BAY AREA
AIR QUALITY
MANAGEMENT
DISTRICT

Final Report

Demonstration of SO_2 Precursor Contributions to $PM_{2.5}$ in the San Francisco Bay Area

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Contents

1. INTRODUCTION AND EXECUTIVE SUMMARY

This report documents a modeling analysis conducted by the Bay Area Air Quality Management District (Air District) that addresses the sensitivity of fine particulate matter ($PM_{2.5}$) concentrations within the San Francisco Bay Area to potential increases in sulfur dioxide (SO_2) emissions from major point sources in the region. This modeling analysis demonstrates that SO_2 emissions increases from major sources will not contribute significantly to any regional $PM_{2.5}$ levels exceeding the $PM_{2.5}$ 24-hour-average National Ambient Air Quality Standards (NAAQS), even if the Bay Area experiences a high level of SO_2 emissions growth in the future. The Air District is submitting this demonstration to the US Environmental Protection Agency (EPA) to support an exemption from the requirement to regulate SO_2 under the District's Nonattainment New Source Review (NNSR) requirements pursuant to Section 189(e) of the Clean Air Act and 40 CFR Section 51.165(a)(13).

The San Francisco Bay Area's air quality currently does not exceed the $PM_{2.5}$ 24-hour-average NAAQS, as EPA concluded in its 2013 "Clean Data Finding" for $PM_{2.5}$. *See Determination of Attainment for the San Francisco Bay Area Nonattainment Area for the 2006 Fine Particle Standard*, 78 FR 1760 (Jan. 9, 2013). By definition, therefore, there are no major sources of SO_2 that contribute significantly to any $PM_{2.5}$ levels exceeding the NAAQS within the meaning of Section 189(e). EPA is nevertheless requiring the Air District to conduct a sensitivity analysis in order to support a Section 189(e) exemption. The Air District has therefore analyzed the potential for future SO_2 emissions increases to contribute significantly to ambient 24-hour-average $PM_{2.5}$ concentrations in accordance with EPA's requirements for making $PM_{2.5}$ precursor demonstrations under 40 CFR Section 51.1006(a)(3), using conservative assumptions about a high level of potential emissions growth.

The analysis conservatively assumed that all existing major SO_2 sources in the Bay Area, and all existing minor SO_2 sources that emit 4 tons per year or more, would increase their emissions by 20%; and also that 7 new major SO_2 emissions sources would be built around the region emitting 370 TPY SO_2 each. These are highly conservative assumptions, as regional SO_2 emissions have been declining for years, not increasing, and are expected to continue to go down; and because it is unlikely that any new major SO_2 sources will be built in the region at all, let alone 7 new major sources with 370 TPY of new SO_2 emissions each. The Air District nevertheless used these very large growth assumptions in its analysis in order to be highly conservative in evaluating what could potentially occur in the future.

This hypothetical future emissions growth was modeled using two models: the CALPUFF plume dispersion model, which modeled impacts throughout an entire calendar year; and the Community Multiscale Air Quality (CMAQ) photochemical grid model, which modeled impacts for December and January, the winter months when the region typically experiences its highest $PM_{2.5}$ levels. The CALPUFF model indicated a maximum modeled impact (as SO_4) of just under 0.7 $\mu g/m^3$, and the CMAQ model indicated a maximum modeled impact of just under 0.6 $\mu g/m^3$.

These results demonstrate that even if the San Francisco Bay Area were to experience a high level of SO_2 emissions growth in the future, the total modeled impact on ambient $PM_{2.5}$ concentrations would not exceed 0.7 $\mu g/m^3$. This level of increase is not statistically significant in light of the

inherent variability in observed ambient $PM_{2.5}$ concentrations due to fluctuating meteorological conditions and changes in day-to-day source operations. This level of modeled impact is only slightly over half of the 1.3 $\mu g/m^3$ level of increase that would be considered significant. The modeling results therefore support the conclusion that SO_2 emissions from major sources in the Bay Area do not and will not contribute significantly to 24-hour $PM_{2.5}$ concentrations exceeding the NAAQS within the meaning of Section 189(e) and 40 CFR Section 51.165(a)(13).

This report describes the results of the Air District's modeling analysis in detail. The report is organized as follows. After this Executive Summary, Section 2 of the report discusses the purpose of the $PM_{2.5}$ Precursor Demonstration project to provide a technical basis for exempting SO_2 from the Clean Air Act's NNSR requirements under Section 189(e) and 40 CFR Section 51.165(a)(13). Section then 3 details the modeling and analysis methodology the Air District used in the analysis. Section 4 presents the results from the two model applications, and Section 5 summarizes the findings of the analysis and presents conclusions. Appendices are included at the end of this report to document the protocol the Air District followed in undertaking this analysis and the data and settings used in the models.

2. PURPOSE OF THE SO_2 DEMONSTRATION

The San Francisco Bay Area has been designated as a nonattainment area for the 2006 24-hour $PM_{2.5}$ NAAQS. The Air District is therefore required under the Clean Air Act to regulate $PM_{2.5}$ emissions from major stationary sources under its NNSR permitting program. The Clean Air Act also requires emissions of $PM_{2.5}$ precursors such as SO_2 to be regulated on the same basis as $PM_{2.5}$, unless EPA determines that emissions of the precursor from major sources do not contribute significantly to $PM_{2.5}$ concentrations exceeding the NAAQS. CAA § 189(e), 42 USC 7513a(e); *see also* 40 CFR § 51.165(a)(13). The purpose of this SO_2 Precursor Demonstration is to provide a technical basis for EPA to make this determination with respect to SO_2 emissions from major sources in the San Francisco Bay Area.

EPA's requirements for making $PM_{2.5}$ precursor demonstrations for NNSR permitting programs are set forth in 40 CFR Section 51.1006(a)(3). That provision requires the Air District to evaluate the sensitivity of ambient $PM_{2.5}$ concentrations in the region to increases in SO_2 emissions resulting from potential major source growth in the area under conservative growth assumptions. If potential future growth in SO_2 emissions from major sources will not have a significant effect on regional $PM_{2.5}$ concentrations, then EPA can exempt the Bay Area from the Clean Air Act's NNSR requirements with respect to SO_2 as a $PM_{2.5}$ precursor. The Air District has designed this SO_2 Precursor Demonstration project to conform to EPA's requirements for a sensitivity analysis under Section 51.1006(a)(3) that will allow EPA to make this exemption determination.

3. SO_2 DEMONSTRATION APPROACH

This section summarizes the Air District's approach for analyzing the $PM_{2.5}$ impacts from potential future SO_2 emissions growth in the Bay Area.

3.1 Development of SO_2 Demonstration Protocol

In undertaking this SO_2 Precursor Demonstration, the Air District followed a Protocol developed in conjunction with staff from EPA Region 9 and EPA's Office of Air Quality Planning and Standards (OAQPS). In drafting the Protocol, the Air District incorporated the principles set forth in EPA's Draft $PM_{2.5}$ Precursor Demonstration Guidance,[1] and Air District staff met several times with EPA staff to discuss and refine the Protocol's approach. The final Protocol that resulted from these planning meetings details and formalizes the modeling methodology the Air District used in the Demonstration. The Protocol is set forth in Appendix A to this Report for reference.

The Protocol describes current trends in 24-hour-average $PM_{2.5}$ concentrations in the Bay Area. The region's "Design Value" for 24-hour-average $PM_{2.5}$ – the statistical metric used to determine compliance with the NAAQS[2] – has held relatively steady from 2010 through 2016 between 25 and 30 $\mu g/m^3$, just below the NAAQS of 35 $\mu g/m^3$. Concentrations exceeded 35 $\mu g/m^3$ on a number of individual days during this period, however. These exceedances are primarily a wintertime phenomenon. They tend to occur during the months of December and January during cold, foggy episodes characterized by strong stability and weak easterly surface winds, and not during the summer months when $PM_{2.5}$ concentrations are relatively low as a result of strong westerly winds that efficiently ventilate the Bay Area. Winter exceedances are primarily impacted from residential woodburning.

The Protocol also describes current trends in SO_4 concentrations in the region. SO_4 is the principal constituent of $PM_{2.5}$ that is generated by SO_2 emissions. SO_2 emissions react in the atmosphere to form SO_4, which forms an aerosol of fine droplets less than 2.5 microns in diameter – *i.e.*, $PM_{2.5}$. This is why SO_2 is a pollutant of concern for regulation as a $PM_{2.5}$ precursor.

SO_4 makes a relatively small contribution to total $PM_{2.5}$ levels in the Bay Area, and it has the biggest effect on $PM_{2.5}$ during the summer months, when $PM_{2.5}$ levels are the lowest. As discussed in the Protocol, monthly-average SO_4 concentration over 2012-2014 reached just over 1 $\mu g/m^3$ in the summer, but were less than 0.5 $\mu g/m^3$ during winter months. Additionally, SO_4 did not vary much across different monitoring sites around the region, suggesting that SO_4 in the Bay Area is primarily the result of background sources well outside the Bay Area, potentially including oceanic sources.

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[1] "$PM_{2.5}$ Precursor Demonstration Guidance", U.S. Environmental Protection Agency, Office of Air Quality Planning and Standards, Air Quality Assessment Division and Air Quality Policy Division, Research Triangle Park, NC (EPA-454/P-16-001, November 2016).

[2] The Design Value is defined as the 3-year average of the highest 98th percentile monitor reading at the monitoring location with the highest such value. Thus, to determine the Design Value, the 98th percentile concentration observed at each monitoring site during each year of a 3-year period is identified; the identified 98th-percentile concentrations for each of the 3 years are averaged for each site; and then the highest of these 3-year-average values out of all of the monitoring locations in the region is defined as the region's Design Value.

The Protocol also describes SO_2 emissions in the Bay Area that contribute to SO_4 formation. According to the Air District's 2012 modeling inventory, SO_2 emissions in the Bay Area total 26.9 tons per day (TPD), which is comprised of 17.7 TPD from stationary point sources; 6.3 TPD from ocean-going vessels (which is likely to be lower by now due to offshore Emission Control Area regulations); 2.5 TPD from mobile sources (both road and non-road); and 0.4 TPD from stationary area sources.

3.2 Selection of Models For Use In The Analysis

The Air District used two different models to assess the potential impacts of SO_2 emissions growth on regional $PM_{2.5}$ concentrations. The first is the CALPUFF plume model, which was run to simulate SO_2 dispersion and subsequent SO_4 production from specific point sources over a domain encompassing the Bay Area. The second is the Community Multiscale Air Quality (CMAQ) photochemical grid model, which was run to simulate the full photochemical evolution of SOx, NOx, and organic compounds in both gas and particulate phase from all sources over a large central California domain.

To model the $PM_{2.5}$ impacts of potential SO_2 emissions increases, the Air District used existing modeling datasets for the year 2012 that address $PM_{2.5}$, SO_2 and SO_2 contributions to fine particulate SO_4. 2012 is an appropriate year for this purpose because it is reasonably recent and representative of current $PM_{2.5}$ patterns in the Bay Area, as detailed in the Protocol. And 2012 has been extensively modeled and analyzed by the Air District to investigate Bay Area patterns and emissions sensitivity for both ozone and $PM_{2.5}$, so modeling datasets for 2012 are readily available and fully vetted.

The modeling analysis was based on a comparison of two modeled scenarios: (i) a "base case" scenario reflecting existing emissions levels (based on the 2012 datasets), and (ii) a "modified case" scenario based on a conservatively high estimate of potential SO_2 emissions growth, as discussed in more detail in Section 3.4 below. Impacts from the potential SO_2 emissions growth were determined by the difference between the base case and modified case scenarios.

The CALPUFF model was run to simulate the impacts from potential SO_2 emissions growth throughout the entire year to address SOx chemistry and transport associated with point source plumes. The CMAQ model was run for the months of December and January – the months when the Bay Area experiences the highest $PM_{2.5}$ concentrations and occasional exceedances of the 35 $\mu g/m^3$ standard – to explicitly treat detailed chemistry and transport from all sources during exceedance-level $PM_{2.5}$ events.

3.3 Evaluation of CMAQ Model Performance Compared To Observed Concentrations

As explained in the Protocol, CMAQ modeling characterizes the Bay Area's observed seasonal $PM_{2.5}$ and SO_4 patterns well, both in magnitude and spatially. The protocol recommended evaluating relative differences in modeled concentrations should the model performance be poor for SO_4 and $PM_{2.5}$. The Air District therefore undertook a more detailed quantitative performance evaluation for the CMAQ model. This evaluation focused on the model's ability to replicate observed patterns of SO_4 and total $PM_{2.5}$ throughout the Bay Area during high/exceedance wintertime pollution episodes. The analysis compared the model's predictions

for January and December with actual observed values from 5 monitoring sites around the Bay Area for SO_4 and 13 monitoring sites for total $PM_{2.5}$. For each day during the periods of January 2-31 and December 2-30, 2012, the analysis compared observed SO_4 and $PM_{2.5}$ concentrations as measured at each monitor with the values predicted by the CMAQ v5.0.2 model for the grid cell containing that monitor. (Not all monitoring sites had valid data for each day throughout this date range, so the analysis was based only on days with non-missing, validated measurements.)

The results are shown in Figure 1 (for SO_4) and Figure 2 (for total $PM_{2.5}$), which plot the observed concentration for each day against the concentration predicted by the model for that day. The plotted values for each day are the average values across all of the monitoring locations used in the analysis for that day. Also shown are four key statistical measures: mean bias (MB), mean (unsigned or gross) error (ME), normalized mean bias (NMB) and normalized mean error (NME). These statistical measures are calculated from individual model/observation differences at each site and for each day, as opposed to being calculated from an average across multiple locations for each day.

This evaluation establishes that model performance is sufficient to base the SO_2 Precursor Demonstration on absolute (rather than relative) simulated impacts to SO_4 and $PM_{2.5}$. For SO_4, the model over-predicted SO_4 concentrations during most of the period evaluated, and it tended to perform best on the days with hightest observed SO_4. It typically over-predicted SO_4 by less than 0.2 $\mu g/m^3$ (MB) in both months, relative to an observed range of 0.2-1.0 $\mu g/m^3$ in January and 0.2-0.6 $\mu g/m^3$ in December (a NMB range of 30-36%). These biases and unsigned errors are typical of model performance achieved throughout the US over the past decade,[3] especially for small observed concentrations below 1 $\mu g/m^3$. For $PM_{2.5}$, the model similarly over-predicted $PM_{2.5}$ in both months, with a nearly consistent absolute bias and gross error each month, but higher normalized relative bias and error in December because of lower observed concentrations than in January. In general, CMAQ replicated the observed day-to-day patterns, but over predicted typically by about 3-4 $\mu g/m^3$ MB (20-45% NMB).

The analysis thus shows that the model is capable of replicating overall SO_4 and $PM_{2.5}$ concentrations and day-to-day variations, with a tendency for slight over-prediction. Evaluating impacts based on absolute modeled concentration changes is therefore appropriate, and may even be conservative, depending on the role of background sources of SO_4 within the modeling domain and as specified via boundary conditions.

[3] Emery, C., Z. Liu, A.G. Russell, M.T. Odman, G. Yarwood, N. Kumar (2016): Recommendations on statistics and benchmarks to assess photochemical model performance, *Journal of the Air & Waste Management Association*, DOI:10.1080/10962247.2016.1265027; Simon, H., K.R. Baker, S., Phillips (2012). Compilation and interpretation of photochemical model performance statistics published between 2006 and 2012. *Atmospheric Environment,* 61:124–39, doi:10.1016/j.atmosenv.2012.07.012.

Figure 1

CMAQ Model Predictions Compared To Observed Concentrations – SO_4

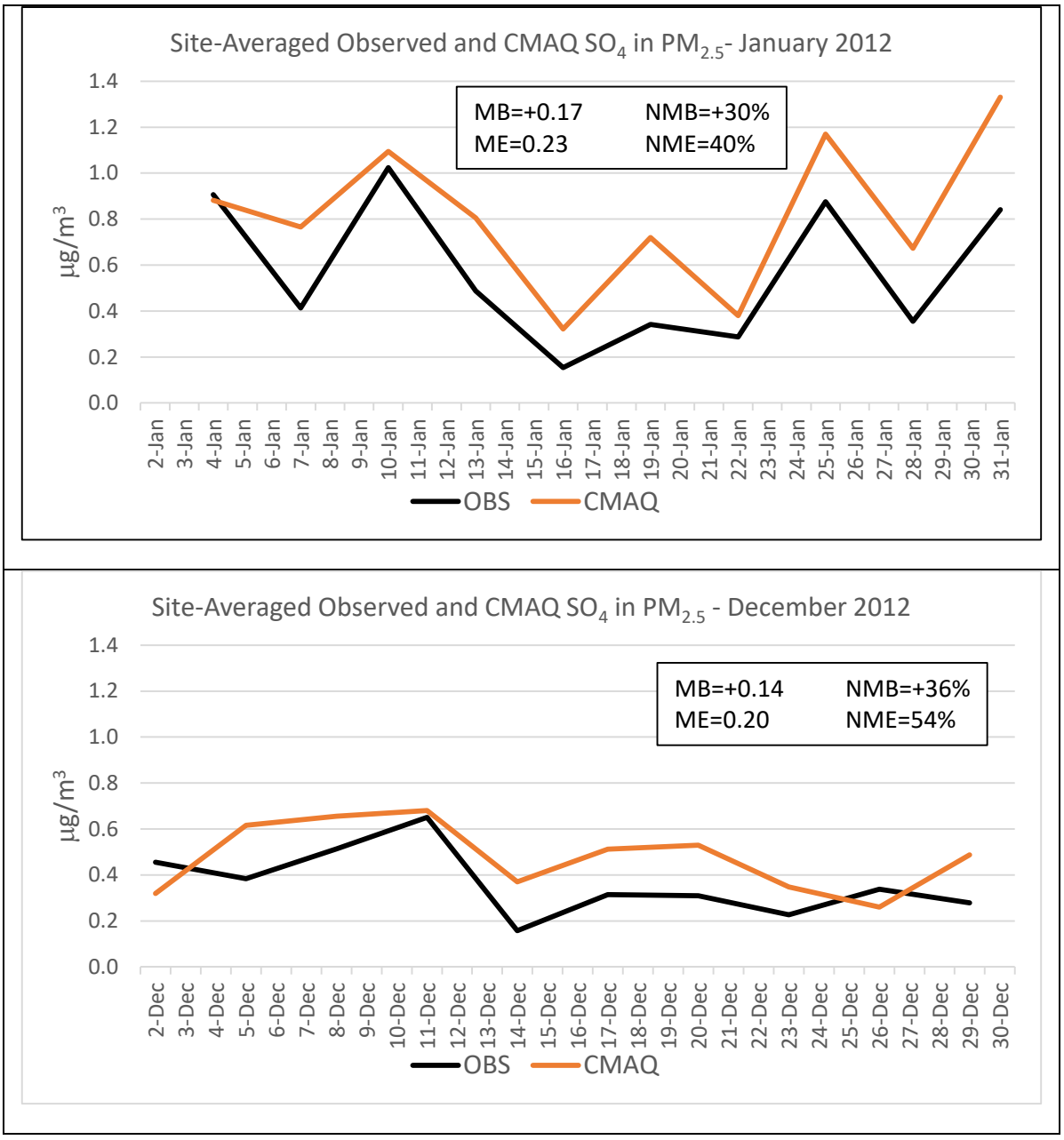


Figure 1 presents a time series of observed and simulated 24-hour SO_4 in $PM_{2.5}$, averaged over 5 measurement sites in the Bay Area with valid data, for the January (top) and December (bottom) 2012 modeling periods. Each plot notes key statistical measures: mean bias (MB), mean unsigned error (ME), normalized mean bias (NMB) and normalized mean error (NME).

Figure 2

CMAQ Model Predictions Compared To Observed Concentrations – Total $PM_{2.5}$

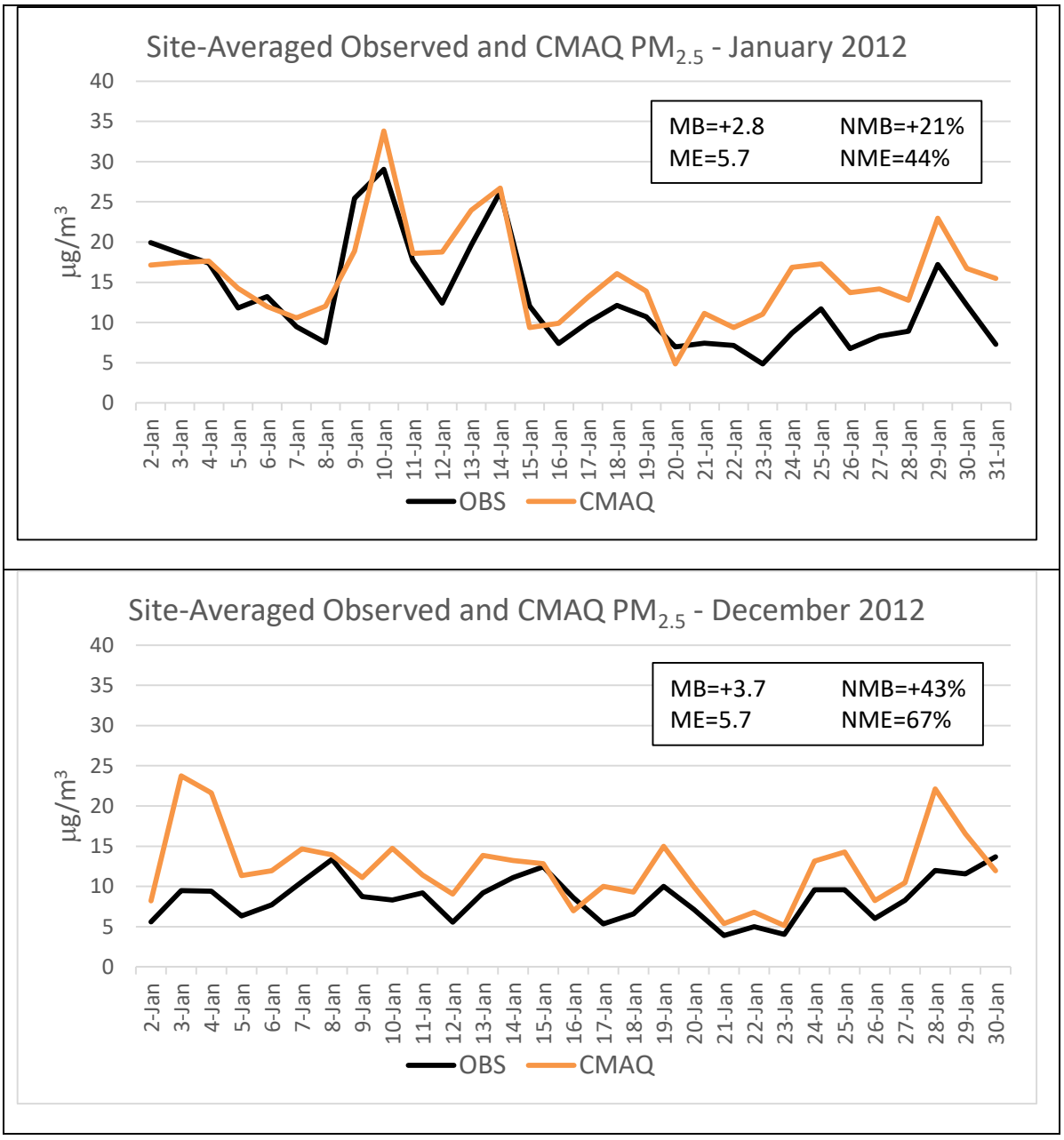


Figure 2 presents a time series of observed and simulated 24-hour total $PM_{2.5}$, averaged over 13 measurement sites in the Bay Area with valid data, for the January (top) and December (bottom) 2012 modeling periods. Each plot notes key statistical measures: mean bias (MB), mean unsigned error (ME), normalized mean bias (NMB) and normalized mean error (NME).

3.4 Selection of Conservative SO_2 Emissions Growth Scenario

The Protocol also outlines the bases for the conservative SO_2 emissions growth assumptions the Air District used in the demonstration. In this context, "conservative" means that the Air District estimated potential new emissions growth on the very high side of what is reasonably expected in order to ensure that the analysis does not underestimate what could occur in the future. As EPA's draft $PM_{2.5}$ Demonstration Guidance states, the demonstration should evaluate more emissions growth "than what is merely 'likely' to occur in the area," so that the NAAQS will be protected even if growth is higher than anticipated.

The Air District developed a conservative SO_2 emissions growth scenario by assuming that all existing stationary sources in the Bay Area that currently emit at least 4 TPY SO_2 (including both major sources and minor sources) would increase their emissions by 20%; and that seven new major sources would be built emitting 370 TPY SO_2 each.

For the increase from existing sources, including all sources with emissions of at least 4 TPY SO_2 encompasses a total of 129 sources emitting 6,082 TPY of SO_2, or 16.7 TPD on average. This accounts for over 94% of all point source SO_2 emissions in the District. The Air District conservatively assumed that each of these 129 sources would increase its SO_2 emissions by 20%. These increases were modeled at the location of the existing sources, using their existing stack parameters and characteristics.

For the 7 hypothetical new major sources, the Air District conservatively assumed that they would emit 370 TPY SO_2 each, which is the average emissions rate among all major SO_2 sources in California. The locations of these hypothetical new major sources were carefully selected to cover the entire Bay Area with reasonable density, including locations that are already populated with existing major sources but also extending to the north and south bay regions where such large sources do not currently exist.

The total increase in SO_2 emissions under this conservative growth scenario would be 3,806 TPY, or 10.4 TPD on average. This represents a 39% increase in Bay Area total SO_2 emissions and a 59% increase in Bay Area point source SO_2 emissions. Again, the District does not anticipate that emission increases of this magnitude will actually occur. But they represent a conservative "worst case" approach in keeping with EPA's draft Demonstration Guidance.

3.5 Determination of Significant Contribution Threshold

The Protocol also outlines the basis for the 1.3 $\mu g/m^3$ threshold below which the modeled SO_2 emissions growth will not be considered to make a "significant" contribution to $PM_{2.5}$ concentrations for purposes of the sensitivity analysis. Due to fluctuating meteorological conditions and changes in day-to-day source operations, there is inherent variability in the air quality in the area of a monitoring site. A concentration difference of 1.3 $\mu g/m^3$ is the 50% confidence interval for the 35 $\mu g/m^3$ 24-hour-average $PM_{2.5}$ NAAQS, representing a "significant" impact. Thus, where the modeled impact from the highly conservative SO_2 emissions growth scenario is less than 1.3 $\mu g/m^3$, the analysis can conclude that such growth will not contribute significantly to any $PM_{2.5}$ concentrations exceeding the NAAQS.

3.6 Methodology For $PM_{2.5}$ Impact Projections

As outlined in the Protocol, the Air District modeled SO_4 and $PM_{2.5}$ concentrations in the "base case" scenario (without any SO_2 emission increases) and the "modified case" scenario with the hypothetical future emissions growth. The $PM_{2.5}$ impacts throughout the Bay Area were assessed using the "brute force" approach, which calculates the difference between the two scenarios. The District compared the base case vs. modified case scenarios on an absolute basis (rather than relative) from the combination of all modified sources (not separately). As discussed in Section 3.3, CMAQ replicates total SO_4 and $PM_{2.5}$ (from all sources) well during high-concentration episodes, with a slight tendency for over prediction, which provides confidence in an assessment of absolute modeled impacts.

Impacts on 24-hour-average SO_4 concentrations (for both CALPUFF and CMAQ) and 24-hour average $PM_{2.5}$ concentrations (for CMAQ) from the increased SO_2 emissions were estimated by applying the following steps to the output of the CMAQ and CALPUFF modeling simulations.

1) The 24-hour SO_4/$PM_{2.5}$ concentration was determined for each grid cell of the modeling domain for each day under the base case scenario. Concentrations were determined from hourly CMAQ and CALPUFF output. In the case of CMAQ, SO_4 and $PM_{2.5}$ concentrations were calculated from the sum of component species (sulfate, nitrate, organics, other) for each day of the January and December 2012 modeling period. For CALPUFF, SO_4 concentrations were calculated for all days of 2012.

2) The 24-hour $PM_{2.5}$ concentration was determined for each grid cell for each day under the modified case scenario, in the same way as the base case for both models.

3) The difference in 24-hour concentrations between the modified case and base case scenarios was tabulated for each grid cell for all of the days evaluated. For CMAQ, the difference in concentration was calculated for SO_4 and $PM_{2.5}$, whereas for CALPUFF the difference was calculated for SO_4. These calculations yielded daily, gridded impacts from the modified case scenario, as compared to the base case.

4) The modeled 24-hour $PM_{2.5}$ and SO_4 impacts from the respective CMAQ and CALPUFF modeled time periods were rank-ordered and assessed for the purpose of the demonstration. Impacts were quantified both in terms of absolute concentration differences and relative percentage differences.

The results of modeling methodology are outlined in the next section.

4. MODELING ANALYSES AND RESULTS

This section discusses the details of the CALPUFF and CMAQ modeling analyses and presents their results.

4.1 CALPUFF Modeling

CALPUFF Model Runs

CALPUFF version 6.42 was run for the entirety of 2012, month-by-month, to simulate the dispersion of SO_2 from point sources and its chemical conversion to SO_4. CALPUFF was configured and run identically to the Air District's existing applications for SO_2 and SO_4 simulations; Appendix B presents the CALPUFF control input file for January. The modeling domain consists of a 67x67 grid covering the 9-county area within the Air District's boundaries, with 4 km horizontal grid spacing and 10 vertical layers extending to 3 km above terrain elevation. The MESOPUFF-II chemistry was invoked to simulate chemical production of SO_4. Background concentrations of certain pollutants such as ozone (O_3), ammonia (NH_3) and hydrogen peroxide (H_2O_2) were specified according to Table 1.

Table 1: Chemistry options selected in the CALPUFF control input file.

Option Name	Value
MCHEM	1, transformation rates computed internally (MESOPUFF II scheme)
MWET	1, wet removal modeled
MDRY	1, dry deposition modeled
MOZ	0, use monthly background ozone values
BCKO3	40 ppb for all 12 months
MNH3	0, use monthly background ammonia values
BCKNH3	10 ppb for all 12 months
BCKH2O2	1 ppb for all 12 months

Hourly meteorological inputs for 2012 were prepared using CALMET version 6.211. Surface and upper-air meteorological measurements were obtained from the National Center for Atmospheric Research (NCAR) and the National Climatic Data Center, respectfully. Surface measurements from NCAR's DS472 included hourly data at 48 sites. Vertical profile measurements included 12-hourly data from the Oakland radiosonde. Terrain elevation and land use data were obtained from the US Geological Survey. CALMET options such as mixing depth processes were carefully selected to best represent the region. CALMET was run one month at a time; CALMET parameters and configuration settings for January are shown in Appendix C. The simulated meteorological fields were evaluated and compared against observations. Graphical displays of key meteorological parameters were generated and visually inspected for accuracy, representativeness and reasonableness.

Point source emissions were taken from the CMAQ point source emissions inventory file for 2012. The CMAQ point source file consists of stack information and emissions for 29,847 individual point processes in the Bay Area. The analysis focused on point sources emitting 4 TPY or more SO_2, as discussed in Section 3.4. There are 129 such sources, which account for over 94% of all

point source SO_2 emissions in the Bay Area. These 129 processes are routed to 114 individual stacks, with specific characteristics (e.g., height, diameter, exit temperature and speed) from which to determine plume rise. A CALPUFF emissions input file was prepared that contains: source ID, latitude, longitude, stack height, base elevation, exit diameter, exit velocity, exit temperature, building downwash, and emissions of SO_2 for each of the 114 stacks. This file represents the "base case" inputs for the CALPUFF simulation.

The "modified case" scenario includes a 20% increase in SO_2 emissions from the 114 existing stacks and the addition of 7 hypothetical new sources, as described above. Stack parameters for the hypothetical new sources were developed based on an evaluation of stack parameters for existing sources of similar size within the Bay Area. Specifically, stack parameters for the two Bay Area sources with annual SO_2 emissions closest to 370 tons (one source was above 370 tons and the other below 370 tons) were tested in CALPUFF, and the set of stack parameters that resulted in the highest SO_4 concentrations was selected. These parameters, which are shown below, are from a representative refinery stack at Tesoro Refinery. Table 2 specifies stack parameters and location coordinates for the representative stack and all 7 hypothetical new sources.

Height: 330 ft
Diameter: 3.25 ft
Temperature: 175.7 °F
Flow Rate: 338.33 ft^3/s
Velocity: 40.75 ft/s

As previously noted, each hypothetical new source was set to emit 370 TPY SO_2; no other precursors were emitted from these sources. Appendix D provides a complete listing of all 121 CALPUFF point sources including stack parameters and emission rates.

Table 2: Stack Parameters and Location Coordinates of the 7 Hypothetical New SO_2 Sources and the Representative Refinery Stack On Which They Are Based

FIPS	PlantID	PointID	StackID	blrID	FCC Name	SCC	Latitude	Longitude
6013	14628	1411	1402	2	TesoroRefining&MarketingCo	30102306	38.0239	-122.0646
6097	99001	1	1	1	New_Petaluma	30102306	38.2389	-122.5895
6013	99002	2	1	1	New_Delta_West	30102306	38.0183	-122.2350
6013	99003	3	1	1	New_Delta_East	30102306	38.0220	-122.0006
6001	99004	4	1	1	New_San_Leandro	30102306	37.6045	-122.0807
6001	99005	5	1	1	New_Livermore	30102306	37.6535	-121.8852
6085	99006	6	1	1	New_Near_Lehigh	30102306	37.2957	-121.9985
6085	99007	7	1	1	New_Gilroy	30102306	36.9939	-121.5573

CALPUFF Results

The results of the CALPUFF modeling are shown in Figure 3. The top graph shows the maximum SO_4 concentration predicted by CALPUFF over the entire modeled domain for each day of 2012 for both the base case (orange) and modified case (blue). (Note that the location of the maximum modeled concentration may differ from day to day.) The bottom graph shows the maximum difference between the modified case and the base case for each day. The difference represents the impact predicted by the model resulting from the additional SO_2 emissions in the modified

case. The modeled increase in SO_4 concentrations corresponds to the predicted increase in $PM_{2.5}$ concentrations, as SO_4 is the principal constituent of $PM_{2.5}$ that is generated from SO_2 emissions.

As Figure 3 shows, the largest predicted increases in SO_4 concentrations reach up to nearly 0.7 $\mu g/m^3$ during two episodes in January and late November. This is about half of the threshold level of 1.3 $\mu g/m^3$ at which a modeled impact would be considered significant, indicating that even with the very conservative (high) SO_2 increases assumed in the modified case scenario, CALPUFF results indicate that maximum incremental impacts from additional SO_2 emissions during winter $PM_{2.5}$ episodes would be well below a significant $PM_{2.5}$ contribution.

The spatial distribution of the modeled impacts around the Bay Area is shown in Figure 4. The top panel in Figure 4 shows a spatial (gridded isopleth) plot of the modeled 24-hour SO_4 impacts on January 4, the day of peak SO_4 impact. The maximum SO_4 impact of 0.68 $\mu g/m^3$ occurs in a small area of western Contra Costa County due to industrial sources in that region. The bottom panel of Figure 4 is a similar plot for SO_2 impacts. It shows the spatial distribution of modeled 24-hour SO_2 impacts on November 2, the day of peak SO_2 impact.

Figure 5 shows the maximum SO_4 and SO_2 impacts predicted for each grid cell throughout the region over the entirety of the modeling period. Note that in this type of plot, the maximum modeled impacts in different grid cells may occur on different dates, and the maximum SO_4 and SO_2 impacts in a given cell may occur on different dates. The highest SO_4 impact of 0.68 $\mu g/m^3$ on January 4 in western Contra County seen in Figure 4 remains the same, but the surrounding areas show higher impacts than in Figure 4 because this plot shows the highest impact of any day throughout the year, not just the impact on January 4. Around the Bay Area, the maximum modeled SO_4 impact for the year is typically in the range of 0.4-0.5 $\mu g/m^3$.

Figure 3:

Modeled $PM_{2.5}$ Impacts From High SO_2 Emissions Growth Scenario

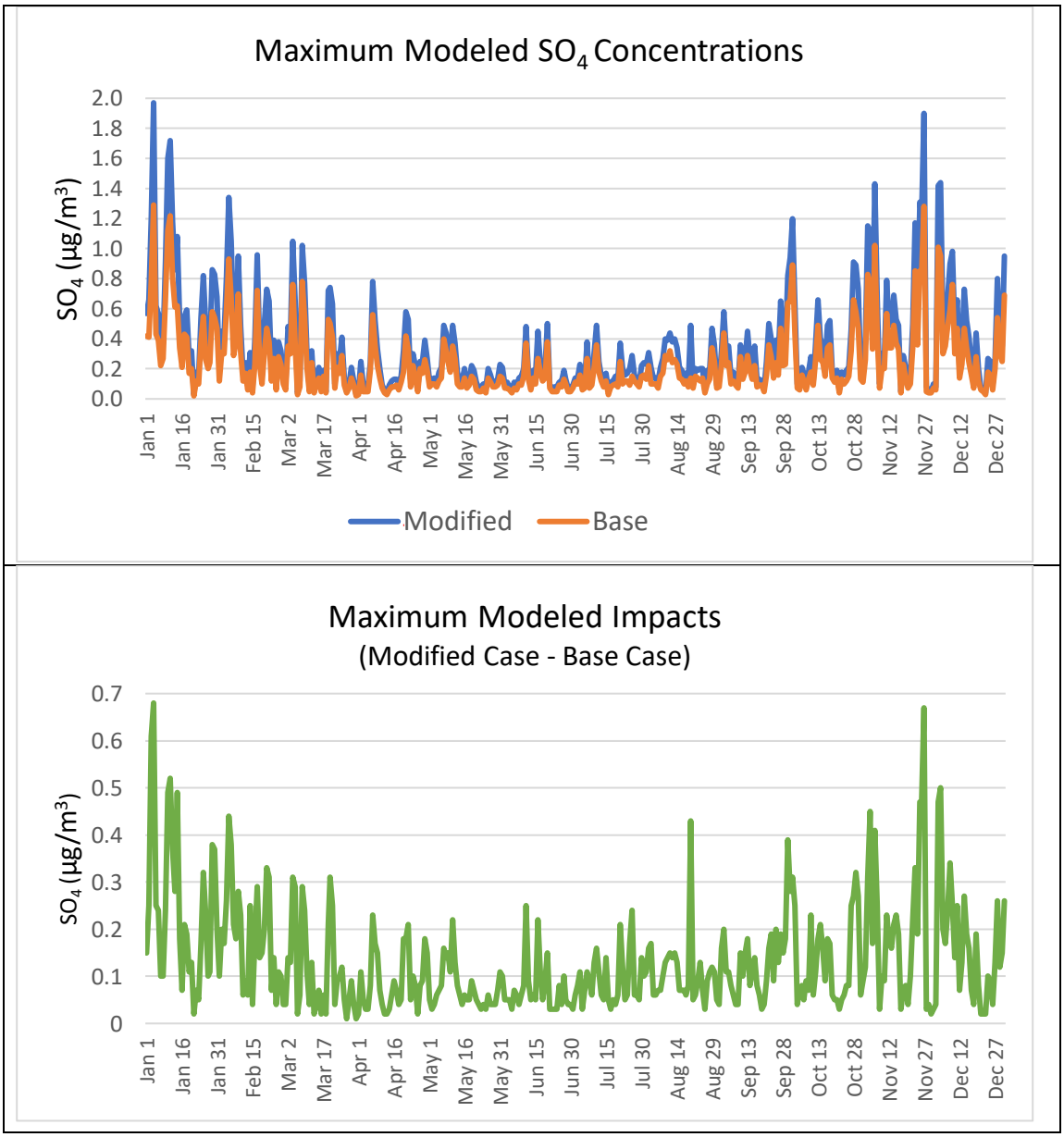


Figure 3 shows the CALPUFF modeling results. The top graph shows the maximum SO_4 concentration predicted by CALPUFF throughout the entire modeled domain for each day of the year for both the base case (orange) and modified case (blue). The bottom graph shows the maximum difference between the modified case and base case for each day, which represents the maximum modeled impact for that day.

Figure 4:
Spatial Distribution of Modeled Impacts On SO_4 (top) and SO_2 (bottom) on Highest-Impact Days

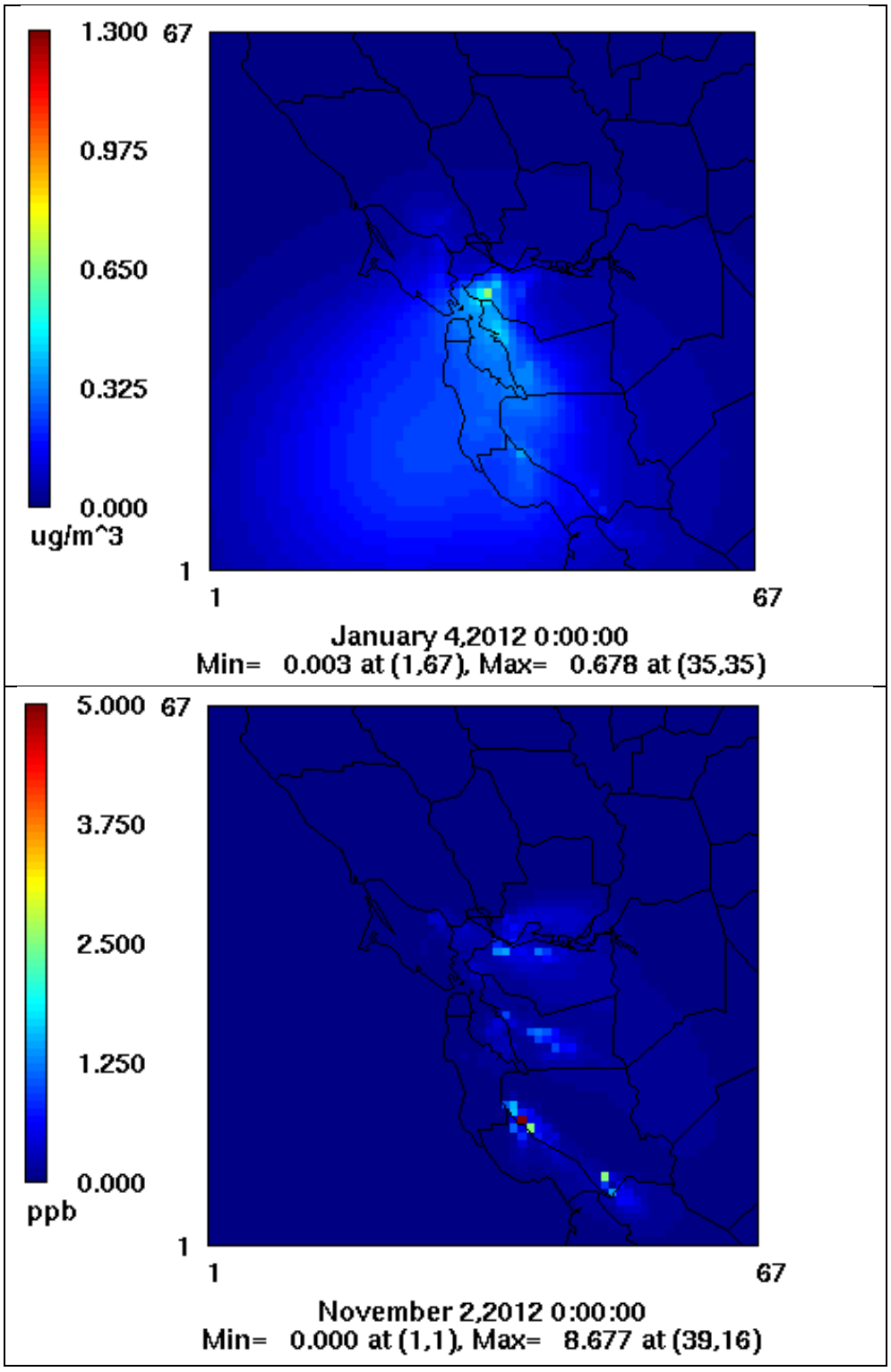


Figure 4 shows the spatial distribution of 24-hour SO_4 difference between the base case and modified scenarios on January 4, 2012 (top), and the 24-hour SO_2 difference on November 2, 2012 (bottom).

Figure 5:

Maximum Modeled Impacts In Each Grid Cell For SO_4 (top) and SO_2 (Bottom)

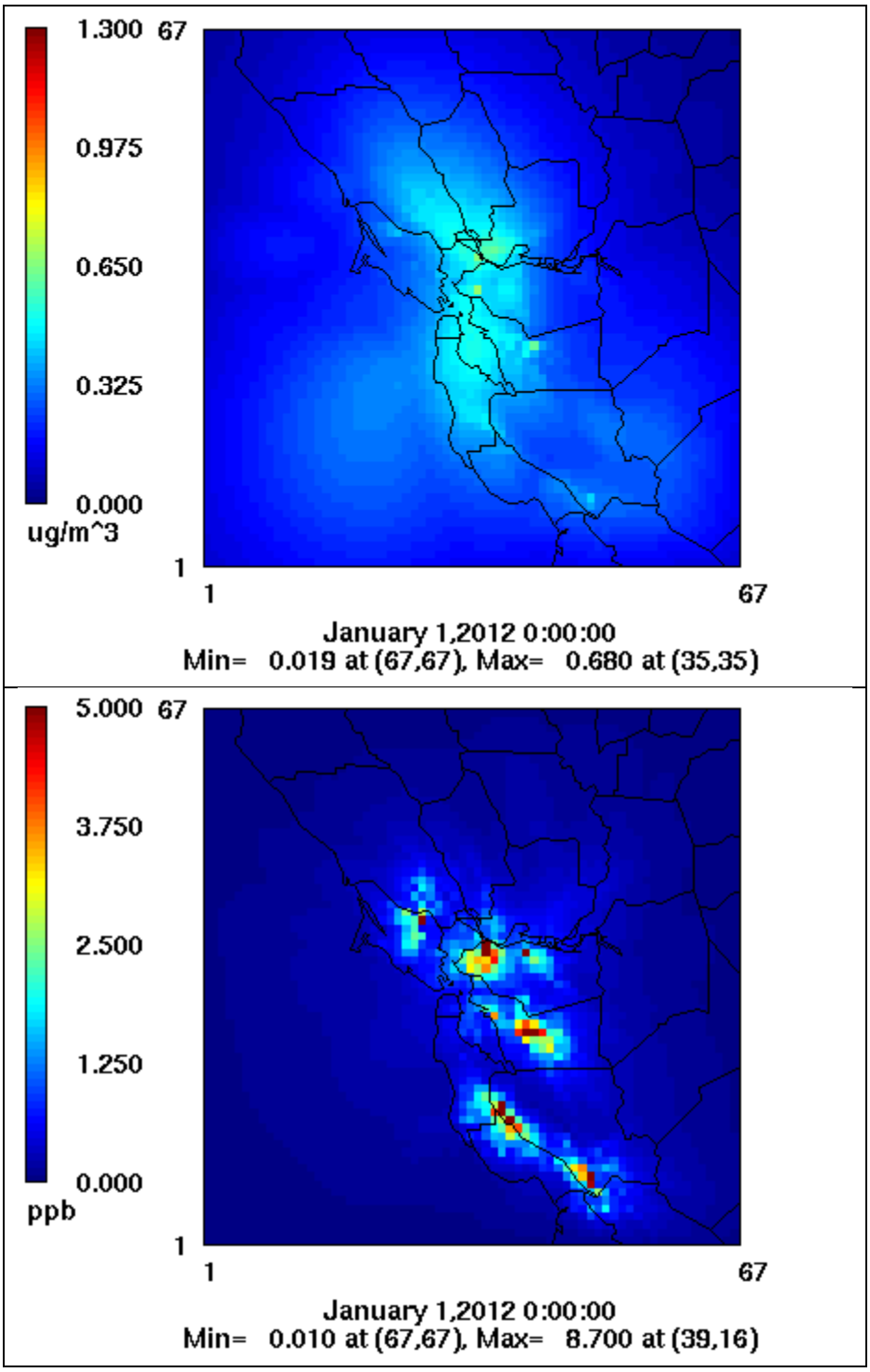


Figure 5 shows the maximum difference between the base case and modified case scenarios over the course of the entire year for each grid cell, for SO_4 (top) and SO_2 (bottom).

4.2 CMAQ Modeling

CMAQ Model Runs

CMAQ version 5.0.2 was run on a single domain with 4 km horizontal grid spacing and 15 vertical layers extending to approximately 16 km above terrain elevation. This domain was established for the 2000 Central California Ozone Study and has been used by various agencies including the CARB and the San Joaquin Valley Air Pollution Control District. CMAQ employed the SAPRC99 gas-phase photochemical mechanism in conjunction with the AE5 aerosol treatment, which includes homogeneous (gas-phase) and heterogeneous (aqueous) inorganic and organic aerosol production and gas-particle partitioning. The performance of CMAQ in replicating observed patterns of ozone, $PM_{2.5}$ and precursors throughout the Bay Area has been rigorously evaluated as part of the Air District's 2017 Clean Air Plan.[4]

Meteorological inputs to CMAQ were prepared using the Weather Research and Forecasting (WRF) model. WRF was run with three nested domains: (1) an outer domain covering the entire western US and the eastern Pacific Ocean at 36 km resolution; (2) an intermediate domain covering all of California and a portion of Nevada at 12 km resolution; and (3) an inner domain extending just beyond the CMAQ grid at 4 km resolution. All three domains included 50 vertical layers to approximately 16 km above terrain elevation, consistent with CMAQ. WRF was run in six-day segments, where the last day of each segment overlapped with the first day of the following segment; the first day of each segment was restricted to WRF spin-up from initial conditions and was not used for air quality modeling. Various model options were tested and a combination of the best-performing options was selected for the final simulation. Four-dimensional data assimilation was used to bring simulations toward observations. A comprehensive model evaluation was conducted and documented as part of the Air District's 2017 Clean Air Plan.

The 2012 emissions inventory was obtained from the CARB and processed using the Sparse Matrix Operator Kernel Emissions (SMOKE) system to prepare hourly emissions inputs for CMAQ. CMAQ boundary conditions (BCs) were generally developed from publicly-available 6-hourly MOZART global chemistry model output specific to the year 2012. However, BCs for ozone were developed from monthly-average ozonesonde measurements collected at Trinidad Head, California, and BCs for six species not treated by MOZART were based on CMAQ default BC profiles. Emissions data and global chemistry data were processed to the 4-km CMAQ grid and speciated to support SAPRC99/AE5 chemistry in CMAQ.

CMAQ was run for two winter months of 2012 (January 2-31 and December 2-30) to comprehensively simulate emissions, dispersion, removal and chemistry of all $PM_{2.5}$ components and associated precursors from all anthropogenic, biogenic and background sources throughout the region. These simulations specifically address conditions that result in exceedance-level $PM_{2.5}$ concentrations in the Bay Area and Central California. The base case scenario modeled the existing 2012 inventory, while the modified case scenario included the 20% increase in SO_2 for the 129 existing sources emitting at least 4 TPY and the 7 hypothetical new major sources, as

[4] The 2017 Clean Air Plan is available online at: www.baaqmd.gov/~/media/files/planning-and-research/plans/2017-clean-air-plan/attachment-a_-proposed-final-cap-vol-1-pdf.pdf?la=en.

described above. The additional emissions and stack data for the hypothetical new sources were incorporated into the Air District's 2012 modeling inventory and processed through SMOKE to generate the modified case scenario inputs for CMAQ.

Both SO_4 and total $PM_{2.5}$ concentrations were modeled. SO_4 is the primary driver of impacts on $PM_{2.5}$ concentrations that result from SO_2 emissions, because SO_2 is converted in the atmosphere into SO_4, which is a constituent of $PM_{2.5}$ as explained above. But some of the SO_4 may subsequently react with ammonia to form ammonium sulfate, which is also a constituent of $PM_{2.5}$. The CMAQ model is capable of modeling the contributions from this formation of ammonium sulfate as well, and so the Air District evaluated both SO_4 and total $PM_{2.5}$ in its analysis. As the results set forth below show, however, in most cases SO_4 accounts for nearly all of the modeled impacts, with the modeled impacts on total $PM_{2.5}$ concentrations (which includes the impacts from conversion to ammonium sulfate) showing only a slight increase over the modeled impacts on SO_4 concentrations.

CMAQ Results

The results of the CMAQ modeling analysis are shown in Figures 6 and 7. Figure 6 shows the results for SO_4, and Figure 7 shows the results for total $PM_{2.5}$. As with the CALPUFF results in Figure 3, the top graphs in Figures 6 and 7 show the maximum modeled concentrations for each day during the modeled period for both the base case (orange) and the modified case (blue). The results shown are from a domain consistent with the CALPUFF grid centered on the Bay Area for each day of January and December 2012. (Note again that the locations of the maximum concentrations may differ from day to day.) The bottom graphs shows the maximum difference between the modified case and base case for each day, which represents the maximum increase in 24-hour concentrations of SO_4 and total $PM_{2.5}$, respectively, predicted by the model for that day as a result of the SO_2 emissions increases in the modified case.

Figure 6 shows predicted increases in SO_4 concentrations reaching up to a maximum of nearly 0.5 $\mu g/m^3$, and Figure 7 shows predicted increases in total $PM_{2.5}$ reaching up to a maximum of nearly 0.6 $\mu g/m^3$. These maximum modeled impacts are consistent with although smaller than the CALPUFF signal. This level of impact is less than half of the threshold level of 1.3 $\mu g/m^3$ at which a modeled impact would be considered significant, indicating that even with the very conservative (high) SO_2 increases included in the modified case scenario, CMAQ predicts that maximum incremental $PM_{2.5}$ impacts from potential future SO_2 emissions growth would be well below a significant $PM_{2.5}$ contribution.

Note also that Figures 6 and 7 show several features that clearly differ from the CALPUFF results. First, CMAQ-simulated total SO_4 concentrations are much higher than the results from the CALPUFF modeling, because CMAQ includes all local, regional and background sources of SOx, whereas CALPUFF modeled only point-source contributions. Second, the temporal patterns of the CMAQ results differ from CALPUFF; this is likely the result of more complex interactions between dispersion, chemistry, and the interplay among local, regional and background sources of SOx that CMAQ takes into account.

Figure 6:
Modeled SO_4 Impacts From High SO_2 Emissions Growth Scenario

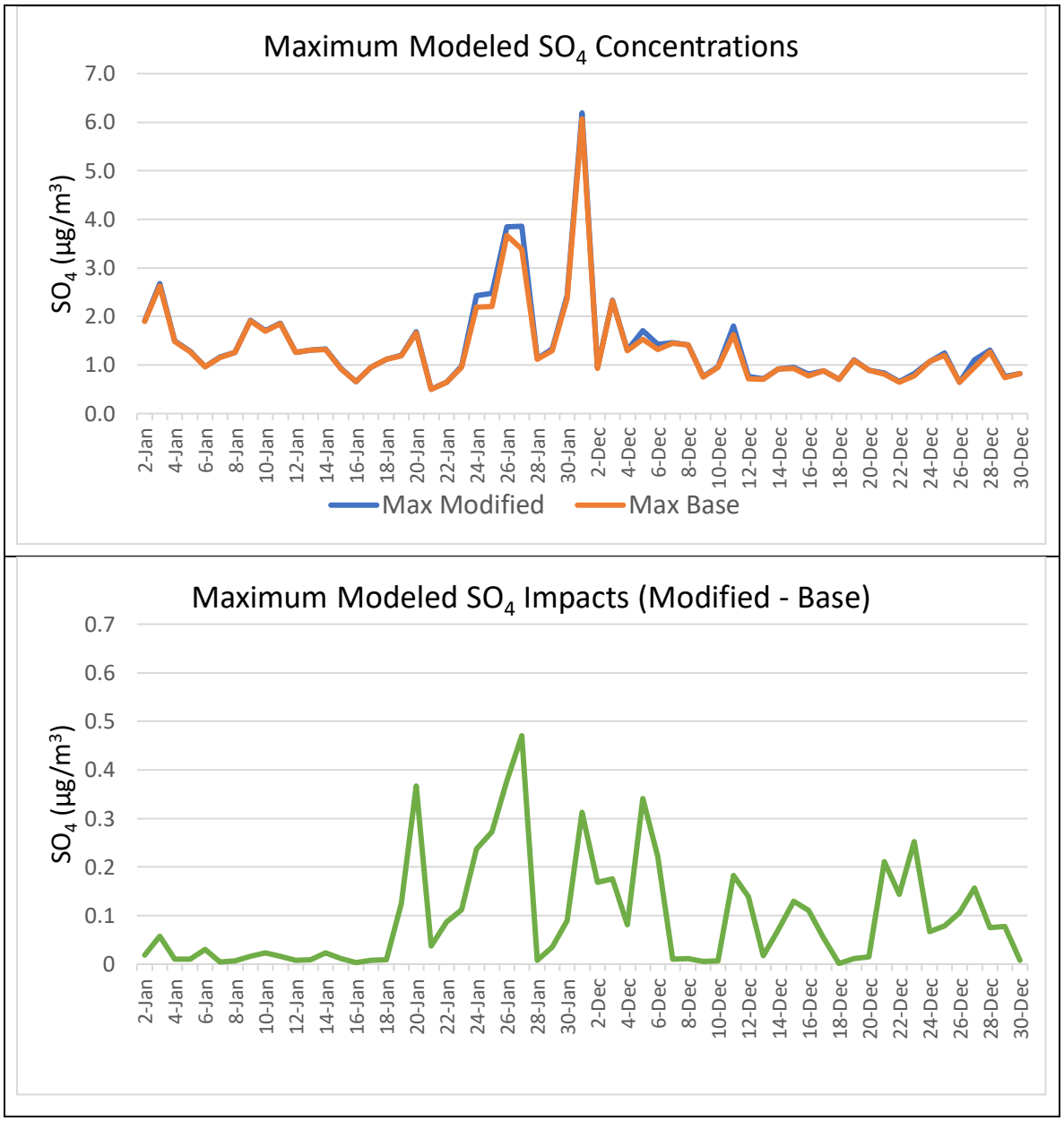


Figure 6 shows the results of the CMAQ modeling analysis for SO_4. The top graph shows the maximum SO_4 concentration predicted by CMAQ for each day of January and December 2012 for both the base case and modified case. The bottom graph shows the maximum difference in SO_4 concentrations between the base case and modified case for each day modeled.

Figure 7:
Modeled Total $PM_{2.5}$ Impacts From High SO_2 Emissions Growth Scenario

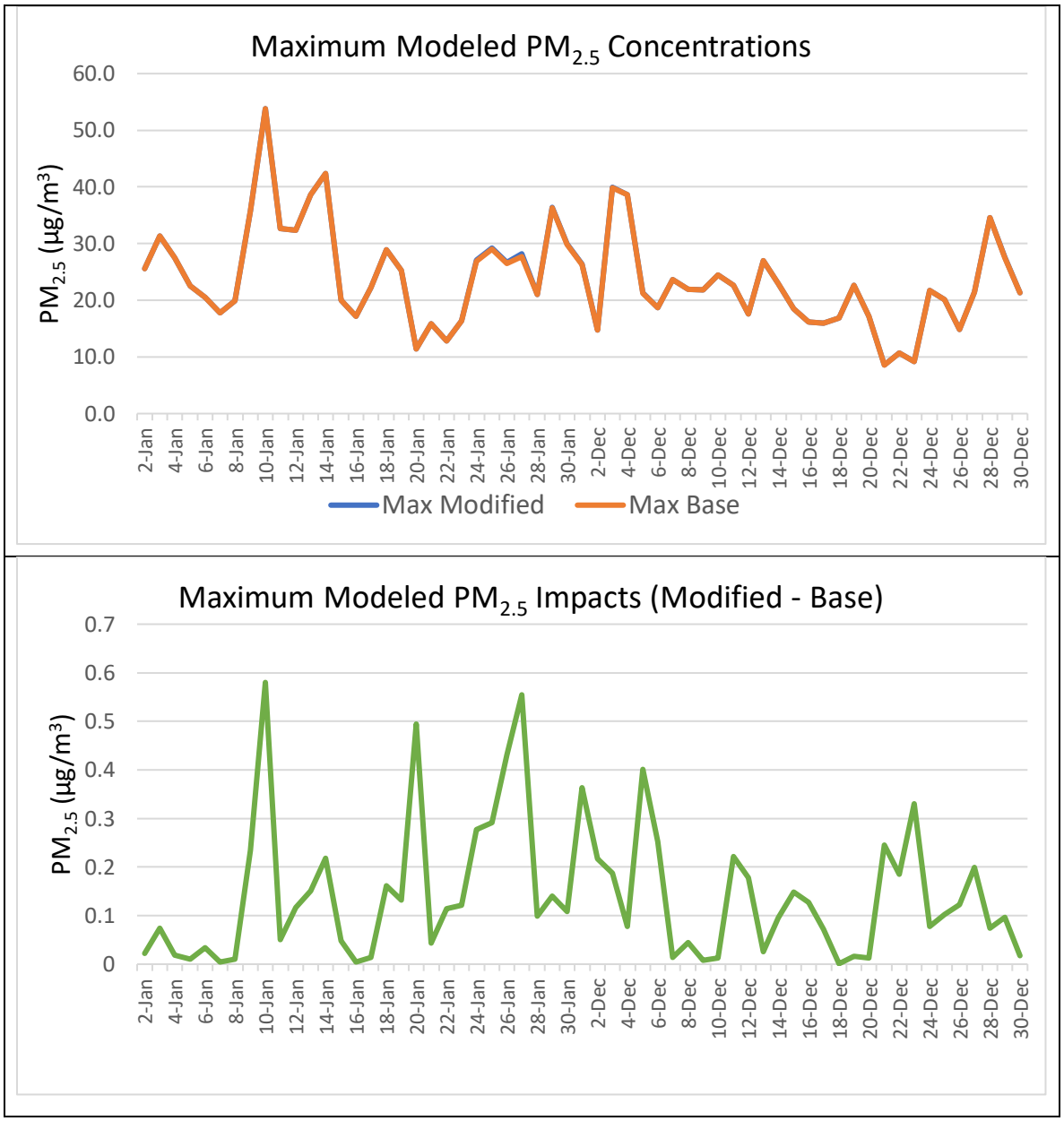


Figure 7 shows the results of the CMAQ modeling analysis for total $PM_{2.5}$. The top graph shows the maximum $PM_{2.5}$ concentration predicted by CMAQ for each day of January and December 2012 for both the base case and modified case. The bottom graph shows the maximum difference in $PM_{2.5}$ concentrations between the base case and modified case for each day modeled.

Comparing the modeled SO_4 impacts in Figure 6 (bottom graph) to the modeled total $PM_{2.5}$ impacts in Future 7 (bottom graph), they generally track each other closely, with $PM_{2.5}$ impacts consistently higher than SO_4 impacts by 0.05-0.1 $\mu g/m^3$ due to the fact that the total $PM_{2.5}$ results reflect the formation of ammonium sulfate in addition to SO_4, as noted above. The two notable exceptions are January 10 and 14, where the model shows total $PM_{2.5}$ impacts that do not have a large SO_4 component, according to the model.

The spatial distribution of the modeled impacts around the Bay Area is shown in Figure 8. These plots show a subset of the CMAQ grid covering the Bay Area consistent with the CALPUFF grid, with predicted 24-hour SO_4 impacts (top plot) and total $PM_{2.5}$ impacts (bottom plot) for January 27, the day with the highest modeled SO_4 impact. The maximum impacts are similar to the maximum impact predicted by CALPUFF, but the day on which the peak impact occurs is different from the peak CALPUFF day, and as a result the spatial patterns are somewhat different.

The spatial distribution of 24-hour SO_2 impacts is shown in Figure 9 for January 24, the day of peak SO_2 impact. The peak SO_2 impact of 1.625 ppb is lower than peak SO_2 impact from CALPUFF by more than a factor of 5. Peak SO_2 impacts occur along the Suisun Bay where many existing and hypothetical new sources are located.

Figure 8:
Spatial Distribution of Modeled Impacts on SO_4 (top) and Total $PM_{2.5}$ (bottom)
On Highest-Impact Day

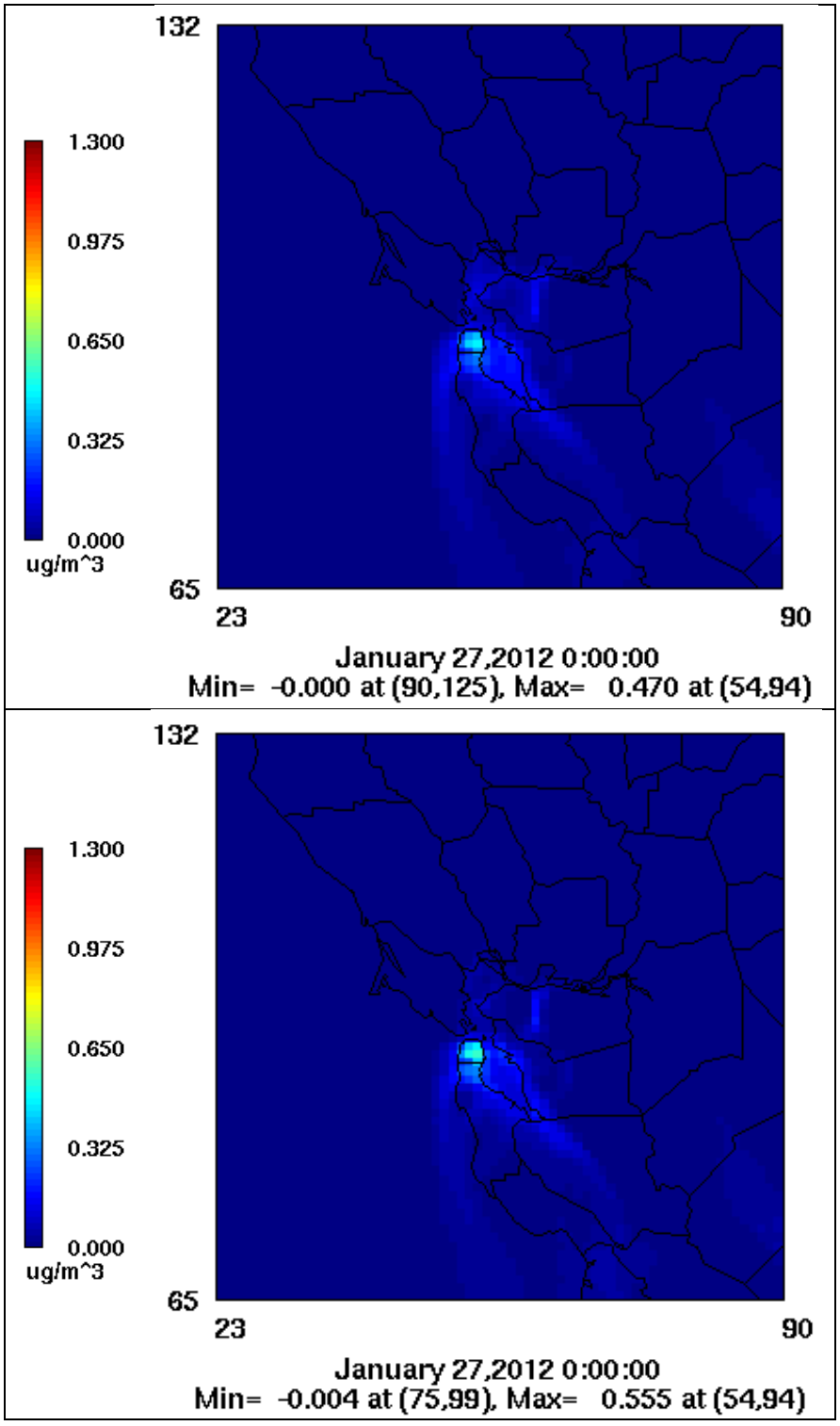


Figure 8 shows the spatial distribution of 24-hour SO_4 and total $PM_{2.5}$ differences between the base case and modified case scenarios on January 27, 2012, the day with the highest predicted impact.

Figure 9:
Spatial Distribution of Modeled SO_2 Impacts On Day Of Highest Impact

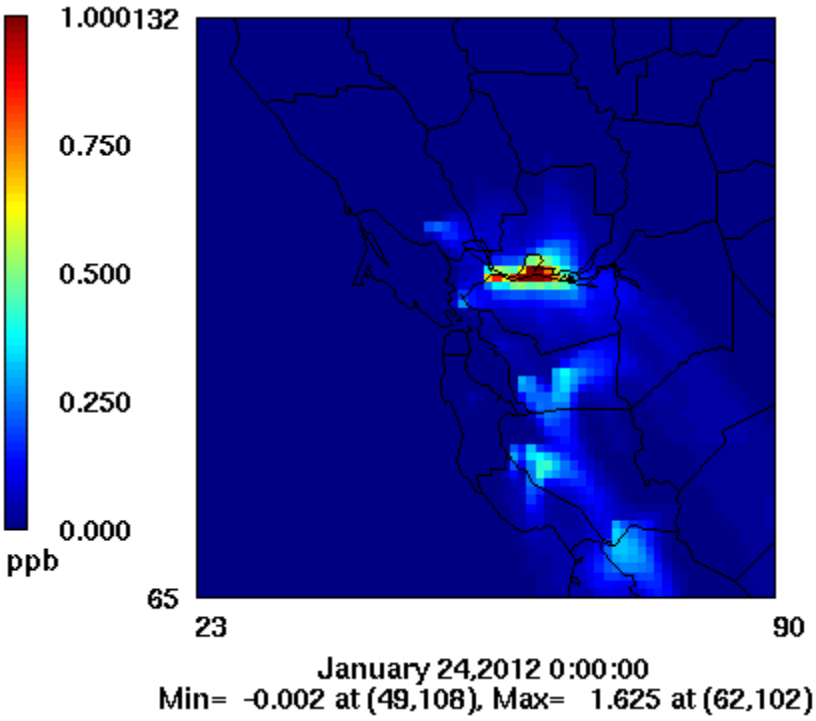


Figure 9 shows the spatial distribution of 24-hour SO_2 difference between the base case and modified case scenarios on January 24, 2012.

Figure 10 shows the maximum SO_4 and total $PM_{2.5}$ impacts predicted for each location (grid cell) throughout the region over the entirety of the January and December 2012 modeling period. These plots are similar to the corresponding plots from CALPUFF in Figure 5. As was the case with the CALPUFF plots in Figure 5, the points of maximum impact remain the same as Figure 8, but the surrounding areas show somewhat higher impacts than in Figure 8 because the plots show the highest impacts from any day during the modeling period, not just the impacts on January 27, the day shown in Figure 8.

The spatial distribution of maximum simulated SO_4 impacts between CALPUFF (Figure 5, top) and CMAQ (Figure 10, top) are quite different, given different models, time periods, and chemistry. As opposed to the more diffuse patterns evident in the CALPUFF results, the CMAQ results shown in the top plot in Figure 10 show much more isolated and localized impacts and sharper gradients. Maximum impacts in western Contra Costa County seen in the CALPUFF results are practically non-existent in the CMAQ results; this could be related to the fact that SO_2 sources in that area are primarily associated with refineries, with high stack releases, and so vertical stratification simulated by CMAQ's vertical layer structure may prevent SOx mass from reaching the surface more so than CALPUFF's vertical dispersion rates. The difference in spatial patterns could also be related to the heterogeneous patterns of clouds and fog, where the treatment of clouds and aqueous PM interactions are better treated by CMAQ than in CALPUFF.

Figure 10:

Maximum Modeled Impacts In Each Grid Cell For SO_4 (top) and $PM_{2.5}$ (Bottom)

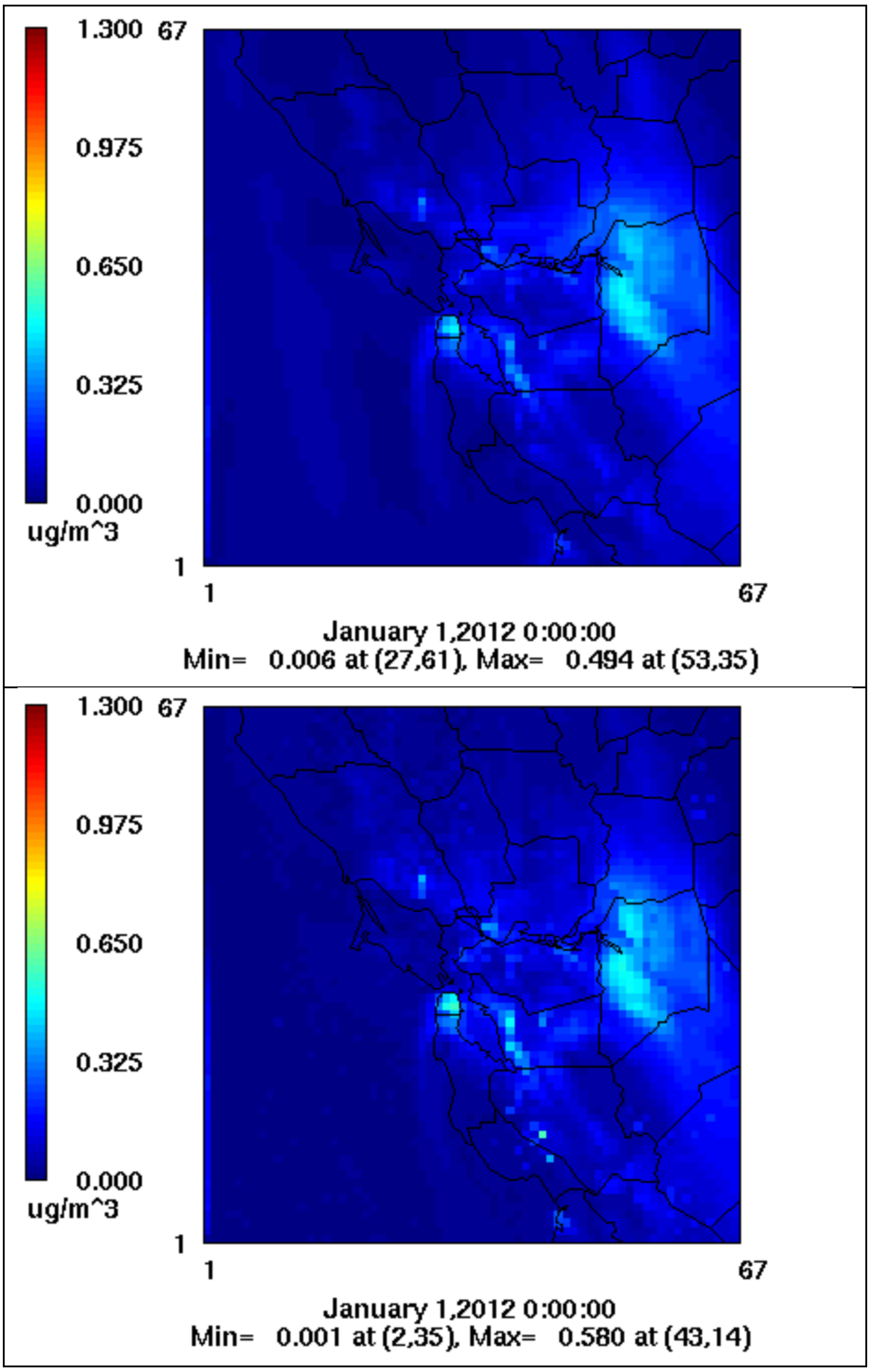


Figure 10 shows the maximum difference between the base case and modified case scenarios in each grid cell during the entirety of the January and December modeling periods for 24-hour SO_4 (top) and $PM_{2.5}$ (bottom).

With respect to maximum $PM_{2.5}$ impacts shown in the bottom plot in Figure 10, the impact patterns correlate directly with the SO_4 impacts in the top plot, but the $PM_{2.5}$ concentrations are slightly higher across the domain. This is attributed to the additional ammonium sulfate associated with the small increases in sulfate, which is not shown in the SO_4 plot. Notably, certain localized $PM_{2.5}$ impacts appear where the associated SO_4 impacts are much smaller or absent. This is particularly true for $PM_{2.5}$ peaks outside the urbanized Bay Area where larger sources of agricultural ammonia exists. Again, maximum $PM_{2.5}$ impacts in the Bay Area remain below 0.6 $\mu g/m^3$.

Figure 11:
Maximum Modeled SO_2 Impacts For Each Grid Cell

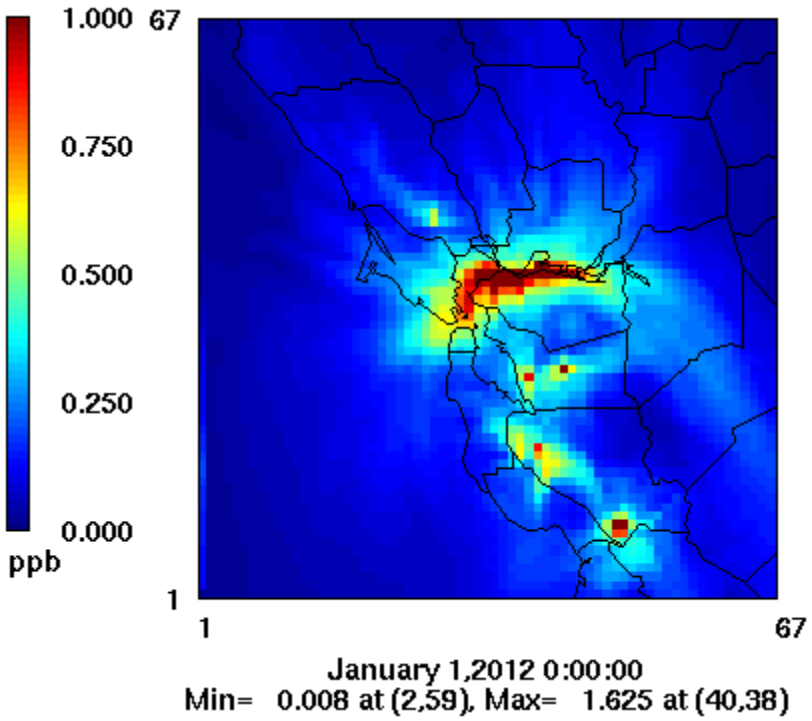


Figure 11 shows the maximum difference in modeled 24-hour SO_2 concentrations between the base case and modified case scenarios for each grid cell throughout the entire modeling period.

The highest modeled SO_2 impact at each grid cell out of all of the days in the modeling period are shown in Figure 11. Note that the maximum SO_2 impact in a given grid cell may occur on a different date than the maximum SO_4 and total $PM_{2.5}$ impacts shown in Figure 10. For SO_2, the CMAQ pattern of maximum impact agrees better with CALPUFF results (Figure 5, bottom) given that this is a directly-emitted precursor, and so the maximum impacts remain near their sources. However, CMAQ-predicted SO_2 impacts are much lower than CALPUFF-predicted impacts. This is likely related to some extent to the fact that in CMAQ, SO_2 emissions are instantly diluted to grid volumes, whereas in CALPUFF they are confined to smaller puff volumes. As mentioned previously, vertical stratification simulated in CMAQ may prevent SOx mass from reaching the surface more so than CALPUFF vertical dispersion rates.

5. CONCLUSIONS

A modeling analysis was conducted in conformance with EPA's requirements for NNSR precursor demonstrations in 40 CFR Section 51.1006(a)(3) to address the sensitivity of $PM_{2.5}$ concentrations in the San Francisco Bay Area to potential increases in SO_2 emissions from major point sources within the region. The analysis was conducted according to a Protocol developed in conjunction with EPA Region 9 and OAQPS Staff, and consistent with EPA's draft $PM_{2.5}$ Precursor Demonstration Guidance.

The modeling analysis evaluated the potential impacts on 24-hour-average $PM_{2.5}$ concentrations in the Bay Area from a conservative high-emissions-growth scenario. This scenario assumed that all point sources currently emitting 4 TPY or more SO_2 would increase their emissions by 20%, and also that 7 new major sources would be built emitting 370 TPY each. This level of emissions growth is not expected, but it was used to ensure that the analysis represented a reasonable "worst-case" scenario.

The analysis compared a "base case" modeled using existing emissions and a "modified case" modeled based on the conservative emissions growth scenario. The two cases were modeled using CALPUFF and CMAQ models, with CALPUFF applied over the entirety of 2012 and CMAQ applied over December and January to explicitly treat detailed chemistry and transport during exceedance-level $PM_{2.5}$ events, which predominantly occur during those months. The predicted impacts from the assumed growth in SO_2 emissions were derived based on the difference between the modeled concentrations from the base case scenario and the modeled concentrations from the modified case scenario.

The CALPUFF and CMAQ analyses were similar in their predicted maximum impacts on 24-hour-average $PM_{2.5}$ concentrations. The maximum modeled CALPUFF impact was just under 0.7 $\mu g/m^3$, and the maximum modeled CMAQ impact was just under 0.6 $\mu g/m^3$. The two models showed different temporal and spatial patterns of impacts, owing to the different source mixtures, chemistry, and heterogeneity addressed by CMAQ and CALPUFF. The results of both analyses are well below the 1.3 $\mu g/m^3$ level at which the impact would be considered significant.

This modeling analysis demonstrates that SO_2 emissions from major sources in the Bay Area will not contribute significantly to $PM_{2.5}$ levels exceeding the 24-hour $PM_{2.5}$ NAAQS, even if the region were to experience a high level of SO_2 emissions growth. The analysis therefore provides a basis for EPA to make a determination under 40 CFR Section 51.165(a)(13) that the Air District's NSR permitting program does not need to apply the Clean Air Act's NNSR requirements to SO_2.

In addition, the performance of the CMAQ model was evaluated. The model was found to perform well in replicating spatial and day-to-day patterns of observed SO_4 concentrations at monitoring locations throughout the Bay Area, with a slight tendency for over prediction. The good performance exhibited by CMAQ supports the focus on absolute modeled impacts in this demonstration, as opposed to relative impacts.

Appendix A:

Protocol For Demonstration of SO_2 Precursor Contributions to $PM_{2.5}$ in the San Francisco Bay Area

This document sets forth a protocol under which the Bay Area Air Quality Management District (District) will evaluate of the sensitivity of fine particulate matter ($PM_{2.5}$) levels within the San Francisco Bay Area to potential increases in sulfur dioxide (SO_2) emissions from point sources within the region. The purpose of this evaluation is to support a demonstration that SO_2 emissions do not contribute significantly to $PM_{2.5}$ levels exceeding the $PM_{2.5}$ National Ambient Air Quality Standards (NAAQS) under 40 CFR section 51.1006(a)(3). The District intends to submit this demonstration to EPA to support an exemption from the requirement to regulate SO_2 under the District's Nonattainment New Source Review (NNSR) requirements pursuant to Section 189(e) of the Clean Air Act and 40 CFR section 51.165(a)(13).

INTRODUCTION

The San Francisco Bay Area is a designated nonattainment area for the 24-hour fine particulate matter ($PM_{2.5}$) National Ambient Air Quality Standard (NAAQS). The Bay Area Air Quality Management District has jurisdiction over permitting and controlling stationary source emissions in the nonattainment area. The District is preparing to demonstrate that sulfur dioxide (SO_2) precursor emissions from major point sources do not currently, and will not under reasonably conservative growth scenarios, contribute significantly to $PM_{2.5}$ exceedances in the Bay Area so that SO_2 may be excluded as a $PM_{2.5}$ precursor from the District's permitting program under the NNSR requirements.

40 CFR section 51.1006(a)(3) sets forth EPA's requirements for making $PM_{2.5}$ precursor demonstrations[1]. The rule provides for agencies to demonstrate that a specific precursor (SO_2, nitrogen oxides [NOx], volatile organic compounds [VOC] or ammonia [NH_3]) does not contribute significantly to $PM_{2.5}$ levels exceeding the NAAQS within their nonattainment area. If approved, the agency's NNSR program may exclude that precursor under 40 CFR section 51.165(a)(13).

The US Environmental Protection Agency (EPA) has issued draft Demonstration Guidance[2] to assist air agencies in developing precursor demonstrations for $PM_{2.5}$ under Section 51.1006. The District's SO_2 demonstration will involve modeling and analyses in accordance with Section 6 of the Demonstration Guidance (NNSR Precursor Demonstration), which outlines procedures for examining and documenting model sensitivity to changes in emissions. The District has previously modeled $PM_{2.5}$, SO_2 and SO_2 contributions to $PM_{2.5}$ sulfate within the Bay Area for the year 2012.

[1] 40 CFR section 51.1006 and related provisions addressing precursor demonstrations were adopted in EPA's $PM_{2.5}$ SIP Requirements Rule, Fine Particulate Matter National Ambient Air Quality Standards: State Implementation Plan Requirements, 81 FR 58010 (Aug. 24, 2016).

[2] "$PM_{2.5}$ Precursor Demonstration Guidance", U.S. Environmental Protection Agency, Office of Air Quality Planning and Standards, Air Quality Assessment Division and Air Quality Policy Division, Research Triangle Park, NC (EPA-454/P-16-001, November 2016).

For the purpose of the precursor demonstration, the District will conduct new simulations using the same modeling system but with increased SO_2 emissions from existing and new hypothetical major point sources representing conservatively large growth[3]. All modeling and analyses will be conducted in accordance with EPA's Demonstration Guidance and discussions with EPA staff from Region 9 and the Office of Air Quality Planning and Standards (OAQPS).

This demonstration protocol first presents the purpose of the $PM_{2.5}$ precursor demonstration project, followed by a detailed methodology of the modeling and analysis. The discussion includes the District's rationales for the increase in major point source SO_2 emissions to be modeled; for the locations of the hypothetical point sources and their emission rates and stack parameters; for the choice of modeling year and the models to be employed; and for the threshold below which the contribution of SO_2 emissions to $PM_{2.5}$ levels exceeding the NAAQS will be considered less than significant. Additional information on the characterization of Bay Area $PM_{2.5}$ emissions and modeling approach is included at the end of this report.

PURPOSE OF THE SO_2 DEMONSTRATION

The District updated its New Source Review rule in District Regulation 2, Rule 2, in 2012 to add $PM_{2.5}$ as a pollutant subject to the rule's NNSR requirements. One outstanding issue from that process concerns whether the District must also subject SO_2 to the NNSR requirements as a $PM_{2.5}$ precursor. EPA's NNSR regulations require that $PM_{2.5}$ precursors such as SO_2 must be subject to NNSR requirements unless the permitting authority can demonstrate that emissions of the precursor from major sources in the region do not contribute significantly to any $PM_{2.5}$ levels exceeding the NAAQS. (See 40 CFR § 51.165(a)(13).) The purpose of this SO_2 demonstration is to make such a showing with respect to SO_2 in the San Francisco Bay Area.[4]

In preparation of the $PM_{2.5}$ precursor demonstration for SO_2, the District met several times with EPA Region 9 and OAQPS in early 2017 to discuss the rationale and approach. This protocol formalizes and builds from that information. The presentation material from those meetings is appended to this protocol.

As described in the characterization section of this protocol, measurements of SO_4 throughout the Bay Area are consistently below 1 $\mu g/m^3$, fairly independent of monitoring site, season and year. The highest SO_4 concentrations approaching 1 $\mu g/m^3$ occur during warm months, whereas the lowest concentrations (<0.5 $\mu g/m^3$) occur during the winter months when the highest exceedance-level $PM_{2.5}$ is measured. Therefore, SO_4 does not contribute significantly to $PM_{2.5}$

[3] In this context, "conservative" means that we have estimated potential new emissions growth on the very high side of what is reasonably expected. EPA's draft Demonstration Guidance advises that the demonstration should evaluate more emissions growth "than what is merely 'likely' to occur in the area," so that the NAAQS will be protected even if growth is higher than actually anticipated.

[4] Note that there are not currently any $PM_{2.5}$ levels in the Bay Area in violation of the NAAQS. EPA has determined this to be the case in its *Determination of Attainment for the San Francisco Bay Area Nonattainment Area for the 2006 Fine Particle Standard*, 78 FR 1760 (Jan. 9, 2013), in which EPA found that "the San Francisco Bay Area . . . has attained the 2006 24-hour $PM_{2.5}$ NAAQS . . . ." By definition, therefore, there are no major sources of SO_2 that are contributing significantly to any $PM_{2.5}$ levels exceeding the NAAQS. The focus of this demonstration is on what could happen in future, if there is significant growth in SO_2 emissions (which the District does not anticipate, but which cannot be ruled out).

levels exceeding the NAAQS in the Bay Area. Even if SO_4 concentrations were doubled, the incremental $PM_{2.5}$ increase would likely be less than the 1.3 $\mu g/m^3$ significant impact threshold recommended by EPA in the draft Demonstration Guidance. Recent modeling conducted by the District indicates that a 20% SO_2 reduction results in less than a 0.04 $\mu g/m^3$ SO_4 impact.

According to the District's 2012 modeling inventory, SO_2 emissions in the Bay Area total 26.9 tons per day (TPD). This is comprised of 17.7 TPD from stationary point sources, 0.4 TPD from stationary area sources, 6.3 TPD from ocean-going vessels, and 2.5 TPD from mobile sources (both on- and non-road).

There are 131 permitted point sources in the Bay Area that emit more than 4 tons per year (TPY) of SO_2; together they contribute 16.7 TPD or over 94% of all stationary point source SO_2 emissions. For the purpose of the demonstration, conservative growth will be applied to these 131 sources in addition to 7 hypothetical new sources.

SO_2 DEMONSTRATION APPROACH

Overview

This SO_2 precursor demonstration will evaluate the extent to which ambient $PM_{2.5}$ concentrations in the Bay Area are sensitive to potential SO_2 emission increases from existing and potential new major stationary sources. To do so, the District will model increases in SO_2 emissions from existing and hypothetical new major point sources. These increases will include two components:

1) A 20% increase in SO_2 emissions from the 131 existing point sources in the Bay Area that emit at least 4 TPY;
2) Seven hypothetical new major point sources located throughout the Bay Area, each emitting 370 TPY of SO_2, based on an analysis of the top 30 facilities across California that emit more than 100 TPY.

The total increase in SO_2 emissions resulting from these changes is 3,780 TPY or 10.4 TPD. This represents a 38% increase in Bay Area total SO_2 and a 59% increase in Bay Area point source SO_2. The District does not anticipate that emissions increases of this magnitude will actually occur, but it will use this approach as a conservative "worst case" approach in keeping with EPA's draft Demonstration Guidance.

To model the $PM_{2.5}$ impacts of these emissions increases, the District will build off of work that the District has previously done in modeling $PM_{2.5}$, SO_2 and SO_2 contributions to $PM_{2.5}$ for the year 2012. Two types of models were used: the CMAQ photochemical grid model applied over January and December 2012, and the CALPUFF plume model applied over the entirety of 2012. The District will conduct additional simulations of the alternative SO_2 emission scenario outlined above, assuming a 20% increase from the 131 existing point sources over 4 TPY and 7 new major sources emitting 370 TPY. The District will compare the modeled $PM_{2.5}$ concentrations under the "base case" (without the increases) and the "modified case" (with the increases) to assess the sensitivity of $PM_{2.5}$ concentrations in the Bay Area to these hypothetical SO_2 emissions increases.

The project will follow Section 6 of EPA's Demonstration Guidance on assessing source-specific significant impact thresholds, as well as District and EPA discussions on the approach.

In developing the protocol for this sensitivity analysis, the District has focused on three questions identified in EPA's draft Demonstration Guidance:

1) What amount of emissions increase should be examined?
2) Where should precursor emissions increases be located?
3) What concentration threshold determines an insignificant modeled 24-hour $PM_{2.5}$ change?

The District's rationale with respect to each of these issues is discussed below.

Rationale for Amount of Emission Increases

The emission increases that the District is proposing to use for the SO_2 precursor demonstration present a reasonably conservative "worst case" scenario for the Bay Area.

With respect to the 20% increase in emissions for the 131 sources that currently emit more than 4 TPY SO_2, this is a conservative estimate because actual emissions of SO_2 from these facilities have decreased over the last decade.

With respect to the seven new hypothetical major SO_2 sources, the District has followed the approach suggested in the draft Demonstration Guidance and assessed what types of potential new major SO_2 sources would be most likely within the Bay Area (to the extent that any new major SO2 sources locate here at all). The District did so by evaluating the largest SO_2 major sources throughout California, based on the California Air Resources Board (CARB) 2015 point source emissions inventory. The 29 largest SO_2 sources in California that emit more than 100 TPY are listed in Table 1. The average SO_2 emission rate among these 29 sources is just under 370 TPY. Ten of these sources exist in the Bay Area, including 8 refineries, 1 cement plant and a carbon plant. These facilities existed prior to the District's permitting program, and thus their SO_2 emission rates are grandfathered. In fact, the District has never permitted a new SO_2 facility larger than 300 TPY since the inception of our permitting program in the 1970s. Any new facility would most likely be capped at less than 300 TPY due to regulations, such as state Best Available Control Technology (BACT) which is required for any new or modified SO_2 source with emissions of 10 pounds per day or more, offset requirements which apply to any proposed new or modified SO_2 source emitting more than 100 TPY, and federal Prevention of Significant Deterioration (PSD) requirements.

For example, the Bay Area cement plant emits more than 1,000 TPY, but if permitted under the current New Source Performance Standard (NSPS) of 0.4 lb SO_2/ton clinker, SO_2 emissions would be capped at 320 TPY, unless BACT was determined to be even more stringent. It is very unlikely that the District will ever permit a new petroleum refinery in the Bay Area. Very few have been permitted nationally in the past decade. The most recent example provided by EPA is for a new refinery in Yuma, Arizona. With a processing capacity of 150,000 barrels/day (typical of Bay Area refineries), the permitted SO_2 emissions rate was set at 251 TPY, well below our proposed 370 TPY hypothetical SO_2 increase for seven new sources.

Table 1. Twenty nine largest SO_2 sources in the CARB 2015 California point source emission inventory.

SIC	Type	City	District	SO_2 Emissions (TPY)
2999	Carbon Plant	**Rodeo**	**Bay Area**	**1519**
2911	Petroleum Refining	**Martinez**	**Bay Area**	**1093**
3241	Cement	**Cupertino**	**Bay Area**	**1058**
3241	Cement	Mojave	Kern County	978
2911	Petroleum Refining	**Martinez**	**Bay Area**	**962**
2911	Petroleum Refining	Carson	South Coast	503
2911	Petroleum Refining	**Richmond**	**Bay Area**	**381**
2911	Petroleum Refining	**Rodeo**	**Bay Area**	**365**
2911	Petroleum Refining	Carson	South Coast	340
2911	Petroleum Refining	Torrance	South Coast	333
3463	Nonferrous Forging	Wilmington	South Coast	329
2911	Petroleum Refining	El Segundo	South Coast	300
3221	Glass Containers	**Oakland**	**Bay Area**	**205**
2819	Inorganic Chemicals	**Martinez**	**Bay Area**	**186**
3241	Cement	Lucerne Valley	Mojave Desert	182
3221	Glass Containers	Modesto	San Joaquin Valley	182
2819	Inorganic Chemicals	**Richmond**	**Bay Area**	**174**
2911	Petroleum Refining	Wilmington	South Coast	163
2911	Petroleum Refining	Arroyo Grande	San Luis Obispo	159
1474	Potash/Soda/Borate	Trona	Mojave Desert	146
3211	Flat Glass	Kingsburg	San Joaquin Valley	144
2873	Nitrogen Fertilizers	Lathrop	San Joaquin Valley	142
4953	Refuse	Whittier	South Coast	137
2911	Petroleum Refining	Wilmington	South Coast	132
4911	Electric Generation	Trona	Mojave Desert	126
3241	Cement	Apple Valley	Mojave Desert	126
2911	Petroleum Refining	**Benicia**	**Bay Area**	**110**
3221	Glass Containers	Madera	San Joaquin Valley	106
1311	Oil & Gas	Kern County	San Joaquin Valley	104

Rationale for Locations of Emissions Increases

The District will model the 20% SO_2 emissions increases from the 131 existing sources at the locations of those existing sources. These locations are shown on the map on the left side of Figure 1, along with areas specifically zoned for industrial use. The map on the right side of Figure 1 indicates the location of the existing sources emitting over 4 TPY as resolved to the 4 km CMAQ modeling grid.

For the 7 hypothetical new SO_2 sources, the locations of these sources are indicated by the black squares on the map on the right side of Figure 1. The locations of these sources were carefully selected to cover the entire Bay Area with reasonable density, including extending to the north and south bay regions where such large sources do not currently exist. There are many restrictions on where new sources of this magnitude could possibly be built. As clearly evident in Figures 1 and 2, considerations must include limitations resulting from the unique geography of the Bay Area (extensive water bodies and surrounding mountain ranges), access to necessary infrastructure and raw materials (railroads, highways, water and fuel pipelines, etc.), population

density and public sensitivity to health and welfare concerns, and the clustering of areas specifically zoned for industrial use.

The 7 hypothetical new sources are located within existing industrial areas of the Bay Area where growth may be expected and allowed via zoning restrictions. These include 2 in the industrialized area along the northern coast of Contra Costa County, 2 in industrial areas of the east bay (Alameda County), one near the existing cement plant (Santa Clara County), one at the south end of the Bay Area (southern Santa Clara County) and one in the north bay near existing landfill activity (Sonoma County). Except for the southern-most source, all are consistently positioned within areas currently occupied by the existing 131 SO_2 sources.

Modeling Methodology

The SO_2 demonstration modeling will build upon existing CALPUFF and CMAQ applications that the District has previously developed for the year 2012. EPA's draft Demonstration Guidance of November 17, 2016 recommends using absolute model outputs to calculate major source impacts for NNSR precursor demonstrations, while acknowledging that examination of relative impacts may be appropriate in some cases. In the Bay Area, sulfate is measured at five sites: four of these sites are on a one-in-three-day schedule, and the remaining site is on a one-in-six-day schedule. There are also gaps in captured sulfate data in January and December 2012. Therefore, determining the true bias between simulated and sparsely measured sulfate is difficult. As a result, we prefer to determine the increase in sulfate concentrations for the hypothetical growth case in an absolute sense. However, we also plan to examine relative differences in sulfate concentrations between the base case and hypothetical control case, and information on both absolute and relative differences will be included in the Demonstration report.

The SO_2 impact will be modeled using the "brute force" approach, which calculates $PM_{2.5}$ impacts by differencing model output from two scenarios: a "base case" (current 2012 inventory) and a "modified case".

The CMAQ photochemical grid model will be run on the District's 4 km Central California modeling grid for two winter months of 2012: January 2-31 and December 2-30. CMAQ emissions will include:

1) 2012 base-year emission inventory, including all "current" sources of SO_2 and other photochemical and PM precursors (NOx, VOC, CO, primary PM);
2) A 20% increase in SO_2 for 131 sources emitting at least 4 TPY of SO_2 in 2012;
3) Seven additional hypothetical new SO_2 sources each emitting 370 TPY.

There are significant variations in stack paraments of existing sources of similar size within the Bay Area. These parameters will be tested with the CALPUFF model and the parameters resulting in the highest SO_4 concentrations will be used for both CMAQ and CALPUFF simulations. For the CMAQ case, the additional emissions and stack data will be incorporated into the District's 2012 modeling inventory using the Sparse Matrix Operator Kernel Emissions (SMOKE) processing system.

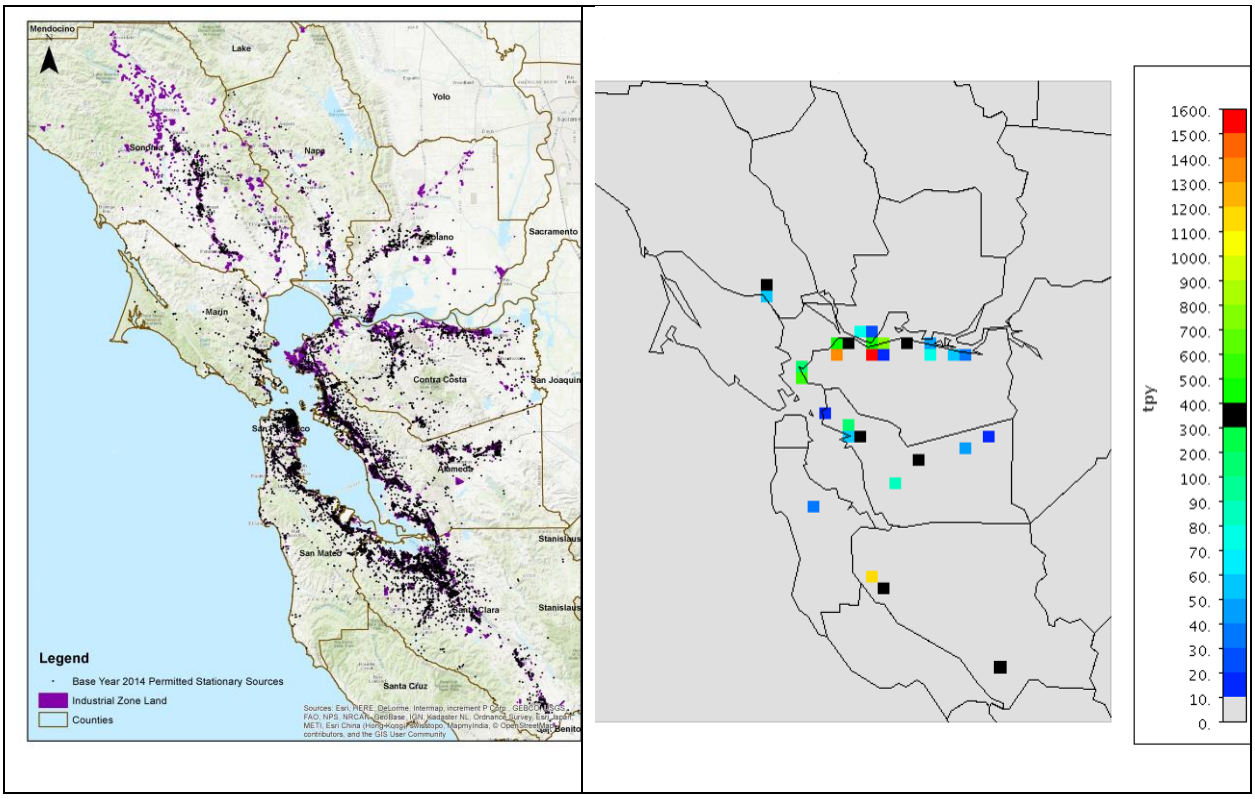


Figure 1. (Left) Locations of permitted point sources in the Bay Area as of 2014 (black) and areas zoned for industrial use (purple). (Right) 2012 point source SO_2 emissions from sources emitting at least 4 TPY (colored), and location of 7 hypothetical SO_2 sources (black). Emissions are represented on the CMAQ 4 km modeling grid; emissions within the same grid cell are summed.

The CALPUFF plume model will be run for the entire 2012 year to simulate the dispersion of SO_2 and resulting chemical conversion to SO_4. CALPUFF will be configured and run identically to the District's existing applications, but will include the following emission updates:

1) A 20% increase in SO_2 for 131 sources emitting at least 4 TPY of SO_2 in 2012;
2) Seven additional hypothetical new SO_2 sources each emitting 370 TPY.

Stack parameters for the new sources will be identical to those developed for the CMAQ runs. New source information will be added to the CALPUFF text point source input files.

The year 2012 is appropriate for the SO_2 modeling demonstration for several reasons. First and most importantly, 2012 is the current model base year established by the CARB, and has been extensively modeled and analyzed by the District to investigate Bay Area patterns and emission sensitivity for both ozone and $PM_{2.5}$. Therefore, modeling datasets are readily available and fully vetted. Second, 2012 provides a reasonable and representative recent year for $PM_{2.5}$ patterns in the Bay Area. As shown in Figure 3, 2012 98th percentile $PM_{2.5}$ concentration patterns across Bay Area monitoring sites are near, yet somewhat below, the 2010-2016 averages and within the minimum-maximum range at all but two sites.

Demonstration Analysis

After CMAQ and CALPUFF simulations are completed, the following post-modeling analysis steps will be conducted to estimate the 24-hour $PM_{2.5}$ impact from increased SO_2 emissions.

5) The 24-hour $PM_{2.5}$ in each model grid cell in the nonattainment area will be determined for each day of CMAQ and CALPUFF output from the base case scenario. In the case of CMAQ, daily component species (sulfate, nitrate, organics, other) will be presented and $PM_{2.5}$ concentrations will be calculated from the sum of component species for each day of the December and January 2012 modeling period. For CALPUFF, daily SO_4 concentrations will be calculated for all days of 2012.

6) The 24-hour $PM_{2.5}$ in each model grid cell will be determined for each day from the modified SO_2 emissions scenario, in the same way as the base case for both models.

7) The daily difference in 24-hour $PM_{2.5}$ between the sensitivity and base case scenarios will be tabulated for each grid cell. For CMAQ, daily differences will be calculated for $PM_{2.5}$, whereas for CALPUFF daily differences will be calculated for SO_4. These calculations yield daily, gridded impacts from the modified SO_2 emission scenario.

8) The maximum 24-hour $PM_{2.5}$ and SO_4 impacts from the respective CMAQ and CALPUFF modeled time periods will be assessed and used for the purpose of the demonstration. If the maximum impact is less than 1.3 $\mu g/m^3$, that will support a conclusion under 40 CFR section 51.1006(a)(3) that the air quality changes associated with the increase SO_2 emissions are not significant.

Rationale for Significance Threshold

The District will use the 1.3 $\mu g/m^3$ threshold recommended by EPA for determining whether SO_2 emissions will make a significant contribution to $PM_{2.5}$ levels exceeding the 24-hour NAAQS. The District has concluded that this is an appropriate measure of whether SO_2 emissions will contribute significantly to $PM_{2.5}$ levels exceeding the NAAQS based on the statistical analyses EPA has conducted in its draft *Technical Basis for the EPA's Development of Significant Impact Thresholds for $PM_{2.5}$ and Ozone* (Aug. 1, 2016). EPA noted that due to fluctuating meteorological conditions and changes in day-to-day source operations, there is inherent variability in the air quality in the area of a monitoring site. This variability can be characterized through the application of a well-established statistical framework for quantifying uncertainty in population statistics. EPA quantified the fluctuations in 24-hour $PM_{2.5}$ concentrations (as measured by design values) and determined that a concentration difference of 1.3 $\mu g/m^3$ is the 50% confidence interval for the 35 $\mu g/m^3$ NAAQS, representing a "significant" impact (pp. 38 and 49). For these reasons, 1.3 $\mu g/m^3$ is an appropriate threshold to use as a first step in evaluating whether the modeled SO_2 emissions increases will contribute significantly to $PM_{2.5}$ concentrations exceeding the NAAQS. However, an increase greater than 1.3 $\mu g/m^3$ would not necessarily preclude the District from making a demonstration since the District does not exceed the $PM_{2.5}$ NAAQS.

CHARACTERIZATON OF $PM_{2.5}$ IN THE BAY AREA

The Bay Area is a designated nonattainment area for the current 24-hour $PM_{2.5}$ NAAQS, which was promulgated in 2006. The form of this standard is the annual 98th percentile 24-hour average $PM_{2.5}$ concentration at each monitor. Each monitor's "Design Value" (DV), which is the metric that determines attainment, is a running 3-year average of the annual 98th percentile; a DV exceeding 35 $\mu g/m^3$ is in violation of the NAAQS.

Figure 2 presents two maps of the Bay Area. The left map includes a satellite-derived image of geography (water bodies, terrain, urbanized areas), county boundaries, and the location of $PM_{2.5}$ monitoring sites. The right map shows color-coded locations of $PM_{2.5}$, SO_2 and speciated SO_4 monitoring sites. Areas of mountainous terrain are generally characterized in Figure 2 by dark green forests, which include many expansive County, State and Federal Parks and Recreation Areas. Urban areas are shown in grey, which primarily rim the Bay and extend to valleys in the North (Santa Rosa), to the east (Concord, Livermore), and to the south (San Jose, Gilroy). The Sacramento River Delta extends eastward from the northern extent of the Bay, past Concord and into the Sacramento and San Joaquin Valleys in the upper right of these maps.

Most $PM_{2.5}$ monitoring sites are operated by the District, with one operated by the Interagency Monitoring of Protected Visual Environments (IMPROVE) program at Point Reyes. There are 15 daily $PM_{2.5}$ monitors operating in the Bay area: 10 of which measure just $PM_{2.5}$, 3 of which are

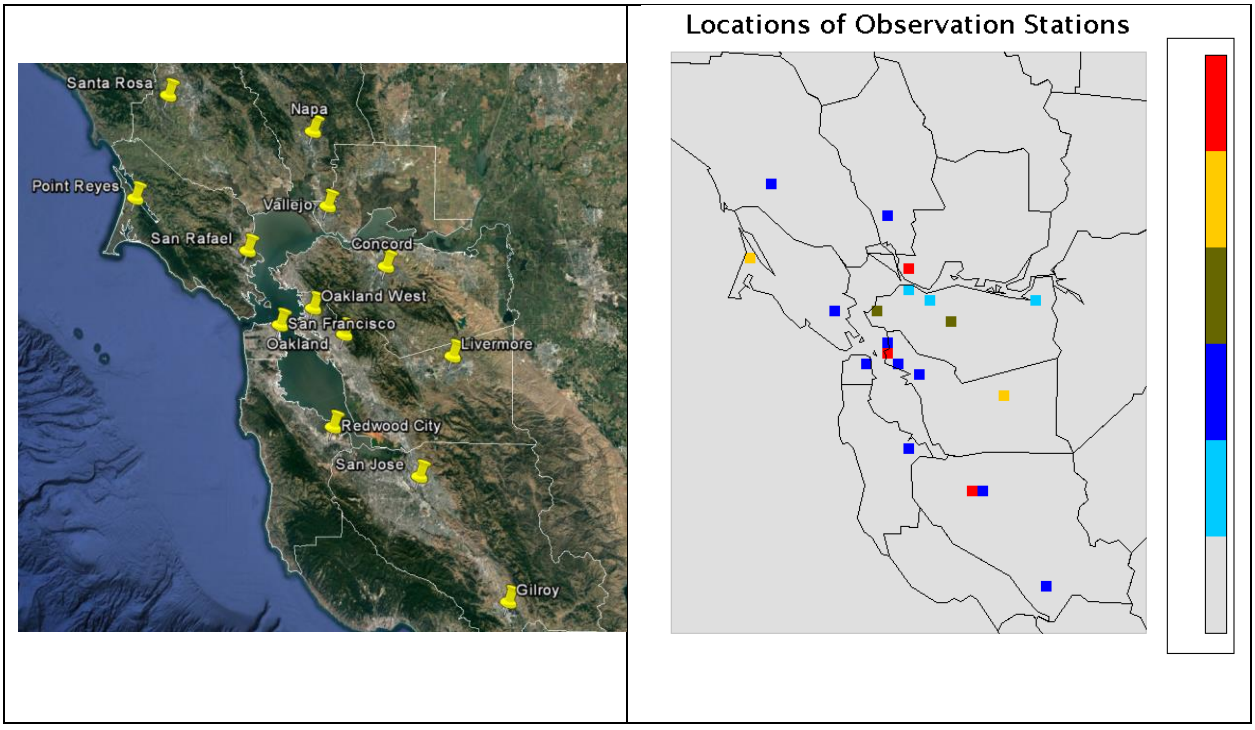


Figure 2. (Left) Satellite-derived geographic image of the San Francisco Bay Area, including county boundaries and the location of $PM_{2.5}$ monitoring sites. (Right) Color-coded locations of $PM_{2.5}$, SO_2 and speciated SO_4 monitoring sites. There are 15 $PM_{2.5}$ monitors operating daily in the Bay area: 10 measure just $PM_{2.5}$ (dark blue), 3 are co-located with SO_2 and SO_4 (red), and 2 are co-located

with SO_2 measurements (brown). Three additional sites measure just SO_2 (light blue), and 2 sites measure SO_4 (gold).

co-located with SO_2 and SO_4 measurements, and 2 of which are co-located with SO_2 measurements. Three additional sites measure just SO_2 in the industrial zone along the Sacramento River (for a total of 8 SO_2 sites). Two sites measure SO_4 every few days in Livermore and Point Reyes (for a total of 5 SO_4 sites).

Figure 3 shows 2010-2016 trends in peak 24-hour $PM_{2.5}$ annual maximum, peak annual 98th percentile, and peak DV among all Bay Area sites. While there is a wide range of inter-annual variability among the number of exceedance days and the annual maxima, the trends in annual 98th percentile and DV are relatively flat and in fact have not exceeded the standard since 2010. Peak DVs range from 25 to 31 μg/m^3 while peak 98th percentiles range from 22 to 35 μg/m^3.

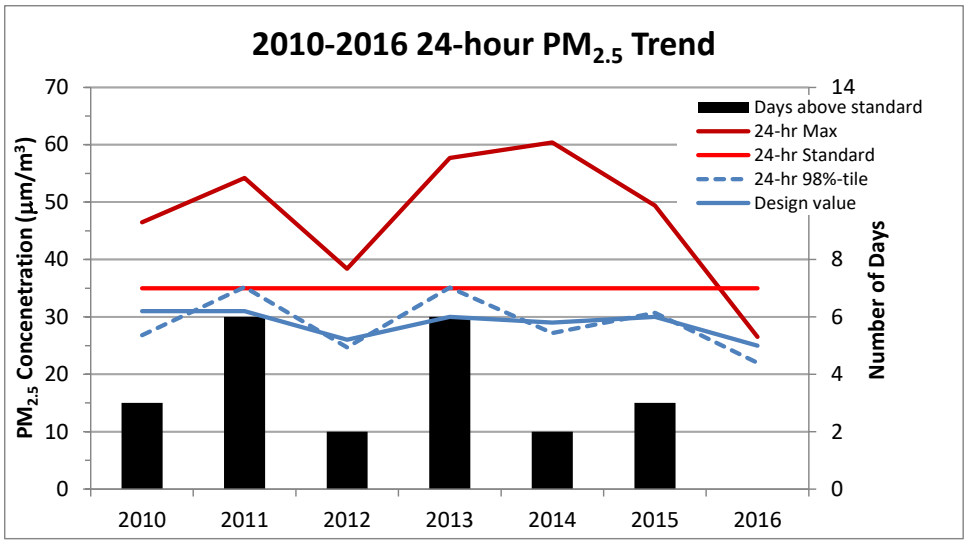


Figure 3. 2010-2016 trends in peak 24-hour $PM_{2.5}$ annual maximum concentration (red), peak annual 98th percentile concentration (blue dash) and peak DV (blue solid) among all sites in the Bay Area (scale on left axis), and number of exceedance days per year (scale on right axis).

Figure 4 shows site-specific minimum, average and maximum annual 98th percentile $PM_{2.5}$ concentrations over the 2010-2016 period, as well as the values for 2012 specifically. The highest concentrations in the Bay Area consistently occur at San Jose, Livermore and Vallejo. The latter two sites are located within the terrain gaps of the eastern Bay Area (Altamont Pass and the Sacramento River, respectively), where high $PM_{2.5}$ concentrations from the Sacramento and San Joaquin Valleys flow into the Bay Area during wintertime exceedance episodes. The strong seasonality of $PM_{2.5}$ events is evident in Figure 5. Daily $PM_{2.5}$ concentrations consistently peak during the months of December and January during cold, foggy episodes characterized by strong stability and weak easterly surface winds. Conversely, SO_2 and particulate SO_4 concentrations tend to be highest during summer months, when $PM_{2.5}$ concentrations are rather low as a result of strong westerly winds that efficiently ventilate the Bay Area. 24-hr $PM_{2.5}$ exceedances are very unusual in the Bay Area outside of winter months. We suspect that these summer and fall exceedances are impacted from wildfire emissions. We will conduct investigations on possible

causes of exceedances and include them in the Demonstration report. In addition, these periods will be simulated with the CALPUFF model.

As shown in Figure 6, monthly-averaged SO_4 concentration over 2012-2014 reach just over 1 $\mu g/m^3$ in the summer, but are less than 0.5 $\mu g/m^3$ during winter months when total $PM_{2.5}$ is highest. Additionally, Figure 6 shows that SO_4 is spatially invariant across the four monitoring sites all year long. This feature is consistent with slow chemical conversion of SO_2 to SO_4 and further suggests that SO_4 in the Bay Area is primarily the result of regional background sources well outside the Bay Area, potentially including oceanic sources of anthropogenic and natural origin.

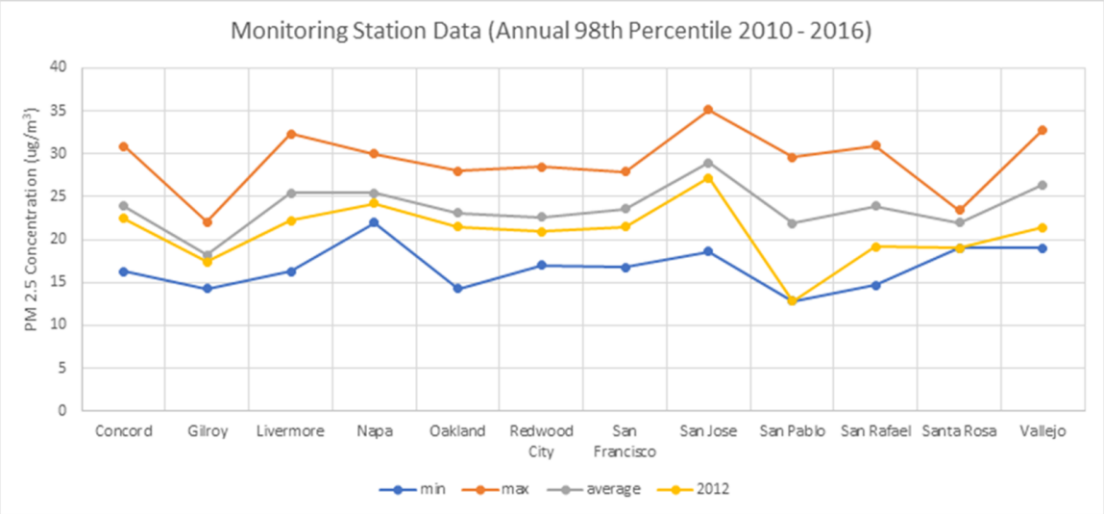


Figure 4. 2010-2016 minimum, average, and maximum annual 98th percentile 24-hour $PM_{2.5}$ concentrations by site. The 98th percentile for 2012 is shown individually in yellow.

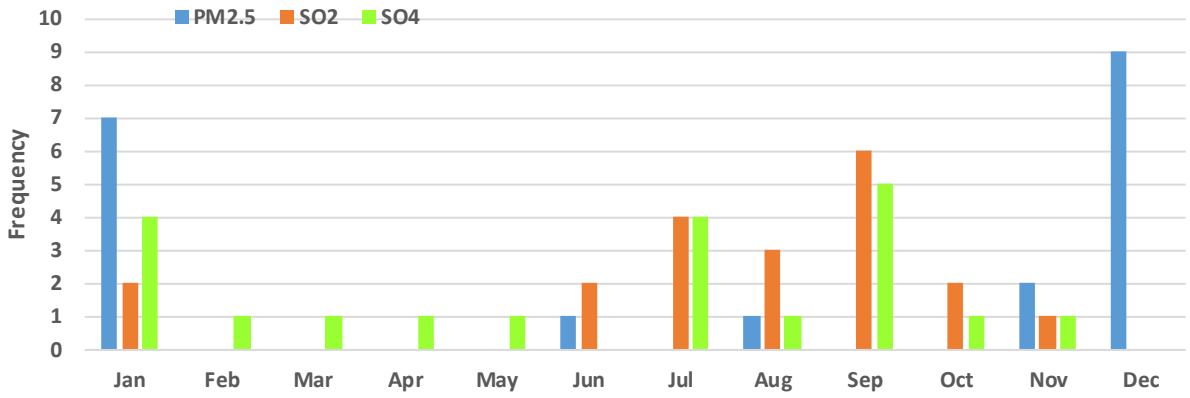


Figure 5. Monthly distribution of the top 20 observed $PM_{2.5}$, SO_2, and SO_4 concentrations over 2010-2016.

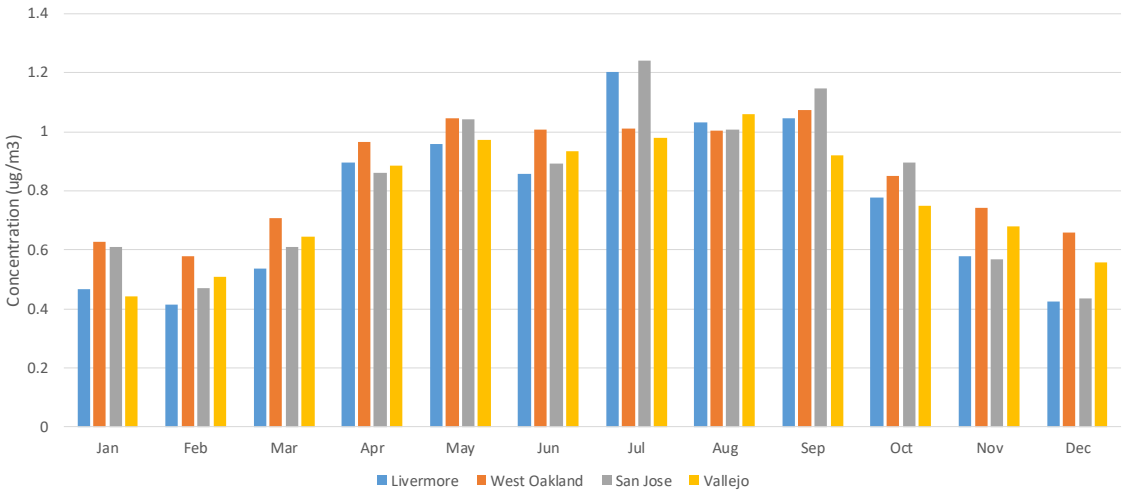
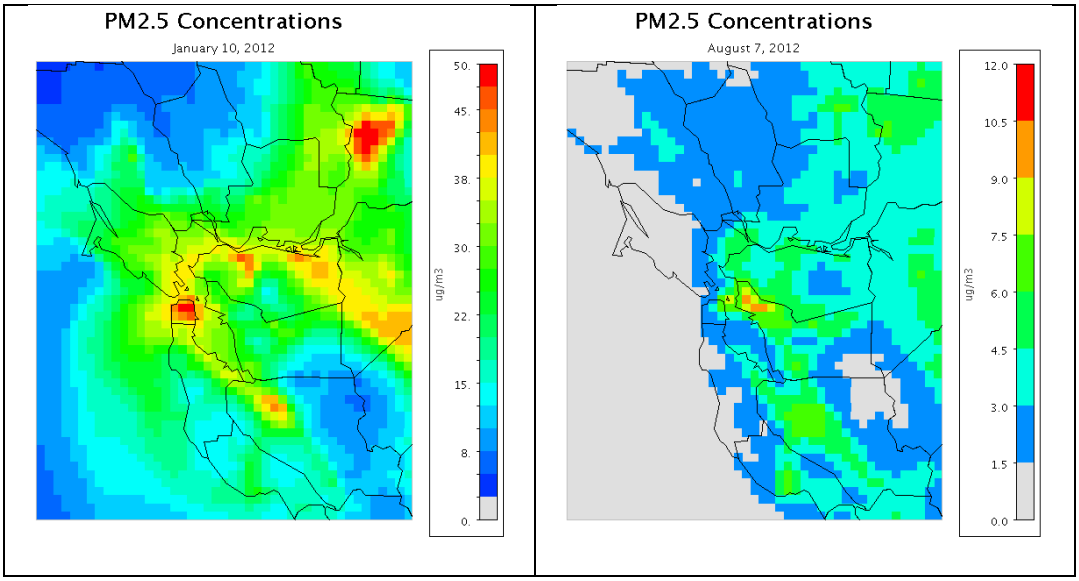


Figure 6. 2012-2014 monthly-average SO_4 concentrations at four sites.



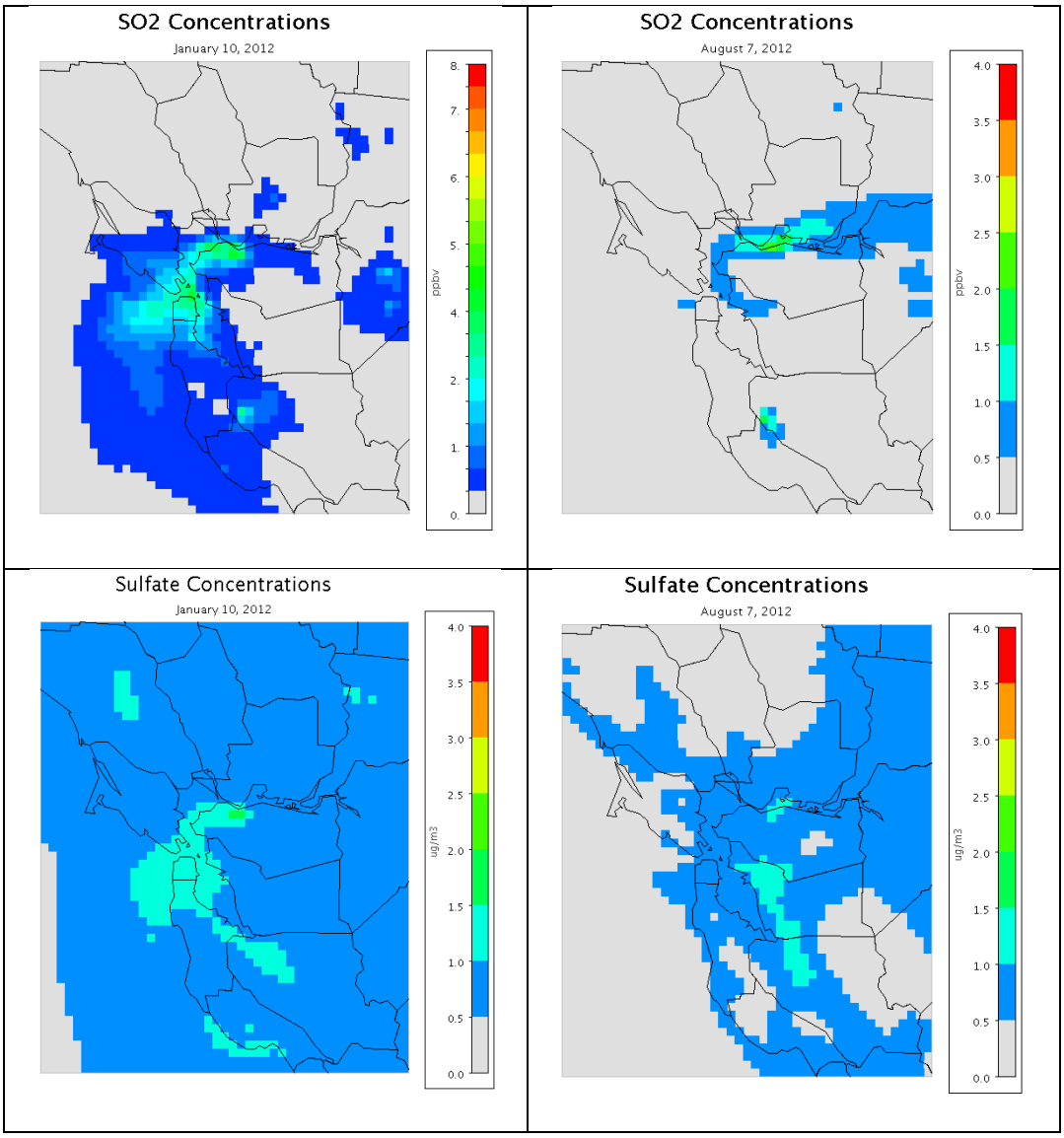


Figure 7. CMAQ modeling results for $PM_{2.5}$ (top), SO_2 (middle) and SO_4 (bottom) on January 10, 2012 (left) and August 7, 2012 (right).

Community Multiscale Air Quality (CMAQ) modeling conducted by the District for the year 2012 characterizes the observed seasonal $PM_{2.5}$ and SO_4 patterns well, both in magnitude and spatially (Figure 7). The model replicates the highest total $PM_{2.5}$ concentrations during January, with strong spatial gradients within the Bay Area, a clear contribution from eastern sources, and plumes directed offshore in the weak westward flow. The summer pattern exhibits much lower $PM_{2.5}$ concentrations with a clear eastward push of pollutants into the interior valleys of California. SO_2 concentrations and resulting SO_4 patterns are clearly aligned along the industrial zones of the Bay Area, and the seasonally opposing transport directions are particularly obvious in the local SO_2 plumes. However, in both seasons SO_4 concentrations are much more spatially invariant than $PM_{2.5}$. A potentially larger regional background SO_4 contribution is evident in January than in August.

MODELING APPROACH

The following describes how the 2012 CMAQ and CALPUFF modeling was done. This same approach will be used for the new modeling, with the 20% emission increase for existing 131 SO_2 sources and 7 new sources described above.

CMAQ Model

7 Meteorological inputs to CMAQ are prepared using the Weather Research and Forecasting (WRF) model. WRF has three nested domains: (1) The outer domain covers the entire western US and a portion of Pacific Ocean with 36 km horizontal (grid) resolution, (2) The intermediate domain covers all of California and a portion of Nevada with 12 km horizontal resolution, (3) The inner domain covers central, and a portion of, northern California with 4 km horizontal resolution. All three domains have 50 vertical layers. The top of the modeling domain extends up to 16 km in elevation.

WRF was applied six days at a time. The last day of each period overlapped with the first day of next period and used for air quality modeling, that is, the first day of each period was not used for air quality modeling. Various model options were tested and a combination of the best performing options were selected for the final simulation. Four dimensional data assimilation was used to bring simulations toward observations. A comprehensive model evaluation was conducted and documented as part of the District's 2016 Clean Air Plan.

The 2012 base-year emissions inventory was obtained from the California Air Resources Board and processed using the SMOKE model to prepare emissions inputs for CMAQ.

The CMAQ model (version 5.0.2) has one domain with 4 km horizontal resolution and covers the innermost domain of WRF, except two grid cells along all lateral boundaries. Lateral boundary conditions for all species, except for ozone are interpolated from MOZART's output with six hours of interval. Ozone boundary condition is specified from monthly averages of ozone measurements via ozonesondes at Trinidad Head, California.

CMAQ has 15 vertical layers, with the top of the modeling domain extending to 16 km in elevation. This domain was established for the 2000 Central California Ozone Study and used by various agencies including the California Air Resources Board, the Bay Area Air Quality Management District and the San Joaquin Valley Air Pollution Control District.

CMAQ uses the SAPRC99 chemical mechanism which works better with California's reformulated gasoline emissions. Like the WRF model, performance of CMAQ was rigorously evaluated, this time for ozone, $PM_{2.5}$ and precursors.

CALPUFF Model

The CALPUFF (version 6.42) domain covers the 9 county Bay Area with 4 km horizontal resolution. It has 18 vertical layers and the top of the modeling domain extends to 3 km in elevation. Primary default options were selected for SO_2 and SO_4 simulations. Meteorological inputs were prepared using CALMET (version 6.211). Meteorological inputs to CALMET were DS472 surface observations and upper air observations from the Oakland sounding.

Appendix B: Example CALPUFF Control Input File for January 2012

```
CALPUFF test case run - 2  point sources
monthly Simulation using CALMET met. data
Gridded receptors on 67x67  4-km met grid
CALPUFF.INP     2.0             File version record
---------------- Run title (3 lines) ------------------------------------------

                    CALPUFF MODEL CONTROL FILE
                    --------------------------

------------------------------------------------------------------------------

INPUT GROUP: 0 -- Input and Output File Names

--------------
Default Name  Type          File Name
------------  ----          ---------
CALMET.DAT    input    ! METDAT =../../calmet/outputs.2012.lyr18/calmet.bayarea_4km.201201.dat
!
    or
ISCMET.DAT    input    * ISCDAT =             *
    or
PLMMET.DAT    input    * PLMDAT =             *
    or
PROFILE.DAT   input    * PRFDAT =             *
SURFACE.DAT   input    * SFCDAT =             *
RESTARTB.DAT  input    * RSTARTB=             *
------------------------------------------------------------------------------
CALPUFF.LST   output   ! PUFLST =../outputs/base.so2_only/base.so2_only.201201.lst  !
CONC.DAT      output   ! CONDAT =../outputs/base.so2_only/base.so2_only.201201.con  !
DFLX.DAT      output   ! DFDAT  =../outputs/base.so2_only/base.so2_only.201201.dflx !
WFLX.DAT      output   ! WFDAT  =../outputs/base.so2_only/base.so2_only.201201.wflx !

VISB.DAT      output   * VISDAT =CALPUFF.VIS  *
TK2D.DAT      output   * T2DDAT =             *
RHO2D.DAT     output   * RHODAT =             *
RESTARTE.DAT  output   * RSTARTE=             *
------------------------------------------------------------------------------
Emission Files
--------------
PTEMARB.DAT   input    * PTDAT  =             *
VOLEMARB.DAT  input    * VOLDAT =             *
BAEMARB.DAT   input    * ARDAT  =             *
LNEMARB.DAT   input    * LNDAT  =             *
------------------------------------------------------------------------------
Other Files
-----------
OZONE.DAT     input    * OZDAT  =OZONE.DAT    *
VD.DAT        input    * VDDAT  =             *
CHEM.DAT      input    * CHEMDAT=             *
AUX           input    * AUXEXT =AUX     *
(Extension added to METDAT filename(s) for files
 with auxiliary 2D and 3D data)
H2O2.DAT      input    * H2O2DAT=             *
NH3Z.DAT      input    * NH3ZDAT=             *
HILL.DAT      input    * HILDAT=              *
HILLRCT.DAT   input    * RCTDAT=              *
COASTLN.DAT   input    * CSTDAT=              *
FLUXBDY.DAT   input    * BDYDAT=              *
BCON.DAT      input    * BCNDAT=              *
DEBUG.DAT     output   * DEBUG =              *
MASSFLX.DAT   output   * FLXDAT=              *
MASSBAL.DAT   output   * BALDAT=              *
FOG.DAT       output   * FOGDAT=              *
RISE.DAT      output   * RISDAT=              *
------------------------------------------------------------------------------
All file names will be converted to lower case if LCFILES = T
Otherwise, if LCFILES = F, file names will be converted to UPPER CASE
         T = lower case      ! LCFILES = T !
         F = UPPER CASE
NOTE: (1) file/path names can be up to 132 characters in length
```

```
Provision for multiple input files
----------------------------------

     Number of Modeling Domains (NMETDOM)
                                     Default: 1       ! NMETDOM =   1   !

     Number of CALMET.DAT files for run (NMETDAT)
                                     Default: 1       ! NMETDAT =   1   !

     Number of PTEMARB.DAT files for run (NPTDAT)
                                     Default: 0       ! NPTDAT =    0   !

     Number of BAEMARB.DAT files for run (NARDAT)
                                     Default: 0       ! NARDAT =    0   !

     Number of VOLEMARB.DAT files for run (NVOLDAT)
                                     Default: 0       ! NVOLDAT =   0   !

!END!

-------------
Subgroup (0a)
-------------

  Provide a name for each CALMET domain if NMETDOM > 1
  Enter NMETDOM lines.
                                    a,b
Default Name              Domain Name
------------              ------------
 none                   * DOMAIN1=     *   *END*
 none                   * DOMAIN2=     *   *END*
 none                   * DOMAIN3=     *   *END*


  The following CALMET.DAT filenames are processed in sequence
  if NMETDAT > 1

  Enter NMETDAT lines, 1 line for each file name.

                                    a,c,d
Default Name  Type           File Name
------------  ----           ---------
 none         input     * METDAT1=     *   *END*
 none         input     * METDAT2=     *   *END*
 none         input     * METDAT3=     *   *END*

-------------
    a
     The name for each CALMET domain and each CALMET.DAT file is treated
     as a separate input subgroup and therefore must end with an input
     group terminator.
    b
     Use DOMAIN1= to assign the name for the outermost CALMET domain.
     Use DOMAIN2= to assign the name for the next inner CALMET domain.
     Use DOMAIN3= to assign the name for the next inner CALMET domain, etc.
      ------------------------------------------------------------------
      |   When inner domains with equal resolution (grid-cell size)      |
      |   overlap, the data from the FIRST such domain in the list will  |
      |   be used if all other criteria for choosing the controlling     |
      |   grid domain are inconclusive.                                  |
      ------------------------------------------------------------------
    c
     Use METDAT1= to assign the file names for the outermost CALMET domain.
     Use METDAT2= to assign the file names for the next inner CALMET domain.
     Use METDAT3= to assign the file names for the next inner CALMET domain, etc.
    d
     The filenames for each domain must be provided in sequential order

-------------
Subgroup (0b)
-------------

  The following PTEMARB.DAT filenames are processed if NPTDAT>0
  (Each file contains a subset of the sources, for the entire simulation)
```

```
Default Name  Type          File Name
------------  ----          ---------
 none         input       * PTDAT=     *   *END*


-------------
Subgroup (0c)
-------------

  The following BAEMARB.DAT filenames are processed if NARDAT>0
  (Each file contains a subset of the sources, for the entire simulation)

Default Name  Type          File Name
------------  ----          ---------
 none         input       * ARDAT=     *   *END*


-------------
Subgroup (0d)
-------------

  The following VOLEMARB.DAT filenames are processed if NVOLDAT>0
  (Each file contains a subset of the sources, for the entire simulation)

Default Name  Type          File Name
------------  ----          ---------
 none         input       * VOLDAT=     *   *END*


------------------------------------------------------------------------------

INPUT GROUP: 1 -- General run control parameters
--------------

    Option to run all periods found
    in the met. file     (METRUN)   Default: 0       ! METRUN =   0  !

         METRUN = 0 - Run period explicitly defined below
         METRUN = 1 - Run all periods in met. file

     Starting date:    Year   (IBYR)  --    No default   ! IBYR  =  2012   !
                       Month  (IBMO)  --    No default   ! IBMO  =  01     !
                       Day    (IBDY)  --    No default   ! IBDY  =  1      !
     Starting time:    Hour   (IBHR)  --    No default   ! IBHR  =  0      !
                       Minute (IBMIN) --    No default   ! IBMIN =  0      !
                       Second (IBSEC) --    No default   ! IBSEC =  0      !

     Ending date:      Year   (IEYR)  --    No default   ! IEYR  =  2012   !
                       Month  (IEMO)  --    No default   ! IEMO  =  01     !
                       Day    (IEDY)  --    No default   ! IEDY  =  31     !
     Ending time:      Hour   (IEHR)  --    No default   ! IEHR  =  23     !
                       Minute (IEMIN) --    No default   ! IEMIN =  0      !
                       Second (IESEC) --    No default   ! IESEC =  0       !

     (These are only used if METRUN = 0)

     Base time zone:          (ABTZ)  --    No default   ! ABTZ= UTC-0800 !
      (character*8)
     The modeling domain may span multiple time zones.  ABTZ defines the
     base time zone used for the entire simulation.  This must match the
     base time zone of the meteorological data.
     Examples:
         Los Angeles, USA          = UTC-0800
         New York, USA             = UTC-0500
         Santiago, Chile           = UTC-0400
         Greenwich Mean Time (GMT) = UTC+0000
         Rome, Italy               = UTC+0100
         Cape Town, S.Africa       = UTC+0200
         Sydney, Australia         = UTC+1000

     Length of modeling time-step (seconds)
     Equal to update period in the primary
     meteorological data files, or an
     integer fraction of it (1/2, 1/3 ...)
     Must be no larger than 1 hour
```

```
   (NSECDT)                        Default:3600     ! NSECDT =  3600  !
                                   Units: seconds

   Number of chemical species (NSPEC)
                                   Default: 5       ! NSPEC =  2      !

   Number of chemical species
   to be emitted  (NSE)            Default: 3       ! NSE =    1      !

   Flag to stop run after
   SETUP phase (ITEST)             Default: 2       ! ITEST =  2      !
   (Used to allow checking
   of the model inputs, files, etc.)
         ITEST = 1 - STOPS program after SETUP phase
         ITEST = 2 - Continues with execution of program
                     after SETUP

   Restart Configuration:

      Control flag (MRESTART)      Default: 0       ! MRESTART =  0   !

         0 = Do not read or write a restart file
         1 = Read a restart file at the beginning of
             the run
         2 = Write a restart file during run
         3 = Read a restart file at beginning of run
             and write a restart file during run

      Number of periods in Restart
      output cycle (NRESPD)        Default: 0       ! NRESPD =  0     !

         0 = File written only at last period
        >0 = File updated every NRESPD periods

   Meteorological Data Format (METFM)
                                   Default: 1       ! METFM =  1      !

         METFM = 1 - CALMET binary file (CALMET.MET)
         METFM = 2 - ISC ASCII file (ISCMET.MET)
         METFM = 3 - AUSPLUME ASCII file (PLMMET.MET)
         METFM = 4 - CTDM plus tower file (PROFILE.DAT) and
                     surface parameters file (SURFACE.DAT)
         METFM = 5 - AERMET tower file (PROFILE.DAT) and
                     surface parameters file (SURFACE.DAT)

   Meteorological Profile Data Format (MPRFFM)
          (used only for METFM = 1, 2, 3)
                                   Default: 1       ! MPRFFM =  1   !

         MPRFFM = 1 - CTDM plus tower file (PROFILE.DAT)
         MPRFFM = 2 - AERMET tower file (PROFILE.DAT)

   PG sigma-y is adjusted by the factor (AVET/PGTIME)**0.2
   Averaging Time (minutes) (AVET)
                                   Default: 60.0    ! AVET = 60. !
   PG Averaging Time (minutes) (PGTIME)
                                   Default: 60.0    ! PGTIME = 60. !


   Output units for binary concentration and flux files
   written in Dataset v2.2 or later formats
   (IOUTU)                         Default: 1       ! IOUTU =  1   !
       1 = mass      -  g/m3 (conc) or g/m2/s (dep)
       2 = odour     -  odour_units (conc)
       3 = radiation -  Bq/m3 (conc) or Bq/m2/s (dep)


   Output Dataset format for binary concentration
   and flux files (e.g., CONC.DAT)
   (IOVERS)                        Default: 2       ! IOVERS =  2   !
       1 = Dataset Version 2.1
       2 = Dataset Version 2.2


!END!
```

```
------------------------------------------------------------------------------

INPUT GROUP: 2 -- Technical options
--------------

     Vertical distribution used in the
     near field (MGAUSS)                  Default: 1     ! MGAUSS =  1   !
        0 = uniform
        1 = Gaussian

     Terrain adjustment method
     (MCTADJ)                             Default: 3     ! MCTADJ =  3   !
        0 = no adjustment
        1 = ISC-type of terrain adjustment
        2 = simple, CALPUFF-type of terrain
            adjustment
        3 = partial plume path adjustment

     Subgrid-scale complex terrain
     flag (MCTSG)                         Default: 0     ! MCTSG =  0   !
        0 = not modeled
        1 = modeled

     Near-field puffs modeled as
     elongated slugs? (MSLUG)             Default: 0     ! MSLUG =  0   !
        0 = no
        1 = yes (slug model used)

     Transitional plume rise modeled?
     (MTRANS)                             Default: 1     ! MTRANS =  1  !
        0 = no  (i.e., final rise only)
        1 = yes (i.e., transitional rise computed)

     Stack tip downwash? (MTIP)           Default: 1     ! MTIP =  1  !
        0 = no  (i.e., no stack tip downwash)
        1 = yes (i.e., use stack tip downwash)

     Method used to compute plume rise for
     point sources not subject to building
     downwash? (MRISE)                    Default: 1     ! MRISE =  1  !
        1 = Briggs plume rise
        2 = Numerical plume rise

     Method used to simulate building
     downwash? (MBDW)                     Default: 1     ! MBDW =   1  !
        1 = ISC method
        2 = PRIME method

     Vertical wind shear modeled above
     stack top (modified Briggs plume rise)?
     (MSHEAR)                             Default: 0     ! MSHEAR =  0  !
        0 = no  (i.e., vertical wind shear not modeled)
        1 = yes (i.e., vertical wind shear modeled)

     Puff splitting allowed? (MSPLIT)     Default: 0     ! MSPLIT =  0  !
        0 = no (i.e., puffs not split)
        1 = yes (i.e., puffs are split)

     Chemical mechanism flag (MCHEM)      Default: 1     ! MCHEM =  1   !
        0 = chemical transformation not
            modeled
        1 = transformation rates computed
            internally (MESOPUFF II scheme)
        2 = user-specified transformation
            rates used
        3 = transformation rates computed
            internally (RIVAD/ARM3 scheme)
        4 = secondary organic aerosol formation
            computed (MESOPUFF II scheme for OH)
        5 = user-specified half-life with or
            without transfer to child species
        6 = transformation rates computed
```

```
       internally (Updated RIVAD scheme with
       ISORROPIA equilibrium)
   7 = transformation rates computed
       internally (Updated RIVAD scheme with
       ISORROPIA equilibrium and CalTech SOA)

Aqueous phase transformation flag (MAQCHEM)
(Used only if MCHEM = 6, or 7)        Default: 0     ! MAQCHEM =  0   !
   0 = aqueous phase transformation
       not modeled
   1 = transformation rates and wet
       scavenging coefficients adjusted
       for in-cloud aqueous phase reactions
       (adapted from RADM cloud model
        implementation in CMAQ/SCICHEM)

Liquid Water Content flag (MLWC)
(Used only if MAQCHEM = 1)            Default: 1     ! MLWC =  1   !
   0 = water content estimated from cloud cover
       and presence of precipitation
   1 = gridded cloud water data read from CALMET
       water content output files (filenames are
       the CALMET.DAT names PLUS the extension
       AUXEXT provided in Input Group 0)

Wet removal modeled ? (MWET)          Default: 1     ! MWET =  1   !
   0 = no
   1 = yes

Dry deposition modeled ? (MDRY)       Default: 1     ! MDRY =  1   !
   0 = no
   1 = yes
   (dry deposition method specified
    for each species in Input Group 3)


Gravitational settling (plume tilt)
modeled ? (MTILT)                     Default: 0     ! MTILT =  0   !
   0 = no
   1 = yes
   (puff center falls at the gravitational
    settling velocity for 1 particle species)

Restrictions:
    - MDRY  = 1
    - NSPEC = 1  (must be particle species as well)
    - sg    = 0  GEOMETRIC STANDARD DEVIATION in Group 8 is
                 set to zero for a single particle diameter

Method used to compute dispersion
coefficients (MDISP)                  Default: 3     ! MDISP =  3   !

   1 = dispersion coefficients computed from measured values
       of turbulence, sigma v, sigma w
   2 = dispersion coefficients from internally calculated
       sigma v, sigma w using micrometeorological variables
       (u*, w*, L, etc.)
   3 = PG dispersion coefficients for RURAL areas (computed using
       the ISCST multi-segment approximation) and MP coefficients in
       urban areas
   4 = same as 3 except PG coefficients computed using
       the MESOPUFF II eqns.
   5 = CTDM sigmas used for stable and neutral conditions.
       For unstable conditions, sigmas are computed as in
       MDISP = 3, described above.  MDISP = 5 assumes that
       measured values are read

Sigma-v/sigma-theta, sigma-w measurements used? (MTURBVW)
(Used only if MDISP = 1 or 5)         Default: 3     ! MTURBVW =  3  !
   1 = use sigma-v or sigma-theta measurements
       from PROFILE.DAT to compute sigma-y
       (valid for METFM = 1, 2, 3, 4, 5)
   2 = use sigma-w measurements
       from PROFILE.DAT to compute sigma-z
       (valid for METFM = 1, 2, 3, 4, 5)
```

```
   3 = use both sigma-(v/theta) and sigma-w
       from PROFILE.DAT to compute sigma-y and sigma-z
       (valid for METFM = 1, 2, 3, 4, 5)
   4 = use sigma-theta measurements
       from PLMMET.DAT to compute sigma-y
       (valid only if METFM = 3)

Back-up method used to compute dispersion
when measured turbulence data are
missing (MDISP2)                      Default: 3     ! MDISP2 =  3  !
(used only if MDISP = 1 or 5)
   2 = dispersion coefficients from internally calculated
       sigma v, sigma w using micrometeorological variables
       (u*, w*, L, etc.)
   3 = PG dispersion coefficients for RURAL areas (computed using
       the ISCST multi-segment approximation) and MP coefficients in
       urban areas
   4 = same as 3 except PG coefficients computed using
       the MESOPUFF II eqns.

[DIAGNOSTIC FEATURE]
Method used for Lagrangian timescale for Sigma-y
(used only if MDISP=1,2 or MDISP2=1,2)
(MTAULY)                              Default: 0     ! MTAULY =  0  !
   0 = Draxler default 617.284 (s)
   1 = Computed as Lag. Length / (.75 q) -- after SCIPUFF
  10 < Direct user input (s)             -- e.g., 306.9


[DIAGNOSTIC FEATURE]
Method used for Advective-Decay timescale for Turbulence
(used only if MDISP=2 or MDISP2=2)
(MTAUADV)                             Default: 0     ! MTAUADV =  0  !
   0 = No turbulence advection
   1 = Computed (OPTION NOT IMPLEMENTED)
  10 < Direct user input (s)   -- e.g., 800


Method used to compute turbulence sigma-v &
sigma-w using micrometeorological variables
(Used only if MDISP = 2 or MDISP2 = 2)
(MCTURB)                              Default: 1     ! MCTURB =  1  !
   1 = Standard CALPUFF subroutines
   2 = AERMOD subroutines

PG sigma-y,z adj. for roughness?      Default: 0     ! MROUGH =  0  !
(MROUGH)
   0 = no
   1 = yes

Partial plume penetration of          Default: 1     ! MPARTL =  1  !
elevated inversion modeled for
point sources?
(MPARTL)
   0 = no
   1 = yes

Partial plume penetration of          Default: 1     ! MPARTLBA =  1  !
elevated inversion modeled for
buoyant area sources?
(MPARTLBA)
   0 = no
   1 = yes

Strength of temperature inversion     Default: 0     ! MTINV =  0  !
provided in PROFILE.DAT extended records?
(MTINV)
   0 = no (computed from measured/default gradients)
   1 = yes

PDF used for dispersion under convective conditions?
                                      Default: 0     ! MPDF =  0  !
(MPDF)
   0 = no
   1 = yes
```

```
Sub-Grid TIBL module used for shore line?
                                    Default: 0     ! MSGTIBL = 0  !
(MSGTIBL)
   0 = no
   1 = yes

Boundary conditions (concentration) modeled?
                                    Default: 0     ! MBCON = 0  !
(MBCON)
   0 = no
   1 = yes, using formatted BCON.DAT file
   2 = yes, using unformatted CONC.DAT file

Note:  MBCON > 0 requires that the last species modeled
       be 'BCON'.  Mass is placed in species BCON when
       generating boundary condition puffs so that clean
       air entering the modeling domain can be simulated
       in the same way as polluted air.  Specify zero
       emission of species BCON for all regular sources.

Individual source contributions saved?
                                    Default: 0     ! MSOURCE = 0  !
(MSOURCE)
   0 = no
   1 = yes


Analyses of fogging and icing impacts due to emissions from
arrays of mechanically-forced cooling towers can be performed
using CALPUFF in conjunction with a cooling tower emissions
processor (CTEMISS) and its associated postprocessors.  Hourly
emissions of water vapor and temperature from each cooling tower
cell are computed for the current cell configuration and ambient
conditions by CTEMISS. CALPUFF models the dispersion of these
emissions and provides cloud information in a specialized format
for further analysis. Output to FOG.DAT is provided in either
'plume mode' or 'receptor mode' format.

Configure for FOG Model output?
                                    Default: 0     ! MFOG =  0   !
(MFOG)
   0 = no
   1 = yes  - report results in PLUME Mode format
   2 = yes  - report results in RECEPTOR Mode format


Test options specified to see if
they conform to regulatory
values? (MREG)                      Default: 1     ! MREG =  0   !

   0 = NO checks are made
   1 = Technical options must conform to USEPA
       Long Range Transport (LRT) guidance
                  METFM    1 or 2
                  AVET     60. (min)
                  PGTIME   60. (min)
                  MGAUSS   1
                  MCTADJ   3
                  MTRANS   1
                  MTIP     1
                  MRISE    1
                  MCHEM    1 or 3 (if modeling SOx, NOx)
                  MWET     1
                  MDRY     1
                  MDISP    2 or 3
                  MPDF     0 if MDISP=3
                           1 if MDISP=2
                  MROUGH   0
                  MPARTL   1
                  MPARTLBA 0
                  SYTDEP   550. (m)
                  MHFTSZ   0
                  SVMIN    0.5 (m/s)
```

```
!END!


------------------------------------------------------------------------------

INPUT GROUP: 3a, 3b -- Species list
-------------------

------------
Subgroup (3a)
------------

  The following species are modeled:

! CSPEC = SO2  ! !END!
! CSPEC = SO4  ! !END!

                                                      Dry                OUTPUT GROUP
    SPECIES          MODELED          EMITTED       DEPOSITED              NUMBER
     NAME         (0=NO, 1=YES)    (0=NO, 1=YES)    (0=NO,                (0=NONE,
   (Limit: 12                                        1=COMPUTED-GAS        1=1st CGRUP,
    Characters                                       2=COMPUTED-PARTICLE   2=2nd CGRUP,
    in length)                                       3=USER-SPECIFIED)     3= etc.)

! SO2  = 1, 1, 1, 0 !
! SO4  = 1, 0, 2, 0 !

!END!

  Note:  The last species in (3a) must be 'BCON' when using the
         boundary condition option (MBCON > 0).  Species BCON should
         typically be modeled as inert (no chem transformation or
         removal).


-------------
Subgroup (3b)
-------------
  The following names are used for Species-Groups in which results
  for certain species are combined (added) prior to output.  The
  CGRUP name will be used as the species name in output files.
  Use this feature to model specific particle-size distributions
  by treating each size-range as a separate species.
  Order must be consistent with 3(a) above.



------------------------------------------------------------------------------


INPUT GROUP: 4 -- Map Projection and Grid control parameters
--------------

     Projection for all (X,Y):
     -------------------------

     Map projection
     (PMAP)                    Default: UTM    ! PMAP = LCC  !

         UTM :  Universal Transverse Mercator
         TTM :  Tangential Transverse Mercator
         LCC :  Lambert Conformal Conic
          PS :  Polar Stereographic
          EM :  Equatorial Mercator
        LAZA :  Lambert Azimuthal Equal Area

     False Easting and Northing (km) at the projection origin
     (Used only if PMAP= TTM, LCC, or LAZA)
     (FEAST)                   Default=0.0     ! FEAST  = 0.000  !
     (FNORTH)                  Default=0.0     ! FNORTH = 0.000  !

     UTM zone (1 to 60)
     (Used only if PMAP=UTM)
     (IUTMZN)                  No Default      ! IUTMZN =  19   !
```

```
     Hemisphere for UTM projection?
     (Used only if PMAP=UTM)
     (UTMHEM)                  Default: N      ! UTMHEM = N  !
         N   :  Northern hemisphere projection
         S   :  Southern hemisphere projection

     Latitude and Longitude (decimal degrees) of projection origin
     (Used only if PMAP= TTM, LCC, PS, EM, or LAZA)
     (RLAT0)                   No Default      ! RLAT0 = 37N  !
     (RLON0)                   No Default      ! RLON0 =120.5W!

         TTM :  RLON0 identifies central (true N/S) meridian of projection
                RLAT0 selected for convenience
         LCC :  RLON0 identifies central (true N/S) meridian of projection
                RLAT0 selected for convenience
         PS  :  RLON0 identifies central (grid N/S) meridian of projection
                RLAT0 selected for convenience
         EM  :  RLON0 identifies central meridian of projection
                RLAT0 is REPLACED by 0.0N (Equator)
         LAZA:  RLON0 identifies longitude of tangent-point of mapping plane
                RLAT0 identifies latitude of tangent-point of mapping plane

     Matching parallel(s) of latitude (decimal degrees) for projection
     (Used only if PMAP= LCC or PS)
     (XLAT1)                   No Default      ! XLAT1 = 30N !
     (XLAT2)                   No Default      ! XLAT2 = 60N !

         LCC :  Projection cone slices through Earth's surface at XLAT1 and XLAT2
         PS  :  Projection plane slices through Earth at XLAT1
                (XLAT2 is not used)

     ----------
     Note:  Latitudes and longitudes should be positive, and include a
            letter N,S,E, or W indicating north or south latitude, and
            east or west longitude.  For example,
            35.9  N Latitude  =  35.9N
            118.7 E Longitude = 118.7E


     Datum-region
     ------------

     The Datum-Region for the coordinates is identified by a character
     string.  Many mapping products currently available use the model of the
     Earth known as the World Geodetic System 1984 (WGS-84).  Other local
     models may be in use, and their selection in CALMET will make its output
     consistent with local mapping products.  The list of Datum-Regions with
     official transformation parameters is provided by the National Imagery and
     Mapping Agency (NIMA).

     NIMA Datum - Regions(Examples)
     ------------------------------------------------------------------------------
     WGS-84    WGS-84 Reference Ellipsoid and Geoid, Global coverage (WGS84)
     NAS-C     NORTH AMERICAN 1927 Clarke 1866 Spheroid, MEAN FOR CONUS (NAD27)
     NAR-C     NORTH AMERICAN 1983 GRS 80 Spheroid, MEAN FOR CONUS (NAD83)
     NWS-84    NWS 6370KM Radius, Sphere
     ESR-S     ESRI REFERENCE 6371KM Radius, Sphere

     Datum-region for output coordinates
     (DATUM)                   Default: WGS-84    ! DATUM = WGS-84 !


METEOROLOGICAL Grid:

     Rectangular grid defined for projection PMAP,
     with X the Easting and Y the Northing coordinate

           No. X grid cells (NX)      No default     ! NX =  67   !
           No. Y grid cells (NY)      No default     ! NY =  67   !
       No. vertical layers (NZ)       No default     ! NZ =  18   !

         Grid spacing (DGRIDKM)       No default     ! DGRIDKM = 4.0 !
                                      Units: km
```

```
               Cell face heights
                   (ZFACE(nz+1))      No defaults
                                      Units: m
   ! ZFACE = .0, 20.0, 40.0, 80.0, 120.,180.,240.,300.,360.,420.,500.,600.,
             700.,800.,1000.,1200.,1500.,2200.,3000. !

            Reference Coordinates
           of SOUTHWEST corner of
                grid cell(1, 1):

            X coordinate (XORIGKM)     No default     ! XORIGKM = -288.0 !
            Y coordinate (YORIGKM)     No default     ! YORIGKM = -36.0  !
                                     Units: km


COMPUTATIONAL Grid:

     The computational grid is identical to or a subset of the MET. grid.
     The lower left (LL) corner of the computational grid is at grid point
     (IBCOMP, JBCOMP) of the MET. grid.  The upper right (UR) corner of the
     computational grid is at grid point (IECOMP, JECOMP) of the MET. grid.
     The grid spacing of the computational grid is the same as the MET. grid.

        X index of LL corner (IBCOMP)      No default     ! IBCOMP =  1   !
                  (1 <= IBCOMP <= NX)

        Y index of LL corner (JBCOMP)      No default     ! JBCOMP =  1   !
                  (1 <= JBCOMP <= NY)


        X index of UR corner (IECOMP)      No default     ! IECOMP =  67   !
                  (1 <= IECOMP <= NX)

        Y index of UR corner (JECOMP)      No default     ! JECOMP =  67   !
                  (1 <= JECOMP <= NY)



SAMPLING Grid (GRIDDED RECEPTORS):

     The lower left (LL) corner of the sampling grid is at grid point
     (IBSAMP, JBSAMP) of the MET. grid.  The upper right (UR) corner of the
     sampling grid is at grid point (IESAMP, JESAMP) of the MET. grid.
     The sampling grid must be identical to or a subset of the computational
     grid.  It may be a nested grid inside the computational grid.
     The grid spacing of the sampling grid is DGRIDKM/MESHDN.

        Logical flag indicating if gridded
        receptors are used (LSAMP)         Default: T     ! LSAMP = T !
        (T=yes, F=no)

        X index of LL corner (IBSAMP)      No default     ! IBSAMP =   1   !
         (IBCOMP <= IBSAMP <= IECOMP)

        Y index of LL corner (JBSAMP)      No default     ! JBSAMP =   1   !
         (JBCOMP <= JBSAMP <= JECOMP)


        X index of UR corner (IESAMP)      No default     ! IESAMP =  67   !
         (IBCOMP <= IESAMP <= IECOMP)

        Y index of UR corner (JESAMP)      No default     ! JESAMP =  67   !
         (JBCOMP <= JESAMP <= JECOMP)


       Nesting factor of the sampling
        grid (MESHDN)                      Default: 1     ! MESHDN =  1  !
        (MESHDN is an integer >= 1)

!END!


--------------------------------------------------------------------------------
```

```
INPUT GROUP: 5 -- Output Options
--------------
                                        *                          *
     FILE                         DEFAULT VALUE             VALUE THIS RUN
     ----                         -------------             --------------

   Concentrations (ICON)              1                   !  ICON =  1   !
   Dry Fluxes (IDRY)                  1                   !  IDRY =  1   !
   Wet Fluxes (IWET)                  1                   !  IWET =  1   !
   2D Temperature (IT2D)              0                   !  IT2D =  0   !
   2D Density (IRHO)                  0                   !  IRHO =  0   !
   Relative Humidity (IVIS)           1                   !  IVIS =  0   !
    (relative humidity file is
     required for visibility
     analysis)
   Use data compression option in output file?
   (LCOMPRS)                          Default: T          ! LCOMPRS = T !

   *
    0 = Do not create file, 1 = create file


    QA PLOT FILE OUTPUT OPTION:

       Create a standard series of output files (e.g.
       locations of sources, receptors, grids ...)
       suitable for plotting?
       (IQAPLOT)                      Default: 1          !  IQAPLOT =  1   !
         0 = no
         1 = yes

    DIAGNOSTIC PUFF-TRACKING OUTPUT OPTION:

       Puff locations and properties reported to
       PFTRAK.DAT file for postprocessing?
       (IPFTRAK)                      Default: 0          ! IPFTRAK =  0   !
         0 = no
         1 = yes, update puff output at end of each timestep
         2 = yes, update puff output at end of each sampling step

    DIAGNOSTIC MASS FLUX OUTPUT OPTIONS:

       Mass flux across specified boundaries
       for selected species reported?
       (IMFLX)                        Default: 0          ! IMFLX =  0  !
         0 = no
         1 = yes (FLUXBDY.DAT and MASSFLX.DAT filenames
                  are specified in Input Group 0)

       Mass balance for each species
       reported?
       (IMBAL)                        Default: 0          ! IMBAL =  0  !
         0 = no
         1 = yes (MASSBAL.DAT filename is
              specified in Input Group 0)


    NUMERICAL RISE OUTPUT OPTION:

       Create a file with plume properties for each rise
       increment, for each model timestep?
       This applies to sources modeled with numerical rise
       and is limited to ONE source in the run.
       (INRISE)                       Default: 0          ! INRISE =  0  !
         0 = no
         1 = yes (RISE.DAT filename is
                  specified in Input Group 0)


    LINE PRINTER OUTPUT OPTIONS:

       Print concentrations (ICPRT)   Default: 0          ! ICPRT =  1   !
       Print dry fluxes (IDPRT)       Default: 0          ! IDPRT =  0   !
       Print wet fluxes (IWPRT)       Default: 0          ! IWPRT =  0   !
       (0 = Do not print, 1 = Print)
```

```
       Concentration print interval
       (ICFRQ) in timesteps            Default: 1         ! ICFRQ =  1   !
       Dry flux print interval
       (IDFRQ) in timesteps            Default: 1         ! IDFRQ =  1   !
       Wet flux print interval
       (IWFRQ) in timesteps            Default: 1         ! IWFRQ =  1   !

       Units for Line Printer Output
       (IPRTU)                         Default: 1         ! IPRTU =  3   !
                     for              for
                Concentration    Deposition
           1 =       g/m**3         g/m**2/s
           2 =      mg/m**3        mg/m**2/s
           3 =      ug/m**3        ug/m**2/s
           4 =      ng/m**3        ng/m**2/s
           5 =     Odour Units

       Messages tracking progress of run
       written to the screen ?
       (IMESG)                         Default: 2         ! IMESG =  2   !
         0 = no
         1 = yes (advection step, puff ID)
         2 = yes (YYYYJJJHH, # old puffs, # emitted puffs)


     SPECIES (or GROUP for combined species) LIST FOR OUTPUT OPTIONS

                  ---- CONCENTRATIONS ----   ------ DRY FLUXES ------   ------ WET FLUXES ------
-- MASS FLUX --
   SPECIES
   /GROUP        PRINTED?  SAVED ON DISK?   PRINTED?  SAVED ON DISK?   PRINTED?  SAVED ON DISK?
SAVED ON DISK?
   -------       ------------------------   ------------------------   ------------------------
---------------
! SO2  = 0, 1, 0, 1, 0, 1, 0 !
! SO4  = 0, 1, 0, 1, 0, 1, 0 !

  Note:  Species BCON (for MBCON > 0) does not need to be saved on disk.


     OPTIONS FOR PRINTING "DEBUG" QUANTITIES (much output)

       Logical for debug output
       (LDEBUG)                                 Default: F     ! LDEBUG = F !

       First puff to track
       (IPFDEB)                                 Default: 1     ! IPFDEB =  1  !

       Number of puffs to track
       (NPFDEB)                                 Default: 1     ! NPFDEB =  1  !

       Met. period to start output
       (NN1)                                    Default: 1     ! NN1 =  1   !

       Met. period to end output
       (NN2)                                    Default: 10    ! NN2 =  10  !

!END!


-------------------------------------------------------------------------------


INPUT GROUP: 6a, 6b, & 6c -- Subgrid scale complex terrain inputs
-------------------------

---------------
Subgroup (6a)
---------------
       Number of terrain features (NHILL)       Default: 0     ! NHILL =  0   !

       Number of special complex terrain
       receptors  (NCTREC)                      Default: 0     ! NCTREC =  0   !
```

```
       Terrain and CTSG Receptor data for
       CTSG hills input in CTDM format ?
       (MHILL)                                  No Default     ! MHILL =  2   !
       1 = Hill and Receptor data created
           by CTDM processors & read from
           HILL.DAT and HILLRCT.DAT files
       2 = Hill data created by OPTHILL &
           input below in Subgroup (6b);
           Receptor data in Subgroup (6c)

       Factor to convert horizontal dimensions  Default: 1.0   ! XHILL2M = 1.0 !
       to meters (MHILL=1)

       Factor to convert vertical dimensions    Default: 1.0   ! ZHILL2M = 1.0 !
       to meters (MHILL=1)

       X-origin of CTDM system relative to      No Default     ! XCTDMKM = 0 !
       CALPUFF coordinate system, in Kilometers (MHILL=1)

       Y-origin of CTDM system relative to      No Default     ! YCTDMKM = 0 !
       CALPUFF coordinate system, in Kilometers (MHILL=1)

! END !

---------------
Subgroup (6b)
---------------

                     1 **
     HILL information


HILL           XC        YC       THETAH  ZGRID  RELIEF    EXPO 1    EXPO 2   SCALE 1    SCALE 2
AMAX1     AMAX2
 NO.          (km)      (km)      (deg.)   (m)     (m)       (m)       (m)       (m)        (m)
(m)       (m)
----          ----      ----      ------  -----  ------    ------    ------   -------    -------
-----     -----

---------------
Subgroup (6c)
---------------

    COMPLEX TERRAIN RECEPTOR INFORMATION

                     XRCT         YRCT        ZRCT          XHH
                     (km)         (km)         (m)
                    ------       -----      ------         ----


-------------------
1
     Description of Complex Terrain Variables:
          XC, YC  = Coordinates of center of hill
          THETAH  = Orientation of major axis of hill (clockwise from
                    North)
          ZGRID   = Height of the  0  of the grid above mean sea
                    level
          RELIEF  = Height of the crest of the hill above the grid elevation
          EXPO 1  = Hill-shape exponent for the major axis
          EXPO 2  = Hill-shape exponent for the major axis
          SCALE 1 = Horizontal length scale along the major axis
          SCALE 2 = Horizontal length scale along the minor axis
          AMAX    = Maximum allowed axis length for the major axis
          BMAX    = Maximum allowed axis length for the major axis

          XRCT, YRCT = Coordinates of the complex terrain receptors
          ZRCT    = Height of the ground (MSL) at the complex terrain
                    Receptor
          XHH     = Hill number associated with each complex terrain receptor
                    (NOTE: MUST BE ENTERED AS A REAL NUMBER)

   **
     NOTE: DATA for each hill and CTSG receptor are treated as a separate
           input subgroup and therefore must end with an input group terminator.
```

```
--------------------------------------------------------------------------------


INPUT GROUP: 7 -- Chemical parameters for dry deposition of gases
--------------

      SPECIES     DIFFUSIVITY      ALPHA STAR      REACTIVITY    MESOPHYLL RESISTANCE     HENRY'S
LAW COEFFICIENT
       NAME        (cm**2/s)                                          (s/cm)
(dimensionless)
      -------     -----------      ----------      ----------    --------------------     -------
----------------

! SO2  = 0.1509, 1000,  8, 0, 0.04 !

!END!


--------------------------------------------------------------------------------


INPUT GROUP: 8 -- Size parameters for dry deposition of particles
--------------

     For SINGLE SPECIES, the mean and standard deviation are used to
     compute a deposition velocity for NINT (see group 9) size-ranges,
     and these are then averaged to obtain a mean deposition velocity.

     For GROUPED SPECIES, the size distribution should be explicitly
     specified (by the 'species' in the group), and the standard deviation
     for each should be entered as 0.  The model will then use the
     deposition velocity for the stated mean diameter.

      SPECIES      GEOMETRIC MASS MEAN        GEOMETRIC STANDARD
       NAME             DIAMETER                 DEVIATION
                        (microns)                (microns)
      -------      -------------------        ------------------
! SO4 = 0.48, 2 !

!END!


--------------------------------------------------------------------------------


INPUT GROUP: 9 -- Miscellaneous dry deposition parameters
--------------

     Reference cuticle resistance (s/cm)
     (RCUTR)                          Default: 30    !  RCUTR = 30.0 !
     Reference ground resistance  (s/cm)
     (RGR)                            Default: 10    !    RGR = 5.0 !
     Reference pollutant reactivity
     (REACTR)                         Default: 8     ! REACTR = 8.0 !

     Number of particle-size intervals used to
     evaluate effective particle deposition velocity
     (NINT)                           Default: 9     !   NINT =  9  !

     Vegetation state in unirrigated areas
     (IVEG)                           Default: 1     !   IVEG =  1   !
        IVEG=1 for active and unstressed vegetation
        IVEG=2 for active and stressed vegetation
        IVEG=3 for inactive vegetation

!END!


--------------------------------------------------------------------------------


INPUT GROUP: 10 -- Wet Deposition Parameters
---------------
```

```
                    Scavenging Coefficient -- Units: (sec)**(-1)

       Pollutant      Liquid Precip.       Frozen Precip.
       ---------      --------------       --------------
! SO2 = 3.00E-05, 0.00E00 !
! SO4 = 1.00E-04, 3.00E-05 !

!END!


-------------------------------------------------------------------------------


INPUT GROUP: 11a, 11b -- Chemistry Parameters
---------------------

---------------
Subgroup (11a)
---------------

     Several parameters are needed for one or more of the chemical transformation
     mechanisms.  Those used for each mechanism are:
                                        M                 B
                                        A  B  R  R  R     C  B        N
                              B         V  C  N  N  N  M  K  C  O     D
                              C  M  G  K  I  I  I  H  H  K  F  V  E
                           M  K  N  N  N  T  T  T  2  2  P  R  C  C
                           O  O  H  H  H  E  E  E  O  O  M  A  N  A
     Mechanism (MCHEM)     Z  3  3  3  3  1  2  3  2  2  F  C  X  Y
     --------------------  ------------------------------------------
     0 None                .  .  .  .  .  .  .  .  .  .  .  .  .  .
     1 MESOPUFF II         X  X  .  .  X  X  X  X  .  .  .  .  .  .
     2 User Rates          .  .  .  .  .  .  .  .  .  .  .  .  .  .
     3 RIVAD               X  X  .  .  X  .  .  .  .  .  .  .  .  .
     4 SOA                 X  X  .  .  .  .  .  .  .  .  X  X  X  .
     5 Radioactive Decay   .  .  .  .  .  .  .  .  .  .  .  .  .  X
     6 RIVAD/ISORRPIA      X  X  X  X  X  X  .  .  X  X  .  .  .  .
     7 RIVAD/ISORRPIA/SOA  X  X  X  X  X  X  .  .  X  X  X  X  .  .


     Ozone data input option (MOZ)     Default: 1            ! MOZ =  0   !
     (Used only if MCHEM = 1, 3, 4, 6, or 7)
        0 = use a monthly background ozone value
        1 = read hourly ozone concentrations from
            the OZONE.DAT data file

     Monthly ozone concentrations in ppb (BCKO3)
     (Used only if MCHEM = 1,3,4,6, or 7 and either
        MOZ = 0, or
        MOZ = 1 and all hourly O3 data missing)
                                       Default: 12*80.
     !  BCKO3 = 40.00, 40.00, 40.00, 40.00, 40.00, 40.00, 40.00, 40.00, 40.00, 40.00, 40.00,
40.00 !

     Ammonia data option (MNH3)        Default: 0            ! MNH3 =  0   !
     (Used only if MCHEM = 6 or 7)
        0 = use monthly background ammonia values (BCKNH3) - no vertical variation
        1 = read monthly background ammonia values for each layer from
            the NH3Z.DAT data file

     Ammonia vertical averaging option (MAVGNH3)
     (Used only if MCHEM = 6 or 7, and MNH3 = 1)
        0 = use NH3 at puff center height (no averaging is done)
        1 = average NH3 values over vertical extent of puff
                                       Default: 1            ! MAVGNH3 =  1   !

     Monthly ammonia concentrations in ppb (BCKNH3)
     (Used only if MCHEM = 1 or 3, or
               if MCHEM = 6 or 7, and MNH3 = 0)
                                       Default: 12*10.
     !  BCKNH3 = 10.00, 10.00, 10.00, 10.00, 10.00, 10.00, 10.00, 10.00, 10.00, 10.00, 10.00,
10.00 !

     Nighttime SO2 loss rate in %/hour (RNITE1)
```

```
    (Used only if MCHEM = 1, 6 or 7)
    This rate is used only at night for MCHEM=1
    and is added to the computed rate both day
    and night for MCHEM=6,7 (heterogeneous reactions)
                                    Default: 0.2          ! RNITE1 = .2 !

    Nighttime NOx loss rate in %/hour (RNITE2)
    (Used only if MCHEM = 1)
                                    Default: 2.0          ! RNITE2 = 2.0 !

    Nighttime HNO3 formation rate in %/hour (RNITE3)
    (Used only if MCHEM = 1)
                                    Default: 2.0          ! RNITE3 = 2.0 !

    H2O2 data input option (MH2O2)    Default: 1          ! MH2O2 =  1   !
    (Used only if MCHEM = 6 or 7, and MAQCHEM = 1)
       0 = use a monthly background H2O2 value
       1 = read hourly H2O2 concentrations from
           the H2O2.DAT data file

    Monthly H2O2 concentrations in ppb (BCKH2O2)
    (Used only if MQACHEM = 1 and either
       MH2O2 = 0 or
       MH2O2 = 1 and all hourly H2O2 data missing)
                                    Default: 12*1.
    !  BCKH2O2 = 1.00, 1.00, 1.00, 1.00, 1.00, 1.00, 1.00, 1.00, 1.00, 1.00, 1.00, 1.00 !


--- Data for SECONDARY ORGANIC AEROSOL (SOA) Options
    (used only if MCHEM = 4 or 7)

    The MCHEM = 4 SOA module uses monthly values of:
         Fine particulate concentration in ug/m^3 (BCKPMF)
         Organic fraction of fine particulate     (OFRAC)
         VOC / NOX ratio (after reaction)         (VCNX)

    The MCHEM = 7 SOA module uses monthly values of:
         Fine particulate concentration in ug/m^3 (BCKPMF)
         Organic fraction of fine particulate     (OFRAC)

    These characterize the air mass when computing
    the formation of SOA from VOC emissions.
    Typical values for several distinct air mass types are:

       Month    1    2    3    4    5    6    7    8    9   10   11   12
                Jan  Feb  Mar  Apr  May  Jun  Jul  Aug  Sep  Oct  Nov  Dec

    Clean Continental
       BCKPMF   1.   1.   1.   1.   1.   1.   1.   1.   1.   1.   1.   1.
       OFRAC  .15  .15  .20  .20  .20  .20  .20  .20  .20  .20  .20  .15
       VCNX    50.  50.  50.  50.  50.  50.  50.  50.  50.  50.  50.  50.

    Clean Marine (surface)
       BCKPMF  .5   .5   .5   .5   .5   .5   .5   .5   .5   .5   .5   .5
       OFRAC  .25  .25  .30  .30  .30  .30  .30  .30  .30  .30  .30  .25
       VCNX    50.  50.  50.  50.  50.  50.  50.  50.  50.  50.  50.  50.

    Urban - low biogenic (controls present)
       BCKPMF  30.  30.  30.  30.  30.  30.  30.  30.  30.  30.  30.  30.
       OFRAC  .20  .20  .25  .25  .25  .25  .25  .25  .20  .20  .20  .20
       VCNX     4.   4.   4.   4.   4.   4.   4.   4.   4.   4.   4.   4.

    Urban - high biogenic (controls present)
       BCKPMF  60.  60.  60.  60.  60.  60.  60.  60.  60.  60.  60.  60.
       OFRAC  .25  .25  .30  .30  .30  .55  .55  .55  .35  .35  .35  .25
       VCNX    15.  15.  15.  15.  15.  15.  15.  15.  15.  15.  15.  15.

    Regional Plume
       BCKPMF  20.  20.  20.  20.  20.  20.  20.  20.  20.  20.  20.  20.
       OFRAC  .20  .20  .25  .35  .25  .40  .40  .40  .30  .30  .30  .20
       VCNX    15.  15.  15.  15.  15.  15.  15.  15.  15.  15.  15.  15.

    Urban - no controls present
       BCKPMF 100. 100. 100. 100. 100. 100. 100. 100. 100. 100. 100. 100.
       OFRAC  .30  .30  .35  .35  .35  .55  .55  .55  .35  .35  .35  .30
```

```
        VCNX     2.   2.   2.   2.   2.   2.   2.   2.   2.   2.   2.   2.

     Default: Clean Continental
     !  BCKPMF = 1.00, 1.00, 1.00, 1.00, 1.00, 1.00, 1.00, 1.00, 1.00, 1.00, 1.00, 1.00 !
     !  OFRAC  = 0.15, 0.15, 0.20, 0.20, 0.20, 0.20, 0.20, 0.20, 0.20, 0.20, 0.20, 0.15 !
     !  VCNX   = 50.00, 50.00, 50.00, 50.00, 50.00, 50.00, 50.00, 50.00, 50.00, 50.00, 50.00,
50.00 !

 --- End Data for SECONDARY ORGANIC AEROSOL (SOA) Option


     Number of half-life decay specification blocks provided in Subgroup 11b
     (Used only if MCHEM = 5)
     (NDECAY)                                    Default: 0      ! NDECAY =  0   !

!END!


--------------
Subgroup (11b)
--------------

     Each species modeled may be assigned a decay half-life (sec), and the associated
     mass lost may be assigned to one or more other modeled species using a mass yield
     factor. This information is used only for MCHEM=5.

     Provide NDECAY blocks assigning the half-life for a parent species and mass yield
     factors for each child species (if any) produced by the decay.
     Set HALF_LIFE=0.0 for NO decay (infinite half-life).


                             a            b
        SPECIES      Half-Life   Mass Yield
         NAME          (sec)       Factor
        -------      ---------   ----------

     *   SPEC1   =    3600.,        -1.0   *    (Parent)
     *   SPEC2   =     -1.0,         0.0   *    (Child)
   *END*

--------
    a
     Specify a half life that is greater than or equal to zero for 1 parent species
     in each block, and set the yield factor for this species to -1
    b
     Specify a yield factor that is greater than or equal to zero for 1 or more child
     species in each block, and set the half-life for each of these species to -1

     NOTE: Assignments in each block are treated as a separate input
           subgroup and therefore must end with an input group terminator.
           If NDECAY=0, no assignments and input group terminators should appear.

------------------------------------------------------------------------------


INPUT GROUP: 12 -- Misc. Dispersion and Computational Parameters
---------------

     Horizontal size of puff (m) beyond which
     time-dependent dispersion equations (Heffter)
     are used to determine sigma-y and
     sigma-z (SYTDEP)                            Default: 550.   ! SYTDEP = 5.5E02 !

     Switch for using Heffter equation for sigma z
     as above (0 = Not use Heffter; 1 = use Heffter
     (MHFTSZ)                                    Default: 0      ! MHFTSZ =  0   !

     Stability class used to determine plume
     growth rates for puffs above the boundary
     layer (JSUP)                                Default: 5      ! JSUP =  5   !

     Vertical dispersion constant for stable
     conditions (k1 in Eqn. 2.7-3)  (CONK1)      Default: 0.01   ! CONK1 = .01 !

     Vertical dispersion constant for neutral/
```

```
unstable conditions (k2 in Eqn. 2.7-4)
(CONK2)                                 Default: 0.1    ! CONK2 = .1 !

Factor for determining Transition-point from
Schulman-Scire to Huber-Snyder Building Downwash
scheme (SS used for Hs < Hb + TBD * HL)
(TBD)                                   Default: 0.5    ! TBD = .5 !
   TBD < 0   ==> always use Huber-Snyder
   TBD = 1.5 ==> always use Schulman-Scire
   TBD = 0.5 ==> ISC Transition-point

Range of land use categories for which
urban dispersion is assumed
(IURB1, IURB2)                          Default: 10     ! IURB1 =  10  !
                                                 19     ! IURB2 =  19  !

Site characterization parameters for single-point Met data files ---------
(needed for METFM = 2,3,4,5)

   Land use category for modeling domain
   (ILANDUIN)                           Default: 20     ! ILANDUIN =  20  !

   Roughness length (m) for modeling domain
   (Z0IN)                               Default: 0.25   ! Z0IN = .25 !

   Leaf area index for modeling domain
   (XLAIIN)                             Default: 3.0    ! XLAIIN = 3.0 !

   Elevation above sea level (m)
   (ELEVIN)                             Default: 0.0    ! ELEVIN = .0 !

   Latitude (degrees) for met location
   (XLATIN)                             Default: -999.  ! XLATIN = .0 !

   Longitude (degrees) for met location
   (XLONIN)                             Default: -999.  ! XLONIN = .0 !

Specialized information for interpreting single-point Met data files -----

   Anemometer height (m) (Used only if METFM = 2,3)
   (ANEMHT)                             Default: 10.    ! ANEMHT = 10.0 !

   Form of lateral turbulance data in PROFILE.DAT file
   (Used only if METFM = 4,5 or MTURBVW = 1 or 3)
   (ISIGMAV)                            Default: 1      ! ISIGMAV =  1  !
       0 = read sigma-theta
       1 = read sigma-v

   Choice of mixing heights (Used only if METFM = 4)
   (IMIXCTDM)                           Default: 0      ! IMIXCTDM =  0  !
       0 = read PREDICTED mixing heights
       1 = read OBSERVED mixing heights

Maximum length of a slug (met. grid units)
(XMXLEN)                                Default: 1.0    ! XMXLEN = 1.0 !

Maximum travel distance of a puff/slug (in
grid units) during one sampling step
(XSAMLEN)                               Default: 1.0    ! XSAMLEN = 1.0 !

Maximum Number of slugs/puffs release from
one source during one time step
(MXNEW)                                 Default: 99     ! MXNEW =  99   !

Maximum Number of sampling steps for
one puff/slug during one time step
(MXSAM)                                 Default: 99     ! MXSAM =  99   !

Number of iterations used when computing
the transport wind for a sampling step
that includes gradual rise (for CALMET
and PROFILE winds)
(NCOUNT)                                Default: 2      ! NCOUNT =  2   !

Minimum sigma y for a new puff/slug (m)
```

```
(SYMIN)                                    Default: 1.0    ! SYMIN = 1.0  !

Minimum sigma z for a new puff/slug (m)
(SZMIN)                                    Default: 1.0    ! SZMIN = 1.0  !

Maximum sigma z (m) allowed to avoid
numerical problem in calculating virtual
time or distance.  Cap should be large
enough to have no influence on normal events.
Enter a negative cap to disable.
(SZCAP_M)                                  Default: 5.0e06 ! SZCAP_M = 5.0E06 !

Default minimum turbulence velocities sigma-v and sigma-w
for each stability class over land and over water (m/s)
(SVMIN(12) and SWMIN(12))

                ----------  LAND  ----------       ---------  WATER  ----------
   Stab Class :  A    B    C    D    E    F        A    B    C    D    E    F
                ---  ---  ---  ---  ---  ---      ---  ---  ---  ---  ---  ---
Default SVMIN : .50, .50, .50, .50, .50, .50,      .37, .37, .37, .37, .37, .37
Default SWMIN : .20, .12, .08, .06, .03, .016,     .20, .12, .08, .06, .03, .016

     ! SVMIN = 0.500, 0.500, 0.500, 0.500, 0.500, 0.500, 0.370, 0.370, 0.370, 0.370, 0.370,
0.370!
     ! SWMIN = 0.200, 0.120, 0.080, 0.060, 0.030, 0.016, 0.200, 0.120, 0.080, 0.060, 0.030,
0.016!

Divergence criterion for dw/dz across puff
used to initiate adjustment for horizontal
convergence (1/s)
Partial adjustment starts at CDIV(1), and
full adjustment is reached at CDIV(2)
(CDIV(2))                                  Default: 0.0,0.0  ! CDIV = .0, .0 !

Search radius (number of cells) for nearest
land and water cells used in the subgrid
TIBL module
(NLUTIBL)                                  Default: 4      ! NLUTIBL =  4  !

Minimum wind speed (m/s) allowed for
non-calm conditions. Also used as minimum
speed returned when using power-law
extrapolation toward surface
(WSCALM)                                   Default: 0.5    ! WSCALM = .5 !

Maximum mixing height (m)
(XMAXZI)                                   Default: 3000.  ! XMAXZI = 3000.0 !

Minimum mixing height (m)
(XMINZI)                                   Default: 50.    ! XMINZI = 20.0 !

Default wind speed classes --
5 upper bounds (m/s) are entered;
the 6th class has no upper limit
(WSCAT(5))                      Default   :
                                ISC RURAL : 1.54, 3.09, 5.14, 8.23, 10.8 (10.8+)

                          Wind Speed Class :  1     2     3     4     5
                                             ---   ---   ---   ---   ---
                                   ! WSCAT = 1.54, 3.09, 5.14, 8.23, 10.80 !

Default wind speed profile power-law
exponents for stabilities 1-6
(PLX0(6))                       Default   : ISC RURAL values
                                ISC RURAL : .07, .07, .10, .15, .35, .55
                                ISC URBAN : .15, .15, .20, .25, .30, .30

                           Stability Class :  A     B     C     D     E     F
                                             ---   ---   ---   ---   ---   ---
                                     ! PLX0 = 0.07, 0.07, 0.10, 0.15, 0.35, 0.55 !

Default potential temperature gradient
for stable classes E, F (degK/m)
(PTG0(2))                       Default: 0.020, 0.035
                                   ! PTG0 = 0.020,   0.035 !
```

```
Default plume path coefficients for
each stability class (used when option
for partial plume height terrain adjustment
is selected -- MCTADJ=3)
(PPC(6))                  Stability Class :  A     B     C     D     E     F
                             Default  PPC : .50,  .50,  .50,  .50,  .35,  .35
                                           ---   ---   ---   ---   ---   ---
                                    !  PPC = 0.50, 0.50, 0.50, 0.50, 0.35, 0.35 !

Slug-to-puff transition criterion factor
equal to sigma-y/length of slug
(SL2PF)                              Default: 10.        ! SL2PF = 10.0 !

Puff-splitting control variables -----------------------

  VERTICAL SPLIT
  --------------

  Number of puffs that result every time a puff
  is split - nsplit=2 means that 1 puff splits
  into 2
  (NSPLIT)                           Default:   3        ! NSPLIT =  3  !

  Time(s) of a day when split puffs are eligible to
  be split once again; this is typically set once
  per day, around sunset before nocturnal shear develops.
  24 values: 0 is midnight (00:00) and 23 is 11 PM (23:00)
  0=do not re-split    1=eligible for re-split
  (IRESPLIT(24))                     Default:  Hour 17 = 1
  !  IRESPLIT = 0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,1,0,0,0,0,0,0 !

  Split is allowed only if last hour's mixing
  height (m) exceeds a minimum value
  (ZISPLIT)                          Default: 100.       ! ZISPLIT = 100.0 !

  Split is allowed only if ratio of last hour's
  mixing ht to the maximum mixing ht experienced
  by the puff is less than a maximum value (this
  postpones a split until a nocturnal layer develops)
  (ROLDMAX)                          Default: 0.25       ! ROLDMAX = 0.25 !


  HORIZONTAL SPLIT
  ----------------

  Number of puffs that result every time a puff
  is split - nsplith=5 means that 1 puff splits
  into 5
  (NSPLITH)                          Default:   5        ! NSPLITH =  5  !

  Minimum sigma-y (Grid Cells Units) of puff
  before it may be split
  (SYSPLITH)                         Default:  1.0       ! SYSPLITH = 1.0 !

  Minimum puff elongation rate (SYSPLITH/hr) due to
  wind shear, before it may be split
  (SHSPLITH)                         Default:  2.        ! SHSPLITH = 2.0 !

  Minimum concentration (g/m^3) of each
  species in puff before it may be split
  Enter array of NSPEC values; if a single value is
  entered, it will be used for ALL species
  (CNSPLITH)                         Default:  1.0E-07   ! CNSPLITH = 1.0E-07 !

Integration control variables -----------------------

  Fractional convergence criterion for numerical SLUG
  sampling integration
  (EPSSLUG)                          Default:   1.0e-04  ! EPSSLUG = 1.0E-04 !

  Fractional convergence criterion for numerical AREA
  source integration
  (EPSAREA)                          Default:   1.0e-06  ! EPSAREA = 1.0E-06 !
```

```
       Trajectory step-length (m) used for numerical rise
       integration
       (DSRISE)                          Default:   1.0      ! DSRISE = 1.0 !

       Boundary Condition (BC) Puff control variables ------------------------

       Minimum height (m) to which BC puffs are mixed as they are emitted
       (MBCON=2 ONLY).  Actual height is reset to the current mixing height
       at the release point if greater than this minimum.
       (HTMINBC)                         Default:   500.     ! HTMINBC = 500.0 !

       Search radius (km) about a receptor for sampling nearest BC puff.
       BC puffs are typically emitted with a spacing of one grid cell
       length, so the search radius should be greater than DGRIDKM.
       (RSAMPBC)                         Default:   10.      ! RSAMPBC = 10.0 !

       Near-Surface depletion adjustment to concentration profile used when
       sampling BC puffs?
       (MDEPBC)                          Default:   1        ! MDEPBC =  1  !
          0 = Concentration is NOT adjusted for depletion
          1 = Adjust Concentration for depletion

!END!


--------------------------------------------------------------------------------


INPUT GROUPS: 13a, 13b, 13c, 13d -- Point source parameters
---------------------------------

---------------
Subgroup (13a)
---------------

     Number of point sources with
     parameters provided below      (NPT1)  No default  !  NPT1 =   129!

     Units used for point source
     emissions below                (IPTU)  Default: 1  !  IPTU =   4  !
           1 =        g/s
           2 =       kg/hr
           3 =       lb/hr
           4 =     tons/yr
           5 =     Odour Unit * m**3/s  (vol. flux of odour compound)
           6 =     Odour Unit * m**3/min
           7 =     metric tons/yr
           8 =     Bq/s  (Bq = becquerel = disintegrations/s)
           9 =     GBq/yr

     Number of source-species
     combinations with variable
     emissions scaling factors
     provided below in (13d)        (NSPT1) Default: 0  !  NSPT1 =  0  !

     Number of point sources with
     variable emission parameters
     provided in external file      (NPT2)  No default  !  NPT2 =  0  !

     (If NPT2 > 0, these point
     source emissions are read from
     the file: PTEMARB.DAT)

!END!

---------------
Subgroup (13b)
---------------
                                    a
          POINT SOURCE: CONSTANT DATA
          ---------------------------
                                                                          b          c
  Source       X         Y       Stack    Base     Stack    Exit  Exit    Bldg.  Emission
   No.     Coordinate Coordinate Height Elevation Diameter  Vel.  Temp.   Dwash   Rates
              (km)      (km)       (m)       (m)       (m)   (m/s) (deg. K)
```

```
------   ---------- ---------- ------  ------   -------- ----- -------- ----- --------
   1 ! SRCNAM =         0001 !
   1 ! X =  -137.27,   35.71,   18.29,  181.00,    1.90,       30.08,  432.59, 0.0,    925.21,
0.00 !
   1 ! ZPLTFM  = 0.0  !
   1 ! FMFAC   = 1.0  ! !END!
   2 ! SRCNAM =         0002 !
   2 ! X =  -148.19,  111.81,   76.20,   54.00,    1.68,       31.16,  546.48, 0.0,    658.64,
0.00 !
   2 ! ZPLTFM  = 0.0  !
   2 ! FMFAC   = 1.0  ! !END!
   3 ! SRCNAM =         0003 !
   3 ! X =  -148.19,  111.81,   76.20,   54.00,    1.68,       31.16,  504.82, 0.0,    480.99,
0.00 !
   3 ! ZPLTFM  = 0.0  !
   3 ! FMFAC   = 1.0  ! !END!
   4 ! SRCNAM =         0004 !
   4 ! X =  -133.46,  112.31,  100.58,    5.00,    0.99,       12.42,  352.59, 0.0,    338.22,
0.00 !
   4 ! ZPLTFM  = 0.0  !
   4 ! FMFAC   = 1.0  ! !END!
   5 ! SRCNAM =         0005 !
   5 ! X =  -137.67,  113.28,   60.96,    1.00,    1.22,       30.80,  343.71, 0.0,    334.26,
0.00 !
   5 ! ZPLTFM  = 0.0  !
   5 ! FMFAC   = 1.0  ! !END!
   6 ! SRCNAM =         0006 !
   6 ! X =  -137.58,  112.07,   49.38,   12.00,    2.43,       15.44,  588.71, 0.0,    244.08,
0.00 !
   6 ! ZPLTFM  = 0.0  !
   6 ! FMFAC   = 1.0  ! !END!
   7 ! SRCNAM =         0007 !
   7 ! X =  -137.56,  112.06,   49.38,   12.00,    2.43,       15.44,  588.71, 0.0,    224.20,
0.00 !
   7 ! ZPLTFM  = 0.0  !
   7 ! FMFAC   = 1.0  ! !END!
   8 ! SRCNAM =         0008 !
   8 ! X =  -160.95,  102.59,   45.72,    5.00,    1.82,        5.99,  357.59, 0.0,    215.91,
0.00 !
   8 ! ZPLTFM  = 0.0  !
   8 ! FMFAC   = 1.0  ! !END!
   9 ! SRCNAM =         0009 !
   9 ! X =  -137.57,  112.07,   49.38,   12.00,    2.43,       15.44,  588.71, 0.0,    186.22,
0.00 !
   9 ! ZPLTFM  = 0.0  !
   9 ! FMFAC   = 1.0  ! !END!
  10 ! SRCNAM =         0010 !
  10 ! X =  -161.65,  103.54,   45.72,   25.00,    2.41,       41.47,  615.93, 0.0,    162.77,
0.00 !
  10 ! ZPLTFM  = 0.0  !
  10 ! FMFAC   = 1.0  ! !END!
  11 ! SRCNAM =         0011 !
  11 ! X =  -147.89,   84.81,   39.62,    8.00,    1.52,       17.74,  692.59, 0.0,    122.58,
0.00 !
  11 ! ZPLTFM  = 0.0  !
  11 ! FMFAC   = 1.0  ! !END!
  12 ! SRCNAM =         0012 !
  12 ! X =  -138.32,  111.63,   19.81,   21.00,    0.25,       20.17, 1271.48, 0.0,    117.15,
0.00 !
  12 ! ZPLTFM  = 0.0  !
  12 ! FMFAC   = 1.0  ! !END!
  13 ! SRCNAM =         0013 !
  13 ! X =  -133.46,  112.31,  106.68,    5.00,    3.66,       16.22,  543.71, 0.0,    104.86,
0.00 !
  13 ! ZPLTFM  = 0.0  !
  13 ! FMFAC   = 1.0  ! !END!
  14 ! SRCNAM =         0014 !
  14 ! X =  -133.46,  112.31,  100.58,    5.00,    2.13,        3.30,  593.71, 0.0,    101.84,
0.00 !
  14 ! ZPLTFM  = 0.0  !
  14 ! FMFAC   = 1.0  ! !END!
  15 ! SRCNAM =         0015 !
  15 ! X =  -126.81,  113.95,   30.48,    2.00,    1.60,       14.49,  427.59, 0.0,     80.38,
0.00 !
  15 ! ZPLTFM  = 0.0  !
```

```
  15 ! FMFAC   = 1.0  ! !END!
  16 ! SRCNAM =         0016 !
  16 ! X =  -131.85,   66.78,   14.63,   15.00,    9.73,        0.89,  532.59, 0.0,     74.46,
0.00 !
  16 ! ZPLTFM  = 0.0  !
  16 ! FMFAC   = 1.0  ! !END!
  17 ! SRCNAM =         0017 !
  17 ! X =  -138.32,  111.63,   54.86,   21.00,    2.74,        9.77,  465.93, 0.0,     68.92,
0.00 !
  17 ! ZPLTFM  = 0.0  !
  17 ! FMFAC   = 1.0  ! !END!
  18 ! SRCNAM =         0018 !
  18 ! X =  -117.13,  109.24,   20.73,   26.00,    0.14,       21.55,  294.82, 0.0,     60.48,
0.00 !
  18 ! ZPLTFM  = 0.0  !
  18 ! FMFAC   = 1.0  ! !END!
  19 ! SRCNAM =         0019 !
  19 ! X =  -137.54,  111.96,  106.68,   12.00,    5.48,        8.14,  699.82, 0.0,     56.56,
0.00 !
  19 ! ZPLTFM  = 0.0  !
  19 ! FMFAC   = 1.0  ! !END!
  20 ! SRCNAM =         0020 !
  20 ! X =  -140.15,  117.93,  108.81,   55.00,    1.19,       18.29, 1143.71, 0.0,     49.46,
0.00 !
  20 ! ZPLTFM  = 0.0  !
  20 ! FMFAC   = 1.0  ! !END!
  21 ! SRCNAM =         0021 !
  21 ! X =  -149.08,  114.47,   82.91,   37.00,    2.74,        4.15,  504.82, 0.0,     48.30,
0.00 !
  21 ! ZPLTFM  = 0.0  !
  21 ! FMFAC   = 1.0  ! !END!
  22 ! SRCNAM =         0022 !
  22 ! X =  -109.42,  110.53,   24.38,   10.00,    1.60,       14.49,  427.59, 0.0,     42.46,
0.00 !
  22 ! ZPLTFM  = 0.0  !
  22 ! FMFAC   = 1.0  ! !END!
  23 ! SRCNAM =         0023 !
  23 ! X =  -145.06,   82.64,   15.24,    2.00,    1.62,       12.53,  438.71, 0.0,     41.71,
0.00 !
  23 ! ZPLTFM  = 0.0  !
  23 ! FMFAC   = 1.0  ! !END!
  24 ! SRCNAM =         0024 !
  24 ! X =  -116.92,  112.58,   20.73,    4.00,    0.14,       21.55,  294.82, 0.0,     41.44,
0.00 !
  24 ! ZPLTFM  = 0.0  !
  24 ! FMFAC   = 1.0  ! !END!
  25 ! SRCNAM =         0025 !
  25 ! X =  -104.87,   77.86,   15.24,  164.00,    3.66,       15.73, 1032.59, 0.0,     36.01,
0.00 !
  25 ! ZPLTFM  = 0.0  !
  25 ! FMFAC   = 1.0  ! !END!
  26 ! SRCNAM =         0026 !
  26 ! X =  -137.27,  111.95,  106.68,   12.00,    5.48,       10.18,  699.82, 0.0,     35.62,
0.00 !
  26 ! ZPLTFM  = 0.0  !
  26 ! FMFAC   = 1.0  ! !END!
  27 ! SRCNAM =         0027 !
  27 ! X =  -138.32,  111.63,   60.96,   21.00,    3.37,        6.95,  421.48, 0.0,     35.58,
0.00 !
  27 ! ZPLTFM  = 0.0  !
  27 ! FMFAC   = 1.0  ! !END!
  28 ! SRCNAM =         0028 !
  28 ! X =  -137.95,  112.20,    6.10,    6.00,    0.24,       20.17, 1271.48, 0.0,     31.35,
0.00 !
  28 ! ZPLTFM  = 0.0  !
  28 ! FMFAC   = 1.0  ! !END!
  29 ! SRCNAM =         0029 !
  29 ! X =  -138.32,  111.63,   45.72,   21.00,    2.64,        3.99,  615.93, 0.0,     30.92,
0.00 !
  29 ! ZPLTFM  = 0.0  !
  29 ! FMFAC   = 1.0  ! !END!
  30 ! SRCNAM =         0030 !
  30 ! X =  -148.42,  115.71,   44.50,   68.00,    2.49,        4.75,  685.93, 0.0,     29.86,
0.00 !
  30 ! ZPLTFM  = 0.0  !
```

```
  30 ! FMFAC   = 1.0  ! !END!
  31 ! SRCNAM =         0031 !
  31 ! X =  -158.40,   58.83,   30.48,  116.00,    0.42,        1.26,  310.93, 0.0,     29.80,
0.00 !
  31 ! ZPLTFM  = 0.0  !
  31 ! FMFAC   = 1.0  ! !END!
  32 ! SRCNAM =         0032 !
  32 ! X =  -161.30,  103.91,   73.15,    2.00,    3.73,        6.81,  949.82, 0.0,     29.50,
0.00 !
  32 ! ZPLTFM  = 0.0  !
  32 ! FMFAC   = 1.0  ! !END!
  33 ! SRCNAM =         0033 !
  33 ! X =  -137.58,  112.07,   49.38,   12.00,    2.43,       15.44,  588.71, 0.0,     29.25,
0.00 !
  33 ! ZPLTFM  = 0.0  !
  33 ! FMFAC   = 1.0  ! !END!
  34 ! SRCNAM =         0034 !
  34 ! X =  -148.42,  115.71,   32.00,   68.00,    1.37,       15.51,  604.82, 0.0,     28.80,
0.00 !
  34 ! ZPLTFM  = 0.0  !
  34 ! FMFAC   = 1.0  ! !END!
  35 ! SRCNAM =         0035 !
  35 ! X =  -148.42,  115.71,   76.20,   68.00,    1.07,        0.77,  810.93, 0.0,     28.40,
0.00 !
  35 ! ZPLTFM  = 0.0  !
  35 ! FMFAC   = 1.0  ! !END!
  36 ! SRCNAM =         0036 !
  36 ! X =  -161.31,  103.91,   73.15,    2.00,    3.73,        6.81,  949.82, 0.0,     28.34,
0.00 !
  36 ! ZPLTFM  = 0.0  !
  36 ! FMFAC   = 1.0  ! !END!
  37 ! SRCNAM =         0037 !
  37 ! X =  -107.20,  110.46,   24.38,    4.00,    1.60,       14.49,  427.59, 0.0,     25.77,
0.00 !
  37 ! ZPLTFM  = 0.0  !
  37 ! FMFAC   = 1.0  ! !END!
  38 ! SRCNAM =         0038 !
  38 ! X =  -138.32,  111.63,   45.42,   21.00,    1.20,        1.00,  421.48, 0.0,     25.18,
0.00 !
  38 ! ZPLTFM  = 0.0  !
  38 ! FMFAC   = 1.0  ! !END!
  39 ! SRCNAM =         0039 !
  39 ! X =  -175.62,  128.47,   15.24,    0.00,    3.66,        5.02, 1365.93, 0.0,     25.13,
0.00 !
  39 ! ZPLTFM  = 0.0  !
  39 ! FMFAC   = 1.0  ! !END!
  40 ! SRCNAM =         0040 !
  40 ! X =  -149.15,  114.66,   53.95,   37.00,    1.83,        8.08,  660.93, 0.0,     24.93,
0.00 !
  40 ! ZPLTFM  = 0.0  !
  40 ! FMFAC   = 1.0  ! !END!
  41 ! SRCNAM =         0041 !
  41 ! X =  -162.46,  104.83,   45.72,    1.00,    1.82,        2.55,  587.59, 0.0,     24.72,
0.00 !
  41 ! ZPLTFM  = 0.0  !
  41 ! FMFAC   = 1.0  ! !END!
  42 ! SRCNAM =         0042 !
  42 ! X =  -137.56,  112.06,   49.38,   12.00,    2.43,       15.44,  588.71, 0.0,     24.54,
0.00 !
  42 ! ZPLTFM  = 0.0  !
  42 ! FMFAC   = 1.0  ! !END!
  43 ! SRCNAM =         0043 !
  43 ! X =  -162.43,  104.81,   45.72,    1.00,    2.54,        2.66,  588.71, 0.0,     22.77,
0.00 !
  43 ! ZPLTFM  = 0.0  !
  43 ! FMFAC   = 1.0  ! !END!
  44 ! SRCNAM =         0044 !
  44 ! X =  -175.62,  128.47,   12.19,    0.00,    3.64,        2.76, 1032.59, 0.0,     22.53,
0.00 !
  44 ! ZPLTFM  = 0.0  !
  44 ! FMFAC   = 1.0  ! !END!
  45 ! SRCNAM =         0045 !
  45 ! X =  -161.74,  104.68,   35.66,    5.00,    1.52,       14.02,  490.93, 0.0,     21.23,
0.00 !
  45 ! ZPLTFM  = 0.0  !
```

```
  45 ! FMFAC   = 1.0  ! !END!
  46 ! SRCNAM =         0046 !
  46 ! X =  -162.48,  104.86,   45.72,    1.00,    1.82,        2.55,  587.59, 0.0,     18.95,
0.00 !
  46 ! ZPLTFM  = 0.0  !
  46 ! FMFAC   = 1.0  ! !END!
  47 ! SRCNAM =         0047 !
  47 ! X =  -137.38,  112.05,  106.68,   12.00,    3.06,       12.09,  671.48, 0.0,     18.44,
0.00 !
  47 ! ZPLTFM  = 0.0  !
  47 ! FMFAC   = 1.0  ! !END!
  48 ! SRCNAM =         0048 !
  48 ! X =  -137.27,  111.95,  106.68,   12.00,    5.48,       10.18,  699.82, 0.0,     18.34,
0.00 !
  48 ! ZPLTFM  = 0.0  !
  48 ! FMFAC   = 1.0  ! !END!
  49 ! SRCNAM =         0049 !
  49 ! X =  -148.42,  115.71,   41.76,   68.00,    1.90,        4.68,  643.71, 0.0,     16.81,
0.00 !
  49 ! ZPLTFM  = 0.0  !
  49 ! FMFAC   = 1.0  ! !END!
  50 ! SRCNAM =         0050 !
  50 ! X =  -137.38,  112.05,  106.68,   12.00,    3.06,       12.09,  671.48, 0.0,     16.61,
0.00 !
  50 ! ZPLTFM  = 0.0  !
  50 ! FMFAC   = 1.0  ! !END!
  51 ! SRCNAM =         0051 !
  51 ! X =  -137.38,  112.05,  106.68,   12.00,    3.06,       12.09,  671.48, 0.0,     16.30,
0.00 !
  51 ! ZPLTFM  = 0.0  !
  51 ! FMFAC   = 1.0  ! !END!
  52 ! SRCNAM =         0052 !
  52 ! X =  -149.10,  114.49,   38.10,   37.00,    1.88,        2.89,  699.82, 0.0,     16.29,
0.00 !
  52 ! ZPLTFM  = 0.0  !
  52 ! FMFAC   = 1.0  ! !END!
  53 ! SRCNAM =         0053 !
  53 ! X =  -133.46,  112.31,    8.23,    5.00,    0.61,        4.37,  495.93, 0.0,     16.26,
0.00 !
  53 ! ZPLTFM  = 0.0  !
  53 ! FMFAC   = 1.0  ! !END!
  54 ! SRCNAM =         0054 !
  54 ! X =  -133.46,  112.31,    8.23,    5.00,    0.61,        4.37,  495.93, 0.0,     16.26,
0.00 !
  54 ! ZPLTFM  = 0.0  !
  54 ! FMFAC   = 1.0  ! !END!
  55 ! SRCNAM =         0055 !
  55 ! X =  -148.42,  115.71,   32.00,   68.00,    3.06,       20.90,  438.71, 0.0,     15.06,
0.00 !
  55 ! ZPLTFM  = 0.0  !
  55 ! FMFAC   = 1.0  ! !END!
  56 ! SRCNAM =         0056 !
  56 ! X =  -148.42,  115.71,   32.00,   68.00,    3.06,       20.90,  438.71, 0.0,     14.90,
0.00 !
  56 ! ZPLTFM  = 0.0  !
  56 ! FMFAC   = 1.0  ! !END!
  57 ! SRCNAM =         0057 !
  57 ! X =  -139.61,  116.99,  108.20,   19.00,    0.39,        6.16,  921.48, 0.0,     14.39,
0.00 !
  57 ! ZPLTFM  = 0.0  !
  57 ! FMFAC   = 1.0  ! !END!
  58 ! SRCNAM =         0058 !
  58 ! X =  -137.27,  111.95,  106.68,   12.00,    5.48,       10.18,  699.82, 0.0,     13.89,
0.00 !
  58 ! ZPLTFM  = 0.0  !
  58 ! FMFAC   = 1.0  ! !END!
  59 ! SRCNAM =         0059 !
  59 ! X =  -148.42,  115.71,   32.00,   68.00,    3.06,       20.90,  438.71, 0.0,     13.18,
0.00 !
  59 ! ZPLTFM  = 0.0  !
  59 ! FMFAC   = 1.0  ! !END!
  60 ! SRCNAM =         0060 !
  60 ! X =  -148.42,  115.71,   32.00,   68.00,    1.37,       15.51,  532.59, 0.0,     13.12,
0.00 !
  60 ! ZPLTFM  = 0.0  !
```

```
  60 ! FMFAC   = 1.0  ! !END!
  61 ! SRCNAM =         0061 !
  61 ! X =  -149.43,  115.23,   45.72,   -2.00,    2.21,       15.51,  576.48, 0.0,     12.83,
0.00 !
  61 ! ZPLTFM  = 0.0  !
  61 ! FMFAC   = 1.0  ! !END!
  62 ! SRCNAM =         0062 !
  62 ! X =  -148.00,   85.00,   39.62,    8.00,    1.52,       11.76,  629.82, 0.0,     12.73,
0.00 !
  62 ! ZPLTFM  = 0.0  !
  62 ! FMFAC   = 1.0  ! !END!
  63 ! SRCNAM =         0063 !
  63 ! X =  -137.27,  111.95,  106.68,   12.00,    5.48,       10.18,  699.82, 0.0,     12.34,
0.00 !
  63 ! ZPLTFM  = 0.0  !
  63 ! FMFAC   = 1.0  ! !END!
  64 ! SRCNAM =         0064 !
  64 ! X =  -140.15,  117.93,   67.06,   55.00,    0.61,       18.33,  307.59, 0.0,     12.20,
0.00 !
  64 ! ZPLTFM  = 0.0  !
  64 ! FMFAC   = 1.0  ! !END!
  65 ! SRCNAM =         0065 !
  65 ! X =  -133.46,  112.31,   13.72,    5.00,    1.22,        2.63,  299.82, 0.0,     12.05,
0.00 !
  65 ! ZPLTFM  = 0.0  !
  65 ! FMFAC   = 1.0  ! !END!
  66 ! SRCNAM =         0066 !
  66 ! X =  -149.26,  114.75,   38.10,   30.00,    1.98,        2.60,  515.93, 0.0,     12.02,
0.00 !
  66 ! ZPLTFM  = 0.0  !
  66 ! FMFAC   = 1.0  ! !END!
  67 ! SRCNAM =         0067 !
  67 ! X =  -148.42,  115.71,   36.58,   68.00,    1.55,        3.25,  660.93, 0.0,     11.27,
0.00 !
  67 ! ZPLTFM  = 0.0  !
  67 ! FMFAC   = 1.0  ! !END!
  68 ! SRCNAM =         0068 !
  68 ! X =  -148.42,  115.71,   36.58,   68.00,    1.91,        3.31,  610.93, 0.0,     10.80,
0.00 !
  68 ! ZPLTFM  = 0.0  !
  68 ! FMFAC   = 1.0  ! !END!
  69 ! SRCNAM =         0069 !
  69 ! X =  -137.54,  111.96,  106.68,   12.00,    5.48,        8.14,  699.82, 0.0,     10.48,
0.00 !
  69 ! ZPLTFM  = 0.0  !
  69 ! FMFAC   = 1.0  ! !END!
  70 ! SRCNAM =         0070 !
  70 ! X =  -161.33,  103.91,   47.24,    2.00,    2.92,        7.59,  810.93, 0.0,     10.44,
0.00 !
  70 ! ZPLTFM  = 0.0  !
  70 ! FMFAC   = 1.0  ! !END!
  71 ! SRCNAM =         0071 !
  71 ! X =  -133.46,  112.31,   48.77,    5.00,    0.61,        6.16, 1091.48, 0.0,     10.29,
0.00 !
  71 ! ZPLTFM  = 0.0  !
  71 ! FMFAC   = 1.0  ! !END!
  72 ! SRCNAM =         0072 !
  72 ! X =  -161.65,  103.54,   42.67,   25.00,    3.51,       10.76,  532.59, 0.0,     10.07,
0.00 !
  72 ! ZPLTFM  = 0.0  !
  72 ! FMFAC   = 1.0  ! !END!
  73 ! SRCNAM =         0073 !
  73 ! X =  -138.32,  111.63,   74.68,   21.00,    3.78,       19.99,  421.48, 0.0,      9.92,
0.00 !
  73 ! ZPLTFM  = 0.0  !
  73 ! FMFAC   = 1.0  ! !END!
  74 ! SRCNAM =         0074 !
  74 ! X =  -137.27,  111.95,  106.68,   12.00,    5.48,       10.18,  699.82, 0.0,      9.74,
0.00 !
  74 ! ZPLTFM  = 0.0  !
  74 ! FMFAC   = 1.0  ! !END!
  75 ! SRCNAM =         0075 !
  75 ! X =  -133.54,  111.75,  106.68,    7.00,    4.58,        4.31,  477.59, 0.0,      9.74,
0.00 !
  75 ! ZPLTFM  = 0.0  !
```

```
  75 ! FMFAC   = 1.0  ! !END!
  76 ! SRCNAM =         0076 !
  76 ! X =  -149.26,  114.75,   38.10,   30.00,    1.98,        2.60,  515.93, 0.0,      9.71,
0.00 !
  76 ! ZPLTFM  = 0.0  !
  76 ! FMFAC   = 1.0  ! !END!
  77 ! SRCNAM =         0077 !
  77 ! X =  -138.32,  111.63,   74.68,   21.00,    3.78,       19.99,  421.48, 0.0,      9.63,
0.00 !
  77 ! ZPLTFM  = 0.0  !
  77 ! FMFAC   = 1.0  ! !END!
  78 ! SRCNAM =         0078 !
  78 ! X =  -137.54,  111.96,  106.68,   12.00,    5.48,        8.14,  699.82, 0.0,      9.27,
0.00 !
  78 ! ZPLTFM  = 0.0  !
  78 ! FMFAC   = 1.0  ! !END!
  79 ! SRCNAM =         0079 !
  79 ! X =  -137.57,  112.07,   49.38,   12.00,    2.43,       15.44,  588.71, 0.0,      8.56,
0.00 !
  79 ! ZPLTFM  = 0.0  !
  79 ! FMFAC   = 1.0  ! !END!
  80 ! SRCNAM =         0080 !
  80 ! X =  -138.32,  111.63,   45.42,   21.00,    1.20,        1.00,  421.48, 0.0,      7.64,
0.00 !
  80 ! ZPLTFM  = 0.0  !
  80 ! FMFAC   = 1.0  ! !END!
  81 ! SRCNAM =         0081 !
  81 ! X =  -149.26,  114.75,   38.10,   30.00,    1.98,        2.60,  515.93, 0.0,      7.54,
0.00 !
  81 ! ZPLTFM  = 0.0  !
  81 ! FMFAC   = 1.0  ! !END!
  82 ! SRCNAM =         0082 !
  82 ! X =  -148.00,   85.00,   39.62,    8.00,    1.52,       11.76,  629.82, 0.0,      7.16,
0.00 !
  82 ! ZPLTFM  = 0.0  !
  82 ! FMFAC   = 1.0  ! !END!
  83 ! SRCNAM =         0083 !
  83 ! X =  -138.32,  111.63,   76.20,   21.00,    1.09,       15.51,  554.82, 0.0,      7.13,
0.00 !
  83 ! ZPLTFM  = 0.0  !
  83 ! FMFAC   = 1.0  ! !END!
  84 ! SRCNAM =         0084 !
  84 ! X =  -138.32,  111.63,   45.72,   21.00,    0.76,        7.84,  643.71, 0.0,      7.08,
0.00 !
  84 ! ZPLTFM  = 0.0  !
  84 ! FMFAC   = 1.0  ! !END!
  85 ! SRCNAM =         0085 !
  85 ! X =  -148.42,  115.71,   41.45,   68.00,    2.20,        1.12,  643.71, 0.0,      7.02,
0.00 !
  85 ! ZPLTFM  = 0.0  !
  85 ! FMFAC   = 1.0  ! !END!
  86 ! SRCNAM =         0086 !
  86 ! X =  -138.32,  111.63,   45.72,   21.00,    0.76,        7.84,  643.71, 0.0,      6.52,
0.00 !
  86 ! ZPLTFM  = 0.0  !
  86 ! FMFAC   = 1.0  ! !END!
  87 ! SRCNAM =         0087 !
  87 ! X =  -149.14,  114.67,   39.01,   37.00,    1.37,        3.83,  627.59, 0.0,      6.38,
0.00 !
  87 ! ZPLTFM  = 0.0  !
  87 ! FMFAC   = 1.0  ! !END!
  88 ! SRCNAM =         0088 !
  88 ! X =  -133.25,  112.43,   60.96,    5.00,    1.98,        5.05,  671.48, 0.0,      6.37,
0.00 !
  88 ! ZPLTFM  = 0.0  !
  88 ! FMFAC   = 1.0  ! !END!
  89 ! SRCNAM =         0089 !
  89 ! X =  -133.46,  112.31,   22.86,    5.00,    0.61,        4.37,  495.93, 0.0,      6.10,
0.00 !
  89 ! ZPLTFM  = 0.0  !
  89 ! FMFAC   = 1.0  ! !END!
  90 ! SRCNAM =         0090 !
  90 ! X =  -161.65,  103.54,   52.73,   25.00,    1.09,        0.72,  421.48, 0.0,      6.05,
0.00 !
  90 ! ZPLTFM  = 0.0  !
```

```
  90 ! FMFAC   = 1.0  ! !END!
  91 ! SRCNAM =         0091 !
  91 ! X =  -137.58,  112.07,   49.38,   12.00,    2.43,       15.44,  588.71, 0.0,      6.04,
0.00 !
  91 ! ZPLTFM  = 0.0  !
  91 ! FMFAC   = 1.0  ! !END!
  92 ! SRCNAM =         0092 !
  92 ! X =  -133.24,  112.39,   38.10,    5.00,    3.05,       10.68,  421.48, 0.0,      6.02,
0.00 !
  92 ! ZPLTFM  = 0.0  !
  92 ! FMFAC   = 1.0  ! !END!
  93 ! SRCNAM =         0093 !
  93 ! X =  -138.32,  111.63,   76.20,   21.00,    1.09,       15.51,  554.82, 0.0,      6.01,
0.00 !
  93 ! ZPLTFM  = 0.0  !
  93 ! FMFAC   = 1.0  ! !END!
  94 ! SRCNAM =         0094 !
  94 ! X =  -137.67,  113.28,    6.10,    1.00,    0.08,        6.33,  371.48, 0.0,      5.80,
0.00 !
  94 ! ZPLTFM  = 0.0  !
  94 ! FMFAC   = 1.0  ! !END!
  95 ! SRCNAM =         0095 !
  95 ! X =  -137.67,  113.28,    7.92,    1.00,    0.10,       25.40,  313.71, 0.0,      5.80,
0.00 !
  95 ! ZPLTFM  = 0.0  !
  95 ! FMFAC   = 1.0  ! !END!
  96 ! SRCNAM =         0096 !
  96 ! X =   -98.45,   81.90,   16.76,  292.00,    3.64,        2.76, 1365.93, 0.0,      5.72,
0.00 !
  96 ! ZPLTFM  = 0.0  !
  96 ! FMFAC   = 1.0  ! !END!
  97 ! SRCNAM =         0097 !
  97 ! X =  -138.32,  111.63,   60.96,   21.00,    3.37,        6.95,  421.48, 0.0,      5.67,
0.00 !
  97 ! ZPLTFM  = 0.0  !
  97 ! FMFAC   = 1.0  ! !END!
  98 ! SRCNAM =         0098 !
  98 ! X =  -153.72,   91.25,   12.19,    1.00,    0.77,       13.51,  432.59, 0.0,      5.65,
0.00 !
  98 ! ZPLTFM  = 0.0  !
  98 ! FMFAC   = 1.0  ! !END!
  99 ! SRCNAM =         0099 !
  99 ! X =  -154.06,   96.05,   10.06,    4.00,    1.22,       18.62,  421.48, 0.0,      5.30,
0.00 !
  99 ! ZPLTFM  = 0.0  !
  99 ! FMFAC   = 1.0  ! !END!
 100 ! SRCNAM =         0100 !
 100 ! X =  -137.38,  112.05,  106.68,   12.00,    3.06,       12.09,  671.48, 0.0,      5.22,
0.00 !
 100 ! ZPLTFM  = 0.0  !
 100 ! FMFAC   = 1.0  ! !END!
 101 ! SRCNAM =         0101 !
 101 ! X =  -138.32,  111.63,   60.96,   21.00,    3.37,        6.95,  421.48, 0.0,      5.20,
0.00 !
 101 ! ZPLTFM  = 0.0  !
 101 ! FMFAC   = 1.0  ! !END!
 102 ! SRCNAM =         0102 !
 102 ! X =  -139.70,  117.08,   76.20,   19.00,    2.53,        4.94,  493.71, 0.0,      5.20,
0.00 !
 102 ! ZPLTFM  = 0.0  !
 102 ! FMFAC   = 1.0  ! !END!
 103 ! SRCNAM =         0103 !
 103 ! X =  -146.45,  115.86,   70.71,   15.00,    5.78,       17.78,  379.82, 0.0,      5.19,
0.00 !
 103 ! ZPLTFM  = 0.0  !
 103 ! FMFAC   = 1.0  ! !END!
 104 ! SRCNAM =         0104 !
 104 ! X =  -133.46,  112.31,  106.68,    5.00,    3.66,       16.22,  543.71, 0.0,      5.15,
0.00 !
 104 ! ZPLTFM  = 0.0  !
 104 ! FMFAC   = 1.0  ! !END!
 105 ! SRCNAM =         0105 !
 105 ! X =  -137.38,  112.05,  106.68,   12.00,    3.06,       12.09,  671.48, 0.0,      5.12,
0.00 !
 105 ! ZPLTFM  = 0.0  !
```

```
 105 ! FMFAC   = 1.0  ! !END!
 106 ! SRCNAM =         0106 !
 106 ! X =  -148.42,  115.71,   49.38,   12.00,    2.43,       15.44,  671.48, 0.0,      4.97,
0.00 !
 106 ! ZPLTFM  = 0.0  !
 106 ! FMFAC   = 1.0  ! !END!
 107 ! SRCNAM =         0107 !
 107 ! X =  -137.57,  112.07,   49.38,   68.00,    2.43,       15.44,  672.04, 0.0,      4.97,
0.00 !
 107 ! ZPLTFM  = 0.0  !
 107 ! FMFAC   = 1.0  ! !END!
 108 ! SRCNAM =         0108 !
 108 ! X =  -137.56,  112.06,   49.38,   12.00,    2.43,       15.44,  588.71, 0.0,      4.96,
0.00 !
 108 ! ZPLTFM  = 0.0  !
 108 ! FMFAC   = 1.0  ! !END!
 109 ! SRCNAM =         0109 !
 109 ! X =   -98.45,   81.90,   10.97,  292.00,    1.32,       31.00,  623.71, 0.0,      4.95,
0.00 !
 109 ! ZPLTFM  = 0.0  !
 109 ! FMFAC   = 1.0  ! !END!
 110 ! SRCNAM =         0110 !
 110 ! X =  -138.32,  111.63,   45.72,   21.00,    2.13,        4.42,  615.93, 0.0,      4.94,
0.00 !
 110 ! ZPLTFM  = 0.0  !
 110 ! FMFAC   = 1.0  ! !END!
 111 ! SRCNAM =         0111 !
 111 ! X =  -148.42,  115.71,   32.00,   68.00,    3.06,       20.90,  438.71, 0.0,      4.93,
0.00 !
 111 ! ZPLTFM  = 0.0  !
 111 ! FMFAC   = 1.0  ! !END!
 112 ! SRCNAM =         0112 !
 112 ! X =  -148.42,  115.71,   38.10,  292.00,    1.27,       31.00,  671.48, 0.0,      4.86,
0.00 !
 112 ! ZPLTFM  = 0.0  !
 112 ! FMFAC   = 1.0  ! !END!
 113 ! SRCNAM =         0113 !
 113 ! X =   -98.45,   81.90,   38.10,   68.00,    1.32,       31.00,  672.04, 0.0,      4.86,
0.00 !
 113 ! ZPLTFM  = 0.0  !
 113 ! FMFAC   = 1.0  ! !END!
 114 ! SRCNAM =         0114 !
 114 ! X =  -153.72,   91.25,   18.90,    1.00,    1.82,       12.97,  438.71, 0.0,      4.85,
0.00 !
 114 ! ZPLTFM  = 0.0  !
 114 ! FMFAC   = 1.0  ! !END!
 115 ! SRCNAM =         0115 !
 115 ! X =  -124.34,   40.35,    5.49,   12.00,    0.61,       10.70,  444.82, 0.0,      4.76,
0.00 !
 115 ! ZPLTFM  = 0.0  !
 115 ! FMFAC   = 1.0  ! !END!
 116 ! SRCNAM =         0116 !
 116 ! X =  -148.42,  115.71,   32.00,   68.00,    3.06,       20.90,  438.71, 0.0,      4.67,
0.00 !
 116 ! ZPLTFM  = 0.0  !
 116 ! FMFAC   = 1.0  ! !END!
 117 ! SRCNAM =         0117 !
 117 ! X =  -137.67,  113.28,    6.10,    1.00,    0.08,        6.73,  371.48, 0.0,      4.64,
0.00 !
 117 ! ZPLTFM  = 0.0  !
 117 ! FMFAC   = 1.0  ! !END!
 118 ! SRCNAM =         0118 !
 118 ! X =  -149.43,  115.23,   45.72,   -2.00,    2.21,       15.51,  576.48, 0.0,      4.47,
0.00 !
 118 ! ZPLTFM  = 0.0  !
 118 ! FMFAC   = 1.0  ! !END!
 119 ! SRCNAM =         0119 !
 119 ! X =  -154.27,   96.55,    9.14,    5.00,    0.70,       30.31,  310.93, 0.0,      4.43,
0.00 !
 119 ! ZPLTFM  = 0.0  !
 119 ! FMFAC   = 1.0  ! !END!
 120 ! SRCNAM =         0120 !
 120 ! X =  -140.15,  117.93,   27.43,   55.00,    3.36,        0.21,  671.48, 0.0,      4.42,
0.00 !
 120 ! ZPLTFM  = 0.0  !
```

```
 120 ! FMFAC   = 1.0  ! !END!
 121 ! SRCNAM =         0121 !
 121 ! X =  -148.42,  115.71,   32.00,   68.00,    3.06,       20.90,  438.71, 0.0,      4.40,
0.00 !
 121 ! ZPLTFM  = 0.0  !
 121 ! FMFAC   = 1.0  ! !END!
 122 ! SRCNAM =         0122 !
 122 ! X =  -137.27,  111.95,  106.68,   12.00,   10.00,       10.18,  699.82, 0.0,      4.37,
0.00 !
 122 ! ZPLTFM  = 0.0  !
 122 ! FMFAC   = 1.0  ! !END!
 123 ! SRCNAM =         0123 !
 123 ! X =  -153.72,   91.25,   12.19,    1.00,    0.77,       13.51,  432.59, 0.0,      4.32,
0.00 !
 123 ! ZPLTFM  = 0.0  !
 123 ! FMFAC   = 1.0  ! !END!
 124 ! SRCNAM =         0124 !
 124 ! X =  -128.47,   54.48,   13.72,    1.00,    2.74,       11.29, 1143.71, 0.0,      4.29,
0.00 !
 124 ! ZPLTFM  = 0.0  !
 124 ! FMFAC   = 1.0  ! !END!
 125 ! SRCNAM =         0125 !
 125 ! X =  -147.24,   81.54,   10.67,   -1.00,    1.22,        0.24,  604.82, 0.0,      4.25,
0.00 !
 125 ! ZPLTFM  = 0.0  !
 125 ! FMFAC   = 1.0  ! !END!
 126 ! SRCNAM =         0126 !
 126 ! X =  -160.95,  102.59,  106.68,   12.00,   10.00,        8.14,  699.82, 0.0,      4.22,
0.00 !
 126 ! ZPLTFM  = 0.0  !
 126 ! FMFAC   = 1.0  ! !END!
 127 ! SRCNAM =         0127 !
 127 ! X =  -137.54,  111.96,  106.68,    5.00,    5.48,        8.14,  699.82, 0.0,      4.22,
0.00 !
 127 ! ZPLTFM  = 0.0  !
 127 ! FMFAC   = 1.0  ! !END!
 128 ! SRCNAM =         0128 !
 128 ! X =  -141.78,   74.09,    7.62,    2.00,    0.22,       34.80,  815.93, 0.0,      4.18,
0.00 !
 128 ! ZPLTFM  = 0.0  !
 128 ! FMFAC   = 1.0  ! !END!
 129 ! SRCNAM =         0129 !
 129 ! X =  -139.73,  117.49,   76.20,   19.00,    2.53,        4.53,  493.71, 0.0,      4.06,
0.00 !
 129 ! ZPLTFM  = 0.0  !
 129 ! FMFAC   = 1.0  ! !END!
--------
```

a

Data for each source are treated as a separate input subgroup
and therefore must end with an input group terminator.

SRCNAM is a 12-character name for a source
(No default)

X is an array holding the source data listed by the column headings
(No default)

SIGYZI is an array holding the initial sigma-y and sigma-z (m)
(Default: 0.,0.)

FMFAC is a vertical momentum flux factor (0. or 1.0) used to represent
the effect of rain-caps or other physical configurations that
reduce momentum rise associated with the actual exit velocity.
(Default: 1.0 -- full momentum used)

ZPLTFM is the platform height (m) for sources influenced by an isolated
structure that has a significant open area between the surface
and the bulk of the structure, such as an offshore oil platform.
The Base Elevation is that of the surface (ground or ocean),
and the Stack Height is the release height above the Base (not
above the platform). Building heights entered in Subgroup 13c
must be those of the buildings on the platform, measured from
the platform deck. ZPLTFM is used only with MBDW=1 (ISC
downwash method) for sources with building downwash.
(Default: 0.0)

b

0. = No building downwash modeled

1. = Downwash modeled for buildings resting on the surface
2. = Downwash modeled for buildings raised above the surface (ZPLTFM > 0.)
NOTE: must be entered as a REAL number (i.e., with decimal point)

[c]
An emission rate must be entered for every pollutant modeled.
Enter emission rate of zero for secondary pollutants that are
modeled, but not emitted. Units are specified by IPTU
(e.g. 1 for g/s).

Subgroup (13c)

BUILDING DIMENSION DATA FOR SOURCES SUBJECT TO DOWNWASH

Source No.	Effective building height, width, length and X/Y offset (in meters) every 10 degrees. LENGTH, XBADJ, and YBADJ are only needed for MBDW=2 (PRIME downwash option) [a]

---

[a]
Building height, width, length, and X/Y offset from the source are treated
as a separate input subgroup for each source and therefore must end with
an input group terminator. The X/Y offset is the position, relative to the
stack, of the center of the upwind face of the projected building, with the
x-axis pointing along the flow direction.

Subgroup (13d)

POINT SOURCE: VARIABLE EMISSIONS DATA [a]

Use this subgroup to describe temporal variations in the emission
rates given in 13b. Factors entered multiply the rates in 13b.
Skip sources here that have constant emissions. For more elaborate
variation in source parameters, use PTEMARB.DAT and NPT2 > 0.

IVARY determines the type of variation, and is source-specific:
(IVARY) Default: 0

0 =	Constant	
1 =	Diurnal cycle	(24 scaling factors: hours 1-24)
2 =	Monthly cycle	(12 scaling factors: months 1-12)
3 =	Hour & Season	(4 groups of 24 hourly scaling factors, where first group is DEC-JAN-FEB)
4 =	Speed & Stab.	(6 groups of 6 scaling factors, where first group is Stability Class A, and the speed classes have upper bounds (m/s) defined in Group 12
5 =	Temperature	(12 scaling factors, where temperature classes have upper bounds (C) of: 0, 5, 10, 15, 20, 25, 30, 35, 40, 45, 50, 50+)

---

[a]
Data for each species are treated as a separate input subgroup
and therefore must end with an input group terminator.

INPUT GROUPS: 14a, 14b, 14c, 14d -- Area source parameters

Subgroup (14a)

Number of polygon area sources with parameters specified below (NAR1) — No default ! NAR1 = 0 !

Units used for area source emissions below (IARU) — Default: 1 ! IARU = 1 !

1 = g/m**2/s
2 = kg/m**2/hr
3 = lb/m**2/hr
4 = tons/m**2/yr
5 = Odour Unit * m/s (vol. flux/m**2 of odour compound)
6 = Odour Unit * m/min
7 = metric tons/m**2/yr
8 = Bq/m**2/s (Bq = becquerel = disintegrations/s)
9 = GBq/m**2/yr

Number of source-species combinations with variable emissions scaling factors provided below in (14d) (NSAR1) Default: 0 ! NSAR1 = 0 !

Number of buoyant polygon area sources with variable location and emission parameters (NAR2) — No default ! NAR2 = 0 !
(If NAR2 > 0, ALL parameter data for these sources are read from the file: BAEMARB.DAT)

!END!

Subgroup (14b)

AREA SOURCE: CONSTANT DATA [a]

Source No.	Effect. Height (m)	Base Elevation (m)	Initial Sigma z (m)	Emission Rates [b]
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---
[a] Data for each source are treated as a separate input subgroup and therefore must end with an input group terminator.

[b] An emission rate must be entered for every pollutant modeled. Enter emission rate of zero for secondary pollutants that are modeled, but not emitted. Units are specified by IARU (e.g. 1 for g/m**2/s).

Subgroup (14c)

COORDINATES (km) FOR EACH VERTEX(4) OF EACH POLYGON

Source No.	Ordered list of X followed by list of Y, grouped by source [a]
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---
[a] Data for each source are treated as a separate input subgroup and therefore must end with an input group terminator.

Subgroup (14d)
---

[a]

AREA SOURCE: VARIABLE EMISSIONS DATA

Use this subgroup to describe temporal variations in the emission rates given in 14b. Factors entered multiply the rates in 14b. Skip sources here that have constant emissions. For more elaborate variation in source parameters, use BAEMARB.DAT and NAR2 > 0.

IVARY determines the type of variation, and is source-specific:
(IVARY) Default: 0

0 =	Constant	
1 =	Diurnal cycle	(24 scaling factors: hours 1-24)
2 =	Monthly cycle	(12 scaling factors: months 1-12)
3 =	Hour & Season	(4 groups of 24 hourly scaling factors, where first group is DEC-JAN-FEB)
4 =	Speed & Stab.	(6 groups of 6 scaling factors, where first group is Stability Class A, and the speed classes have upper bounds (m/s) defined in Group 12
5 =	Temperature	(12 scaling factors, where temperature classes have upper bounds (C) of: 0, 5, 10, 15, 20, 25, 30, 35, 40, 45, 50, 50+)

---

a
Data for each species are treated as a separate input subgroup and therefore must end with an input group terminator.

INPUT GROUPS: 15a, 15b, 15c -- Line source parameters

Subgroup (15a)

Number of buoyant line sources with variable location and emission parameters (NLN2) No default ! NLN2 = 0 !

(If NLN2 > 0, ALL parameter data for these sources are read from the file: LNEMARB.DAT)

Number of buoyant line sources (NLINES) No default ! NLINES = 0 !

Units used for line source emissions below (ILNU) Default: 1 ! ILNU = 1 !

1 =	g/s
2 =	kg/hr
3 =	lb/hr
4 =	tons/yr
5 =	Odour Unit * m**3/s (vol. flux of odour compound)
6 =	Odour Unit * m**3/min
7 =	metric tons/yr
8 =	Bq/s (Bq = becquerel = disintegrations/s)
9 =	GBq/yr

Number of source-species combinations with variable emissions scaling factors provided below in (15c) (NSLN1) Default: 0 ! NSLN1 = 0 !

Maximum number of segments used to model each line (MXNSEG) Default: 7 ! MXNSEG = 7 !

The following variables are required only if NLINES > 0. They are used in the buoyant line source plume rise calculations.

Number of distances at which transitional rise is computed Default: 6 ! NLRISE = 6 !

```
        Average building length (XL)               No default   ! XL = .0 !
                                                   (in meters)

        Average building height (HBL)              No default   ! HBL = .0 !
                                                   (in meters)

        Average building width (WBL)               No default   ! WBL = .0 !
                                                   (in meters)

        Average line source width (WML)            No default   ! WML = .0 !
                                                   (in meters)

        Average separation between buildings (DXL) No default   ! DXL = .0 !
                                                   (in meters)

        Average buoyancy parameter (FPRIMEL)       No default   ! FPRIMEL = .0 !
                                                   (in m**4/s**3)

!END!

---------------
Subgroup (15b)
---------------

          BUOYANT LINE SOURCE: CONSTANT DATA
          ----------------------------------
                                                                                 a
Source     Beg. X      Beg. Y      End. X    End. Y     Release    Base        Emission
 No.     Coordinate  Coordinate  Coordinate Coordinate  Height    Elevation     Rates
           (km)        (km)        (km)       (km)       (m)       (m)
------   ----------  ----------  ---------  ----------  -------   ---------    ---------

--------

    a
     Data for each source are treated as a separate input subgroup
     and therefore must end with an input group terminator.

    b
     An emission rate must be entered for every pollutant modeled.
     Enter emission rate of zero for secondary pollutants that are
     modeled, but not emitted.  Units are specified by ILNTU
     (e.g. 1 for g/s).

---------------
Subgroup (15c)
---------------
                                                  a
          BUOYANT LINE SOURCE: VARIABLE EMISSIONS DATA
          --------------------------------------------

     Use this subgroup to describe temporal variations in the emission
     rates given in 15b.  Factors entered multiply the rates in 15b.
     Skip sources here that have constant emissions.

     IVARY determines the type of variation, and is source-specific:
     (IVARY)                                Default: 0
           0 =       Constant
           1 =       Diurnal cycle (24 scaling factors: hours 1-24)
           2 =       Monthly cycle (12 scaling factors: months 1-12)
           3 =       Hour & Season (4 groups of 24 hourly scaling factors,
                                    where first group is DEC-JAN-FEB)
           4 =       Speed & Stab. (6 groups of 6 scaling factors, where
                                    first group is Stability Class A,
                                    and the speed classes have upper
                                    bounds (m/s) defined in Group 12
           5 =       Temperature   (12 scaling factors, where temperature
                                    classes have upper bounds (C) of:
                                    0, 5, 10, 15, 20, 25, 30, 35, 40,
                                    45, 50, 50+)



--------
```

[a] Data for each species are treated as a separate input subgroup and therefore must end with an input group terminator.

INPUT GROUPS: 16a, 16b, 16c -- Volume source parameters

Subgroup (16a)

Number of volume sources with parameters provided in 16b,c (NVL1) No default ! NVL1 = 0 !

Units used for volume source emissions below in 16b (IVLU) Default: 1 ! IVLU = 1 !

1 = g/s
2 = kg/hr
3 = lb/hr
4 = tons/yr
5 = Odour Unit * m**3/s (vol. flux of odour compound)
6 = Odour Unit * m**3/min
7 = metric tons/yr
8 = Bq/s (Bq = becquerel = disintegrations/s)
9 = GBq/yr

Number of source-species combinations with variable emissions scaling factors provided below in (16c) (NSVL1) Default: 0 ! NSVL1 = 0 !

Number of volume sources with variable location and emission parameters (NVL2) No default ! NVL2 = 0 !

(If NVL2 > 0, ALL parameter data for these sources are read from the VOLEMARB.DAT file(s))

!END!

Subgroup (16b)

---

[a]

VOLUME SOURCE: CONSTANT DATA

X Coordinate (km)	Y Coordinate (km)	Effect. Height (m)	Base Elevation (m)	Initial Sigma y (m)	Initial Sigma z (m)	Emission Rates [b]

---

[a] Data for each source are treated as a separate input subgroup and therefore must end with an input group terminator.

[b] An emission rate must be entered for every pollutant modeled. Enter emission rate of zero for secondary pollutants that are modeled, but not emitted. Units are specified by IVLU (e.g. 1 for g/s).

Subgroup (16c)

---

[a]

VOLUME SOURCE: VARIABLE EMISSIONS DATA

Use this subgroup to describe temporal variations in the emission rates given in 16b. Factors entered multiply the rates in 16b. Skip sources here that have constant emissions. For more elaborate variation in source parameters, use VOLEMARB.DAT and NVL2 > 0.

IVARY determines the type of variation, and is source-specific:
(IVARY) Default: 0

0 =	Constant	
1 =	Diurnal cycle	(24 scaling factors: hours 1-24)
2 =	Monthly cycle	(12 scaling factors: months 1-12)
3 =	Hour & Season	(4 groups of 24 hourly scaling factors, where first group is DEC-JAN-FEB)
4 =	Speed & Stab.	(6 groups of 6 scaling factors, where first group is Stability Class A, and the speed classes have upper bounds (m/s) defined in Group 12
5 =	Temperature	(12 scaling factors, where temperature classes have upper bounds (C) of: 0, 5, 10, 15, 20, 25, 30, 35, 40, 45, 50, 50+)

---

a Data for each species are treated as a separate input subgroup and therefore must end with an input group terminator.

INPUT GROUPS: 17a & 17b -- Non-gridded (discrete) receptor information

---

Subgroup (17a)

Number of non-gridded receptors (NREC) No default ! NREC = 0 !

!END!

Subgroup (17b)

NON-GRIDDED (DISCRETE) RECEPTOR DATA[a]

Receptor No.	X Coordinate (km)	Y Coordinate (km)	Ground Elevation (m)	Height Above Ground[b] (m)

---

a Data for each receptor are treated as a separate input subgroup and therefore must end with an input group terminator.

b Receptor height above ground is optional. If no value is entered, the receptor is placed on the ground.

Appendix C: Example CALMET Control Input File for January 2012

```
CALMET.INP      2.1             Hour Start and End Times with Seconds
CALMET 67 by 67 by 10 4km meteorological grid
48 surface and precip and 1 upper air
---------------- Run title (3 lines) ------------------------------------------

                   CALMET MODEL CONTROL FILE
                   -------------------------

--------------------------------------------------------------------------------

INPUT GROUP: 0 -- Input and Output File Names


Subgroup (a)
------------
Default Name  Type          File Name
------------  ----          ---------
GEO.DAT       input    ! GEODAT=../inputs/makegeo/geo.bayarea_4km.dat          !
SURF.DAT      input    ! SRFDAT=../inputs/ds2surf/output/surf.201201.bayarea.dat !
CLOUD.DAT     input    * CLDDAT=            *
PRECIP.DAT    input    ! PRCDAT=../inputs/ds2surf/output/precip.201201.bayarea.dat !
WT.DAT        input    * WTDAT=             *

CALMET.LST    output   ! METLST=../outputs.2012.lyr18/calmet.bayarea_4km.201201.lst !
CALMET.DAT    output   ! METDAT=../outputs.2012.lyr18/calmet.bayarea_4km.201201.dat !
PACOUT.DAT    output   * PACDAT=            *

All file names will be converted to lower case if LCFILES = T
Otherwise, if LCFILES = F, file names will be converted to UPPER CASE
         T = lower case      ! LCFILES = T !
         F = UPPER CASE

NUMBER OF UPPER AIR & OVERWATER STATIONS:

    Number of upper air stations (NUSTA)  No default     ! NUSTA =  1  !
    Number of overwater met stations
                                (NOWSTA) No default     ! NOWSTA = 0  !

NUMBER OF PROGNOSTIC and IGF-CALMET FILEs:

    Number of MM4/MM5/3D.DAT files
                                (NM3D) No default       ! NM3D =  0  !

    Number of IGF-CALMET.DAT files
                                (NIGF)   No default     ! NIGF =  0  !

                      !END!
--------------------------------------------------------------------------------
Subgroup (b)
---------------------------------
Upper air files (one per station)
---------------------------------
Default Name  Type       File Name
------------  ----       ---------
UP1.DAT       input     1  ! UPDAT=../inputs/read62/upoak2012.dat!    !END!
--------------------------------------------------------------------------------
Subgroup (c)
-----------------------------------------
Overwater station files (one per station)
-----------------------------------------
Default Name  Type       File Name
------------  ----       ---------
SEA1.DAT       input     1  * SEADAT=../inputs/buoy/46012-2006-7.dat*    *END*
--------------------------------------------------------------------------------
Subgroup (d)
------------------------------------------------
MM4/MM5/3D.DAT files (consecutive or overlapping)
------------------------------------------------
Default Name  Type       File Name
------------  ----       ---------
MM51.DAT       input     1  * M3DDAT= /home/yjia/tmp/calwrf/2012-08-01_12.m3d* *END*
MM51.DAT       input     2  * M3DDAT= /home/yjia/tmp/calwrf/2012-08-05_12.m3d* *END*
```

```
MM51.DAT       input     3  * M3DDAT= /home/yjia/tmp/calwrf/2012-08-09_12.m3d* *END*
MM51.DAT       input     4  * M3DDAT= /home/yjia/tmp/calwrf/2012-08-13_12.m3d* *END*
-------------------------------------------------------------------------------
Subgroup (e)
------------------------------------------------
IGF-CALMET.DAT files (consecutive or overlapping)
------------------------------------------------
Default Name  Type       File Name
------------  ----       ---------
IGFn.DAT       input     1  * IGFDAT=CALMET0.DAT *    *END*
-------------------------------------------------------------------------------
Subgroup (f)
----------------
Other file names
----------------

Default Name  Type       File Name
------------  ----       ---------
DIAG.DAT      input      * DIADAT=                  *
PROG.DAT      input      * PRGDAT=                  *

TEST.PRT      output     * TSTPRT=                  *
TEST.OUT      output     * TSTOUT=                  *
TEST.KIN      output     * TSTKIN=                  *
TEST.FRD      output     * TSTFRD=                  *
TEST.SLP      output     * TSTSLP=                  *
DCST.GRD      output     * DCSTGD=                  *

-------------------------------------------------------------------------------
NOTES: (1) File/path names can be up to 70 characters in length
       (2) Subgroups (a) and (f) must have ONE 'END' (surrounded by
           delimiters) at the end of the group
       (3) Subgroups (b) through (e) are included ONLY if the corresponding
           number of files (NUSTA, NOWSTA, NM3D, NIGF) is not 0, and each must have
           an 'END' (surround by delimiters) at the end of EACH LINE

                        !END!


-------------------------------------------------------------------------------

INPUT GROUP: 1 -- General run control parameters
--------------

     Starting date:    Year   (IBYR)  --    No default   ! IBYR  = 2012 !
                       Month  (IBMO)  --    No default   ! IBMO  = 01 !
                       Day    (IBDY)  --    No default   ! IBDY  = 01 !
     Starting time:    Hour   (IBHR)  --    No default   ! IBHR  =  0  !
                       Second (IBSEC) --    No default   ! IBSEC =  0  !

     Ending date:      Year   (IEYR)  --    No default   ! IEYR  = 2012 !
                       Month  (IEMO)  --    No default   ! IEMO  = 01 !
                       Day    (IEDY)  --    No default   ! IEDY  = 31 !
     Ending time:      Hour   (IEHR)  --    No default   ! IEHR  =  24 !
                       Second (IESEC) --    No default   ! IESEC =  0  !

      UTC time zone         (ABTZ) -- No default       ! ABTZ= UTC-0800 !
         (character*8)
         PST = UTC-0800, MST = UTC-0700 , GMT = UTC-0000
         CST = UTC-0600, EST = UTC-0500

     Length of modeling time-step (seconds)
     Must divide evenly into 3600 (1 hour)
     (NSECDT)                        Default:3600     ! NSECDT =  3600  !
                                     Units: seconds

     Run type            (IRTYPE) -- Default: 1       ! IRTYPE=  1  !

        0 = Computes wind fields only
        1 = Computes wind fields and micrometeorological variables
            (u*, w*, L, zi, etc.)
        (IRTYPE must be 1 to run CALPUFF or CALGRID)

     Compute special data fields required
     by CALGRID (i.e., 3-D fields of W wind
```

```
     components and temperature)
     in additional to regular            Default: T    ! LCALGRD = T !
     fields ? (LCALGRD)
     (LCALGRD must be T to run CALGRID)

      Flag to stop run after
      SETUP phase (ITEST)             Default: 2       ! ITEST=  2   !
      (Used to allow checking
      of the model inputs, files, etc.)
      ITEST = 1 - STOPS program after SETUP phase
      ITEST = 2 - Continues with execution of
                  COMPUTATIONAL phase after SETUP

!END!

--------------------------------------------------------------------------------

INPUT GROUP: 2 -- Map Projection and Grid control parameters
--------------

     Projection for all (X,Y):
     -------------------------

     Map projection
     (PMAP)                     Default: UTM    ! PMAP = LCC  !

         UTM :  Universal Transverse Mercator
         TTM :  Tangential Transverse Mercator
         LCC :  Lambert Conformal Conic
          PS :  Polar Stereographic
          EM :  Equatorial Mercator
        LAZA :  Lambert Azimuthal Equal Area

     False Easting and Northing (km) at the projection origin
     (Used only if PMAP= TTM, LCC, or LAZA)
     (FEAST)                    Default=0.0     ! FEAST  = 0.000  !
     (FNORTH)                   Default=0.0     ! FNORTH = 0.000  !

     UTM zone (1 to 60)
     (Used only if PMAP=UTM)
     (IUTMZN)                   No Default      ! IUTMZN =  10   !

     Hemisphere for UTM projection?
     (Used only if PMAP=UTM)
     (UTMHEM)                   Default: N      ! UTMHEM = N  !
         N   :  Northern hemisphere projection
         S   :  Southern hemisphere projection

     Latitude and Longitude (decimal degrees) of projection origin
     (Used only if PMAP= TTM, LCC, PS, EM, or LAZA)
     (RLAT0)                    No Default      ! RLAT0 = 37N     !
     (RLON0)                    No Default      ! RLON0 = 120.5W  !

         TTM :  RLON0 identifies central (true N/S) meridian of projection
                RLAT0 selected for convenience
         LCC :  RLON0 identifies central (true N/S) meridian of projection
                RLAT0 selected for convenience
         PS  :  RLON0 identifies central (grid N/S) meridian of projection
                RLAT0 selected for convenience
         EM  :  RLON0 identifies central meridian of projection
                RLAT0 is REPLACED by 0.0N (Equator)
         LAZA:  RLON0 identifies longitude of tangent-point of mapping plane
                RLAT0 identifies latitude of tangent-point of mapping plane

     Matching parallel(s) of latitude (decimal degrees) for projection
     (Used only if PMAP= LCC or PS)
     (XLAT1)                    No Default      ! XLAT1 = 30N  !
     (XLAT2)                    No Default      ! XLAT2 = 60N  !

         LCC :  Projection cone slices through Earth's surface at XLAT1 and XLAT2
         PS  :  Projection plane slices through Earth at XLAT1
                (XLAT2 is not used)

     ----------
     Note:  Latitudes and longitudes should be positive, and include a
```

```
       letter N,S,E, or W indicating north or south latitude, and
       east or west longitude.  For example,
       35.9  N Latitude  =  35.9N
       118.7 E Longitude = 118.7E


  Datum-region
  ------------

  The Datum-Region for the coordinates is identified by a character
  string.  Many mapping products currently available use the model of the
  Earth known as the World Geodetic System 1984 (WGS-84).  Other local
  models may be in use, and their selection in CALMET will make its output
  consistent with local mapping products.  The list of Datum-Regions with
  official transformation parameters is provided by the National Imagery and
  Mapping Agency (NIMA).

  NIMA Datum - Regions(Examples)
  ------------------------------------------------------------------------------
  WGS-84    WGS-84 Reference Ellipsoid and Geoid, Global coverage (WGS84)
  NAS-C     NORTH AMERICAN 1927 Clarke 1866 Spheroid, MEAN FOR CONUS (NAD27)
  NAR-C     NORTH AMERICAN 1983 GRS 80 Spheroid, MEAN FOR CONUS (NAD83)
  NWS-84    NWS 6370KM Radius, Sphere
  ESR-S     ESRI REFERENCE 6371KM Radius, Sphere

  Datum-region for output coordinates
  (DATUM)                   Default: WGS-84    ! DATUM = WGS-84 !


  Horizontal grid definition:
  ---------------------------

  Rectangular grid defined for projection PMAP,
  with X the Easting and Y the Northing coordinate

       No. X grid cells (NX)      No default     ! NX =   67  !
       No. Y grid cells (NY)      No default     ! NY =   67  !

  Grid spacing (DGRIDKM)          No default     ! DGRIDKM = 4. !
                                  Units: km

  Reference grid coordinate of
  SOUTHWEST corner of grid cell (1,1)

     X coordinate (XORIGKM)       No default     ! XORIGKM = -288.0 !
     Y coordinate (YORIGKM)       No default     ! YORIGKM =  -36.0 !
                                  Units: km


  Vertical grid definition:
  -------------------------

     No. of vertical layers (NZ)  No default     ! NZ =  18  !

     Cell face heights in arbitrary
     vertical grid (ZFACE(NZ+1))  No defaults
                                  Units: m
     ! ZFACE =
0.,20.,40.,80.,120.,180.,240.,300.,360.,420.,500.,600.,700.,800.,1000.,1200.,1500.,2200.,3000. !


!END!


--------------------------------------------------------------------------------

INPUT GROUP: 3 -- Output Options
--------------


    DISK OUTPUT OPTION

       Save met. fields in an unformatted
       output file ?             (LSAVE)  Default: T     ! LSAVE = T !
       (F = Do not save, T = Save)
```

```
   Type of unformatted output file:
   (IFORMO)                          Default: 1    ! IFORMO =  1  !

        1 = CALPUFF/CALGRID type file (CALMET.DAT)
        2 = MESOPUFF-II type file     (PACOUT.DAT)


LINE PRINTER OUTPUT OPTIONS:

   Print met. fields ?  (LPRINT)       Default: F     ! LPRINT = F !
   (F = Do not print, T = Print)
   (NOTE: parameters below control which
          met. variables are printed)

   Print interval
   (IPRINF) in hours                   Default: 1     ! IPRINF =  6  !
   (Meteorological fields are printed
    every  1  hours)


   Specify which layers of U, V wind component
   to print (IUVOUT(NZ)) -- NOTE: NZ values must be entered
   (0=Do not print, 1=Print)
   (used only if LPRINT=T)        Defaults: NZ*0
   ! IUVOUT =  0 ,  0 ,  0 ,  0 ,  0 ,  0 ,  0 ,  0 ,  0 ,  0  !
   ------------------------


   Specify which levels of the W wind component to print
   (NOTE: W defined at TOP cell face --  10  values)
   (IWOUT(NZ)) -- NOTE: NZ values must be entered
   (0=Do not print, 1=Print)
   (used only if LPRINT=T & LCALGRD=T)
   -----------------------------------
                                       Defaults: NZ*0
    ! IWOUT =  0 ,  0 ,  0 ,  0 ,  0 ,  0 ,  0 ,  0 ,  0 ,  0  !


   Specify which levels of the 3-D temperature field to print
   (ITOUT(NZ)) -- NOTE: NZ values must be entered
   (0=Do not print, 1=Print)
   (used only if LPRINT=T & LCALGRD=T)
   -----------------------------------
                                       Defaults: NZ*0
    ! ITOUT =  0 ,  0 ,  0 ,  0 ,  0 ,  0 ,  0 ,  0 ,  0 ,  0  !

   Specify which meteorological fields
   to print
   (used only if LPRINT=T)             Defaults: 0 (all variables)
   -----------------------


     Variable            Print ?
                        (0 = do not print,
                         1 = print)
     --------          ------------------

  !  STABILITY  =           0           ! - PGT stability class
  !  USTAR      =           0           ! - Friction velocity
  !  MONIN      =           0           ! - Monin-Obukhov length
  !  MIXHT      =           0           ! - Mixing height
  !  WSTAR      =           0           ! - Convective velocity scale
  !  PRECIP     =           0           ! - Precipitation rate
  !  SENSHEAT   =           0           ! - Sensible heat flux
  !  CONVZI     =           0           ! - Convective mixing ht.


   Testing and debug print options for micrometeorological module

      Print input meteorological data and
      internal variables (LDB)         Default: F       ! LDB = F !
      (F = Do not print, T = print)
      (NOTE: this option produces large amounts of output)
```

```
          First time step for which debug data
          are printed (NN1)               Default: 1       ! NN1 =  1  !

          Last time step for which debug data
          are printed (NN2)               Default: 1       ! NN2 =  1  !

          Print distance to land
          internal variables (LDBCST)     Default: F       ! LDBCST = F !
          (F = Do not print, T = print)
          (Output in .GRD file DCST.GRD, defined in input group 0)

       Testing and debug print options for wind field module
       (all of the following print options control output to
        wind field module's output files: TEST.PRT, TEST.OUT,
        TEST.KIN, TEST.FRD, and TEST.SLP)

          Control variable for writing the test/debug
          wind fields to disk files (IOUTD)
          (0=Do not write, 1=write)       Default: 0       ! IOUTD =  0  !

          Number of levels, starting at the surface,
          to print (NZPRN2)               Default: 1       ! NZPRN2 =  1  !

          Print the INTERPOLATED wind components ?
          (IPR0) (0=no, 1=yes)            Default: 0       !  IPR0 =  0  !

          Print the TERRAIN ADJUSTED surface wind
          components ?
          (IPR1) (0=no, 1=yes)            Default: 0       !  IPR1 =  0  !

          Print the SMOOTHED wind components and
          the INITIAL DIVERGENCE fields ?
          (IPR2) (0=no, 1=yes)            Default: 0       !  IPR2 =  0  !

          Print the FINAL wind speed and direction
          fields ?
          (IPR3) (0=no, 1=yes)            Default: 0       !  IPR3 =  0  !

          Print the FINAL DIVERGENCE fields ?
          (IPR4) (0=no, 1=yes)            Default: 0       !  IPR4 =  0  !

          Print the winds after KINEMATIC effects
          are added ?
          (IPR5) (0=no, 1=yes)            Default: 0       !  IPR5 =  0  !

          Print the winds after the FROUDE NUMBER
          adjustment is made ?
          (IPR6) (0=no, 1=yes)            Default: 0       !  IPR6 =  0  !

          Print the winds after SLOPE FLOWS
          are added ?
          (IPR7) (0=no, 1=yes)            Default: 0       !  IPR7 =  0  !

          Print the FINAL wind field components ?
          (IPR8) (0=no, 1=yes)            Default: 0       !  IPR8 =  0  !

!END!


--------------------------------------------------------------------------------

INPUT GROUP: 4 -- Meteorological data options
--------------

    NO OBSERVATION MODE             (NOOBS)  Default: 0     ! NOOBS =  0   !
          0 = Use surface, overwater, and upper air stations
          1 = Use surface and overwater stations (no upper air observations)
              Use MM4/MM5/3D for upper air data
          2 = No surface, overwater, or upper air observations
              Use MM4/MM5/3D for surface, overwater, and upper air data

    NUMBER OF SURFACE & PRECIP. METEOROLOGICAL STATIONS

       Number of surface stations   (NSSTA)  No default     ! NSSTA =  45 !
```

```
   Number of precipitation stations
   (NPSTA=-1: flag for use of MM5/3D precip data)
                              (NPSTA)  No default     ! NPSTA =  45 !

CLOUD DATA OPTIONS
   Gridded cloud fields:
                              (ICLOUD)  Default: 0     ! ICLOUD =  0  !
   ICLOUD = 0 - Gridded clouds not used
   ICLOUD = 1 - Gridded CLOUD.DAT generated as OUTPUT
   ICLOUD = 2 - Gridded CLOUD.DAT read as INPUT
   ICLOUD = 3 - Gridded cloud cover computed from prognostic fields

FILE FORMATS

   Surface meteorological data file format
                              (IFORMS)  Default: 2     ! IFORMS =  2  !
   (1 = unformatted (e.g., SMERGE output))
   (2 = formatted   (free-formatted user input))

   Precipitation data file format
                              (IFORMP)  Default: 2     ! IFORMP =  2  !
   (1 = unformatted (e.g., PMERGE output))
   (2 = formatted   (free-formatted user input))

   Cloud data file format
                              (IFORMC)  Default: 2     ! IFORMC =  2  !
   (1 = unformatted - CALMET unformatted output)
   (2 = formatted   - free-formatted CALMET output or user input)

!END!


-------------------------------------------------------------------------------

INPUT GROUP: 5 -- Wind Field Options and Parameters
--------------


WIND FIELD MODEL OPTIONS
   Model selection variable (IWFCOD)     Default: 1      ! IWFCOD =  1  !
      0 = Objective analysis only
      1 = Diagnostic wind module

   Compute Froude number adjustment
   effects ? (IFRADJ)                    Default: 1      ! IFRADJ =  1  !
   (0 = NO, 1 = YES)

   Compute kinematic effects ? (IKINE)   Default: 0      ! IKINE  =  0  !
   (0 = NO, 1 = YES)

   Use O'Brien procedure for adjustment
   of the vertical velocity ? (IOBR)     Default: 0      ! IOBR =  0  !
   (0 = NO, 1 = YES)

   Compute slope flow effects ? (ISLOPE) Default: 1      ! ISLOPE  =  1  !
   (0 = NO, 1 = YES)

   Extrapolate surface wind observations
   to upper layers ? (IEXTRP)            Default: -4     ! IEXTRP = -4  !
   (1 = no extrapolation is done,
    2 = power law extrapolation used,
    3 = user input multiplicative factors
        for layers 2 - NZ used (see FEXTRP array)
    4 = similarity theory used
    -1, -2, -3, -4 = same as above except layer 1 data
        at upper air stations are ignored

   Extrapolate surface winds even
   if calm? (ICALM)                      Default: 0      ! ICALM  =  0  !
   (0 = NO, 1 = YES)

   Layer-dependent biases modifying the weights of
   surface and upper air stations (BIAS(NZ))
     -1<=BIAS<=1
   Negative BIAS reduces the weight of upper air stations
```

```
     (e.g. BIAS=-0.1 reduces the weight of upper air stations
   by 10%; BIAS= -1, reduces their weight by 100 %)
   Positive BIAS reduces the weight of surface stations
     (e.g. BIAS= 0.2 reduces the weight of surface stations
   by 20%; BIAS=1 reduces their weight by 100%)
   Zero BIAS leaves weights unchanged (1/R**2 interpolation)
   Default: NZ*0
                          ! BIAS =  0 ,  0 ,  0 ,  0 ,  0 ,  0 ,  0 ,  0 ,  0 ,  0  !

   Minimum distance from nearest upper air station
   to surface station for which extrapolation
   of surface winds at surface station will be allowed
   (RMIN2: Set to -1 for IEXTRP = 4 or other situations
    where all surface stations should be extrapolated)
                                       Default: 4.     ! RMIN2 = -1.0 !

   Use gridded prognostic wind field model
   output fields as input to the diagnostic
   wind field model (IPROG)            Default: 0      ! IPROG =  0  !
   (0 = No, [IWFCOD = 0 or 1]
    1 = Yes, use CSUMM prog. winds as Step 1 field, [IWFCOD = 0]
    2 = Yes, use CSUMM prog. winds as initial guess field [IWFCOD = 1]
    3 = Yes, use winds from MM4.DAT file as Step 1 field [IWFCOD = 0]
    4 = Yes, use winds from MM4.DAT file as initial guess field [IWFCOD = 1]
    5 = Yes, use winds from MM4.DAT file as observations [IWFCOD = 1]
    13 = Yes, use winds from MM5/3D.DAT file as Step 1 field [IWFCOD = 0]
    14 = Yes, use winds from MM5/3D.DAT file as initial guess field [IWFCOD = 1]
    15 = Yes, use winds from MM5/3D.DAT file as observations [IWFCOD = 1]

   Timestep (hours) of the prognostic
   model input data   (ISTEPPG)        Default: 1      ! ISTEPPG =  1   !

   Use coarse CALMET fields as initial guess fields (IGFMET)
   (overwrites IGF based on prognostic wind fields if any)
                                       Default: 0      ! IGFMET =  0  !

RADIUS OF INFLUENCE PARAMETERS

   Use varying radius of influence     Default: F      ! LVARY =  T!
   (if no stations are found within RMAX1,RMAX2,
    or RMAX3, then the closest station will be used)

   Maximum radius of influence over land
   in the surface layer (RMAX1)        No default      ! RMAX1 = 30. !
                                       Units: km
   Maximum radius of influence over land
   aloft (RMAX2)                       No default      ! RMAX2 = 30. !
                                       Units: km
   Maximum radius of influence over water
   (RMAX3)                             No default      ! RMAX3 = 50. !
                                       Units: km


OTHER WIND FIELD INPUT PARAMETERS

   Minimum radius of influence used in
   the wind field interpolation (RMIN) Default: 0.1    ! RMIN = 0.1 !
                                       Units: km
   Radius of influence of terrain
   features (TERRAD)                   No default      ! TERRAD = 12. !

                                       Units: km
   Relative weighting of the first
   guess field and observations in the
   SURFACE layer (R1)                  No default      ! R1 = 1. !
   (R1 is the distance from an         Units: km
   observational station at which the
   observation and first guess field are
   equally weighted)

   Relative weighting of the first
   guess field and observations in the
   layers ALOFT (R2)                   No default      ! R2 = 1. !
   (R2 is applied in the upper layers  Units: km
   in the same manner as R1 is used in
```

```
      the surface layer).

      Relative weighting parameter of the
      prognostic wind field data (RPROG)    No default      ! RPROG = 0. !
      (Used only if IPROG = 1)              Units: km
      ------------------------

      Maximum acceptable divergence in the
      divergence minimization procedure
      (DIVLIM)                              Default: 5.E-6  ! DIVLIM= 5.0E-06 !

      Maximum number of iterations in the
      divergence min. procedure (NITER)     Default: 50     ! NITER =  50  !

      Number of passes in the smoothing
      procedure (NSMTH(NZ))
      NOTE: NZ values must be entered
           Default: 2,(mxnz-1)*4 ! NSMTH =
2 ,  4 ,  4 ,  4 ,  4 ,  4 ,  4 ,  4 ,  4 ,  4  !

      Maximum number of stations used in
      each layer for the interpolation of
      data to a grid point (NINTR2(NZ))
      NOTE: NZ values must be entered       Default: 99.    ! NINTR2 =
99 ,  99 ,  99 ,  99 ,  99 ,  99 ,  99 ,  99 ,  99 ,  99 !

      Critical Froude number (CRITFN)       Default: 1.0    ! CRITFN = 1. !

      Empirical factor controlling the
      influence of kinematic effects
      (ALPHA)                               Default: 0.1    ! ALPHA = 0.1 !

      Multiplicative scaling factor for
      extrapolation of surface observations
      to upper layers (FEXTR2(NZ))          Default: NZ*0.0
      ! FEXTR2 = 0., 0., 0., 0., 0., 0., 0., 0., 0., 0. !
      (Used only if IEXTRP = 3 or -3)


   BARRIER INFORMATION

      Number of barriers to interpolation
      of the wind fields (NBAR)             Default: 0      ! NBAR =  0  !

      Level (1 to NZ) up to which barriers
      apply (KBAR)                          Default: NZ     ! KBAR =  10  !

      THE FOLLOWING 4 VARIABLES ARE INCLUDED
      ONLY IF NBAR > 0
      NOTE: NBAR values must be entered     No defaults
            for each variable               Units: km

         X coordinate of BEGINNING
         of each barrier (XBBAR(NBAR))      ! XBBAR = 0. !
         Y coordinate of BEGINNING
         of each barrier (YBBAR(NBAR))      ! YBBAR = 0. !

         X coordinate of ENDING
         of each barrier (XEBAR(NBAR))      ! XEBAR = 0. !
         Y coordinate of ENDING
         of each barrier (YEBAR(NBAR))      ! YEBAR = 0. !


   DIAGNOSTIC MODULE DATA INPUT OPTIONS

      Surface temperature (IDIOPT1)         Default: 0      ! IDIOPT1 =  0  !
         0 = Compute internally from
             hourly surface observations
         1 = Read preprocessed values from
             a data file (DIAG.DAT)

         Surface met. station to use for
         the surface temperature (ISURFT)   No default     ! ISURFT =  45 !
         (Must be a value from 1 to NSSTA)
         (Used only if IDIOPT1 = 0)
```

```
   --------------------------

Domain-averaged temperature lapse
rate (IDIOPT2)                          Default: 0     ! IDIOPT2 =  0  !
   0 = Compute internally from
       twice-daily upper air observations
   1 = Read hourly preprocessed values
       from a data file (DIAG.DAT)

   Upper air station to use for
   the domain-scale lapse rate (IUPT) No default     ! IUPT   =  1  !
   (Must be a value from 1 to NUSTA)
   (Used only if IDIOPT2 = 0)
   --------------------------

   Depth through which the domain-scale
   lapse rate is computed (ZUPT)      Default: 200.  ! ZUPT = 200. !
   (Used only if IDIOPT2 = 0)         Units: meters
   --------------------------

Domain-averaged wind components
(IDIOPT3)                               Default: 0     ! IDIOPT3 =  0  !
   0 = Compute internally from
       twice-daily upper air observations
   1 = Read hourly preprocessed values
       a data file (DIAG.DAT)

   Upper air station to use for
   the domain-scale winds (IUPWND)    Default: -1    ! IUPWND = -1  !
   (Must be a value from -1 to NUSTA)
   (Used only if IDIOPT3 = 0)
   --------------------------

   Bottom and top of layer through
   which the domain-scale winds
   are computed
   (ZUPWND(1), ZUPWND(2))        Defaults: 1., 1000. ! ZUPWND= 1., 1000. !
   (Used only if IDIOPT3 = 0)    Units: meters
   --------------------------

Observed surface wind components
for wind field module (IDIOPT4)  Default: 0     ! IDIOPT4 =  0  !
   0 = Read WS, WD from a surface
       data file (SURF.DAT)
   1 = Read hourly preprocessed U, V from
       a data file (DIAG.DAT)

Observed upper air wind components
for wind field module (IDIOPT5)  Default: 0     ! IDIOPT5 =  0  !
   0 = Read WS, WD from an upper
       air data file (UP1.DAT, UP2.DAT, etc.)
   1 = Read hourly preprocessed U, V from
       a data file (DIAG.DAT)

LAKE BREEZE INFORMATION

   Use Lake Breeze Module  (LLBREZE)
                                    Default: F      ! LLBREZE = F !

    Number of lake breeze regions (NBOX)            ! NBOX =  0  !

 X Grid line 1 defining the region of interest
                                                    ! XG1 = 0. !
 X Grid line 2 defining the region of interest
                                                    ! XG2 = 0. !
 Y Grid line 1 defining the region of interest
                                                    ! YG1 = 0. !
 Y Grid line 2 defining the region of interest
                                                    ! YG2 = 0. !

  X Point defining the coastline (Straight line)
            (XBCST)  (KM)   Default: none    ! XBCST = 0. !

  Y Point defining the coastline (Straight line)
            (YBCST)  (KM)   Default: none    ! YBCST = 0. !
```

```
          X Point defining the coastline (Straight line)
                    (XECST)  (KM)   Default: none    ! XECST = 0. !

          Y Point defining the coastline (Straight line)
                    (YECST)  (KM)   Default: none    ! YECST = 0. !


       Number of stations in the region     Default: none ! NLB =  0 !
       (Surface stations + upper air stations)

       Station ID's  in the region   (METBXID(NLB))
       (Surface stations first, then upper air stations)
         ! METBXID =  0 !

!END!

------------------------------------------------------------------------------

INPUT GROUP: 6 -- Mixing Height, Temperature and Precipitation Parameters
--------------

    EMPIRICAL MIXING HEIGHT CONSTANTS

       Neutral, mechanical equation
       (CONSTB)                            Default: 1.41   ! CONSTB = 1.41 !
       Convective mixing ht. equation
       (CONSTE)                            Default: 0.15   ! CONSTE = 0.15 !
       Stable mixing ht. equation
       (CONSTN)                            Default: 2400.  ! CONSTN = 2400.!
       Overwater mixing ht. equation
       (CONSTW)                            Default: 0.16   ! CONSTW = 0.16 !
       Absolute value of Coriolis
       parameter (FCORIOL)                 Default: 1.E-4  ! FCORIOL = 1.0E-04!
                                           Units: (1/s)

    SPATIAL AVERAGING OF MIXING HEIGHTS

       Conduct spatial averaging
       (IAVEZI)  (0=no, 1=yes)             Default: 1      ! IAVEZI =  1  !

       Max. search radius in averaging
       process (MNMDAV)                    Default: 1      ! MNMDAV =  1  !
                                           Units: Grid
                                                  cells
       Half-angle of upwind looking cone
       for averaging (HAFANG)              Default: 30.    ! HAFANG = 30. !
                                           Units: deg.
       Layer of winds used in upwind
       averaging (ILEVZI)                  Default: 1      ! ILEVZI =  1  !
       (must be between 1 and NZ)


    CONVECTIVE MIXING HEIGHT OPTIONS:
       Method to compute the convective
       mixing height(IMIHXH)               Default: 1      ! IMIXH =  1  !
           1: Maul-Carson for land and water cells
          -1: Maul-Carson for land cells only -
              OCD mixing height overwater
           2: Batchvarova and Gryning for land and water cells
          -2: Batchvarova and Gryning for land cells only
              OCD mixing height overwater

       Threshold buoyancy flux required to
       sustain convective mixing height growth
       overland (THRESHL)                  Default: 0.05   ! THRESHL = 0.05 !
       (expressed as a heat flux           units: W/m3
        per meter of boundary layer)


       Threshold buoyancy flux required to
       sustain convective mixing height growth
       overwater (THRESHW)                 Default: 0.05   ! THRESHW = 0.05 !
       (expressed as a heat flux           units: W/m3
```

```
    per meter of boundary layer)


   Option for overwater lapse rates used
   in convective mixing height growth
   (ITWPROG)                          Default: 0      ! ITWPROG =  0  !
   0 : use SEA.DAT lapse rates and deltaT (or assume neutral
       conditions if missing)
   1 : use prognostic lapse rates (only if IPROG>2)
       and SEA.DAT deltaT (or neutral if missing)
   2 : use prognostic lapse rates and prognostic delta T
       (only if iprog>12 and 3D.DAT version# 2.0 or higher)

   Land Use category ocean in 3D.DAT datasets
   (ILUOC3D)                          Default: 16     ! ILUOC3D =  16  !
   Note: if 3D.DAT from MM5 version 3.0, iluoc3d = 16
         if MM4.DAT,           typically iluoc3d = 7


OTHER MIXING HEIGHT VARIABLES

   Minimum potential temperature lapse
   rate in the stable layer above the
   current convective mixing ht.      Default: 0.001  ! DPTMIN = 0.001 !
   (DPTMIN)                           Units: deg. K/m
   Depth of layer above current conv.
   mixing height through which lapse  Default: 200.   ! DZZI = 200. !
   rate is computed (DZZI)            Units: meters

   Minimum overland mixing height     Default:  50.   ! ZIMIN = 50. !
   (ZIMIN)                            Units: meters
   Maximum overland mixing height     Default: 3000.  ! ZIMAX = 3000. !
   (ZIMAX)                            Units: meters
   Minimum overwater mixing height    Default:   50.  ! ZIMINW = 50. !
   (ZIMINW) -- (Not used if observed  Units: meters
   overwater mixing hts. are used)
   Maximum overwater mixing height    Default: 3000.  ! ZIMAXW = 3000. !
   (ZIMAXW) -- (Not used if observed  Units: meters
   overwater mixing hts. are used)


OVERWATER SURFACE FLUXES METHOD and PARAMETERS
      (ICOARE)                        Default: 10      ! ICOARE =  10   !
       0: original deltaT method (OCD)
      10: COARE with no wave parameterization (jwave=0, Charnock)
      11: COARE with wave option jwave=1 (Oost et al.)
          and default wave properties
     -11: COARE with wave option jwave=1 (Oost et al.)
          and observed wave properties (must be in SEA.DAT files)
      12: COARE with wave option 2 (Taylor and Yelland)
           and default wave properties
     -12: COARE with wave option 2 (Taylor and Yelland)
          and observed wave properties (must be in SEA.DAT files)

      Coastal/Shallow water length scale (DSHELF)
      (for modified z0 in shallow water)
      ( COARE fluxes only)
                                    Default : 0.        ! DSHELF = 0. !
                                    units: km

       COARE warm layer computation (IWARM)              ! IWARM =  0   !
       1: on - 0: off (must be off if SST measured with
       IR radiometer)               Default: 0

       COARE cool skin layer computation (ICOOL)         ! ICOOL =  0   !
       1: on - 0: off (must be off if SST measured with
       IR radiometer)               Default: 0

RELATIVE HUMIDITY PARAMETERS

   3D relative humidity from observations or
   from prognostic data? (IRHPROG)    Default:0        ! IRHPROG =  0   !

      0 = Use RH from SURF.DAT file
          (only if NOOBS = 0,1)
```

```
          1 = Use prognostic RH
              (only if NOOBS = 0,1,2)

    TEMPERATURE PARAMETERS

       3D temperature from observations or
       from prognostic data? (ITPROG)        Default:0        ! ITPROG =  0   !

          0 = Use Surface and upper air stations
              (only if NOOBS = 0)
          1 = Use Surface stations (no upper air observations)
              Use MM5/3D for upper air data
              (only if NOOBS = 0,1)
          2 = No surface or upper air observations
              Use MM5/3D for surface and upper air data
              (only if NOOBS = 0,1,2)

       Interpolation type
       (1 = 1/R ; 2 = 1/R**2)                Default:1         ! IRAD =  1  !

       Radius of influence for temperature
       interpolation (TRADKM)                Default: 500.     ! TRADKM = 20. !
                                             Units: km

       Maximum Number of stations to include
       in temperature interpolation (NUMTS)  Default: 5        ! NUMTS = 5  !

       Conduct spatial averaging of temp-
       eratures (IAVET)  (0=no, 1=yes)       Default: 1        ! IAVET =  1  !
       (will use mixing ht MNMDAV,HAFANG
        so make sure they are correct)

       Default temperature gradient          Default: -.0098   ! TGDEFB = -0.0098 !
       below the mixing height over          Units: K/m
       water (TGDEFB)

       Default temperature gradient          Default: -.0045   ! TGDEFA = -0.0045 !
       above the mixing height over          Units: K/m
       water (TGDEFA)

       Beginning (JWAT1) and ending (JWAT2)
       land use categories for temperature                     ! JWAT1 =  55  !
       interpolation over water -- Make                        ! JWAT2 =  55  !
       bigger than largest land use to disable

   PRECIP INTERPOLATION PARAMETERS

       Method of interpolation (NFLAGP)      Default: 2        ! NFLAGP =  2  !
        (1=1/R,2=1/R**2,3=EXP/R**2)
       Radius of Influence  (SIGMAP)         Default: 100.0    ! SIGMAP = 50. !
        (0.0 => use half dist. btwn          Units: km
         nearest stns w & w/out
         precip when NFLAGP = 3)
       Minimum Precip. Rate Cutoff (CUTP)    Default: 0.01     ! CUTP = 0.01 !
        (values < CUTP = 0.0 mm/hr)          Units: mm/hr
!END!


-------------------------------------------------------------------------------

INPUT GROUP: 7 -- Surface meteorological station parameters
--------------

     SURFACE STATION VARIABLES
     (One record per station --  5  records in all)


             1     2
         Name   ID            X coord.   Y coord.   Time   Anem.
                               (km)       (km)      zone   Ht.(m)
       ---------------------------------------------------------
! SS1   ='KAPC', 00001,   -151.643    133.567   8    10 !
! SS002 ='KAUN', 00002,    -48.889    211.886   8    10 !
! SS003 ='KBAB', 00003,    -78.212    231.453   8    10 !
! SS004 ='KBLU', 00004,    -16.720    247.221   8    10 !
```

```
! SS005 ='KCCR', 00005,   -132.296    107.889   8    10 !
! SS006 ='KCIC', 00006,   -111.947    302.125   8    10 !
! SS007 ='KCVH', 00007,    -79.043    -11.134   8    10 !
! SS008 ='KDVO', 00008,   -175.380    125.832   8    10 !
! SS009 ='KEDU', 00009,   -108.854    166.815   8    10 !
! SS010 ='KFAT', 00010,     68.150    -24.998   8    10 !
! SS011 ='KHAF', 00011,   -171.934     57.862   8    10 !
! SS012 ='KHJO', 00012,     76.276    -73.732   8    10 !
! SS013 ='KHWD', 00013,   -138.717     71.900   8    10 !
! SS014 ='KLHM', 00014,    -71.488    207.246   8    10 !
! SS015 ='KLVK', 00015,   -112.890     76.847   8    10 !
! SS016 ='KMAE', 00016,     32.952     -2.092   8    10 !
! SS017 ='KMCC', 00017,    -75.989    180.990   8    10 !
! SS018 ='KMCE', 00018,     -8.630     30.746   8    10 !
! SS019 ='KMER', 00019,     -5.749     39.789   8    10 !
! SS020 ='KMHR', 00020,    -67.672    168.279   8    10 !
! SS021 ='KMOD', 00021,    -38.624     68.798   8    10 !
! SS022 ='KMRY', 00022,   -117.787    -44.261   8    10 !
! SS023 ='KMYV', 00023,    -89.439    227.995   8    10 !
! SS024 ='KNLC', 00024,     48.176    -72.263   8    10 !
! SS025 ='KNUQ', 00025,   -133.485     46.500   8    10 !
! SS026 ='KO22', 00026,      7.284    111.712   8    10 !
! SS027 ='KOAK', 00027,   -147.482     79.822   8    10 !
! SS028 ='KOVE', 00028,    -93.336    270.682   8    10 !
! SS029 ='KPAO', 00029,   -139.118     52.035   8    10 !
! SS030 ='KRHV', 00030,   -113.544     37.098   8    10 !
! SS031 ='KRNO', 00031,     59.707    270.869   8    10 !
! SS032 ='KSAC', 00032,    -84.634    164.868   8    10 !
! SS033 ='KSCK', 00033,    -64.102     97.887   8    10 !
! SS034 ='KSFO', 00034,   -161.673     68.792   8    10 !
! SS035 ='KSJC', 00035,   -122.763     40.064   8    10 !
! SS036 ='KSMF', 00036,    -92.825    184.801   8    10 !
! SS037 ='KSNS', 00037,    -95.852    -35.535   8    10 !
! SS038 ='KSQL', 00038,   -150.469     57.695   8    10 !
! SS039 ='KSTS', 00039,   -196.103    165.371   8    10 !
! SS040 ='KSUU', 00040,   -121.787    138.380   8    10 !
! SS041 ='KTRK', 00041,     30.640    250.879   8    10 !
! SS042 ='KTVL', 00042,     42.506    205.736   8    10 !
! SS043 ='KUKI', 00043,   -226.228    234.811   8    10 !
! SS044 ='KVCB', 00044,   -123.832    150.679   8    10 !
! SS045 ='KWVI', 00045,   -111.078     -6.710   8    10 !
--------------------
      1
        Four character string for station name
        (MUST START IN COLUMN 9)

      2
        Six digit integer for station ID

!END!


--------------------------------------------------------------------------------

INPUT GROUP: 8 -- Upper air meteorological station parameters
--------------

     UPPER AIR STATION VARIABLES
     (One record per station --  3  records in all)

              1     2
          Name    ID      X coord.   Y coord.  Time zone
                            (km)       (km)
        ------------------------------------------------
! US1  ='OAK '   23230   -147.347     82.919    8  !
--------------------
      1
        Four character string for station name
        (MUST START IN COLUMN 9)

      2
        Five digit integer for station ID

!END!
```

```
--------------------------------------------------------------------------------

INPUT GROUP: 9 -- Precipitation station parameters
--------------

     PRECIPITATION STATION VARIABLES
     (One record per station --  16  records in all)
     (NOT INCLUDED IF NPSTA = 0)

           1          2
         Name   Station    X coord.  Y coord.
                  Code       (km)      (km)
          ------------------------------------
! PS1   ='KAPC', 00001,   -151.643    133.567 !
! PS002 ='KAUN', 00002,    -48.889    211.886 !
! PS003 ='KBAB', 00003,    -78.212    231.453 !
! PS004 ='KBLU', 00004,    -16.720    247.221 !
! PS005 ='KCCR', 00005,   -132.296    107.889 !
! PS006 ='KCIC', 00006,   -111.947    302.125 !
! PS007 ='KCVH', 00007,    -79.043    -11.134 !
! PS008 ='KDVO', 00008,   -175.380    125.832 !
! PS009 ='KEDU', 00009,   -108.854    166.815 !
! PS010 ='KFAT', 00010,     68.150    -24.998 !
! PS011 ='KHAF', 00011,   -171.934     57.862 !
! PS012 ='KHJO', 00012,     76.276    -73.732 !
! PS013 ='KHWD', 00013,   -138.717     71.900 !
! PS014 ='KLHM', 00014,    -71.488    207.246 !
! PS015 ='KLVK', 00015,   -112.890     76.847 !
! PS016 ='KMAE', 00016,     32.952     -2.092 !
! PS017 ='KMCC', 00017,    -75.989    180.990 !
! PS018 ='KMCE', 00018,     -8.630     30.746 !
! PS019 ='KMER', 00019,     -5.749     39.789 !
! PS020 ='KMHR', 00020,    -67.672    168.279 !
! PS021 ='KMOD', 00021,    -38.624     68.798 !
! PS022 ='KMRY', 00022,   -117.787    -44.261 !
! PS023 ='KMYV', 00023,    -89.439    227.995 !
! PS024 ='KNLC', 00024,     48.176    -72.263 !
! PS025 ='KNUQ', 00025,   -133.485     46.500 !
! PS026 ='KO22', 00026,      7.284    111.712 !
! PS027 ='KOAK', 00027,   -147.482     79.822 !
! PS028 ='KOVE', 00028,    -93.336    270.682 !
! PS029 ='KPAO', 00029,   -139.118     52.035 !
! PS030 ='KRHV', 00030,   -113.544     37.098 !
! PS031 ='KRNO', 00031,     59.707    270.869 !
! PS032 ='KSAC', 00032,    -84.634    164.868 !
! PS033 ='KSCK', 00033,    -64.102     97.887 !
! PS034 ='KSFO', 00034,   -161.673     68.792 !
! PS035 ='KSJC', 00035,   -122.763     40.064 !
! PS036 ='KSMF', 00036,    -92.825    184.801 !
! PS037 ='KSNS', 00037,    -95.852    -35.535 !
! PS038 ='KSQL', 00038,   -150.469     57.695 !
! PS039 ='KSTS', 00039,   -196.103    165.371 !
! PS040 ='KSUU', 00040,   -121.787    138.380 !
! PS041 ='KTRK', 00041,     30.640    250.879 !
! PS042 ='KTVL', 00042,     42.506    205.736 !
! PS043 ='KUKI', 00043,   -226.228    234.811 !
! PS044 ='KVCB', 00044,   -123.832    150.679 !
! PS045 ='KWVI', 00045,   -111.078     -6.710 !
-------------------
      1
        Four character string for station name
        (MUST START IN COLUMN 9)

      2
        Six digit station code composed of state
        code (first 2 digits) and station ID (last
        4 digits)

!END!
```

Appendix D: List of Point Sources Modeled with CALPUFF

Facility Name	StackID	StkHgt (ft)	StkDia (ft)	Temp (F)	Exit Vel (ft/sec)	Baseline SO2 (tpy)	Hypothetical SO2 (tpy)
Potential New Source - DeltaEast	1402	330	3.25	175.7	40.75	--	370.0
Potential New Source - Delta West	1402	330	3.25	175.7	40.75	--	370.0
Potential New Source - Gilroy	1402	330	3.25	175.7	40.75	--	370.0
Potential New Source - Livermore	1402	330	3.25	175.7	40.75	--	370.0
Potential New Source - Lehigh	1402	330	3.25	175.7	40.75	--	370.0
Potential New Source - Petaluma	1402	330	3.25	175.7	40.75	--	370.0
Potential New Source - San Leandro	1402	330	3.25	175.7	40.75	--	370.0
Chevron Products Company	151	150	5.97	598.7	8.37	19.0	22.7
Chevron Products Company	152	150	5.97	598.7	8.37	24.7	29.7
Chevron Products Company	153	150	8.33	600.5	8.73	22.8	27.3
Chevron Products Company	57	240	12.24	1,250.3	22.34	29.5	35.4
Chevron Products Company	58	240	12.24	1,250.3	22.34	28.3	34.0
Chevron Products Company	59	155	9.58	1,000.1	24.90	10.4	12.5
Chevron Products Company	127	117	4.99	424.1	46.00	21.2	25.5
Chevron Products Company	260	140	11.52	499.7	35.30	10.1	12.1
Chevron Products Company	-9	174	3.58	299.9	2.36	6.1	7.3
Chevron Products Company	133	150	7.91	649.1	136.06	162.8	195.3
Shell Martinez Refinery	26	162	7.97	600.5	50.66	5.0	6.0
Shell Martinez Refinery	27	162	7.98	749.9	50.67	5.0	6.0
Shell Martinez Refinery	28	162	7.97	600.5	50.66	6.0	7.3
Shell Martinez Refinery	26	162	7.97	600.5	50.66	24.5	29.5
Shell Martinez Refinery	27	162	7.97	600.5	50.66	8.6	10.3
Shell Martinez Refinery	28	162	7.97	600.5	50.66	29.3	35.1
Shell Martinez Refinery	26	162	7.97	600.5	50.66	224.2	269.0
Shell Martinez Refinery	27	162	7.97	600.5	50.66	186.2	223.5
Shell Martinez Refinery	28	162	7.97	600.5	50.66	244.1	292.9
Shell Martinez Refinery	4190	245	12.40	299.9	65.58	9.6	11.6
Shell Martinez Refinery	4192	245	12.40	299.9	65.58	9.9	11.9
Shell Martinez Refinery	-9	150	3.94	299.9	3.28	25.2	30.2
Shell Martinez Refinery	25	350	10.04	749.9	39.67	32.9	39.5
Shell Martinez Refinery	1518	150	2.49	699.5	25.72	7.1	8.5
Shell Martinez Refinery	25	350	10.04	749.9	39.67	10.3	12.4
Shell Martinez Refinery	1518	150	2.49	699.5	25.72	6.5	7.8
Shell Martinez Refinery	-9	180	8.99	379.1	32.05	68.9	82.7
Shell Martinez Refinery	23	350	17.98	800.3	33.40	89.9	107.9
Shell Martinez Refinery	23	350	32.81	800.3	33.40	4.4	5.2
Shell Martinez Refinery	24	350	17.98	800.3	26.71	76.3	91.6
Shell Martinez Refinery	24	350	32.81	800.0	26.71	4.2	5.1
Shell Martinez Refinery	25	350	10.04	749.9	39.67	18.4	22.1
Shell Martinez Refinery	1760	150	6.99	649.1	14.50	4.9	5.9
Shell Martinez Refinery	1763	150	8.66	649.1	13.09	30.9	37.1
Shell Martinez Refinery	4002	250	3.58	539.3	50.89	13.1	15.8

Shell Martinez Refinery	-9	150	3.94	299.9	3.28	7.6	9.2
Shell Martinez Refinery	1	20	0.79	1,829.9	66.17	31.4	37.6
Shell Martinez Refinery	102	65	0.82	1,829.9	66.17	117.2	140.6
Shell Martinez Refinery	4161	200	11.06	299.9	22.80	5.2	6.2
Shell Martinez Refinery	4161	200	11.06	299.9	22.80	41.3	49.5
Lehigh Southwest Cement Company	141	60	6.23	319.7	98.69	925.2	1,110.3
General Chemical West LLC	1	150	5.97	184.7	19.65	215.9	259.1
General Chemical West LLC	-9	350	17.98	800.3	26.71	4.2	5.1
Owens Brockway Glass Container	3	130	4.99	787.7	58.20	122.6	147.1
Owens Brockway Glass Container	4	130	4.99	674.3	38.58	19.9	23.9
AB&I Foundry	-9	50	5.31	330.5	41.11	41.7	50.1
United States Pipe & Foundry Co.	9	48	31.92	499.7	2.92	74.5	89.4
Berkeley Asphalt Co.	-9	34	4.00	299.9	61.09	5.3	6.4
East Bay Municipal Utility District	56	62	5.97	330.5	42.55	4.9	5.8
East Bay Municipal Utility District	38	40	2.53	319.7	44.32	4.3	5.2
East Bay Municipal Utility District	39	40	2.53	319.7	44.32	5.7	6.8
Pacific Steel Casting Co., Plant #2	3	30	2.30	100.1	99.44	4.4	5.3
San Mateo Water Quality Control	-9	100	1.38	100.1	4.13	29.8	35.8
Oro Loma Sanitary District	3	25	0.72	1,009.1	114.17	4.2	5.0
Redwood Landfill Inc.	55	50	12.01	1,999.1	16.47	25.1	30.2
Redwood Landfill Inc.	60	40	11.94	1,399.7	9.06	22.5	27.0
Rolls Royce Engine Services	1	35	4.00	629.3	0.79	4.3	5.1
Waste Management of Alameda Co.	6	36	4.33	663.5	101.71	5.0	5.9
Waste Management of Alameda Co.	7	125	4.17	749.9	101.69	4.9	5.8
Waste Management of Alameda Co.	210	55	11.94	1,999.1	9.06	5.7	6.9
TriCities Recycling	3	45	8.99	1,599.5	37.04	4.3	5.2
Diana Fruit Company Inc.	-9	18	2.00	341.3	35.10	4.8	5.7
GWF Power Systems LP (Site1)	1	68	0.46	71.3	70.70	41.4	49.7
GWF Power Systems LP (Site2)	1	68	0.46	71.3	70.70	60.5	72.6
GWF Power Systems LP (Site3)	1	80	5.25	310.7	47.54	42.5	51.0
GWF Power Systems LP (Site4)	1	80	5.25	310.7	47.54	25.8	30.9
GWF Power Systems LP (Site5)	1	100	5.25	310.7	47.54	80.4	96.5
Republic Services Vasco Road	-9	50	12.01	1,399.7	51.61	36.0	43.2
Crockett Cogeneration ACalLP	201	232	18.96	224.3	58.33	5.2	6.2
Rhodia Inc.	1	200	4.00	159.5	101.05	334.3	401.1
Rhodia Inc.	-9	20	0.26	209.9	20.77	5.8	7.0
Rhodia Inc.	-9	20	0.26	209.9	22.08	4.6	5.6
Rhodia Inc.	-9	27	0.33	105.5	83.33	5.8	7.0
Valero Refining Company California	47	90	11.02	749.9	0.69	4.4	5.3
Valero Refining Company California	-9	220	2.00	94.7	60.14	12.2	14.6
Valero Refining Company California	-9	357	3.90	1,599.5	60.01	49.5	59.4
Valero Refining Company California	4	355	1.28	1,199.9	20.21	14.4	17.3
Valero Refining Company California	30	250	8.30	429.5	14.86	4.1	4.9
Valero Refining Company California	32	250	8.30	429.5	16.21	5.2	6.2
Tesoro Refining & Marketing Co.	10	350	15.03	400.7	14.14	9.7	11.7

Tesoro Refining & Marketing Co.	81	350	12.01	519.5	53.22	5.2	6.2
Tesoro Refining & Marketing Co.	1402	330	3.25	175.7	40.75	338.2	405.9
Tesoro Refining & Marketing Co.	1401	330	6.99	609.5	10.83	101.8	122.2
Tesoro Refining & Marketing Co.	1422	45	4.00	80.3	8.63	12.1	14.5
Tesoro Refining & Marketing Co.	26	200	6.50	749.9	16.57	6.4	7.6
Tesoro Refining & Marketing Co.	29	125	10.01	299.9	35.04	6.0	7.2
Tesoro Refining & Marketing Co.	81	350	12.01	519.5	53.22	104.9	125.8
Tesoro Refining & Marketing Co.	-9	28	2.00	433.1	14.34	32.5	39.0
Tesoro Refining & Marketing Co.	-9	75	2.00	433.1	14.34	6.1	7.3
Tesoro Refining & Marketing Co.	87	160	2.00	1,505.9	20.21	10.3	12.4
Phillips 66 Company San Francisco	8	128	4.49	670.7	12.57	6.4	7.7
Phillips 66 Company San Francisco	73	105	10.04	330.5	68.57	4.9	5.9
Phillips 66 Company San Francisco	74	105	10.04	330.5	68.57	4.7	5.6
Phillips 66 Company San Francisco	75	105	10.04	330.5	68.57	4.4	5.3
Phillips 66 Company San Francisco	73	105	10.04	330.5	68.57	13.2	15.8
Phillips 66 Company San Francisco	74	105	10.04	330.5	68.57	14.9	17.9
Phillips 66 Company San Francisco	75	105	10.04	330.5	68.57	15.1	18.1
Phillips 66 Company San Francisco	4	120	6.27	640.1	10.86	10.8	13.0
Phillips 66 Company San Francisco	5	120	5.09	730.1	10.66	11.3	13.5
Phillips 66 Company San Francisco	6	162	7.97	750.0	50.66	5.0	6.0
Phillips 66 Company San Francisco	9	177	6.00	730.1	26.51	24.9	29.9
Phillips 66 Company San Francisco	10	125	6.17	800.3	9.48	16.3	19.6
Phillips 66 Company San Francisco	11	125	4.33	750.0	101.71	4.9	5.8
Phillips 66 Company San Francisco	12	146	8.17	775.1	15.58	29.9	35.8
Phillips 66 Company San Francisco	13	272	8.99	449.3	13.62	48.3	58.0
Phillips 66 Company San Francisco	15	125	6.50	469.1	8.53	29.3	35.1
Phillips 66 Company San Francisco	26	137	6.23	699.5	15.35	16.8	20.2
Phillips 66 Company San Francisco	27	136	7.22	699.5	3.67	7.0	8.4
Phillips 66 Company San Francisco	63	150	7.25	578.9	50.89	17.3	20.8
Phillips 66 Company San Francisco	70	105	4.49	629.3	50.89	28.8	34.6
Phillips 66 Company San Francisco	72	105	4.49	499.7	50.89	13.1	15.7
Phillips 66 Company San Francisco	-9	250	3.51	1,000.1	2.53	28.4	34.1
Phillips 66 Carbon Plant	5	250	5.51	524.9	102.23	658.6	790.4
Phillips 66 Carbon Plant	6	250	5.51	449.3	102.23	481.0	577.2
Total						**6,082.3**	**9,888.7**