

N.C. EXCEPTIONAL EVENT (JUNE, 2008)

EVANS ROAD WILDFIRE, HYDE CO., NC

5/15/2009

NC DAQ

AMBIENT MONITORING SECTION

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ACRONYMS AND ABBREVIATIONS

AOD	Aerosol Optical Depth
FRM	Federal Reference Method
GASP	GOES Aerosol Smoke Product
GOES	Geostationary Operational Environmental Satellite
NC	North Carolina
NC DAQ	North Carolina Division of Air Quality
OC	Organic Carbon
OM	Organic Mass
OMI	Organic Mass Index
PM2.5	Particulate Matter with an Aerodynamic Diameter of 2.5 microns or less
TEOM	Tapered Elemental Oscillating Microbalance

SUMMARY

Quick Overview

The NC DAQ believes that the PM2.5 FRM data in Table 1 were elevated above the PM2.5 daily standard by the Evans Road wildfire in Hyde County and should be excluded from regulatory decisions because:

- The “but for” analysis shows that the OMI reduced gravimetric PM2.5 mass by 50 to 70 percent on the samples impacted by the Evans Road Fire. (Organic carbon is associated with wood smoke from forest fires).
- The sulfate levels measured as the wildfire’s plume passed through Raleigh were sufficiently low (less than 10 $\mu\text{g}/\text{m}^3$).
- The causal relationship is established by wind roses, forward/backward trajectories of air, satellite imagery of AOD, and ground level photos. Transport of the smoke to several NC DAQ monitoring locations across North Carolina is indicated.
- Ground photos taken statewide http://www.wral.com/news/local/image_gallery/3033022 indicate the smoke remained near the ground as it drifted inland.
- Statistical modeling predicts much lower PM2.5 FRM concentrations expected at the sites in Table 1.

Fire Start Date: June 1, 2008
Fire End Date: January 9, 2009 (<http://www.fws.gov/pocosinlakes/erf.html>)
Fire Cause: Lightning
Fire Location: Pocosin Lakes Wildlife Refuge in Hyde County, North Carolina
Latitude: 35.66 Longitude: -76.43

Note to reviewer: The hyperlinks provide extremely useful information and support the NC DAQ report detailing the evidence of the Evans Road wildfire, transport of the smoke, impacts on PM2.5 FRM concentrations, “atypical”, and “but for” analysis.

Data Requested for Exclusion

The PM_{2.5} FRM data requested for exclusion due to the Evans Road Fire are listed in Table 1:

Table 1: North Carolina PM 2.5 ($\mu\text{g m}^{-3}$) Samples Affected by the Evans Road Fire Incident

Site Name	Sampling Frequency	County	Site ID	5-Jun	11-Jun	12-Jun	13-Jun
Jamesville	1-in-3 day	Martin	371170001	91.88			
Greenville	1-in-3 day	Pitt	371470005		107.63		
Ag Center	1-in-3 day	Pitt	371470006		72.93		
Lenoir College	1-in-3 day	Lenoir	371070004		38.33		
Dillard School	1-in-3 day	Wayne	371910005		36.67		
Pittsboro	1-in-3 day	Chatham	370370004			71.79	
Millbrook	Everyday	Wake	371830014			99.04	
Mendenhall	Everyday	Guilford	370810013				68.68

The counties closest to the fire are at the top of Table 1, and move further west from the fire as you move down the list. Figure 1 depicts the location of the fire in red (Hyde Co.) with counties in Table 1 in orange. The colors, orange and red, do not signify the AQI index.

Counties with an FRM PM_{2.5} Monitor that were affected by the Hyde County Fire.

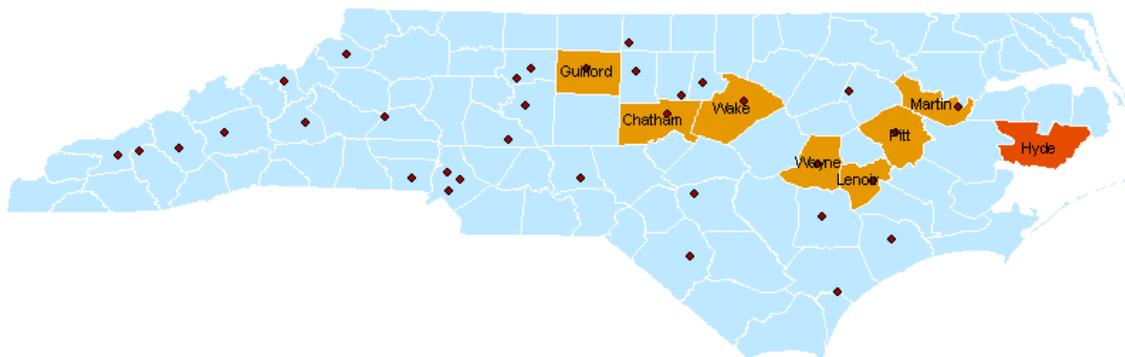


Figure 1: The statewide PM_{2.5} FRM monitoring network. Only the monitors in the orange colored counties were impacted by the Evans Road Fire. The other monitors were spared primarily because June 12 and 13 were not FRM run days for the 1 in 3 day monitors.

The data for these exceedances of the 24-hour PM_{2.5} air quality standard are exceptionally high, and most of these days were characterized by poor visibility and very smoky conditions because the smoke remained below the boundary layer which varied from 6000ft, 5000ft, 4500ft, and 5500 ft on June 5, 11, 12, and 13, respectively. For example, smoke engulfed the Raleigh area on June 12, 2008 (Figure 2).



Figure 2: Smoky skies are visible over Raleigh from the Bank of America building. Shown is The Memorial Center in downtown Raleigh (Lenoir St.) as seen from the Bank of America building. See full image gallery of smoke reaching several areas within the State at http://www.wral.com/news/local/image_gallery/3033022

Evidence of Flagging – RT (U.S. – Wildfire)

Evans Road Fire/Pocosin Lakes National Wildlife Refuge

The Evans Road fire was started by lightning on June 1st, 2008, on private land south of the Pocosin Lakes National Wildlife Refuge. This fire was declared 100% contained on September 24, 2008, and officially declared “out” on January 9, 2009. Originally on private land, the fire ran into the Pocosin Lakes National Wildlife Refuge, a 110,000 acre refuge home to the endangered red wolf, black bear, hundreds of species of migratory birds, and a variety of other native wildlife. This fire has burned 41,060 acres, approximately 64 square miles, in North Carolina’s Hyde, Tyrrell, and Washington counties. 60% of the burned area is within the Pocosin Lakes National Wildlife Refuge.



Figure 3: Evans Road Fire (picture courtesy of NC Dept. of Forestry)

According to the Fish and Wildlife Service, all of eastern North Carolina was in a very high fire danger condition for most of the summer of 2008. Fuel moisture for fine- to medium-sized fuel was measured at 4% in early June, and combustibility of these fuels reached an all time record high for June in the North Carolina Coastal Plain. As with the Great Dismal Swamp, much of this area is covered in organic soils or peat. In these soils water levels are generally high; however, in the summer of 2008, the organic soils were exceedingly dry and measured very little moisture content due to the prolonged drought experienced in North Carolina. This drought, believed to be the worst in North Carolina's history, and the unusual weather experienced in eastern North Carolina during June of 2008 (high temperatures coupled with low relative humidity) are the primary factors in the spread of this fire.

The organic soils allowed the fire to smolder for long periods of time, making the fire difficult to extinguish and producing great quantities of air pollution though the starved-oxygen combustion process. At the height of the fire, smoke reached thousands of feet in the air and obscured vision in the area.



Figure 4: Evans Road Fire (picture courtesy of NC Dept. of Forestry)

North Carolina Department of Forestry personnel estimate that over 500 people from 50 different agencies were working the Evans Road fire at its height. Pumping crews flooded the area with two billion gallons of water to help extinguish fires burning deep under the surface. More than \$18,000,000 was spent containing the blaze.

Several articles and Pictures on the Evans Road Fire are located at the following website: <http://www.witn.com/home/headlines/19456249.htmle> **Articles**

On June 5 and 11, the winds shifted towards the west , and the plume came inland. The plume from this fire crossed several monitor locations in the State of North Carolina during the month of June 2008. The full list of monitors impacted by the smoke from this fire is presented in Table 1.

The fire pixels of the Hazard Mapping Service (June 1 to 4, 2008) indicate location of Evans Road Fire (-76.43, 35.67) in Hyde County, North Carolina in relation to some Eastern NC DAQ monitoring sites.

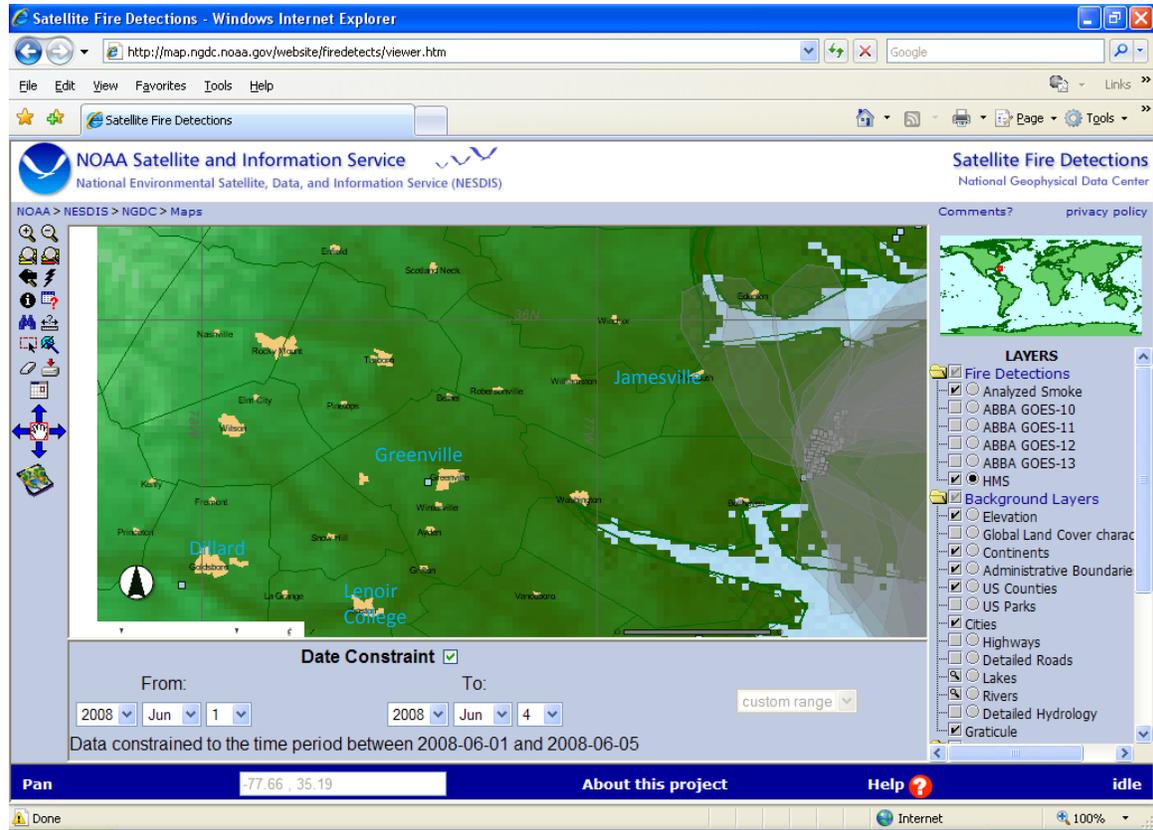


Figure 5: HMS fire pixels with analyzed smoke from June 1 to June 4, 2008.

Auxiliary and qualitative observations can provide additional evidence and confirmation for the occurrence of exceptional events. The general public who took several ground level photographs of the smoke in various counties provided qualitative observations of this exceptional event. Image gallery of ground pictures is available here:

http://www.wral.com/news/local/image_gallery/3033022

CHRONOLOGY OF EVENTS

Thursday, June 5, 2008

June 5, 2008 was a 1/3 run day for the PM2.5 FRM network. Jamesville is about 45 miles northwest of the fire location. The daily average PM2.5 FRM concentration on June 5, 2008 for Jamesville was $91.88 \mu\text{g}/\text{m}^3$, which exceeds the PM2.5 24-hour standard. Jamesville TEOM-PM2.5 indicates that the Evans Road Fire made a major impact beginning around 6 PM with hourly concentrations climbing to $200 \mu\text{g}/\text{m}^3$, the maximum range of the TEOM-PM2.5 instrument (Figure 6).

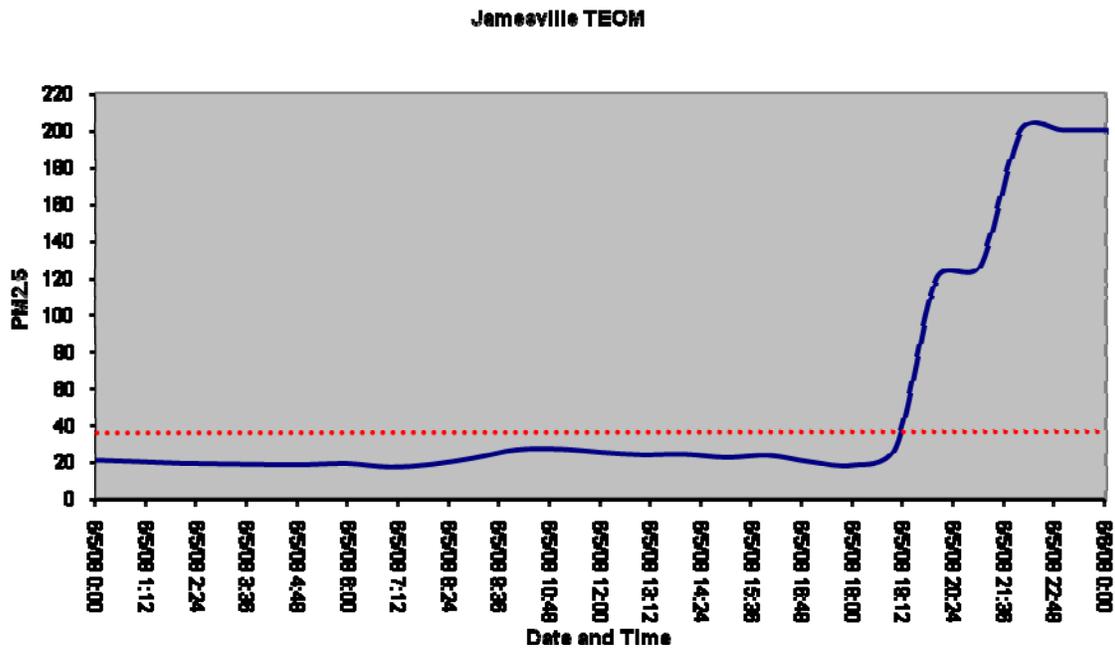


Figure 6: Jamesville TEOM-PM2.5 highlights the smoke impact that starts 6/5/08 around 6PM. The Jamesville FRM measured a PM2.5 reading of $91.88 \mu\text{g}/\text{m}^3$ - this data point is being requested for exclusion by the NC DAQ.

Tuesday, June 11, 2008

NC DAQ began advising PM2.5 in code orange or higher in areas near the fire starting on June 6, 2008.

On Monday June 11, 2008, the smoke from the Evans Road fire began to drift inland. NC DAQ operates PM2.5 FRMs at Greenville and Ag Center (Pitt County), Lenoir (Lenoir County), and Dillard School (Wayne County). These four monitors, which run on a 1/3 day schedule, exceeded the 24-hour PM2.5 air quality standard with concentrations of 107.63 $\mu\text{g}/\text{m}^3$, 72.93 $\mu\text{g}/\text{m}^3$, 38.33 $\mu\text{g}/\text{m}^3$, and 36.67 $\mu\text{g}/\text{m}^3$, respectively.

Hourly average concentrations from the continuous particulate monitor at Wayne County for the 24-hour period beginning at midnight on June 10 appear below (Figure 7).

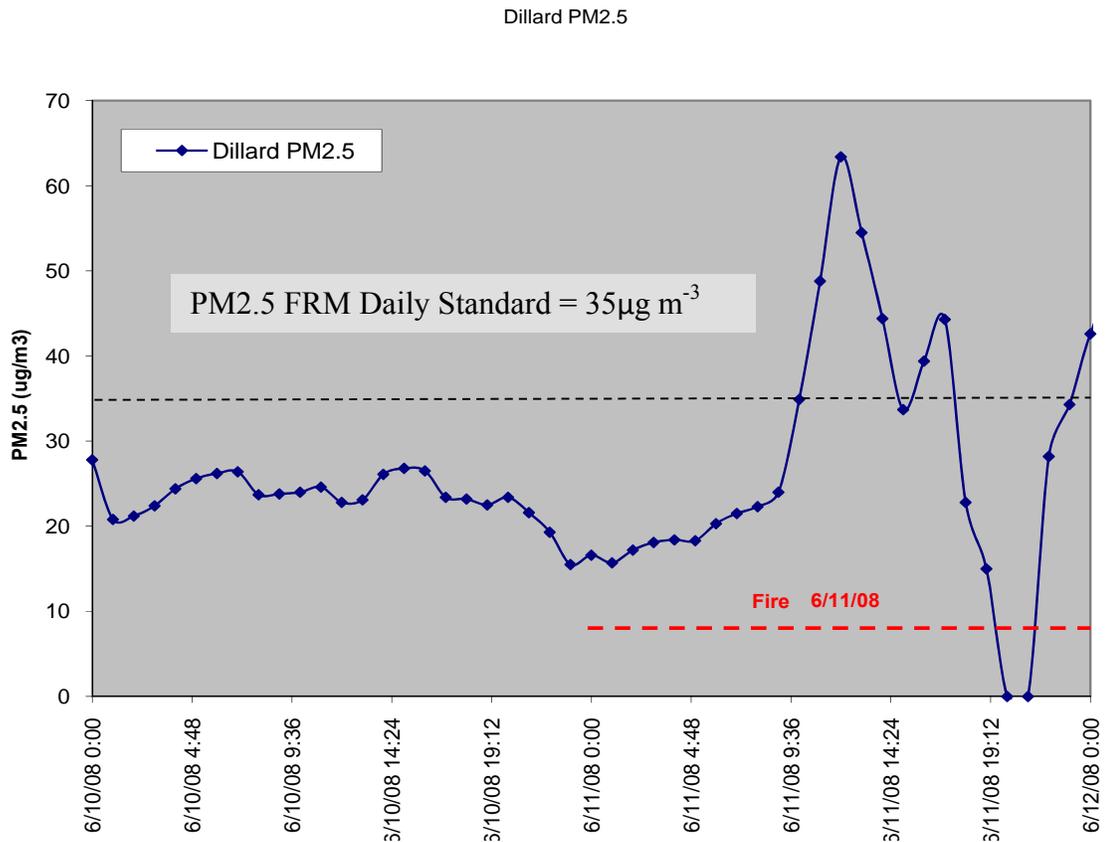


Figure 7: Hourly Average concentrations from TEOM monitor for June 10-11, 2008

There were no PM2.5 TEOM hourly average concentrations available in Pitt County or Lenoir County, as the NC DAQ does not operate a PM2.5 TEOM in either of these counties. These Eastern counties are closer to the fire. The Greenville and Pitt Ag monitoring sites are only 60 miles from the source of the fire; the Dillard site is only 90 miles from the source of the fire; and the Lenoir site is only 71 miles from the source of the fire.

Around noon, on June 11, 2008, surface winds near the fire area were from the east/southeast (See ground transport section for June 11, 2008).

GASP AOD indicated a high AOD of 1.5 (Figure 20) captured over much of eastern North Carolina on June 11, 2008. AOD is the extent to which light is extinguished as it moves down a column of air. Unlike western fires that had a high plume rise, most of the aerosol from the Evans Road Fire stayed within the boundary layer; therefore, AOD is representative of impacts on ground particulate concentrations.

Thursday, June 12, 2008

The smoke that had started to drift westward on June 10, 2008 had reached Raleigh by early afternoon of June 11, 2008. The hourly PM_{2.5} concentrations measured with the TEOM-PM_{2.5} in Wake County begins to rise around 2 PM on June 11, 2008.

Because June 12, 2008 was not a normal run day for 1/3-day PM_{2.5} FRM monitors, much of the State's particulate monitors were spared from the impact. However, on June 12, 2008, the everyday PM_{2.5} FRM at the Millbrook monitoring station in Wake County recorded an exceedance of the 24-hour PM_{2.5} standard with a measured daily value of 99 µg/m³. The hourly average concentrations from the continuous particulate monitor at Wake County beginning at mid-night on June 10, 2008 appear in Figure 8.

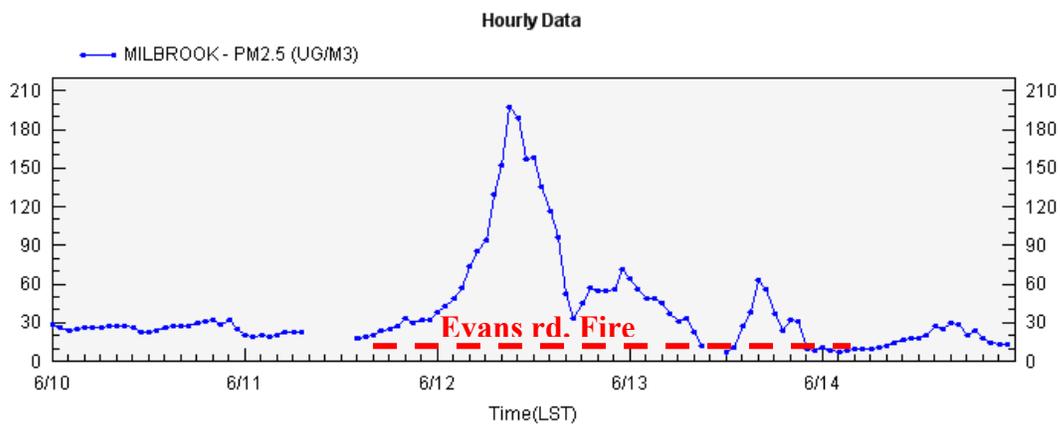


Figure 8: Graph of PM_{2.5} TEOM data at Millbrook for June 10-14, 2008 (from AirNOW)

The Millbrook FRM-PM_{2.5} monitor could have had an impact on June 13, 2008; however, the monitor was down because the operator had to perform an annual calibration on June 13, 2008.

The PM_{2.5} TEOM data trace for 2008 (Figure 9) indicate that the hourly average values on June 12, 2008 were the highest recorded in 2008.

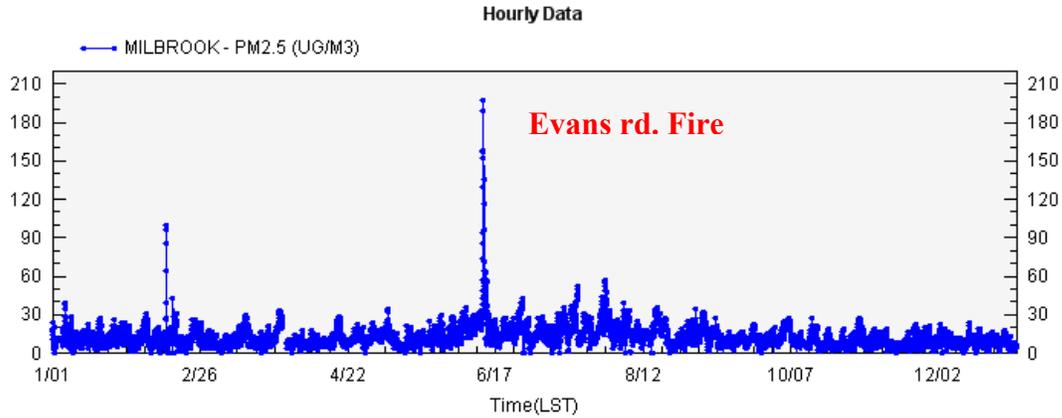


Figure 9: Graph of PM2.5 TEOM data for 2008 at Millbrook (from AirNOW).

Organic Carbon at Millbrook, Raleigh, NC

The fire smoke increased the levels of several NC DAQ monitors in Raleigh on June 12, 2008. The speciated monitor (Met ONE SASS) did not run on June 12, 2008 as this day was not a 1/3 run day. The aetholometer at the Millbrook site shows a marked increase in organic carbon beginning on midnight of June 10, 2008 (Figure 10). When smoke impacts the aetholometer, the uv-carbon (organic carbon; blue line) separates from the black carbon (elemental carbon; black line); otherwise, the difference between the two channels is practically zero.

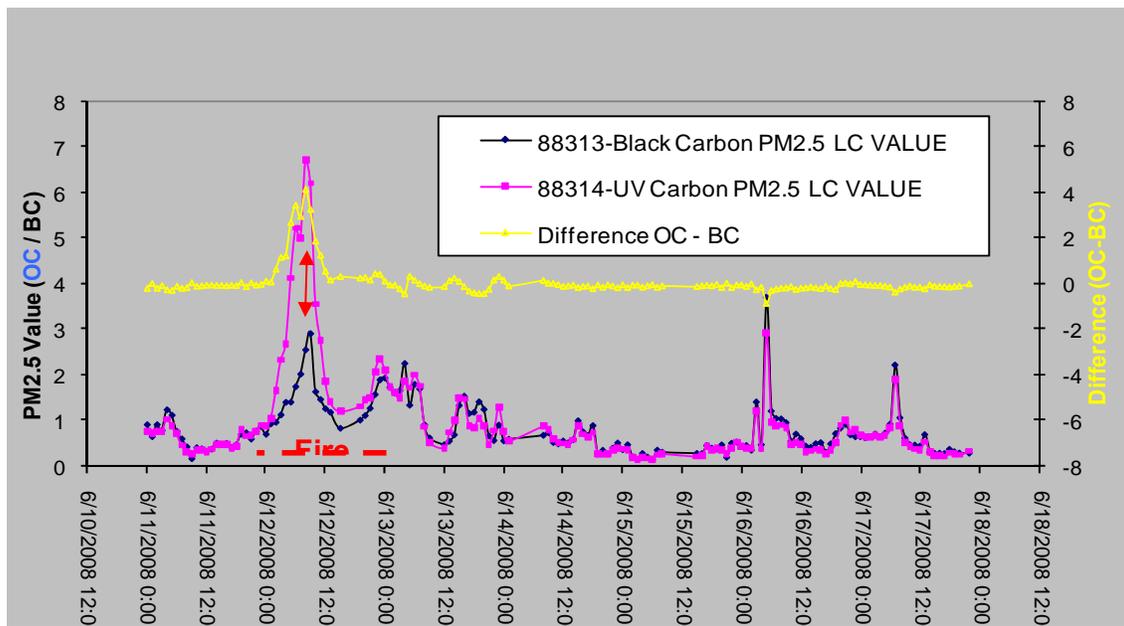


Figure 10: Organic Carbon with the Aetholometer at the Millbrook site in Raleigh, NC (P:\exceptional events\data\Wayne_Evansroadspocr2-1.xls)

Sulfates at Raleigh Millbrook site

Sulfates did not make a large contribution to the PM_{2.5} load during the Evans Road fire. The sulfate levels at Millbrook did not show a sharp rise and remained below 6 $\mu\text{g}/\text{m}^3$ for much of 2008. The sulfate diurnal profile was impaired when the plume passed through Raleigh on June 12, 2008 due to a calibration and a constant reading (4 $\mu\text{g}/\text{m}^3$) that lasted part of the morning (Figure 11). The briefly higher sulfate level after the calibration was not exceptional when compared to the rest of the year and could be due to post calibration effects on the data (Figure 12 and Figure 13).

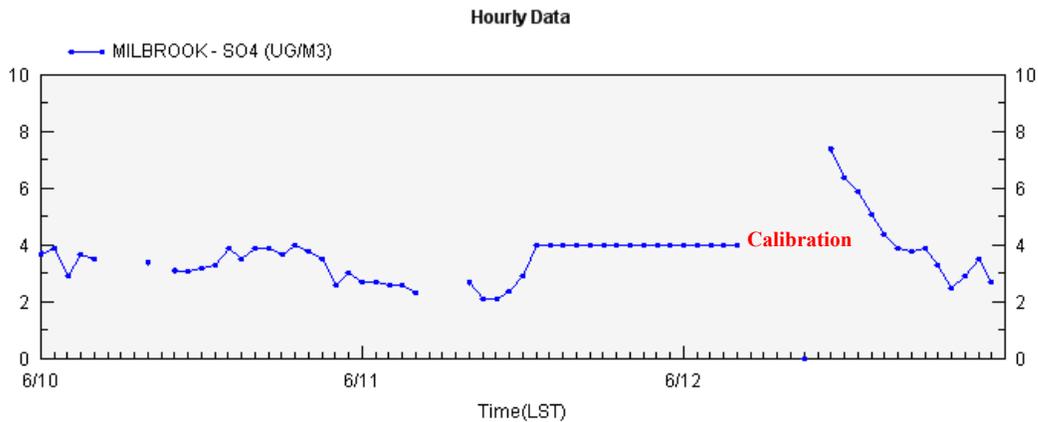


Figure 11: Millbrook SO₄ on June 12, 2008

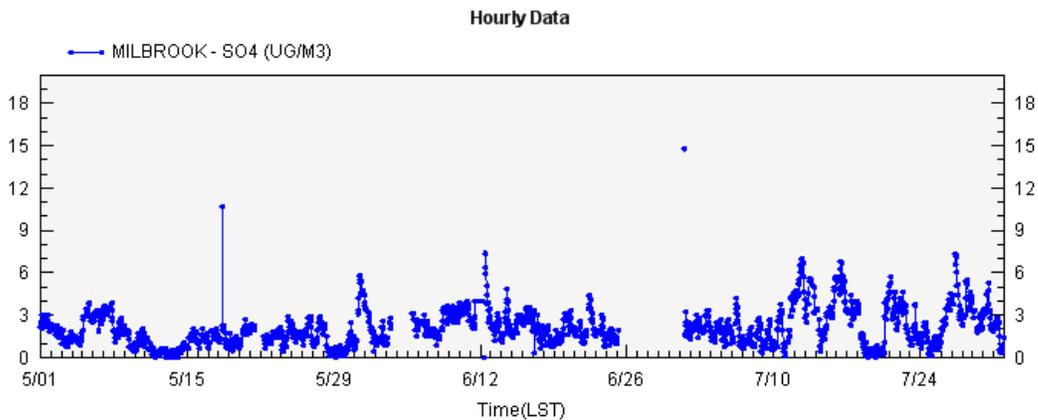


Figure 12: Millbrook sulfates (May to July). As stated, the sulfate levels on June 12, 2008 were not exceptional for the second quarter. A closer examination of the reading on June 12, 2008 indicates that the monitor read a 4 $\mu\text{g}/\text{m}^3$ in the morning.

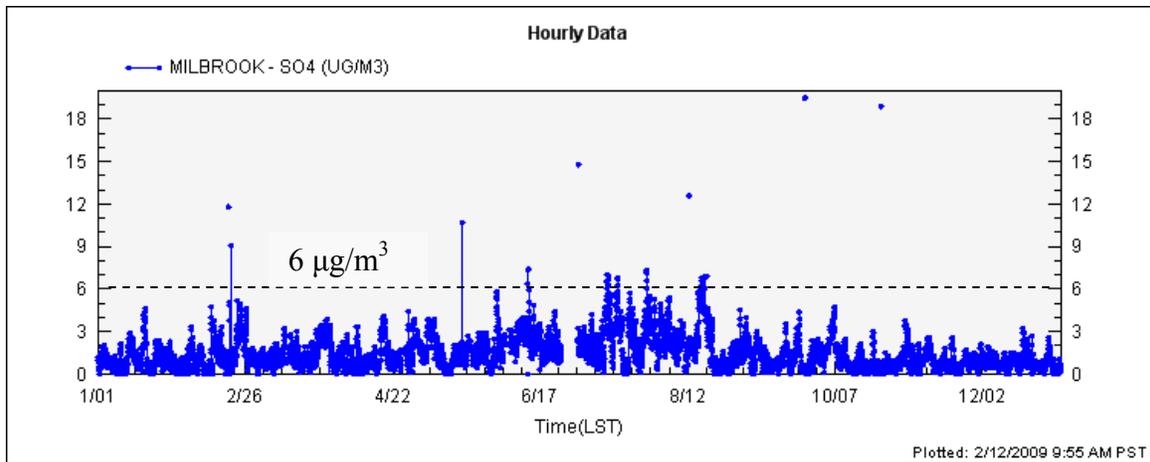


Figure 13: Millbrook Sulfate (2008): no large and sustained spikes were seen in sulfate data in 2008.

Organic Carbon at Duke Forest, near Durham, NC

Figure 14 shows the Organic Carbon via automated semi-continuous thermal optical analyzer. The data in Figure 14 was provided by Dr. Chris Geron and Dr. John Walker of the Atmospheric Protection Branch of US EPA. The monitoring occurred at Duke Forest, an EPA research site located about 25 miles directly Northwest of the Millbrook NC DAQ site in Raleigh, NC.

The highest OC daily average ($27 \mu\text{g}/\text{m}^3$) and the highest 3-hour average ($48.66 \mu\text{g}/\text{m}^3$) at Duke Forest were observed on June 12, 2008. Dr. Geron indicates in his paper¹ that the organic carbon has an average summer value of $3.70 \mu\text{g}/\text{m}^3$. Smoke plumes from the Evans Road Fire, and the Great Dismal Swamp fire are shown heading west toward the Duke Forest site on June 12, 2008 in Figure 15.

¹ Geron, Chris. Carbonaceous aerosol over a Pinus taeda forest in Central North Carolina, USA. *Atmospheric Environment*, 43 (2009) 959-969

Duke OC & EC data

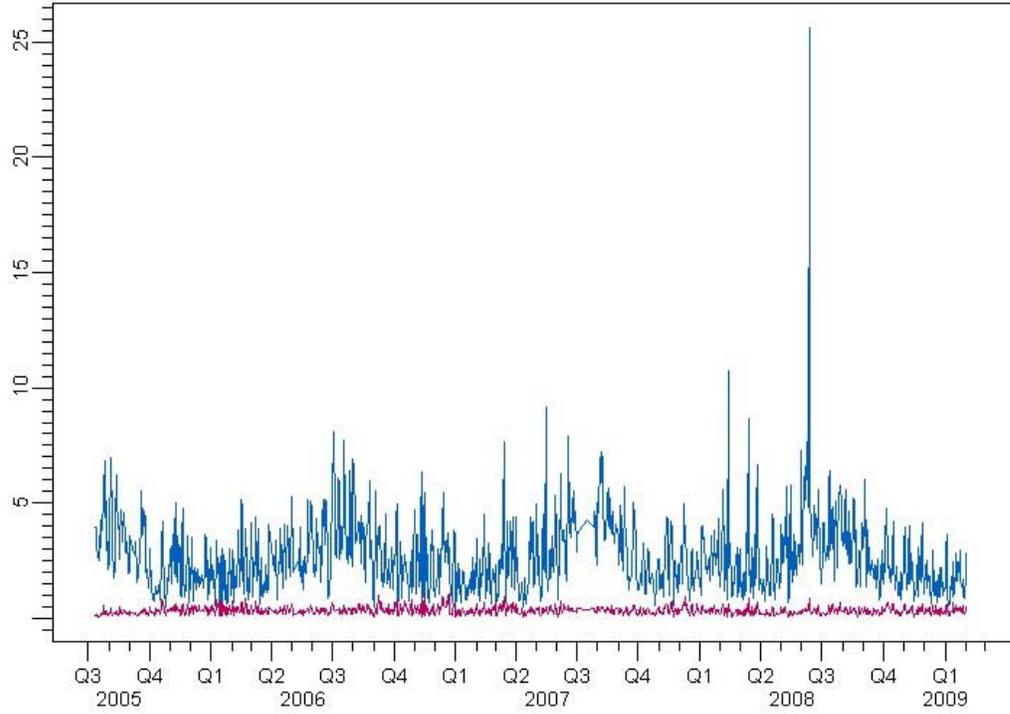


Figure 14: Duke Forest (Durham, NC) ¹: organic and elemental carbon for July 2005- February 2009. The OC is the blue line and the EC is the red line.



Figure 15: This picture was taken from the article by Dr. Chris Geron¹. This image was captured by the MODIS satellite. It shows two smoke plumes from the Great Dismal Swamp fire and the Evans Road Fire heading toward the Duke Forest site on June 12, 2008. The NC DAQ Millbrook monitoring station is approximately 25 miles east of the Duke Forest site.

Using the organic carbon and PM_{2.5} data from the Duke Forest site, the NC DAQ summarizes the relationship between PM_{2.5}, organic carbon, elemental carbon, and OC/EC ratio for June 12, 2008 in Figure 16. The spikes of PM_{2.5} (156 $\mu\text{g}/\text{m}^3$) and organic carbon (48.66 $\mu\text{g}/\text{m}^3$) occur at approximately 3:30 PM on 6/12/08. At this time the EC/OC ratio drops sharply to 0.015.

The organic mass in the fine particulate matter is approximately twice the measured organic carbon measurement (Turpin and Lim (2001)²). Many recent studies have indicated that the Organic Mass:Organic Carbon (OM:OC) ratio could be much higher than the factor of 2 assumed (personal communication by Dr. Chris Geron, US EPA, RTP, NC) in calculating the OMI. Hence, the total smoke contribution to particulate mass on June 12, 2008 is significant. A back of the paper calculation by NC DAQ indicates

² Turpin, B.J., Lim, H.J., 2001. Species contributions to PM_{2.5} mass concentrations: revisiting common assumptions for estimating organic mass. *Aerosol Science and Technology* 35(1), 602-610.

that smoke may have contributed *at least* 62% to the total particulate mass $\left[\frac{2 \times 48.66}{156} \times 100 \right]$. Moreover, sulfates levels were low during the fire episode.

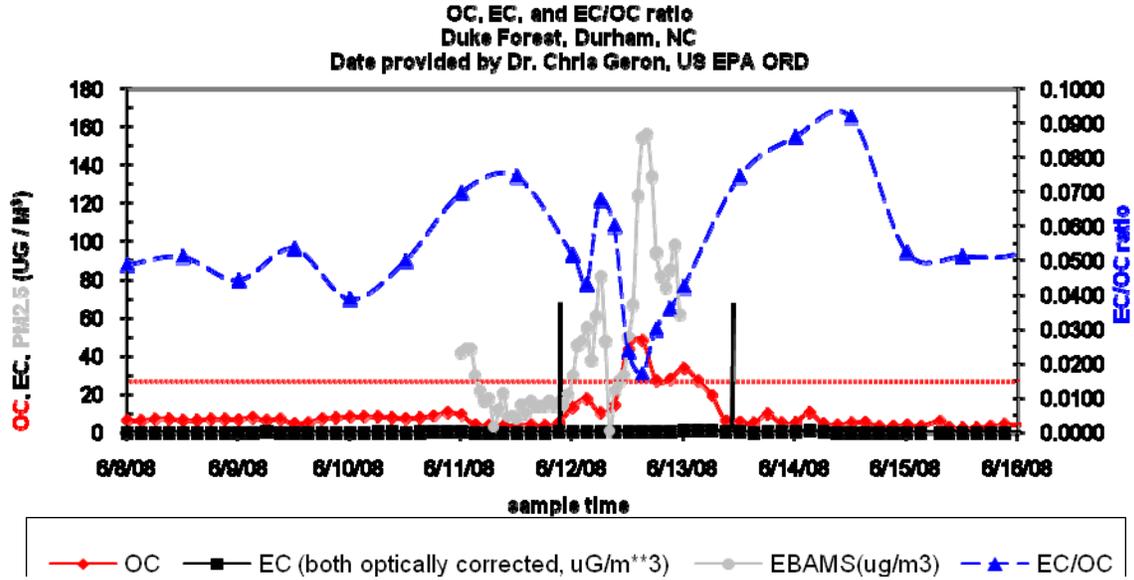


Figure 16: PM_{2.5} hourly concentrations, EC/OC, and carbon analysis at the Duke Forest site in Durham, NC during the Evans Road Fire impact in Raleigh/Durham, NC. The two vertical bars enclose the June 12, 2008 to June 13, 2008 impact.

Friday, June 13, 2008

June 13, 2008 was not a 1/3 run day for FRM monitors, however, Mendenhall is an everyday NC DAQ PM2.5 FRM monitoring site located in Greensboro, North Carolina. Mendenhall is approximately 200 miles from the Hyde County Fire. Figure 17 and Figure 18 indicate the impact of the Evans Road Fire on hourly PM2.5 measured by the TEOM. The TEOM-PM2.5 appears to rise the late morning of June 12, 2008 and the full impact was felt on June 13, 2008. The FRM measured a PM2.5 reading of 68.68 $\mu\text{g}/\text{m}^3$.

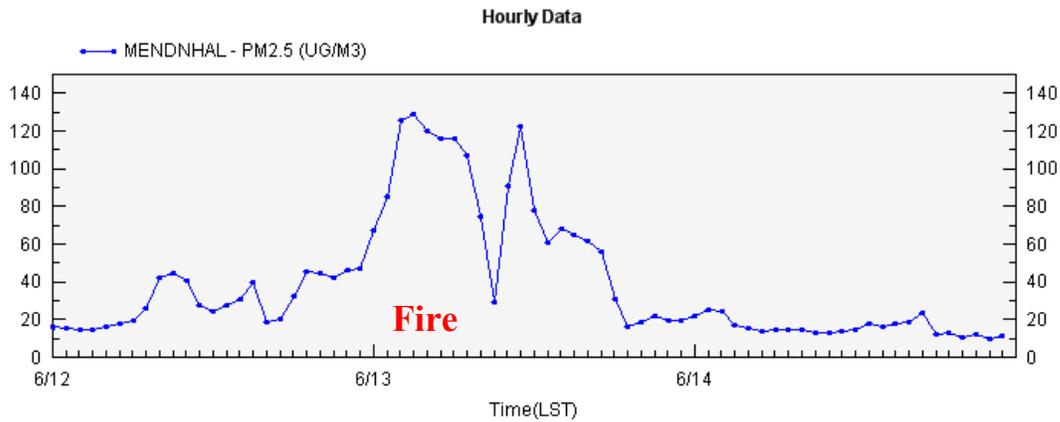


Figure 17: Mendenhall TEOM PM2.5 (June 13, 2008)

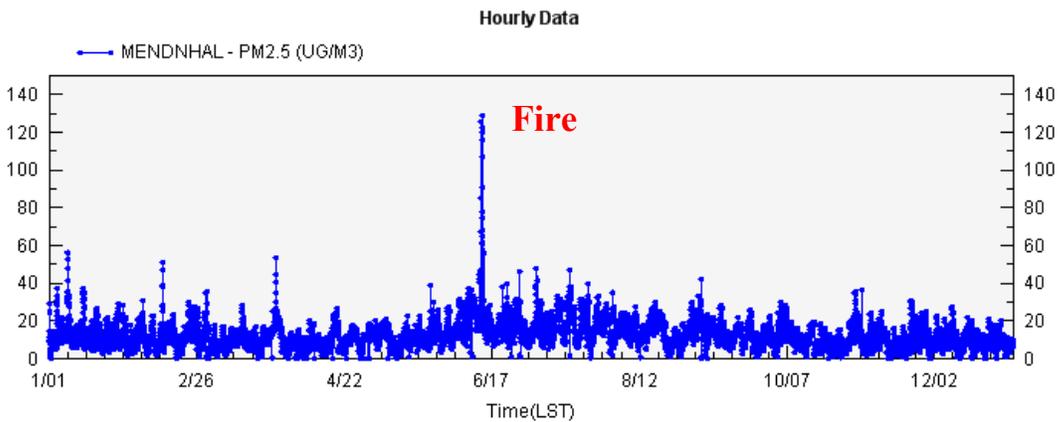


Figure 18: Mendenhall TEOM-PM2.5 (2008)

EVIDENCE OF TRANSPORT

Overall transport summary via satellite

For most of the fire incident, which began on June 1, 2008, the winds were headed out of the west, and took the smoke out to the Atlantic. On June 9, the smoke was still over the Atlantic as seen by the high Aerosol Optical Depth (AOD) in Figure 19.

Daily composited GASP AOD for June 09 2008

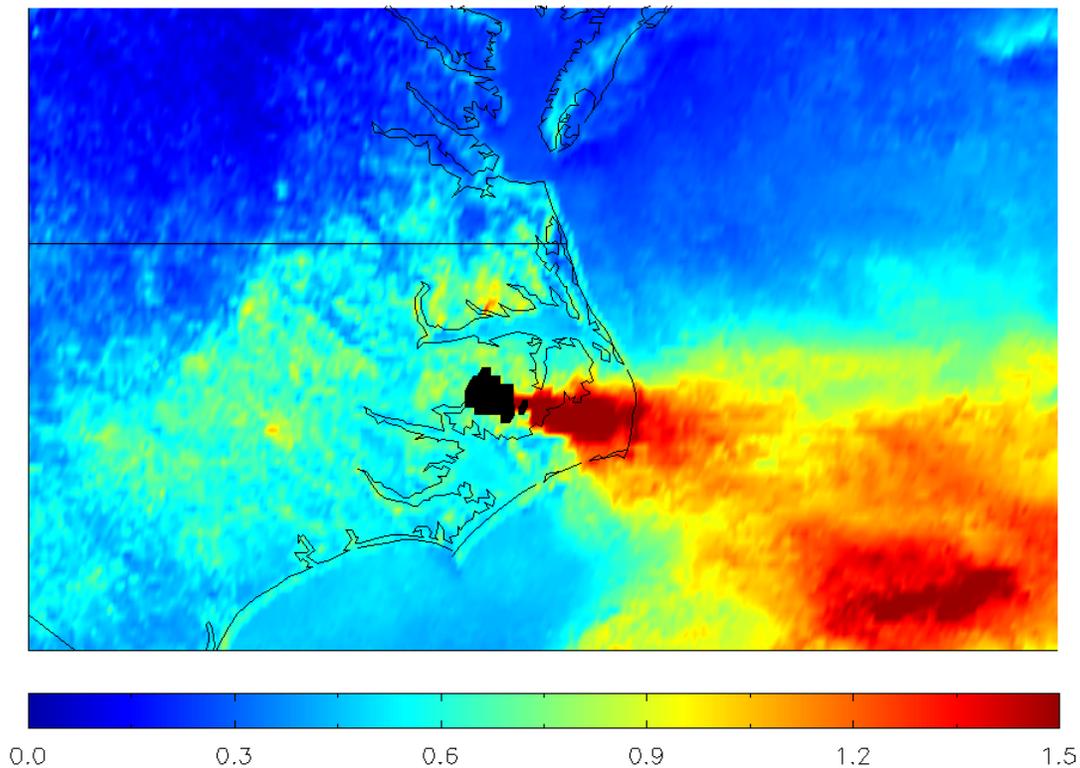


Figure 19: AOD on June 9, 2008 shows the smoke over the Atlantic. Image provided by Shoba Kundragunta of NOAA.

On June 11, these winds shifted inland, and AOD over large portions of North Carolina shows the plume location. (see Figure 20).

Daily composited GASP AOD for June 11, 2008

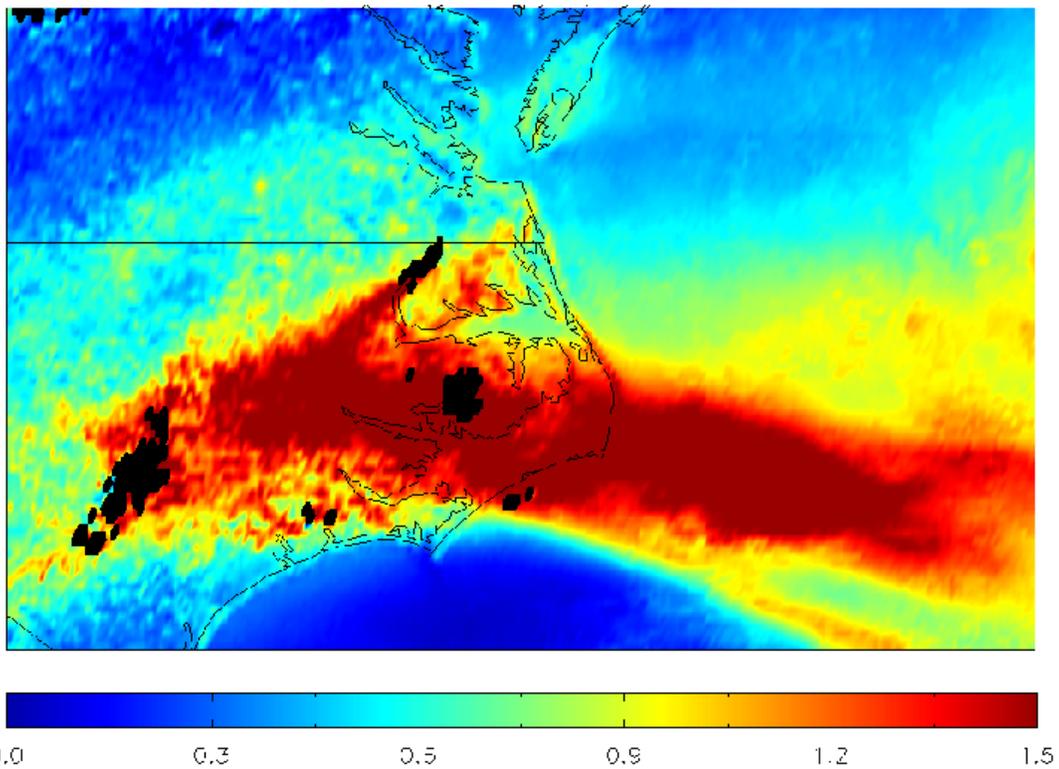


Figure 20: AOD on June 11, 2008 shows the smoke making it's way inland. Image provided by Shoba Kundragunta of NOAA.

The plumes from these fires (Evans Road Fire and Great Dismal Swamp fires) crossed several monitor locations in the State of North Carolina on June 12, 2008 (see Figure 21).

Daily composited GASP AOD for June 12 2008

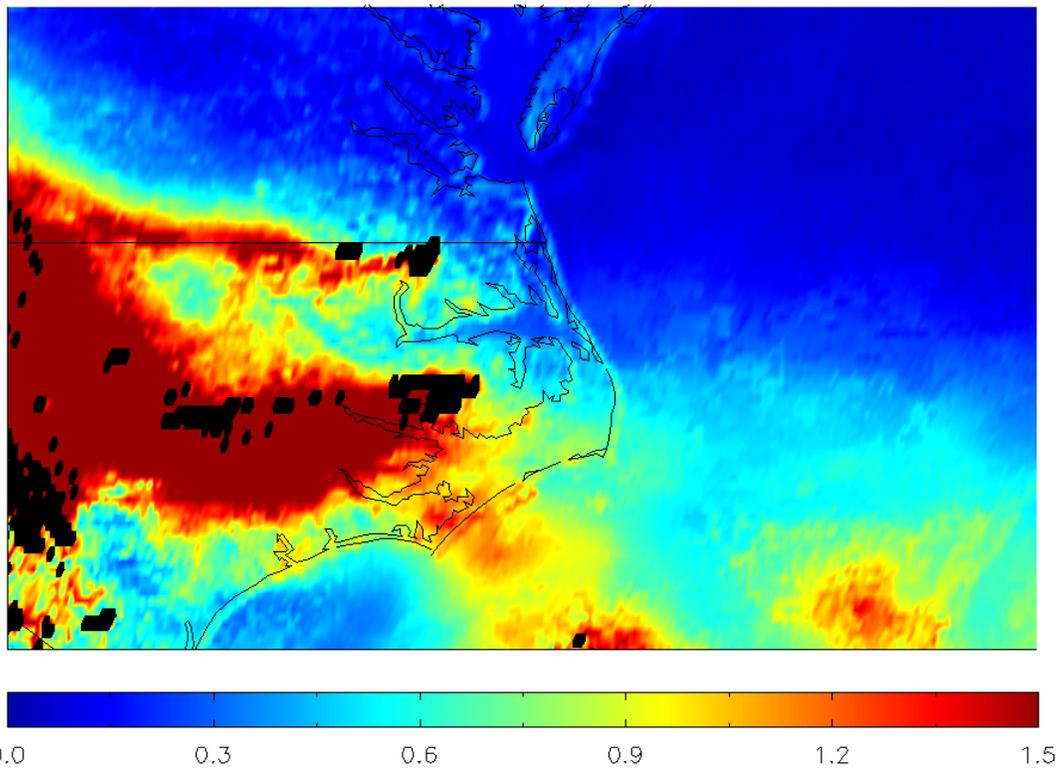


Figure 21: AOD on June 12, 2008 shows the smoke over vast regions of North Carolina. Image provided by Shoba Kundragunta of NOAA.

On June 13, 2008, the smoke reached as far as Guilford County, which is located in the central region of North Carolina.

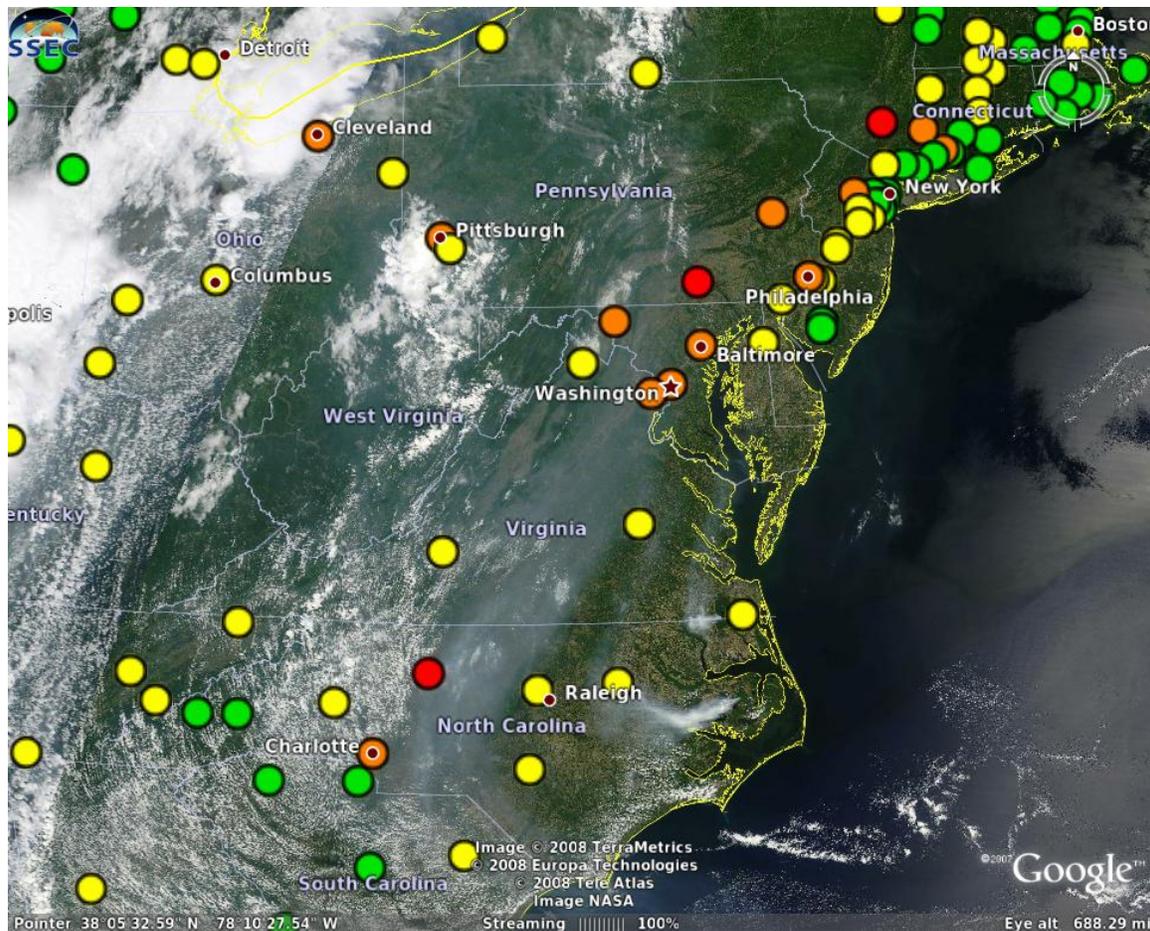


Figure 22 Google_modis_terra_airnow composite for June 13, 2008 (Source: smog blog). The Great Dismal Swamp fire (top) and the Evans Road Fire in North Carolina (bottom).

The curving smoke bands on June 13, 2008 reached well into the central areas of the State. Figure 23 explains that the smoke bands were formed by the curving trajectories originating in the area of the smoke, which lay over the Atlantic on June 9, 2008.

NOAA HYSPLIT MODEL source 500 m AGL
Backward trajectories ending at 21 UTC 13 Jun 08
NAM Meteorological Data

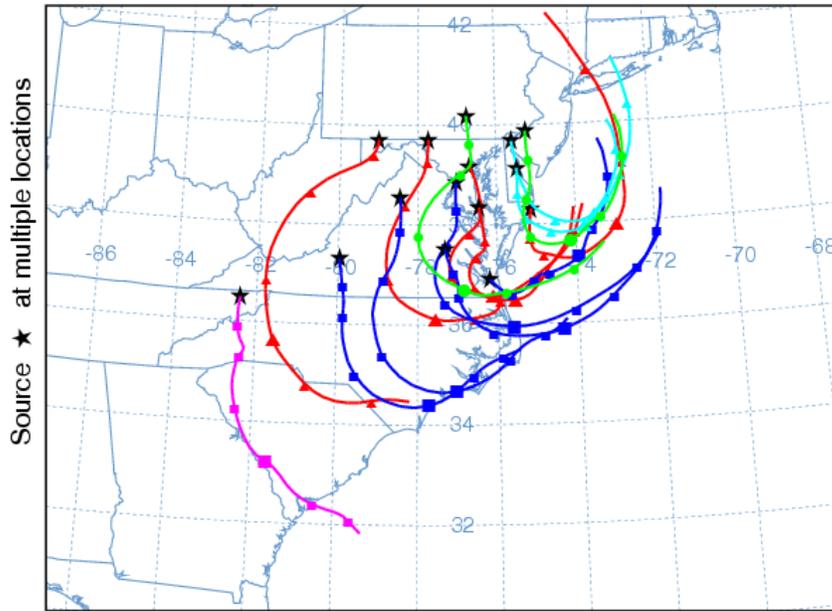


Figure 23: Curving trajectories out of the Atlantic transported the smoke over the Atlantic inland over North Carolina.

Ground level transport data

Wednesday, June 5 (Jamesville, 371170001, 91.88 $\mu\text{g}/\text{m}^3$)

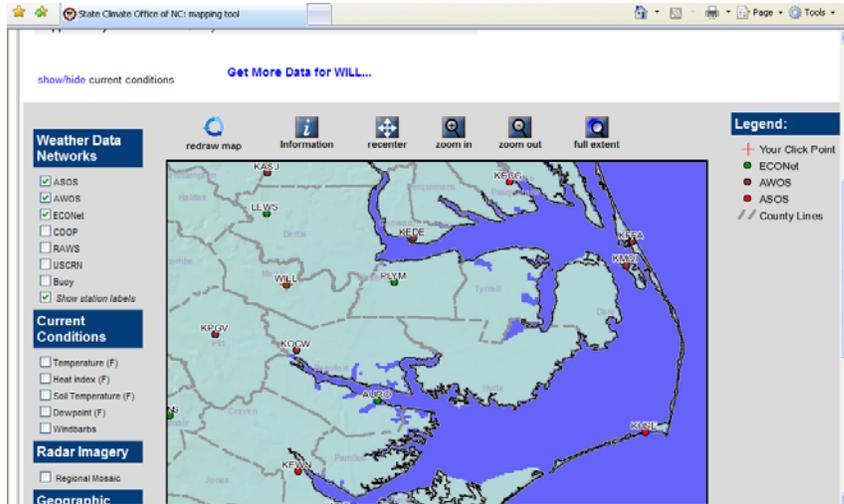


Figure 24: A ground station in Martin County where the Jamesville monitor is located is part of the State Climate Office (<http://www.nc-climate.ncsu.edu/cronos/>). Climate Station is identified as WILL (Figure 24).

Winds were out of the East beginning around 4 PM. And, around 6 PM, back trajectories (Figure 2) begin to originate from over the smoke in Hyde County (Figure 1) and last until the end of June 5, 2008. Back Trajectories to Jamesville were run at 100m and 200m on June 5, 2008 at 4AM, 8AM, 12PM, 4PM, 8PM, 10PM, and 11PM.

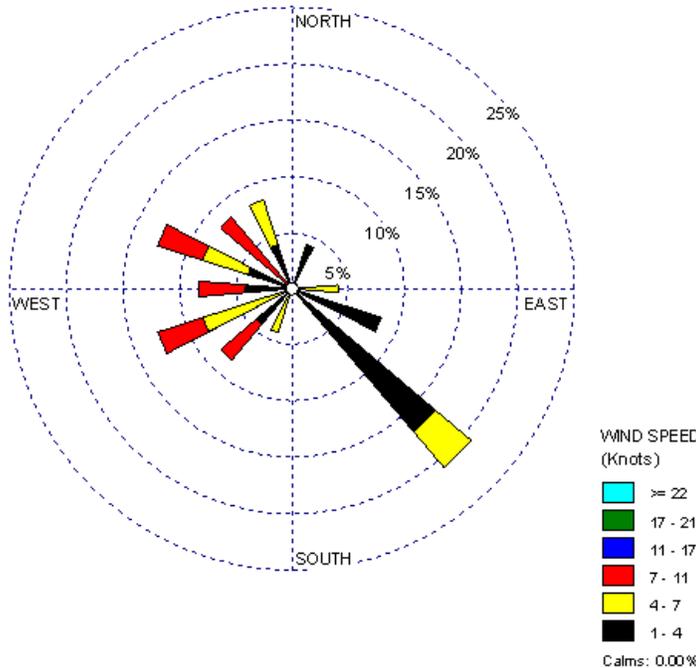


Figure 25: Jamesville Wind Rose (June 5, 2008; 1 Knot \approx 1mph)

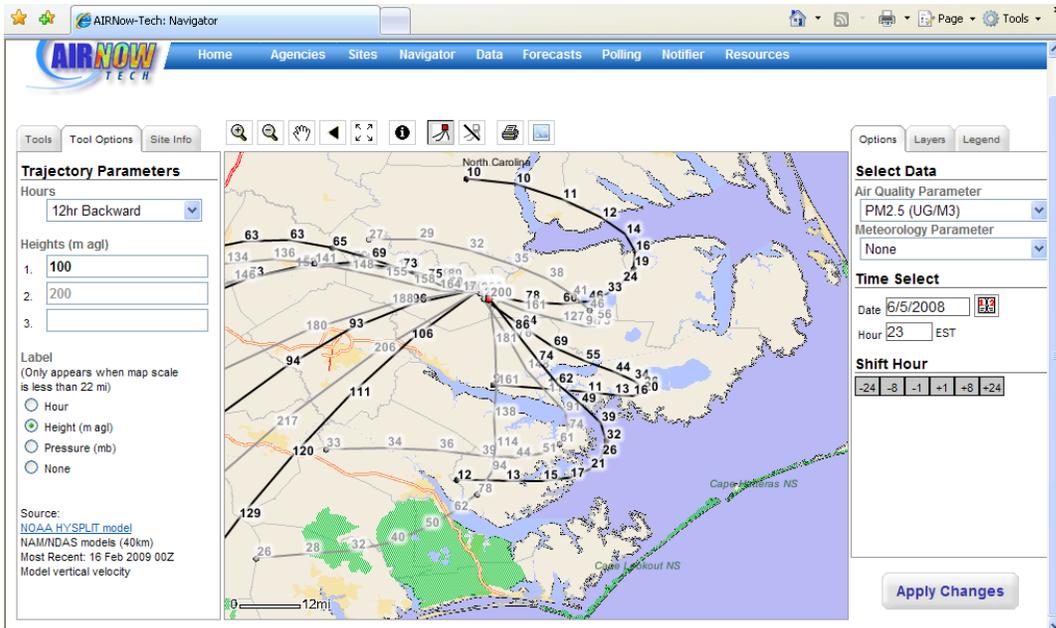


Figure 26: 12-hr back trajectories to Jamesville on June 5, 2008.

The 12-hr forward trajectories from the fire area in Hyde county to the Jamesville Monitor were run at the 100m and 200m starting heights on June 5, 2008 on 2AM, 6AM, 10AM, 2PM, 3PM, and 4PM. The trajectories begin to turn inland towards Jamesville around 1 PM.

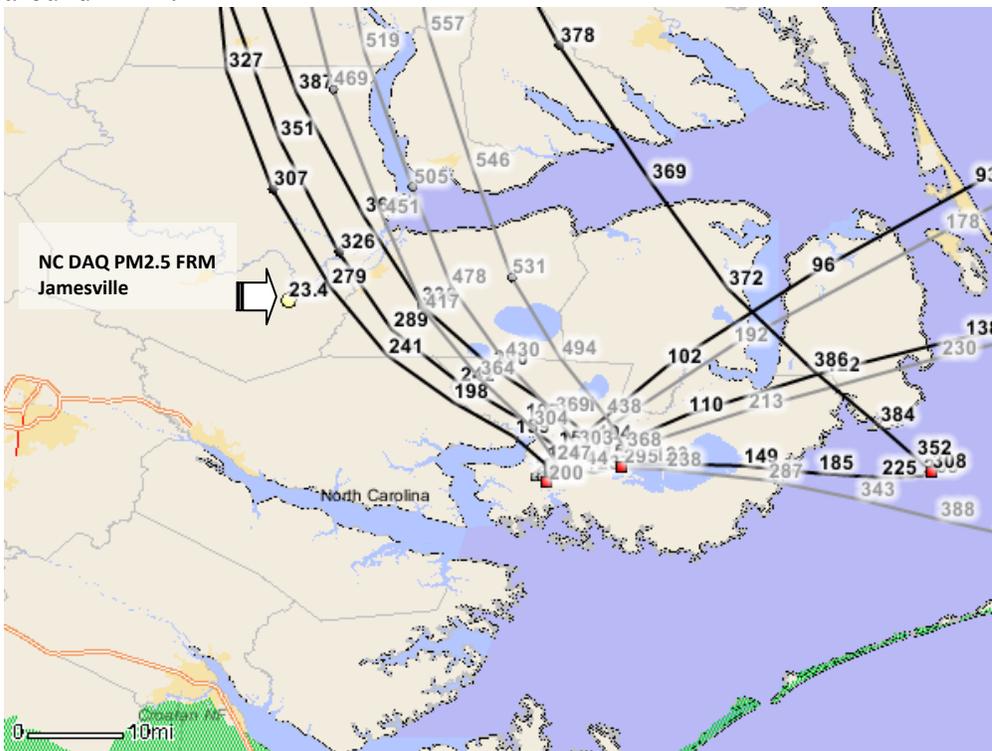


Figure 27: Forward trajectories to Jamesville on June 5, 2008. Obtained using the Navigator tool in Air Now Tech.

Wednesday, June 11 (Greenville, Ag. Ctr., Lenoir College, and Dillard School)

Greenville (June 11, 2008; 107.63 $\mu\text{g}/\text{m}^3$; 371470005)

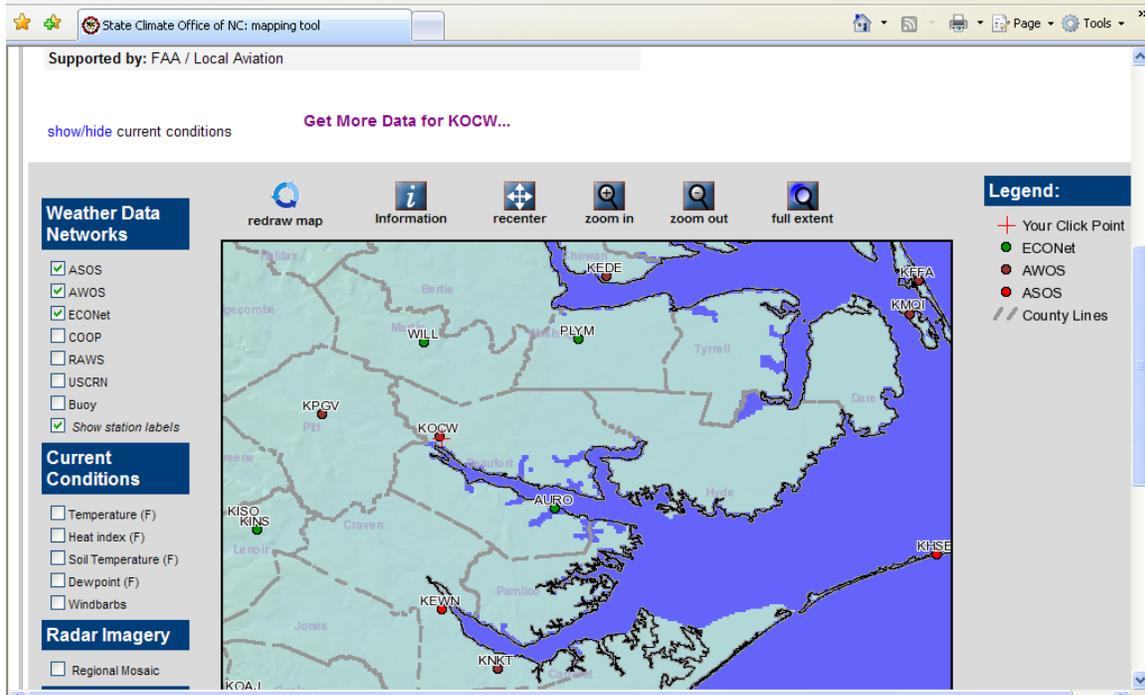


Figure 28: Greenville surface wind station on June 11, 2008. Station name is KOCW.

Surface winds became easterly on June 11, 2008. Greenville backward trajectories at 200 m and 500 m for 4 AM, 8 AM, 12 PM, 2 PM, 4 PM, 6 PM, and 8 PM indicate that the winds gradually became easterly. GASP AOD indicates large plume over Greenville on June 11, 2008. A comparison of the GASP AOD and Greenville back trajectories indicate that air arriving in Greenville throughout June 11, 2008 traveled through the smoke.

Daily composited GASP AOD for June 11, 2008

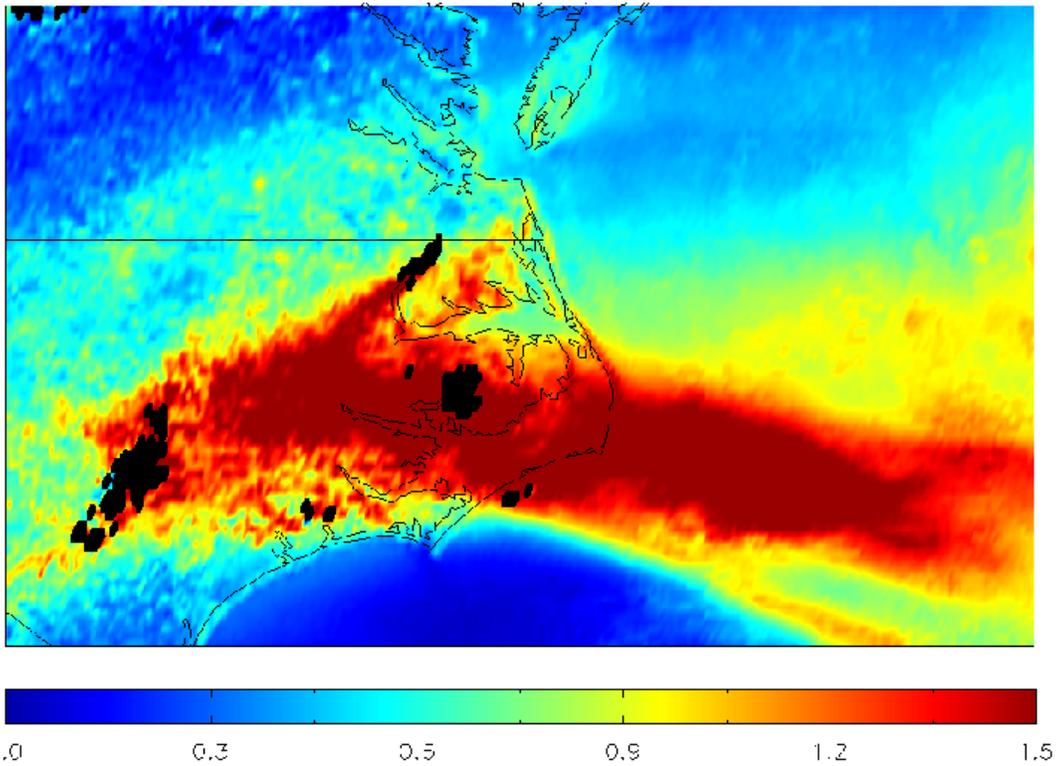


Figure 29: GASP AOD on June 11, 2008 shows a large plume over Greenville.

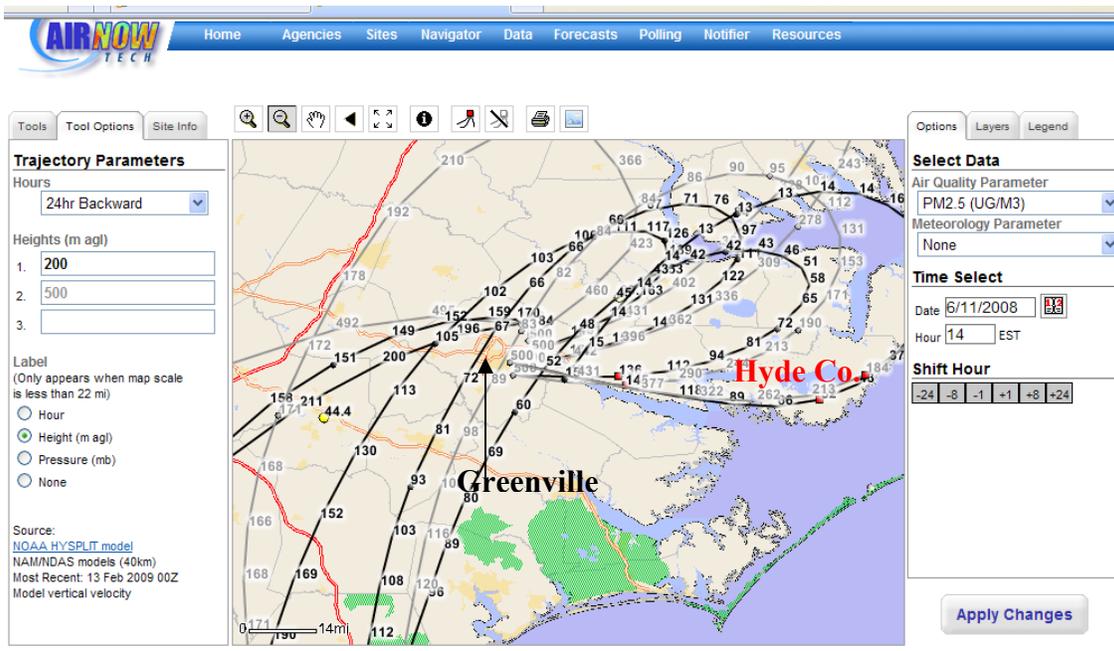


Figure 30: Greenville backward trajectories at 200 m and 500 m for 4 AM, 8 AM, 12 PM, 2 PM, 4 PM, 6 PM, and 8 PM. The trajectories loop into Hyde County bringing smoke to the Greenville monitor.

Wednesday, June 12 (Milbrook and Pittsboro)

Millbrook (June 12, 2008, 99.04 $\mu\text{g}/\text{m}^3$, 371830014)

The surface winds across the state (Figure 32) were directly out of the East on June 12, 2008.

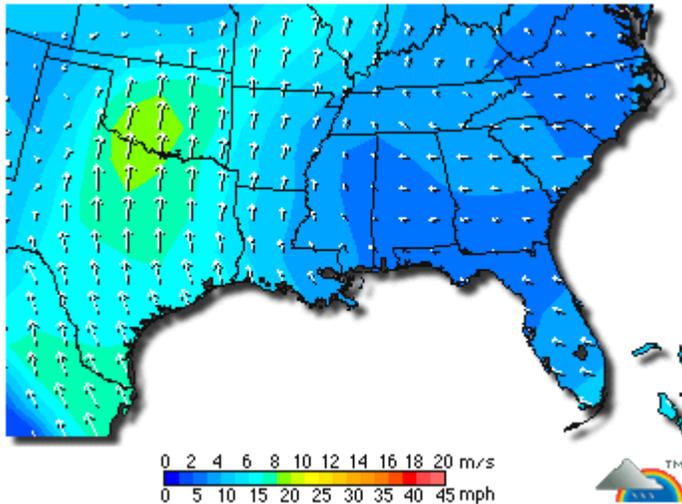


Figure 32: On June 12, the wind direction was directly out of the east (weather underground).

Figure 33 is a wind rose for RDU airport (KRDU) for June 11, 2008 to June 12, 2008. KRDU is part of the statewide network of meteorological stations. RDU is located approximately 10 miles west of Millbrook. The surface winds at RDU airport were mostly from the east.

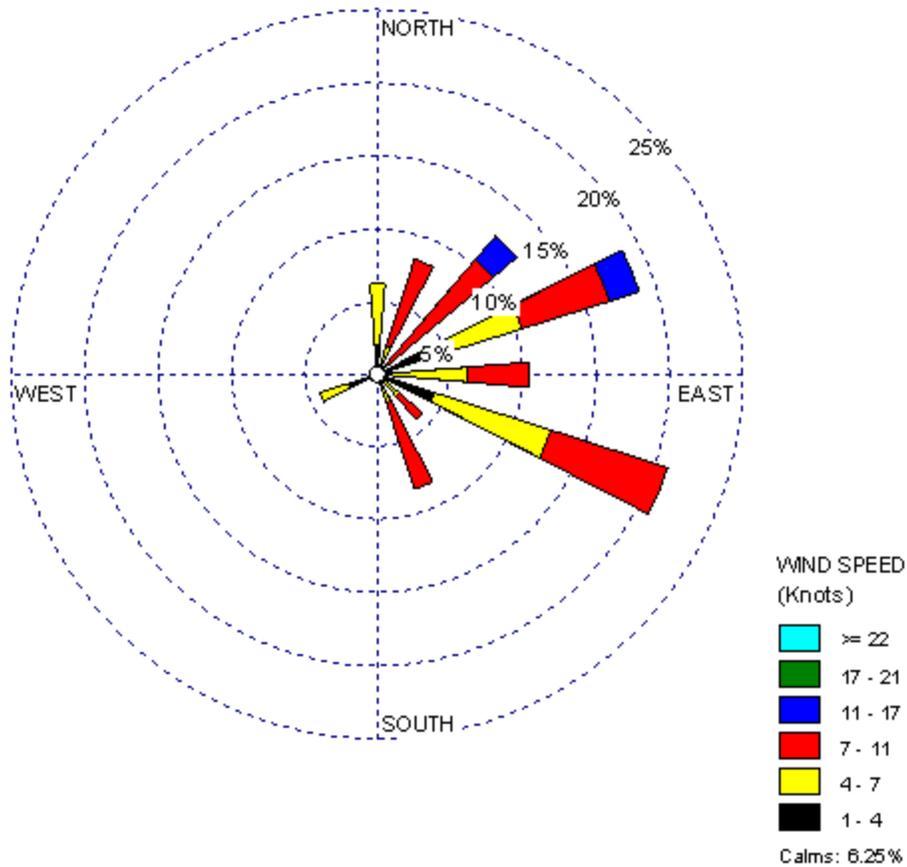


Figure 33: Wind rose for RDU airport for June 11-12, 2008. RDU is approximately 10 miles west of Millbrook.

The backward trajectories to the Raleigh Millbrook PM_{2.5} everyday FRM came directly from the fire area. These trajectories were run at 200m and 500m heights at 4 AM, 8AM, 2PM, and 8PM. The Raleigh Millbrook PM_{2.5} TEOM was reading 158.5 μg/m³ on June 12, 2008 at Noon (Figure 34).

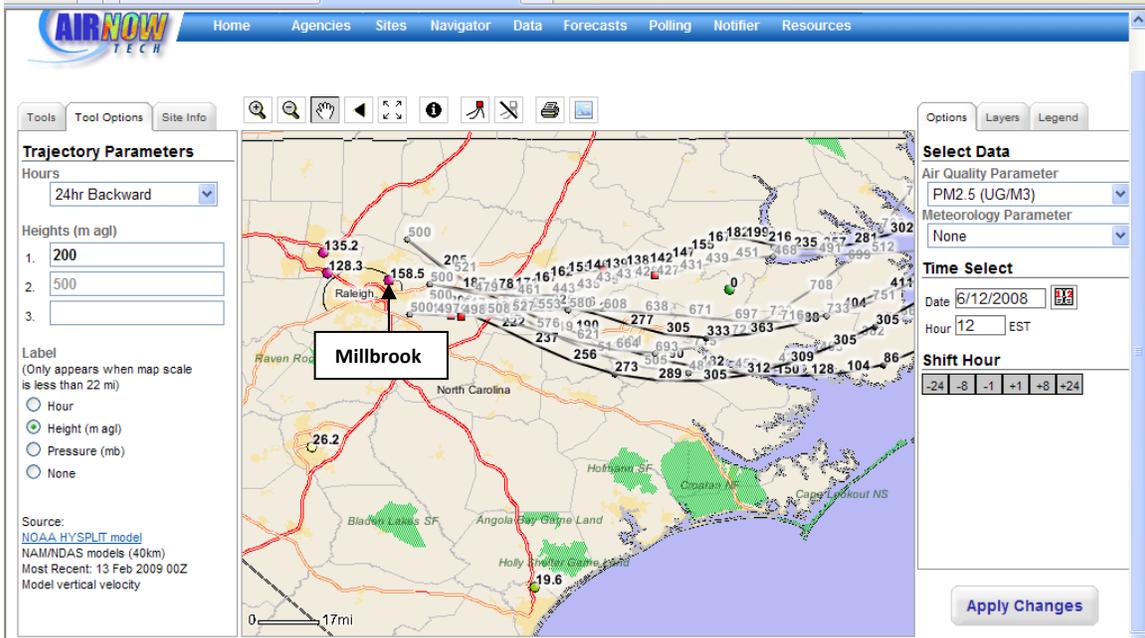


Figure 34: 24-hour back trajectories to Raleigh on June 12, 2008.

24-hr forward trajectories at starting heights of 200 and 400 meters to Millbrook from the Evans Road Fire were run at 2AM, 6AM, 12PM, and 4PM on the day before the exceedance of $99.04 \mu\text{g}/\text{m}^3$ on June 12, 2008 (Figure 35).

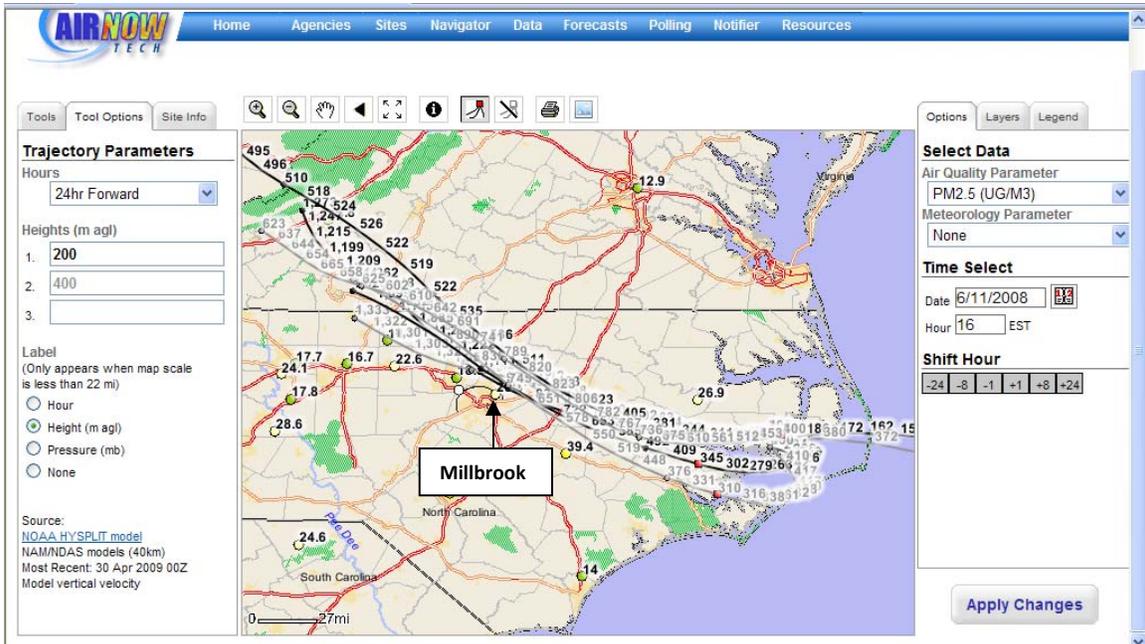


Figure 35: 24-hour forward trajectories to Millbrook from the Evans Road Fire location. Start times were 2AM, 6AM, 12 Noon, and 4PM on June 11, 2008.

Pittsboro (June 12, 2008, 71.8 $\mu\text{g}/\text{m}^3$, 370370004)

Surface winds are represented in Figure 36 using wind speed/direction data from RDU airport (KRDU) for June 11, 2008 to June 12, 2008. KRDU is part of the statewide network of meteorological stations. RDU is located approximately 20 miles Northeast of Pittsboro. The surface winds at RDU airport were mostly from the east.

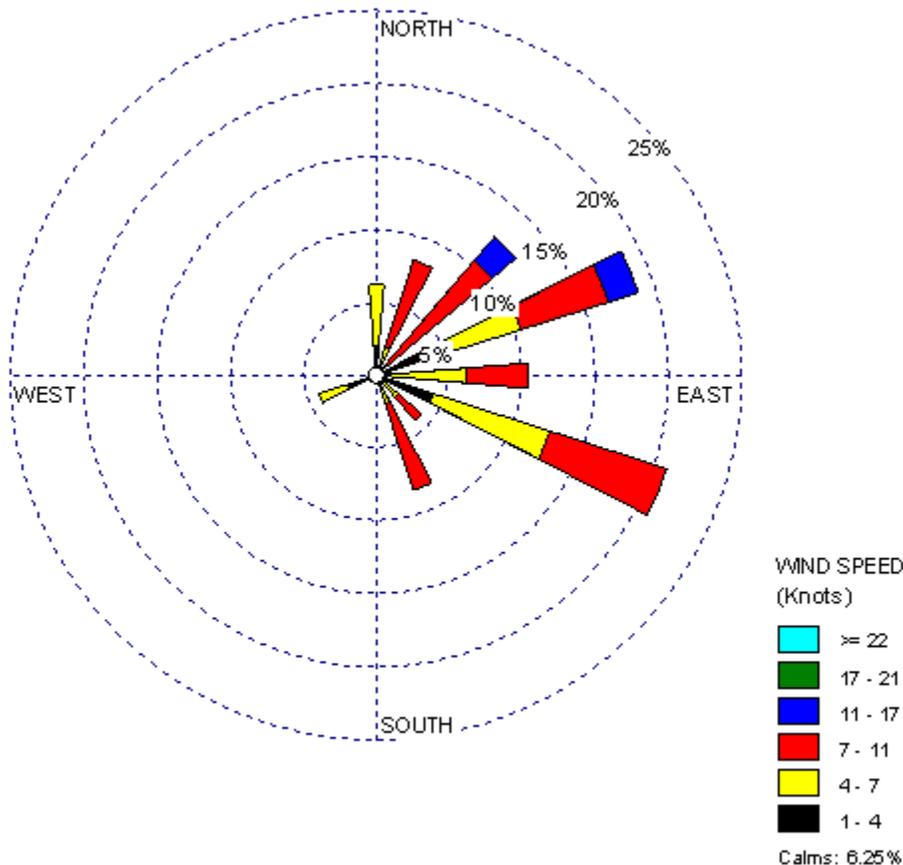


Figure 36: Wind rose for RDU airport for June 11-12, 2008. RDU is approximately 20 miles Northeast of Pittsboro.

24-hr backward trajectories (Figure 37) were run at start heights of 300 m and 600 m at start times of 2AM, 6AM, 10AM, 2PM, and 6PM. The smoke plume's arrival in the Triangle Area (Raleigh, Cary, and Chapel Hill) created large gradients in concentration on June 12, 2008. The surface map of hourly PM_{2.5} monitors in AirNow Navigator shows a monitor in South Carolina reading 18.7 $\mu\text{g}/\text{m}^3$ to monitors in North Carolina reading 96.5 $\mu\text{g}/\text{m}^3$ at 6PM of 6/12/08. This spatial gradient indicates that the smoke was at ground level and concentrated over Pittsboro Raleigh, Durham, and Chapel Hill on June 12, 2008, and, on June 13, 2008, it reached further west to Greensboro, NC.

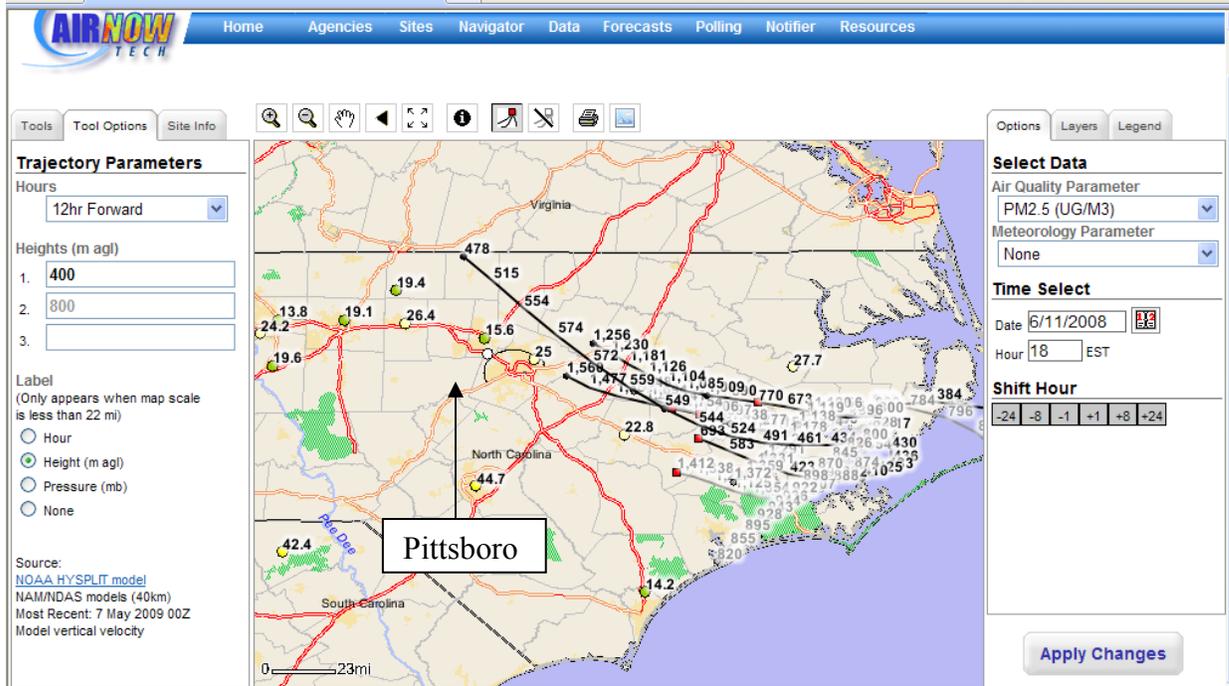


Figure 38: 24-hr Forward trajectories to Pittsboro indicate that the air from the fire region was drifting towards the Pittsboro monitor in Chatham County.

Wednesday, June 13 (Mendenhall)

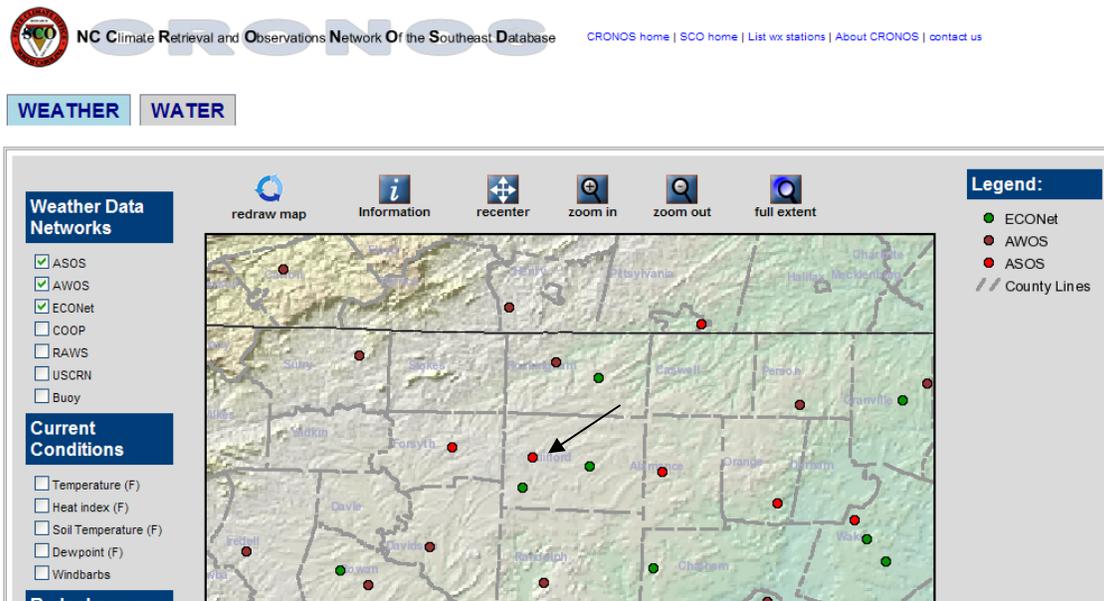


Figure 39: The circles are Met Stations that feed a statewide database (<http://www.nc-climate.ncsu.edu/cronos/>). Ground Station Wind Speed and direction on June 13, 2008 -- Greensboro where Mendenhall is located.

The Met Station near Mendenhall is KGSO. The wind rose from this met station is shown in Figure 40. The predominant ground level wind direction (south/southeast) is due to the curving trajectories originating from in the fire area (Figure 41). In Figure 41, the large concentration of TEOM-PM_{2.5} monitors around the Mendenhall site are reading well over the daily PM_{2.5} FRM standard of 35 $\mu\text{g}/\text{m}^3$. Forward trajectory analysis is presented in Figure 42.

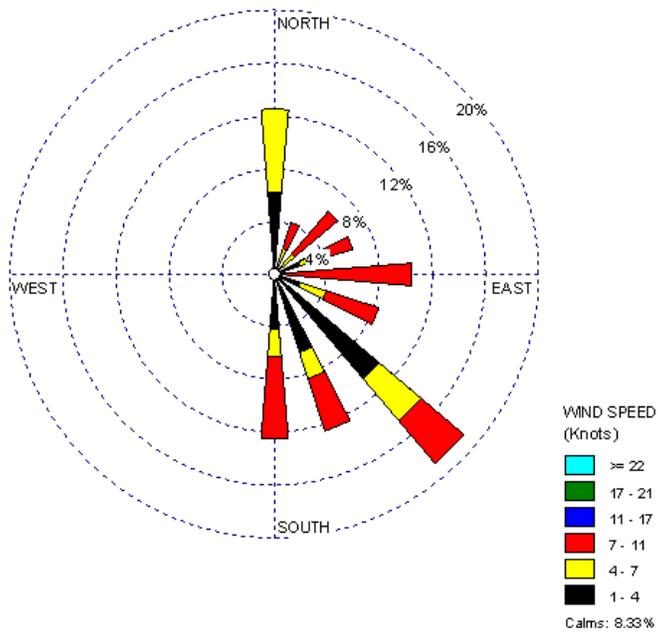


Figure 40: Wind Rose for KGSO near the Mendenhall Monitoring Station.

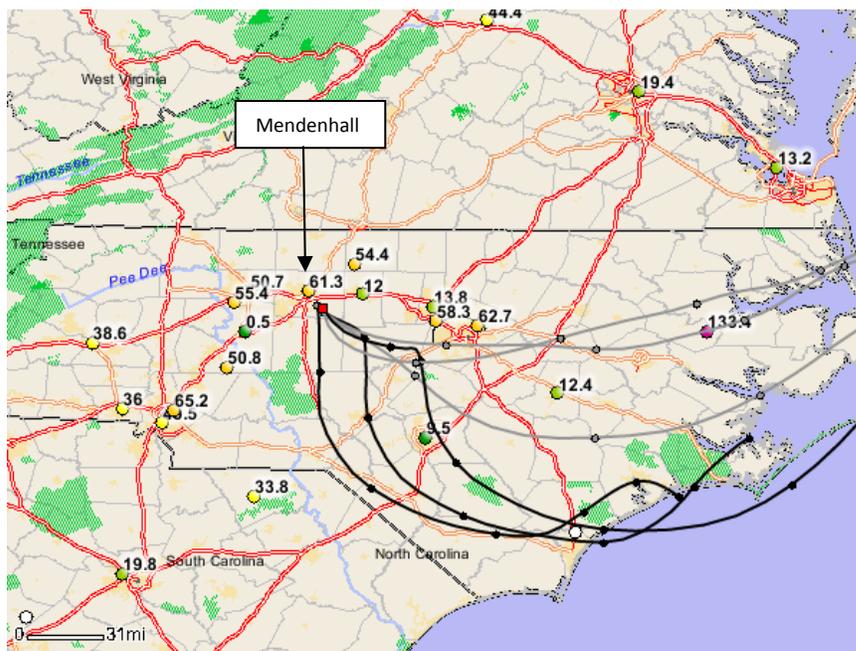


Figure 41: Ground level PM_{2.5} stations and trajectory analysis. Mendenhall TEOM reads 61.3 ug/m³ at 4PM. On June 13, 2008, the trajectories to Mendenhall (Greensboro) were run at 8 AM, 12 NOON, and 4 PM. The darker trajectories are 100 m; the others are 1000 m.

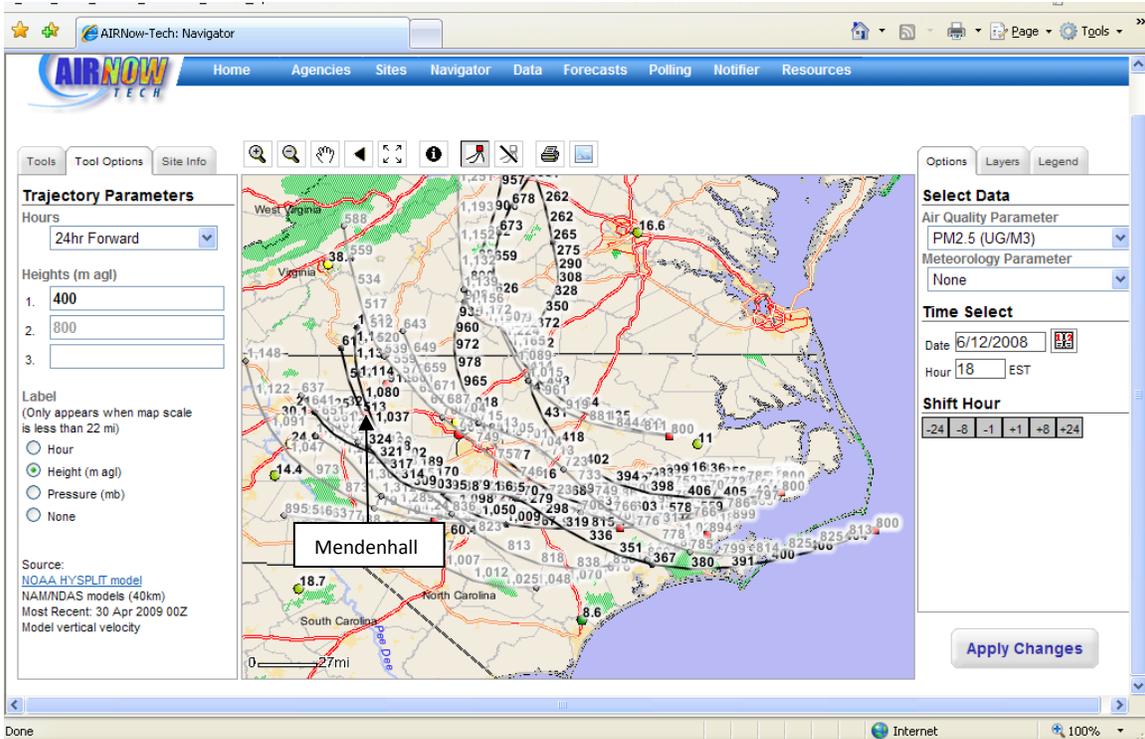


Figure 42: Ground level PM_{2.5} stations and forward trajectory analysis. Forward trajectories start from the Evans Road Fire on 6/12/08 at 2AM, 6AM, 10AM, 2PM, and 6PM. The endpoint of the trajectory represents the air parcel location on 6/13/08. Mendenhall (Greensboro, NC) exceeded the daily PM_{2.5} standard at 68.68 $\mu\text{g}/\text{m}^3$ on 6/13/08.

ATYPICAL ANALYSIS

The atypical analysis shows, quite thoroughly, the extent of the influence to the monitoring data caused by the Evans Road Fire. Shown in Table 2 are the actual values measured (2008 Exceptional Candidate) and their percentile ranking. The actual values are also compared to the benchmark 84th and 95th percentile. The values were flagged in AQS with an “e” flag for Forest Fire. EPA concurrence for the forest fire flag is sought.

Table 2: Atypical Analysis for NC DAQ PM2.5 FRM samples affected by the Evans Road Fire

Site Name	Site Id	Historical Percentiles from 2005 to 2008 (4 years)							Exceedances (2005-2008)	2008 Exceptional Candidate	Ratio to percentiles		Flag
		0%	25%	50%	75%	84%	95%	100%			84%	95%	
Dillard	371910005	2.4	9.08	13.2	16.8	19	23.3	36.67	36.67	36.67	1.93	1.57	e
Lenoir	371070004	2.8	8.05	11.21	15.4	17.5	22.31	38.33	38.33	38.33	2.19	1.71	e
Mendenhall	370810013	2.1	8.68	11.9	16.6	18.97	26.3	68.68	68.68	68.68	3.62	2.61	e
Pittsboro	370370004	1.1	9.05	11.37	14.6	19.41	21.7	71.79	71.79	71.79	3.70	3.30	e
A g. Ctr.	371470006	2.63	7.61	11.61	14.12	20.33	28.99	72.93	72.93	72.93	3.58	2.51	e
Jamesville	371170001	2.71	7.1	10.87	14.05	16.4	21.89	91.88	91.88	91.88	5.60	4.19	e
Millbrook	371830014	2.6	8.76	12.5	16.9	19.52	23.51	99.04	99.04	99.04	5.07	4.21	e
Greenville	371470005	3.17	7.8	11.7	14.9	16	22.47	107.63	107.63	107.63	6.73	4.79	e

BUT-FOR USING ORGANIC CARBON AND STATISTICAL MODELS

To demonstrate that the Evans Road wildfire in Hyde County caused exceedances of the daily fine particle standard of 35 micrograms per cubic meter at the monitoring sites listed in table one, we need to find a way to either estimate (1) how many fine particles the wildfires contributed to the fine particle concentration measured at the monitoring sites in Table one and/or (2) what the fine particle concentration value would have been on the exceedance dates if the wildfires had not been present.

The NC DAQ used both approaches to show what the concentration would have been at the various monitoring sites in Table 1 without the fire impact. The first approach is to use statewide organic carbon in PM_{2.5} to determine the organic mass increment added to the fine particulate concentration by the wildfire. The second approach is presented in a different section and it utilizes a statistical model to predict an uninfluenced daily concentration with 99% confidence bounds.

How many fine particles the wildfire contributed

The exceedances of the PM_{2.5} daily standard would not have occurred but for the Evans Road Fire impact. The organic mass index or OMI removes nearly 50-70 percent of the measured PM_{2.5} gravimetric mass per cubic meter of air volume for the Evans Road Fire samples. Both estimates (50% and 70% OMI reductions) are used because Andrews, et. al (2000)³ has noted that the *differences* between gravimetric mass and reconstructed mass were *greatest* when aerosol was influenced by *forest fire emissions* and aged anthropogenic pollutants. The actual values and the adjusted values of PM_{2.5} FRM concentrations (i.e, adjusted for the OMI) are shown in Table 3.

Table 3: North Carolina PM 2.5 (µg m⁻³) Samples adjusted for the OMI of the Evans Road Fire

Site Name	County	Monitor	Actual	Adjusted ¹ OMI = 46	Adjusted ² OMI = 66
Dillard School	Wayne	371910005	36.67	18.33	11.01
Lenoir College	Lenoir	371070004	38.33	19.17	11.49
Mendenhall	Guilford	370810013	68.68	34.34	20.60
Pittsboro	Chatham	370370004	71.8	35.9	21.54
Ag Center	Pitt	371470006	72.93	36.47	21.88
Jamesville	Martin	371170001	91.88	45.94	27.56
Millbrook	Wake	371830014	99.04	49.52	29.71
Greenville	Pitt	371470005	107.63	53.81	32.28

¹PM_{2.5} FRM_{adjusted} ≈ actual value × 0.5, ²PM_{2.5} FRM_{adjusted} ≈ actual value × 0.3

The expected or typical June 12 values at these sites are provided in the Statistical “but for” section following this section.

³ Andrews, E., Saxena, P., Musarra, S., Hildemann, L. M., Koutrakis, P., McMurry, P. H., Olmez, I., and White, W. H. (2000). Concentration and Composition of Atmospheric Aerosols from the 1995 SEAVS Experiment and a Review of the Closure between Chemical and Gravimetric Measurements, *J. Air Waste Manag. Assoc.* 50:648–664.

Using the Duke Forest organic carbon data collected on June 12, 2008 (Table 4), the NC DAQ obtained two estimates of OMI. The OMI was 46 $\mu\text{g}/\text{m}^3$ using the daily OC average, and 66 $\mu\text{g}/\text{m}^3$ for the times (12PM – 12AM) of greatest impact of the Evans Road fire.

Table 4: Duke Forest Organic Carbon (Dr. Chris Geron, US EPA ORD, RTP, NC)

Date	Time	Organic Carbon ($\mu\text{g m}^{-3}$)
6/12/08	12:00 AM	13.53
6/12/08	3:00 AM	17.83
6/12/08	6:00 AM	10.48
6/12/08	9:00 AM	14.64
6/12/08	12:00 PM	44.17
6/12/08	3:00 PM	48.66
6/12/08	6:00 PM	27.53
6/12/08	9:00 PM	28.2
6/13/08	12:00 AM	33.96
Daily Average OC		26.5
Average (12PM – 12 AM)		36.5

Many recent studies have indicated that the Organic Mass:Organic Carbon (OM:OC) ratio could be much higher than the factor of 2 assumed (personal communication by Dr. Chris Geron, US EPA ORD, RTP, NC) in calculating the OMI. The organic mass increment (OMI) to the fine particle concentration (PM2.5) was calculated using the following equation⁴:

$$\text{OMI} = (\text{OC}_{\text{observed}} - \text{OC}_{\text{average}}) \times 2$$

Table 5: PM2.5 adjustment factors using the OMI

Organic Carbon ($\mu\text{g m}^{-3}$) at Duke Forest (Durham, NC)		OMI ($\mu\text{g m}^{-3}$)	Adjustment Factor
Observed (6/12/08)	Summer Avg (2005-2008)		
26.6	3.70	46	0.5
36.5		66	0.3

The two OMI's adjust the PM2.5 FRM concentration at Millbrook, the closest NC DAQ site to Duke Forest, as follows:

$$\text{PM}_{2.5} \text{ FRM}_{\text{adjusted}} = 99.04 - 46 = 52.04 \mu\text{g}/\text{m}^3 (\approx 0.5 \times \text{actual value})$$

$$\text{PM}_{2.5} \text{ FRM}_{\text{adjusted}} = 99.04 - 66 = 33.04 \mu\text{g}/\text{m}^3 (\approx 0.3 \times \text{actual value})$$

We assume similar OMI adjustment factors as Millbrook (0.5 and 0.3) for the other NC DAQ sites affected by the smoke from the Great Dismal Swamp Fire and the Evans Road Fire.

⁴ Daniel Garver, EPA 2009 Region 4 Presentation (<http://www.epa.gov/region4/sesd/training/air/>)

Statistical “But For”

Linear models can indicate with probability bounds the concentrations that would have occurred at the monitoring sites without the wildfire influence. The linear model is based on several years of historical monitoring data for the same quarter in which the exceedance occurred. Explanatory variables included in the model are wind speed, wind direction, precipitation, precipitation lag, ambient temperature, relative humidity, etc. The modeled concentration (expectation) is capped with a 99% (UPLimit.99) confidence level that has only a 1% chance of being exceeded at that site. Table 6 was generated using the output of the linear model:

Table 6: Statistical model predictions of PM2.5 FRM values without Evans Road Fire influences

RowNames	actual	expectation	UPLimit.99	Df	R.2
PG.event	72.93	14.83	28.4	22	0.5461
UP.event	71.79	18.17	27.46	98	0.5399
GV.event	107.63	13.22	23.58	106	0.3536
MH.event	68.68	17.14	28.6	305	0.3734
ML.event	99.04	16.86	26.77	347	0.4438
JV.event	91.88	11.52	23.2	112	0.1393
DM.event	36.67	14.6	26.54	92	0.307
LC.event	38.33	11.97	23.86	106	0.2046

The actual values had a 1% chance of exceeding the 99% upper confidence limit; therefore, they are unlikely to represent normal pollution levels at the site unless they are influenced by an exceptional event. The R.2 is an indication of the predictive power of the model, and smaller R.2 values greatly widen the 99% confidence band making it more difficult to exceed the 99% confidence band.

These high level concentrations of particle matter could not have been caused by industrial emissions because the NC DAQ has an extensive permitting, compliance, and enforcement program designed to minimize industrial emissions. Mandatory controls on industrial atmospheric particulate emissions are often 99.97% effective. Moreover, influences from historical industrial emissions are implicitly included in the linear model. Lastly, this is a statewide event, whereas industrial emissions would tend to have a local influence.