PEER REVIEW OF THE INTERAGENCY WORKGROUP ON AIR QUALITY MODELING PHASE 2 SUMMARY REPORT AND RECOMMENDATIONS FOR MODELING LONG RANGE TRANSPORT IMPACTS

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SUMMARY

The U.S. Environmental Protection Agency commissioned a panel of four reviewers to assess scientific basis of the Interagency Workgroup on Air Quality Modeling (IWAQM) Phase 2 Recommendations on Modeling Long Range Transport Impacts. The panel of four reviewers, Mr. Mark Garrison, Dr. H. Andrew Gray, Dr. S.T. Rao, and Dr. Mark Scruggs all concluded that the IWAQM Phase 2 Recommendations were scientifically sound. They concurred with IWAQM that the sulfate and nitrate chemistry treatment available within the CALPUFF modeling system was limited (especially as it does not address adequately aqueous phase in-cloud chemistry). They concurred with IWAQM that use of the screening technique was a judgment decision, as the technique although inherently conservative, could not be guaranteed to always yield conservative concentration and deposition flux impacts. They were concerned with IWAQM's suggestion that less than five years of analysis might be acceptable, if mesoscale meteorological modeling results were used in characterizing the meteorological conditions (in lieu of only relying on the available National Weather Service routine observations). They felt that the results shown on year-to-year variability in the concentration and flux impacts argued for at least several years of analysis.

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

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

CONTENTS

INTRODUCTION

The Phase 2 Summary Report and Recommendations for Modeling Long Range Transport Impacts report was meant to provide a summary and status report of the activities sponsored or initiated by the Interagency Workgroup on Air Quality Modeling (IWAQM) for modeling long-range transport impacts. In 1993, IWAQM provided interim Phase 1 recommendations that provided the best approach from existing "off-the-shelf-techniques." IWAQM provided a status report of ongoing activities at the Sixth Modeling Conference, which was held in Washington, D.C. August 9-10, 1995. As a result of comments received, a series of investigations were undertaken. Based on the findings of the various investigations, IWAQM is now providing a Phase 2 recommendation to replace the interim Phase 1 recommendation. The CALPUFF modeling system is recommended in place of the MESOPUFF II modeling system for a number of reasons. A primary consideration is that the CALMET meteorological processor is capable of diagnostically characterizing geographic terrain slope flows, and has been updated to allow use of sophisticated output from modern mesoscale meteorological processors. Another important consideration is that the CALPUFF puff dispersion algorithms have been fashioned to allow characterization of both local-scale and long-range transport and dispersion. This allows use of one model for all sources with a consistent treatment of the chemistry and fate of the pollutants. This Phase 2 recommendation was meant to provide a major improvement in the treatment and characterization of the meteorological conditions and the mesoscale transport. The IWAQM recommends the CALPUFF modeling system for use as a refined long-range transport and dispersion modeling technique for characterizing reasonably attributable pollutant impacts from one or a few sources. Given the complexity of the problems being addressed in the Phase 2 Recommendations, EPA assembled a panel of four reviewers to assess whether the recommendations were scientifically sound and whether the report adequately summarized the basis for the recommendations. This report gives the results of that peer review.

The panel of four reviewers, Mr. Mark Garrison, Dr. H. Andrew Gray, Dr. S.T. Rao, and Dr. Mark Scruggs were charged by EPA (Appendix D) to evaluate the summary descriptions of the investigations and activities sponsored by IWAQM that lead up to and provide the basis for the Phase 2 recommendations. They were asked whether these investigations and activities were adequately summarized. They were then asked whether the recommendations on the use of the CALPUFF modeling system were scientifically sound and whether the report adequately summarized the basis for the recommendations made. The reviewers were not compensated for their time, and the report is lengthy (on the order of 150 pages). Not all of the reviewers were able to devote as much time as they might have liked in reviewing the report. Fortunately, the background and expertise of the reviewers was sufficiently diverse that they each quite naturally focused on different aspects of the recommendations in a complimentary manner. Garrison has an ongoing investigation that is using the CALPUFF modeling system to simulate nitrogen impacts over the Eastern Shore region of the United States. Thus he naturally focused on the nitrogen chemistry and the specification of meteorological input. Also as he is experienced in regulatory permitting, he focused on the testing results of the screening technique proposed. Gray has tested the interim Phase 1 recommendations and is experienced in visibility impact assessments. Thus he

focused on the evaluation results and on the recommendations made regarding visibility impact assessment. Rao is experienced with regional-scale transport assessment, model evaluation studies, atmospheric natural variability effects, and ozone chemistry. He therefore devoted most of his efforts in these areas, looking not so much a the details in the recommendations but rather at broader issues. Scruggs is very experienced in Air Quality Related Value (AQRV) impact assessments, long-range transport modeling, and with regulatory permitting assessments. He focused on the modeling requirements and the recommendations on AQRV impact assessment.

In the next section a summary is provided of the review comments received. Appendices A, B, C and D give the full text of the reviews. EPA's Charge to Peer reviewers is given in Appendix E, an overview of the review process is provided in Appendix F, and the reviewer resumes are provided in Appendix G.

PRIMARY RESULTS, CONCLUSIONS AND RECOMMENDATIONS

All of the reviewers were dissatisfied with the presentation order of the material in the draft version of the report. They offered specific edits to clarify and improve the text. They made various recommendations for reordering the sequence of the chapters and suggested that some of the material might be moved to one or more appendices.

All of the reviewers agreed that the sulfate and nitrate chemistry treatment available within the CALPUFF modeling system was limited (especially as it does not address adequately aqueous phase in-cloud chemistry).

All of the reviewers expressed concerns regarding the use of the screening technique. They agreed that it was inherently conservative (would provide estimates of impacts greater than likely would result if a more refined analysis was performed), but also recognized that it could not be guaranteed to always yield conservative concentration and deposition flux impacts. They suggested that if the screening technique is recommended, it should be made clear that it may not provide conservative impact estimates, and that the technique is applicable for one or several closely spaced sources of emissions (not for multiple sources that are widely spaced around a Class I area).

They were concerned with IWAQM's suggestion that less than five years of analysis might be acceptable, if mesoscale meteorological modeling results were used in characterizing the meteorological conditions (in lieu of only relying on the available National Weather Service routine observations). They felt that the results shown on year-to-year variability in the concentration and flux impacts argued for at least several years of analysis.

Regarding the use of sophisticated mesoscale meteorological models for preparing the meteorological input to CALMET, concerns were expressed that the use of these models is a developing art that requires experience and expertise. Even when operated by skilled personnel, the characterization of the meteorological conditions will differ, depending on which of several available models is selected for use, the options used and the manner in which the model is implemented.

APPENDIX A

GARRISON REVIEW

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Dear Mr. Irwin,

This letter provides my final comments on the "Interagency Workgroup on Air Quality Modeling (IWAQM) Phase 2 Summary Report and Recommendations for Modeling Long Range Transport Impacts", in response to your 18 September, 1998 letter forwarding the report and requesting my participation in a peer review of the report. As you know, the peer review group has conducted several conference calls over the past few months to discuss the report and the views of the group's members. I found the conference calls to be interesting and stimulating. The comments contained in this letter are my own, but they have been influenced and tempered by the discussions among the members of the group.

Much of my experience with CALPUFF has been gained through model application and evaluation related to modeling nitrogen deposition impacts in the Chesapeake Bay Watershed. This work has been sponsored by the Maryland Department of Natural Resources, Power Plant Research Program (PPRP) under the direction of Dr. John Sherwell. John has provided substantial technical support and guidance in this work. While the comments in this letter are, once again, my own and do not necessarily represent PPRP's views, I wanted to acknowledge PPRP's participation in and support of the CALPUFF modeling experience that forms the basis for my comments.

My comments are organized around the questions that you posed in the charge to the peer reviewers contained in your letter. The questions are repeated, followed by my response. I have not provided editorial comments, and I have also attempted to focus on issues that have not been dealt with in other write-ups that I have seen to-date or where I have a somewhat different view than others.

1. Did Chapter 1 meet its intended goal of setting the regulatory context, such that the modeling needs are apparent? If not, what information do you recommend be added or deleted?

Chapter 1 meets the intended goal. The only change that I would suggest is in the way that Chapter 5 is introduced and discussed. This chapter (recommendations) is clearly the most important part of the document, and this could be emphasized very simply by starting a new paragraph when Chapter 5 is introduced. In discussions with other group members regarding the overall organization of the document, the view was expressed that the material in between the introduction and the recommendation section could be placed in an appendix to ensure that proper emphasis is placed on the recommendations. My view is that chapters 2, 3 and 4 lead up to and present a necessary "story" that supports the recommendations. If a reader is really only interested in the bottom line recommendations, the reader can just as easily decide to skip the story and go right to Chapter 5 as to read the recommendations without reading the appendices. Having this material in the report does make it long, but may encourage more users to get some feel for the complex issues involved by reading it, than would otherwise turn to appendices to read that information.

2. Did Chapter 2 meet its intended goal of summarizing the events associated with IWAQM that occurred at the Sixth Modeling Conference? Do you come away from Chapter 2 with an understanding of the major science and policy concerns expressed by the public at the conference? If not, what information do you recommend be added or deleted?

Chapter 2 addresses the concerns raised at the sixth modeling conference adequately. I have a few observations about some of the specific responses to these concerns; I should note that these observations were developed after reviewing the summary in Chapter 2 and the more detailed discussion of the appropriate topic in Chapter 3.

Regional Approach: this approach has a lot of appeal. My experience with regional scale modeling with CALMET and CALPUFF suggests that it takes a great deal of time, work, evaluation, and thought to develop a scientifically sound framework for evaluating impacts beyond 50 kilometers taking into account meteorology that varies in space as well as time, for a given geographic setting. The many specific decisions that are made to arrive at this sound framework are by no means monolithic in the sense that they are unassailable from every point of view, but have the characteristic that they work together to produce impacts that are reasonably supportable. The participation of different stakeholders in the process holds out the best promise, for each Class I area, of producing impact analyses that are sufficiently protective of resources (AQRVs) from a regulatory perspective, and provide a non-moving target with a reasonable level of effort and outcome for applicants. The recommendations are correct in not requiring this approach, but are also correct in encouraging its use. The actual implementation of a regional approach may be somewhat difficult to accomplish; however, the recommendation - including the concept of developing initialization model runs - strikes the right balance in my view. The issue discussed elsewhere of having impacts at receptors from a source when two mountain ridges intervene between the source and receptor area could at least be addressed up-front in an initialization study that considers the modeling domain and possible different approaches for sources in different parts of the domain.

Model Evaluations for the 50 to 200 km Range: I am not sure that the conclusion regarding "unbiased estimates" is fully supported by the evaluations described in Section 3. Most of the studies that support this conclusion were tracer studies that considered only short time periods. A stronger case could be made for concluding that the estimates are unbiased if evaluations could be conducted on longer-term, "consequence" focused data sets (i.e. long-term average pollutant concentrations or deposition rates, or maximum short-term values over a full year). Having said this, however, the paucity of such data bases and the resources required to conduct evaluations make it impractical to accomplish for this round of recommendations. Even though it is easy to identify uncertainties with using a model at these distance ranges, I do not object to the conclusion that CALPUFF can be used for this distance range, based on the "best currently available scientific information and evaluations". The views expressed in this section of application of the model at distances beyond 300 km strike the appropriate balance.

Develop a better screening technique: I believe that the screening technique identified in this section, that was developed in response to concerns that the previous "Level I" screening technique was too conservative, is a good example of finding a balance between the need to be

conservative and the need to be practical. I had some initial reservations and thought that this technique could be refined further by limiting the results to the general direction of the receptor area, but now believe that it could provide a way for some sources whose emissions and impacts are truly inconsequential, to "screen out" of a more resource-intensive analysis. This screening technique is really only applicable to single sources (or at least, single source areas) and this point should be brought out in this section or at least in the recommendations section. The screening technique may be of somewhat limited usefulness because of this, but I think that it is fair to say that the resource burden on individual applicants who need to go beyond the screen should be minimized as much as possible by the existence of a comprehensive initialization analysis.

3. Chapter 3 summarizes a series of separate studies. Are the summaries sufficiently complete that you understand what the goals were of the studies and conclusions reached? Is additional information needed for some, or are too many details provided in some?

Chapter 3 represents a remarkable achievement to me. I found the summaries to be extremely useful in understanding the motivation for and conclusions of the studies cited (in most cases, admittedly, I did not have a great deal of familiarity with the original study). Although there was some discussion in the peer review group of placing this material in an appendix, I think that it provides an important link to the recommendations and should be kept here. There is no question but that the use of CALPUFF to predict long range impacts is complex - and an understanding of this material can help even the experienced user learn from the experience and evaluations performed by others. If the reader's interest is primarily in the recommendations section, Chapter 3 can be easily skipped. My only specific comment on the entire section is that Figure 21 (from the 1997 AWMA paper) was of poor quality - I have included a new figure in the electronic version of this report (WP format) that may be a bit better.

4. Chapter 4 is meant to outline how the output from CALPUFF can be used to derive haze and deposition impacts from one or several sources involving long range transport. Is the description sufficiently complete? Is more information needed in order for the reader to have a basis for understanding where simplifications have been made and the resulting consequences?

All of the material in Chapter 4 is important and well-presented (since my own experience has been primarily related to deposition modeling, I can speak with more confidence on this subject than on the visibility section). I think that the discussion on deposition could benefit from a (brief) discussion of how the parameters such as scavenging coefficients, chemical parameters for gas-phase dry deposition, etc. can affect deposition rates. I also think that it is too much to expect that there can be enough discussion in this section to give the reader a picture with any real level of understanding of the simplifications that have been made - an experienced photochemical modeler reading this section will understand those simplifications much more thoroughly than an experienced ISC modeler. Likewise, the information in this section will not make an experienced modeler out of an inexperienced modeler - but it does provide a starting point and the real work of gaining experience will be accomplished with experience with using CALPUFF. Other than the suggestion regarding deposition parameters, I believe that this section does not need to be modified further. In terms of understanding simplifications and the possible

consequences of the simplifications, I actually feel that Chapter 5 did a pretty good job of this; maybe the question should have been asked with respect to Chapter 5.

5. Chapter 5 and associated appendices are meant to outline IWAQM's recommendations on how the CALMET/CALPUFF modeling system should be applied. It was intended to provide enough information that if one were qualified and had the expertise they would have sufficient information to know where the major science uncertainties are, and where expert judgement will be most needed. It was not intended to provide a cookbook for the unskilled or inexperienced. Has this goal been met? If not, what information would you recommend be added or deleted?

I believe that the right balance has been achieved. The following represents my comments on the substance of the recommendations (please note that since chapter 2 presented what was in essence an introduction to the recommendations, my response to question 2 was in essence an introduction to my comments on the recommendations!)

Screening analysis: Receptor spacing should be a function of the specific geographic situation (mainly the distance from the source to the Class I area); 2-degree spacing may be enough (or even too much) in some situations and not in others. The recommendation should provide some guidance for situations that may occur if the Class I area is located in terrain that is considerably different than terrain in other directions from the source being modeled. Should terrain in the other directions be specified to be similar to the Class I area, since these other directions are surrogates for the Class I area? The recommendation should also include a discussion that clarifies that this screening analysis is appropriate only for single sources or at most a single source area. Domain average values for ozone should include averages for daytime hours only.

Refined analysis: Considering the amount of work involved with running the model, setting up an hourly ozone data file is a relatively small task. The recommendation for ozone should be changed to include the use of hourly data with the appropriate caveats regarding the typical urban/suburban location of ozone monitors. A single, average value tends to kick off the chemistry immediately after sunrise and slow it down during the afternoon. Although CALPUFF does not contain a complete photochemical mechanism, using hourly ozone values allows it to at least match some of the overall characteristics of a more complete mechanism, and I think is more in keeping with the way in which the empirical approach to transformation rates was developed in the first place.

I am also concerned with the relaxation of the length of record requirement for applications using enhanced local data or prognostic data sets. Ideally, the advanced data could be used for the available time period, and NWS data could be used for a five-year period that spans the advanced data period. Design concentrations would be developed by default from use of the advanced data period; the NWS long-term analysis would be used to assess whether the year modeled was representative. This approach is a good example of the kind of analysis that could be more objectively carried out during an initialization study than in the heat of permitting for a specific application. From a practical perspective, this level of analysis is probably not justifiable for a single source permit application, and the recommendation as written (relying heavily on case-by-case determinations) is after all the best solution.

6. The evaluation results presented are admittedly anecdotal. High quality mesoscale tracer field data are scarce. In you opinion, has enough been done for the recommendation presented? One can always ask for more. If more is needed prior to release of this recommendation, what would be the goals of these evaluations, and which data sets are recommended for each of these goals that have the requisite information?

My response to this question is relatively simple. I strongly believe that enough has been done to go forward with this recommendation. If the recommendation was highly prescriptive, or if there was a compelling need for all Class I area analyses to be identical, I would not feel this way. I believe, however, that enough opportunity for the careful tayloring of analyses to fit specific Class I areas is provided in the way that the recommendations are worded, and that iron-clad certainty regarding the correctness of this approach is not necessary (nor is it even possible, even with a vastly increased level of evaluation). I just as strongly believe that the process of model evaluation and improvement should continue unabated. One approach that could possibly add some useful information is described in my response to question 7.

7. Each of you have your own experiences. You may have personal experiences that warn you where some pitfalls are that have not been addressed in the current draft of this report. If so, what would you suggest be given more attention and for what purpose?

There are two areas that are worth mentioning. First, under PPRP sponsorship, we have modeled nitrogen deposition in the Chesapeake Bay Watershed for 1990 with the IWAQM MM4 data set and with a data set derived entirely from NWS data (surface, upper air, precipitation). The results on a watershed-wide, annual average basis show that total nitrogen deposition using NWS data is only 9% less than the n-deposition values using MM4. The results of this study have not been published yet, but will be in a PPRP report within a reasonable time period. We are hopeful that we will be able to provide insights into differences for short-term averages as well.

Second, again under PPRP sponsorship, we have conducted evaluations of (non-ammonia) inorganic nitrate wet deposition predicted by CALPUFF compared to data collected at NADP sites. The first set of evaluations was published in a 1998 AWMA paper (I've included a copy attached; WORD unfortunately). This study showed a tendency for CALPUFF to underpredict (P/O ratios of 0.5-0.75) wet inorganic nitrate deposition at two NADP sites in Maryland. We further evaluated a modification to CALPUFF that set a higher minimum NOx concentration in the rate equation (default in CALPUFF is 0.1 ppb; we tested 5 and 10 ppb). Evaluation results improved remarkably (P/O rations 0.75-1.0). The justification for increasing the minimum NOx value is that, in the more heavily industrialized northeast background NOx is likely to be high, even if individual plume concentrations are low - more so since CALPUFF does not account for neighboring puffs.

Additional evaluations have been conducted, expanding the evaluation sites to more that 45 NADP, CASTNET, and AIRS sites in the area of the Chesapeake Bay Watershed, and comparing predicted and observed concentrations of HNO3, NO3 aerosol, and NO2/NOx. These additional evaluations are still in the process of being analyzed. I cannot guarantee the pace or the level of attention paid to these additional evaluations, but we (I think it is safe to speak for John on this) would be happy to share results with you as they become available. The scale of our evaluations

is necessarily large, much larger than the 300 kilometer limit that the Phase 2 report carves out as the “niche” for CALPUFF, but I believe that these evaluations will eventually lead to better deposition estimates using CALPUFF. We have also recently been looking at the use of CALPUFF’s nitrogen budget approach to make estimates of NOy concentrations as a surrogate for the “maximum ozone potential” of NOx sources - these investigations too are in a tentative, early stage.

It is fair to summarize my comments by stating that I believe that EPA would be justified in moving forward with the Phase 2 report with only minor corrections/additions. I think that the recommendations strike an appropriate balance between guidance that is specific enough to provide direction, and guidance that allows for flexibility in individual Class I areas. Model evaluation and improvement should also move forward, and as improvements are made and justified they should be reflected in revisions as necessary.

In closing I would like to say that I think the IWAQM committee did a very respectable job of grappling with, and producing some workable guidance for, the difficult issue of Class I area impact analyses. I appreciate the opportunity of providing some input to this process. If you have any questions, please do not hesitate to call me at (610) 524-3674.

Sincerely,

Mark E. Garrison

APPENDIX B

GRAY REVIEW

Review of IWAQM Phase II Summary Report

1. Did Chapter 1 set the regulatory context, such that the modeling needs were apparent?

Generally, the chapter reads very well, and adequately sets the regulatory context. Somewhere in this chapter should be a clear discussion of which modeling approach should be used in which situation for example, does the typical "user" need to model all existing sources for a PSD determination, or will the existing increment be provided which is then added to the modeled increment due to the single (new or modified) source in question? Some of the philosophy related to how the model will be employed in practice would be helpful. Maybe these are regulatory issues that are beyond IWAQM's responsibility, but it would add to the usefulness of the report to include a discussion of what is required for each type of application, and then what is the Phase II recommended modeling approach for satisfying the regulatory requirements.

At the end of Chapter 1, there is a brief description of the following chapters, which is necessary. But unless the reader is paying close attention, the structure of the report may be forgotten by the time Chapter 5 is reached. In other words, Chapter 1 discusses a recommended Phase II modeling approach that has been developed following Phase I, conferences, comments, evaluations, etc. But then there is a 107 page detour until we get to Chapter 5 and see what the recommended approach is. Readers who want to "use" this report to learn how to apply CALPUFF for their particular situation are required to have a long attention span...

2. Did Chapter 2 adequately summarize the events associated with IWAQM at the Sixth Modeling Conference?

The chapter does a good job of describing the conference presentations, comments, and subsequent responses. At the conference, the initial recommendations for using CALPUFF were presented. A number of issues were raised (described in the comments section) which were then addressed by IWAQM. The responses then become part of the (evolving) recommendations, which are presented later (in Chapter 5). For example, it was generally agreed at the conference that a superior screening technique was needed. At the end of Chapter 2, a revised screening approach is presented that uses maximum concentrations on receptor rings.

I have some concerns about the recommended screening approach. Using maximum predicted values on receptor rings that pass through the Class I area (as opposed to using values predicted within the Class I area) is based upon the assumption that the transport would be inaccurate due to use of simpler wind fields (from ISC). However, this approach therefore assumes that the chemistry is reasonably correct. But evidence is presented that the screening estimates of sulfate and deposition were "sometimes higher and sometimes lower" than the model with CALMET inputs.

The approach is then justified by using the maximum on a ring rather than at the actual Class I receptor, in effect choosing a conservative (maximum) value to replace the inaccurate prediction at the Class I receptor. For many applications, this will more than likely provide an upper estimate of the impact and therefore is ideal for screening. However, consider a situation where a source is located in such a way so that the maximum impact emanating from the source is in the direct line of the Class I receptor. In other words, the actual maximum is IN (or near) the Class I area. In this case, there is a significant probability (50%?) that the maximum value chosen by the screening model would be lower than that suggested by the full model. This is inconsistent with the intention of the screening tool which is to predict a concentration that is almost certainly (probability exceeding 95% or more?) higher than the actual value (as estimated by the full model). The current approach is to add a positive bias to the screening result, however the bias will not be present in many cases.

Choosing a maximum in this manner is somewhat arbitrary. And certainly there will be many cases where the opposite situation will exist when the maximum impact is in the opposite direction from the source (away from the Class I area). Maybe only a sector of the ring should be used that adds 30 to 45 degrees to the edges of the Class I area. But there still needs to be some better assurance that the maximum will almost certainly provide the required upper bound (conservative) estimate in cases where the maximum impact, in fact, coincides with the Class I area.

In addition, the screening approach appears to only make sense for single source analyses; are there situations where a screening model is needed for multiple sources?

3. Are the studies and conclusions reached described in Chapter 3 sufficiently complete?

Chapter 3 contains descriptions of a number of separate studies. While each is presented well, there is little or no flow from one section to the next. Some sections are sufficiently detailed (e.g., 3.1, 3.6 and 3.8) whereas others are brief and provide little more than a summary (e.g., 3.4 and 3.5). Many discussions in this chapter are directly relevant to and provide support for the recommendations presented in Chapter 5, but there is much tangential material that is background in nature. The more I read through this chapter, the more I feel that much of the material (if not the entire chapter) belongs in one or more appendices.

4. Is the Chapter 4 description of the visibility and deposition calculations sufficiently complete?

The chemistry and visibility discussions are reasonably complete. A disclaimer up front states that the chemistry algorithm within CALPUFF is adequate for representing gas-phase SOx oxidation but is not adequate for aqueous phase oxidation. In humid environments, this reaction pathway will dominate the formation of sulfate (typical rates can reach a few percent per minute). It is very likely, especially in the East, that high humidity will coincide with peak levels of

sulfate, particularly for long-distance regional applications. The use of the aqueous term, $k_{1(aq)}$, attempts to overcome the deficiency, but for humidities over about 70 percent, the aqueous rate will rise rapidly so that the maximum of 3% per hour is probably much too low.

The 3.912 in the numerator of equation 1 (pg 103) assumes a 2 percent contrast threshold for the viewer. Many researchers have assumed a 5 percent threshold, which would change the value to 2.995.

Some justification for the selection of extinction efficiencies should be provided. I have seen data which suggest that different efficiencies (and RH functions) may be appropriate for eastern and western locations.

The value of 20 for the EC absorption efficiency is much too high. Literature data suggest a value of about 9 m^2/g for EC absorption. Since the scattering efficiency of EC is similar to other fine mass, a value of about 1 m^2/g is usually added (if not accounted for in b_{sp}).

There are a number of different f(RH) available in the literature. Why was this one (shown in Fig 28) selected? Also, because these functions are usually exponential with RH, for most applications a maximum RH is allowed otherwise extremely high extinctions will be predicted during very wet conditions. If a gridded RH value is above about 95%, there is likely precipitation occurring somewhere in the grid cell. Although sulfate can be formed rapidly in such conditions, it is likely also being rapidly deposited through wet deposition.

It is not clear what CALPUFF does in terms of postprocessing the concentrations. Does the model compute extinction or does the user have to do it? The visibility summary on page 109 implies that the user must perform this calculation. Why not include it in a postprocessor?

5. Are the recommendations for applying CALMET/CALPUFF sufficiently documented?

The tables in Chapter 5 are very helpful in outlining the recommendations. The tables address the major elements of the modeling procedure. These tables should be expanded to include (briefly) the treatment of background data, precipitation, terrain, etc., which are then described more fully on the subsequent pages. In other words, there should be more of a one-to-one correspondence between the table and the text that follows. That way a user could use the table as a checklist of issues to address before running the model. The text would be referred to for more in-depth discussion on each issue.

The use of a single domain-wide ozone background value can cause significant problems. The chemistry is very dependent on the ozone concentrations (used as a surrogate for the oxidizing potential of the atmosphere). If the domain is small enough, then a domain-wide value may be reasonable, but a realistic diurnal cycle MUST be included. And if the domain is large (such as the 400 by 400 km domain mentioned in the text), then it is probably necessary to include some real data to adequately represent both spatial and temporal patterns. If real data are

to be used, the user should be cautioned concerning the scarcity of rural ozone data and possibly given some guidance on how to overcome this problem. In modeling studies I have conducted, pseudo-sites were added where needed in rural locations with assumed diurnal concentrations, and then these assumed data were interpolated along with the real hourly ozone data to provide realistic spatial patterns. That way if the plume should pass near an urban area, sufficient oxidation will occur in the model.

General comments:

1. The report contains a lot of useful information, the majority of which is probably relevant and therefore should be included in the report. However, the structure of the report may not adequately serve one of main intended purposes. The report will be used by those in the regulatory and regulated communities to develop modeling protocols for specific applications. The report reads too much like a history report it is useful as background info to know what was the course of events leading up to the present recommendations, but the most important knowledge are the recommendations themselves.

A restructuring of the report may be warranted where the chapter five recommendations are moved in front of the current chapter 2. Then after the recommendations are spelled out, the historical, scientific and practical justifications (with all the anecdotal evidence) that support the recommendations would be presented.

2. Mark Scruggs raised a good point during our recent conference call and I didn't see it addressed in his comments. The visibility calculation procedure, whereby extinction is reconstructed from pollutant concentrations and extinction efficiencies, is an evolving science. Some mechanism should be in place for updating the procedure, in particular, the extinction efficiencies and relative humidity function should be selected to represent the most recently available and most relevant data. It has also been common practice to use different values in the East vs. West, which would presumably account for differing particle morphologies, etc.

APPENDIX C

RAO REVIEW

S.T. Rao's Comments on IWAQM Phase 2 Summary Report

In general, I find that the report is well written with adequate technical justifications for the recommendations made here. My specific comments on the report are as follows:

- On page 3, would it be appropriate to state that this report addresses only PM10 and that issues relating to PM2.5 would be covered elsewhere?

- On page 4, it is stated that "...use of mesoscale meteorological analyses provided a significant improvement in the accord of modeled and observed trajectories." How are trajectories observed? It is important to recognize that errors are inherent to all trajectory computations. Please refer to Stohl's recent paper on this subject in AE.

- On page 7, it is stated that a five-year meteorological data base was developed. This data base can be used to assess the impact of the year-to-year variability in meteorology on the predicted concentration fields since you are considering the acceptability of shorter time periods of meteorological data. For example, you can use the first 3/4 years, second 3/4 years, etc. in this assessment.

- If FDDA-MM are recommended as the preferred approach, it is important to recognize that differences in the meteorological fields can exist if different models (e.g., RAMS versus MM5) are used or different options and/or initializations are used in one model. The resulting trajectories would also be different.

- On page 114, the use of PCRAMMET is suggested. Since the predicted concentration fields are very sensitive to the mixing height, there is a concern that RAMMET might have bias toward low mixing heights. How should this be accounted for?

- I don't believe that less than five years of FDDA-MM or on-site data is equivalent to five years of routine NWS observations. Since the object here is to properly capture the year-to-year variations in meteorology, the use of time periods shorter than five years should be carefully evaluated before such a procedure is accepted.

- Regarding ozone data, it is important to consider the temporal variability of ozone. Hence, one should not use a single typical background value.

APPENDIX D

SCRUGGS REVIEW

November 3, 1998

John S. Irwin
USEPA (MD-14)
Research triangle Park, North Carolina 27711

Dear Mr. Irwin:

Below is my review of "Interagency Workgroup on Air Quality Modeling (IWAQM) Phase 2 Summary Report and Recommendations for Modeling Long-Range Transport Impacts." I have used the questions you provided as a framework on which to transmit my comments. I will also provide some additional thoughts at the conclusion of those comments.

Did Chapter 1 set the regulatory context, such that the modeling needs were apparent?

In general, the regulatory context and the chronology of IWAQM activities have been adequately covered. I offer only a few suggested additions and revisions:

In addition to the modeling capabilities listed in the first paragraph of page 2, the need for the recommendation to be able to address multiple, geographically disperse sources should be mentioned. Cumulative analyses of all PSD sources affecting a Class I may be a frequent requirement.

The Phase 1 IWAQM recommendation also included a screening level model. It should be mentioned here to put later comments on the Sixth Modeling Conference in perspective.

Near the top of page 3, the sentence beginning "The PSD NAAQS Pollutants of concern", should be deleted or corrected. All NAAQS are of concern in PSD. A source cannot be permitted if it is going to cause a violation of a NAAQS.

Others would probably also argue that the recommendations were superior to assuming 100% conversion of gaseous pollutants to particulates.

Editorial comments: Change all Class 1 to Class I throughout document. One sulfur with a "p" slipped in. Subscript the "10" in PM10 to be consistent with thee rest of the document.

Did Chapter 2 adequately summarize the events associated with IWAQM at the Sixth Modeling Conference?

The reader can easily track the sequence of IWAQM activities at the Modeling Conference. However, I was caught off guard be the excursion of IWAQM into the policy arena, i.e., the recommendation for a committee of public and private stakeholders for Class I areas (bottom of page 14). How would such a group deal with interstate issues? What would be the FACA

implications? What be the relationship of this group to the permitting authority? The concept of consistent, cumulative analyses is certainly appealing, but it is not clear who would have the responsibility of developing the infrastructure of such a group. I guess I thought of IWAQM's role as being to offer the best modeling tool to address the modeling scenarios described in Chapter 1.

Other specific comments:

The introduction in Section 2.1.3 mentions a numerical simulation study, but the subheading refers to the "CALMET trajectory comparisons." (See Section 3.3, page 37).

I am confused by the sentence in Section 2.1.5, which begins "The inventory could differ" Why wouldn't an AQRV analyses be conducted for a new source using allowable emissions? I think I understand the point you are trying to make here, but I believe some elaboration is needed.

I also got confused with the ISC/CALPUFF comparisons described on page 18. I interpreted the second paragraph to mean that the CALPUFF was run in a steady-state mode and compared with typical ISC results and that these comparisons were very favorable. However, the third paragraph starts of with "When the meteorology was allowed to vary from one hour to the next, but not in space" Isn't that how a steady-state model normally runs? Do you mean persistence?

Editorial comments: Under section 2.1.5 (second paragraph), do you mean flora and fauna?

Are the studies and conclusions reached described in Chapter 3 sufficiently complete?

If this report stays in its present form, I believe that Chapter 3 is prime appendix material. It is an excellent compendium of the data available for model assessment purposes and a good discussion of how this candidate model performed. Other comments:

I'm not sure what Section 3.1 on the MESOPUFF II adds to the Phase 2 recommendations. It is interesting work, but what is the significance to Phase 2?

Editorial comments: I can guess what it is, but I couldn't find a definition of the "slug" model. I can't make out the x's and o's in Figure 5.

Is the Chapter 4 description of the visibility and deposition calculations sufficiently complete?

The treatment in this chapter is basically complete, but I believe there are several places where some clarification is needed.

The reasons (i.e., ozone and ammonia availability) for the recommended limitation on the number of new sources in a CALPUFF application (bottom page 100 and the top of 101), would suggest to me that application of CALPUFF to existing sources is even more suspect.

The sentence (last full paragraph of page 101 beginning "Also, unlike sulfate" is over-generalized. While the formation of sulfuric acid aerosol is independent of the available ammonia, the neutralized form clearly is not. Because it is the neutralized form that is used in the extinction calculations this sentence should be clarified or just omitted since the preferential formation of ammonium sulfate over ammonium nitrate has already been mentioned.

Not being a chemist, I am confused by the rate constants given on page 102. How does the particulate nitrate formed under k2 processes differ from the k3? Is there any double counting here?

Comments on Section 4.2

Atmospheric extinction is used in Equation 1 and 2 before it is defined. I would prefer to see extinction lead the discussion. Also, it's looking more and more like the change of extinction is going to be the preferred visibility metric. Therefore, while the change in deciview discussion is all right, the calculation of change of extinction should receive equal treatment.

The bEC should be removed from Equation 3 and Equation 6.

The present thinking is that bab = 10 [EC], so Equation 5 should be changed.

I could not find a reference for the f(RH) adjustment. One should be provided.

Comments on Section 4.3

In the opening paragraph, the sentence beginning with "Generally deposition values are given," should be revised to open with "Generally AQRV analyses require deposition values given." Otherwise the reader may think that CALPUFF provides deposition values. In the next sentence, add "from CALPUFF" after "oxides of sulfur and nitrogen."

There is no similar treatment of background as there was for the visibility section. One should be added.

Comments on Section 4.4

I recommend deleting this section. The treatment of background is already in or can easily be added to the previous sections. The Larsen material is not relevant to the discussion or the Phase 2 recommendation.

Was the CALMET/CALPUFF application sufficiently documented?

The prescriptions for the screening and refined analyses are well laid out in Table 12 and 13. The caveats are also well documented.

As I expressed on the phone, I have some difficulty with the length and breadth of scope of the document. I strongly recommend that Chapters 2, 3, and, possibly, 4 be placed in appendices. I believe that this would enhance the presentation of each of the important topics you have treated.

You and IWAQM have accomplished a gargantuan task and should be commended for it. I thank you for the opportunity to have reviewed this recommendation.

Sincerely.

Mark A. Scruggs
Chief, Research and Monitoring Branch
ARD-DEN: Reading and Project File
ARD-DEN:Mscruggs:ms:11/03/98:x2077:IWAQM.LTR.DOC

APPENDIX E

EPA'S CHARGE TO PEER REVIEWERS

Instructions to Peer Reviewers for Reviewing the Interagency Workgroup on Air Quality Modeling (IWAQM) Phase 2 Summary Report and Recommendations for Modeling Long-Range Transport Impacts.

The U.S. EPA is conducting a peer review of recommendations and conclusions reached by the Interagency Workgroup on Air Quality Modeling (IWAQM) in their Phase 2 Summary Report. This peer review is meant to ensure that science is used credibly and appropriately in derivation of the conclusions and recommendations reached. You have been chosen as an expert in this scientific discipline. Four peer reviewers have been chosen. The names and contact information for the peer reviewers are provided at the end of these instructions. You may conduct your review independently, or you can consult with the other reviewers as you desire.

The Phase 2 report is not intended to provide a summary of the science within the CALPUFF modeling system. It provides a summary of IWAQM's experiences and activities with the modeling system, and IWAQM's recommendation on the use of CALPUFF for long-range transport assessments (with a particular emphasis on haze and deposition assessments, reflecting the interagency interests of the National Park Service, the Forest Service, and the Fish and Wildlife Service, who are members of IWAQM).

- Chapter 1 sets the regulatory context and need for a long-range transport model.

- Chapter 2 provides a summary of the presentations provided at the EPA Sixth Modeling Conference in 1995, the comments received, and the responses to the comments.

- Chapter 3 provides a bit more information on the Sixth Modeling Conference presentations in the first five subsections, and the last 4 subsections summarize the work accomplished since the Sixth Modeling Conference (most of which is in direct response to comments received at the Sixth Modeling Conference).

- Chapter 4 is specific to how one could use the modeling results from CALPUFF for addressing assessment of regional haze or deposition impacts from one or several sources.

- Chapter 5 summarizes how the Interagency Workgroup on Air Quality Modeling (IWAQM) envisions use of the CALPUFF modeling system, input requirements, expertise needed, etc. The information in Chapters 2 through 4 is intended to provide readers with sufficient information that they can appreciate the rationale for the conclusions and recommendations presented in Chapter 5.

The Phase 2 report is nearly complete. The few edits and additions needed were deemed sufficiently minor that it was anticipated that they would not inhibit conducting a peer review of the report at this time. Some of the references shown are place-holders for reports that are being drafted and have yet to be finalized. As noted in the appendices, there is some minor information

yet to be added. We are hoping to get a clearer version of Figure 21. Figures 23 and 24 have labeling problem (noticeable at the lower right corner of the figures).

Below are some questions that are meant to assist and guide your deliberations in conducting a peer review.

1. Did Chapter 1 meet its intended goal of setting the regulatory context, such that the modeling needs are apparent? If not, what information do you recommend be added or deleted?

2. Did Chapter 2 meet its intended goal of summarizing the events associated with IWAQM that occurred at the Sixth Modeling Conference? Do you come away from Chapter 2 with an understanding of the major science and policy concerns expressed by the public at the conference? If not, what information do you recommend be added or deleted?

3. Chapter 3 summarizes a series of separate studies. Are the summaries sufficiently complete that you understand what the goals were of the studies and conclusions reached? Is additional information needed for some, or are too many details provided in some?

4. Chapter 4 is meant to outline how the output from CALPUFF can be used to derive haze and deposition impacts from one or several sources involving long range transport. Is the description sufficiently complete? Is more information needed in order for the reader to have a basis for understanding where simplifications have been made and the resulting consequences?

5. Chapter 5 and associated appendices are meant to outline IWAQM's recommendations on how the CALMET/CALPUFF modeling system should be applied. It was intended to provide enough information that if one were qualified and had the expertise they would have sufficient information to know where the major science uncertainties are, and where expert judgement will be most needed. It was not intended to provide a cookbook for the unskilled or inexperienced. Has this goal been met? If not what information would you recommend be added or deleted?

6. The evaluation results presented are admittedly anecdotal. High quality mesoscale tracer field data are scarce. In your opinion, has enough been done for the recommendation presented? One can always ask for more. If more is needed prior to release of this recommendation, what would be the goals of these evaluations, and which data sets are recommended for each of these goals that have the requisite information?

7. Each of you have your own experiences. You may have personal experiences that warn you where some pitfalls are that have not been addressed in the current draft of this report. If so, what would you suggest be given more attention and for what purpose?

APPENDIX F

OVERVIEW OF PEER REVIEW PROCESS

The peer review was organized and monitored by John S. Irwin of the Air Quality Modeling Group of the Office of Air Quality Planning & Standards. The reviewers were chosen as either having direct "hands-on" experience with the CALPUFF modeling system (Garrison and Gray), or as having especial insight in regional-scale modeling issues including chemistry and natural variability (Rao), or as having direct experience in AQRV modeling assessments as they affect decisions being made by Federal Land Managers (Scruggs). Since no compensation was possible, the EPA considers itself fortunate that these experts were willing to donate their time to the peer review task.

Letters were sent to each of the reviewers on September 18, 1995. A copy of the letter is included at the end of this appendix. Included with the letter was EPA's charge to peer reviewers (Appendix E). At the conference call held on September 23, 1995, the reviewers agreed that they wanted to hold a series of conference calls, so that they could discuss concerns and ideas as the progressed through the report. Accordingly, conference call were held on October 20, 1998, November 3, 1998 and November 17, 1998. The reviewers were hoping to complete their respective reviews by Thanksgiving, but this proved to not be possible. Review comments were finally received from all the reviewers on January 21, 1999. It had been hoped that Mr. Leon Sedefian would be able to participate, but his schedule precluded his participation. Likewise, towards the end of November, Dr. Rao's schedule precluded him from revising his initial draft of his review comments. However, he agreed that his major concerns were appropriately captured by his initial draft.

After all the review comments were received, John S. Irwin compiled a draft version of this report, which was distributed via E-mail to all parties for their review and concurrence.

Dr. Mark Scruggs
National Park Service
Air Resources Division
7333 West Jefferson, Suite 450
Lakewood, Colorado 80225

Dear Dr. Scruggs,

The U.S. Environmental Protection Agency (EPA) is conducting a peer review of recommendations and conclusions reached by the Interagency Workgroup on Air Quality Modeling (IWAQM) in their Phase 2 Summary Report. This peer review is meant to ensure that science is used credibly and appropriately in derivation of the conclusions and recommendations reached. You have been chosen as an expert in this scientific discipline. Four peer reviewers have been chosen. The names and contact information for the peer reviewers are provided as Enclosure A to this letter. Enclosure B to this letter is the 'charge to the peer reviewers,' which basically ask the reviewers to focus attention on the merit of the conclusions reached, rather than on editorial issues. Some leading questions are provided as an aid in your review of the report.

To insure that we are all on the same schedule and are clear as to the focus of the peer review, I ask you to:

1. When you receive this letter, would you either call me or email me, that you have received this letter, Enclosures A and B, and the draft Phase 2 report. When you do this would you tell me when would be a good time for an initial conference call (see item 2). I can be reached at:

Mr. John S. Irwin
USEPA (Mail Drop 14)
Research Triangle Park, NC 27711

Phone: (919)541-5682
Fax: (919)541-0044
Email: irwin.john@epa.gov

2. Once I have heard from everyone, I will schedule a conference call. I would like to have this call as soon as possible, say Thursday September 24. I know many of you have travel scheduled for late September and early October. I hope the call can be rather brief (less than 1 hour). The purpose of the call is to introduce everyone, to discuss and agree on the ground rules and schedule, and to insure everyone is clear as to what is needed.

3. Deliverables. As this is a formal process, a written response is needed from each of the reviewers. You can use whatever style or format is suitable (memo, letter, etc.), just so long as it is a written and signed response. It is my hope to have your responses by the end of October. We can discuss and agree on the actual schedule during the initial conference call (item 2).

You may conduct your review independently, or you can consult with the other reviewers as you desire. I have participated in peer reviews, and have found that the most useful and successful are those in which the peer reviewers discussed (in some manner) their ideas and concerns, prior to drafting their final responses. It is helpful if consensus can be reached on the major ideas, concerns and recommendations. I can initiate conference calls to facilitate such interaction, if you wish. We can discuss this during the conference call suggested in item 2.

I thank each of you for agreeing to undertake this work. The report is lengthy and the only compensation is knowledge that you have helped IWAQM in its endeavors to improve the technical modeling guidance for characterizing impacts resulting from long-range transport. If there is anything I can do to help, please contact me at the above address. Thanks again for your help in this matter.

Sincerely,

John S. Irwin, Meteorologist
Air Quality Modeling Group

Enclosures

Enclosure A

List of Peer Reviewers

Mr. Mark Garrison
Environmental Resources Management
855 Springdale Drive
Exton, PA 19341
Phone: (610) 524-3674
Fax: (610) 524-7798

email: mark_garrison@erm.com

Dr. H. Andrew Gray
Gray Sky Solutions
900 Appleberry Drive
San Rafael, CA 94903
Phone: (415) 472-0960
Fax : (415) 472-0959

Email: gray@grayskysolutions.com

Dr. S. T. Rao and Mr. Leon Sedefian
New York Department of Environmental Conservation
Office of Science and Technology
50 Wolf Road, Room 198
Albany, N.Y. 12233-3259
Phone: (518)457-3200
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Email: strao@air.dec.state.ny.usEmail: Lxsedefi@gw.dec.state.ny.us

Dr. Mark Scruggs
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Air Resources Division
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For Overnight Mailings use:

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12795 West Alameda Parkway
Lakewood, CO 80228

Email: mark_scruggs@nps.gov

APPENDIX G

PEER REVIEW PANEL QUALIFICATIONS
RESUMES

RESUME

Mark E. Garrison

Key Projects

Participated in a peer review panel for the new AERMOD model. Developed comments on scientific and performance aspects of AERMOD.

Performed a full-scale analysis using the CALMET/CALPUFF modeling system to assess Nitrogen deposition to the Chesapeake Bay resulting from NOx emissions from sources located up to 1000 kilometers from the Bay. Conducted evaluations of the performance of CALPUFF and developed proposed improvements.

Conducted a model intercomparison study between existing complex terrain models and test versions of EPA's new AERMOD model to evaluate AERMOD's performance. Recommended changes in AERMOD formulation were implemented by EPA.

Conducted air quality modeling for two manufacturing facilities in support of insignificant impact determinations of plant modifications requiring PSD review.

Performed dispersion modeling in support of accidental release assessments for Clean Air Act 112(r) Risk Management Plan for chemical, paper and other industries at over a dozen facilities.

Performed modeling for two Pennsylvania facilities to address attainment of SO2 NAAQS due to multiple regional sources. Developed an innovative approach to determining background concentrations.

Performed dispersion modeling to demonstrate PM10 NAAQS attainment in the vicinity of a mining operation in Pennsylvania.

Performed air quality analyses to support PSD application for an 800 MW pulverized coal-fired generating station in South Central Virginia. Contributed substantially to preparation of PSD application. Developed IGM for use in this project.

Performed a deposition modeling study of the long-term (fifty years of plant operation)impacts of a pesticide manufacturing plant in New York State. Assisted in interface with NYSDEC and EPA Region II to resolve impact issues.

Performed dispersion modeling studies in support of present and future plans for additional generating capacity at a utility power plant, including an assessment of existing units. Models

used included IGM in the RTDM/ISCST2 mode, CTSCREEN and CTDMPLUS. Provided interface with New Jersey Bureau of Air Quality Evaluation as needed for permitting modeling support.

Performed a dispersion modeling study in support of system planning that examined the air quality impacts of an existing coal-fired power plant in complex terrain, and the effect of different stack configuration and control
alternatives. Utilized IGM configured as RTDM/ISCST2 and COMPLEX-I/ISCST2, CTSCREEN and CTDMPLUS, and the LAPPES model.

Developed and presented a two-day training course for ERM offices nationwide. Course included modeling fundamentals, application of models in regulatory settings, overview of models used for accidental release modeling.

Managed a fugitive dust quantification study for six coal-fired power plants to identify Title V emissions fees.

Managed the performance of dispersion modeling for two chemical manufacturer R&D facilities to address Responsible Care requirements.

Directed the completion of a major fugitive emissions impact analysis for a non-utility generator coal-fired power plant in support of PSD application. Interaction with NJBAQEv responding to comments and providing timely
responses for fugitives analysis and other modeling analyses.

Fields of Competence

Air quality dispersion modeling
Dispersion model development
PSD and Nonattainment New Source Review modeling
Exposure assessment and toxic pollutant impact evaluations
Air emissions inventory development
Ambient impact assessments of hazardous waste sites
Clean Air Act strategic planning
Electric utility power plant permitting
Expert testimony
Title V permitting

Experience Summary

Twenty years of experience as a meteorologist and air quality dispersion modeler in the environmental consulting field and for industry and the US EPA. Extensive experience in the

application of air quality models to assess releases of criteria and toxic air pollutants. Detailed knowledge of the technical, regulatory, and policy issues related to dispersion modeling of new and existing sources; special expertise in modeling sources in complex terrain and in the application of advanced models (e.g., CALPUFF, CTDMPLUS, AERMOD). Principal author and programmer of the Integrated Gaussian Model (IGM), an air quality model approved as an equivalent model by the US EPA, developed to streamline obtaining source contribution information and to efficiently implement procedures for intermediate terrain. Experience in modeling for PSD and Nonattainment NSR permitting, with special emphasis on electric utility power plants.

Credentials

B.S., Environmental Engineering Technology, Temple University, 1977
M.S., Environmental Science, Drexel University, 1981

Professional Affiliations

Air and Waste Management Association
American Meteorological Society

RESUME

H. ANDREW GRAY

EDUCATION

Ph.D. environmental engineering science, California Institute of Technology, Pasadena, California, 1986

M.S. environmental engineering science, California Institute of Technology, Pasadena, California, 1980

B.S. civil engineering/engineering and public policy, Carnegie-Mellon University, Pittsburgh, Pennsylvania, 1979

EXPERIENCE

Dr. H. Andrew Gray has 20 years experience in air pollution research, focusing on particulate matter and visibility, including the development and application of computer-based air quality models. His areas of expertise are air pollution control strategy design and evaluation, computer modeling of the atmosphere, statistical data analysis, aerosol monitoring and modeling, visibility, receptor modeling, mathematical programming, numerical methods, and analysis of environmental public policy. Dr. Gray is currently an independent contractor focusing on particulate matter and visibility related research issues.

Before starting Gray Sky Solutions, Dr. Gray was the manager of the PM10 and Visibility Program at Systems Applications International (SAI). At SAI, Dr. Gray conducted and managed a number of varied air pollution research projects. Dr. Gray directed a large (over $1 million) air-quality modeling program to determine the impact of SO2 emissions from a large coal-fired power plant on Grand Canyon sulfate and visibility levels. He managed projects to develop carbon particle emission data for the Denver area, designed a PM10 monitoring and modeling program for the El Paso area, determined the appropriate tradeoffs between direct PM10 emissions and emissions of PM10 precursors, estimated the visibility effects in federal Class I areas due to the 1990 Clean Air Act Amendments (results of which were incorporated into EPA's 1993 Report to Congress on the expected visibility consequences of the 1990 Clean Air Act Amendments), and provided assistance to EPA Region VIII's tribal air programs. Other projects include emission inventory development for Sacramento and carbon monoxide modeling of Phoenix, Arizona to support federal and regional implementation plans in those regions, systematic evaluation of the Interagency Workgroup on Air Quality Modeling (IWAQM) recommendations for the use of MESOPUFF II, a critical assessment of exposures to particulate diesel exhaust in California, and an evaluation of PM2.5 and PM10 air quality data in support of EPA's recent review of the federal particulate matter air quality standards. Recent projects include a study of micrometeorology and modeling of low wind speed stable conditions in the San Joaquin Valley (CA), an assessment of the reductions in nationwide ambient particulate nitrate exposures due to mobile source NOx emission reductions, an evaluation of visibility conditions in the Southern Appalachian Mountains region, a review of cotton ginning emission factors, and a critical review and assessment of the PM10 Attainment Demonstration Plan for the

San Joaquin Valley. Dr. Gray was a member of the modeling subcommittee of the technical committee of the Grand Canyon Visibility Transport Commission.
Previous to his tenure at SAI, Dr. Gray was responsible for the PM10 and visibility programs at the South Coast Air Quality Management District which involved directing monitoring, analysis, and modeling efforts to support the design of air pollution control strategies for the California South Coast Air Basin. He developed and applied many of the methodologies for modeling PM10 concentrations that are currently in use by the District. Dr. Gray authored portions of the 1989 Air Quality Management Plan issued by the District that describe the results of modeling and data analyses used to evaluate particulate matter control strategies. Dr. Gray was instrumental in promoting the development and application of state-of-science models for predicting particulate matter concentrations. His responsibilities included direction and oversight of numerous aerosol-related contracts, including development of the SEQUILIB model, construction of an ammonia emission database, and development of sulfate, nitrate and organic chemical mechanisms.

In research carried out at the California Institute of Technology, Dr. Gray studied control of atmospheric fine primary carbon particle concentrations and performed computer programming tasks for acquisition and analysis of real-time experimental data. He designed, constructed, and operated the first long-term fine particle monitoring network in Southern California in the early 1980s. He also developed and applied deterministic models to predict source contributions to fine primary carbon particle concentrations and constructed objective optimization procedures for control strategy design. In research carried out for the Department of Mechanical Engineering at Carnegie-Mellon University, Dr. Gray developed fuel use data for input to an emission simulation model for the northeastern United States.

Specialized Professional Competence

Air pollution control strategy design
Atmospheric air quality characterization
Aerosols and visibility
Computer modeling and data analysis
Dispersion modeling for particulate matter and visibility
Receptor modeling including Chemical Mass Balance (CMB) and factor analysis
Analysis of environmental public policy

Professional Experience

Systems Applications International (SAI)"PM10 and visibility program manager"participated in and managed numerous air quality modeling and analysis projects for public and private sector clients, with emphasis on particulate matter and visibility research.

South Coast Air Quality Management District, El Monte, California"air quality specialist"developed and applied air quality modeling analyses to support air pollution control strategy design for the South Coast Air Basin of California

California Institute of Technology, Pasadena, California"research assistant"Ph.D. candidate in environmental engineering science. Thesis: Control of atmospheric fine primary carbon particle concentrations
California Institute of Technology, Pasadena, California"laboratory assistant"performed computer programming tasks for acquisition and analysis of real-time experimental data

Department of Mechanical Engineering, Carnegie-Mellon University, Pittsburgh, Pennsylvania"research assistant"developed fuel use data for an emissions simulation model for the northeastern United States. Grant from the U.S. Department of Energy for evaluation of national energy policy

Department of Civil Engineering, Carnegie-Mellon University, Pittsburgh, Pennsylvania"consultant"analyzed structural retrofit design for Ferrari Dino import automobile for United States five mph crash test

HONORS AND AWARDS

Harold Allen Thomas Scholarship Award, Carnegie-Mellon University
University Honors, Carnegie-Mellon University

PROFESSIONAL AFFILIATIONS

Air and Waste Management Association
American Association for Aerosol Research
American Society of Civil Engineers

SELECTED PUBLICATIONS AND PRESENTATIONS

"Monitoring and Analysis of the Surface Layer at Low Wind Speeds in Stable PBL"s in the Southern San Joaquin Valley of California" (with others), to be presented at the American Meteorological Society"s 12th Symposium on Boundary Layers and Turbulence, Vancouver, British Columbia (July 1997)

"Estimation of Current and Future Year NOx to Nitrate Conversion for Various Regions of the United States" (with A. Kuklin), to be presented at the 90th Meeting of the Air and Waste Management Association, Toronto, Ontario (June 1997)

Integrated Monitoring Study (IMS) 1995: Characterization of Micrometeorological Phenomena -- Mixing and Diffusion in Low Wind Speed Stable Conditions: Study Design and Preliminary Results (with others), in Measurement of Toxic and Related Air Pollutants, Air and Waste Management Association, Pittsburgh, Pennsylvania, pp. 484-500 (1996)

"Source Contributions to Atmospheric Fine Carbon Particle Concentrations" (with G.R. Cass), Atmospheric Environment, submitted for publication (1996)

"Assessment of the Effects of the 1990 Clean Air Act Amendments on Visibility in Class I Areas" (with others), presented at the 86th Annual Meeting & Exhibition of the Air and Waste Management Association, Denver, Colorado (June 1993)
"Source Contributions to Atmospheric Carbon Particle Concentrations" (with others), presented at the Southern California Air Quality Study Data Analysis Conference, Los Angeles, California (July 1992)

"Modeling Wintertime Sulfate Production in the Southwestern United States" (with M. Ligocki), presented at the AWMA/EPA International Specialty Conference on PM10 Standards and Nontraditional Particulate Source Controls, Scottsdale, Arizona (January 1992)

"Deterministic Modeling for the Navajo Generating Station Visibility Impairment Study: An Overview," presented at the 84th Meeting of the Air and Waste Management Association, Vancouver, British Columbia (June 1991)

"Receptor and Dispersion Modeling of Aluminum Smelter Contributions to Elevated PM10 Concentrations" (with R. G. Ireson and A. B. Hudischewskyj), presented at the 84th Meeting of the Air and Waste Management Association, Vancouver, British Columbia (June 1991)
Visibility and PM-10 in the South Coast Air Basin of California (with J.C. Marlia), in Visibility and Fine Particles, Air and Waste Management Association, Pittsburgh, Pennsylvania, pp. 468-477 (1990)

Chemical characteristics of PM10 aerosols collected in the Los Angeles area (with others), J. Air Pollut. Control Assoc., 39:154-163 (1989)

Atmospheric carbon particles and the Los Angeles visibility problem (with others), Aerosol Sci. Technol., 10:118-130 (1989)

Receptor modeling for PM10 source apportionment in the South Coast Air Basin of California (with others), in PM-10: Implementation of Standards, Air Pollution Control Association, Pittsburgh, Pennsylvania, pp. 399-418 (1988)

Optimization of PM10 control strategy in the South Coast Air Basin (with others), in PM-10: Implementation of Standards, Air Pollution Control Association, Pittsburgh, Pennsylvania, pp. 589-600 (1988)

Quantitative high-resolution gas chromatography and high-resolution gas chromatography/mass spectrometry analyses of carbonaceous fine aerosol particles (with others), Int. J. Environ. Anal. Chem., 29:119-139 (1987)

"Development of an Objective Ozone Forecast Model for the South Coast Air Basin" (with others), presented at the 80th Meeting of the Air Pollution Control Association, New York (June 1987)

"PM10 Modeling in the South Coast Air Basin of California" (with others), presented at the 79th Annual Meeting of the Air Pollution Control Association, Minneapolis, Minnesota (1986)
Characteristics of atmospheric organic and elemental carbon particle concentrations in Los Angeles (with others), Environ. Sci. Technol., 20:580-589 (1986)

"Chemical Speciation of Extractable Organic Matter in the Fine Aerosol Fraction" (with others), presented at the 1984 International Chemical Congress of Pacific Basin Societies, Honolulu, Hawaii (1984)

"Source Contributions to Atmospheric Carbon Particle Concentrations" (with others), presented at the First International Aerosol Conference, Minneapolis, Minnesota (1984)
Elemental and organic carbon particle concentrations: A long term perspective (with others), Sci. Total Environ., 36:17-25 (1984)

"Meteorological and Chemical Potential for Oxidant Formation" (with others), presented at the Conference on Air Quality Trends in the South Coast Air Basin, California Institute of Technology, Pasadena, California (1980)
Containing recombinant DNA: How to reduce the risk of escape (with others), Nature, 281:421-423 (1979)

OTHER PUBLICATIONS

"Assessment of the Impacts of Clean Air Act and Other Provisions on Visibility in Class I Areas" (with others), prepared for American Petroleum Institute, Washington, D.C. (1998)

"California Regional PM10 Air Quality Study: 1995 Integrated Monitoring Study Data Analysis: Time and Length Scales for Mixing Secondary Aerosols During Stagnation Periods" (with others), prepared for California Air Resources Board, Sacramento (1997)

"San Joaquin Valley Regional PM10 Study: Characterizing Micrometeorological Phenomena: Mixing and Diffusion in Low Wind Speed Conditions Phase III: Monitoring and Data Analysis" (with others), prepared for California Air Resources Board, Sacramento (1997)

"Cotton Gin Particulate Emission Factors," prepared for U.S. Environmental Protection Agency, Region VIII, San Francisco, California (1997)

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"Deterministic Modeling for Navajo Generating Station Visibility Study. Volume I. Technical Report" (with others), SYSAPP-91/045a, prepared for Salt River Project, Phoenix, Arizona (1991)

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"Control of Atmospheric Fine Primary Carbon Particle Concentrations," (EQL report No. 23), Ph.D. thesis, California Institute of Technology, Pasadena, California (1986)

"Policy on Recombinant DNA Activities: Relaxing Guidelines While Increasing Safety," project report, Department of Engineering and Public Policy, Carnegie-Mellon University, Pittsburgh, Pennsylvania (1978)
"Air Pollution Control Analyses for State Implementation Plan Revisions in Allegheny County," project report, Department of Engineering and Public Policy, Carnegie-Mellon University, Pittsburgh, Pennsylvania (1978)

EMPLOYMENT HISTORY

1989-1997 Systems Applications International, Manager, PM-10 and Visibility Program

1985-1989 South Coast Air Quality Management District, Air Quality Specialist

1979-1985	California Institute of Technology Pasadena, California, Research Assistant
1979	Laboratory Assistant, Carnegie-Mellon University
1978-1979	Research Assistant, Dept. of Mechanical Engineering, Pittsburgh, Pennsylvania

RESUME

S. TRIVIKRAMA RAO - 49 Timberwick Drive, Clifton Park, N.Y. 12065

Born: July 2, 1944 Citizenship: U.S.A.
Married: Marcia Lee Neiss - June 1974 Telephone: 518/457-3200(office)

PROFESSIONAL EXPERIENCE:

June 1995- Assistant Commissioner, Office of Science and Technology
New York State Department of Environmental Conservation

Nature of Duties: Coordinate, plan, direct environmental research, and provide a sound scientific and technical basis for regulatory policies. Advice the Commissioner on scientific matters.

June 1985- Director, Bureau of Air Research, Division of Air Resources,

May 1995 New York State Department of Environmental Conservation

Nature of Duties: Coordinate, plan, direct, initiate, and conduct research in air pollution. Manage, supervise and direct the activities of the Bureau of Air Research in the Division of Air Resources.

Sept. 1998-Sept. 1981 Professor of Environmental Statistics, Department of Biometry & Statistics- Research Professor of Atmospheric Science, Department of Earth & Atmospheric Sciences, State University of New York at Albany

Nature of Duties: Teach graduate level courses, serve as advisor to students on their Masters and Doctoral thesis.

Dec. 1982-May 1985 Research Scientist 5, Division of Air Resources, New York State Department of Environmental Conservation

Nature of Duties: As the Division's principal scientist, direct and conduct research in atmospheric dynamics, and air pollution meteorology & modeling. Supervise and manage research staff and funds.

Aug. 1974-Nov. 1982 Research Scientist & Chief - Atmospheric Modeling Section, New York State Department of Environmental Conservation

Nature of Duties: Initiate, conduct and direct research related to mathematical modeling of pollutant transport and dispersion. Supervise and manage the Section resources.

Feb. 1973-July 1974 Post-Doctoral Research Associate, Dept. of Atmospheric Science, State University of New York at Albany

Nature of Duties: Conduct research on the parameterization of cloud droplet growth in the condensational phase and on modeling the interactions between micro- and macro-structures of convective clouds.

Sept. 1969-Dec. 1972 Teaching/Research Assistant, State University of New York at Albany

Nature of Duties: Assist faculty in teaching undergraduate courses in climatology, oceanography and introductory meteorology and graduate level course in Geophysical Fluid Dynamics.

Sept. 1966-Aug. 1969 Senior Scientific Assistant Institute of Tropical Meteorology, Govt. of India

Nature of Duties: Conduct research on synoptic and theoretical aspects of the large-scale atmospheric motions in the tropics.

Oct. 1965-Aug. 1966 Lecturer of Physics Govt. Arts College, Nizamabad, India

Nature of Duties: Offer courses in Electricity and Magnetism, Heat transfer, and properties of matter.

EDUCATION:

1969-1972	State University of New York at Albany, Ph.D. in Atmospheric Science
1962-1965	Andhra University, Waltair, India,M.Sc (Tech) in Geophysics (graduated with honors)
1958-1962	Andhra Loyola College, Vijayawada, India, B.Sc in Mathematics, Physics and Chemistry (triple major)

PROFESSIONAL CERTIFICATION:

Certified Consulting Meteorologist (CCM)- Certified by the American Meteorological Society in 1980

PROFESSIONAL ORGANIZATIONS:

Member: American Meteorological Society (since 1970); Air & Waste Management Association (since 1978)

Fellow of the Air & Waste Management Association (since 1996)

JOURNAL ARTICLES (Peer-Reviewed)

"After-shock Sequence of Kurile Islands Earthquake of October 13, 1963" (B.P. Murty, R.B. Pathak, and S.T. Rao), J. Ind. Geophy. Union, 1969, Vol. VI, No. 2.

"On Some Aspects of the Stationary Harmonics of the Atmosphere" (V.B. Rao and S.T. Rao), J. Ind. Geophy. Union, 1969, Vol. VI, No. 2.

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"Parameterization of Cloud Droplet Growth by Condensation" (S.T. Rao and Z.H. Feng), J. Appl. Meteor., 1977, Vol. 16, No. 5.

"Characteristics of Turbulence and Dispersion of Pollutants Near Major Highways" (S.T. Rao, L. Sedefian, and U. Czapski), J. Appl. Meteor., March 1979.

"A Study of Pollutant Dispersion Near Roadways" (G. Sistla, M. Keenan, P. Samson, and S.T. Rao), Atmos. Environment, 1979, Vol. 13, No. 5.

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"A Comparative Study of Two Trajectory Models of Long-Range Transport" (S.T. Rao, J. Pleim and U. Czapski), J. Air Poll. Cont. Assoc., January, 1983.

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"Evaluation of the Performance of RAM with the Regional Air Pollution Study Data Base" (S.T. Rao, G. Sistla, V. Pagnotti, W. Petersen, J. Irwin and B. Turner), Atmos. Environ., February, 1985.

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"Linking changes in ozone to changes in emissions in the presence of meteorological fluctuations" (D. Chan, S.T. Rao, and I. Zurbenko) Submitted to J. Air & Waste Manage. Assoc., October 1998.

"Identifying Pollution Source Regions Using Multiply-Censored Data" (E. Brankov, S.T. Rao, and P.S. Porter), Environmental Science & Technology, In Press, 199.

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"New York State Research on Automobile Pollutant Dispersion", (S.T. Rao) presented at the EPA Catalyst Research Program, Hendersonville, NC, February, 1977.

"Structure of Turbulence Generated by Flow Over a Major Highway", (S.T. Rao, L. Sedefian and U. Czapski), presented at the Amer. Geophys. Union Fall Meeting, San Francisco, December, 1977.

"Overview of the NYS-Long Island Expressway Dispersion Experiment", (S.T. Rao, M. Chen, M. Keenan, G. Sistla, P. Samson, D. Romano), Proc. of the Annual Meeting of the Transportation Research Board, Washington, D.C., Jan 1978.

"Sulfate and Lead Concentrations Adjacent to the Long Island Expressway Near Huntington, NY," (M. Keenan, G. Sistla, A. Peddada, P. Samson, and S.T. Rao), Proceedings of the Question of Sulfates Conference, Air Poll. Cont. Assoc., Philadelphia, April, 1978.

"The Long Island Expressway Dispersion Experiment," (W. Petersen and S.T. Rao), Proceedings of the Symposium on Atmospheric Turbulence, Diffusion and Air Pollution, Amer. Meteor. Soc., Reno, Nevada, January, 1979.

"The Use of Trajectory Models and Extreme Value Statistics in Estimating the Ozone Impact from Urban Area Emissions," (J. Visalli, S.T. Rao, and J. Wilson), Proceedings of the Second Joint Conference on Applications of Air Pollution Meteorology, Amer. Meteor. Soc., New Orleans, LA, March, 1980.

"Measurement and Prediction of Traffic-Induced Turbulence and Velocity Changes Near Roadways," (R. Eskridge and S. T. Rao), Proceedings of the Third Joint Conference on Applications of Air Pollution Meteorology, Amer. Meteor. Soc., San Antonio, Texas, January, 1982.

"Modeling Carbon Monoxide Hot Spots Near Roadway Intersections," (S.T. Rao) Proceedings of the 10th Annual North American Motor Vehicle Emissions Control Conference, STAPPA, New York, NY, April, 1984.

"Effect of Traffic Speed on the Ambient Pollutant Concentration Near Roadways," (W. Petersen, R. Eskridge, S.T. Rao, and V. Pagnotti), Proceedings of the 77th Annual Meeting of the Air Pollution Control Assoc., San Francisco, June, 1984.

"Turbulent Diffusion Behind Vehicles: Experiments and Verification of Roadway Models," (R. Eskridge, W. Petersen, S.T. Rao, and G. Sistla), Proc. of the 77th Annual Meeting of the Air Pollution Control Association, San Francisco, June, 1984.

"Examination of the Performance of RAM with the RAPS Data Base," (S.T. Rao, G. Sistla, V. Pagnotti, W. Petersen, J. Irwin, and D.B. Turner), Proceedings of the 77th Annual Meeting of the Air Pollution Control Association, San Francisco, June, 1984.

"Resampling and Extreme Value Statistics in Air Quality Model Evaluation," (S.T. Rao, G. Sistla, V. Pagnotti, W. Petersen, J. Irwin, and D.B. Turner), Proceedings of the Joint AMS/APCA Conference on Air Pollution Meteorology, Portland, Oregon, October, 1984.

"Evaluation, Selection, and Economic Assessment of Control Strategies for Acid Deposition" (with H. Hovey, E. Davis, G. Sistla, P. Galvin, S.T. Rao, and R. Twaddell), Proceedings of the 78th Annual Meeting of the Air Pollution Control Assoc., Detroit, MI, June, 1985.

"Application of Two Long-Range Transport Models to New York State's Sulfur Dioxide Emissions Policy" (P. Galvin, G. Sistla, S.T. Rao, and H. Hovey), Proceedings of the 78th Annual Meeting of the Air Pollution Control Association, Detroit, MI, June, 1985.

"Application of Long-Range Transport Models to the Development of a Sulfur Emissions Policy" (P. Galvin, G. Sistla, and S.T. Rao), Proc. of the International Symposium on Acidic Precipitation, Muskoka, Ontario, Canada, Sept 15-20, 1985.

"Cost of Sulfur Emissions Reduction: A Case Study for New York State" (G. Sistla, P. Galvin, and S.T. Rao), Proceedings of the International Symposium on Acidic Precipitation, Muskoka, Ontario, Canada, Sept 15-20, 1985.

"Evaluation of the Performance of Air Pollution Models," (S.T. Rao) Proceedings of the International Symposium on Recent Advances in Numerical Modeling for the Dispersion of Atmospheric Pollutants, New Delhi, India, Jan., 1986.

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"Temporal and Spatial Variability of Acidic Deposition Events," (P. Galvin, M. Ku, S.T. Rao, and V. Pagnotti), Proceedings of the APCA/AMS Joint Conference on Applications of Air Pollution Meteorology, Research Triangle Park, Oct., 1986.

"Assessment of the Ozone Problem in the New York Metropolitan Area," (S.T. Rao, G. Sistla, R. Twaddell, and N. Possiel), Proceedings of the North American Oxidant Symposium, Quebec City, Canada, Feb., 1987.

"Examination of the Urban Airshed Model Performance in the New York Metropolitan Area," (S.T. Rao, et al.), Proceedings of the 80th Annual Meeting of the Air Pollution Control Association, New York City, June, 1987.

"Assessment of the Ozone SIP Strategies in the New York Metropolitan Area" (S.T. Rao, et al.), Proceedings of the APCA International Specialty Conference on the Scientific and Technical Issues Facing Post-1987 Ozone Control Strategies, Hartford, CT, November, 1987.

"Evaluation of Post-1987 Ozone Control Strategies with the Urban Airshed Model" (R. Miles-McLean, S.T. Rao, G. Sistla, R. Twaddell, and E. Davis), Proceedings of the APCA

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"Modeling Photochemical Oxidants in the Urban Environment" (S.T. Rao and G. Sistla), Proceedings of the International Conference on Tropical Micro-Meteorology and Air Pollution, New Delhi, India, February, 1988.

"Evaluation of the Urban Airshed Model with Recent Field Measurements in NY York" (S.T. Rao), Presented at the US/FRG Workshop on the Photochemical Ozone Problem and Its Control, Cologne, West Germany, May, 1988.

"Dispersion of Dense Gas Releases in a Wind Tunnel" (W. Petersen, W. Snyder, J. Ku, and S.T. Rao), Proceedings of the NATO/CCMS Meeting, Cambridge, England, September, 1988.

"Nested Grid Modeling Approach for Assessing Ozone Air Quality" (S.T. Rao, G. Sistla, J. Ku, K. Schere, J. Godowitch, and R. Scheffe), Proceedings of the1989 Annual AWMA Meeting, Anaheim, CA, June 1989.

"On the Problems of Ozone Compliance in the Northeastern Urban Corridor" (T. Allen, S.T. Rao, and G. Sistla), Proceedings of the 1989 Annual AWMA Meeting, Anaheim, CA, June 1989.

"Uncertainties in the Assessment of Toxic Air Contaminants" (S.T. Rao and K.S. Rao), U.S.-India Workshop on Environmental Risk Analysis, New Delhi, December 1989.

"On the Treatment of Ambient Pollutant Concentrations Below the Limit of Detection" (S.T. Rao, J.Y. Ku, and K.S. Rao), U.S.-India Workshop on Environmental Risk Analysis, New Delhi, December 1989.

"Sampling Strategies for the Measurement of Toxic Air Contaminants" (S.T. Rao, J.Y. Ku, and K.S. Rao), U.S.-India Workshop on Environmental Risk Analysis, New Delhi, December 1989.

"Analysis of Air Pollutant Concentrations Below the Detection Limit" (S.T. Rao, J.Y. Ku, and K.S. Rao), Proceedings of the EPA/AWMA Interntl Symposium on Measurement of Air Toxic and Related Pollutants, Raleigh, NC, May 1990.

"Sensitivity Analysis of a Nested Ozone Air Quality Model" (S.T. Rao, G. Sistla, and J. Godowitch), Proceedings of the AMS/AWMA Joint Conference on Applications of Air Pollution Meteorology, New Orleans, LA, January, 1991.

"Sensitivity Analysis of the Urban Airshed Model Nested with the Regional Oxidant Model" (G. Sistla, S.T. Rao, D. Doll and E. Meyer), Proceedings of the NATO/CCMS Meeting, Ierapetra, Crete, Greece, October, 1991.

"On the Use of Numerical Photochemical Models for Ozone Attainment Demonstration" (S.T. Rao and G. Sistla), Proceedings of the NATO/CCMS Meeting, Ierapetra, Crete, Greece, October, 1991.

"Air Quality Management in New York" (S.T. Rao), Invited Paper on Air Quality Management Programs: An International Workshop on Lessons Learned, Sponsored by the U.S. Department of Energy & Petroleos Mexicanos, Mexico, October, 1991.

"Estimation of Central Tendency from Multiply-Censored Air Monitoring Data" (S.T. Rao and P.S. Porter), Proceedings of the EPA/A&WMA International Symposium on Measurement of Toxic and Related Pollutants, Durham, NC, May, 1992.

"On the Design of the Modeling Domain for the Regulatory Application of the Urban Airshed Model" (G. Sistla, R. Henry, and S.T. Rao), Proceedings of the Annual Air & Waste Mgmt. Assoc. Meeting, Kansas City, Kansas, June, 1992.

"Examination of the Efficacy of VOC and NOx Emissions Reductions on Ozone Improvement in the Northeastern United States as Predicted by Regional and Urban Models" (S.T. Rao, K. John, G. Sistla, N. Zhou, W. Hao, K. Schere, S. Resolle, N. Possiel, R. Scheffe, and G. Carmichael), Proceedings of the 20th NATO-CCMS International Technical Meeting on Air Pollution Modeling and Its Applications, Valencia, Nov. 1993.

"Sensitivity of the UAM-predicted Ozone Concentrations to Wind Fields in the New York Metropolitan Area" (G. Sistla, J. Ku, N. Zhou, W. Hao, S.T. Rao, P. Thunis, R. Bornstein, and F. Freedman), Proceedings of the A&WMA's Regional Photochemical Measurement & Modeling Studies Conference, San Diego, Nov. 1993.

"Sensitivity of the Urban Airshed Model to Spatially Varying Mixing Height Profile: (S.T. Rao, G. Sistla, J. Ku, N. Zhou, W. Hao), Presented at the A&WMA's Regional Photochemical Measurement & Modeling Studies Conference, San Diego, Nov. 1993.

"Urban Airshed Model Simulations of NOx and VOC Emission Reductions in the New York Airshed" (R.D. Scheffe, S.T. Rao, G. Sistla,, and K. Schere), Presented at the AWMA's Regional Photochemical Measurement & Modeling Studies Conference, San Diego, Nov. 1993.

"Relating Changes in Ozone Concentrations to Changes in Emissions in the Presence of Meteorological Fluctuations" (E. Zalewsky, S.T. Rao, and I. Zurbenko) Proc. AWMA Conf. on Ozone: Critical Issues, Orlando, FL, May 1994.

"Sensitivity of the Urban Airshed Model to the Boundary Conditions" (G. Sistla, N. Zhou, W. Hao, S.T. Rao, K. Schere, and K. Allopathy) Proceedings of the Joint AMS & AWMA Conference on Applications of Air Pollution Meteorology, Atlanta, January 1995.

"Uncertainty in the Estimation of the Mixing Height and its Impact on Ozone Control Strategies" (S.T. Rao, J.Y. Ku, N. Zhou, and G. Sistla) Proceedings of the Air Pollution '95 Conference, Porto Carras, Greece, September, 1995.

"On the Assessment of Ozone Control Policies for the Northeastern United States" (S.T. Rao, G. Sistla, W. Hao, K. John, and J. Biswas), Proceedings of the NATO/CCMS Meeting on Air Pollution Modeling and Its Applications XI, Eds. S.E. Gryning and F. Schiermeier, Plenum Press, 1996.

"Integrating Observations and Modeling in Ozone Management Efforts" (S.T. Rao, et al.) Proceedings of the NATO-CCMS Meeting on Air Pollution Modeling and Its Applications XII, Ed. S.E. Gryning, Plenum Press, May 1997.

"Filtering the Effects of Meteorology on Ambient Ozone Concentrations" (M. Milanchus, S.T. Rao, and I. Zurbenko), Proceedings of the 1997 Annual A&WMA Meeting, Toronto, June 1997.

"An Integrated Modeling and Observational Approach for Evaluating the Long-Range Transport of Air Pollutants" (S.T. Rao), Invited Lead Paper, First International Conference on Asian Monsoon and Pollution over the Monsoon Environment, December 1997, New Delhi, India.

"Atmospheric Transport of Trace Level Toxic Pollutants" (E. Brankov, S.T. Rao, and P.S. Porter) Proceedings of the 10th Joint AMS/AWMA Conference on Applications of Air Pollution Meteorology, Phoenix, AZ, January 1998.

"An Integrated Observational and Modeling Approach for Designing Ozone Control Strategies over the Eastern United States" (S.T. Rao et al.) **Invited Paper**, Proceedings of the NATO-CCMS Meeting on Air Pollution Modeling and Its Applications XII, Ed. S.E. Gryning, Plenum Press, September 1998.

"Seasonal Photochemical Modeling over the Eastern United States: Model Performance on Different Space and Time Scales and Implications to the Use of Models in a Regulatory Setting" (C. Hogrefe, S.T. Rao, and I. Zurbenko), Proceedings of the 1999 Annual Meeting of the American Meteorological Society, Dallas, TX, January 1999.

"Spatial-Temporal Analysis of Ozone, Precursors, and Indicator Species over the Eastern United States" (J. Biswas, C. Hogrefe, S.T. Rao, and W. Hao), Proceedings of the 1999 Annual Meeting of the American Meteorological Society, Dallas, TX, January 1999.

TECHNICAL REPORTS (Peer-Reviewed)

"Dispersion of Pollutants Near Highways: Experimental Design and Data Acquisition Procedures," (S.T. Rao, M. Chen, M. Keenan, G. Sistla, A. Peddada, G. Wotzak, and N. Kolak), EPA-600/4-80-054, June, 1978.

"Dispersion of Pollutants Near Highways: Data Analysis and Model Evaluation," (S.T. Rao, M. Keenan, G. Sistla, and P. Samson), EPA-600/4-79-011, February, 1979.

"Atmospheric Turbulence & Pollutant Dispersion Near Roadways," (S.T. Rao, M. Keenan, G. Sistla, and J. Wilson), EPA-600/4-80-054, December, 1980.

"On the Calibration of Intersection Mid-Block Model for Screening Potential Hot Spots Near Roadway Intersections," (S.T. Rao), New York State Department of Environmental Conservation, October 1983.

"A Policy for New York State to Reduce Sulfur Dioxide Emissions-Draft Environmental Impact Statement" (S.T. Rao et al), New York State Department of Environmental Conservation, July 1984.

"Evaluation of the Performance of Air Quality Models - Project Summary", (S.T. Rao and W. Petersen), U.S. EPA, January, 1985.

"Application of the Urban Airshed Model to New York Metropolitan Area," (S.T. Rao), EPA-450/4-87-011, May, 1987.

"Photochemical Modeling Analysis of Emission Control Strategies in the New York Metropolitan Area" (S.T. Rao, G. Sistla, and R. Twaddell), EPA-230/2-89-026, February 1989.

"Statistical Methods for the Analysis of Pollutant Concentrations Affected by Measurement Uncertainties" (P.S. Porter, S.T. Rao, J.Y. Ku, and R.L. Poirot), NESCAUM Technical Report, Boston, MA, Sept. 1993.

"Modeling Analysis of the Ozone Problem in the Northeast" (K. John, S.T. Rao, G. Sistla, W. Hao, and N. Zhou), EPA 230-R-94-018, November 1994.

"Least-Cost Solutions for Ozone Attainment in New York State: I. Photochemical Modeling Analysis" (S.T. Rao and T.D. Mount), Project Final Report to Niagara Mohawk Power Corporation, 1994.

"Application of a Moving Average Filter to Meteorological and Air Quality Problems" (J. Flaum, S.T. Rao, and I. Zurbenko), NOAA Technical Report, National Climatic Data Center, 1996.

"Statistical Characteristics of Spectrally-Decomposed Ambient Ozone Data" (P.S. Porter, S.T. Rao, I. Zurbenko) Web Site, OTAG, University of Washington, St. Louis, (http://capita.wustl.edu/otag/reports/StatChar/otagrep.htm), 1996.

"An Economic Assessment of Ozone Control Strategies for the Northeastern United States" (G. Dorris, T. Mount, G. Sistla, and S.T. Rao) Project Final Report to NYSERDA, August 1998.

RESEARCH PROJECTS:

"Research on Automobile Pollution Dispersion (ROAD)". Funded by U.S.E.P.A. ($200,000). This project also received support in the amount of $76,000 from U.S. Dept. of Transportation through NYS Dept. of Transportation, Principal Investigator. (1975-1979)

"Measurement of Re-suspended Roadway Dust in New York," Funded by U.S. Dept. of Transportation, FHWA, ($12,000), Principal Investigator. (1976-1977)

"Diffusion Analysis of a Line Source (DALS)," Funded by U.S.E.P.A. ($78,000), Principal Investigator. (1977-1979)

"Atmospheric Turbulence & Pollutant Dispersion Near Roadways," Funded by U.S.E.P.A. ($55,000), Principal Investigator. (1979-1980)

"Modeling of Photochemical Oxidants," Funded by U.S.E.P.A. ($50,000), Project Director. (1979-1980)

"Carbon Monoxide: Atmospheric Dispersion Modeling," Funded by U.S.E.P.A. ($50,000), Principal Investigator. (1982-1984)

"Performance Measures for Air Quality Models," Funded by U.S.E.P.A. ($70,000), Principal Investigator. (1983-84)

"New York State Sulfur Emissions Policy - Modeling Phase," Funded by U.S.E.P.A. ($150,000), Project Director. (1983-1984)

"Development and Evaluation of Urban Air Pollution Models," Funded by NOAA ($40,000), Principal Investigator. (1984-1985)

"Oxidant Modeling for New York Metropolitan Area Project (OMNYMAP)," Funded by U.S.E.P.A. ($315,000), Principal Investigator. (1984-1986)

"Evaluation of Strategies for Controlling the Oxidant Problem (SCOPE)," Funded by U.S.E.P.A., ($125,000), Principal Investigator, (1987-1989).

"Photochemical Modeling Evaluation of Urban Ozone Levels (O_3PLUME)," Principal Investigator, Funded by U.S.E.P.A., ($105,000), (1989-1991).

"Confidence Intervals for Estimates of Central Tendency from Air Monitoring Data" Co-Principal Investigator, Funded by N.E.S.C.A.U.M., ($20,000), (Feb 1992 - Sept 1992).

"Statistical Techniques for Detecting Trends and Biases in Time Series of Upper Air Data," Principal Investigator, Funded by NOAA, ($200,000), (1992-1995).

"Modeling Analysis of Photochemical Oxidants in the Northeast (MAPONE)," Principal Investigator, Funded by U.S.E.P.A., ($350,000), (1992-1997).

"Statistical Methods for the Analysis of Trace Level Environmental Data with Multiple Detection Limits," Co-Principal Investigator, Funded by U.S.E.P.A., ($300,000) (1993-1997).

"Implementation of High Performance Air Quality Modeling and Decision Support Systems for the Northeast Ozone Transport Commission" Principal Investigator, Funded by U.S.E.P.A. ($60,000) (1994-1997).

"Least-cost Solutions for Ozone Attainment in New York State," Principal Investigator, Funded by Niagara Mohawk Power Corporation, ($550,000) (1993-1998).

"Evaluating Air Quality Effects of Urban Trees: Developing Directionally Sound Programs for Use in State Ozone Attainment Goals" Principal Investigator, Funded by U.S.D.A's Forest Service ($100,000) (1995-1998).

"Least-Cost Options for Ozone Improvement in the Eastern United States" Principal Investigator, Funded by New York State Energy Research and Development Authority, ($287,000) (1996-1998).

"Evaluation of Ozone Trends and Uncertainties in Ozone Modeling Approaches" Principal Investigator, Funded by EPRI ($626,000) (1996-1999).

"Integrating Modeling and Observational Analysis in Ozone Management Efforts" Principal Investigator, Funded by U.S. Environmental Protection Agency, ($370,000) (1996-1999).

"Mixing Heights, Ambient Ozone and VOC/NOx Levels, and Their Impact on Ozone Attainment Strategies" Principal Investigator, Funded by ESEERCO and New York State Energy Research and Development Authority, ($300,000) (1994-1998).

"Factors Influencing Ozone and Fine Particles in the Northeast U.S.A." Co-Principal Investigator, A University Consortium Research Grant that involves multiple universities in the Northeast, Funded by U.S. Environmental Protection Agency, ($3,000,000) (1998-2001)

"Analysis of Ozone and Fine Particles in the Northeast" Principal Investigator, Funded by New York State Energy Research and Development Authority, ($550,000) (1998-2001).

EXTERNAL ACTIVITIES:

Professor - Department of Earth and Atmospheric Sciences and Department of Biometry and Statistics, State University of New York at Albany (SUNYA)

Member - Editorial Board of *Atmospheric Environment*, an International Journal for Air Pollution Research

Member - National Academy of Sciences' Committee on "Ozone Forming Potential of Reformulated Gasoline" (1997-98)

Consultant - United Nations Development Program on Air Pollution Research Programs in India (1994-1995)

Member - Graduate Committee, Dept. of Atmospheric Science, SUNYA (1993-1994)

External Examiner - Ph.D. Dissertations in Meteorology, Indian Inst. of Tech., New Delhi; Andhra University, India.

Peer Reviewer - Research Programs and Publications, Scientific Journals.

Panel Member - National Cooperative Highway Research Program, National Academy of Sciences, Washington, D.C. (1978-1982)

Member - Meteorology Committee; Atmospheric Deposition & Chemistry Committee, and Education & Training Committee, Air & Waste Management Association.

Member - Committee on Meteorological Aspects of Air Pollution, American Meteorological Society (1993-).

Listed - Who's Who in America; American Men and Women in Science, Jacques Cattell Press, 1982.

Member - CReME Project Steering Committee (Research Project Funded by the Private Sector)

Member - Modeling Committee, Ozone Transport Commission, Washington, DC

Co-Chair - Modeling & Chemistry Team, EPA's NARSTO Program

Member - Analysis & Assessment Workgroup, EPA's NARSTO Program

Member - Indian Institute of Technology's Steering Committee on the US-India Bilateral Agreement on Environment

Secretary - Eastern Chapter of A&WMA (1991-1992)

Member - Board of Directors of A&WMA's Middle Atlantic States Section (1992-1994)

GRADUATE STUDENTS ADVISED:

Leon Sedefian, 1977 MS Thesis - "Characteristics of turbulence & diffusion of pollutants near highways"

Jonathan Pleim, 1981 MS Thesis - "A comparative study of two trajectory models of long-range transport"

Eli Jacks, 1984 MS Thesis - "An examination of the MOS objective temperature prediction model"

Jia-Yeong Ku, 1985 Ph.D Thesis - "Numerical modeling of air pollution urban areas" (Won Outstanding Thesis Award)

Eric Zalewsky, 1995 MS Thesis - "Trends in temperature-adjusted ozone concentrations over eastern United States"

Jennifer Flaum, 1995 MS Thesis - "Application of an adaptive moving average filter to climate and air quality data"

Christian Hogrefe, 1996 MS Thesis - "Seasonal variations, biases and trends in ozonesonde data"

Meagan Milanchus, 1997 MS Thesis - "Discerning changes in ambient ozone concentrations in the presence of meteorological fluctuations"

Daniel Chan, 1998 MS Thesis - "Linking Changes in Ozone Concentrations to Changes in Emissions and Meteorology"

Elvira Brankov, 1998 Ph. D - "Influence of Atmospheric Transport on Toxic Air Contaminant Levels over the Northeastern United States"

Jian Zhang, 1998 Ph. D - "Atmospheric Transport and Vertical Mixing Processes and their Impact on Ambient Ozone Concentrations in the Northeastern United States"

Jhumoor Biswas, Ph. D Thesis in Progress - "Modeling photochemical oxidants in the Eastern United States"

Christian Hogrefe, Ph. D Thesis in Progress - "Spatial-Temporal Analysis Modeled and Measured Ozone Concentrations in the Eastern United States"

MANAGEMENT TRAINING:

June 1990	"Managing New York State: Leadership Classroom Level I" - Harvard through GOER
June 1988	"Building the Secretary-Manager Team" - Choice Associates.
June 1986	"How to be a Successful Project Manager" - American Management Association.
March 1984	"Project Management: Planning, Scheduling and Control" - Rensselaer Polytechnic Institute.
August 1983	"Assertive Management" - Rensselaer Polytechnic Institute.
February 1982	"Managing Effectively Through the 1980's" - Booth Associates.
Jan - Dec 1982	"Public Management Project" - NYS Department of Civil Service.
July 1979	"Supervisors Workshop on Performance Evaluation" - NYS Department of Civil Service.
January 1979	"Program Planning & Budgeting" - Graduate School of Public Affairs, SUNYA.
December 1978	"Grants & Project Administration" - Graduate School of Public Affairs, SUNYA.
March 1978	"Manager's Advancement Programs" - American Management Association.
September 1978	"Leadership Styles for Managers" - Madden Associates.

RESUME

Mark A. Scruggs, Chief, Research Branch, Air Resources Division, National Park Service

Dr. Scruggs has been Chief of the Research and Monitoring Branch since 1997. He currently directs the Air Resources Division activities concerning dispersion model development and application, assessment of the effects of air pollution on terrestrial and aquatic ecosystems (with a special emphasis on ozone effects on natural vegetation), research into the sources and causes of visibility impairment, and the deployment and operation of national ozone, wet deposition, fine particle, and visibility monitoring networks. He has also served as Chief of the Research Branch from 1986 to 1997 and the Permit Review and Technical Support Branch from 1985 through 1986. From 1981 until 1985 he was primarily involved in the review of air quality analyses of environmental impact statements and permit applications for sources that could affect park service units.

He has served as Chair of the Modeling Subcommittee of the Grand Canyon Visibility Transport Commission, the first chair of the Interagency Workgroup for Air Quality Modeling, and serves as a Co-chair of the Research and Development Forum of the Western Regional Air Partnership (WRAP). He was the Federal Representative on the Science and Technical Support Workgroup of the EPA FACA Subcommittee on Ozone, Particulate Matter, and Regional Haze and is the Alternate to the Federal representative for WRAP Technical Oversight Committee.

From 1979 to 1980, he served as the senior meteorologist with an environmental consulting firm where he directed projects designed to assess the cost impacts of stack height regulations, proposed sulfur dioxide, nitrogen dioxide and particulate matter ambient standards, documentation of mobile source modeling techniques, and air quality effects of fugitive emissions from synthetic fuel development. From 1976 to 1979 he was with the Environmental Protection Agency, Office of Air Quality Planning and Standards, in Research Triangle Park, North Carolina, and the Regional Office in Dallas, Texas. He was responsible for the modification of existing air quality models for nontraditional applications including visibility, lead and fugitive emissions, and took part in the standard setting process for lead. At the Regional Office he was responsible for the use, interpretation, and revisions to air quality models for all regional applications including State implementation plans and prevention of significant deterioration applications.

Education:

B.A. - Physics, University of South Florida, 1966
M.A. - Physics, University of South Florida, 1969
Ph.D. - Atmospheric Physics, Florida State University, 1976

PUBLICATIONS

Scruggs, M.A., "Proposed Action Will Improve Visibility in the Grand Canyon," Highlights of Natural Resources Management 1990, Natural Resources Programs Report, NPS/NRPO/NRR-91/03, National Park Service, 1991.

Scruggs, M.A., "NAPAP Summary," Highlights of Natural Resources Management 1990, Natural Resources Programs Report, NPS/NRPO/NRR-91/03, National Park Service, 1991.

Scruggs, M.A., "Winter Haze Intensive Tracer Experiment (WHITEX) Assesses Visibility Impairment at Colorado Plateau Parks," Highlights of Natural Resources Management 1990, Natural Resources Programs Report, NPS/NRPO/NRR-90/03, National Park Service, 1990.

Christiano, J.P., M.A. Scruggs, "Permit Application Guidance for New Air Pollution Sources," Natural Resources Report Series 85-2, National Park Service, 1985.

Keyes, D.L., M.A. Scruggs, and B. Kumar, "A Reexamination of the Ozone Limiting Approach to Estimating Short-Term NO_2 Concentrations," Journal of the Air Pollution Control Association of America, **31**:671, 1981.

CONTRIBUTED TO THE FOLLOWING TECHNICAL REPORTS

"Status of Air Quality and Related Values in Class I National Parks and Monuments of the Colorado Plateau," National Park Service Air Resources Division, April 1997.

"Inventory and Monitoring Program, Annual Report, Fiscal Year 1997," Department of the Interior, National Park Service, 1997

"Results of Workshop on Modeling Review," Modeling Subcommittee, Grand Canyon Visibility Transport Commission, 1994.

"Draft Environmental Impact Statement on Conversion of Oil and Gas Leases to Combined Hydrocarbon Leases, Tar Sand Triangle, Utah," U.S. Department of the Interior, National Park Service and Bureau of Land Management, July 1984.

"Feasibility of a Welfare Benefits Analyses for Particulate Matter and Sulfur Dioxide," prepared for the U.S. Environmental Protection Agency by Energy and Environmental Analysis, Inc., January 1980.

"A Case Study of Control Strategies to Attain Alternative SO_2 Ambient Standards in Chicago," draft report, prepared for the U.S. Environmental Protection Agency by Energy and Environmental Analysis, Inc., April 1980.

"Methodology to Conduct Air Quality Assessments of National Mobile Source Emission Control Strategies," prepared for the U.S. Environmental Protection Agency by Energy and Environmental Analysis, Inc., October 1980.

"The Impact of Including Fugitive Emissions from Mining Operations on Contiguous Processing Facilities," prepared for the U.S. Environmental Protection Agency by Energy and Environmental Analysis, Inc., October 1980.

"Regional MOBILE2 Variable Estimates," prepared for the U.S. Environmental Protection Agency by Energy and Environmental Analysis, Inc., July 1980.

"Techniques for Estimating MOBILE2 Variables," prepared for the U.S. Environmental Protection Agency by Energy and Environmental Analysis, Inc., July 1980.

"Energy Conservation and Attainment and Maintenance of Ambient Air Quality, Volume II: Application of Conservation Technology," draft report, prepared for the U.S. Environmental Protection Agency by Energy and Environmental Analysis, Inc., June 1980.

"Estimates of Ambient Air Lead Concentrations Caused by Stationary and Mobile Sources," U.S. Environmental Protection Agency, Staff Report, June 1978.

"An Implementation Plan for Suspended Particulate Matter in the Phoenix Area, Volume III. Model Simulation of the Total Suspended Particulate Levels," prepared for the U.S. Environmental Protection Agency by TRW Environmental Division, August 1977.