Review of the Sasol Atmospheric Impact Report

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Acronyms and Abbreviations

AIR	Atmospheric Impact Report
Airshed	Airshed Planning Professionals (Pty) Ltd.
deg	degrees
DEA	Department of Environmental Affairs
EPA	United States Environmental Protection Agency
GAQM	US EPA Guideline on Air Quality Models
IOA	Index of Agreement
IHD	Integrated Hourly Dataset
K	Kelvin
km	kilometer
LCC	Lambert Conic Conformal
m	meter
MES	Minimum Emission Standards
m/s	meters per second
NAAQS	National Ambient Air Quality Standards
No- Obs	No Observations
NO_2	Nitrogen Dioxide
PDF	Probability Density Function
PM	Particulate Matter
$PM_{2.5}$	Particulate Matter less than 2.5 microns in diameter
PM_{10}	Particulate Matter less than 10 microns in diameter
RMSE	Root Mean Square Error
SO	Sasol’s Sasolburg Operations
SO_2	Sulfur Dioxide
SO_x	Oxides of Sulfur
WRF	Weather Research and Forecast

Limitations

This report summarizes work performed to date and presents the findings resulting from that work. The findings presented herein are made to a reasonable degree of scientific certainty and are based on the material provided to Exponent, Inc. (Exponent) by the client or by Airshed Planning Professionals (Pty) Ltd. of South Africa ("Airshed").

Exponent reserves the right to supplement this report and to expand or modify opinions based on review of any additional material that becomes available.

1 Introduction

Exponent has been retained by Sasol South Africa (Pty) Ltd. to conduct a peer review of the methodology used in dispersion modeling analyses conducted by Airshed Planning Professionals (“Airshed”) of emissions from the Sasol Sasolburg site. The modeling analyses were conducted to support an application for the postponement of certain Minimum Emission Standards (MES) that would otherwise apply to some sources at some Sasol facilities beginning on April 1, 2020. The modeling analyses are documented in the September 2018 Atmospheric Impact Report (AIR) prepared by Airshed and entitled “Atmospheric Impact Report Sasol Sasolburg Operations”. Modeling and associated data files were also provided to Exponent by Sasol and Airshed for our consideration and review.

The scope of the Exponent peer review includes review and comments on the following:

- Modeling techniques used in the dispersion modeling analyses and their appropriateness for the application;
- Prognostic meteorological data incorporated in the modeling;
- CALMET, CALPUFF, and CALPOST settings and model options;
- Analysis of background ambient air concentrations used in the modeling analysis
- Any obvious information gaps, omissions, or inaccuracies;
- Key assumptions and uncertainties.

The information used in our review was limited to the information in the Airshed report, the modeling and data files provided by Airshed, and additional meteorological data that we obtained. Note that our review did not include consideration or evaluation of the emissions data, source configuration data, or the comparison of predicted concentrations to ambient standards or to other ambient limits.

The files reviewed by Exponent were limited to those associated with Sasol’s Sasolburg Operations (SO). Similar files associated with other Sasol facilities that may be applying for a similar postponement of MES were not available for our review. Our review focused on the modeling analyses for sulfur dioxide (SO_2), nitrogen dioxide (NO_2), and particulate matter (PM).

1.1 Summary of Major Comments

The list below summarizes the most important comments from the peer review of the report and the modeling data files provided. Additional informational comments or comments of a less significant nature are provided in the main body of the report.

- Weather Research and Forecast (WRF) summary:
  - WRF generated fields show a positive bias in wind speed and a negative bias in wind direction when compared with the surface stations used in the CALMET modeling. We recommend that a review of the station siting be conducted to determine if siting issues are the cause of mismatches in wind speed and wind direction.
  - Agreement of the WRF fields with data from the OR Tambo meteorological station shows less wind bias and a better over-all agreement for wind direction.
  - While some values exceed the standard benchmarks used to evaluate WRF performance, the modeled fields still appear reliable and appropriate for air dispersion modeling. Some additional benchmark standards are provided which may be useful in characterizing the results.

- CALMET Summary:
  - The CALMET modeling used a partial No Observations (partial No-Obs) approach in which WRF meteorological fields are augmented by surface observations, but no upper air observations are included. Weighting parameters for the surface observations were set such that observed winds would have an influence out to 4 km from the observation location. There are times when these surface observations may be in disagreement with the WRF data fields. Disagreement in wind direction between values calculated by WRF and the surface observations can result in unrealistic flow patterns.
  - The use of small radius of influence parameters for the surface stations would greatly reduce the potential for artificial and unrealistic flow patterns.

- CALPUFF:
  - Gridded receptors were included using 5 as a nesting factor of the sampling gird. This produces elevations at gridded receptors spaced at 200 meter intervals that are interpolated from the original 1 kilometer CALMET grid. More precise receptor elevations could be achieved by using TERREL to extract elevations at discrete receptors at 200 meter intervals based on the available higher resolution terrain data. If conclusions are being drawn based on results at the gridded receptors, it would be advisable to use a grid with resolution higher than 200 m in the near field.
  - The CALPUFF modeling used a computational grid with dimensions of 50 km by 50 km. The CALPUFF sampling grid has the exact same dimensions. It should be noted that grid points near the edge of the sampling domain may not see the full influence of recirculation. Since a larger CALMET domain was run, a larger computational grid would have better allowed for calculation of recirculation impacts at the edge of the domain.

2 Choice of Modeling Techniques

The Republic of South Africa Department of Environmental Affairs ("DEA") has developed "Regulations Regarding Air Dispersion Modelling" and an associated "Code of Practice for Air Dispersion Modelling in Air Quality Management in South Africa" ("Code of Practice"). The Code of Practice is considered a supplement to the air dispersion modelling regulations developed under the Air Quality Act ("Act"). The air dispersion modelling regulations and Code of Practice apply to a wide range of regulatory activities. The current version of the Regulations Regarding Air Dispersion Modelling was issued July 11, 2014 and includes the Code of Practice as Appendix A. The Code of Practice recommends the use of specific dispersion models and also provides guidance on modelling procedures.

The methodology used in the AIR is a Level 3 assessment as defined in the Code of Practice. A Level 3 analysis uses sophisticated modeling techniques in cases where a detailed understanding of the time and space variation of impacts is needed. The Code of Practice states that Level 3 assessments may be used to "evaluate air quality consequences under a permitting or environmental assessment process for large industrial developments that have considerable social, economic and environmental consequences". Level 3 analyses may include consideration of variable wind and turbulence fields, causality effects, curved trajectories, recirculation, stagnation/calm wind conditions, fumigation, and chemical transformation. This type of modeling requires more detailed meteorological and geophysical data than that required by Level 1 or Level 2 assessments.

Airshed considered a variety of models recommended in the Code of Practice and provided a detailed justification in its draft report for the use of the CALPUFF model (Scire et al., 2000) as the Level 3 model for this study. The Code of Practice recommends the use of CALPUFF in complex modelling situations, especially those involving non-steady-state flows that may occur during stagnant or near stagnant conditions and for other local circulations that may develop in rugged terrain and at water/land interfaces. CALPUFF is well suited for the types of industrial sources and areas of interest in this study. CALPUFF can provide estimates of cumulative impacts from a variety of sources over a relatively large area. The model contains algorithms for assessing near-field effects, such as building downwash, transitional plume rise, and momentum rise, as well as far-field effects such as chemical transformation and deposition. When combined with three-dimensional meteorological data from a numerical weather prediction model (the Weather Research and Forecasting [WRF] mesoscale model in this study) and surface-based observations, the data requirements for a proper assessment with CALPUFF are satisfied.

Exponent agrees that the selection of the CALPUFF model is appropriate for this study (i.e., to predict impacts of emissions from the Sasol Sasolburg site on nearby communities). Exponent also agrees that use of the CALPUFF model for this study with three-dimensional meteorological fields generated by CALMET is consistent with applicable regulatory modeling guidance.

3 WRF Meteorological Data

3.1 WRF Model Setup

The WRF data set used in the CALPUFF modeling assessment was generated by Lakes Environmental. The WRF model grid resolution in the analysis is 4 km with 34 vertical levels using a Lambert Conic Conformal (LCC) grid. The original model simulations included 69 x 69 grid cells, and the 3D.DAT files are based on a subset with 55 x 55 grid cells. This would indicate that all of the provided WRF data are likely at least several grid cells from the edge of the original model nest and free of any edge effects.

The use of 34 vertical layers is reasonable. In the current application, the first layer is centered at approximately 10 meters with 4 layers being located within 100 meters above the surface. These lowest layers provide sufficient resolution to define 10-meter level winds and the vertical temperature profiles.

3.2 WRF Evaluation

Table 1 shows a set of generally accepted benchmarks for WRF performance statistics for wind speed, wind direction, and temperature.[1] These benchmark values are designed to represent the bulk model performance over the entire modeling domain and modeling period and are computed as an average over all observations used in the analysis. These benchmarks are not intended as pass/fail criteria but provide a method of characterizing the mesoscale model performance relative to available observational data. Calculated differences for mean bias are based on predicted minus observed values, so that a positive bias indicates over-prediction by WRF. In Table 1, IOA stands for “Index of Agreement” and RMSE refers to “root mean square error.”

[1] See Emery (2001), Tesche et. al. (2001), and Wilmott (1981) for information on performance benchmarks.

Table 1 Benchmarks for WRF Model Evaluation

	IOA	Mean Bias	RMSE	Gross Error
Wind Speed (m/s)	≥ 0.6	≤ ±0.5 m/s	≤ 2 m/s	-
Wind Direction (deg)	-	≤ ±10 deg	-	≤ 30 deg
Temperature (deg K)	≥ 0.8	≤ ±0.5 K	-	≤ 2 K
Humidity (g/kg)	≥ 0.6	≤ ±1 g/kg	-	≤ 2 g/kg

The AIR presents a pair of performance assessments for WRF data compared individually with two stations located within the CALMET modeling domain (OR Tambo and Eco Park). The results of these analyses are summarized in Table 2.

The site identified as OR Tambo represents meteorological data collected at the international airport located in Johannesburg. As noted in the text of the AIR, data quality at this station is generally expected to be good. It should also be noted that OR Tambo was likely an observation station included in the WRF analysis conducted by Lakes Environmental. WRF employs a nudging process where model fields are pushed towards observational data. The WRF model will not force the output to exactly match observations, but the observations will influence the resultant WRF meteorological fields. As a consequence, it is expected that model performance will be better at OR Tambo than at stations that were not included in the WRF modeling.

The analysis at OR Tambo shows that gross error for wind direction and bias and gross error for temperature fall outside of the benchmarks summarized in Table 1. A wind rose presented in the AIR for OR Tambo shows good agreement between observed and predicted winds. Performance on the wind direction statistics is slightly worse at Eco Park with a bias value which falls outside of the benchmark range.

Table 2 WRF Performance for OR Tambo and Eco Park as Summarized in the AIR

	IOA	Mean Bias	RMSE	Gross Error
OR Tambo				
Wind Speed (m/s)	0.60	0.05	1.55	
Wind Direction (deg)		0.39		36.26
Temperature (K)	0.84	-1.27		2.22
Humidity (g/kg)	0.6	-0.54		1.11
Eco Park				
Wind Speed (m/s)	0.64	0.41	1.72	
Wind Direction (deg)		-18.48		46.76
Temperature (K)	0.88	-0.81		2.27
Humidity (g/kg)	0.56	0.47		1.20

In order to supplement this evaluation, we prepared an analysis of the six stations included in the CALMET modeling. The benchmarks summarized in Table 1 are conventionally applied against all available stations within a region, so it is beneficial to consider comparisons at as many available stations as possible. Observed and predicted wind roses for the six stations are presented in Figure 1 through Figure 6.

The wind roses for observed and predicted winds for these stations are not in as close agreement as those for OR Tambo. This is not unexpected, since these stations were likely not included in the WRF simulations. Overall, these wind rose comparisons show some similarities and some differences. There is a noticeable positive wind speed bias in the WRF data compared with the observations. Additionally, the frequency of winds in some sectors is not well matched.

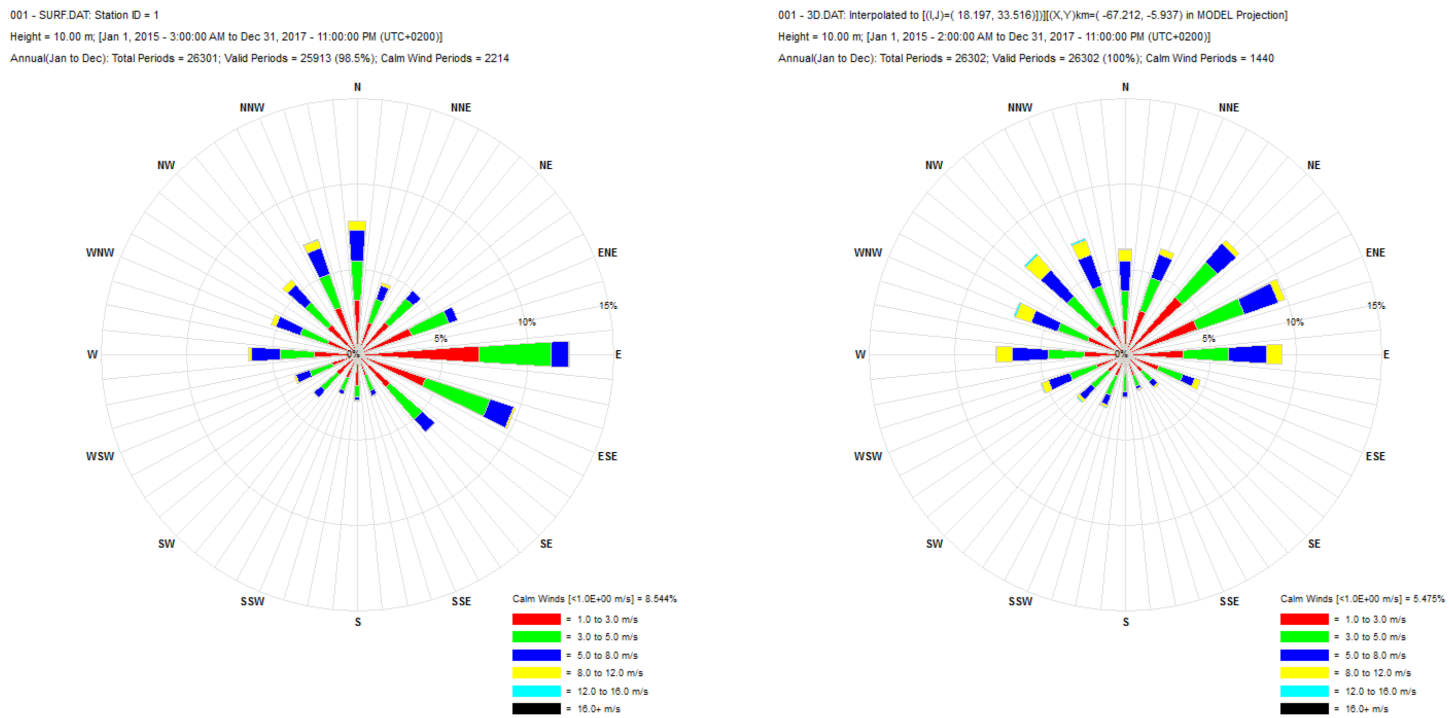

Figure 1 Wind rose for Observed (left) and WRF modeled (right) winds at CALMET Surface Station 1.

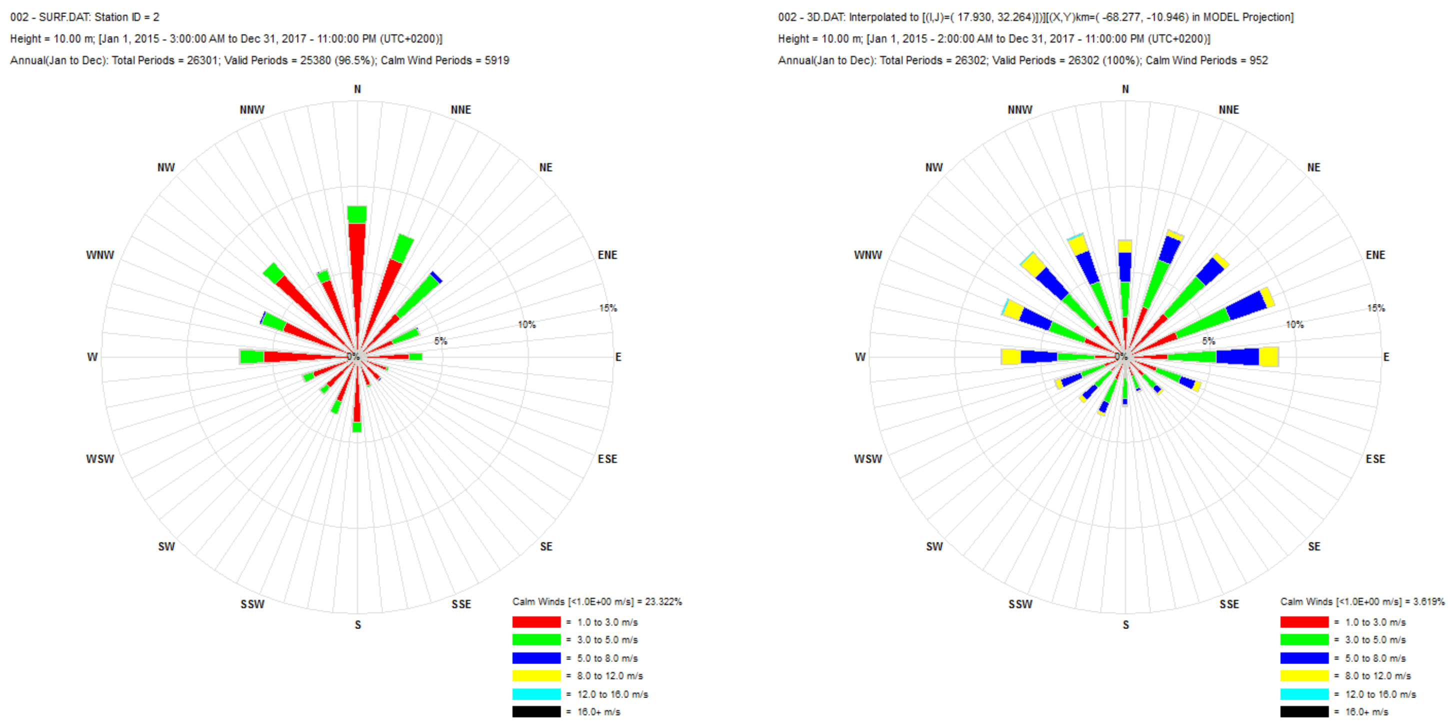

Figure 2 Wind rose for Observed (left) and WRF modeled (right) winds at CALMET Surface Station 2.

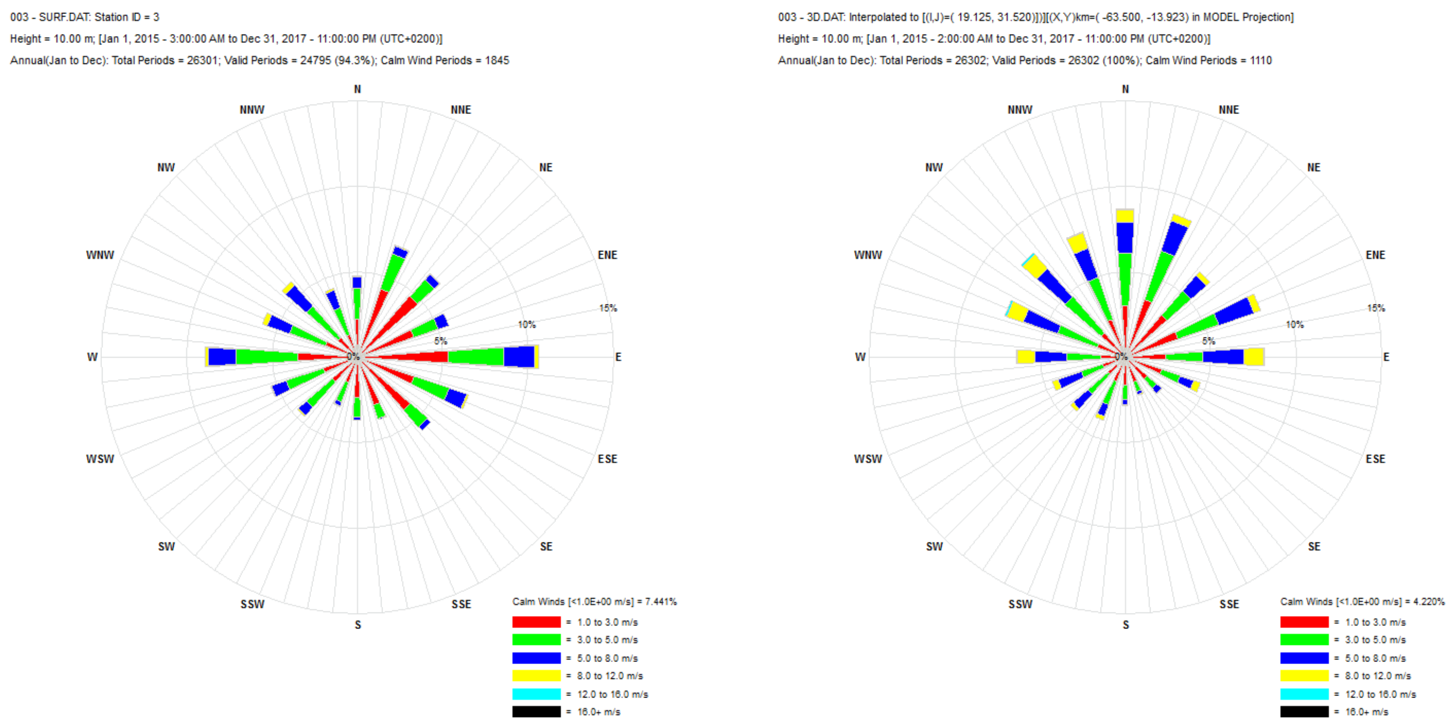

Figure 3 Wind rose for Observed (left) and WRF modeled (right) winds at CALMET Surface Station 3.

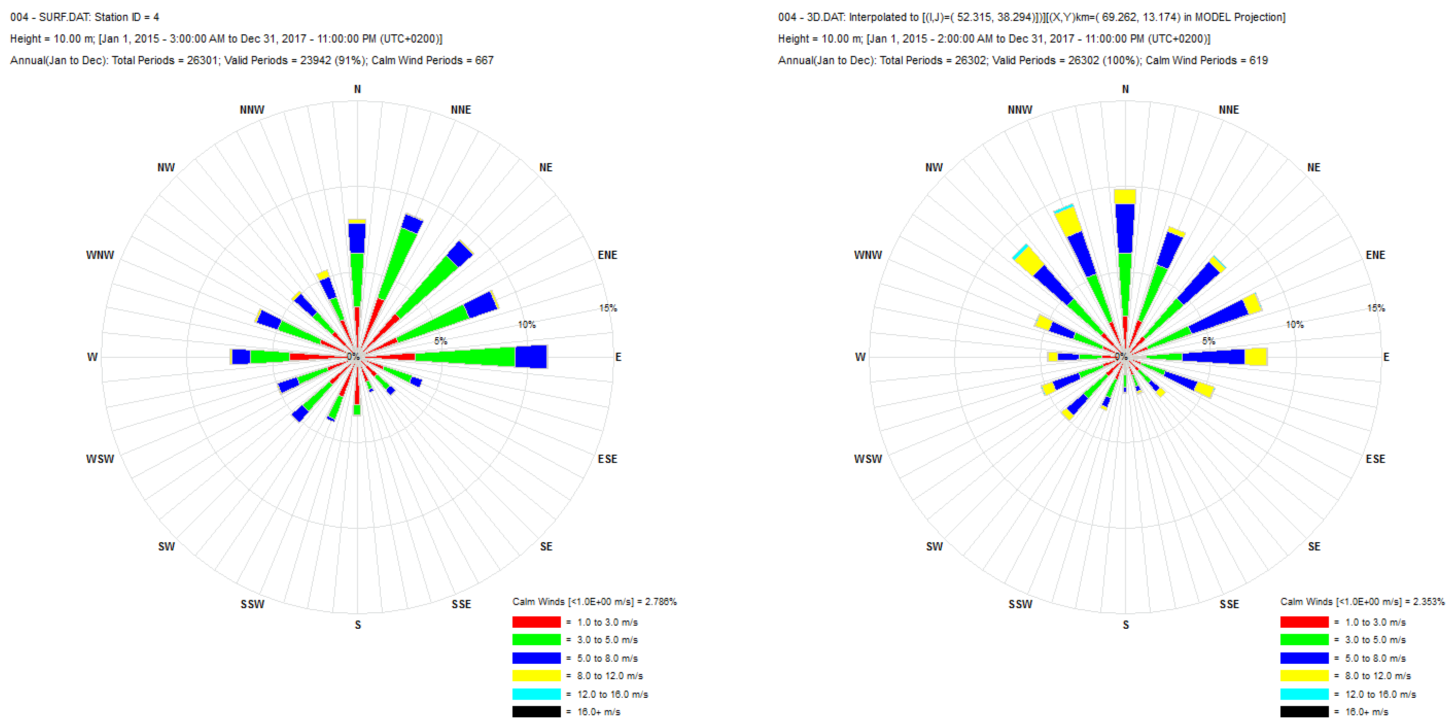

Figure 4 Wind rose for Observed (left) and WRF modeled (right) winds at CALMET Surface Station 4.

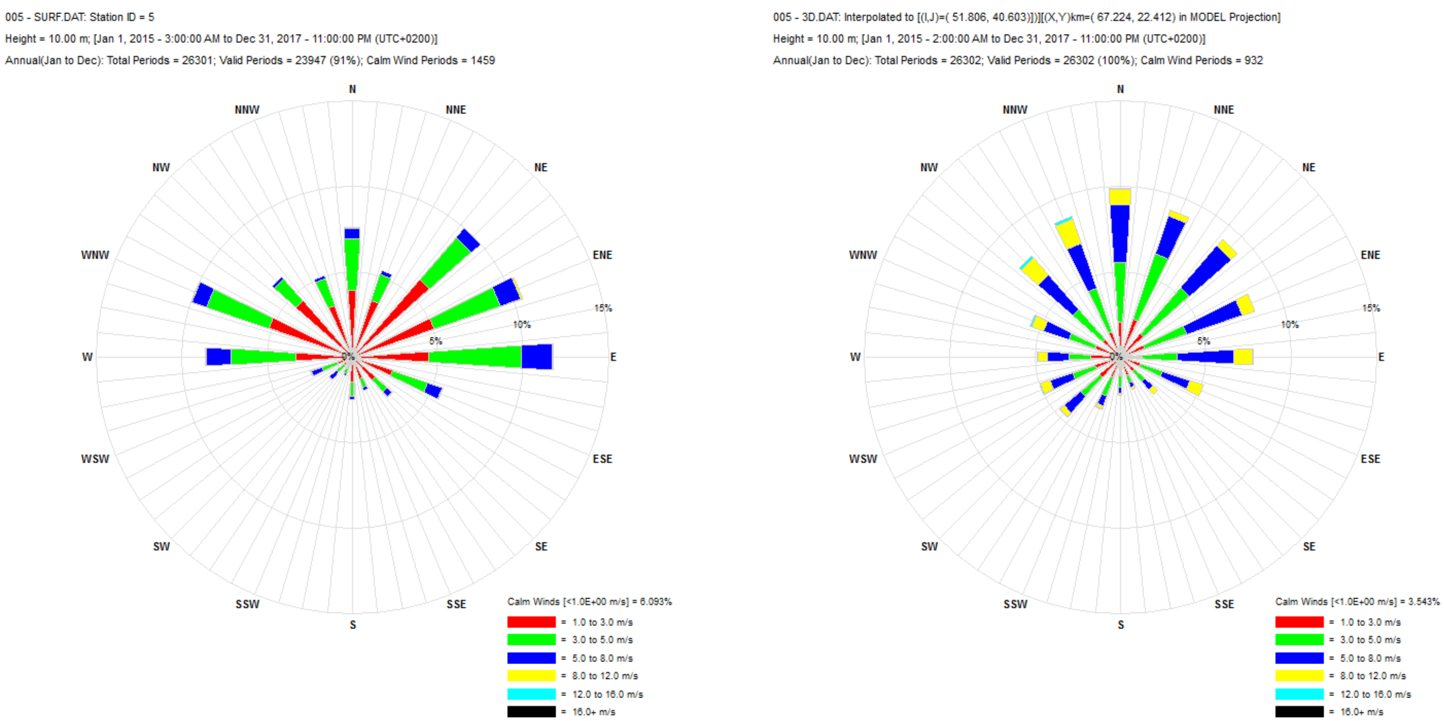

Figure 5 Wind rose for Observed (left) and WRF modeled (right) winds at CALMET Surface Station 5.

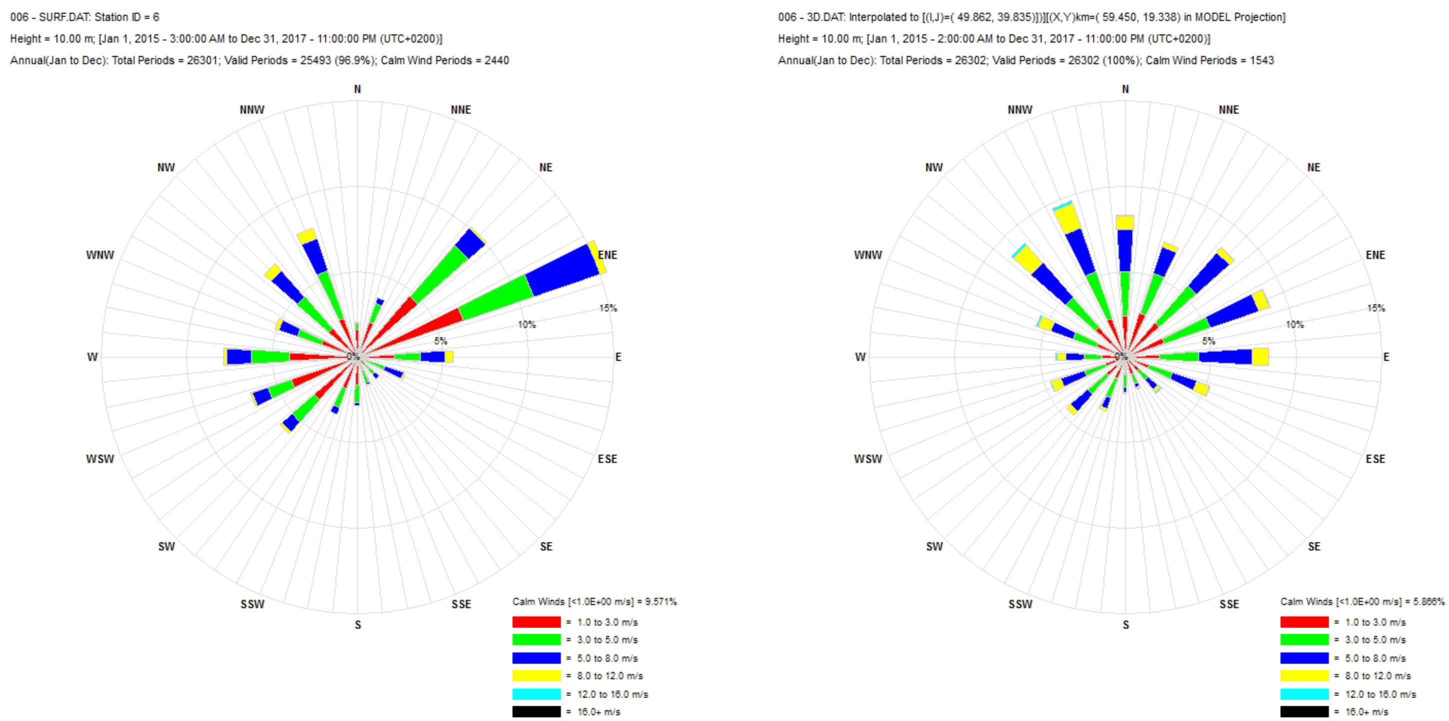

Figure 6 Wind rose for Observed (left) and WRF modeled (right) winds at CALMET Surface Station 6.

The most dramatic difference occurs for the station labeled as Station 2 in the CALMET simulation (AJ Jacobs) which is located in the Sasolburg CALPUFF domain. This station shows very light observed winds when compared with the WRF simulation and when compared with the two stations surrounding it (Station 1 and Station 3). Given the close proximity of these three stations to each other and the lack of any dramatic terrain features in that region, the reported frequency of light winds at Station 2 looks questionable. We suggest that the wind data recorded at Station 2 be reviewed to determine if the data are reliable. Appendix I of the AIR indicates that this station may be influenced by nearby trees and building structures. As a result, we have not incorporated this station in our statistical analysis.

The performance statistics calculated based on the remaining five observation stations are summarized in Table 3 and Table 4. These data can be considered in conjunction with the results prepared by AirShed for OR Tambo in order to evaluate the WRF model performance. The results at the stations used in CALMET show slightly higher wind speed bias and wind speed RMSE compared to the results at the OR Tambo. They show a similar gross error in wind direction, but less wind direction bias. Given the site limitations often present when installing a meteorological station, it is possible that less than perfect exposure may be an issue for some of these sites. This might explain the larger wind bias at these sites. We recommend that a review of the station siting be conducted to determine if siting issues are the cause of mismatches in wind speed and wind direction.

Overall, while some of the presented statistics fall outside of the performance benchmarks presented in Table 1, the results appear reasonable for the intended air quality modeling purposes. The benchmarks are not meant to represent a bright line between acceptance and rejection of the predicted WRF fields, and some exceedances can be considered to be acceptable. In addition, in recent years, other WRF metrics have been accepted by various regulatory groups in the United States (U.S.)[2] Recent modeling protocols for analyses in the western and Great Lakes regions of the U.S have incorporated the use of different performance metrics for complex areas, described as areas with more complex terrain and more complicated

[2] See Talgo et al. (2015) and LADCO (2018)

meteorological conditions. While the region modeled using WRF for this application is not as complex as the western United States, it does have some significant terrain features. These alternate WRF performance metrics could be referenced or used, if appropriate, for the AIR to provide additional context to the WRF evaluation. Table 5 lists the alternate benchmarks for complex areas that differ from those in Table 1.

Table 3 Statistics of WRF model performance for wind speed and wind direction

	Wind Speed			**Wind Direction**	
	IOA -	Mean Bias m/s	RMSE m/s	Mean Bias deg	Gross Error deg
Benchmark	≥ 0.6	≤ ±0.5	≤ 2	≤ ±10	≤ 30
2015					
Mean	0.58	1.33	2.31	-6.37	44.13
Daily Minimum	0.17	0.26	1.01	-58.01	14.07
Daily Maximum	0.92	3.39	4.21	29.40	98.34
2016					
Mean	0.57	1.44	2.34	-6.18	44.36
Daily Minimum	0.18	0.04	1.01	-54.77	15.44
Daily Maximum	0.92	3.77	5.02	37.22	87.81
2017					
Mean	0.57	1.48	2.30	-6.10	43.22
Daily Minimum	0.24	-0.13	0.85	-46.38	11.28
Daily Maximum	0.89	3.59	4.62	29.33	81.54

Table 4 Statistics of WRF model performance for temperature and relative humidity

	Temperature			Specific Humidity		
	IOA	Mean Bias K	Gross Error K	IOA	Mean Bias g/kg	Gross Error g/kg
Benchmark	≥ 0.8	≤ ±0.5	≤ 2.0	≥ 0.6	≤ ±1.0	≤ 2.0
2015						
Mean	0.94	0.36	2.04	0.59	0.36	1.10
Daily Minimum	0.56	-2.81	1.04	0.11	-2.68	0.25
Daily Maximum	0.99	3.26	4.14	0.97	3.79	3.94
2016						
Mean	0.91	0.02	2.26	0.57	0.33	1.09
Daily Minimum	0.35	-2.74	1.08	0.03	-2.80	0.18
Daily Maximum	0.98	3.75	4.37	0.96	3.58	3.85
2017						
Mean	0.92	0.67	2.16	0.50	1.14	1.58
Daily Minimum	0.21	-1.70	0.85	0.00	-2.57	0.27
Daily Maximum	0.99	4.27	4.83	0.95	10.65	10.65

Table 5 Alternate Benchmarks for WRF Model Evaluation for Complex Areas

	IOA	Mean Bias	RMSE	Gross Error
Wind Speed (m/s)	-	≤ ±1.5 m/s	≤ 2.5 m/s	-
Wind Direction (deg)	-	-	-	≤ 55 deg
Temperature (K)	-	≤ ±2.0 K	-	≤ 3.5 K
Humidity (g/kg)	-	-	-	-

4 CALMET Modeling Options

This section discusses the CALMET model option settings in the CALMET.INP file used in the modeling for this study. We provide recommendations for the use of different model options where appropriate.

CALMET simulations were performed for the three year period, 2015 through 2017, with the modeling period divided into four runs. Each CALMET input file references six (6) surface meteorological stations. The remainder of the meteorological data is supplied by the WRF simulations described in Section 3. CALMET version v6.5.0 was used to perform the simulations. This represents the most recent version of the code. The Code of Practice specifically references an earlier version of CALMET (Version 6.334) but also notes the importance of using a code version which is free of known bugs. CALMET Version 6.5.0 fixes several known bugs in the prior code and, as a result, we recommend and agree with its use for this application.

There are individual hours at the beginning and at the end of the modeled time period which are not included in the modeling. We presume this is due to issues related to the time zone off-set.

CALMET includes default values for many model parameters and switches. Although the default values may not be appropriate in all circumstances, a review of non-default switches selected provides an initial screening of model selections. Table 6 summarizes all non-default values used when running CALMET. The following sections detail some additional suggestions and comments regarding the set-up of the CALMET modeling.

Table 6 Summary of CALMET Options Selected That Differ from Default Values

Variable	Description	Default Value	Value Used in Modeling	Comments
NOOBS	No Observation Mode	0 (Full Obs)	1 (No Upper Air Obs)	Appropriate with the use of WRF prognostic data.
IEXTRP	Extrapolate surface wind observations	-4	1	Appropriate with the use of WRF prognostic data. Will lessen the impact of surface observations.
IPROG	Use gridded prognostic wind field model output fields	0	14	Appropriate with the use of WRF prognostic data.
IRHPROG	Use gridded prognostic relative humidity output fields	0	1	Appropriate with the use of WRF prognostic data.
ITPROG	Use 3D temperature from observations or from prognostic data	0	1	Appropriate with the use of WRF prognostic data.

4.1 Selection of CALMET Critical Parameters

The variables R1 and RMAX1 are used to control the radius over which surface wind observations will be considered. R1 represents the distance at which the surface observations will be weighted equally with the Step 1 wind field. RMAX1 represents the maximum radius of influence for the surface observations.

In this application, RMAX1 was set to 4.0 km and R1 was set to 2.0 km. This means that the surface observed wind speed and direction will have influence only out to 4.0 km. Given the 4.0 kilometer resolution of the WRF simulations, this is a reasonably small region of influence for the surface observations. However, in cases where the surface observed wind direction is substantially different from the WRF predicted wind direction, the CALMET model will attempt to resolve these differences and may produce some anomalous wind flow patterns at grid points within 4.0 kilometers from the surface station.

As was noted in Section 3, there are hours when the WRF wind direction and the observed wind direction differ by a significant amount. This may be due to local effects at the monitoring site, data quality, or a difference in timing between the observed and modeled fields. An example hour is shown in Figure 7. In this example, WRF has generated a wind flow which is generally out of the north across the model domain. The wind direction measured at the three surface observation stations is from the southwest or south. CALMET has attempted to resolve these two directions, and the result is a region of convergent flow and very light or stagnant winds surrounding the observation stations. This flow pattern is artificial and may have an impact on the predicted concentrations during this hour. It is difficult to determine how these types of wind fields impact the overall conclusions of the modeling.

A potential solution is to limit the radius of influence for the surface stations to a very small distance (for example 0.01 km). This will result in the wind speed and direction being entirely or almost entirely defined by the WRF model fields. This approach would be valid if the distribution of winds produced by the WRF model is determined to reliably reproduce the actual wind distributions over the model period. Due to the statistical nature of air quality standards, the modeled meteorological fields do not need to exactly match observations in time but do need to be free of any large biases and represent a realistic distribution of conditions. Based on the WRF analysis, the prognostic data used in this analysis meet those requirements.

One additional critical parameter set in the modeling is the value for TERRAD. This represents the region over which terrain features will have influence on the wind fields. There is no default value for TERRAD and it should be selected based on an inspection of the terrain within the domain. The selected value of 4.0 kilometers appears appropriate for this domain and application.

Table 7 Summary of Critical CALMET Variables

Variable	Description	Value Used in Modeling
TERRAD	Radius of influence of terrain features	4
RMAX1	Maximum radius of influence in the surface layer	4
R1	Distance of equal weight between observations and WRF fields in the surface layer	2

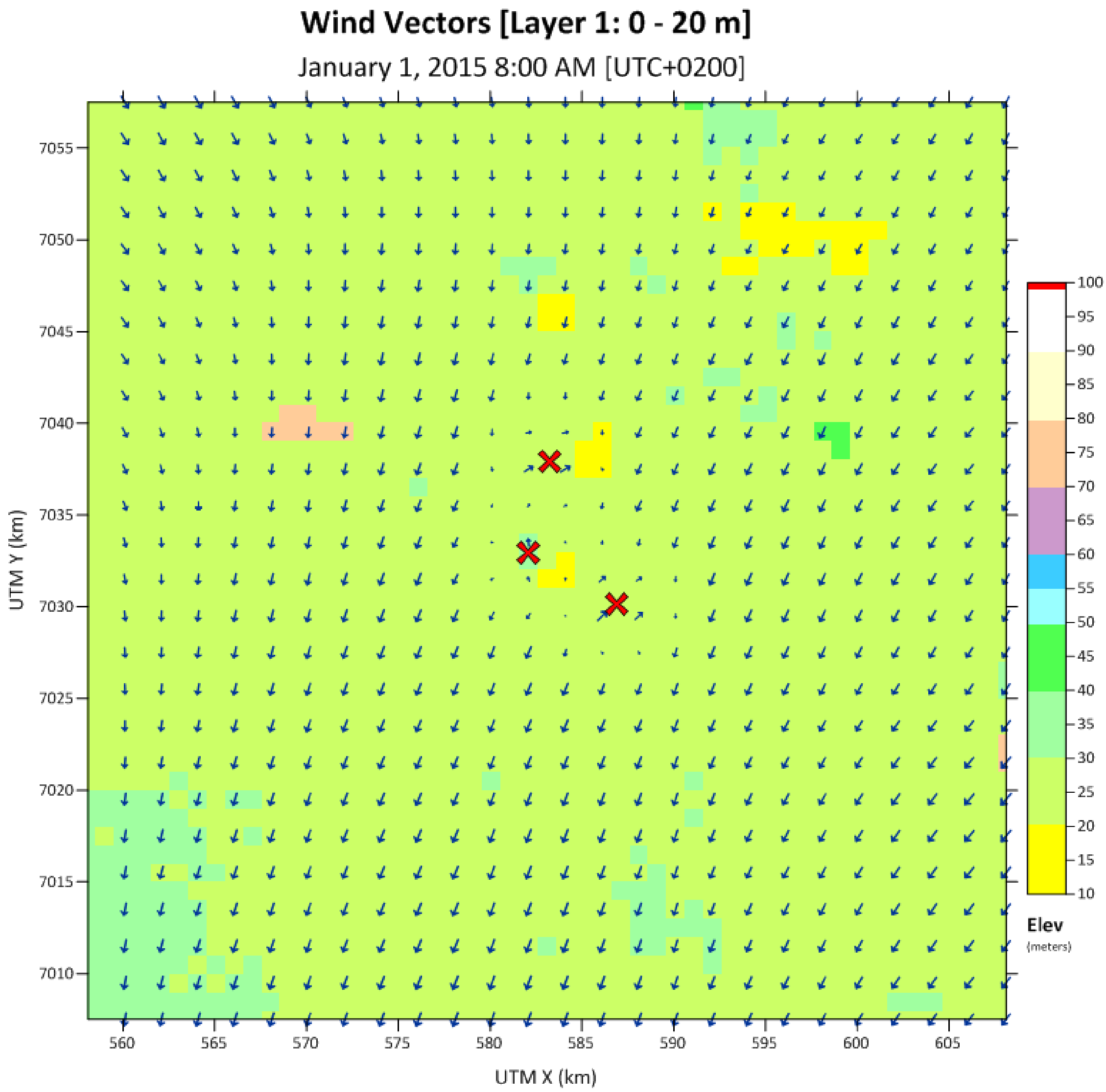

Figure 7 CALMET generated 10 meter wind vectors demonstrating influence of inconsistent observation and WRF wind fields.

5 CALPUFF Model Options

CALPUFF version 7.2.1 was used. This code represents the most up-to-date release of the model from the CALPUFF website and incorporates several important bug fixes found in the prior version (Version 6.42). We do note that Code of Practice recommends use of Version 6.42 which was the current release at the time of publication. It also notes the importance of using the more recent code version which fixes any noted coding errors. We believe that the use of version 7.2.1 is appropriate for this application and consistent with the goals of the Code of Practice.

CALPUFF includes default values for many model parameters and switches. Although the default values are not appropriate in some circumstances, a review of non-default switches selected provides an initial screening of model selections. Table 8 identifies and summarizes the non-default values used in this analysis. In most cases, the non-default values selected are appropriate given the goals of this analysis. The following sections provide some suggestions and comments on specific parameters used in the CALPUFF modeling.

Table 8 Summary of CALPUFF Options Selected that differ from Default Values

Variable	Description	Default	Selected Value	Comments
MDISP	Method used to compute dispersion coefficients	3 (PG/MP coefficients)	2 (Internally calculated)	The use of internally calculated dispersion coefficients is appropriate. This option should be used in conjunction with setting MPDF=1 for convective conditions.
MPDF	Use of probability density function under convective conditions	0 (No)	1 (Yes)	The use of PDF is appropriate when internally calculated dispersion coefficients are being used.
MPARTLBA	Partial plume penetration of elevated inversion modeled for buoyant area sources	0 (No)	1 (Yes)	Use of partial plume penetration is recommended. See Section 5.3 below for additional discussion
MESHDN	Mesh density of modeled sampling receptors	1	5	Use of mesh density to generate sampling receptors results in simplified terrain resolution. See Section 5.1 below for additional discussion.
MXNEW	Maximum number of puffs released during one time step	99	25	Use of default values is recommended. See Section 5.4 below for additional discussion.
MXSAM	Maximum number of sampling steps for one puff during one time step	99	10	Use of default values is recommended. See Section 5.4 below for additional discussion.
CNSPLITH	Minimum concentration required for puff splitting	1.0E-7	0.0	Non default value will not cause any issues.
MREG	Check for regulatory values	1 (Yes)	0 (No)	Checks for regulatory values are not relevant for this application.

5.1 Receptors

The computational grid specified in the CALPUFF modeling file covers a 50 km x 50 km square region with a grid resolution of 1 kilometer. The gridded receptors are defined using a sampling grid which covers a subset of this range with MESHDN set to 5, resulting in grid points spaced at 200-meter intervals. Sampling grid receptor elevations are computed within CALPUFF based on the original CALMET 1 kilometer resolution terrain data. This 1 kilometer resolution limits the precision of the elevation estimates, especially in areas of complex terrain. The use of discrete receptors would allow higher resolution terrain elevations to be extracted directly from the original digital elevation model files.

We also note that a receptor spacing of 200 meters may not be sufficient to identify and resolve peak concentrations in the near field. To the extent that the gridded receptors will be used to define peak impacts, additional gridded receptors with a spacing of 50 meters may be needed along the fence line and in the near field. A receptor spacing of 50 meters would also be consistent with recommendations in the Code of Practice.

There is some inconsistency regarding the number of discrete receptors discussed in the AIR. Section 5.1.8 refers to 52 sensitive receptors, while Table K-1 in Appendix K shows 42 receptors.

We also note that the modeling files that were provided for review contain 93 discrete receptors along with the 200 meter spaced gridded receptors. Predicted concentrations at the additional discrete receptors and at gridded receptors are not discussed in the AIR beyond their use to generate contour plots. We assume that this is due to the intent to identify potential concentrations and changes in concentrations only at the sensitive receptors.

5.2 CALPUFF Computational Grid

In the CALPUFF modeling, both the computational and sampling grid are set to matching 50 kilometer square domains. The sampling domain represents the receptors where concentrations are calculated based on the modeled puff locations, dimensions, and mass. The computational grid represents the domain over which puffs are tracked. Once puffs move off the computational grid, their mass is lost. Typically the computational grid should be set to be larger than the sampling grid in order to allow for recirculation. Some gridded receptors are near the boundary of the computational grid. As a result, concentrations predicted at these receptors may not fully account for the possible effects of recirculation. This issue is not a significant factor for receptors close to the project site. The 42 discrete receptors identified in Appendix K are all sufficiently far from the model boundary that any edge effects should be minimal.

5.3 Partial Plume Penetration

CALPUFF includes the ability to model elevated plumes which partially penetrate an inversion at the top of the mixed layer. The mass which is above the inversion is not available to mix down to the ground. This option is a default in CALPUFF for both points and buoyant area sources and is recommended in order to accurately calculate ground level concentrations, especially in the case of tall stacks or sources with significant plume rise. This modeling study used partial plume penetration for point sources, but turned off the partial plume penetration option for buoyant area sources. This means that the plume from a buoyant area source would be determined to be entirely above or entirely below the top of the mixed layer. The samples of files reviewed in this evaluation do not contain any buoyant area sources, so this parameter is of no impact for those sources. If other modeling files do contain buoyant area sources, a more robust and accurate result would be achieved by using the partial plume penetration option for all sources.

5.4 Puffs and Sampling Steps

The CALPUFF model includes several switches which control the number of puffs released and how those puffs are tracked during a model time step. In this CALPUFF application, two of those variables (MXNEW and MXSAM) were altered from the default values. MXNEW controls the maximum number of puffs released during a time step. The default value is set to 99, which is intended to be equivalent to “unlimited”. Similarly, the variable MXSAM sets the maximum number of sampling steps during one time step. Again the default value is set to a high value of 99. The values used in this application are 25 for MXNEW and 10 for MXSAM.

CALPUFF will automatically calculate the number of puffs and number of sampling steps needed on each hour. If the calculated values are below the set limits, then the limits will have no impact on the runs. As a general practice, it is recommended that the higher default values be used. The use of significantly lower limits can produce some run time savings, but only at the cost of model resolution and accuracy.

5.5 Deposition Parameters

CALPUFF allows the definition of wet scavenging coefficients for both liquid and frozen precipitation. The values being used are appropriate for the species listed. We do note that in one of the input files (BI23.INP), wet scavenging coefficients for frozen precipitation are not included. This will result in wet removal being neglected during times of frozen precipitation. We anticipate that this represents few, if any, hours in the modeling period and even if a limited number of periods are being neglected, it results in conservative (high) predictions of airborne concentrations.

For dry deposition of particles, mean diameters of 0.48 µm have been set for the three particle species. These values are generally considered appropriate for both sulfate and nitrate particles. For PM_{10}, the appropriate diameter will depend on the emission source. While combustion sources will tend to produce relatively small particles, a diameter of 0.48 µm likely still represents a conservatively small particle size. Small particles will result in less removal and conservatively high airborne concentrations. We judge this to be an appropriate assumption to be used in this modeling analysis for the purpose of calculating airborne concentrations.

Section 5.2.2 of the Sasolburg AIR includes an analysis of dustfall. The calculations presented are described as deposition rates based on the simulated PM concentrations and a stated settling velocity for 10 µm particles. This analysis appears to have been conducted external to the CALPUFF modeling. Because the analysis is external to the model and was not part of the modeling files reviewed by Exponent, we are not able to provide a final opinion on the appropriateness of the approach. However, there are a few important considerations that should be mentioned. First, the airborne concentrations calculated by CALPUFF already account for wet and dry removal of particulate matter. As a result, the modeled puffs have already undergone wet and dry depletion, and recalculating deposition from those depleted concentrations will under estimate deposition rates. Additionally, CALPUFF is currently configured to calculate and save deposition. This calculation is based on a much smaller estimate of mean particle size (0.48 µm) which should be conservative for airborne concentrations but potentially not conservative for deposition. The approach being used in the AIR may represent an appropriate screening level analysis, but only if precautions are taken to ensure it is adequately conservative.

6 Ambient Monitoring Data and Background

The AIR includes various summaries of ambient data measured at various air quality monitoring stations. As part of our review, we spot checked the determination of average concentrations and various ranked values at some stations by independently processing the hourly concentration that had been provided. We also checked the Excel calculations that were used.

In general, the values that were checked were consistent with those in Tables 5-11 through 5-18 of the AIR We note a fine point regarding the determination of specific percentile concentrations. The Excel function used ("PERCENTILE") incorporates the use of interpolated values in its calculations. Although the calculated value provided by this Excel function will typically be approximately correct, it will not necessarily correspond to an actual observation. In other jurisdictions (in the U.S., for example), specific concentrations are based on a particular ranked value that is a function of the number of observations.[3]

The tables and figures in Section 5.1.5.4 of the AIR provide a wealth of information concerning measured concentrations. The time variation plots are useful for illustrating how average monitored concentrations vary diurnally and by day. However, the use of "normalized" concentrations obviously limits information on absolute pollutant concentrations. The text does not explain how the concentrations were normalized.

The polar plots of concentrations at each monitor also provide valuable information concerning the dependence of monitored concentrations on wind direction and wind speed. However, the size of the plots and the difficulty of reading some of the labels detract from their usefulness. Larger figures would likely be more effective in conveying the desired information.

The determination of background concentrations is not fully documented in the AIR or in the files that were provided for review. Language in Section 9(d) of the AIR states that background values correspond to observed concentrations when predicted impacts at a monitoring site are

[3] See, for example, the following tables in 40 CFR Part 50: Table 1 in Appendix N for $PM_{2.5}$; Table 1 in Appendix S for NO_2; and Table 1 in Appendix T for SO_2.

near zero. Language in Tables H-1 and H-2 indicate that a threshold of 0.1 micrograms per cubic meter ($\mu g/m^3$) was used to determine periods when predicted impacts at a monitoring site were near zero.

It is not documented how background concentrations were determined for use in later National Ambient Air Quality Standards (NAAQS) compliance demonstrations, and files needed to verify background concentrations listed in Tables H-1 and H-2 were not provided.

An associated uncertainty is when background values are incorporated in various tables and figures. We assume or infer that the tables and figures in Section 1.8 of the AIR include background concentrations. Similarly, we assume that the concentrations in Equation 1 used to determine percentage changes in concentration include background. However, we were unable to verify this based on the information provided. While the evaluation of predicted concentrations relative to ambient standards is outside the stated scope of our review, we suggest that the AIR text provide greater clarity about when background concentrations are included.

7 Post Processing

Post processing involved the application of CALSUM to combine CALPUFF generated concentration files, POSTUTIL to scale and combine the primary and secondary particulate matter species, and CALPOST to calculate ranked 1-hour and 24-hour average concentrations. The CALPOST, POSTUTIL and CALSUM input files provided to us were reviewed to determine the model option settings that were used. The format and use of these files appear appropriate for this application.

Certain aspects of the post processing appear to occur outside of the standard CALPUFF model codes. For example, there are output files which are labeled as being 99th percentile values both in the filename and in the header documentation. While these appear in a typical CALPOST output format, they are not produced by CALPOST. The notes provided with the modeling files indicate that various files are produced by CALPUFFView which is an add-on GUI for the CALPUFF model. Apparently CALPUFFView will over-write some input and output files and appears to do some additional re-labeling of files or calculations. We assume for example, that the 99th percentile file represents a specific ranked value (for example the 88th highest for 1-hour concentrations). A limited number of spot checks confirms that the calculation has been performed as expected.

8 Uncertainties

Appendix I of the AIR identifies the primary areas of uncertainty relevant to this modeling study. In particular, it reviews uncertainties in the observed meteorological data, modeled WRF fields, source emissions data, and ambient air quality monitoring data. These data elements represent the most important sources of uncertainty in the model inputs and are well described in the AIR. The data used in the AIR appear to be sufficient and representative for the purposes of the study, and the uncertainties are typical for regulatory evaluations.

The AIR notes that uncertainty in the model results also includes uncertainty based on the use of computational models to represent atmospheric processes that are, by their nature, highly chaotic and variable. In order to assess the reliability and performance of the modeling process, the AIR included a comparison of modeled and monitored concentrations using a fractional basis method. This is an appropriate method to use for model evaluation purposes. The modeled values used in the comparison included a component for background air quality concentrations. Including background in the comparison is appropriate in this context.

The fractional bias analyses showed that the model results were within a factor of two of the observed values, a level of performance that is generally considered to be acceptable for analyses conducted for regulatory purposes. The comparisons were made at specific monitors that were matched in space but not in time. Matching concentrations in time and space is more difficult and generally not required for regulatory models.

We note that Appendix I references the 2005 version of the EPA Guideline on Air Quality Models (GAQM) and also quotes language that appears therein. Revisions to the GAQM were published in January 2017 and went into effect in May 2017. The discussion of uncertainty in the GAQM was substantially revised, and much of the quoted language (such as references to a "factor of two") no longer appears in the current version.

The uncertainty of model predicted concentrations will scale directly with uncertainty in the emissions estimates. Exponent has not reviewed the emission calculations used in this study, but we note that emission rates were reported to be based on actual emissions monitoring (in the case of the baseline scenario) or on future MES limits for the 2020 compliance case. The AIR also includes a detailed discussion about levels of uncertainty associated with various emissions monitoring programs. The use of long-term average emissions for the baseline case will introduce some uncertainty associated with shorter-term variations in operations, but in the absence of actual hourly data, this is probably a reasonable approach. This approach will likely provide a conservative estimate of potential differences between the baseline case (which incorporates average emissions) and the 2020 compliance case (which uses ceiling limit values).

Uncertainty in measured ambient concentrations is another potential source of error. However, Sasol has minimized the associated uncertainty by conducting regular assessments and calibration of the ambient monitoring stations used in the analysis. Sasol estimated the uncertainty in measured concentrations as 3% to 5% with a confidence level of 95%.

Another source of uncertainty is that associated with how accurately or faithfully the actual wind fields and other meteorological parameters are represented in the modeling. As noted in Section 3, there are some differences between the WRF predicted wind speeds and temperature fields and values recorded at available observational stations. These differences would be expected to increase the levels of uncertainty in the modeling results. Appendix I also identifies some potential data problems with meteorological parameters measured at the AJ Jacobs station due to nearby trees and structures. This likely explains the dramatically different frequency of low wind speeds at this station compared to other nearby stations. It also supports our recommendation that this station be excluded from WRF performance analyses.

Exponent did not review the determination of background concentrations, the calculation of total modeled concentrations, or the fractional bias calculations presented in the AIR. The files necessary to conduct these reviews were not provided, and these tasks were beyond the scope of the requested services.

9 References

Emery, C., E. Tai, and G. Yarwood, 2001: Enhanced meteorological modeling and performance evaluation for two Texas ozone episodes. ENVIRON International Corporation, Novato, CA.

Lake Michigan Air Directors Consortium (LADCO), 2018: 2016 Weather Research and Forecasting (WRF) Modeling Protocol for the LADCO States. Lake Michigan Air Directors Consortium, Rosemont, IL and Wisconsin Department of Natural Resources, Madison, WI.

Lakes Environmental Software, 2015. Lakes Environmental WRF Modeling.

Scire, J.S. and M. Borissova, 2011: An Empirical Method for Modeling Short-Term and Annual NO_2 Concentrations in Regulatory Models. Energy & Environment Conference (EUEC), Phoenix, Arizona. February 2011.

Scire, J.S., F.R. Robe, M.E. Fernau and R.J. Yamartino, 2000: A User's Guide for the CALMET Meteorological Model. (Version 5.0). Earth Tech., Inc. Concord, MA.

Scire, J.S., D.G. Strimaitis and R.J. Yamartino, 2000: A User's Guide for the CALPUFF Dispersion Model. (Version 5.0). Earth Tech, Inc., Concord, MA.

Talgo, K., J. Bowden, Z. Adelman, R. Morris, 2015: Western Air Quality Study (WAQS) Weather Research Forecast (WRF) Meteorological Model Final Modeling Protocol 2014 Modeling Year. University of North Carolina, Campus Hill, NC and Ramboll-Environ US Corporation, Novato, CA.

Tesche, T. W., D.E. McNally, C.A. Emery, E. Tai. 2001: Evaluation of the MM5 Model Over the Midwestern U.S. for Three 8-hour Oxidant Episodes, Prepared for the Kansas City Ozone Technical Workgroup. Alpine Geophysics, LLC, Ft. Wright, KY and ENVIRON International Corp., Novato, CA.
Wilmott, C.J., 1981: On the validation of models, *Phys. Geogr.*, 2, 168-194.

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9 November 2018

Attention: Avishkar Ramandh and Warren Carter

Subject: Response to Comments Raised by Independent Peer Review of the Dispersion Modelling Methodology Used in Support of the Sasol Atmospheric Impact Reports

An independent peer review of the dispersion modelling methodology used in support of the Sasol Atmospheric Impact Reports was undertaken in October 2018. Responses to comments raised have been provided below.

I trust this meets with your consideration. Should there be any further concerns, please do not hesitate to contact us.

Yours sincerely,

Ms Reneé von Gruenewaldt | Dr Terri Bird | Dr Lucian Burger

Response to Comments Outlined in the Peer Review

1. WRF DATA

Summary from the Peer Review:

WRF generated fields show a positive bias in wind speed and a negative bias in wind direction when compared with the surface stations used in the CALMET modelling. We recommend that a review of the station siting be conducted to determine if siting issues are the cause of mismatches in wind speed and wind direction.

Agreement of the WRF fields with data from the OR Tambo meteorological station shows less wind bias and a better over-all agreement for wind direction.

While some values exceed the standard benchmarks used to evaluate WRF performance, the modelled fields still appear reliable and appropriate for air dispersion modelling.

Response:

The data for the surface stations was checked for invalid and spurious information before being included into CALMET. Although varying wind fields was noted at the surface stations (and particularly AJ Jacobs as noted in the Peer Review), there was no indication that the data was invalid. It is likely that the readings are different due to local effects that may be of importance close to receptors. For this reason, it was decided to include all surface stations in the modelling to take these local effects into account. It should also be noted that the siting of the monitoring stations is surveyed every 18 months and confirmed every 5 years as part of the ISO/IEC17025 accreditation.

2. CALMET

Summary from the Peer Review:

The CALMET modelling used a partial No Observations (partial No-Obs) approach in which WRF meteorological fields are augmented by surface observations, but no upper air observations are included. Weighting parameters for the surface observations were set such that observed winds would have an influence out to 4 km from the observation location. There are times when these surface observations may be in disagreement with the WRF data fields. Disagreement in wind direction between values calculated by WRF and the surface observations can result in unrealistic flow patterns.

The use of small radius of influence parameters for the surface stations would greatly reduce the potential for artificial and unrealistic flow patterns.

Response:

Six surface stations were included in the model (three surface stations in Sasolburg and three surface stations in Secunda). Only one radius of influence can be selected in the CALMET setup, therefore RMAX1 was set to 4 km and R1 was set to 2 km. As pointed out in the Peer Review, given the 4 km resolution of the WRF simulations, this is a reasonably small region of influence for surface stations.

The Peer Review points out, however, that in cases where the surface observed wind direction is substantially different from the WRF predicted wind direction, the CALMET model will attempt to resolve these differences and may produce some anomalous wind flow patterns at grid points within 4 km from the surface station. Such an event was pointed out to occur on 1 January 2015 at 08:00. The wind direction at all Sasolburg surface stations during this period changed by 180° with an increase in wind speed. This flow pattern lasted for an hour before wind speeds decreased and wind direction returned. This indicates that a localised micro-scale system moved through the area that would not have been picked up in the WRF data.

Understandably these types of conditions will result in CALMET producing anomalous flow patterns when trying to resolve the differences in wind direction. The bias in wind direction of the WRF data to surface observations is however within the acceptable criteria, indicating that on average there is good agreement. Thus, conditions when wind direction from surface observations are substantially different to WRF predictions is minimal.

3. CALPUFF

Summary from the Peer Review:

Gridded receptors were included using 5 as a nesting factor of the sampling gird. This produces elevations at gridded receptors spaced at 200 m intervals that are interpolated from the original 1 km CALMET grid. More precise receptor elevations could be achieved by using TERREL to extract elevations at discrete receptors at 200 m intervals based on the available higher resolution terrain data. If conclusions are being drawn based on results at the gridded receptors, it would be advisable to use a grid with resolution higher than 200 m in the near field.

The CALPUFF modelling used a computational grid with dimensions of 50 km by 50 km. The CALPUFF sampling grid has the exact same dimensions. It should be noted that grid points near the edge of the sampling domain may not see the full influence of recirculation. Since a larger CALMET domain was run, a larger computational grid would have better allowed for calculation of recirculation impacts at the edge of the domain.

Response:

For this study a Cartesian grid of equal spacing was selected (200m resolution) in order to adequately display contour plots of the results. The resolution of the Cartesian grid was selected based on detail required to display contours for the entire modelling domain (57 km north-south and 57 km east-west) and computation time. In order to capture maximum concentrations at sensitive receptors within the modelling domain, schools, hospitals and clinics were modelled as receptor points. The approach thus captures maximum concentrations at sensitive receptors and provides a high resolution for the entire domain for contour purposes.

Airshed agree with the Peer Reviewer that a larger computational grid would better allow for calculation of recirculation impacts. However, over the Highveld, the recirculation pattern is of a much larger scale and the increase of the computational grid by a few kilometres would still not adequately capture the influence of recirculation.

4. RECEPTORS

Summary from the Peer Review:

There is some inconsistency regarding the number of discrete receptors discussed in the AIR. Section 5.1.8 refers to 52 sensitive receptors, while Table K-1 in Appendix K shows 42 receptors.

It was also noted that the modelling files that were provided for review contain 93 discrete receptors along with the 200 m spaced gridded receptors. Predicted concentrations at the additional discrete receptors and at gridded receptors are not discussed in the AIR beyond their use to generate contour plots. We assume that this is due to the intent to identify potential concentrations and changes in concentrations only at the sensitive receptors.

Response:

Forty-two sensitive receptors, including all schools, clinics and hospitals in the modelling domain, were included as discreet receptors in CALPUFF. The inclusion of these sensitive receptors is driven by legislation. For the analysis of results, the closest 20 receptors were reported on. In addition to the sensitive receptors, boundary receptors were included in the modelling making up the additional receptors to total to 93 receptors. The gridded receptors and all discreet receptors were used for the generation of isopleth plots.

The reference to 52 receptors in Section 5.1.8 is a typing error and has been corrected to 42 receptors.

5. PUFFS AND SAMPLING STEPS

Summary from the Peer Review:

The CALPUFF model includes several switches which control the number of puffs released and how those puffs are tracked during a model time step. In this CALPUFF application, two of those variables (MXNEW and MXSAM) were altered from the default values. MXNEW controls the maximum number of puffs released during a time step. The default value is set to 99, which is intended to be equivalent to “unlimited”. Similarly, the variable MXSAM sets the maximum number of sampling steps during one time step. Again the default value is set to a high value of 99. The values used in this application are 25 for MXNEW and 10 for MXSAM.

CALPUFF will automatically calculate the number of puffs and number of sampling steps needed on each hour. If the calculated values are below the set limits, then the limits will have no impact on the runs. As a general practice, it is recommended that the higher default values be used. The use of significantly lower limits can produce some run time savings, but only at the cost of model resolution and accuracy.

Response:

Due to the complexity of the model setup (e.g. number of sources, grid resolution, chemical transformation scheme, building downwash, and deposition), the number of puffs had to be reduced from default values to allow for reasonable run times of the dispersion model.

6. DEPOSITION PARAMETERS

Summary from the Peer Review:

CALPUFF allows the definition of wet scavenging coefficients for both liquid and frozen precipitation. The values being used are appropriate for the species listed. It is noted that in one of the input files (BI23.INP), wet scavenging coefficients for frozen precipitation are not included. This will result in wet removal being neglected during times of frozen precipitation. We anticipate that this represents few, if any, hours in the modeling period and even if a limited number of periods are being neglected, it results in conservative (high) predictions of airborne concentrations.

Response:

This was an oversight. The impacts due to this oversight on a single file where only one source was simulated, however, would result in a conservative impact prediction.

Summary from the Peer Review:

Section 5.2.2 of the Sasolburg AIR includes an analysis of dustfall. The calculations presented are described as deposition rates based on the simulated PM concentrations and a stated settling velocity for 10 µm particles. This analysis appears to have been conducted external to the CALPUFF modelling. Because the analysis is external to the model and was not part of the modelling files reviewed by Exponent, we are not able to provide a final opinion on the appropriateness of the approach. However, there are a few important considerations that should be mentioned. First, the airborne concentrations calculated by CALPUFF already account for wet and dry removal of particulate matter. As a result, the modelled puffs have already undergone wet and dry depletion, and recalculating deposition from those depleted concentrations will under estimate deposition rates. Additionally, CALPUFF is currently configured to calculate and save deposition. This calculation is based on a much smaller estimate of mean particle size (0.48 µm) which should be conservative for airborne concentrations but potentially not conservative for deposition. The approach being used in the AIR may represent an appropriate screening level analysis, but only if precautions are taken to ensure it is adequately conservative.

Response:

Due to time constraints, the deposition impacts were estimated based on the application of a settling velocity on the simulated concentrations. The limitations of this approach are understood; however, the results are provided as a screening level only.

7. AMBIENT MONITORING DATA AND BACKGROUND

Summary from the Peer Review:

The tables and figures in Section 5.1.5.4 of the AIR provide a wealth of information concerning measured concentrations. The time variation plots are useful for illustrating how average monitored concentrations vary diurnally and by day. However, the use of "normalized" concentrations obviously limits information on absolute pollutant concentrations. The text does not explain how the concentrations were normalized.

Response:

The ambient data was "normalised" with the aid of the *Openair* package for R software and is for illustrative purposes only in order to understand daily peaks in concentrations. The intension was to provide all data on the same scale mainly for temporal comparison and not absolute concentrations.

Summary from the Peer Review:

The determination of background concentrations is not fully documented in the AIR or in the files that were provided for review. Language in Section 9(d) of the AIR states that background values correspond to observed concentrations when predicted impacts at a monitoring site are near zero. Language in Tables H-1 and H-2 indicate that a threshold of 0.1 micrograms per cubic meter ($\mu g/m^3$) was used to determine periods when predicted impacts at a monitoring site were near zero.

It is not documented how background concentrations were determined for use in later National Ambient Air Quality Standards (NAAQS) compliance demonstrations, and files needed to verify background concentrations listed in Tables H-1 and H-2 were not provided.

An associated uncertainty is when background values are incorporated in various tables and figures. We assume or infer that the tables and figures in Section 1.8 of the AIR include background concentrations. Similarly, we assume that the concentrations in Equation 1 used to determine percentage changes in concentration include background. However, we were unable to verify this based on the information provided. While the evaluation of predicted concentrations relative to ambient standards is outside the stated scope of our review, we suggest that the AIR text provide greater clarity about when background concentrations are included.

Response:

The determination of background concentrations was only provided for model validation purposes. The background was not included in the assessment of project operations and the comparison to NAAQS. Comment is noted on providing more clarity on the use of background concentrations in the AIR and the reports have been updated accordingly.

8. UNCERTAINTIES

Summary from the Peer Review:

We note that Appendix I references the 2005 version of the EPA Guideline on Air Quality Models (GAQM) and also quotes language that appears therein. Revisions to the GAQM were published in January 2017 and went into effect in May 2017. The discussion of uncertainty in the GAQM was substantially revised, and much of the quoted language (such as references to a “factor of two”) no longer appears in the current version.

Response:

Comment has been noted and the AIRs have been updated accordingly.