Letter Report

MILDOS4 AIR DISPERSION BENCHMARK STUDY

Prepared by

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Submitted to

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Letter Report for NRC Task Order NRC-HQ-60-15-T-0022

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1. INTRODUCTION

Argonne National Laboratory (Argonne) was tasked with benchmarking the performance of the air dispersion model in MILDOS 4.x (MILDOS4) (Biwer et al. 2019) against the U.S. Environmental Protection Agency's (EPA's) regulatory model AERMOD (EPA 2004). MILDOS4 employs a standard chronic release Gaussian plume model that was originally developed for use at locations on flat terrain. Because many uranium in situ recovery (ISR) facilities are located in more complex terrain, the purpose was to determine how well MILDOS4 performs at complex terrain sites relative to AERMOD which includes a complex terrain model.

AERMOD was officially adopted as the preferred dispersion model for many regulatory applications in the *Federal Register* on November 9, 2005 (70 FR 68218). By that time, air dispersion studies at a number of sites had been used in validating the code (Paine et al. 1998, EPA 2003). Studies at six of these sites with at least one year of monitoring data were used as the basis for comparison between AERMOD and MILDOS4. Thus, the results from MILDOS4 are compared with both the original field data and the AERMOD results. Table 1 lists the sites and the number of sources and receptors associated with each one. Because these studies all involve tall stack releases, they do not directly reflect the release conditions most often associated with ISR facilities. However, they are the only ones with longer monitoring times available to better assess chronic releases.

AERMOD has evolved since its initial development in 1991 and adoption as the EPA's preferred regulatory air quality dispersion model in 2005. AERMOD results from some of the original studies used in development and validation are reported here with the results obtained using the latest versions of AERMOD (version 18081) and MILDOS4.

2. METEOROLOGICAL DATA PREPARATION

The six datasets identified for comparison of calculated gaseous downwind air concentrations between AERMOD and MILDOS4 are listed in Table 2. As such, these data will also provide an indication of how well the MILDOS4 model performs compared to real world data in addition to the benchmark against AERMOD. These data and supporting documentation can be found on the EPA website (EPA 2020).

The major difference between the two models are that AERMOD is a short-term model, while MILDOS4 is a long-term model. AERMOD runs on an hourly basis with hourly emission rates and hourly meteorological conditions but hourly averages can be aggregated to arrive at annual averages. In contrast, MILDOS4 runs on an annual basis with fixed emission rates and STability ARray (STAR) meteorological data for a year, which represent the joint frequency distribution of three parameters: wind direction, wind speed, and stability class.

The six studies listed in Table 2 were all point stack releases of SO_2 gas and contain at least one year of monitoring data. At the time of each study, all but the Westvaco location (pulp and paper mill), were coal-fired power plants. As indicated in Tables 1 and 2, three of the locations are located in complex terrain (Lovett, Martins Creek, and Westvaco), one in intermediate terrain (Clifty Creek), and two in flat terrain (Baldwin and Bowline).

2.1 AERMOD

The AERMOD modeling system is composed of three components:

- AERMET – the meteorological data preprocessor
- AERMAP – the terrain data preprocessor
- AERMOD – the air dispersion model

AERMET and AERMAP provide input for the AERMOD calculations. AERMET is a meteorological data preprocessor that incorporates air dispersion based on planetary boundary layer turbulence structure and scaling concepts; AERMAP is a terrain data preprocessor that incorporates complex terrain using USGS Digital Elevation Data; and AERMOD incorporates air dispersion based on planetary boundary layer turbulence structure and scaling concepts, including treatment of both surface and elevated sources, and both simple and complex terrain (EPA 2020).

2.2 MILDOS4

MILDOS4 incorporates a standard chronic Gaussian plume model with a simple terrain elevation model (Biwer et al. 2019). In this study, STAR meteorological data files were generated using the meteorological preprocessor in MILDOS4 using the AERMET data files as input. Receptor and source locations and elevations used as input to MILDOS4 are provided in Appendix A.

Table 1. Study Sites

Site	Terrain	Sources	Number of Receptors	Receptor – Source Distances	Receptor to Source Elev. Difference(s)
Baldwin	Flat	3 colocated	10	1.3 to 9.9 km	-188 to -168 m
Bowline	Flat	2 colocated, about 90 m apart	4	211 to 883 m	-87 m
Clifty Creek	Flat/ Elevated	3 colocated	6	3.1 to 15.0 km	-205 to -74 m
Lovett	Complex	1 source	9	2.1 to 3.6 km	5 to 176 m
Martins Creek	Complex	8 scattered sources, some in pairs or near triples	8	3.0 to 17.2 km	-12 to 214 m
Westvaco	Complex	1 source	11	743 m to 3.4 km	-160 to 195 m

Table 2. Summary of AERMOD Datasets Used in Benchmark Comparison[a]

Location	Stack heights	Urban /rural	Terrain	Downwash	Site specific AERMET inputs	Duration of Met Data	Period of Met Data	Met Data Info in *.SFC Files[b]
Baldwin (IL)	3 stacks 184.4 m	Rural	Flat	Yes	10 and 100 m wind, temperature	1 year	4/1/82 - 3/31/83	38.20N / 89.86W 03879 / 13802 / 00001 8759 (10m) / 1 (100m)
Bowline (NY)	2 stacks 86.87 m	Rural	Flat	Yes	100 m wind and temperature	1 year	1/1/81 - 12/31/81	41.2N / 73.97W 14735 / 14734 / 99999 8760 (100m)
Clifty Creek (IN)	3 stacks 207.9 m	Rural	Flat/Elev	No	10 m temperature; 60 m wind	1 year	1/1/75 - 12/31/75	38.71N / 85.42W 13840 / 93814 / 000001 8760 (60m)
Lovett (NY)	145 m	Rural	Complex	No	10, 50, and 100 m wind, temperature	1 year	1/1/88 - 12/31/88	41.3N / 74.0W 14735 / 14735 / LOVETT 3155 (10m) / 5598 (50m) / 31 (100m)
Martins Creek (PA/NJ)	59, 76, 183 m	Rural	Complex	Yes	10 m wind, temperature; 90-420 m wind (every 30 m).	1+ year	5/1/92 - 5/19/93	40.79N / 75.14W 14735 / 14737 / 00001 7483 (10m) / 1277 (90m)
Westvaco (MD/VA)	190 m	Rural	Complex	No	30, 210, 326, 366, and 416 m wind, temperature	1 year	12/1/80 - 11/30/81	39.47N / 79.05W 94823 / 94823 / 00001 8760 (30m)

[a] Based on Table 1 in Appendix B of EPA (2018)

[b] The first line: latitude / longitude; the second line: upper air data station identifier / surface data station identifier / site-specific identifier; the third or fourth line: number of data (measurement height).

3. CALCULATIONS AND RESULTS

Two sets of three MILDOS4 calculations were performed for each of the six locations. All releases were from stacks with defined thermal and exit velocity characteristics. The two plume rise options, momentum-driven and buoyant, were each evaluated using the three different dispersion coefficient options – Pasquill-Gifford (PG), Briggs rural (open terrain), or Briggs urban, respectively. Note that, in general, the more turbulent nature of urban areas due to greater surface roughness and the heat absorption capacity of roads, buildings, and other structures means lower concentrations from ground-level releases in urban areas than in rural areas. However, for elevated releases, the plume hits the ground closer to the source, leading to higher ground-level concentrations in urban areas than in rural areas. As shown in Table 2, all sites are mostly in rural environments, but urban dispersion could affect the plume around the facility to some extent as discussed just above, so results for Briggs urban should be interpreted in that context.

With respect to plume rise, temperatures on the order of 5 to 20°C warmer than ambient air (greater temperature differences for smaller diameter stacks) tend to result in buoyant plume rise greater than that due to momentum (Turner and Schulze 2007). Buoyancy flux is proportional to the heat release rate, which can be represented as being proportional to stack exit velocity, temperature difference, and stack diameter squared. For smaller diameter (less than 0.5 meter) stacks, larger temperature differences may be needed to make buoyancy dominant. Conversely, buoyancy-dominated rise occurs with only small temperature differentials from large diameter (greater than 3 meters) stacks. In the cases investigated, the temperature differences in the database are around 100°C (~150°C for Clifty Creek) along with stack diameters of 3 meters or larger except three stacks (two 1.87- and one 2.7-meter stacks) for Martins Creek (see Table A.2). Thus, general overprediction of MILDOS4 over observations and AERMOD predictions might result from using momentum rise, rather than buoyant rise.

For each location considered, the source and receptor locations are shown on a map that includes elevation contours for general reference. Also provided is a graphical representation of the annual meteorological data. Air concentrations at each receptor location calculated with each set of dispersion coefficients are plotted on a graph against the actual measured concentrations and the results using the latest version of AERMOD. For reference, calculated values below the upper dotted line or above the lower dotted line fall within a factor of 2 of the measured values. In practice, calculated-to-measured ratios within a factor of two are considered very good performance in air dispersion modeling. Calculated air concentrations and value comparisons are provided in Appendix B.

3.1 Baldwin Site

The Baldwin Power Plant was located in relatively flat terrain in southwestern Illinois with three 184 m stacks having a horizontal spacing of about 60 m between the central and each of the two-outlying stacks in a roughly north-south alignment (EPA 2003). A map of the local area is provided in Figure 1. Receptors are located at distances from 1.3 to 9.9 km from the source stacks. Meteorological data was collected on-site (EPA 2003). Figure 2 summarizes the meteorological data for the site.

Figures 3 through 5 present the graphs of the calculated results using the three sets of dispersion coefficients, PG, Briggs rural, or Briggs urban, respectively, plotted against the average measured values (EPA 2020). Each figure has separate plots for the (a) momentum-driven and (b) buoyant plume rise options. Data points would be along the solid black line in each case if the calculated value matched the measured value.

It can be seen in the graphs and Table B.1 that MILDOS4 overestimates the SO_2 gas concentrations at all receptor locations for a buoyant plume and using the Briggs urban coefficients for a momentum driven plume whereas the AERMOD estimates either match or underestimate the measured values. Using the momentum-driven plume in MILDOS4 results are closer to the observed values in general for the PG and Briggs rural coefficients. It is clear from these results, that the Briggs urban coefficients are not appropriate for this site because of the higher overestimates and lack of any potential heat island effects.

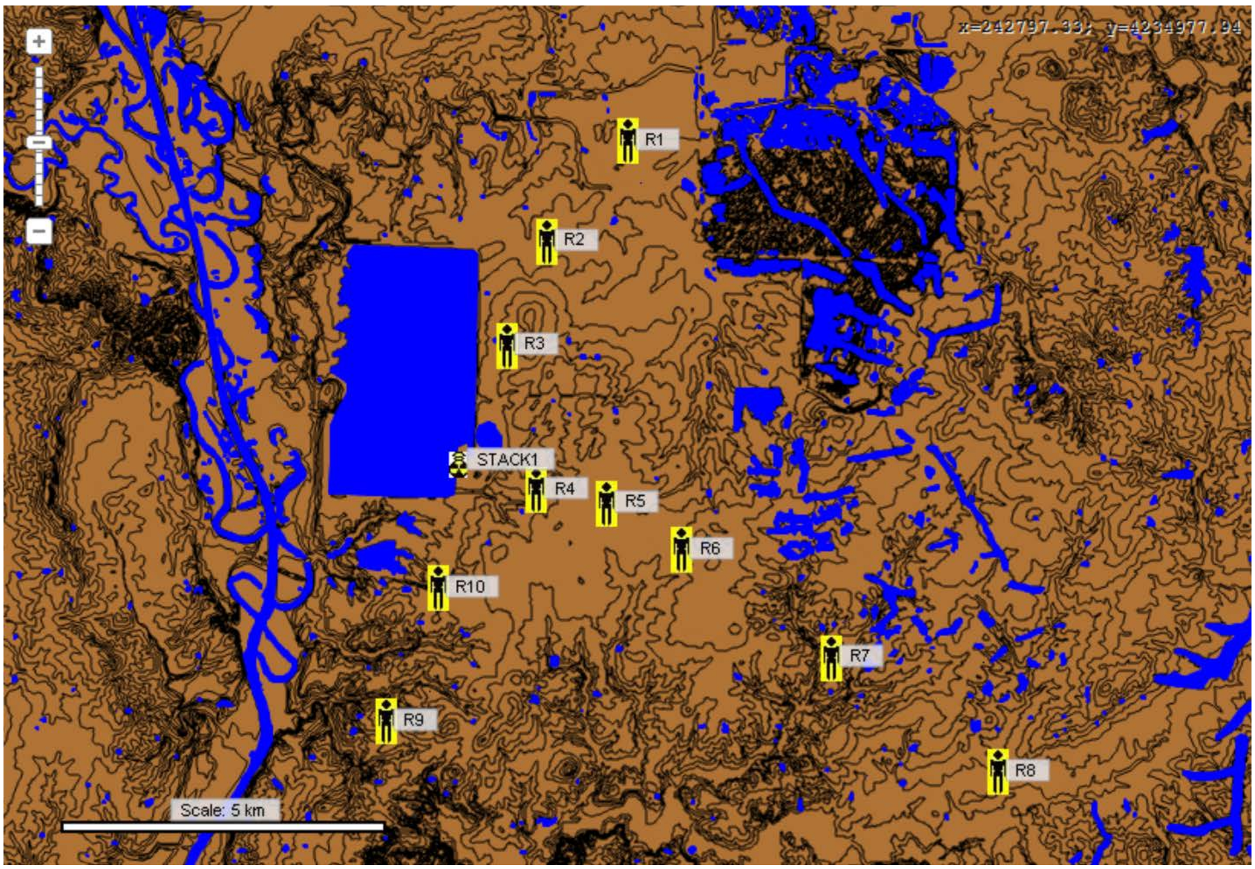


Figure 1. Local Map of the Baldwin Power Plant Location along with Emission Sources and Receptors

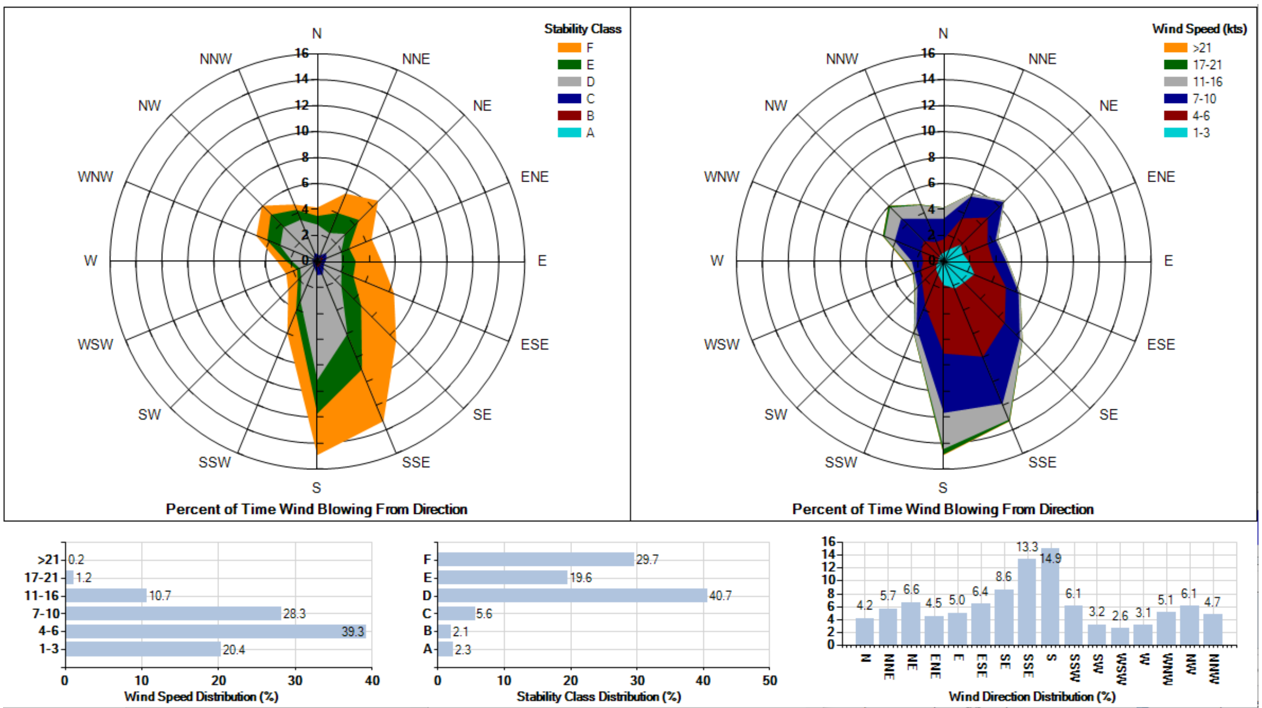
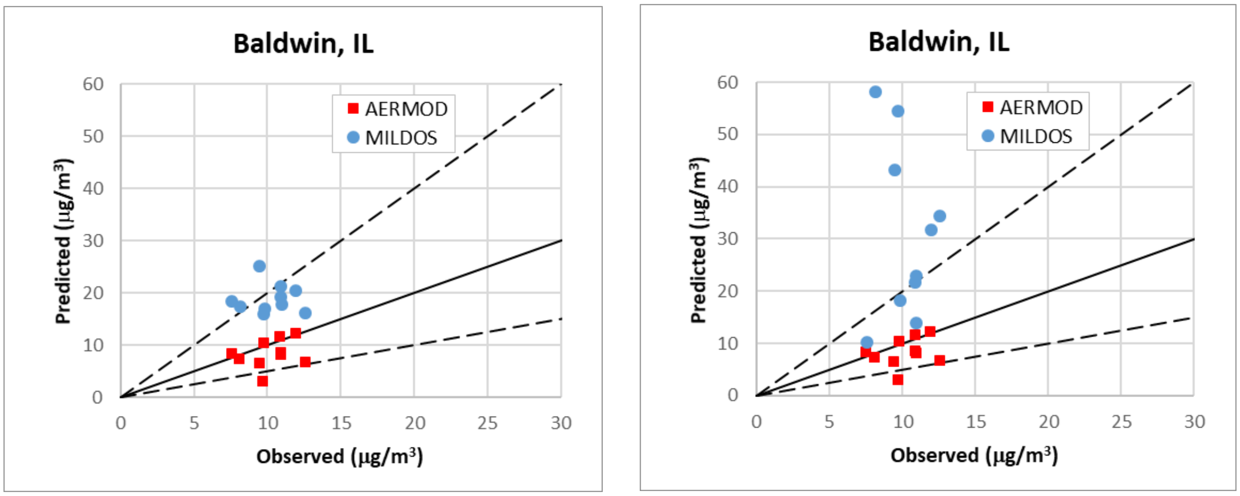


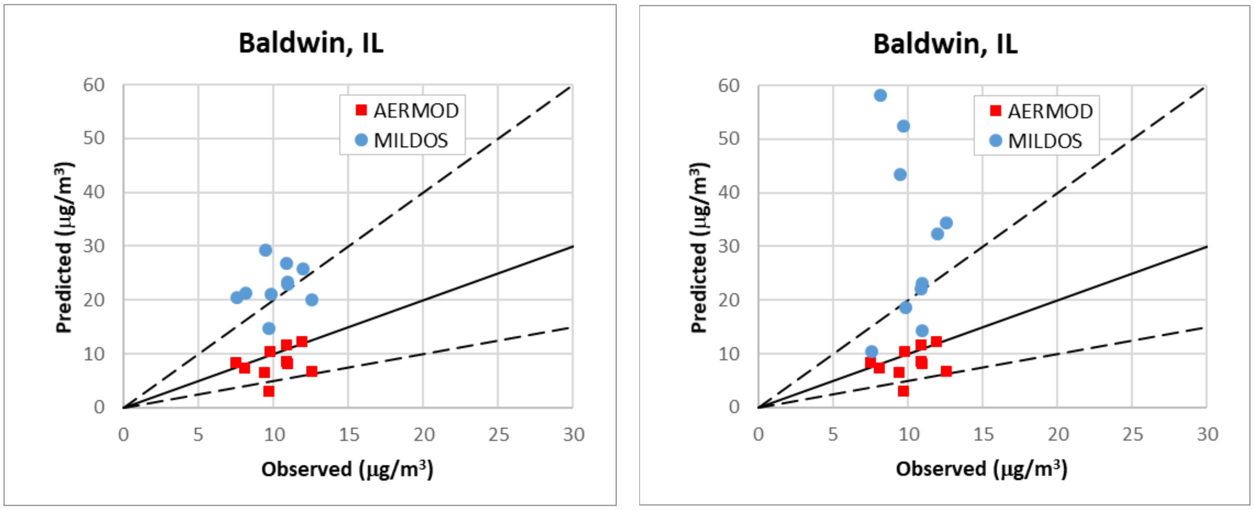
Figure 2. Meteorlogical Data Summary for the Baldwin Site



(a) Momentum plume rise

(b) Buoyant plume rise

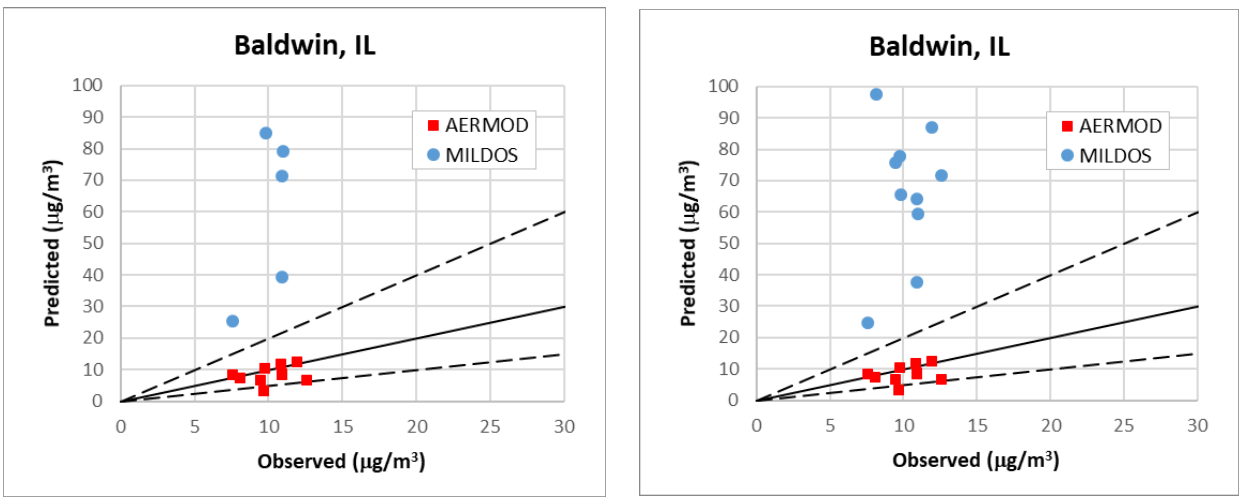
Figure 3. MILDOS – PG Coefficients



(a) Momentum plume rise

(b) Buoyant plume rise

Figure 4. MILDOS – Briggs Rural Coefficients



(a) Momentum plume rise
(receptors R2 – R5 and R10 are off-scale)

(b) Buoyant plume rise

Figure 5. MILDOS – Briggs Urban Coefficients

3.2 Bowline Site

The Bowline Point power plant stacks are located along the Hudson River valley in New York state. The two stacks are 86.9 m in height (EPA 2003), with a separation of about 90 m. Each stack is flanked by a facility roof at a height of 65.2 m. A map of the local area is provided in Figure 6. Four receptors are located at distances from 211 to 883 m from the source stacks at approximately the same elevation as the base of the stacks, with hills to the west and south.

Meteorological data was collected on-site (EPA 2003). Figure 7 summarizes the meteorological data for the site.

Figures 8 through 10 present the graphs of the calculated results using the three sets of dispersion coefficients, PG, Briggs rural, or Briggs urban, respectively, plotted against the average measured values (EPA 2020). Each figure has separate plots for the (a) momentum-driven and (b) buoyant plume rise options. Data points would be along the solid black line in each case if the calculated value matched the measured value.

For the momentum-driven plume rise option, it can be seen that MILDOS4 generally underestimates the SO_2 gas concentrations using the PG or Briggs rural coefficients and overestimates using the Briggs urban coefficients, as explained previously. In the latter case, the primarily downwind receptors R1 and R3 are highly overestimated. A similar trend is seen using the buoyant plume option, except in the case of the Briggs urban coefficients where the results are closer to the observed values.

AERMOD does a reasonable job of estimating air concentrations except in the case of receptor R4, which is near the hillside with the facility buildings between its location and the stacks.

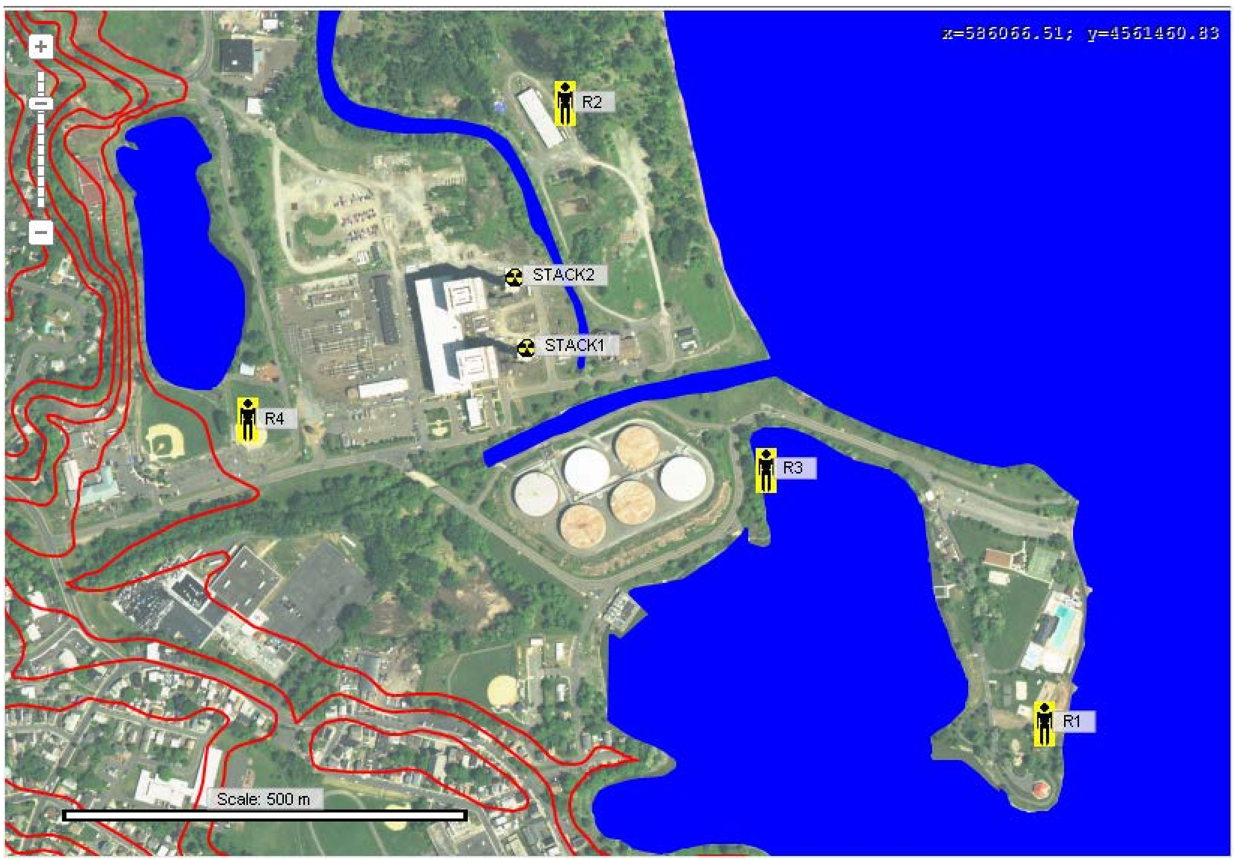


Figure 6. Local Map of the Bowline Point Location along with Emission Sources and Receptors (elevation isocontours in red)

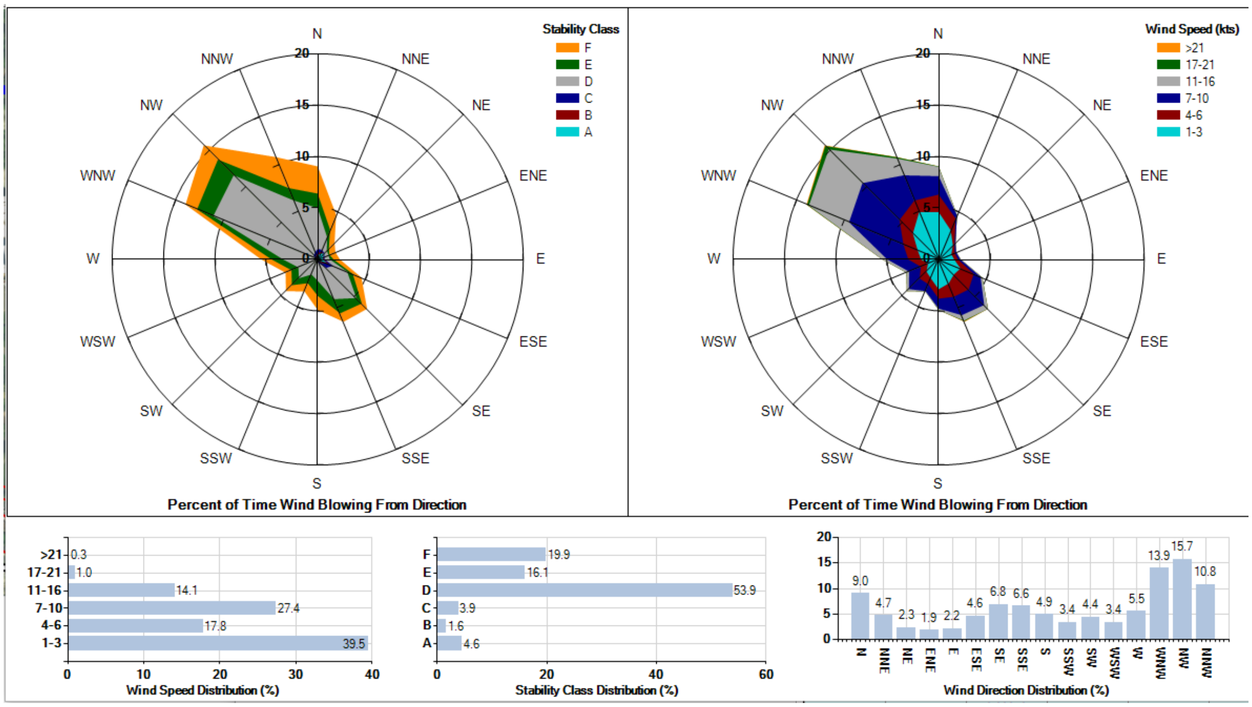
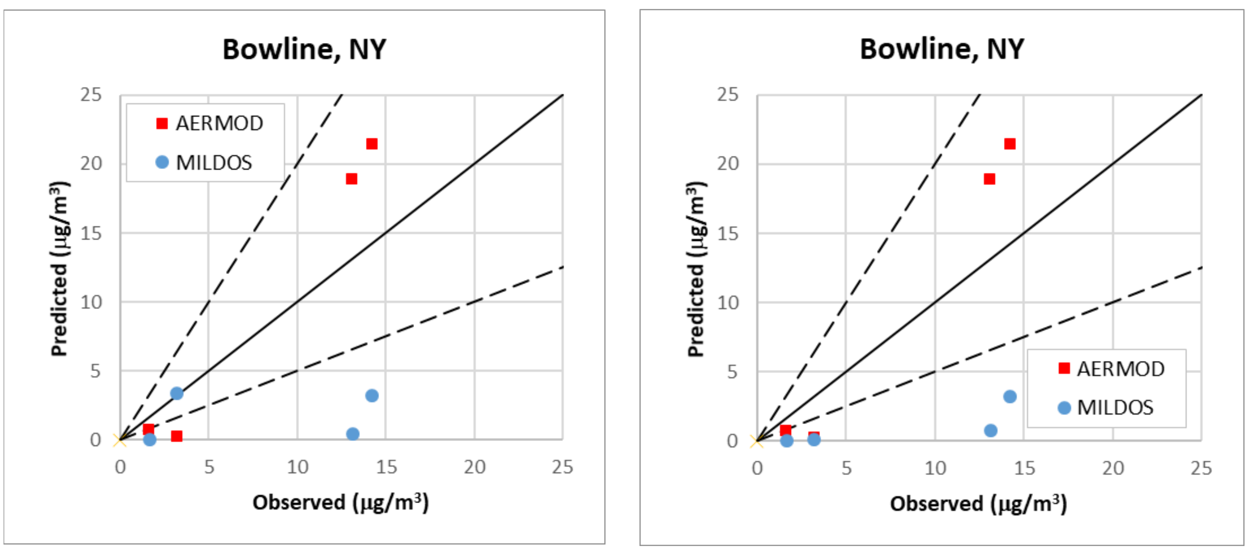


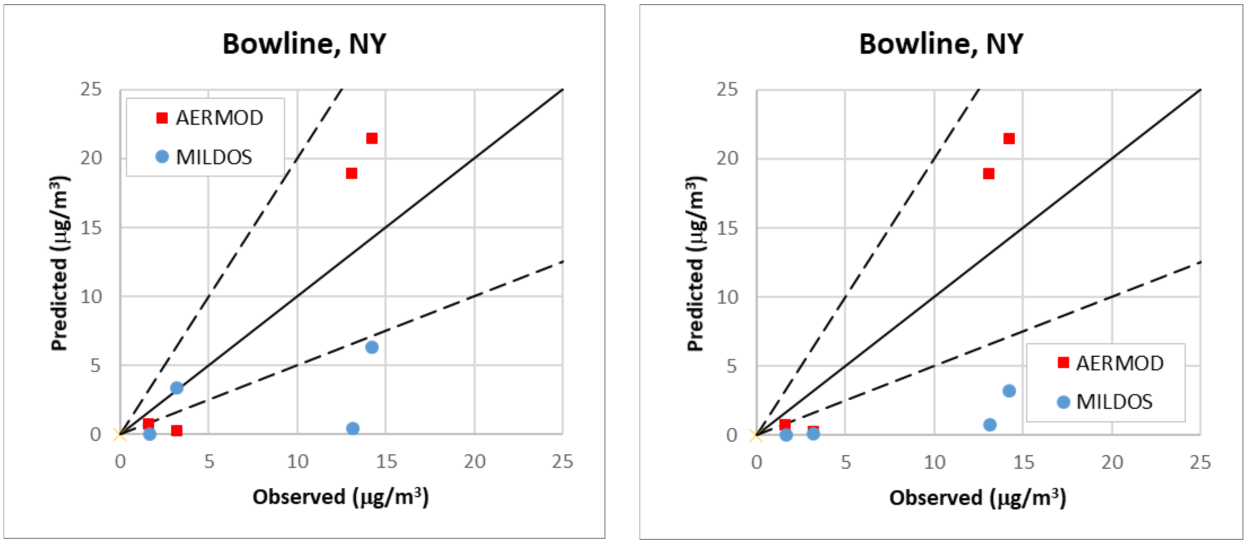
Figure 7. Meteorlogical Data Summary for the Bowline Site



(a) Momentum plume rise

(b) Buoyant plume rise

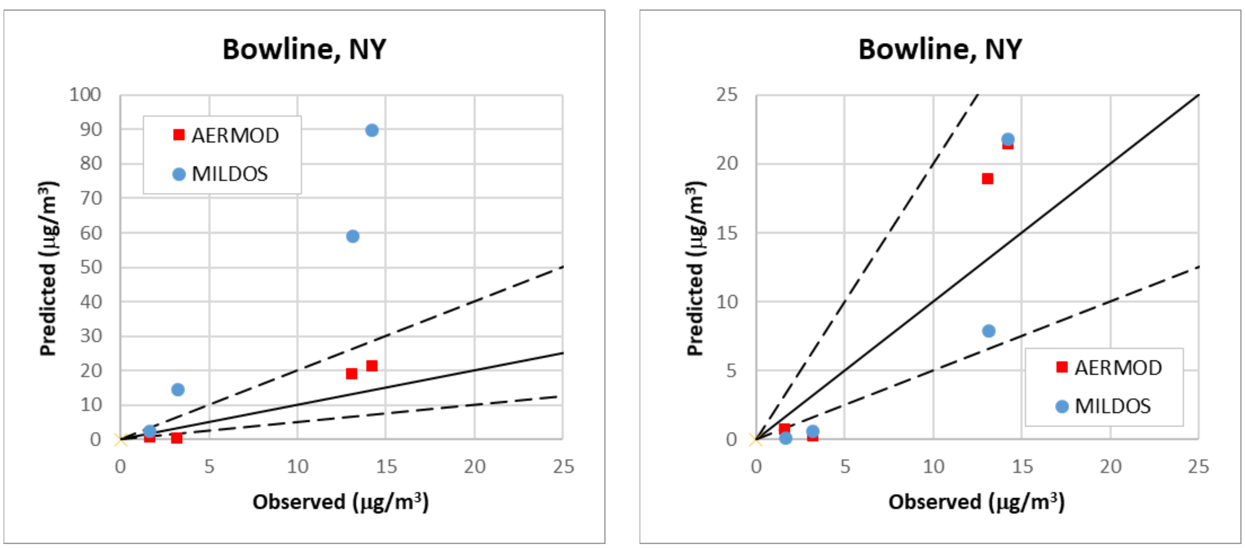
Figure 8 MILDOS – PG Coefficients



(a) Momentum plume rise

(b) Buoyant plume rise

Figure 9 MILDOS – Briggs Rural Coefficients



(a) Momentum plume rise

(b) Buoyant plume rise

Figure 10 MILDOS – Briggs Urban Coefficients

3.3 Clifty Creek Site

The Clifty Creek power plant is located on the north side of the Ohio River in southern Indiana (EPA 2003). Emissions are from three 208 m stacks. Located in a moderately hilly site, the stacks rise from the river valley and reach more than 80 m above the surrounding cliffs on either side of the river (Paine et al. 1998). A map of the local area is provided in Figure 11. Six receptors are located at distances from 3.1 to 15.0 km from the source stacks. All receptors are at elevations below the stack release heights. Meteorological data was collected approximately 3 km south of the site on the south side of the Ohio River (EPA 2003). Figure 12 summarizes the meteorological data for the site.

Figures 13 through 15 present the graphs of the calculated results using the three sets of dispersion coefficients, PG, Briggs rural, or Briggs urban, respectively, plotted against the average measured values (EPA 2020). Each figure has separate plots for the (a) momentum-driven and (b) buoyant plume rise options. Data points would be along the solid black line in each case if the calculated value matched the measured value.

For the momentum-driven plume rise results, it can be seen that MILDOS4 slightly underestimates or is in relatively good agreement with the SO_2 gas concentrations using the PG or Briggs rural coefficients and is in relatively good agreement or slightly overestimates using the Briggs urban coefficients. For the Briggs urban coefficients, the value for receptor R3 is off-scale. The buoyant plume rise results show a similar trend, with the Briggs urban option results with a slightly better fit to the observed values. The AERMOD results are more than about a factor of 2 lower (half the value of) the measured results.

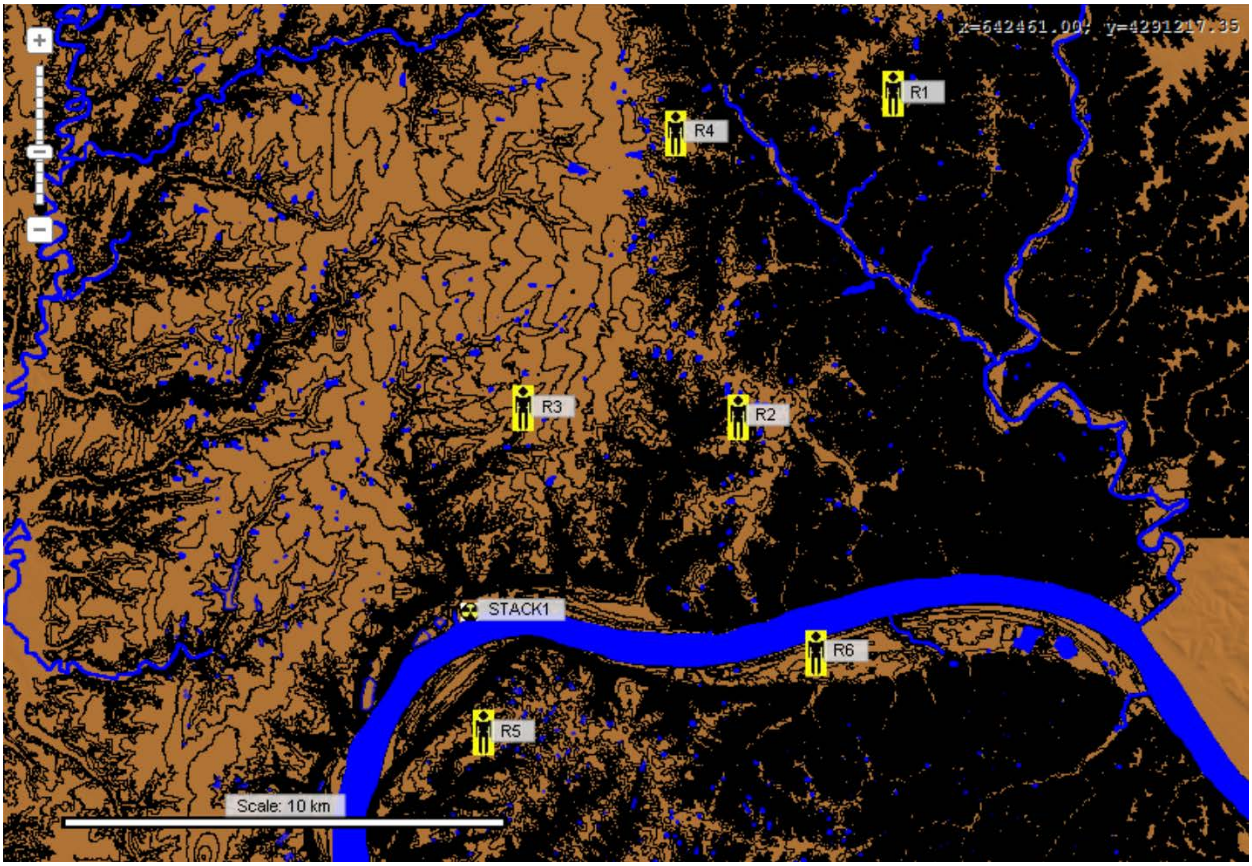


Figure 11. Local Map of the Clifty Creek Location along with Emission Sources and Receptors

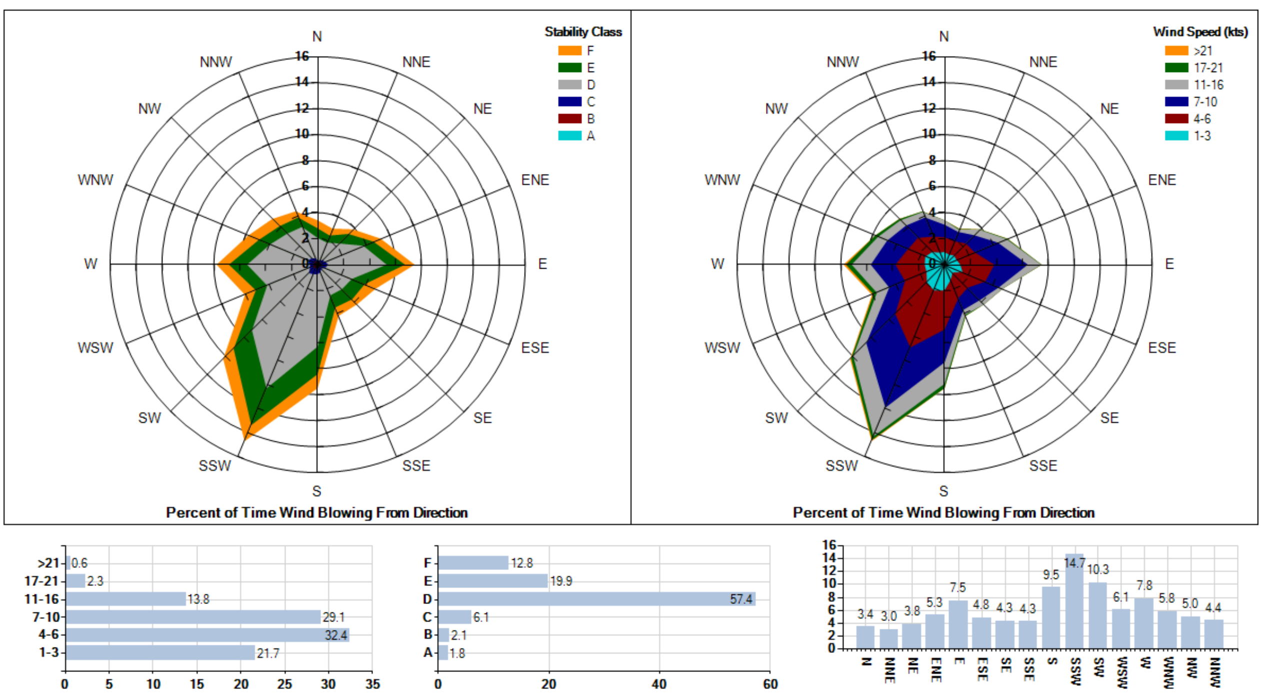
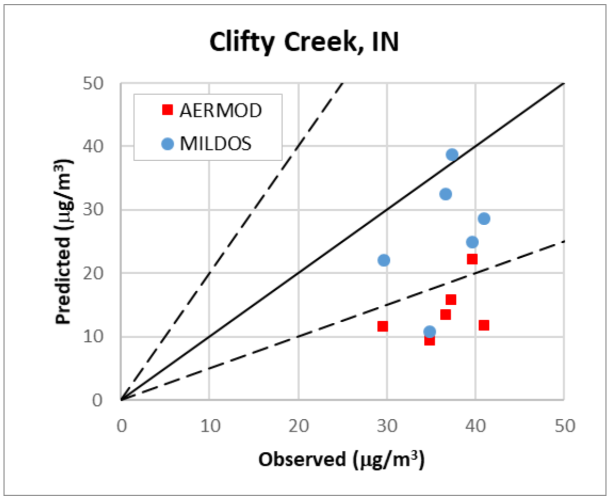
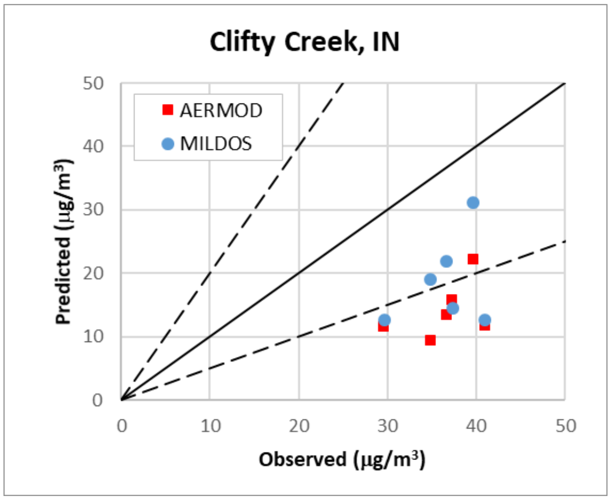


Figure 12. Meteorlogical Data Summary for the Clifty Creek Site

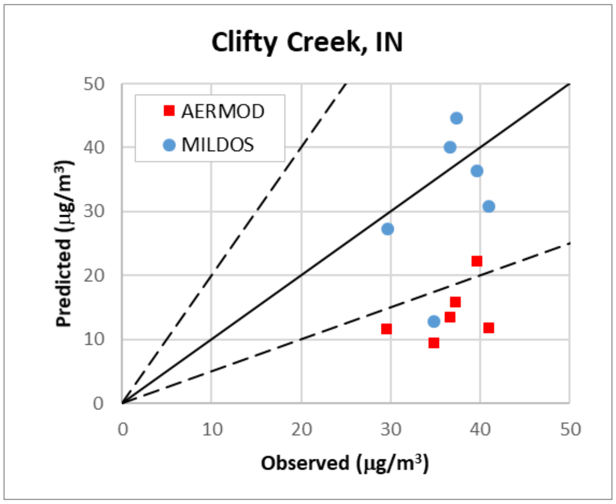


(a) Momentum plume rise

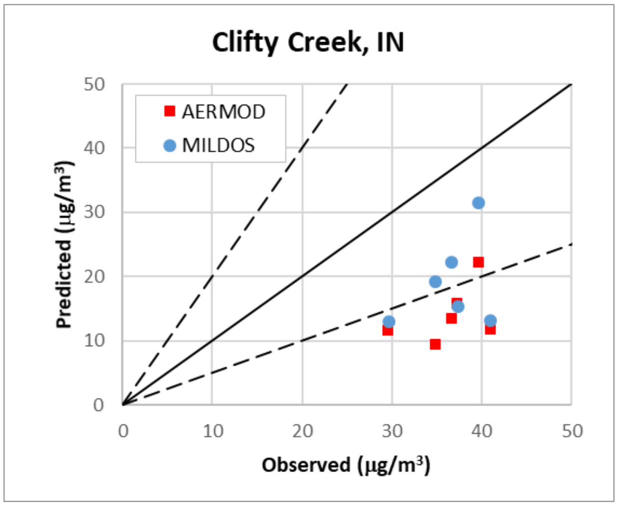


(b) Buoyant plume rise

Figure 13 MILDOS – PG Coefficients

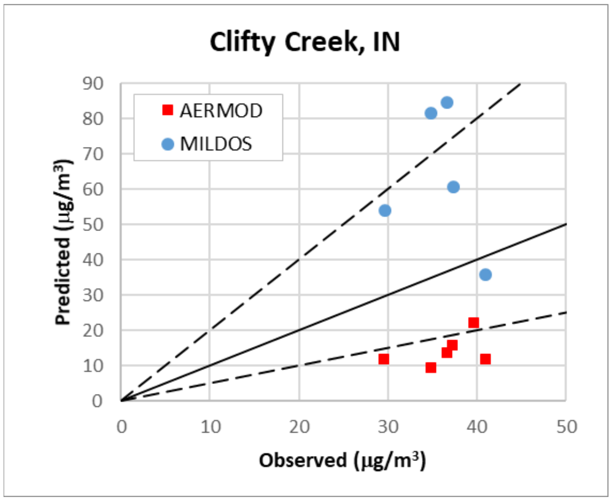


(a) Momentum plume rise

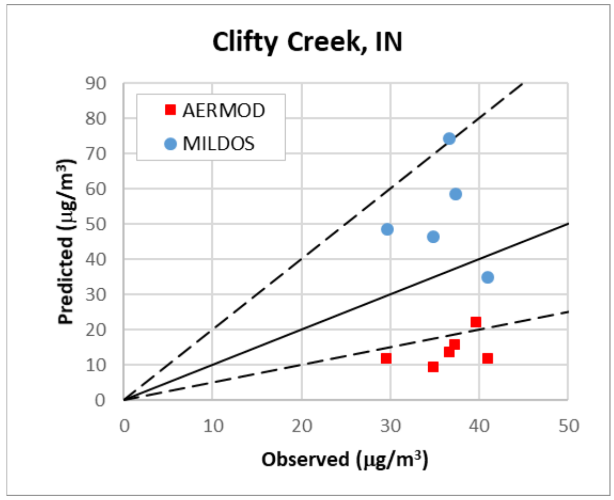


(b) Buoyant plume rise

Figure 14 MILDOS – Briggs Rural Coefficients



(a) Momentum plume rise



(b) Buoyant plume rise

Figure 15 MILDOS – Briggs Urban Coefficients

3.4 Lovett Site

The Lovett generating station was located in southeastern New York state in hilly terrain on the west bank of the Hudson River, approximately 70 km north of New York City (Paumier 1992). Emission was from a single 145 m stack. A map of the local area is provided in Figure 16. Nine receptors are located at distances from 2.1 to 3.6 km from the source stacks. All receptors are situated at elevations above the stack release height. Near surface winds and temperature for the meteorological data was collected approximately 1 km south-southwest of the site (Paumier 1992). Figure 17 summarizes the meteorological data for the site.

Figures 18 through 20 present the graphs of the calculated results using the three sets of dispersion coefficients, PG, Briggs rural, or Briggs urban, respectively, plotted against the average measured values (EPA 2020). Each figure has separate plots for the (a) momentum-driven and (b) buoyant plume rise options. Data points would be along the solid black line in each case if the calculated value matched the measured value.

For the momentum-driven plume rise option, It can be seen that MILDOS4 is generally in good agreement with the SO_2 gas concentrations using the PG or Briggs rural coefficients and slightly overestimates using the Briggs urban coefficients. For the PG and Briggs rural calculations, the concentration estimates for the TIMP3, DD4, DD6, and DD7 receptors, the highest receptor locations relative to the stack, are the highest, presumably because the elevated plume (physical stack height plus plume rise) hits the higher-ground receptors. For the buoyant plume rise option, use of the PG and Briggs rural coefficients also provides relatively good agreement with the observed values. Use of the Briggs urban coefficients slightly overestimates the observed values. The AERMOD results are about the same or underestimate the measured results.

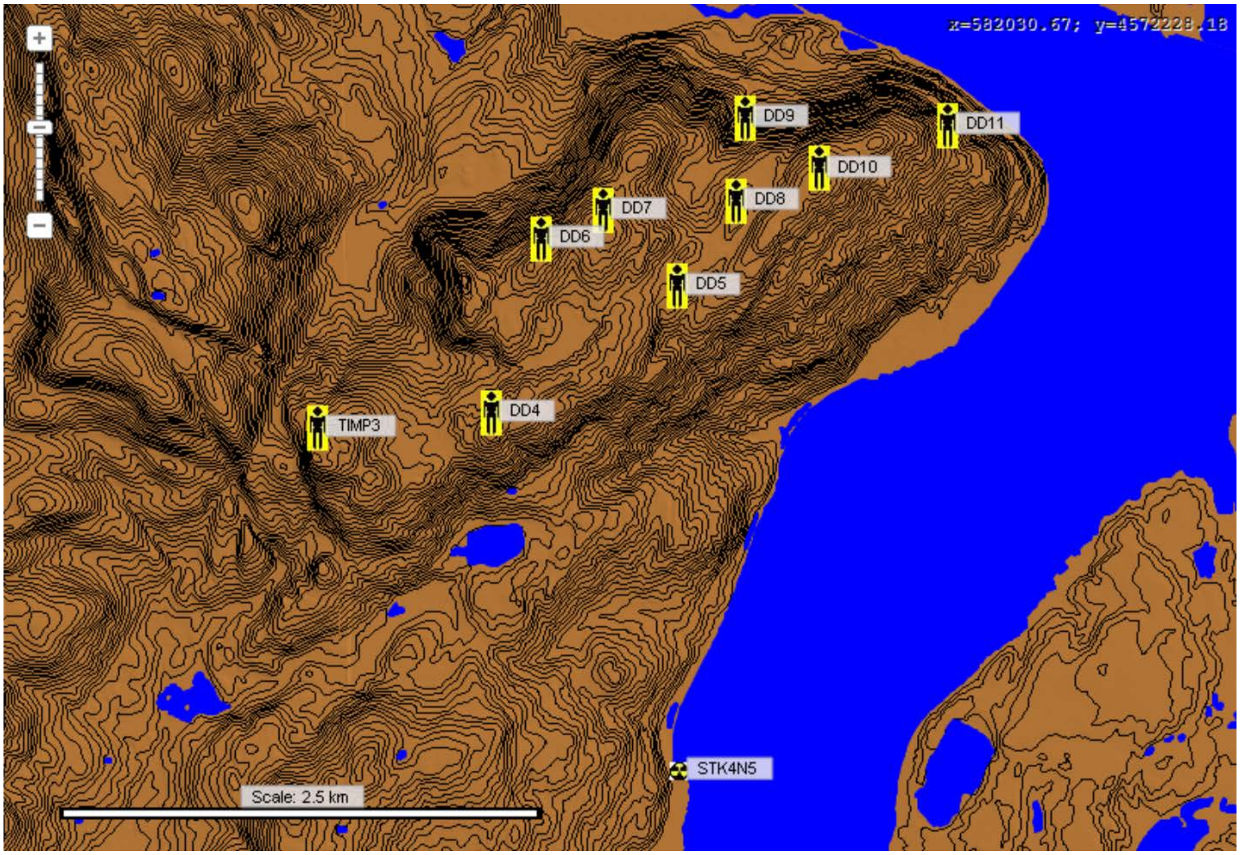


Figure 16. Local Map of the Lovett Location along with the Emission Source and Receptors

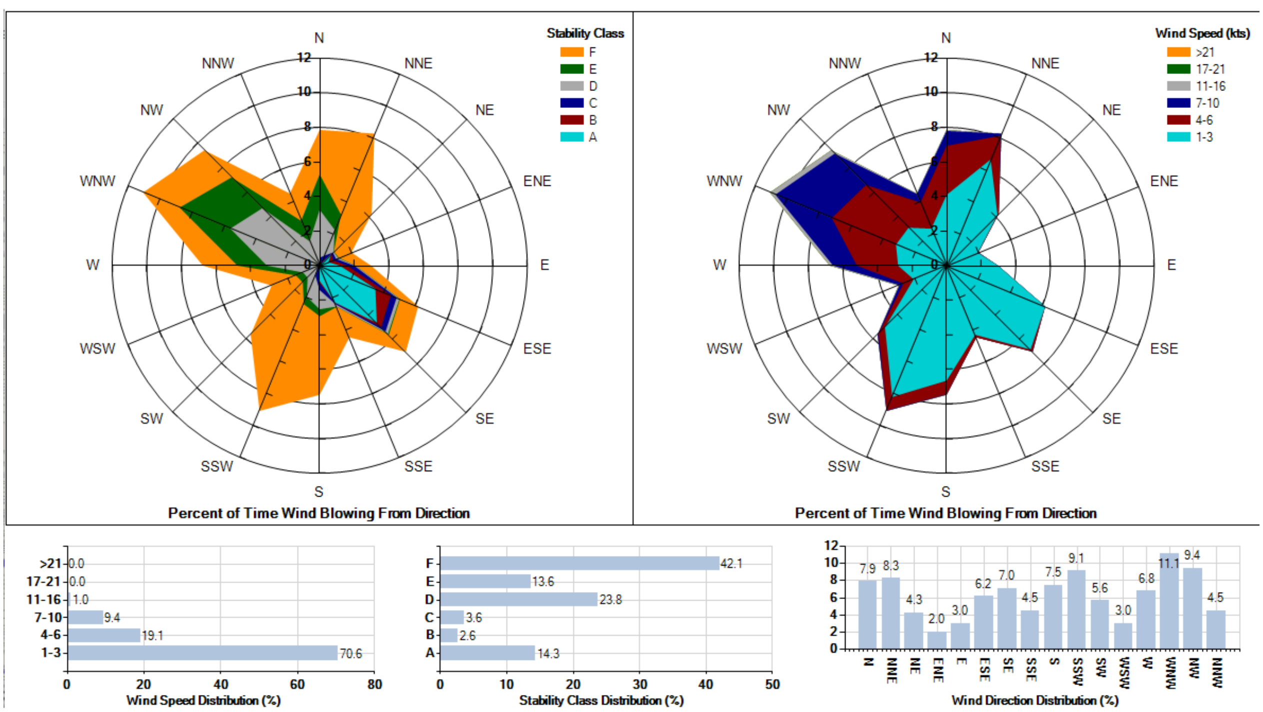
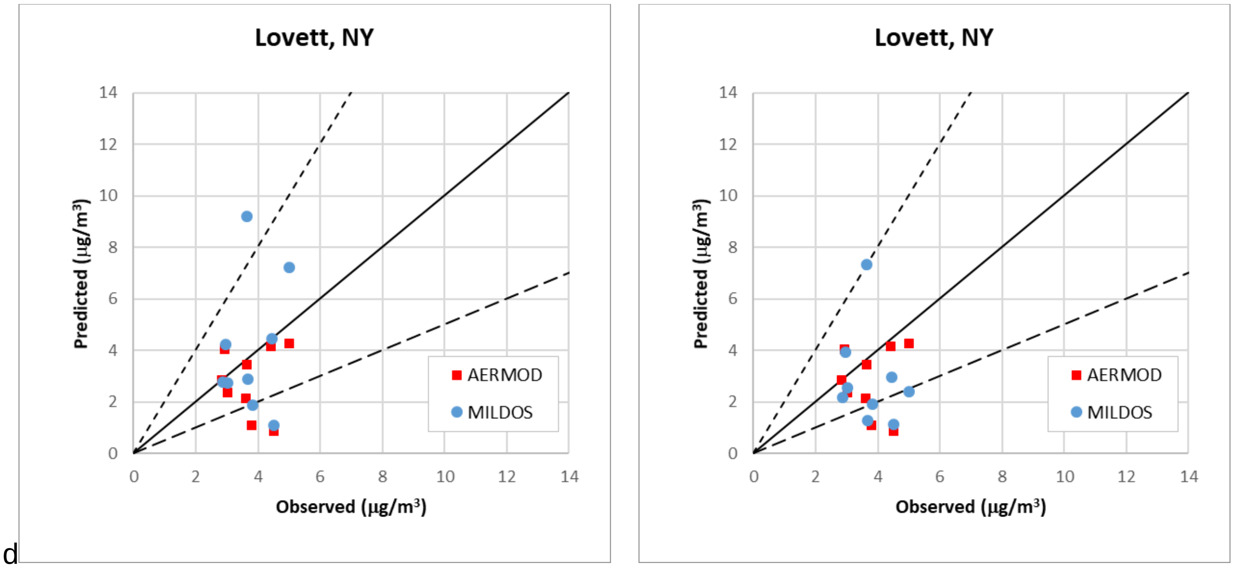


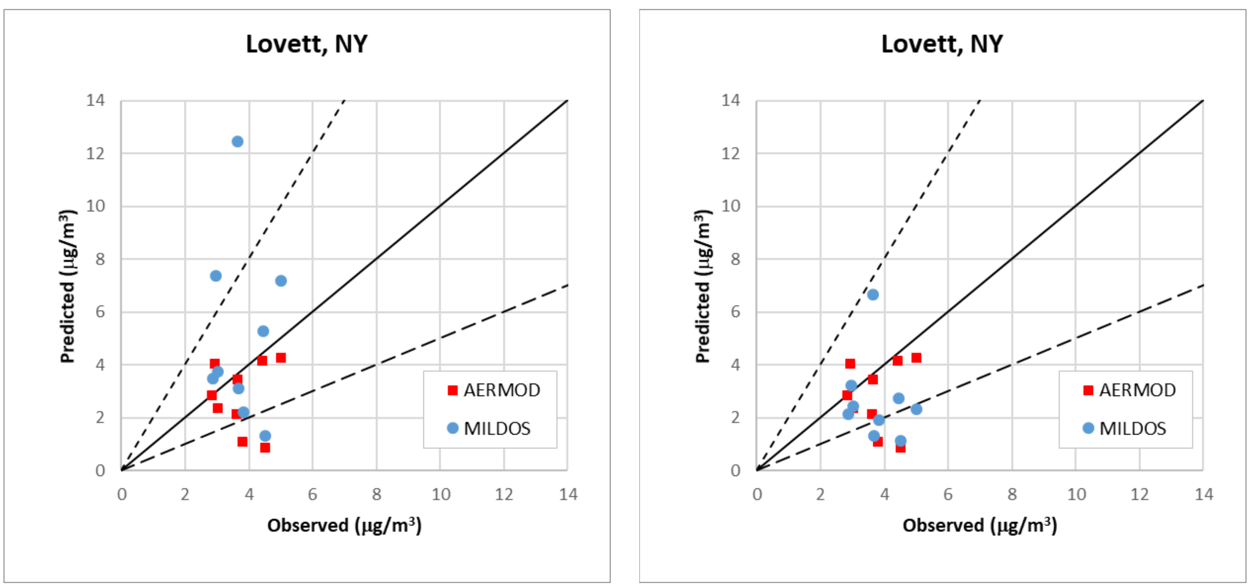
Figure 17. Meteorlogical Data Summary for the Lovett Site



d

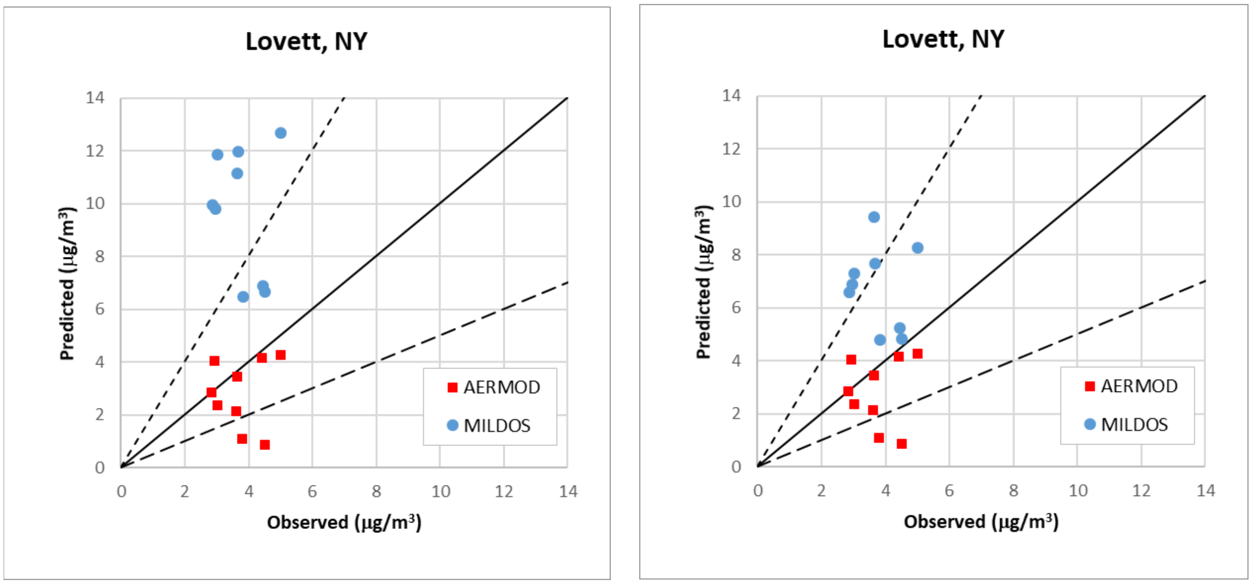
(a) Momentum plume rise (b) Buoyant plume rise

Figure 18 MILDOS – PG Coefficients



(a) Momentum plume rise (b) Buoyant plume rise

Figure 19 MILDOS – Briggs Rural Coefficients



(a) Momentum plume rise (b) Buoyant plume rise

Figure 20 MILDOS – Briggs Urban Coefficients

3.5 Martins Creek Site

The Martins Creek site is located in hilly terrain on the Pennsylvania side of the Pennsylvania – New Jersey border marked by the Delaware River (EPA 2016). Emissions were from a number of sources in the area – the Martins Creek power plant (3 – 183 m stacks), the Portland generating station (2 – 122 m stacks), Hoffman-LaRoche (a single 59 m stack), and Warren County Resource Recovery Facility (2 – 76 m stacks) (EPA 2016). A map of the local area is provided in Figure 21. Eight receptors are located at distances from 3.0 to 17.2 km from the eight source stacks. All but one of the receptors (R3) are situated at elevations above the stack release heights. Meteorological data was collected at a meteorological tower located 2.5 km to the west-southwest of the Martins Creek power plant (Paine 1998). Figure 22 summarizes the meteorological data for the site.

Figures 23 through 25 present the graphs of the calculated results using the three sets of dispersion coefficients, PG, Briggs rural, or Briggs urban, respectively, plotted against the average measured values (EPA 2020). Each figure has separate plots for the (a) momentum-driven and (b) buoyant plume rise options. Data points would be along the solid black line in each case if the calculated value matched the measured value.

As seen in Figures 23 to 25, MILDOS4 provided estimates of the SO_2 gas concentrations within a factor of two using all three sets of dispersion coefficients. In the buoyant plume case, good agreement was also seen for the Briggs urban coefficients, but the PG and Briggs rural coefficients resulted in underestimates related to the observed values. The AERMOD results tended to underestimate the measured results.

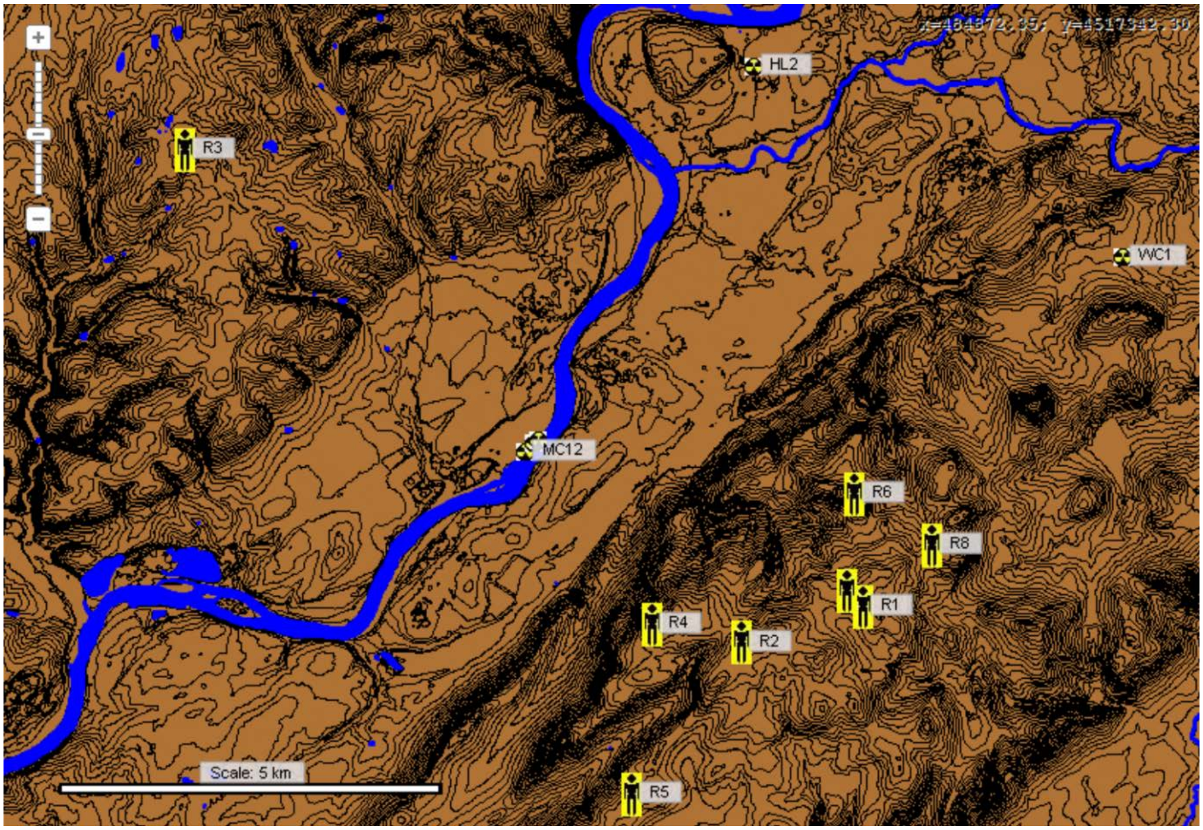


Figure 21. Local Map of the Martins Creek Location along with Emission Sources (MCxx-Martins Creek power plant, HL2-Hoffman-LaRoche, WCx-Warren, EDx-Portland off map to the north) and Receptors

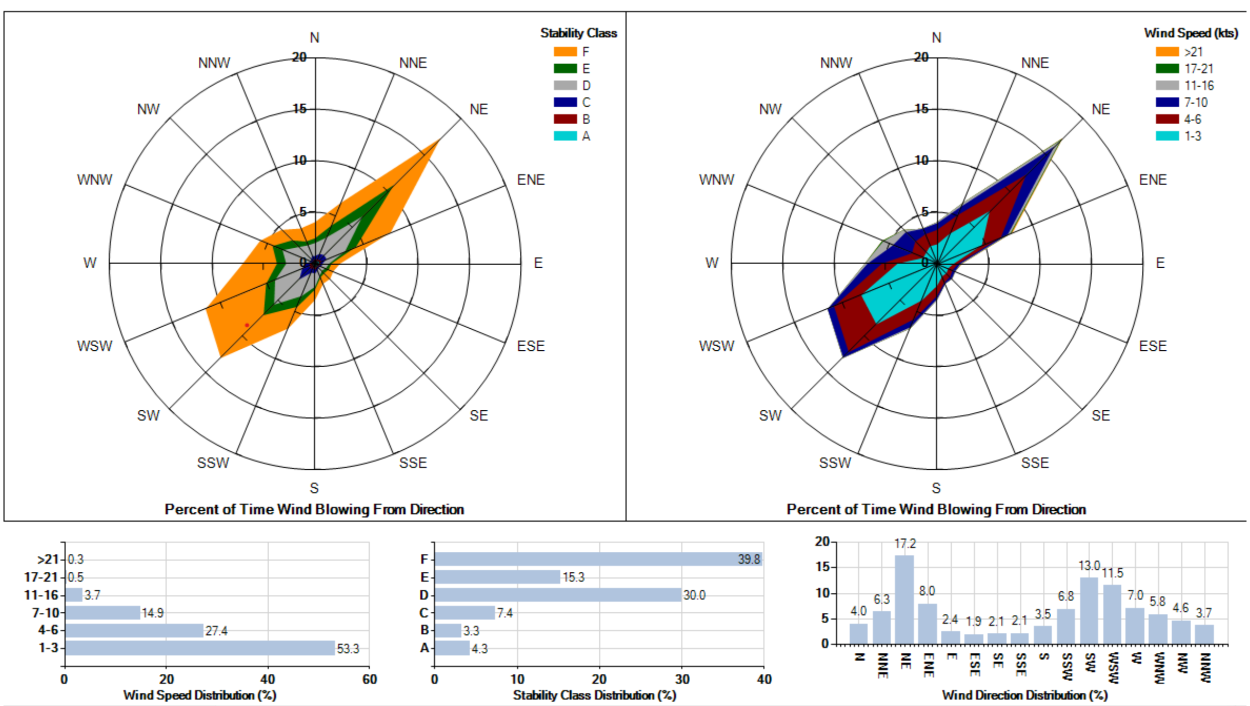
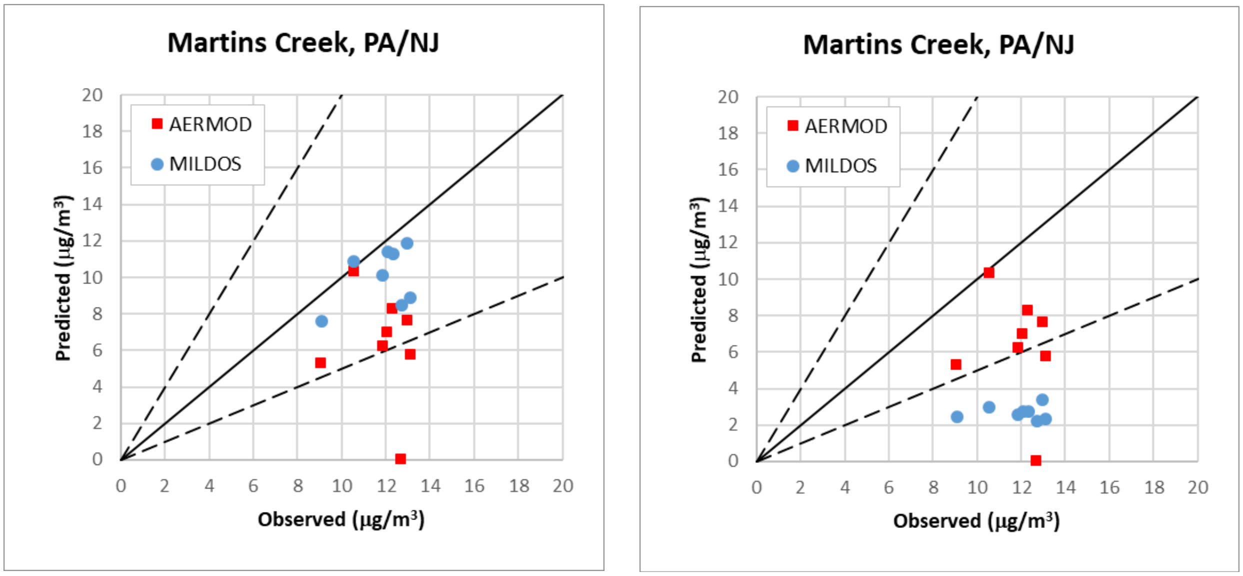
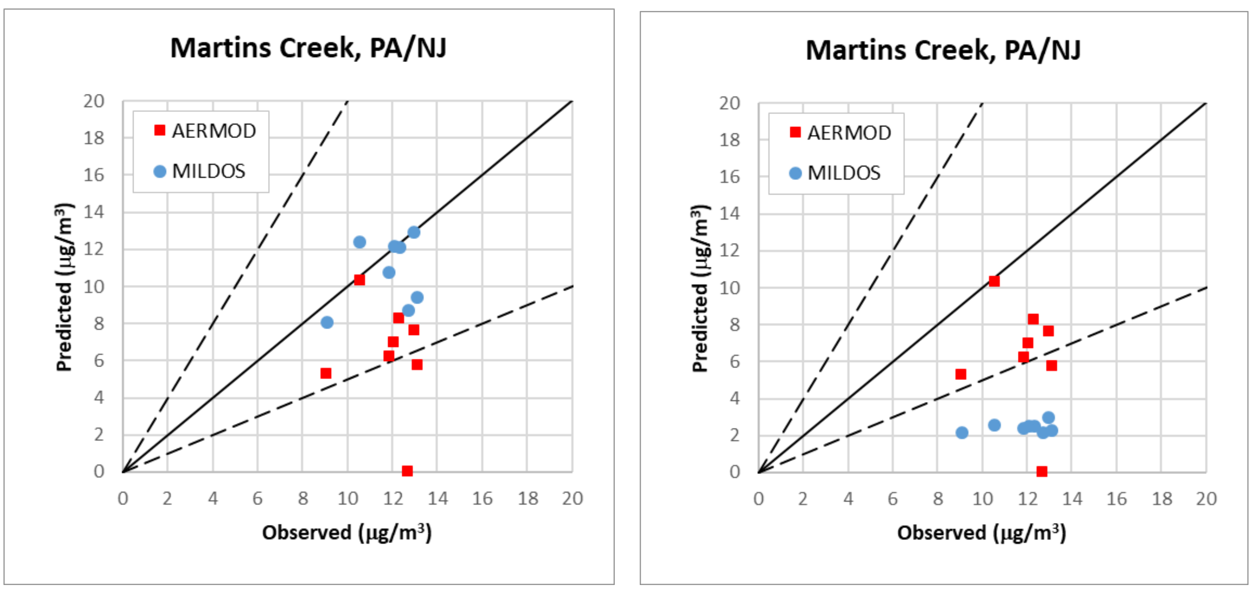


Figure 22. Meteorlogical Data Summary for the Martins Creek Site



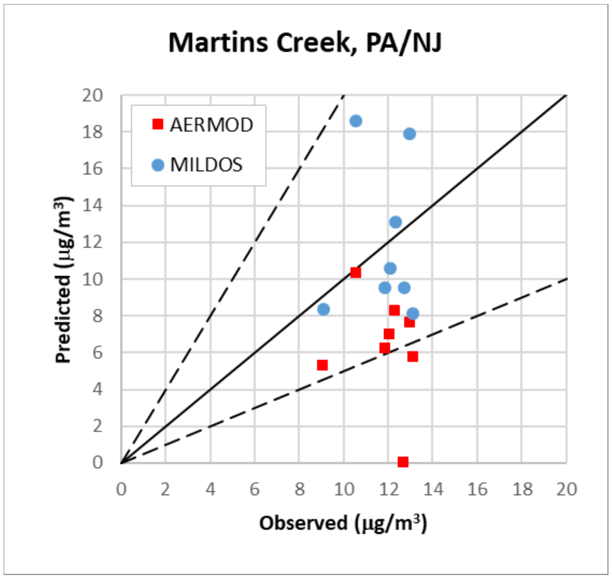
(a) Momentum plume rise (b) Buoyant plume rise

Figure 23 MILDOS – PG Coefficients

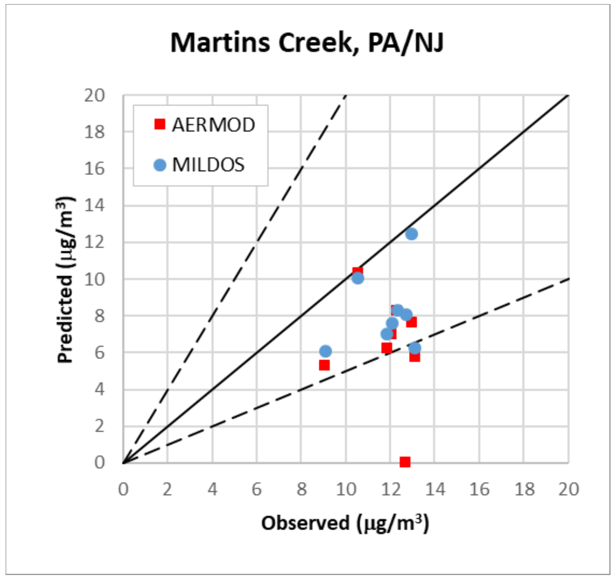


(a) Momentum plume rise (b) Buoyant plume rise

Figure 24 MILDOS – Briggs Rural Coefficients



(a) Momentum plume rise



(b) Buoyant plume rise

Figure 25 MILDOS – Briggs Urban Coefficients

3.6 Westvaco Site

The Westvaco pulp and paper mill was situated on the Potomac River valley in a complex terrain setting in rural Luke, MD (EPA 2003). Emissions were from one 190 m stack. A map of the local area is provided in Figure 26. Eleven receptors are located at distances from 743 m to 3.4 km from the source stack. All but two of the receptors, R2 and R11, were situated at an elevation above the physical stack height. Meteorological data was collected at three locations: in the river valley about 400 m southwest of the mill, on a ridge 900 m north-northwest of the mill (receptor 1 [R1] location), and on a ridge across the river approximately 900 m east-southeast of the mill (receptor 2 [R2] location) (EPA 2003). Figure 27 summarizes the meteorological data for the site.

Figures 28 through 30 present the graphs of the calculated results using the three sets of dispersion coefficients, PG, Briggs rural, or Briggs urban, respectively, plotted against the average measured values (EPA 2020). Each figure has separate plots for the (a) momentum-driven and (b) buoyant plume rise options. Data points would be along the solid black line in each case if the calculated value matched the measured value. For reference, calculated values below the upper dotted line or above the lower dotted line fall within a factor of 2 of the measured values.

It can be seen in Tables B.1 and C.1 and Figs. 28 through 30 that MILDOS4 significantly underestimates the measured SO_2 gas concentrations for the PG and Briggs rural dispersion coefficients and both plume rise options. Somewhat better agreement is obtained with the Briggs urban coefficients, but estimated gas concentrations remain lower than observed for most receptors. AERMOD underestimates the measured values at the receptor locations except for receptors R1 and R6 which have estimates within a factor of 2.

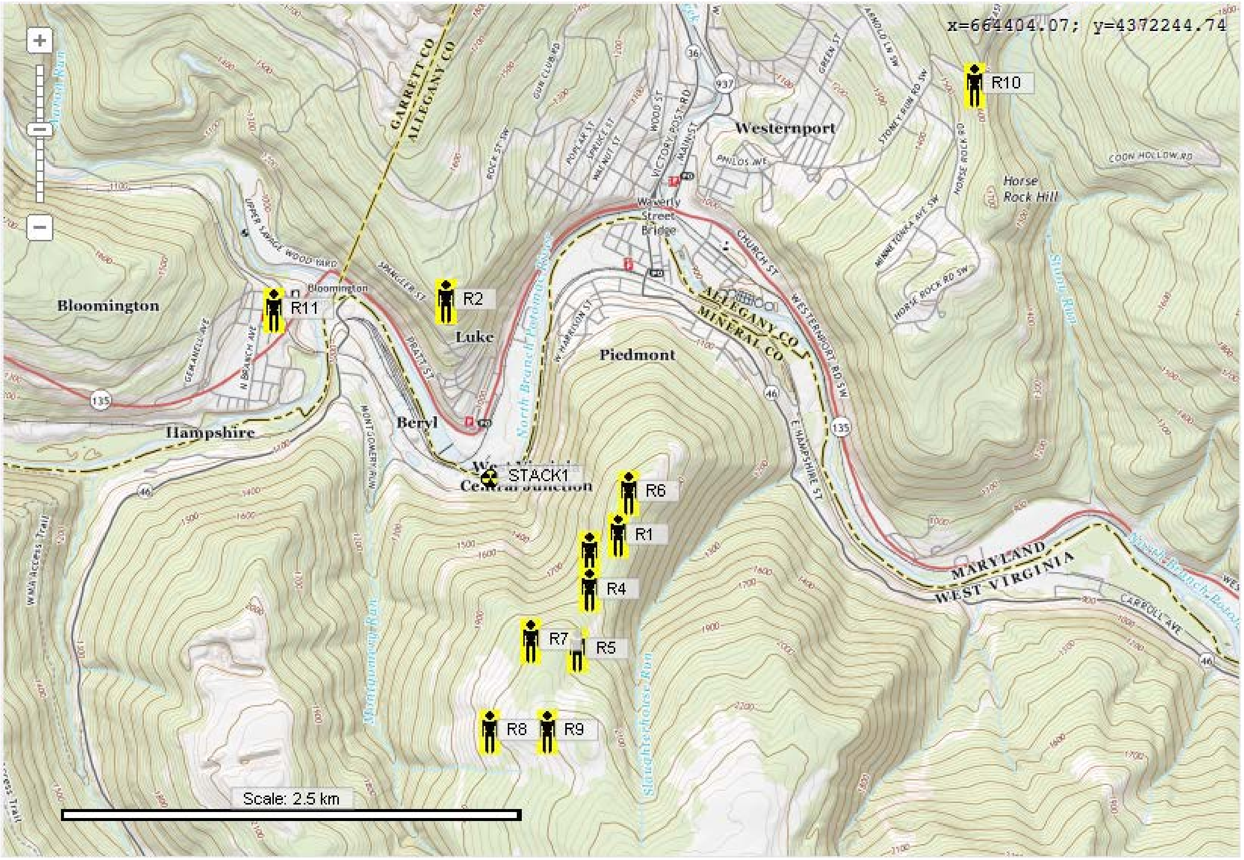


Figure 26 Local Map of the Westvaco Location along with the Emission Source and Receptors

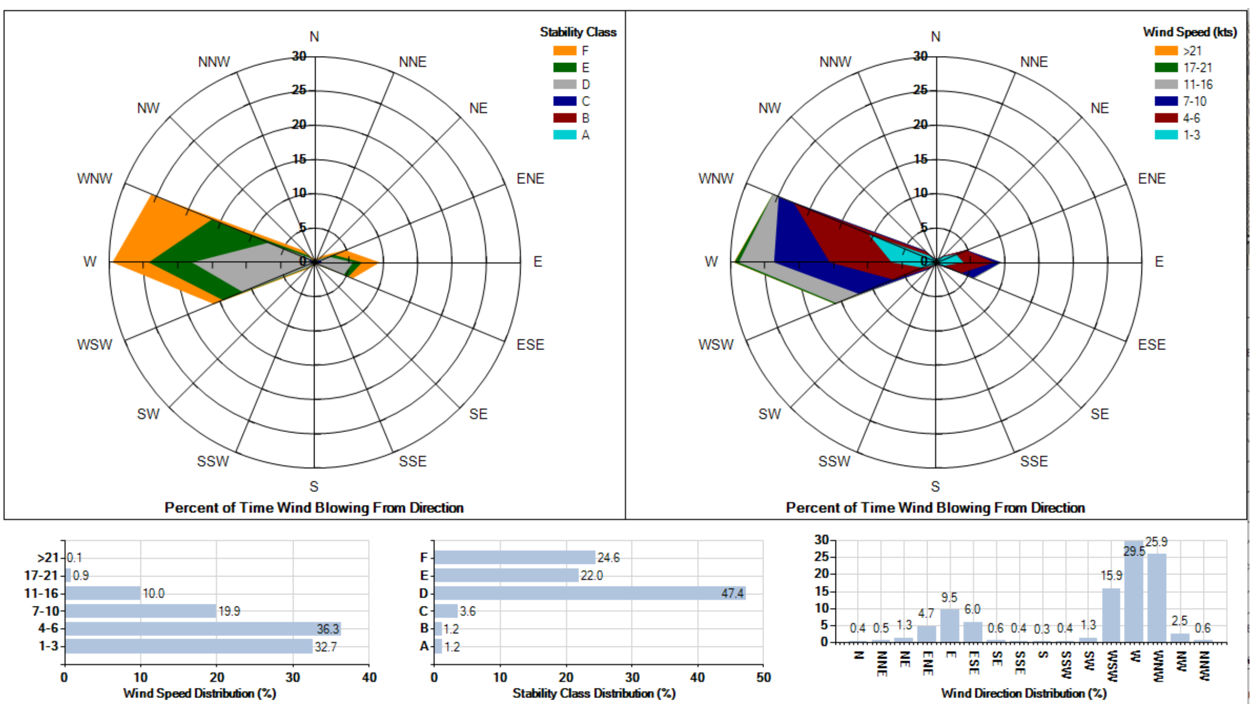
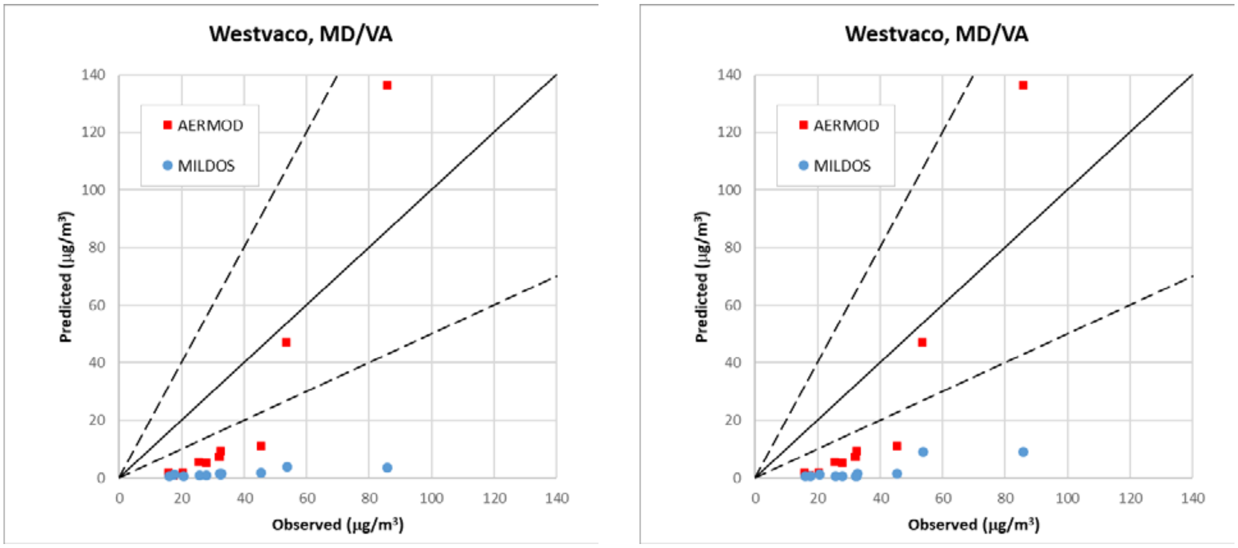


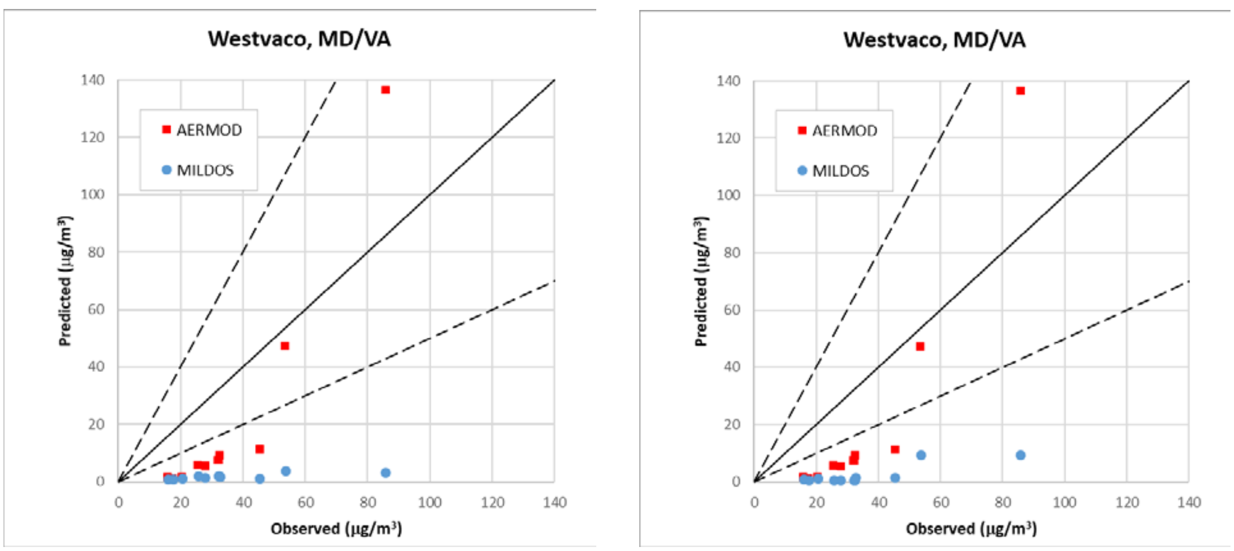
Figure 27 Meteorlogical Data Summary for the Westvaco Site



(a) Momentum plume rise

(b) Buoyant plume rise

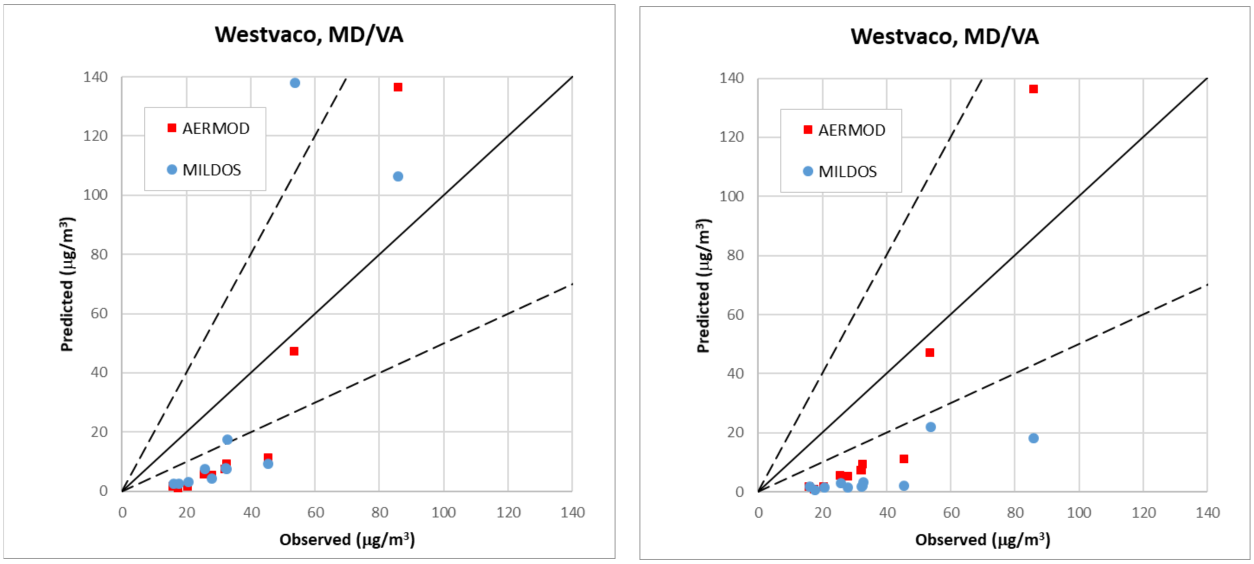
Figure 28 MILDOS – PG Coefficients



(a) Momentum plume rise

(b) Buoyant plume rise

Figure 29 MILDOS – Briggs Rural Coefficients



(a) Momentum plume rise (b) Buoyant plume rise

Figure 30 MILDOS – Briggs Urban Coefficients

Large variations in MILDOS4 values compared with the measured values in this complex terrain environment are expected. It was not uncommon for the wind direction as measured at the R1 and R2 locations to vary by as much as 180 degrees (EPA 1983).

3.7 Area Source Comparison

Because no area source validation studies have been performed, a direct comparison study between MILDOS4 and AERMOD using a square 40,000 m^2 area source was performed. Flat terrain was assumed and the meteorological data from the Lovett site was used. In this case, the MILDOS4 results were obtained using the Pasquill-Gifford dispersion coefficients. Figure 31 shows the receptor locations relative to the area source and Figure 17 provides information on the meteorological data. A second set of results was also calculated by replacing the area source by a point source at the center of the area source for perspective and comparison. Table 3 presents the results. Figures 32 and 33 show comparison plots for the point source and area source, respectively. Nine values are within a factor of two (within the dashed lines) of where they would be if the models agreed at each location (solid line). The remaining six values are generally within a factor of three.

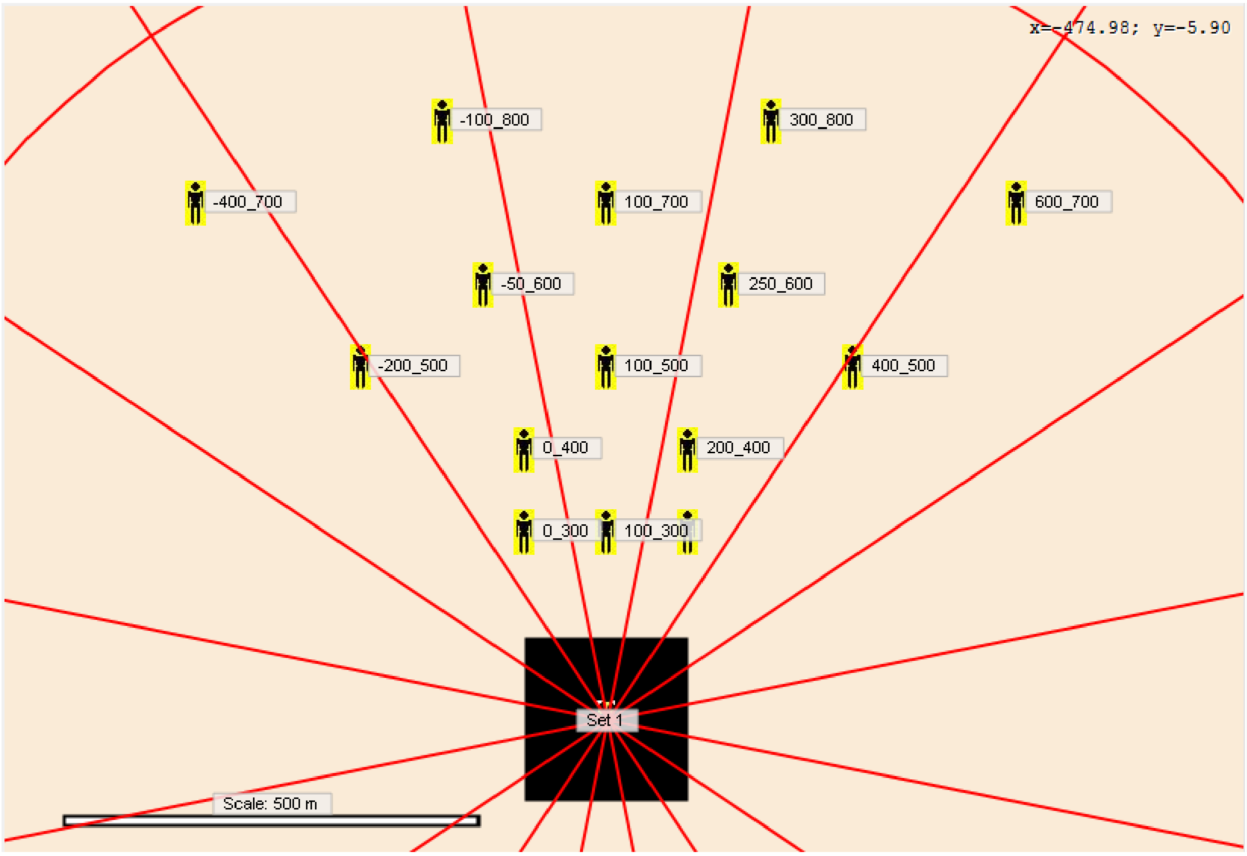


Figure 31 Receptor Locations for Area Source Comparison

Table 3. Area and Point Source Comparison between AERMOD and MILDOS4

		Normalized χ/Q (s/m³)			
Receptor		**AERMOD Area Source**	**AERMOD Point Source**	**MILDOS Area Source**	**MILDOS Point Source**
R1	0_300	3.02E-04	1.42E-04	1.03E-04	6.98E-05
R2	100_300	2.33E-04	1.52E-04	2.11E-04	1.98E-04
R3	200_300	1.18E-04	1.27E-04	2.11E-04	2.28E-04
R4	0_400	1.79E-04	9.47E-05	5.49E-05	3.64E-05
R5	200_400	7.68E-05	7.61E-05	1.13E-04	1.22E-04
R6	-200_500	8.06E-05	4.76E-05	1.50E-05	1.42E-05
R7	100_500	7.53E-05	5.28E-05	5.71E-05	5.64E-05
R8	400_500	2.78E-05	3.70E-05	4.19E-05	3.42E-05
R9	-50_600	7.49E-05	4.20E-05	1.98E-05	1.43E-05
R10	250_600	3.08E-05	3.49E-05	4.72E-05	5.00E-05
R11	-400_700	3.45E-05	2.17E-05	6.14E-06	6.01E-06
R12	100_700	4.10E-05	2.76E-05	2.77E-05	2.73E-05
R13	600_700	1.28E-05	1.75E-05	1.65E-05	1.56E-05
R14	-100_800	4.55E-05	2.34E-05	1.01E-05	7.78E-06
R15	300_800	1.95E-05	2.05E-05	2.64E-05	2.78E-05

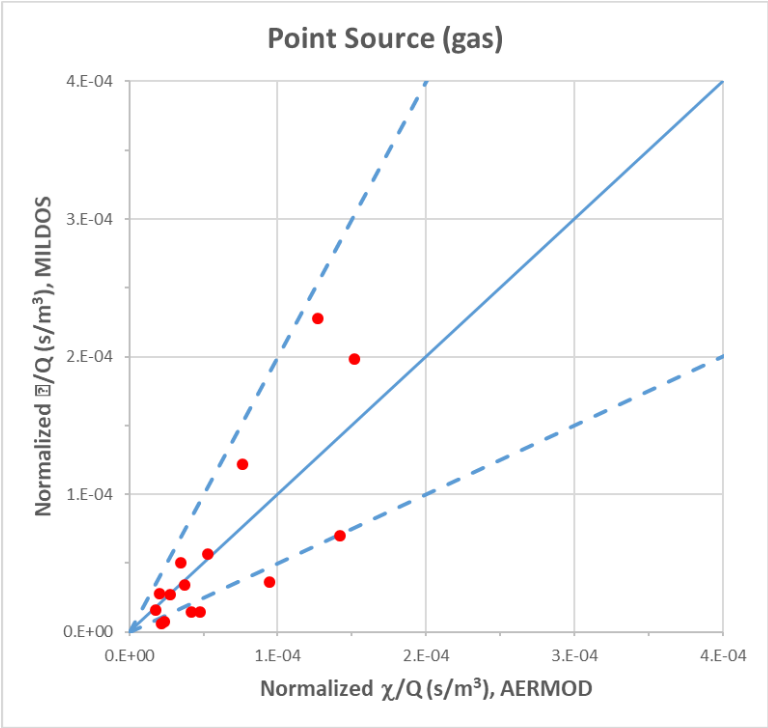


Figure 32 Point Source Comparions between AERMOD and MILDOS4

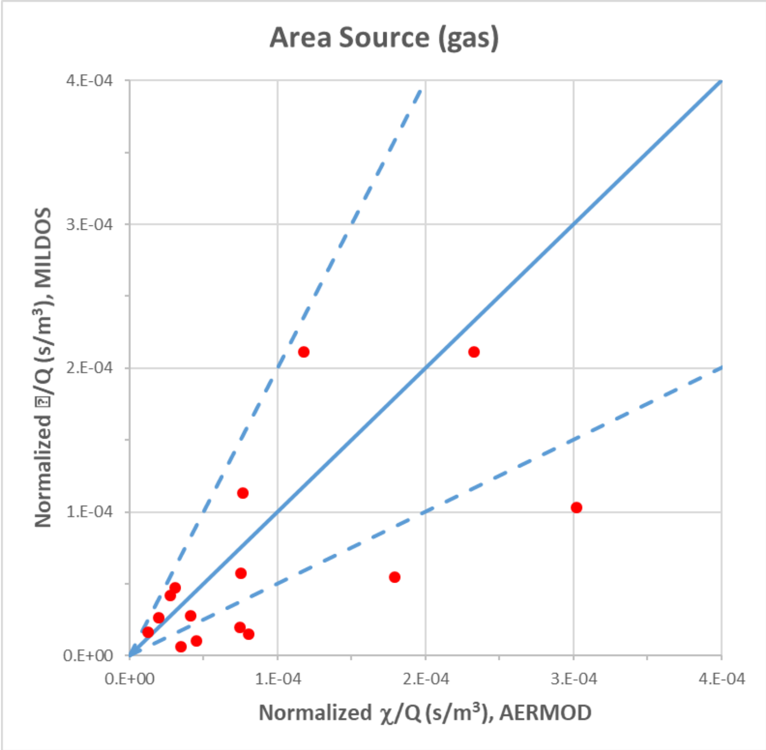


Figure 33 Area Source Comparions between AERMOD and MILDOS4

4. DISCUSSION AND SUMMARY

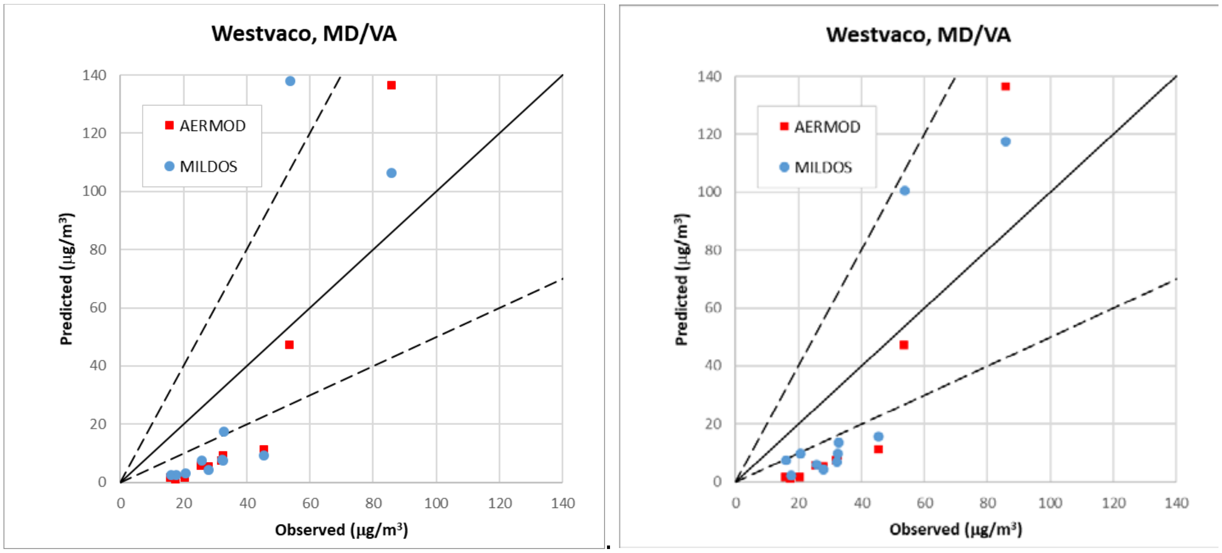
As noted in Paine et al. (1998), there are a number of uncertainties in both the data measurements and modeling approach, including the proper consideration of background SO_2 concentrations and the accurate measurement of low SO_2 values. The current study was undertaken to determine if there was sufficient cause to replace the current basic, straight-line Gaussian plume model with the AERMOD system in order to better estimate downwind environmental concentrations in complex terrain. In general, MILDOS4 provided about the same or higher (more conservative) estimated values than did AERMOD in the six case studies. However, AERMOD did not perform noticeably better against the measured data than did MILDOS4 except in the case of the Westvaco site which is an extremely complex situation. Thus, incorporating the AERMOD dispersion model into MILDOS4 is not recommended at this time.

Application of a flat terrain model as used in MILDOS to a complex terrain environment comes with a certain challenge as related to the relative elevation inputs (z values) for the sources and receptors. There is no universal convention regarding where the reference elevation value (z = 0) should be. It could be set to mean sea level, the location of the lowest release, or the location of the meteorological data collection. As done for this study with MILDOS4, it is recommended to use the location of the lowest release location to set z = 0, which is most consistent with a flat terrain implementation. Also, the use of mean sea level as the zero reference is inconsistent with the calculation of the wind speed at the effective release height (Equation 3.12 in the User's Guide [Biwer et al. 2019]) which has the inherent assumption that the meteorological data is collected at the source location.

In the direct comparison of MILDOS4 and AERMOD area sources using meteorological data at the Lovett site, there is some disparity in the results. The most common errors in the meteorological parameters used in dispersion models are of two types: inaccuracies in wind direction and errors in determining dispersion parameters. AERMOD uses wind directions to the nearest degree. In contrast, MILDOS4 uses a joint frequency distribution of three parameters (wind direction, wind speed, and stability class), in which wind directions are grouped into 16 sectors. Each sector is assigned an annual frequency of occurrence based on wind speed and stability class. If a receptor is near the edge of the sector, and the adjoining sector has a much different frequency of occurrence, this variation is not taken into account. Smoothing the frequency distribution between adjacent sectors was performed in AERMOD's predecessor (ISC3) to help alleviate this problem (EPA 1992).

An experimental alteration of the MILDOS code was used to look at how such frequency smoothing might affect the results for the Westvaco site using Briggs urban coefficients with a momentum-driven plume. Figure 34 shows the results without the smoothing (a), same as Figure 30(a), versus with smoothing (b). Receptors R1 and R6 are near transitions between sectors where winds predominantly blow towards (see Figure 35). The calculated air concentration at Receptor R1 without smoothing is 138 $\mu g/m^3$ (see Table B.1). With smoothing, it is 101 $\mu g/m^3$, closer to the observed value of 53.6 $\mu g/m^3$. A number of other receptor estimates also moved towards the observed values as seen in Figure 34. On the other hand, the calculated air concentration at Receptor R6 went from 106 (see Table B.1) to 117 $\mu g/m^3$ with smoothing, away from the observed value of 85.8 $\mu g/m^3$.

Another cause of differences in the models are the dispersion coefficients. AERMOD uses continuous ones of Monin-Obukhov length, while MILDOS4 uses discrete ones of stability



(a) Without frequency smoothing (same as Figure 30(a))

(b) With frequency smoothing

Figure 34 MILDOS – Momentum-Driven Plume Using Briggs Urban Coefficients

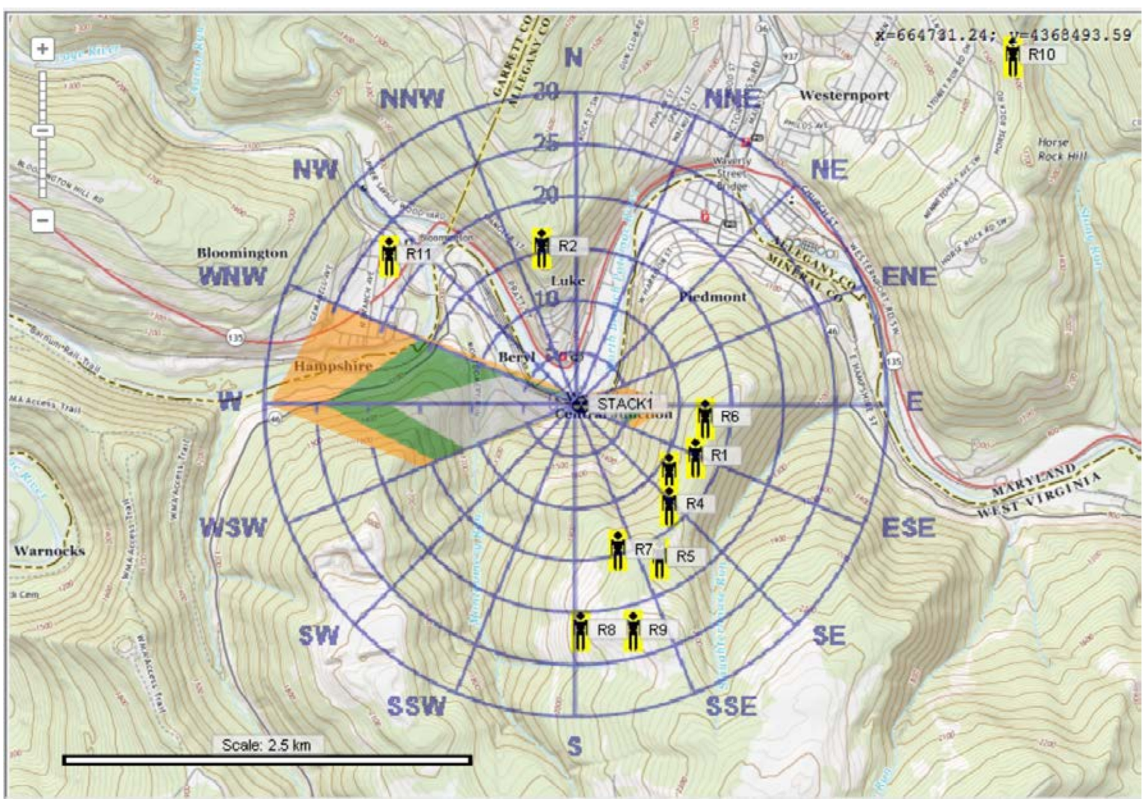


Figure 35 Overlay of Wind Rose on the Westvaco Site

classes, which covers a wide range of atmospheric conditions with only six classes. An error of one stability category often results in a calculation error of 50 percent or more at a specified receptor. In addition, to use AERMOD model evaluation databases, conversion from Monin-Obukhov length in AERMET files to Pasquill-Gifford stability class was made based on an empirical relationship (Golder 1972), which can introduce additional uncertainties.

Albeit not a significant factor, emission rates, wind speeds, and ambient temperatures in AERMOD vary hourly, but MILDOS4 uses one fixed emission rate, wind speed, and ambient temperature throughout the year. Depending on these parameters, effective stack height (physical stack height plus plume rise) might vary from hour to hour and thus the ground-level concentrations could vary between the two model results to some extent.

Considering the aforementioned differences in algorithms, area source comparisons between the two models are acceptable.

Looking forward, improvements to MILDOS4's air dispersion model could be made in a number of areas –

1. Inclusion of a building cavity/wake/downwash model is important to better account for releases from short stacks on ISR facility buildings. In general, building cavity/wake/downwash could increase concentrations significantly, especially at receptors in close proximity to buildings.

2. Implementing a smoothing routine to adjust wind frequency values at the 16 direction sector boundaries is needed to avoid abrupt transitions in air concentration values across these boundaries.

3. The plume rise calculations in MILDOS4 are quite old and need to be revised and updated as needed. As noted above, the calculation of the effective release height can have a significant effect on estimated air concentrations.

4. The terrain height adjustment in MILDOS4 is a simple model not intended for use in complex terrain situations. For a more appropriate analysis of ISR facilities in the western U.S., MILDOS4 would benefit from the incorporation of a model more suited to complex terrain situations. Investigation of advanced terrain models may identify a reasonable upgrade.

5. An extension of this study would be to evaluate the dry and wet deposition routines, formulated decades ago, against avaiable data and more advanced deposition models with the intention of upgrading these routines if appropriate.

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APPENDIX A MILDOS4 SOURCE AND RECEPTOR INPUT

Table A.1 Source and Receptor Location Coordinate Information

Site	ID	UTME (m)	UTMN (m)	Elevation (m)[a]	Stack Height (m)	Release Height (m)
Baldwin						
Sources	STACK1	249945	4232200	0	184.4	184
	STACK2	249945	4232140	0	184.4	184
	STACK3	249942	4232075	0	184.4	184
Receptors	R1	252600	4237000	-4	---	---
	R2	251330	4235420	2	---	---
	R3	250700	4233790	6	---	---
	R4	251170	4231530	7	---	---
	R5	252270	4231320	15	---	---
	R6	253450	4230590	17	---	---
	R7	255800	4228900	7	---	---
	R8	258410	4227110	2	---	---
	R9	248800	4227900	-2	---	---
	R10	249620	4229990	7	---	---
Bowline						
Sources	STACK1	586693	4562048	0	86.9	86.9
	STACK2	586677	4562136	0	86.9	86.9
Receptors	R1	587344	4561558	0	---	---
	R2	586741	4562337	0	---	---
	R3	586993	4561876	0	---	---
	R4	586342	4561939	0	---	---
Clifty Creek						
Sources	STACK1	637250	288600	0	208	208
	STACK2	637250	288600	0	208	208
	STACK3	637250	288600	0	208	208
Receptors	R1	646890	300090	134	---	---
	R2	643380	292740	131	---	---
	R3	638490	292930	124	---	---
	R4	641970	299200	130	---	---
	R5	637570	285520	110	---	---
	R6	645150	287350	3	---	---
Lovett						
Source	STK4N5	585559	4568160	0	145	145
Receptors	TIMP3	583649	4569900	318	---	---
	DD4	584569	4569980	291	---	---
	DD5	585549	4570650	230	---	---
	DD6	584829	4570900	321	---	---
	DD7	585159	4571050	318	---	---

Site	ID	UTME (m)	UTMN (m)	Elevation (m)[a]	Stack Height (m)	Release Height (m)
	DD8	585859	4571100	248	---	---
	DD9	585909	4571540	166	---	---
	DD10	586299	4571270	272	---	---
	DD11	586979	4571500	150	---	---
Martins Creek						
Sources	MC12	491010	4515910	0	182.9	183
	MC3	491123	4516030	0	182.9	183
	MC4	491190	4516068	0	182.9	183
	ED1	493350	4528370	18	121.9	140
	ED2	493350	4528370	18	121.9	140
	HL2	494050	4521040	30	59.4	90
	WC1	498950	4518500	101	76.2	177
	WC2	498950	4518500	101	76.2	177
Receptors	R1	495510	4513680	280	---	---
	R2	493900	4513200	304	---	---
	R3	486500	4519750	171	---	---
	R4	492700	4513440	297	---	---
	R5	492440	4511190	267	---	---
	R6	495400	4515180	283	---	---
	R7	495300	4513880	293	---	---
	R8	496430	4514500	268	---	---
Westvaco						
Source	STACK1	667090	370760	0	189.7	190
Receptors	R1	667800	370360	316	---	---
	R2	666850	371660	180	---	---
	R3	667640	370260	276	---	---
	R4	667640	370060	315	---	---
	R5	667580	369730	351	---	---
	R6	667860	370600	303	---	---
	R7	667320	369780	349	---	---
	R8	667090	369280	355	---	---
	R9	667410	369280	385	---	---
	R10	669770	372850	216	---	---
	R11	665900	371610	30	---	---

[a] Elevation relative to lowest source.

Table A.2 Source Stack Diameter, Exit Velocity, Exit Temperature, and Heat Release

Site	Source	Diameter (m)	Exit Velocity (m/s)	Exit Temperature (K)	Heat Release[a] (cal/s)
Baldwin	STACK1	5.94	28.5	423.3	2.10E+07
	STACK2	5.94	29.8	420.0	2.16E+07
	STACK3	5.94	30.6	403.9	2.03E+07
Bowline	STACK1	5.72	15.0	369.7	7.33E+06
	STACK2	5.72	15.0	377.6	7.61E+06
Clifty Creek	STACK1	4.63	45.0	445.4	2.24E+07
	STACK2	4.63	46.0	445.4	2.29E+07
	STACK3	4.63	46.8	445.4	2.33E+07
Lovett	STK4N5	4.5	15.7	389.7	5.58E+06
Martins Creek	MC12	5.3	17.1	400.8	9.10E+06
	MC3	6.9	17.6	402.9	1.61E+07
	MC4	6.9	19.1	402.4	1.74E+07
	ED1	3.1	33.4	395.0	5.87E+06
	ED2	3.6	26.4	400.0	6.47E+06
	HL2	2.7	6.8	452.4	1.19E+06
	WC1	1.87	3.3	404.5	2.27E+05
	WC2	1.87	3.4	409.8	2.35E+05
Westvaco	STACK1	3.36	23.0	421.2	5.44E+06

[a] Heat release was calculated by the following formula derived from Eqn. 4-3 in Turner and Schulze 2007:

$$Q_H = \frac{C_p \rho_a T V_o \Delta T}{T_o}$$

Where:

Q_H = Stack heat release (cal/s),
C_p = Specific heat of air (0.24 cal/g-K),
ρ_a = Air density (1,205 g/m^3 at sea level);
T = Ambient air temperature (K); used annual average temperature at each site,
V_o = Volume flux of exit gases (m^3/s); exit velocity multiplied by the area of the stack opening,
ΔT = Difference between the stack gas and ambient air temperatures (K), and
T_o = Stack gas temperature (K).

APPENDIX B AERMOD AND MILDOS4 CALCULATIONS RESULTS WITH A MOMENTUM-DRIVEN PLUME

Table B.1. Comparison of Annual Average Gas (SO_2) Concentrations Between Observed and Estimated Values

		Annual Average Gas Concentration (μg/m³)					
Study Location	**Receptor**	**Observed Values**	**Original AERMOD**	**Current AERMOD**	**MILDOS / Pasquill-Gifford Coefficients**	**MILDOS / Briggs Rural Coefficients**	**MILDOS / Briggs Urban Coefficients**
Original Point Sources (gas)							
Baldwin (IL)	R1	10.9	11.6	12.9	21.2	26.9	71.3
	R2	12.0	12.2	13.6	20.5	25.9	123
	R3	8.1	7.3	8.3	17.3	21.3	204
	R4	9.7	3.0	3.9	16.0	14.8	169
	R5	12.6	6.6	7.7	16.1	20.1	127
	R6	11.0	8.1	9.2	17.9	23.0	79.1
	R7	10.9	8.6	9.6	19.2	23.3	39.5
	R8	7.6	8.3	9.1	18.4	20.4	25.4
	R9	9.8	10.3	11.5	17.0	21.1	85.0
	R10	9.5	6.4	7.7	25.2	29.3	135
Bowline (NY)	R1	14.2	21.4	21.4	3.2	6.3	89.8
	R2	1.7	0.7	0.8	0.009	0.027	2.3
	R3	13.1	18.9	18.6	0.47	0.46	59.1
	R4	3.2	0.3	0.4	3.4	3.4	14.6
Clifty Creek (IN)	R1	41.0	11.7	12.3	28.6	30.8	35.7
	R2	36.7	13.4	14.5	32.5	40.1	84.6
	R3	39.7	22.1	24.1	25.0	36.4	204.0
	R4	37.4	15.7	16.7	38.6	44.6	60.5
	R5	34.9	9.3	11.5	10.7	12.8	81.4
	R6	29.6	11.6	12.8	22.1	27.2	54.0

Study Location	Receptor	Annual Average Gas Concentration (μg/m³) Observed Values	Original AERMOD	Current AERMOD	MILDOS / Pasquill-Gifford Coefficients	MILDOS / Briggs Rural Coefficients	MILDOS / Briggs Urban Coefficients
Lovett (NY)	TIMP3	3.6	2.1	2.3	9.2	12.4	11.1
	DD4	3.0	4.0	4.1	4.2	7.4	9.8
	DD5	3.0	2.3	2.4	2.7	3.8	11.9
	DD6	4.4	4.1	4.2	4.5	5.3	6.9
	DD7	5.0	4.3	4.3	7.2	7.2	12.7
	DD8	2.9	2.8	2.9	2.8	3.5	9.9
	DD9	3.8	1.1	1.2	1.9	2.2	6.5
	DD10	3.7	3.4	3.5	2.9	3.1	12.0
	DD11	4.5	0.9	1.0	1.1	1.3	6.7
Martins Creek (PA/NJ)	R1	11.9	6.3	6.5	10.1	10.8	9.6
	R2	12.3	8.3	8.7	11.3	12.1	13.1
	R3	12.7	not available	not available	8.5	8.7	9.6
	R4	10.6	10.3	10.6	10.9	12.4	18.6
	R5	9.1	5.3	5.6	7.6	8.1	8.4
	R6	13.0	7.6	7.9	11.8	12.9	17.9
	R7	12.1	7.0	7.3	11.4	12.2	10.6
	R8	13.1	5.8	6.0	8.9	9.4	8.1
Westvaco (MD/VA)	R1	53.6	47.1	48.5	3.8	3.59	138
	R2	17.6	0.9	1.2	1.4	0.92	2.4
	R3	45.5	11.1	11.4	1.7	1.02	9.2
	R4	32.6	9.2	9.8	1.6	1.67	17.4
	R5	32.4	7.3	7.8	1.2	1.83	7.6
	R6	85.8	136.2	135.8	3.7	3.05	106
	R7	32.1	7.3	7.9	1.5	1.89	7.8
	R8	28.0	5.3	5.9	0.9	1.47	4.2
	R9	25.7	5.5	6.0	1.0	1.81	7.4
	R10	15.9	1.5	1.7	0.7	0.84	2.5
	R11	20.5	1.6	1.9	0.8	1.09	3.0

Table B.2. Percentage Difference Between Observed and Estimated Values

		Percentage Difference from Annual Average Observed Values					
Study Location	**Receptor**	**Observed Values**	**Original AERMOD**	**Current AERMOD**	**MILDOS / Pasquill-Gifford Coefficients**	**MILDOS / Briggs Rural Coefficients**	**MILDOS / Briggs Urban Coefficients**
Original Point Sources (gas)							
Baldwin (IL)	R1	-----	7	18	95	147	555
	R2	-----	2	14	72	117	925
	R3	-----	-11	2	112	162	2406
	R4	-----	-69	-60	64	52	1639
	R5	-----	-48	-39	28	60	910
	R6	-----	-26	-17	63	109	621
	R7	-----	-22	-13	76	114	261
	R8	-----	9	21	142	169	236
	R9	-----	5	17	73	115	765
	R10	-----	-33	-19	166	209	1322
Bowline (NY)	R1	-----	50	50	-77	-56	531
	R2	-----	-58	-54	-99	-98	36
	R3	-----	44	42	-96	-96	350
	R4	-----	-92	-88	6	6	354
Clifty Creek (IN)	R1	-----	-71	-70	-30	-25	-13
	R2	-----	-64	-61	-11	9	131
	R3	-----	-44	-39	-37	-8	414
	R4	-----	-58	-55	3	19	62
	R5	-----	-73	-67	-69	-63	134
	R6	-----	-61	-57	-25	-8	82

		Percentage Difference from Annual Average Observed Values					
Study Location	**Receptor**	**Observed Values**	**Original AERMOD**	**Current AERMOD**	**MILDOS / Pasquill-Gifford Coefficients**	**MILDOS / Briggs Rural Coefficients**	**MILDOS / Briggs Urban Coefficients**
Lovett (NY)	TIMP3	-----	-42	-37	153	242	206
	DD4	-----	36	37	43	149	232
	DD5	-----	-23	-21	-11	24	290
	DD6	-----	-7	-5	0	19	55
	DD7	-----	-15	-14	44	44	153
	DD8	-----	-2	0	-2	22	248
	DD9	-----	-72	-69	-51	-42	70
	DD10	-----	-6	-6	-22	-15	227
	DD11	-----	-81	-78	-76	-71	48
Martins Creek (PA/NJ)	R1	-----	-47	-45	-15	-9	-20
	R2	-----	-33	-30	-9	-2	6
	R3	-----	not available	not available	-33	-32	-25
	R4	-----	-2	0.9	3	18	77
	R5	-----	-42	-39	-16	-11	-8
	R6	-----	-41	-39	-9	0	38
	R7	-----	-42	-40	-5	1	-12
	R8	-----	-56	-54	-32	-28	-38
Westvaco (MD/VA)	R1	-----	-12	-10	-93	-93	157
	R2	-----	-95	-93	-92	-95	-86
	R3	-----	-76	-75	-96	-98	-80
	R4	-----	-72	-70	-95	-95	-47
	R5	-----	-78	-76	-96	-94	-77
	R6	-----	59	58	-96	-96	24
	R7	-----	-77	-75	-95	-94	-76
	R8	-----	-81	-79	-97	-95	-85
	R9	-----	-79	-77	-96	-93	-71
	R10	-----	-90	-89	-96	-95	-84
	R11	-----	-92	-91	-96	-95	-85

Table B.3. Percentage Difference Between AERMOD and MILDOS Values

Study Location	Receptor	MILDOS / Pasquill-Gifford Coefficients	MILDOS / Briggs Rural Coefficients	MILDOS / Briggs Urban Coefficients
Original Point Sources (gas)				
Baldwin (IL)	R1	65	108	453
	R2	51	91	802
	R3	107	156	2345
	R4	310	278	4232
	R5	109	161	1549
	R6	95	151	764
	R7	101	144	313
	R8	101	123	178
	R9	47	83	637
	R10	229	283	1659
Bowline (NY)	R1	-85	-71	319
	R2	-99	-96	193
	R3	-97	-98	218
	R4	821	815	3840
Clifty Creek (IN)	R1	132	150	189
	R2	125	177	484
	R3	4	51	746
	R4	131	167	262
	R5	-7	11	605
	R6	73	113	323
Lovett (NY)	TIMP3	303	445	387
	DD4	4	81	141
	DD5	13	56	392
	DD6	6	25	63
.	DD7	67	67	194
	DD8	-3	22	246
	DD9	57	86	445
	DD10	-17	-10	247
	DD11	13	33	582

Study Location	Receptor	MILDOS / Pasquill-Gifford Coefficients	MILDOS / Briggs Rural Coefficients	MILDOS / Briggs Urban Coefficients
Martins Creek (PA/NJ)	R1	55	65	47
	R2	30	39	51
	R3	not available	not available	not available
	R4	2	17	75
	R5	37	45	51
	R6	51	64	127
	R7	58	68	46
	R8	48	56	35
Westvaco (MD/VA)	R1	-92	-93	184
	R2	17	-21	107
	R3	-85	-91	-20
	R4	-83	-83	77
	R5	-84	-76	-3
	R6	-97	-98	-22
	R7	-81	-76	-2
	R8	-84	-75	-29
	R9	-84	-70	23
	R10	-60	-50	48
	R11	-60	-43	58

APPENDIX C AERMOD AND MILDOS4 CALCULATIONS RESULTS WITH A BUOYANT PLUME

Table C.1. Comparison of Annual Average Gas (SO_2) Concentrations Between Observed and Estimated Values

		Annual Average Gas Concentration (μg/m^3)					
Study Location	**Receptor**	**Observed Values**	**Original AERMOD**	**Current AERMOD**	**MILDOS / Pasquill-Gifford Coefficients**	**MILDOS / Briggs Rural Coefficients**	**MILDOS / Briggs Urban Coefficients**
Original Point Sources (gas)							
Baldwin (IL)	R1	10.9	11.6	12.9	21.7	22.1	64.3
	R2	12.0	12.2	13.6	31.8	32.3	87.0
	R3	8.1	7.3	8.3	58.1	58.2	97.5
	R4	9.7	3.0	3.9	54.5	52.5	77.8
	R5	12.6	6.6	7.7	34.4	34.4	71.6
	R6	11.0	8.1	9.2	22.9	23.1	59.5
	R7	10.9	8.6	9.6	13.9	14.2	37.5
	R8	7.6	8.3	9.1	10.1	10.5	24.7
	R9	9.8	10.3	11.5	18.2	18.6	65.6
	R10	9.5	6.4	7.7	43.1	43.4	75.7
Bowline (NY)	R1	14.2	21.4	21.4	3.2	3.2	21.8
	R2	1.7	0.7	0.8	0.01	0.01	0.15
	R3	13.1	18.9	18.6	0.76	0.77	7.9
	R4	3.2	0.3	0.4	0.10	0.10	0.57
Clifty Creek (IN)	R1	41.0	11.7	12.3	12.6	13.2	34.9
	R2	36.7	13.4	14.5	21.8	22.2	74.3
	R3	39.7	22.1	24.1	31.2	31.5	133.3
	R4	37.4	15.7	16.7	14.5	15.3	58.5
	R5	34.9	9.3	11.5	19.1	19.2	46.4
	R6	29.6	11.6	12.8	12.6	13.0	48.5

		Annual Average Gas Concentration (μg/m^3)					
Study Location	**Receptor**	**Observed Values**	**Original AERMOD**	**Current AERMOD**	**MILDOS / Pasquill-Gifford Coefficients**	**MILDOS / Briggs Rural Coefficients**	**MILDOS / Briggs Urban Coefficients**
Lovett (NY)	TIMP3	3.6	2.1	2.3	7.3	6.6	9.4
	DD4	3.0	4.0	4.1	3.9	3.2	6.9
	DD5	3.0	2.3	2.4	2.6	2.4	7.3
	DD6	4.4	4.1	4.2	3.0	2.7	5.3
	DD7	5.0	4.3	4.3	2.4	2.3	8.3
	DD8	2.9	2.8	2.9	2.2	2.1	6.6
	DD9	3.8	1.1	1.2	1.9	1.9	4.8
	DD10	3.7	3.4	3.5	1.3	1.3	7.7
	DD11	4.5	0.9	1.0	1.1	1.1	4.8
Martins Creek (PA/NJ)	R1	11.9	6.3	6.5	2.5	2.4	7.0
	R2	12.3	8.3	8.7	2.8	2.5	8.3
	R3	12.7	not available	not available	2.2	2.2	8.1
	R4	10.6	10.3	10.6	3.0	2.6	10.1
	R5	9.1	5.3	5.6	2.5	2.2	6.1
	R6	13.0	7.6	7.9	3.4	3.0	12.5
	R7	12.1	7.0	7.3	2.8	2.5	7.6
	R8	13.1	5.8	6.0	2.3	2.2	6.3
Westvaco (MD/VA)	R1	53.6	47.1	48.5	9.2	9.2	22
	R2	17.6	0.9	1.2	0.7	0.5	0.8
	R3	45.5	11.1	11.4	1.5	1.5	2.1
	R4	32.6	9.2	9.8	1.6	1.4	3.3
	R5	32.4	7.3	7.8	0.8	0.6	2.1
	R6	85.8	136.2	135.8	9.2	9.2	18
	R7	32.1	7.3	7.9	0.7	0.5	1.7
	R8	28.0	5.3	5.9	0.7	0.6	1.6
	R9	25.7	5.5	6.0	0.7	0.6	3.1
	R10	15.9	1.5	1.7	0.7	0.7	1.7
	R11	20.5	1.6	1.9	1.2	1.1	1.6

Table C.2. Percentage Difference Between Annual Average Observed and Estimated Values

		Percentage Difference from Annual Average Observed Values					
Study Location	**Receptor**	**Observed Values**	**Original AERMOD**	**Current AERMOD**	**MILDOS / Pasquill-Gifford Coefficients**	**MILDOS / Briggs Rural Coefficients**	**MILDOS / Briggs Urban Coefficients**
Original Point Sources (gas)							
Baldwin (IL)	R1	-----	7	18	99	103	491
	R2	-----	2	14	166	170	628
	R3	-----	-11	2	614	615	1098
	R4	-----	-69	-60	460	440	700
	R5	-----	-48	-39	173	173	468
	R6	-----	-26	-17	108	111	442
	R7	-----	-22	-13	27	30	243
	R8	-----	9	21	34	39	226
	R9	-----	5	17	85	89	568
	R10	-----	-33	-19	355	359	699
Bowline (NY)	R1	-----	50	50	-77	-78	53
	R2	-----	-58	-54	-99	-99	-91
	R3	-----	44	42	-94	-94	-40
	R4	-----	-92	-88	-97	-97	-82
Clifty Creek (IN)	R1	-----	-71	-70	-69	-68	-15
	R2	-----	-64	-61	-40	-39	102
	R3	-----	-44	-39	-21	-21	236
	R4	-----	-58	-55	-61	-59	57
	R5	-----	-73	-67	-45	-45	33
	R6	-----	-61	-57	-57	-56	64

		Percentage Difference from Annual Average Observed Values					
Study Location	**Receptor**	**Observed Values**	**Original AERMOD**	**Current AERMOD**	**MILDOS / Pasquill-Gifford Coefficients**	**MILDOS / Briggs Rural Coefficients**	**MILDOS / Briggs Urban Coefficients**
Lovett (NY)	TIMP3	-----	-42	-37	101	82	159
	DD4	-----	36	37	33	8	133
	DD5	-----	-23	-21	-16	-20	140
	DD6	-----	-7	-5	-34	-39	18
	DD7	-----	-15	-14	-52	-53	65
	DD8	-----	-2	0	-24	-25	130
	DD9	-----	-72	-69	-50	-50	25
	DD10	-----	-6	-6	-65	-64	109
	DD11	-----	-81	-78	-75	-75	7
Martins Creek (PA/NJ)	R1	-----	-47	-45	-79	-80	-41
	R2	-----	-33	-30	-78	-80	-33
	R3	-----	not available	not available	-83	-83	-37
	R4	-----	-2	0.9	-72	-76	-5
	R5	-----	-42	-39	-73	-76	-33
	R6	-----	-41	-39	-74	-77	-4
	R7	-----	-42	-40	-77	-79	-37
	R8	-----	-56	-54	-82	-83	-52
Westvaco (MD/VA)	R1	-----	-12	-10	-83	-83	-59
	R2	-----	-95	-93	-96	-97	-96
	R3	-----	-76	-75	-97	-97	-95
	R4	-----	-72	-70	-95	-96	-90
	R5	-----	-78	-76	-98	-98	-94
	R6	-----	59	58	-89	-89	-79
	R7	-----	-77	-75	-98	-98	-95
	R8	-----	-81	-79	-98	-98	-94
	R9	-----	-79	-77	-97	-98	-88
	R10	-----	-90	-89	-96	-96	-89
	R11	-----	-92	-91	-94	-94	-92

Table C.3. Percentage Difference Between AERMOD and MILDOS Values

Study Location	Receptor	MILDOS / Pasquill-Gifford Coefficients	MILDOS / Briggs Rural Coefficients	MILDOS / Briggs Urban Coefficients
Original Point Sources (gas)				
Baldwin (IL)	R1	68	71	399
	R2	134	138	541
	R3	596	598	1069
	R4	1296	1246	1893
	R5	346	345	827
	R6	150	153	550
	R7	46	49	292
	R8	11	15	170
	R9	58	61	469
	R10	463	468	889
Bowline (NY)	R1	-85	-85	2
	R2	-98	-98	-81
	R3	-96	-96	-58
	R4	-72	-72	52
Clifty Creek (IN)	R1	2	7	183
	R2	51	53	413
	R3	29	31	453
	R4	-13	-8	250
	R5	65	66	302
	R6	-1	2	280
		2	7	183
Lovett (NY)	TIMP3	221	190	313
	DD4	-3	-21	69
	DD5	6	1	202
	DD6	-30	-36	25
.	DD7	-44	-46	91
	DD8	-24	-26	129
	DD9	59	60	303
	DD10	-63	-62	122
	DD11	15	16	394

Study Location	Receptor	MILDOS / Pasquill-Gifford Coefficients	MILDOS / Briggs Rural Coefficients	MILDOS / Briggs Urban Coefficients
Martins Creek (PA/NJ)	R1	-61	-64	8
	R2	-68	-71	-4
	R3	not available	not available	not available
	R4	-72	-76	-5
	R5	-56	-61	10
	R6	-57	-62	58
	R7	-62	-65	5
	R8	-61	-63	4
Westvaco (MD/VA)	R1	-81	-81	-55
	R2	-41	-53	-34
	R3	-87	-87	-82
	R4	-84	-85	-67
	R5	-90	-92	-73
	R6	-93	-93	-86
	R7	-91	-94	-79
	R8	-89	-90	-72
	R9	-88	-91	-49
	R10	-60	-60	1
	R11	-37	-41	-16