# Exceptional Events Demonstration
# for the
# Greater Connecticut Nonattainment Area
# for the
# 2023 Ozone Season

***Connecticut Department of Energy and Environmental Protection***
***Bureau of Air Management***

***DRAFT for Public Comment............................................................ April 2024***

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# Acronyms and Abbreviations

| | |
|---|---|
| AOD | Aerosol Optical Depth |
| AQI | Air Quality Index |
| CAA | Clean Air Act |
| CDD | Cooling Degree Day |
| CFR | Code of Federal Regulations |
| CO | Carbon Monoxide |
| CONUS | Continental/Contiguous United States |
| CSAPR | Cross-State Air Pollution Rule |
| DEEP | Department of Energy and Environmental Protection (Connecticut) |
| DV | Design Value |
| EGU | Electric Generating Unit |
| EPA | Environmental Protection Agency (United States) |
| FEM | Federal Equivalency Method |
| FRM | Federal Reference Method |
| FRP | Fire Radiative Power |
| HMS | Hazard Mapping System |
| IMPROVE | Interagency Monitoring of Protected Visual Environments |
| IR | Infrared |
| lbs | Pounds |
| LIS | Long Island Sound |
| LISTOS | Long Island Sound Tropospheric Ozone Study |
| mb | millibar |
| MDA8 | Maximum Daily 8-hour Average |
| NAAQS | National Ambient Air Quality Standards |
| NEI | National Emissions Inventory |
| NESCAUM | Northeast States for Coordinated Air Use Management |
| NO | Nitric Oxide |
| $NO_2$ | Nitrogen Dioxide |
| NOx | Oxides of Nitrogen |
| NOy | Oxides of Nitrogen excluding NO and $NO_2$ |
| $O_3$ | Ozone |
| OMI | Ozone Monitoring Instruments |
| OTC | Ozone Transport Commission |
| OTR | Ozone Transport Region |
| PBL | Planetary Boundary Layer |
| PM2.5 | Fine Particulate Matter |
| ppb | parts per billion |
| ppm | parts per million |
| $SO_2$ | Sulfur Dioxide |
| TOPAZ | Tunable Optical Profiler for Aerosol and Ozone |
| tpd/km | tons per day per kilometer |

| | |
|---|---|
| TROPOMI | Tropospheric Monitoring Instrument |
| UV | Ultraviolet |
| VOC | Volatile Organic Compound |

# 1 Overview

## 1.1 Introduction

The 2023 ozone monitoring season (March 1 – September 30) in the northeastern United States was unusual due to fires burning throughout the season over extraordinarily large areas of the US and Canada. Several events in particular affected ozone levels in Connecticut to the extent that they caused noticeable deviations in expected ozone levels relative to the meteorological conditions.

Though smoke was a recurring regional theme throughout the season, the more critical of these events to the Greater Connecticut area occurred on April 13th and 14th, June 30th and July 1st and on July 12th.

On April 13th -14th, nearby wildfires in Pennsylvania, New York and New Jersey aligned with winds from the west -- already laden with smoke, ozone and precursors from fires out west -- to cause exceptionally high pre-season ozone levels throughout the state.[1] With only the exception of New Haven, all monitors in the state exceeded the level of the ozone standards for one or both of these days. Not since May 18, 2017, had Connecticut seen such widespread statewide ozone exceedances.[2]

An unusually dry Canadian winter provided ready tinder for northern wildfires in 2023. The Canadian wildfire season, which began in the end of April, and typically tapers off by the end of August, continued into October.[3] By the end of the season over 18 million hectares were burned, vastly exceeding the forty-year record, set in 1995, of just over 7 million hectares burned throughout Canada.[4] Five of those 18 million hectares burned in Quebec.[5]

[1] While the ozone monitoring season begins in May, Connecticut regulations [22a-174-22e(23)] define the ozone season as "the period beginning May 1 of a calendar year and ending on September 30 of the same year, inclusive." Throughout this document, DEEP uses the term "pre-season" to indicate yearly ozone monitoring data prior to May 1st.
[2] See Figure 2-1.
[3] https://earthobservatory.nasa.gov/images/151905/a-smoky-pall-over-canada
[4] Canadian Interagency Forest Fire Centre at: https://www.ciffc.ca/index.php?option=com_content&task=view&id=59&Itemid=129
[5] Canadian Interagency Forest Fire Centre at: https://ciffc.net/situation/

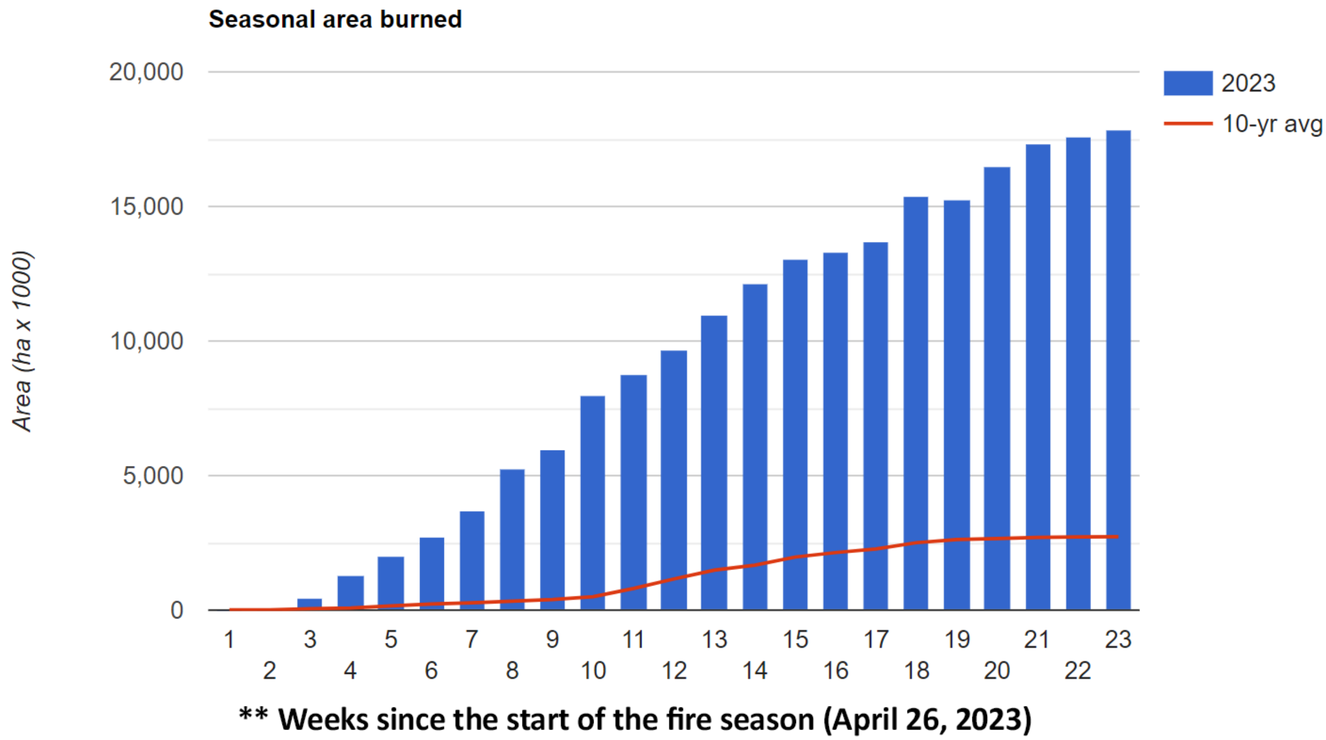


**Figure 1-1.** Cumulative weekly hectares burned by Canadian wildfires for the 23 weeks beginning April 26th, the start of the fire season, as compared to the 10 year average. Source: https://cwfis.cfs.nrcan.gc.ca/report/graphs#gr6

The 2023 wildfire season escalated rapidly as a cold front moved across Quebec on June 1st. The front created lightning storms and ignited fires along its path as it moved east across Canada's dry wilderness. Whereas the smoke from these fires would typically travel east across the Atlantic, an unusual low-pressure system off the coast of Prince Edward Island funneled smoke south into the northeastern United States.

Smoke from Canadian wildfires continued to flow into the US and dominated the news throughout the summer. On June 6th, thick smoke from Quebec caused particulate levels in New York City to reach their highest levels since 2002 and shaded the skies orange. By June 7th the plume had reached the District of Columbia and particulate levels were at their highest levels in 25 years.[6] As it traveled south, the plume was sufficiently dispersed to allow enough light through so that ozone could form. Thus, sites in Maryland's Dorchester and Charles counties, which had been in attainment for ozone for years, registered unusually high ozone exceedances.

[6] *Smoke Smothers the Northeast* https://earthobservatory.nasa.gov/images/151433/smoke-smothers-the-northeast

**Figure 1-2** View of Fayerweather Island on a smoke filled hazy afternoon in Bridgeport, Connecticut. June 7, 2023, posted by the Connecticut Insider.

Deeper into summer, July 18th, smoke from western Canadian wildfires was reported to reach as far south as North Carolina causing particulate levels to reach code red on the Air Quality Index.[7] These particulate levels coincided with excessive ozone levels throughout the state. In Mecklenburg and Rowan counties, monitors which for years have been comfortably below the ozone standards were registering ozone levels as high as 85 parts per billion (ppb) for a maximum daily 8-hour average.

Connecticut was no different, and by June 30th, reports of wildfire smoke from Canada were becoming routine. News reports showed images of the return of the now familiar *"… orange, hazy post-apocalyptic smoke from the Canadian wildfires…"*.[8] Maximum daily 8-hour average (MDA8) ozone levels reached as high as 85 ppb with exceedances throughout western Connecticut. Accompanying particulate levels reached as high as 60 $\mu g/m^3$ (24-hour average) – approaching twice the level of the short-term standard. The next day, July 1st, ozone levels were exceeded at every monitor in the state with a high of 86 ppb MDA8 at Stratford – a level that would be exceeded only by another event on July 12th.[9]

[7] https://www.wxii12.com/article/wildfires-smoky-hazy-north-carolina-code-orange-action-day-winston-salem-greensboro-air-quality-alerta/44556338#
[8] https://www.wfsb.com/2023/06/30/air-quality-concerns-return-wildfire-smoke-impacts-connecticut/
[9] Greenwich, Stratford and Westport all registered an MDA8 concentration of 89 ppb on July 12th, the highest levels recorded for the season in Connecticut.

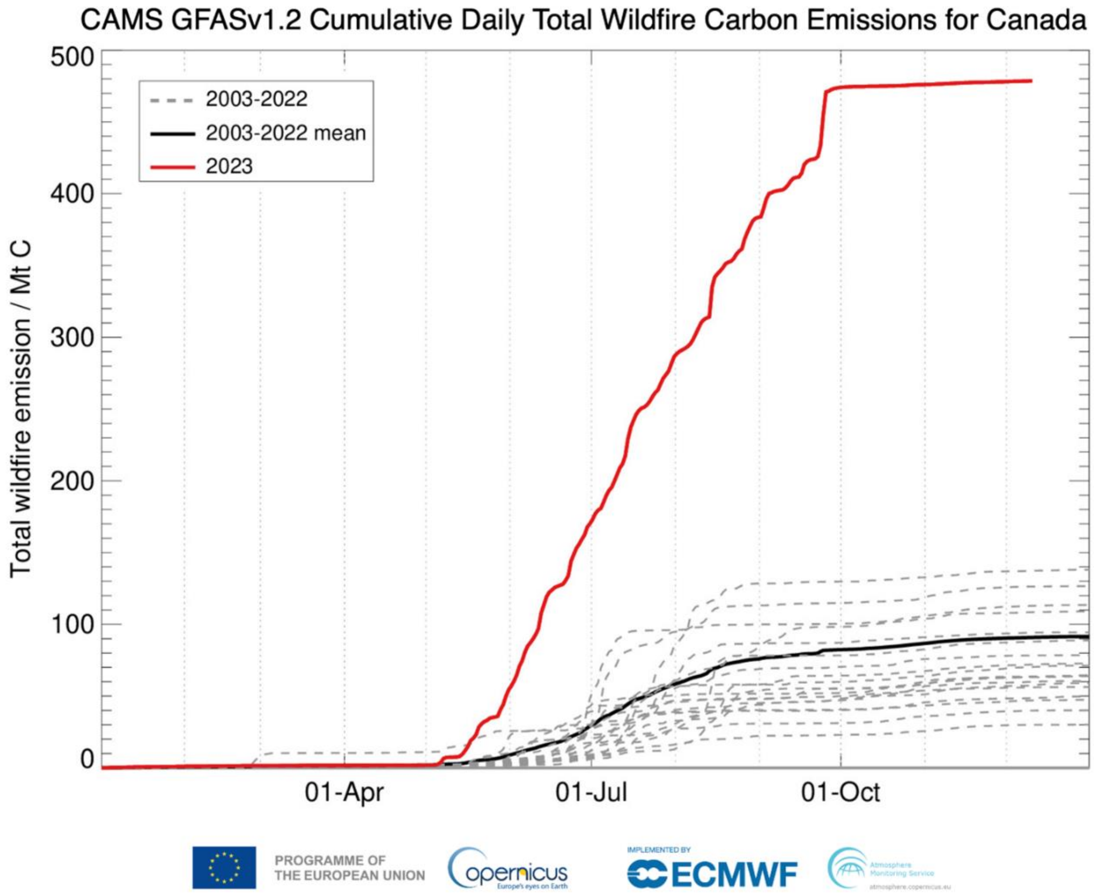


**Figure 1-3.** Cumulative carbon emissions from Canadian wildfires comparing 2023 to the prior twenty years. Source https://atmosphere.copernicus.eu/copernicus-canada-produced-23-global-wildfire-carbon-emissions-2023

An exceptional event is defined in 40 CFR 50.1(j) as an event, or events, and the "…resulting emissions that affect air quality in such a way that there exists a clear causal relationship between the specific event(s) and the monitored exceedance(s) or violation(s), is not reasonably controllable or preventable, is an event(s) caused by human activity that is unlikely to recur at a particular location or a natural event(s)…" Such events may include prescribed burns and wildfires.

Ozone and ozone precursors emitted from these unusually widespread and persistent fires caused regional exceedances of the ozone and particulate standards throughout the summer as plumes reached the surface. Several of these events qualify for data exclusion under EPA's exceptional events rule due to their regulatory significance to Connecticut's attainment of the national ambient air quality standards (NAAQS) for ozone.

## 1.2 EPA Exceptional Event Guidance

EPA's home page for exceptional events provides guidance and examples for making demonstrations that exceptional events, such as wild and prescribed fires, have influenced air quality. The Exceptional Events Rule, contained in Title 40 of the Code of Federal Regulations Part 50.14 (40CFR50.14), was last revised by EPA in October of 2016.[10] The rule describes the procedures for treating data which has been influenced by an exceptional event. Accordingly, an exceptional events demonstration must include the following elements:

1) A narrative conceptual model that describes the event(s) causing the exceedance or violation and a discussion of how emissions from the event(s) led to the exceedance or violation at the affected monitor(s);

2) A demonstration that the event affected air quality in such a way that there exists a clear causal relationship between the specific event and the monitored exceedance or violation;

3) Analyses comparing the claimed event-influenced concentration(s) to concentrations at the same monitoring site at other times. The Administrator shall not require a State to prove a specific percentile point in the distribution of data;

4) A demonstration that the event was both not reasonably controllable and not reasonably preventable;

5) A demonstration that the event was caused by human activity that is unlikely to recur at a particular location or was a natural event; and

6) Documentation that the submitting air agency followed the public comment process.

Wildfires are defined at 40 CFR 50.1(n) as "…any fire started by an unplanned ignition caused by lightning; volcanoes; other acts of nature; unauthorized activity; or accidental, human-caused actions, or a prescribed fire that has developed into a wildfire. A wildfire that predominantly occurs on wildland is a natural event." EPA has prepared guidance specific to analyzing the influence of wildfires on ozone events.[11]

Furthermore, 40 CFR 50.14(b)(4) states that the EPA " … shall exclude data from use in determinations of exceedances and violations where a State demonstrates to the Administrator's satisfaction that emissions from wildfires caused a specific air pollution concentration in excess of one or more national ambient air quality standard (*sic*) at a particular air quality monitoring location and otherwise satisfies the requirements of this section. Provided the Administrator determines that there is no compelling evidence to the contrary in the record, the Administrator will determine every wildfire occurring predominantly on wildland to have met

[10] https://www.epa.gov/sites/default/files/2018-10/documents/exceptional_events_rule_revisions_2060-as02_final.pdf
Federal Register / Vol. 81, No. 191 / Monday, October 3, 2016: Treatment of Data Influenced by Exceptional Event

[11] Guidance on the Preparation of Exceptional Events Demonstrations for Wildfire Events that May Influence Ozone Concentrations, Final, US EPA OAQPS, Research Triangle Park, North Carolina, September 2016.

the requirements identified in paragraph (c)(3)(iv)(D) [item (4) above] of this section regarding the not reasonably controllable or preventable criterion."

We address each of the elements above, excluding item (4), in the subsequent sections of this document generally relying on the EPA guidance for wildfires.[12] EPA guidance offers suggestions for appropriate analyses to demonstrate the clear causal relationship between the wildfire and excessive ozone levels and recognizes that appropriate levels of analysis will vary for particular locations and conditions. EPA does not intend for the guidance to constrain the analysis, and we include some of the suggested analytics, and variations of those methods, to support our conclusion that the ozone exceedances throughout the State were caused or worsened by the wildfire plumes from several events prior to, and during, the 2023 ozone season.

## 1.3 Initial Notification and Description of Events

The Connecticut Department of Energy and Environmental Protection (DEEP) conducted preliminary investigation of multiple events in the state where smoke and ozone coincided. Weighing priorities and recommendations from EPA, DEEP limited its notification of exceptional events to those described in this section, and on January 10, 2024, submitted formal notification of the events to EPA through its Central Data Exchange.

### April 13-14, 2023 Ozone Event

Agricultural burning and prescribed fires take place every year, especially in the southern U.S and the Flint Hills region of Kansas. Connecticut forecasters have observed enhanced early season ozone levels due to a combined light smoke plume blanketing the eastern States in the past, but weather patterns this April caused this smoke to be transported to Connecticut for an extended period with unusually warm temperatures. In concert with this smoke, nearby wildfires occurred just upwind in Pennsylvania, New York, and New Jersey to further raise ozone levels. Collectively, and perhaps individually, these fires qualify April 13-14, 2023, as an exceptional event.

Figure 1-4 shows the buildup of regional ozone levels as indicated by air quality index (AQI) levels. Moderate levels (shaded yellow) cover most of the eastern U.S. and exceedances (shaded orange) occur as pollutants in the smoke plumes react near the surface or mix with urban or local pollutants. A few monitors recorded their highest ozone levels for the year on these dates.

[12] To the extent this demonstration relies on prescribed fires, EPA guidance for prescribed fires states that air agencies do not need to justify the "not reasonably controllable or preventable" criterion for emissions-from outside the State's boundaries.

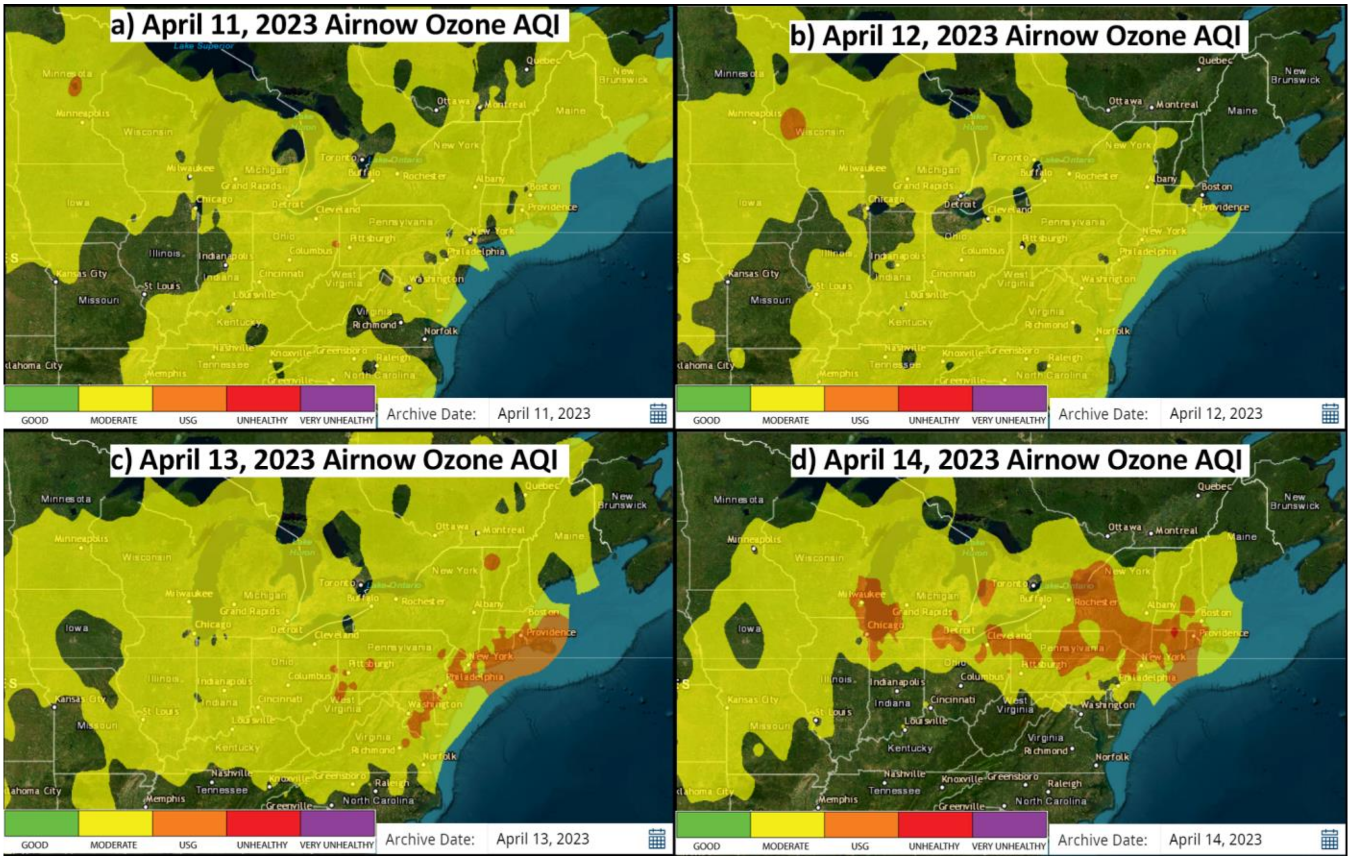


**Figure 1-4.** Extent of elevated ozone AQI levels in the northeast from April 11 through April 14, 2023.

The following figure shows that back trajectories from our Cornwall monitor, three days prior to the exceedance event on April 13$^{th}$, originated near fires in the Flint Hills area of Kansas.

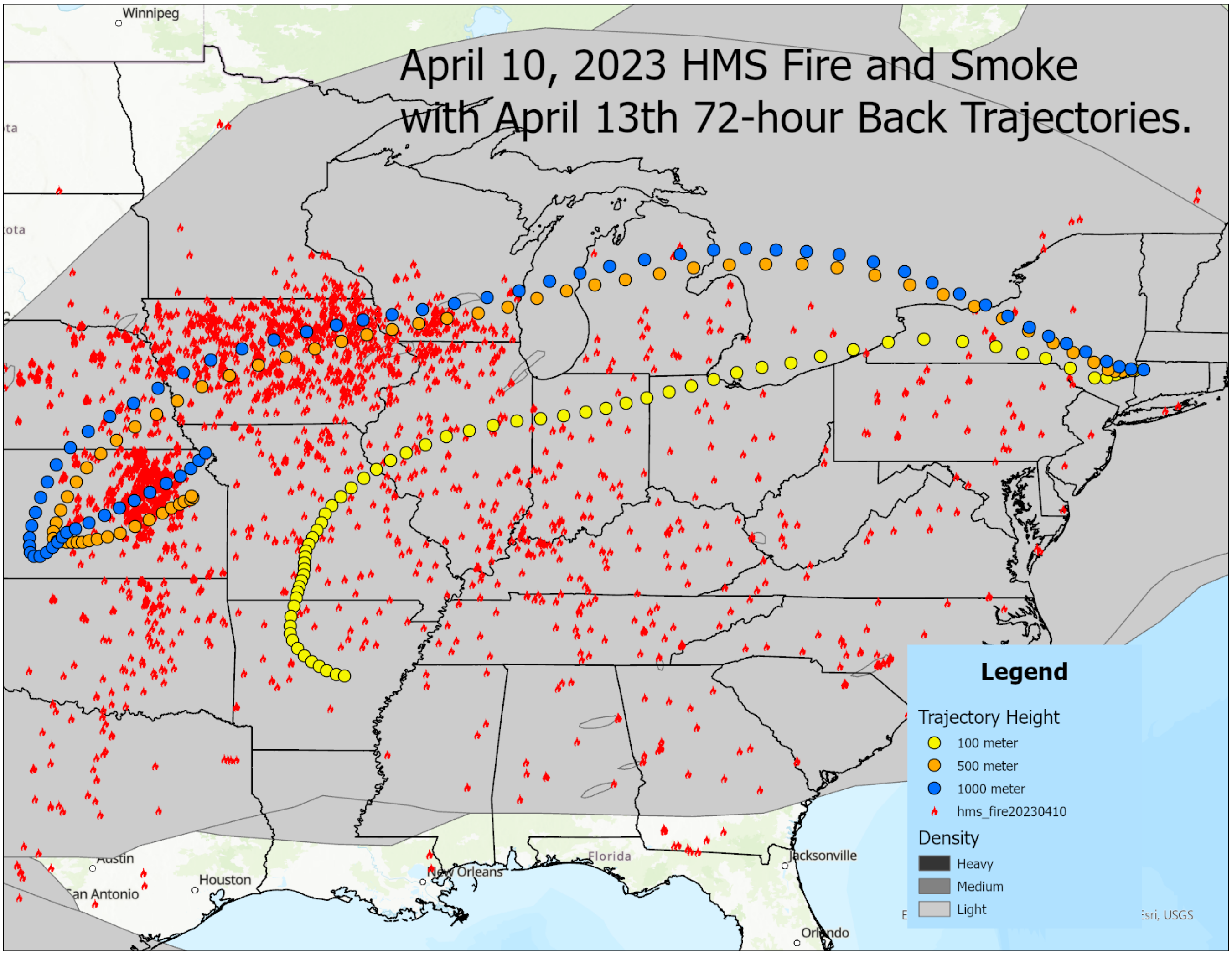


**Figure 1-5.** Three-day back trajectories starting April 13 from the Cornwall monitor overlaying the HMS smoke/fire analysis for April 10th. This is a more realistic depiction of the fires that would have contributed to the smoke near the beginning of the trajectory. Note the fires burning at the Flint Hills of eastern Kansas.

On April 13-14th, wildfires were also burning in Pennsylvania, New York, and New Jersey. The following satellite image from April 13th shows 24-hour back trajectories from our Cornwall monitor on April 14th. Smoke transport into Connecticut from these fires was responsible for a further increase in the ozone levels.

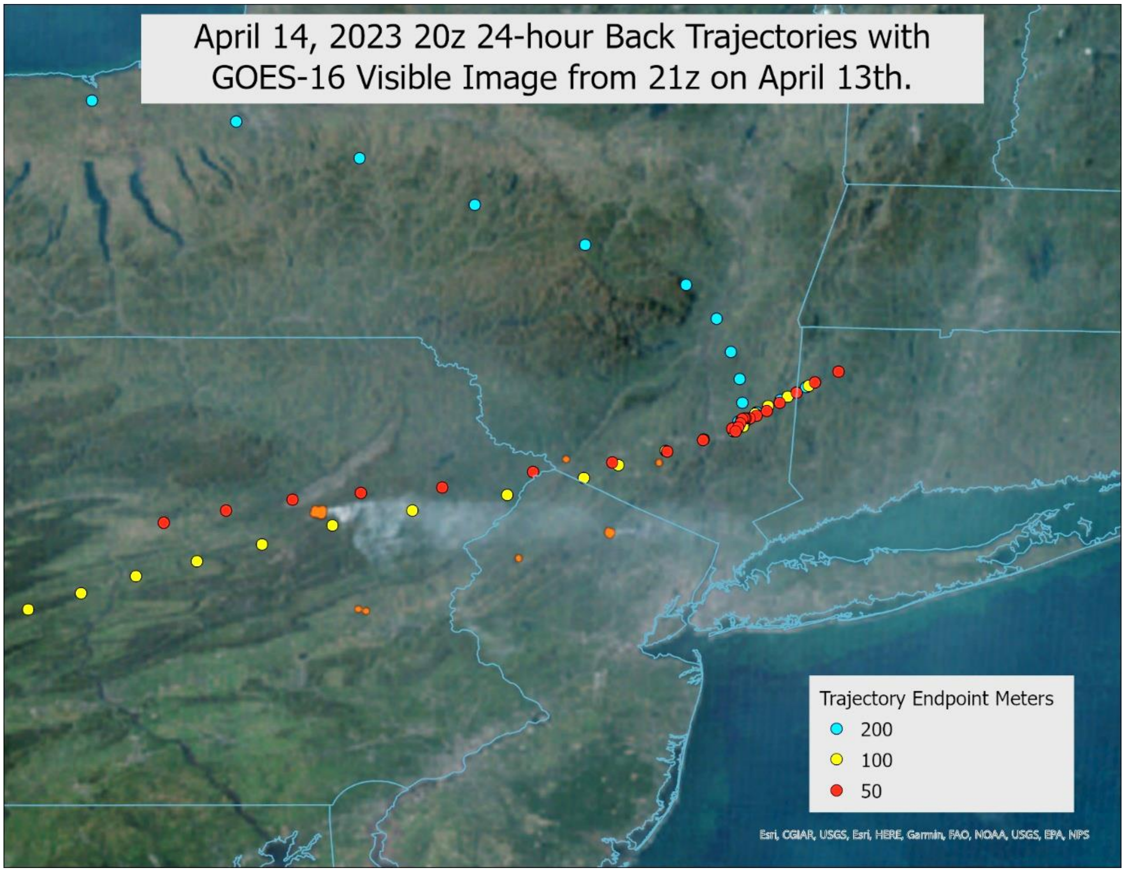


**Figure 1-6.** Visible smoke plumes from fires in neighboring states spread out over Connecticut on April 13th.

## June 30 – July 1, 2023 Ozone Event

The Quebec fires that brought the area extremely high PM2.5 during early June, began burning as result of lightning strikes around June 1st. Figure 1-7 is a satellite image of smoke plumes being transported south over Quebec on June 2nd. Although PM2.5 levels would be the main air quality issue for the next several days, continued burning of the Quebec fires throughout the summer, and the transported smoke plumes, would elevate ozone levels throughout Connecticut by June 30th.

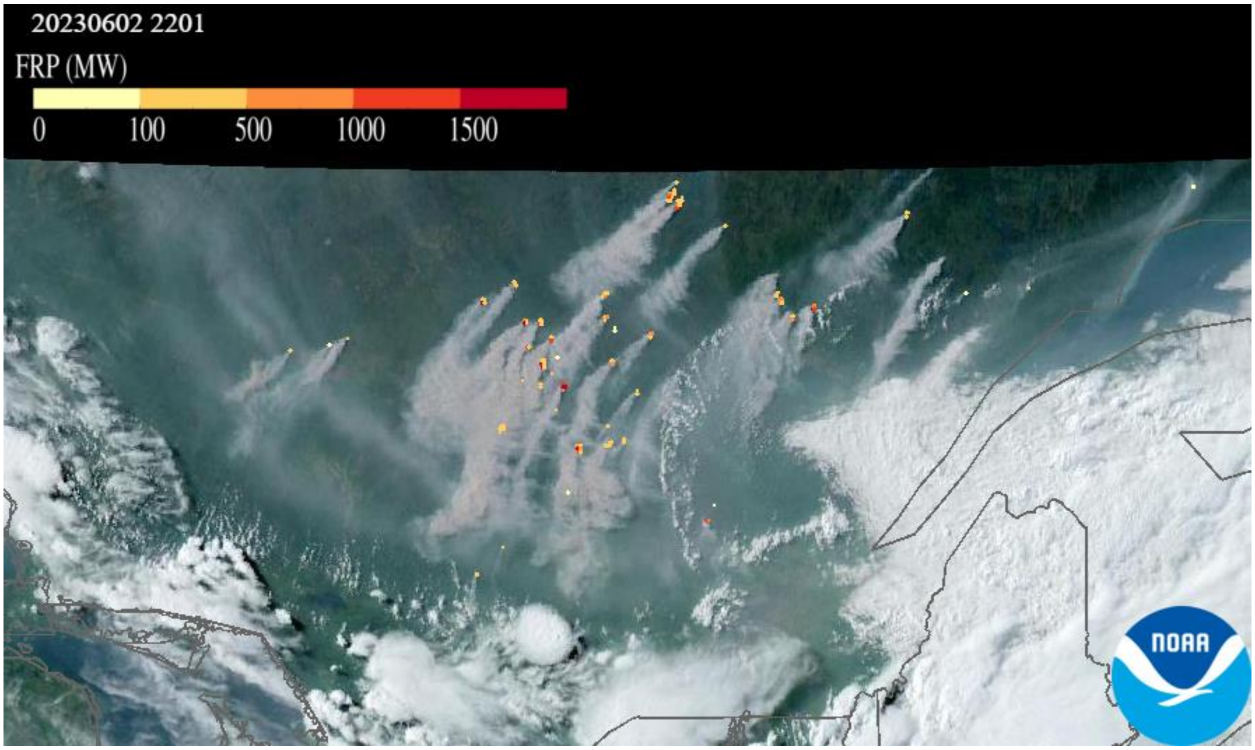


**Figure 1-7.** Satellite image of smoke plumes from fires ignited in early June in Quebec, Canada.

Smoke from Quebec settled into the region on June 30th with fine particulate levels in Connecticut and surrounding areas reaching unhealthy levels and prompting EPA and DEEP officials to release health advisories.[13, 14]

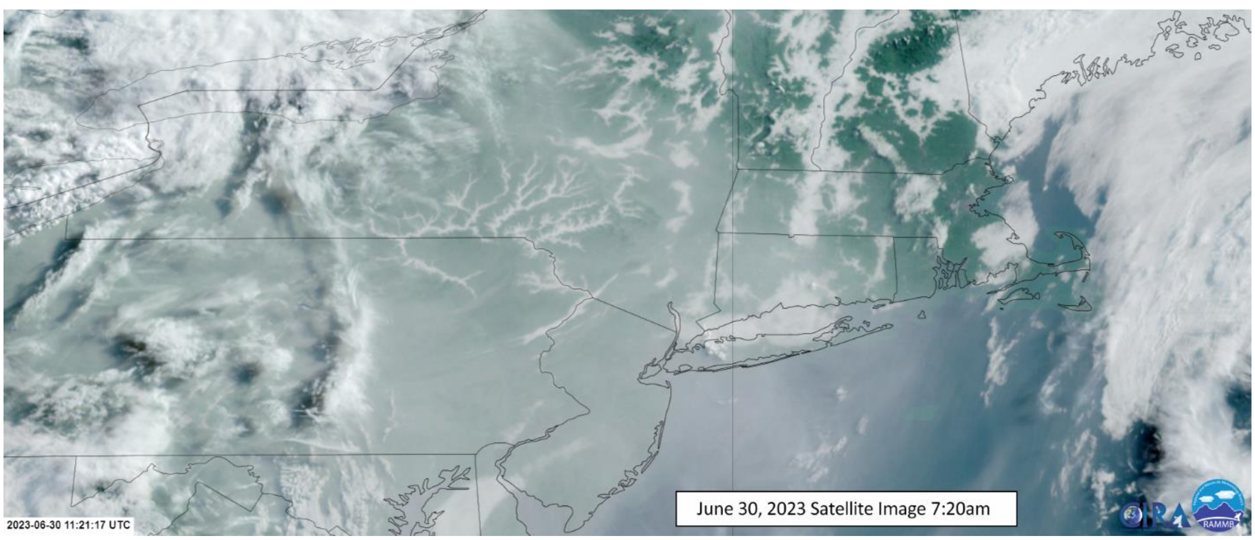


**Figure 1-8.** Satellite image of smoke covering multiple northeast states, including Connecticut, on June 30, 2023.

[13] https://www.epa.gov/newsreleases/new-england-continues-experience-poor-air-quality-due-smoke-canadian-wildfires-friday
[14] https://portal.ct.gov/DEEP/News-Releases/News-Releases---2023/DEEP-Forecasts-PM2-5-Levels-on-Saturday-will-be-Unhealthy-for-Sensitive-Groups-for-the-Entire-State

So also began a two-day ozone episode in Connecticut with elevated ozone levels across much of the northeastern United States as shown in Figure 1-9.

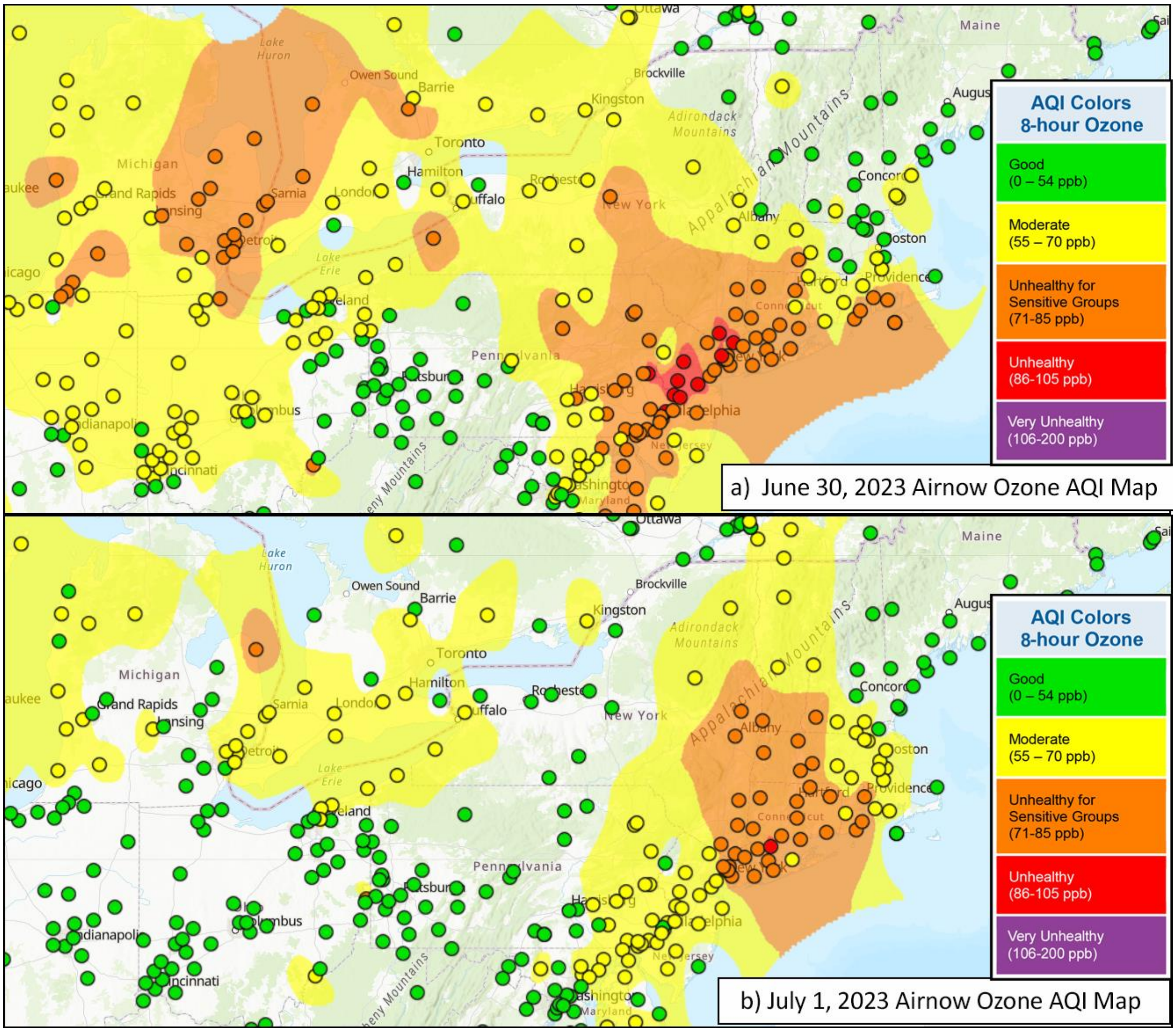


**Figure 1-9.** Regions of moderate (yellow) to unhealthy (orange and red) ozone AQI levels in the northeastern United States from June 30- July 1, 2023.

## July 12, 2023 Ozone Event

July 12$^{th}$ saw the highest ozone levels in the state for 2023 with a few coastal monitors registering maximum daily 8-hour averages of 89 ppb as smoke from the western Canadian wildfires moved into the area. Figure 1-10 shows the highest ozone values for July 12$^{th}$ occurring over the Connecticut coastline. By midafternoon clouds formed over the northern half of the state and inhibited ozone production, and while ozone in the northern section of the state was generally elevated, it did not exceed moderate levels.

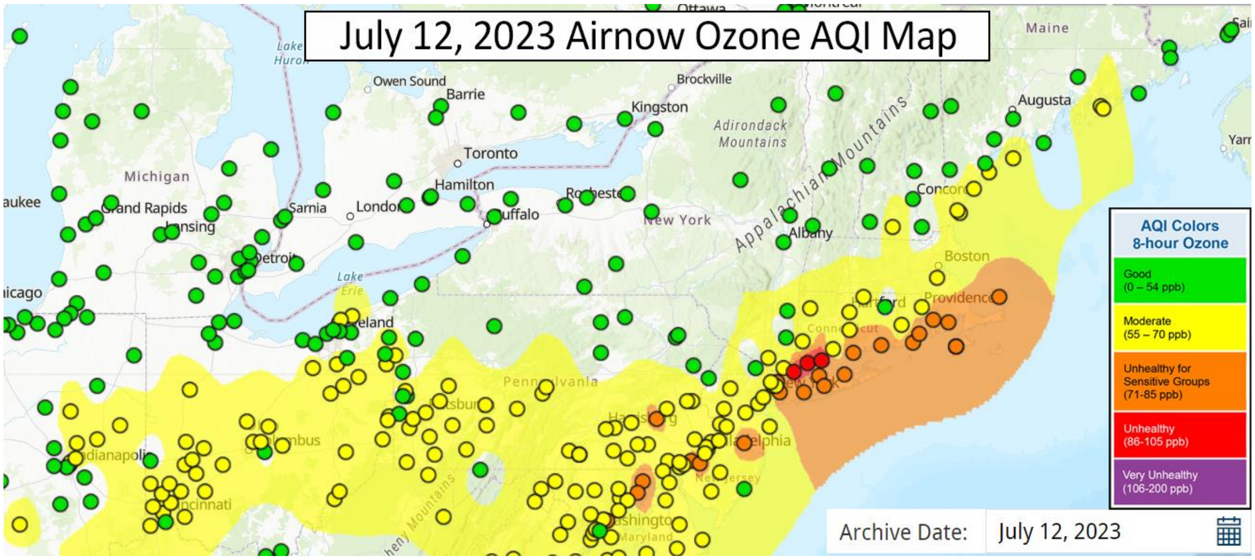


**Figure 1-10.** Maximum daily 8-hour average ozone AQI levels in the northeastern United States for July 12, 2023.

Figure 1-11 shows an extensive smoke plume over the northeast states on the morning and late afternoon of July 12th. Late day clouds and precipitation, seen in the afternoon image, limited ozone production in northern Connecticut.

Figure 1-12 shows the same plume 38 hours earlier in the Midwest, and Figure 1-13 shows the plume forming over western Canada on July 7th.

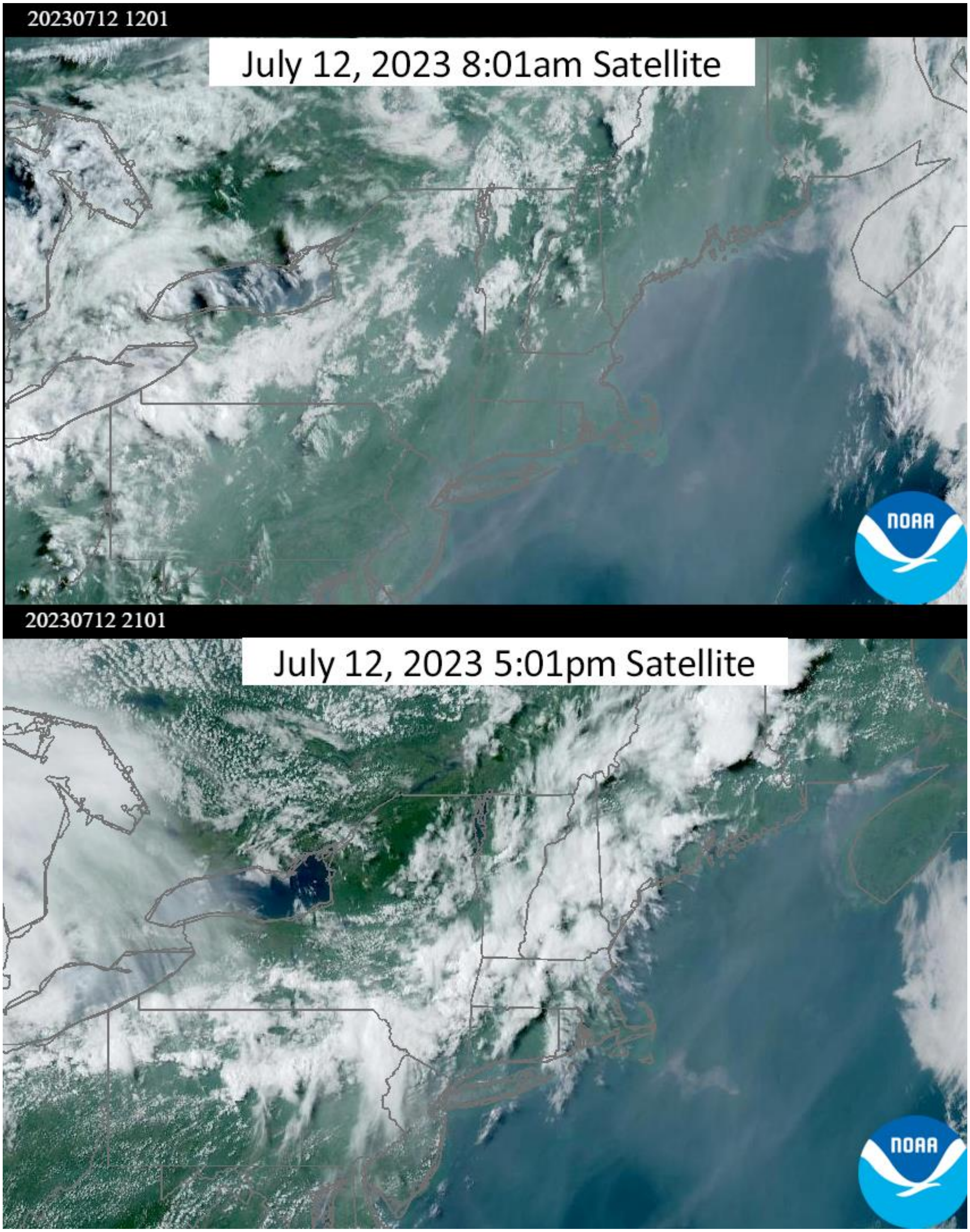


**Figure 1-11.** Morning and afternoon satellite images showing smoke plume over the northeast states on July 12th.

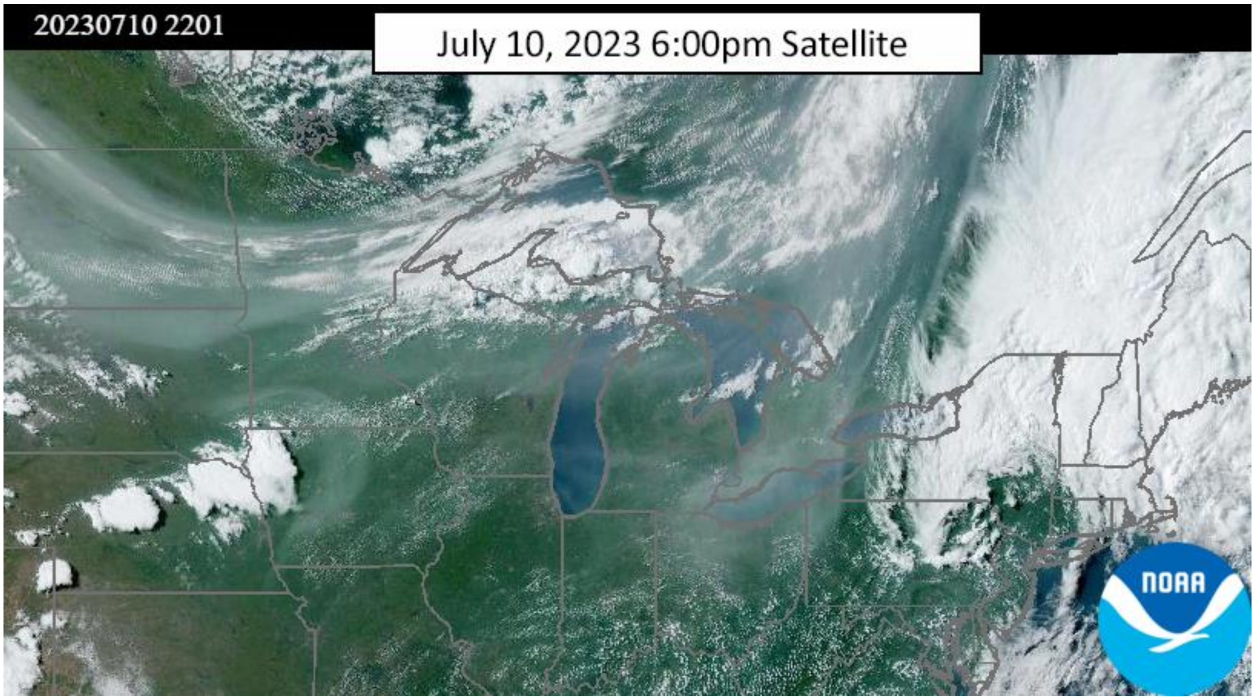


**Figure 1-12.** Satellite image of smoke plume over the midwestern states on the evening of July 10th.

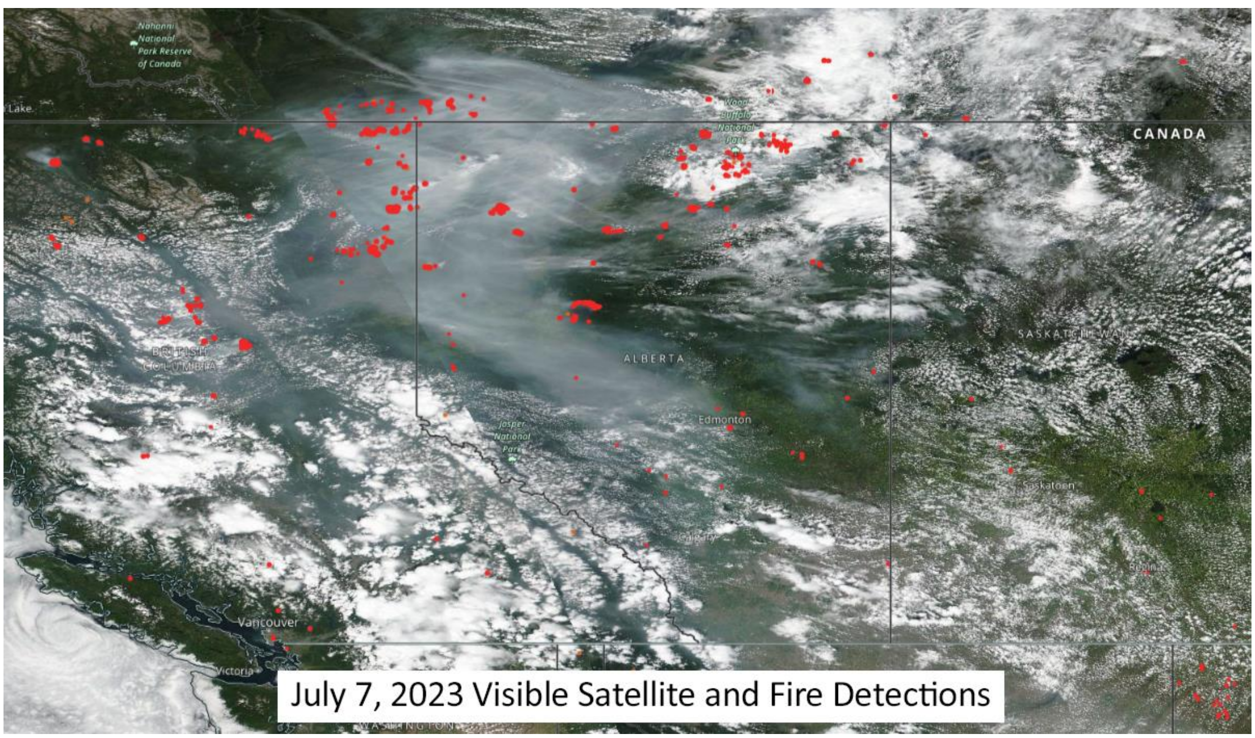


**Figure 1-13.** Satellite image of smoke plume forming over northern British Columbia and Alberta on July 7th.

These three events are investigated further in this document. We look in detail at ozone and particulate concentrations, satellite imagery of fires and smoke plumes, backward and forward trajectories between monitoring locations and fires, and other data to show clear causal relationship between the fires and elevated ozone concentrations during these events.

## 1.4 Regulatory Significance

The exceptional events rule applies to unusual or natural events that are not reasonably controllable or preventable but that can cause an exceedance or violation of a National Ambient Air Quality Standard (NAAQS or standard) or which may affect regulatory determinations regarding attainment designations, classifications, determinations regarding attaining the level of the standard, or any other action on a case-by-case basis as determined by the Administrator. Under the rule, data influenced by these events which may affect the outcome of a regulatory determination is considered to have regulatory significance and should be excluded from the determination.

National Ambient Air Quality Standards are made up of four basic elements.[15] These are the indicator, the form, the averaging time, and the level. Ozone is the indicator for photochemical oxidants. The form of both the 2015 and 2008 ozone NAAQS is the fourth highest daily maximum, averaged across three consecutive years. The averaging time for both standards is 8-hours, and the level is 0.070 parts per million (ppm) for the 2015 NAAQS and 0.075 ppm for the 2008 NAAQS.

Regulatory status is determined by calculating a design value using monitored data and comparing it to the standard. For each monitor, the design value for ozone is determined by averaging the fourth highest maximum daily 8-hour average for each of three consecutive years. The highest of these in a nonattainment area is the area's design value and is used to determine attainment with the standard. Any concentration affecting an area's maximum design value may have regulatory significance. Because the form of the standard spans three years, the fourth highest values for 2023 will be considered in design values which are averaged with the fourth highest values dating back to 2021 and forward to 2025. Therefore, regulatory significance may not be fully assessed until data for 2025 has been validated. However, in preliminary meetings regarding this demonstration, EPA Region 1 indicated that it will only process data exclusion requests where regulatory significance is dependent on current and past data. Therefore, this demonstration is limited to current design values. Any future regulatory significance may be addressed at a later time.

While the plumes from wildfires affecting Connecticut's ozone levels during 2023 were regional in nature, not all monitor exceedances were such that they would likely affect attainment designation status or other EPA actions, such as clean data determinations. Here we attempt to determine regulatory significance of the data that affects current design values in the Greater Connecticut nonattainment area. We do not consider how data may affect any of Connecticut's future design values for their potential regulatory significance. We consider only the maximum daily 8-hour average ozone concentrations (MDA8) at each site in the Greater Connecticut nonattainment area and examine how it affects the 2023 design values.

[15] https://www.epa.gov/criteria-air-pollutants/process-reviewing-national-ambient-air-quality-standards

**Selection of Data Exclusion for 2023 in the Greater Connecticut Nonattainment Area**

Table 1-1 lists, from highest to lowest, the ten highest MDA8 ozone concentrations for each of the monitors in the Greater Connecticut nonattainment area. Without consideration of the exceptional events, the fourth highest values range from 63 ppb in Abington to 76 ppb in Cornwall. The table highlights the fourth highest values that would result if all data affected by exceptional events were excluded. The resulting fourth highs, highlighted in yellow in the table, would range from 61 ppb in Abington to 69 ppb in East Hartford.

**Table 1-1.** Maximum daily 8-hour average (MDA8) ozone concentrations at monitoring sites in the Greater Connecticut nonattainment area. The ten highest MDA8 values are shown with dates of occurrence. Dates shaded in pink are days affected by wildfire smoke. MDA8 values highlighted in yellow indicate the fourth highest level that would result if all higher data impacted by smoke were excluded.

| Greater Connecticut<br>10 Highest Ozone Values per Monitor | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Cornwall | 4/14/2023 | 7/1/2023 | 6/30/2023 | 6/1/2023 | 4/13/2023 | 7/26/2023 | 5/12/2023 | 6/11/2023 | 4/12/2023 | 7/13/2023 |
| | 82 | 79 | 78 | 76 | 67 | 67 | 65 | **65** | 62 | 62 |
| East Hartford | 4/14/2023 | 7/1/2023 | 6/30/2023 | 6/1/2023 | 5/28/2023 | 7/6/2023 | 6/2/2023 | 4/13/2023 | 7/12/2023 | 7/26/2023 |
| | 84 | 82 | 73 | 73 | 70 | 69 | **69** | 67 | 64 | 64 |
| Groton | 7/12/2023 | 7/1/2023 | 4/13/2023 | 4/14/2023 | 7/29/2023 | 6/30/2023 | 5/12/2023 | 7/28/2023 | 9/7/2023 | 7/6/2023 |
| | 81 | 76 | 76 | 73 | 71 | 70 | 70 | 69 | **64** | 62 |
| Stafford | 4/14/2023 | 7/1/2023 | 4/13/2023 | 5/28/2023 | 6/30/2023 | 6/1/2023 | 5/12/2023 | 6/12/2023 | 9/2/2023 | 4/4/2023 |
| | 88 | 76 | 71 | 70 | 68 | 65 | 64 | **63** | 62 | 61 |
| Abington | 4/14/2023 | 7/1/2023 | 4/13/2023 | 5/12/2023 | 5/16/2023 | 5/28/2023 | 6/1/2023 | 6/12/2023 | 7/13/2023 | 4/12/2023 |
| | 74 | 71 | 69 | 63 | 63 | 62 | **61** | 61 | 59 | 58 |

Table 1-2 shows the 2023 design values with and without exclusion of data from the exceptional events. Design values at the Abington and Stafford sites meet the 2015 ozone NAAQS even with data affected by the exceptional events. Therefore, there is no regulatory significance to pursuing an exceptional event request for those sites at this time.

The design value for the Groton site meets the standard only by excluding all five days selected for the exceptional events demonstration. Therefore, April 13-14, June 30-July 1 and July 12 are all regulatorily significant for Groton.

**Table 1-2.** Resulting fourth high and 2023 design values (DVs) for monitors in the Greater Connecticut nonattainment area determined with, and without, the exceptional events data.

| Greater Connecticut | | | | | | |
|---|---|---|---|---|---|---|
| | | | Ignoring EE | | Excluding All EE | |
| Site | 2021 4th High | 2022 4th High | Current 4th High | Current DV | Resulting 4th High | Resulting DV |
| | | | | | | |
| **Abington** | 68 | 64 | 63 | 65 | 61 | 64 |
| **Cornwall** | 68 | 70 | **76** | **71** | 65 | 67 |
| **East Hartford** | 66 | **74** | **73** | **71** | 69 | 69 |
| **Groton** | **75** | **71** | **73** | **73** | 64 | 70 |
| **Stafford** | 67 | 68 | 70 | 68 | 63 | 66 |

Design values at East Hartford and Cornwall fall below the 2015 ozone NAAQS when all exceptional events data is excluded. Design values need only meet the standard. Therefore, not all data need to be excluded for these two sites at this time. To minimize the data that needs to be excluded, we consider the highest fourth highest MDA8 that would result in a design value of less than 71 ppb at each of these two sites. Since the design value is calculated by average of the current 4th highest MDA8, C, with the fourth highest MDA8s from the two previous years, A and B, we have that (A+B+C)/3 must be less than 71. Or that C must be less than 3*71 -(A+B). The values determining C are given in Table 1-3 and show that Cornwall's critical fourth highest value must be less than 75, and East Hartford's must be less than 73.

The MDA8 for Cornwall that is next lower in value to 75 in Table 1-1 is the fifth highest value, 67, occurring on April 13th. For this value to be considered in the design value calculation for Cornwall only one of the three exceptional event days which exceed it need to be excluded. The days are April 14, July 1 and June 30.

The MDA8 for East Hartford that is next lower in value to 73 in Table 1-1 is the fifth highest value, 70, occurring on May 28th. For this value to be considered in the design value calculation for East Hartford only one of the three exceptional event days which exceed it need to be excluded. The days are, as with the Cornwall site, April 14, July 1 and June 30.

Therefore, Groton will be considered for April 13 and 14, June 30, July 1, and July 12, as each of these smoke-affected days cause the design value for Groton to exceed the standard. Cornwall and East Hartford need only be considered for one day each of April 14, July 1, or June 30 to obtain a compliant 2023 design value at these sites. DEEP focuses on July 1st for exclusion for East Hartford and Cornwall because it represents the highest levels recorded at these monitors during the regular ozone season.

**Table 1-3.** Determination of the Critical Value that the fourth highest MDA8 for 2023, represented by C, cannot exceed in order to obtain a site design value that meets the 2015 ozone NAAQS.

| Site | (A) 2021 4th High | (B) 2022 4th High | (C) Highest Allowed Critical Value C < 3*71 -(A+B) |
|---|---|---|---|
| **Cornwall** | 68 | 70 | C < 213-(68+70) = 75 |
| **East Hartford** | 66 | 74 | C < 213-(66+74) = 73 |

## 1.5 Summary

While smoke exacerbated ozone and particulate levels throughout the spring and early summer of 2023, the regulatory significance of these events to Greater Connecticut is currently limited to ozone levels at the East Hartford, Cornwall, and Groton monitoring sites. Each of the following event days: April 13, April 14, June 30, July 1, and July 12 will be examined in detail in this exceptional events demonstration at these and other monitors to show that smoke caused excess levels of ozone.

As shown in Table 1-2, excess ozone levels cause design values for ozone to exceed the level of the standards at Cornwall, East Hartford, and Groton. The design value for Groton meets the standard with the exclusion of each of the five smoke affected days. Therefore, each of the five days are regulatorily significant, and proposed for exclusion, at the Groton site.

Exclusion of all five days is not necessary for Cornwall or East Hartford to meet the standard. Exclusion of only one of the five days is sufficient for these two sites to meet the standard. Therefore, DEEP focuses on and proposes exclusion of the data for July 1 from regulatory determinations regarding the East Hartford and Cornwall sites.

DEEP proposes these exclusions based on consultation with EPA Region 1 and with the intent to limit the amount of effort necessary for these demonstrations to address current regulatory status. DEEP notes that regulatory significance may change as future data becomes available and finalized and may revisit the issue in the future.

# 2 Conceptual Model

## 2.1 Introduction

Connecticut monitors ozone throughout the year at three sites and from March 1st through September 30th of each year for the remaining sites. However, ozone exceedances are not expected during months with less heat and sunlight. Therefore, Connecticut DEEP and nearby states generally incorporate ozone into the daily air quality forecasts only from May 1st through September 30th each year.[16]

An exceedance day for the 8-hour ozone NAAQS is defined as a day, measured from midnight to midnight, on which any one or more monitors in the state record a forward 8-hour average ozone concentration greater than or equal to the standard. Typically, most ozone exceedance days occur between June and August, with fewer exceedances during May and September. Exceedances have occurred during April, but only rarely.

[16] Recognizing the smoke influence on unexpectedly high ozone values for April 13th, regional forecasters took the unusual step of including ozone in an AQI forecast for April. DEEP issued notice of operating restrictions based on forecasted ozone exceedances for the 14th. See: https://portal.ct.gov/-/media/DEEP/air/AQI/Forecasted-Ozone-Exceedance/2023-Ozone-Exceedance-PDF/ozonereg-04-14-2023.pdf

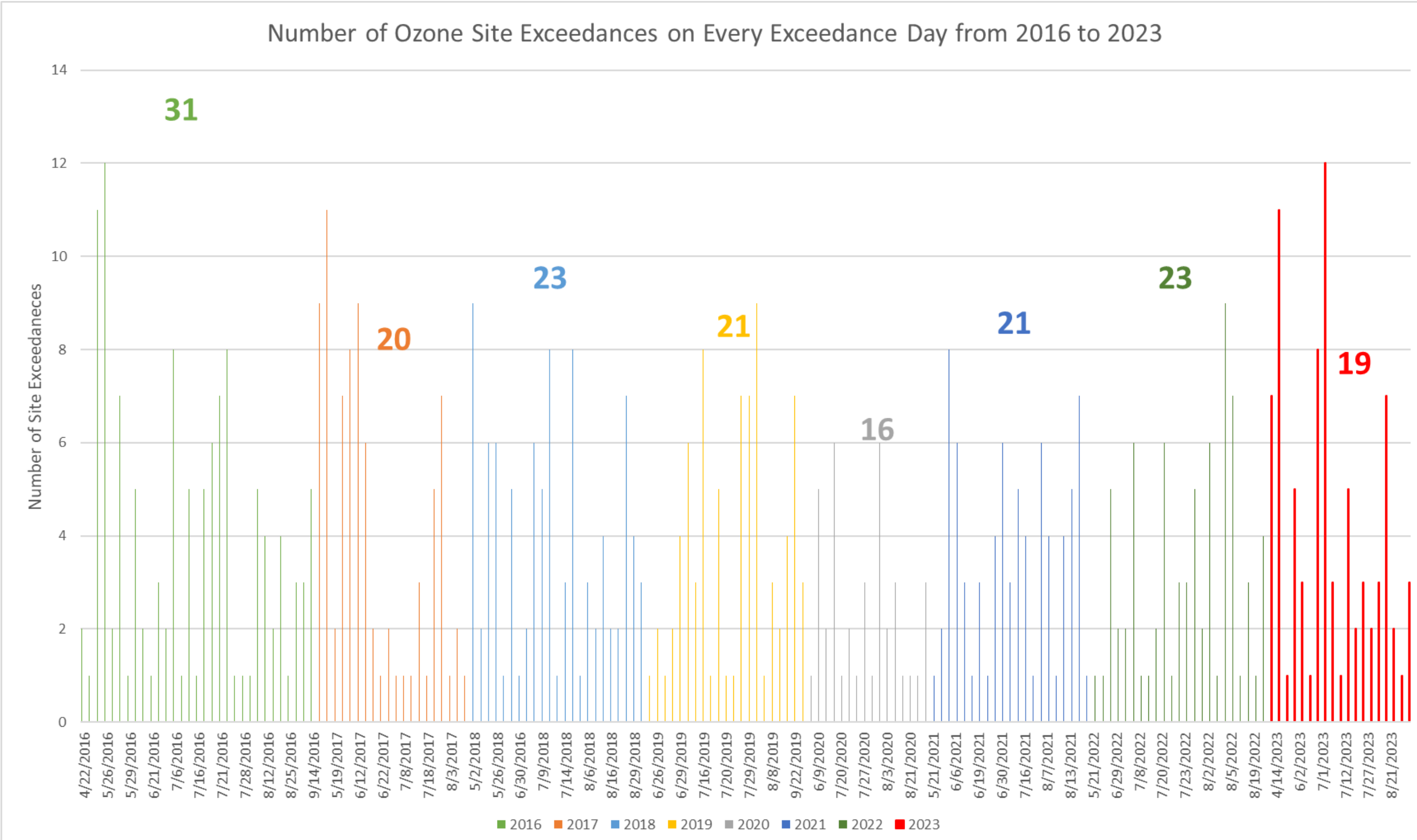


**Figure 2-1.** Number of monitors exceeding the level of the 2015 ozone standard from 2016 through 2023 for each exceedance day. Total yearly exceedance days are indicated above each set of annual data.

As indicated in Figure 2-1, April 22, 2016, was the most recent pre-season ozone exceedance day prior to 2023. The 2016 event included only two site exceedances compared to seven and eleven, respectively, for the two-day episode of April 13-14, 2023. In Figure 2-1, both of the two-day smoke episodes considered here for 2023 stand out along with the May 25-26, 2016 Fort McMurray Exceptional Event.[17] In spite of the smoke events, the 2023 total yearly exceedance days were only lower for 2020, a year which included the full impact of the COVID lockdowns.

This downward trend in exceedances can better be seen in Figure 2-2 which focuses on annual exceedance days for the Greater Connecticut area. There is only a one exceedance day difference between a 2023 design value that meets the 2015 ozone standard and a smoke influenced design value that does not.

[17] https://portal.ct.gov/DEEP/Air/Planning/Ozone/May-2016-Exceptional-Event-Request

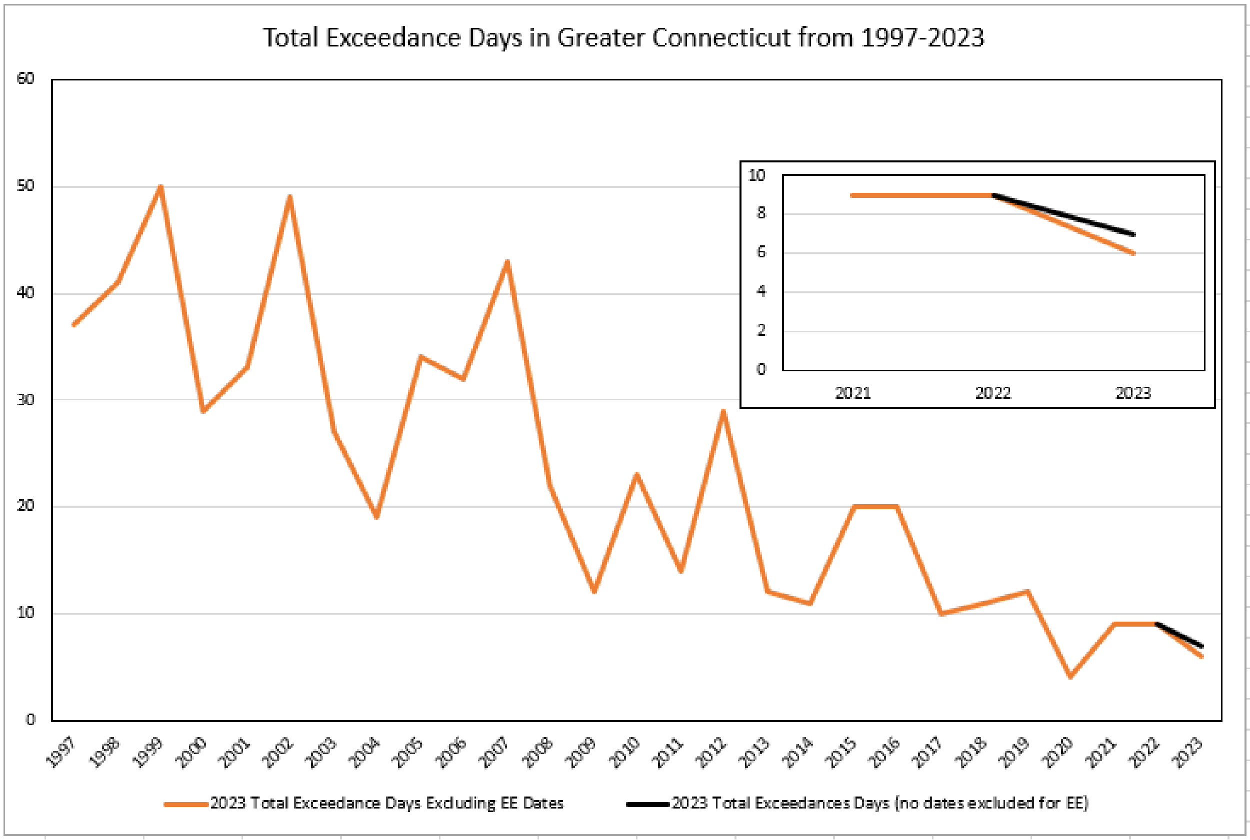


**Figure 2-2.** Trend in Ozone Exceedance Days in Greater Connecticut. The orange line shows the trend that results from exclusion of the data identified as having regulatory significance. The black line indicates where the trend would be if the exceptional events (EE) requests were not pursued.

The total number of annual exceedance days measured in Greater Connecticut from 1997 to 2023 is shown in Figure 2-2. Exceedance days were back calculated for years prior to establishment of 2015 NAAQS. The number of Connecticut exceedance days has decreased by over seventy-five percent over the interval.

Greater Connecticut shows a strong downward trend in exceedance days in recent years. The inset in Figure 2-2 indicates the trend with and without the exceptional events data. The exclusion of the data affected by this request achieves attainment of the standard with only one less exceedance day in the nonattainment area. This is because overlap of site exceedances on days for monitoring sites which were not considered regulatorily significant.[18]

[18] The seven days which monitored exceedances in 2023 are April 13 and 14, June 1 and 30, and July 1, 12 and 29. Upon concurrence, only July 12 will no longer be an exceedance day for regulatory purposes.

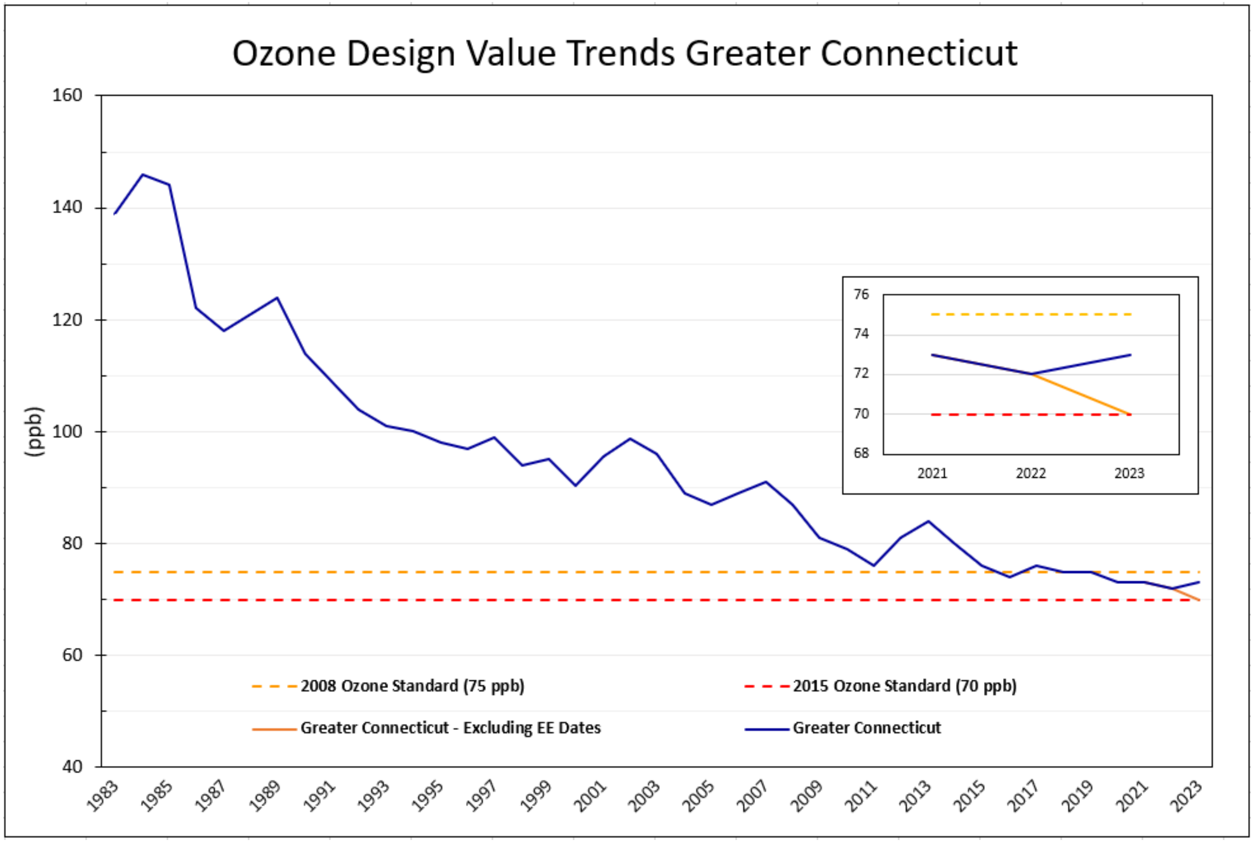


**Figure 2-3.** Greater Connecticut Ozone Design Values Trends.

Although the number of ozone exceedance days in Greater Connecticut shows only a slight decline with an exceptional event exclusion, the impact on the region's design value is much more significant. Figure 2-3 shows that the region's design value would fall from 73 ppb to 70 ppb, which would put Greater Connecticut into attainment for the 2015 ozone NAAQS.

Regionally, 2023 stands out as distinct from prior years in both the number and magnitude of exceedances. Figure 2-4 contrasts these data for 2022, a more typical year with relatively few smoke events, and 2023, a year with an abundance of smoke events and for which several ozone transport region (OTR) states are making exceptional event requests.[19] While no days in 2022 had more than thirty site exceedances, 2023 had seven days with over thirty-five site exceedances -- April 13-14, June 1-2, June 29-30 and July 1st – all of which are being considered for exceptional event requests by one or more states. The smoke event of July 12, 2023, with 25 site exceedances, was exceeded by only one day in 2022.

[19] As of this writing the following days from the 2023 season were being considered by OTR states for exclusion due to exceptional events caused by smoke from wildfires: April 13 (CT, NJ), April 14 (CT), June 1 (PA), June 2 (PA, MD), June 7 (MD), June 29 (MD, PA, NJ), June 30 (MD, CT, PA, NJ), July 1 (CT), July 11 (MD), July 12(MD, CT), July 17 (MD), July 18 (MD). Source: OTC Modeling Committee Notes, email summary sent January 22, 2024.

The magnitude of the exceedances also corroborates the unusual events of 2023. Region-wide maximum exceedance levels only occasionally approached 90 ppb in 2022, while maximum exceedances in 2023 approached and exceeded 110 ppb.

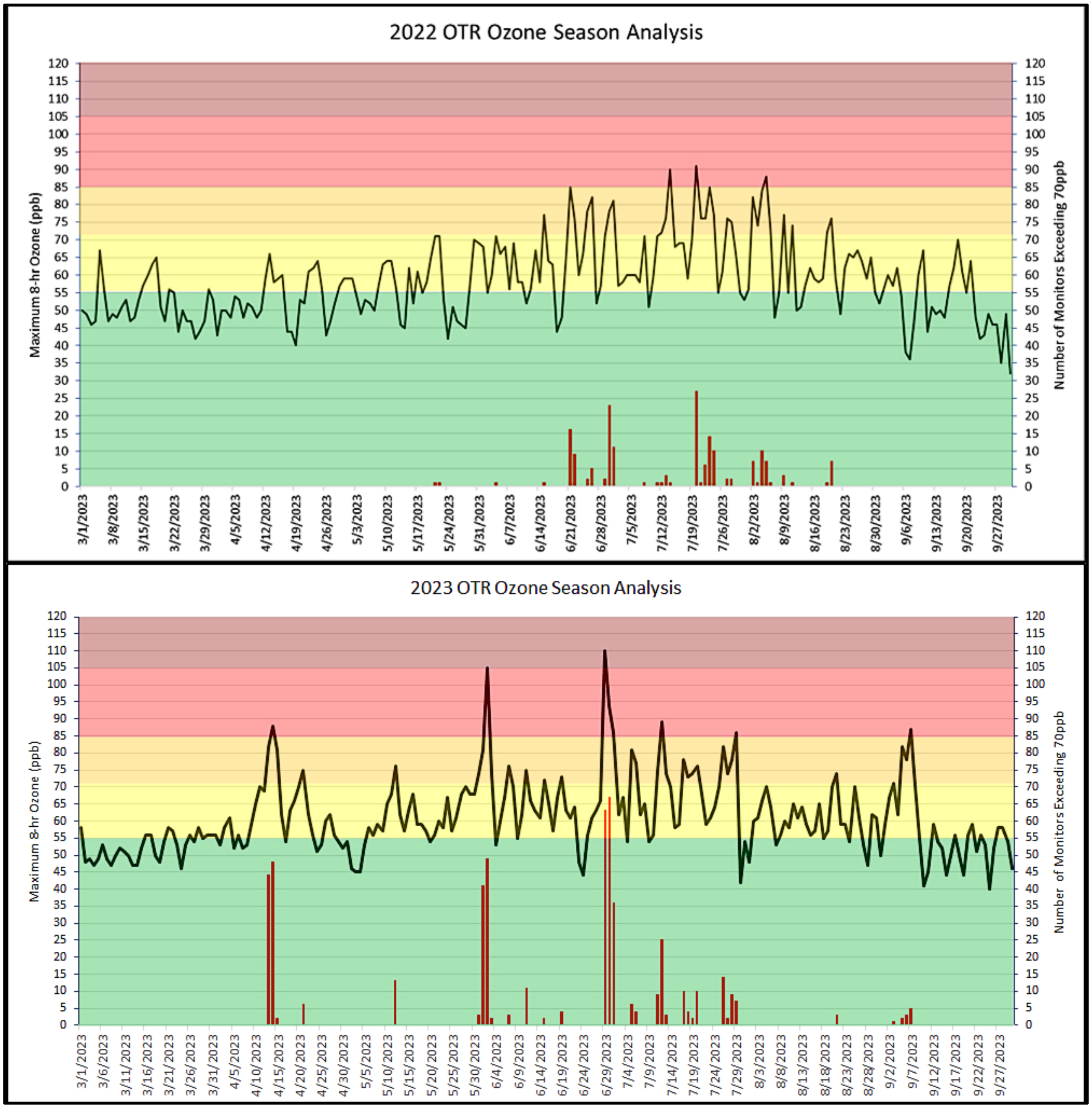


**Figure 2-4.** Charts contrasting regional maximum daily ozone levels and site exceedances for the 2022 and 2023 ozone monitoring seasons.

Exceedances diminish significantly in August 2023 as did the incidence of smoke events. Notably, there were no exceedances in August 2023 in the Greater Connecticut nonattainment area and only two exceedances, both on August 21st, in the Southwest Connecticut nonattainment area – and that day did not exceed the 2008 ozone standard. More importantly, Connecticut's attainment plan for Greater Connecticut showed through modeling analyses conducted independently by EPA and the OTC, that Greater Connecticut would have attained the 2015 ozone NAAQS in 2023.[20] This modeling is based on a worst-case meteorological conditions more conductive to ozone formation than the meteorological conditions which occurred in 2023 would indicate but for the unusual smoke conditions. Thus, indicating the likelihood that these exceedances are eligible for exclusion under the exceptional events rule.

## 2.2 Typical Exceedance Day Meteorological Scenarios

Ozone exceedances in Connecticut were traditionally classified into four categories based on spatial patterns of measured ozone and the contributing meteorological conditions. Historically, most exceedances occurred on sunny summer days with inland maximum surface temperatures approaching or above 90°F, surface winds from the southwest (favorable for transport of pollutants from the New York metropolitan area and the I-95 corridor) and aloft winds from the west-southwest (favorable for transport of pollutants from Midwest power plants).

These exceedances were categorized as:

- Inland-only Exceedances,
- Coastal-only Exceedances,
- Western Boundary-only Exceedances,
- Statewide Exceedances.

**Inland-only Exceedances:** Ozone is transported aloft from the west and mixed down to the surface as daytime heating occurs. At times, transport from the southwest can also occur overnight at lower levels aloft due to the formation of a nocturnal jet. Strong southerly surface winds during the day bring in clean maritime air from the Atlantic Ocean, resulting in relatively low ozone levels along the coast. The maritime front may not penetrate very far inland, and therefore does not mitigate transported and local pollutants' contribution to inland exceedances.

**Coastal-only Exceedances:** Strong westerly surface winds transport polluted air across Long Island Sound from source regions to the west (e.g., New York and New Jersey). The relatively cool waters of Long Island Sound confine the pollutants in the shallow marine boundary layer (Figure 2-5). Afternoon heating over coastal land creates a localized sea breeze with a southerly component, resulting in ozone exceedances along the coast (Figure 2-6). Inland winds from the west carry cleaner air to inland areas and prevent sea breeze penetration, sometimes contributing to the formation of a convergence zone that can further concentrate ozone along the coast.

[20] https://portal.ct.gov/DEEP/Air/Planning/Ozone/Attainment-Demonstrations-for-the-2015-Ozone-NAAQS

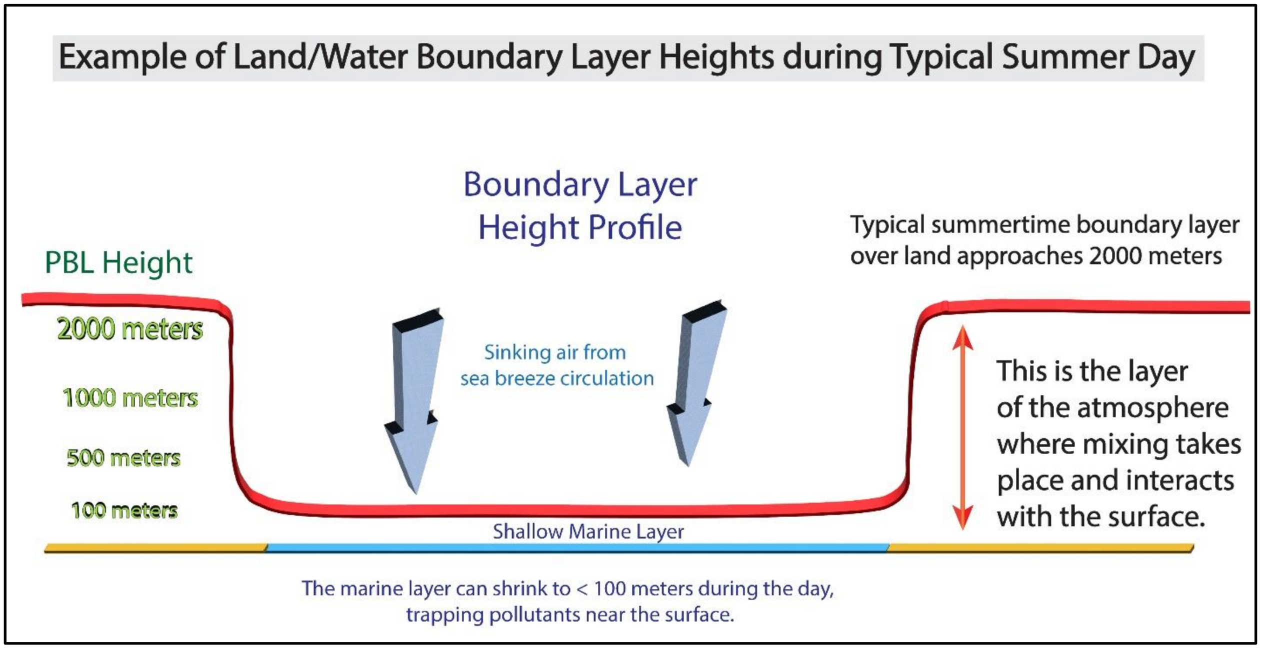


**Figure 2-5.** Illustration of Typical Summer Day PBL Profile over LIS.

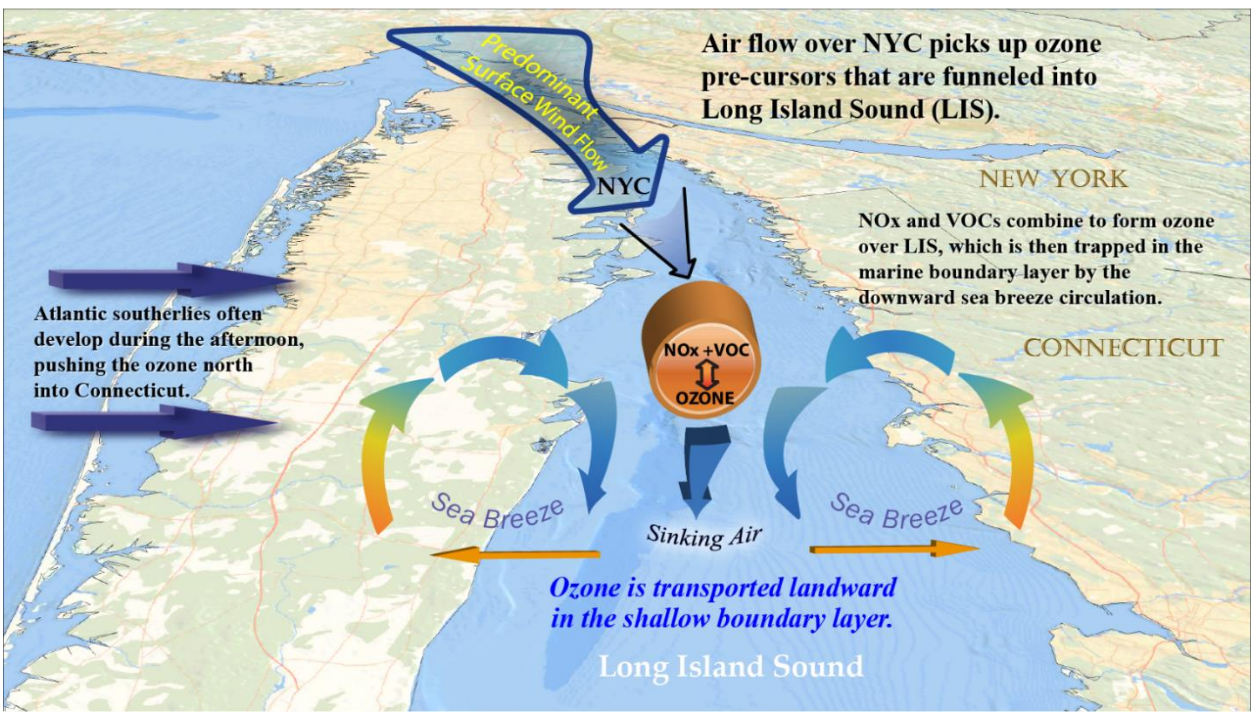


**Figure 2-6.** Conceptual Model of Ozone Formation over LIS with Seabreeze Circulation.

**Western Boundary-only Exceedances:** Southerly maritime surface flow invades the eastern two-thirds of Connecticut, keeping ozone levels in that portion of the state low. The south to southwest winds out of the New York City (NYC) urban area result in exceedances along Connecticut's western boundary. Winds aloft are often weak for this scenario.

**State-wide Exceedances:** Figure 2-7 represents this classical worst-case pattern, with flow at the surface from the southwest, up the Interstate-95 corridor, with transport at mid-levels also from the southwest via the low-level jet and flow at upper levels from the west. These flows are all from emission rich upwind areas, serving to transport ozone precursors and previously formed ozone into Connecticut. A sea breeze may also develop, which would transport ozone pooling over Long Island Sound into the State.

**Figure 2-7.** State-wide Ozone Exceedance Scenario.

In more recent years, the extent and magnitude of ozone episodes have since diminished (Figure 2-8). Due to the success of regional control strategies, statewide exceedances rarely occur, and summertime exceedances are most likely to be coastal only. As the New York metropolitan plume has shortened and narrowed, the coastal only scenario now usually encompasses one to a few monitors along the coast nearer to the plume origin.

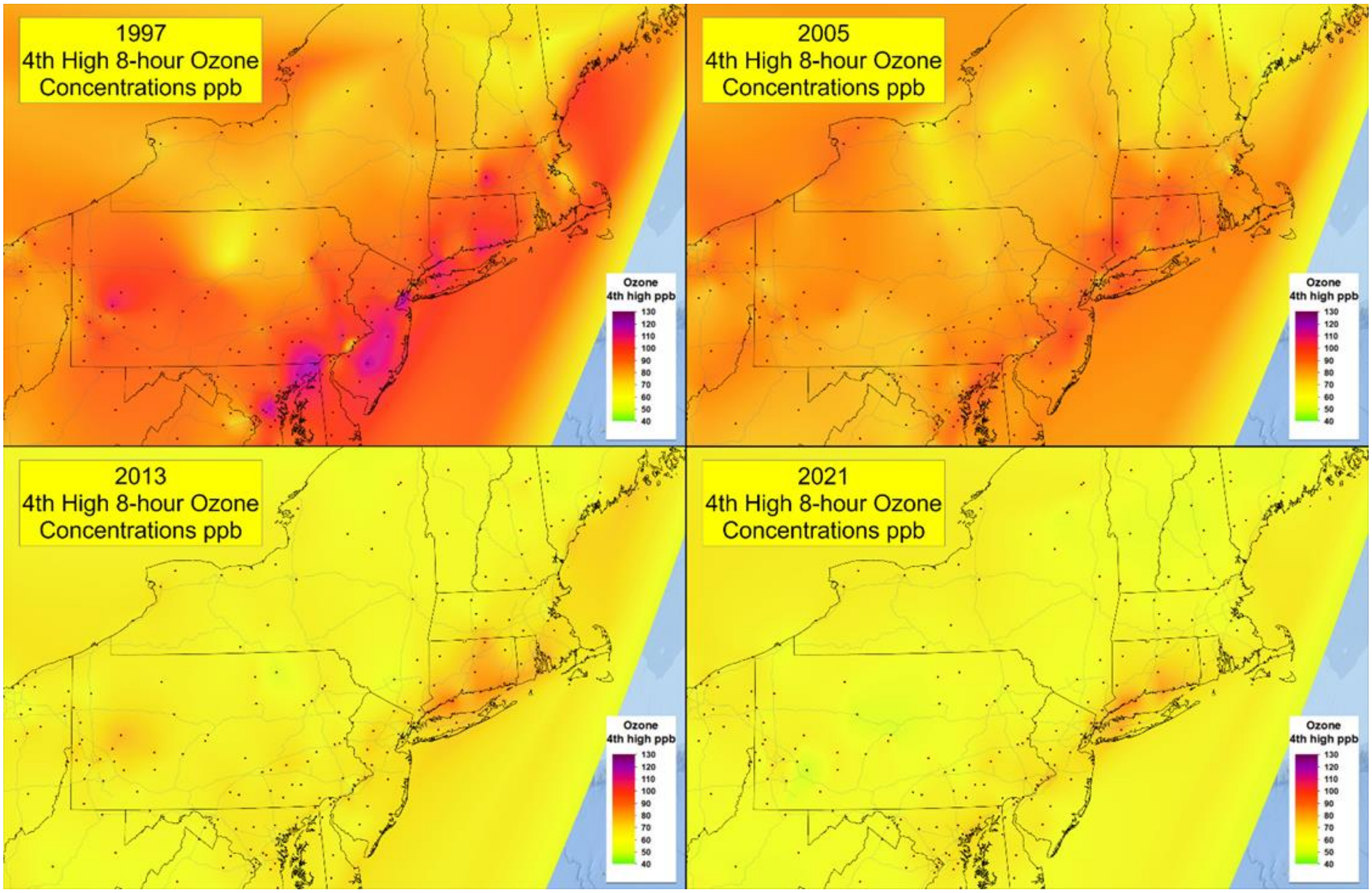


**Figure 2-8**. Images showing a trend toward diminished extent and magnitude of ozone exceedances in the northeast. Source: https://portal.ct.gov/DEEP/Air/Monitoring/Trends/Ozone-Trends

## 2.3 Regional and Local Ozone Precursor Emissions

The scenarios described above occur because winds transport ozone precursors, nitrogen oxides (NOx) and volatile organic compounds (VOC), from regional emission sources into Connecticut on sunny days which are conducive to ozone formation. When there is insufficient sunlight or insufficient emissions, ozone episodes do not occur.

Regional strategies targeting control of ozone precursor emissions have helped to lessen the severity and extent of ozone episodes. Figure 2-9 displays county-level annual anthropogenic NOx and VOC emission density maps (tons/square mile) in the Northeast for 1990 and 2017. The reductions in emission density is comparable to the reduction in extent and magnitude of ozone concentrations seen in Figure 2-8 for ozone concentrations. Whereas in 1990 there were multiple counties in the area with high concentrations of emissions, by 2017 few high-emissions density counties remain.

The 2017 maps below show that the location of most of the regional upwind NOx and VOC emissions are now concentrated over the NYC urban area.  Winds blowing out of the southwest would typically bring ozone precursors into Long Island Sound from NYC to produce ozone, but the strength and coverage of the ozone plume has decreased in recent years and mostly effects our southwest Connecticut coastal monitors during the summer months. Greater Connecticut monitors, including Groton, have monitored much fewer ozone exceedances in recent years and ‘clean’ data for ozone was expected for 2023, especially given the number of rainy days experienced last July.

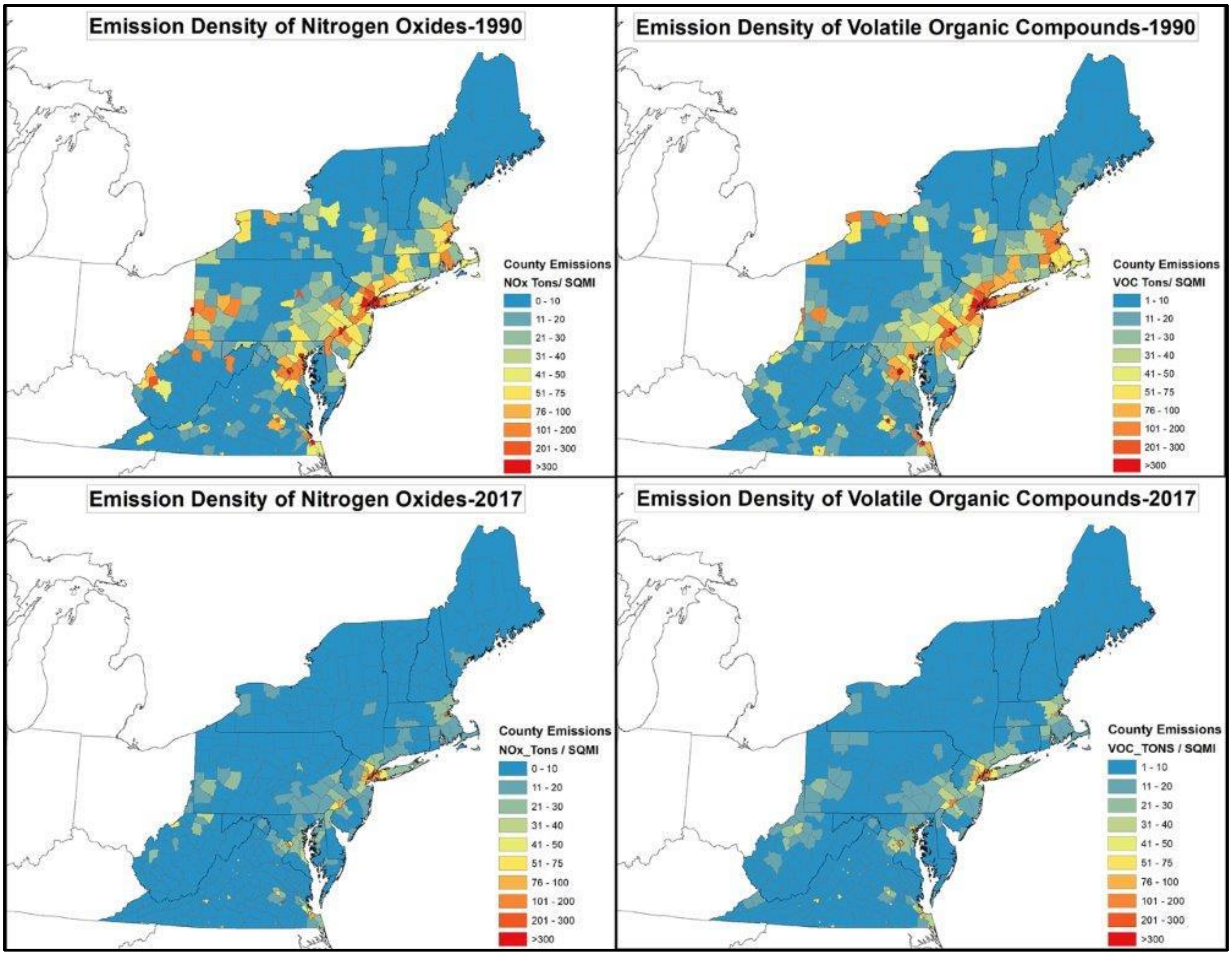


**Figure 2-9.** NEI County level annual anthropogenic NOx Emission Density (left) and VOC Emission Density (right) as changed from 1990 (top) to 2017 (bottom).

## 2.4 Electric Generating Unit Nitrogen Oxide Emissions

Power facilities, or electric generating units (EGUs), have traditionally played a major role during ozone events on the East Coast. EGUs are capable of producing a large amount of emissions over a short duration and generally emit at elevations conducive to transport. Therefore, during hot days many of the less frequently used high emitting EGUs come online to supply the high electric demand of air conditioning and refrigeration along with base load units operating at full capacity.

Recognizing the ability of these sources to affect air pollution, EPA monitors and tracks emissions from these facilities on their Clean Air Markets Program Data (CAMPD) web site.[21] The following figures (Figure 2-10 through Figure 2-13) show the actual total daily NOx emissions from EGU sources for our closest upwind States -- New York, New Jersey and Pennsylvania, as well as Connecticut – for the 2022 and 2023 ozone seasons. Plotted on the right hand axis, as orange bars, are the number of Connecticut monitors that exceeded the 70 ppb NAAQS each day. It can be observed on the following charts that the highest NOx tons/day emissions do not always track with the Connecticut site exceedance days. Summertime electrical demand is most correlated with maximum daytime temperature for space cooling, and the resulting emissions from any one source may not necessarily have a trajectory towards Connecticut.

EGU emissions have been decreasing for many years and Table 2-1 shows that there was a further decrease from 2023-2023. The highest EGU NOx emissions for 2023 occurred later in the summer, following the dates of our exceptional event episodes.

**Table 2-1.** 2022-2023 CAMPD NOx Emissions from Connecticut and nearby states.

| | CT NOx Tons | NJ NOx Tons | NY NOx Tons | PA NOx Tons |
|---|---|---|---|---|
| **2022 Total** | 480.3 | 1291.0 | 4508.9 | 8871.9 |
| **2023 Total** | 433.4 | 1065.8 | 4125.7 | 7233.3 |

Connecticut's 2023 ozone season EGU emissions fluctuate only slightly, never exceeding ten tons per day and show little, if any, correlation to the season's exceedance days. The April 13-14 event shows emissions increasing slightly over baseline, but not by nearly as much as the increase which occurred approximately one week prior. During the June 30-July 1 event, Connecticut's EGU emissions remain near baseline. Emissions during the July 12 event increase only slightly, but not nearly as much as the week prior or near the end of July. Overall, the 2023 exceedance days selected as exceptional events do not correlate with EGU emissions. Such a correlation would have been expected in non-event years and is more evident in the graphs for 2022.

[21] Emissions data can be found at https://campd.epa.gov/

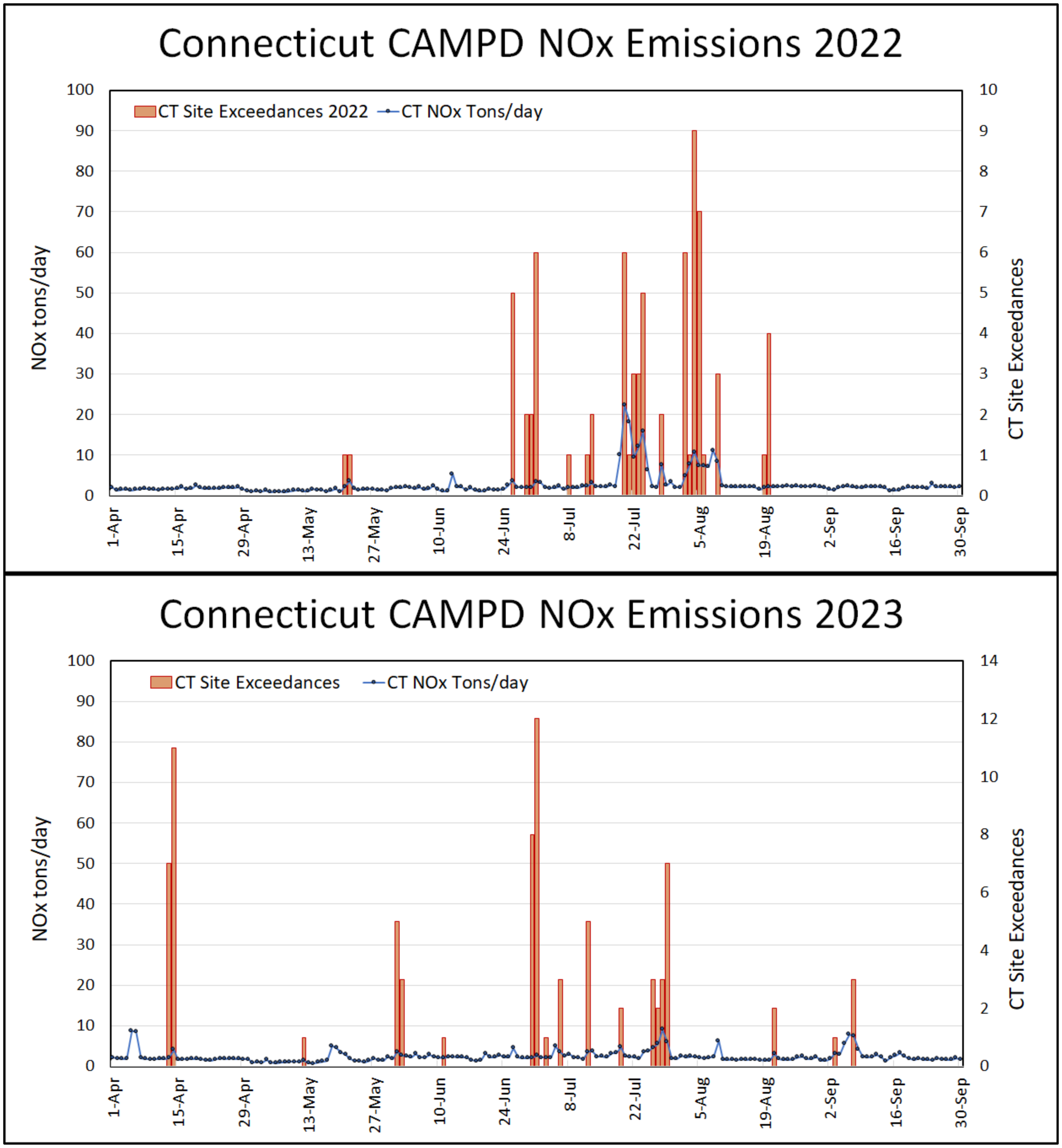


**Figure 2-10.** 2022-2023 Connecticut CAMPD NOx emissions with Connecticut site exceedances.

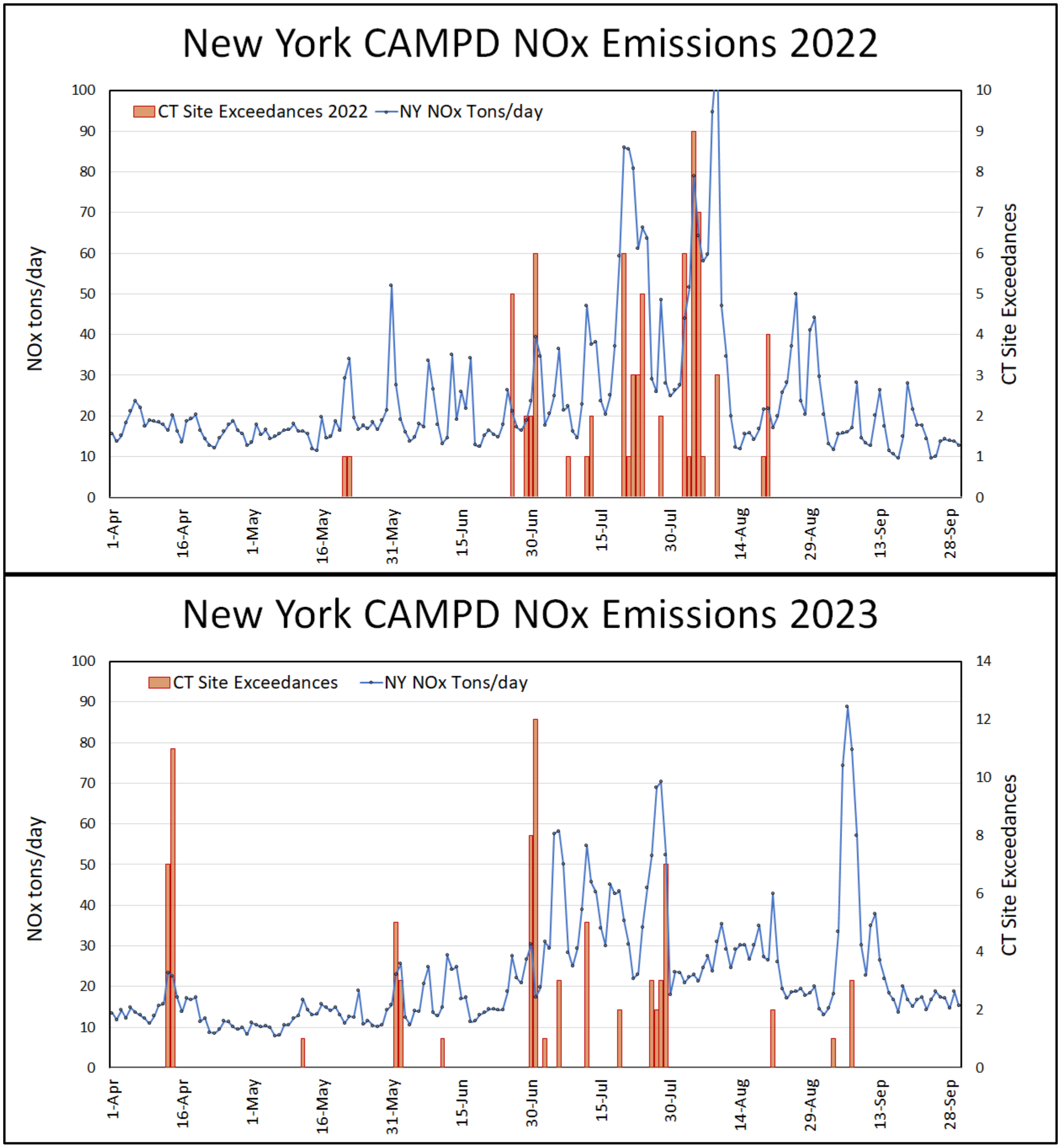


**Figure 2-11.** 2022-2023 New York CAMPD NOx emissions with Connecticut site exceedances.

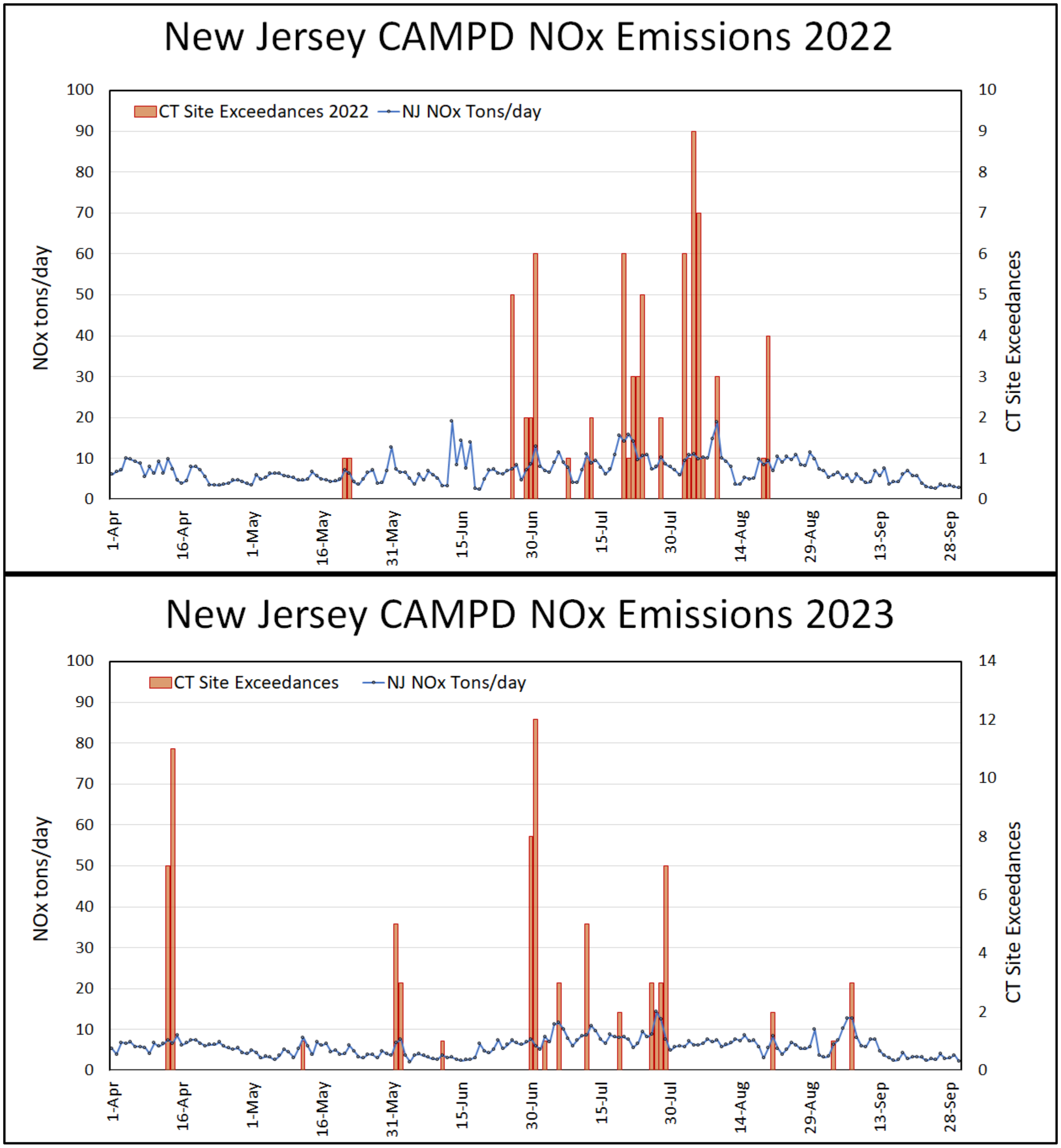


**Figure 2-12.** 2022-2023 New Jersey CAMPD NOx emissions with Connecticut site exceedances.

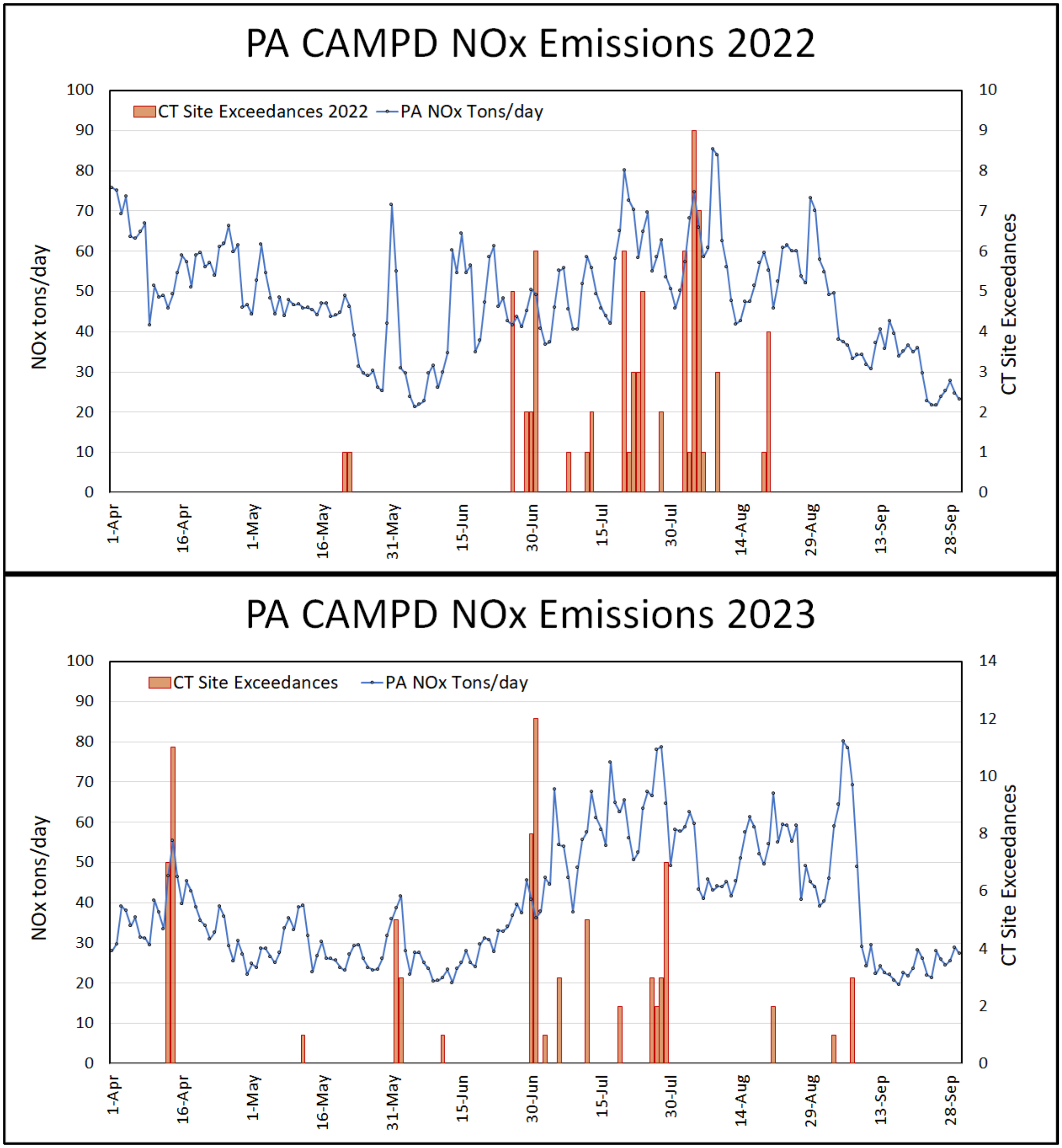


**Figure 2-13**. 2022-2023 Pennsylvania CAMPD NOx emissions with Connecticut site exceedances.

EGU emissions from western states are also unlikely to have caused any of our exceptional events. Figure 2-14 shows the CAMPD NOx emissions from four upwind states traditionally thought to contribute to long range ozone transport into Connecticut. The figure shows the EGU emissions from Indiana, Michigan, Ohio, and Illinois from April through September for 2022 and 2023 with days surrounding the 2023 ozone events highlighted in yellow. Emissions surrounding the April 13-14, 2023, event were no higher than later peak-season emissions and were less than the emissions from the same time in 2022. Similarly, the emissions for the June 30-July 1 and July 12 event emissions are below season peaks and less than prior year same day emissions.

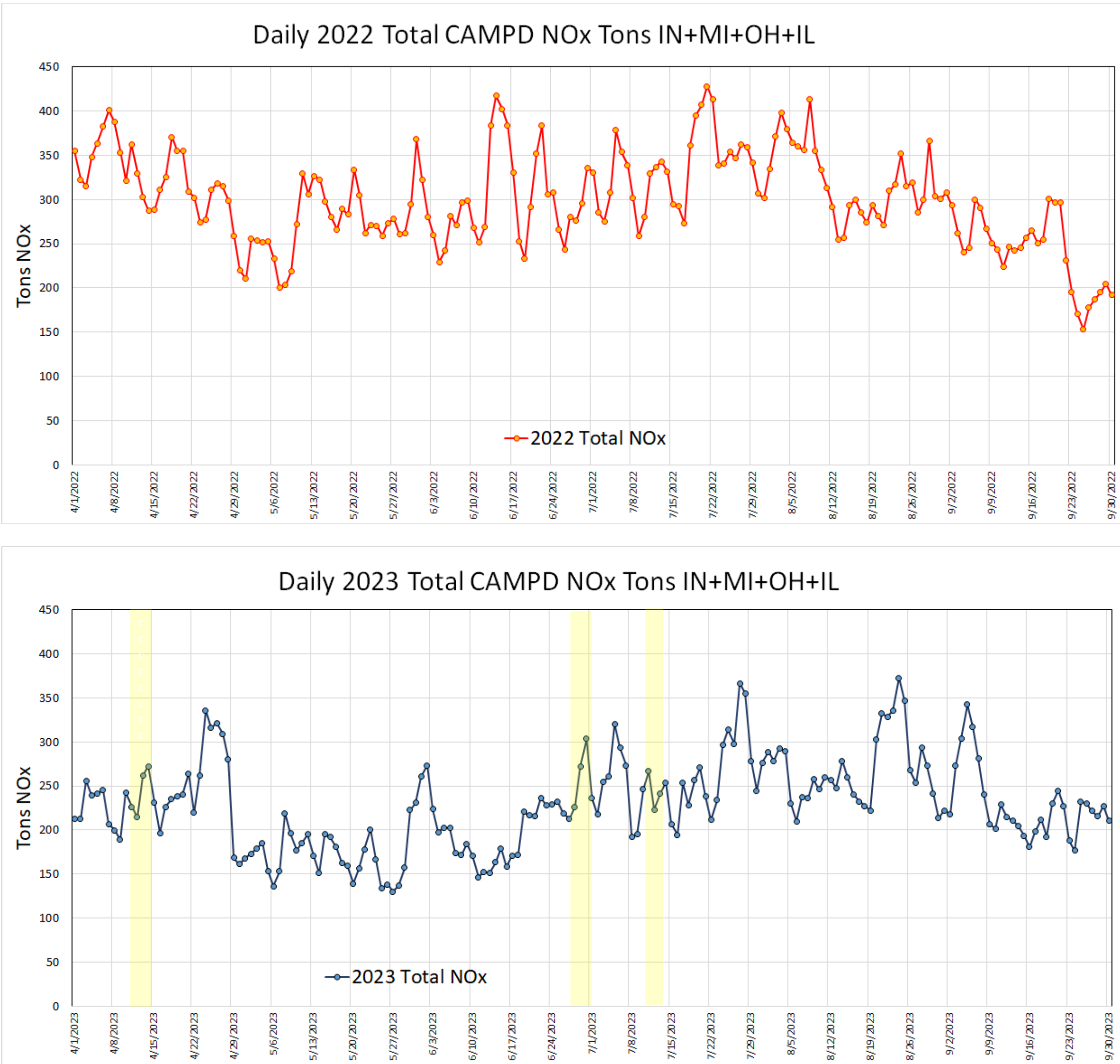


**Figure 2-14.** Total CAMPD NOx emissions from Indiana, Michigan, Ohio and Illinois from April through September for 2022 and 2023. Days surrounding the events are highlighted in yellow.

Therefore, EGU emissions are unlikely to have caused these exceptional events.

## 2.5 Transport of Ozone and Precursors from Biomass Burning

Wildfire smoke plumes contain gases including non-methane hydrocarbons (NMHCs), carbon monoxide (CO), nitrogen oxides (NOx), and aerosols, which are all important precursors to photochemical production of tropospheric ozone ($O_3$) and can travel thousands of kilometers. This may cause urban areas where forest fires seldom occur to see greater enrichment of ozone, as much as 25 ppb in the northeastern United States, than areas where wildfires more frequently occur.[22]

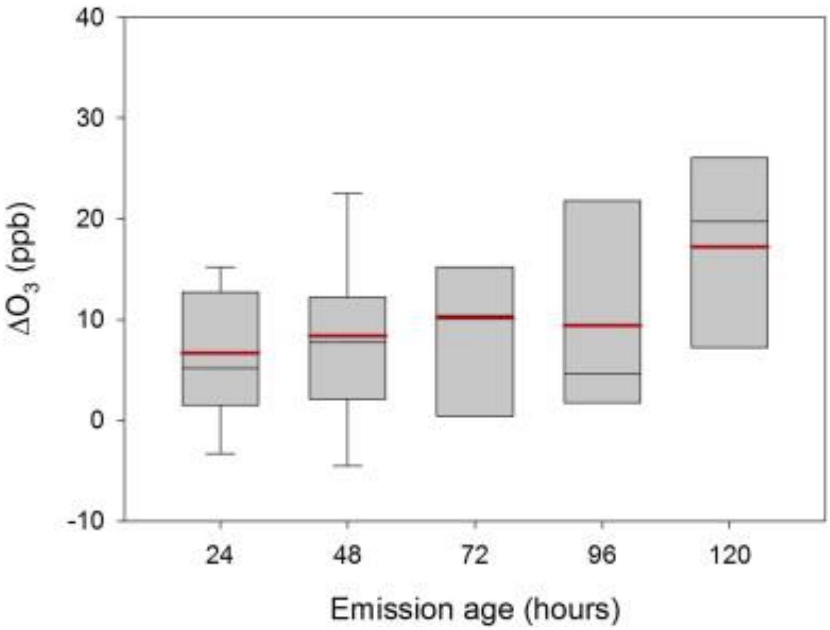


**Figure 2-15.** Ozone Enrichment by Age of Plume. This figure, taken from Putero et al.[23] shows the results of their study on the influence of biomass burning on ozone concentrations. Ozone enhancement increases as the plume ages. Here we see increases on the order of 20 ppb from a five-day old plume.

Many variables can affect the ability of a plume to affect downwind ozone production. Emissions from boreal forest fires, such as occur in northern latitudes, result not just from the consumption of the standing mass and litter, but as much as 80% of the available biomass (on the order of 100 tons per acre) may be stored in the forest floor as lichens, moss, peat and duff.[24] Under these conditions fires can burn and smolder deeper into the forest floor to add considerable emissions to the plume.

Typically, NOx emissions react within a few days and are no longer available to participate in ozone reactions. However, cooler ambient temperatures, as occur at high latitudes and as plumes ascend to cooler altitudes, are conducive to the sequestering of NOx emissions as Peroxyacetyl Nitrates (PAN), aerosols which can decompose back to NOx far downwind. Study of boreal wildfires indicate that as much as 40% of the NOx emitted from the fire can be converted to PAN and transported downwind for six to fifteen days before returning to NOx.[25]

The impact of wildfires on $O_3$ level on downwind regions can vary significantly with the magnitude of aged plumes, the amount of biomass consumed, and the emissions produced, fuel

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[22] Brey, Steven J. and Emily V. Fischer, Smoke in the City: How Often and Where Does Smoke Impact Summertime Ozone in the United States?, Environmental Science and Technology, vol. 50, pp1288-1294, 2016.
[23] Putero, D. et. al., Influence of open vegetation fires on black carbon and ozone variability in the southern Himilayas, Environmental Pollution, vol 184, pp 597-604, 2014.
[24] Ottmar, Roger D. and Stephen P. Baker, Forest Floor Consumption and Smoke Characterization in Boreal Forested Fuelbed Types of Alaska, Final Report JFSP Project #03-1-3-08, May 25, 2007.
[25] Jaffe, Daniel A. and Nicole L. Wigder, *Ozone production from wildfires: A critical review*, Atmospheric Environment, 2012, vol 51, pp1-10.

type, burning area, and combustion conditions (Jaffe et al., 2003, 2008; Martin et al., 2006). Jaffe and Wigder[26] and others have confirmed that the maximum $O_3$ production is often observed substantially downwind of the fire, after the smoke plumes have aged for several days.

Dreesen et al. (2016) have noted in their analysis of a June 2015 wildfire that at peak smoke concentrations in Maryland, wildfire-attributable Volatile Organic Compounds (VOCs) more than doubled, while non-NOx oxides of nitrogen (NOz) tripled, suggesting long range transport of NOx within the smoke plume. They also noted that ozone peaks a few days after the maximum plume due to ultraviolet (UV) light attenuation, lower temperatures, and non-optimal surface layer composition.[27]

Similarly, Kalashnikov et al. (2022), in their study of western wildfires relative to peak (exceeding the annual 90th percentile) particulate and ozone concentrations, concludes that the highest correlations between burn area and co-occurrence with peak fine particulate and ozone concentrations occur within 3 to 7 days.[28]

Fresh smoke plumes tend toward an overabundance of VOC's compared to NOx. When these plumes mix with NOx-rich urban plumes, ozone production increases and, along with ozone already produced in the smoke plume, elevates ozone in the urban plume. Buysse et al. (2019) found that smoke plumes caused a linear increase in ozone peaking when daily average fine particulate (PM2.5) concentrations approached 30 $\mu g/m^3$, then plateau and begin to decline as daily PM2.5 concentrations exceed approximately 70 $\mu g/m^3$. The decline is attributed, in part, to aerosol shading preventing photochemical reactions.[29] Langford et al. (2023) confirm Buysse and find that pyrogenic VOCs in smoke plumes increase ozone concentrations from 3 -12 ppb when combined with anthropogenic NOx in the urban and downwind areas of Boulder and Denver.[30]

[26] Jaffe, D.; Wigder, N. *Ozone production from wildfires: A critical review*. Atmos. Environ. 2012, 51, 1–10

[27] Dreessen, Joel; John Sullivan & Ruben Delgado (2016) *Observations and impacts of transported Canadian wildfire smoke on ozone and aerosol air quality in the Maryland region on June 9–12, 2015*, Journal of the Air & Waste Management Association, 66:9, 842-862, https://doi.org/10.1080/10962247.2016.1161674.

[28] Dmitri A. Kalashnikov et al., *Increasing co-occurrence of fine particulate matter and ground-level ozone extremes in the western United States.* Science Advances, **8**, eabi9386 (2022). DOI: 10.1126/sciadv.abi9386.

[29] Buysse*, Claire E., Aaron Kaulfus, Udaysankar Nair and Daniel A. Jaffe*, *Relationships between Particulate Matter, Ozone, and Nitrogen Oxides during Urban Smoke Events in the Western US*, Environ. Sci. Technol. 2019, 53, 21, 12519–12528, https://doi.org/10.1021/acs.est.9b05241.

[30] Langford, A. O., Senff, C. J., Alvarez, R. J. II, Aikin, K. C., Ahmadov, R., Angevine, W. M., et al. (2023). Were wildfires responsible for the unusually high surface ozone in Colorado during 2021? Journal of Geophysical Research: Atmospheres, 128, e2022JD037700. https://doi.org/10.1029/2022JD037700

# 3 Satellite Imagery of Plume with Evidence of the Plume Impacting the Ground

Guidance states that "because plume elevation is not directly available from simple satellite imagery, plume imagery alone does not conclusively show that wildfire emissions transported aloft reached a ground-level monitor. If plume arrival at a given location coincides with elevation of wildfire plume components (such as PM2.5, CO or organic and elemental carbon), those two pieces of evidence combined can show that smoke was transported from the event location to the monitor with the elevated $O_3$ concentration." We will present the satellite imagery in this section. Later, we discuss smoke indicators and evidence of the smoke plume reaching the surface. Supplementary satellite images and videos are available at https://portal.ct.gov/DEEP/Air/Planning/Ozone/2023-exceptional-events.

## 3.1 Satellite Images

### April 13-14 Event

Numerous fires were detected by satellite prior to the April 13-14 event, the majority of which were prescribed burns. Although the smoke plume was light, compared with later wildfire plumes, the Cornwall Aeronet sensor was able to distinguish between column aerosol optical depth (AOD) measurements on a clean day, April 9$^{th}$, versus an event day, April 14$^{th}$. Figure 3-1 shows the afternoon Aeronet AOD-340nm levels less than 0.08, while Figure 3-2 shows the afternoon AOD-340nm levels rising above 0.20. Although it is not a thick smoke plume, it confirms the presence of aerosols from the transported smoke.

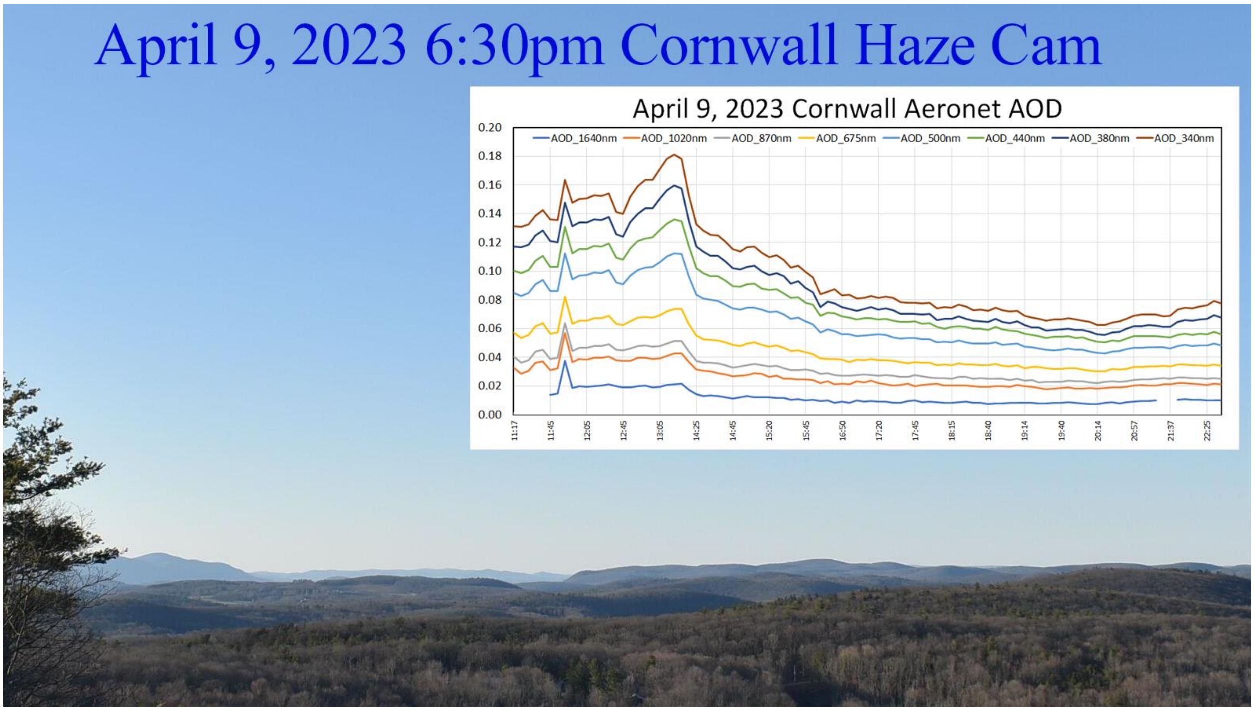



**Figure 3-1.** April 9, 2023, Cornwall Connecticut haze camera image showing a low PM2.5 day with AOD typically below 0.10.

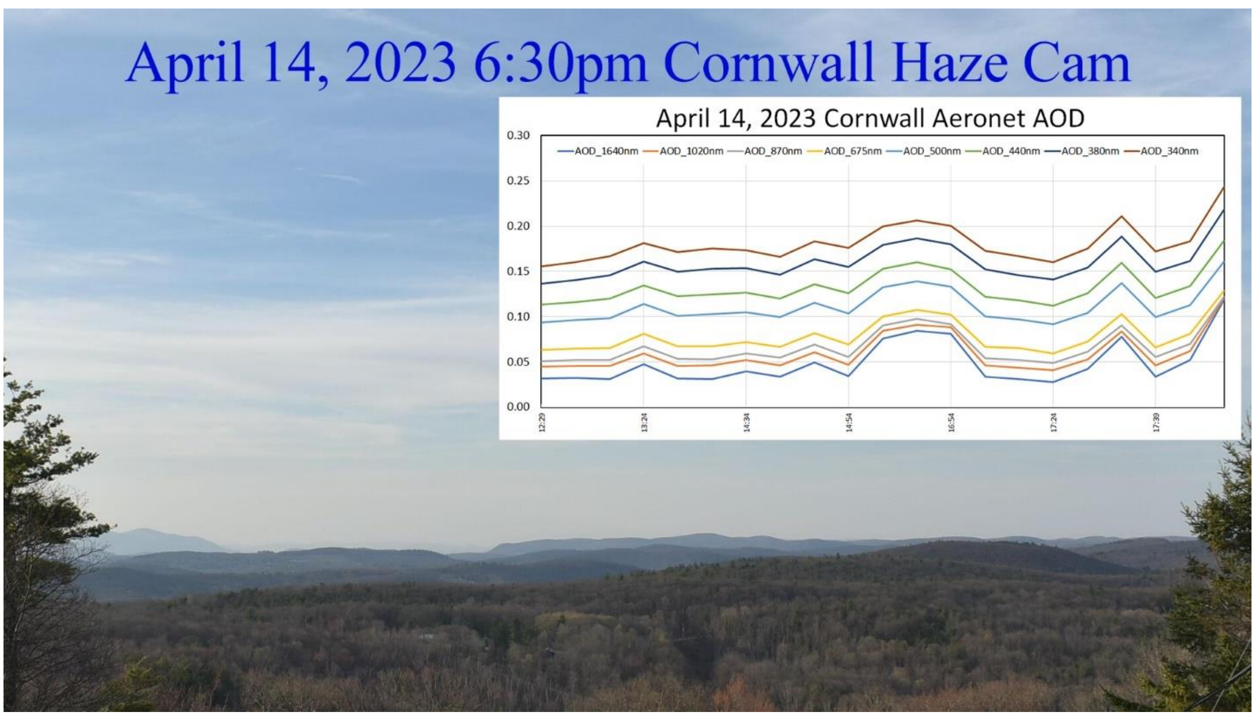



**Figure 3-2.** April 14, 2023, Cornwall Connecticut haze camera image showing an elevated PM2.5 day with smoke.

For this event, most of the background smoke precursors would have been advected to Connecticut around April 10th from the more than 8000 satellite detections of fire radiative power (FRP) as shown in Figure 3-3 from the National Oceanic and Atmospheric Administration's Hazard Mapping System (HMS). Most of the intense burning would have occurred in eastern

Kansas around this time, due to the prescribed burning in the Flint Hills area (see section 8-1). A satellite image from April 11th, Figure 3-4, shows visible smoke plumes emanating from that region, as well as other surrounding areas.

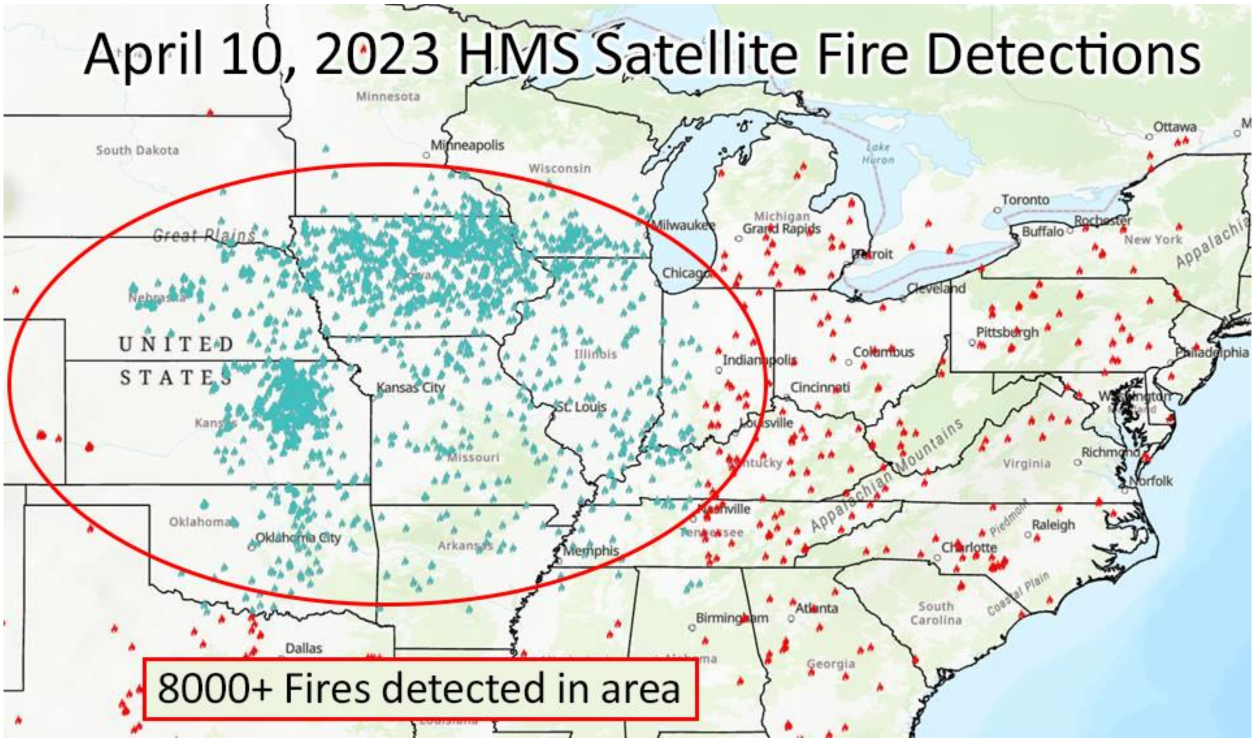



**Figure 3-3.** Satellite fire detections on April 10, 2023.

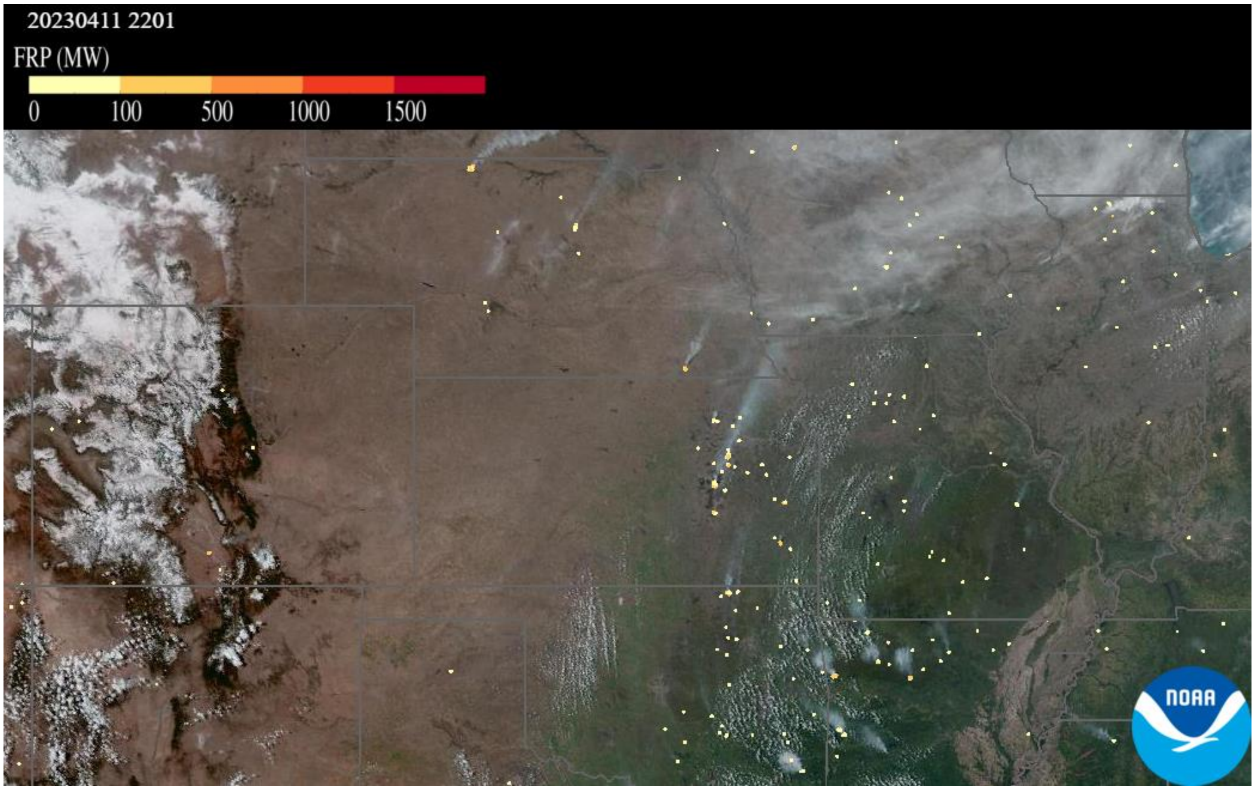



**Figure 3-4.** Visible satellite image of the Midwest from April 11, 2023, with FRP fire detections.

On April 12-13, 2023, wildfires occurred in northeast Pennsylvania and northern New Jersey that further impacted the ozone levels in Connecticut. Figure 3-5 clearly shows the smoke plumes from these nearby fires.

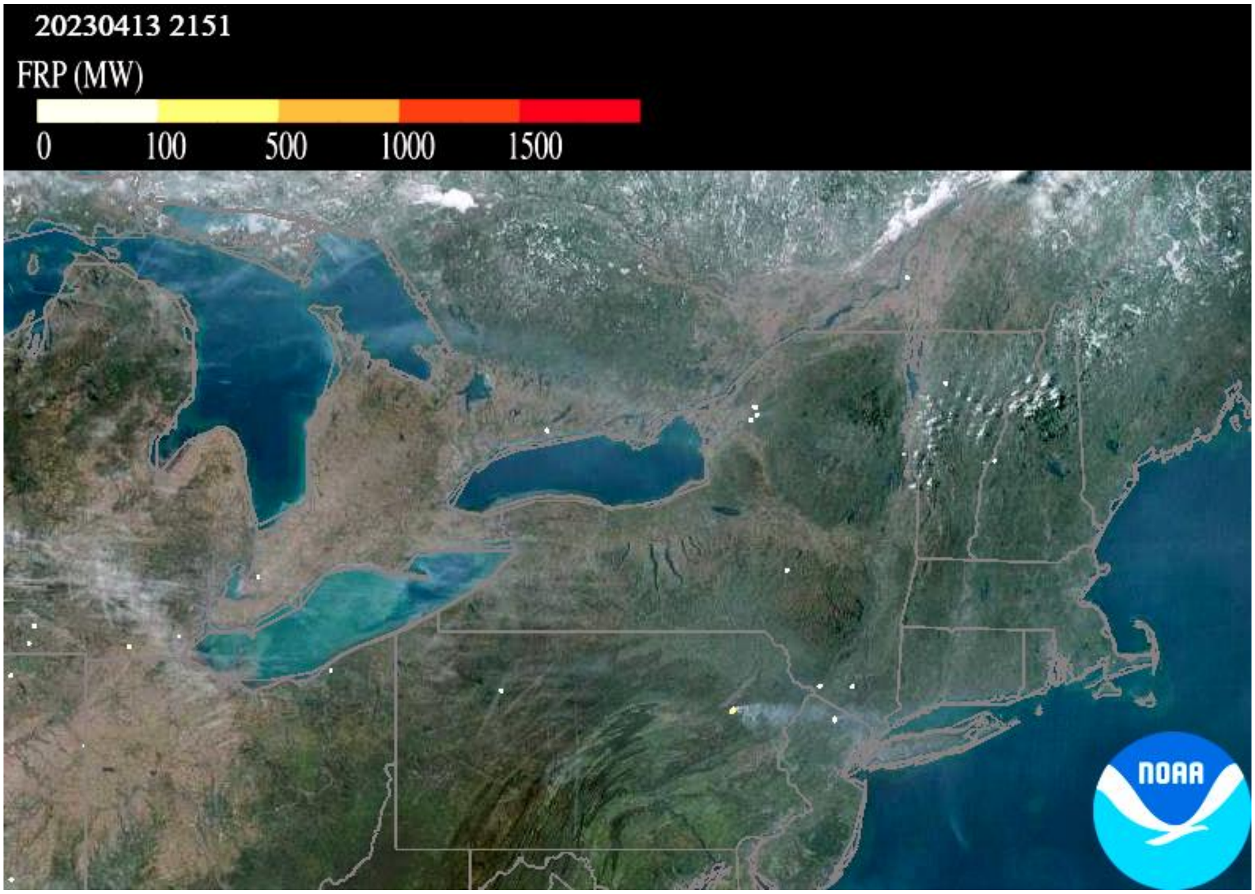



**Figure 3-5.** April 13, 2023, visible satellite showing smoke plumes from fires in Pennsylvania and New Jersey.

### June 30-July 1 Event

The Quebec wildfires had been burning since early June, and by late June smoke from these fires were once again advected to the eastern States. Figure 3-6 shows the early morning visible satellite image over Connecticut for June 30th and Figure 3-7 shows the image for July 1st. Surface PM2.5 levels were also elevated, as can be seen in Figure 3-8, which shows the analyzed smoke plume and PM2.5 AQI levels. Both days of the event had exceedances of the ozone and PM2.5 NAAQS. Figure 3-9 shows the haze camera image from Cornwall with an inset charting the Aeronet AOD data. Levels of AOD-340nm below 0.10 are indicative of clean air. During this smoke event, the AOD-340nm levels were at least ten times higher, at well above 1.0.

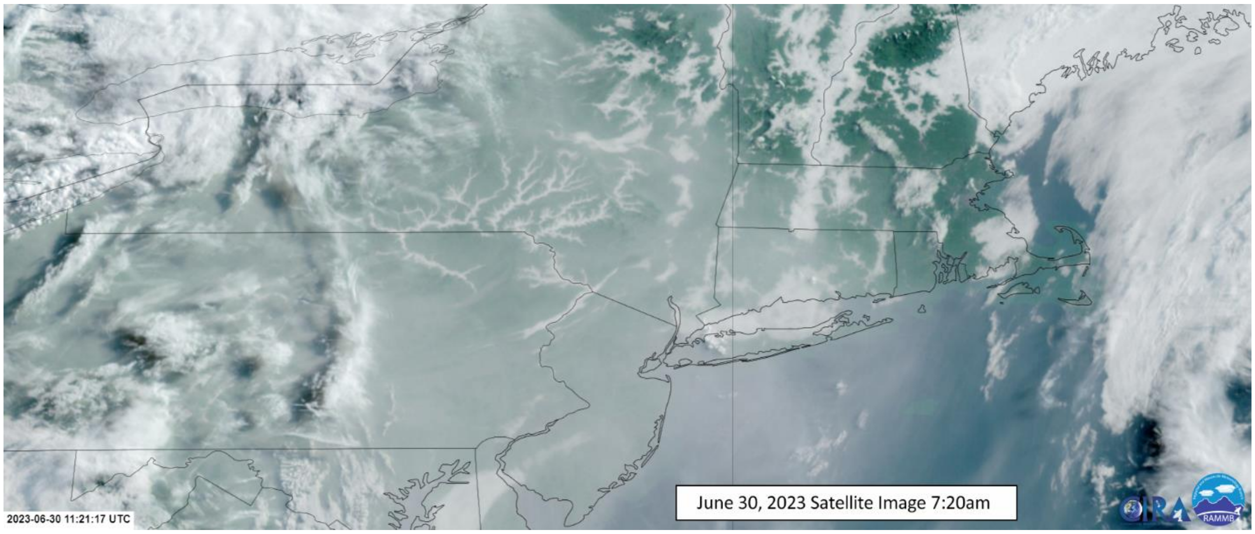



**Figure 3-6.** June 30, 2023, visible satellite image.

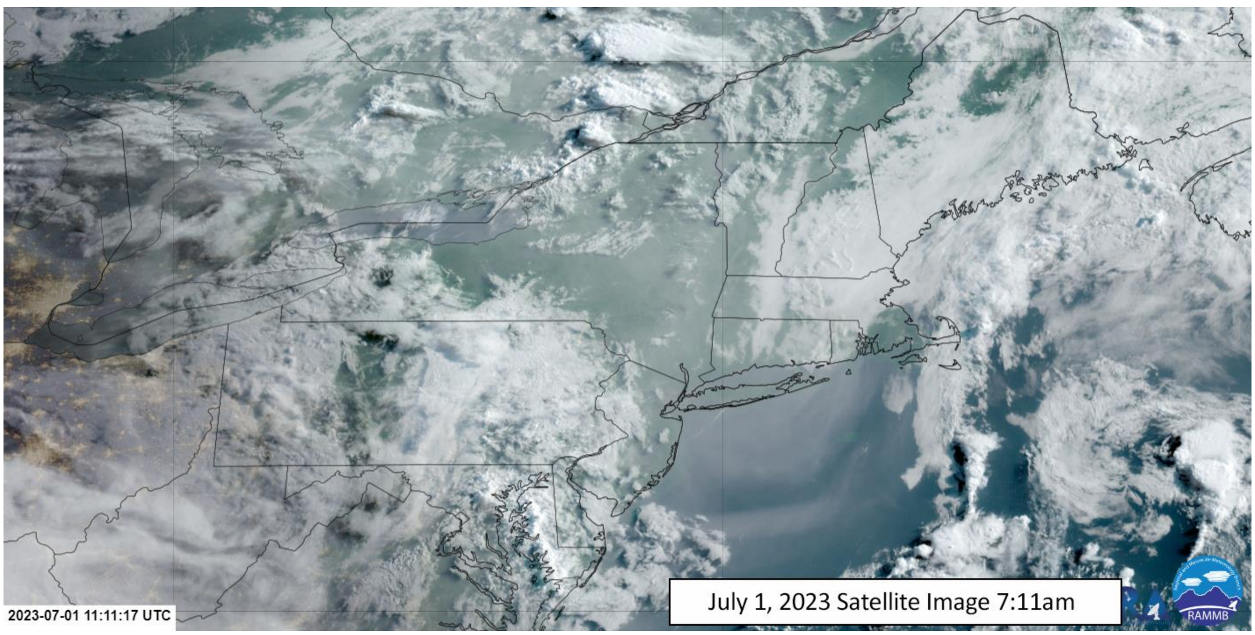



**Figure 3-7.** July 1, 2023, visible satellite image.

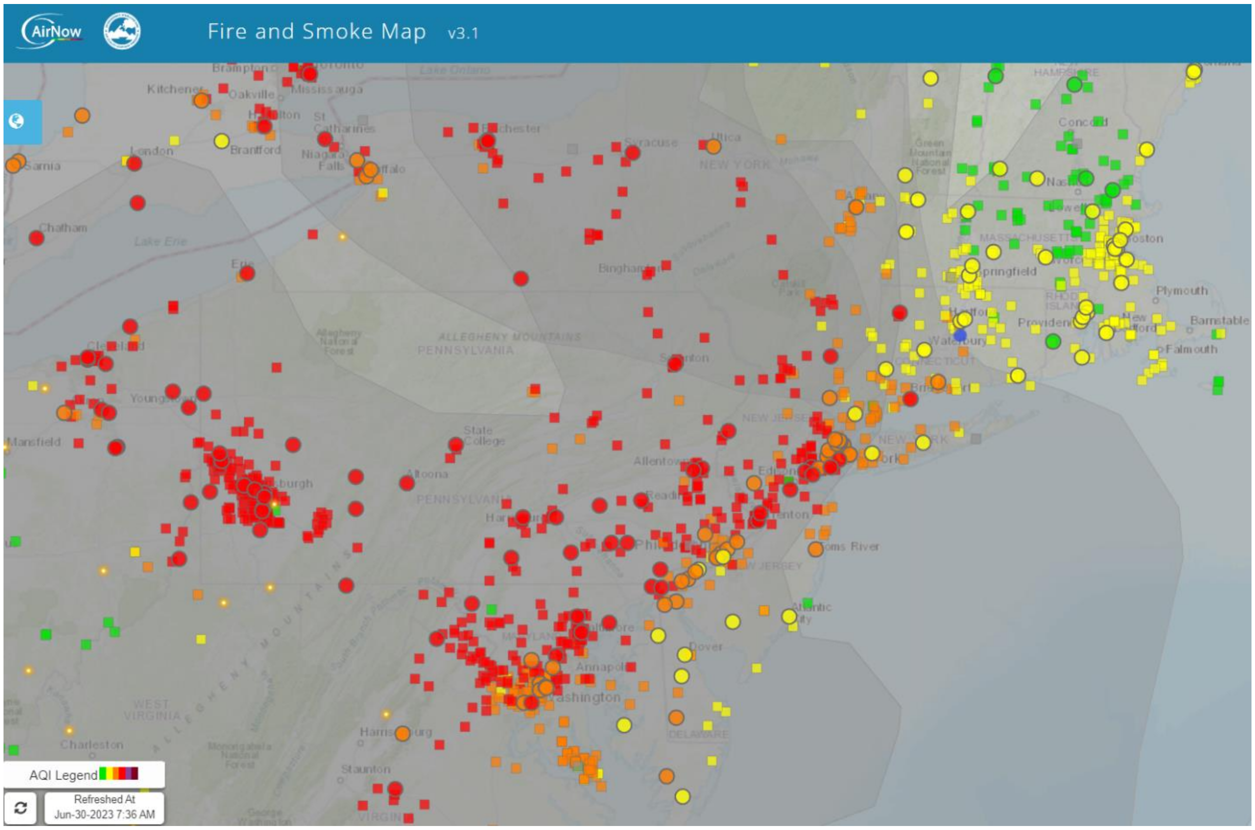



**Figure 3-8.** EPA AirNow Fire and Smoke Map for June 30, 2023, showing smoke plume and PM2.5 levels.

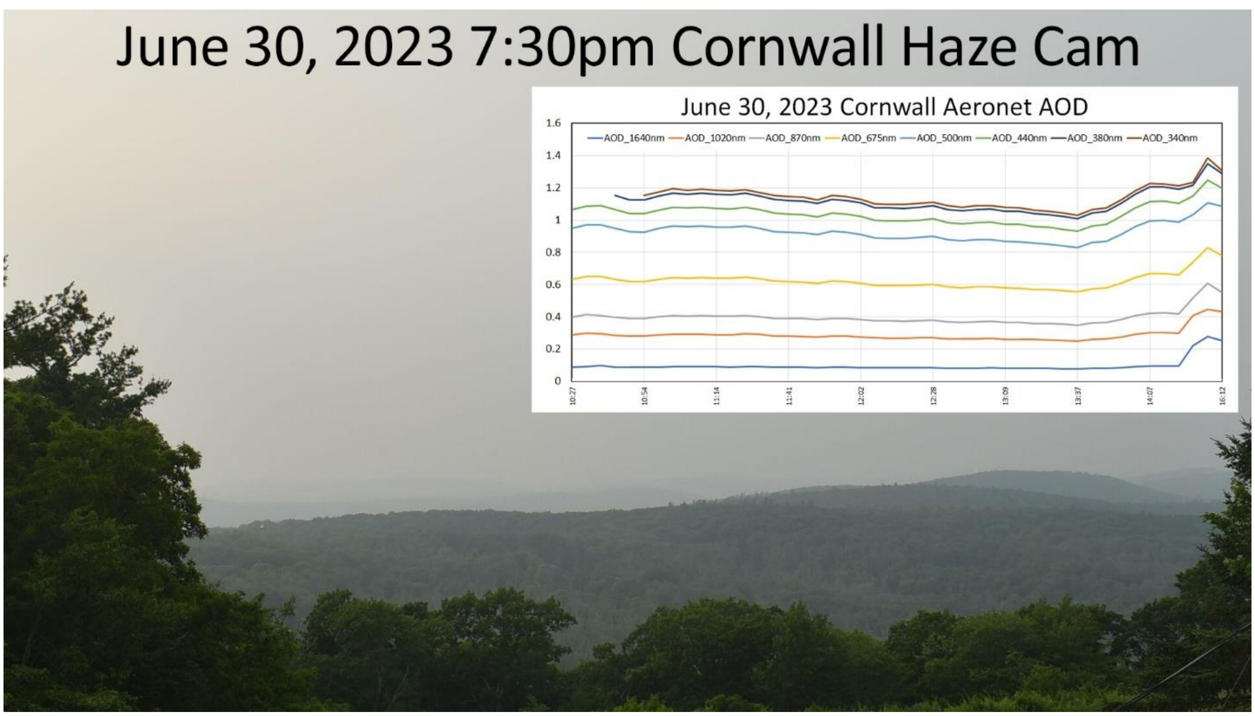



**Figure 3-9.** June 30, 2023, Cornwall haze camera with Aeronet AOD levels.

## July 12th Event

Although fires were still burning in Quebec around the time of this event, smoke from fires in northwest Canada were responsible for elevating ozone levels over coastal Connecticut on July 12th. Figure 3-10 shows the visible satellite image with the smoke plume, originating from northwest Canada, arriving over the Great Lakes region. Two days later, on July 12th, as shown in Figure 3-11, the smoke plume is seen arriving over Connecticut. Figure 3-12 shows the full progression of the plume as it travels from northwest Canada and into Connecticut on July 12th. Additional satellite images were shown in section 1.3 describing the event. Figure 3-13 shows an HMS analyzed moderate smoke plume over the eastern U.S. with the maximum 8-hour ozone AQI colors for that day. Figure 3-14 shows the haze camera image from Cornwall with the Aeronet AOD levels. Aerosol levels were significant, with several hours above 0.50, though they decreased at Cornwall as a front moved into the northern part of the state later in the day.

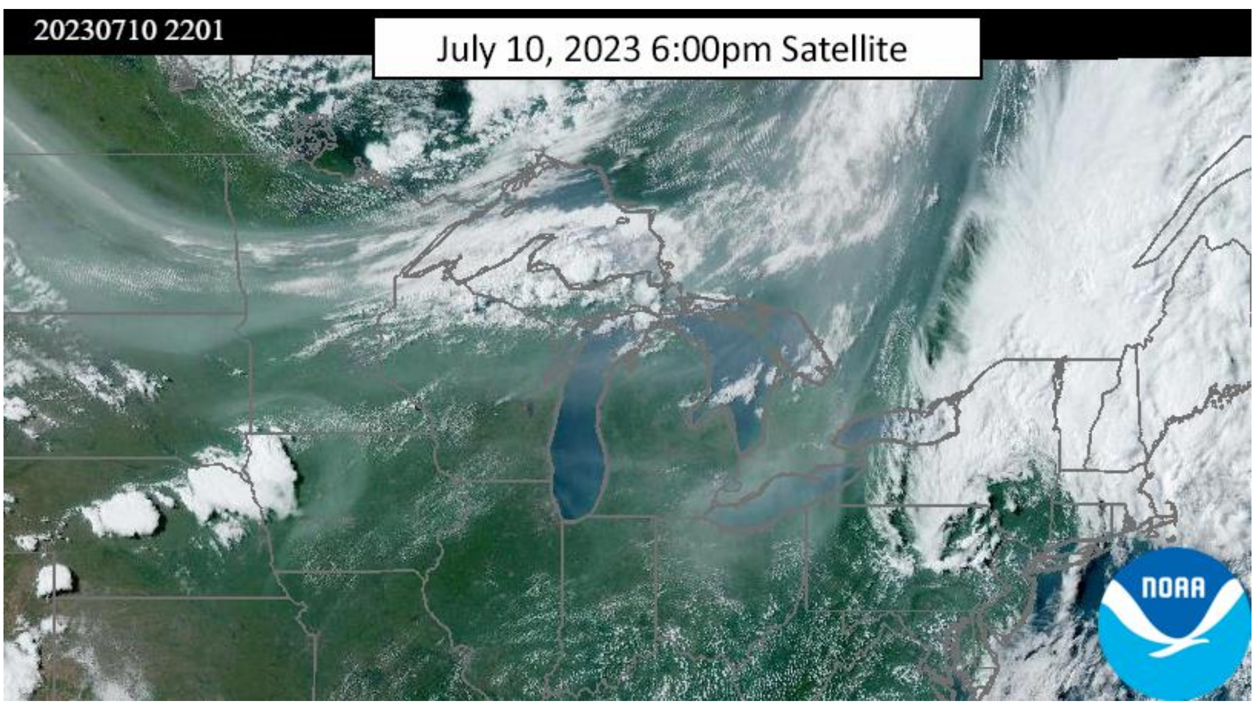



**Figure 3-10.** July 10, 2023, satellite image show smoke from fires from northwest Canada being transported to the Great Lakes region.

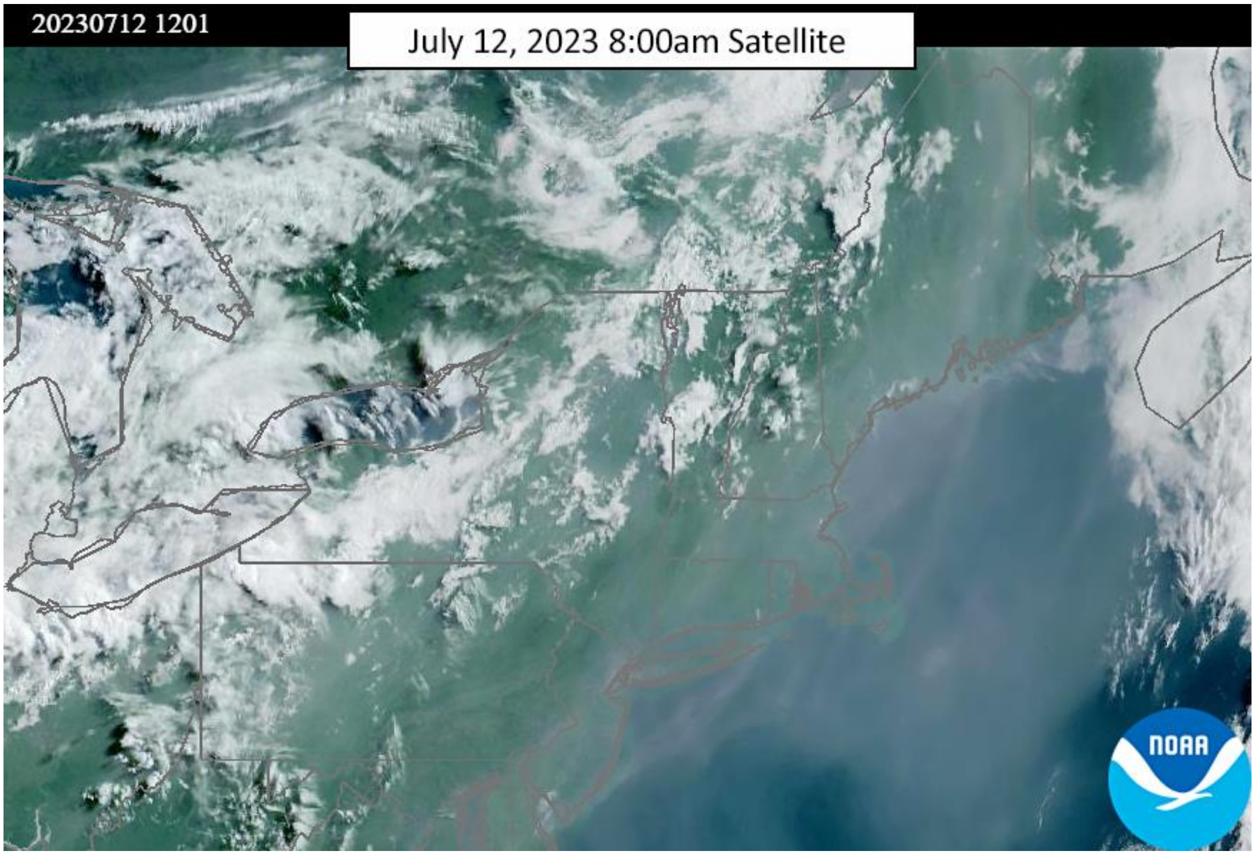



**Figure 3-11.** July 12, 2023, visible satellite showing smoke plume and approaching frontal system.

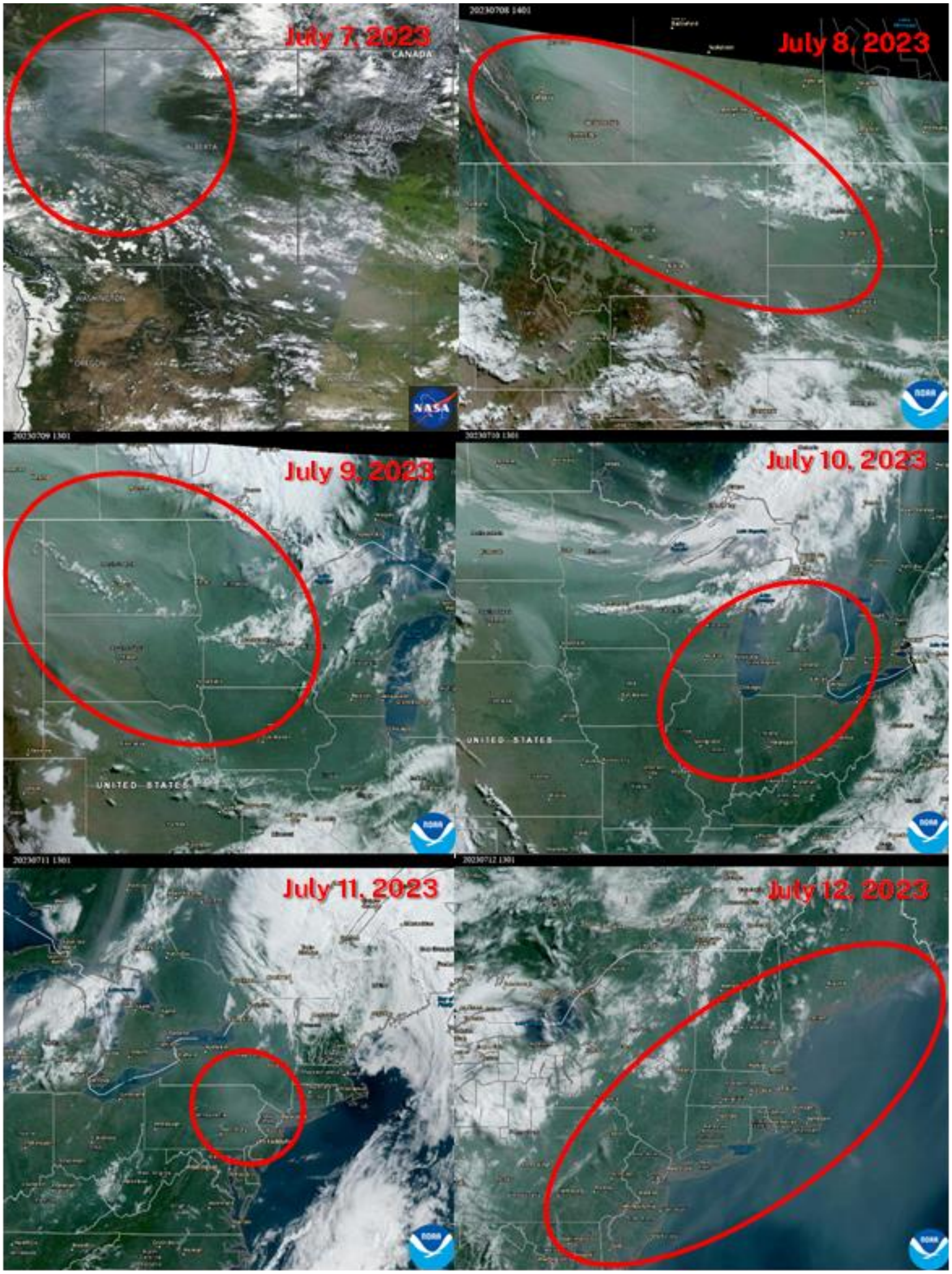



**Figure 3-12**. Satellite images showing progression of the smoke plume from northwest Canada to New England from July 7 to July 12, 2023.

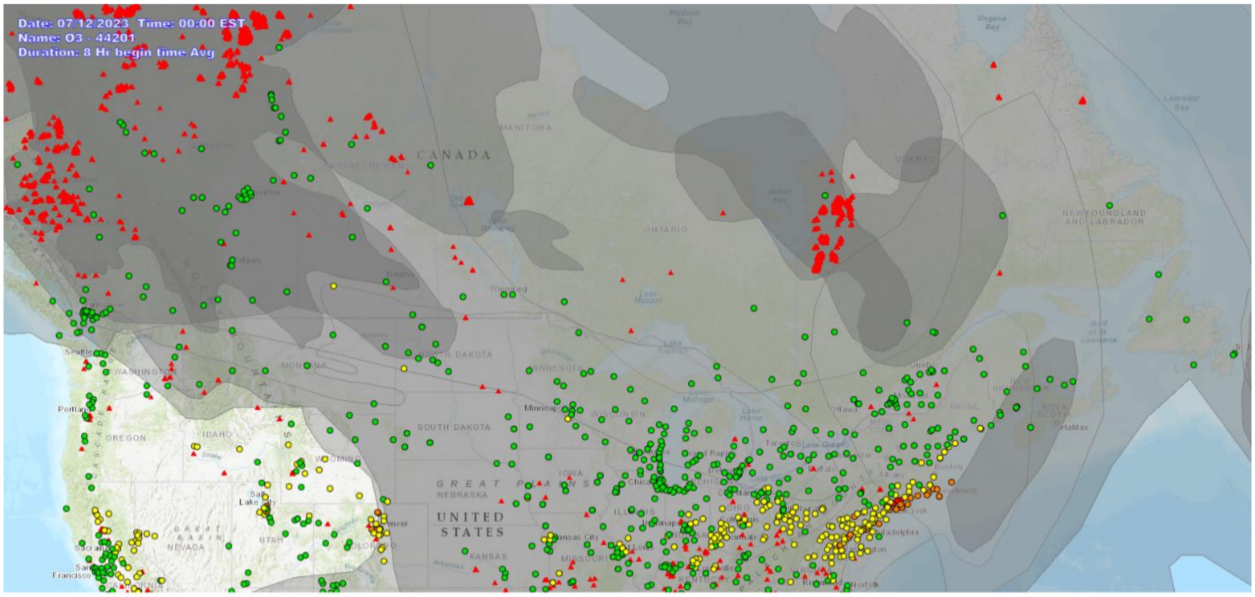



**Figure 3-13.** July 12, 2023, HMS analyzed smoke plume with maximum 8-hour ozone AQI levels.

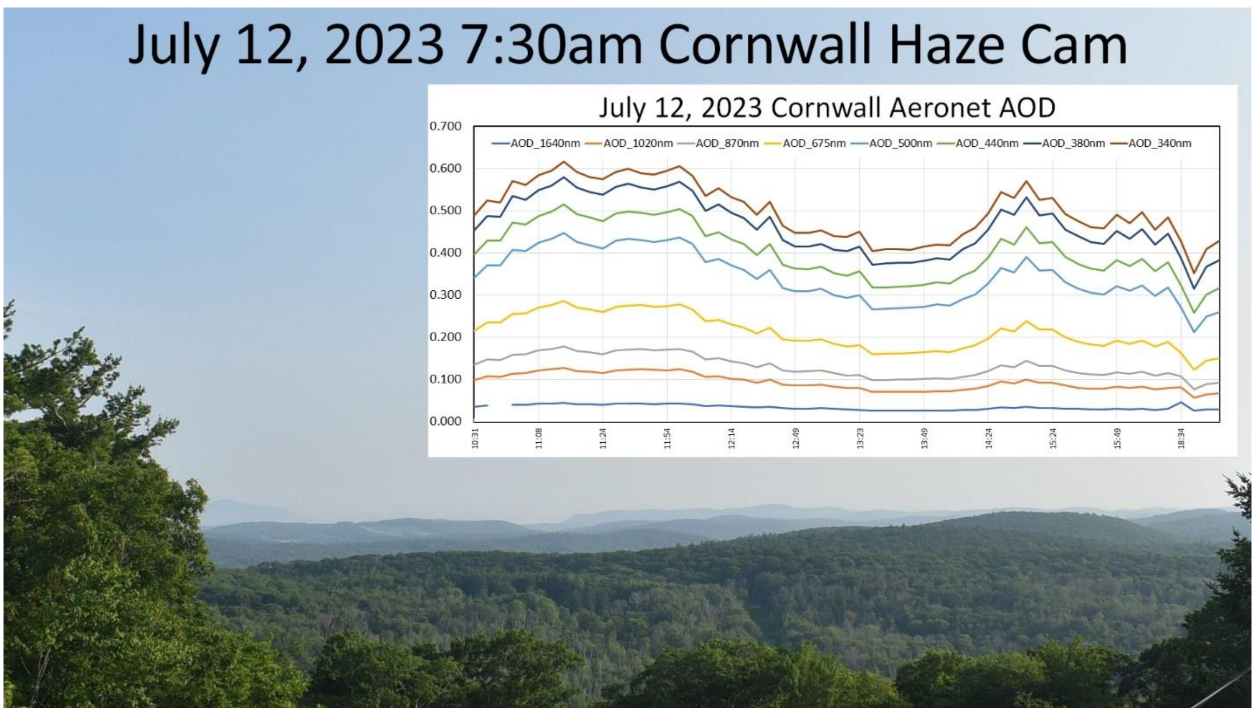



**Figure 3-14.** July 12, 2023, Cornwall haze camera with Aeronet AOD levels inset.

## 3.2 Fire Radiative Power

In addition to detecting pollutant column concentrations, satellites can locate and size fires by evaluating the transmitted radiative energy. One important variable for wildfire characterization is Fire Radiative Power (FRP). FRP represents the instantaneous radiative energy that is released from actively burning fires with greater values for FRP being indicative of hotter fires.

Wiggins et al. (2020), show a strong correlation between increasing FRP and increasing emissions. These correlations are useful in tracking plumes, particularly for more abundant and stable pollutants such as carbon dioxide (CO2), carbon monoxide (CO), and black carbon (BC).[31]

Figure 3-15 shows a comparison of the sum of FRP across all fires in the northern Flint Hills area during early April from 2020 through 2023. The April dates were used for this analysis due to the consistency of fires burning at this location during this time and the proximity to the April 13-14 Event. April 2023 shows the highest value for the last four years, indicative of the dry conditions in the Flint Hills region and the likelihood of significantly greater emissions from the prescribed burns for this year.

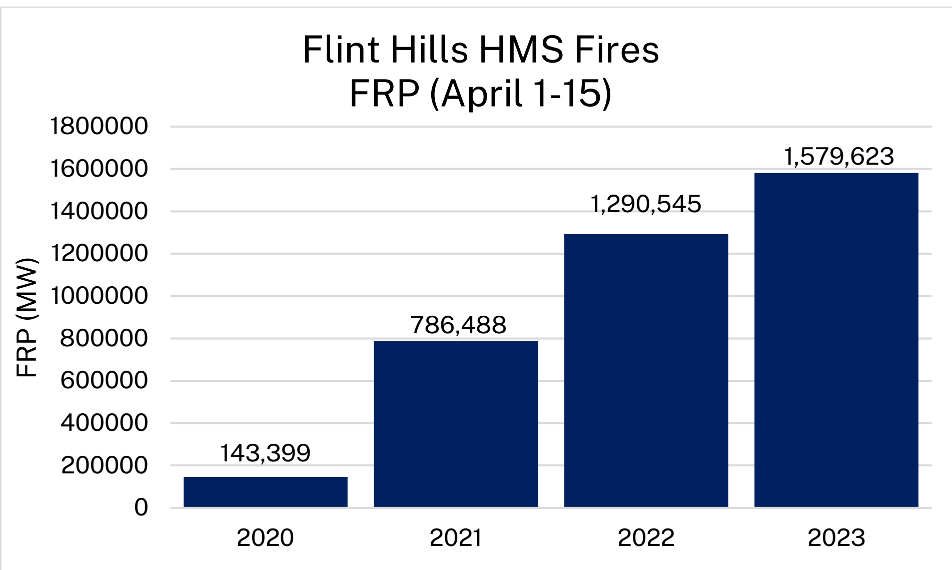



**Figure 3-15.** FRP for Flint Hills using Hazard Mapping System (HMS) Fire data for the beginning of April from 2020 – 2023 https://www.ospo.noaa.gov/Products/land/hms.html#data.

## 3.3 Satellite Observed Carbon Monoxide Plumes

Evidence of smoke plumes can be found in the satellite detection of carbon monoxide (CO),

[31] Wiggins, E. B., Soja, A. J., Gargulinski, E., Halliday, H. S., Pierce, R. B., Schmidt, C. C., et al., (2020). High temporal resolution satellite observations of fire radiative power reveal link between fire behavior and aerosol and gas emissions. Geophysical Research Letters, 47, e2020GL090707. https://doi.org/10.1029/2020GL090707

which is a by-product of combustion. The CO plumes that were produced by these fires appear to have been transported over Connecticut. Figure 3-16 shows the TROPOMI CO column for April 10-13, 2023. The highest CO column can be observed on April 11th over the lower Midwest, with the elevated CO levels reaching New England on April 12-13. TROPOMI CO was unavailable on April 14th, so the AIRS CO total column was used to show a high CO column concentration over the Northeast on that day. Section 7-2 will show that steadily rising CO levels were detected at Connecticut's monitors during this period in April.

A more significant TROPOMI CO plume is evident as shown for June 30th in Figure 3-18. It was during this June 30-July 1 event when PM2.5 levels were exceeding the level of the NAAQS.

Figure 3-19 shows the TROPOMI CO column for the July 12th event, when levels were lower than June 30th, but still significant.

All the figures verify that elevated CO levels were present, and they were the product of combustion from transported wildfire smoke.

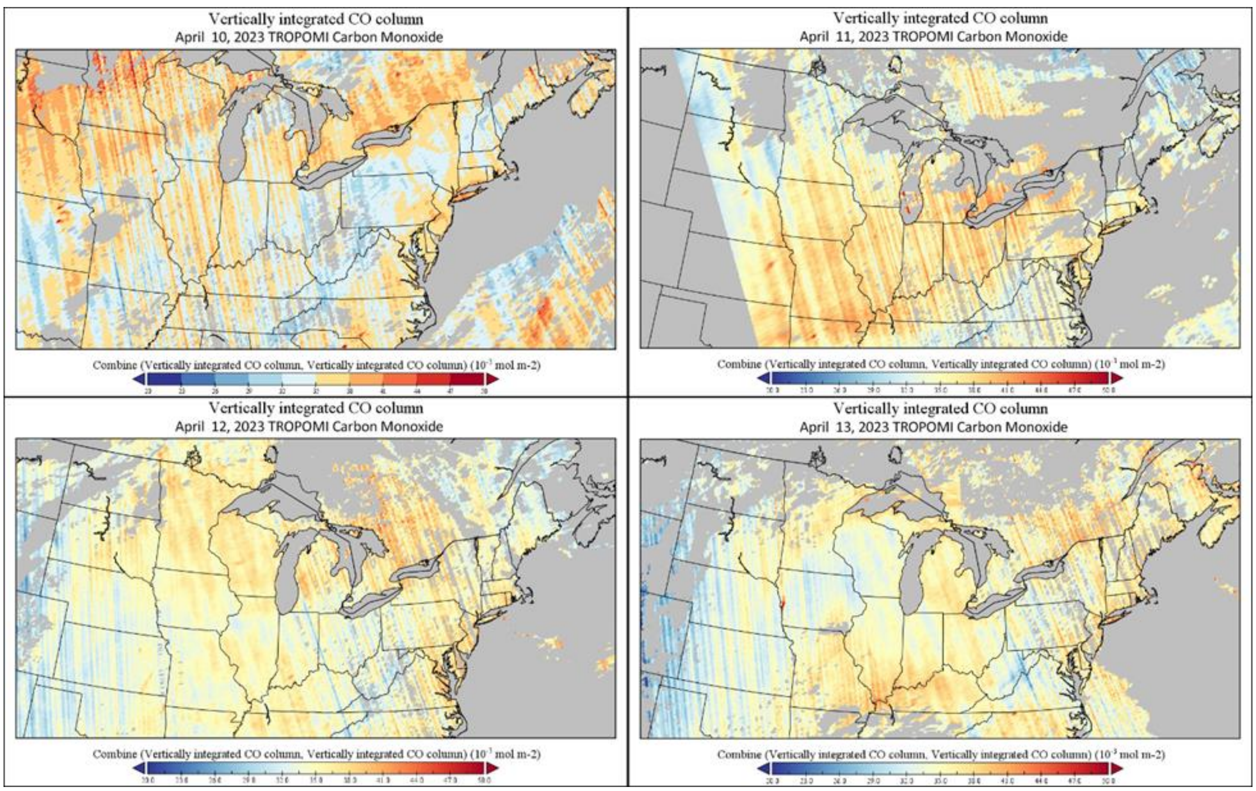



**Figure 3-16.** April 10 through 13, 2023, TROPOMI satellite CO column.

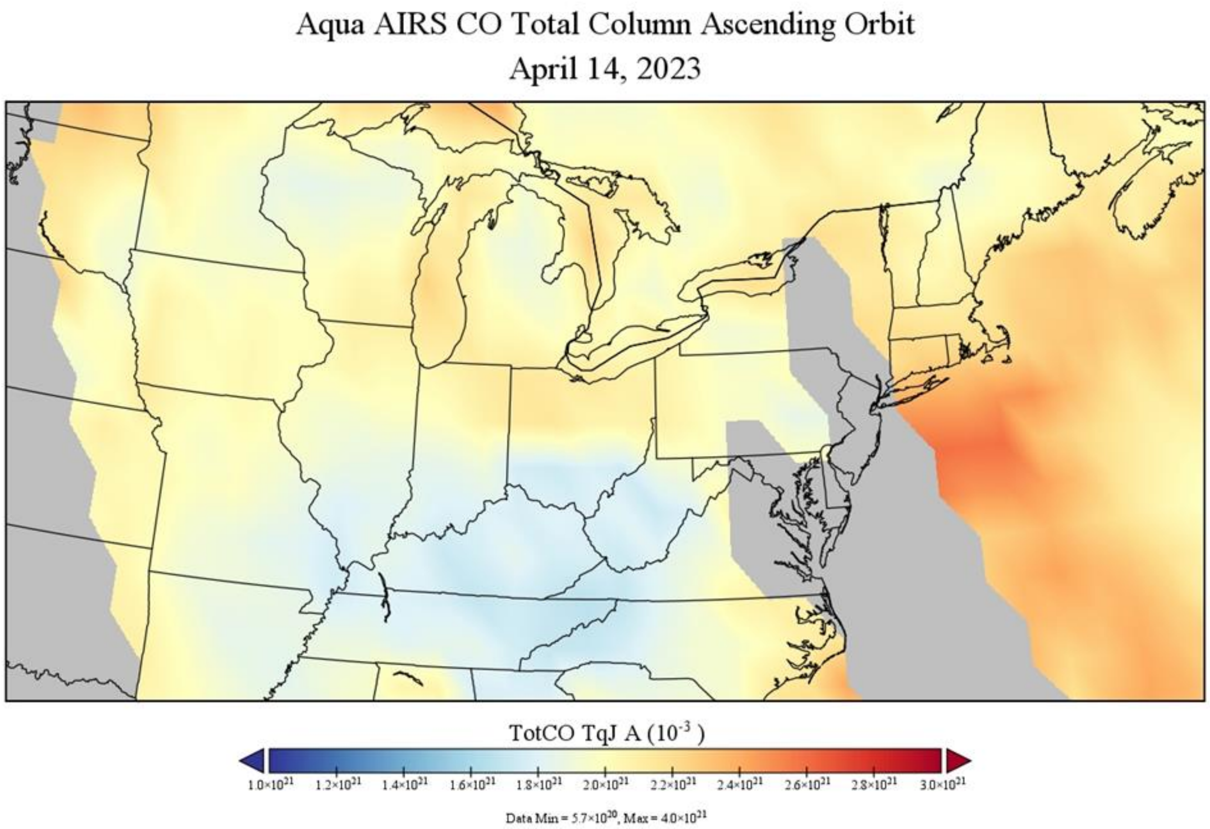



**Figure 3-17.** AIRS CO total column April 14, 2023.

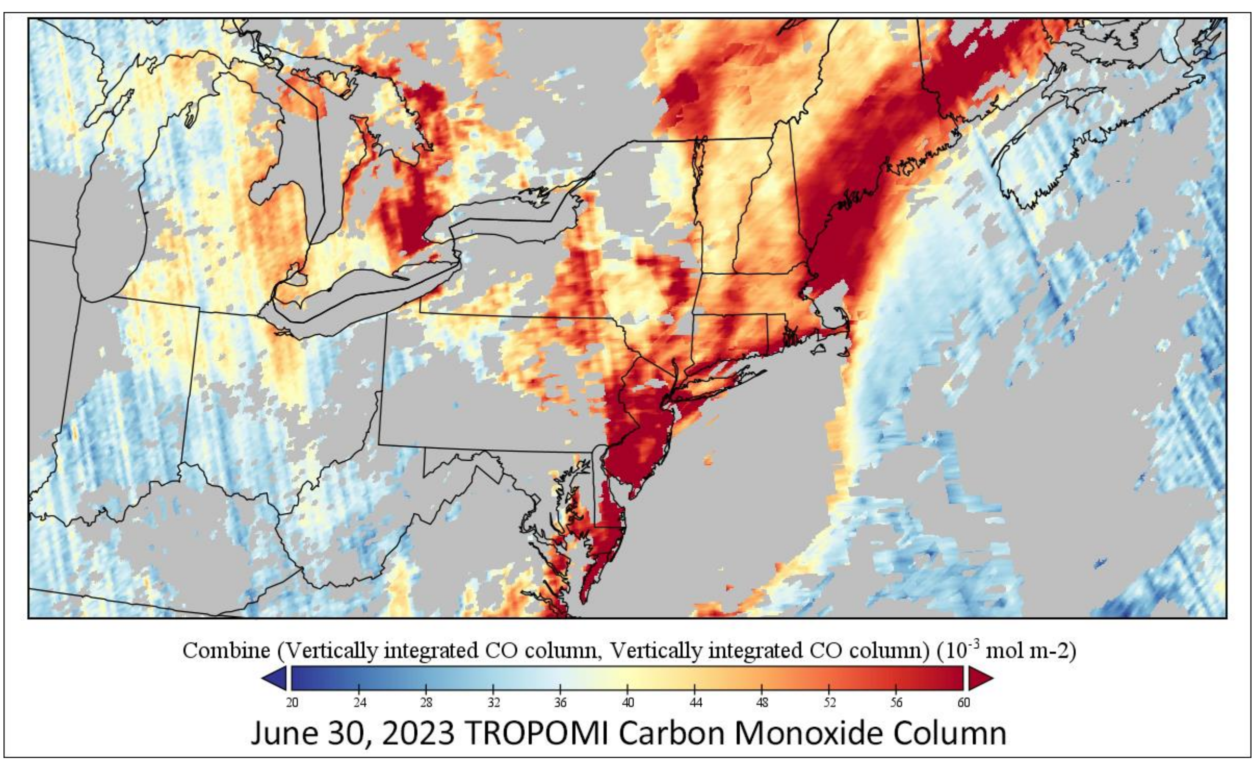



**Figure 3-18.** June 30, 2023, TROPOMI CO Column.

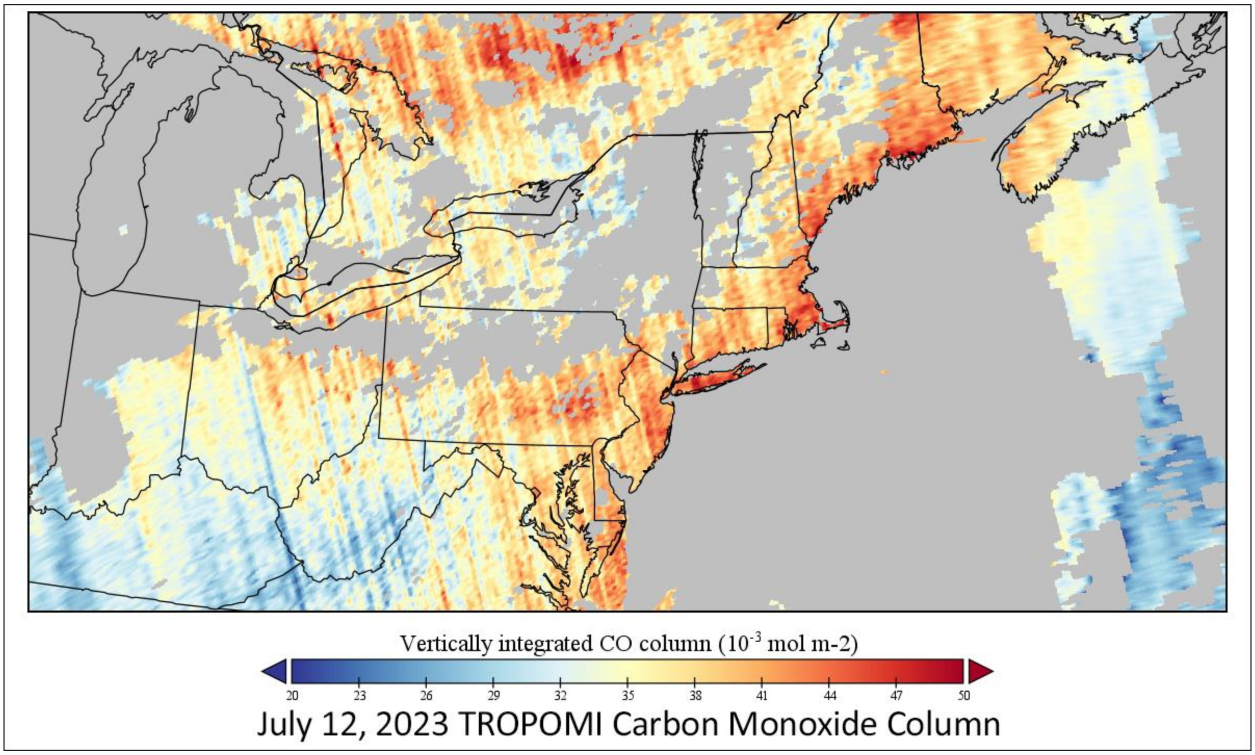



**Figure 3-19.** July 12, 2023, TROPOMI CO Column.

# 4 Description of the Fires

This section provides a description of the fires relevant to the events, including descriptions from news reports.

## 4.1 Description of the Fires

### Fires Impacting the April 13-14 Event

Throughout the April 13 – April 14 event, air quality was affected by smoke carried aloft from distant out-of-state western fires reaching the surface layer in the region. Simultaneously, smoke from nearby fires in New Jersey, New York, and Pennsylvania were carried into Connecticut on low level winds.

Back trajectories from Connecticut monitors show upper-level winds on the 13th originate three days earlier above intense fires burning in the Flint Hills of Kansas where prescribed burning had caused additional wildfires. Prescribed burning takes place annually in the Flint Hills region to preserve tall grass prairies which range from north central Kansas into northern Oklahoma. Over one quarter of a million acres of prairie burned from April 9 – April 12, 2023, in the Flint Hills.[32]


**Figure 4-1.** The Flint Hills tallgrass prairie region. Source: https://lowestravels.com/2015/06/29/exploring-the-flint-hills-strong-city-ks/

[32] https://www.ksfire.org/new-media-archives/index.html

**Figure 4-2.** Two images above show prescribed burns in the Konza Prairie section of Flint Hills, April 2023. Photos by Evert Nelson / The Capital-Journal https://www.chonline.com/story/news/state/2023/04/26/tallgrass-prarie-fires-in-kansas-flint--hills-burn-for-research/70146219007/

NASA's Earth Observatory reported, regarding the Flint Hills burns that, *"Abundant rainfall during the 2022 growing season produced an above-average amount of grass available to be* *burned by fires in 2023. On April 4, conditions favorable for wildfires — dry fuels, low humidity, and gusty winds — led the National Weather Service to issue a fire weather watch."* [33]

Occasionally, during prescribed burns, control of the fire is lost. For example, two major fires burned out of control starting on April 6th and 7th in Riley County Kansas. A total of 3,500 acres of land were burned in these fires.

> *On Thursday, April 6, Riley County Fire District #1 crews were dispatched to Halls Ravine Road, north of Randolph for reports of a wildfire. A prescribed burn in the area got out of control, burning private land and igniting flood debris on U.S. Army Corps of Engineer property…An estimated total of 1,500 acres were burned in this fire.*
>
> *…On Friday, April 7, RCFD#1 was dispatched to Tabor Valley Road in SE Riley County for reports of a prescribed burn that was out of control. Upon arrival, crews found heavy smoke and a large area burning. The fire was maintained the very same day but was able to burn 2,000 acres of land.*
>
> *According to the Deputy Fire Chief Doug Russell, "Conditions are extremely dry, and several fires have gotten out of control."--* Two out-of-control fires burn thousands of acre | Riley County Kansas

Reporting on burn scars of fires in the region between Topeka and Riley County in the same time period indicate that additional prescribed fires may also have burned out of control.[34]

Closer to Connecticut, wildfires were burning in Pennsylvania, New York and New Jersey. Several of these fires, described below, aligned with surface winds to carry smoke from the multiple fires into Connecticut.

The Crystal Lake fire in Luzerne County, Pennsylvania began on Wednesday, April 12th and burned over 2,500 acres as of Friday April 14th. According to news reports, the fire was contained by April 18th having burned just under 4,500 acres.[35]

> *"With little snowpack this year,* [Katie] *Dildine* [Fire Operations Technician/PA DCNR] *said the leaf litter was still relatively fluffy, letting it dry out quicker than if it had been wet and packed down heavy."* -- What's Pennsylvania's wildfire season been like so far? | 90.5 WESA
>
> *"The fire is burning in an area that has a dense understory of volatile oak scrub, heath layer and overstory of mature oak."* --Fire crews expected to battle wildfire near Crystal Lake for many more days | WOLF (fox56.com)
>
> *"As the fire spread in the direction of the Pennsylvania Turnpike Northeast Extension (Interstate 476), fire managers coordinated with the turnpike commission to close a*

[33] https://earthobservatory.nasa.gov/images/151223/burn-scars-in-kansas
[34] News Flash • Two out-of-control fires burn thousands of acre (rileycountyks.gov)
[35] Northeast Pa. wildfire contained after burning 4,376 acres, state says - lehighvalleylive.com

*20-mile stretch of the highway in both directions between the Pocono (Exit 95) and Wyoming Valley (Exit 115) interchanges, from 8 p.m. Thursday* [April 13th] *to 4 a.m. Friday* [April 14th]." --Lehigh Valley Live

**Figure 4-3.** Smoke from the Crystal Lake Fire as photographed April 13, 2023. Source: Mike Nester | lehighvalleylive.com

In New York, fires burning in Orange and Rockland Counties added smoke to the plume as it advanced into Connecticut. The Shin Hollow fire in Orange County started on April 12th and burned 350 acres near the town of Deerpark.[36]

*"The fire was sparked on the morning of April 12 when debris-burning by a Shin Hollow Road resident grew out of control, according to the New York State Department of Environmental Conservation (DEC).*

*By the end of the day, the fire had spread to 48 acres; by two days later, it had burned up to 300 acres, according to updates by the Huguenot Fire Company.*

[36] https://midhudsonnews.com/2023/04/17/deerpark-brush-fire-consumes-350-acres-video/

*The resident was issued three citations by DEC: one for setting a fire that endangers another property, one for leaving a fire unattended, and one for failure to clear three feet of flammable materials from the fire.*

*The county also had a wildfire in the Town of Blooming Grove, which burned 98 acres over three days."* – [Wildfire in Deerpark, Orange County, Out After Burning 350 Acres Over 3 Days | The Epoch Times]

**Figure 4-4.** Photo of the Shin Hollow Fire in Deerpark, Orange County, NY. Source: 26 Wildfires in 16 Counties Burn Nearly 1,000 Acres - New York Almanack

In the town of Blooming Grove, the Round Hill Fire was reported to be burning simultaneously with the Shin Hollow Fire. The Round Hill fire broke out on Thursday April 13th and burned approximately 80 acres by 10pm on Friday the 14th, before coming under control.[37,38] Further to the east, in Rockland County, dozens of fires broke out as a CSX freight train sparked the tracks

[37] Extreme heat and dry conditions add to brush and forest fires - Mid Hudson News
[38] Officials hope Orange County fire will be 100% contained overnight (news12.com)

on Friday afternoon and burned 50-70 acres in rapidly moving fires along the Hudson River rail line from Congers to Tomkins Cove.[39,40]

NYDEC reported that over the week 26 fires burned over 1000 acres. In addition to the Orange and Rockland County fires described above, NYDEC conducted prescribed burns of 31 acres in Suffolk County, Long Island on land in Riverhead on April 10, 13 and 14.[41]

In Ocean County, New Jersey, a fire that started at the Pine Barrens in Manchester on the 11th had burned 2500 acres by the morning of the 12th and increased to 3800 acres before the end of the day.[42,43,44] Though it had been 75% contained, Chief Greg McLaughlin of the New Jersey Forest Fire Service advised residents that billowing smoke would be visible for days.[45] It was not until Thursday morning that the fire, known as the Jimmy's Waterhole Fire, was fully contained.

> *"This fire exhibited extreme fire behavior. We saw a wall of fire, 200-foot flames, raining fire embers. I don't mean to be dramatic but this was a severe situation." John Cecil, Assistant Commissioner of State Parks, Forests, and Historic Sites, said."* -- Firefighters Battle Big Flames, Raining Embers During Massive NJ Forest Fire – NBC New York


**Figure 4-5.** Update from the New Jersey Forest Fire Service on the Jimmy's Waterhole Fire, April 13, 2023.

[39] About 100 homes evacuated in Rockland County as crews battle large brush fire - CBS New York (cbsnews.com)
[40] Rockland County officials, residents demand investigation into CSX after freight train ignited brush fires - CBS New York (cbsnews.com)
[41] DEC Forest Rangers - Week in Review - NYDEC
[42] Forest fire in Ocean County grows to 2,500 acres; residents evacuated - nj.com
[43] N.J. wildfire grows to more than 3,800 acres, but is 50% contained, officials say - nj.com
[44] NJ wildfire: 'Jimmy's Waterhole' fire in Manchester updates (app.com)
[45] Residents will see billowing smoke for days as crews battle N.J. wildfire - nj.com

**Figure 4-6.** Image of the Jimmy's Waterhole Fire which burned nearly 4,000 acres in Manchester Township and Lakehurst Borough, Ocean County, NJ between April 11 and April 13, 2023. Source: *NJ wildfires: State gets $3M after worst season in a decade (northjersey.com)*

Just as the Jimmy's Waterhole Fire was coming under control on Wednesday afternoon, fire fighters were turning their attention to newly started Kanouse Wildfire in West Milford Township, Passaic County, New Jersey.[46] The Kanouse fire was located in a mountainous area of an oak-hickory forest with clusters of dead aspen that ignited like paper and threw sparks assisting in spread of the fire.[47] By late morning on Thursday the 13th, the Kanouse fire had burned 250 acres.[48] By the next morning, the fire had reportedly burned 972 acres.[49]

> *"Inside this forest are dying ash trees, eaten out by an invasive insect, the emerald ash borer, and they're going up like paper.*
> *Fire is being brought up in the trees, all the way up to the canopy and the wind is only spreading it." --* West Milford wildfire burns hundreds of acres in New Jersey, largest since 2010 (fox5ny.com)

46 Wildfire in North Jersey spreading, officials say - nj.com
47 Stubborn wildfire continues to burn in West Milford, NJ (nj1015.com)
48 Two major wildfires burning in N.J., though officials say they are making progress getting them contained - nj.com
49 Stubborn wildfire continues to burn in West Milford, NJ (nj1015.com)


**Figure 4-7.** Posting on X by the New Jersey Forest Fire Service showing images of the Kanouse fire in West Milford, Passaic County, NJ .

On April 14th the Log Swamp Fire continued the trend, eventually burning over 1600 acres in Little Egg Harbor Township, Ocean County. New Jersey ended 2023 with 14 major fires over what was the busiest fire season in a decade.[50]

## Fires Impacting the June 30-July 1 Event

Canada has had an extreme 2023 fire season which has been described as "record-breaking and shocking" according to the NASA Earth Observatory.[51] During the 2023 season, more than 15 million hectares burned across the country, killing 17, and forcing the evacuations of more than 150,000 people.[52] On June 1st lightning strikes from severe storms caused wildfires to ignite in Quebec, Canada. These fires were ignited simultaneously throughout remote areas in the dense Canadian forest and quickly spread due to dry weather conditions. Over the course of the summer months, the fires continued to burn sending smoke into the atmosphere. By the end of

[50] New Jersey's 14 major wildfires in 2023 (nj1015.com)
[51] Tracking Canada's Extreme 2023 Fire Season (nasa.gov)
[52] Quebec, Canada wildfires made twice as likely through climate change | CNN

the season, approximately 5.1 million hectares were burned.[53] Figure 4-8 depicts the annual acres burned in Quebec since 1972. It is evident that 2023 has had the highest area burned in the last 50 years by a large margin.

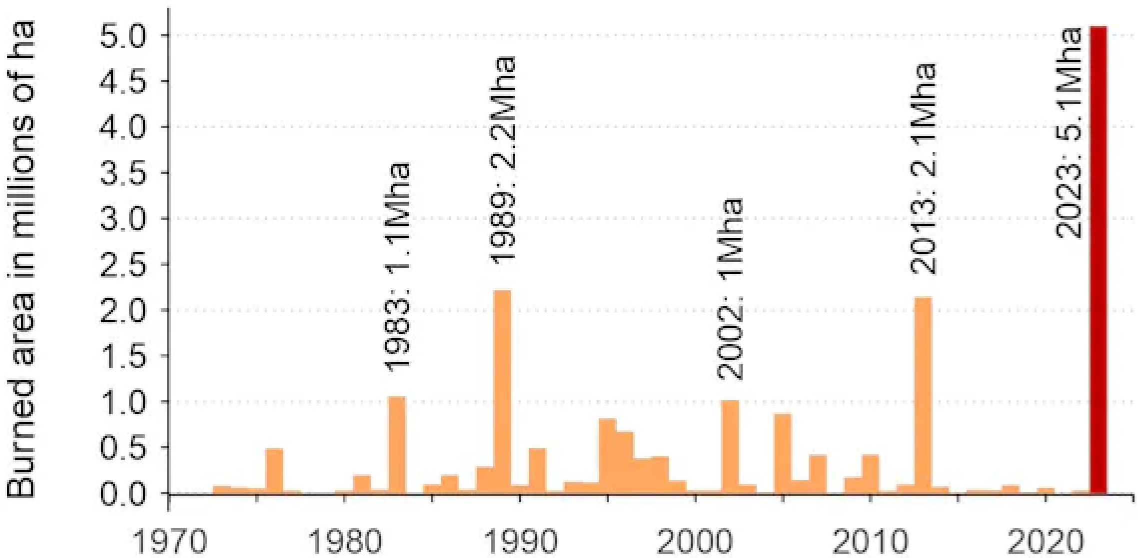



**Figure 4-8.** Annual area burned between 1972 and 2023 in Québec in millions of hectares. Courtesy of The Conversation

*"'Lightning-caused fires often occur in remote areas where human life, property and timber values are not threatened,' states Natural Resources Canada on its website. 'Fire suppression in these areas may therefore be intentionally limited, leaving fire to play its natural role.'* What's believed to have sparked the Canadian wildfires | FOX Weather

[53] Québec's summer 2023 wildfires were the most devastating in 50 years. Is the worst yet to come? (theconversation.com)

**Figure 4-9** Flames reach upwards along the edge of a wildfire as seen from a Canadian Forces helicopter surveying the area near Mistassini, Quebec, Canada June 12, 2023. Courtesy of REUTERS

Dependent on meteorological factors, smoke plumes, some larger than others, traveled into Connecticut throughout the summer causing air quality issues. During the June 30– July 1 event, a thick plume of smoke from the Quebec wildfires recirculated into the state causing elevated levels of PM2.5 and ozone. Hazy skies covered most of New England resulting in air quality alerts from affected areas.

> *"New England state air quality forecasters are predicting elevated concentrations of fine particle air pollution due to wildfires in Quebec and Northern Ontario."*-- *New England Continues to Experience Poor Air Quality due to Smoke from Canadian Wildfires on Saturday July 1, 2023 | EPA*

## Fires Impacting the July 12 Event

Continuing into Canada's record-breaking fire season, Western Canada had significant fires contributing to the smoke events. Lightning and a dry rain season were again the source of many of these fires. Several fires took place during the summer throughout Saskatchewan, British Columbia, Alberta, and the Northwest Territories. As of September 19, the fires had burned through Western Canada resulting in over 2 million hectares of charred land. The figure below depicts the different wildfires in Western Canada and how many hectares were burned in result.

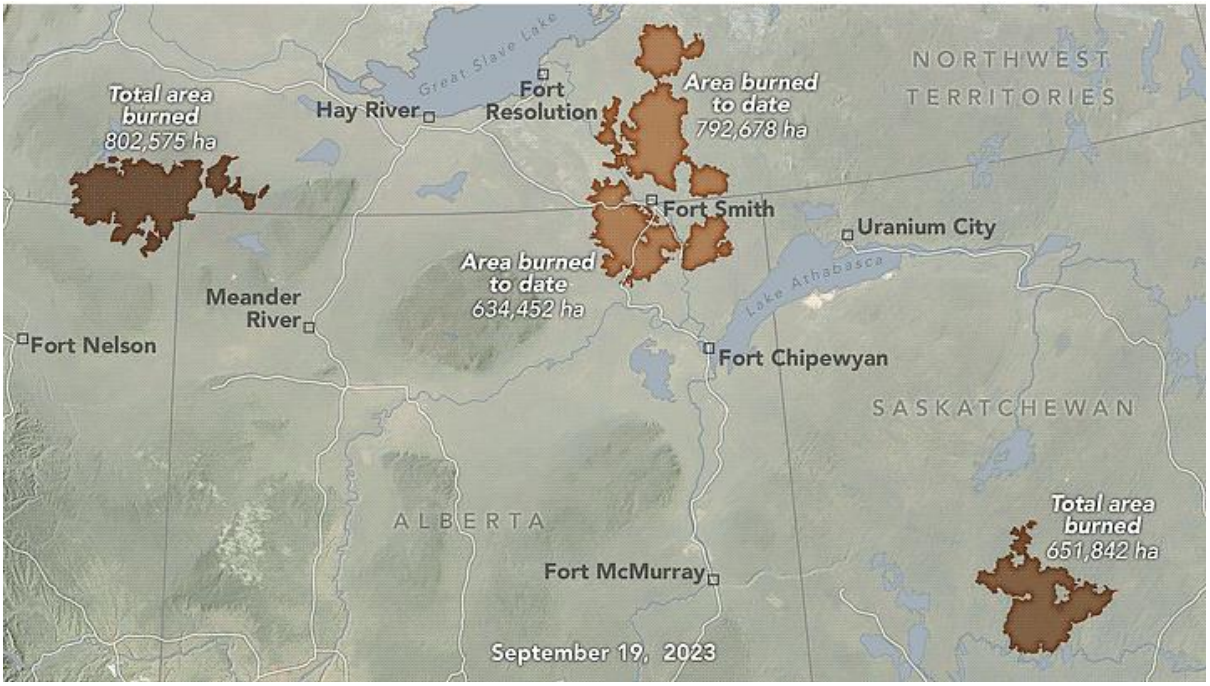


**Figure 4-10:** Map of hectares burned in Western Canada. May 12 - September 19, 2023.

According to NASA, "The second-largest fire as of September 19, 2023… raged throughout much of June and July near Fort Nelson, where the borders of British Columbia, the Northwest Territories, and Alberta intersect".[54] This fire itself began in late May and was ablaze until August, burning 802,575 hectares. Though the fire began in May, several new fires ignited on July 4, 2023 creating a larger issue.[55]

> *"Record high temperatures and a record fire season are hitting Canada at the same time this summer, leading to an unprecedented combination of heat, fire and dangerous smoke plumes."--* *Canada record heat meets record wildfires; new reality say scientists (cnbc.com)*

[54] Tracking Canada's Extreme 2023 Fire Season (nasa.gov)
[55] Lightning strikes cause new wildfires near Fort Nelson | CJDC TV News

**Figure 4-11** Trees scorched by the Donnie Creek wildfire line a forest north of Fort St. John, British Columbia, Sunday, July 2, 2023. Wildfires have burned a record amount of area in the Canadian province of British Columbia | AP News

**Figure 4-12** Wildfire in British Columbia on July 10, 2023. Canada record heat meets record wildfires; new reality say scientists (cnbc.com)

Fires were burning throughout Canada during early July, but the most significant smoke impact to Connecticut shifted to the western Canadian fires beginning on July 6th. The following figure shows the HMS satellite detected fire locations for the period from July 6-10th with the area of interest in the red circle. Also depicted is an arrow showing the 850mb mean wind vector (~5000 feet) where much of the transport would occur. Smoke from these fires were transported into the upper Midwest States by July 10th and then to New England by July 12th.

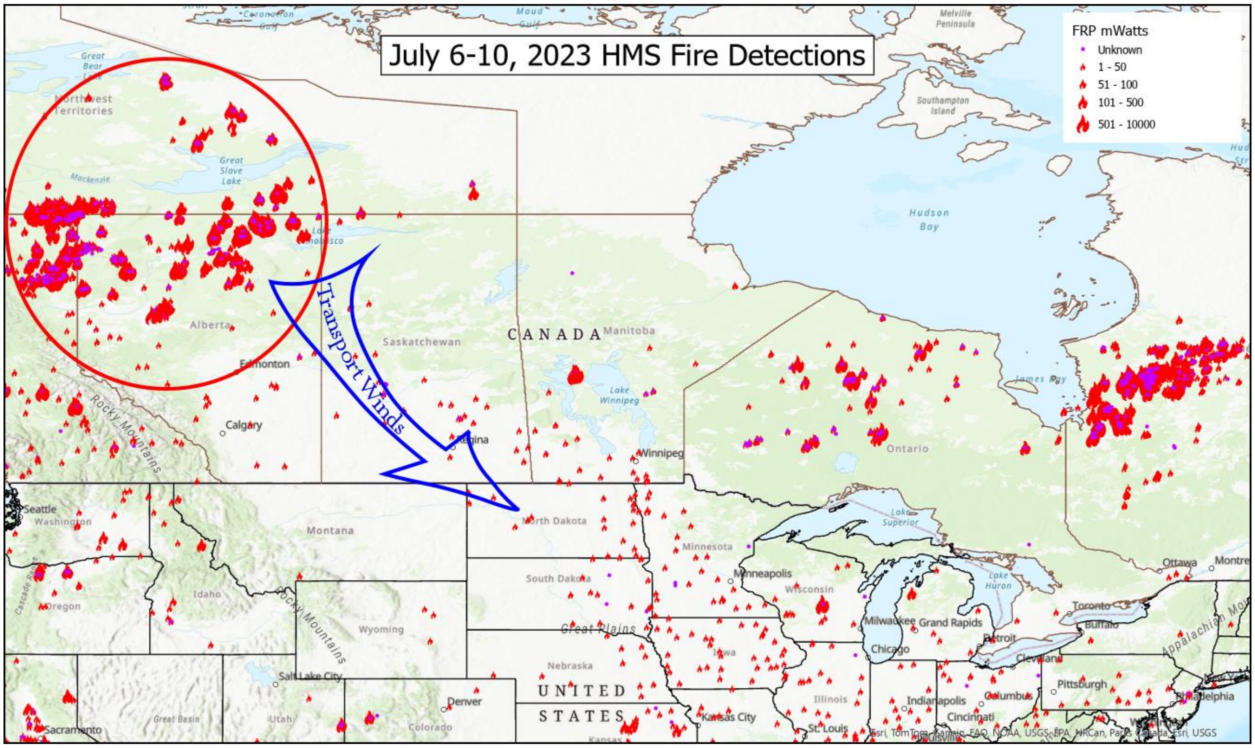



**Figure 4-13.** Location of HMS fire detections during July 6-10, 2023, with direction of mean 850mb transport winds.

# 5 Wildfire Emissions Impact on Connecticut using a Q/d Analysis

EPA guidance[56] recommends conducting a Q/d analysis as a rough assessment of the ability of a wildfire to cause increased ozone concentrations. The Q/d analysis is simply a comparison of the ratio of Q, the daily tons of VOC and NOx emitted from the fire, to d, the distance in kilometers from the fire to the point of concern. If the Q/d value compares favorably to analytical data from other fires, then the fire can be presumed to have had a causal effect on ozone concentrations at the point of concern.

EPA guidance indicates that a fire should have a Q/d in excess of 100 tons per day per kilometer (tpd/km) in order to be considered to have a clear causal impact on ozone. This method is intended to be a simple and conservative approach to establishing clear causality. Failure to meet the 100 ton per day per kilometer threshold does not preclude a finding clear causality. EPA developed this value based on limited analyses of four fires which occurred in 2011.

**Estimate of Q**

The emissions from a fire can be estimated using information from EPA's AP-42 *Compilation of Air Emission Factors Section 13.1 Wildfires and Prescribed Burning*.[57] The equations given are as follows:

$F_i = P_i * L$ (Equation 1)
$E_i = F_i * A$ (Equation 2)

$F_i$ = emission factor (mass of pollutant/unit area of forest consumed)
$P_i$ = yield for pollutant "i" (mass of pollutant/unit mass of forest fuel consumed)
= 12 kg/Mg (24 lb/ton) for total hydrocarbon (as $CH_4$)
= 2 kg/Mg (4 lb/ton) for nitrogen oxides ($NO_x$)
L = fuel loading consumed (mass of forest fuel/unit land area burned)
A = land area burned
$E_i$ = total emissions of pollutant "i" (mass pollutant)

Combining equations 1 and 2, we have:

$E_i = P_i * L * A$

Pi is given above for total hydrocarbons and for nitrogen oxides. The fuel loading is given in AP-42 for different regions of the United States and ranges from 9 to 60 tons per acre. Conservatively, we will generally estimate a low-end emission rate using 10 tons per acre which is associated with North Central US conifer forests. Note that our results could increase by a factor of 6 were we to expect the high end of fuel loading appropriate to northern regions.

[56] Guidance on the Preparation of Exceptional Events Demonstrations for Wildfire Events that May Influence Ozone Concentrations, Final, EPA, September 2016
[57] https://www.epa.gov/sites/default/files/2020-10/documents/13.1_wildfires_and_prescribed_burning.pdf

**Estimate of d**

We estimate d, the distance from the fire center to the monitor of interest, using the straight-line distance obtained from google maps.

## 5.1 Emissions Impact on the April 13-14 Event

Multiple fires burned in the nearby upwind states from Connecticut on April 13th and 14th.

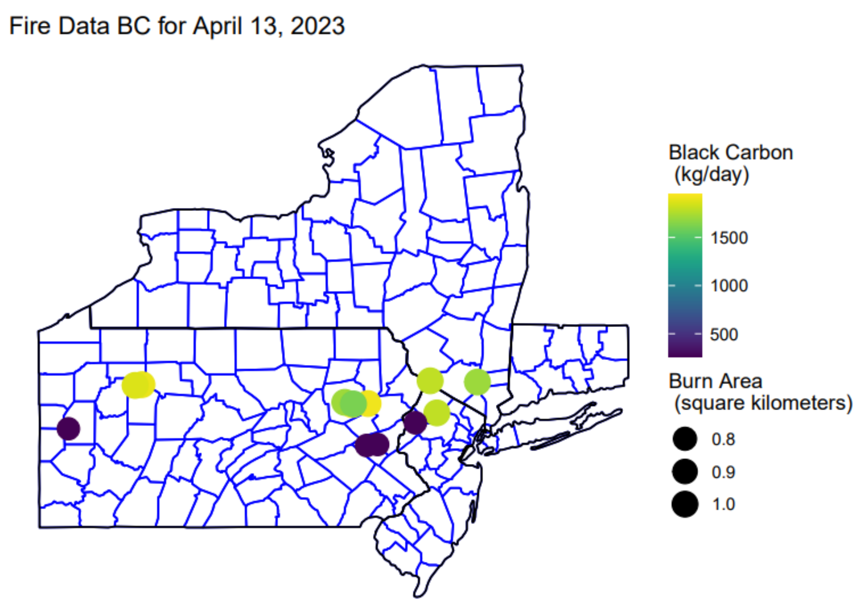



**Figure 5-1.** Locations and black carbon emissions of fires reported by FINN for April 13th in States nearby and upwind of Connecticut. The Crystal Lake fire is in the vicinity of the collocated green and yellow dots shown in eastern Pennsylvania.

**Figure 5-2.** Visible smoke plume from the Crystal Lake Fire (northeastern Pennsylvania) as seen by satellite on April 13, 2023. Fires indicated by yellow/white dots. The two fires in southern New York are the Shin Hollow fire in the Town of Deerpark, Orange County (western most) and smaller fire in the town of the Blooming Grove, New York (eastern most). The Kanouse fire in West Milford Township, Passaic County, New Jersey is also shown.

## Calculation of Q/d using the Crystal Lake Fire

### Estimate of Q

The Crystal Lake fire in Luzerne County, Pennsylvania began on Wednesday, April 12th, and burned over 2,500 acres as of Friday April 14th. It was contained by April 18th having burned just under 4,500 acres according to news reports.[58] This indicates a daily average of 833 acres burned between April 12th and 14th. According to the National Center for Atmospheric Research's Fire Inventory (FINN), which characterizes fires using satellite data, approximately 1 million square meters, 247 acres, of forest were burned on April 13th by a single fire in the vicinity of Crystal Lake.[59] In fact, FINN shows two fires of approximately 1 million square meters in the vicinity of Crystal Lake on April 13th.[60] We will base our calculations on the smallest estimate of daily acreage burned, 247 acres, as determined from the satellite data and consider scaling the estimate by a factor of 3 to match the higher estimate provided by the news report.

Therefore, for the Crystal Lake fire we estimate the daily total hydrocarbon emissions to be:

Ehc = 24 lbs of HC / ton of forest fuel consumed * 10 tons fuel / acre * 247 acres

[58] https://www.lehighvalleylive.com/news/2023/04/northeast-pa-wildfire-contained-after-burning-4376-acres-state-says.html
[59] https://www.acom.ucar.edu/acresp/MODELING/finn_emis_txt/ Near-real-time Fire Inventory of National Center for Atmospheric Research
[60] One fire is given with Latitude 41.14315 deg, Longitude-75.81628 deg; the second at Latitude 41.15726, Longitude -75.85535 deg.

Ehc = 59,280 pounds of HC

Ehc = 29.64 tons of HC emitted per day.

Similarly for NOx:

Enox = 4 lbs of NOx / ton of forest fuel consumed * 10 tons fuel / acre * 247 acres

Enox = 9880 pounds of NOx

Enox = 4.94 tons of NOx emitted per day.

Q is the total daily emission rate in tons per day of reactive hydrocarbons and nitrogen oxides. EPA recommends, in the exceptional events guidance, that only 60% of the hydrocarbons should be considered reactive. Therefore, the reactive hydrocarbon emissions become rHC = 0.6 * Ehc or 0.6 * 29.64 = 17.78 tons of reactive HC emitted on April 13 from one fire in the vicinity of Crystal Lake. No adjustments are suggested for the NOx emissions. Therefore, the total rHC and NOx emissions from the fire for the day are 17.78 + 4.94, or 22.72 tons. Thus, Q is 22.72 tons per day.

**Estimate of d**

Of the three monitors under consideration, the most distant monitor from Crystal Lake is at the Groton site. It is approximately 290 kilometers in a straight line from Groton to Crystal Lake.

**Q/d Estimate**

Using the values determined above, Q/d then becomes 22.72 tpd divided by 290 km, or 0.08 tpd/km. This value is well below the EPA recommended level of 100 tpd/km indicating clear causality.

**Additional Nearby Fires**

Recognizing that the FINN data indicated multiple similarly sized fires in the vicinity of Crystal Lake, we could increase the estimate by a factor of three. This is more consistent with reported data.

Additionally, several similarly sized fires were burning in the region including in southern New York and northern New Jersey. The table below summarizes the Q/d results that would result from these nearby fires using data from the news articles in Section 4.1, "Description of the Fires." In all cases Groton was the most distant of the three monitors.

**Table 5-1.** Minimum impacts on Connecticut's monitors from individual nearby fires using the Q/d method. The Groton monitor was used for calculation of distance (d) in all cases as was a fuel loading of 10 tons/acre.

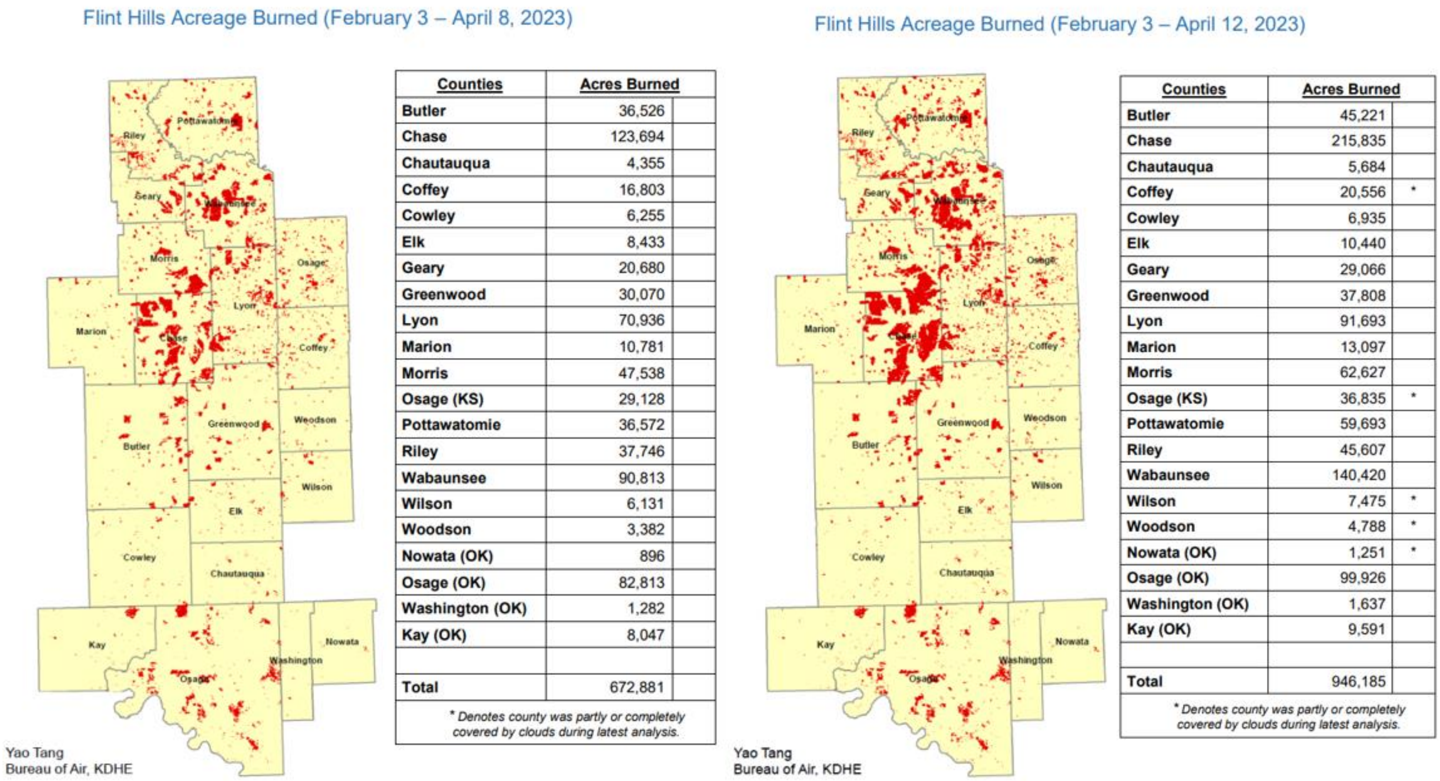
| Fire | Burn Days | Acreage Burned | Average Daily Acreage | Ehc (tons/day) | rHC (tons/day) | Enox (tons/day) | Q (tons/day) | d (km) | Q/d (tons/day/km) |
|---|---|---|---|---|---|---|---|---|---|
| Crystal Lake | April 12 -14 | 2500 | 833 | 99.96 | 59.98 | 16.66 | 76.64 | 290 | 0.26 |
| Shin Hollow | April 12 -14 | 300 | 100 | 12.00 | 7.20 | 2.00 | 9.20 | 215 | 0.04 |
| Jimmy's Water Hole | 12-Apr | 1300 | 1300 | 156.00 | 93.60 | 26.00 | 119.60 | 244 | 0.49 |
| Kanouse | 13-Apr | 722 | 722 | 86.64 | 51.98 | 14.44 | 66.42 | 195 | 0.34 |
| Round Hill | 14-Apr | 80 | 80 | 9.60 | 5.76 | 1.60 | 7.36 | 177 | 0.04 |
| CSX Freight | 14-Apr | 60 | 60 | 7.20 | 4.32 | 1.20 | 5.52 | 160 | 0.03 |
| **Emission Totals:** | | | | **371.40** | **222.84** | **61.90** | | | |

Including these fires does not increase the Q/d to significantly approach the 100 tpd/km clear causality threshold.

### The Flint Hills Fires

For the Flint Hills fires we use the same procedure, but with a fuel loading of 2 tons/acre based on data from test burns specific to tall grass prairies.[61] Data for acreage burned is available from reports posted at the Kansas Flint Hills Management website and is reproduced below.

[61] Leis, Sherry A. and Hinman, Sarah E., "Prescribed Fire Monitoring Report, Tallgrass Prairie National Preserve 2014 (IQCS fire number 285382, 285383, 266782, 285677)" (2015). U.S. National Park Service Publications and Papers. 298. https://digitalcommons.unl.edu/natlpark/298




| Counties | Acres Burned | |
|---|---|---|
| Butler | 36,526 | |
| Chase | 123,694 | |
| Chautauqua | 4,355 | |
| Coffey | 16,803 | |
| Cowley | 6,255 | |
| Elk | 8,433 | |
| Geary | 20,680 | |
| Greenwood | 30,070 | |
| Lyon | 70,936 | |
| Marion | 10,781 | |
| Morris | 47,538 | |
| Osage (KS) | 29,128 | |
| Pottawatomie | 36,572 | |
| Riley | 37,746 | |
| Wabaunsee | 90,813 | |
| Wilson | 6,131 | |
| Woodson | 3,382 | |
| Nowata (OK) | 896 | |
| Osage (OK) | 82,813 | |
| Washington (OK) | 1,282 | |
| Kay (OK) | 8,047 | |
| | | |
| Total | 672,881 | |

| Counties | Acres Burned | |
|---|---|---|
| Butler | 45,221 | |
| Chase | 215,835 | |
| Chautauqua | 5,684 | |
| Coffey | 20,556 | * |
| Cowley | 6,935 | |
| Elk | 10,440 | |
| Geary | 29,066 | |
| Greenwood | 37,808 | |
| Lyon | 91,693 | |
| Marion | 13,097 | |
| Morris | 62,627 | |
| Osage (KS) | 36,835 | * |
| Pottawatomie | 59,693 | |
| Riley | 45,607 | |
| Wabaunsee | 140,420 | |
| Wilson | 7,475 | * |
| Woodson | 4,788 | * |
| Nowata (OK) | 1,251 | * |
| Osage (OK) | 99,926 | |
| Washington (OK) | 1,637 | |
| Kay (OK) | 9,591 | |
| | | |
| Total | 946,185 | |

**Figure 5-3.** Flint Hills burn data by county from April 7 and April 21, 2021, reports available at https://www.ksfire.org/new-media-archives/index.html.

**Table 5-2.** Minimum impacts on Connecticut's monitors from the Flint Hills fires using the Q/d method. Distance (d) was based on the Groton monitor and the calculation used a fuel loading of 2 tons/acre.

| Fire | Burn Days | Acreage Burned | Average Daily Acreage | Ehc (tons/day) | rHC (tons/day) | Enox (tons/day) | Q (tons/day) | d (km) | Q/d (tons/day/km) |
|---|---|---|---|---|---|---|---|---|---|
| Flint Hills | April 9 - 12 | 273304 | 68326 | 1639.82 | 983.89 | 273.30 | 1257.20 | 2086 | 0.60 |

While the Q/d from the distant Flint Hills exceeds any of the nearby fires, it is also well below the EPA threshold of 100 tons/day/km for establishing clear causality.[62]

Notably, the Flint Hills fires alone approximate the Q/d determined for the Fort McMurray fire which was approved for concurrence and had a Q/d of 0.69 tpd/km.[63] Additionally, the nearby fires collectively exceed the Q/d for the Fort McMurray fire.

[62] EPA guidance for prescribed fires, while otherwise similar to its wildfire guidance, does not require a Q/d analysis. We nevertheless include it here for completeness of the comparison.
[63] CT DEEP's Fort McMurray Exceptional Events Demonstration.

## 5.2 Emissions Impact on the June 30-July 1 Event

Determining the emissions-to-distance ratio (Q/d) for the June 30-July 1 event is done following the same procedures as described above. Burn data is obtained from the Canadian Wildfire Information Website as indicated in Table 5-3.

**Table 5-3.** Cumulative and increase in daily burn area of Quebec fires in hectares. Source: cba2023.csv at *https://cwfis.cfs.nrcan.gc.ca/downloads/hotspots*

| Quebec, Canada Wildfire Burn Area | | |
|---|---|---|
| Date | Cumulative hectares burned for season | Daily increase in hectares burned |
| 6/27/2023 | 2,900,939 | 4,623 |
| 6/28/2023 | 2,964,162 | 63,223 |
| 6/29/2023 | 3,029,372 | 65,210 |
| 6/30/2023 | 3,072,102 | 42,730 |
| 7/01/2023 | 3,113,536 | 41,434 |

To be conservative, we consider the June 27$^{th}$ burn area increase, 4,623 hectares (11,424 acres) for Quebec. Using the equations from the prior section we obtain Ehc=(24*10*11,424)/2000=1371 tons of HC emitted that day. For rHC, we have .6*1371=822 tons rHC emitted from Quebec fires on the 27$^{th}$ of June.

Similarly, Enox = (4*10*11,424)/2000 = 228 tons of NOx emitted on June 27.

Thus, Q=822+228=1050 tons of reactive hydrocarbons and nitrogen oxides emitted from the increased acreage burned in Quebec on June 27$^{th}$.

The distance from Quebec (an area just south of Lake Mistassini) to Connecticut's furthest monitor, Groton, is approximately 1000km.

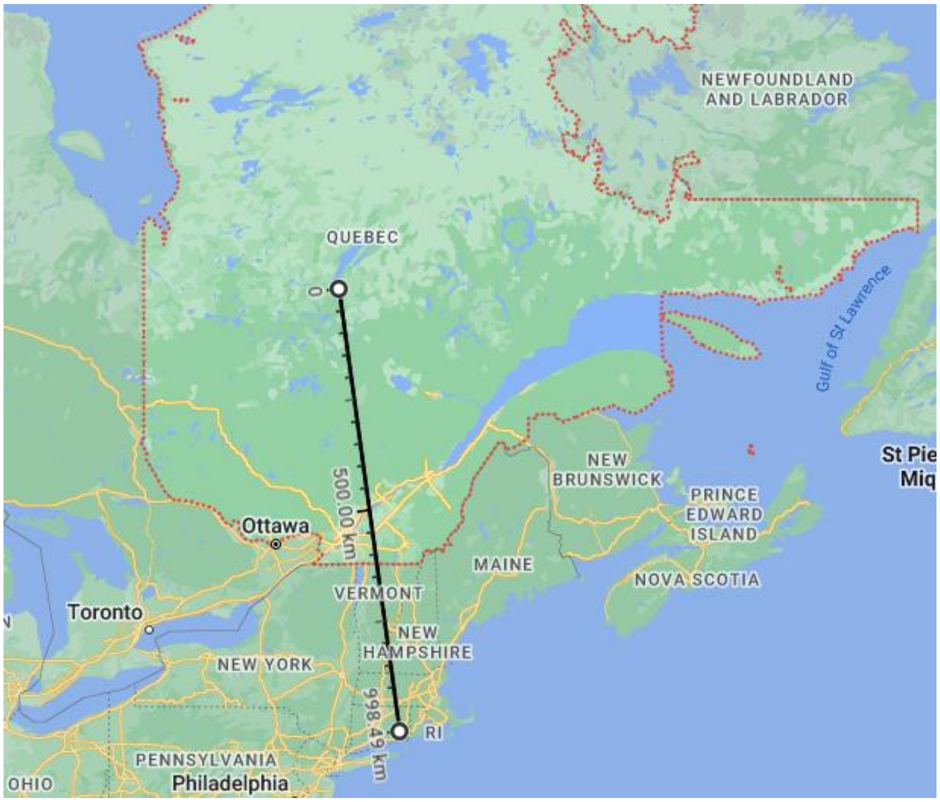



**Figure 5-4.** Map showing approximate distance from Quebec fires to the Groton monitor using google maps.

Therefore Q/d is approximately 1050 tons/1000 km on June 27th, or 1.05 tons/day/km, well short of EPA's 100 ton/day/km threshold. Nevertheless, this value is -- as with the April 13-14 event -- in excess of the Q/d determined by the same process for the Fort McMurray fire. Furthermore, the increased acreage burned in Quebec on the 28th was more than 13 times the acreage increase on the 27th and would result in a Q/d greater than 13 tons/day/km from the increase in acreage burned on that day.

## 5.3 Emissions Impact on the July 12 Event

Determining the emissions to distance ratio (Q/d) for the July 12 event is again conducted following the same procedures used for the prior two events. Burn data is obtained from the [Canadian Wildfire Information Website.](https://cwfis.cfs.nrcan.gc.ca)

**Table 5-4.** Cumulative and increase in daily burn area of Western Canadian fires in hectares. Source: cba2023.csv at *https://cwfis.cfs.nrcan.gc.ca/downloads/hotspots*

| Alberta, Canada Wildfire Burn Area | | |
|---|---|---|
| Date | Cumulative hectares burned for season | Daily increase in hectares burned |
| 7/06/2023 | 1,767,601 | 21,220 |
| 7/07/2023 | 1,779,810 | 12,209 |
| 7/08/2023 | 1,810,131 | 30,321 |
| 7/09/2023 | 1,858,262 | 48,131 |
| 7/10/2023 | 1,878,408 | 20,146 |
| 7/11/2023 | 1,892,974 | 14,566 |
| 7/12/2023 | 1,938,838 | 45,864 |

To be conservative, we consider the July 7$^{th}$ burn area increase, 12,209 hectares (30,169 acres) burned in Alberta. Using the equations from the prior section we obtain Ehc=(24*10*30,169)/2000=3620 tons of HC emitted that day. For rHC,we have .6*3620=2172 tons rHC emitted from increased acreage burned in Alberta fires on the 7$^{th}$ of July.

Similarly, Enox = (4*10*30,169)/2000 = 603 tons of NOx emitted.

Thus, Q=2172+603=2775 tons of reactive hydrocarbons and nitrogen oxides emitted as a result of the increase in acreage burned in Alberta on July 7$^{th}$.

The distance from Alberta (midway of the southern edge of MacKenzie County) to Connecticut's furthest monitor, Groton, is approximately 3515km.

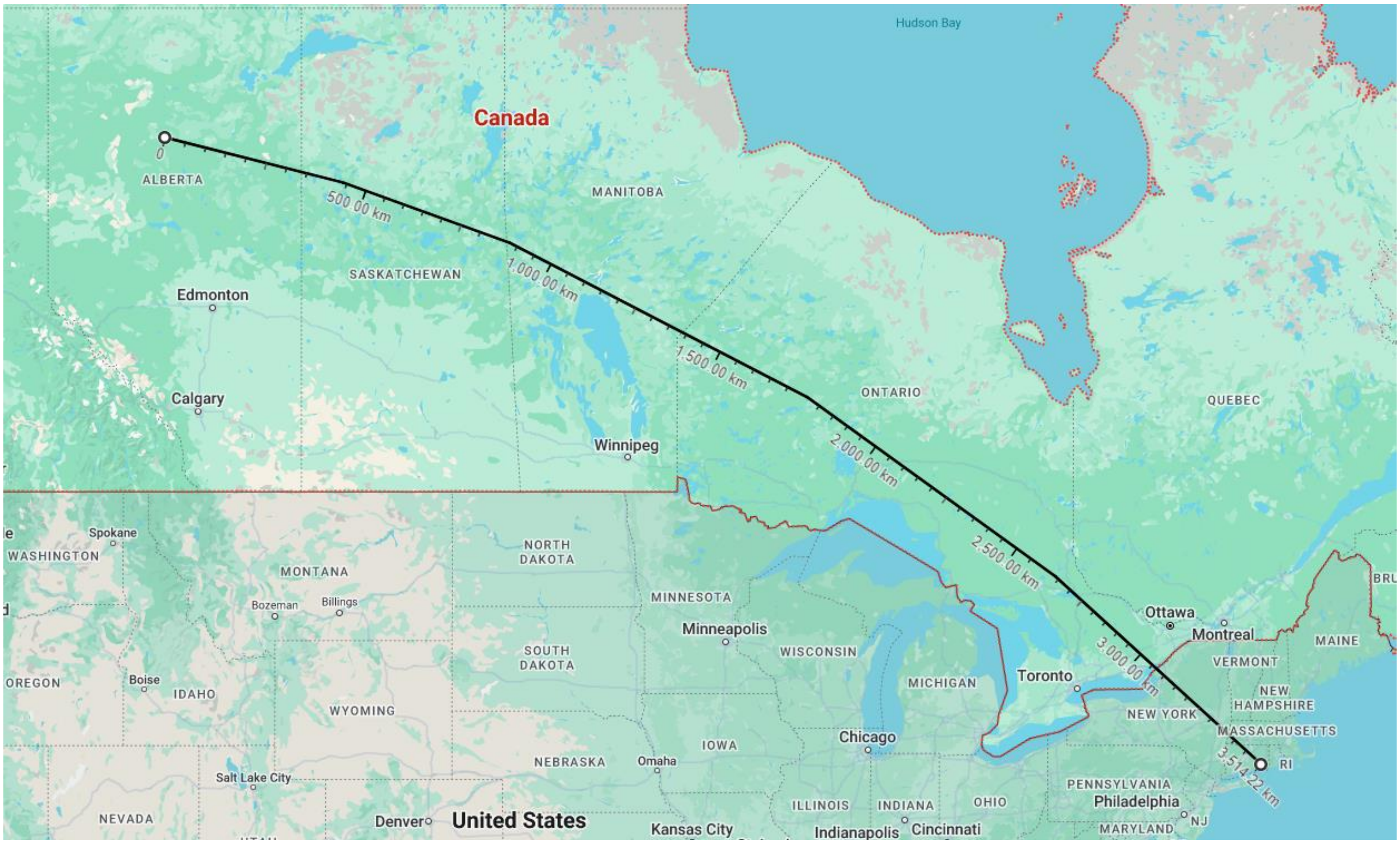


**Figure 5-5.** Map showing approximate distance from Alberta fires to the Groton monitor using google maps.

Therefore Q/d is approximately 2775 tons/3515 km, or 0.79 tons/day/km, well short of EPA's 100 ton/day/km threshold. Nevertheless, this value is -- as with the prior two events discussed -- in excess of the Q/d determined by the same process for the Fort McMurray fire. Furthermore, the increase in acreage burned in Alberta on the 9th was approximately four times the increased acreage burned on the 7th and would result in a Q/d greater than 3 tons/day/km.

## 5.4 Summary of Potential Emissions Impacts

The Q/d approach is intended to be a simple method to show that a fire has an effect on a monitor. EPA established the 100 ton/day/km threshold for establishing clear causality through analysis of four fires. Since development of that guidance, additional fire analyses have been conducted. Exceptional event demonstrations for these fires have resulted in EPA concurrence with Q/d values far less than the originally proposed 100 ton/day/km threshold.[64] We have shown that each of these events resulted in a Q/d greater than the Q/d of 0.69 tons/day/km

[64] As of this writing, none of the fires approved for concurrence by EPA under the 2016 wildfire guidance for ozone exceptional events approached the 100 tpd/km threshold. See https://www.epa.gov/air-quality-analysis/exceptional-events-submissions-table-2016-rule for a list of events. Generally, the reported Q/d values were less than 5 tpd/km.

determined for the 2016 Fort McMurray fire which was ultimately recognized as having causality.[65]

For the nearby fires for the April 13-14 event, it is reasonable to consider the direct emissions in comparison to ozone season day emissions. Emissions from the nearby fires totaled approximately and 62 tons of nitrogen oxides and 371 tons of hydrocarbons, 223 tons of which were reactive. These emissions exceed the total daily emissions from Greater Connecticut. Furthermore, single day emissions from just the Kanouse fire in New Jersey resulted in 14 tons of nitrogen oxides and 52 tons of reactive hydrocarbons. These emissions exceed the total anthropogenic NOx and VOC emissions in Greater Connecticut for most source categories as shown in Table 5-5.

**Table 5-5**. Summary of Anthropogenic NOx and VOC emissions in the Greater Connecticut area for a 2017 ozone season day.

| Source Category | Ozone Season Day NOx (tons/ozone season day) | Ozone Season Day VOC (tons/ozone season day) |
|---|---|---|
| Stationary Point | 6.8 | 1.4 |
| Stationary Area | 10.4 | 42.4 |
| On-Road Mobile | 22.2 | 15.9 |
| Non-Road Mobile | 11.1 | 15.6 |
| Total Anthropogenic | 50.5 | 75.3 |

Source: Estimates of 2017 emissions are based on EPA's 2017 inventory except for on-road mobile emissions which are from CTDOT's Air Quality Conformity Determination.

Table 5-5 also provides context for understanding just how conservative EPA's 100 tpd/km threshold is. If the entire total daily anthropogenic emissions from Greater Connecticut for either VOC or NOx were moved to within 1 kilometer of a monitor, the emissions would not be considered to have clear causal impact on ozone at that monitor using the recommended threshold.

While the Q/d guidance threshold of 100 tpd/km is highly conservative, these fires are comparable to other fires that were shown to cause exceptional events and the emissions from these fires are likely to have caused excess ozone production in Connecticut. Nevertheless, we present additional evidence showing that these fires caused elevated ozone levels in Connecticut.

[65] CT DEEP's Fort McMurray Exceptional Events Demonstration.

# 6 Ozone and Particulate Air Quality Levels in Connecticut and Recent Trends

DEEP has been monitoring ambient ozone levels throughout the state since the early 1970s. The current ozone network consists of twelve sites within the overall monitoring network. In addition to ozone monitoring, Connecticut implements an enhanced monitoring plan for ozone, which includes monitoring of nitrogen oxides and other parameters to help assess the causes of ozone exceedances in Connecticut.

## 6.1 Monitoring Network

**Network Overview:** DEEP currently operates 14 air monitoring stations in its state-wide network. These include two national core multi-pollutant sites: Criscuolo Park in New Haven, and Mohawk Mountain in Cornwall. In addition, EPA operates an ozone site in Abington, in the town of Pomfret, as part of the *Clean Air Status and Trends Network*. Table 6-1 provides a summary of pollutant and meteorological parameters currently monitored in the network.

The DEEP air monitoring network meets the minimum monitoring requirements for criteria pollutants as put forth in Title 40 Part 58 of the Code of Federal Regulations (CFR), Appendix D. More detailed descriptions of the monitoring network are provided in the Connecticut 2023 Annual Air Monitoring Network Plan and the Connecticut 2020 Air Monitoring Network Assessment.

**Table 6-1.** List of Connecticut ambient air monitoring sites and parameters recorded.

| Town | Site | PM2.5 (FRM) | PM2.5 (FRM, Collocated) | PM2.5 (Continuous - FEM) | PM2.5 (Continuous – FEM, secondary) | PM10/PM10-2.5 (FRM) | PM10/PM10-2.5 (FRM, Collocated) | PM10/PM10-2.5 (Cont. FEM) | PM10/PM10-2.5 (Cont. FEM,2ndry) | PM Speciation (CSN) | PM Speciation (IMPROVE) | PM2.5 Carbon (BC/UVC, Continuous) | Ozone | SO2 | CO | $NO_2$ | NO/NOy | HCHO (continuous) | Total Column NO2/HCHO | Traffic Count | Wind Speed | Wind Direction | Temperature | Dew Point / Rel. Humidity | Barometric Pressure | Solar Radiation | Mixing Height |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Bridgeport | Roosevelt School | | 1/6 | X | | | | X | | | | | | X | | | | | | | | | X | | | | |
| Cornwall | Mohawk Mountain | 1/3 | | X | | | | | | | 1/3 | X | X | X | X | | X | | X | | X | X | X | X | X | X | |
| Danbury | Western Connecticut State University | 1/6 | | X | | | | | | | | X | X | | | | | | | | X | X | X | | X | | |
| East Hartford | McAuliffe Park | | | X | | | | X | | | | X | X | | | X | | | | | X | X | X | X | X | | |
| Greenwich | Point Park | | | | | | | | | | | | X | | | | | | | | X | X | X | | | | |
| Groton | Fort Griswold | | | X | | | | | | | | | X | | | | | | | | | | X | | | | |
| Hartford | Huntley Place | 1/6 | | X | | | | X | | | | X | | | X | X | | | | X | X | X | X | | X | | |
| Madison | Hammonasset State Park | | | | | | | | | | | | X | | | | | | X | | X | X | X | | | | |
| Middletown | Connecticut Valley Hospital | | | | | | | | | | | | X | | | | | | | | X | X | X | | X | | |
| New Haven | Criscuolo Park | 1/3 | 1/6 | X | X | 1/3 | 1/6 | | | 1/3 | | X | X | X | X | X | X | | X | | X | X | X | X | X | X | X |
| **Pomfret** | **Abington (EPA)** | | | | | | | | | | | | **X** | | | | | | | | | | | | | | |
| Stafford | Shenipsit State Forest | | | | | | | | | | | | X | | | | | | | | X | X | X | | | | |
| Stratford | Stratford Lighthouse | | | | | | | | | | | | X | | | | | | | | | | X | | | | |
| Waterbury | Bank Street | | | X | | | | | | | | | | | | | | | | | X | X | X | | | | |
| Westport | Sherwood Island State Park | | | | | | | | | | | | X | | | X | | P | X | | X | X | X | | X | | X |

1/3=1 in 3 day sampling schedule    1/6=1 in 6 day sampling schedule    P=Tentatively Planned in 2024/2025

Ozone is monitored in Connecticut at 12 sites, 11 DEEP sites and 1 EPA site, as shown in Figure 11. As of 2017, the ozone monitoring season is March 1 through September 30; previously it was April 1 through September 30. Three sites, Cornwall, New Haven and East Hartford, monitor ozone year-round. This exceptional event demonstration is focused on two of those sites, Cornwall and East Hartford, as well as the monitor in Groton (Fort Griswold) which operates only from March through September. These three sites are described in greater detail below with an emphasis on ozone and wind direction.

Seasonal and event specific ozone wind roses shown in Figure 6-2 through Figure 6-4 were constructed for the period of April 1, 2023, through September 30, 2023, for each of the three sites from which we are requesting the data exclusion. These ozone wind roses are constructed by matching hourly averaged wind vectors to hourly monitored ozone concentrations (ppb). Hours with average wind speeds less than 0.50 m/s, or with missing ozone data, were not plotted. These ozone wind roses show the prevailing wind directions divided into 16 sectors around a compass circle, with due north at the top. The longer ‘petals’ of the rose represent sectors where the wind direction is more prominent. Overlaid on these petals are color bars representing specific ranges of ozone concentrations for each wind direction sector. The wind patterns at each site differ based on geographical differences, as such, only limited conclusions can be obtained from these surface wind observations in relation to ozone concentrations. Moreover, for the Groton site, there is no collocated wind data, so data from the similarly situated coastal Madison site, 25 miles to the west was used. For Cornwall and East Hartford, ozone wind roses were included for the July 1st event, while Groton has all five event days included.

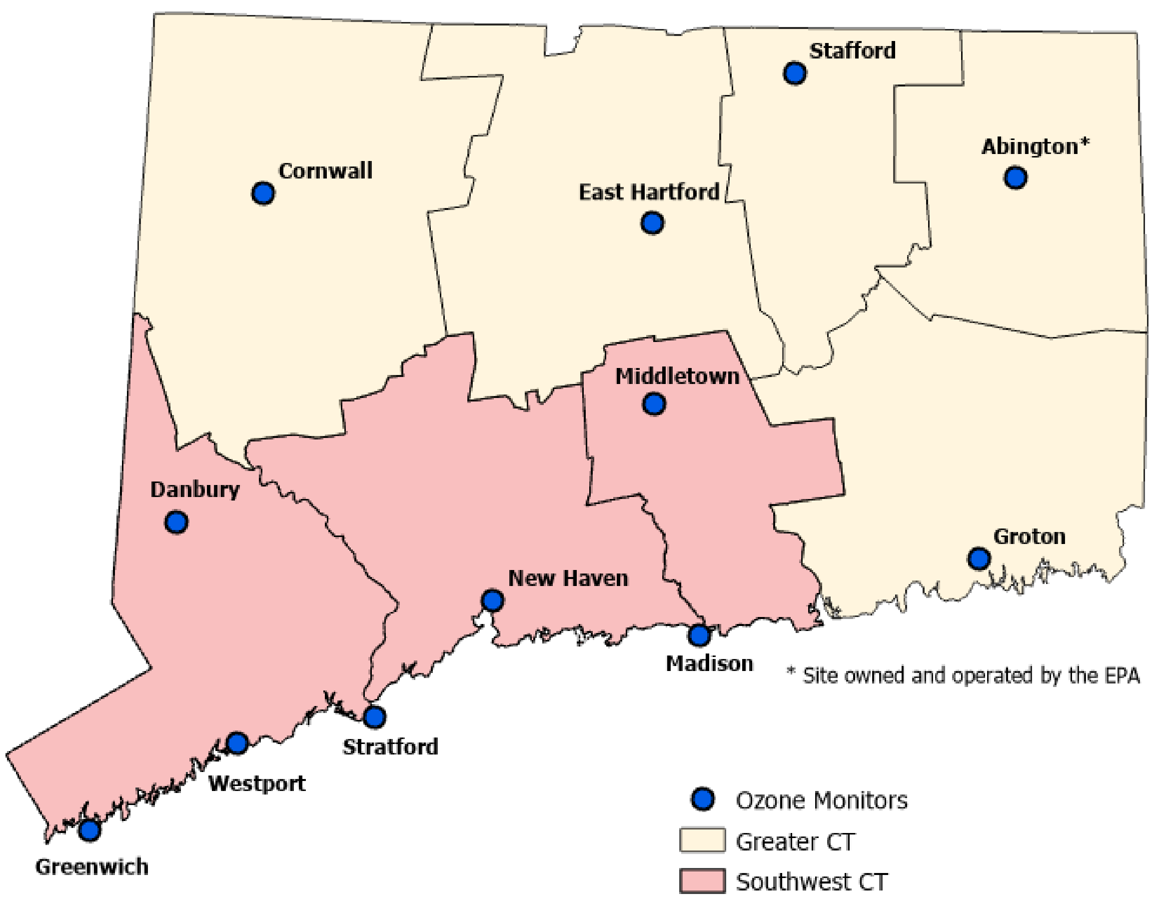



**Figure 6-1.** Connecticut ozone monitors and their locations in the Greater Connecticut and Southwest Connecticut nonattainment areas.

**Cornwall (Mohawk Mountain): AQS ID: 09-005-0005; Lat: 41.82140°, Lon: -73.29733°.**
The Mohawk Mountain site is a regional-scale site located in northwestern Connecticut in the town of Cornwall. The site is located at the summit of Mohawk Mountain with an elevation of 505 m (1656 ft) and is approximately 17 km to the east of the New York border and 25 km to the south of the Massachusetts border. Figure 6-2 shows the dominant wind direction from the north-northwest, which shows the influence of the low-pressure system which transported the smoke from the Quebec fires during much of the early summer of 2023. The highest ozone concentrations of 70-85 ppb (orange color bar) are shown to occur when the wind is blowing from the south, which is generally expected when there is transport from New York City area. Moderate levels of ozone (55-70 ppb) are shown to occur in the northwest, southwest and southeast quadrants, and the most frequent direction for good air quality (<55 ppb) occurs when the wind blows from the north-northwest. The July 1st image (right), during the Quebec fire ozone event, shows high ozone from the southern direction as the smoke was recirculated from the south.

**East Hartford (McAuliffe Park): AQS ID: 09-003-1003; Lat: 42.78471°; Lon: -72.63158°.**
The McAuliffe Park site is neighborhood-scale site located in central Connecticut in the town of East Hartford. The site is located approximately 120 m to the east of Route 5, 2.0 km to the east of I-91 and 2.5 km to the south of I-291. This site is located 3.7 km to the northeast of the city of Hartford. Residential neighborhoods are located in all directions from this site. Since the East Hartford site is located in the Connecticut River Valley, the dominant wind directions are typically oriented from the southerly or northerly directions, depending on the weather pattern, as reflected in Figure 6-3. The highest ozone concentrations, represented in the orange and red color bars, are plainly visible as coming from the south and south-southwest wind directions, however elevated ozone occasionally is channeled from the northerly directions. The majority of low ozone concentrations occur when the wind blows from the north. The July 1st image (right), during the Quebec fire ozone event, shows high ozone from the south and south-southwest direction as the smoke was recirculated from the south.

**Groton (Fort Griswold): AQS ID: 09-011-0124; Lat; 41.35348°; Lon; -72.07886°.**
The Fort Griswold site is a neighborhood-scale site located in southeastern Connecticut in the town of Groton. This site is located approximately 1.1 km to the south of I-95 and 0.5 km to the east of New London Harbor. Residential neighborhoods are located in all directions around this site. The highest ozone concentrations, represented in the orange and red color bars, generally coincide with winds from the southwest to southeast quadrants, indicative of a sea-breeze circulation during the warmer months, as shown in Figure 6-4 (upper left). Moderate ozone a ppears in the westerly, southerly to easterly directions and the lowest ozone concentrations occur when the wind blows from the east and northeast. Note that the strong north-northwest wind direction component, as evident in the inland sites, does not appear at Groton because of the sea breeze influence.

The April 13-14 images, during the pre-season ozone event, shows high ozone from the west and southwest which is consistent with the back trajectories shown later in section 8.1. The ozone wind roses for June 30-July 1 show a strong south to southeasterly component both days, as the Quebec wildfire smoke that pushed to the mid-Atlantic states was transported back north by the Atlantic southerlies. The July 12th wind rose shows the highest ozone concentration occurring in the south to southeasterly directions. This is not a typical wind direction for high ozone concentrations off the ocean, so a low-level back trajectory analysis was done ending at 4:00pm to confirm this wind direction. As described in section 9 of this document, smoke from the northwest Canadian wildfires was transported southeast in advance of a frontal system. These low-level trajectories pass north of NYC before turning north into southeast coastal Connecticut. This is further evidence that emissions from the NYC urban area were not the main contributor to the monitored ozone levels at Groton.

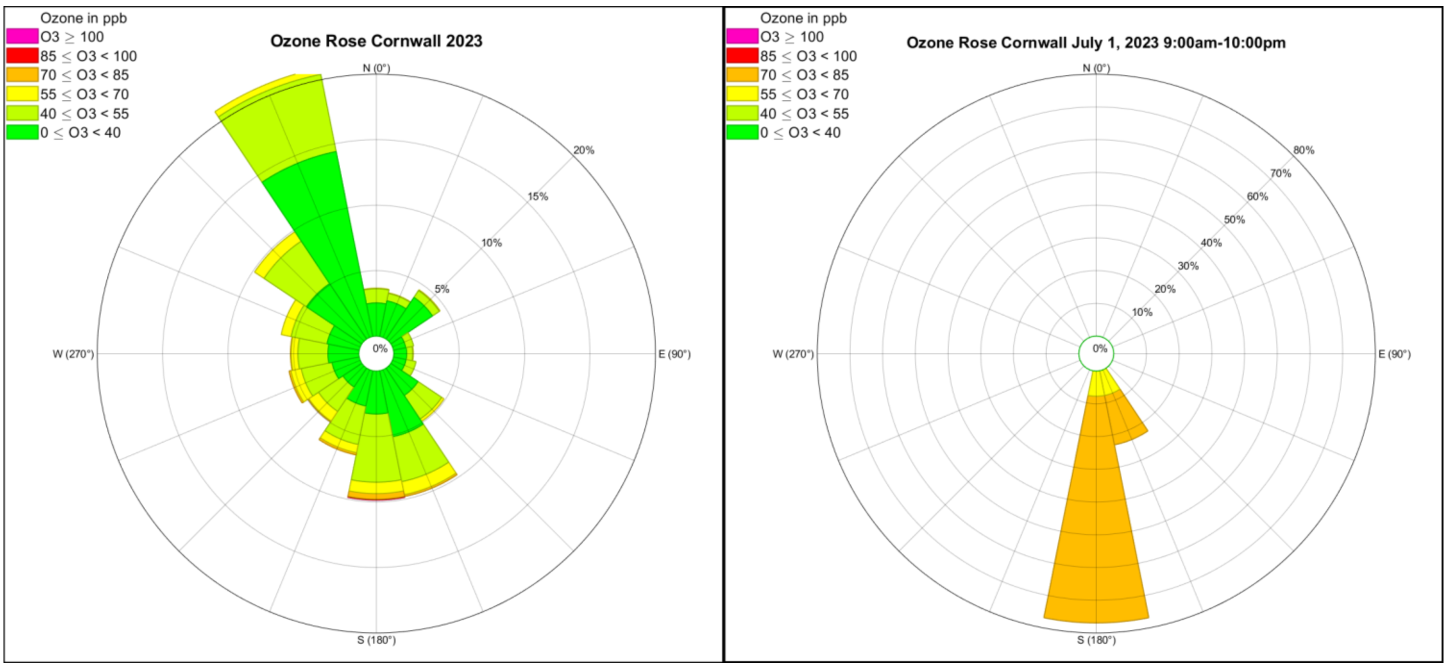



**Figure 6-2.** Ozone wind rose Cornwall, with image for July 1st, during Quebec fire event.

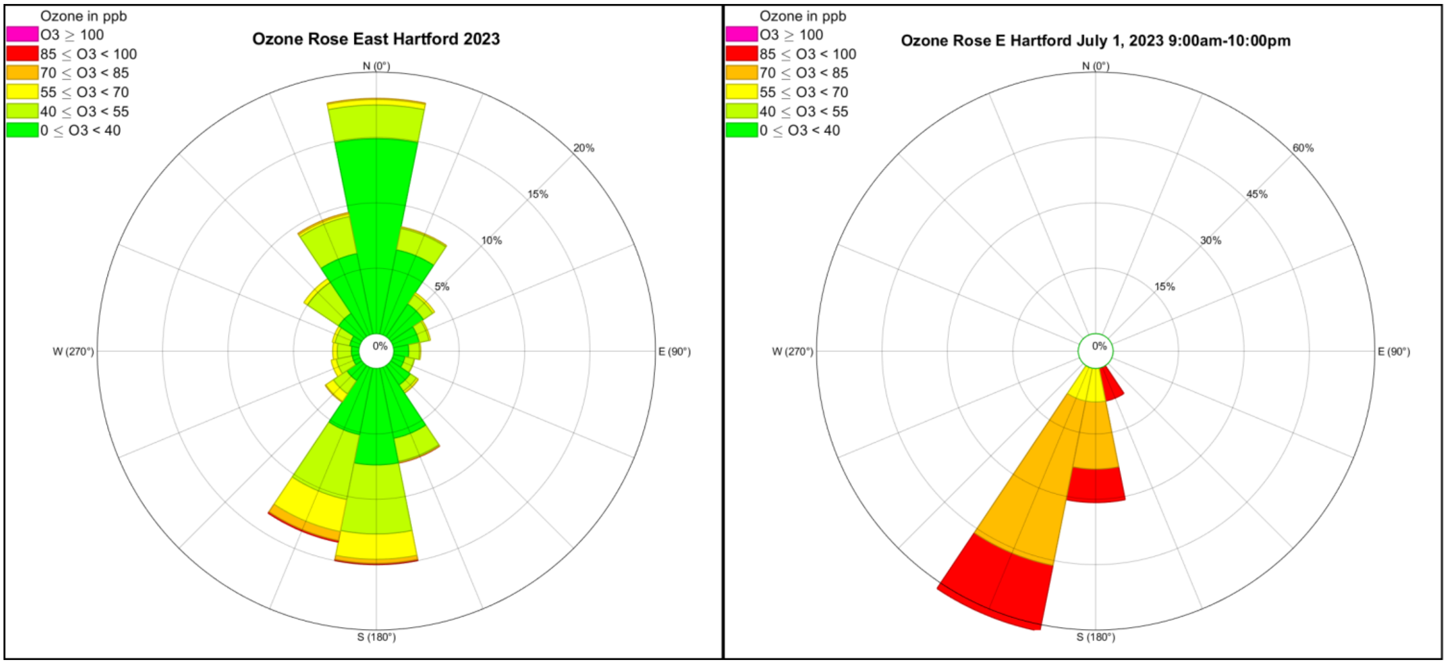



**Figure 6-3.** Ozone wind rose for East Hartford, with image for July 1st, showing the effect of recirculation during Quebec fire event.

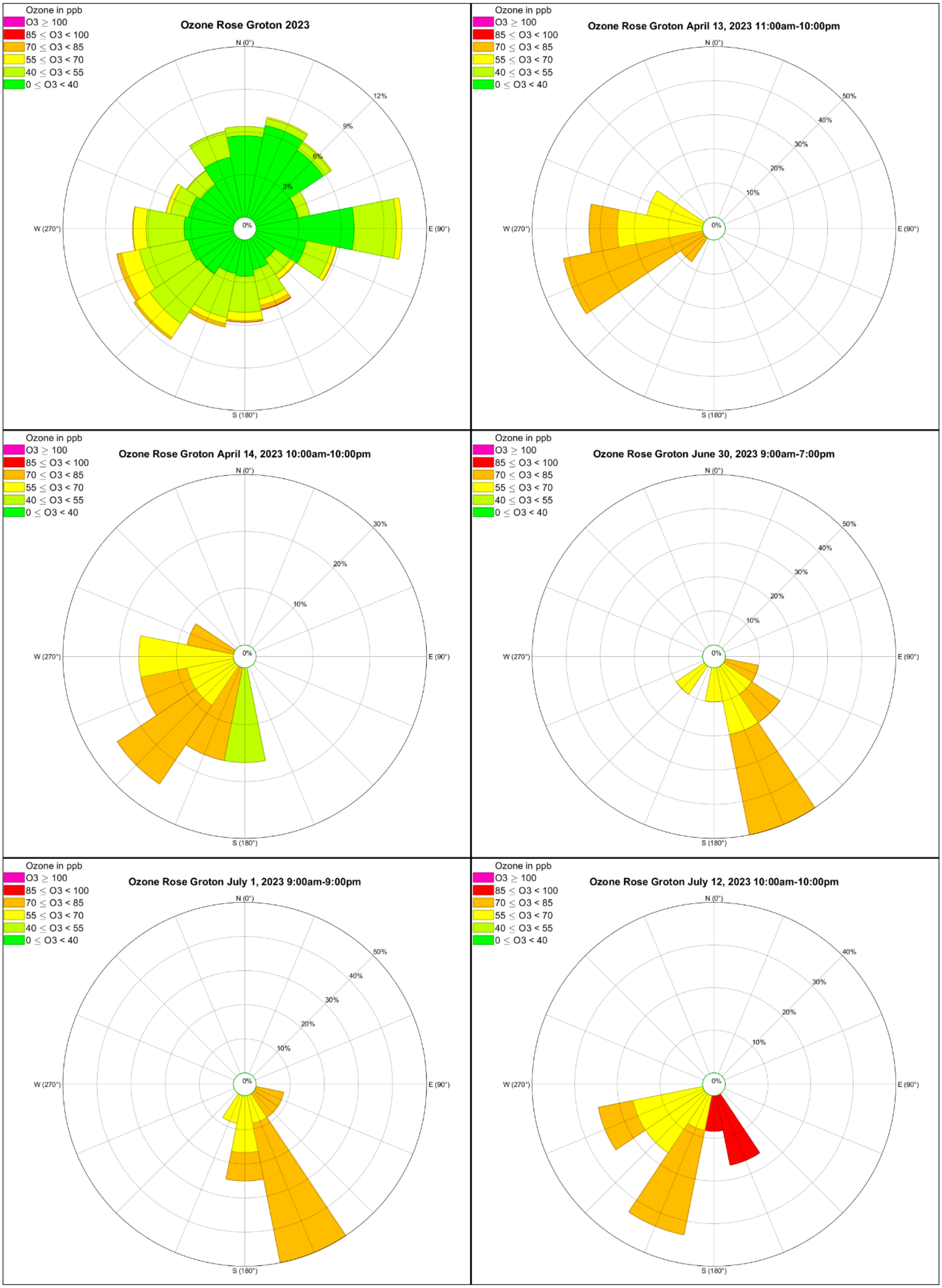



**Figure 6-4.** Ozone wind rose for Groton, with daily images for April 13-14, June 30-July 1 and July 12.

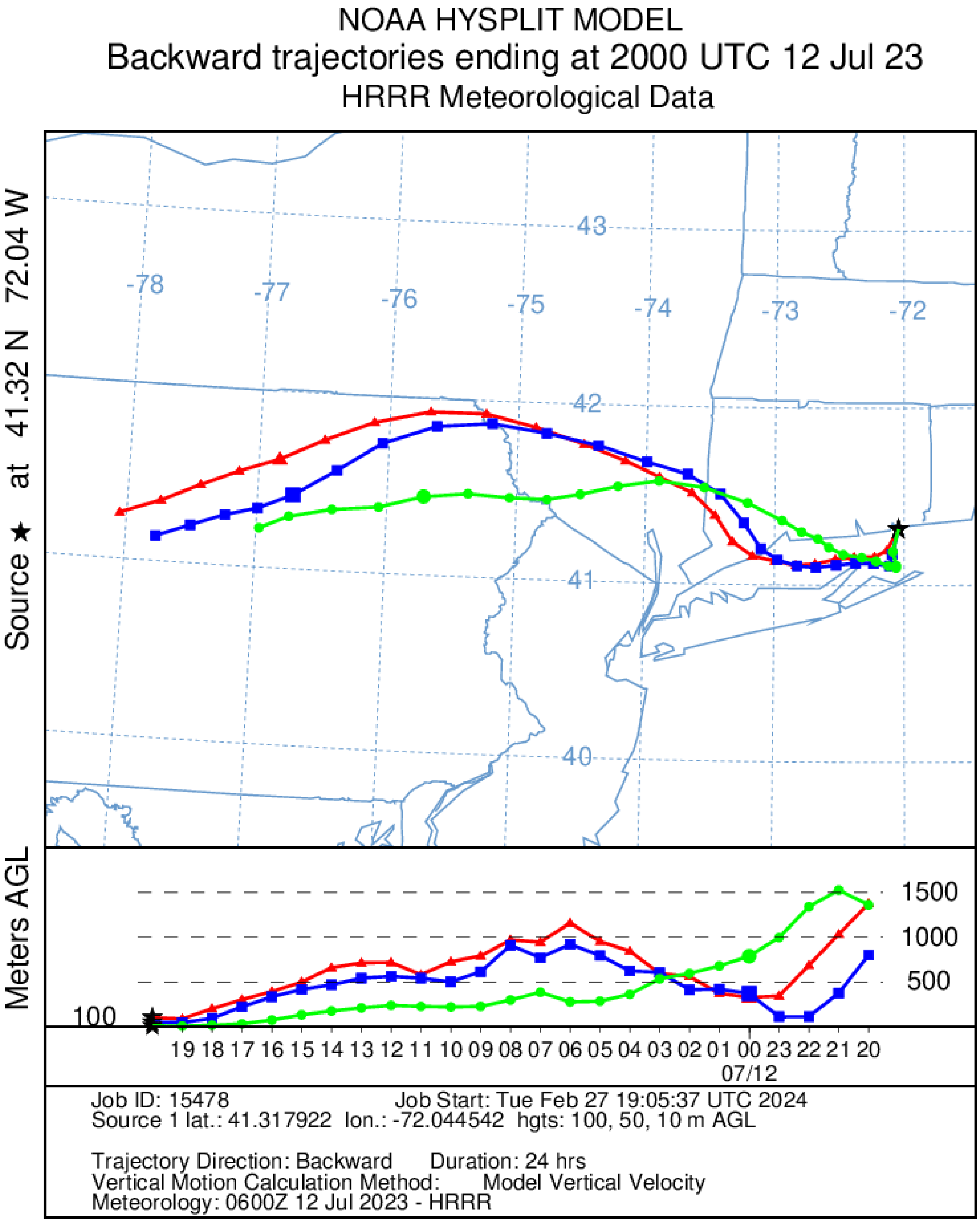



**Figure 6-5.** Low-level back trajectories for July 12 confirming northward turn of the winds.

## 6.2 Site Specific Ozone Outlier Analyses

EPA guidance suggests that for each monitor requested for data exclusion, a 5-year percentile of the data on a per monitor basis be determined. If the flagged data is above the $99^{th}$ or higher percentile of the 5-year distribution of ozone monitoring data, or is one of the four highest ozone concentrations within 1 year, these data can be considered outliers and provide strong evidence for the event.

The following table shows the maximum 8-hour daily ozone levels observed at the three sites on the days being considered compared with the $99^{th}$ percentile ranked 8-hour ozone levels observed during the last five years. The ozone levels at Cornwall and East Hartford exceeded the $99^{th}$ percentile on July $1^{st}$ by 10 and 9 ppb, respectively. Groton reached the $99^{th}$ percentile on one day during each of the two-day events and exceeded it on the single day event, July $12^{th}$, by 5 ppb.

While the Groton site did not exceed the $99^{th}$ percentile on one day of each of the two-day events, i.e. April 14 and June 30, substantial exceedances at the Cornwall and East Hartford sites on those date further illustrate the unusual nature of those event days.

**Table 6-2:** Maximum 8-hour average ozone concentrations on the days of interest (shaded yellow) along with each site's $99^{th}$ Percentile over the past five ozone seasons (2019-2023). Values at or above the $99^{th}$ percentile are shown in red.

| 2023 Maximum Daily 8-Hour Ozone ppb and five year $99^{th}$ Percentile. | | | | | | |
|---|---|---|---|---|---|---|
| **Site** | **April 13** | **April 14** | **June 30** | **July 1** | **July 12** | **99th Percentile** |
| Cornwall | 67 | **82** | **78** | **79** | 57 | **69** |
| East Hartford | 67 | **84** | **73** | **82** | 64 | **73** |
| Groton | **76** | 73 | 70 | **76** | **81** | **76** |

To further illustrate the outlier status of the events, Figure 6-6 through Figure 6-8 show the ranked percentile 8-hour ozone observations at each site with five years of ozone season data.

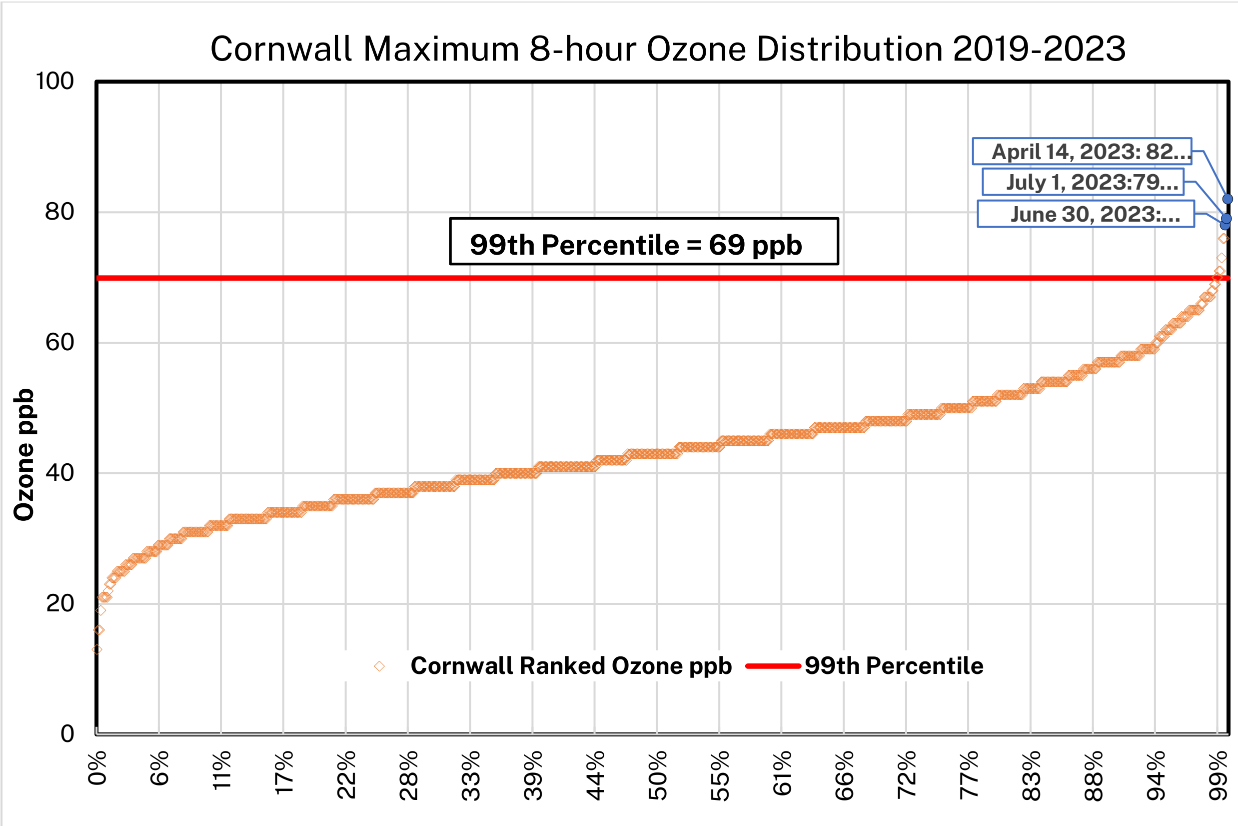



**Figure 6-6.** Ranked maximum daily average 8-hour ozone distribution for the Cornwall monitor (2019-2023).

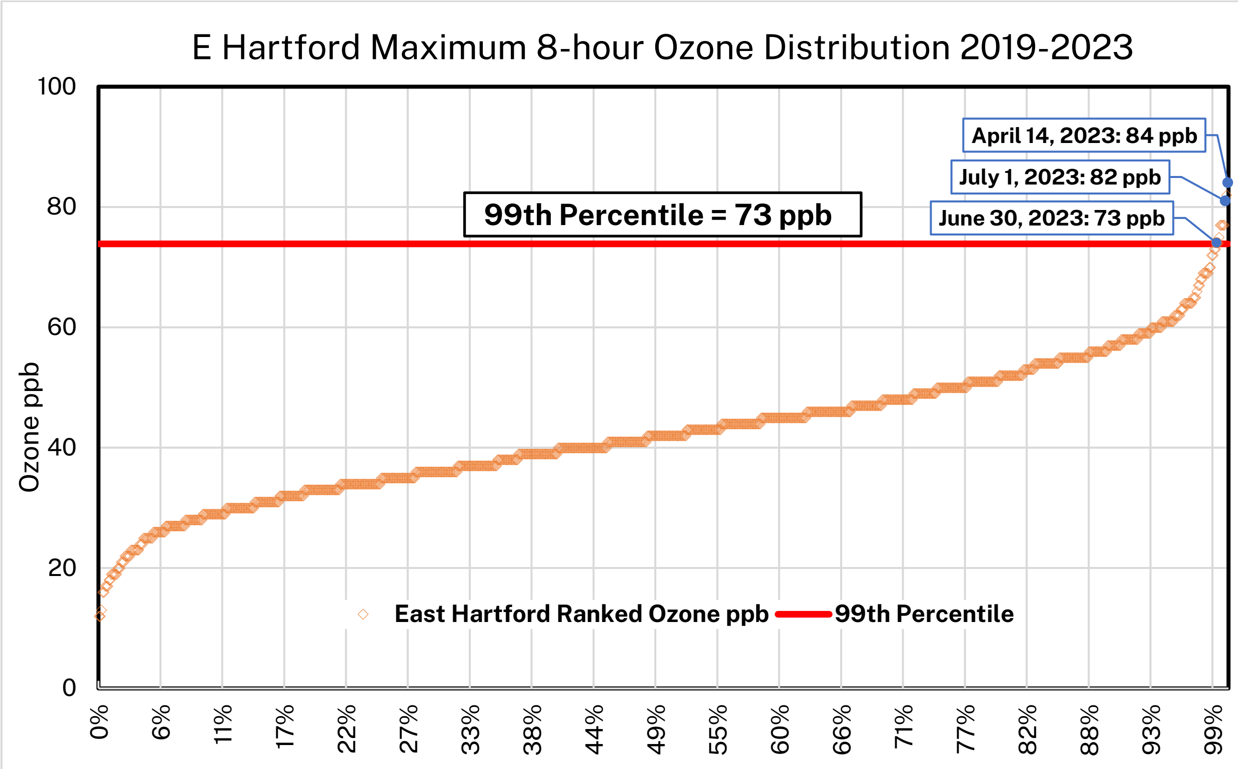



**Figure 6-7.** Ranked maximum daily average 8-hour ozone distribution for the East Hartford monitor (2019-2023).

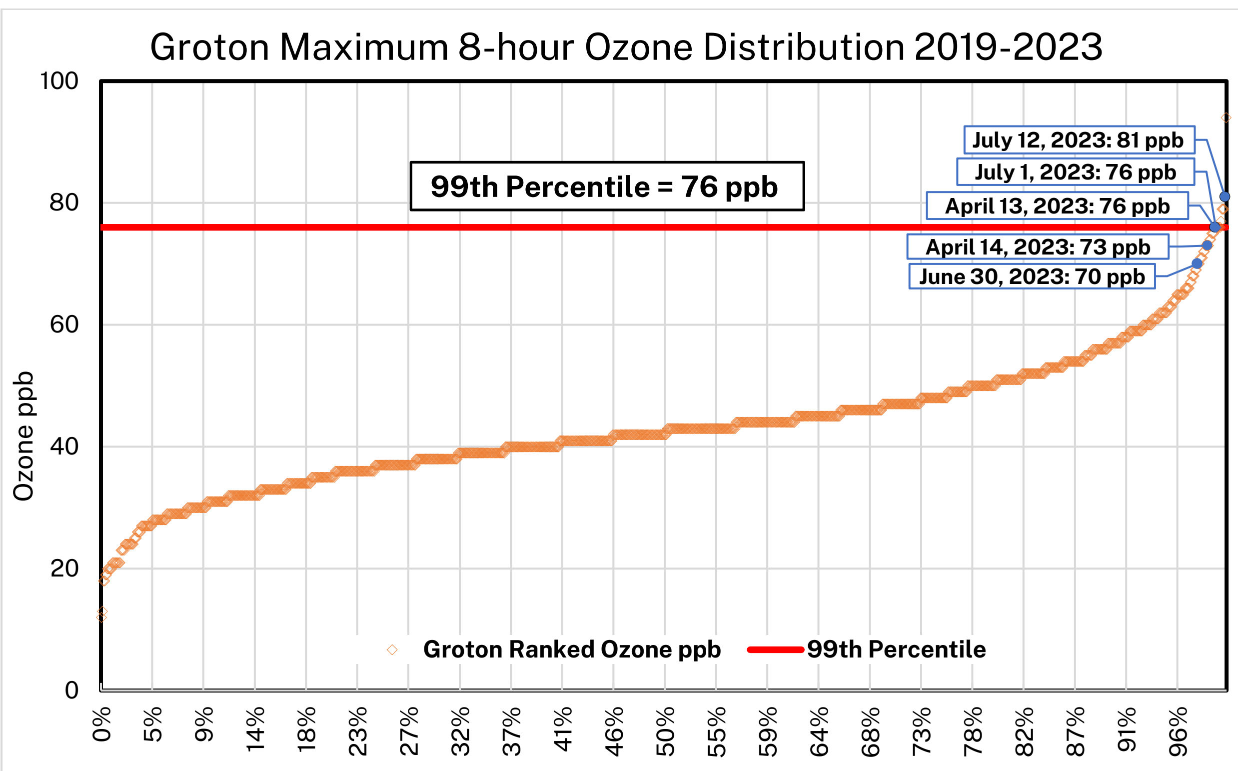



**Figure 6-8.** Ranked maximum daily average 8-hour ozone distribution for the Groton monitor (2019-2023).

Figure 6-9 through Figure 6-11 show plots of daily maximum ozone values for each of the three monitors of interest in Connecticut using five years of data. The 8-hour ozone concentrations for the events have been circled and the percentile rankings have been labeled next to those data points. June 1, 2023, highlighted in the Cornwall figure, was a day that was influenced by smoke, but is not being pursued as an exceptional event. Also, while April 13 and June 30 of 2023 at Groton do not reach the 99th percentile they are at the 98.5 and 97.6 percentiles, respectively.

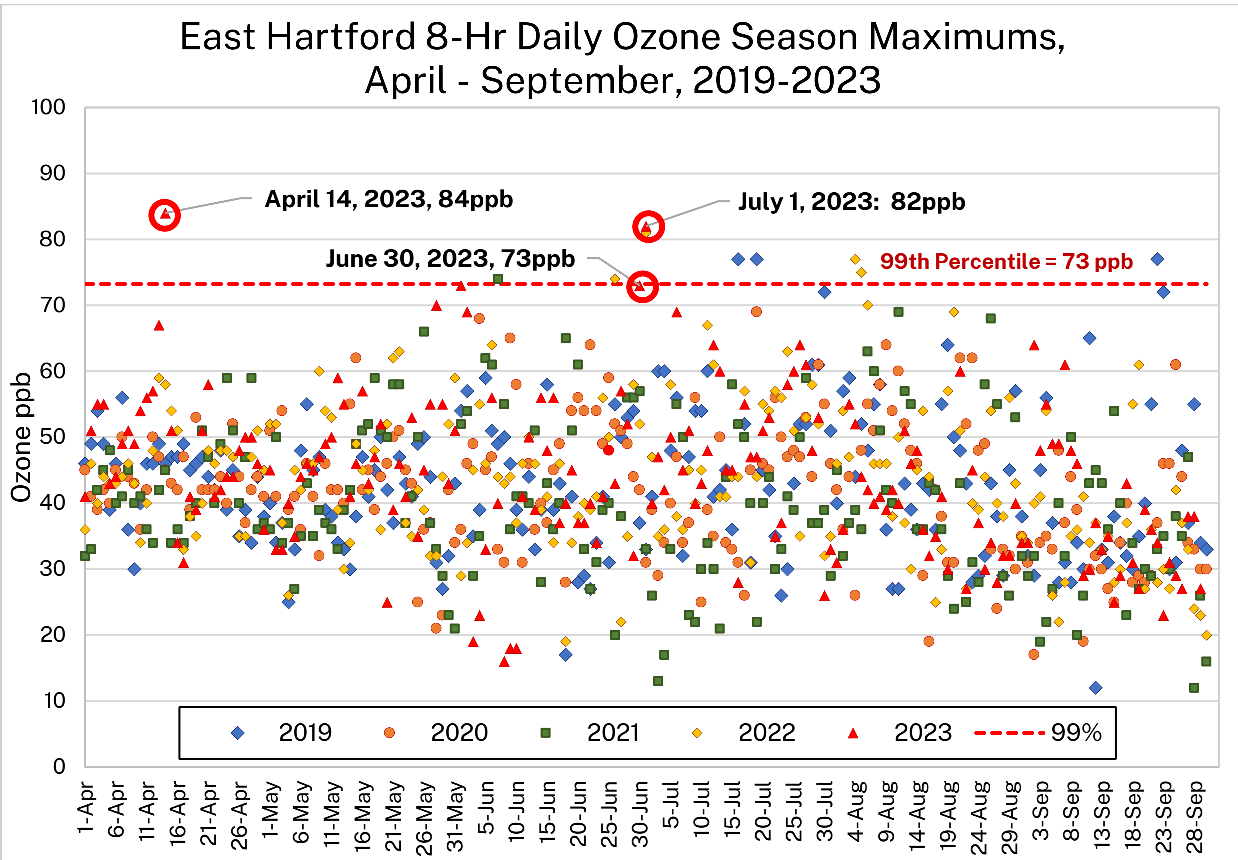



**Figure 6-9.** East Hartford daily ozone maximums, 2019-2023

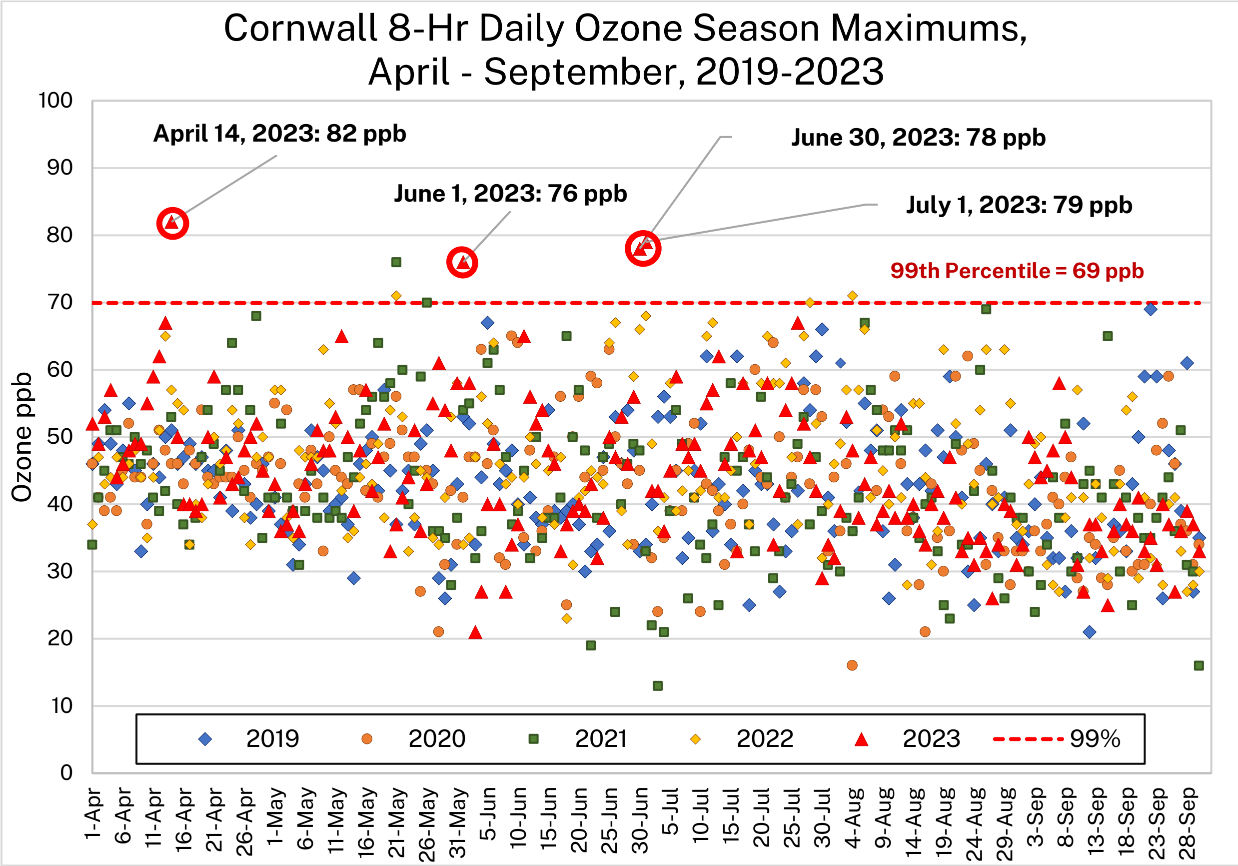



**Figure 6-10.** Cornwall daily ozone maximums, 2019-2023

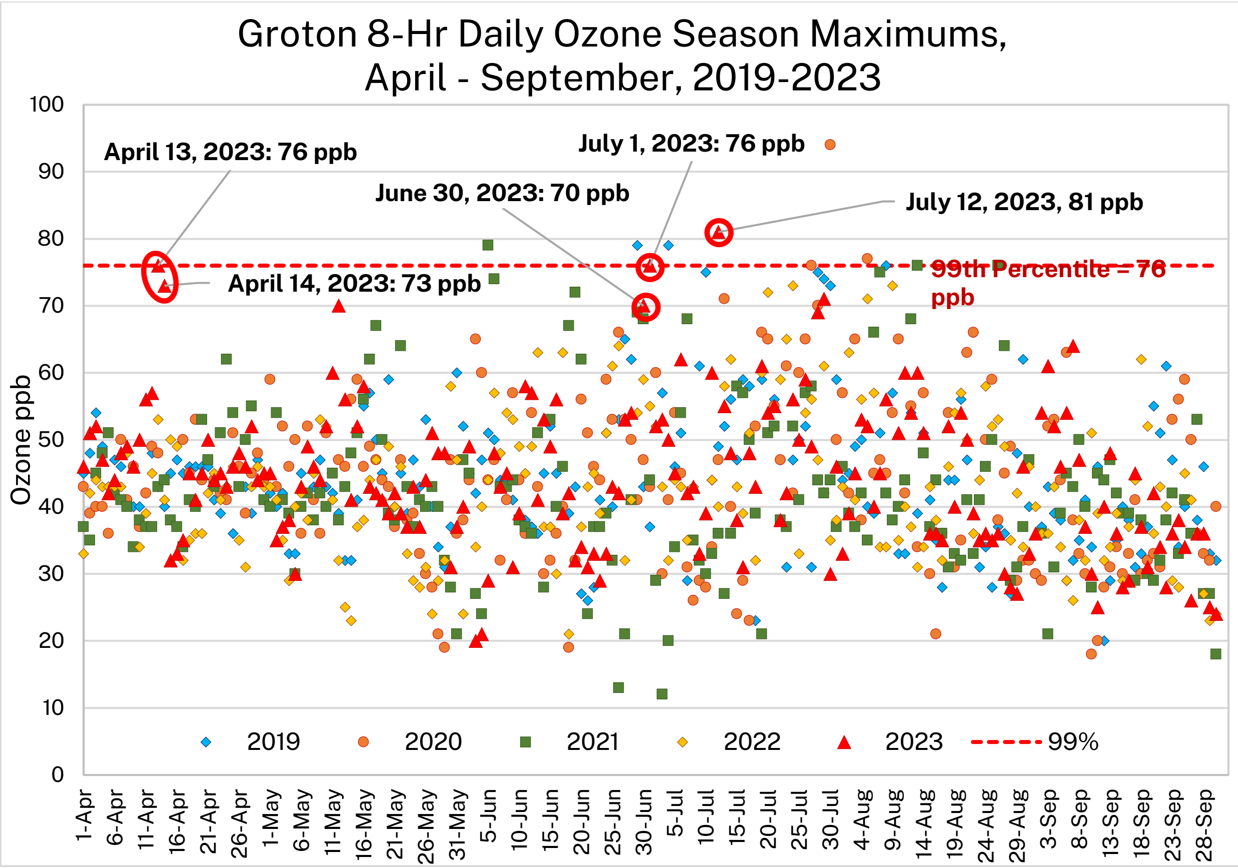



**Figure 6-11.** Groton daily ozone maximums, 2019-2023

## 6.3 Trends in Fine Particulate Matter (PM2.5)

Particulate pollution is commonly emitted from combustion related sources. Particulate Matter less than 2.5 micrometers in size, also known as fine particulate or PM2.5, is one of the main pollutants emitted by fires. Though a small fraction of coarser particulate is emitted from wildfires, coarse particulate is more likely to originate from mechanical and agricultural sources.[66] PM2.5 variability is heavily influenced by intermittent sources such as fires and monitored levels will reflect the intensity of surface level smoke.

Figure 6-12 shows the maximum PM2.5 value across Connecticut for each day from April 1 through September 30 from 2017 through 2023. Record setting peak PM2.5 levels stand out in 2023. Additionally, multiple temporally localized peaks in 2023 are also some of the highest for the past seven years, particularly around the ozone event days of April 13 – 14, June 30 – July 1, and July 12 but also including June 1, June 6-8, June 11-12, and July 17-19, and September 30. During the heaviest PM2.5 event in 2023, June 6-8, the smoke was too thick for significant ozone production to occur at the surface, featuring primarily good ozone levels with a few sites

[66] https://www.epa.gov/wildfire-smoke-course/why-wildfire-smoke-health-concern

reaching low moderate AQI levels. The severity and abundance of these PM2.5 spikes in Figure 6-12 show the exceptional nature of the 2023 season. Peaks in July of 2021 also stand out as extreme and were attributed to smoke from western wildfires.[67] Ozone levels surrounding the 2021 PM2.5 spikes were categorized as good but rose to the moderate to unhealthy levels while the smoke was present. At the beginning of July in 2018, there were also elevated PM2.5 levels associated with a smoke plume. Ozone exceeded levels of the standard for multiple monitor sites across the state, and even reached unhealthy AQI levels at Danbury.[68]

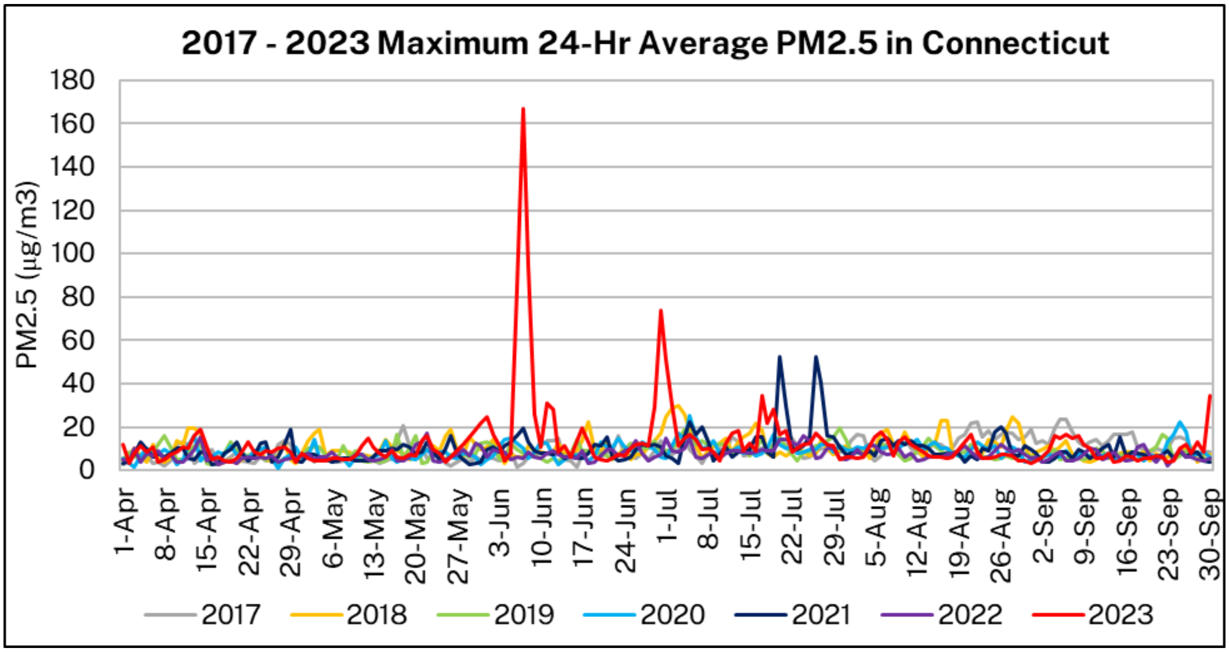



**Figure 6-12.** Variation in maximum daily average PM2.5 concentrations in Connecticut for April through September from 2017 through 2023.

To better show the exceptional nature of PM2.5 levels in 2023, Figure 6-13 shows a zoomed in view of the ozone events and compares 2023 with the multi-year, 2017 – 2023, average. For the April 13-14 event, particulate levels reached nearly 20 µg/m$^3$ while levels in this timeframe for other years are generally nearer to 10 µg/m$^3$. April 12-13, 2018 levels match 2023 levels and can be attributed through back trajectories to fires in the southeastern states.[69] The June 30 – July 1, 2023 event stands out as unusual for the timeframe and, peaking out at twice the level of the 24-hour particulate standard, is compelling evidence for smoke at surface levels. While the July 12, 2023, event shows the lowest particulate levels, it too is several µg/m$^3$ above the levels for the timeframe when compared to recent years.

[67] https://portal.ct.gov/-/media/DEEP/air/SIPRAC/2021/August/1---Recent-Wildfire-Smoke-Event-Impacting-CT.pdf
[68] https://portal.ct.gov/-/media/DEEP/air/SIPRAC/2018/CT2018OzoneSummarySampdf.pdf
[69] DEEP analysis. Levels of ozone were also elevated to marginal during this event: see https://portal.ct.gov/-/media/DEEP/air/ozone/Monthly_Ozone_Tables/2018Monthly8hourOzonepdf.pdf.

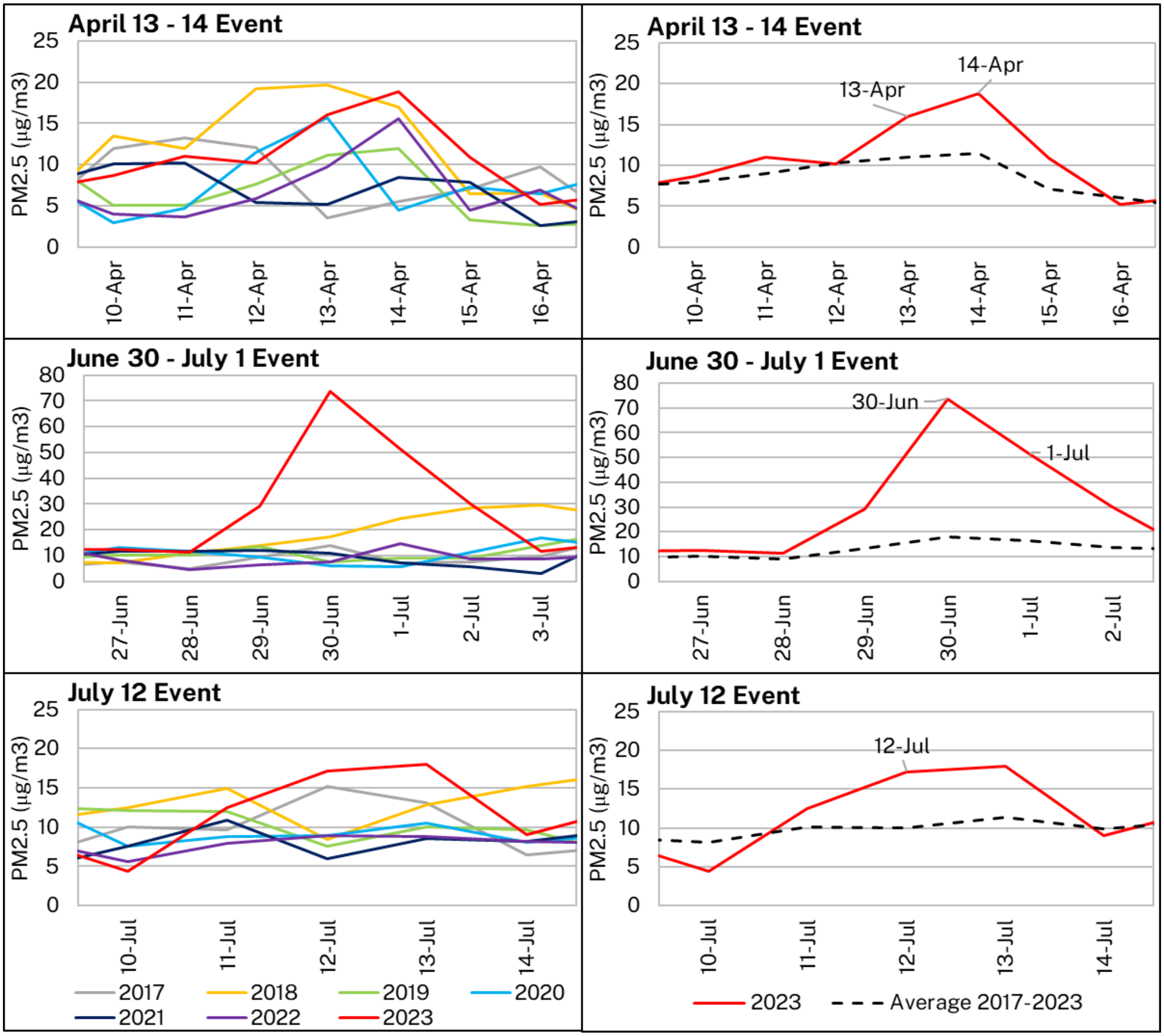



**Figure 6-13.** Variation in maximum daily average PM2.5 concentrations in Connecticut surrounding the April 13-14 Event, June 30 – July 1 Event, and July 12 Event.

Another view of the overall PM2.5 trends includes breaking down the average values by month and year. Figure 6-14 shows monthly average daily maximum statewide PM2.5 concentrations for April-September of 2017 – 2023. In 2023, PM2.5 averages for April and June are the highest amongst the previous seven years of data. The second highest levels occur for May, July, and September. Only in August does the level recede to the average. These levels coincide with the observable smoke persistent throughout much of the 2023 spring and summer in Connecticut.

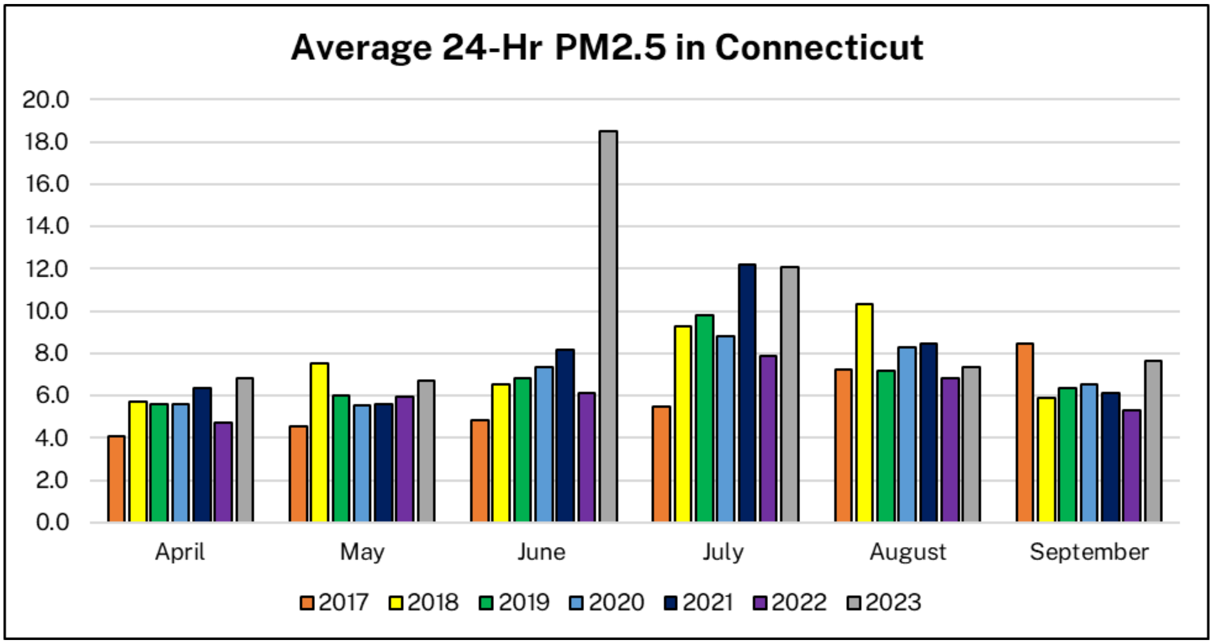



**Figure 6-14.** Monthly average peak daily statewide PM2.5 concentrations for April through September from 2017 to 2023.

Boxplots are an additional form of data analysis which can be used to further investigate the monthly PM2.5 trends throughout the past seven years. The box plots below show hourly PM2.5 levels for April to September from 2017 to 2023, with a horizontal dashed line representing the 2023 median value. The monthly median PM2.5 concentrations for April, June, and July –months for the events-- are all highest in 2023. Additionally, April, June, and July 2023 all have a median line that is above the box, i.e., 75 percent of the data, for 2022. A key difference between these years is that 2023 is the year with the greatest ground level smoke impacts, and 2022 had generally lower than average PM2.5 levels. Even September 2023, another month with smoke impacts at the surface, features this similar pattern.

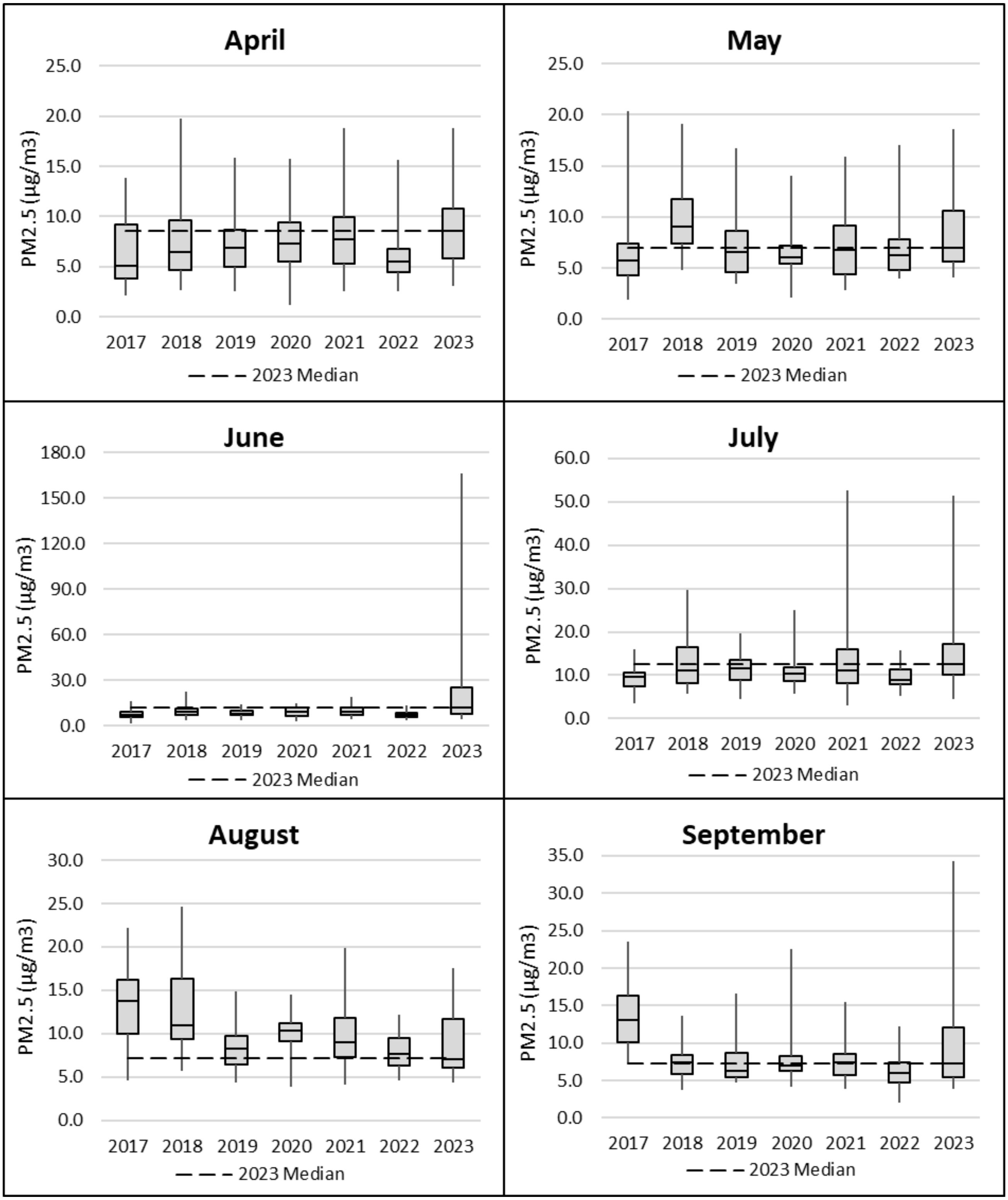



**Figure 6-15.** Average PM2.5 monthly boxplots for 2017-2023.

Therefore, monthly averages and monthly boxplots show unusually high PM2.5 levels at the surface during the 2023 ozone season that occurred primarily in April, June, and July and, to a lesser extent, in September. Daily data show that higher particulate levels occurred during the three events selected for consideration for exclusion under the exceptional events rule, April 13-14, June 30-July 1, and July 12, 2023.

## 6.4 Hourly Ozone and Particulate Levels During the Events at Monitors of Concern

Fine Particulate Matter (PM2.5) showed an upward trend along with ozone in the period up to and during each of the events. This trend would be expected when a smoke plume interacts with the surface.

### Hourly Ozone and PM2.5 Levels during the April 13-14 Event

Figure 6-17 shows the hourly ozone concentrations for the three monitors from April 9-16, 2023. Ozone levels from April 9-12 are fairly typical for the month of April but show a slight upward trend. Overnight levels at the Cornwall monitor, which is atop Mohawk Mountain, remain high leading up to the event. There is little diurnal variation on the $12^{th}$ at any of the three sites with overnight levels nearly 30 ppb higher than the previous night's levels. This is typically indicative of transport. Levels spike on the $13^{th}$ and $14^{th}$ and then decrease to pre-event levels by April $15^{th}$. A cleaner air mass dominates Connecticut as winds shift due to the frontal passage. The rise in ozone levels up through the event, followed by the sudden drop-off on the $15^{th}$, mirrors the trend in hourly particulate for the same time period as presented in Figure 6-16 for all three sites.

Comparing the hourly particulate with the hourly ozone we see Groton particulate peaking in the early morning hours of the $13^{th}$, then dropping slightly for a few hours only to increase through the late afternoon of the $14^{th}$ to a second peak near 20 $\mu g/m^3$ before declining rapidly to the single digits on the $15^{th}$. This rapid decline is also attributed to the wind shift due to the frontal passage moving across Connecticut.

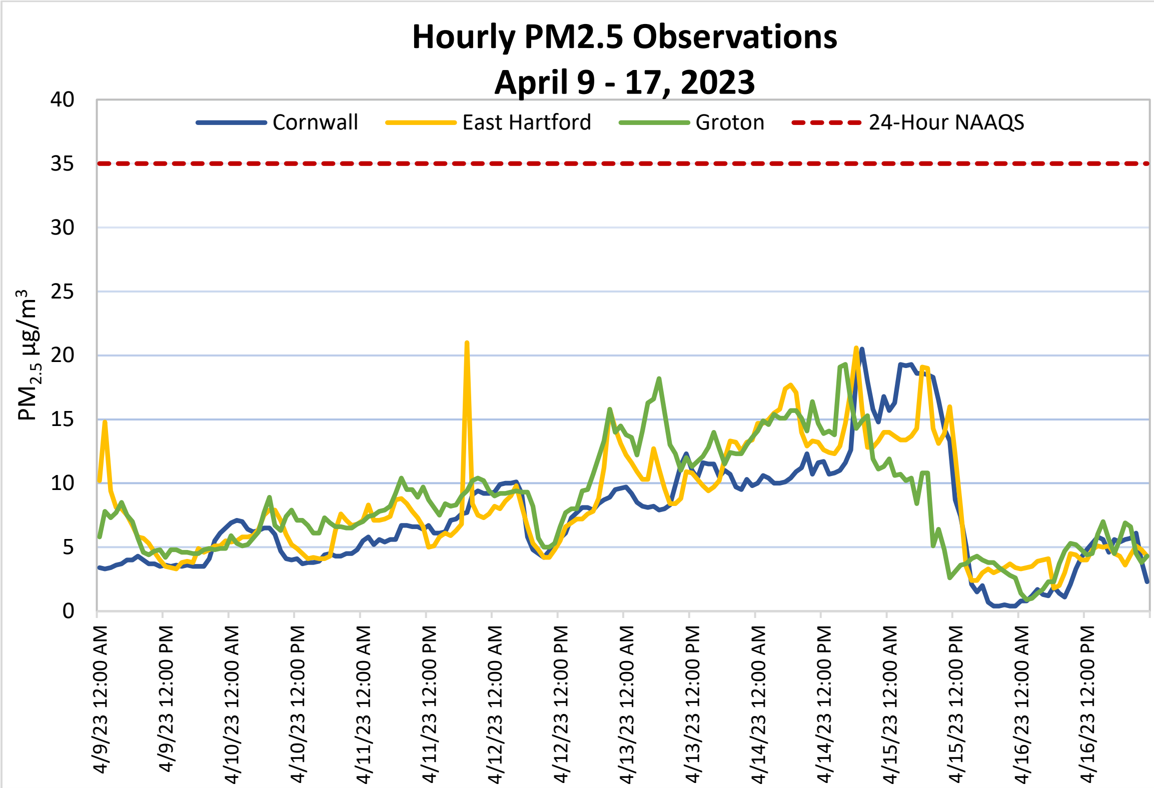



**Figure 6-16.** Hourly PM2.5 concentrations recorded at data exclusion monitors from April 9-17, 2023.

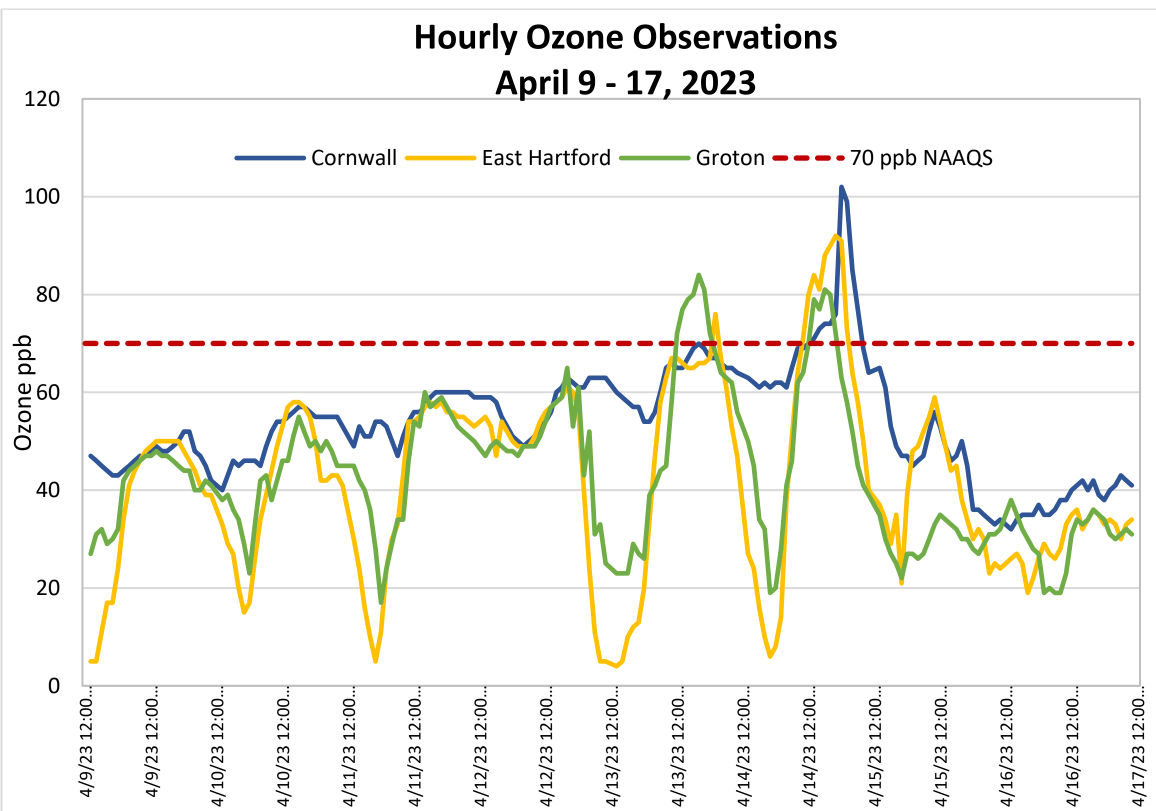



**Figure 6-17.** Hourly ozone concentrations recorded at data exclusion monitors from April 9-17, 2023.

## Hourly Ozone and PM2.5 Levels during the June 30-July 1 Event

Particulate levels at all three sites selected for exclusion for days during the June 30-July 1 event exceed the level of PM2.5 standard on both days. PM2.5 exceedances are rare in Connecticut and levels are typically lower during the summer. Figure 6-18 shows particulate increasing from June 28$^{th}$ and peaking on June 30$^{th}$ first at Cornwall, then East Hartford and later in the day at Groton. The smoke plume recirculates from the Mid-Atlantic region as a frontal system slides across New England and high pressure builds into Connecticut. Concentrations at each of the sites exceed the level of the PM2.5 standard by early morning on June 30$^{th}$ and drop off to more normal levels by July 3$^{rd}$ when the high-pressure system pushes the smoke plume offshore. Levels at the Cornwall monitor peak first and highest, indicating transport to this remote and usually clean site. Also notable is an early peak at Groton on June 28$^{th}$, indicating the plume was present prior to the event.

Ozone levels show a fairly typical summertime diurnal pattern up to and after the event. As seen in Figure 6-19, hourly levels at Groton approach the standard and exceed levels at the other sites on the 28$^{th}$, perhaps due to smoke as indicated by the higher-than-normal particulate measurements at that location that morning. Levels at all sites exceed the standard on June 30$^{th}$ and July 1$^{st}$. Overnight ozone levels during the event remain high, dropping only as low as 50 ppb at the Cornwall site, again indicating transport of pollutants.

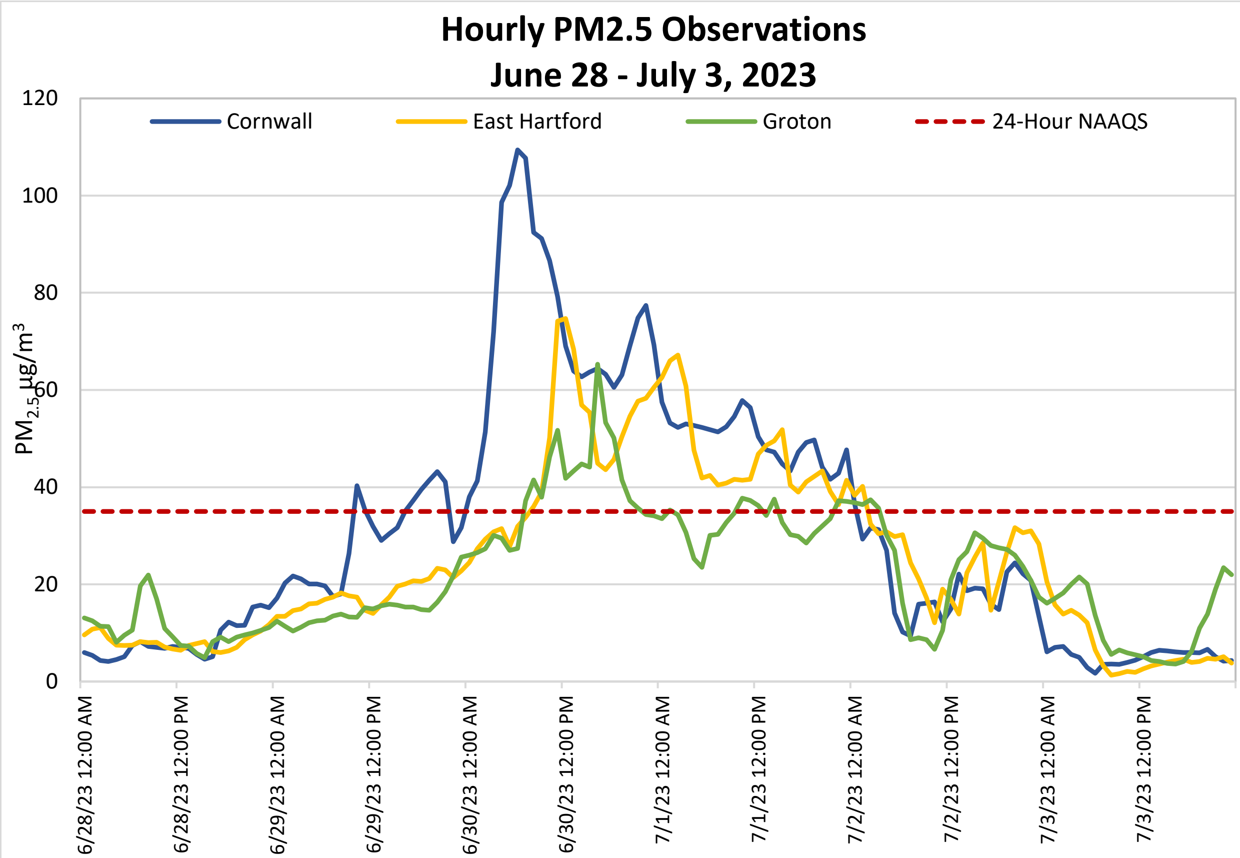



**Figure 6-18.** Hourly PM2.5 concentrations recorded at data exclusion mMonitors from June 28-July3, 2023.

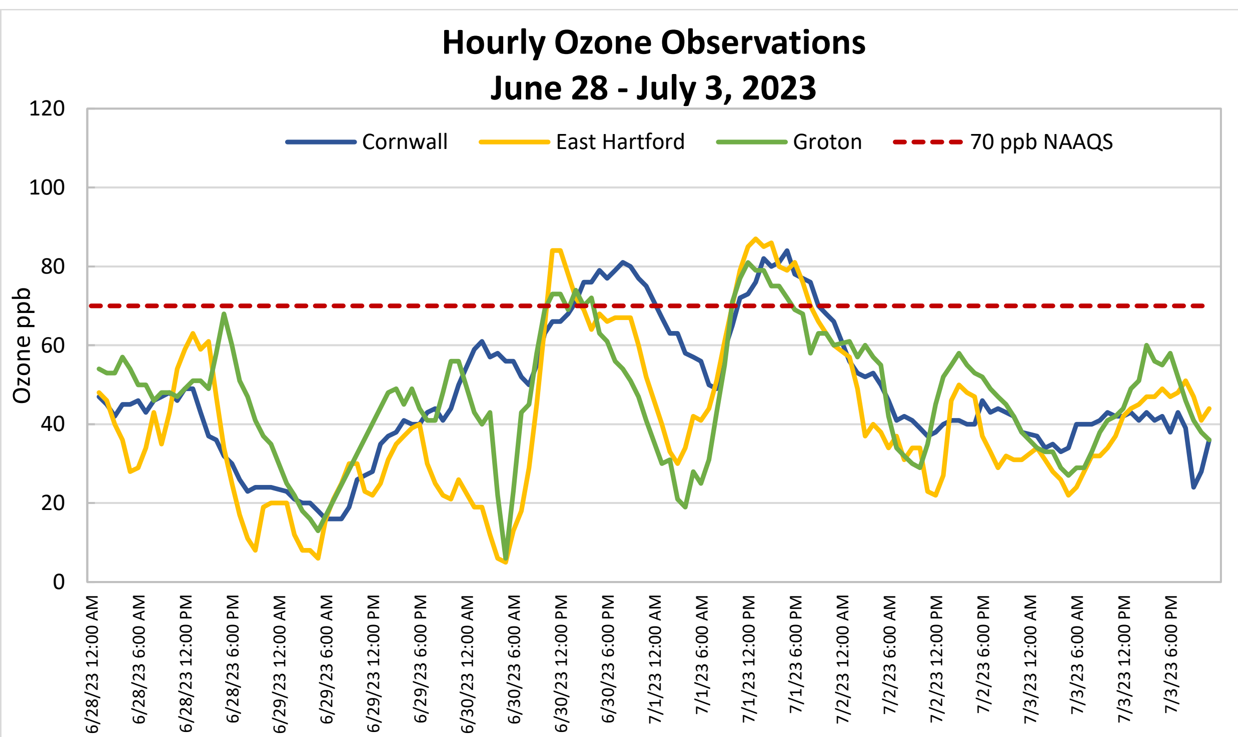



**Figure 6-19.** Hourly ozone concentrations recorded at data exclusion monitors from June 28-July 3, 2023.

## Hourly Ozone and PM2.5 Levels during the July 12 Event

As the smoke event of July 12th affected just the southern half of the State due to cloud cover in the northern half of the State, Figure 6-21 shows an ozone exceedance only at the Groton site. Particulate levels shown in Figure 6-20 show a build up at all three sites through the late evening of the 11th, corresponding with high pressure building into the region, and remaining above normal until dropping sharply late on the 13th when the high-pressure system moves offshore. Overnight ozone halts its decrease at the East Hartford site coincident with a spike in PM2.5, again indicating a strong correlation between ozone and particulate which is attributable to a surface level smoke plume transported across the country by a high-pressure system.

All sites show consistently elevated particulate levels surrounding the July 12th event. PM2.5 levels at Groton increase throughout the morning of the 12th while the other two sites begin decreasing. Ozone and particulate coincidentally peak during the late evening on the 12th at Groton with ozone levels approaching 100 ppb at 5:00pm. Diurnal variation in ozone is very weak between the 12 and 13th at Cornwall with little decrease in overnight levels and daytime levels suppressed by cloud cover.

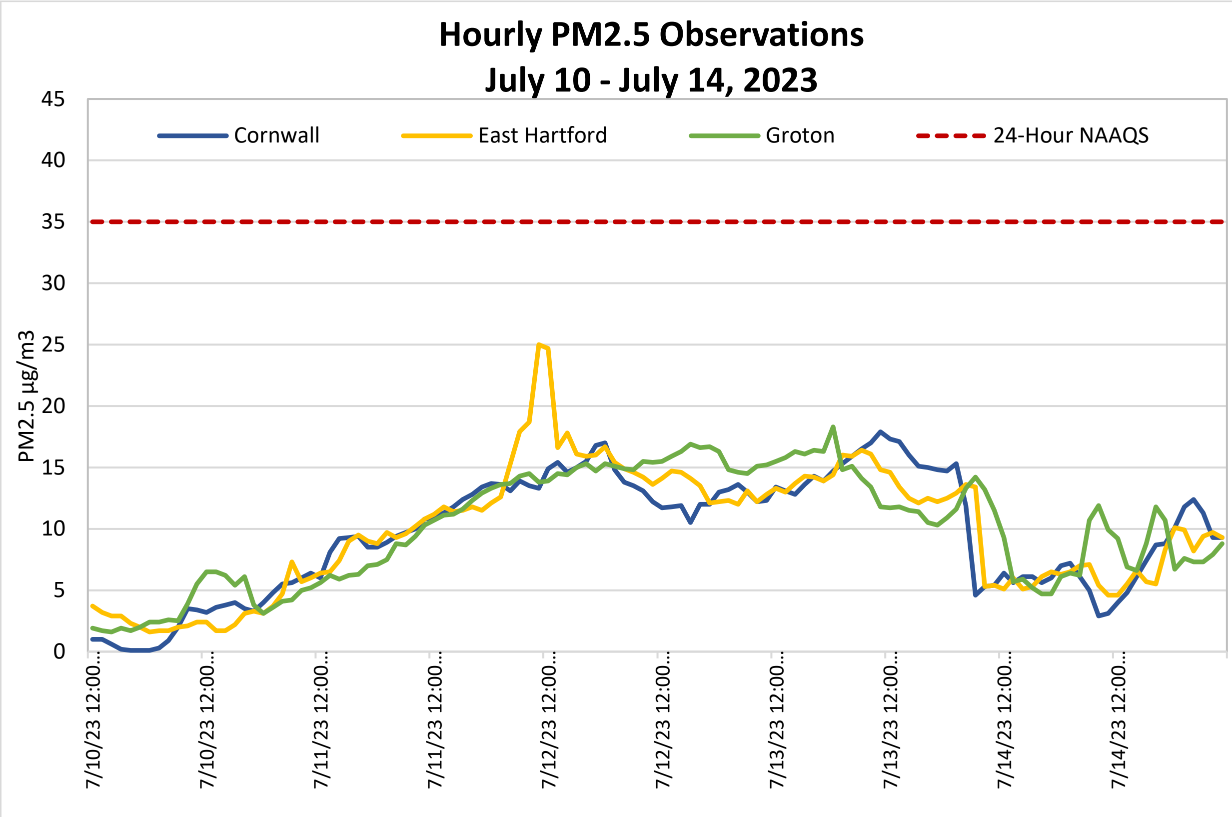



**Figure 6-20.** Hourly PM2.5 concentrations recorded at data exclusion monitors from July 10-14, 2023.

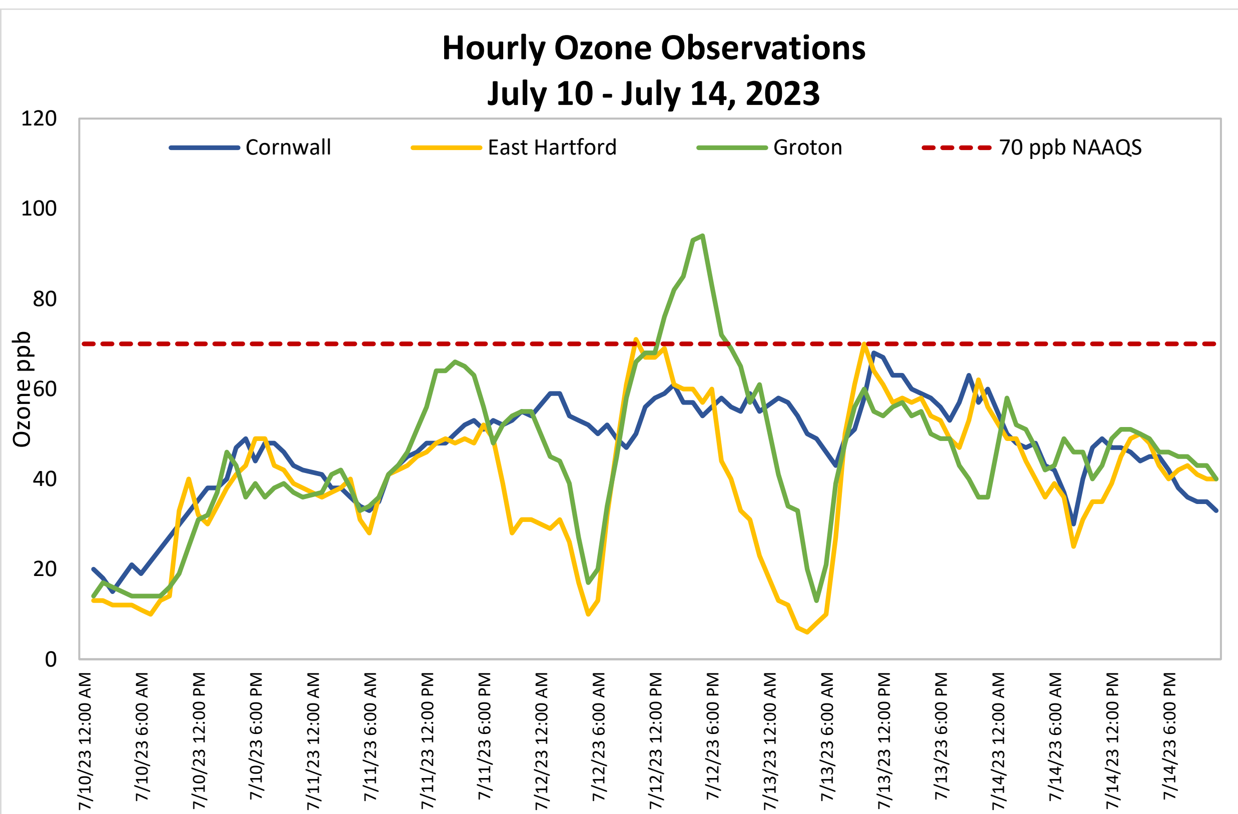



**Figure 6-21.** Hourly ozone concentrations recorded at data exclusion monitors from July 10-14, 2023.

## 6.5 Summary

Data indicate that record level PM2.5 impacts in Connecticut over the two days of the June 30-July 1 event coincided with ozone levels that exceeded the level of the standard. Higher than normal PM2.5 levels during the April 13-14 and July 12 event also coincided with elevated ozone levels at all three monitors selected for data exclusion. These excessive PM2.5 levels were transported into the state as evident by conditions at the usually pristine Cornwall site and coincide with smoke plumes indicated by satellite and other data during the critical ozone events of April 13-14, June 30-July 1, and July 12 at all three sites for which data exclusion is proposed.

# 7 Additional Smoke Related Monitoring Data

## 7.1 Ceilometers and Aerosol Data

At the New Haven and Westport monitoring sites, Connecticut operates aerosol backscatter ceilometers from which graphical aerosol backscatter images can be produced. The CL-51 ceilometer is manufactured by Vaisala and provides lidar backscatter plots up to a height of 4000 meters. This instrument runs continuously and the BLVIEW software calculates the height of the maximum aerosol gradients, which are typically the height of the boundary layer(s). For these events, the New Haven and Westport ceilometer images could not be used until the July 12th event, because of equipment failure.

Data produced by ceilometers from the Unified Ceilometer Network (https://ucn-portal.org/), as well as back-scatter lidar from the NYS Mesonet network (https://www.nysmesonet.org/), are also used in the analyses of these events. Mesonet has several Leosphere WindCube WLS-100 series Doppler lidar sites that were useful for tracking aerosols entering Connecticut. Figure 7-1 shows the location of the closest Mesonet lidar used for aerosol backscatter images for our analysis.

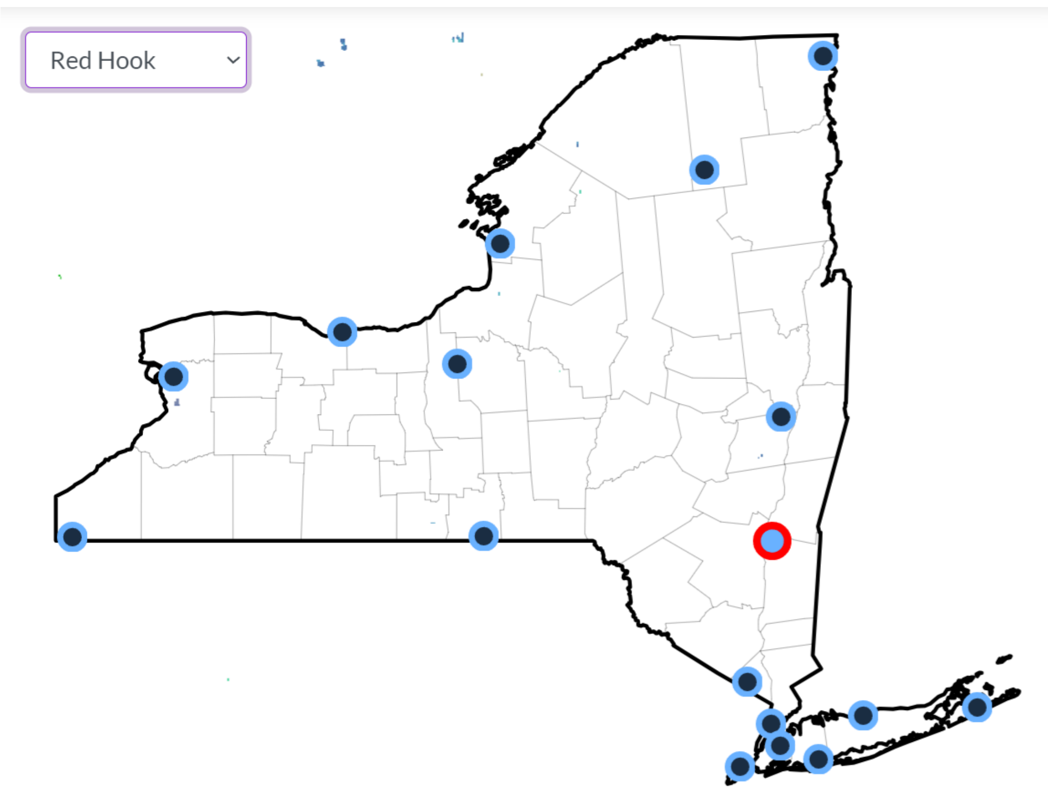



**Figure 7-1.** Location of Redhook, NY Mesonet lidar used for aerosol backscatter.

**April 13-14, 2023 Event**

The following figure shows the Redhook, New York, backscatter images with the Cornwall ozone images. Note the bright orange backscatter intensity the morning of April 14th. This was likely due to the smoke plume arriving from the Pennsylvania wildfire. A few hours later, Cornwall ozone levels spike in response to this plume arriving at the monitor. This image also shows the backscattering reaching the ground, with the most intense levels staying a few hundred meters above the surface.

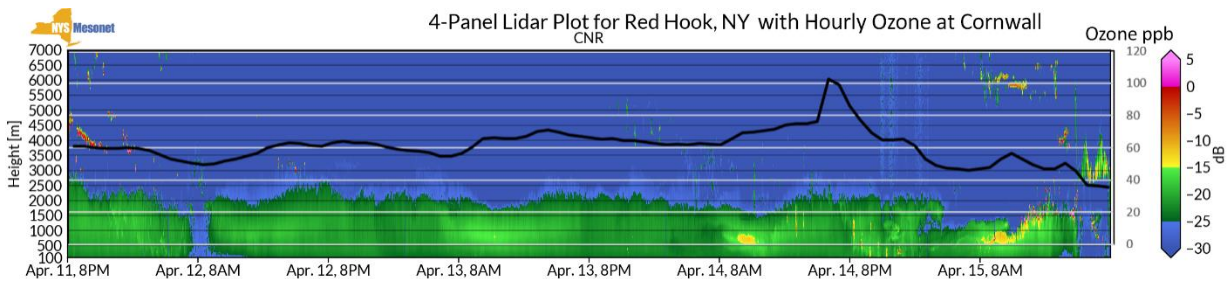



**Figure 7-2.** Redhook, NY Mesonet lidar backscatter image with Cornwall hourly ozone.

Figure 7-3 shows the Providence, Rhode Island, ceilometer image from April 12-14, 2023. Similar to the Redhook image above, the most intense aerosol backscattering (lighter blue/green) occurs on April 14th, below 2000 meters, under a nearly clear sky. For reference, Figure 7-4 is an image from January 11, 2023, over Providence, showing the aerosol backscatter image on a day with a clear sky, northwest winds, and very low PM2.5 levels.

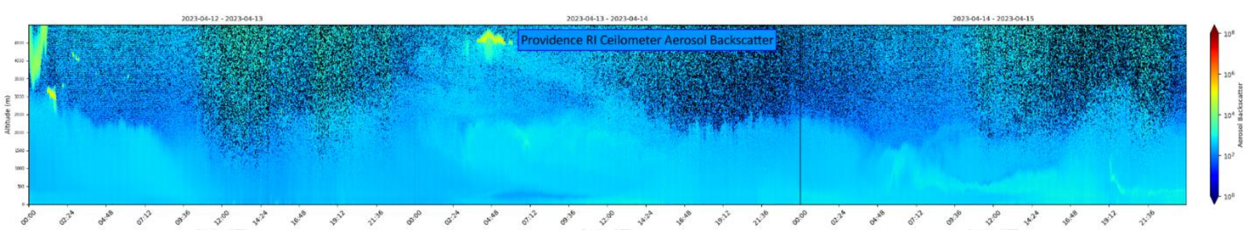



**Figure 7-3.** Providence, RI ceilometer backscatter images from April 12-14, 2023.

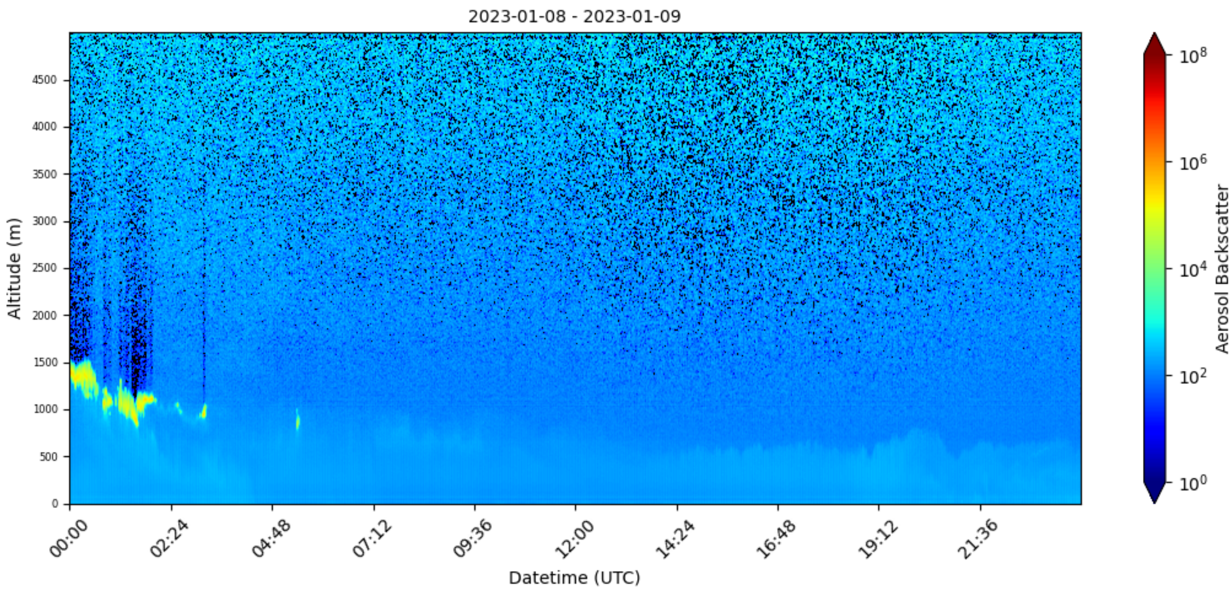



**Figure 7-4.** Providence, RI ceilometer backscatter clean air reference day.

### June 30-July 1, 2023 Event

The source of the smoke for this event originated from the Quebec fires, and although the surface PM2.5 levels were not as high as earlier in the month, the conditions were more favorable for ozone formation. Figure 7-5 shows the extent of the smoke plume and PM2.5 AQI levels during the morning of June 30, 2023.

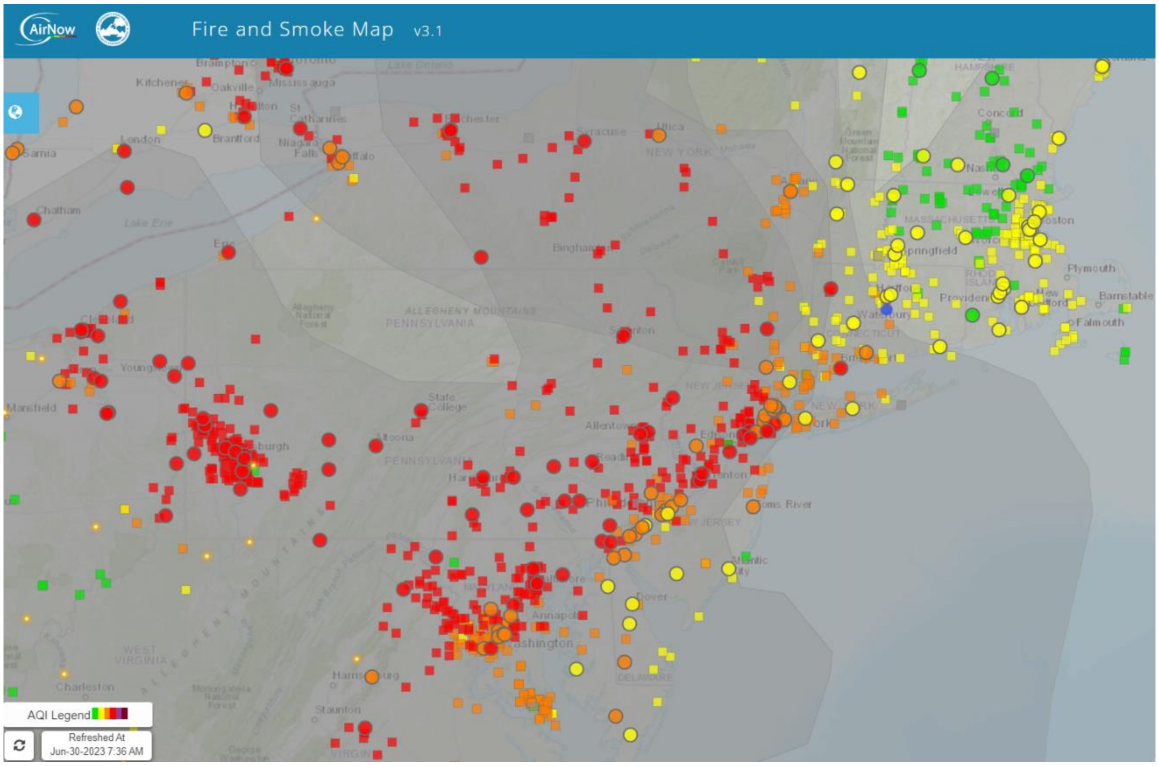



**Figure 7-5.** EPA AirNow Fire and Smoke Map for June 30, 2023, 7:36am showing the PM2.5 AQI levels.

Figure 7-6 shows the aerosol backscatter from the Redhook lidar for June 30- July 1, 2023. Note the much greater intensity indicated in orange and red. This accurately reflects the highest surface PM2.5 levels that were monitored on July 1, when the highest ozone levels were also monitored. This plume was aged and advected northeast after dipping down to the mid-Atlantic states.

Figure 7-7 shows the Providence ceilometer backscatter image for June 30 through early morning July 1, 2023. The densest part of the aerosol plume settles down to within 500 meters of the surface. The highest surface PM2.5 concentrations generally stayed west of Rhode Island during this event, but ozone exceedances did occur at the Rhode Island monitors.

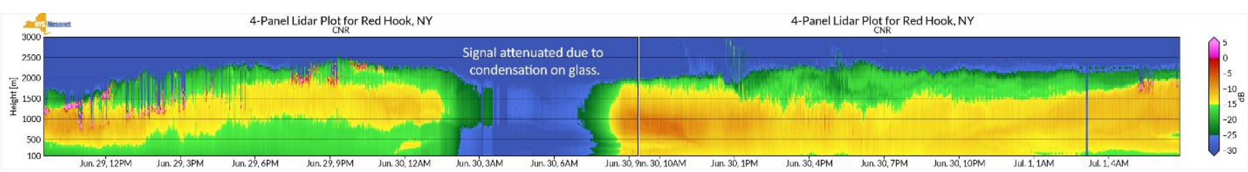



**Figure 7-6.** Redhook Mesonet lidar images from June 30-July 1, 2023.

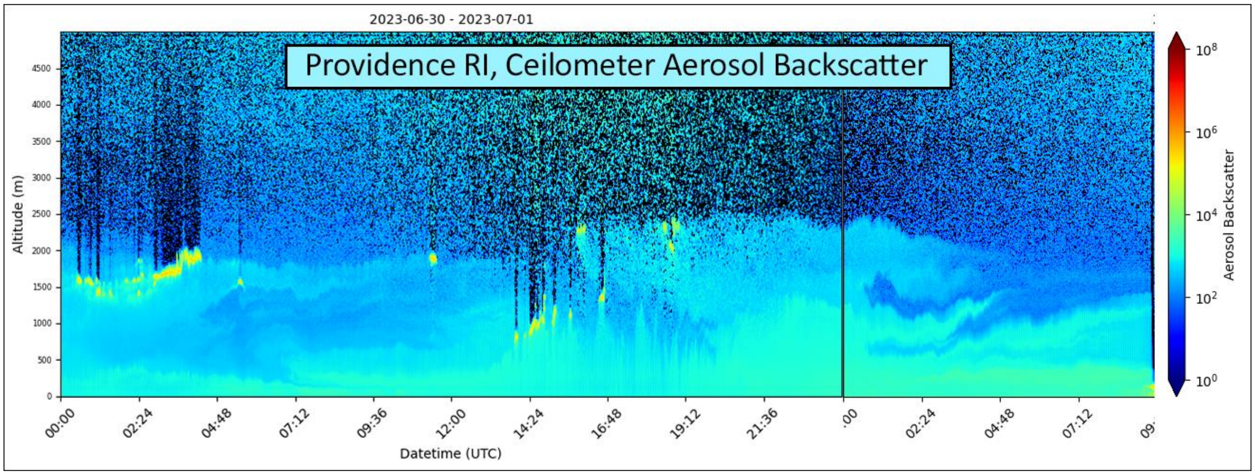



**Figure 7-7.** Providence, RI ceilometer aerosol backscatter June 30- early July 1, 2023.

### The July 12, 2023 Event:

Although the local smoke plume for this event was far less dense than the previous event, the smoke was being propelled southeast from the fires in northwest Canada and had settled over Connecticut's coastal monitors by July 12th. Figure 7-8 shows the extent of the smoke and the ozone exceedances on the EPA AirNow map. Figure 7-9 shows the ceilometer aerosol backscatter from the Westport, Connecticut, site on July 11-12, 2023. Figure 7-10 shows the ceilometer aerosol backscatter for Providence on July 12. Note the increasing aerosol backscatter intensity at the Westport site from July 11th to July 12th. The Westport monitor is on the coast of Long Island Sound (LIS), and the ceilometer image indicates a very low marine layer (~100 meters) during the overnight. The aerosol layer extends above 2000 meters at both Westport and Providence, with the highest concentrations appearing to settle below 1000 meters above ground level. This thickness of aerosols is consistent with aerosols transported in a smoke plume and not produced locally. As with the Westport site, the aerosols at Providence appear to increase toward the surface July 12th, descending from 3000 meters.

Figure 7-11 also shows significant aerosol backscattering on July 12, 2023 at the Redhook, NY Mesonet site, just west of Cornwall. By mid-afternoon clouds and precipitation appear as more intense backscatter echoes, which lowers the aerosol levels. This is consistent with the clouds and precipitation limiting ozone production in northern Connecticut.

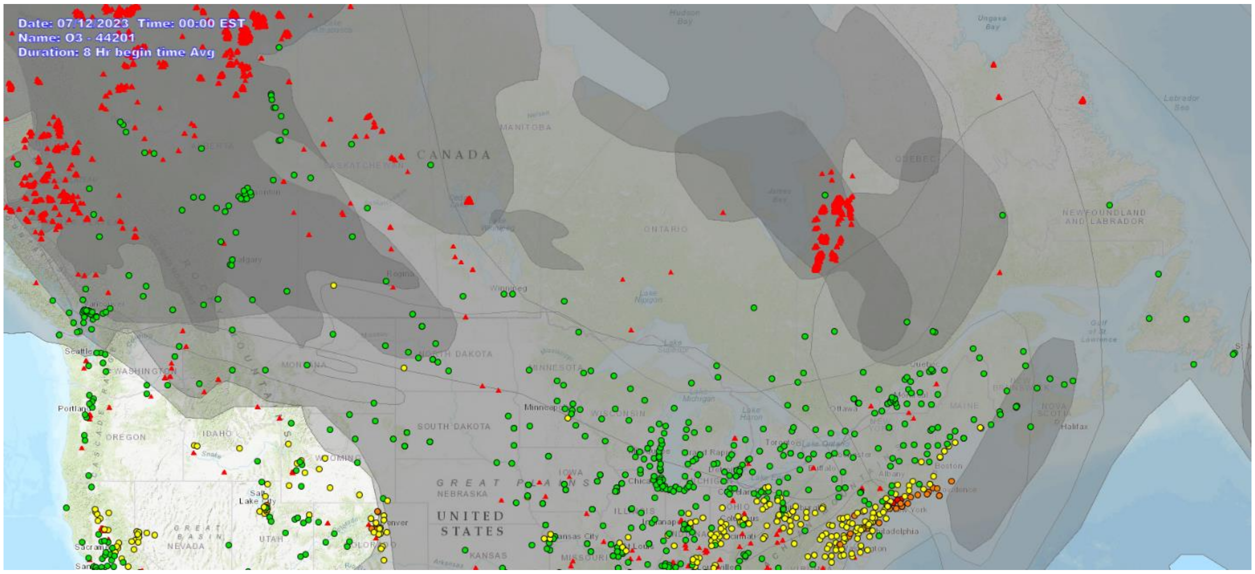



**Figure 7-8.** EPA AirNow Ozone AQI map with satellite analyzed fires and smoke for July 12, 2023.

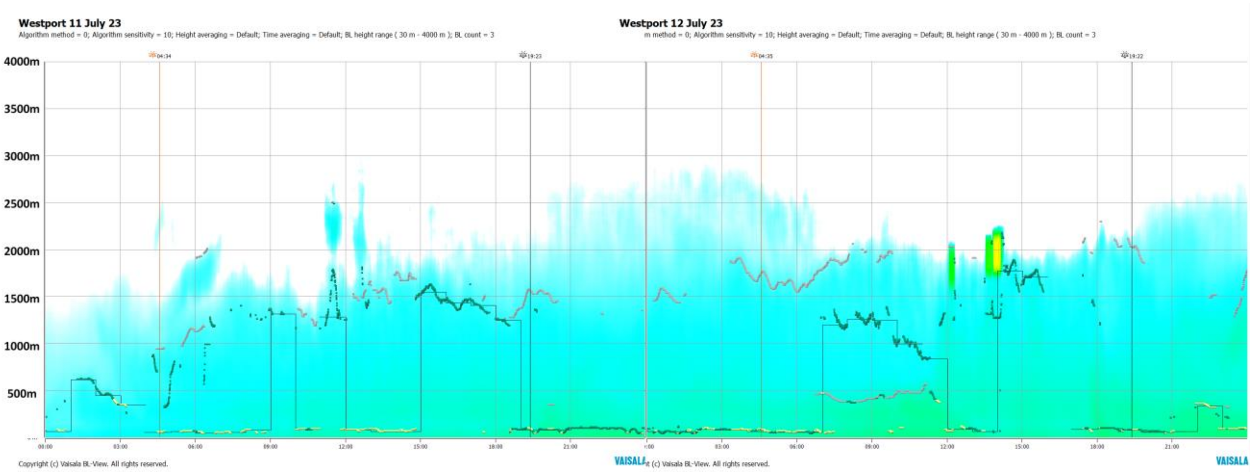



**Figure 7-9.** Westport, Connecticut, ceilometer aerosol backscatter image for July 11-12, 2023.

During July of 2023, as part of a larger air quality study, a group of researchers installed ozone lidar instruments at sites in Flax Pond, New York, and Branford, Connecticut. The instrument at Branford was an innovative Tunable Optical Profiler for Aerosol and oZone (TOPAZ) lidar that could be tilted from vertical to produce images over LIS. One of the first (preliminary) images produced, was on July 12$^{th}$ (Figure 7-12), which shows a thick layer of ozone aloft, to about 2000 meters, which coincides with the height of the backscatter aerosols. This provides more evidence of the likely contribution of the smoke chemistry to ozone production on that day.

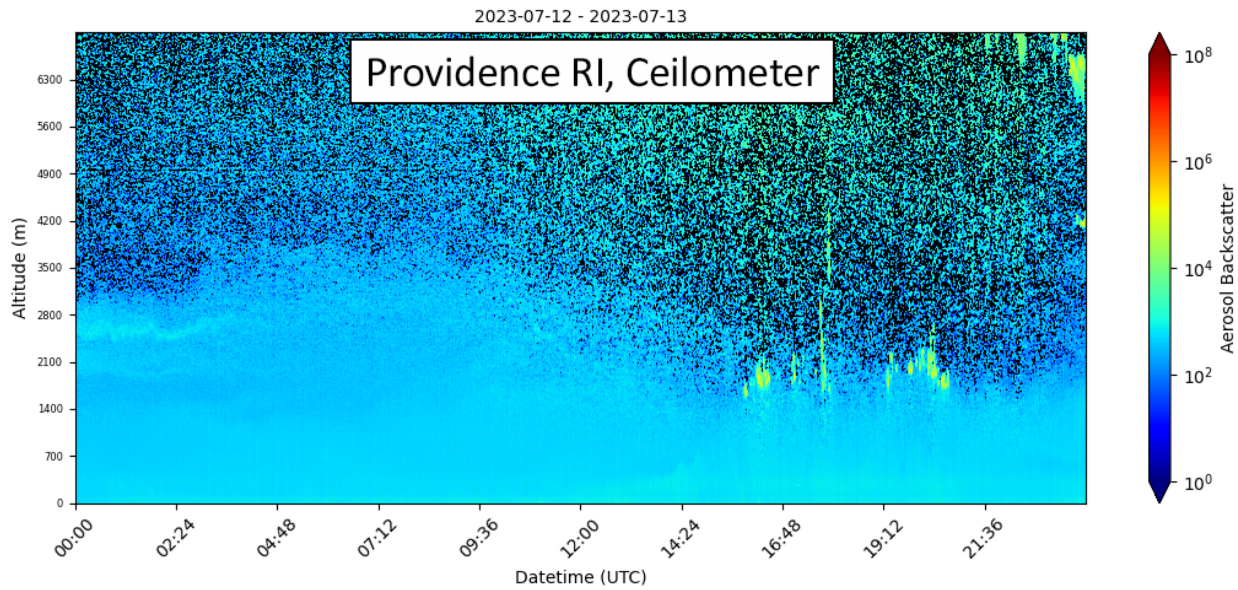



**Figure 7-10.** Providence, Rhode Island, ceilometer aerosol backscatter image for July 12, 2023.

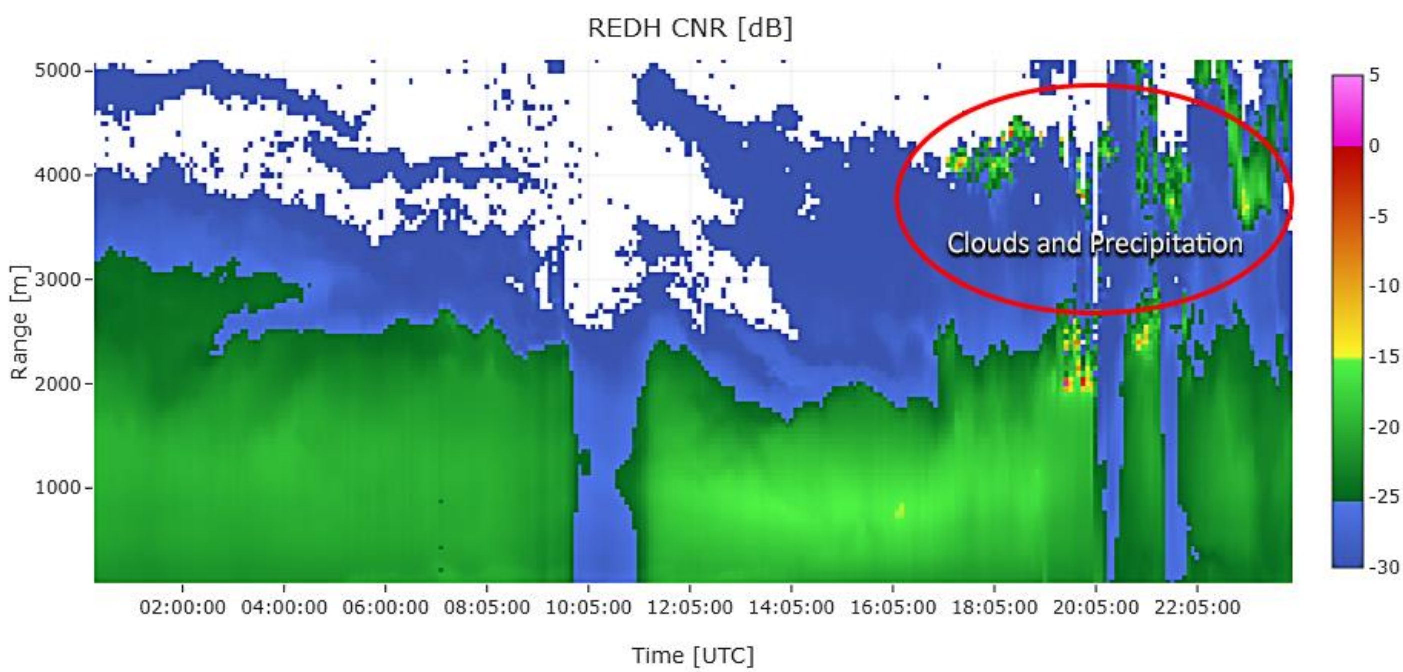



**Figure 7-11.** Aerosol backscatter image for Redhook, New York on July 12, 2023.

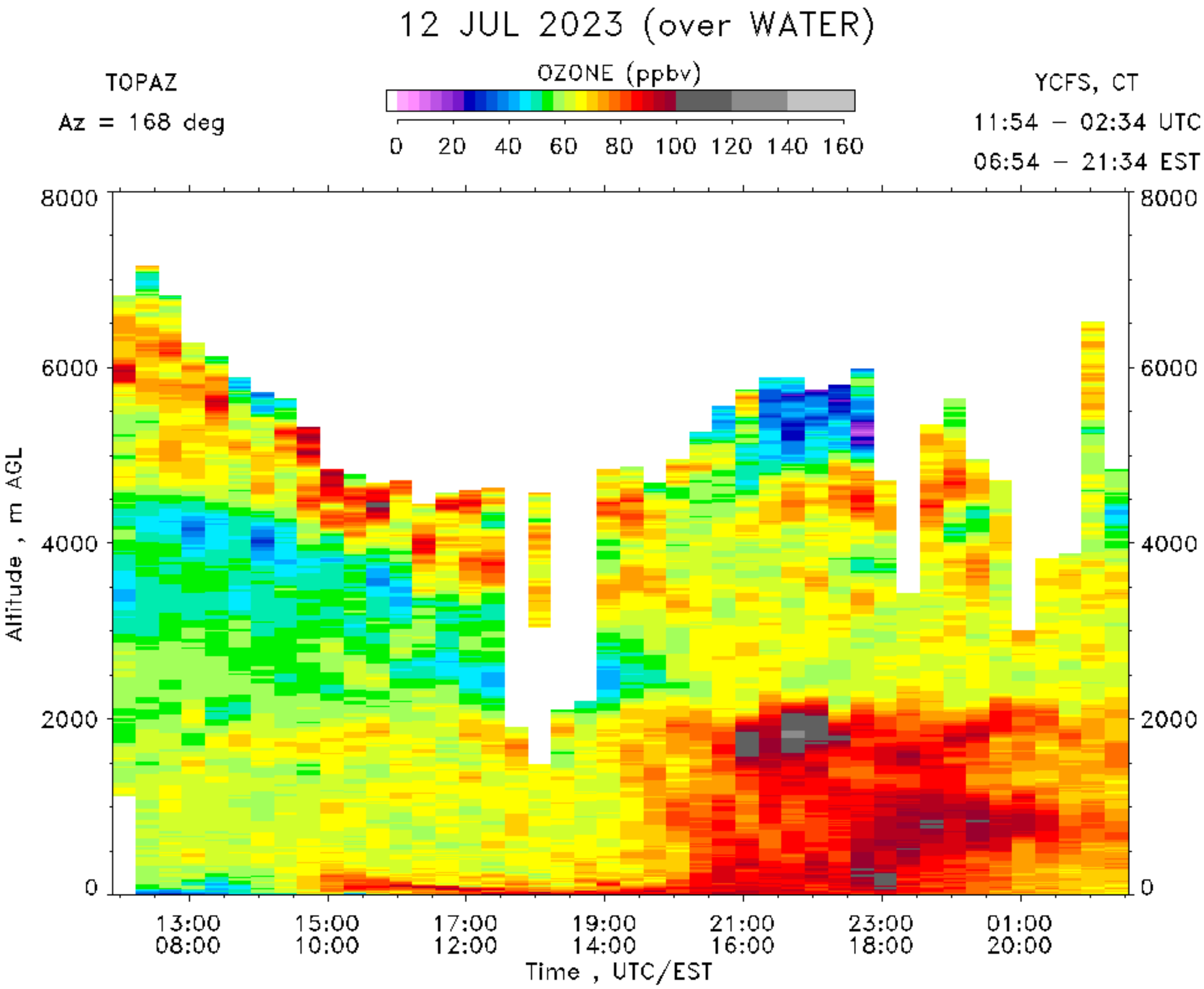



**Figure 7-12.** TOPAZ ozone lidar image from Branford, Connecticut, showing ozone layer to 2000 meters above LIS.

## 7.2 Smoke Indicators in Local Monitored Data

Other monitored parameters that show the likely presence of a smoke plume include black carbon (BC), DeltaC, and carbon monoxide (CO). The aethalometer measures the attenuation of light through a filter spot at multiple wavelengths, usually at least at near-infrared (IR) (880 nm, indicating BC) and near-ultraviolet (UV) (370 nm, "UV-C"). DeltaC is the difference between the 370 and 880 aethalometer measurements in µg/m$^3$. It is a semi-quantitative indicator of biomass combustion. At rural summertime sites, DeltaC is very specific to woodsmoke. Woodsmoke has a BC component to it, approximately 10% of woodsmoke PM2.5 is BC. We have plotted the DeltaC PM2.5 parameter, which is calculated by multiplying DeltaC by 10, although multipliers up to 15 have been used.[70]

[70] Allen GA, Babich P, Poirot RL (2004) *Evaluation of a new approach for real time assessment of woodsmoke PM. In "Proceedings of the Regional and Global Perspectives on Haze: Causes, Consequences and Controversies*, Paper #16, Air and Waste Management Association Visibility Specialty Conference, Asheville, NC.

## April 13-14, 2023 Ozone Event

For the April 13-14 event, the pollutants at each site generally built up over a period of a few days prior to the actual ozone exceedances. To begin, Figure 7-13 shows hourly ozone concentrations along with smoke related pollutant data, including CO, DeltaC PM2.5, BC, and PM2.5 at the Cornwall monitor. All these pollutants continued building, up to and throughout the event, and ozone levels remained elevated during overnight hours. This data suggests the high-pressure system was transporting smoke and related pollutants slowly into Connecticut even prior to the two-day ozone event. There were various peaks in the days leading up to and during the event, with the greatest occurring in the early evening hours on April 14 for each pollutant. This timing supports the added impact from local fires in Pennsylvania, New York, and northern New Jersey, as seen on satellite images.

Data for the Danbury site, Figure 7-14, shows a similar pattern of pollutant buildup prior to the event, with a few differences. Ozone levels show more of a diurnal pattern with spikes increasing in magnitude each day, particularly during the event. DeltaC PM2.5 and BC show more building during the event, rather than leading up to it. PM2.5 levels also follow the building pattern leading up the event. However, they are stagnant for the majority of April 13, but spike quickly on the afternoon of April 14. The greatest difference is the timing of the largest spike. Spikes at Danbury occur earlier in the day than at Cornwall due to a south wind developing in the afternoon. Danbury's data reinforces other data indicating that the origin of the smoke impacting Connecticut was from distant (Flint Hills) fires and shows influence from local fires toward the end of the event. Note that CO data was not available at Danbury for this event.

Figure 7-15 shows hourly ozone concentrations along with DeltaC PM2.5, BC, and PM2.5 at East Hartford. CO data was not available at East Hartford during this event so data from the nearby Hartford site was used. Ozone concentrations follow a similar pattern to Danbury with the diurnal variations and increasing magnitudes for each peak leading up to and during the event. DeltaC PM2.5 and BC show various peaks with slight buildup throughout the time period. The PM2.5 trend is very similar to Danbury and Cornwall, including the largest spike on the evening of April 14. The CO trend is similar to the PM2.5 trend.

Figure 7-16 focuses on hourly ozone concentrations and smoke related pollutants at the coastal New Haven monitor. Hourly ozone concentrations are very similar to Danbury and East Hartford, featuring increasingly larger ozone peaks each day. The other pollutants also follow a similar building pattern with the greatest spikes occurring earlier in the day on April 14 and quickly decreasing by midday.

All the sites show a rapid decrease in pollutants by midday on April 14, but New Haven cleared out earlier than the other sites due to winds turning east about 12 hours earlier. All the data shown here for the April 13-14 event show hourly ozone concentrations and smoke related pollutants increasing up to and during the event with maximum peaks on April 14. The timing of the buildup and the wind patterns indicate transport of a smoke plume that originated in Flint Hills, Kansas and added smoke from local fires in Pennsylvania, New York, and northern New

Jersey.  This smoke enhanced ozone production, leading to widespread ozone exceedances during this two-day event.

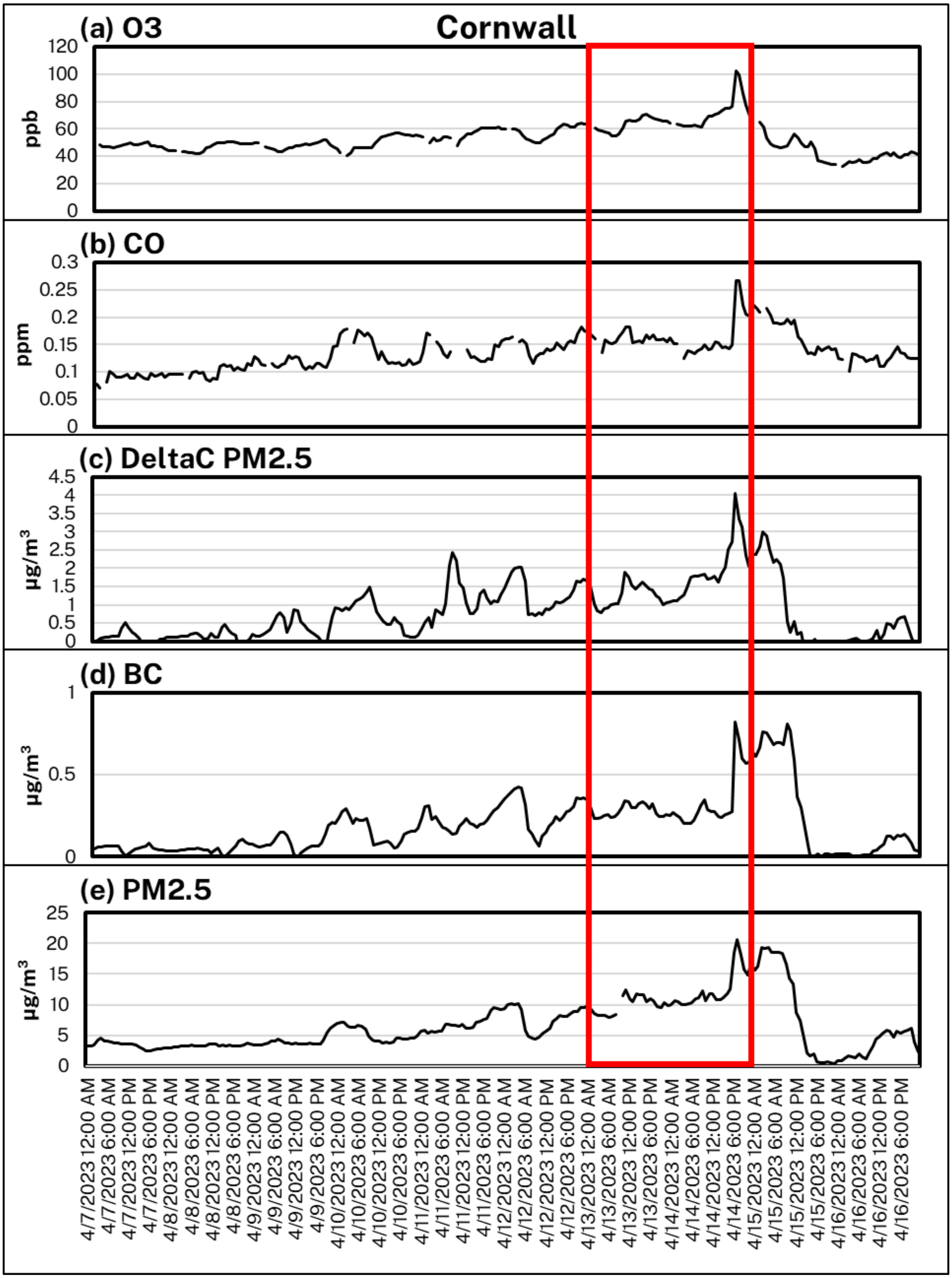



**Figure 7-13.** Monitored (a) Ozone, (b) Carbon Monoxide (CO), (c) DeltaC PM2.5 (d) Black Carbon (BC), and (e) PM2.5 at the Cornwall monitor for the April 13-14 event.

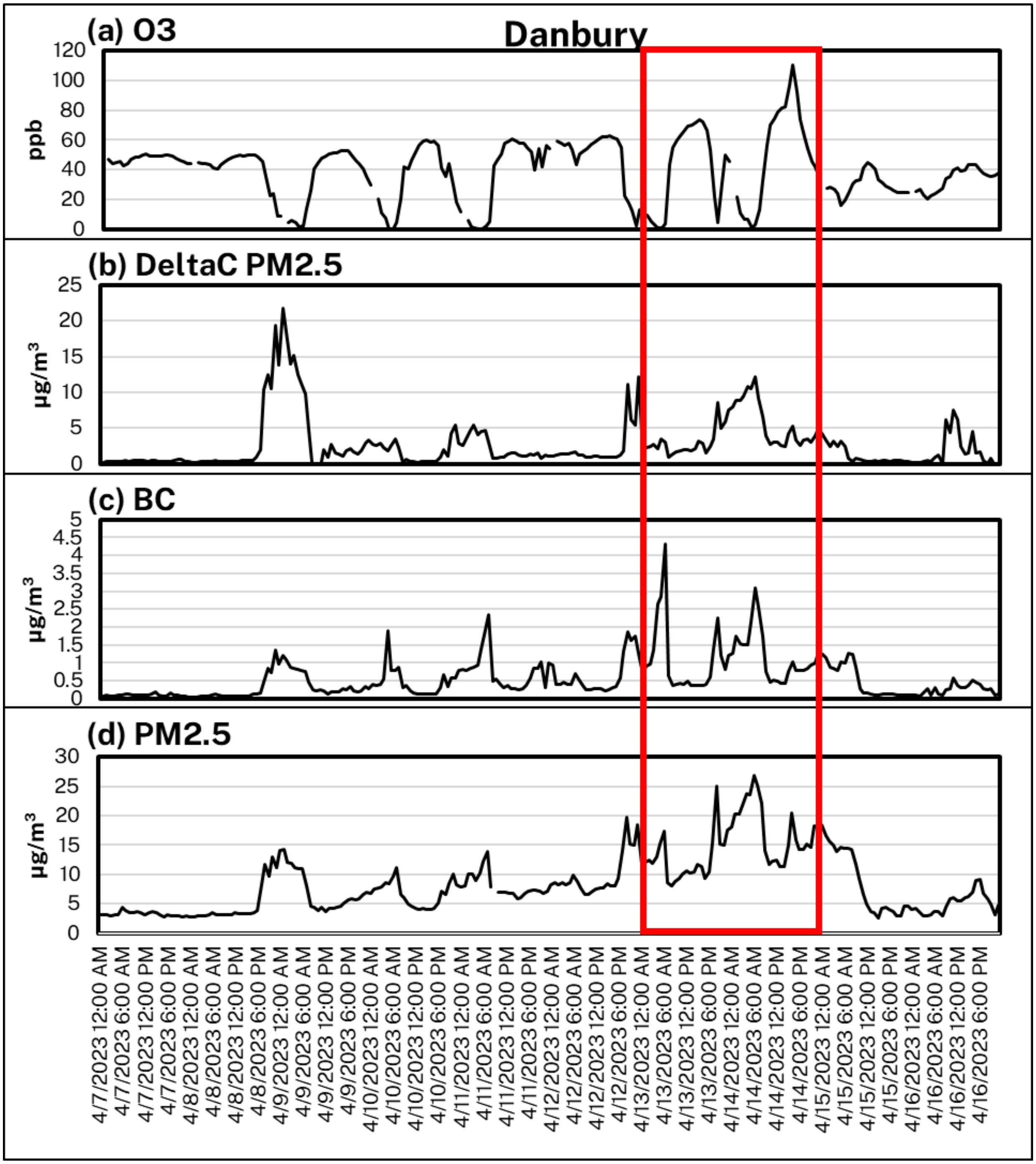



**Figure 7-14.** Monitored (a) Ozone, (b) DeltaC PM2.5 (c) Black Carbon (BC), and (d) PM2.5 at the Danbury monitor for the April 13-14 event.

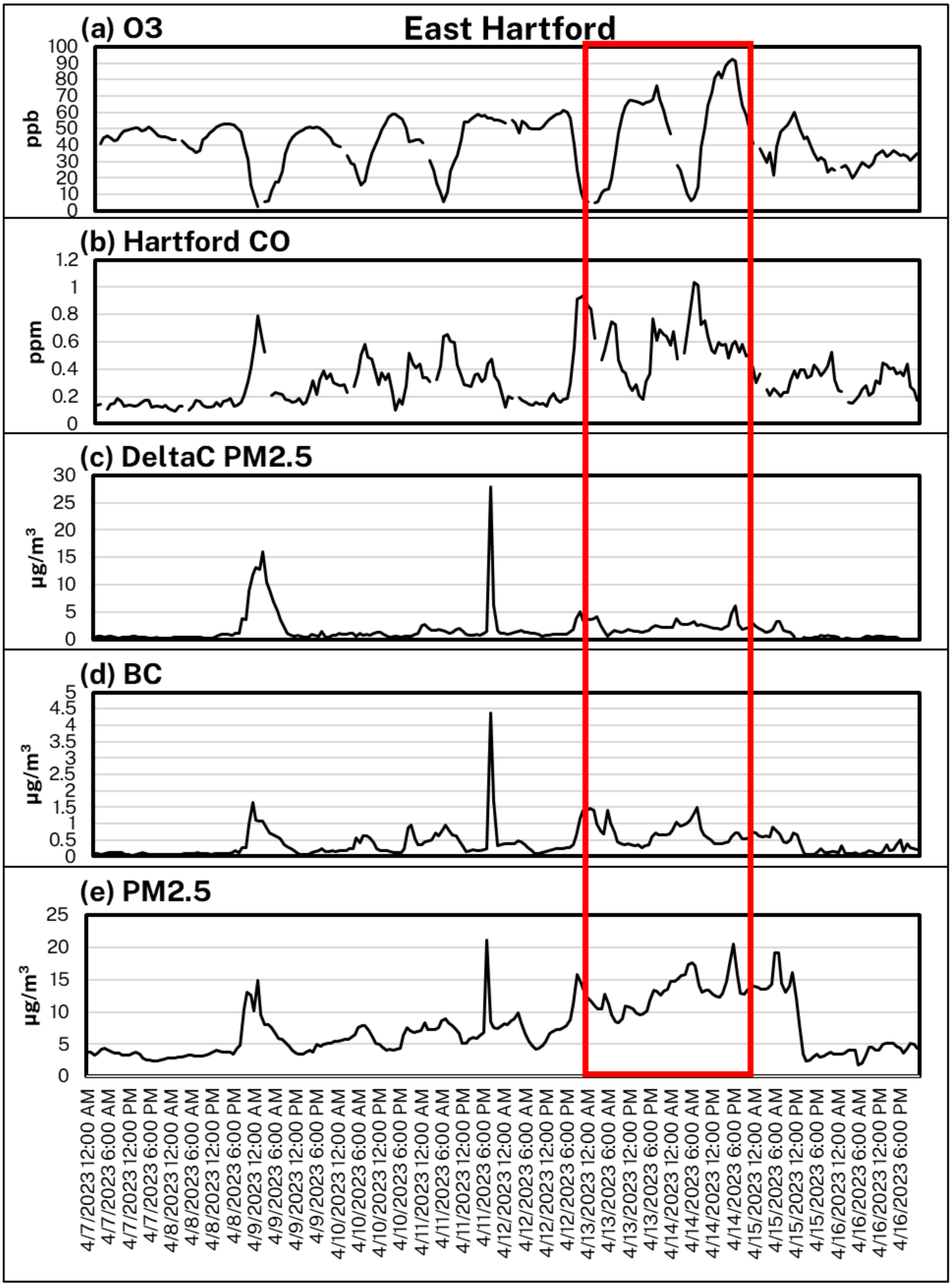



**Figure 7-15**. Monitored (a) Ozone, (b) Carbon Monoxide (CO), (c) DeltaC PM2.5 (d) Black Carbon (BC), and (e) PM2.5 at the East Hartford monitor for the April 13-14 event. Note that CO data is from the nearby Hartford monitor.

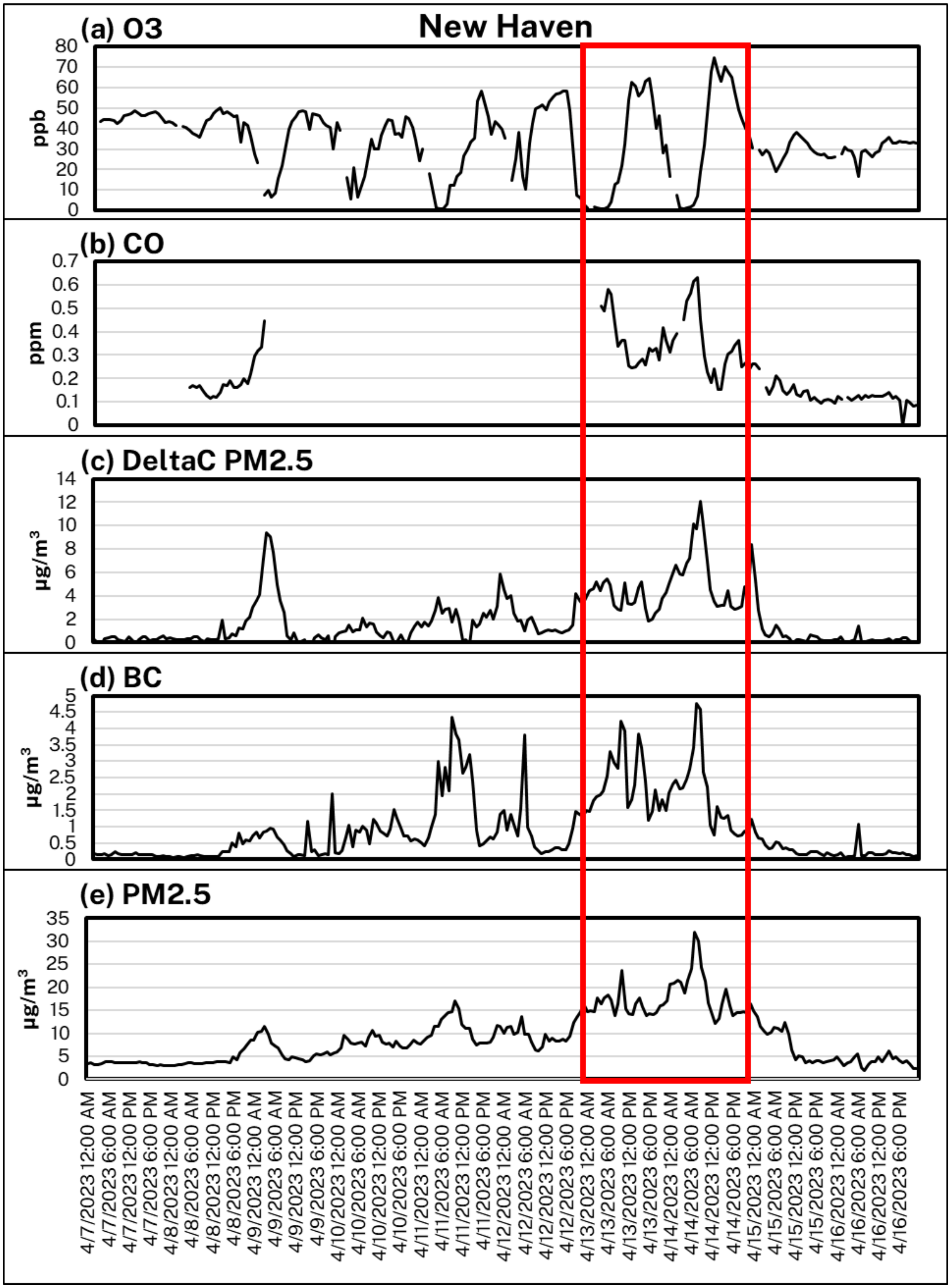



**Figure 7-16.** Monitored (a) Ozone, (b) Carbon Monoxide, (c) DeltaC PM2.5 (d) Black Carbon (BC), and (e) PM2.5 at the New Haven monitor for the April 13-14 event.

## June 30 – July 1, 2023 Ozone Event

For the June 30 – July 1 event, pollutants start to build on June 29th and decrease to typical levels by July 3rd. DeltaC PM2.5, BC, and PM2.5 data are shown for this event with the hourly ozone concentrations. CO was not available at any of the monitor sites during this event, though Hartford data is shown with the nearby East Hartford site.

Figure 7-17 shows ozone levels rising to similar magnitudes on both days at Cornwall with levels remaining elevated overnight. DeltaC PM2.5, BC, and PM2.5 all slowly built up on June 29 before spiking and peaking in the morning on June 30. All three of these pollutants gradually decreased as the event progressed and returned to typical levels by July 3.

At Danbury, Figure 7-18 shows hourly ozone concentrations are higher on June 30 and July 1 compared to the surrounding days and shows more diurnal variation than Cornwall. The other pollutants follow similar patterns to the Cornwall data. This includes a slight buildup on June 29 as high pressure was building into Connecticut. This is followed by a rapid increase on June 30 when high pressure dominated the eastern seaboard and allowed for recirculation of the smoke plume through New England. Finally, a gradual decline in pollutant levels is seen as the event progresses and high pressure slowly moves offshore. The event ends with the return to typical levels as the high-pressure system completely moved the smoke offshore.

East Hartford (Figure 7-19) and New Haven (Figure 7-20) show more variability in the data than Danbury and Cornwall while also showing similar large scale patterns. For ozone, the peaks on each exceedance day are around the same magnitude, and they are significantly higher than the surrounding days. DeltaC PM2.5 was variable throughout the June 30 – July 1 event for both East Hartford and New Haven. However, BC and PM2.5 followed a similar pattern as Cornwall and Danbury with the highest values remaining from midday on June 30 through the early morning on July 1. The Hartford CO data is elevated during, and leading up to, the event.

All these sites and pollutants show the impact of the smoke plume that originated in Quebec and was recirculated over New England.

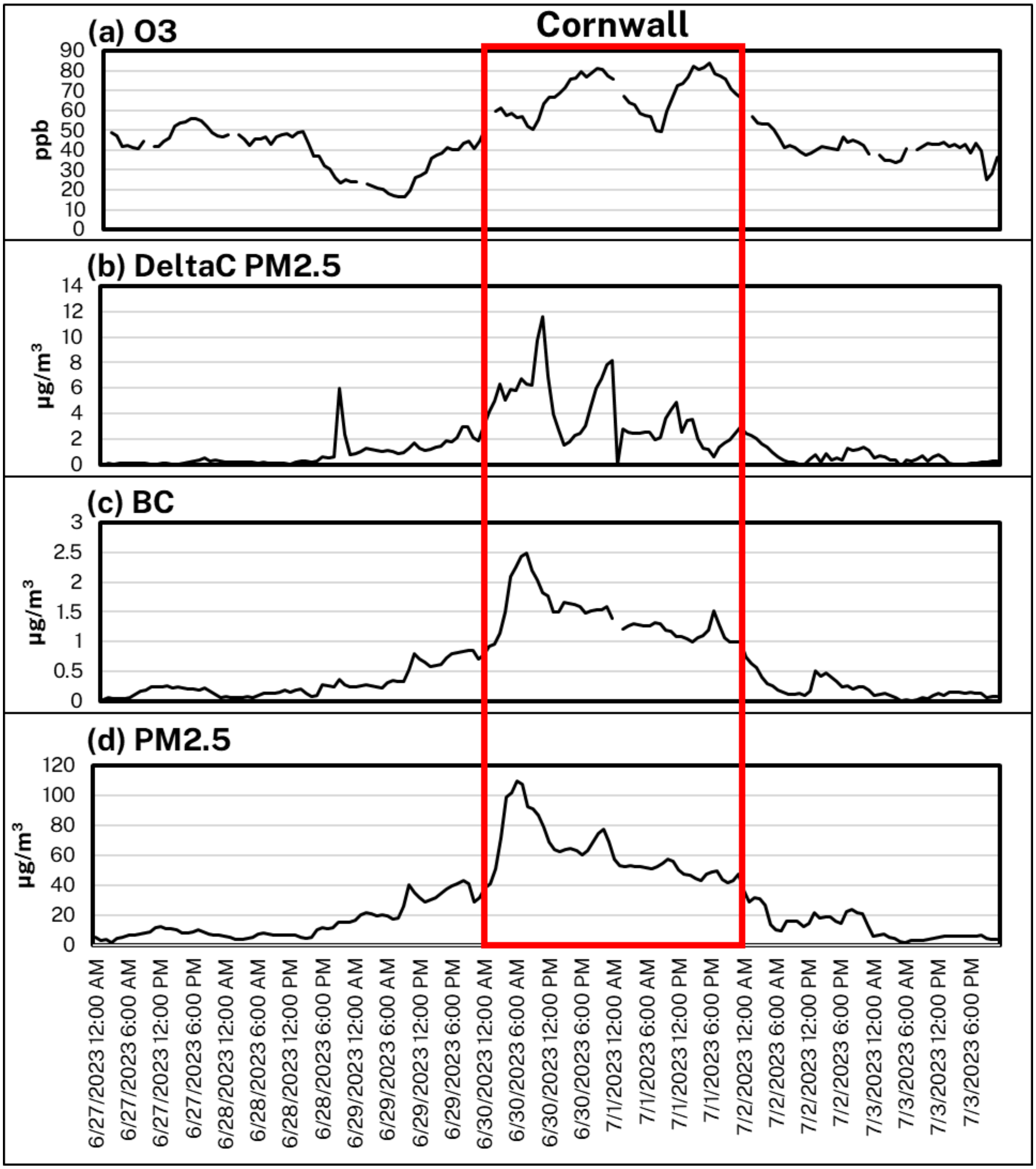



**Figure 7-17.** Monitored (a) Ozone, (b) DeltaC PM2.5 (c) Black Carbon (BC), and (d) PM2.5 at the Cornwall monitor for the June 30-July 1 event.

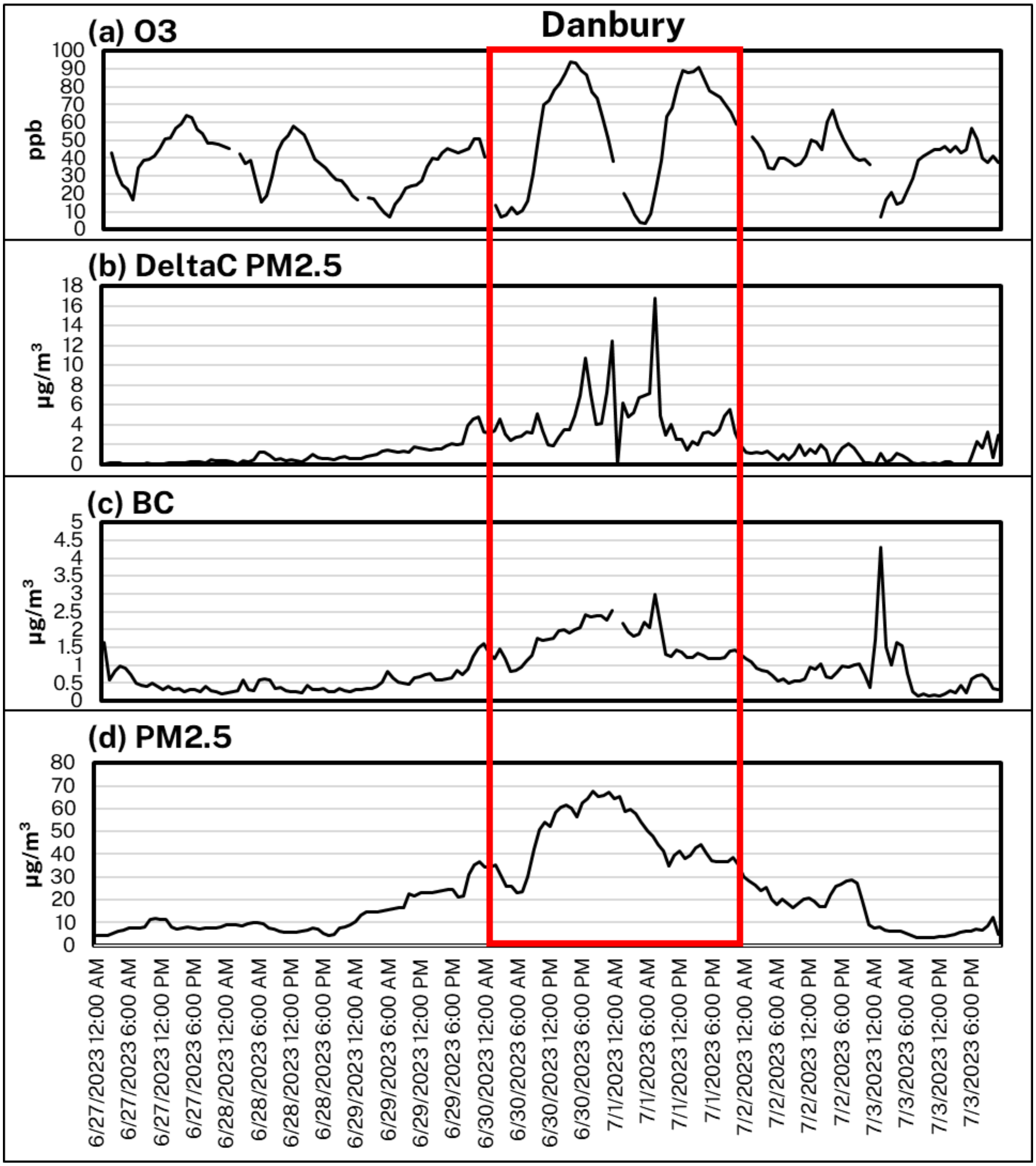



**Figure 7-18.** Monitored (a) Ozone, (b) DeltaC PM2.5 (c) Black Carbon (BC), and (d) PM2.5 at the Danbury monitor for the June 30-July 1 event.

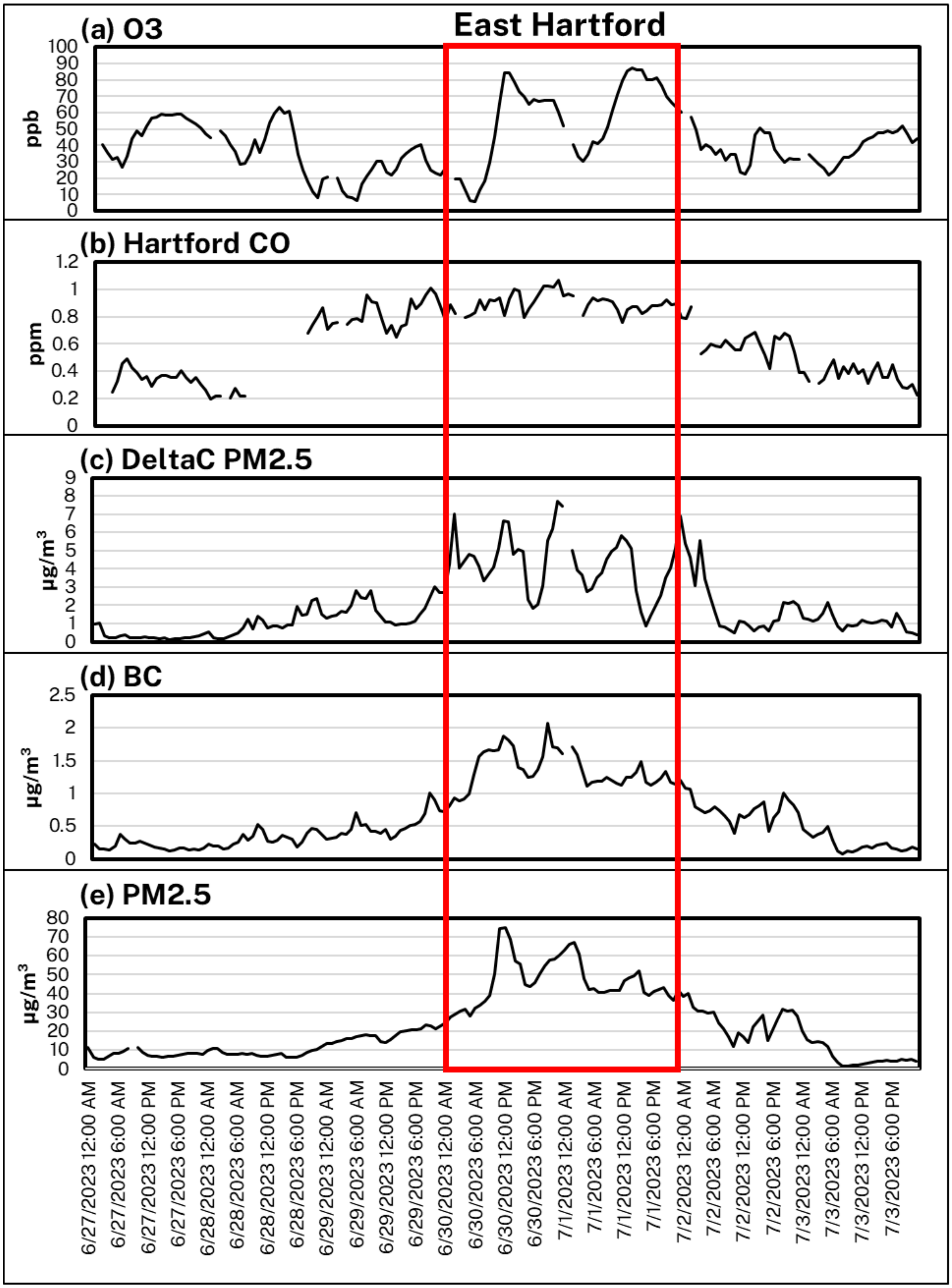



**Figure 7-19.** Monitored (a) Ozone, (b) Carbon Monoxide (CO), (c) DeltaC PM2.5 (d) Black Carbon (BC), and (d) PM2.5 at the East Hartford monitor for the June 30-July 1 event. Note that CO data is from the nearby Hartford site.

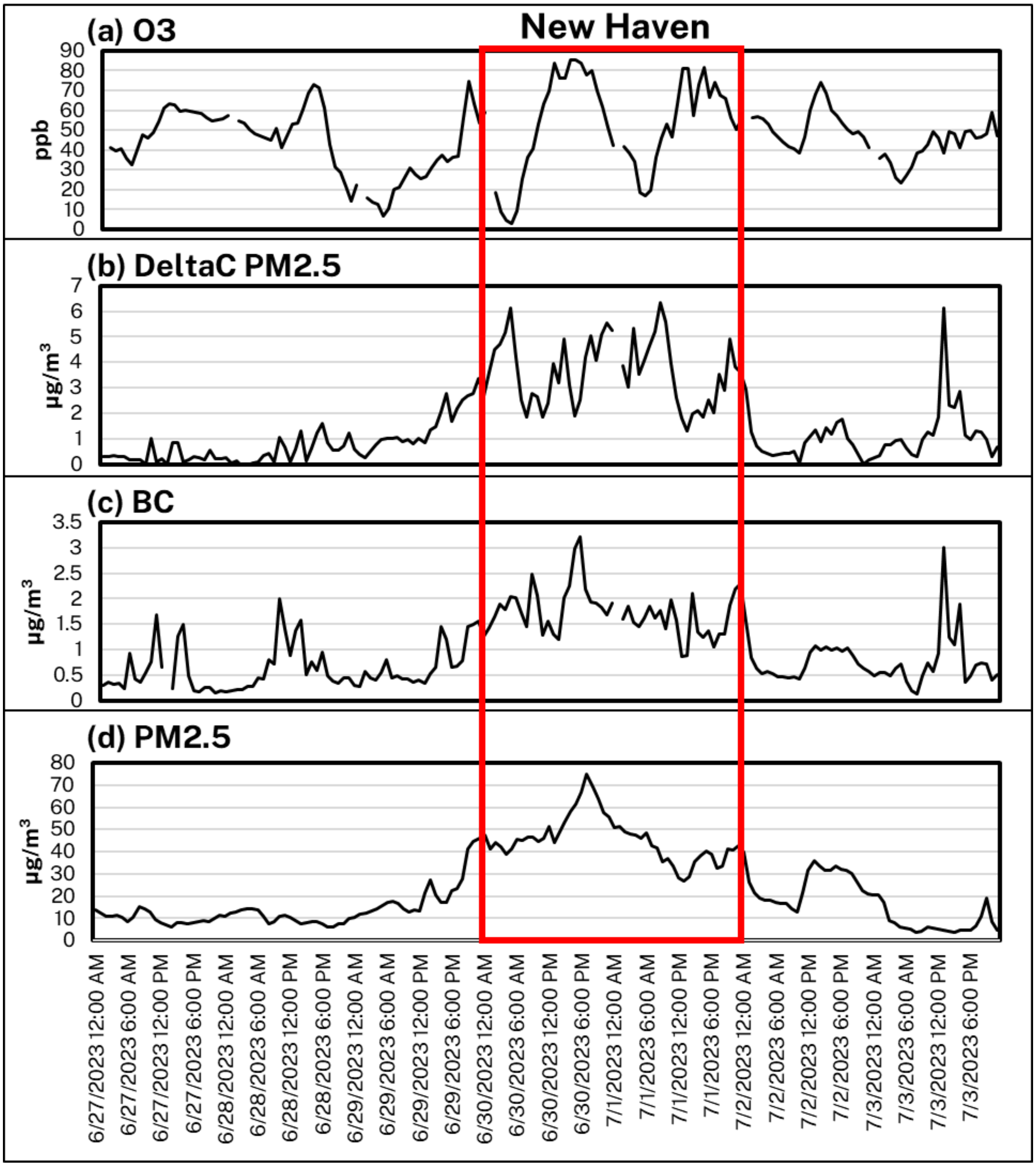



**Figure 7-20.** Monitored (a) Ozone, (b) DeltaC PM2.5 (c) Black Carbon (BC), and (d) PM2.5 at the New Haven monitor for the June 30-July 1 event.

## July 12, 2023 Ozone Event

For the July 12 event, smoke was transported by a high-pressure system and led by frontal systems from further away than for the previous two events, which shows up differently in the this series of plots.

Figure 7-21 shows the hourly ozone concentration and smoke related pollutant data surrounding the July 12 event for the Cornwall monitor. Ozone remained in the mid to high moderate levels for most of the time with little to no diurnal variation. CO increased on July 11, and gradually decreased in the days following the event. Cornwall is the only site with valid CO data surrounding July 12. DeltaC PM2.5 fluctuated but was generally the highest on the morning of July 12. BC and PM2.5 built up as high pressure was building over New England, peaked on the morning of July 12 as high pressure was in control, began to decrease as high pressure slowly moved offshore, and drastically dropped when high pressure moved the smoke offshore.

Figure 7-22 shows Danbury hourly ozone concentrations with smoke related pollutant data surrounding the event. Ozone levels show a typical diurnal variation with July 12 having the highest peak. Again, DeltaC PM2.5 shows variation with the highest peak occurring on the morning of July 12. BC and PM2.5 show a similar building up as Cornwall, with the higher values also occurring in the morning hours, then values plateau and reach a second peak on July 13 before the steep drop.

Figure 7-23 shows the hourly ozone concentrations and smoke related trends at East Hartford. Ozone levels rise rapidly in the morning on July 12 with a peak around noon and slowly decrease during the afternoon and evening. This peak was higher than for the days leading up to the event, but about the same as the peak on July 13. DeltaC PM2.5, BC, and PM2.5 all show a large spike just before midnight on July 12 with levels gradually decreasing throughout the day and the few days after the event. Valid Hartford CO data was not available for this event.

Figure 7-24 shows the hourly ozone concentrations and smoke related pollutant trends at New Haven. For ozone, there are two spikes, one around noon and the other in the evening, that are both higher than the surrounding days. DeltaC PM2.5 and BC show more variability with the largest spike for DeltaC being a few hours after midnight and for BC being in the late afternoon. PM2.5 steadily increases from July 10 to July 12 at noon before slowly decreasing for the remainder of the event and the days following.

Once again, the coincident rise in ozone with CO, DeltaC, BC, and PM2.5 is consistent with what would be expected when ozone production is enhanced from pollutants in a smoke plume.

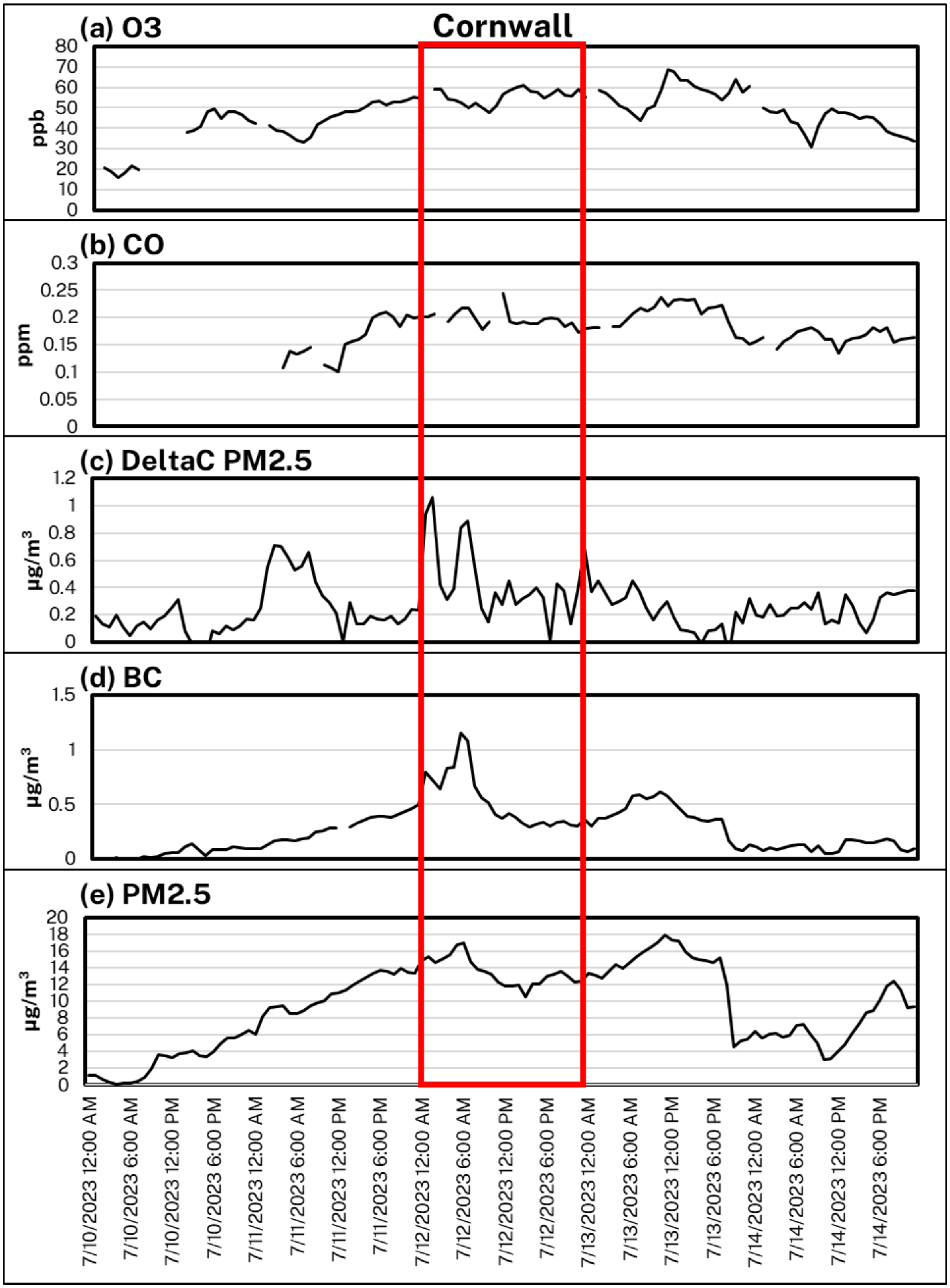



**Figure 7-21.** Monitored (a) Ozone, (b) Carbon Monoxide (CO) (c) DeltaC PM2.5 (d) Black Carbon (BC), and (e) PM2.5 at the Cornwall monitor for the July 12 event.

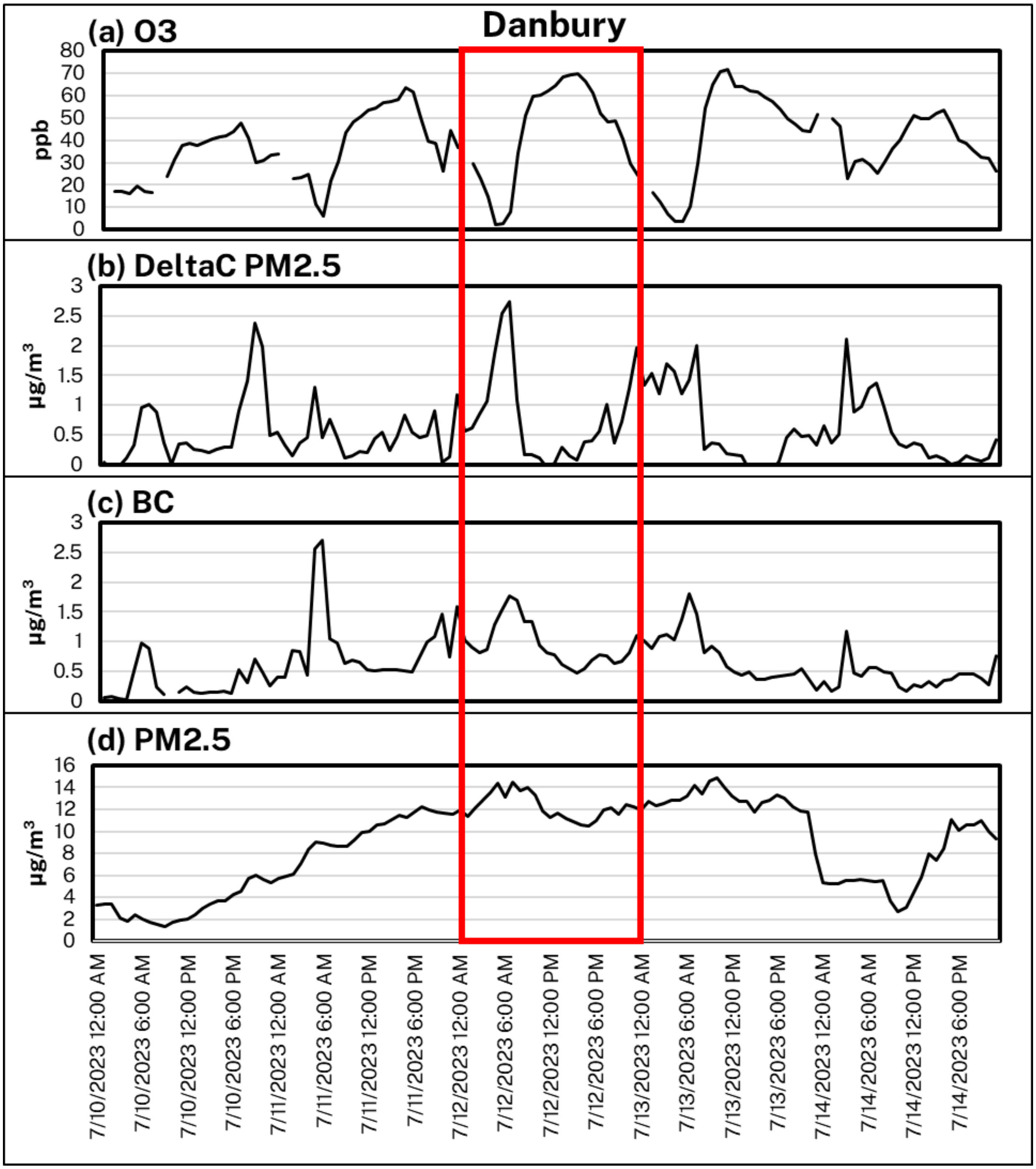



**Figure 7-22.** Monitored (a) Ozone, (b) DeltaC PM2.5 (c) Black Carbon (BC), and (d) PM2.5 at the Danbury monitor for the July 12 event.

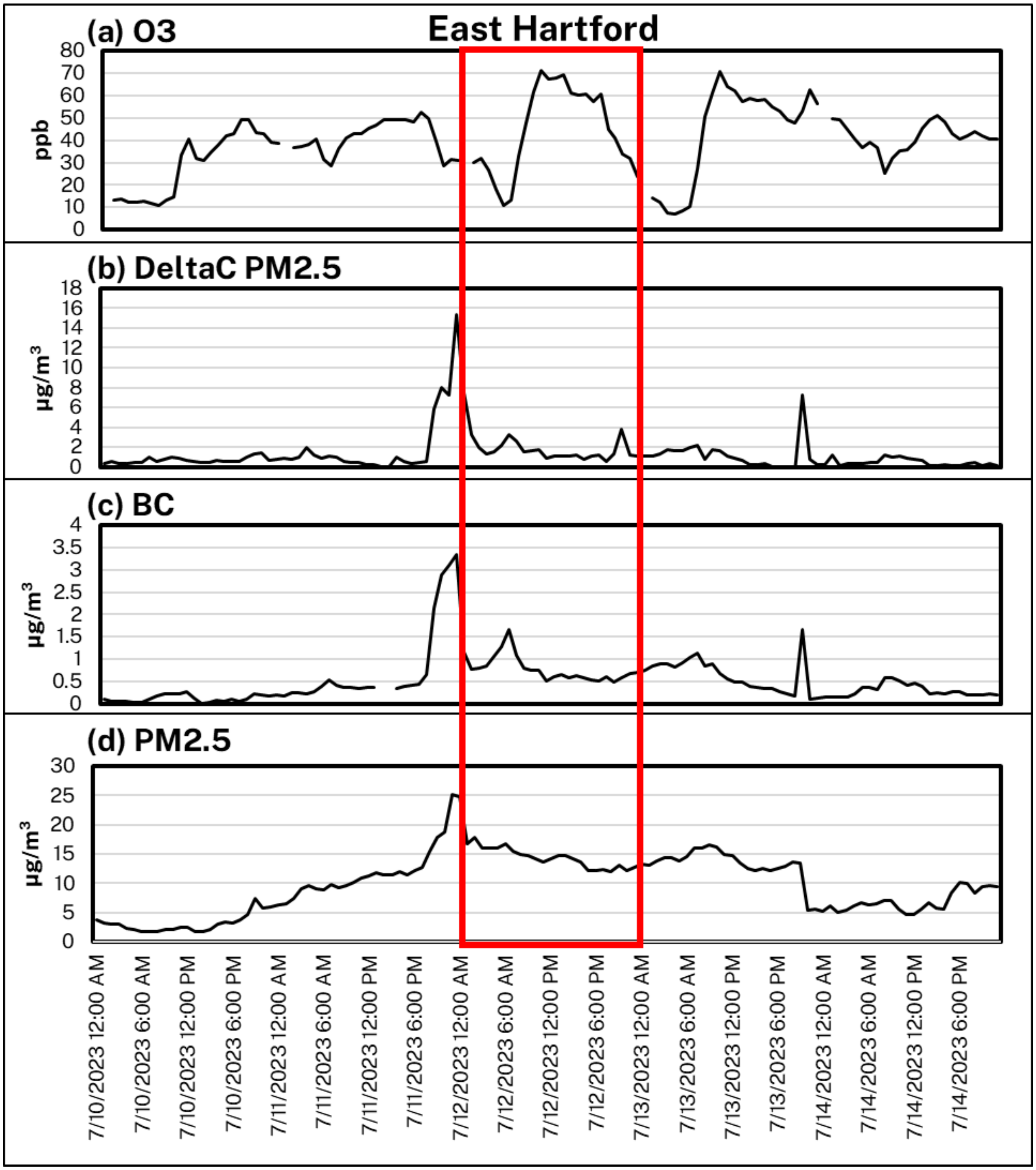



**Figure 7-23.** Monitored (a) Ozone, (b) DeltaC PM2.5 (c) Black Carbon (BC), and (d) PM2.5 at the East Hartford monitor for the July 12 event.

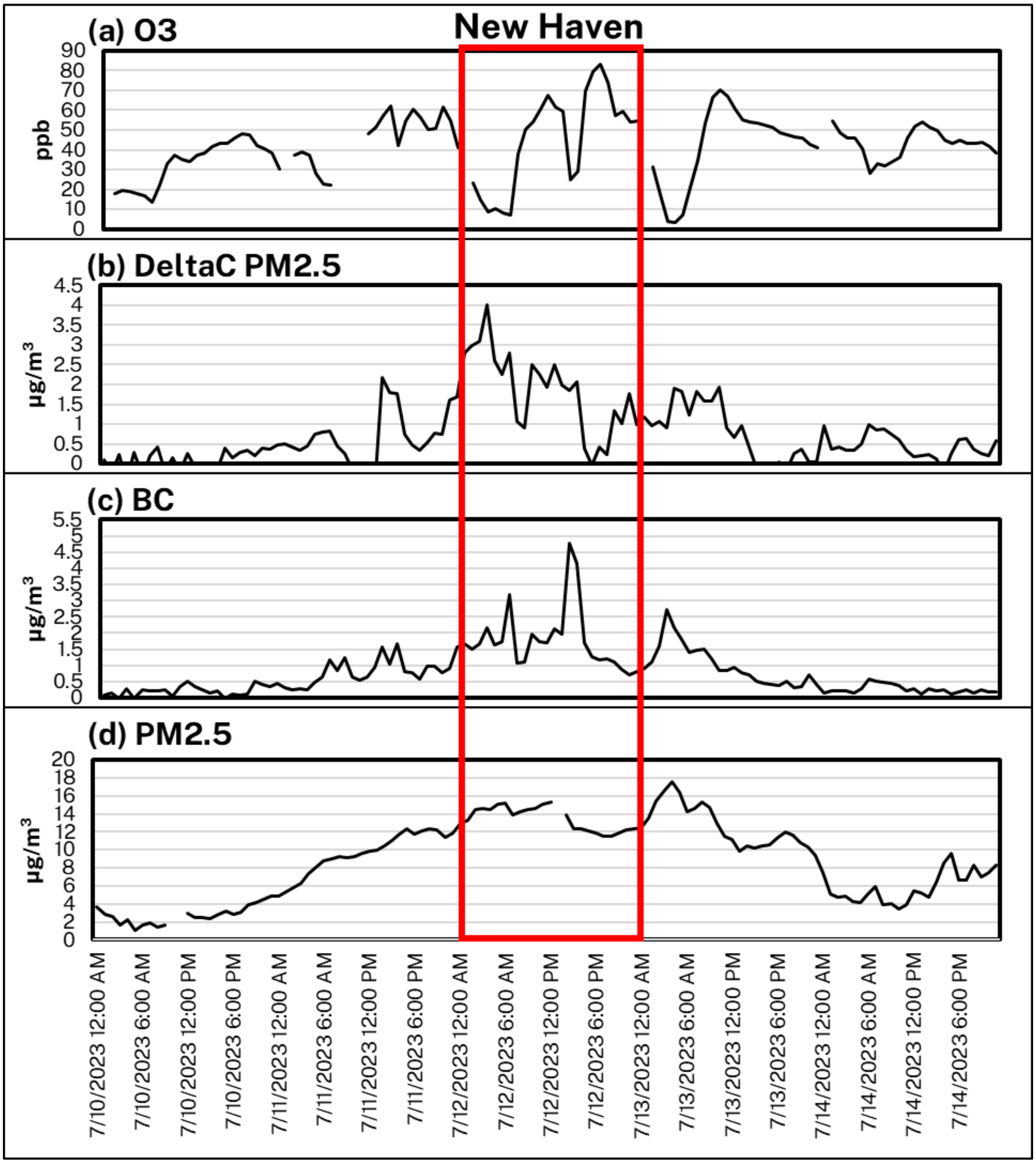



**Figure 7-24.** Monitored (a) Ozone, (b) DeltaC PM2.5 (c) Black Carbon (BC), and (d) PM2.5 at the New Haven monitor for the July 12 event.

## 7.3 Smoke Indicators in Regional Monitored Data

To observe similar monitored parameters as those in Connecticut and to characterize the regional extent of plume impacts, Fort Lee New Jersey was chosen for PM2.5, CO and the aethalometer carbon species and the nearby Leonia NJ monitor was selected for hourly ozone data. These sites are approximately 40 miles to the southwest of our Westport monitor and serve as a good comparison for all the events to show the presence of a regional smoke plume to the west of Connecticut. East Providence data is used to show the existence of the plume impacts to the east of Connecticut.

**Fort Lee/Leonia, New Jersey**

Figure 7-25 through Figure 7-27 are charts of the monitored pollutants that shows similar trends as those observed at the Connecticut monitors with peaks in BC, CO, and PM2.5. Note the greater, second spike in BC, CO, and PM2.5 at Fort Lee on the morning of April 14 corresponding with a second peak later in the day for the Connecticut monitors.

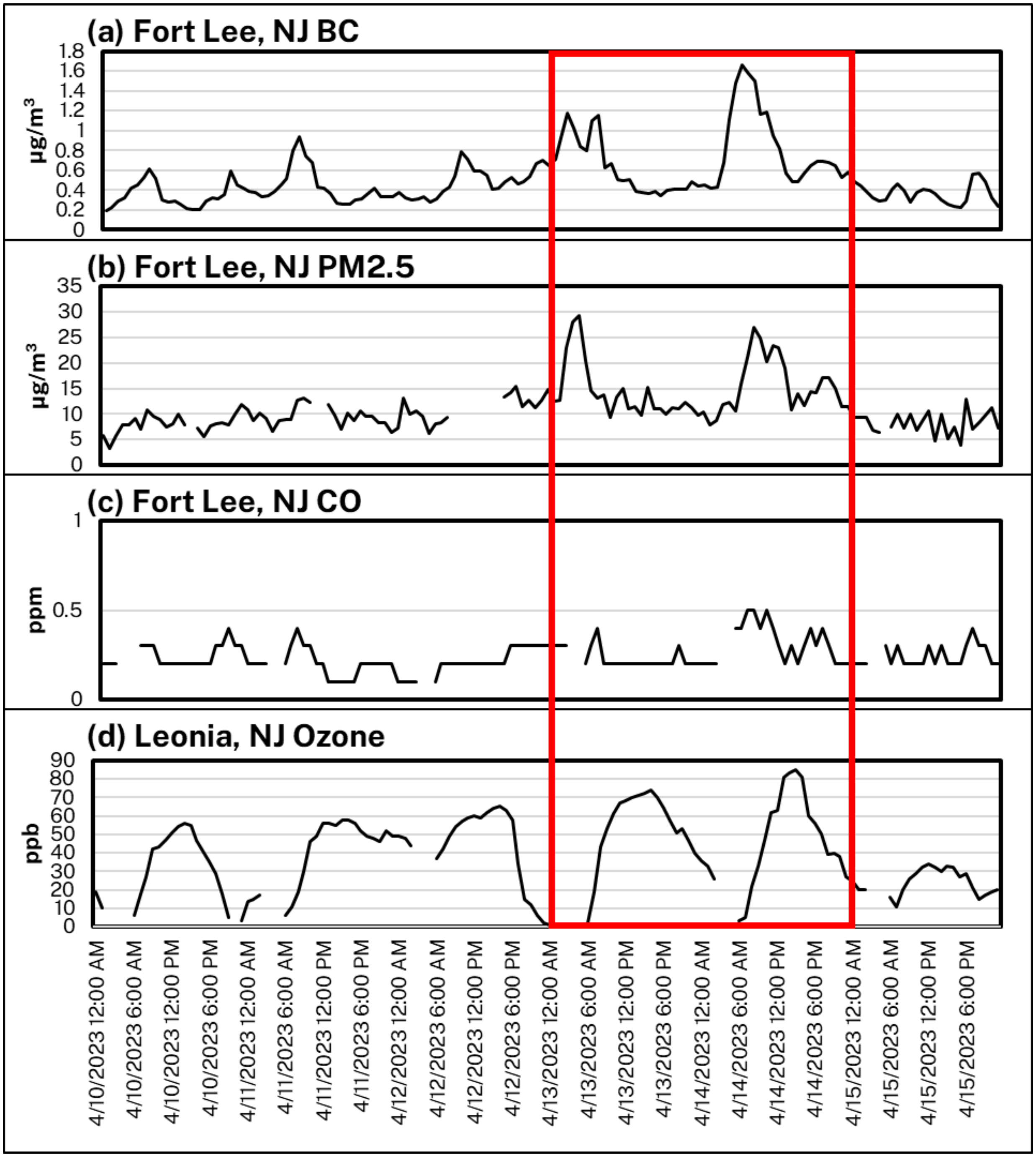



**Figure 7-25.** Monitored (a) Black Carbon, (b) PM2.5, (c) CO at the Fort Lee, New Jersey, monitor, and (d) Ozone at the Leonia, New Jersey, monitor surrounding the April 13-14 event.

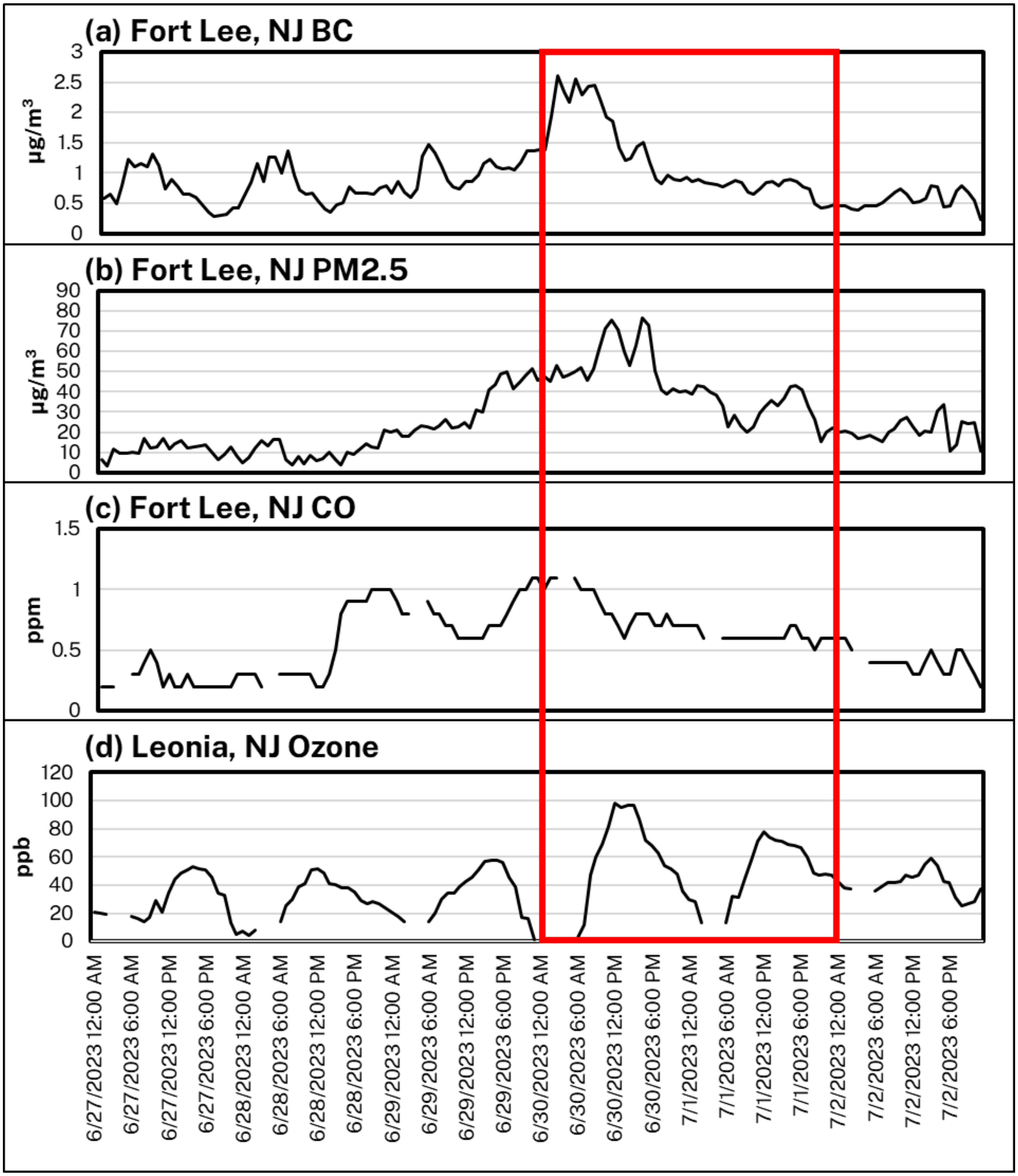



**Figure 7-26.** Monitored (a) Black Carbon, (b) PM2.5, (c) CO at the Fort Lee, NJ monitor, and (d) Ozone at the Leonia, New Jersey, monitor surrounding the June 30 - July 1 event.

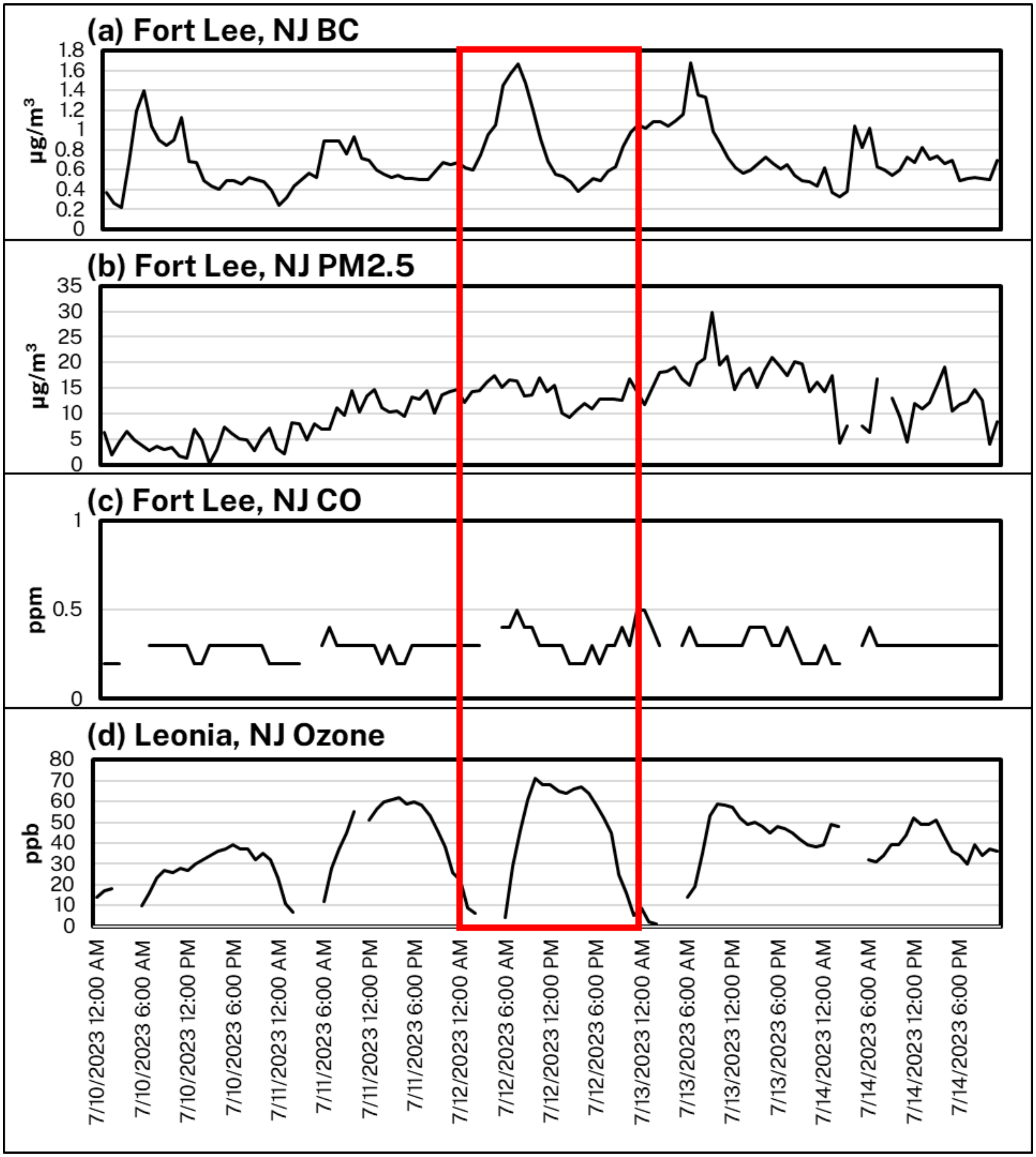


**Figure 7-27.** Monitored (a) Black Carbon, (b) PM2.5, (c) CO at the Fort Lee, New Jersey, monitor, and (d) Ozone at the Leonia, New Jersey, monitor surrounding the July 12 event.

**East Providence, Rhode Island**

During the April event, Figure 7-28 shows similar peaks for black carbon, just a few hours later, and it shows similar peaks for ozone with a delayed spike on April 13 for East Providence. However, PM2.5 increases more steadily at East Providence and CO spikes higher. Figure 7-29 shows similar spikes and patterns at Fort Lee and Leonia, but the black carbon is lower at East Providence. For the July 12 event, Figure 7-30 shows similar patterns and magnitudes for all the pollutants with more of a building effect for East Providence. This suggests that the extent of the smoke plume impacted New York, New Jersey, Connecticut, and Rhode Island at a minimum for each of the ozone events.

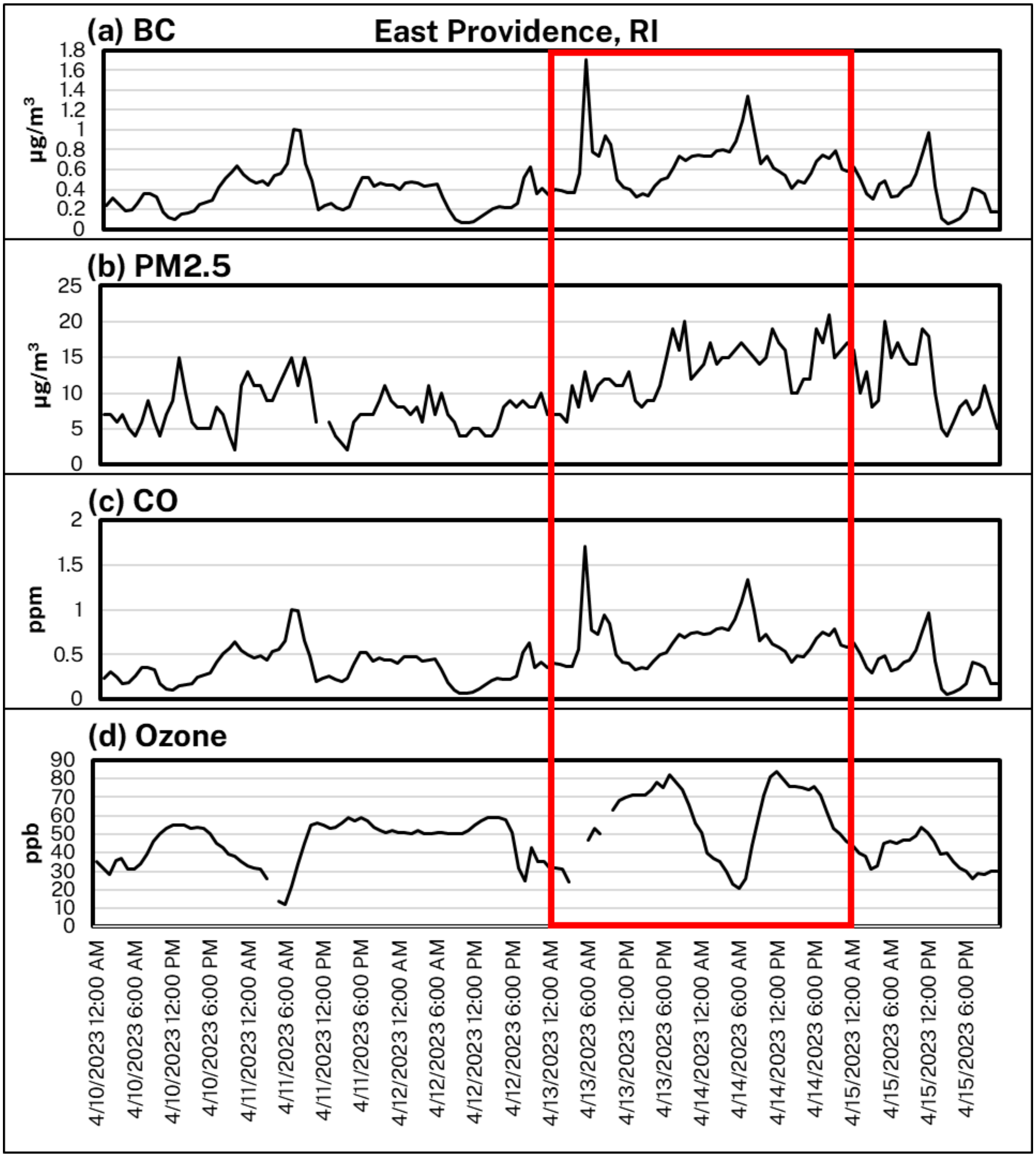



**Figure 7-28.** Monitored (a) Black Carbon, (b) PM2.5, (c) CO, and (d) Ozone at the East Providence, Rhode Island, monitor surrounding the April 13-14 event.

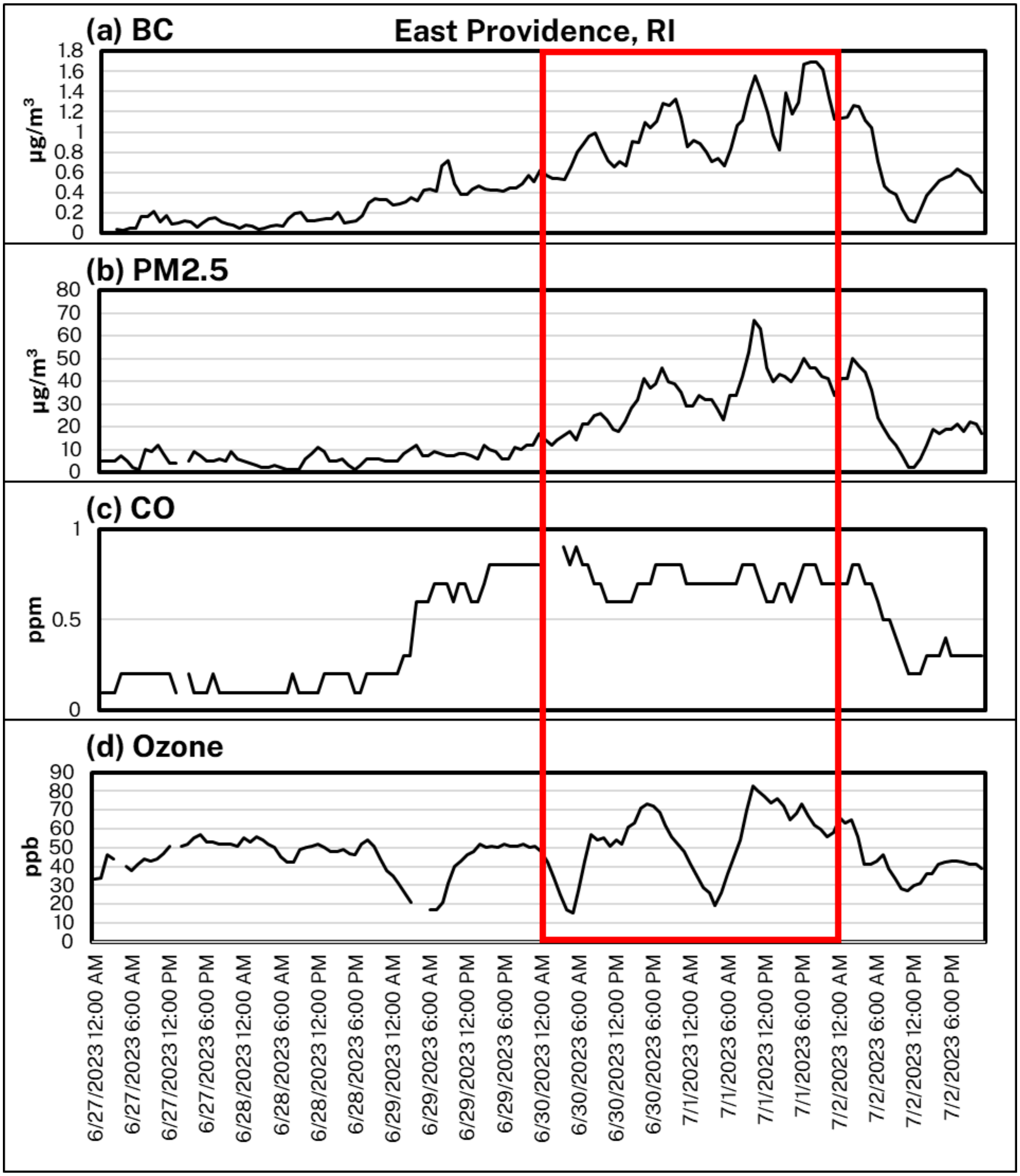



**Figure 7-29.** Monitored (a) Black Carbon, (b) PM2.5, (c) CO, and (d) Ozone at the East Providence, Rhode Island, monitor surrounding the June 30 - July 1 event.

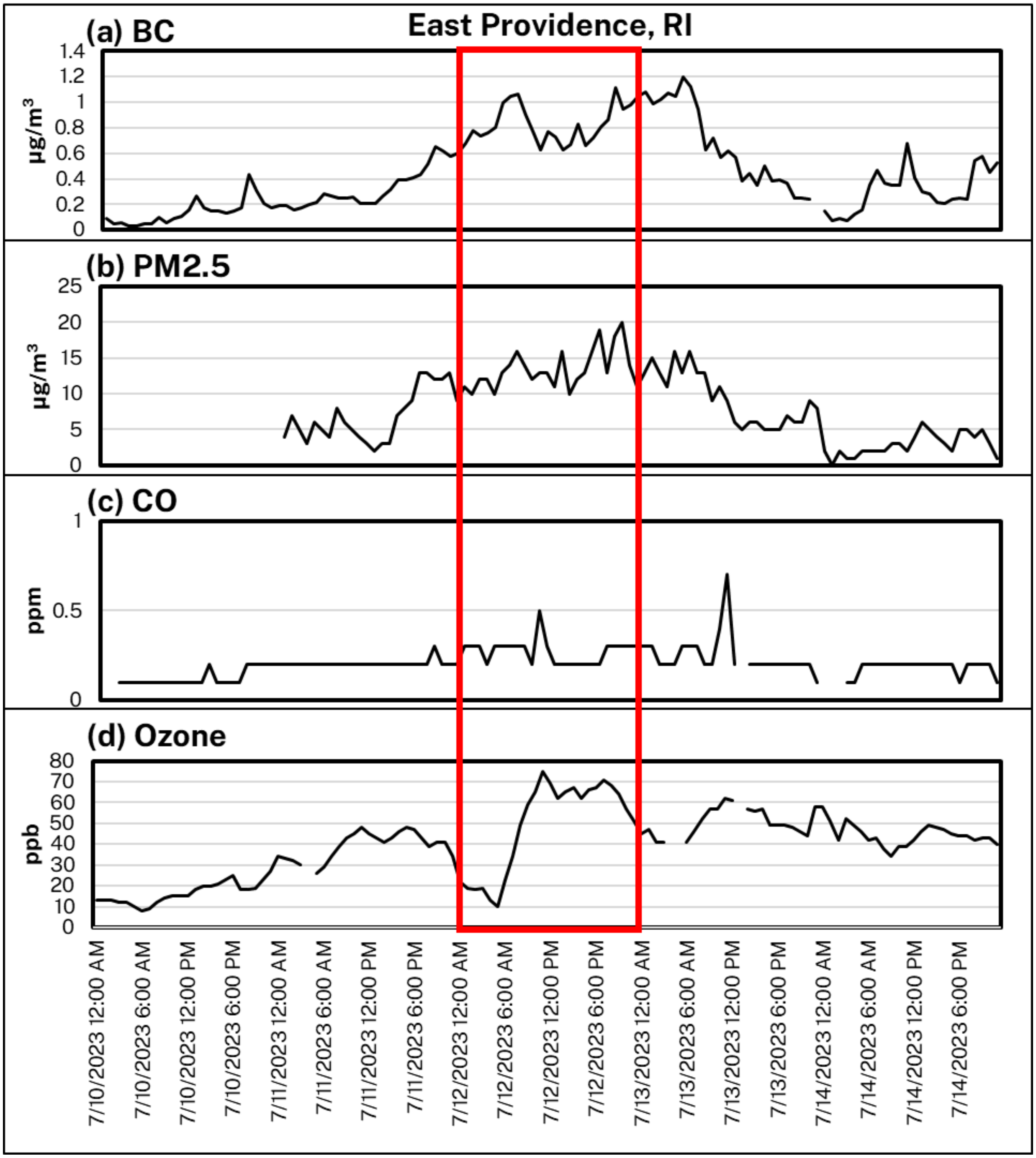



**Figure 7-30.** Monitored (a) Black Carbon, (b) PM2.5, (c) CO, and (d) Ozone at the East Providence, Rhode Island monitor surrounding the July 12 event.

## 7.4 Regional Ozone Data

Areas immediately surrounding Connecticut rarely exceed the ozone standard. Therefore, Connecticut considers data from nearby upwind and downwind ozone monitors to further support the case that these events were unusual. Figure 7-31 shows the map highlighting monitor locations used for this multiyear ozone analysis. Each of the selected sites monitor ozone year-round and the full year data is presented.

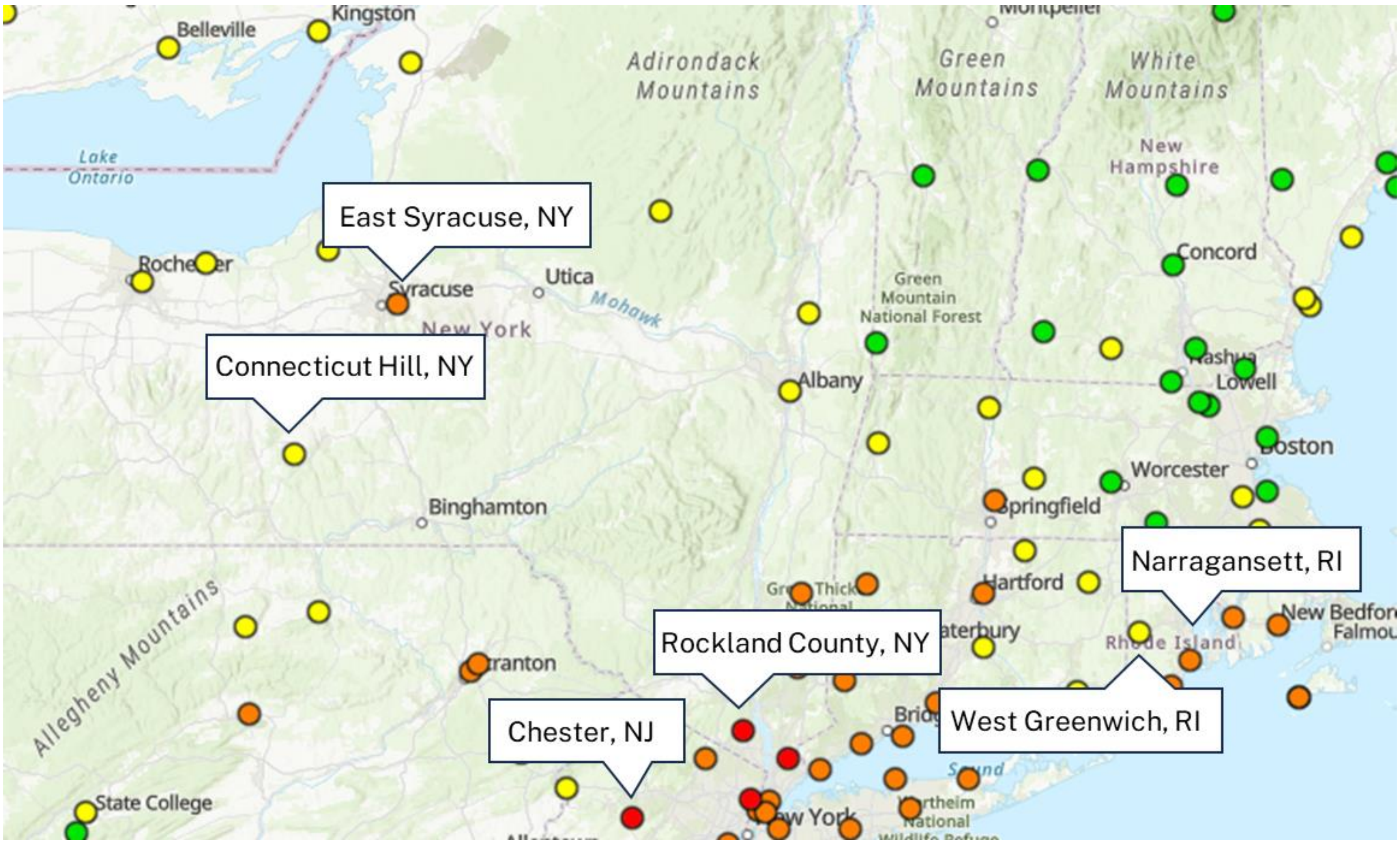



**Figure 7-31.** Map of regional monitors used for yearly ozone level charts.

**Connecticut Hill, New York**

Figure 7-32 shows daily 8-hour maximum monitored ozone for the years of 2017-2023 at the Connecticut Hill monitor in New York. The 70 ppb 8-hour maximum ozone noted for April 14th, 2023, was one of the highest ozone values reported during those 7 years. 2018 and 2021 stand out as having slightly higher values on a few occasions, but 2023 stands out for having a greater number of high ozone days compared to other years.

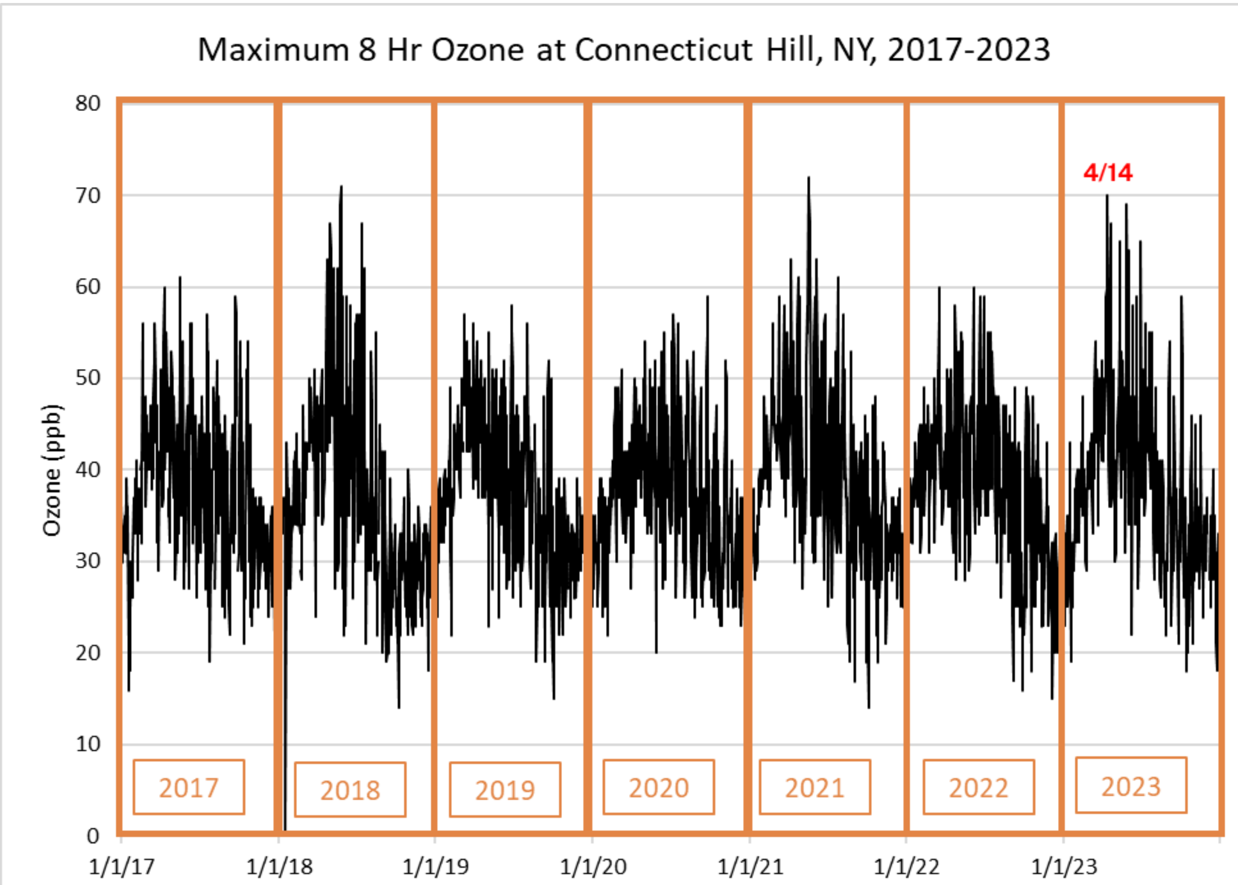



**Figure 7-32.** Monitored daily maximum 8-hour ozone for 2017-2023 at Connecticut Hill, New York.

**East Syracuse, New York**

Figure 7-33 shows daily 8-hour maximum monitored ozone for the years of 2017-2023 at the East Syracuse monitor in New York. The 76 ppb 8-hour maximum ozone noted for April 14th, 2023, and the 74 ppb 8-hour maximum ozone noted for June 30, 2023, were the among the three highest ozone values reported during those 7 years.

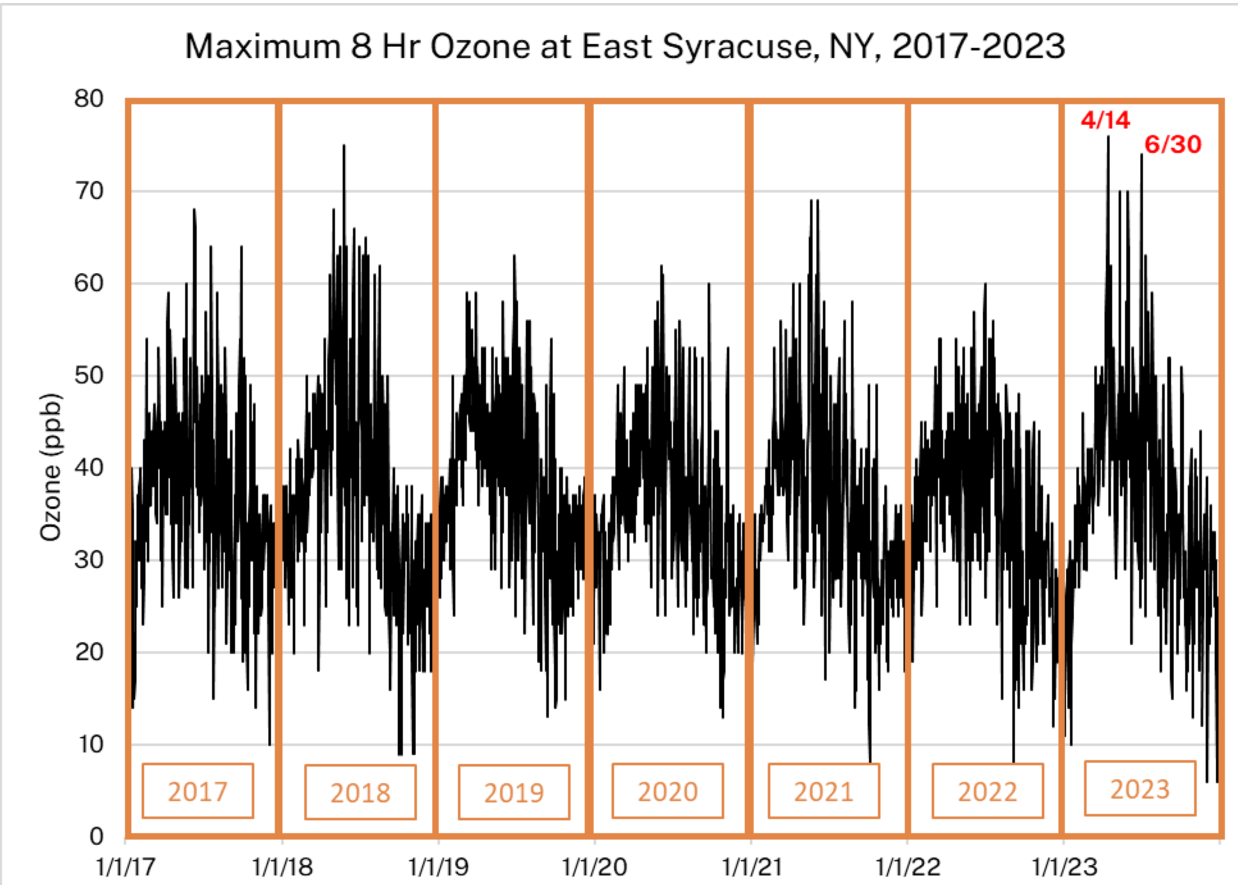



**Figure 7-33.** Monitored daily maximum 8-hour ozone for 2017-2023 at East Syracuse, NewYork.

## Rockland County, New York

Figure 7-34 shows daily 8-hour maximum monitored ozone for the years of 2017-2023 at the Rockland County monitor in New York. The 80 ppb 8-hour maximum ozone noted for April 14th, 2023, and the 86 ppb 8-hour maximum ozone noted for June 30th, 2023, were among the three highest ozone values reported during those 7 years. Many other days in 2023 also rank among the outliers for the period.

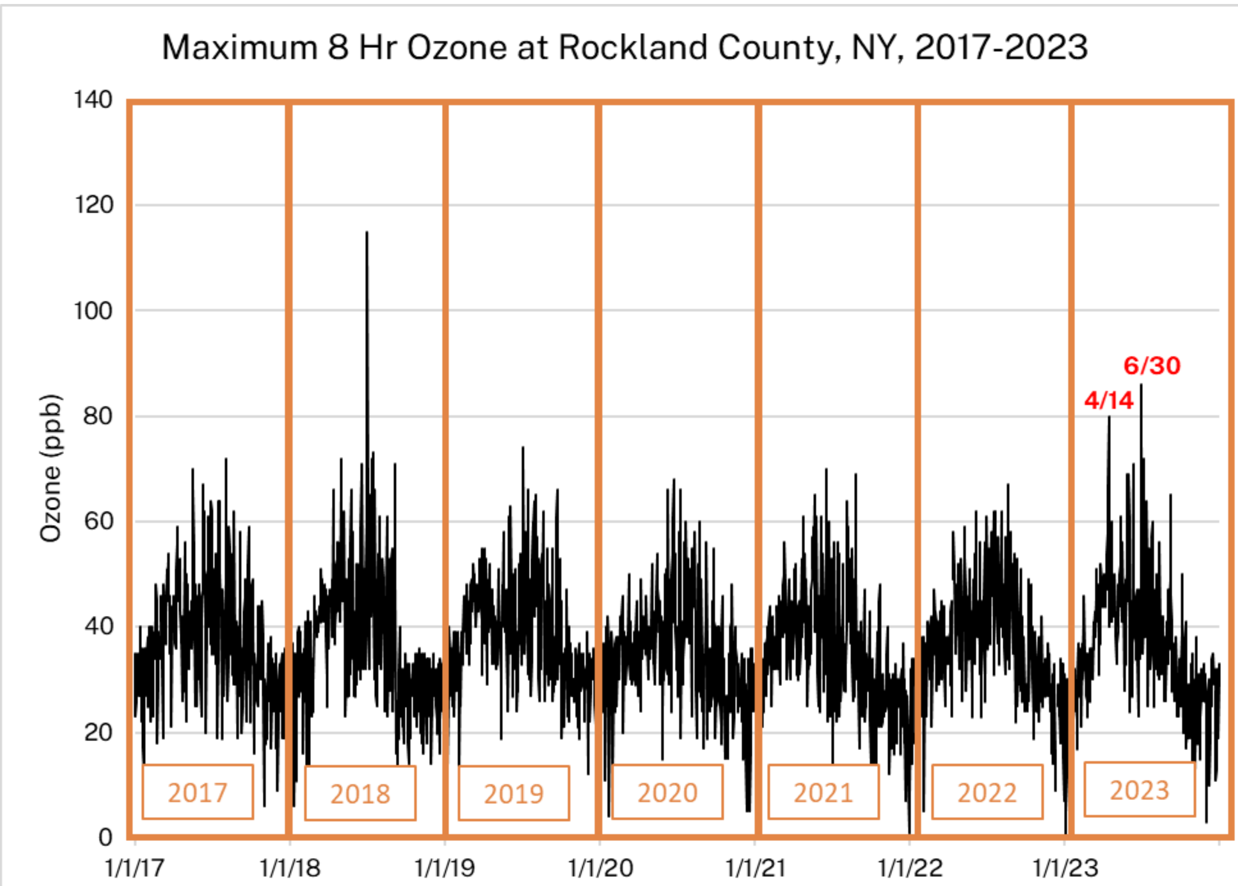



**Figure 7-34.** Monitored daily maximum 8-hour ozone for 2017-2023 at Rockland County, New York.

**Chester, New Jersey**

Figure 7-35 shows daily 8-hour maximum monitored ozone for the years of 2017-2023 at the Chester monitor in New Jersey. The 87 ppb 8-hour maximum ozone noted for June 30th, 2023, and the 77 ppb 8-hour maximum ozone noted for April 14th, 2023, were the highest ozone values reported during those 7 years. Multiple days in 2023 were outliers when compared to other years.

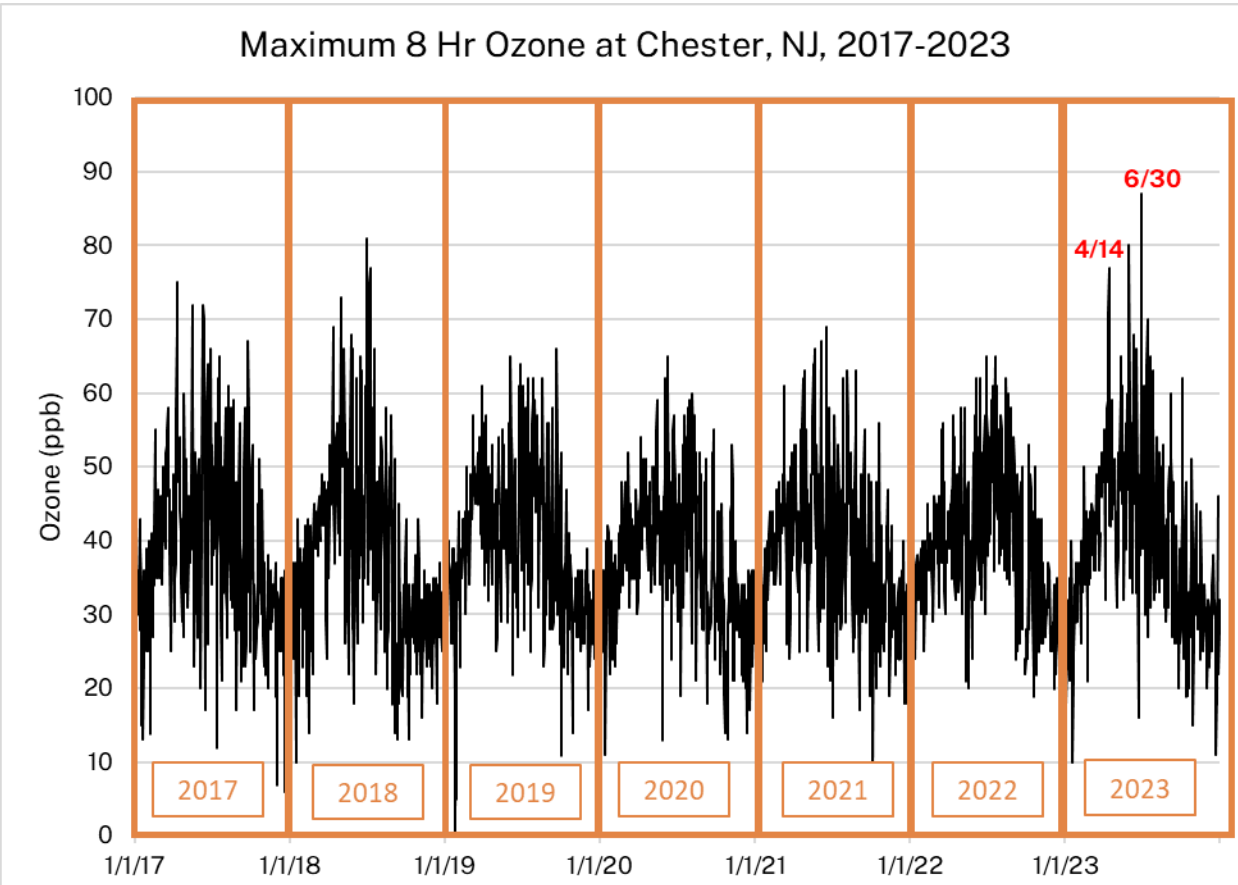



**Figure 7-35.** Monitored daily maximum 8-hour ozone for 2017-2023 at Chester, New Jersey.

## Narragansett, Rhode Island

Figure 7-35 shows daily 8-hour maximum monitored ozone for the years of 2017-2023 at the Narragansett monitor in Rhode Island. The 81 ppb 8-hour maximum ozone noted for April 13, 2023, and the 75 ppb 8-hour maximum ozone noted for July 1, 2023, were amongst the highest ozone values reported during those 7 years. The April 13 and July 1 maximum values are of particular interest signaling the extent of the impacts on ozone from the smoke plumes reaching eastward across Connecticut and into Rhode Island. Multiple days in 2023 at Narragansett were outliers when compared to other years including the April14, June 30 and July12 event days with MDA8 values of 73, 78 and 78 ppb, respectively.

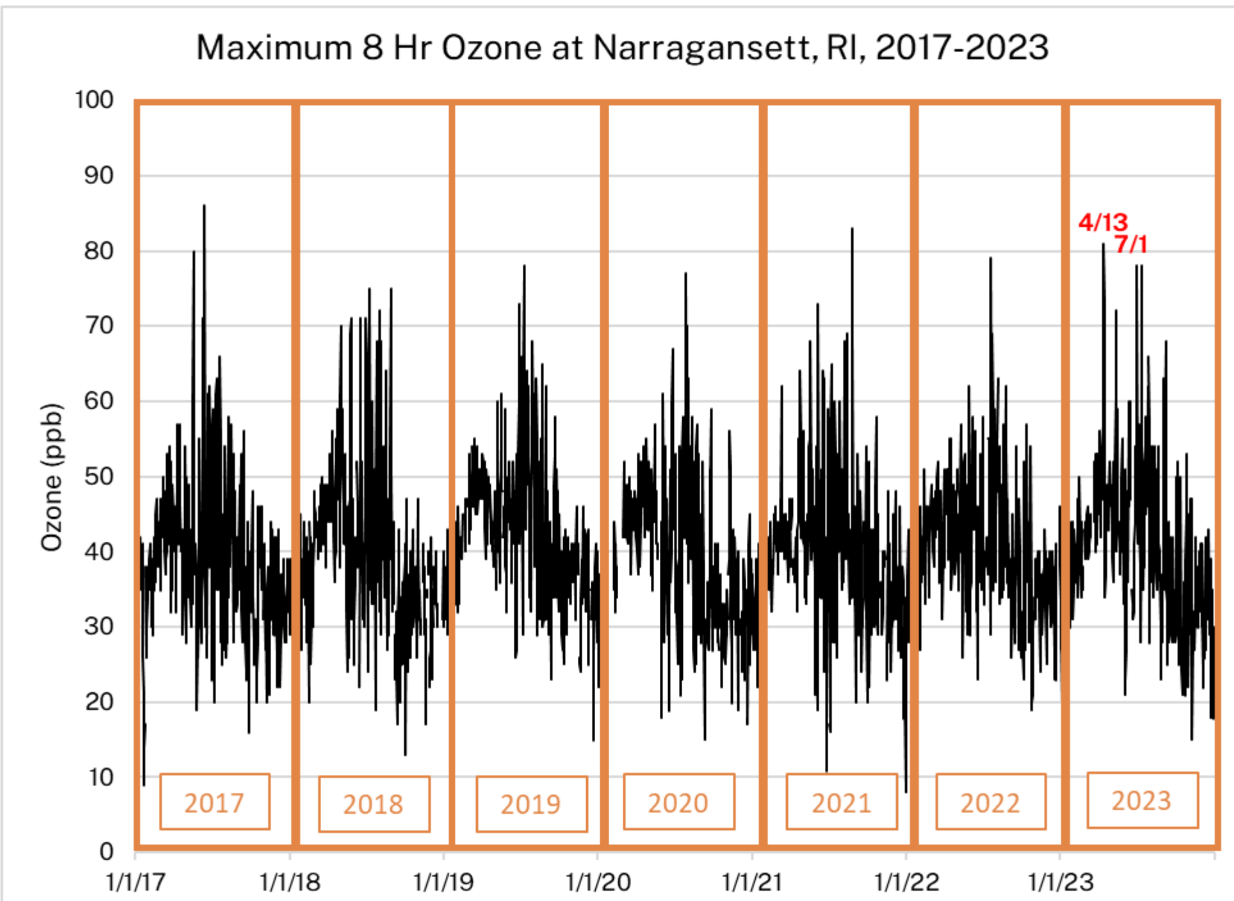



**Figure 7-36** Monitored daily maximum 8-hour ozone for 2017-2023 at Narragansett, Rhode Island.

## West Greenwich, Rhode Island

Figure 7-35 shows daily 8-hour maximum monitored ozone for the years of 2017-2023 at the West Greenwich monitor in Rhode Island. The 78 ppb 8-hour maximum ozone noted for April 13-14, 2023 and the 70 ppb 8-hour maximum ozone noted for June 30, 2023, were amongst the highest ozone values reported during those 7 years. Multiple days in 2023 were outliers when compared to other years.

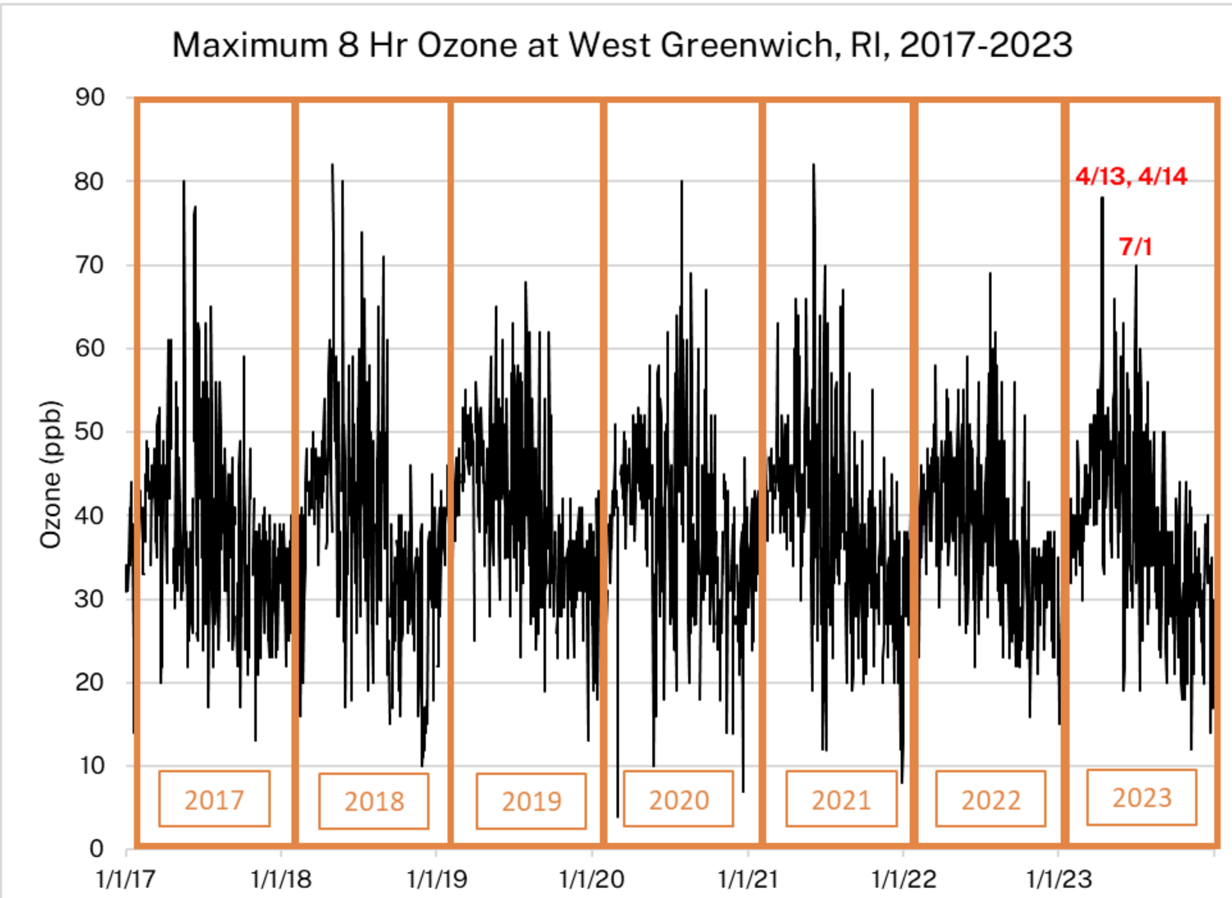



**Figure 7-37.** Monitored daily maximum 8-hour ozone for 2017-2023 at West Greenwich, Rhode Island.

## 7.5 Smoke Indicators in Local and Regional Speciated Particulate Data

The U.S. EPA initiated the national PM2.5 Chemical Speciation Monitoring Network (CSN) in 2000 to support evaluation of long-term trends and to better quantify source impacts of particulate matter (PM) in the size range below 2.5 micrometers aerodynamic diameter (PM2.5; fine particles). EPA also administers the long-standing Interagency Monitoring of Protected Visual Environments (IMPROVE) visibility monitoring network in rural Class 1 Areas across the country. Both networks measure the major chemical components of PM2.5 using historically accepted filter-based methods.

Organic Carbon (OC) and Potassium (K) speciated PM2.5 are most closely associated with wildfire emissions. The Cornwall, New Haven, Rochester, Pinnacle State Park, Providence, and Chester sites, shown on the map below, all have speciated PM2.5 data completed through April 30th.[71]

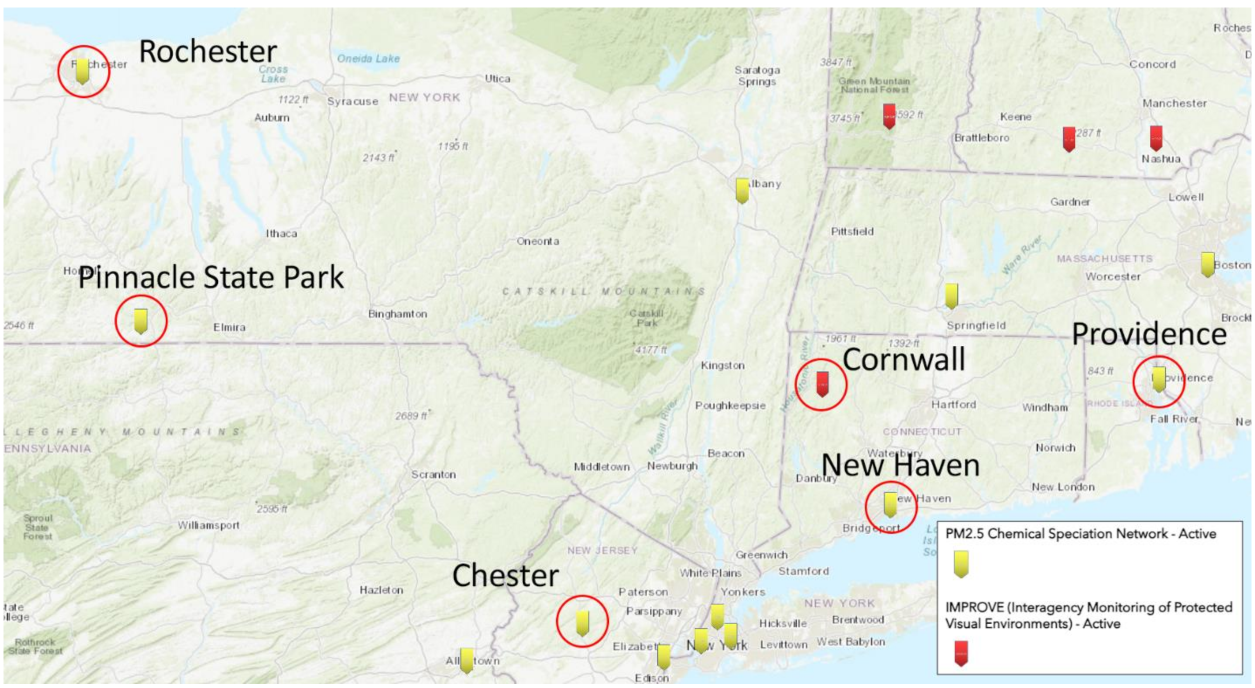



**Figure 7-38.** Map showing locations of speciated PM2.5 and IMPROVE monitoring sites.

The following figures generally show that K and OC obtained from the speciated data from these sites exhibited upward trends, coinciding with elevated ozone levels during the April 13-14th ozone event. There was also a spike in the OC and K on February 26th at Cornwall and New Haven, which was determined to be from a wildfire in southern New Jersey. The Rochester and Pinnacle State Park sites also showed elevated K and OC from smoke plumes that were confirmed by HMS analysis. All sites show a clear relationship between the OC, K and the rise in the ozone during the April 13-14 event.

[71] Data beyond this date was not available at the time of this writing.

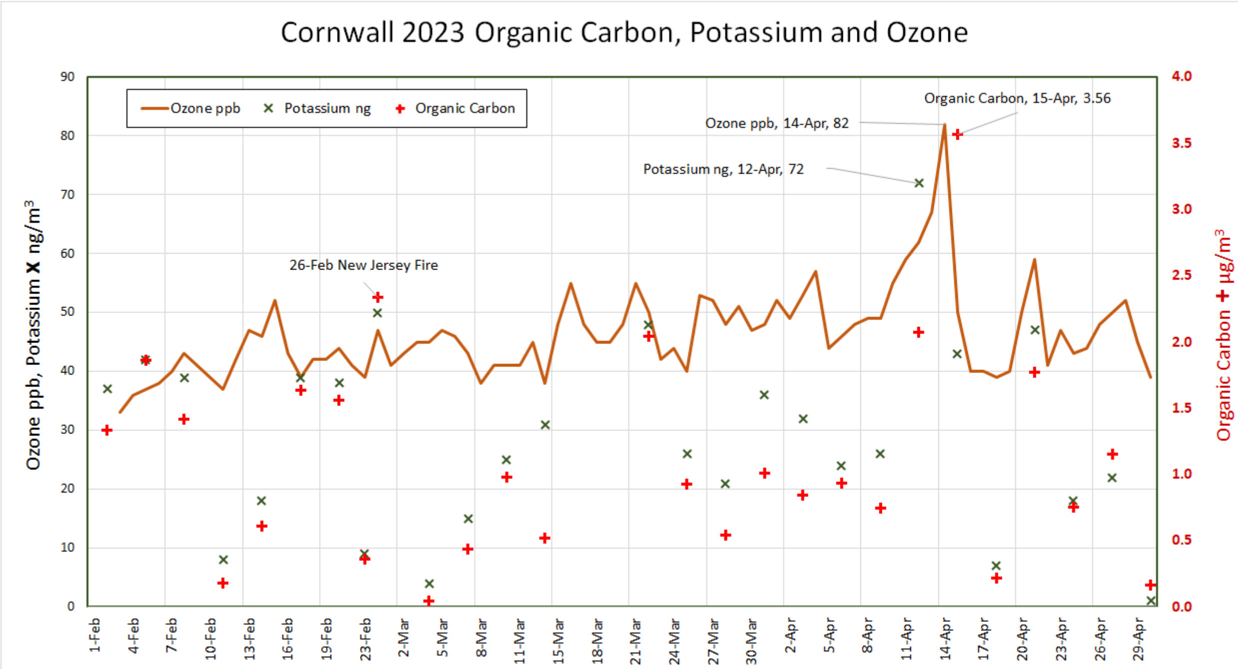



**Figure 7-39.** Cornwall organic carbon, potassium and ozone, February-April 2023.

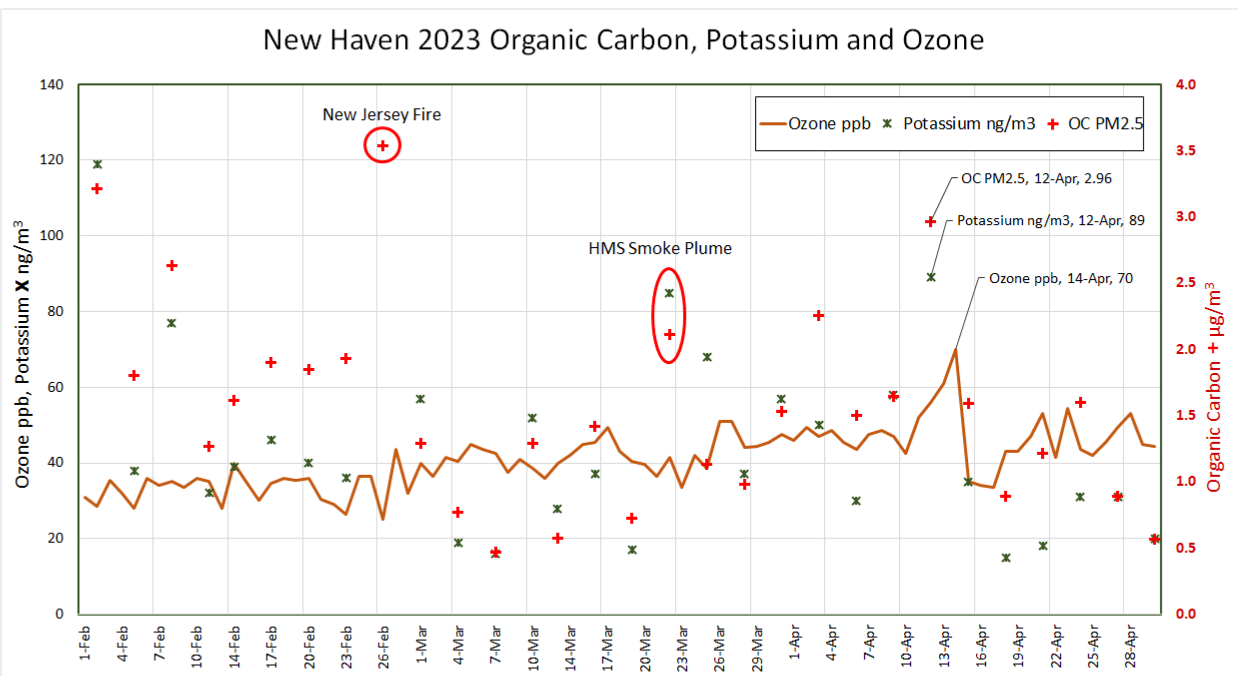



**Figure 7-40.** New Haven organic carbon, potassium and ozone, February-April 2023.

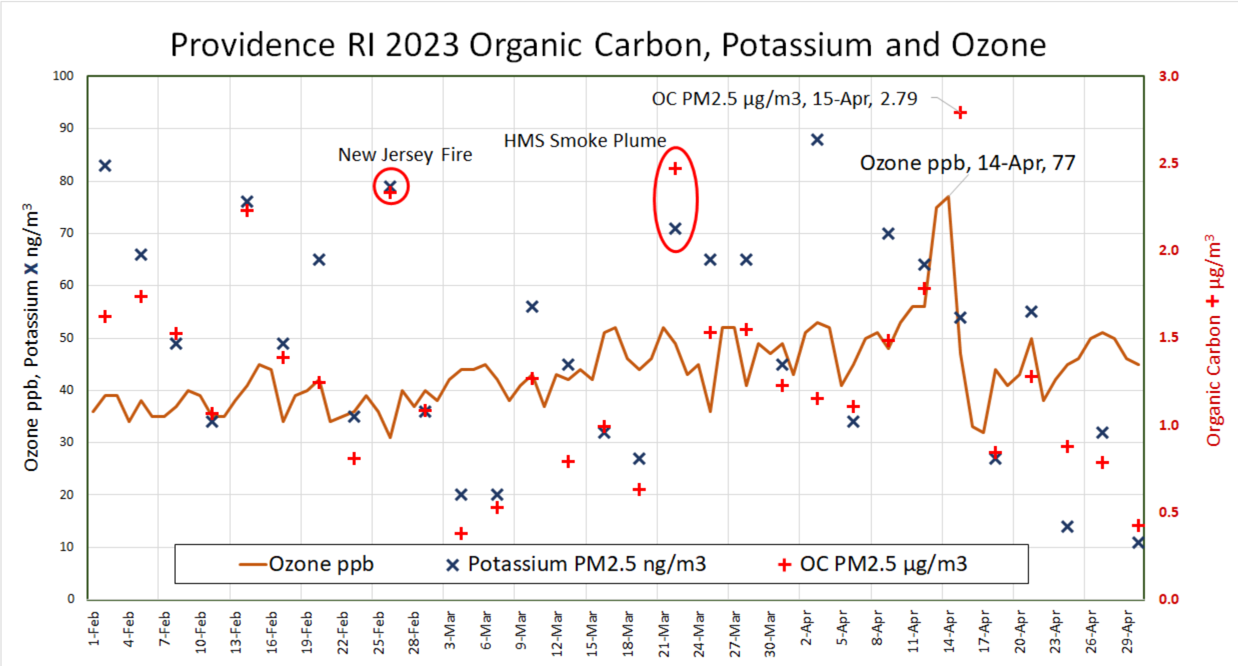



**Figure 7-41.** Providence, RI, organic carbon, potassium and ozone, February-April 2023.

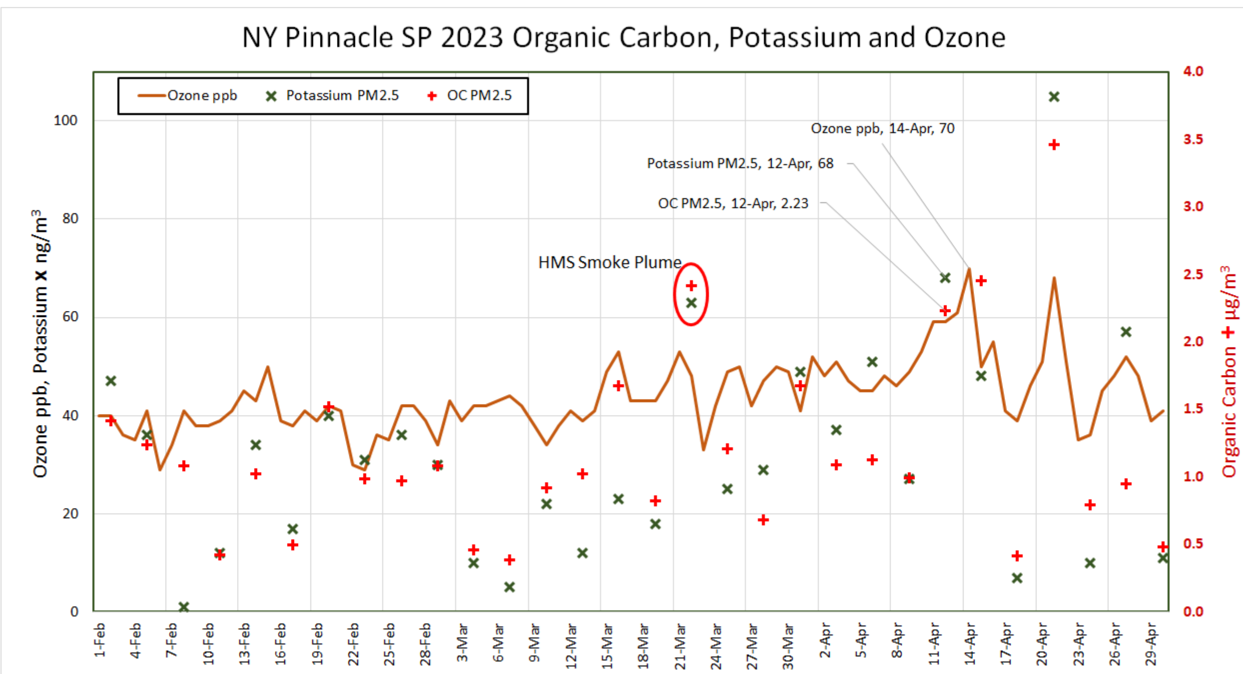



**Figure 7-42.** Pinnacle State Park, NY, organic carbon, potassium and ozone, February-April 2023.

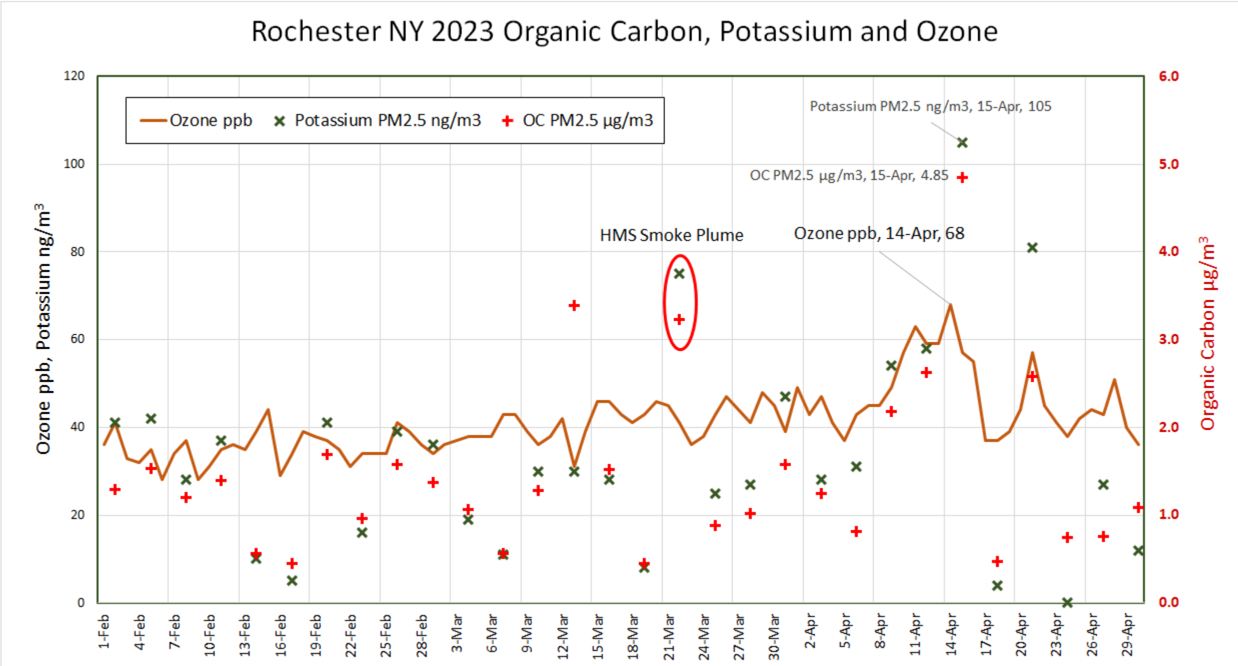



**Figure 7-43.** Rochester, NY, organic carbon, potassium and ozone, February-April 2023.

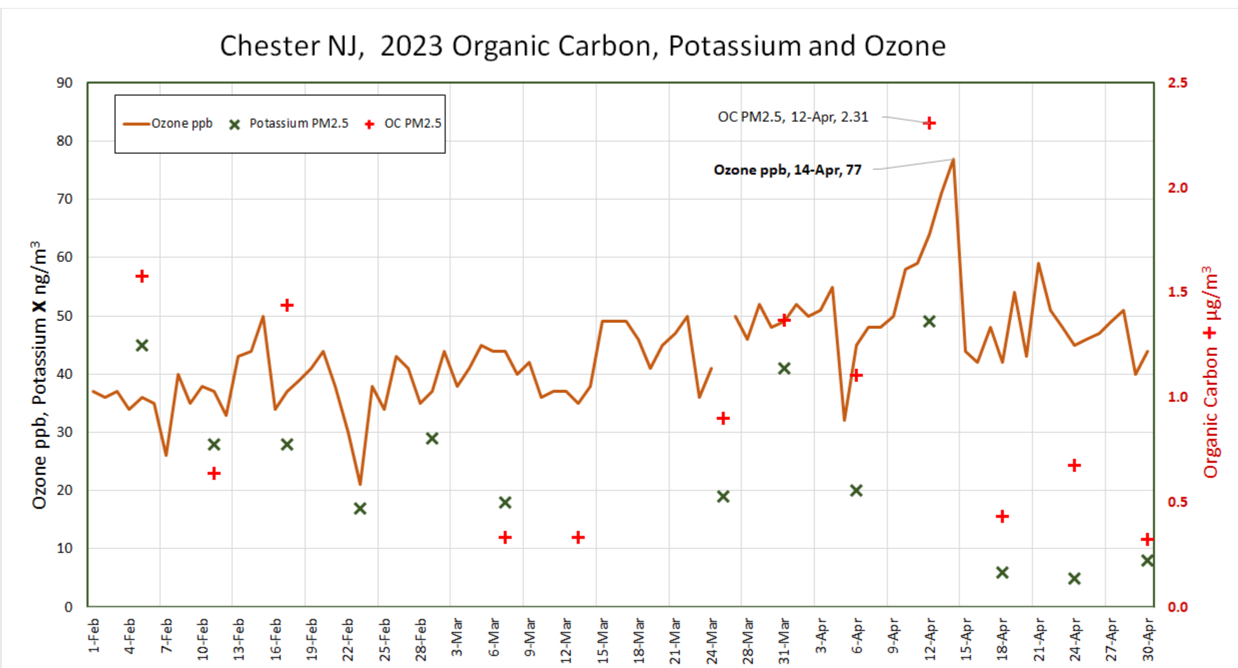



**Figure 7-44.** Chester, NJ, organic carbon, potassium and ozone, February-April 2023.

IMPROVE speciated data is not immediately available and additional data becomes available months after it is collected. Data for the June 30-July 1 event is, as of this writing, only available through June 30. Figure 7-45 shows the organic carbon and potassium data from Cornwall on June 8th when a major PM2.5 event impacted the northeast, including Connecticut. Additional peaks are noted near the April 13-14 and June 30-July 1 smoke events when ozone levels were also affected. Figure 7-46 shows similar event day peaks for organic carbon and carbon monoxide with data extending through July at the Providence monitor. Localized peaks in both carbon monoxide and organic carbon occur surrounding the July 12 smoke event as well.

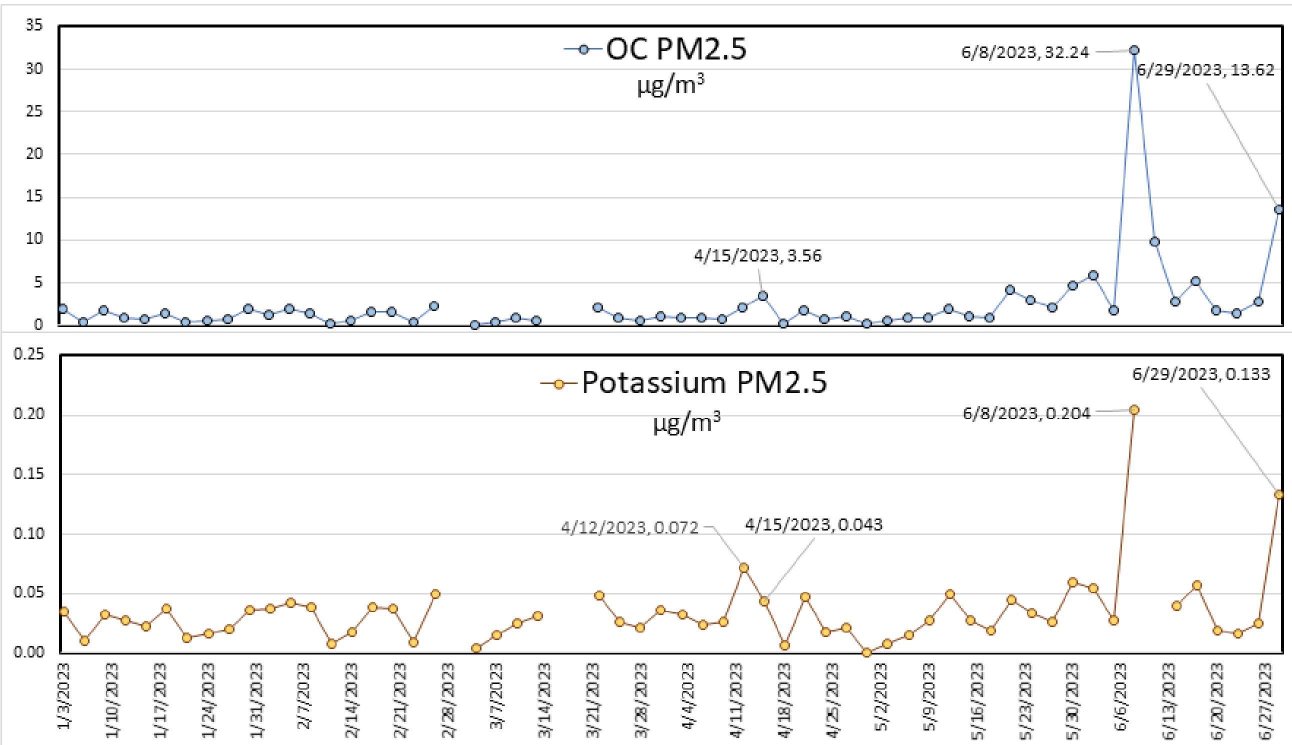



**Figure 7-45.** PM.25 data speciated for organic carbon and potassium through June 30, 2023, from the Cornwall site.

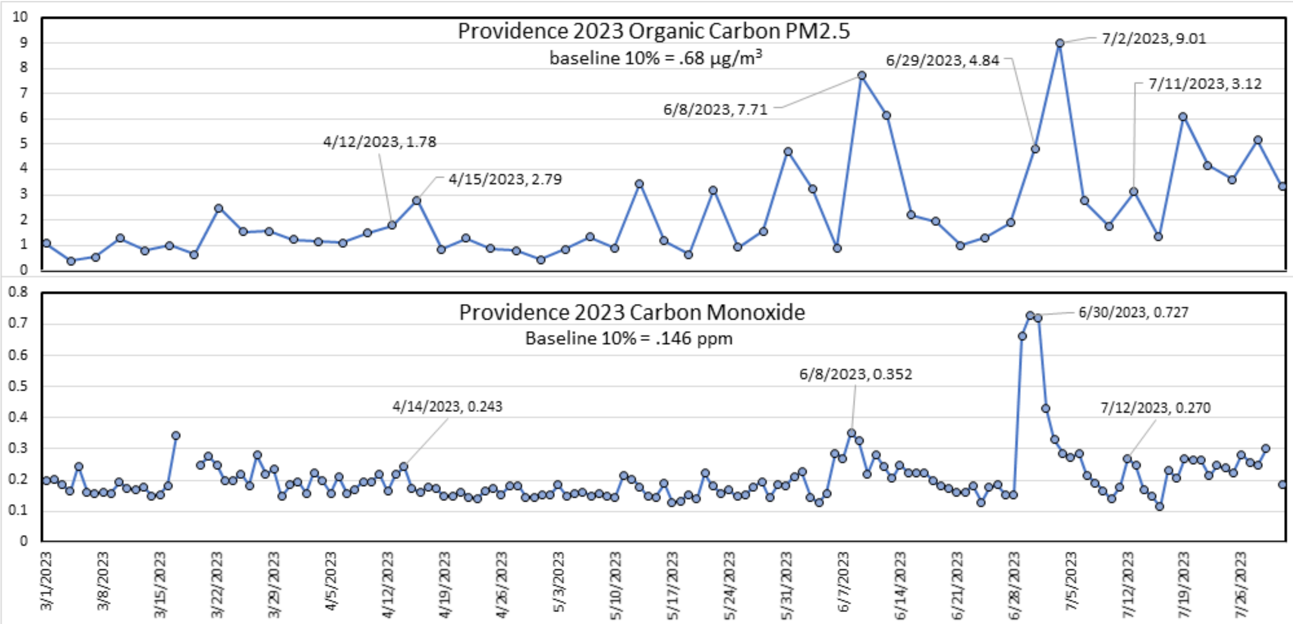



**Figure 7-46.** PM.25 data speciated for organic carbon and potassium through June 30, 2023, from the Providence site.

# 8 Hysplit Trajectory Analyses

*"Air agencies can produce HYSPLIT trajectories for various combinations of time, locations and plume rise. HYSPLIT back-trajectories generated for specific monitor locations for days of high $O_3$ concentrations illustrate the potential source region for the air parcel that affected the monitor on the day of the high concentration and provide a useful tool for identifying meteorological patterns associated with monitored exceedances. Forward-trajectories from specific wildfire events to specific monitors can also be used to indicate potential receptors."*

-EPA guidance: Treatment of Data Influenced by Exceptional Events

## 8.1 April 13-14, 2023 Ozone Event

### Backward Trajectories

Ozone exceeded the levels of the standard for multiple monitor sites in southern New England and one monitor site in northern New England on April 13, 2023, with ozone intensifying on April 14, 2023. High pressure over the mid-Atlantic region and the southeastern United States allowed for flow from the Midwest to southern New England.

The model of choice for all forward and backward trajectories is the North American Mesoscale Forecast System (NAM), which uses a 12 km grid. Figure 8-1 shows a matrix of backward trajectories from various locations in New England on April 13 and 14 confirming the source of the smoke being the Flint Hills prescribed burns in Kansas (yellow stars). The northeastern locations in the matrix show backward trajectories pointing towards the northern United States on April 13 and western Canada on April 14. These areas, including northern New Hampshire and western Maine, recorded moderate ozone levels on each day.

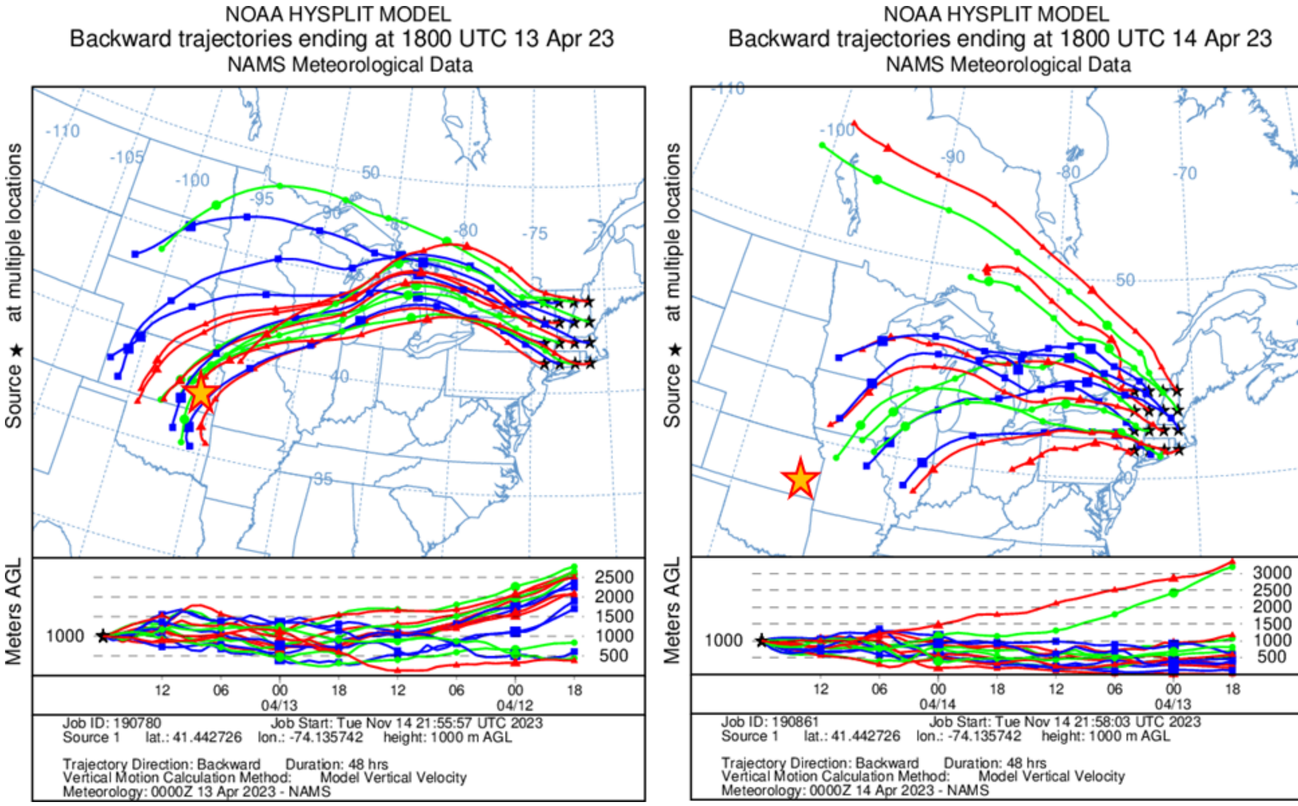



**Figure 8-1.** HYSPLIT 48-hour backward trajectories from New England: April 13, 2:00 PM EDT (left); April 14, 2:00 PM EDT (right).

Focusing on Connecticut, Figure 8-2 and Figure 8-3 show the backward trajectories from Cornwall on April 13 and 14 along with HMS Fires and Smoke from three days prior. For both days, the backward trajectories, fire locations, and smoke plumes confirm that smoke and ozone precursors from the Flint Hills prescribed fires were transported into Connecticut. This event was atypical for Connecticut due to the presence of smoke along with an abnormal wind pattern for an exceedance day. A typical ozone exceedance day features southwest winds allowing for transport along the I-95 corridor. However, on April 13-14, winds were primarily west or northwest, transporting pollutants across the country from the Great Lakes region, which typically includes a cleaner air mass.

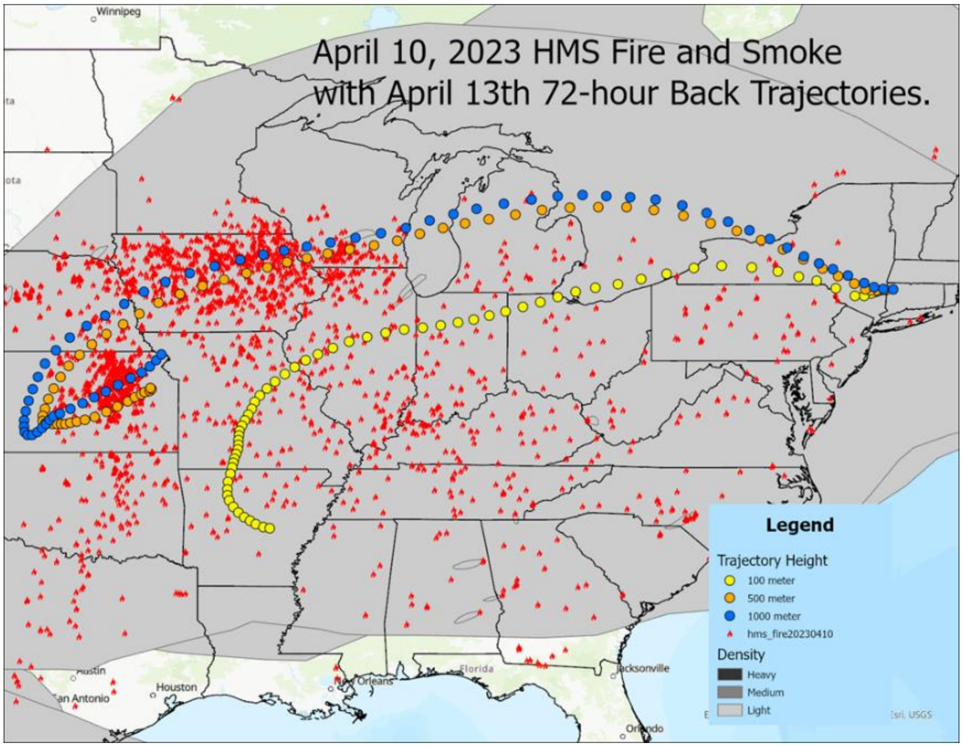



**Figure 8-2.** HYSPLIT 72-hour backward trajectories from Cornwall on April 13 with HMS fire locations and smoke plumes from April 10, showing the path of transport of smoke to Connecticut.

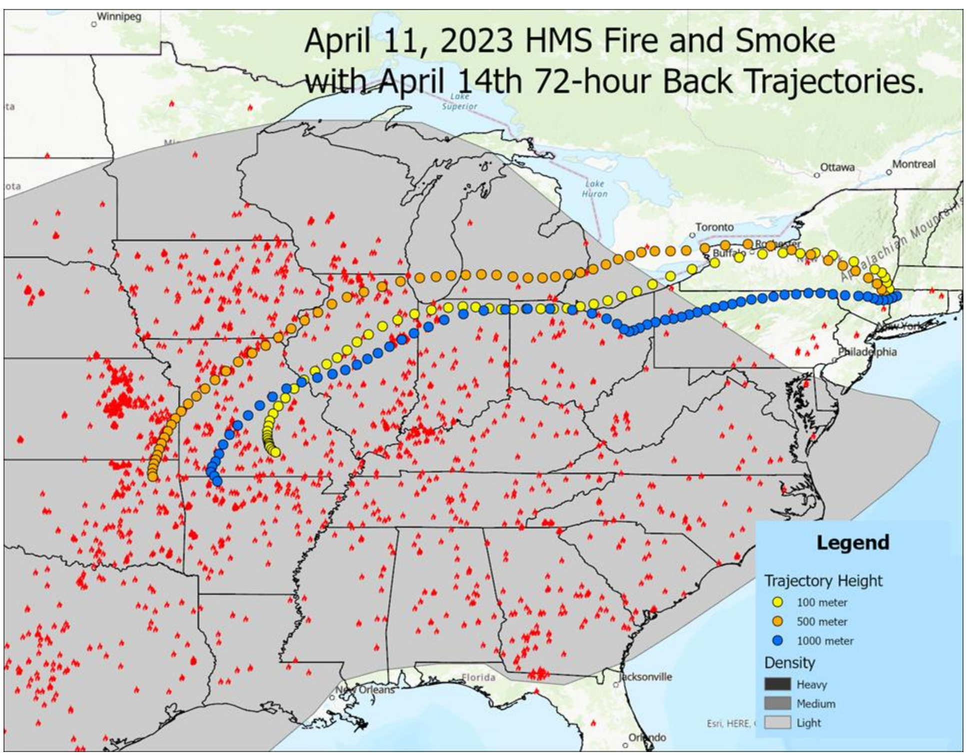



**Figure 8-3.** HYSPLIT 72-hour backward trajectories from Cornwall on April 14 with HMS fire locations and smoke plumes from April 11, showing path of transport of smoke to Connecticut.

To determine if local sources may have impacted air quality during this event, backward trajectories at 100-meter heights are also examined. For Cornwall on April 13 and 14, backward trajectories remain north of Pennsylvania with primarily west or northwest winds (Figure 8-4). For East Hartford, winds are very similar to Cornwall with backward trajectories remaining north of Pennsylvania (Figure 8-5). Days with these backward trajectories do not typically exceed the ozone standard, instead ozone levels are usually within the good to moderate range. For Groton, Figure 8-6, backward trajectories are similar to the other Greater Connecticut sites, but the winds have a southwest component in the afternoon on both days. This wind pattern allows for additional smoke from local fires in Pennsylvania, New York, and northern New Jersey to increase ozone precursors and enhance ozone formation over Long Island Sound. These pollutants would have been trapped within the shallow, marine boundary layer and result in increased ozone levels at Groton and shoreline sites. All three of the Connecticut sites shown with 100 meter back trajectories show the air parcels either at the surface or closer to the surface beginning on April 13. VOCs from the smoke source originating at the Flint Hills agricultural burns in Kansas likely mixed with urban emission sources to enhance ozone production over LIS and along the Connecticut coastline. Backward trajectory analysis for April 13 and 14 strongly suggests that the Flint Hills burns were the main cause of the ozone exceedances.

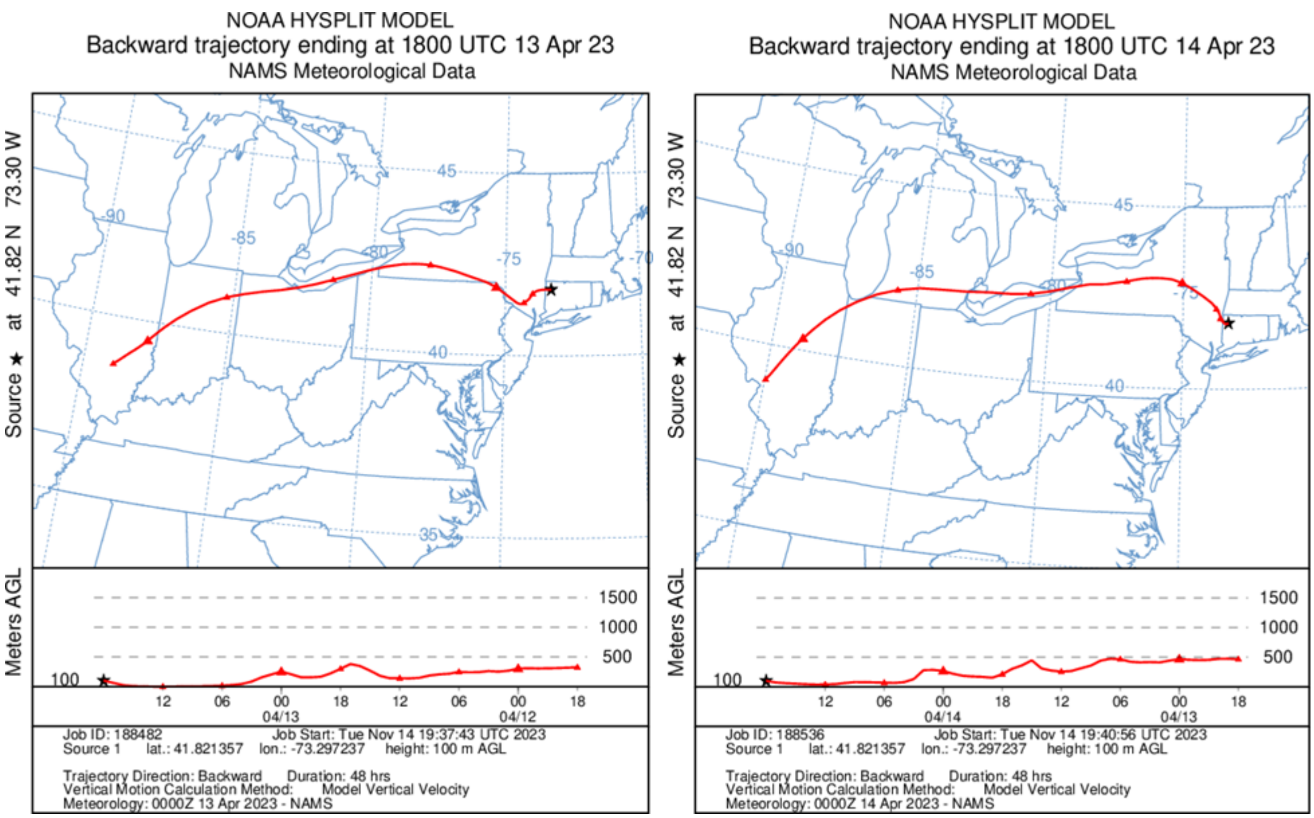



**Figure 8-4.** 100-meter backward trajectory from Cornwall, Connecticut: April 13, 2:00 PM EDT(left); April 14, 2:00 PM EDT (right).

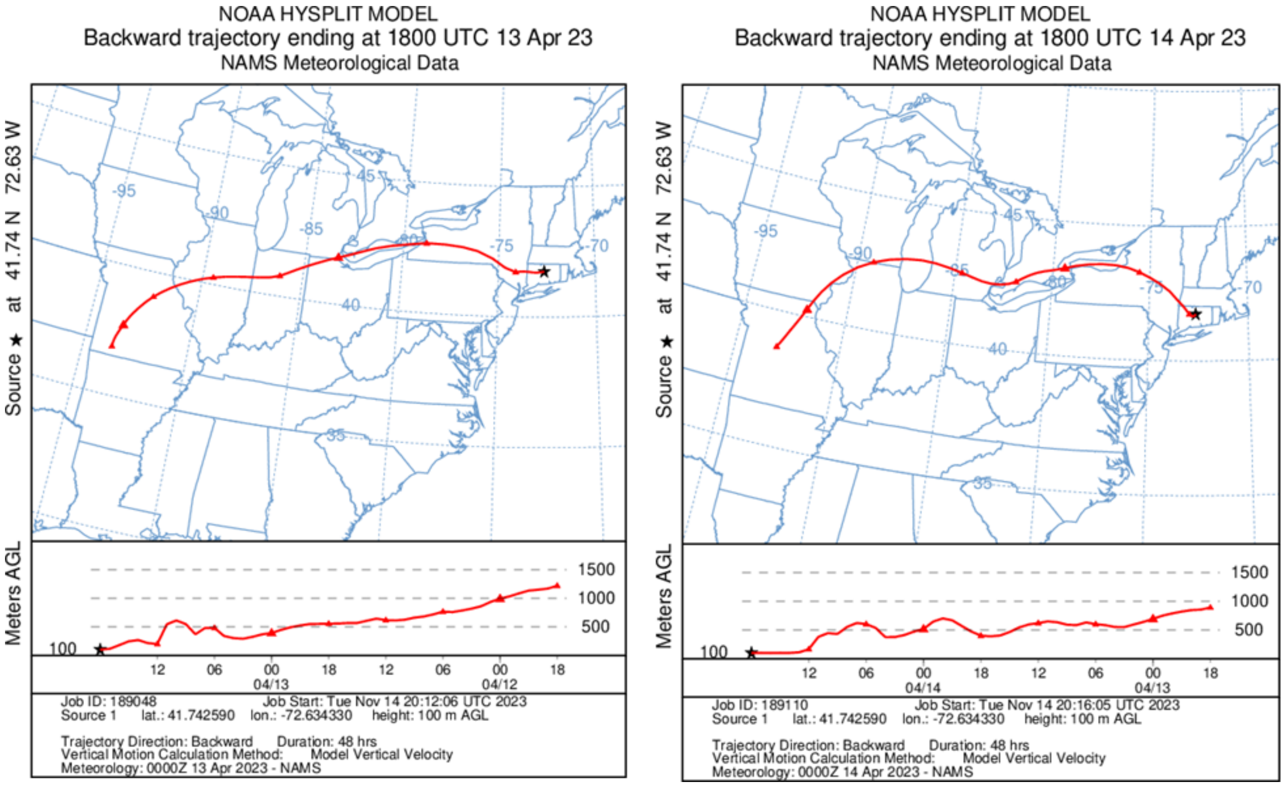



**Figure 8-5.** 100-meter backward trajectory from East Hartford, Connecticut: April 13, 2:00 PM EDT (left); April 14, 2:00 PM EDT (right).

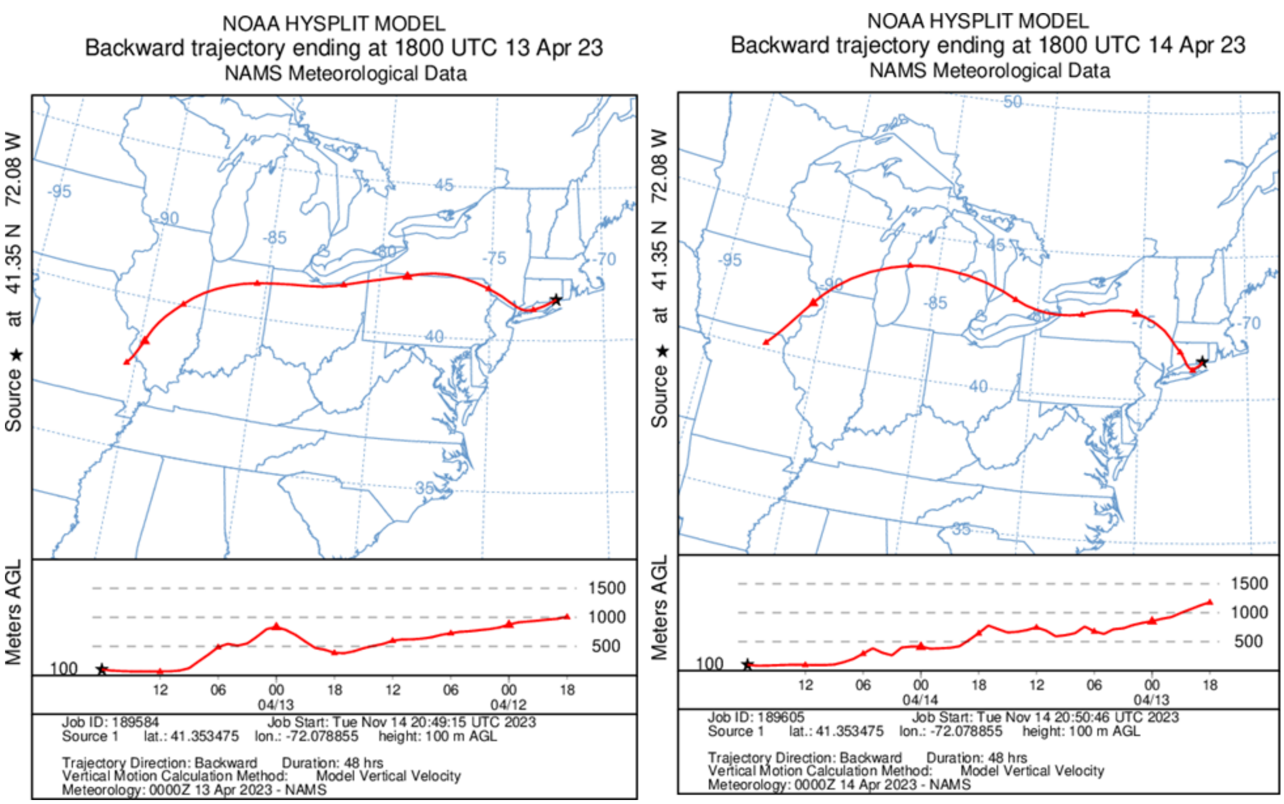



**Figure 8-6.** 100-meter backward trajectory from Groton, Connecticut: April 13, 2:00 PM EDT (left); April 14, 2:00 PM EDT (right).

## Forward Trajectories

For additional verification of the smoke source, forward trajectories are also investigated. Although the actual ozone event occurred on April 13 -14, 2023, the prescribed burns in the Flint Hills which contributed to the event had been burning since the beginning of April. Due to meteorological conditions previously mentioned, smoke was transported from Kansas to Connecticut from April 10 through April 14.

Forward trajectories from Flint Hills, Kansas on April 10-11, 2023, are shown below. The 72-hour forward trajectories were used to allow for transport time, and Figure 8-7 shows those trajectories moving northeastward over the Great Lakes before impacting Connecticut. In Connecticut, the ozone plume was being pushed from the northwesternmost corner of the state at the Cornwall monitor to the southeasternmost corner at the Groton monitor.

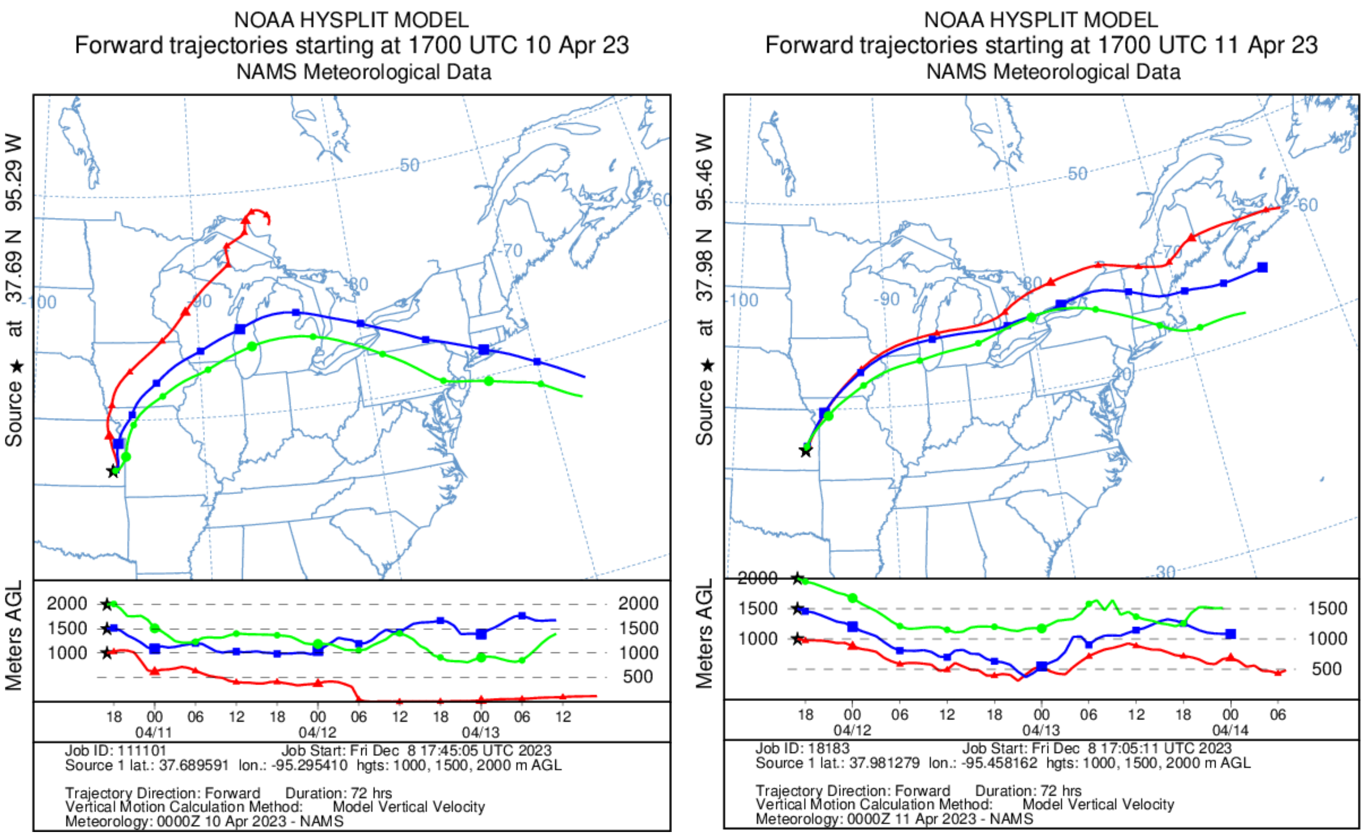



**Figure 8-7.** HYSPLIT 72-hour forward trajectories from Flint Hills, Kansas: April 10, 2:00 PM EDT (left); April 11, 2:00 PM EDT (right).

## 8.2 June 30 – July 1, 2023 Ozone Event

### Backward Trajectories

Figure 8-8 shows a matrix of backward trajectories for western New England on June 30 and July 1. On June 30, most of the matrix points show backward trajectories pointing to the Quebec wildfires (yellow star). However, the matrix points in northern New England are further east than the rest of the region allowing for a cleaner airmass for those areas. On July 1, all matrix points in New England are showing backward trajectories to the Quebec wildfires, allowing for widespread ozone exceedances and high moderate levels.

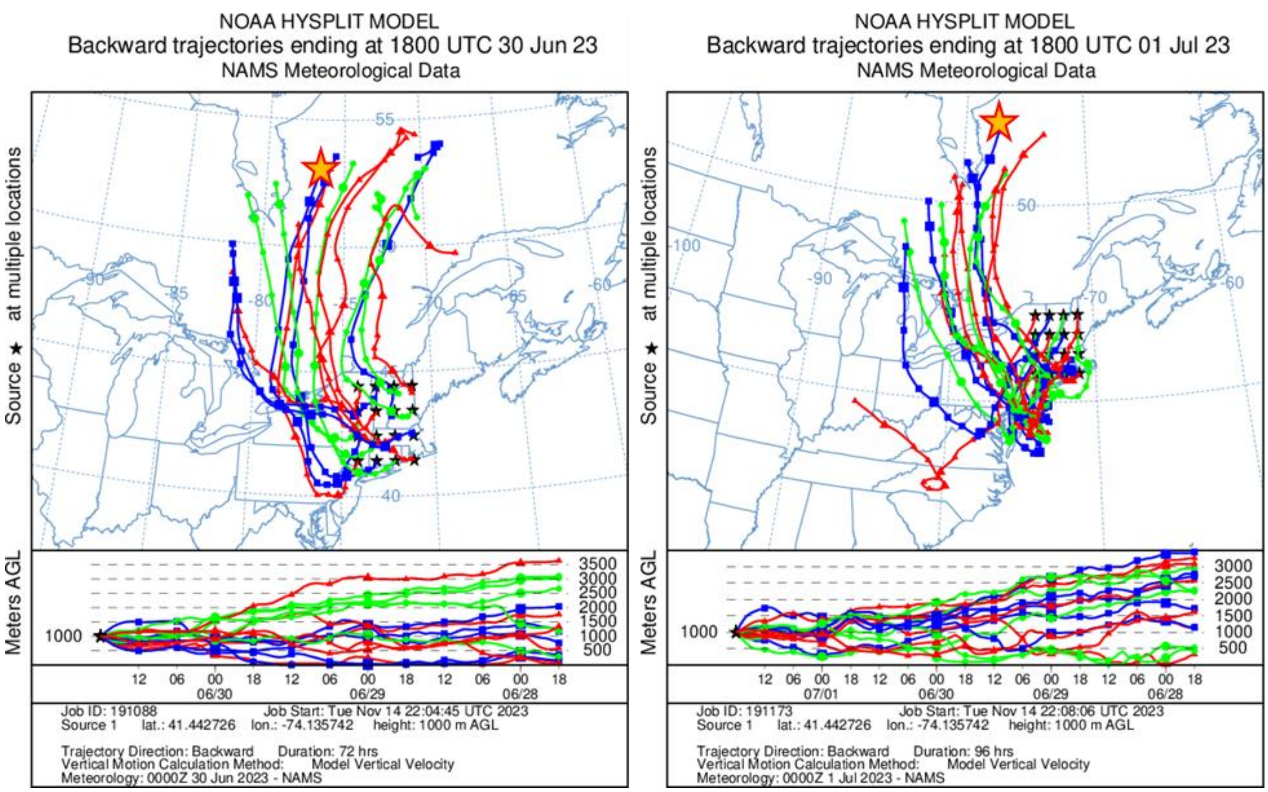



**Figure 8-8.** HYSPLIT backward trajectories from New England (left) 72-hour backward trajectories on June 30, 2:00 EDT, (right) 96-hour backward trajectories on July 1, 2:00 EDT.

Focusing on Connecticut, Figure 8-9 shows the June 30 backward trajectories overlaid on the June 27 HMS Fire and Smoke map. Similarly, Figure 8-10 shows backward trajectories for July 1 overlaid with the HMS Fire and Smoke map for June 28. On both June 30 and July 1, the backward trajectories point toward the smoke plume created from the Quebec fires.

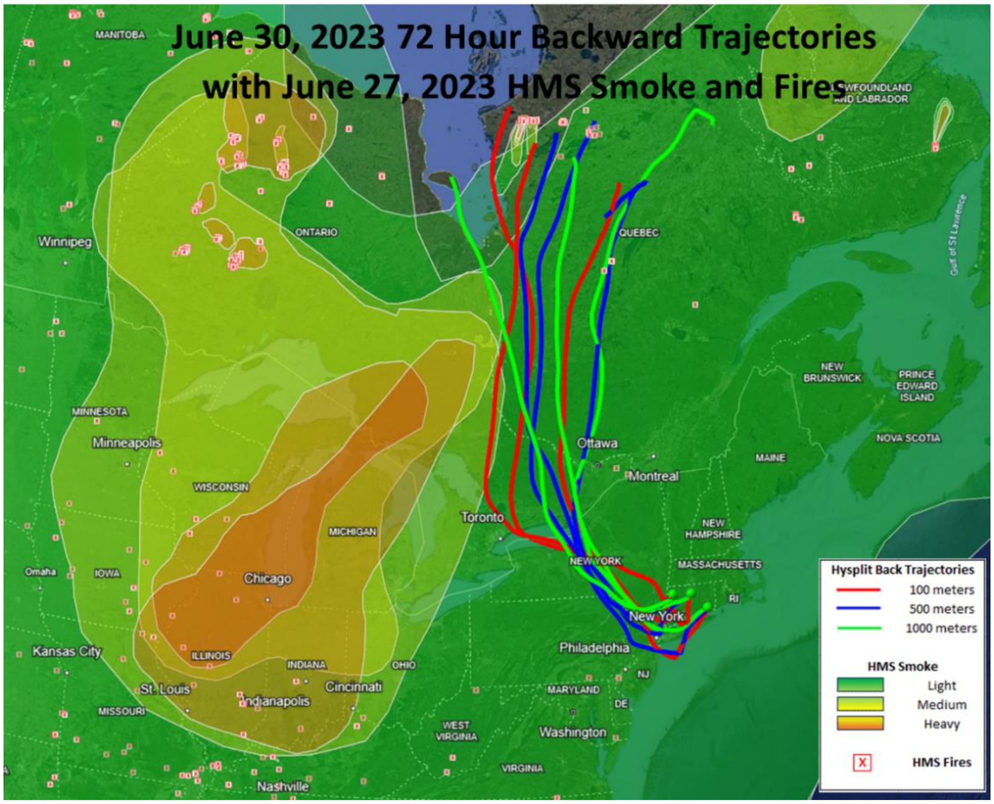



**Figure 8-9.** HYSPLIT 72-hour backward trajectories from Cornwall, East Hartford, and Groton ending at 9:00 AM EDT on June 30 with HMS Fire Locations and Smoke Plumes from June 27, showing path of transport to Connecticut.

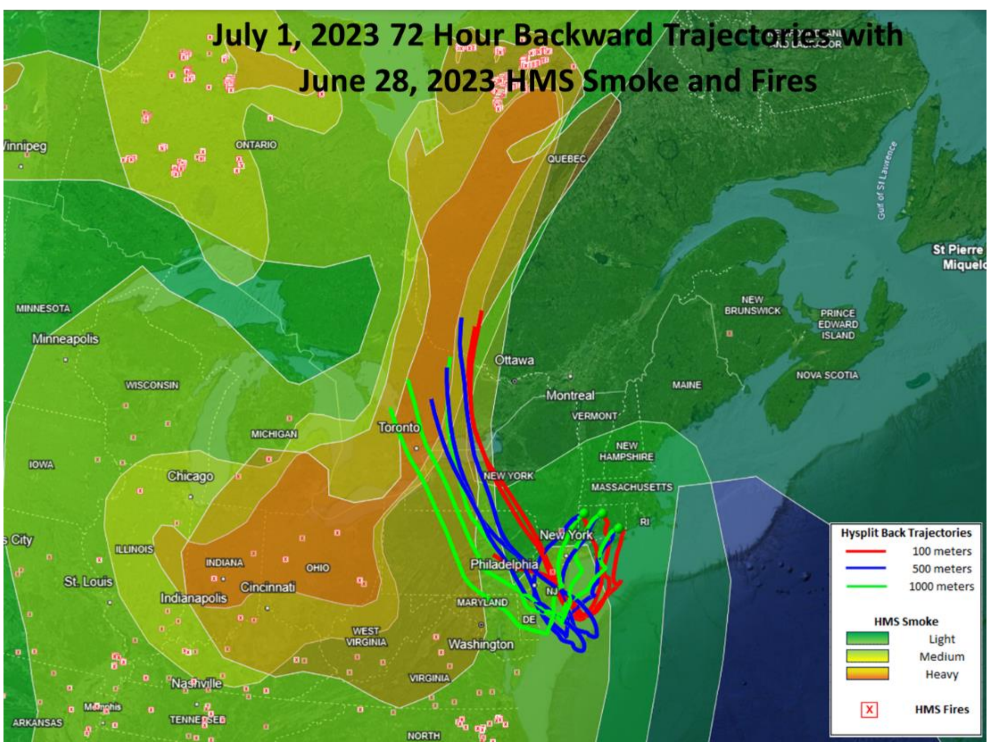



**Figure 8-10.** HYSPLIT 72-hour backward trajectories from Cornwall, East Hartford, and Groton ending at 9:00 AM EDT on July 1 with HMS Fire Locations and Smoke Plumes from June 28, showing path of transport to Connecticut.

On a smaller scale, 100-meter backward trajectories are also utilized for this ozone event. For Cornwall, June 30 backward trajectories show the source of the smoke in Quebec along with south winds that transported smoke and ozone precursors into Connecticut (Figure 8-11). The July 1 backward trajectories show the same smoke source as the previous day. For East Hartford and Groton, similar backward trajectories confirm the smoke impacts from the Quebec wildfires while also featuring smoke enhancement over LIS (Figure 8-12 and Figure 8-13). The south winds that are further offshore for more than a few hours typically bring cleaner air to Connecticut. Precursors and ozone in smoke enhanced ozone production and created worse air quality than would normally occur under these conditions. Backward trajectories for June 30 and July 1 strongly suggest the Quebec wildfires are the main cause of the ozone exceedances.

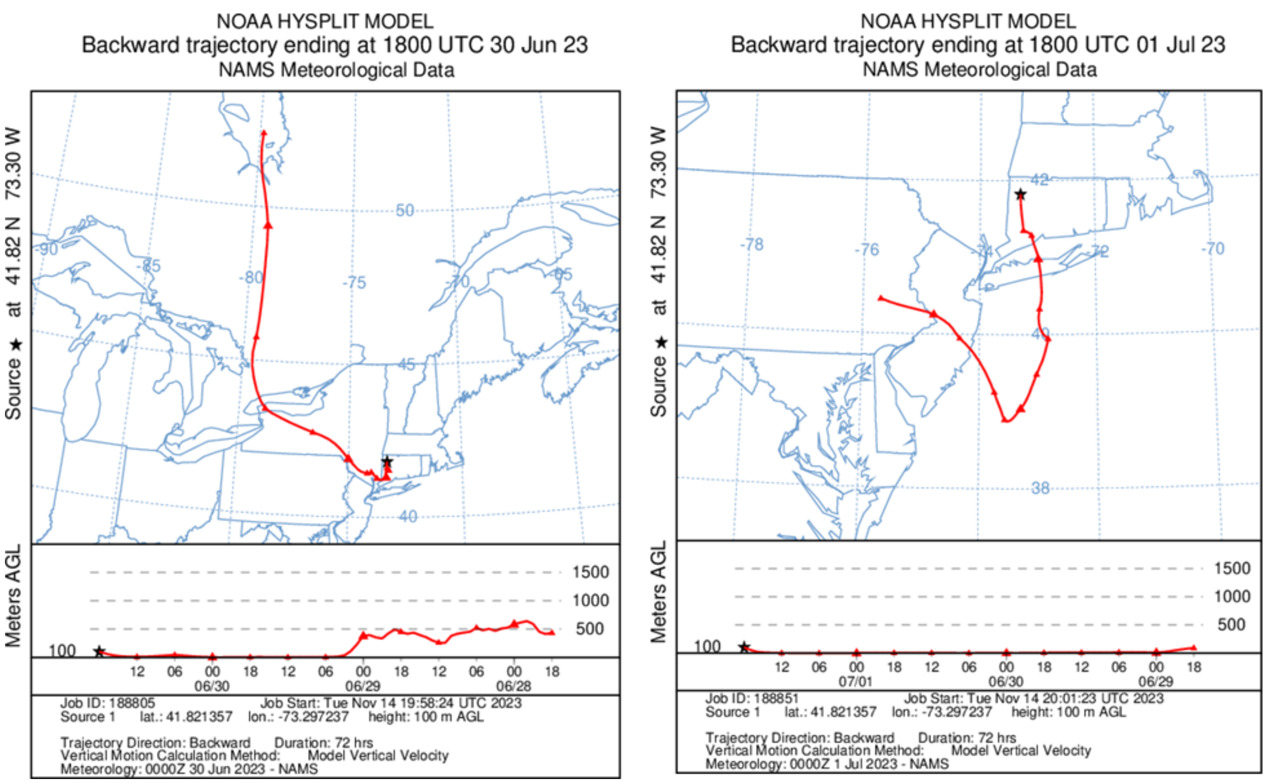



**Figure 8-11.** 100-meter backward trajectory from Cornwall Connecticut (left) June 30, 2:00 PM EDT, (right) July 1, 2:00 PM EDT.

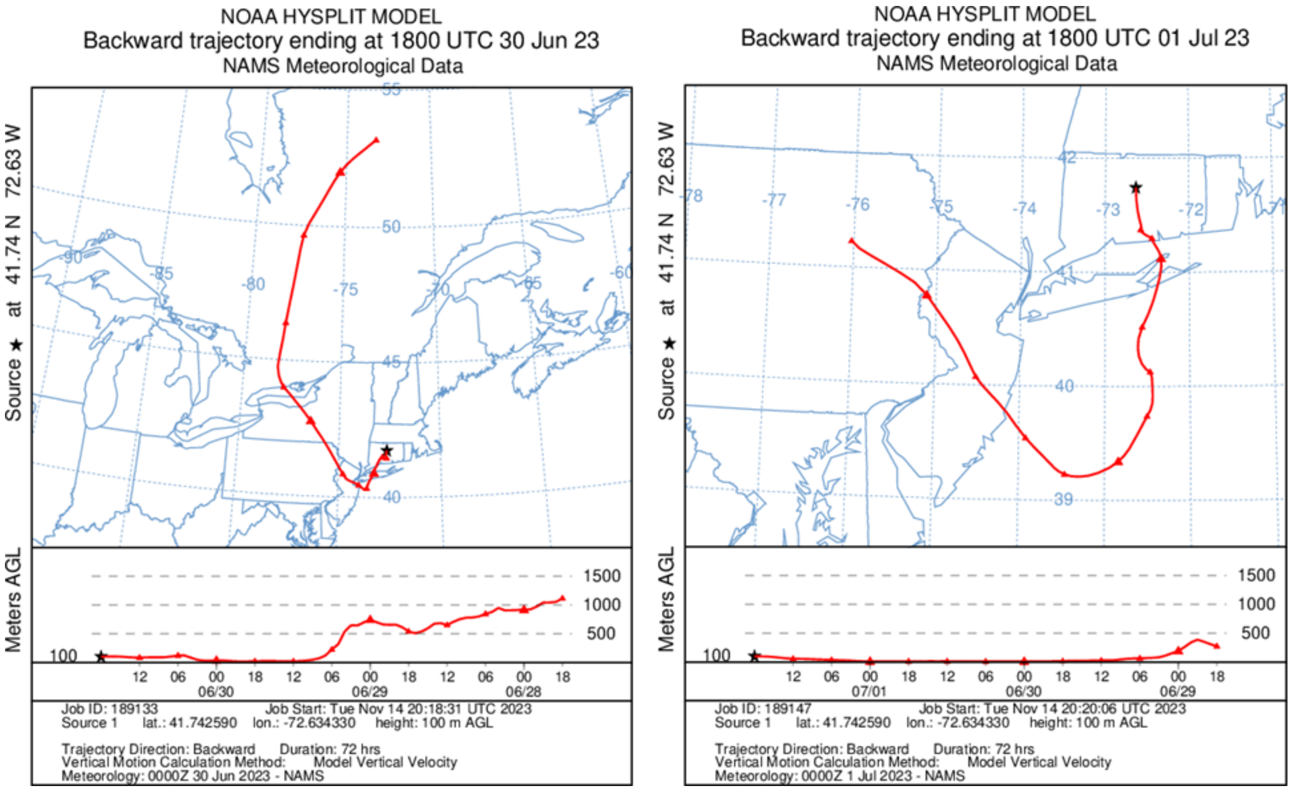



**Figure 8-12.** 100-meter backward trajectory from East Hartford Connecticut (left) June 30, 2:00 PM EDT, (right) July 1, 2:00 PM EDT.

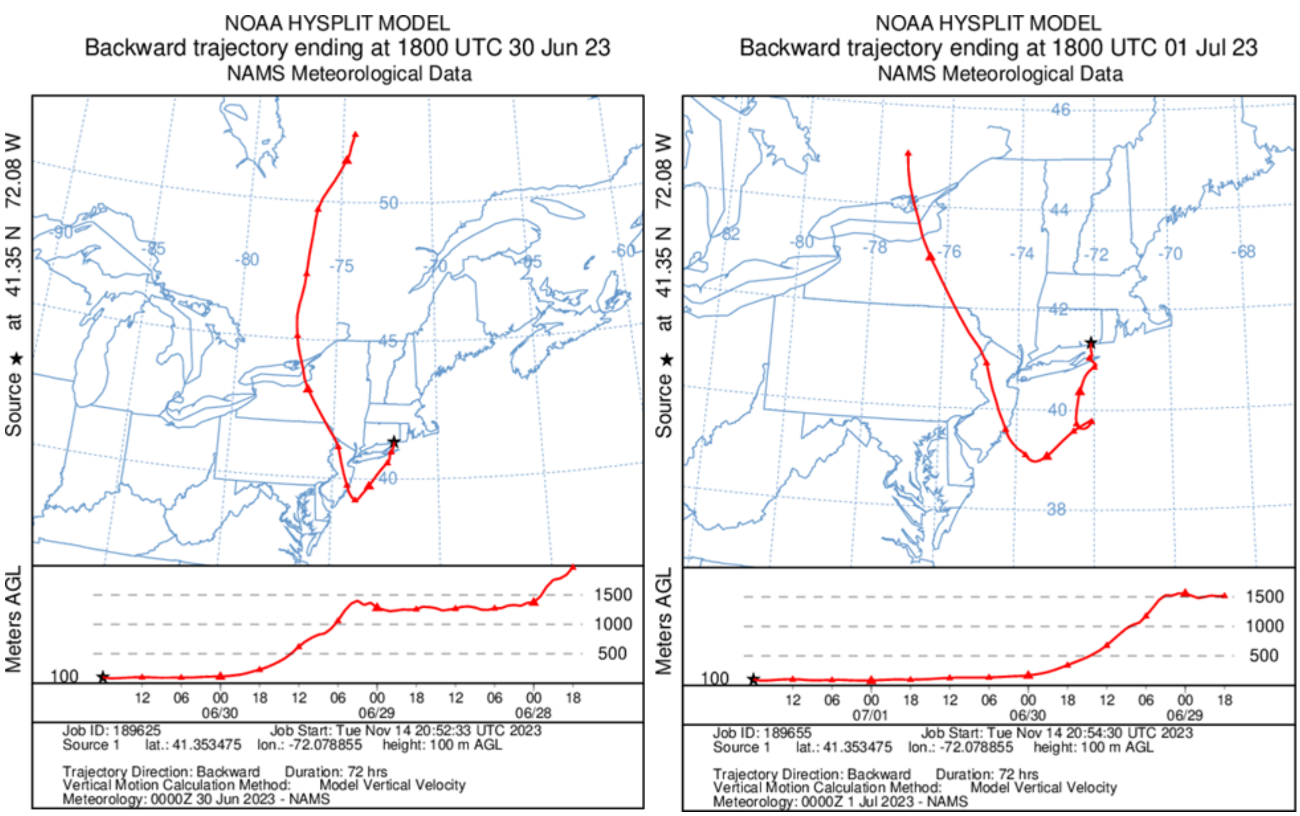



**Figure 8-13.** 100-meter backward trajectory from Groton Connecticut (left) June 30, 2:00 PM EDT, (right) July 1, 2:00 PM EDT.

## Forward Trajectories

On June 27, 2023, smoke funneled southward from the Quebec wildfires before moving eastward. By June 30, the smoke plume impacted the US east coast as it recirculated from the mid-Atlantic region. 72-hour forward trajectories were used to allow for transport over the Great Lakes and Mid-Atlantic regions and into Connecticut. Figure 8-14 shows the trajectories that would transport smoke into Connecticut on June 30 – July 1, 2023, from the area of the Quebec fires.

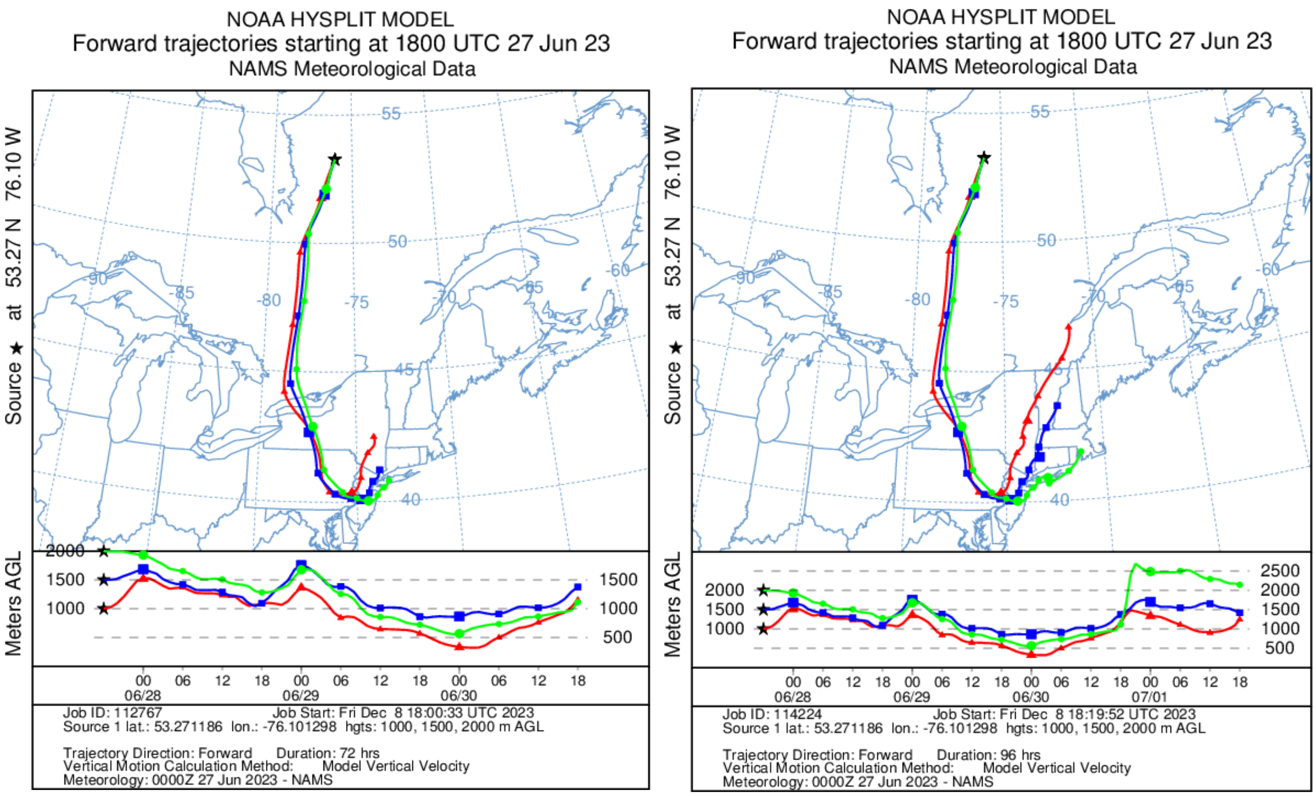



**Figure 8-14.** HYSPLIT 72-hour forward trajectories from Quebec: June 27, 2:00 PM EDT (left); June 28, 2:00 PM EDT (right).

## 8.3 July 12, 2023 Ozone Event

### Backward Trajectories

Ozone began building up around the Great Lakes on July 9th and 10th (Figure 8-15) due to the smoke from fires in western Canada. Trajectories and plume analysis show that the smoke plume settled over this area for several days before moving eastward over Connecticut. Back trajectory analysis for this area confirms the source of the ozone precursors from the wildfires in western Canada, contributing to ozone enhancement for the Great Lakes region (Figure 8-16).

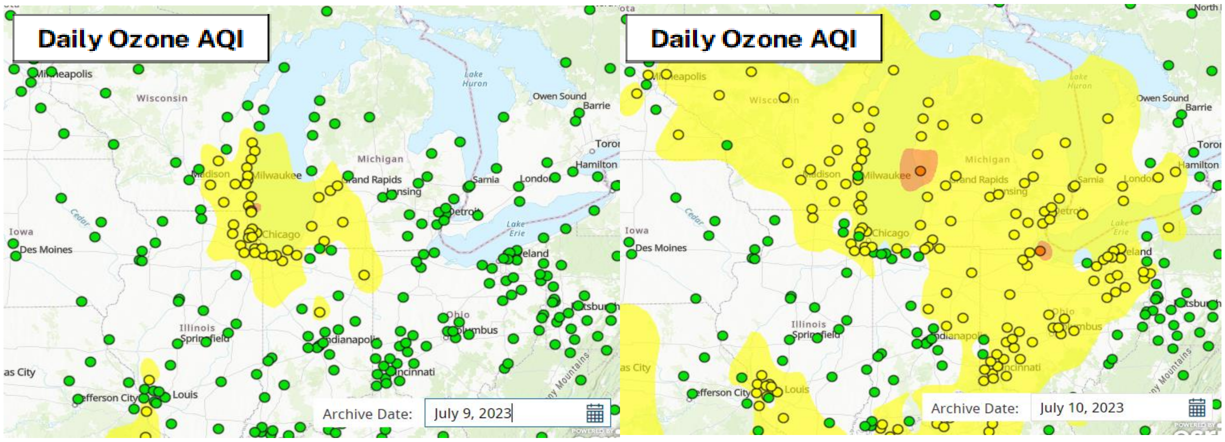



**Figure 8-15.** Daily ozone AQI for the Great Lakes region on July 9, 2023 (left) and July 10, 2023 (right).

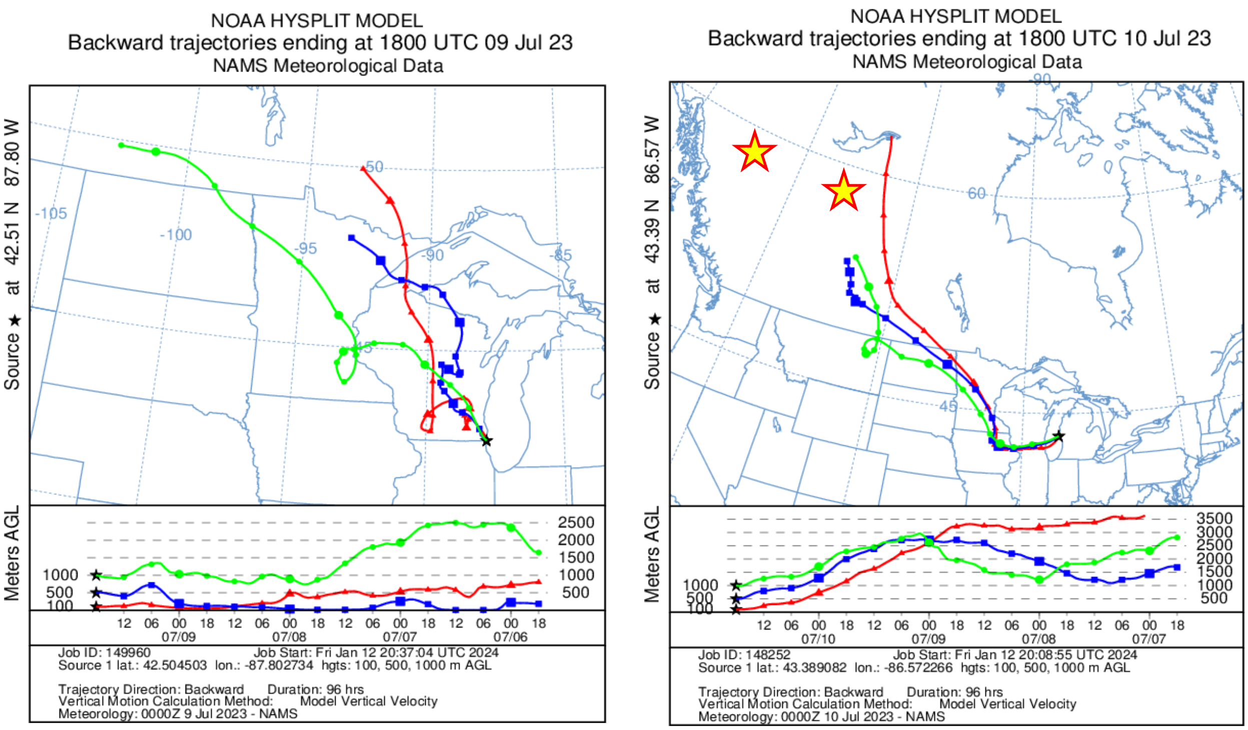



**Figure 8-16.** 96-hour backward trajectories from the Great Lakes region on July 9, 2023 (left) and July 10, 2023 (right).

A 120-hour backward trajectory matrix was computed across western New England (Figure 8-17) for July 12. The source region, 48 hours before, is clearly the Great Lakes region where elevated ozone values were located. Going beyond the Great Lakes, the backward trajectories suggest that the source of the smoke is the western Canada wildfires, particularly northern British Columbia and Alberta.

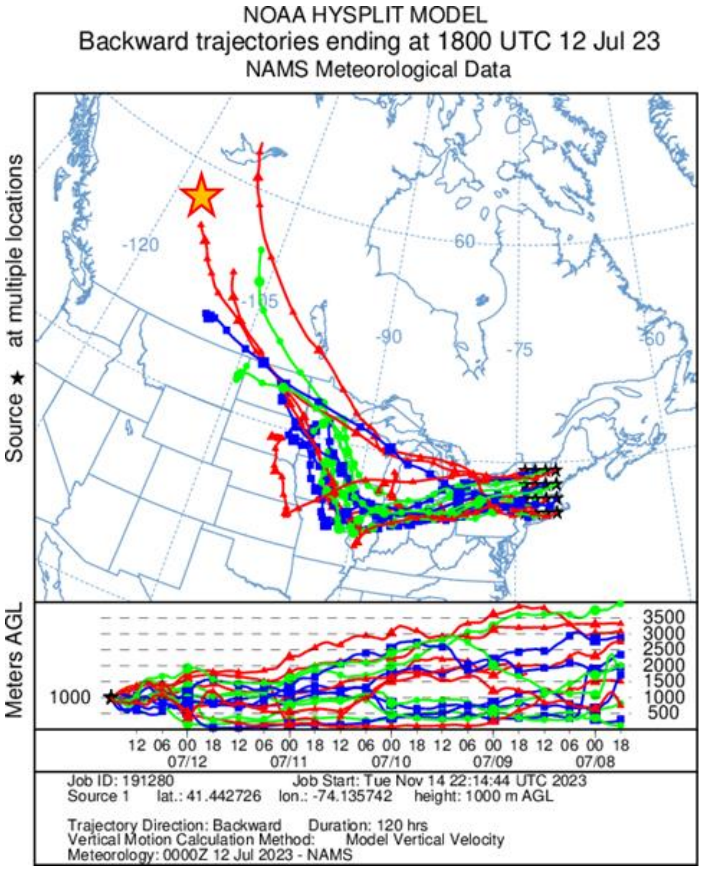


**Figure 8-17.** HYSPLIT 120-hour backward trajectories from New England (left) July 12, 2:00 EDT.

Taking a closer look at Connecticut using 144-hour backward trajectories and HMS Fire and Smoke confirms the source of the smoke from western Canada (Figure 8-18). In addition, 96-hour backward trajectories and HMS Fire and Smoke show a heavy smoke plume southeast of the fires, further verifying the smoke source (Figure 8-19)

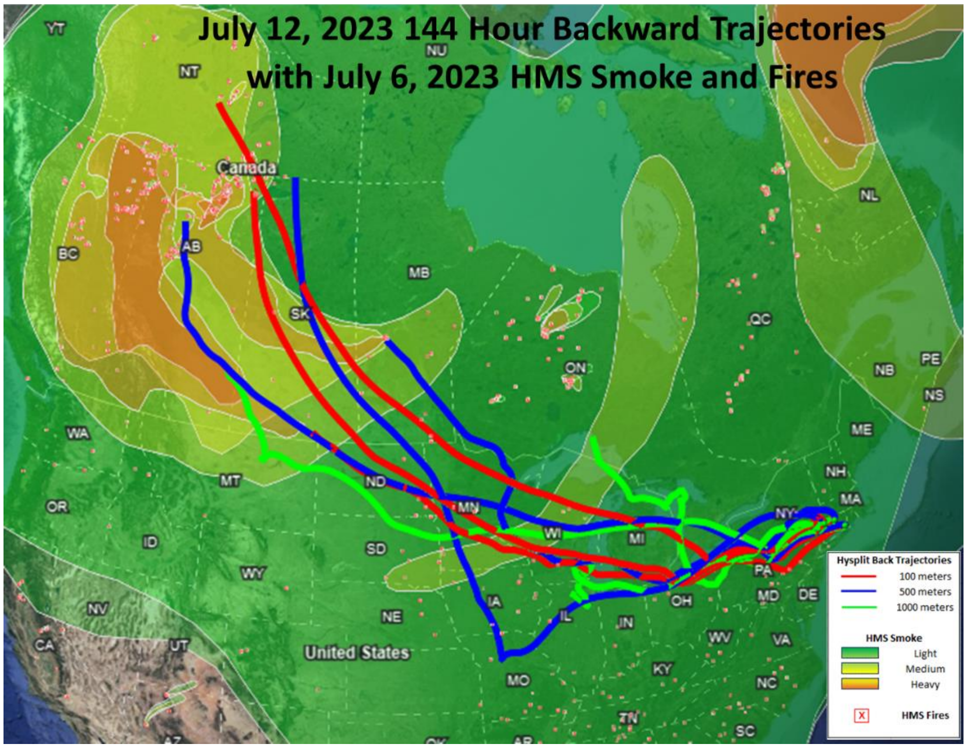



**Figure 8-18.** HYSPLIT 144-hour backward trajectories from Cornwall, East Hartford, and Groton ending at 9:00 AM EDT on July 12 with HMS Fire Locations and Smoke Plumes from July 6, showing path of transport to Connecticut.

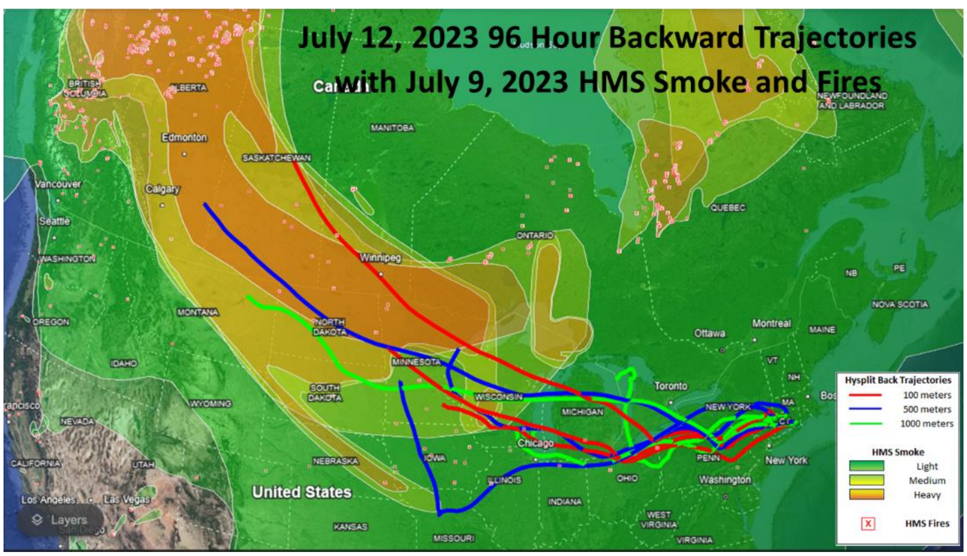



**Figure 8-19.** HYSPLIT 96-hour backward trajectories from Cornwall, East Hartford, and Groton ending at 9:00 AM EDT on July 12 with HMS Fire Locations and Smoke Plumes from July 9, showing path of transport to Connecticut.

It is necessary to consider the 100-meter height backward trajectories to determine if any local sources may have impacted ozone levels. For Cornwall, there is a southwest component for the wind; however, the trajectory remains north of New York City and LIS (Figure 8-20). For East Hartford, there is a similar, but more westerly, backward trajectory (Figure 8-21). For Groton, Figure 8-22, winds are primarily west; although, the trajectory does travel over LIS, which allows for the ozone to be trapped in the shallow, marine boundary layer. This is another opportunity for smoke to enhance ozone productions over LIS and along the Connecticut coastline. The backward trajectory analysis suggests that western Canada is the source of the smoke leading to ozone enhancement along the US east coast.

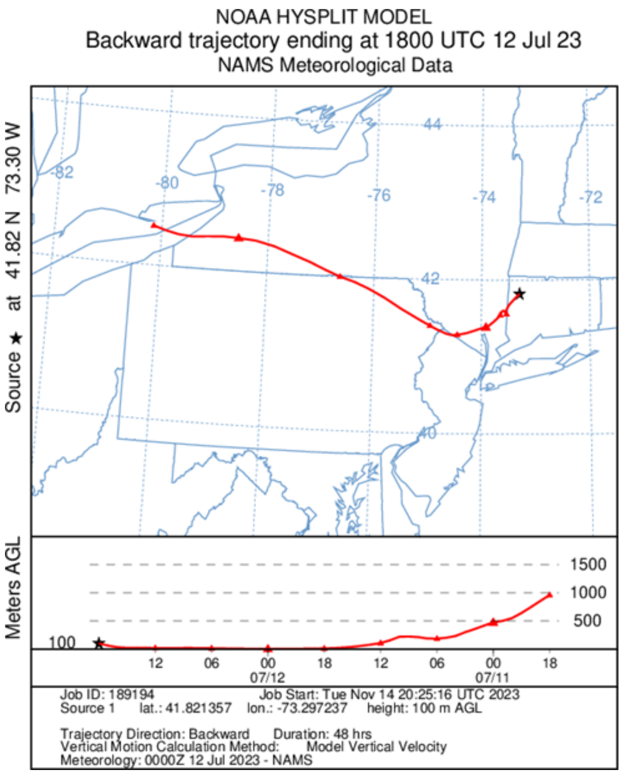



**Figure 8-20.** 100-meter backward trajectory from Cornwall Connecticut July 12, 2:00 PM EDT.

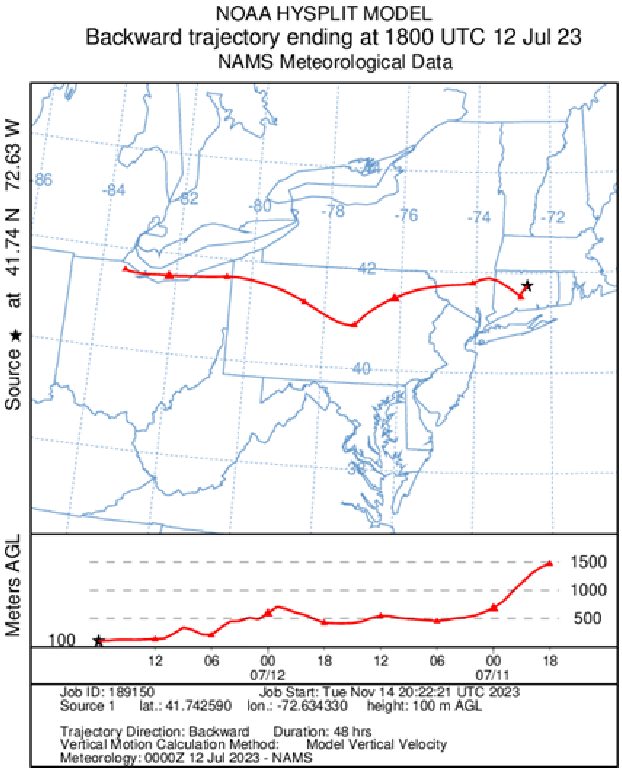



**Figure 8-21.** 100-meter backward trajectory from East Hartford Connecticut July 12, 2:00 PM EDT.

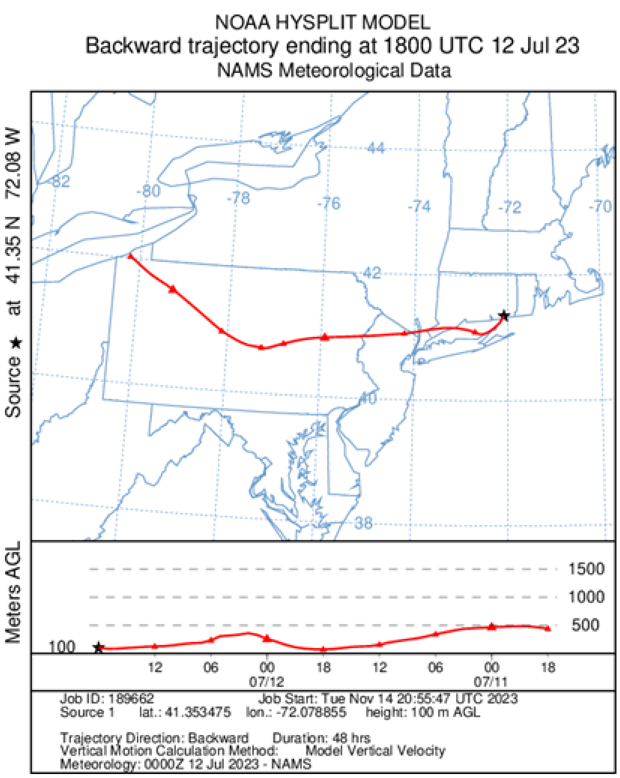



**Figure 8-22.** 100-meter backward trajectory from Groton Connecticut July 12, 2:00 PM EDT.

### Forward Trajectories

Smoke impacting Connecticut on July 12, 2023, traveled from further away than for the previous two events. Satellite images show fires burning over western Canada this summer and conditions were conducive to transport smoke from the western Canada to Connecticut at the beginning of July. The smoke plume formed on July 7 and was transported eastward across the northern Midwest and Great Lakes region before impacting Connecticut.

Due to the fires burning in western Canada, it is most useful to begin forward trajectories in western Canada on July 6, 2023. 144 Hour trajectories were used to allow for an adequate amount of time for smoke transport from western Canada. Figure 8-23 shows the smoke transport near the Great Lakes region and then moving into Connecticut.

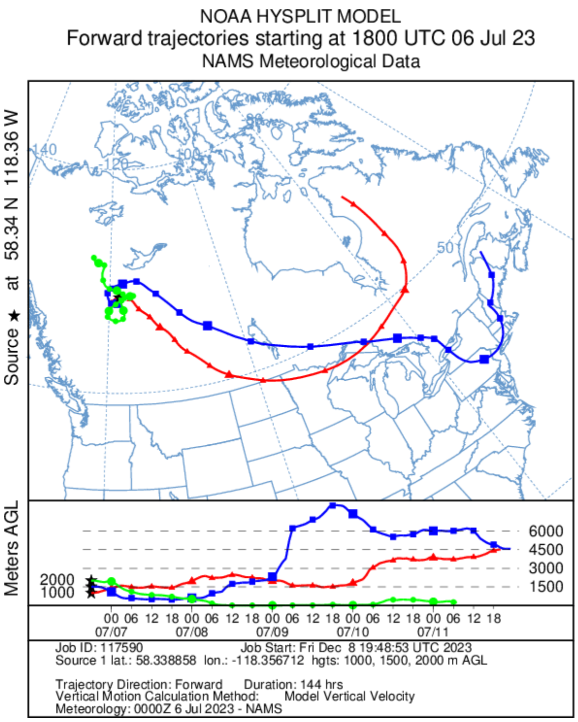



**Figure 8-23.** HYSPLIT 144-hour forward trajectories from Western Canada on July 6, 2023.

## 8.4 Summary of Trajectory Analyses

Long range backward and forward trajectories confirm the origin of fires and transport of smoke for each of these ozone events. Short range trajectories indicate local fires influenced the April 13-14 event and indicate transport from otherwise clean areas during the events.

For the April 13-14 ozone event, forward and backward trajectories suggest smoke from the Flint Hills fires along with smoke from local fires in Pennsylvania, New York, and northern New Jersey contributed to excess ozone formation impacting Connecticut.  The smoke from the Flints Hills region travelled over the Great Lakes before moving into Connecticut on April 13 and 14.

For the June 30 – July 1 ozone event, forward and backward trajectories suggest smoke from the Quebec wildfires enhanced ozone levels across Connecticut.  In this instance, the smoke moved southward over the mid-Atlantic region before winds shifted, transporting ozone and ozone precursors into Connecticut on June 30 and July 1.

For the July 12 ozone event, forward and backward trajectories suggest smoke from fires in western Canada impacted ozone levels in Connecticut.  The smoke travelled over the northern midwest and Great Lakes regions before enhancing ozone in Connecticut on July 12.

# 9 Meteorological Conditions During the Events

## 9.1 April 13-14, 2023 Ozone Event

By April 10, 2023, smoke from prescribed burning in the Flint Hills began moving east. The surface analysis for April 10th shows high pressure over the midwestern United States (Figure 9-1). High pressure remains over the southeastern United States on April 11, 2023 and April 12, 2023 as a frontal system slowly moves across the country (Figure 9-2 and Figure 9-3). The front stalled over the northern Great Lakes and Midwest regions allowing for smoke to be transported to Connecticut on April 13, 2023 and April 14, 2023 as the high pressure system again slowly moves eastward (Figure 9-4 and Figure 9-5).

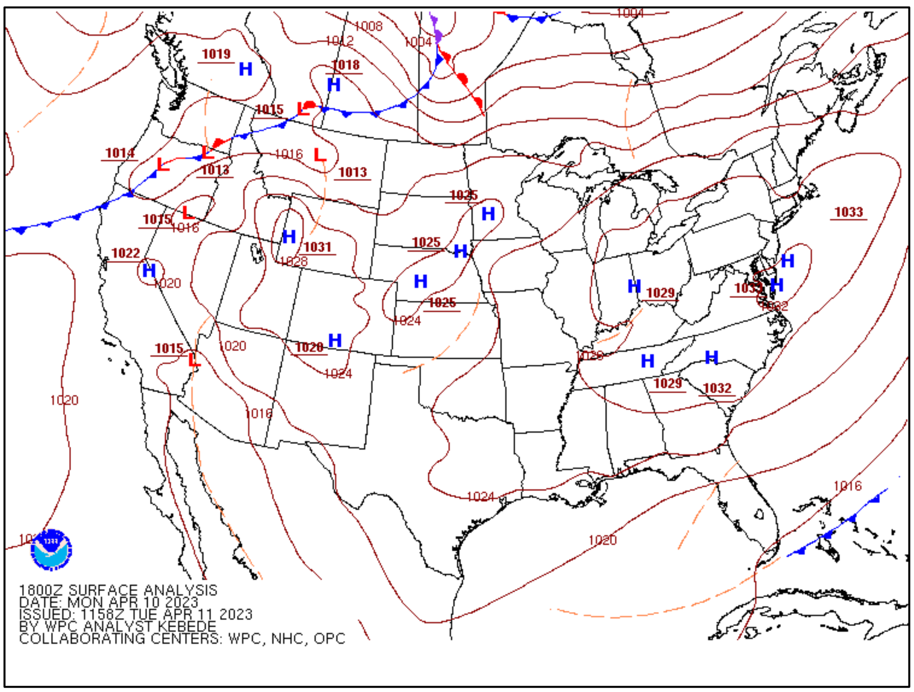



**Figure 9-1.** Surface analysis for April 10, 2023, at 2 PM.

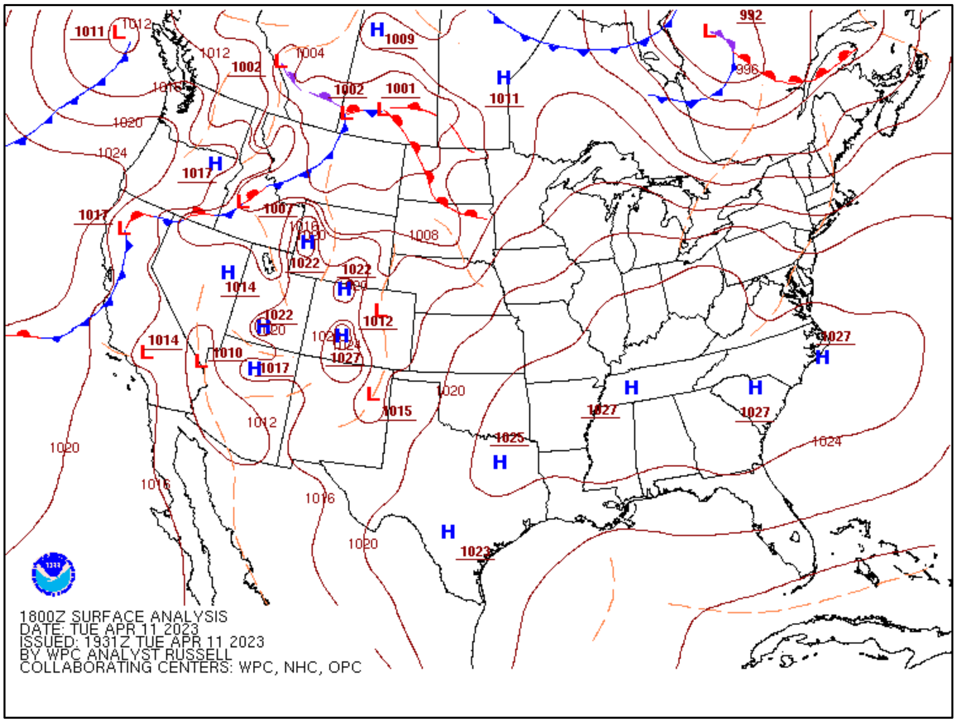



**Figure 9-2.** Surface analysis for April 11, 2023, at 2 PM.

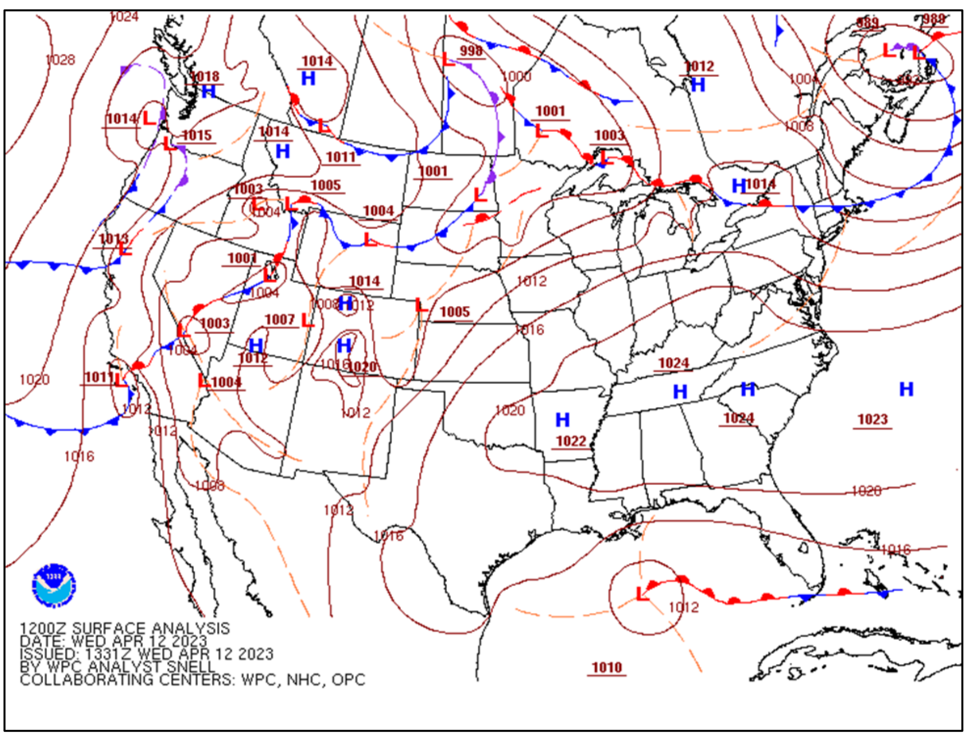



**Figure 9-3.** Surface analysis for April 12, 2023, at 2 PM.

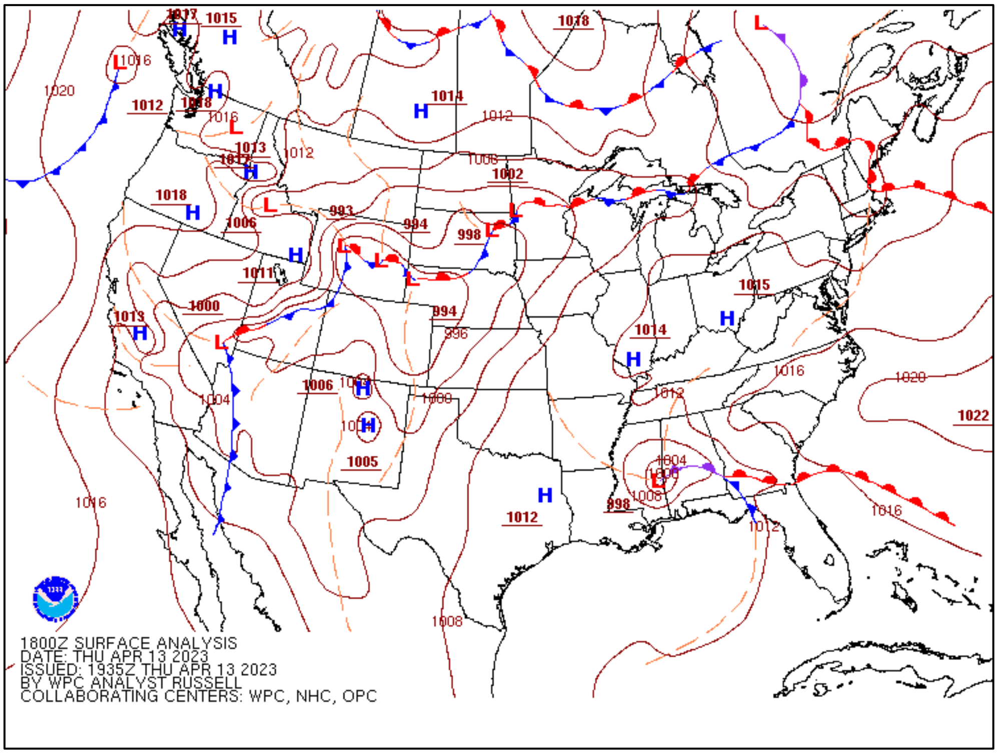



**Figure 9-4.** Surface analysis for April 13, 2023, at 2 PM.

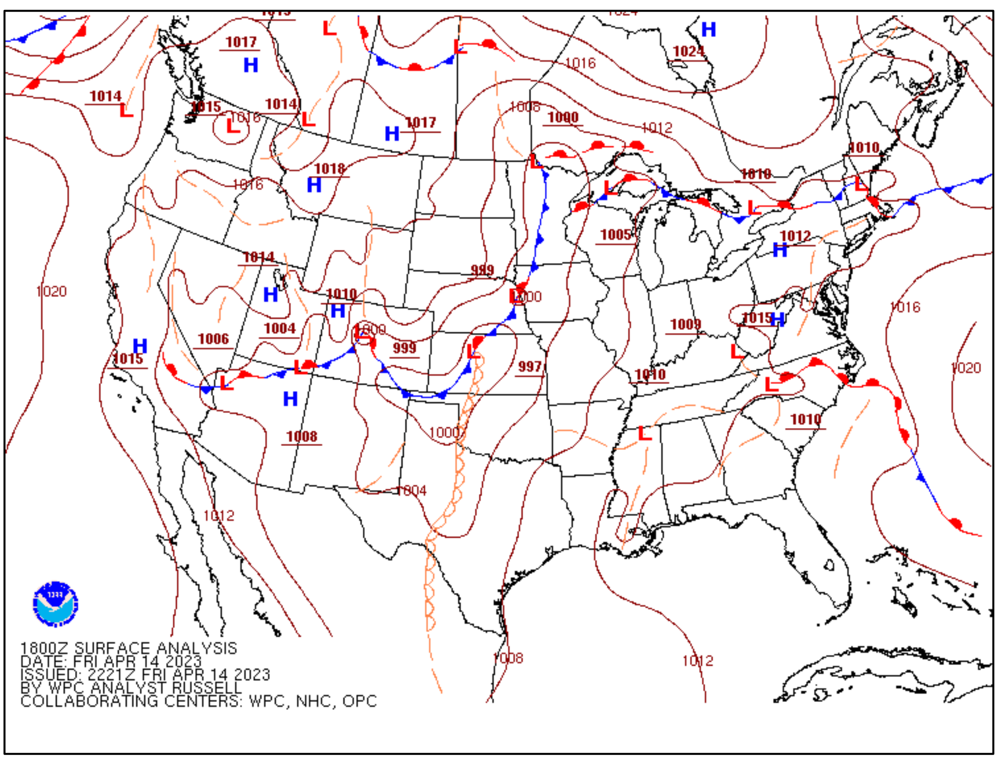



**Figure 9-5.** Surface analysis for April 14, 2023, at 2 PM.

Weather maps showing conditions at the height where pressure is at 850 millibar (mb) is generally above the boundary layer (~1500m) where long range transport occurs. On April 10, 2023, at the 850 mb level a high-pressure center lies over the mid-Atlantic region allowing smoke from the Flint Hills to be funneled toward Connecticut (Figure 9-6). The high-pressure center moves slightly southward over the southeastern US on April 11, 2023. The center continues moving south on April 12th funneling smoke towards Connecticut (Figure 9-7). By April 13 and 14, the high pressure center moves east into the Atlantic, channeling smoke into Connecticut, with west winds at the 850 mb level (Figure 9-8 and Figure 9-9).

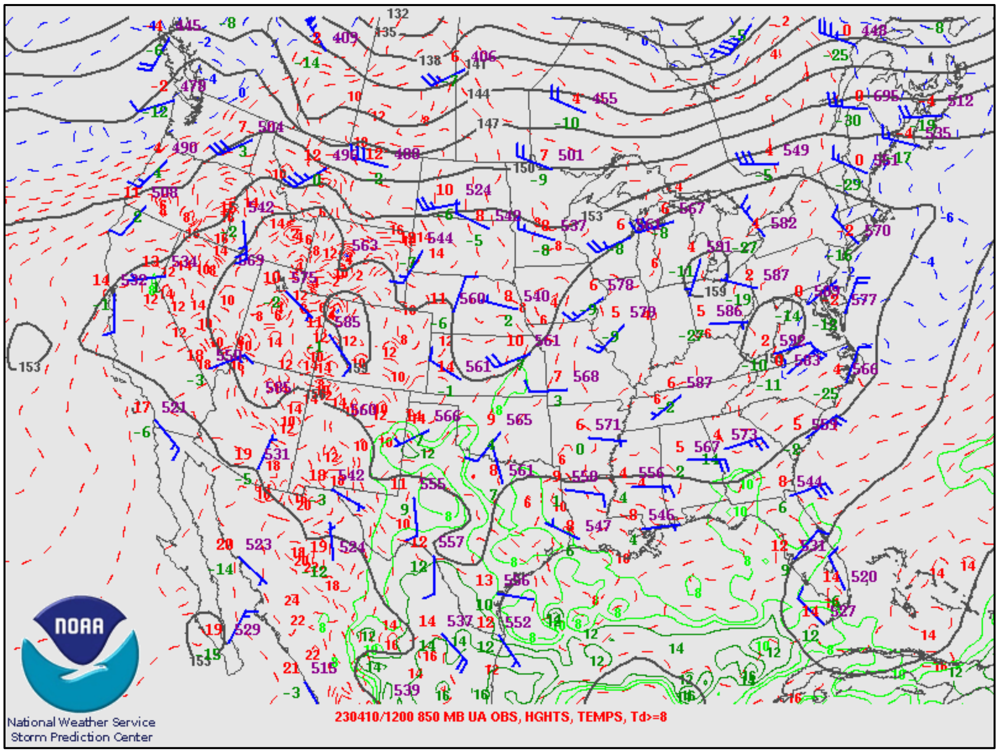



**Figure 9-6.** 850 mb pressure pattern with winds on April 10, 2023, at 8 AM.

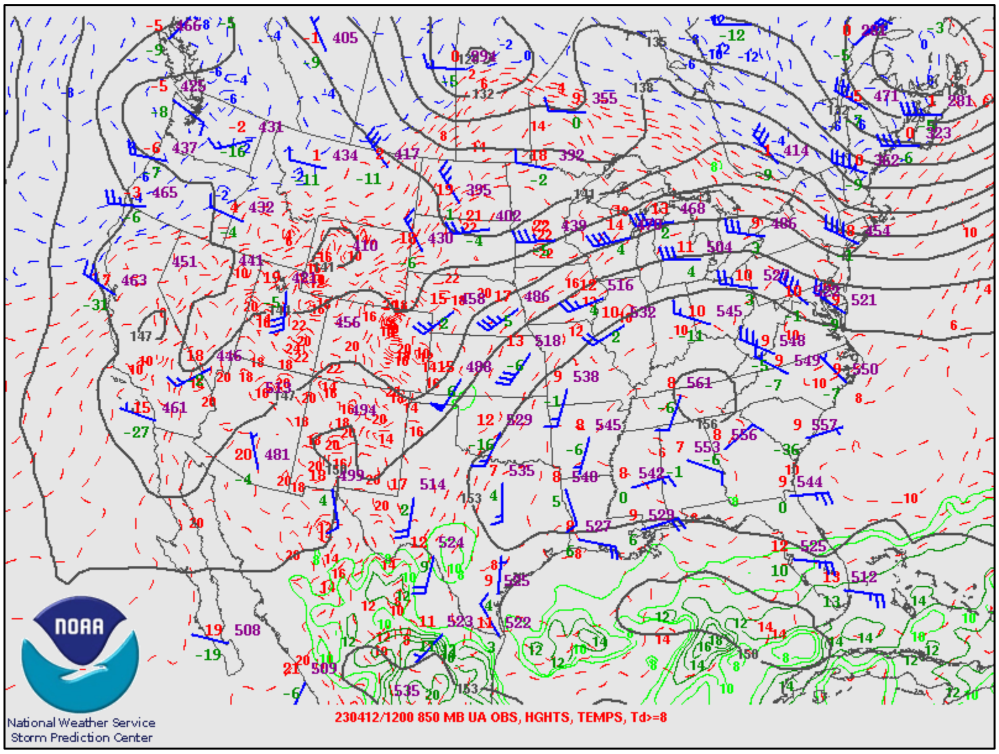



**Figure 9-7.** 850 mb pressure pattern with winds on April 12, 2023, at 8 AM.

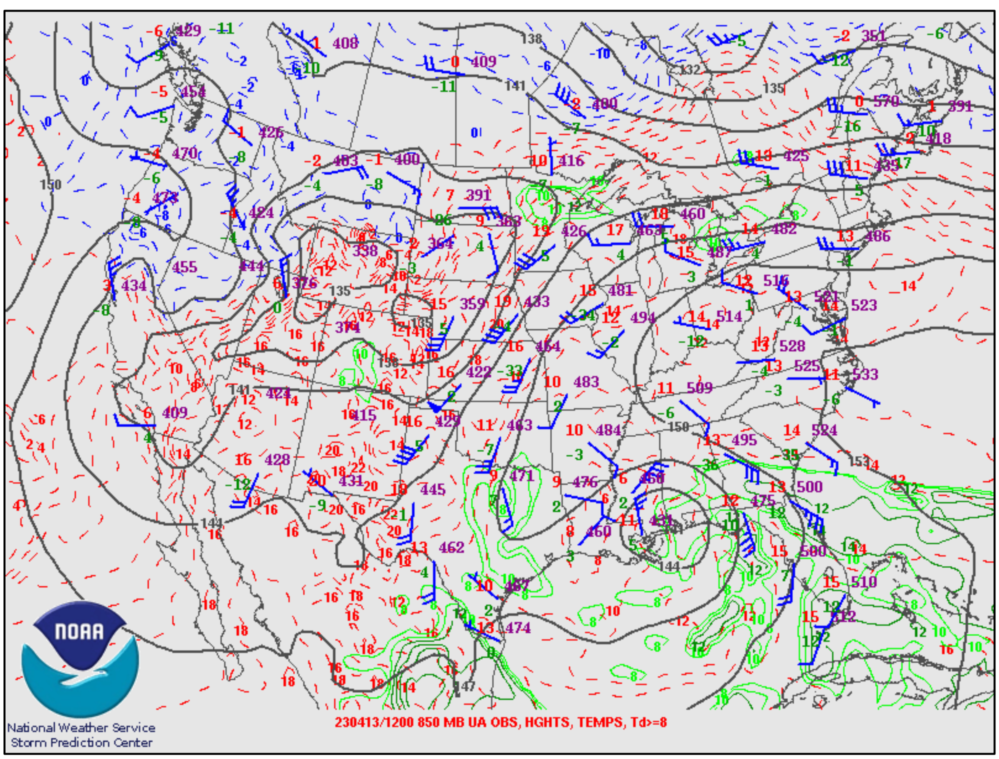



**Figure 9-8.** 850 mb pressure pattern with winds on April 13, 2023, at 8 AM.

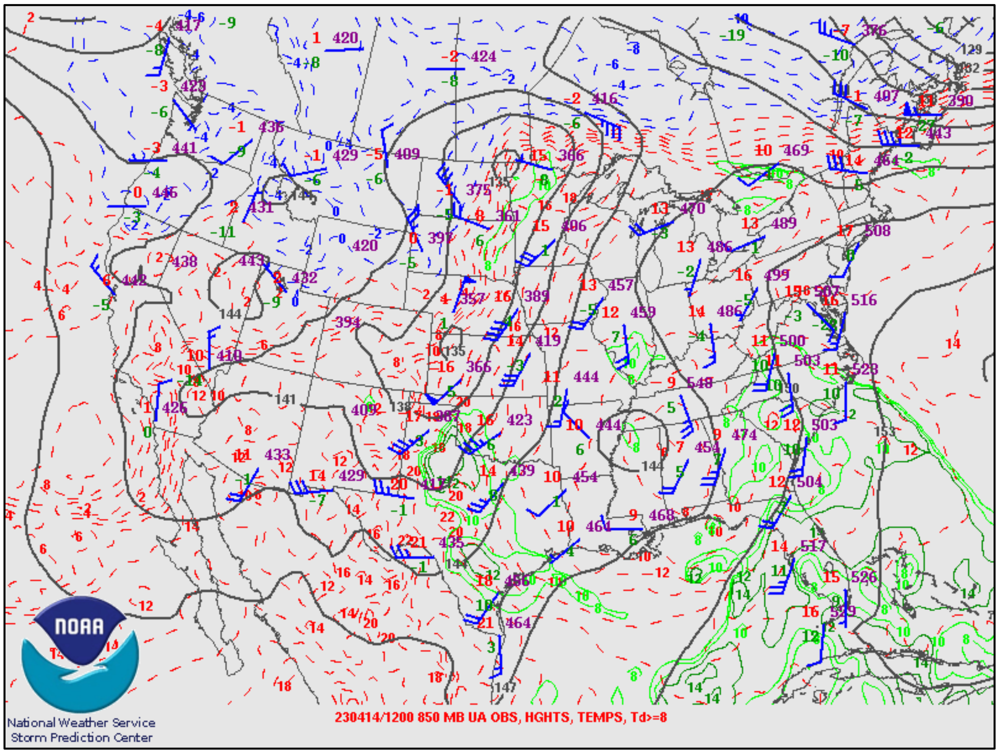



**Figure 9-9.** 850 mb pressure pattern with winds on April 14, 2023, at 8 AM.

Observational data at local monitors is shown in Figure 9-10 through Figure 9-13. The top graph for each site shows the hourly ozone with temperatures and the bottom graph shows the hourly ozone with wind direction for the days surrounding the April 13-14 event at Cornwall, East Hartford, Stafford, and Westport, respectively. Groton was not selected because complete meteorological data was not available.

At each of these sites, the ozone levels generally trended with temperatures with slightly increasing temperatures and ozone levels each day. However, by April 13 and 14, the ozone levels were slightly offset from the temperatures with a short period of time where temperatures were decreasing, and ozone was still increasing. This pattern is more obvious at Stafford and Cornwall and is typical of transport.

On April 14, monitoring sites show northwest and west winds in the morning hours before quickly shifting south later in the day. Some sites show southwest winds on both days, with most of the smoke being transported near the surface. Stafford and Cornwall are good examples of how exceptional this event was by showing north and northwest winds along with elevated ozone levels. This is a scenario where we would typically see good ozone levels if smoke were not present, especially at a site that rarely exceeds the standard. The ozone spike at these sites is indicative of the influence from the wildfires in nearby states. This meteorological scenario would not typically lead to Greater Connecticut exceeding the ozone standard.

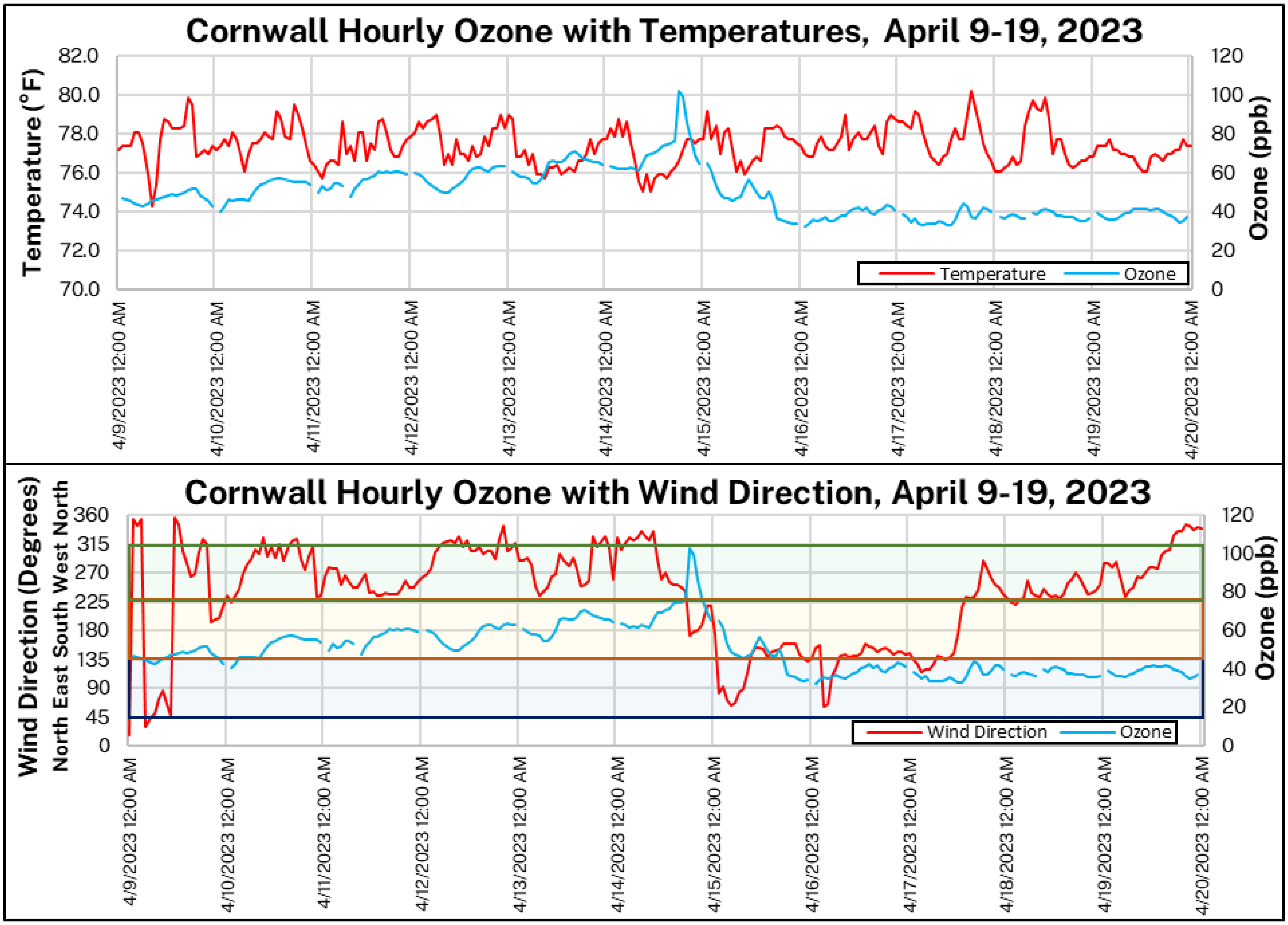



**Figure 9-10.** Cornwall hourly ozone with temperatures (top); hourly ozone with wind direction (bottom) surrounding the April 13-14 event.

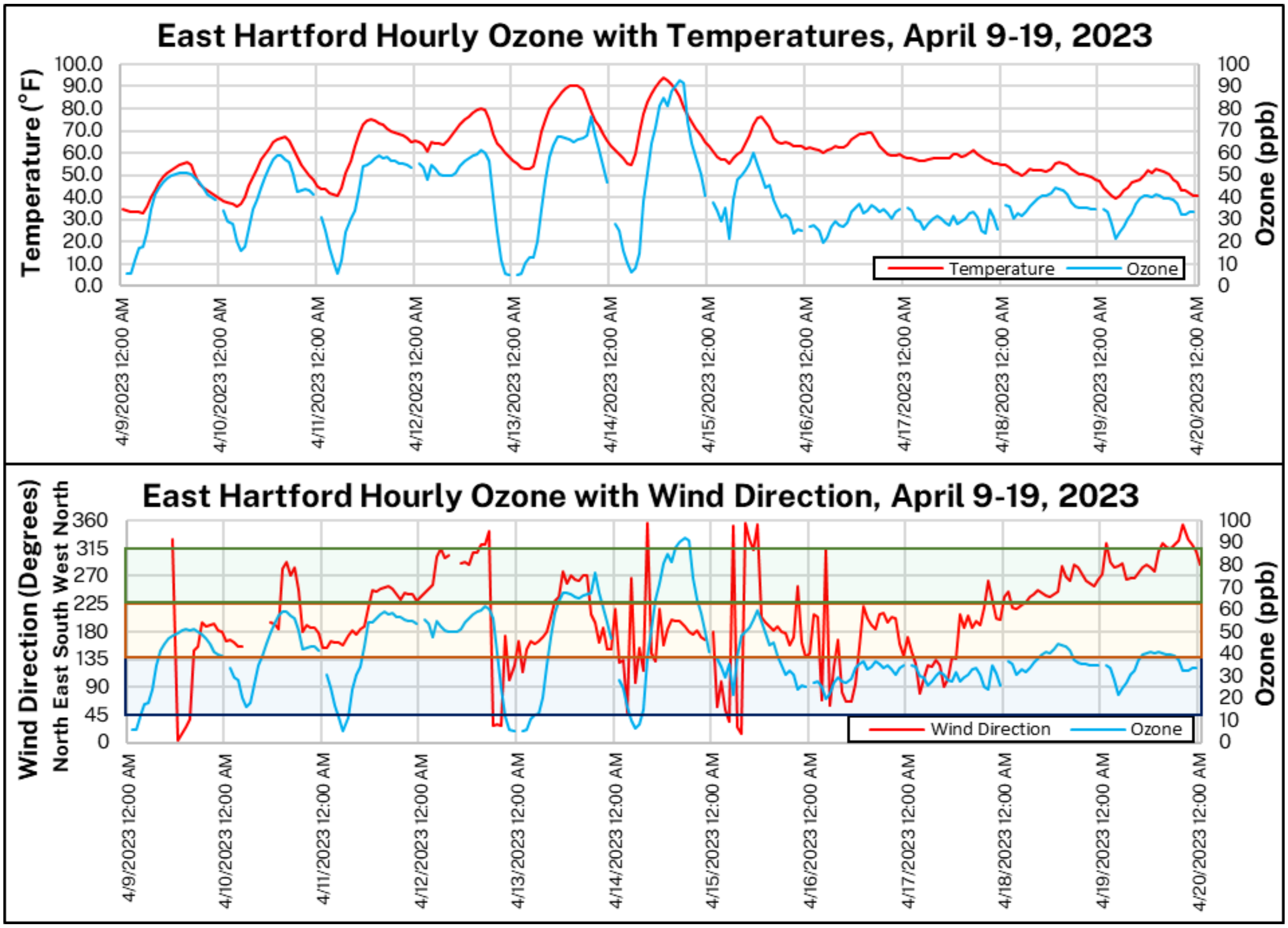



**Figure 9-11.** East Hartford hourly ozone with temperatures (top); hourly ozone with wind direction (bottom) surrounding the April 13-14 event.

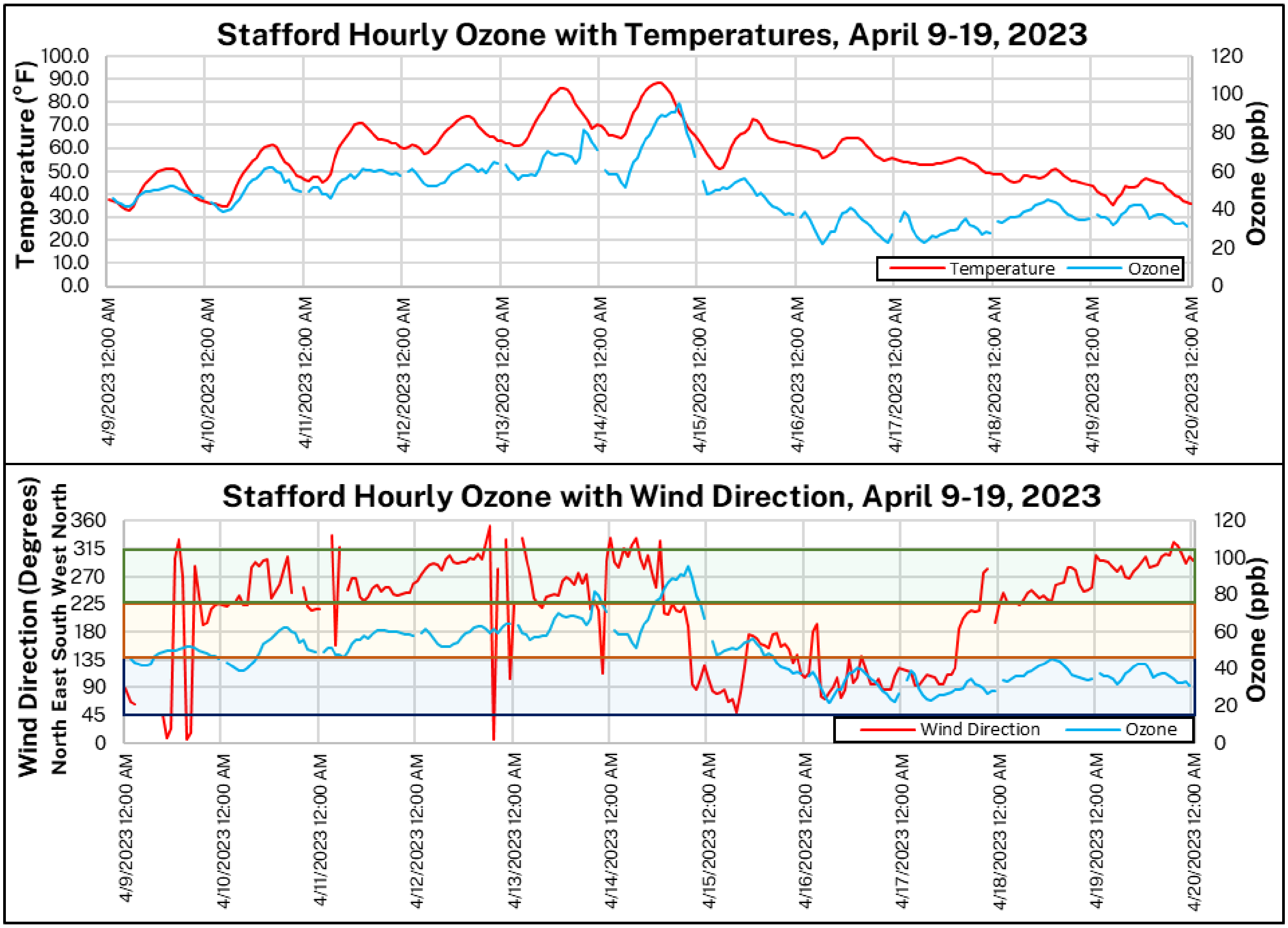



**Figure 9-12.** Stafford hourly ozone with temperatures (top); hourly ozone with wind direction (bottom) surrounding the April 13-14 event.

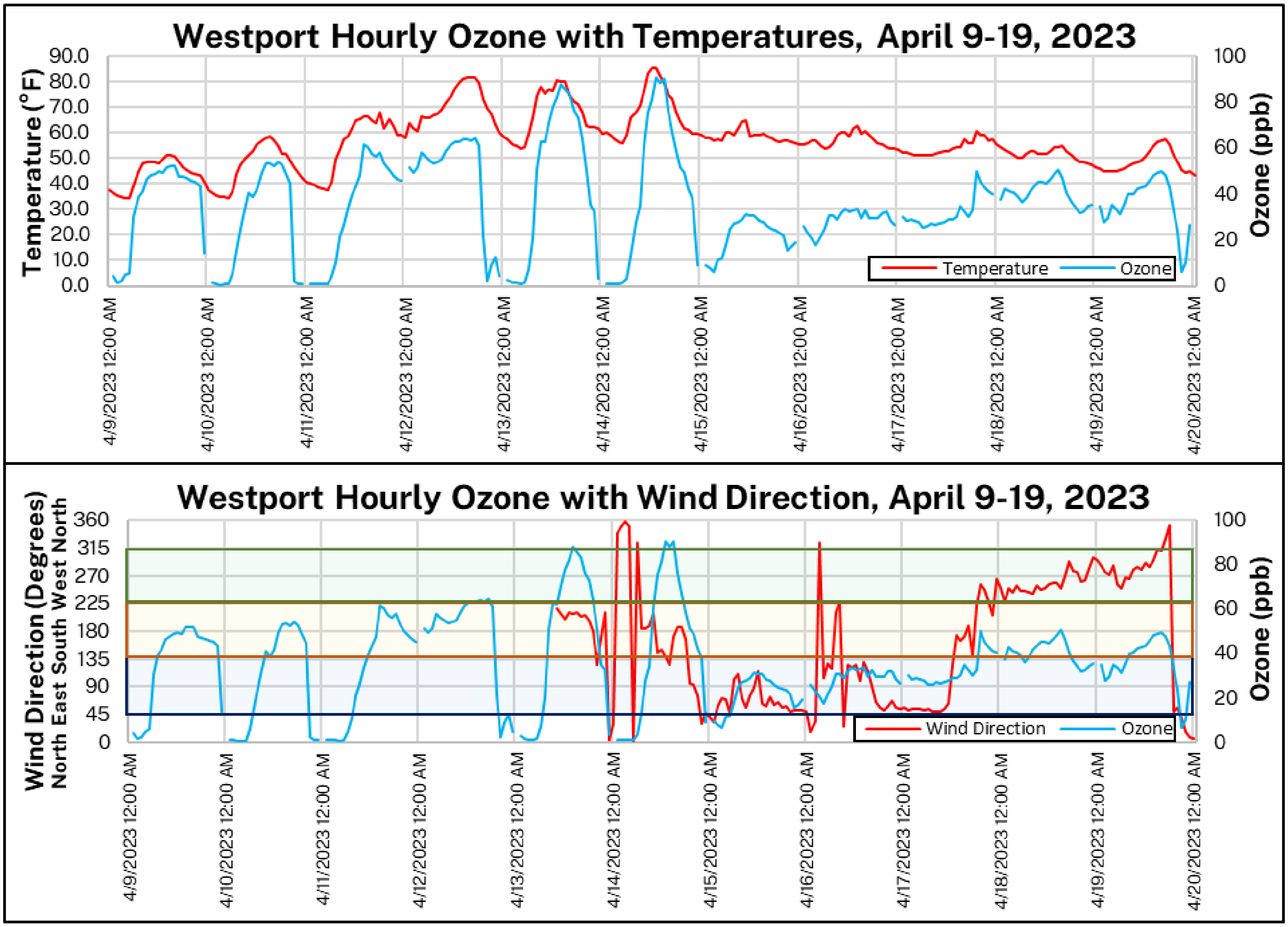



**Figure 9-13.** Westport hourly ozone with temperatures (top); hourly ozone with wind direction (bottom) surrounding the April 13-14 event.

## 9.2 June 30 – July 1, 2023 Ozone Event

On June 28, 2023, low pressure moves over the northeast allowing pollutants from fires burning in Quebec to funnel southward towards the Great Lakes region (Figure 9-14). On June 29, the low-pressure system moves slightly eastward with continued smoke transport from the Quebec wildfires toward the Great Lakes and mid-Atlantic regions (Figure 9-15). By June 30, the low-pressure system shielding Connecticut moves offshore transporting the smoke plume over the east coast while high pressure builds into New England (Figure 9-16). The high-pressure system remains over New England on July 1 allowing the smoke plume to remain over Connecticut, impacting PM2.5 and ozone levels at the surface (Figure 9-17).

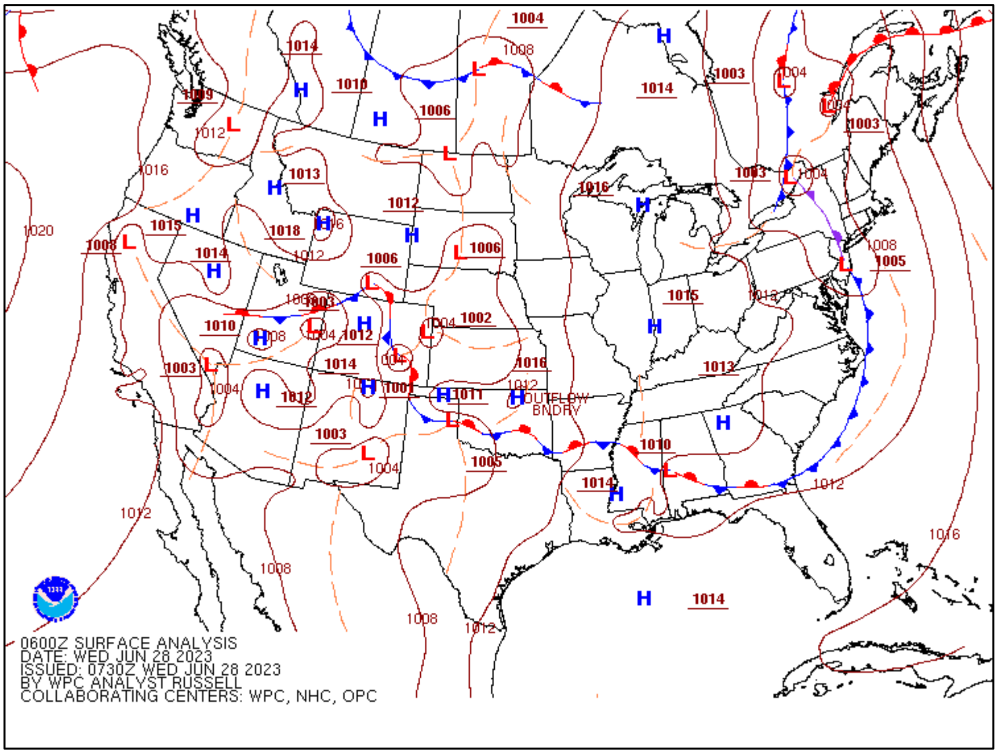



**Figure 9-14.** Surface analysis for June 28, 2023, at 2 AM.

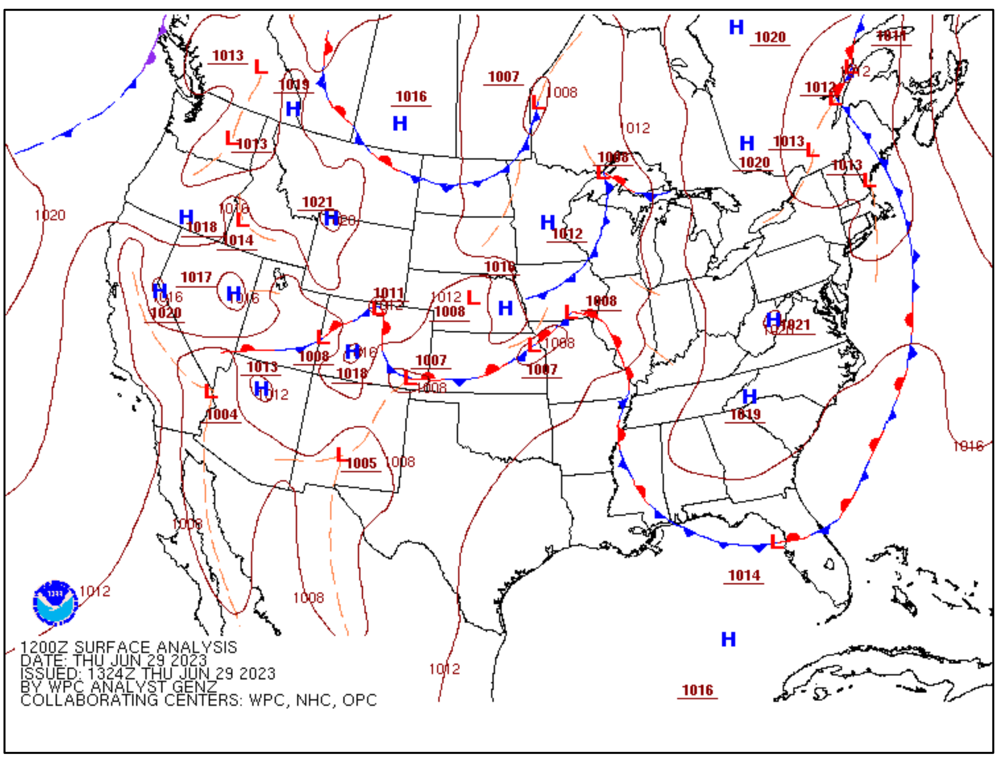



**Figure 9-15.** Surface analysis for June 29, 2023, at 8 AM.

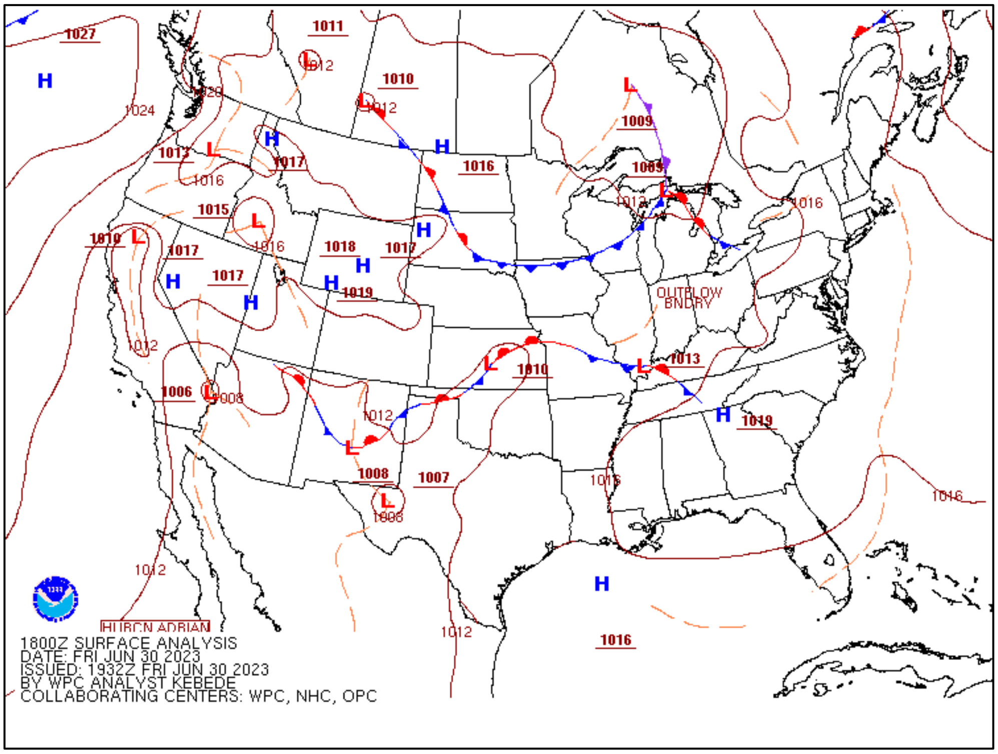



**Figure 9-16.** Surface analysis for June 30, 2023, at 2 PM.

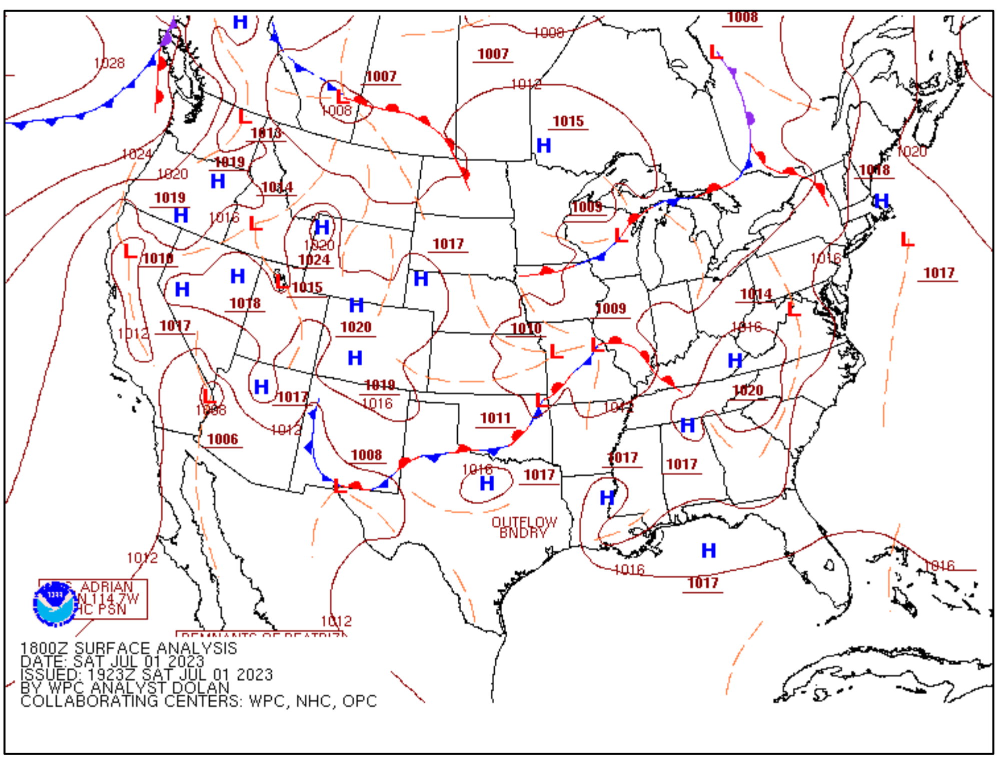



**Figure 9-17.** Surface analysis for July 1, 2023, at 2 PM.

At the 850 mb level, similar patterns develop, especially for the wind direction. On June 28, a trough develops over New York and New England allowing north winds to transport smoke to the Great Lakes region (Figure 9-18). On June 29, the trough moves eastward allowing for the smoke to impact New York and the mid-Atlantic region (Figure 9-19). On June 30, the trough moves offshore, pushing the smoke eastward into Connecticut (Figure 9-20). With the trough offshore, south winds continue to recirculate the smoke plume northward and impact ozone levels at the surface (Figure 9-21).

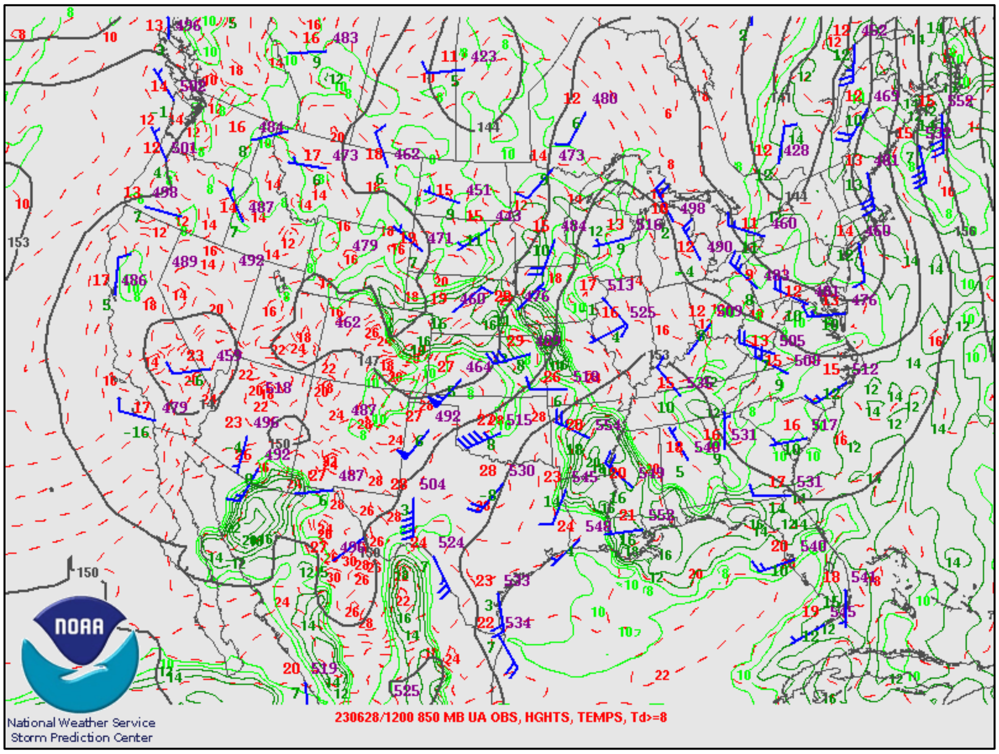



**Figure 9-18.** 850 mb pressure pattern with winds for June 28, 2023, at 8 AM.

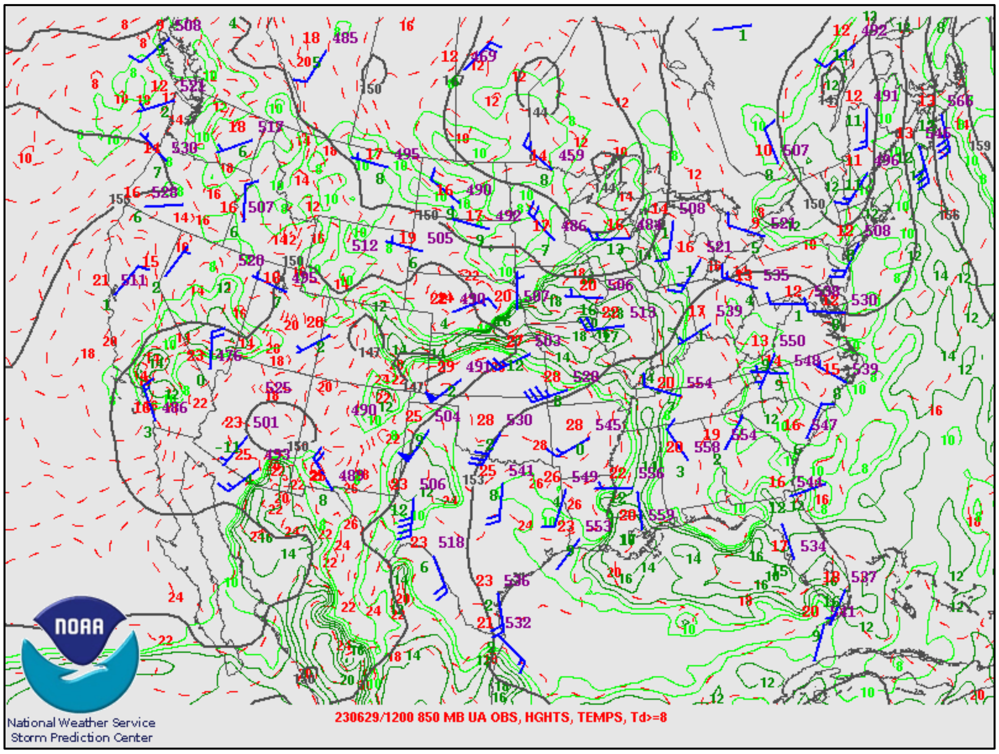



**Figure 9-19.** 850 mb pressure pattern with winds for June 29, 2023, at 8 AM.

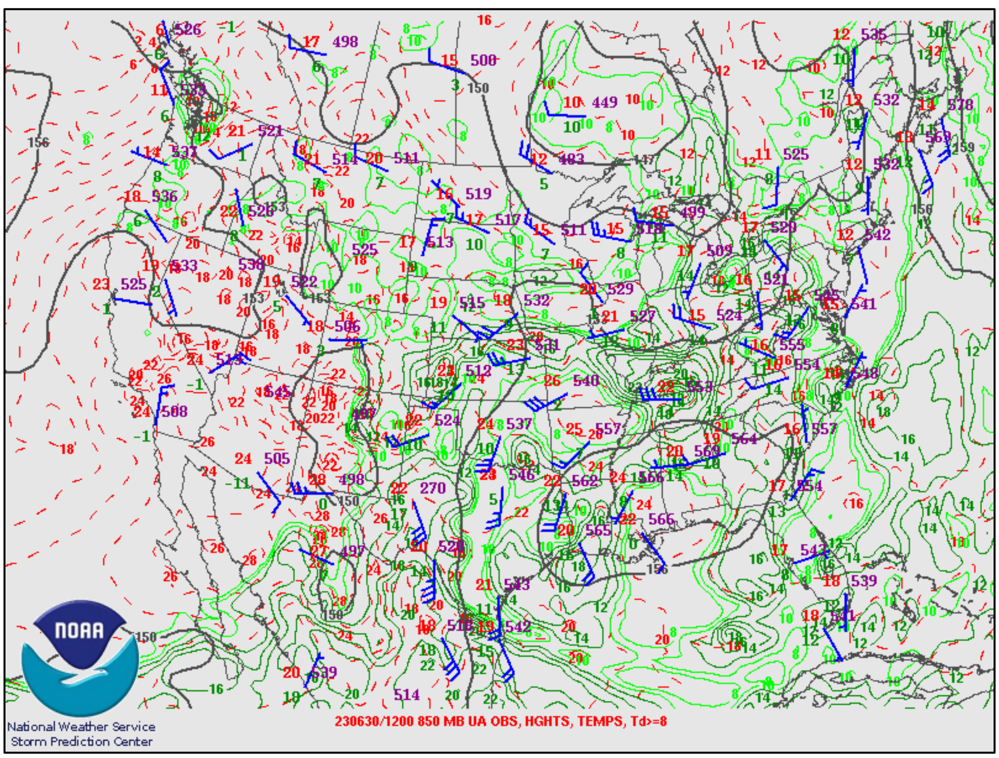



**Figure 9-20.** 850 mb pressure pattern with winds for June 30, 2023, at 8 AM.

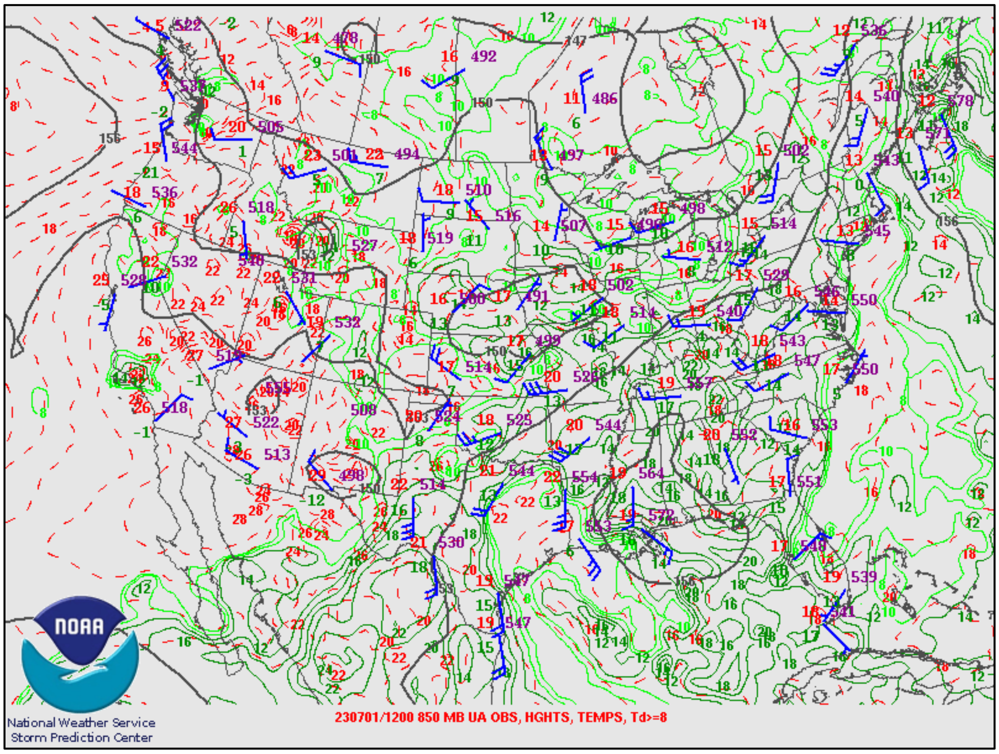



**Figure 9-21.** 850 mb pressure pattern with winds for July 1, 2023, at 8 AM.

Turning to the local meteorology, daily high temperatures remain near 80 degrees Fahrenheit from June 28 – July 3 with varying ozone levels each day (Figure 9-22 through Figure 9-25). Winds mostly originate from the south or southeast; although, Cornwall and Wesport featured minimal north winds during the early morning hours. With these temperature and southeast wind directions, Connecticut would typically not see ozone exceedances.

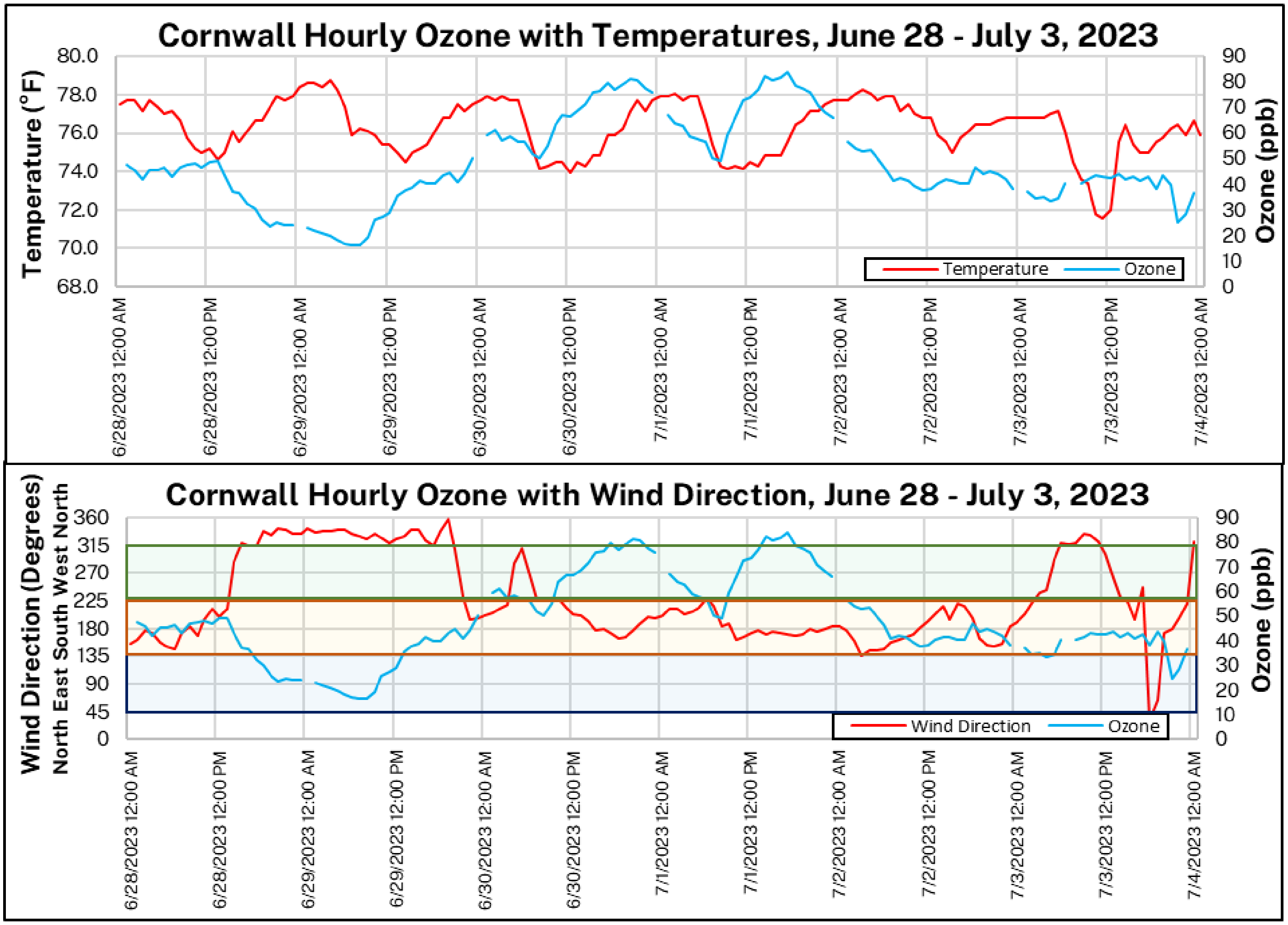



**Figure 9-22**. Cornwall hourly ozone with temperatures (top); hourly ozone with wind direction (bottom) surrounding the June 30 – July 1 event.

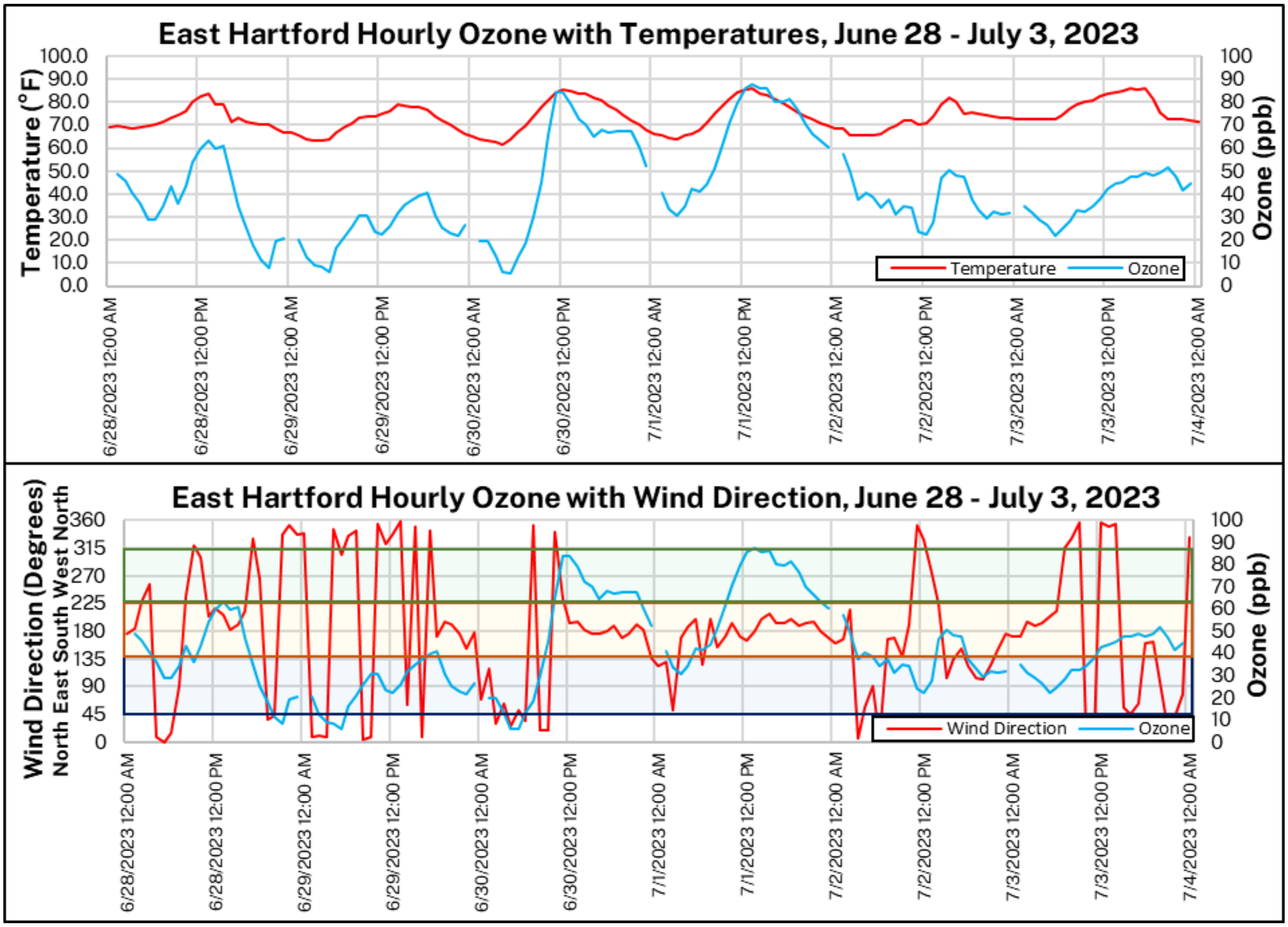



**Figure 9-23.** East Hartford hourly ozone with temperatures (top); hourly ozone with wind direction (bottom) surrounding the June 30 – July 1 event.

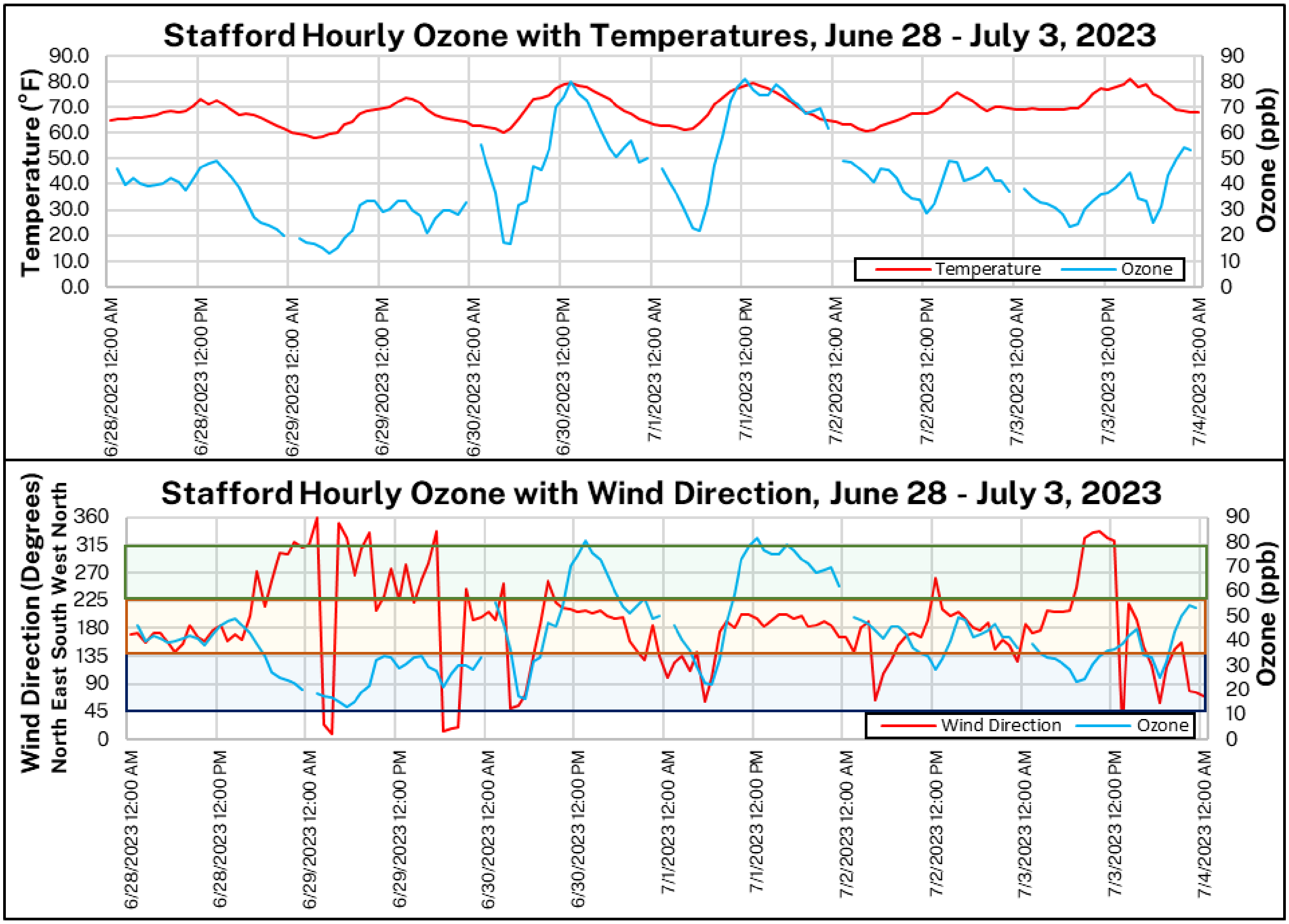



**Figure 9-24.** Stafford hourly ozone with temperatures (top); hourly ozone with wind direction (bottom) surrounding the June 30 – July 1 event.

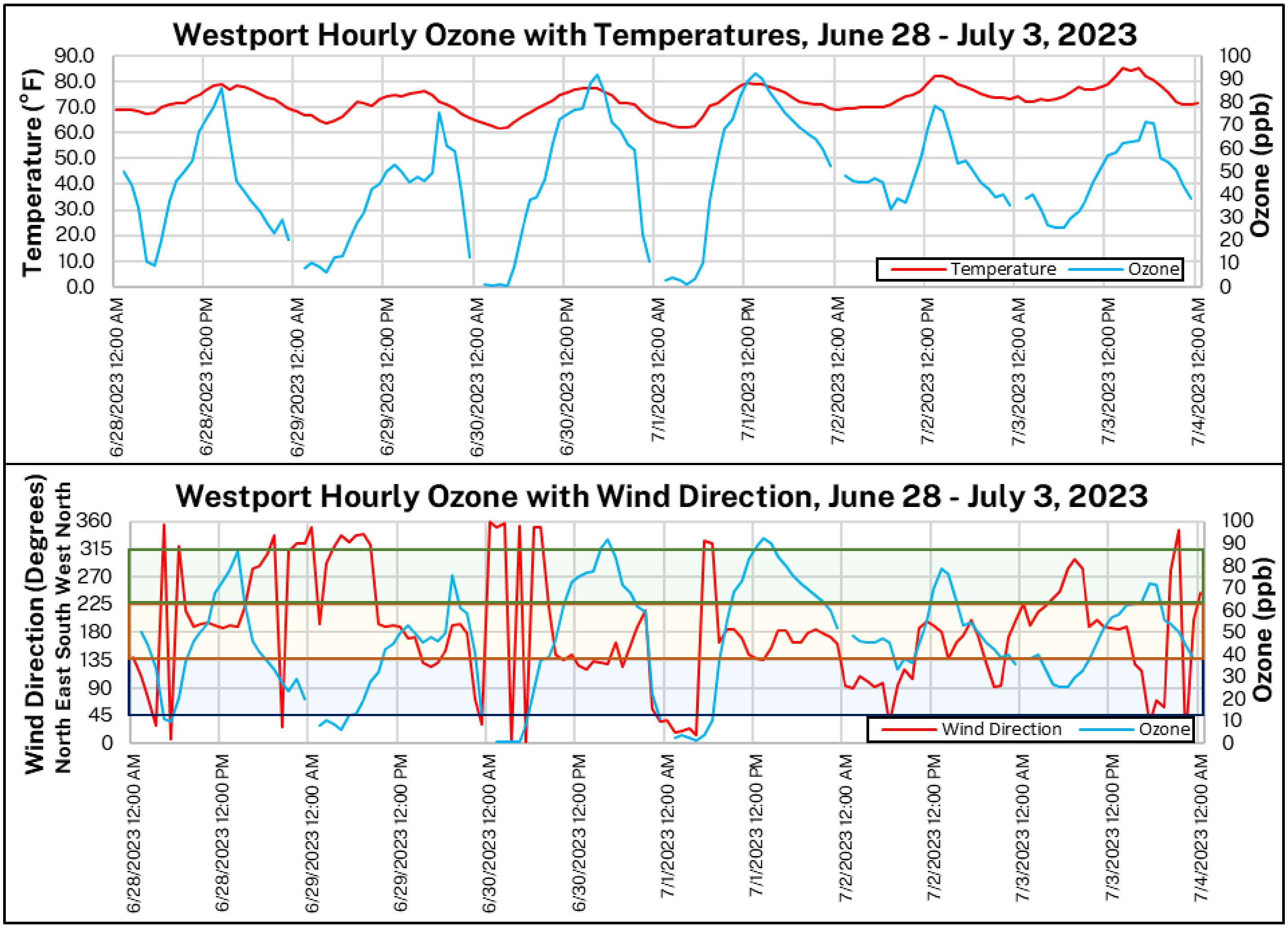



**Figure 9-25.** Westport hourly ozone with temperatures (top); hourly ozone with wind direction (bottom) surrounding the June 30 – July 1 event.

## 9.3 July 12, 2023 Ozone Event

Fires burning in western Canada during this event resulted in transport of smoke to Connecticut. Figure 9-26 shows high pressure over western Canada behind a frontal system on July 7 carrying the smoke plume aloft. On July 9, a cold front behind the area of smoke pushes south with the high-pressure system (Figure 9-27). Smoke continues moving southeastward with the high-pressure system and begins to impact the Great Lakes region by July 10 (Figure 9-28). On July 11 the cold front reaches the eastern Great Lakes (Figure 9-29). On July 12, the front stalls along the Canadian and United States border allowing for continued smoke impacts and enhancement to ozone levels (Figure 9-30).

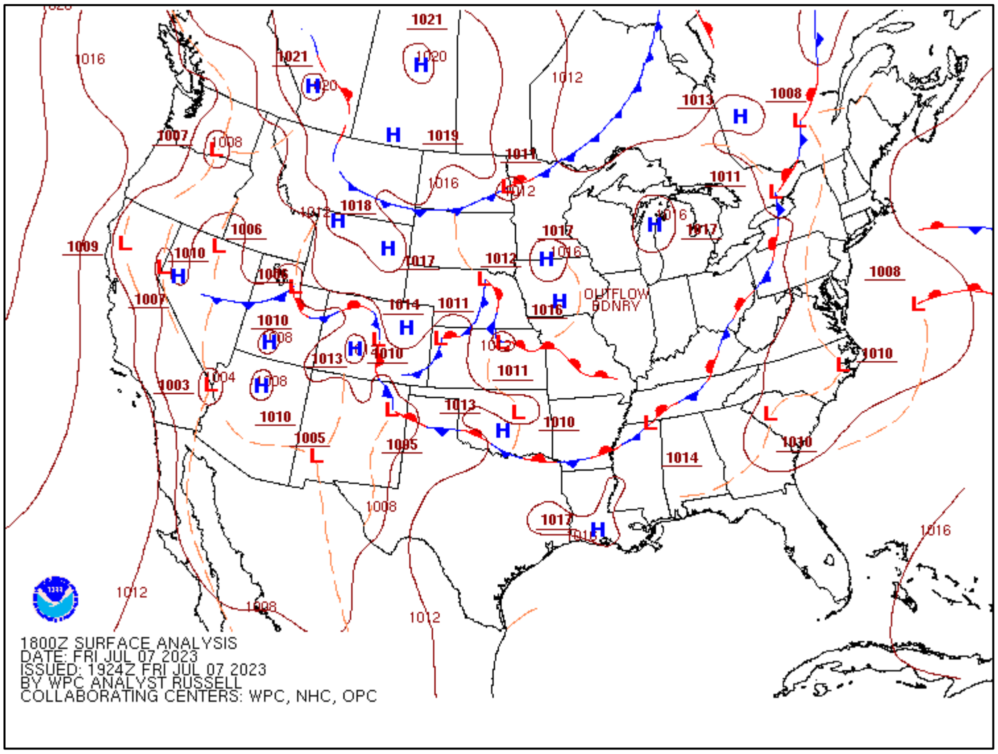



**Figure 9-26.** Surface analysis for July 7, 2023, at 2 PM.

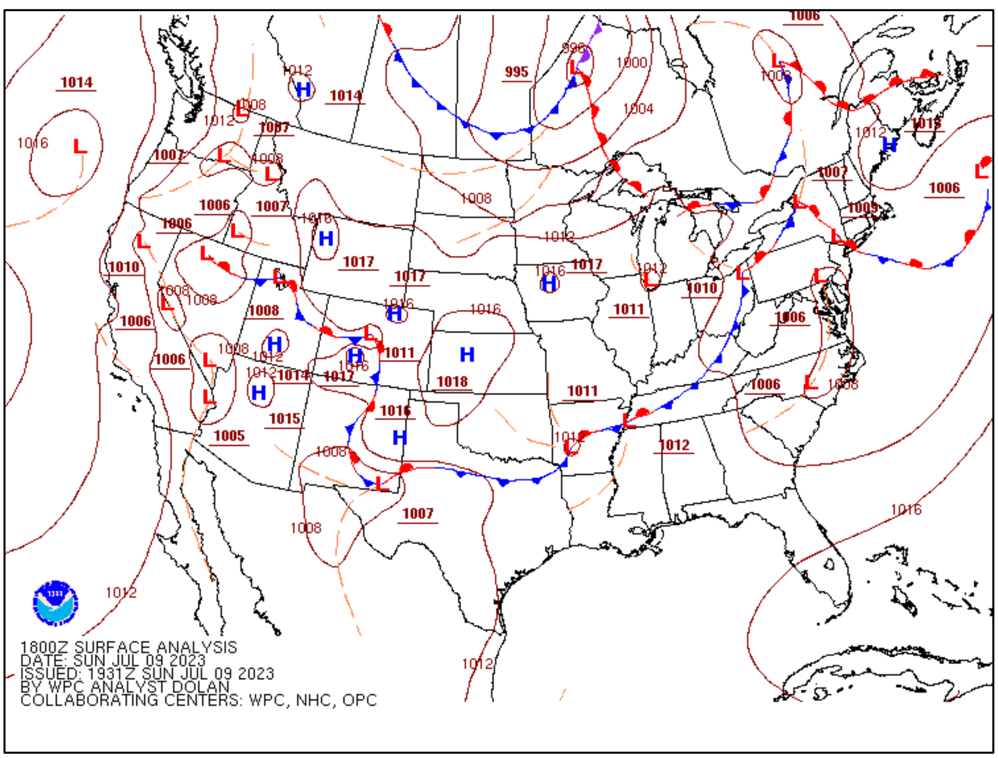



**Figure 9-27.** Surface analysis for July 9, 2023, at 2 PM.

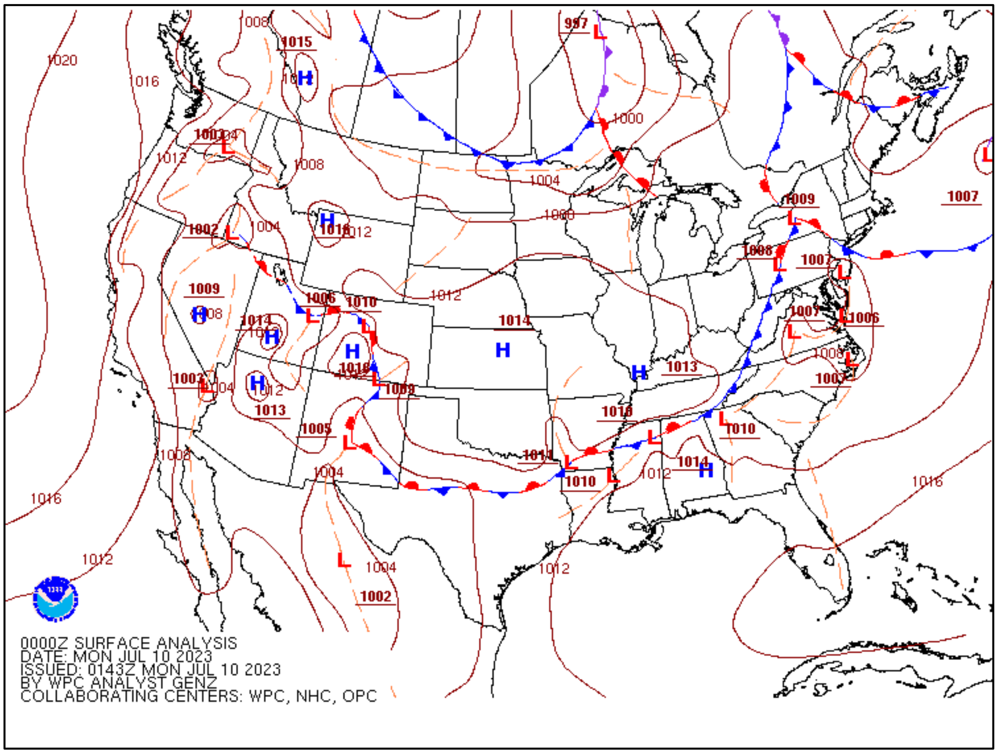



**Figure 9-28.** Surface analysis for July 10, 2023, at 2 PM.

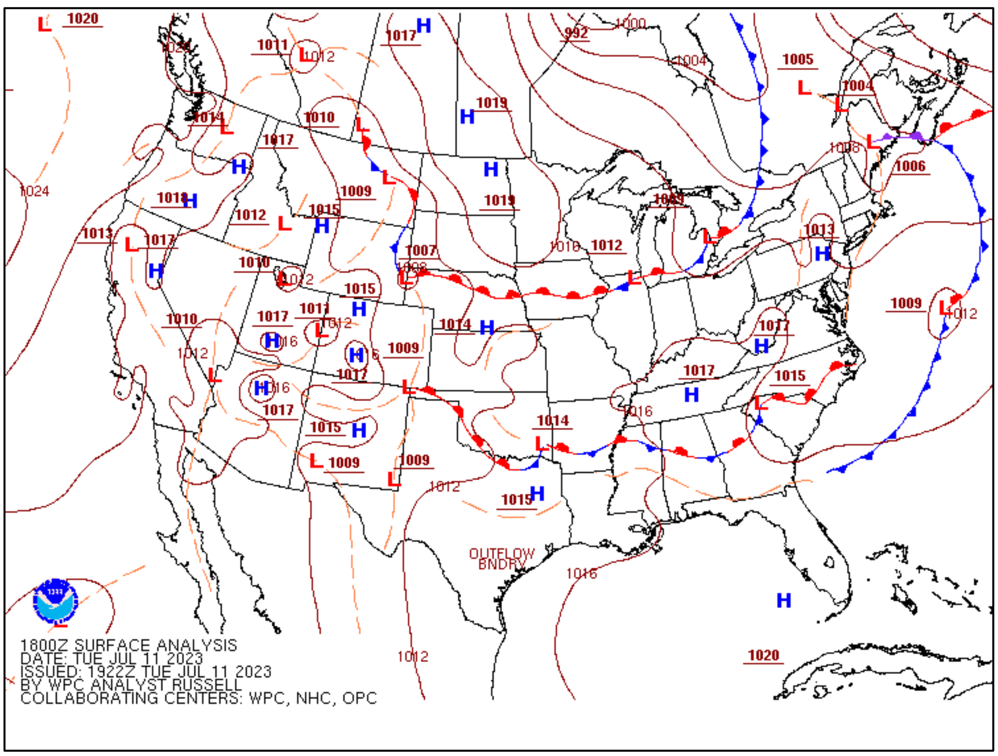



**Figure 9-29.** Surface analysis for July 11, 2023, at 2 PM.

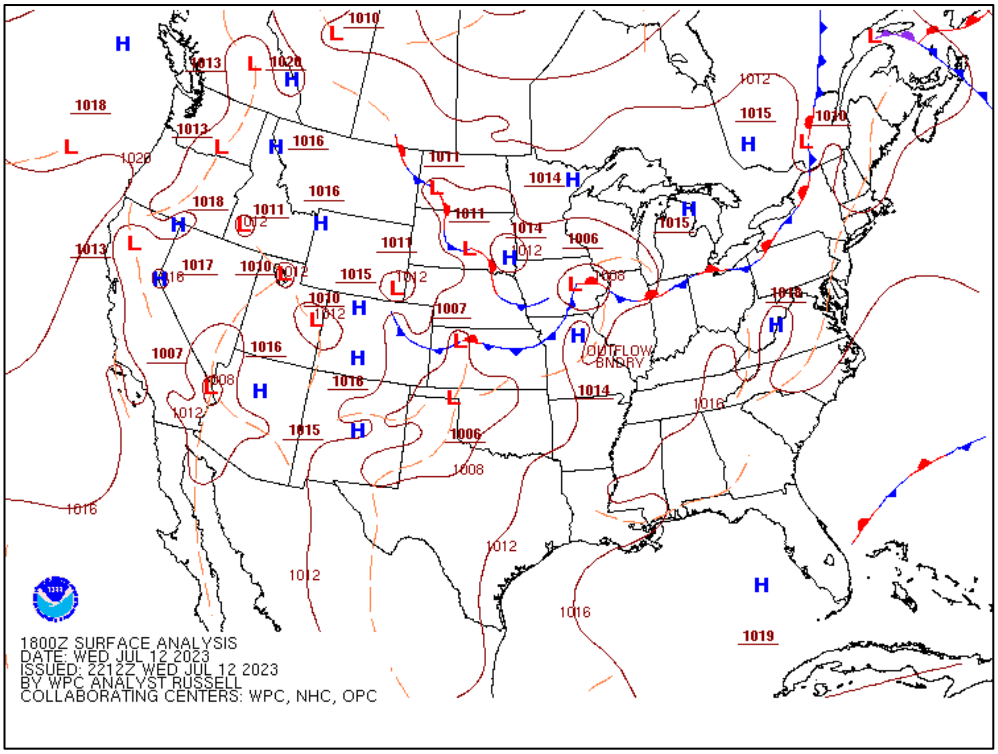



**Figure 9-30.** Surface analysis for July 12, 2023, at 2 PM.

At the 850 mb level, light winds on July 7th predominate in the area of the western Canada fires (Figure 9-31). A low pressure center over northern Canada allows for west-to-northwest winds to transport smoke eastward towards the northern mid-west and Great Lakes region on July 8 and 9 (Figure 9-32 and Figure 9-33). By July 10, a low-pressure trough forms over New England and winds shift to the northwest (Figure 9-34). On July 11, the northwest flow continues to transport smoke towards Connecticut from the Great Lakes region (Figure 9-35). By July 12, the low-pressure center retreats toward Hudson Bay causing winds to shift westward over Connecticut (Figure 9-36).

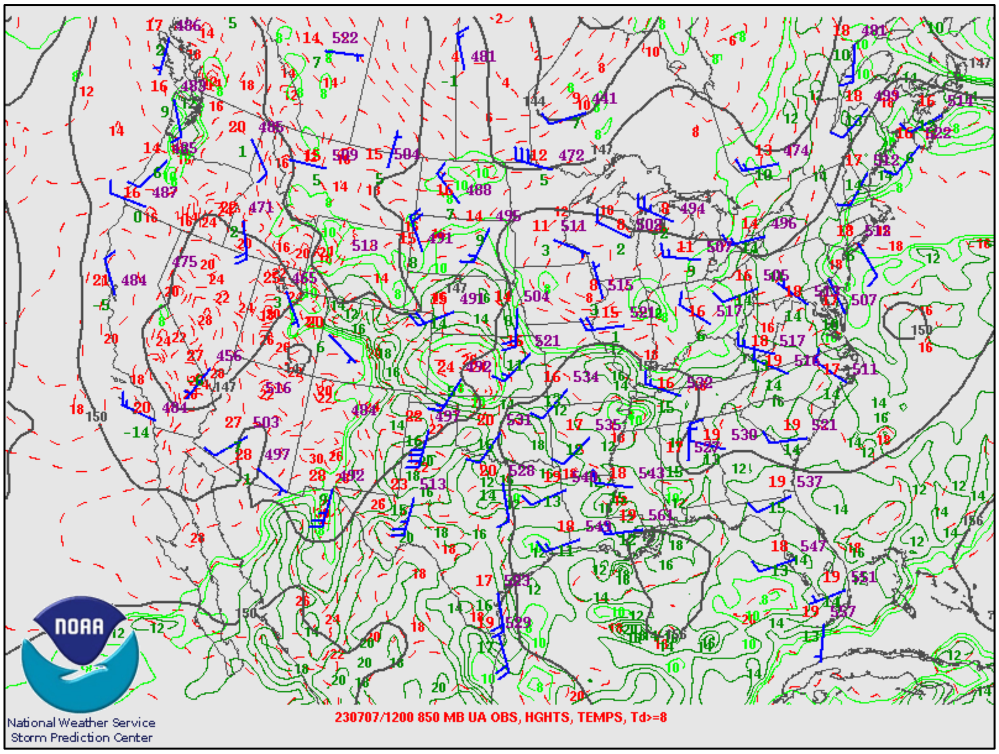



**Figure 9-31.** 850 mb pressure pattern with winds for July 7, 2023, at 8 AM.

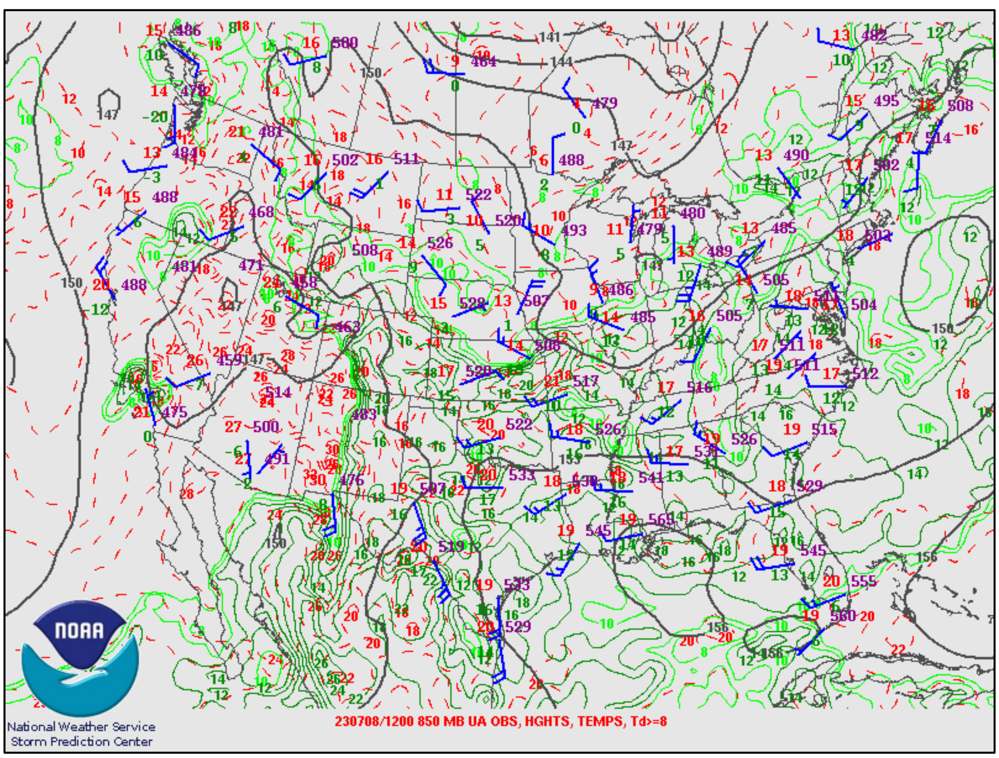



**Figure 9-32.** 850 mb pressure pattern with winds for July 8, 2023, at 8 AM.

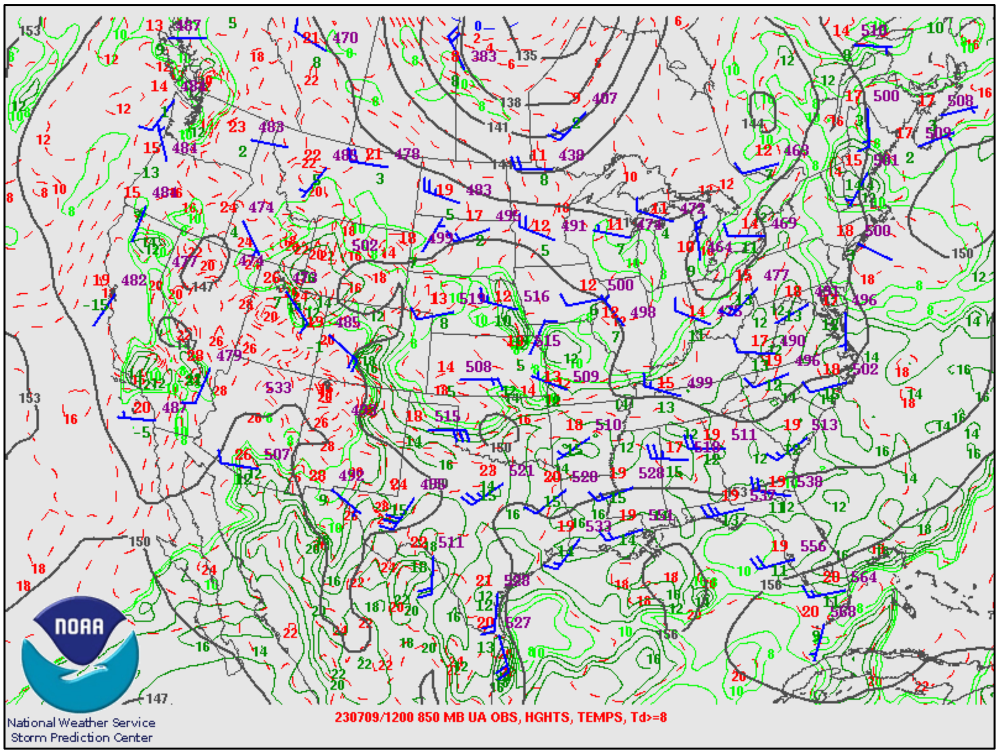



**Figure 9-33.** 850 mb pressure pattern with winds for July 9, 2023, at 8 AM.

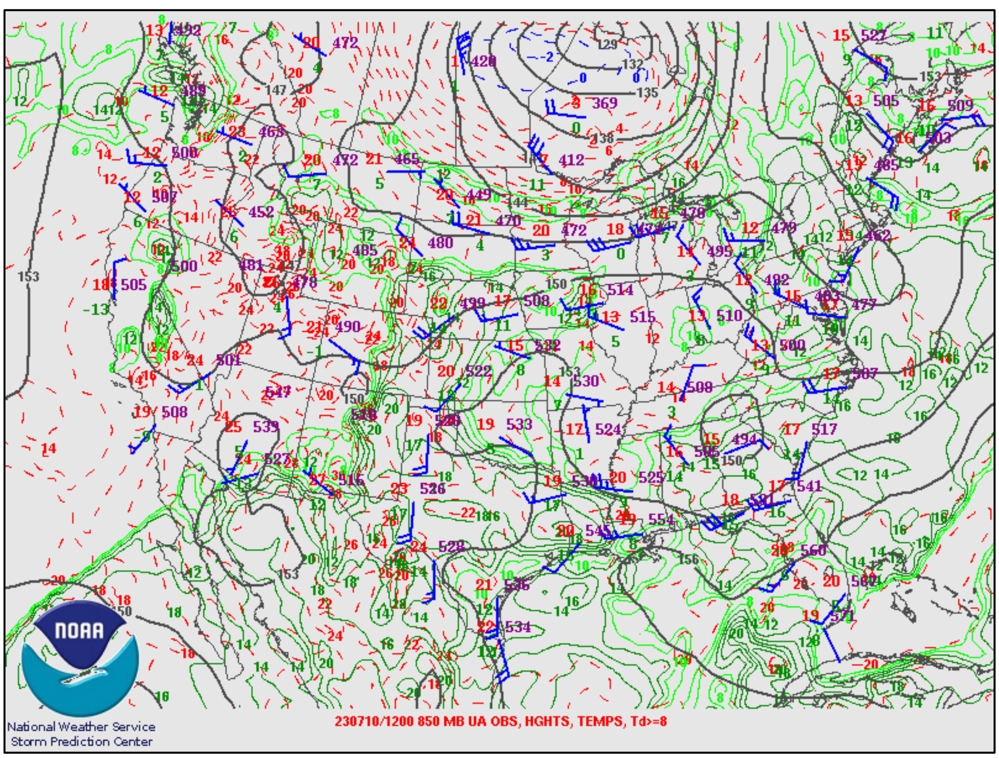



**Figure 9-34.** 850 mb pressure pattern with winds for July 10, 2023, at 8 AM.

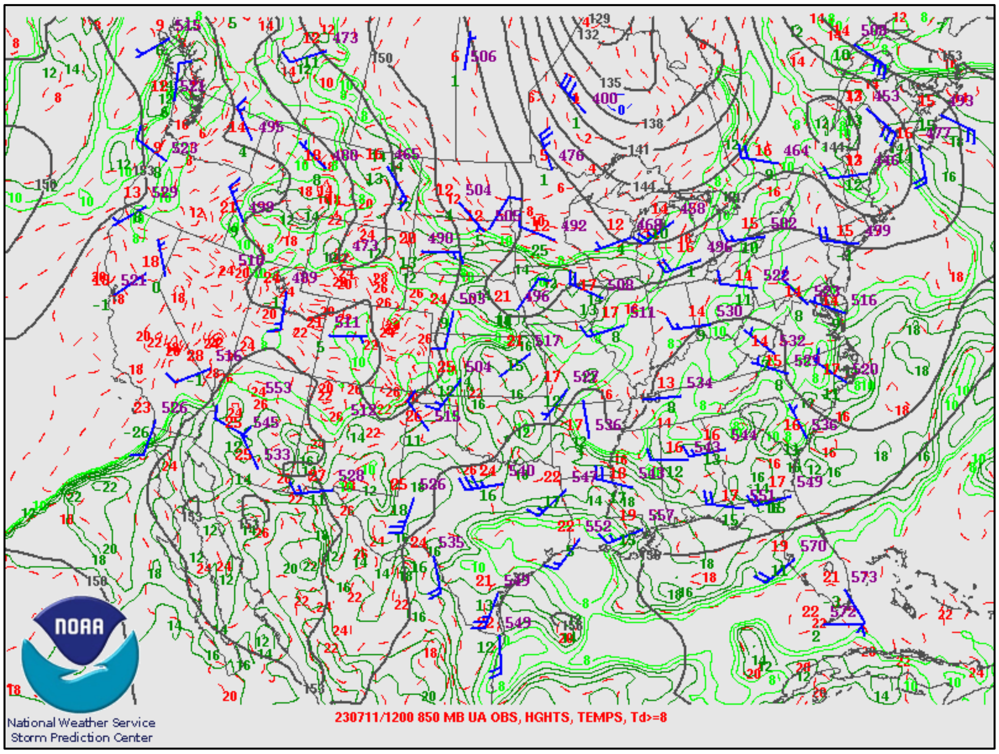



**Figure 9-35.** 850 mb pressure pattern with winds for July 11, 2023, at 8 AM.

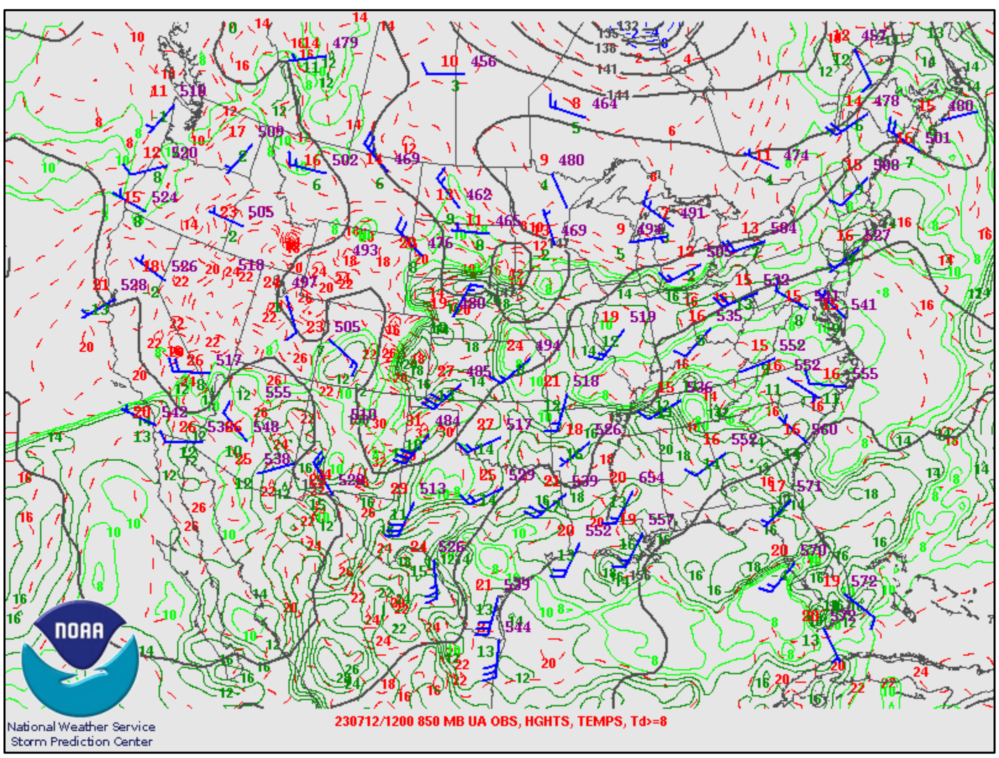



**Figure 9-36.** 850 mb pressure pattern with winds for July 12, 2023, at 8 AM.

Hourly ozone with temperatures and hourly ozone with wind direction are plotted for Cornwall, East Hartford, Stafford, and Westport (Figure 9-37 through Figure 9-40). The temperatures surrounding the July 12 event were in the mid-to-upper 80s. Ozone levels buildup prior to the event, even though daily high temperatures remained steady. For each site, winds quickly shifted from northwest to south during the day. This is a scenario where Connecticut might see coastal exceedances had winds traversed the NY metropolitan area.

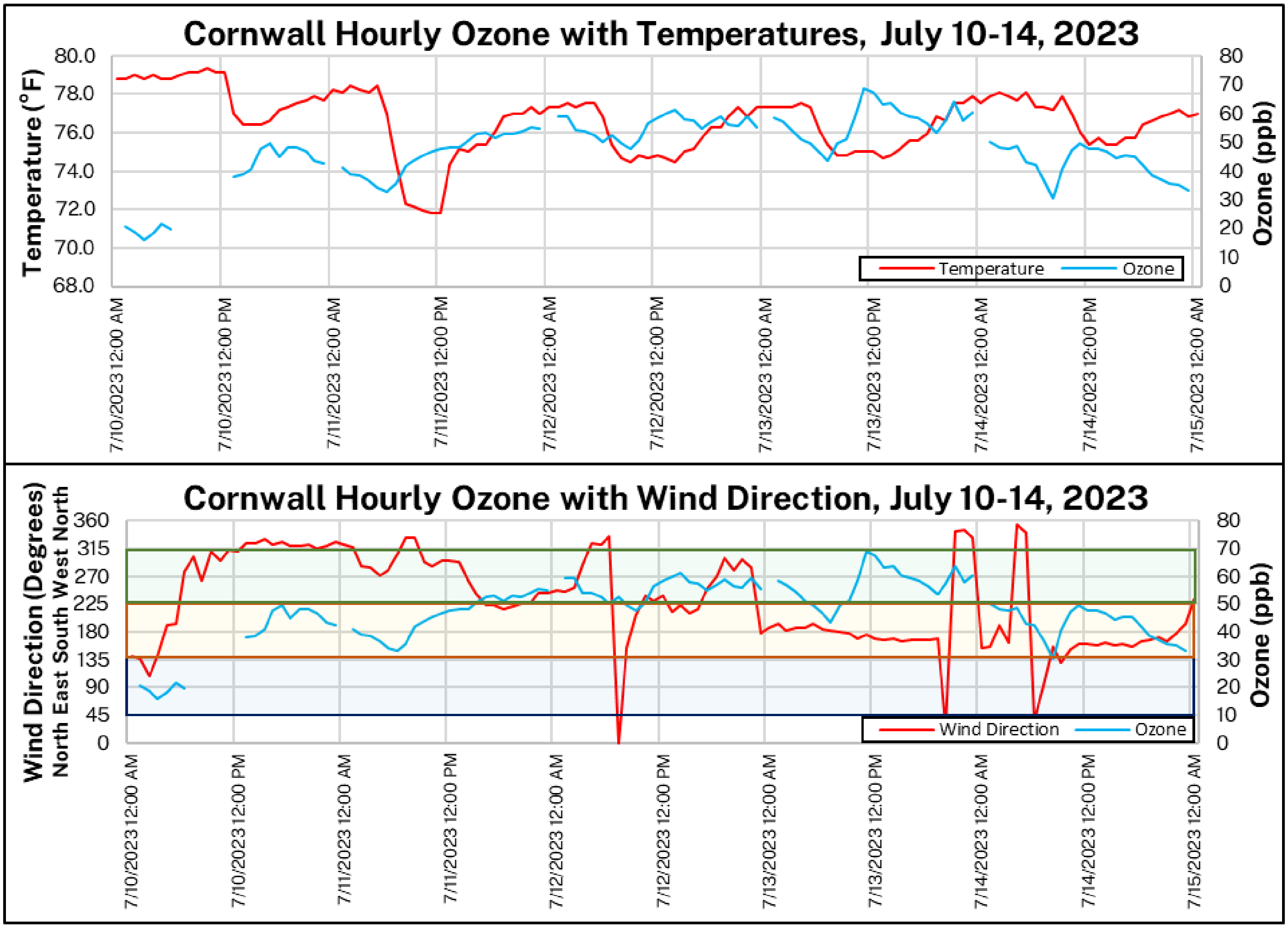



**Figure 9-37.** Cornwall hourly ozone with temperatures (top); hourly ozone with wind direction (bottom) surrounding the July 12 event.

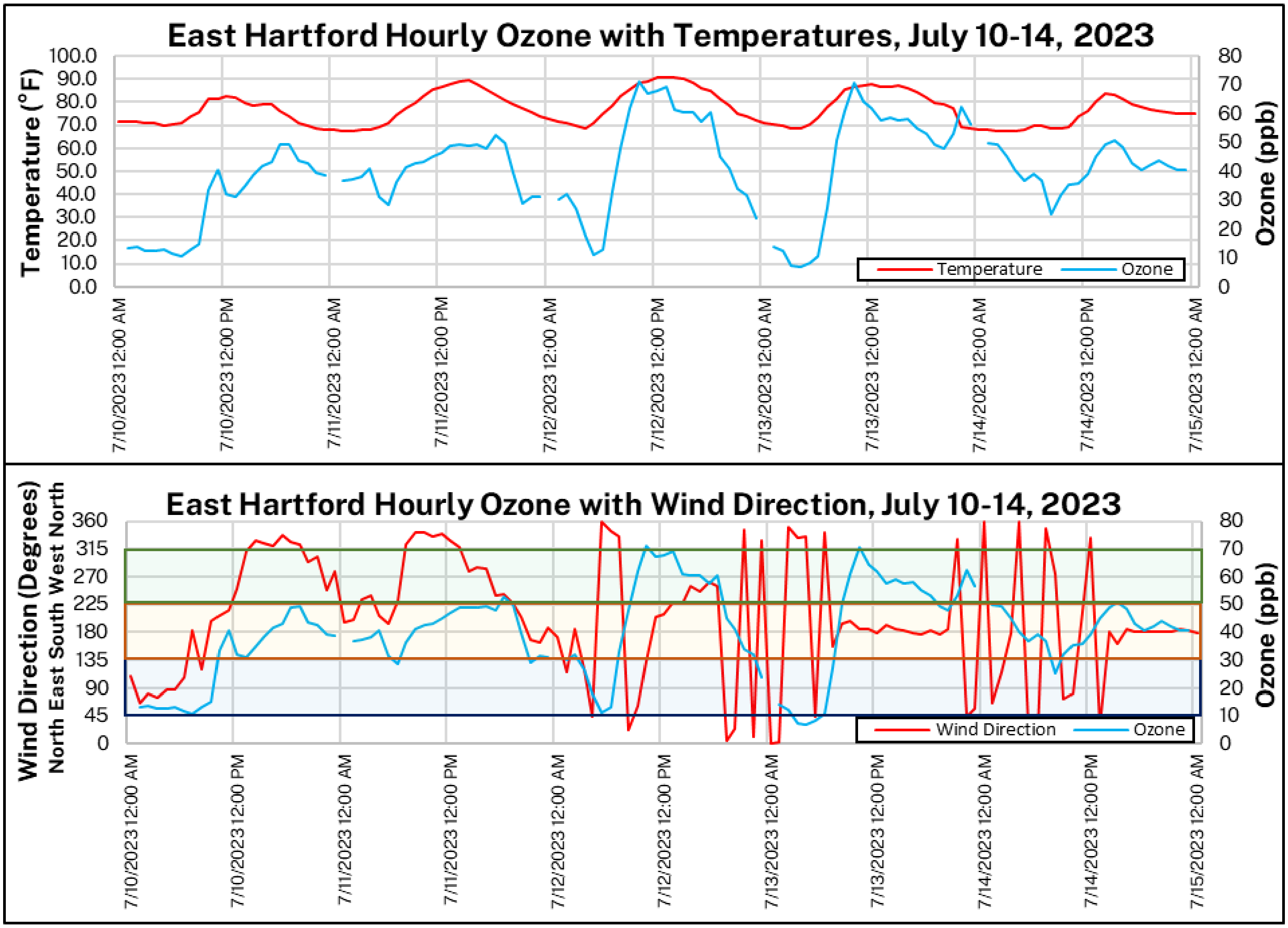



**Figure 9-38.** East Hartford hourly ozone with temperatures (top); hourly ozone with wind direction (bottom) surrounding the July 12 event.

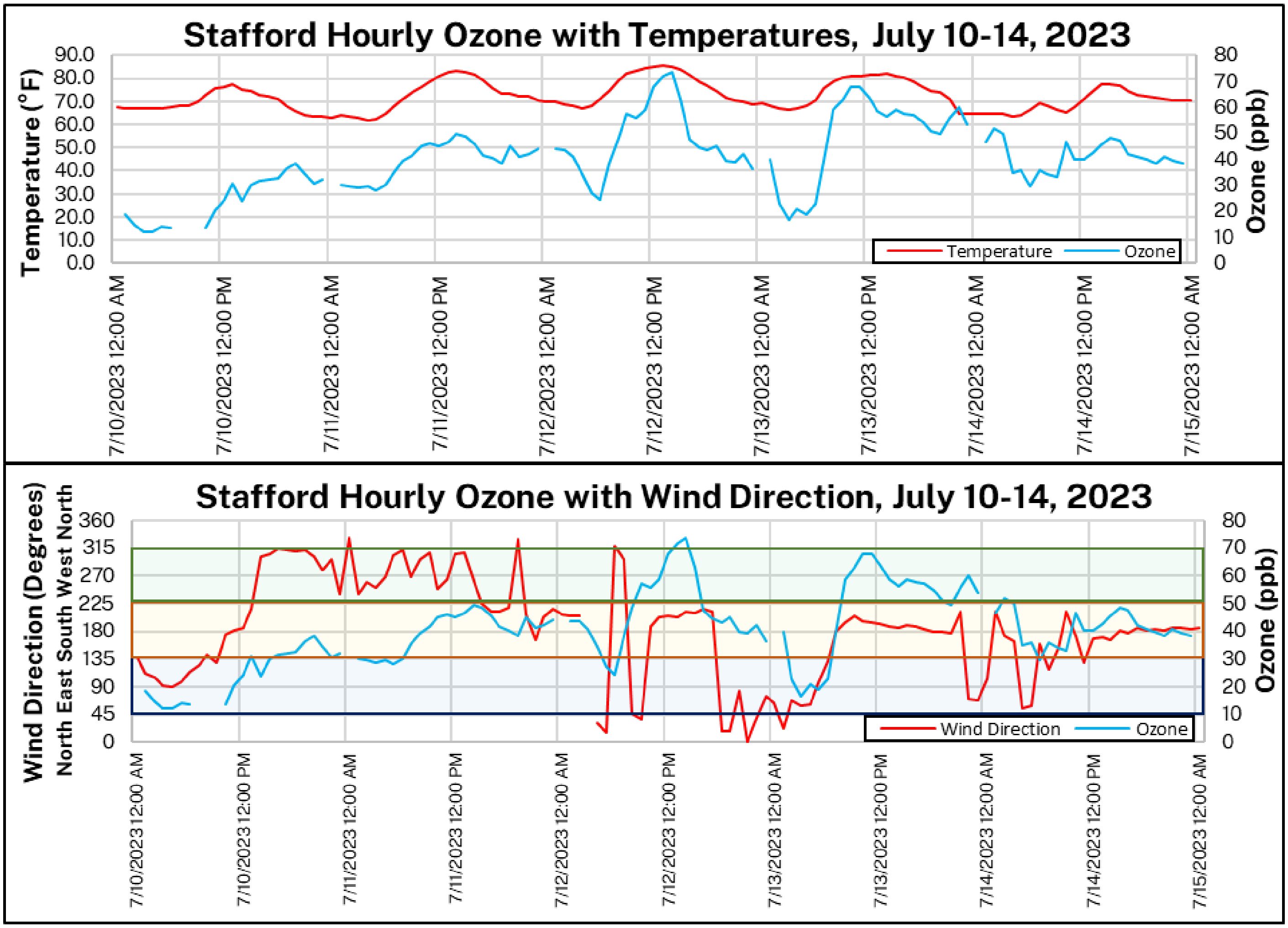



**Figure 9-39.** Stafford hourly ozone with temperatures (top); hourly ozone with wind direction (bottom) surrounding the July 12 event.

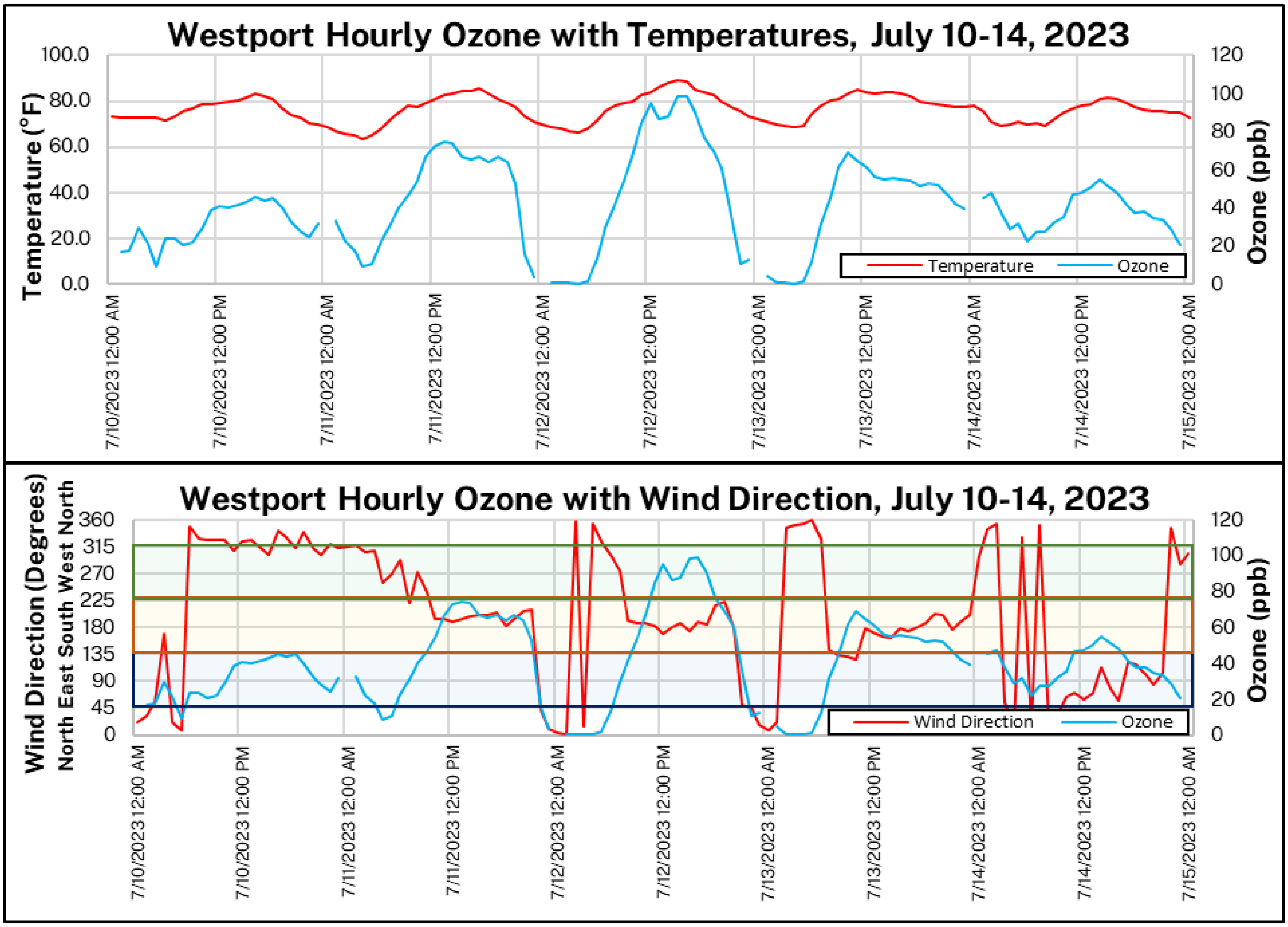



**Figure 9-40.** Westport hourly ozone with temperatures (top); hourly ozone with wind direction (bottom) surrounding the July 12 event.

## 9.4 Event Meteorology Compared to Exceedance Scenarios

Each of the 2023 ozone exceedance events highlighted in this document differ from the predefined typical ozone exceedance scenarios. The April 13-14 event occurred before ozone season typically begins, with a mix of coastal and eastern inland site exceedances on April 13, and all but one monitoring site exceeding on April 14. The June 30 – July 1 event stands out because of the widespread ozone exceedances for a scenario that typically only impacts the westernmost monitor sites. The July 12 event is unique because of the magnitude and extent of the ozone exceedances, with rare exceedances in Rhode Island and southeastern Massachusetts.

# *10 Similar Day Analyses*

*"Comparison of $O_3$ Concentrations on Meteorologically Similar Days (Matching Day Analysis). $O_3$ formation and transport are highly dependent upon meteorology. Therefore, a comparison between $O_3$ on meteorologically similar days with and without fire impacts could support a clear causal relationship between the fire and the monitored concentration. Both $O_3$ concentrations and diurnal behaviors on days with similar meteorological conditions can be useful to compare with days believed to have been influenced by fire. Since similar meteorological days are likely to have similar $O_3$ concentrations, significant differences in $O_3$ concentrations among days with similar meteorology may indicate influences from non-typical sources."*

-EPA guidance: Treatment of Data Influenced by Exceptional Events

## 10.1 Methodology

Characterizing the relationship between ozone and surface winds and/or temperatures at monitors can be useful for indicating emissions sources and increased photochemical reactivity. However, simply using surface winds and/or temperatures at our Connecticut monitors as a predictor for ozone can be problematic because of the land/sea interface. Inland ozone monitoring sites can observe northwest winds and very warm temperatures while the coastal sites will experience a southwest sea breeze and much cooler temperatures. Historically, temperatures over 90 °F have been a good indicator for ozone production, but very warm temperatures do not always lead to an ozone exceedance in Connecticut.

Figure 10-1 charts the monitored maximum temperature with the daily maximum 8-hour ozone concentration at each of the monitors selected for data exclusion over the five years from 2019 through 2023. A vertical red line indicates the level of the 2015 ozone standard. Each of the sites indicates that a majority of high temperature days do not result in exceedances of the standard.

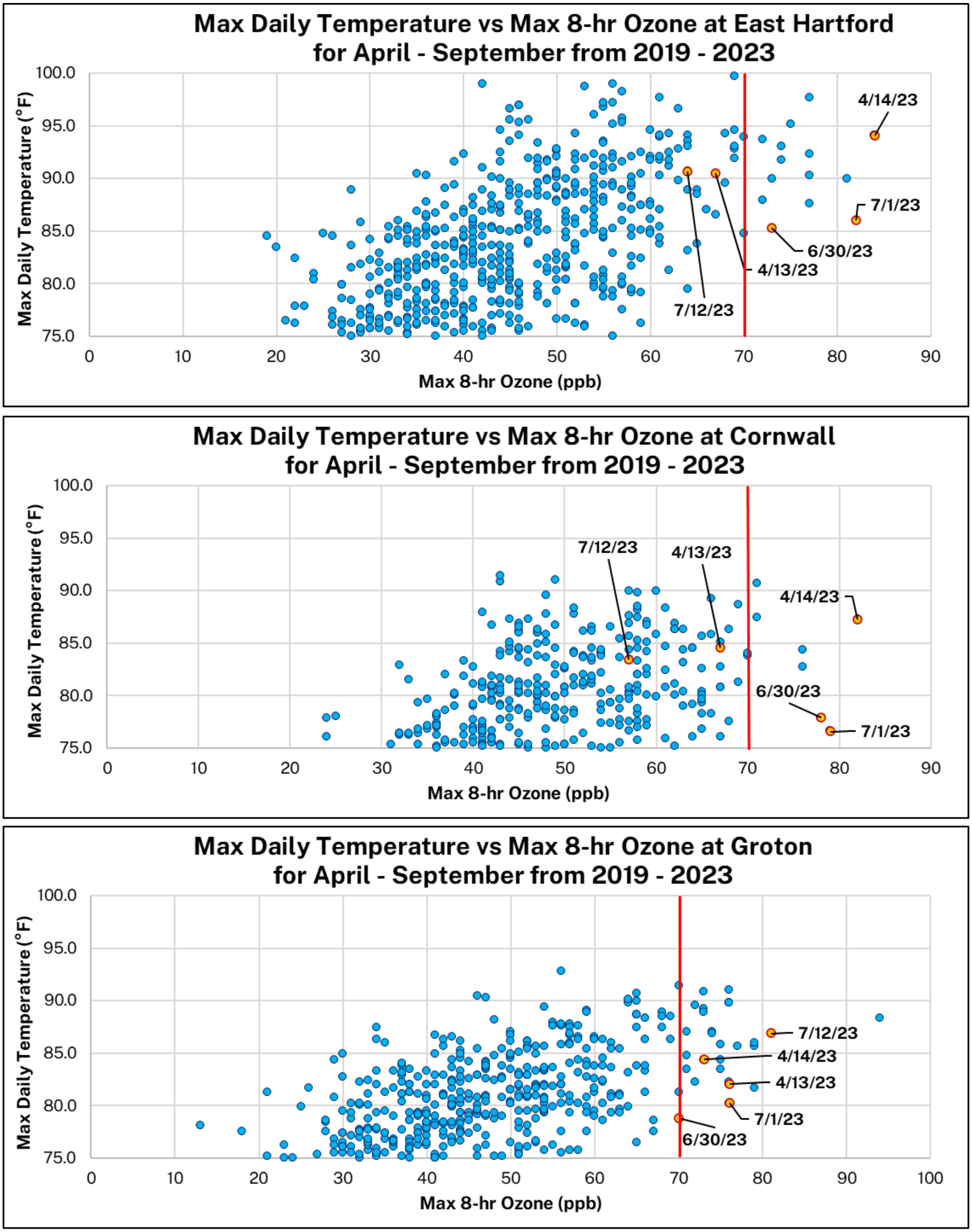



**Figure 10-1.** Charts of monitored maximum temperature versus maximum daily 8-hour average ozone concentration for each of the monitors of interest.

For a detailed example, consider July 21, 2019, when high temperature recorded at Bradley International Airport was 100° F. Figure 10-2 shows that there was a west wind flow for most of the state, except the coastline. Back trajectory analysis shows the air parcels originated in the Great Lakes region and travelled north of New York City before arriving in Connecticut. While July 21, 2019, was not a similar day to the events in question, it is an illustration how extreme heat is not the main factor for an ozone exceedance in Connecticut. Wind trajectories must also pass through polluted areas and into Connecticut. Surface wind trajectories often will not coincide with those trajectories from higher in the atmosphere. Upper-level winds have the ability to transport pollutants from great distances, even across oceans and continents, while the surface winds are more indicative of more localized transport.

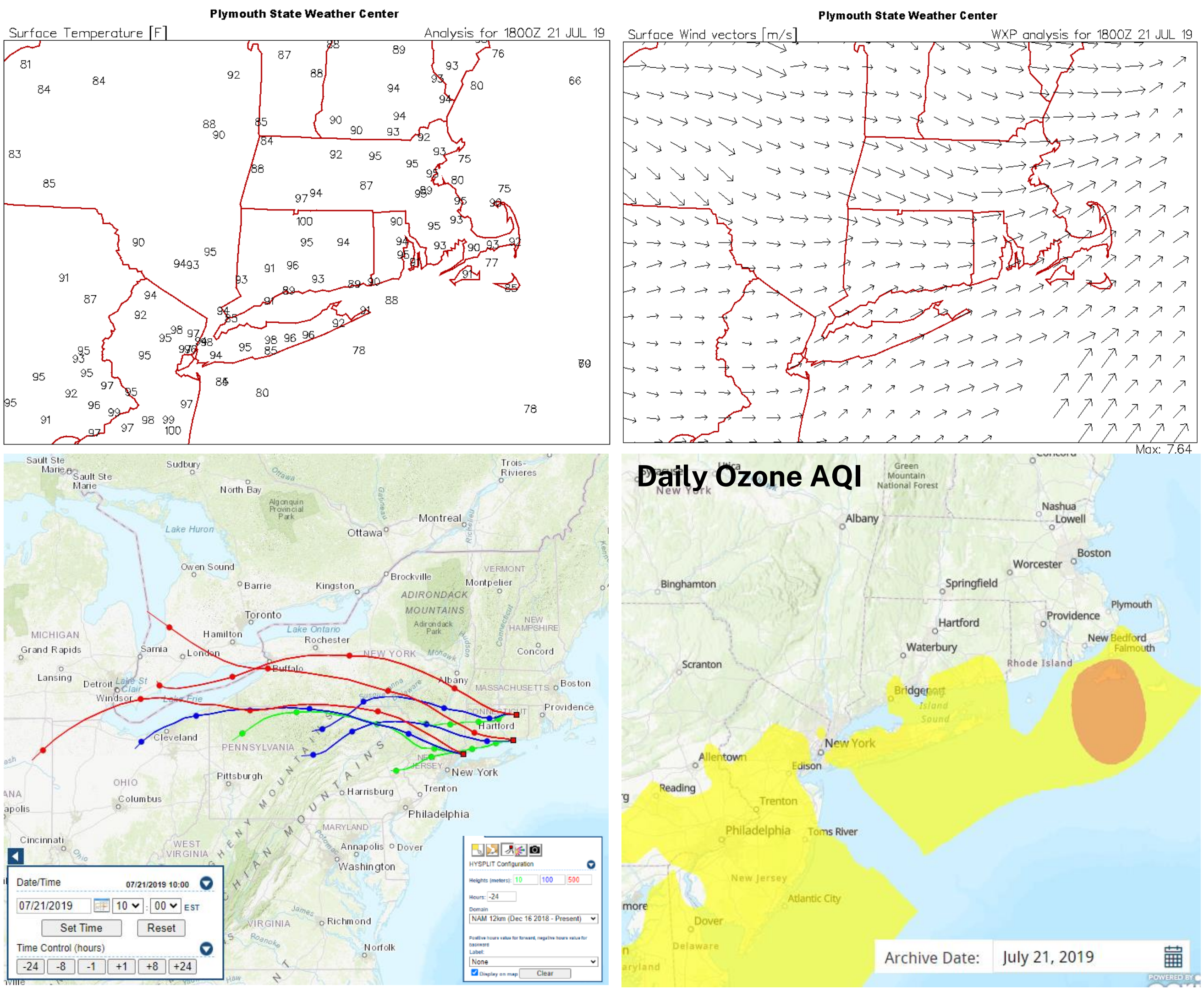



**Figure 10-2.** Temperatures, winds, and ozone levels across Connecticut on July 21, 2019.

A reliable procedure for identifying similar days from past years is to look for similar 850 mb pressure and wind patterns. The following method was used for this analysis:

- Determine early ozone season days, particularly in April and early May, where temperatures were above 85 degrees Fahrenheit (used only for the April 13-14 event);
- Analyze 12z (8:00 EDT) modeled sounding data from Albany (ALB) for April 13, April 14, June 30 and July 1, and 12z modeled sounding data from Groton (GON) for July 12 to determine 850 mb winds;
- Filter wind data for wind direction and speed for each day;
- Run 24-hour HYSPLIT back trajectories from 18z (2 PM) for those days that fit these criteria;
- Choose the days that most closely match 500m/1500m back-trajectories to the areas of interest for each day;
- Plot 850 mb North American Regional Reanalysis (NAM) maps for those dates, to examine similarity of pressure height patterns.

For the April 13-14 event, dates were selected to closely match the leaf out conditions and unseasonably high temperatures to account for similar ozone production conditions. Sounding data from ALB (12z) was selected as most representative of upwind conditions. Figure 10-3 shows the 12z sounding data for April 13 and 14. For April 13, the 850 mb wind from ALB was from 315 (from the west) degrees at 25 knots, and for April 14, the 850 mb wind from ALB was also from 315 degrees but slightly slower at 15 knots. The wind speed/wind direction flags on the right vertical bar in the figures show northwest flow for all levels on April 13 and the lowest levels for April 14 with west winds for the upper levels. Therefore, we filtered wind direction for 270 – 330 degrees (from the west to northwest) and wind speed greater than or equal to 10 knots. In addition, we chose two days that matched 500m/1500m back trajectories to the northern Pennsylvania area.

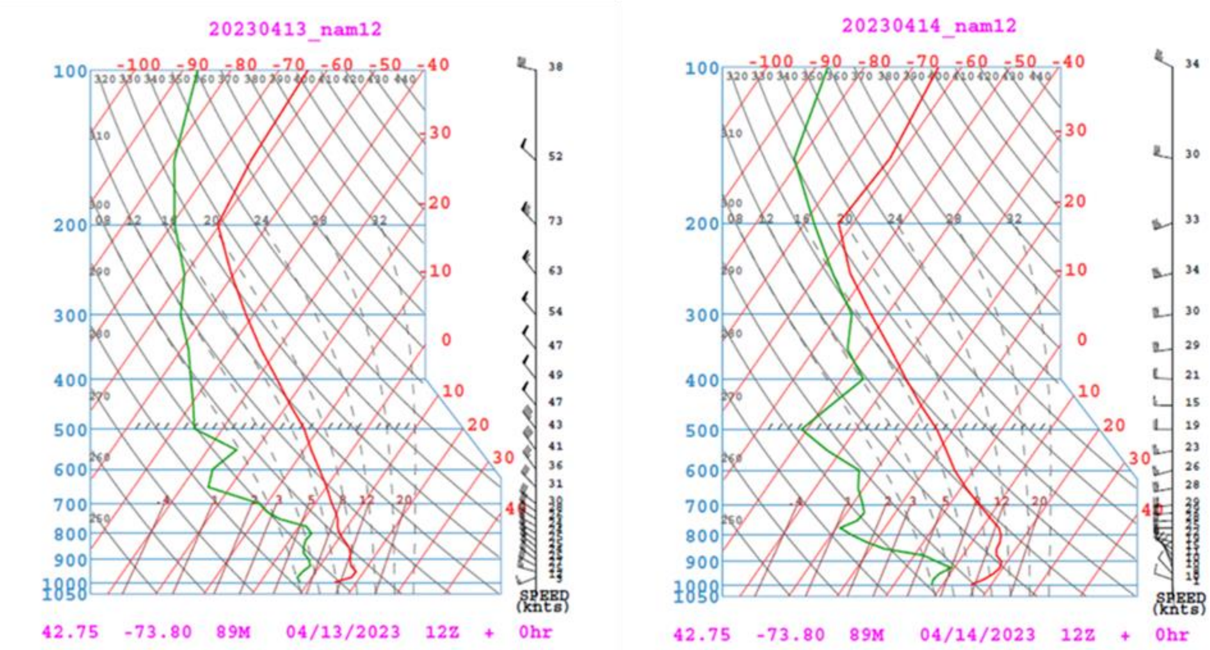



**Figure 10-3.** Sounding from Albany, NY (ALB) at 8:00 AM (12Z) on April 13, 2023 (left) and April 14, 2023 (right).

For the June 30 – July 1 event, sounding data from ALB was used for the reasons stated above. It was determined from the 12z sounding on June 30 that the 850 mb wind from ALB was from 225 degrees (from the southwest) at 15 knots, and for July 1, the 850 mb wind from ALB was from 210 degrees (from the southwest) at 7 knots (Figure 10-4). Therefore, we filtered wind direction for 200 – 235 degrees (from the southwest) and wind speed greater than or equal to 5 knots. In addition, a few days that matched 500m/1500m back trajectories to coastal New Jersey were selected.

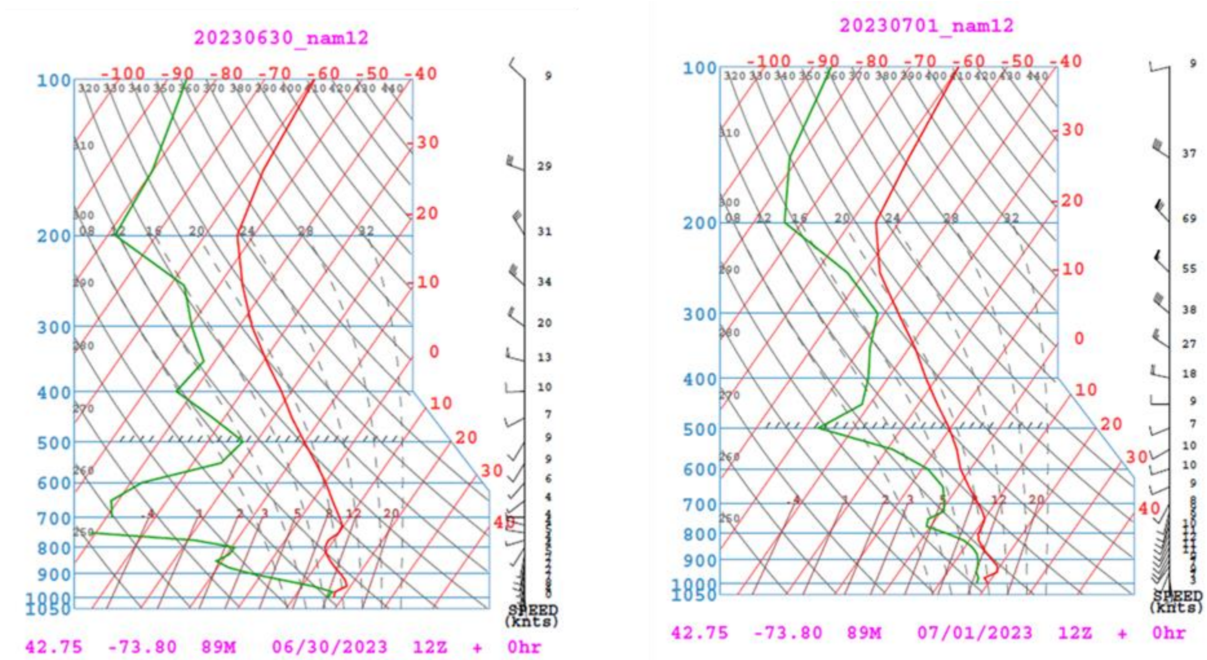



**Figure 10-4.** 12Z ALB Sounding from June 30, 2023 (left) and July 1, 2023 (right).

For July 12, sounding data from Groton was selected as it is our main site of interest for this event. It was determined from the 12z sounding on July 12 that the 850mb wind from GON was from 270 degrees at 7 knots (Figure 10-5). Therefore, wind direction was filtered for 260 to 280 degrees and wind speed greater than or equal to 5 knots. In addition, a few days that matched 500m/1500m back trajectories to the New Jersey/Pennsylvania border were selected.

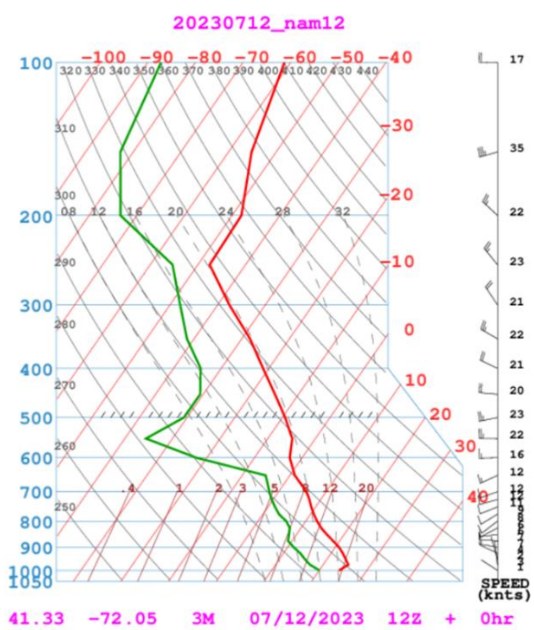
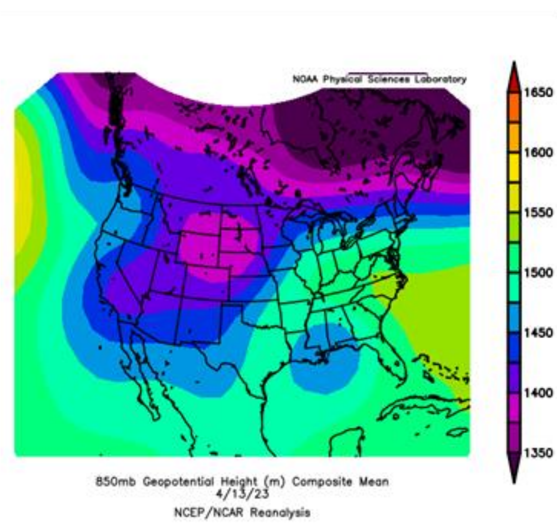
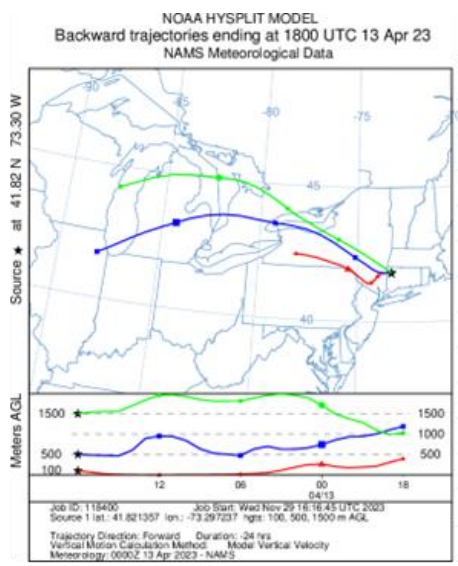



**Figure 10-5.** Sounding from Groton, CT (GON) from July 12, 2023.

## 10.2 Similar Day Maps for the April 13-14, 2023 Ozone Event

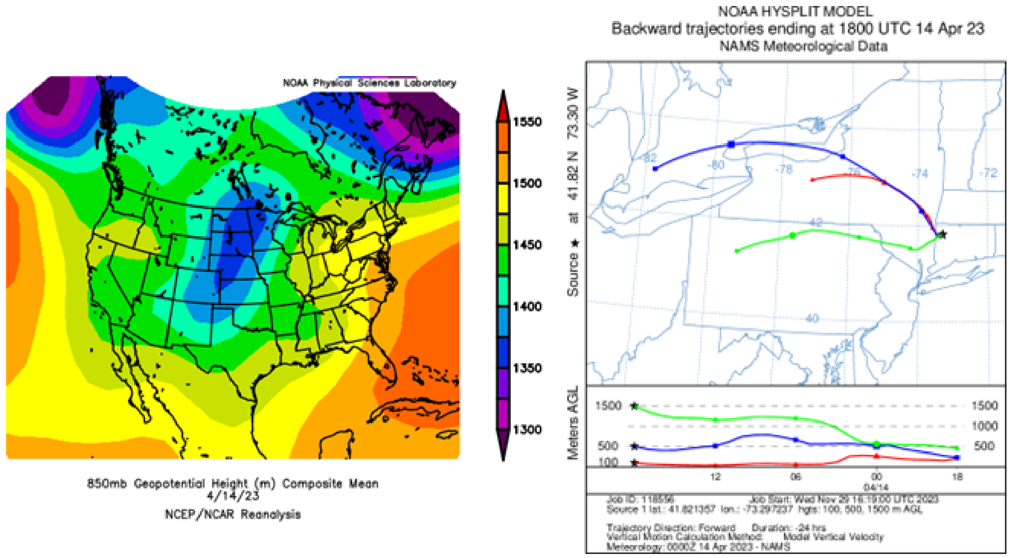
Figure 10-6 and Figure 10-7 show the reference 850 mb maps, reference back trajectories, and ozone observations on April 13 and April 14, respectively. The 850 mb height maps were generated for April 13th and 14th to create a reference pattern for comparison. These figures show a low-pressure area over the high plains and into eastern Canada. With this pattern, source winds to Connecticut would be expected to originate over western New York and the Great Lakes region, which is generally air that is low in ozone precursors barring any wildfires in the region. The 100, 500 and 1500 meter HYSPLIT back trajectories for these days originate near the Great Lakes region, western New York, and northern Pennsylvania. On April 13, ozone levels exceed the standard for most of the coastal sites and some inland sites in eastern Connecticut. Meanwhile, on April 14, every monitor site, except New Haven, exceeded the standard with two sites reaching unhealthy (red) levels.




| Ozone (ppb) | |
|---|---|
| | 4/13/2023 |
| Abington | 69 |
| Cornwall | 67 |
| Danbury | 68 |
| East Hartford | 67 |
| Greenwich | 72 |
| Groton | 76 |
| Madison | 82 |
| Middletown | 75 |
| New Haven | 58 |
| Stafford | 71 |
| Stratford | 77 |
| Westport | 79 |

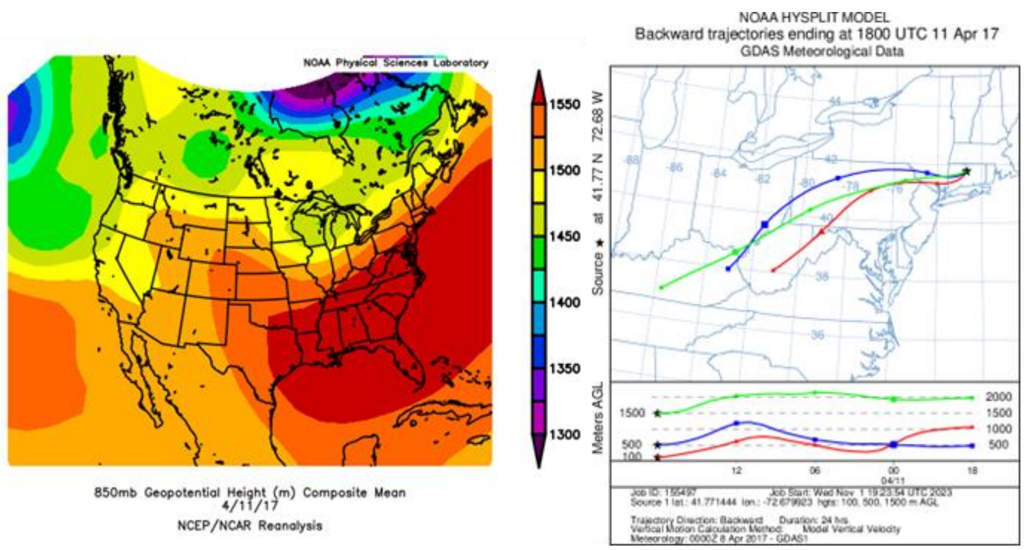
**Figure 10-6.** 850 mb reference pressure pattern with HYSPLIT reference trajectories and ozone observations from April 13, 2023. Maximum temperature at Bradley was 92°F.




| Ozone (ppb) | |
|---|---|
| | 4/14/2023 |
| Abington | 74 |
| Cornwall | 82 |
| Danbury | 85 |
| East Hartford | 84 |
| Greenwich | 76 |
| Groton | 73 |
| Madison | 75 |
| Middletown | 82 |
| New Haven | 66 |
| Stafford | 88 |
| Stratford | 72 |
| Westport | 78 |

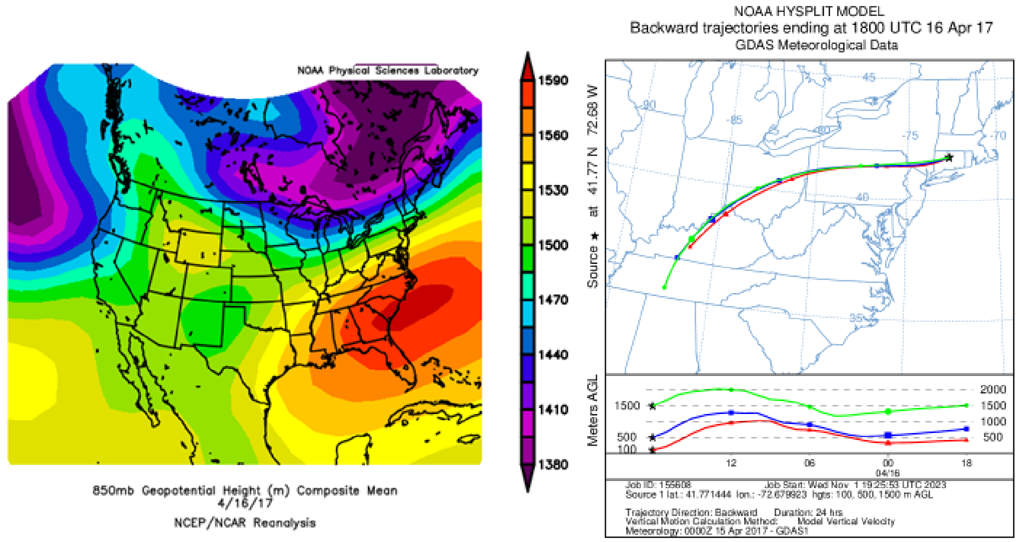
**Figure 10-7.** 850 mb reference pressure pattern with HYSPLIT reference trajectories and ozone observations from April 14, 2023. Maximum temperature at Bradley was 96°F.

Figure 10-8 and Figure 10-9 represent closely matching 850 mb examples for April 11 and 16, 2017 with the accompanying ozone AQI tables for those days. In each of these cases, the ozone levels were in the good (green) to moderate (yellow) range with no wildfire smoke influences and temperatures reaching 87 degrees Fahrenheit on April 11, 2017, and 88 degrees Fahrenheit on April 16, 2017.




| Ozone (ppb) | |
|---|---|
| | 4/11/2017 |
| Abington | 66 |
| Cornwall | 69 |
| Danbury | 63 |
| East Hartford | 64 |
| Greenwich | 48 |
| Groton | 51 |
| Madison | 55 |
| Middletown | 63 |
| New Haven | 51 |
| Stafford | 69 |
| Stratford | 50 |
| Westport | 52 |

**Figure 10-8.** Matching 850 mb pressure pattern with backward trajectories and ozone observations in Connecticut on April 11, 2017. Maximum temperature at Bradley was 87°F.

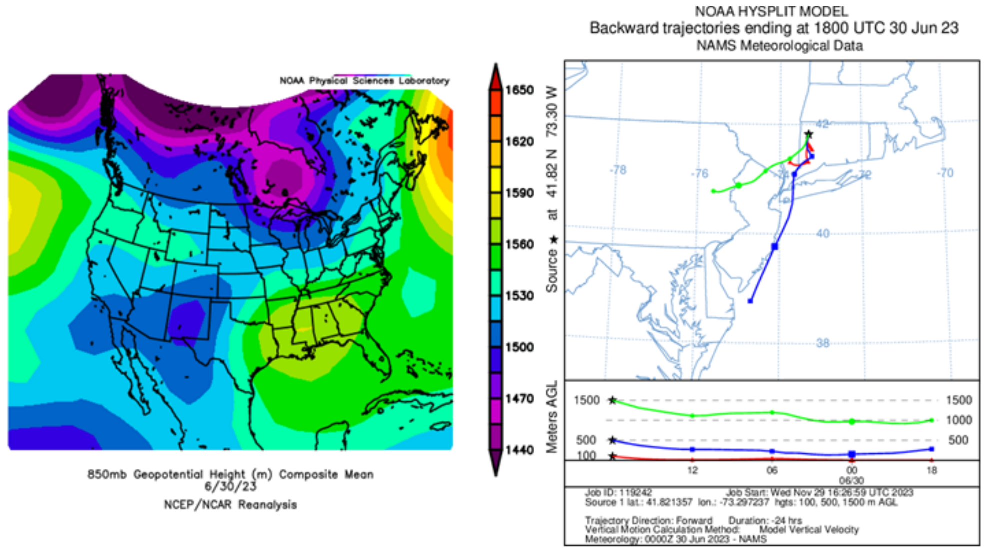



| Ozone (ppb) | |
|---|---|
| | 4/16/2017 |
| Abington | 57 |
| Cornwall | 55 |
| Danbury | 54 |
| East Hartford | 55 |
| Greenwich | 57 |
| Groton | 60 |
| Madison | 63 |
| Middletown | 59 |
| New Haven | 45 |
| Stafford | 56 |
| Stratford | 60 |
| Westport | 57 |

**Figure 10-9.** Matching 850 mb pressure pattern with backward trajectories and ozone observations in Connecticut on April 16, 2017. Maximum temperature at Bradley was 88°F.

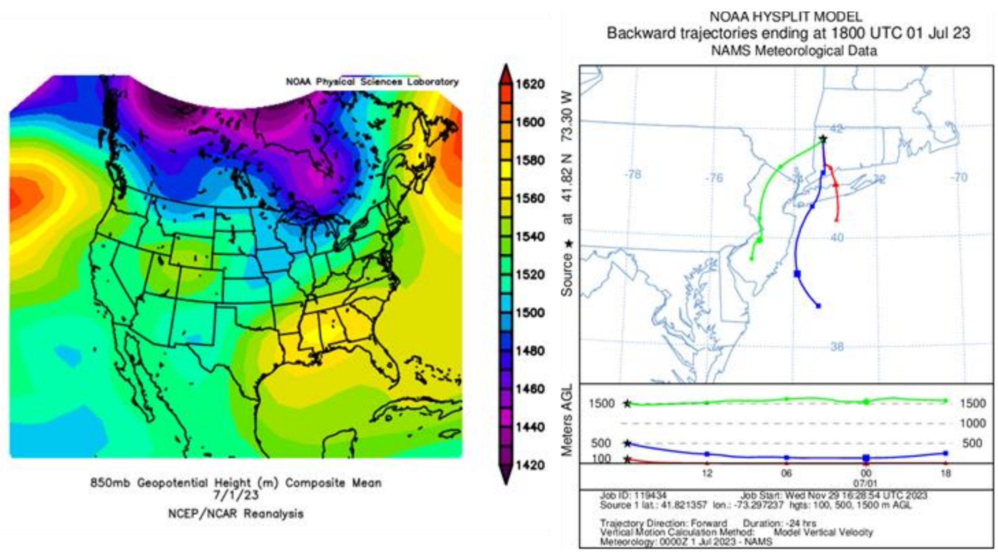
## 10.3 Similar Day Maps for the June 30 – July 1, 2023 Ozone Event

Figure 10-10 and Figure 10-11 show the 850 mb reference pressure patterns, HYSPLIT reference trajectories, and ozone observations for June 30 and July 1, respectively. The 850 mb height maps were generated for June 30th and July 1st to create a reference pattern for comparison. These figures show a low-pressure area near the Hudson Bay with high-pressure east of Nova Scotia. With this pattern, source winds to Connecticut would be expected to originate offshore along the New Jersey coastline. The HYSPLIT trajectories for these days show the 100 and 500 meter backward trajectories originating offshore along the New Jersey coastline. While the 1500 meter backward trajectories originate over inland New Jersey. On June 30, ozone levels exceed the standard along the Connecticut coast and western Connecticut inland areas. On July 1, every monitor in Connecticut exceeds the standard with one monitor site reaching unhealthy levels.




| Ozone (ppb) | |
|---|---|
| | 6/30/2023 |
| Abington | 57 |
| Cornwall | 78 |
| Danbury | 85 |
| East Hartford | 73 |
| Greenwich | 81 |
| Groton | 70 |
| Madison | 78 |
| Middletown | 69 |
| New Haven | 80 |
| Stafford | 68 |
| Stratford | 81 |
| Westport | 79 |

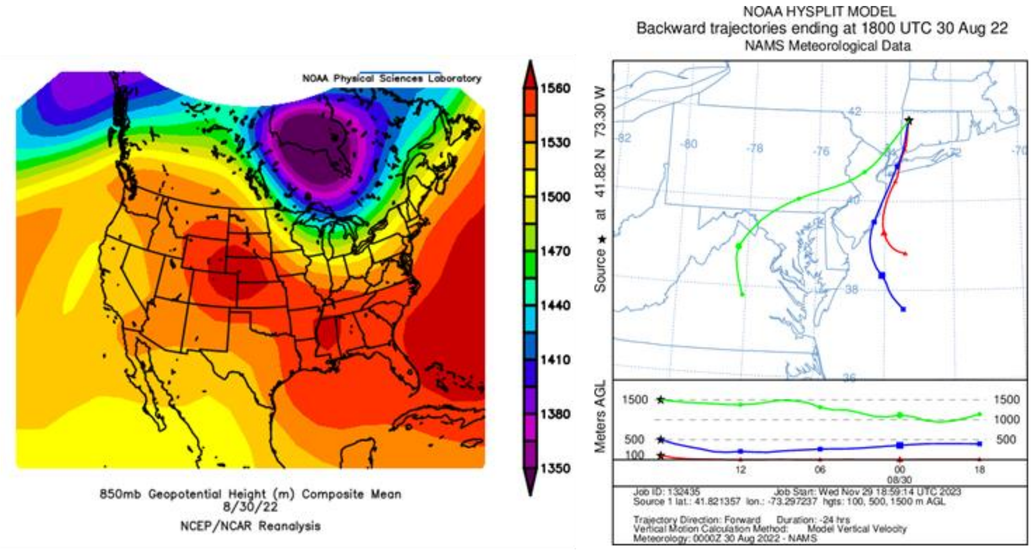
**Figure 10-10.** 850 mb reference pressure patterns with HYSPLIT reference trajectories and ozone observations from June 30, 2023. Maximum temperature at Bradley was 85°F.




| Ozone (ppb) | |
|---|---|
| | 7/1/2023 |
| Abington | 71 |
| Cornwall | 79 |
| Danbury | 83 |
| East Hartford | 82 |
| Greenwich | 82 |
| Groton | 76 |
| Madison | 77 |
| Middletown | 80 |
| New Haven | 72 |
| Stafford | 76 |
| Stratford | 86 |
| Westport | 82 |

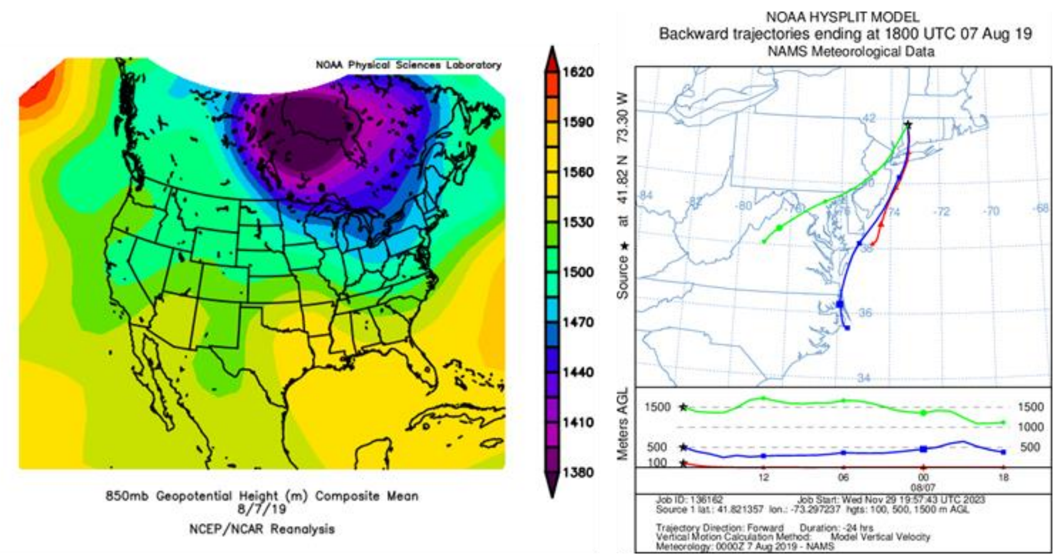
**Figure 10-11.** 850 mb reference pressure patterns with HYSPLIT reference trajectories and ozone observations from July 1, 2023. Maximum temperature at Bradley was 85°F.

Figure 10-12 through Figure 10-16 represent closely matching 850 mb examples from the previous few years with accompanying ozone AQI tables for those days. In every one of these cases, the ozone levels were in the good to moderate range with no wildfire smoke influences.



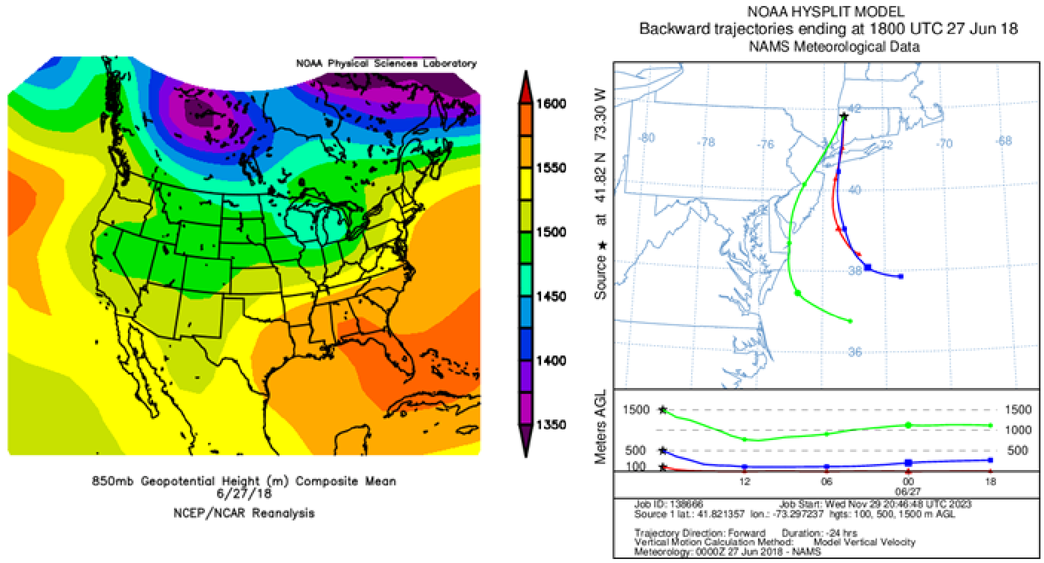

| Ozone (ppb) | |
|---|---|
| | 8/30/2022 |
| Abington | 37 |
| Cornwall | 55 |
| Danbury | 52 |
| East Hartford | 43 |
| Greenwich | 46 |
| Groton | 34 |
| Madison | 38 |
| Middletown | 42 |
| New Haven | 40 |
| Stafford | 44 |
| Stratford | 43 |
| Westport | 43 |

**Figure 10-12.** Matching 850 mb pressure patterns with backward trajectories and ozone observations in Connecticut on August 30, 2022. Maximum temperature at Bradley was 90°F.



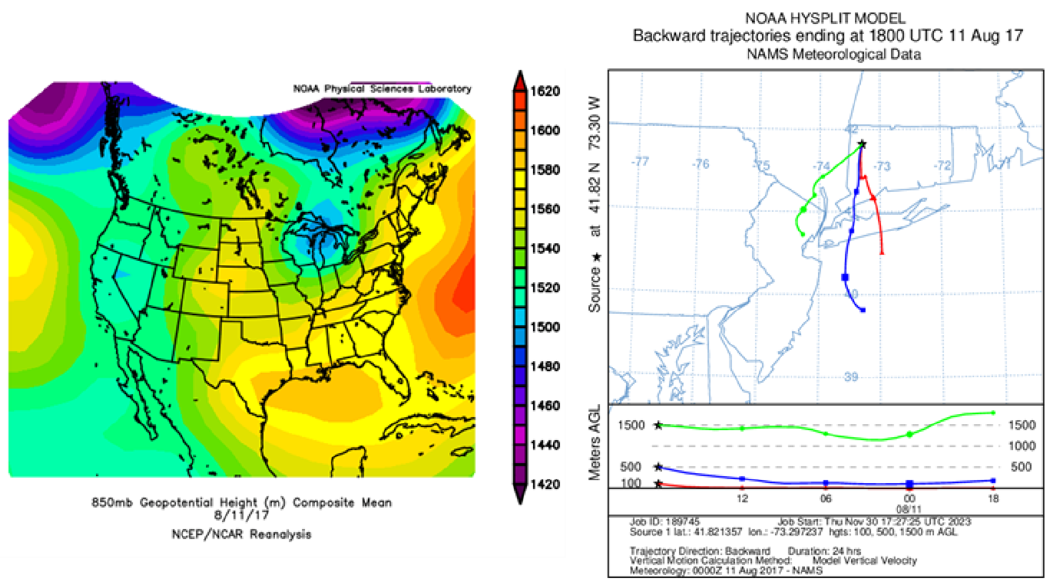

| Ozone (ppb) | |
|---|---|
| | 8/7/2019 |
| Abington | 47 |
| Cornwall | 48 |
| Danbury | 54 |
| East Hartford | 55 |
| Greenwich | 51 |
| Groton | 51 |
| Madison | M |
| Middletown | 53 |
| New Haven | 53 |
| Stafford | 53 |
| Stratford | 55 |
| Westport | 46 |

**Figure 10-13.** Matching 850 mb pressure patterns with backward trajectories and ozone observations in Connecticut on August 7, 2019. Maximum temperature at Bradley was 89°F.



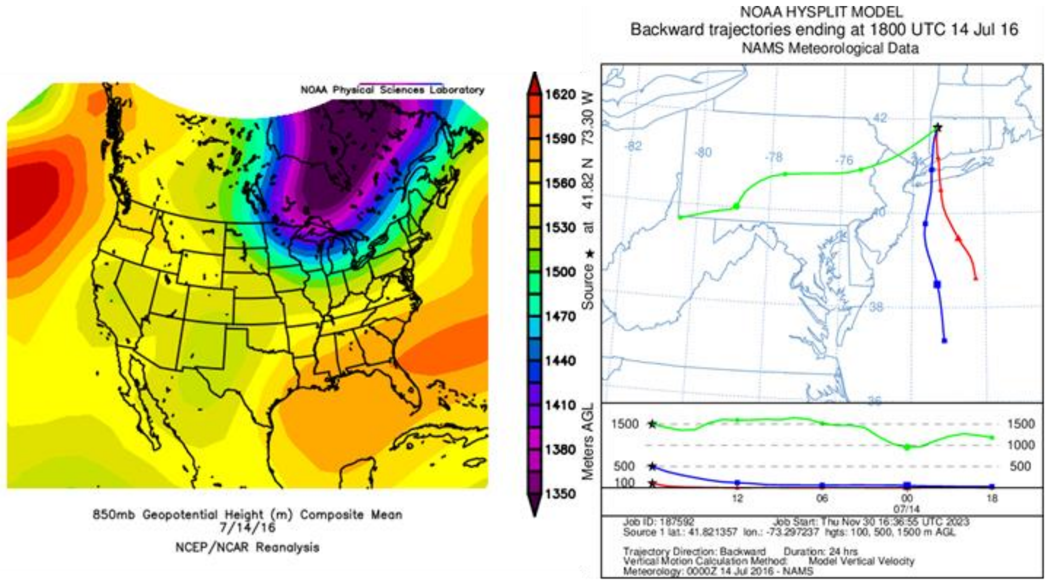

| Ozone (ppb) | |
|---|---|
| | 6/27/2018 |
| Abington | 40 |
| Cornwall | 40 |
| Danbury | 38 |
| East Hartford | 39 |
| Greenwich | 41 |
| Groton | 37 |
| Madison | 40 |
| Middletown | 41 |
| New Haven | 38 |
| Stafford | 40 |
| Stratford | 41 |
| Westport | 38 |

**Figure 10-14.** Matching 850 mb pressure patterns with backward trajectories and ozone observations in Connecticut on June 27, 2018. Maximum temperature at Bradley was 76°F.




| Ozone (ppb) | |
|---|---|
| | 8/11/2017 |
| Abington | 50 |
| Cornwall | 59 |
| Danbury | 66 |
| East Hartford | 55 |
| Greenwich | 55 |
| Groton | 47 |
| Madison | 50 |
| Middletown | 51 |
| New Haven | 49 |
| Stafford | 54 |
| Stratford | 56 |
| Westport | 56 |

**Figure 10-15.** Matching 850 mb pressure patterns with backward trajectories and ozone observations in Connecticut on August 11, 2017. Maximum temperature at Bradley was 83°F.

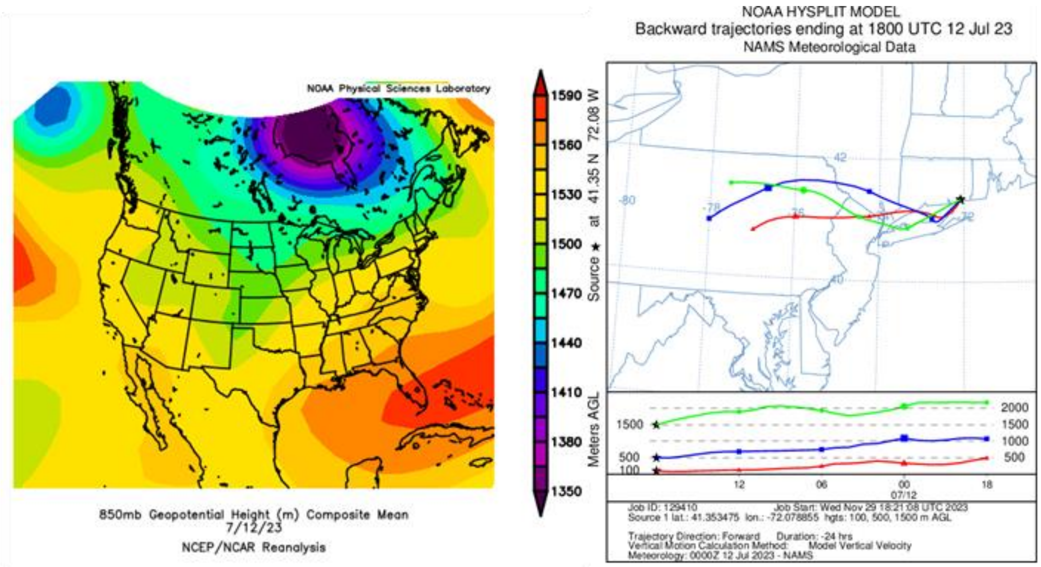



| Ozone (ppb) | |
|---|---|
| | 7/14/2016 |
| Abington | 40 |
| Cornwall | 55 |
| Danbury | 46 |
| East Hartford | 55 |
| Greenwich | 43 |
| Groton | 42 |
| Madison | 44 |
| Middletown | 48 |
| New Haven | 43 |
| Stafford | 43 |
| Stratford | 56 |
| Westport | 55 |

**Figure 10-16.** Matching 850 mb pressure patterns with backward trajectories and ozone observations in Connecticut on July 14, 2016. Maximum temperature at Bradley was 88°F.

## 10.4 Similar Day Maps for the July 12, 2023 Ozone Event

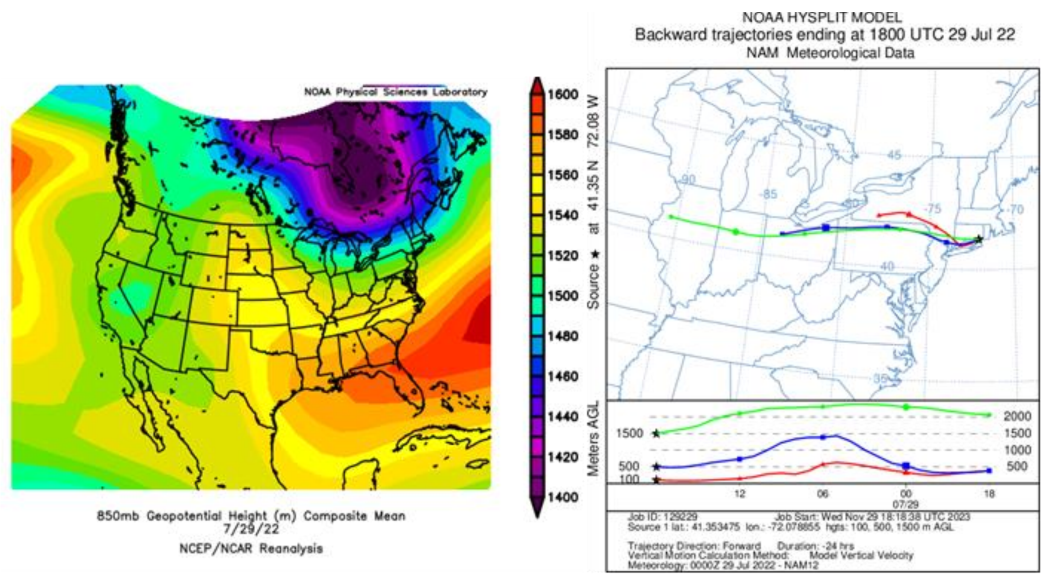
Figure 10-17 shows the 850 mb reference pressure pattern with reference backward trajectories and ozone observations from July 12. The 850 mb height map was generated for July 12th to create a reference pattern for comparison. The reference pattern shows a high-pressure system lying over the Gulf of Mexico and Florida into the southeastern United States with a low-pressure trough over Hudson Bay. With this pattern, source winds to Connecticut are expected to originate over western New York and northern Pennsylvania, which is generally air that is low in ozone precursors barring any wildfires in the region. The HYSPLIT trajectories for this day show the 100, 500 and 1500 meter back trajectories passing over northern Pennsylvania and north of New York City. On July 12, ozone levels exceed the standard at almost every coastal site and reached unhealthy levels at the southwest Connecticut coastal monitors with mid-to-high moderate ozone levels inland.




| Ozone (ppb) | |
|---|---|
| | 7/12/2023 |
| Abington | 53 |
| Cornwall | 57 |
| Danbury | 64 |
| East Hartford | 64 |
| Greenwich | 89 |
| Groton | 81 |
| Madison | 81 |
| Middletown | 70 |
| New Haven | 66 |
| Stafford | 61 |
| Stratford | 89 |
| Westport | 89 |

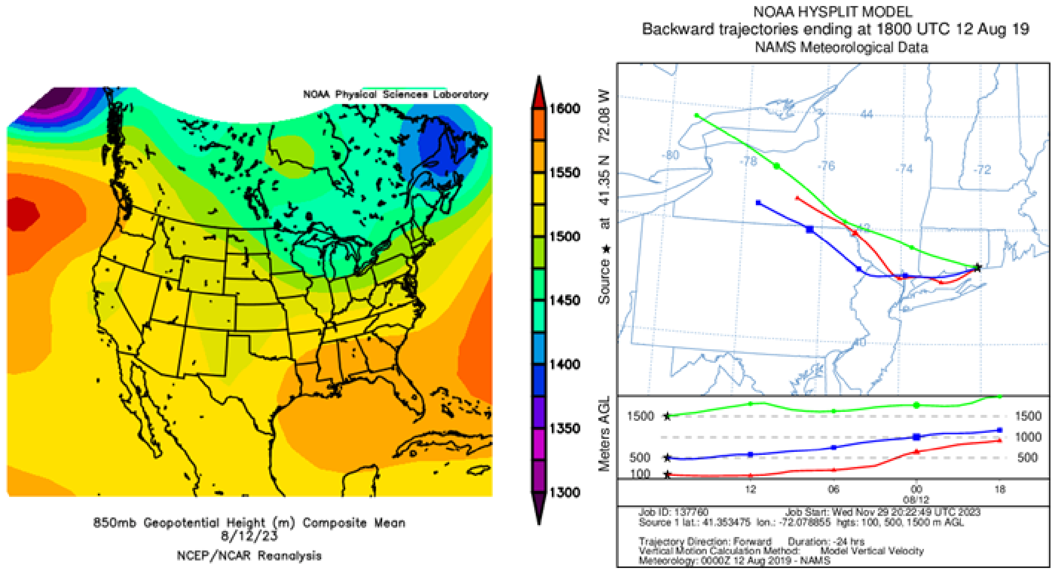
**Figure 10-17.** 850 mb reference pressure pattern with HYSPLIT reference trajectories and ozone observations from July 12, 2023. Maximum temperature at Bradley was 91°F.

Figure 10-18 through Figure 10-22 represent closely matching 850 mb examples from previous years with the accompanying ozone AQI tables for those days. In every one of these cases, the ozone levels were in the good to moderate range with no wildfire smoke influences.



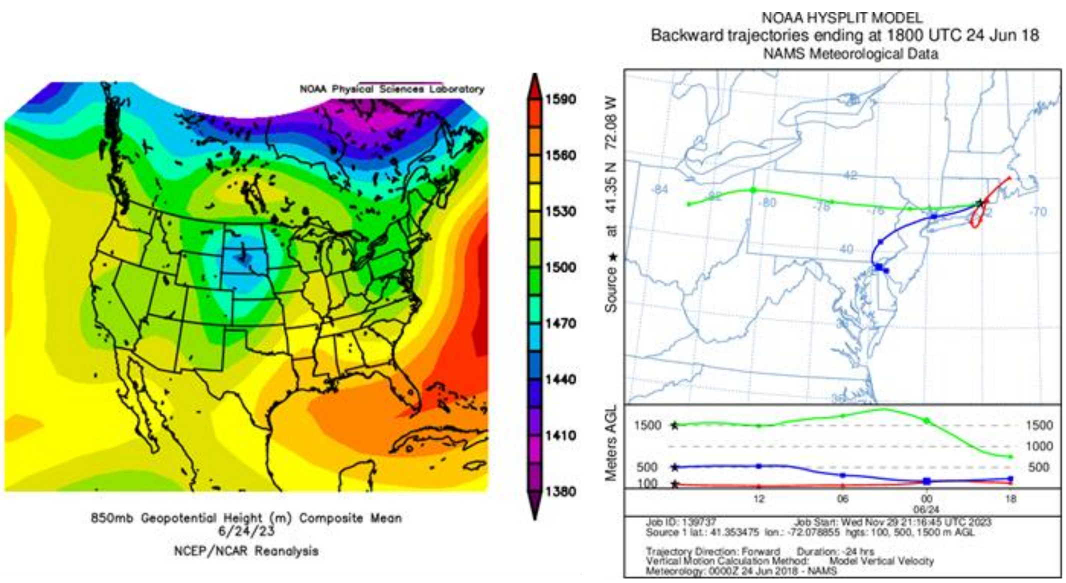

| Ozone (ppb) | |
|---|---|
| | 7/29/2022 |
| Abington | 60 |
| Cornwall | 52 |
| Danbury | 54 |
| East Hartford | 52 |
| Greenwich | 56 |
| Groton | 61 |
| Madison | 64 |
| Middletown | 64 |
| New Haven | 63 |
| Stafford | 49 |
| Stratford | 66 |
| Westport | 61 |

**Figure 10-18.** Matching 850 mb pressure patterns with back trajectories and ozone observations in Connecticut on July 29, 2022. Maximum temperature at Bradley was 91°F.



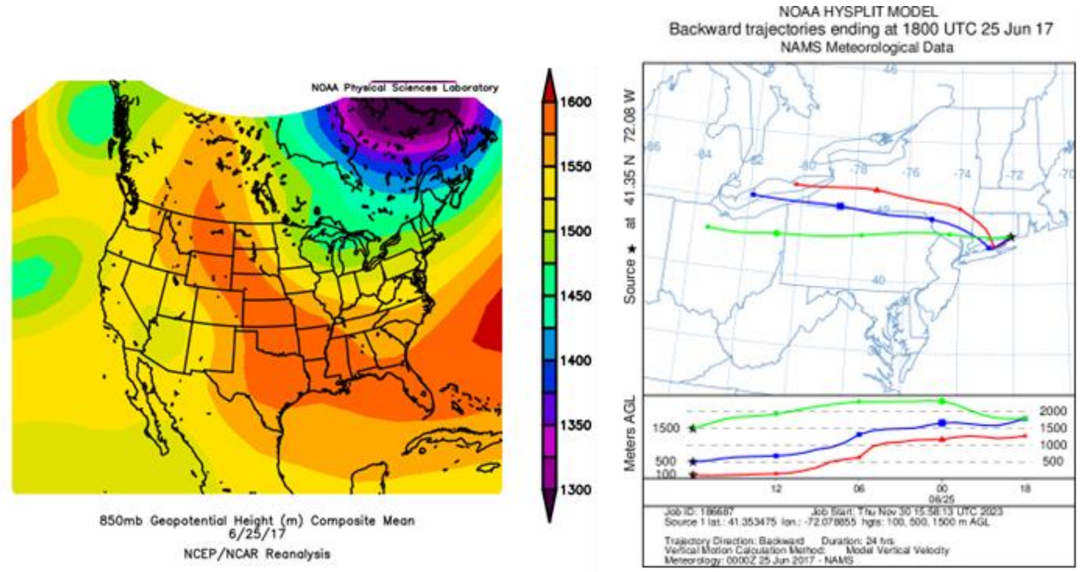

| Ozone (ppb) | |
|---|---|
| | 8/12/2019 |
| Abington | 51 |
| Cornwall | 54 |
| Danbury | 50 |
| East Hartford | 43 |
| Greenwich | 59 |
| Groton | 54 |
| Madison | 64 |
| Middletown | 51 |
| New Haven | 58 |
| Stafford | 46 |
| Stratford | 67 |
| Westport | 62 |

**Figure 10-19.** Matching 850 mb pressure patterns with back trajectories and ozone observations in Connecticut on August 12, 2019. Maximum temperature at Bradley was 87°F.



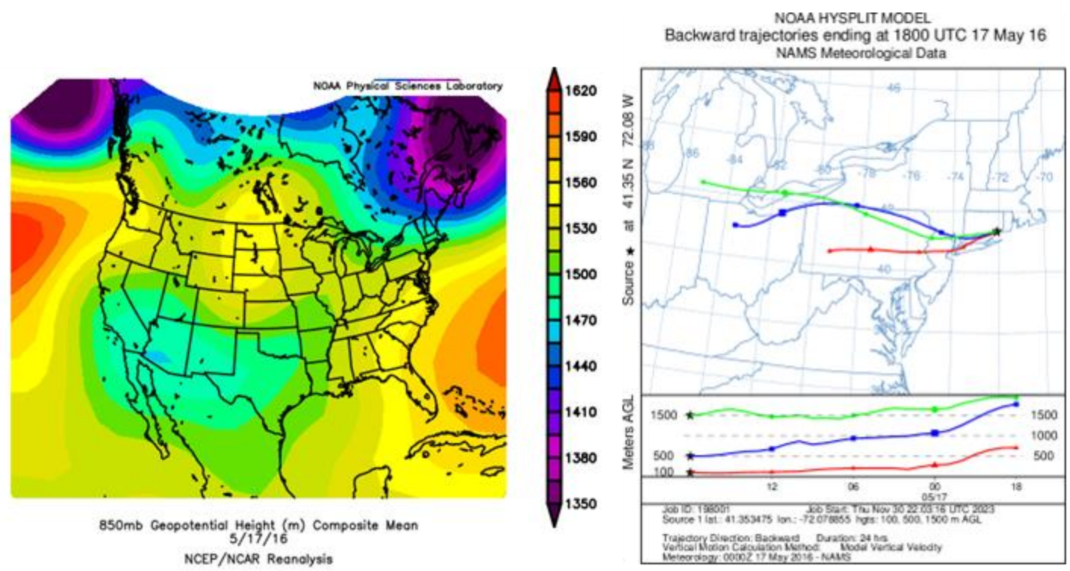

| Ozone (ppb) | |
|---|---|
| | 6/24/2018 |
| Abington | 37 |
| Cornwall | 38 |
| Danbury | 50 |
| East Hartford | 45 |
| Greenwich | 48 |
| Groton | 36 |
| Madison | 41 |
| Middletown | 44 |
| New Haven | 47 |
| Stafford | 39 |
| Stratford | 45 |
| Westport | 47 |

**Figure 10-20.** Matching 850 mb pressure patterns with back trajectories and ozone observations in Connecticut on June 24, 2018. Maximum temperature at Bradley was 79°F.




| Ozone (ppb) | |
|---|---|
| | 6/25/2017 |
| Abington | 46 |
| Cornwall | 44 |
| Danbury | 48 |
| East Hartford | 46 |
| Greenwich | 51 |
| Groton | 48 |
| Madison | 53 |
| Middletown | 58 |
| New Haven | 47 |
| Stafford | 49 |
| Stratford | 47 |
| Westport | 50 |

**Figure 10-21.** Matching 850 mb pressure patterns with back trajectories and ozone observations in Connecticut on June 25, 2017. Maximum temperature at Bradley was 84°F.




| Ozone (ppb) | |
|---|---|
| | 5/17/2016 |
| Abington | 47 |
| Cornwall | 51 |
| Danbury | 49 |
| East Hartford | 48 |
| Greenwich | 43 |
| Groton | 50 |
| Madison | M |
| Middletown | 44 |
| New Haven | 38 |
| Stafford | 47 |
| Stratford | 43 |
| Westport | 41 |

**Figure 10-22.** Matching 850 mb pressure patterns with back trajectories and ozone observations in Connecticut on May 17, 2016. Maximum temperature at Bradley was 71°F.

## 10.5 Summary

A comparison was made for each of the event days, April 13-14, June 30-July 1, and July 12, with multiple days having similar meteorology. Based on weather patterns, back trajectories, and smokeless skies for each of the similar day examples, exceedances would not typically occur in Connecticut without the presence of smoke.

# 11 Conclusion

During the summer of 2023, record breaking wildfires burned throughout Canada and inundated North America with unprecedented smoke plumes.  Similarly, hot dry conditions and weather patterns were such that wildfires in early April 2023 broke out in nearby states, and coupled with unusually intense prescribed burns in the Flint Hills, lead to exceptionally elevated pre-season ozone in Connecticut and the northeast region.

Using satellite imagery, local and regional monitoring and meteorological data, it was demonstrated that smoke reached the surface and clearly caused excess ozone production on April 13-14, June 30-July 1 and July 12.  Although wildfire smoke impacted most monitors in Connecticut on these days, only three monitors in Greater Connecticut are currently considered to have regulatory significance. These smoke events were determined to have regulatory significance for all these days at Groton and for at least July 1 at the East Hartford and Cornwall monitors.

Furthermore, meteorological conditions and trajectory analyses during the events were not consistent with historically high concentrations, as the similar day analyses for each of the events has shown.  Due to emission reductions over the past decades, ozone exceedances are now mostly monitored at the southwest Connecticut coastal sites, even with warm summertime temperatures.  These events were exceptional for both the exceedance levels and for the locations where they were monitored.  This demonstration supports DEEP's position that the prescribed and wildfire events affected air quality in such a way that there exists a clear causal relationship between the specific events and the monitored ozone levels which lead to a nonattainment ozone design value for Greater Connecticut in 2023.  Exclusion of the of data for the event dates at the three monitors will result in attainment of the standard by the attainment date and is consistent with the trends and model predicted ozone levels for the area.

## 11.1 Caused by a Natural Event / Unlikely to Recur

Based on the documentation provided in Section 4 of this submittal, the events qualify as a wildfire, because all events included unplanned wildfires.  The EPA generally considers the emissions of ozone precursors from wildfires on wildland to meet the regulatory definition of a natural event at 40 CFR 50.1(k), defined as one 'in which human activity plays little or no direct causal role.'  These wildfire events occurred on wildland in the US and Canada as documented in the introduction and descriptions, and accordingly, DEEP has shown that the events are natural and may be considered for treatment as exceptional events.

To the extent this demonstration relies on the Flint Hills prescribed burns, DEEP quotes from a Kansas Department of Health and Environment exceptional events demonstration:

> *"Research shows that historically, the natural fluctuation of fire (i.e. the natural fire return interval) of a tall grass ecosystem averaged every 2- 5 years. Data show that on average,*

*prescribed fire is applied to approximately 1/3 of the tall grass prairie every year. While some lands within this vast ecosystem may burn almost every year others may burn every 5 years or less, depending on a number of uncontrollable variables such as precipitation, temperature and flora growth. However, one can use these average numbers to make two general interpretations, (1) prescribed fire is used roughly once every 3 years in the Flint Hills and (2) this fire frequency mimics the natural fire return interval for this ecosystem dating back hundreds of years. In fact, through research and practice, it has been proven that lower frequencies of burning will lead to a loss of the ecosystem in only a matter of a few burn cycles.*

*This evaluation demonstrates that the likelihood of prescribed fire recurrence is within the range of the natural fire return interval established historically for the tall grass prairie ecosystem and thus meets the ''unlikely to recur at a particular location'' requirement of the statutory language."*

## 11.2 Not Reasonably Controllable or Preventable

Based on the documentation provided in the introduction and Section 4 of this submittal, the wildfires were naturally caused and/or caused by human activity. DEEP is not aware of any evidence clearly demonstrating that prevention or control efforts beyond those actually made would have been reasonable. Therefore, emissions from these fires were not reasonably controllable or preventable.