Appendix D

Protocol for Regulatory Photochemical Air Quality Modeling of the Baltimore-Washington DC Region

Attainment Demonstration Modeling Report for the Washington DC-MD-VA Ozone Nonattainment Area

Episode Selection

Modeling Inventory Preparation and Quality Assurance

Air Quality and Meteorological Data Preparation

Model Performance Evaluation for Baltimore-Washington UAM-IV Modeling Domain

EPA Analysis of Regional Model Results

Protocol for Regulatory Photochemical Air Quality Modeling of the Baltimore-Washington DC Region

PROTOCOL

For Regulatory Photochemical Air Quality Modeling Of The Baltimore-Washington, DC Region

Prepared by

Air and Radiation Management Administration

Maryland Department of the Environment

Domain Lead

In Consultation With:

Virginia Department of Environmental Quality

District of Columbia Department of Consumer and Regulatory Affairs

Metropolitan Washington Council of Governments

U. S. Environmental Protection Agency, Region III

University of Maryland, Department of Meteorology

DRAFT REVISION

September 1996

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PROTOCOL
For Regulatory Photochemical Air Quality Modeling
Of The Baltimore-Washington, DC Region

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I. MODELING STUDY DESIGN

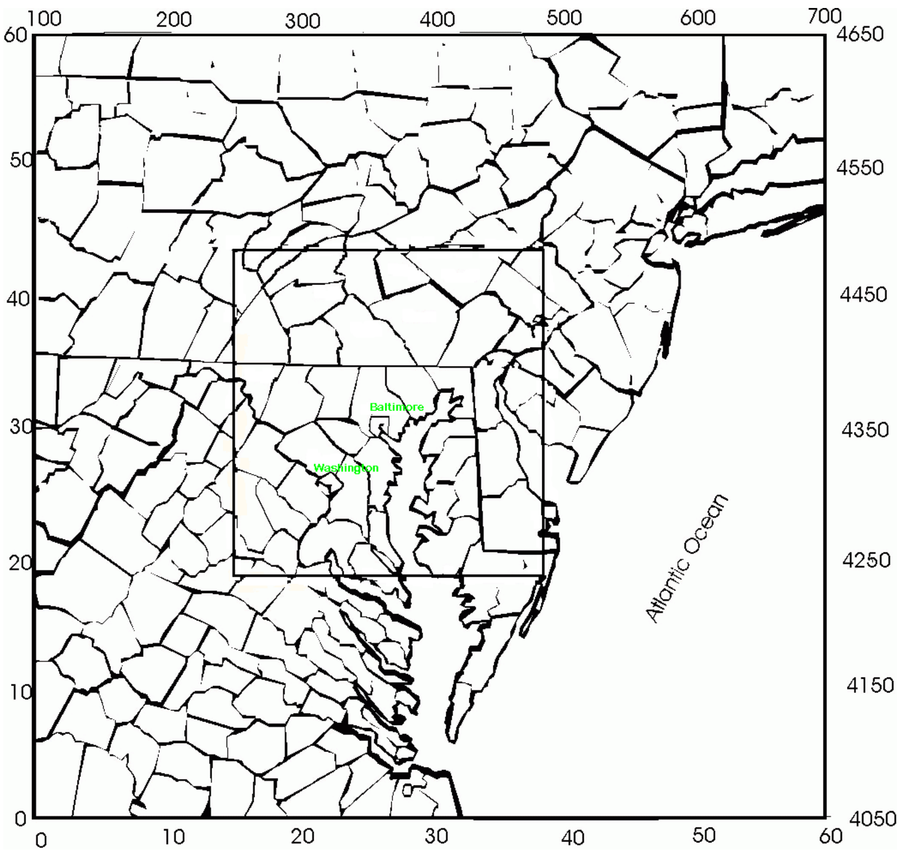
Background and Objectives

In accordance with the provisions of Section 182(C)(2)(A) of the Clean Air Act, as amended on November 15, 1990, serious and severe ozone nonattainment areas must submit, as part of their State Implementation Plan (SIP), a demonstration using photochemical grid modeling that attainment will be achieved by the applicable date. The Washington Metropolitan Statistical Area (MSA) has been classified a serious nonattainment area for ozone with an attainment year of 1999. The Baltimore Metropolitan Statistical Area (MSA), excluding Queen Anne's County, has been classified a severe nonattainment area for ozone with an attainment deadline of 2005.

The Baltimore and Washington metropolitan areas are in close physical proximity (40 miles separate the city centers) and their suburban communities overlap. Based upon 1990 census data by the Office of Management and Budget (OMB), the Baltimore-Washington region has been classified a Consolidated Metropolitan Statistical Area (Washington-Baltimore CMSA). In addition, observations of wind motions in the region indicate that emissions from one city travel enough to affect air quality in the other, often within one day. Therefore, the agencies responsible for making the attainment demonstration for these two metropolitan ozone non-attainment areas, including the District of Columbia Department of Consumer and Regulatory Affairs (DC DCRA), the Virginia Department of Environmental Quality (VADEQ), and the Maryland Department of the Environment (MDE), in consultation with the Metropolitan Washington Council of Governments (MWCOG), the Baltimore Metropolitan Council (BMC, formerly Baltimore Regional Council of Governments), and the Tri-County Council for Southern Maryland (TCC), have acceded to U.S. Environmental Protection Agency (EPA) requests that the modeling domain for ozone in the two ozone non-attainment areas include both cities and their surrounding nonattainment counties. Strategy analysis may be performed for each nonattainment area separately, and within inter-jurisdictional nonattainment areas separately. However, the selected final strategies for both areas will be modeled jointly in the modeling attainment demonstration. The boundaries of the proposed modeling domain and its location in the mid-Atlantic region are illustrated in Figure 1.

The objective of this modeling study is to enable the various agencies responsible for attainment demonstrations to analyze the efficacy of control strategies, and to demonstrate that the measures adopted as part of the State Implementation Plan for each nonattainment area will result in attainment of the ozone standard by the required dates.

The procedures set forth in this protocol were developed in accordance with Guideline for Regulatory Application of the Urban Airshed Model and other current EPA guidance on the Urban Airshed Model (UAM). The Modeling and Policy Committees will agree upon the contents of the document before submitting it to EPA for approval. Submission of the protocol and its subsequent approval by EPA do not preclude future changes in the document deemed necessary by the involved parties described above. Such changes will be approved by the Urban Airshed Modeling Policy and Technical Committees. These changes may reflect evolving EPA guidance, or the development or refinement of existing procedures by consent of the involved parties.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30
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60
Baltimore
Washington
Atlantic Ocean

Figure 1
Location of UAM Modeling Domain
for Baltimore-Washington, DC CMSA

Scale: 1".50 km
UTM zone 18, Eastings in km on top, Northings on right
Bottom and left borders denote number of 5 km cells

Schedule

The Maryland Department of the Environment (MDE) and the Virginia Department of Environmental Quality (VADEQ) are working together to conduct UAM runs for the entire Baltimore-Washington domain. Installation of the models in both modeling centers has been completed and diagnostic procedures have been run. Baseline modeling has been completed and is under quality assurance and refinement. The proposed modeling sequence is illustrated in Figure 2.

Deliverables

The deliverables for this modeling project are:

1. Results of sensitivity analyses of region-specific modeling runs to guide the selection of strategies;
2. Baseline modeling runs for episodes selected by Technical Committee for the entire modeling domain;
3. Baseline modeling runs for Washington or Baltimore areas separately if warranted by different episode conditions;
4. Projection modeling runs for 1999 using strategies selected by the Metropolitan Washington Air Quality Committee;
5. Projection modeling runs for 2005 using strategies selected by the Baltimore Certified Structure;
6. Maintenance runs, if required by EPA.

All interim and final deliverables will be submitted first to the Technical and Policy Committees for comment and preliminary approval. Additional comments and suggestions may be provided by the Technical Information Providers, contractual advisors, or other interested parties. Following comment and preliminary approval by the Technical and Policy Committees, the final modeling results will be submitted to the Technical Advisory Committee (TAC) (see Appendix A) and the Transportation Steering Committee (TSC) (see Appendix B) for evaluation. They will recommend actions to the Metropolitan Washington Air Quality Committee (MWAQC) (see Appendix A) and the Baltimore Certified Structure (see Appendix B), respectively.

Figure 2. Draft Baltimore - Washington Domain UAM Order of Operation

VADEQ Modeling for 1999

Phase I
Propose procedure for conducting sensitivity runs
Propose procedure for base-case bench-marking
Propose sub-domain extension
Meteorological, ROM, and base year emission data collection
Base year emission inventory pre-processing (EPS2.0)
Evaluation of MDE wind fields and mixing heights
Selection of wind fields and mixing heights
Diagnostic analysis and sensitivity studies
Base case model performance evaluation

Phase II
Propose 1990 growth and control factors
Develop 1999 emission inventories for the Washington area
Develop 1999 emission inventories for the rest of the domain

Phase III
Propose procedure for determining BCs
Propose procedures for attainment demonstration
1999 base year simulation runs
Evaluation of 1999 ROM BCs
Evaluation of 1999 OTAG BCs
Evaluation of control strategies
Preliminary attainment demonstration

Phase IV
Meet with Air Directors
Documentation
Final attainment demonstration modeling with official OTAG boundary conditions

MDE Modeling for 2005

Phase I
Comment on VADEQ sensitivity run proposal
Comment on VADEQ bench-marking proposal
Comment on VADEQ's sub-domain extent
Process any needed ROM BCs& ICs
Obtain corrected spatial allocation data
Process base inventories for all episodes (except III)
Evaluate each episode's base case performance and diagnostic analysis.

Phase II
Coordinate with VADEQ on growth and control factor development
Process 2005 inventories for each episode

Phase III
Comment on VADEQ's procedure for determining BCs
Comment on VADEQ's procedure for attainment demonstration
Run 2005 base year simulation with ROM BCs
Run 2005 base simulation with early OTAG BCs
Do Sensitivity modeling
Model control strategies

Phase IV
Finalize attainment demonstration
Documentation and submittal

Management Structure and Committees

The Baltimore and Washington metropolitan areas have organizations certified to develop air quality plans for their respective area that will enable the area to comply with federal ozone standards. The organizations will develop control strategies in these plans using data compiled and submitted to them by the Urban Airshed Modeling Committee. The modeling will be based on strategies selected by these organizations.

The Maryland Department of the Environment, the Virginia Department of Environmental Quality, and the District of Columbia Department of Consumer and Regulatory Affairs are the agencies responsible for submittal of regional Urban Airshed Modeling attainment demonstrations for applicable years to EPA. The lead modeling agency is the Maryland Air and Radiation Management Administration, although the modeling project will be managed jointly by Maryland, Virginia and Washington, D.C. through a Policy Committee and a Technical Committee within the framework of the certified organizations.

Urban Airshed Modeling Committee Members

Domain Lead	Policy Committee	Technical Committee
George (Tad) Aburn MDE (410) 631-3245 (410) 631-3202FAX	George (Tad) Aburn MDE (410) 631-3245 (410) 631-3202FAX	Diane Franks/John Haus MDE (410) 631-3240/3245 (410) 631-3202FAX
	James Sydnor (VA) VADEQ (804) 698-4424 (804) 698-4510FAX	Kirit Chaudhari (VA) VADEQ (804) 698-4414 (804) 698-4510FAX
	Donald Wambsgans DC DCRA (202) 645-6093 (202) 645-6102FAX	David Krask (DC) DC DCRA (202) 645-3065 (202) 645-6102FAX
	Stuart Freudberg MWCOG (202) 962-3340 (202) 962-3203	Jacquelyn Magness Seneschal MWCOG (202) 962-3354 (202) 962-3203
		Todd Ellsworth/Ruth Knapp EPA Region III (215) 566-2195 (215) 566-2124FAX
		Bill Ryan U. of MD (301) 405-7668 (301) 314-9482FAX

Ellen Baldridge/Chet Wayland /Norm Posseil
EPA OAQPS
(919) 541-4603/5692
(919) 541-2357FAX

The role of the Technical Committee will be to assemble the necessary modeling inputs in the proper format, to recommend the meteorological episodes and report on the effectiveness of control strategies that are modeled.

The Policy Committee will evaluate the recommended episodes and strategies, and the overall modeling methodology to ensure that these are appropriate and consistent with the directions of the three participating state agencies, the certified organizations, and EPA advisors.

The Domain Lead will prepare progress reports, either written or verbal, to the Policy Committee highlighting the status of tasks in the schedule shown in Figure 2, identifying significant conflicts or decisions, and recommending actions. Copies of the reports will be sent to EPA, all Policy and Technical Committee members, the Executive Directors of MWCOG, the Executive Director of Baltimore Metropolitan Council, and the members of appropriate technical committees established by the certified organizations (see Appendix A and B).

The Domain Lead, in conjunction with the Technical Committee members, will obtain information from the Technical Information Providers listed below, identified by their respective agencies as responsible for providing the air monitoring, meteorological, emission inventory and control strategy information necessary to perform the modeling described in this protocol.

Contractual advisors, also listed below, will provide detailed technical advice on episode selection, sensitivity analyses, and the interpretation of meteorological output data from the model. They will also assist in obtaining more detailed meteorological and monitoring data for use in the model.

Technical Information Providers

STATE	EMISSION INVENTORY	AEROMETRIC AND MONITORING DATA	STRATEGIES
MD	Diane Franks (410) 631-3240	Dick Wies (410) 631-3280	Tad Aburn/ (410) 631-3245 Carl York (410) 631-3240
VA	Kirit Chaudhari (804) 698-4414 Thomas Ballou (804) 698-4406	John Daniel (804) 698-4311	Kirit Chaudhari (804) 698-4414
DC	Don Wambsgans (202) 645-6093	Dave Krask (202) 645-6093	Don Wambsgans (202) 645-6093
MWCOG	Jacquelyn M. Seneschal		Jacquelyn M. Seneschal

	(202) 962-3354		(202) 962-3354
DE	Al Deramo (302) 739-4791	Joe Kliment (302) 323-4542	Mohanned Mazeed (302) 739-4791
NJ	Paul Anderson (609) 633-1109	C. Pietarinen (609) 292-0138	Chris Salmi (609)292-6722
WV	Dave Porter (304) 558-1213		
PA	Wick Havens (717) 787-4310	Jeff Miller (717) 787-6548	Wick Havens (717) 784-4310
EPA-OAQPS	Chet Wayland (919) 541-4603	Rich Scheffe (919) 541-4650	
EPA-REGIII	Rose Quinto (215) 566-2182	Todd Ellsworth (215) 566-2195	Dave Arnold (215) 566-2172
U of MD	Russ Dickerson (301) 405-5364	Bill Ryan (301) 405-7668	

Contractual Advisors

University of Maryland, Department of Meteorology

Russell Dickerson
(301) 405-5364
(301) 314-9482FAX

William Ryan
(301) 405-7668
(301) 314-9482FAX

Participating Organizations

The lead agency for coordinating the running of the model and performing the modeling runs is the Maryland Air and Radiation Management Administration of the Maryland Department of Environment. This agency, in consultation with other member agencies, will schedule meetings of the appropriate working groups and determine the location of the meetings.

The Maryland Air and Radiation Management Administration (MARMA), the District of Columbia Department of Consumer and Regulatory Affairs (DC DCRA) and the Air Division of the Virginia Department of Environmental Quality (VADEQ), will develop the air quality data and point source emission inventories required for running the urban airshed model. To the extent that Delaware, Pennsylvania and West Virginia are included in the modeling domain, the air agencies from those states will also provide the requisite modeling input information.

Metropolitan Washington Council of Governments (MWCOG), in cooperation with the Tri-County Council (TCC) and the state air agencies, will compile the emission inventories for mobile and area sources in the Washington MSA and incorporate the point source data provided by the states into a model-readable inventory file. MDE will develop the point, mobile and area source inventory files for the balance of Maryland, using transportation modeling information provided by BMC. Virginia DEQ will develop the same categories of emission inventory data for the balance of Virginia outside of the Washington MSA. For the Pennsylvania and Delaware portions of the domain, the point source and area source inventories will be obtained by MDE from the respective state agencies, while the mobile source inventory will be obtained from the Delaware Valley Regional Planning Council (DVRPC).

The members of the Baltimore Certified Structure and the Metropolitan Washington Air Quality Committee will develop a process to recommend strategies to be modeled and to evaluate the benefits of the recommended strategies. The process will include a selection and ratification procedure through which the selected strategies will become part of the final air quality plan for the respective ozone non-attainment area.

The University of Maryland will provide meteorological expertise, advice on speciation of hydrocarbons, and upper air data measurements.

EPA Region III and OAQPS will provide guidance and most of the funding necessary to successfully carry out this project.

Committee/Participant Interaction

The Domain Lead and the Technical Committee will obtain information from the individuals identified by each agency as responsible for providing the air monitoring, meteorological, emission inventory and control strategy information necessary to perform the modeling described in this protocol. Strategies other than those mandated by the Clean Air Act will be developed by the certified organizations through their strategy selection process. The Domain Lead will gather the necessary data to model both the required and selected strategies and compile the results for review by the Policy Committee. Representatives of the Technical and Policy Committees will present the modeling results to the Technical Advisory Committee of the Metropolitan Washington Air Quality Committee (Appendix A) and members of the Baltimore Certified Structure (Appendix B) for evaluation according to their established evaluation procedures. Further analysis may be necessary as determined by the involved committees or the strategy may be recommended to the certified organizations for incorporation into the air quality plans. Insofar as resources permit, sufficient model runs will be completed to evaluate any policy option a state or locality wishes to implement.

For the Washington metropolitan ozone non-attainment area, the emission projections and strategies used in the final attainment demonstration will be those adopted by the Metropolitan Washington Air Quality Committee. Delaware and Pennsylvania's projections and strategies will be obtained from those states as needed.

In general, the Policy and Technical Committees will attempt to avoid conflict regarding technical modeling issues by holding joint meetings, building consensus among the members, and regularly briefing and obtaining guidance from the two air quality committees. If consensus cannot be achieved, the Policy Committee may seek further technical advice from a variety of sources: the Technical Staff Coordination Committee of the Metropolitan Washington Air Quality Committee, the University of Maryland meteorological advisors, EPA advisors, EPA-provided contractors, technical information providers, or technical personnel from other UAM domains. It is the agencies' intent that modeling will in all cases be consistent with established EPA policies.

In cases of policy disputes, the State Air Directors and Secretaries or their equivalents shall be consulted for guidance. The State Air Directors will resolve the conflict in consultation with the certified organizations.

Relationship to Regional Modeling Protocols

The state members of the committees for this study are also members of the Ozone Transport Commission (OTC) Modeling Committee and the Ozone Transport Assessment Group (OTAG). This membership will allow them to coordinate the analyses performed by UAM with regional model runs performed by OTAG for the Baltimore and Washington ozone non-attainment areas. UAM runs using OTAG episodes and strategies will be performed to the extent that it is feasible. OTAG outputs will be used to obtain boundary conditions for UAM runs for the domain. Based on analyses of ozone episode meteorology and model sensitivity performed by the University of Maryland, the Technical Committee members and the Domain Lead will recommend the episodes to be modeled using ROM or its substitute to the Policy Committee. Upon the Policy Committee's approval, EPA will be requested to run ROM or its substitute for those days in order to develop UAM model run files.

The procedure for coordinating the implementation of the Urban Airshed Modeling Project with the implementation of the Regional Oxidant Modeling for the Northeast Transport Region Project will be set by the Technical Committee. The Policy Committee and the certified organizations will oversee these decisions through regular briefings and offer guidance in cases where these decisions may have later policy implications. The Technical Committee members and members of other committees involved in the UAM project who are also members of ROMNET-II committees will make sure that there is discussion and agreement on selection and evaluation of regional control strategies, and on use of emission inventories, selection of projection years, modeling domains and episodes, etc., so that consistency between the regional and urban modeling efforts is assured.

The following members of the Baltimore-Washington Urban Airshed Modeling Project are also members of the ROMNET-II committees:

ROMNET-II Modeling Committee

Rich Scheffe, EPA OAQPS (919) 541-4650

Todd Ellsworth, EPA Region III (215) 597-2906

Tad Aburn, Maryland MDE (410) 631-3245

Kirit Chaudhari, Virginia DEQ (804) 698-4414

ROMNET-II Emissions Committee

Chet Wayland, EPA OAQPS (919) 541-4603

Rich Scheffe, EPA OAQPS (919) 541-4650

David Arnold, EPA Region III (215) 597-4556

Don Wambsgans, District of Columbia DCRA (202) 645-6093

ROMNET-II Strategy Committee

Rich Scheffe, EPA OAQPS (919) 541-4650

David Arnold, EPA Region III (215) 597-4556

James Sydnor, Virginia DEQ (804) 698-4424

Relationship to Other Urban Area Modeling Protocols

The Domain Lead shall meet periodically with the leads of other domains in the Northeast. Quarterly meetings or conference calls are envisioned. EPA Regional and OAQPS participation is essential for these meetings, so OAQPS will be requested to organize these meetings. All members of individual domain policy and technical committees will be invited to attend these meetings.

The domain leads for the other domains of the Northeast are:

New York: Gopal Sistla, New York State DEC (518) 457-3200

Philadelphia-New Jersey: Chris Salmi, EOHSI (609) 984-3009

New England: Steve Dennis, Massachusetts DEP (617) 292-5766

Relationship to Other Interested Parties

A periodic modeling newsletter will be made available to interested parties so that industries, businesses, and the public in general can receive information about the project. An ad hoc Technical Advisory Group composed of representatives from industries, businesses, and academic institutions was established to provide an open framework for technical cooperation in the domain modeling effort and as much consistency as possible with outside parties performing urban airshed modeling. The Domain Lead, in consultation with the Policy Committee, may schedule periodic open meetings or consultation sessions with interested parties. Outside interest group participation and review of the modeling project will also be accomplished regionally through the ROMNET-II and OTC framework.

II. DOMAIN AND DATABASE ISSUES

Preprocessor Programs

EPA's Emissions Preprocessor System (EPS 2.0) will be used to process all emissions data including biogenic emissions. Motor vehicle emission factors will be calculated by EPA's Mobile 5.0a. Projection year inventories will be calculated using Mobile 5.0a. The emissions inventory will be gridded and temporally allocated using EPS 2.0.

EPA's ROM-UAM Interface System will be used to process boundary and meteorological data. EPA's Diagnostic Wind Model will be used to calculate wind fields for those episodes not obtainable from the ROM-Interface.

Databases

Meteorological data will consist of National Weather Service surface airways observations and upper-air observations obtained from the National Climatic Data Center. Surface data will be supplemented by MDE regional and middle scale air monitors. Missing data will be processed according to Atkinson and Russell, Procedures for Substituting Values for Missing NWS Meteorological Data for Use in Regulatory Air Quality Models. Additionally, MDE has obtained upper air data from military and private observation stations located within the domain.

Even though they are outside of the domain, upper air observations from Atlantic City, New Jersey and Wallops Island, Virginia may be used in addition to Dulles Airport observations depending on the results of the sensitivity analysis.

Emissions data will be processed from the AIRS database through EPS 2.0. The Policy and Technical Committees will decide on the method used to determine the mobile source emissions data.

Air quality data will be obtained from state urban and regional scale monitors as available through AIRS.

Episode Selection

The most recent EPA guidance will be followed except as noted below. Meteorological regimes associated with high O_3 episodes will be identified, for the period 1987-1990, with conditions resulting in distinctly different source-receptor relationships given prime consideration (EPA, 1991).

The procedure for identifying meteorological regimes will vary from the procedure recommended in Appendix B of the EPA guidelines. In particular, the use of surface wind roses to distinguish meteorological regimes has been investigated for the Baltimore-Washington domain and has been found to be insufficient to distinguish between weather patterns associated with severe O_3 episodes. In general, the wind conditions for O_3 exceedance events (1983-1990) do not vary significantly from mean summer conditions in which frequencies are fairly uniform throughout the south to west quadrant.

In order to provide more insight into the question of characteristic weather regimes, the episode selection procedure will include subjective and objective analyses. The type of objective analysis to be used is the classification and regression tree analysis (CART) (Horie, 1987). CART is used in the meteorological community for both categorization and prediction (e.g., Burrows, 1991). It has been cited as particularly applicable to O_3 studies by previous EPA guidance as well as independent researchers (Seinfeld, 1988; National Research Council, 1991). A more detailed description of the CART analysis is given in Appendix C. In general, CART creates clusters (terminal nodes) of cases using meteorological variables as predictors and an O_3 measure as the predictand. Each node contains cases which have similar meteorological conditions and O_3 concentrations. The predictors used will be surface observations (4 times daily) at Baltimore-Washington International Airport (BWI) and twice daily upper air data from the nearest radiosonde station, Dulles International Airport (DIA) for the period 1983-1990. A number of variables relating to transport and vertical stability will be derived from the upper air data. Data from June through August will be used in order to provide a data set that is seasonally consistent with respect to characteristic weather patterns. For the purposes of final selection, of course, all O_3 exceedance days will be considered.

Because the CART analysis relies on station data alone, additional subjective analysis will be undertaken to identify characteristic O_3 weather patterns. In particular, subjective analysis will be used to determine source-receptor relationships that are evidenced by region-wide transport. For this purpose, multi-day O_3 events for the period 1983-1990 will be analyzed for surface pressure patterns, frontal zone position and upper air transport patterns. Multi-day events will be the focus of the subjective analysis because 29 of the top 30 O_3 days in the 1983-1990 period were part of multi-day events. The upper air data will be provided by National Weather Service (NWS) constant pressure charts for 850 millibar (mb). The height of the 850 mb surface is typically 1500 m and is indicative of conditions at the top of the UAM model volume. Wind data at 850 mb is more reflective of domain-wide, and regional, transport because it is less likely to be corrupted by micro-scale effects related to surface station location and meso-scale effects such as the bay breeze regimes that are common in the Baltimore and Washington ozone non-attainment areas (Segal, et al., 1982; Scofield and Weiss, 1977).

The results from the subjective and objective analyses will be compared with each candidate from the CART terminal nodes and the subjective analysis ranked by peak domain O_3 observations (severity measure) and domain mean maximum O_3 observations (pervasiveness). To the extent practicable, efforts will be made to mesh the high-ozone terminal nodes from CART with the source-receptor regimes determined by subjective analysis. In the event of disagreement, the prime consideration will be different source-receptor relationships as evidenced by transport patterns.

The episode days to be modeled will be selected from among the three highest ranked episode days from each meteorological regime with at least one day modeled from each identifiable regime. In choosing from among the top-ranked episode days, consideration will be given to the availability and quality of the air quality and meteorological data base as well as the likelihood of good model performance given the meteorological conditions. In particular, the episode must be of a type that the UAM can adequately simulate (Seinfeld, 1988). Thus, cases which include unusual discontinuities in meteorological variables, such as often occur with frontal zones, may not be acceptable.

Simulations will start at least 24 hours prior to 8:00 a.m. on the day of interest to mitigate the effects of potentially poorly defined initial conditions on modeling results.

Size of the Modeling Domain

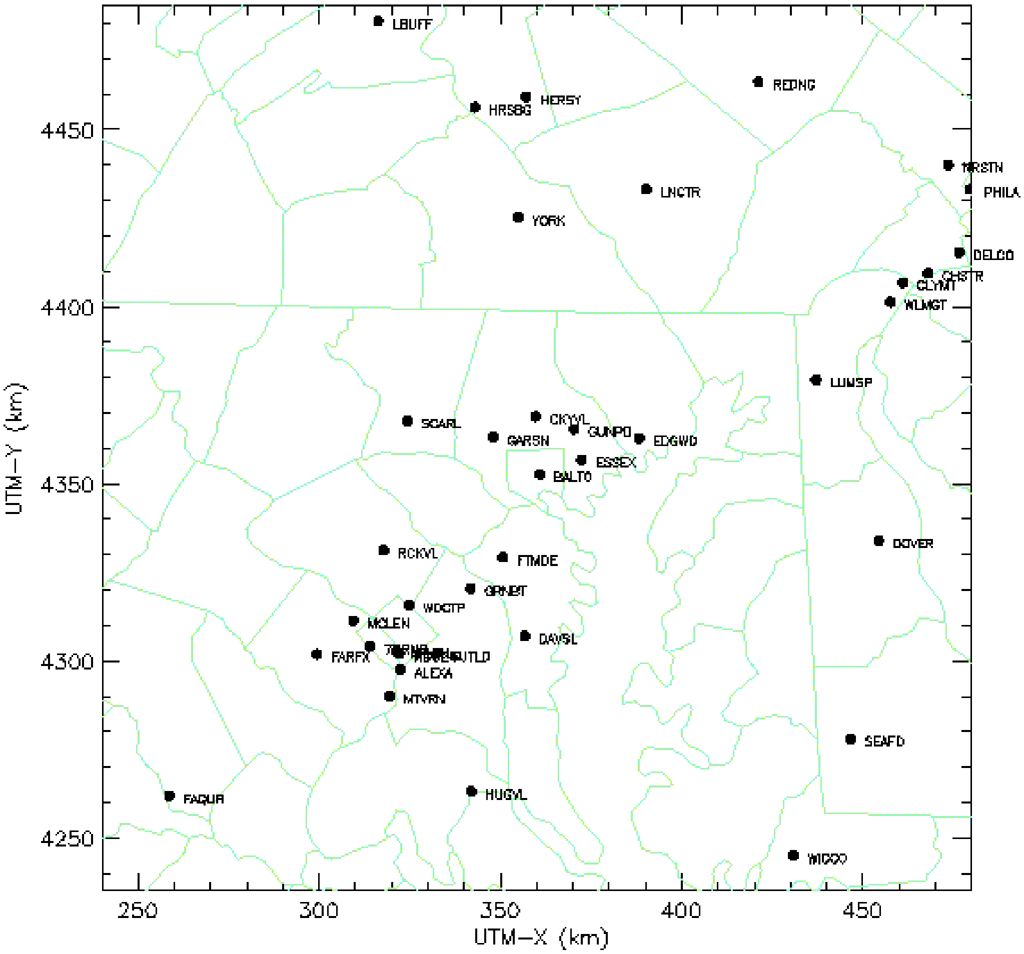
The origin of the initial grid will be at 250 km E and 4,235 km N, in UTM zone 18, near the Virginia town of Richards Shop. Its northward extent will be 250 km north and its eastward extent will be 230 km east of the origin. This domain includes all non-attainment counties and all major area and point sources in the Baltimore and Washington ozone non-attainment areas. The boundaries may be expanded if, after modeling, wind field analysis indicates that emissions from the Baltimore or Washington area leave the domain before 8 PM of the episode day. A map of the proposed modeling domain is shown on Figure 3.

Horizontal Grid Size

Each grid cell in the domain will be a square, 5 km on a side.

Number of Vertical Layers

The model will be run using five vertical layers with three layers above the morning mixing height (diffusion break in UAM). Additionally, the top of the modeling domain (region top in UAM) will be specified above the mixing height by at least the depth of one upper layer cell. This will be done by setting the region top value equal to the maximum mixing depth plus the minimum depth of the upper layer cells.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NRSTN
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LNCTR
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CKYVL
GUNPD
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GRNBT
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MCLEN
DAVSL
FARFX
ALEXA
MTVRN
SEAFD
FAQUR
HUGVL
WICCO
4450
4400
4350
4300
4250
250
300
350
400
450
UTM–Y (km)
UTM–X (km)

Figure 3
UAM Modeling Domain
for Baltimore-Washington, DC CMSA

Scale: 1".25 km, each tick mark is 10 km
UTM zone 18, Eastings in km on top, Northings on right

Emission Inventory

The assumptions, methodologies, appropriate guidance references and quality assurance procedures to be used in constructing the modeling emission inventory for both attainment and nonattainment areas are described in the Inventory Preparation Plan (IPP) of the respective jurisdictions. For attainment counties within the modeling domain, the inventory preparation methods will be much less rigorous. For these counties, point sources will be used if they exceed a 100 ton per year VOC, NO_x, or CO actual emissions level. The 25 mile nonattainment area boundary concept for inclusion of sources in the inventory will not be used. The inclusion boundary is the boundary of the modeling domain.

Area sources will be inventoried on a countywide basis based on the simplest surrogate indicators, such as population or housing units. Mobile source emissions will be inventoried using MOBILE 5.0a and Highway Performance Monitoring Statistics (HPMS) estimates of countywide VMT provided by state highway administrations or other individualized methods approved by EPA. For the projection year mobile source emissions estimates, MOBILE 5.0a will be used.

Emissions obtained via AIRS will be processed into model format by the Emissions Preprocessor System Version 2.0. As described by the User's Guide for the Urban Airshed Model (Volume IV Revised: User's Manual for Emissions Preprocessor System 2.0).

VOC Speciation

EPA default profiles will be used, because no speciated VOC emissions data compatible with the UAM's Carbon IV mechanism is available for the modeling domain. If speciated emissions data for some sources is developed in the future, it will be used in lieu of default values.

Spatial Gridding of Area Sources

EPA guidance contained in the Procedures for the Preparation of Emission Inventories for Volatile Organic Compounds, Volume II: Emission Inventory Requirements for Photochemical Air Quality Simulation Models will be followed to allocate area sources into model grids.

Mobile Sources

Within the inner urban core of nonattainment area counties, bottom/up methods will be used to develop the VMT inputs for the most recent MOBILE model to resolve variations in speed and VMT among different grids over hourly time slices. Peripheral or less dense traffic areas within nonattainment counties will be treated with top/down methods. In the attainment counties located within the modeling domain, available countywide VMT estimates from state highway agencies will be used.

Episode-specific Adjustments

The emission inventories prepared for 1990 will be adjusted to reflect specific inventory characteristics consistent with the year of each episode being modeled. For point sources, this will mean that gross changes in emissions from year to year at a source will require case-by-case adjustments to that source's emission rate used for modeling. Adjustments for area source categories will be made by using EPS 2.0 Bureau of Economic Analysis growth factors.

Mobile emissions will be adjusted for episode-specific temperatures and years. This will be done by running the MOBILE model using episode-specific maximum and minimum temperatures and fleet descriptions to create look-up tables for use in developing the gridded inventory.

If available, episode-specific operating rates for point sources will be used for estimating temporal point source emissions.

Biogenic Emissions

Biogenic emissions will be developed for each model simulation (i.e. base case and control strategy). Biogenic Emission Inventory System (BEIS/BEISII) will be used to derive the inventory. If alternative land use factors are used in BEIS/BEISII, they will be described and documented. Methods other than BEIS/BEISII may be considered for deriving the biogenic emissions if they become available for future model applications.

Point Source and Plume Rise Cut-Off Levels

For modeling purposes, point sources will be selected using the minimum cutoff levels for VOC, NOx, and CO in the following table.

Point source records will have stack data to calculate effective plume height and determine the height emissions are injected into the modeling system. Below an effective plume height of 50 meters, emissions will be allocated as an area source.

Minimum Levels for Point Source Inventory by Area

Designation/ Classification	VOC (T/Y)	NO_x(T/Y)	CO (T/Y)
Severe	10	25	100
Serious	10	50	100
Moderate*	10	100	100
Marginal*	10	100	100
Transport Region	100**	100	100
Attainment/Unclassifiable	100	100	100

*For marginal or moderate areas within the Northeast Transport Region, requirements for the transport region supersede less stringent classification requirements.

**Some states have individually inventoried sources at a lower minimum; in such cases this expanded data will be used.

Consistency with National Inventories

Documentation will be provided that shows that the modeling emissions inventory is consistent with the emissions inventory reported to AIRS.

Additional Input Data Sources (from Appendix A of EPA's "Guidelines"):

Cloud Cover .... NWS
Water Vapor.......................... Calculated from relative humidity and surface temperature
Radiation.............................. From UAM's "sunfunc" and "metscl" preprocessor
Surface Temperature............. NWS
Terrain.................................. ROM/UAM interface
Land Use.............................. ROM/UAM interface

Wind Fields

The Diagnostic Wind Models will be used to derive most of the UAM gridded wind fields for all episodes. Since ROM applications are inappropriate in the judgement of the Technical Committee, the Diagnostic Wind Model (DWM) contained in UAM will be used.

Data Needs for Wind Field Development

At a minimum, meteorological data from the National Weather Service (NWS) hourly surface and upper air observations will be used for the UAM modeling demonstrations. Additional meteorological data from other sources in the domain, such as on-site meteorological monitoring programs at industrial facilities and the states' air monitoring stations may be used to supplement the NWS data provided the data have been adequately quality assured. The U.S. EPA guidance document entitled On-Site Meteorological Program Guidance for Regulatory Modeling Application will be consulted for proper siting of the on-site meteorological program.

Mixing Heights

At a minimum, the techniques described in Volume II of the UAM User's Guide will be used in establishing the mixing height field for the domain. If more than one upper air station is available, then a spatially varying mixing height field will be developed.

The choice of upper air station that will be used in the mixing height calculations will be based on prevailing wind fields and the location of the upper air stations within the domain. These include Dulles International Airport in Virginia and Aberdeen Proving Ground in Maryland. Stations outside the domain, such as Wallops Island, VA and Atlantic City, NJ may also be used.

EPA's ROM/UAM interface system cannot handle spatially varying mixing heights. Therefore, one aim of the sensitivity analysis will be to evaluate the effect of this simplification on ozone levels when compared to a more realistic variable mixing height across the domain.

Clear Sky Assumptions for Photolysis Rate Calculations

Clear sky conditions will be assumed for all runs.

Specification of Initial and Boundary Conditions

The ROM-UAM Interface System will be applied to derive the initial and boundary conditions for the episodes being modeled. In cases for which ROM predictions are not available, default background values will be used in accordance with the procedures recommended in the UAM "Guidance" for applying this approach. However, measured data will be used if the Technical Committee determines that sufficient measured data exists to justify the usage.

Performance Evaluation Data

The existing monitoring network is designed to observe high ozone levels under the meteorological regimes conducive to high ozone production in the modeling domain. The sampling and analysis program at each monitoring site provides data to calculate hourly values for ozone, NO, and NO_2. Monitors are generally sited to capture samples representative of the surrounding area and are not unduly influenced by nearby emission sources. At least one site is capable of sampling for speciated hydrocarbons with appropriate temporal and composition resolution. In the event future regulations on enhanced monitoring networks for severe, serious and extreme areas differ from these recommendations, those regulations will be followed.

III. MODEL DIAGNOSTIC ANALYSIS

Quality Assurance Testing of Component Fields

Prior to conducting sensitivity analyses and base case simulations, air quality, emissions and meteorological component fields will be reviewed for obvious omissions and inconsistencies. Such reviews will include but not be limited to the following:

Air Quality: compare plots of temporal and spacial fields with monitored data.

Emissions: compare spacial and temporal plots by emissions categories with major highway routes and locations of major point sources; trace emissions subcategory totals produced by the emissions preprocessor system.

Meteorology: plots of wind, temperature, and diffusion break fields will be reviewed by a meteorologist who is familiar with local meteorology. Reports of National Climatic Data Center quality assurance information and missing data will be reviewed. Approval from EPA will be sought for methods used to replace missing data values.

Diagnostic Testing of the Base Case Episodes

To aid the interpretation of simulation results, predicted and observed ozone concentration maps will be constructed for each base case episode. These concentration maps will present spatial information on the structure of the ozone plume.

Maps of concentrations at one or two hour intervals will be constructed over periods of most interest, including recirculation, stagnation and transport conditions.

Maps depicting the highest predicted daily maximum ozone value for each grid cell will also be prepared.

Predicted concentration to be used in the time-series plot will be consistent with a four-cell weighted average using bilinear interpolation of the prediction from the four adjacent grid cells nearest to the monitor location. Time-series plots will also be developed for NO, NO_2, and VOC species at selected locations, particularly for cases in which ozone time-series or mapping results do not appear consistent with observations.

Comparison of ozone precursors will be done for concentration levels above the monitoring equipment's detectable limits.

Additional Base Case Diagnostic Testing

Diagnostic testing of the model will begin with quality assurance testing on input data files other than aerometric data and the emissions inventory. Diagnostic testing of each base case episode will follow. Additional diagnostic tests for the base case will be considered through performance of various sensitivity tests. These may include using zero emissions, zero boundary conditions, and varying mixing height and wind speed estimates. Sensitivity testing of the model will be performed as described in Appendix D. The University of Maryland Department of Meteorology will be contracted to perform sensitivity analyses.

Consensus agreement will be sought among members of the Technical Committee responsible for implementing the modeling protocol concerning modifications made to input fields arising from the quality assurance testing. Any modifications will be documented and presented to the Policy Committee. In addition, all diagnostic steps will be documented to avoid misinterpretation of model performance results. Once confidence is gained through subjective analysis of the ozone concentration maps that the simulation is based on reasonable interpretations of observed data and that model concentration fields generally track, spatially and temporally, known urban scale plumes, a performance evaluation based on numerical measures will be conducted for each base case episode.

IV. **MODEL PERFORMANCE EVALUATION**

Performance Measures

At a minimum, the following statistical performance measures will be applied as measures for model performance evaluation:

1. Unpaired peak prediction accuracy[1] - percentage difference between domain wide simulated and observed peak unpaired in space or time.

2. Normalized bias[2] test - to provide a measure of the model's ability to replicate observed patterns during the times of day when available monitoring and modeled data are most likely to represent similar spatial scales.

3. Gross error[3] of all pairs above 60 ppb - in conjunction with bias, this metric will be used to assess base case performance and as a reference to other modeling applications. Gross error can be interpreted as precision.

4. Average station peak prediction accuracy - used to measure peak performance at all monitor sites through pairings based on time and space.

5. Bias of all pairs above 60 ppb - bias is a measure of the overall degree to which model predictions over or underestimate observed values. Zero bias for several observation-prediction pairs can be caused by a canceling effect of over and underprediction in different subregions. Overall accuracy can thus be associated with overall bias.

6. Bias of all station peaks - bias calculations will be performed on observation-prediction pairs associated with peak ozone values for each monitoring station to provide information on the ability of the model to replicate peak ozone observations.

7. Fractional bias for peak concentration, calculated for the mean and standard deviation of peak predicted and observed values, will be used to assess the model's ability to replicate peak ozone observations.

8. Spatial pattern comparisons of predicted and observed ozone concentrations, including a comparison of the predicted and observed daily ozone maxima will be used to provide an indication of the comparability of the predicted and observed ozone plumes.

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1 **Accuracy** is a measurement of how closely the results generated by a process (such as a computer model) correspond with the real values experienced in the population as a whole.

2 **Bias** is a measurement of the tendency of a process to produce results that are consistently higher or lower than the real (population) values. A statistic for a sample derived from an unbiased process is numerically the same as the corresponding statistic for the entire population.

3 **Error** is the combination of accuracy and precision, where precision is a measurement of the variability in a process.

9. Graphical displays, including time-series plots, ground-level isopleths, quantile-quantile

plots and scatterplots of predictions and observations will be developed for each modeled episode.

(See "Guideline for Regulatory Application of the Urban Airshed Model," EPA-450/4-91-013 for a full description of these measures.)

Assessing Model Performance Results

The results from the model performance simulation will be assessed by the following steps:

1. All the performance measures specified above will be applied.
2. A comparison will be made of the simulation performance measures with the following ranges:
   - X peak prediction accuracy: ± 15-20 percent
   - X normalized bias: ± 5-15 percent
   - X gross error of all pairs > 60 ppb: 30-35 percent
3. If all the simulation performance measures are within these ranges, and the additional performance measures specified above are within acceptable limits, the model will be judged to be performing as expected based on similar model applications.
4. If any of the simulation performance measures suggest performance worse than these ranges, then documentation will be prepared explaining why the performance is poorer than that generally expected. Also, the potential adverse effects of the poor model performance on control strategy evaluations will be documented.

Additionally, if the performance is worse than the above ranges, then the quality assurance record will be reviewed and the diagnostic testing will be reviewed to uncover neglected problems. Additional diagnostic tests as described in Tesche, et. al. may be performed to discover the cause of the poor performance. [See: Tesche, et. al.]

A complete description of the plan for analyzing the performance of the model is included in Ryan, et al., "Model Performance Analyses Plan" (Appendix D) and "Discussion of Model Performance Analysis Plan" (Appendix E).

V. ATTAINMENT DEMONSTRATION

Developing Future Year Base Case Model Inputs

Emission inventory guidance documents will be followed for developing projection year inventories for point, area, mobile, and biogenic emissions. These procedures address projections of spatial, temporal, and chemical composition change between the base year and projection year.

Wherever regional modeling predictions for the future base case are available, they will be used to project future base case initial and boundary conditions. If ROM results are not available for a future year, the data will be obtained according to EPA's Criteria for Assessing the Role of Transported Ozone in Ozone Nonattainment Areas.

Construction of Future Year Emission Control Strategies

The alternative control strategies for evaluation in the attainment demonstration will be selected by the Metropolitan Washington Air Quality Committee for the Washington ozone non-attainment area and by the Air and Radiation Management Administration for the Baltimore ozone non-attainment area. These will be selected from groups of strategies developed by the technical subcommittees responsible for identifying and developing the regulations and/or control measures for each ozone non-attainment area.

Consideration will be given to maintaining consistency with control measures likely to be implemented by other modeling domains which may be involved in region-wide analysis. Also, technology-based emission reduction requirements mandated by the Clean Air Act will be included in the future year model runs.

If regional modeling predictions for control strategy scenarios are compatible with the area-specific UAM control strategy, they will be used to establish the initial and boundary conditions for UAM simulations.

Procedures for selecting strategies will be developed by the certified organizations for Washington and Baltimore, the groups responsible for strategy selection.

Performing Future Year Simulations to Assess Various Control Strategies

The focus of the ozone attainment demonstration will be on the daily maximum one-hour concentration predicted at each location in the modeling domain. However, the scope of the attainment demonstration may examine the impact on other important metrics, such as concentration averaging times, population exposure, sub-domain and temporal impacts and effects on other pollutant species.

Since the attainment deadline for the Washington ozone nonattainment area is 1999 and the attainment deadline for the Baltimore ozone nonattainment area is 2005, control strategy analysis will be performed separately for the two areas. The Virginia Department of Environmental Quality will be responsible for performing 1999 UAM modeling for the entire Baltimore-Washington Domain with attainment analysis for the Washington nonattainment area. The Maryland Department of the Environment will be responsible for performing 2005 UAM modeling for the entire Baltimore-Washington domain with attainment analysis for the Baltimore nonattainment area.

To insure coordination and consistency between the activities of the two groups preparing modeling for the Baltimore-Washington Domain, all model inputs, parameters, assumptions (i.e. boundary conditions), analysis, and results for both attainment demonstrations shall be reviewed and approved by the UAM Technical Committee. A single schedule for all modeling activities will be prepared and maintained by the Technical Committee and approved by the UAM Policy Committee. The UAM Technical Committee will address the 1999 attainment demonstration and the 2005 attainment demonstration concurrently; every effort shall be made to consolidate data requests to other states, conduct similar types of analysis and to prepare the demonstrations within similar time frames. The Technical Committee shall review and approve any modeling information, such as model inputs, parameters and assumptions and any model results, before it may be used in presentations to the Policy Committee, the Ozone Transport Assessment Group, the Ozone Transport Commission, the Technical Advisory Group or to any organizations.

For the Washington ozone nonattainment area, modeling runs will be performed for the whole modeling domain using 1999 projection inventories developed for the entire domain. Ozone concentrations will be calculated for all grids within the entire domain. The 1999 modeling attainment analysis and demonstration will be focused on a subdomain which includes the Washington ozone nonattainment area as shown in Figure 4. A larger subdomain may be considered if the UAM Technical Committee agrees that the urban plume from the Washington nonattainment area is causing or significantly contributing to modeled exceedances in locations outside the proposed subdomain. All control measures expected to be in effect in 1999 within the entire Baltimore-Washington Domain will be included in the 1999 UAM model runs.

For the Baltimore ozone nonattainment area, modeling runs will be performed for the whole modeling domain using 2005 projection inventories developed for the entire domain. The 2005 modeling attainment analysis and demonstration will include the entire domain. All control measures expected to be in effect in 2005 within the entire Baltimore-Washington Domain will be included in the 2005 UAM model runs.

The attainment demonstrations for the Washington ozone nonattainment area for 1999 and for entire domain for 2005 will be based on EPA guideline documents. The SIP submittal will be made consistent with Section 110 (a)(2) (D) of the Clean Air Act.

Section 110(a)(2)(D) of the Clean Air Act requires each State Implementation Plan to contain provisions that prohibit emissions activity within the state that contribute significantly to violations of any National Ambient Air Quality Standard or the maintenance thereof, in another state. If emissions from either nonattainment area are shown by the model to significantly contribute to violations of the ozone standard anywhere in the domain in 2005, additional control measures will be expected from that nonattainment area after 1999 to further reduce emissions.

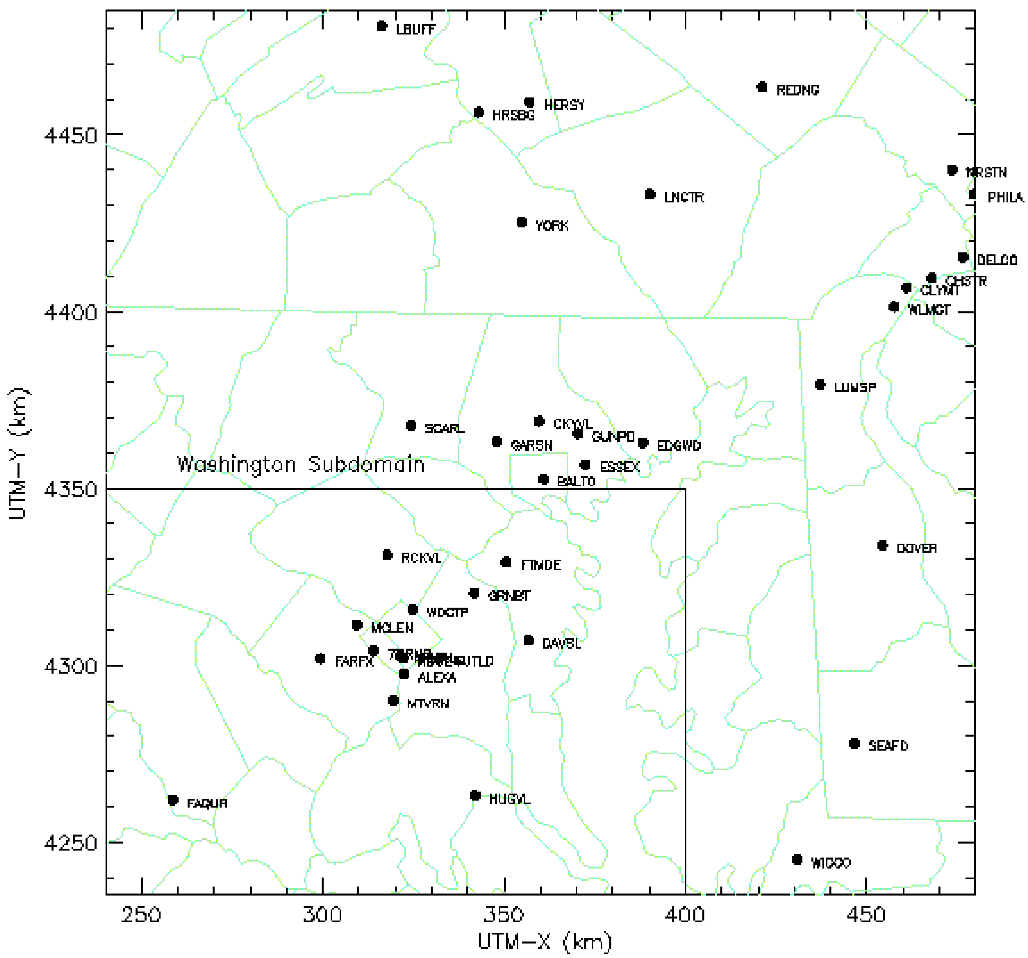

Figure 4

Washington UAM Analysis Subdomain

Scale: 1".25 km, each tick mark is 10 km

UTM zone 18, Eastings in km on top, Northings on right

Procedures for Attainment Demonstration

Attainment will be demonstrated when no predicted daily maximum ozone concentrations equal to or greater than 0.125 ppm are predicted anywhere within the nonattainment area for any of the 3 primary episode days modeled.

This deterministic approach, as recommended in EPA's Guideline for Regulatory Application of the Urban Airshed Model, does not correspond to the statistical nature of the ozone NAAQS. Therefore, the Technical Committee will explore alternative statistical approaches for demonstrating attainment. Any alternative approach will be approved by the Technical and Policy Committee, documented and submitted to EPA as an amendment to this protocol.

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APPENDIX A

Metropolitan Washington Certified Organization

APPENDIX B

Metropolitan Baltimore Certified Organization (Proposed)

Baltimore Regional Structure for Air Quality Plan Development

Air quality plan development responsibilities will remain similar to the 1982 SIP efforts. The stationary source portion of the 1982 SIP was primarily the responsibility of the Air Management Administration (now Air and Radiation Management Administration) while the Baltimore Regional Council of Governments (now Baltimore Metropolitan Council) was responsible for the transportation plans and demographic forecasts.

Responsibilities for the Air Quality Plan are outlined below. Three workgroups will provide the technical information as follows: Transportation Control Measure Workgroup, Fuels and Mobile Source Standards Workgroup, and Stationary Source Workgroup. The workgroups are designed to best utilize existing expertise in developing the air quality plan. The groups are assigned responsibility for plan development for the portion of the air quality plan in which they have the most expertise. It is envisioned that the workgroups will interact freely with each other and with the advisory groups so that each group will be able to participate in the development of the entire plan. This arrangement allows the individual workgroups to have the most direct input into strategies associated with areas directly under their control and at the same time allows them to participate in the development of the entire air quality plan.

Transportation Control Measure (TCM) Workgroup

As the Metropolitan Planning Organization, the Transportation Steering Committee (TSC) will be responsible for transportation control measure strategies that require commitment and support from the local governments. TSC has proposed a smaller subcommittee to select and prepare transportation control measures for the review of TSC. Subsequent to strategy selection TSC will build consensus for the strategies at the local level. TSC and the Technical Committee will be briefed regularly on the technical aspects of plan development from the other workgroups.

Fuels and Mobile Source Standards Workgroup

Responsibility for standards development for both fuels and vehicles will handled by the Mobile Sources Control Program of the Maryland Air and Radiation Management Administration. Development and evaluation of these strategies will require specific engineering expertise. This workgroup will work closely with Maryland Department of Transportation to plan these strategies.

Stationary Source Workgroup

The Maryland Air and Radiation Management Administration will develop stationary source strategies for both point and area sources.

Workgroup Interaction

Workgroup chairs will meet as soon as possible to establish a more formal process to insure interaction between the three workgroups.

ADVISORY GROUPS

Air Quality Control Advisory Council

The Air Quality Control Advisory Council is a legislatively mandated group responsible for reviewing regulations proposed by the Air and Radiation Management Administration (ARMA). The Administration is not bound by their advice, but their comments are almost always incorporated into air quality regulations. The Council is made of 15 members representing a variety of groups including industry, academia, professional associations, environmental groups, local governments, and the general public. Local elected officials have representatives on the Council and can voice opinions, assenting or dissenting, though the representative.

Public Awareness Workshops

Workshops will be held to brief the public on elements of the Air Quality Plan. Special efforts will be made to invite business, industrial, environmental, and representatives as well as the public at large.

PERIODIC POLICY BRIEFING BETWEEN MDE AND BMC

Briefing Council

The elected officials of the Baltimore Metropolitan Council will receive periodic briefings on the air quality plan by the Secretary of MDE at major decision points before the final SIP recommendations are made to the Governor.

APPENDIX C
Ozone Episode Selection:
Review and Recommendations

Ozone Episode Selection:
Review and Recommendations

for the Air Management Administration
Maryland Department of the Environment

W.F. Ryan
R.R. Dickerson

Department of Meteorology
University of Maryland

March, 1991

APPENDIX D

Model Performance Analyses Plan

Model Performance Analyses Plan

for the Air Management Administration
Maryland Department of the Environment

W.F. Ryan
R.R. Dickerson

Department of Meteorology
University of Maryland

11/12/91

APPENDIX E
Discussion of
Model Performance Analyses Plan

Discussion of Model Performance
Analyses Plan

for the Air Management Administration
Maryland Department of the Environment

W.F. Ryan
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Department of Meteorology
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11/12/91

Attainment Demonstration Modeling Report for the Washington DC-MD-VA Ozone Nonattainment Area

DRAFT

Attainment Demonstration Modeling Report for the Washington DC-MD-VA Ozone Nonattainment Area

Prepared by:

Commonwealth of Virginia
Virginia Department of Environmental Quality

January 15, 1998

Table of Contents

Executive Summary

Background

In accordance with the provisions of Section 182(C)(2)(A) of the Clean Air Act, as amended on November 15, 1990, serious and above ozone nonattainment areas must submit, as part of their State Implementation Plan (SIP), a demonstration using photochemical grid modeling that attainment will be achieved by the applicable date. The Washington Metropolitan Statistical Area (MSA) has been classified as a serious nonattainment area for ozone with an attainment year of 1999.

This document presents the 1999 UAM modeling attainment analysis and demonstration for the Washington ozone nonattainment area. The modeling runs were performed for the Baltimore-Washington UAM-IV domain using the 1999 modeling inventories developed for the entire domain. All control measures expected to be in effect in 1999 within the domain were included in the 1999 model runs.

UAM Model Inputs

<u>Emissions</u>

Two different future year base case emission scenarios were modeled:

Base 1 (99bs1): includes controls in the 1999 Rate-of-Progress Plan.
Base 2 (99bs2): includes Base 1 controls plus Phase II OTC-MOU NOx control in the Washington nonattainment area.

Eight sensitivity scenarios were also modeled.

<u>Boundary Conditions</u>

Boundary conditions were derived from the Ozone Transport Assessment Group (OTAG) regional modeling results. The 1999 attainment demonstration analyses focus on the Washington Subdomain, which includes most of the Washington ozone nonattainment area.

Summary of Modeling Results

The 1999 Phase I Attainment Plan for the Washington D.C. nonattainment area would result in significant ozone benefits in terms of peak ozone concentrations and the number of grid cell hours greater than 125 ppb over the base case conditions.

Boundary condition sensitivity runs show that the Baltimore/Washington domain experiences overwhelming transport of ozone from upwind areas. The Regional NOx controls, such as OTAG

Strategy Run I, would result in widespread significant ozone benefit in the Washington nonattainment area.

NOx reduction from point sources was predicted by the model to create small, localized increases in ozone concentration in the vicinity of the sources and urban centers, but decrease ozone concentration in a greater downwind area.

Additional NOx reductions of 60% (beyond the 1999 Rate-of-Progress Plan) from all point sources in the Washington nonattainment area would produce some local ozone benefits as well as regional benefit.

An additional NOx control of 30% (beyond the 1999 Rate-of-Progress Plan) from area and mobile sources in the Washington nonattainment area results in a significant ozone benefit to a larger area of the domain. Control of NOx from area and mobile sources yields greater benefits in peak ozone concentrations and grid cell hours greater than 125 ppb than as provided by the point source NOx control in the Washington D.C. area alone.

Further, additional reductions of VOC of 30% (beyond the 1999 Rate-of-Progress Plan) from area and mobile source controls in the Washington nonattainment area produce ozone reductions, but in a lesser magnitude and spatial extend than that of the NOx controls in the same categories.

Because of its technical limitations and the limitations on the accuracy of emissions and meteorological input data, modeling alone does not provide conclusive evidence of an ability or nonability of a particular strategy or group of strategies to attain the ozone standard. As correctly recognized by EPA, a “weight of evidence” consideration must be factored into the prediction of attainment. When examining the downward trend of ozone pollution, fewer monitored exceedances of the standard, and the shrinking number of monitors experiencing exceedances, it is appropriate to conclude that the anticipated control measures will achieve the one hour NAAQS for ozone.

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1. Introduction

The Washington D.C. Metropolitan Statistical Area (MSA) was designated as a "serious" ozone non-attainment area by the U.S. Environmental Protection Agency (EPA) based upon the air quality data during the period from 1987 to 1989. In accordance with the EPA's interpretation of Section 182(b) of the 1990 Clean Air Act Amendments (CAAA), "serious" ozone (O_3) non-attainment areas must submit, as part of their State Implementation Plan (SIP), an attainment demonstration using photochemical grid modeling. For the Washington D.C. ozone non-attainment area, the CAAA requires the use of a photochemical model to demonstrate the attainment of the one-hour ozone NAAQS by year 1999. This document has been prepared to comply with the Act and with the EPA memorandum of March 2, 1995 on the phased attainment demonstration process.

The selected modeling tool for 1999 modeling is the Urban Airshed Model (UAM)-version IV, which was adopted by EPA as the preferred guideline model for applications involving entire urban areas. The Virginia Department of Environmental Quality (VDEQ) is responsible for modeling the entire Baltimore-Washington domain for 1999 and preparing the attainment demonstration for the Washington D.C. ozone non-attainment area. The Washington D.C. ozone non-attainment area incudes the District of Columbia, Arlington, Fairfax, Loudoun, Prince William, and Stafford Counties, and the Cities of Alexandria, Falls Church, Fairfax, Manassas, and Manassas Park in Virginia; as well as Calvert, Charles, Frederick, Montgomery, and Prince George's Counties and the Cities of Bowie, College Park, Gaithersburg, Greenbelt, Frederick, Rockville, and Takoma Park in Maryland. Figure 1-1 depicts the Baltimore-Washington UAM modeling domain, the Washington Subdomain, and ozone monitoring sites. The Maryland Department of the Environment (MDE) is responsible for modeling the entire Baltimore-Washington domain for year 2005 and preparing the attainment demonstration for the other ozone nonattainment area inside the domain, the Baltimore ozone non-attainment area.

VDEQ is using the UAM to evaluate the effectiveness of ozone control strategies adopted in the regional air quality plan titled Proposed State Implementation Plan (SIP) Revision, Phase I Attainment Plan, and Revision to the SIP to Achieve a Fifteen Percent Reduction in Volatile Organic Compound Emissions, and Revision to the 1990 Base Year Emissions Inventory for Stationary Anthropogenic, Biogenic Sources and Highway Vehicle Emissions of Ozone Precursors for the Washington DC-MD-VA Non-attainment Area, October 27, 1999 (thereafter referred to as Phase I Attainment Plan) and additional controls needed for the area to achieve attainment. The Phase I Attainment Plan has been prepared by the Metropolitan Washington Air Quality Committee (MWAQC). MWAQC was established by the governors of Maryland and Virginia and the mayor of the District of Columbia to prepare a regionally coordinated air quality plan. MWAQC will incorporate the UAM modeling results and attainment demonstration information into the Phase I Attainment Plan and prepare a "Phase II Attainment Plan" for the region.

Virginia, Maryland, and the District of Columbia will also use the modeling results and the Phase I Attainment Plan as the foundation for the SIP Revision each jurisdiction must submit to the U.S. EPA in April 1998.

The Phase I Attainment Plan contains control measures designed to meet the 15% Rate-of-

Progress Plan (ROP), the Post-1996 9% Rate-of-Progress Plan requirements of the CAAA, and additional control measures not required by the CAAA such as the Phase II NOx controls.

The attainment demonstration is summarized in the following seven sections: 1. Modeling Protocol; 2. Episode Selection; 3. Modeling Inventory Preparation and Quality Assurance; 4. Air Quality and Meteorological Data Preparations; 5. Model Performance Evaluations; 6. 1999 Future Year simulations; and 7. Data Access. Details of these sections are contained in the seven attached appendices.

2. Modeling Protocol

The modeling protocol describes the scope of the analysis, including the days modeled (modeling episodes), the domain size, and the participating state and federal agencies. "Protocol for Regulatory Photochemical Air Quality Modeling of the Baltimore-Washington, DC Region" has been approved by EPA and is found in Appendix B1. The protocol details and formalizes procedures for conducting all phases of the modeling study such as:

- Stating the background, objectives, tentative schedule and organizational structure for the study
- Developing the necessary input databases
- Conducting quality assurance and diagnostic model analyses
- Conducting model performance evaluations and interpreting modeling results
- Describing procedures for using the model to demonstrate whether proposed strategies are sufficient to attain the O_3 National Ambient Air Quality Standards (NAAQS).

The Protocol was prepared by the Maryland Department of the Environment in consultation with the Virginia Department Environmental Quality, the District of Columbia Department of Consumer and Regulatory Affairs, the Metropolitan Washington Council of Governments, the U.S. Environmental Protection Agency, Region III and the University of Maryland, Department of Meteorology. The protocol has been approved by the EPA.

Figure 1-1. Baltimore-Washington UAM-IV Domain

3. Episode Selection

Appendix B2, Episode Selection, describes the selection of ozone episodes used in the modeling process. Episodes within the period of non-attainment classification (1987-1991) were considered. A primary consideration in the selection process is the determination of meteorological regimes which will adequately represent conditions present during the majority of high ozone episodes. The goal of the attainment demonstration is to determine the robustness of proposed control strategies under a variety of weather scenarios. A classification scheme of meteorological regimes present during the high ozone episodes and the methodology used for determining the candidate episodes to be modeled for attainment demonstration purposes are presented here.

The selected episodes for the Baltimore-Washington UAM simulation process were:

Episode 1: July 5- 7, 1988
Episode 2: July 29-30, 1988
Episode 3: July 18-20, 1991
Episode 1a: June 12-14, 1988
Episode 3b: July 14-16, 1991

Due to time constraints of the phased attainment demonstration requirements, Episode 1, Episode 1a and Episode 2 are not included in this document.

4. Modeling Inventory Preparation and Quality Assurance

The development of base case modeling inventories is essential for evaluating the performance of the UAM model. In this section, the discussions will briefly describe the emissions database used to develop base case modeling inventories and the quality assurance applied. Appendix B3 contains detailed discussions of the development of base case and future year modeling inventories and QA/QC procedures applied.

The base case inventories were compiled for each day of the three episodes. In general, the 1990 SIP emission inventories served as the basis for the development of 1988 and 1991 base case modeling inventories.

The development of the base case point, area, off-road and on-road source modeling inventories for Virginia, Washington, D.C., and Maryland portions of the domain were derived by extracting the 1990 SIP emissions from the USEPA Aerometric Information Retrieval System (AIRS) - AIRS Facility Subsystem (AFS) and Area & Mobile Source Subsystem (AMS) in an EPS2.0 ready format. The OTAG emissions inventories were used for the remainder of the modeling domain. This includes portions of Pennsylvania, New Jersey, Delaware and West Virginia. The 1990 emissions were back casted to 1988 and forecasted to 1991 using growth rates from the Bureau of Economic Analysis (BEA). The BEA data used in the growth factor development were found in the EPS2.0 system.

VDEQ performed extensive quality assurance and quality control (QA/QC) review of the 1990 base year emission inventories for the Washington non-attainment area . It was assumed that the integrity of the base-year data provided by OTAG for Pennsylvania, New Jersey, Delaware and West Virginia have also received adequate QA/QC review.

The QA/QC procedures ensure that the emissions produced by the AFS and AMS work-files for modeling purpose match that reported in the Phase I Attainment Plan. During the QA/QC process, necessary changes have been made to AFS and AMS work-files. Table 4-1 through 4-4 shows comparison of emissions produced by EPS2.0 using AFS and AMS work-files with that reported in the Phase I Attainment Plan for the Washington ozone nonattainment area.

Another important component of the modeling inventory is the biogenic emissions. Biogenic emissions come from natural sources, such as, trees and agriculture crops. Both UAM-BEIS1 and UAM-BEIS2 computer software were used to estimate biogenic emissions. Figure 4-1 shows total gridded VOC and NOx emissions within the Baltimore-Washington modeling domain for July 18, 1999. Figure 4-2 and Figure 4-3 show comparisons of gridded emissions between sources for July 18, 1991. When UAM-BEIS1 is used, biogenic VOC emissions account for approximately 37.19% of the total VOC emissions within the domain. When UAM-BEIS2 is used, biogenic VOC emissions account for approximately 64.83% of the total VOC emissions within the domain.

Table 4-2. Comparison of 1990 Base Year Point Source Emission Estimates for Washington Non-attainment Area

VOC Estimates (Tons/Day)

Jurisdiction	Phase I	EPS2.0	Difference
District of Columbia	1.0	1.0	0.0
Maryland	5.5	5.6	0.1
Virginia	8.1	7.7	-0.4
Total	14.6	14.3	-0.3

NO_x Estimates (Tons/Day)

Jurisdiction	Phase I	EPS2.0	Difference
District of Columbia	7.6	7.6	0.0
Maryland	267.4	266.7	-0.7
Virginia	59.8	58.4	-1.4
Total	334.8	332.7	-2.1

Table 4-3. Comparison of 1990 Base Year Area Source Emission Estimates for Washington

Non-attainment Area

VOC Estimates (Tons/Day)

Jurisdiction	Phase I	EPS2.0	Difference
District of Columbia	20.0	19.5	-0.5
Maryland	94.2	92.8	-1.4
Virginia	77.0	77.0	0.0
Total	187.1	185.7	-1.9

NO_x Estimates (Tons/Day)

Jurisdiction	Phase I	EPS2.0	Difference
District of Columbia	3.4	3.0	-0.4
Maryland	15.8	15.8	0.0
Virginia	28.1	28.2	0.1
Total	47.3	47.0	-0.3

Table 4-4. Comparison of 1990 Base Year Non-Road Source Emission Estimates for Washington Non-attainment Area

VOC Estimates (Tons/Day)

Jurisdiction	Phase I	EPS2.0	Difference
District of Columbia	5.5	5.8	0.3
Maryland	32.1	31.7	-0.4
Virginia	32.8	32.9	0.1
Total	70.4	70.4	0.0

NOx Estimates (Tons/Day)

Jurisdiction	Phase I	EPS2.0	Difference
District of Columbia	5.5	5.6	0.1
Maryland	43.5	44.0	0.5
Virginia	36.0	35.3	-0.7
Total	85.0	84.9	-0.1

Table 4-5. Comparison of 1990 Base Year Mobile Source Emission Estimates for Washington Non-attainment Area

VOC Estimates (Tons/Day)

Jurisdiction	Phase I	EPS2.0	Difference
District of Columbia	32.6	32.9	0.3
Maryland	108.4	109.6	1.2
Virginia	110.1	110.0	-0.1
Total	251.1	252.5	1.4

NOx Estimates (Tons/Day)

Jurisdiction	Phase I	EPS2.0	Difference
District of Columbia	25.8	26.0	0.2
Maryland	129.1	127.6	-1.5
Virginia	106.8	108.4	1.6
Total	261.7	262.0	0.3

1991 Gridded Emission Totals
B/W Domain

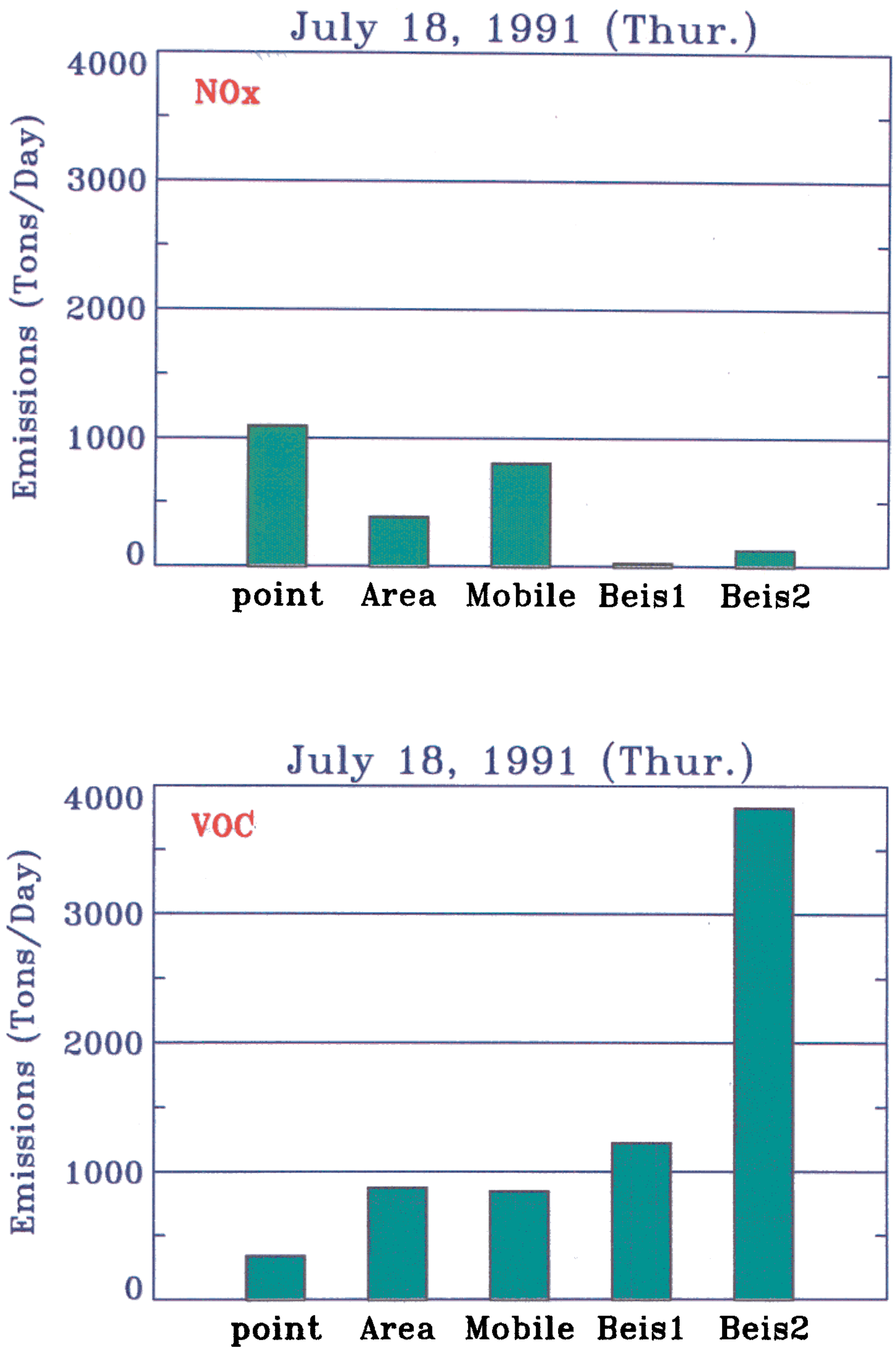

Figure 4-1. 1991 Gridded Emission Totals for B/W Domain

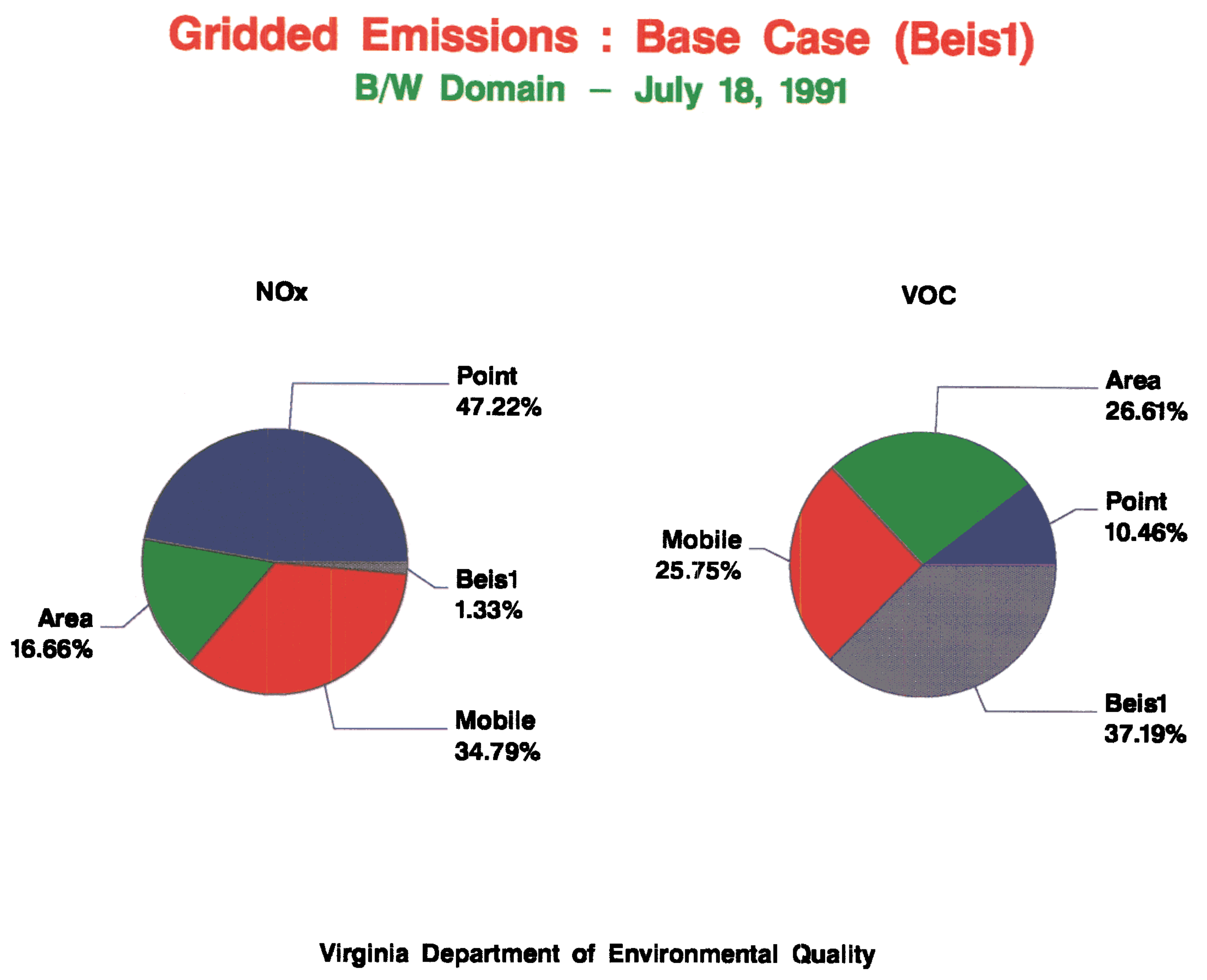

Figure 4-2. Gridded Emissions: Base Case (BEIS1)

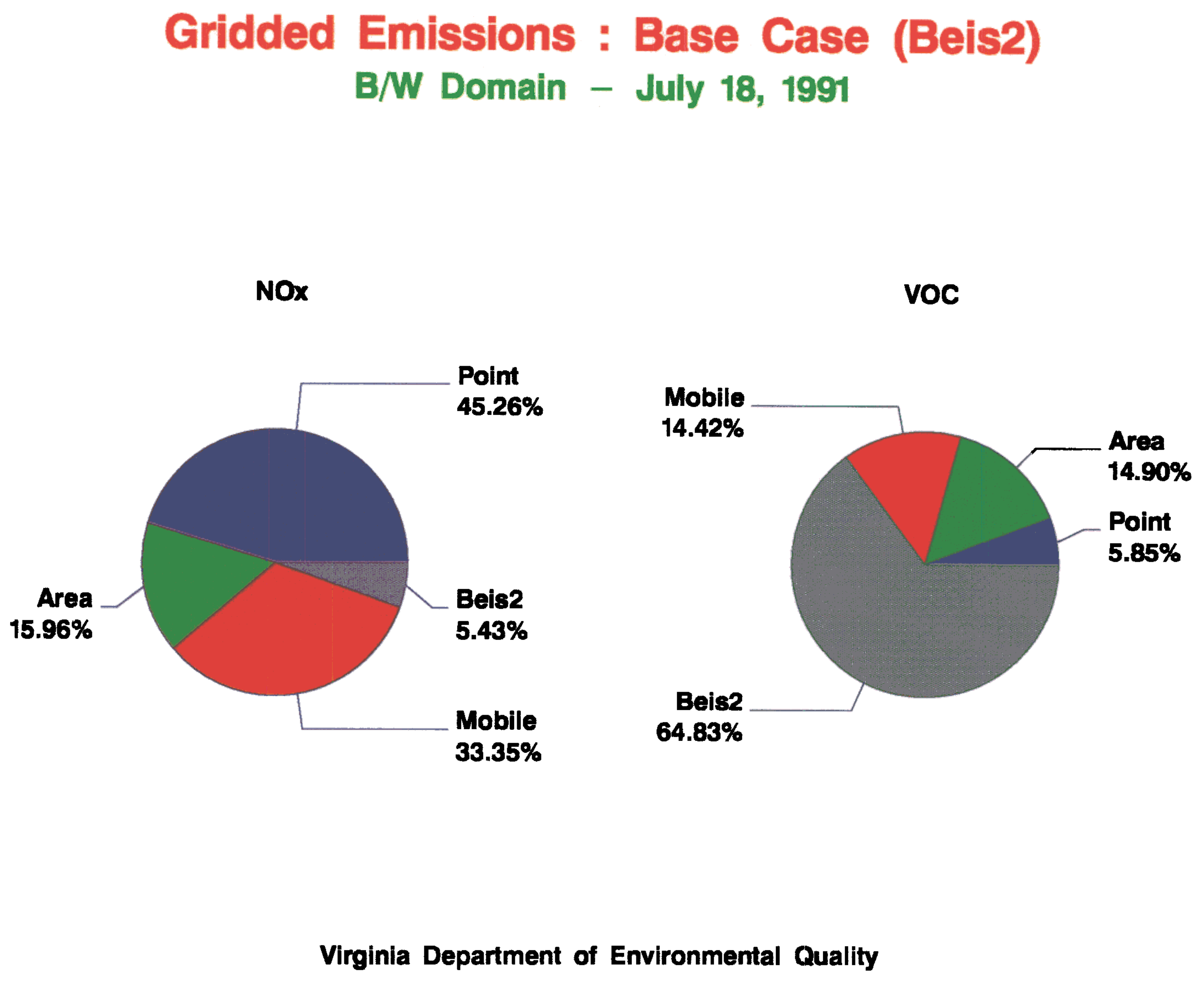

Figure 4-3. Gridded Emissions: Base Case (BEIS2)

5. Air Quality and Meteorological Data Preparations

Applications of the UAM require air quality and meteorological databases for simulating selected ozone episodes. Meteorological inputs for Baltimore-Washington UAM application have been prepared by the University of Maryland at College Park (UMCP). The primary meteorological components are temperature, wind and mixing heights. These fields are developed by assembling an extensive quality assured data base, processing this data, and developing meteorological fields that are realistic and acceptable to the UAM. The UAM requires the aforementioned components to be input in a three dimensional hourly grid. The procedures for data acquisition, quality assurance, and processing are supplied in Appendix B4. Also provided are the rationales for data inclusion or exclusion, and manual adjustments to the meteorological components. The ultimate goal of meteorologists involved in the UAM projects is to develop the most physically realistic UAM meteorological components possible.

6. Model Performance Evaluation

The model performance evaluation for two episodes during the summer of 1991 was completed with both BEIS1 and BEIS2 biogenic emissions. The two episode are Episode 3 (July 18-20, 1991) and Episode 3b (July 14 - 16, 1991). The observed ozone data from 38 ozone monitoring sites within the modeling domain was used for the model performance evaluation. The detailed graphical and statistical analyses of observed and predicted ozone data as well as information about the ability of the model to reproduce observed spatial and temporal patterns are provided in Appendix B5.

Tables 6-1 and Table 6-2 list statistical measures for the simulations of the two episodes. With either BEIS1 or BEIS2 biogenic emissions, the model generally overpredict the domain peak ozone concentrations based on unpaired peak accuracy, except for the BEIS1 simulation for July 20. Overprediction associated with BEIS2 biogenic emissions is more significant than that with BEIS1. However, for the second day and third day of the episodes the values of the unpaired peak accuracy meet the performance goal set by EPA for the two episodes with BEIS1, and nearly meet the performance goal with BEIS2.

The values of normalized bias of all pair greater than 60 ppb are within 12% and both episodes meet the acceptable performance goal for bias (±15%). The positive and negative signs of normalized bias indicate that the model overpredict in some cases and underpredict in others. The gross errors for the two episodes are within 25% and meet the EPA's performance goal regardless of BEIS1 or BEIS2 biogenic emissions. The differences in the values of gross error between BEIS2 and BEIS1 simulations are within 5%, indicating that the overall performance with BEIS2 is comparable to that with BEIS1.

Based on the time series plots (see Appendix B5), the model replicates the diurnal patterns of the hourly observed ozone reasonably well at most sites.

Ground-level isopleth plots of predicted daily maximum ozone concentrations for the episodes are displayed in Figures 6-1 through Figure 6-4. The observed daily maximum ozone concentrations at all sites are superimposed on the same plots. The ozone isopleth plots shown in the figures indicate that the spatial pattern of the predicted daily maximum ozone concentrations is reasonable for the two episodes. However, errors in the wind fields may have caused a small displacement of the elevated ozone plume downwind of Washington D.C. area on July 20. The daily maximum ozone were underpredicted in most Virginia portion of the domain on July 20. This may be due to the underpredictions of boundary ozone by regional model simulations. It apperas that the BEIS2 simulations overpredicted peak ozone concentrations, especially in the Baltimore area.

In summary, the model performance evaluation statistical measures and graphical displays show good agreement between observed and simulated ozone concentrations. The statistical measures also indicate that the model performance is acceptable for the two 1991 episodes with either BEIS 1 or 2 based on the EPA’s guideline. The model replicates the diurnal patterns of the hourly observed ozone reasonably well at most monitoring sites. Although the BEIS2 simulations may overpredict the peak ozone concentrations, the overall model performance with BEIS2 biogenic emissions is comparable to that with BEIS1 biogenic emissions. Model performance may be improved with more representative wind fields, emission data and boundary conditions for the episodes. Based on the acceptable performance, the two 1991 episodes can be used for the future year control strategy evaluations.

Table 6-1. UAM-IV Model Performance Statistics
Episode 3 (July 18-20, 1991)

Statistical Measures	7/18/91		7/19/91		7/20/91		EPA Criteria
	BEIS1	BEIS2	BEIS1	BEIS2	BEIS1	BEIS2	
Predicted Peak (ppb)	132.7	150.5	151.2	168.4	168.1	210.4	
Observed Peak (ppb)	127.0	127.0	132.0	132.0	178.0	178.0	
N. of Cells >= 125 ppb	24	111	100	203	213	394	
Recommended Performance Measures							
Unpaired Peak Accuracy (%)							
Normalized Bias > 60 ppb (%)	4.5	18.8	14.5	27.6	-5.6	18.2	± 20%
Gross Error > 60 ppb (%)	-7.8	-9.9	4.2	8.3	-10.4	0.6	± 15%
	22.1	22.1	17.7	24.2	24.0	24.1	35%
Additional Performance Measures							
Avg. Station Peak Accuracy(%)							
Bias of All Pairs>60 ppb	20.9	22.0	14.1	21.3	23.0	21.3	
Bias of All Station Peak(ppb)	-8.6	-10.6	2.3	5.6	-12.4	-1.1	
	-17.5	-16.6	-2.0	0.8	-19.0	-5.7	

Note: Negative sign indicates under-prediction

Table 6-2. UAM-IV Model Performance Statistics
Episode 3b (July 14-16, 1991)

Statistical Measures	7/14/91		7/15/91		7/16/91		EPA Criteria
	BEIS1	BEIS2	BEIS1	BEIS2	BEIS1	BEIS2	
Predicted Peak (ppb)	108.8	122.8	115.0	125.9	154.3	167.2	
Observed Peak (ppb)	82.0	82.0	102.0	102.0	137.0	137.0	
N. of Cells >= 125 ppb	0	0	0	1	113	245	
Recommended Performance Measures							
Unpaired Peak Accuracy (%)	32.7	49.8	12.7	23.5	12.6	22.0	± 20%
Normalized Bias > 60 ppb (%)	-0.7	-11.9	5.1	0.1	-5.3	-4.5	± 15%
Gross Error > 60 ppb (%)	12.8	16.7	13.8	19.0	18.2	23.4	35%
Additional Performance Measures							
Avg. Station Peak Accuracy(%)	15.2	16.9	15.0	20.6	15.3	21.0	
Bias of All Pairs>60 ppb	-0.6	-7.9	3.1	0.1	-4.7	-3.7	
Bias of All Station Peak(ppb)	1.5	-7.1	2.0	-2.7	-10.9	-10.4	

Note: Negative sign indicates under-prediction

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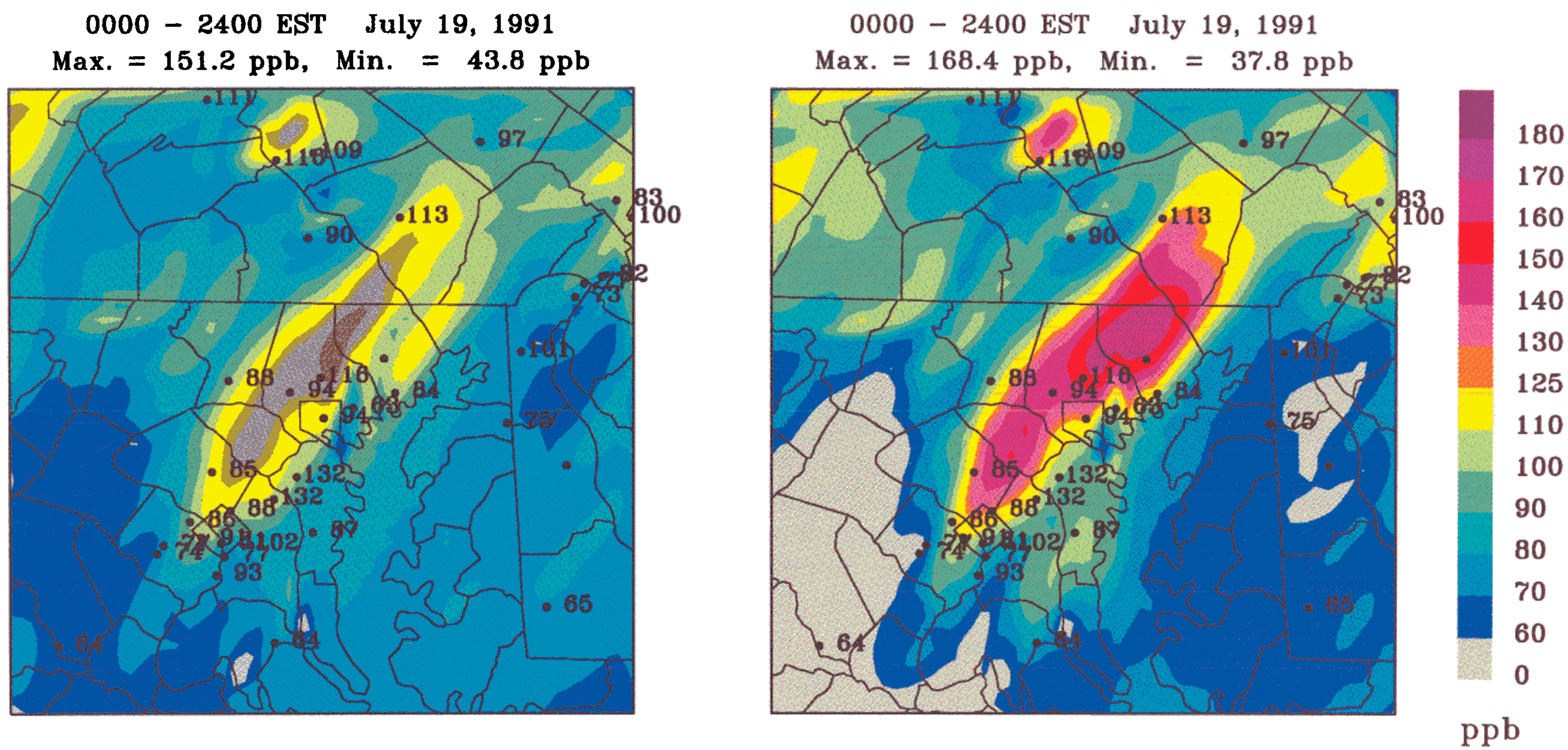
Figure 6-1

UAM Predicted Daily Max Ozone - 1991 Base Case

July 19, 1991

BEIS−1 | BEIS−2



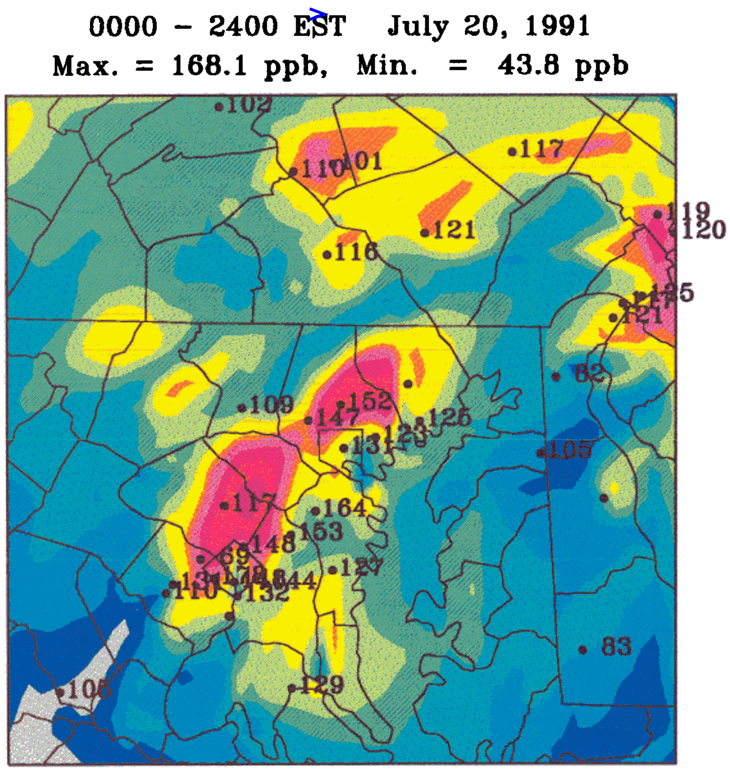
D-79

Figure 6-2

UAM Predicted Daily Max Ozone - 1991 Base Case

July 20, 1991

BEIS-1



BEIS-2

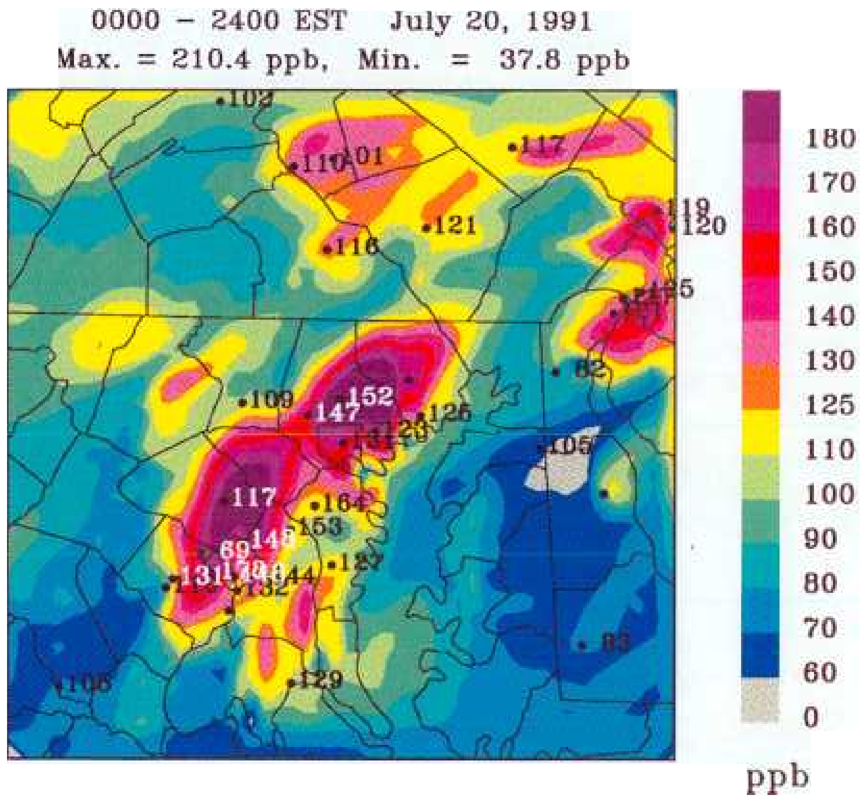


Figure 6-3

UAM Predicted Daily Max Ozone - 1991 Base Case

July 15, 1991

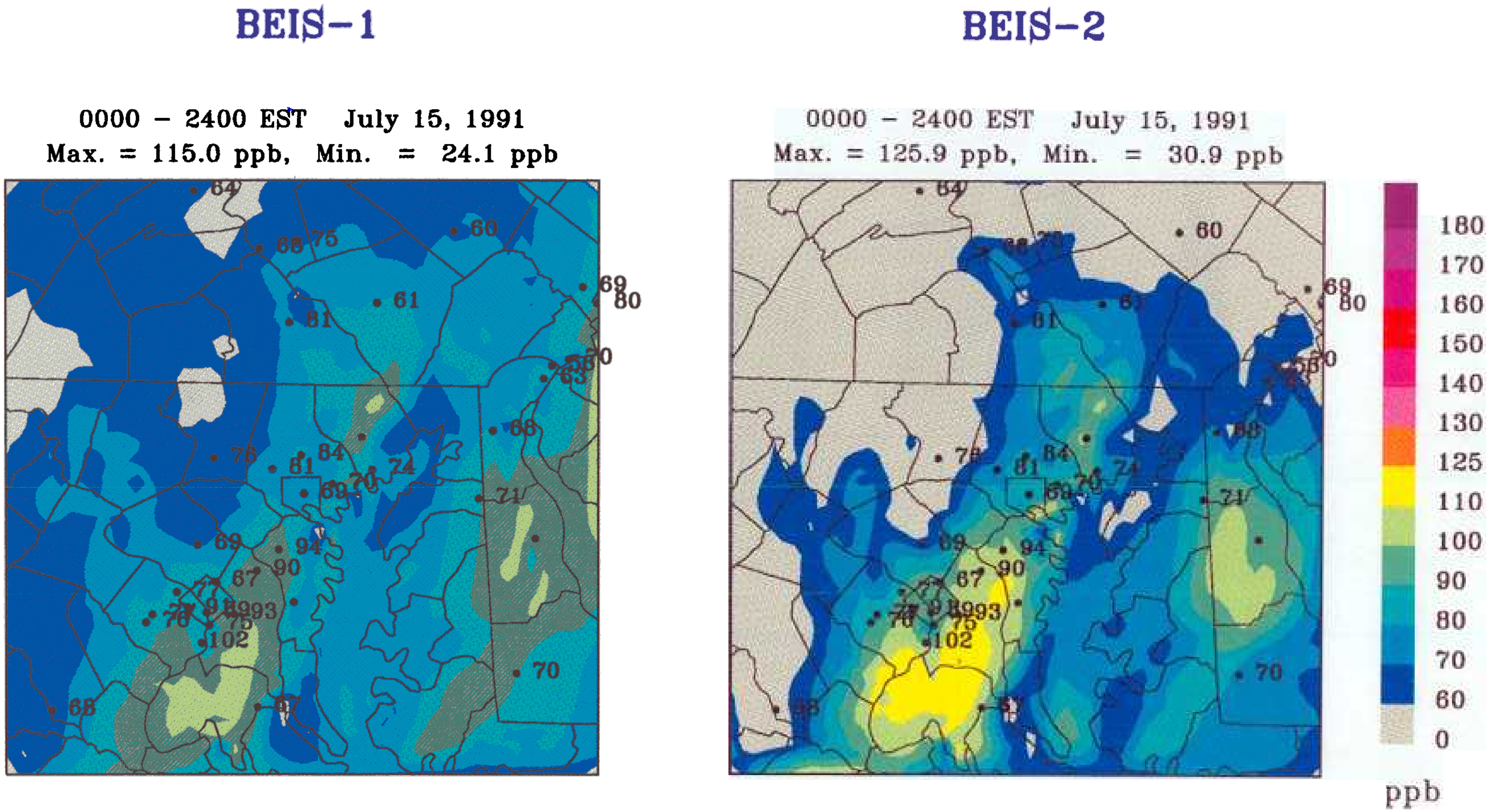


Figure 6-4

UAM Predicted Daily Max Ozone - 1991 Base Case

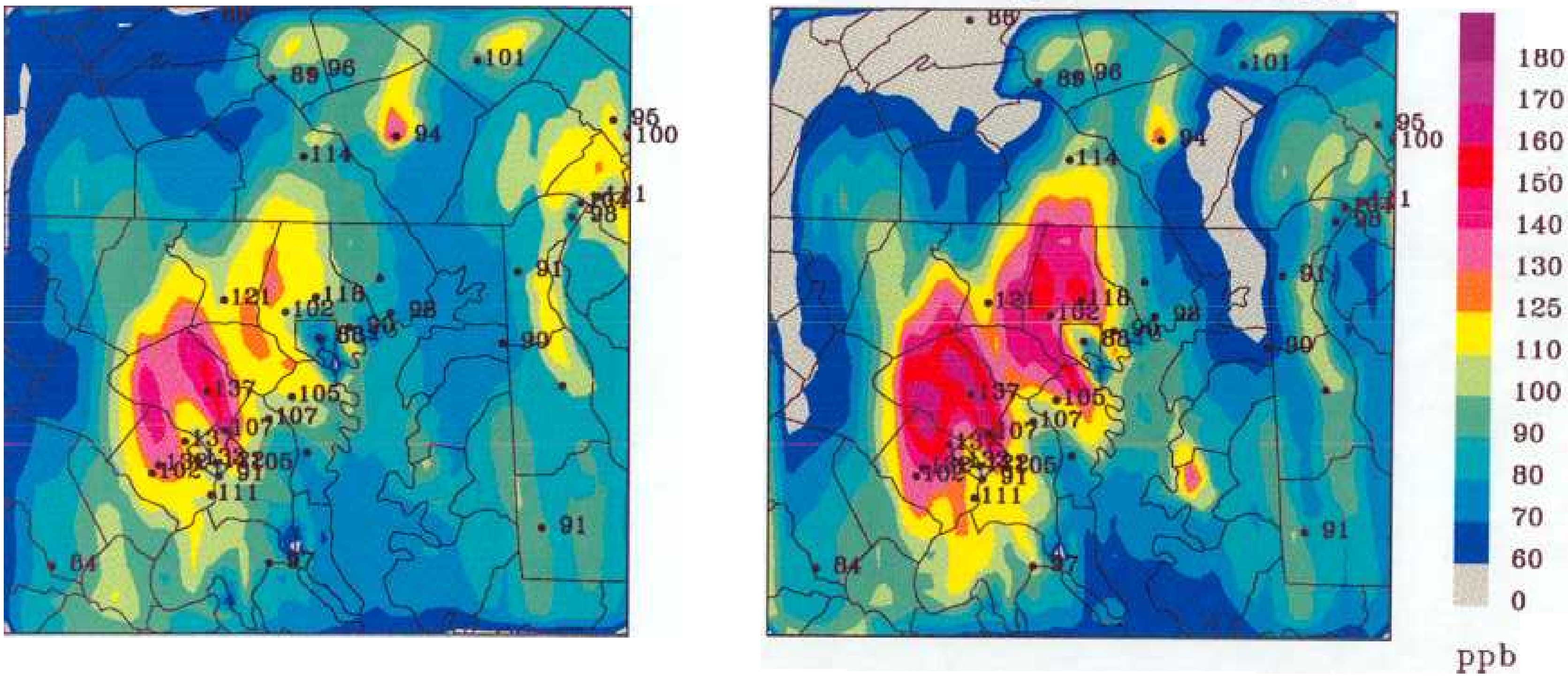
July 16, 1991

BEIS-1

0000 – 2400 EST July 16, 1991
Max. = 154.2 ppb, Min. = 24.1 ppb

BEIS-2

0000 – 2400 EST July 16, 1991
Max. = 167.2 ppb, Min. = 30.9 ppb



7. Future-Year Simulations

A series of UAM simulations were conducted for year 1999 in order (1) to evaluate the effectiveness of emission reductions adopted in the Phase I Attainment Plan, including 1999 Rate-of-Progress Plan and Phase II OTC-MOU NOx controls; (2) to examine the influence of transport across the inflow boundaries on ozone concentrations within the domain; and (3) to identify additional controls needed to bring the area into attainment with the current 1-hour ozone standard.

EPA has recommended that states use BEIS1 with UAM-IV for attainment demonstrations because of the old isoprene chemistry mechanism still applied in the UAM-IV code. When used with BEIS2, the old isoprene chemistry mechanism is expected to overestimate the peak ozone concentrations in some urban scale modeling domains in the Eastern U.S. Our model performance evaluation has shown that UAM-IV predictions for ozone concentrations with BEIS2 are comparable to (although higher than) those with BEIS1 as discussed in the previous chapter. It is known that BEIS1 significantly underestimates biogenic emission rate. The model tends to underestimate the impact of NOx controls and overestimate the impact of anthropogenic VOC controls. The Ozone Transport Assessment Group (OTAG) has applied the BEIS2 for its modeling due to the fact that BEIS2 is more scientifically advanced. It is also found during the OTAG modeling process that the new isoprene chemistry mechanism employed in the UAM-V(v1.24) did not result in significant differences (about 5%) in ozone predictions compared to the old isoprene mechanism. In order to be consistent with OTAG modeling process and apply the most scientifically advanced biogenic data, the modeling analysis here are mostly based on the results from BEIS2 biogenic inventory. Comparisons of impacts of the two different biogenic emissions have also been made in the analysis.

1999 Future Year Modeling Inventories

The Baltimore-Washington UAM domain covers six states and the District of Columbia. In order to obtain future year modeling inventories, local growth and control factors are needed. These factors were not available for the portion of the domain that covers Pennsylvania, New Jersey, Delaware and West Virginia for 1999 modeling purpose. Therefore, OTAG 2007 Base 1C emissions inventories for the four states were used for the 1999 modeling.

The 1999 future year point, area and non-road modeling emission inventories for the Washington nonattainment area were developed based on the 1990 base year inventories and local growth and control factors. These factors are the same factors used in the Phase I Attainment Plan. Intensive QA/QC has been performed throughout the development of the 1999 future year modeling inventories. Appendix B3 documents in detail the procedures and the QA/QC process used to derive the 1999 inventories.

The 1999 on-road mobile source emissions inventories for the Washington nonattainment area were developed based on projected 1999 VMT data and control strategies adopted in the Phase I Attainment Plan. The emission factors were estimated using MOBILE5a with appropriate inputs to reflect the 1999 conditions. The inputs include an enhanced I/M Program and the continuation of current control measures such as the basic I/M program, the RVP gasoline volatility program, the

Federal motor vehicle control program (FMVCP), and CAAA Tier 1 emission standard. The 1999 projected VMTs were derived from the National Capital Region Transportation Planning Board's FY97-2002 Transportation Improvement Program (TIP) and the Constrained Long Range Plan (CLRP) Conformity Determination.

For rural Virginia counties located outside of the Washington nonattainment area, BEA growth factors were used to grow point, area, and non-road source emissions to year 1999. No control measures were applied to those Virginia counties.

For Maryland counties outside of the Washington nonattainment area, the Maryland Department of the Environment (MDE) provided the growth and control factors for their point, area, and non-road mobile sources. Same procedures used for the Washington nonattainment area were used to produce the 1999 modeling inventories for those Maryland counties. However, for the on-road mobile sources, the MDE provided the projected 1999 emission estimates.

Biogenic emission inventories for 1999 are the same as those used for the base-case for the entire domain, which were derived from ROM-BEIS1 and UAM-BEIS2 processors.

The control strategies modeled included 1999 Rate-of-Progress Plan (15% and 9% Plans) and Phase II NOx OTC-MOU. The following is a list of control measures included in the 1999 modeling inventories for Washington nonattainment area based on Phase I Attainment Plan document:

- Enhanced Inspection/Maintenance (I/M240)
- Stage II Vapor Recovery Nozzles
- Federal "Tier I" Vehicle Standards and New Car Evaporative Standards
- Non-CTG RACT to 50 tpy
- Phase II Gasoline Volatility Controls
- EPA Non-Road Gasoline Engines Rule
- EPA Non-Road Diesel Engines Rule
- State NOx RACT Requirement
- Reformulated Surface Coatings
- Reformulated Consumer Products
- Reformulated Gasoline(on-road)
- Reformulated Gasoline(off-road)
- Surface Cleaning/Degreasing for Machinery/Automobile Repair
- Landfill Regulations
- Seasonal Open Burning Restrictions
- Stage I Enhancement (Tank Truck Unloading
- Expanded State Point Source Regulations to 25 tons/yr
- Graphic Arts Controls
- Autobody Refinishing
- Transportation Control Measures
- Phase II NO_x Requirements

The emission summary, in tons per day, for the Washington D.C. nonattainment area for each source category is shown in Table 7-1. The control measures in the Post-1996 Rate-of-Progress Plan result in emission reductions of 124 tons per day (17.1%) of NOx and 164 tons per day (31.3%) of VOC from the 1990 emissions levels. With the Phase II OTC-MOU NOx controls, NOx emissions are projected to be reduced by 202 tons per day or 27.8 percent from the 1990 level.

Table 7-1. Emission Summary for Washington D.C. Ozone Nonattainment Area (EPS2.0 output).

	NO_x Emissions (tons/day)				
	1990 Base-Year	1999 9% Plan		1999 9% Plan and Phase II NOx MOU	
			Reduction from 1990		Reduction from 1990
Point	332.7	252.0	80.7	174.0	158.7
Area	47.0	53.3	-6.3	53.3	-6.3
Non-Road	84.9	92.3	-7.4	92.3	-7.4
Mobile	262.0	205.0	57.0	205.0	57.0
Total	726.6	602.6	124.0 (17%)	524.6	202 (27.8%)

	VOC Emissions (ton/day)				
	1990 Base-Year	1999 9% Plan		1999 9% Plan and Phase II NOx MOU	
			Reduction from 1990		Reduction from 1990
Point	14.3	12.6	1.7	12.6	1.7
Area	185.7	152.3	33.4	152.3	33.4
Non-Road	70.4	70.4	0.0	70.4	0.0
Mobile	252.0	123.5	128.5	123.5	128.5
Total	522.4	358.8	163.6 (31%)	358.8	163.6 (31%)

Figure 7-1 displays the NOx and VOC total emission inventories for the 1990 base-year, and the 1999 Rate-of-Progress control cases. The dramatic VOC reduction in mobile source emissions from 1990 to 1999 is due to the lower RVP, fleet turnover, and additional mobile source controls. The on-road mobile source contribution to the total anthropogenic VOC emissions is reduced from 48% in 1990 to 34% in 1999.

Boundary Conditions

The OTAG UAM-V simulations are expected to be used for deriving the future year boundary conditions for the local attainment demonstration modeling. However, OTAG did not model the 1999 scenarios. Preliminary local sensitivity modeling shows that it would be extremely difficult for the Washington D.C. area to achieve attainment if the boundary conditions are not significantly reduced. Therefore, 1999 future year base case boundary conditions were derived from the OTAG UAM-V 2007 Base case 1C, and Strategy Run I simulations for the two 1991 episodes (Episode 3 and Episode 3b). The OTAG Strategy Run I, which includes 85% utility NOx emission reduction from the 1990 rate level or a rate of 0.15 lb/MMBtu limit in most OTAG fine grid areas, is the most stringent emission reduction scenario modeled for OTAG Round 3 modeling.

Future Base Case Simulations

Two future base emission scenarios were simulated for 1999 to estimate the benefits of the proposed strategies for the Washington Metropolitan Nonattainment Area. The two scenarios are:

Base 1:1999 Rate-of-Progress Plan (99bs1);
Base 2: Base 1 plus Phase II OTC-MOU NOx control in Washington nonattainment area (99bs2).

The 1999 Base 1 case (99bs1) was simulated with three boundary conditions derived from OTAG Base 1C, Strategy Run I, and clean condition to evaluated the impact of ozone transport and the region-wide NOx controls in the Baltimore/Washington domain. The 1999 Base 2 (99bs2) was simulated with OTAG Run I boundary conditions only. The four base case simulations are:

(1) 99bs1A2a: 99bs1 emission with OTAG Base 1C boundary conditions;
(2) 99bs1A2b: 99bs1 emission with OTAG Run I boundary condition;
(3) 99bs1A2c: 99bs1 emission with clean boundary condition;
(4) 99bs2A2b: 99bs2 emission with OTAG Run I boundary condition.

A subdomain, which contained 32x23 grid cells and covered most of the Washington nonattainment area as well as the surrounding area possibly affected by the Washington DC urban plume, was designed to evaluated the effectiveness of simulated control strategies in Washington area.

Additional Sensitivity Runs

In order to provide some information on the development of additional local controls and to evaluate the impacts of regional controls on ozone in Washington nonattainment area to meet the 1-hour ozone air quality standard, additional sensitivity model runs have been performed. The sensitivity runs and the percent reductions of NOx and VOC from source categories are identified in Table 7-2. The emission reductions for these sensitivity runs were based on Base 1 (99bs1) case.

Table 7-2. Additional 1999 Emission Reduction Sensitivity Runs for Washington Nonattainment Area

	Point Sources		Area Sources		Mobile Sources		Control Region
	NOx	VOC	NOx	VOC	NOx	VOC	
s1	60%						Washington NAA
s2	60%		30%		30%		Washington NAA
s3	60%			30%		30%	Washington NAA
s4	60%		30%	30%	30%	30%	Washington NAA
s5	60%		30%	30%	30%	30%	Washington & Baltimore NAA
s6	60%		30%	30%	30%	30%	Domain wide
s7	60%						Domain wide
s8	80%		30%	30%	30%	30%	Domain wide

Note: Emission reductions are based on 1999 Base 1 (99bs1) case

1999 base case results

Table 7-3 summarizes the four 1999 base case simulation results for the Washington subdomain for the July 19-20, 1991 (Episode 3) and July 16, 1991 (Episode 3b) episodes along with the base case. The results are presented as peak daily maximum ozone concentrations and the number of grid cell hours greater than 125 ppb ozone. The spatial distributions on the predicted daily maximum ozone concentrations are displayed in Figure 7-2 for the 1999 Base 1 with OTAG Base 1C boundary condition (bs1A2a). The Washington subdomain boundary is also shown on these maps. There are significant reductions between the 1991 base case and the 1999 Base 1 case (bs1A2a) in the predicted peak daily maximum ozone concentrations (by 11 - 17 ppb) and in the numbers of cell hours when the predicted ozone concentrations were greater than or equal to 125 ppb for Washington subdomain. These ozone decreases in Washington nonattainment area were mainly attributed to the 1999 Rate-of-Progress Plan, and somewhat to the decreased ozone concentration at the inflow boundaries. However, the daily maximum ozone concentrations were still predicted to be well above current 1-hour ozone standard over a large area (Figure 7-2). The peak ozone concentrations for the Washington subdomain range from 141 ppb to 183 ppb (Table 7-3). It should be mentioned here that the base case performance evaluation has shown that peak ozone concentrations were overpredicted by approximately 20%.

Table 7-3. Predicted Daily Maximum Ozone Concentrations in ppb and Number of Cell Hours > 125 ppb for Washington Subdomain. The biogenic emissions were derived from BEIS2.

	7/19/91	7/20/91	7/16/91
1991 base	152.2/132	198.5/642	167.1/503
bs1A2a	141.0/78	182.7/463	150.4/252
bs1A2b	138.9/60	178.5/375	150.1/239
bs1A2c	130.4/22	164.8/187	148.3/200
bs2A2b	138.8/59	178.5/365	150.1/237

Figure 7-3 plots the differences between the predicted daily maximum ozone concentrations for the 1999 Base 1 and 1991 base case for the two episodes. The negative values in the plots represent the benefit (ozone decrease), and the positive values represent the disbenefit (ozone increase) of the 1999 Base 1 controls on daily maximum ozone concentration. The 125 ppb level contours for the two 1991 base cases are also superimposed on these plots. Figure 7-3 shows that the 1999 Base 1 control strategy produces large areas of ozone concentration decreases. The ozone decreases occurred in the areas where base case daily maximum ozone were above 125 ppb, which suggests that, with the implementation of the 9% plan for the Washington D.C. nonattainment area, it will result in air quality improvement toward attainment of ozone standard in the area. Some small areas near major point sources show increases in ozone concentrations due to NOx reductions (such as NOx RACT control) occurring at these major point sources. The increased ozone concentration at the southern boundary of the domain may be attributed to the higher growths in the southeastern part of the U.S. projected by the OTAG 2007 Base 1C case.

Impacts of Boundary Conditions

1999 Base 1 case was also simulated with OTAG Strategy Run I and clean boundary conditions to evaluate the effects of regional controls on ozone in Washington subdomain. Figure 7-4 shows the spatial plots of ozone benefit from Strategy Run I applied outside of the Baltimore/Washington domain. These plots clearly illustrate that the regional utility NOx controls such as the OTAG Strategy Run I provides an ozone benefit within the entire Baltimore-Washington domain. The daily maximum ozone concentrations decreased from 5 to 10 ppb in the area above 125 ppb in the Washington nonattainment area. While the reduction in peak ozone was 4 ppb (Table 7-3) in the Washington subdomain, the number of grid cell hours exceeding 125 ppb decreased significantly. The clean boundary condition runs show that ozone transport contributes to more than 40 ppb in daily maximum ozone concentrations in the Washington D.C area (Figure 7-5). However, local emissions alone would produce daily maximum ozone concentration above 125 ppb (Figure 7-6).

Impacts of Phase II NOx MOU in Washington Nonattainment Area

The Phase II NOx OTC-MOU in Washington D.C. area identified in the Phase I Attainment Plan was applied to three power plants in the area. The 1999 Base 2 and Base 1 ozone different plots (in Figure 7-7) show that Phase II NOx MOU in Washington D.C area alone may provide little local ozone benefit to the areas with ozone concentrations above 125 ppb. It is also shown in the same figure that controlling the NOx from major point sources (such as the Phase II MOU) leads to an increase in the ozone concentrations at the vicinity of the sources, but a decrease in the ozone concentration at a greater downwind area. The beneficial area may expand more than 100 km downwind. The results indicate that NOx controls from major point sources have a regional impact on reducing ozone, which is consistent with the OTAG finding. The NOx control from major utilities is a the regional control strategy. Therefore, the ozone benefit due to the utility NOx control should be evaluated on the regional bases.

Additional sensitivity run results

The predicted peak ozone concentrations and number of cell hours greater than 125 ppb are summarized in Table 7-4 for eight additional sensitivity runs as identified in Table 7-2 for the two July 1991 episodes. The same numerical matrices are also displayed as bar charts in Figure 7-8.

Impact of additional NOx control from point sources

In order to further evaluate the impact of point source NOx controls on local and regional ozone levels, two sensitivity runs, s1 and s7, were simulated and compared to the 1999 Base 1 case. The s1 case represents an additional 60% point source NOx reduction in Washington area only, and s7 case represents an additional 60% point source NOx reduction domain-wide. The ozone difference plots in Figure 7-9 show that there are some ozone benefit to the cells with ozone above 125 ppb by the 60% NOx reduction from all point source within the Washington nonattainment area. However, unlike Phase II OTC-MOU case (1999 Base 2), this scenario results in ozone increase in a large area inside Washington D.C. urban center on July 20 (day 3 of Episode 2) and July 16 (day 3 of Episode 3b).

Figure 7-10 illustrated that reducing NOx from all point source domain-wide by 60%, and OTAG Strategy Run I (85% NOx reductions or 0.15 lb/MMBtu NOx limit for most OTAG fine grid) applied outside the B/W domain would provide a widespread significant ozone benefit within the Washington UAM domain. The ozone disbenefit in Washington urban area should be reduced both in magnitude and spatial extent. Ozone exceedances in Washington D.C. area mostly occur when enhanced ozone level exist within the region. Under the impact of the regional NOx controls (OTAG-wide), the NOx control from point source in Washington D.C. would enhance the ozone benefit in both local and the downwind areas for July 20. However, the same simulations indict an ozone disbenefit in the eastern Baltimore urban area for July 20, and over a large area north of Baltimore, even inside southern PA for July 16 of Episode 3b. A review of ambient ozone data found that exceedance of the 1-hour ozone standard was not observed in Baltimore area and southern PA on July 16. The model significantly over predicted the ozone level in Baltimore area on that day.

Impact of additional local controls from low level sources

Figure 7-11 displays the impact of additional 30% NOx reductions from area and mobile (low level) source in Washington nonattainment area in addition to the s1 case. This control scenario would results in significant ozone reductions as high as 22.5 ppb in Washington D.C. area for July 20, 1991. The peak ozone concentrations would be reduced by 12 ppb on the same day. Additional 30% VOC controls from areas and mobile sources would also produce ozone reductions (Figure 7-12), but with a less of a magnitude and within a smaller area than the NOx controls from the same source categories. The bar charts in Figure 7-8 also demonstrated that the low level NOx controls are more beneficial in reducing peak ozone as well as number of cell hours greater than 125 ppb than low level VOC controls in Washington subdomain.

Impact of combined controls (elevated NOx, low level NOx and VOC reductions)

The effectiveness of combined regional and local emission reductions from all sources have been examined through four additional sensitivity runs (s4,s5,s6, and s8). The scenario (s6) represents a 60% point source NOx, a 30% area and mobile source NOx and VOC reductions inside the domain, and OTAG Run I applied outside of the domain. It demonstrates a significant ozone benefit across the entire domain (Figure 7-13). The peak ozone in Washington subdomain has been reduced from 183 to 156 ppb on July 20, and from 150 to 133 ppb (Table 7-4) on July 16. More point source NOx reductions inside the domain results in more ozone reductions, especially in Baltimore area (Figure 7-14).

Table 7-4. Peak predicted ozone concentrations (ppb) and Number of Grid Cell Hours $\geq$ 125 ppb for Washington Subdomain

	Domain: Baltimore/Washington UAM-4 Biogenic Emissions: UAM-BEIS2 Boundary Conditions: Clean Boundary (40 ppb), OTAG bas1c OTAG RunIC2			
Runs	Episode 3		Episode 3b	Episode 2
	July 19,1991	July 20,1991	July 16,1991	July 30,1988
bs1A2a	140.98 / 78	182.70 / 463	150.39 / 252	N/A
bs1A2b	138.87 / 60	178.53 / 375	150.14 / 239	N/A
bs2A2b	138.82 / 59	178.49 / 365	150.07 / 237	N/A
s1A2b	137.44 / 52	172.69 / 361	148.67 / 241	N/A
s2A2b	125.32 / 1	160.08 / 216	139.93 / 127	N/A
s3A2b	135.30 / 42	170.51 / 347	145.62 / 189	N/A
s4A2b	124.19 / 0	156.19 / 207	136.65 / 105	N/A
s5A2b	122.92 / 0	156.19 / 196	133.94 / 74	N/A
s6A2b	122.76 / 0	156.02 /196	132.76 / 60	N/A
s7A2b	137.51 / 22	172.69 / 78	148.97 / 72	N/A
s8A2b	121.76 / 0	155.20 / 53	137.57 / 32	N/A

Compared to Figure 7-13 to Figure 7-14, it appears that the low level NOx and VOC controls can offset some of the ozone disbenefits resulted from point source NOx controls at least in Washington nonattainment area.

Impact of BEIS2 vs. BEIS1

The predicted daily maximum ozone concentrations with BEIS1 are lower than that of BEIS2. While the ozone level has been shown to attain the 1-hour ozone standard with the 1999 Rate-of-Progress Plan on July 16, 1991, ozone concentration is still predicted to exceed the ozone standard on July 20, 1991.

When the clean boundary condition was used for the modeling, the ozone levels have been shown to attain the ozone standard for both episodes modeled. The daily maximum ozone seems to respond more from changes of boundary condition and VOC reductions. The ozone disbenefit associated with point source NOx control increased in both magnitude and spatial extend.

Summary

The modeling results to date have shown that the Phase I Attainment plan is not sufficient to demonstrate ozone attainment (with either BEIS2 and BEIS1) by 1999 for the Washington D.C nonattainment area. Some future year emission sensitivity simulations indicated that further NOx and VOC emission reductions beyond the Phase I Attainment Plan will be needed to reach attainment in the Washington D.C. area. However, as previously mentioned, boundary condition sensitivity analyses have shown that the Washington nonattainment area experienced overwhelming transport of ozone and its precursors from upwind areas. Both horizontal and vertical transport, for example, contribute more than 40 ppb daily maximum ozone in the Washington D.C. area for the July 19-20 1991 episode. Under this meteorological regime, more than 30% additional NO_x and VOC reductions from low level sources may be needed for the Washington D.C. area to demonstrate attainment. On the other hand, it was demonstrated with UAM-4 and OTAG UAM-V modeling analyses that further emission reduction from upwind urban or industrial areas will likewise be effective in reducing ozone concentrations for the Baltimore-Washington UAM domain.

Data Access

For information regarding file archives and administrative and technical procedures for accessing files, please contact Mr. Kirit Chaudhari, Director, Office of Air Data Analysis, Virginia Department of Environmental Quality, P.O. Box 10009, Richmond, VA 23240-0009, (804)698-4414. All computer input and output files are available for inspection via request.

Figure 7-1

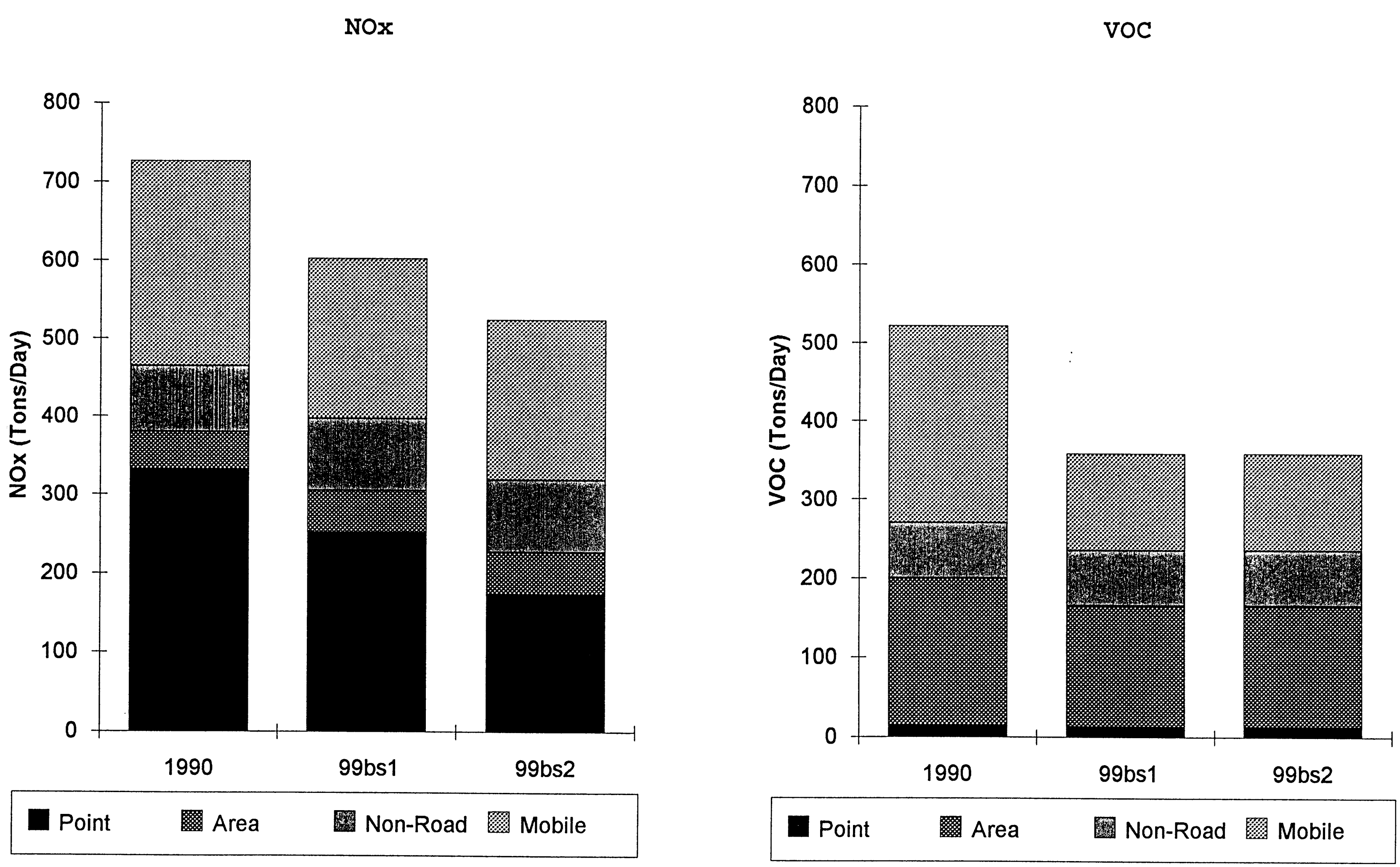


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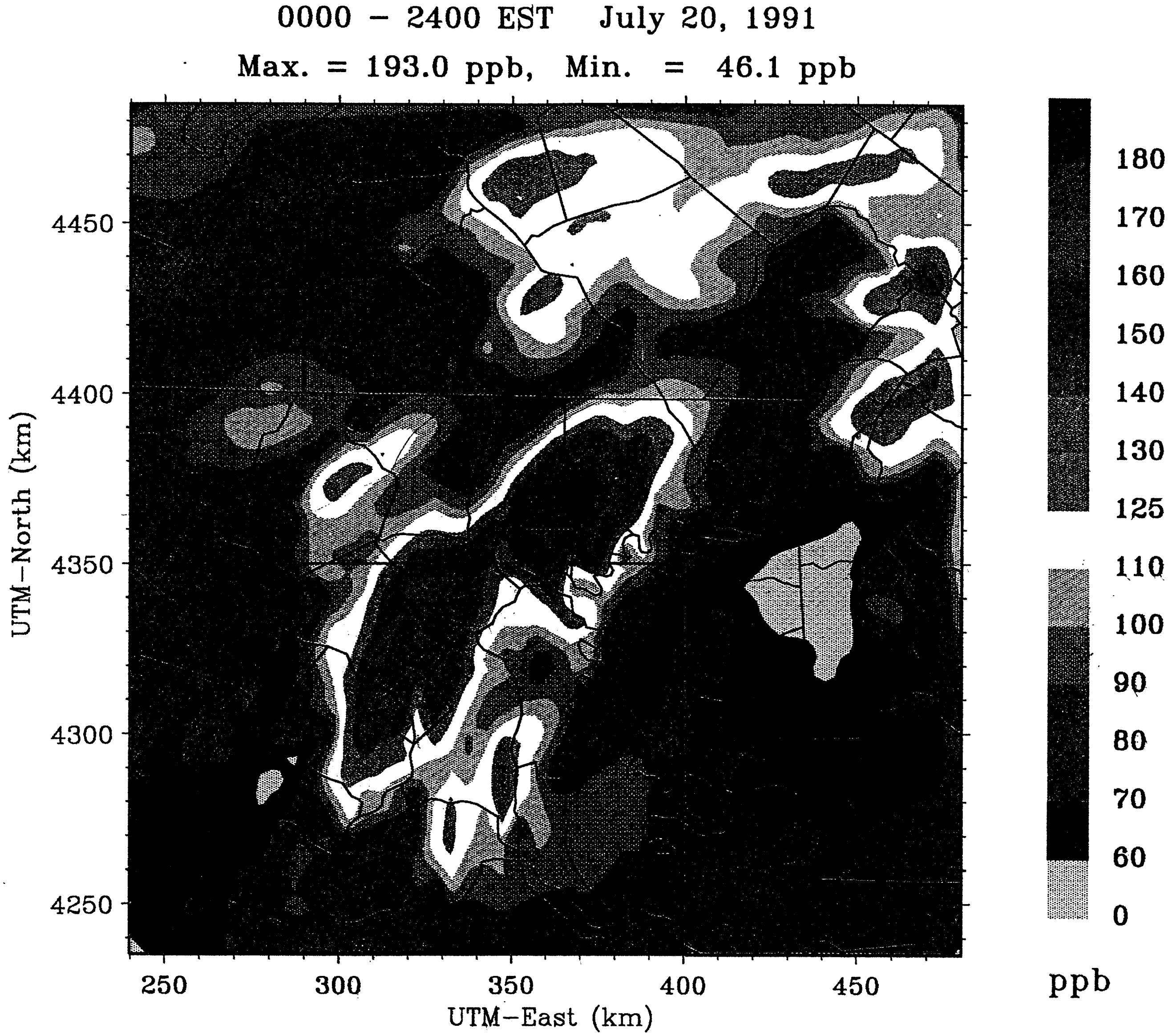
Figure 7-2(a)

Predicted Daily Max Ozone – 1999 base (99bs1A2a)
UAM–IV Layer 1, Beis2, B/W Domain



Anthro. emission : 1999 Base 1 case (99bs1)
Biogenic emission : UAM–BEIS2
Boundary condition : OTAG 2007 Base 1C

Table 4-3. Comparison of 1990 Base Year Area Source Emission Estimates for Washington Non-attainment Area

VOC Estimates (Tons/Day)

Jurisdiction	Phase I	EPS2.0	Difference
District of Columbia	20.0	19.5	-0.5
Maryland	94.2	92.8	-1.4
Virginia	77.0	77.0	0.0
Total	187.1	185.7	-1.9

NO_x Estimates (Tons/Day)

Jurisdiction	Phase I	EPS2.0	Difference
District of Columbia	3.4	3.0	-0.4
Maryland	15.8	15.8	0.0
Virginia	28.1	28.2	0.1
Total	47.3	47.0	-0.3

Table 4-4. Comparison of 1990 Base Year Non-Road Source Emission Estimates for Washington Non-attainment Area

VOC Estimates (Tons/Day)

Jurisdiction	Phase I	EPS2.0	Difference
District of Columbia	5.5	5.8	0.3
Maryland	32.1	31.7	-0.4
Virginia	32.8	32.9	0.1
Total	70.4	70.4	0.0

NOx Estimates (Tons/Day)

Jurisdiction	Phase I	EPS2.0	Difference
District of Columbia	5.5	5.6	0.1
Maryland	43.5	44.0	0.5
Virginia	36.0	35.3	-0.7
Total	85.0	84.9	-0.1

Table 4-5. Comparison of 1990 Base Year Mobile Source Emission Estimates for Washington Non-attainment Area

VOC Estimates (Tons/Day)

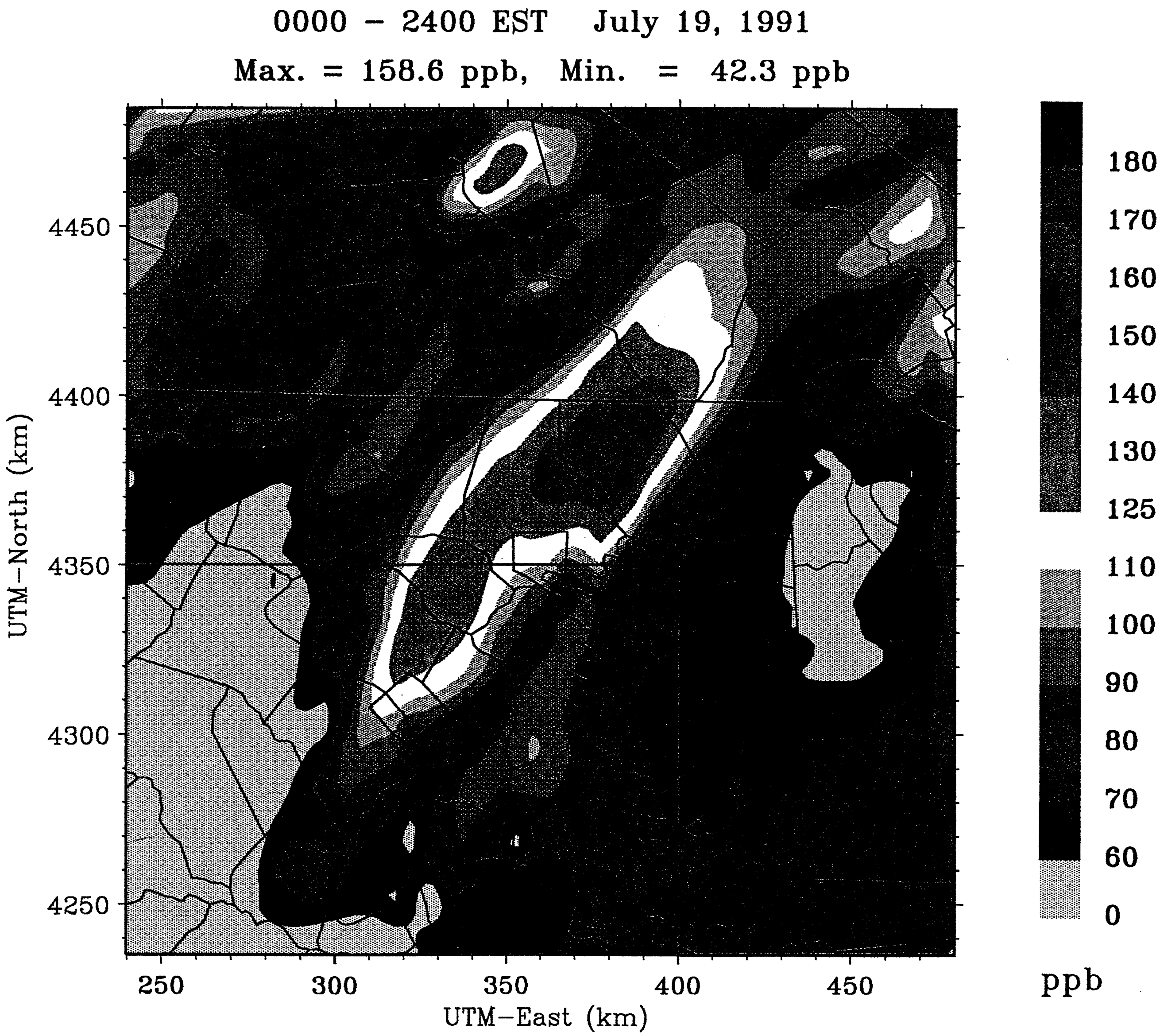
Jurisdiction	Phase I	EPS2.0	Difference
District of Columbia	32.6	32.9	0.3
Maryland	108.4	109.6	1.2
Virginia	110.1	110.0	-0.1
Total	251.1	252.5	1.4

NOx Estimates (Tons/Day)

Jurisdiction	Phase I	EPS2.0	Difference
District of Columbia	25.8	26.0	0.2
Maryland	129.1	127.6	-1.5
Virginia	106.8	108.4	1.6
Total	261.7	262.0	0.3

Figure 7-2(b)

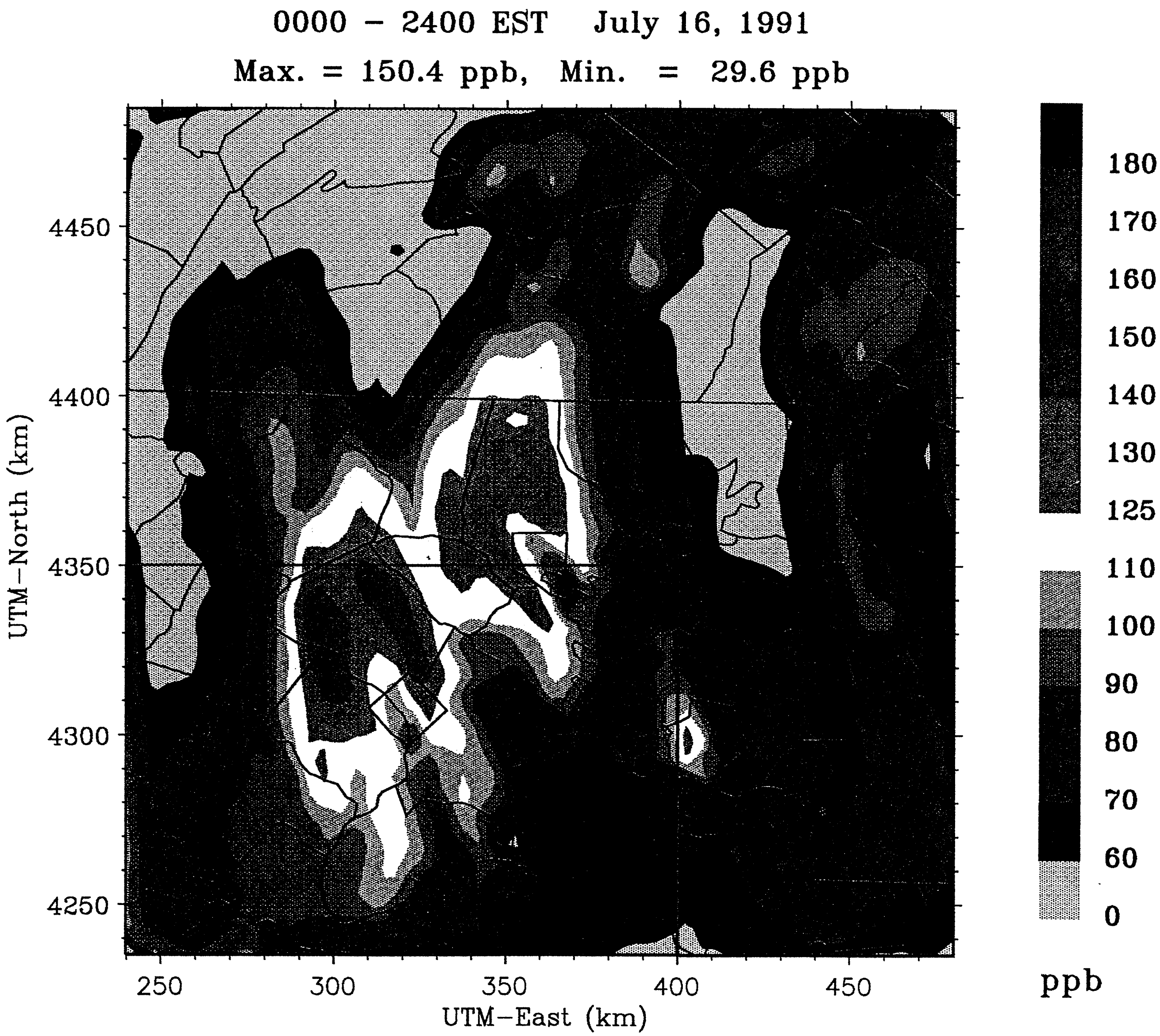
Predicted Daily Max Ozone – 1999 base (99bs1A2a)
UAM–IV Layer 1, Beis2, B/W Domain



Anthro. emission : 1999 Base 1 case (99bs1)
Biogenic emission : UAM–BEIS2
Boundary condition : OTAG 2007 Base 1C

Figure 7-2(c)

Predicted Daily Max Ozone – 1999 base (99bs1A2a)
UAM–IV Layer 1, Beis2, B/W Domain

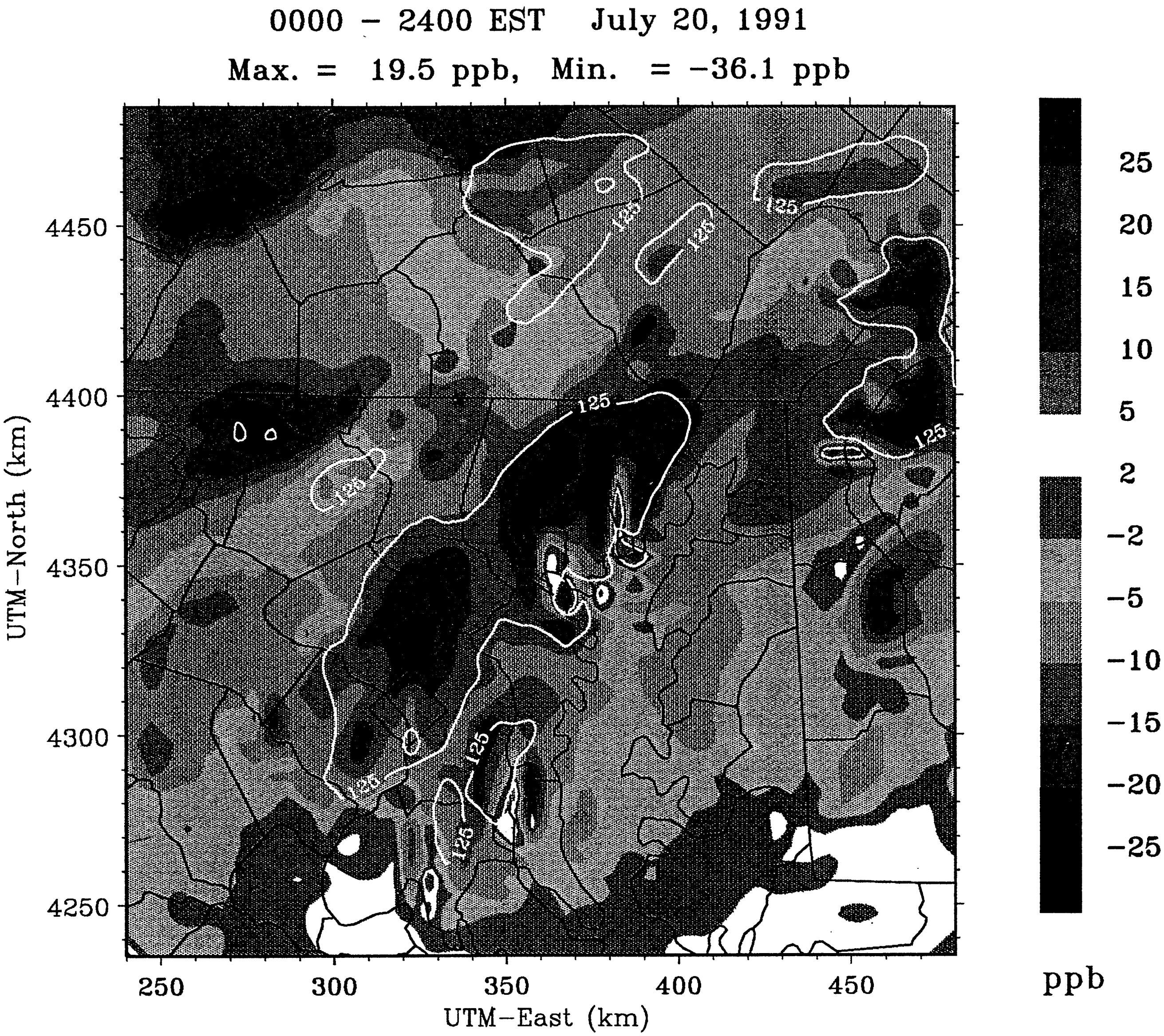


Anthro. emission : 1999 Base 1 case (99bs1)
Biogenic emission : UAM–BEIS2
Boundary condition : OTAG 2007 Base 1C

Figure 7-3(a)

Max Ozone Diff: 99bs1A2a - basA2D2

UAM-IV Layer 1, Beis2, B/W Domain

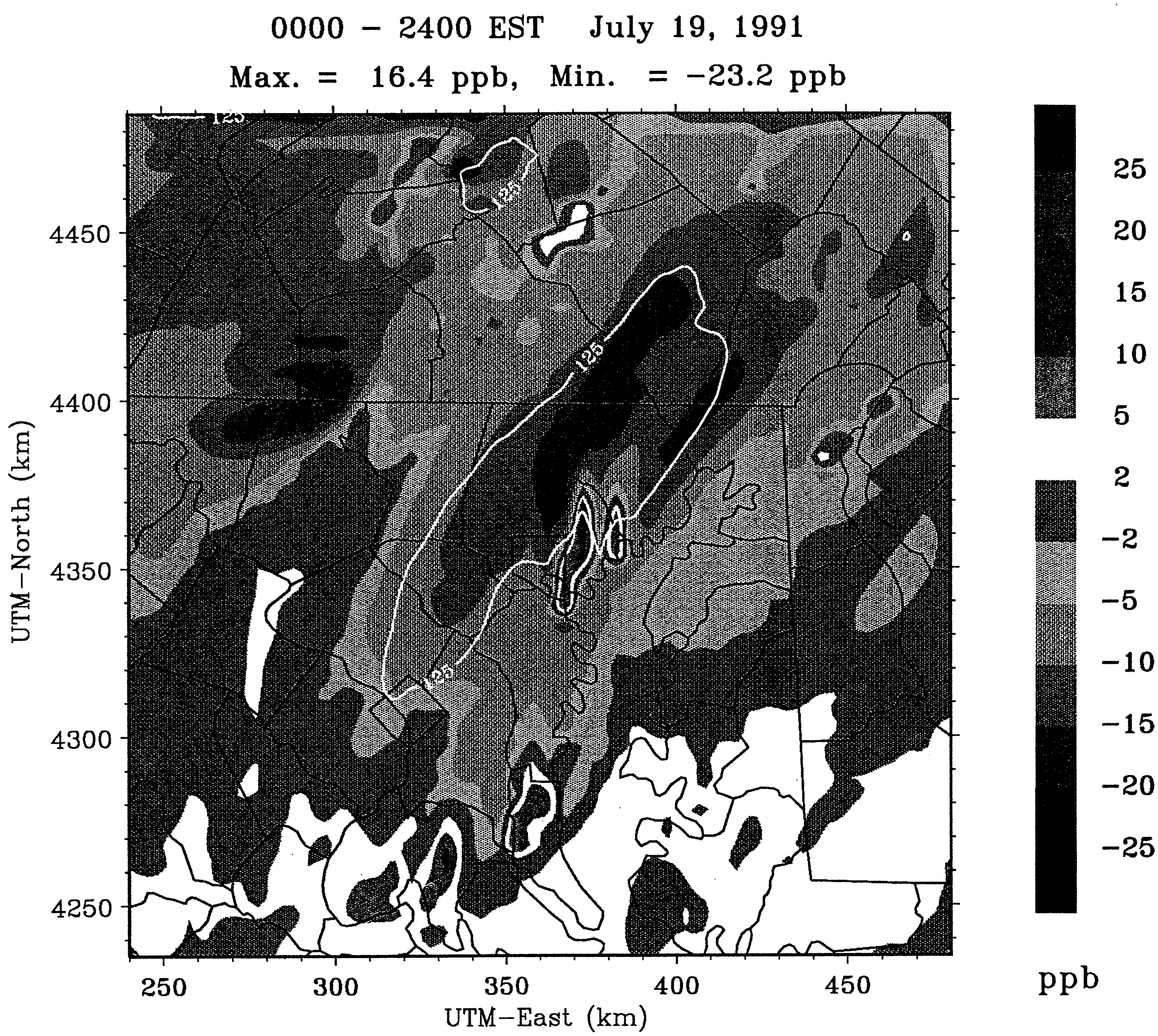


Difference in daily max ozone due to Clean Air Act controls for 1999 in both Washington and Baltimore nonattainment areas, and OTAG 2007 Base 1C controls applied in PA, DE, NJ, WV, and outside the B/W domain. Max ozone for 1991 base case (basA2D2) has been superimposed.

Figure 7-3(b)

Max Ozone Diff: 99bs1A2a - basA2D2

UAM-IV Layer 1, Beis2, B/W Domain



Difference in daily max ozone due to Clean Air Act controls for 1999 in both Washington and Baltimore nonattainment areas, and OTAG 2007 Base 1C controls applied in PA, DE, NJ, WV, and outside the B/W domain. Max ozone for 1991 base case (basA2D2) has been superimposed.

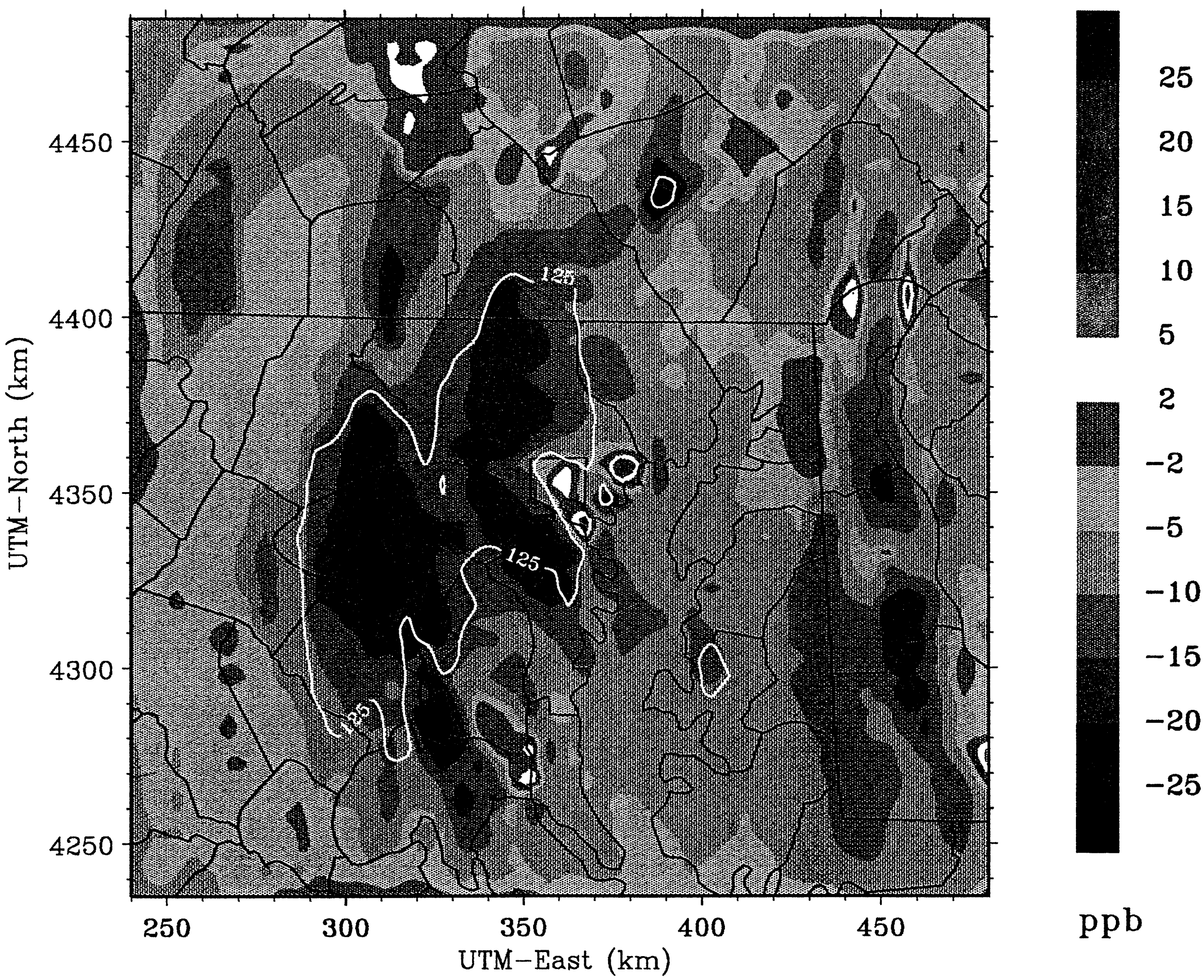
Figure 7-3(c)

Max Ozone Diff: 99bs1A2a - basA2D2

UAM-IV Layer 1, Beis2, B/W Domain

0000 – 2400 EST July 16, 1991

Max. = 12.4 ppb, Min. = −41.6 ppb

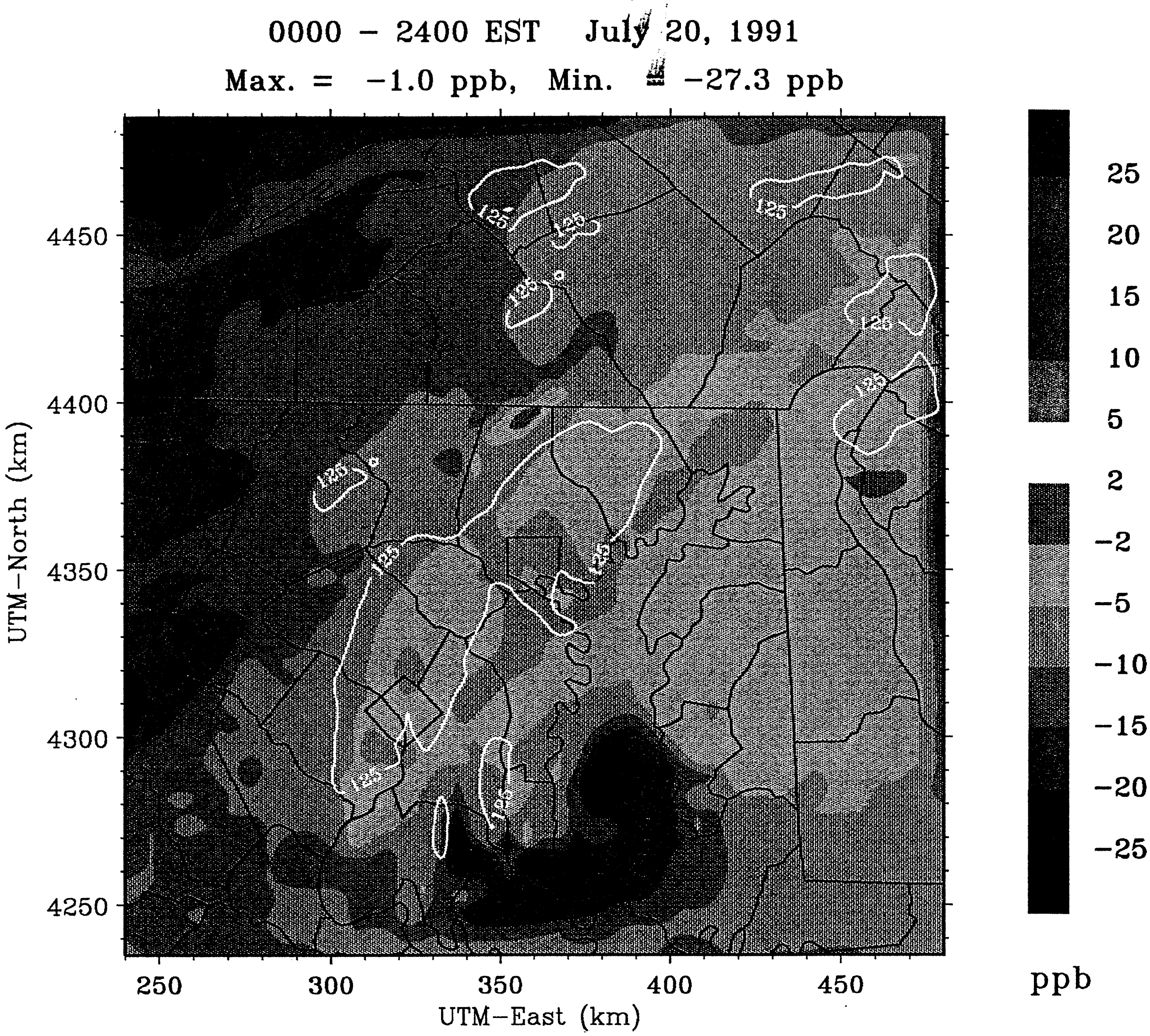


Difference in daily max ozone due to Clean Air Act controls for 1999 in both Washington and Baltimore nonattainment areas, and OTAG 2007 Base 1C controls applied in PA, DE, NJ, WV, and outside the B/W domain. Max ozone for 1991 base case (basA2D2) has been superimposed.

Figure 7-4(a)

Max Ozone Diff: 99bs1A2b - 99bs1A2a

UAM-IV Layer 1, Beis2, B/W Domain

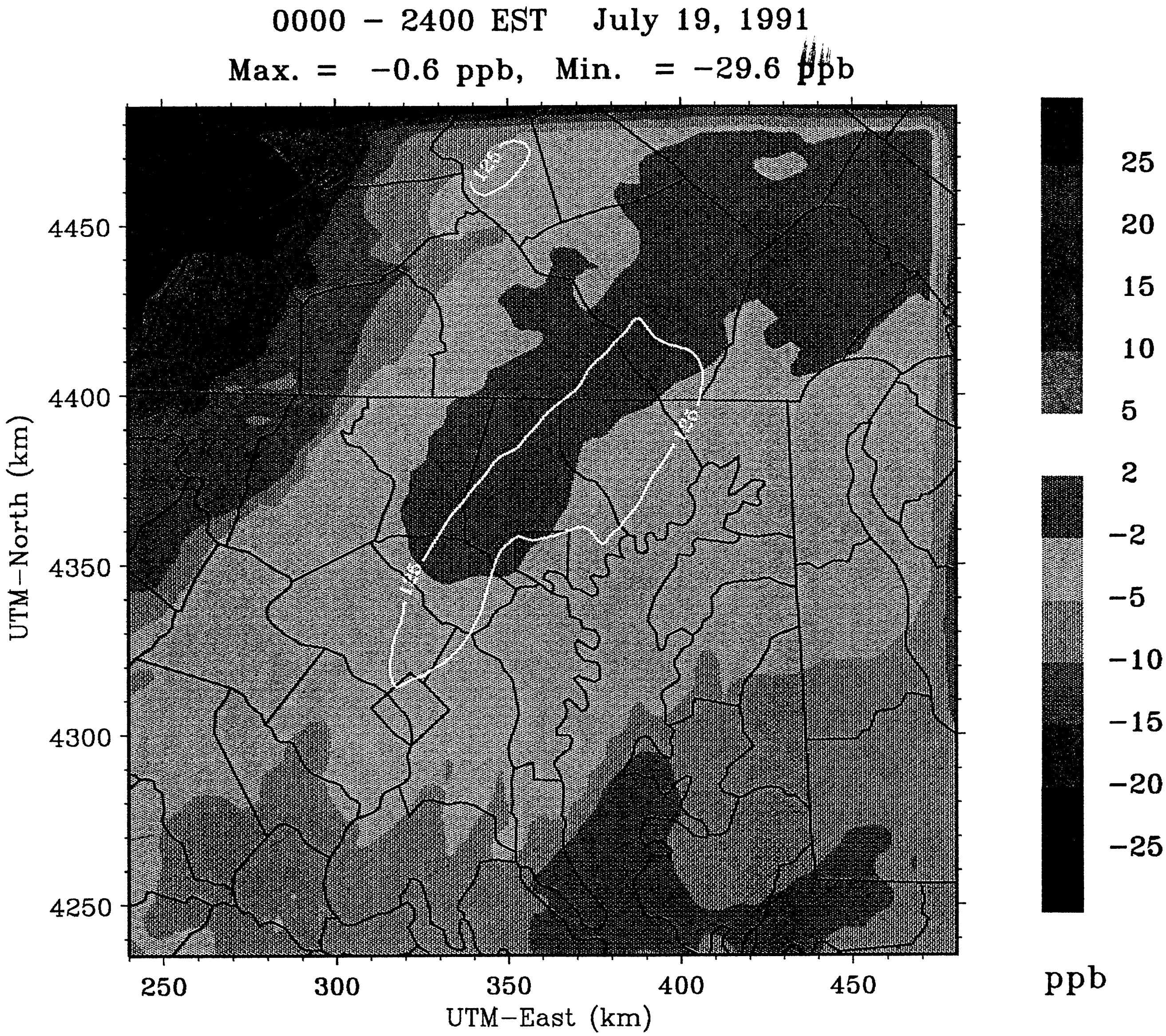


Difference in daily max ozone due to OTAG Strategy Run I applied outside B/W domain with no additional controls applied inside the domain. Max ozone for 1999 Base 1 case (99bs1A2a) has been superimposed.

Figure 7-4(b)

Max Ozone Diff: 99bs1A2b - 99bs1A2a

UAM-IV Layer 1, Beis2, B/W Domain

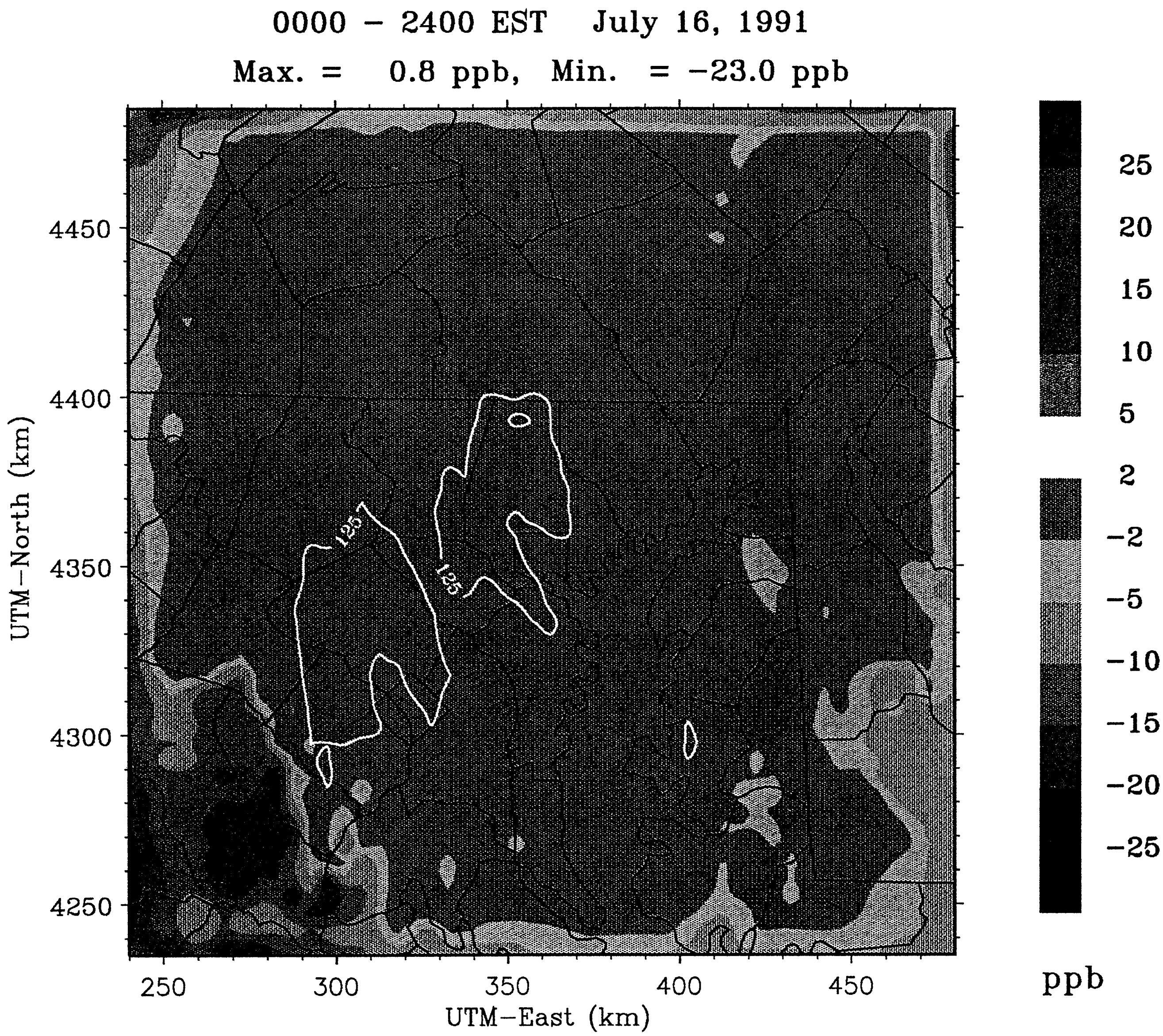


Difference in daily max ozone due to OTAG Strategy Run I applied outside B/W domain with no additional controls applied inside the domain. Max ozone for 1999 Base 1 case (99bs1A2a) has been superimposed.

Figure 7-4(c)

Max Ozone Diff: 99bs1A2b - 99bs1A2a

UAM-IV Layer 1, Beis2, B/W Domain

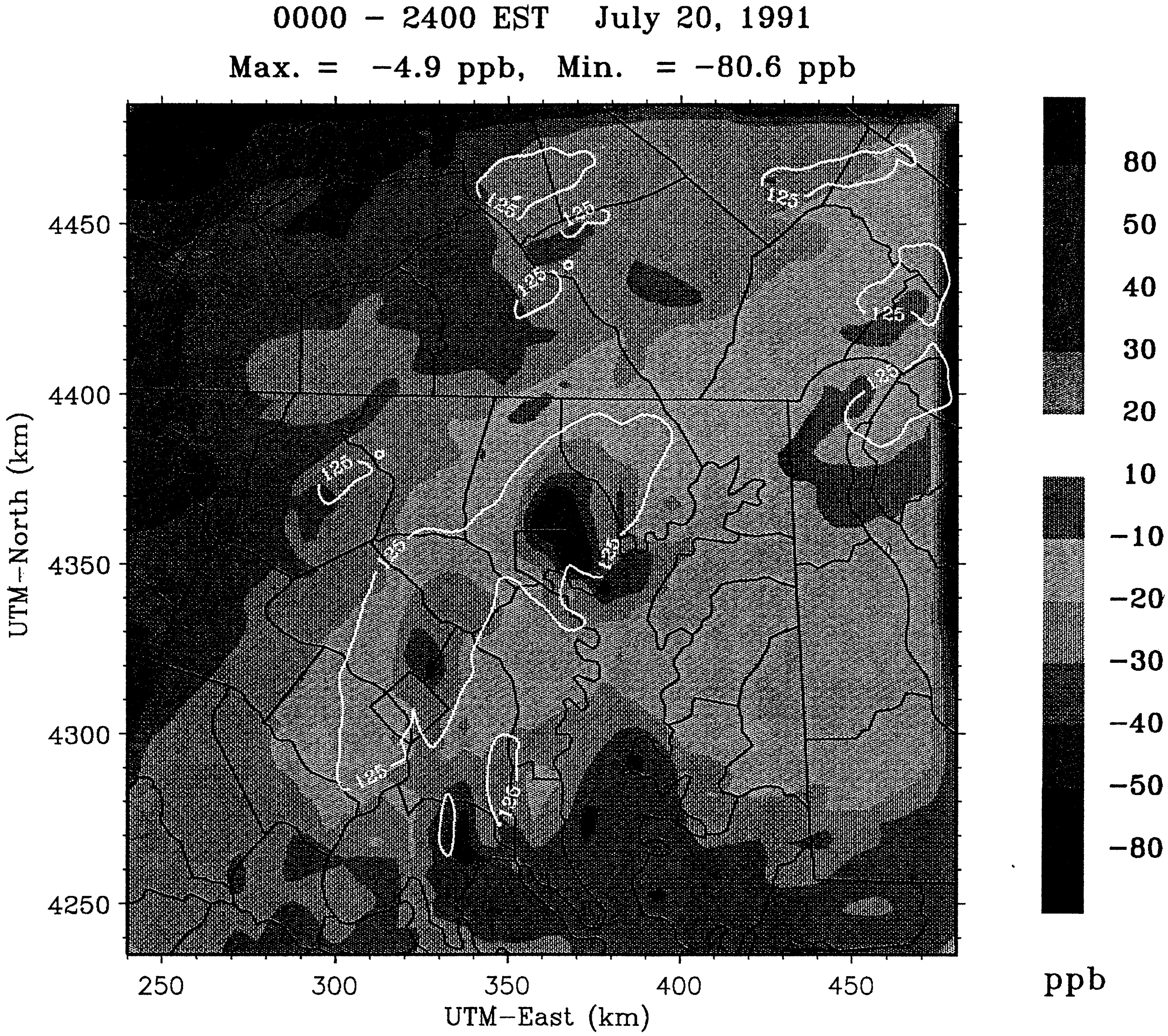


Difference in daily max ozone due to OTAG Strategy Run I applied outside B/W domain with no additional controls applied inside the domain. Max ozone for 1999 Base 1 case (99bs1A2a) has been superimposed.

Figure 7-5(a)

Max Ozone Diff: 99bs1A2c - 99bs1A2a

UAM-IV Layer 1, Beis2, B/W Domain

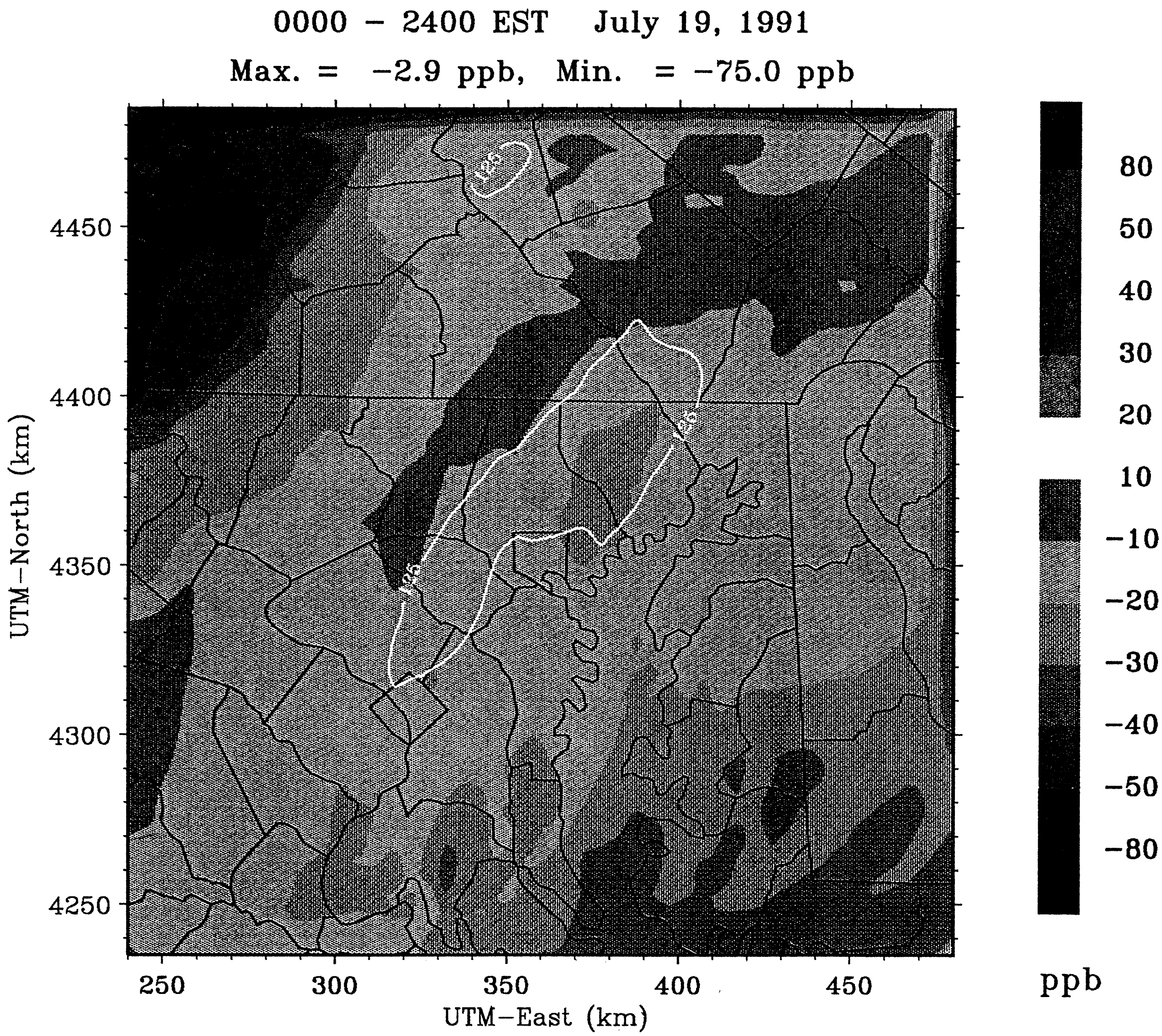


Difference in daily max ozone due to a clean boundary condition applied for the domain. Max ozone for 1999 base case (99bs1A2a) has been superimposed.

Figure 7-5(b)

Max Ozone Diff: 99bs1A2c - 99bs1A2a

UAM-IV Layer 1, Beis2, B/W Domain

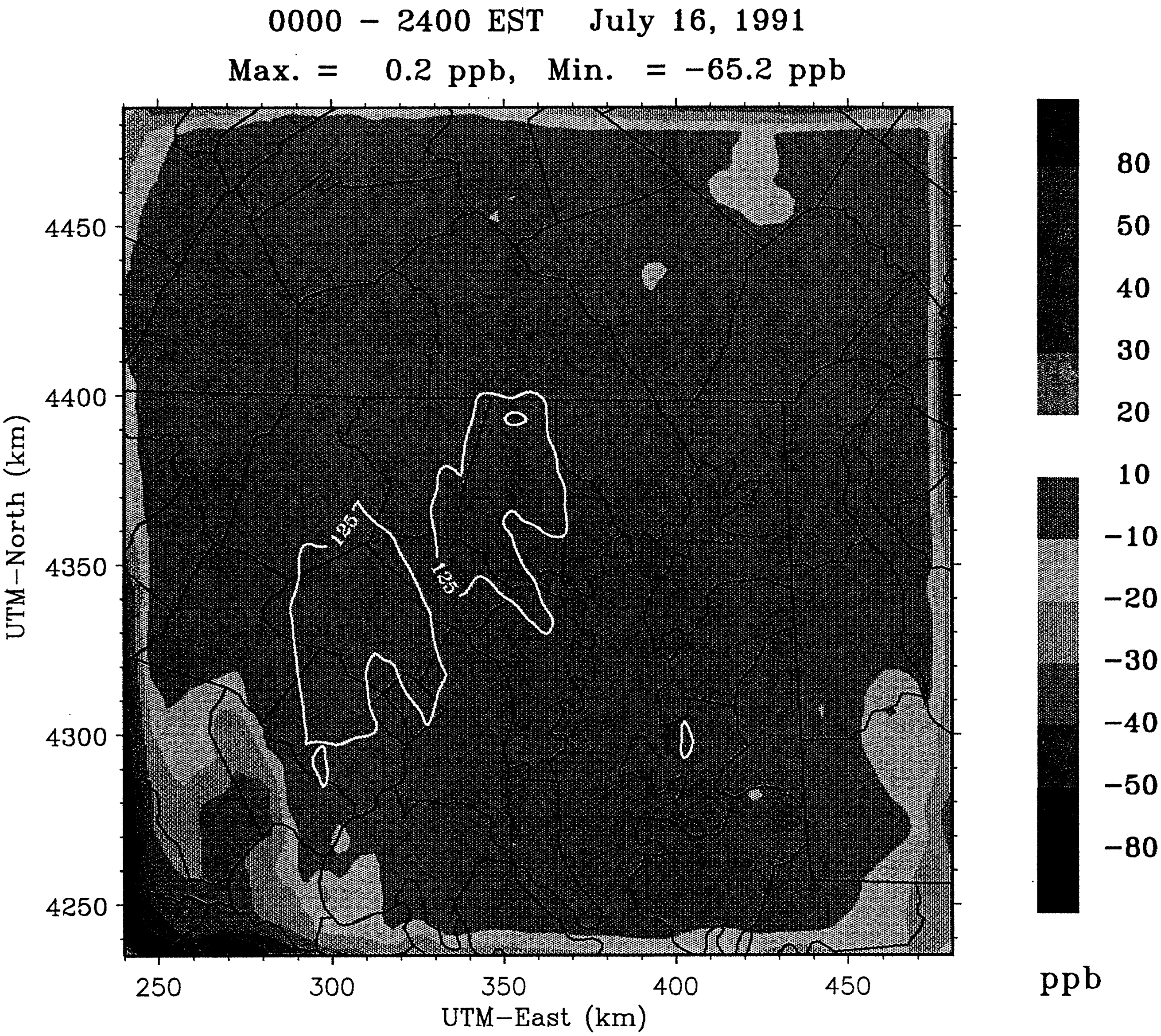


Difference in daily max ozone due to a clean boundary condition applied for the domain. Max ozone for 1999 base case (99bs1A2a) has been superimposed.

Figure 7-5(c)

Max Ozone Diff: 99bs1A2c - 99bs1A2a

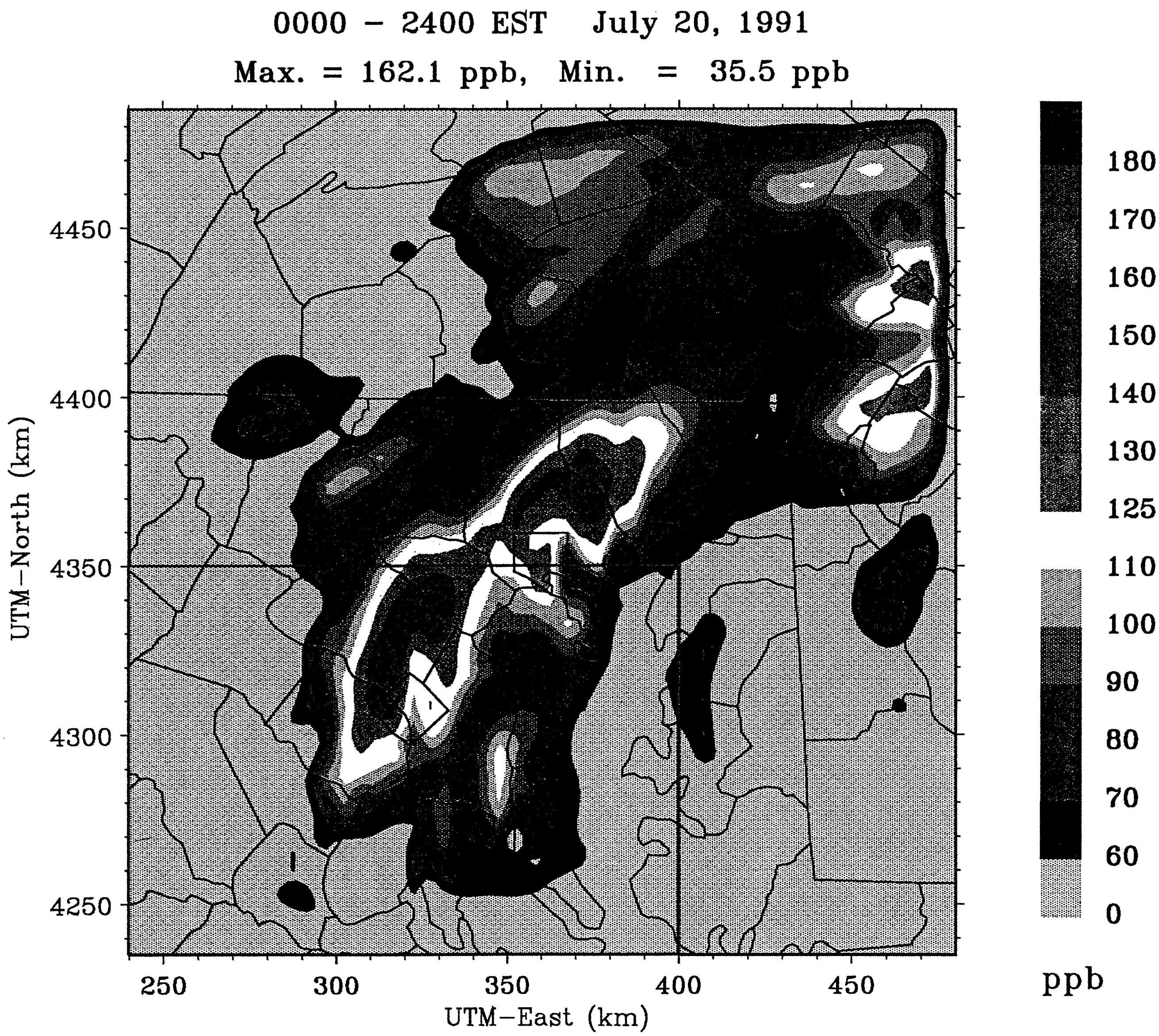
UAM-IV Layer 1, Beis2, B/W Domain



Difference in daily max ozone due to a clean boundary condition (40 ppb ozone) applied for the domain. Max ozone for 1999 Base 1 (99bs1A2a) has been superimposed.

Figure 7-6(a)

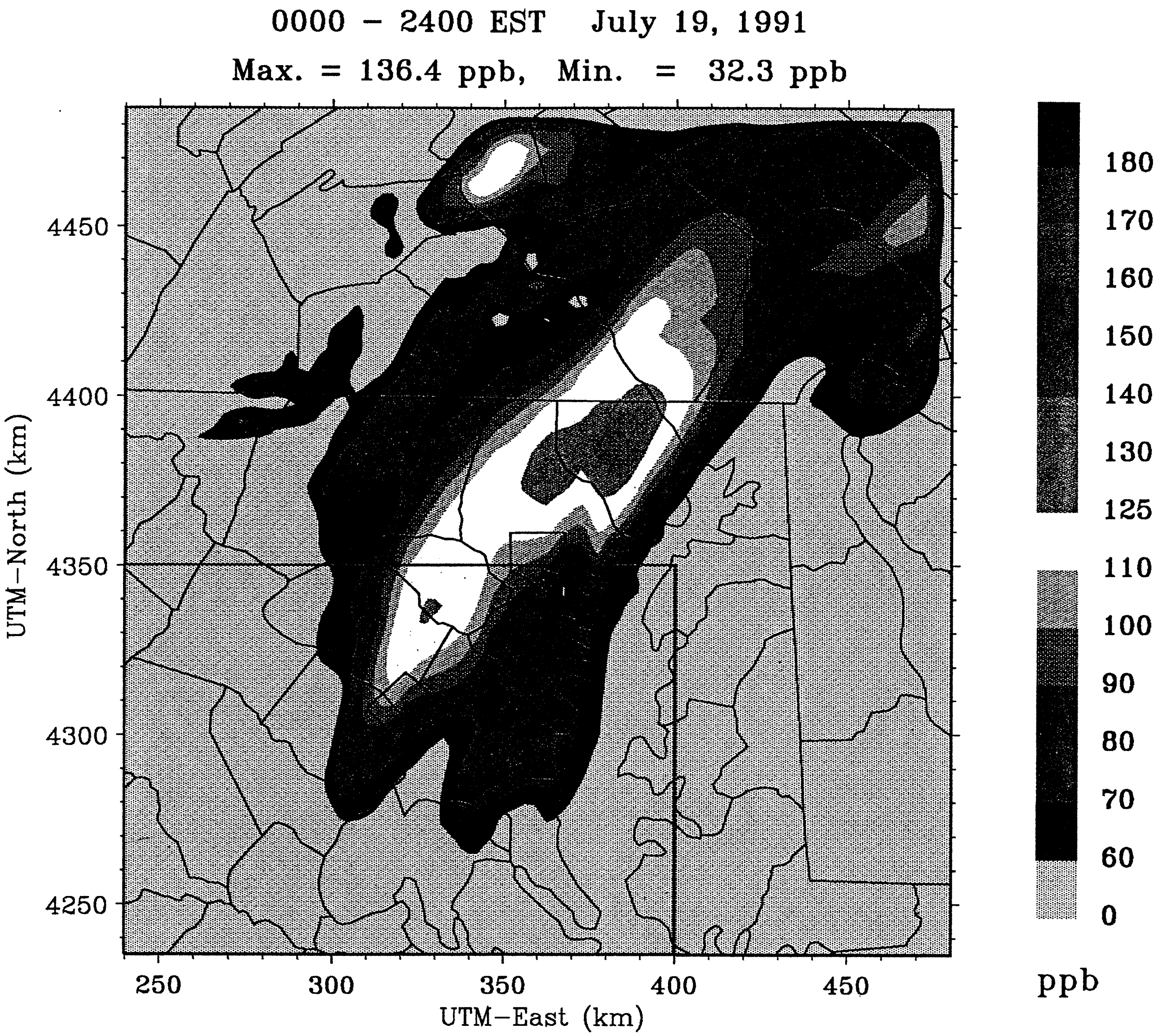
Predicted Daily Max Ozone – 1999 base (99bs1A2c)
UAM–IV Layer 1, Beis2, B/W Domain



Anthro. emission : 1999 Base 1 case (99bs1)
Biogenic emission : UAM–BEIS2
Boundary condition : clean

Figure 7-6(b)

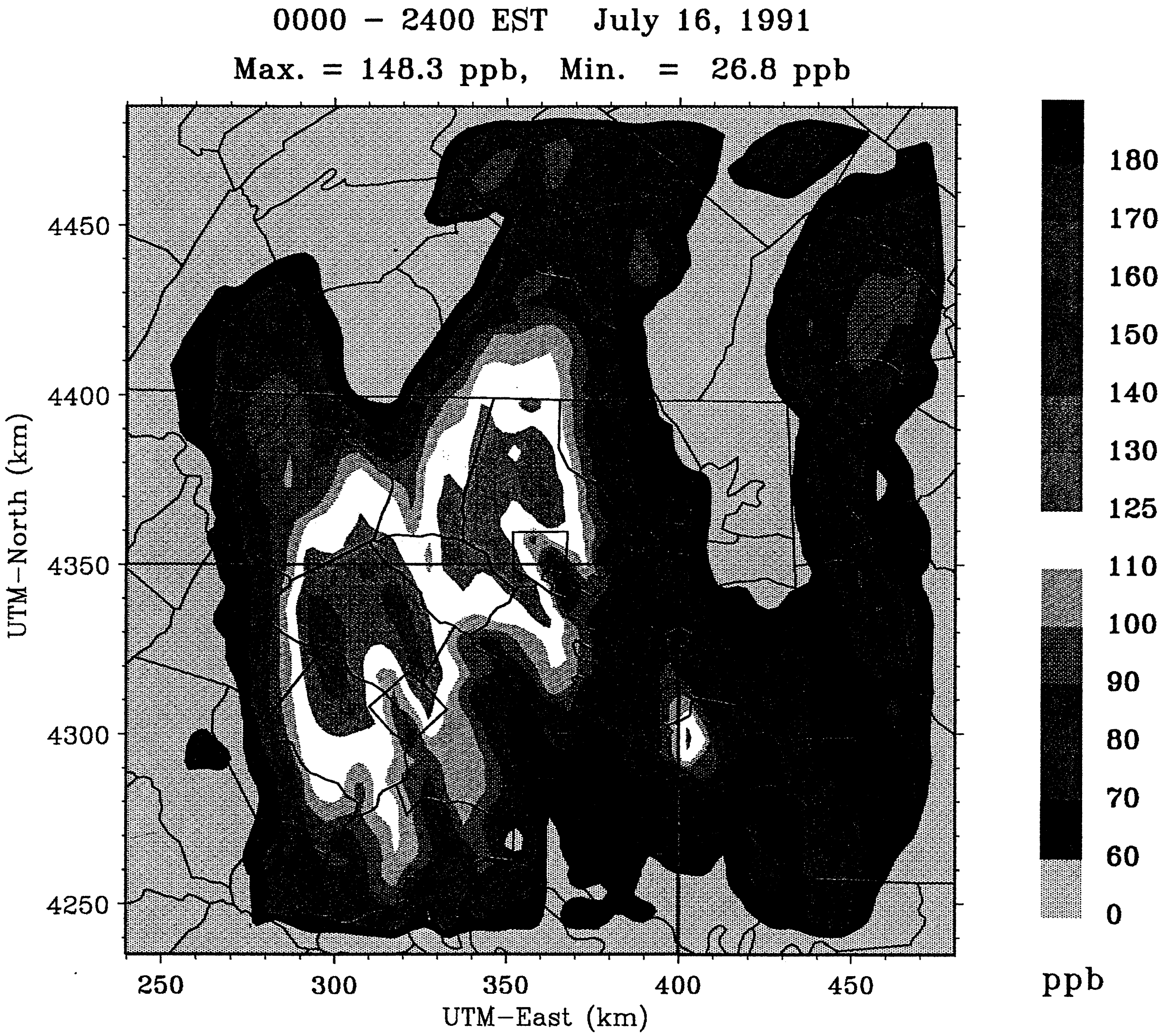
Predicted Daily Max Ozone – 1999 base (99bs1A2c)
UAM–IV Layer 1, Beis2, B/W Domain



Anthro. emission : 1999 Base 1 case (99bs1)
Biogenic emission : UAM–BEIS2
Boundary condition : clean

Figure 7-6(c)

Predicted Daily Max Ozone – 1999 base (99bs1A2c)
UAM–IV Layer 1, Beis2, B/W Domain



Anthro. emission : 1999 Base 1 case (99bs1)
Biogenic emission : UAM–BEIS2
Boundary condition : clean