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Guidance on the Use of the Mesoscale Model Interface Program (MMIF) for AERMOD Applications

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Preface

This document provides guidance on the use of prognostic meteorological data and the Mesoscale Model Interface Program (MMIF) in AERMOD. Included in this document are descriptions of the inputs to MMIF and recommendations on using MMIF output in AERMOD. This document is an update to Section 3.4 of the December 2016 MMIF guidance document (EPA-454/B-16-003) issued as part of the 2016 final update to the *Guideline on Air Quality*.

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1. Introduction

The guidance discussed in this document are recommendations for running the Mesoscale Model Interface (MMIF) program[1] to generate inputs for AERMET and AERMOD. The guidance discussed in this document is an update to the July 2015 MMIF guidance (EPA-454/B-15-001). In this guidance document, when references are made to running MMIF for AERMOD, it should be inferred that this refers to AERMET as well. For regulatory applications, MMIF should be run to generate AERMET inputs as stated in section 8.4.2(a) and 8.4.5.1(b) of the final revisions to EPA's *Guideline on Air Quality Models* (U.S. EPA, 2016)[2]. Regulatory applications that do not follow these sections of Appendix W will need to consult with the appropriate reviewing authority and guidelines outlined in section 3.2 of Appendix W. Given that Appendix W and specific EPA modeling guidance are often cited in relation to other non-regulatory modeling applications, such as air quality analysis and disclosure purposes under NEPA, the approach presented in this guidance document for regulatory applications also has relevance to these non-regulatory applications. While MMIF can process data for other air quality models (e.g., CALPUFF and SCICHEM), the emphasis in this guidance is for AERMOD applications conducted for regulatory purposes.

This guidance document will summarize some of the inputs needed for AERMET and AERMOD MMIF processing, but will refer to the MMIF User's Guide (Ramboll Environ, 2016) for more details. MMIF users are strongly encouraged to read this user's guide to obtain specific details on running MMIF.

2. Guidance on using prognostic meteorological data for use in AERMOD

In general, air quality modeling applications rely on the use of meteorological grid models. These models are used to more accurately simulate atmospheric processes (e.g., temperature, wind speed and direction, etc.) across a specific area. In retrospective simulations (i.e., modeling past events), the blending of observed data with computed fields yields results that are bound by ground truth.

There are several meteorological grid models that can be used to develop inputs for air quality models. The most commonly used by EPA and the modeling community is the Weather Research and Forecasting (WRF) model (Skamarock et al., 2008)[3], which is supported across a broad community and provides state-of-the-science parameterizations of the atmosphere. Additionally, the Fifth Generation Penn State/NCAR Mesoscale Model (MM5) (Grell et al.,

[1] http://www.epa.gov/ttn/scram/dispersion_related.htm#mmif

[2] Hereafter, the Guideline will be referred to as Appendix W.

[3] http://www.wrf-model.org/index.php

1994) is capable of generating the necessary meteorological inputs to air quality models; however, its development and maintenance is no longer supported.

2.1 Number of years to model

As discussed in Section 8.4.2(e) of Appendix W, at least three consecutive years are required to be modeled in the prognostic model. The most recent three years are preferred and the prognostic model domain or selected grid cells should be representative of the domain. See Section 8.4.b of Appendix W for more details about representativeness of meteorological data.

2.2 Prognostic model options

2.2.1 Development of meteorological fields

For development of prognostic meteorological fields, a rigorous approach has been established within the atmospheric chemistry community. In this section, a basic guideline for recommendations on producing prognostic meteorological data will be provided. For more details related to approaches on developing modeled meteorology, please see Section 2.6 of the *Modeling Guidance for Demonstrating Attainment of Air Quality Goals for Ozone, PM2.5, and Regional Haze (U.S. EPA, 2014).*

Dynamic meteorological models such as WRF and MM5, have myriad options available to solve for various processes within the atmosphere. Specific model options will not be provided, given that different areas of interest may respond differently under certain conditions. It is expected that the physical options chosen will be thoroughly evaluated to support their use.

With regards to defining a meteorological modeling domain, it is recommended that the domain be of sufficient size and resolution to adequately capture mesoscale characteristics that impact a source location. As an example, in an area of complex, mountainous terrain, the nearest NWS observation site may not be adequately representative. In this case, the scale of meteorological model is recommended to be high enough to capture specific mountain/valley flows and be large enough to represent the upstream and other mesoscale meteorological features. Conversely, in areas where terrain and mesoscale characteristics may be more homogenous, a reasonably coarse model resolution may be applied. In addition, to avoid issues with grid boundary effects, it is recommended the modeling domains be centered over the source location. Specific case examples are provided in U.S. EPA (2018a).

It is also recommended that any meteorological modeling be performed using four dimensional data assimilation (FDDA) as outlined in U.S. EPA (2014). FDDA involves providing the model with inputs related to observed and/or analyzed meteorological conditions. This technique is useful in improving atmospheric simulations and constraining the model from varying widely from actual observations.

2.3 Model output quality assurance

2.3.1 Operational evaluation

Demonstration of the adequacy of prognostic meteorological fields can be established through appropriate diagnostic and statistical performance evaluations consistent with recommendations provided in the appropriate EPA guidance. A quantitative, statistical, and graphical analysis of the prognostic data should be completed, comparing the data to available NWS automated surface observation station (ASOS) data, as well as operational profiler data (if available), pairing both in space and time. This analysis should be completed for all years (at least three) of prognostic meteorological data to be used in the air quality simulations. Since the spatial scope of each variable could be different, representativeness should be judged for each variable separately as discussed in Section 8.4.2(b) of the final Appendix W (U.S. EPA, 2016). For example, for a variable such as wind direction, the data should ideally be collected near plume height to be adequately representative; especially for sources located in complex terrain, whereas, for a variable such as temperature, data from a station several kilometers away from the source may be considered to be adequately representative. The grid resolution of the prognostic meteorological data should also be considered and evaluated appropriately, particularly for projects involving complex terrain. Several software packages are available for use in completing this evaluation (e.g., AMET (Appel et al., 2011) and METSTAT (http://www.camx.com/download/support-software.aspx)). The adequacy of output from the meteorological models is contingent upon the concurrence with the appropriate reviewing authorities as defined in section 8.4.5.2(a) of the final Appendix W.

3. Guidance on running MMIF for AERMOD

Much of the guidance presented here follows the MMIF user's guide (Ramboll Environ, 2016). Relevant information from the user's guide is summarized in this guidance for convenience but the user is strongly encouraged to read the full MMIF user's guide before attempting to run MMIF. Section 3.1 below discusses the inputs to MMIF, Section 3.2 discusses the relevant options to AERMOD and grid cells to process. Section 3.3 discusses the use of surface characteristics outside of MMIF, Sections 3.4 and 3.5 discuss the use of minimum wind speeds, mixing height and Monin-Obukhov length, and Section 3.6 discusses post-processing the output from MMIF needed for input into AERMOD.

3.1 MMIF Input File

MMIF processing is done via a control file with keywords to denote inputs, processing options, and outputs. Table 1 lists the keywords used to run MMIF for AERMET and AERMOD input. A sample control file that illustrates all of the keywords can be generated for MMIF by typing “mmif –sample” at the command prompt. See Section 4.2 of the User’s Guide (Ramboll Environ, 2016) for more information.

Table 1. AERMET/AERMOD keywords in MMIF input file.

Keyword	Description	Syntax
Start	Date and time (Local Standard Time) to start processing	Start YYYY MM DD HH Or Start YYYYMMDDHH Or Start YYYY-MM-DD_HH:mm:ss
Stop	Date and time (LST) to stop processing	Stop YYYY MM DD HH Or Stop YYYYMMDDHH Or Stop YYYY-MM-DD_HH:mm:ss
Timezone	The global time zone shift from Greenwich Mean Time (GMT); Western hemisphere time zones are denoted by negative numbers	Timezone HH
Grid	Specifies the requested output sub-grid's lower left (LL) and upper right (UR) corners; Grid corners can be specified by grid cell I, j coordinates (IJ), latitude and longitude (LL or LATLON) or MM5/WRF projected coordinate system (KM)	GRID IJ iLL jLL iUR jUR Or GRID LL LatLL LonLL LatUR LatRR Or GRID KM xLL yLL xUR yUR
Point	Output point for AERMET, AERMOD, or AERCOARE processing. The point can be specified by grid cell I, j coordinates (IJ), latitude and longitude (LL or LATLON) or MM5/WRF projected coordinate system (KM). An optional time zone shift can also be listed[1]. The point keyword can be repeated for each point to be outputted.	Point IJ I J [Timezone] Or POINT LL Lat Lon [Timezone] Or POINT KM X Y [Timezone]
Layers	Specify the output layer structure. Layers can be aggregated (K), interpolated using layer tops (TOP), or interpolated using mid layer (MID).	Layers K $Layer_1$ $Layer_2$…$Layer_N$ Or Layers TOP Top_1 Top_2…Top_N Or Layers MID Mid_1 Mid_2…Mid_N
Origin	Over-ride the X,Y grid origin values found in the MM5 or WRF output file. The user specifies a latitude (LAT) and longitude (LON).	Origin LAT LON
CALSCI_MIXHT	A value of WRF causes MMIF to pass through the PBL depth from the model with no changes. A value of MMIF causes MMIF to re-calculate PBL depths using a Bulk Richardson approach with 20 times the vertical resolution of the model data.	WRF or MMIF
AER_MIXHT	Option to specify what mixing heights to use for MMIF to AERMET processing. Options are WRF (no recalculation of mixing heights), MMIF (MMIF recalculated mixing heights) or AER_MIXHT(allow AERMET to calculate mixing heights)	WRF, MMIF, or AER_MIXHTS
AER_MIN_MIXHT	Specify the minimum allowed mixing height for AERMOD SFC output. Default is 1 m as based on AERMET	AER_MIN_MIXHT VALUE

Table 1. Continued

Keyword	Description	Syntax
AER_MIN_OBUK	Specify the minimum allowed absolute value of the Monin-Obukhov length for AERMOD SFC output. The default is 1 m as based on AERMET	AER_MIN_OBUK VALUE
AER_MIN_SPEED	Specify the minimum wind speed in m/s (VALUE) for AERMOD surface output file. This value should be set to 0 for both MMIF to AERMET and MMIF to AERMOD output.	AER_MIN_SPEED VALUE
FSL_INTERVAL	Specify the number of hours (VALUE) to write for each day to the upper air file for input into AERMET. The default value is 12 representing the 00Z and 12Z soundings. A value of 6 would write output for 00Z, 06Z, 12Z, and 18Z. A value of 1 would write output for each model hour.	FSL_INTERVAL VALUE
AER_LAYERS	Specify the lowest and highest layer indices (two integers) to write to the AERMET input site-specific data and AERMOD profile file (PFL file). All layers between the two indices will be written to the file.	AER_LAYERS VALUE
OUTPUT	Specifies the outputs from MMIF for AERMET, AERCOARE, and AERMOD (MODEL keyword) and output files[2].	OUTPUT MODEL FORMAT FILENAME
INPUT	Input MM5 or WRF filename. This input is repeatable for a MMIF run.	INPUT FILENAME
METFORM	Keyword to tell MMIF which model MM5 or WRF is being accessed. MMIF can auto-detect the model type so in general this is not needed.	METFORM MM5 Or METFORM WRF

1. See Section 4.2 of the MMIF user's guide regarding the global time zone shift and point specific time zone shifts.
2. More information about the output options are discussed in Section 3.2 below.

3.2 Recommended options for selected keywords

While most input options will be left to the discretion of the user, some recommendations on inputs are made in this guidance. One such option is the output option of MMIF, keyword OUTPUT. While MMIF can process data for input into AERMET, or AERMOD, the requirement for regulatory applications is to process the prognostic meteorological data for input into AERMET as discussed in Sections 8.4.2(a) and 8.4.5.1(b) of Appendix W, as AERMET is the meteorological pre-processor for AERMOD as discussed in those sections. The data is then processed in AERMET for input into AERMOD. Processing MMIF output through AERMET also allows the user to take advantage of some of the options in AERMET, such as the u* adjustment option. See the AERMET user's guide for details about options (U.S. EPA, 2018b). For non-regulatory applications, the user may choose AERMET or AERMOD and should consult with and seek concurrence from collaborating agencies or parties involved in such modeling applications.

3.2.1 Outputs

For any particular air quality model, the OUTPUT option is used to specify several files. While these are discussed in the MMIF user's guide in detail, they are summarized below for AERMET and subsequent input AERMOD and direct input into AERMOD as well (non-regulatory applications).

3.2.1.1 AERMET

For AERMET, the first set of files is specified using the USEFUL keyword. This keyword creates a DOS batch file or Linux shell script that is used to run all three stages of AERMET in batch mode. It also creates the stage 1, stage 2, and stage 3 input files with the appropriate values set for the AERMET keywords such as LOCATION, XDATES, etc. Once the stage 1, 2, and 3 input files have been created, the user should check those files to ensure the correct GMT offset is used. For the upper air pathway of the stage 1 file, the LOCATION keyword should have a GMT offset corresponding to the station's location. For example, if the processed grid cell is in the Eastern time zone of the U.S. the GMT offset on the LOCATION keyword should be 5. For the surface data, the offset should be zero as that has been formatted for local time.

The second file that is generated is specified using the keyword ONSITE. This creates a site-specific type meteorological file that is processed via the ONSITE keyword in AERMET (U.S. EPA, 2014). This file contains 2-meter and 10-meter data and upper air data up to levels specified with the keywords MIN_LAYER, MAX_LAYER, or LAYERS to control the number of output layers.

The third keyword, FSL creates a file that mimics an upper air data file in the Forecast Systems Laboratory (FSL) format. The keyword UPPERAIR can also be used. See Section 2.2.1 of the MMIF user's guide for more details.

The final keyword is AERSFC, which generates an AERSURFACE type output file with surface characteristics (albedo, Bowen ratio, and surface roughness). Note, that these are monthly surface characteristics for the period being processed. See Section 2.2.1 of the MMIF user's guide for more details.

3.2.1.2 AERMOD

Three files are generated for AERMOD. The USEFUL file is a file containing the ME pathway information of the AERMOD input file, i.e. ME STARTING, SURFFILE, PROFFILE, SURFDATA, UADATA, etc. information. The SFC keyword generates the AERMOD ready surface data file and the PFL keyword generates the profile data file for input into AERMOD.

3.2.2 PBL calculations

Three options are available for PBL or mixing height calculations when processing MMIF to output files for AERMET inputs via the AER_MIXHT option, 1) a pass through of the WRF PBL heights (AER_MIXHT=WRF), 2) recalculation of the PBL heights using a Bulk Richardson approach (AER_MIXHT=MMIF), based on Vogelezang and Holtslag (1996) and Louis (1979) and, no PBL heights passed to the AERMET site-specific data file (AER_MIXHT=AERMET). This option uses AERMET to use its own algorithms to calculate mixing heights. For MMIF inputs to AERMOD, there are still two options available via the CALSCI_MIXHT option (formerly the PBL_recalc option). The two options are passing the WRF mixing heights (MIXHT=WRF) or recalculation by MMIF (MIXHT=MMIF). At this time, the choice of which option to use is left to the discretion of the user as limited evaluations (EPA, 2018a) have shown little difference in the three methods. Note that if a user utilizes the PBL pass through or recalculation method and wishes to use AERMET derived mixing heights later, the user can rerun MMIF or just omit the MIXHT variable and modify the read statement for the site-specific meteorological file.

3.2.3 Output layers and heights

An important keyword for output is the LAYERS keyword. As shown in Table 1, the user can specify different options for the output layers from MMIF. While the choice of layers is case specific and may be dependent on the prognostic model's layer structure, two possible defaults should be adequate in most cases. The first is based on the FLM guidance and the second is aa default use of MID (interpolation using layer mid-point heights) and the specification of heights corresponding to the AERMOD vertical grid. These heights are: 25, 50, 75, 100, 125, 150, 175, 200, 250, 300, 350, 400, 450, 500, 600, 700, 800, 900, 1000, 1500, 2000, 2500, 3000, 3500, 4000, 4500, and 5000. These values have been used in past MMIF evaluations (U.S. EPA, 2015c). The LAYERS keyword controls the output of the FSL formatted upper air file used by AERMET and the profile file used by AERMOD when processing MMIF to AERMOD. The

AER_LAYERS keyword is used to control the output of the site-specific data file read by AERMET. The AER_LAYERS can be a subset of the LAYERS values.

3.2.4 Grid cells to process

An AERMOD run uses surface meteorological data from one point and upper air data from one point. While MMIF can process multiple points, i.e. grid cells, the grid cell used in the AERMOD simulation should be representative of the modeling domain, following the recommendations of Section 8.4.5(b) of Appendix W. Depending on the size of the modeling domain and the grid resolution of the prognostic meteorological data, most often the representative grid cell will be the grid cell containing the facility of interest. This will often be the case for NSR/PSD types of applications. When the AERMOD modeling domain overlaps several grid cells of the prognostic meteorological data, such as for SIP demonstrations, the grid cell that is most representative of the domain should be selected following guidance on representativeness in Sections 8.4.1.b and 8.4.2.b of the final Appendix W, or it may be necessary to conduct multiple AERMOD runs for different grid cells and post-process the results to calculate the appropriate concentration metrics for the application (i.e. design values).

3.3 Surface characteristics

MMIF will output surface characteristics, albedo, Bowen ratio, and surface roughness for input into AERMET and also in the AERMOD ready surface meteorological file. When outputting data for AERMET, MMIF outputs surface characteristics for one 360^{o} sector at monthly resolution. The surface characteristics are based on the land use data used by the prognostic meteorological model. These surface characteristics should be used as they are representative of the processed grid cell as discussed in Section 8.4.2(b) of the final Appendix W.

3.4 Treatment of low winds

When processing MMIF for input into AERMET or AERMOD, MMIF will use the AER_MIN_SPEED value as a wind speed threshold, for which winds below that threshold are treated as calms. This is for winds at any vertical level in the input dataset. For input to AERMET, MMIF will generate the onsite wind speed threshold option (THRESHOLD keyword) with the user supplied value (AER_MIN_SPEED) for the stage 1 AERMET input file. Normally, the purpose of the threshold in AERMET is to treat winds below the threshold as calm and the threshold speed is a function of the starting threshold of a site-specific anemometer. See the AERMET user's guide (U.S. EPA, 2018b) for details about this option in AERMET. When generating MMIF output for direct AERMOD input, winds below the AER_MIN_SPEED value will be treated as calms in the AERMOD surface file. For both MMIF to AERMET and MMIF to AERMOD, the user should set the minimum wind speed, AER_MIN_SPEED, to zero, since the input is prognostic data and does not have a functional minimum threshold as found in an anemometer.

When processing MMIF output in AERMET, if the lowest level's wind speed is below the AERMET allowable limit ($2^{1/2}$ x σ_{vmin}, where σ_{vmin}=0.2 m/s), AERMET will reset the wind speed to the lower limit allowed in AERMET for output to the surface file. This adjustment does not take place for other levels in the WRF output file. See Section 4.5.11 in the AERMET user's guide for more details (U.S. EPA, 2018b). When processing MMIF output for direct input to AERMOD, no such adjustment will occur in MMIF. The wind speed from WRF is output to the AERMOD surface and profile files.

3.5 Minimum mixing height and absolute value of Monin-Obukhov length

New in MMIF 3.3, is the ability to specific a minimum mixing height and minimum value of Monin-Obukov length when processing MMIF for AERMOD output. The default minimum values for each option are 1 m, as defined in Table 1 and discussed in the MMIF User's Guide (Ramboll Environ, 2016). At this time, the defaults are the recommended values for these options.

3.6 Post-processing of outputs

When processing MMIF for AERMET files, a single MMIF run will produce an upper air file in the FSL format, a surface data file that will be read into AERMET as site-specific data, and surface characteristics (albedo, Bowen ratio, and surface roughness) at monthly resolution for twelve sectors. These output files will cover the period processed in MMIF. In most situations, a single MMIF run will not cover an entire three period or even a one-year period. If that is the case, the ONSITE files generated by the MMIF can be simply concatenated into a single file for the three-year period or individual yearly files before input into AERMET. The files must be concatenated in temporal order. The same can be done for the FSL files. If using the MMIF surface characteristics files, the AERSFC files cannot be simply concatenated. For a single MMIF run, the surface characteristics are output for all twelve months and sectors. The months outside of the data processing window set by START and STOP will have missing values, while the months inside the window will have non-missing values. To create a valid AERSFC file covering the entire three-year period or desired period, an AERSURFACE file must be created with non-missing values for all months and sectors. This can be created by simply cutting and pasting the non-missing values for each month/sector combination into a single file. When creating this file, the user should make sure to incorporate the header line from one of the files into the concatenated file. This line is "** Generated by MMIF…" This line indicates to AERMET that the meteorological data comes from MMIF and not an observed site-specific dataset. This information is then passed to AERMOD via the surface meteorological file created by AERMET. While this does not affect the data calculations in AERMET and AERMOD, including the line ensures transparency when data files are reviewed.

An alternative approach to the file concatenation steps described above, is to run AERMET for each period processed and concatenate AERMOD ready surface and profile files from the multiple AERMET runs. For the profile files, the files can be simply concatenated together, preserving the temporal order of the data (e.g., January 1, hour 1 of the first processed year is the first line and December 31, hour 24 of the last processed year is the last record of the concatenated file). For the surface files, AERMET generates a header record for each file (the record that lists the location, station identifiers, and AERMET version). When concatenating the surface files, the header record for the first concatenated file should be retained. Only the data records from the remaining surface files are needed. If the header records are retained for all files, AERMOD will not run correctly. Again, the files should be concatenated in temporal order. These steps also apply for processing AERMOD ready files when post-processing MMIF output for AERMOD.

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