A Modeling and Analytical Work Plan For Assessment of the National Ambient Air Quality Standards for Ozone in the Ozone Transport Region

DRAFT

The Modeling Committee of the Ozone Transport Commission

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EXECUTIVE SUMMARY

The Modeling Committee of the Ozone Transport Commission (OTC) has been charged with the task of developing a modeling and analysis framework that the members can utilize to address emerging issues related to ozone from both regional and local perspectives. The overall goal of this initiative is to improve the understanding of how ozone pollution forms within, and transports into the Ozone Transport Region (OTR) so that the ozone nonattainment problem plaguing the region can be addressed. The data generated by the initiative will provide the U.S. Environmental Protection Agency (EPA), universities, research institutions, and interested stakeholders with valuable information for evaluating and assessing ozone within the Northeast and Mid-Atlantic regions. Also inherent in this goal is to develop the ability of member States to exercise the photochemical modeling system in-house in support of their State Implementation Plan (SIP) process. It is the intent of the initiative to develop a modeling framework that provides a common basis for examining other air management issues with regional and local signatures similar to ozone, such as regional haze and fine particles (smaller than 2.5 microns in diameter).

The scope of the project initially involves photochemical modeling over large portions of the eastern United States with a major focus on high-resolution modeling of the OTR. The study will be based on a multi-event (40^+ day) episode in 1997 within the Eastern Unified Modeling Domain, a domain similar in size and dimension to the one used by the Ozone Transport Assessment Group (OTAG). Once the framework is in place, this initiative will provide a means by which OTC States can objectively evaluate the effectiveness of candidate air pollution control measures.

The modeling initiative will also incorporate a comprehensive data analysis component to assess current air quality conditions and air pollution dynamics within the Northeast and Mid-Atlantic regions. The aim of the ambient air quality assessments is to understand the formation patterns of ozone and its precursors on a regional and urban-area basis, and formulate to the extent possible, techniques to elucidate the response to ozone mitigation measures.

The following table provides several of the major tasks involved in the study and their anticipated, approximate completion dates. Reports summarizing and analyzing the modeling results and SIPs will still need to be prepared beyond the completion date of the modeling.

Major Tasks	Target Date
Draft Modeling Protocol	June 2001
Emissions Inventory for 1996-97	July 2001
Design and Testing of Modeling Platform	December 2001
Model Assessment for the 40^+ days	August 2002
Sensitivity Simulations	November 2002
Future Year Emissions Inventory	December 2002
Control Strategy Modeling	April 2003

As part of this effort, the Committee proposes to establish a data library and clearinghouse for easy access and distribution of the work plan products to interested parties. The Committee also plans to hold periodic public meetings to share findings and results.

While this state-of-the art modeling initiative is expected to provide the best understanding of the Northeast and Mid-Atlantic airsheds available to date, the scope and the aggressive timeline of the project requires a major commitment from each of the OTR States. An on-going commitment is needed from the States involved to provide the resources for emission inventories, data quality review, photochemical modeling, and analyses of results.

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List of Websites

Ozone Transport Commission – http:/www.sso.org/otc
Mid-Atlantic Regional Air Management Association – http:/www.marama.org
Northeast States for Coordinated Air Use Management – http:/www.nescaum.org
Central States Air Resource Agencies – http:/www.censara.org
Lake Michigan Air Directors Consortium – http:/www.ladco.org
Southeastern States Air Resource Managers (SESARM) – http:/www.metro4.org
U.S. Environmental Protection Agency Office of Air and Radiation – http:/www.epa.gov/oar

List of Acronyms

BC	Boundary Condition
BEA	Bureau of Economic Affairs
BEIS	Biogenic Emissions Inventory System
CALGRID	California Grid Model
CAMx	Comprehensive Air quality Model with extensions
CENSARA	Central States Air Resource Agencies
CIT	California Institute of Technology model
CMAQ	Community Multi-Scale Air Quality--an air quality modeling system
CMSA	Consolidated Metropolitan Statistical Area
CPU	Central Processing Unit
DV	Design Value
DVC	Current monitored design values
EGAS	Economic Growth Analysis System
EMS95	Emissions Modeling System 95
EPA	Environmental Protection Agency
H2O2	Hydrogen peroxide, an oxidant that drives side air pollution reactions
IC	Initial condition
IPP	Inventory Preparation Plans
LADCO	Lake Michigan Air Directors Consortium
LLJ	Low Level Jets
LCC	Lambert Conformal Conic
MARAMA	Mid-Atlantic Regional Air Management Association
mb	Millibar
MM5	Mesoscale Model (Fifth Generation)
MODELS3	An air quality modeling system being developed by the EPA
MSA	Metropolitan Statistical Area
NAAQS	National Ambient Air Quality Standard
NCAR/PSU	National Center for Atmospheric Research/Pennsylvania State University
NESCAUM	Northeast States for Coordinated Air Use Management
NOx	Nitrogen oxides (nitric oxide (NO) and nitrogen dioxide (NO_2))
NOy	Sum of all nitrogen compounds that are products of atmospheric oxidation
NOz	NOy - NOx, where NOx = NO + NO2
O3	Ozone
OAQPS	Office of Air Quality Planning and Standards
OTAG	Ozone Transport Assessment Group
OTC	Ozone Transport Commission
OTR	Ozone Transport Region
PBL	Planetary Boundary Layer
PiG	Plume-in-grid
ppb	Parts per billion
ppm	Parts per million
QA/QC	Quality assurance/quality control
RAMS	Regional Atmospheric Meteorological System
ROM	Regional Oxidant Model
RRF	Relative reduction factor
SESARM	Southeastern States Air Resource Managers
SIP	State Implementation Plan
SMOKE	Sparse Matrix Operator Kernel Emission
UAM	Urban Airshed Model
UAM-V	Urban Airshed Model Variable grid
URM	Urban Regional Model
VOC	Volatile Organic Compounds

1. Goals and Objectives of the Program

The overall goal of the Ozone Transport Commission's (OTC's) modeling and air quality data analysis program is to improve our understanding not only of how ozone pollution is formed in and transported into the Ozone Transport Region (OTR), but also of the nonattainment problem that continues to plague the region. Ultimately the scope of the modeling initiative is to develop the modeling expertise, structure, and databases to enable the modeling of other regional pollutants, such as fine particles (less than 2.5 microns) and regional haze. The scope of the current project will involve photochemical modeling of large portions of the eastern United States, with a major focus of the effort devoted to high resolution modeling of the OTR. In addition to modeling, the program will also include a review and analysis of air quality, meteorological and emissions data in the OTR. The program should provide each State in the OTR a more complete picture of the nature and cause of ground-level ozone pollution from a regional perspective.

On a practical level, the program has two major objectives. The program will assess air quality in the OTR and evaluate the effectiveness of air quality control strategies to mitigate ozone pollution. The program will provide a means by which OTC members can objectively evaluate candidate air quality control measures and determine if a suite of measures will result in attainment of the National Ambient Air Quality Standard (NAAQS) for ozone. The program will also develop the databases and other inputs that individual States will need to perform local air quality assessments for ozone. The results from the program will be used to further understanding for future ozone NAAQS. The results of the modeling and analytical efforts will also provide the U.S. Environmental Protection Agency (EPA), universities, research institutions and interested stakeholders with valuable tools to evaluate and assess ozone attainment in the Northeast and Mid-Atlantic regions.

2. Participants and Program Organization

2.1. Participants

2.1.1. State Participation

The member jurisdictions of the Ozone Transport Commission are: Connecticut, Delaware, the District of Columbia, Maine, Maryland, Massachusetts, New Hampshire, New Jersey, New York, Pennsylvania, Rhode Island, Vermont, and Virginia. The OTC Modeling Committee, comprised of designated representatives from each of these jurisdictions, will plan, organize, lead and manage the modeling and data analysis program. To a great extent, OTC members will perform the substantive work of the program by committing, to the extent possible, in-house resources to complete the effort. Private contractors and/or universities will likely perform some elements of the program.

2.1.2. EPA Participation

EPA is a non-voting member of OTC and representatives from Regions I-III and OAQPS participate on the OTC Modeling Committee. The Committee will request that the EPA play an active role in the technical program by reviewing and commenting on the work plan and products that will be subsequently developed.

2.1.3. Multi-State Organization Participation

The Mid-Atlantic Regional Air Management Association (MARAMA) and the Northeast States for Coordinated Air Use Management (NESCAUM), and associated regional technical centers, will play an important role in the technical program. They will perform technical analyses and provide workshops and training on modeling, data analysis and other pertinent topics. MARAMA is currently sponsoring the important task of developing consistent and quality assured emission inventories for the States within the OTR. Other activities may include a peer review of the MM5 meteorological modeling data developed by the University of Maryland. NESCAUM may perform air quality trends analysis or other technical tasks associated with the analytical program. In addition to these activities, NESCAUM and MARAMA will provide contractor support for tasks that cannot be performed by State staff due to time and other limitations. Information on NESCAUM's and MARAMA's activities is available at their respective web sites (www.nescaum.org and www.marama.org).

The OTC Modeling Committee will coordinate its ozone modeling and analysis program with other regional organizations. The Committee will work closely with:

- The Lake Michigan Air Directors Consortium (LADCO),
- Southeastern States Air Resource Managers (SESARM),
- Central States Air Resource Agencies (CENSARA),
- Other regional organizations and modeling groups.

The purpose of this collaboration is to share data, expertise and experience; develop consistent data and technical approaches; and resolve the problems that often occur in the course of air quality modeling analyses. The Committee believes close coordination with other modeling groups provides a mechanism for exchanging information and

databases. It is also suggested that many of the participants would significantly benefit from reduced costs associated with these technical efforts. Furthermore, coordination should also improve the quality and consistency of regional modeling programs.

2.1.4. Public and Stakeholder Participation

The Modeling Committee will encourage stakeholder input and comment on the analytical program. The Committee also will encourage stakeholders to provide revisions and/or corrections to data or databases that might be useful in the modeling effort. Information will be available at OTC's web site (www.sso.org/otc) as well as MARAMA's (www.marama.org) and NESCAUM's (www.nescaum.org). The Committee will not seek stakeholders to fund or perform technical elements of the modeling program.

2.2. Organization

2.2.1. Meetings

The OTC Modeling Committee will have one or more public meetings a year to describe the status of regional modeling work, discuss technical issues or proposed activities, and solicit public or stakeholder comment. Meetings of the OTC Modeling Committee will be announced on the OTC web site (www.sso.org/otc). The Committee may arrange additional public meetings on an as-needed basis to solicit comments on its analytical program or to present modeling results.

2.2.2. Roles and Responsibilities of the Participants

The OTC Modeling Committee will plan, organize and lead the regional ozone modeling and analysis program. The Committee is expected to engage in a wide range of activities that will include:

- Facilitating the work of participants including the work of States, regional technical centers and contractors,
- Identifying funding and resource needs,
- Recommending funding and resource solutions,
- Investigating and resolving technical problems and issues,
- Monitoring and reporting on the progress of work,
- Reviewing the work of participants and providing comment/feedback, and
- Presenting modeling and analytical findings and results.

Each jurisdiction in the OTC that has volunteered to actively participate in this effort will be responsible for the timely completion of its part of the analytical program. Final results of the technical program will be reviewed and approved by the full Commission.

2.2.3. Decision Making

The Modeling Committee will arrive at decisions relevant to executing the work plan and recommendations to the Commission through a deliberative process that places a high priority on consensus building. As in past Committee work, all Committee members will be encouraged to provide their views and comments on any issue before the Committee.

After carefully examining an issue, the Committee will attempt to adopt a consensus position that accommodates the views of its membership. Each of the States and the District of Columbia will have equal standing on the Committee.

2.2.4. Resolving Disputes

While disputes are not expected in the development and completion of this program, the full Commission will resolve matters that cannot be resolved within the Modeling Committee.

2.2.5. Revisions to the Work Plan or Work Schedule

The Modeling Committee may revise this work plan, work schedule or any other Committee document to accommodate changes in Committee needs or priorities or to respond to technical, scientific or regulatory changes. Information regarding changes to the work plan or schedule will be presented at public meetings or posted on the web site.

3. Planning the Modeling and Analytical Program

Pursuant to the direction of the OTC, this work plan has been developed through a collaborative effort of the members of the Modeling Committee. The initial draft work plan was tabled in 1999, and due to a variety of reasons, delays have occurred. This necessitated an update to that draft. The intent of this work plan is to provide the members of the OTC with the necessary analytical tools to address the one-hour and eight-hour ozone NAAQS issues in the region.

3.1. The Modeling and Analytical Work Plan

This work plan describes the analytical program adopted to address the regional ozone problem. The plan describes the work that participating States will accomplish. The work plan presents a "conceptual description" of the ozone problem in the Northeast and Mid-Atlantic regions, describes proposed photochemical modeling activities, provides insights into the types of air quality trends analyses that may be performed for the OTR, and summarizes the "weight of evidence" methodology that members may choose to follow in demonstrating ozone attainment. Following the work plan, a modeling protocol will be prepared.

3.2. The Program Work Schedule and Commitments

Table 3-1 summarizes the major activities of the technical program, gives an estimated completion date and lists the State, regional organization or contractor who will perform that activity.

Table 3-1 Modeling and Air Quality Data Analysis Tasks

Task No.	Activity or Task	Date	Organization(s) Performing Task
	Initial Planning Tasks		
1	Develop a modeling/air quality data analysis work plan and schedule for addressing ozone nonattainment in the OTR.	Oct 99/ Rev May 01	States and OTC staff.
2	Develop a "conceptual description" of the attainment problem.	Apr 01	States and OTC staff.
3	Coordinate State Inventory Preparation Plans (IPPs) and develop a protocol for modeling emission inventories.	On-going	States and MARAMA. PA lead.
4	Prepare a draft modeling protocol.	Jun 01	States and OTC staff. NY lead.
	Emissions Tasks		
5	Compile base year (1996/97) inventory inside the OTR.	Jul 01	States and MARAMA. PA lead.
6	Compile base year (1996) inventory outside the OTR.	Jul 01	EPA, ad hoc groups and MARAMA.
7	Compile land use and gridded surrogate data.	Dec 99	Contractor for NY. NY lead.
8	Quality assure 1996/97 base year inventory.	Jul 01	States, EPA, MARAMA, contractor.
9	Process the 1996 base year emissions for modeling inventory for 1997.	Aug 01	States, EPA, MARAMA, contractor
10	Process emission inventory data for the model year-- prepare emission inputs for the photochemical models. (EMS95 and/or SMOKE processing.)	Dec 01	States, EPA, MARAMA, contractor.
11	Develop future year emission inventories with control options and prepare emission inputs for photochemical models. (EMS95 and/or SMOKE processing)	Jun 02	States, MARAMA, contractor.
	Meteorology		
12	Complete MM5 modeling work.	Dec 00	Univ. of Maryland. NY and MD lead.
13	Evaluate MM5 data.	Aug 01	NY, CT, NH lead.
14	Process for photochemical model(s).	Dec 01	NY, NH, CT, lead.
	Modeling		
15	Set up photochemical model per protocol.	Dec 01	NH, NY, VA and other States.
16	Create and maintain a data library and information clearinghouse.	Mar 02	States, EPA, MARAMA, contractor.
17	Complete photochemical model testing and evaluation.	Jun 02	NH, NY, VA and other States.
18	Prepare test and evaluation report.	Aug 02	States, OTC staff and MARAMA.
19	Test model sensitivity to NOx and VOC reductions.	Oct 02	NH, NY, VA and other States.
20	Test model sensitivity to control measure options.	Dec 02	NH, NY, VA and other States.
21	Complete modeling of control measure options.	Apr 03	NH, NY, VA and other States.
22	Complete modeling report summarizing findings.	Jun 03	States, OTC staff, and/or MARAMA.
	Air Quality Analysis		
23	Develop consensus on techniques to analyze and evaluate air quality data and trends in OTR	Jun 02	States, EPA, OTC, MARAMA, NESCAUM.
24	Complete air quality and emission trends analysis in the OTR.	Dec 02	NESCAUM, MARAMA, States, contractor.
25	Complete receptor model analysis with air quality data.	Dec 02	NESCAUM, MARAMA, States, contractor.
	Placeholders for SIP Planning		
26	Develop draft plans for any State commitments to local and regional controls.	Sep 03	States and the OTC.
27	Implementation of any State commitments through rules and regulations.	Mar 04+	States.
	Reports		
28	Complete technical support documents presenting the regional modeling and air quality analysis. (These documents will provide technical support for a States' ozone SIP revision.)	Dec 03	States, OTC staff, NESCAUM and MARAMA.
	Training, Outreach, Management		
29	Provide training and technical seminars.	On-going	MARAMA, NESCAUM, States, contractor.
30	Solicit stakeholder input and report on progress on the modeling and analytical effort.	On-going	OTC Modeling Committee.
31	Day-to-day management and coordination.	On-going	OTC Modeling Committee.

4. Technical Elements of the Modeling and Analytical Program

The technical elements required of any modeling work plan include a conceptual plan describing the problem, and approach adopted to meet set goal(s). The approach identifies the salient elements of the work plan designed to meet the goals set forth in the conceptual plan. In this work plan we attempted to identify the goal as developing a framework for the application of photochemical grid model(s) to the OTR by taking into consideration the prior technical work performed as part of OTAG and building over that to address ozone non-attainment issues from both regional and urban-level. The other aspect of the goal is to provide the OTC members a technical tool that can be adapted to meet their needs in the development of their State-level actions such as SIPs. The work plan also has an analytical component that examines the ambient air quality in terms of trends and develops methods to corroborate the changes in air quality to the changes predicted by the photochemical models.

4.1. A "Conceptual Description" of the Ozone Nonattainment Problem

The purpose of the conceptual description is to understand and characterize the nature of the ozone non-attainment problem within the Ozone Transport Region (OTR). In addition, the conceptual description should aid in determining what can be done in order to bring the OTR into compliance with the ozone National Ambient Air Quality Standard (NAAQS).

4.1.1. Identification of Key Components that Describe Nature of Nonattainment Problem

The key components that describe the nature of the ozone non-attainment problem involve: 1) chemistry, 2) meteorology (includes transport and local topography), and 3) emissions sources. Ground level ozone is a seasonal problem, occurring in varying degrees of intensity during the months of May – September. Meteorology is a *stochastic* variable which can't be controlled, and therefore, needs to be fully understood to better conceptualize the ozone non-attainment problem.

CHEMISTRY

The photochemical formation of surface ozone is a very complex, non-linear and sometimes chaotic process. Briefly, the main ingredients needed are ultraviolet radiation (sunlight), nitrogen oxides (NOx), and reactive hydrocarbons (i.e., volatile organic compounds (VOCs)). In general, ozone forms when the NOx reacts with strong sunlight in the presence of VOCs.

METEOROLOGY

Ozone episodes in the Mid-Atlantic and Northeast are highly influenced by meteorology. Not only are synoptic scale features, such as high and low pressure systems, important, but other local, smaller scale weather features play a role. Smaller scale features can include planetary boundary layer (PBL) processes (the height of temperature inversions), land-sea breezes (bay breezes), and mountain/valley interactions (low level jets). All of the weather factors listed can affect ozone levels in certain areas of the OTR. An important seasonal weather feature, which effects ozone production over much of the OTR during the summer time, is the "Bermuda High" (also known as the Western Atlantic Ridge). When the Bermuda High migrates west to over the continent,

light winds, clear skies and stable conditions can cause elevated ozone levels within the OTR.

Ozone episodes within the OTR are also influenced by ozone transported into and within the OTR from the west or southwest. Based on numerous aircraft measurements taken in the early morning hours over rural areas it has been shown that typically ozone is transported into the OTR on upper level winds from the west and southwest at levels of about 2000-4000 meters. These measurements indicate high concentrations of ozone and ozone precursors upwind of the OTR. As the PBL breaks down, ozone (and ozone precursors) mixes down to the ground, which often results in increased ground level ozone concentrations. This downward mixing can be clearly seen at Mt. Washington, NH, where ozone monitors are located at the summit (6288 feet) and at the base of the mountain. At ground level, ozone can now be transported by local surface winds and other low level winds (i.e. low level jets). The air quality model used must accurately reflect the effect of transported ozone on the OTR.

The unique topography of the Mid-Atlantic and the Northeast regions may lend itself to certain types of transport phenomena. The Appalachian Mountains to the west, and the Atlantic Ocean to the east, create an environment where a low level jet (LLJ) can form. The LLJ likely is a nocturnal phenomenon and occurs on a scale that challenges current operational numerical weather models. It is theorized that this LLJ might carry ozone precursors and ozone northward from the south. In addition, long-range transport from outside the OTR into the OTR, and regional transport within the OTR must be examined.

It should be noted that not all clouds are the same and, thus, two days that are both overcast may be very different in regard to ultraviolet flux and will likely have different ozone values. Further, the non-linear connection between clouds, surface temperature and vertical mixing of the boundary layer is a challenging concept to articulate in a conceptual description.

EMISSIONS

Accurately assaying local, and regional, NOx and VOC emissions sources is vital in describing the ozone non-attainment problem. NOx and VOC emissions come from both human and natural activities. NOx is primarily a result of combustion (i.e., electric generating units, industrial boilers, motor vehicles), with natural sources only accounting for 3 percent of the regional load. Thus NOx emissions are generally highest in urban areas. VOCs are a result of motor vehicle exhaust emissions, evaporation of gasoline, and other petroleum products. In addition, natural VOC emissions are also very high. Thus VOC emissions are from both urban and rural areas. Controlling the emissions of VOCs and NOx from both local and regional emissions sources must be better evaluated.

It should be noted that ground level ozone production is sufficiently complicated that any conceptual description will labor to fully describe some of the subtle features of the process. For instance, because NOx is a precursor to ozone, a reduction in NOx emissions will often lead to lower ozone values. However, in those instances when NOx levels are very high (such as in an interior urban area) reducing local NOx emissions may actually lead to increases in local ozone levels due to scavenging. Further NOx reductions will typically reverse this phenomenon and result in reducing ozone concentrations, particularly downwind.

4.1.2. Analyses that Would Develop or Refine the Conceptual Description

Now that the key components of the conceptual description have been identified, there are various types of analyses that can be completed. A list of these analyses follows:

- A literature search to identify previous ozone analyses that were done to gain insight into better methods of analysis.
- Develop a map of NOx and VOC sources.
- Develop a map of other trace gases and aerosols.
- Conduct an ozone trends data analysis by filtering out certain meteorological factors.
- Run the appropriate trajectory model to develop a climatology of "back trajectories" during high ozone episodes to determine where transported ozone precursors and ozone may be coming from.
- Review available data and reports that pertain to the modeled 1997 ozone episode cases.
- Evaluate the model's performance spatially, and temporally, by comparing the modeling results with actual monitored ozone concentrations.
- Determine the reasons why, or why not, the modeling results were, or were not verified, by the actual ozone data (make sure we are not getting the right answer for the wrong reason).
- Study the role clouds play in photochemistry
- Improve emission inventories

These types of analyses may be useful identifying potential stakeholders and formulating a modeling analysis protocol.

References

Sonoma Technology, Inc., 1997: Transported and Mixing Phenomena Related to Ozone Exceedances in the Northeast U.S., Working Draft No. 1.1, Prepared by Sonoma Technology, Inc. and Earth Tech, February 1997.

Maryland Department of the Environment: The Conceptual Model; An Overview of Ozone.

Sonoma Technology, Inc., 1999: Phase II Attainment Plan for the Baltimore Region and Cecil County, April 1998.

Sonoma Technology, Inc., 1999: Characteristics of Volatile Organic Compounds in the Mid-Atlantic Region, Final Report.

MARAMA, 1997: 1995 Ozone Atlas for the Mid-Atlantic Region, Mid-Atlantic Regional Air Management Association, June 20, 1997.

4.2. Modeling System

The modeling system envisioned in this work plan comprises of the three basic components of any photochemical modeling exercise – emissions modeling, meteorological modeling, and air quality modeling. In the following sections, an overall approach is provided for the modeling and analytical work contemplated in the OTR.

4.2.1. Domain and Grid Selection

The 1990 Clean Air Act Amendments recognized the regional nature and extent of the ozone problem in the Northeast and Mid-Atlantic regions. In response to the problem, the Act set up the Ozone Transport Region (OTR), an area that extends from Northern Virginia to Maine, with its western boundary extending to the Ohio/Pennsylvania border. In 1994, several States of the OTR developed and submitted State Implementation Plans (SIPs) to improve air quality and attain one-hour standard for ozone. The SIPs addressed non-attainment areas located in Consolidated Metropolitan Statistical Areas (CMSAs) or Metropolitan Statistical Areas (MSAs) in the OTR. The photochemical modeling used to assess air quality for the SIPs demonstrated the regional transport of ozone and ozone precursors and highlighted the need for its reduction. In response to this and problems similar to this in other parts of the country, the EPA in conjunction with the Environmental Commissioners Organization (ECO) of the National Governor's Association (NGA) and 37 States formed the Ozone Transport Assessment Group (OTAG). As part of this effort, the areal extent of the photochemical modeling extended from central Kansas to the Atlantic Coast and from the Gulf of Mexico to portions of the Canadian provinces of Ontario and Quebec, and commonly referred to as the OTAG domain. In addition to the States and EPA, the OTAG participants included several stakeholder organizations, and in a process based on consensus developed recommendations that lead the EPA to propose the NOx SIP call for 22 of the 37 States.

In this work plan, a modeling approach is envisioned that is similar to what was applied in the OTAG process, but with improved meteorology and emissions data, as well as model improvements addressing advection and source attribution schemes of photochemical grid models for estimating ground-level ozone. The selection of a domain extending well beyond the OTR accounts for interactions between regional and urban-scale processes. This differs from the earlier approach used by the States in the SIPs which was urban scale modeling with boundary conditions obtained from regional model simulations to capture regional transport effects.

Given the need to adequately represent regional/urban interactions, and the requirements for modeling of urban areas, the domain should be fairly large but not so large as would require that it could pose computational difficulties in terms of data collection and processing. One of the important inputs is the meteorological database and current indications are that it may be a limiting factor in the selection of the areal extent of the domain. It should be noted that the meteorological models themselves are also grid-based and have limitations in terms of computational times as we move towards higher resolution of less than about 12 km.

4.2.1.1. Urban vs. Regional Modeling Considerations

As noted before, it is essential that ozone modeling in the OTR take place over a large geographical domain that adequately captures transport within the OTR and regional

transport from outside the OTR. Modeling conducted during OTAG and modeling in support of EPA's NOx SIP call supports this view. The OTC Modeling Committee previously suggested adoption of the OTAG domain. The coordinate system used in OTAG work was dictated by the design of the photochemical grid model UAM-V, requiring transformation of RAMS meteorological data from its native polar stereographic coordinate system. However, this process required translation and transformation of the meteorological fields, and it is inevitable that such steps may affect the integrity of some of the meteorological fields.

One approach considered in this study is the use of meteorological fields in their native mode to drive the photochemical grid model. A viable meteorological model for this purpose is MM5 with its Lambert Conformal Conic (LCC) coordinate system. The MM5 is a community model in the public domain, and is currently used in EPA's MODELS3 framework. A draft regional domain in the LCC coordinate system was proposed. Briefly, the center of the domain was set at (90° W, 40° N) with parallels at 30° N and 60° N, with a 36/12km grid system closely matching to that of the OTAG domain. The exact extent and grid definition, as proposed, were discussed, and based on the need for coordination and cooperation with other States and entities undertaking photochemical modeling work, the need for a unified regional domain became one of the prime requirements. On further examination, the OTC Modeling Committee proposed a regional domain projected with a center point projection of (90° W, 40° N), extending westward to about the eastern border of Kansas, and eastward over the State of Maine. This domain is displayed in Figure 4-1.

4.2.1.2. Horizontal Grid Selection

The areal extent of the regional domain displayed in Figure 4-1 can be expressed in several configurations depending upon the selected horizontal grid spacing. The domain at a horizontal grid spacing of 12 km corresponds to 234 by 201 grid cells. Depending upon the need and the computer resource limitations the grid spacing could be appropriately selected for a nested-grid system. For instance a nested domain can be chosen at 36 km and 12 km grid spacing for a region within the regional modeling domain. However any such selection of a grid design is dependent upon the availability of the meteorological data. The MM5 modeling domain is shown in Figure 4-2. The MM5 modeling domain utilizes a 2-way nesting grid at 36 and 12 km spacing, with the 36 km grid significantly larger than the domain displayed in Figure 4-1, while the 12 km defined under the MM5 system is smaller. Depending upon the need, either a 36/12 km grid or a 12 km photochemical modeling domain can be developed. The Committee recommends the use of a 12 km domain for photochemical modeling. Smaller, 4 km "nested" grids, covering areas of particular interest, will be modeled within the larger domain to assess ozone attainment within the OTR.

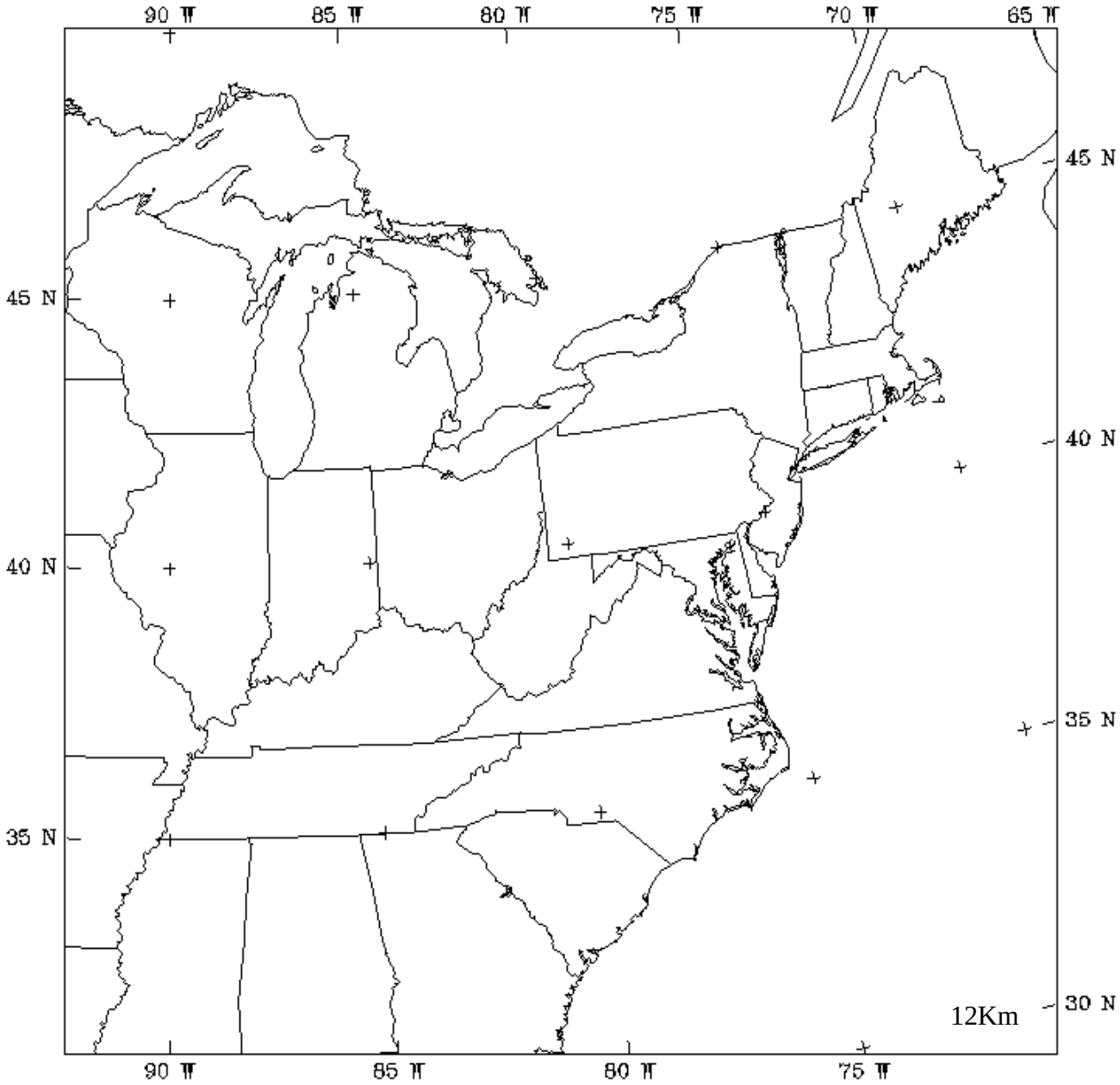

Figure 4-1 - The Regional Modeling Domain
(90° W, 40° N Projection)

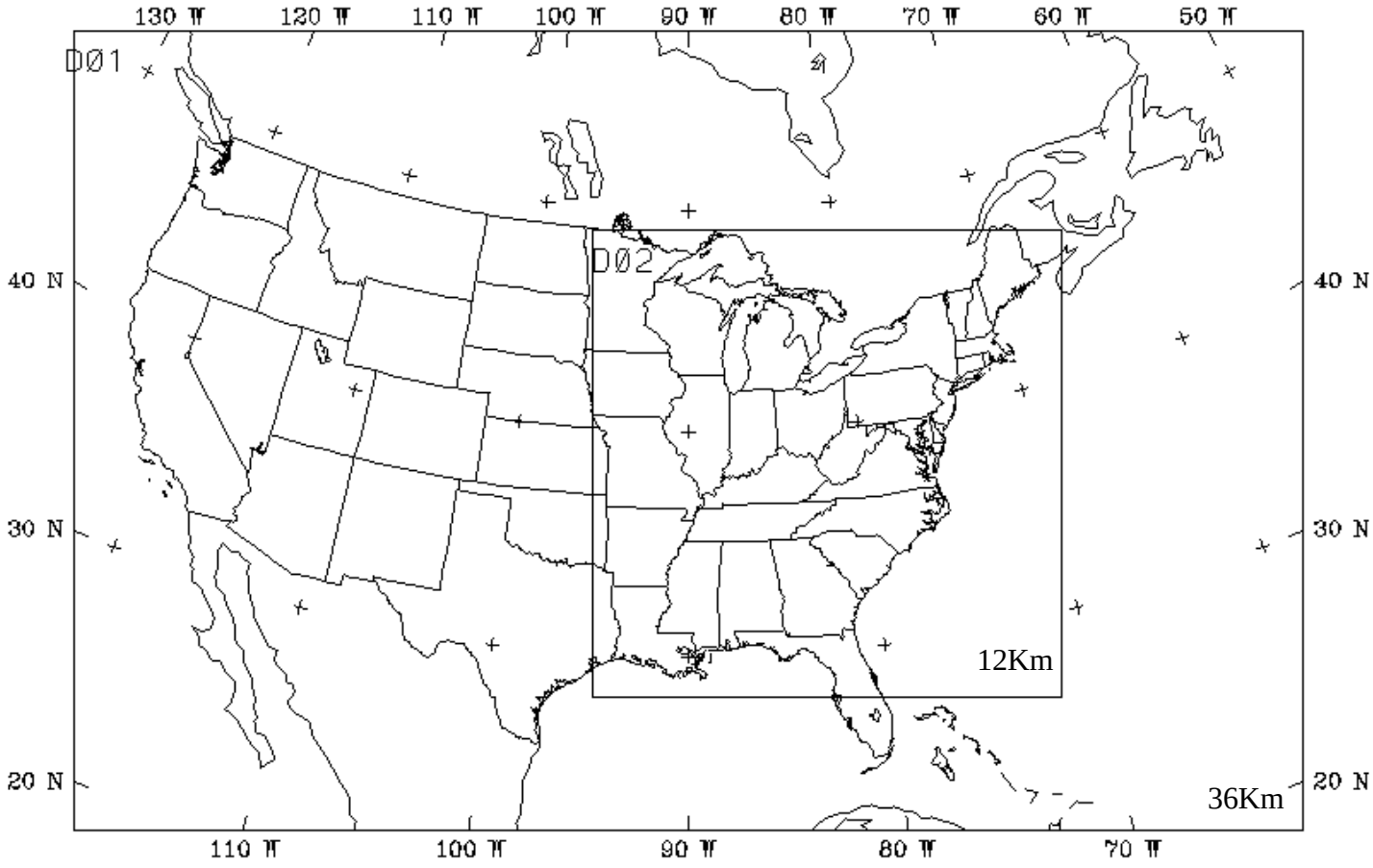

Figure 4-2 - The MM5 Modeling Domain
(90° W, 40° N Projection)

4.2.1.3. Vertical Grid Selection

As noted above, one reason for using the LCC system for the modeling domain is the need to use the meteorological data in its native mode. The vertical grid structure would essentially follow that of the MM5, with a one-to-one transfer of the meteorological variables to drive the photochemical grid model. An example of the vertical structure that could be used is displayed in Figure 4-3, although the specifics are to be worked out by undertaking a series of test simulations. Even though the MM5 model vertical structure extends up to 18 km, a limitation is made in the transfer scheme to limit to about 4 to 6 km, with some aggregation of the levels above 1500 to 2000 m primarily aimed at conserving computational resources.

Figure 4-3 – Possible Vertical Structure for Modeling

4.2.1.4. Nested Grid Considerations

The use of nested grid and attendant savings in computational resources is to some extent dependent upon the photochemical grid model's ability to accept a 2-way nesting approach. Currently, there are several photochemical models with nesting capability. Initial testing will be necessary to determine how to setup and define a nested grid system. The OTAG process utilized nested grids at 36/12 km grid spacing. At this writing, the Committee is considering modeling approximately the entire OTAG domain at 12 km grid spacing with a nested grid (or grids) at 4 km spacing. OTC States directly involved in photochemical modeling will test the feasibility of employing multiple 4 km nested grids embedded in the 12 km domain versus use of a large, single 4 km nested grid over the region of interest, such as high source density areas, land-sea interfaces, and other topographical features where a larger grid resolution may not be able to capture important local transport phenomenon. After feasibility tests, the Committee will recommend a preferred nesting approach.

4.2.1.5. Coordinating Domain Selection with Other Regional Modeling Programs

Coordination with other modeling efforts is an important consideration in the effort to develop a unified or common regional domain for assessing photochemical oxidants. The need for coordination is obvious with a regional domain that extends over the eastern United States as well as parts of Canada. When the areas of the Northeast corridor undertook their 1994 SIP-related ozone modeling, the urban domains were centered over the CMSA/MSAs, with extended modeling regions resulting in the overlapping of these domains (see Figure 4-4). Even though each of the areas applied the EPA regulatory model UAM-IV with 1-way nesting using the output from ROM to provide the initial and boundary conditions (IC/BCs), predicted ozone levels in areas common to more than one modeling domain tended to show differences in predicted ozone levels. It was suggested these differences were due to differences arising from the assumed meteorological fields as well other input data, and computer resources effectively limited the application of a unified domain in the region.

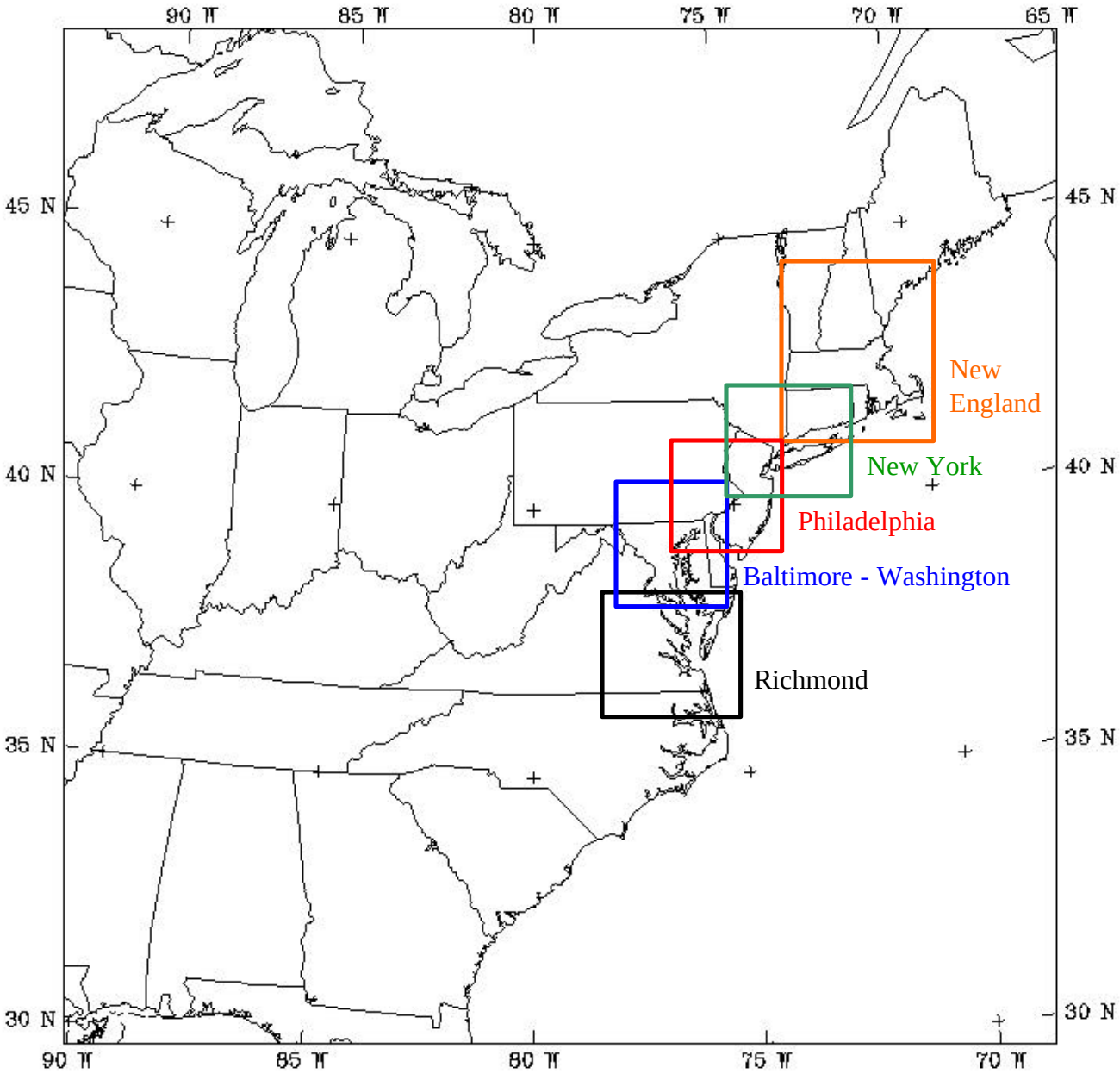

Figure 4-4 – Overlapping Domains in the Ozone Transport Region Used in 1994 SIP Modeling

However, with the experience gained from OTAG and improved computer resources, the use of a unified regional grid is an extremely important first step in addressing the ozone problem over the eastern United States. Another reason for a unified domain and coordination with other ongoing or planned photochemical modeling work, is the regional nature of ozone and its precursors and the effect of transport on downwind ozone levels. In the case of the OTR, the area has been shown to be recipient of ozone and its precursor transport from upwind regions and as such any future year scenario requires information on the upwind region and their expected or projected change in emissions. Lack of this type of information could result in hodgepodge plans for mitigating the ozone problem over the eastern United States.

4.2.1.6. Resources

The development and adoption of an appropriate regional grid with consideration for urban-level modeling requires the design and careful analysis of a series of simulations with a selected modeling domain and photochemical grid model. To date, there are at least 2 or 3 potential candidate models that would require this type of assessment and depending on the resources, costs could vary considerably. Seeking external support or outsourcing of work should be evaluated on an overall basis rather than on individual issue, since many of the tasks are interdependent.

4.2.2. Episode Selection

The OTC Modeling Committee has decided to proceed in developing a 1997 based, long-duration (over 40 days), multi-event ozone modeling episode. The Committee considered EPA guidance and recent research in its episode selection to ensure that the OTC Modeling platform will meet current and future needs of its members in the demonstration of attainment of all applicable ozone standards. Details of the episode selection process are summarized in this section.

In its May 1999 draft modeling guidance, EPA proposed selection criteria to ensure that photochemical modeling produces emission reduction strategies that will meet the eight-hour ozone NAAQS. The task of episode selection is made complicated by the various possible transport trajectories that may produce ozone exceedances. Previously, photochemical modeling focused primarily on the severe one-hour ozone peak concentrations that are the result of well-documented “classic transport patterns.” The eight-hour ozone standard is more complicated in that the severity of the top three eight-hour concentrations for a monitor in a given year is not as important. Only concentrations ranging from the level of the standard (85 ppb) up to the 4th highest annual concentration are primarily targeted for emission reduction strategies to ensure attainment. This however is not to imply that the highest 3 ozone events in a year do not need be addressed. EPA’s draft modeling guidance was prepared with the intent of assisting States select appropriate episodes to model on a State-by-State basis. The guidance allows for some flexibility in its selection criteria for a State participating in a multi-State modeling effort, such as is proposed here. Tradeoffs between criteria are to be resolved on a case-by-case basis.

Reference

EPA, 1999: Draft Guidance on the Use of Models and Other Analyses in Attainment Demonstrations for the 8-Hour Ozone NAAQS. EPA-454/R-99-004, Office of Air Quality Planning and Standards, U.S. Environmental Protection Agency, Research Triangle Park, NC.

4.2.2.1. Primary Selection Criteria

EPA's draft modeling guidance recommends that States follow the following primary selection criteria for meteorological episode selection:

- Choose frequently occurring episodes containing days reflecting a variety of wind orientations observed to occur when eight-hour daily maxima exceed 84 ppb at one or more monitors.

- Choose episodes containing days with observed eight-hour daily maximum ozone concentrations close to (e.g., ± 10 ppb) the average 4th high daily maximum observed at monitoring sites during a 3-year period straddling the period from which each episode is drawn (i.e., days approximately as severe as implied by the form of the NAAQS).

- Choose episodes containing days for which measurements aloft, measurements of indicator species and/or precursor measurements exist.

- Choose a sufficient number of days so that several days are available for use in the modeled attainment test for each monitoring site where the NAAQS is violated.

4.2.2.2. Secondary Selection Criteria

In order to resolve conflicts among the four primary selection criteria, EPA's draft modeling guidance proposes the following five secondary selection criteria:

- Give preference to previously modeled episodes.

- Give preference to episodes occurring during the period corresponding to the current design value.

- Give preference to episodes maximizing the number of days and sites observing eight-hour daily maxima close to the level of severity specified in the NAAQS.

- Include weekends among the selected days, especially if daily maxima exceeding 84 ppb are observed on such days.

- If applying a regional model, choose episodes meeting the other primary and secondary criteria in as many nonattainment areas as possible.

4.2.2.3. The Rationale for Episode Selection in the OTC Modeling Effort

To adequately treat meteorological and transport effects, OTC States have agreed to perform photochemical modeling over a domain that is similar to that of the OTAG fine grid. This modeling domain will capture most sources with the potential to affect ozone concentrations in the OTR (See Section 4.2.1). The inclusion of sources that are far distant from the OTR is not intended to imply predetermined culpability to ozone NAAQS violations within the OTR. Rather the source regions are included to accurately establish boundary conditions for modeling as well as to allow for additional transport range analyses.

Because of the size and diversity of the modeling domain, it would be impossible to meet all of the primary selection criteria in all portions of the domain. After a careful assessment of alternatives, the OTC Modeling Committee has decided to model an extended continuous episode of 30-50 days that meet the selection criteria in as much of the domain as possible. By modeling a long duration episode, transport patterns can be assessed over a range of meteorological conditions leading to concentrations in the range of the form of the standard up to severe peak concentrations. The duration also allows for emission build-up, transport, and event resolution of multiple events throughout most of the domain. At first glance, a long modeling period on the order of 50 days seems a bit excessive. On closer inspection, however, modeling an extended period has significant advantages and economies of scale.

The Modeling Committee concluded an extended modeling period was best for several reasons. First, by modeling a continuous that includes several episodes, the number of ramp-up days is minimized. Typically, 3-4 ramp-up days are needed for an individual episode. If six short duration ozone events were modeled as individual episodes, approximately 18 to 24 ramp-up days would be needed to properly model these episodes. The large number of ramp-up days required for modeling these ozone episodes is a poor use of resources. Second, major ozone episodes often involve time periods of episode development, transport, and dissipation. To capture and adequately characterize episodes over time, a large domain must be modeled with episode durations on the order of 6-12 days. In the case of modeling six shorter-duration episodes, this would result in 36-72 days of modeling, plus 15-18 days of ramp-up for a total of 51 to 90 days. Third, adding to the complexity of the meteorological and emissions data preparation is the likely possibility that the six short duration episodes would span multiple calendar years, demanding additional resources. The efficiencies gained by developing databases for a continuous period, minimizing ramp-up days, will ultimately result in significant cost and labor savings.

4.2.2.4. Consideration of Episodes

EPA recommends that episodes be drawn from the years that make up the design value (1996-1998). It is also preferred that selected episodes fall within the 3-year period straddling the most recent emission inventory year. The most recent emission inventory year is 1999. Quality assured emission data for 1999 is not currently available however. Until complete and quality assured data is available for 1999, the Committee plans to use 1996 based emission inventory data for its modeling program where 1997 based information is not available. The design value years 1996 through 1998 include the most recent complete emission inventory year 1996, and are therefore the years preferred for selecting episodes. Currently the Committee is not planning to model episodes in 1998

because the 1999 emission inventory will not be finalized for some time and because of the lack of widespread ozone events during 1998 ozone season. Episodes in the year 1995 were also evaluated for consideration due to their severity and data availability through the OTAG process.

Each of the OTC States was asked to review its eight-hour ozone monitoring records for 1995, 1996, and 1997 to determine which of the episode years best met the primary criteria as documented in the EPA draft modeling guidance. Based on the results of these studies, two modeling periods were thought to be the best options for the proposed modeling effort: June 16 – August 4, 1995 (50 days) and June 19 – August 11, 1997 (54 days).

Modeling a period in 1996 can be safely ruled out due to the lack of widespread ozone episodes that meet selection guidelines. The years 1995 and 1997 were reviewed in greater detail, each providing ample opportunity for effective regional modeling (see Table 4-1).

Table 4-1 - Comparison of Episode Years 1995 and 1997

Year	Plus (+)	Minus (-)
1995	1. Large, widespread events. 2. Intensive databases (OTAG). 3. Upper air observations.	1. Some events almost too severe for eight-hour ozone study. 2. Redundancy with OTAG. 3. Long gaps between events.
1996	1. Year of emission base.	1. Lack of events. 2. Lack of widespread events. 3. Meets needs of too few States.
1997	1. Most recent year. 2. Most O_3 monitors. 3. Short intervals between events. 4. Most events within 10% DV target.	1. Few (if any) upper air monitoring observations. 2. Some severe events.

The ozone seasons of 1995 and 1997 were assessed on a sub-OTR regional basis for ozone severity, wind speed, wind direction, presence of large-scale meteorological features (such as high and low pressure systems), at ground level and at the transport elevation of 850 millibars (mb). Figure 4-5 shows the sub-regional areas within the OTR that were used in the meteorological analysis. Breaking down the OTR into sub regions was done to simplify the task of categorizing important meteorological regimes that operate in the region. The sub-regional break out should not be interpreted to mean that sub-regional areas are independent any air quality control regions or airsheds.

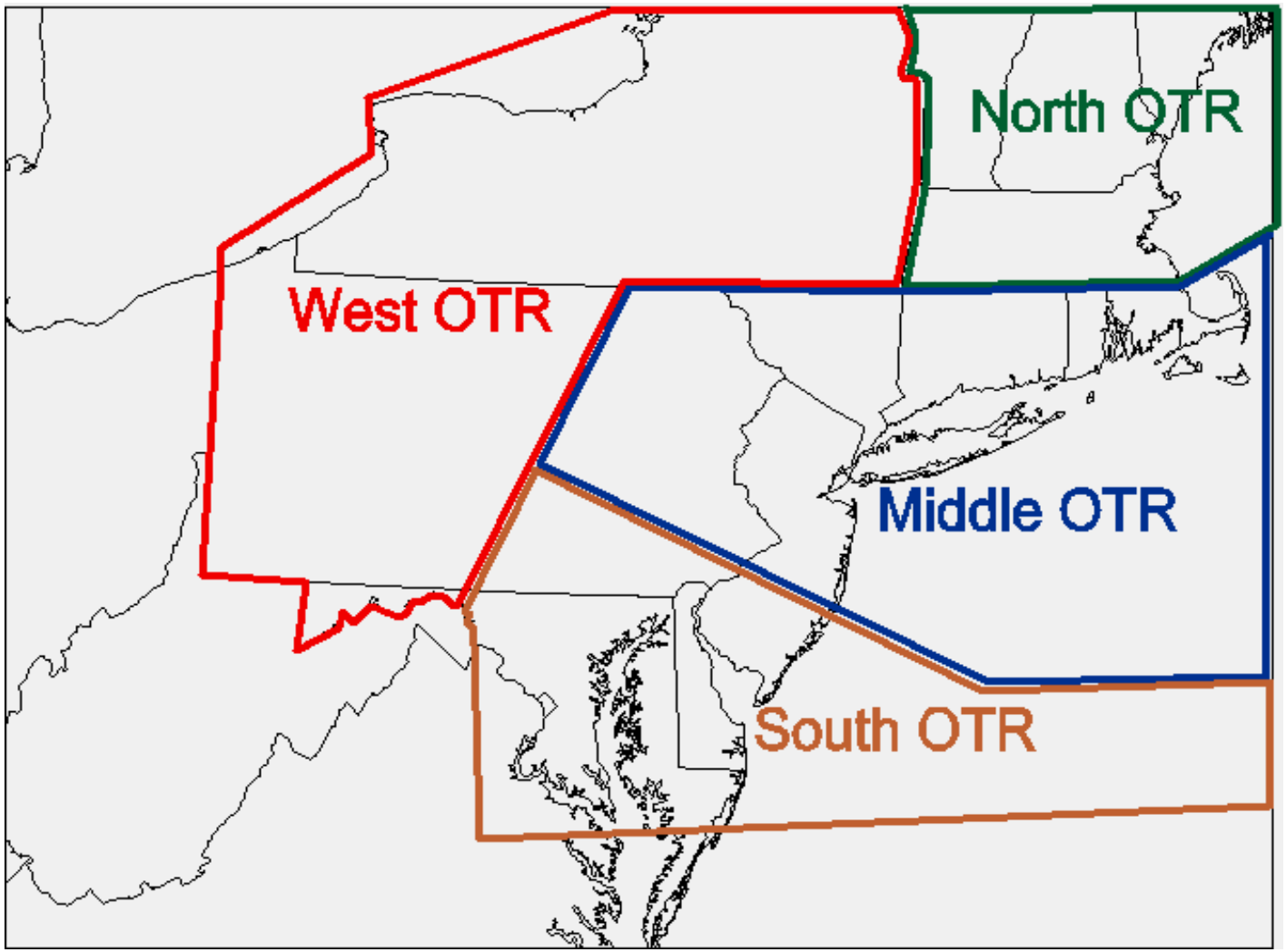

Figure 4-5 - Sub-regional Breakdown of the OTR for Meteorological Assessment

4.2.2.5. 1995 Episodes

Major 1995 ozone episodes occur over 50 days including three widespread events and several smaller (sub-regional) events. There is a 12-day gap between events in the southern OTR and an 8-day gap in the middle OTR. Table 4-2 shows1995 surface wind observations.

4.2.2.6. 1997 Episodes

1997 includes one major widespread episode lasting for up to 8 days, and 4 short-duration widespread events. The longest gap between events is 4 days for the southern OTR and 5 days for the middle OTR. Table 4-3 shows1997 surface wind observations.

4.2.2.7. Comparison of 1995 and 1997 Episodes

Tables 4-4 and 4-5 provide 1995 and 1997 surface wind observations, respectively. In most sub-regions, the most common (coded orange) surface level wind direction during ozone events is from the south and southwest or during periods of light or stagnant winds. Occasional (coded yellow) ozone events also occur with surface wind flows from a range of northwest through southwest to southeast.

In most sub-regions, the most common (coded orange) 850mb level wind direction during ozone events is from the west and southwest during 1995 (see Table 4-6) and from northwest through southwest in 1997 (see Table 4-7). Occasional (coded yellow) ozone events also occur with surface wind flows from a range of northwest through south for 1995 and from the north through southwest in 1997. It is interesting to note that in 1997 there is a small rotation to the event wind flow from high ozone events (northwest to southwest) to moderate ozone events (north to west).

Meteorology Summary for the 1995 Ozone Episodes for the Northeastern United States

Occurances of (one count per day):

Surface Level Observations	Region*	June 16	17	18	19	20	21	22	23	24	25
			High Pressure off Coast					High Pressure off Cape Cod			
	North OTR	NW	SW	W	WSW	WNW	NE	V_{LT}	SW_{LT}	V/SSW	SSW
	Mid OTR	NNW_{LT}	SW	W	WSW	NNW	NNE	SE	SE	SE_{LT}	SE_{LT}
	South OTR	SSE_{LT}	SE	V_{LT}	V_{LT}	V_{LT}	V_{LT}	SE	SE	E/NE	SE
	West OTR	V_{LT}	SW_{LT}	V_{LT}	W	NW	NE	E	ESE	SE_{LT}	SE

	Region*	June 26	27	28	29	30	July 1	2	3	4	5
					High Pressure off Cape Cod					High Pressure off Coast	
	North OTR	S	E	V	SW	SW	SW	SW	NW/W	NW_{LT}	SW
	Mid OTR	S	SSE	SE	SSE	S	SW	V_{LT}	NW	NW_{LT}	S
	South OTR	SSE	SE	SE	SE	SSE	S	V_{LT}	NNW_{LT}	SE	S
	West OTR	V_{LT}	ESE	SE	SSE	S	SW	NW	NW	V_{LT}	S

	Region*	July 6	7	8	9	10	11	12	13	14	15
	North OTR	S	SW	S	S/SW	W	SW	S	SW_{LT}	SW	W
	Mid OTR	S	SW	S	V/NW	WNW	SSW	W	SW_{LT}	WSW	W
	South OTR	S	S	SW	NW	SW	S	V	SSE_{LT}	S	W
	West OTR	S	SW	SW	NW	W	WNW	NNW	SSW_{LT}	WSW	W

	Region*	July 16	17	18	19	20	21	22	23	24	25
				Low Pressure North of Great Lakes				Low Pressure in N Virginia			
	North OTR	NNW	SE	SE	SSW	WNW	SW	WNW	S	SSW	V_{LT}
	Mid OTR	NW	SE	SE	SW	WNW	SW	SW	SE	SW	V
	South OTR	SW	SSE	SE	WNW	W_{LT}	S	SSW	SSE	W	S
	West OTR	NNW	V	W	W	W_{LT}	SW	V_{LT}	SSE	NNW	SSW_{LT}

	Region*	July 26	27	28	29	30	HP in N Pr 31	August 1	2	Low over NE 3	4
	North OTR	S	SW	V_{LT}	SSE	WSW	NW	WSW	SW	V_{LT}	S
	Mid OTR	SSW	SW	SW	SW	WSW	NNE_{LT}	SW_{LT}	SW	SW	SSW
	South OTR	S	SW	S	SSW	WSW	NNE_{LT}	SE	S	S	S
	West OTR	SSW	WNW_{LT}	V_{LT}	SW	WSW	V_{LT}	SW	WSW	V_{LT}	SW

	> 100 ppb
	90 - 100
	80 - 90
	70 - 80
	60 - 70
	50 - 60
	40 - 50
	< 40

*Colors are based on the maximum 8-hour ozone recorded in each of the 4 OTR Subregions.

Table 4-2 - 1995 Surface Wind Observations

Meteorology Summary for the 1997 Ozone Episodes for the Northeastern United States

Occurances of (one count per day):

Surface Level Observations

	June	High off coast			High pressure over midwest					
Region*	19	20	21	22	23	24	25	26	27	28
North OTR	NW	NE	SW	SW	NW	NW	C	W	WNW	N_{LT}
Mid OTR	NW	NE_{LT}	S_{LT}	W	NW	C	C	SW	NNW	N_{LT}
South OTR	N	C	SSW	W	NW	V_{LT}	SW	W	NW	C
West OTR	W	C	SSW	NW	NW	SW_{LT}	W	W	NW	S

	June		July						High over midatlantic	
	29	30	1	2	3	4	5	6	7	8
North OTR	NW	S	SW_{LT}	SW_{LT}	S	W	W	SW	SW	W
Mid OTR	SW_{LT}	SSW	S	SSW_{LT}	S	WSW	S	C	S	SW_{LT}
South OTR	SW_{LT}	S_{LT}	S	C	S	WNW	V	NW_{LT}	NW_{LT}	S_{LT}
West OTR	S_{LT}	SW	SE	SE_{LT}	SW	NW	SW	V_{LT}	SW	SW_{LT}

	July	High pressure over midwest			High pressure over southeast					
	9	10	11	12	13	14	15	16	17	18
North OTR	S	NW	W_{LT}	NW	W_{LT}	W	C	E_{LT}	SW	W
Mid OTR	SW	N	NW_{LT}	NW_{LT}	NW_{LT}	W	SW	C	SW_{LT}	WSW
South OTR	S	N	N_{LT}	NW_{LT}	W_{LT}	W	W_{LT}	W	SW	WNW
West OTR	SW	N_{LT}	V_{LT}	C	C	SW	W_{LT}	SW	SW	W

	July				High pressure over midwest					
	19	20	21	22	23	24	25	26	27	28
North OTR	NW	W	W	SSW	WSW	C	N	NW_{LT}	SW_{LT}	SW
Mid OTR	NW	SW	SW	SSE	V	NE	N	NW_{LT}	SW	W
South OTR	NW	S	V	S	ENE	ESE	NNW	SW	SW	W
West OTR	NW	V	C	NE	E	E	V_{LT}	SSW_{LT}	W	SW

	July	High over WI - MI		August	High over OH, WV, VA		Low over New England			Lt winds mw
	29	30	31	1	2	3	4	5	6	7
North OTR	NW	SSE_{LT}	C	WSW_{LT}	W_{LT}	NE_{LT}	E_{LT}	C	S_{LT}	S
Mid OTR	N	S_{LT}	S	W	SW	WSW_{LT}	SE_{LT}	N	S	S
South OTR	NNE	N	NE	SSW	SW_{LT}	SSE_{LT}	C	WNW_{LT}	C	V
West OTR	N	V	WSW	WSW_{LT}	SW_{LT}	N	N	NNW	WNW_{LT}	C

	August	Bermuda High		Very light flow over OTAG						
	8	9	10	11	12					
North OTR	C	SW_{LT}	S_{LT}	S	S_{LT}					
Mid OTR	S_{LT}	S	S_{LT}	S	SE					
South OTR	W_{LT}	S_{LT}	SSE_{LT}	SSW_{LT}	V					
West OTR	V	SW_{LT}	WSW_{LT}	V	V					

	> 100 ppb
	90 - 100
	80 - 90
	70 - 80
	60 - 70
	50 - 60
	40 - 50
	< 40

*Colors are based on the maximum 8-hour ozone recorded in each of the 4 OTR Subregions.

Table 4-3 - 1997 Surface Wind Observations

TABLE 4-4 - 1995 Surface Wind Observation Summary

Peak 8-Hour O3		N	NW	W	SW	S	SE	E	NE	Calm/Var	Total
Very High Ozone	North OTR	0	0	0.5	4.5	0	0	0	0	0	5
(> 100 ppb)	Mid OTR	1	0.5	4	7.5	1.5	0	0	0.5	1	16
	South OTR	0.5	0	1	0.5	5.5	2	0	0.5	5	15
1995	West OTR	0	0	3	2.5	0.5	0	0	0	2	8
High Ozone	North OTR	0	2.5	4	2.5	0	0	0	0	1	10
(80 ppb - 100 ppb)	Mid OTR	1	2	0	6	2.5	2.5	0	0	0	14
	South OTR	0	0.5	3	5	4.5	4	0	0	0	17
1995	West OTR	0.5	1.5	2.5	2.5	0	0	1	1	3	12
Moderate Ozone	North OTR	0	2.5	2.5	6.5	6	1.5	0	0	3	22
(60 ppb - 80 ppb)	Mid OTR	0	2.5	1	2.5	3	3	0	0	0	12
	South OTR	0.5	1.5	0	0	6.5	1.5	0	0	1	11
1995	West OTR	1	4	3	5	3	1.5	0.5	0	4	22

TABLE 4-5 - 1997 Surface Wind Observation Summary

Peak 8-Hour O3		N	NW	W	SW	S	SE	E	NE	Calm/Var	Total
Very High Ozone	North OTR	0	1	1	3	3	0	0	0	1	9
(> 100 ppb)	Mid OTR	0	2	1.5	7	4.5	0	0	1	3	19
	South OTR	0	1.5	4.5	5	4	0	0	0	2	17
1997	West OTR	0	0	0	2	0	0	0	0	2	4
High Ozone	North OTR	0	0	2	3	1	0	0	0	1	7
(80 ppb - 100 ppb)	Mid OTR	1	3	3	4	3	0	0	0	1	15
	South OTR	1	2	3	2.5	3.5	1	0	1	3	17
1997	West OTR	0	1	4	6.5	2.5	0	0	0	5	19
Moderate Ozone	North OTR	1	2	3.5	4	1.5	0	1	2	1	16
(60 ppb - 80 ppb)	Mid OTR	1.5	2.5	1	1	5.5	1.5	0	0	1	14
	South OTR	3.5	4	1.5	0	2	0	0	0	3	14
1997	West OTR	1	3	3.5	4	0.5	1	0	0	4	17

TABLE 4-6 - 1995 850mb Wind Observation Summary

Peak 8-Hour O3		N	NW	W	SW	S	SE	E	NE
Very High Ozone	North OTR	0	1	2	1	0	0	0	0
(> 100 ppb)	Mid OTR	0.5	4	3.5	6.5	0.5	0	0	0
	South OTR	0	1	2	6.5	0.5	0	0	0
1995	West OTR	0.5	1.5	1	3	0	0	0	0
High Ozone	North OTR	0.5	3.5	1	2	0	0	0	0
(80 ppb - 100 ppb)	Mid OTR	1	0.5	1.5	9	0	0	0	0
	South OTR	0.5	1	5.5	6	1	0	0	0
1995	West OTR	3	2.5	1.5	1.5	0	1	0	0.5
Moderate Ozone	North OTR	0.5	2	4.5	9.5	1	0	0	0.5
(60 ppb - 80 ppb)	Mid OTR	0	2	2.5	3	1.5	2	0	0
	South OTR	0.5	1.5	0	6.5	1.5	0	0	0
1995	West OTR	0	4.5	2.5	10	3	1	0	0

TABLE 4-7 - 1997 850mb Wind Observation Summary

Peak 8-Hour O3		N	NW	W	SW	S	SE	E	NE	Calm/Var	Total
Very High Ozone	North OTR	0	2.5	2.5	3	1	0	0	0	0	9
(> 100 ppb)	Mid OTR	1	3.5	10.5	4	0	0	0	0	0	19
	South OTR	0	4.5	10.5	2	0	0	0	0	0	17
1997	West OTR	0	2	2	0	0	0	0	0	0	4
High Ozone	North OTR	0	0	5.5	1.5	0	0	0	0	0	7
(80 ppb - 100 ppb)	Mid OTR	1	4	7	2	1	0	0	0	0	15
	South OTR	1.5	4.5	5.5	3.5	1	0	0	1	0	17
1997	West OTR	0	3	9	7	0	0	0	0	0	19
Moderate Ozone	North OTR	3	7	5	1	0	0	0	0	0	16
(60 ppb - 80 ppb)	Mid OTR	2.5	8.5	1.5	0	0	0	0	1.5	0	14
	South OTR	1.5	6	5	0	0	0	0	0.5	0	13
1997	West OTR	3	6.5	4.5	3	0	0	0	0	0	17

4.2.3. Photochemical Models

In the regulatory application arena, the EPA has often identified guideline models for use by the regulated community. For example, in urban-scale photochemical model applications the guideline model is UAM-IV with CBIV chemistry, with the requirement that other models be demonstrated to be equal or better for their use in regulatory setting. However, in recent years the trend has been shifted away from the regulatory only approach to the use of others that have been peer-reviewed and accepted by the scientific community at large. This type of process was adopted for the OTAG modeling work, where the model chemistry itself was modified to provide a better assessment of the role of biogenic emissions on ozone chemistry. The goal of this study is for the use of photochemical model or models that have a proven track record, are not encumbered by restrictions on their use, and have a reasonable computational time(s). Also, the study is also aimed at providing information on the demonstration of attainment of the ozone NAAQS, and as such should be able to account for the EPA's regulatory framework associated with attainment demonstration process.

4.2.3.1. Pre-requisites for Selection of a Photochemical Model

As noted above, while there are no specific guidelines or pre-requisites for which the photochemical model should be used in the assessment of air quality, it is quite important that the model has been reported in scientific literature and has demonstrated its ability to reproduce observed pollutant levels. However, there may be several air quality models that may fall under such a broad criteria, and therefore it is perhaps realistic to take into consideration some pre-requisites in the selection of the model(s). Thus one of the main requirements would be, as noted above, its availability and lack of restrictions on its use. The other requirement would be its ability to use 2-way interactive nesting as opposed to exercising the model several times at different horizontal grid resolution. This is important to consider, as there may be a need to have a finer mesh over the urban areas and a coarser mesh over the rural areas. Another important aspect is the CPU time for completing the simulation. While the CPU time and ancillary resources associated with running the photochemical grid models are a function of the number of grid cells in the modeling domain, it is not unreasonable for a turn-around time to be about 1 day or 1 1/2 days for 1-day of simulation. Also, another important consideration is the input requirements of the model and their availability.

Currently some of the modeling systems provide information on the type and nature of the processes that go within a grid or a set of grids in terms of their contribution to the predicted ozone levels, often termed as process analysis. Similarly there are modeling systems which provide the contribution from transported versus local production of ozone, termed as culpability analysis. While this optional information would be a valuable diagnostic tool in the assessment of the model, such tools also add to the computational requirements. While this optional information may be of help, it should not be considered as a prerequisite for selection or rejection of a photochemical grid model. Therefore, some initial testing may be required before choosing optional tools and other features that could be incorporated into the current generation of grid-based photochemical models.

Another important aspect of a model is the map projection under which the code is designed. By translating and transforming the input meteorological and emissions data,

there is a potential for introducing errors that may have an affect on the simulation results**,** and therefore it is preferable that the emissions, meteorology and the photochemical grid model use the same map projection.

4.2.3.2. Photochemical Models

There are currently several photochemical grid models that are available in public domain for application to regional/urban-scale assessment of ozone. Some of the models are: UAM-V, CAMx, CIT, URM, CALGRID, MODELS3/CMAQ to name a few. A majority of the OTR States have experience in the setup and application of UAM-V, and CAMx with CBIV chemistry. Also, many of these models have different options such as plume-in-grid (PiG) that could be used to provide diagnostic assessment. While there is support for a coordinated effort with other upwind modeling programs on the selection and use of a common photochemical model, this step would require intense cooperation and planning among the various groups. Based on the domain definition outlined above, the candidates for the modeling exercise that are currently under consideration are UAM, CAMx, and MODELS3/CMAQ. These models are available or expected to be available in public domain, and have been applied previously in regional/urban-scale modeling studies. It is anticipated that the OTC States will undertake a set of modeling exercises using these models before making a selection of one or more models. The details of these exercises and methodology would be discussed in the modeling protocol document.

4.2.3.3. Rationale for the Models Selected

The OTC Modeling Committee has identified several candidate models for use in this ozone modeling and analysis program. The candidate models include: UAM-V, CAMx, and MODELS3/CMAQ These models:

- Have demonstrated that they can, with reasonable accuracy, reproduce observed ozone levels,
- Are in the public domain and are well documented,
- Have nesting capabilities that allow fine grid modeling of urban areas in the OTR,
- Have been applied in various studies both by EPA, States and the private sector, and
- Have reasonable run times/turnaround times.

In addition, States within the OTR have experience running these models.

4.2.4. Photochemical Model Data Input Development

Development of model inputs is one of the most basic steps, and in the case of the modeling system it constitutes three sets of data--the emissions, meteorology, and air quality data. Preparation of each of these data requires some degree of specialization in each one of these areas and also the quality assurance of these data is of paramount importance for a successful simulation of the photochemical model. Assuming that a modeling domain consists of about 200 by 200 grids with 14 layers in the vertical has in its temperature data set about half-a million data points, along with other input files of similar information. Examination of any individual or group of grid cells is next to impossible and therefore several stages of quality controls are needed as the data

processing moves from the raw data to photochemical model-ready stage. Also among the input parameters required are the initial and boundary conditions. Often many of the input data are not available at the spatial and temporal resolution of the modeling system, and general approximations are made by adopting clean air concentrations for ozone and precursor species. This practice is commonly followed in regional-scale modeling studies. Details of these inputs will be provided in the modeling protocol.

4.2.4.1. Land Use and Surrogate Data Development

This is one of the important data sets required for the development of gridded emissions inventories for both anthropogenic and biogenic sources. Often the emissions data for low-level sources are reported on a countywide basis, requiring appropriate surrogate(s) to allocate them to the grids. Utilizing recent census data on population, transportation information, road and rail links, as well geographical data such as water bodies, forests, agricultural tracts, the areal extent of the modeling domain is gridded for use by the emissions modeling systems. This approach allows for allocation of the emissions, depending upon the resolution of the input data to the selected grid size. In general the formulation and allocation is performed under GIS. In this study, the surrogate files are to be developed at a grid resolution of 4 km for the emissions domain displayed in Figure 4-1. This higher resolution is selected so as to enable undertaking 2-way nested modeling at this higher resolution.

In the case of biogenic emissions, the data required is the type and extent of vegetation over the emissions domain displayed in Figure 4-1. Towards this end, data from USGS and other sources will be utilized to develop the inputs to the EPA's BEIS modeling system.

The quality assurance aspects of these data are to be undertaken as a cooperative effort with other modeling groups since this type of information on a local-basis would help to correct any errors that might have been made in such a large and detailed database. The specific types of quality assurance procedures also need to be worked out and are likely to be included in the modeling protocol.

4.2.4.2. Meteorological Data and Meteorological Modeling

As noted above, the choice of meteorological model is the NCAR/PSU community model - MM5 to be applied in the LCC system over the domain displayed in Figure 4-2. The modeling system design and analysis of the data are to be discussed in detail in the modeling protocol. Briefly, the MM5 will be applied in a nested mode at 36/12 km grid spacing in the horizontal and 25 layers in the vertical extending to about 16 km with about 10 layers below the 500mb level. The model will be applied for the June – July '97 period noted previously. Details of the model setup and application will be documented, along with post-processing of the data.

The MM5 model outputs will be processed and archived for access and use by other interested parties, depending on available resources. Since the modeling system is a community model and as there are several options that can vary, and therefore it is suggested caution be used in comparing the results from different groups.

4.2.4.3. Emissions Inventory Preparation and Emissions Preprocessing

A baseline year of 1996 will be used initially for the modeling effort. This inventory will be adjusted to the year specific episode selected for model verification. Depending on the timing of this modeling process, it may be necessary to update the baseline data to 1999, particularly for point source information for projection to future years. Other issues, which may require revision to the baseline, include release of the Mobile 6 model, the off-road model, and/or BEIS 3.

Baseline data for the modeling effort will be provided by each OTC State in appropriate electronic format for point, stationary area, off-road, and highway vehicle emissions. Biogenic emissions will be calculated based on day specific conditions by the BIES 2 model. Non-OTC States within the modeling domain will be contacted to request their 1996 data. Where such data is not readily available, the most recent EPA 1996 National Emission Trends (NET) database will be used. Currently, MARAMA has a contract with PES to develop a quality assured ozone modeling emissions inventory for 1996 and 1997 for the MARAMA and NESCAUM States. It is anticipated that this inventory will be used for baseline model evaluation if available in time.

An emissions preprocessor must be selected to properly transform emissions data for use by the photochemical model. Emissions must be speciated, temporarily allocated, spatially allocated (gridded) and for point sources, divided into low level and elevated sources (where plume-in grid would be necessary). Speciation refers to grouping VOC emissions based on their reactivity for use in the carbon bond mechanism of the photochemical model. In temporally allocating, the preprocessor applies assumptions concerning the typical operating schedule of sources in a given category based source classification codes. Source specific data can be entered where available. Area sources emissions are generally prepared at the county level and must be allocated to the modeling grid system based on a surrogate parameter (typically population). For point sources decisions must be made for sources whose plumes will penetrate the model's ground level and whether or not use of plume-in-grid is appropriate. Because of the large number of small point sources, it is impractical to treat every point source individually. Sources emitting more than 10 tons per day or exhibiting plume rises above 25 meters are normally treated as point sources while the remaining ones are treated as area sources but are maintained in a separate emission file.

Attainment year inventories will be projected once the future modeling year has been selected. Uncertainties must be resolved to allow the use of only one projection year for the OTR. In general projection of electric generating units will be based on the IPM model and be consistent with the EPA NOx SIP call inventory. Other emissions projections will be based on EGAS or BEA data depending on availability at the time for projection of data. Highway vehicle data will be projected to generally be consistent with conformity projections but adjusted by the emissions preprocessor to day specific conditions. Where appropriate, documented and reliable state-specific projection data are available, they will be used for specific categories.

Quality assurance of emissions data will be completed using the emissions preprocessor. EMS95 and/or SMOKE provide for quality assurance software and algorithms to facilitate inventory review. Graphical plots will also be used to assure proper location and gridding of emissions. State review of processed data is critical to

good quality assurance. It is anticipated that this will be one of the most labor-intensive tasks in emission modeling but one of the most critical activities.

Substantial resources from member agencies will be required to complete quality control and quality assurance of emissions data. Once emissions data is preprocessed the review will need to be completed again to assure data is processed properly. Another substantial resource requirement will be storing, maintaining, and preprocessing the emissions data and providing public review. It is likely that contractor support will be necessary for this effort to gather, store project, QA/QC etc. data for all States within the modeling domain. The MARAMA baseline ozone precursor emissions inventory project contains many of these work products and could significantly reduce the need for additional contractor support.

4.2.5. Evaluating Photochemical Model Performance

One of the most important and perhaps most basic question frequently posed is 'how good is the model in predicting air quality'. To address this question, it is important to remember that there are no guidelines for assessing a regional-scale photochemical grid model, and the EPA guidance on assessment (EPA, 1991*)* applies mainly to urban-scale photochemical grid modeling. Given the nature of modeling in terms of grid resolution, domain, and length of simulation, there are no standard procedures for quantifying model's ability to predict ozone concentrations at this time. In many instances the standard statistical procedures used for Gaussian dispersion models or the urban-scale photochemical grid model have been accepted as a set of screening tools. Also, the proposed modeling work needs to develop the necessary measures and metrics that would enable quantification of the model's performance in predicting air quality taking into consideration the grid resolution, areal extent of the modeling domain, the length of the simulation, etc. These will be expanded upon in the modeling protocol along with expectations and limitations in assessing model performance. However, we provide here some of the aspects that would be examined in this assessment.

Screening techniques that can be helpful to determine the model's performance qualitatively are comparison of predicted and measured concentrations of ozone, NO_2, and CO, recognizing that the monitoring network for some of these pollutants may be reflective of local-scale phenomenon. One such useful qualitative and quantitative test compares the model's predictive ability to urban elevated measurement stations: Sears Tower in Chicago, IL; World Trade Center in New York City, NY; and the CN Tower, Toronto, Canada. Similarly, the model can be compared to several rural elevated measurement locations such as Cadillac Mountain, ME; Mount Washington, NH; Whiteface Mountain, and NY, Shenandoah National Park, VA. Such an assessment would provide an understanding of the model's ability to predict in a meaningful way at these non-source and thus emissions-poor areas of the modeling domain. Again, the metrics and measures that are needed are to be developed appropriately. Another preliminary screening technique could be to examine the predictive ability of the model with respect to rural monitor networks such as CASTNET and NPS. The next step could be to focus more closely on certain urban areas of interest to establish qualitatively the response of the model to the urban network.

Another test that could provide insight into the performance of the modeling system is the comparison with PAMS network. The PAMS network is concentrated around urban areas that are classified as severe and serious non-attainment areas for ozone. The

network consists of about 20 or so monitoring sites over the eastern US. The data from the PAMS network could be utilized to provide an assessment of the input emissions as well as the photochemical model output fields.

It is also recommended that other performance measures be proposed and investigated as part of the model assessment work. As noted above, the details will be addressed in the modeling protocol.

It is important to recognize that no model simulation will be able to meet the 'set goals' for every location of the modeling domain at all times. Recognizing that model predictions are simply 'snapshots' of model inputs, which in turn are themselves based on estimates and approximations. This points out the inherent limitations of the modeling system.

Reference

EPA, 1991: Guideline for Regulatory Application of the Urban Airshed Model. EPA-450/4-91-013, Office of Air Quality Planning and Standards, U.S. Environmental Protection Agency, Research Triangle Park, NC.

4.2.6. Sensitivity Analyses

Based on a review of recent air quality data and air quality modeling performed by the EPA in connection with the NOx SIP Call and the Tier 2/low sulfur proposal, it is anticipated that additional VOC and/or NOx emission reductions will be needed in States within the OTR to attain the eight-hour ozone standard. The future base year scenario, representing emissions projected out to an appropriate attainment year, will serve as the basis for evaluating any additional control measure candidates. This future base year will assume: (1) implementation of Clean Air Act measures, (2) Regional NOx reductions similar to these envisioned in the EPA NOx SIP Call budgets, and (3) adoption of the EPA Tier 2/low sulfur rule proposal and any other measures that have been proposed or adopted by the States. The details of proposed sensitivity runs will be planned in consultation with other OTC committees.

Relative to the base case, it is proposed that a set matrix of sensitivity modeling runs will consider individual and combinations of VOC and NOx reductions in the range of 25 to 50%. In this regard it should be noted that one of the photochemical models, CAMx has the capability to track the proportion of ozone that was generated under VOC and NOx limited conditions within a particular modeling grid cell, and thereby generate grid cell specific sensitivity factors as part of the simulation. These factors may vary depending on the degree of emission changes and may be able to limit the number of sensitivity simulations.

4.2.6.1. Sensitivity Analyses: An Explanation

The following rationale describes approaches that could be adopted for undertaking sensitivity simulations.

4.2.6.2. NOx Sensitivity

Currently, the maximum eight-hour ozone design values within the OTR are about 105 ppb. Regional NOx reductions associated with the NOx Budget caps in the EPA SIP Call provide about a 12% reduction over a broad geographic area (with exceptions as discussed below), bringing the 105 ppb to about 92 ppb. The Tier 2/low sulfur initiative provides approximately an additional 2 ppb reduction, leaving a potential gap of 6 ppb to be filled (90 ppb - 84 ppb). Emission reductions and air quality benefits associated with the EPA NOx Budget and Tier 2/low sulfur proposal suggest that a 1 ppb reduction occurs for every 3% NOx reduction within the region. This rate is relative to the baseline identified in the Sensitivity Analyses discussion above (i.e., post NOx Budget, Tier 2/low sulfur environment). In the absence of any other weight-of-evidence analyses, a NOx reduction of 6 ppb, divided by (1 ppb/3% NOx emissions) results in an 18% NOx emission reduction. Therefore a 25% NOx emission reduction range is assumed for analytical purposes, to add some conservatism and assure that an adequate range is spanned.

4.2.6.3. VOC Sensitivity

A review of the modeling results associated with the recent EPA Tier 2/low sulfur proposal, indicates that there are a few sites in or near certain highly urbanized areas that may not have the highest design values in the area, but may be critically important to a successful sensitivity analysis. Such locations are apparently affected much less by Regional NOx Caps than the normally targeted sites. The 1995-1997 design values for these sites targeted here are about 100 ppb. After the NOx Budget caps and the Tier 2/low sulfur standards are applied these sites are projected to drop to about 95 ppb. Therefore an additional 11 ppb reduction will still be needed to reach 84 ppb levels, absent any other weight-of-evidence arguments.

The EPA modeling, being focused primarily on NOx reductions, does not provide a clear basis for assessing the degree of additional VOC reductions to close an 11 ppb gap in eight-hour ozone concentrations. However for early planning purposes it may be reasonable to assume that the effect of VOC reductions in highly urbanized areas is comparable to NOx reductions over broader geographical areas. Therefore assuming the same 1 ppb/3% emission reduction ratio above for NOx reductions, an additional 33% reduction of VOC emissions might be needed to bring these urban sites into attainment with the eight-hour standard. Accounting for that fact there is a high degree of biogenic VOC emissions, a 50% range is assumed in the sensitivity analysis to assure that an adequate range is spanned. This range might be reduced if initial sensitivity results indicate a greater VOC effectiveness than the 1ppb per 3% VOC emission reduction assumed above.

4.2.7. Control Measure Evaluation

The sensitivity analyses discussed above will provide an estimate of the magnitude of various combinations of the VOC and NOx emission reductions that are necessary to sufficiently reduce ozone levels (e.g., in the case of the eight-hour ozone NAAQS, 84 ppb or less). To assure that a sufficient suite of control options is available to the States that are commensurate with the needs indicated from the sensitivity analyses, a comprehensive analysis of potential control measures should be undertaken in consultation with other OTC committees. First, this would consist of a screening

analysis to identify and facilitate comparisons among different measures. In this analysis all possible control measures should be identified and to the extent possible, their emission benefits quantified relative to a common emission baseline to facilitate comparisons of emission reductions from different measures. In addition, other factors, such as cost effectiveness and considerations regarding time frames and relative ease of implementation, should be considered. These measures would also be categorized based on their geographic scope using the same area categories as in the sensitivity analysis. This will facilitate a matching of the potential emission reductions afforded by the selected options with the results from the sensitivity analysis.

Following completion of the control measure screening analyses, the OTC Modeling Committee will consult with the other OTC Committees to recommend to the Commission a subset of measures for further and more detailed analyses. This would be based on preset control measure criteria (to be developed), and would take into consideration the sensitivity analysis results. The measures recommended should together exceed the expected emission reduction needs stemming from the sensitivity analysis to account for the possibility that certain measures may be discarded based on the more detailed analysis. Detailed analysis of selected options would then be used to further select those options that would comprise the control strategy modeling runs.

The control strategy runs would be used to confirm that the measures selected from the detailed analysis are sufficient, based on the weight of evidence, to attain applicable ozone standards in the OTR. Once final modeling results are confirmed, the OTC may wish to consider the development of "model rules," in coordination with individual States.

4.3. Data Analyses

In addition to the photochemical modeling described in preceding sections, the States of the OTC plan to perform air quality data and trend analyses to support and corroborate ozone modeling results. Conceptually, there are a variety of techniques that could be used to analyze ozone precursor emissions, monitored ozone data, and meteorological data with the goal of correlating these data with observed ozone values. Since data and trend analysis for an area as large as the OTR could require large resources and available resources are quite small, the OTC Modeling Committee believes that States need to review available techniques for analyzing air quality data before committing to a extensive analytical program. At a minimum, the Committee believes it must determine 1) which techniques provide the most useful information about ozone trends and ozone attainment and 2) which techniques can be used to best corroborate modeling results.

Many different techniques could be used, but resource limitations preclude using all of them. The criteria used for choosing analytical techniques will be as follows:

- Data sufficiency - The quality and quantity of the data required by each analytical method will be considered. Analyses will not be done if the data required to do them is of insufficient quality or quantity. A reasonable effort will be made to address data quality and quantity where necessary.
- Comparability of results – Comparability of results relates to the method and metric used to compare photochemical model results with observational model results. Consideration will be given to the degree of similarity between metrics derived from the photochemical modeling results and those from the observational modeling results. Comparability also implies the use of a method

of comparison. These may range from statistical techniques to the less quantitative methods of visual analysis. Lack of comparability may preclude the use of some analytical methods.

- Uncertainty of results - Because certain analytical techniques rely on a large number of assumptions and have inherent limitations, their results are relatively uncertain compared to the accuracy of air quality measurements used in the performance evaluation. Methods that produce highly uncertain results may mislead the weight-of-evidence determination and therefore will not be used.

The following sections describe analyses that could potentially be performed to characterize air quality or meteorology at a site or collection of sites. Completing all the analyses listed below for all monitoring sites would require extraordinary resources and is not contemplated.

4.3.1. Air Quality Trend Analyses

Air quality trend analyses have been performed for ozone by a number of researchers that generally have found declining ozone levels throughout the OTR since the beginning of monitoring. The techniques applied vary from counting episode site days to sophisticated meteorological adjustment schemes to account for weather variability (S.T. Rao et al.). Because of monitor additions, deletions, and relocations as well as weather pattern changes from year to year, it becomes difficult to determine exactly what role, if any, emission reductions have made toward ozone reductions. Recent studies by Rao et al. and Underhill, of long-term ozone monitoring trends (one-hour ozone design value) adjusted by some form of meteorological accountability scheme, have confirmed that long-term ozone reductions have in fact taken place in the Northeast, but more recently the ozone tendencies have become inconclusive, especially in rural areas (some increases and some decreases). While it is assumed that eight-hour ozone trends generally follow the one-hour trends, it is not a given since the transport dynamics are somewhat different.

Design values are the metric EPA chooses to evaluate air quality attainment status and therefore trends of this metric should be reviewed. However, since this metric is based on a three year averaging value for the 4th maximum eight-hour ozone concentrations, it minimizes the effect that one very bad year may have on the overall record, in effect, smoothing the data. Therefore some other metrics should also be reviewed to ensure real trends of ozone exposure are measured

Some additional metrics that may be employed in eight-hour trends analyses are listed below.

- Annual average of the maximum daily eight-hour ozone concentrations takes into account *all* days during the season. This metric is highly influenced by meteorology for the season. (i.e., warm year or cold year)
- Maximum eight-hour concentration for each year - the most extreme episodes will be highlighted.
- 90th and 10th percentile ozone - filters the highest and lowest values out of the annual averages. A more realistic analysis of the correlation between emissions and air quality may be derived this way.

- Rao and Zurbenko use a mathematical filtering technique to remove the effects of meteorology on the time series. This technique would also more realistically tie emissions and air quality.

4.3.2. Addressing Conceptual Plan Issues

4.3.2.1. Chemistry

CONFIRMING PHOTOCHEMICAL MODEL RESULTS

This section describes OTC Modeling Committee's plan for using various types of air quality analyses to confirm predictions made by the photochemical model. Work proposed under this section will complement the model performance evaluation (Section 4.2.5) by seeking to confirm those conclusions made by the photochemical model that could not be corroborated by the performance evaluation (e.g. ozone's sensitivity to NOx or VOC)[1]. Some of the analytical techniques used to make these confirmations are called observational models. For example, MAPPER is an observational model used to determine ozone's sensitivity to NOx or VOC, (Blanchard and Roth, 1995). Results of work completed under this section will be used in the weight–of-evidence determination. The scope of the work will be limited to OTR for the episode(s) being modeled.

The photochemical model results identified below cannot be directly verified by the performance evaluation (Section 4.2.5). Each of these photochemical model predictions has an important consequence for developing control strategies. A literature search will be done to identify earlier analyses whose results can be used for the purposes of this section. SIPs may provide another source of useful results.

- Ozone's Sensitivity to NOx or VOC – Erroneous predictions about the direction of control could result in choices of control strategies that fail to reduce emissions sufficiently. The following methods will be examined according to the criteria in Section 4.3.1:
  - MAPPER is an observational model that uses an adaptation of the Smog Production Algorithm (Blanchard and Roth, 1995).
  - Other

- Indicator ratios include ratios of H_2O_2/NOz, O_3/NOy, O_3/NOz, etc. Without doing a formal survey, the OTC Modeling Committee has determined that most NOy measurements made in 1997 do not satisfy the data requirements of this method. However, the results of special studies involving these indicators may be used for purposes of this section (Indicator ratios identified by Sillman, 1997).

[1] Different combinations of NOx and VOC can lead to the same or nearly the same concentration of ozone. Hence, the accuracy of model predictions for the base case does not guarantee that model predictions for control strategies will be accurate (Sillman, 1998). Relying on performance evaluation, only, can lead to getting the right answer for the wrong reason.

- Morning ratio of VOC/NOx has long been used as a means to determine ozone sensitivity. The OTC Modeling Committee has found that the uncertainties associated with its use are unacceptably high, especially given that the commonly measured TNMOC is a bad estimate of VOC.

- Others

4.3.2.2. Meteorology

SITE ANALYSIS

Air quality trends are due to two factors, emissions and meteorology. To determine the effects of meteorology over time, a time series of some temperature metrics such as number of days above 90 degrees must be correlated with air quality. If air quality improves with the same or more favorable conditions for producing ozone, the conclusion is that changes in emissions are driving the downward trend.

To determine if transport is a problem at sites, analyses of ozone concentration vs. time and wind speed would be helpful. If a site frequently violates on a southwest wind and never violates on a northwest-southeast wind, it may be logical to conclude that sources to the southwest may be the cause of the problem. However, if the winds are light, this may point to local sources as the cause of the problem. Conversely if wind speeds are strong and air quality is worse, this points to interregional transport as the cause of the problem. (Stronger winds tend to disperse pollution from local sources.)

Meteorological site analyses could include plots of the following values:

- Ozone vs. temperature
- Ozone vs. wind direction

SYNOPTIC METEOROLOGICAL ANALYSES

A very important factor in determining causes for air pollution episode lies in understanding the meteorological patterns occurring during violations. Equally as important is the link between meteorology and severity of the event. Particular patterns often yield similar air quality events. Temperature, flow field patterns, and cloud cover are the most valuable indicators. It is important to categorize meteorological events by these parameters and compare them with the air quality observed.

Synoptic meteorological analyses should include at a minimum, prevailing synoptic patterns such as high pressure ridges, Bermuda highs, etc.

TRAJECTORY ANALYSES

Since transport plays a significant role in poor air quality for downwind sites, trajectory analyses can be used as a tool for establishing source-receptor relationships. Analyzing trajectories at several vertical layers in the atmosphere can help identify patterns of particular source regions contributing to a receptor area's poor air quality. This can be done on an episode-by-episode basis or in aggregate (all trajectory paths during exceedances vs. all trajectory paths on non-exceedance days). Climatological residence time analyses can be performed which take into account air mass time spent over a source region before transport (Poirot, 1997).

- Transport of Ozone and Its Precursors – Knowing how to partition emissions controls between regional and local sources is vital to identifying efficient control strategies. Errors made about this can result in expensive control strategies that fail to attain the NAAQS.

The OTC Modeling Committee will evaluate the following methods:

- Back trajectory analyses such as (Brankov, et. al.) and (Poirot and Wishinski,'96). Using this analysis, verify whether patterns are continuing to occur for the most recent time periods since the OTAG analyses (Comment via Paul Wishinski).
- Spectral Decomposition, such as (Hogrefe, et. al., 2000).
- Others.

Plots might include:

- Spatial plot of 72-hr back trajectories during unhealthy days for selected sites;
- Spatial plot of 72-hr back trajectories during non-unhealthy days for selected sites;
- Spatial plot of 72-hr back trajectories during all days for selected sites;
- Grid cell (1^o x 1^o latitude-longitude) contribution during unhealthy vs. healthy days (residence time analysis).

4.3.2.3. Emissions

Ideally, correlating NOx and VOC emission trends with meteorologically adjusted ozone concentrations would be an effective means of establishing emission reduction effectiveness. However, detailed emission inventories of high quality, historically do not exist much beyond 1990. Emission inventories developed since 1990 are based on data collected once every three years (i.e., 1990, 1993, 1996, and 1999-currently under development). Of these, the inventories for 1990 and 1993 are generally considered insufficient for several emission categories when compared to today's calculation standards, and thus are likely to produce poor quality and/or unreliable correlation analyses. Instead of using the potentially poor quality emissions trend information, meteorologically adjusted ozone responses will be tracked over several specific regional and national emission control strategies. Control strategies to be considered include: reformulated gasoline, Phase I of the Clean Air Act acid rain provisions, and Phases I and II of the OTC NOx MOU. Responses of certain ozone precursors, such as NOx, NOy, and several VOC species could also be evaluated this way.

4.3.3. Reports of Results

Results of all major data analyses performed under the scope of this work plan will be posted on the OTC website and presented at open meetings of the OTC Modeling Committee. At a minimum, results will be reported along with a description of the methods used, assumptions, limitation of application, and associated uncertainties.

References

Blanchard and Roth, 1995: User's Guide Ozone Measurement-based Analysis of Preferences in Planned Emission Reductions.

Brankov, Rao, Porter, 1998: A Trajectory Clustering Correlation Methodology For Examining The Long Range Transport of Air Pollutants. Atmos. Environ. Vol. 32, No. 9, 1998.

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Sillman, 1997: Total Reactive Nitrogen as an Indicator of the Sensitivity of Ozone to Reductions in Hydrocarbon and NO_X Emissions. J. Of Geophysical Research, vol. 99, 1997.

Underhill, 2000: Ozone Trends in the Northeast United States. Presentation to the OTC Modeling Committee, Oct. 2000.

5. Conclusion

One of the important aspects of this work plan is to address the ozone non-attainment problem in the OTR as a whole, and its mitigation on both regional and urban scales. This is unlike what was done for prior SIPs, which were developed solely on an area-by-area basis. Also inherent in this goal is to develop the ability for OTC members to utilize the photochemical modeling system in-house to support their SIP processes, as well as to have access to databases and information to address stakeholder claims. This work plan evolved from the initial 1999 draft proposal aimed at assessment and attainment of the then-proposed eight-hour ozone NAAQS. The work plan is a joint effort of the OTC, its members and the regional organizations. The effort is expected to provide a better understanding of the ozone problem in the OTR and a common basis for evaluating the issues related to fine particulate and regional haze.