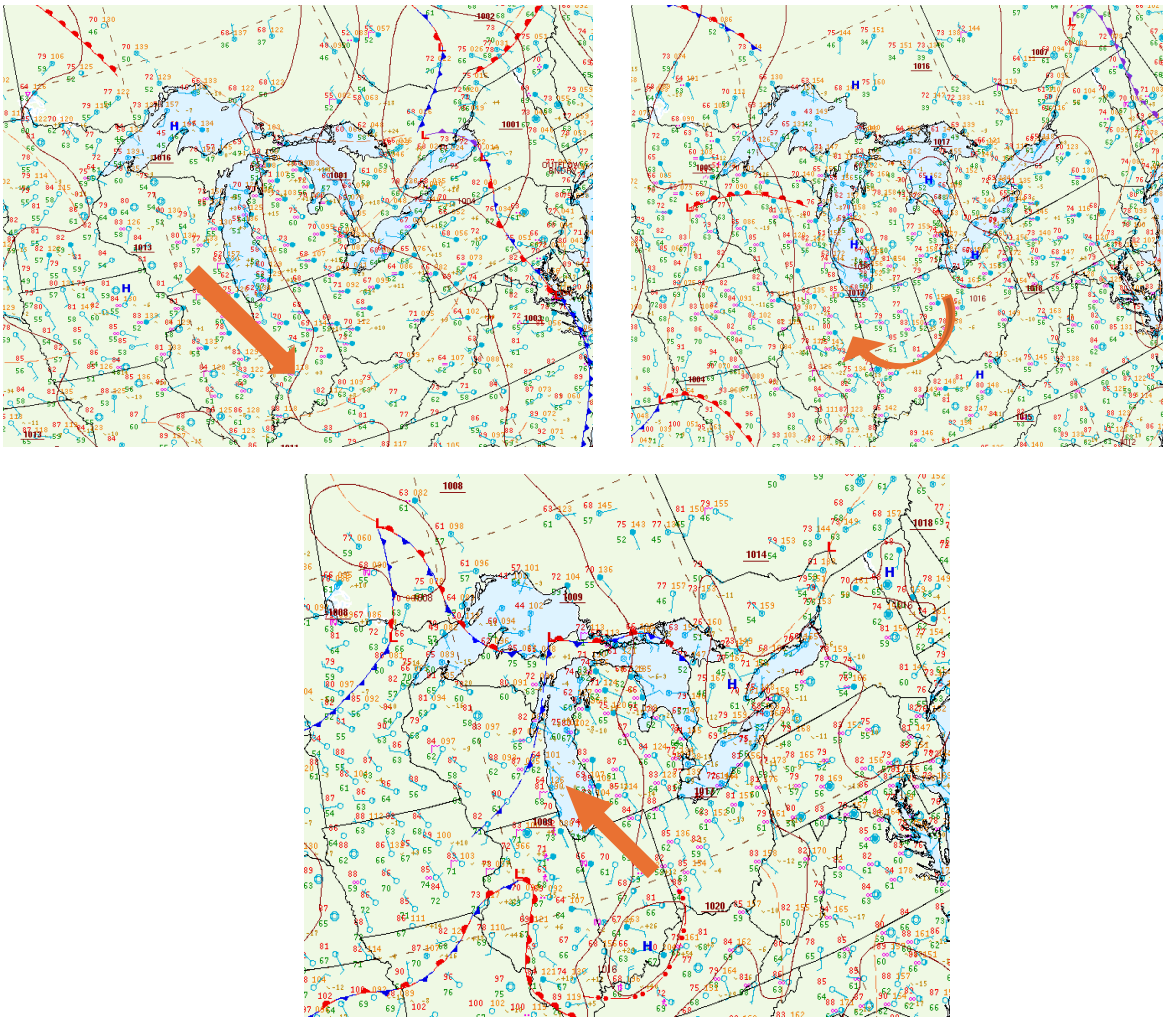
The 21Z June 26, 2023, surface analysis shows a high pressure air mass over Manitoba and an occluded low pressure air mass over the lower peninsula of Michigan (Figure 13). Wildfires across Quebec are injecting smoke into the low pressure air mass, with counter-clockwise winds wrapping smoke into the Great Lakes region around the northwest quadrant of the low (orange arrow in Figure 13).

Figure 13: 21Z June 26, 2023, surface map centered over Great Lakes.



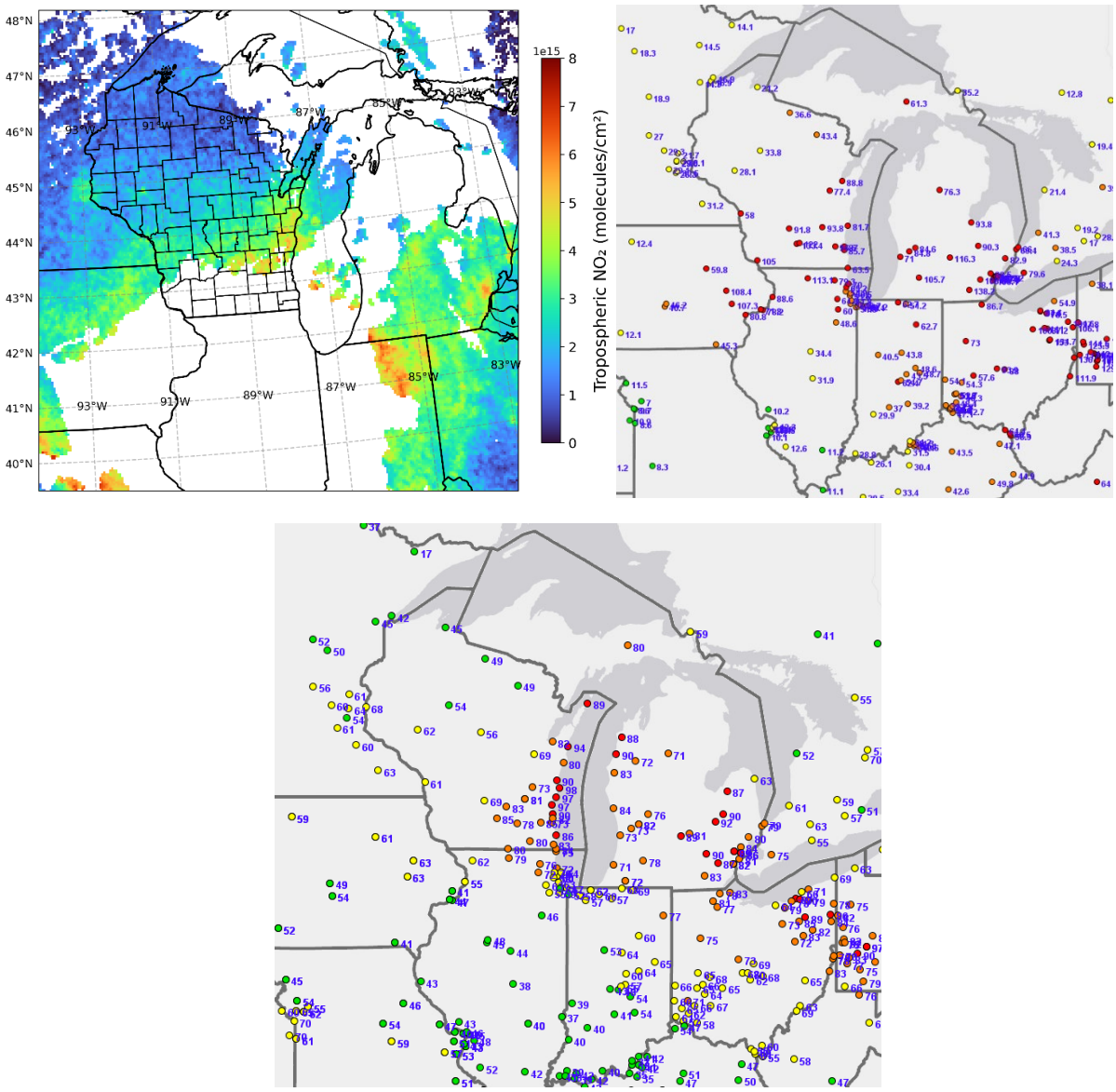
Over the next three days, the mature low drifts northeast out of the Great Lakes region towards New Brunswick, while high pressure filling in behind the departing low becomes the dominant dynamic driver. The evolving near-surface flow which had wrapped smoke around the northwest and west side of the low on June 26 and 27 now continues to pull smoke south along the eastern side of the high into the Ohio River valley on June 27 and 28. On June 28 and 29, the smoke recirculates back north along the west side of the high towards Lake Michigan (orange arrows in Figure 14).

Figure 14: 21Z Surface maps centered over Great Lakes on June 27 (Top Left), June 28 (Top Right) and June 29 (Bottom), 2023.



A southeasterly synoptic flow pattern, as experienced on June 29, can contribute to elevated O_3 production on non-event days. Satellite tropospheric NO_2 over the Milwaukee area was obscured by cloud cover on this day, however, anomalous tropospheric NO_2 readings from smoke impacts can still be observed throughout the region (Figure 15 top left). Furthermore, daily average fine particulate matter ($PM_{2.5}$) and MDA8 O_3 concentration anomalies were significant and widespread on this day (Figure 15 top right and bottom, respectively).

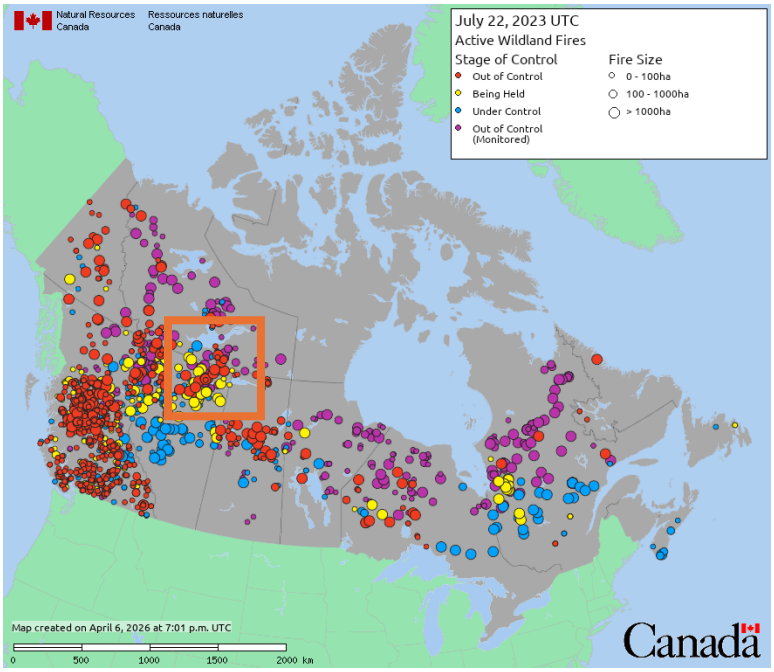
Figure 15: All maps valid June 29, 2023. (Top Left) TROPOMI NO2 retrieval; (Top Right) AirNow daily average $PM_{2.5}$; (Bottom) AirNow MDA8 O_3.

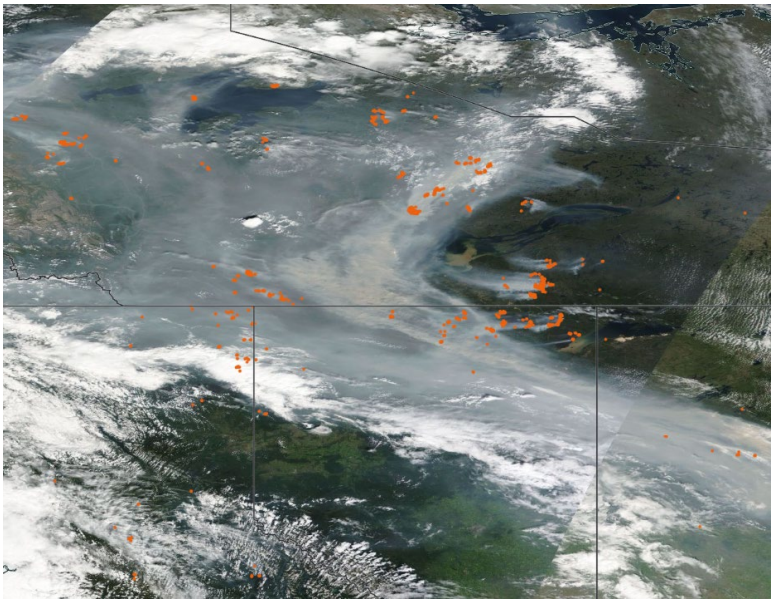


July 25, 2023

The CWFIS active wildfire map for July 22, 2023, shows a multitude of out of control, large-scale wildfire complexes near Great Slave Lake in southern Northwest Territories (Figure 16 top). Notably, these fires are surrounded by numerous other wildfires established across northern British Columbia, Alberta and Saskatchewan (Figure 16).

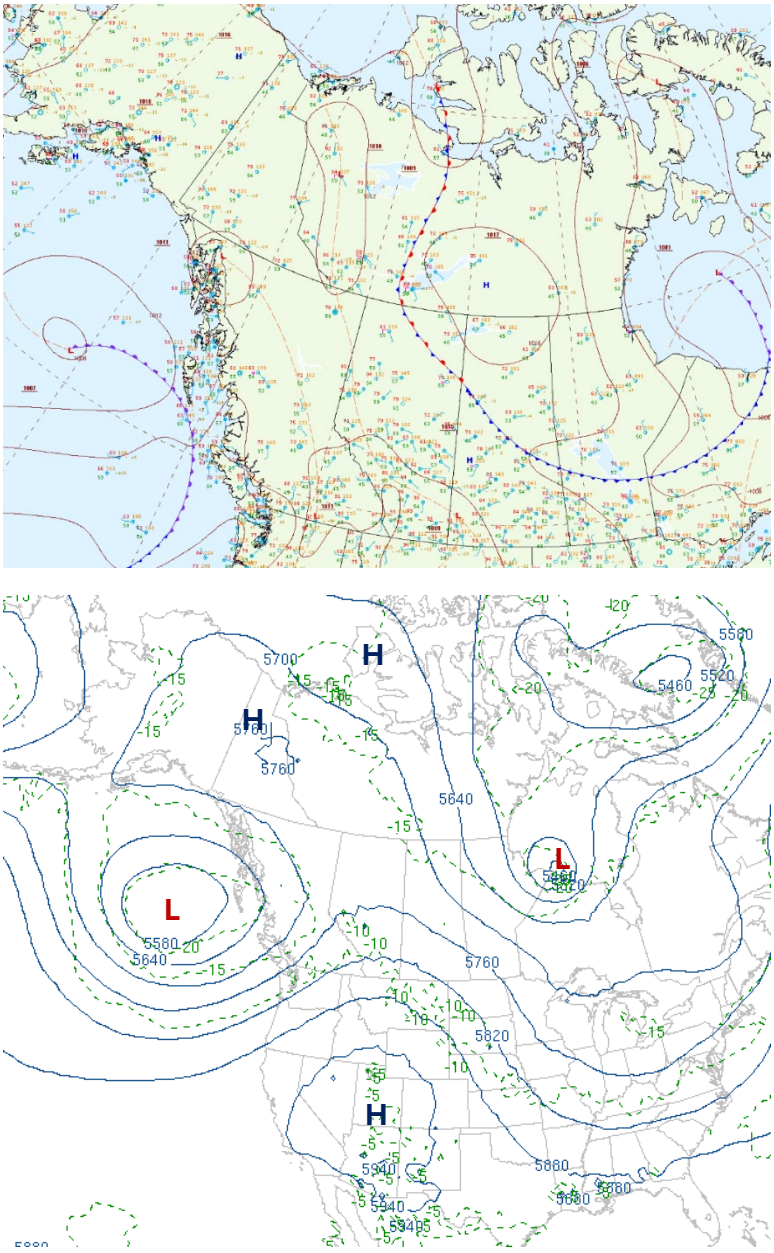
Figure 16: (Top) CWFIS active wildfires on July 22, 2023; (Bottom) Visible satellite imagery of wildfires near Great Slave Lake on July 22, 2023.





The 21Z July 22, 2023, surface analysis shows a boundary associated with an occluded low pressure system over Hudson Bay and an adjoining high pressure air mass to its west (Figure 17 top). Coupling this analysis with the visible satellite imagery (Figure 16 bottom), it is evident that smoke plumes from wildfires across Northwest Territories, British Columbia, Alberta and Saskatchewan accumulated along the southern and western edges of this boundary, with relatively cleaner air north and east of the boundary, as well as within a Four Corners high and associated ridging over the Rocky Mountains, which is evident in the 500-mb analysis for 00Z July 23 (Figure 17 bottom).

Figure 17: (Top) 21Z July 22, 2023, surface map centered over Canada; (Bottom) 500mb chart from 00Z July 23, 2023.



Over the course of the next three days, 500-mb analysis shows the ridging associated with the Four Corners high was dampened and displaced eastward as the Pacific low moved east to the British Columbia and Alberta border (Figure 18). Wildfire smoke spilled over the eastern edge of the ridge into the upper-Great Lakes area during this time, with significant $PM_{2.5}$ and O_3 impacts observed at the surface (Figure 19).

Figure 18: 500mb chart from 00Z July 24 (Top), July 25 (Middle) and July 26 (Bottom), 2023.

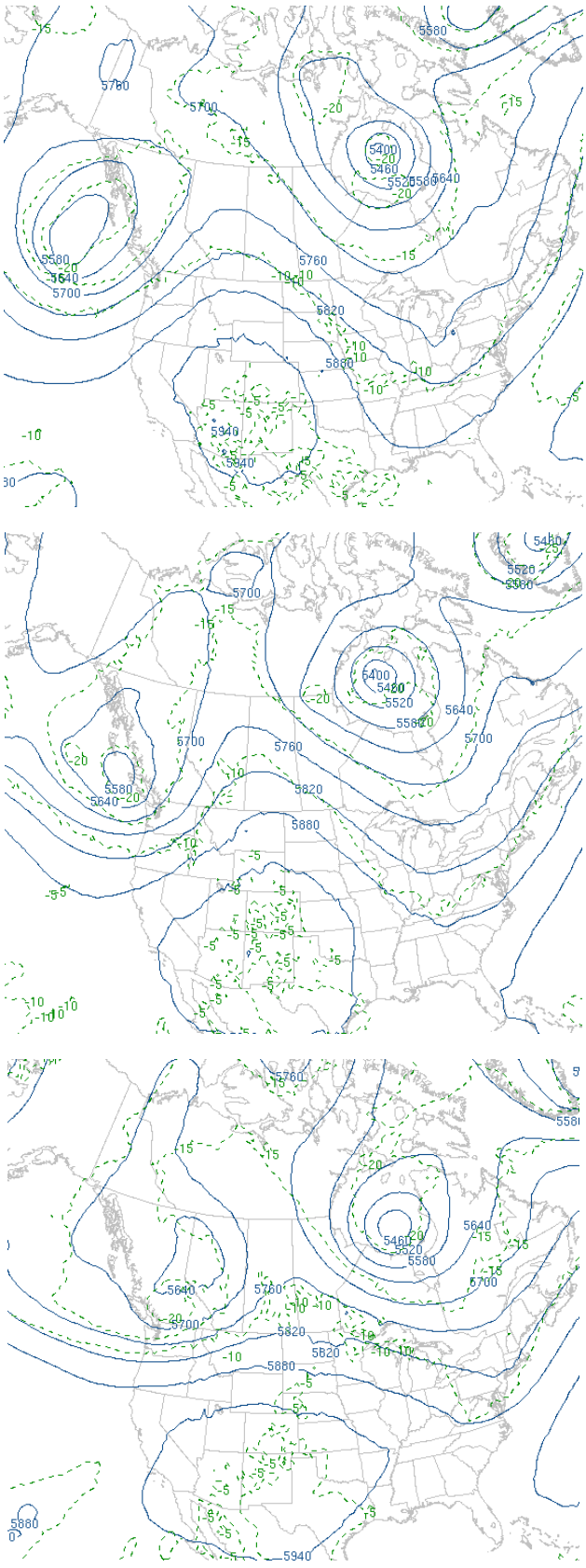
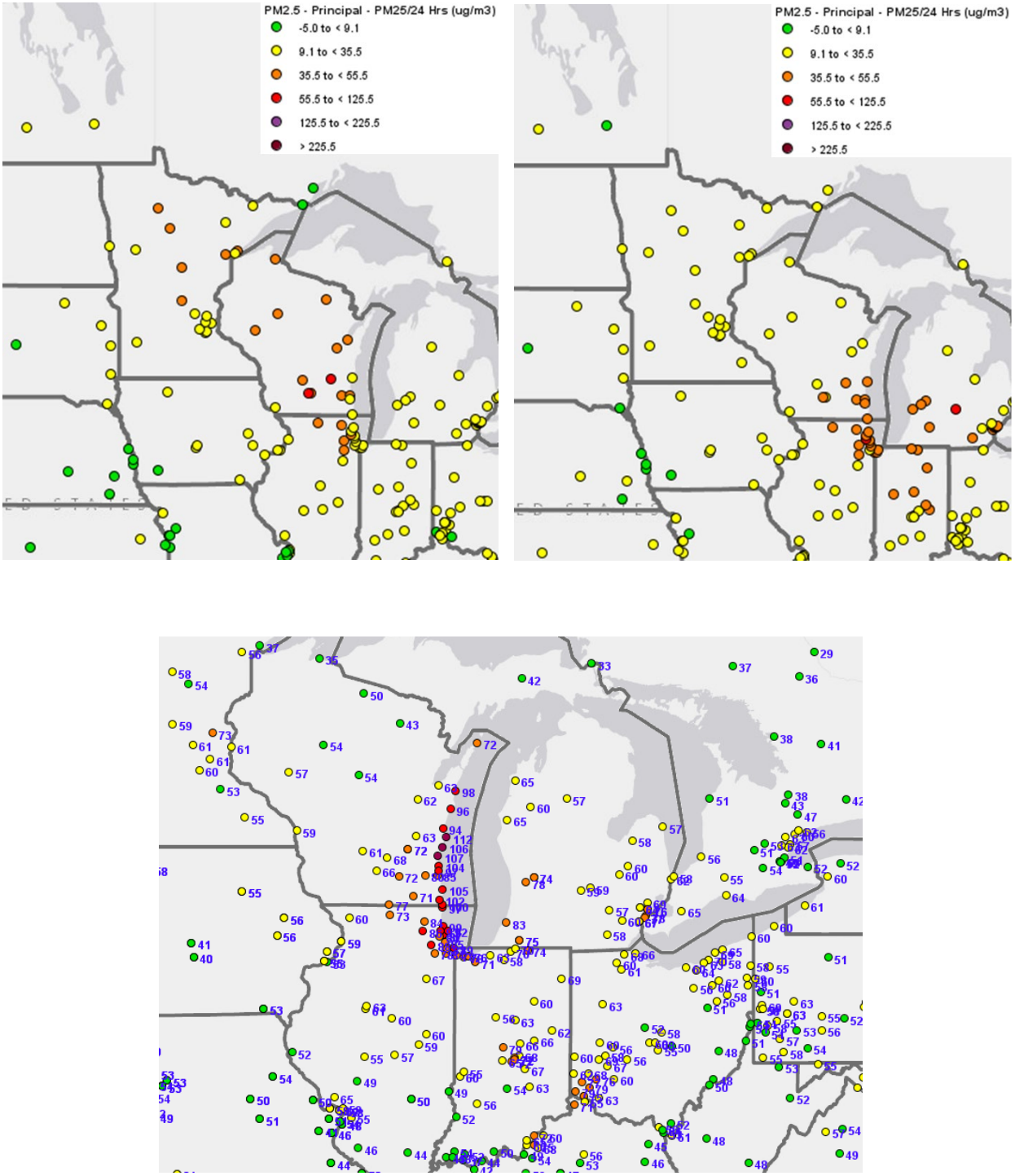


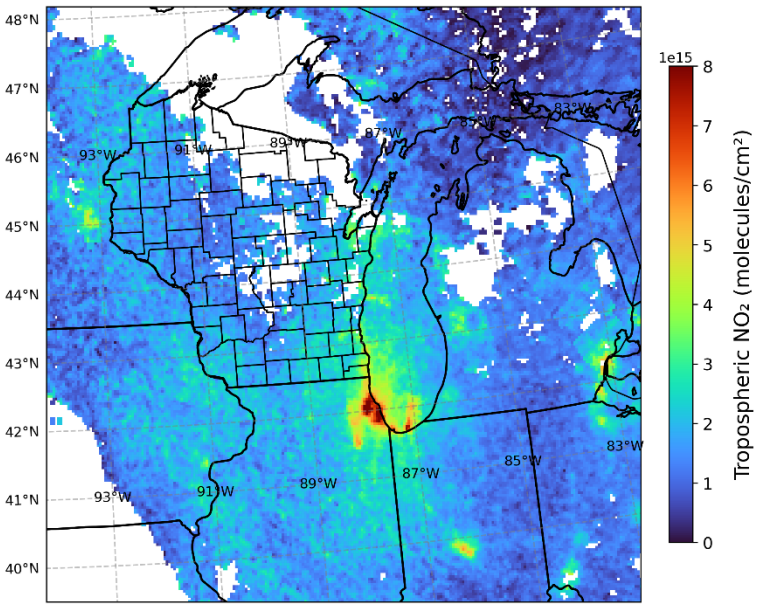
Figure 19: (Top Left) July 24, 2023, AirNow daily average $PM_{2.5}$; (Top right) July 25, 2023, AirNow daily average $PM_{2.5}$; (Bottom) July 25, 2023, AirNow MDA8.



A light southerly synoptic flow pattern was present on July 25, and tropospheric NO_2 shows the Chicago urban core and northern Indiana plumes had advected over Lake Michigan

(Figure 20). When coupled with the presence of wildfire smoke (as evidenced by highly anomalous surface $PM_{2.5}$ observations – Figure 19 top panels), MDA8 O_3 concentrations along Wisconsin's lakeshore reached their highest levels since 2003 (Figure 19 bottom).

Figure 20: TROPOMI NO2 retrieval on July 25, 2023.



Clear Causal Relationship

Event Related Concentrations in the context of Historical Concentrations

The EE rule requires demonstrating a clear, causal relationship between the event and the monitor values to show that the event affected air quality, in accordance with 40 CFR Part 50.14(c)(3)(iv)(B). In support of this demonstration, 40 CFR Part 50.14(c)(3)(iv)(C) requires a comparison of the event-influenced concentrations to concentrations at the same monitoring site at other times. An analysis of all O_3 MDA8 O_3 concentrations spanning the most recent 5-year dataset of 2021 through 2025 for both the MilwUPark and WCA monitoring sites is provided below.

Figure 21 shows all MDA8 O_3 concentrations from 2021 through 2025 at the MilwUPark monitor. The identified event day of July 25, 2023, produced an O_3 MDA8 concentration of 97 ppb (red star), which was also the highest O_3 MDA8 concentration recorded at the MilwUPark monitor throughout the 2021–2025 period. The event-associated O_3 MDA8 of 97 ppb was 24 ppb higher than the 5-year 99th percentile value of 73.0 ppb (brown dashed line), indicating that O_3 concentrations observed on this day were anomalously high.

Figure 21: O_3 MDA8s from MilwUPark for all 2021–2025 O_3 season days. Includes MDA8 for July 25, 2023 (red star), 5-year 99th percentile (brown dashed line), and 2015 O_3 NAAQS (blue dotted line).

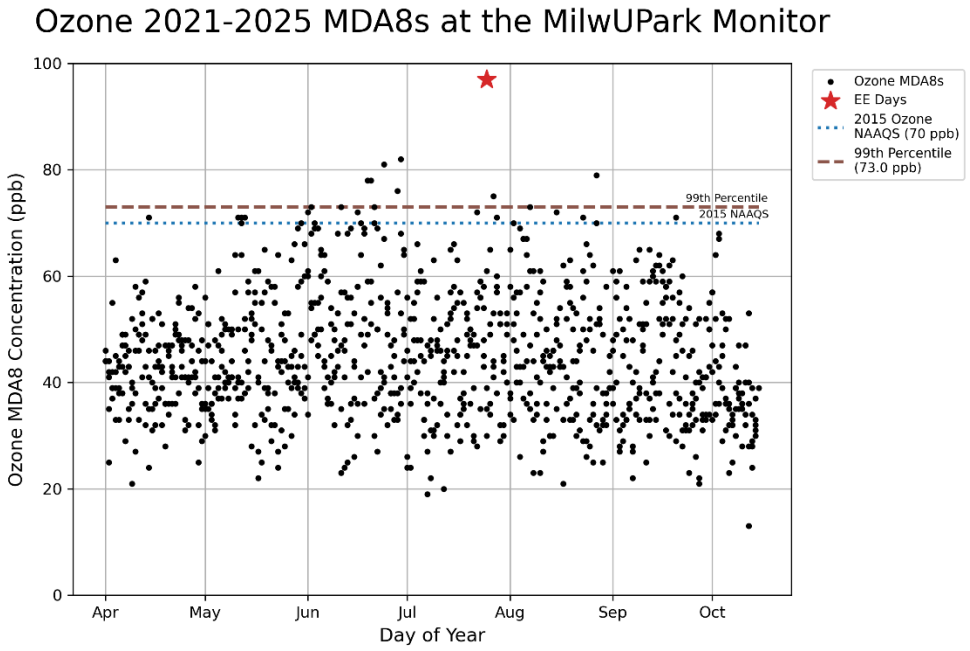
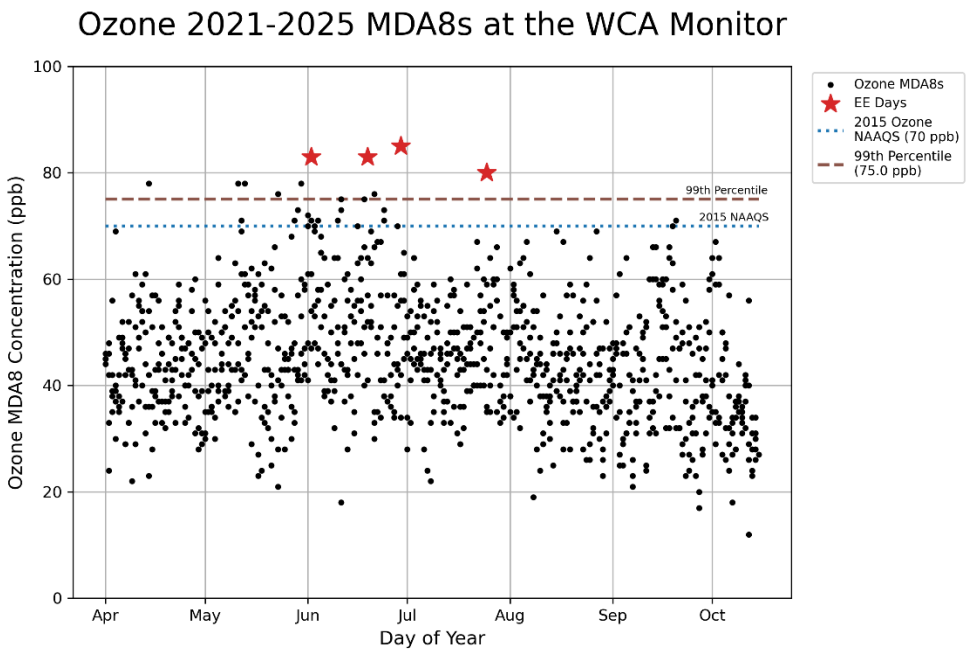


Figure 22 shows all MDA8 O_3 concentrations from 2021 through 2025 at the WCA monitor. The identified event days of June 2, June 19, June 29, and July 25, 2023, produced O_3 MDA8 concentrations of 80 to 85 (red stars), which were also the four highest O_3 MDA8 concentrations recorded at the WCA monitor throughout the 2021–2025 period. The event-associated O_3 MDA8s of 80 to 85 ppb ranged from 5 to 10 ppb higher than the 5-year 99th percentile value of 75.0 ppb (brown dashed line), indicating that O_3 concentrations observed on these days were anomalously high.

Figure 22: O_3 MDA8s from WCA for all 2021–2025 O_3 season days. Includes MDA8 for June 2, June 19, June 29, and July 25, 2023 (red stars), 5-year 99th percentile (brown dashed line), and 2015 O_3 NAAQS (blue dotted line).



Tier 3 Weight of Evidence Analyses

While the regional wildfire smoke episodes spanned multiple days in the summer of 2023, the MilwUPark and WCA monitors experienced greatly enhanced ground-level O_3 formation during the wildfire-related O_3 episode on July 25, 2023. The WCA monitor also observed significantly enhanced ground-level O_3 formation during the wildfire-related O_3 episodes on June 2, June 19, and June 29, 2023. All four dates have been treated as Tier 3 category due to event complexity, requiring a weight of evidence approach to establish a clear causal relationship between the Canadian wildfires and subsequent O_3 impacts at the MilwUPark and WCA monitors. The analysis products in this section that are used as weight of evidence include the following information:

- Hazard Mapping System (HMS) fire locations and smoke polygons
- Air Quality System (AQS) daily average $PM_{2.5}$ concentrations

- Hybrid Single-Particle Lagrangian Integrated Trajectory (HYSPLIT) model 168-hour back trajectories from June 2, 2023, initiated at 100, 200, and 300 meters above ground level (AGL)
- HYSPLIT 168-hour forward trajectories from May 27, 2023, initiated at 2000, 2100, and 2200 meters AGL
- HYSPLIT 108-hour back trajectories from June 19, 2023, initiated at 100, 250, and 500 meters AGL
- HYSPLIT 108-hour forward trajectories from June 15, 2023, initiated at 400, 500, and 600 meters AGL
- HYSPLIT 78-hour back trajectories from June 29, 2023, initiated at 100, 250, and 500 meters AGL
- HYSPLIT 78-hour forward trajectories from June 26, 2023, initiated at 250, 500, and 750 meters AGL
- HYSPLIT 96-hour back trajectories from July 25, 2023, initiated at 100, 200, and 300 meters AGL
- HYSPLIT 96-hour forward trajectories from July 22, 2023, initiated at 3000, 3250, and 3500 meters AGL
- Aerosol optical depth (AOD) from the Moderate Resolution Imaging Spectroradiometer (MODIS) combined Terra and Aqua Multi-Angle Implementation of Atmospheric Correction (MAIAC) Land AOD level 2 product overlaid on Terra MODIS corrected reflectance (true color) satellite imagery
- Results and residual estimates of wildfire-related MDA8 O_3 concentration impacts from the generalized additive model (GAM) developed by Dan Jaffe and Haebum Lee of the University of Washington (UW)
- Estimates of wildfire-related impacts to MDA8 O_3 concentrations from EPA's Expedited Modeling of Burn Events Results (EMBER) dataset tool
- Analysis of hourly average $PM_{2.5}$ concentrations measured during the wildfire-related O_3 episodes compared to historical average values during the months of June and July
- Analysis of hourly average CO concentrations measured during the wildfire-related O_3 episodes compared to historical average values during the months of June and July

The clear causal relationships between the Canadian wildfires and MDA8 O_3 concentrations at the WCA monitor during the wildfire-related O_3 episodes on June 2, June 19, and June 29, 2023, and at the MilwUPark and WCA monitors during the wildfire-related O_3 episode on July 25, 2023, are presented in the following pages. Weight of evidence

analysis components used to show a clear causal relationship are presented separately for each episode.

June 2, 2023

Transport of O_3 Precursors for June 2, 2023

The HYSPLIT 168-hour back and forward trajectories show the long-range transport of wildfire smoke plumes carrying O_3 precursors that greatly enhanced ground-level O_3 formation and contributed to high monitored MDA8 O_3 concentrations at the WCA monitor on June 2, 2023.

Figure 23 shows the HYSPLIT 168-hour back trajectory plot initiated from the WCA monitoring site at 18Z on June 2, 2023, alongside the HYSPLIT 168-hour forward trajectory plot initiated over the wildfire burning southwest of Shelburne, Nova Scotia at 00Z on May 27, 2023. Appendix A3 in EPA's *Guidance on the Preparation of Exceptional Events Demonstrations for Wildfire Events that May Influence Ozone Concentrations* published in September 2016 notes that starting heights are typically no less than 100 meters AGL to avoid direct interference of terrain, and are typically no greater than 1500 meters AGL to confine the air parcel within the mixed layer.[11] For locations along the Wisconsin lakeshore, it has been thoroughly documented that lake breezes play a critical role on days with high ozone.[12] Thus, the starting heights for the backwards trajectories were confined to lower elevations of 100, 200, and 300 meters AGL to ensure that parcels were initiated from within the marine boundary layer associated with the lake breeze that was observed on this day. In addition, the trajectory duration of 168 hours was necessary to properly show the long-distance transport from Nova Scotia to WCA. As described above in the narrative conceptual model for June 2, synoptic high pressure dominated conditions across the region leading to widespread weak flow for multiple days leading up to the event. High pressure influence and slow westward transport is evident in Figure 23 with the clockwise nature of the trajectories coupled with minimal spacing between markers representative of 6-hour intervals.

Figure 24 shows maps of satellite-derived AOD and monitored daily average $PM_{2.5}$ concentrations at the surface with HMS smoke layers and fire locations for June 2, 2023. The location of the fires across southern Nova Scotia shown in Figure 2 align with the 100-meter release height trajectory from WCA, passing over southern Nova Scotia 2200–2300 meters AGL. The 168-hour forward trajectory initiated at 2200 meters AGL over the southern Nova Scotia fires ends just 50 meters AGL over southeastern Wisconsin.

[11] https://www.epa.gov/system/files/documents/2023-12/guidance-on-the-preparation-of-ee-wf-ozone.pdf
[12] Dickens, A. F. (2023). *Conceptual Models of Ozone Formation in the Great Lakes Region*. Lake Michigan Air Directors Consortium. Ozone-conceptual-model-report-FINAL-Feb-2023.pdf. p. 115.

The connection between these forward and back trajectories show clear evidence of smoke plumes carrying O_3 precursors being transported into Wisconsin from the southern Nova Scotia fires and causing high O_3 concentrations at the WCA monitor on June 2, 2023. Higher values of AOD (orange and red colors) in locations that are void of cloud cover indicate the presence of wildfire smoke in the column, apparent over southeastern Wisconsin, Michigan, and the northern Indiana/Ohio borders in Figure 24. Coupled with HMS polygons indicating overhead smoke and elevated $PM_{2.5}$ concentrations at the surface, these data provide additional evidence that wildfire smoke containing O_3 precursors was present over the WCA monitor on June 2, 2023.

Figure 23: HYSPLIT 168-hour back trajectories from WCA at 18 UTC 06/02/2023 (left). HYSPLIT 168-hour forward trajectories from the Nova Scotia fire at 00 UTC 05/27/2023 (right).

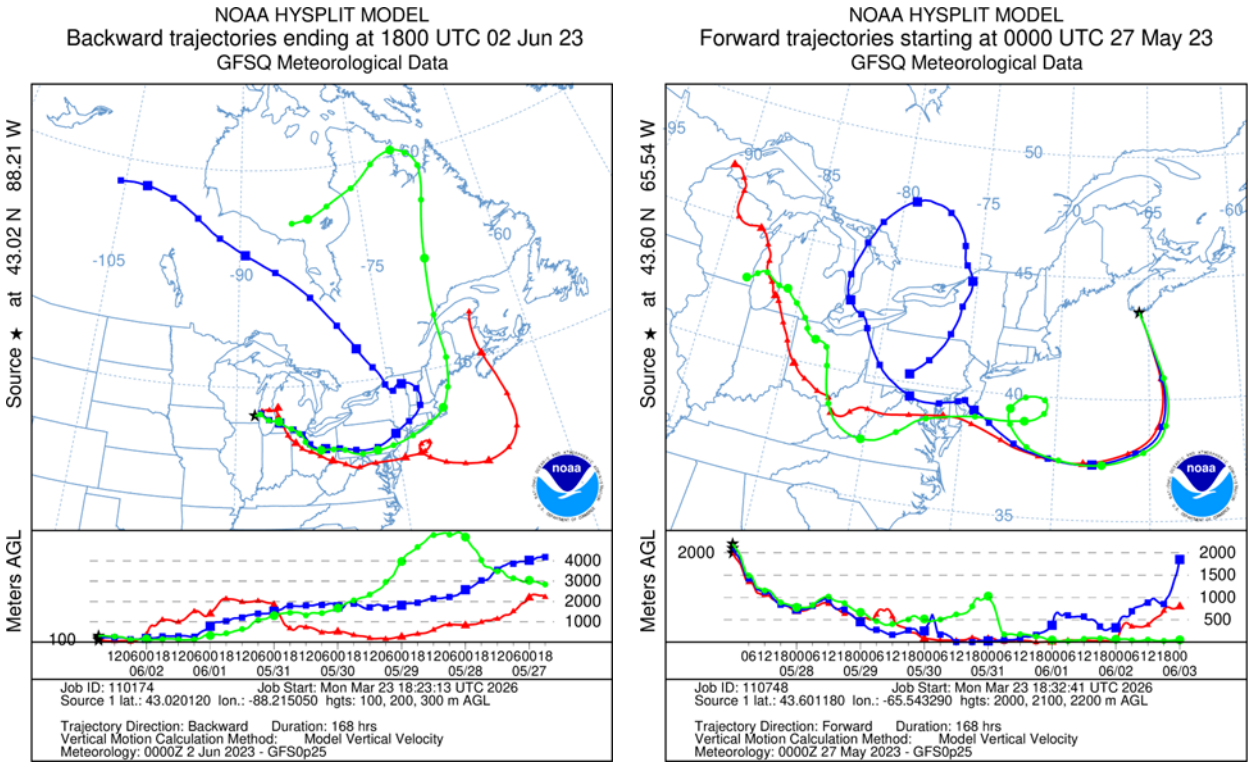
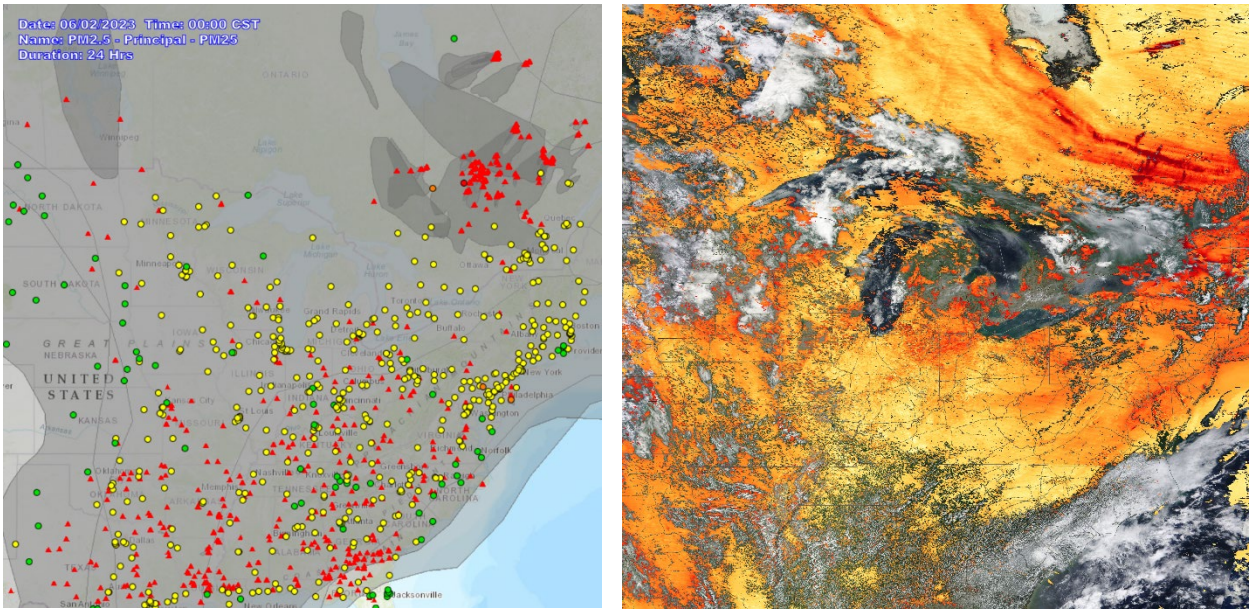


Figure 24: Daily average $PM_{2.5}$ concentrations with HMS smoke layers and fire locations (left) and MAIAC AOD satellite imagery (right) for June 2, 2023.



Comparison of Observed and Modeled O_3 for June 2, 2023

Further evidence that wildfire smoke impacted O_3 concentrations at the WCA monitor on June 2, 2023, stems from the analysis of observed MDA8 O_3 values compared to model predictions of O_3 and associated fire impacts from the same day. A large difference between the observed MDA8 O_3 value and the predicted MDA8 O_3 value, referred to herein as residual, indicates that the model has underpredicted the monitored MDA8 O_3 value, which suggests that there were additional impacts increasing O_3 concentrations that were not accounted for in the modeling, such as an influx of O_3 precursors transported from wildfires. Multiple models with large residuals for O_3 predictions at the WCA monitor on this date would serve as additional evidence that monitored O_3 concentrations on this date were impacted by other factors unaccounted for in the models, such as wildfire smoke containing O_3 precursors.

The estimated fire impact for the EPA EMBER modeling analysis was calculated as the direct modeled impact of Canadian wildfires on MDA8 O_3 concentrations by taking the difference in predicted values between the base scenario and the no Canadian wildfires (NCW) scenario. While photochemical modeling explicitly simulates the impacts of wildfires on O_3 concentrations within the modeling domain, statistical modeling predicts O_3 concentrations as a function of several meteorological and other variables. However, statistical models do not explicitly include wildfire indicators as dependent variables. Thus, the residuals for the statistical model predicted MDA8 O_3 values can be interpreted as the upper bound for O_3 impacts caused by factors unaccounted for in the model, such as wildfire smoke containing O_3 precursors.

The predicted values and residuals from the UW GAM statistical modeling analyses were assessed alongside the estimated fire impacts and model biases based on the EPA EMBER photochemical modeling simulations dataset. The EMBER and GAM models both reported the presence of smoke at the WCA monitoring site on June 2, 2023. Table 2 shows the predicted values and residuals for each modeling analysis at the WCA monitoring site on June 2, 2023. In the EMBER dataset, the estimated impact from Canadian wildfires to the WCA monitoring site was 2 ppb on June 2, 2023. However, the EMBER model underpredicted the O_3 MDA8 at the WCA monitor on June 2, 2023, by 17 ppb, suggesting that these fire impacts could be considered low confidence estimates. The GAM also underpredicted the O_3 MDA8 at the WCA monitor, with a residual of 28.1 ppb. These large residual O_3 impacts are attributable to the presence of O_3 precursors transported from the wildfires in southern Nova Scotia.

Table 2: Predicted MDA8 O_3 values and associated model residuals and estimated fire impacts at WCA on June 2, 2023.

Site	Observed MDA8 (ppb)	GAM Predicted MDA8 (ppb)	GAM Residual (ppb)	EMBER Base Predicted MDA8 (ppb)	EMBER NCW Predicted MDA8 (ppb)	EMBER Canadian Fire Impact (ppb)
WCA	83	54.9	28.1	66	64	2

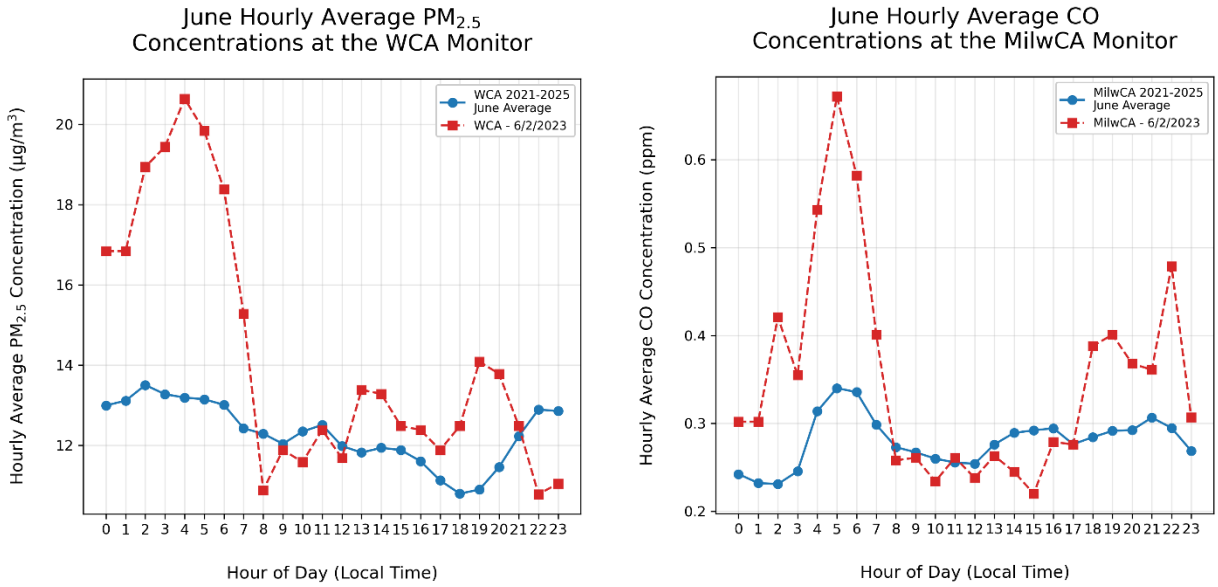
Analysis of Other Wildfire-Related Pollutants for June 2, 2023

The plumes from the wildfires burning in southern Nova Scotia also directly transported $PM_{2.5}$ and CO to southeastern Wisconsin on June 2, 2023. These pollutants are directly emitted from wildfires and can be transported long distances, making them effective tracers for identifying impacts from wildfire smoke. Spikes in monitored concentrations of these pollutants may be expected at certain hours of the day due to typical urban area traffic patterns. However, elevated concentrations of these pollutants that persist for long periods are the result of wildfire smoke plumes transported into the area.

Comparisons of the mean hourly average concentrations on all June days across 2021-2025 to the hourly average concentrations on June 2, 2023, provide additional evidence that the plumes transported smoke and O_3 precursors from the wildfires burning in southern Nova Scotia to the WCA monitoring site. Figure 25 shows the hourly average $PM_{2.5}$ and CO concentrations at the WCA and Milwaukee-College Ave (MilwCA; AQS ID 55-079-0056) monitoring sites on June 2, 2023, as well as the corresponding June 2021-2025 mean hourly average $PM_{2.5}$ and CO concentrations. Hourly average $PM_{2.5}$ concentrations at the WCA monitoring site were notably elevated across an 8-hour period in the morning and another 8-hour period through the afternoon and early evening on June 2, 2023, even when accounting for the typical spikes due to urban area traffic patterns. A similar pattern was observed with CO, as significantly elevated values were observed over the same 8-hour window morning window on June 2, 2023. Elevated hourly CO concentrations were also observed over a 5-hour period in the evening outside of the typical window for evening urban traffic emissions.

The elevated hourly average concentrations of both $PM_{2.5}$ and CO from the WCA and MilwCA monitoring sites serve as additional evidence of the wildfire impacts on observed O_3 concentrations at the WCA monitor on June 2, 2023.

Figure 25: 2021-2025 June average $PM_{2.5}$ by hour from WCA (left) and 2021-2025 June average CO by hour from MilwCA (right). Hourly data from June 2, 2023, are overlaid for both pollutants (dashed lines).



June 19, 2023

Transport of O_3 Precursors for June 19, 2023

The HYSPLIT 108-hour back and forward trajectories show the long-range transport of wildfire smoke plumes carrying O_3 precursors that greatly enhanced ground-level O_3 formation and contributed to high monitored MDA8 O_3 concentrations at the WCA monitor on June 19, 2023.

Figure 26 shows the HYSPLIT 108-hour back trajectory plot initiated from the WCA monitoring site at 12Z on June 19, 2023, alongside the HYSPLIT 108-hour forward trajectory plot initiated over wildfires burning east of Wemindji, Quebec at 00Z on June 15, 2023. The starting heights of 100, 250, and 500 meters AGL were chosen for the backwards trajectories to ensure that the parcels initiated from within the marine boundary layer associated with the lake breeze that was observed on this day. It has been thoroughly documented that lake breezes play a critical role on days with high ozone along the Wisconsin lakeshore.

Figure 27 shows maps of satellite-derived AOD and monitored daily average $PM_{2.5}$ concentrations at the surface with HMS smoke layers and fire locations for June 19, 2023. The location of the fires in central Quebec shown in Figure 7 align with the 100-meter release height trajectory from WCA, passing over the fires in central Quebec 400–500 meters AGL. The 108-hour forward trajectory initiated at 500 meters AGL over the central Quebec fires ends just 53 meters AGL over southeastern Wisconsin.

The connection between these forward and back trajectories are clear evidence of smoke plumes carrying O_3 precursors being transported into Wisconsin from the central Quebec fires and causing high O_3 concentrations at the WCA monitor on June 19, 2023. Higher values of AOD in locations that are void of cloud cover indicate the presence of wildfire smoke in the column. Coupled with HMS polygons indicating overhead smoke and elevated $PM_{2.5}$ concentrations at the surface, these data provide additional evidence that wildfire smoke containing O_3 precursors was present over the WCA monitor on June 19, 2023.

Figure 26: HYSPLIT 108-hour back trajectories from WCA at 12 UTC 06/19/2023 (left). HYSPLIT 108-hour forward trajectories from the central Quebec fire at 00 UTC 06/15/2023 (right).

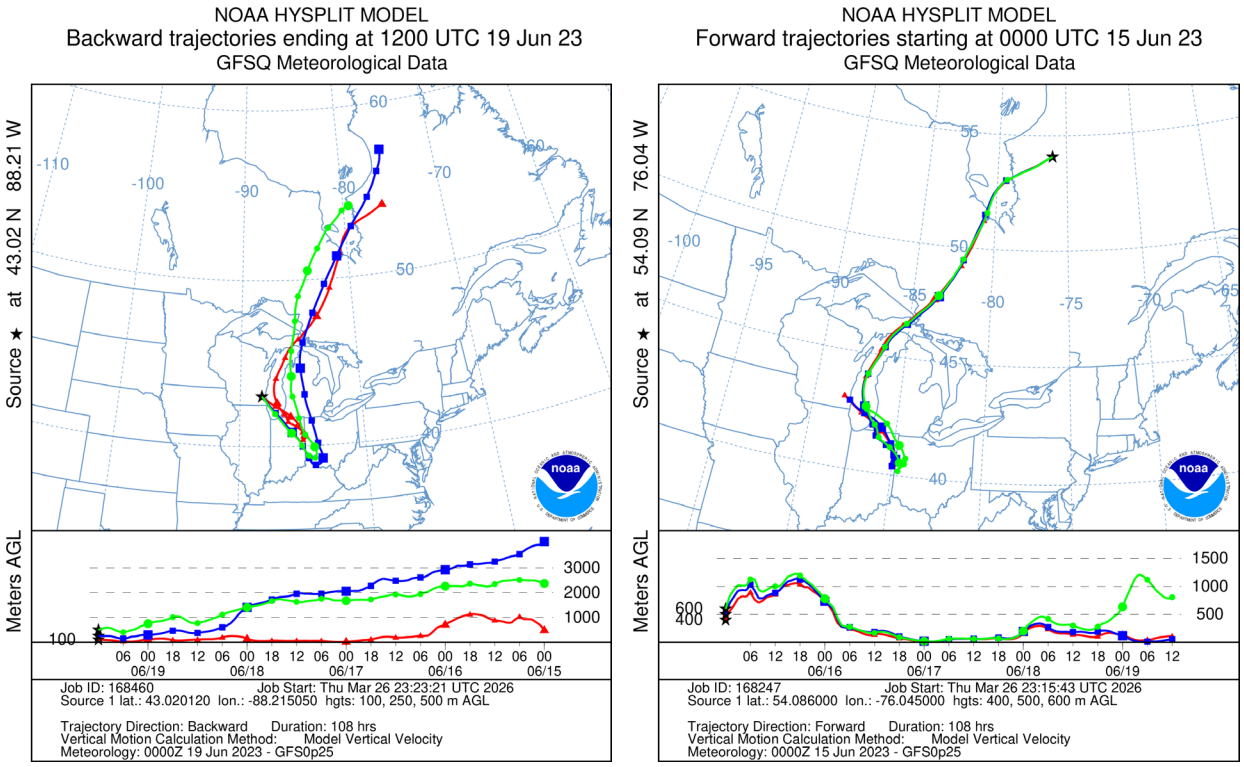
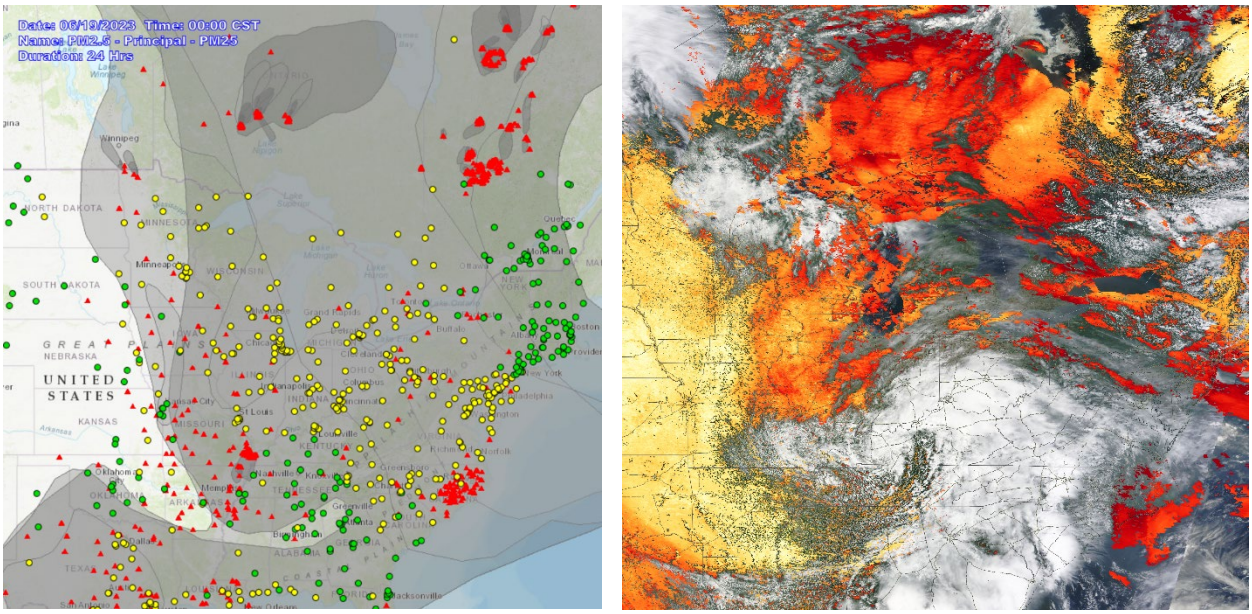


Figure 27: Daily average $PM_{2.5}$ concentrations with HMS smoke layers and fire locations (left) and MAIAC AOD satellite imagery (right) for June 19, 2023.



Comparison of Observed and Modeled O_3 for June 19, 2023

Further evidence that wildfire smoke impacted O_3 concentrations at the WCA monitor on June 19, 2023, stems from the analysis of observed MDA8 O_3 values compared to model predictions of O_3 and associated fire impacts from the same day. The predicted values and residuals from the UW GAM statistical modeling analyses were assessed alongside the estimated fire impacts and model biases based on the EPA EMBER photochemical modeling simulations dataset, including the EPA EMBER base scenario modeling analysis and the EPA EMBER NCW scenario modeling analysis. The EMBER and GAM models both reported the presence of smoke at the WCA monitoring site on June 19, 2023. Table 3 shows the predicted values and residuals for each modeling analysis at the WCA monitoring site on June 19, 2023.

In the EMBER dataset, the estimated impact from Canadian wildfires to the WCA monitoring site was 4 ppb on June 19, 2023. However, the EMBER model underpredicted the O_3 MDA8 at the WCA monitor on June 19, 2023, by 18 ppb, suggesting that these fire impacts could be considered low confidence estimates. The GAM also underpredicted the O_3 MDA8 at the WCA monitor, with a residual of 22.9 ppb. These large residual O_3 impacts are attributable to the presence of O_3 precursors transported from the wildfires in central Quebec.

Table 3: Predicted MDA8 O_3 values and associated model residuals and estimated fire impacts at WCA on June 19, 2023.

Site	Observed MDA8 (ppb)	GAM Predicted MDA8 (ppb)	GAM Residual (ppb)	EMBER Base Predicted MDA8 (ppb)	EMBER NCW Predicted MDA8 (ppb)	EMBER Canadian Fire Impact (ppb)
WCA	83	60.1	22.9	65	61	4

Analysis of Other Wildfire-Related Pollutants for June 19, 2023

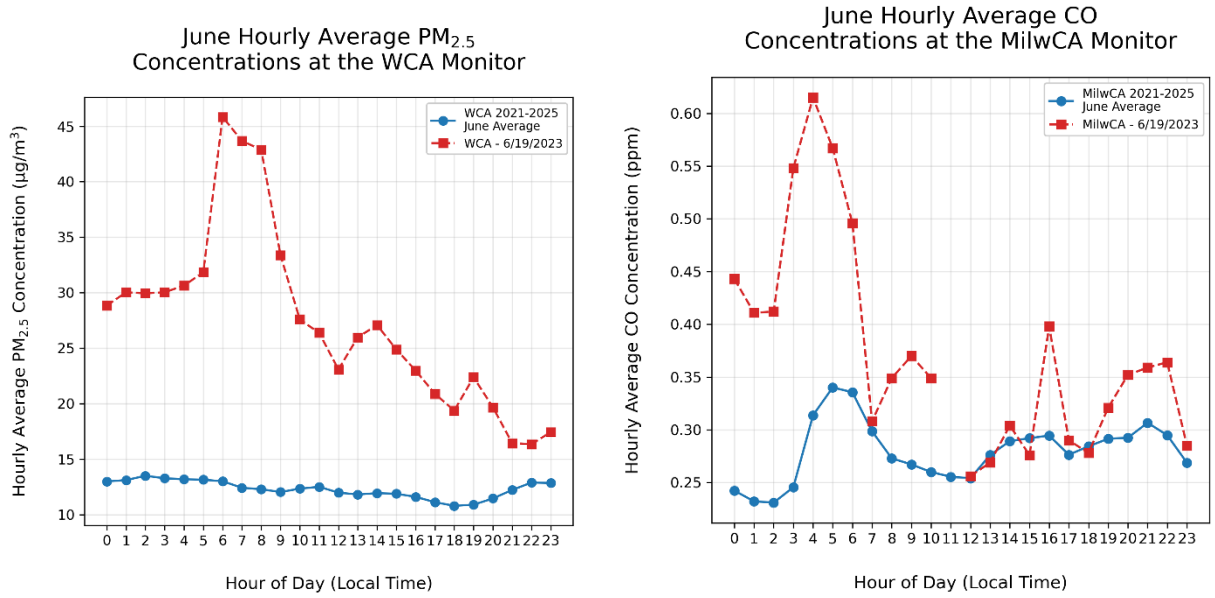
The plumes from the wildfires burning in central Quebec also directly transported $PM_{2.5}$ and CO to southeastern Wisconsin on June 19, 2023. These pollutants are directly emitted from wildfires and can be transported long distances, making them effective tracers for identifying impacts from wildfire smoke. Spikes in monitored concentrations of these pollutants may be expected at certain hours of the day due to typical urban area traffic

patterns. However, elevated concentrations of these pollutants that persist for long periods are the result of wildfire smoke plumes transported into the area.

Comparisons of the mean hourly average concentrations on all June days across 2021-2025 to the hourly average concentrations on June 19, 2023, provide additional evidence that the plumes transported smoke and O_3 precursors from the wildfires burning in central Quebec to the WCA monitoring site. Figure 28 shows the hourly average $PM_{2.5}$ and CO concentrations at the WCA and MilwCA monitoring sites on June 19, 2023, as well as the corresponding June 2021-2025 mean hourly average $PM_{2.5}$ and CO concentrations. Hourly average $PM_{2.5}$ concentrations at the WCA monitoring site were significantly elevated throughout the entire day on June 19, 2023, particularly in the morning. Hourly average CO was also significantly elevated in the morning hours on June 19, 2023, outside of the typical window for morning urban traffic emissions.

The elevated hourly average concentrations of both $PM_{2.5}$ and CO from the WCA and MilwCA monitoring sites serve as additional evidence of the wildfire impacts on observed O_3 concentrations at the WCA monitor on June 19, 2023.

Figure 28: 2021-2025 June average $PM_{2.5}$ by hour from WCA (left) and 2021-2025 June average CO by hour from MilwCA (right). Hourly data from June 19, 2023, are overlaid for both pollutants (dashed lines).



June 29, 2023

Transport of O_3 Precursors for June 29, 2023

The HYSPLIT 78-hour back and forward trajectories show the long-range transport of wildfire smoke plumes carrying O_3 precursors that greatly enhanced ground-level O_3 formation and contributed to high monitored MDA8 O_3 concentrations at the WCA monitor on June 29, 2023.

Figure 29 shows the HYSPLIT 78-hour back trajectory plot initiated from the WCA monitoring site at 18Z on June 29, 2023, alongside the HYSPLIT 78-hour forward trajectory plot initiated over the wildfire complex burning west of the Gouin Reservoir in southern Quebec at 12Z on June 26, 2023. The starting heights of 100, 250, and 500 meters AGL were chosen for the backwards trajectories to ensure that the parcels initiated from within the marine boundary layer associated with the lake breeze that was observed on this day. It has been thoroughly documented that lake breezes play a critical role on days with high ozone along the Wisconsin lakeshore.

Figure 30 shows maps of satellite-derived AOD and monitored daily average $PM_{2.5}$ concentrations with HMS smoke layers and fire locations for June 29, 2023. The location of the fires in southern Quebec shown in Figure 12 align with the 100-meter release height trajectory from WCA, passing over the fires in southern Quebec 700–800 meters AGL. The 78-hour forward trajectory initiated at 750 meters AGL over the southern Quebec fires ends just 68 meters AGL over southeastern Wisconsin.

The connection between these forward and back trajectories show clear evidence of smoke plumes carrying O_3 precursors being transported into Wisconsin from the southern Quebec fires and causing high O_3 concentrations at the WCA monitor on June 29, 2023. Higher values of AOD in locations that are void of cloud cover indicate the presence of wildfire smoke in the column. Coupled with HMS polygons indicating overhead smoke and elevated $PM_{2.5}$ concentrations at the surface, these data provide additional evidence that wildfire smoke containing O_3 precursors was present over the WCA monitor on June 29, 2023.

Figure 29: HYSPLIT 78-hour back trajectories from WCA at 18 UTC 06/29/2023 (left). HYSPLIT 78-hour forward trajectories from the southern Quebec fire at 12 UTC 06/26/2023 (right).

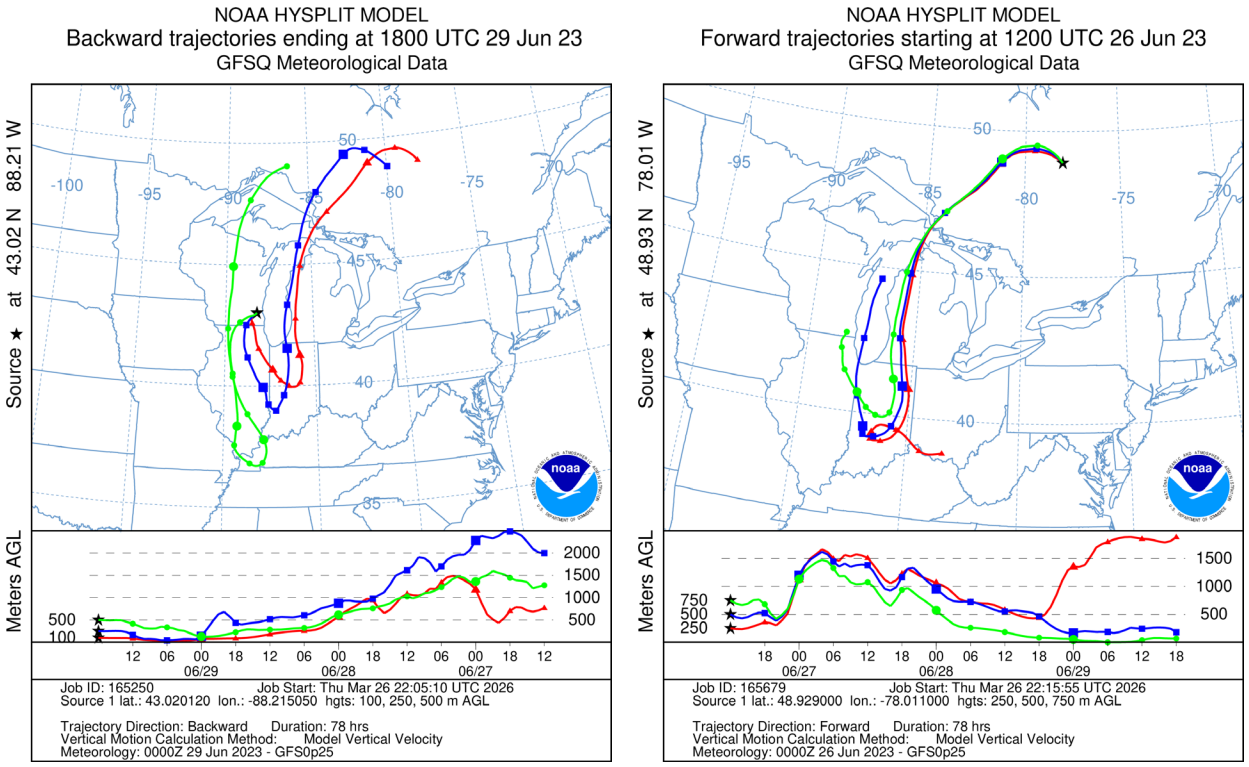
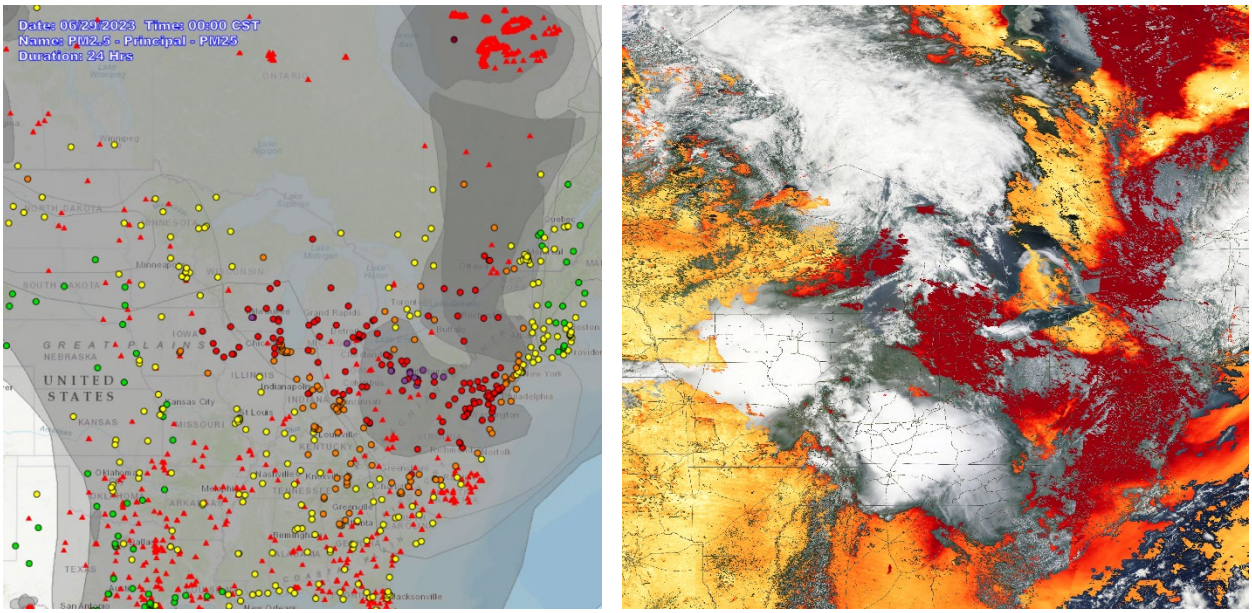


Figure 30: Daily average $PM_{2.5}$ concentrations with HMS smoke layers and fire locations (left) and MAIAC AOD satellite imagery (right) for June 29, 2023.



Comparison of Observed and Modeled O_3 for June 29, 2023

Further evidence that wildfire smoke impacted O_3 concentrations at the WCA monitor on June 29, 2023, stems from the analysis of observed MDA8 O_3 values compared to model predictions of O_3 and associated fire impacts from the same day. The predicted values and residuals from the UW GAM statistical modeling analyses were assessed alongside the estimated fire impacts and model biases based on the EPA EMBER photochemical modeling simulations dataset, including the EPA EMBER base scenario modeling analysis and the EPA EMBER NCW scenario modeling analysis. The EMBER and GAM models both reported the presence of smoke at the WCA monitoring site on June 29, 2023.

Table 4 shows the predicted values and residuals for each modeling analysis at the WCA monitoring site on June 29, 2023. In the EMBER dataset, the estimated impact from Canadian wildfires to the WCA monitoring site was 4 ppb on June 29, 2023. However, the EMBER model underpredicted the O_3 MDA8 at the WCA monitor on June 29, 2023, by 15 ppb, suggesting that these fire impacts could be considered low confidence estimates. The GAM also underpredicted the O_3 MDA8 at the WCA monitor, with a residual of 22 ppb. These large residual O_3 impacts are attributable to the presence of O_3 precursors transported from the wildfires in southern Quebec.

Table 4: Predicted MDA8 O_3 values and associated model residuals and estimated fire impacts at WCA on June 29, 2023.

Site	Observed MDA8 (ppb)	GAM Predicted MDA8 (ppb)	GAM Residual (ppb)	EMBER Base Predicted MDA8 (ppb)	EMBER NCW Predicted MDA8 (ppb)	EMBER Canadian Fire Impact (ppb)
WCA	85	63	22	60	56	4

Analysis of Other Wildfire-Related Pollutants for June 29, 2023

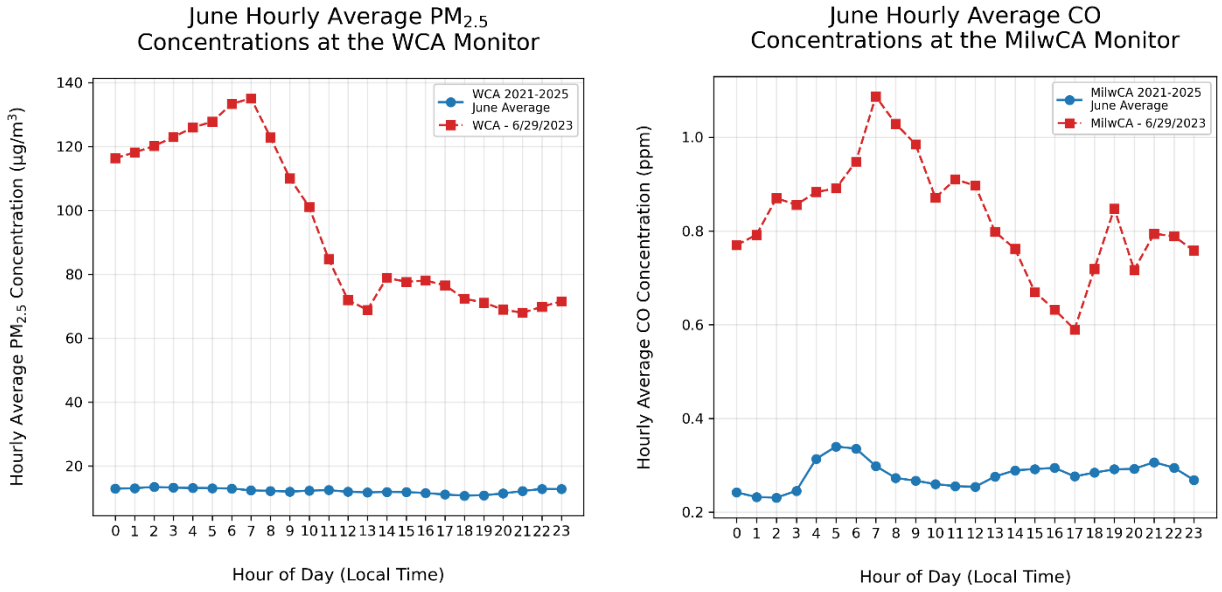
The plumes from the wildfires burning in southern Quebec also directly transported $PM_{2.5}$ and CO to southeastern Wisconsin on June 29, 2023. These pollutants are directly emitted from wildfires and can be transported long distances, making them effective tracers for identifying impacts from wildfire smoke. Spikes in monitored concentrations of these pollutants may be expected at certain hours of the day due to typical urban area traffic

patterns. However, elevated concentrations of these pollutants that persist for long periods are the result of wildfire smoke plumes transported into the area.

Comparisons of the mean hourly average concentrations on all June days across 2021-2025 to the hourly average concentrations on June 29, 2023, provide additional evidence that the plumes transported smoke and O_3 precursors from the wildfires burning in southern Quebec to the WCA monitoring site. Figure 31 shows the hourly average $PM_{2.5}$ and CO concentrations at the WCA and MilwCA monitoring sites on June 29, 2023, as well as the corresponding June 2021-2025 mean hourly average $PM_{2.5}$ and CO concentrations.

Hourly average $PM_{2.5}$ concentrations at the WCA monitoring site and hourly average CO concentrations at the MilwCA monitoring site were both extremely elevated throughout the entire day on June 29, 2023, serving as additional evidence of the wildfire impacts on observed O_3 concentrations at the WCA monitor on June 29, 2023.

Figure 31: 2021-2025 June average $PM_{2.5}$ by hour from WCA (left) and 2021-2025 June average CO by hour from MilwCA (right). Hourly data from June 29, 2023, are overlaid for both pollutants (dashed lines).



July 25, 2023

Transport of O_3 Precursors for July 25, 2023

The HYSPLIT 96-hour back and forward trajectories show the long-range transport of wildfire smoke plumes carrying O_3 precursors that greatly enhanced ground-level O_3 formation and contributed to high monitored MDA8 O_3 concentrations at the MilwUPark and WCA monitors on July 25, 2023.

Figure 32 shows the HYSPLIT 96-hour back trajectory plot initiated from the MilwUPark monitoring site at 21Z on July 25, 2023, alongside the HYSPLIT 96-hour forward trajectory plot initiated over the wildfire complex burning south of Great Slave Lake in the southeastern portion of the Northwest Territories, Canada, at 05Z on July 22, 2023. The starting heights of 100, 200, and 300 meters AGL were chosen for the backwards trajectories to ensure that the parcels initiated from within the marine boundary layer associated with the lake breeze that was observed on this day. It has been thoroughly documented that lake breezes play a critical role on days with high ozone along the Wisconsin lakeshore.

Figure 33 shows maps of satellite-derived AOD and monitored daily average $PM_{2.5}$ concentrations with HMS smoke layers and fire locations for July 25, 2023. The location of the fires in the southeast portion of the Northwest Territories shown in Figure 16 align with the 200-meter and 300-meter release height trajectories from MilwUPark, passing over the fires in southeastern Northwest Territories 3000-3500 meters AGL. The 96-hour forward trajectory initiated at 3500 meters AGL over the southeastern Northwest Territories fires passes over southeastern Wisconsin just 424 meters AGL at 18Z on July 25, 2023.

The connection between these forward and back trajectories show clear evidence of smoke plumes carrying O_3 precursors being transported into Wisconsin from the southeastern Northwest Territories fires and causing high O_3 concentrations at the MilwUPark and WCA monitors on July 25, 2023. Higher values of AOD in locations that are void of cloud cover indicate the presence of wildfire smoke in the column. Coupled with HMS polygons indicating overhead smoke and elevated $PM_{2.5}$ concentrations at the surface, these data provide additional evidence that wildfire smoke containing O_3 precursors was present over the MilwUPark and WCA monitors on July 25, 2023.

Figure 32: HYSPLIT 96-hour back trajectories from MilwUPark at 21 UTC 07/25/2023 (left). HYSPLIT 96-hour forward trajectories from the southeastern Northwest Territories fire at 05 UTC 07/22/2023 (right).

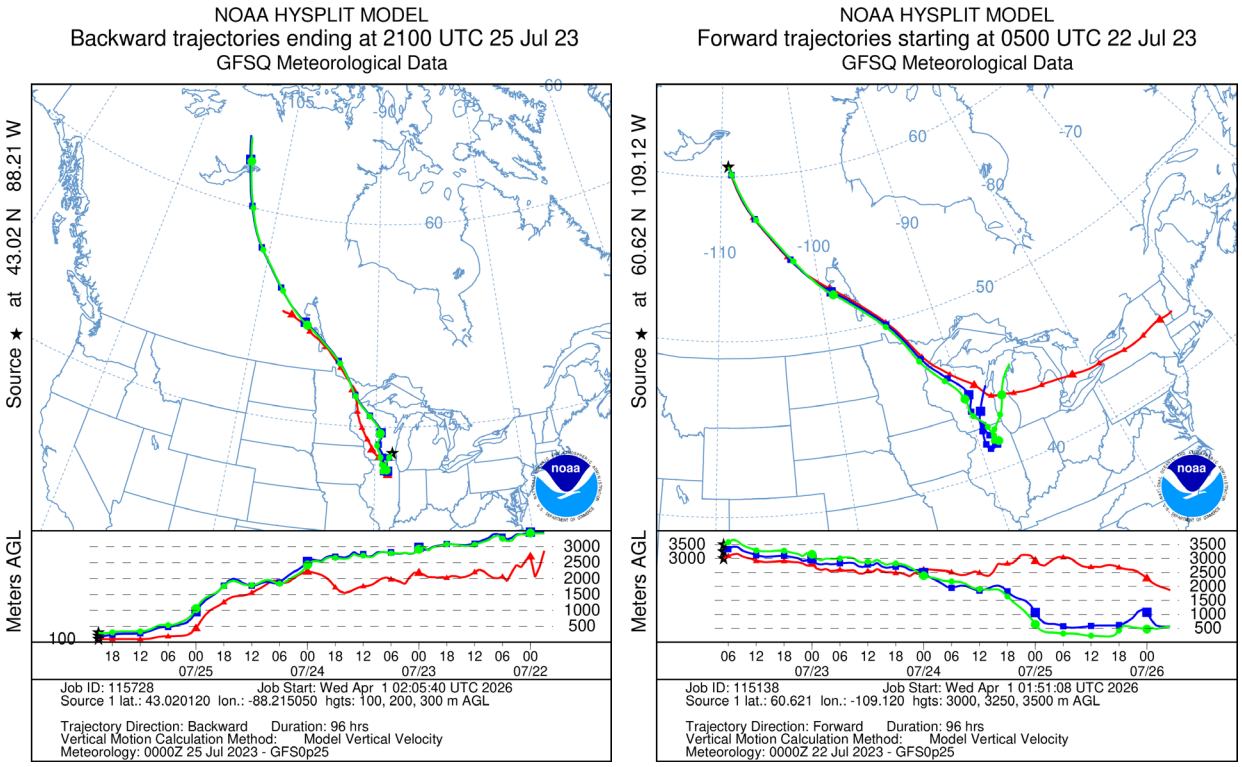
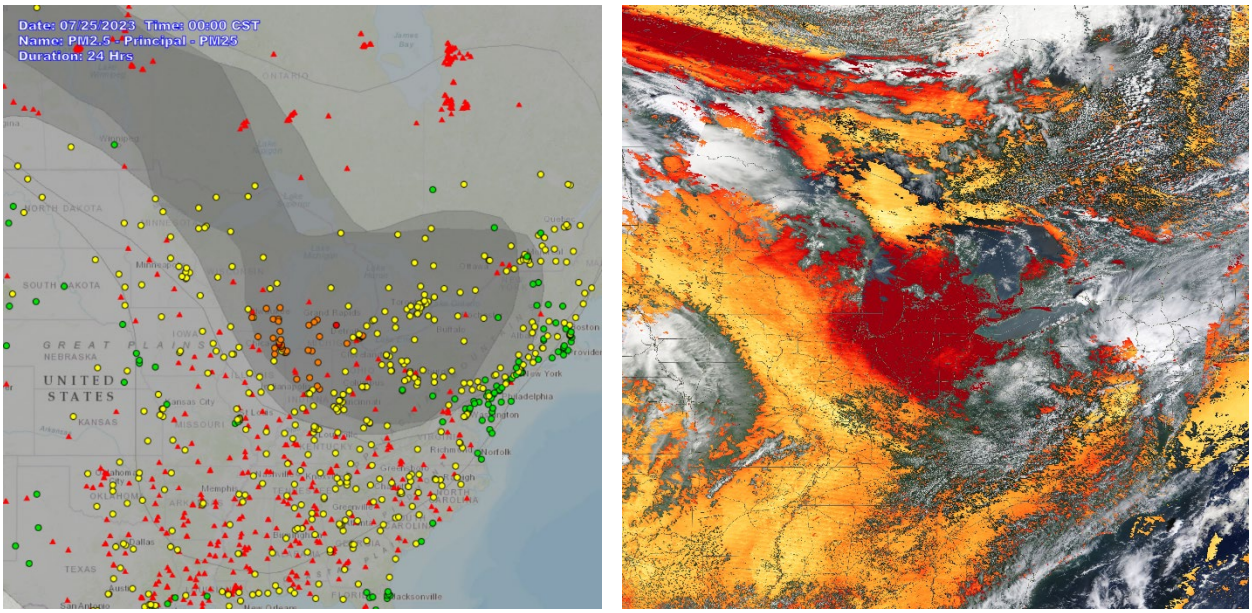


Figure 33: Daily average $PM_{2.5}$ concentrations with HMS smoke layers and fire locations (left) and MAIAC AOD satellite imagery (right) for July 25, 2023.



Comparison of Observed and Modeled O_3 for July 25, 2023

Further evidence that wildfire smoke impacted O_3 concentrations at the MilwUPark and WCA monitors on July 25, 2023, stems from the analysis of observed MDA8 O_3 values compared to model predictions of O_3 and associated fire impacts from the same day. The predicted values and residuals from the UW GAM statistical modeling analyses were assessed alongside the estimated fire impacts and model biases based on the EPA EMBER photochemical modeling simulations dataset, including the EPA EMBER base scenario modeling analysis and the EPA EMBER NCW scenario modeling analysis. The EMBER model reported the presence of smoke at both the MilwUPark and WCA monitoring sites on July 25, 2023. The GAM model also reported the presence of smoke at the WCA monitoring site on July 25, 2023. GAM results were not available for the MilwUPark site.

Table 5 shows the predicted values and residuals for each modeling analysis at the MilwUPark and WCA monitoring sites on July 25, 2023. In the EMBER dataset, the estimated impact from Canadian wildfires was 5 ppb for the MilwUPark site and 4 ppb for the WCA site on July 25, 2023. However, the EMBER model underpredicted the O_3 MDA8 at both the MilwUPark and WCA monitors on July 25, 2023, by 29 ppb and 26 ppb respectfully, suggesting that these fire impacts could be considered low confidence estimates. The GAM also underpredicted the O_3 MDA8 at the WCA monitor, with a residual of 21.8 ppb. These large residual O_3 impacts are attributable to the presence of O_3 precursors transported from wildfires in the southeastern Northwest Territories.

Table 5: Predicted MDA8 O_3 values and associated model residuals and estimated fire impacts at MilwUPark and WCA on July 25, 2023.

Site	Observed MDA8 (ppb)	GAM Predicted MDA8 (ppb)	GAM Residual (ppb)	EMBER Base Predicted MDA8 (ppb)	EMBER NCW Predicted MDA8 (ppb)	EMBER Canadian Fire Impact (ppb)
MilwUPark	97	-	-	68	63	5
WCA	80	58.2	21.8	54	50	4

Analysis of Other Wildfire-Related Pollutants for July 25, 2023

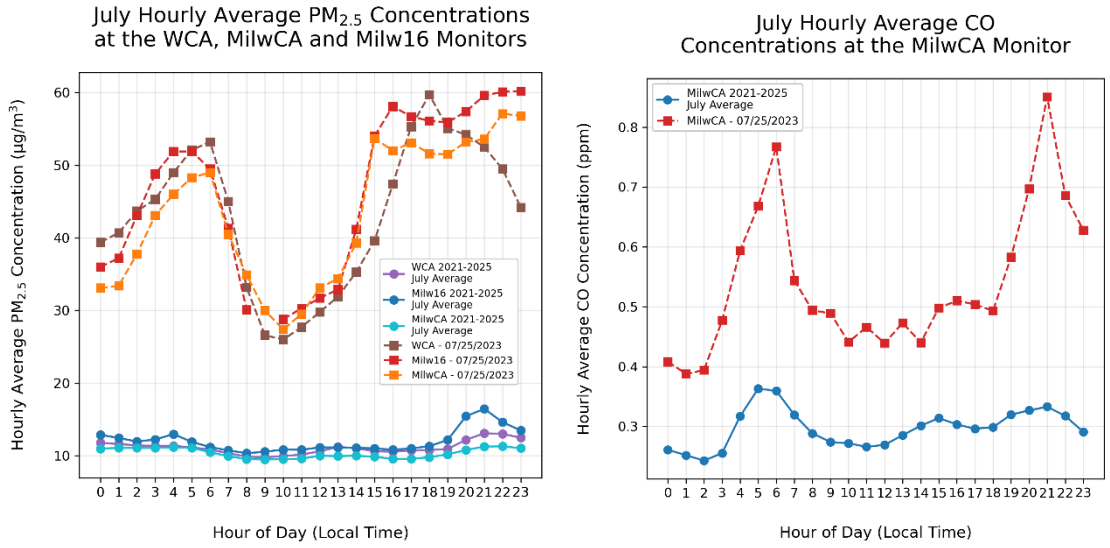
The plumes from the wildfires burning in the southeastern portion of the Northwest Territories also directly transported $PM_{2.5}$ and CO to southeastern Wisconsin on July 25,

2023. These pollutants are directly emitted from wildfires and can be transported long distances, making them effective tracers for identifying impacts from wildfire smoke. Spikes in monitored concentrations of these pollutants may be expected at certain hours of the day due to typical urban area traffic patterns. However, elevated concentrations of these pollutants that persist for long periods are the result of wildfire smoke plumes transported into the area.

Comparisons of the mean hourly average concentrations on all July days across 2021-2025 to the hourly average concentrations on July 25, 2023, provide additional evidence that the plumes transported smoke and O_3 precursors from the wildfires burning in the southeastern portion of the Northwest Territories to the MilwUPark and WCA monitoring sites. Figure 34 show the hourly average $PM_{2.5}$ and CO concentrations at the MilwCA, Milwaukee-16th St (Milw16; AQS ID 55-079-0010) and WCA monitoring sites on July 25, 2023, as well as the corresponding July 2021-2025 mean hourly average $PM_{2.5}$ and CO concentrations.

Hourly average concentrations of both $PM_{2.5}$ and CO at all three monitoring sites were extremely elevated throughout the entire day on July 25, 2023, serving as additional evidence of the wildfire impacts on monitored O_3 concentrations at the MilwUPark and WCA monitors on July 25, 2023.

Figure 34: 2021-2025 July average $PM_{2.5}$ by hour from WCA, MilwCA and Milw16 (left) and 2021-2025 July average CO by hour from MilwCA (right). Hourly data from July 25, 2023, are overlaid for both pollutants (dashed lines).



Conclusion Statement

Elevated O_3 concentrations were observed at the MilwUPark and WCA monitors on June 2, June 19, June 29, and July 25, 2023, associated with additional O_3 precursors that were generated by Canadian wildfires and transported to Wisconsin from Nova Scotia, Quebec, and Northwest Territories. The event-related O_3 MDA8 concentrations at MilwUPark (97 ppb on July 25) and WCA (83 ppb on June 2, 83 ppb on June 19, 85 ppb on June 29, and 80 ppb on July 25) were all well above the respective 2021–2025 99^{th} percentile values of 73 for MilwUPark and 75 ppb for WCA. The analysis and comparison of HYSPIT trajectories, satellite AOD imagery, HMS smoke polygons, modeled O_3 predictions with associated wildfire impact estimations, and monitored concentrations of O_3, $PM_{2.5}$, and CO compared to historical averages collectively provide evidence that the wildfires in Nova Scotia, Quebec, and Northwest Territories, Canada, affected air quality in such a way that there exists a clear causal relationship between the wildfires and the monitored exceedances on June 2, June 19, June 29 and July 25, 2023, and thus satisfies the clear causal relationship criterion.

Not Reasonably Controllable or Preventable

40 CFR 50.14 (c)(3)(iv)(D) requires a demonstration that the event was both not reasonably controllable and not reasonably preventable. 40 CFR 50.14(b)(4) states that every wildfire occurring predominantly on wildland satisfies both the not reasonably controllable and not reasonably preventable criteria unless there is evidence that demonstrates otherwise.

The Canadian Broadcasting Corporation reported that 59% percent of the wildfires across Canada in 2023 were caused by lightning strikes, leading to more than 93% of the total area burned for the year.[13] Early in the fire season, the CIFFC noted seven new natural wildland fires had begun burning across Nova Scotia on May 28, 2023, most likely started by lightning strikes.[14] Numerous fires broke out across Quebec in early June, with the CIFFC later reported that 99.9% of the area burned in Quebec Province in 2023 was caused by lightning.[15] Widespread burning continued through the summer, with the CIFFC also reporting 8 new natural wildland fires beginning in the Northwest Territories on July 22, 2023, also likely caused by lightning.[16] Thus, the aforementioned wildfires in Nova Scotia, Quebec, and Northwest Territories were originally ignited by lightning and consumed natural fuels (trees, brush, grass, etc.) as they grew. Therefore, emissions from these wildfires that subsequently impacted ground-level O_3 concentrations at the MilwUPark and WCA monitors were not reasonably controllable or preventable, nor were they the result of emissions from anthropogenic sources.

[13] https://www.cbc.ca/news/climate/canada-wildfire-starts-1.7219681
[14] https://ciffc.net/situation/2023-05-29
[15] https://ciffc.ca/download/canada-reports/?wpdmdl=1585&ind=1773515613432&refresh=0aea3cdd&filename=CIFFC_2023CanadaReport_FINAL.pdf
[16] https://ciffc.net/situation/2023-07-23

Demonstration that the Event was Natural

The EE Rule requires a demonstration that the event was a human activity that is unlikely to recur at a particular location or was a natural event (40 CFR 50.14(c)(3)(iv)(E)). The definition of wildfire in the EE Rule is: "… any fire started by an unplanned ignition caused by lightning; … A wildfire that predominately occurs on wildland is a natural event." The EE Rule also defines a natural event as, "an event and its resulting emissions, which may recur at the same location, in which human activity plays little or no direct causal role."[17]

Based on the documentation provided in this demonstration, the four identified 2023 wildfires events across Nova Scotia, Quebec, and Northwest Territories qualify as wildland fires because they were ignited by lightning and consumed natural fuels (trees, brush, grass, etc.). As the wildfire events that are subject of this demonstration occurred on wildlands and were most likely caused by lightning, they were natural and should be considered for treatment as EEs.

[17] 81 F.R. 68216

Public Outreach

The DNR's air quality forecasters tracked numerous Canadian wildfires and their impact on Wisconsin's air quality through the spring and summer of 2023. Air Quality Advisories for ozone were in effect for both Milwaukee-and Waukesha Counties on June 2, June 19, June 29 and July 25, which were distributed on the DNR's air quality homepage (https://airquality.wi.gov), to the National Weather Service and to subscribers of the DNR's GovDelivery service. The air quality homepage provided real-time air quality information to this site and to AirNow throughout all four wildfire-related ozone events.

Public Comment Process Documentation

The DNR published a notice of availability for this proposed exceptional events demonstration on its website on May 8, 2026, making this document available for public comment through June 8, 2026. The DNR received four comments which have been included in this section of the demonstration in order of receipt, along with DNR's responses to these comments.

June 5, 2026

Wisconsin Department of Natural Resources
Air Program
101 S. Webster Street PO Box 7921
Madison, WI 53707-7921
Submitted to: alex.oser@wisconsin.gov

RE: Exceptional Event Demonstration: 2023 June and July Canadian Wildfire Impacts on Ozone Concentrations in the Milwaukee Area

The American Lung Association is the oldest voluntary health organization in the United States, representing the more than 34 million individuals living with lung disease. The Lung Association is the leading organization working to save lives by improving lung health and preventing lung disease through research, education and advocacy.

In this document, the Wisconsin Department of Natural Resources Air Program is proposing to request EPA concurrence to exclude certain monitoring data from regulatory determinations pursuant to the United States Environmental Protection Agency's (EPA) Exceptional Event Rule.

We strongly oppose Exclusion of Air Quality Data from Regulatory Consideration. The wildfire-related pollution on the days listed in the report, though external in origin, had real and measurable public health impacts on Wisconsin residents which cannot be discounted. Excluding these data minimizes the lived experience of communities exposed to elevated levels of ozone and $PM_{2.5}$, which are linked to adverse health impacts including:

- Increased respiratory and cardiovascular hospitalizations
- Asthma exacerbations, especially in children and older adults
- Premature mortality

The decision to exclude pollution data from several days of poor air quality will have a real and measurable impact on public health. Whether it is coming from elsewhere or nearby, pollution from wildfires is still impacting people's health. Wildfires are no longer rare "exceptional" anomalies - they are increasingly predictable consequences of global warming and climate change occurring at increasing frequency. The Clean Air Act's Section 319(b) was not designed to accommodate the new normal of climate-driven air pollution. Excluding data from such events undermines the urgency of addressing climate resilience and air quality comprehensively.

This is also a matter of regulatory integrity and accountability. Removing data from consideration may artificially improve attainment status and could potentially delay necessary regulatory interventions by:

- Reducing pressure to strengthen local air pollution controls
- Undermining public trust in environmental governance
- Creating a precedent for excluding other climate-related pollution events

Vulnerable communities in Milwaukee, Racine, Kenosha, and other historically overburdened areas already face disproportionate exposure to air pollution. The way a society takes care of its most vulnerable people is a measure of how well that society is functioning. Excluding wildfire-related data may obscure cumulative impacts and hinder efforts to achieve equitable environmental protections for all, particularly for the most vulnerable groups.

We strongly urge DNR to reconsider the exclusion of ozone and $PM_{2.5}$ data from design value calculations and other regulatory decisions related to the attainment of National Ambient Air Quality Standards (NAAQS). The 2023 wildfires, which were exceptional in scale, but not in relevance, may become the new norm of future. Their impact on air quality in Wisconsin is a stark reminder of the interconnectedness of climate, health, and policy. We ask that this department lead with transparency and integrity by acknowledging—not excluding—the full scope of air pollution challenges facing the greater Milwaukee area. These are our recommendations:

- Withdraw the Exceptional Events Demonstration and retain all days in the design value calculations for ozone and for $PM_{2.5}$. Retain wildfire-related data in regulatory assessments to reflect the true air quality conditions experienced by residents and inform future regulatory decisions to effectively protect public health.
- Use the data to strengthen local preparedness, including early warning systems, public health advisories, and other risk communications.
- Advocate for regional and national climate mitigation strategies, recognizing the role of climate change in shaping air quality trends and that transboundary pollution is a growing threat.
- Invest in climate-resilient infrastructure and clean energy transitions to reduce local contributions to air pollution as well as community-centered air quality strategies that prioritize health equity and long-term sustainability.

Thank you,

Molly Collins
Advocacy Director for Wisconsin and South Dakota
American Lung Association
13100 W. Lisbon Rd. | Suite 700 | Brookfield, WI 53005
Phone: 262-395-1700
Lung HelpLine: 1-800-LUNGUSA
Lung.org | Molly.Collins@Lung.org

From: Louise Petering
To: Oser, Alex C - DNR
Subject: SE Wisconsin air quality
Date: Monday, June 8, 2026 11:51:53 AM

Mr. Oser,

The proposal before you today to exclude days of poor air quality assessment in SE WI due to wildfire smoke is unwise and unhealthy. Frankly, it smacks of denial of reality. Please include all days in SE Wisconsin air quality measurements and calculations; there is no other air for all of us to breathe and we need to know the true quality of the air.

Sincerely,
Louise Petering
7229 N. Santa Monica Blvd.
Fox Point, WI 53217

MKE FreshAir Collective

To the Wisconsin Department of Natural Resources:

Thank you for the opportunity to provide public comment on the Wisconsin Department of Natural Resources' exceptional event demonstration related to the 2023 Canadian wildfire smoke impacts on ozone concentrations in the Milwaukee area.

While we support the Department's efforts to recognize the significant role wildfire smoke played in air quality conditions during June and July 2023. **We write to express concern with the proposed exclusion of wildfire smoke-impacted air quality data from regulatory consideration.** While we recognize that the 2023 wildfire season was extraordinary in scale, the lived experience of Wisconsin residents makes clear that wildfire smoke is no longer a rare or distant issue. It is becoming part of our seasonal reality, and it directly affects the health, behavior, and daily decision-making of people across Wisconsin.

Whether wildfire smoke originates in Canada, the western United States, or elsewhere, it still reaches our communities. It still affects what people breathe. It still influences whether children can play outside, whether older adults and people with asthma or heart disease can safely leave home, whether outdoor workers face added risk, and whether families need timely, trusted information to make health-protective decisions.

For Milwaukee residents, this issue is especially urgent. **Southeast Wisconsin already carries a disproportionate burden of air pollution from industrial sources, transportation corridors, regional ozone transport, and historic environmental inequities.** Communities in Milwaukee, Racine, Kenosha, and surrounding areas should not have their real-world exposure minimized through data exclusions that make air quality appear cleaner or less harmful than what residents actually experienced.

The Department's own demonstration shows that the 2023 wildfire events had measurable impacts on ozone concentrations in the Milwaukee area and that excluding these dates changes the design value calculations for affected monitors. That fact alone underscores why this data matters. These were not theoretical conditions; they were measurable pollution events that shaped public health risk and community experience.

We are concerned that removing wildfire-related pollution data from regulatory datasets could have unintended consequences. It may make it more difficult for decision-makers, health systems, local governments, schools, community organizations, and residents to fully understand air quality trends and prepare for future events. It could also reduce urgency around the need to strengthen local emissions reductions, improve public health response systems, and invest in climate-resilient infrastructure.

Wildfire smoke may be considered "exceptional" under current regulatory rules, but it is increasingly common in the lives of Wisconsinites. Climate change is changing the conditions under which air quality must be understood, measured, and managed. Our regulatory systems and public reporting practices must evolve accordingly.

We urge the Wisconsin Department of Natural Resources to retain wildfire smoke-impacted data in regulatory assessments and public-facing air quality reporting so that Wisconsin's air quality records reflect the actual conditions experienced by residents. We also encourage the Department to clearly identify wildfire-related days in public reports, analyze their health and environmental justice implications, and use this information to strengthen preparedness, public communication, and long-term climate response.

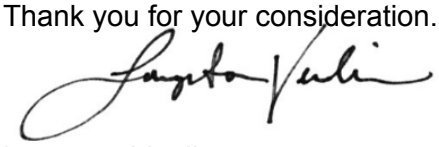
Specifically, we recommend that DNR:

- Retain wildfire-related air quality data in design value calculations and other regulatory assessments;
- Clearly report wildfire smoke-impacted days in public-facing air quality summaries and trend analyses;
- Use wildfire smoke data to strengthen early warning systems, public health advisories, school and outdoor activity guidance, and community risk communication;
- Prioritize environmental justice analysis in communities already burdened by cumulative air pollution;
- Continue reducing Wisconsin's local and regional contributions to ozone and particulate matter pollution;
- Treat wildfire smoke as part of Wisconsin's long-term climate and public health planning, not as an isolated anomaly.

The people of Wisconsin deserve air quality data that reflects the air they actually breathe. Excluding wildfire smoke data may satisfy a narrow regulatory purpose, but it risks obscuring the full scope of pollution exposure and climate-related health risks facing our communities.

We respectfully urge the Department to lead with transparency, public health, environmental justice, and climate accountability by retaining and reporting the full air quality record, including wildfire smoke-impacted days.

Thank you for your consideration.



Langston Verdin
Milwaukee Resident (3159 N Humboldt Blvd, Milwaukee 53212)
Founder & Co-Executive Director
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Danika Hill-Paulus
Milwaukee Resident (3116 N Fratney St, Milwaukee WI 53212)
Co-Executive Director
MKE FreshAir Collective

June 8, 2026
Wisconsin Department of Natural Resources
Air Program
101 S. Webster Street PO Box 7921
Madison, WI 53707-7921
Submitted to: alex.oser@wisconsin.gov

RE: Exceptional Event Demonstration: 2023 June and July Canadian Wildfire Impacts on Ozone Concentrations in the Milwaukee Area

Healthy Climate Wisconsin (HCW) is a nonprofit organization comprised of over 1,200 doctors, nurses, therapists, and public health workers across the state, committed to addressing and preventing pollution to our air, water, and land, to improve the health of our patients and communities. We recognize climate change is a global pubic health crisis, we see the health harms of climate change impacting our patients and communities every day, and we are committed to pursuing policy and action that prevents the continued acceleration of climate harms. Air pollution, which is both a driver and symptom of climate change, results in some of the most devastating health impacts. Unfortunately, as climate change continues to accelerate, wildfire smoke episodes are becoming seasonal realities rather than exceptional events. Therefore, HCW is formally requesting that the Wisconsin Department of Natural Resources (WI DNR) include all days, including the days with high pollution from wildfire smoke, within its data sets.

The decision to exclude pollution data from several days of poor air quality will have a real and measurable impact on public health. Whether it is coming from out-of-state or nearby, wildfire smoke pollution results in significant impacts on people's health. These harms include, but are not limited to:

- Increased asthma exacerbations and hospitalization,
- Increased lung and cardiovascular hospitalization,
- Early mortality.

HCW staff and members strongly oppose the exclusion of any air quality data from regulatory consideration. The wildfire-related pollution on the days listed in the report had real, measurable, and devastating public health impacts on Wisconsin residents, which cannot be discounted. Emergency rooms were full, and rates of asthma and cardiovascular emergencies jumped. Excluding this data not only minimizes the lived experience of communities exposed to elevated levels of ozone and PM 2.5, but it also excludes impacts to Wisconsin's health systems, clinics, and the greater public health network. The exclusion of this data could result in data that is misleading for state agencies, lawmakers, and decision makers, especially when it comes to correlating air pollution trends and impacts on Wisconsin's greater health system and undermines the urgency of addressing climate resilience and air quality in a comprehensive manner.

This is also a matter of regulatory integrity and accountability. Removing data from consideration artificially improves attainment status and could potentially delay necessary regulatory interventions by:

- Misleading elected officials and boards into thinking air quality in WI is better than the reality
- Reducing pressure to strengthen local air pollution controls
- Negating stronger protections that would have otherwise been in place if found in non-attainment
- Undermining public trust in environmental governance
- Creating a precedent for excluding other climate-related pollution events

Southeast Wisconsin has been historically overburdened with industrial and regional air pollution. Communities such as Milwaukee, Racine, and Kenosha experience high levels of environmental injustices associated with pollution and climate change. It is the imperative of our state regulators to prioritize the health and well-being of our state's most vulnerable when it comes to not only air pollution, but also climate change impacts. The exclusion of wildfire-related pollution data could obscure cumulative impacts analysis and slow efforts to achieve equitable environmental protections across Wisconsin.

We strongly urge the DNR to reconsider the exclusion of ozone and PM 2.5 data from the design value calculations and other regulatory decisions related to the attainment of National Ambient Air Quality Standards (NAAQS). The 2023 wildfires were exceptional in size and scale, but unfortunately not in relevance, and they are becoming the new norm. The wildfire smoke impact on air quality in Wisconsin is a stark reminder of the interconnectedness of climate, health, and policy, and our policymakers need factual and whole data sets to work from.

In alignment with the American Lung Association (ALA), HCW recommends:

- Withdraw the 'Exceptional Events Demonstration' and retain all days in the design value calculations for ozone and for PM 2.5.

- Retain wildfire-related data in regulatory assessments to reflect the true air quality conditions experienced by residents and inform future regulatory decisions to effectively protect public health.
- Use the data to strengthen local preparedness, including early warning systems, public health advisories, and other risk communications.
- Advocate for regional and national climate mitigation strategies, recognizing the role of climate change in shaping air quality trends and that transboundary pollution is a growing threat.
- Recommend strengthened 'Air Quality Standards' for Wisconsin. Appreciating the added pollution burden from wildfire smoke season will add to communities across the state, it is imperative that the WI DNR lead by enforcing the drawdown of Wisconsin's emissions and air pollution.
- Invest in climate-resilient infrastructure and clean energy transitions to reduce local contributions to air pollution. Community-centered air quality strategies that prioritize health, environmental justice, and long-term sustainability.

We humbly conclude with the request that this department lead with transparency and integrity by acknowledging—not excluding—the full scope of air pollution challenges facing Southeast Wisconsin.

This letter is supported by the following organizations:

Healthy Climate Wisconsin

MKE Freshair Collective

Physicians for Social Responsibility

Sierra Club Wisconsin

Wisconsin Environmental Health Network

American Lung Association, Healthy Climate Wisconsin, MKE FreshAir Collective, Physicians for Social Responsibility, Sierra Club Wisconsin and Wisconsin Environmental Health Network response:

Exceptional events are unusual or naturally occurring events that can affect air quality but are not reasonably controllable and are not addressed through the normal planning and regulatory process established by the Clean Air Act (CAA). The CAA section 391(b)(3)(B) allows state agencies to exclude air quality monitoring data influenced by exceptional events from use in regulatory determinations such as exceedances or violations of the NAAQS. This includes the exclusion of ozone data impacted by wildfire smoke, as described in the 2016 documents: Treatment of Data Influenced by Exceptional Events Rule (EE Rule, 81 FR 68216) and Preparation of Exceptional Events Demonstrations for Wildfire Events that May Influence Ozone Concentrations Guidance.

Following this guidance, the DNR demonstrated that ozone concentrations measured at WCA or MilwUPark on June 2, June 19, June 29 and July 25 of 2023 were impacted by wildfire smoke. An EPA concurrence with this demonstration would exclude this data from determination of exceedances of the NAAQS, however, the data remain on record and are publicly accessible through EPA's Air Quality System (AQS). In addition, this demonstration specifically pertains to ozone data. The regulatory use of $PM_{2.5}$ data recorded on June 2, June 19, June 29 and July 25 will remain unchanged.

Wildfire smoke is more than an air quality issue, it can have serious impacts on the health and well-being of communities. The DNR prioritizes early warning systems, public health advisories and other risk communications to ensure people have timely access to information about wildfire smoke. Since 2023, the DNR has updated both internal and external procedures and tools related to air quality forecasting, advisory issuance and associated public communication. Specifically, the DNR:

- Increased coordination and communication with border states to ensure consistent messaging during regional wildfire smoke events.
- Upgraded its Air Quality Data Map, which shows real-time data for monitors across the state, to include new tools for communicating during wildfire smoke events.
- Used DNR press releases, social media and Air News E-newsletter platform to communicate directly with areas forecasted to experience wildfire smoke impacts.

The DNR also worked with the Wisconsin Department of Health Services (DHS) and Wisconsin Department of Public Instruction (DPI) to form the Wildfire Smoke Interagency Workgroup in 2023. This group meets regularly during wildfire season to share information and maintain preparedness for smoke events. Specific outcomes of this group have been:

- DNR established advance notice protocols which give a 2-3 day advance notice to DHS and DPI that advisories for wildfire smoke may be impacting the state.
- DPI created an AQI graphic, available in English with Spanish translation available. It was created for pre-reading aged children and people who do not speak or read English.
- Agencies in the group share information and resources like template language, graphics and signage to align messaging and serve specific audiences that may be most vulnerable to wildfire smoke episodes like daycares and summer camps.

Louise Petering response:

Measured air quality certified by EPA, including wildfire impacted ozone data at the WCA and MilwUPark monitors on June 2, June 19, June 29 and July 25, is publicly available and can be accessed at the following EPA website:

https://aqs.epa.gov/aqsweb/airdata/download_files.html