Appendix 3

Analysis Of Urban Scale Modeling For Southwestern And Southeastern Pennsylvania

Introduction

The Urban Airshed Modeling (UAM-IV) for the Pittsburgh-Beaver Valley domain demonstrates that ozone concentrations at the Pennsylvania border are well in excess of typical background levels for ozone.

The model shows ground-level ozone concentrations of up to 164 ppb upwind to the west of Pennsylvania and over 120 ppb as the air mass crossed the border.

The modeling estimates similar ozone levels above the nocturnal boundary layer at the border. This impacts the ground-level concentrations when the inversion layer breaks down in the daytime and the pollutants mix down to the ground level. The result of this is higher ozone levels further inside the Pennsylvania border. Nighttime ozone concentrations of up to 113 ppb along the Pennsylvania border were demonstrated by the model. The point of maximum concentration was 133 ppb outside Pennsylvania and gradual decreased to 123 ppb as the air mass moved across the border. (See Part 1 Southwestern Pennsylvania)

Rutgers University completed two simulations for the Philadelphia Domain's July 19-20, 1991 episode. Boundary conditions for the Philadelphia Domain came from OTAG's 2007 base 1c simulation. The OTAG 2007 base 1c simulation ozone concentrations for the year 2007 using estimated growth rates and emission controls. The 2007 OTAG simulation included mandated Clean Air Act (CAA) emission controls in all nonattainment areas within the OTAG domain. Additional emission controls within the Philadelphia Domain were also included. One hour ozone concentrations in the Philadelphia nonattainment area were in excess of 150 ppb. This indicated that regions within the Philadelphia Consolidated Metropolitan Statistical Area (CMSA) can not comply with the one-hour ozone standard with mandated CAA controls in the OTAG domain and additional controls inside the Philadelphia Domain. This conclusion is consistent with the results of EPA's Policy Run[1].

An additional simulation was run with all man-made emissions inside the Philadelphia Domain set to zero. Even with no man-made emissions inside the Philadelphia Domain ozone concentrations were greater than 80 ppb, approximately twice the background concentration. This result showed that there are significant contributions to Philadelphia's nonattainment problem from regions outside the Philadelphia domain. Similar modeling studies have concluded that outside transport accounts for up to 90% of Philadelphia's peak ozone concentrations[2]. (See Part 2 Southeastern Pennsylvania)

Part 1. Southwestern Pennsylvania

Introduction

This report presents the results of urban-scale photochemical modeling analyses. It demonstrates the transport of ozone and ozone precursors into southwestern

Pennsylvania. It is based on a series of reports prepared on behalf of the Pennsylvania Department of Environmental Protection (DEP) by Alpine Geophysics, LLC (AG) describing the modeling approach, interim results, and final analyses of modeling in the Pittsburgh area. (McNally and Tesche, 1996; McNally et al., 1997; Tesche and McNally, 1996a,c; Tesche et al., 1996, 1997). The analysis considers the three primary ozone modeling episodes from 1995 (Episodes 1, 2 and 3) developed for the Pittsburgh-Beaver Valley region.

Background

The 1990 Clean Air Act Amendments (CAA) established deadlines for the EPA and the states to develop implementation plans aimed at reducing emissions of volatile organic compounds (VOCs) and nitrogen oxides (NOx) within ozone nonattainment areas and in contributing (upwind) source regions in order to reduce peak ozone concentrations below the levels of the one-hour National Ambient Air Quality Standard (NAAQS). Specific control measures and timetables were mandated, depending upon the severity of the ozone problem. However, on July 19, 1995 EPA published a determination (60 FR 37015) indicating that the Pittsburgh-Beaver Valley area had attained the federal ozone standard based on monitoring data collected up to that time. Accordingly, the SIP requirements for Reasonable Further Progress (RFP) and other CAA contingency measures no longer applied so long as the region did not violate the ozone standard.

Upon review of the 1995 ambient air quality data, the EPA subsequently determined that the Pittsburgh-Beaver Valley ozone nonattainment area was in fact not in attainment of the federal one-hour standard based. During the 1995 summer ozone season, seventeen (17) ozone exceedances of the one-hour NAAQS were monitored as were two recorded violations. Based on the ozone monitoring data from the 1993-1995 period, EPA identified the current design value in the region to be 133 ppb with an average annual number of expected exceedances of 8.2 for the same time period. Accordingly, the EPA renewed the nonattainment status of the region.

In response, the Commonwealth formed the Southwestern Pennsylvania Ozone Stakeholder's group to analyze the formation and transport of ozone and to develop appropriate emissions reduction stratagies. The Commonwealth contracted with Alpine Geophysics, LLC to perform the meteorological, and photochemical, modeling for the region.

The first goal of the Pittsburgh Ozone Modeling Study was to successfully apply EPA-approved models to three different ozone episodes in the Pittsburgh region to characterize the processes whereby ozone is formed and/or transported into the region during high ozone episodes. Figure 3-1 shows the Pittsburgh-Beaver Valley modeling domain and nonattainment area.

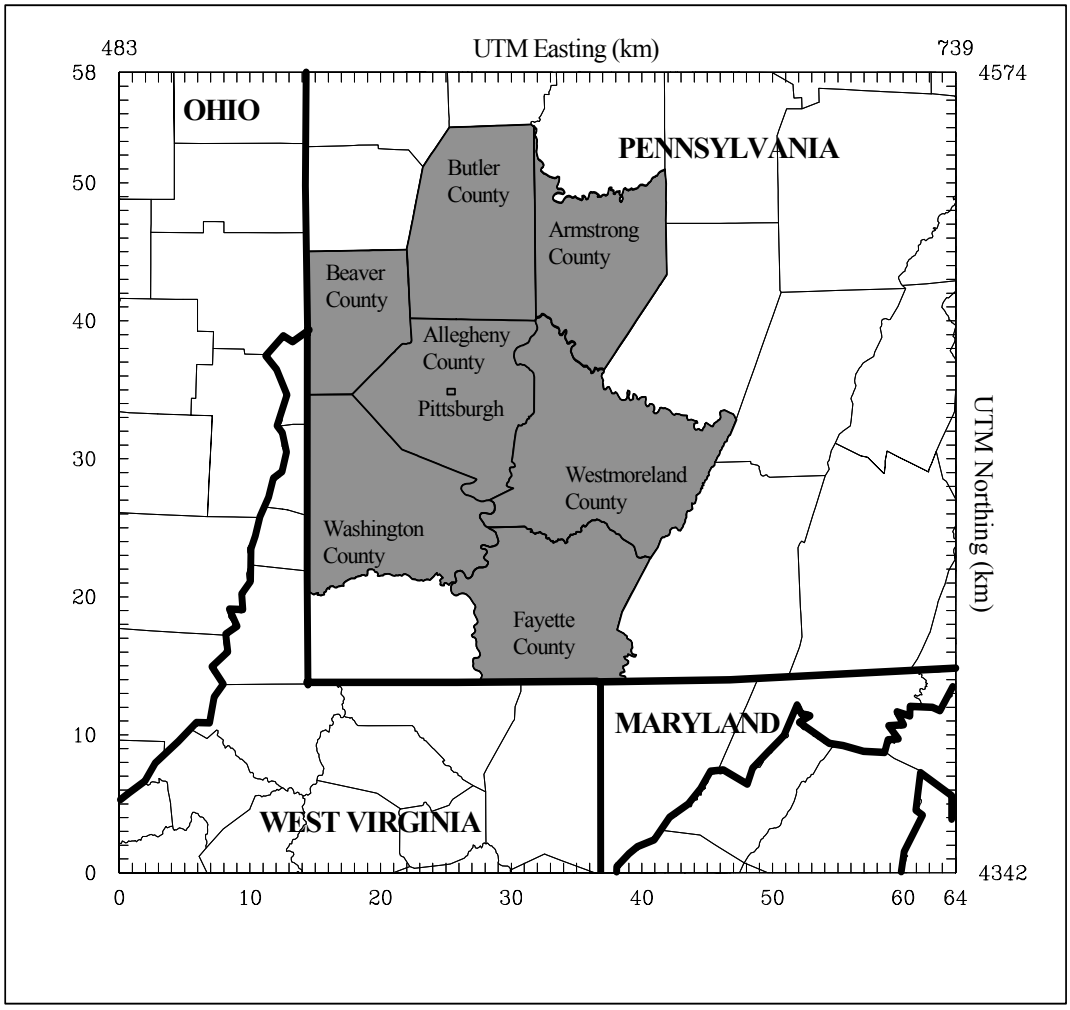


Figure 3-1. Pittsburgh-Beaver Valley Ozone Modeling Region (Non-Attainment Counties Are Shaded.)

Emission Inventory Development

The EMS-95 emissions modeling system was used to prepare a 1995 base year inventory (Tesche et al., 1997a). This was the same utility that was used to prepare inventory information for the Ozone Transport Assessment Group's (OTAG) modeling initiative.

NOx emissions from utility point sources were reviewed to verify they were appropriate considering the reported usage of the plant and the operating permits.

Motor vehicle emissions were estimated using the fleet profile for 1995 and vehicle miles traveled (VMTs) in the Pennsylvania portion of the modeling region. The VMT data for the domain were developed and provided by E. H. Pechan. Emission factors were produced using MOBILE5a with the 1995 vehicle fleet profiles. The MOVEM portion of EMS-95 was executed using 1995 vehicle emissions inspection and maintenance (I/M) options along with the VMT and emission factors.

To calculate biogenic emissions, the EPA's Biogenic Emissions Inventory System

(BEIS-1) methodology was used.

Photochemical Modeling Results

Episode 1 showed transport of ozone precursors, specifically NOx plumes, into southwestern Pennsylvania. In contrast, Episode 2 more clearly shows the movement of a large mass of ozone, both at ground level and aloft, moving into the commonwealth from the west.

Analysis of Ground Level Data

The modeling for Episode 2 (July 13 – 15, 1995) consisted of those days and also included July 12 as a "ramp up" day to allow the model to fully consider boundary conditions. Figure 3-2 shows the modeled daily maximum ozone concentration for July 13, which is the first day an exceedance is reported in the Pittsburgh domain. Table 3-1 shows the maximum daily monitored value in the Pennsylvania portion of the Pittsburgh domain over the course of the three day episode.

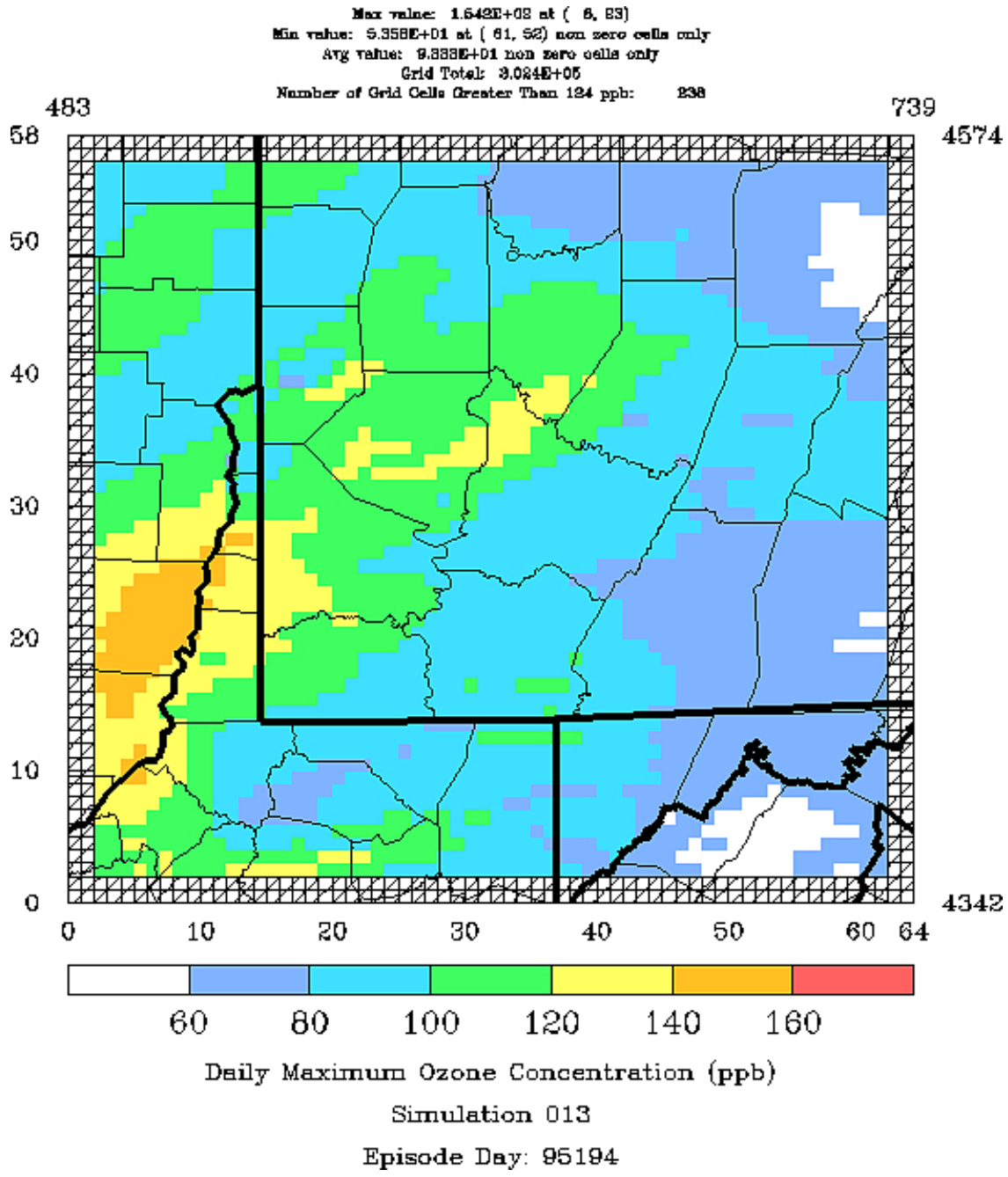

Max value: 1.642E+02 at (6, 53)
Min value: 9.358E+01 at (61, 52) non zero cells only
Avg value: 9.888E+01 non zero cells only
Grid Total: 3.024E+05
Number of Grid Cells Greater Than 124 ppb: 238
483
739
4574
4342
58
50
40
30
20
10
0
0
10
20
30
40
50
60
64
60
80
100
120
140
160
Daily Maximum Ozone Concentration (ppb)
Simulation 013
Episode Day: 95194

Figure 3-2.

Table 3-1.

Date	Site	Ozone (ppb)
7/13/95	Harrison Twp.	127
7/14/95	Harrison Twp.	129
7/15/95	Harrison Twp.	138

Figure 3-2 shows that on the first day of the episode, the highest concentrations of ozone are upwind of the Pennsylvania border. As would be expected, the following days show an increase in the daily maximum monitored value as this air mass moves into the state.

Analysis of Modeled Data at Upper Levels

Because of the diurnal effects of mixing in the atmosphere it is difficult to clearly see the process of ozone transport at ground level. During the nighttime a mixing layer is established and ozone below that layer is quickly scavenged by ground level NOx emissions. During the daylight hours, air is typically mixed more uniformly and there is also the solar radiation required for ozone generation. As a result, transport of ozone occurs primarily at altitudes above the mixing, or nocturnal boundary, layer. For this reason, data from layer 4 in the model was used to demonstrate transport.

Two different examples were selected to show the transport of ozone in Episode 2. The first example is on July 13, 1995. Figures 3-3 to 3-5 show the upper level concentrations for 5:00 p.m., 7:00 p.m. and 9:00 p.m. This shows a mass of ozone, well in excess of background levels, entering Pennsylvania from the west.

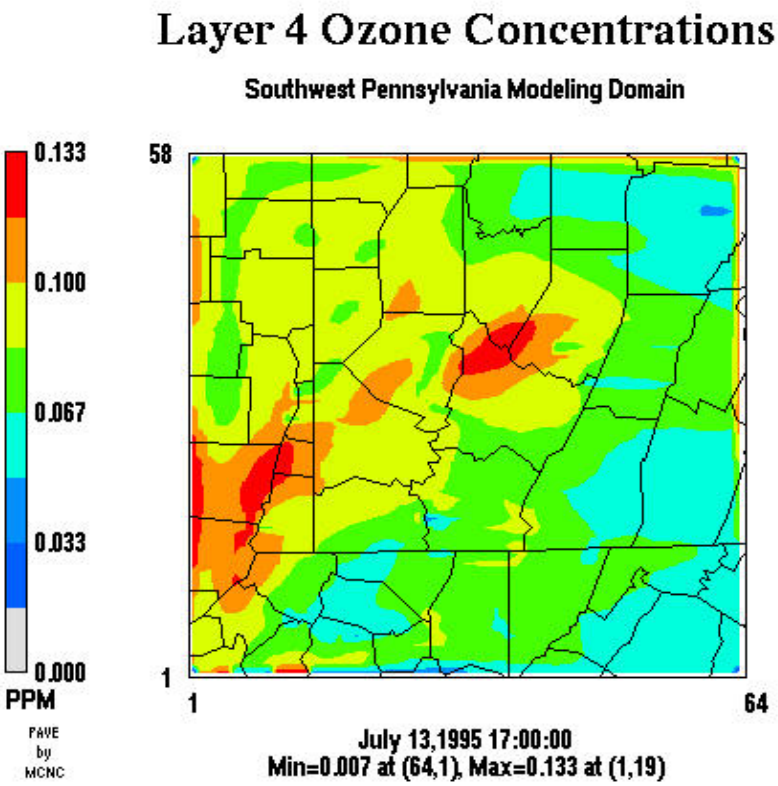
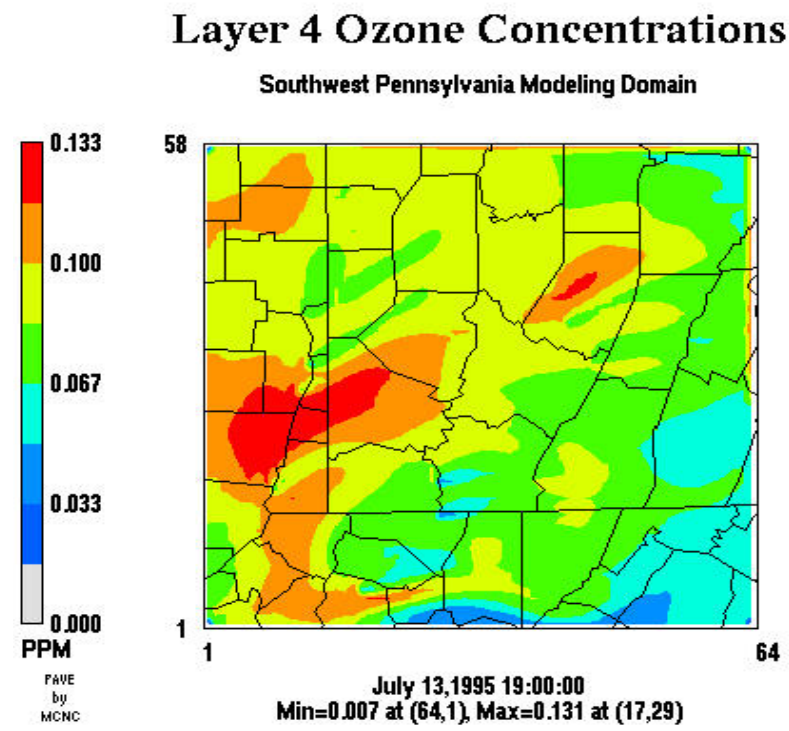

Layer 4 Ozone Concentrations
Southwest Pennsylvania Modeling Domain
0.133
0.100
0.067
0.033
0.000
PPM
PAVE
by
MCNC
58
1
1
64
July 13,1995 17:00:00
Min=0.007 at (64,1), Max=0.133 at (1,19)

Fig 3-3


Layer 4 Ozone Concentrations
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0.133
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PPM
PAVE
by
MCNC
58
1
1
64
July 13,1995 19:00:00
Min=0.007 at (64,1), Max=0.131 at (17,29)

Fig 3-4

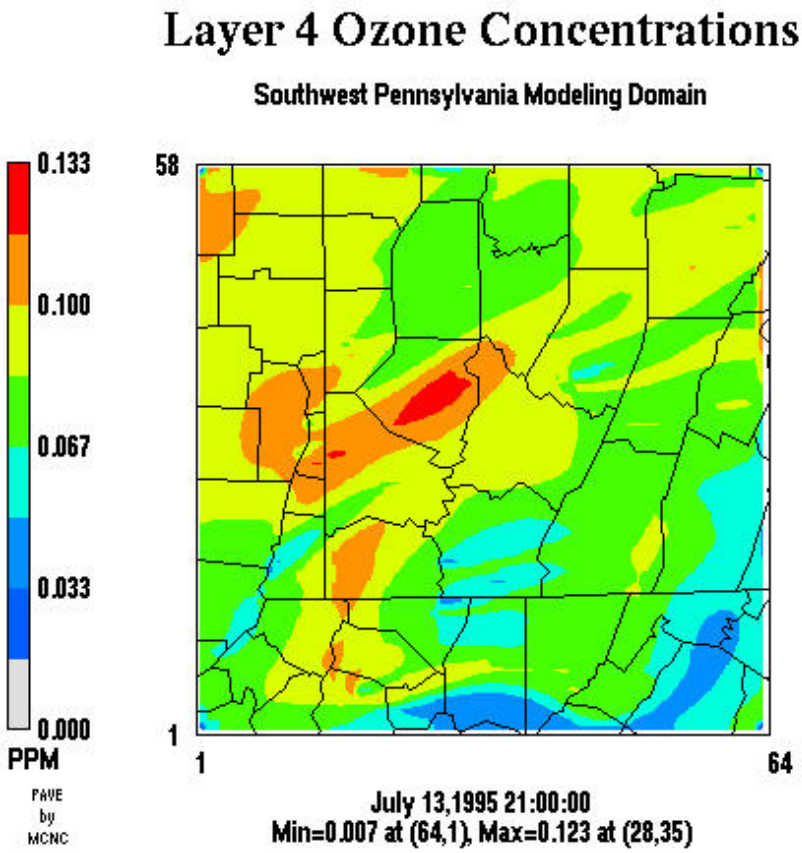


Fig 3-5

Figures 3-6 and 3-7 also show transport of aloft ozone into the state, in addition these plots also show plumes of NOx crossing Pennsylvania's border. These plumes appear because of the scavenging effects they have on ozone. This scavenging occurs when NO reacts with ozone to form nitrogen dioxide and oxygen ($NO + O_3 \rightarrow NO_2 + O_2$). Although there is a local reduction in ozone levels, in the presence of sunlight this equation reverses and produces ozone, which contributes to increased concentrations downwind.

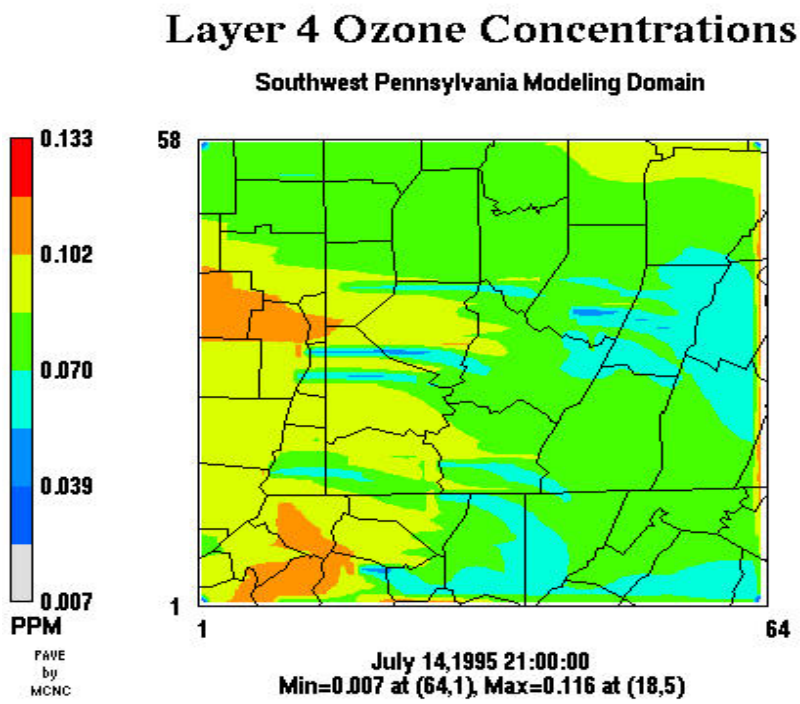


Fig 3-6

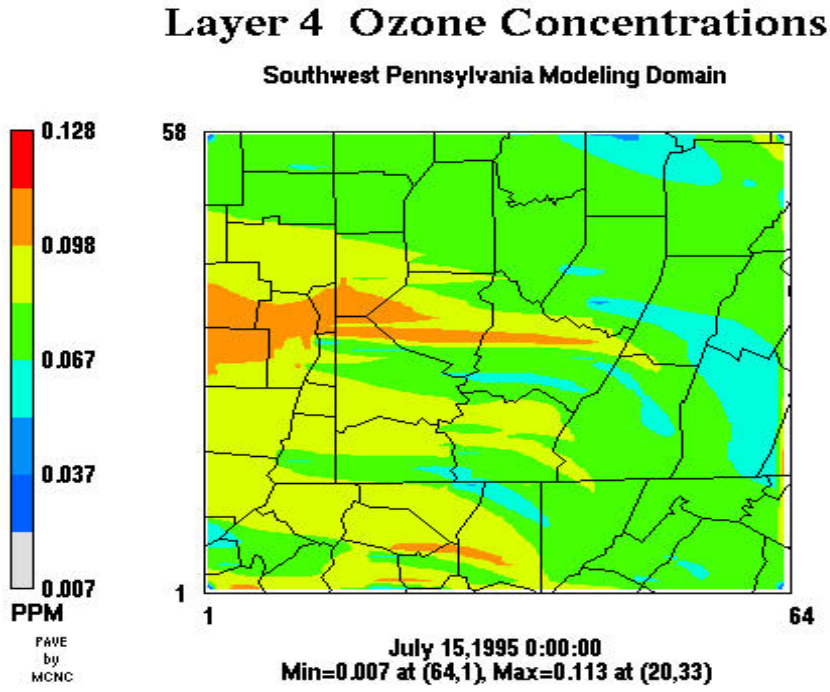


Fig 3-7

The data demonstrates that NOx emissions from major sources impact Southwestern Pennsylvania. The modeling shows ozone levels exceeding the one-hour standard in areas to the west and southwest of Pennsylvania. This ozone cloud then enters Pennsylvania, demonstrating transport.

Part 2. Southeastern Pennsylvania

Introduction

Two coupled OTAG-Philadelphia domain simulations were run for the July 19-20, 1991 episode. The OTAG simulation used UAM-V to simulate ozone concentrations within its 37-state domain (includes eastern US). UAM-IV, an earlier version of the Urban Air-shed Model (UAM), simulated ozone concentrations within a smaller subset of OTAG's domain that included the greater Philadelphia area. Values from the OTAG UAM-V simulation were used as initial conditions for the Philadelphia domain at model start-up, and along the UAM-IV's boundary throughout the simulation. UAM-IV wind fields and mixing layer heights came from the Diagnostic Wind Model (DWM) and MIXEMUP. The 1990 inventories from the states of Delaware, New Jersey and Pennsylvania provided the basis for emission rates within the Philadelphia domain. The 1990 base-line emissions were "grown" to 2005 levels (estimate of emissions for the scheduled attainment date). The following emission controls were applied to the Philadelphia domain's 2005 emission inventory:

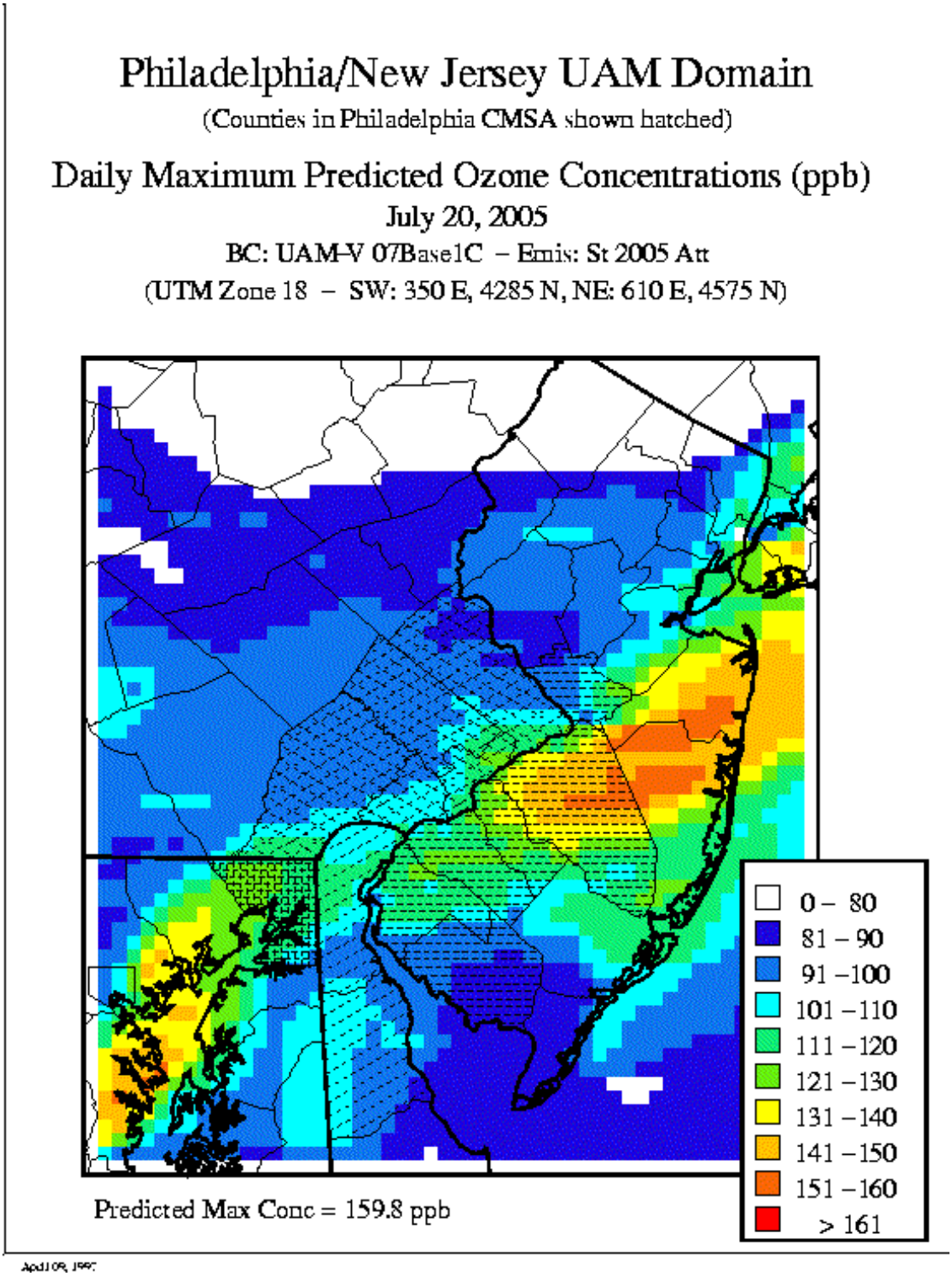
- RACT
- Title IV NOx
- Clean Air Act (CAA) Non-Attainment Provisions
- OTR NOx MOU Phase III
- LEV

OTAG's Emission Inventory Workgroup developed the inventory used in the UAM-V simulation. The inventory compiled by the workgroup covered 37 states along with portions of Canada and Mexico making it one of the most extensive emission inventory efforts to date. The OTAG inventory went through several revisions. The final emission inventory was called base 1c. Again, 1990 emissions were "grown" to 2007 levels (scheduled date of attainment for Severe areas). Emission controls used to "grow" the 1990 OTAG inventory included the following:

- RACT
- Title IV NOx
- CAA Non-Attainment Provisions

Discussion of Results

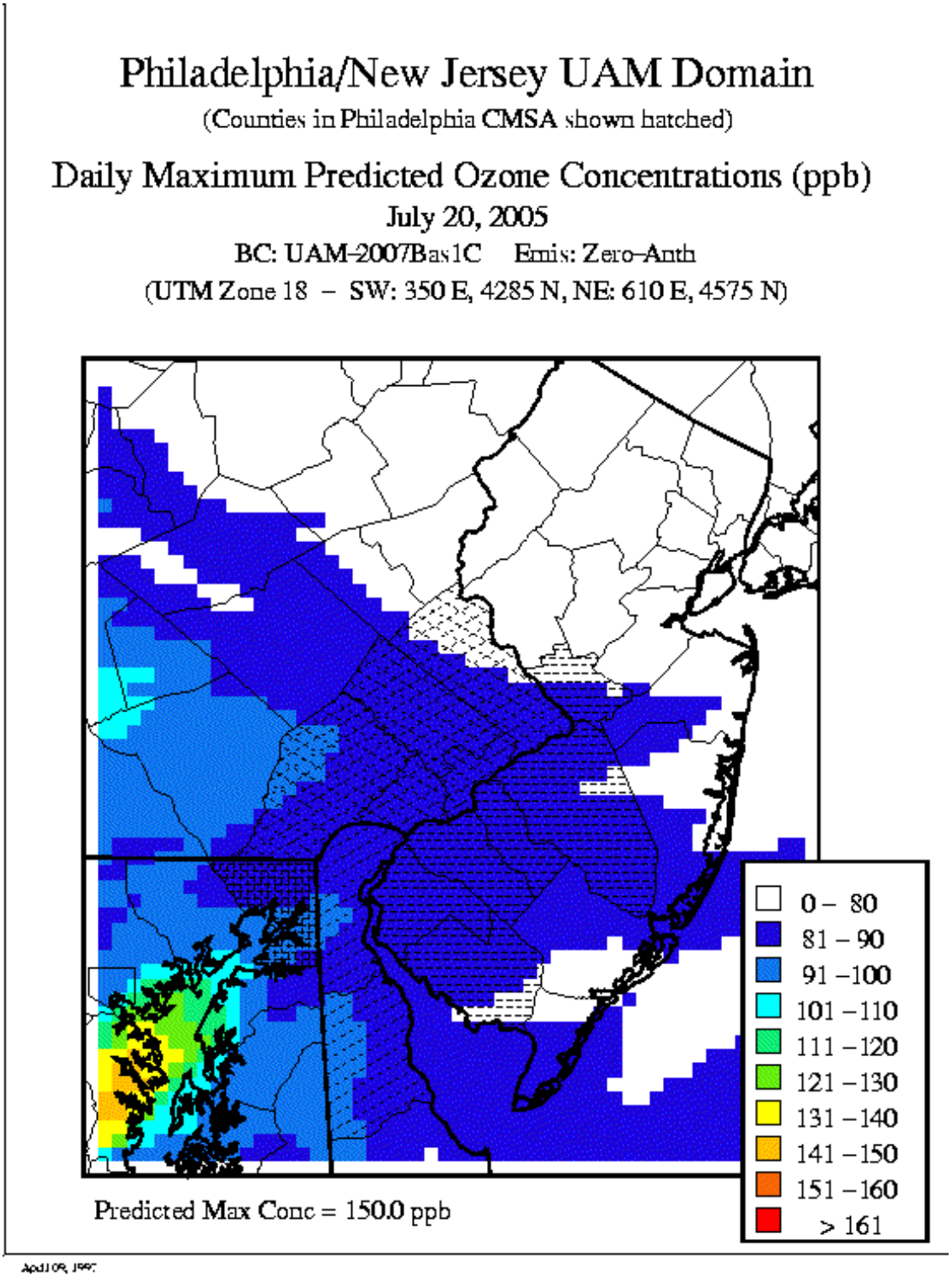
Two coupled OTAG-Philadelphia domain simulations were run for the July 19-20, 1991 episode. The OTAG simulation used the 2007 base 1c emission inventory and the Philadelphia domain simulation used the 2005 emission inventory. Results for the second day (highest modeled ozone concentrations) are shown below. Maximum modeled ozone concentrations on July 20, 1991 exceeded the current one-hour ozone standard (159.8ppb). This result indicates that even with current, proposed, and mandated emission controls, ozone concentrations within the Philadelphia domain will still exceed the current one-hour standard.



Philadelphia Domain-OTAG 2007 Simulation

The second coupled simulation was completed using the same boundary conditions from the OTAG 2007 base 1c simulation. All anthropogenic (man made) emissions within the Philadelphia domain were set to zero. This run represents the

maximum emission control scenario possible. Results from this simulation are shown below. Ozone concentrations within the Philadelphia domain (downwind of Washington



DC) still exceeded the current one-hour standard. Ozone concentrations remained above

80 ppb in most of the southwest portion of the domain. This result demonstrates that areas outside the Philadelphia domain make significant contributions to the Philadelphia non-attainment problem. Other modeling studies have come to the same conclusion siting that up to 90% of Philadelphia's peak ozone concentration is attributed to outside sources[2]. This shows that reductions in ozone and ozone precursor concentrations coming into the Philadelphia domain are essential for Philadelphia to achieve and maintain the ozone standard. Additional emission controls from large fossil fired combustion units, beyond those used in the OTAG 2007 base 1c run, have to be adopted to further decrease ozone and ozone precursor concentrations entering the Philadelphia domain.

References

1. OTAG's Regional and Urban Scale Modeling Workgroup's Clearinghouse, web address: *http://www.iceis.mcnc.org/OTAGDC/browse_images/otagdc_ftp/aqm/uamv/jul88/07bas1c/tiles/conc/bas1c-ep.gif.*
2. Preliminary Assessment of States Making Significant Contribution to Downwind Ozone Nonattainment, EPA Staff Report, April 1997, p 16.