EXCEPTIONAL EVENTS UPDATES
Case Study: Wildfire Ozone Event for 2016 Ft. McMurray Wildfire

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Emissions Inventory Conference – Baltimore, MD
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Overview

- Exceptional Event Regulations & Guidance
- Background on Ft. McMurray Wildfire
- Case Study of a Wildfire Ozone Demonstration*
  - Conceptual Model
  - Clear Causal Relationship
- Examples of Evidence and Analysis
  - Tier 1
  - Tier 2
  - Tier 3

EPA

Guidance on the Preparation of Exceptional Events Demonstrations for Wildfire Events that May Influence Ozone Concentrations

Final

September 2016

U.S. Environmental Protection Agency
Office of Air Quality Planning and Standards
Air Quality Policy Division
Geographic Strategies Group
Research Triangle Park, North Carolina

*Acknowledgement: All graphics and illustrations were provided by Connecticut Department of Energy and Environmental Protection.

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Regulatory Background

- Exceptional Events Rule addresses CAA Section 319(b), which allows for the exclusion of air quality monitoring data influenced by exceptional events from use in regulatory decisions regarding the National Ambient Air Quality Standards (NAAQS).

- Exceptional Event Demonstrations must include 6 elements:
  1. Narrative conceptual model of how the event emissions affected monitors;
  2. Clear causal relationship between the event and exceedance at monitors;
  3. Analysis comparing event-influenced concentrations to non-event data;
  4. Event is not reasonably controllable and preventable;
  5. Event caused by human activity unlikely to recur or natural event; and
  6. Opportunity for public comment.

Ozone Wildfire Guidance

- September 16, 2016: Guidance on the Preparation of Exceptional Events Demonstrations for Wildfire Events that May Influence Ozone Concentrations
- Guidance outlines tiered approach to apply clear causal relationship
  - Tier 1: Events that clearly influence concentrations
    - Key Factor: Seasonality and/or distinctive level of the monitored concentration
  - Tier 2: Do not meet criteria for Tier 1, more analysis required
    - Key Factor 1: Fire emissions and distance of fires to monitoring site (Q/D analysis)
    - Key Factor 2: Comparison of event-related O_3 with non-event high O_3
  - Tier 3: Most complex, multiple analysis needed to support weight of evidence
    - In addition to Tier 1 and Tier 2 key factors, provide additional evidence to show fire emissions were transported to monitor and caused O_3 exceedance

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Exceptional Event - 2016 Ft. McMurray Wildfire

- Wildfire began May 1, 2016 in Ft. McMurray area of Alberta, Canada
- Fire spread across 1.5 million acres before declared under control on July 5, 2016
- Fire destroyed approximately 2,400 homes and was the costliest disaster in Canadian history
- Smoke was eventually transported to New England and eastern United States
- Multiple air agencies have submitted exceptional event demonstrations
- Increased coordination across relevant state agencies and EPA offices

Photo of the Fort McMurray Wildfire Plume on May 8, 2016

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Case Study: Connecticut Exceptional Event Demonstration

- Initial notification of potential exceptional event received September 28, 2016
- Frequent EPA collaboration with Connecticut Department of Energy & Environmental Protection (CT DEEP) on the development of the demonstration
- Public Comment Period April 18 to May 19, 2017
- Final demonstration submitted May 23, 2017
- Requested exclusion of ozone data at 4 monitoring locations:
  - Abington
  - Cornwall
  - East Hartford
  - Westport
- EPA concurrence on July 31, 2017.

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Conceptual Model

- Summary of fire
  - Map and description of the wildfire
  - Media coverage and news reports
- Description of the geographic area
  - Map of relevant monitors
- Typical non-event O_3 formation and meteorology
  - General atmospheric circulation characteristics and transport
  - Differences between event and non-event conditions
- Wildfire emissions and associated O_3 production
- Event specific O_3 concentrations & regulatory significance

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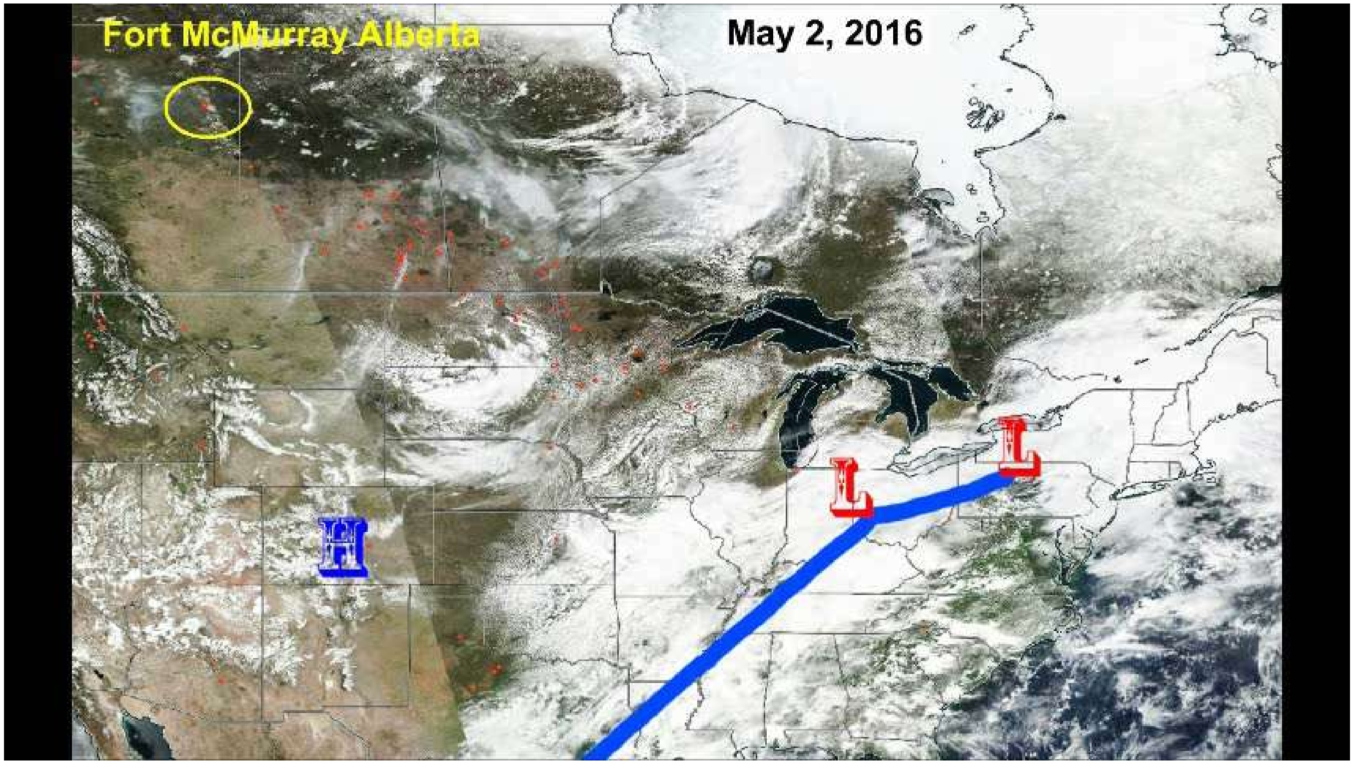
Conceptual Model: Map and Description of Wildfire



Satellite Time Lapse of Ft. McMurray Wildfire

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Conceptual Model: Media Reports

- "Fort McMurray wildfire ash reaches all the way to Spain"
  - By Wallis Snowdon, CBC News, May 25, 2016
- "Wildfires in western Canada send haze to New England"
  - WMTW News 8, Portland Maine, May 12, 2016
- "Alberta battles The Beast, a fire that creates its own weather and causes green trees to explode",
  - By David Staples, Edmonton Journal, May 7, 2016

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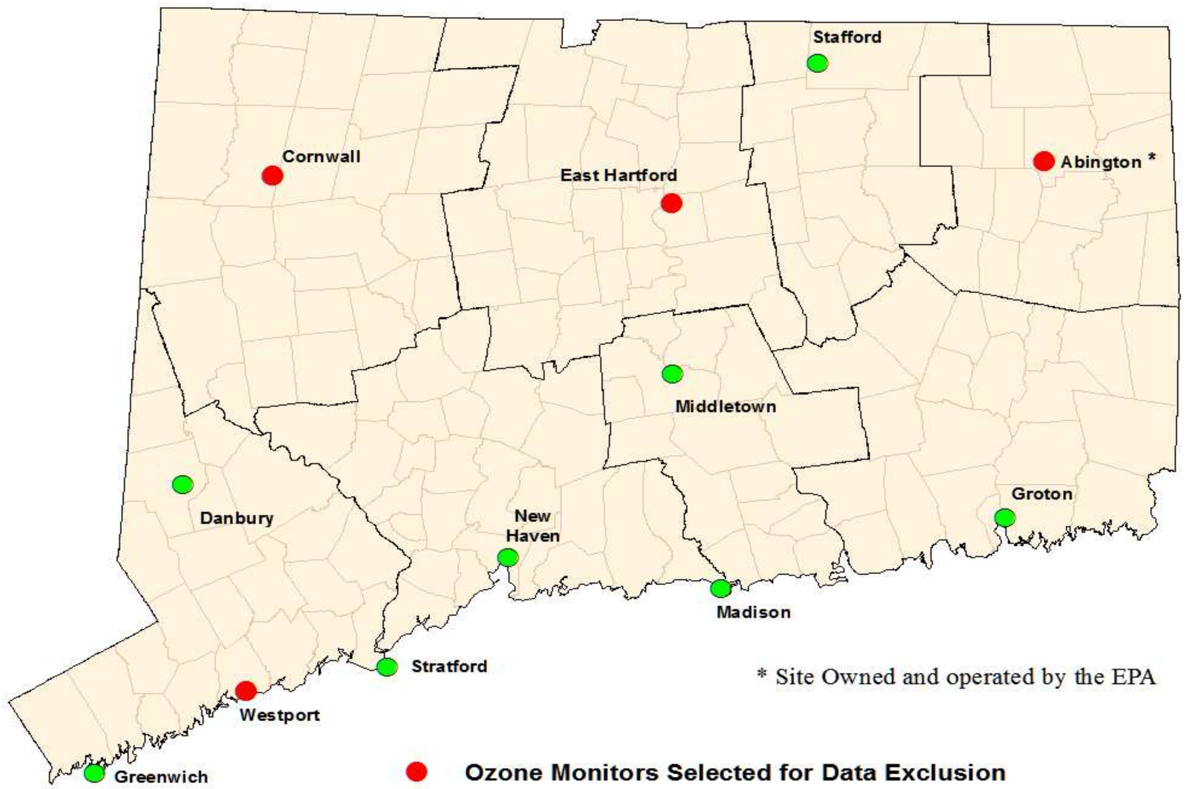
Conceptual Model: CT Monitoring Sites



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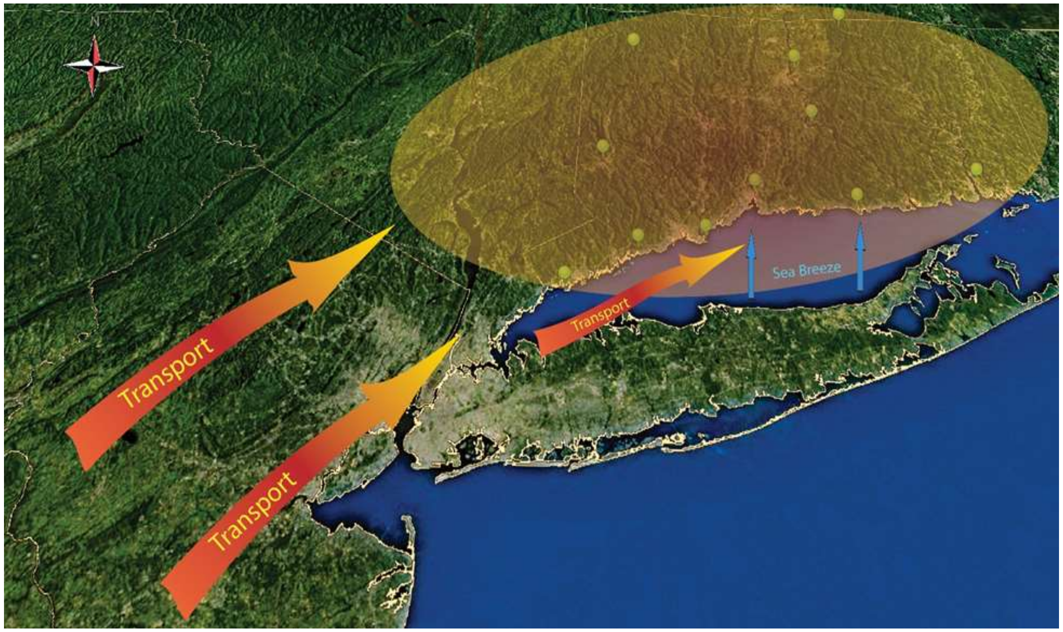
Conceptual Model: Typical State-Wide Ozone Scenario

- Ozone exceedances classified into four categories based on spatial patterns of measured ozone and the contributing meteorological conditions:
  - Inland-only
  - Coastal-only
  - Western Boundary-only
  - State-wide
- State-Wide: Transport from emission-rich upwind areas, serving to transport ozone precursors and previously formed ozone into Connecticut



State-wide Ozone Exceedance Scenario

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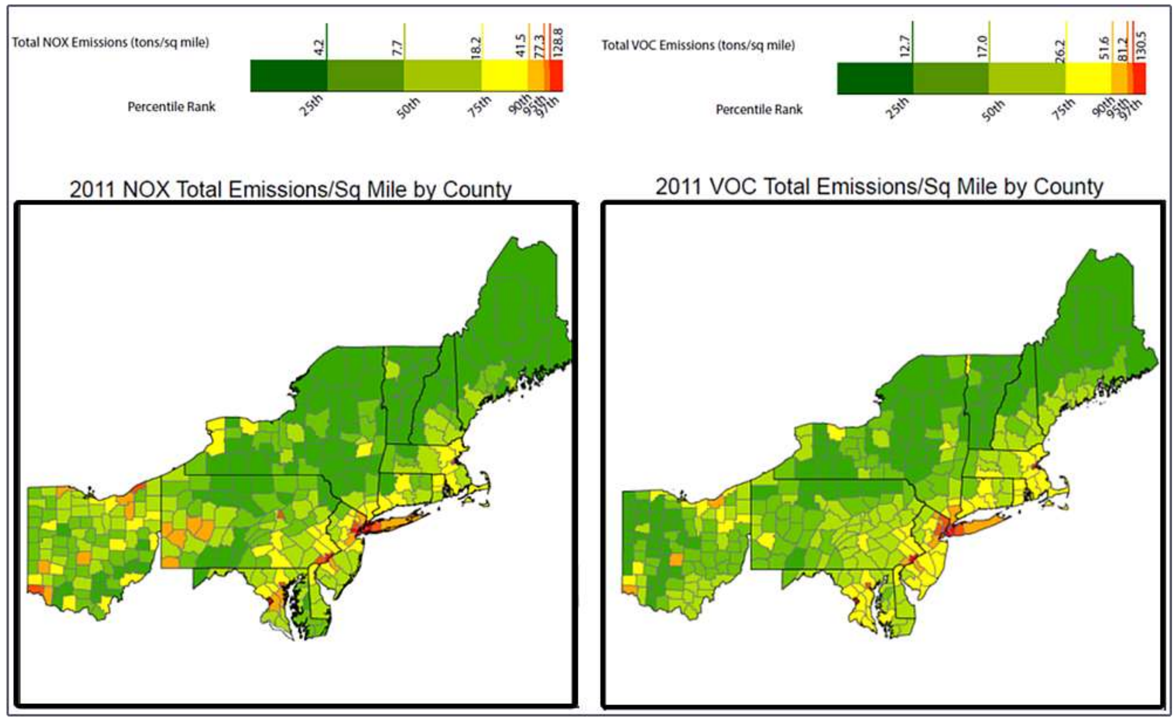
Conceptual Model: Regional Emissions Data

- NEI data shows emission rich areas southwest of CT
- Southwest wind flows correspond with state-wide exceedance scenario in CT
- Wind direction during event was from northwest



2011 NEI County Percentile Map of Total NOx Emissions per square mile and Total VOC Emissions per square mile

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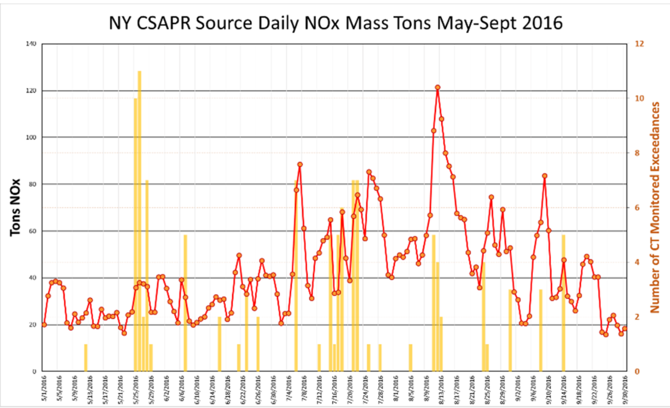
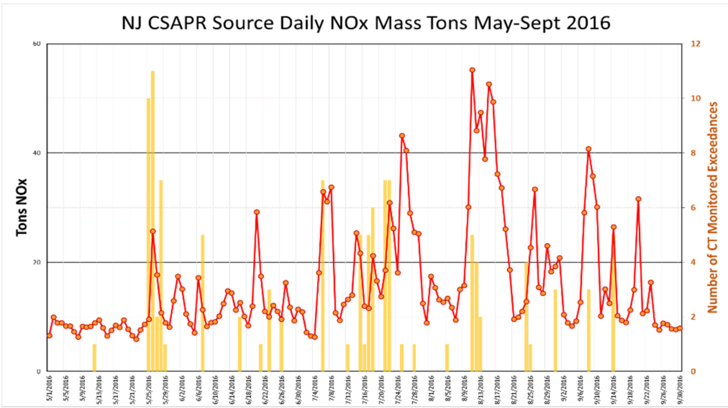
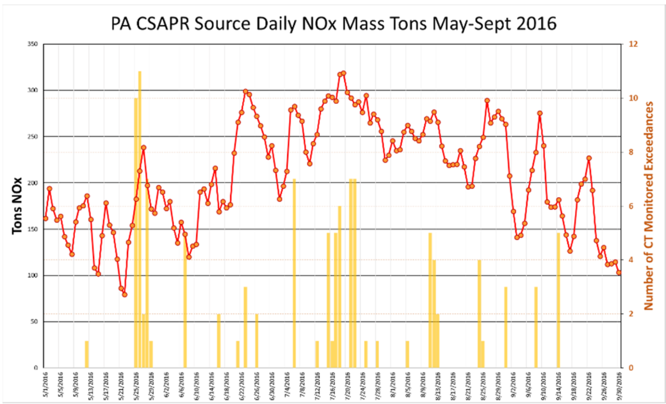
Conceptual Model: Regional Emissions Data







- Electric generating unit emissions contribute to ozone events on the East Coast
- May 25-26th ozone event had the most monitored daily exceedances of the summer, while peak NO_X emissions from these facilities did not occur until later in the season

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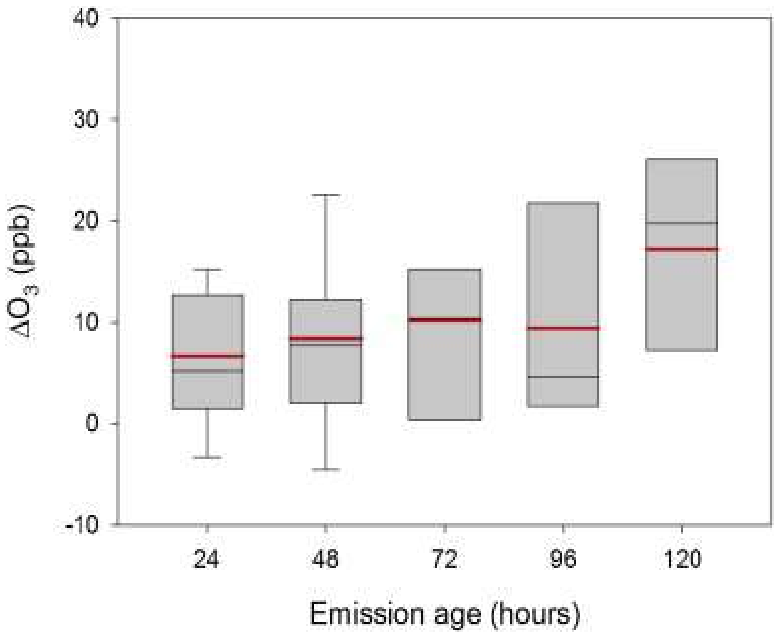
Conceptual Model: Biomass Burning and Ozone Production

- 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 O_3, and can travel thousands of kilometers.
- Many variables, such as type of fuel or forest burned, plume path and distance burned, affect the intensity of the fire and ability of a plume to enhance downwind O_3 production.
- Studies show O_3 enhancement increases as the plume ages.



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.

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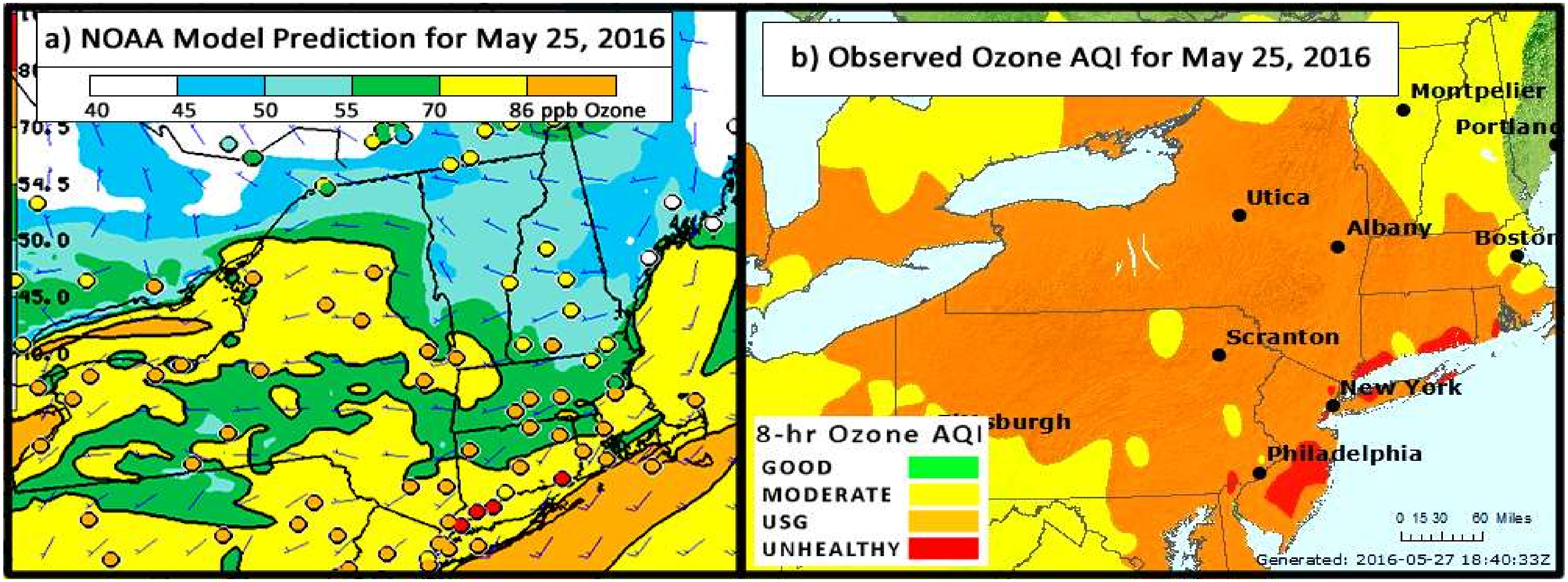
Conceptual Model: Forecasted vs. Observed Ozone



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Conceptual Model: Event Specific Concentrations

	Values With May 25-26, 2016 (ppb)						Values Without May 25 - 26, 2016 (ppb)		
Site Name	4th High 2014	4th High 2015	4th High 2016	**2014-2016 DV**	2017 Critical Value (NAAQS Standard)		4th High 2016	**2014-2016 DV**	2017 Critical Value (NAAQS Standard)
Abington	67	70	74	**70**	69 (70)		67	**68**	76 (70)
Cornwall	68	76	78	**74**	74 (75)		74	**72**	78 (75)
East Hartford	77	75	75	**75**	78 (75)		72	**74**	81 (75)
Westport	81	87	87	**85**	81 (84)		81	**83**	87 (84)

- Once the data for the Westport monitor is excluded, R1 can proceed with a proposed clean data determination for the NY-NJ-CT nonattainment area meeting the 1997 ozone NAAQS (84 ppb)

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Clear Causal Relationship: Tier 1

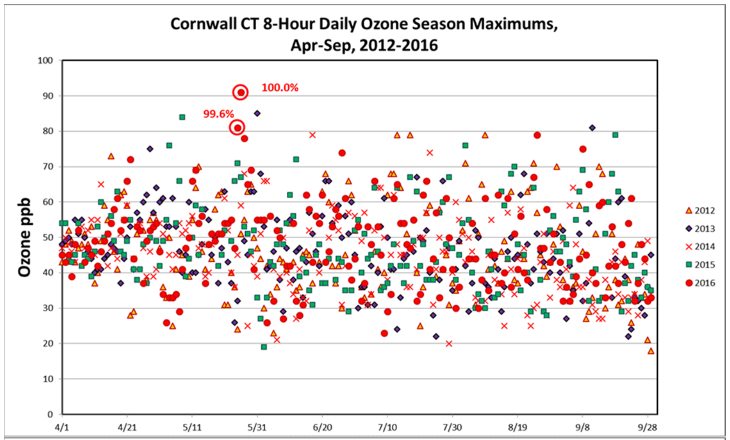
Wildfire events that clearly influence O_3 exceedances or violations in areas that typically experiences lower O_3 concentrations. This tier is associated with an O_3 concentration that is clearly higher than non-event related concentrations, or occur outside of the area's normal O_3 season.

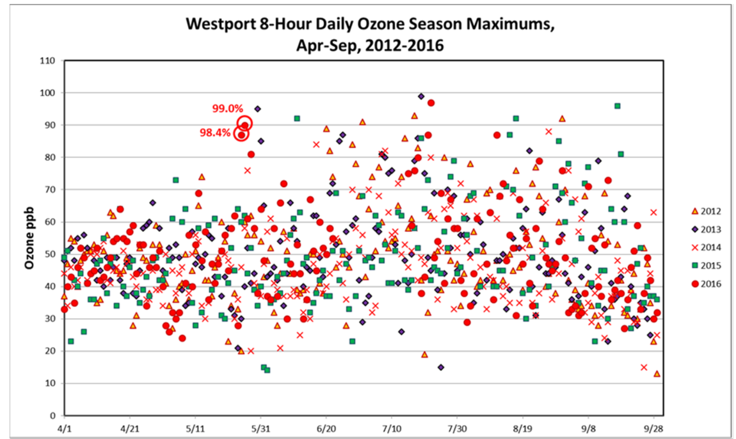
Key Factor

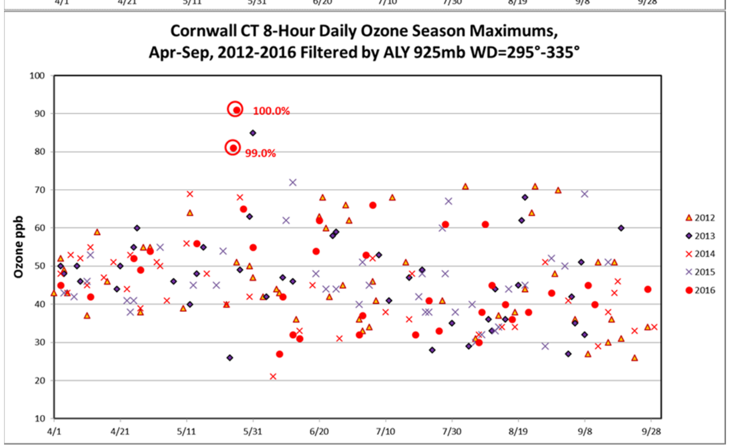
Seasonality or distinctive level of the monitored O_3 exceedance

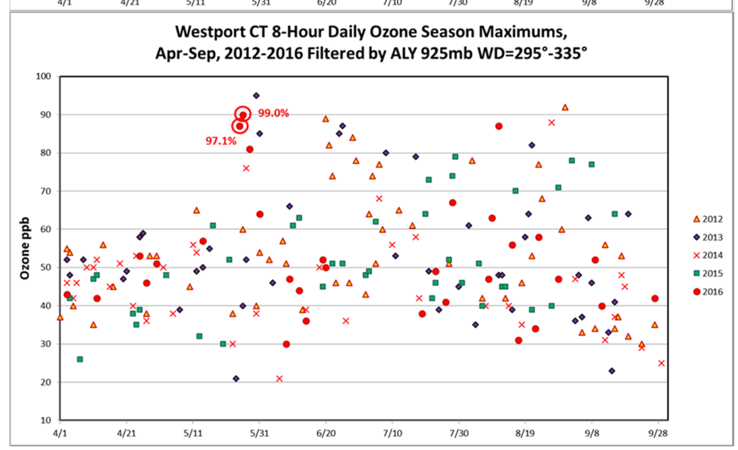
- *Outside normal O_3 season*
- *5-10 ppb higher than non-event related concentrations*

Clear Causal Relationship: Tier 1









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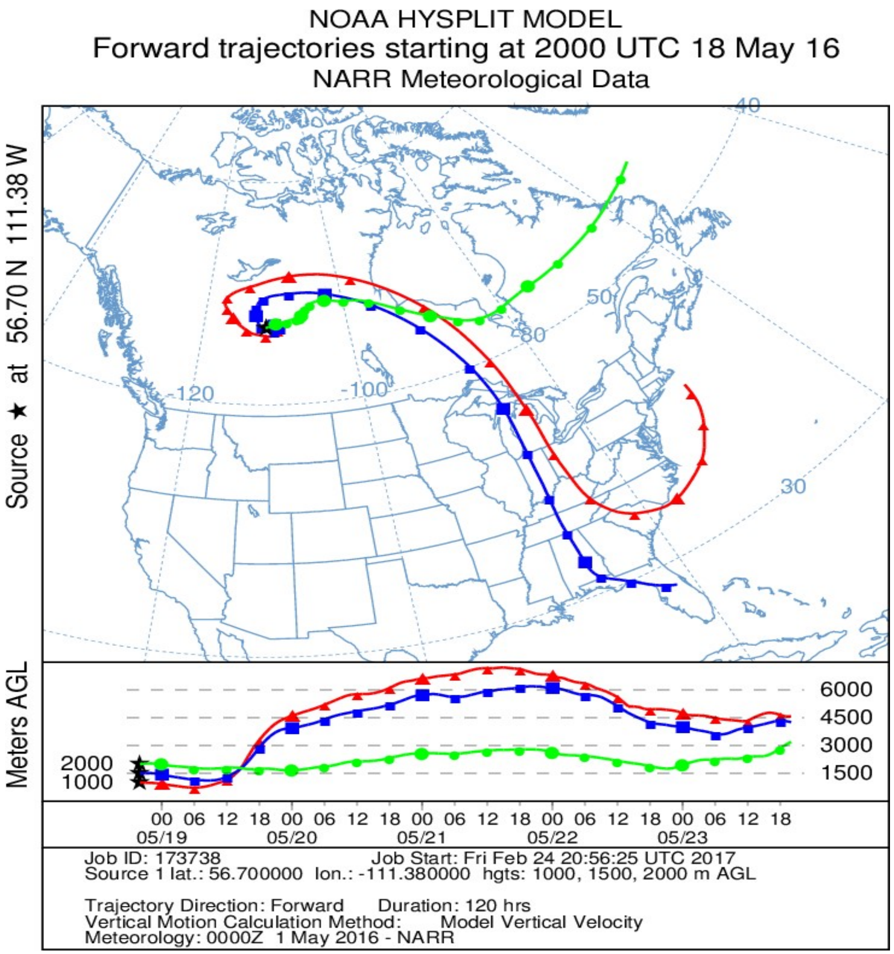
Clear Causal Relationship: Tier 1



Evidence that the wildfire emissions were transported to the monitor.

Potential analyses include:

- Trajectory analysis
- Satellite imagery with evidence of the plume impacting the ground

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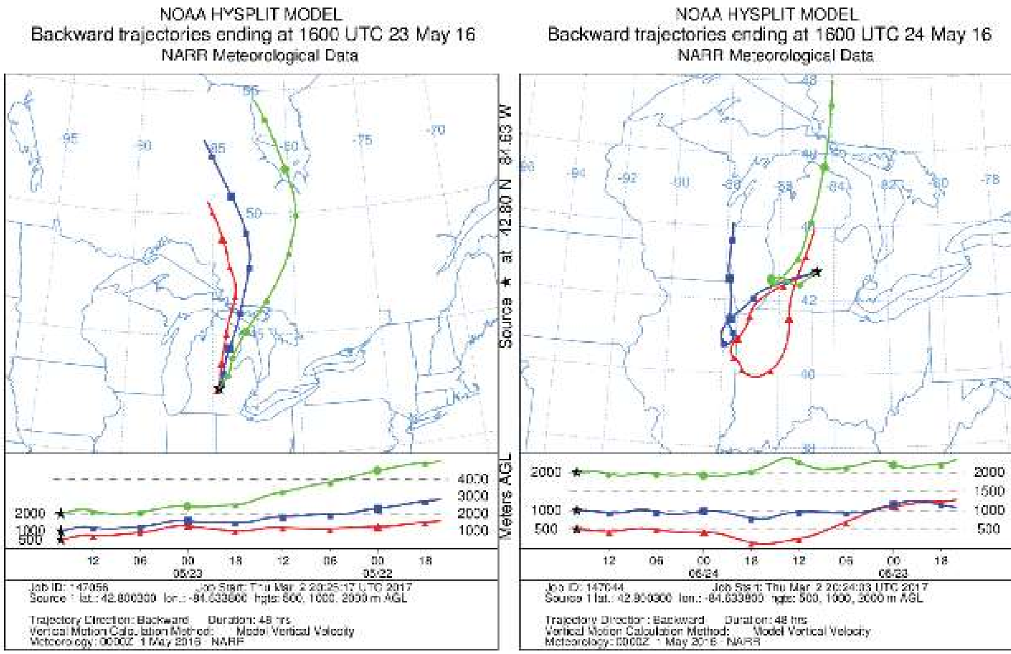
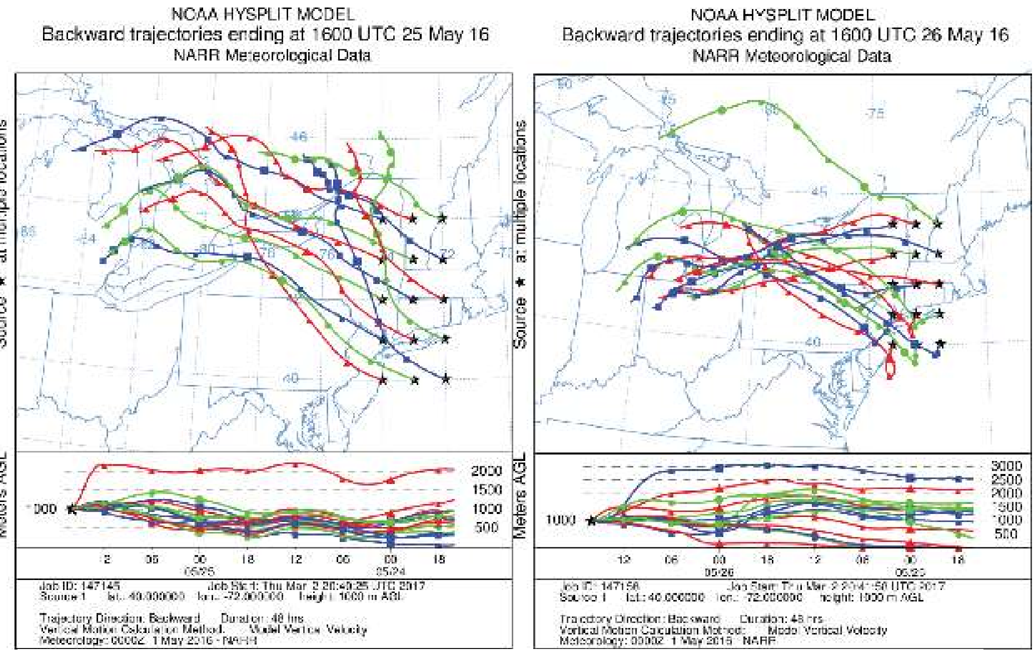
Trajectory Analysis



HYSPLIT Back Trajectories from Michigan, May 23-24, 2016



HYSPLIT Back Trajectories from New England, May 25-26, 2016

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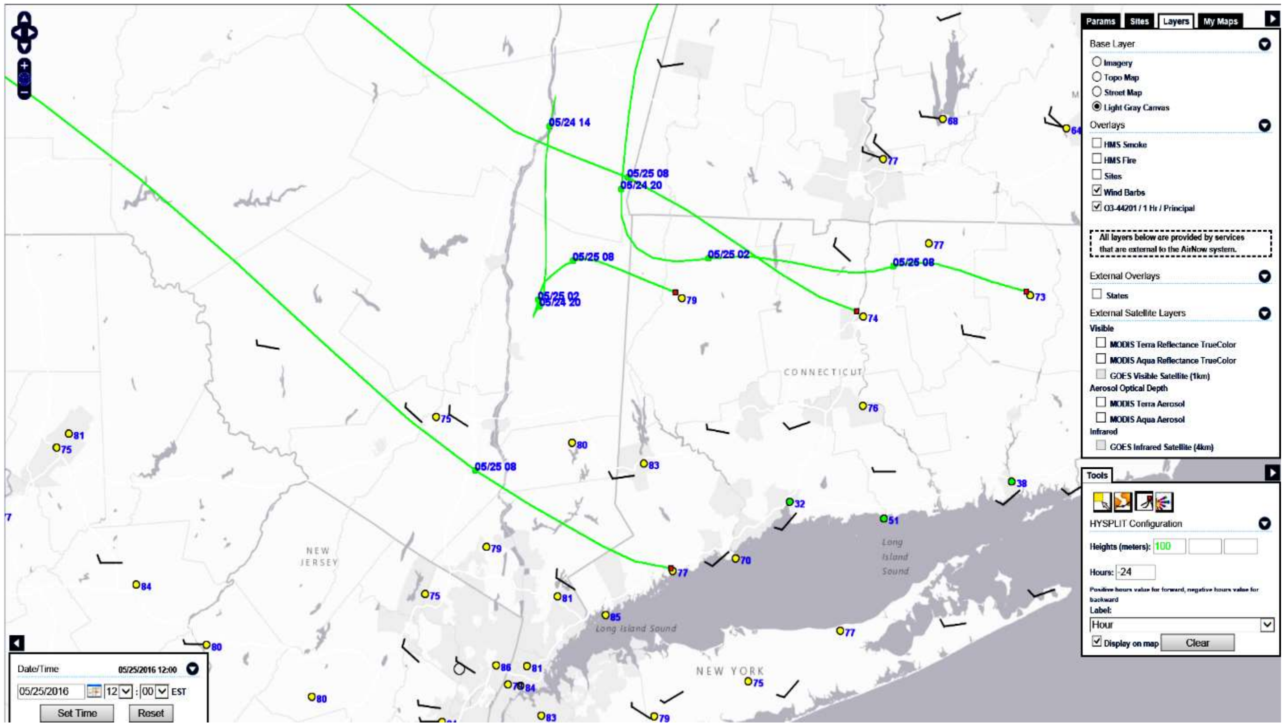
Trajectory Analysis



May 25th 24-hour Back Trajectories ending at 12:00 EST.

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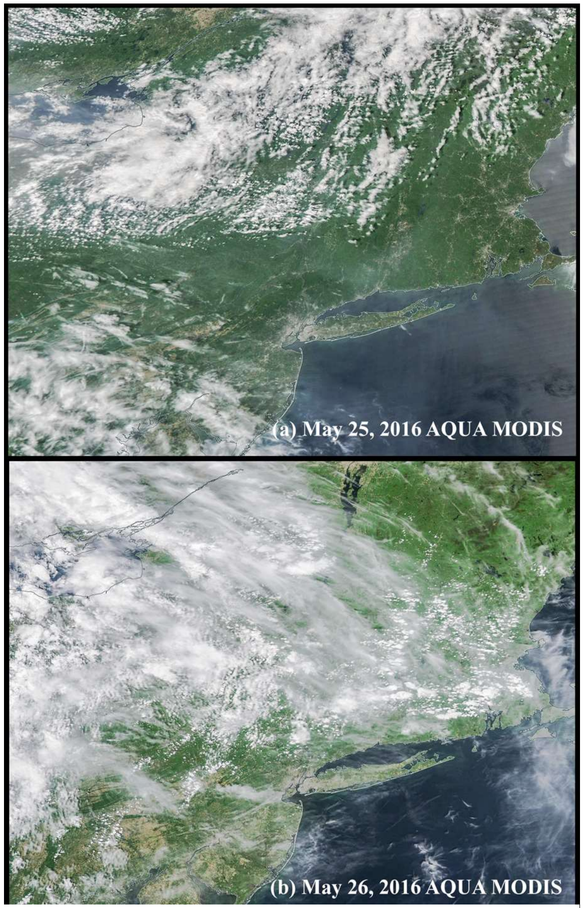
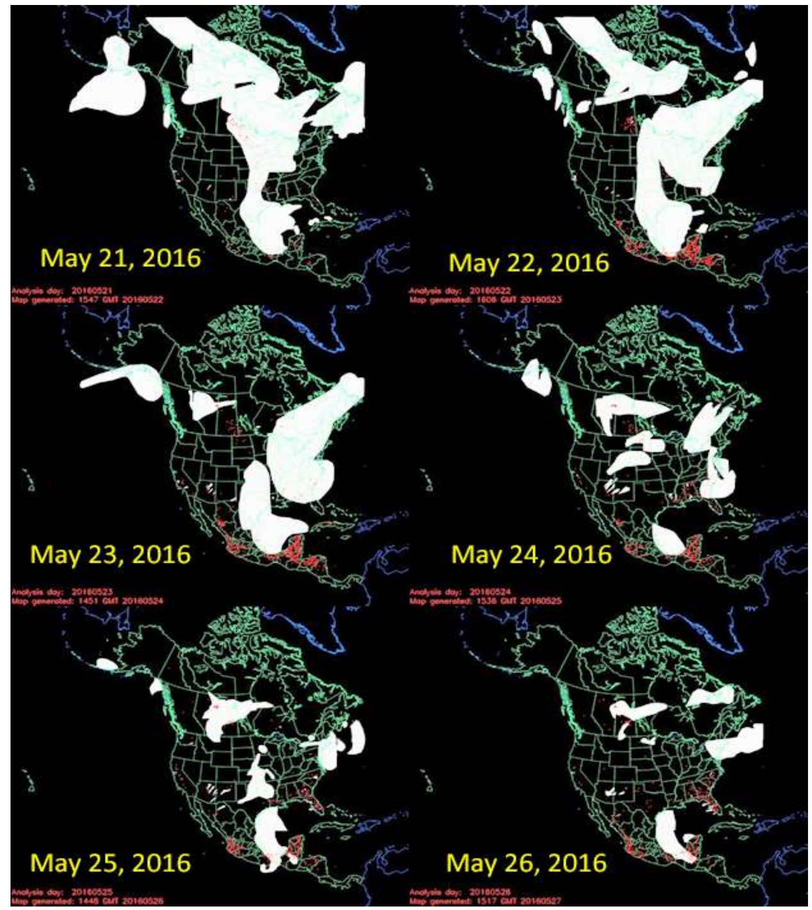
Satellite Imagery & Smoke Movement



Visible Satellite Photograph over Connecticut. (a) May 25th and (b) May 26th, 2016, showing visible smoke plume.



HMS Smoke Analysis from May 21-26th, 2016.

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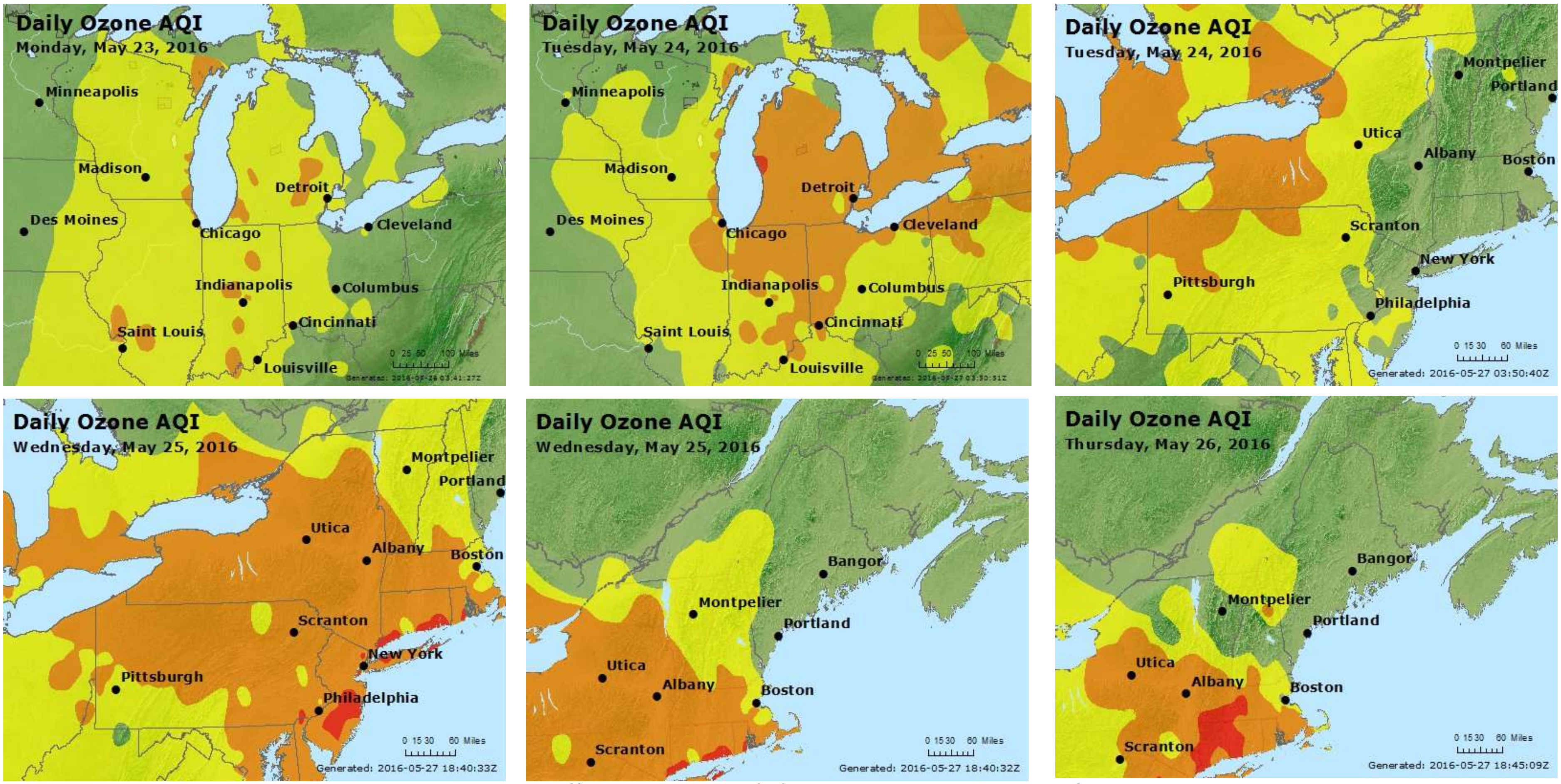
Ozone Movement Across Northern United States, May 23-26, 2016



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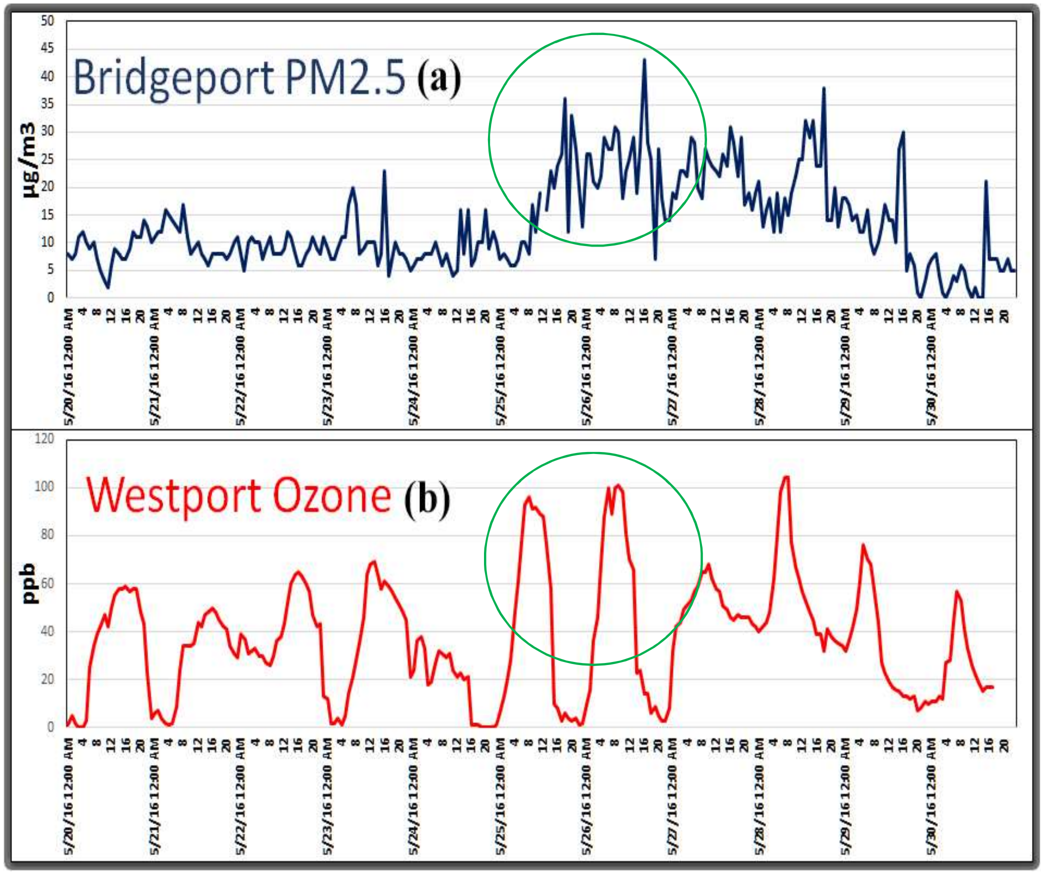
Evidence of Plume Impacting the Ground



- May 20-30, 2016 plots of (a) Bridgeport CT PM2.5 and (b) Westport Ozone Hourly Concentrations
- Ozone peaks at Westport on May 25-26 coincide with the PM2.5 peaks at the Bridgeport monitor

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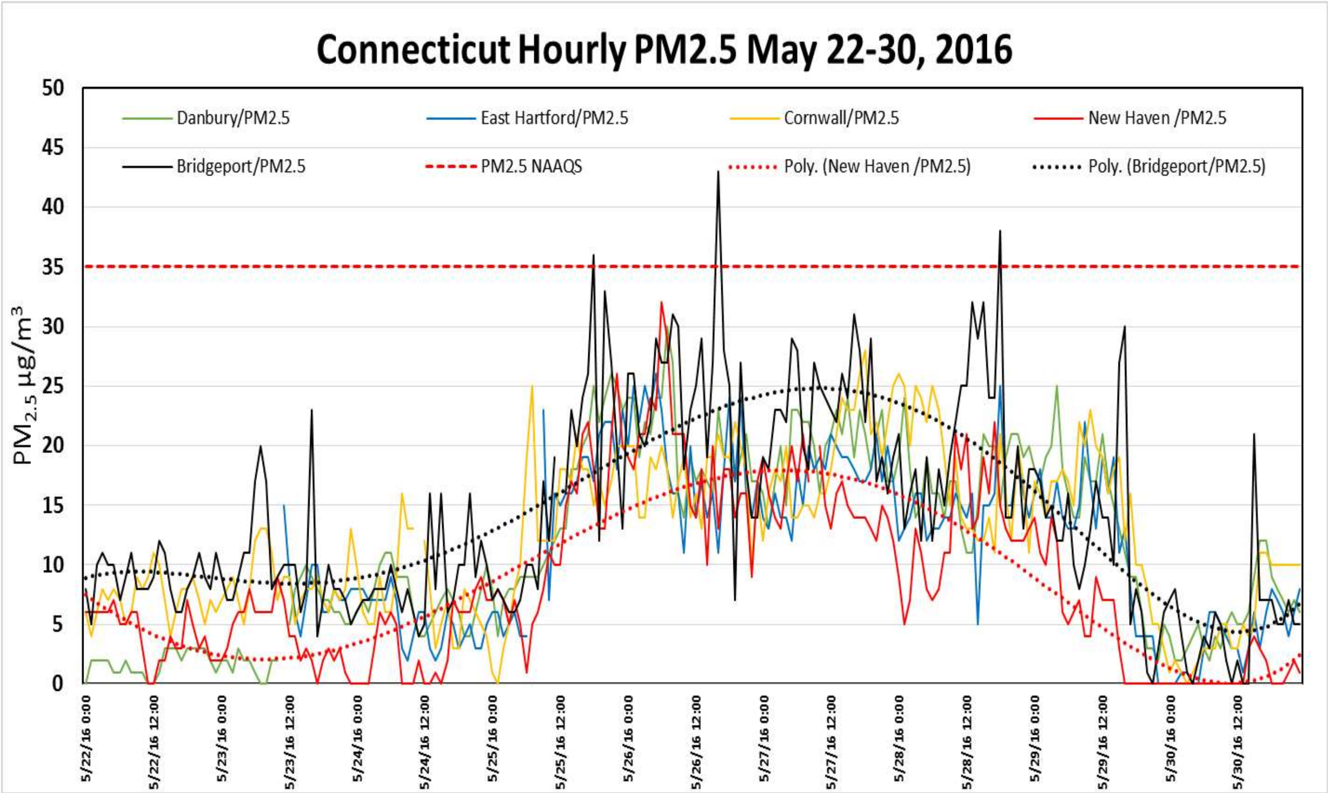
Evidence of Plume Impacting the Ground



Hourly PM2.5 Concentrations Recorded at Connecticut Monitors from May 22-30, 2016

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Clear Causal Relationship: Tier 2

Wildfire events that do not meet the criteria of Tier 1

Key Factor #1

Fire emissions and distance of fire(s) to affected monitoring site location

- *Q/D ≥ 100 tons/km*

Key Factor #2

Comparison of the event-related O_3 concentration with non-event high O_3 concentrations

- *99^{th} or higher percentile of 5-year distribution*
- *One of the four highest values within 1 year*

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Clear Causal Relationship: Tier 2 – Key Factor 1 (Q/D)

- Q/D relationship is used as key factor to determine influence of emissions to downwind monitor
  - Q = maximum daily sum of the NO_X and reactive VOC emissions (tons per day)
  - D = distance between fire and affected monitor (kilometers)

- Q/D ≥ 100 tons / km as indicator of clear causal O_3 impacts from event

- Obtain Q using AP-42 Emission Factors for Wildfires and Prescribed Burning
  - Ei = Pi * L * A
    - Pi = yield for pollutant "i" (mass of pollutant/unit mass of forest fuel consumed)
      - = 12 kg/Mg (24 lb/ton) for total hydrocarbon (as CH4)
      - = 2 kg/Mg (4 lb/ton) for nitrogen oxides (NOx)
    - L = fuel loading consumed (mass of forest fuel/unit land area burned)
    - A = land area burned
    - Ei = total emissions of pollutant "i" (mass pollutant)

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Clear Causal Relationship: Tier 2 – Key Factor 1 (Q/D)

- Fuel loading emission rate for North Central US conifer forests = 10 tons / acre
- Week prior to event, fire grew by 60,000 hectares or 148,263 acres (May 19-24)
- E_{HC} = 24 lbs of HC / ton of fuel consumed * 10 tons fuel / acre * 148,263 acres
  - E_{HC} = 17,791 tons of HC
  - $E_{rHC} = 0.6 * E_{HC}$ = 10,674 tons of reactive HC
- E_{NOx} = 4 lbs of NOx / ton of fuel consumed * 10 tons fuel / acre * 148,263 acres
  - E_{NOx} = 2,965 tons of NOx
- $Q = E_{rHC} + E_{NOx}$ = 13,639 tons / 6 days = 2,273 tons / day
- D = 3,286 km
- **Q/D = 0.69 tpd/km**

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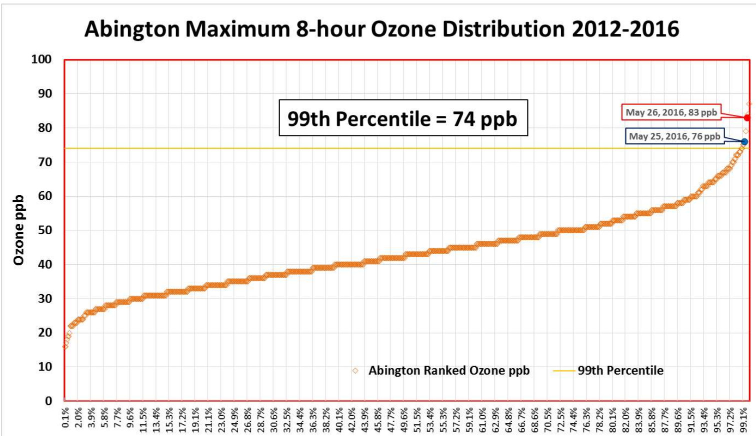
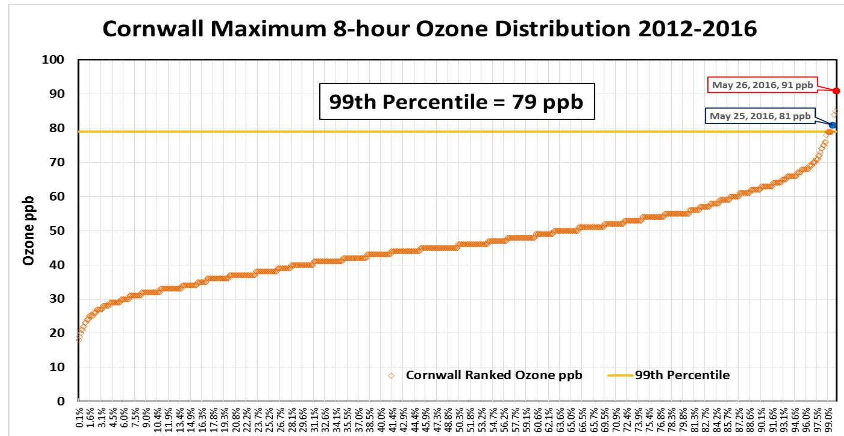
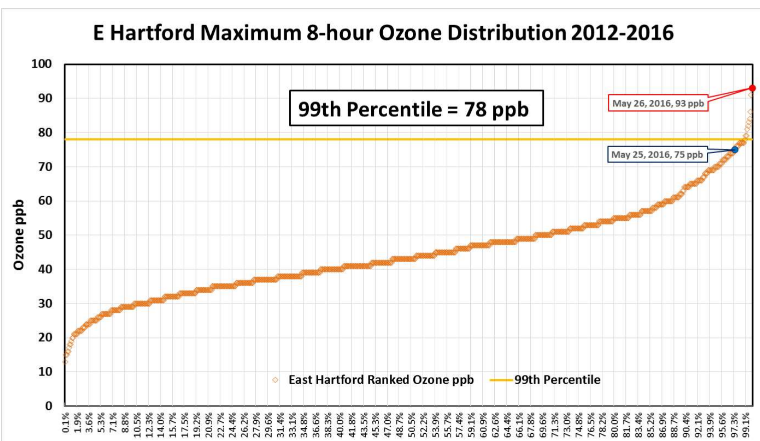
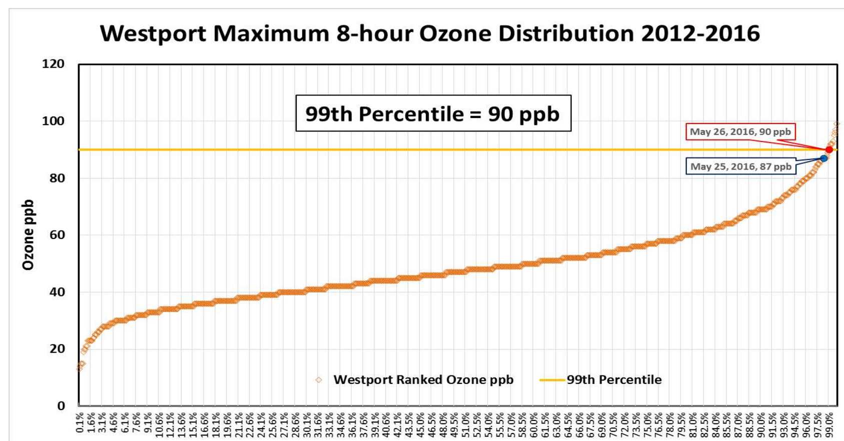
Clear Causal Relationship: Tier 2 – Key Factor 2









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Clear Causal Relationship: Tier 2

(1) Tier 1 key factor analysis and evidence
(2) Tier 2 key factor analyses
(3) Tier 2 additional evidence that the emissions from the wildfire affected the monitored O_3 concentration
  - Supporting information (photographic evidence of smoke, visibility data, media reports, area forecasts)
  - Concentrations of O_3 and other wildfire-relevant pollutants ($PM_{2.5}$, CO, NO_x, VOCs)
  - Analyses of tracers or indicators specifically of fire emissions (e.g. PM speciation such as organic carbon or potassium, or DeltaC)
  - Satellite evidence of smoke or precursors

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Visibility Impacts – Photographic Evidence

Cornwall Connecticut Webcam. (a)May 24-6:00pm, (b)May 25- 6:00am), (c)May 25- 3:30pm and (d)May 26-11:00am, 2016.

Talcott Mountain Connecticut Webcam. (a)May 24-7:00pm, (b)May 25- 8:00am), (c)May 25- 2:00pm and (d)May 26-10:00am, 2016.

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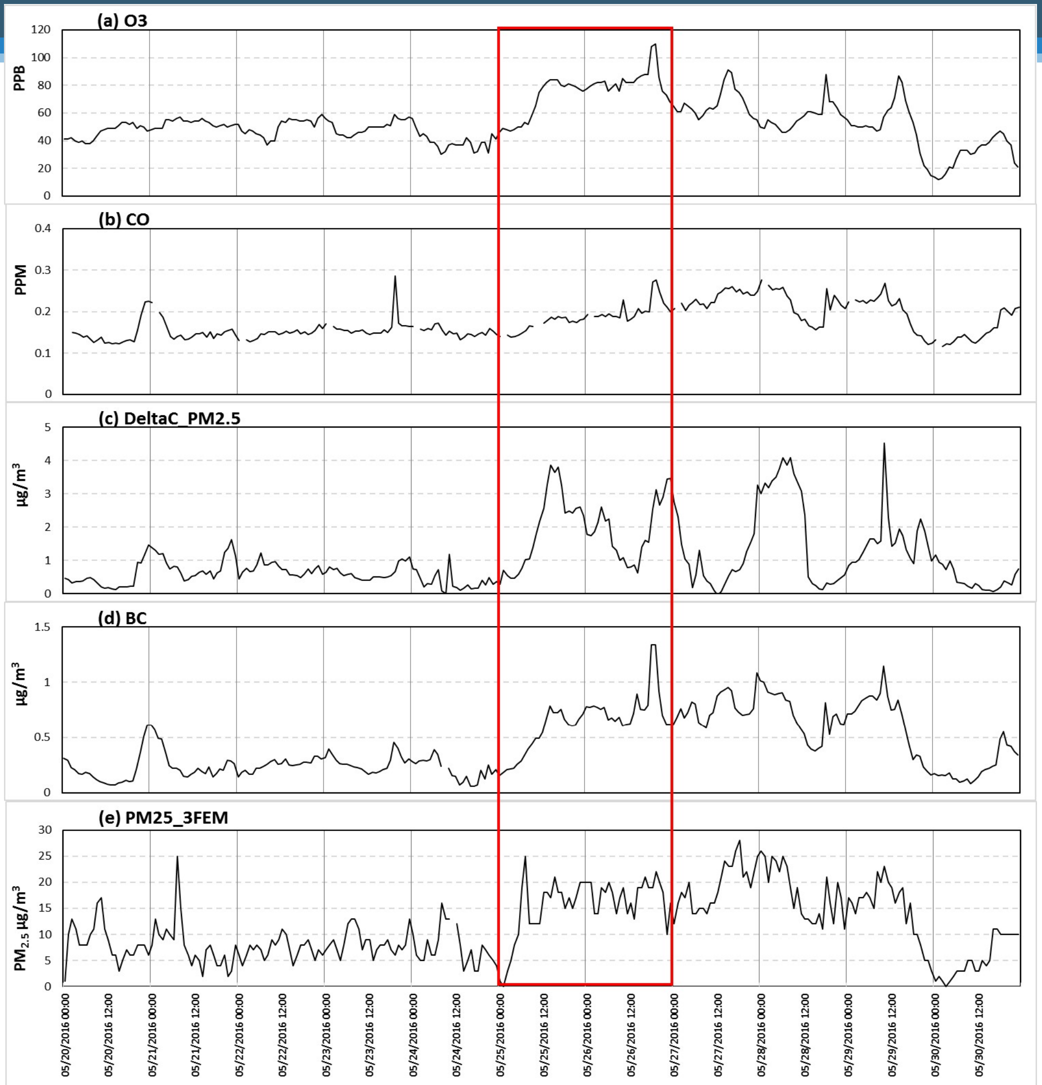
Evidence of Plume Impacting the Ground



Monitored (a) Ozone, (b) Carbon Monoxide (CO) (c) DeltaC PM2.5 (d) Black Carbon (BC), and (e) PM2.5 at the Cornwall CT Monitor

- Other monitored parameters that show the likely presence of a smoke plume include black carbon (BC), DeltaC, and carbon monoxide (CO)

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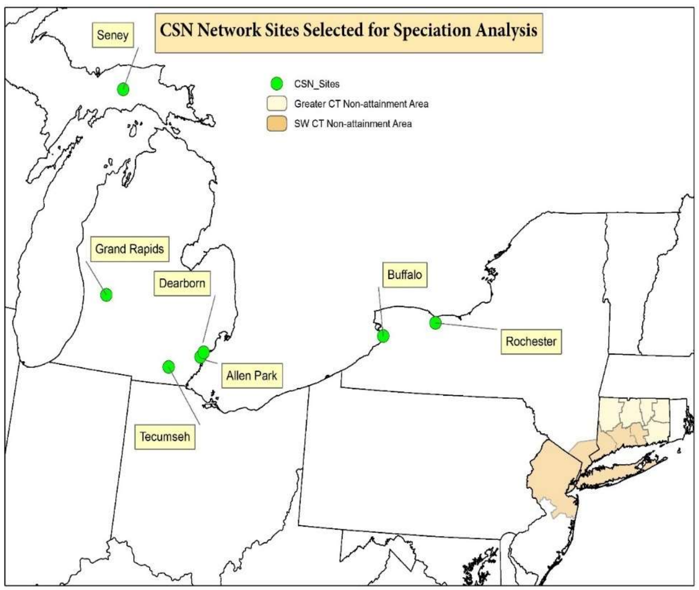
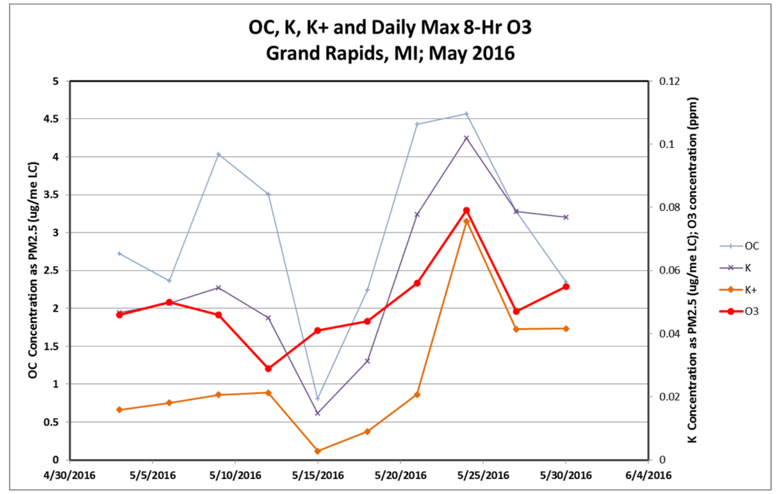
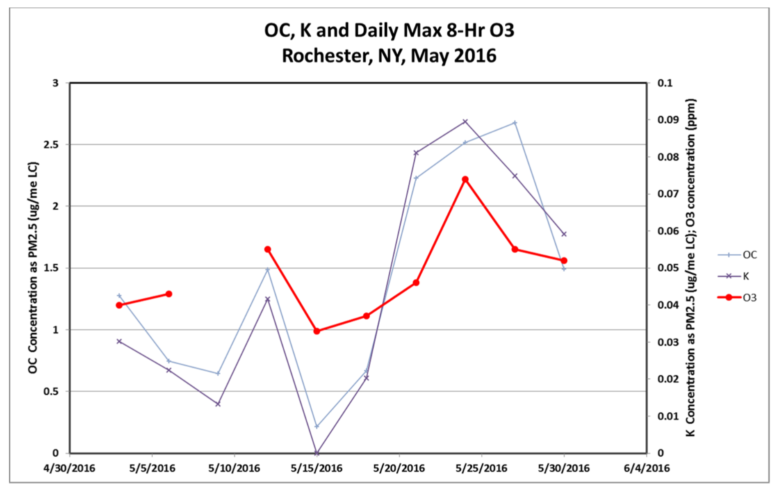
Evidence of Plume Impacting the Ground at Upwind Monitors







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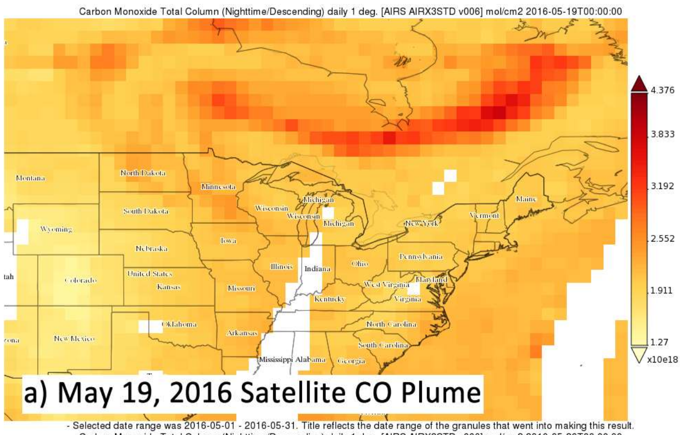
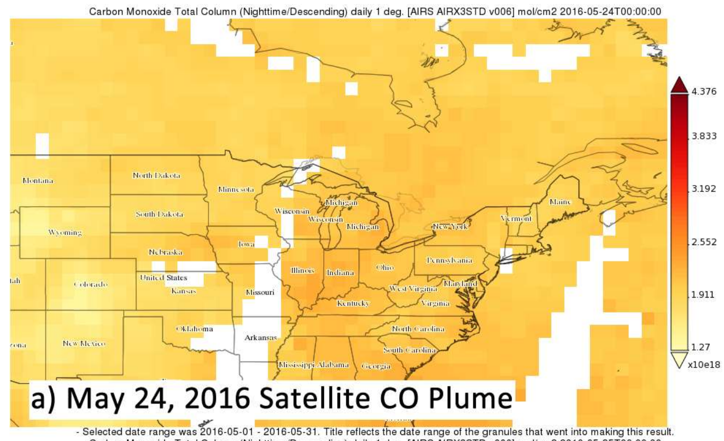
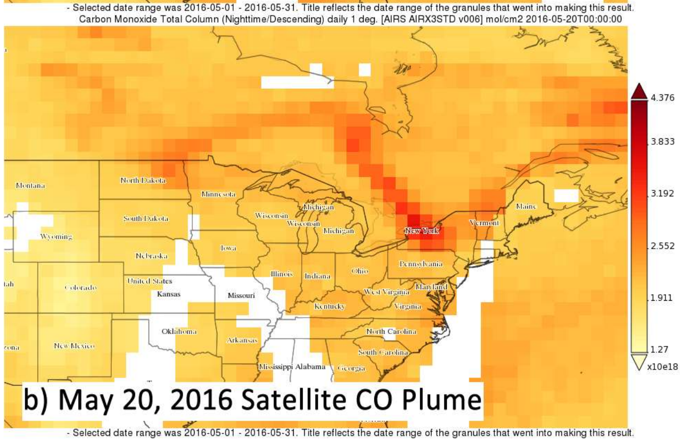
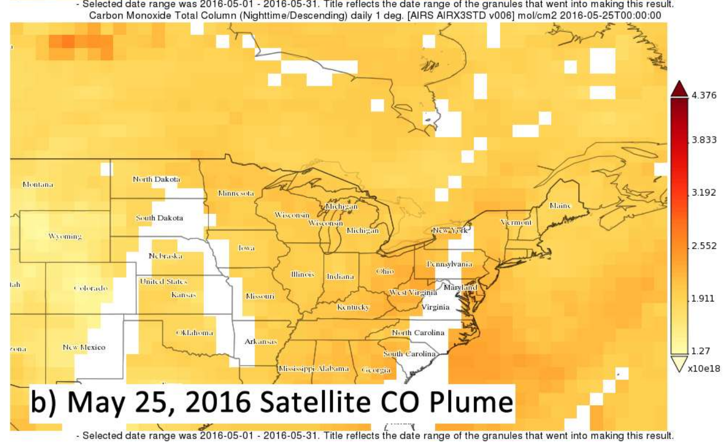
Satellite CO Enhancement









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Clear Causal Relationship: Tier 3

Wildfire events that do not meet the criteria of Tier 2

(1) Tier 1 key factor analysis and additional evidence
(2) Tier 2 key factor analyses and additional evidence
(3) Tier 3 additional analysis that the fire caused the exceedance
- Comparison of O_3 concentrations on Meteorologically Similar Days (Matching Day Analysis)
- Aerosol analysis
- Statistical Regression Modeling
- Photochemical Modeling

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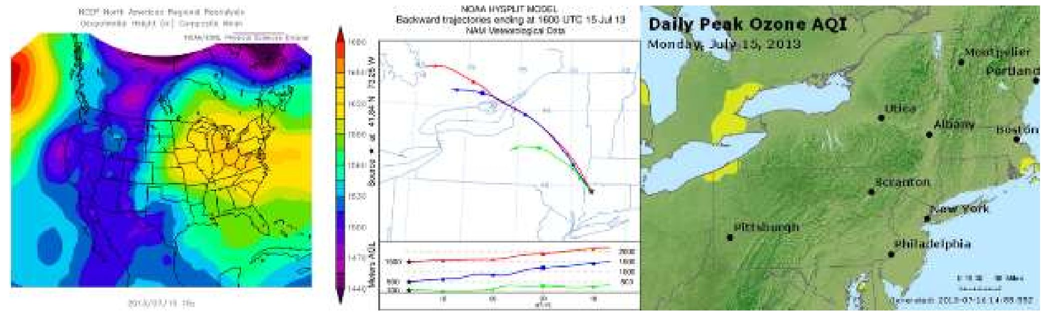
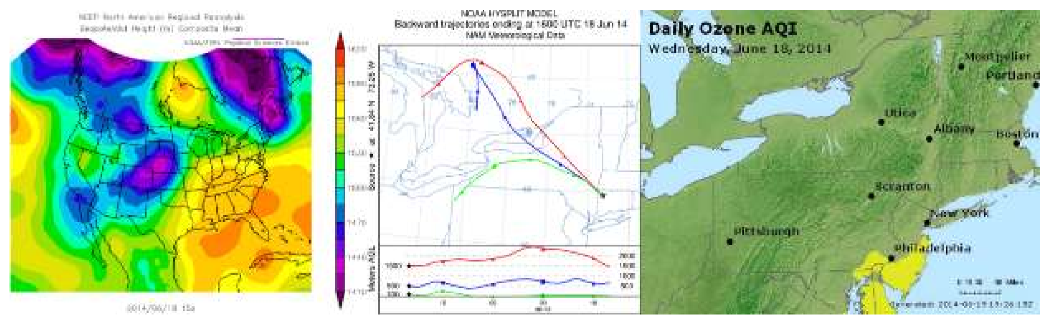
Matching Day Analysis

- High surface temperatures are not always correlated with high ozone concentrations
- Upper level winds have the ability to transport pollutants from great distances, while the surface winds are more indicative of more localized transport
- Generally, winds from the west/northwest do not produce elevated ozone as the air transported into New England is clean



Matching 850 mb Pressure Pattern with Back Trajectories July 15, 2013



Matching 850 mb Pressure Pattern with Back Trajectories June 18, 2014

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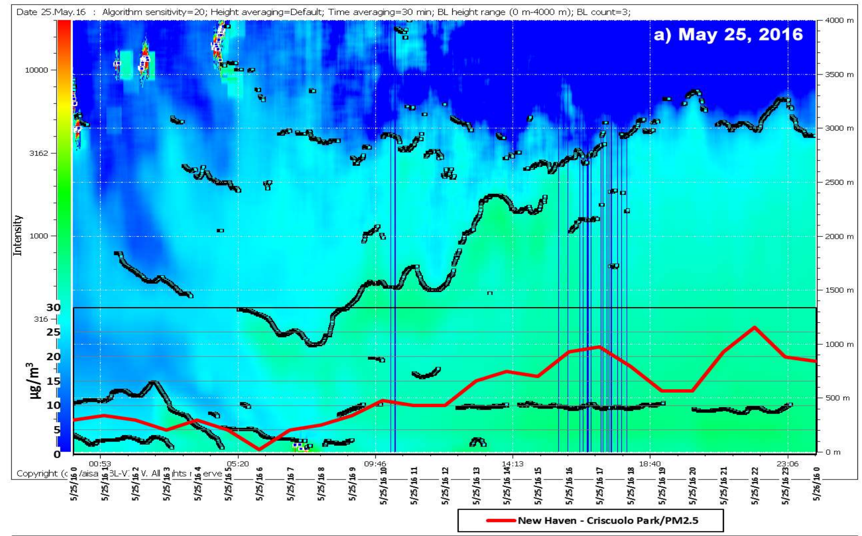
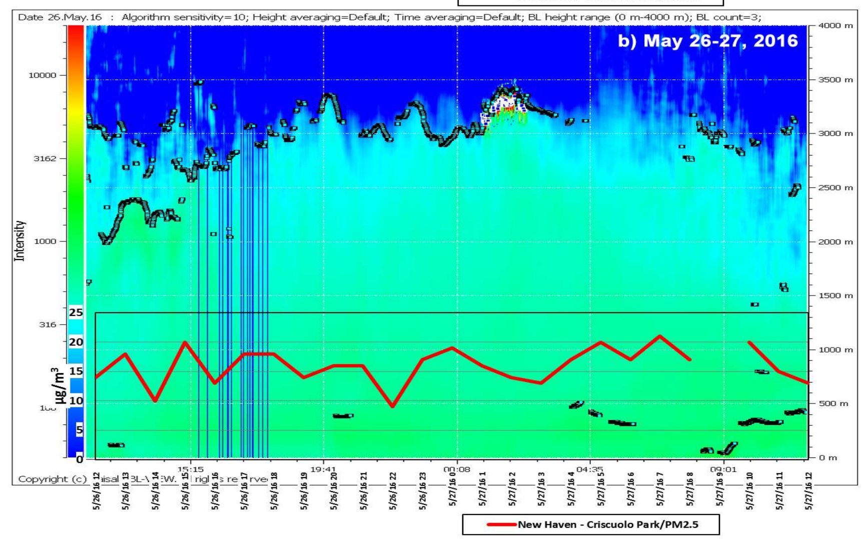
Aerosol Backscatter Intensity over CT with $PM_{2.5}$ Levels

- Aerosol backscatter ceilometer at New Haven monitoring site provides LIDAR backscatter plots up to a height of 4 km
- Time series shows an unusually dense region of aerosols reaching a height of 3 kilometers
- Coincides exactly with the increase in monitored surface $PM_{2.5}$ and the arrival of the smoke plume over Connecticut on May 25th





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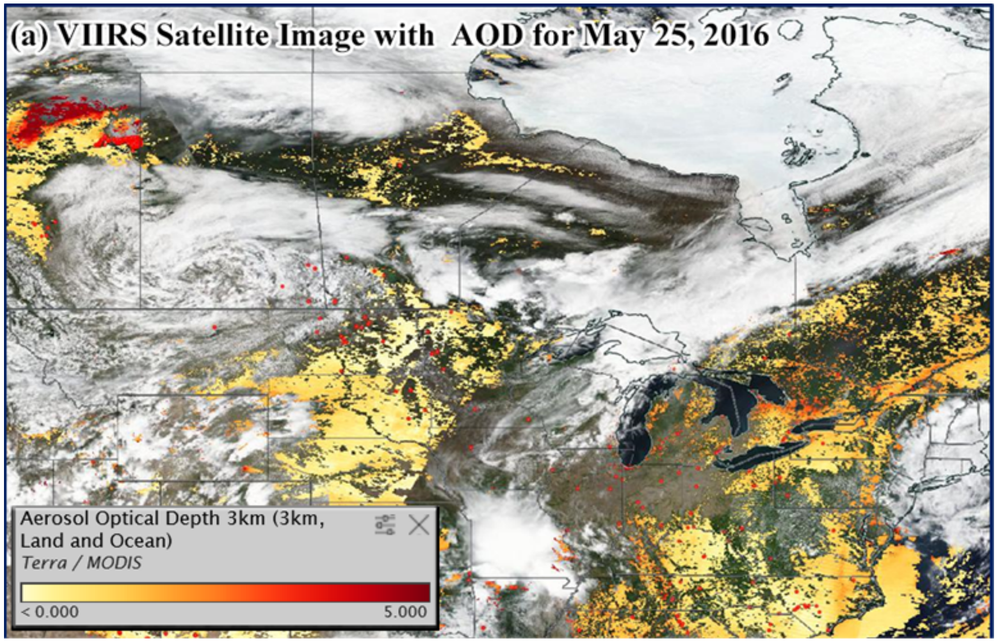
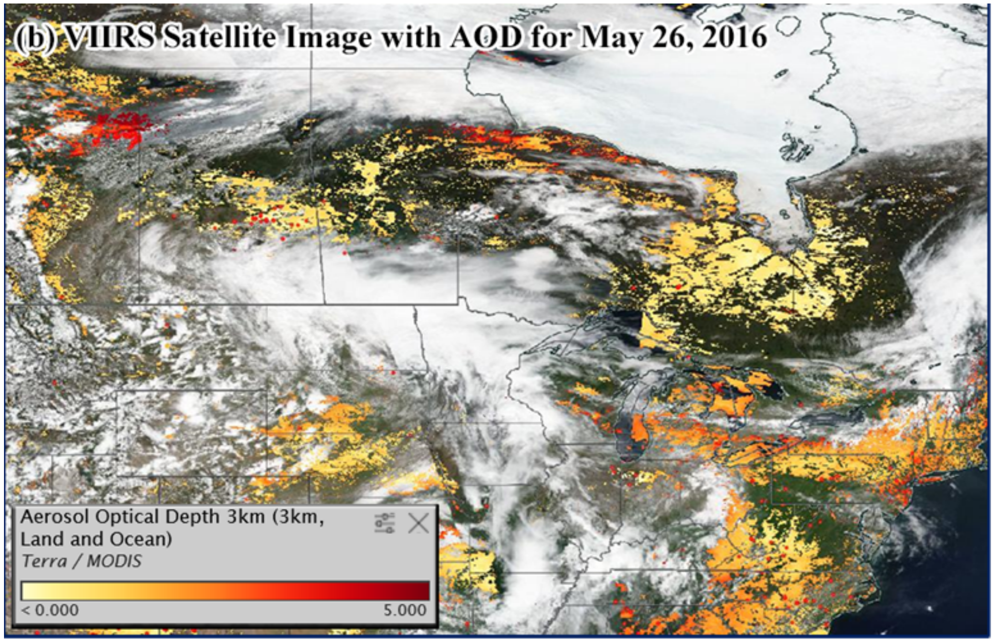
VIIRS Satellite Images with AOD





- 3 km aerosol optical depth (AOD) overlaid on Visible Infrared Imaging Radiometer Suite (VIIRS) satellite image indicative of PM in smoke plume

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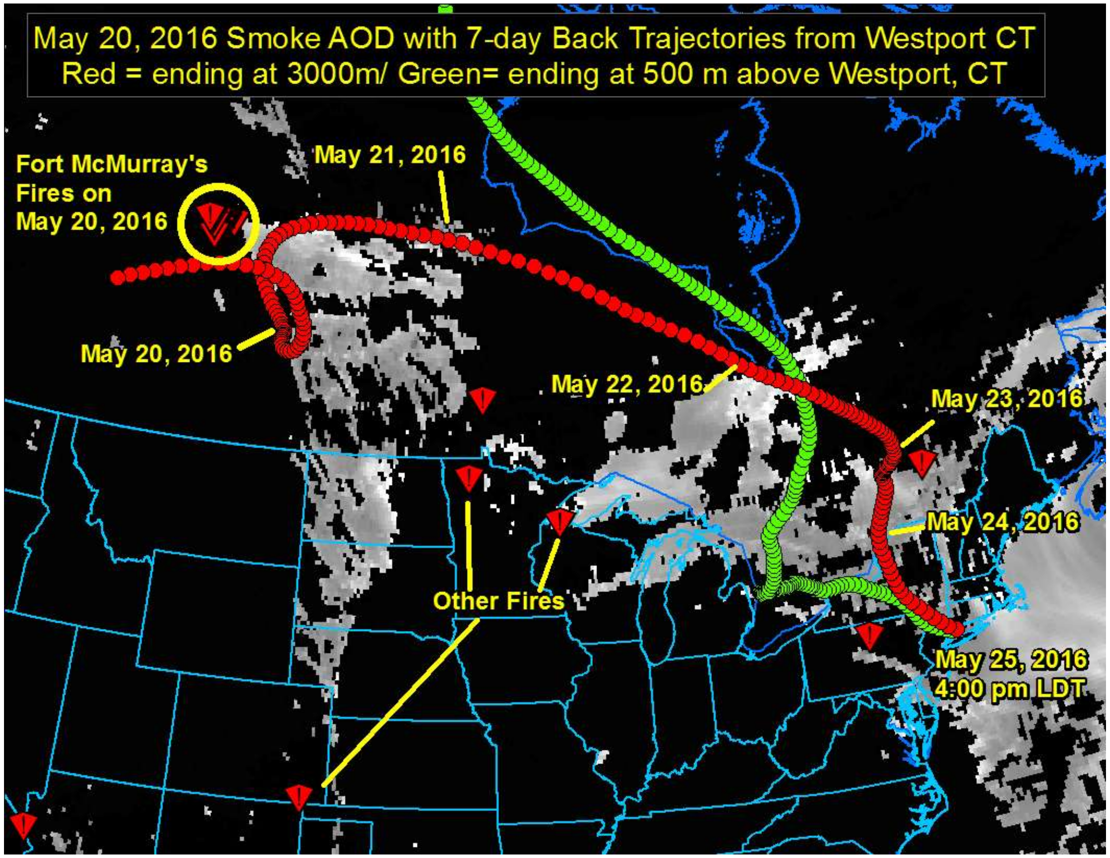
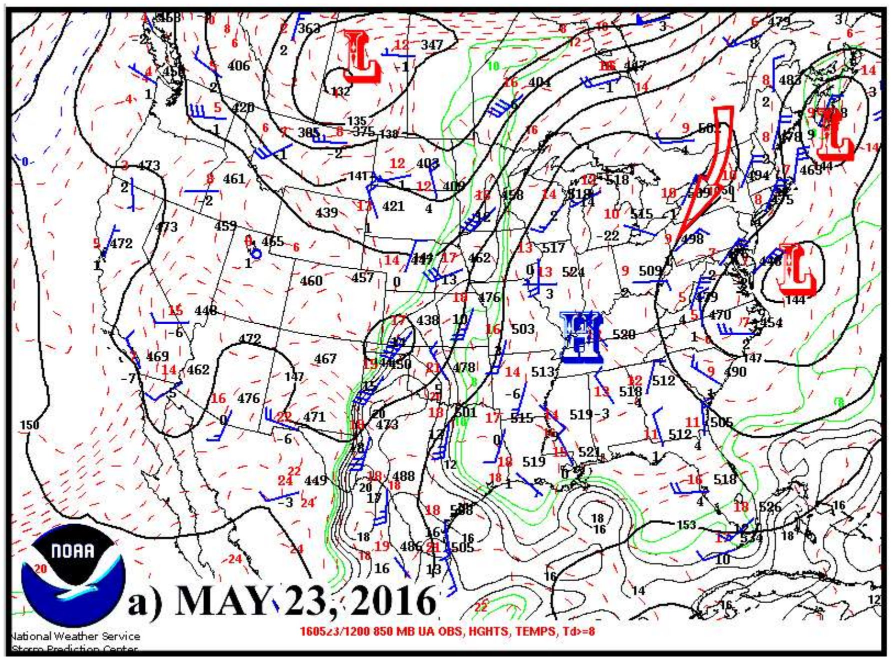
Smoke Movement

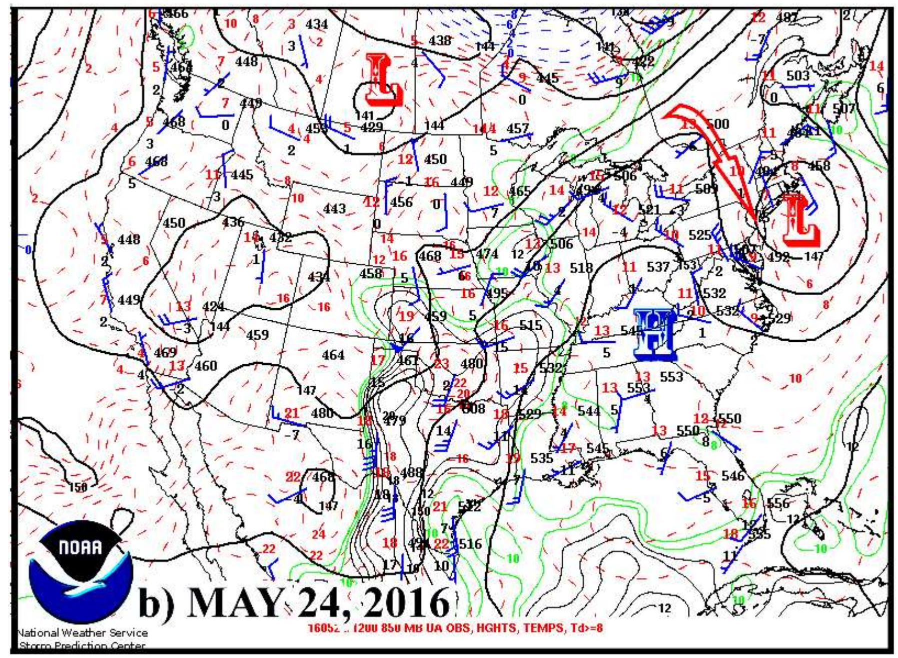
- Fire locations with the aerosol plumes on May 20th with the HYSPLIT trajectory paths from May 19-25th



For illustration and discussion purposes only

Weather Pattern During Event





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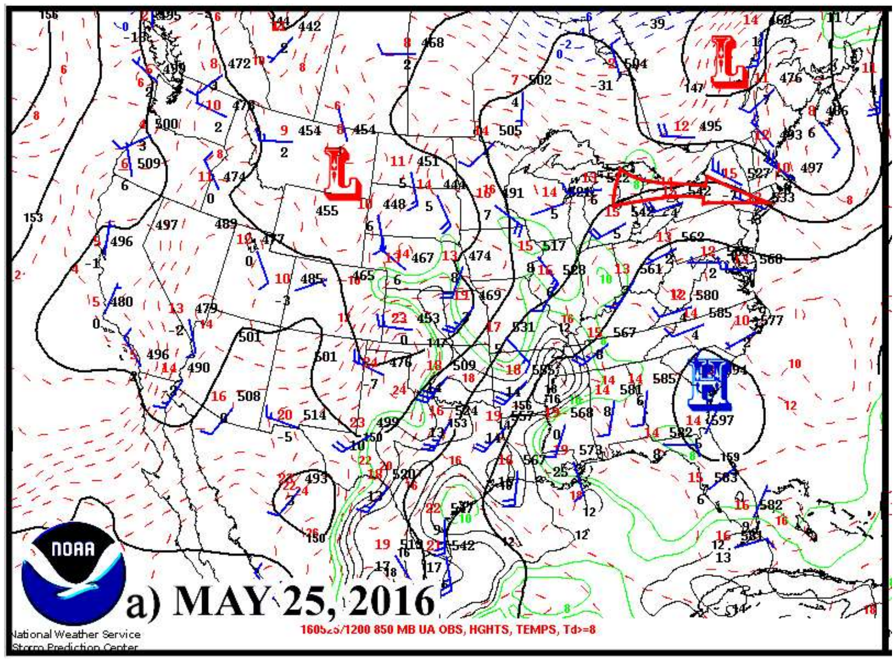
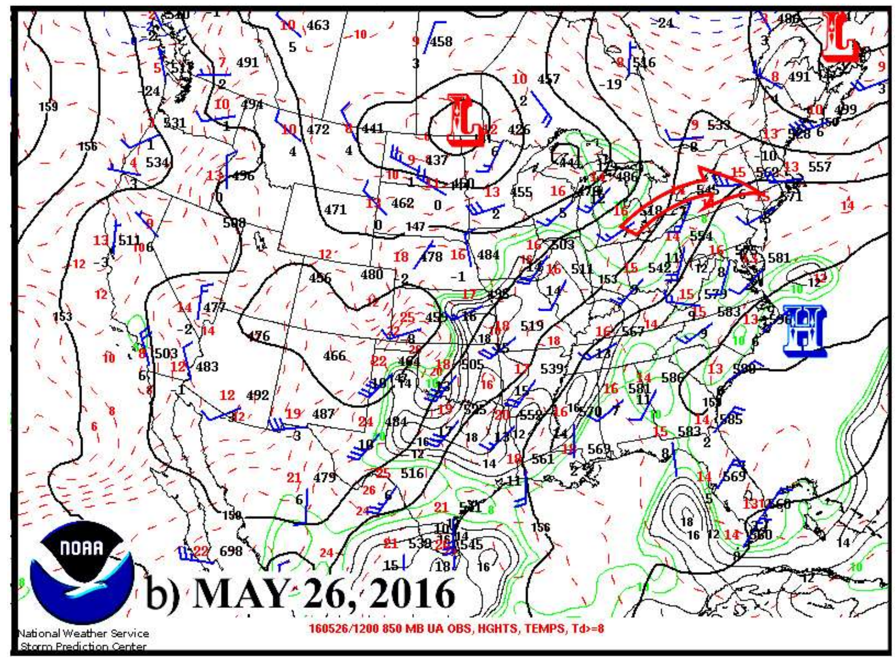
Weather Pattern During Event





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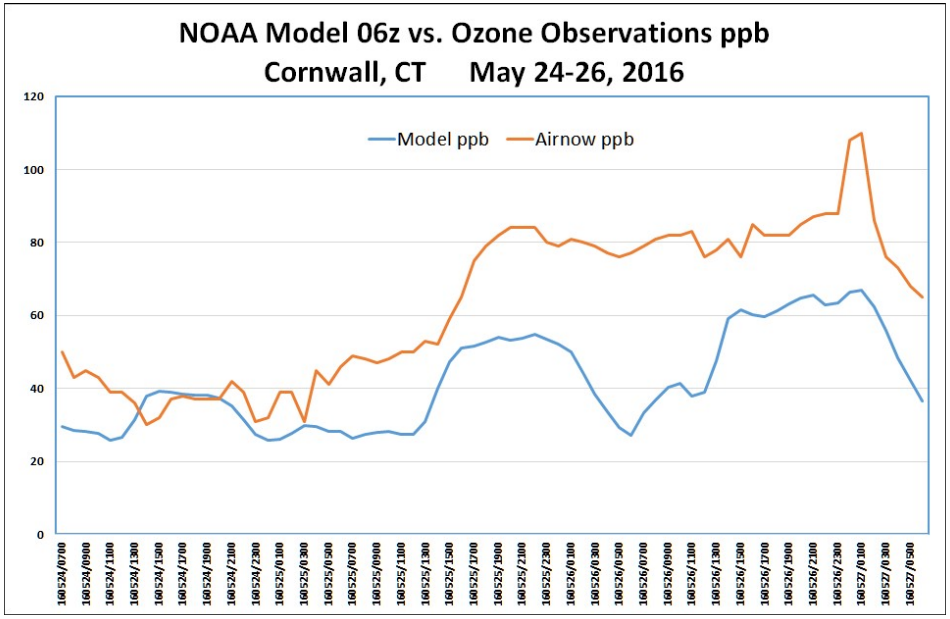
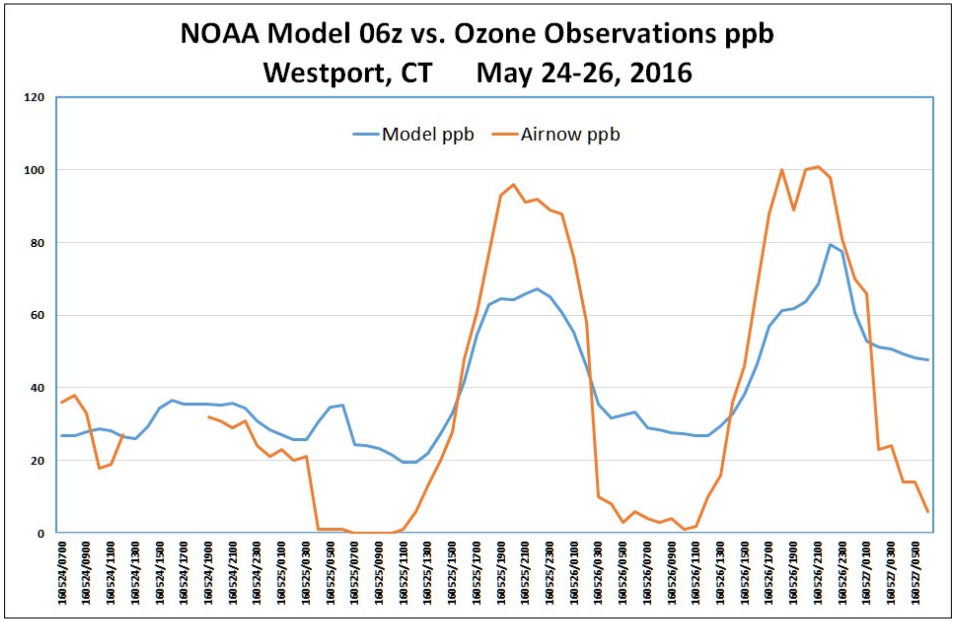
Modeled vs. Observed Ozone During Event





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Questions and Comments