Indiana Department of Environmental Management
We Protect Hoosiers and Our Environment.
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Michael R. Pence
Governor

Carol S. Comer
Commissioner

December 28, 2016

Mr. Robert Kaplan
Acting Regional Administrator
U.S. Environmental Protection Agency
Region 5
77 West Jackson Boulevard
Chicago, IL 60604-3950

Re: Weight of Evidence Analysis for Interstate Transport "Good Neighbor" Provision for the 2012 Annual Fine Particulate Matter ($PM_{2.5}$) National Ambient Air Quality Standard; Infrastructure (Sections 110(a)(1) and 110(a)(2)) State Implementation Plan Submittal

Dear Mr. Kaplan:

The Indiana Department of Environmental Management (IDEM) developed and is providing additional technical supporting documentation (TSD) to the Indiana Infrastructure (Sections 110(a)(1) and 110(a)(2)) State Implementation Plan Submittal: 2012 Annual Primary Fine Particulate Matter ($PM_{2.5}$) National Ambient Air Quality Standards (NAAQS). IDEM submitted this document to United States Environmental Protection Agency (U.S. EPA) for review and approval on June 10, 2016.

This Weight of Evidence Analysis addresses the significance of Indiana's emissions on the results of U.S. EPA's March 2016 "Good Neighbor" Provision projected $PM_{2.5}$ modeling of 2017 and 2025. It fulfills the requirements of Section 110(a)(2)(D)(i)(I) (Prong 1 and 2) and (II) (Prong 4) of Indiana Infrastructure (Sections 110(a)(1) and 110(a)(2)) State Implementation Plan Submittal: 2012 Annual Primary Fine Particulate Matter ($PM_{2.5}$) National Ambient Air Quality Standards (NAAQS).

This submittal consists of one (1) hard copy of the required documentation. An electronic version of this submittal, in PDF format that is identical to the attached hard copy, has been sent to Doug Aburano, Chief of Region 5's Attainment Planning and Maintenance Section and Chris Panos of U.S. EPA Region 5.

IDEM believes that this technical supporting documentation in conjunction with the rules and measures outlined in the Infrastructure SIP, meet the requirements under Sections 110(a)(1) and 110(a)(2) of the CAA and U.S. EPA guidance. This includes the requirements of Prong 1, 2, and 4 of Sections 110(a)(2)(D)(i)(I) and 110(a)(2)(D)(i)(II) for interstate transport as outlined in the June 10, 2016, submittal.

IDEM requests that U.S. EPA proceed with review and approval of the Indiana Infrastructure (Sections 110(a)(1) and 110(a)(2)) State Implementation Plan Submittal: 2012 Annual Primary Fine Particulate Matter ($PM_{2.5}$) National Ambient Air Quality Standards (NAAQS). If you have any questions or need additional information, please call me at (317) 232-8244 or bcallaha@idem.IN.gov.

Sincerely,

Brian E. Callahan

Brian E. Callahan, Chief
Air Quality Standards and
Implementation Section
Office of Air Quality

BEC/sad/gf/lf
Enclosure:

Indiana Weight of Evidence Analysis for Interstate Transport "Good Neighbor" Provision for the 2012 Annual Fine Particulate Matter ($PM_{2.5}$) National Ambient Air Quality Standard; Infrastructure (Sections 110(a)(1) and 110(a)(2)) State Implementation Plan Submittal

cc: Doug Aburano, U.S. EPA Region 5 (w/ enclosures)
Steve Rosenthal, U.S. EPA Region 5 (no enclosures)
Chris Panos, U.S. EPA Region 5 (no enclosures)
Keith Baugues, IDEM-OAQ (no enclosures)
Scott Deloney, IDEM-OAQ (no enclosure
Brian Callahan, IDEM-OAQ (w/ enclosures)
Gale Ferris, IDEM-OAQ (no enclosure)
Leslie Ferguson, IDEM-OAQ (w/ enclosures)
File Copy

Indiana Weight of Evidence Analysis for the Interstate Transport “Good Neighbor” Provision for the 2012 Annual Fine Particulate Matter ($PM_{2.5}$) National Ambient Air Quality Standard

Indiana Infrastructure (Sections 110(a)(1) and 110(a)(2)) State Implementation Plan Submittal

December 2016

IDEM

INDIANA DEPARTMENT OF ENVIRONMENTAL MANAGEMENT

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Executive Summary

On June 10, 2016, Indiana submitted an Infrastructure State Implementation Plan (SIP) for the 2012 Fine Particulate Matter ($PM_{2.5}$) National Ambient Air Quality Standard (NAAQS). To fulfill the requirements of Section 110(a)(2)(D)(i)(I) (Prong 1 and 2) and Section 110(a)(2)(D)(i)(II) (Prong 4) of this SIP, Indiana must provide technical supporting documentation that addresses interstate transport of $PM_{2.5}$ and its precursor pollutants originating in Indiana.

On March 17, 2016, the United States Environmental Protection Agency (U.S. EPA) released a memorandum titled "Information on the Interstate Transport 'Good Neighbor' Provision for the 2012 Fine Particulate Matter National Ambient Air Quality Standards under Clean Air Act Section 110(a)(2)(D)(i)(I)". This memorandum identified air quality modeled receptors that are projected to be classified as either in nonattainment or maintenance for the 2012 fine particulate matter annual NAAQS by 2017 and 2025. U.S. EPA used photochemical air quality modeling to identify 19 total receptors; 17 of these receptors were located in California, while Idaho and Pennsylvania each had one receptor.

Typically, once the U.S. EPA identifies nonattainment or maintenance receptors, it would identify states that contribute to the nonattainment or maintenance status of those downwind receptors. However, due to the low number of receptors projected to be either in nonattainment or maintenance, U.S. EPA elected not to identify those contributing states. Instead, states are required to conduct a weight of evidence analysis to determine their contributions to the downwind nonattainment or maintenance receptors that they may affect.

This document presents the Indiana Department of Environmental Management's (IDEM) Weight of Evidence analysis of its possible contribution to downwind air quality receptors identified as either nonattainment or maintenance of the 2012 fine particulate annual NAAQS in the U.S. EPA's March 17th, 2016, memorandum. As stated in U.S. EPA's memo, the only receptor identified as nonattainment or maintenance on which Indiana might have an impact is the Liberty monitor in Allegheny County, Pennsylvania (42-003-0064) located in southwest Pennsylvania. Since the Allegheny County, Pennsylvania, receptor (AQS ID 42-003-0064, site name Liberty) is the only location considered downwind of Indiana, this document focuses on that single receptor that modeled maintenance in 2017 and attainment in 2025. The California and Idaho receptors are excluded from this analysis, since they are upwind of Indiana and IDEM does not expect any fine particulate matter impacts from Indiana at those receptors.

IDEM analyzed hourly monitoring data from 2012-2015 at the Liberty monitoring site and identified 26 days with 24-hour average fine particulate matter concentrations greater than the NAAQS of 35 $\mu g/m^3$ (micrograms per cubic meter). These elevated monitored averages were due to high fine particulate matter values occurring during the late evening and early morning hours. Wind and pollution roses were analyzed for these days and showed high hourly fine particulate matter values occurred with southerly and westerly winds. Several facilities that emit large quantities of fine particulate matter and precursor emissions of nitrogen oxides (NO_x) and sulfur dioxide (SO_2) were found to be located within four kilometers to the south and west of the Liberty monitor. Back trajectory analyses determined that ambient air arriving at the receptor on these high pollution days rarely traveled over Indiana. Based on this technical analysis, IDEM concludes that the Liberty monitor in Allegheny County, Pennsylvania, measures the higher fine particulate matter concentrations on the local scale while surrounding fine particulate matter monitors measure significantly lower concentrations overall. Indiana's fine particulate matter, nitrogen oxides, and sulfur dioxide emissions would have more expected impacts on all fine particulate matter monitors in the area. IDEM concludes that local emissions reductions are necessary to lower fine particulate matter design values at the Liberty monitor and Indiana does not have a significant impact on the projected maintenance status of the monitor as it relates to the 2012 fine particulate matter NAAQS.

Weight of Evidence Evaluation of Indiana's Impact on $PM_{2.5}$ Concentrations at the Liberty Monitor in Allegheny County, Pennsylvania

Background

On March 17, 2016, the United States Environmental Protection Agency (U.S. EPA) released a memorandum from Stephen D. Page titled "Information on the Interstate Transport 'Good Neighbor' Provision for the 2012 Fine Particulate Matter National Ambient Air Quality Standards under Clean Air Act Section 110(a)(2)(D)(i)(I)". In this memo, the U.S. EPA identified the areas in the United States that have the potential to be either nonattainment or maintenance in 2017 and 2025 with respect to the 2012 fine particulate matter (otherwise known as $PM_{2.5}$) National Ambient Air Quality Standard (NAAQS). Because of the small number of nonattainment and maintenance receptors identified, the U.S. EPA did not conduct contribution analyses to link upwind states with downwind receptors, and requested that states conduct a weight of evidence (WOE) evaluation to address their impacts to downwind receptors.

The March 17, 2016, memorandum did not identify any potential nonattainment sites for the eastern half of the United States for either 2017 or 2025 and identified a single receptor in Pennsylvania (the Liberty monitor) as the only maintenance site, for 2017 only. Although U.S. EPA's memorandum recognized only the Pennsylvania site, there is also a $PM_{2.5}$ nonattainment area in Cleveland, Ohio. The Cleveland, OH nonattainment area has been addressed by the Ohio Environmental Protection Agency through the submittal of an attainment demonstration which demonstrates the area will attain the 2012 standard by the attainment date, i.e. 12/31/2021. As stated in U.S. EPA's memo, the only receptor identified as nonattainment or maintenance on which Indiana might have an impact is the Liberty monitor in Allegheny County, Pennsylvania (42-003-0064) located in southwest Pennsylvania. This monitor is designed to measure $PM_{2.5}$ at the neighborhood scale, with a spatial definition of 500 meters to 4 kilometers.

The Indiana Department of Environmental Management (IDEM) examined meteorological conditions, backward trajectories, $PM_{2.5}$ measurements, and emissions sources within the southwest Pennsylvania airshed. The results conclude that the high $PM_{2.5}$ concentrations are caused by local meteorological conditions and emission sources located near the monitor. Any $PM_{2.5}$ primary or precursor emission reductions that Indiana could make would have little effect on the $PM_{2.5}$ concentrations measured at the Liberty monitor. This analysis will examine the effects of the local meteorology and emission sources on the monitor. The modeled annual design values are then re-evaluated with elimination of local meteorological processes. These results show that the Liberty monitor would then be projected to be in attainment of the 2012 standard in 2017 and beyond.

Evaluation of How Hourly $PM_{2.5}$ Concentrations Affect the Annual $PM_{2.5}$ Concentration

The annual $PM_{2.5}$ design value calculation is dependent on the daily average of the measured $PM_{2.5}$ concentration at a monitoring site. The steps in the calculation of the annual design value are given in Section 4.4 of Appendix N to 40 CFR Part 50. The calculation requires that the calendar year be divided into four quarters and an average of the daily averages over each quarter be calculated. The 2012-2015 monitoring data shows that daily $PM_{2.5}$ concentrations at the Liberty monitor are highest during the months of January through March and October through December, with an occasional high value in May. IDEM concluded that while there may not be a single quarter that dominates the annual average, a quarterly average may be dominated by a few days of high $PM_{2.5}$ concentrations.

IDEM selected daily $PM_{2.5}$ concentrations at the Liberty monitor that exceed the 2006 $PM_{2.5}$ 24-hour NAAQS of 35 $\mu g/m^3$ (micrograms per cubic meter) for the years 2012 to 2015 for analysis. There were 26 days in this period that exceeded the standard. IDEM analyzed hourly $PM_{2.5}$ concentrations from these 26 days to determine if there was a temporal pattern in elevated concentrations during these days. Appendix A shows time plots for the Liberty monitor during these 26 days. Based on these time plots, a clear pattern of high $PM_{2.5}$ concentrations during the morning and occasional evening hours is evident at this monitor. In examining the hourly data for these 26 days, IDEM found the following: of 283 hours of $PM_{2.5}$ concentrations measured greater than 35 $\mu g/m^3$, 192 (68%) occurred before 9 a.m.; of 91 hours of $PM_{2.5}$ concentrations measured greater than 70 $\mu g/m^3$, 71 (78%) of those hours occurred before 9 a.m.; of 29 hours of $PM_{2.5}$ concentrations measured greater than 100 $\mu g/m^3$, 26 (90%) occurred before 9 a.m. It is evident that local meteorological conditions and emission sources play a major factor in high $PM_{2.5}$ concentrations at the Liberty monitor.

Effects of Local Meteorological Conditions on Hourly $PM_{2.5}$ Concentrations

The high $PM_{2.5}$ concentrations seen in the morning and evening hours during colder months at the Liberty monitor led IDEM to investigate the possibility that temperature inversions could have been present in the atmospheric vertical profile near the monitor. Temperature inversions occur when warmer air is present above a cooler layer of air at the ground level. Temperature inversions prevent the vertical mixing of air, and therefore the pollutants in the air, leading to high pollution concentrations at the ground-level monitoring height. These inversions are more prolonged and pronounced during colder months when solar heating is weaker. IDEM obtained temperature vertical profiles up to 700 millibars of pressure (approximately 3,000 meters above ground level) from the Pittsburgh International Airport for each of the 26 days. Appendix A shows these temperature profiles. IDEM found that temperature inversions did occur during the days that high $PM_{2.5}$ concentrations were measured.

Given the proximity of the Liberty monitor to the Allegheny River Valley, any pollutants emitted during a temperature inversion could be recirculated within the valley leading to a buildup of pollutants at ground level. IDEM obtained wind speed and direction data for the 26 days from the Allegheny County Regional Airport, located about four miles to the northwest of the Liberty monitor. IDEM then created a pollution rose for each of these 26 days, shown in Figure 1, pairing the hourly wind direction with the hourly PM2.5 concentrations measured at the Liberty monitor. This pollution rose shows that there was strong $PM_{2.5}$ impact from the south. IDEM also created pollution roses for hourly $PM_{2.5}$ concentrations greater than 35 µg/m^3, 70 µg/m^3, and 100 µg/m^3 (Figures 2, 3, and 4) at Liberty. The strong $PM_{2.5}$ influence from the south is still evident, but another influence is seen from the west as well.

Using information available on the Allegheny County Health Department website, IDEM determined that two large U.S. Steel facilities are located to the south and west of the monitor as well as two large oxide of nitrogen (NO_x) and sulfur dioxide (SO_2) emitting facilities also to the south. Figure 5 shows the location of these facilities with respect to the monitor. Table 1 shows the annual emissions of $PM_{2.5}$, NO_x, and SO_2 from these four facilities as reported in the 2011 and 2014 National Emission Inventories (NEI) along with Indiana's emissions. IDEM believes that emissions from these facilities are the cause of high $PM_{2.5}$ concentrations at the Liberty monitor.

Figure 1: Pollution Rose for the Liberty Monitor for High $PM_{2.5}$ Days from 2012-2015

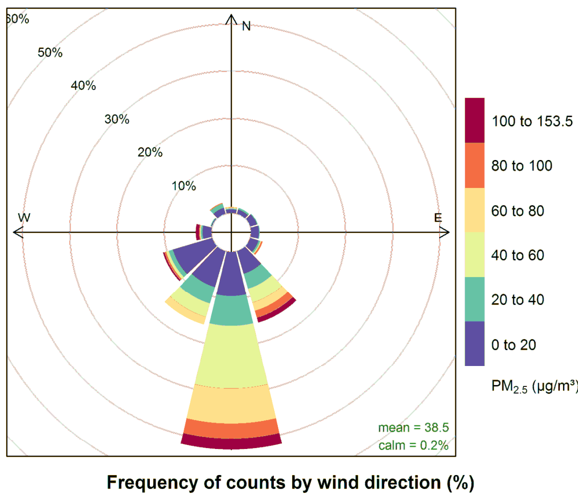
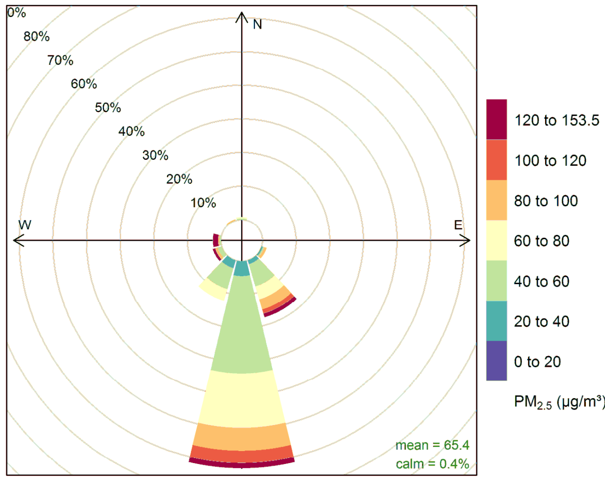
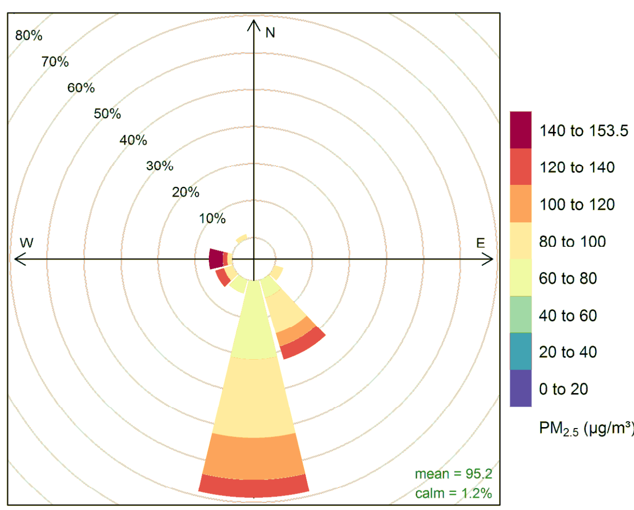


Figure 2: Hourly Values Greater Than 35 μg/m^3 at the Liberty Monitor on High $PM_{2.5}$ Days from 2012-2015



Frequency of counts by wind direction (%)

Figure 3: Hourly Values Greater Than 70 μg/m^3 at the Liberty Monitor on High $PM_{2.5}$ Days from 2012-2015



Frequency of counts by wind direction (%)

Figure 4: Hourly Values Greater Than 100 at the Liberty Monitor on High PM2.5 Days from 2012-2015

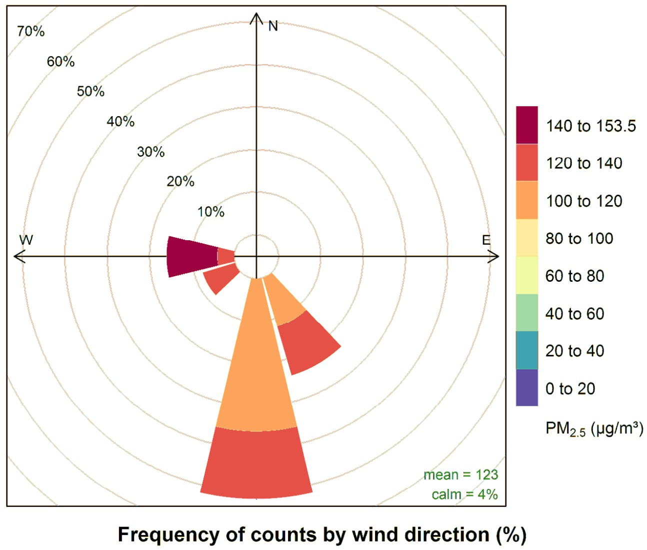


Figure 5: Location of Local Emission Sources with Respect to the Liberty Monitor

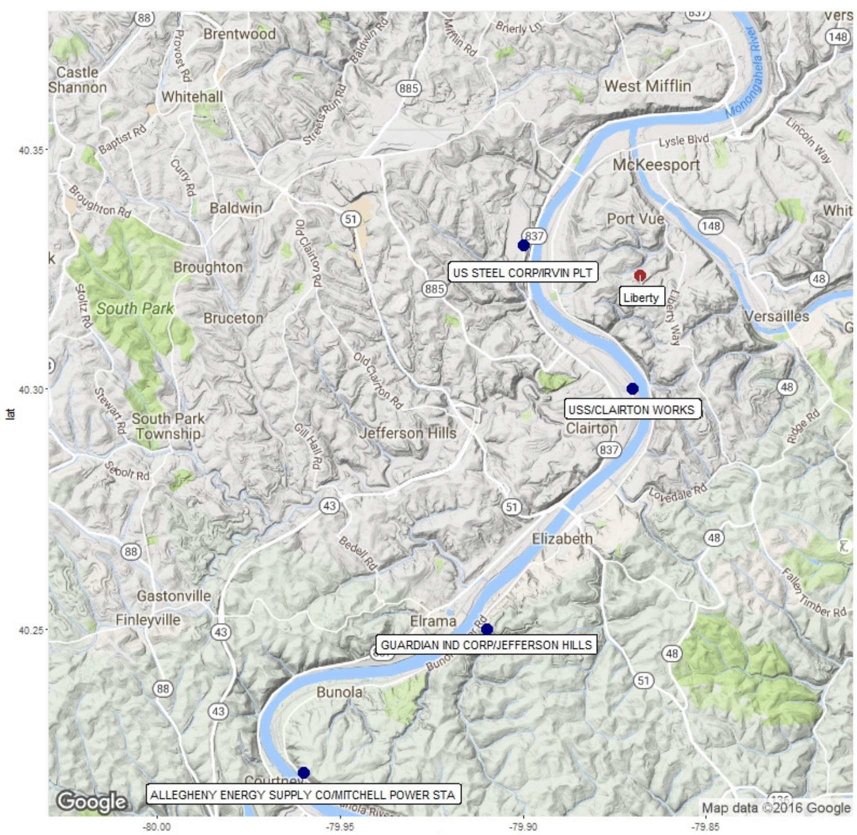
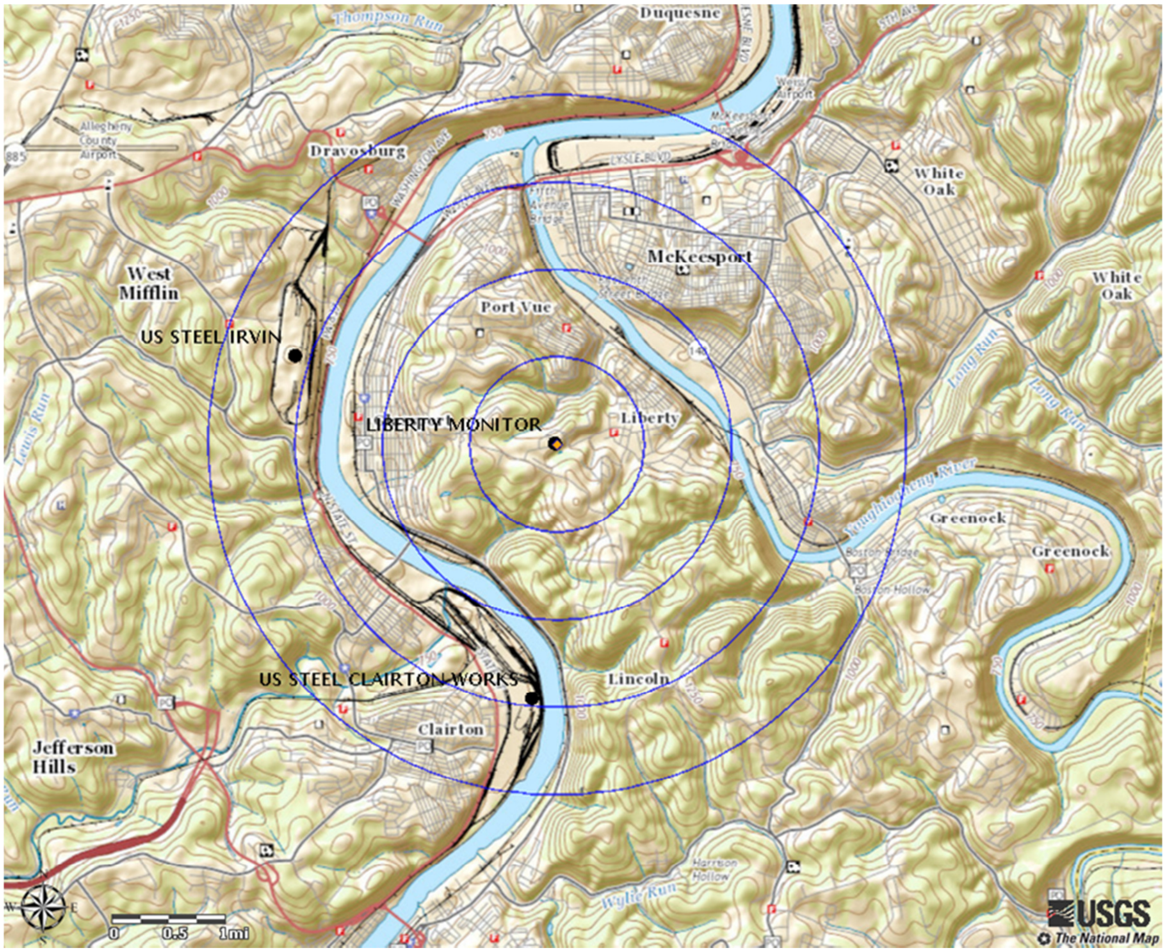


Table 1: Annual Emissions of $PM_{2.5}$, NOx, and SO_2 from the Four Facilities Mapped in Figure 5 Compared to Indiana Emissions (Tons Per Year)

	2011 NEI			2014 NEI		
Site Name	$PM_{2.5}$	NO_x	SO_2	$PM_{2.5}$	NO_x	SO_2
USS/CLAIRTON WORKS	500	3,075	1,468	639	3,795	1,512
ALLEGHENY ENERGY SUPPLY CO/MITCHELL POWER STA	85	1305	863	Closed in 2013		
US STEEL CORP/IRVIN PLT	72	762	419	78	708	716
GUARDIAN IND CORP/JEFFERSON HILLS	22	978	73	22	521	109
Total	**679**	**6,120**	**2,823**	**739**	**5,024**	**2,337**
Indiana Emissions	**125,468**	**466,112**	**425,202**	**158,518**	**410,833**	**345,145**

U.S. Steel Corporation has two facilities located within four kilometers of the Liberty monitor (Figure 6): Clairton Works to the south and Irvin Plant to the west. The Mitchell Power Station, which is located 14 kilometers to the southwest of the Liberty monitor, was shut down in October 2013. Even with the closure of the power station, the measured $PM_{2.5}$ annual concentration increased in 2014 and 2015 when compared to 2013. Total direct $PM_{2.5}$ and precursor emissions from the two U.S. Steel facilities increased in the 2014 NEI over the 2011 NEI, which could contribute to the increase in the $PM_{2.5}$ annual concentrations. However, since 2013 emission data is not publicly available through U.S. EPA, it is not possible to determine if emissions from the U.S. Steel facilities actually increased from 2013 to 2014.

Figure 6: Proximity of U.S. Steel Facilities to the Liberty Monitor
(Each ring represents an additional 1 kilometer)



Direct emissions of $PM_{2.5}$ from Indiana sources would likely have no effect on the Liberty monitor, as these emissions would most likely settle out after being released to the atmosphere. The eastern border of Indiana is more than 400 kilometers away from the monitor. Any impact from Indiana on $PM_{2.5}$ concentrations measured at the Liberty monitor would result from secondary formation from NO_x and SO_2 emissions.

IDEM created seasonal wind roses and pollution roses for 2012-2015, which are shown in Figures 7-10. Comparing seasonal wind roses to pollution roses allows for determination of which wind directions correlate with high pollution values. For instance, for the 1st quarter, wind is generally from the west and northwest; the highest hourly $PM_{2.5}$ values occur with southerly winds. The impacts of the southerly winds on the $PM_{2.5}$ values are evident in each quarter.

Figure 7: Quarter 1 Wind and Pollution Roses

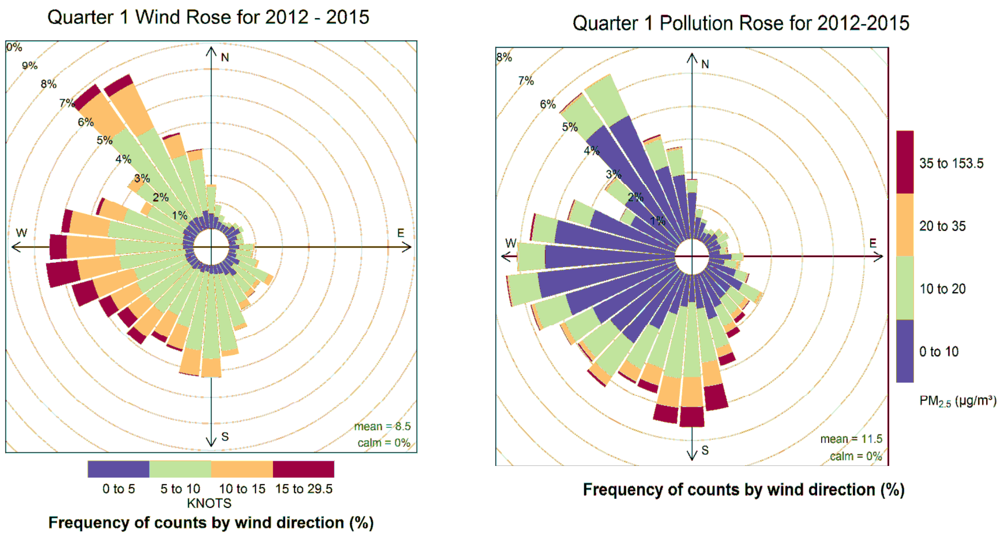


Figure 8: Quarter 2 Wind and Pollution Roses

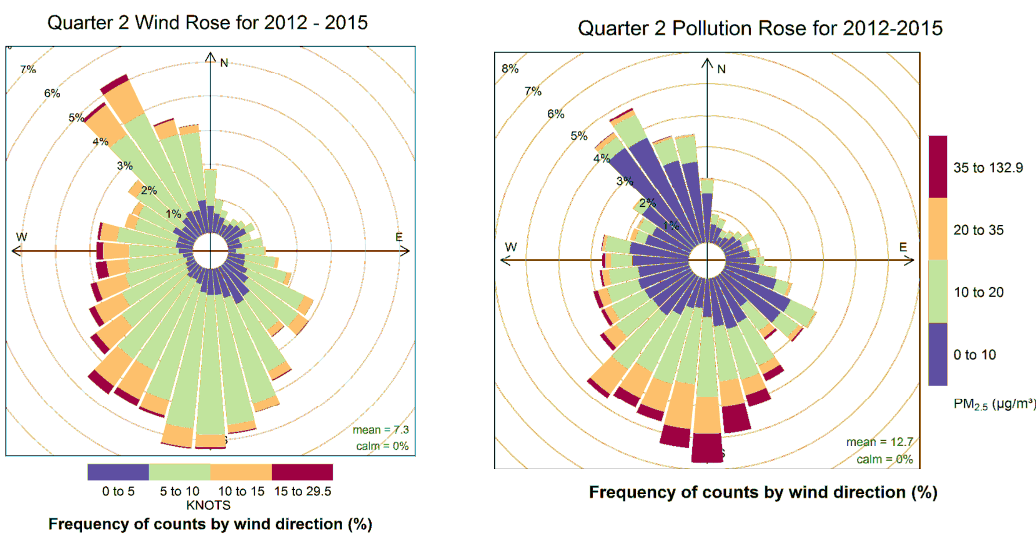


Figure 9: Quarter 3 Wind and Pollution Roses

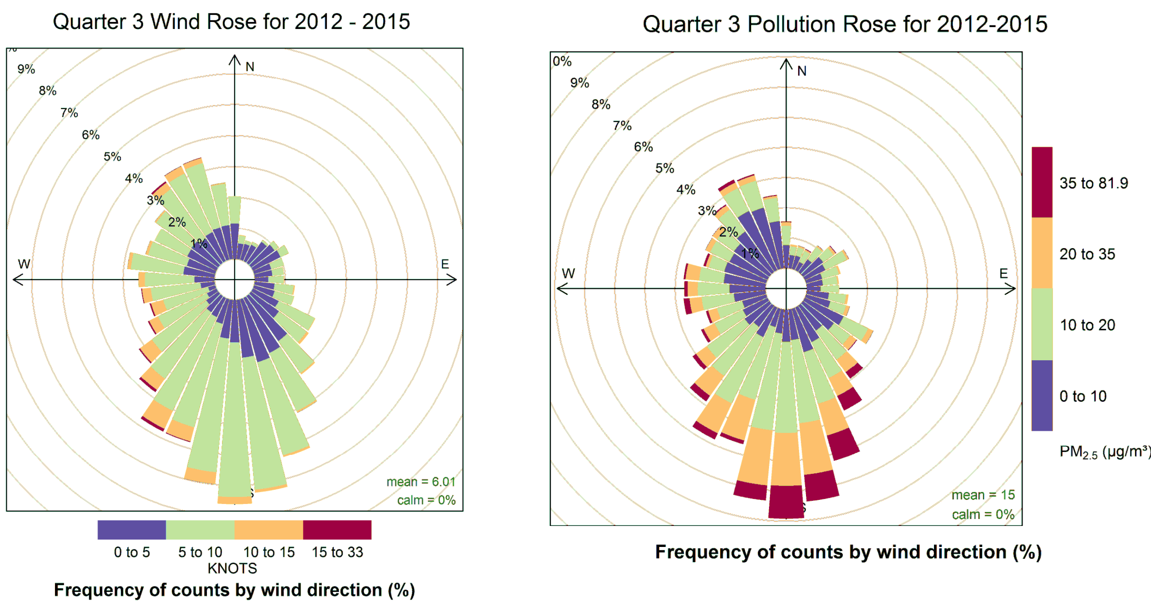
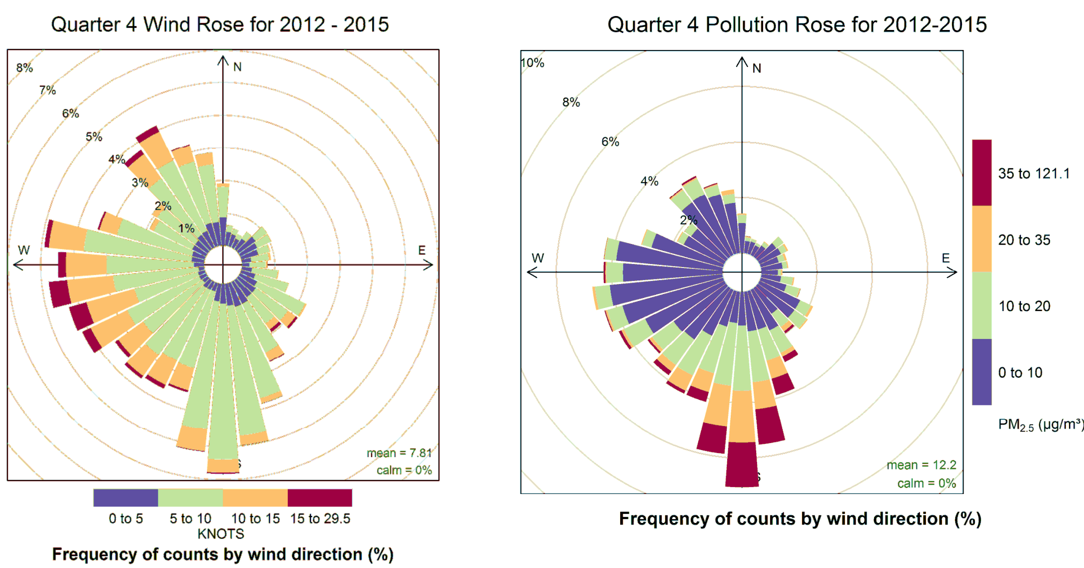


Figure 10: Quarter 4 Wind and Pollution Roses



IDEM also analyzed hourly $PM_{2.5}$ data from other monitors throughout the southwest Pennsylvania airshed on these 26 days to see if the high $PM_{2.5}$ concentrations are observed at those monitors as well. If values are truly from interstate transport, all monitors in the area should be affected. However, other monitors in the area do not measure elevated $PM_{2.5}$ concentrations similar to the Liberty monitor. These monitors also do not show the same intermittent pattern that is evident at the Liberty site. Appendix B shows the time plots of the hourly $PM_{2.5}$ concentrations for these other monitors compared with the Liberty monitor. The weighted annual mean values of the seven $PM_{2.5}$ monitors in the area show distinctly lower values when compared to the Liberty monitor's $PM_{2.5}$ values. The differences range from one to two micrograms per cubic meter or higher at the Liberty monitor.

Based on the intermittent pattern of the $PM_{2.5}$ concentrations, the presence of temperature inversions, the topography, the proximity of major emission sources to the monitor, and the lack of a similar pattern at other area monitors, IDEM concludes that the high $PM_{2.5}$ concentrations at the Liberty monitor are due to local causes. The high concentration days could be replaced with average concentrations in the calculation of the annual design value to determine that the monitor would be in attainment of the 2012 annual fine particulate matter standard.

Recalculation of the Annual Design Value and Application of Cross State Air Pollution Rule Modeling

IDEM recalculated the 5-year weighted annual design value for the Liberty monitor for each year for the periods 2009-2013, 2010-2014, and 2011-2015 (Appendix C). In order to eliminate the effect of local influences, IDEM removed days with a 24-hour $PM_{2.5}$ average above the 24-hour NAAQS of 35 $\mu g/m^3$ from their respective quarters, and the average 24-hour $PM_{2.5}$ concentration of the remaining days was used to calculate the revised annual $PM_{2.5}$ average. From these revised annual averages, the 3-year design values were recalculated for the periods of 2009-2011, 2010-2012, 2011-2013, 2012-2014, and 2013-2015. Each of these 3-year annual $PM_{2.5}$ design values were then used in calculating a new 5-year weighted annual design value.

The updated CSAPR modeling had a 5-year weighted average design value of 14.4 $\mu g/m^3$ for the period 2009-2013 at the Liberty monitor. The modeled 2017 average design value was 11.67 $\mu g/m^3$. The ratio of the 2017 design value to the 2009-2013 design value is equivalent to the relative response factor (RRF) obtained from photochemical modeling, and has a value of 0.81 for the Liberty monitor. This RRF value was applied to the recalculated 5-year weighted annual design values and the maximum 3-year annual design value for each 5-year period. Table 2 shows each recalculated 5-year weighted design value, the maximum design value for each 5-year period, the average design value in 2017, the maximum design value in 2017, and the final attainment status for each 5-year period applied to 2017. If the local meteorological effects on the $PM_{2.5}$ concentrations are removed, the Liberty monitor would be assumed to be in attainment of the 2012 Annual $PM_{2.5}$ Standard in 2017.

Table 2: Recalculated Design Values for 5-Year Monitoring Periods and 2017 (using a Relative Response Factor of 0.81)

Period	Original 5-Year Weighted Average Design Value (µg/m^3)	Recalculated 5-Year Weighted Average Design Value (µg/m^3)	Maximum Recalculated Design Value (µg/m^3)	Average Recalculated 2017 Design Value (µg/m^3)	Maximum Recalculated 2017 Design Value (µg/m^3)	2017 Attainment Status with Recalculated Design Values
2009-2013	14.4	13.2	13.5	10.7	10.9	Attainment
2010-2014	13.7	12.8	13.4	10.4	10.9	Attainment
2011-2015	13.0	12.4	12.7	10.0	10.3	Attainment

Backward Trajectory Analysis

A back trajectory analysis using the National Oceanic and Atmospheric Administration's HYSPLIT model was performed to evaluate Indiana's contribution to $PM_{2.5}$ in Allegheny County, Pennsylvania. In total, 35,040 trajectories were run for 100, 500, and 1000 meters above ground level (AGL). Back trajectories were run starting at each hour of the day, every day, over a four-year period from 2012 through 2015. The trajectories started in the center of Allegheny County, PA and were run backwards over a 24-hour period. Meteorological data used in this analysis consisted of the North American Regional Reanalysis (NARR) dataset. In total, 31 values on 26 days from 2012-2015 at monitor ID 42-003-0064 (Liberty) were identified as exceeding the 24-hour $PM_{2.5}$ NAAQS. This analysis shows that Indiana does not contribute significantly to Allegheny County $PM_{2.5}$ concentrations and that a corridor of probable transport exists along and near the Appalachian mountain range and Ohio River Valley for the lower 100 and 500 meter levels.

A general climatological analysis of trajectories was conducted to assess the general air flow patterns for air arriving in the Allegheny County area during the four-year period from 2012 to 2015. This analysis included both graphical representations of trajectory point frequency, as well as a numerical and statistical analysis of this data by state. 24-hour $PM_{2.5}$ data from U.S. EPA's Air Quality System (AQS) AMP501 report were matched with daily trajectory data to calculate average $PM_{2.5}$ concentrations associated with all trajectory points in a given state. Figures 11 and 12 show the frequency of trajectory points at 100 and 500 meters AGL. An axis of higher trajectory points exists to the south and southwest of Allegheny County, PA along the Ohio River Valley. A statistical analysis breakdown by state also indicates that this corridor of higher frequencies of trajectories also exhibits higher average $PM_{2.5}$ concentrations when trajectories are matched by their corresponding 24-hour $PM_{2.5}$ concentrations.

In addition to a general climatological analysis of trajectories, individual exceedance days and their associated trajectories were also examined. This analysis shows that at 100 meters AGL, which is closest to the level of the monitor recording the sample value, air arriving in Allegheny County, PA passes through Indiana very infrequently. For air arriving at higher levels above the monitor, at 500 and 1000 meters, air flow has a southerly or southwesterly flow, which will also transport $PM_{2.5}$ and precursor pollution from local major sources upwind of the Liberty monitor (See map of local sources in Figure 5 above). Even at these higher levels, exceedance trajectories only pass through Indiana about half of the time and the climatological analysis indicates a much more likely corridor of transport exists along the Appalachian Mountain Range in West Virginia and the Ohio River valley. When a trajectory passes over Indiana, there are usually other trajectories associated with the same 24-hour period that follow along the corridor of higher frequencies and $PM_{2.5}$ concentrations.

Figure 11: Frequency Plot of Trajectory Points for Air Arriving at 100 Meters AGL

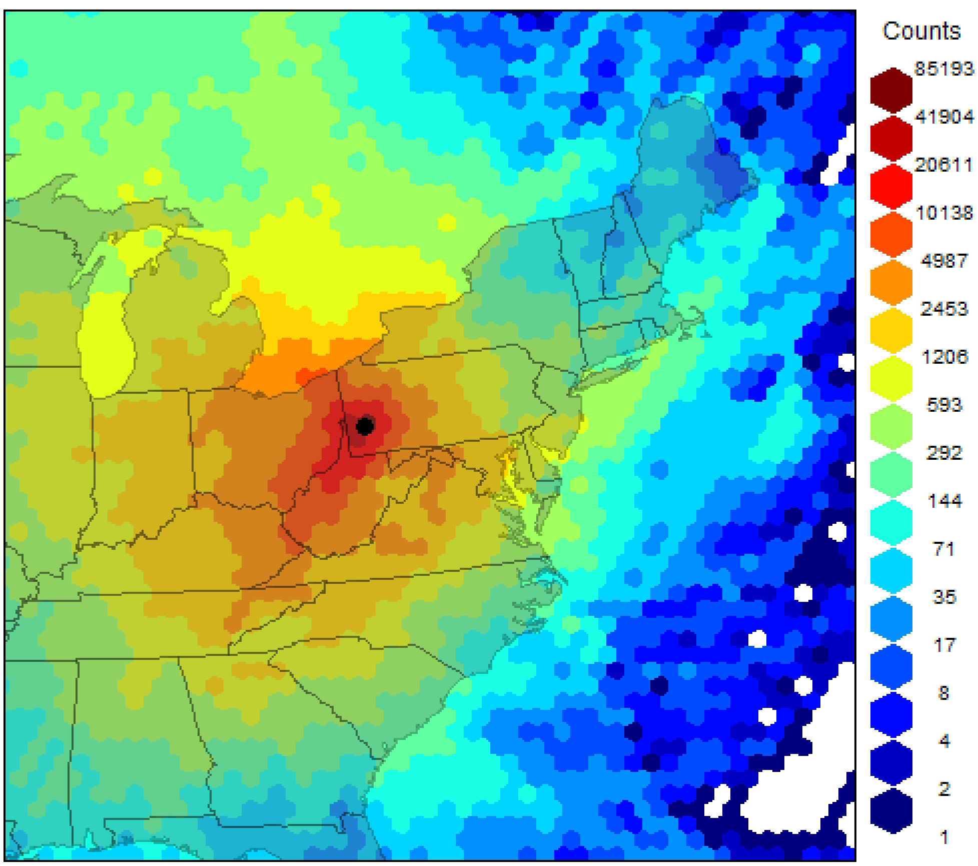
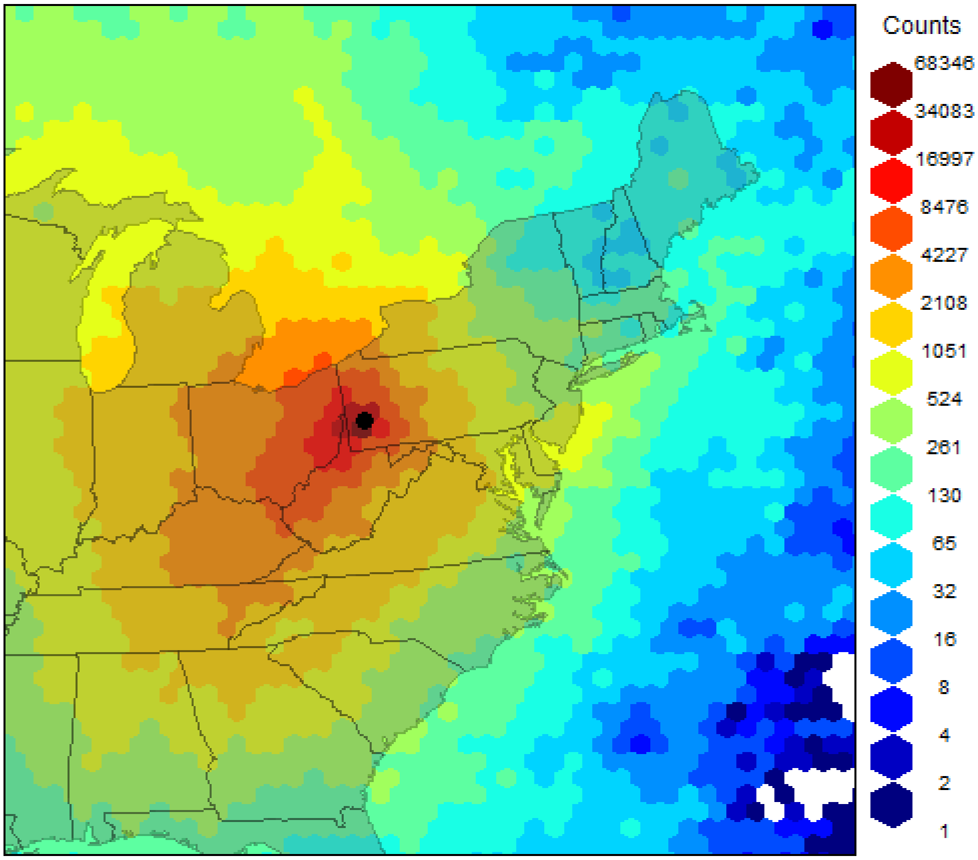


Figure 12: Frequency Plot of Trajectory Points for Air Arriving at 500 Meters AGL



The state-by-state statistics listed in Appendix D show the average 24-Hour $PM_{2.5}$ concentrations recorded at the Liberty monitor when a trajectory passes through the listed state. On average, if a state has a high averaged $PM_{2.5}$ value, then when trajectories pass through the state, they are more likely to be associated with higher $PM_{2.5}$ values at the monitor location. This analysis was done for concentrations at the Liberty monitor, as well as with all Allegheny County monitors. Also provided in Appendix D is the number of $PM_{2.5}$ values used to calculate the average. This is the same value as the number of days a state had any trajectory pass through the state.

From the state-by-state analysis, Indiana had one or more trajectory point pass through the state for only 25.9% of all the readings available at the Liberty monitor at the 100 meter level. For a large majority of the readings at the Liberty monitor, no trajectory passed through Indiana. Furthermore, only a very small percentage of all trajectory points pass through Indiana. Of the 16,200 trajectory points associated with exceedances at the 100 meter level, only 49 points, or 0.3% were located in Indiana. At the 500 meter level, 617 out of the 16,200 points (3.8%) passed through Indiana. Figures 13 and 14 show the frequency of trajectory points for the 100 meter and 500 meter levels, respectively.

Figure 13: Frequency Plot of Trajectory Points for Air Arriving at 100 Meters AGL and Associated with Exceedances of the 24-Hour $PM_{2.5}$ Standard at the Liberty Monitor

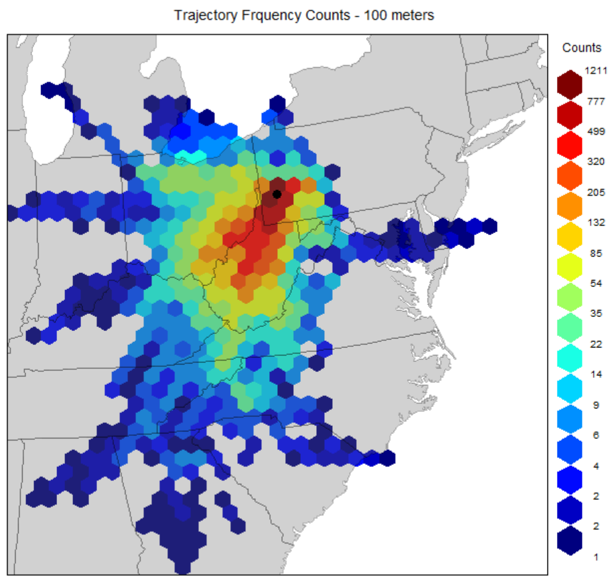
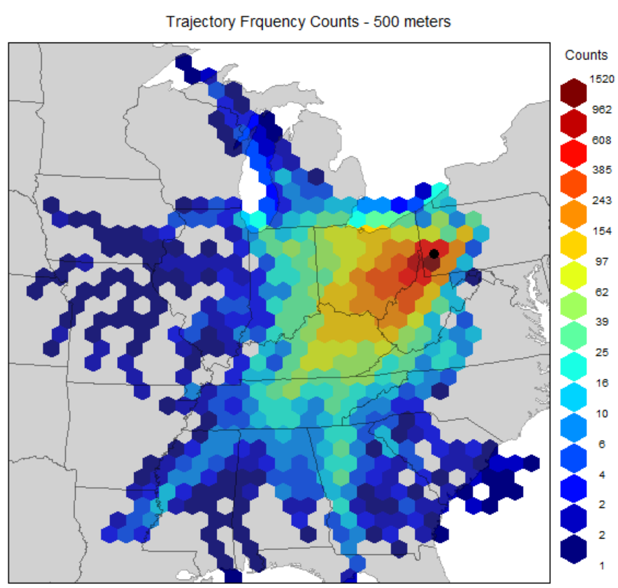


Figure 14: Frequency Plot of Trajectory Points for Air Arriving at 500 Meters AGL and Associated with Exceedances of the 24-Hour $PM_{2.5}$ Standard at the Liberty Monitor



Finally, Appendix E shows the individual exceedance day trajectories at 100, 500, and 1000 meters above ground level. From these plots, it is clear that no single synoptic pattern is associated with an exceedance at the Liberty monitor. Exceedances can occur even with northerly winds. One pattern that is common, however, is for south or southwesterly trajectories to occur on exceedance days. This wind direction also corresponds to the wind rose analysis above and highlights impacts from the facilities to the south and southwest of the monitor (Figures 5 and 6). The trajectories in Appendix E are also color coded to the time of day to attempt to determine if Indiana potentially contributes to the maximum hourly $PM_{2.5}$ values. The highest hourly $PM_{2.5}$ values do not appear to correlate to the trajectories' direction or flow pattern. If a particular trajectory pattern were to cause exceedances, other monitors in the area would also see increases in their concentrations as well. It is unlikely that a particular synoptic or larger scale pattern contributes significantly to these exceedances. If there is any transport affecting this monitor, the HYSPLIT analysis indicates that the air flow contributing to these concentrations is along the Appalachian Mountain Range and not from Indiana sources.

Conclusion

IDEM concludes that the high $PM_{2.5}$ concentrations measured at the Liberty monitor in Allegheny County, Pennsylvania are a consequence of the local meteorology, topography, and close proximity of emission sources to the site. IDEM feels that any emission reductions implemented on sources in Indiana would have very little impact on improving the attainment status of the Liberty monitor with regards to the 2012 Annual $PM_{2.5}$ Standard.

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APPENDIX A

Time Plots, Pollution Roses and Atmospheric Soundings for High $PM_{2.5}$ Days at the Liberty Monitor in Allegheny County, PA

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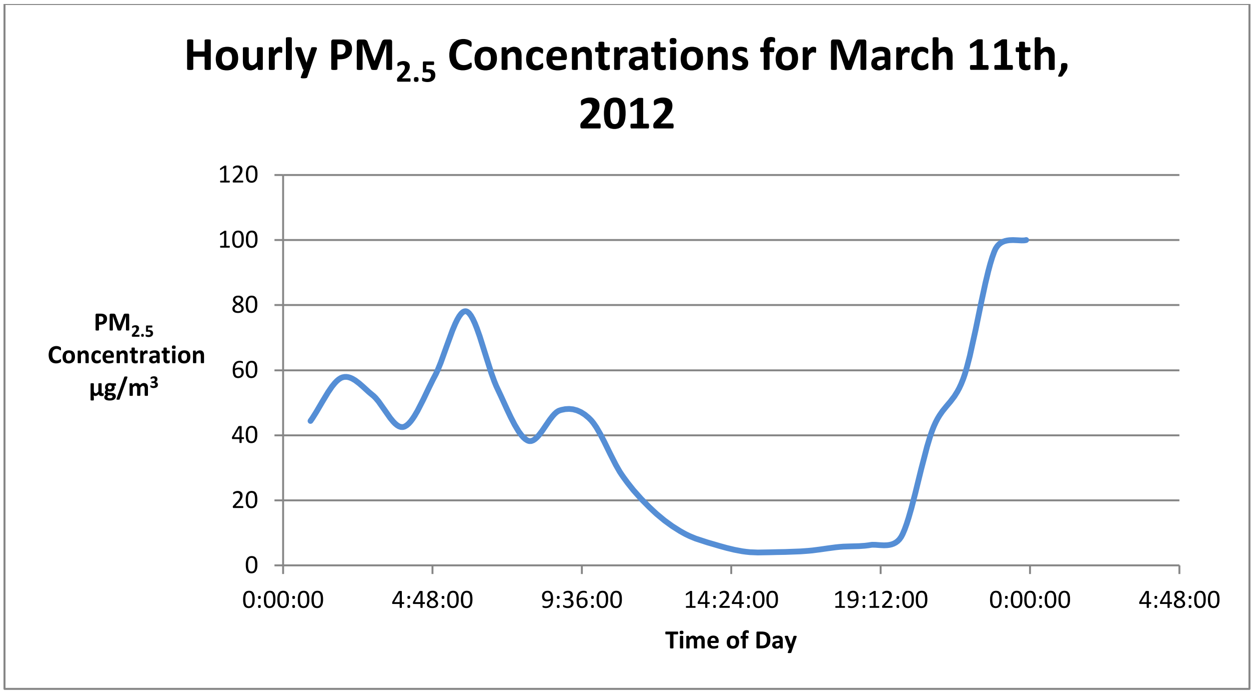
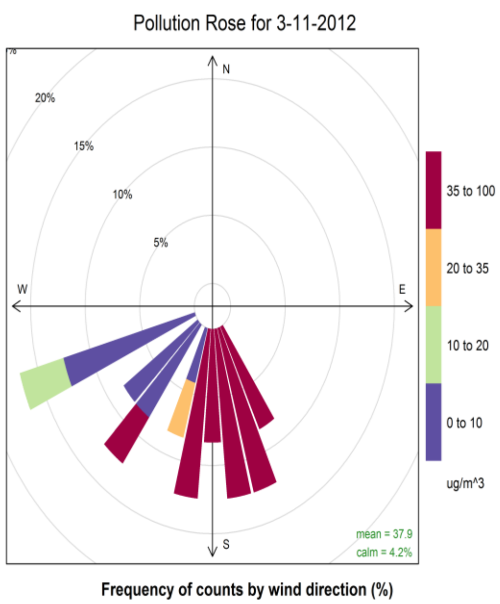
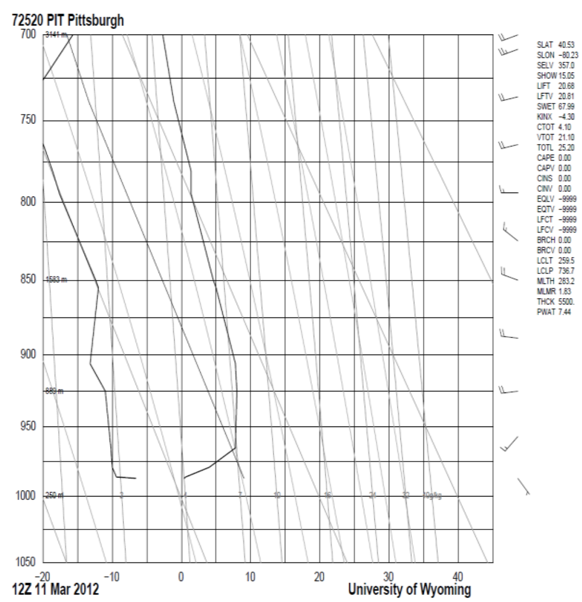
Table B-1: Days with 24-hour $PM_{2.5}$ averages greater than 35 μg/m^3 for the years 2012-2015, maximum 24-hour and hourly concentrations, hour of occurrence of maximum reading, and whether the day was a holiday.

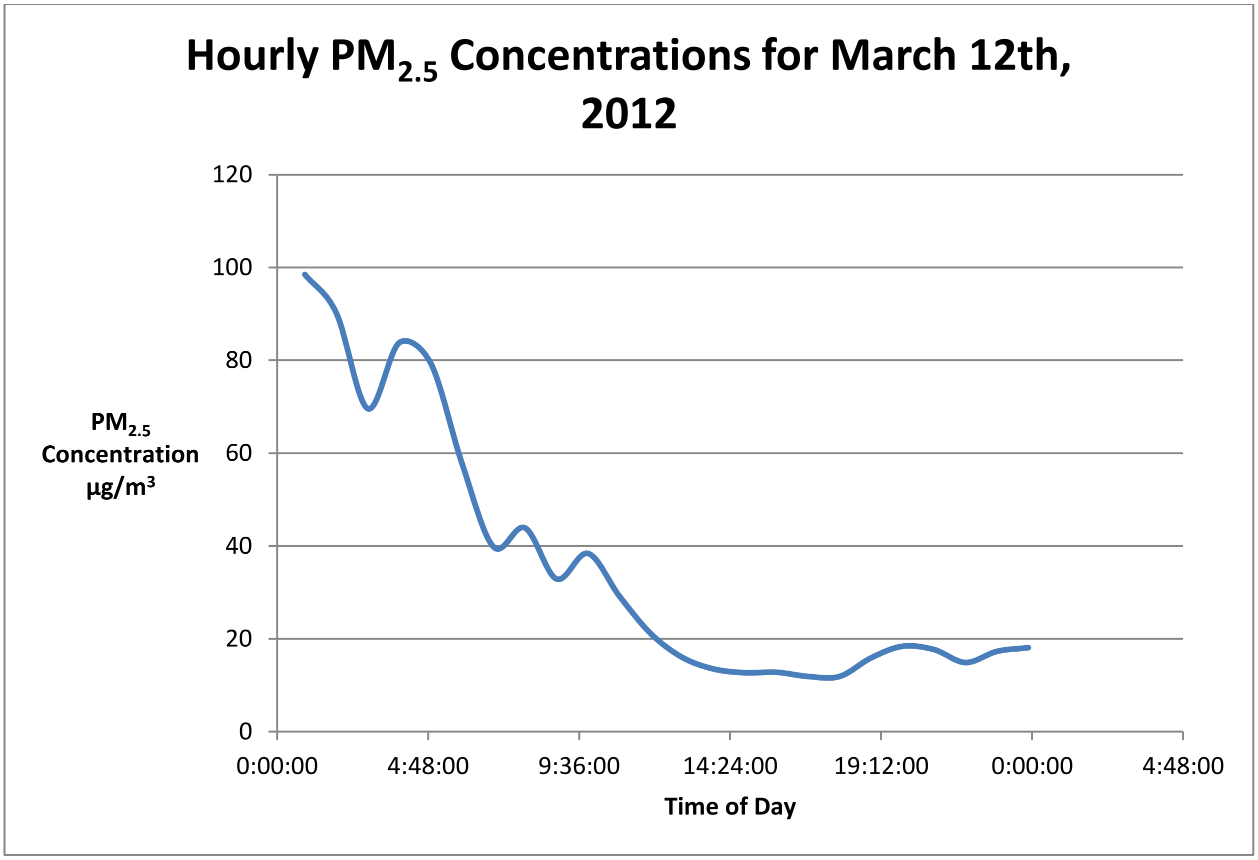
Date	24-Hour	Maximum Hourly Reading	Hour of Maximum Reading
Thursday, November 22, 2012*	54.7	96.5	2:00 AM
Sunday, March 11, 2012	54.3	100	11:00 PM
Friday, December 14, 2012	48.9	66.4	9:00 PM
Thursday, March 15, 2012	48.6	116.9	5:00 AM
Thursday, November 29, 2012	47.1	64.4	9:00 PM
Wednesday, October 24, 2012	42.8	110.6	2:00 AM
Monday, March 12, 2012	42.5	98.5	12:00 AM
Saturday, December 01, 2012	38.1	66.3	7:00 AM
Sunday, May 20, 2012	36.9	132.9	3:00 AM
Saturday, January 12, 2013	43.6	82.5	10:00 AM
Tuesday, January 08, 2013	41.9	66	10:00 AM
Wednesday, January 09, 2013	38.1	67.4	7:00 AM
Sunday, December 01, 2013	37.5	81.7	3:00 AM
Thursday, January 03, 2013	36.1	77.6	8:00 AM
Monday, October 28, 2013	35.5	52.9	1:00 AM
Tuesday, February 11, 2014	63.8	153.5	5:00 AM
Sunday, January 05, 2014	53.6	136.4	6:00 AM
Saturday, March 08, 2014	48.7	62.1	3:00 AM
Monday, October 27, 2014	36.1	84	12:00 AM
Monday, December 07, 2015	58.1	116.1	4:00 AM
Sunday, December 06, 2015	44.9	121.1	12:00 PM
Tuesday, March 10, 2015	42.9	95.9	4:00 AM
Wednesday, October 21, 2015	42.1	83.6	3:00 AM
Monday, November 16, 2015	38.3	78.3	3:00 AM
Sunday, May 03, 2015	37.4	70.3	10:00 PM
Saturday, December 05, 2015	36.9	71.7	12:00 PM

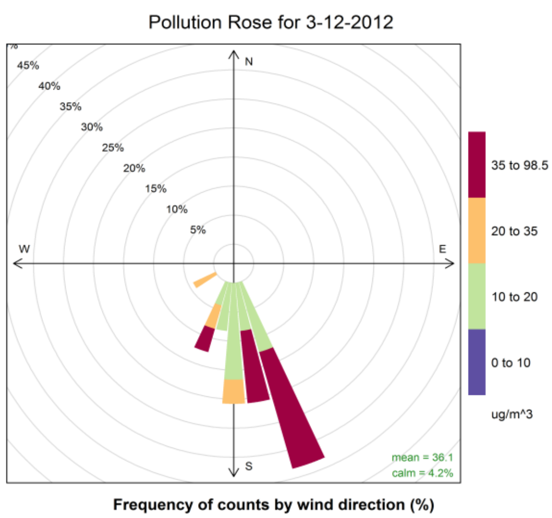
***Thanksgiving Holiday**

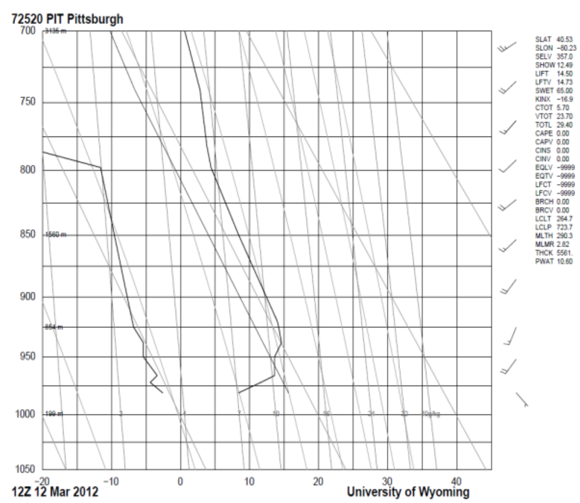

Hourly PM2.5 Concentrations for March 11th, 2012
PM2.5 Concentration µg/m3
120
100
80
60
40
20
0
0:00:00
4:48:00
9:36:00
14:24:00
19:12:00
0:00:00
4:48:00
Time of Day

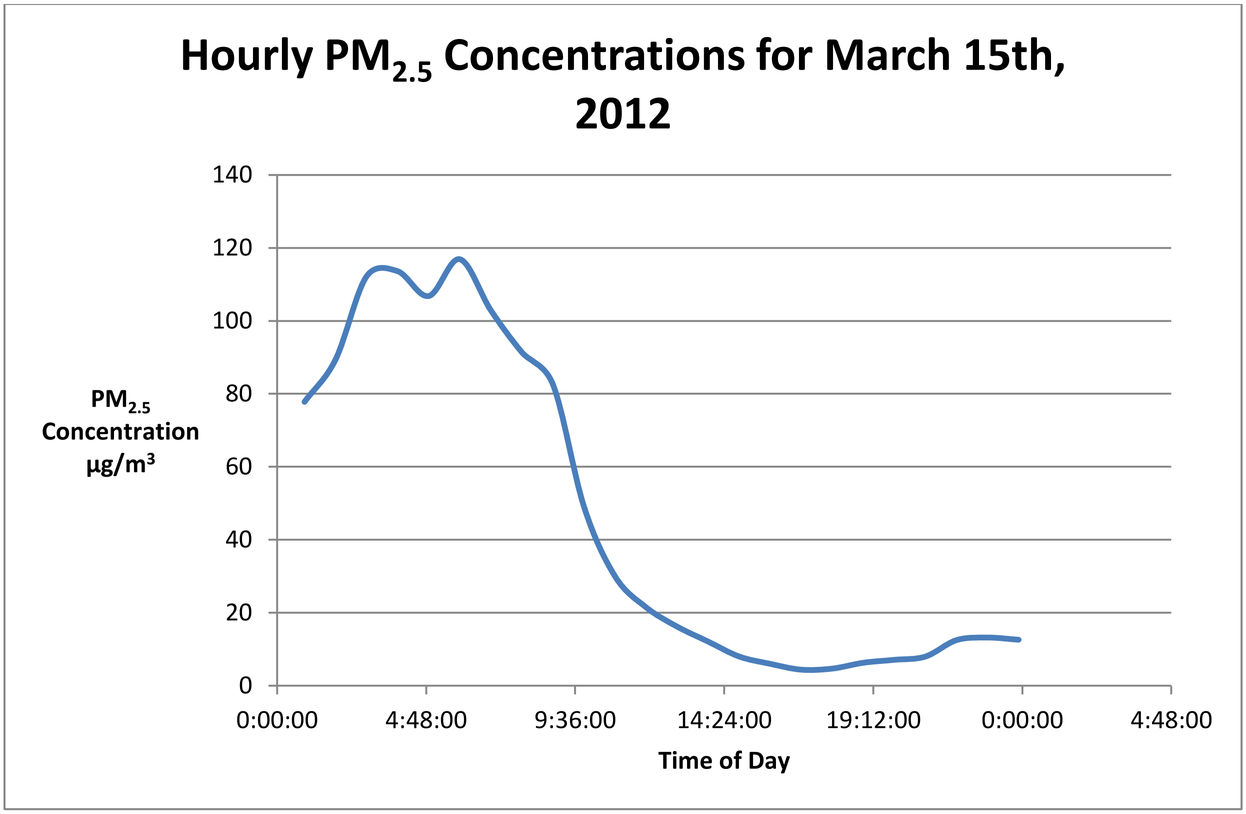

Pollution Rose for 3-11-2012
N
E
S
W
20%
15%
10%
5%
35 to 100
20 to 35
10 to 20
0 to 10
ug/m^3
mean = 37.9
calm = 4.2%
Frequency of counts by wind direction (%)

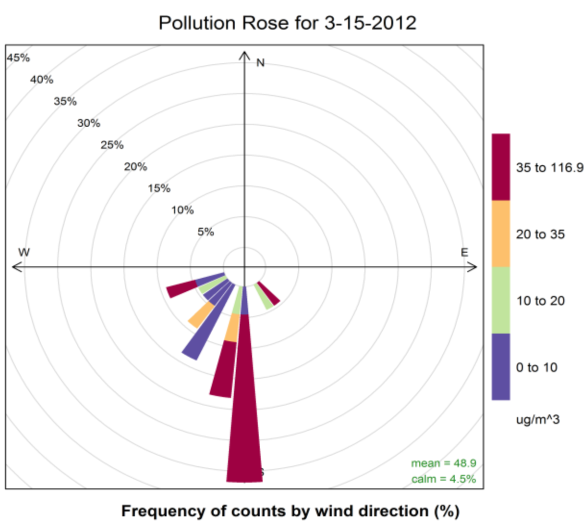

72520 PIT Pittsburgh
700
750
800
850
900
950
1000
1050
−20
−10
0
10
20
30
40
12Z 11 Mar 2012
University of Wyoming

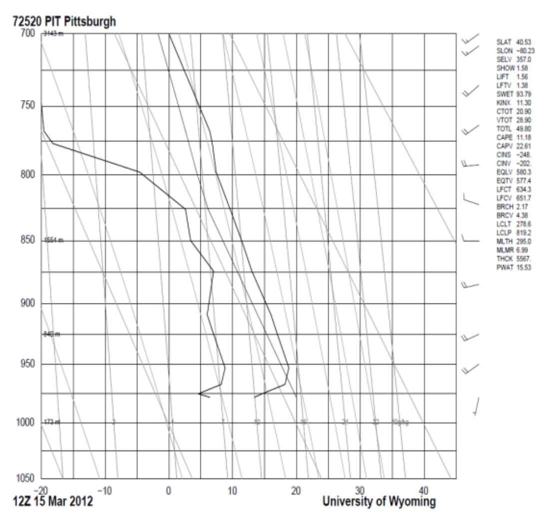

Hourly PM2.5 Concentrations for March 12th, 2012
PM2.5 Concentration µg/m³
120
100
80
60
40
20
0
0:00:00
4:48:00
9:36:00
14:24:00
19:12:00
0:00:00
4:48:00
Time of Day

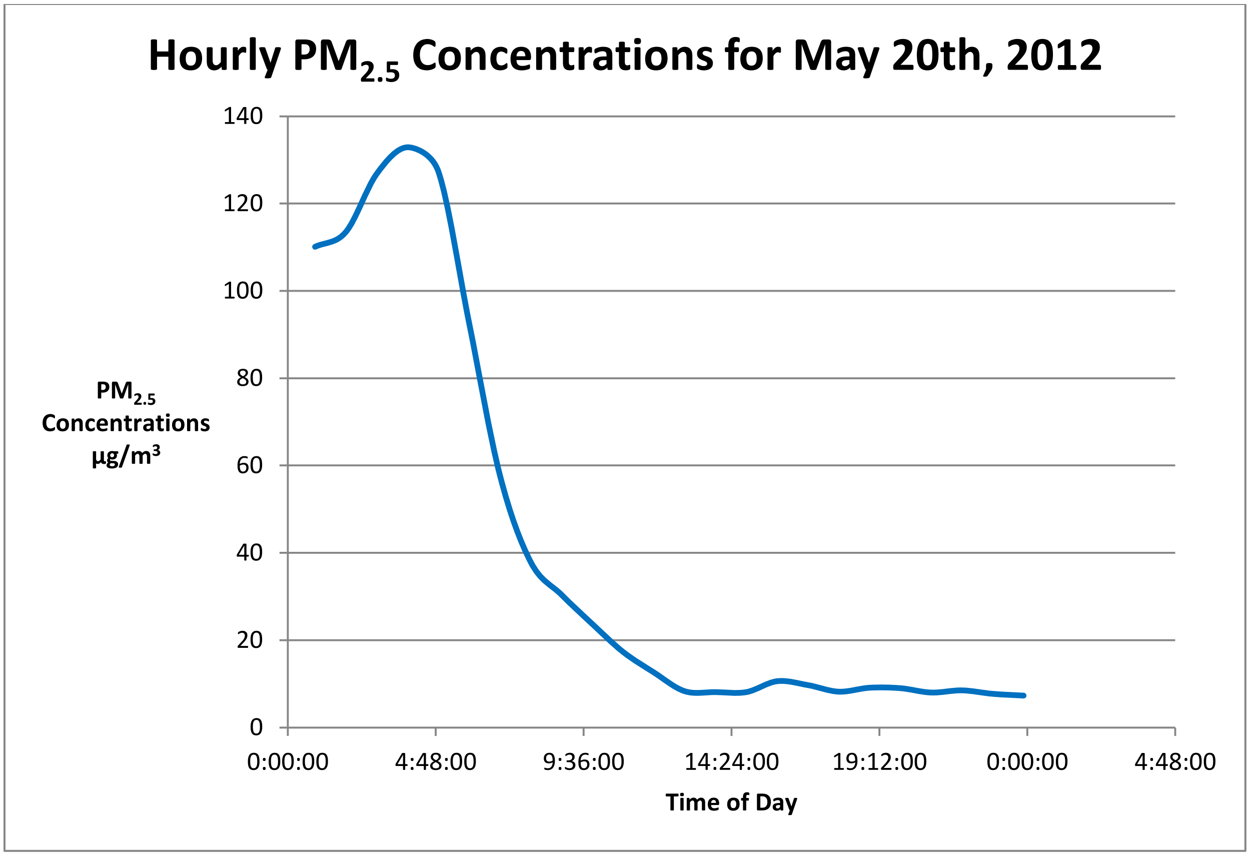

Pollution Rose for 3-12-2012
N
E
S
W
45%
40%
35%
30%
25%
20%
15%
10%
5%
35 to 98.5
20 to 35
10 to 20
0 to 10
ug/m^3
mean = 36.1
calm = 4.2%
Frequency of counts by wind direction (%)

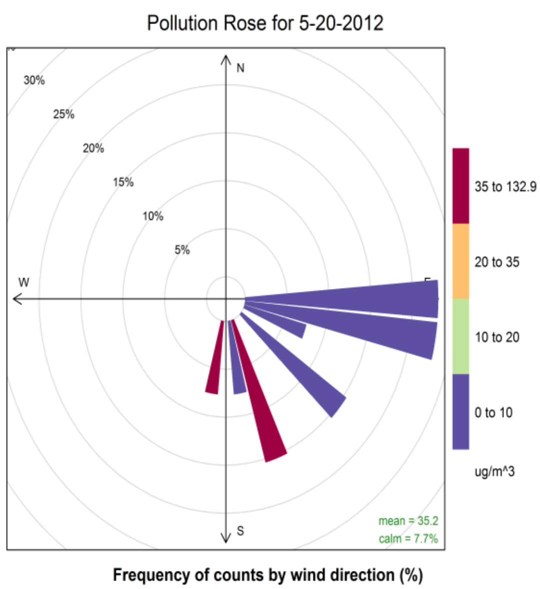

72520 PIT Pittsburgh
700
750
800
850
900
950
1000
1050
-20
-10
0
10
20
30
40
12Z 12 Mar 2012
University of Wyoming

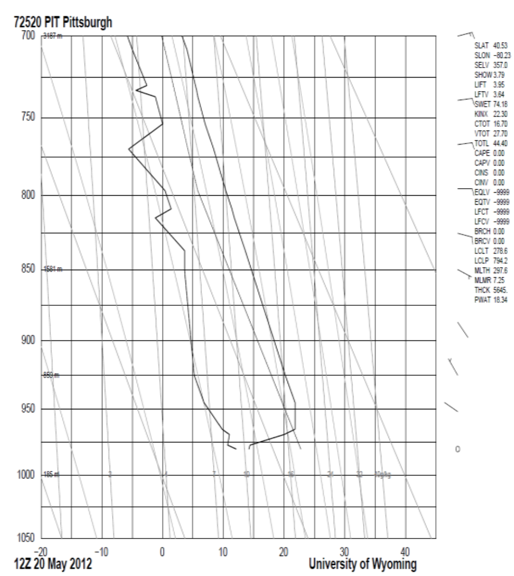

Hourly $PM_{2.5}$ Concentrations for March 15th, 2012
$PM_{2.5}$ Concentration µg/m³
140
120
100
80
60
40
20
0
0:00:00
4:48:00
9:36:00
14:24:00
19:12:00
0:00:00
4:48:00
Time of Day

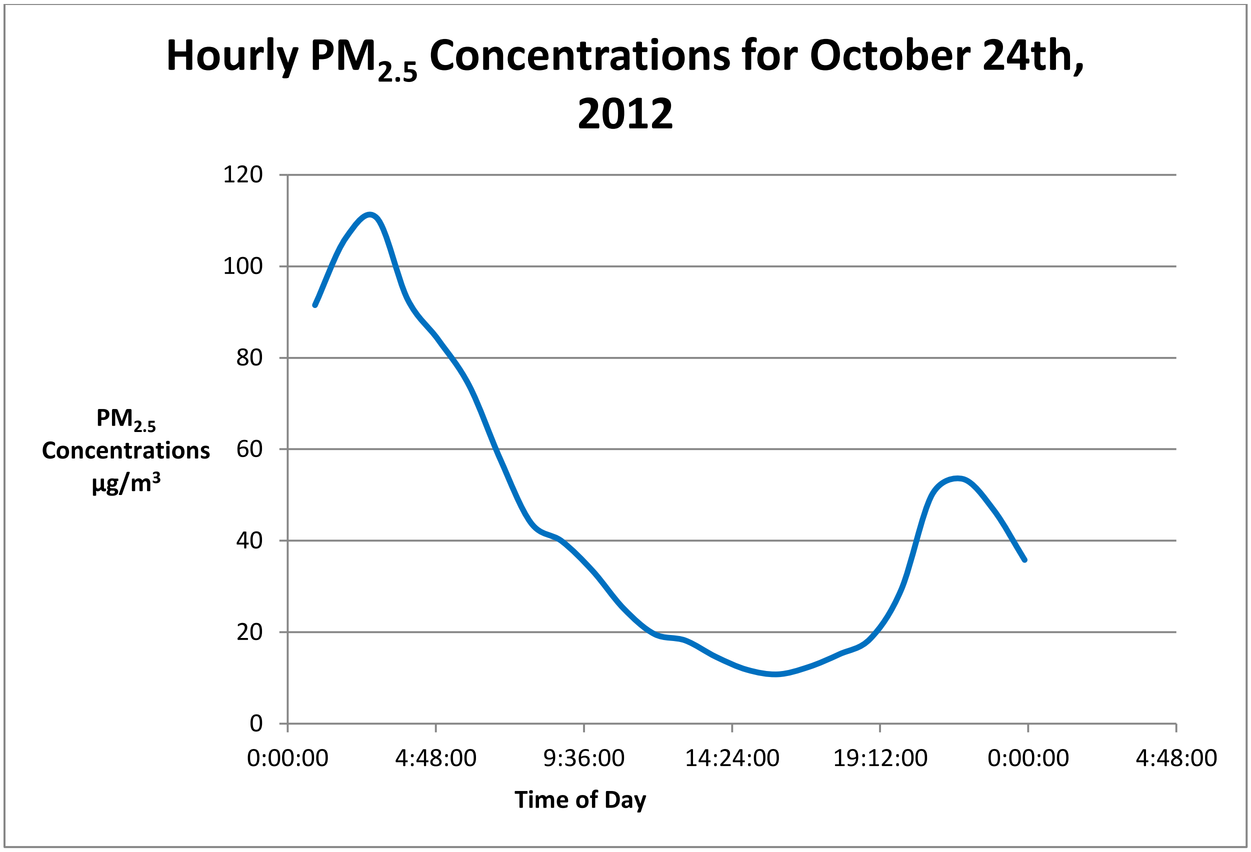

Pollution Rose for 3-15-2012
45%
40%
35%
30%
25%
20%
15%
10%
5%
N
W
E
35 to 116.9
20 to 35
10 to 20
0 to 10
ug/m^3
mean = 48.9
calm = 4.5%
Frequency of counts by wind direction (%)

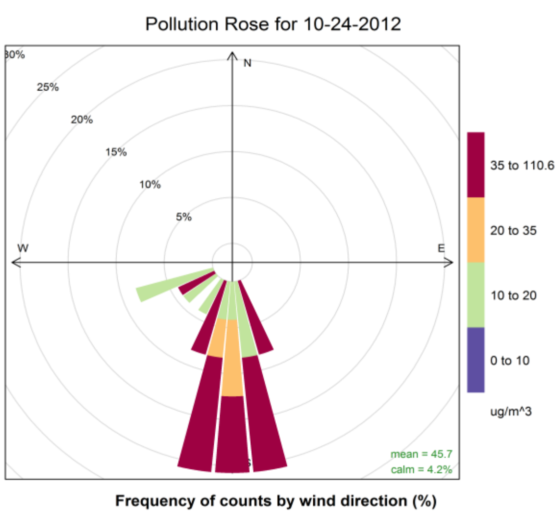

72520 PIT Pittsburgh
700
750
800
850
900
950
1000
1050
−20
−10
0
10
20
30
40
12Z 15 Mar 2012
University of Wyoming

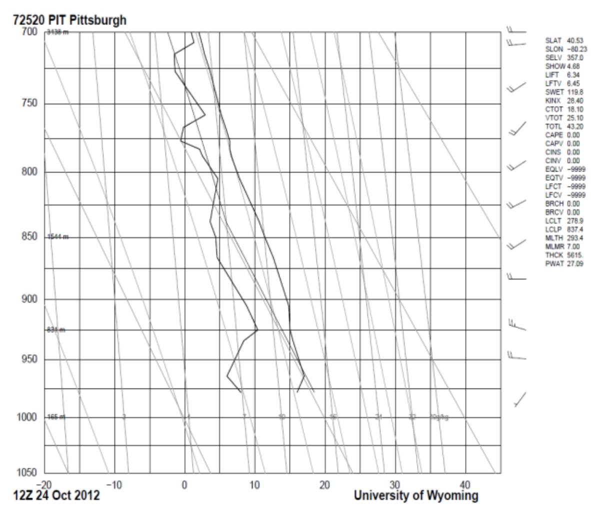

Hourly $PM_{2.5}$ Concentrations for May 20th, 2012
$PM_{2.5}$ Concentrations µg/m³
140
120
100
80
60
40
20
0
0:00:00
4:48:00
9:36:00
14:24:00
19:12:00
0:00:00
4:48:00
Time of Day

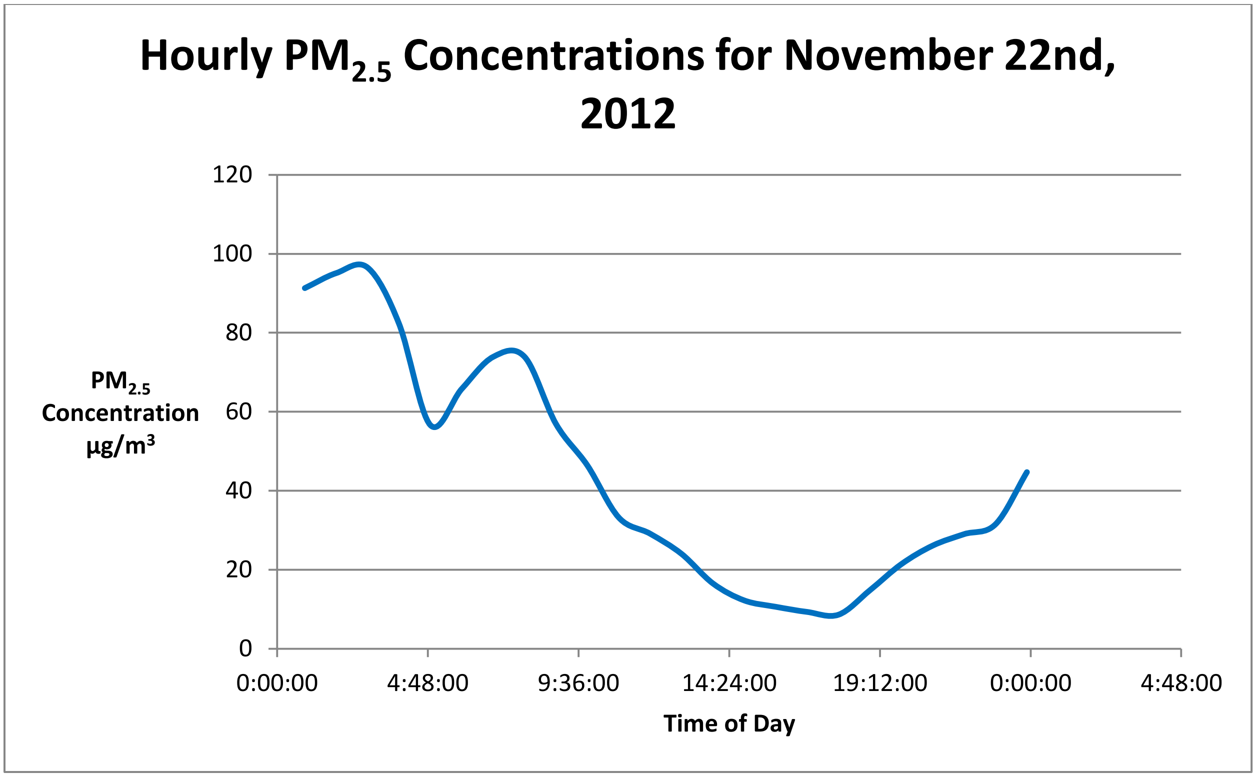

Pollution Rose for 5-20-2012
30%
25%
20%
15%
10%
5%
N
W
E
S
35 to 132.9
20 to 35
10 to 20
0 to 10
ug/m^3
mean = 35.2
calm = 7.7%
Frequency of counts by wind direction (%)

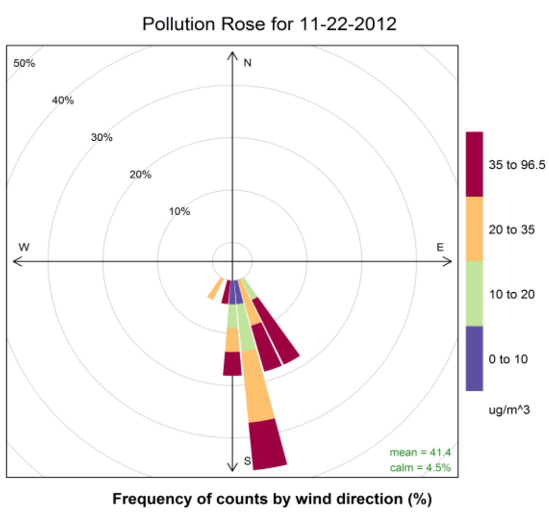

72520 PIT Pittsburgh
700
750
800
850
900
950
1000
1050
−20
−10
0
10
20
30
40
12Z 20 May 2012
University of Wyoming

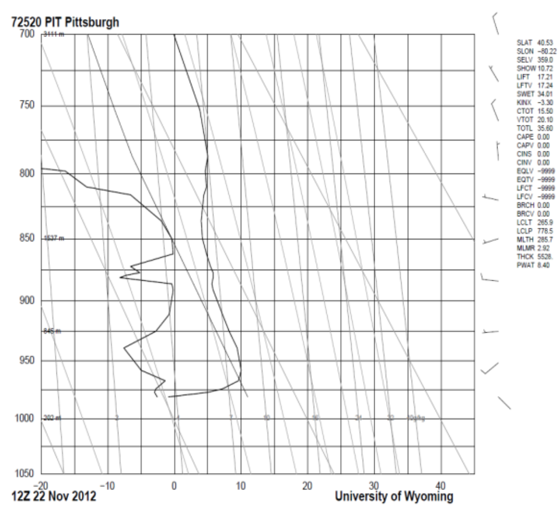

Hourly PM2.5 Concentrations for October 24th, 2012
120
100
80
60
40
20
0
PM2.5 Concentrations µg/m3
0:00:00
4:48:00
9:36:00
14:24:00
19:12:00
0:00:00
4:48:00
Time of Day

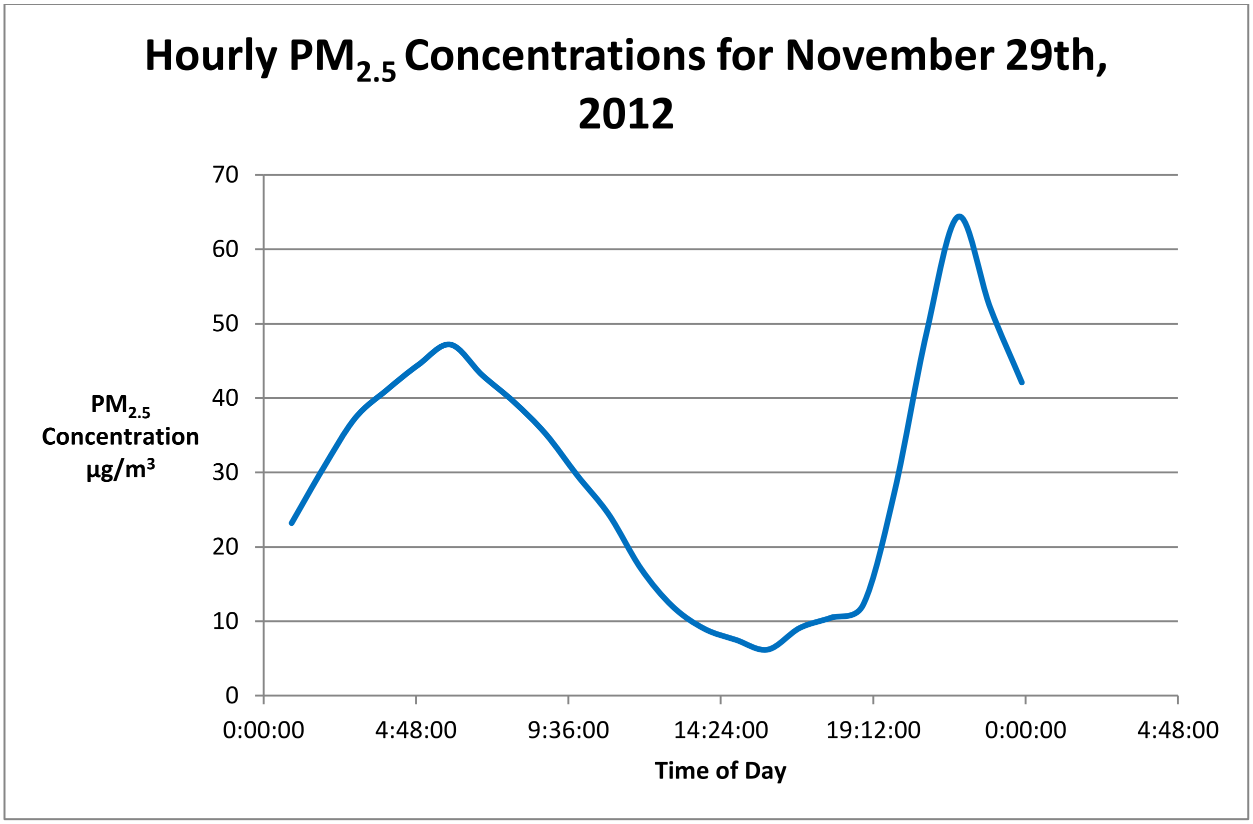

Pollution Rose for 10-24-2012
30%
25%
20%
15%
10%
5%
N
W
E
35 to 110.6
20 to 35
10 to 20
0 to 10
ug/m^3
mean = 45.7
calm = 4.2%
Frequency of counts by wind direction (%)

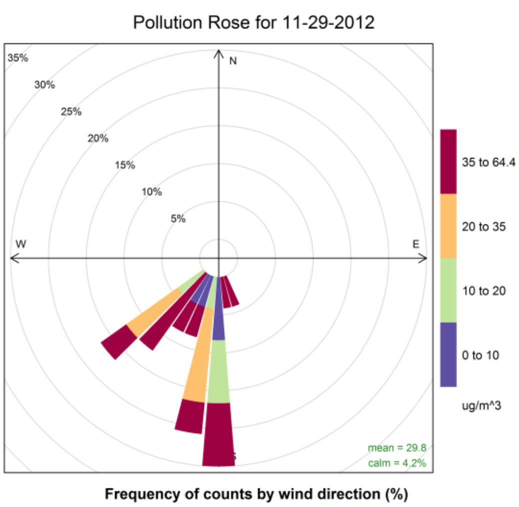

72520 PIT Pittsburgh
700
750
800
850
900
950
1000
1050
−20
−10
0
10
20
30
40
12Z 24 Oct 2012
University of Wyoming

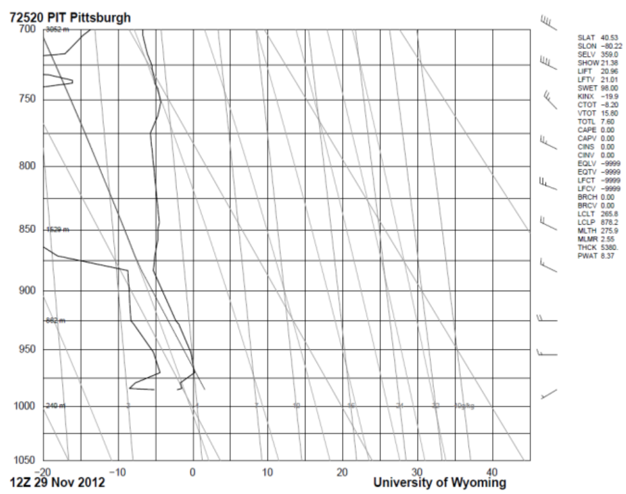

Hourly PM2.5 Concentrations for November 22nd, 2012
PM2.5 Concentration µg/m³
120
100
80
60
40
20
0
0:00:00
4:48:00
9:36:00
14:24:00
19:12:00
0:00:00
4:48:00
Time of Day

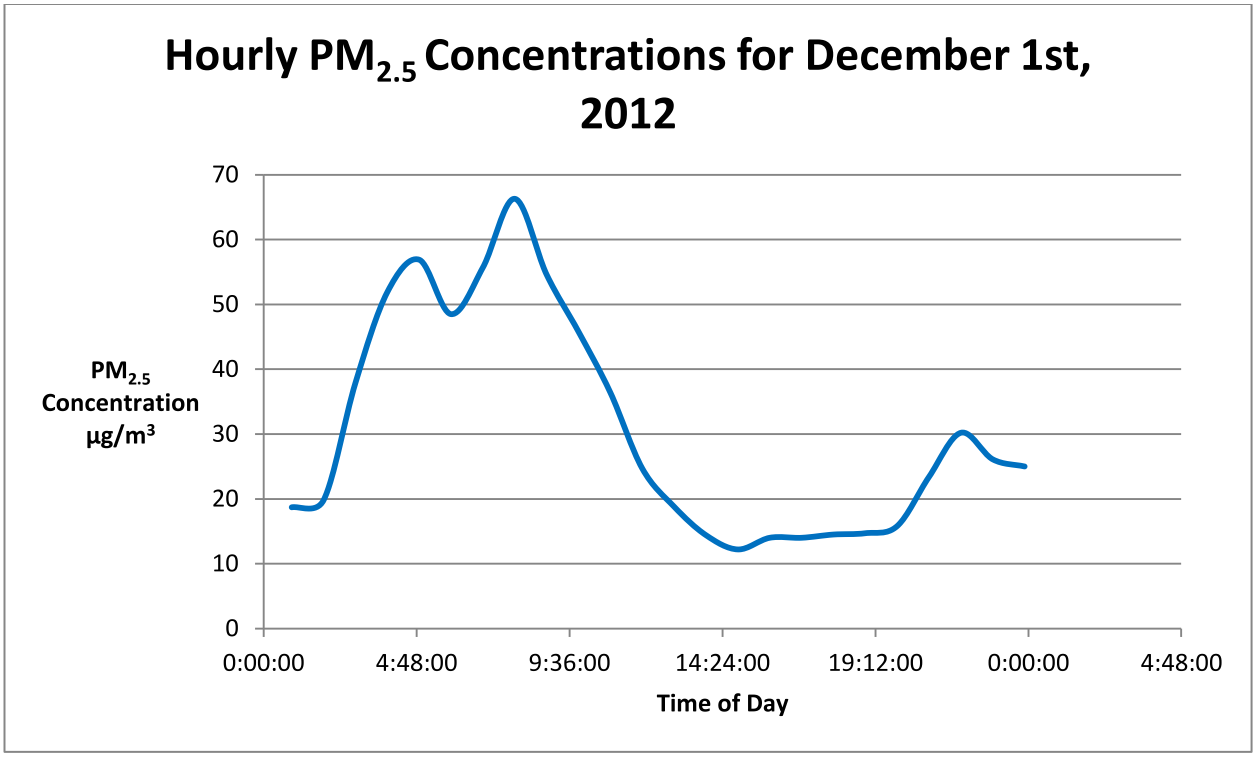

Pollution Rose for 11-22-2012
50%
40%
30%
20%
10%
N
W
E
S
35 to 96.5
20 to 35
10 to 20
0 to 10
ug/m^3
mean = 41.4
calm = 4.5%
Frequency of counts by wind direction (%)

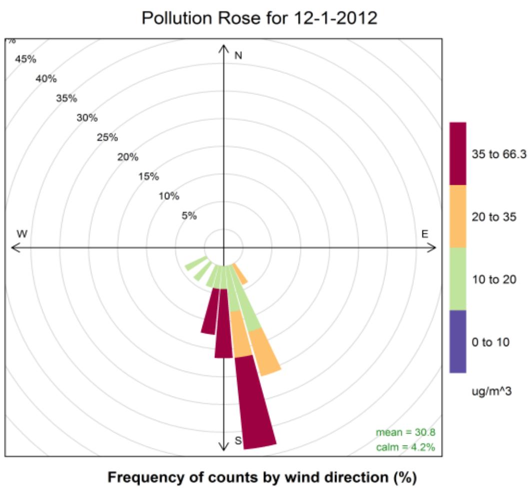

72520 PIT Pittsburgh
700
750
800
850
900
950
1000
1050
-20
-10
0
10
20
30
40
12Z 22 Nov 2012
University of Wyoming

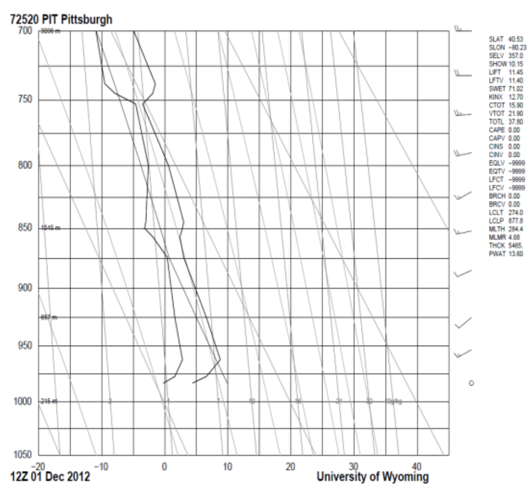

Hourly PM2.5 Concentrations for November 29th, 2012
PM2.5 Concentration µg/m3
70
60
50
40
30
20
10
0
0:00:00
4:48:00
9:36:00
14:24:00
19:12:00
0:00:00
4:48:00
Time of Day

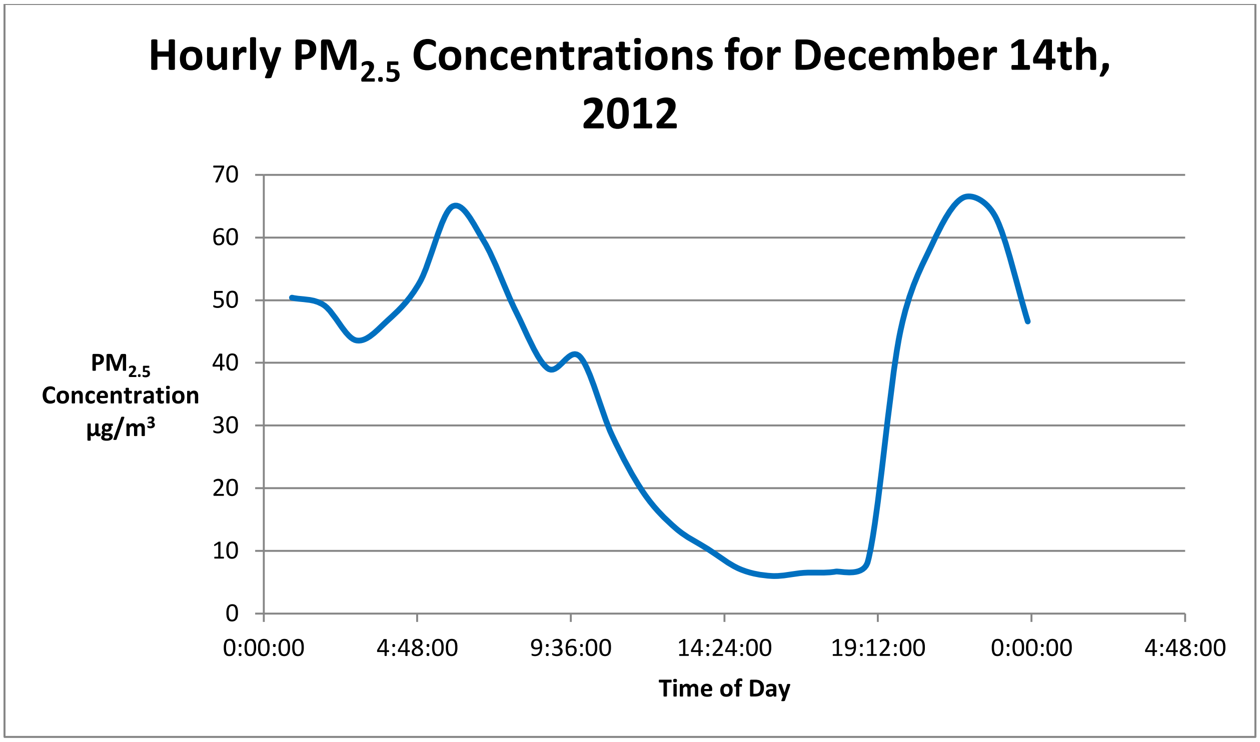

Pollution Rose for 11-29-2012
35%
30%
25%
20%
15%
10%
5%
N
W
E
35 to 64.4
20 to 35
10 to 20
0 to 10
ug/m^3
mean = 29.8
calm = 4.2%
Frequency of counts by wind direction (%)

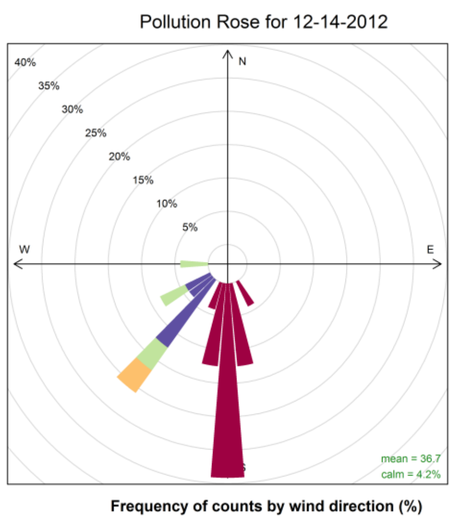

72520 PIT Pittsburgh
700
750
800
850
900
950
1000
1050
−20
−10
0
10
20
30
40
12Z 29 Nov 2012
University of Wyoming

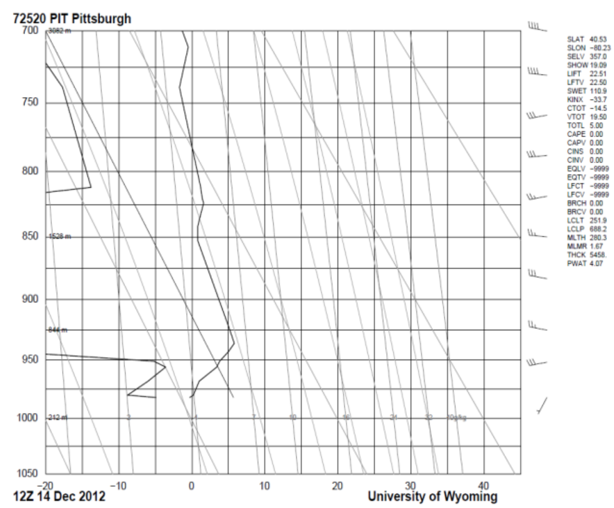

Hourly PM2.5 Concentrations for December 1st, 2012
PM2.5 Concentration µg/m3
0
10
20
30
40
50
60
70
0:00:00
4:48:00
9:36:00
14:24:00
19:12:00
0:00:00
4:48:00
Time of Day

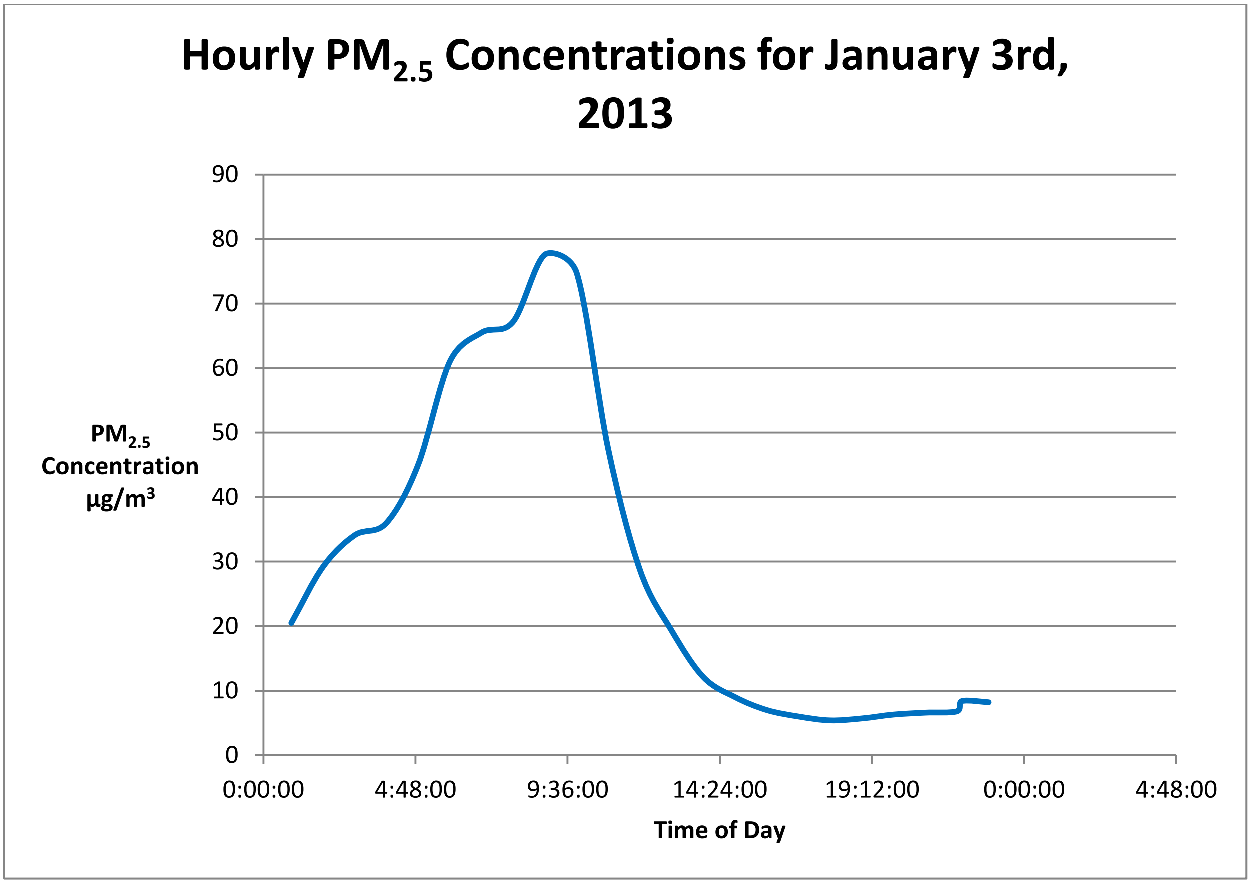

Pollution Rose for 12-1-2012
N
E
S
W
5%
10%
15%
20%
25%
30%
35%
40%
45%
35 to 66.3
20 to 35
10 to 20
0 to 10
ug/m^3
mean = 30.8
calm = 4.2%
Frequency of counts by wind direction (%)

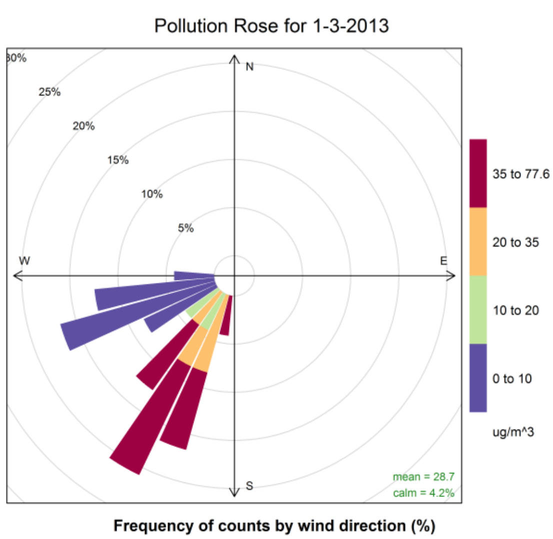

72520 PIT Pittsburgh
700
750
800
850
900
950
1000
1050
−20
−10
0
10
20
30
40
12Z 01 Dec 2012
University of Wyoming

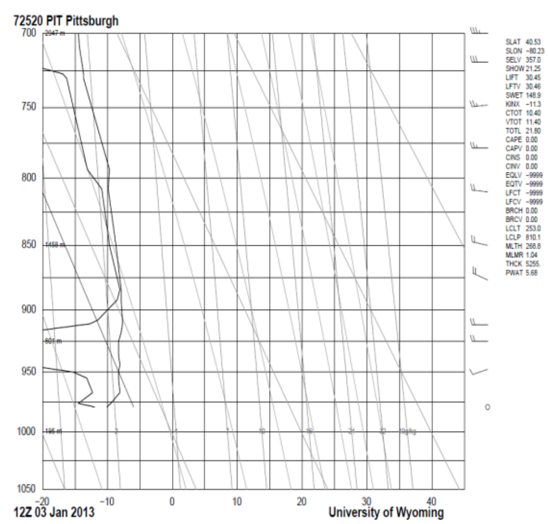

Hourly PM2.5 Concentrations for December 14th, 2012
PM2.5 Concentration µg/m³
70
60
50
40
30
20
10
0
0:00:00
4:48:00
9:36:00
14:24:00
19:12:00
0:00:00
4:48:00
Time of Day

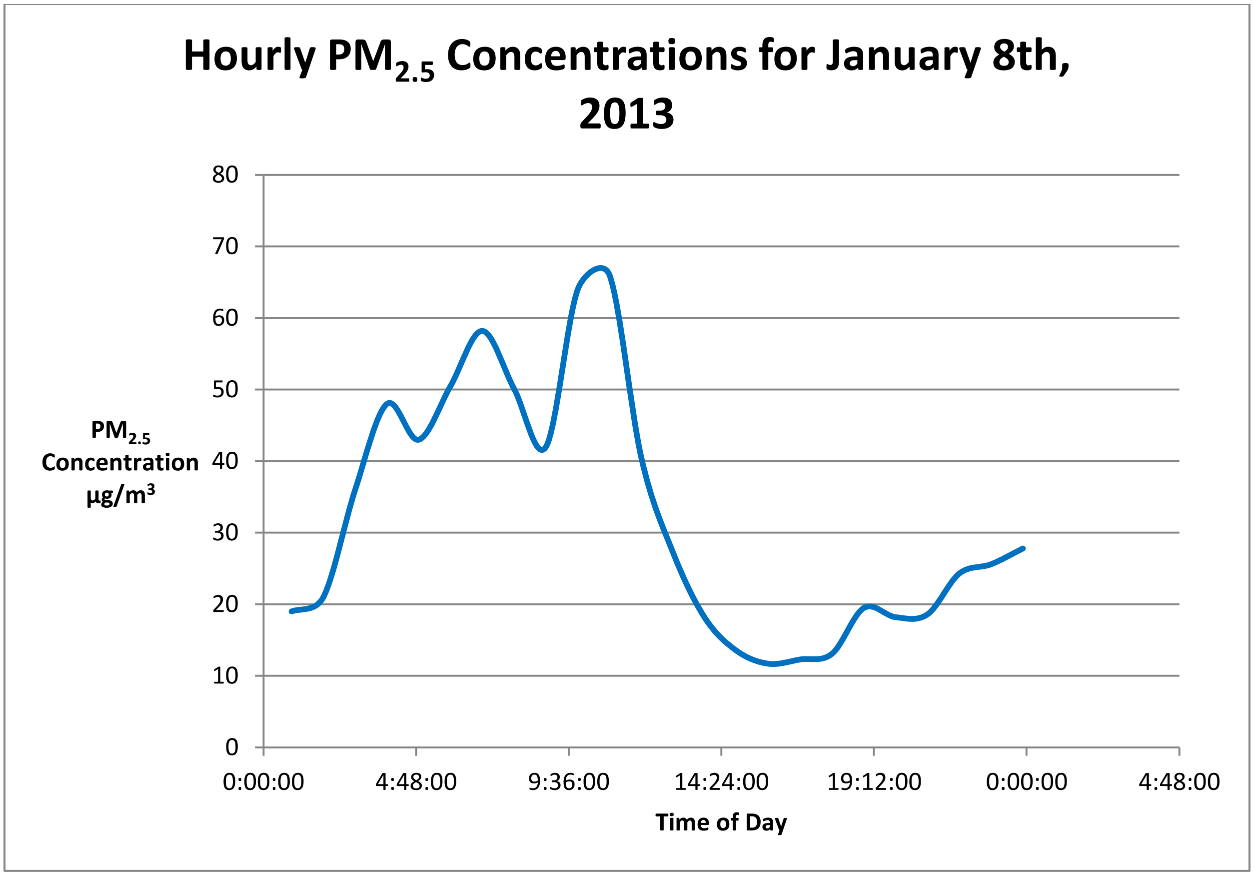

Pollution Rose for 12-14-2012
N
E
W
40%
35%
30%
25%
20%
15%
10%
5%
35 to 66.4
20 to 35
10 to 20
0 to 10
ug/m^3
mean = 36.7
calm = 4.2%
Frequency of counts by wind direction (%)


72520 PIT Pittsburgh
700
750
800
850
900
950
1000
1050
−20
−10
0
10
20
30
40
12Z 14 Dec 2012
University of Wyoming

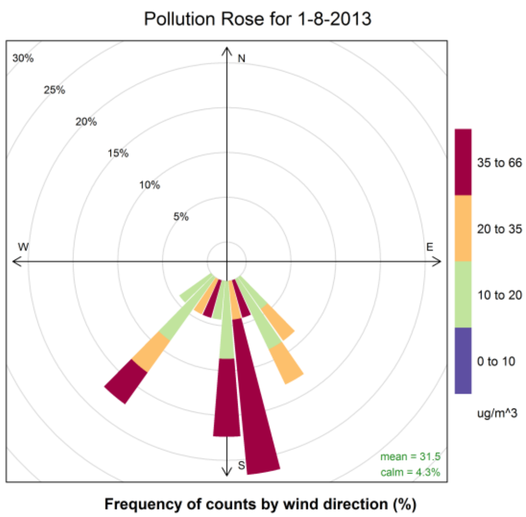

Hourly PM2.5 Concentrations for January 3rd, 2013
90
80
70
60
50
40
30
20
10
0
PM2.5 Concentration µg/m3
0:00:00
4:48:00
9:36:00
14:24:00
19:12:00
0:00:00
4:48:00
Time of Day


Pollution Rose for 1-3-2013
30%
25%
20%
15%
10%
5%
N
W
E
S
35 to 77.6
20 to 35
10 to 20
0 to 10
ug/m^3
mean = 28.7
calm = 4.2%
Frequency of counts by wind direction (%)

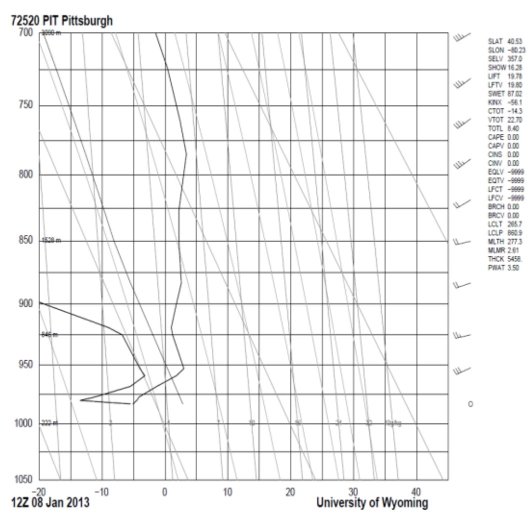

72520 PIT Pittsburgh
700
750
800
850
900
950
1000
1050
−20
−10
0
10
20
30
40
12Z 03 Jan 2013
University of Wyoming



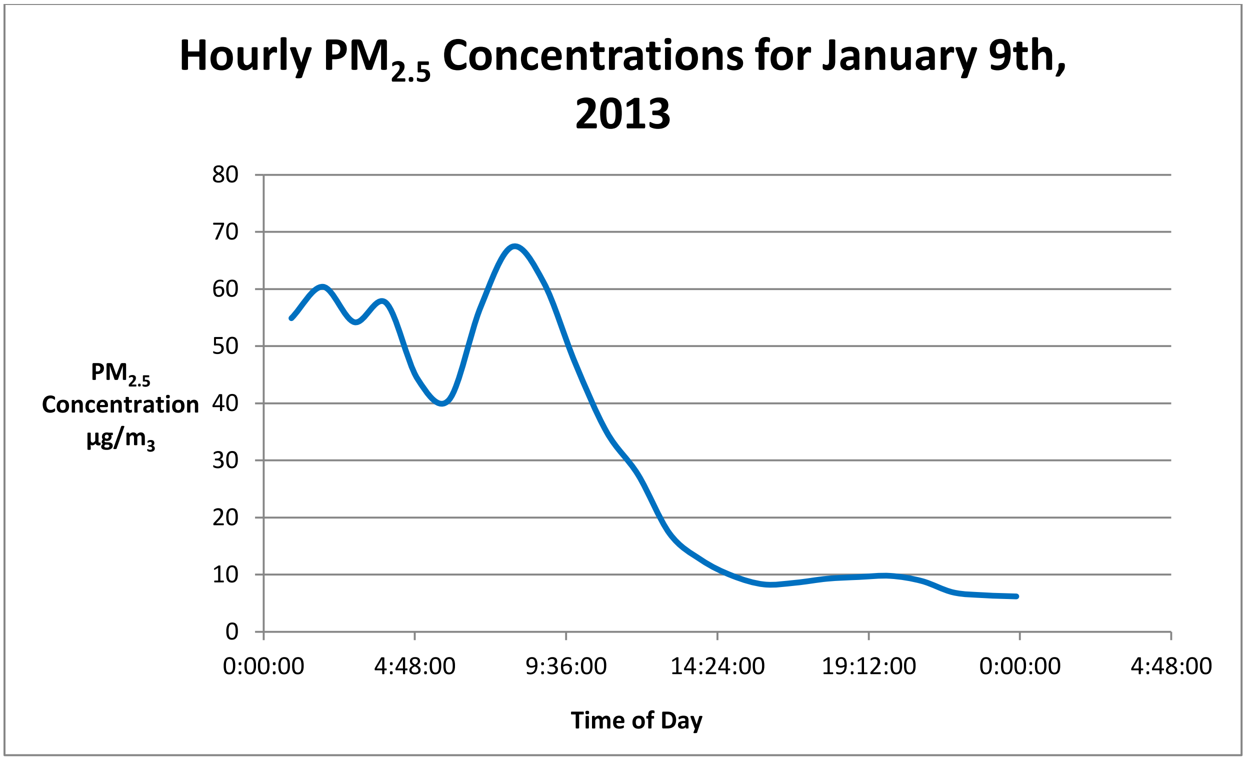
Hourly $PM_{2.5}$ Concentrations for January 8th, 2013
$PM_{2.5}$ Concentration µg/m³
0
10
20
30
40
50
60
70
80
0:00:00
4:48:00
9:36:00
14:24:00
19:12:00
0:00:00
4:48:00
Time of Day

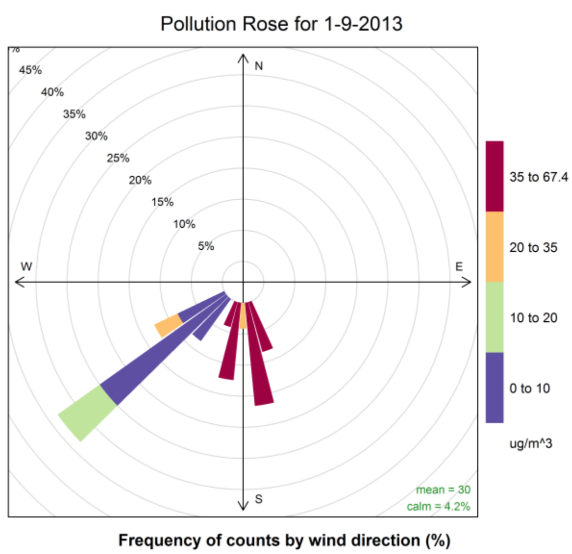


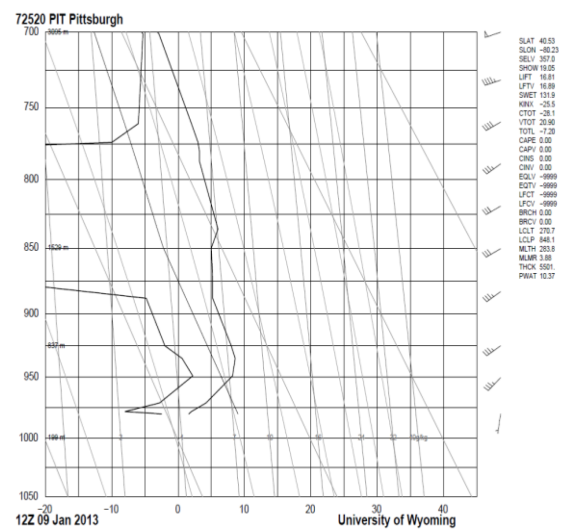
Pollution Rose for 1-8-2013
30%
25%
20%
15%
10%
5%
N
W
E
S
35 to 66
20 to 35
10 to 20
0 to 10
ug/m^3
mean = 31.5
calm = 4.3%
Frequency of counts by wind direction (%)

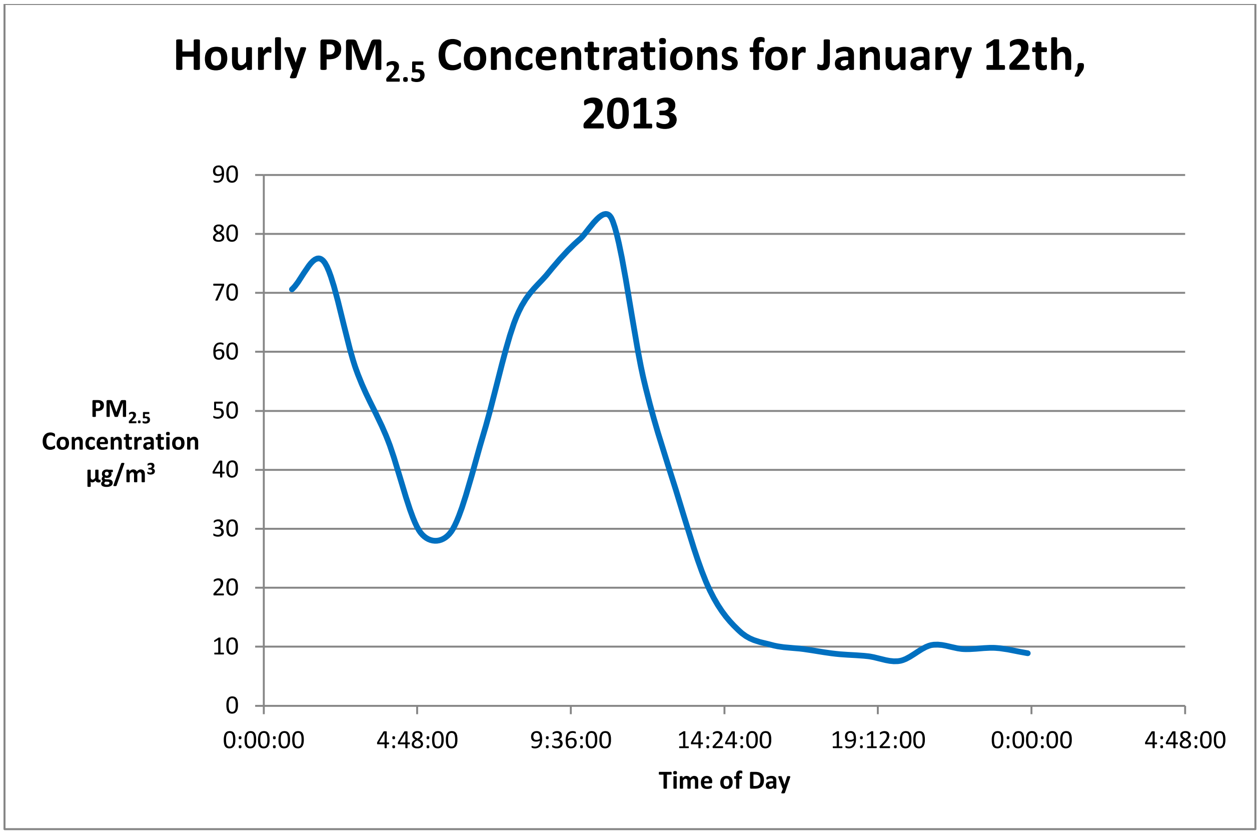


72520 PIT Pittsburgh
12Z 08 Jan 2013
University of Wyoming

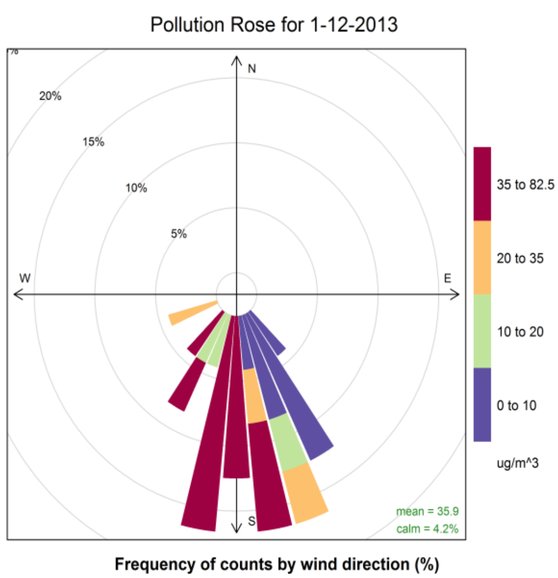

Hourly PM2.5 Concentrations for January 9th, 2013
PM2.5 Concentration μg/m3
80
70
60
50
40
30
20
10
0
0:00:00
4:48:00
9:36:00
14:24:00
19:12:00
0:00:00
4:48:00
Time of Day


Pollution Rose for 1-9-2013
45%
40%
35%
30%
25%
20%
15%
10%
5%
N
W
E
S
35 to 67.4
20 to 35
10 to 20
0 to 10
ug/m^3
mean = 30
calm = 4.2%
Frequency of counts by wind direction (%)

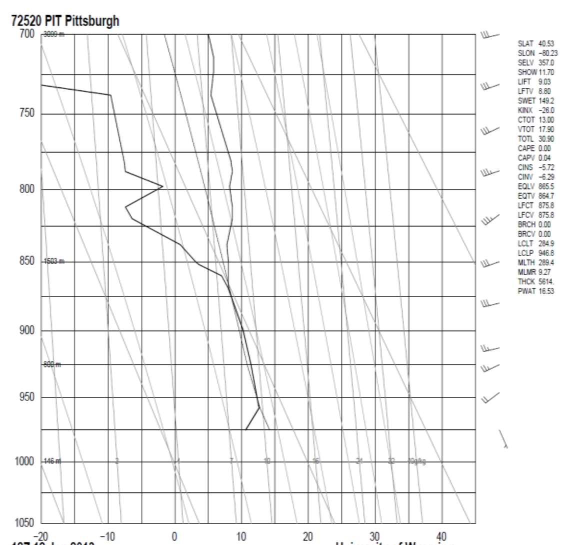

72520 PIT Pittsburgh
700
750
800
850
900
950
1000
1050
−20
−10
0
10
20
30
40
12Z 09 Jan 2013
University of Wyoming



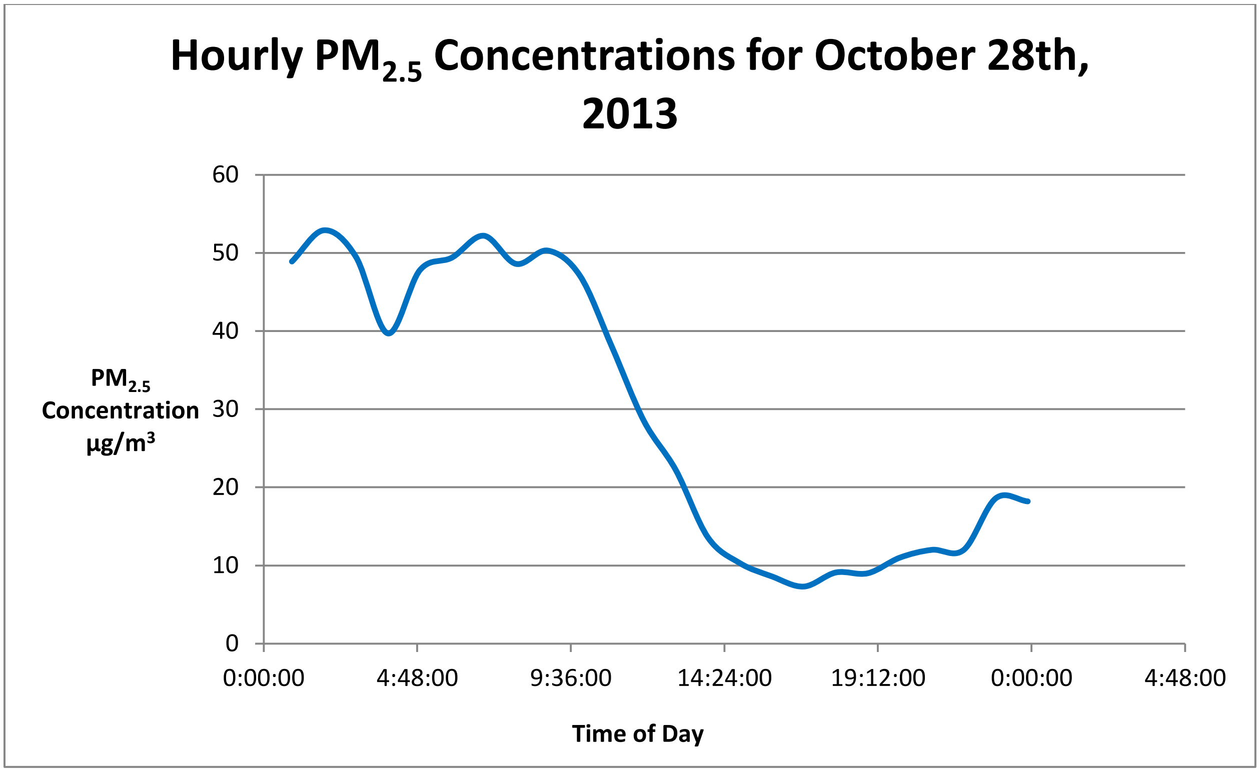
Hourly $PM_{2.5}$ Concentrations for January 12th, 2013
90
80
70
60
50
40
30
20
10
0
$PM_{2.5}$ Concentration µg/m³
0:00:00
4:48:00
9:36:00
14:24:00
19:12:00
0:00:00
4:48:00
Time of Day

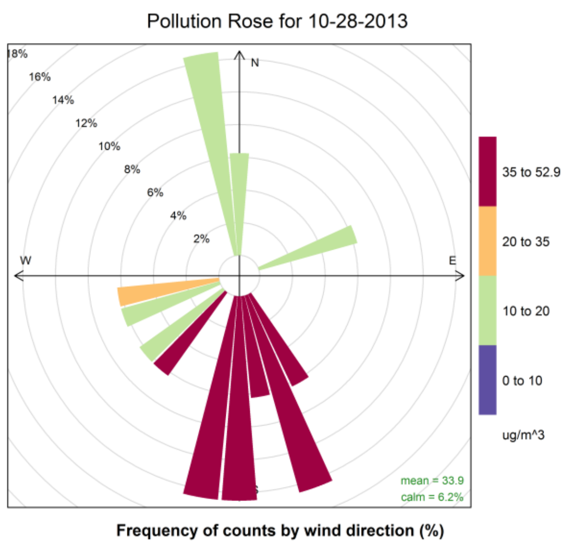


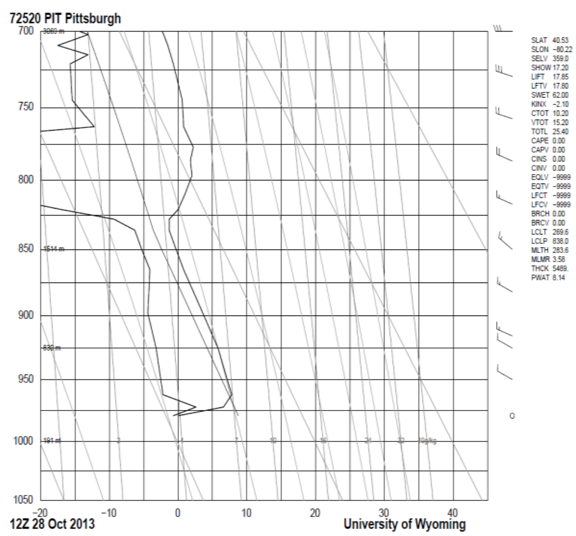
Pollution Rose for 1-12-2013
N
E
S
W
20%
15%
10%
5%
35 to 82.5
20 to 35
10 to 20
0 to 10
ug/m^3
mean = 35.9
calm = 4.2%
Frequency of counts by wind direction (%)

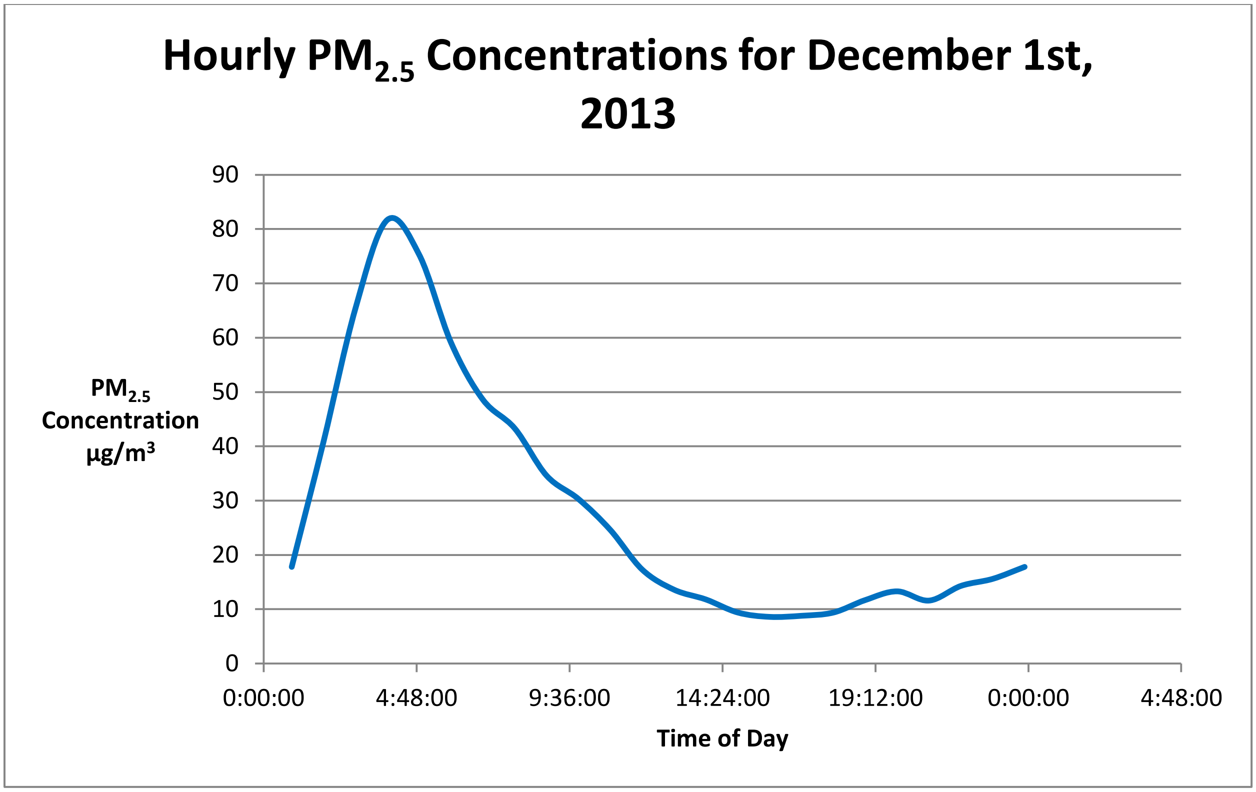


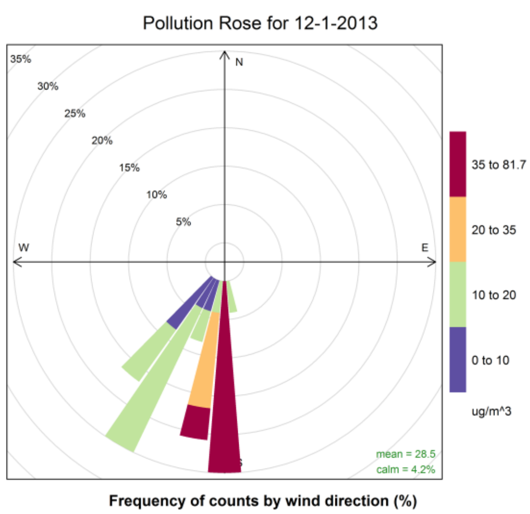
72520 PIT Pittsburgh
700
750
800
850
900
950
1000
1050
−20
−10
0
10
20
30
40
12Z 12 Jan 2013
University of Wyoming
SLAT 40.53
SLON −80.23
SELV 357.0
SHOW 11.70
LIFT 9.03
LFTV 8.80
SWET 149.2
KINX −26.0
CTOT 13.00
VTOT 17.90
TOTL 30.90
CAPE 0.00
CAPV 0.04
CINS −5.72
CINV −6.29
EQLV 865.5
EQTV 864.7
LFCT 875.8
LFCV 875.8
BRCH 0.00
BRCV 0.00
LCLT 284.9
LCLP 946.8
MLTH 289.4
MLMR 9.27
THCK 5614.
PWAT 16.53

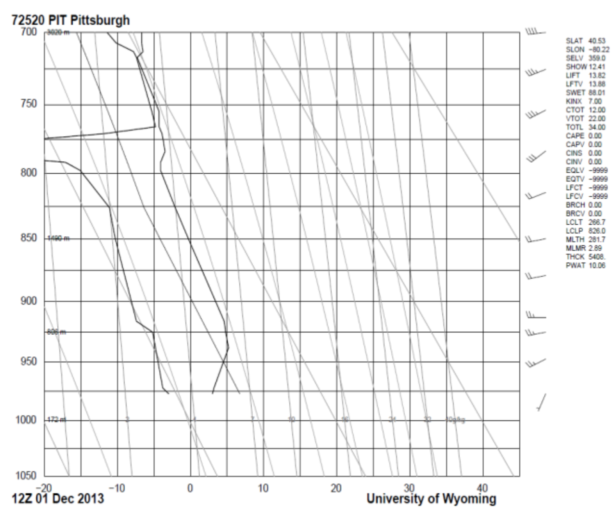

Hourly $PM_{2.5}$ Concentrations for October 28th, 2013
60
50
40
30
20
10
0
$PM_{2.5}$ Concentration µg/m³
0:00:00
4:48:00
9:36:00
14:24:00
19:12:00
0:00:00
4:48:00
Time of Day

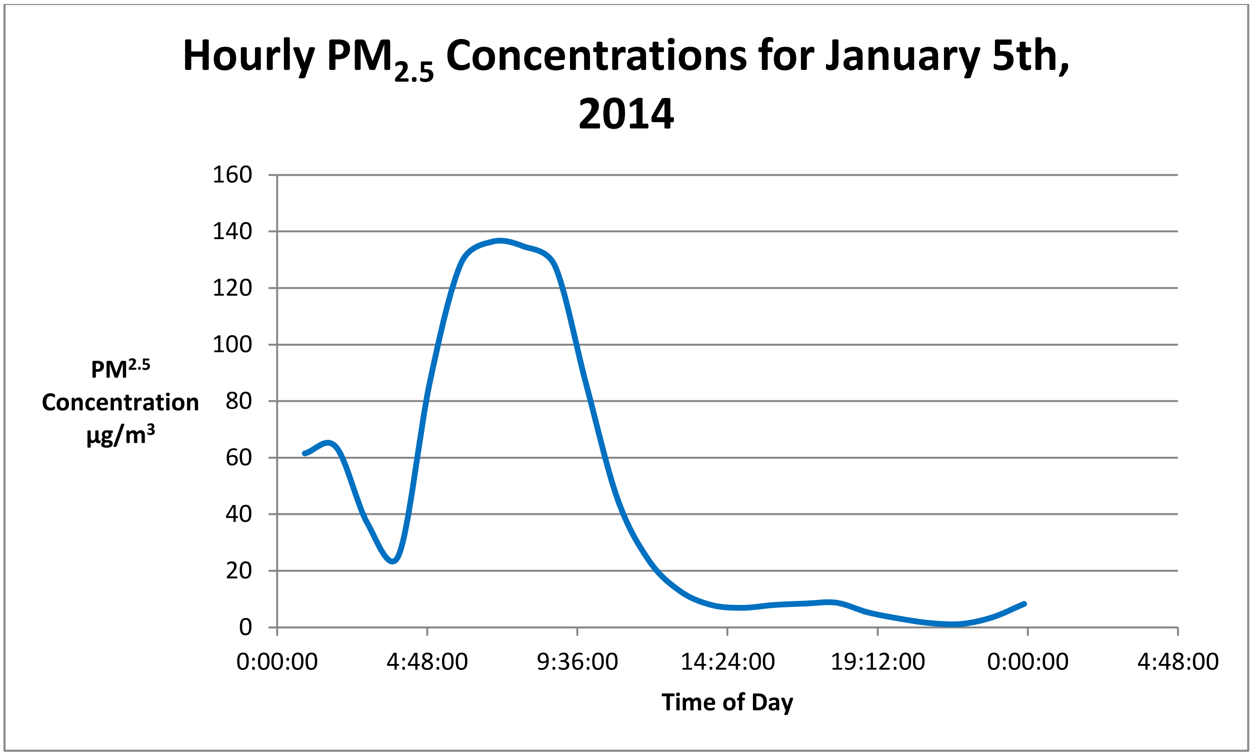

Pollution Rose for 10-28-2013
18%
16%
14%
12%
10%
8%
6%
4%
2%
N
W
E
35 to 52.9
20 to 35
10 to 20
0 to 10
ug/m^3
mean = 33.9
calm = 6.2%
Frequency of counts by wind direction (%)

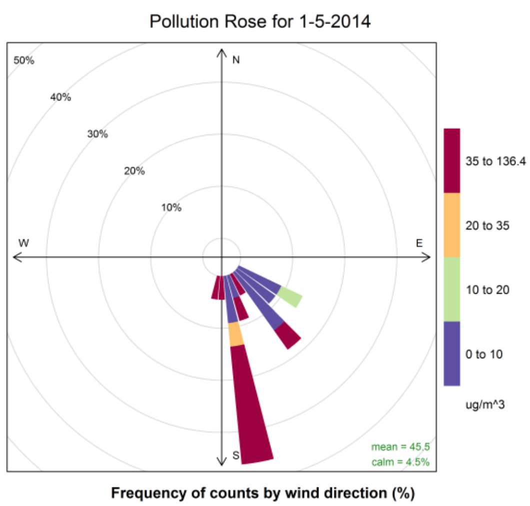

72520 PIT Pittsburgh
700
750
800
850
900
950
1000
1050
−20
−10
0
10
20
30
40
12Z 28 Oct 2013
University of Wyoming

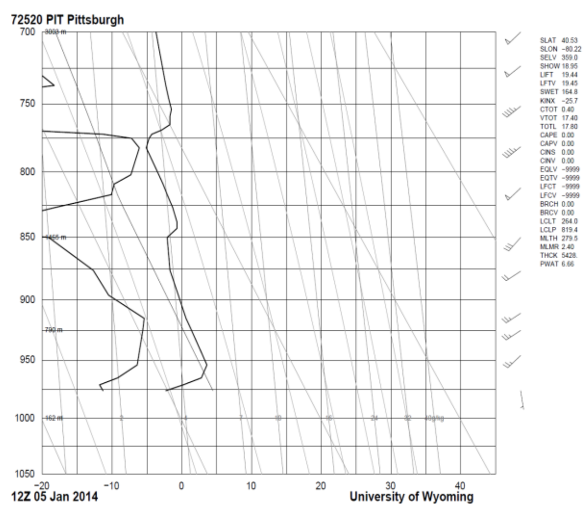

Hourly $PM_{2.5}$ Concentrations for December 1st, 2013
$PM_{2.5}$ Concentration µg/m³
90
80
70
60
50
40
30
20
10
0
0:00:00
4:48:00
9:36:00
14:24:00
19:12:00
0:00:00
4:48:00
Time of Day

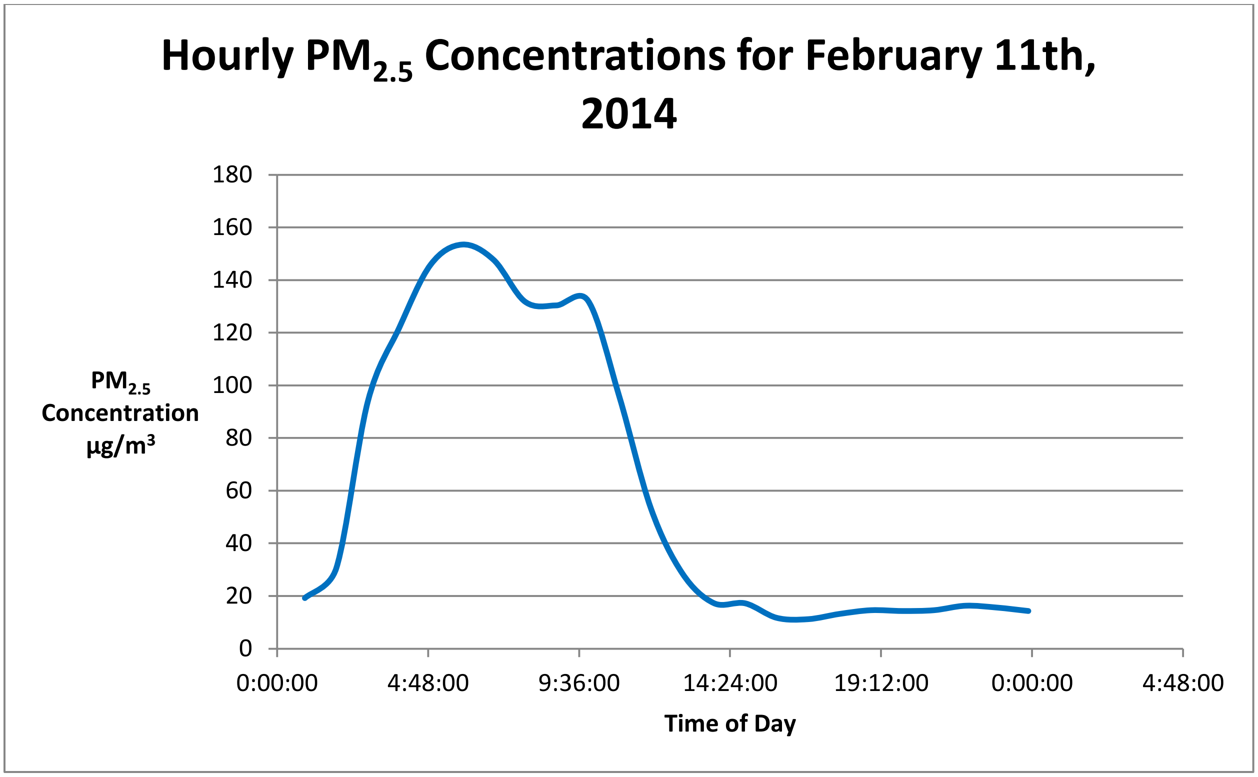

Pollution Rose for 12-1-2013
35%
30%
25%
20%
15%
10%
5%
N
W
E
S
35 to 81.7
20 to 35
10 to 20
0 to 10
ug/m^3
mean = 28.5
calm = 4.2%
Frequency of counts by wind direction (%)

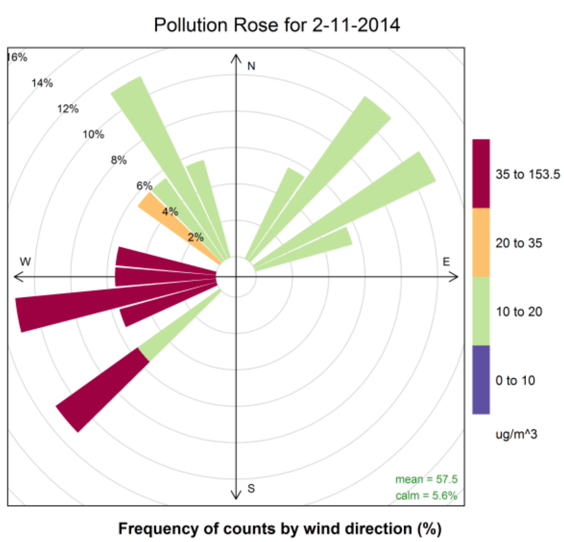

72520 PIT Pittsburgh
700
750
800
850
900
950
1000
1050
−20
−10
0
10
20
30
40
12Z 01 Dec 2013
University of Wyoming

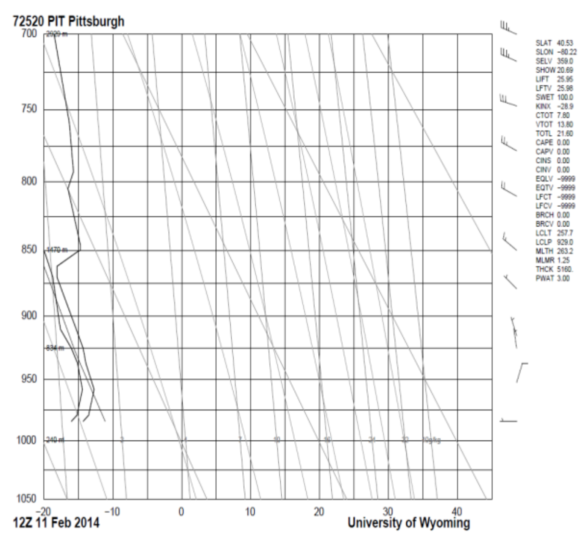

Hourly PM2.5 Concentrations for January 5th, 2014
160
140
120
100
80
60
40
20
0
PM2.5 Concentration µg/m3
0:00:00
4:48:00
9:36:00
14:24:00
19:12:00
0:00:00
4:48:00
Time of Day

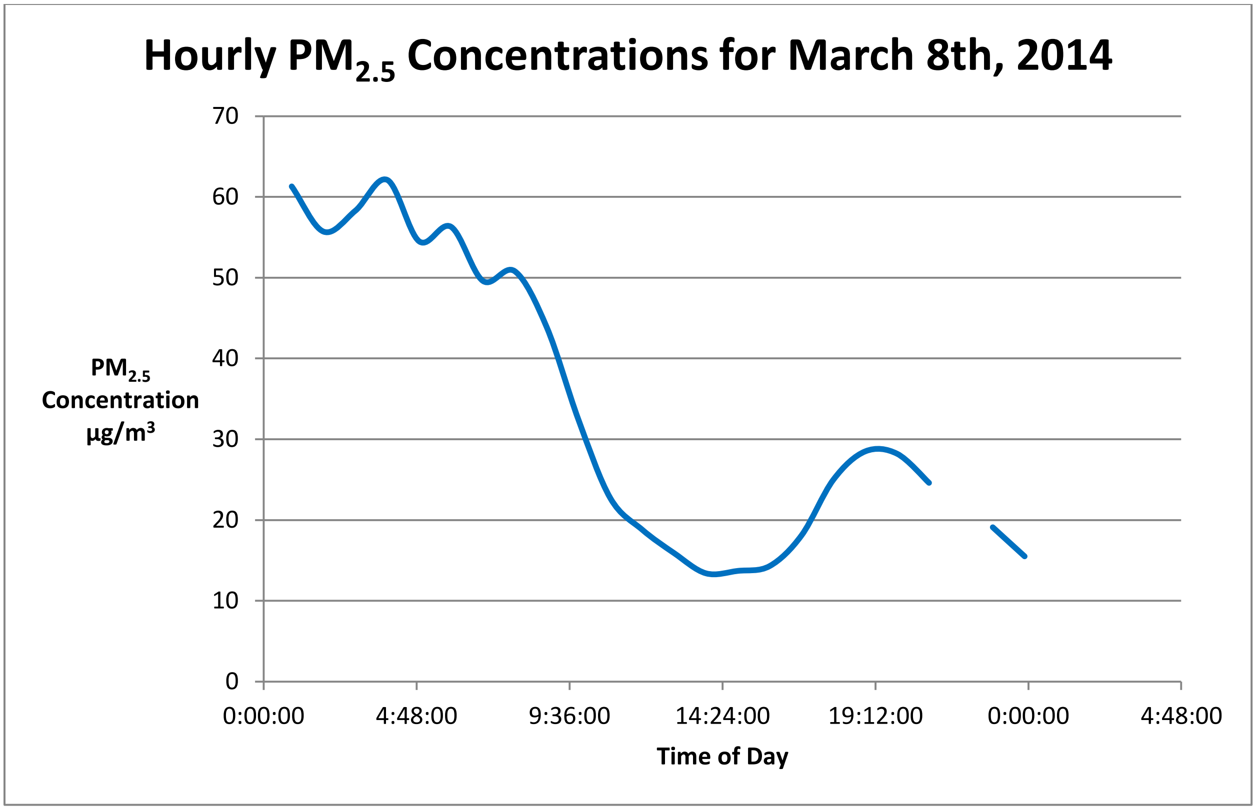

Pollution Rose for 1-5-2014
50%
40%
30%
20%
10%
N
W
E
S
35 to 136.4
20 to 35
10 to 20
0 to 10
ug/m^3
mean = 45.5
calm = 4.5%
Frequency of counts by wind direction (%)

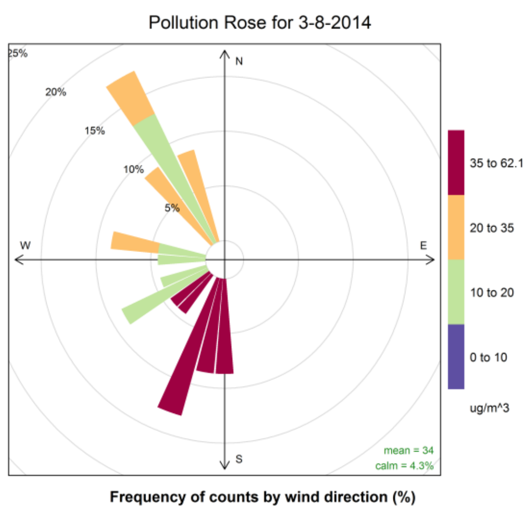

72520 PIT Pittsburgh
700
750
800
850
900
950
1000
1050
−20
−10
0
10
20
30
40
12Z 05 Jan 2014
University of Wyoming


Hourly PM2.5 Concentrations for February 11th, 2014
PM2.5 Concentration µg/m³
180
160
140
120
100
80
60
40
20
0
0:00:00
4:48:00
9:36:00
14:24:00
19:12:00
0:00:00
4:48:00
Time of Day

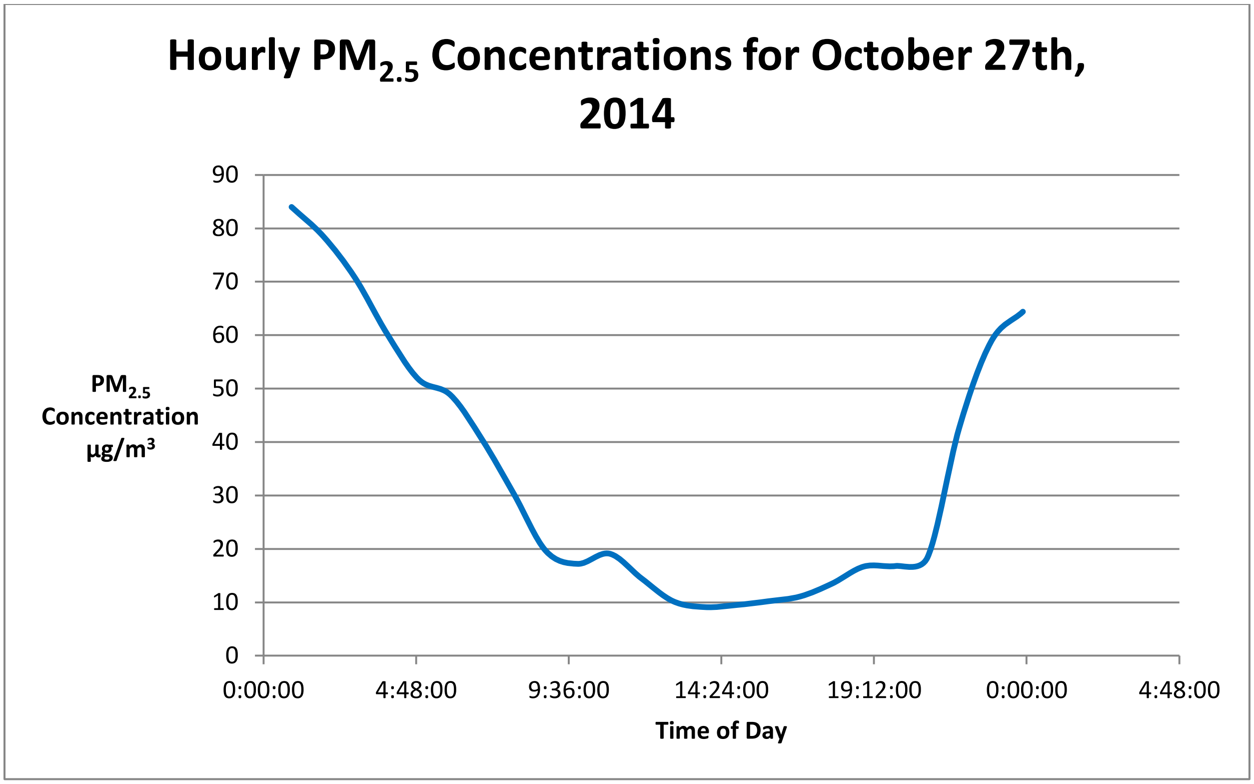

Pollution Rose for 2-11-2014
N
E
S
W
16%
14%
12%
10%
8%
6%
4%
2%
35 to 153.5
20 to 35
10 to 20
0 to 10
ug/m^3
mean = 57.5
calm = 5.6%
Frequency of counts by wind direction (%)


72520 PIT Pittsburgh
700
750
800
850
900
950
1000
1050
−20
−10
0
10
20
30
40
12Z 11 Feb 2014
University of Wyoming

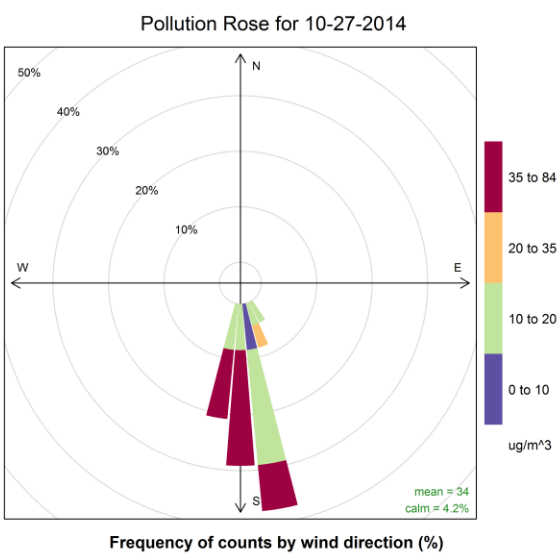




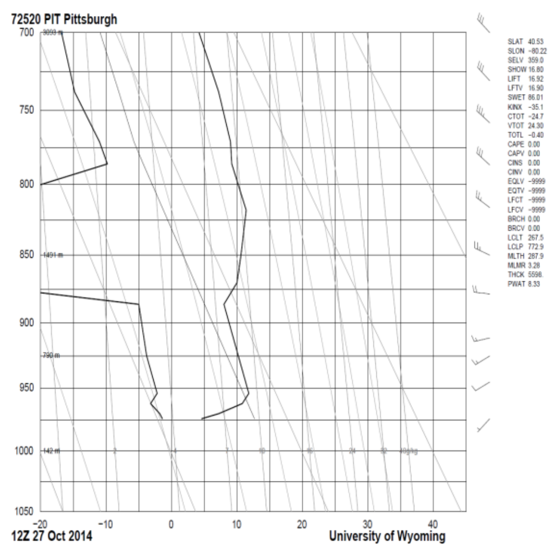
No sounding available for this day.



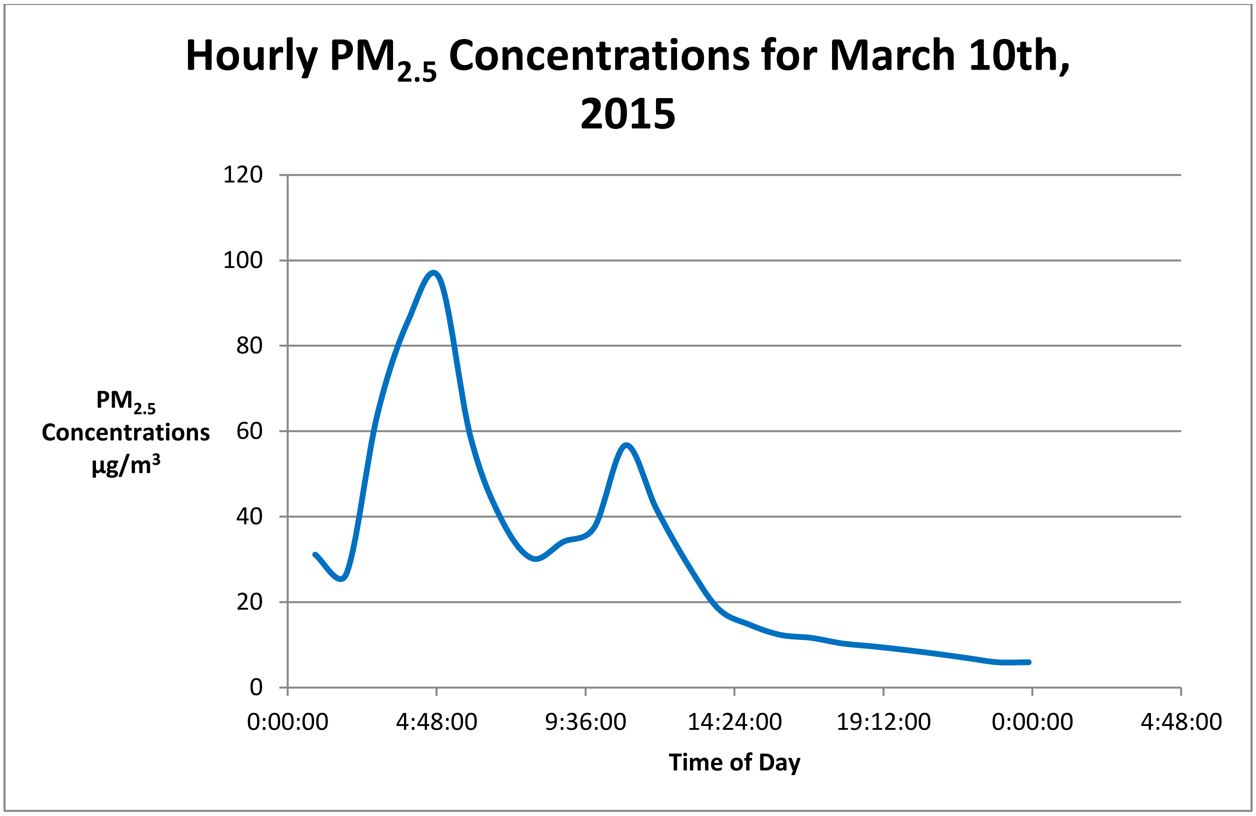
Hourly $PM_{2.5}$ Concentrations for October 27th, 2014
$PM_{2.5}$ Concentration µg/m³
90
80
70
60
50
40
30
20
10
0
0:00:00
4:48:00
9:36:00
14:24:00
19:12:00
0:00:00
4:48:00
Time of Day



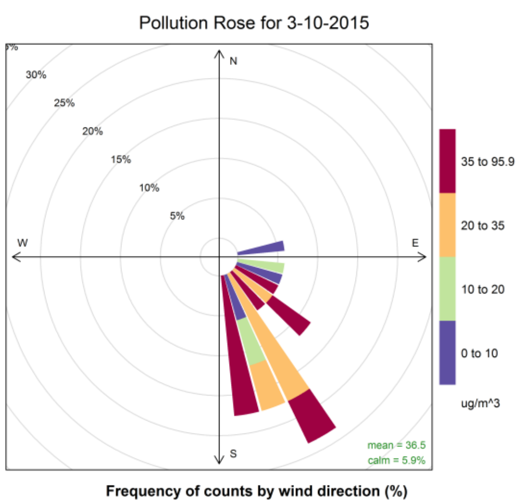
Pollution Rose for 10-27-2014
50%
40%
30%
20%
10%
N
W
E
S
35 to 84
20 to 35
10 to 20
0 to 10
ug/m^3
mean = 34
calm = 4.2%
Frequency of counts by wind direction (%)



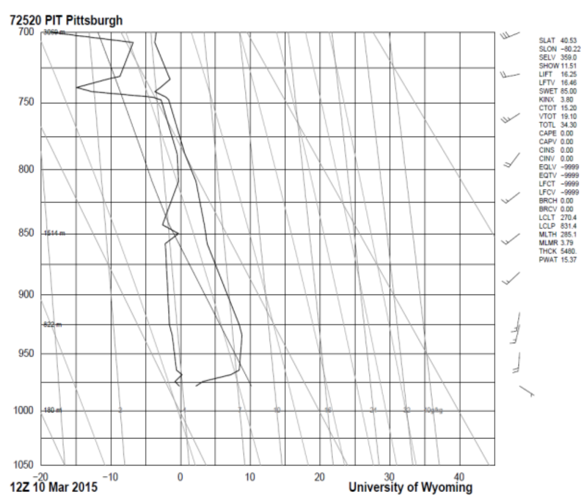
72520 PIT Pittsburgh
700
750
800
850
900
950
1000
1050
−20
−10
0
10
20
30
40
12Z 27 Oct 2014
University of Wyoming
SLAT 40.53
SLON -80.22
SELV 359.0
SHOW 16.80
LIFT 16.92
LFTV 16.90
SWET 86.01
KINX −35.1
CTOT −24.7
VTOT 24.30
TOTL −0.40
CAPE 0.00
CAPV 0.00
CINS 0.00
CINV 0.00
EQLV −9999
EQTV −9999
LFCT −9999
LFCV −9999
BRCH 0.00
BRCV 0.00
LCLT 267.5
LCLP 772.9
MLTH 287.9
MLMR 3.28
THCK 5598.
PWAT 8.33



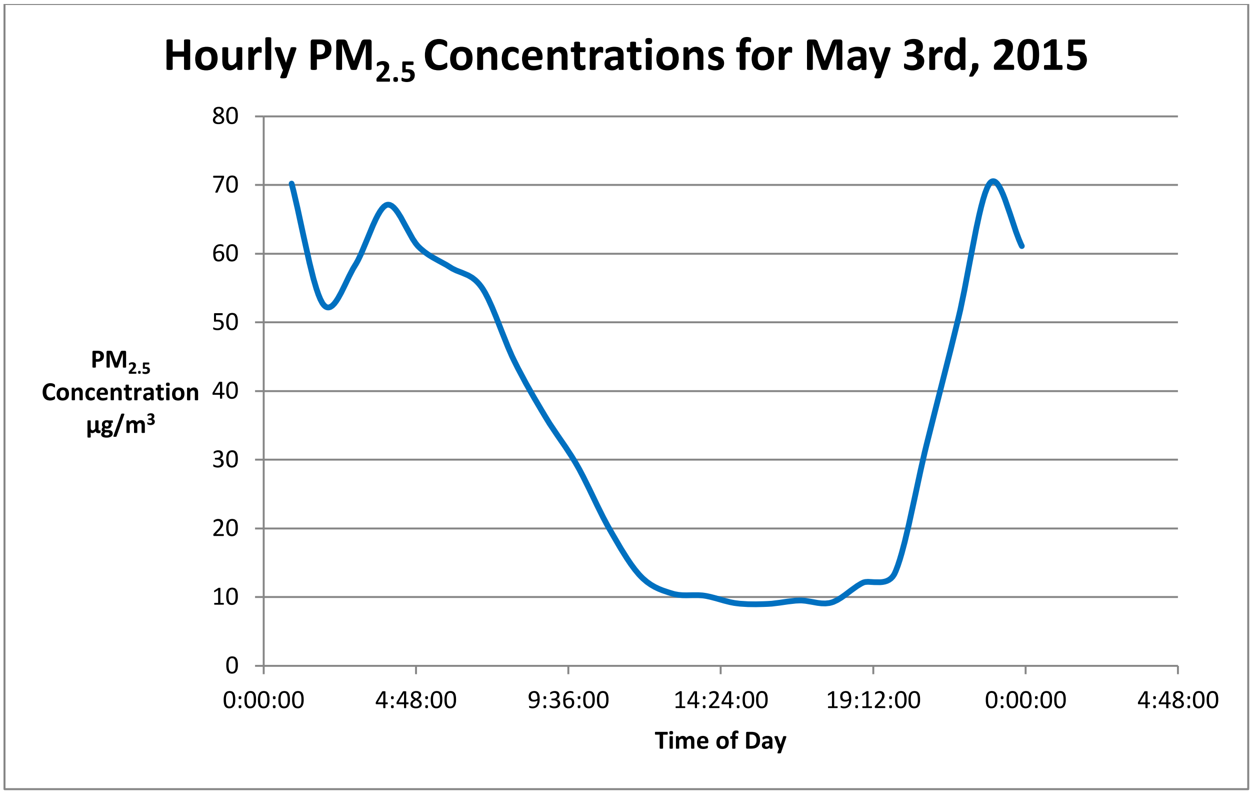
Hourly PM2.5 Concentrations for March 10th, 2015
PM2.5 Concentrations µg/m3
120
100
80
60
40
20
0
0:00:00
4:48:00
9:36:00
14:24:00
19:12:00
0:00:00
4:48:00
Time of Day

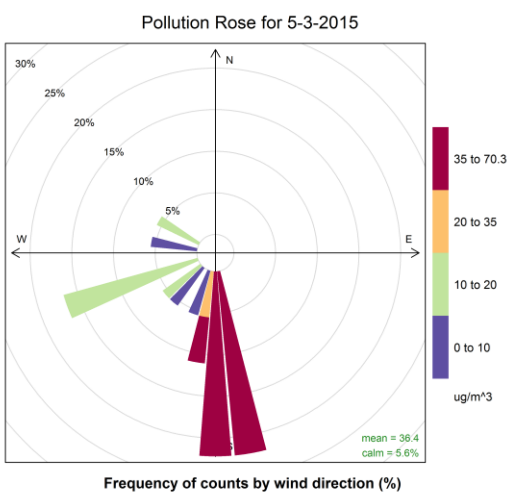


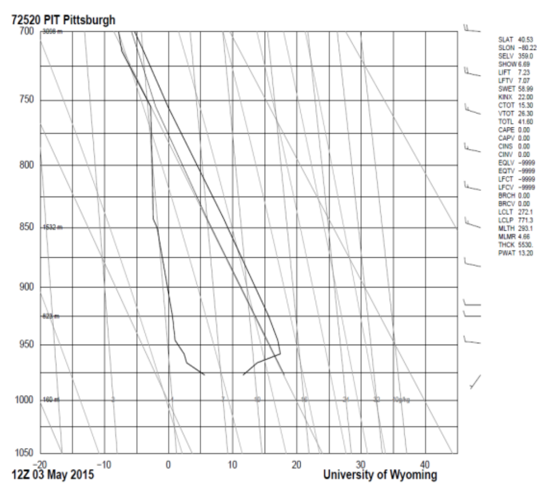
Pollution Rose for 3-10-2015
30%
25%
20%
15%
10%
5%
N
W
E
S
35 to 95.9
20 to 35
10 to 20
0 to 10
ug/m^3
mean = 36.5
calm = 5.9%
Frequency of counts by wind direction (%)

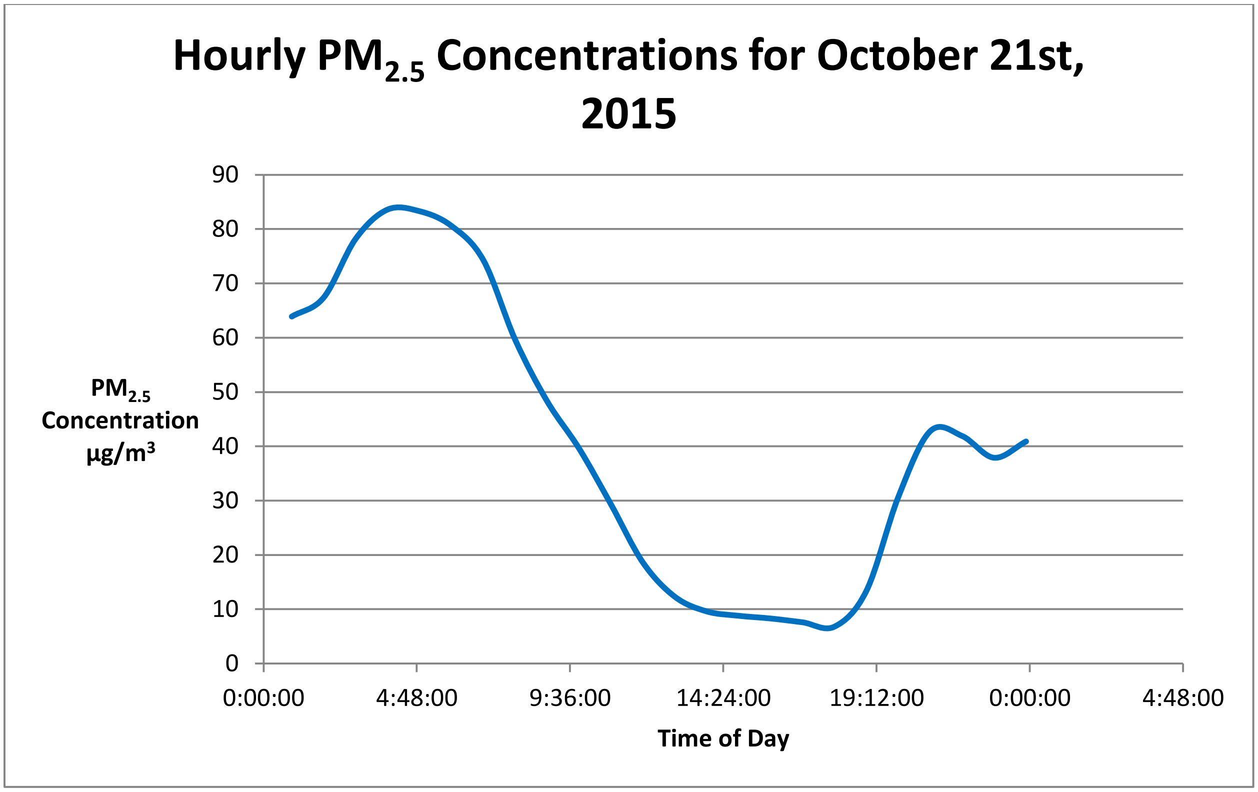


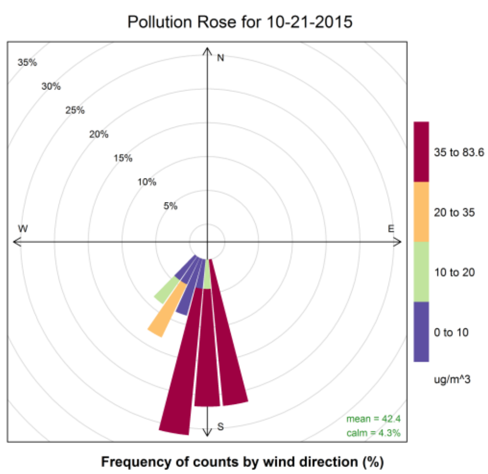
72520 PIT Pittsburgh
700
750
800
850
900
950
1000
1050
-20
-10
0
10
20
30
40
12Z 10 Mar 2015
University of Wyoming

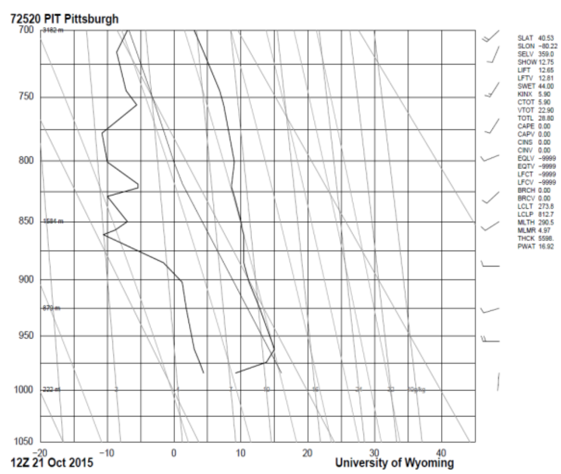

Hourly PM2.5 Concentrations for May 3rd, 2015
PM2.5 Concentration µg/m³
0
10
20
30
40
50
60
70
80
0:00:00
4:48:00
9:36:00
14:24:00
19:12:00
0:00:00
4:48:00
Time of Day

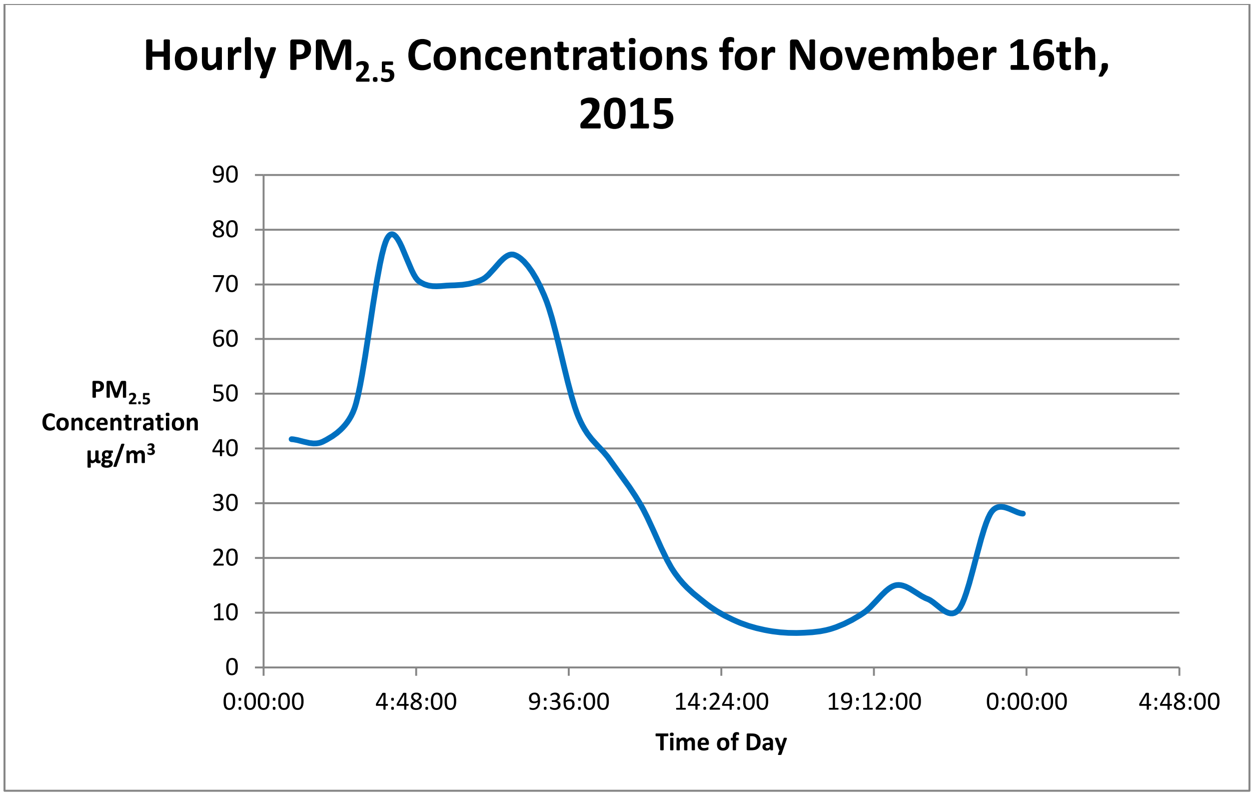

Pollution Rose for 5-3-2015
N
E
W
30%
25%
20%
15%
10%
5%
35 to 70.3
20 to 35
10 to 20
0 to 10
ug/m^3
mean = 36.4
calm = 5.6%
Frequency of counts by wind direction (%)

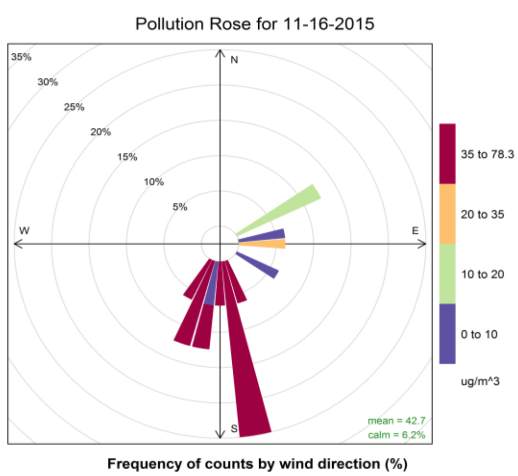

72520 PIT Pittsburgh
700
750
800
850
900
950
1000
1050
-20
-10
0
10
20
30
40
12Z 03 May 2015
University of Wyoming

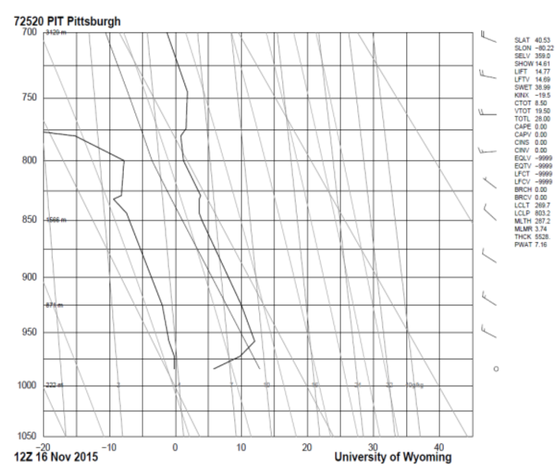

Hourly PM2.5 Concentrations for October 21st, 2015
90
80
70
60
50
40
30
20
10
0
PM2.5 Concentration µg/m³
0:00:00
4:48:00
9:36:00
14:24:00
19:12:00
0:00:00
4:48:00
Time of Day

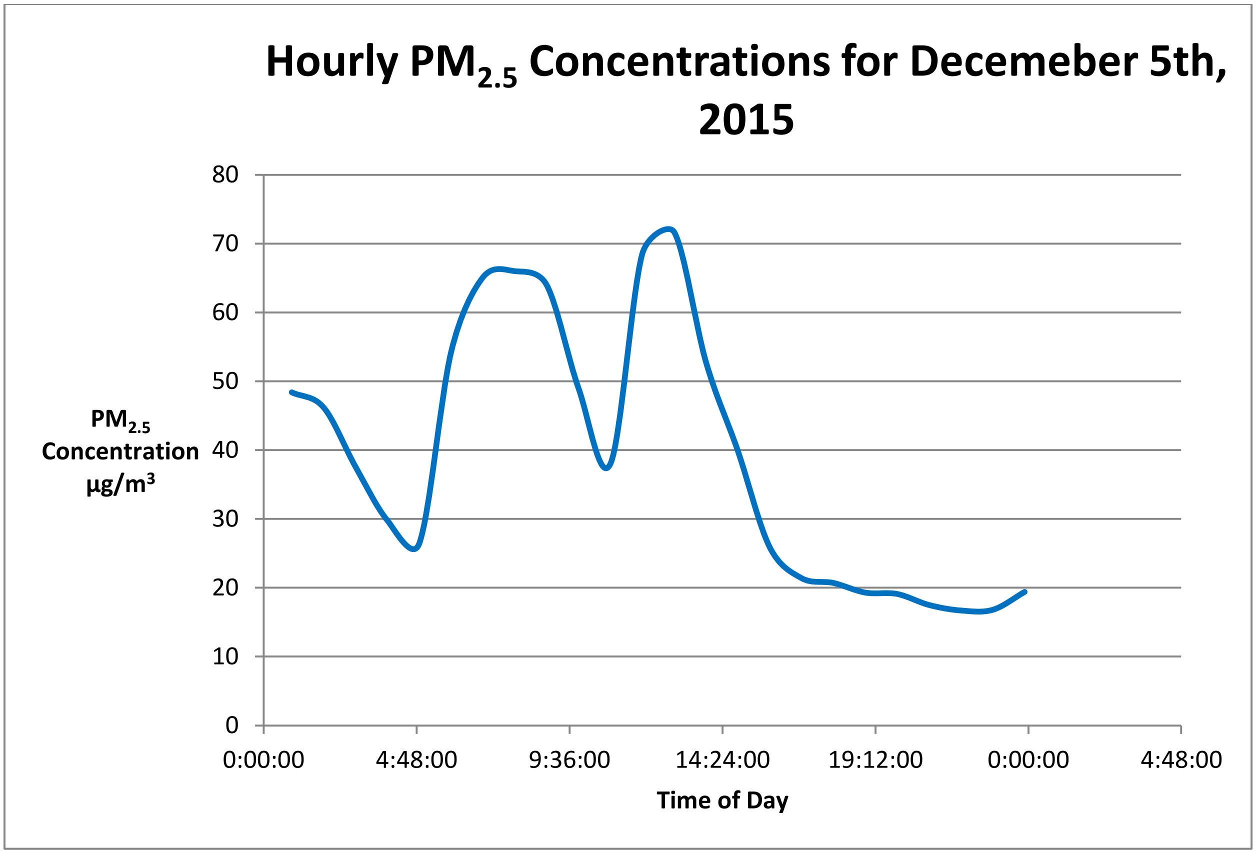

Pollution Rose for 10-21-2015
35%
30%
25%
20%
15%
10%
5%
N
W
E
S
35 to 83.6
20 to 35
10 to 20
0 to 10
ug/m^3
mean = 42.4
calm = 4.3%
Frequency of counts by wind direction (%)


72520 PIT Pittsburgh
700
750
800
850
900
950
1000
1050
−20
−10
0
10
20
30
40
12Z 21 Oct 2015
University of Wyoming

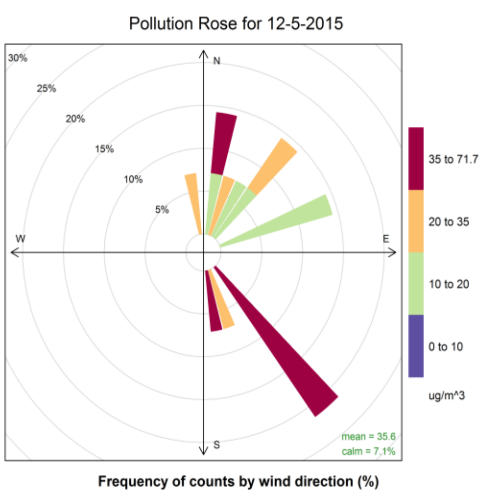

Hourly PM2.5 Concentrations for November 16th, 2015
PM2.5 Concentration µg/m³
0
10
20
30
40
50
60
70
80
90
0:00:00
4:48:00
9:36:00
14:24:00
19:12:00
0:00:00
4:48:00
Time of Day


Pollution Rose for 11-16-2015
N
E
S
W
35%
30%
25%
20%
15%
10%
5%
35 to 78.3
20 to 35
10 to 20
0 to 10
ug/m^3
mean = 42.7
calm = 6.2%
Frequency of counts by wind direction (%)

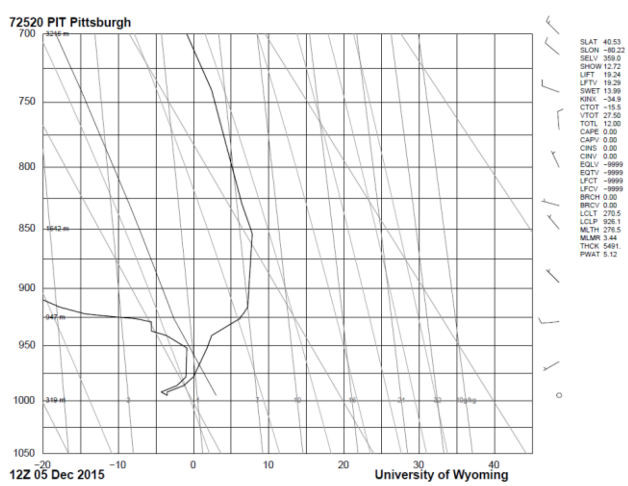

72520 PIT Pittsburgh
700
750
800
850
900
950
1000
1050
−20
−10
0
10
20
30
40
12Z 16 Nov 2015
University of Wyoming



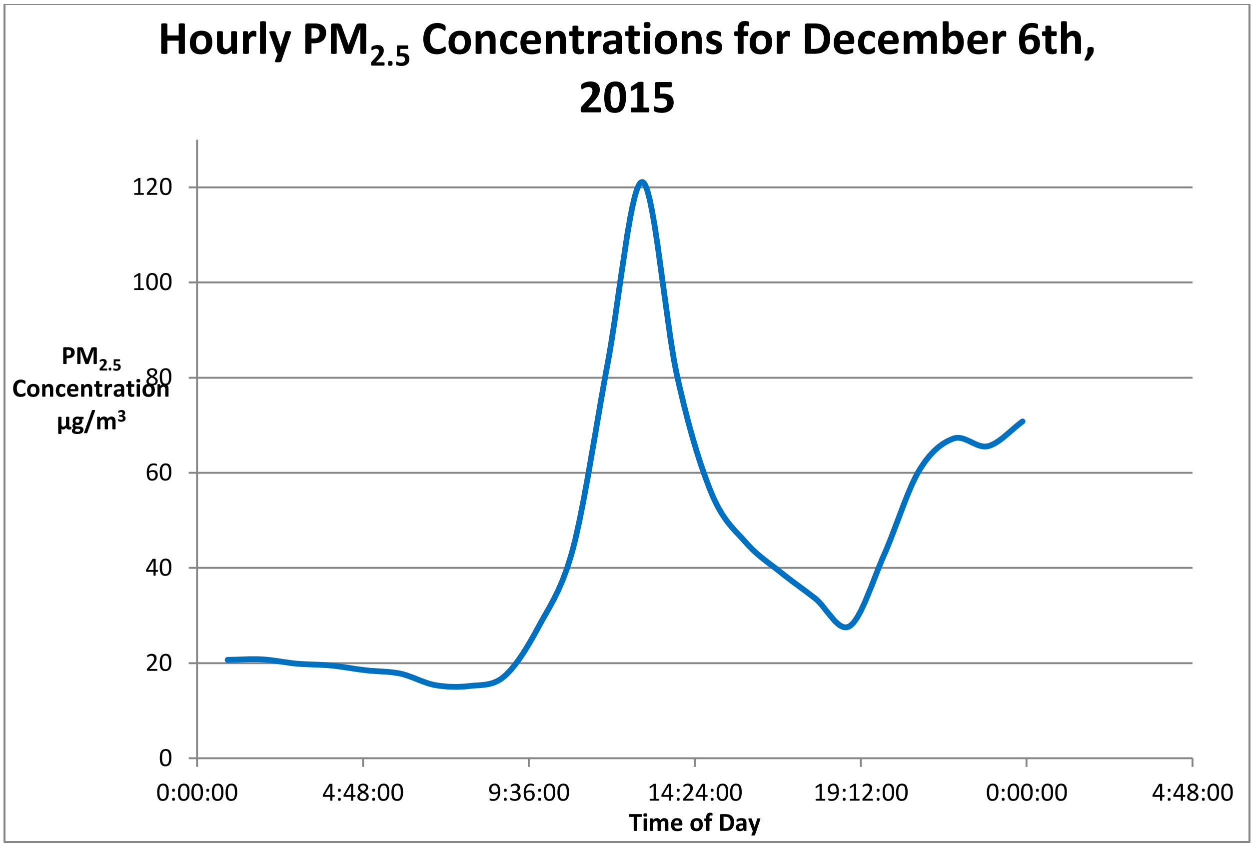
Hourly PM2.5 Concentrations for Decemeber 5th, 2015
PM2.5 Concentration µg/m3
80
70
60
50
40
30
20
10
0
0:00:00
4:48:00
9:36:00
14:24:00
19:12:00
0:00:00
4:48:00
Time of Day

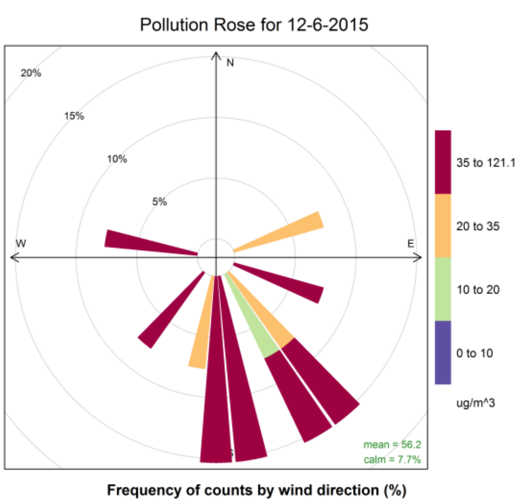


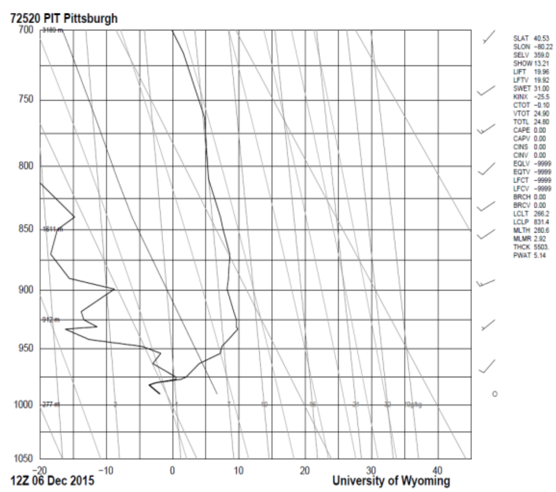
Pollution Rose for 12-5-2015
30%
25%
20%
15%
10%
5%
N
W
E
S
35 to 71.7
20 to 35
10 to 20
0 to 10
ug/m^3
mean = 35.6
calm = 7.1%
Frequency of counts by wind direction (%)

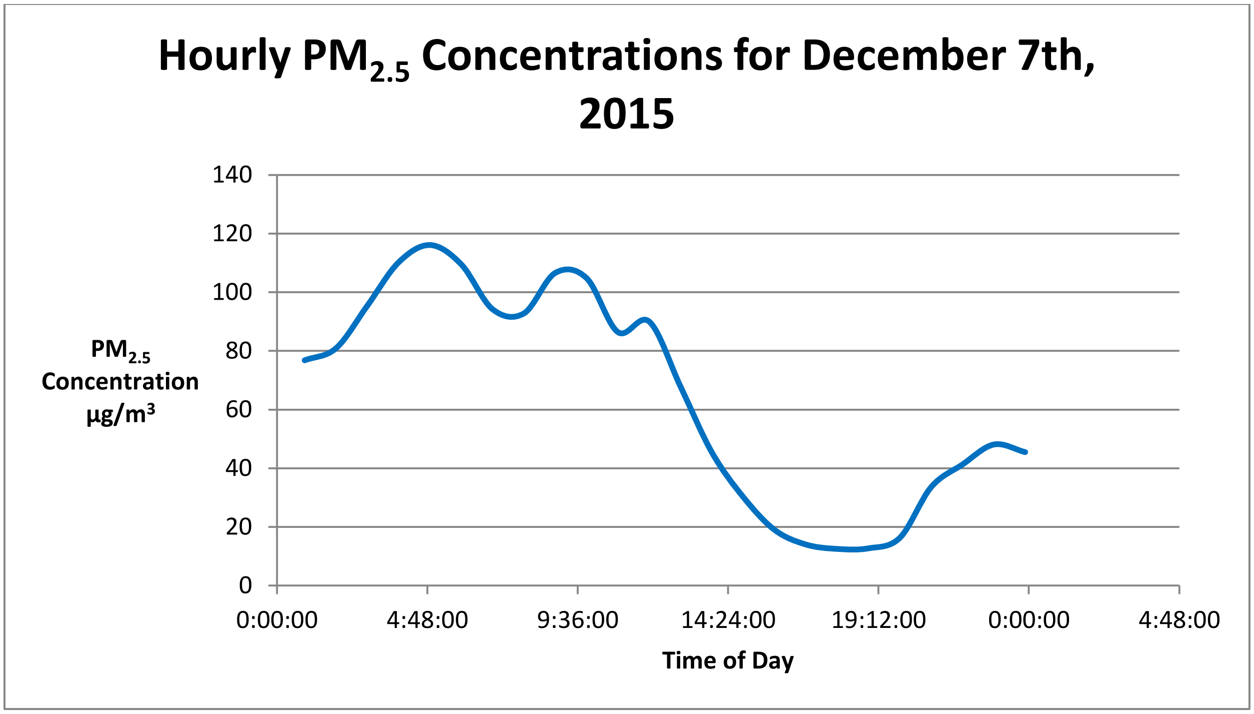


72520 PIT Pittsburgh
700
750
800
850
900
950
1000
1050
−20
−10
0
10
20
30
40
12Z 05 Dec 2015
University of Wyoming
SLAT 40.53
SLON −80.22
SELV 359.0
SHOW 12.72
LIFT 19.24
LFTV 19.29
SWET 13.99
KINX −34.9
CTOT −15.5
VTOT 27.50
TOTL 12.00
CAPE 0.00
CAPV 0.00
CINS 0.00
CINV 0.00
EQLV −9999
EQTV −9999
LFCT −9999
LFCV −9999
BRCH 0.00
BRCV 0.00
LCLT 270.5
LCLP 926.1
MLTH 276.5
MLMR 3.44
THCK 5491.
PWAT 5.12

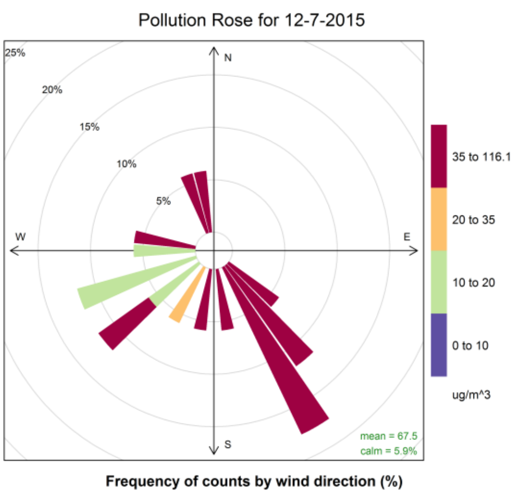

Hourly PM2.5 Concentrations for December 6th, 2015
PM2.5 Concentration µg/m³
120
100
80
60
40
20
0
0:00:00
4:48:00
9:36:00
14:24:00
19:12:00
0:00:00
4:48:00
Time of Day


Pollution Rose for 12-6-2015
N
E
W
20%
15%
10%
5%
35 to 121.1
20 to 35
10 to 20
0 to 10
ug/m^3
mean = 56.2
calm = 7.7%
Frequency of counts by wind direction (%)

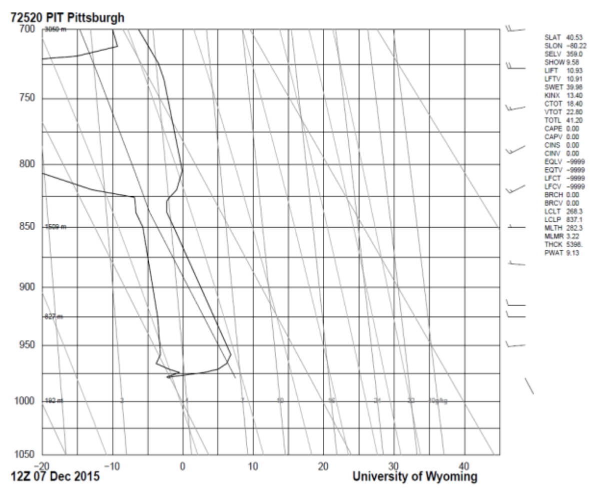

72520 PIT Pittsburgh
700
750
800
850
900
950
1000
1050
−20
−10
0
10
20
30
40
12Z 06 Dec 2015
University of Wyoming



Hourly PM2.5 Concentrations for December 7th, 2015
PM2.5 Concentration µg/m3
140
120
100
80
60
40
20
0
0:00:00
4:48:00
9:36:00
14:24:00
19:12:00
0:00:00
4:48:00
Time of Day



Pollution Rose for 12-7-2015
25%
20%
15%
10%
5%
N
W
E
S
35 to 116.1
20 to 35
10 to 20
0 to 10
ug/m^3
mean = 67.5
calm = 5.9%
Frequency of counts by wind direction (%)



72520 PIT Pittsburgh
700
750
800
850
900
950
1000
1050
-20
-10
0
10
20
30
40
12Z 07 Dec 2015
University of Wyoming

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APPENDIX B

Time Plots for Southwest Pennsylvania

Monitors on High $PM_{2.5}$ Days at the Liberty Monitor

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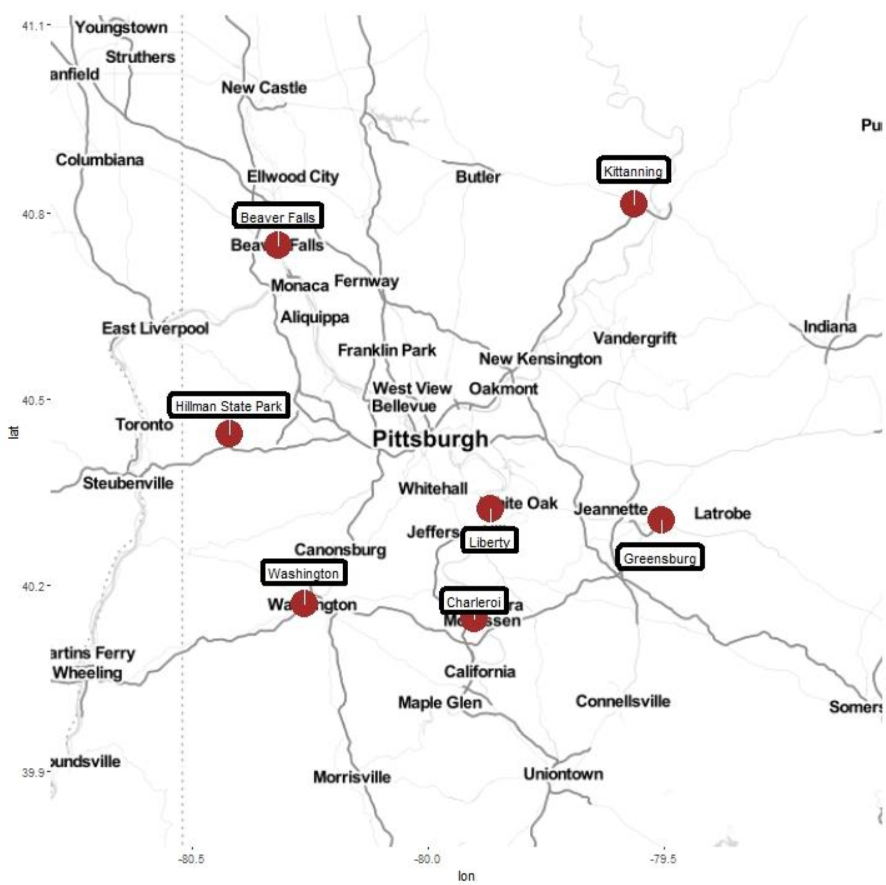
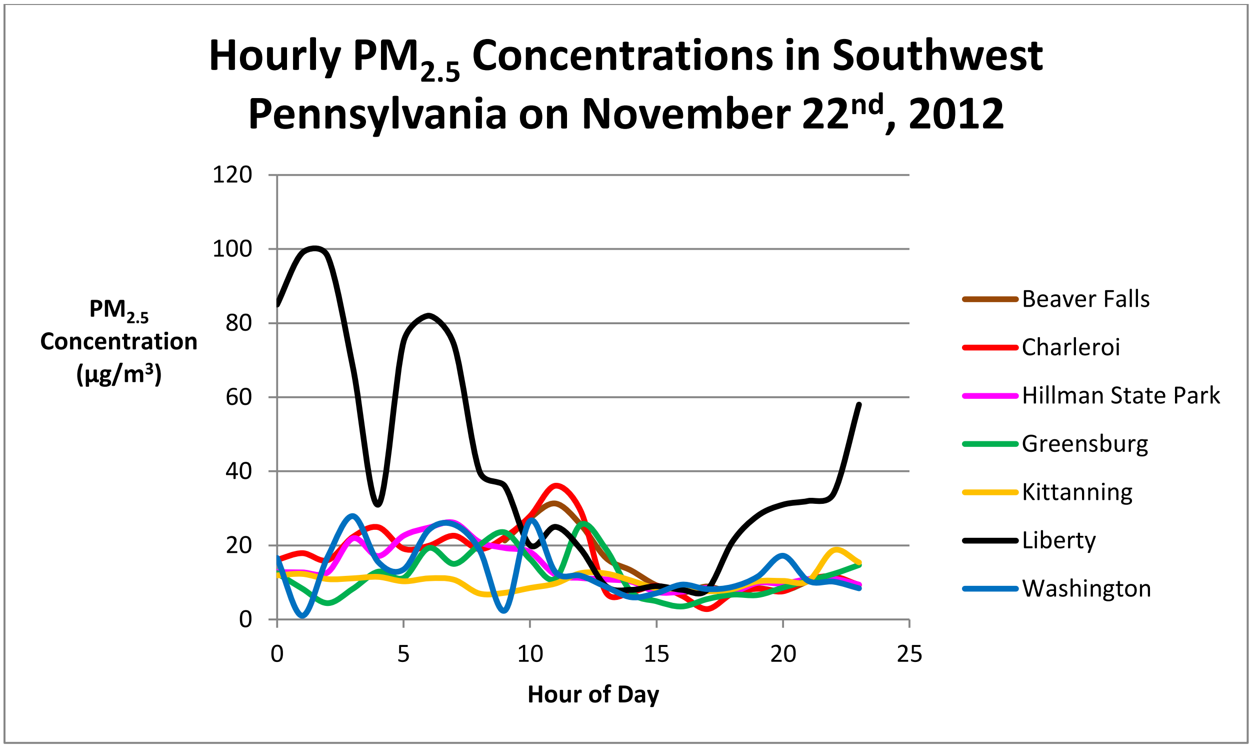
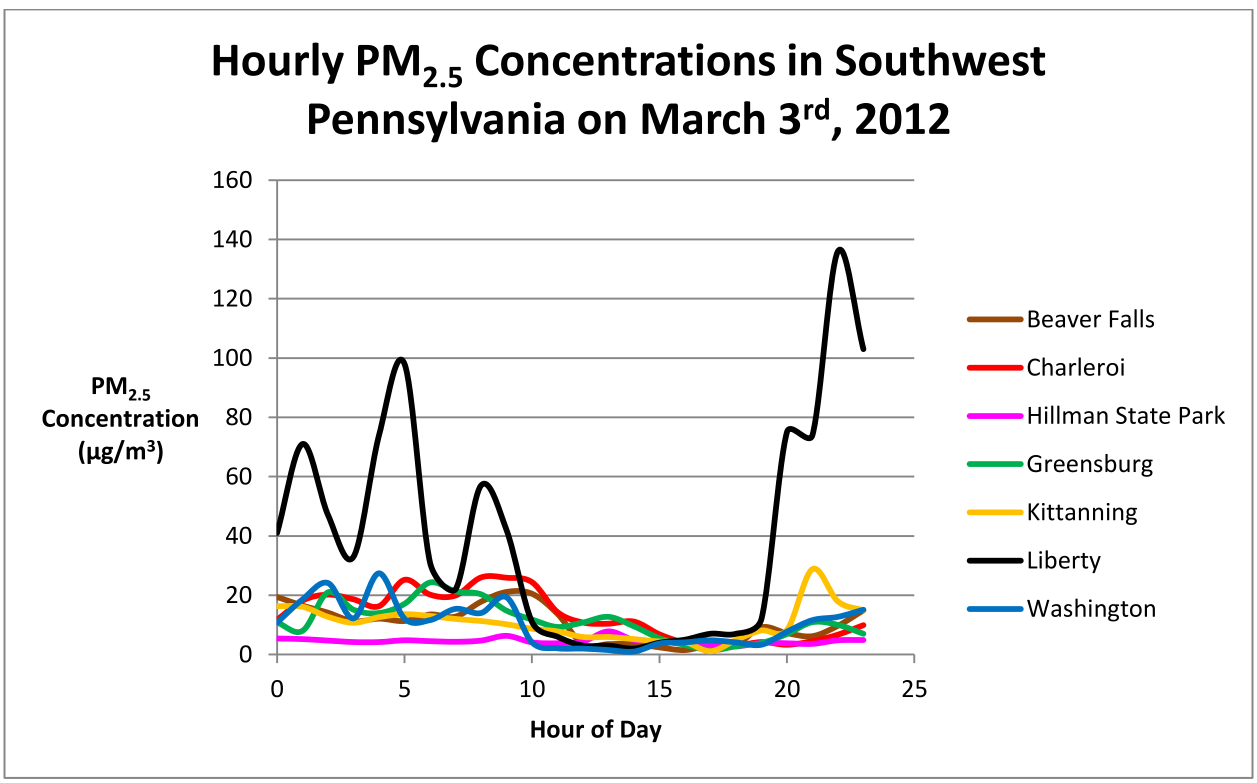
Table C-1: Monitors in the Southwest Pennsylvania airshed that measure hourly $PM_{2.5}$ concentrations and Weighted Annual Mean $PM_{2.5}$ Values from 2012 to 2015

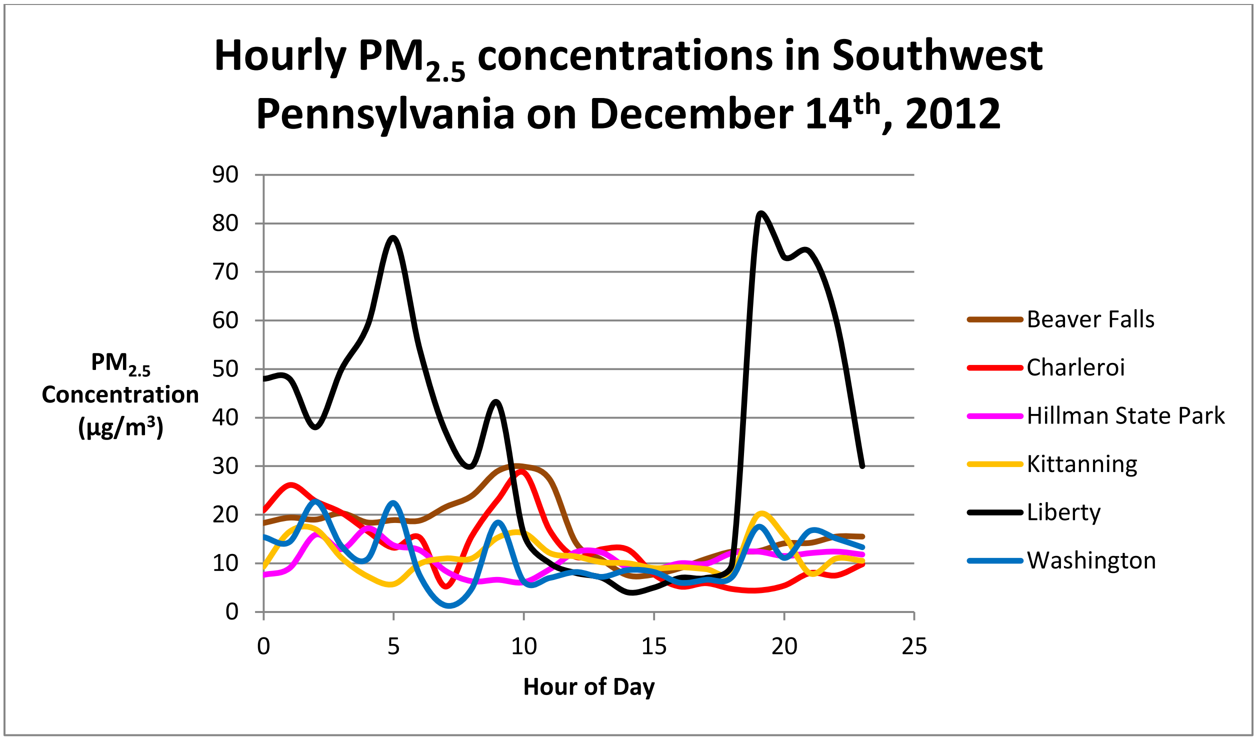
AQS Monitor ID	Site Name	County	2012 Annual PM2.5	2013 Annual PM2.5	2014 Annual PM2.5	2015 Annual PM2.5
42-003-0064	**Liberty**	**Allegheny**	**14.3**	**12**	**12.8**	**12.9**
42-007-0014	Beaver Falls	Beaver	12.2	11.2	11	10.5
42-125-0005	Charleroi	Washington	10.4	10.6	13.4	11.0
42-125-5001	Hillman State Park	Washington	9	10.2	8.9	10.6
42-129-0008	Greensburg	Westmoreland	12	13	9.5	9.8
42-005-0001	Kittanning	Armstrong	9.7	10.7	11.4	11.2
42-125-0200	Washington	Washington	10.6	10.5	11	9.4

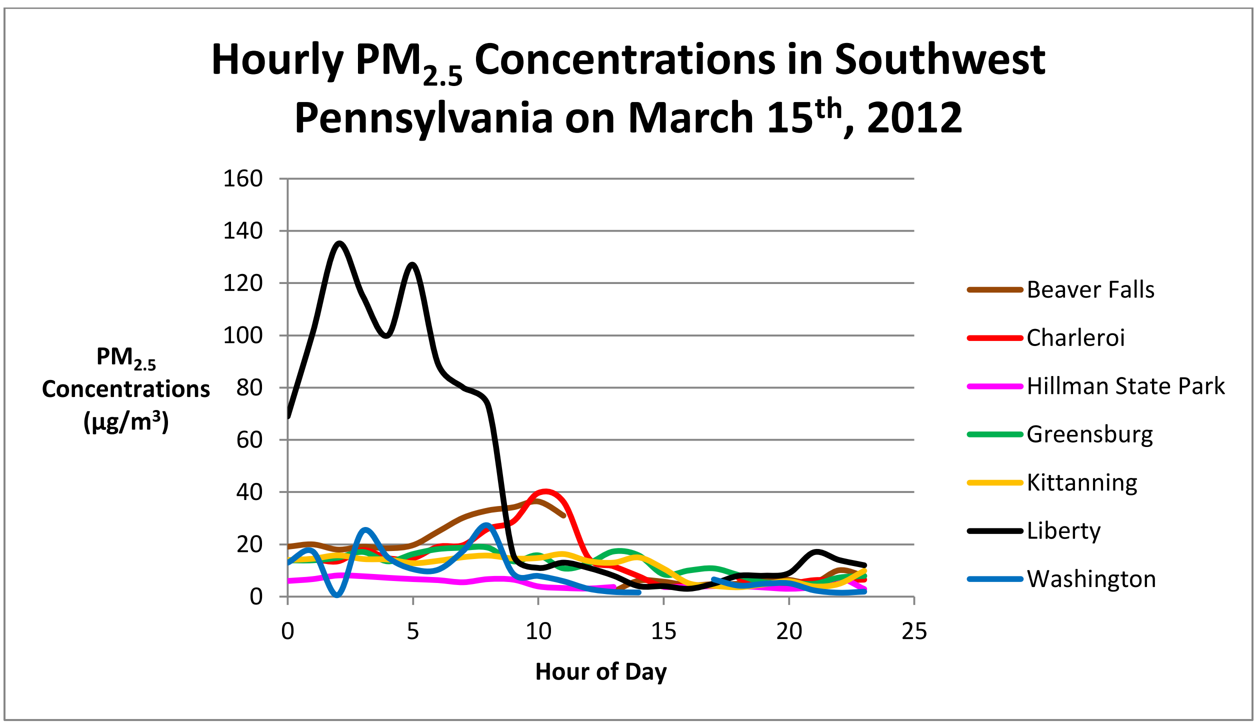
Figure C-1: Map of Hourly $PM_{2.5}$ Monitor Locations

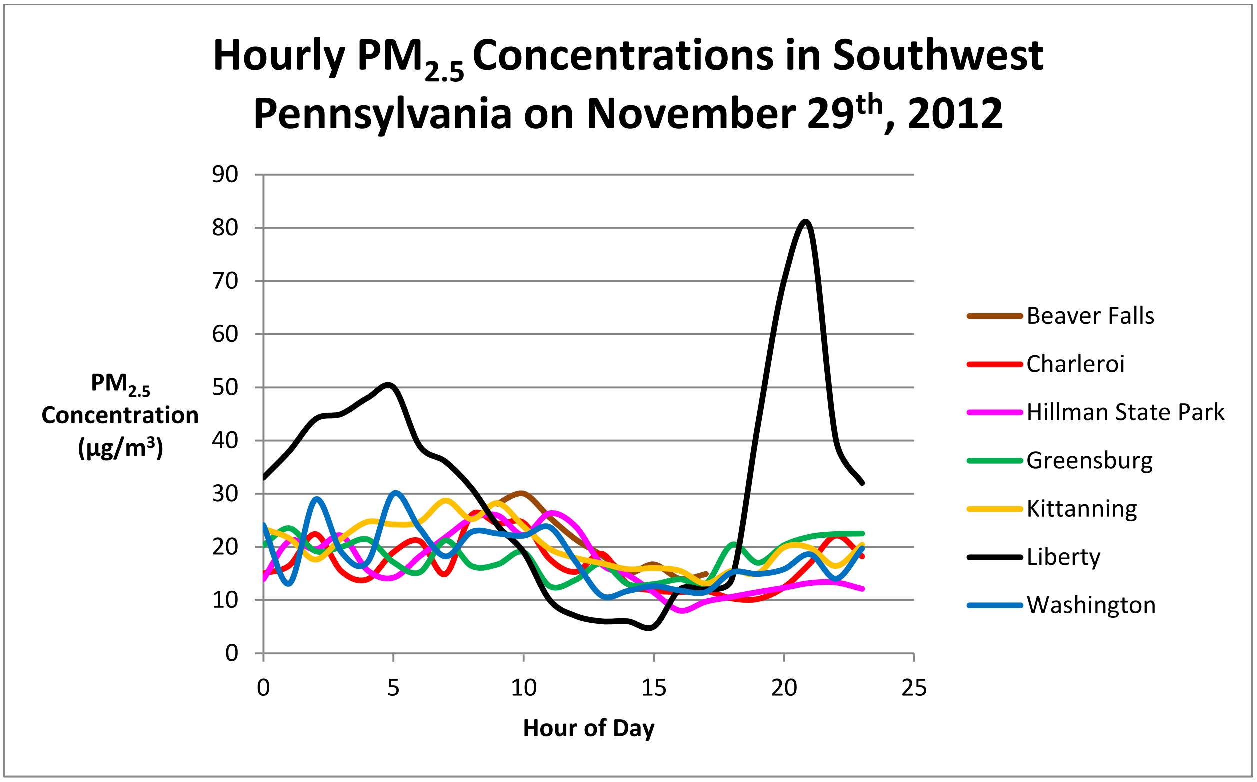


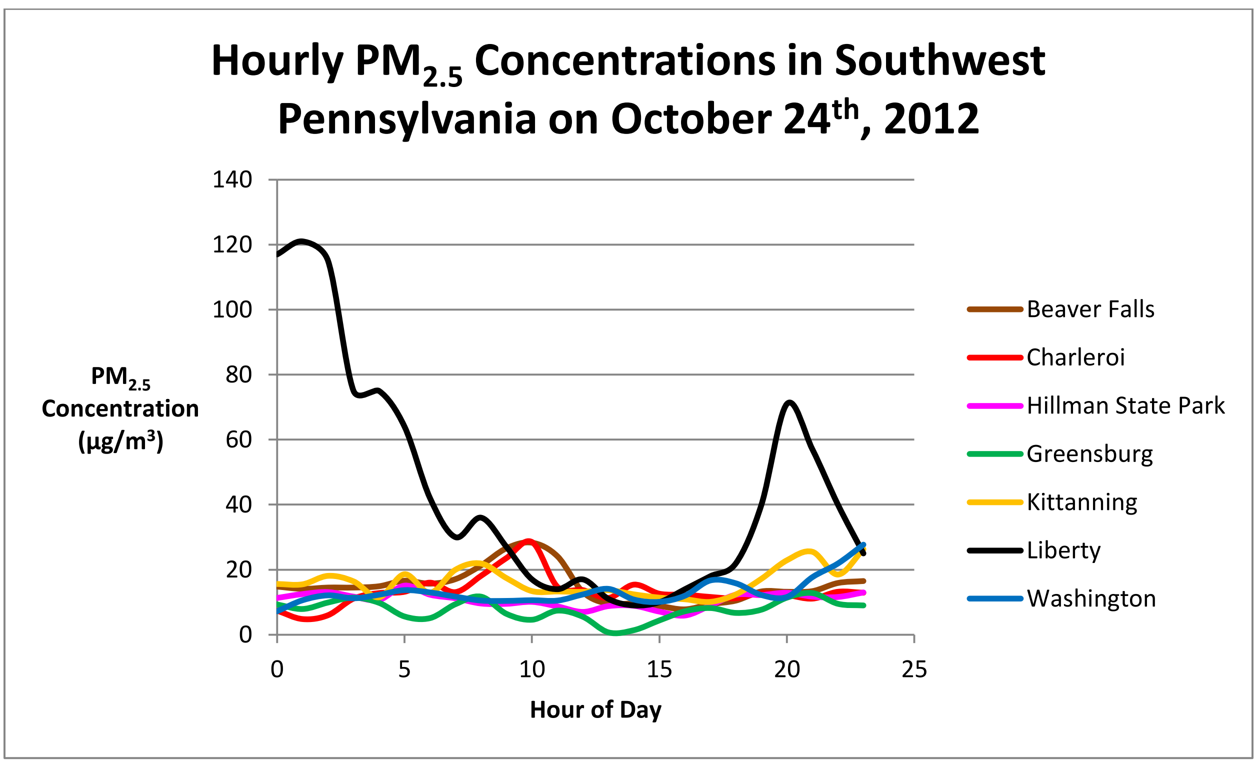

Hourly PM2.5 Concentrations in Southwest Pennsylvania on November 22nd, 2012
PM2.5 Concentration (µg/m³)
120
100
80
60
40
20
0
0
5
10
15
20
25
Hour of Day
Beaver Falls
Charleroi
Hillman State Park
Greensburg
Kittanning
Liberty
Washington

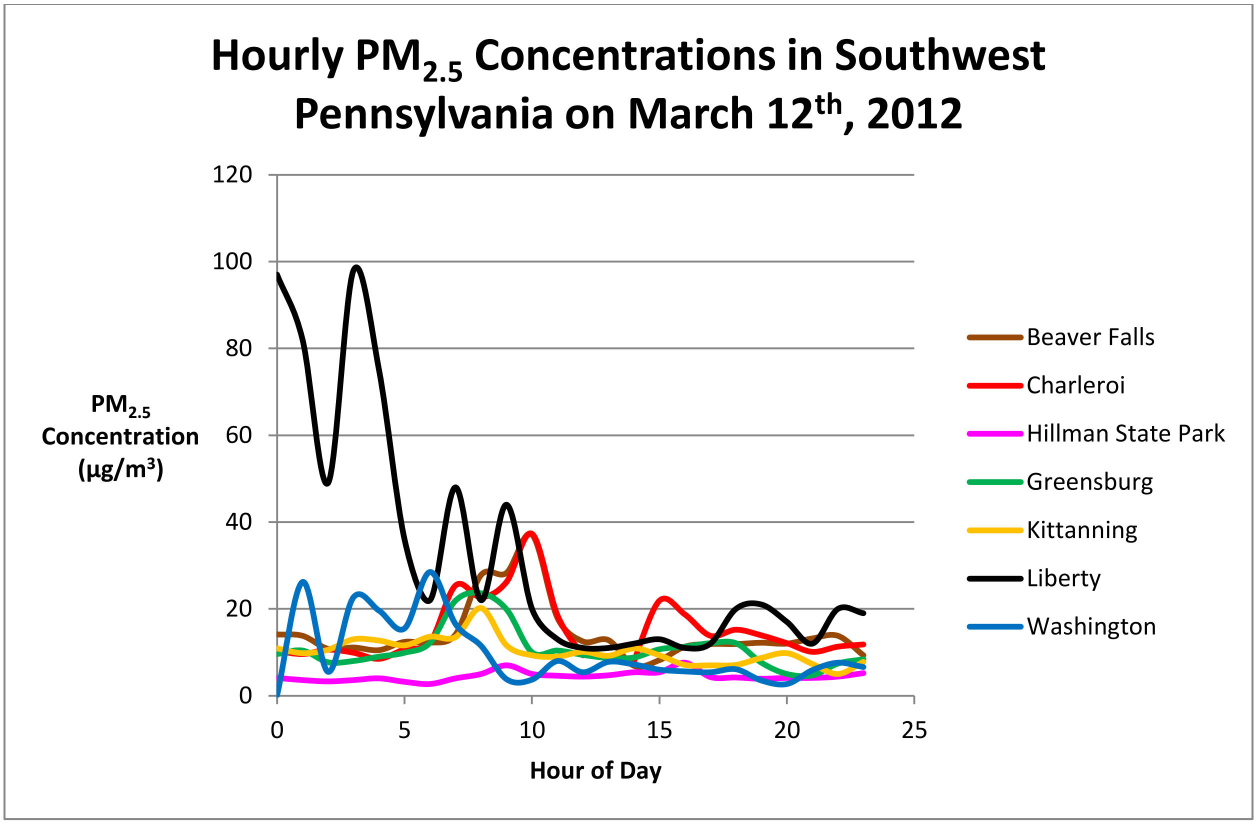

Hourly PM2.5 Concentrations in Southwest Pennsylvania on March 3rd, 2012
PM2.5 Concentration (µg/m³)
160
140
120
100
80
60
40
20
0
0
5
10
15
20
25
Hour of Day
Beaver Falls
Charleroi
Hillman State Park
Greensburg
Kittanning
Liberty
Washington

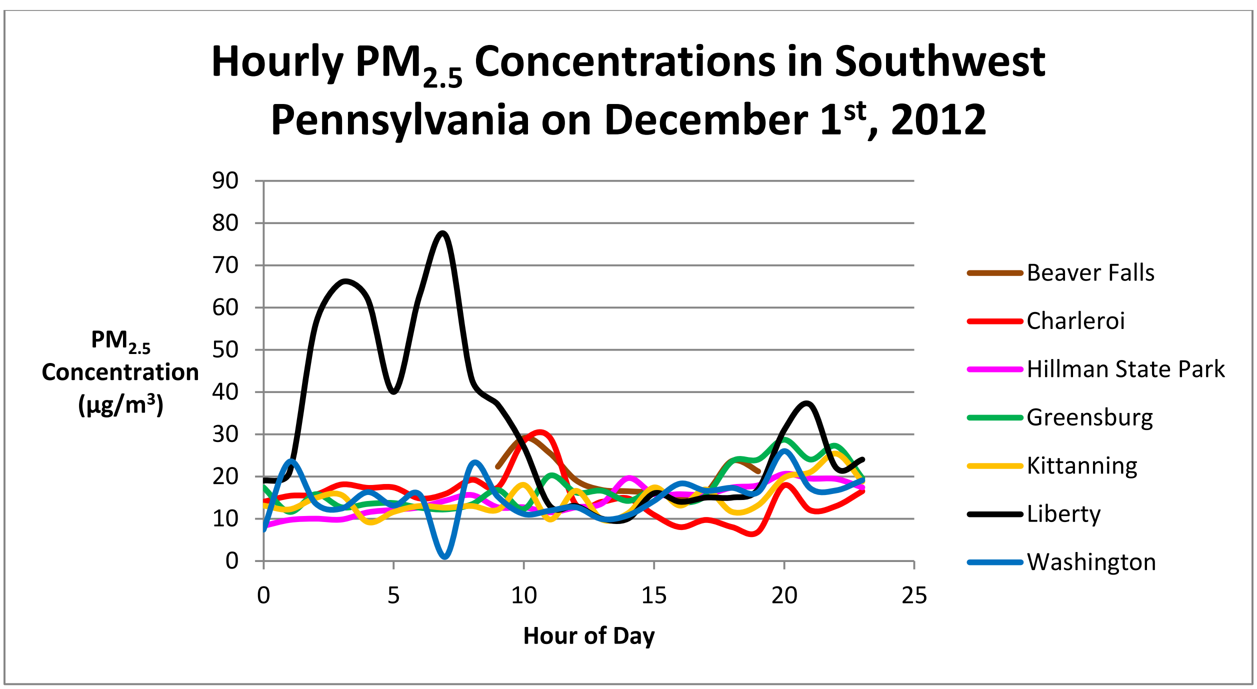

Hourly $PM_{2.5}$ concentrations in Southwest Pennsylvania on December 14th, 2012
$PM_{2.5}$ Concentration (µg/m³)
90
80
70
60
50
40
30
20
10
0
0
5
10
15
20
25
Hour of Day
Beaver Falls
Charleroi
Hillman State Park
Kittanning
Liberty
Washington

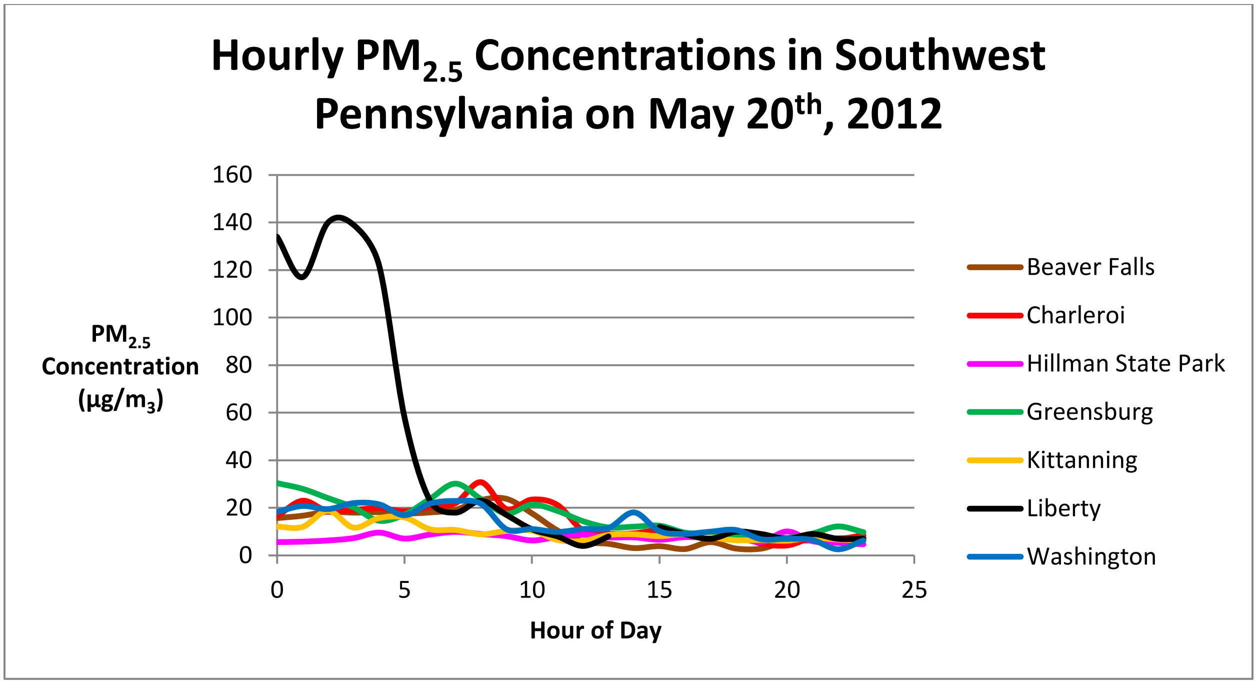

Hourly $PM_{2.5}$ Concentrations in Southwest Pennsylvania on March 15th, 2012
$PM_{2.5}$ Concentrations (µg/m³)
160
140
120
100
80
60
40
20
0
0
5
10
15
20
25
Hour of Day
Beaver Falls
Charleroi
Hillman State Park
Greensburg
Kittanning
Liberty
Washington

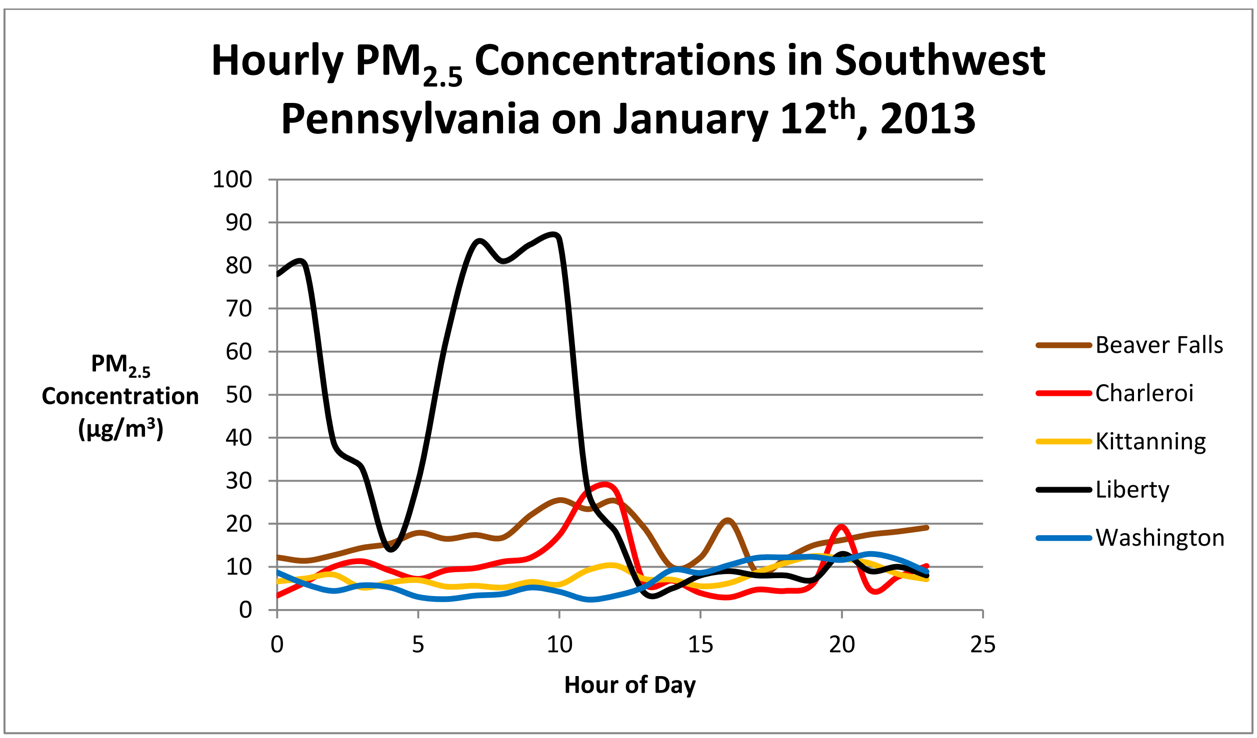

Hourly PM2.5 Concentrations in Southwest Pennsylvania on November 29th, 2012
PM2.5 Concentration (µg/m³)
Hour of Day
Beaver Falls
Charleroi
Hillman State Park
Greensburg
Kittanning
Liberty
Washington

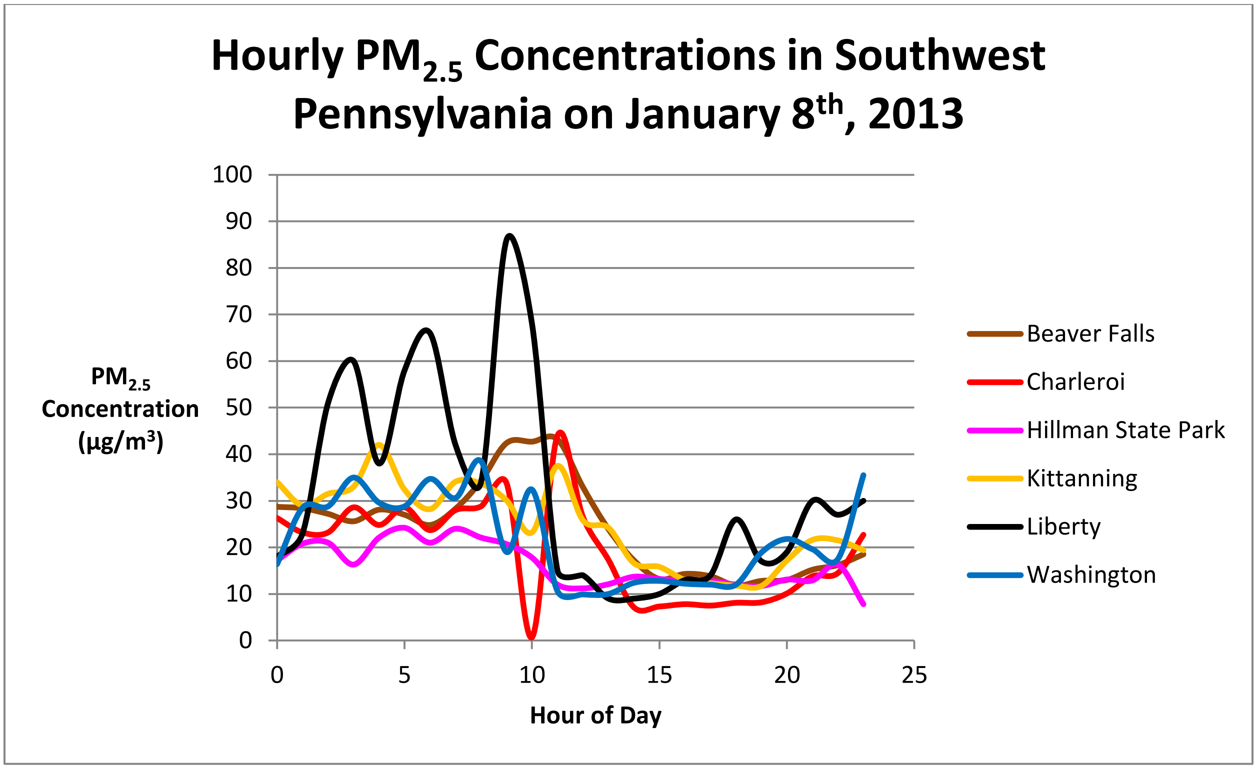

Hourly PM2.5 Concentrations in Southwest Pennsylvania on October 24th, 2012
PM2.5 Concentration (µg/m³)
Hour of Day
Beaver Falls
Charleroi
Hillman State Park
Greensburg
Kittanning
Liberty
Washington

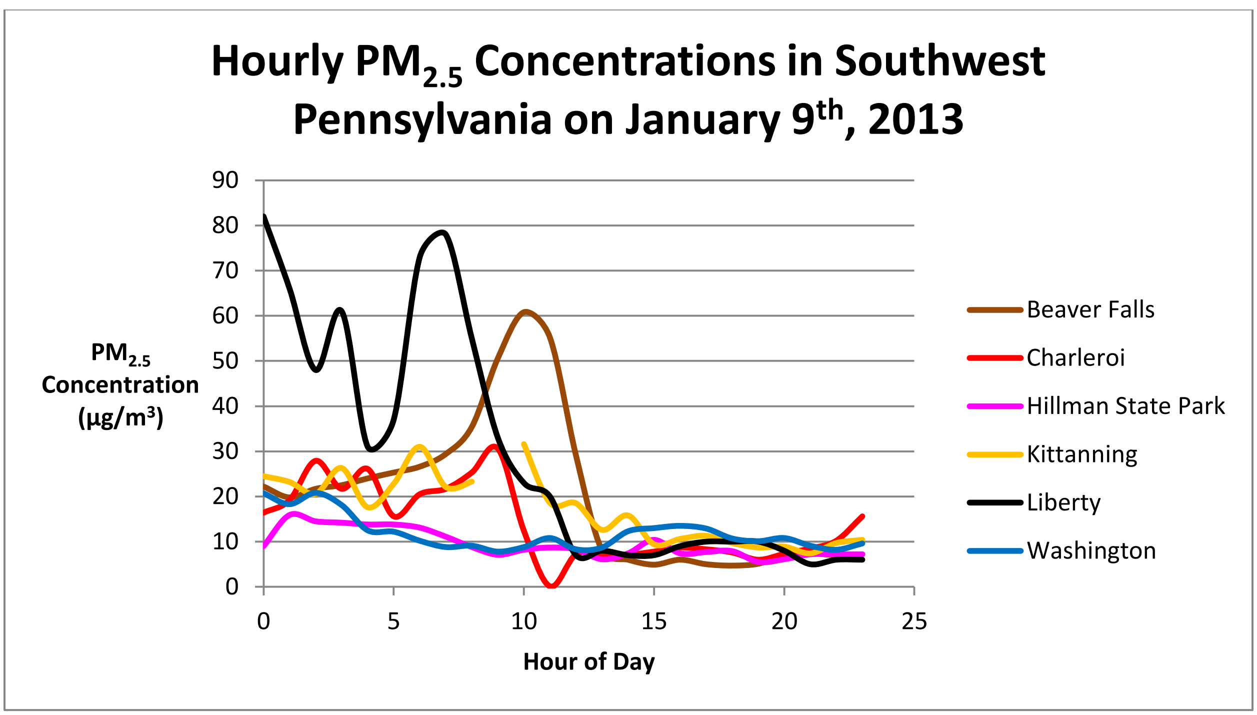

Hourly PM2.5 Concentrations in Southwest Pennsylvania on March 12th, 2012
PM2.5 Concentration (µg/m³)
Hour of Day
0
5
10
15
20
25
0
20
40
60
80
100
120
Beaver Falls
Charleroi
Hillman State Park
Greensburg
Kittanning
Liberty
Washington

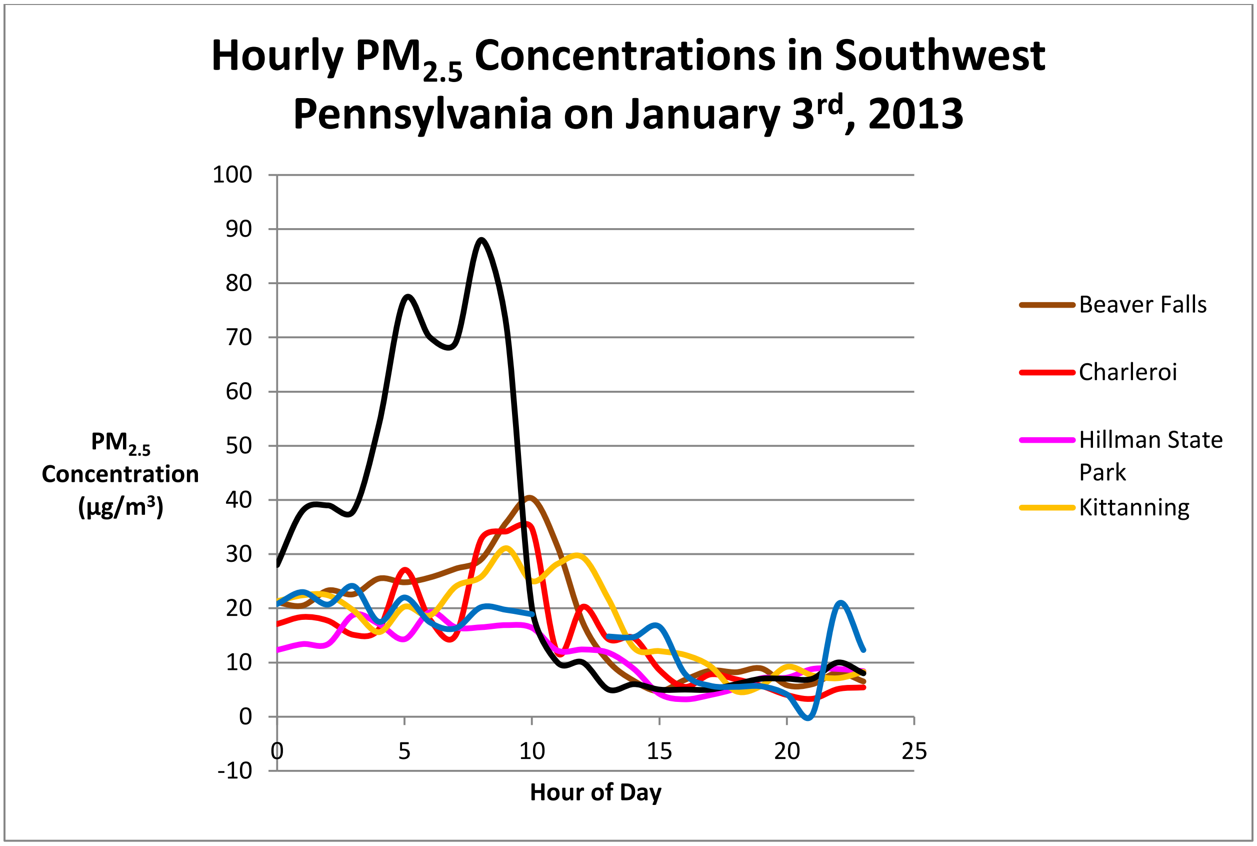

Hourly PM2.5 Concentrations in Southwest Pennsylvania on December 1st, 2012
PM2.5 Concentration (µg/m³)
Hour of Day
0
5
10
15
20
25
0
10
20
30
40
50
60
70
80
90
Beaver Falls
Charleroi
Hillman State Park
Greensburg
Kittanning
Liberty
Washington


Hourly PM2.5 Concentrations in Southwest Pennsylvania on May 20th, 2012
PM2.5 Concentration (µg/m3)
160
140
120
100
80
60
40
20
0
0
5
10
15
20
25
Hour of Day
Beaver Falls
Charleroi
Hillman State Park
Greensburg
Kittanning
Liberty
Washington

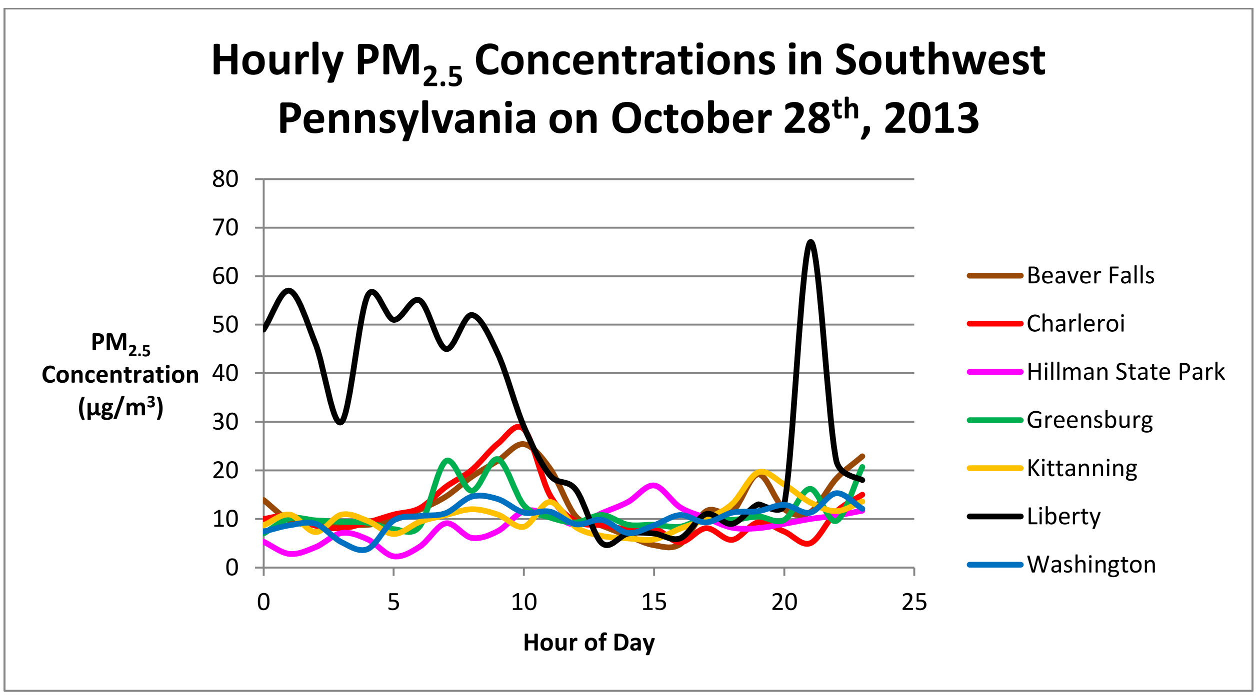

Hourly PM2.5 Concentrations in Southwest Pennsylvania on January 12th, 2013
PM2.5 Concentration (µg/m³)
100
90
80
70
60
50
40
30
20
10
0
0
5
10
15
20
25
Hour of Day
Beaver Falls
Charleroi
Kittanning
Liberty
Washington


Hourly PM2.5 Concentrations in Southwest Pennsylvania on January 8th, 2013
PM2.5 Concentration (µg/m³)
0
10
20
30
40
50
60
70
80
90
100
0
5
10
15
20
25
Hour of Day
Beaver Falls
Charleroi
Hillman State Park
Kittanning
Liberty
Washington

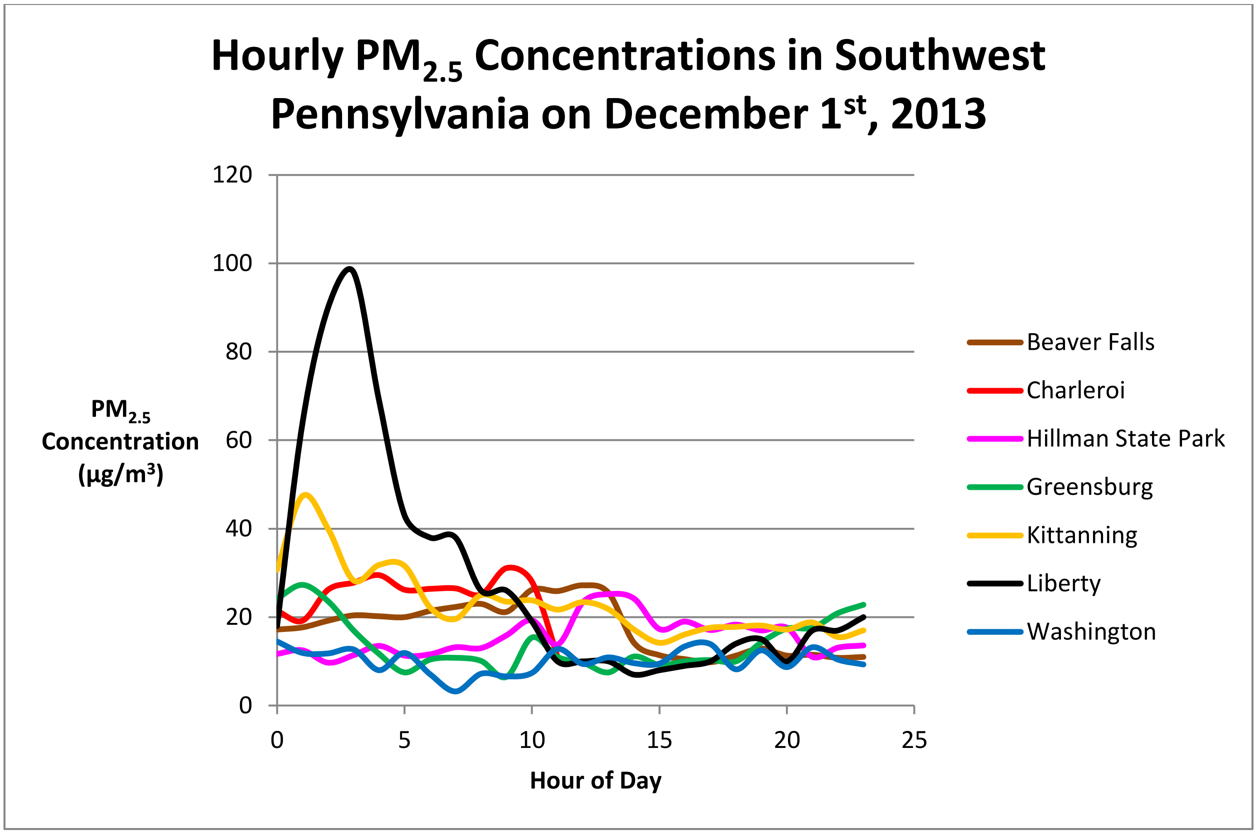

Hourly PM2.5 Concentrations in Southwest Pennsylvania on January 9th, 2013
PM2.5 Concentration (µg/m³)
0
10
20
30
40
50
60
70
80
90
0
5
10
15
20
25
Hour of Day
Beaver Falls
Charleroi
Hillman State Park
Kittanning
Liberty
Washington



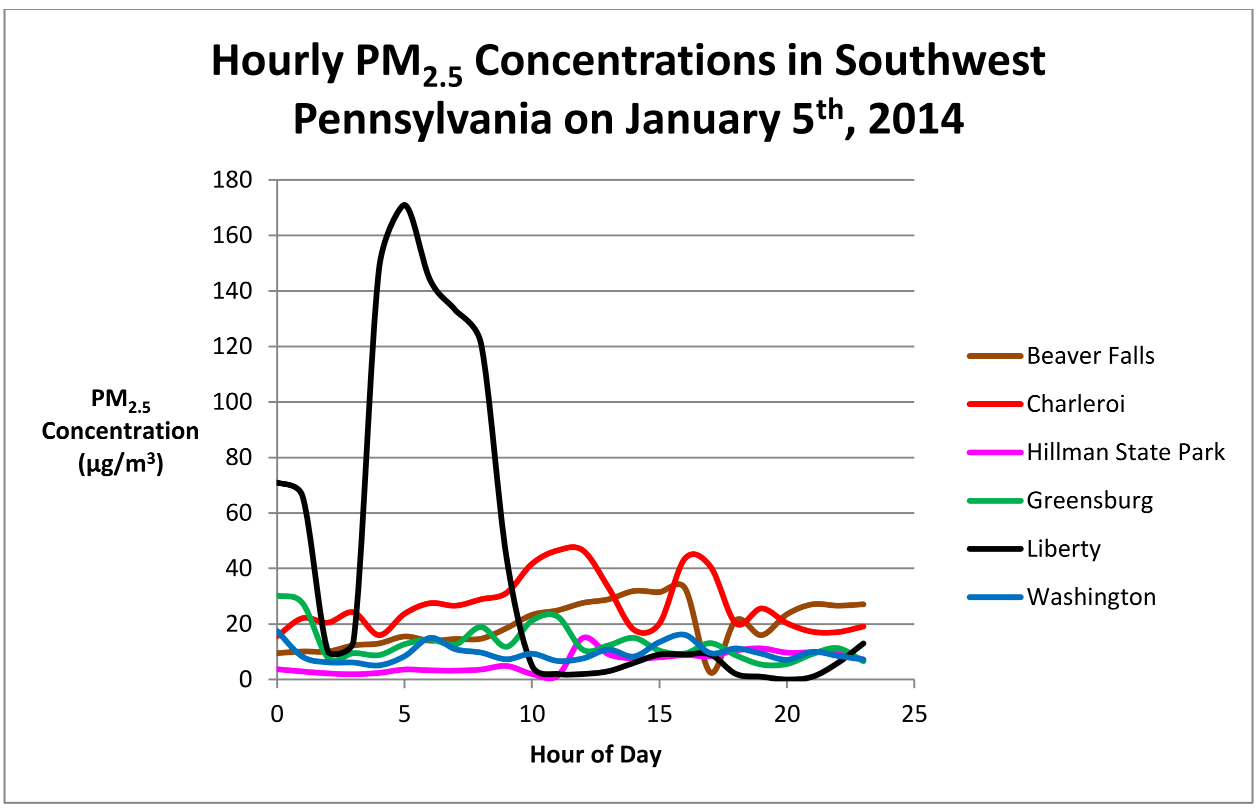
Hourly $PM_{2.5}$ Concentrations in Southwest Pennsylvania on January 3rd, 2013
100
90
80
70
60
50
40
30
20
10
0
-10
0
5
10
15
20
25
$PM_{2.5}$ Concentration ($\mu g/m^3$)
Hour of Day
Beaver Falls
Charleroi
Hillman State Park
Kittanning



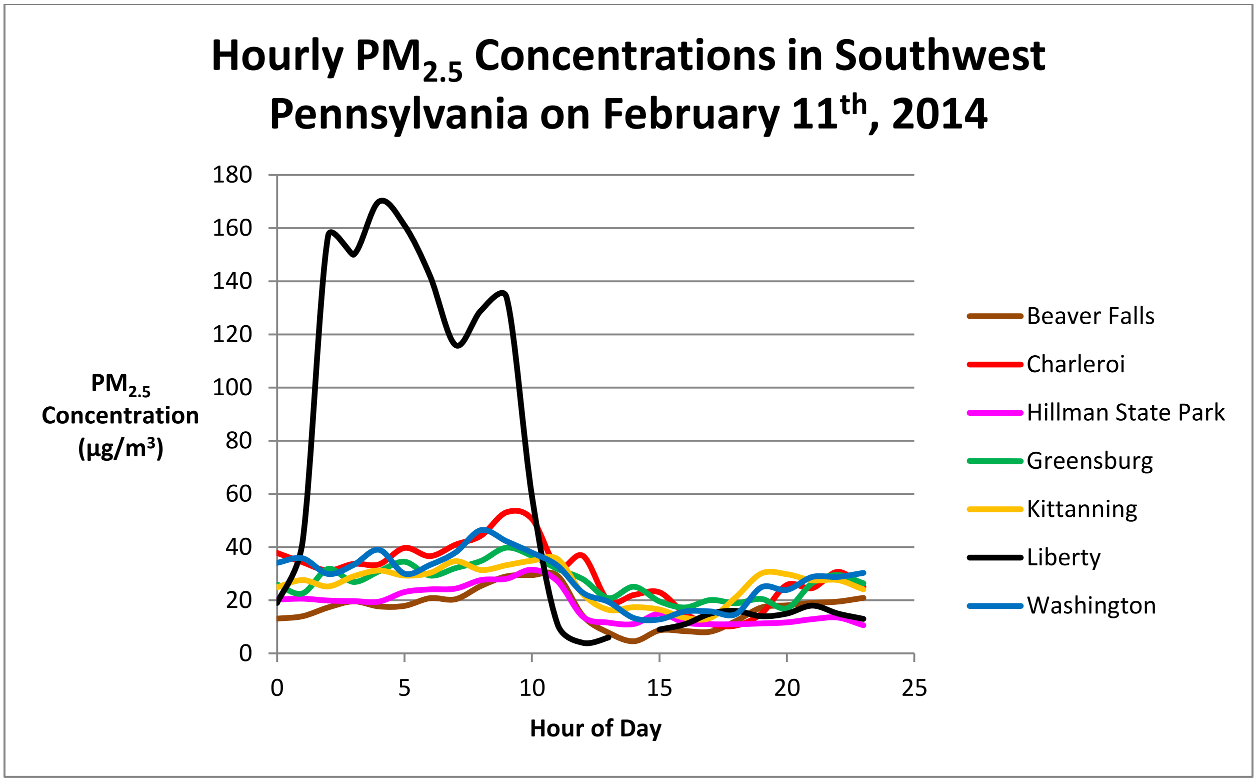
Hourly $PM_{2.5}$ Concentrations in Southwest Pennsylvania on October 28th, 2013
80
70
60
50
40
30
20
10
0
0
5
10
15
20
25
$PM_{2.5}$ Concentration ($\mu g/m^3$)
Hour of Day
Beaver Falls
Charleroi
Hillman State Park
Greensburg
Kittanning
Liberty
Washington

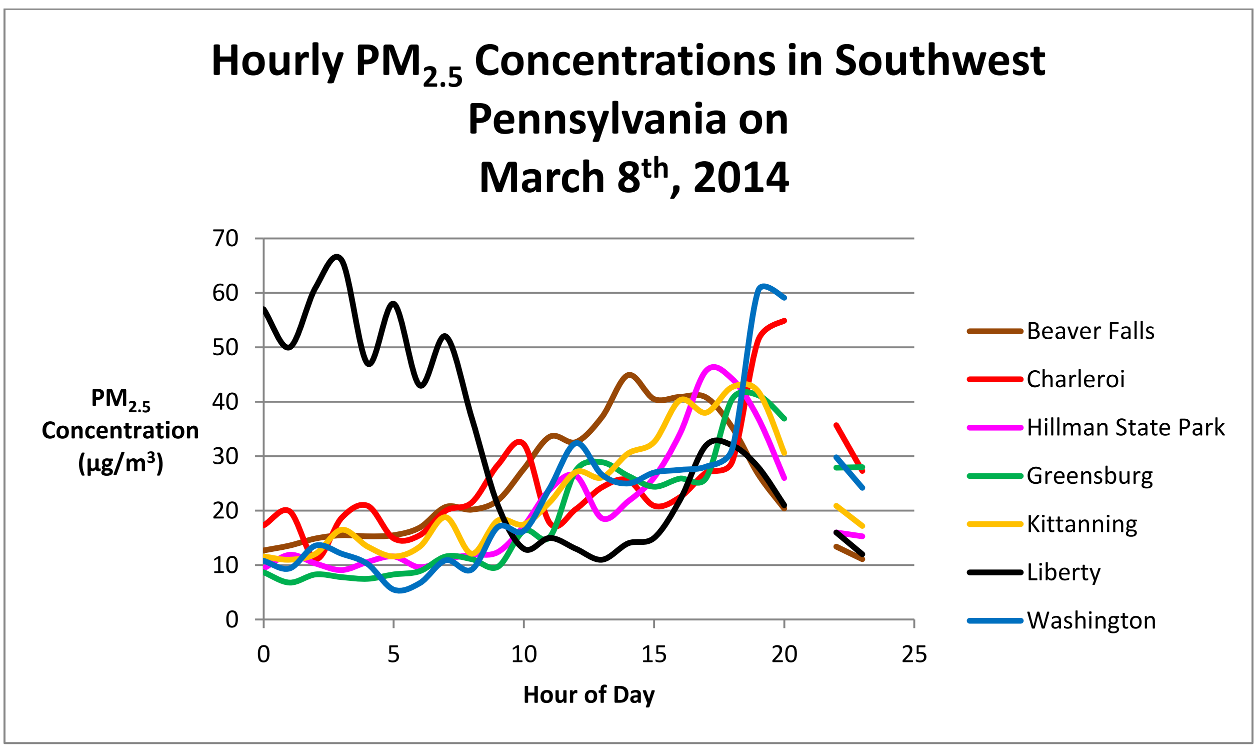


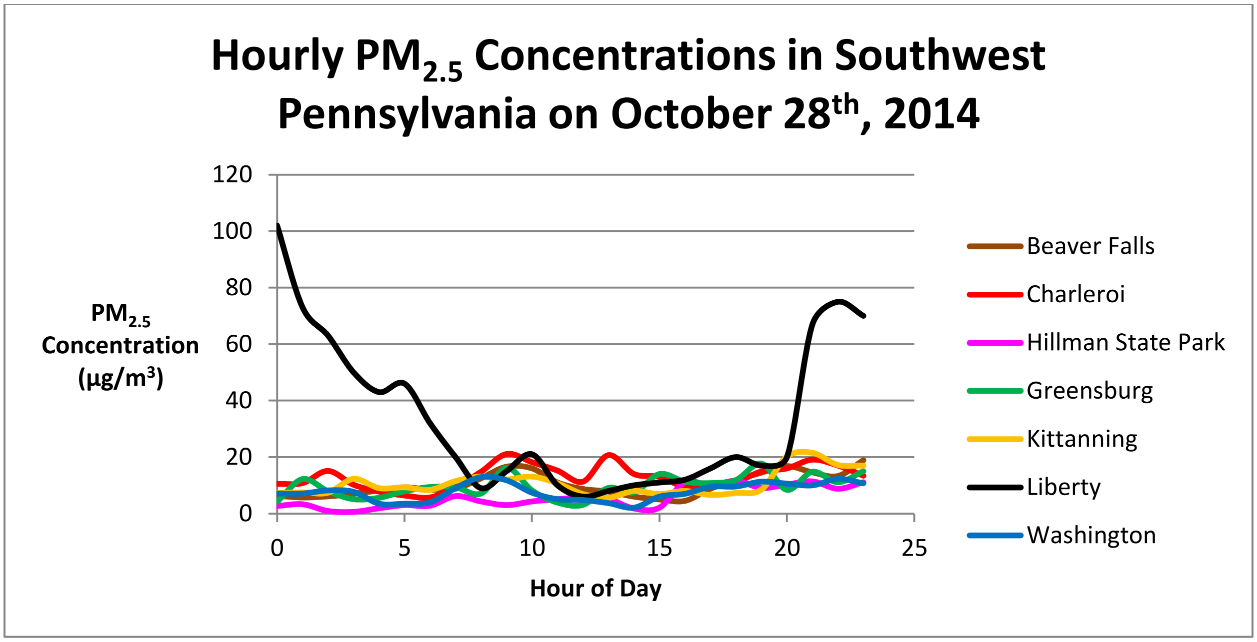
Hourly $PM_{2.5}$ Concentrations in Southwest Pennsylvania on December 1st, 2013
$PM_{2.5}$ Concentration (µg/m³)
120
100
80
60
40
20
0
0
5
10
15
20
25
Hour of Day
Beaver Falls
Charleroi
Hillman State Park
Greensburg
Kittanning
Liberty
Washington

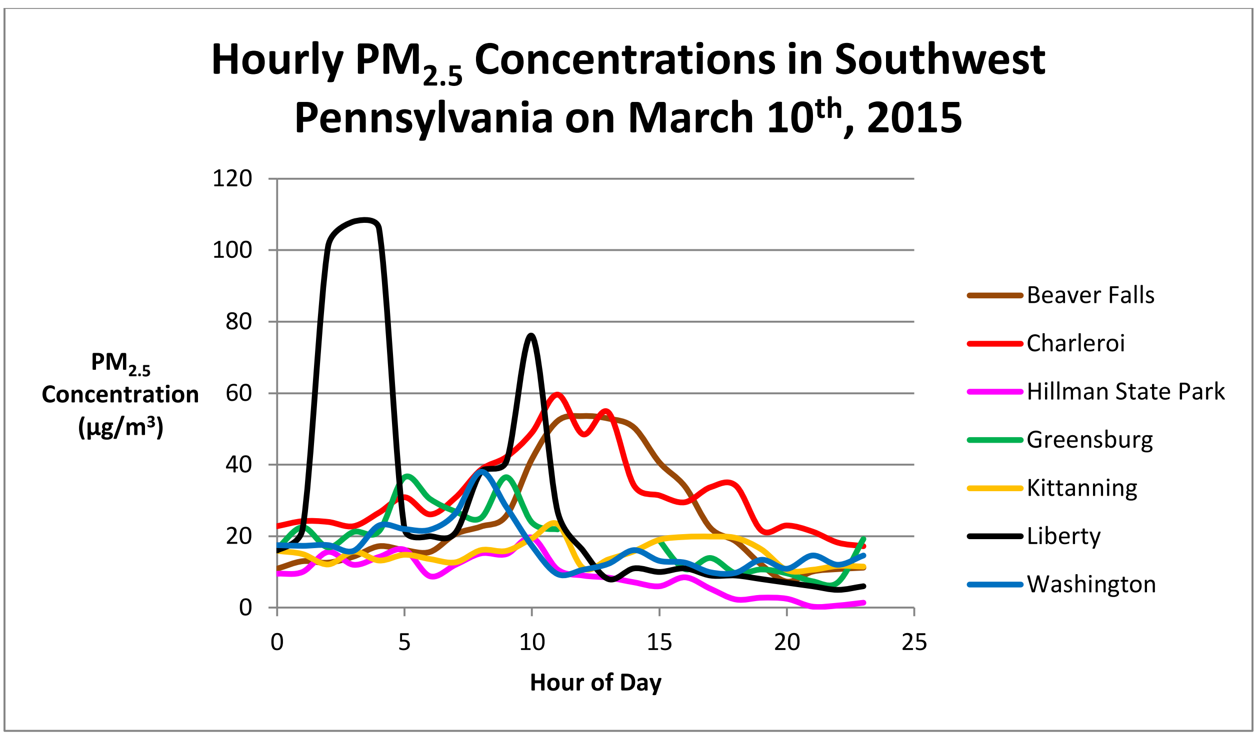


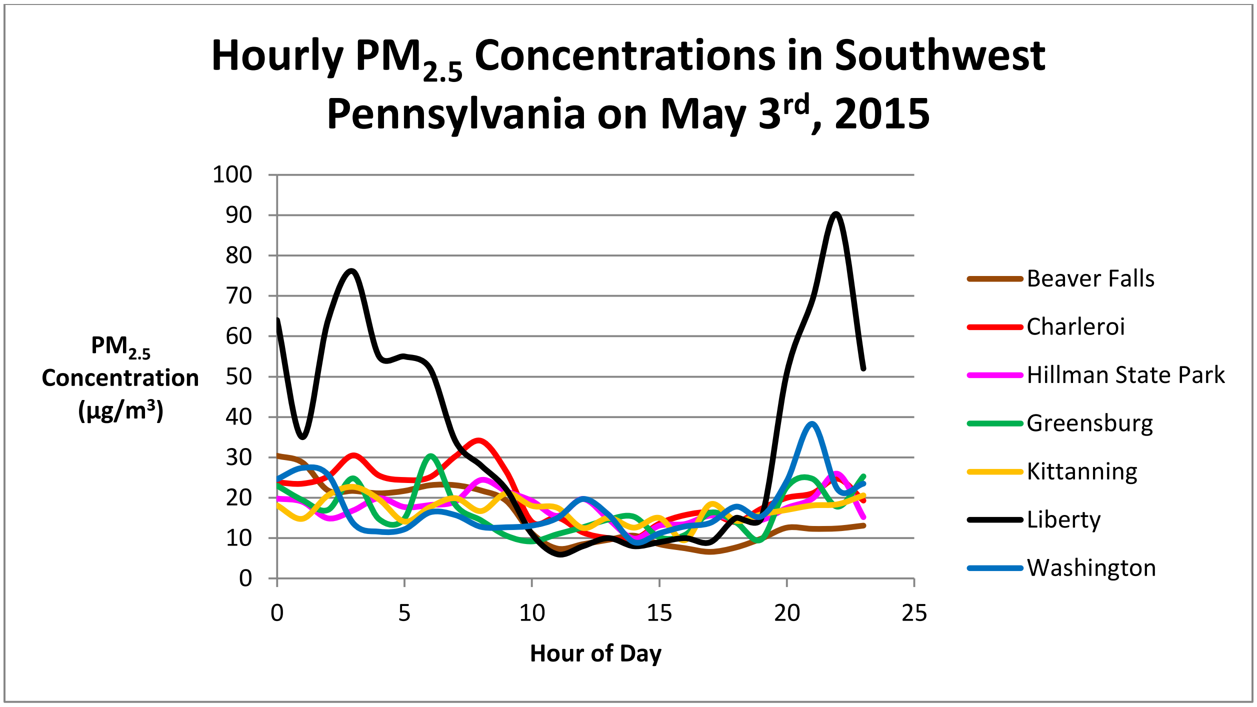
Hourly $PM_{2.5}$ Concentrations in Southwest Pennsylvania on January 5th, 2014
$PM_{2.5}$ Concentration (µg/m³)
180
160
140
120
100
80
60
40
20
0
0
5
10
15
20
25
Hour of Day
Beaver Falls
Charleroi
Hillman State Park
Greensburg
Liberty
Washington


Hourly PM2.5 Concentrations in Southwest Pennsylvania on February 11th, 2014
180
160
140
120
100
80
60
40
20
0
0
5
10
15
20
25
PM2.5 Concentration (µg/m³)
Hour of Day
Beaver Falls
Charleroi
Hillman State Park
Greensburg
Kittanning
Liberty
Washington

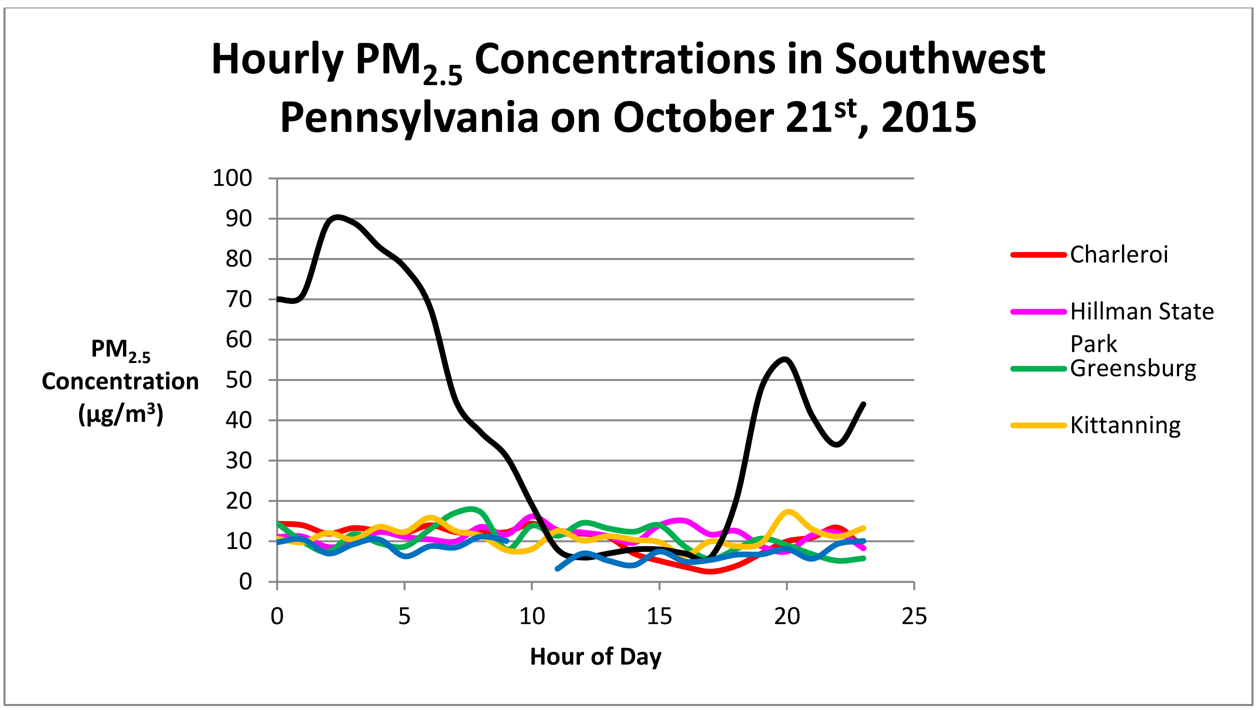

Hourly PM2.5 Concentrations in Southwest Pennsylvania on March 8th, 2014
70
60
50
40
30
20
10
0
0
5
10
15
20
25
PM2.5 Concentration (µg/m³)
Hour of Day
Beaver Falls
Charleroi
Hillman State Park
Greensburg
Kittanning
Liberty
Washington


Hourly $PM_{2.5}$ Concentrations in Southwest Pennsylvania on October 28th, 2014
120
100
80
60
40
20
0
$PM_{2.5}$ Concentration ($\mu g/m^3$)
0
5
10
15
20
25
Hour of Day
Beaver Falls
Charleroi
Hillman State Park
Greensburg
Kittanning
Liberty
Washington

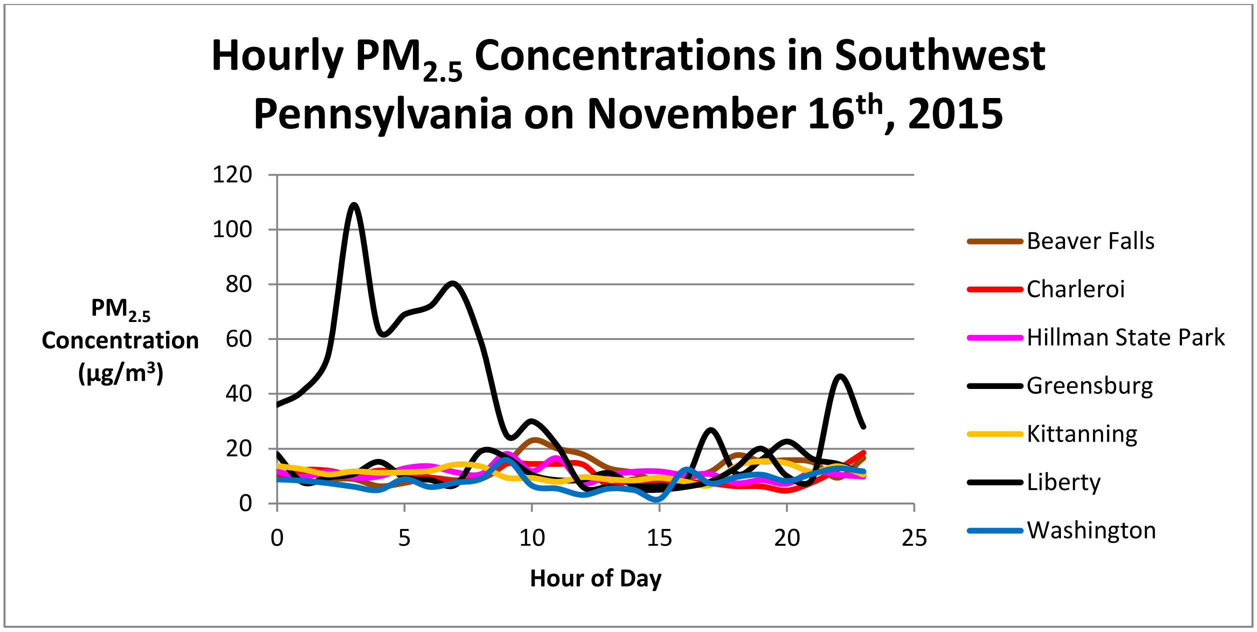

Hourly $PM_{2.5}$ Concentrations in Southwest Pennsylvania on March 10th, 2015
120
100
80
60
40
20
0
$PM_{2.5}$ Concentration ($\mu g/m^3$)
0
5
10
15
20
25
Hour of Day
Beaver Falls
Charleroi
Hillman State Park
Greensburg
Kittanning
Liberty
Washington

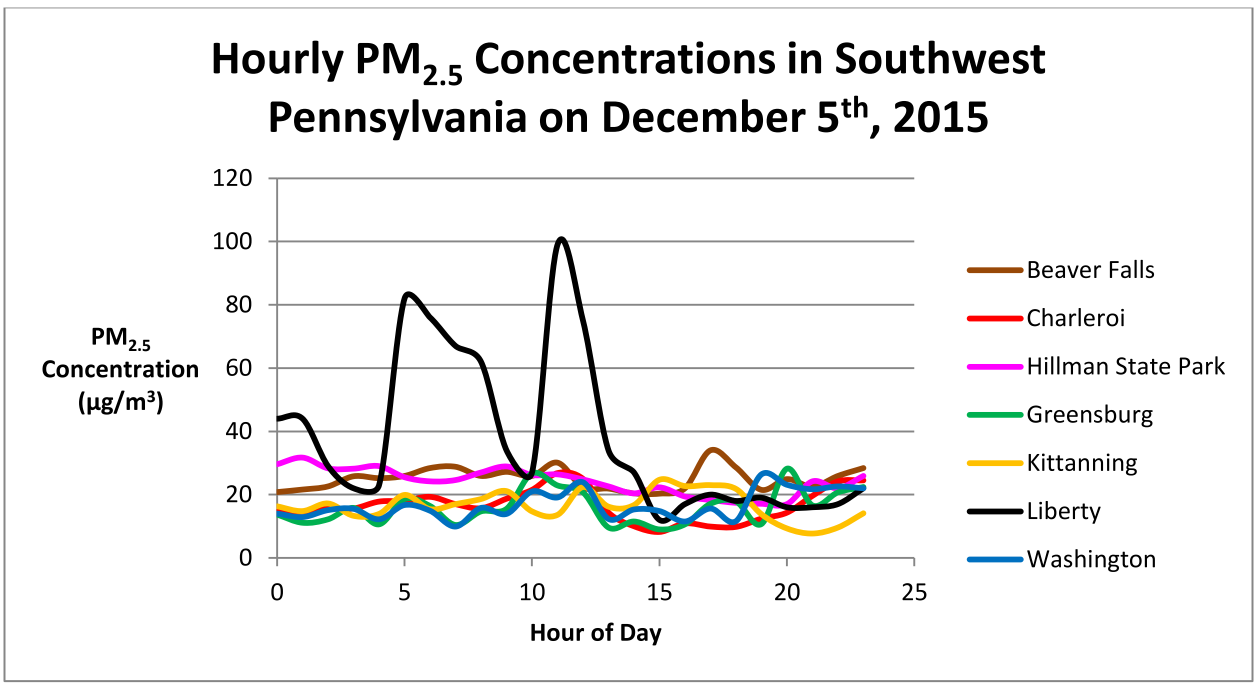


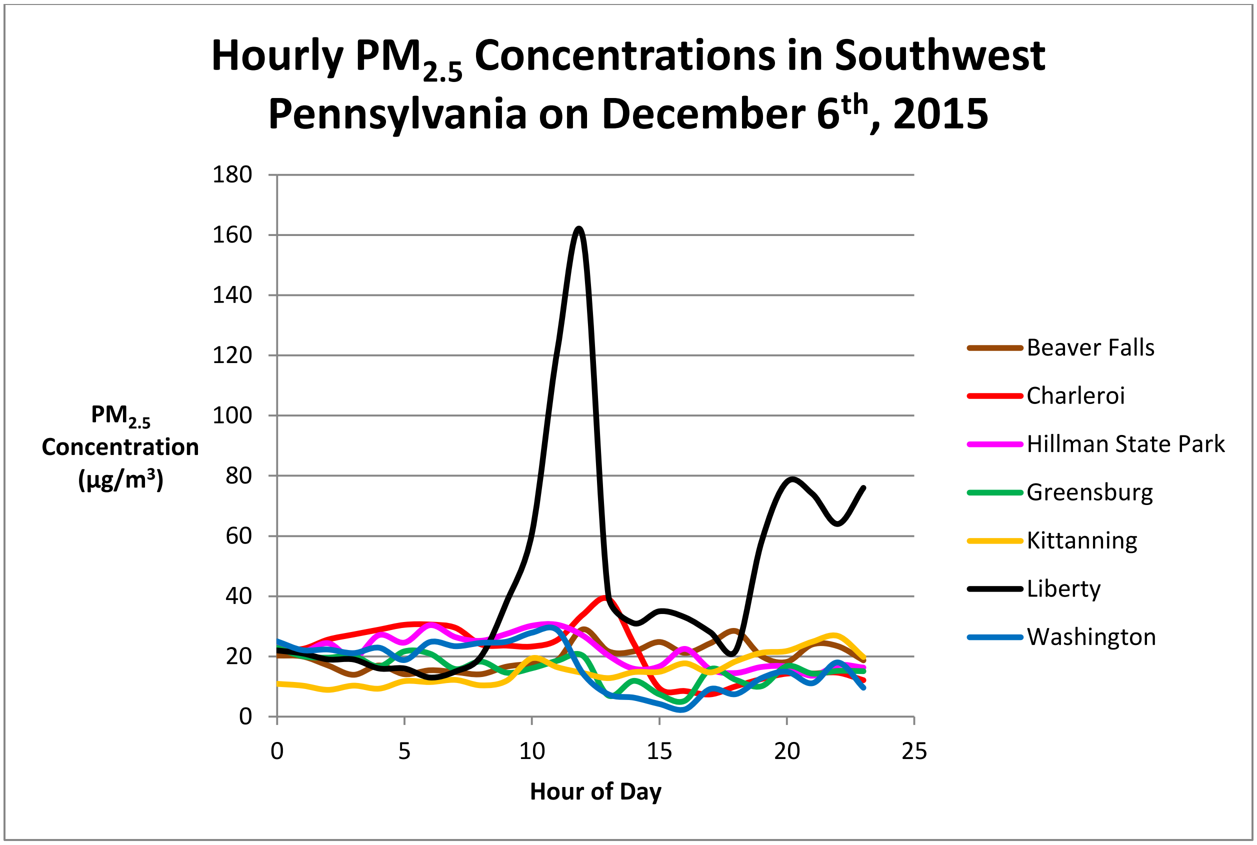
Hourly PM2.5 Concentrations in Southwest Pennsylvania on May 3rd, 2015
PM2.5 Concentration (µg/m³)
100
90
80
70
60
50
40
30
20
10
0
0
5
10
15
20
25
Hour of Day
Beaver Falls
Charleroi
Hillman State Park
Greensburg
Kittanning
Liberty
Washington

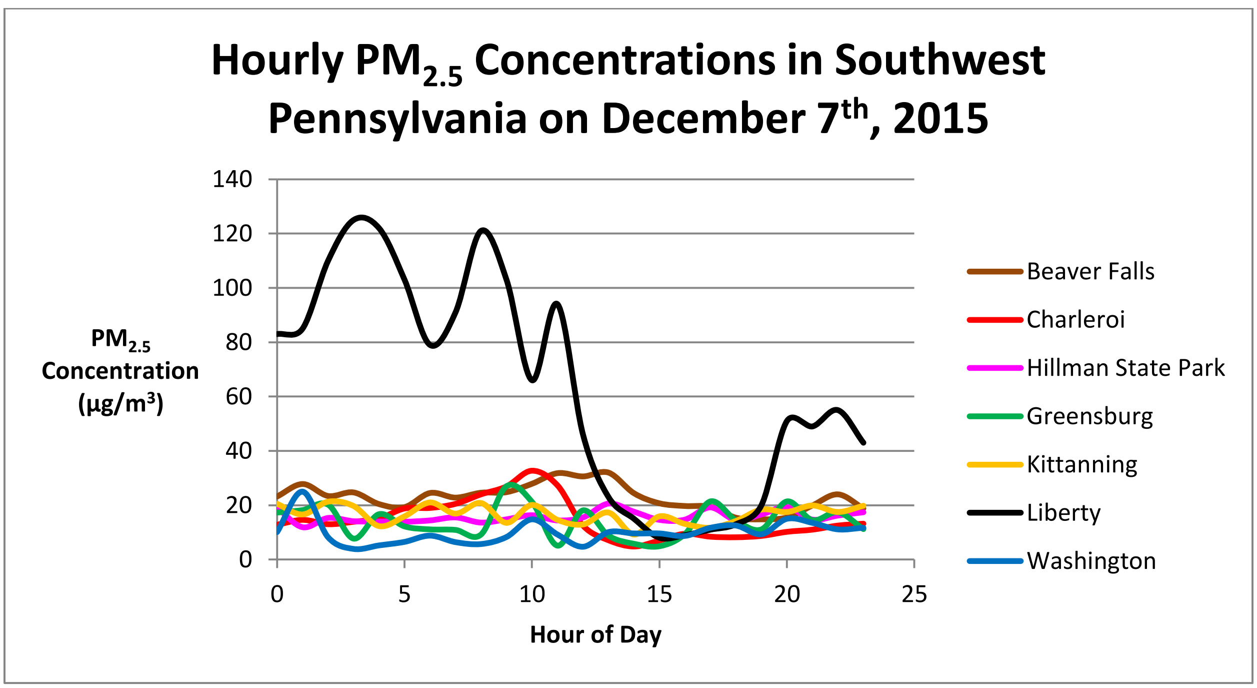


Hourly PM2.5 Concentrations in Southwest Pennsylvania on October 21st, 2015
PM2.5 Concentration (µg/m³)
100
90
80
70
60
50
40
30
20
10
0
0
5
10
15
20
25
Hour of Day
Charleroi
Hillman State Park
Greensburg
Kittanning


Hourly PM2.5 Concentrations in Southwest Pennsylvania on November 16th, 2015
PM2.5 Concentration (µg/m³)
120
100
80
60
40
20
0
0
5
10
15
20
25
Hour of Day
Beaver Falls
Charleroi
Hillman State Park
Greensburg
Kittanning
Liberty
Washington


Hourly PM2.5 Concentrations in Southwest Pennsylvania on December 5th, 2015
PM2.5 Concentration (µg/m³)
120
100
80
60
40
20
0
0
5
10
15
20
25
Hour of Day
Beaver Falls
Charleroi
Hillman State Park
Greensburg
Kittanning
Liberty
Washington


Hourly $PM_{2.5}$ Concentrations in Southwest Pennsylvania on December 6th, 2015
180
160
140
120
100
80
60
40
20
0
$PM_{2.5}$ Concentration (μg/m³)
0
5
10
15
20
25
Hour of Day
Beaver Falls
Charleroi
Hillman State Park
Greensburg
Kittanning
Liberty
Washington


Hourly $PM_{2.5}$ Concentrations in Southwest Pennsylvania on December 7th, 2015
140
120
100
80
60
40
20
0
$PM_{2.5}$ Concentration (μg/m³)
0
5
10
15
20
25
Hour of Day
Beaver Falls
Charleroi
Hillman State Park
Greensburg
Kittanning
Liberty
Washington

APPENDIX C

Quarterly and Annual Averages for 2009-2015 with and without 24- Hour Average $PM_{2.5}$ Concentrations Greater Than 35 $\mu g/m^3$ Included

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	Quarter				Annual
2009	1st	2nd	3rd	4th	Average
All Concentrations	15.0	13.7	15.1	16.4	15.1
Concentrations <35 μg/m^3	13.8	13.7	14.8	12.3	13.7

	Quarter				Annual
2010	1st	2nd	3rd	4th	Average
All Concentrations	14.7	15.0	18.6	15.8	16.0
Concentrations <35 μg/m^3	11.4	14.1	15.8	13.3	13.7

	Quarter				Annual
2011	1st	2nd	3rd	4th	Average
All Concentrations	12.2	12.4	15.4	16.0	14.0
Concentrations <35 μg/m^3	12.2	12.4	15.2	12.4	13.1

	Quarter				Annual
2012	1st	2nd	3rd	4th	Average
All Concentrations	14.2	13.7	15.4	13.9	14.3
Concentrations <35 μg/m^3	12.9	13.5	15.4	11.7	13.4

	Quarter				Annual
2013	1st	2nd	3rd	4th	Average
All Concentrations	12.8	10.8	12.6	11.7	12.0
Concentrations <35 μg/m^3	11.5	10.8	12.6	11.2	11.5

	Quarter				Annual
2014	1st	2nd	3rd	4th	Average
All Concentrations	14.7	12.6	12.8	10.9	12.8
Concentrations <35 μg/m^3	13.3	12.6	12.8	10.7	12.4

	Quarter				Annual
2015	1st	2nd	3rd	4th	Average
All Concentrations	13.2	11.7	14.7	12.2	13.0
Concentrations <35 μg/m^3	12.8	11.4	14.7	10.3	12.3

ANNUAL DESIGN VALUES		
Period	All Concentrations	Concentrations <35 μg/m^3
2009-2011	15.0	13.5
2010-2012	14.8	13.4
2011-2013	13.4	12.7
2012-2014	13.0	12.4
2013-2015	12.6	12.1

Highlighted values are maximum design values used to determine maintance status of the monitor for 5-year period

5-YEAR WEIGHTED DESIGN VALUES		
Period	All Concentrations	Concentrations <35 μg/m^3
2009-2013	14.4	13.2
2010-2014	13.7	12.8
2011-2015	13.0	12.4

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APPENDIX D

State-by-State Trajectory Statistical Summary Tables

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The state by state statistics listed in the tables below show the average 24-hour $PM_{2.5}$ concentration recorded at both the Liberty monitor alone as well as with all Allegheny County monitors, when a trajectory passes through the listed state. If a state has a high averaged $PM_{2.5}$ value, then when trajectories pass through the state, they are more likely to be associated with higher $PM_{2.5}$ values at the monitor location. Also given in the tables below are the number of $PM_{2.5}$ values used to comprise the average.

Table D-1: 100 Meter Trajectory Analysis – All Concentrations and 24-Hour Back Trajectories
Liberty Monitor (42-003-0064)

STATE	AVERAGE CONCENTRATION ($\mu g/m^3$)	NUMBER OF 24-HOUR $PM_{2.5}$ READINGS
WEST VIRGINIA	13.52	1184
KENTUCKY	13.31	503
OHIO	13.19	1088
PENNSYLVANIA	12.98	1410
GEORGIA	12.89	94
SOUTH CAROLINA	12.66	77
VIRGINIA	12.39	490
MARYLAND	12.13	310
TENNESSEE	12.09	249
NORTH CAROLINA	11.90	196
ALABAMA	10.75	50
INDIANA	10.66	366
OTHER (OUTSIDE U.S., GREAT LAKES)	10.33	632
MICHIGAN	9.91	345
ILLINOIS	9.69	155
NEW YORK	9.51	222
WISCONSIN	8.92	80
ARKANSAS	8.40	6
MISSOURI	8.25	25
MISSISSIPPI	8.05	11
DELAWARE	7.76	26
MINNESOTA	7.43	11
NEBRASKA	7.30	1
FLORIDA	7.03	10
DISTRICT OF COLUMBIA	7.01	22
IOWA	6.98	29
CONNECTICUT	5.82	5
NEW JERSEY	5.60	27
KANSAS	5.60	2
SOUTH DAKOTA	5.25	2
VERMONT	1.35	2
MAINE	1.35	2
NEW HAMPSHIRE	1.35	2
MASSACHUSETTS	1.35	2

Table D-2: 100 Meter Trajectory Analysis – All Concentrations and 24-Hour Back Trajectories
All Allegheny County Monitors

STATE	AVERAGE CONCENTRATION ($\mu g/m^3$)	NUMBER OF 24-HOUR $PM_{2.5}$ READINGS
WEST VIRGINIA	11.42	4363
MARYLAND	11.10	1109
OHIO	11.05	3979
PENNSYLVANIA	11.01	5144
KENTUCKY	10.90	1866
VIRGINIA	10.63	1723
SOUTH CAROLINA	10.37	242
GEORGIA	10.24	302
TENNESSEE	9.80	873
NORTH CAROLINA	9.80	687
INDIANA	9.21	1356
OTHER (OUTSIDE U.S., GREAT LAKES)	8.95	2257
NEW YORK	8.87	773
ILLINOIS	8.73	601
MINNESOTA	8.56	38
MICHIGAN	8.46	1245
ALABAMA	8.20	167
ARKANSAS	8.07	21
MISSISSIPPI	7.86	38
WISCONSIN	7.71	298
MISSOURI	7.32	111
DISTRICT OF COLUMBIA	6.87	70
NEBRASKA	6.80	2
CONNECTICUT	6.45	16
DELAWARE	6.41	100
IOWA	6.30	101
FLORIDA	6.01	32
NEW JERSEY	5.58	105
SOUTH DAKOTA	4.98	4
KANSAS	4.23	9
VERMONT	2.40	9
MAINE	2.40	9
NEW HAMPSHIRE	2.40	9
MASSACHUSETTS	2.40	9

Table D-3: 500 Meter Trajectory Analysis – All Concentrations and 24-Hour Back Trajectories
Liberty Monitor (42-003-0064)

STATE	AVERAGE CONCENTRATION ($\mu g/m^3$)	NUMBER OF 24-HOUR $PM_{2.5}$ READINGS
KENTUCKY	13.90	666
WEST VIRGINIA	13.67	1187
OHIO	13.62	1202
LOUISIANA	13.50	14
TENNESSEE	13.26	467
PENNSYLVANIA	12.98	1410
ALABAMA	12.98	178
INDIANA	12.68	602
GEORGIA	12.57	229
VIRGINIA	12.30	486
TEXAS	11.74	5
ARKANSAS	11.69	42
NORTH CAROLINA	11.61	288
MISSISSIPPI	11.44	76
MICHIGAN	11.40	525
ILLINOIS	11.08	354
SOUTH CAROLINA	10.86	149
FLORIDA	10.77	35
NEBRASKA	10.58	15
IOWA	10.53	138
MISSOURI	10.38	115
KANSAS	10.27	26
MARYLAND	10.19	232
WISCONSIN	10.05	228
NEW YORK	9.40	242
OKLAHOMA	9.21	8
MINNESOTA	8.73	83
SOUTH DAKOTA	8.14	14
DISTRICT OF COLUMBIA	6.67	29
NORTH DAKOTA	6.31	9
DELAWARE	5.95	45
MASSACHUSETTS	5.88	14
NEW JERSEY	5.40	46
RHODE ISLAND	5.22	5
CONNECTICUT	5.14	15
VERMONT	2.91	8
NEW HAMPSHIRE	2.83	8
MAINE	2.07	7

Table D-4: 500 Meter Trajectory Analysis – All Concentrations and 24-Hour Back Trajectories – All Allegheny County Monitors

STATE	AVERAGE CONCENTRATION ($\mu g/m^3$)	NUMBER OF 24- HOUR $PM_{2.5}$ READINGS
WEST VIRGINIA	11.50	4414
KENTUCKY	11.42	2415
OHIO	11.33	4405
PENNSYLVANIA	11.01	5144
VIRGINIA	10.81	1753
TENNESSEE	10.79	1687
INDIANA	10.64	2215
GEORGIA	10.30	950
NORTH CAROLINA	10.22	797
ALABAMA	10.17	992
MARYLAND	10.11	602
TEXAS	9.86	843
FLORIDA	9.69	13
MICHIGAN	9.68	124
SOUTH CAROLINA	9.67	1885
ILLINOIS	9.50	509
IOWA	9.43	1274
WISCONSIN	8.83	519
MISSISSIPPI	8.78	822
ARKANSAS	8.74	256
MISSOURI	8.72	170
NEW YORK	8.46	444
KANSAS	8.34	843
LOUISIANA	8.26	84
OKLAHOMA	8.25	54
NEBRASKA	8.18	25
SOUTH DAKOTA	7.93	55
MINNESOTA	7.68	54
NORTH DAKOTA	6.59	339
DISTRICT OF COLUMBIA	6.05	51
DELAWARE	5.82	94
NEW JERSEY	5.60	150
MASSACHUSETTS	5.54	162
CONNECTICUT	4.89	33
RHODE ISLAND	4.65	44
VERMONT	2.91	15
NEW HAMPSHIRE	2.89	28
MAINE	2.45	28

Table D-5: 100 Meter Trajectory Data, 24-Hour Back Trajectories, 35 µg/m^3 and greater

State	Trajectory Points Count	Percentage of Exceedance Trajectory Points	Rank (Trajectory Points Count)	Average Concentration (µg/m^3, Rounded to nearest tenth)	Days Potentially Contributed to Exceedances
West Virginia	5578	34.43%	1	44.7	27
Pennsylvania	5327	32.88%	2	44.7	27
Ohio	3545	21.88%	3	44.3	19
Virginia	477	2.94%	4	45.5	9
Kentucky	406	2.51%	5	42.1	11
North Carolina	259	1.60%	6	44.0	5
Tennessee	168	1.04%	7	44.0	6
Maryland	108	0.67%	8	48.0	6
Other Locations (Outside U.S., Great Lakes)	89	0.55%	9	47.3	6
Georgia	77	0.48%	10	48.7	2
Indiana	**49**	**0.30%**	**11**	**40.5**	**3**
South Carolina	46	0.28%	12	45.4	4
Michigan	31	0.19%	13	50.0	2
Alabama	24	0.15%	14	43.6	1
New York	7	0.04%	15	37.4	1
Illinois	5	0.03%	16	47.1	1
Delaware	4	0.02%	17	48.7	1

Table D-6: 500 Meter Trajectory Data, 24-Hour Back Trajectories, 35 µg/m^3 and greater

State	Trajectory Points Count	Percentage of Exceedance Trajectory Points	Rank (Trajectory Points Count)	Average Concentration (µg/m^3, Rounded to nearest tenth)	Days Potentially Contributed to Exceedances
Pennsylvania	3377	20.85	2	44.7	27
West Virginia	2413	14.90	3	44.7	26
Ohio	5633	34.77	1	44.3	25
Kentucky	1969	12.15	4	43.6	18
Tennessee	550	3.4	6	44.0	13
Indiana	**617**	**3.81**	**5**	**42.9**	**12**
Other Locations (Outside U.S., Great Lakes)	228	1.41	9	46.1	12
Virginia	235	1.45	8	46.3	8
Michigan	195	1.20	10	44.7	7
Alabama	134	0.83	11	44.3	5
North Carolina	98	0.60	13	47.3	5
Georgia	333	2.06	7	44.0	4
Illinois	93	0.57	14	40.1	4
Missouri	40	0.25	16	41.7	3
Arkansas	7	0.04	22	43.4	3
South Carolina	58	0.36	15	48.0	2
Iowa	22	0.14	19	42.6	2
Wisconsin	11	0.07	20	41.6	2
Mississippi	105	0.65	12	43.6	1
Louisiana	39	0.24	17	43.6	1
New York	27	0.17	18	54.7	1
Florida	8	0.05	21	53.6	1
Kansas	6	0.04	23	38.1	1
Maryland	1	0.01	24	36.9	1
Nebraska	1	0.01	24	38.1	1
Total	16200	100.00	--		

APPENDIX E

Individual Exceedance Day Trajectories at 100, 500, and 1000 Meter Heights

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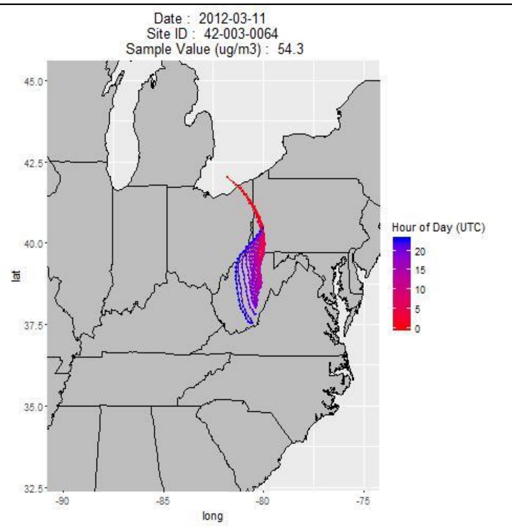
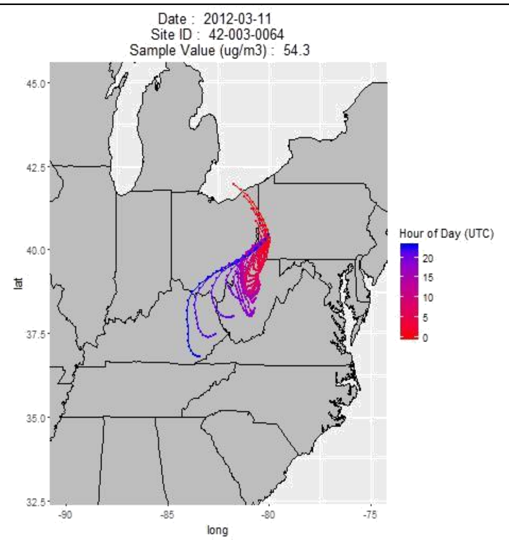
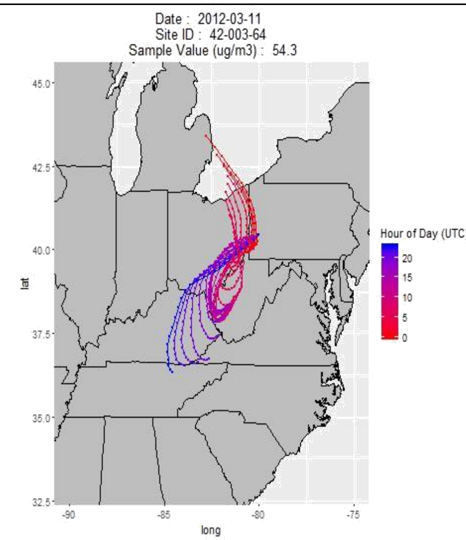
Daily Trajectory Plots

The following plots show each exceedance day's trajectories. A 24-hour back trajectory was calculated for each hour of the day for a conservative analysis of potential transport regions. In total, 26 exceedance days at the Liberty Monitor (42-003-0064) were identified during the 2012-2015 period. Plots for each day were constructed for each of the following heights AGL: 100, 500, and 1000m. The trajectories are color coded to the hour of day to match the highest hourly concentrations from the hourly $PM_{2.5}$ time series analysis to determine if Indiana potentially contributes to the highest hourly readings.

Date	100 meters	500 meters	1000 meters
03-11-2012			

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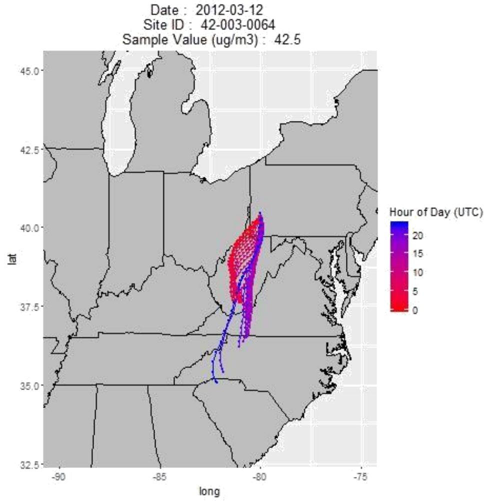
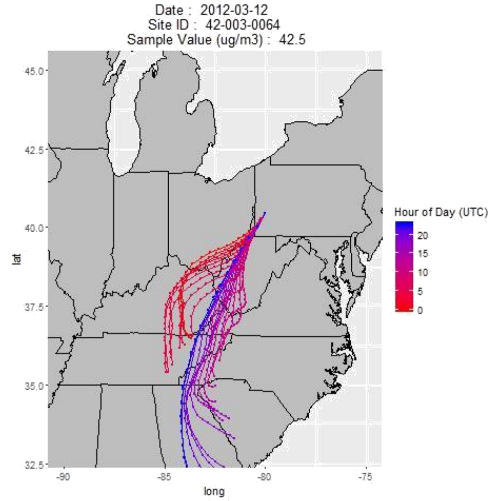
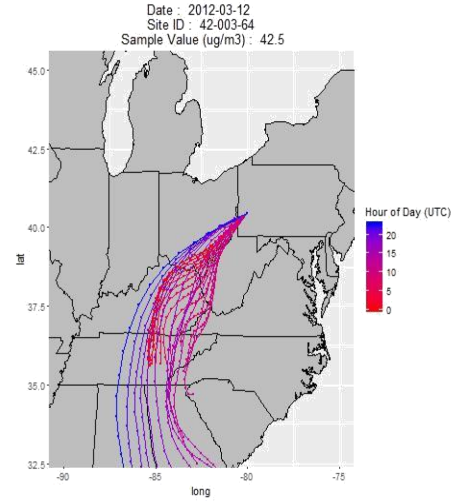
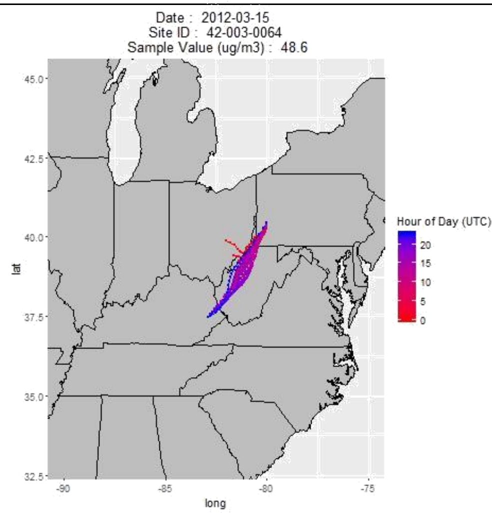
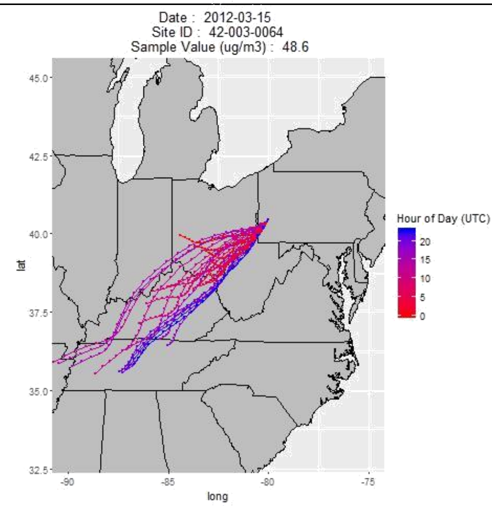
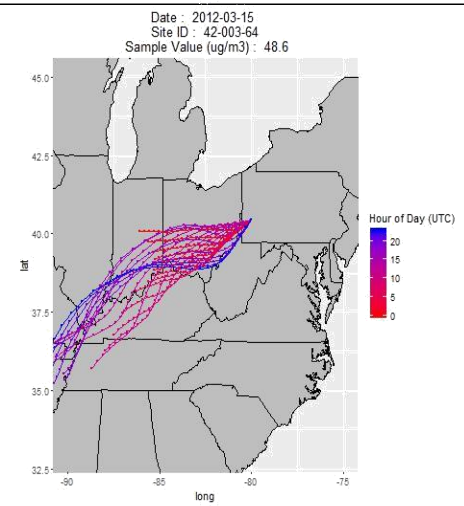
03-12-2012			
03-15-2012			

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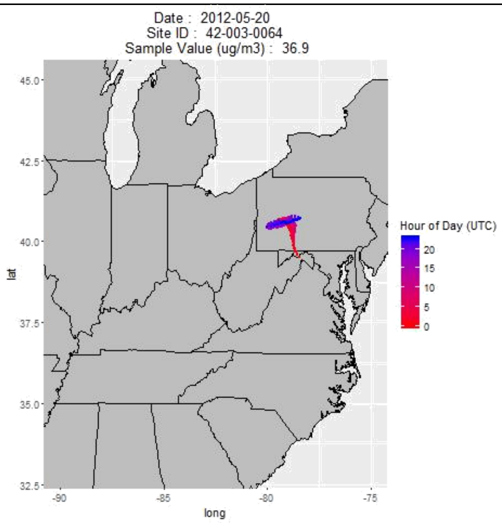
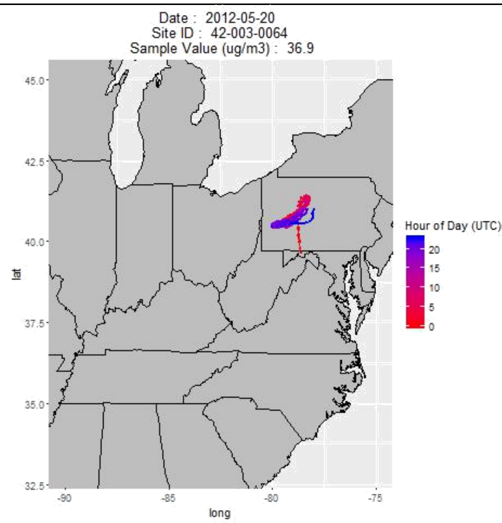
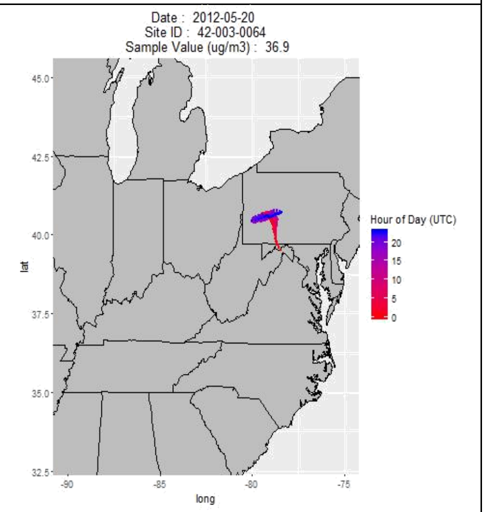
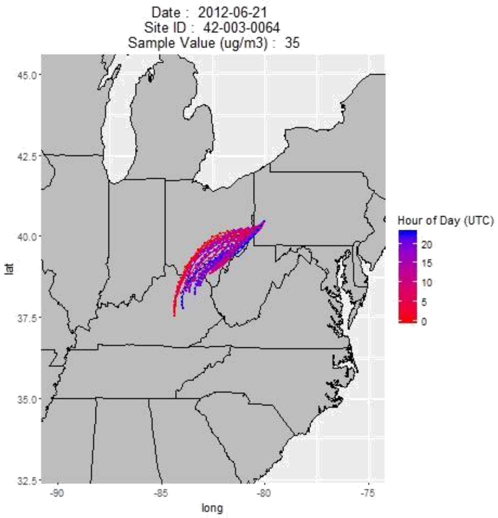
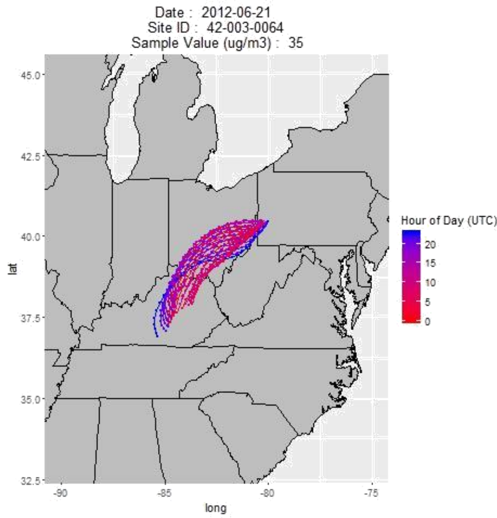
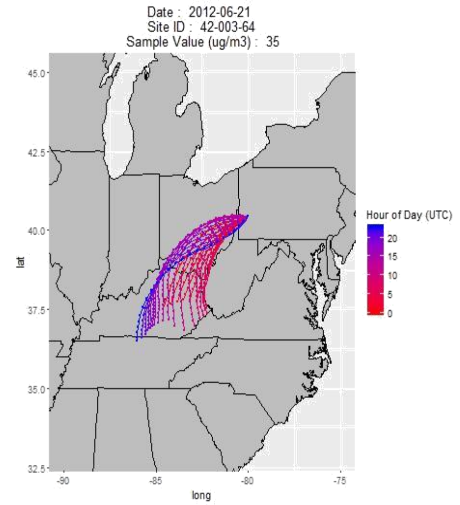
05-20-2012			
06-21-2012			

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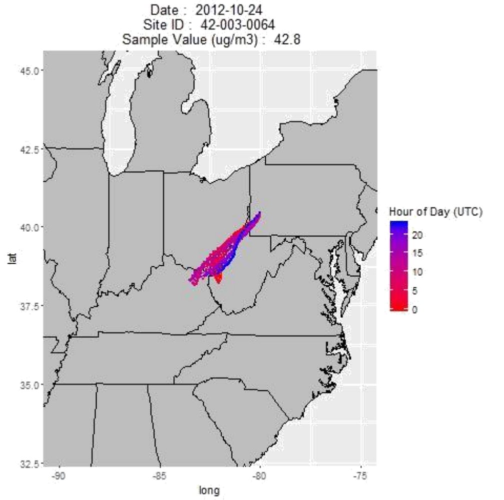
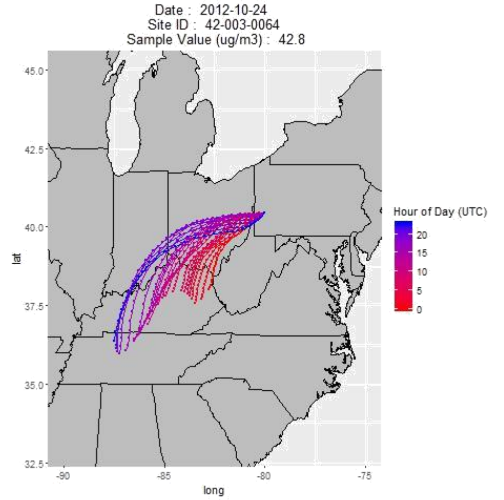
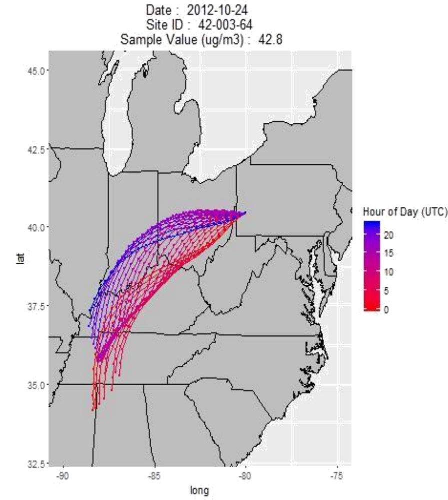
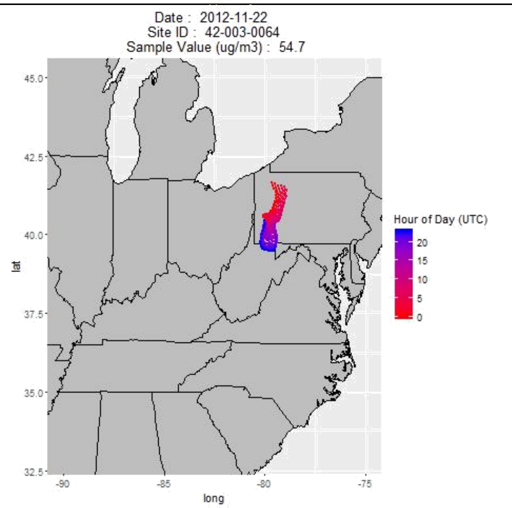
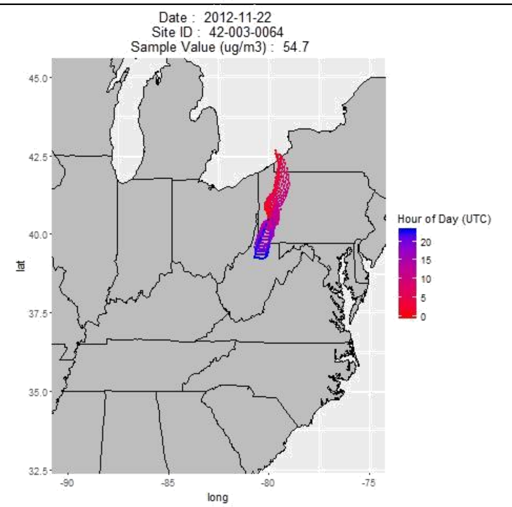
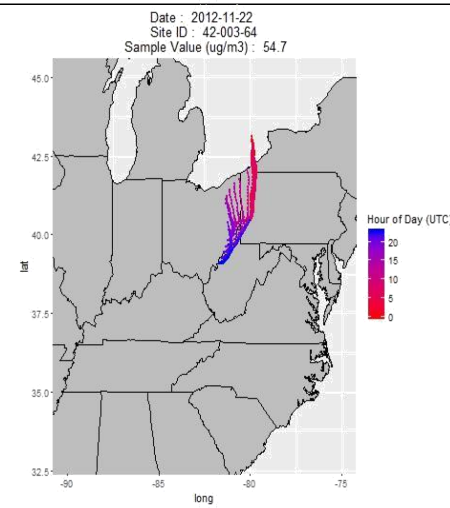
10-24-2012			
11-22-2012			

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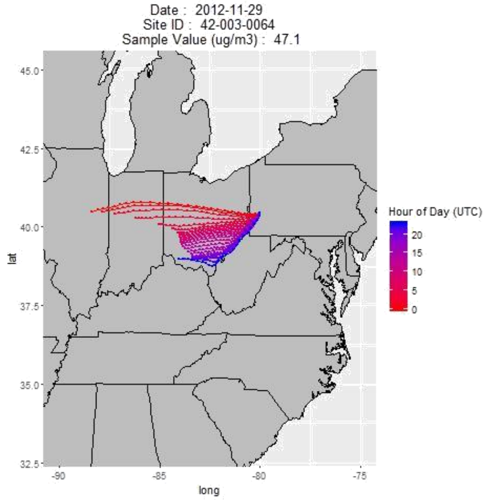
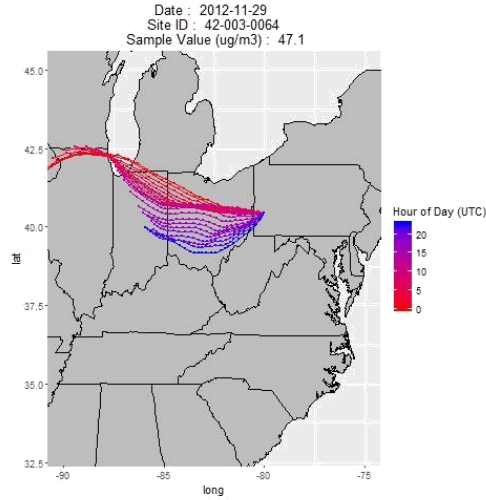
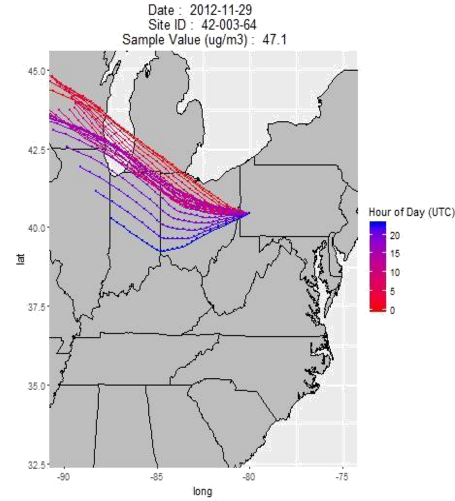
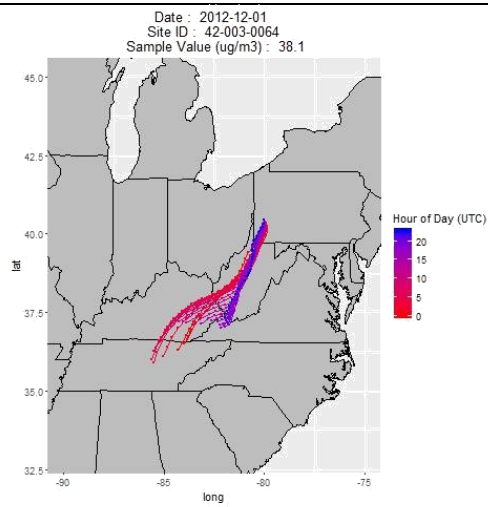
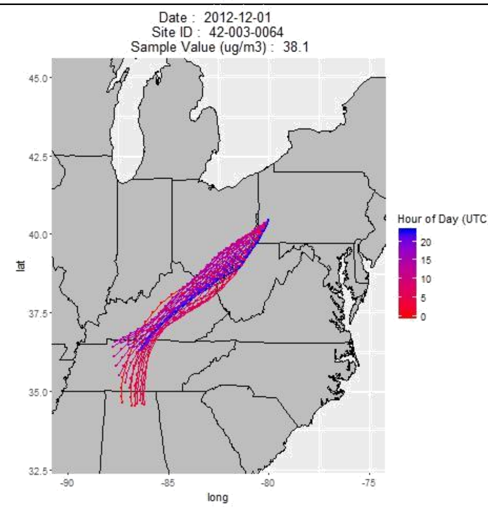
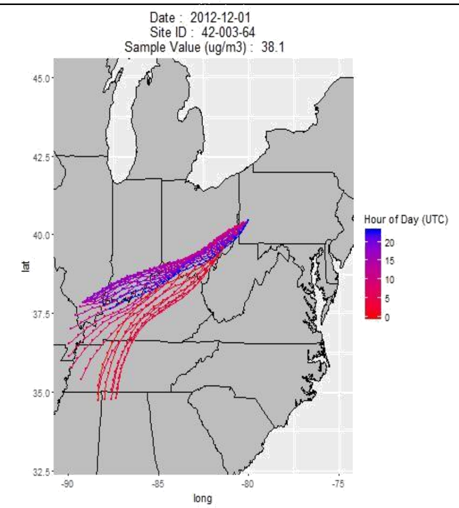
11-29-2012			
12-01-2012			

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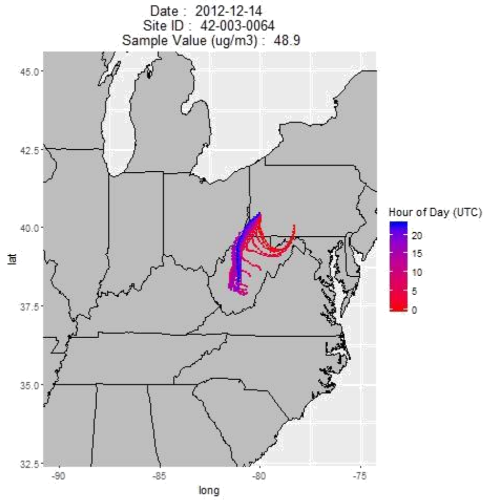
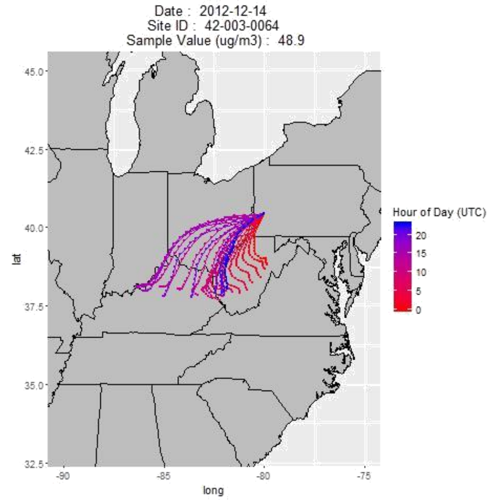
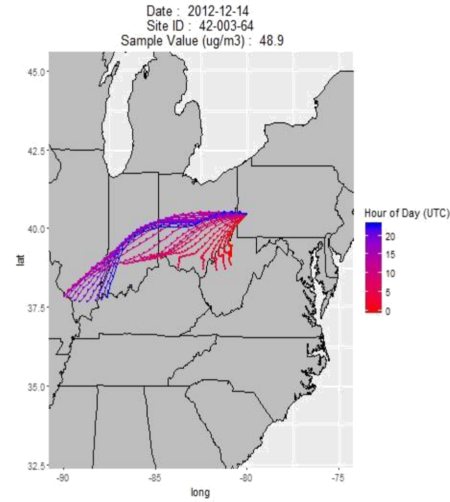
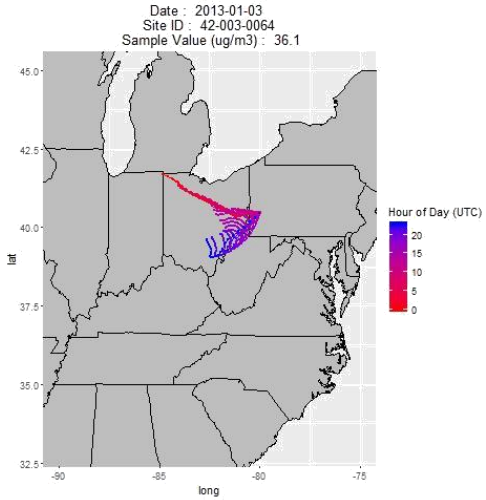
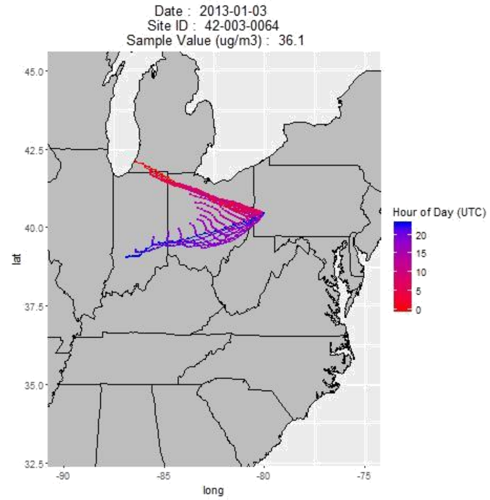
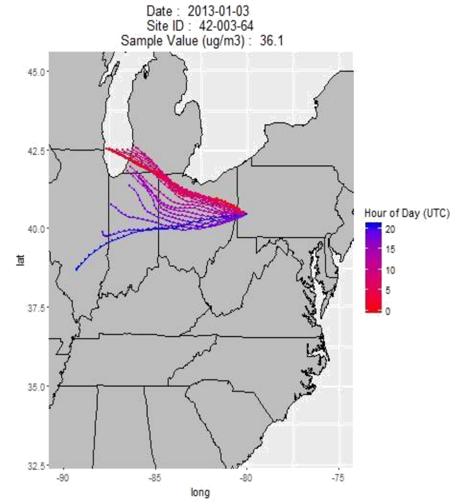
<tr><td>12-14-2012</td><td></td><td></td><td></td></tr>
<tr><td>01-03-2013</td><td></td><td></td><td></td></tr>
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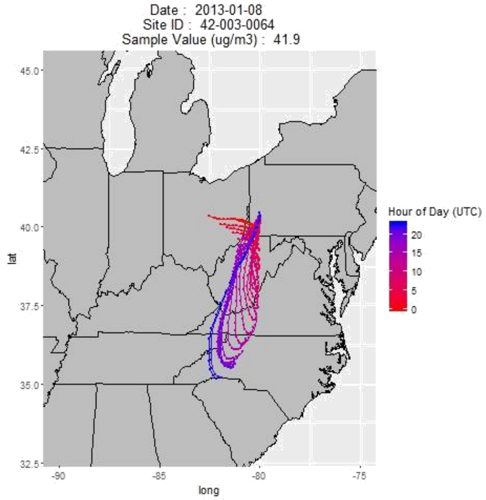
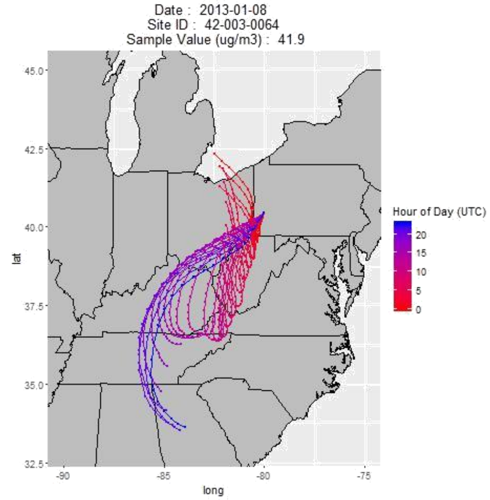
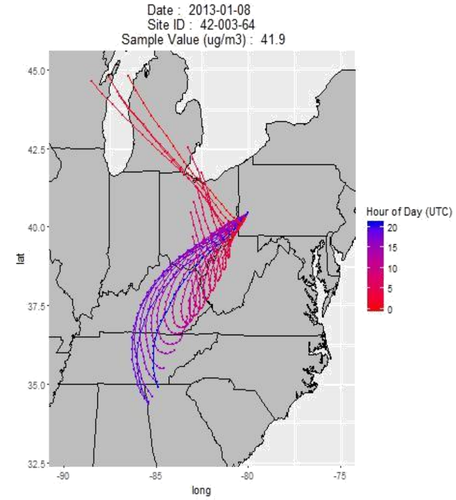
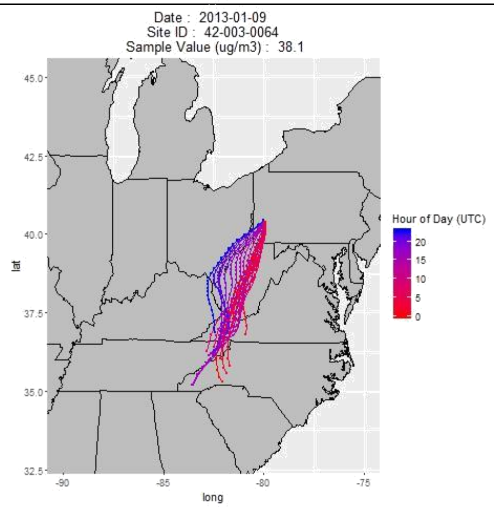
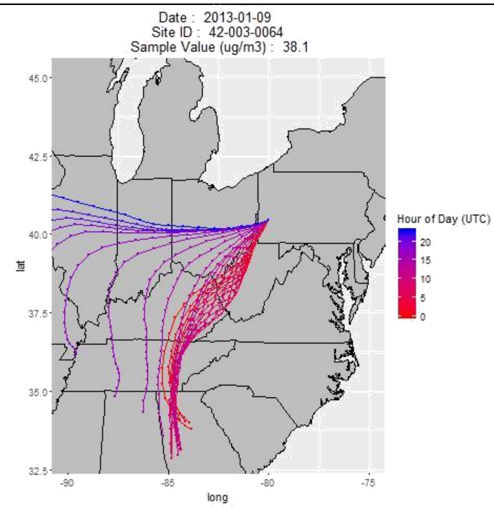
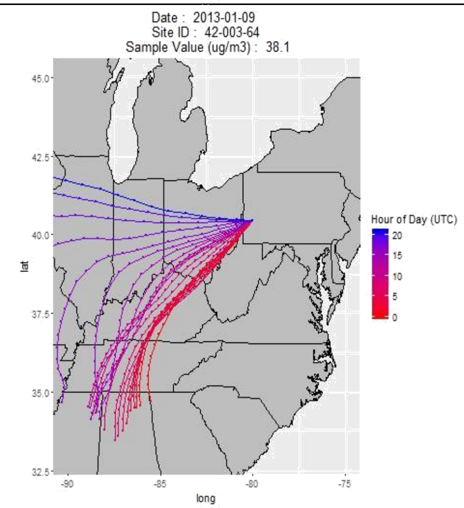
01-08-2013			
1-09-2013			

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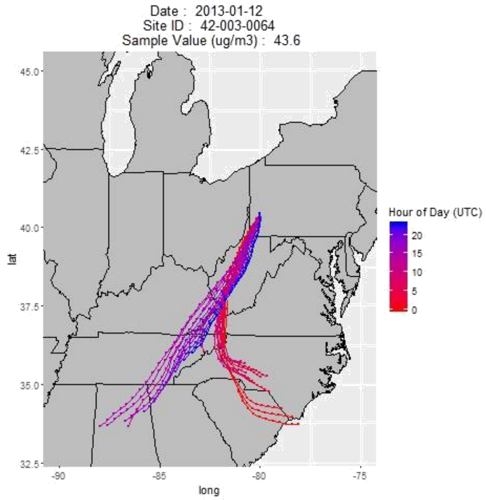
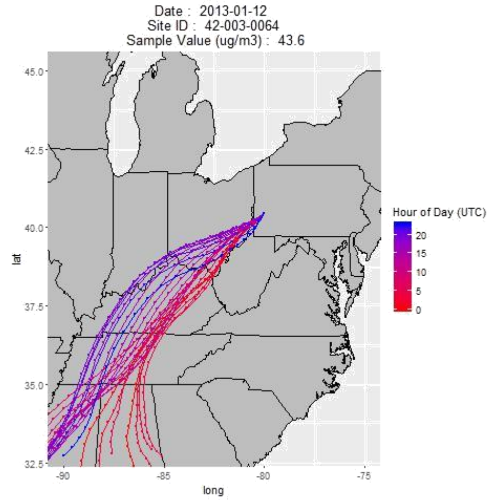
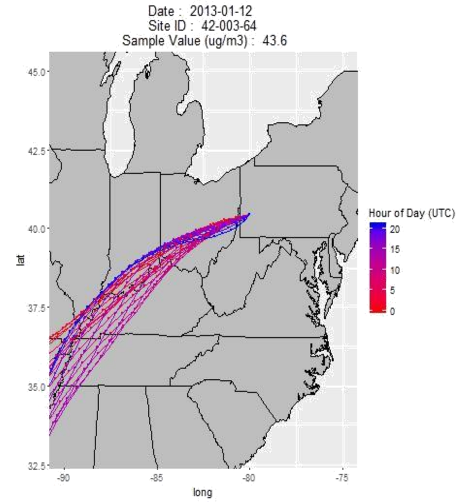
<tr><td>01-12-2013</td><td>
</td><td>
</td><td>
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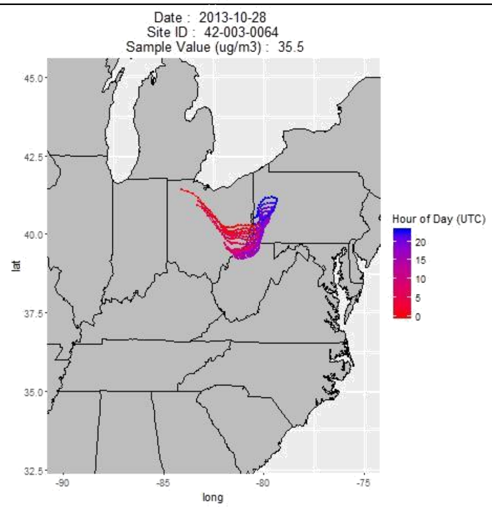
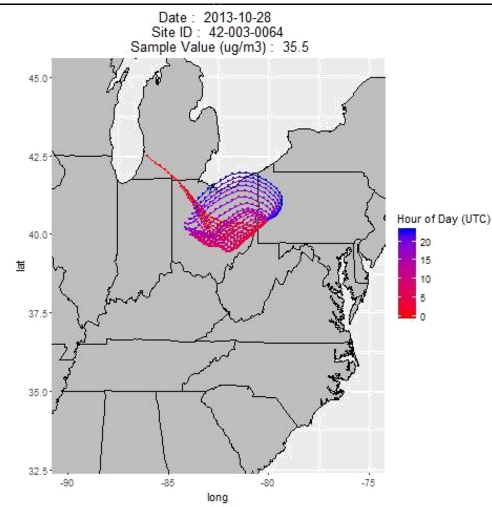
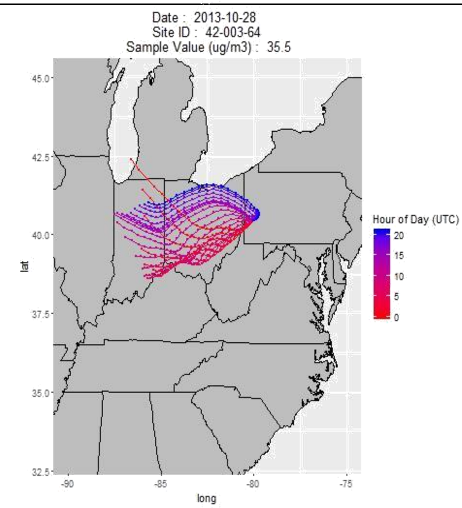
<tr><td>10-28-2013</td><td>
</td><td>
</td><td>
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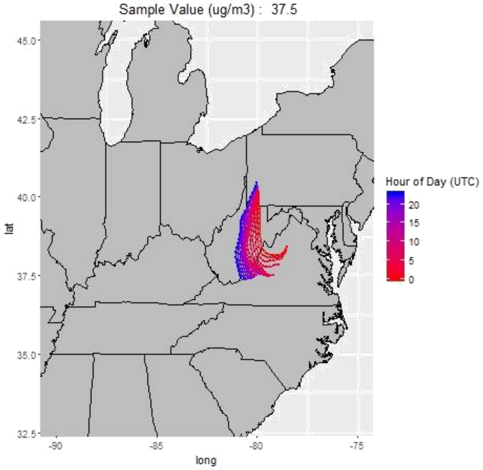
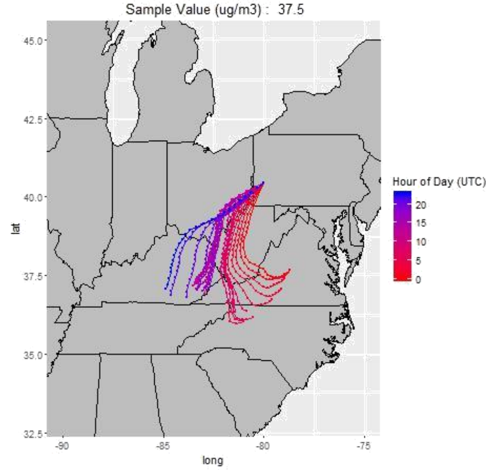
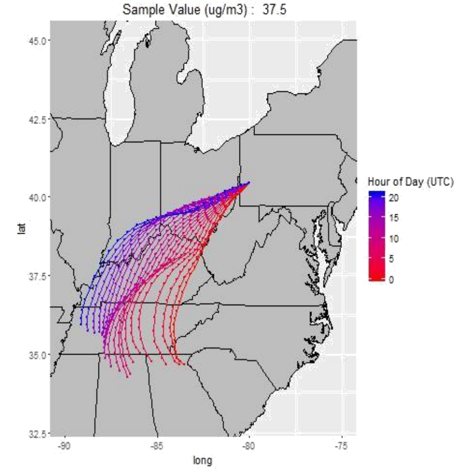
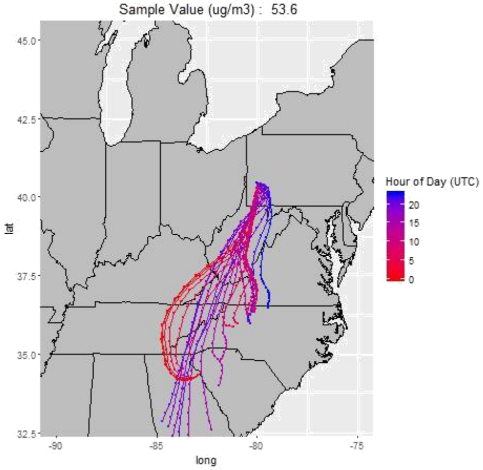
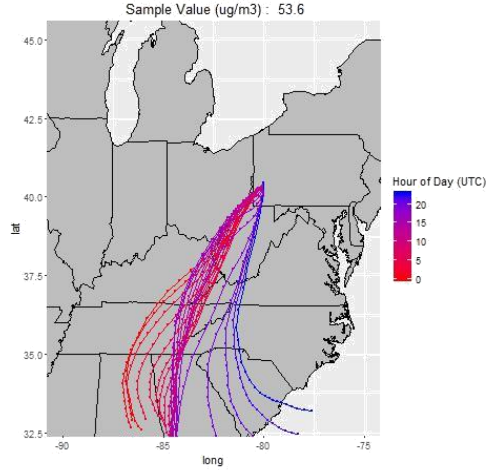
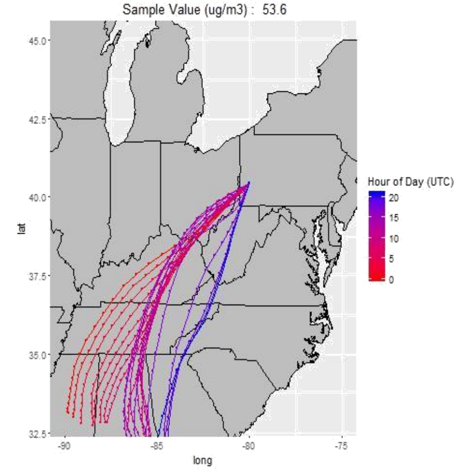
12-01-2013	Date : 2013-12-01 Site ID : 42-003-0064 Sample Value (ug/m3) : 37.5 	Date : 2013-12-01 Site ID : 42-003-0064 Sample Value (ug/m3) : 37.5 	Date : 2013-12-01 Site ID : 42-003-64 Sample Value (ug/m3) : 37.5 
01-05-2014	Date : 2014-01-05 Site ID : 42-003-0064 Sample Value (ug/m3) : 53.6 	Date : 2014-01-05 Site ID : 42-003-0064 Sample Value (ug/m3) : 53.6 	Date : 2014-01-05 Site ID : 42-003-64 Sample Value (ug/m3) : 53.6 

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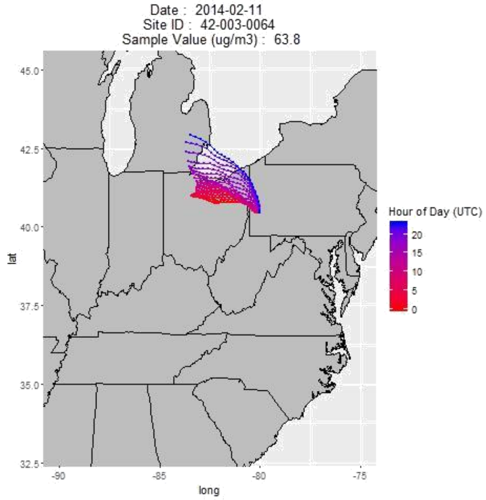
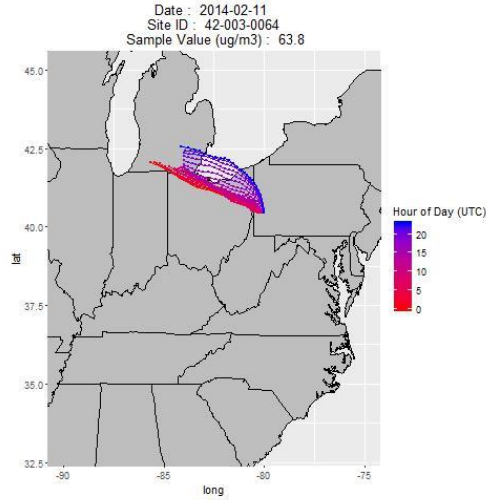
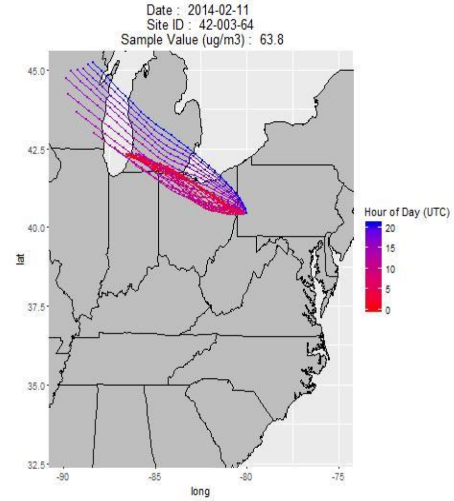
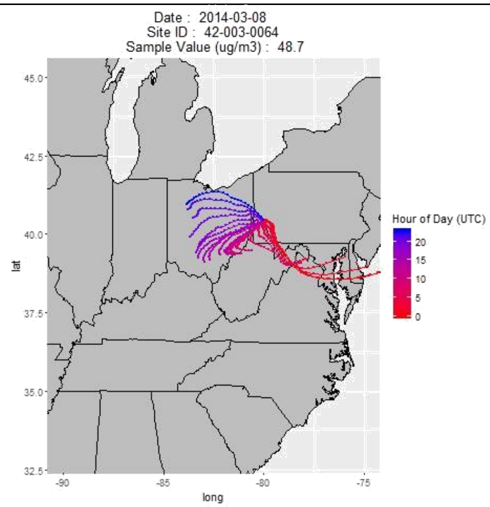
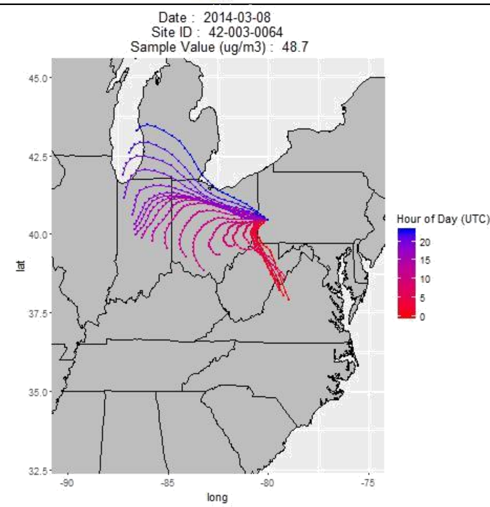
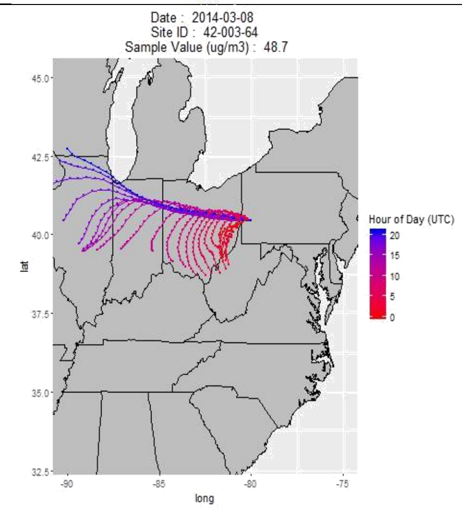
02-11-2014			
03-08-2014			

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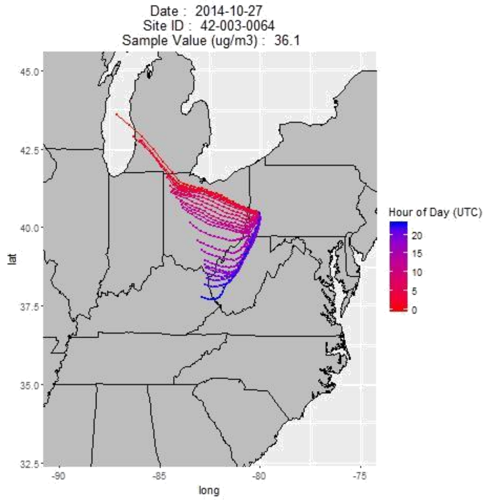
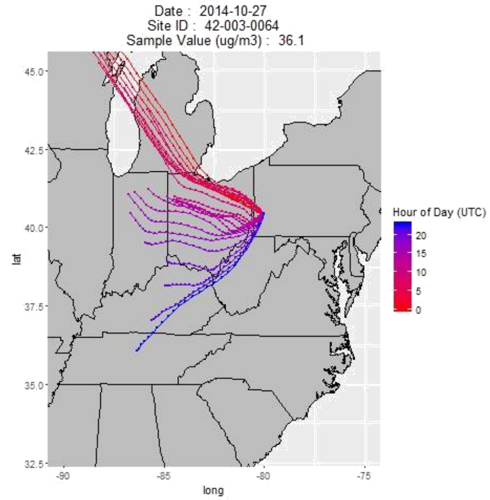
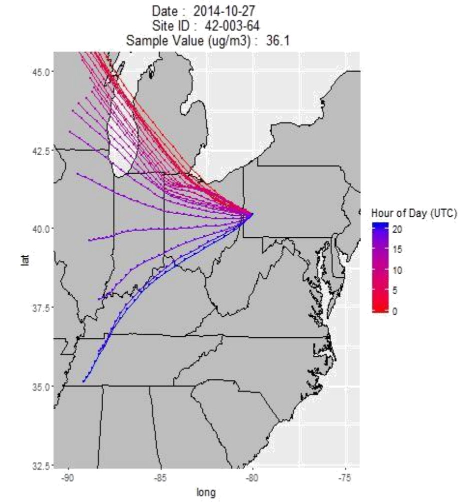
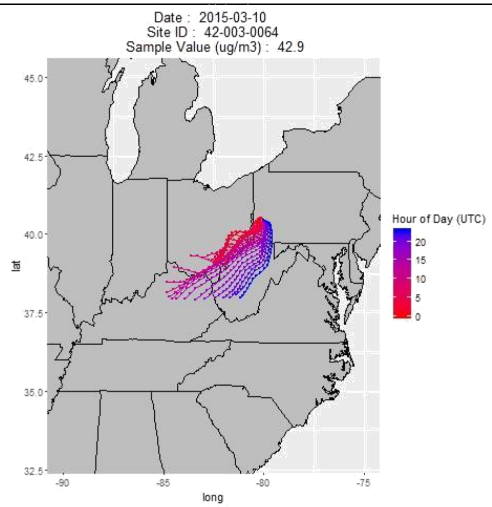
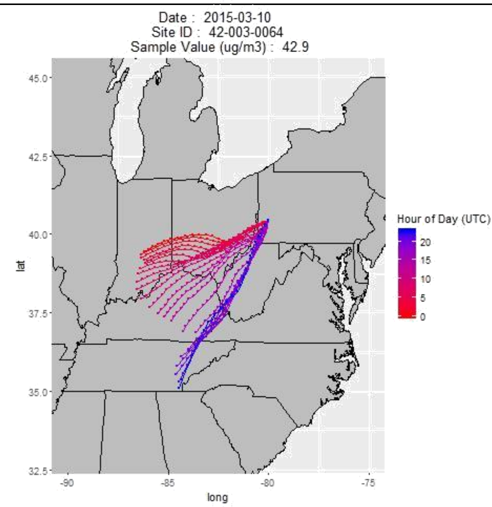
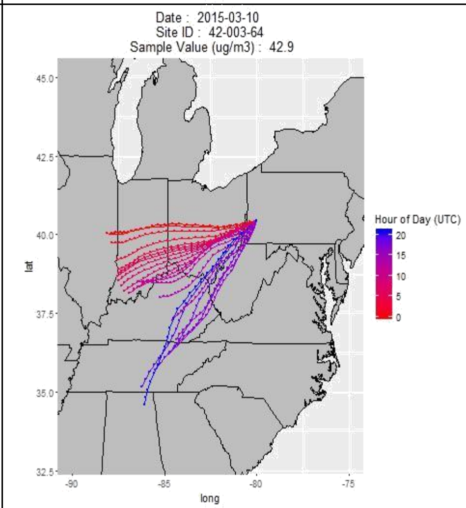
10-27-2014			
03-10-2015			

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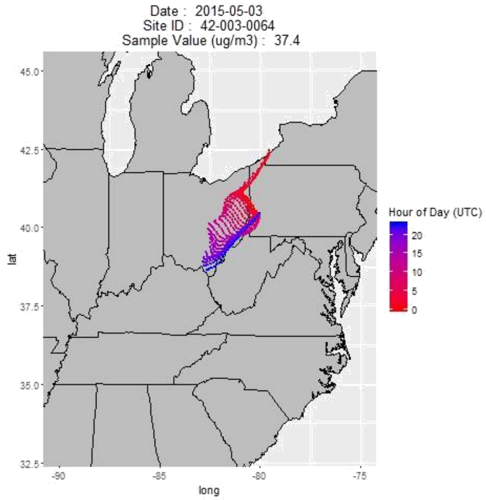
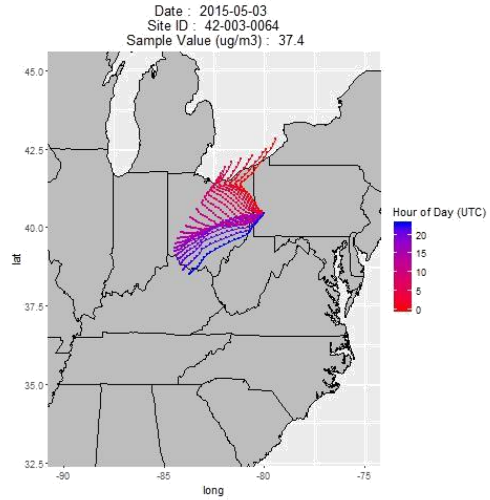
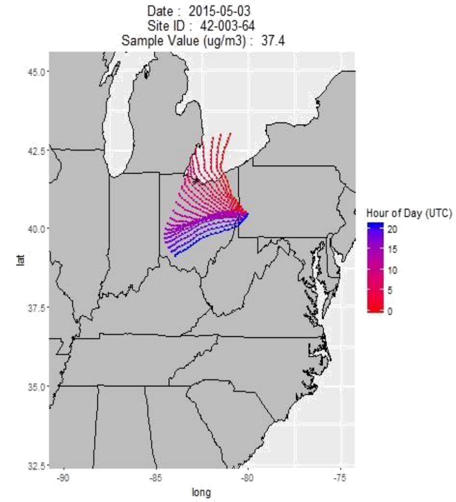
<tr><td>05-03-2015</td><td>
</td><td>
</td><td>
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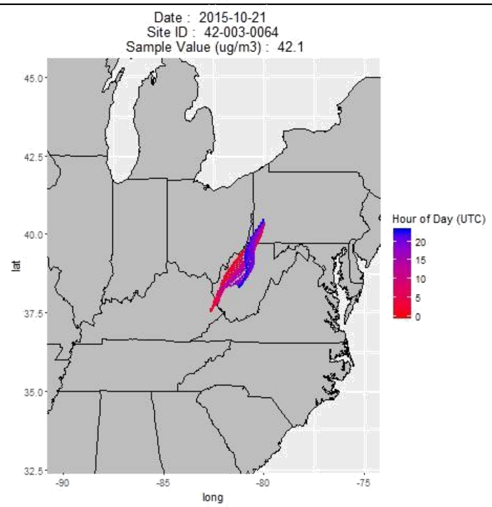
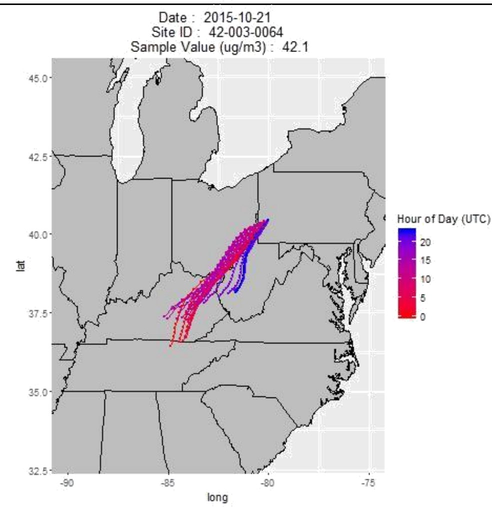
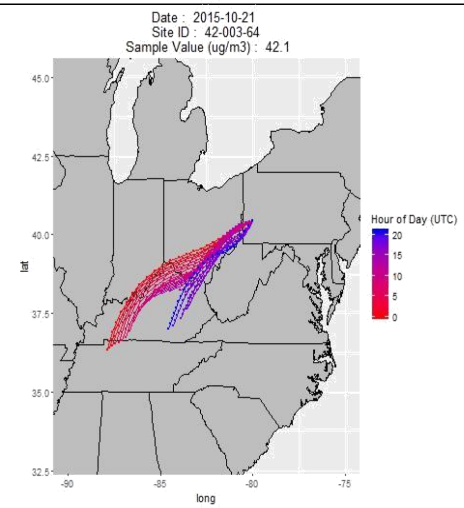
<tr><td>10-21-2015</td><td>
</td><td>
</td><td>
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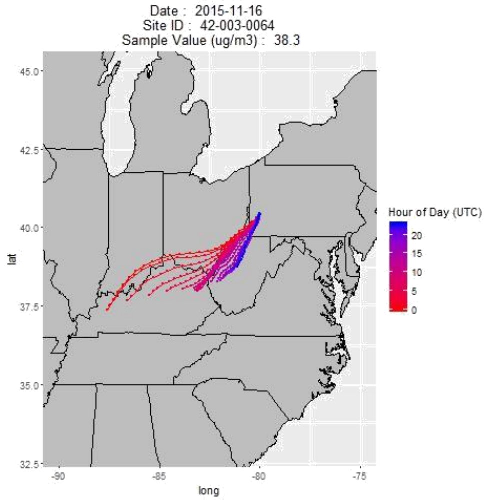
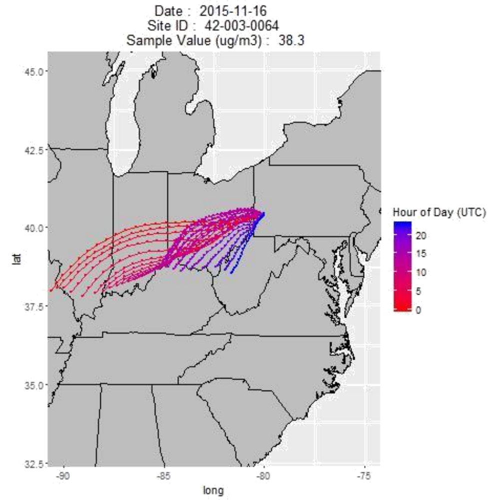
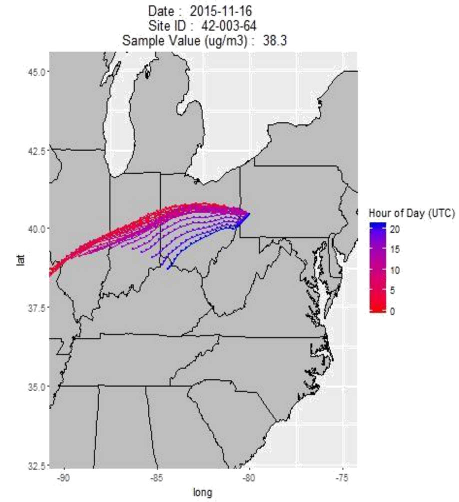
<tr><td>11-16-2015</td><td>
</td><td>
</td><td>
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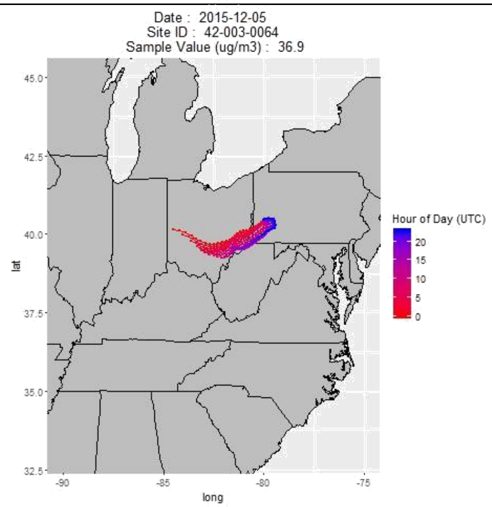
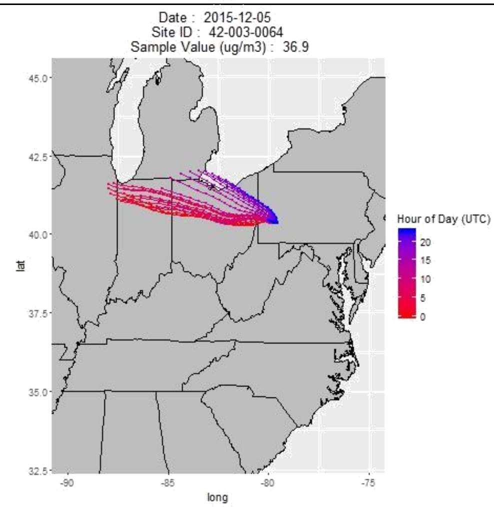
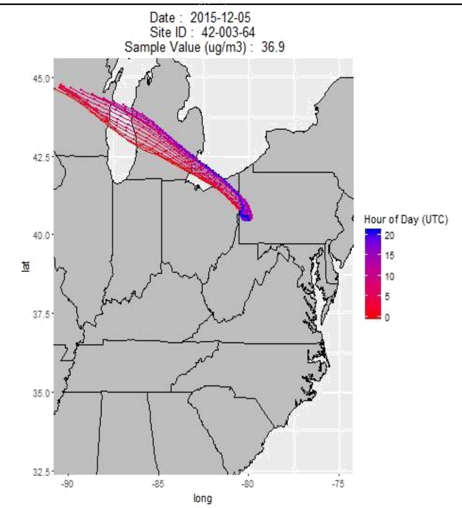
<tr><td>12-05-2015</td><td>
</td><td>
</td><td>
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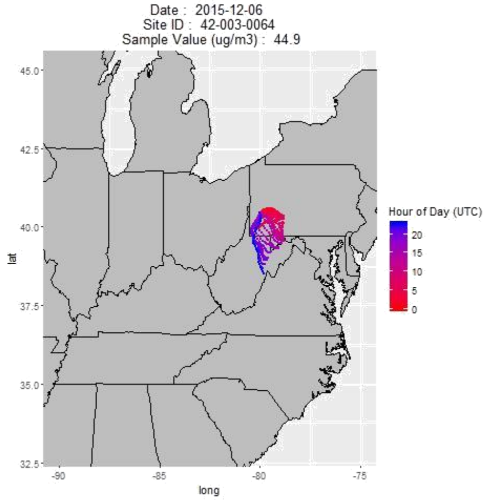
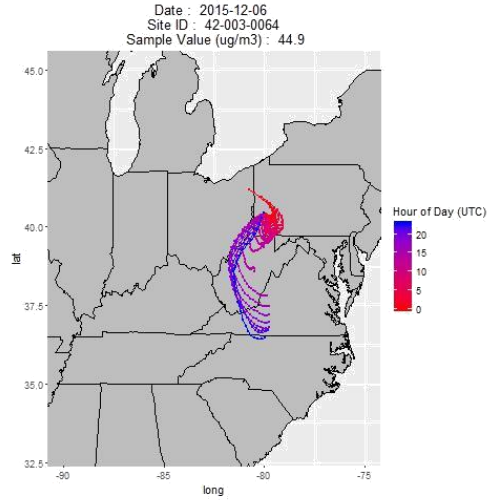
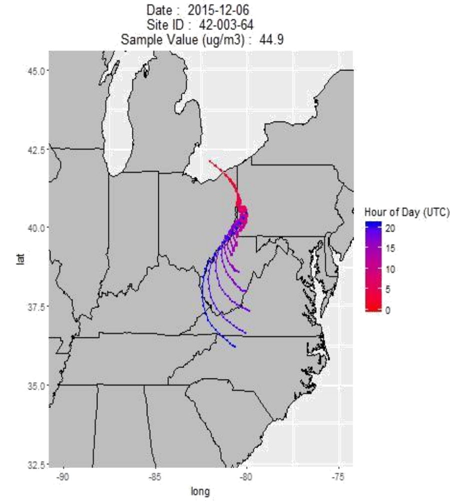
12-06-2015			
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