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PEER REVIEW OF THE CALMET/CALPUFF MODELING SYSTEM

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SUMMARY

The U.S. Environmental Protection Agency, through their contractor, commissioned a panel of three reviewers to assess whether or not the EPA should recommend use of the CALMET/CALPUFF modeling system for long-range transport assessments in Class I areas, and allow its use in near-field applications. The panel of three reviewers, Dr. K. Jerry Allwine, Dr. Walter F. Dabberdt and Mr. Larry L. Simmons all concluded that the CALMET/CALPUFF modeling system is scientifically sound and represents a significant advancement in regulatory air quality modeling. They recommend its use after revisions to the CALMET and CALPUFF User's Guides. The recommended revisions are to provide more instructions for setting-up and operating the models. After the User's Guides are revised, the models should be operated by an independent reviewer (experienced air quality modeler) to verify that sufficient details are given in the revised User's Guides for setup and operation of the models.

This report gives EPA's charge to peer reviewers, the list of documents available for the review, the primary conclusions and comments resulting from the peer review, and the complete text of review comments from each of the three peer reviewers.

A detailed overview of the mechanics of this peer review process is presented as Appendix E. The qualifications of each of the peer review panel members is presented via copies of their respective resumes in Appendix G.

The KEVRIC Company Inc. provided the administrative management necessary to conduct this peer review. KEVRIC's efforts are outlined in the overview of the process included as Appendix E.

CONTENTS

INTRODUCTION

The CALMET/CALPUFF modeling system can simulate atmospheric dispersion on transport scales of from tens of meters to tens of kilometers (near-field) and from tens of kilometers to hundreds of kilometers (far-field). In the U.S. Environmental Protection Agency's Charge to Peer Reviewers (Appendix D), "EPA is specifically proposing to recommend use of the CALMET/CALPUFF modeling system for long-range transport assessments in Class I areas, and allowing its use in near-field applications." EPA assembled a panel of three reviewers to assess whether or not the CALMET/CALPUFF modeling system should be recommended for use. This report gives the results of that peer review.

The panel of three reviewers, Dr. K. Jerry Allwine, Dr. Walter F. Dabberdt and Mr. Larry L. Simmons were charged by EPA (Appendix D) to evaluate four aspects of the CALMET/CALPUFF modeling system: 1) Model Formulation, 2) Documentation, 3) Performance Evaluation, and 4) User Friendliness of Entire System. The CALMET/CALPUFF modeling system is very complex with numerous model features and options. Nearly one thousand pages of documentation (11 documents) were available for the peer review. Because of the limited resources available to perform this peer review (20 h per reviewer), each reviewer focused on certain portions of the charge. Fortunately, each reviewer focused on complimentary aspects: Allwine primarily focused on Documentation and User Friendliness, Dabberdt primarily focused on Model Formulation and Documentation, and Simmons focused on model operation in near-field applications.

One reviewer (KJA) summarized the results from the three reviews. The significant results of the peer review are given next, with reviewers initials listed with comments attributed to them. All reviewers concur with the significant results listed. Appendices A, B and C give the full text of Allwine's, Dabberdt's and Simmons' peer reviews. EPA's Charge to Peer reviewers is given in Appendix D and the list of documentation considered in the review is given in Appendix F.

PRIMARY RESULTS, CONCLUSIONS AND RECOMMENDATIONS

Model Formulation

1. The CALMET/CALPUFF modeling system represents the state-of-the-practice insofar as dispersion models are concerned. The explicit integration of mesoscale meteorological models such as MM4/5 and CSUMM with a diagnostic, mass-consistent wind model in CALMET is an important and welcome advance in dispersion modeling. The model should serve as a flexible and robust system for a wide range of applications both in the near field and the far field. CALMET provides the ability to simulate a number of important local effects, such as: slope flows, kinematic terrain effects, terrain blocking, and sea breeze circulations. [WFD]

2. The CALPUFF model represents a very significant advance over MESOPUFF II. CALPUFF explicitly treats virtually all of the important physical processes affecting transport, diffusion, deposition, and transformation. The three most important areas of improvement are: a) the wind field representation provided by CALMET and the explicit integration of mesoscale model outputs, b) the explicit treatment of terrain effects, both in the wind-field model and the dispersion model, and c) a comprehensive treatment of near-field effects, including building effects. [WFD]

3. No aspects of the CALMET and CALPUFF model formulations need to be changed prior to release. If the EPA has not already done so, it is encouraged to retain an independent firm or consultant to perform in-depth tests and checks of the model to ensure that there are not errors in coding. [WFD]

4. The CALMET/CALPUFF modeling system clearly represents the state-of-practice in Lagrangian puff modeling for assessing impacts of the long-range transport of certain air pollutants (represented by first-order chemical transformations). [KJA]

5. The CALMET/CALPUFF modeling system is a significant improvement for long-range transport modeling over MESOPUFF II primarily in: a) the improved treatment of complex wind fields through advanced flow models and the capability of "puff splitting," b) the more general treatment of diffusion using boundary-layer parameterizations, and c) the improved treatment of dry deposition using a "resistance model" formulation. [KJA]

Documentation / User Friendliness

1. The CALMET User's Guide gives sufficient technical detail of the model formulation to understand the scientific foundations of the model. However, the instructions and discussions for operating the CALMET model are unclear and the documentation is not sufficient to guide a typical user in the use of the model and its preprocessors. The CALMET User's Guide is not ready for release without revisions as described in Appendix A. [KJA]

2. The CALPUFF User's Guide gives sufficient technical detail of the model formulation to understand the scientific foundations of the model. However, the instructions and discussions for operating the CALPUFF model are unclear and the documentation is not sufficient to guide a typical user in the use of the model and its preprocessors. The CALPUFF User's Guide is not ready for release without revisions as described Appendix A. [KJA]

3. After revisions to the CALMET and CALPUFF User's Guides are completed, an independent reviewer (experienced air quality modeler not necessarily familiar with CALMET/CALPUFF) should take the User's Guides and the release-ready code (with all preprocessors) and show that the guides and code are complete by setting-up and running CALMET/CALPUFF for applications of their choice (possibly a near-field and a far-field application). The models should not be released until the document and code pass a minimum "user-friendliness" criteria, that of, "An experienced air quality modeler can efficiently setup and execute the model without external guidance or additional input." The

tests by the independent reviewer should not include the use of CSUMM or MM5 results in CALMET. [KJA]

4. The CALMET and CALPUFF User's Guides are well written for technical critique and understanding of the model formulations. The User's Guides organization is similarly appropriate. The presentation of the models and their features are largely very clear and well documented. Some areas requiring clarification are given in Appendix B. [WFD]

5. The CALMET and CALPUFF User's Guides are sufficient to guide a typical user in the use of the models and their preprocessor. However, this reviewer did not attempt to load and execute the model in the course of the review, and there may be implementation issues that require further attention. [WFD]

6. User friendliness concerns do not outweigh general release of the CALMET/CALPUFF modeling system at this time. I envision the release of the modeling system as having two significant benefits to the user community. One, it will provide informed users with a more powerful, flexible, and realistic simulation tool. And two, it may help increase the level of expertise within the user community. (See Appendix B for suggested training program.) [WFD]

7. Assessing the appropriateness of input selections to CALMET would be greatly improved if the user can graphically view the three-dimensional time-varying wind fields. A utility program for easily visualizing the wind fields would be very useful. [LLS]

8. The CALMET and CALPUFF graphical user interfaces (GUIs) are generally easy to use and simple to understand. The help feature is especially useful. Some changes/clarifications to the GUIs are recommended in Appendix A. [KJA]

Performance Evaluation

1. At this stage, the extent of evaluation of CALPUFF performance is probably superior to that of many other models. This extent of evaluation is probably sufficient to allow judgement to be made regarding model performance because CALPUFF incorporates a basic formalism that is well understood and numerous algorithms, each of which has been reasonably well characterized individually. It is the composite that has seen modest but meaningful performance evaluation. Further, the mesoscale and diagnostic wind field modeling approaches used in CALMET have undergone a history of more than 20 years of test and evaluation in the meteorological and wind power communities. [WFD]

2. Enough evaluation work has been done to recommend use of the CALPUFF model as proposed. The EPA is encouraged to seek an independent assessment of the performance of the model against field experimental data, and against other, less comprehensive - but well characterized - models. Much of this has already been done as reflected in the interim draft report of the IWAQM from the Sixth Modeling Conference and the draft EPA report comparing CALPUFF with ISC3. However, a summary study that seeks to integrate the

findings from the many individual CALPUFF evaluations done to date would be a valuable addition to what has been an impressive body of work. [WFD]

Additional Comments

1. The application of CALMET using CSUMM or MM5 data should be evaluated on a case-by-case basis rather than allowing this feature to be generally used. The gridded fields from CSUMM and MM5 need to be verified before use in CALMET. A defensible verification procedure should be made available. [KJA]

2. After release of the CALMET/CALPUFF modeling system for general use, the EPA should undertake sensitivity studies of the models in order to provide guidance to users on specifying model options. [KJA]

3. A valuable, future addition would be the ability to use nested grids both in the diagnostic wind field model and in the diffusion model (CALPUFF). This approach could facilitate the treatment of local terrain variations and might avoid some of the complexities of the numerical schemes in CALPUFF which are designed to deal with terrain-induced flow effects on the subgrid scale. [WFD]

4. A future area for improvement in the CALMET/CALPUFF modeling lies in its quantification of uncertainty (as reflected in the model inputs, in the model physics, and through the stochastic nature of the atmosphere). Significant advances are being realized in weather and climate forecasting through the use of ensemble simulations which enable the user to consider the range of likely end states and the associated range of uncertainty. [WFD]

5. Need a "Regulatory Default" Model Protocol (model parameter settings) defined for the CALMET/CALPUFF modeling system so users trained in the world of the Meteorological Processor for Regulatory Models (MPRM) and the Industrial Source Complex (ISC) model will have a smoother transition into using the CALMET/CALPUFF modeling system. [LLS]

6. CALMET and CALPUFF Model Protocols developed during various regulatory applications of the CALMET/CALPUFF modeling system would be useful references for subsequent applications of the models. (Appendix C gives example protocols.) [LLS]

7. User's should exercise caution when preparing the geophysical data (e.g., terrain elevations and land use categories) for use in CALMET/CALPUFF. The user should verify that the gridded land use categories overlay the gridded terrain elevations correctly. (Appendix C gives an example of a misalignment of topographic information.) [LLS]

8. The CALMET model assumes that upper-air data is in the National Climatic Data Center's TD6201 format, where wind speed is given to the nearest integer. However, CALMET has an option to read TD6201-type data to the nearest tenth for wind speed. This CALMET option should be invoked when using vertical profiles of wind data from low-threshold sensors (e.g., sodars, towers). [LLS]

APPENDIX A

ALLWINE PEER REVIEW

Peer Review of CALMET/CALPUFF

K. Jerry Allwine
August 1998

INTRODUCTION AND APPROACH

The CALMET/CALPUFF modeling system can simulate atmospheric dispersion on transport scales of from tens of meters to tens of kilometers (near-field) and from tens of kilometers to hundreds of kilometers (far-field). In their Charge to Peer Reviewers, "EPA is specifically proposing to recommend use of the CALMET/CALPUFF modeling system for long-range transport assessments in Class I areas, and allowing its use in near-field applications." This peer review is to assess whether or not the CALMET/CALPUFF modeling system should be recommended for use by EPA.

The peer review was to focus on four aspects of the CALMET/CALPUFF modeling system: 1) Model Formulation, 2) Documentation, 3) Performance Evaluation, and 4) User Friendliness of Entire System. The CALMET/CALPUFF modeling system is very complex with numerous model features and options. Nearly one thousand pages of documentation (11 documents) were available for the peer review. Because of the limited resources available to perform this peer review (20 h), I focused most of my effort (~50 h) on reviewing the CALMET and CALPUFF User's Guides (roughly 750 pages), interacting in a limited fashion with the CALMET and CALPUFF graphical-user-interfaces (GUIs), and documenting the results of my review.

Next are summarized the significant results of my peer review. More detailed results and comments from my peer review are given in the last section.

SIGNIFICANT RESULTS

1. The CALMET/CALPUFF modeling system represents the state-of-science in Lagrangian puff modeling for assessing impacts of the long-range transport of certain air pollutants (first-order chemical transformations).

2. The CALMET/CALPUFF modeling system is a significant improvement in long-range transport modeling over MESOPUFF II primarily in: a) the improved treatment of complex wind fields through advanced flow models and the capability of "puff splitting," b) the more general treatment of diffusion using boundary-layer parameterizations, and c) the improved treatment of dry deposition using a "resistance model" formulation.

3. The CALMET User's Guide gives sufficient technical detail of the model formulation to understand the scientific foundations of the model. However, the instructions and discussions for operating the CALMET model are unclear and the documentation is not sufficient to guide a typical user in the use of the model and its preprocessors. The CALMET User's Guide is not ready for release without revisions as described in the next section.

4. The CALPUFF User's Guide gives sufficient technical detail of the model formulation to understand the scientific foundations of the model. However, the instructions and discussions for operating the CALPUFF model are unclear and the documentation is not sufficient to guide a typical user in the use of the model and its preprocessors. The CALPUFF User's Guide is not ready for release without revisions as described in the next section.

5. After revisions to the CALMET and CALPUFF User's Guides are completed, an independent reviewer (experienced air quality modeler not necessarily familiar with CALMET/CALPUFF) should take the User's Guides and the code (ready for release with all preprocessors) and show that the guides and code are complete by setting-up and running CALMET/CALPUFF for applications of their choice (possibly a near-field and a far-field application). The models should not be released until the document and code pass a minimum "user-friendliness" criteria, that of, "An experienced air quality modeler can efficiently setup and execute the model without external guidance or additional input." The tests by the independent reviewer should not include the use of CSUMM or MM5 results in CALMET.

6. The application of CALMET using CSUMM or MM5 data should be evaluated on a case-by-case basis rather than allowing this feature to be generally used. The gridded fields from CSUMM and MM5 need to be verified before use in CALMET. A defensible verification procedure should be made available.

7. The CALMET and CALPUFF graphical user interfaces (GUIs) are generally easy to use and simple to understand. The help feature is especially useful. Some changes are recommended in the next section.

In summary, the scientific foundations of the models are sound and represent the state-of-science for applications models. I recommend that the CALMET/CALPUFF modeling system be recommended for use after revisions to the CALMET and CALPUFF User's Guides as described in the next section, and after an independent air quality modeler has exercised the models with the revised User's Guides and the "release-ready" code. After release of the CALMET/CALPUFF modeling system for general use, the EPA should undertake sensitivity studies of the models in order to provide guidance to users on specifying model options.

<u>DETAILED RESULTS AND COMMENTS</u>

REVIEW OF THE CALMET USER'S GUIDE

GENERAL CONCLUSIONS AND RECOMMENDATIONS

1. The CALMET User's Guide gives sufficient technical detail of the model formulation to understand the scientific foundations of the model. However, the instructions and discussions for operating the CALMET model are unclear and the documentation is not sufficient to guide a typical user in the use of the model and its preprocessors. The CALMET User's Guide is not ready for release without revisions.

2. Sections 1 (Introduction) and 4 (User Instructions) should be revised as discussed below. Sections 2 (Technical Description) and 3 (CALMET Model Structure) are adequate.

3. After revisions are completed, an independent reviewer (experienced air quality modeler not necessarily familiar with CALMET) should take the User's Guide and the code (ready for release with all preprocessors) and show that the guide and code are complete by setting-up and running CALMET for applications of their choice (possibly a near-field and a far-field application). The model should not be released until the document and code pass a minimum "user-friendliness" criteria, that of, "An experienced air quality modeler can efficiently setup and execute the model without external guidance or additional input." The tests by the independent reviewer should not include the use of CSUMM or MM5 results in CALMET.

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SPECIFIC CONCLUSIONS AND RECOMMENDATIONS

Section 1. Introduction - This section begins by describing a "Modeling System" that consists of several components. It is not initially clear which components are provided with the CALMET/CALPUFF modeling system. This initial discussion of the "Modeling System" adds an unnecessary level of confusion when trying to understand the basic formulation and features of the already complex CALMET/CALPUFF modeling system. Following are comments/suggestions for improving the Introduction section:

Section 1.2 Comments/Suggestions -

1. Add the following sentence after the first sentence of the first paragraph: "The shaded model components in Figure 1-1 are included in the CALMET/CALPUFF modeling system, whereas the other components are external programs that can be used with CALMET/CALPUFF, but are not required."

2. Change Figure 1-1 by shading the Preprocessors, CALMET, CALPUFF, CALPOST and PRTMET boxes. Change the figure caption to identify the shaded boxes as components of the CALMET/CALPUFF modeling system.

3. Modify Figure 1-2 to show the Geophysical data preprocessor programs (e.g., TERREL, CTGCOMP, CTGPROC, MAKEGEO) and their required input files (e.g., USGS terrain files).

4. Remove the "CSUMM - Prognostic Wind Field Model" box from Figure 1-2 since it is not a model component provided with CALMET.

5. Add a new program box in Figure 1-2 called "CALMM5 Preprocessor" above box titled "MM4/MM5 Data". The CALMM5 preprocessor is provided with CALMET. May want to add a box above this new box called "Gridded Output from MM4/MM5."

6. Shade or hatch all the program boxes in Figure 1-2 to distinguish the computer programs from the computer files. Modify the figure caption to identify shading.

7. Add the word "(Optional)" to the following boxes in Figure 1-2: "MM4/MM5 Data", "MM4 Terrain Weighting Factor File" and "Overwater Data Files."

8. Change the "Prognostic Gridded Wind Field" box in Figure 1-2 to "CSUMM Gridded Wind Field."

9. Add the "OPTHILL" program box to Figure 1-3 (CALPUFF model).

10. Shade or hatch all the program boxes (EPM, OPTHILL and CALPUFF) in Figure 1-3 to distinguish the computer programs from the computer files. Modify the figure caption to identify shading.

11. Shade or hatch all the program boxes (CALPOST and PRTMET) in Figure 1-4 to distinguish the computer programs from the computer files. Modify the figure caption to identify shading.

12. The list of model components after the 1st paragraph in Section 1.2 is incomplete. Descriptions of the following components should be added to make the discussion complete: KSP, EPM, READ56, TERREL, CTGCOMP, CTGPROC, PRLND1, MAKEGEO and CALMM5. The list of model components should be organized under three subheadings:

    • CALMET/CALPUFF Modeling System:
    CALMET, CALPUFF, PRTMET, CALPOST

    • CALMET/CALPUFF Preprocessor Programs:
    METSCAN, READ56, READ62, SMERGE, PXTRACT, PMERGE, CALMM5, TERREL, CTGCOMP, CTGPROC, PRLND1, MAKEGEO, OPTHILL

    • Optional External Programs Interfacing with CALMET/CALPUFF:
    CSUMM, MM4/MM5, CALGRID, KSP, EPM

Section 1.3 Comments/Suggestions -

1. Rename Section 1.3 to "CALMET Features and Options"

2. The statement on "Lambert Conformal Projection" in paragraph 1 is confusing - give some dimension to "large domains," and clarify what you mean by adjusting input winds to a Lambert Conformal projection (and why input winds in a Transverse Mercator projection - UTM grid - are not adjusted). Need brief description of model coordinate system and when to use UTM or Lambert Conformal. Note that UTM grids are given on various topographic maps.

3. In the first paragraph, identify how the initial guess field is typically determined (e.g., interpolation of upper-air observations).

4. Remove CSUMM from Table 1-1 since it is not a module provided with CALMET.

Section 1.4 Comments/Suggestions -

1. Rename Section 1.4 to "Summary of CALMET Data and Computer Requirements"

Add New Section 1.5 -

Add a new Section 1.5 titled "Basic Setup and Operation of CALMET." This new section should give a brief description (details given in Section 4) of the steps and considerations required to run CALMET. The steps should include:

a. <u>Specify Domain and Coordinate System</u> - Define modeling domain depending on application (e.g., near-field, far-field). Brief discussion on choice of domain size, coordinate system, grid resolution.

b. <u>Prepare Geophysical Data</u> - Discuss where can get data and what preprocessing programs to run and how to setup and run preprocessing programs.

c. <u>Prepare Meteorological Data</u> - Discuss where can get data and what preprocessing programs to run and how to setup and run preprocessing programs. Discuss input of optional data (e.g., CSUMM, MM5) and what observations (if any) are required with optional data.

d. <u>Prepare User Control File</u> - Specify run options/conditions using the CALMET GUI. Briefly discuss choice of various options. Discuss "Help" feature of GUI.

e. <u>Run CALMET and Produce Outputs</u> - Discuss the two run options in the GUI. Also discuss how errors are trapped and presented to the user. Describe the outputs and how they are used.

f. <u>Postprocessing Output</u> - Discuss how to setup PRTMET and describe the results.

<u>Section 2. Technical Description</u> - This section adequately describes the scientific basis of the CALMET model. The foundations of the model are sound and are the "state-of-science" for applications models. I did not have time in this review to check in detail that all the equations are correctly formulated and stated. I'm assuming that with the long development and testing history of this model that the equations are formulated correctly.

<u>Section 3. CALMET Model Structure</u> - This section adequately describes the CALMET model structure.

<u>Section 4. User Instructions</u> - This section needs to be enhanced and extensively reorganized such that a typical user has sufficient instructions and guidance to setup and successfully execute the CALMET model, and to understand and use the outputs from the model. Section 4 should cover the same topics as in the new Section 1.5, only in considerably more detail.

[I consider the revised Section 4 to be very important. This section should lead a user through each step of setting-up and running CALMET including identifying data sources, identifying important model features for typical applications and providing guidance on setting model parameters. The author of this revised Section 4 should start with a new modeling problem (conceptually) and lead the reader through each step and decision he/she needs to accomplish to successfully apply CALMET.]

A possible structure of Section 4 is

- 4.1 Overview - gives a summary of how to setup and run CALMET, gives an overview of what is contained in Section 4, and briefly describes how the user should apply Section 4.

- 4.2 Specify Domain and Coordinate System - gives guidance on how to determine the modeling domain (e.g., near-field or far-field, locations of sources and receptor areas, locations of prominent topographic features that can significantly influence meteorological fields, extent of local circulations); gives guidance on choice of grid size to resolve important topographic influences verses trade-off in computational time; give guidance on which map projection to use, UTM or Lambert Conformal.

- 4.3 Prepare Geophysical Input Data File - gives guidance on where to get data and how to run preprocessor programs to prepare CALMET inputs. This section contains original Sections 4.2 and 4.3.2.

- 4.4 Prepare Meteorological Input Data Files - gives guidance on where to get data, what data to use (should CSUMM or MM5 results be acquired and used) and instructions on how to create CALMET input files. This section contains original Section 4.1 and original Sections 4.3.3 through 4.3.10.

- 4.5 Prepare User Control File - gives guidance on importance of various control parameters and sensitivity of model results to control parameters (which parameters will most likely not be changed from default values?). Refer to CALMET GUI as easiest approach for preparing CALMET control file and executing CALMET. This section contains original Section 4.3.1.

- 4.6 Run CALMET and Produce Output Files - model can be run from GUI. Describe output files. Describe error trapping in model, where errors are identified to the user, and give actions to be taken by the user in case errors are encountered. This section contains original Section 4.3.11.

- 4.7 Postprocessing of CALMET Results - This section contains original Section 4.4.

SOME COMMENTS ON THE CALMET GUI

1. The CALMET graphical user interface is generally easy to use and simple to understand. The help feature is especially useful. I didn't have time in this review to see that all features of the GUI are working correctly and as expected.

2. The "CALMET Help" screen should include a discussion of the preprocessing that is required before CALMET can be run. This should include as a minimum a brief discussion of specifying the modeling domain and preparing the geophysical and meteorological data files.

3. The "Overview of Modeling System" in the "CALMET Help" screen should be revised to reflect my comments above concerning Section 1 of the CALMET User's Guide. Including CSUMM, MM5 and CALGRID in the list implies that these programs are provided with CALMET/CALPUFF.

4. Some of the technical discussions available under the help feature cannot be printed - the "PRINT" button is not always available in the help window. If possible, it would be useful if all the technical discussions and instructions could be printed from the GUI.

5. Would be useful to describe in the Help utility of what happens when CALMET encounters errors. I found that the error is listed in the LST file with no indication in the execution window that an error occurred during execution.

6. The HELP button on the "Surface Meteorological Stations" input screen is labeled OK.

7. In the "Wind Field Options" screen the "Use Preprocessed Data" option is not described in the help menu. Would be useful if a discussion of this feature can be added.

REVIEW OF THE CALPUFF USER'S GUIDE

GENERAL CONCLUSIONS AND RECOMMENDATIONS

1. The CALPUFF User's Guide gives sufficient technical detail of the model formulation to understand the scientific foundations of the model. However, the instructions and discussions for operating the CALPUFF model are unclear and the documentation is not sufficient to guide a typical user in the use of the model and its preprocessors. The CALPUFF User's Guide is not ready for release without revisions.

2. Sections 1 (Introduction) and 4 (User Instructions) should be revised as discussed below. Sections 2 (Technical Description) and 3 (CALPUFF Model Structure) are adequate.

3. After revisions are completed, an independent reviewer (experienced air quality modeler not necessarily familiar with CALPUFF) should take the User's Guide and the code (ready for release with all preprocessors) and show that the guide and code are complete by setting-up and running CALPUFF for applications of their choice (possibly a near-field and a far-field

application). The model should not be released until the document and code pass a minimum "user-friendliness" criteria, that of, "An experienced air quality modeler can efficiently setup and execute the model without external guidance or additional input."

SPECIFIC CONCLUSIONS AND RECOMMENDATIONS

Section 1. Introduction - Revise Section 1.2 as described in the above suggested revisions to the CALMET User's Guide, and add a new Section 1.5.

Add New Section 1.5 -

Add a new Section 1.5 titled "Basic Setup and Operation of CALPUFF." This new section should give a brief description (details given in Section 4) of the steps and considerations required to run CALPUFF. The steps should include:

a. Overview - Give a brief overview of setup requirements for typical near-field and far-field (long-range transport) applications of CALPUFF. For example, a typical far-field application of CALPUFF could require a minimum of just two input files, CALMET.DAT and CALPUFF.INP, for sources with constant release rates. The CALMET model would first be run to produce the CALMET.DAT file, and then the CALPUFF GUI could be used to produce the CALPUFF.INP file and run the model. Summarize the number of parameters that need to be specified (different from default) in the INP file for typical near-field and far-field applications of CALPUFF. What model features would typically be invoked for near-field (e.g., building downwash, subgrid scale complex terrain) and for far-field (e.g., puff splitting, deposition) applications. Discuss why CALPUFF was designed to be able to use meteorological files from other models (ISCST3, AUSPLUME, CTDMPLUS). Was this for convenience of comparing with the other models or does this capability extend the technical sophistication of CALPUFF over using the meteorological fields produced by CALMET? This feature of using single station met files in CALPUFF should not be used in far-field applications.

b. Specify Domain and Coordinate System - Similar discussion as in CALMET. Will want to discuss that any user-defined Cartesian (rectangular) coordinate system can be used. The coordinate system is not limited to just UTM and Lambert Conformal as is implied in the documentation. May want to discuss the computation grid (different from meteorological grid) and how to decide its size. Identify INP file inputs.

c. Prepare Geophysical Data - Discuss what data comes from CALMET. If not using CALMET.DAT file from a run of CALMET, where are the terrain heights, land use, etc. data specified. Discuss the generation of hill data for CTDM. Identify INP file inputs.

d. Prepare Meteorological Data - If using CALMET output refer to CALMET documentation. Discuss preparation of the other meteorological data files that can be used by CALPUFF. Identify INP file inputs.

e. Specify Sources, Species and Emissions Data - Discuss what species list should be used. Discuss how emission data specified (INP file or emission files). May want to identify interaction with EPM. Identify INP file inputs.

f. Specify Chemistry and Deposition Data - Discuss chemistry and deposition data. Where from and where specified. Identify INP file inputs.

g. Specify Receptor Coverage - Discuss choice of receptor coverage. Identify where specified. Identify INP file inputs.

h. Specify Run Conditions - Specify run options/conditions using the CALPUFF GUI. Briefly discuss choice of various options. Discuss "Help" feature of GUI.

i. Run CALPUFF and Produce Outputs - Discuss the two run options in the GUI. Also discuss how errors are trapped and presented to the user. Describe the outputs and how they are used.

j. Postprocessing Output - Discuss how to setup CALPOST and describe the results.

Section 2. Technical Description - This section adequately describes the scientific basis of the CALPUFF model. The foundations of the model are sound and are the "state-of-science" for applications models. I did not have time in this review to check in detail that all the equations are correctly formulated and stated. I'm assuming that with the long development and testing history of this model that the equations are formulated correctly.

Section 3. CALPUFF Model Structure - This section adequately describes the CALPUFF model structure.

Section 4. User Instructions - This section needs to be enhanced and possibly reorganized such that a typical user has sufficient instructions and guidance to setup and successfully execute the CALPUFF model, and to understand and use the outputs from the model. A possible structure of Section 4 is to add a new Section 4.1 called SETUP AND OPERATION OF CALPUFF with the subsections listed below. This new Section 4.1 should cover the same topics as in the new Section 1.5 (see discussion above), only in considerably more detail. Existing Sections 4.1 through 4.14 would be renumbered 4.2 through 4.15. The new Section 4.1 would refer to the subsequent sections of 4.

[I consider the new Section 4.1 to be very important. This section should lead a user through each step of setting-up and running CALPUFF, including identifying data sources, identifying important model features for typical applications (near-field, far-field), and providing guidance on setting model parameters. The author of this new Section 4.1 should start with a new modeling problem (conceptually) and lead the reader through each step and decision he/she needs to accomplish to successfully apply CALPUFF.]

- 4.1.1 Overview - In addition to that described in the new Section 1.5 above, this subsection should give a summary of how to setup and run CALPUFF, give an overview of what is contained in Section 4, and briefly describe how the user should apply Section 4.

- 4.1.2 Specify Domain and Coordinate System -
- 4.1.3 Prepare Geophysical Data -
- 4.1.4 Prepare Meteorological Data -
- 4.1.5 Specify Sources, Species and Emissions Data -
- 4.1.6 Specify Chemistry and Deposition Data -
- 4.1.7 Specify Receptor Coverage -
- 4.1.8 Specify Run Conditions -
- 4.1.9 Run CALPUFF and Produce Outputs -
- 4.1.10 Postprocessing Output -

SOME COMMENTS ON THE CALPUFF GUI

1. The CALPUFF graphical user interface is generally easy to use and simple to understand. The help feature is especially useful. I didn't have time in this review to see that all features of the GUI are working correctly and as expected.

2. The "Overview of Modeling System" in the "CALPUFF Help" screen should be revised to reflect my comments above concerning Section 1 of the CALPUFF User's Guide. Including CSUMM, MM5 and CALGRID in the list implies that these programs are provided with CALMET/CALPUFF.

3. The "CALPUFF Help" screen should include a discussion of the preprocessing that is required before CALPUFF can be run. This should include as a minimum a brief discussion of specifying the modeling domain and preparing the geophysical and meteorological data files.

4. Would be useful to describe in the Help utility of what happens when CALPUFF encounters errors.

APPENDIX B

DABBERDT PEER REVIEW

Review of CALMET and CALPUFF Models

This review is a high-level review owing to the extensive documentation and reports provided for the two models and the limited time available to conduct the review. The review focused primarily on the scientific and engineering aspects of the CALMET/CALPUFF modeling system as described in their respective user's manuals. Numerous, varied reports and papers addressing various aspects of model application and performance were also perused, but were not considered in a substantive way in these comments.

In EPA's "Charge to Peer reviewers," it was indicated that the EPA specifically proposes to "recommend use of CALMET/CALPUFF modeling system for long-range transport assessments" **and** "allow its use [for] near-field applications. Accordingly, this review focused both on near- and far-field aspects of the models.

Questions posed by EPA are indicated in *italics* and reviewer comments in normal type face.

1. Model Formulation
    a. *As a non-steady-state Lagrangian plume model, does CALPUFF represent the state-of-the-practice in its handling of mesoscale meteorological phenomena?*

The CALMET/CALPUFF modeling system indeed represents the state-of-the-practice insofar as dispersion models are concerned. The explicit integration of mesoscale meteorological models such as MM4/5 and CSUSUM with a diagnostic, mass-consistent wind model in CALMET is an important and welcome advance in dispersion modeling. The model should serve as a flexible and robust system for a wide range of applications both in the near field and the far field.

CALMET provides the ability to simulate a number of important local effects, such as: slope flows, kinematic terrain effects, terrain blocking, and sea breezes. It also allows the user the ability to isolate localized effects reflected in observations by the use of computational barriers. A valuable, future addition would be the ability to use nested grids both in the diagnostic wind field model and in the diffusion model (CALPUFF). This approach could facilitate the treatment of local terrain variations and might avoid some of the complexities of the numerical schemes in CALPUFF which are designed to deal with terrain-induced flow effects on the subgrid scale.

Other positive attributes of CALMET are:

Reasonable scheme for estimating vertical velocities
Appropriate smoothing features
Ability to consider an unlimited number of surface and upper-air
stations (MESOPAC II is limited to 25 surface and 10 upper air stations)
Multiple vertical layers allowed (MESOPAC II is limited to two)

The following are comments and observations that either require further explanation in the documentation or could perhaps form the basis for future CALMET improvements; they are not intended to detract from the positive nature of the recommendations of this review:

- Clarify the limitations of the wind turning options available. They do not explicitly consider thermal wind effects leading to backing or enhanced veering. These can only be represented through the "user-defined" scaling factors.
- Discussion on the lake/sea breeze option is not clear
- Have the authors considered a vorticity conservation option in addition to divergence minimization for the diagnostic wind field model?
- Bowen ratio specification does not explicitly consider whether precipitation has occurred recently, thereby modifying the Bowen ratio
- Recommend adding an algorithm to specifically incorporate ACARS profiles from landing and departing commercial aircraft
- Unclear whether Mahrt's "shooting slope flow parameterization" is a standard feature of CALMET
- Update PC performance values to Pentium class PC's
- Add discussion concerning the proper use of mesoscale model outputs when 4DDA has been undertaken. Should the observations used in the 4DDA then be excluded from the diagnostic model application, etc.? When might it be more appropriate to explicitly model terrain effects in the mesoscale models, rather than approximate these effects in the DWM?
- Unclear whether the 3D temperature fields can be obtained directly from the mesoscale model for use in CALMET.
- Are there plans to incorporate other modeled or analyzed fields into CALMET, such as the Univ. Oklahoma mesoscale model, NCEP's Eta model, and NCEP's analyzed fields?

On the dispersion side, CALPUFF also represents significant advances over MESOPUFF II. This is especially the case regarding CALPUFF treatment of near-field building effects and near- and far-field terrain effects on both transport and diffusion. The developers have tried, and I believe succeeded, in building into CALPUFF explicit treatment of virtually all of the important physical processes affecting transport, diffusion, deposition, and transformation. This is not to say that there is not room for improvements in the individual parameterizations, but the present model configuration represents a significant advance over other puff and plume models such as MESOPUFF II and ISC. The report from the IWAQM indicates there may still be limitations in the CALPUFF treatment of the linear chemistry involving SO_2 and other pollutants; I have not considered these issues in this review.

b. *Within the context of regulatory dispersion models in the US, does CALPUFF provide significant advances over MESOPUFF II? If so, what do you think are the most important scientific advancements of CALPUFF?*

As indicated in my response to Issue 1-a., it is my opinion that **CALPUFF indeed represents a very significant advance over MESOPUFF II**. The three most important areas of improvement are:

- The wind field representation provided by CALMET and the explicit integration of mesoscale model outputs

The explicit treatment of terrain effects, both in the windfield model and the dispersion model
A comprehensive treatment of near-field effects, including building effects

c. *Are there modules or features of CALPUFF in which an improved formulation or treatment is necessary? If so, please discuss what is needed prior to release of the model for general use.*

It is not my opinion that any aspect of the CALMET/CALPUFF system needs to be changed prior to release. This is not to say that there may not be errors in the code or in the algorithms, but such checking goes far beyond the scope of this review. In fact, if the Agency has not already done so, I would encourage it to retain an independent firm or consultant to perform independent, in-depth tests and checks of the model to ensure that there are not errors in coding and the like. The Agency is also encouraged to seek an independent assessment of the performance of the model against field experimental data, and against other, less comprehensive - but well characterized - models. Much of this has already been done as reflected in the interim draft report of the IWAQM from the Sixth Modeling Conference and the draft EPA report comparing CALPUFF with ISC3. However, a summary study that seeks to integrate the findings from the many individual CALPUFF evaluations done to date would be a valuable addition to what has been an impressive body of work.

Are there areas where the model might be improved? Nesting would represent an important improvement to both CALMET and CALPUFF. In the case of the latter, it might improve the treatment of terrain effects on the transport fields and on dispersion, while perhaps simplifying the model as well. The developers and the Agency might consider pursuing nesting as a means to explicitly consider terrain effects, especially with the rapid advances in PC and workstation processing speeds and RAM.

Another area for improvement of this and other models lies in their quantification of uncertainty (as reflected in the model inputs, in the model physics, and through the stochastic nature of the atmosphere). Significant advances are being realized in weather and climate forecasting through the use of ensemble simulations which enable the user to consider the range of likely end states and the associated range of uncertainty. This expertise may be highly transferable to the problem of dispersion simulation.

2. Documentation

a. *Is the current organization of the CALMET and CALPUFF User's Guides adequate? Are the model formulations sufficiently documented for technical critique and understanding?*

Both user's guides are well written and provide very adequate documentation. The organization is similarly appropriate. And the availability of user tutorials given by the developers is an added positive factor.

b. *Is the discussion and presentation of the model and its features clear? Please note any sections of the documentation that were unclear or confusing.*

The presentations are largely very clear and well documented (and supported by the liberal use of references). Where certain areas were not clear, they have been identified in Section 1 (e.g. CALMET lake/sea breeze discussion of this review).

c. *Is the documentation sufficient to guide a typical user in the use of the model and its preprocessors?*

Yes. However, this reviewer did not attempt to load and execute the model, and so I am only indicating my opinion based on the documentation I have read. There may be implementation issues that would require further attention. A second issue concerns what constitutes a "typical user?" Given the applications and users with whom I am familiar, I expect that most informed users will find the documentation at least sufficient, if not far superior to many other models.

3. Performance Evaluation

a. *Have sufficient comparisons and sensitivity studies been completed to allow judgement to be made regarding model performance? If more comparisons are needed, are data available or would this entail new field studies?*

A very difficult set of questions to answer. At this stage, the extent of evaluation of CALPUFF performance is probably superior to that of many other models. Is this sufficient? Probably yes, because CALPUFF incorporates a basic formalism that is well understood and numerous algorithms, each of which has been reasonably well characterized individually. It is the composite that has seen modest but meaningful performance evaluation. Further, the mesoscale and DWM modeling approaches used in CALMET have undergone a history of more than 20 years of test and evaluation in the meteorological and wind power communities.

b. *Has enough evaluation work been done to recommend use of the model?*

Yes, the model is recommended for use as proposed. Additionally, I recommend that the Agency pursue additional studies to further characterize its performance, and make further improvements. This issue was addressed earlier in my response to Issue 1-c.

4. User Friendliness of Entire System

a. *Do "user friendliness" concerns outweigh general release of the system at this time?*

No, they do not in this reviewer's opinion. I envision the release of CALMET/CALPUFF as having two significant benefits to the user community. One, it will provide informed users with a more powerful, flexible, and realistic simulation tool. And two, it may help increase the level of expertise within the user community.

b. *If 'yes' to (a.), what specifically needs to be addressed?*

Although I responded 'no,' I suggest that a more formal user orientation and training program be adopted. This could be the EARTH TECH program, or other programs conducted by other firms. In any case, it would be helpful and desirable to have EPA involvement to ensure the quality of such programs. For example, EPA might seek to develop a series of computer-based learning modules to provide tutorials. The University Corporation for Atmospheric Research through its COMET program has a very successful history of providing similar training modules to the weather forecasting community.

APPENDIX C

SIMMONS PEER REVIEW

Peer Review Comments by Larry L. Simmons

The combination of CALMET and CALPUFF is under consideration by the U.S. Environmental Protection Agency for "Guideline" status. CALMET creates the wind fields and CALPUFF advects and disperses along the wind vectors created by CALMET. This model combination is a major departure from the past Guideline models that have relied on a single hourly wind vector that applied over the entire modeling domain run in a steady-state mode. The CALMET and CALPUFF approach allows for dynamic wind fields that change spatially and temporally, a characteristic that we all see in the real world.

We must pay a price for this sophistication. There is a steep learning curve for this model. For those of us trained in the "Regulatory Default" world of the Meteorological Processor for Regulatory Models (MPRM) and the Industrial Sources Complex (ISC) model, the CALMET/CALPUFF model can seem very confusing. We need some format that serves as a "Regulatory Default" to help state agency personnel in their review.

Earth Tech, Inc., as authors of the model, have provided software tools to aid in the transition of ISC and CTDMPLUS files to CALPUFF. They have also provided Graphical User Interface (GUI) files to aid in setup of the CALMET and CALPUFF input files and the post-processor CALPOST. Their GUI software has a standard windows interface with Help Files that can assist the user in selecting a variable setting. Earth Tech, Inc. also provides a 2.5 day hands-on training course. I attended the course in Charlottesville, Virginia over May 20 through 22, 1998 and found it very helpful.

One weakness with implementation of CALMET is in the area of visualization of the wind fields. The utility, PRTMET, can give a snap-shot of a single layer for a single period. While that is helpful, it is not always sufficient in assessing the appropriateness of input selection to CALMET. This problem has been addressed partially by a third party vendor. Enviromodeling Ltd. of Santiago, Chile provides a product called CalDESK that takes the CALMET input and output files and allows for animation of the wind fields. I have used CalDESK for about five months. It was very helpful as part of a study in Abu Dhabi over a domain of 350 by 150 kilometers in seeing the coastal influence and how the emissions from off-shore platforms were impacting the main land. CalDESK contains a feature that allows forward or backward trajectory of a plume from a single source.. This feature is helpful in explaining how varying wind fields like cyclonic flow can bring emissions from sources in different directions to impact a specific receptor. Tools like CalDESK must come forward for CALMET/CALPUFF to be effectively utilized. Earth Tech, Inc indicated that they are working on such a tool and it should be available late this year.

Our firm assisted in preparing a Model Protocol to use CALMET/CALPUFF for a sulfur dioxide State Implementation Plan (SIP) project for a section of the Ohio River Valley based in Marshall County, West Virginia. That protocol relied on integrating the data from four 100-meter towers and co-located SODARs extending over a 15 kilometer section of the Ohio River Valley. A consortium of industries in the area pooled their resources to collect the meteorological data and to conduct the study. This group is comprised of the local facilities of CONOCO, Columbian Chemicals, PPG, Bayer and ORMET and operates under the name Industrial Sources Group (ISG). The Division of Environmental Protection (DEP) in West Virginia is the lead agency.

The DEP established a stakeholders group called the Technical Assessment Group to prepare the technical protocol. Representatives from U.S. EPA in Regions III and V participated with those from Ohio EPA under the leadership of the DEP. NOAA personnel assisted the DEP in review of the SODAR data. Representatives from the local electric utilities, American Electric Power and First Energy Corporation and their consultants participated in the group. Finalization of the Model Protocol occurred in December, 1997. Approval of the protocol occurred in May, 1998. Extensive testing was undertaken in selecting the switch settings for the model.

An important input to CALMET is the GEO.DAT file. This file contains the terrain heights and land use characteristics for the area of the modeling domain. These data are available from Digital Elevation Model (DEM) files and Land Use and Land Classification (LULC) files provided by the U.S. Geological Survey. The CALMET tool CTGPROC.EXE is used to prepare the LULC data. The CALMET tool MAKEGEO.EXE then prepares the GEO.DAT file. However, the user must exercise some judgement in preparing these files. An example is the use of LULC data. Our project utilized the LULC information directly from the U.S. Geological Survey files for a section of the Ohio River centered on the Mitchell Power Station. The result was that the land typing for the river was shifted west in the northern portion of the drawing and east in the southern portion of the drawing. This mis-matching of terrain elevation to land typing would yield inappropriate local slope flows. The user must be cautioned to review the LULC data closely and make appropriate corrections. This is commonly seen with electrical transmission line corridors that have a LULC category of 14 and corresponding CALMET input value of 10. These corridors may be better classified as pasture with significantly different characteristics for purposes of CALMET.

At this time the only way to get vertical profile meteorological data into CALMET is to use the UP.DAT file. Up until recently, that file relied on the TD6201 format. Velocity is limited to integer values in TD6201. Therefore, a threshold velocity of 1 meter per second is assumed in TD6201 and is an artifact of the National Weather Service instrumentation. Today we use wind sensors with threshold values in the area of 0.22 meters per second. The TD6201 format does not reflect this sensitivity in wind speed. The TD6201 formatted data for valley settings would define many hours as calms when in fact wind speeds would exceed 0.22 meters per second. The influence of the TD6201 format was tested in several CALPUFF runs for the Ohio River sites. We modified TD6201 to allow wind speeds with a FORTRAN format of F5.1 for contrast. TD6201 model runs showed unrealistically high impact in the valleys after extended calms. The same model runs with the modified TD6201 data did not show these unrealistically high impacts because the buildup of pollutants did not occur as shown with the original TD6201 formatted data. Earth Tech, Inc. has addressed this issue in CALMET by allowing for a modified TD6201 format. The user can specify comma delimited data of a TD6201 type that allows non-integer wind speeds. I highly recommend this option be used to input on-site meteorological data to CALMET.

I recommend the use of CALMET and CALPUFF.

APPENDIX D

EPA'S CHARGE TO PEER REVIEWERS

Charge to Peer Reviewers

EPA is proposing the use of CALPUFF for regulatory applications. It is therefore prudent that a science peer review be done to assess to modeling systems formulation, documentation, existing performance evaluations, and user friendliness. EPA is specifically proposing to recommend use of the CALMET/CALPUFF modeling system for long range transport assessments in Class I areas, and allowing its use near-field applications.

1. Model formulation

Note that exact calculation of visibility impairment (or any other air quality related value) is the purview of the applicable Federal Land Manager. (i.e., EPA is only offering specific guidance on the basic parameters.)

a. As a non-steady-state Lagrangian plumemodel, does CALPUFF represent the state-of-the-practice in its handling of mesoscale meteorological phenomena?

b. Within the context of regulatory dispersion models in the US, does CALPUFF provide significant scientific advances over MESOPUFF II? If so, what do you think are the most important scientific advancements of CALPUFF?

c. Are there any modules or features of CALPUFF in which an improved formulation or treatment is necessary? If so, please discuss what is needed prior to release of the model for general use.

2. Documentation

a. Is the current organization of the CALMET and CALPUFF User's Guides adequate? Are the model formulations sufficiently documented for technical critique and understanding?

b. Is the discussion and presentation of the model and its features clear? Please note any specific sections of the documentation that were unclear or confusing.

c. Is the documentation sufficient to guide a typical user in the use of the model and its preprocessors.

3. Performance Evaluation

CALPUFF has been evaluated with data from several field studies. Availability of suitable data is limited. EPA is unaware of any evaluation that has assessed CALPUFF's treatment of secondary pollutants. (Note that EPA is recommending that CALPUFF's outputs be used for assessment of secondary pollutants, but is not requiring it.) Given this:

a. Have sufficient comparisons and sensitivity studies been completed to allow judgment to be made regarding model performance? If more comparisons are needed, are data available or would this retail new field studies?

b. Has enough evaluation work been done to recommend use of the model?

4. User Friendliness of Entire System

EPA and IWAQM recognize that operation of the CALMET/CALPUFF system as presently configured is arduous. It is believed, though, that with time and experience and the expenditure of additional resources in the future, the system's ease of use will improve. Nevertheless, it would be useful to know:

a. Do "user friendliness" concerns outweigh general release of the system at this time?

b. If "yes" to (a.), what specifically needs to be addressed?

APPENDIX E

OVERVIEW OF PEER REVIEW PROCESS

OVERVIEW OF THE PEER REVIEW PROCESS
for the
PEER REVIEW OF CALMET/CALPUFF AIR DISPERSION MODELING SYSTEM

The US Environmental Protection Agency, Office of Air Quality Planning & Standards, Air Quality Modeling Group, in an effort to provide for independent, credible peer reviews of air dispersion models and studies retained a contractor, The KEVRIC Company Inc. of Silver Spring MD/Durham, NC to manage and coordinate the peer review project.

The peer review as handled as a work assignment under a general contract with the KEVRIC Company. Once the work assignment was issued, KEVRIC prepared a detailed work plan for the approval of the Work Assignment Manager (WAM). For the CALMET/CALPUFF project, the official WAM was Warren Peters. The acting WAM was Tom Coulter. Other EPA technical support was provided by John Irwin.

The work plan provided a description of the tasks to be completed, the estimated time frame and estimated manhours/cost requirements. The description below describes the process by which the peer review for CALMET/CALPUFF Air Dispersion Modeling system was conducted.

The information provided to KEVRIC under the Work Assignment Statement of Work included;

- a "Charge to Reviewers", formulated by EPA, that outline the specific direction and technical scope of the task for the peer review team.
- a list of qualified candidates, as known to EPA
- a list of materials to provided to the peer reviewers by KEVRIC/EPA

KEVRIC contacted several persons on the qualified candidate list, described the project to them and requested their participation based on their interest and availability. Three candidates were retained, Dr. Jerry Allwine, Mr. Larry Simmons and Dr. Walt Dabberdt. Dr. Allwine, consented to act as chairperson, in that he would, in addition to providing peer review, compile a report that would summarize all of the peer reviewers comments and opinions into one concise report. This peer review team was approved by the acting WAM.

KEVRIC provided a sub-contract mechanism for the peer reviewers to be compensated for their time. It was estimated that each peer reviewer would spend up to 20 hours on the review and Dr. Allwine would spend an additional 20 hours compiling a report.

KEVRIC then arranged for the review materials to be reproduced and distributed to each reviewer. The materials provided to be reviewed were those provided to KEVRIC by USEPA as provided under the work assignment. These materials were as follows:

1) Users Guide for the CALMET meteorological Model

2) Users Guide for the CALPUFF Dispersion Model
3) EPA, 1998. Inter-Agency Workgroup on Air Quality Modeling (IWAQM) Phase II Final Report and Summary: Recommendations for Modeling Long Range Transport Impacts. EPA-454/R-98/XXX.
4) An executable copy of the code for the CALMET/CALPUFF models.

Once these materials were distributed, KEVRIC scheduled a teleconference call which involved the team members, V. Hanzel of KEVRIC, and Tom Coulter and John Irwin of EPA. The conference call was conducted to discuss the charge to the reviewers and establish commonality in the peer reviewers efforts and to initiate the peer review. This discussion resulted in another piece of documentation being requested as background information. Subsequently, KEVRIC reproduced and distributed he MESOPUFF II Users manual to the team members. In addition, Dr. Allwine indicated that here were two recent reports that would be of interest to the team members and that he would provide them to the other reviewers.

The peer reviewers were instructed to perform their review according to the "Charge to Reviewers". It was agreed that contact amongst them was permissible and encouraged. The comments for Dr. Dabberdt and Mr. Simmons were to be forwarded to Dr. Allwine via email.

After the reviewers provided comment, a draft report was compiled by Dr. Allwine that provided a summary of the opinions of the team and specific individual comment, as appropriate. This report was distributed via email to all parties for their review.

A second conference call was scheduled by KEVRIC to discuss the draft report and determine if any changes, modifications or clarifications were needed. Dr. Allwine revised the draft report and redistributed the final version to the team members.

The final version of the report was compiled, reproduced and submitted to EPA by KEVRIC. This compilation included addition of other documentation such as resumes of the reviewers, this overview of the process and additional reports reviewed (as provided by Dr. Allwine).

APPENDIX F

LIST OF DOCUMENTS REVIEWED

Robe, F.R. and J.S. Scire. 1998. "Combining Mesoscale Prognostic and Diagnostic Wind Models: A Practical Approach for Air Quality Applications in Complex Terrain." Preprints, Tenth Joint Conference on the Application of Air Pollution Meteorology, Phoenix, Arizona. American Meteorological Society, Boston, MA. January 11-16, 1998.[1]

Scire, J.S. 1997. "A Simple Soil Moisture Model for Air Quality Applications." Presented at the 12th AMS Symposium on Boundary Layers & Turbulence, Vancouver, BC, Canada, July 28 - August 1, 1997. Earth Tech, Inc., Concord, MA.[2]

Scire, J.S. and F.R. Robe 1997. "Fine-Scale Application of the CALMET Meteorological Model to a Complex Terrain Site." Presented at the AWMA's 90th Annual Meeting and Exhibition, Toronto, Ontario, Canada, June 8-13, 1997. Earth Tech, Inc., Concord, MA.[2]

Scire, J.S., D.G. Strimaitis and R.J. Yamartino. 1998. A User's Guide for the CALPUFF Dispersion Model (Version 5.0) - DRAFT. Earth Tech, Inc., Concord, MA.[2]

Scire, J.S., F.R. Robe, M.E. Fernau and R.J. Yamartino. 1998. A User's Guide for the CALMET Meteorological Model (Version 5.0) - DRAFT. Earth Tech, Inc., Concord, MA.[2]

Stimaitis, D.G., J.S. Scire and J.C. Chang. 1998. "Evaluation of the CALPUFF Dispersion Model with Two Power Plant Data Sets." Preprints, Tenth Joint Conference on the Application of Air Pollution Meteorology, Phoenix, Arizona. American Meteorological Society, Boston, MA. January 11-16, 1998.[2]

U.S. EPA. 1992. A Modeling Protocol for Applying MESOPUFF II to Long Range Transport Problems. EPA-454/R-92-021. U.S. Environmental Protection Agency, Research Triangle Park, NC.[2]

U.S. EPA. 1994. A Revised User's Guide to MESOPUFF II (v 5.1). EPA-454/B-94-025. U.S. Environmental Protection Agency, Research Triangle Park, NC.[2]

U.S. EPA. 1998. A Comparison of CALPUFF with ISC3 - DRAFT. U.S. Environmental Protection Agency, Research Triangle Park, NC.[2]

U.S. EPA. 1998. Interagency Workgroup on Air Quality Modeling (IWAQM) Phase 2 Summary Report and Recommendations for Modeling Long-Range Transport Impacts - DRAFT. U.S. Environmental Protection Agency, Research Triangle Park, NC.[2]

Wu, Z.X., J.S. Scire and R. O'Neal. 1998. "Comparison of One Year of MM5 and CALMET Meteorological Fields with Observations in the Western United States." Preprints, Eighth PSU/NCAR Mesoscale Model User's Workshop, , Boulder, Colorado. June 15-16, 1998, pp. 131-137.[1]

[1] Provided to team members by Dr. Jerry Allwine. Copy attached.
[2] Provided by EPA as part of review.

Preprints Eighth PSU/NCAR Mesoscale Model User's Workshop, 15-16 June 1998, Boulder, CO, pp. 131-137.

Comparison of One Year of MM5 and CALMET Meteorological Fields with Observations in the Western United States

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Abstract

Results of a one year MM5 run over the western United States are compared with the observations from 18 surface, 2 upper air sounding, and 67 precipitation stations. The comparison shows that at the surface, the MM5 wind direction is generally consistent with observations. The MM5 wind speed differs from the observations within 1 ms^{-1} at 11 of 18 stations. At upper levels, the MM5 models the wind direction quite well at one station (Lander, WY; Station 24021), but not at the other (Salt Lake City, UT; Station 24127). The MM5 wind speed at upper levels is higher than observed. The difference between MM5 and observations is less than 1 ms^{-1} below 500 m at Salt Lake City, but reaches 4-5 ms^{-1} at Lander's. Using the MM5 wind field as an initial guess, CALMET can improve significantly the wind field near Salt Lake City. MM5 simulates the 1995 annual precipitation reasonably well. The maximum observed precipitation is located at one of the MM5 wet areas, the observed amount is also close to the modeled amount.

1. Introduction

Pursuing better meteorological fields is a constant effort in air quality modeling. Small scale wind convergence or temperature inversion over complex terrain is often responsible for the non-compliance of air quality standards, but modeling these small features is difficult. Precipitation is crucial for the atmospheric scavenging process which cleans the atmosphere, but it is highly variable, and rarely measured in high mountain regions, where the precipitation can be 5-10 times more than that in the areas nearby at low elevation (Daly et al., 1994). We tried to use the Fifth-Generation NCAR/Penn State Mesoscale Model (MM5, Hassgenson et al., 1994) and CALMET (Scire et al., 1990) together to improve the simulated meteorological fields, which then drive a dispersion and transformation model for regulatory purposes. CALMET is a meteorological diagnostic model. It was designed to be capable of handling a domain size from tens of meters to hundreds of kilometers. The MM5 wind field is used as an initial guess in CALMET. CALMET then generates its wind field in two steps; the initial wind is first adjusted to account for the kinematic and thermal effects of terrain on wind (Scire and Robe, 1997); then the observations are introduced using objective analysis to obtain the final wind field.

The MM5 main domain covers an area of 1500 km in the east-west direction and 1380 km in the south-north direction, centered at 42.55°N, 108.55°W. The MM5 nested domain and CALMET domain are shown in Figure 1; They cover most of Wyoming and part of Colorado, Utah and Idaho. The grid size is 60 km for the main MM5 domain, 20 km for the MM5 sub-domain, and 4 km for CALMET. The MM5 has been run for the year 1995 based on about every 10-days period with a spin-up time of 12 hours. The main physics options used in the MM5 modeling are the Grell cumulus parameterization, the MRF planetary boundary layer scheme, the Goddard micro-physics for moisture scheme, cloud radiation scheme, and multi-layer soil scheme. In CALMET, the vertical resolution varies from 10 m near the surface to 900 m at 2500 m. Eighteen surface stations and two upper air stations are used in the comparison of MM5 wind field with observations; their locations are given in Figure2. Also shown in Figure 1 is the terrain height used in CALMET, which is based on the 3-arc second elevation data from Rocky Mountain Communications Inc. The land-use data are from the U.S. Geological Survey. The 1995 CALMET run is only completed for an area about 120 km by 120 km near Salt Lake City, where significant differences exist between MM5 and the observations. Modeling over the whole domain is still in progress.

2. Wind Direction

The MM5 wind direction for a one-year run is generally consistent with that of station observations. An example is given in Figure 2, which is the annual wind-roses from Station 10 (Amoco) and from MM5 at the same location. The dominant wind direction is west, and MM5 preserves this feature. MM5 also catches the relatively high wind frequencies in the southeast direction. Figure 3 shows the upper level wind-roses from the upper air sounding station Lander (Station ID 24012) and from the corresponding MM5 grid. Note that the station wind-rose is based on twice daily soundings, but the MM5 wind-rose is from the hourly model wind. The observed dominant wind is from west. the MM5 wind shows a similar tendency.

The wind direction at Salt Lake City, however, shows a large discrepancy between the observations and the MM5 results (Figure 4). At the surface, the dominant wind direction is from south to southeast and the second dominant wind direction is north - northwest. From the surface to about 1000 m above ground level, the dominant wind directions do not change much (not shown). The MM5 wind shows only slightly the dominant southern wind at the surface, and it misses entirely the observed south-southeast dominant wind at upper levels.

3. Wind Speed

The surface wind speed from the surface and upper air stations, and from MM5 are shown in Table 1. Shown in Table 1a, at the surface, the difference between observations and the model is within 1 ms^{-1} for 11 stations, within 2 ms^{-1} for 5 stations, and larger than 2 ms^{-1} for 2 stations. At 11 out of 18 stations, the model wind speed is lower than observations, while the other 7 stations show the opposite. Since log-profile interpolation is applied to the MM5 wind to calculate the wind speed at the anemometer height, increasing vertical model resolution near the surface to model the wind speed at the anemometer height directly would improve the model wind at the surface. However layers too thin near the surface raise computation problems.

At the upper levels (Table 1b), the MM5 model shows consistently higher wind speed than those observed, especially at the lower levels at Lander (Station ID 24021). At Salt Lake City (Station ID 24127) the difference between the model and observations is less than 1 ms^{-1} from 50 m to 500 m, but at Lander, the model wind speed is more than doubled compared to observations. The higher model wind speed can also been seen in the wind-roses in Figure 4. The 10-day integration of MM5 was suspected to cause the higher wind bias, but the statistics for the first three days of each integration period still shows the same tendency.

The comparison shows the improvement of MM5 wind field over complex terrain areas is needed for the air quality study. More tuning of model parameters may give better results. A joint use with other higher resolution models may offer another way for the improvement.

4. Improvement of Wind Field near Salt Lake City Using CALMET

The large discrepancy between the model and observations has significant effect on the air quality modeling. CALMET has proven to be very successful in reducing this discrepancy. Figure 5 shows the CALMET wind-rose at Salt Lake City (left panel). Both the wind direction and wind speed in Figure 5 shows good agreement with the observations given in Figure 4. The dominant south-southeast wind and second dominant north-northwest wind in the observations are simulated successfully in the model. The improvement at levels is remarkable; the lost southern dominant wind is recovered very well in the CALMET wind, so is the second dominant north-northwest wind.

Since the observations from Salt Lake City are used in the second step of wind computation in CALMET, it is necessary to examine the model sensitivity to the introduced observations, or the relative importance of the first step wind adjustment (kinematic and thermal effects) to that of the second step adjustment (nudging to observations). CALMET was run again without both the surface and upper air sounding observations from Salt Lake City; the results are also shown in Figure 5 (right panel); the main feature remains. CALMET can keep it even when only one surface and one upper air station are used in the modeling, indicating that the kinmatic and thermal adjustment in CALMET is capable of catching the small scale variations of wind field over a complex terrain area. The terrain elevation in Figure 1 suggests the existence of a strong channeling effect near Salt Lake City. The terrain height is about 2000-2400 m to the east, but lower than 1400 m to the west. The channeling effect should disappear above 2400 m. The observations and model wind above this level are westerlies, same as that at Lander's. The elevation gradient in the MM5 terrain data is greatly reduced near Salt Lake City (not shown), which is likely the reason for the lack of dominant southern or northern winds in MM5.

5. Precipitation

1995 annual precipitation from MM5 is shown in Figure 6. High precipitation is located in the northwest and southeast of the MM5 sub-domain at the areas of high elevation; between them and in the western edge of the model domain is dry areas. The precipitation pattern is consistent with that in PRISM (Daly et al., 1994), which is the 30-year climatology for the period of 1961-1990. The difference of precipitation between high and low elevations is substantial, more than ten times higher at high altitude than at low altitude. The MM5 precipitation reaches 98 cm in the Rocky Mountains, but it can be as low as 10 cm in the Lee area. The seasonal variations of precipitation are obvious in MM5. The high precipitation is located in the west and south of the MM5 domain in January, but moves to the north and east in June.

The observations from 67 precipitation stations are also given in Figure 6 (plotted numbers). The observations show that the MM5 simulates the 1995 precipitation reasonably well. The observed peak annual precipitation is 84 cm in the Rocky Mountains, located at one of the modeled wet areas, where the MM5 maximum is 96 cm. In the modeled dry area, the observations are all low, providing reasonable agreement.

6. Summary and Conclusion

One year of MM5 modeling results over the western part of the United States are compared with the observations from 18 surface, 2 upper air sounding, and 67 precipitation stations. The comparison shows that the MM5 wind direction agrees generally with the observations. The MM5 wind speed at the surface differs from observations within 1 ms^{-1} for most stations. At upper levels the MM5 wind speed is usually higher than observations, especially below 500 m at the station in Lander, WY. The channeling effect on the wind near Salt Lake City is missed in MM5. Using the MM5 wind field as an initial guess field, CALMET can significantly improve the wind field over complex terrain areas.

The MM5 annual precipitation pattern is consistent with the PRISM climatology and with the observations from 67 precipitation stations. The model precipitation on the upper elevation of the Rocky Mountains can be ten times as large as that in its lee area.

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Table 1. Comparison of the MM5 wind speed with the station observations. (a) with surface stations, (b) with upper air sounding stations.

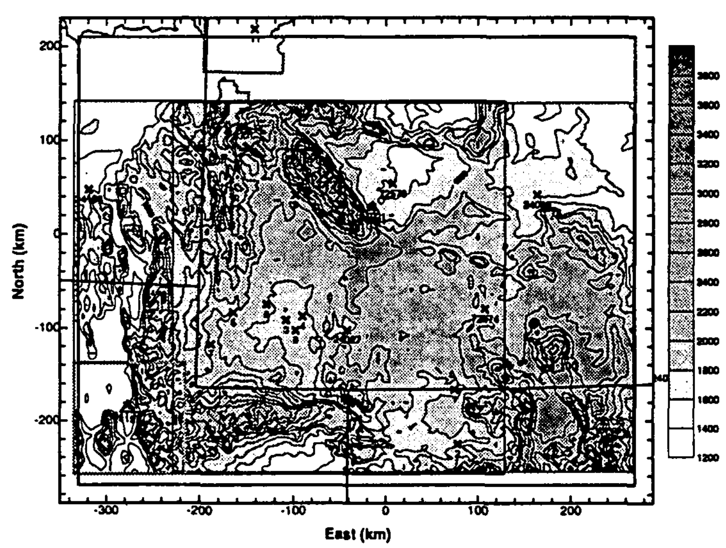
a. Surface

STN_ID	WS_MM5 m/s	WS_STN m/s	DIF_WS m/s
1	4.03	2.12	1.91
2	3.63	2.04	1.59
3	3.25	2.82	0.43
4	3.03	3.67	-0.64
5	4.08	4.65	-0.57
6	3.13	3.86	-0.73
7	4.79	5.68	-0.89
8	3.24	4.28	-1.04
9	3.73	4.11	-0.39
10	5.17	4.63	0.54
11	4.48	1.52	2.96
24021	6.06	2.81	3.25
24027	3.99	4.74	-0.75
24089	4.29	4.92	-0.63
24127	3.46	3.80	-0.34
24156	3.42	4.52	-1.11
72574	5.19	6.60	-1.41
72576	3.42	3.35	0.07

b. Upper Air

Height (m)	Station ID 24021	MM5 (m/s)	Station ID 24127	MM5 (m/s)
50	3.83	7.96	4.32	4.93
100	4.04	8.88	4.60	5.03
150	4.21	9.32	4.87	5.23
200	4.34	9.71	5.17	5.45
300	4.56	10.11	5.44	5.69
500	4.86	10.59	5.36	6.11
1000	6.09	11.02	5.61	7.28
1500	7.95	11.38	6.61	8.60
2000	10.06	12.02	8.00	9.96
2500	12.17	12.88	9.51	11.32
3000	13.66	13.79	11.11	12.51

Figure 1. MM5 and CALMET domains, CALMET terrain elevations, and the eighteen surface stations (X) and two upper air sounding station(triangle) used in the paper.



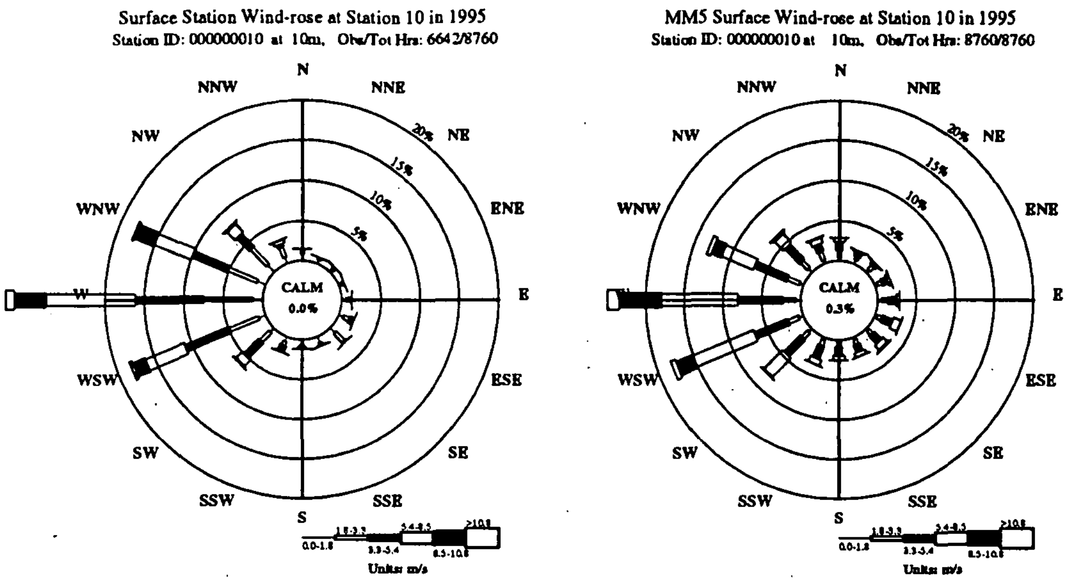


Figure 2. Surface station and MM5 wind-roses at Station 10

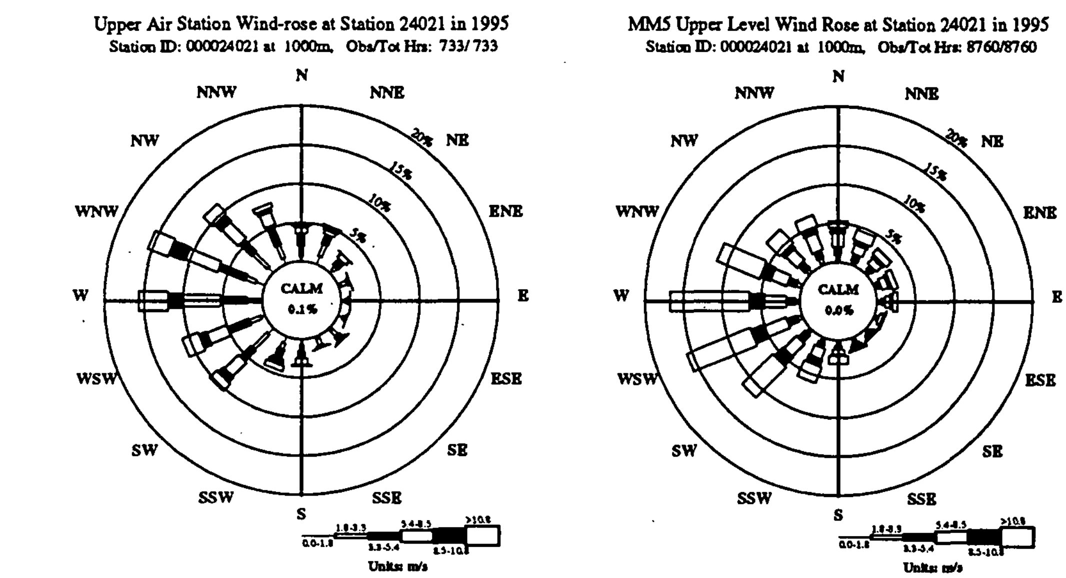


Figure 3. Upper air station and MM5 wind-roses at Station 24021

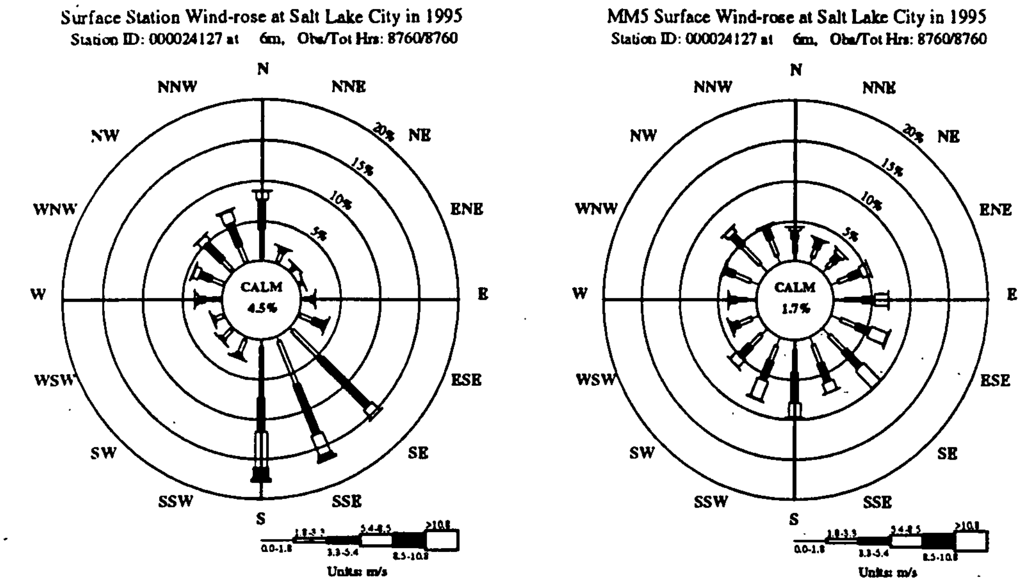


Figure 4. Surface station and MM5 wind-roses at Salt Lake City

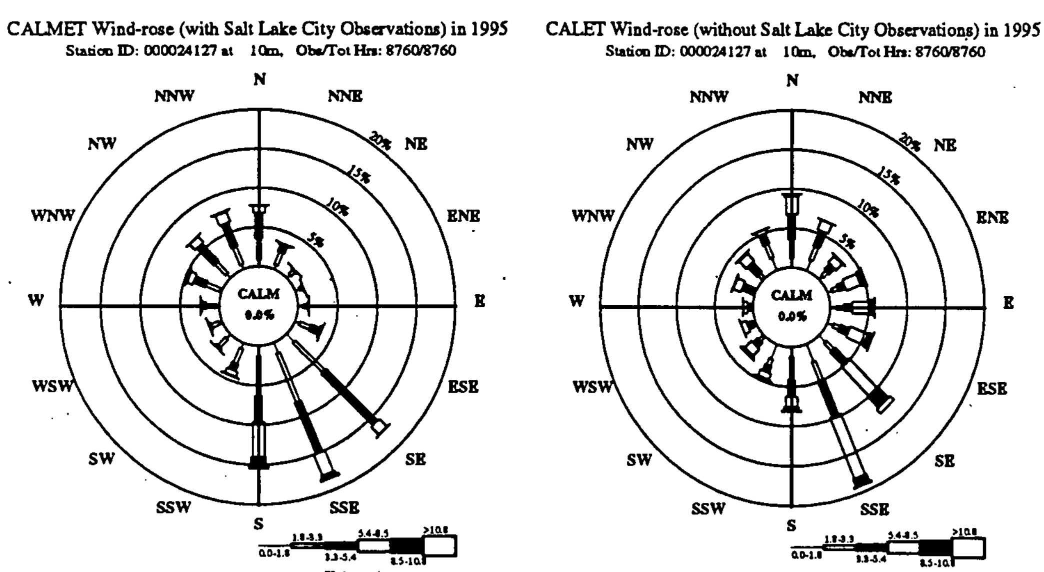
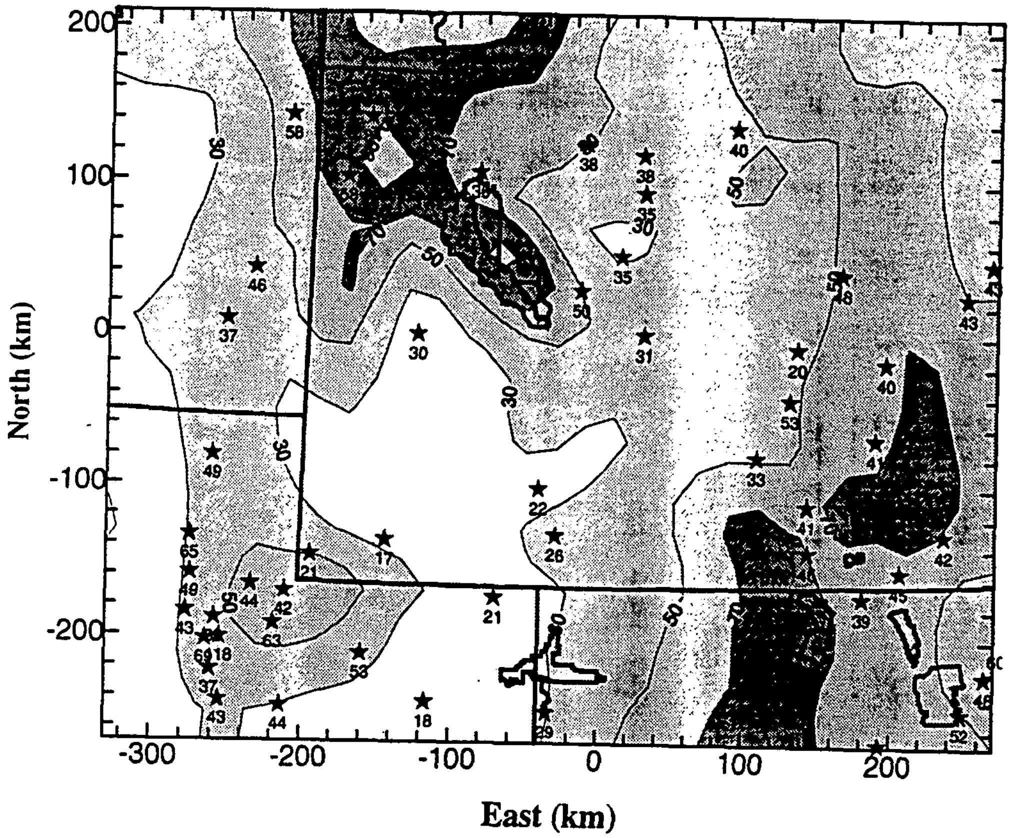


Figure 5. CALMET surface wind-rose at Salt Lake City

Figure 6. MM5 precipitation (shaded contour) and observations for 67 stations.



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5B.4

COMBINING MESOSCALE PROGNOSTIC AND DIAGNOSTIC WIND MODELS: A PRACTICAL APPROACH FOR AIR QUALITY APPLICATIONS IN COMPLEX TERRAIN

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1. INTRODUCTION*

Complex terrain regions constitute challenging areas for air quality modeling. Sophisticated mesoscale models cannot practically be run with fine enough resolution over large areas and for long periods of time as required by many air quality applications. On the other hand, predictions solely based on diagnostic wind models may suffer from the scarcity of observations, especially in the layers above the surface.

In this paper, we investigate the possibility of combining the virtues of both approaches, while avoiding most of their drawbacks. In order to supply better spatial and temporal coverage of the upper flows, as well as resolving terrain features, we have combined runs of a sophisticated mesoscale model, the NCAR/PSU Mesoscale Modeling System MM5 (Grell et al., 1996), with those of a high quality three-dimensional diagnostic model, CALMET (Scire et al., 1997). The mesoscale model is run with a relatively coarse resolution, and its output is used as the initial guess fields for the diagnostic model. The latter is run at a very fine resolution.

Two experiments are presented here in order to compare the performances in a data sparse area of joint modeling (combined MM5-CALMET runs) and pure prognostic modeling (nested MM5 runs). The area of interest is located in southwestern Colorado, in a region where the closest observation site is more than 100 km away.

The first experiment (A) consists of running MM5 with three two-way nested domains. The coarsest, medium-sized, and finest grids have resolutions of 18 km, 6 km, and 2 km respectively.

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In the second experiment (B), MM5 is run on the same 18 km grid as in experiment A. Its hourly output is then interpolated to a 2 km grid by CALMET and used as an initial guess field. Complex terrain effects are thus computed diagnostically by CALMET. The topography data in CALMET is the same as for the 2 km MM5 domain in experiment A (i.e. 30 arc second, or roughly 900 m).

2. EXPERIMENT A: MM5 simulations

2.1 *Modeling domains*

MM5 is run over three two-way nested domains, all centered at 37.51 N and 107.86 W. The largest and coarsest domain (Domain 1) has 25 meshes of 18 km in both north-south (NS) and west-east (WE) directions. Domain 1 encompasses most of southwestern Colorado as well as northern New Mexico, northeastern Arizona and southeastern Utah. A coarse terrain elevation data set (5 min or roughly 9 km resolution) is used for that domain.

Nested in Domain 1 lies Domain 2 with a 6 km grid. Domain 2 has 25 meshes in the WE direction and 25 in the NS direction and thus covers a 150 km by 150 km area. Topography data with a 30 arc second resolution (roughly 900 m) is used for that domain.

Finally, a 2 km mesh domain, Domain 3, is nested within Domain 2. It covers the area of interest near the Weminuche Wilderness Area. The ratio 1:3 between successive grids is a requirement for two-way nesting MM5 simulations which produces best results.

The locations and relative positions of the three MM5 domains are shown in Figure 1.

2.2 *Physical options*

MM5 is run in a non-hydrostatic mode with 17 sigma levels in the vertical. Grell's scheme is use to parameterize unresolved convection, Dudhia's scheme is used for warm rain and ice processes, and the MRF scheme for ground temperature calculations Radiative fluxes are computed every 30 minutes. Four dimension data assimilation (FDDA) of 12-hourly NMC analysis insures that the modeled fields do not drift away from large scale observed features (used for Domain 1 only).

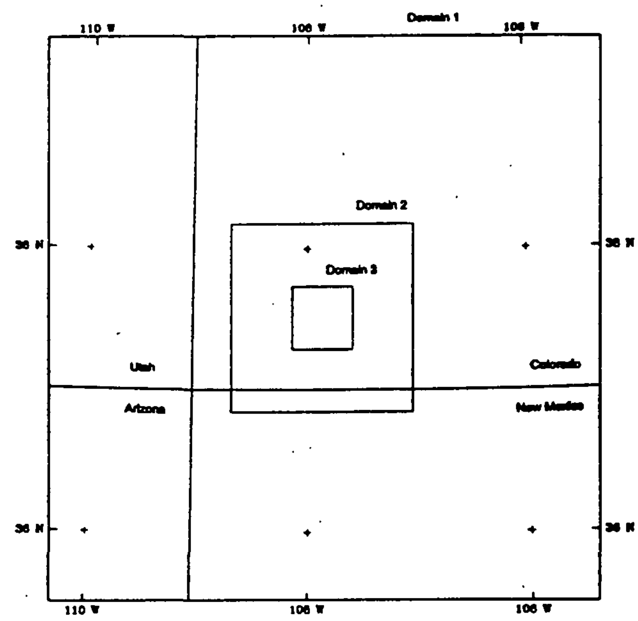

Figure 1 - MM5 modeling domains. Domain 1 (450 km x 450 km, 18 km resolution), Domain 2 (150 km x 150 km, 6 km resolution) and Domain 3 (50 km x 50 km, 2 km resolution). Latitude, longitude and state boundaries are shown.

2.3 *Results*

The simulation is started on October 2, 1995 at 0 GMT (5 PM local time on October 1) and conducted for 24 hours. Terrain effects such as blocking and downslope flows are most pronounced at night and close to the surface. For this reason, surface wind fields at 0 AM are presented here.

At 18 km resolution, the dominant wind direction over the area of interest (center of Domain 1) is from the north at 0 AM and the intensities reach 7 to 8 m/s. The surface winds over Domain 1 are shown in Figure 2.

The surface wind field over Domain 3 is presented at 0 AM in Figure 3. The wind vectors are superimposed on topography contours. The latter show a two-branch canyon in the center of the domain. surrounded by high peaks on the southwest and northeast.

The large scale northerly flow impinges on the northern side of the domain, then is deflected by the SW peak. and channeled along the canyons. Strong down slope components are visible along all slopes and particularly on the downstream side of the SW peak, while the mountain flow slows down the incoming flow on the northern side of the peak.

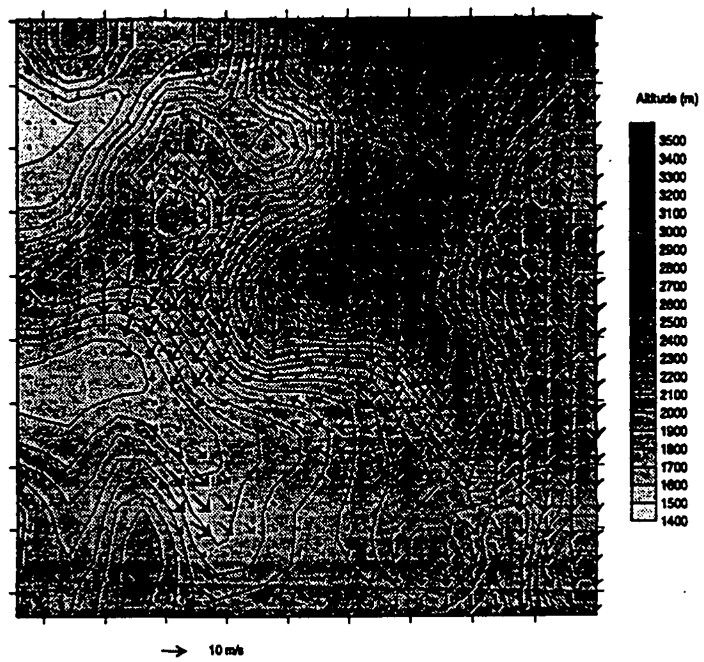

Figure 2 - MM5 surface winds at 0 AM over Domain 1 (18 km resolution). Experiment A: 3 two-way nested domains (18 km - 6 km - 2 km). Domain 3 corresponds to the 3 by 3 gridpoints at the very center of Domain 1

3. EXPERIMENT B: MM5 -CALMET simulations

3.1 *Experimental setup*

The 18 km MM5 fields are interpolated back onto pressure levels by INTERP (MM5 postprocessor), and reformatted to provide vertical soundings. These soundings are interpolated by CALMET to its 2 km grid and used as initial guess fields. Hourly fields of geopotential height, horizontal wind speed and wind direction are fed into CALMET. Identical Lambert conformal projections are used in CALMET and MM5.

In a first step, CALMET diagnostically computes terrain effects (Douglas and Kessler, 1988). The kinematic adjustment is computed after Liu and Yocke (1990). Blocking effects are parameterized in terms of the local Froude number (Allwine and Whiteman, 1985).

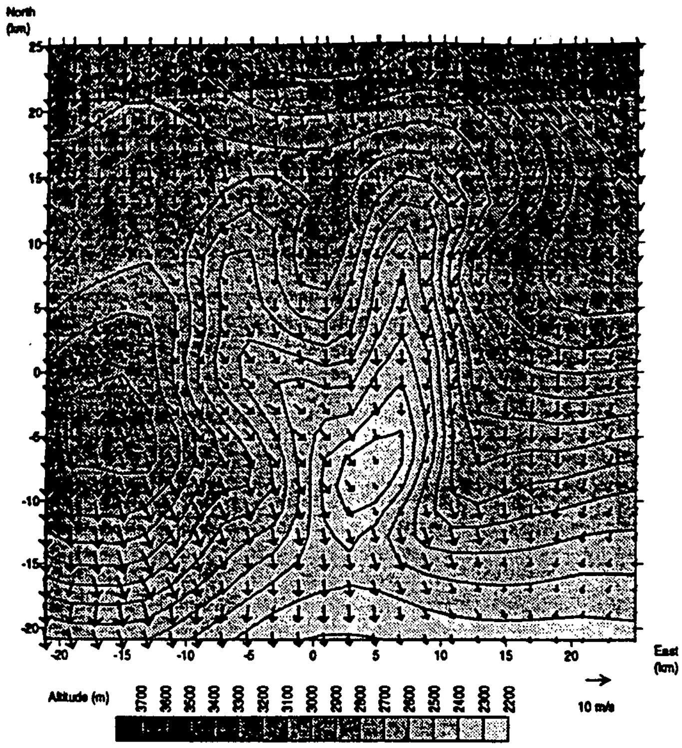

Figure 3 - MM5 surface winds at 0 AM (2 km resolution. Experiment A: 3 two-way nested domains (18 km - 6 km - 2 km).

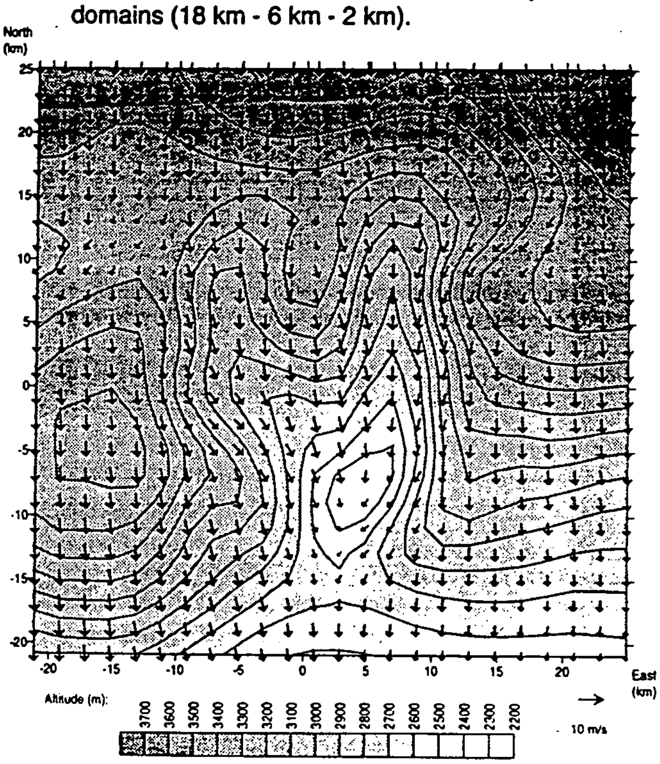

Figure 4 - CALMET surface winds at 0 AM (2 km resolution) Same domain as in Experiment A (Figure 3). Initial guess field: MM5 wind field at 18 km resolution.

Slope flows are computed after Scire and Robe (1997), based on the shooting flow parameterization of Mahrt (1982).

The second step in CALMET, where additional observations can be merged to the step1-fields, is effectively bypassed as this process would bias the comparison with experiment A. Only the vertical gradient of temperature is computed from the nearest sounding (Grand Junction): the vertical gradient of temperature near the surface is used to compute the Froude number and assess blocking effects. The temperature gradient could easily be retrieved from the MM5 input (18 km resolution) but is not in the current version of CALMET (Version 5.0) However simulated and observed gradients of temperature have very close values.

All CALMET parameterizations are described in detail in the CALMET User's Guide (Scire et al., 1997).

3.2 *Results*

The surface winds at 0 AM over the CALMET domain (identical to Domain 3 in experiment A) are presented in Figure 4.

The CALMET wind fields show excellent agreement with the MM5 Domain 3 wind fields. Terrain effects such as channeling along the canyons, deflection of the northerly winds on the northern (upwind) side of the SW peak, are clearly visible and very similar to those in experiment A.

Slope components over the SW peak are somewhat less marked than in the MM5 experiment. In CALMET, the slope components owing to gravity flows reach a few m/s (about 2 m/s for a 500 m drop in altitude and a sensible heat flux of 50 W/m^2). In experiment A, slope components appear to reach 6 to 7 m/s in some areas, which is unlikely to be solely attributable to gravity flows.

CALMET winds are somewhat more intense than MM5 winds in the southeast corner of the domain. This is not owing to terrain effects however as gravity flows should accelerate and not decelerate the flows in that area. This particular wind pattern must be owing to mesoscale dynamic effects not present in CALMET.

5. DISCUSSION

The excellent agreement between CALMET and MM5 simulations over complex terrain areas strongly suggests the practicality and utility of combining MM5 and CALMET for long term air quality studies.

Obviously, mesoscale weather events not resolved by MM5 on the coarse grid (for example, convective storms) won't be generated by CALMET unless they are reflected in the observations input into CALMET or parameterized by one of CALMET's diagnostic algorithms, but would be by a fine scale MM5 simulation. Such events, if important for the air quality study, should be modeled adequately with a prognostic model.

The main advantage of the combined approach is obviously a huge reduction in simulation time, compared to a full mesoscale simulation. Best results for such a prognostic simulation are obtained with two-way nested domains, which, as of now, requires nested domains with a resolution ratio of 1 to 3. Therefore, in the case presented here, an intermediate domain, with a 6 km mesh size, has to be modeled. Experiment A (one day simulation) took about 8 hours of CPU time on a Cray J916. It is impractical to conduct a one-year air-quality study with MM5 in that fashion. On the other hand, CALMET took only a couple of minutes to run on a PC 200 MHz.

Moreover, there is no restriction on the CALMET resolution. The same MM5 winds at 18 km resolution could be used to drive CALMET on a much finer grid. CALMET has been run successfully in narrow valleys with 250 m resolution (Scire and Robe, 1997). In the case discussed here, the topography is much more complex than apparent with a 2 km grid. Results of 250 m resolution CALMET runs, driven by the 18 km resolution MM5, will be further discussed at the conference.

There is also no restriction about the location of the CALMET domain within the large scale MM5 domain. The same large scale MM5 simulation can initialize several CALMET simulations in a given region. One could imagine creating a one-year MM5 data set at moderate resolution (say about 20 km) over a very large area (e.g. the country) and use it repetitively to initialize high-quality diagnostic modeling studies. This would further reduce the cost of air quality studies. Such a data set has been created with an earlier version of the prognostic model (MM4) over the continental US for the year 1990, with a rather coarse resolution of 80 km (NCDC, 1995)

6. ACKNOWLEDGMENTS

The authors thank the NCAR-MM5 scientists. in particular, Wei Wang and Jimy Dudhia, for providing copies of the MM5 code, as well as expert advice during the course of this work. The MM5 simulations were run on a Cray J916 (Paiute) at NCAR, under a commercial agreement.

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APPENDIX G

PEER REVIEW PANEL MEMBER'S QUALIFICATIONS

RESUMES

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K. JERRY ALLWINE

Senior Staff Engineer

EDUCATION

B.S.	Mechanical Engineering, Washington State University (WSU)	1970
M.S.	Environmental Engineering (Air Pollution), WSU	1974
Ph.D.	Engineering Science (Fluid Dynamics and Mathematics), WSU	1991

EXPERIENCE

Dr. Allwine has 25 years experience in the fields of environmental engineering, atmospheric sciences, fluid dynamics and mathematics, specializing in atmospheric transport, complex terrain meteorology, air quality, and air-surface exchange processes. He has authored or co-authored numerous scientific papers and reports, and has written four fully documented computer models on atmospheric transport and diffusion. Dr. Allwine recently left the U.S. Department of Energy's Pacific Northwest National Laboratory (PNNL) after 17 years to form his own consulting business, Allwine Environmental Services. Throughout his professional career, Dr. Allwine has made substantial contributions to the following programs and technical areas:

- Atmospheric Dispersion Models for Emergency Response Applications. Dr. Allwine lead the development of an atmospheric dispersion computer model, PGEMS, for the Pacific Gas and Electric Company for use in their service area in California. He recently finished adapting this model as the emergency response model for use at PG&E's Diablo Canyon Nuclear power plant. The PGEMS model computes ground-level concentrations and deposition fields of air contaminants released from point sources. The model treats both wet and dry deposition and radioactive decay (or first-order chemical transformation) of the released material. The model operates at two "nested" grid resolutions; a fine grid to resolve the dispersion within a few kilometers of the release, and a coarse grid to track plume transport tens to hundred of kilometers from the source.

- Atmospheric Dispersion Models to Estimate Drift from Aerial Spraying. The U.S. Forest Service has a need to estimate the drift of pesticides from aerial spraying operations. Dr. Allwine lead the development of a computer model, VALDRIFT, which accounts for the physics governing the transport and diffusion of a spray cloud in a mountain valley. The VALDRIFT model computes three-dimensional concentration fields and ground-level deposition fields of air contaminants released from area, line and point sources located within a mountain valley. The model is applicable under relatively cloud-free, undisturbed synoptic conditions and is configured to operate through one diurnal cycle for a single valley.

- Passive Soil Vapor Extraction for Remediation of Contaminated Soils. Dr. Allwine worked with PNNL staff on a Department of Energy program (VOC-Arid) investigating Passive Soil Vapor Extraction as a viable technology for remediation of soils contaminated with volatile organic compounds. PSVE is an emerging remediation technology where natural variations in atmospheric pressure are exploited for removal or control of the volatile organic compounds in the soil. Dr. Allwine developed and used an instrument system for measuring the transfer rate of carbon tetrachloride from the soil-surface to the atmosphere.

- Atmospheric Studies in Complex Terrain (ASCOT) Program. This Department of Energy program investigates the basic understanding of atmospheric dynamics, and transport and diffusion in the boundary layer over complex terrain. Dr. Allwine worked as a lead scientist in the ASCOT program for several years. He conducted research on the energy and solar radiation balance at the earth's surface, on atmospheric mass and thermal energy budgets of valley atmospheres, on the effects of the interactions of various circulations (e.g., valley, synoptic) on dispersion, and on atmospheric diffusion in complex terrain.

- Atmospheric Radiation Measurements (ARM) Program. This program is one of the Department of Energy's major programs for addressing issues associated with global climate change. Dr. Allwine worked on specifying and procuring surface flux stations for measuring surface fluxes of heat, moisture and momentum. He also developed computer programs for quality controlling the collected data and calculating other pertinent meteorological quantities from the measured quantities.

- Characterization of Winter Meteorology in the Grand Canyon Region. The Salt River Project funded a field study investigating the effects of the Navajo Generating station on winter visibility in the Grand Canyon region. Dr. Allwine analyzed meteorological data characterizing the pollutant dispersion potential of the air in the Grand Canyon region. He formulated, developed and tested mathematical methods for quantifying the atmospheric stagnation, recirculation and ventilation potential of various airsheds.

- Other Programs. Dr. Allwine has worked on several other programs for the Department of Energy, other government agencies, and private companies. The majority of these have dealt with characterizing and modeling of transport and diffusion in the atmospheric boundary layer on horizontal scales of from a few kilometers to hundreds of kilometers. The programs have included the development of a valley-scale and a regional-scale air quality computer model for the Environmental Protection Agency, the assessment of the air quality implications of the use of alternate energy technologies (including solar) in the United States, the dispersion of trace metals from power plants in Canada, and the investigation of a new method for the electrostatic collection of fine particles.

- Early Experience. Dr. Allwine held positions with Washington State University as Assistant Environmental Engineer in research, Puget Sound Naval Shipyard as General Engineer and Colorado State University as research assistant. He gained considerable experience in aircraft and ground-based measurements of gaseous pollutants in both urban and remote areas. Dr. Allwine contributed significantly in numerous long-range photochemical oxidant transport studies in various parts of the United States. He also made measurements of chlorofluorocarbons and ozone at remote locations in Antarctica and the Pacific Ocean off the coast of South America. While at Colorado State University, Dr. Allwine was involved with the physical modeling of the atmospheric boundary layer. He carried out a wind tunnel study measuring the dispersion of pollutants in building wakes under various simulated atmospheric stabilities.

PROFESSIONAL AFFILIATIONS

Air and Waste Management Association

PUBLICATIONS

I have authored or co-authored nearly 100 scientific papers, reports, articles in reports and presentations, and have written four fully documented computer models on atmospheric transport and diffusion. See attached publication list.

K. JERRY ALLWINE

PUBLICATIONS, REPORTS AND PRESENTATIONS

Allwine, K. J. 1998. *QEDPS 2.0 - A Near-Field Dose Assessment Model for Emergency Response at the WNP-2 Nuclear Facility.* Prepared for the Washington Public Power Supply System under contract C31445 by Allwine Environmental Services, Richland, Washington.

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Allwine, K. J. and C. D. Whiteman. 1994. "Single-Station Integral Measures of Atmospheric Stagnation, Recirculation and Ventilation." *Atmos. Environ.* **28** 713-721.

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Hubbe, J. M., and K. J. Allwine. 1993. "Observations of Winds Near Rocky Flats Under Stable Conditions." Presented at the ASCOT Scientific Meeting, Salt Lake City, February 9-11, 1993. PNL-SA-21892A, Pacific Northwest Laboratory, Richland, Washington.

Hubbe, J. M., and K. J. Allwine. 1993. "Mesoscale Meteorological Measurements Characterizing Complex Flows." *Preprints, Environmental Transport and Dosimetry*, Charleston, South Carolina. American Nuclear Society, La Grande Park, Illinois. August 31 - September 3, 1993.

Hauser, R. K., K. J. Allwine and C. D. Whiteman. 1993. "Short Tower Sigma Theta Measurements in the Colorado Plateaus Region." Presented at the ASCOT Scientific Meeting, Salt Lake City, February 9-11, 1993. PNL-SA-21872A, Pacific Northwest Laboratory, Richland, Washington.

Allwine, K. J. and J. M. Hubbe. 1993. "Atmospheric Diffusion in Complex Terrain." In Part 3 of *Pacific Northwest Laboratory Annual Report for 1992 to the DOE Office of Energy Research.* PNL-8500 PT3, Pacific Northwest Laboratory, Richland, Washington.

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VITA

WALTER F. DABBERDT

EDUCATION:

1964	B.S. (Meteorology and Marine Transportation), magna cum laude	State University of New York, Maritime College
1966	M.S. (Meteorology)	University of Wisconsin, Madison
1969	Ph.D. (Meteorology)	University of Wisconsin, Madison

EXPERIENCE:

1995-Present	Associate Director, National Center for Atmospheric Research, Boulder, CO
1987-1995	Manager, Surface and Sounding Systems Facility, and Scientist III, National Center for Atmospheric Research
1985-1987	Scientist III, Field Observing Facility, NCAR, and Head, Boundary Layer Sensing Group
1970-1985	Associate Director, Atmospheric Science Center and Head, Environmental Meteorology Program, SRI International (formerly Stanford Research Institute), Menlo Park, CA
1977-1978	Research Fellow, Alexander von Humboldt Foundation at Meteorological Institute, University of Munich (on sabbatical from SRI)
1974-1977	Instructor, Environmental Studies, Foothills Junior College, Los Altos, CA
1969-1970	Postdoctoral Fellow, National Academy of Sciences/National Research Council, at U.S. Army Earth Sciences Laboratory, Natick, MA
1964	Brookhaven National Laboratory, Upton, NY, summer intern

AWARDS AND MEMBERSHIPS:

American Merchant Marine Institute award for the Honor Cadet in
Marine Society of the City of New York award for proficiency in Seamanship
U.S. Coast Guard, Licensed Third Officer, Any Tonnage, Oceans Unlimited
American Meteorological Society
American Geophysical Union
Sigma Xi (elected member)
Alexander von Humboldt Society of America

PUBLICATIONS SUMMARY:

Author of more than 160 papers, reports and conference presentations including 50 formal, refereed publications. Also, author of two layman's weather books and eight magazine articles, and editor of one technical book, one dispersion modeling, and one layman's book on weather in the western states.

PROFESSIONAL ACTIVITIES:

Member, Editorial Advisory Board, *Atmospheric Environment,* (1995-)

U.S. Weather Research Program, Prospectus Development Team on Data Needs (co-

U.S. Department of Energy/ARM Science Advisory Committee for the Southern Great Plains CART Site; Chair (1995-)

Program Chairman, AMS Ninth Symposium on Meteorological Observations and Instrumentation, 27-31 March 1995, Charlotte, NC

Keynote Speaker, Third International Tropospheric Profiling Symposium, 29 August - 2 September 1994, Hamburg, Germany

National Research Council, Board on Environmental Studies and Toxicology, Committee on Research and Peer Review in EPA (1994-)

GvaP Working Group for Improvement of Operational Upper-Air Humidity Measurements; Chair (1994-1995)

Associate Editor, *J. Atm. Ocean. Tech.* (1993-1997)

AMS Committee on Measurements (Chairman, 1993-)

Member, U.S. EPA Expert Panels for Technical Workshop on WTI Incinerator Risk Issues, and Chair, Meteorology/Air Dispersion Modeling Group, December 8-9, 1993, Washington, DC and January 1996.

AMS Committee on Meteorological Aspects of Air Pollution (Member, 1989-1993; Chairman, 1990-1992)

Program Co-Chairman, AWMA/AMS Specialty Conference on The Role of Meteorology in Managing the Environment in the 90's, 26-28 January, 1993, Scottsdale, AZ.

California Model Advisory Committee, California Air Resources Board, Vice-Chairman (1988-92)

Associate Editor, (Boundary Layer Meteorology/North America), *Atmospheric Environment-Urban Atmosphere* (1991-)

General Co-Chairman, International Symposium on Tropospheric Profiling, September 10-13, 1991, Boulder, CO

Program Co-Chairman, AMS Seventh Symposium on Meteorological Observations and Instrumentation, 13-18 Jan., 1991, New Orleans, LA

Strategic Highway Research Program, National Research Council, Expert Task Group on Environmental Data (1990)

Chairman, Atmospheric Instrumentation Workshop, Central Weather Bureau, Republic of China, March 13-16, 1990, Taipei, Taiwan, ROC

Program Co-Chairman, Symposium on Lower Tropospheric Profiling, May 31-June 3, 1988, Boulder, CO

Invited Lecturer, National Science Council Lectureship Program, Republic of China (1988)

Atmospheric Boundary Layer Panel, Battan Memorial and 40th Anniversary Conference on Radar Meteorology, November 9-13, 1987, Boston, MA

Field Program Manager and Member, Scientific Advisory Committee for South Central CaliforniaCoast Atmospheric Measurements Program (SCCCAMP) (1985-89)

U.S. Environmental Protection Agency, Science Advisory Board (Consultant to Environmental Engineering Committee, 1983-)

International Center for Transportation Studies (Rome), Scientific Committee (1981-90)

Transportation Research Board, Committee on Highways and Air Quality (1973-)

AMS Turbulence and Diffusion Committee (past member)

San Francisco Bay Area Air Quality Management District, Advisory Council (past member); Chair, Technical Advisory Committee

Guest Editor: Journal of Atmospheric and Oceanic Technology, Special Issue on Meteorological Observations and Instrumentation, February 1998

Guest Editor: Journal of Atmospheric and Oceanic Technology, Special Issue on Lower Tropospheric Profiling, October 1989

Guest Editor: Journal of Applied Meteorology, Special Issue on the Role of Meteorology in Managing the Environment in the 1990's, March 1995

NCAR ACTIVITIES:

- Member, Facility Advisory Council (1990-91)
- Member, CASH Sensor Advisory Board (1991-94)
- Chair, ATD/RAF Manager Search Committee (1990)
- Chair, Cost Recovery Review Committee (1988-89)
- Member, New Building Review Committee (1988-89)
- Member, A&E (New Building) Selection Committee (1989)
- Chair, NCAR Technology Advancement Award Selection Committee (1987)
- Member, NCAR Technical Support Award Selection Committee (1986)

LARRY L. SIMMONS, P.E. PRINCIPAL

EDUCATION:

- MS, Civil Engineering, 1979, University of Pittsburgh
- BSE, Mechanical Engineering, 1970, Florida Atlantic University

On the Bachelor level, Mr. Simmons graduated with a major in Mechanical Engineering and a minor in Oceanography, which included studies in dispersion analysis. His Master level Civil Engineering studies were in the field of Environmental Engineering with concentrations in Sanitary Engineering and hydro-dynamics.

EXPERIENCE:

- Energy & Environmental Management, Inc., 1981 to Present

As Program Director for major projects, Mr. Simmons has been successful in assisting clients in the utility and steel industries. Some of those projects are described as follows:

-Industrial Sources Group (ISG) - Program Manager - Responsible for structuring air monitoring program with four 100-meter towers and four acoustical SODARs in Marshall County, West Virginia for Venco, Columbian Chemicals, PPG, Bayer and Ormet and air quality dispersion modeling with that data using ISCST3, CTDMPLUS and CALPUFF.

-North Branch Power Partners - Project Manager - Prepared Prevention of Significant Deterioration (PSD) application and obtained air quality permit for 80 MWe waste coal-fired CFB at Bayard, West Virginia.

-Ormet Primary Aluminum Corporation - Project Manager - Prepared a PM_{10} field monitoring and air dispersion program for pot liner emissions that were used in a Superfund Risk Assessment for their Hannibal, Ohio facility. Complex and intermediate terrain were significant factors in the dispersion analysis. Ohio EPA and EPA Region V accepted the modeling procedure and results.

-American Bituminous Power Partners Grant Town Energy Project - Project Manager - Directed the BACT and PSD modeling analysis at the Grant Town, West Virginia project. Specialty software was developed to address the complex terrain near the project. Violations of the National Ambient Air Quality Standards were found, but a detailed analysis showed the Grant Town project was not a significant source during the violation events.

-Wheeling-Pittsburgh Steel Corporation - Project Manager - Prepared PSD Feasibility study for Electric Melt Shop addition to their Mingo Junction, Ohio facility including assessment under Ohio EPA Air Toxics program.

-Sinter Bubble at USX Fairless Works - Project Manager - Conducted a detailed PM_{10} Bubble analysis for the sinter plant at the USX facility in Fairless Hills, Pennsylvania. Specialty software was developed for processing over 1200 sources in complex terrain. Agency involvement with Pennsylvania, New Jersey and EPA Region III was required to accept the specialty software.

-Jefferson County, Ohio PM_{10} SIP - Project Manager - Directed the complex and intermediate terrain modeling for the Steubenville, Ohio PM_{10} SIP for Wheeling-Pittsburgh Steel Corporation. Ohio EPA and West Virginia OAQ utilized the complex terrain modeling output to devise the final PM_{10} control strategies.

-TRICO - Subcontractor - Prepared air quality dispersion analysis for increment consumption and ambient standards impacts for their proposed Electric Melt Shop in Decatur, Alabama. Permit was issued and construction will be completed soon.

-Weirton, West Virginia PM_{10} SIP - Project Manager - Conducted complex and intermediate terrain dispersion modeling for the immediate vicinity of the Ohio River valley at Weirton, WV. West Virginia OAQ and EPA Region III are following these activities closely.

-Allegheny County PM_{10} SIP - Project Manager - Developed specialty software at the request of USX Corporation to address dispersion of PM_{10} emissions from their Coke Plant at Clairton, PA. USX made the software available to the PM_{10} SIP agency via modem access to devise final control strategies.

-Aristech Corporation - Project Manager - Determined that source modifications at their Haverhill, Ohio plant did not trigger PSD review.

-J & L Specialty Steel - Subcontractor - Prepared a dispersion model analysis of HF emissions during a spill event. The HF releases would be in a river valley with complex terrain. The Emergency Preparedness Agency and Pennsylvania DER accepted the modeling procedure.

-National Steel Corporation - Project Manager - Responsible for evaluation of PDER and NYS DEC challenge to Weirton Steel's SO_2 emissions under §126. Developed technical response with client counsel for submission to docket.

-Atlantic Steel - Subcontractor - Conducted PSD air dispersion modeling for the Melt Shop expansion outside Atlanta, Georgia. Complex terrain required approval by the Georgia DNR of the detailed model protocol. Final approval of the permit was received based on the complex and intermediate terrain modeling.

-Lukens Steel Corporation - Project Manager - Determined feasibility of using fugitive road dust emissions under the Emissions Trading Policy of the Clean Air Act as a trade for the Electric Melt Shop at Coatesville, Pennsylvania. Provided technical support to Lukens at PDER agency meetings in Harrisburg and Norristown.

-Southern Research Institute - Subcontractor - One of four firms selected nationwide under EPA RTP contract to develop a fugitive dust quantification protocol. Conducted side-by-side field tests to assess merits of various techniques.

-L. Robert Kimball & Associates - Subcontractor - Responsible for evaluation of compliance programs to reduce fugitive dust emissions from the GM&W Coal Company's Grove #3 Mine near Jennerstown as per PDER order.

-The Potomac Edison Company - Project Manager - Responsible for conducting dispersion analyses with ISCST air quality model to develop less-than-GEP stack for approval by Maryland Department of Health and Mental Hygiene for the R. Paul Smith Power Station near Williamsport, Maryland.

-Bethlehem Steel Corporation - Project Manager - Responsible for NYS DEC using ISCLT in lieu of CDM as a validation tool under SIP revisions for complex sources and where multiple field monitors are available for validation.

- Energy Impact Associates, Inc., 1977 to 1981

As a Project Manager and Project Engineer, he participated in strategic development of more than 25 projects for variances and permits as revisions to State Implementation Plans and 40 projects for variances and permits under the National Pollutant Discharge Elimination System. As Project Manager, his primary responsibility was to lead an interdisciplinary team of engineers and scientists directed to permit acquisition within budget and on schedule. Mr. Simmons was associated with the following programs:

-Shenango Incorporated - Project Manager - Responsible for team of engineers compiling fugitive dust emissions inventory and air quality scientists conducting dispersion analyses for first TSP Bubble approved in EPA Region III. Obtained PDER and EPA approval for protocol for quantifying fugitive dust from roads. Expert testimony given at SIP hearing in Allegheny County.

-Pennsylvania Power/Ohio Edison Company - Project Manager - Responsible for air quality monitoring network of 31 sites for SO_2 and TSP including personnel administration, equipment, reporting of data, project budgets and response to agency questions from PDER and OEPA.

-Allegheny Power Service Corporation - Project Manager - Responsible for team of biologists and engineers in follow-up work on NPDES studies at their 12 plants in Pennsylvania, West Virginia, Maryland and Virginia.

-Bethlehem Mines - Subcontractor - Had overall responsibility for environmental program and provided hydrology sections for applications under interim OSM regulations for nine existing deep coal mines in Cambria County, Pennsylvania.

-Mead Paper - Project Manager - Directed investigation of existing waste disposal area for hazardous and non-hazardous waste under interim RCRA. Conducted ground-water investigation of leachate migration. Helped develop operational and closure plans for continued area use.

- Westinghouse Electric Corporation, Environmental Systems Department, 1970 to 1977

While at Westinghouse Electric Corporation, Mr. Simmons was responsible for the development of data processing, field collection and data analysis for water resources projects in Montana, Nevada, Illinois, Missouri, Indiana, Ohio, Pennsylvania, West Virginia, Michigan, New York, Florida, Georgia and Tennessee. He participated in testimony before several state agencies on NPDES permit issues.

PUBLICATIONS AND PROFESSIONAL ACTIVITIES:

- Samples, W.R., W.V. Polomik, Jr. and L.L. Simmons, "Recognizing Buoyancy of Heated Fugitive Emissions From Basic Oxygen Furnaces and Blast Furnaces," Air & Waste Management Association Specialty Conference, Pittsburgh, Pennsylvania, March 31 - April 2, 1998.

- Gendron, L.J., R.J. Paine and L.L. Simmons, "Operation of a Comprehensive Network of Tall Meteorological Towers and Acoustic SODARs for use in Modeling in the Ohio River Valley," American Meteorological Society Conference, Phoenix, Arizona, January 1998.

- Leger, M.E., T.A. Moore, G.S. Casuccio, L.L. Simmons and C.A. Francy, "Receptor Modeling: Innovative Approaches to Assist in the Identification of Source/Receptor Relationships," 86th Annual Meeting & Exhibition of the Air & Waste Management Association, Denver, Colorado, June 13-18, 1993.

- Simmons, L.L. and L.E. Lambert, "Coal Processing," Air Pollution Engineering Manual, 1992.

- Maser, J.A., C.L. Norton and L.L. Simmons, "Cost/Benefit of Fugitive Emissions Controls for TSP and Possible PM_{10} Compliance," Symposium on Iron and Steel Pollution Abatement Technology for 1983, Chicago, Illinois, October 18-20, 1983.

- Simmons, L.L., C.L. Norton and M.J. DeBiase, "Fugitive Dust Emissions From Roads in Iron and Steel Mills: Compilation of Results and Use Under EPA's Emission Trading Policy," Symposium on Iron and Steel Pollution Abatement Technology for 1982, Pittsburgh, Pennsylvania, November 16-18, 1982.

- Simmons, L.L., C.L. Norton and P.R. Edmonds, "Practical Aspects of Matching an Emissions Inventory to an Air Quality Dispersion Model," Air Pollution Control Association Specialty Conference, Kansas City, Missouri, April 1982.

- Maser, J.A., C.L. Norton and L.L. Simmons, "Uncontrolled and Controlled Emissions from Nontraditional Sources in a Coke and Iron Plant: A Field Study Analysis," APCA Specialty Conference On: Air Pollution Control in the Iron and Steel Industry, Chicago, Illinois, April 21-23, 1981.

- Plumb, R.H., L.L. Simmons and M. Collins, "Assessment of Intermittently Chlorinated Discharges Using Chlorine Half-Life," Third Conference on Water Chlorination: Environmental Impact and Health Effects, Colorado Springs, Colorado, October 28-30, 1979.

- Simmons, L.L., "Practical Aspects of the Resource Conservation and Recovery Act," 40th Annual Meeting of the International Water Conference of the Engineers' Society of Western Pennsylvania, Pittsburgh, Pennsylvania, November 1979.

- Simmons, L.L., "Conducting a Section 316(a) Demonstration at the Cheswick Power Station," Pennsylvania Electric Association Annual Meeting, Greentree, Pennsylvania, March 1976.

- Simmons, L.L., "Hydrothermal Processes Related to Steam Electric Stations," lecture presented at the annual Westinghouse Environmental Management School, Fort Collins, Colorado, 1973 through 1977.

- Simmons, L.L., P.E. Kueser, J.H. Wright and G.M. Jouris, "Near-Field Thermal Plume Parameters for Electric-Power Plants Discharging into Rivers or Transverse Currents," AICHE Heat Transfer Symposium Series, 1973.

- Simmons, L.L. and J.A. Nutant, "Measuring Thermal Plumes in Three Dimensions," Power Engineering, October 1971.

- Member of Engineers' Society of Western Pennsylvania, Water Environment Federation and Air & Waste Management Association.

- Member of Allegheny County Board of Health's Air Pollution Control Advisory Committee and Chair of its Criteria Pollutants Subcommittee.

RESPONSE TO PEER REVIEW COMMENTS OF CALMET/CALPUFF MODELING SYSTEM

U.S. Environmental Protection Agency
Office of Air Quality Planning and Standards
Air Quality Modeling Group
Research Triangle Park, NC 27711

November, 1998

Introduction

During July and August of 1998 a peer review was conducted of the CALMET/CALPUFF modeling system (Allwine et al., 1998). The comments received from the peer review of the modeling system can be summarized into several general areas:

1) the technical descriptions of the model formulations were considered sufficient to understand the science foundation of the modeling system, and the formulations were considered to be state-of-practice and a significant advance over those within MESOPUFF II;

2) the extent of the performance evaluations were considered superior to that of many other models, and probably sufficient to recommend use of the modeling system as proposed;

3) the CALMET and CALPUFF graphical user interfaces (GUIs) were considered helpful and easy to use, but the user instructions of the model options and implications of alternative choices were unclear, and

4) several suggestions were provided on future enhancements, and some reservations were expressed in use of mesoscale meteorological modeling results and United States Geological Service (USGS) geophysical data.

The following discussion provides a brief summary of the main points of the peer review comments, and describes how the Environmental Protection Agency (EPA) intends to address the comments received.

Model Formulations

Comment Summary. The peer reviewers did not believe any aspect of the model formulations or descriptions of model formulations needed to be changed prior to release. They believed the descriptions were sufficiently complete with liberal references, such that the science foundation of the modeling system was understandable and well documented. They believed that the CALMET/CALPUFF modeling system provides a state-of-the-practice puff dispersion model. The modeling system contains very significant advances over MESOPUFF II, in that it explicitly treats virtually all of the important physical processes affecting transport, diffusion, deposition, and transformation. Important areas of improvement are: a) the wind field representation provided by CALMET and the explicit integration of mesoscale model outputs; b) the explicit treatment of terrain effects, both in the wind-field model and the dispersion model, c) a comprehensive treatment of near-field effects, including building effects; and d) the more general treatment of diffusion using boundary-layer parameterizations. They encouraged EPA to retain an independent firm or consultant to perform in-depth test and checks of the model to detect errors in coding.

Response. The EPA intents to formally submit the CALMET/CALPUFF modeling system as a refined modeling technique for inclusion in Appendix W of 40 CFR Part 51 (Guideline On Air Quality Models). When this occurs the EPA will likely receive comments from the public regarding the efficacy of routinely using the modeling system as proposed. The suggestion of having an independent firm capable of providing tests of the modeling system is worthwhile, but the EPA believes it would be prudent to review the suggestion in light of comments and recommendations received from the public when the modeling system is formally proposed for use.

Performance Evaluations

Comment Summary. The reviewers believed that the extent of the evaluation of the CALMET/CALPUFF modeling system was sufficient to recommend use of the system as proposed (a refined modeling system for routine use for characterization of long-range transport impacts, and a refined modeling system for case-by-case use for characterization of short-range transport impacts). This judgement was based in part on a recognition that the modeling system incorporates basic concepts that are well understood, and numerous algorithms, each of which has been reasonably well characterized. It is the composite that has seen modest but meaningful performance evaluation. Further, the mesoscale and diagnostic wind field modeling approaches used in CALMET have undergone a history of more than 20 years of testing and evaluation in the meteorological and wind power communities. They did encourage EPA to seek independent assessment of the performance of the modeling system against other, less comprehensive, but well characterized models. They recognized that much of this has been accomplished and summarized in the Phase II report currently being drafted by the Interagency Workgroup on Air Quality Modeling (IWAQM).

Response. The EPA believes that the CALMET/CALPUFF modeling system will likely be involved in various evaluation studies over the next few years, especially as various groups become familiar with its capabilities, and test various extensions to its model formulations. The EPA maintains a web site for the distribution of modeling guidance, and will invite the public to provide appropriate summaries of their findings for posting on the EPA web site.

User Documentation and Instructions

Comment Summary. The peer reviewers found the CALMET and CALPUFF GUIs to be helpful. They offered some possible corrections to the CALMET and CALPUFF GUIs. It was their belief that user friendliness concerns do not outweigh general release of the CALMET/CALPUFF modeling system at this time. They believed that the release of the modeling system will have two significant benefits to the user community. One, it will provide informed users with a more powerful, flexible, and realistic simulation tool. And two, it may help increase the level of expertise within the user community. The reviewers considered the user instructions of the options and implications and tradeoffs between options to be unclear. They recommended an independent review be performed of the user instructions, once they have been revised in accordance with the review comments.

Response. The EPA discussed the reviewer's suggestions and concerns with Earth Tech Inc., who developed the modeling system and was charged with finalizing the user's guides, code and test cases for public release. To the extent that resources were available, Earth Tech agreed to address the reviewer's concerns. It is EPA's and Earth Tech's opinion that several clear example problems (including application of the modeling system to both short-range and long-range model situations) would greatly assist understanding by the users. In remains to be seen whether development of these examples will resolve all of the concerns expressed, but EPA believes that the new examples will go a long way toward helping a user through the process. In addition, Earth Tech intends to provide example test cases of the various processors that organize the input data for use by CALMET (which includes processing the geophysical data, the upper-air observations, and the hourly surface weather data). The EPA decided not to include the descriptions of the various example problems within the user's guides, as they may require further enhancements in the future, and EPA waned to finalize the user's guides. The EPA intends to reevaluate the adequacy of the user instructions once the modeling system has been formally proposed for routine use and comments have been received from the public.

Reservations on Use and Future Enhancements

Comment Summary. The reviewers expressed concern against cart-blanche acceptance of 1) the output from sophisticated mesoscale meteorological models, and 2) the USGS elevation data and land use data. In the first case, the reviewers felt that although the output from mesoscale meteorological models would be valuable, a review of such data was needed on a case-by-case basis prior to its use. Likewise, the reviewers were aware of instances where the USGS elevation data and land use data were not in accord, as evidenced by noticeable inappropriate alignment between the terrain elevations of river boundaries and the land use characterizations.

Response. The EPA believes that both of the cautions expressed are reasonable, given the lack of experience that exist in the routine use of these data sources for air pollution model applications. With more experience and (as the reviewers suggest) a collection of model protocols that the public can review where the modeling system has been successfully applied, these concerns will likely diminish in time. The EPA envisions that most long-range modeling assessments will involve development of a modeling protocol. The EPA intends to provide protocols that appear to be instructive as they become available. The EPA will caution users to review all input data for appropriateness, especially given that this will be the first puff modeling system offered for routine use, and the regulatory modeling community has little experience with such models.

Comment Summary. The reviewers offered several studies that they felt would prove useful in the future. They suggested that sensitivity studies might provide insight to users in the tradeoffs between model options. They suggested that a future enhancement to CALMET and CALPUFF might allow use of nested grids to provide higher resolution to facilitate better treatment of local terrain effects. They offered the idea that the use of ensemble simulations (currently being investigated in climate and weather forecasting) might provide a means for characterizing uncertainties in simulated pollution impacts, due to stochastic effects that can be characterized by ensemble meteorological simulations. They strongly emphasized the need for some graphical visualization system to aid the review of the output from CALMET and CALPUFF. They were aware of one such system, called CalDESK, and hoped that other systems would be forthcoming. They encouraged EPA to support training programs in the CALMET/CALPUFF modeling system to aid a user community that is largely experienced in steady-state plume modeling.

Response. In reviewing these suggestions for future enhancements and activities, EPA is encouraged that the reviewers share EPA's outlook that the CALMET/CALPUFF modeling system represents a valuable and significant advance over commonly used plume modeling systems, that likely will see increased use and application (in lieu of plume modeling) in future years as experience is gained. The suggested studies, training and possible enhancements can be pursued in future years as resources allow. The EPA currently views its primary mission to complete the effort started, which is focused on routine use for long-range transport applications, and case-by-case use for short-range applications. In this regard, EPA shares the reviewers views that good user instructions and training are needed. The user instructions will be revised, and likely will be updated as future comments are received. The training will evolve as more experience is gained and EPA has a better appreciation of where to focus the training.

References

Allwine, K.J., W.F. Dabberdt, and L.L. Simmons. 1998. Peer Review of the CALMET/CALPUFF Modeling System. EPA Contract No. 68-D-98-092, Work Assignment No. 1-03 report.