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AERMIC:

I think this should be the final version of the Peer Review Response. I've considered or accounted for all the comments provided. Thanks for your help.

Jeff

[illegible]

Prepared by

AMS/EPA Regulatory Model Improvement Committee (AERMIC)

May 26, 1999

1. Introduction

In the following, AERMIC responds to comments provided in the AERMOD Peer Review Final Report (Hanna et al., 1999) that assessed several documents describing the dispersion model AERMOD. In March 1998, a Peer Review Panel was established by EPA to review AERMOD, a new short-range dispersion model for industrial source applications and a potential replacement for the ISC3 Model. The Panel reviewed numerous documents pertaining to the formulation, user guidance, and evaluation of AERMOD and produced a Draft Peer Review Report (Hanna et al., May 1998). As a result of the Panel's comments, AERMIC has: 1) revised and expanded the AERMOD Model Formulation Description (MFD, December 1998), 2) modified the AERMOD code accordingly, 3) evaluated the complex terrain portion of the model with two additional data bases (the Tracy and Westvaco data sets), and 4) revised and clarified the model evaluation documentation (December 1998). The Panel has reviewed these revised documents, provided comments on them, and modified their responses to a set of twelve general questions posed by the EPA (Hanna et al., 1999).

As expressed in our earlier response (AERMIC, December 1998), AERMIC is grateful to the Peer Review Panel for their time, effort, and completeness in examining the revised AERMOD documents and providing their assessment. The basic conclusion of the Panel is that AERMOD is ready to be proposed as a replacement for the ISC3 Model for regulatory air quality applications, but they have some comments on further AERMOD development and evaluation work. In the following, we summarize and respond to what we perceive as the major issues or questions by the Panel concerning AERMOD, its evaluation and implementation. This is done by section of the final report (Hanna et al., 1999), but omitting Section 1 on "Background."

2. Response to Section 2: Introduction and General Comments

The Panel states that they believe AERMOD to be a significant improvement over ISC3 and that it contains many new state-of-the-science concepts and approaches including a unique meteorological interface. Their basic conclusion is that AERMOD is ready to be proposed as a replacement for ISC3. They raise four issues or concerns discussed below: 1) limitations of source types in the AERMOD evaluation, 2) the downwash algorithm, 3) the need for more experience with AERMOD results and sensitivity tests, and 4) the need for a "break-in" period.

2.1. Source Types in AERMOD Evaluation

The Panel noted that with the exception of Prairie Grass (surface release), all of the AERMOD evaluation data bases involved buoyant releases from tall stacks at power plants. They also noted that the majority of ISC3 applications pertain to "modest" buoyancy fluxes and "modest" stacks, many of which are subject to aerodynamic downwash.

AERMIC agrees that further testing and evaluation with "intermediate stack height" data bases would be desirable and would merit attention in the future given appropriate data sets and the resources to analyze them. We note two factors to reduce this concern. First, AERMOD has been formulated as a continuous function of source height (z_s) and buoyancy flux and tested in the limits of: 1) a nonbuoyant surface release (Prairie Grass), and 2) buoyant releases in the upper part of the atmospheric surface layer (lowest 10% of the boundary layer) or in the mixed-layer (upper 90%) of the convective boundary layer (CBL). Simple interpolation formulas are used that give a continuous variation of dispersion (sigma_y, sigma_z) with z_s between these limits. Thus, we believe that the parameterization of dispersion from intermediate stack heights should be reasonable.

Second, AERMIC has conducted a consequence analysis in which AERMOD and ISC were run for a large number (72) of source, meteorological, terrain, and urban/rural combinations. Thus, the difference between the AERMOD and ISC results or their similarity can be determined for the type of source, source height, etc. of interest.

2.2. The Downwash Algorithm

AERMIC plans to introduce an improved building downwash algorithm into AERMOD as resources permit. This could include the EPRI-sponsored PRIME algorithm or another alternative that overcomes the deficiencies of the existing ISC3 downwash model. AERMIC notes that the existing AERMOD downwash algorithm may be an improvement over that of ISCST3 because of the associated advances in the treatment of meteorological profiles in AERMOD. During the period in which the downwash model is incomplete, AERMOD can be used for other types of applications or for mixed applications in which the downwash algorithm does not dominate the highest concentration predictions. If the use of the current AERMOD with downwashed sources shows
that other effects, such as terrain impacts, dominate, then AERMIC suggests that AERMOD can be used to assess compliance with ambient standards. Alternatively, another model such as ISC-PRIME could be used to assess a limited receptor area where downwash effects dominate. Since near-field downwash effects are likely to be influenced mainly by source effects rather than atmospheric turbulence, the use of ISC-PRIME in the near field and AERMOD everywhere else should be considered as a possible interim solution.

2.3. Additional AERMOD Experience

The Panel recommends that AERMOD be applied to a wide variety of sources, terrain settings, and meteorological data bases to learn more about the model behavior, i.e., conduct a large number of sensitivity tests. Exercises of this type have been conducted under two activities: 1) a Technology Transfer Workgroup (TTW) during 1998, and 2) a consequence analysis to compare AERMOD and ISC results.

2.3.1. TTW Activity

In 1998, EPA under the leadership of Mr. Robert Wilson of Region 10, assembled a TTW, to conduct a variety of test runs of AERMOD. The TTW had several participants from a number of states, EPA Regions, and even a representative from British Columbia. The numerous trial runs of AERMOD conducted by the TTW on a variety of source types provided valuable feedback to AERMIC and resulted in the elimination of some "odd predictions under certain combinations of inputs" referred to by the Panel. This is not to say that our work is complete in this area. AERMIC welcomes results from other work similar to that conducted by the 1998 AERMOD TTW, either by organized groups or individuals who are exercising the model.

We note that ISCST3 itself is not immune to unusual predictions caused by discontinuities in its formulation, or by known problems that have gone uncorrected due to their low priority. This has not prevented ISCST3 from being promulgated and maintained as a guideline model. AERMOD has been formulated and tested to eliminate, to the extent possible, any problems. However, AERMIC acknowledges that with testing conducted over time, adjustments in certain algorithms may be necessary.

2.3.2. Consequence Analysis

The consequence analysis is designed to provide regulatory design-concentration comparisons between old (ISC3) and new (AERMOD) models for a number of typical source scenarios. The purpose of such a study is to give the modeling community a sense of the regulatory impacts of using the new model for source types that they have or may evaluate. Although not designed to be an exhaustive sensitivity study, the consequence analysis for AERMOD and ISC3 included 72 combinations of source, meteorological, terrain, and urban/rural situations.

Although similar to the earlier consequence analyses in that 2 meteorological data bases and 2 different land classifications were used (urban and rural), the AERMOD consequence analysis evaluated all three types of sources (point, volume and area) in three types of terrain (flat, simple and complex). There were 24 flat terrain point source combinations (6 stack heights, 2 met sites, 2 land classifications); there were 8 simple terrain point source combinations (2 stack heights, 2 met sites, 2 land classifications); there were 8 volume source combinations (2 stack heights, 2 met sites , 2 land classifications); there were 4 area source combinations (1 release height, 2 met sites, 2 land classifications); and there were 32 point source combination for the complex terrain (2 stack heights, 2 buoyancy types [medium and high], 2 distances to the hills, 4 hill types).

We believe that this consequence analysis is comprehensive in that most reasonably expected source combinations have been evaluated by the latest version of AERMOD and successfully completed. Of course, other analyses such as the evaluation -data- base reruns became part of the testing of this last version of the model; thus, the testing of the model did not end with the consequence analysis. These many computer runs have satisfied AERMIC that the current version of the model is stable and does not provide erroneous results for the large majority of source combinations.

2.4. Break-In Period

The panel recommends that in view of the new approaches integrated into the AERMOD modeling system, there should be a time period during which the public gains experience with this new model, i.e., a break-in period. During this period, the panel notes that some enhancements to AERMOD (e.g., downwash, wet and dry deposition) also could be added as well as further model evaluations. AERMIC believes that the EPA OAQPS will establish something akin to a break-in period during which both AERMOD and ISC3 may be used.

3. Response to Sections 3 and 4: General and Specific Comments on AERMIC Response Document (December 15, 1998)

The comments in these two sections deal primarily with the AERMIC response (December 1998) to the Panel Peer Review Draft Report of May 1998. As such they pertain to the earlier version of the AERMOD MFD (March 1998). The focus of the current response document is the Panel review of the most recent versions (December 1998) of the MFD and the model evaluation document. Thus, with the exception of the AERMOD development process discussed below, we do not address the discussion of the earlier AERMOD documents.

In a number of places, the Panel questions AERMIC's consideration of submodels and algorithms (dispersion, etc) from other models—ADMS, HPDM, OML, and particularly SCIPUFF—in developing AERMOD. We point out, however, that there are important links of AERMOD to earlier models. For example, the PDF model for buoyant plume dispersion in the CBL (Weil et al., 1986) was adopted in HPDM (Hanna and Paine, 1989; Hanna and Chang, 1993). This model has been modified since the HPDM version to deal more effectively with highly-buoyant plumes and CBL turbulence, including near-neutral conditions (Weil et al., 1997). This modification was made to provide a continuous variation of the modeled concentration field with source buoyancy and stability. The main point, however, is that the PDF model has an HPDM connection.

Likewise, the preprocessing of meteorological data in AERMET is similar to that done for HPDM (Hanna and Paine, 1989; Hanna and Chang, 1993) and CTDMPLUS (Perry, 1992) as stated in the most recent AERMOD MFD (December 1998); several of the processing schemes were borrowed from these earlier models. In addition, most or many of the profiling expressions for winds, temperature, and turbulence are similar to or are borrowed directly from earlier profile models as referenced in the Interface section of the MFD.

For terrain effects, much of our initial thinking of the problem was guided by concepts in CTDMPLUS, as indicated in the most recent MFD, e.g., the dividing streamline height and its dependence on wind speed, stratification, and hill height. However, our intent was to simplify considerably the concentration calculations for terrain effects by comparison to the treatment in CTDMPLUS, where subjectively-defined, idealized hill shapes and considerable terrain data are required to define them. In addition, the AERMOD vertical dispersion (sigma_z) model for elevated plumes in stable conditions has its origin in the early CTDMPLUS developments.

For AERMOD, our main aim was to develop a simple plume model for routine air quality predictions much in the spirit of ISC3, but with dispersion and other processes based on state-of-the-art understanding. Three of our key design goals were to: 1) provide reasonable concentration estimates over a wide variety of conditions with minimal discontinuities, 2) be user friendly and require reasonable input data and computer resources as in the current ISC3 model, and 3) capture the essential physical processes while remaining simple.

In considering SCIPUFF, part of our rationale for not pursuing it was: 1) the lack of complete documentation for the model when the AERMIC activity began, and 2) the absence of treatment for a number of conditions (full elevated terrain, downwash, etc) required by a new US regulatory model. SCIPUFF treatments for several of these conditions have been added since the AERMIC activity began. However, another major reason for not pursuing SCIPUFF was its basis—as a puff or integrated puff (for plumes) model and the detailed, numerically-intensive calculations and resources required for its operation. This contrasts with the relative simplicity of the plume models such as AERMOD and ISC3. Note that our goal was for the new model to be run with a year or perhaps five years of meteorological data to identify the worst-case concentrations for comparison with air quality standards. Our understanding is that SCIPUFF is not intended nor well-suited for operation in this mode. Instead, it is intended for modeling shorter time periods (e.g., 24 hours or less) in a more intensive and detailed manner (Sykes, 1999; private communication to R. Paine).

AERMIC is very interested in the numerous field data sets with which SCIPUFF has been evaluated as reported in the Panel final report (Hanna et al., 1999). We are especially interested in those data sets that fill some of the evaluation needs of AERMOD—continuous surface sources, short stacks in the planetary boundary layer, downwash situations, etc. We would be grateful for references to all of these evaluations, including those in the peer-reviewed literature.

In summary, we believe that AERMOD incorporates some of the best features of the other models mentioned by the Peer Review Panel. AERMIC is pleased that the Panel endorses the substitution of AERMOD for ISC.

4. Response to Section 5: Comments on AERMOD Description of Model Formulation: Dated 15 December 1998

In the following, we respond to the discussion of: 1) specific comments on the MFD, 2) vertical profiling of meteorological data, 3) other model formulation comments, and 4) minimum meteorological data requirements.

4.1. Specific Comments on the MFD

The Panel lists a number of specific comments by page (in the MFD) such as justification for certain assumptions, editorial comments, etc. AERMIC intends to update the MFD with further clarifications, corrections, etc. and these comments will be addressed in a future version of the MFD. Furthermore, the MFD will be updated on a continuing basis in the future as algorithms are modified and/or improved. In addition, AERMIC intends to publish several journal articles describing AERMOD and its evaluation. Many of the specific comments listed on pages 7 and 8 of the Panel Report also will be dealt with in these articles.

With respect to the urban boundary layer, further discussion of the model treatment of the nighttime situation will be given in an updated MFD. We note that in Eq. (129), a coefficient of 0.1 preceding the ln (P/P_o) term was omitted, but this was included in the AERMOD code. With this coefficient included, the urban - rural temperature difference is positive for population P > 100; a simple modification is being added to maintain a positive (or zero) temperature difference for all P.

4.2. Vertical Profiling of Meteorological Data

The Panel comments about the lack of an evaluation of the AERMOD Interface and its potential sensitivity to poorly-understood or difficult-to-measure parameters. The Interface uses parameterized profiles of wind, temperature, and turbulence that are generally consistent with profiles obtained by other investigators and that have been compared with observations (e.g., see the Paine (1993) reference cited in the MFD as well as the Stull (1988) textbook and other references in the MFD). We have relied on these earlier model/observation comparisons for Interface support since there has been a fair amount of testing in this area, and we did not wish to repeat the same comparisons. However, this is not to say that the algorithms will always work perfectly, or not be overly sensitive to variations in certain input data. AERMIC welcomes reports of the modeling community's experience with the model in this regard.

A specific mention is made by the Panel of the temperature gradient profiling algorithm. The panel notes that the expected drop-off of the temperature gradient with height in stable conditions results in better AERMOD model performance for tall stack sources. It notes that the performance could be worse than ISC3 for short stacks since the AERMOD temperature gradients could be greater than the ISC default values. However, we note that the plume rise depends on the temperature gradient to the 1/3 power. Thus, for gradients a factor of 1.5 or 2 greater than the ISC values, the plume rise would be only 13% and 20% lower, respectively, than the ISC plume rise.

As noted earlier, a number of AERMOD/ISC3 comparisons have been carried out in the Consequence Analysis for different stack heights, buoyancy fluxes, stabilities, and downwind distances. One can consult this document to gain an idea of the AERMOD/ISC concentration differences for a particular scenario of concern.

4.3. Other Model Formulation Comments

These comments are generally of an editorial nature or require further explanation in the MFD and will be addressed in an updated MFD. We note that Eq. (96) does have an error; the 2 sigma_{wT} term in the denominator should be replaced by sigma_{wT} t/2. The correct expression is used in the AERMOD code.

4.4. Minimum Meteorological Data Requirements

The AERMIC recommendations regarding minimum meteorological data for AERMOD are now available for review on EPA's SCRAM web site. It is not AERMIC's intent nor recommendation that only National Weather Service (NWS) data be used in, or sufficient for, all applications. The NWS data may be acceptable for some sources in simple terrain settings. However, in complex terrain, one may need a tall tower and sodar to provide the meteorological input if representative data from NWS sources are not available. Consideration of meteorological data representativeness on a case-by-case basis is an important aspect of the recommendations.

5. Response to Section 6: Comments on AERMOD Model Performance Document Dated 15 December 1998

The Panel notes that even if AERMOD's formulation were adjusted to improve its performance on some of the databases, its consistently good performance on a large number of databases is significant. The adjustment that improved the performance at the Lovett and Martins Creek plants was the sigma_z formulation for stable conditions, Eq. (96) with the correction noted above. This formulation adopts the same Lagrangian time-scale model used in CTDMPLUS (see Venkatram et al., 1982); it results in a smaller sigma_z than in the earlier AERMOD version and hence higher concentrations on elevated terrain.

5.1. Performance at Lovett

The Panel notes some confusion in the choice of concentration C or C/Q, where Q is the emission rate, in forming the quantile - quantile (q-q) plots for Lovett and Martins Creek. At Lovett, the concentration q-q plots were examined for the 1-, 3-, and 24-hr average concentrations, whereas C/Q plots were presented for the 1-hr averages segregated by stability, i.e., convective and stable. For averaging times greater than 1 hr, we adopted the C q-q plots because Q can vary over the 3- or 24-hr period, and there is an issue of the representative Q for normalizing C. For steady operation of a single source, the 1-hr average q-q plots could be presented either as C or C/Q. The choice of the C q-q plots was done primarily for consistency with the 3- and 24-hr averages and because the data record contained some low emission hours with highly uncertain Q values as discussed below.

The use of C/Q plots for the data separated by stability was a carryover from our earlier analysis and was not intended to confuse. However, we can understand the potential for confusion because of the underpredicted C/Q values at the upper end of the q-q plots. The plots (Figs. A-27, A-28) in the most recent AERMOD evaluation document (December 1998) contain data with quite low and uncertain Q values at the upper end. For the convective periods (Fig. A-27), the mean and maximum SO_2 emission rates for the data record were 160 g/s and 360 g/s, respectively. The highest observed C/Q value (5.87) was obtained for a Q = 2.2 g/s, which is only 1.4% of the mean Q, and the observed C was only 12.9 mu g/m**3. In contrast, the highest observed C during convective conditions was 442 mu g/m**3 with a Q = 129 g/s, and yields a C/Q = 3.43. Thus, one can see that the C/Q ratios for the very low Q hours can give a misleading impression about performance, i.e., the highest observed C/Q values are associated with relatively low concentrations. We believe that the cases with extremely low Q's should be de-emphasized; hence, we chose to focus on the C q-q plots for assessing performance. Similar findings occurred for the stable hours (Fig. A-28), where the Q's for the highest two observed C/Q values were only 4 and 5.4 g/s.

In hindsight, it would have been better to have eliminated the C/Q q-q plots or to have restricted the analyzed cases to some minimum Q as had been done in the earlier CTDMPLUS work, where a minimum Q = 40 g/s was adopted. In summary, we believe that focusing attention on the C q-q plots (Figs. A-24 to A-26) is the appropriate course for judging the AERMOD performance.

5.2. Performance at Martins Creek

For the Martins Creek plant, there are three reasons for choosing the C q-q plots for assessing model performance. The first two are the same as above for Lovett: 1) variation of Q over the 3- or 24-hr period and selecting a representative Q, and 2) de-emphasizing any cases with low and uncertain Q values. The third reason is that other sources in the Martins Creek area contribute to the concentrations; thus, there is again the issue of a representative Q for normalizing the concentrations.
In addition, it should be noted that the modeling of the concentrations from the other sources is less than ideal because the Martins Creek meteorological measurements were used for all sources. The other sources—Hoffman-LaRoche, Warren County Resource Recovery Facility, and Metropolitan Ed Portland Station—are approximately 9, 12, and 15 km from the Martins Creek sodar site (see Fig. 10 in the model evaluation document). Probably the most

questionable extrapolated variable is wind direction, and hence there is the problem of getting the plumes from the different sources properly "aimed." This is always a problem in air quality modeling. However, it is particularly exacerbated in the situation of a winding river valley surrounded by elevated terrain with non-colocated sources and only one meteorological site.

5.3. Overall Performance at a Number of Sites

The Panel questions the AERMOD performance for surface releases and the Indianapolis (urban) power plant because there is a slight tendency for underprediction relative to observations and to ISC3. They go on to state: "It is much easier to accept a model like ISC3 for regulatory applications based on fewer and less extensive evaluations, with its clear tendency to overpredict." However, the last statement is not true. ISC3 underpredicts the highest concentrations for the Kincaid SF_6 1-hr concentrations and the Kincaid SO_2 concentrations for 1-, 3-, and 24-hr averages based on the robust highest concentration (RHC, Table 1). Underpredictions also are found in the q-q plots for the same cases (Figs. A-8, and A-19 to A-21). We note that the ISC3 underpredictions for these cases are more significant than those of AERMOD for the Prairie Grass and Indianapolis data.

It is probably fair to say that a single model will not perform uniformly well or the same at a large number of sites due to a variety of factors:
1) random or stochastic variability in the observed concentrations (Note that models, as used here, are intended to predict ensemble mean or average concentrations over a large number of repetitions, whereas the observed concentrations are single realizations obtained from such an ensemble, i.e., from a statistical or probability distribution of concentration.),
2) uncertainty or errors in the meteorology and/or unrepresentative meteorological inputs, 3) errors in the model physics (e.g., unaccounted-for site features), etc.

For regulators and regulatory applications, a key question is: Within what tolerance or range of the peak observed concentrations, especially on the low side, are the model predictions acceptable? This is especially an issue when considering a large number of data bases and comparisons with varying degrees of performance. An example of the performance range can be found in Table 1 of the model evaluation document. For 1- to 24-hr average concentrations, the lowest and highest ratios of modeled/observed RHC's are 0.72 and 1.72 for AERMOD, and 0.45 and 9.11 for ISC3; for CTDMPLUS and the complex terrain sites only, the lowest and highest ratios are 0.77 and 5.56. Thus, one can see that AERMOD has the narrowest range of ratios centered about the ideal value of 1. This is not to say that the model is perfect, but it does have the smallest range of variation.

We believe that model evaluation, model performance over a wide range of data bases, and model acceptance in light of some underprediction are important topics and require further analysis and discussion.