

GAO

Report to the Chairman, Subcommittee on Oversight and Investigations, Committee on Energy and Commerce, House of Representatives

December 1987

AIR POLLUTION

Information on EPA's Efforts to Control Emissions of Sulfur Dioxide



RESTRICTED—Not to be released outside the General Accounting Office except on the basis of the specific approval by the Office of Congressional Relations.

**Resources, Community, and
Economic Development Division**

B-217221

December 7, 1987

The Honorable John D. Dingell
Chairman, Subcommittee on Oversight
and Investigations
Committee on Energy and Commerce
House of Representatives

Dear Mr. Chairman:

As required by the Clean Air Act, the Environmental Protection Agency (EPA) established national ambient air quality standards for sulfur dioxide and five other widespread pollutants. While EPA has set these standards at levels intended to protect the public's health and welfare, the states are responsible for developing implementation plans to achieve the standards and assure that necessary measures are adopted to prevent unhealthy emissions. Over and above the health risks associated with sulfur dioxide emissions, its contribution to the formation of acid rain has also prompted congressional concerns. To address acid rain concerns, lawmakers have introduced several legislative proposals mandating large-scale reductions in sulfur dioxide emissions.

In August 1985 we reported to you that, during 1981 through 1983, EPA had approved over 100 state implementation plan revisions which increased allowable sulfur dioxide emissions¹. We reported that the revisions and EPA's related policy were consistent with the act's requirements in that the increases did not violate national standards or allow significant deterioration of air quality. We also pointed out that there were varying ranges of uncertainties associated with air quality dispersion models used by EPA to evaluate requests for increasing pollutant emissions and that EPA had research efforts underway to develop better models.

In September 1985, you asked the EPA Administrator to respond to questions based on our August 1985 report. Specifically, you asked EPA to explain its efforts to develop a regional model to address the acid rain issue and a complex terrain model to improve capabilities for modeling mountainous areas. You also asked EPA to provide additional information on several state implementation plan revisions and to provide an update on the number of revisions since the issuance of our report. As

¹ EPA-Approved Revisions to State Implementation Plans Allowing Increased Sulfur Dioxide Emissions Were Legal (GAO/RCED-85-129, August 16, 1985).

you requested, EPA provided a copy of its response to us for review and comment.

We found that EPA generally responded satisfactorily to your questions. However, we agreed with your office to develop additional information on the status of EPA's efforts to develop two models — the Regional Acid Deposition Model (RADM) and the Complex Terrain Dispersion Model (CTDM) — to improve its ability to estimate the movement and effect of sulfur dioxide and other airborne pollutants. Specifically, we determined for each model the purpose, costs, current status, planned completion dates, and expected performance when completed. Further, we obtained updated information on sulfur dioxide state implementation plan revisions through 1986, determining their number and the increase in sulfur dioxide emissions allowed by them.

In summary, we found that the RADM and CTDM models are encountering cost overruns and delays. The following is the status of each model as of September 30, 1987:

- EPA initially estimated the cost to develop the RADM would be about \$11.5 million, but through fiscal year 1987 it had expended \$15 million — an increase of \$3.5 million. The extra costs of developing the RADM are generally attributable to problems incurred in developing the model and increases in the scope of work for the model. Further, an evaluation to determine the model's accuracy and reliability was not as comprehensive as planned because of the high costs of conducting field studies to compile meteorological and pollution data for the evaluation. Consequently, the final evaluation of the model has become more critical than originally anticipated. Beginning in late 1984, the Atmospheric Sciences Research Laboratory began planning for the final evaluation of the model by proposing several evaluation scenarios to EPA headquarters with cost estimates ranging from \$20 million to \$30 million. The evaluation plan which EPA decided to use for the final evaluation of the model is expected to cost \$30 million and be completed by 1990. The agency notes, however, that completion of the final evaluation may be delayed because additional time has been required to develop the model and prepare necessary supporting documentation.
- EPA's initial estimated cost of developing and evaluating the CTDM was \$5.7 million but through fiscal year 1987 it had expended \$8.5 million — an increase of \$2.8 million. Further, its completion date has been delayed by more than three years. Funding constraints and changes in the scope of work increased the cost and caused the delays of the CTDM. When completed in late 1987, the model will need further improvement

to provide EPA the capability for estimating the effect of pollutants for periods longer than one hour and during unstable atmospheric conditions before it can be used for regulatory purposes.

EPA approved 48 revisions to nineteen state and three territory implementation plans from 1984 through 1986, increasing net allowable sulfur dioxide emissions by an average of about 250,000 tons per year. Annually, the number of such revisions has declined from 55 in 1981 to 6 in 1986. Furthermore, the 250,000-ton net increase in allowable emissions per year represented less than one percent of total man-made emissions of sulfur dioxide nationwide in 1985.

We discussed the information in this report with EPA officials during our audit, and their comments have been incorporated where appropriate. However, at your request, we did not obtain official agency comments on a draft of this report.

As arranged with your office, unless you publicly release its contents earlier, we plan no further distribution until 30 days from the date of this letter. At that time copies of the report will be sent to appropriate congressional committees; the Administrator, Environmental Protection Agency; and the Director, Office of Management and Budget. Major contributors to this report are listed in appendix V.

Sincerely yours,



Hugh J. Wessinger
Senior Associate Director

Contents

Letter		1
<hr/>		
Appendix I		6
Status of the Regional Acid Deposition Model and the Complex Terrain Dispersion Model	Development of the Regional Acid Deposition Model	7
	Development of the Complex Terrain Dispersion Model	16
<hr/>		
Appendix II		22
State Implementation Plan Revisions for Sulfur Dioxide	Background	22
	EPA's Response to Request for Additional Data on Sulfur Dioxide State Implementation Plan Actions	23
<hr/>		
Appendix III		25
Objectives, Scope, and Methodology		
<hr/>		
Appendix IV		27
GAO Reports to the Subcommittee on Oversight and Investigations, House Committee on Energy and Commerce, for Its Examination of Actions Controlling Emissions of Sulfur Dioxide		

Appendix V		28
Major Contributors to This Report	Resources, Community, and Economic Development Division, Washington, D.C.	28
	Norfolk Regional Office	28
Tables		
	Table I.1: Contract Modifications Providing for Time Extensions and/or Cost Increases for Development of the CTDM	19
	Table II.1: Sulfur Dioxide State Implementation Plan Revisions Approved by EPA From 1981 to 1986	24
Figures		
	Figure 1.1: Diagram Showing the Overall Planned Development of the Regional Acid Deposition Model	10

Abbreviations

CTDM	Complex Terrain Dispersion Model
EPA	Environmental Protection Agency
GAO	General Accounting Office
RADM	Regional Acid Deposition Model
RCED	Resources, Community, and Economic Development Division

Status of the Regional Acid Deposition Model and the Complex Terrain Dispersion Model

One of the most controversial issues of our time, acidic deposition,¹ is a major concern for EPA and has been the focus of scientific symposia, international conferences, and presidential summit meetings. Acidic deposition is formed when sulfur dioxide and nitrogen oxides emitted by coal-fueled power plants, motor vehicles, and other man-made or natural sources are transported and transformed in the atmosphere and returned to earth as acidic compounds. It has been linked to a number of environmental problems, including (1) declining fish populations in the northeastern United States and southeastern Canada; (2) forest damage in the eastern United States and Canada; and (3) material damage, such as building erosion. Estimating the effect of pollution, such as sulfur dioxide, in mountainous areas is also an issue which concerns EPA in its current regulatory program. However, EPA lacks the modeling capability to estimate the effects of acidic deposition and develop a national policy or make regulatory decisions for controlling these pollution emissions in mountainous areas.

EPA is currently developing two air quality dispersion models — the Regional Acid Deposition Model (RADM) and the Complex Terrain Dispersion Model (CTDM) — to address these issues. The Agency contends that such models have proved less costly and more practical for estimating the impact of EPA's regulatory efforts to reduce pollution than other techniques, such as large-scale field studies to measure actual meteorological and pollution conditions.

Although the RADM and the CTDM are still being developed, both models are encountering cost overruns and delays. Initiated in 1983 to address the complex issues of acidic deposition, the RADM has already exceeded EPA's original \$11.5 million cost estimate by \$3.5 million. Additionally, EPA estimated as of September 1987 that a developed model would be completed in February 1988, compared with an original estimate of January 1987. Further, an initial evaluation to determine the model's accuracy and reliability was not as comprehensive as planned because of the high costs of conducting field studies to compile meteorological and pollution data for the evaluation. Thus, EPA officials said that a planned final evaluation is more critical than originally anticipated because of the limited evaluation. EPA estimates the final evaluation will cost about \$30 million when completed in September 1990.

¹Over time, several terms have been used to describe this phenomenon, including acid rain, acid precipitation, acid deposition, and acidic deposition. For purposes of this report, we use the more technically correct term, acidic deposition, which refers to the deposition of acidic materials in both wet and dry forms.

EPA initiated the CTDM in 1980 in an effort to better estimate the effects of airborne pollutants in mountainous terrain. The CTDM's completion date has already been delayed by more than three years. Further, although EPA originally estimated the cost of developing and evaluating the model would be \$5.7 million, the Agency had expended \$8.5 million through fiscal year 1987, an increase of \$2.8 million. EPA expects to receive the completed model in late 1987; however, agency officials anticipate that the model will require additional improvements and refinements before EPA can use it to make regulatory decisions.

Development of the Regional Acid Deposition Model

The authority for development of the RADM dates back to 1980, when the Congress enacted the Acid Precipitation Act, establishing a 10-year, interagency research program — the National Acid Precipitation Assessment Program — to help resolve the scientific uncertainties associated with acidic deposition and to determine if and how it should be controlled. The National Acid Precipitation Assessment Program formed several task groups to address various issues related to acidic deposition, with the Atmospheric Transport Task Group being tasked with developing an accurate and reliable model to estimate the source, transport, transformation, and deposition of pollutants which contribute to acidic deposition. Because of its responsibility for regulating pollution emissions, EPA was given the responsibility in 1982 for developing an acidic deposition model.

In early 1983 the task group and EPA decided that the National Center for Atmospheric Research was the best agency to develop the conceptual framework for the acidic deposition model.² Subsequently, in June of 1983, an interagency agreement was signed between EPA and the National Center for Atmospheric Research for the development of the RADM. EPA designated a scientist from its Meteorology and Assessment Division, Atmospheric Sciences Research Laboratory, as the Project Officer to manage the development and evaluation of the RADM. Similarly, the principal scientist at the National Center for Atmospheric Research, who had overall responsibility for developing the model, was designated as the Project Manager.

EPA plans to ultimately use the RADM results in conjunction with economic models to estimate "what if" scenarios for economic analysis in

²The National Center for Atmospheric Research is operated, under the National Science Foundation sponsorship, by a non-profit corporation composed of 50 U.S. institutions with doctoral programs in the atmospheric sciences.

making regulatory and policy decisions. According to EPA, if the RADM showed that acidic deposition should be reduced by 50 percent in New York, EPA could determine the amount that sulfur dioxide emissions would have to be reduced within a geographic area, such as the Ohio River Valley, to achieve this reduction. Also, EPA could determine the economic hardships on industry that would be expected if the emissions were reduced by this amount. According to EPA officials, no other model currently available is capable of producing information on the relationships between the sources and deposition of acidic compounds that can be used in economic analyses.

The Complexity of the Regional Acid Deposition Model

The issue of acidic deposition is very complex because of the intricate nature in which pollutants are transported and transformed in the atmosphere and returned to earth as acidic compounds. To identify the causes and address the problems of acidic deposition, the RADM will take into account (1) the emission of materials that cause acidity in wet and dry deposition; (2) the various layers of meteorological patterns; (3) the mixing of pollutants during transport; (4) the scavenging process (i.e. rain washing pollutants out of the clouds) during the transport of pollutants; and (5) the estimation of acidic concentrations when the acidic deposition returns to the earth. Because the RADM program is very complex, it is run on a Cray computer — one of the fastest and most powerful computers in the United States.

Because of the overall complexity of the model, EPA decided to develop the RADM through five sub-projects or components. The components were developed concurrently by scientists from federal agencies and other organizations considered experts in their fields. A brief description of each of the RADM components follows.

- The Gas Phase Chemistry component simulates the chemical transformation process as different gases mix in the atmosphere.
- The Mesoscale Meteorological component generates data on wind, precipitation, and cloud conditions as well as temperature and humidity, which may be affected by the pollutants.
- The Cloud Chemistry component focuses primarily on the wet chemical transformation processes.
- The Precipitation Scavenging component simulates the conditions of rain washing pollutants out of the clouds.
- The Dry Deposition component estimates dry acidic deposition to the ecosystem and the atmospheric concentrations as a function of distances from source areas.

Development of the components required an understanding of the wide range of physical and chemical processes involved with each component and the interactions among the components. Further, EPA's evaluation of each of the components prior to merging them into a complete model was difficult because individual data bases were needed to evaluate each component. Upon merging the components into a complete model, EPA plans a final evaluation of the RADM to include conducting numerous field studies and using the data from these studies to evaluate the accuracy and reliability of the model. Figure I.1 on the following page illustrates the concurrent development of the five components and the evaluation of each of them. It also illustrates the merging of the components into the complete model and its final evaluation.

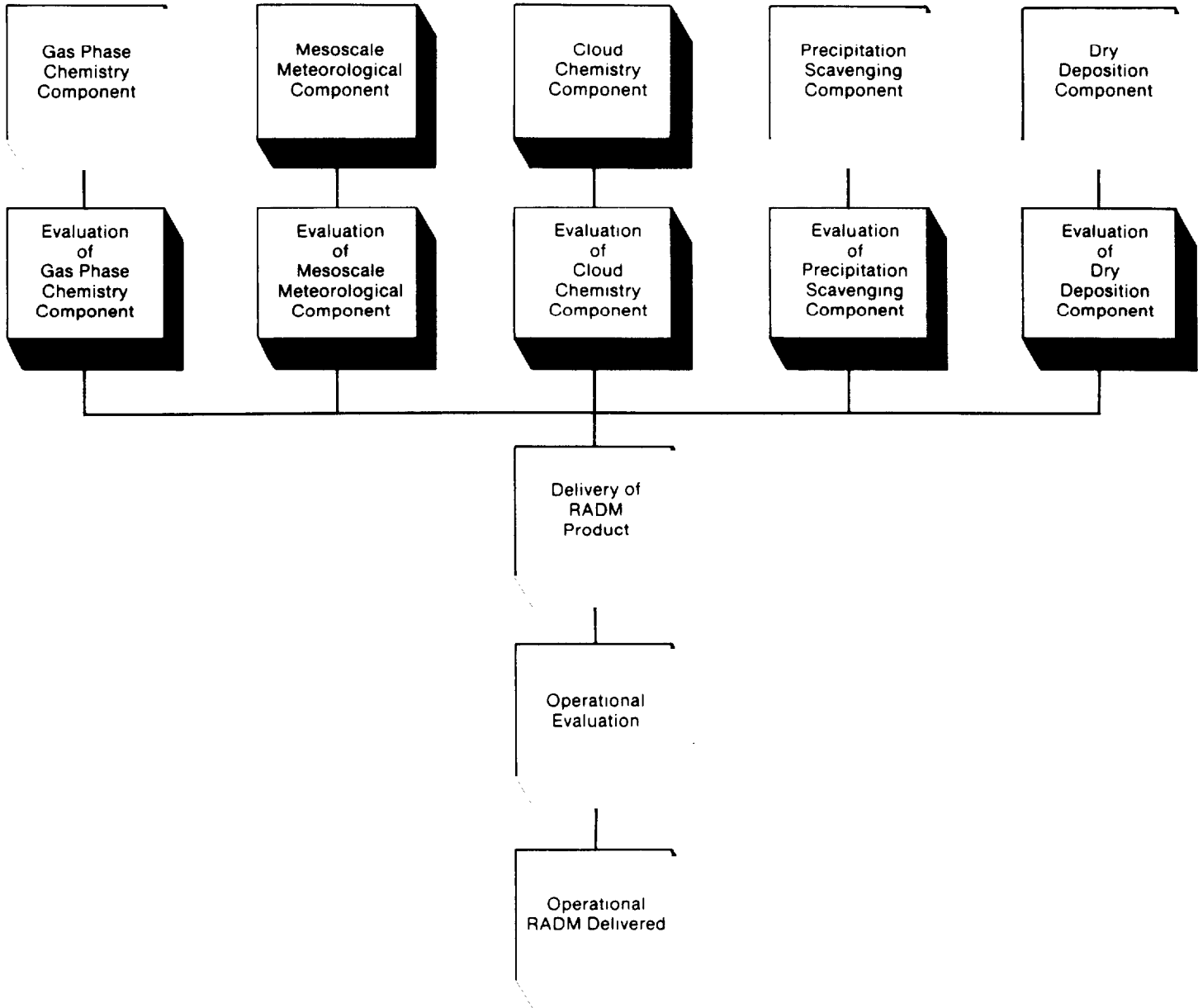
Cost and Status of the Regional Acid Deposition Model

EPA's initial estimated cost for the RADM's development was about \$11.5 million. However, through fiscal year 1987, EPA had expended approximately \$15 million for the development phase of the model — \$3.5 million more than estimated — and has budgeted \$300,000 for fiscal year 1988. Further, EPA estimates the evaluation phase will cost about \$30 million. The extra costs of developing the RADM are generally attributable to problems incurred in developing the model and increases in the scope of work for the model. According to the Director of the Meteorology and Assessment Division, Atmospheric Sciences Research Laboratory, and the Project Officer, the increased cost of the RADM was generally due to the overall complexity and difficulty of developing the model and its components. For example, in developing the Cloud Chemistry component the National Center for Atmospheric realized that additional chemistry measurements should be incorporated into the component and that some measurements needed to be conducted concurrently. The Center increased the number of measurements as well as conducting some measurements concurrently. Therefore, additional time and effort was required to accomplish these measurements. Thus, the additional efforts to address the complexity problems increased the cost of developing the RADM. The same officials told us that another factor contributing to the agency's low initial estimates for RADM was pressure to keep 5-year budget estimates down when initial estimates for RADM were prepared.

By 1984 EPA realized that it would be very expensive to operate the RADM with the numerous meteorological and pollution scenarios necessary to estimate acidic deposition. Thus, EPA decided to develop a condensed version, the Engineering Model, which could be run on computers smaller than the Cray and would require considerably less

Appendix I
Status of the Regional Acid Deposition Model
and the Complex Terrain Dispersion Model

Figure 1.1: Diagram Showing the Overall Planned Development of the Regional Acid Deposition Model



computer time to operate than the RADM. The development of the Engineering Model cost about \$1 million. The Engineering Model is not a component of RADM. Rather, it is a separate, scaled-down, and condensed model which will mimic the RADM. The Engineering Model is planned to allow EPA to run typical scenarios and screen out the ones which would not be useful in estimating acidic deposition. Subsequently, the scenarios which may be useful can then be run through the RADM. By using the Engineering Model, EPA will save the costs of the extensive computer time necessary to run the scenarios with the RADM. For example, the Project Officer said a typical scenario run with the Engineering Model will cost about 10 percent of what it would cost for a comparable RADM run.

EPA expects about a one-year delay from its original plan for completing the development phase of the RADM. While there have been several time extensions for developing individual components, they are not expected to delay the merging of the components into the completed RADM, according to the Project Officer. However, EPA has provided additional time for the Project Manager to deliver the model and its supporting documentation. EPA considers documentation for the model important because these instructions and manuals are necessary for EPA and others to understand and operate the model.

According to the Director of the Meteorology and Assessment Division, Atmospheric Sciences Research Laboratory, and the Project Officer, the Project Manager has delayed delivering the model and its documentation because he believes the model should be further developed before EPA starts the evaluation phase. EPA has agreed for the Project Manager to delay delivery of the RADM from October 1987 to February 1988 and delivery of the documentation will slip from October 1987 to late summer 1988. According to the Project Officer, requiring the Project Manager to prepare the documentation before starting the evaluation phase would have delayed its start significantly. Therefore, EPA decided to allow the Project Manager the additional time to develop the RADM and prepare the documentation to minimize any possible delay in the evaluation.

The Project Manager stated that EPA will not need all the documentation for the model to start the evaluation phase if he and his staff are allowed to perform the evaluation. As of September 1987, the Director of the Meteorology and Assessment Division, Atmospheric Sciences Research Laboratory, and the Project Officer, indicated that EPA planned

to award a cooperative agreement to the Project Manager and his staff for the final evaluation of the model.

Concern Over the Quality of the Regional Acid Deposition Model

To insure the quality of the RADM, EPA planned to use two quality assurance methods — peer review conferences and evaluations. With the peer review conferences, independent scientists who are experts on modeling techniques review the design and development of the RADM and report their approval and/or concern over problems or flaws with the model. The evaluation phases use data from field studies to evaluate the model for accuracy and reliability.

Peer Reviews

Two peer review conferences were conducted to determine whether the RADM was based on sound, reasonable judgments supported by the best available scientific knowledge. In holding the peer review conferences, EPA obtained the independent opinions of scientists, who were not involved with the development of the model, on how well the RADM had been developed and would operate. During the peer review conferences the scientists who developed the components of the model gave presentations on how the RADM had been designed and developed and how it was expected to operate. The peer review panel, in turn, critiqued the design and development of the model to identify the model's limitations and recommended ways for improving it. According to the Director of the Meteorology and Assessment Division, Atmospheric Sciences Research Laboratory, the Project Officer, and the Project Manager, problems or flaws in RADM are likely to surface during a peer review conference of this type.

The first peer review conference was held in March 1985. Overall, the panel concluded that the RADM was on or ahead of schedule and promised major improvements in regional model performance and reliability, if the model was fully developed. While they were favorably impressed by the high quality and promise of the RADM research, concern was expressed about the lack of coordination and communication among the scientific teams who were developing the RADM components. Further, they stated that it was essential for the model to be evaluated with adequate data from field studies to ensure the credibility of the model. The panel also offered comments on the quality of the individual components:

- The Gas Phase Chemistry component should examine aspects of the atmospheric sulfur cycle, including a study of the seasonal behavior of sulfate and sulfur dioxide.
- The techniques for simulating deposition in the Dry Deposition component were state-of-the-art but could still fall short of the required accuracy and precision.

EPA, the National Acid Precipitation Assessment Program task group, and the National Center for Atmospheric Research initiated a number of actions to address the concerns raised by the peer review panel. For example:

- To deal with the coordination and communication issue, the National Center for Atmospheric Research established a work group of more than two dozen scientists who meet annually, conduct annual and special workshops, and discuss the RADM components directly with the model's developers.
- EPA, in conjunction with other federal agencies, prepared a plan for evaluating the RADM and subsequently performed a limited interim evaluation of the components in 1986 because fewer field study data were used than planned.
- The National Acid Precipitation Assessment Program task group said that an examination of sulfur-related problems would be considered in the development of the Gas Phase Component.
- The National Acid Precipitation Assessment Program task group also stated that the shortcomings of the Dry Deposition component would be addressed by developing and using more detailed computerized surface maps and more information on vegetation.

According to the Director of the Meteorology and Assessment Division, Atmospheric Sciences Research Laboratory, and the Project Officer, these actions resulted in an improved RADM. Further, in the opinions of the Director and Project officer, the comments from the May 1987 peer review conference also showed that the concerns from the first peer review had generally been addressed. They also acknowledged that the limited use of field study data for the evaluation of the components did not fully satisfy the peer review panel's recommendation.

The May 1987 peer review panel concluded that overall, the RADM demonstrated a good effort on the part of EPA and the National Acid Precipitation Assessment Program to address the acidic deposition problem and that the science and architecture of the model were of high quality. They commended EPA and the National Acid Precipitation

use the RADM Project Manager would insure continuity of knowledge and therefore provide a better evaluation of the model. Also, the Project Manager stated that he and his staff could do a better job of assisting with the model evaluation than another agency or contractor who has no prior knowledge of the RADM. However, as of September 1987, EPA had not awarded the cooperative agreement for the evaluation phase because of the Project Manager's delay in providing all the documentation for the RADM, according to the Project Officer.

The first step of the final evaluation is scheduled to start in June 1988 at which time EPA plans to conduct field studies to compile data bases to evaluate the RADM. During the remaining time EPA plans to (1) run scenarios of various pollutant emissions and meteorological conditions from the field study data through the model, (2) evaluate the results from these runs to identify problems and weak links with the model, (3) make adjustments to the RADM to correct the identified problems and weaknesses, and (4) gather additional field study data for a final validation and correction of the RADM. At this point the RADM is scheduled to be delivered to EPA as an operational model in September 1990. According to the Project Officer, it will probably be 1991 before the final evaluation is completed and RADM becomes an operational model.

The Director of the Meteorology and Assessment Division, Atmospheric Sciences Research Laboratory, and Project Officer stated that the final evaluation is even more important since the individual components were not evaluated with field study data specifically compiled for the evaluation. Further, the Director and Project Officer said that to perform less than a complete evaluation would jeopardize the reliability and credibility of the RADM. Therefore, considering the magnitude of EPA's decisions which would be based on the RADM, the Director and Project Officer stated that it is imperative for the final evaluation of the RADM to be performed.

Development of the Complex Terrain Dispersion Model

In the late 1970s EPA realized the limitations of the mathematical models which it was using to estimate the effect of pollutants from, and make regulatory decisions for, power plants and other sources in mountainous areas. Emissions from these sources affect mountainous terrain differently than level terrain. Thus, the estimations from existing models will not be as accurate as those from a model designed for complex terrain. Consequently, when EPA has to decide whether to approve the emissions from a power source in mountainous areas such as a new coal-fueled

power plant it can not be sure of the accuracy of the data upon which it based its decisions.

In 1979 EPA sponsored a workshop to discuss the issues and problems of modeling a pollutant's dispersion in complex terrain and to recommend ways for EPA to address these problems. Based on these recommendations, EPA initiated a multi-year integrated program to develop a series of air dispersion models that would improve its ability to determine a pollutant's movement and the effect on mountainous terrain. The CTDM was the first of these models.³

Description of the Complex Terrain Dispersion Model

Development of the CTDM was undertaken to estimate the effect of a single pollutant on the prevailing wind side of a mountain during stable atmospheric conditions and for a one-hour period. Because the highest concentration of a pollutant occurs on the prevailing wind side of a mountain and during stable atmospheric conditions, EPA decided to develop a model with the capability to estimate the affects of these conditions first, according to the Director of the Meteorology and Assessment Division, Atmospheric Sciences Research Laboratory.

In June 1980, EPA awarded a contract to Environmental Research and Technology, Inc. for the development and evaluation of the CTDM. In developing the model the contractor was to (1) use existing modeling techniques and results from previous field studies to help design the model, (2) prepare a laboratory demonstration of a complex terrain air dispersion model, (3) conduct two field studies on small hills to measure the effect of a pollutant, (4) conduct a full-scale field study at an existing power plant in mountainous terrain, and (5) evaluate the completed model. During the evaluation phase, the contractor was required to (1) determine the model's confidence limits, (2) delineate the model's applicability and limitations, and (3) examine the model's performance using different atmospheric and pollution data.

Cost and Status of the Complex Terrain Dispersion Model

The contract for developing and evaluating the CTDM required 3 years longer than planned and cost \$2.8 million more than estimated. The contract's original period of performance of 4 years and 3 months and cost of \$5.7 million has increased to 7 years and 5 months and \$8.5 million,

³According to the Director of the Meteorology and Assessment Division, Atmospheric Sciences Research Laboratory, EPA's efforts to develop the other models will probably not be completed because of budget constraints and funding of higher priority research.

respectively. According to EPA, constraints in funding and changes in the scope of work caused delays and increased the cost of the CTDM. Specifically, in fiscal year 1981 the EPA Administrator reduced the funding for the CTDM by withdrawing part of the funds for other programs. Similarly, in fiscal year 1986, funding for the model was cut by the Balanced Budget and Emergency Deficit Control Act of 1985 and the EPA Administrator's reallocation of funds to other programs.

In October 1980 the contractor notified EPA that it was in a potential cost overrun situation. EPA's evaluation of the contractor's justification for the cost increases identified a number of reasons, including problems performing the first field study and processing the data from the study and increased quality assurance requirements imposed by EPA. To prevent a work stoppage by the contractor, EPA modified the contract three times between November 1980 and June 1981 to increase its authorized funding. Also, because of reduced CTDM funding during 1981, the contractor was forced to stop work on the model in June and December 1981. In March 1982 the contract was again modified to increase its authorized funding and extend its period of performance by 6 months. The four modifications to the contract increased its costs by \$685,000. The Director of the Meteorology and Assessment Division, Atmospheric Sciences Research Laboratory, also attributed the increased costs and delays to the EPA Administrator's June 1981 decision to cut funding for the CTDM program.

Another delay and cost increase resulted because one of two field studies could not be conducted in the fall during stable atmospheric conditions. The two field studies were scheduled for the fall of 1980 and 1981; however, the second field study was delayed by a year because of the funding cuts and change of site for performing the study. For this reason, in June 1982 the contract's cost was increased by \$491,000 and the period of performance extended an additional 6 months.

By March 1984 EPA realized that the delays caused by the funding reduction in 1981 did not leave enough time to complete several tasks, such as (1) conducting a full-scale field study at an existing power plant, (2) using the data from the study to improve the model, and (3) delivering a completed model by October 1985. Thus, in March 1985 the contract's period of performance was increased by an additional 15 months, which extended the completion date to December 1986. Also, in conjunction with the time extension, EPA modified the contract to incorporate a number of changes that would improve the quality of the CTDM, such as (1) changing the location of the full-scale field study to a site to provide

**Appendix I
Status of the Regional Acid Deposition Model
and the Complex Terrain Dispersion Model**

a setting to more fully validate the CTDM, (2) assigning the responsibility for collecting air samples at the field study to the National Oceanic and Atmospheric Administration and, (3) imposing more stringent quality assurance requirements. Because of the time extension and changes to the scope of work, EPA renegotiated the contract in March 1985 and increased the cost by \$1.6 million.

During fiscal year 1986 the CTDM funding was again cut due to the Balanced Budget and Emergency Deficit Control Act of 1985 and the reallocation of funds by the EPA Administrator, according to the Director of the Meteorology and Assessment Division, Atmospheric Sciences Research Laboratory. Therefore, in December 1986, EPA modified the contract to extend the period of performance by another 9 months to September 1987. Also in August 1987, EPA extended the contract's delivery date for 2 months to November 1987, because the contractor was experiencing problems with the computer model codes during the final stages of the model's evaluation.

Table I.1 summarizes the time extensions and cost increases caused by the delays and budgetary constraints.

**Table I.1: Contract Modifications
Providing for Time Extensions and/or
Cost Increases for Development of the
CTDM**

Date	Modification no. and reasons for extension	Extension (Months)	Cost (\$1,000)
3/26/82	Modification #9 (Cost increases and 1981 funding cuts)	6	685
2/10/83	Modification #14 (Change site location for small hill site 2)	6	491
3/07/84	Modification #22 (Additional time to complete full field study due to 1981 cuts)	15	1,637
12/17/86	Modification #31 (Slow down progress due to 1986 funding cuts)	9	•
9/9/87	Modification #33 (Problems with computer model codes)	2	•

**Modifications Planned to
the Complex Terrain
Dispersion Model**

The CTDM was planned to be EPA's first in a series of efforts to develop complex terrain models to estimate the effect of various pollutants in mountainous areas. EPA planned to develop follow-on models that would further expand its complex terrain modeling capability by estimating the effect of a pollutant during (1) unstable atmospheric conditions, (2) a pollutant's transport over or around a mountain and impaction on the opposite side of the mountain, and (3) a pollutant's stagnation in a valley.

Appendix I
Status of the Regional Acid Deposition Model
and the Complex Terrain Dispersion Model

The CTDM which EPA plans to accept from the contractor in the fall of 1987 will meet the requirements specified in the contract, according to the Director of the Meteorology and Assessment Division, Atmospheric Sciences Research Laboratory. However, since EPA is not developing the planned follow-on models, it has to modify the CTDM before it uses the model to make regulatory decisions, according to the Director and Project Officer. As noted earlier, the current CTDM will only estimate the effect of a pollutant during stable atmospheric conditions. Thus, the model will not enable EPA to adequately estimate the effects of pollutants during unstable atmospheric conditions, such as daytime hours or during periods of the year other than the fall.

While the CTDM can only estimate a pollutant's effect for a one-hour period, EPA will be able to produce data for an unlimited number of one-hour periods. For example, the model will provide data for 24 one-hour periods of stable atmospheric conditions. However, this data would not be representative of a 24-hour day since a day also includes periods of unstable atmospheric conditions. To illustrate, the national ambient air quality standard for sulfur dioxide has a three-hour standard. Thus, EPA's use of three one-hour periods of data from the CTDM would not adequately estimate the effect of sulfur dioxide in mountainous terrain, especially during daytime hours.

The Regional/State Modelers Workshop also recognized the need to modify the CTDM.⁴ During the May 1987 meeting, the members of the Workshop concluded that the model, in its current state, would be limited to modeling stable atmospheric conditions and thus not be capable of providing a complete estimate of pollutant concentrations. The Workshop discussed two options: (1) limit the CTDM's use by modeling worst case scenario or (2) expand the model to include the capability to model unstable atmospheric conditions. In a June 1987 memorandum to EPA's Office of Research and Development, the Workshop recommended that the model's capability be expanded to include unstable atmospheric conditions.

According to the Director of the Meteorology and Assessment Division, Atmospheric Sciences Research Laboratory, the complex terrain modeling program has approximately \$144,000 for fiscal year 1988 and no funds for fiscal year 1989. EPA expects to use the available fiscal year

⁴The Workshop is an annual meeting of EPA and state staff who develop models and use them for regulating pollution emissions. The workshop participants review various models which are being developed or used by EPA and the states and provide comments on improving their development and use.

Appendix I
Status of the Regional Acid Deposition Model
and the Complex Terrain Dispersion Model

1988 complex terrain program funding for EPA staff to expand the existing CTDM capabilities to estimate unstable atmospheric conditions and to model for longer time periods.

The Source Receptor Analysis Branch, Office of Air Quality Planning and Standards, whose primary function is to deal with regulatory and technical issues related to air quality models, will use the CTDM when it becomes operational. The Chief of this branch said that he also plans to work with the laboratory to improve the CTDM so that it can be used to make regulatory decisions. The Chief estimated that the CTDM will be improved enough for EPA to use it in making regulatory decisions in about 2 years.

State Implementation Plan Revisions for Sulfur Dioxide

The Clean Air Act requires, among other things, a process for limiting high concentrations of sulfur dioxide in the ambient air. The process entails having (1) EPA-developed national standards designed to protect the public health and welfare and (2) state-developed implementation plans containing strategies to limit emissions of the pollutant where warranted. Concern over the process mounted with news in the early 1980s that the states and EPA were taking actions that allowed more rather than fewer emissions of sulfur dioxide into the air.

Background

Many of the states developed their original implementation plans based on a strategy of establishing stringent sulfur-in-fuel limitations for business and industry as a means of restricting sulfur dioxide emissions. Subsequently, some of the states determined that their original sulfur-in-fuel limitations were more stringent than necessary to attain and maintain the National Ambient Air Quality Standards. These states began submitting plan revisions to EPA, asking the agency to relax some of the sulfur-in-fuel limitations.

In order to assess the relative impact of the plan revisions, EPA adopted two measures for the change in sulfur dioxide emissions. First, it compared the existing implementation plan limit and the revised limit to determine the "allowable" change in emissions; EPA has also called this the "paper" increase or decrease in emissions. Second, since many of the emission sources were not complying with the existing state implementation plans, EPA compared what the sources were actually doing with the revised plan limit to determine the "actual" increase or decrease in emissions.

The following description illustrates the difference in the two EPA measures. One state had established in its approved state implementation plan a sulfur dioxide emission limit of 6.0 pounds per million British Thermal Units and proposed to relax its plan to allow a source to emit 9.57 pounds per million British Thermal Units. Based on the size of the emission source, EPA determined the "allowable" or "paper" change to be an increase of 41,000 tons per year. However, considering that the source was already burning the higher sulfur-content coal, the "actual" increase in emissions was determined to be zero. The State Implementation Plan revision approved by EPA merely reflected what the source was already doing and did not result in increasing sulfur dioxide emissions. In another situation, when EPA approved several revisions in March 1984, it said "allowable" emissions would be increased by about 123,000 tons per year while "actual" increases would be only 16,000 tons per

year. EPA determined that none of the allowable or actual increases being approved would result in violations of national air quality standards for sulfur dioxide.

EPA's Response to Request for Additional Data on Sulfur Dioxide State Implementation Plan Actions

Citing his concern for the continued controversy over the issue of sulfur dioxide emissions, the Chairman, Subcommittee on Oversight and Investigations, House Committee on Energy and Commerce, in a September 1985 letter to EPA, included a request for updated information. EPA's response in January 1986 provided data showing rule making actions for sulfur dioxide state implementation plan revisions for 1984 and 1985. We obtained similar data from EPA for 1986 and analyzed the data for the number of approvals made and the net changes in sulfur dioxide emissions levels. It is important to note that although most revisions increase allowable sulfur dioxide emissions, some plan revisions may decrease allowable emissions or make no changes. EPA approved 32 state implementation plan revisions in 1984 whose coverage ranged from single sources to statewide. EPA's 1984 data indicated a net increase in allowable emissions of 267,230 tons per year and a net increase in actual emissions of 30,472 tons.

The 1985 data showed 10 sulfur dioxide plan revisions with a net decrease in allowable emissions of 18,000 tons per year and a net increase in actual emissions of 12,000 tons per year. EPA approved only 6 revisions in 1986, with the increase in both allowable and actual emissions being 2,326 tons per year.

There has generally been a steady decline in state implementation plan revisions since 1981, except for an increase in 1984. This trend was also indicated in our prior report, and was explained by EPA officials as stemming, in part, from increased concern over acid rain and also the belief that the sources who wanted changes in their sulfur dioxide emission limits had already applied for them. The declining number of state implementation plan revisions noted in our prior report and in the additional data provided by EPA is summarized in table II.1.

**Appendix II
State Implementation Plan Revisions for
Sulfur Dioxide**

**Table II.1: Sulfur Dioxide State
Implementation Plan Revisions
Approved by EPA From 1981 to 1986**

Year	Total number	Allowable emissions change in tons per year and number of revisions		Revisions with no emissions change
		Increase	Decrease	
1981	55	1,104,475 (36)	33,550 (5)	(14)
1982	39	704,207 (15)	230,395 (6)	(18)
1983 ^a	20	23,423 (7)	42,649 (2)	(7)
1984 ^a	32	274,285 (18)	7,055 (2)	(11)
1985 ^a	10	26,000 (2)	44,000 (1)	(6)
1986 ^a	6	2,326 (4)	•	(1)

^aAccording to EPA, emissions changes for seven revisions between 1983 and 1986 were not readily available.

The state implementation plan revisions we reviewed indicated that states are taking necessary measures to attain and maintain the established standards and at the same time wish to avoid imposing unnecessary and overly expensive burdens on industry. The history of the Massachusetts State Implementation Plan for sulfur dioxide illustrates the point. The state's original plan was approved by EPA in 1972, generally for sources to burn fuels with low sulfur content. In 1974, however, the state enacted a law requiring that its Department of Environmental Quality Engineering review the implementation plan portions pertaining to the sulfur content of fuel to determine whether any of the regulations were more stringent than necessary. The Department completed several such reviews for different air pollution control districts in 1976 and began submitting revisions to its State Implementation Plan to EPA to approve relaxations of the sulfur-in-fuel limitations. Generally, the sulfur content limits have been relaxed from the equivalent of about 1 percent to about 2.2 percent. The different air pollution control districts and sources involved have been covered in a series of implementation plan proposals and EPA approvals from 1976 through 1986. We concluded, based on our review, that EPA approved the revisions only where its evaluations indicated that no violations of the air quality standards would occur.

Objectives, Scope, and Methodology

Because of congressional concern over the impact of sulfur dioxide emissions and whether these emissions should be controlled, the Chairman, Subcommittee on Oversight and Investigations, House Committee on Energy and Commerce, asked us to assist the Subcommittee in its examination of EPA efforts (1) to control sulfur dioxide emissions and (2) to develop two models for estimating the movement, transformation, and effect of sulfur dioxide and other airborne pollutants. As agreed with the Chairman's office, we determined for each model the purpose, costs, current status, planned completion dates, and the expected performance when completed. Further, we obtained updated information on sulfur dioxide state implementation plan revisions through 1986 and determined the number of revisions and the increase in sulfur dioxide emissions allowed by these revisions.

Our work was performed primarily at EPA's Atmospheric Sciences Research Laboratory and Contract Management Division in Research Triangle Park, North Carolina, and the Office of Air Quality Planning and Standards in Durham, North Carolina. We also visited the Grants Administration and Analysis Branch at EPA Headquarters in Washington, D.C. In addition, we interviewed the Project Manager for the Regional Acid Deposition Model from the National Center for Atmospheric Research in Boulder, Colorado.

To determine the status and cost of the two models, we interviewed officials and reviewed EPA records to determine the cost and progress of the models' development as well as memorandums explaining the causes of cost increases and delays in completing the models. We discussed with these officials the accuracy and reliability of the models and the implications of EPA using them to support its regulatory decisions. Also, we attended a peer review conference on the Regional Acid Deposition Model to obtain the comments of the independent panel of modeling experts relative to the accuracy and reliability of the model.

In answering the questions on revisions to state implementation plans, we interviewed officials of EPA's Office of Air Quality Planning and Standards to determine EPA's current policy and practices for reviewing and approving sulfur dioxide state implementation plan revisions. We obtained a list of revisions since our prior report, which identified the state, the facility, data on the old and new emission levels, and comments relative to the reasons for the increased emissions. Further, we reviewed EPA documentation supporting its decision to approve the sulfur dioxide state implementation plan revisions.

Appendix III
Objectives, Scope, and Methodology

Our audit work was conducted between May 1986 and September 1987. We discussed the issues in this report with EPA officials and have incorporated their comments where appropriate. However, in accordance with the Chairman's request, we did not obtain formal comments from EPA on a draft of this report. Our review was performed in accordance with generally accepted government audit standards.

GAO Reports to the Subcommittee on Oversight and Investigations, House Committee on Energy and Commerce, for Its Examination of Actions Controlling Emissions of Sulfur Dioxide

1. EPA-Approved Revisions To State Implementation Plans Allowing Increased Sulfur Dioxide Emissions Were Legal

GAO/RCED-85-129, Aug. 16, 1985.

2. GAO letters to the Honorable John D. Dingell, discussing EPA's use of section 115 of the Clean Air Act to address transboundary air pollution affecting the United States and Canada

B-219567, Sept. 3, 1985, and Nov. 6, 1985.

3. Acid Rain: Federal Research Into Effects on Waters and Forests

GAO/RCED-86-7, Dec. 17, 1985.

4. Air Pollution: Improvements Needed in Developing and Managing EPA's Air Quality Models

GAO/RCED-86-94, Apr. 22, 1986.

5. Air Pollution: Sulfur Dioxide Emissions From Nonferrous Smelters Have Been Reduced

GAO/RCED-86-91, Apr. 29, 1986.

6. GAO letter to the Honorable John D. Dingell, discussing EPA's July 18, 1986, response on sulfur dioxide emissions from nonferrous smelters

B-208593, Oct. 9, 1986.

7. Acid Rain: Delays and Management Changes in the Federal Research Program

GAO/RCED-87-89, Apr. 29, 1987.

Major Contributors to This Report

Resources,
Community, and
Economic
Development Division,
Washington, D.C.

Hugh J. Wessinger, Senior Associate Director, 275-5489
William F. McGee, Group Director-In-Charge
Clarence E. Seigler, Evaluator-In-Charge
Tajuana Leach, Secretary

Norfolk Regional
Office

Ernest W. Taylor, Assistant Regional Manager
for Planning and Reporting
Paul A. Latta, Regional Management Representative
Joseph L. Turlington, Regional Assignment Manager
Jeanette Hamlin, Evaluator
James B. Hayward, Evaluator
Rosalyn J. Brinkley, Typist