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Development of a Model to Assess the Effect of Ozone on Public Health Using Models-3/CMAQ

Pedro Alex Sanhueza H.
University of Tennessee - Knoxville

To the Graduate Council:

I am submitting herewith a dissertation written by Pedro Alex Sanhueza H. entitled "Development of a Model to Assess the Effect of Ozone on Public Health Using Models-3/CMAQ." I have examined the final electronic copy of this dissertation for form and content and recommend that it be accepted in partial fulfillment of the requirements for the degree of Doctor of Philosophy, with a major in Civil Engineering.

Gregory D. Reed, Major Professor

We have read this dissertation and recommend its acceptance:

Susan M. Smith, Wayne T. Davis, Terry L. Miller

Accepted for the Council:

Carolyn R. Hodges

Vice Provost and Dean of the Graduate School

(Original signatures are on file with official student records.)

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Dr. Anne Mayhew

Vice Provost and Dean of
Graduate Studies

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DEVELOPMENT OF A MODEL TO ASSESS THE EFFECT OF OZONE ON PUBLIC HEALTH USING MODELS-3/CMAQ

A Dissertation Presented for the Doctor of Philosophy Degree
The University of Tennessee, Knoxville

Pedro A. Sanhueza H.
August 2002

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ABSTRACT

According to the Clean Air Act, the establishment of priorities in air pollution control should be based on benefits to public health and welfare. Given this mandate, EPA has incorporated the health effect evaluation in the regulatory impact analysis of its rulemaking, such as Tier2 sulfur gasoline reduction and HDE diesel emission reduction. The Tennessee Department of Environment and Conservation (TDEC) has identified ozone as the primary pollutant of concern. All these antecedents provided the basis for developing a decision-making tool that helps to evaluate the various regulatory options in controlling the emission of ozone precursors from a health-effects point of view.

In this context, a computer model called ORAM (Ozone Risk Assessment Model) was developed to evaluate the health-effects caused by ground level ozone exposure. ORAM was coupled with Models-3/CMAQ the EPA state-of-the-art air quality model that predicts ozone concentration and allows the examination of various emission scenarios in which emission rates of ozone precursors (basically NOx and VOC) are varied. Given that ozone is a local and regional problem, ORAM allows the health evaluation for local, regional, and continental scales. The principal analyses in ORAM are exposure model performance evaluation, health-effects calculations (expected number of respiratory hospital admissions), economic valuation, sensitivity, and uncertainty analysis through a Monte Carlo simulation.

To demonstrate the system's effectiveness, ORAM was applied to the East Tennessee region, and the entire ozone season was simulated for a base case (actual, typical emissions) and three different emission scenarios using an available hospital admissions database. The results indicated that a synergism occurs when NOx emissions from mobile (50%) and point (70%) sources were simultaneously reduced. A 19% in reduction on hospital admissions for respiratory diseases occurs when both mobile and point sources NOx emissions are reduced versus 8% due to mobile source and 7% due to point source when these source's emissions are applied singly.

ORAM has the flexibility to easily incorporate other health-endpoints such as mortality and minor restrictive activity days (MRAD) and also other pollutants such as particulate matter and other gases. Finally, because the equations in ORAM are for short-term effects (daily variation), the system developed can be used in a forecasting mode as a complementary tool in the ozone action programs such as Spare the Air or Ozone Action Days.

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NOMENCLATURE

BC	Boundary Conditions
CAA	Clean Air Act
CAPMS	Criteria Air Pollutant Modeling System
CCTM	CMAQ Chemistry and Transport Model
CDF	Cumulative Density Function
CI	Confidence Interval
CMAQ	Community Multi-scale Air Quality model
CO	Carbon Monoxide
COH	Cost Of Hospital
COI	Cost Of Illness
COPD	Chronic Obstructive Pulmonary Disease
COPD65	Chronic Obstructive Pulmonary Disease in the group of 65 years and older
C-R	Concentration-Response
EPA	Environmental Protection Agency
FDDA	Four Dimension Data Assimilation
FEV	Forced Expiratory Volume
FVC	Forced Vital Capacity
HDE	Heavy Duty Engine
HPA	High Paired Accuracy
IC	Initial Conditions
MCS	Monte Carlo Simulation

MM5	Fifth Generation Mesoscale Meteorological Model
Model-3	Third generation of air quality model
MRAD	Minor Restrictive Activity Days
NAAQS	National Ambient Air Quality Standard
NBE	Normalized Bias Error
NGE	Normalized Gross Error
NOx	Oxides of Nitrogen
MCIP	Meteorology and Chemistry Interface Processor
ORAM	Ozone Risk Assessment Model
PBL	Planetary Boundary Layer
PM	Particulate Matter
PMF	Probability Mass Function
PRE_ORAM	ORAM preprocessor
QA	Quality Assurance
QC	Quality Control
R^2	Coefficient of Determination
RIA	Regulatory Impact Analysis
SI	Sensitivity Index
SMOKE	Sparse Matrix Operator Kernel Emission system
TDEC	Tennessee Department of Environment and Conservation
VOC	Volatile Organic Compound
WTP	Willingness To Pay

CHAPTER 1

INTRODUCTION

Photochemical oxidants such as ozone, in addition to damaging ecosystems, diminishing visibility, and degrading private/public property, directly impact the health of the people, mostly as an exacerbation of existing respiratory diseases. The degree to which the various sub-populations are affected by poor air quality is an important public health topic and a challenging scientific question.

The science of ozone formation, transport, and accumulation is complex. Ground-level ozone is produced and destroyed in a cyclical set of chemical reactions involving NOx, VOC, heat, and sunlight. As a result, differences in NOx and VOC emissions and weather patterns contribute to daily, seasonal, and yearly differences in ozone concentrations and differences from city to city. Many of the chemical reactions that are part of the ozone-forming cycle are sensitive to temperature and sunlight. When ambient temperatures and sunlight levels remain high for several days and the air is relatively stagnant, ozone and its precursors can build up and produce more ozone than typically would occur on a single high-temperature day. Further complicating matters, ozone also can be transported into an area from pollution sources found hundreds of miles upwind, resulting in elevated ozone levels even in areas with low VOC or NOx emissions.

The severity, frequency, and duration of high ozone events exhibit complex patterns and source receptor relationships, such that the most efficient strategies to reduce local or regional ozone exposures are not obvious.

Based on a large number of recent studies, EPA has identified several key health effects caused when people are exposed to levels of ozone found today in many areas of the country (Delfino et al 1994, Burnett et al 1997, Lipsett et al 1997, Steadman et al 1997). Short-term exposures (1-3 hours) to high ambient ozone concentrations have been linked to increased hospital admissions and emergency room visits for respiratory problems. For example, studies conducted in the northeastern U.S. and Canada show that ozone air pollution is associated with 10-20 % of all of the summertime respiratory-related hospital admissions. Repeated exposure to ozone can make people more susceptible to respiratory infection and lung inflammation and can aggravate preexisting respiratory diseases, such as asthma. Prolonged (6 to 8 hours), repeated exposure to ozone can cause inflammation of the lung, impairment of lung defense mechanisms, and possibly irreversible changes in lung structure, which over time could lead to premature aging of the lungs and/or chronic respiratory illnesses such as emphysema and chronic bronchitis.

Air quality models are valuable air quality management tools. Models are mathematical descriptions of pollution transport, dispersion, and related processes in the atmosphere. Air quality models estimate the air pollutant concentration at many locations, which are referred to as receptors. The number of receptors in a model far exceeds the number of monitors one could typically afford to deploy in a monitoring study. Therefore, models

provide a cost-effective way to analyze impacts over a wide spatial area where factors such as meteorology, topography, and emissions from nearby sources could be important.

Large-scale or regional models are sometimes used to simulate the air quality impacts from all sources in a wide area. This more complex analysis is usually reserved for developing plans to clean up areas where air quality does not comply with the NAAQS. These models are useful for determining the effectiveness of regional air pollution control strategies such as vehicle inspection or fuels programs and of point source control measures.

The uncertainty in the level when the ozone effect is significant and in the exposure of the people to ozone levels provides the basis to develop research in this area. Thus this work was oriented to determine the relationships of ozone and respiratory diseases under exposures simulated with an urban air quality model for real conditions and using different emissions scenarios.

The objective of this project was to develop a computer-based method to quantify the health risks posed by the air pollution on an urban to regional area, based on different emission scenarios by linking the concentration of ozone predicted by an air quality model, with the risk factors associated with the number of hospital admissions by asthma and COPD.

To simulate the formation and transport of photochemical smog, Models-3/CMAQ was used (EPA Models-3 2001). The principal contribution of this research was to develop a model called ORAM (Ozone Risk Assessment Model) that was coupled to the Models-3/CMAQ output data to make the connection between air quality and public health. As a test case, ORAM was applied to East Tennessee and the health effects associated with three emission scenarios (reduction in NOx for mobile and point sources) were evaluated. To do that, the Models-3/CMAQ results were used to determine the spatial and temporal variations of ozone levels in the modeling domain. These concentration fields were transferred to the ORAM model as local environmental conditions that set the stage for human exposure calculations based on different ozone exposure times (daily maximum 1-hr, daily maximum 8-hr). The exposure data were then translated into excess risk to human health by using the equations developed for Knox County (Reed et al 2000, Sanhueza et al 2002) for the excess number of hospital admissions for Asthma and COPD.

The utility of the proposed modeling approach is that it can be used as a predictive tool to guide policy-making decisions. Toward this goal, the integrated Models3-CMAQ/ORAM system could be applied to estimate the consequences of changes in the emissions of the mobile fleet (for example, the benefits gained by shifting to NLEV or Tier-2) and reductions in the emissions from principal point sources in the area by using SCR (Selective Catalytic Reduction) or other measures. The combined Models3-CMAQ/ORAM model would facilitate these and other sensitivity analyses.

CHAPTER 2

LITERATURE REVIEW

According to the premise of the Clean Air Act, the establishment of priorities in air pollution control should be based on benefits to public health (Clean Air Act 1990). Ozone has been identified as the primary air pollutant of concern for Tennessee (TDEC 2001), and no policy-related studies have been conducted to evaluate the impact of current air quality and health effects data on future policy decisions. Benefits of improved air quality would reduce lost work time, improve productivity, slow rising health care costs (with special benefits for the young and old), offset negative influences on tourism, and promote sustainable development.

East Tennessee with two million inhabitants is a region recognized by its ozone problems, specifically in the more heavily populated counties (Knox, Hamilton) and the Great Smoky Mountains National Park. According to the report on ozone released by the American Lung Association (ALA 2002), Knoxville MSA is ranked the 8th worst ozone-polluted metropolitan area in the United States. In terms of people at risk, 11% of the people living in Knoxville MSA have some respiratory disease such as asthma (5%) or chronic obstructive pulmonary disease (COPD) (6%). In the Knoxville area, respiratory diseases, and specifically asthma and COPD, have increased dramatically during the last few years. For the period from 1994 to 1998 asthma admissions have augmented 90.5% and COPD 48.7%. This increase is found nationwide and ozone has been indicated as one of the causes. The maximum 1-hr ground-level ozone in Knoxville has increase by

34% from 1994 to 1998 and could be one of the potential causes of the increased number of respiratory admissions (Reed et al 2000).

2.1 Ozone and human health effects

After many years of research, scientists and the media have made it clear that ozone can affect people's health in many ways such as irritation of the respiratory system, reducing lung function, aggravating asthma and other chronic lung diseases (emphysema, bronchitis), and inflaming and temporarily damaging the lining of the lung (EPA-Air & Radiation 2001). The question that is still controversial is the level at which the effects begin because most people only have to worry about ozone exposure when concentrations reach high or very high levels. Some groups of people are particularly sensitive to ozone, and members of these groups are likely to experience health effects before ozone concentrations reach high levels. However, when ozone levels are very high, everyone should be concerned about ozone exposure. In general, as ozone concentrations increase, more and more people experience health effects and the effects become more serious. People most sensitive to ozone include children, adults who are active outdoors, people with respiratory disease (such as asthma), and people with unusual susceptibility to ozone. Active children are the group at the highest risk from ozone exposure. Such children often spend a large part of their summer vacation outdoors, engaged in vigorous activities either in their neighborhoods or at summer camp. Children are also more likely to have asthma or other respiratory illnesses. Asthma is the

most common chronic disease for children and may be aggravated by ozone exposure (EPA-Air & Radiation 2001).

There is no evidence that ozone causes asthma or other chronic respiratory disease, but these diseases do make the lungs more vulnerable to the effects of ozone. Thus, individuals with these conditions will generally experience the effects of ozone earlier and at lower levels than less sensitive individuals. One must recognize that not only ozone is responsible for respiratory impairments but also many others factors such as weather conditions (temperature, relative humidity), epidemiological conditions, and ages and health status of the individuals.

In 1997, EPA adopted a new, more stringent standard for ozone, based on research that found that the original NAAQS for ozone, known as the 1-hr standard, was not adequately protective of human health (EPA 1997). The 1-hr standard limited ozone levels to 0.12 parts per million averaged over a 1-hr period. The new standard, known as the 8-hour standard, requires that a community's ozone levels be no higher than 0.08 parts per million when averaged over an 8-hour period. In 1999 numerous parties challenged the standard in the courts, and on February 27, 2001, the Supreme Court handed down a decision, upholding EPA on the major issues while requiring the Agency to develop a new approach to implementing the standard for ozone. Finally, on March 26, 2002, the D.C. Circuit Court rejected all remaining challenges to EPA's 1997 protective ambient standard for ground-level ozone. With this support, the EPA is now moving forward with programs to implement the new standard.

In the United States and other countries, many studies have been conducted to determine the relationship between ozone and respiratory endpoints (Delfino et al 1994, Burnett et al 1994, Thurston et al 1994, Kesten et al 1995, Stieb et al 1996, Burnett et al 1997, Lipsett et al 1997). Tables II.1 and II.2 summarize the findings in ozone and morbidity studies, with emphasis in the significance of the association between daily ground level of ozone and respiratory disease, for different exposure levels and age group populations under study.

In Ponka's study (Ponka et al 1994), the ozone levels were very low even in summer, which explains the lack of significance between ozone and respiratory hospital admissions. Schwartz (Schwartz 1995) studied the association between air pollution and respiratory admissions among the elderly population in Tacoma and New Haven. He found a significant association between respiratory hospital admission and ozone in Tacoma but not in New Haven. Even though the concentrations of ozone were less in Tacoma than in New Haven, the meteorology could be the explanation because Tacoma has milder weather in summer with fewer hot hazy days than New Haven. He suggested that the use of air conditioning in New Haven could have reduced the actual exposure in this city. In the study of Castellsague (Castellsague et al 1995), there is no significance between ozone and respiratory emergency visits, probably because of the low levels of ozone. Lipsett (Lipsett et al 1997) studied only the winter period and for this reason did not find a relationship with ozone in his study. All other studies found significant association between ground-level ozone and respiratory admissions, regardless of the model structure and seasonal control applied.

Table II.1 Summary of findings in ozone and hospital admission studies

Nº	Author	YP	Period	Years	O31hr	SD	Max_O_3	Age	City	Results
1	Ponka	94	Jun-Aug	87-89	12	13	45	All	Helsinki	N/S
2	Delfino	94	Jul-Aug	84-88	72	35	118	All	Montreal	N/S
3	Burnett	94	May-Aug	83-88	70	--	107	All	Ontario	Sign.
4	Thurston	94	Jul-Aug	86-88	70	--	159	All	Toronto	Sign.
5	White	94	Jun-Aug	90	78	24	163	<16 yr	Atlanta	Sign.
6	Kesten	95	Jan-Dec	90-91	---	---	---	All	Toronto	Sign
7	Schwartz	95	All year	88-90	29 25	-- --	45 36	>65 yr >65 yr	New Haven Tacoma	N/S Sign.
8	Castellsague	95	Su/Win	85-89	43	--	71	>14 yr	Barcelona	N/S
9	Romieu	95	Jan-Jun	90	90	--	250	<16 yr	Mexico City	Sign
10	Stieb	96	May-Sep	84-92	42	---	160	All	Saint John Ca	Sign
11	Lipsett	97	Winters	88-92	24	10	70	All	Santa Clara	N/S
12	Delfino	97	Jun-Sep	92-93	36	14	67	>65	Montreal	Sign.
13	Burnett	97	Sp,Su,Fa	81-91	38	--	84	All	16 Ca. cities	Sign.
14	Sanhueza	02	Apr-Oct	94-98	65	21	148	>20	Knoxville TN	Sign

YP : Year of publication
O31h : Average of ozone maximum 1-hr (ppb) during the period
SD : Standard deviation of ozone concentration
N/S : Not significant (Relative Risks <=1.0)
Sig : Significant association between ozone and hospital admissions (Relative Risk >1.0)
Sp,Su,Fa,Win : Spring, Summer, Fall, Winter

Table II.2 Summary of significance in ozone and hospital admission studies

Nº	Author	YP	Model	Control Seasonality	Co-pollutants	Lag	Relative Risk[1]
1	Burnett	94	Random Effect Model	High pass filter	SO_4, NO_2	1	1.02
2	Thurston	94	Multiple Regression	Fourier transformation	H+, SO_4, TSO, PM10	1	1.03
3	White	94	Poisson Regression	Dummies	SO_2, PM10, Pollen	1	1.07
4	Kesten	95	Autoregressive Regression	--	SO_2, NO2	7	--
5	Romieu	95	Poisson Regression	Dummies	SO_2, NO2, TSP	1	1.07
6	Schwartz	95	Poisson Regression	High pass filter	SO_2, PM10	2	1.08
7	Stieb	96	Non-linear Regression	High pass filter	SO_2, NO2, SO_4, TSP	2	--
8	Delfino	97	GLM regression	High pass filter	SO_4, PM10, PM2.5, H^+	1	1.05
9	Burnett	97	Random Effect Model	High pass filter	SO_2, NO_2, CO, COH	1	1.02
10	Sanhueza	02	Poisson Regression	Dummies and Fourier transformation	PM2.5, PM10, PM coarse	0	1.05

YP :Year of publication
1 :Normalized to 10 ppb O_3 change

From the results of previous studies performed in different cities with different weather conditions and populations structure, we see that some of them have found significant association between ozone and respiratory disease but others not, even though all of them have used a methodology that included a control for seasonality and confounders. The review of different epidemiological studies shows that at present, some sort of relationship between ozone and respiratory diseases exists, but due to the uncertainties in actual exposures and the health base line of the population, the threshold when the effect begins remains essentially questionable.

2.2 Health risk modeling

The study of the relationship between daily counts of health events and daily air pollution is performed using multiple regression techniques with filtering steps in order to incorporate seasonality and the confounders before the introduction of the pollutant predictors. The multiple regressions can be linear or non-linear depending on the characteristics of the relationship among the variables, which are checked step by step during the process through the non-parametric regression analysis using generalized additive models that have the following general form:

$$Y = \alpha + \sum_{i=1}^{p} f_i(X_i) + \varepsilon \qquad \text{(Equation 2-1)}$$

Where,

Y	=	Respiratory response to be fitted
α	=	Constant term in the equation
f_i	=	The adjusted function modeled using a locally weighted smoother estimation
X_i	=	Confounders and predictor variables
ε	=	Error term

The control for seasonality is performed using Dummy and Fourier variables. Dummies are used to control the trend (annual variation) and day of the week variation, and Fourier series are used to control the low frequency noise attributable to monthly variations (Thurston and Ito 1999).

Most of the studies linking air pollution and health have used a Poisson multiple regression model (Schwartz et al 1996), in which the mean of the daily effects (Y) is modeled as an exponential function of the explanatory variables (X_i):

$$E[Y] = \exp(\Sigma\lambda_i X_i) \qquad \text{(Equation 2-2)}$$

Where,

Y	=	Number of respiratory hospital admissions (asthma, COPD, etc.)
X_i	=	Vector of covariates (air pollution and meteorology)
λ_i	=	Vector of coefficients associated with each covariate.

In this model, if β represents the coefficient associated with ozone, then the relative risk (RR) related with a change in the ozone levels (ΔO_3), is given by

$$RR(\Delta O_3) = \exp(\beta\Delta O_3) \qquad \text{(Equation 2-3)}$$

The RR measures the increase (or decrease) in the expected number of respiratory admissions as a result of an increase of the ozone concentration above a certain value (the threshold or average); it is also the parameter required to perform an economic and environmental impact analysis of different air quality scenarios.

2.2.1 Concentration-Response equation

Results from epidemiological studies are used as the basis for determining the health effect through the concentration-response functions (C-R). As the functional form of the ozone-health effect is log-linear, the relationship between a change in the concentration (ΔO_3) and the change in hospital admissions (ΔAdm) is given by the following equation (EPA 1999a):

$$\Delta Adm = r_0(e^{\beta \Delta O3} - 1)p \qquad \text{(Equation 2-4)}$$

Where,

r_0 = Baseline incidence of the health effect (daily hospital admission rate as the number of hospitalization divided by the population)

β = Ozone coefficient (obtained through Poisson regression with control for seasonality and other confounders)

ΔO_3 = ($C-C_T$) is the change in ozone concentrations from a reference concentration or if it exists, from the threshold value (C_T)

p = Exposed population.

For short-term studies, like the daily time series studies, the above formula applies to daily effects, and the effects rate should be expressed as the number of effects per day. To obtain the number of excess effects in a year (EY), it is necessary to add the effects

for all days of the year. If the effects rate and population exposed are constant throughout the year, we obtain

$$EY = pr_0 \sum_{i=1}^{365} \left(e^{\beta(Ci - CT)} - 1\right), \quad \text{for } C_i > C_T, \text{ or } 0 \text{ other case} \qquad \text{(Equation 2-5)}$$

There are several epidemiological studies that have produced the required parameters to be used in the C-R functions for many health effects (mortality and morbidity); however, they vary in the number of pollutants included, the target population, the years where the data base was obtained, the study area, and the way they control the confounders. In its studies for determining the benefits and costs of the Clean Air Act Amendments, EPA has developed criteria for selecting appropriate studies for each health endpoint. Among these criteria are peer review, study type, study population, study period, study location, and pollutants included in the model (EPA 1999a).

When applying the C-R functions, two major issues need to be considered if the epidemiological parameters are not available for the study area: (1) the regional variation of the C-R relationship and (2) the baseline incidence rate.

(1) EPA recognizes that there are a limited number of cities where the C-R functions have been calculated, so for each city or area where the health effects need to be evaluated, EPA recommends selecting one of them or a pooled function of them and applying the same C-R relationship everywhere in the current application.

(2) Unfortunately, the baseline incidence data associated with ambient levels of air pollutants cannot easily be obtained, and the EPA recommends the use of those rates available from some specific cities as representative of all the study area (EPA 1999a). Table II.3 shows some of the C-R functions used by EPA in its regulatory impact analysis (RIA) studies.

2.2.2 Modeling the effect of ozone on health in Knoxville

A study was performed using a state-of-the-art statistical techniques discussed in section 2.2, to control for confounders in order to determine the possible threshold in the relationship of ozone and respiratory diseases in the Knoxville area, where the maximum ground-level ozone concentration has increased during a recent five-year period (34% between 1994-1998, daily maximum 1-hr) (Reed et al 2000, Sanhueza et al 2002). The information used corresponds to daily registers from April to October (1994-1998) of morbidity, air quality, and meteorological variables. The morbidity data were obtained from the records of a major hospital in Knoxville. The data consisted of respiratory and digestive (as a control) daily admissions records. The ozone data were obtained from monitoring stations located in Knox County and reported in the U.S. EPA Aerometric Information Retrieval System database. The meteorological data were obtained from the NCDC for McGee-Tyson Airport located 13 miles from Knoxville. Tables II.4 and II.5 show each variable and give a description of each one of them. The dependent variables were selected for people age 20 years and older.

Table II.3 Concentration-Response functions for ozone

Health endpoint	C-R function	Source
All respiratory hospital admissions	$\Delta Resp = r_0*(e^{\beta*\Delta O3} - 1)*p$ r_0 = 2.58E-5 β = 0.00489 σ_β = 0.00106 p = all ages O_3 = 12 hrs average	Burnett et al 1997 Location: Toronto, Canada Other pollutants in the model: PM coarse, NO_2, SO_2
Asthma hospital admissions	$\Delta Asthma = r_0*(e^{\beta*\Delta O3} - 1)*p$ r_0 = 5.75E-6 β = 0.00250 σ_β = 0.000718 p = all ages O_3 = daily average	Burnett et al 1999 Location: Toronto, Canada Other pollutants in the model: PM coarse, CO
COPD hospital admissions	$\Delta COPD = r_0*(e^{\beta*\Delta O3} - 1)*p$ r_0 = 1.56E-5 β = 0.00303 σ_β = 0.00110 p = all ages O_3 = daily average	Burnett et al 1999 Location: Toronto, Canada Other pollutants in the model: PM coarse, CO
COPD hospital admissions	$\Delta COPD65 = r_0*(e^{\beta*\Delta O3} - 1)*p$ r_0 = 3.75E-5 β = 0.00274 σ_β = 0.00170 p = age 65 and older O_3 = daily average	Moolgavkar et al 1997 Location: Minneapolis, MN Other pollutants in the model: PM10, CO
COPD hospital admissions	$\Delta COPD65 = r_0*(e^{\beta*\Delta O3} - 1)*p$ r_0 = 3.05E-5 β = 0.00549 σ_β = 0.00205 p = age 65 and older O_3 = daily average	Schwartz 1994 Location: Detroit, MI Other pollutants in the model: PM10

Source: EPA 1999a

Table II.4 Environmental variables

Variable name	Unit	Description
Month	April – October	Month
DOW	Monday-Sunday	Day of the week
Kx1	ppb	$[O_3]$ daily max 1-hr in Knoxville
Kx8	ppb	$[O_3]$ daily max 8-hr in Knoxville
Kte	ppb	$[O_3]$ average :10-18-hr in Knoxville
PM10	$\mu g/m^3$	$[PM_{10}]$ as a function of meteorology
PM2.5	$\mu g/m^3$	$[PM_{2.5}]$ as a function of meteorology
Tx	º C	Daily maximum temperature
Ti	º C	Daily minimum temperature
Ta	º C	Daily average temperature
Dwpa	º C	Dew-point temperature (daily average)
RH	%	Relative humidity (daily average)
THI	º C	Thermohygrometric index
SI	--	Steadman index
WSPa	m/s	Daily average wind speed
Diravg	Grads	Daily average wind direction
Dirstd	Grads	Standard deviation of the wind direction
Visa	Mile	Visibility

Source: Sanhueza et al 2002

Table II.5 Morbidity indicators

Variable's name	Unit	Description
Asthma	Number	Daily count : ICD-9: 493
COPD	Number	Daily count: ICD-9: 490-496 (-493)
COPD65	Number	COPD for people over 65 years old
Digestive disease	Number	Daily count used as a control: ICD-9:520-529, 531-535

ICD-9 : International Classification Disease 9º Revision

Source: Sanhueza et al 2002

COPD : Chronic Obstructive Pulmonary Disease

COPD65: Chronic Obstructive Pulmonary Disease for people > 65 years

The following pages were excerpted from previous studies (Reed et al 2000, Sanhueza et al 2002).

Model development

In order to determine the relationship between ozone and the respiratory diseases asthma and chronic obstructive pulmonary disease (COPD), the Air Pollution Health European Approach (APHEA) protocol (Katsouyanni et al 1995) was followed. The model development protocol begins with the study of the probability distribution of the dependent variables (COPD, COPD65 [age 65 and older] and asthma). The lag structure between the independent and the dependent variables and the influence of the confounders in the relationship were also analyzed. Confounders studied included the day of the week, meteorology variables (temperature, dew point temperature, relative humidity, wind speed, wind direction, standard deviation of the wind direction, and visibility), and particulate matter (PM_{10}, $PM_{2.5}$ and Coarse). After this preliminary examination, a multivariate analysis to determine the interaction among the variables was incorporated in the model. A regression tree with prune analysis was used to perform this task. Finally, by using a non-parametric regression model with Generalized Additive Model (GAM) and locally weighted smoother estimation (LOESS), and incorporating the confounders as was suggested by this analysis, models were built that gave the relationship of ozone (after controlling for seasonality and confounders) with the respiratory diseases. In each step, the significance of the parameters and the autocorrelation of the residuals were checked in order to select the best model.

Models for COPD

Applying the protocol for determining the best model for COPD, the control for trend and seasonality was the first step. Then using the residuals of this model (called Model1), a non-parametric smoothing regression was performed against the confounder variables (meteorological and particulate matter variables). The objective was to determine the strength and form of the relationship in order to incorporate those variables that can help explain part of the COPD's variability. From this analysis it was determined that the relative humidity and the wind speed performed the best control. This new model was called Model2. The next step was again to perform a non-parametric smoothing regression but now between the residuals of the Model2 with the ozone concentrations, using different ozone metrics. This analysis showed that after controlling by seasonality and confounders, ozone 1-hr had a positive relationship with COPD for concentrations above approximately 50 ppb, but not for particulate matter as was observed in the correlation matrix of the unadjusted series. Before introducing ozone 1-hr into the model, a check procedure was tried using different lags of ozone 1-hr with the same non-parametric estimation. The results indicated that the best relationship was with ozone on the same day (lag [0]). That confirmed the first analysis of the raw data, that the ozone of the same day has powerful influence in the COPD admissions.

As was expected from the non-parametric analysis, introducing ozone 1-hr as a predictor in the third model did not pass the significance test. For this reason only those days where the ozone 1-hr values were greater than a threshold value were included. Next, analyses were performed (using the output graphs of the GAM analysis) with values

around 50 ppb, and the best significance was obtained using ozone 1-hr greater than or equal to 48 ppb given a value of 0.00327 as the parameter, with t-value = 3.82 (P-value<0.001). Using ozone 8-hr as a predictor in the model, it was found that the best control for confounders was obtained with the relative humidity and the wind speed. After the control for annual trend, seasonality, and confounders, the ozone 8-hr begins to be significant at 35 ppb, with p-value < 0.004.

Models for COPD65

The development of this model followed the same protocol as for COPD. Using Poisson regression techniques, the best meteorological confounder descriptor (after controlling by trend seasonality) was again relative humidity and wind speed. Using the maximum 1-hr ozone concentration as a predictor, the model began to be significant for concentrations above 45 ppb with the ozone on the same day (P-value<0.002). With ozone 8-hr, the threshold was 40 ppb with p-value <0.006.

Models for Asthma

For this model, the meteorological confounder selected was the average dew point temperature, which gives the best adjustment. The maximum 1-hr ozone concentration for the same day was significant for those values greater than or equal to 45 ppb with p-value<0.005. Using ozone 8-hr, the best control was performed again with dew point temperature, p-value<0.005. Tables II.6 and II.7 show the results for 1-hr and 8-hr ozone metrics.

Table II.6 Relative risk for April-October for ozone maximum 1-hr

	COPD	COPD65	ASTHMA
Met-Confounder	RH-WSPa	RH-WSPa	DWPa
Ozone-Threshold (ppb)	48	45	45
Increment (ppb)	24	25	25
Parameter (Beta)	0.00327	0.00315	0.00478
Standard error	0.00086	0.00111	0.00185
Relative Risk (RR)	**1.082**	**1.082**	**1.127**
Lower Limit (95%)	1.039	1.024	1.029
Upper Limit (95%)	1.126	1.143	1.234

Source: Sanhueza et al 2002

Table II.7 Relative risk for April-October for ozone maximum 8-hr

	COPD	COPD65	ASTHMA
Met-Confounder	RH-WSPa	RH-WSPa	DWPa
Ozone-Threshold (ppb)	35	40	40
Increment (ppb)	22	21	21
Parameter (Beta)	0.00302	0.00341	0.00510
Standard error	0.00097	0.00136	0.00221
Relative Risk (RR)	**1.069**	**1.074**	**1.113**
Lower Limit (95%)	1.025	1.016	1.016
Upper Limit (95%)	1.114	1.136	1.219

Source: Sanhueza et al 2002

Important findings of this analysis were the existence of thresholds in the Respiratory-Ozone exposure relationship. The threshold found was specific for each respiratory endpoint (asthma and COPD), and the endpoints were different for each ozone metric. A consistency was observed among the respiratory causes analyzed and the ozone metrics, where asthma presents the highest risk, then COPD for elderly people, and finally total COPD.

Figures 2-1 to 2-3 show the relative risk estimations as a function of ozone concentrations (both metrics) for each respiratory endpoint. These figures show that at any given ozone level above the threshold, the risk of hospital admission for asthma is greater than the risks for COPD and COPD65. Another interesting aspect of these results is that for any ozone concentration, the 8-hr ozone metric represents a higher risk as compared with 1-hr metric as is expected due to the longer exposure period in the 8-hr.

Another way to represent the results was by calculating the number of hospital admissions per million people expected under different ozone levels. This is shown in Figures 2-4 to 2-6 (exposure-effect curves) for each respiratory outcome, where the 5% and 95% intervals were included to visualize the uncertainty in this kind of analysis. These figures show that the expected number of hospital admissions is greater for COPD than for asthma, because even though asthma has a higher risk of admissions, in Knoxville there are more admissions for COPD than asthma (44 people/day and 6 people/day as average, respectively).

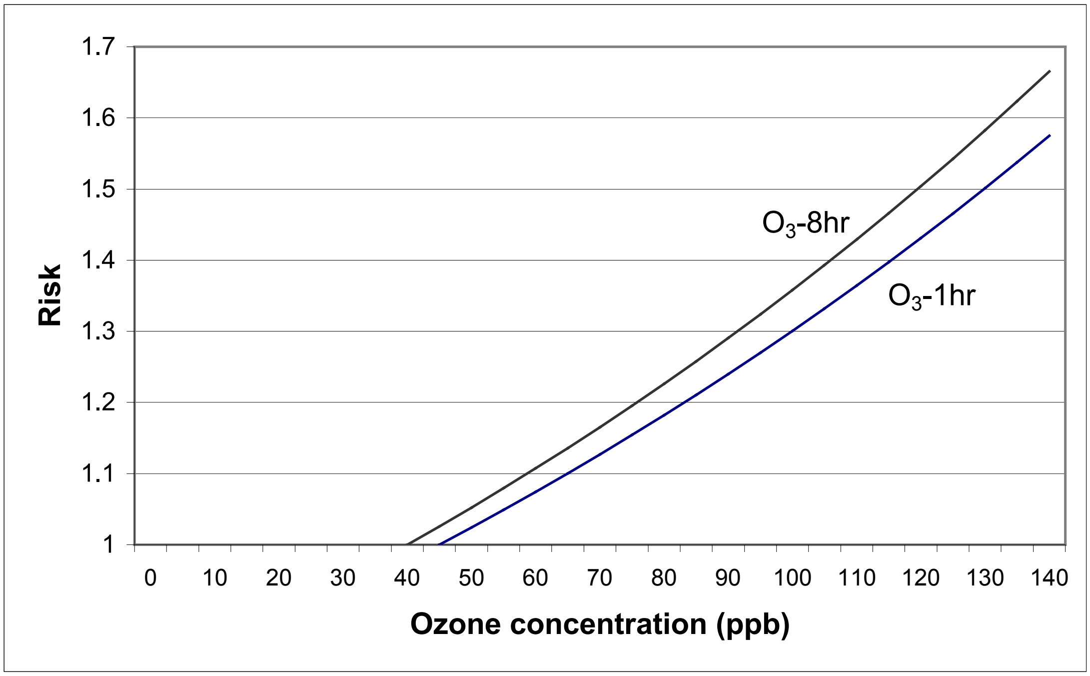


Figure 2-1: Risk of asthma hospital admissions as a function of ozone concentrations (Sanhueza et al 2002).

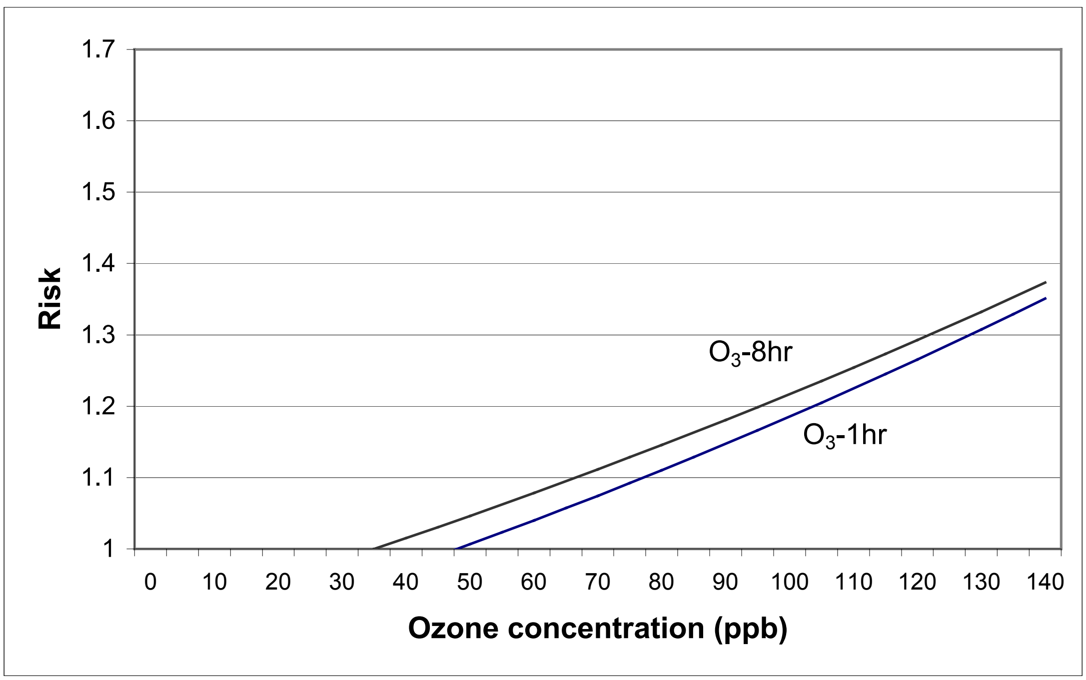


Figure 2-2: Risk of COPD hospital admissions as a function of ozone concentrations (Sanhueza et al 2002).

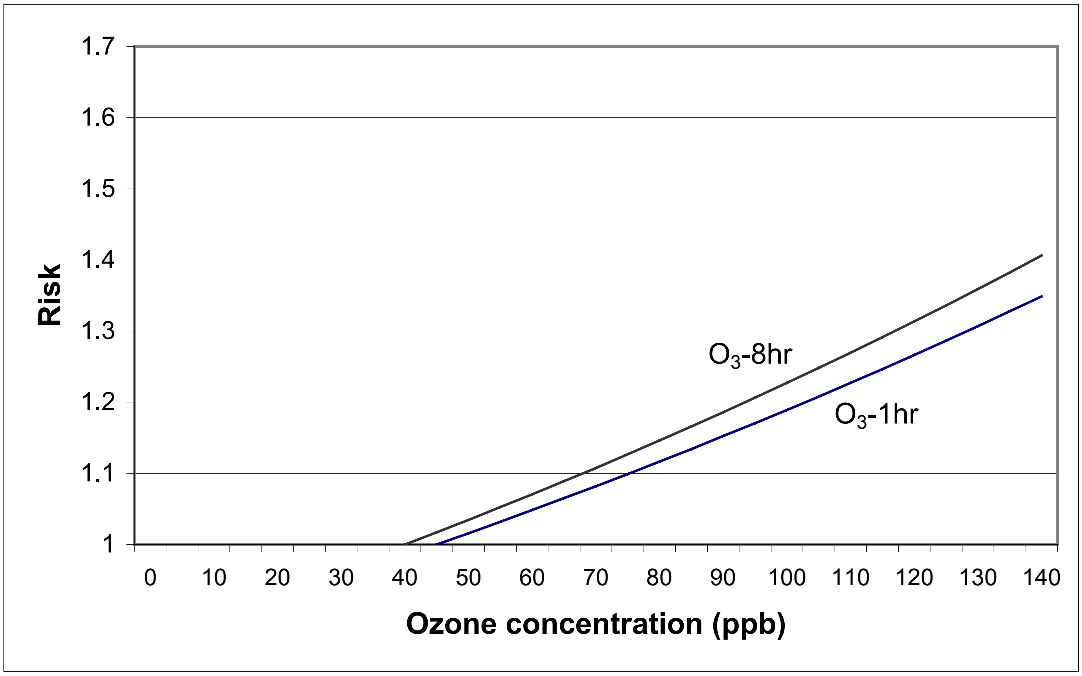
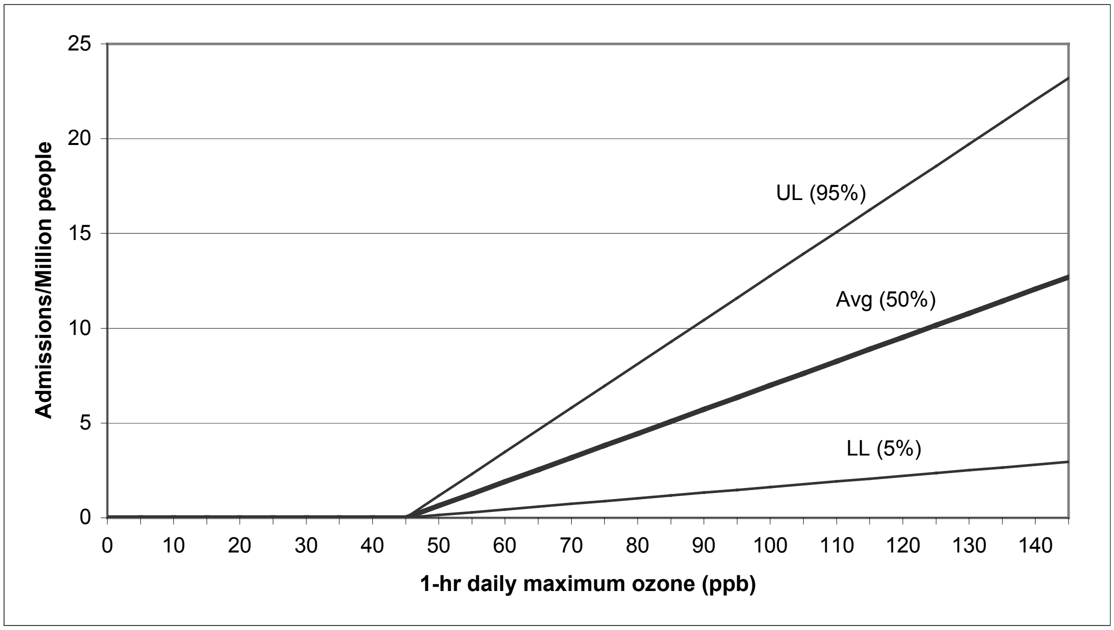
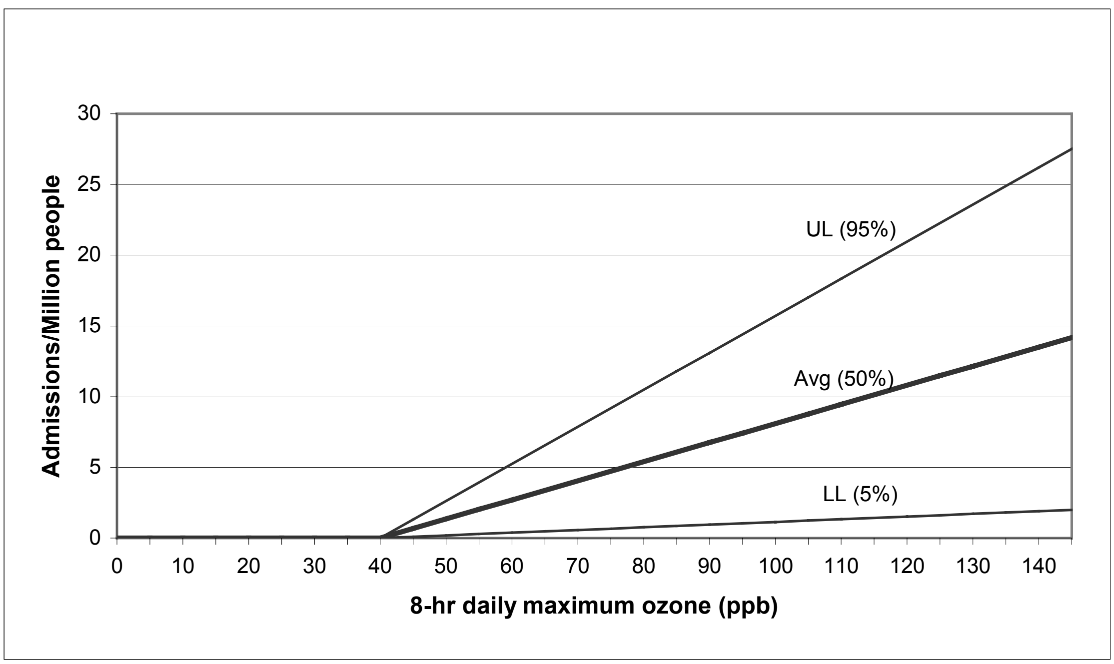


Figure 2-3: Risk of COPD65 hospital admissions as a function of ozone concentrations (Sanhueza et al 2002).

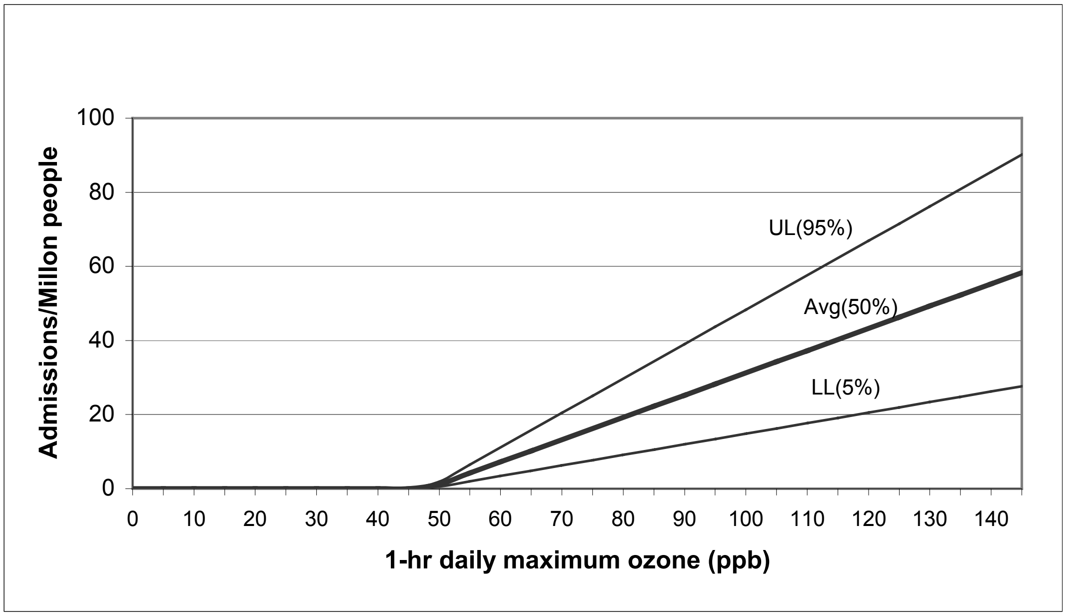


(a)

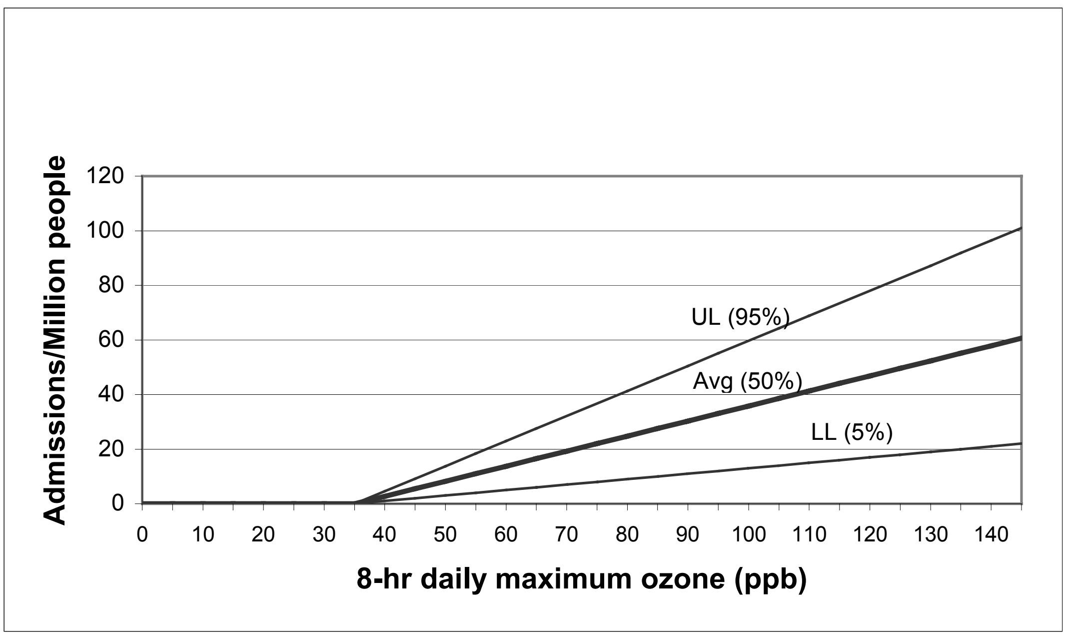


(b)

Figure 2-4: Exposure-effect curves for asthma admissions: (a) ozone max 1-hr and (b) ozone max 8-hr (Sanhueza et al 2002).

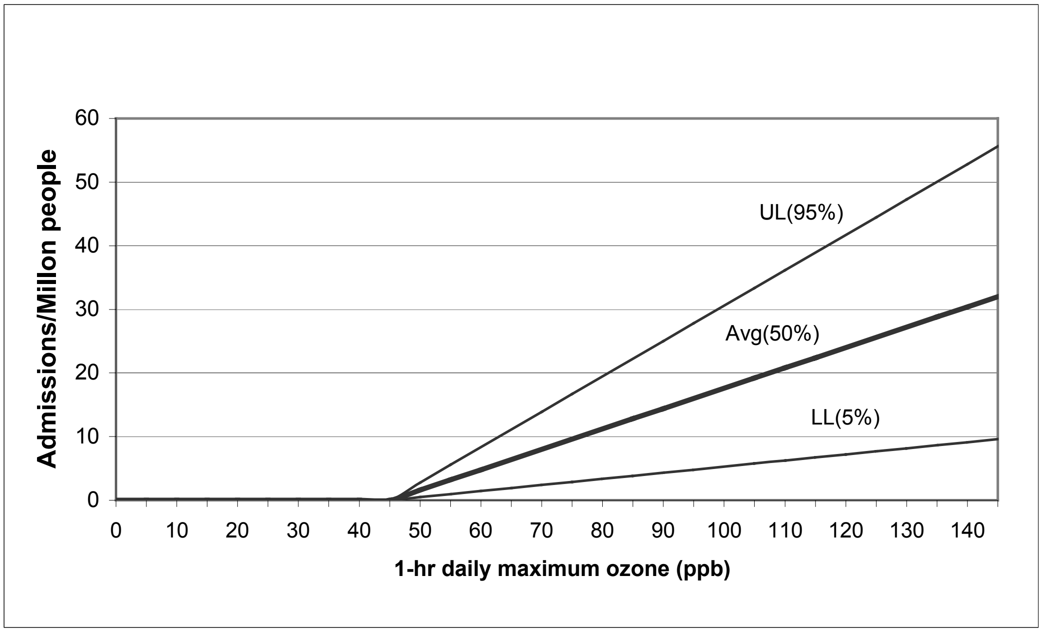


(a)

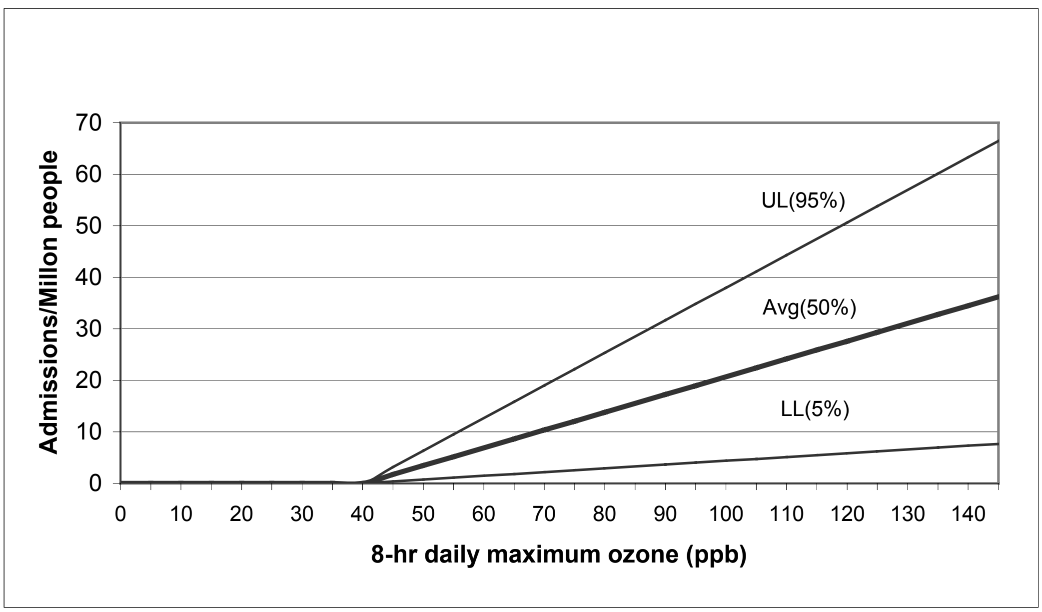


(b)

Figure 2-5: Exposure-effect curves for COPD admissions: (a) ozone max 1-hr and (b) ozone max 8-hr (Sanhueza et al 2002).



(a)



(b)

Figure 2-6: Exposure-effect curves for COPD65 admissions: (a) ozone max 1-hr and (b) ozone max 8-hr (Sanhueza et al 2002).

2.2.3 Health effect assessment in EPA rulemaking

In the last two Regulatory Impact Assessment (RIA) studies (Tier-2 and HDE), EPA has utilized the Criteria Air Pollutant Modeling System (CAPMS) to estimate ozone and PM health-effects. This model belongs to Abt Associates, Inc., which is under contract to with EPA for performing the health and benefit analysis.

CAPMS is a population-based system for modeling exposures to criteria air pollutants and is used to estimate health and visibility benefits. CAPMS divides the United States into 8-km by 8-km grid cells and estimates the changes in incidence of adverse health and welfare effects associated with given changes in air quality in each grid cell. The national incidence change (or the changes within individual states or counties) is then calculated as the sum of grid-cell-specific changes.

CAPMS uses the output from the variable-grid Urban Airshed Model (UAM-V) and observed ozone data to generate “adjustment factors” that quantify the relationship between modeled levels of ozone in the base year and the future year. The adjustment factors are combined with actual monitoring data to generate estimates of the future year levels of ozone. The modeling data are not used directly (i.e., in an absolute sense) to estimate future year ozone levels. Instead, CAPMS uses them in a relative sense simply to adjust actual monitor levels. The ozone level in each cell is interpolated using inverse-distance, from those monitors that best “surround” the grid cell.

To reduce computational time when estimating the change in health effects associated with daily ozone levels, CAPMS approximates a season's worth of daily ozone measures at each CAPMS grid-cell by 20 “bins.” Each bin represents 5% of the daily ozone concentrations, and the value for each bin is set at the midpoint of the percentile range it represents. After generating 20 bins for both the baseline and control scenarios, the difference between these two values at each bin is calculated. Then the baseline value in the first bin is subtracted from the control value in the first bin, and so on for each of the 20 bins. For each CAPMS grid-cell, 20 values representing the difference between the baseline and control are gotten, and these differences are used to estimate the change in adverse effects associated with the implementation of the policy. Since each value represents 7.65 days, then multiplying each of the 20 incidence-change estimates by 7.65 allows reconstruction of the entire season's worth of incidence changes in the CAPMS grid cell (EPA 1999b).

2.3 Valuation of human health

As was explained in section 2.1, there are many epidemiological studies that have demonstrated associations between daily counts of respiratory admissions and daily changes in ground-level ozone concentrations. For poly-decisions, not only this information is relevant but also the cost and benefits of improving the air quality. Much of the justification for environmental rulemaking rests on estimates of the benefits to society of reduced mortality and morbidity rates. Reductions in risk of these health endpoints are the most important societal benefit underlying many of the EPA legislative

mandates. For example, in two recent analyses of the benefits of the U.S. air quality legislation, the benefits and cost of the Clean Air Act, 1970 to 1990 (EPA 1997a), and the benefits and cost of the Clean Air Act, 1990 to 2010 (EPA 1999d), more than 80% of the benefits were attributed to reductions in premature mortality and morbidity.

Monetary valuation of health benefits

To assign a dollar value to the benefits of a regulation involves estimating society's willingness to pay (WTP) for quantifying changes in the air quality. In economics, WTP refers to the maximum amount an individual is willing to pay to acquire a benefit. It is measured as the reduction in income required returning an individual to the level of utility he or she enjoyed prior to receiving the benefit (OAQPS EPA 1999).

When estimates of WTP are difficult to obtain, a cost-of-illness (COI) approach can be used. The COI valuation method measures the direct costs resulting from a health effect. These costs include the value of goods and services used to diagnose and treat individuals suffering from health effects (clinics or hospital costs) and the cost expensed by the patient. Because the COI approach does not account for the full range of costs associated with an illness or injury (e.g., pain and suffering are not included), the results of these analyses should be viewed as lower-bound estimates of society's WTP for reductions in such risk (OAQPS EPA 1999).

Both methods (WTP and COI) can be seen as complementary in a valuation analysis, because COI measures costs after a health effects has occurred and WTP is a measure of

the individual's avoidance of the health effect. In addition, COI measures the costs to the individual (out-of-pocket costs and lost wages) and the costs to third-party payers (payment of insurance companies), but not changes in individual well being caused by the illness. Table II.8 shows the WTP values that EPA has used in health benefit analysis (Sunstein 2000).

2.4 Models-3/CMAQ system

Models-3/CMAQ is a third-generation air quality modeling system for urban to regional scale air-quality simulation of tropospheric ozone, acid deposition, visibility, and fine particulate. First-generation air quality models dealt with tropospheric air quality with simple chemistry at local scales using Gaussian plume formulation as the basis for prediction. Second-generation models covered a broader range of scales (local, urban, regional) and pollutants, addressing each scale with a separate model and often focusing on a single pollutant.

Table II.8 Willingness-to-pay estimates

Health endpoint	WTP value per incident (1990 $)
Mortality:	
Life saved	$4.8 millions
Morbidity (Hospital admissions):	
Asthma	$9,000
COPD	$13,400
COPD >65 yr	$15,900
Ischemic heart disease <65 yr	$20,600
Congestive heart disease >65 yr	$16,600
Acute Bronchitis	$45
Restrictive Activity Days (RAD)	$38

Source: Sunstein 2000, cited from EPA Innovative Strategies Group 1998.

Third-generation models treat multiple pollutants simultaneously up to continental scales and incorporate feedback between chemical and meteorological components. Future efforts toward fourth-generation systems will extend linkages and process feedback to include air, water, land, and biota to simulate the transport and fate of chemicals and nutrients throughout an ecosystem (EPA Models-3 2001). The Models-3/CMAQ contains three types of environmental modeling systems: meteorological, emission, and chemistry transport. It also includes a visualization and analysis system. Figure 2.7 illustrates the relationships among these systems

The following discussion is an EPA description of each principal component of Models-3/CMAQ extracted from the EPA Models3 web site (EPA Models-3 2001).

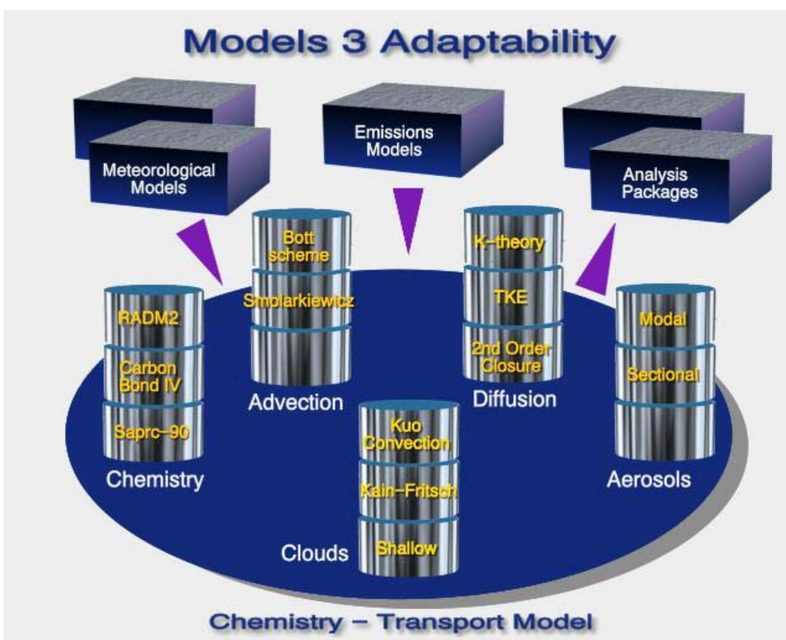


Figure 2-7: Models-3/CMAQ system components (EPA Models-3 2001)

Meteorological Modeling System: Currently, the Mesoscale Modeling System (MM5) is the meteorological model included in Models-3/CMAQ (Grell et al 1994). MM5 provides descriptions of atmospheric motions; fields of pressure, moisture, and temperature; fluxes of momentum, moisture, and heat; turbulence characteristics; clouds and precipitation; and atmospheric radiative characteristics. The MM5 meteorological modeling system in this Models-3/CMAQ release contains 5 individual processors. These processors include the TERRAIN processor for defining the simulation domain, the PREGRID processor for processing background fields, the RAWINS processor for objective analysis, the INTERPF processor for setting the initial and boundary conditions for the meteorological model, and the MM5 main model processor.

Emission Modeling System: Simulates trace gas and particulate emission into the atmosphere depending on surrounding meteorological conditions and socioeconomic activities. Typically, emissions are broken down into point sources, line sources (on-road mobile), and area sources. A point source tracks emissions from a single source (e.g., a boiler stack or a dry cleaner). A line source tracks emissions that follow a road (e.g., cars or trucks). Area sources include off-road mobile sources, biogenic emissions, and other sources that are often related to the earth's surface where humans, animals, and plants reside. The current emission processor supported by Models-3/CMAQ is the Sparse Matrix Operator Kernel Emission processor (SMOKE). SMOKE contains 5 individual processors. These processors include the Inventory Data Analyzer (IDA), the Grid, Temporal Allocation, Speciation, and Merge processor.

Chemistry-Transport Modeling System: Simulates various chemical and physical processes that are thought to be important for understanding atmospheric trace gas transformations and distributions. Generally, the chemistry-transport model relies on a meteorological model for the description of atmospheric states and motions and depends on emission models for the anthropogenic and biogenic emissions that are injected into the atmosphere.

Visualization and Analysis System: Visualization techniques are an important part of air quality data analysis. The Models-3/CMAQ visualization and analysis system provides several packages that can plot or graph data that have been created by one of the Models-3/CMAQ modeling systems. Three-dimensional animation capabilities are also provided in the system. The visualization and analysis system contains two individual visualization packages, including Vis5D (five dimensional visualization package) and PAVE (application for visualizing multivariate, gridded datasets).

2.5 Aggregation and selection of simulation days

Ozone is being created and destroyed in the atmosphere at all times; high concentrations are observed only under conditions that lead to accumulation of ozone within an air mass. This happens when an air mass becomes stagnant (i.e., does not mix efficiently with other air masses) and is relatively slow moving so that a large burden of ozone precursors is accumulated. These “stagnant, stationary” conditions are a characteristic meteorological regime leading to episodes of elevated ozone concentrations, often over broad regions.

The indicators for these episodes include high temperatures, low wind speeds, and high insolation.

Most of the EPA's evaluations have used episodic days to assess the effectiveness of a particular rulemaking. To assess the health-effects of air pollution, not only the worst days must be considered but all variations in the pollutant season. If running a photochemical model for 214 days (ozone season) is not feasible because of the computer-resources (consider 214 days times the number of scenarios required in a particular application), then the question of how to determine a number of days that represents the variation for the entire season must be considered.

EPA (EPA 1999) has proposed a technique called aggregation and episodic selection that supports models-based annual and seasonal air quality estimates and allows Models-3/CMAQ to be executed for a finite number of days or "events," which are selected to represent a wide variety of meteorological classes. The approach involves the determination of meteorologically representative categories that account for a significant proportion of the variability exhibited by the air quality characterization of interest, and the selection of events from those categories.

The technique that determines the categories of meteorological events that are likely to produce certain levels or air pollution corresponds to classification method such as regression tree or cluster analysis, which minimize within-cluster sums of squares, in an agglomerative, hierarchical mode. The classification analysis has as a major objective to

discover meteorological regimes that are likely to produce different levels of ground-level ozone concentrations. Classification and regression tree analysis (CART) share the features of typical regression analysis but allow more than one function to be used to partition the data. In short, by performing an optimal separation of the values of a dependant variable in terms of a set of independent variables, the CART technique provides a non-linear method of partitioning a dataset into discrete subsets.

The CART technique performs binary splits on the values of independent variables. The combination of various binary splits leads to a node in the classification tree. Each node contains days with similar values of the dependent variable. As a consequence of this partitioning scheme, a single equation is not forced to explain the full relationship between the dependent and independent variables, as is the case in regression analysis. In addition, there may be multiple regimes with similar values of the dependent variable (e.g., daily maximum 8-hr ozone concentration) but quite different independent variable paths, indicating that there may be different causative mechanisms for the same outcome (e.g. high ozone concentration due to local formation, or due to transport).

The next step in the process is to select some day in each category. This is performed in a process called stratified sampling, which exploits the internal homogeneity of the meteorological categories to achieve more precise estimates than would be possible using simple random sampling. From a theoretical point of view, there are several alternatives to select a number of days from each stratum. One of them, called "equal allocation," is to select one or several days in each category randomly. A variation called "proportional

allocation," involves selecting the numbers of days in direct proportion to the size of the stratum. A third alternative, called "optimal allocation," is to select the number of days in each category in direct proportion to the product of the size of the stratum times the internal variability within the stratum.

The equal allocation is the cheapest method, and the optimal allocation the one that requires much information, but as the EPA has established (EPA 1999), the final decision will depend on the objective and resources for each specific application.

CHAPTER 3

METHODOLOGY

The methodology presented in this chapter has the objective of giving a framework to develop an analytical tool to assess the health benefits of regulatory actions (emission control) that reduce ozone concentrations. As the EPA Office of Air Quality Planning and Standards (OAQPS) has established, "the benefits of all OAQPS regulations can be described as a function of reductions in human health and environmental impacts caused by exposure of humans and the environment to ambient concentrations of air pollutants" (EPA 1999a). Evaluating the benefits of an environmental regulation is performed by measuring the effects that an improvement in environmental quality has on human welfare. Figure 3-1 shows the variables and relationship involved in this analysis.

3.1 Conceptual model's development

The model developed here, called Ozone Risk Assessment Model (ORAM) allows the estimation of the number of hospital admission for respiratory disease under different emission scenarios, by taking into account two principal components: the ozone concentrations obtained as output of the Models-3/CMAQ (exposure model), and the concentration-response equations determined for a particular location. With these two components, the number of hospital admissions expected in a particular domain can be calculated and compared for different emission scenarios.

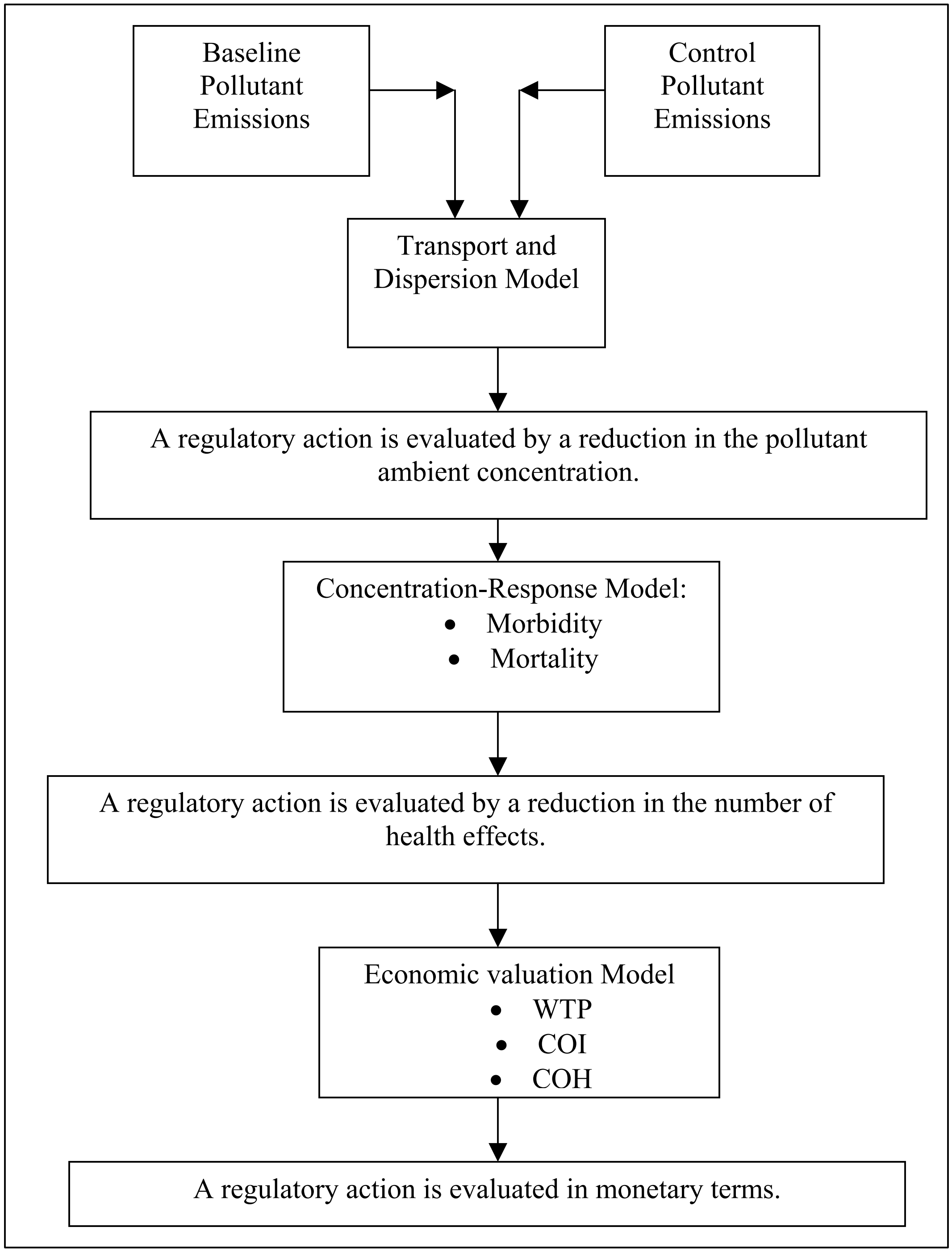


Figure 3-1: Elements in the Regulatory-Health assessment (Modified from EPA 1999c).

Figure 3-2 shows a scheme of the ORAM modeling tools.

Exposure model

The output of Model-3/CMAQ (version released in February 2001) was used as the exposure concentration file. This output contains hourly concentrations of 68 pollutants at different layers, for each grid of the modeling domain. Only ozone for the first layer was extracted from this output file for the ORAM application.

Exposure-response equations

As was explained in Chapter 2, section 2.2.1, the exposure-response equations for ozone and respiratory diseases were obtained from previous studies (EPA 1999a, Sanhueza et al 2002). ORAM accepts these coefficients but also others provided by the user for a particular area of application if these coefficients exist; if not, the EPA default coefficient can be used.

3.2 ORAM: Ozone risk assessment model

ORAM was designed as an analysis tool to evaluate air pollution regulatory alternatives to improve the environment and human health. The principal objective of ORAM is to assess the health impact associated with changes in ground-level ozone concentration due to regulations applied to its precursors (basically NOx and VOC from anthropogenic emissions). ORAM provides a structure to develop quantified health impacts that can be used in benefit-cost analyses for decision-makers.

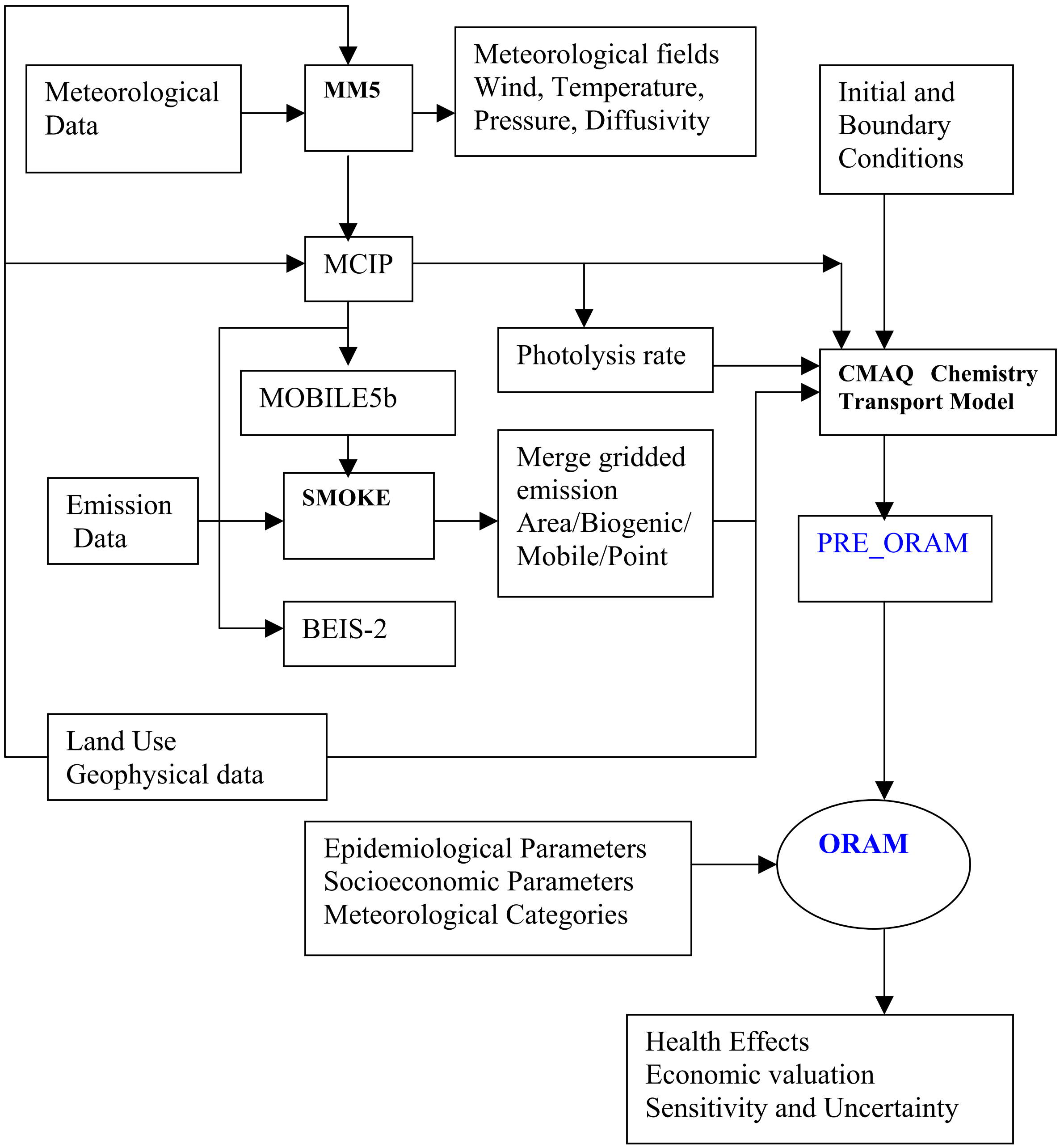


Figure 3-2: ORAM modeling tools.

ORAM needs an exposure model, which in its current version is Models-3/CMAQ. This combination gives much flexibility for future enhancement of ORAM by incorporating particulate matter and other gases rather than only ozone, and that is because Models-3/CMAQ calculates 68 air pollutant concentrations that could be used in health assessment.

As its health endpoint, ORAM calculates the number of asthma and COPD hospital admissions, and the number of doctor visits for respiratory problems. The ozone metrics are related with the C-R equations and basically correspond to daily maximum 1-hr ozone and daily maximum 8-hr ozone concentrations. The spatial resolution corresponds to a county, state, or region, according to the resolution of the exposure model. The temporal resolution is for the entire ozone season (March to September or April to October).

3.2.1 ORAM System

The ORAM system was written in PV-WAVE™ scientific interactive programming language. The ORAM system is formed by a preprocessor called Pre_ORAM, which performs an evaluation of the output of Models-3/CMAQ and produces the ozone metrics, and the ORAM model itself, which performs the health-effects and economic valuation calculations. Additionally, two other codes were written to perform the evaluation of the meteorology (ORAM_Met) and emission (ORAM_Emi) output files from MM5 and SMOKE, respectively.

3.2.2 Preprocessor Pre_ORAM

A preprocessor called Pre_ORAM was developed to calculate the ground-level ozone metrics (daily maximum 1-hr and 8-hr) required by the health-effects model. This preprocessor extracts hourly, surface-layer ozone concentrations for each grid-cell from the standard Models3/CMAQ output file containing hourly average ozone values. Pre_ORAM also accomplishes a performance model evaluation following the EPA guidance for attainment demonstration (EPA 1991, EPA 1999e). An additional input file is required for this option, which contains the observed ozone data for the area of interest (see Figure 3-3).

Pre_ORAM has graphical capabilities to visualize the concentrations of ozone in the entire modeling domain using 2D (isopleths) and 3D (surface) plots. The time-series plot option allows the user to evaluate the hourly ozone profile for the period of simulation, visualizing the spin-up days and the target day evolution outline.

Operationally, Pre_ORAM has to be run for as many times as meteorological categories exist to represent the ozone season (see section 3.4). Thus each output file generated by Pre_ORAM is an input for ORAM, and the county code is the common element to associate the maximum 1-hr and 8-hr ozone concentration calculated by this preprocessor, with the demographic data input for the ORAM model.

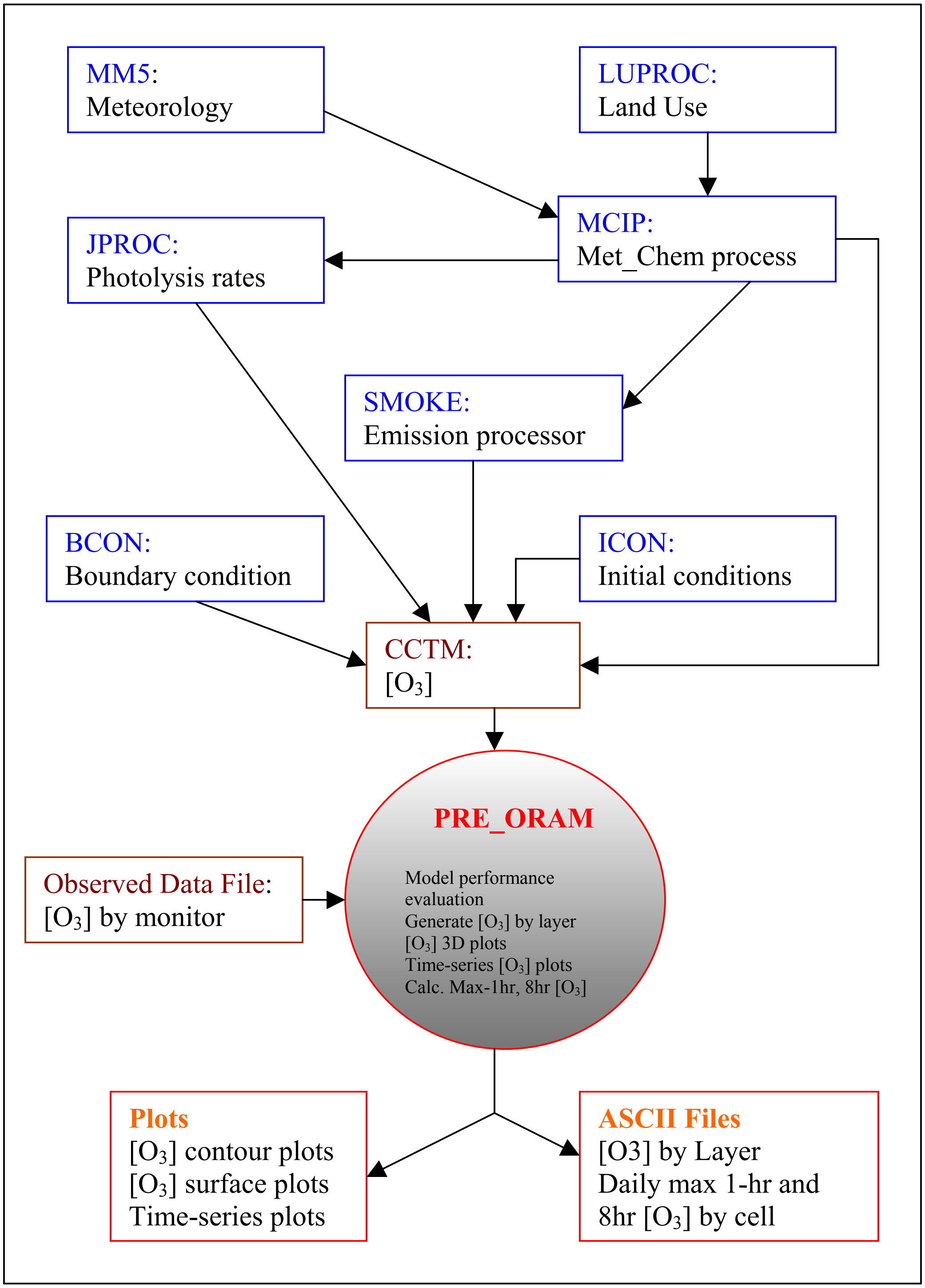


Figure 3-3: Pre_ORAM diagram.

3.2.3 ORAM model

The structure of ORAM is shown in Figure 3-4. The inputs files provide ORAM the flexibility to change the area of application, the health-effect coefficients, the admission rates, the number of days to represent the ozone season, and the economic parameters.

The core of ORAM is based on concentration-response functions from epidemiological studies and Monte Carlo simulation techniques (to handle the uncertainty of key parameters such as ozone threshold and concentration response coefficients). The uncertainty is studied by incorporating an option for sensitivity analysis.

ORAM presents flexibility in choosing different parameters. As a default it is set with parameters for the City of Knoxville, but the parameters can be easily changed for the EPA or other users for applications in other locations if this information exists. Also, if new morbidity and mortality indicators (ozone-disease) other those for asthma and COPD are available, they can be easily incorporated into the system to estimate the ozone-related health effects.

ORAM produces two types of outputs: ASCII files and graph results via monitor screen. The files generated allow further analysis and comparison when more than one scenario are being evaluated. The graphical outputs provide a quick evaluation of the results and help to summarize the information generated.

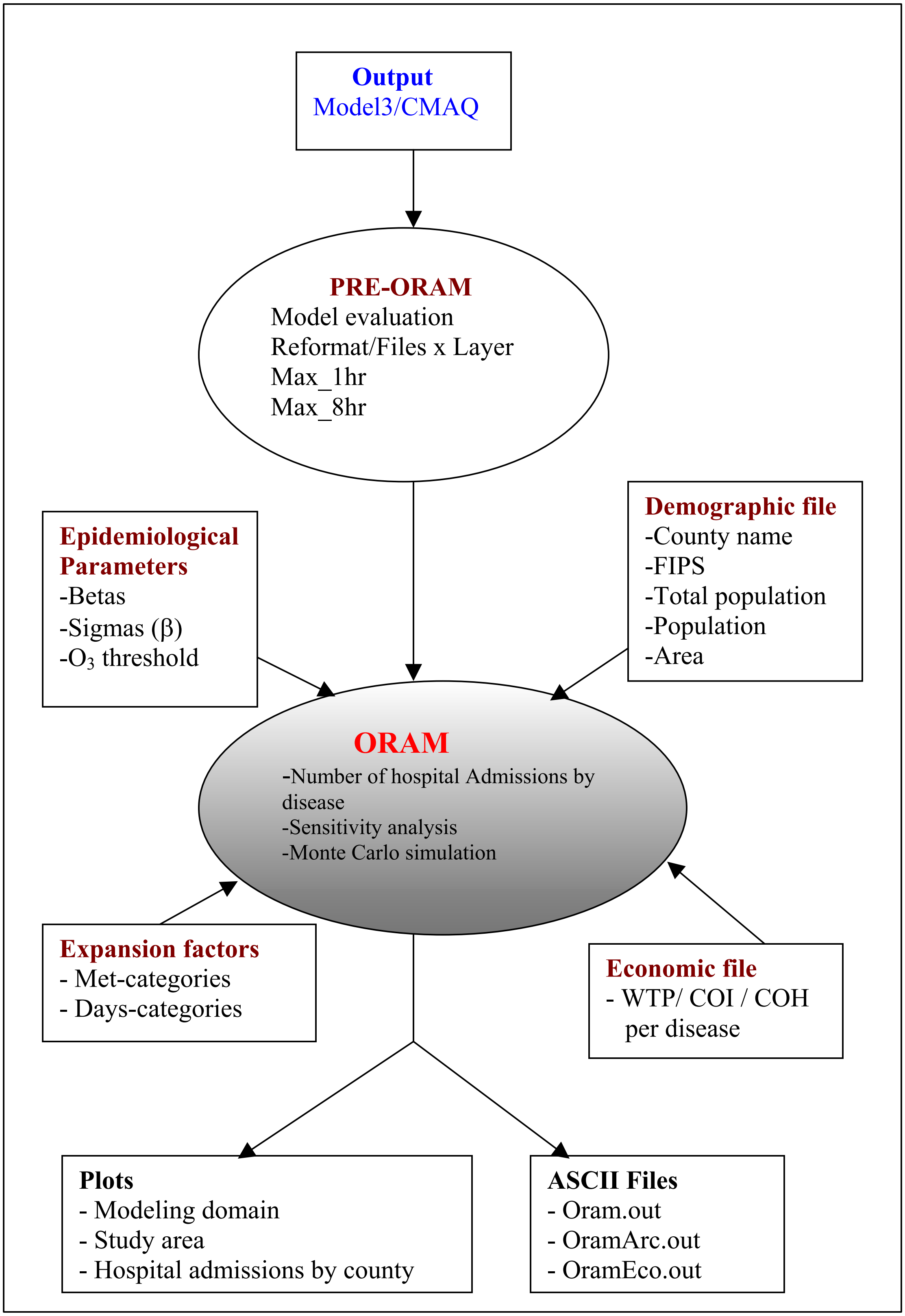


Figure 3-4: Diagram of ORAM structure.

3.2.4 Heath effect estimation

With the concentration-response coefficients obtained from the health-effect equations and the ozone concentrations metrics from Pre_ORAM, the number of hospital admissions due to ground level ozone exposure is calculated as follows:

$$\Delta HA_{dk} = K_d(e^{\beta d(O-Otd)} - 1)P_k \qquad \text{(Equation 3-1)}$$

Where,

ΔHA_{dk}	=	Number of hospital admissions for disease d (asthma, COPD) in county k
K_d	=	Daily hospital admissions rate for disease d (hospital adm/pop)
β_d	=	Estimated coefficient for each respiratory disease (hospital adm/ppb)
O	=	Ozone concentration (ppb)
O_{td}	=	Ozone threshold (ppb) for disease d
P_k	=	Population of county k

The total number of hospital admissions (TΔHA) during the ozone season for these respiratory diseases, is calculated as follows:

$$T\Delta HA_d = \sum_{i=1}^{Nc} \Delta HA_{di} F_i \qquad \text{(Equation 3-2)}$$

Where,

$T\Delta HA_d$	=	Total number of hospital admissions for disease d during the ozone Season, attributable to ground-level ozone concentration
Nc	=	Number of ozone concentration categories (see section 3.4)
F_i	=	Expansion factor for each met-category (see section 3.4)

The concentration-response coefficients (β) used in ORAM correspond to those used by EPA in its Regulatory Impact Analysis (RIA) (EPA 2000), and those obtained for Knoxville by Sanhueza (Sanhueza et al 2002). All of the coefficients correspond to morbidity indicators of short-term effects that relate the ozone levels with respiratory effects (asthma and COPD). The values used are presented in Table III.1.

The probability density function of each respiratory effect coefficient along with its standard errors allow one to carry out a Monte Carlo simulation analysis to determine, in a more realistic way (by incorporating the uncertainty), the ozone health-effects relationship. This analysis is accomplished by an option in ORAM, which produces a summary table showing the 5th and 95th percentile along with the expected value for the health impact expressed as the number of people treated by respiratory diseases for each county in East Tennessee.

Table III.1 Hospital admission concentration-response coefficients

Disease	**Age group**	**O_3 metric**	**Coefficient (β)**	**Std_err (β)**	**Base Rate of effects**	**Source**
Asthma	>20 yrs	1-hr	0.00478	0.00185	2.51E-05	Sanhueza et al 2002
COPD	>20 yrs	1-hr	0.00327	0.00086	1.77E-04	Sanhueza et al 2002
COPD	>65 yrs	1-hr	0.00315	0.00111	5.74E-04	Sanhueza et al 2002
Asthma	>20 yrs	8-hr	0.00510	0.00221	2.51E-05	Sanhueza et al 2002
COPD	>20 yrs	8-hr	0.00302	0.00097	1.77E-04	Sanhueza et al 2002
COPD	>65 yrs	8-hr	0.00341	0.00136	5.74E-04	Sanhueza et al 2002
Asthma	All	1-hr	0.00250	0.00072	5.75E-06	EPA 1999a
COPD	All	1-hr	0.00303	0.00110	1.56E-05	EPA 1999a
COPD	>65	1-hr	0.00274	0.00170	3.75E-05	EPA 1999a

3.2.5 Economic valuation

A natural extension of the output from ORAM is the determination of the economic valuation associated with each morbidity endpoint. The willingness-to-pay (WTP) is the most common method for estimating the economic value of improvements in (or deterioration of) environmental quality and has been used by EPA to quantify the monetary value of the benefits included in its Regulatory Impact Assessments (EPA 1999b, EPA 2000). The cost of illness (COI) estimate is another way to valuate health effects. COI represents the medical costs that reflect the direct expenditures related to treatment but not the value of avoided pain and suffering from the health effect, so even it is a good indicator, it must be used along with WTP, which is a more comprehensive measure. A third method incorporated in ORAM is the Cost of the hospital (COH). This factor has not been used in previous pollution health-effect studies but is a complementary measure associated with social costs. For this method, the economic value associated with the number of hospital admissions (V_i) is given by

$$V_i = Ai*W_i \qquad \text{(Equation 3-3)}$$

Where,

A_i = Number of people treated by disease “i” (asthma or COPD)
W_i = Value of the WTP, or COI, or COH by disease.

The greater benefit of this equation is when it is used as a relative measure by comparing two or more regulatory options (emission scenarios). Table III.2 gives the central estimation for WTP values used by the EPA in its RIA analysis (Sunstain 2000), and COI and COH from Reed’s study (Reed et al 2000) for Knoxville, Tennessee.

Table III.2 Economic valuation coefficients ($/incident)

Respiratory disease	Mean WTP[1]	COI[2]	COH[2]
Asthma	9,000	2629	934
COPD	13,400	6110	2294
COPD65	15,900	8795	3377

1 :EPA 1998 (cited by Sunstain 2000).
2 :Reed et al 2000

3.2.6 Sensitivity and uncertainty analysis

Sensitivity analysis (SA) is used to increase the confidence in the model and its predictions, by providing an understanding of how the model response variables respond to changes in the inputs.

This information can be invaluable, as

• Different level of acceptance (by the decision-makers and stakeholders) may be attached to different types of uncertainty.

• Different uncertainties impact differently on the reliability, the robustness and the efficiency of the model.

ORAM includes options for Sensitivity Analysis (SA) and Uncertainty Analysis (UA). For SA, the system asks for perturbations (variations) in the inputs of the health-effect equation that affect the outputs of that analysis. SA uses the Sensitivity Index (Young et al 1997) defined as follows:

$$SI = \frac{[f(x+dx) - f(x)]}{f(x)}/(dx/x) \qquad \text{(Equation 3-4)}$$

Were,

x	=	One of the parameters
$f(x)$	=	The calculated result using the parameter x
dx	=	Perturbation of x.

SI is used to identify key parameters. The larger the magnitude of the SI, the more important the parameter is. A negative SI indicates that the calculated health-effects decrease with the parameter.

SA is closely linked to uncertainty analysis (UA), which aims to quantify the overall uncertainty associated with the response as a result of uncertainties in the model input.

In ORAM, the UA is performed using a Monte Carlo sampling method. In this method, the parameters are varied randomly over a range of values from a specified frequency distribution to generate corresponding sets of model predictions.

3.2.7 Outputs from ORAM

For each run (emission scenario), ORAM produces three output files that help decision-makers to understand and evaluate air pollution regulatory options. The files correspond to ORAM.OUT, ORAMARC.OUT and ORAMECO.OUT. All of them are in ASCII format and can be exported to spreadsheets for future analyses. The model also has the capability of performing a Monte Carlo simulation by determining all the possible values of the respiratory admissions and determining the relative likelihood of each value.

Finally, ORAM offers several graphs that help us summarize and understand the results such as plots of the number of respiratory admissions (by county and region), relative risks by disease, correlation (tornado graph), histograms (admission frequency), and cumulative probability distributions by disease and ozone metric.

ORAM.OUT gives, by county and by ozone metric, the number of people treated for asthma and COPD during the simulated ozone season. Also this file gives the ratio between the number of hospitalizations and the actual population in each county. This last indicator can be used as a means for the comparison of the health risks by county. A summary with the number of people treated for respiratory diseases in all the counties in the study area is also provided. If the uncertainty analysis is performed in a particular run of ORAM, then the output of the Monte Carlo simulation is written in ORAM.OUT.

ORAMARC.OUT produces a file ready-to-use by the GIS ArcView™. This output helps decision-makers to perform a spatial analysis that aids understanding of the spatial impact of the ground-level ozone concentrations from a health point of view. Finally, ORAMECO.OUT presents the results of ozone-health effect in a quantitative way, by giving the number of dollars by county that the people are willing to pay in order to avoid the health impairment. This output also provides the structure to be used by the GIS ArcView™ for spatial analysis.

Simulation outputs

When ORAM runs a Monte Carlo simulation, the health effects are calculated over and over again, and each recalculation is an iteration with a set of new possible values sampled from each input distribution each time. All the possible results give the probability distribution of the respiratory admissions. This output is then analyzed, and statistics are calculated to determine how the number of hospital admissions is distributed across its range. In addition, a sensitivity analysis is performed to identify the input distributions most critical to the respiratory admissions. The graphs include frequency distribution of possible output variable values through probability mass functions (PMF), cumulative distribution functions (CDF), and Tornado graphs.

3.3 Modeling domain

The modeling domain represents the geographical bounds of the area to be modeled. This area should include the area of interest with its local emissions (study area) and an external extra area sufficient to represent the transported emissions according to the wind pattern. The size of the domain depends on the problem to be addressed, the input information required (concentrations, emissions, meteorology, and land use), and the computer resources. For air pollution health-effects evaluations, the spatial variability of the pollutants of interest is also an important parameter to be considered when deciding the modeling domain and its horizontal resolution (the size of the grid cells).

Most of the pollution health-effects assessments are required when changing the emissions due to new regulations, so the size of the domain is typically in the urban or regional scales. The urban scale domain is one having horizontal dimensions less than 300 km on a side, and regional scale domain has horizontal dimensions exceeding 1000 km (EPA 1999e). In any case, the area of interest should be located near the center of the domain, and the domain must be large enough to ensure that the emissions and wind pattern reflect the local and transport issues to be addressed.

3.4 Selection of modeling days

Using the EPA's methodology described in Chapter 2, section 2.4, a CART regression tree analysis might be applied to characterize the meteorology associated with each category of ozone concentrations. For a particular application, the following independent variables can be used: wind speed, wind direction, relative humidity, ambient temperature, solar radiation, and atmospheric pressure at different altitudes. After the categorization of meteorological regimes is performed, the output is a number of ozone-intervals (Nc) associated with each of these meteorological conditions, and the number of days (during the ozone season) in each of these categories (bins). These last data are the expansion factor (Fi) used to represent the entire ozone season in ORAM.

The next step is to select a representative day in each category for running Models-3/CMAQ. EPA suggests a random selection in each category to choose a representative day, but this technique can come up with a weekend day or days with concentration in the

boundary of each category. For these reasons, the following improved criteria are proposed for choosing the more representative meteorological day in each rank.

- Weekdays are preferred to weekend days when possible.
- For the exceedance range, use the highest ozone concentration's day.
- The day closest to the average rank is preferred for intermediate categories.
- Over several days, the above criteria should be matched to choose the higher day's frequency.
- Tuesday, Wednesday, and Thursday are preferable to Monday or Friday.
- Different months should be represented.

3.5 Running ORAM

The procedure for calculating the health-effects using ORAM is shown in Figure 3-5. First the ozone and meteorological data must be collected; then CART analysis gives the number of category-days (Nc) and the intervals of ozone. Second, selecting a day for the first category-day, Models-3/CMAQ is run and its results evaluated through Pre_ORAM. If the output from Models-3/CMAQ do not pass the EPA test, then another day is selected from the current category-day and the process is repeated until the output is satisfactory. When the output from Model-3/CMAQ passes the EPA test, then Pre_ORAM calculates the ozone metrics. The procedure follows taking a day for the second category, and the second step is repeated for this category. After the ozone metrics for all of the category-days is calculated, ORAM is run, and the health-effects and economic valuation are calculated.

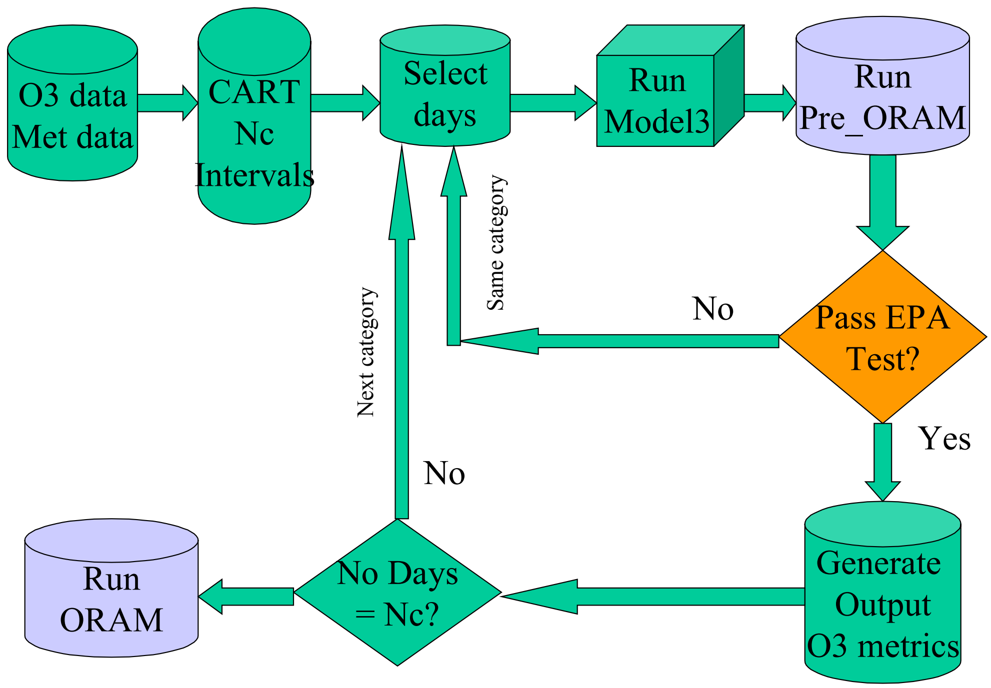


Figure 3-5: Scheme for running ORAM

CHAPTER 4

APPLICATION: TEST CASE FOR EAST TENNESSEE

As a test case, the ORAM system was applied to East Tennessee (33 counties) to evaluate the health benefits of different emission scenarios in the study area. To perform this task, it was necessary to prepare several input files for the modeling domain in order to run the exposure module (Models-3/CMAQ) and the demographic, economic and epidemiological files for the ORAM system.

Basically the tasks for an application are

- Define the modeling domain
- Select the simulation days
- Define the emission scenarios
- Run Models-3/CMAQ
- Run Pre_ORAM
- Run ORAM

4.1 Modeling domain

For this work, the modeling domain included in the tutorial of Models-3/CMAQ released by EPA on February 2001 (version 4.1) was used because the emission surrogate files required for running the model were already available. The creation of these files would demand a great deal of effort that would not add anything to the purpose of this work,

which was to link the meteorology, emission, and air quality models with the health-effects model developed here, as a decision-making tool. Using this modeling domain does not pose a severe limitation because it was necessary to run MM5 and SMOKE models for the selected days and emissions scenarios. Figure 4-1 shows the modeling domain (NE USA), with Tennessee in the lower part of this domain. The domain has 45x36 horizontal grid cells (1620-km x1260-km) using 36-km resolution based on Lambert Conformal map projection centered at 40ºN and 90ºW. Six vertical layers were configured following the sigma-pressure structure with denser grids at lower levels to better resolve the boundary layer. The study area, where the health effect was determined, corresponds to East Tennessee (see Figure 4-2).

4.2 Selected simulation days

Using the EPA's methodology described in Chapter 2, section 2.5, a CART regression tree analysis and a stratifying sampling method was applied to the 1998 ozone season data for Knoxville, to determine the specific days that were used to run in Models-3/CMAQ for the test case application. The classification analysis had as a major objective to discover meteorological regimes that were likely to produce different levels of ground-level ozone concentrations. By using that, the ozone records for 1998 along with meteorological variables generate a classification and regression tree model. After the construction of the meteorological regimes (classification stage), the specific days in each category used to represent the entire ozone season was selected. The selection technique corresponds to an improved methodology used by EPA and is discussed in Chapter 3, section 3.4.

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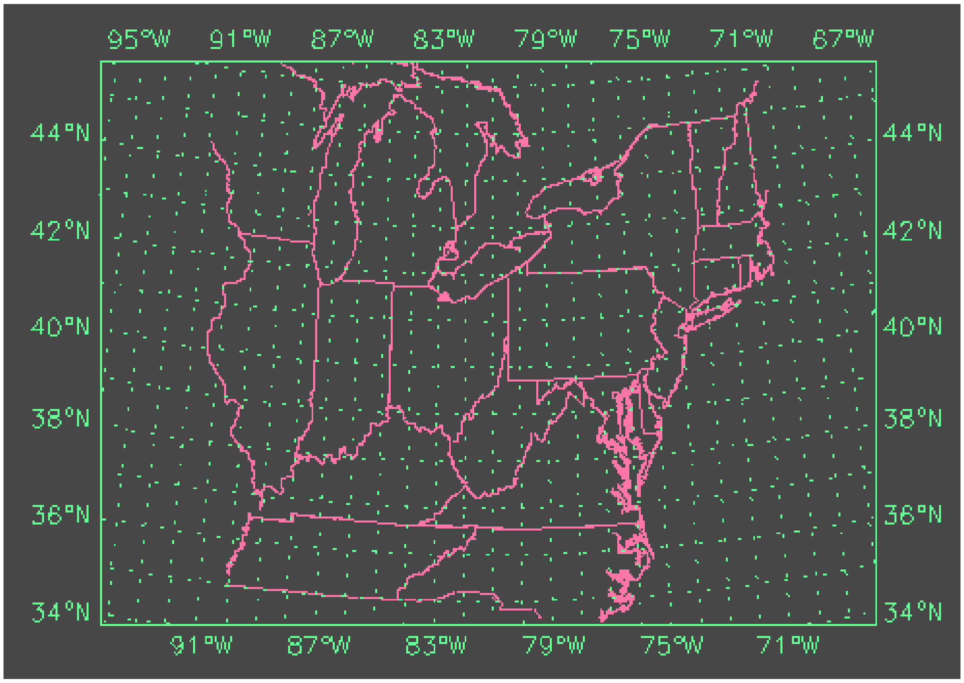


1 **Figure 4-1: Modeling domain. Output from Pre_ORAM** 45

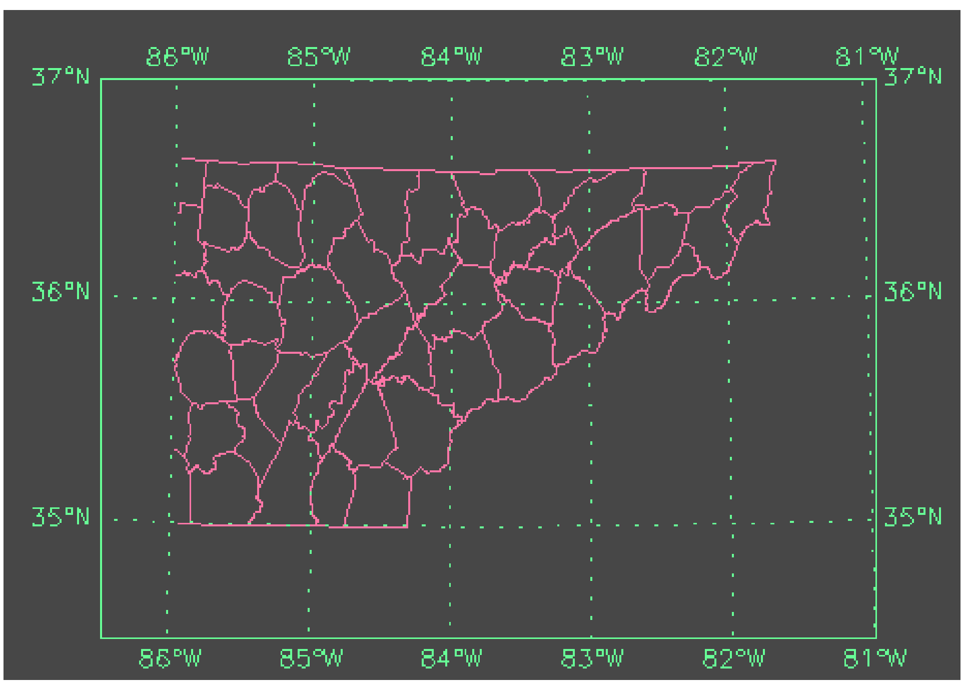


Figure 4-2: Study area. Output from Pre_ORAM

4.2.1 CART results for the ozone season

Using daily meteorological and ozone data for the ozone season of 1998, a CART analysis was performed to determine the classification scheme to be used in the day selection process (see Chapter 3, section 3.4). This year was selected because it was the latest year that we had with detailed meteorological records used for health-effects modeling research (Reed et al 2000).

The CART analysis considered the dependent variable to be the daily maximum 8-hr ozone concentration observed in Knoxville during 1998. The independent variables were the daily maximum temperature (Tmx), the daily average relative humidity (RH), the daily average wind speed (WSPa), and the daily average visibility (VISa). Each of these independent meteorological and environmental variables was obtained from McGhee-Tyson Airport

Figure 4-3 shows the optimal tree obtained for the partitioning of the ozone concentration in different meteorological regimes. Basically the results show 29 terminal nodes or bins representing meteorological conditions that allow ozone formation in different levels. The order of importance of the independent variables used to split the ozone values was daily maximum temperature, then relative humidity, then wind speed, and finally visibility. The numbers in each bin run from 1 to 5, and they are associated with a meteorological regime. For example, the second bin (1.800) is associated with category-day 2, i.e., with ozone concentration in the range of 40 to 55 ppb.

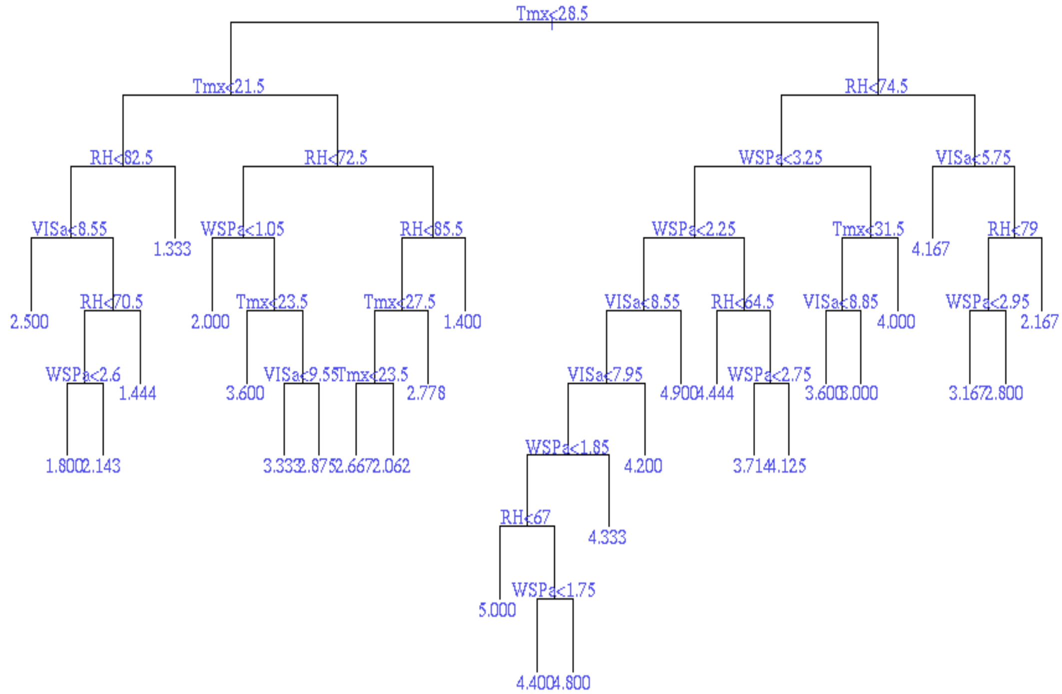


Figure 4-3: Tree output from CART analysis for ozone 8-hr

The bins and the number of days in each category are presented in Table IV.1. From this table we see that a given ground-level ozone concentration could be associated with more than one meteorological regime. In particular, high ozone concentrations (category-day 5: maximum 8-hr ozone concentration >= 85 ppb), are expected when maximum temperature is greater than 28.5ºC (83 F), wind speed less than 1.8 m/s, relative humidity less than 67%, and visibility less than 8 km. High concentrations are also formed when maximum temperature is greater than 28.5ºC, wind speed less than 2.3 m/s, relative humidity less than 74%, and visibility greater than 8.6 km. The goodness of fit for this model is shown in Table IV.2. Good classification was achieved within most categories, and in most cases days that were misclassified were put into an adjacent category.

Table IV.1 Ozone categories from CART analysis

[O3] 8-hr (ppb)	Bins	Nº days
<= 40	4,5,13	25
40 – 55	1,2,3,6,11,29	34
55-70	8,9,10,12,24,27,28	52
70 – 85	7,15,17,18,20,21,22,23,25,26	82
>85	14,16,19	21

Table IV.2 Classification matrix for ozone 8-hr in Knoxville 1998

		O	**B**	**S**	**E**	**R**	
P	**[O3]_Cat**	**1**	**2**	**3**	**4**	**5**	**TOT**
R	**1**	15	10	0	0	0	25
E	**2**	2	28	4	0	0	34
D	**3**	2	7	34	9	0	52
I	**4**	3	5	14	42	18	82
C	**5**	0	0	0	2	19	21
TOT		22	50	52	53	37	**214**
%		68	56	65	79	51	

During the 214 days included in this analysis, there were 37 exceedance days, and 19 of these are properly classified as having maximum 8-hr ozone concentrations that are greater than or equal to 85 ppb (Category 5). The remaining (18) exceedance days are misclassified, all of these having a maximum ozone concentration greater than or equal to 70 ppb but less than 85 ppb (Category 4). The best classification was achieved for category 4 (70-85 ppb) where 42 out of 53 days were correctly assigned (79%), and as with the rest of classifications, the misclassified are located in the adjacent categories. The worst classification occurs for category 5 (>85 ppb) with a goodness of fit of 51%. It is interesting to note that the days that were incorrectly classified were distributed evenly during the days of the week meaning that the misclassification of ozone is not expected to be correlated with the emission patterns. The overall goodness of fit of this model was 65%.

After running CART analysis, the number of category-days and the days in each category were obtained. The next step was to select a representative day in each category-days to run the exposure model (Models-3/CMAQ). Following the selection criteria described in Chapter 3, section 3.4, the simulation days were chosen. Table IV.3 shows the representative days for each category. Unfortunately, only one selected day (Category 1) presented a wind pattern suitable for the modeling domain used in the test case. Further analyses were required to attain the specific modeling domain (see section 4.2.2).

4.2.2 Restrictions on the modeling domain

Because East Tennessee was the target area for the test-case application and this area is located in the bottom of the available modeling domain (see Figure 4-1), it was necessary to consider only those days when the wind blew from the NNW to NNE (315º – 45º) in the area. This condition takes into account not only the local ozone but also the transported ozone that is requisite to evaluate the emission control scenarios strategies. In a normal application, the modeling domain and the study area should be selected as is explained in Chapter 3, section 3.3.

Table IV.3 Selected simulation days per ozone category

O3 8-hr Rank	Category	Nº days	Target day	[O3] 8-hr ppb	Back-Traj[1]
<= 40	1	15	Thursday-08-October	34	Y
40 – 55	2	28	Thursday-23-July	47	N
55-70	3	34	Tuesday-18-Aug	63	N
70 – 85	4	42	Wednesday-17-June	78	N
>85	5	19	Tuesday-25-August	122	N

1 :Back-Trajectory analysis: Does wind came from the Models-3 Modeling Domain? N=No, Y=Yes

Wind rose and Back-trajectory analysis

The first task was to analyze the wind pattern in the modeling domain. As the objective was to determine some representative days to use in Models-3/CMAQ runs, this analysis considered the 214 days (April-October) for the year 1998. As a first filter, the days were selected when the winds blew from the NNW-NNE using the records of wind direction from McGhee Tyson Airport (see Table IV.4).

During the ozone season of 1998 and using the data from McGhee Tyson Airport, it was found that 54% of the time (115 days) the wind presented a pattern where it blew from NNW-NNE, which was the requisite to use the EPA's modeling domain in this test run. For those 115 days the back-trajectories were calculated using the HYSPLIT4 model from NOAA (Hysplit4 1997).

After running the HYSPLIT4 model, it was noticed that not all of the days when the measured average wind direction came from the NNW-NNE sector had back-trajectories that showed the same results. Only 59 out of 115 days (51%) presented modeled and observed back-trajectories suitable for using the EPA's modeling domain in the test case.

Table IV.4 Days when the wind blows from the selected sector (315º-45º) in 1998

Wind Dir	Apr	May	Jun	July	Aug	Sep	Oct	Tot
315-360	5	4	5	7	5	9	6	41
0 – 45	10	6	4	8	17	11	18	74
315-45	15	10	9	15	22	20	24	115

Table IV.5 shows that these 59 potential simulation days have high and low ozone concentrations, which is the requisite for applying the aggregation technique in order to have a good representation (all spectrum) of the ground-level ozone concentrations during the ozone-season.

Using these 59 days, a regression tree analysis was performed again. The optimal tree produced 11 terminal nodes or bins that represent the meteorological conditions for ozone formation in different levels. The order of importance of the independent variables used to split the ozone values was daily maximum temperature, then relative humidity, then wind speed, and finally visibility. The characteristics of each bin and the number of days in each are presented in Table IV.6. Using the above information, an interval of ozone concentrations was built according to the meteorological regimes (see Table IV.7).

Table IV.5 Monthly distribution of days when the wind back-trajectory came from NNW/NNE

Month	**Wind in Modeling**		**Wind out Modeling**		**Total**	
	Nº days	**Nº[O3]>=85**	**Nº Days**	**Nº[O3]>=85**	**Ndays**	**Nº[O3]>=85**
Apr	6	0	9	0	15	0
May	2	0	8	2	10	2
Jun	3	0	6	0	9	0
July	9	2	6	1	15	3
Aug	10	1	12	6	22	7
Sep	12	5	8	4	20	9
Oct	17	0	7	0	24	0
Tot	**59**	**8**	**56**	**13**	**115**	**21**

Table IV.6 Meteorological regimes from regression tree analysis using 59 days

Bins	Meteorological regime	Nº days
1	TX<22 / RH>70.5 / VS >9.3	5
2	TX<22 / RH<70.5 / VS >9.3	5
3	22<TX<28.5 / RH>58.5 / WS <2.35	7
4	TX<22 / RH>58.5 / VS <9.3	5
5	22<TX<28.5 / RH>58.5 / WS >2.35	5
6	TX<28.5 / RH<58.5	6
7	28.5 <TX<30.5 / RH>61.5	5
8	TX>30.5 / RH>61.5 / WS >2.5	6
9	TX>30.5 / RH>61.5 / WS <1.55	5
10	TX>30.5 / RH>61.5 / 1.55<WS <2.5	5
11	TX>30.5 / RH<61.5	5

TX : Maximum temperature (ºC)
RH : Relative humidity (%)
WS : Wind speed (m/s)
VS : Visibility (km)

Table IV.7 Ozone categories from regression tree analysis using 59 days

[O3]_Cat	[O3] 8-hr (ppb)	Bins	Nº days
1	<= 40	4	5
2	40 – 55	2,3,5	17
3	55-70	1,6,8	16
4	70 – 85	9,10,11	16
5	>85	7	5

Finally, a CART analysis was performed with the ozone ranks. The results are depicted in Table IV.8. The classification tree consisted of 10 bins. Of these, 1 terminal node represented the lower rank, and one represented the exceedance bin, whereas 4, 2, and 2 bins represented the intermediate ranks, respectively.

The goodness of fit for this model is shown in the Table IV.9. Good classification was achieved within most categories and, in most cases days that are misclassified are put into an adjacent category. During the 59 days included in this analysis, there were 7 exceedance days. Five of these are properly classified as having maximum ozone concentrations that are greater than or equal to 85 ppb (Category 5). Two exceedance days are misclassified, both of these having a maximum ozone concentration greater than or equal to 70 ppb but less than 85 ppb (Category 4). The best classification is achieved for Category 2 (40-55 ppb) where 16 out of 19 days were correctly assigned (84%), and as with the rest of classifications, the misclassified are located in the adjacent categories. The worst classification occurs for Category 1 (<= 40 ppb) with a goodness of fit of 43% and 1 day assigned to Category 3.

It is interesting to note, that the days that are incorrectly classified are distributed evenly during the days of the week, meaning that the misclassification of ozone is not expected to be correlated with the emission patterns. The total goodness of fit of this model was 71%, and the misclassification occurs in the vicinity of each category.

Table IV.8 Meteorological regimes from CART analysis using 59 days

[O3]_Cat	Bins	Meteorological regime	Nº days
1	2	18.5<TX<20.5	5
2	1,3,4,5	TX<18.5 20.5<TX<26.5	22
3	6,10	26.5<TX<28.5 TX>28.5 / WS >2.15 / RH>69.5	12
4	8,9	TX>28.5 / WS<2.15 / RH>65 T>28.5/ WS>2.15 / RH<69.5	14
5	7	TX>28.5 / WS <2.15 / RH<65	6

TX : Maximum temperature (ºC)
RH : Relative humidity (%)
WS : Wind speed (m/s)

Table IV.9 Classification matrix for ozone 8-hr in Knoxville 1998 using 59 days

P		**O**	**B**	**S**	**E**	**R**	
R	**[O3]_Cat**	**1**	**2**	**3**	**4**	**5**	**TOT**
E	**1**	3	2	0	0	0	5
D	**2**	3	16	3	0	0	22
I	**3**	1	1	7	3	0	12
C	**4**	0	0	1	11	2	14
T	**5**	0	0	0	1	5	6
TOT		7	19	11	15	7	59
%		43	84	64	73	71	

4.2.3 Selecting representative days

Using the selection criteria described in Chapter 3, section 3.4, the meteorological regimes were calculated, and the simulation days were obtained as shown in Table IV.10. The back-trajectory for each representative day is shown in Figure 4-4 using the HYSPLIT4 model.

Aggregation to ozone season

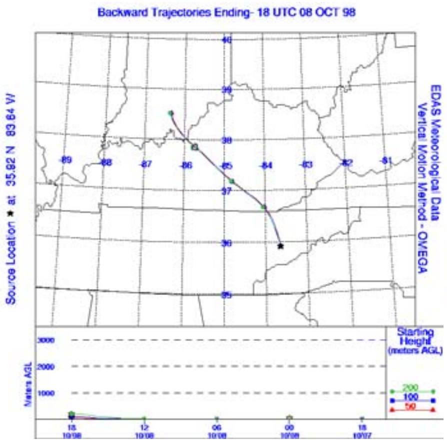
Table IV.11 shows the frequency of each ozone category (daily maximum 8-hr) using monitored data for 1998 in Knox County. These values were used to expand the simulation categories to 214 days as is required by the concentration-response equation to estimate the total health effect during the ozone season (Equation 3-2).

Table IV.10 Selected simulation days per ozone category

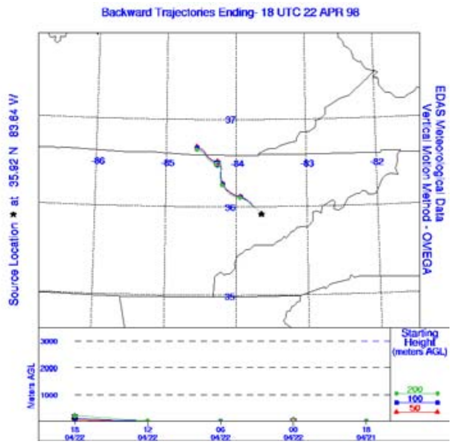
[O3] 8-hr_Cat	Category	Target day	[O3] 8-hr ppb
<= 40	1	Thursday-08-October	34
40 – 55	2	Wed-22-April	48
55-70	3	Tuesday-08-September	60
70 – 85	4	Thursday-27-August	82
>85	5	Friday-18-September	100

Table IV.11 Expansion factors by ozone category

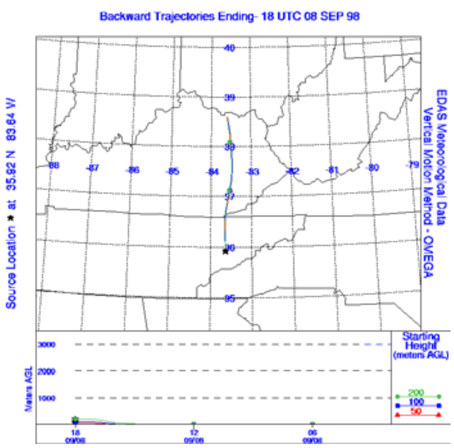
Ozone Category	Ozone (ppb)	Nº days
1	< =40	22
2	(40 – 55]	50
3	(55 – 70]	52
4	(70 – 85]	53
5	> 85	37
Total		**214**



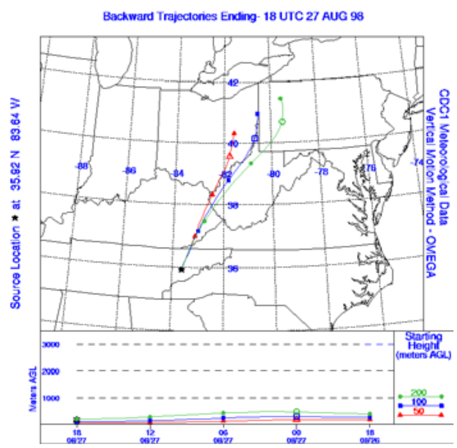
Category1 (<=40 ppb)



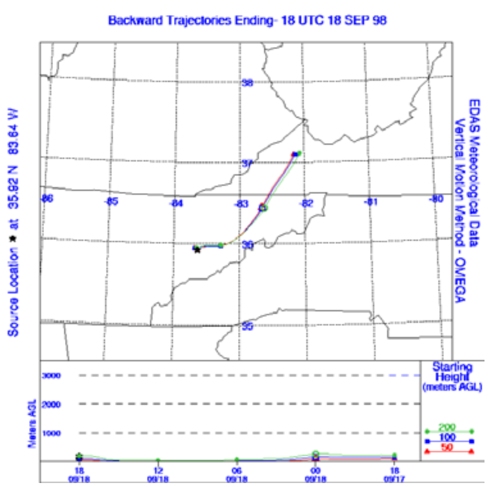
Category 2 (40-55 ppb)



Category 3 (55-70 ppb)



Category 4 (70-85 ppb)



Category 5 (> 85 ppb)

Figure 4-4: Back-trajectories for selected days using HYSPLIT4 model

4.3 Models-3/CMAQ input data

In order to run the exposure model (Models-3/CMAQ), several input files and programs were prepared and executed. Table IV.12 shows the principal input files for each of the main processors in Models-3/CMAQ.

Meteorological inputs

MM5 was run for 108-km and 36-km grid sizes for an extended modeling domain, as is required for CCTM processor in Models-3/CMAQ. The meteorological modeling was performed using 23 vertical layers, and the planetary boundary layer was simulated using the MRF physic option, even though two other suitable methods were analyzed (see discussion in Chapter 5, section 5.2.2).

The Meteorological-Chemistry Interface Processor (MCIP) was used to extract data for the appropriate CCTM domain and translate data from MM5 to CCTM formats and units. Also MCIP was used to collapse the 23 vertical layers from MM5 to 6 vertical layers as required by CCTM.

Table IV.12 Data input files for the exposure model (Models-3/CMAQ)

Meteorology **MM5**	**Emission** **SMOKE**	**Concentration** **CCTM**
Land use data Analysis data Observational data	Inventory by source Surrogate files Meteorology County codes	Land use Boundary conditions Initial conditions Photolysis rates Meteorology Emission

Emission inputs

The emission input used in the simulation corresponds to EPA 1995 emission inventory. All emission inventory data are in Inventory Data Analyzer (IDA) format as is required by the emission processor. The inventory data were processed using the Sparse Matrix Operator Kernel Emissions (SMOKE) program that performed the tasks of speciation, spatial allocation, temporization, and merging all of the sources categories of emissions to form input files for the air quality model (CCTM). The biogenic sources were processed using BEIS2, which is included in SMOKE, and the mobile sources were processed using MOBILE5b, also included in the SMOKE program.

CMAQ Chemistry and Transportation Model

The modeling used the CB4 chemistry mechanism with the Modified Euler Backward Iterative (MEBI) chemical mechanism solver. The piecewise parabolic method (PPM) was chosen for the advection scheme, and vertical diffusion was based on eddy diffusivity. The spin-up period, the boundary and initial conditions, and the vertical layer depth were evaluated to determine the best approximation using the EPA model performance evaluation protocol included in the Pre_ORAM model.

Emission Scenarios

In order to demonstrate the applicability of the tool developed here (ORAM), three emissions scenarios were considered along with the base case. Rather than changing to a future year, the scenarios consider the same year but with different emission controls.

This reduces in part the uncertainty in projecting population and emissions to the future from the base year. The scenarios were

(1) : Base case (actual emissions)

(2) : 50% NOx emission reduction in mobile (on-road) sources

(3) : 70% NOx emission reduction in major point sources

(4) : (2) and (3) simultaneously

The mobile source emission reduction was applied across the board, and the point source emission reduction was applied only for major sources (>=100 tpy) in the domain. These scenarios allowed the determination of the relative contribution of different sources to the human health-effects. Only NOx reduction was considered because according to other studies (Chameides and Cowling 1995), the study area is NOx limited, meaning that only reduction in NOx has a significant effect on the reduction of ozone. The 70% reduction in point sources was used because it is the expected reduction using SCR (EPA 1994, OTAG 1996), and the 50% reduction in NOx due to mobile sources is expected when all new regulations will be in place (Tang 2001).

4.4 Models-3/CMAQ performance evaluation

The first step in the modeling process is to verify the model's performance in terms of its ability to predict the ozone in the right locations and at the right levels. To do this, the model predictions for the base scenario simulation are compared to the ambient data

observed at the monitors located in the study area. This verification is a combination of statistical and graphical evaluations. If the model appears to be producing ozone in the right locations for the right reasons, then the model can be used as a predictive tool to evaluate various control strategies and their effects on ozone.

Several runs were performed before the outputs of Models-3/CMAQ were used in the health assessments. These previous runs had the objective to evaluate the response of different options for running the exposure model. Basically the spin-up period, the boundary conditions, the initial conditions, PBL parameterizations, and the depth of the vertical layers were evaluated. The ozone concentration obtained in each evaluation was analyzed according to EPA criteria for photochemical model performance evaluation (EPA 1991) using the Pre_ORAM preprocessor. After this analysis, the selected options were chosen (see Table IV.13):

GK corresponds to equations developed by Gi-Dong Kim to estimate hourly vertical ozone concentrations profiles by using the daily maximum ozone and the hour of the day (Kim 2001).

Using the 5 days selected by the criteria for representing the ozone season (section 4.2), Models-3/CMAQ was run to calculate the hourly ozone concentration in the modeling domain. Pre_ORAM processed the Models-3/CMAQ predictions for the first layer, and then the 1-hr and the 8-hr maximum ozone concentrations for each target day in each county in East Tennessee were calculated.

Table IV.13 Options for running Models-3/CMAQ exposure model

Options	**Alternatives evaluated**	**Alternative selected**
Spin-up period	1, 2, and 3 days	2 days
Boundary conditions	EPA default / GK equations	EPA default
Initial conditions	EPA default / GK equations	EPA default
PBL parameterization	Blackadar / MRF /Gayno-Seaman	MRF
Vertical depth 1st Layer (sigma pressure)	0.995; 0.990; 0.985; 0.98; 0.975	0.98

Both metrics were then compared with ambient monitoring data for each target-day and graphical, and statistical measures of model performance for each day were determined. The graphical analyses consisted of time-series plots of hourly observed and predicted ozone concentrations and tile plots to see the spatial distribution of the ozone levels in the modeling domain.

Although there is no EPA guideline to evaluate model performance in simulating ozone concentrations for health-effects applications, the same statistical measures recommended for regulatory applications of photochemical models (EPA 1991, EPA 1999e) were applied to each selected day in this work.

The statistical measures are the normalized gross error (NGE), the normalized gross bias (NGB), and the unpaired highest-prediction accuracy (HPA). Since NGE and NGB are normalized with respect to the observed ozone concentration at each hour, EPA suggests a cutoff level of 60 ppb in the observation to avoid contamination of statistics (EPA 1991). As this work focuses on health effects associated with ozone concentration during the ozone season (meaning that not only episodic days but all the ozone spectrum need to

be considered), the NGE and NGB statistics were calculated using daily maximum 1-hr and 8-hr zone concentrations instead of hourly values.

4.4.1 Pre_ORAM Results

As was explained in Chapter 3, Pre_ORAM is the preprocessor that performs the model evaluation and also generates the ozone concentration metrics (1-hr and 8-hr) required by ORAM. Pre_ORAM was run for each category-day, and the graphical and analytical outputs were analyzed. Figure 4-5 shows the main menu of this program. Seven options are included in Pre_ORAM and the options are entered interactively (see Appendix E for a detailed explanation on how to use Pre_ORAM).

Figures 4-6 and 4-7 show some graphical (2D and 3D) representations of ozone concentrations for the whole modeling domain, obtained by the preprocessor Pre_ORAM. The major utility of these figures is when using as comparison (QA/QC) with the tile plots obtained with PAVE, the visualization package included in Models-3/CMAQ.

Figure 4-8 presents a time-series plot of the hourly ozone concentration in each of the six layers (144 m, 514 m, 1,223 m, 3,462 m, 7,518 m, and 16,468 m) for Knox County for Category-day 5. Pre_ORAM produces this kind of plots for as many counties as the user set in the program protocol.

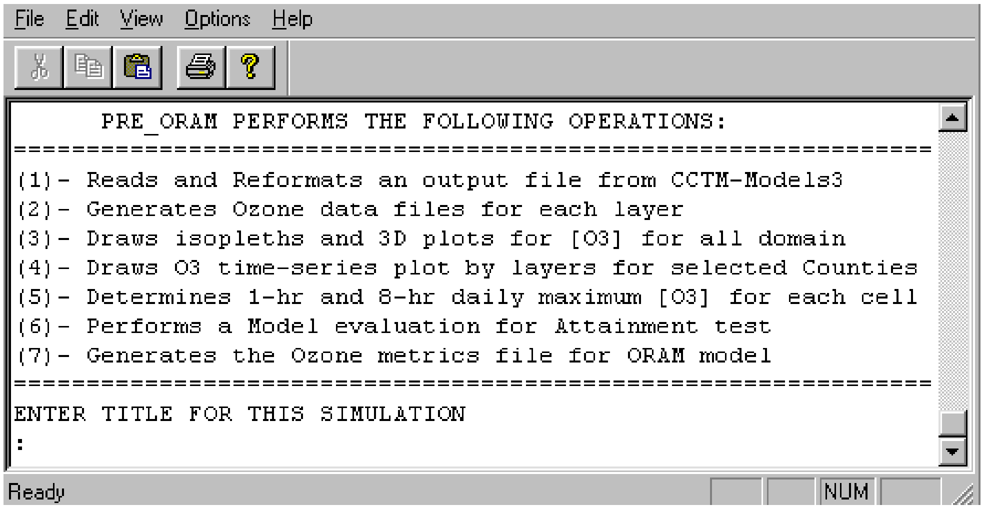


Figure 4-5: Pre_ORAM main menu

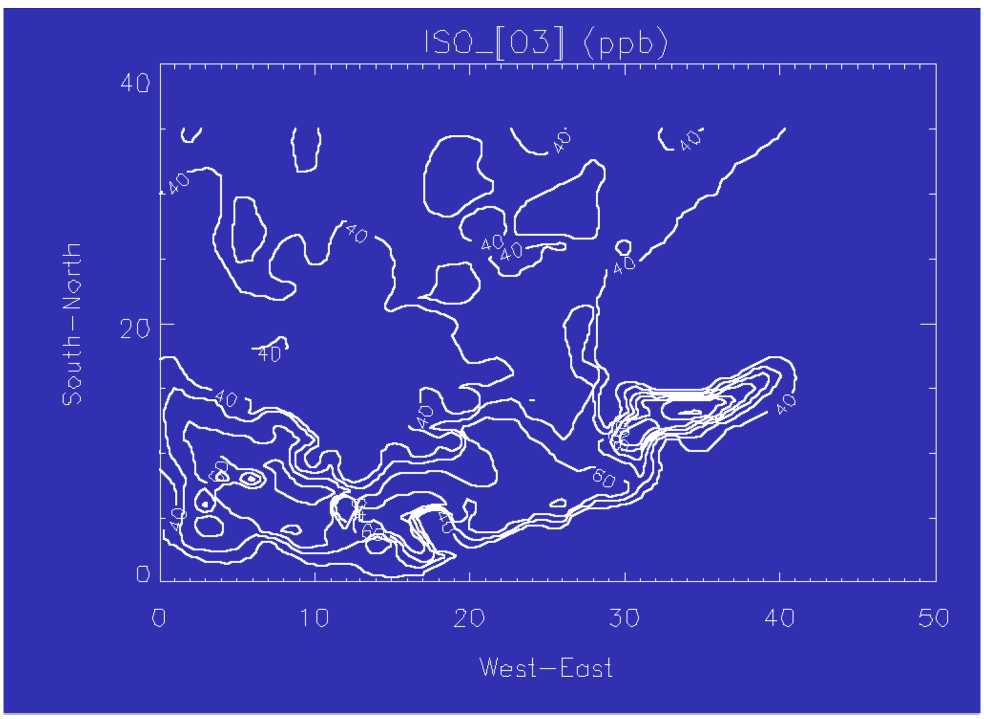


Figure 4-6: Contour plot of ozone concentrations in the modeling domain. Output from Pre_ORAM

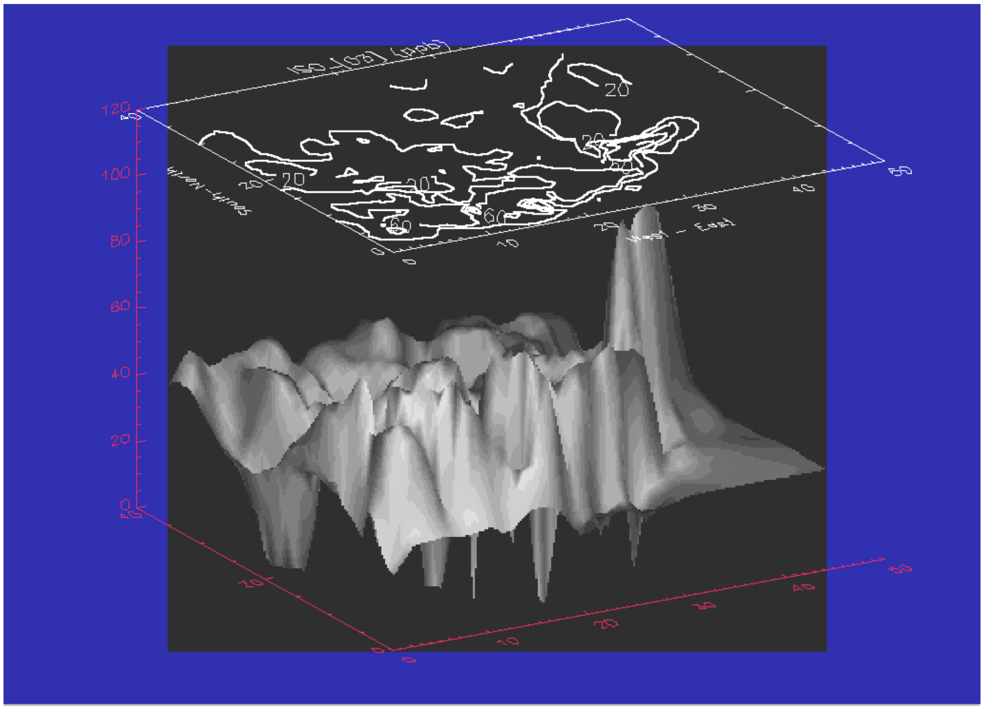


Figure 4-7: Surface plot of ozone concentrations in the modeling domain. Output from Pre_ORAM

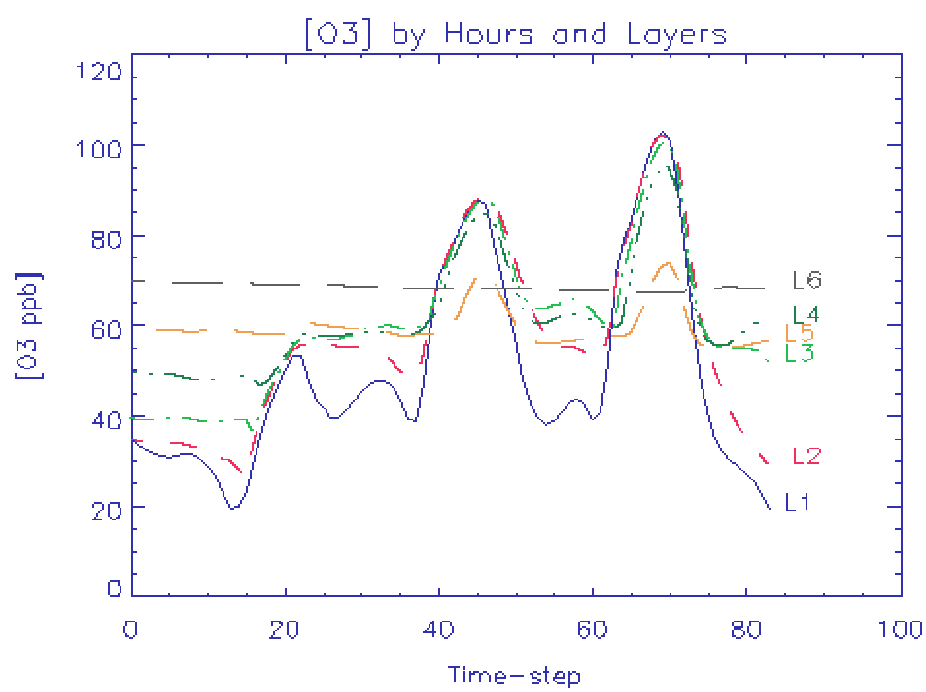


Figure 4-8: Time-series plot for Knox County. Output from Pre_ORAM

4.4.2 Ozone concentrations

After running Models-3/CMAQ for each of the five category-days selected in section 4.2, and applying the statistical measures, unfortunately three out of five days did not pass the performance test (Category-days 1,3,and 4), so new days were run (the second best in each category), until every representative day passed the criteria for using a photochemical air quality model for attainment demonstration (EPA 1991). The final representative days for each ozone-category are shown in Table IV.14.

Figures 4-9 and 4-10 show the time series plots for each category-day in Knox County. From these graphs, it is believed that there is a fairly good model performance, except for Category 4, where for the target day (August 12-1998), the ozone profile does not go down during the early morning as was expected; nevertheless, it must be considered that we are interested in ozone metric rather than ozone profile (C-R functions use max 1-hr and 8-hr ozone concentrations), and we are comparing model prediction in a 36-km grid size where the monitor is located. For these reasons, the EPA's statistics test was the final criterion for choosing these days as representative for health-effects impact evaluation.

Table IV.14 Representative days for each ozone-category

Category	O_3 max 8-hr (ppb)	Day	Nº days
C1	<= 40	Thursday-October-22	22
C2	(40 – 55]	Wednesday-April-22	50
C3	(55 – 70]	Wednesday-September-23	52
C4	(70 – 85]	Wednesday-August-12	53
C5	> 85	Friday-September-18	37

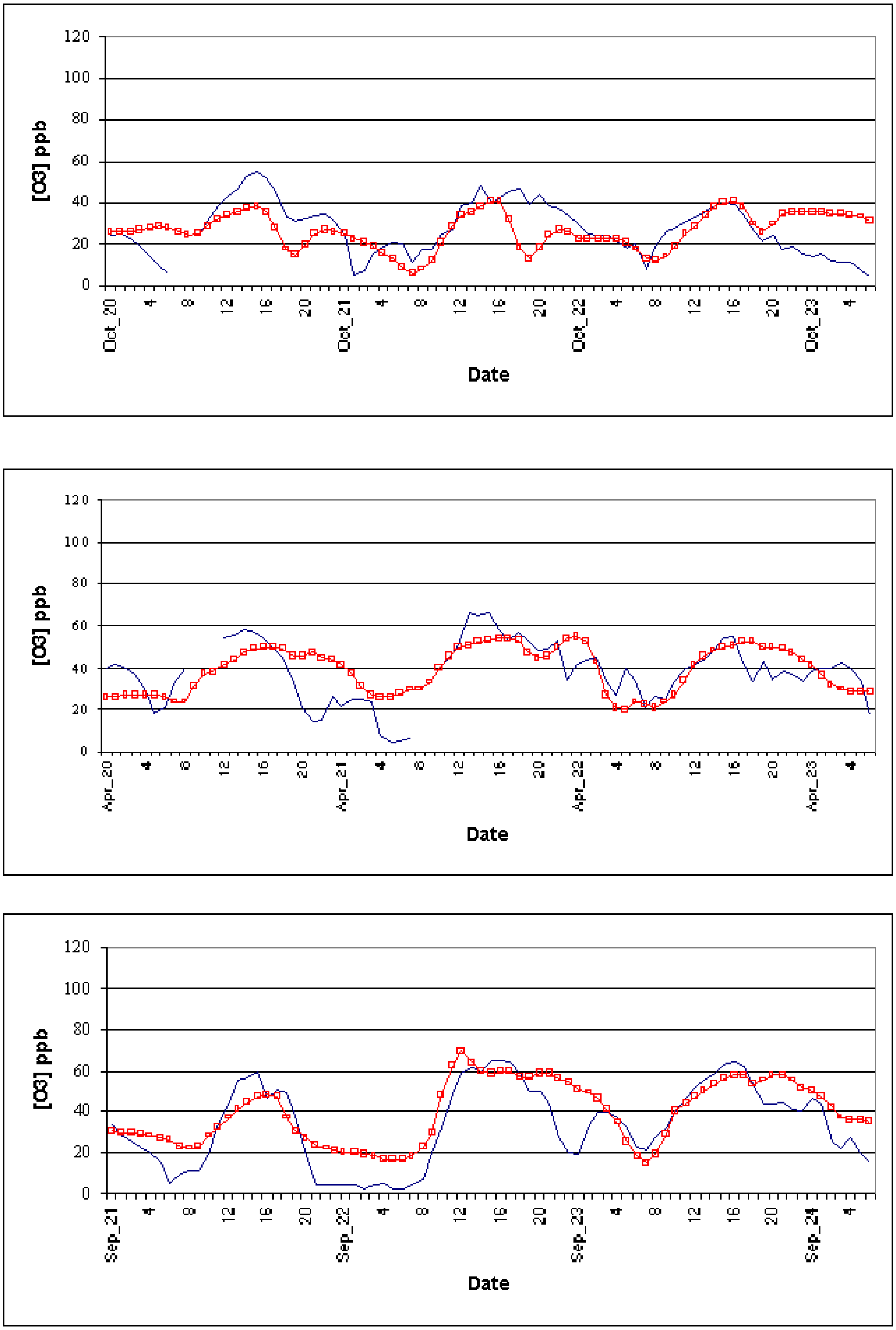
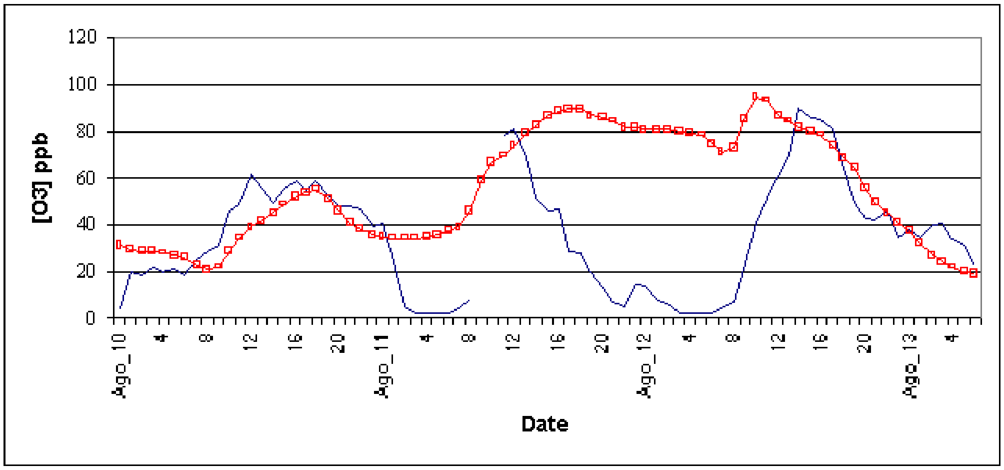


Figure 4-9: Time-series plots of observed (blue) and predicted (red square) ozone concentrations: Category days C1, C2, and C3 for Knox County.



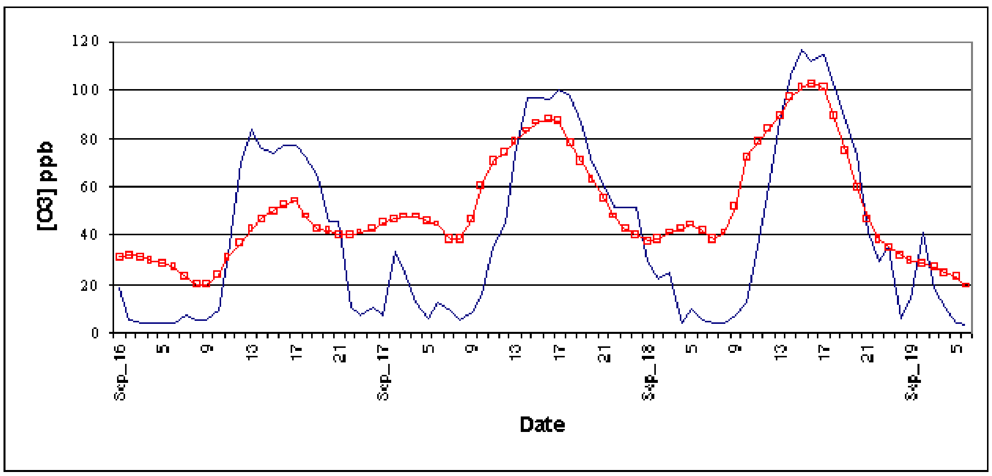


Figure 4-10: Time-series plots of observed (blue) and predicted (red square) ozone concentrations: Category days C4 and C5 for Knox County.

Tables IV.15 and IV.16 present the observed and predicted ozone maximum 1-hr and 8-hr, respectively, for each East Tennessee county that has an ozone monitoring station, and Tables IV.17 and IV.18 summarize the EPA's statistics measures for model performance evaluation. The statistics show that the selected days are appropriate to be used in Models-3/CMAQ for emission control scenarios in East Tennessee. The goodness of fit scatter-plots for ozone 1-hr and 8-hrs are shown in Figures 4-11 and 4-12, respectively.

Finally, using these criteria, the model performance was deemed to be suitable for moving forward to the health-effects evaluation for different emission control strategies.

4.4.3 Meteorology

The fifth-generation mesoscale meteorological prognostic model (MM5) was used to generate the meteorological fields required for Models-3/CMAQ. A complete evaluation of the meteorological modeling is beyond the scope and purposes of this work; nevertheless, it is recognized that the meteorological input is important in photochemical model predictions. The discussion here is focused on wind and temperature comparisons and mostly graphical outputs that help us understand the ozone concentrations. MM5 was run for each category day with 2 days used as the spin-up period. MM5 was set to run with 2 domains; a coarse domain with a horizontal resolution of 108-km, and an inner-grid that covers the CCTM modeling region with 36-km grid size (Figure 4-13).

Table IV.15 Observed and predicted ozone (ppb) max 1-hr by category-day

	Category1		Category2		Category3		Category4		Category5	
County	**Obs**	**Pred**	**Obs**	**Pred**	**Obs**	**Pred**	**Obs**	**Pred**	**Obs**	**Pred**
Anderson	33	37	48	61	56	53	65	76	94	93
Blount	38	42	58	57	65	70	70	82	87	68
Hamilton	36	44	60	69	65	76	71	68	81	57
Jefferson	37	46	52	57	60	67	79	96	100	103
Knox	41	41	56	55	64	58	88	95	114	103
Sevier	48	42	67	57	69	70	86	82	94	75
Sullivan	32	26	52	42	62	39	76	84	104	79

Table IV.16 Observed and predicted ozone (ppb) max 8-hr by category-day

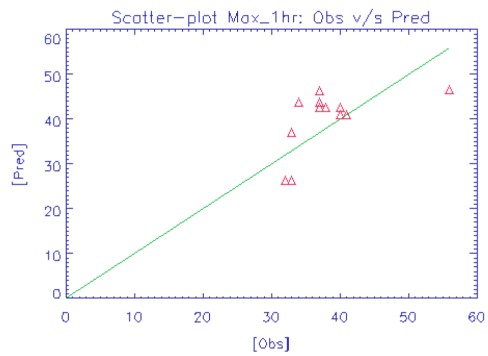
	Category1		Category2		Category3		Category4		Category5	
County	**Obs**	**Pred**	**Obs**	**Pred**	**Obs**	**Pred**	**Obs**	**Pred**	**Obs**	**Pred**
Anderson	30	32	44	55	51	46	54	65	82	83
Blount	35	39	55	53	60	66	65	77	78	85
Hamilton	33	40	54	65	58	73	57	54	76	53
Jefferson	34	43	50	54	56	63	73	94	93	94
Knox	36	35	48	50	58	56	76	85	100	93
Sevier	48	39	66	53	66	66	82	77	84	73
Sullivan	30	21	42	37	54	34	74	74	96	69

Table IV.17 Model performance statistics for ozone 1-hr in East Tennessee

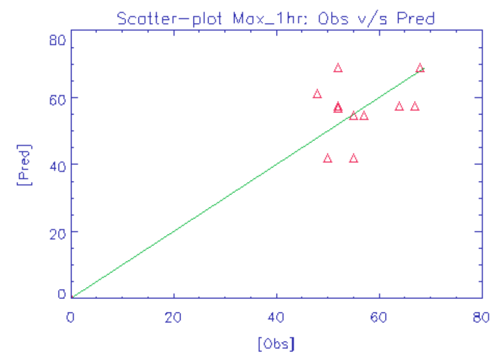
Category	**Day**	**NGE (%)**	**NGB (%)**	**HPA (%)**	**R2**
C1	Thu-Oct-22	15	-9	-1	0.6
C2	Wed-Apr-22	14	-1	2	0.9
C3	Wed-Sep-23	14	3	10	0.5
C4	Wed-Aug-12	14	-10	-8	0.6
C5	Fri-Sep-18	18	18	9	0.8
EPA	Recommended	35	20	20	

Table IV.18 Model performance statistics for ozone 8-hr in East Tennessee

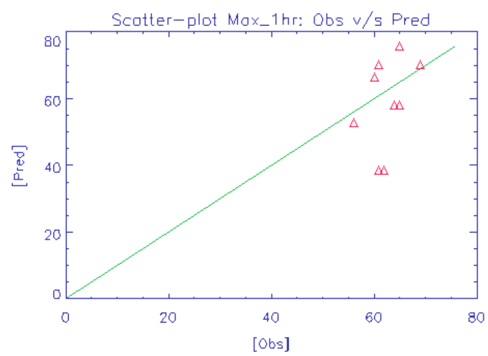
Category	**Day**	**NGE (%)**	**NGB (%)**	**HPA (%)**	**R2**
C1	Thu-Oct-22	16	-1	4	0.6
C2	Wed-Apr-22	14	-4	-5	0.9
C3	Wed-Sep-23	15	0	3	0.5
C4	Wed-Aug-12	12	-9	-13	0.7
C5	Fri-Sep-18	17	16	6	0.7
EPA	Recommended	35	20	20	



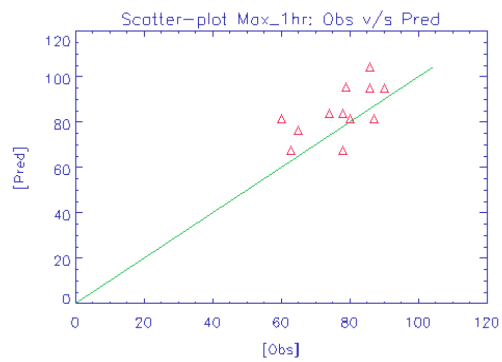
C1



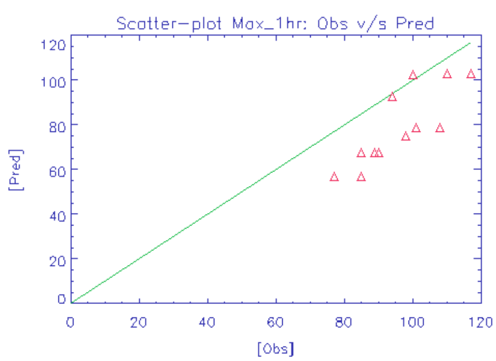
C2



C3

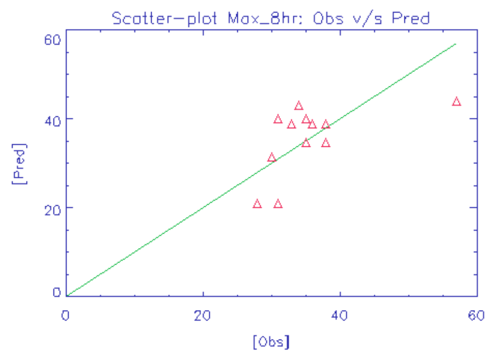


C4

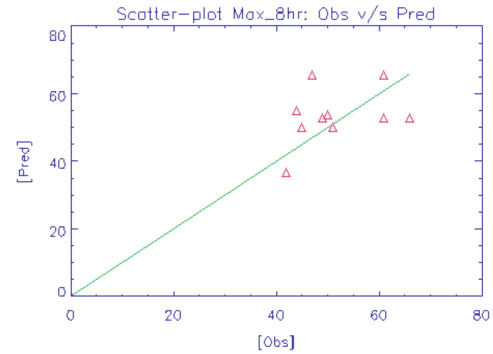


C5

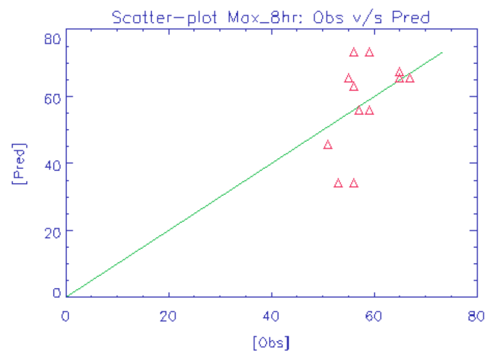
Figure 4-11: Goodness of fit plots for maximum 1-hr ozone by category day in East Tennessee. Output from Pre_ORAM.



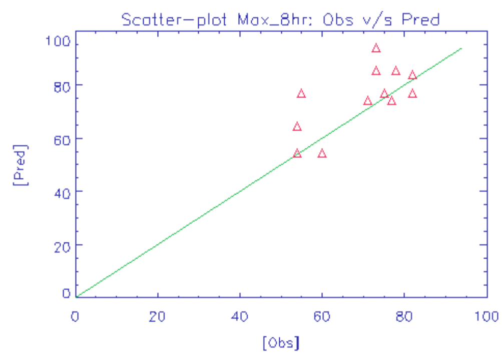
C1



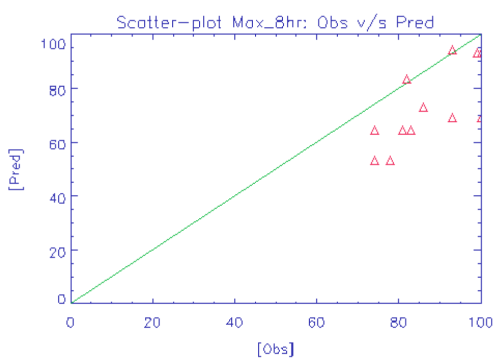
C2



C3



C4



C5

Figure 4-12: Goodness of fit plots for maximum 8-hr ozone by category day in East Tennessee. Output from Pre_ORAM.

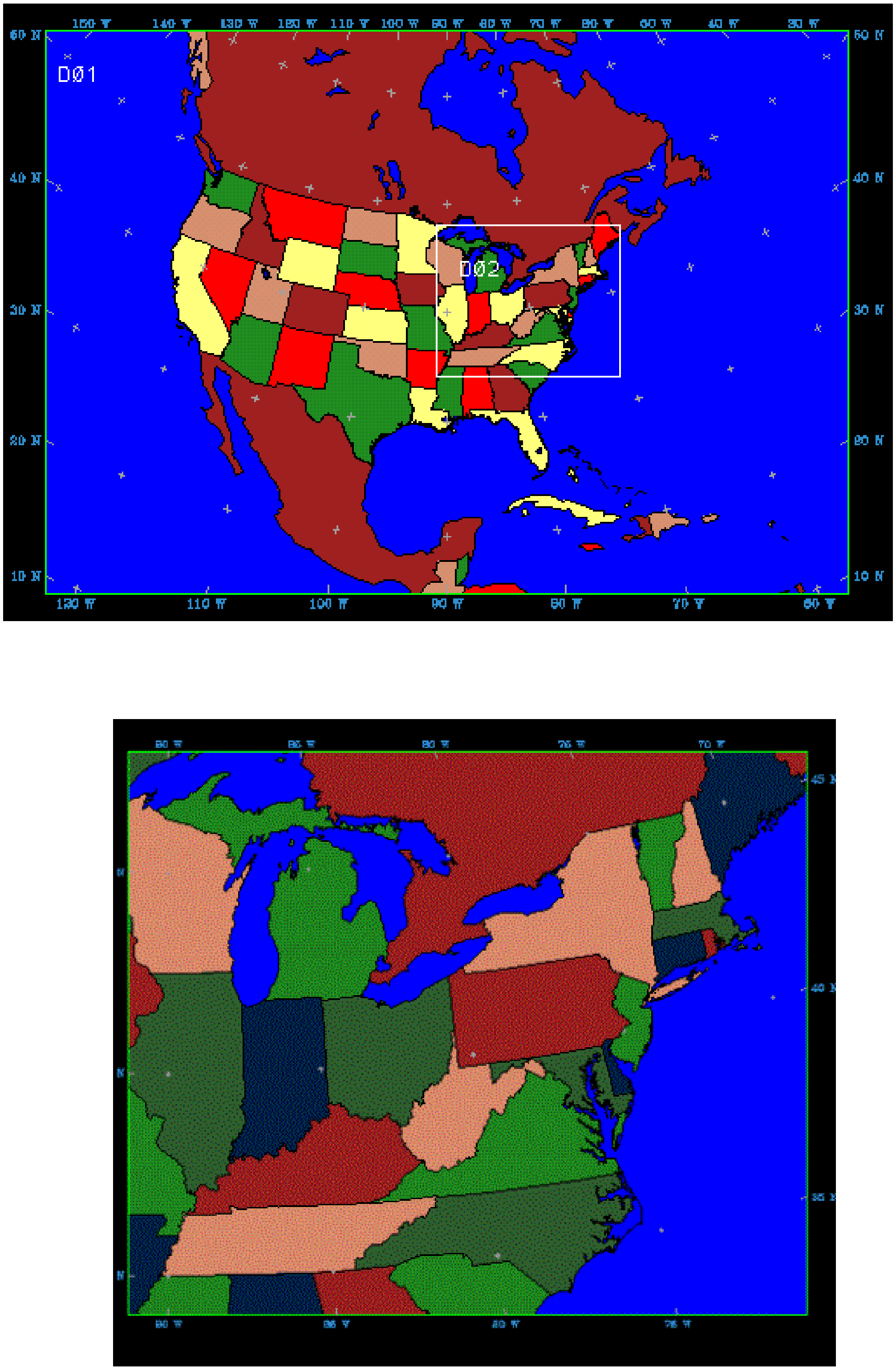


Figure 4-13: MM5 Coarse (108-km) and nested (36-km) modeling domain.

Due to the length of the simulation period, it was not necessary to use FDDA, which is a requisite for simulation of five or more days (due to the actual limitation in the number of time-step associated with RAWINS a preprocessor of MM5 in its version 3.4).

The back-trajectories for the new representative days are shown in Figure 4-14, and the wind fields after MM5 runs in Figure 4-15. The vertical wind fields are shown in Figures 4-16 to 4-18 for each category-day. Table IV.19 shows the daily average wind speed observed in McGhee Tyson Airport and the predicted value from MM5 after being processed by MCIP. Note that MM5/MCIP consistently overpredicts the winds. This overprediction of the wind speed is mostly associated with the height of the first layer used in this application. Even though MM5 had 38 m as the height of the first layer, after collapsing from 23 to 6 vertical layers using MCIP (for the CMAQ run), the first layer was 144 m. The observed wind speed is measured at 10 m, and MCIP calculates an average wind speed in a volume of 36-km by 3- km and 144 m high.

Table IV.19 Wind speed (m/s) comparison

Category	Day	Observed	MM5/MCIP
C1	Thu-Oct-22	5.4	6.6
C2	Wed-Apr-22	2.8	5.5
C3	Wed-Sep-23	3.8	5.6
C4	Wed-Aug-12	1.4	3.0
C5	Fri-Sep-18	1.7	2.1

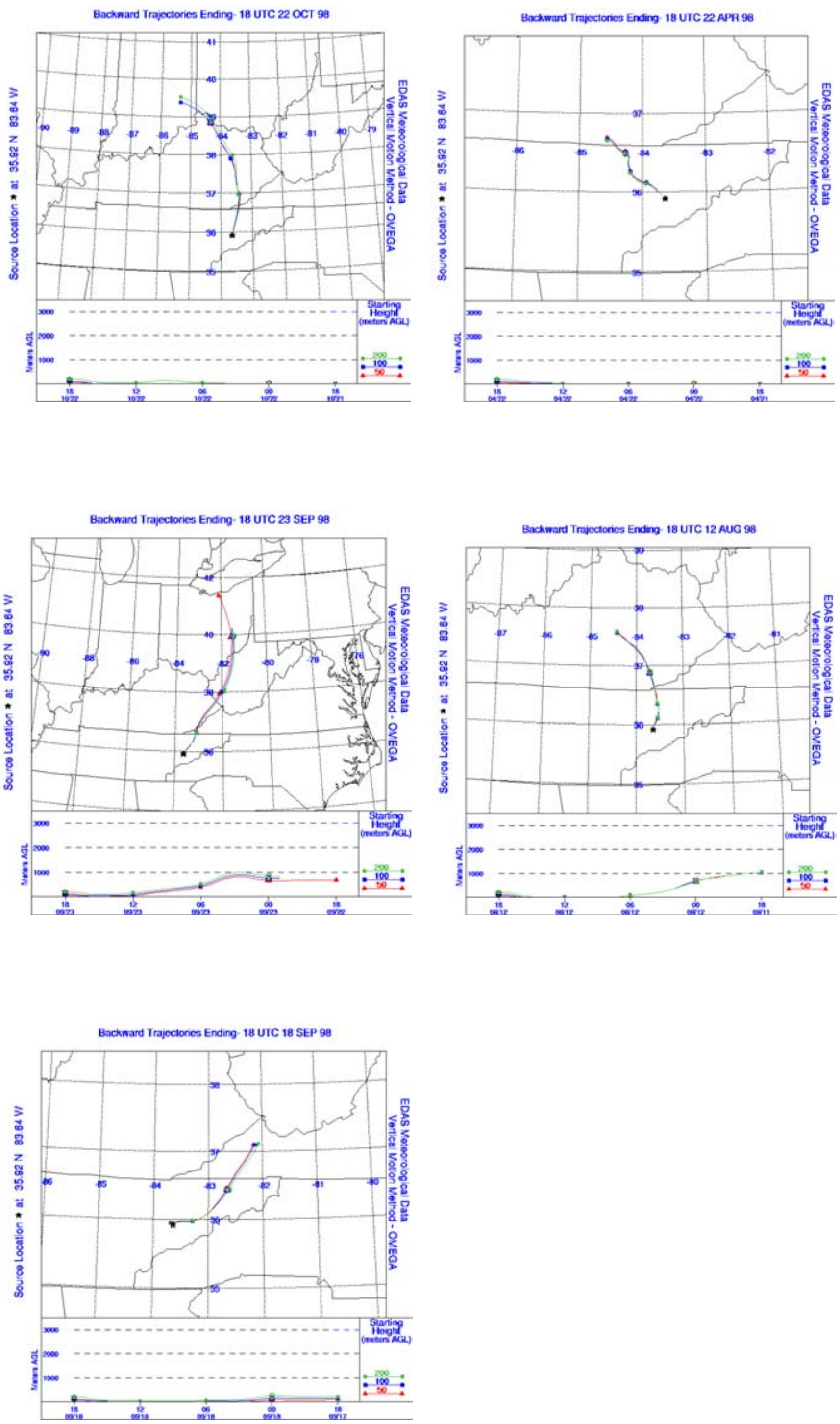


Figure 4-14 Back-trajectories for the new selected days using HYSPLIT4 model.

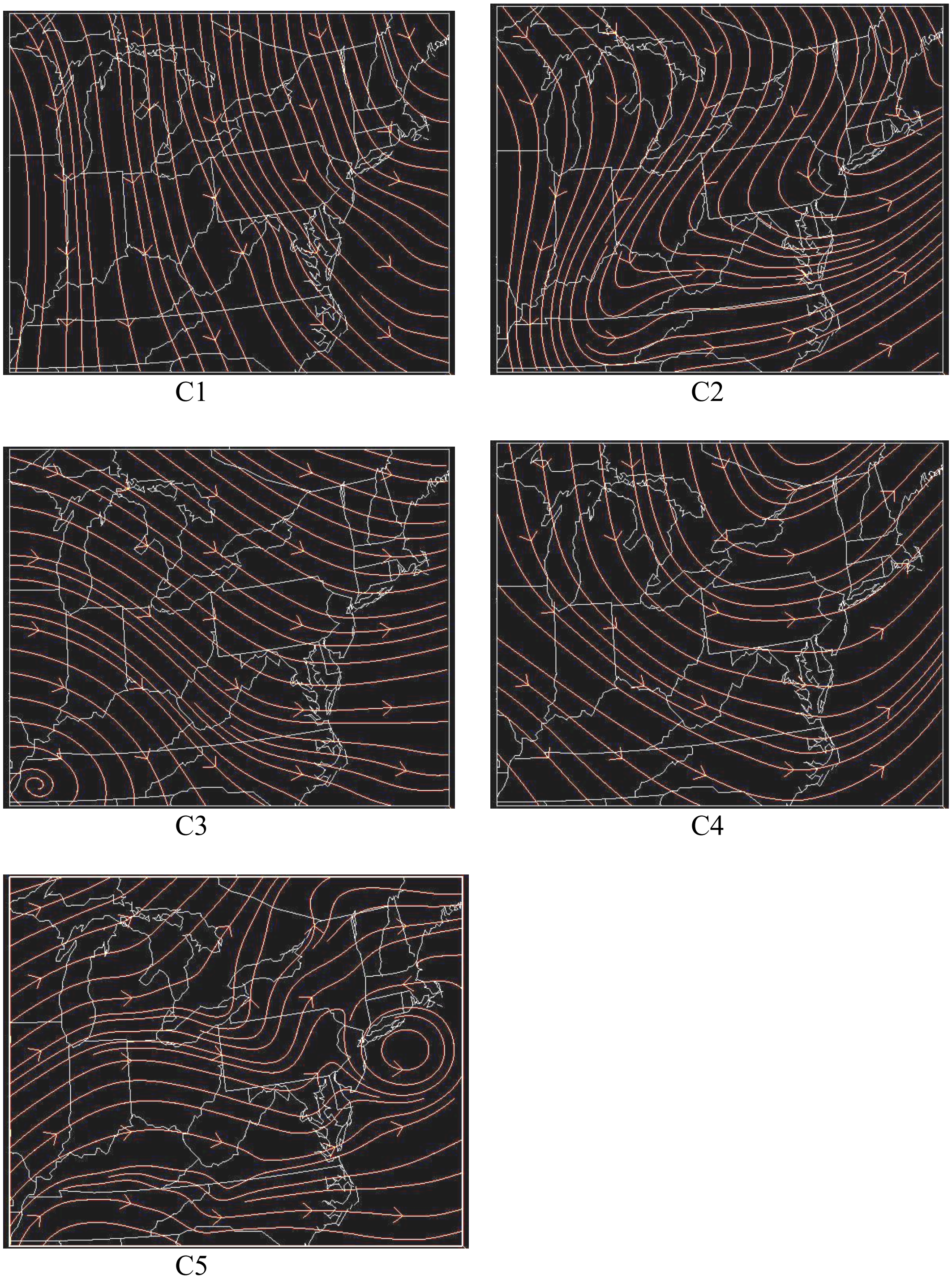
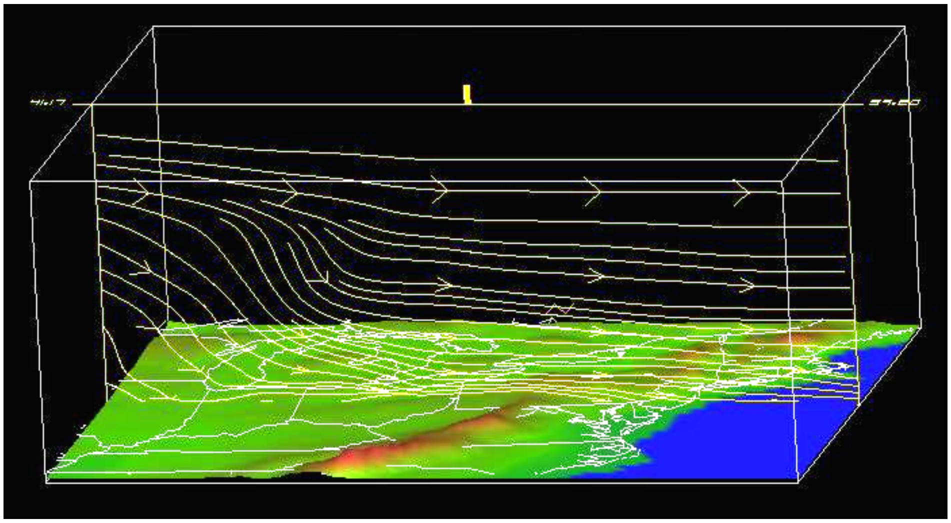
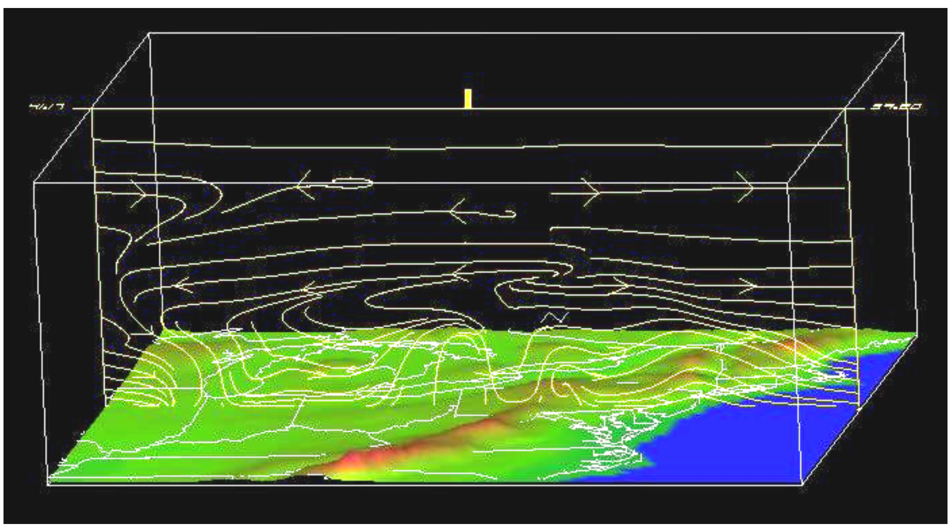


Figure 4-15: Wind fields by category day after MM5 runs.

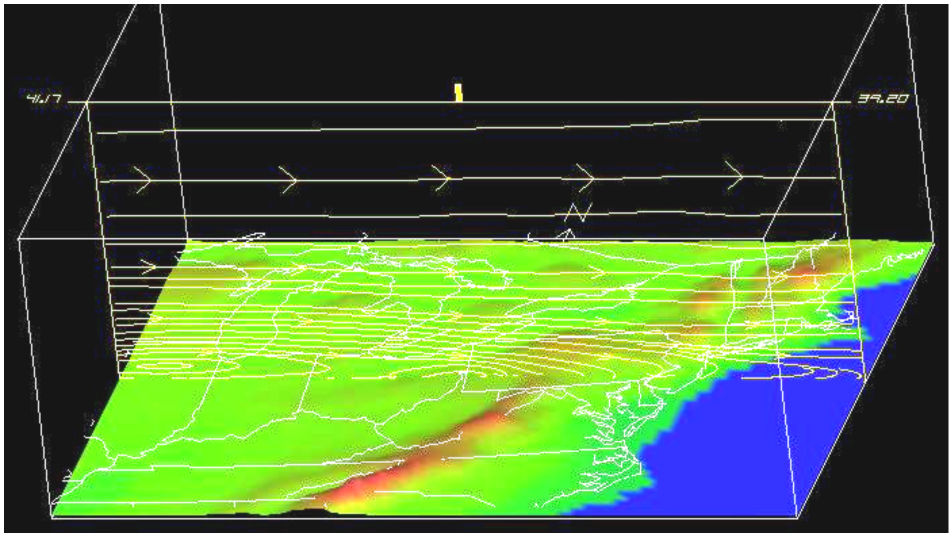


Category-day 1

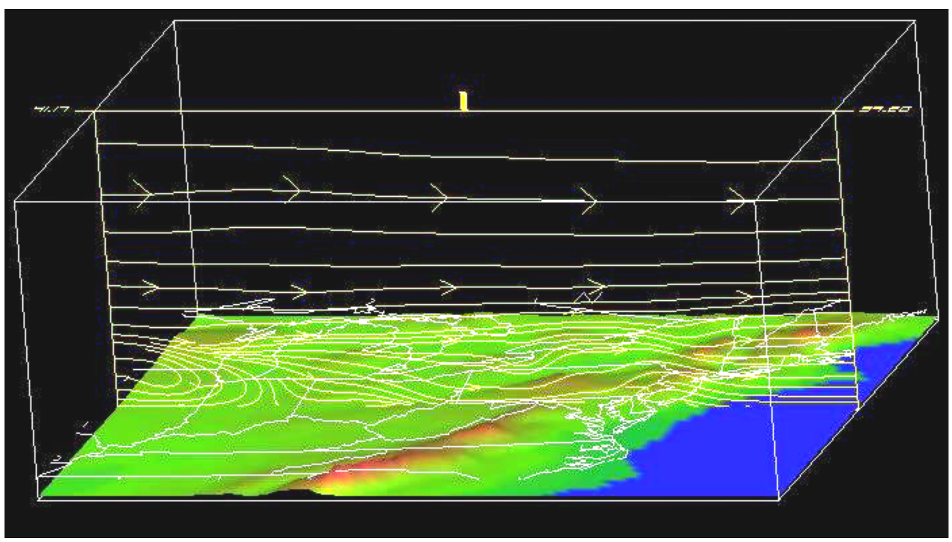


Category-day 2

Figure 4-16: Vertical wind fields for Category-days C1 and C2.

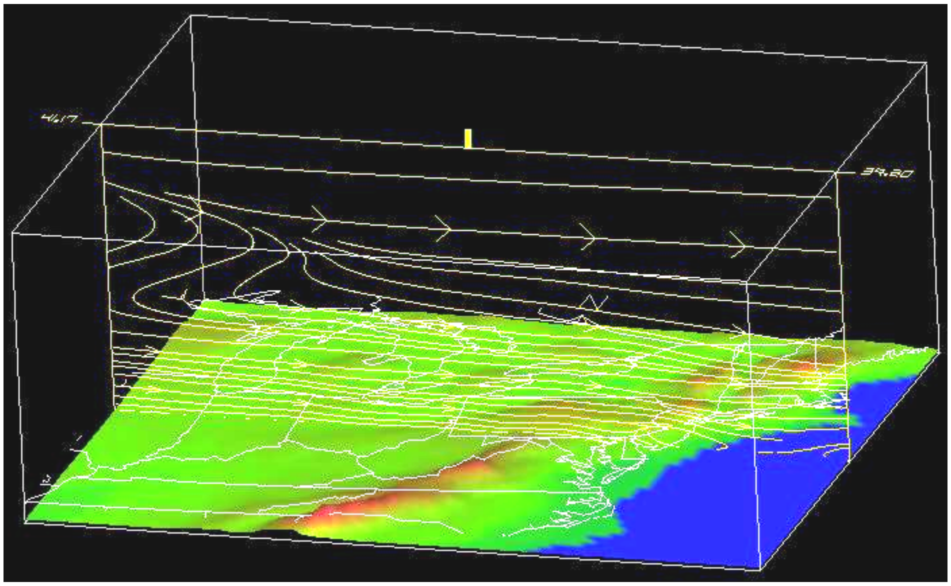


Category-day 3

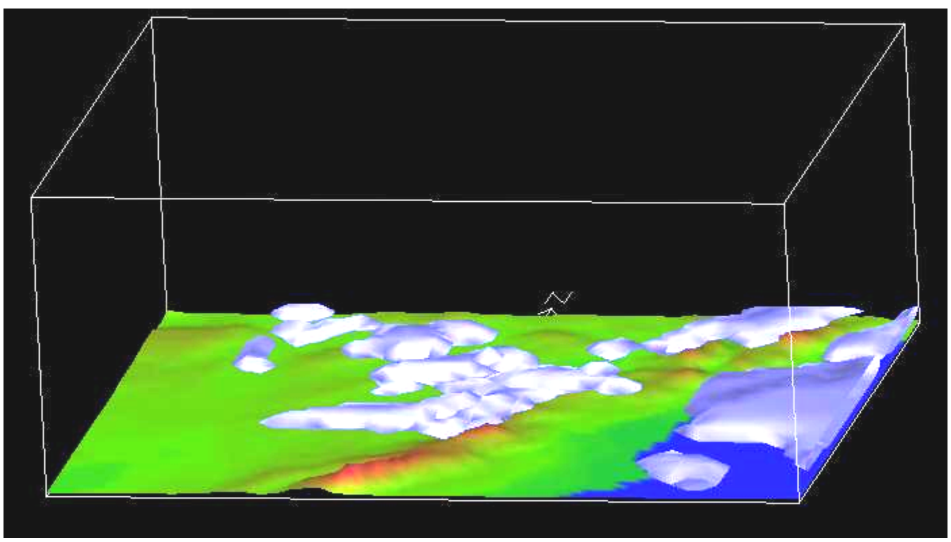


Category-day 4

Figure 4-17: Vertical wind fields for Category-days C3 and C4.



Category-day 5



Category 1: Only category simulated with clouds

Figure 4-18: Vertical wind fields (C5) and cloud distribution for Category-day C1.

Temperature and Mixing heights

Table IV.20 summarizes the meteorological parameters observed during each category-day at McGhee-Tyson Airport located in Blount County. From Table IV.20 we see that low wind speed and high temperature are the principal meteorological parameters required to generate local ozone concentrations (C5 is maximum 8-hr ozone concentrations >= 85 ppb).

Figures 4-19 to 4-21 present tile maps of temperature distribution in the modeling domain for each category day, and Figure 4-22 shows the PBL development for Category-day 3.

Finally, Figure 4-23 helps us understand why Category-day 4 presents such an irregular profile during the early morning. One possible explanation is through mechanical rather than thermal mixing. During late afternoon of August 11, until 05:00 AM August 12 (local time), a strong downward wind produced a mix of upper high-level ozone concentrations with lower layers near the surface. This phenomenon was not observed in other simulated days. Category 5 is shown as an example of typical day wind behavior.

Table IV.20 Meteorological parameters for category-day: McGhee Tyson Airport

Category	**Day**	**Tmx** (ºC)	**Tmi** (ºC)	**Ta** (ºC)	**Dpt** (ºC)	**RH** (%)	**Wind** (m/s)
C1	Thu-Oct-22	13	4	9	1	59	5.4
C2	Wed-Apr-22	13	9	11	9	92	2.8
C3	Wed-Sep-23	27	18	22	13	60	3.8
C4	Wed-Aug-12	31	19	25	20	78	1.4
C5	Fri-Sep-18	33	22	27	18	61	1.7

Tmx : Daily maximum temperature
Tmi : Daily minimum temperature
Ta : Daily average temperature
Dpt : Dew point temperature
R : Daily average relative humidity

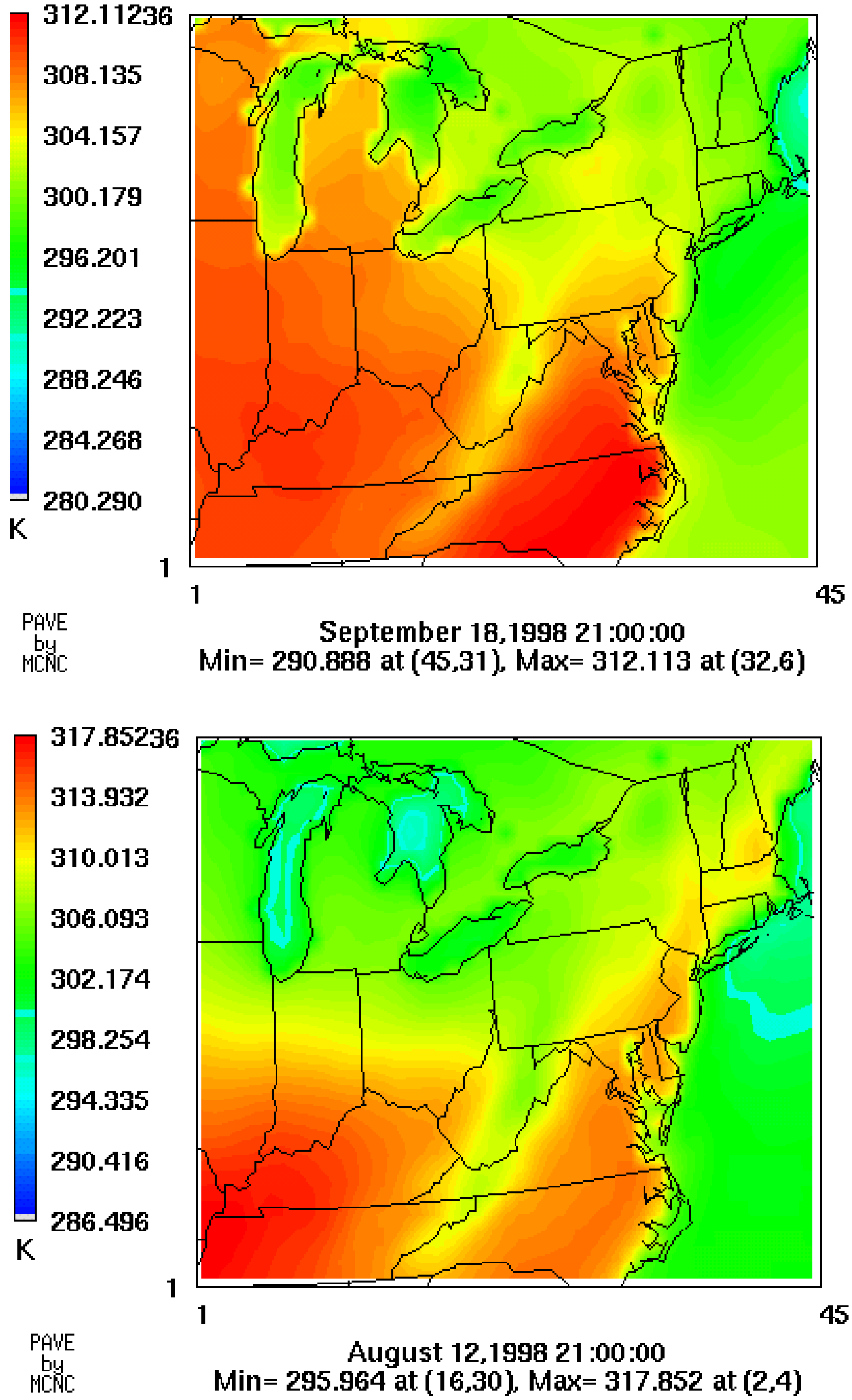


Figure 4-19: Temperature distribution for Category-days C5 and C4.

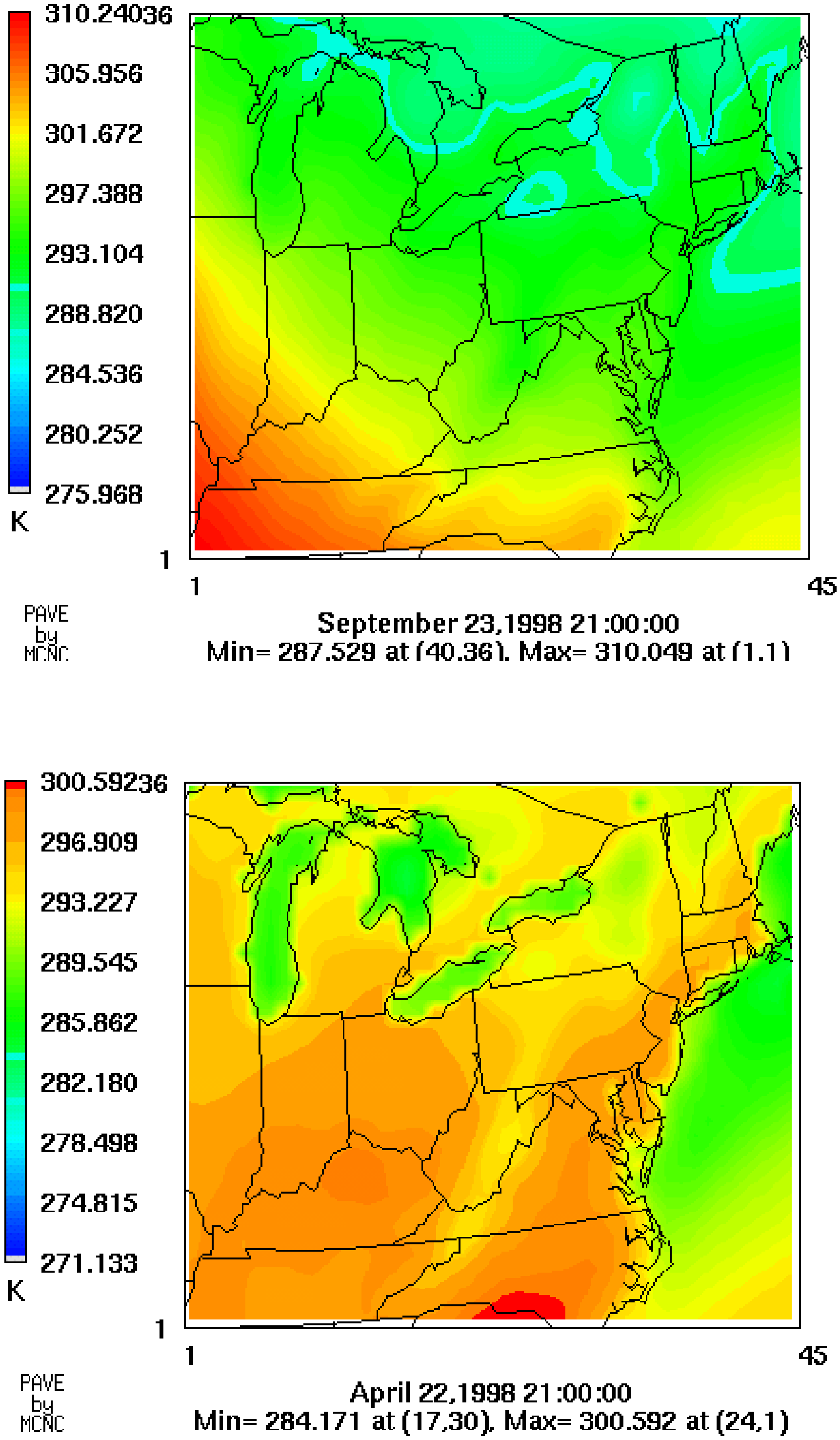


Figure 4-20: Temperature distribution for Category-days C3 and C2.

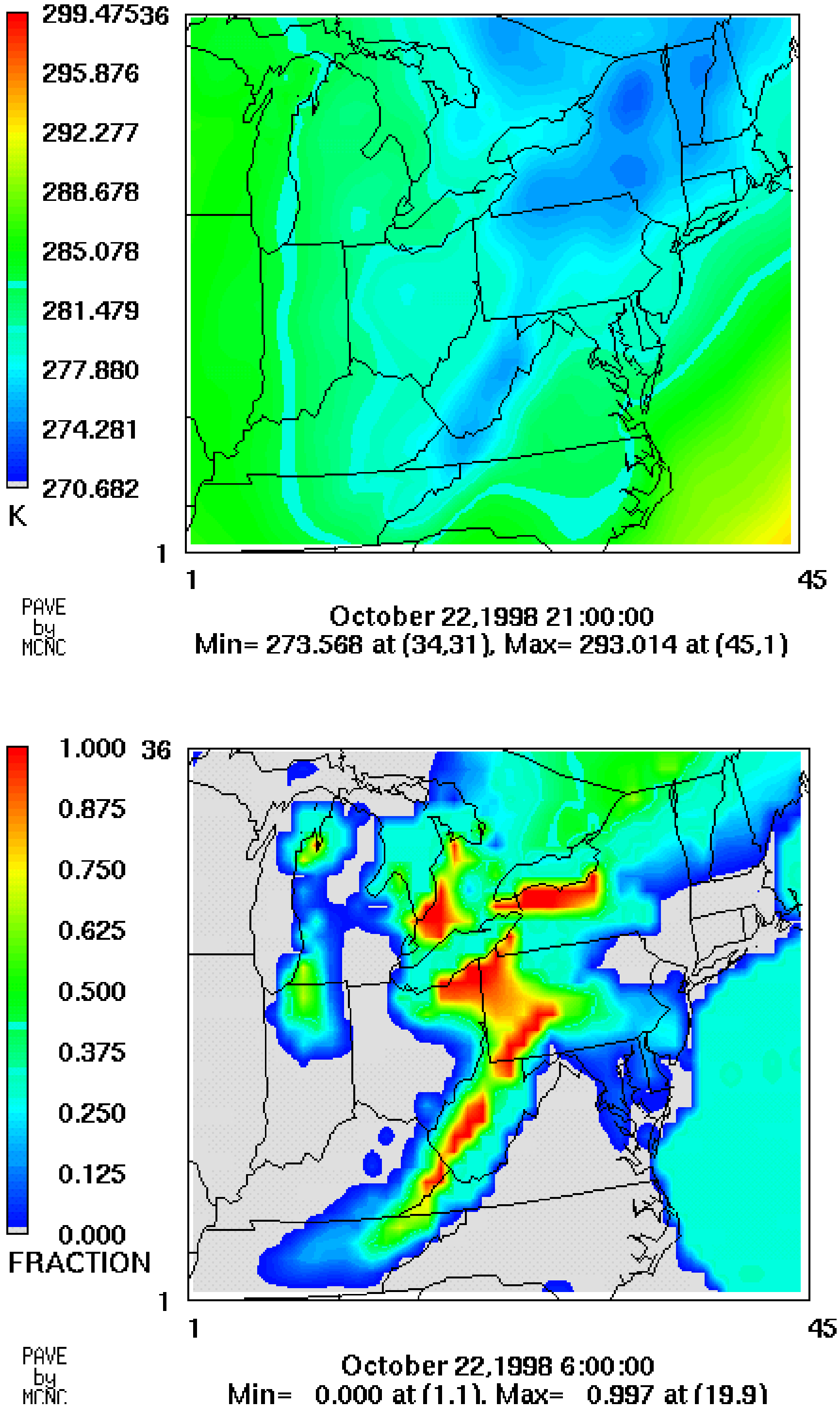


Figure 4-21: Temperature distribution for Category-day C1 and cloud fraction for Category-day C1.

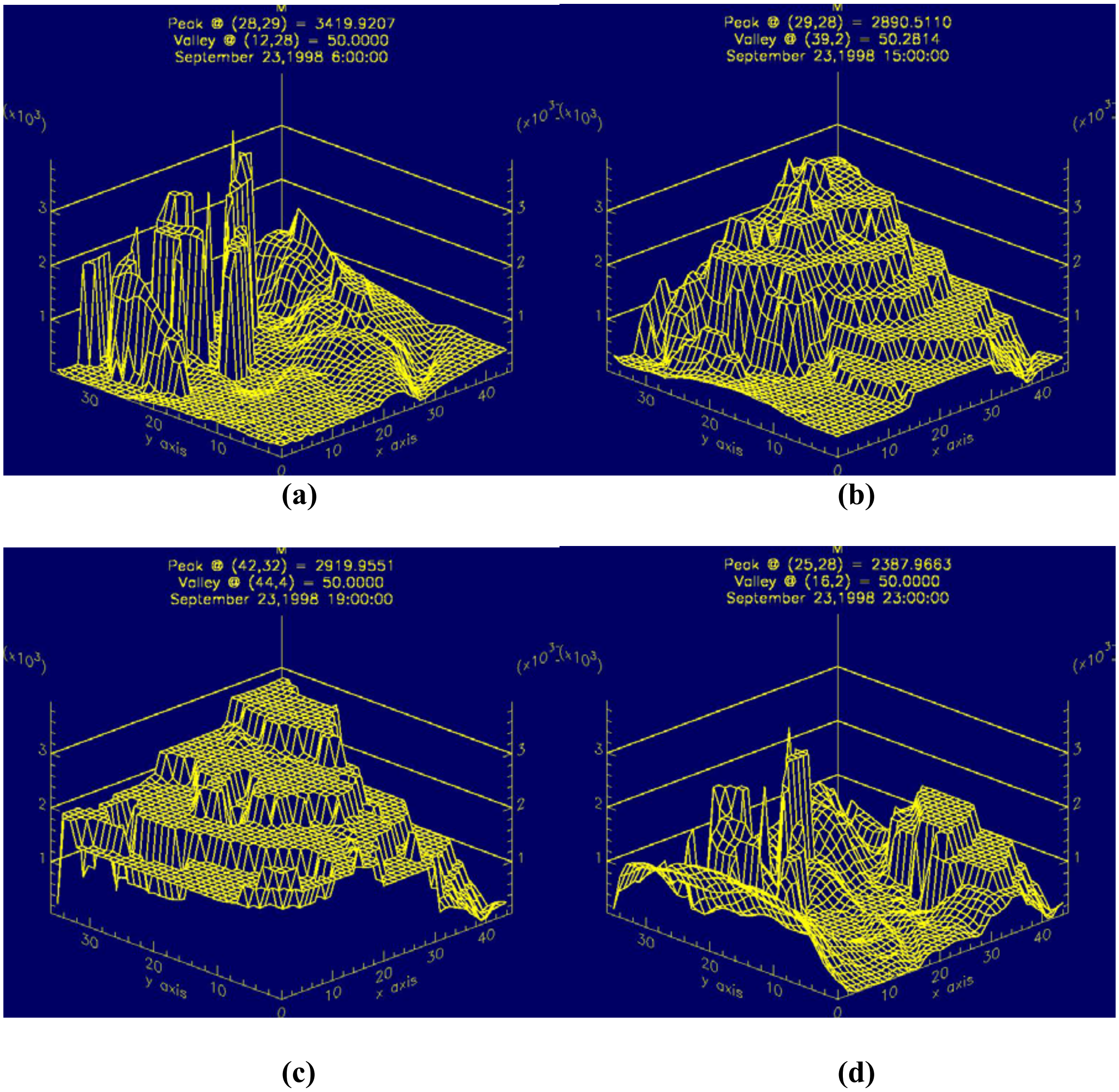
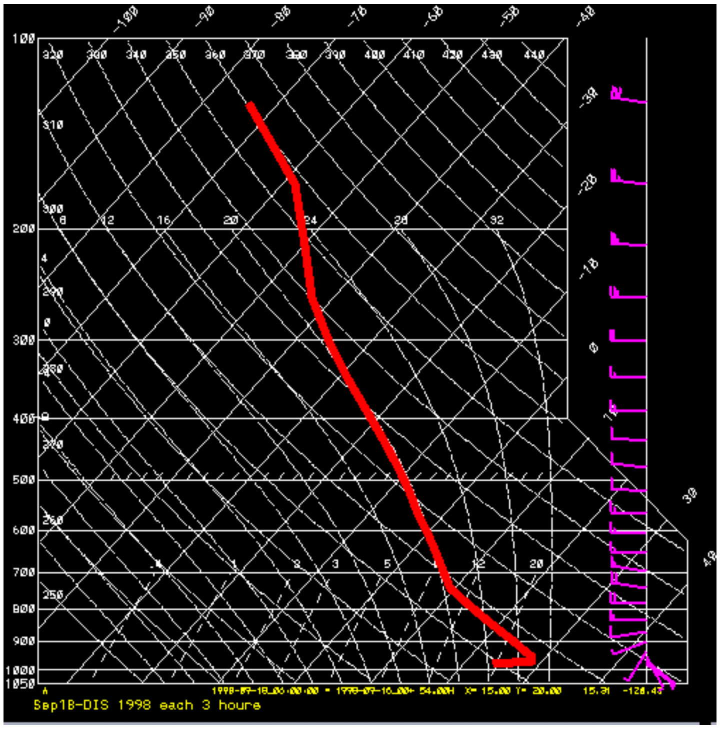
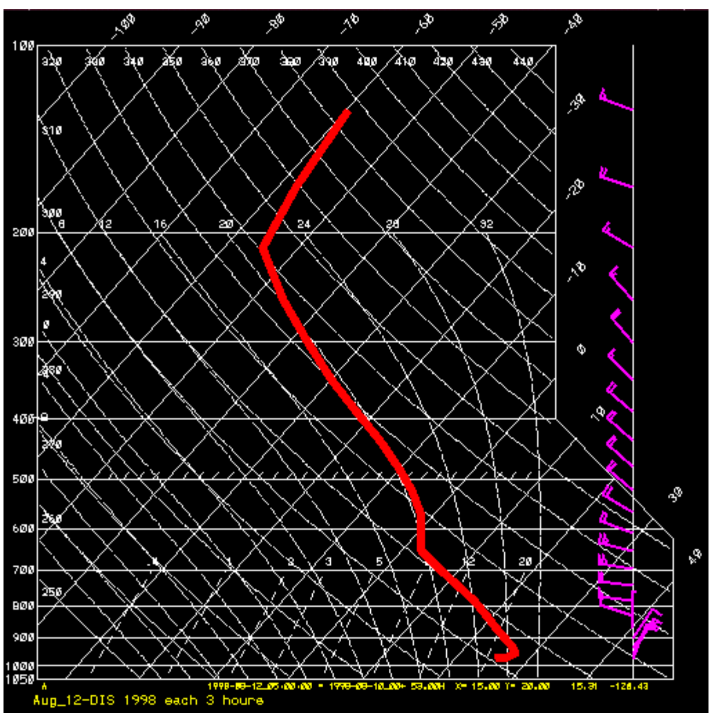


Figure 4-22: PBL development (a) 01:00 hr (b) 10:00 hr (c) 14:00 hr (d) 18:00 hr: Category-day C3 (September 23 1998).



Category-day 5



Category-day 4

Figure 4-23: SkewT-logP diagram for Category-days C5 and C4.

4.4.4 Emissions

As was explained before, the EPA 1995 emission inventory was used in the simulation, with SMOKE as the processor for gridding, area, mobile, point, and biogenic emission in the modeling domain. The ozone-day option was used, as this work focuses on ozone season estimates. Figures 4-24 to 4-27 show the NO, Isoprene, CO, and Toluene emission distribution in moles/s, in the modeling domain, respectively. Only Category 1 shows all days presenting a similar pattern.

Analysis of the emissions for each category-day in Knox County shows clearly that NOx emissions are fairly constant during the ozone season, but the Isoprene emissions vary according to each month during the ozone season, being higher during the days of strong solar radiation (see Figures 4-28 and 4-29).

Table IV.21 presents a summary of the relative importance of ozone precursors by source in East Tennessee.

Table IV.21 Emission distribution (%) by source in East Tennessee

Source	NO	ISOP	CO
Area	11.96	0.01	29.48
Biogenic	2.57	99.97	0.00
Mobile	18.13	0.01	68.03
Point	67.34	0.01	2.49

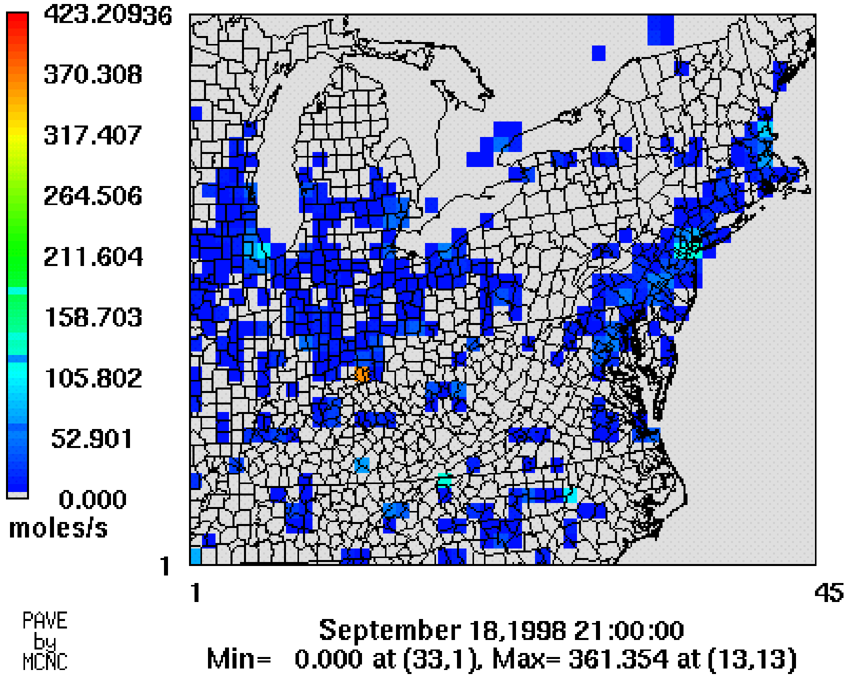


Figure 4-24: NOx emissions (moles/s) tile plot: Category-day C1.

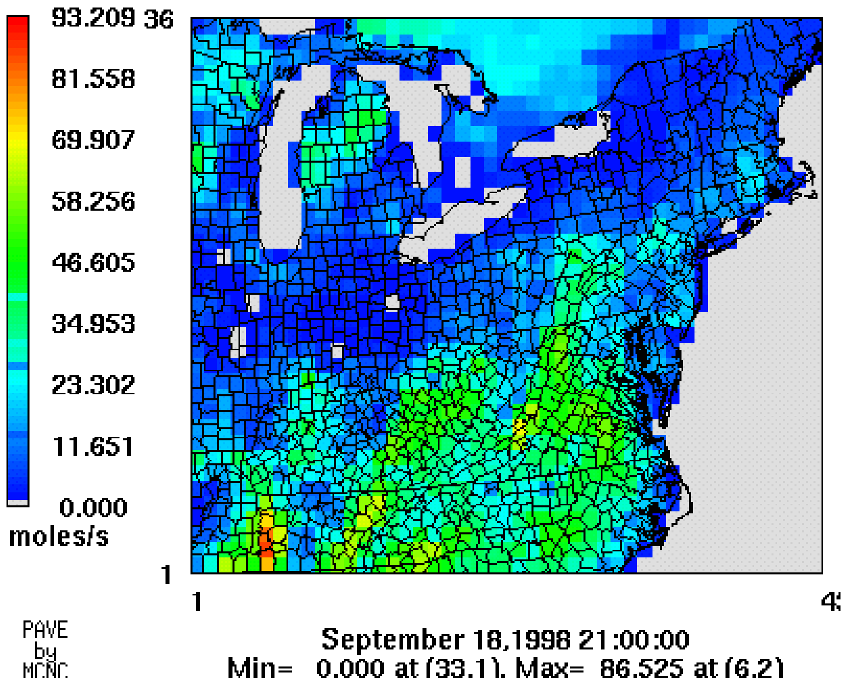


Figure 4-25: Isoprene emissions (moles/s) tile plot: Category–day C1.

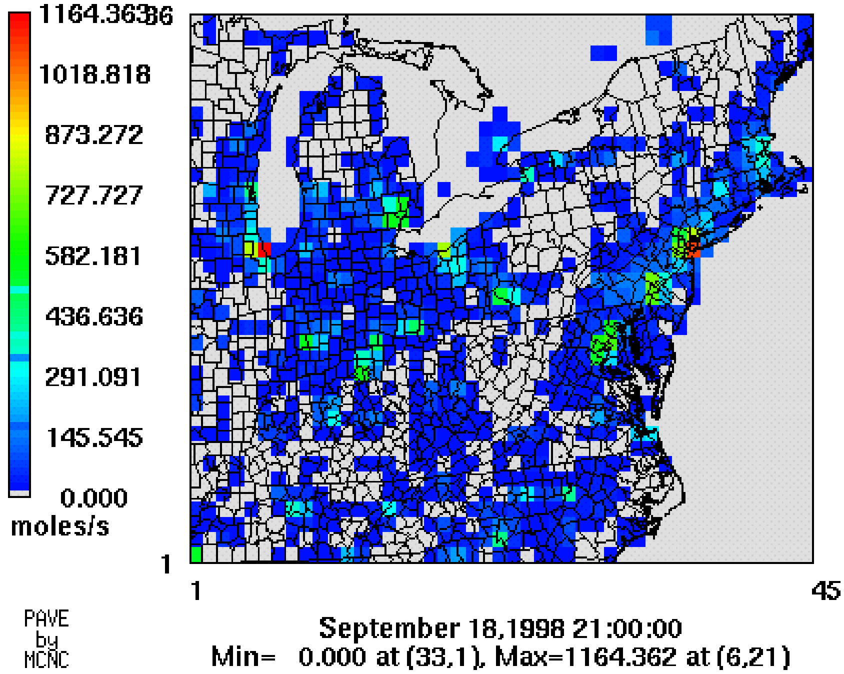


Figure 4-26: CO emissions (moles/s) tile plot: Category-day C1.

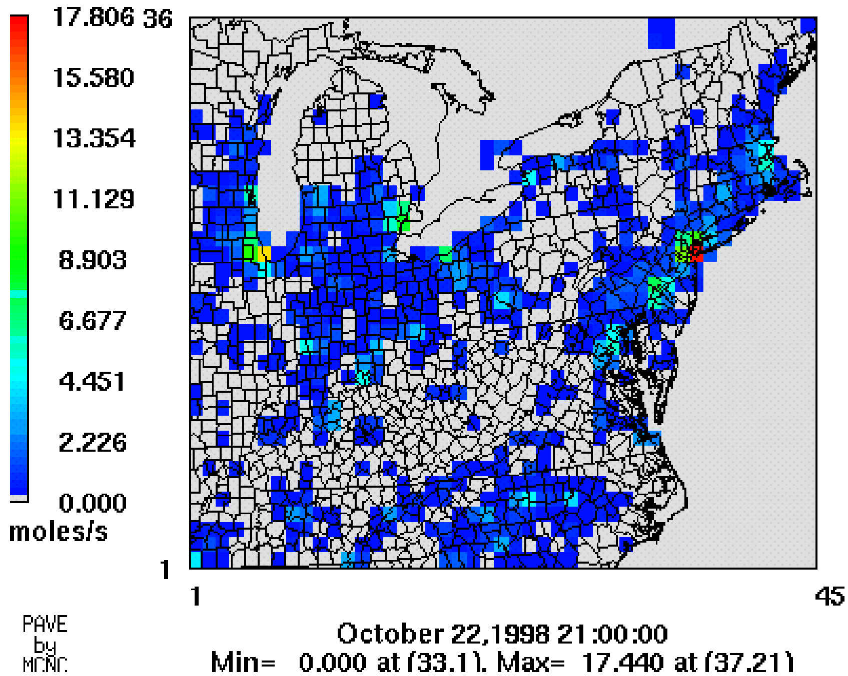


Figure 4-27: Toluene emissions (moles/s) tile plot: Category-day C1.

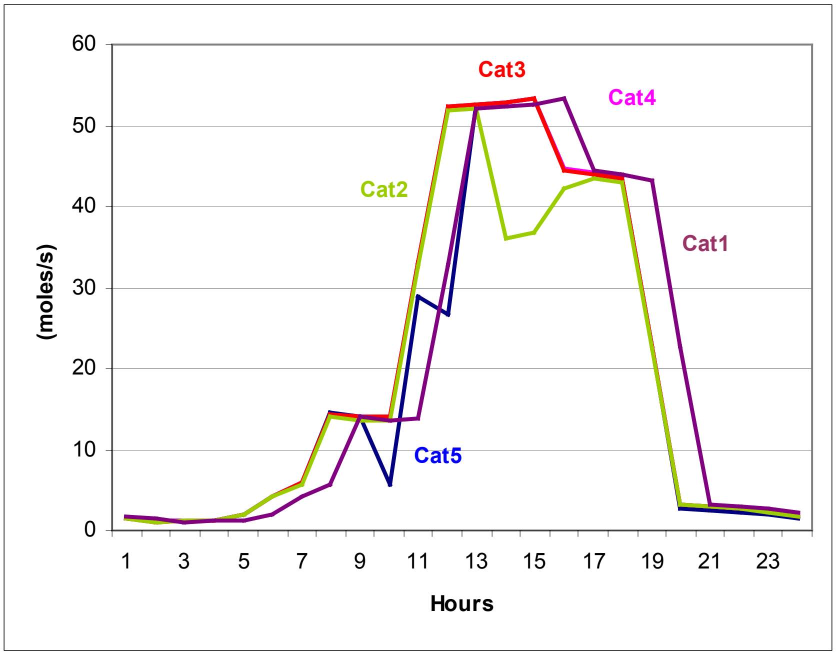


Figure 4-28: NOx emissions: hourly distribution in Knox County by Category-days.

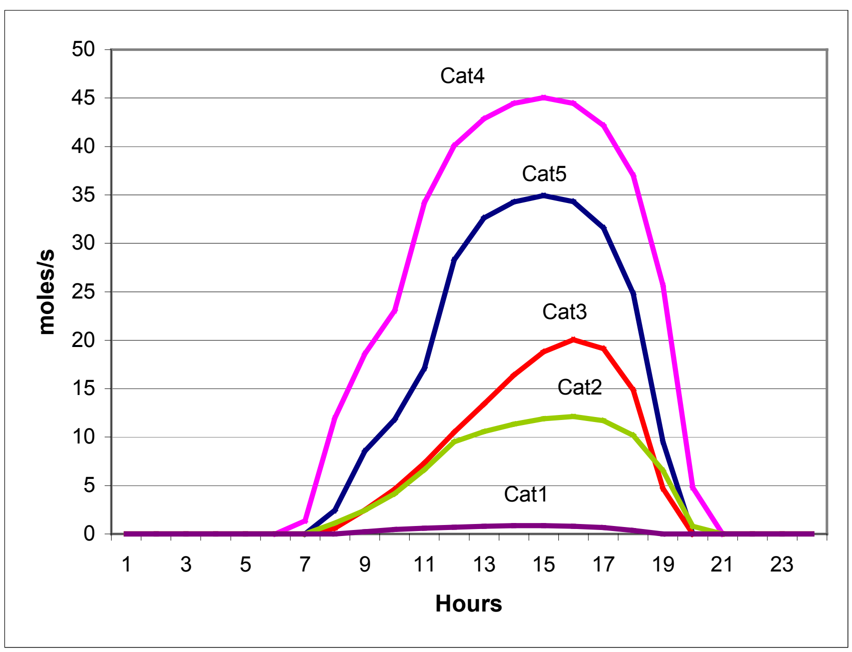


Figure 4-29: Isoprene emissions: hourly distribution in Knox County by Category-days.

4.5 Ozone concentrations by emission scenario

Once Models-3/CMAQ performed according to the criteria for regulatory purposes for each representative day, new runs were conducted but now simulating ozone exposure under different NOx emission reduction scenarios. Basically, each category day was run four times: (1) base case, (2) mobile source NOx emission control (50% reduction), (3) major point sources NOx emission control (70%), and (4) Scenarios 2) and 3) simultaneously.

One of the best ways to visualize the ozone model results is through color contour plots or tile plots, which show the predicted concentrations in each of the model cells as a color on a map. Figures 4-30 to 4-34 show the tile plots of ozone distribution at 5 p.m. for the entire modeling domain, for each category-day. Each figure shows the base-case and the difference between the base-case and emission-scenario. The difference-maps show that even when NOx emissions are reduced, many cells will experience an increase in the ozone levels because of the complicated photochemical mechanism that requires NOx for formation and scavenging of ozone. The direction of the reaction will depend on the concentrations of ozone and its precursors.

Another item of information that can be extracted from the figures is that a combination of mobile and point emission reduction produces a better reduction (synergism) as compared with any of the measures by itself.

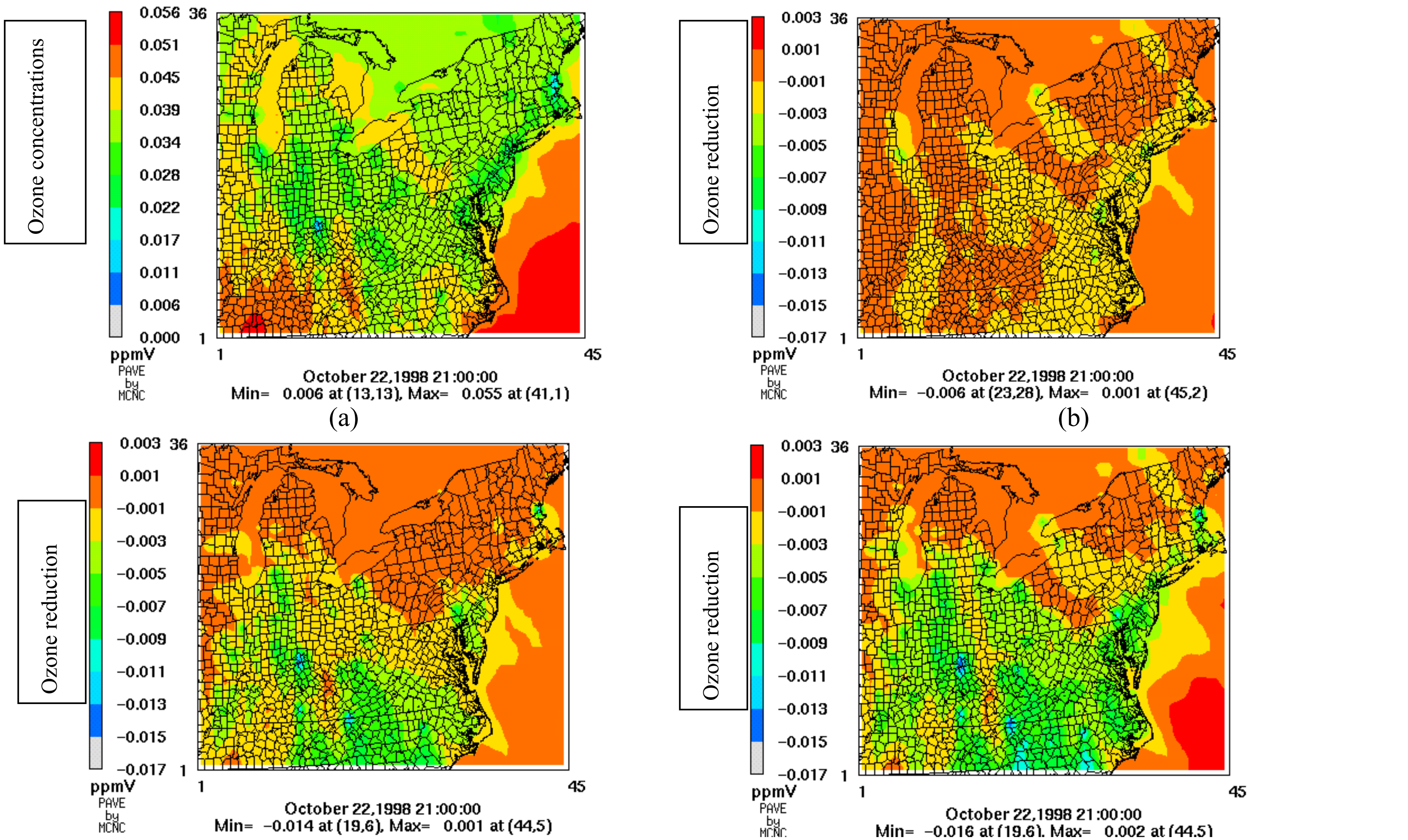


Figure 4-30: Ozone distribution Category-day C1: a) Base b) Base-Esc_Mobil c) Base-Esc_Point d) Base-Esc_M+P.

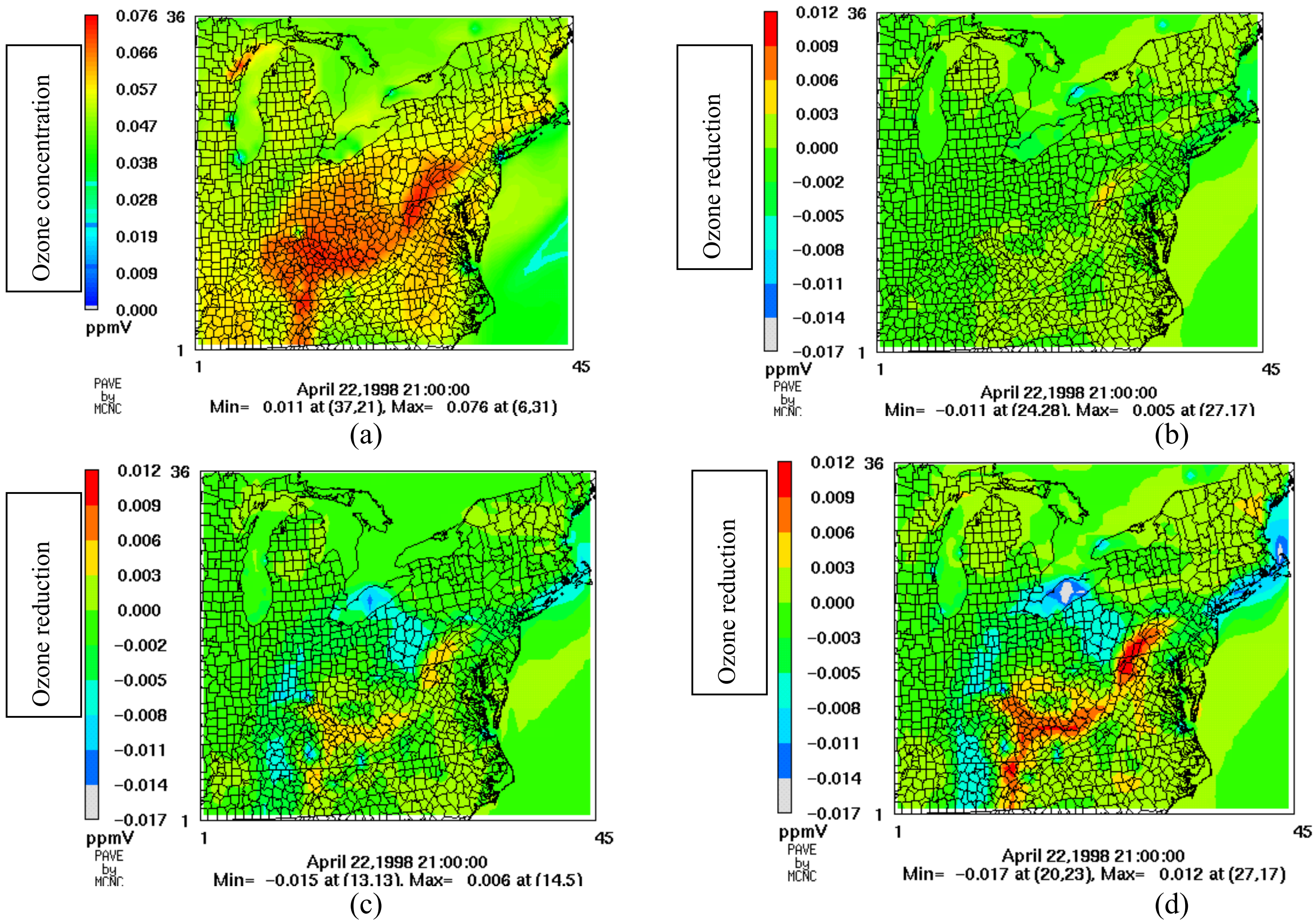


Figure 4-31: Ozone distribution Category-day C2: a) Base b) Base-Esc_Mobil c) Base-Esc_Point d) Base-Esc_M+P.

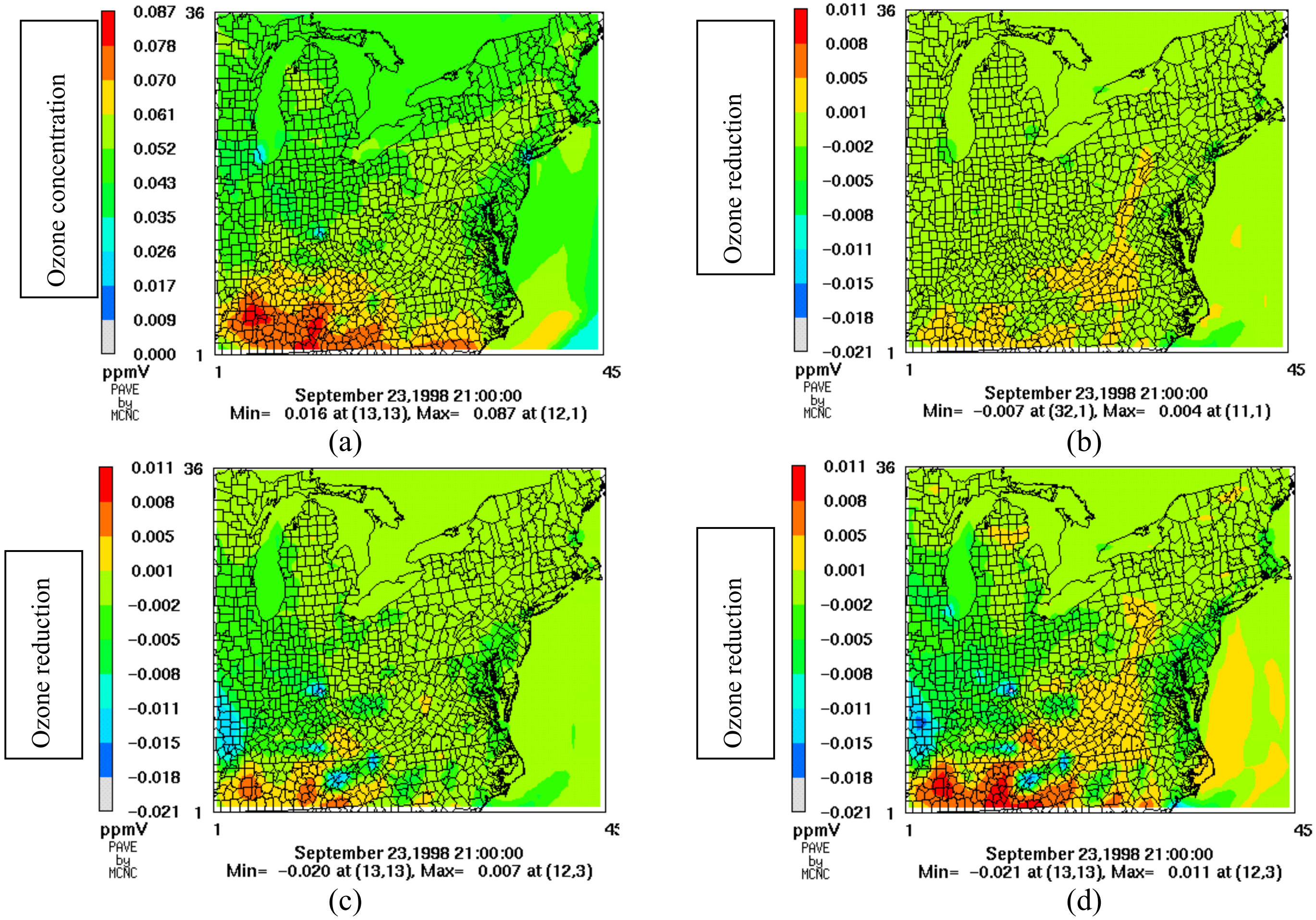


Figure 4-32: Ozone distribution Category-day C3: a) Base b) Base-Esc_Mobil c) Base-Esc_Point d) Base-Esc_M+P.

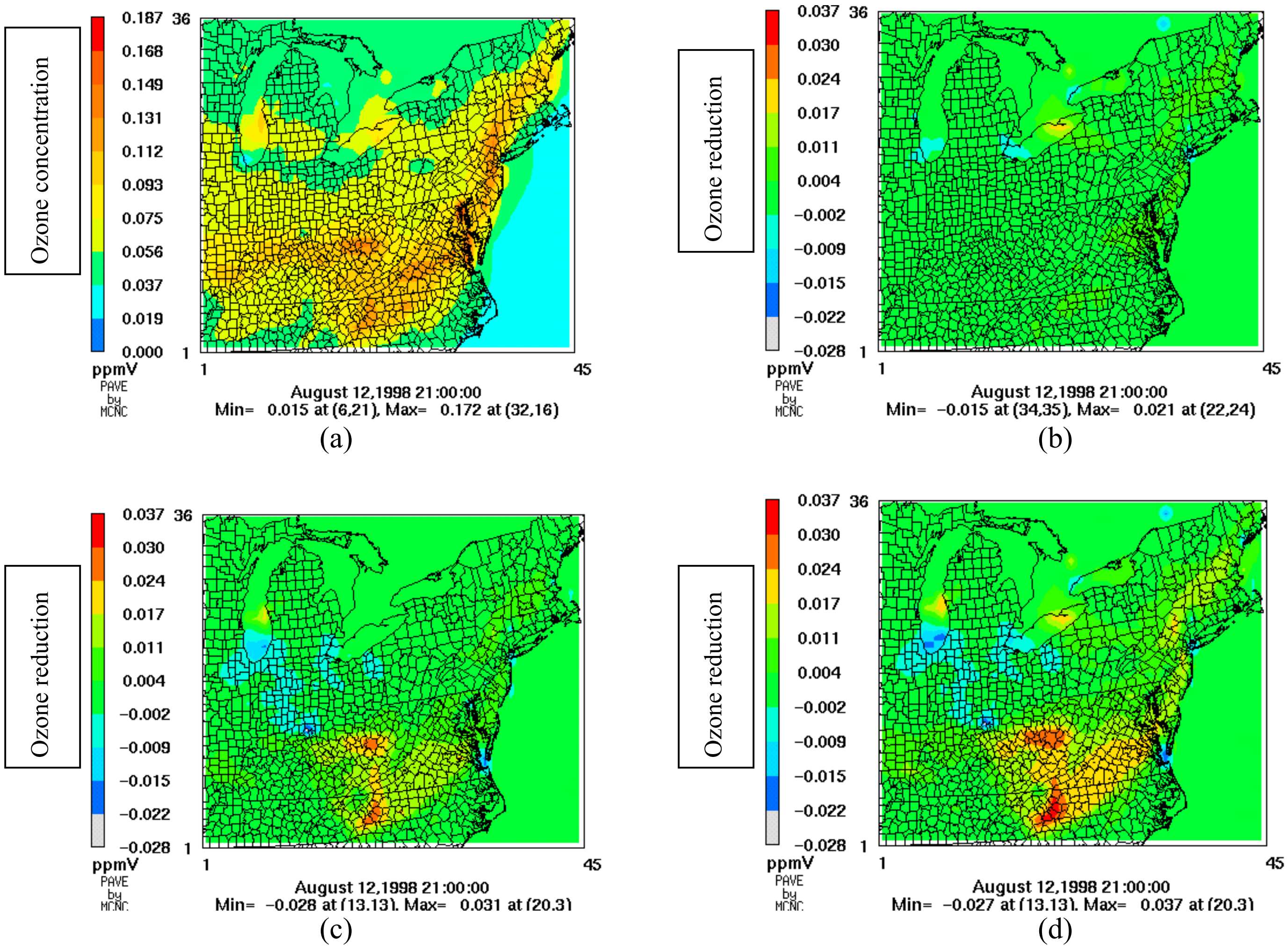


Figure 4-33: Ozone distribution Category-day C4: a) Base b) Base-Esc_Mobil c) Base-Esc_Point d) Base-Esc_M+P.

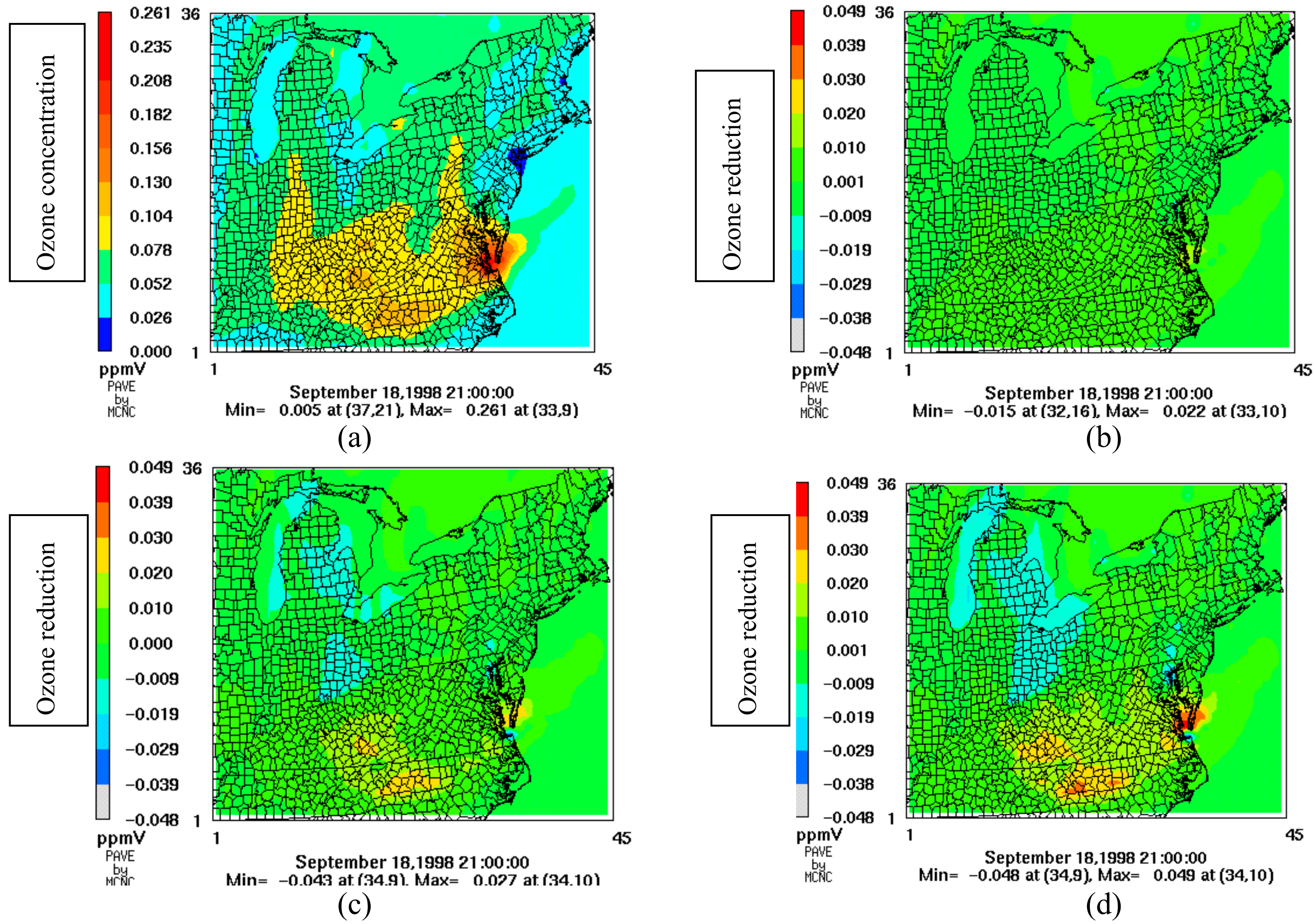


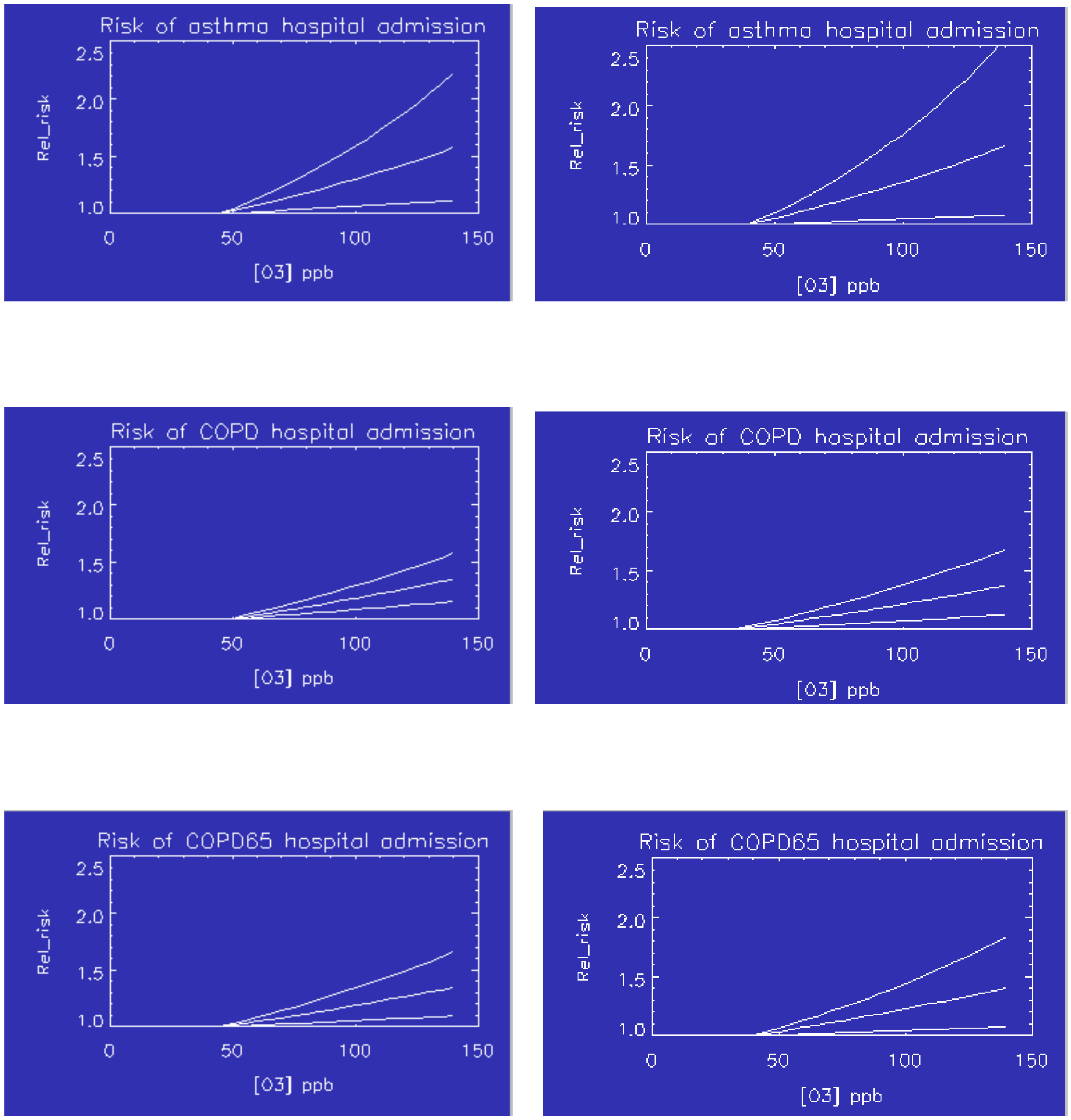
Figure 4-34: Ozone distribution Category-day C5: a) Base b) Base-Esc_Mobil c) Base-Esc_Point d) Base-Esc_M+P.

4.6 Health effects by emission scenario

After running Models-3/CMAQ for each category-day and emission-scenario, Pre_ORAM was run to calculate the ozone metric by county in East Tennessee. With the output file generated by Pre_ORAM, ORAM model was run and the number of hospital admissions and the cost associated, by respiratory impairment, for each emission scenario was calculated.

Figure 4-35 shows the relative risk for hospital admissions using the epidemiological parameters obtained for Knoxville (Reed et al 2000, Sanhueza et al 2002). This indicator measures the chance of going to the hospital as the exposure ozone level goes above the threshold, for each respiratory disease. The figure also shows the uncertainty of this relationship by using the 5% and 95% percentile for the parameter estimation. This uncertainty in the ozone-effect relationship was considered in the hospital admission calculation and also in the Monte Carlo simulation analysis (see section 4.9).

For each emission scenario, ORAM produces a large output file that includes ozone-season admissions and costs, by disease, and by county in East Tennessee. It also generates a summary table with the result for the entire region. Table IV.22 presents the summary of the hospital admissions for the region, due to each scenario for maximum 1-hr ozone exposure and Table IV.23 the same information for 8-hr. Figure 4-36 shows a pie chart of the respiratory admissions in East Tennessee for each ozone metric exposure, and Figure 4-37 the error graph for total admission by disease and ozone metric.



(a) (b)

Figure 4-35: Relative risk of hospital admissions due to ozone (a) 1-hr (b) 8-hr. Output from ORAM.

Table IV.22 Total expected respiratory admissions for maximum 1-hr ozone exposure by emission-scenario in East Tennessee – ozone season

Disease	Expected	5%	95%	%P_avg	%P_5%	%P_95%
	Scenario BASE					
Asthma	1103	249	2084	0.068	0.015	0.128
Copd	4595	2160	7181	0.282	0.133	0.441
Copd65	2889	858	5093	0.982	0.292	1.731
Doctor_visits	14560	3281	27510	0.894	0.201	1.689
	Scenario MOBIL (50%)					
Asthma	1028	233	1935	0.063	0.014	0.119
Copd	4252	2002	6633	0.261	0.123	0.407
Copd65	2698	803	4745	0.917	0.273	1.613
Doctor_visits	13574	3070	25543	0.833	0.188	1.568
	Scenario POINT (70%)					
Asthma	1042	238	1942	0.064	0.015	0.119
Copd	4277	2022	6646	0.263	0.124	0.408
Copd65	2762	826	4833	0.939	0.281	1.643
Doctor_visits	13750	3136	25640	0.844	0.192	1.574
	Scenario MOBILE + POINT					
Asthma	921	211	1707	0.057	0.013	0.105
Copd	3722	1764	5768	0.228	0.108	0.354
Copd65	2450	735	4273	0.833	0.250	1.453
Doctor_visits	12157	2789	22536	0.746	0.171	1.383

Table IV.23 Total expected respiratory admissions for maximum 8-hr ozone exposure by emission-scenario in East Tennessee – ozone season

Disease	Expected	5%	95%	%P_avg	%P_5%	%P_95%
	Scenario BASE					
Asthma	1166	162	2339	0.072	0.010	0.144
Copd	5625	2007	9524	0.345	0.123	0.585
Copd65	3096	644	5792	1.052	0.219	1.969
Doctor_visits	15385	2143	30881	0.944	0.132	1.895
	Scenario MOBIL (50%)					
Asthma	1098	154	2193	0.067	0.009	0.135
Copd	5366	1919	9066	0.239	0.118	0.556
Copd65	2921	610	5448	0.993	0.207	1.852
Doctor_visits	14493	2028	28942	0.890	0.125	1.776
	Scenario POINT (70%)					
Asthma	1125	159	2226	0.069	0.010	0.137
Copd	5548	1990	9344	0.341	0.122	0.574
Copd65	3023	634	5610	1.028	0.215	1.907
Doctor_visits	14849	2095	29382	0.911	0.129	1.803
	Scenario MOBILE + POINT					
Asthma	1016	144	1996	0.062	0.009	0.123
Copd	5116	1840	8591	0.314	0.113	0.527
Copd65	2738	576	5061	0.931	0.196	1.721
Doctor_visits	13408	1904	26351	0.823	0.117	1.617

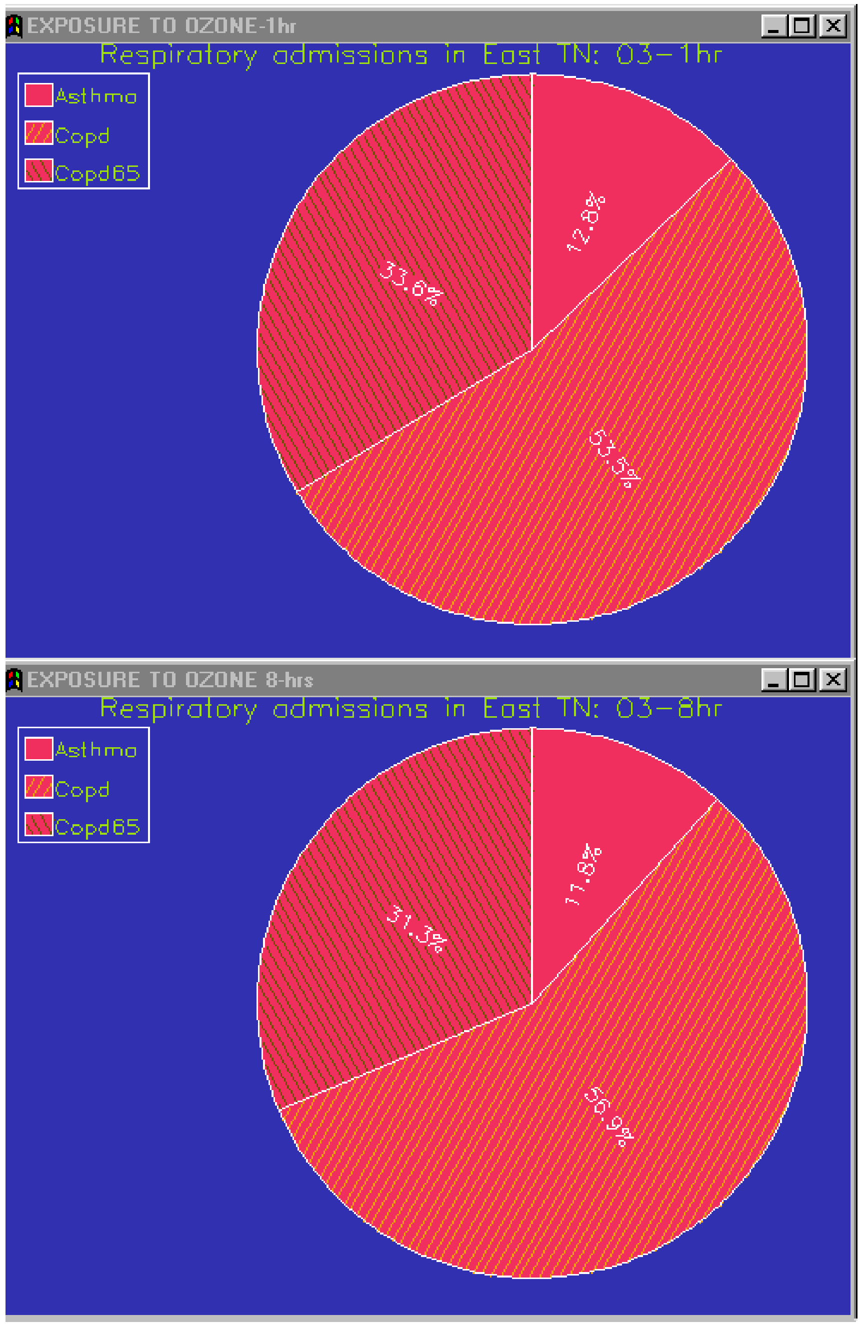


Figure 4-36: Respiratory admission in East Tennessee for maximum 1-hr and 8-hr ozone exposure. Output from ORAM.

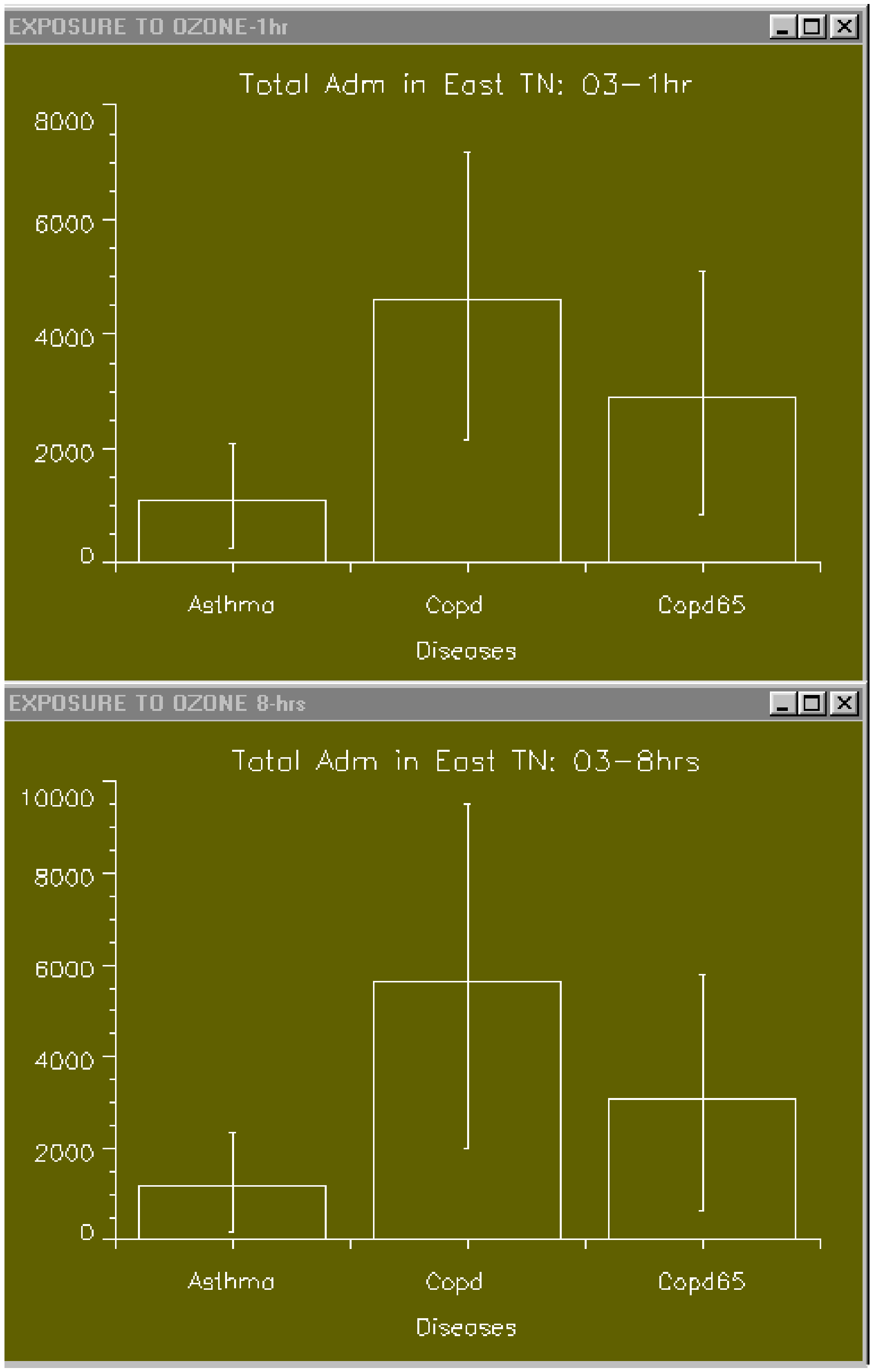


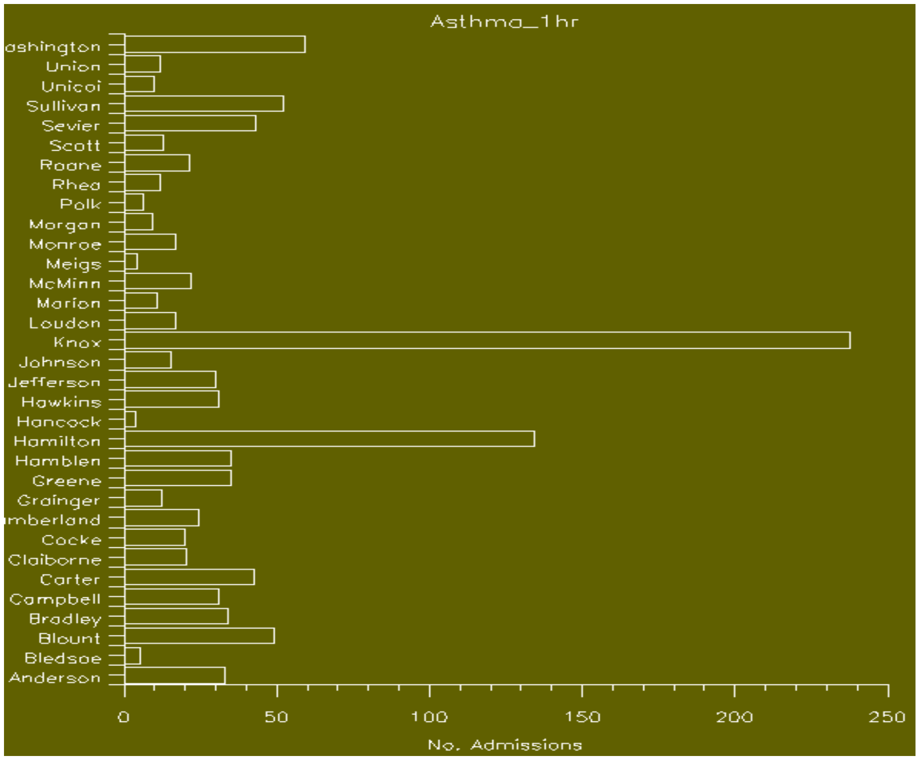
Figure 4-37: Error graph for respiratory admissions in East Tennessee by ozone exposure. Output from ORAM.

Admissions by County

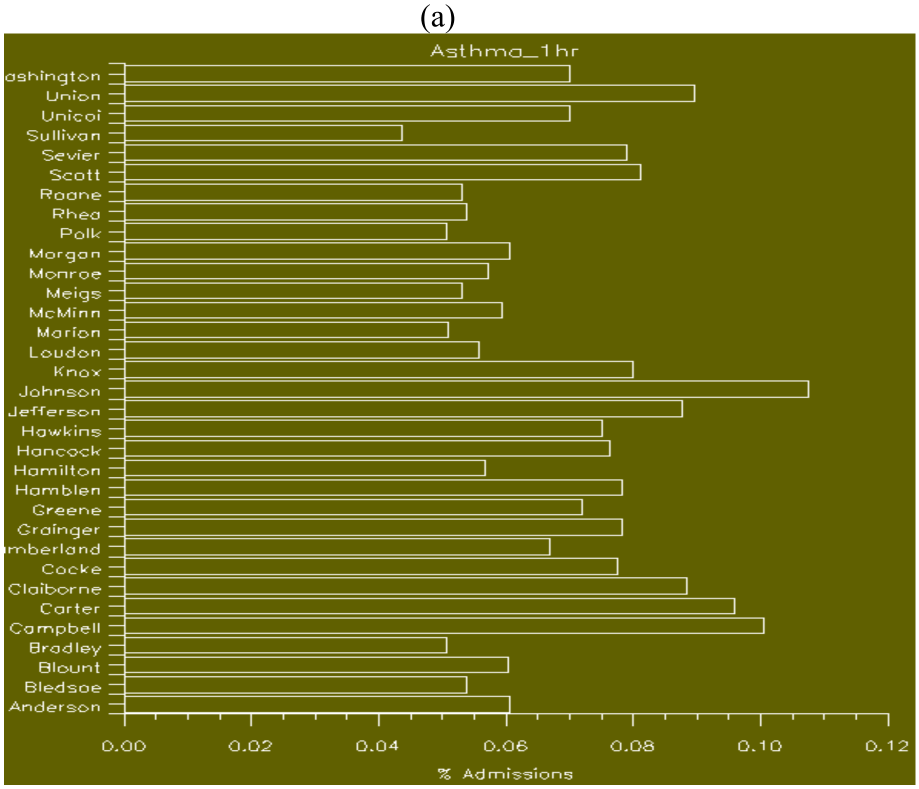
Given the amount of data generated by the ORAM model (4 health endpoints, 2 ozone metrics, 4 scenarios), for explanatory purposes, only the asthma results will be presented here, but Appendices A through D present all the information in detail. These appendices show the expected number of respiratory admissions and the standard error obtained through the uncertainty in the ozone-effect relationship using error propagation. Also, the proportion of the admission to the target population by county is presented. All the results are presented for ozone maximum 1-hr and 8-hr for the base case and the three emission scenarios.

Figure 4-38 shows a graph of the asthma admission distribution by county in East Tennessee and the value normalized by the target population (>=20 years) due to ozone maximum 1-hr exposure during the ozone season. Even though Knox County presents the greater number of asthma admissions due to ozone exposure, it is Johnson County that shows the greater impact in terms of percentage of population affected by ozone exposure. The impact on East Tennessee varies from 0.04% to 0.11% for ozone maximum 1-hr exposure.

Figures 4-39 to 4-41 show the spatial distribution of the number of respiratory disease admission by county in East Tennessee due to exposure of ground-level ozone maximum 1-hr. Figure 4-42 shows the respiratory admission distribution in East Tennessee for ozone maximum 1-hr exposure.

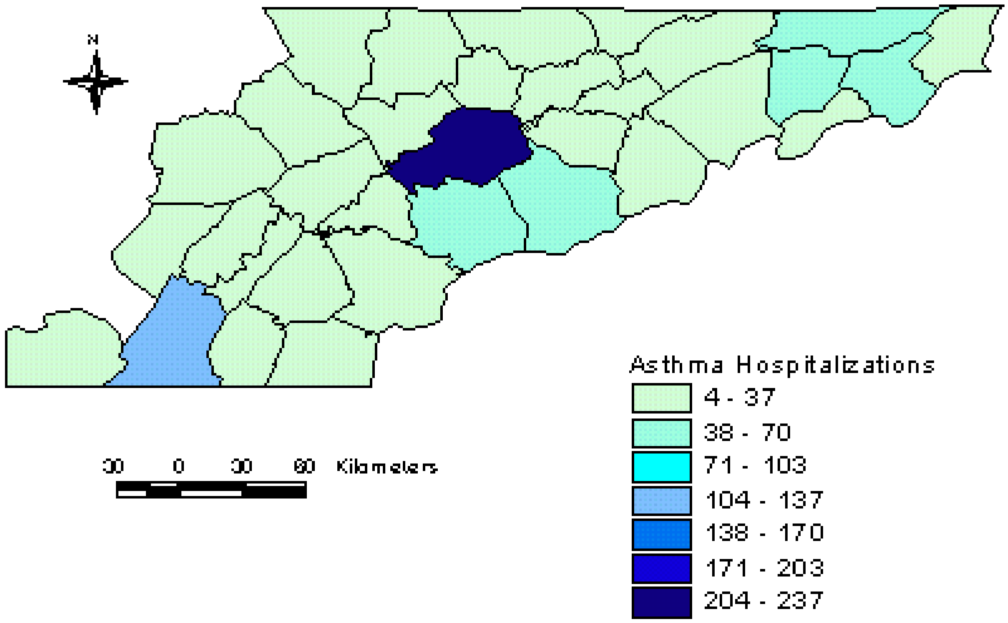


(a)

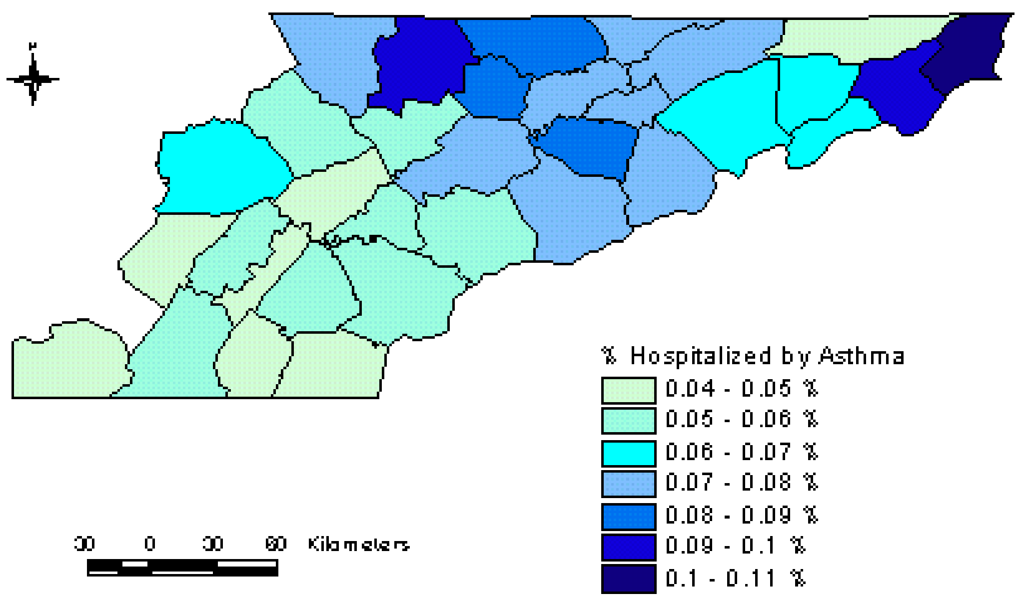


(b)

Figure 4-38: Asthma admission by county in East Tennessee (a) absolute value (b) normalized by population. Output from ORAM.

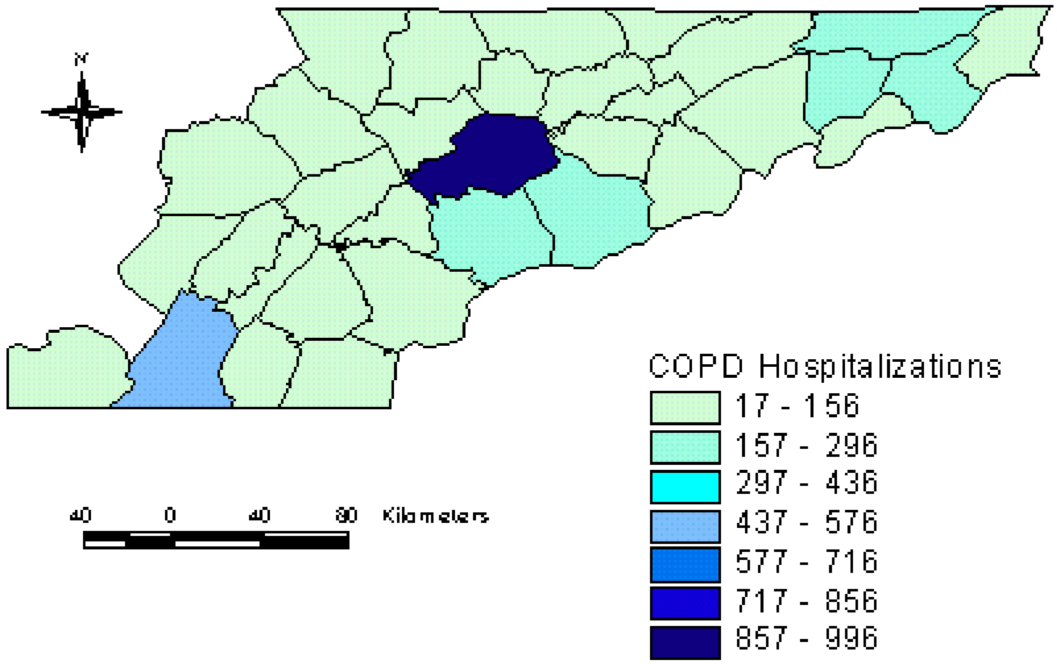


(a)

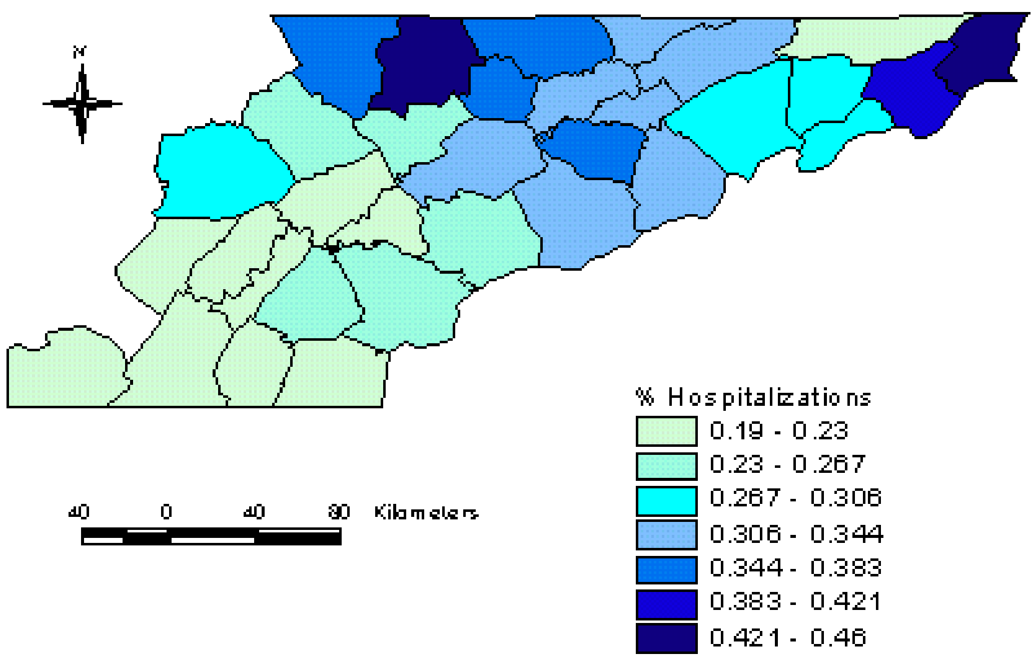


(b)

Figure 4-39: Asthma admission distribution in East Tennessee due to ozone max 1-hr exposure (a) Total (b) Percent of population hospitalized due to asthma (normalized by county population).

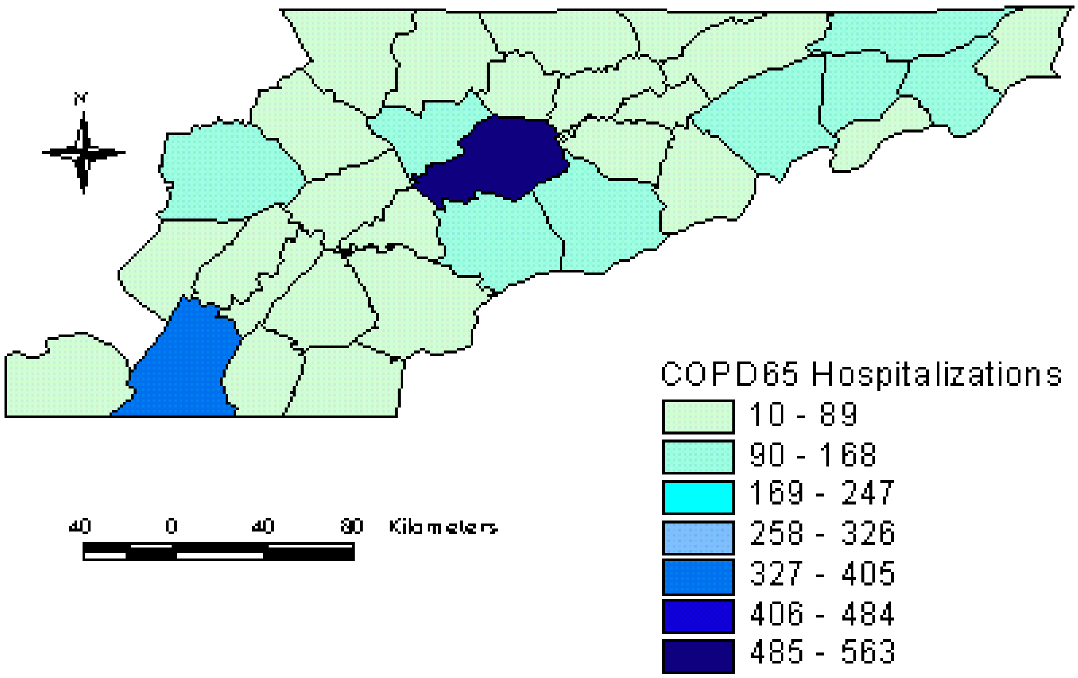


(a)

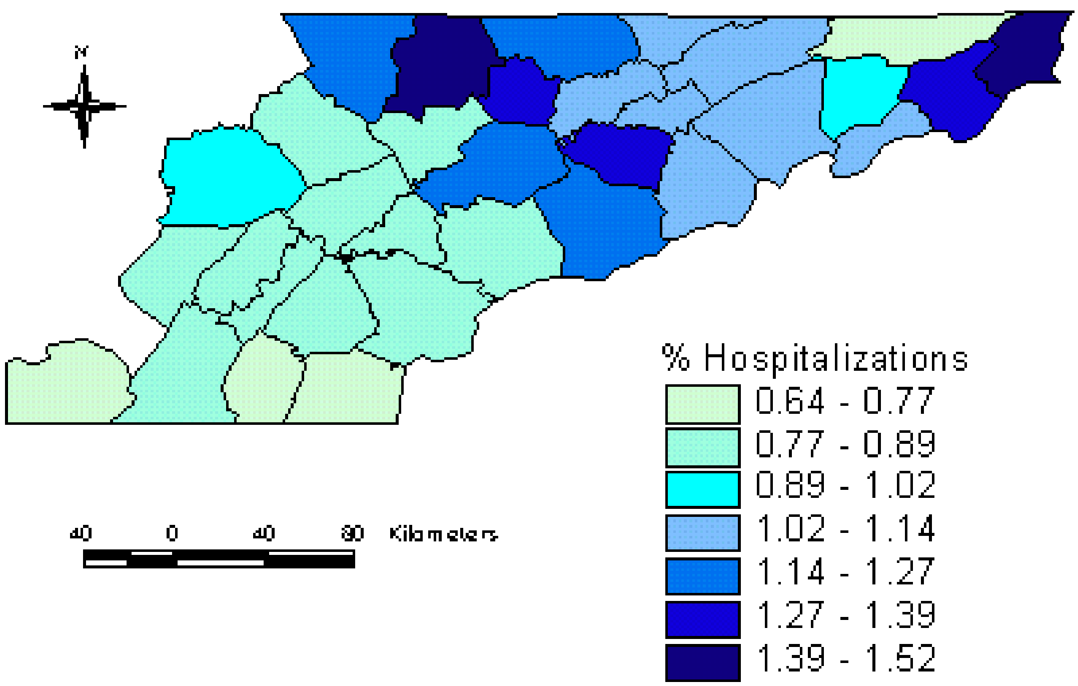


(b)

Figure 4-40: COPD admission distribution in East Tennessee due to ozone max 1-hr exposure (a) Total (b) Percent of population hospitalized due to COPD (normalized by county population).



(a)



(b)

Figure 4-41: COPD65 admission distribution in East Tennessee due to ozone max 1-hr exposure (a) Total (b) Percent of population greater than 65 years hospitalized due to COPD (normalized by county population).

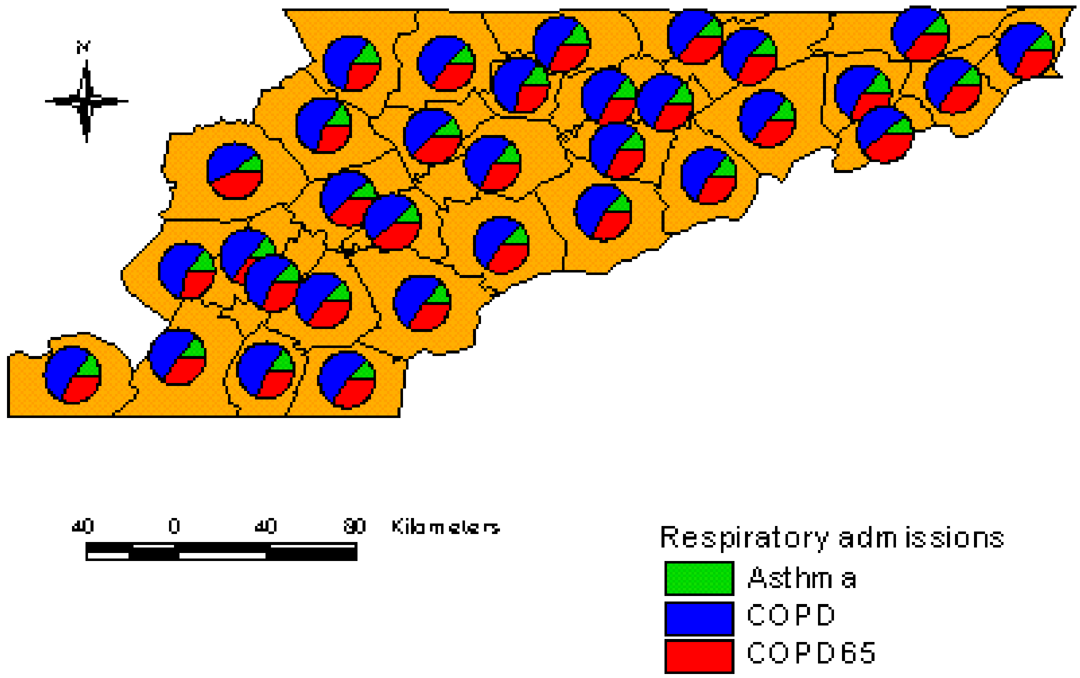


Figure 4-42: Respiratory hospital admissions distribution in East Tennessee due to maximum 1-hr ozone exposure.

4.7 Economic Valuation by emission scenario

For each hospital admission endpoint, the economic valuation gives three different cost measures. The willingness to pay (WTP), which represents the cost of avoiding hospitalization; the cost of illness (COI), which corresponds to the cost that a patient has to pay for treatment; and finally the cost for the hospital (COH), which represents the cost incurred by the hospital to treat a patient. The calculation is straightforward using equation (3-2) from section 3.2.4 and multiplying by the EPA factors from Table III.2 associated with each heath endpoint.

Appendices A through D show the outputs for this option for each emission scenario. The output gives the cost estimation by county in the study area (East Tennessee) and also a summary for the region.

Tables IV.24 and IV.25 summarize the WTP for East Tennessee during the ozone season due to ozone maximum 1-hr and 8-hr exposure, respectively. The tables show that the costs for avoiding respiratory hospitalization are greater using the 8-hr ozone exposure than 1-hr. This is because a higher number of hospital admissions are expected for an 8-hr exposure (greater risk due to longer exposure). Figure 4-43 shows the spatial distribution of the cost for avoiding COPD admissions in East Tennessee due to exposure to ground-level ozone maximum 8-hr for the base case, and Figure 4-44 the same information but for the scenario with mobile source and major point source NOx reductions (50% mobile and 70% point).

Table IV.24 Total respiratory admissions cost (WTP million US$) for maximum 1-hr ozone exposure by emission-scenario in East Tennessee – ozone season

Disease	Expected	5%	95%	$_avg/capita
	Scenario BASE			
Asthma	9.93	2.24	18.76	6.09
Copd	61.57	28.94	96.22	37.79
Copd65	45.94	13.64	80.97	156.16
	Scenario MOBIL (50%)			
Asthma	9.26	2.09	17.42	5.68
Copd	56.97	26.83	88.88	34.97
Copd65	42.90	12.77	75.44	145.84
	Scenario POINT (70%)			
Asthma	9.37	2.14	17.48	5.75
Copd	57.32	27.10	89.05	35.18
Copd65	43.91	13.13	76.85	149.27
	Scenario MOBILE + POINT			
Asthma	8.29	1.90	15.37	5.09
Copd	49.88	23.64	77.30	30.62
Copd65	38.96	11.69	67.94	132.43

Table IV.25 Total respiratory admissions cost (WTP million US$) for maximum 8-hr ozone exposure by emission-scenario in East Tennessee – ozone season

Disease	Expected	5%	95%	$_avg/capita
	Scenario BASE			
Asthma	10.49	1.46	21.06	6.44
Copd	75.38	26.90	127.63	46.27
Copd65	49.22	10.25	92.09	167.33
	Scenario MOBIL (50%)			
Asthma	9.88	1.38	19.73	6.07
Copd	71.90	25.71	121.48	44.13
Copd65	46.44	9.69	86.63	157.87
	Scenario POINT (70%)			
Asthma	10.12	1.43	20.03	6.21
Copd	74.35	26.67	125.21	45.64
Copd65	48.06	10.08	89.20	163.38
	Scenario MOBILE + POINT			
Asthma	9.14	1.30	17.97	5.61
Copd	68.55	24.65	115.12	42.08
Copd65	43.53	9.16	80.47	147.99

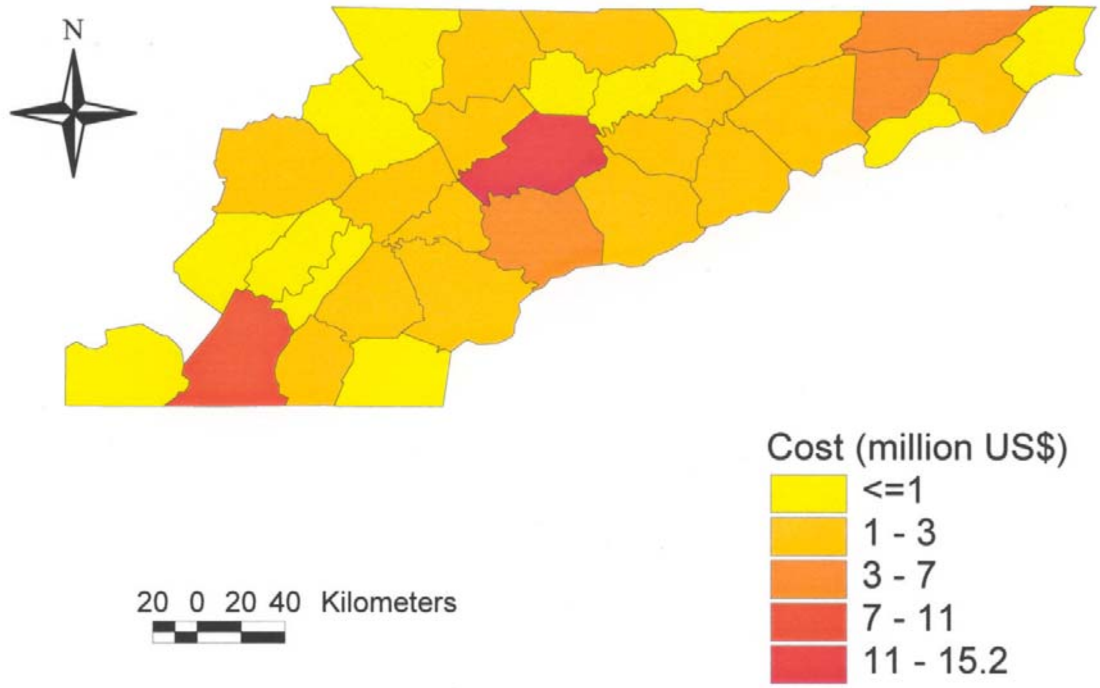


Figure 4-43: Total cost (WTP) distribution in East Tennessee for COPD admissions due to maximum 8-hr ozone exposure for the Base case.

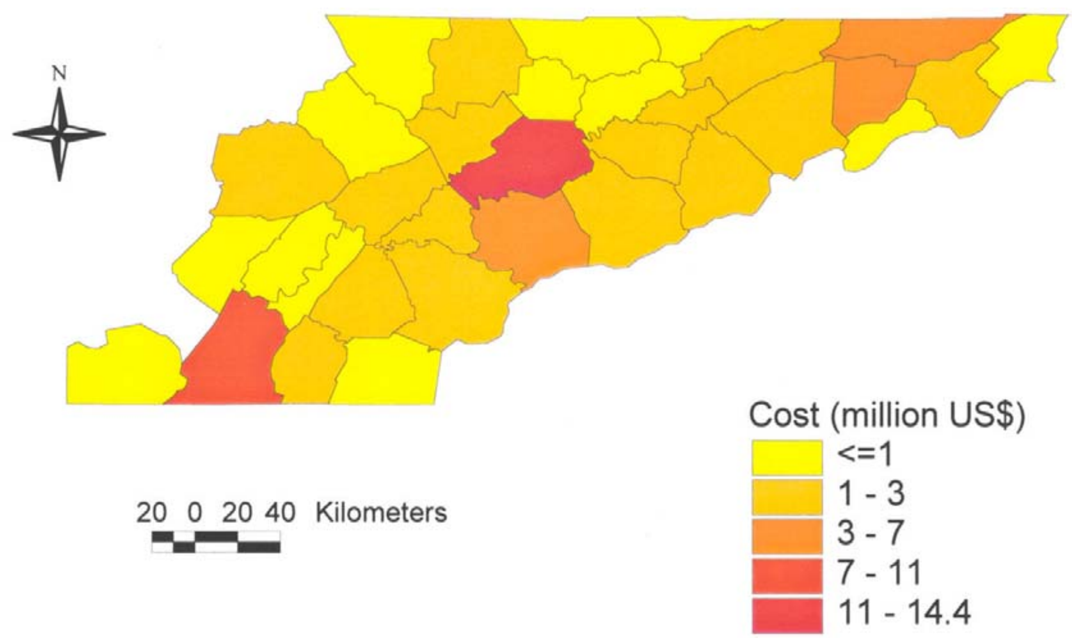


Figure 4-44: Total cost (WTP) distribution in East Tennessee for COPD admissions due to maximum 8-hr ozone exposure for the scenario control of NOx (mobile source 50% and point source 70%).

4.8 Sensitivity analysis

ORAM has two ways of performing sensitivity analysis on the parameters of the health-effects equation: first, running the program with different values of the parameter of interest in order to analyze the variation in the respiratory outcome; second, using an index, the SI (Sensitivity Index) to determine which parameter in the health-effects equation is the most sensitive.

By using the first approach, the ozone threshold was modified in each ORAM run, from 0 to 120 ppb. Figure 4-45 shows the effect of the ozone threshold in the expected COPD hospital admission. The 90% confidence interval was also included in the figure.

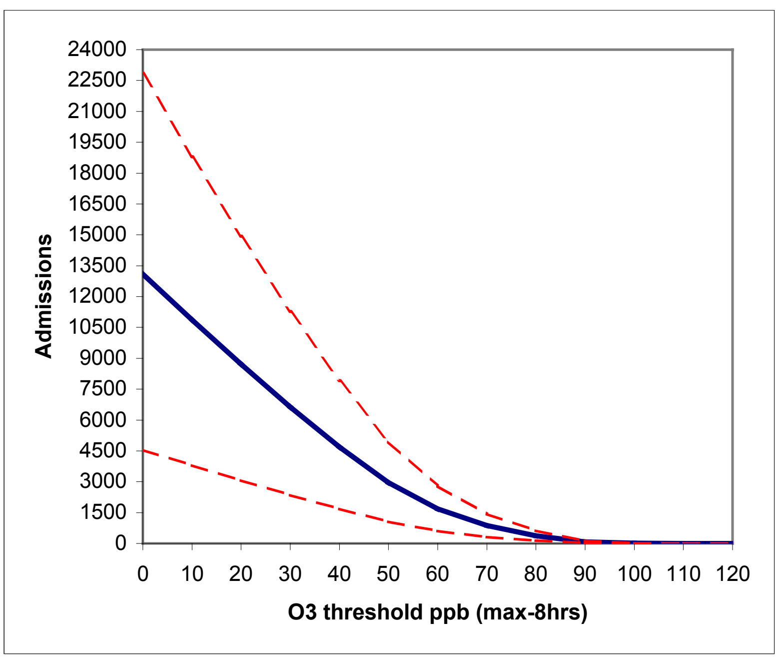


Figure 4-45 Effect of ozone threshold on COPD admissions in East Tennessee

Using the Sensitivity Index (Equation 3-4), the relative importance of each uncertain parameter in the health-effects equation was studied. As an example, Tables IV.26 and IV.27 present the SI for perturbations from 10% to 150% for ozone 1-hr and 8-hr, respectively. The negative SI value in the ozone threshold parameter indicates that there is an inverse relationship between the number of hospital admissions and the ozone threshold, i.e., the number of hospital admissions decrease when this parameter increases.

From these tables, we see that the importance of each parameter in the health-effects equation is relative and depends on the magnitude of the perturbation, thus for small perturbations in the parameters, the ozone threshold is more important, but for big perturbations, the beta coefficient begins to be more important. Also, the admission-rate presents a constant SI value of 100% because this parameter enters linearly in the equation.

Table IV.26 Sensitivity index (%): Parameters of the health-effects for ozone 1-hr

	Beta			Admissions rate			Ozone threshold		
Pert(%)	Asthma	COPD	C65	Asthma	COPD	C65	Asthma	COPD	C65
10	113	108	108	100	100	100	-149	-173	-148
50	118	112	111	100	100	100	-110	-114	-109
90	124	115	115	100	100	100	-91	-99	-91
150	133	120	120	100	100	100	-67	-67	-67

Table IV.27 Sensitivity index (%): Parameters of the health-effects for ozone 8-hr

	Beta			Admissions rate			Ozone threshold		
Pert(%)	Asthma	COPD	C65	Asthma	COPD	C65	Asthma	COPD	C65
10	112	108	108	100	100	100	-140	-167	-138
50	117	111	111	100	100	100	-113	-114	-112
90	122	114	114	100	100	100	-91	-98	-90
150	131	119	120	100	100	100	-67	-65	-67

4.9 Monte Carlo simulation

One useful way to analyze the uncertainty in the ozone-health-effects relationship is through the study of the probability distributions of the health endpoint using Monte Carlo simulation (MCS) to help us answer questions of sensitive analysis and to search for relevant parameters in the relationship. In the health-effects model, four parameters are subject to uncertainty:

1. Beta (relationship between ozone and hospital admissions)
2. Admission rate
3. Ozone threshold
4. Ozone exposure level

The exposure to ozone is determined by Models-3/CMAQ, and even though the result is uncertain, it was not considered here in the simulation analysis because the output of CCTM does not include a measure of the precision of each ozone concentration. For the test case, the following simulation was run (see Table IV.28).

Table IV.28 Parameters for Monte Carlo simulation: Ozone 1-hr

Disease	Parameter	Mean	Variation	Prob. Distribution
Asthma	Beta Admission rate Ozone threshold	0.00478 2.51×10^{-05} 45	+/- SE (0.00185) +/- 30% +/- 5 ppb	Normal/Uniform Uniform Uniform
COPD	Beta Admission rate Ozone threshold	0.00327 1.77×10^{-04} 48	+/- SE (0.00086) +/- 30% +/- 5 ppb	Normal/Uniform Uniform Uniform
COPD65	Beta Admission rate Ozone threshold	0.00315 5.74×10^{-04} 45	+/- SE (0.00111) +/- 30% +/- 5 ppb	Normal/Uniform Uniform Uniform

Once the parameters shown in Table IV.28 were read by the ORAM model, the MCS option was selected, and the model performed a replication of 1,000 times. The output of the MCS option in ORAM gives the probability mass function (PMF) and the cumulative distribution function (CDF) for the number of hospital admissions attributable to ground-level ozone exposure. Figures 4-46 and 4-47 show the PMF and CDF for ozone maximum 1-hr exposure, and Figures 4-48 and 4-49 for ozone maximum 8-hr exposure. These figures show that the probability distributions present a positive skewness and a broad variation.

A correlation analysis was performed to determine which parameter is more sensitive to changes in the number of admissions for respiratory diseases. It was done by calculating the correlation coefficient between the health-endpoint and each input in the model subject to variation. Figure 4-50 presents the tornado graph for this analysis showing that the Beta coefficient is the relevant parameter in the relationship, followed by the admission rate and finally the ozone threshold. This hierarchy is valid for both ozone metrics (1-hr and 8-hr). This analysis also gives us information on what should be the parameter most likely to estimate more accurately if the uncertainty is to be reduced.

Figures 4-51 and 4-52 show the scatter-plot for health-endpoints (asthma COPD and COPD65 hospital admissions), and the beta coefficient for ozone maximum 1-hr and 8-hr, respectively. Both figures show that the uncertainty increases as the value of the parameter increases, presenting a sort of heteroscedasticity.

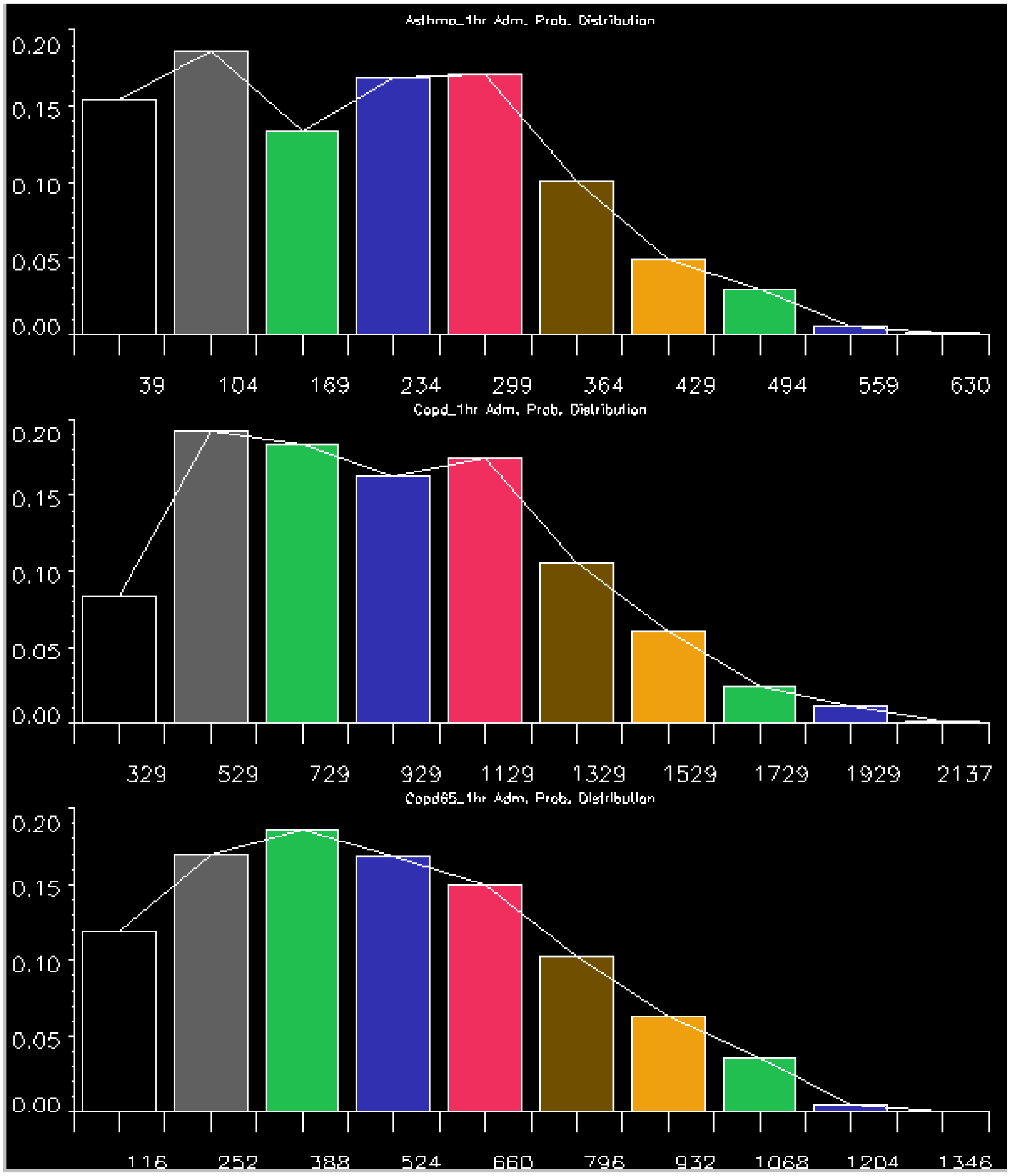


Figure 4-46: PMF of respiratory admissions in Knox County: Ozone 1-hr. Output from ORAM.

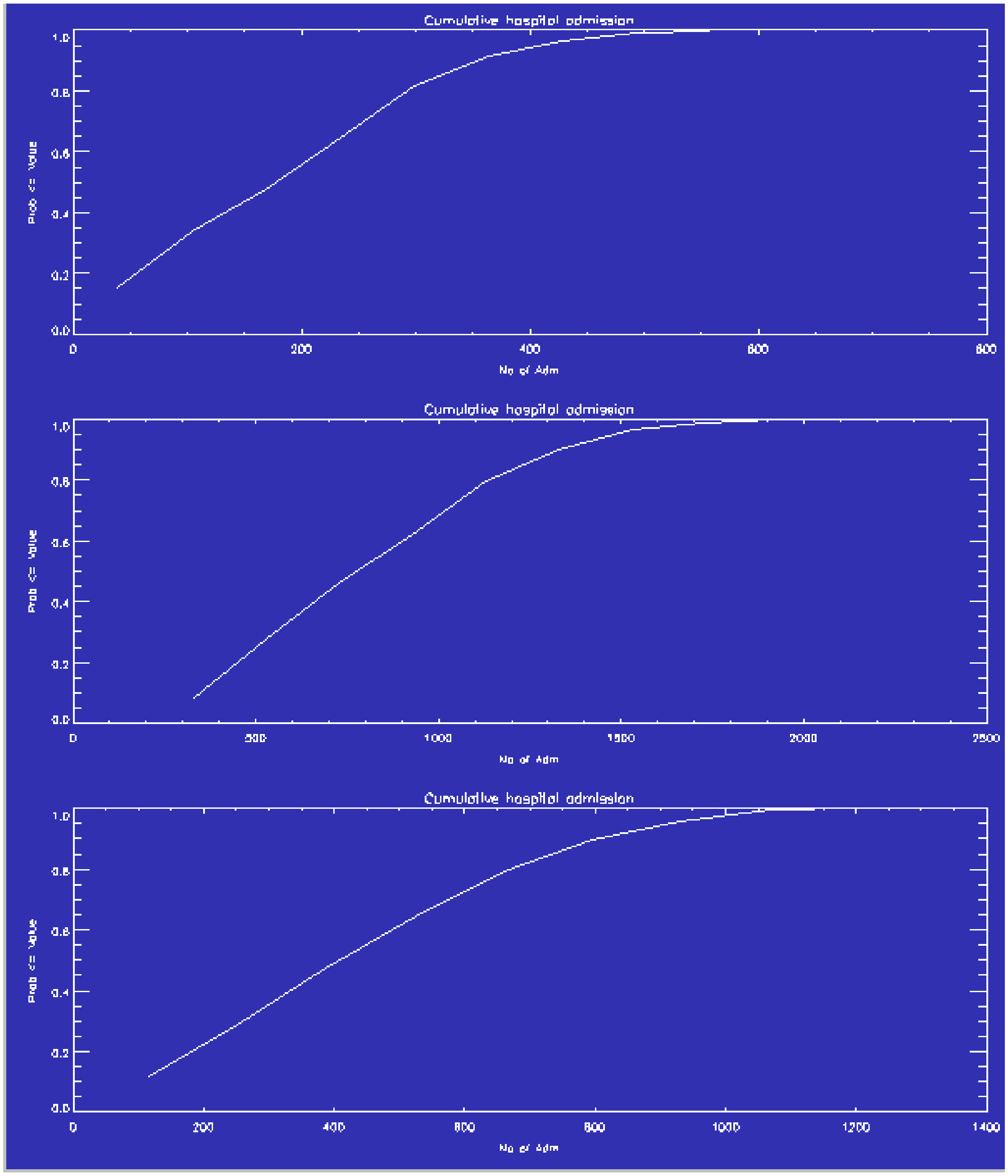


Figure 4-47: CDF of respiratory admissions in Knox County: Ozone 1-hr. Output from ORAM.

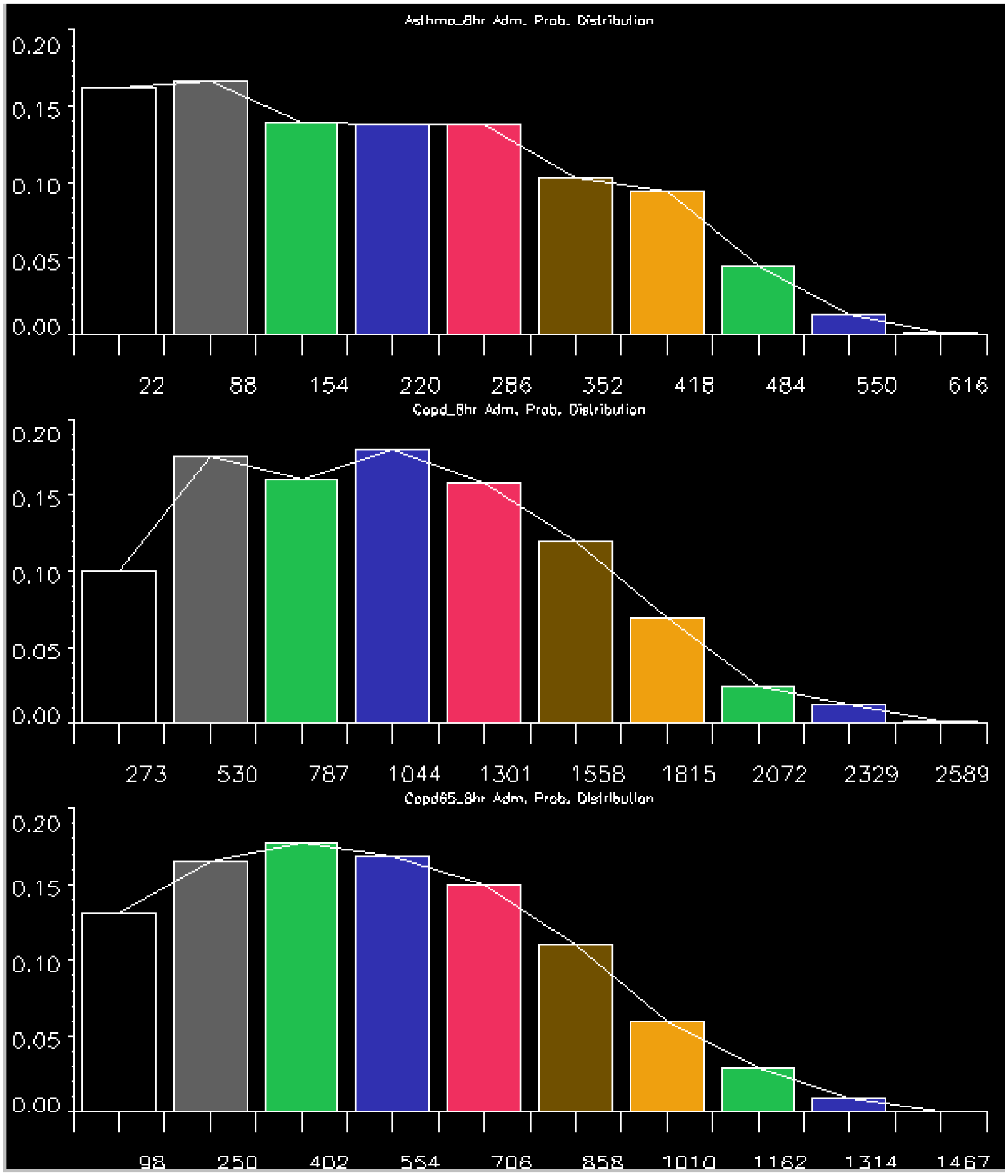


Figure 4-48: PMF of respiratory admissions in Knox County: Ozone 8-hr. Output from ORAM.

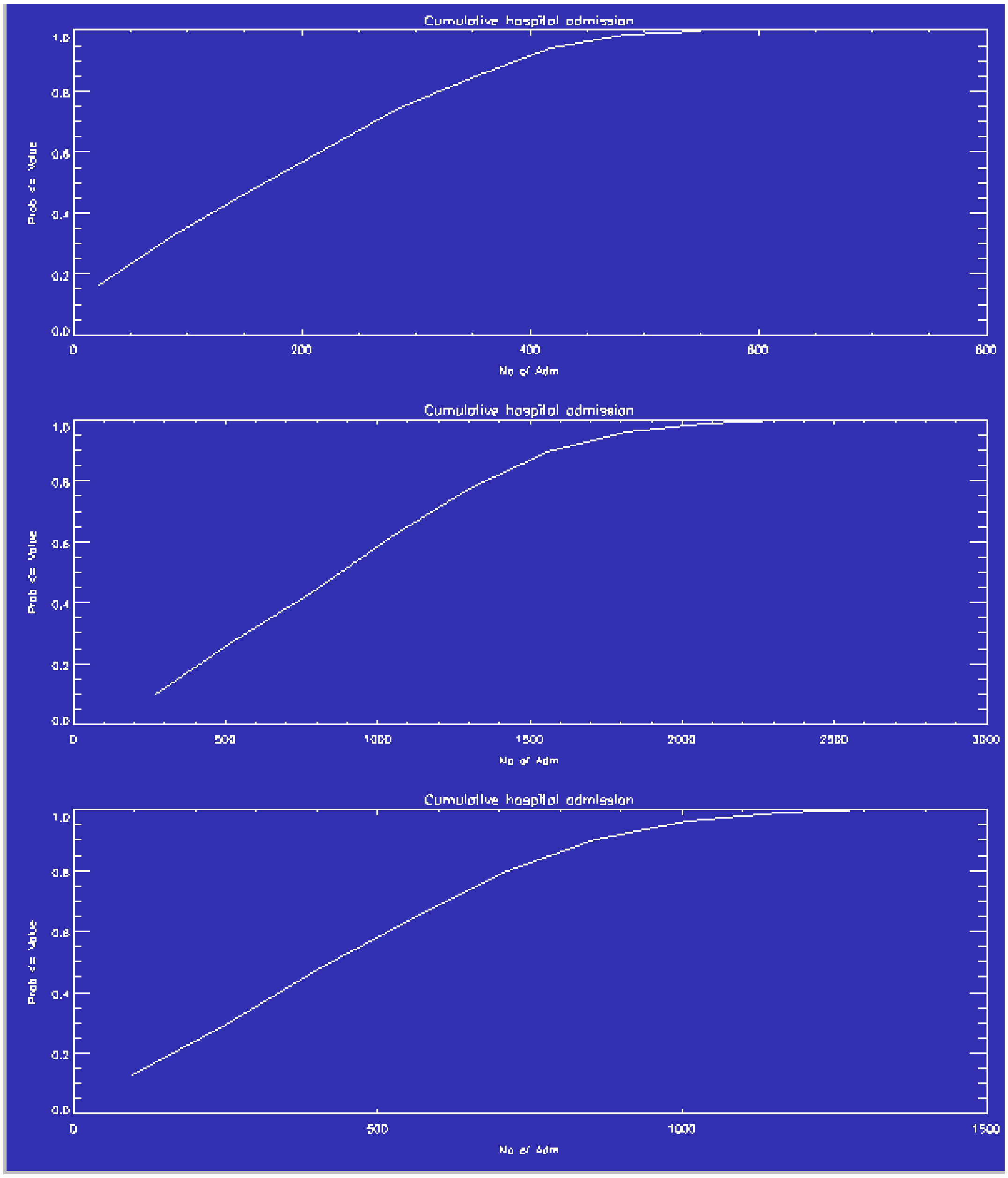


Figure 4-49: CDF of Respiratory admissions in Knox County: Ozone 8-hr. Output from ORAM.

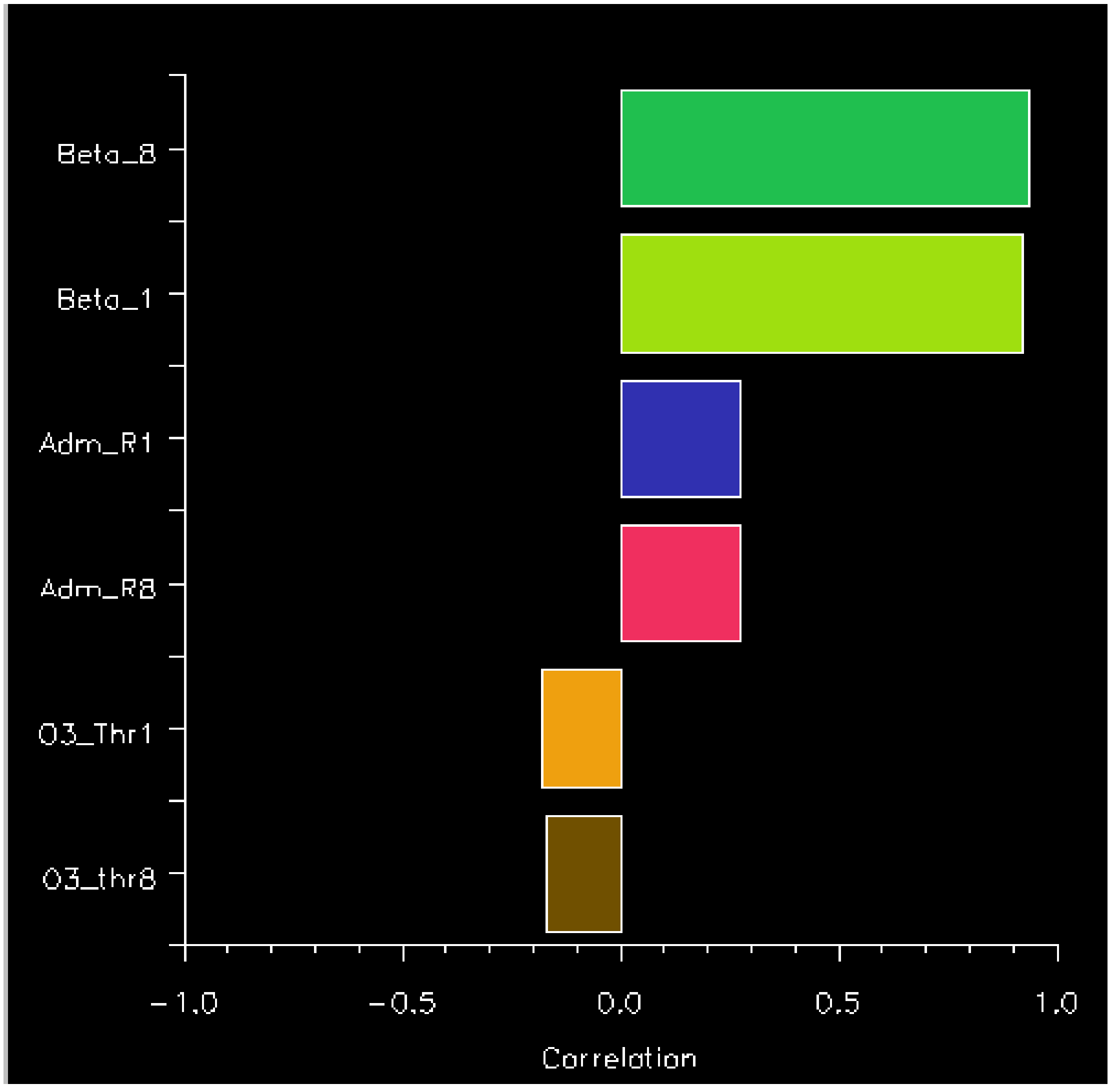


Figure 4-50: Tornado graph showing the parameter-correlation for Knox County. Output from ORAM.

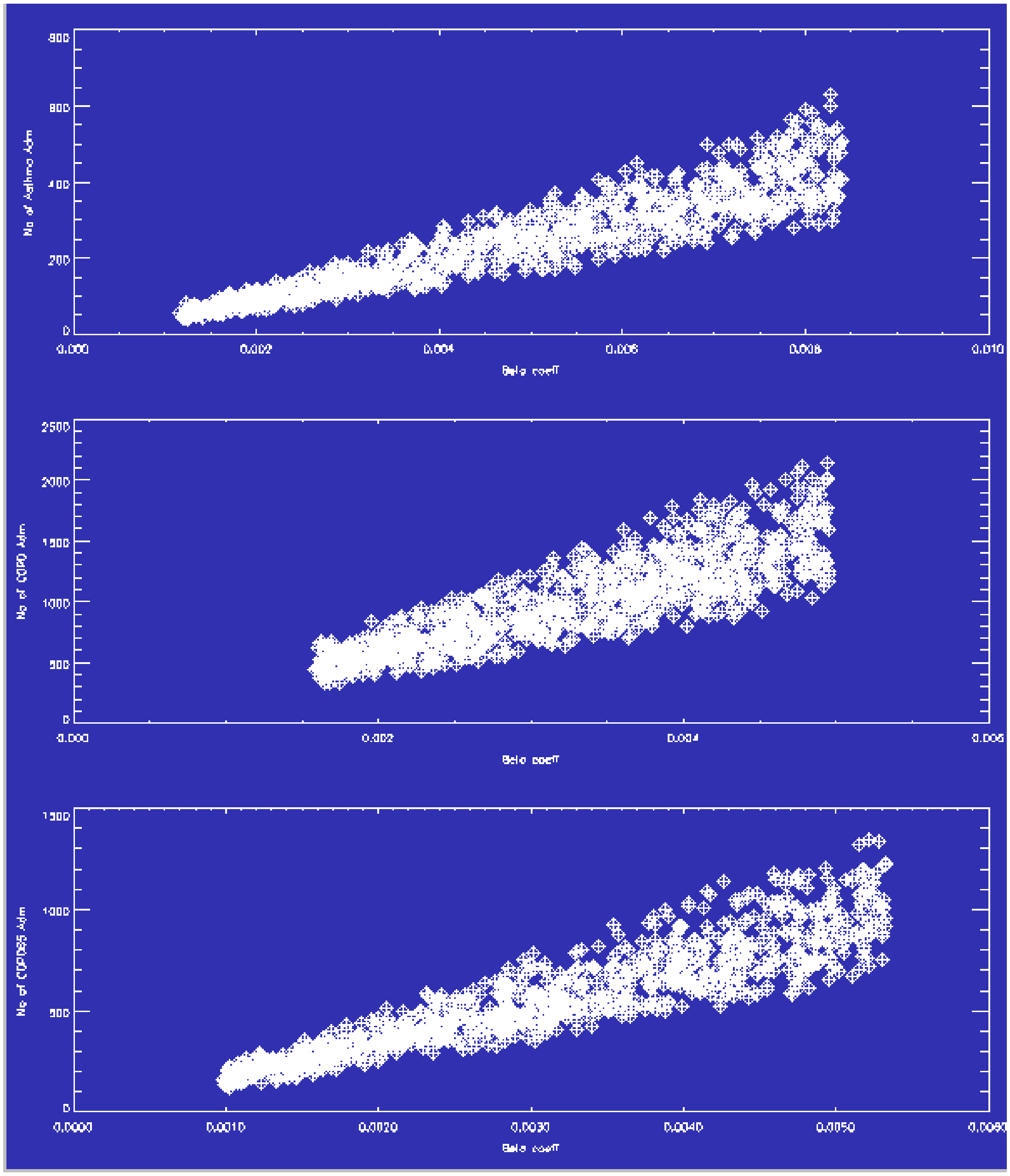


Figure 4-51: Scatter-plots of sensitive analysis in Knox County: Ozone 1-hr. Output from ORAM.

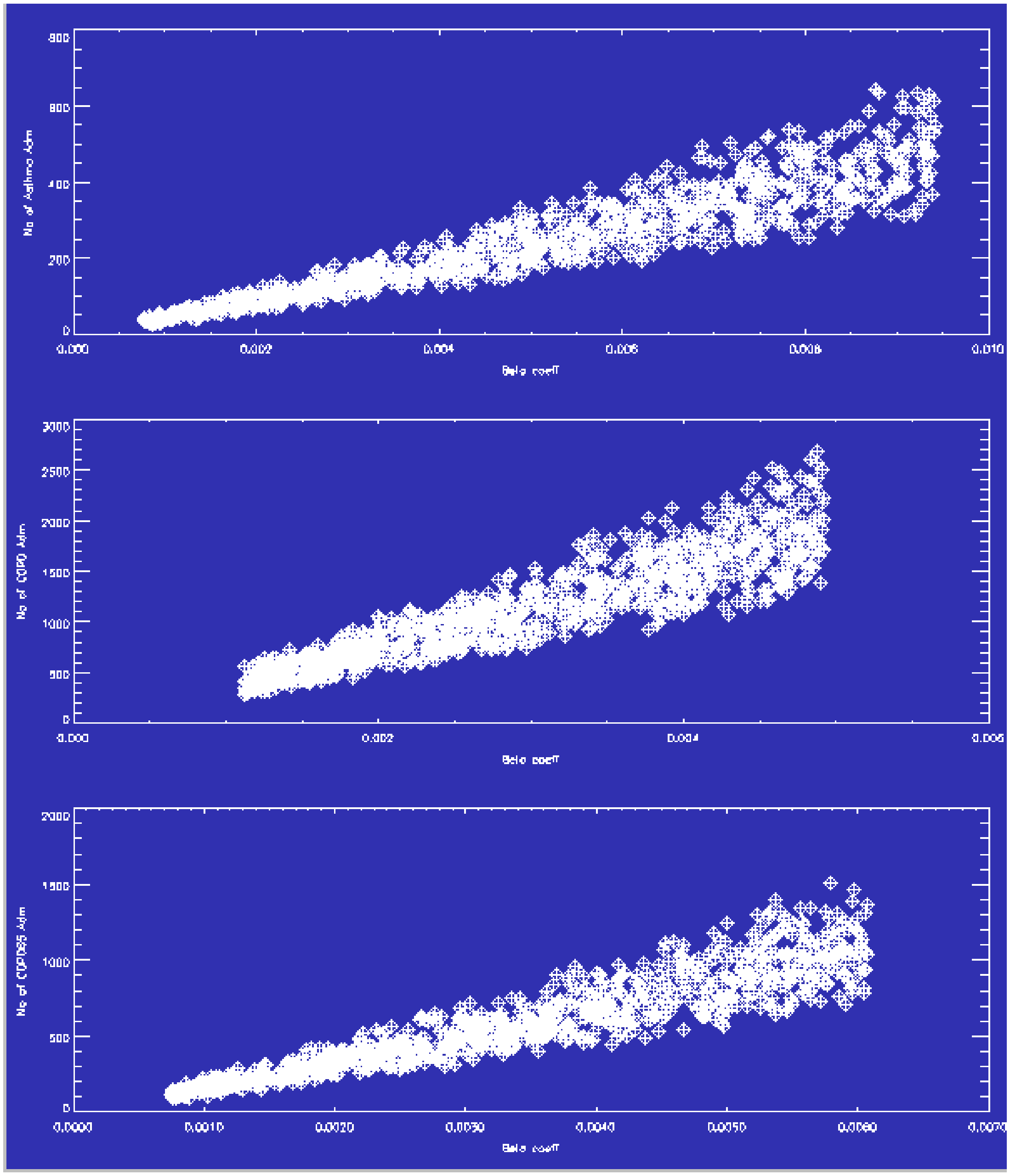


Figure 4-52: Scatter-plots of sensitive analysis in Knox County: ozone 8-hr. Output from ORAM.

CHAPTER 5

DISCUSSION OF RESULTS

5.1. Selection of simulation days

Classification and regression tree analysis was performed to generate the ozone intervals (number and limits) associated with meteorological regimes. This analysis determined five ozone intervals representative of five distinctive meteorological regimes. Using these five intervals, the observed ozone data were used to determine the number of days in each category and the criteria for choosing representative days.

After applying the criteria for selection of representative days and running Models3/CMAQ for those five category-days, it was found that three days did not pass the EPA criteria for using the model results in regulatory applications (EPA 1991). That forced the search for other days in each category until the EPA requirements were fulfilled.

For Category-day 1 ($[O_3]<=40$ ppb) the second trial met the criteria. Category-day 3 ($55<[O_3]<=70$) the second trial met the criteria, and for Category-day 4 ($70<[O_3]<=85$), the criteria were met in the fourth trial.

The poor agreement between predictions and observations is inherent to any model application because of the uncertainties and errors. In general, the prediction of an

individual day's maximum 1-hr or 8-hr ozone level at a grid of a photochemical model has been shown to have a typical uncertainty of ~ 30% (Hogrefe et al 2001). Also Hogrefe says that comparisons between observations and model predictions are complicated by the fact that observations are point measurements while model predictions are Reynolds's average mean variables.

Sources of uncertainties and errors

There are many sources of errors in complex applications like Models-3/CMAQ and even ORAM, which requires several input data that are outputs from different models. One can classify the sources of errors as input data, model specification (equations), model parameters, spatial and temporal resolutions, and error propagation. Table V.1 presents some of the errors associated with each of the principal models used in this work.

In the context of the health-effects evaluation, the results are subject to many uncertainties, and for this reason EPA encourages performance of sensitive and uncertainty analyses.

ORAM assumes that the exposure model (Models-3/CMAQ) produces reasonable ozone concentrations, and performs a sensitivity and uncertainty analyses on the parameters of the concentration-response equation (admission rate, ozone threshold, and beta coefficients).

Table V.1 Principal sources of error by model

Error source	Model	Source
Input data	MM5	Re-analysis data / Land use
	SMOKE	Emission inventory / Surrogates
	CCTM	Land use / Initial and boundary conditions/ Gridded meteorology and emissions
	ORAM	Ozone max 1-hr /8-hr / Admission rates / Health cost
Equations	MM5	Physical options / Solvers
	SMOKE	PinG / BEIS2 / Mobile5b
	CCTM	Physical and chemical options /Solvers
	ORAM	Concentration-Response equation
Parameters	MM5	PBL parameterization
	SMOKE	Speciation / Diurnal profiles
	CCTM	Photolytic rates / Diffusion / Advection
	ORAM	Concentration-response coefficients
Resolution	MM5	Grid size / Vertical layers
	SMOKE	Grid size / Vertical layers
	CCTM	Grid size / Vertical layers
	ORAM	Grid size
Propagation	MM5	Terrain→Regridder→Rawins→Interpf
	SMOKE	Inventory→Gridded→Temporal→Speciation→Merge
	CCTM	MM5→MCIP→SMOKE
	ORAM	MM5→MCIP→SMOKE→CCTM

5.2 Models-3/CMAQ

The Models-3/CMAQ system represents the state-of-the-art in multi-scale, comprehensive air quality modeling systems. Models-3/CMAQ is increasingly being adopted as a community modeling system, and scientists at EPA and at several universities are continuing to develop new algorithms and modules for use in the system. Models-3/CMAQ allows for the choice of highly accurate algorithms such as the GEAR and MEBI gas phase chemistry solvers. The meteorological preprocessor in Models-3/CMAQ also facilitates making changes in the number of vertical layers so that it can easily adapted to increase or decrease the vertical grid resolution. The primary limitation of Models-3/CMAQ is that these improved modeling algorithms are also much more computationally expensive than the approaches used in many other air quality models.

5.2.1 Run-time and storage requirements

The components of Models-3/CMAQ were run in a Sun Ultra SPARC II machine, with 1024 RAM and 450 MHz. Each run simulation period consisted of 3.5 days (it considered a spin period of two days previous to the target day and half a day after the target day). The horizontal model size was 45 x 36 cells of 36 Km grid size. The meteorological input fields were developed using MM5 and converted via MCIP (Models-3/CMAQ preprocessor) from 23 to 6 vertical layers. Table V.2 shows the run-time for each component (MM5, SMOKE, and CCTM) and the memory required by each run for the modeling domain used in the test application case.

Table V.2 Time and storage requirements by run

Model	Run time (hours)	%	Memory (MB)	%
MM5/MCIP	4.5	41	506	61
SMOKE	3.0	27	59	7
CCTM	3.5	32	260	32
Total	11.0	100	825	100

Table V.2 shows only the size of the output files for each model, so the raw input data needed for MM5 and SMOKE are not included in the calculation of storage requirements. For the complete test application (base case and three scenarios for five category-days), the total required output memory was 8.15 GB.

5.2.2 Exposure model performance evaluation

The outputs of Models-3/CMAQ were evaluated using the EPA recommended statistical measures (EPA 1991). The criteria consider the hourly comparison of observed and predicted values for those observed concentrations where the ozone level is above a cutoff value of 60 ppb (observation-prediction pairs are excluded from the analysis for observed concentrations below of the cutoff value). Nevertheless, for the purpose of this work, not only episodic days were considered but also lower ozone days in order to represent the entire ozone season. For this reason, the statistics were calculated for the daily maximum 1-hr and 8-hr ozone concentrations, which are the metrics used in the ozone health-effects model and are also consistent with other measures proposed recently (Hogrefe et al 2001). In their study, Hogrefe and colleagues propose to apply time-scale analysis to evaluate ozone predictions as an additional tool for performing model

evaluations. The time-scale introduced by this group consisted of intra-day (<12-hr), diurnal (24-hr), synoptic (2-21-day), and long-term (>21-day). By applying these metrics to UAM-V and MAQSIP (Models-3/CMAQ prototype), the group found that current regional-scale models are most suitable in characterizing average patterns over extended periods, rather than in predicting concentrations at specific locations and 1-2-day episodic events.

MM5 physics options

Additional meteorological tests were run to evaluate different configurations in the MM5 modeling system (see Figure 5-1). As it is pointed out in Arunachalam (Arunachalam et al. 2001), the PBL parameterization is a key issue in the meteorological modeling, and the three types of schemes suitable for air quality modeling applications were used to compare its impacts on ozone predictions for Category-day 5 (September 18 1998). Table V.3 shows the PBL scheme and the ozone concentrations for some counties in East Tennessee and the maximum domain-wide. Gayno-Seaman PBL scheme has a superior scientific basis (it is a TKE-based scheme) compared to Blackadar or MRF (Richardson number turbulence scheme), but MRF seems to perform better and is the NCAR recommended PBL scheme. For this reason MRF scheme was used in all MM5 runs.

Table V.3 Ozone concentrations by different PBL scheme

PBL Scheme	Max Domain wide		Knox		Anderson		Jefferson	
	1-hr	8-hr	1-hr	8-hr	1-hr	8-hr	1-hr	8-hr
Blackadar	245	209	96	87	86	77	98	90
Gayno-Seaman	244	199	99	91	96	82	94	88
MRF	261	223	103	93	93	83	103	94
Observed			114	100	94	82	100	93

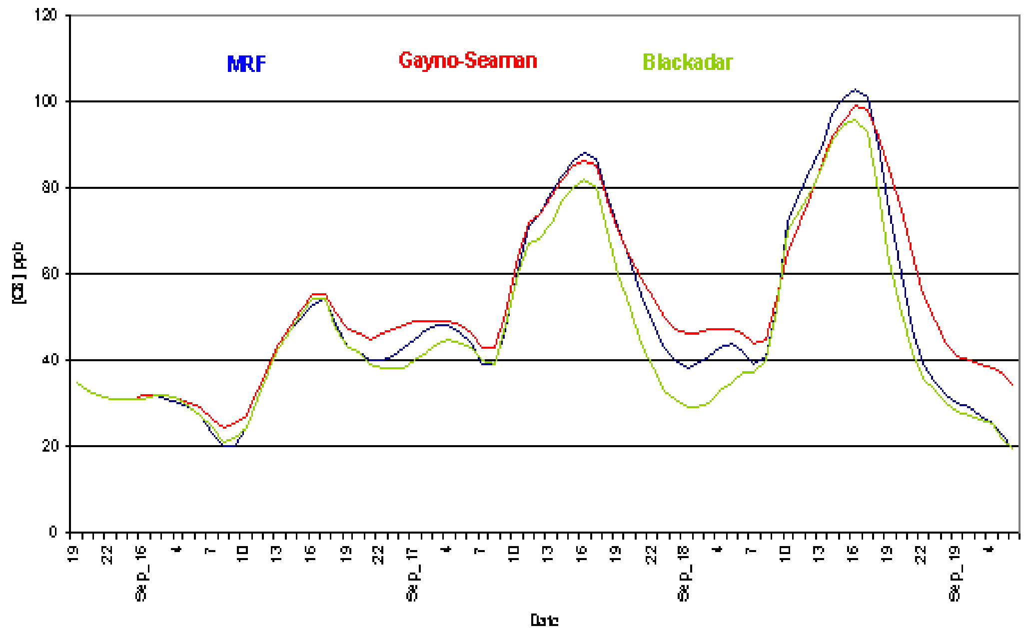


Figure 5-1: Ozone concentration in Knox County by PBL model.

Planetary Boundary Layer

It was found that the ozone concentrations predicted with Models-3/CMAQ tend to retain more ozone at night. This phenomenon was found also in other Models-3/CMAQ applications (Arunachalam et al 2001), and it is explained by the fact that MCIP rediagnoses the PBL height to be the layer top of the layer in which the predicted PBL height falls, resulting in significantly higher mixing heights used in CCTM than those predicted by MM5. This higher mixing height allows titration of NOx at night that reduces its capacity to scavenge ozone. See Figure 5-2 from Arunachalam's study for 36-km and 12-km grid size.

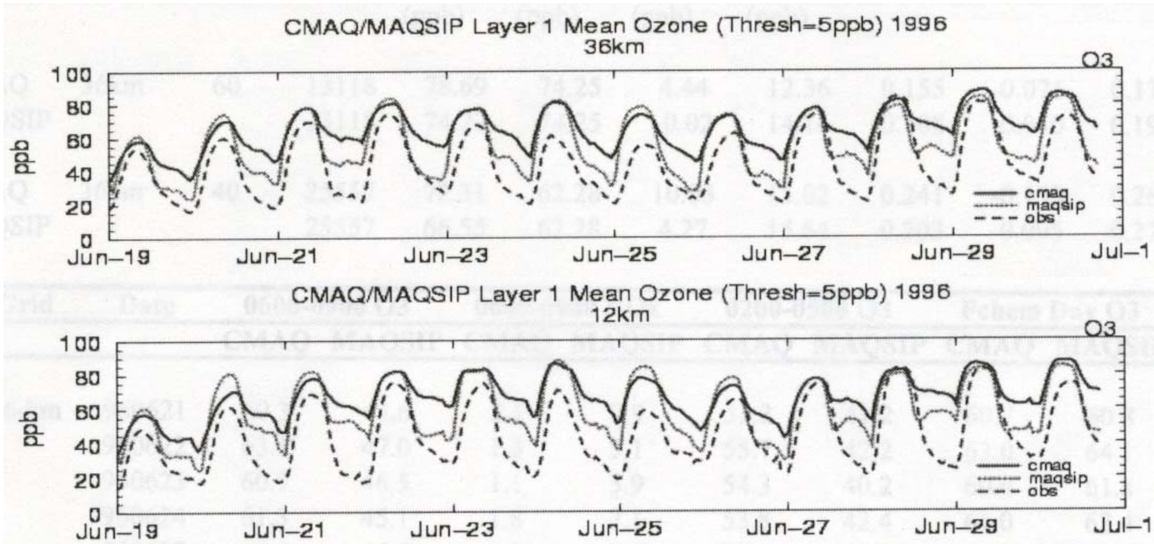


Figure 5-2: Diurnal variation of modeled and observed ozone levels in North Carolina showing the high ozone levels at night (Arunachalam et al 2001).

The layer structure chosen for a modeling application should be capable of adequately resolving diurnal variations in boundary layer growth and mixing processes therein, wind shear, and transport to and from the free troposphere and consequent effects of long-range transport processes. It is often desirable to use the same layer structure in the air quality model as in the MM5, to prevent errors associated with aggregating layer data and to maintain consistency between data produced by the meteorological model and those used by the chemistry transport model (CCTM). Because of computational restrictions or differing vertical coordinate systems, however, data derived from MM5 model are often mapped to a coarser layer structure utilized by the CCTM (see Figure 5-3).

Such an approach can lead to data consistency problems. For instance, the boundary layer heights may not be exactly represented, or in some cases (if special care is not

taken) mass conservation errors may be exacerbated if the wind fields used by the CCTM in its vertical structure are not consistent with those produced by the MM5.

Vertical layer collapsing has been used in previous modeling studies to reduce the computational costs associated with using a larger number of vertical layers. In this approach, meteorological data from selected vertical layers are averaged to a single layer, thereby reducing the total number of layers used by the CCTM. The MCIP processor contains a provision for collapsing layers by performing a mass-weighted averaging of data in the vertical direction. Even though this procedure reduces the computational time and save disk space, the averaged meteorological parameters could not adequately represent what was calculated with the MM5 model.

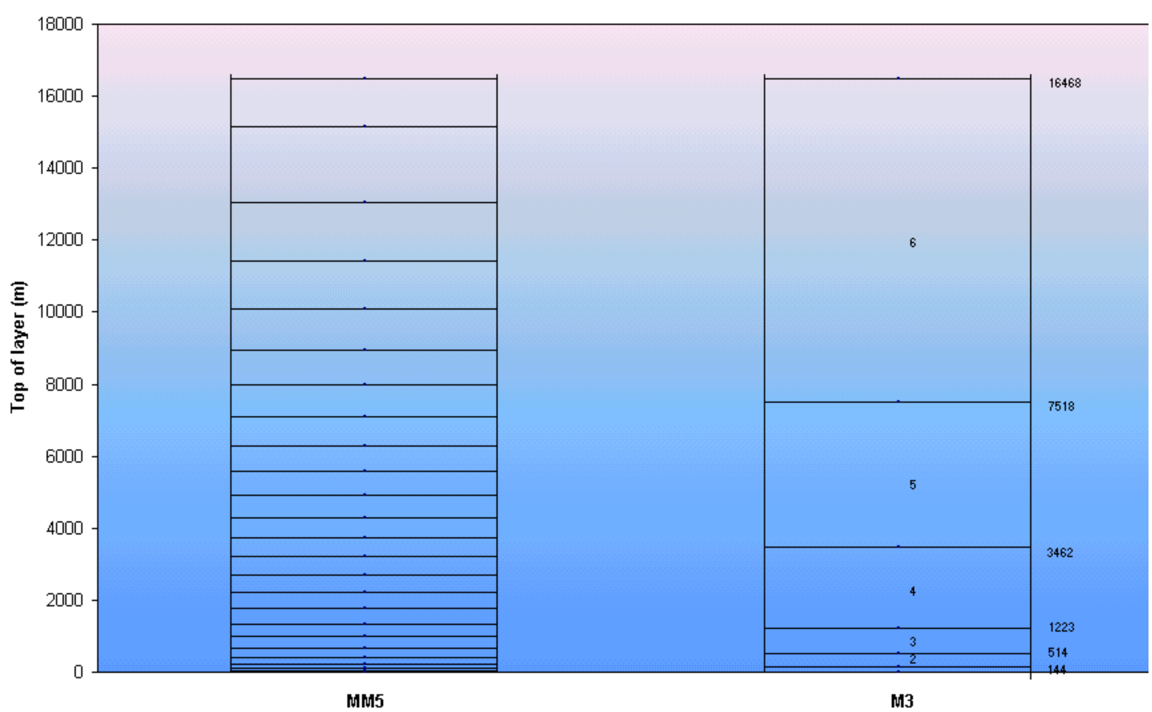


Figure 5-3:Vertical layer structures in MM5 and MCIP for ORAM application case.

Wind and Temperature evaluation

As was presented in Chapter 4, the daily average wind speeds predicted by MM5/MCIP are always higher than the observations. It is likely that the depth of the first layer used in MM5/MCIP (144 m) was not adequate for representing surface variations. The comparison of wind speeds was then between the predicted MM5/MCIP average of the first layer with the observations at 10 m.

It was also found that the MM5/MCIP predictions show less diurnal variation than the observations, often overpredicting wind speed at night. These last two findings were also noticed in the MM5 evaluation performed by SMRAQ project (SMRAQ 1998).

The temperature predicted by MM5/MCIP showed a reasonable agreement for Category-days 1,3 and 5 (bias of 1-3ºC), but for Category-days 2 and 4, the bias was 9 and 7ºC, respectively. In general nighttime temperatures are close to observations, while a bias exists during the day. Again, the SMRAQ project found the same good nocturnal agreement but diurnal bias in its MM5 evaluation. All daily maximums were overpredicted, except the first category-day (O_3-8hr <= 40 ppb), where the MM5/MCIP values were underpredicted all day long.

Chemical mechanism

The choice of gas phase photochemical mechanism is a particularly important issue. Current options include the Carbon IV (CB4) (Gery et al 1989) and the Regional Acid Deposition Mechanism (RADM2) (Stockwell 1997).

In addition, implementation of the SAPRC99 mechanism (Carter 2000) is underway but has not yet been completed. While the CB4 provides the greatest computational efficiency, it was developed for high NOx, typically urban conditions. A number of "patches" have been made to the CB4 over the years to attempt to address the concern for regional, low-NOx modeling, but it remains uncertain whether the CB4 is an appropriate mechanism for regional scale modeling (Khasibatla et al 1997). Both the RADM2 and SAPRC99 gas phase mechanisms were specifically developed for regional, low-NOx conditions and therefore these mechanisms include a more detailed representation of the fate of NOx and of the chemistry of peroxyl radical species (which are important at low NOx).

Emissions

The inventory of emissions is recognized to be a critical issue in air quality modeling. As a means of validation, the on-road NOx mobile source emission for Knox County, East Tennessee Region, and the state of Tennessee, calculated by the emission processor (SMOKE) were compared with the values generated by the University of Tennessee for TDOT (Tang et al 2001). Table V.4 summarizes the results. It is clear that the vehicle emission is underestimated in SMOKE (1995 emission inventory) and likely in the other sources as well.

Table V.4 NOx emission comparison (ton/d)

	UTK-CEE 1999	SMOKE 1995	SMOKE/UTK (%)
Knox County	54	23	43
East Tennessee	326	118	36
Tennessee	793	283	36
Knox/ET (%)	16.6	19.5	
ET/TN (%)	41.1	41.7	

5.2.3 Predicted ozone concentration by emission scenario

It is known that the relationship between VOC, NO_X, and ozone is not straightforward, and reducing one of the two principal precursors does not necessarily result in a similar reduction in ozone levels. Instead, this relationship involves a large number of chemical reactions that, as a set, are highly non-linear. Indeed, reducing one of the precursors may lead to very little change or may even increase ozone in some cases and lead to very substantial decreases in others. In addition, other processes, such as transport (ozone and precursors) and vegetation coverage, can be very important.

As a result of the above, the ozone levels in East Tennessee should not be viewed as purely local phenomena. One finding of the Southern Oxidants Study is the regional nature of ozone in the southeast United States (Chameides and Cowling 1995). That is observed in East Tennessee, where periods of elevated or lower ozone tend to coincide throughout the counties (see Table IV.16).

It was found that during high-ozone-level days (Categories 4 and 5), the peak ozone concentrations appear to be NOx limited; that is, decreasing NOx emissions locally, and from upwind areas, will generally decrease significantly the ozone levels in East Tennessee counties. However, reducing NOx emissions can lead to increases in ozone at night. Similar findings were observed in Russell's study (Russell et al 2000). Also, this study found that in areas that have a significant transport of ozone into the city, local NOx emissions will often lead to local decreases in ozone (i.e., local NOx emissions

scavenge the ozone when sufficient VOC's are present), but downwind increases in ozone (i.e., local NOx emissions are transported downwind to areas where sufficient VOC's are present and photochemical production and accumulation of ozone can occur). This distinction complicates identifying the most effective strategies to reduce ozone impact.

Similar findings were observed in the SAMI (Ozone Modeling for the Southern Appalachian Mountains Initiative) project (Odman et al 2000). In their study, Odman and colleagues conclude that by applying a reduction of 39% in NOx emissions, the ozone concentration increased by 20 ppb at night and decreased at the diurnal peak by 7 ppb. The explanation given is that the reduced NOx levels scavenged less ozone at night.

5.3. ORAM performance evaluation

As it was shown in the concentration-response equation, the admission rate is one of the parameters required for calculating the expected number of hospital admissions due to ozone ground level concentrations. In the test case, a value of 2.51×10^{-05} was used as admission rate for asthma; 1.77×10^{-04} for COPD; and 5.74×10^{-04} for COPD65. These values were calculated by considering that St Mary's hospital represents 20% of the admissions in Knox County (see Table V.5). That is because St Mary's hospital admissions were used to estimate the parameters in the C-R equation (Sanhueza et al 2002). This rate was used for all the counties in East Tennessee because of the lack of information on this parameter for the rest of the region. As the EPA has established, the

baseline incidence data associated with ambient levels of air pollutants cannot easily be obtained, so the EPA recommends using those rates available from some specific cities as representative of all the study area (EPA 1999a).

The concentration-response coefficient (β) is one of the most sensitive relative parameters in the ozone health-effect relationship, and the EPA recognizes that there are a limited number of cities where the C-R functions have been calculated, so for each city or area where the health effects need to be evaluated, the EPA recommends selecting one of them or a pooled function of them, and applying the same C-R relationship everywhere in the current application. Here for the test case, the concentration-response coefficient found for Knox County (Sanhueza et al 2002) was used for all East Tennessee counties. To see the flexibility of the model developed, and as a mean of comparison with the epidemiological parameters that the EPA has used in its applications, ORAM was run with the concentration-response coefficients used by the EPA. The results are summarized in Tables V.6 to V.8 for asthma, COPD, and COPD65, respectively.

Table V.5 Hospital statistics for Knox County

Hospital	**Beds**		**Admissions**		**Employees**	
	Nº	**%**	**Nº**	**%**	**Nº**	**%**
Baptist	438	18.6	13000	16.5	1630	15.0
Fort Sanders Parkway	325	13.8	11522	14.6	1292	11.9
Fort Sanders Regional	541	22.9	17260	21.9	2200	20.3
St Mary's	**473**	**20.1**	**16168**	**20.5**	**2175**	**20.1**
UT	581	24.6	20944	26.5	3538	32.7
Total	2358	100	78894	100	10835	100

Source: Hospital Blue Book 2000

Table V.6 Comparison of asthma admissions in East Tennessee using Knox and EPA epidemiological parameters

Parameter	Knox	EPA
Beta	0.00478	0.0025
Standard error of Beta	0.00185	0.000718
Admission rate	2.51E-05	5.75E-06
Asthma admissions	1103 ± 133	377 ± 33
WTP (Mill $)	9.93 ± 1.20	3.39 ± 0.30
COI (Mill $)	2.90 ± 0.35	0.99 ± 0.09
COH (Mill $)	1.03 ± 0.12	0.35 ± 0.03

Table V.7 Comparison of COPD admissions in East Tennessee using Knox and EPA epidemiological parameters

Parameter	Knox	EPA
Beta	0.00327	0.00303
Standard error of Beta	0.00086	0.0011
Admission rate	1.77E-04	1.56E-05
COPD admissions	4595 ± 367	1265 ± 143
WTP (Mill $)	61.57 ± 4.91	16.95 ± 1.92
COI (Mill $)	28.07 ± 2.24	7.73 ± 0.87
COH (Mill $)	10.54 ± 0.84	2.90 ± 0.33

Table V.8 Comparison of COPD65 admissions in East Tennessee using Knox and EPA epidemiological parameters

Parameter	Knox	EPA
Beta	0.00315	0.00549
Standard error of Beta	0.00111	0.00205
Admission rate	5.74E-04	3.05E-05
COPD65 admissions	2889 ± 295	888 ± 109
WTP (Mill $)	45.94 ± 4.69	14.12 ± 1.73
COI (Mill $)	25.41 ± 2.60	7.81 ± 0.96
COH (Mill $)	9.76 ± 1.00	3.00 ± 0.37

The values shown in the Tables V.6 to V.8 indicate that there is a very large uncertainty in the health-effects estimation by either set of parameters (Knox and EPA). The error estimation using Knox data varies from 8.0% to 12.1% and using the EPA default values, the errors are in the range of 8.8% and 12.3%. Another issue is that the absolute values for hospital admissions due to ground-level ozone exposure are between 2.9 to 3.6 times larger using local data than the EPA defaults for the US. That has some real policy implications because not only is the number of people affected by ozone 2.9 to 3.6 times larger, but also the cost associated with these effects. The larger potential benefit could be used to justify larger costs in emission control to reduce ozone precursors.

5.3.1 Health-effects

As a general validation of the ORAM system, the number of hospital admissions by disease available for Knox County during the ozone season was compared with the predicted output. According to Reed (Reed et al 2000), the attributable proportion (AP) of the hospitalization due to ozone in Knox County is 11.3%, 7.6%, and 7.6% for asthma, COPD, and COPD65, respectively. The AP represents the percentage of hospitalizations due to ozone exposure. Table V.9 summarizes the comparison using local versus the EPA (default) epidemiological parameters.

Table V.9 Hospital admissions observed in Knox and predicted by ORAM using two sets of epidemiological parameters

Health endpoint	Hospital admissions	Due to O_3	ORAM-Knox		ORAM-EPA	
			Pred	Error	Pred	Error
Asthma	1895	**214**	**237**	-10.7%	**73**	65.9%
COPD	11745	**890**	**996**	-11.9%	**246**	72.4%
COPD65	6560	**499**	**563**	-12.8%	**158**	68.3%

This validation indicates that not only the equations involved in the model, but also the criteria for choosing category-days to represent the ozone season were performed adequately (see the observed number of respiratory admissions due to ozone and the values predicted by ORAM using the epidemiological parameters calculated for Knox County). It is interesting to note that the observed number of respiratory admissions is the aggregation of daily admissions from April to October (ozone season), and the value calculated by the ORAM model is just using five representative days (representative of different meteorological regimes associated with different ozone levels), and expanded to the ozone season (214 days) by using the expansion factors as described in Chapter 3, section 3.4. Table V.9 also shows that the local parameters (concentration-response coefficients) are better than the EPA default for East Tennessee (they produce a lower error estimation).

Tables V.10 to V.13 summarize the absolute and relative contributions to the number of hospital admissions by disease and by emission scenario, by ozone metric. These tables show that the benefits gained in decreasing hospital admissions due to reductions in mobile source NOx emissions (50%) and major point sources (70%) have almost the same effect. Nevertheless, when both reductions are applied simultaneously, the synergism produces a bigger reduction in the number of expected respiratory hospitalizations (more than the sum of each contribution independently). The tables also show that for the 8-hr ozone exposure, the benefits are less than with 1-hr ozone exposure, meaning that more stringent measures are required to reduce the risk of longer ozone exposure.

Table V.10 Hospital admissions by emission scenario: Ozone max 1-hr

Health endpoint	Base	50% Mobile	70% Point	Mob+Point
Asthma admissions	1103	1028	1042	921
COPD admissions	4595	4252	4277	3722
COPD65 admissions	2889	2698	2762	2450
Resp. Doctor Visits	14560	13574	13750	12157

Table V.11 Hospital admission reduction by emission scenario: Ozone max 1-hr

	Fewer cases			Relative benefit (%)		
Health endpoint	B-M	B-P	B-(M+P)	B-M	B-P	B-(M+P)
Asthma admissions	75	61	182	6.8	5.5	16.5
COPD admissions	343	318	873	7.5	6.9	19.0
COPD65 admissions	191	127	439	6.6	4.4	15.2
Doctor Visits	986	810	2403	6.8	5.6	16.5

B-M :Base case – Mobile source scenario
B-P :Base case – Point source scenario
B- (M+P) :Base case – Mobile and Point sources scenario

Table V.12 Hospital admission by emission scenario: Ozone max 8-hr

Health endpoint	Base	50% Mobile	70% Point	Mob+Point
Asthma admissions	1166	1098	1125	1016
COPD admissions	5625	5366	5548	5116
COPD65 admissions	3096	2921	3023	2738
Resp. Doctor Visits	15385	14493	14849	13408

Table V.13 Hospital admission reduction by emission scenario: Ozone max 8-hr

	Fewer cases			Relative benefit (%)		
Health endpoint	B-M	B-P	B-(M+P)	B-M	B-P	B- (M+P)
Asthma admissions	68	41	150	5.8	3.5	12.9
COPD admissions	259	77	509	4.6	1.4	9.0
COPD65 admissions	175	73	358	5.7	2.4	11.6
Doctor Visits	892	536	1977	5.8	3.5	12.9

B-M :Base case – Mobile source scenario
B-P :Base case – Point source scenario
B- (M+P) :Base case – Mobile and Point sources scenario

5.3.2 Economic valuation

Tables V.14 to V.25 summarize for East Tennessee the absolute and relative contribution to the costs of hospital admissions expressed as willingness to pay (WTP), cost of illness (COI), and cost for the hospital (COH), by disease, by emission scenario, and by ozone metric (max 1-hr and 8-hr). Appendices A through D contain the detailed information by county and the summary for the entire region.

From Table V.15 it can be seen that a cost reduction of \$5.27 million (\$0.67 million asthma + \$4.60 million COPD) per ozone season could be achieved if a reduction of 50% in NOx emissions from mobile sources is implemented. This cost reduction is attributed to fewer hospital admissions for asthma and COPD. If a reduction of 70% in NOx emissions from major point sources is implemented, a \$4.81 million (\$0.56 million asthma + \$4.25 million COPD) cost could be realized for hospital admissions during the ozone season. If both regulatory alternatives were implemented simultaneously, then \$13.33 million cost reduction per ozone season could be achieved in this region due to fewer hospital admissions for respiratory diseases.

The economic valuation considered only respiratory admissions, but it is recognized that other benefits could be incorporated in the analysis such as premature mortality, doctor visits, and minor restricted activity days. The key issue here is the availability of the ozone-effect coefficients and the monetary values for each health endpoint, which are not always available.

Table V.14 WTP to avoid hospital admission in East Tennessee by emission scenario: Maximum 1-hr ozone exposure (millions of dollars per ozone season)

Health endpoint	Base	50% Mobile	70% Point	Mob+Point
Asthma admissions	9.93	9.26	9.37	8.29
COPD admissions	61.57	56.97	57.32	49.88
COPD65 admissions	45.94	42.9	43.91	38.96

Table V.15 Cost reduction (WTP) by emission scenario: Maximum 1-hr ozone exposure (millions of dollars per ozone season)

	Fewer costs			Relative benefit (%)		
Health endpoint	B-M	B-P	B- (M+P)	B-M	B-P	B- (M+P)
Asthma admissions	0.67	0.56	1.64	6.8	5.5	16.5
COPD admissions	4.60	4.25	11.69	7.5	6.9	19.0
COPD65 admissions	3.04	2.03	6.98	6.6	4.4	15.2

B-M :Base case – Mobile source scenario
B-P :Base case – Point source scenario
B- (M+P) :Base case – Mobile and Point sources scenario

Table V.16 WTP to avoid hospital admission in East Tennessee by emission scenario: Maximum 8-hr ozone exposure (millions of dollars per ozone season)

Health endpoint	Base	50% Mobile	70% Point	Mob+Point
Asthma admissions	10.49	9.88	10.12	9.14
COPD admissions	75.38	71.9	74.35	68.55
COPD65 admissions	49.22	46.44	48.06	43.53

Table V.17 Cost reduction (WTP) by emission scenario: Maximum 8-hr ozone exposure (millions of dollars per ozone season)

	Fewer costs			Relative benefit (%)		
Health endpoint	B-M	B-P	B-(M+P)	B-M	B-P	B- (M+P)
Asthma admissions	0.61	0.37	1.35	5.8	3.5	12.9
COPD admissions	3.48	1.03	6.83	4.6	1.4	9.0
COPD65 admissions	2.78	1.16	5.69	5.7	2.4	11.6

B-M :Base case – Mobile source scenario
B-P :Base case – Point source scenario
B- (M+P) :Base case – Mobile and Point sources scenario

Table V.18 Cost of illness in East Tennessee by emission scenario: Maximum 1-hr ozone exposure (millions of dollars per ozone season)

Health endpoint	Base	50% Mobile	70% Point	Mob+Point
Asthma admissions	2.90	2.70	2.74	2.42
COPD admissions	28.07	25.98	26.14	22.74
COPD65 admissions	25.41	23.73	24.29	21.55

Table V.19 Cost reduction (COI) by emission scenario: Maximum 1-hr ozone exposure (millions of dollars per ozone season)

	Fewer costs			Relative benefit (%)		
Health endpoint	B-M	B-P	B-(M+P)	B-M	B-P	B- (M+P)
Asthma admissions	0.20	0.16	0.48	6.8	5.5	16.5
COPD admissions	2.09	1.93	5.33	7.5	6.9	19.0
COPD65 admissions	1.68	1.12	3.86	6.6	4.4	15.2

B-M :Base case – Mobile source scenario
B-P :Base case – Point source scenario
B- (M+P) :Base case – Mobile and Point sources scenario

Table V.20 Cost of illness in East Tennessee by emission scenario: Maximum 8-hr ozone exposure (millions of dollars per ozone season)

Health endpoint	Base	50% Mobile	70% Point	Mob+Point
Asthma admissions	3.06	2.89	2.96	2.67
COPD admissions	34.37	32.79	33.90	31.26
COPD65 admissions	27.23	25.69	26.58	24.08

Table V.21 Cost reduction (COI) by emission scenario: Maximum 8-hr ozone exposure (millions of dollars per ozone season)

	Fewer costs			Relative benefit (%)		
Health endpoint	B-M	B-P	B-(M+P)	B-M	B-P	B- (M+P)
Asthma admissions	0.17	0.10	0.39	5.8	3.5	12.9
COPD admissions	1.58	0.47	3.11	4.6	1.4	9.0
COPD65 admissions	1.54	0.65	3.15	5.7	2.4	11.6

B-M :Base case – Mobile source scenario
B-P :Base case – Point source scenario
B- (M+P) :Base case – Mobile and Point sources scenario

Table V.22 Cost of hospital in East Tennessee by emission scenario: Maximum 1-hr ozone exposure (millions of dollars per ozone season)

Health endpoint	Base	50% Mobile	70% Point	Mob+Point
Asthma admissions	1.03	0.96	0.97	0.86
COPD admissions	10.54	9.75	9.81	8.54
COPD65 admissions	9.76	9.11	9.33	8.27

Table V.23 Cost reduction (COH) by emission scenario: Maximum 1-hr ozone exposure (millions of dollars per ozone season)

	Fewer costs			Relative benefit (%)		
Health endpoint	B-M	B-P	B-(M+P)	B-M	B-P	B- (M+P)
Asthma admissions	0.07	0.06	0.17	6.8	5.5	16.5
COPD admissions	0.79	0.73	2.00	7.5	6.9	19.0
COPD65 admissions	0.65	0.43	1.49	6.6	4.4	15.2

B-M :Base case – Mobile source scenario
B-P :Base case – Point source scenario
B- (M+P) :Base case – Mobile and Point sources scenario

Table V.24 Cost of hospital in East Tennessee by emission scenario: Maximum 8-hr ozone exposure (millions of dollars per ozone season)

Health endpoint	Base	50% Mobile	70% Point	Mob+Point
Asthma admissions	1.09	1.03	1.05	0.95
COPD admissions	12.9	12.31	12.73	11.74
COPD65 admissions	10.45	9.86	10.2	9.25

Table V.25 Cost reduction (COH) by emission scenario: Maximum 8-hr ozone exposure (millions of dollars per ozone season)

	Fewer costs			Relative benefit (%)		
Health endpoint	B-M	B-P	B-(M+P)	B-M	B-P	B- (M+P)
Asthma admissions	0.06	0.04	0.14	5.8	3.5	12.9
COPD admissions	0.59	0.17	1.16	4.6	1.4	9.0
COPD65 admissions	0.59	0.24	1.20	5.7	2.4	11.6

B-M :Base case – Mobile source scenario
B-P :Base case – Point source scenario
B- (M+P) :Base case – Mobile and Point sources scenario

Assessing the health benefits of reduced ozone concentrations

By combining the results from the base scenario with mobile source, point source, and mobile plus point sources scenarios, the estimation of the ozone-season monetary value of health benefits from reducing ozone concentrations in East Tennessee was calculated. Tables V.26 and V.27 show the dollars per part per billion per person ($/ppb-person) from reducing ground-level ozone concentrations in East Tennessee for ozone maximum 1-hr and 8-hr exposures, respectively.

Levy (Levy et al 2001), found $20 per ppb per person ($1.4 – $80.0, 90% confidence interval) as the annual monetary value of health effects from reducing ozone levels in Houston. This estimate considered not only respiratory hospital admissions but also premature mortality and minor restricted activity days. When mortality was extracted from this calculation, a central estimation of $2.0/ppb-person was obtained, close to the value obtained in this study ($1.8/ppb-person) for East Tennessee (calculation given by Dr. Levy through personal communication).

Table V.26 $/ppb-person from reducing ozone levels in East Tennessee: Ozone 1-hr

Scenario (NOx reduction)	Expected	5%	95%
Mobile (50%)	1.8	0.8	2.9
Point (70% Major Sources)	1.8	0.8	3.1
Mobile + Point	1.7	0.8	2.8

Table V.27 $/ppb-person from reducing ozone levels in East Tennessee: Ozone 8-hr

Scenario (NOx reduction)	Expected	5%	95%
Mobile (50%)	1.5	0.5	2.7
Point (70% Major Sources)	0.6	0.1	1.3
Mobile + Point	1.2	0.4	2.2

Another economic impact estimation for ozone reduction can be calculated using information from EPA in its Regulatory Impact Analysis for Tier2 (EPA 1999b). In this study, EPA estimates $260 million as the projected benefit for 2030 for all ozone-related health-endpoints, and only $11 million for hospital admissions. The average concentration reduction from May to September was 0.5 ppb and the projected at-risk population was 345 million (for the US). Table V.28 shows the results of these three studies by considering only the cost of respiratory hospital admissions. The big difference between the EPA's rulemaking benefits, and other study results is in part because the EPA used a health coefficient developed for New York as valid for the entire US and also because of some inaccuracies in the model used (see section 5.4).

5.3.3 Sensitivity and uncertainty analysis

Using the Sensitivity Index (SI) explained in Chapter 3, section 3.2.6, the variation in the output of ORAM was apportioned quantitatively, to different sources of variation in each one at a time. SI aims to ascertain how the model depends upon the information fed into it. Figure 5-4 shows the SI variation for each parameter in the C-R equation. The values of SI for the ozone threshold parameter are negatives (indicating inverse relationship), but the absolute values are used in the figure for comparison purposes.

Table V.28 Health-benefits comparison

Study	$/ppb-person
EPA-1999 Tier2 (All US) (O_3 season)	0.06
Levy et al 2001 Houston (Year)	2.00
ORAM 2002 East Tennessee (O_3 season)	1.80

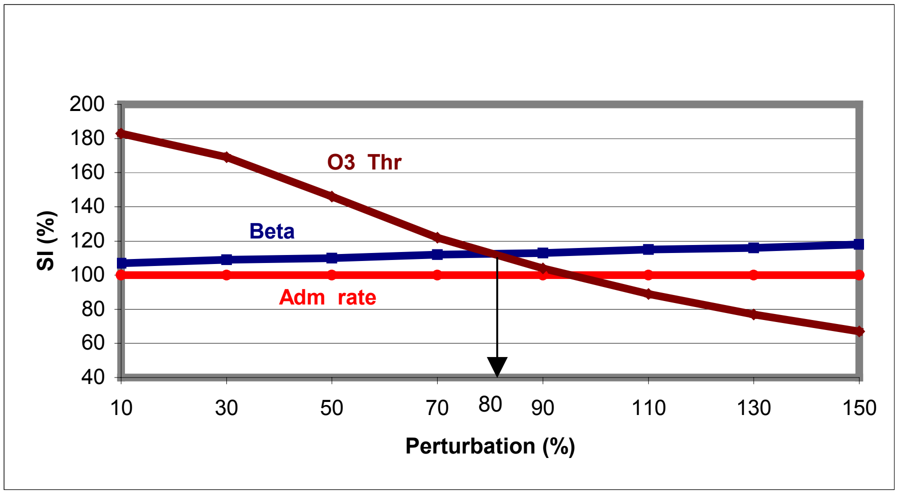


Figure 5-4: Sensitivity Index in the C-R equation.

It was found that for perturbations less than 80% of the expected value, the ozone threshold is the most sensitive parameter in the health-effect equation, but for perturbations greater than 80%, the beta coefficient begins to have more significance.

In the uncertainty analysis all the parameters are modified simultaneously rather than each one at a time as in the sensitivity analysis. The variations are selected randomly and based upon the probability distribution of each input parameter. The general purpose is to determine the Probability Mass Function (PMF) of the outcome (number of hospital admissions) as is requested by EPA for risk assessment.

After running the Monte Carlo simulation option in ORAM, the variability of the hospital admissions and the probability associated to each admission were calculated. The results for the test application in East Tennessee show that a great uncertainty is expected in the number of hospital admissions using either maximum 1-hr or 8-hr ozone exposure.

That information means that a decision maker should be cautious in using and communicating the results of the health evaluation, and it also shows the need for improving the information required for reducing the uncertainty (in this case, the admission rate by county).

5.4 Comparison between ORAM and CAPMS models

ORAM (Ozone Risk Assessment Model) is the model developed in this dissertation project. CAPMS (Criteria Air Pollutant Model System) is the model developed by Abt Associates, Inc., that EPA has been using for its Regulatory Impact Assessment rulemaking that affects the air quality.

Even though both models are based upon the same basic equation, the calculation of the health-effects from a regulatory measure that reduces the emissions of the ozone precursors is different. The basic equation, assuming Poisson regression for the ozone health-effects, is given by

$$HA = yP\,[\mathrm{Exp}\,(\beta O_3) - 1] \qquad \text{(Equation 5-1)}$$

Where,

HA	=	Hospital admission due to ozone concentration
y	=	Admission rate
P	=	Population
β	=	Ozone coefficient from the epidemiological model
O_3	=	Ozone exposure level

Health-effect calculation of a regulatory measure

a) ORAM calculation

ORAM calculates first the number of hospital admission for the base case, then the number of hospital admission due to the regulatory measure; finally, it subtracts these two quantities to obtain the number of hospital admissions saved if the regulation is in place.

$$HA_B = yP\ [(Exp\ (\beta O_{3B}) - 1] \quad \text{(Equation 5-2)}$$

$$HA_M = yP\ [(Exp\ (\beta O_{3M}) - 1] \quad \text{(Equation 5-3)}$$

$$\Delta HA = HA_B - HA_M \quad \text{(Equation 5-4)}$$

Or $$\Delta HA = yP\ [(Exp\ (\beta O_{3B}) - (Exp\ (\beta O_{3M})] \quad \text{(Equation 5-5)}$$

Where,

HA_B = Nº of Hospital admissions due to ozone concentration in the base case
HA_B = Nº of Hospital admissions with the control scenario
ΔHA = Number of hospital admissions saved if the regulatory measure is implemented
O_{3B} = Ozone concentration with the base case emission scenario
O_{3M} = Ozone concentration with the emission control scenario

b) CAPMS calculation

CAPMS calculates first the difference between base case ozone concentration and the ozone due to the regulatory measure; then it applies the basic equation:

$$\Delta HA = yP\ [(Exp\ (\beta\{O_{3B} - O_{3M}\} - 1] \quad \text{(Equation 5-6)}$$

CAPMS has two errors in the way it calculates the health-effects impact due to a regulatory action. First, its assumes that the health benefits are the same if the ozone concentration reduces from 120 to 110 or 60 to 50, because it considers the difference between the base case and the future case regardless of the absolute concentration values, which is incorrect. Secondly, the equation used is not correct because

$$[(\mathrm{Exp}\ (\beta O_{3B}) - (\mathrm{Exp}\ (\beta O_{3M})] \neq \qquad [(\mathrm{Exp}\ (\beta(O_{3B} - O_{3M}) - 1]$$

This expression is valid only if O_{3M} is zero.

The error using the CAPMS equation will produce an underestimation in the number of hospital admissions and also in the associated cost. The absolute error will depend on the base case and predicted ozone concentration. For example, if the base case ozone level is 125 ppb and the predicted ozone when the NOx emission control is in place is 110 ppb, and by using the admission rate, beta coefficient, and population as in Tier-2 rulemaking, an underestimation of 40% is expected in the number of hospital admissions and the costs associated with them using CAPMS instead of ORAM.

CAPMS also does not take into account that at night the ozone concentration increases when implementing a regulatory action that reduces the ozone precursors. That is because of the lack of NOx available to scavenge the ground-level ozone at night. CAPMS takes the reduction of the peak hour and applies this factor to the hourly ozone distribution, meaning that every hour will have less ozone concentration, proportional to the reduction

of the maximum during the day. Because the ORAM criteria used to select representative days consider not only episodic but also low ozone days, that mechanism allows for a more realistic picture that is more representative of the entire ozone season.

CHAPTER 6

CONCLUSIONS AND RECOMMENDATIONS

6.1 Conclusions

The evaluation of the health-effects associated with air pollutant emission control will continue to be one of the key issues in the EPA rulemaking if the objectives of the CAA must be met. In this context, ORAM, the model developed in this study can, be used by decision-makers in the quantitative assessment of new policies that will affect the air quality.

Upon completion, this work demonstrates that:

- ORAM can be applied to policy-decisions with regard to emission regulations
- Models-3/CMAQ coupled with ORAM is suitable for ozone-health assessment
- ORAM has the flexibility to incorporate new health-effects data and other pollutants, and is therefore applicable to a more comprehensive economic valuation.
- Local input data should be used in environmental decision-making because default values could lead to different policy decisions.
- Even though the exposure model (Models-3/CMAQ) is the state-of-the-art EPA photochemical model, it is still under development and several issues need to be

addressed before it can be used it in regulatory applications (vertical layer collapse, chemical mechanisms, and PM speciation, among others).

Running Models-3/CMAQ for developing the ozone concentrations inputs for ORAM has contributed greatly to enriching the experience in air quality modeling. This experience can be summarized as follows:

- º A great deal of experience was gained in installing, configuring, and running Models-3/CMAQ and associated software. Also it was a gain in understanding the key components of Models-3/CMAQ.

- º It was possible to perform meteorological modeling of selected days and periods using MM5, emission processing using SMOKE, and ozone simulations using CCTM. All these software applications represent the state-of-the-art in air quality modeling and were used to generate inputs for ORAM, the model developed in this work.

Models-3/CMAQ

During the model performance evaluation step, when comparing model data with observations, one must take into account that the evaluation is based on comparing modeled grid-average values with point measurements. For this reason, a perfect agreement is not expected. Also, from a health-effects point of view, the ozone metric

(daily ozone maximum 1-hr and daily ozone maximum 8-hr) is the relevant measure rather than hourly agreements.

The layer structure chosen for a modeling application should be capable of adequately resolving diurnal variations in boundary layer growth and mixing processes therein, wind shear, and transport to and from the free troposphere and consequent effects of long-range transport processes. To eliminate errors associated with aggregating layer data, it was desirable to use the same layer structure in the chemistry-transport model (CCTM) as in the meteorological model (MM5), but because of resource restrictions (computational costs and time), the data generated by MM5 had to be aggregated to a coarse layer structure using MCIP processor. This approach leads to some problems with the PBL and wind fields. In Models-3/CMAQ, documentation (Byun et al 1999) cautions users about potential consistency problems with the collapsing of layers and recommends using the procedure only for system test runs, code development, and debugging.

The wind speeds were overpredicted in all category-days, and it is likely that the depth of the first layer used in MM5/MCIP (144m) was not adequate to represent surface variations. Furthermore, MM5 is more suitable for mesoscale applications, and for this reason, predictions above the PBL show a very good agreement (>90% as reported by SMRAQ 1998).

In Models-3/CMAQ, the Initial and Boundary conditions are time-invariant and are applied to the entire modeling domain, which produces a limitation in the emission

control scenario for analyzing the transport and local contribution. The limitation arises because the user cannot set different initial conditions in an inner sub-domain like other photochemical models such as the URM (Russell et al 2000).

It was demonstrated that during expected high-ozone days in East Tennessee, the NOx control strategies tested produced a decrease of the peak ozone concentration during the day (as it is expected), but an increase in ozone concentration during the night (see Figure 6-1). This phenomenon was also found in other modeling applications in Columbus, Georgia, and the Appalachian areas (Russell et al 2000) and it was explained because of the lack of NOx that reduce the capacity for scavenging ozone in NOx-limited areas. This phenomenon generates a reduction in the health-effects impact when using maximum 8-hr ozone exposure, because of the way this metric is calculated (moving average).

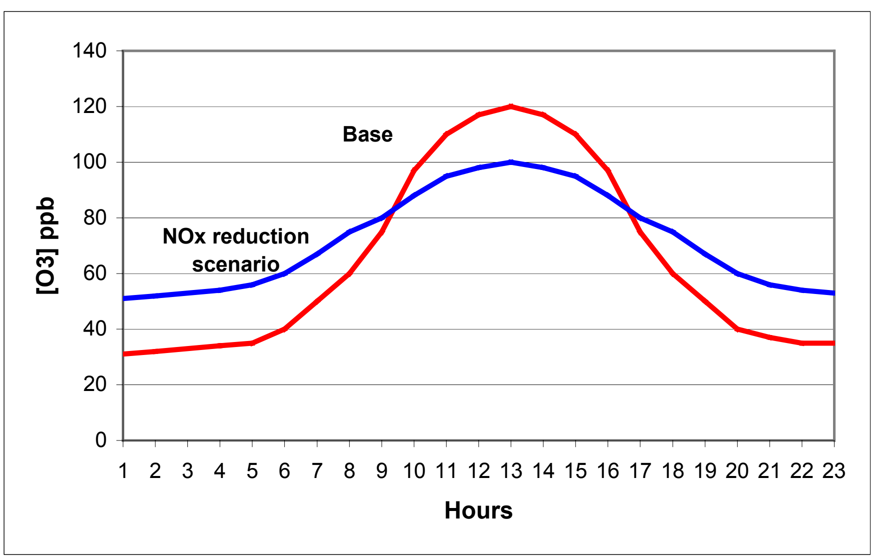


Figure 6-1: Hourly ozone profile for two NOx emission scenarios

Another finding of this study was that during expected low ozone days in East Tennessee, the NOx reduction produces an increase in the ozone concentration during each hour of the day (an upward shift in the ozone hourly profile). This finding has not been discussed in the literature because previous modeling applications have been based on episodic days rather than lower ozone days. The explanation for this phenomenon is not clear at all, but it is likely that the transport of ozone from other areas (specially VOC limited areas) may contribute to an increase in the ozone in East Tennessee. On lower-ozone days, the temperature was low, and the wind speed was high (see Figure 6-2), meaning that local emissions had an impact on ozone several miles downwind. For the same reason, it was highly likely that regional transport could be the dominant effect in the ozone distribution. The ORAM model accounts for these phenomena by considering low as well as episodic days as a means of expanding the health-effects to the ozone season. Indeed, it was during the analysis of the ORAM results that these singularities were discovered.

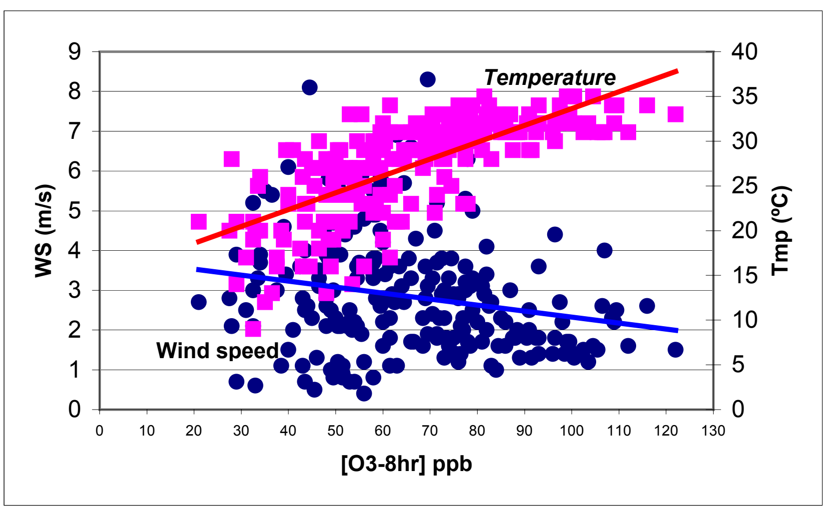


Figure 6-2: Ozone concentrations (maximum 8-hr) versus wind speed and temperature in Knoxville, 1998.

ORAM application test for East Tennessee

The reduction of NOx emissions (50% mobile source, and 70% Point sources) has only a positive effect (reduction in ground-level ozone concentrations) in those days when the expected level of ozone was greater than approximately 55 ppb (max 1-hr) or 50 ppb (max 8-hr), and that happens in 82% and 76% of the ozone season, respectively. When the expected ozone concentration was less than the threshold above, there was not enough NOx to scavenge the ozone to NO_2 or NO_3.

From a health point of view, the reduction of NOx emissions by 50% from mobile sources or 70% from major point sources produces almost the same effect (number of admissions), but when both reductions are applied simultaneously, the synergism in the ozone reduction produces better results. For example, by using ozone maximum 1-hr exposure, the percentage reduction in asthma hospital admissions was 8% for mobile source and 7% for point source, but combined reductions lowered admissions by 19%.

The reduction in the number of hospitalizations for respiratory diseases, when there was a decrease in NOx emissions, was more significant in the short-term exposure (1-hr) than 8-hr exposure. That result was particularly true for point source reduction with 8-hr ozone exposure (e.g., COPD 4.6% reduction with mobile source control and 1.4% reduction with point source control). Thus, to reduce the risk on health-effects for ozone 8-hr exposure, more stringent control measures should be applied to NOx sources in East Tennessee. Also, mobile source emission reductions are more effective in reducing the maximum 8-hr ozone concentrations than point source emission reductions.

People in East Tennessee are willing to pay \$4.6 million per ozone season to reduce 50% of mobile source NOx emissions and avoid hospitalization for respiratory obstructive diseases. With this emission scenario, \$2.1 million are saved from treatment costs and \$0.8 million are avoided in hospital costs.

Reducing 70% of NOx emissions from major point sources represents \$4.2 million that the people in East Tennessee are willing to pay to avoid hospitalization for respiratory obstructive diseases during the ozone season; \$1.9 million are saved from treatment costs, and \$0.7 million are avoided in hospital costs.

Reducing 50% of mobile NOx emissions and 70% of NOx in point sources simultaneously, represents \$11.7 million per ozone season that the people in East Tennessee are willing to pay to avoid hospitalization for respiratory obstructive diseases; \$5.3 million are saved from treatment costs, and \$2.0 million are avoided in hospital costs.

6.2 Recommendations

Based upon the experienced gained in running different scenarios and from the literature review, the following list presents the main recommendations for improving air quality modeling:

º In order to improve the ozone predictions, it is desirable to increase the number of vertical layers to as many as those used by the meteorology model, or to reduce the thickness of the first layers. These provisions allow a better treatment of the nighttime scavenging of ozone by surface NO emissions.

º One of the weaknesses of MCIP is that it rediagnoses the PBL parameters to be at the top of the layer in which the predicted PBL height falls. It is expected that a new version of MCIP will pass-through the option of PBL and will allow use of the same parameters as those simulated by MM5.

º While the CB4 provides the greatest computational efficiency, it was developed for high NOx, typically urban conditions. Both the RADM2 and SAPRC99 gas phase mechanisms were specifically developed for regional, low-NOx conditions, and therefore these mechanisms include a more detailed representation of the fate of NOx and of the chemistry of peroxyl radical species (which are important at low NOx).

6.3 Future work

Model development is a learning process, beginning with a prototype that can meet the initial objectives; then, it grows in complexity through new options included each time new inputs or ideas come up in this learning process. It requires decisions about the level of detail, computer run-time and memory, and between the policy questions of concern, and the limitations on what questions the model can address.

In this context, the ORAM model was developed following this process. Many new ideas of improvement were natural extensions of a decision-making tool that is to be used for evaluating regulatory emission actions. Still ORAM can be improved by incorporating other health endpoints such as mortality, cardiovascular diseases, and minor restricted activity days, among others, and not only ozone pollutant but also other gases and particulate matter could be included in the health evaluation. The only restriction is the availability of local parameters of the concentration-response functions and its admission rates. As a general estimation, it could be possible to use the EPA default values, but as this study shows, local parameters provide better estimates of pollution and human health. Another improvement in ORAM is to incorporate the error estimation in the economic coefficients (WTP, COI and COH), to reflect the uncertainty in the economic valuation calculation.

Finally, the ORAM model was designed as a tool for health evaluation of regulatory actions that impact air quality. In this regard, ORAM can be extended to run in three different modes. Currently ORAM runs under the *emission regulatory mode* that affects the ozone precursors (basically NOx and VOC). Another mode could be to evaluate the health impact of a new ozone *air quality standard* (NAAQS). This mode could evaluate the what-if scenario for different proposed NAAQS for ozone and other pollutants. Also, in a more ambitious way, the ORAM system could be used in a *forecast mode* to predict the number of hospital admissions for respiratory disease expected tomorrow, by using the MM5 forecast capabilities. This last mode could be useful in ozone action programs such as Spare the Air or Ozone Action Days

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APPENDICES

Appendix A
ORAM Output: Base Case

```
 OUTPUT FROM ORAM SYSTEM     Version 1.0
         PSH (December 2001)
=========================================

 Name for this simulation : SCENARIO BASE
 Date of simulation       : Sat Dec 14 16:45:22 2001
 Health parameters        : KNOX
```

Relative Risk by Respiratory Disease: O3-1hr

Disease	RR	LL(5%)	UL(95%)
Asthma	1.127	1.029	1.234
Copd	1.082	1.039	1.126
Copd65	1.082	1.025	1.142

Relative Risk by Respiratory Disease: O3-8hr

Disease	RR	LL(5%)	UL(95%)
Asthma	1.113	1.016	1.219
Copd	1.069	1.025	1.114
Copd65	1.074	1.016	1.136

***** Hospital Admissions Deterministic Results *****

ASTHMA ADMISSIONS USING OZONE_1hr

County	Expected	+/- SE	%Population
Anderson	33.	14.	0.06
Bledsoe	5.	2.	0.05
Blount	49.	20.	0.06
Bradley	34.	14.	0.05
Campbell	31.	13.	0.10
Carter	43.	19.	0.10
Claiborne	20.	9.	0.09
Cocke	20.	9.	0.08
Cumberland	25.	10.	0.07
Grainger	12.	5.	0.08
Greene	35.	15.	0.07
Hamblen	35.	15.	0.08
Hamilton	134.	55.	0.06
Hancock	4.	2.	0.08
Hawkins	31.	13.	0.08
Jefferson	30.	13.	0.09
Johnson	15.	7.	0.11
Knox	237.	102.	0.08
Loudon	17.	7.	0.06
Marion	11.	4.	0.05
McMinn	22.	9.	0.06
Meigs	4.	2.	0.05
Monroe	17.	7.	0.06
Morgan	9.	4.	0.06
Polk	6.	3.	0.05
Rhea	12.	5.	0.05
Roane	21.	9.	0.05
Scott	13.	5.	0.08
Sevier	43.	19.	0.08
Sullivan	52.	22.	0.04
Unicoi	10.	4.	0.07
Union	12.	5.	0.09
Washington	59.	25.	0.07

COPD ADMISSIONS USING OZONE_1hr

County	Expected	+/- SE	%Population
Anderson	136.	38.	0.25
Bledsoe	21.	6.	0.22
Blount	204.	56.	0.25
Bradley	137.	37.	0.20
Campbell	132.	37.	0.43
Carter	182.	52.	0.41
Claiborne	85.	24.	0.37
Cocke	84.	23.	0.32
Cumberland	103.	28.	0.28
Grainger	52.	15.	0.33
Greene	147.	41.	0.30
Hamblen	146.	41.	0.33
Hamilton	551.	150.	0.23
Hancock	17.	5.	0.32
Hawkins	130.	36.	0.32
Jefferson	126.	36.	0.37
Johnson	64.	19.	0.46
Knox	996.	281.	0.34
Loudon	70.	19.	0.23
Marion	43.	12.	0.21
McMinn	91.	25.	0.24
Meigs	18.	5.	0.22
Monroe	69.	19.	0.23
Morgan	38.	10.	0.25
Polk	25.	7.	0.20
Rhea	47.	13.	0.22
Roane	87.	24.	0.22
Scott	54.	15.	0.34
Sevier	181.	51.	0.33
Sullivan	223.	62.	0.19
Unicoi	41.	11.	0.29
Union	50.	14.	0.38
Washington	245.	69.	0.29

COPD65 ADMISSIONS USING OZONE_1hr

County	Expected	+/- SE	%Population
Anderson	105.	39.	0.89
Bledsoe	11.	4.	0.79
Blount	133.	49.	0.89
Bradley	77.	28.	0.75
Campbell	87.	33.	1.45
Carter	118.	45.	1.38
Claiborne	51.	19.	1.28
Cocke	52.	19.	1.13
Cumberland	94.	35.	0.98
Grainger	29.	11.	1.14
Greene	98.	37.	1.05
Hamblen	88.	33.	1.14
Hamilton	356.	131.	0.84
Hancock	12.	4.	1.11
Hawkins	78.	29.	1.10
Jefferson	73.	27.	1.27
Johnson	40.	16.	1.54
Knox	563.	213.	1.16
Loudon	52.	19.	0.82
Marion	27.	10.	0.75
McMinn	61.	23.	0.87
Meigs	10.	4.	0.79
Monroe	43.	16.	0.84
Morgan	20.	7.	0.89
Polk	17.	6.	0.75
Rhea	31.	11.	0.79
Roane	66.	24.	0.79
Scott	28.	11.	1.19
Sevier	103.	39.	1.15
Sullivan	155.	58.	0.64
Unicoi	33.	12.	1.02
Union	25.	9.	1.30
Washington	152.	57.	1.02

ASTHMA ADMISSIONS USING OZONE_8hr

County	Expected	+/- SE	%Population
Anderson	30.	20.	0.05
Bledsoe	6.	3.	0.06
Blount	55.	30.	0.07
Bradley	37.	21.	0.06
Campbell	28.	18.	0.09
Carter	47.	26.	0.10
Claiborne	22.	12.	0.10
Cocke	23.	12.	0.09
Cumberland	26.	15.	0.07
Grainger	15.	8.	0.09
Greene	41.	22.	0.08
Hamblen	41.	21.	0.09
Hamilton	138.	81.	0.06
Hancock	5.	2.	0.09
Hawkins	34.	19.	0.08
Jefferson	34.	18.	0.10
Johnson	17.	9.	0.12
Knox	242.	140.	0.08
Loudon	19.	10.	0.06
Marion	12.	7.	0.06
McMinn	23.	14.	0.06
Meigs	5.	3.	0.06
Monroe	19.	10.	0.06
Morgan	10.	6.	0.07
Polk	7.	4.	0.06
Rhea	13.	7.	0.06
Roane	24.	13.	0.06
Scott	13.	7.	0.08
Sevier	42.	25.	0.08
Sullivan	48.	30.	0.04
Unicoi	11.	6.	0.08
Union	13.	7.	0.10
Washington	67.	36.	0.08

COPD ADMISSIONS USING OZONE_8hr

County	Expected	+/- SE	%Population
Anderson	152.	68.	0.28
Bledsoe	30.	11.	0.31
Blount	270.	105.	0.33
Bradley	192.	77.	0.29
Campbell	132.	57.	0.43
Carter	210.	81.	0.47
Claiborne	102.	39.	0.45
Cocke	108.	41.	0.42
Cumberland	128.	50.	0.35
Grainger	68.	25.	0.43
Greene	194.	73.	0.40
Hamblen	190.	71.	0.43
Hamilton	705.	290.	0.30
Hancock	22.	8.	0.42
Hawkins	163.	62.	0.40
Jefferson	155.	59.	0.45
Johnson	75.	28.	0.53
Knox	1135.	459.	0.38
Loudon	94.	36.	0.31
Marion	63.	24.	0.30
McMinn	117.	47.	0.31
Meigs	25.	10.	0.30
Monroe	94.	36.	0.32
Morgan	50.	20.	0.33
Polk	36.	14.	0.29
Rhea	67.	26.	0.31
Roane	122.	48.	0.30
Scott	61.	25.	0.39
Sevier	205.	85.	0.37
Sullivan	233.	104.	0.19
Unicoi	53.	20.	0.37
Union	60.	23.	0.45
Washington	315.	119.	0.37

COPD65 ADMISSIONS USING OZONE_8hr

County	Expected	+/- SE	%Population
Anderson	97.	57.	0.82
Bledsoe	13.	6.	0.92
Blount	149.	73.	1.00
Bradley	85.	44.	0.83
Campbell	81.	45.	1.35
Carter	130.	63.	1.53
Claiborne	57.	28.	1.42
Cocke	60.	28.	1.31
Cumberland	102.	51.	1.06
Grainger	35.	16.	1.34
Greene	114.	54.	1.23
Hamblen	104.	48.	1.34
Hamilton	371.	198.	0.87
Hancock	14.	7.	1.32
Hawkins	87.	42.	1.23
Jefferson	83.	39.	1.44
Johnson	46.	22.	1.76
Knox	583.	301.	1.20
Loudon	59.	29.	0.93
Marion	31.	15.	0.87
McMinn	65.	34.	0.93
Meigs	11.	6.	0.89
Monroe	50.	24.	0.97
Morgan	22.	11.	0.98
Polk	19.	10.	0.83
Rhea	36.	17.	0.92
Roane	75.	37.	0.89
Scott	29.	15.	1.20
Sevier	103.	55.	1.15
Sullivan	146.	80.	0.60
Unicoi	37.	18.	1.17
Union	28.	13.	1.43
Washington	175.	83.	1.17

RESPIRATORY DOCTOR VISITS USING OZONE_1hr

County	Expected	+/- SE	%Population
Anderson	438.	183.	0.80
Bledsoe	68.	28.	0.71
Blount	652.	269.	0.80
Bradley	449.	184.	0.67
Campbell	407.	176.	1.33
Carter	565.	247.	1.27
Claiborne	266.	115.	1.17
Cocke	265.	113.	1.02
Cumberland	325.	135.	0.88
Grainger	165.	70.	1.03
Greene	465.	196.	0.95
Hamblen	461.	196.	1.03
Hamilton	1773.	728.	0.75
Hancock	53.	22.	1.01
Hawkins	407.	173.	0.99
Jefferson	395.	170.	1.16
Johnson	200.	89.	1.42
Knox	3135.	1353.	1.06
Loudon	225.	92.	0.74
Marion	142.	58.	0.67
McMinn	292.	122.	0.78
Meigs	58.	24.	0.70
Monroe	222.	91.	0.76
Morgan	121.	50.	0.80
Polk	83.	34.	0.67
Rhea	154.	63.	0.71
Roane	283.	115.	0.70
Scott	167.	70.	1.07
Sevier	572.	245.	1.04
Sullivan	688.	291.	0.57
Unicoi	130.	55.	0.92
Union	157.	67.	1.18
Washington	779.	333.	0.92

RESPIRATORY DOCTOR VISITS USING OZONE_8hr

County	Expected	+/- SE	%Population
Anderson	396.	259.	0.72
Bledsoe	77.	41.	0.81
Blount	720.	391.	0.88
Bradley	489.	279.	0.73
Campbell	369.	232.	1.20
Carter	614.	338.	1.38
Claiborne	290.	159.	1.27
Cocke	303.	161.	1.17
Cumberland	347.	192.	0.94
Grainger	192.	100.	1.20
Greene	537.	284.	1.10
Hamblen	537.	281.	1.20
Hamilton	1820.	1074.	0.77
Hancock	62.	32.	1.18
Hawkins	453.	246.	1.10
Jefferson	443.	238.	1.30
Johnson	225.	122.	1.60
Knox	3193.	1854.	1.08
Loudon	251.	136.	0.82
Marion	163.	89.	0.77
McMinn	306.	178.	0.82
Meigs	65.	36.	0.78
Monroe	251.	134.	0.86
Morgan	132.	73.	0.87
Polk	91.	52.	0.73
Rhea	176.	94.	0.81
Roane	317.	174.	0.78
Scott	167.	96.	1.07
Sevier	560.	335.	1.02
Sullivan	638.	390.	0.53
Unicoi	147.	79.	1.05
Union	170.	94.	1.28
Washington	885.	474.	1.05

+++++++ STATISTICS FOR EAST TENNESSEE ++++++++

Name for this simulation : SCENARIO BASE
Total Expected Hospital admissions in East TN - O3 season

Due to short exposure: O3-1hr

Disease	Expected	±SE	5%	95%	%_Pop_Avg	%_Pop_5%	%_Pop_95%
Asthma	1103.	134.	249.	2084.	0.068	0.015	0.128
Copd	4595.	367.	2160.	7181.	0.282	0.133	0.441
Copd65	2889.	295.	858.	5093.	0.982	0.292	1.731
Resp_DV	14560.	1763.	3281.	27510.	0.894	0.201	1.689

Due to medium exposure: O3-8hr

Disease	Expected	±SE	5%	95%	%_Pop_Avg	%_Pop_5%	%_Pop_95%
Asthma	1166.	187.	162.	2339.	0.072	0.010	0.144
Copd	5625.	628.	2007.	9524.	0.345	0.123	0.585
Copd65	3096.	426.	644.	5792.	1.052	0.219	1.969
Resp_DV	15385.	2467.	2143.	30881.	0.944	0.132	1.895

*** ECONOMIC VALUATION USING WTP/COI/COH ESTIMATION ***

$$

Name for this simulation : SCENARIO BASE

WTP ESTIMATION
COST (Million US$) OF AVOIDING ASTHMA HOSPITALIZATION (OZONE_1hr)
(Expected and 90% CI)

County	Cost_avg	Cost_L(5%)	Cost_U(95%)
Anderson	0.298	0.068	0.559
Bledsoe	0.046	0.011	0.085
Blount	0.444	0.102	0.823
Bradley	0.306	0.071	0.562
Campbell	0.278	0.061	0.535
Carter	0.385	0.084	0.750
Claiborne	0.182	0.040	0.349
Cocke	0.181	0.041	0.343
Cumberland	0.221	0.051	0.412
Grainger	0.112	0.025	0.213
Greene	0.317	0.072	0.598
Hamblen	0.314	0.070	0.597
Hamilton	1.209	0.279	2.227
Hancock	0.036	0.008	0.068
Hawkins	0.278	0.062	0.526
Jefferson	0.269	0.060	0.516
Johnson	0.136	0.029	0.269
Knox	2.137	0.474	4.108
Loudon	0.153	0.035	0.282
Marion	0.097	0.023	0.178
McMinn	0.199	0.046	0.371
Meigs	0.040	0.009	0.073
Monroe	0.151	0.035	0.279
Morgan	0.083	0.019	0.152
Polk	0.057	0.013	0.104
Rhea	0.105	0.024	0.194
Roane	0.193	0.045	0.354
Scott	0.114	0.026	0.213
Sevier	0.390	0.087	0.746
Sullivan	0.469	0.106	0.885
Unicoi	0.088	0.020	0.168
Union	0.107	0.024	0.205
Washington	0.531	0.119	1.012

COST (Million US$) OF AVOIDING COPD HOSPITALIZATION (OZONE_1hr)
(Expected and 90% CI)

County	Cost_avg	Cost_L(5%)	Cost_U(95%)
Anderson	1.824	0.861	2.841
Bledsoe	0.279	0.133	0.431
Blount	2.729	1.294	4.227
Bradley	1.835	0.874	2.831
Campbell	1.766	0.823	2.784
Carter	2.434	1.129	3.854
Claiborne	1.140	0.532	1.795
Cocke	1.125	0.528	1.762
Cumberland	1.375	0.651	2.133
Grainger	0.700	0.328	1.097
Greene	1.975	0.929	3.084
Hamblen	1.960	0.919	3.070
Hamilton	7.382	3.510	11.403
Hancock	0.223	0.105	0.349
Hawkins	1.735	0.815	2.713
Jefferson	1.690	0.789	2.658
Johnson	0.862	0.397	1.374
Knox	13.344	6.224	21.023
Loudon	0.933	0.444	1.441
Marion	0.583	0.278	0.898
McMinn	1.220	0.577	1.894
Meigs	0.241	0.115	0.371
Monroe	0.922	0.438	1.427
Morgan	0.509	0.242	0.786
Polk	0.340	0.162	0.524
Rhea	0.636	0.302	0.983
Roane	1.170	0.558	1.803
Scott	0.720	0.340	1.120
Sevier	2.420	1.131	3.806
Sullivan	2.993	1.409	4.672
Unicoi	0.546	0.256	0.857
Union	0.673	0.315	1.059
Washington	3.280	1.535	5.149

COST (Million US$) OF AVOIDING COPD65 HOSPITALIZATION (OZONE_1hr)
(Expected and 90% CI)

County	Cost_avg	Cost_L(5%)	Cost_U(95%)
Anderson	1.670	0.498	2.930
Bledsoe	0.178	0.054	0.310
Blount	2.111	0.633	3.681
Bradley	1.226	0.370	2.126
Campbell	1.391	0.408	2.481
Carter	1.874	0.547	3.361
Claiborne	0.816	0.240	1.452
Cocke	0.820	0.243	1.450
Cumberland	1.499	0.449	2.620
Grainger	0.468	0.139	0.828
Greene	1.558	0.463	2.745
Hamblen	1.403	0.415	2.480
Hamilton	5.664	1.705	9.845
Hancock	0.189	0.056	0.333
Hawkins	1.233	0.366	2.175
Jefferson	1.156	0.340	2.055
Johnson	0.644	0.187	1.165
Knox	8.946	2.631	15.932
Loudon	0.829	0.249	1.440
Marion	0.429	0.130	0.744
McMinn	0.973	0.291	1.701
Meigs	0.159	0.048	0.276
Monroe	0.690	0.207	1.201
Morgan	0.323	0.097	0.561
Polk	0.273	0.082	0.474
Rhea	0.495	0.149	0.861
Roane	1.045	0.316	1.811
Scott	0.451	0.134	0.791
Sevier	1.636	0.482	2.907
Sullivan	2.463	0.731	4.339
Unicoi	0.517	0.153	0.917
Union	0.398	0.117	0.708
Washington	2.410	0.712	4.272

COST (Million US$) OF AVOIDING ASTHMA HOSPITALIZATION (OZONE_8hr)
(Expected and 90% CI)

County	Cost_avg	Cost_L(5%)	Cost_U(95%)
Anderson	0.270	0.038	0.534
Bledsoe	0.053	0.008	0.103
Blount	0.491	0.069	0.967
Bradley	0.334	0.048	0.651
Campbell	0.252	0.035	0.508
Carter	0.419	0.056	0.871
Claiborne	0.198	0.027	0.404
Cocke	0.206	0.028	0.419
Cumberland	0.236	0.033	0.466
Grainger	0.131	0.018	0.266
Greene	0.366	0.051	0.740
Hamblen	0.366	0.050	0.745
Hamilton	1.241	0.177	2.430
Hancock	0.042	0.006	0.085
Hawkins	0.309	0.043	0.627
Jefferson	0.302	0.041	0.619
Johnson	0.154	0.020	0.328
Knox	2.177	0.299	4.427
Loudon	0.171	0.024	0.335
Marion	0.111	0.016	0.216
McMinn	0.209	0.029	0.414
Meigs	0.044	0.006	0.087
Monroe	0.171	0.024	0.337
Morgan	0.090	0.013	0.176
Polk	0.062	0.009	0.121
Rhea	0.120	0.017	0.236
Roane	0.216	0.031	0.420
Scott	0.114	0.016	0.225
Sevier	0.382	0.053	0.763
Sullivan	0.435	0.061	0.866
Unicoi	0.100	0.014	0.204
Union	0.116	0.016	0.236
Washington	0.603	0.083	1.228

COST (Million US$) OF AVOIDING COPD HOSPITALIZATION (OZONE_8hr)
(Expected and 90% CI)

County	Cost_avg	Cost_L(5%)	Cost_U(95%)
Anderson	2.032	0.729	3.418
Bledsoe	0.396	0.142	0.664
Blount	3.621	1.300	6.091
Bradley	2.572	0.928	4.306
Campbell	1.763	0.627	2.993
Carter	2.812	0.989	4.833
Claiborne	1.367	0.484	2.332
Cocke	1.449	0.515	2.464
Cumberland	1.717	0.616	2.889
Grainger	0.912	0.323	1.554
Greene	2.595	0.923	4.406
Hamblen	2.553	0.905	4.348
Hamilton	9.452	3.404	15.847
Hancock	0.294	0.104	0.500
Hawkins	2.183	0.776	3.713
Jefferson	2.080	0.736	3.553
Johnson	1.005	0.350	1.744
Knox	15.203	5.396	25.885
Loudon	1.261	0.454	2.117
Marion	0.847	0.306	1.418
McMinn	1.565	0.561	2.634
Meigs	0.338	0.122	0.565
Monroe	1.264	0.454	2.124
Morgan	0.669	0.241	1.122
Polk	0.476	0.172	0.797
Rhea	0.901	0.324	1.512
Roane	1.641	0.592	2.747
Scott	0.814	0.292	1.373
Sevier	2.747	0.982	4.645
Sullivan	3.120	1.116	5.269
Unicoi	0.704	0.250	1.198
Union	0.800	0.283	1.364
Washington	4.227	1.500	7.199

COST (Million US$) OF AVOIDING COPD65 HOSPITALIZATION (OZONE_8hr)
(Expected and 90% CI)

County	Cost_avg	Cost_L(5%)	Cost_U(95%)
Anderson	1.537	0.323	2.852
Bledsoe	0.207	0.044	0.382
Blount	2.363	0.496	4.376
Bradley	1.354	0.286	2.493
Campbell	1.289	0.267	2.419
Carter	2.065	0.421	3.948
Claiborne	0.902	0.186	1.705
Cocke	0.949	0.196	1.787
Cumberland	1.624	0.341	3.009
Grainger	0.552	0.114	1.042
Greene	1.819	0.377	3.418
Hamblen	1.653	0.341	3.120
Hamilton	5.894	1.243	10.871
Hancock	0.224	0.046	0.421
Hawkins	1.386	0.286	2.610
Jefferson	1.312	0.270	2.487
Johnson	0.734	0.148	1.425
Knox	9.272	1.915	17.489
Loudon	0.936	0.197	1.729
Marion	0.497	0.105	0.914
McMinn	1.033	0.217	1.918
Meigs	0.181	0.038	0.332
Monroe	0.793	0.167	1.466
Morgan	0.355	0.075	0.656
Polk	0.302	0.064	0.556
Rhea	0.575	0.121	1.061
Roane	1.185	0.251	2.178
Scott	0.457	0.096	0.849
Sevier	1.639	0.342	3.059
Sullivan	2.325	0.486	4.330
Unicoi	0.596	0.123	1.125
Union	0.438	0.090	0.827
Washington	2.776	0.573	5.240

COI ESTIMATION

COST (Million US$) OF ASTHMA HOSPITALIZATION (OZONE_1hr)
(Expected and 90% CI)

County	Cost_avg	Cost_L(5%)	Cost_U(95%)
Anderson	0.087	0.020	0.163
Bledsoe	0.013	0.003	0.025
Blount	0.130	0.030	0.240
Bradley	0.089	0.021	0.164
Campbell	0.081	0.018	0.156
Carter	0.113	0.025	0.219
Claiborne	0.053	0.012	0.102
Cocke	0.053	0.012	0.100
Cumberland	0.065	0.015	0.120
Grainger	0.033	0.007	0.062
Greene	0.093	0.021	0.175
Hamblen	0.092	0.021	0.174
Hamilton	0.353	0.081	0.651
Hancock	0.010	0.002	0.020
Hawkins	0.081	0.018	0.154
Jefferson	0.079	0.017	0.151
Johnson	0.040	0.009	0.079
Knox	0.624	0.138	1.200
Loudon	0.045	0.010	0.082
Marion	0.028	0.007	0.052
McMinn	0.058	0.013	0.108
Meigs	0.012	0.003	0.021
Monroe	0.044	0.010	0.082
Morgan	0.024	0.006	0.045
Polk	0.017	0.004	0.030
Rhea	0.031	0.007	0.057
Roane	0.056	0.013	0.103
Scott	0.033	0.008	0.062
Sevier	0.114	0.025	0.218
Sullivan	0.137	0.031	0.258
Unicoi	0.026	0.006	0.049
Union	0.031	0.007	0.060
Washington	0.155	0.035	0.296

COST (Million US$) OF COPD HOSPITALIZATION (OZONE_1hr)
(Expected and 90% CI)

County	Cost_avg	Cost_L(5%)	Cost_U(95%)
Anderson	0.832	0.392	1.295
Bledsoe	0.127	0.060	0.197
Blount	1.244	0.590	1.927
Bradley	0.837	0.398	1.291
Campbell	0.805	0.375	1.270
Carter	1.110	0.515	1.757
Claiborne	0.520	0.243	0.818
Cocke	0.513	0.241	0.804
Cumberland	0.627	0.297	0.972
Grainger	0.319	0.150	0.500
Greene	0.901	0.424	1.406
Hamblen	0.893	0.419	1.400
Hamilton	3.366	1.600	5.199
Hancock	0.102	0.048	0.159
Hawkins	0.791	0.372	1.237
Jefferson	0.771	0.360	1.212
Johnson	0.393	0.181	0.626
Knox	6.084	2.838	9.586
Loudon	0.426	0.202	0.657
Marion	0.266	0.127	0.410
McMinn	0.556	0.263	0.863
Meigs	0.110	0.052	0.169
Monroe	0.421	0.200	0.651
Morgan	0.232	0.110	0.359
Polk	0.155	0.074	0.239
Rhea	0.290	0.138	0.448
Roane	0.534	0.254	0.822
Scott	0.328	0.155	0.511
Sevier	1.103	0.516	1.735
Sullivan	1.365	0.642	2.130
Unicoi	0.249	0.117	0.391
Union	0.307	0.144	0.483
Washington	1.496	0.700	2.348

COST (Million US$) OF COPD65 HOSPITALIZATION (OZONE_1hr)
(Expected and 90% CI)

County	Cost_avg	Cost_L(5%)	Cost_U(95%)
Anderson	0.924	0.276	1.621
Bledsoe	0.098	0.030	0.171
Blount	1.168	0.350	2.036
Bradley	0.678	0.204	1.176
Campbell	0.769	0.226	1.373
Carter	1.037	0.303	1.859
Claiborne	0.451	0.133	0.803
Cocke	0.454	0.134	0.802
Cumberland	0.829	0.248	1.449
Grainger	0.259	0.077	0.458
Greene	0.862	0.256	1.518
Hamblen	0.776	0.230	1.372
Hamilton	3.133	0.943	5.446
Hancock	0.104	0.031	0.184
Hawkins	0.682	0.202	1.203
Jefferson	0.639	0.188	1.136
Johnson	0.356	0.103	0.644
Knox	4.949	1.455	8.813
Loudon	0.458	0.138	0.797
Marion	0.237	0.072	0.411
McMinn	0.538	0.161	0.941
Meigs	0.088	0.027	0.153
Monroe	0.382	0.115	0.664
Morgan	0.178	0.054	0.310
Polk	0.151	0.046	0.262
Rhea	0.274	0.082	0.476
Roane	0.578	0.175	1.002
Scott	0.249	0.074	0.438
Sevier	0.905	0.267	1.608
Sullivan	1.362	0.404	2.400
Unicoi	0.286	0.085	0.507
Union	0.220	0.065	0.392
Washington	1.333	0.394	2.363

COST (Million US$) OF ASTHMA HOSPITALIZATION (OZONE_8hr)
(Expected and 90% CI)

County	Cost_avg	Cost_L(5%)	Cost_U(95%)
Anderson	0.079	0.011	0.156
Bledsoe	0.015	0.002	0.030
Blount	0.143	0.020	0.283
Bradley	0.097	0.014	0.190
Campbell	0.074	0.010	0.148
Carter	0.122	0.016	0.255
Claiborne	0.058	0.008	0.118
Cocke	0.060	0.008	0.122
Cumberland	0.069	0.010	0.136
Grainger	0.038	0.005	0.078
Greene	0.107	0.015	0.216
Hamblen	0.107	0.015	0.218
Hamilton	0.363	0.052	0.710
Hancock	0.012	0.002	0.025
Hawkins	0.090	0.012	0.183
Jefferson	0.088	0.012	0.181
Johnson	0.045	0.006	0.096
Knox	0.636	0.087	1.293
Loudon	0.050	0.007	0.098
Marion	0.032	0.005	0.063
McMinn	0.061	0.009	0.121
Meigs	0.013	0.002	0.025
Monroe	0.050	0.007	0.098
Morgan	0.026	0.004	0.051
Polk	0.018	0.003	0.035
Rhea	0.035	0.005	0.069
Roane	0.063	0.009	0.123
Scott	0.033	0.005	0.066
Sevier	0.112	0.016	0.223
Sullivan	0.127	0.018	0.253
Unicoi	0.029	0.004	0.060
Union	0.034	0.005	0.069
Washington	0.176	0.024	0.359

COST (Million US$) OF COPD HOSPITALIZATION (OZONE_8hr)
(Expected and 90% CI)

County	Cost_avg	Cost_L(5%)	Cost_U(95%)
Anderson	0.926	0.333	1.559
Bledsoe	0.180	0.065	0.303
Blount	1.651	0.593	2.777
Bradley	1.173	0.423	1.964
Campbell	0.804	0.286	1.365
Carter	1.282	0.451	2.204
Claiborne	0.623	0.221	1.063
Cocke	0.661	0.235	1.123
Cumberland	0.783	0.281	1.317
Grainger	0.416	0.148	0.708
Greene	1.183	0.421	2.009
Hamblen	1.164	0.413	1.983
Hamilton	4.310	1.552	7.226
Hancock	0.134	0.048	0.228
Hawkins	0.996	0.354	1.693
Jefferson	0.948	0.335	1.620
Johnson	0.458	0.160	0.795
Knox	6.932	2.460	11.803
Loudon	0.575	0.207	0.965
Marion	0.386	0.139	0.647
McMinn	0.713	0.256	1.201
Meigs	0.154	0.056	0.258
Monroe	0.576	0.207	0.968
Morgan	0.305	0.110	0.512
Polk	0.217	0.078	0.363
Rhea	0.411	0.148	0.690
Roane	0.748	0.270	1.252
Scott	0.371	0.133	0.626
Sevier	1.253	0.448	2.118
Sullivan	1.423	0.509	2.403
Unicoi	0.321	0.114	0.546
Union	0.365	0.129	0.622
Washington	1.927	0.684	3.282

COST (Million US$) OF COPD65 HOSPITALIZATION (OZONE_8hr)
(Expected and 90% CI)

County	Cost_avg	Cost_L(5%)	Cost_U(95%)
Anderson	0.850	0.178	1.577
Bledsoe	0.114	0.024	0.211
Blount	1.307	0.275	2.420
Bradley	0.749	0.158	1.379
Campbell	0.713	0.148	1.338
Carter	1.142	0.233	2.184
Claiborne	0.499	0.103	0.943
Cocke	0.525	0.109	0.988
Cumberland	0.898	0.189	1.665
Grainger	0.305	0.063	0.576
Greene	1.006	0.209	1.891
Hamblen	0.914	0.189	1.726
Hamilton	3.260	0.688	6.013
Hancock	0.124	0.026	0.233
Hawkins	0.766	0.158	1.444
Jefferson	0.726	0.149	1.376
Johnson	0.406	0.082	0.788
Knox	5.129	1.059	9.674
Loudon	0.518	0.109	0.957
Marion	0.275	0.058	0.505
McMinn	0.571	0.120	1.061
Meigs	0.100	0.021	0.184
Monroe	0.439	0.092	0.811
Morgan	0.197	0.041	0.363
Polk	0.167	0.035	0.307
Rhea	0.318	0.067	0.587
Roane	0.655	0.139	1.205
Scott	0.253	0.053	0.470
Sevier	0.906	0.189	1.692
Sullivan	1.286	0.269	2.395
Unicoi	0.330	0.068	0.622
Union	0.242	0.050	0.458
Washington	1.536	0.317	2.898

COH ESTIMATION

HOSPITAL COST (Million US$) OF ASTHMA (OZONE_1hr)
(Expected and 90% CI)

County	Cost_avg	Cost_L(5%)	Cost_U(95%)
Anderson	0.031	0.007	0.058
Bledsoe	0.005	0.001	0.009
Blount	0.046	0.011	0.085
Bradley	0.032	0.007	0.058
Campbell	0.029	0.006	0.056
Carter	0.040	0.009	0.078
Claiborne	0.019	0.004	0.036
Cocke	0.019	0.004	0.036
Cumberland	0.023	0.005	0.043
Grainger	0.012	0.003	0.022
Greene	0.033	0.007	0.062
Hamblen	0.033	0.007	0.062
Hamilton	0.125	0.029	0.231
Hancock	0.004	0.001	0.007
Hawkins	0.029	0.006	0.055
Jefferson	0.028	0.006	0.054
Johnson	0.014	0.003	0.028
Knox	0.222	0.049	0.426
Loudon	0.016	0.004	0.029
Marion	0.010	0.002	0.018
McMinn	0.021	0.005	0.039
Meigs	0.004	0.001	0.008
Monroe	0.016	0.004	0.029
Morgan	0.009	0.002	0.016
Polk	0.006	0.001	0.011
Rhea	0.011	0.003	0.020
Roane	0.020	0.005	0.037
Scott	0.012	0.003	0.022
Sevier	0.040	0.009	0.077
Sullivan	0.049	0.011	0.092
Unicoi	0.009	0.002	0.017
Union	0.011	0.002	0.021
Washington	0.055	0.012	0.105

HOSPITAL COST (Million US$) OF COPD (OZONE_1hr)
(Expected and 90% CI)

County	Cost_avg	Cost_L(5%)	Cost_U(95%)
Anderson	0.312	0.147	0.486
Bledsoe	0.048	0.023	0.074
Blount	0.467	0.222	0.724
Bradley	0.314	0.150	0.485
Campbell	0.302	0.141	0.477
Carter	0.417	0.193	0.660
Claiborne	0.195	0.091	0.307
Cocke	0.193	0.090	0.302
Cumberland	0.235	0.111	0.365
Grainger	0.120	0.056	0.188
Greene	0.338	0.159	0.528
Hamblen	0.335	0.157	0.526
Hamilton	1.264	0.601	1.952
Hancock	0.038	0.018	0.060
Hawkins	0.297	0.140	0.465
Jefferson	0.289	0.135	0.455
Johnson	0.148	0.068	0.235
Knox	2.284	1.065	3.599
Loudon	0.160	0.076	0.247
Marion	0.100	0.048	0.154
McMinn	0.209	0.099	0.324
Meigs	0.041	0.020	0.064
Monroe	0.158	0.075	0.244
Morgan	0.087	0.041	0.135
Polk	0.058	0.028	0.090
Rhea	0.109	0.052	0.168
Roane	0.200	0.095	0.309
Scott	0.123	0.058	0.192
Sevier	0.414	0.194	0.652
Sullivan	0.512	0.241	0.800
Unicoi	0.093	0.044	0.147
Union	0.115	0.054	0.181
Washington	0.562	0.263	0.881

HOSPITAL COST (Million US$) OF COPD65 (OZONE_1hr)
(Expected and 90% CI)

County	Cost_avg	Cost_L(5%)	Cost_U(95%)
Anderson	0.355	0.106	0.622
Bledsoe	0.038	0.011	0.066
Blount	0.448	0.135	0.782
Bradley	0.260	0.079	0.452
Campbell	0.295	0.087	0.527
Carter	0.398	0.116	0.714
Claiborne	0.173	0.051	0.308
Cocke	0.174	0.052	0.308
Cumberland	0.318	0.095	0.556
Grainger	0.099	0.029	0.176
Greene	0.331	0.098	0.583
Hamblen	0.298	0.088	0.527
Hamilton	1.203	0.362	2.091
Hancock	0.040	0.012	0.071
Hawkins	0.262	0.078	0.462
Jefferson	0.245	0.072	0.436
Johnson	0.137	0.040	0.247
Knox	1.900	0.559	3.384
Loudon	0.176	0.053	0.306
Marion	0.091	0.028	0.158
McMinn	0.207	0.062	0.361
Meigs	0.034	0.010	0.059
Monroe	0.147	0.044	0.255
Morgan	0.069	0.021	0.119
Polk	0.058	0.018	0.101
Rhea	0.105	0.032	0.183
Roane	0.222	0.067	0.385
Scott	0.096	0.029	0.168
Sevier	0.347	0.102	0.617
Sullivan	0.523	0.155	0.922
Unicoi	0.110	0.032	0.195
Union	0.085	0.025	0.150
Washington	0.512	0.151	0.907

HOSPITAL COST (Million US$) OF ASTHMA (OZONE_8hr)
(Expected and 90% CI)

County	Cost_avg	Cost_L(5%)	Cost_U(95%)
Anderson	0.028	0.004	0.055
Bledsoe	0.005	0.001	0.011
Blount	0.051	0.007	0.100
Bradley	0.035	0.005	0.068
Campbell	0.026	0.004	0.053
Carter	0.043	0.006	0.090
Claiborne	0.021	0.003	0.042
Cocke	0.021	0.003	0.043
Cumberland	0.025	0.003	0.048
Grainger	0.014	0.002	0.028
Greene	0.038	0.005	0.077
Hamblen	0.038	0.005	0.077
Hamilton	0.129	0.018	0.252
Hancock	0.004	0.001	0.009
Hawkins	0.032	0.004	0.065
Jefferson	0.031	0.004	0.064
Johnson	0.016	0.002	0.034
Knox	0.226	0.031	0.459
Loudon	0.018	0.003	0.035
Marion	0.012	0.002	0.022
McMinn	0.022	0.003	0.043
Meigs	0.005	0.001	0.009
Monroe	0.018	0.003	0.035
Morgan	0.009	0.001	0.018
Polk	0.006	0.001	0.013
Rhea	0.012	0.002	0.024
Roane	0.022	0.003	0.044
Scott	0.012	0.002	0.023
Sevier	0.040	0.006	0.079
Sullivan	0.045	0.006	0.090
Unicoi	0.010	0.001	0.021
Union	0.012	0.002	0.024
Washington	0.063	0.009	0.127

HOSPITAL COST (Million US$) OF COPD (OZONE_8hr)
(Expected and 90% CI)

County	Cost_avg	Cost_L(5%)	Cost_U(95%)
Anderson	0.348	0.125	0.585
Bledsoe	0.068	0.024	0.114
Blount	0.620	0.223	1.043
Bradley	0.440	0.159	0.737
Campbell	0.302	0.107	0.512
Carter	0.481	0.169	0.827
Claiborne	0.234	0.083	0.399
Cocke	0.248	0.088	0.422
Cumberland	0.294	0.105	0.495
Grainger	0.156	0.055	0.266
Greene	0.444	0.158	0.754
Hamblen	0.437	0.155	0.744
Hamilton	1.618	0.583	2.713
Hancock	0.050	0.018	0.086
Hawkins	0.374	0.133	0.636
Jefferson	0.356	0.126	0.608
Johnson	0.172	0.060	0.299
Knox	2.603	0.924	4.431
Loudon	0.216	0.078	0.362
Marion	0.145	0.052	0.243
McMinn	0.268	0.096	0.451
Meigs	0.058	0.021	0.097
Monroe	0.216	0.078	0.364
Morgan	0.114	0.041	0.192
Polk	0.081	0.029	0.136
Rhea	0.154	0.056	0.259
Roane	0.281	0.101	0.470
Scott	0.139	0.050	0.235
Sevier	0.470	0.168	0.795
Sullivan	0.534	0.191	0.902
Unicoi	0.120	0.043	0.205
Union	0.137	0.049	0.233
Washington	0.724	0.257	1.232

HOSPITAL COST (Million US$) OF COPD65 (OZONE_8hr)
(Expected and 90% CI)

County	Cost_avg	Cost_L(5%)	Cost_U(95%)
Anderson	0.327	0.069	0.606
Bledsoe	0.044	0.009	0.081
Blount	0.502	0.105	0.929
Bradley	0.288	0.061	0.529
Campbell	0.274	0.057	0.514
Carter	0.439	0.089	0.838
Claiborne	0.192	0.039	0.362
Cocke	0.202	0.042	0.380
Cumberland	0.345	0.072	0.639
Grainger	0.117	0.024	0.221
Greene	0.386	0.080	0.726
Hamblen	0.351	0.072	0.663
Hamilton	1.252	0.264	2.309
Hancock	0.047	0.010	0.089
Hawkins	0.294	0.061	0.554
Jefferson	0.279	0.057	0.528
Johnson	0.156	0.031	0.303
Knox	1.969	0.407	3.714
Loudon	0.199	0.042	0.367
Marion	0.106	0.022	0.194
McMinn	0.219	0.046	0.407
Meigs	0.038	0.008	0.071
Monroe	0.168	0.035	0.311
Morgan	0.075	0.016	0.139
Polk	0.064	0.014	0.118
Rhea	0.122	0.026	0.225
Roane	0.252	0.053	0.463
Scott	0.097	0.020	0.180
Sevier	0.348	0.073	0.650
Sullivan	0.494	0.103	0.920
Unicoi	0.127	0.026	0.239
Union	0.093	0.019	0.176
Washington	0.590	0.122	1.113

CDV ESTIMATION

COST (Million US$) OF DOCTOR VISITS (OZONE_1hr)
(Expected and 90% CI)

County	Cost_avg	Cost_L(5%)	Cost_U(95%)
Anderson	0.123	0.028	0.229
Bledsoe	0.019	0.004	0.035
Blount	0.182	0.042	0.338
Bradley	0.126	0.029	0.231
Campbell	0.114	0.025	0.220
Carter	0.158	0.035	0.308
Claiborne	0.075	0.017	0.143
Cocke	0.074	0.017	0.141
Cumberland	0.091	0.021	0.169
Grainger	0.046	0.010	0.088
Greene	0.130	0.029	0.246
Hamblen	0.129	0.029	0.245
Hamilton	0.496	0.114	0.915
Hancock	0.015	0.003	0.028
Hawkins	0.114	0.026	0.216
Jefferson	0.111	0.025	0.212
Johnson	0.056	0.012	0.110
Knox	0.878	0.195	1.687
Loudon	0.063	0.015	0.116
Marion	0.040	0.009	0.073
McMinn	0.082	0.019	0.152
Meigs	0.016	0.004	0.030
Monroe	0.062	0.014	0.115
Morgan	0.034	0.008	0.063
Polk	0.023	0.005	0.043
Rhea	0.043	0.010	0.080
Roane	0.079	0.018	0.145
Scott	0.047	0.011	0.088
Sevier	0.160	0.036	0.306
Sullivan	0.193	0.043	0.363
Unicoi	0.036	0.008	0.069
Union	0.044	0.010	0.084
Washington	0.218	0.049	0.416

COST (Million US$) OF DOCTOR VISITS (OZONE_8hr)
(Expected and 90% CI)

County	Cost_avg	Cost_L(5%)	Cost_U(95%)
Anderson	0.111	0.016	0.219
Bledsoe	0.022	0.003	0.042
Blount	0.202	0.029	0.397
Bradley	0.137	0.020	0.268
Campbell	0.103	0.014	0.209
Carter	0.172	0.023	0.358
Claiborne	0.081	0.011	0.166
Cocke	0.085	0.012	0.172
Cumberland	0.097	0.014	0.191
Grainger	0.054	0.007	0.109
Greene	0.150	0.021	0.304
Hamblen	0.150	0.021	0.306
Hamilton	0.510	0.073	0.998
Hancock	0.017	0.002	0.035
Hawkins	0.127	0.017	0.257
Jefferson	0.124	0.017	0.254
Johnson	0.063	0.008	0.135
Knox	0.894	0.123	1.818
Loudon	0.070	0.010	0.138
Marion	0.046	0.007	0.089
McMinn	0.086	0.012	0.170
Meigs	0.018	0.003	0.036
Monroe	0.070	0.010	0.138
Morgan	0.037	0.005	0.072
Polk	0.025	0.004	0.050
Rhea	0.049	0.007	0.097
Roane	0.089	0.013	0.173
Scott	0.047	0.007	0.092
Sevier	0.157	0.022	0.313
Sullivan	0.179	0.025	0.356
Unicoi	0.041	0.006	0.084
Union	0.048	0.007	0.097
Washington	0.248	0.034	0.504

Statistics for East Tennessee
$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$
Name for this simulation : SCENARIO BASE
Total Expected Cost ($x10^6) per Respiratory disease in East TN - O3 season

WTP Total in ET (O3-1hr)

Disease	Cost_avg	±SE	Cost(5%)	Cost(95%)	Cost_avg/Pop
Asthma	9.93	1.20	2.24	18.76	6.09
Copd	61.57	4.91	28.94	96.22	37.79
Copd65	45.94	4.69	13.64	80.97	156.16

WTP Total in ET (O3-8hr)

Disease	Cost_avg	±SE	Cost(5%)	Cost(95%)	Cost_avg/Pop
Asthma	10.49	1.68	1.46	21.06	6.44
Copd	75.38	8.42	26.90	127.63	46.27
Copd65	49.22	6.78	10.25	92.09	167.33

COI Total in ET (O3-1hr)

Disease	Cost_avg	±SE	Cost(5%)	Cost(95%)	Cost_avg/Pop
Asthma	2.90	0.35	0.65	5.48	1.78
Copd	28.07	2.24	13.20	43.87	17.23
Copd65	25.41	2.60	7.55	44.79	86.38

COI Total in ET (O3-8hr)

Disease	Cost_avg	±SE	Cost(5%)	Cost(95%)	Cost_avg/Pop
Asthma	3.06	0.49	0.43	6.15	1.88
Copd	34.37	3.84	12.26	58.19	21.10
Copd65	27.23	3.75	5.67	50.94	92.56

COH Total in ET (O3-1hr)

Disease	Cost_avg	±SE	Cost(5%)	Cost(95%)	Cost_avg/Pop
Asthma	1.03	0.12	0.23	1.95	0.63
Copd	10.54	0.84	4.95	16.47	6.47
Copd65	9.76	1.00	2.90	17.20	33.17

COH Total in ET (O3-8hr)

Disease	Cost_avg	±SE	Cost(5%)	Cost(95%)	Cost_avg/Pop
Asthma	1.09	0.17	0.15	2.19	0.67
Copd	12.90	1.44	4.60	21.85	7.92
Copd65	10.45	1.44	2.18	19.56	35.54

```
 Statistics for this run
^^^^^^^^^^^^^^^^^^^^^^^^^^

    Name for this simulation : SCENARIO BASE


Operation                                        Flag
------------------------------------------------------
Generate output file with healt impact      :    OramKX_b.sal
Display Modeling Domain and Study Area      :    N
Display Relative Risk uncertainties         :    N
Display Hospital admissions by County in ET :    N
Display Summary graphs of Admissions in ET  :    N
Perform and Economic Valuation              :    Y
Perform Sensitivity analysis                :    Y
Perform Monte Carlo simualation             :    Y
Display Tornado graphs for Indep Variables  :    Y
Display Scatter plots for var correlations  :    Y
------------------------------------------------------



--->> Normal Completion of program ORAM
```

Appendix B

ORAM Output: Scenario Mobile source NOx reduction

OUTPUT FROM ORAM SYSTEM Version 1.0
PSH (December 2001)

Name for this simulation : SCENARIO MOBILE 50% REDUCTION IN NOx
Date of simulation : Sat Dec 14 17:23:20 2001
Health parameters : KNOX

Relative Risk by Respiratory Disease: O3-1hr

Disease	RR	LL(5%)	UL(95%)
Asthma	1.127	1.029	1.234
Copd	1.082	1.039	1.126
Copd65	1.082	1.025	1.142

Relative Risk by Respiratory Disease: O3-8hr

Disease	RR	LL(5%)	UL(95%)
Asthma	1.113	1.016	1.219
Copd	1.069	1.025	1.114
Copd65	1.074	1.016	1.136

***** Hospital Admissions Deterministic Results *****

ASTHMA ADMISSIONS USING OZONE_1hr

County	Expected	+/- SE	%Population
Anderson	32.	13.	0.06
Bledsoe	5.	2.	0.05
Blount	48.	20.	0.06
Bradley	30.	12.	0.04
Campbell	30.	13.	0.10
Carter	41.	18.	0.09
Claiborne	18.	8.	0.08
Cocke	19.	8.	0.07
Cumberland	22.	9.	0.06
Grainger	12.	5.	0.07
Greene	34.	14.	0.07
Hamblen	33.	14.	0.07
Hamilton	117.	48.	0.05
Hancock	4.	2.	0.07
Hawkins	28.	12.	0.07
Jefferson	28.	12.	0.08
Johnson	14.	6.	0.10
Knox	227.	97.	0.08
Loudon	16.	7.	0.05
Marion	10.	4.	0.05
McMinn	19.	8.	0.05
Meigs	4.	2.	0.05
Monroe	16.	6.	0.05
Morgan	8.	3.	0.05
Polk	5.	2.	0.04
Rhea	11.	4.	0.05
Roane	20.	8.	0.05
Scott	11.	5.	0.07
Sevier	40.	17.	0.07
Sullivan	48.	20.	0.04
Unicoi	9.	4.	0.07
Union	11.	5.	0.08
Washington	57.	24.	0.07

COPD ADMISSIONS USING OZONE_1hr

County	Expected	+/- SE	%Population
Anderson	131.	36.	0.24
Bledsoe	19.	5.	0.20
Blount	198.	54.	0.24
Bradley	116.	31.	0.17
Campbell	128.	36.	0.42
Carter	172.	49.	0.39
Claiborne	77.	22.	0.34
Cocke	79.	22.	0.30
Cumberland	91.	25.	0.25
Grainger	49.	14.	0.31
Greene	140.	39.	0.29
Hamblen	136.	38.	0.31
Hamilton	471.	128.	0.20
Hancock	15.	4.	0.29
Hawkins	118.	33.	0.29
Jefferson	118.	33.	0.35
Johnson	61.	18.	0.43
Knox	951.	267.	0.32
Loudon	66.	18.	0.22
Marion	39.	11.	0.18
McMinn	78.	21.	0.21
Meigs	17.	5.	0.20
Monroe	63.	17.	0.22
Morgan	34.	9.	0.22
Polk	21.	6.	0.17
Rhea	42.	12.	0.20
Roane	81.	22.	0.20
Scott	48.	13.	0.31
Sevier	167.	47.	0.30
Sullivan	204.	57.	0.17
Unicoi	39.	11.	0.28
Union	47.	13.	0.35
Washington	235.	66.	0.28

COPD65 ADMISSIONS USING OZONE_1hr

County	Expected	+/- SE	%Population
Anderson	101.	37.	0.86
Bledsoe	10.	4.	0.72
Blount	130.	48.	0.87
Bradley	67.	24.	0.65
Campbell	85.	32.	1.41
Carter	112.	43.	1.32
Claiborne	47.	18.	1.18
Cocke	49.	18.	1.07
Cumberland	84.	31.	0.88
Grainger	28.	10.	1.07
Greene	94.	35.	1.01
Hamblen	83.	31.	1.07
Hamilton	311.	113.	0.73
Hancock	11.	4.	1.02
Hawkins	71.	27.	1.01
Jefferson	69.	26.	1.20
Johnson	39.	15.	1.47
Knox	540.	203.	1.11
Loudon	50.	18.	0.79
Marion	25.	9.	0.69
McMinn	54.	20.	0.77
Meigs	9.	3.	0.74
Monroe	40.	15.	0.78
Morgan	18.	7.	0.81
Polk	15.	5.	0.65
Rhea	28.	10.	0.72
Roane	62.	23.	0.74
Scott	26.	9.	1.08
Sevier	96.	36.	1.07
Sullivan	143.	53.	0.59
Unicoi	31.	12.	0.98
Union	24.	9.	1.22
Washington	146.	55.	0.98

ASTHMA ADMISSIONS USING OZONE_8hr

County	Expected	+/- SE	%Population
Anderson	29.	19.	0.05
Bledsoe	5.	3.	0.06
Blount	53.	29.	0.06
Bradley	33.	19.	0.05
Campbell	27.	17.	0.09
Carter	44.	24.	0.10
Claiborne	20.	11.	0.09
Cocke	22.	12.	0.08
Cumberland	24.	13.	0.07
Grainger	14.	7.	0.09
Greene	38.	21.	0.08
Hamblen	38.	20.	0.09
Hamilton	126.	73.	0.05
Hancock	4.	2.	0.08
Hawkins	32.	17.	0.08
Jefferson	32.	17.	0.09
Johnson	16.	9.	0.12
Knox	235.	135.	0.08
Loudon	18.	10.	0.06
Marion	11.	6.	0.05
McMinn	22.	12.	0.06
Meigs	5.	3.	0.06
Monroe	18.	10.	0.06
Morgan	9.	5.	0.06
Polk	6.	3.	0.05
Rhea	13.	7.	0.06
Roane	23.	13.	0.06
Scott	12.	7.	0.07
Sevier	39.	24.	0.07
Sullivan	44.	27.	0.04
Unicoi	10.	6.	0.07
Union	12.	7.	0.09
Washington	63.	34.	0.07

COPD ADMISSIONS USING OZONE_8hr

County	Expected	+/- SE	%Population
Anderson	149.	66.	0.27
Bledsoe	28.	11.	0.29
Blount	265.	103.	0.32
Bradley	177.	70.	0.26
Campbell	127.	56.	0.41
Carter	201.	77.	0.45
Claiborne	95.	37.	0.42
Cocke	103.	39.	0.40
Cumberland	119.	47.	0.32
Grainger	64.	24.	0.40
Greene	184.	70.	0.38
Hamblen	180.	67.	0.40
Hamilton	659.	265.	0.28
Hancock	21.	8.	0.39
Hawkins	153.	58.	0.37
Jefferson	148.	56.	0.43
Johnson	72.	27.	0.51
Knox	1111.	452.	0.37
Loudon	92.	36.	0.30
Marion	60.	23.	0.28
McMinn	110.	44.	0.30
Meigs	24.	9.	0.29
Monroe	90.	34.	0.31
Morgan	47.	18.	0.31
Polk	33.	13.	0.26
Rhea	64.	24.	0.29
Roane	117.	46.	0.29
Scott	57.	23.	0.36
Sevier	192.	81.	0.35
Sullivan	217.	98.	0.18
Unicoi	50.	19.	0.36
Union	57.	22.	0.43
Washington	300.	115.	0.36

COPD65 ADMISSIONS USING OZONE_8hr

County	Expected	+/- SE	%Population
Anderson	95.	55.	0.80
Bledsoe	12.	6.	0.86
Blount	144.	71.	0.97
Bradley	77.	39.	0.75
Campbell	78.	44.	1.29
Carter	124.	60.	1.45
Claiborne	52.	26.	1.30
Cocke	56.	27.	1.23
Cumberland	93.	46.	0.97
Grainger	33.	15.	1.26
Greene	107.	52.	1.15
Hamblen	97.	46.	1.26
Hamilton	340.	178.	0.80
Hancock	13.	6.	1.22
Hawkins	81.	39.	1.14
Jefferson	78.	37.	1.37
Johnson	44.	21.	1.68
Knox	567.	290.	1.17
Loudon	57.	28.	0.90
Marion	29.	14.	0.81
McMinn	60.	31.	0.86
Meigs	11.	5.	0.84
Monroe	47.	23.	0.91
Morgan	21.	10.	0.92
Polk	17.	9.	0.75
Rhea	34.	16.	0.86
Roane	70.	35.	0.84
Scott	27.	14.	1.11
Sevier	95.	52.	1.06
Sullivan	135.	74.	0.55
Unicoi	35.	17.	1.10
Union	26.	13.	1.35
Washington	164.	80.	1.10

RESPIRATORY DOCTOR VISITS USING OZONE_1hr

County	Expected	+/- SE	%Population
Anderson	421.	175.	0.77
Bledsoe	61.	25.	0.64
Blount	637.	264.	0.78
Bradley	391.	159.	0.58
Campbell	395.	170.	1.29
Carter	538.	234.	1.21
Claiborne	244.	104.	1.07
Cocke	250.	106.	0.97
Cumberland	290.	120.	0.79
Grainger	155.	65.	0.97
Greene	446.	188.	0.91
Hamblen	433.	183.	0.97
Hamilton	1544.	630.	0.65
Hancock	48.	20.	0.92
Hawkins	373.	157.	0.91
Jefferson	372.	159.	1.09
Johnson	190.	84.	1.35
Knox	2998.	1285.	1.01
Loudon	215.	88.	0.70
Marion	130.	53.	0.61
McMinn	257.	106.	0.69
Meigs	55.	22.	0.66
Monroe	206.	85.	0.70
Morgan	110.	45.	0.72
Polk	72.	29.	0.58
Rhea	140.	57.	0.64
Roane	267.	109.	0.66
Scott	151.	63.	0.97
Sevier	532.	227.	0.97
Sullivan	633.	266.	0.53
Unicoi	125.	53.	0.89
Union	147.	63.	1.11
Washington	749.	319.	0.89

RESPIRATORY DOCTOR VISITS USING OZONE_8hr

County	Expected	+/- SE	%Population
Anderson	387.	250.	0.71
Bledsoe	72.	38.	0.76
Blount	698.	383.	0.85
Bradley	442.	250.	0.66
Campbell	354.	225.	1.15
Carter	583.	321.	1.31
Claiborne	266.	146.	1.16
Cocke	285.	152.	1.10
Cumberland	317.	174.	0.86
Grainger	179.	94.	1.12
Greene	503.	272.	1.03
Hamblen	501.	264.	1.12
Hamilton	1670.	962.	0.71
Hancock	57.	30.	1.09
Hawkins	418.	227.	1.02
Jefferson	419.	225.	1.23
Johnson	215.	116.	1.53
Knox	3097.	1776.	1.04
Loudon	243.	131.	0.80
Marion	152.	82.	0.72
McMinn	284.	161.	0.76
Meigs	62.	34.	0.74
Monroe	236.	126.	0.81
Morgan	123.	67.	0.81
Polk	82.	46.	0.66
Rhea	165.	87.	0.76
Roane	299.	166.	0.74
Scott	154.	88.	0.99
Sevier	516.	313.	0.94
Sullivan	586.	360.	0.49
Unicoi	138.	75.	0.98
Union	160.	88.	1.21
Washington	830.	453.	0.98

+++++++ STATISTICS FOR EAST TENNESSEE ++++++++

Name for this simulation : SCENARIO MOBILE 50% REDUCTION IN NOx

Total Expected Hospital admissions in East TN - O3 season

Due to short exposure: O3-1hr

Disease	Expected	±SE	5%	95%	%_Pop_Avg	%_Pop_5%	%_Pop_95%
Asthma	1028.	125.	233.	1935.	0.063	0.014	0.119
Copd	4252.	341.	2002.	6633.	0.261	0.123	0.407
Copd65	2698.	276.	803.	4745.	0.917	0.273	1.613
Resp_DV	13574.	1645.	3070.	25543.	0.833	0.188	1.568

Due to medium exposure: O3-8hr

Disease	Expected	±SE	5%	95%	%_Pop_Avg	%_Pop_5%	%_Pop_95%
Asthma	1098.	176.	154.	2193.	0.067	0.009	0.135
Copd	5366.	604.	1919.	9066.	0.329	0.118	0.556
Copd65	2921.	403.	610.	5448.	0.993	0.207	1.852
Resp_DV	14493.	2327.	2028.	28942.	0.890	0.125	1.776

*** ECONOMIC VALUATION USING WTP/COI/COH ESTIMATION ***
$$

Name for this simulation : SCENARIO MOBILE 50% REDUCTION IN NOx

WTP ESTIMATION
COST (Million US$) OF AVOIDING ASTHMA HOSPITALIZATION (OZONE_1hr)
(Expected and 90% CI)

County	Cost_avg	Cost_L(5%)	Cost_U(95%)
Anderson	0.287	0.066	0.536
Bledsoe	0.042	0.010	0.077
Blount	0.434	0.100	0.806
Bradley	0.266	0.062	0.487
Campbell	0.269	0.060	0.518
Carter	0.367	0.081	0.710
Claiborne	0.166	0.037	0.318
Cocke	0.170	0.038	0.322
Cumberland	0.198	0.045	0.366
Grainger	0.105	0.024	0.199
Greene	0.304	0.069	0.572
Hamblen	0.295	0.066	0.558
Hamilton	1.053	0.244	1.930
Hancock	0.033	0.007	0.062
Hawkins	0.255	0.058	0.479
Jefferson	0.254	0.057	0.484
Johnson	0.129	0.028	0.254
Knox	2.044	0.456	3.905
Loudon	0.147	0.034	0.270
Marion	0.088	0.021	0.162
McMinn	0.175	0.040	0.324
Meigs	0.037	0.009	0.068
Monroe	0.141	0.032	0.259
Morgan	0.075	0.017	0.137
Polk	0.049	0.011	0.090
Rhea	0.095	0.022	0.176
Roane	0.182	0.042	0.333
Scott	0.103	0.024	0.191
Sevier	0.363	0.081	0.690
Sullivan	0.432	0.098	0.810
Unicoi	0.085	0.019	0.162
Union	0.100	0.022	0.190
Washington	0.511	0.114	0.971

COST (Million US$) OF AVOIDING COPD HOSPITALIZATION (OZONE_1hr)
(Expected and 90% CI)

County	Cost_avg	Cost_L(5%)	Cost_U(95%)
Anderson	1.751	0.828	2.721
Bledsoe	0.249	0.119	0.386
Blount	2.659	1.260	4.121
Bradley	1.551	0.740	2.388
Campbell	1.711	0.799	2.694
Carter	2.310	1.074	3.649
Claiborne	1.038	0.486	1.630
Cocke	1.053	0.495	1.645
Cumberland	1.214	0.576	1.879
Grainger	0.652	0.306	1.020
Greene	1.880	0.885	2.932
Hamblen	1.826	0.858	2.855
Hamilton	6.308	3.006	9.723
Hancock	0.203	0.095	0.316
Hawkins	1.579	0.744	2.463
Jefferson	1.583	0.741	2.484
Johnson	0.817	0.377	1.300
Knox	12.742	5.960	20.017
Loudon	0.888	0.423	1.371
Marion	0.520	0.248	0.801
McMinn	1.051	0.499	1.628
Meigs	0.224	0.107	0.345
Monroe	0.849	0.403	1.313
Morgan	0.455	0.217	0.701
Polk	0.287	0.137	0.442
Rhea	0.568	0.270	0.879
Roane	1.090	0.520	1.678
Scott	0.646	0.306	1.001
Sevier	2.232	1.046	3.500
Sullivan	2.739	1.292	4.265
Unicoi	0.524	0.245	0.821
Union	0.627	0.294	0.983
Washington	3.145	1.474	4.931

COST (Million US$) OF AVOIDING COPD65 HOSPITALIZATION (OZONE_1hr)
(Expected and 90% CI)

County	Cost_avg	Cost_L(5%)	Cost_U(95%)
Anderson	1.611	0.482	2.819
Bledsoe	0.162	0.049	0.281
Blount	2.063	0.618	3.599
Bradley	1.069	0.323	1.849
Campbell	1.351	0.397	2.406
Carter	1.786	0.523	3.194
Claiborne	0.750	0.221	1.330
Cocke	0.775	0.230	1.366
Cumberland	1.343	0.403	2.339
Grainger	0.441	0.131	0.778
Greene	1.496	0.445	2.632
Hamblen	1.320	0.392	2.329
Hamilton	4.944	1.492	8.568
Hancock	0.173	0.052	0.305
Hawkins	1.133	0.337	1.992
Jefferson	1.092	0.323	1.936
Johnson	0.613	0.178	1.106
Knox	8.581	2.532	15.227
Loudon	0.794	0.239	1.378
Marion	0.392	0.118	0.677
McMinn	0.857	0.257	1.493
Meigs	0.150	0.045	0.260
Monroe	0.642	0.193	1.117
Morgan	0.292	0.088	0.507
Polk	0.238	0.072	0.412
Rhea	0.449	0.135	0.781
Roane	0.985	0.298	1.705
Scott	0.408	0.122	0.714
Sevier	1.527	0.452	2.702
Sullivan	2.270	0.676	3.988
Unicoi	0.498	0.147	0.882
Union	0.374	0.111	0.662
Washington	2.322	0.687	4.108

COST (Million US$) OF AVOIDING ASTHMA HOSPITALIZATION (OZONE_8hr)
(Expected and 90% CI)

County	Cost_avg	Cost_L(5%)	Cost_U(95%)
Anderson	0.264	0.037	0.520
Bledsoe	0.049	0.007	0.097
Blount	0.476	0.067	0.938
Bradley	0.301	0.043	0.585
Campbell	0.241	0.034	0.484
Carter	0.397	0.054	0.821
Claiborne	0.181	0.025	0.367
Cocke	0.194	0.027	0.391
Cumberland	0.216	0.031	0.424
Grainger	0.122	0.017	0.247
Greene	0.343	0.048	0.688
Hamblen	0.342	0.047	0.691
Hamilton	1.138	0.163	2.220
Hancock	0.039	0.005	0.078
Hawkins	0.285	0.040	0.573
Jefferson	0.286	0.039	0.582
Johnson	0.147	0.019	0.311
Knox	2.112	0.292	4.271
Loudon	0.166	0.024	0.324
Marion	0.103	0.015	0.201
McMinn	0.194	0.027	0.382
Meigs	0.042	0.006	0.082
Monroe	0.161	0.023	0.316
Morgan	0.084	0.012	0.163
Polk	0.056	0.008	0.108
Rhea	0.113	0.016	0.220
Roane	0.204	0.029	0.396
Scott	0.105	0.015	0.207
Sevier	0.352	0.050	0.699
Sullivan	0.400	0.056	0.791
Unicoi	0.094	0.013	0.190
Union	0.109	0.015	0.221
Washington	0.566	0.078	1.143

COST (Million US$) OF AVOIDING COPD HOSPITALIZATION (OZONE_8hr)
(Expected and 90% CI)

County	Cost_avg	Cost_L(5%)	Cost_U(95%)
Anderson	1.998	0.719	3.356
Bledsoe	0.376	0.135	0.630
Blount	3.546	1.274	5.961
Bradley	2.374	0.858	3.968
Campbell	1.705	0.608	2.887
Carter	2.691	0.949	4.613
Claiborne	1.272	0.452	2.163
Cocke	1.378	0.491	2.338
Cumberland	1.597	0.574	2.683
Grainger	0.862	0.307	1.465
Greene	2.460	0.878	4.165
Hamblen	2.414	0.859	4.100
Hamilton	8.833	3.187	14.784
Hancock	0.275	0.098	0.467
Hawkins	2.046	0.729	3.467
Jefferson	1.988	0.705	3.388
Johnson	0.968	0.338	1.677
Knox	14.889	5.295	25.294
Loudon	1.233	0.444	2.068
Marion	0.801	0.289	1.340
McMinn	1.476	0.530	2.480
Meigs	0.323	0.117	0.540
Monroe	1.208	0.435	2.027
Morgan	0.633	0.228	1.059
Polk	0.440	0.159	0.735
Rhea	0.856	0.308	1.436
Roane	1.570	0.567	2.624
Scott	0.764	0.274	1.285
Sevier	2.572	0.921	4.337
Sullivan	2.911	1.043	4.903
Unicoi	0.668	0.238	1.134
Union	0.762	0.271	1.296
Washington	4.014	1.429	6.815

COST (Million US$) OF AVOIDING COPD65 HOSPITALIZATION (OZONE_8hr)
(Expected and 90% CI)

County	Cost_avg	Cost_L(5%)	Cost_U(95%)
Anderson	1.505	0.317	2.785
Bledsoe	0.194	0.041	0.357
Blount	2.293	0.482	4.245
Bradley	1.223	0.259	2.247
Campbell	1.239	0.258	2.317
Carter	1.964	0.402	3.740
Claiborne	0.829	0.172	1.560
Cocke	0.895	0.186	1.679
Cumberland	1.486	0.313	2.746
Grainger	0.517	0.107	0.972
Greene	1.707	0.355	3.195
Hamblen	1.548	0.321	2.910
Hamilton	5.414	1.145	9.962
Hancock	0.207	0.043	0.388
Hawkins	1.282	0.266	2.403
Jefferson	1.245	0.257	2.351
Johnson	0.703	0.142	1.360
Knox	9.013	1.867	16.946
Loudon	0.907	0.191	1.674
Marion	0.463	0.098	0.851
McMinn	0.960	0.202	1.779
Meigs	0.171	0.036	0.314
Monroe	0.746	0.157	1.377
Morgan	0.332	0.070	0.611
Polk	0.273	0.058	0.501
Rhea	0.538	0.114	0.993
Roane	1.121	0.238	2.057
Scott	0.423	0.089	0.783
Sevier	1.514	0.317	2.816
Sullivan	2.139	0.449	3.972
Unicoi	0.561	0.116	1.053
Union	0.414	0.086	0.779
Washington	2.612	0.542	4.907

COI ESTIMATION

COST (Million US$) OF ASTHMA HOSPITALIZATION (OZONE_1hr)
(Expected and 90% CI)

County	Cost_avg	Cost_L(5%)	Cost_U(95%)
Anderson	0.084	0.019	0.156
Bledsoe	0.012	0.003	0.023
Blount	0.127	0.029	0.235
Bradley	0.078	0.018	0.142
Campbell	0.079	0.017	0.151
Carter	0.107	0.024	0.207
Claiborne	0.049	0.011	0.093
Cocke	0.050	0.011	0.094
Cumberland	0.058	0.013	0.107
Grainger	0.031	0.007	0.058
Greene	0.089	0.020	0.167
Hamblen	0.086	0.019	0.163
Hamilton	0.308	0.071	0.564
Hancock	0.010	0.002	0.018
Hawkins	0.074	0.017	0.140
Jefferson	0.074	0.017	0.141
Johnson	0.038	0.008	0.074
Knox	0.597	0.133	1.141
Loudon	0.043	0.010	0.079
Marion	0.026	0.006	0.047
McMinn	0.051	0.012	0.095
Meigs	0.011	0.003	0.020
Monroe	0.041	0.009	0.076
Morgan	0.022	0.005	0.040
Polk	0.014	0.003	0.026
Rhea	0.028	0.006	0.051
Roane	0.053	0.012	0.097
Scott	0.030	0.007	0.056
Sevier	0.106	0.024	0.201
Sullivan	0.126	0.029	0.237
Unicoi	0.025	0.006	0.047
Union	0.029	0.007	0.056
Washington	0.149	0.033	0.284

COST (Million US$) OF COPD HOSPITALIZATION (OZONE_1hr)
(Expected and 90% CI)

County	Cost_avg	Cost_L(5%)	Cost_U(95%)
Anderson	0.799	0.378	1.241
Bledsoe	0.114	0.054	0.176
Blount	1.212	0.575	1.879
Bradley	0.707	0.337	1.089
Campbell	0.780	0.364	1.228
Carter	1.053	0.490	1.664
Claiborne	0.473	0.222	0.743
Cocke	0.480	0.226	0.750
Cumberland	0.554	0.263	0.857
Grainger	0.297	0.140	0.465
Greene	0.857	0.404	1.337
Hamblen	0.833	0.391	1.302
Hamilton	2.876	1.371	4.433
Hancock	0.092	0.043	0.144
Hawkins	0.720	0.339	1.123
Jefferson	0.722	0.338	1.133
Johnson	0.373	0.172	0.593
Knox	5.810	2.717	9.127
Loudon	0.405	0.193	0.625
Marion	0.237	0.113	0.365
McMinn	0.479	0.227	0.742
Meigs	0.102	0.049	0.158
Monroe	0.387	0.184	0.599
Morgan	0.207	0.099	0.320
Polk	0.131	0.062	0.202
Rhea	0.259	0.123	0.401
Roane	0.497	0.237	0.765
Scott	0.294	0.139	0.457
Sevier	1.018	0.477	1.596
Sullivan	1.249	0.589	1.945
Unicoi	0.239	0.112	0.374
Union	0.286	0.134	0.448
Washington	1.434	0.672	2.248

COST (Million US$) OF COPD65 HOSPITALIZATION (OZONE_1hr)
(Expected and 90% CI)

County	Cost_avg	Cost_L(5%)	Cost_U(95%)
Anderson	0.891	0.266	1.560
Bledsoe	0.089	0.027	0.155
Blount	1.141	0.342	1.991
Bradley	0.591	0.179	1.023
Campbell	0.747	0.220	1.331
Carter	0.988	0.289	1.767
Claiborne	0.415	0.123	0.736
Cocke	0.429	0.127	0.756
Cumberland	0.743	0.223	1.294
Grainger	0.244	0.072	0.430
Greene	0.828	0.246	1.456
Hamblen	0.730	0.217	1.288
Hamilton	2.734	0.825	4.739
Hancock	0.096	0.028	0.169
Hawkins	0.626	0.186	1.102
Jefferson	0.604	0.178	1.071
Johnson	0.339	0.098	0.612
Knox	4.746	1.400	8.423
Loudon	0.439	0.132	0.762
Marion	0.217	0.065	0.375
McMinn	0.474	0.142	0.826
Meigs	0.083	0.025	0.144
Monroe	0.355	0.107	0.618
Morgan	0.162	0.049	0.280
Polk	0.132	0.040	0.228
Rhea	0.249	0.075	0.432
Roane	0.545	0.165	0.943
Scott	0.226	0.068	0.395
Sevier	0.845	0.250	1.495
Sullivan	1.256	0.374	2.206
Unicoi	0.276	0.082	0.488
Union	0.207	0.061	0.366
Washington	1.284	0.380	2.272

COST (Million US$) OF ASTHMA HOSPITALIZATION (OZONE_8hr)
(Expected and 90% CI)

County	Cost_avg	Cost_L(5%)	Cost_U(95%)
Anderson	0.077	0.011	0.152
Bledsoe	0.014	0.002	0.028
Blount	0.139	0.020	0.274
Bradley	0.088	0.013	0.171
Campbell	0.071	0.010	0.141
Carter	0.116	0.016	0.240
Claiborne	0.053	0.007	0.107
Cocke	0.057	0.008	0.114
Cumberland	0.063	0.009	0.124
Grainger	0.036	0.005	0.072
Greene	0.100	0.014	0.201
Hamblen	0.100	0.014	0.202
Hamilton	0.333	0.048	0.649
Hancock	0.011	0.002	0.023
Hawkins	0.083	0.012	0.167
Jefferson	0.083	0.011	0.170
Johnson	0.043	0.006	0.091
Knox	0.617	0.085	1.248
Loudon	0.048	0.007	0.095
Marion	0.030	0.004	0.059
McMinn	0.057	0.008	0.112
Meigs	0.012	0.002	0.024
Monroe	0.047	0.007	0.092
Morgan	0.024	0.004	0.048
Polk	0.016	0.002	0.032
Rhea	0.033	0.005	0.064
Roane	0.060	0.009	0.116
Scott	0.031	0.004	0.060
Sevier	0.103	0.014	0.204
Sullivan	0.117	0.016	0.231
Unicoi	0.028	0.004	0.056
Union	0.032	0.004	0.065
Washington	0.165	0.023	0.334

COST (Million US$) OF COPD HOSPITALIZATION (OZONE_8hr)
(Expected and 90% CI)

County	Cost_avg	Cost_L(5%)	Cost_U(95%)
Anderson	0.911	0.328	1.530
Bledsoe	0.171	0.062	0.287
Blount	1.617	0.581	2.718
Bradley	1.083	0.391	1.809
Campbell	0.777	0.277	1.316
Carter	1.227	0.433	2.104
Claiborne	0.580	0.206	0.986
Cocke	0.629	0.224	1.066
Cumberland	0.728	0.262	1.223
Grainger	0.393	0.140	0.668
Greene	1.122	0.400	1.899
Hamblen	1.101	0.392	1.870
Hamilton	4.028	1.453	6.741
Hancock	0.126	0.045	0.213
Hawkins	0.933	0.333	1.581
Jefferson	0.907	0.321	1.545
Johnson	0.441	0.154	0.764
Knox	6.789	2.415	11.533
Loudon	0.562	0.202	0.943
Marion	0.365	0.132	0.611
McMinn	0.673	0.242	1.131
Meigs	0.147	0.053	0.246
Monroe	0.551	0.198	0.924
Morgan	0.289	0.104	0.483
Polk	0.200	0.072	0.335
Rhea	0.391	0.141	0.655
Roane	0.716	0.259	1.197
Scott	0.348	0.125	0.586
Sevier	1.173	0.420	1.977
Sullivan	1.327	0.476	2.236
Unicoi	0.305	0.108	0.517
Union	0.348	0.123	0.591
Washington	1.830	0.651	3.107

COST (Million US$) OF COPD65 HOSPITALIZATION (OZONE_8hr)
(Expected and 90% CI)

County	Cost_avg	Cost_L(5%)	Cost_U(95%)
Anderson	0.833	0.175	1.540
Bledsoe	0.107	0.023	0.198
Blount	1.268	0.267	2.348
Bradley	0.677	0.143	1.243
Campbell	0.685	0.143	1.282
Carter	1.086	0.222	2.069
Claiborne	0.459	0.095	0.863
Cocke	0.495	0.103	0.929
Cumberland	0.822	0.173	1.519
Grainger	0.286	0.059	0.538
Greene	0.944	0.196	1.767
Hamblen	0.856	0.177	1.609
Hamilton	2.995	0.633	5.511
Hancock	0.114	0.024	0.215
Hawkins	0.709	0.147	1.329
Jefferson	0.689	0.142	1.301
Johnson	0.389	0.078	0.752
Knox	4.985	1.033	9.373
Loudon	0.502	0.106	0.926
Marion	0.256	0.054	0.471
McMinn	0.531	0.112	0.984
Meigs	0.095	0.020	0.174
Monroe	0.413	0.087	0.762
Morgan	0.184	0.039	0.338
Polk	0.151	0.032	0.277
Rhea	0.298	0.063	0.549
Roane	0.620	0.131	1.138
Scott	0.234	0.049	0.433
Sevier	0.837	0.175	1.557
Sullivan	1.183	0.248	2.197
Unicoi	0.310	0.064	0.583
Union	0.229	0.047	0.431
Washington	1.445	0.300	2.714

COH ESTIMATION

HOSPITAL COST (Million US$) OF ASTHMA (OZONE_1hr)
(Expected and 90% CI)

County	Cost_avg	Cost_L(5%)	Cost_U(95%)
Anderson	0.030	0.007	0.056
Bledsoe	0.004	0.001	0.008
Blount	0.045	0.010	0.084
Bradley	0.028	0.006	0.051
Campbell	0.028	0.006	0.054
Carter	0.038	0.008	0.074
Claiborne	0.017	0.004	0.033
Cocke	0.018	0.004	0.033
Cumberland	0.021	0.005	0.038
Grainger	0.011	0.002	0.021
Greene	0.032	0.007	0.059
Hamblen	0.031	0.007	0.058
Hamilton	0.109	0.025	0.200
Hancock	0.003	0.001	0.006
Hawkins	0.026	0.006	0.050
Jefferson	0.026	0.006	0.050
Johnson	0.013	0.003	0.026
Knox	0.212	0.047	0.405
Loudon	0.015	0.004	0.028
Marion	0.009	0.002	0.017
McMinn	0.018	0.004	0.034
Meigs	0.004	0.001	0.007
Monroe	0.015	0.003	0.027
Morgan	0.008	0.002	0.014
Polk	0.005	0.001	0.009
Rhea	0.010	0.002	0.018
Roane	0.019	0.004	0.035
Scott	0.011	0.002	0.020
Sevier	0.038	0.008	0.072
Sullivan	0.045	0.010	0.084
Unicoi	0.009	0.002	0.017
Union	0.010	0.002	0.020
Washington	0.053	0.012	0.101

HOSPITAL COST (Million US$) OF COPD (OZONE_1hr)
(Expected and 90% CI)

County	Cost_avg	Cost_L(5%)	Cost_U(95%)
Anderson	0.300	0.142	0.466
Bledsoe	0.043	0.020	0.066
Blount	0.455	0.216	0.705
Bradley	0.266	0.127	0.409
Campbell	0.293	0.137	0.461
Carter	0.395	0.184	0.625
Claiborne	0.178	0.083	0.279
Cocke	0.180	0.085	0.282
Cumberland	0.208	0.099	0.322
Grainger	0.112	0.052	0.175
Greene	0.322	0.152	0.502
Hamblen	0.313	0.147	0.489
Hamilton	1.080	0.515	1.665
Hancock	0.035	0.016	0.054
Hawkins	0.270	0.127	0.422
Jefferson	0.271	0.127	0.425
Johnson	0.140	0.065	0.223
Knox	2.181	1.020	3.427
Loudon	0.152	0.072	0.235
Marion	0.089	0.042	0.137
McMinn	0.180	0.085	0.279
Meigs	0.038	0.018	0.059
Monroe	0.145	0.069	0.225
Morgan	0.078	0.037	0.120
Polk	0.049	0.023	0.076
Rhea	0.097	0.046	0.150
Roane	0.187	0.089	0.287
Scott	0.111	0.052	0.171
Sevier	0.382	0.179	0.599
Sullivan	0.469	0.221	0.730
Unicoi	0.090	0.042	0.141
Union	0.107	0.050	0.168
Washington	0.538	0.252	0.844

HOSPITAL COST (Million US$) OF COPD65 (OZONE_1hr)
(Expected and 90% CI)

County	Cost_avg	Cost_L(5%)	Cost_U(95%)
Anderson	0.342	0.102	0.599
Bledsoe	0.034	0.010	0.060
Blount	0.438	0.131	0.764
Bradley	0.227	0.069	0.393
Campbell	0.287	0.084	0.511
Carter	0.379	0.111	0.678
Claiborne	0.159	0.047	0.283
Cocke	0.165	0.049	0.290
Cumberland	0.285	0.086	0.497
Grainger	0.094	0.028	0.165
Greene	0.318	0.095	0.559
Hamblen	0.280	0.083	0.495
Hamilton	1.050	0.317	1.820
Hancock	0.037	0.011	0.065
Hawkins	0.241	0.072	0.423
Jefferson	0.232	0.068	0.411
Johnson	0.130	0.038	0.235
Knox	1.822	0.538	3.234
Loudon	0.169	0.051	0.293
Marion	0.083	0.025	0.144
McMinn	0.182	0.055	0.317
Meigs	0.032	0.010	0.055
Monroe	0.136	0.041	0.237
Morgan	0.062	0.019	0.108
Polk	0.051	0.015	0.088
Rhea	0.095	0.029	0.166
Roane	0.209	0.063	0.362
Scott	0.087	0.026	0.152
Sevier	0.324	0.096	0.574
Sullivan	0.482	0.144	0.847
Unicoi	0.106	0.031	0.187
Union	0.079	0.023	0.141
Washington	0.493	0.146	0.872

HOSPITAL COST (Million US$) OF ASTHMA (OZONE_8hr)
(Expected and 90% CI)

County	Cost_avg	Cost_L(5%)	Cost_U(95%)
Anderson	0.027	0.004	0.054
Bledsoe	0.005	0.001	0.010
Blount	0.049	0.007	0.097
Bradley	0.031	0.004	0.061
Campbell	0.025	0.003	0.050
Carter	0.041	0.006	0.085
Claiborne	0.019	0.003	0.038
Cocke	0.020	0.003	0.041
Cumberland	0.022	0.003	0.044
Grainger	0.013	0.002	0.026
Greene	0.036	0.005	0.071
Hamblen	0.035	0.005	0.072
Hamilton	0.118	0.017	0.230
Hancock	0.004	0.001	0.008
Hawkins	0.030	0.004	0.059
Jefferson	0.030	0.004	0.060
Johnson	0.015	0.002	0.032
Knox	0.219	0.030	0.443
Loudon	0.017	0.002	0.034
Marion	0.011	0.002	0.021
McMinn	0.020	0.003	0.040
Meigs	0.004	0.001	0.008
Monroe	0.017	0.002	0.033
Morgan	0.009	0.001	0.017
Polk	0.006	0.001	0.011
Rhea	0.012	0.002	0.023
Roane	0.021	0.003	0.041
Scott	0.011	0.002	0.021
Sevier	0.037	0.005	0.072
Sullivan	0.041	0.006	0.082
Unicoi	0.010	0.001	0.020
Union	0.011	0.002	0.023
Washington	0.059	0.008	0.119

HOSPITAL COST (Million US$) OF COPD (OZONE_8hr)
(Expected and 90% CI)

County	Cost_avg	Cost_L(5%)	Cost_U(95%)
Anderson	0.342	0.123	0.574
Bledsoe	0.064	0.023	0.108
Blount	0.607	0.218	1.021
Bradley	0.406	0.147	0.679
Campbell	0.292	0.104	0.494
Carter	0.461	0.162	0.790
Claiborne	0.218	0.077	0.370
Cocke	0.236	0.084	0.400
Cumberland	0.273	0.098	0.459
Grainger	0.148	0.053	0.251
Greene	0.421	0.150	0.713
Hamblen	0.413	0.147	0.702
Hamilton	1.512	0.546	2.531
Hancock	0.047	0.017	0.080
Hawkins	0.350	0.125	0.593
Jefferson	0.340	0.121	0.580
Johnson	0.166	0.058	0.287
Knox	2.549	0.907	4.330
Loudon	0.211	0.076	0.354
Marion	0.137	0.050	0.229
McMinn	0.253	0.091	0.424
Meigs	0.055	0.020	0.092
Monroe	0.207	0.074	0.347
Morgan	0.108	0.039	0.181
Polk	0.075	0.027	0.126
Rhea	0.147	0.053	0.246
Roane	0.269	0.097	0.449
Scott	0.131	0.047	0.220
Sevier	0.440	0.158	0.742
Sullivan	0.498	0.179	0.839
Unicoi	0.114	0.041	0.194
Union	0.130	0.046	0.222
Washington	0.687	0.245	1.167

HOSPITAL COST (Million US$) OF COPD65 (OZONE_8hr)
(Expected and 90% CI)

County	Cost_avg	Cost_L(5%)	Cost_U(95%)
Anderson	0.320	0.067	0.591
Bledsoe	0.041	0.009	0.076
Blount	0.487	0.102	0.902
Bradley	0.260	0.055	0.477
Campbell	0.263	0.055	0.492
Carter	0.417	0.085	0.794
Claiborne	0.176	0.036	0.331
Cocke	0.190	0.039	0.357
Cumberland	0.316	0.066	0.583
Grainger	0.110	0.023	0.206
Greene	0.363	0.075	0.679
Hamblen	0.329	0.068	0.618
Hamilton	1.150	0.243	2.116
Hancock	0.044	0.009	0.082
Hawkins	0.272	0.057	0.510
Jefferson	0.264	0.055	0.499
Johnson	0.149	0.030	0.289
Knox	1.914	0.397	3.599
Loudon	0.193	0.041	0.356
Marion	0.098	0.021	0.181
McMinn	0.204	0.043	0.378
Meigs	0.036	0.008	0.067
Monroe	0.158	0.033	0.293
Morgan	0.071	0.015	0.130
Polk	0.058	0.012	0.106
Rhea	0.114	0.024	0.211
Roane	0.238	0.050	0.437
Scott	0.090	0.019	0.166
Sevier	0.322	0.067	0.598
Sullivan	0.454	0.095	0.844
Unicoi	0.119	0.025	0.224
Union	0.088	0.018	0.165
Washington	0.555	0.115	1.042

CDV ESTIMATION

COST (Million US$) OF DOCTOR VISITS (OZONE_1hr)
(Expected and 90% CI)

County	Cost_avg	Cost_L(5%)	Cost_U(95%)
Anderson	0.118	0.027	0.220
Bledsoe	0.017	0.004	0.032
Blount	0.178	0.041	0.331
Bradley	0.109	0.025	0.200
Campbell	0.111	0.025	0.213
Carter	0.151	0.033	0.291
Claiborne	0.068	0.015	0.130
Cocke	0.070	0.016	0.132
Cumberland	0.081	0.019	0.150
Grainger	0.043	0.010	0.082
Greene	0.125	0.028	0.235
Hamblen	0.121	0.027	0.229
Hamilton	0.432	0.100	0.793
Hancock	0.013	0.003	0.025
Hawkins	0.105	0.024	0.197
Jefferson	0.104	0.023	0.199
Johnson	0.053	0.012	0.105
Knox	0.840	0.187	1.604
Loudon	0.060	0.014	0.111
Marion	0.036	0.008	0.066
McMinn	0.072	0.017	0.133
Meigs	0.015	0.004	0.028
Monroe	0.058	0.013	0.107
Morgan	0.031	0.007	0.056
Polk	0.020	0.005	0.037
Rhea	0.039	0.009	0.072
Roane	0.075	0.017	0.137
Scott	0.042	0.010	0.079
Sevier	0.149	0.033	0.283
Sullivan	0.177	0.040	0.332
Unicoi	0.035	0.008	0.066
Union	0.041	0.009	0.078
Washington	0.210	0.047	0.399

COST (Million US$) OF DOCTOR VISITS (OZONE_8hr)
(Expected and 90% CI)

County	Cost_avg	Cost_L(5%)	Cost_U(95%)
Anderson	0.108	0.015	0.213
Bledsoe	0.020	0.003	0.040
Blount	0.196	0.028	0.385
Bradley	0.124	0.018	0.240
Campbell	0.099	0.014	0.199
Carter	0.163	0.022	0.337
Claiborne	0.074	0.010	0.151
Cocke	0.080	0.011	0.161
Cumberland	0.089	0.013	0.174
Grainger	0.050	0.007	0.101
Greene	0.141	0.020	0.282
Hamblen	0.140	0.019	0.284
Hamilton	0.467	0.067	0.912
Hancock	0.016	0.002	0.032
Hawkins	0.117	0.016	0.235
Jefferson	0.117	0.016	0.239
Johnson	0.060	0.008	0.128
Knox	0.867	0.120	1.754
Loudon	0.068	0.010	0.133
Marion	0.042	0.006	0.082
McMinn	0.080	0.011	0.157
Meigs	0.017	0.002	0.033
Monroe	0.066	0.009	0.130
Morgan	0.034	0.005	0.067
Polk	0.023	0.003	0.044
Rhea	0.046	0.007	0.091
Roane	0.084	0.012	0.163
Scott	0.043	0.006	0.085
Sevier	0.145	0.020	0.287
Sullivan	0.164	0.023	0.325
Unicoi	0.039	0.005	0.078
Union	0.045	0.006	0.091
Washington	0.232	0.032	0.470

Statistics for East Tennessee
$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$

Name for this simulation : SCENARIO MOBILE 50% REDUCTION IN NOx
Total Expected Cost ($x10^6) per Respiratory disease in East TN - O3 season

WTP Total in ET (O3-1hr)

Disease	Cost_avg	±SE	Cost(5%)	Cost(95%)	Cost_avg/Pop
Asthma	9.26	1.12	2.09	17.42	5.68
Copd	56.97	4.57	26.83	88.88	34.97
Copd65	42.90	4.39	12.77	75.44	145.84

WTP Total in ET (O3-8hr)

Disease	Cost_avg	±SE	Cost(5%)	Cost(95%)	Cost_avg/Pop
Asthma	9.88	1.59	1.38	19.73	6.07
Copd	71.90	8.10	25.71	121.48	44.13
Copd65	46.44	6.40	9.69	86.63	157.87

COI Total in ET (O3-1hr)

Disease	Cost_avg	±SE	Cost(5%)	Cost(95%)	Cost_avg/Pop
Asthma	2.70	0.33	0.61	5.09	1.66
Copd	25.98	2.08	12.23	40.53	15.95
Copd65	23.73	2.43	7.06	41.73	80.67

COI Total in ET (O3-8hr)

Disease	Cost_avg	±SE	Cost(5%)	Cost(95%)	Cost_avg/Pop
Asthma	2.89	0.46	0.40	5.76	1.77
Copd	32.79	3.69	11.72	55.39	20.12
Copd65	25.69	3.54	5.36	47.92	87.33

COH Total in ET (O3-1hr)

Disease	Cost_avg	±SE	Cost(5%)	Cost(95%)	Cost_avg/Pop
Asthma	0.96	0.12	0.22	1.81	0.59
Copd	9.75	0.78	4.59	15.22	5.99
Copd65	9.11	0.93	2.71	16.02	30.97

COH Total in ET (O3-8hr)

Disease	Cost_avg	±SE	Cost(5%)	Cost(95%)	Cost_avg/Pop
Asthma	1.03	0.16	0.14	2.05	0.63
Copd	12.31	1.39	4.40	20.80	7.56
Copd65	9.86	1.36	2.06	18.40	33.53

```
  Statistics for this run
^^^^^^^^^^^^^^^^^^^^^^^^^^


    Name for this simulation : SCENARIO MOBILE 50% REDUCTION IN NOx


Operation                                       Flag

------------------------------------------------------

Generate output file with healt impact      :    OramKX_m.sal
Display Modeling Domain and Study Area      :    N
Display Relative Risk uncertainties         :    N
Display Hospital admissions by County in ET :    N
Display Summary graphs of Admissions in ET  :    N
Perform and Economic Valuation              :    Y
Perform Sensitivity analysis                :    N
Perform Monte Carlo simulation              :    N
Display Tornado graphs for Indep Variables  :    N
Display Scatter plots for var correlations  :    N
------------------------------------------------------


 --->> Normal Completion of program ORAM
```

Appendix C

ORAM Output: Scenario Point source NOx reduction

```
 OUTPUT FROM ORAM SYSTEM     Version 1.0
         PSH (December 2001)
=========================================

 Name for this simulation : SCENARIO POINT 70% REDUCTION IN NOx
 Date of simulation       : Sat Dec 16 17:34:36 2001
 Health parameters        : KNOX
```

Relative Risk by Respiratory Disease: O3-1hr

Disease	RR	LL(5%)	UL(95%)
Asthma	1.127	1.029	1.234
Copd	1.082	1.039	1.126
Copd65	1.082	1.025	1.142

Relative Risk by Respiratory Disease: O3-8hr

Disease	RR	LL(5%)	UL(95%)
Asthma	1.113	1.016	1.219
Copd	1.069	1.025	1.114
Copd65	1.074	1.016	1.136

***** Hospital Admissions Deterministic Results *****

ASTHMA ADMISSIONS USING OZONE_1hr

County	Expected	+/- SE	%Population
Anderson	38.	16.	0.07
Bledsoe	5.	2.	0.05
Blount	51.	21.	0.06
Bradley	30.	12.	0.04
Campbell	28.	12.	0.09
Carter	34.	14.	0.08
Claiborne	16.	7.	0.07
Cocke	19.	8.	0.07
Cumberland	22.	9.	0.06
Grainger	11.	4.	0.07
Greene	34.	14.	0.07
Hamblen	30.	12.	0.07
Hamilton	121.	49.	0.05
Hancock	3.	1.	0.06
Hawkins	27.	11.	0.07
Jefferson	24.	10.	0.07
Johnson	11.	5.	0.08
Knox	220.	92.	0.07
Loudon	19.	8.	0.06
Marion	10.	4.	0.05
McMinn	21.	9.	0.06
Meigs	5.	2.	0.06
Monroe	15.	6.	0.05
Morgan	9.	4.	0.06
Polk	6.	2.	0.04
Rhea	11.	4.	0.05
Roane	23.	9.	0.06
Scott	11.	4.	0.07
Sevier	30.	13.	0.06
Sullivan	73.	31.	0.06
Unicoi	11.	5.	0.08
Union	10.	4.	0.07
Washington	68.	29.	0.08

COPD ADMISSIONS USING OZONE_1hr

County	Expected	+/- SE	%Population
Anderson	159.	44.	0.29
Bledsoe	19.	5.	0.20
Blount	206.	57.	0.25
Bradley	116.	31.	0.17
Campbell	120.	34.	0.39
Carter	141.	39.	0.32
Claiborne	65.	18.	0.29
Cocke	79.	22.	0.30
Cumberland	89.	24.	0.24
Grainger	43.	12.	0.27
Greene	140.	39.	0.29
Hamblen	122.	34.	0.27
Hamilton	479.	130.	0.20
Hancock	13.	4.	0.26
Hawkins	111.	31.	0.27
Jefferson	99.	27.	0.29
Johnson	46.	13.	0.33
Knox	919.	254.	0.31
Loudon	77.	21.	0.25
Marion	39.	11.	0.19
McMinn	83.	23.	0.22
Meigs	19.	5.	0.23
Monroe	60.	16.	0.21
Morgan	39.	11.	0.25
Polk	22.	6.	0.17
Rhea	43.	12.	0.20
Roane	93.	25.	0.23
Scott	44.	12.	0.28
Sevier	122.	33.	0.22
Sullivan	298.	83.	0.25
Unicoi	47.	13.	0.34
Union	39.	11.	0.30
Washington	285.	80.	0.34

COPD65 ADMISSIONS USING OZONE_1hr

County	Expected	+/- SE	%Population
Anderson	121.	45.	1.02
Bledsoe	10.	4.	0.74
Blount	136.	50.	0.91
Bradley	68.	25.	0.66
Campbell	81.	30.	1.34
Carter	94.	35.	1.10
Claiborne	41.	15.	1.02
Cocke	49.	18.	1.08
Cumberland	84.	31.	0.87
Grainger	25.	9.	0.98
Greene	95.	35.	1.02
Hamblen	75.	28.	0.98
Hamilton	321.	117.	0.76
Hancock	10.	4.	0.92
Hawkins	68.	25.	0.96
Jefferson	59.	22.	1.03
Johnson	30.	11.	1.13
Knox	526.	195.	1.09
Loudon	57.	21.	0.90
Marion	25.	9.	0.70
McMinn	58.	21.	0.82
Meigs	11.	4.	0.84
Monroe	39.	14.	0.76
Morgan	21.	8.	0.92
Polk	15.	6.	0.66
Rhea	29.	11.	0.74
Roane	70.	26.	0.84
Scott	24.	9.	1.00
Sevier	73.	27.	0.82
Sullivan	216.	80.	0.89
Unicoi	37.	14.	1.17
Union	20.	8.	1.05
Washington	174.	65.	1.17

ASTHMA ADMISSIONS USING OZONE_8hr

County	Expected	+/- SE	%Population
Anderson	39.	22.	0.07
Bledsoe	6.	3.	0.06
Blount	54.	30.	0.07
Bradley	34.	19.	0.05
Campbell	26.	16.	0.08
Carter	38.	20.	0.09
Claiborne	18.	10.	0.08
Cocke	19.	11.	0.07
Cumberland	25.	13.	0.07
Grainger	12.	6.	0.08
Greene	36.	20.	0.07
Hamblen	34.	18.	0.08
Hamilton	129.	74.	0.05
Hancock	4.	2.	0.07
Hawkins	29.	16.	0.07
Jefferson	28.	14.	0.08
Johnson	13.	7.	0.09
Knox	239.	131.	0.08
Loudon	21.	11.	0.07
Marion	12.	6.	0.06
McMinn	23.	13.	0.06
Meigs	5.	3.	0.07
Monroe	18.	9.	0.06
Morgan	11.	6.	0.07
Polk	6.	4.	0.05
Rhea	13.	7.	0.06
Roane	26.	14.	0.07
Scott	12.	6.	0.08
Sevier	35.	19.	0.06
Sullivan	79.	44.	0.07
Unicoi	10.	6.	0.07
Union	11.	6.	0.08
Washington	62.	39.	0.07

COPD ADMISSIONS USING OZONE_8hr

County	Expected	+/- SE	%Population
Anderson	192.	78.	0.35
Bledsoe	30.	11.	0.31
Blount	268.	107.	0.33
Bradley	178.	71.	0.27
Campbell	123.	54.	0.40
Carter	180.	68.	0.40
Claiborne	86.	33.	0.38
Cocke	93.	38.	0.36
Cumberland	124.	47.	0.34
Grainger	59.	22.	0.37
Greene	174.	70.	0.36
Hamblen	166.	62.	0.37
Hamilton	669.	271.	0.28
Hancock	19.	7.	0.36
Hawkins	143.	56.	0.35
Jefferson	133.	49.	0.39
Johnson	60.	22.	0.43
Knox	1148.	446.	0.39
Loudon	103.	40.	0.34
Marion	62.	23.	0.29
McMinn	115.	46.	0.31
Meigs	27.	10.	0.33
Monroe	90.	34.	0.31
Morgan	54.	20.	0.35
Polk	33.	13.	0.27
Rhea	68.	25.	0.31
Roane	132.	50.	0.33
Scott	57.	22.	0.37
Sevier	175.	67.	0.32
Sullivan	383.	151.	0.32
Unicoi	50.	22.	0.36
Union	51.	19.	0.39
Washington	301.	131.	0.36

COPD65 ADMISSIONS USING OZONE_8hr

County	Expected	+/- SE	%Population
Anderson	126.	65.	1.06
Bledsoe	13.	6.	0.92
Blount	146.	75.	0.98
Bradley	77.	40.	0.75
Campbell	75.	42.	1.24
Carter	107.	51.	1.26
Claiborne	47.	22.	1.16
Cocke	50.	26.	1.09
Cumberland	98.	47.	1.02
Grainger	30.	14.	1.15
Greene	101.	52.	1.08
Hamblen	89.	42.	1.15
Hamilton	346.	182.	0.82
Hancock	12.	5.	1.10
Hawkins	74.	37.	1.05
Jefferson	69.	32.	1.20
Johnson	35.	16.	1.34
Knox	579.	286.	1.19
Loudon	65.	32.	1.02
Marion	30.	15.	0.85
McMinn	64.	32.	0.91
Meigs	12.	6.	0.98
Monroe	46.	22.	0.90
Morgan	24.	12.	1.08
Polk	17.	9.	0.75
Rhea	36.	17.	0.92
Roane	82.	39.	0.98
Scott	27.	13.	1.13
Sevier	85.	41.	0.95
Sullivan	237.	120.	0.98
Unicoi	35.	20.	1.10
Union	23.	11.	1.19
Washington	164.	91.	1.10

RESPIRATORY DOCTOR VISITS USING OZONE_1hr

County	Expected	+/- SE	%Population
Anderson	501.	209.	0.92
Bledsoe	63.	26.	0.66
Blount	667.	276.	0.82
Bradley	396.	160.	0.59
Campbell	374.	160.	1.22
Carter	444.	188.	1.00
Claiborne	209.	88.	0.92
Cocke	251.	106.	0.97
Cumberland	288.	119.	0.78
Grainger	140.	58.	0.88
Greene	449.	188.	0.92
Hamblen	391.	163.	0.88
Hamilton	1592.	648.	0.67
Hancock	43.	18.	0.83
Hawkins	356.	149.	0.87
Jefferson	315.	132.	0.92
Johnson	144.	61.	1.02
Knox	2901.	1215.	0.98
Loudon	246.	101.	0.81
Marion	132.	54.	0.62
McMinn	274.	113.	0.74
Meigs	62.	26.	0.75
Monroe	199.	82.	0.68
Morgan	125.	51.	0.82
Polk	73.	30.	0.59
Rhea	143.	59.	0.66
Roane	303.	124.	0.75
Scott	140.	58.	0.90
Sevier	401.	166.	0.73
Sullivan	959.	403.	0.80
Unicoi	149.	64.	1.06
Union	125.	53.	0.95
Washington	893.	382.	1.06

RESPIRATORY DOCTOR VISITS USING OZONE_8hr

County	Expected	+/- SE	%Population
Anderson	515.	294.	0.94
Bledsoe	78.	40.	0.82
Blount	708.	402.	0.87
Bradley	444.	251.	0.66
Campbell	339.	213.	1.10
Carter	502.	268.	1.13
Claiborne	236.	127.	1.03
Cocke	251.	148.	0.97
Cumberland	331.	176.	0.90
Grainger	162.	85.	1.02
Greene	470.	268.	0.96
Hamblen	454.	238.	1.02
Hamilton	1696.	983.	0.72
Hancock	51.	27.	0.98
Hawkins	384.	215.	0.93
Jefferson	365.	191.	1.07
Johnson	169.	88.	1.21
Knox	3149.	1734.	1.06
Loudon	275.	150.	0.90
Marion	158.	84.	0.75
McMinn	299.	169.	0.80
Meigs	72.	38.	0.86
Monroe	234.	124.	0.80
Morgan	145.	76.	0.95
Polk	82.	46.	0.66
Rhea	177.	90.	0.82
Roane	349.	186.	0.86
Scott	155.	84.	1.00
Sevier	460.	247.	0.84
Sullivan	1040.	584.	0.87
Unicoi	137.	85.	0.98
Union	140.	76.	1.06
Washington	823.	513.	0.98

+++++++ STATISTICS FOR EAST TENNESSEE ++++++++

Name for this simulation : SCENARIO POINT 70% REDUCTION IN NOx

Total Expected Hospital admissions in East TN - O3 season

Due to short exposure: O3-1hr

Disease	Expected	±SE	5%	95%	%_Pop_Avg	%_Pop_5%	%_Pop_95%
Asthma	1042.	123.	238.	1942.	0.064	0.015	0.119
Copd	4277.	337.	2022.	6646.	0.263	0.124	0.408
Copd65	2762.	279.	826.	4833.	0.939	0.281	1.643
Resp_DV	13750.	1627.	3136.	25640.	0.844	0.192	1.574

Due to medium exposure: O3-8hr

Disease	Expected	±SE	5%	95%	%_Pop_Avg	%_Pop_5%	%_Pop_95%
Asthma	1125.	178.	159.	2226.	0.069	0.010	0.137
Copd	5548.	614.	1990.	9344.	0.341	0.122	0.574
Copd65	3023.	414.	634.	5610.	1.028	0.215	1.907
Resp_DV	14849.	2347.	2095.	29382.	0.911	0.129	1.803

*** ECONOMIC VALUATION USING WTP/COI/COH ESTIMATION ***
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Name for this simulation : SCENARIO POINT 70% REDUCTION IN NOx

WTP ESTIMATION
COST (Million US$) OF AVOIDING ASTHMA HOSPITALIZATION (OZONE_1hr)
(Expected and 90% CI)

County	Cost_avg	Cost_L(5%)	Cost_U(95%)
Anderson	0.342	0.078	0.637
Bledsoe	0.043	0.010	0.079
Blount	0.455	0.104	0.843
Bradley	0.270	0.063	0.491
Campbell	0.255	0.057	0.487
Carter	0.303	0.068	0.574
Claiborne	0.143	0.032	0.268
Cocke	0.171	0.039	0.323
Cumberland	0.196	0.045	0.363
Grainger	0.095	0.022	0.177
Greene	0.306	0.069	0.573
Hamblen	0.266	0.061	0.496
Hamilton	1.086	0.252	1.986
Hancock	0.029	0.007	0.055
Hawkins	0.243	0.055	0.453
Jefferson	0.215	0.049	0.401
Johnson	0.098	0.022	0.187
Knox	1.978	0.449	3.704
Loudon	0.168	0.039	0.310
Marion	0.090	0.021	0.164
McMinn	0.187	0.043	0.346
Meigs	0.043	0.010	0.078
Monroe	0.136	0.031	0.250
Morgan	0.085	0.020	0.157
Polk	0.050	0.012	0.091
Rhea	0.097	0.022	0.179
Roane	0.207	0.048	0.381
Scott	0.095	0.022	0.177
Sevier	0.273	0.063	0.506
Sullivan	0.654	0.148	1.229
Unicoi	0.101	0.023	0.193
Union	0.086	0.019	0.160
Washington	0.609	0.136	1.161

COST (Million US$) OF AVOIDING COPD HOSPITALIZATION (OZONE_1hr)
(Expected and 90% CI)

County	Cost_avg	Cost_L(5%)	Cost_U(95%)
Anderson	2.131	1.008	3.309
Bledsoe	0.253	0.120	0.390
Blount	2.760	1.308	4.277
Bradley	1.558	0.745	2.395
Campbell	1.606	0.752	2.521
Carter	1.893	0.889	2.961
Claiborne	0.877	0.413	1.367
Cocke	1.058	0.498	1.651
Cumberland	1.195	0.568	1.849
Grainger	0.582	0.275	0.904
Greene	1.878	0.886	2.923
Hamblen	1.630	0.771	2.531
Hamilton	6.425	3.064	9.894
Hancock	0.179	0.085	0.278
Hawkins	1.494	0.706	2.322
Jefferson	1.321	0.624	2.055
Johnson	0.614	0.288	0.963
Knox	12.309	5.809	19.158
Loudon	1.027	0.488	1.589
Marion	0.526	0.251	0.810
McMinn	1.119	0.531	1.732
Meigs	0.256	0.122	0.396
Monroe	0.806	0.384	1.245
Morgan	0.518	0.246	0.801
Polk	0.288	0.138	0.443
Rhea	0.576	0.274	0.889
Roane	1.245	0.592	1.922
Scott	0.589	0.279	0.912
Sevier	1.632	0.774	2.529
Sullivan	3.992	1.880	6.228
Unicoi	0.635	0.298	0.997
Union	0.528	0.249	0.823
Washington	3.817	1.787	5.990

COST (Million US$) OF AVOIDING COPD65 HOSPITALIZATION (OZONE_1hr)
(Expected and 90% CI)

County	Cost_avg	Cost_L(5%)	Cost_U(95%)
Anderson	1.918	0.574	3.356
Bledsoe	0.165	0.050	0.287
Blount	2.160	0.648	3.768
Bradley	1.084	0.328	1.872
Campbell	1.283	0.379	2.276
Carter	1.490	0.442	2.631
Claiborne	0.647	0.192	1.137
Cocke	0.780	0.232	1.374
Cumberland	1.334	0.401	2.322
Grainger	0.400	0.120	0.701
Greene	1.507	0.450	2.643
Hamblen	1.199	0.359	2.098
Hamilton	5.103	1.542	8.833
Hancock	0.156	0.047	0.273
Hawkins	1.083	0.324	1.897
Jefferson	0.932	0.278	1.633
Johnson	0.472	0.139	0.835
Knox	8.371	2.497	14.689
Loudon	0.906	0.272	1.577
Marion	0.399	0.121	0.690
McMinn	0.915	0.275	1.594
Meigs	0.171	0.051	0.296
Monroe	0.622	0.187	1.079
Morgan	0.332	0.100	0.577
Polk	0.242	0.073	0.417
Rhea	0.460	0.138	0.798
Roane	1.119	0.337	1.943
Scott	0.379	0.114	0.661
Sevier	1.164	0.349	2.029
Sullivan	3.436	1.023	6.042
Unicoi	0.593	0.175	1.052
Union	0.322	0.096	0.565
Washington	2.765	0.817	4.900

COST (Million US$) OF AVOIDING ASTHMA HOSPITALIZATION (OZONE_8hr)
(Expected and 90% CI)

County	Cost_avg	Cost_L(5%)	Cost_U(95%)
Anderson	0.351	0.050	0.694
Bledsoe	0.053	0.008	0.104
Blount	0.483	0.069	0.947
Bradley	0.303	0.044	0.585
Campbell	0.231	0.032	0.461
Carter	0.343	0.047	0.693
Claiborne	0.161	0.023	0.321
Cocke	0.171	0.024	0.339
Cumberland	0.225	0.032	0.443
Grainger	0.110	0.016	0.220
Greene	0.320	0.045	0.634
Hamblen	0.309	0.043	0.615
Hamilton	1.157	0.166	2.247
Hancock	0.035	0.005	0.069
Hawkins	0.262	0.037	0.518
Jefferson	0.249	0.035	0.497
Johnson	0.116	0.016	0.236
Knox	2.147	0.301	4.277
Loudon	0.188	0.027	0.369
Marion	0.108	0.015	0.209
McMinn	0.204	0.029	0.401
Meigs	0.049	0.007	0.096
Monroe	0.159	0.023	0.311
Morgan	0.099	0.014	0.194
Polk	0.056	0.008	0.108
Rhea	0.121	0.017	0.236
Roane	0.238	0.034	0.466
Scott	0.106	0.015	0.209
Sevier	0.314	0.045	0.615
Sullivan	0.709	0.099	1.424
Unicoi	0.093	0.013	0.186
Union	0.096	0.013	0.191
Washington	0.561	0.079	1.118

COST (Million US$) OF AVOIDING COPD HOSPITALIZATION (OZONE_8hr)
(Expected and 90% CI)

County	Cost_avg	Cost_L(5%)	Cost_U(95%)
Anderson	2.568	0.921	4.324
Bledsoe	0.398	0.143	0.668
Blount	3.594	1.293	6.034
Bradley	2.388	0.864	3.985
Campbell	1.648	0.589	2.784
Carter	2.419	0.860	4.108
Claiborne	1.156	0.413	1.954
Cocke	1.246	0.447	2.100
Cumberland	1.666	0.599	2.799
Grainger	0.797	0.285	1.345
Greene	2.336	0.837	3.935
Hamblen	2.231	0.798	3.765
Hamilton	8.958	3.236	14.975
Hancock	0.252	0.090	0.426
Hawkins	1.916	0.687	3.227
Jefferson	1.781	0.636	3.010
Johnson	0.804	0.285	1.372
Knox	15.377	5.498	25.978
Loudon	1.386	0.498	2.330
Marion	0.828	0.299	1.384
McMinn	1.537	0.553	2.583
Meigs	0.365	0.131	0.612
Monroe	1.206	0.435	2.022
Morgan	0.722	0.259	1.213
Polk	0.442	0.160	0.738
Rhea	0.908	0.327	1.523
Roane	1.773	0.638	2.974
Scott	0.770	0.276	1.294
Sevier	2.350	0.846	3.944
Sullivan	5.135	1.832	8.694
Unicoi	0.672	0.240	1.135
Union	0.685	0.245	1.157
Washington	4.034	1.442	6.815

COST (Million US$) OF AVOIDING COPD65 HOSPITALIZATION (OZONE_8hr)
(Expected and 90% CI)

County	Cost_avg	Cost_L(5%)	Cost_U(95%)
Anderson	1.998	0.419	3.707
Bledsoe	0.207	0.044	0.382
Blount	2.329	0.491	4.301
Bradley	1.232	0.262	2.256
Campbell	1.190	0.249	2.218
Carter	1.707	0.354	3.210
Claiborne	0.741	0.155	1.382
Cocke	0.794	0.166	1.474
Cumberland	1.551	0.327	2.867
Grainger	0.471	0.098	0.876
Greene	1.603	0.336	2.977
Hamblen	1.409	0.295	2.623
Hamilton	5.509	1.168	10.113
Hancock	0.186	0.039	0.347
Hawkins	1.184	0.248	2.199
Jefferson	1.094	0.228	2.039
Johnson	0.561	0.116	1.062
Knox	9.213	1.924	17.171
Loudon	1.027	0.216	1.900
Marion	0.483	0.102	0.886
McMinn	1.010	0.213	1.869
Meigs	0.199	0.042	0.367
Monroe	0.739	0.156	1.361
Morgan	0.389	0.082	0.720
Polk	0.275	0.058	0.503
Rhea	0.576	0.121	1.063
Roane	1.303	0.275	2.403
Scott	0.427	0.090	0.790
Sevier	1.356	0.286	2.504
Sullivan	3.774	0.785	7.065
Unicoi	0.558	0.117	1.041
Union	0.365	0.076	0.680
Washington	2.600	0.543	4.848

COI ESTIMATION

COST (Million US$) OF ASTHMA HOSPITALIZATION (OZONE_1hr)
(Expected and 90% CI)

County	Cost_avg	Cost_L(5%)	Cost_U(95%)
Anderson	0.100	0.023	0.186
Bledsoe	0.012	0.003	0.023
Blount	0.133	0.030	0.246
Bradley	0.079	0.018	0.144
Campbell	0.075	0.017	0.142
Carter	0.089	0.020	0.168
Claiborne	0.042	0.009	0.078
Cocke	0.050	0.011	0.094
Cumberland	0.057	0.013	0.106
Grainger	0.028	0.006	0.052
Greene	0.089	0.020	0.167
Hamblen	0.078	0.018	0.145
Hamilton	0.317	0.074	0.580
Hancock	0.009	0.002	0.016
Hawkins	0.071	0.016	0.132
Jefferson	0.063	0.014	0.117
Johnson	0.029	0.006	0.055
Knox	0.578	0.131	1.082
Loudon	0.049	0.011	0.091
Marion	0.026	0.006	0.048
McMinn	0.055	0.013	0.101
Meigs	0.012	0.003	0.023
Monroe	0.040	0.009	0.073
Morgan	0.025	0.006	0.046
Polk	0.015	0.003	0.027
Rhea	0.028	0.007	0.052
Roane	0.060	0.014	0.111
Scott	0.028	0.006	0.052
Sevier	0.080	0.018	0.148
Sullivan	0.191	0.043	0.359
Unicoi	0.030	0.007	0.056
Union	0.025	0.006	0.047
Washington	0.178	0.040	0.339

COST (Million US$) OF COPD HOSPITALIZATION (OZONE_1hr)
(Expected and 90% CI)

County	Cost_avg	Cost_L(5%)	Cost_U(95%)
Anderson	0.972	0.460	1.509
Bledsoe	0.115	0.055	0.178
Blount	1.258	0.596	1.950
Bradley	0.711	0.340	1.092
Campbell	0.732	0.343	1.150
Carter	0.863	0.405	1.350
Claiborne	0.400	0.188	0.623
Cocke	0.482	0.227	0.753
Cumberland	0.545	0.259	0.843
Grainger	0.265	0.126	0.412
Greene	0.856	0.404	1.333
Hamblen	0.743	0.351	1.154
Hamilton	2.930	1.397	4.512
Hancock	0.082	0.039	0.127
Hawkins	0.681	0.322	1.059
Jefferson	0.602	0.285	0.937
Johnson	0.280	0.131	0.439
Knox	5.613	2.649	8.735
Loudon	0.468	0.222	0.725
Marion	0.240	0.115	0.369
McMinn	0.510	0.242	0.790
Meigs	0.117	0.056	0.180
Monroe	0.368	0.175	0.567
Morgan	0.236	0.112	0.365
Polk	0.132	0.063	0.202
Rhea	0.262	0.125	0.405
Roane	0.568	0.270	0.876
Scott	0.269	0.127	0.416
Sevier	0.744	0.353	1.153
Sullivan	1.820	0.857	2.840
Unicoi	0.290	0.136	0.455
Union	0.241	0.114	0.375
Washington	1.741	0.815	2.731

COST (Million US$) OF COPD65 HOSPITALIZATION (OZONE_1hr)
(Expected and 90% CI)

County	Cost_avg	Cost_L(5%)	Cost_U(95%)
Anderson	1.061	0.317	1.856
Bledsoe	0.091	0.028	0.159
Blount	1.195	0.358	2.084
Bradley	0.600	0.182	1.035
Campbell	0.710	0.209	1.259
Carter	0.824	0.244	1.455
Claiborne	0.358	0.106	0.629
Cocke	0.432	0.128	0.760
Cumberland	0.738	0.222	1.284
Grainger	0.221	0.066	0.388
Greene	0.834	0.249	1.462
Hamblen	0.663	0.198	1.160
Hamilton	2.823	0.853	4.886
Hancock	0.086	0.026	0.151
Hawkins	0.599	0.179	1.049
Jefferson	0.515	0.154	0.903
Johnson	0.261	0.077	0.462
Knox	4.631	1.381	8.125
Loudon	0.501	0.151	0.873
Marion	0.221	0.067	0.382
McMinn	0.506	0.152	0.882
Meigs	0.094	0.028	0.164
Monroe	0.344	0.104	0.597
Morgan	0.183	0.055	0.319
Polk	0.134	0.041	0.231
Rhea	0.254	0.077	0.442
Roane	0.619	0.186	1.075
Scott	0.210	0.063	0.366
Sevier	0.644	0.193	1.122
Sullivan	1.901	0.566	3.342
Unicoi	0.328	0.097	0.582
Union	0.178	0.053	0.313
Washington	1.529	0.452	2.710

COST (Million US$) OF ASTHMA HOSPITALIZATION (OZONE_8hr)
(Expected and 90% CI)

County	Cost_avg	Cost_L(5%)	Cost_U(95%)
Anderson	0.103	0.014	0.203
Bledsoe	0.015	0.002	0.030
Blount	0.141	0.020	0.277
Bradley	0.088	0.013	0.171
Campbell	0.068	0.009	0.135
Carter	0.100	0.014	0.202
Claiborne	0.047	0.007	0.094
Cocke	0.050	0.007	0.099
Cumberland	0.066	0.009	0.129
Grainger	0.032	0.005	0.064
Greene	0.094	0.013	0.185
Hamblen	0.090	0.013	0.180
Hamilton	0.338	0.049	0.656
Hancock	0.010	0.001	0.020
Hawkins	0.076	0.011	0.151
Jefferson	0.073	0.010	0.145
Johnson	0.034	0.005	0.069
Knox	0.627	0.088	1.249
Loudon	0.055	0.008	0.108
Marion	0.031	0.005	0.061
McMinn	0.060	0.008	0.117
Meigs	0.014	0.002	0.028
Monroe	0.047	0.007	0.091
Morgan	0.029	0.004	0.057
Polk	0.016	0.002	0.032
Rhea	0.035	0.005	0.069
Roane	0.069	0.010	0.136
Scott	0.031	0.004	0.061
Sevier	0.092	0.013	0.180
Sullivan	0.207	0.029	0.416
Unicoi	0.027	0.004	0.054
Union	0.028	0.004	0.056
Washington	0.164	0.023	0.327

COST (Million US$) OF COPD HOSPITALIZATION (OZONE_8hr)
(Expected and 90% CI)

County	Cost_avg	Cost_L(5%)	Cost_U(95%)
Anderson	1.171	0.420	1.971
Bledsoe	0.182	0.065	0.305
Blount	1.639	0.590	2.751
Bradley	1.089	0.394	1.817
Campbell	0.752	0.269	1.270
Carter	1.103	0.392	1.873
Claiborne	0.527	0.188	0.891
Cocke	0.568	0.204	0.958
Cumberland	0.760	0.273	1.276
Grainger	0.363	0.130	0.613
Greene	1.065	0.382	1.794
Hamblen	1.017	0.364	1.717
Hamilton	4.085	1.476	6.828
Hancock	0.115	0.041	0.194
Hawkins	0.874	0.313	1.472
Jefferson	0.812	0.290	1.372
Johnson	0.367	0.130	0.626
Knox	7.011	2.507	11.845
Loudon	0.632	0.227	1.062
Marion	0.378	0.136	0.631
McMinn	0.701	0.252	1.178
Meigs	0.166	0.060	0.279
Monroe	0.550	0.198	0.922
Morgan	0.329	0.118	0.553
Polk	0.202	0.073	0.336
Rhea	0.414	0.149	0.694
Roane	0.809	0.291	1.356
Scott	0.351	0.126	0.590
Sevier	1.072	0.386	1.798
Sullivan	2.341	0.835	3.964
Unicoi	0.306	0.109	0.517
Union	0.312	0.112	0.528
Washington	1.839	0.658	3.108

COST (Million US$) OF COPD65 HOSPITALIZATION (OZONE_8hr)
(Expected and 90% CI)

County	Cost_avg	Cost_L(5%)	Cost_U(95%)
Anderson	1.105	0.232	2.050
Bledsoe	0.115	0.024	0.212
Blount	1.288	0.271	2.379
Bradley	0.681	0.145	1.248
Campbell	0.658	0.138	1.227
Carter	0.944	0.196	1.775
Claiborne	0.410	0.085	0.765
Cocke	0.439	0.092	0.815
Cumberland	0.858	0.181	1.586
Grainger	0.260	0.054	0.485
Greene	0.887	0.186	1.647
Hamblen	0.779	0.163	1.451
Hamilton	3.047	0.646	5.594
Hancock	0.103	0.022	0.192
Hawkins	0.655	0.137	1.216
Jefferson	0.605	0.126	1.128
Johnson	0.310	0.064	0.587
Knox	5.096	1.064	9.498
Loudon	0.568	0.120	1.051
Marion	0.267	0.057	0.490
McMinn	0.559	0.118	1.034
Meigs	0.110	0.023	0.203
Monroe	0.409	0.086	0.753
Morgan	0.215	0.045	0.398
Polk	0.152	0.032	0.278
Rhea	0.319	0.067	0.588
Roane	0.721	0.152	1.329
Scott	0.236	0.050	0.437
Sevier	0.750	0.158	1.385
Sullivan	2.087	0.434	3.908
Unicoi	0.309	0.064	0.576
Union	0.202	0.042	0.376
Washington	1.438	0.300	2.682

COH ESTIMATION

HOSPITAL COST (Million US$) OF ASTHMA (OZONE_1hr)
(Expected and 90% CI)

County	Cost_avg	Cost_L(5%)	Cost_U(95%)
Anderson	0.035	0.008	0.066
Bledsoe	0.004	0.001	0.008
Blount	0.047	0.011	0.088
Bradley	0.028	0.007	0.051
Campbell	0.026	0.006	0.051
Carter	0.031	0.007	0.060
Claiborne	0.015	0.003	0.028
Cocke	0.018	0.004	0.034
Cumberland	0.020	0.005	0.038
Grainger	0.010	0.002	0.018
Greene	0.032	0.007	0.059
Hamblen	0.028	0.006	0.052
Hamilton	0.113	0.026	0.206
Hancock	0.003	0.001	0.006
Hawkins	0.025	0.006	0.047
Jefferson	0.022	0.005	0.042
Johnson	0.010	0.002	0.019
Knox	0.205	0.047	0.384
Loudon	0.017	0.004	0.032
Marion	0.009	0.002	0.017
McMinn	0.019	0.004	0.036
Meigs	0.004	0.001	0.008
Monroe	0.014	0.003	0.026
Morgan	0.009	0.002	0.016
Polk	0.005	0.001	0.009
Rhea	0.010	0.002	0.019
Roane	0.021	0.005	0.040
Scott	0.010	0.002	0.018
Sevier	0.028	0.007	0.053
Sullivan	0.068	0.015	0.128
Unicoi	0.011	0.002	0.020
Union	0.009	0.002	0.017
Washington	0.063	0.014	0.120

HOSPITAL COST (Million US$) OF COPD (OZONE_1hr)
(Expected and 90% CI)

County	Cost_avg	Cost_L(5%)	Cost_U(95%)
Anderson	0.365	0.173	0.566
Bledsoe	0.043	0.021	0.067
Blount	0.473	0.224	0.732
Bradley	0.267	0.127	0.410
Campbell	0.275	0.129	0.432
Carter	0.324	0.152	0.507
Claiborne	0.150	0.071	0.234
Cocke	0.181	0.085	0.283
Cumberland	0.205	0.097	0.317
Grainger	0.100	0.047	0.155
Greene	0.321	0.152	0.500
Hamblen	0.279	0.132	0.433
Hamilton	1.100	0.525	1.694
Hancock	0.031	0.014	0.048
Hawkins	0.256	0.121	0.398
Jefferson	0.226	0.107	0.352
Johnson	0.105	0.049	0.165
Knox	2.107	0.994	3.280
Loudon	0.176	0.084	0.272
Marion	0.090	0.043	0.139
McMinn	0.191	0.091	0.296
Meigs	0.044	0.021	0.068
Monroe	0.138	0.066	0.213
Morgan	0.089	0.042	0.137
Polk	0.049	0.024	0.076
Rhea	0.099	0.047	0.152
Roane	0.213	0.101	0.329
Scott	0.101	0.048	0.156
Sevier	0.279	0.132	0.433
Sullivan	0.683	0.322	1.066
Unicoi	0.109	0.051	0.171
Union	0.090	0.043	0.141
Washington	0.653	0.306	1.025

HOSPITAL COST (Million US$) OF COPD65 (OZONE_1hr)
(Expected and 90% CI)

County	Cost_avg	Cost_L(5%)	Cost_U(95%)
Anderson	0.407	0.122	0.713
Bledsoe	0.035	0.011	0.061
Blount	0.459	0.138	0.800
Bradley	0.230	0.070	0.398
Campbell	0.272	0.080	0.483
Carter	0.316	0.094	0.559
Claiborne	0.137	0.041	0.241
Cocke	0.166	0.049	0.292
Cumberland	0.283	0.085	0.493
Grainger	0.085	0.025	0.149
Greene	0.320	0.095	0.561
Hamblen	0.255	0.076	0.446
Hamilton	1.084	0.328	1.876
Hancock	0.033	0.010	0.058
Hawkins	0.230	0.069	0.403
Jefferson	0.198	0.059	0.347
Johnson	0.100	0.030	0.177
Knox	1.778	0.530	3.120
Loudon	0.192	0.058	0.335
Marion	0.085	0.026	0.146
McMinn	0.194	0.058	0.339
Meigs	0.036	0.011	0.063
Monroe	0.132	0.040	0.229
Morgan	0.070	0.021	0.123
Polk	0.051	0.016	0.089
Rhea	0.098	0.029	0.170
Roane	0.238	0.072	0.413
Scott	0.081	0.024	0.140
Sevier	0.247	0.074	0.431
Sullivan	0.730	0.217	1.283
Unicoi	0.126	0.037	0.223
Union	0.068	0.020	0.120
Washington	0.587	0.173	1.041

HOSPITAL COST (Million US$) OF ASTHMA (OZONE_8hr)
(Expected and 90% CI)

County	Cost_avg	Cost_L(5%)	Cost_U(95%)
Anderson	0.036	0.005	0.072
Bledsoe	0.005	0.001	0.011
Blount	0.050	0.007	0.098
Bradley	0.031	0.005	0.061
Campbell	0.024	0.003	0.048
Carter	0.036	0.005	0.072
Claiborne	0.017	0.002	0.033
Cocke	0.018	0.003	0.035
Cumberland	0.023	0.003	0.046
Grainger	0.011	0.002	0.023
Greene	0.033	0.005	0.066
Hamblen	0.032	0.005	0.064
Hamilton	0.120	0.017	0.233
Hancock	0.004	0.001	0.007
Hawkins	0.027	0.004	0.054
Jefferson	0.026	0.004	0.052
Johnson	0.012	0.002	0.025
Knox	0.223	0.031	0.444
Loudon	0.019	0.003	0.038
Marion	0.011	0.002	0.022
McMinn	0.021	0.003	0.042
Meigs	0.005	0.001	0.010
Monroe	0.017	0.002	0.032
Morgan	0.010	0.001	0.020
Polk	0.006	0.001	0.011
Rhea	0.013	0.002	0.025
Roane	0.025	0.004	0.048
Scott	0.011	0.002	0.022
Sevier	0.033	0.005	0.064
Sullivan	0.074	0.010	0.148
Unicoi	0.010	0.001	0.019
Union	0.010	0.001	0.020
Washington	0.058	0.008	0.116

HOSPITAL COST (Million US$) OF COPD (OZONE_8hr)
(Expected and 90% CI)

County	Cost_avg	Cost_L(5%)	Cost_U(95%)
Anderson	0.440	0.158	0.740
Bledsoe	0.068	0.025	0.114
Blount	0.615	0.221	1.033
Bradley	0.409	0.148	0.682
Campbell	0.282	0.101	0.477
Carter	0.414	0.147	0.703
Claiborne	0.198	0.071	0.335
Cocke	0.213	0.076	0.360
Cumberland	0.285	0.103	0.479
Grainger	0.136	0.049	0.230
Greene	0.400	0.143	0.674
Hamblen	0.382	0.137	0.645
Hamilton	1.534	0.554	2.564
Hancock	0.043	0.015	0.073
Hawkins	0.328	0.118	0.552
Jefferson	0.305	0.109	0.515
Johnson	0.138	0.049	0.235
Knox	2.632	0.941	4.447
Loudon	0.237	0.085	0.399
Marion	0.142	0.051	0.237
McMinn	0.263	0.095	0.442
Meigs	0.062	0.022	0.105
Monroe	0.207	0.074	0.346
Morgan	0.124	0.044	0.208
Polk	0.076	0.027	0.126
Rhea	0.155	0.056	0.261
Roane	0.304	0.109	0.509
Scott	0.132	0.047	0.222
Sevier	0.402	0.145	0.675
Sullivan	0.879	0.314	1.488
Unicoi	0.115	0.041	0.194
Union	0.117	0.042	0.198
Washington	0.691	0.247	1.167

HOSPITAL COST (Million US$) OF COPD65 (OZONE_8hr)
(Expected and 90% CI)

County	Cost_avg	Cost_L(5%)	Cost_U(95%)
Anderson	0.424	0.089	0.787
Bledsoe	0.044	0.009	0.081
Blount	0.495	0.104	0.913
Bradley	0.262	0.056	0.479
Campbell	0.253	0.053	0.471
Carter	0.363	0.075	0.682
Claiborne	0.157	0.033	0.294
Cocke	0.169	0.035	0.313
Cumberland	0.329	0.069	0.609
Grainger	0.100	0.021	0.186
Greene	0.341	0.071	0.632
Hamblen	0.299	0.063	0.557
Hamilton	1.170	0.248	2.148
Hancock	0.040	0.008	0.074
Hawkins	0.252	0.053	0.467
Jefferson	0.232	0.048	0.433
Johnson	0.119	0.025	0.226
Knox	1.957	0.409	3.647
Loudon	0.218	0.046	0.403
Marion	0.103	0.022	0.188
McMinn	0.215	0.045	0.397
Meigs	0.042	0.009	0.078
Monroe	0.157	0.033	0.289
Morgan	0.083	0.017	0.153
Polk	0.058	0.012	0.107
Rhea	0.122	0.026	0.226
Roane	0.277	0.058	0.510
Scott	0.091	0.019	0.168
Sevier	0.288	0.061	0.532
Sullivan	0.801	0.167	1.501
Unicoi	0.119	0.025	0.221
Union	0.077	0.016	0.144
Washington	0.552	0.115	1.030

CDV ESTIMATION

COST (Million US$) OF DOCTOR VISITS (OZONE_1hr)
(Expected and 90% CI)

County	Cost_avg	Cost_L(5%)	Cost_U(95%)
Anderson	0.140	0.032	0.262
Bledsoe	0.018	0.004	0.032
Blount	0.187	0.043	0.346
Bradley	0.111	0.026	0.202
Campbell	0.105	0.023	0.200
Carter	0.124	0.028	0.236
Claiborne	0.059	0.013	0.110
Cocke	0.070	0.016	0.133
Cumberland	0.081	0.019	0.149
Grainger	0.039	0.009	0.073
Greene	0.126	0.029	0.235
Hamblen	0.109	0.025	0.204
Hamilton	0.446	0.104	0.816
Hancock	0.012	0.003	0.023
Hawkins	0.100	0.023	0.186
Jefferson	0.088	0.020	0.165
Johnson	0.040	0.009	0.077
Knox	0.812	0.184	1.521
Loudon	0.069	0.016	0.127
Marion	0.037	0.009	0.068
McMinn	0.077	0.018	0.142
Meigs	0.017	0.004	0.032
Monroe	0.056	0.013	0.103
Morgan	0.035	0.008	0.064
Polk	0.021	0.005	0.037
Rhea	0.040	0.009	0.074
Roane	0.085	0.020	0.156
Scott	0.039	0.009	0.072
Sevier	0.112	0.026	0.208
Sullivan	0.268	0.061	0.505
Unicoi	0.042	0.009	0.079
Union	0.035	0.008	0.066
Washington	0.250	0.056	0.477

COST (Million US$) OF DOCTOR VISITS (OZONE_8hr)
(Expected and 90% CI)

County	Cost_avg	Cost_L(5%)	Cost_U(95%)
Anderson	0.144	0.020	0.285
Bledsoe	0.022	0.003	0.043
Blount	0.198	0.028	0.389
Bradley	0.124	0.018	0.240
Campbell	0.095	0.013	0.189
Carter	0.141	0.019	0.284
Claiborne	0.066	0.009	0.132
Cocke	0.070	0.010	0.139
Cumberland	0.093	0.013	0.182
Grainger	0.045	0.006	0.090
Greene	0.132	0.019	0.260
Hamblen	0.127	0.018	0.252
Hamilton	0.475	0.068	0.923
Hancock	0.014	0.002	0.028
Hawkins	0.107	0.015	0.213
Jefferson	0.102	0.014	0.204
Johnson	0.047	0.006	0.097
Knox	0.882	0.124	1.757
Loudon	0.077	0.011	0.152
Marion	0.044	0.006	0.086
McMinn	0.084	0.012	0.165
Meigs	0.020	0.003	0.039
Monroe	0.065	0.009	0.128
Morgan	0.040	0.006	0.080
Polk	0.023	0.003	0.044
Rhea	0.050	0.007	0.097
Roane	0.098	0.014	0.191
Scott	0.043	0.006	0.086
Sevier	0.129	0.018	0.253
Sullivan	0.291	0.041	0.585
Unicoi	0.038	0.005	0.076
Union	0.039	0.006	0.078
Washington	0.230	0.032	0.459

Statistics for East Tennessee
$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$

Name for this simulation : SCENARIO POINT 70% REDUCTION IN NOx
Total Expected Cost ($x10^6) per Respiratory disease in East TN - O3 season

WTP Total in ET (O3-1hr)

Disease	Cost_avg	±SE	Cost(5%)	Cost(95%)	Cost_avg/Pop
Asthma	9.37	1.11	2.14	17.48	5.75
Copd	57.32	4.51	27.10	89.05	35.18
Copd65	43.91	4.44	13.13	76.85	149.27

WTP Total in ET (O3-8hr)

Disease	Cost_avg	±SE	Cost(5%)	Cost(95%)	Cost_avg/Pop
Asthma	10.12	1.60	1.43	20.03	6.21
Copd	74.35	8.23	26.67	125.21	45.64
Copd65	48.06	6.58	10.08	89.20	163.38

COI Total in ET (O3-1hr)

Disease	Cost_avg	±SE	Cost(5%)	Cost(95%)	Cost_avg/Pop
Asthma	2.74	0.32	0.62	5.11	1.68
Copd	26.14	2.06	12.36	40.61	16.04
Copd65	24.29	2.45	7.26	42.51	82.57

COI Total in ET (O3-8hr)

Disease	Cost_avg	±SE	Cost(5%)	Cost(95%)	Cost_avg/Pop
Asthma	2.96	0.47	0.42	5.85	1.82
Copd	33.90	3.75	12.16	57.09	20.81
Copd65	26.58	3.64	5.58	49.34	90.37

COH Total in ET (O3-1hr)

Disease	Cost_avg	±SE	Cost(5%)	Cost(95%)	Cost_avg/Pop
Asthma	0.97	0.12	0.22	1.81	0.60
Copd	9.81	0.77	4.64	15.25	6.02
Copd65	9.33	0.94	2.79	16.32	31.70

COH Total in ET (O3-8hr)

Disease	Cost_avg	±SE	Cost(5%)	Cost(95%)	Cost_avg/Pop
Asthma	1.05	0.17	0.15	2.08	0.64
Copd	12.73	1.41	4.56	21.44	7.81
Copd65	10.21	1.40	2.14	18.95	34.70

```
 Statistics for this run
^^^^^^^^^^^^^^^^^^^^^^^^^^


    Name for this simulation : SCENARIO POINT 70% REDUCTION IN NOx


Operation                                       Flag
------------------------------------------------------
Generate output file with healt impact      :    OramKX_p.sal
Display Modeling Domain and Study Area      :    N
Display Relative Risk uncertainties         :    N
Display Hospital admissions by County in ET :    N
Display Summary graphs of Admissions in ET  :    N
Perform and Economic Valuation              :    Y
Perform Sensitivity analysis                :    N
Perform Monte Carlo simualation             :    N
Display Tornado graphs for Indep Variables  :    N
Display Scatter plots for var correlations  :    N
------------------------------------------------------


 --->> Normal Completion of program ORAM
```

Appendix D

ORAM Output: Scenario Mobile + Point source NOx reduction

OUTPUT FROM ORAM SYSTEM Version 1.0
PSH (December 2001)

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Name for this simulation : SCENARIO MOBILE 50% AND POINT 70% REDUCTION IN NOx
Date of simulation : Sat Dec 16 17:45:18 2001
Health parameters : KNOX

Relative Risk by Respiratory Disease: O3-1hr

Disease	RR	LL(5%)	UL(95%)
Asthma	1.127	1.029	1.234
Copd	1.082	1.039	1.126
Copd65	1.082	1.025	1.142

Relative Risk by Respiratory Disease: O3-8hr

Disease	RR	LL(5%)	UL(95%)
Asthma	1.113	1.016	1.219
Copd	1.069	1.025	1.114
Copd65	1.074	1.016	1.136

***** Hospital Admissions Deterministic Results *****

ASTHMA ADMISSIONS USING OZONE_1hr

County	Expected	+/- SE	%Population
Anderson	36.	15.	0.07
Bledsoe	4.	2.	0.04
Blount	45.	19.	0.06
Bradley	25.	10.	0.04
Campbell	25.	10.	0.08
Carter	29.	12.	0.07
Claiborne	13.	5.	0.06
Cocke	17.	7.	0.06
Cumberland	18.	7.	0.05
Grainger	9.	4.	0.06
Greene	30.	13.	0.06
Hamblen	26.	11.	0.06
Hamilton	101.	41.	0.04
Hancock	3.	1.	0.05
Hawkins	25.	10.	0.06
Jefferson	21.	9.	0.06
Johnson	10.	4.	0.07
Knox	199.	83.	0.07
Loudon	17.	7.	0.05
Marion	9.	4.	0.04
McMinn	18.	7.	0.05
Meigs	4.	2.	0.05
Monroe	13.	5.	0.05
Morgan	8.	3.	0.05
Polk	5.	2.	0.04
Rhea	9.	4.	0.04
Roane	20.	8.	0.05
Scott	9.	4.	0.06
Sevier	25.	10.	0.05
Sullivan	68.	28.	0.06
Unicoi	11.	5.	0.08
Union	8.	3.	0.06
Washington	64.	27.	0.08

COPD ADMISSIONS USING OZONE_1hr

County	Expected	+/- SE	%Population
Anderson	149.	41.	0.27
Bledsoe	16.	4.	0.17
Blount	181.	49.	0.22
Bradley	92.	25.	0.14
Campbell	103.	29.	0.34
Carter	121.	34.	0.27
Claiborne	53.	15.	0.23
Cocke	69.	19.	0.27
Cumberland	73.	20.	0.20
Grainger	37.	10.	0.23
Greene	123.	34.	0.25
Hamblen	103.	28.	0.23
Hamilton	388.	105.	0.16
Hancock	11.	3.	0.22
Hawkins	101.	28.	0.25
Jefferson	84.	23.	0.25
Johnson	40.	11.	0.28
Knox	823.	226.	0.28
Loudon	67.	18.	0.22
Marion	33.	9.	0.16
McMinn	69.	19.	0.18
Meigs	16.	4.	0.20
Monroe	51.	14.	0.18
Morgan	33.	9.	0.22
Polk	17.	5.	0.14
Rhea	36.	10.	0.17
Roane	80.	22.	0.20
Scott	35.	9.	0.22
Sevier	97.	26.	0.18
Sullivan	275.	76.	0.23
Unicoi	45.	13.	0.32
Union	33.	9.	0.25
Washington	270.	75.	0.32

COPD65 ADMISSIONS USING OZONE_1hr

County	Expected	+/- SE	%Population
Anderson	114.	42.	0.96
Bledsoe	9.	3.	0.64
Blount	121.	45.	0.81
Bradley	56.	20.	0.55
Campbell	71.	26.	1.17
Carter	82.	30.	0.96
Claiborne	34.	13.	0.85
Cocke	43.	16.	0.95
Cumberland	70.	26.	0.73
Grainger	22.	8.	0.85
Greene	85.	31.	0.91
Hamblen	65.	24.	0.85
Hamilton	269.	97.	0.63
Hancock	8.	3.	0.79
Hawkins	63.	23.	0.88
Jefferson	51.	19.	0.89
Johnson	26.	10.	1.00
Knox	478.	176.	0.98
Loudon	51.	19.	0.80
Marion	22.	8.	0.61
McMinn	49.	18.	0.70
Meigs	9.	3.	0.74
Monroe	34.	13.	0.67
Morgan	18.	7.	0.79
Polk	13.	5.	0.55
Rhea	25.	9.	0.64
Roane	62.	23.	0.74
Scott	19.	7.	0.82
Sevier	60.	22.	0.67
Sullivan	201.	75.	0.83
Unicoi	35.	13.	1.11
Union	17.	6.	0.91
Washington	165.	62.	1.11

ASTHMA ADMISSIONS USING OZONE_8hr

County	Expected	+/- SE	%Population
Anderson	37.	21.	0.07
Bledsoe	5.	3.	0.05
Blount	48.	28.	0.06
Bradley	29.	16.	0.04
Campbell	23.	14.	0.07
Carter	34.	18.	0.08
Claiborne	15.	8.	0.07
Cocke	17.	10.	0.07
Cumberland	22.	11.	0.06
Grainger	11.	6.	0.07
Greene	32.	18.	0.07
Hamblen	31.	16.	0.07
Hamilton	113.	64.	0.05
Hancock	3.	2.	0.06
Hawkins	26.	15.	0.06
Jefferson	24.	13.	0.07
Johnson	12.	6.	0.08
Knox	220.	120.	0.07
Loudon	19.	10.	0.06
Marion	11.	6.	0.05
McMinn	20.	11.	0.05
Meigs	5.	3.	0.06
Monroe	16.	8.	0.05
Morgan	10.	5.	0.06
Polk	5.	3.	0.04
Rhea	12.	6.	0.05
Roane	24.	13.	0.06
Scott	10.	5.	0.06
Sevier	30.	16.	0.05
Sullivan	74.	41.	0.06
Unicoi	10.	6.	0.07
Union	9.	5.	0.07
Washington	58.	37.	0.07

COPD ADMISSIONS USING OZONE_8hr

County	Expected	+/- SE	%Population
Anderson	184.	75.	0.34
Bledsoe	27.	10.	0.28
Blount	247.	99.	0.30
Bradley	160.	63.	0.24
Campbell	112.	48.	0.37
Carter	165.	61.	0.37
Claiborne	76.	29.	0.33
Cocke	85.	35.	0.33
Cumberland	111.	42.	0.30
Grainger	54.	20.	0.34
Greene	160.	64.	0.33
Hamblen	151.	56.	0.34
Hamilton	607.	241.	0.26
Hancock	17.	6.	0.32
Hawkins	130.	53.	0.32
Jefferson	120.	44.	0.35
Johnson	55.	20.	0.39
Knox	1073.	414.	0.36
Loudon	97.	37.	0.32
Marion	57.	21.	0.27
McMinn	105.	41.	0.28
Meigs	25.	9.	0.30
Monroe	83.	31.	0.28
Morgan	49.	18.	0.33
Polk	30.	12.	0.24
Rhea	62.	22.	0.28
Roane	123.	46.	0.30
Scott	51.	19.	0.32
Sevier	156.	59.	0.28
Sullivan	364.	145.	0.30
Unicoi	47.	21.	0.34
Union	46.	17.	0.35
Washington	285.	126.	0.34

COPD65 ADMISSIONS USING OZONE_8hr

County	Expected	+/- SE	%Population
Anderson	120.	62.	1.01
Bledsoe	12.	5.	0.82
Blount	132.	68.	0.89
Bradley	68.	34.	0.66
Campbell	67.	37.	1.12
Carter	97.	45.	1.13
Claiborne	40.	19.	1.01
Cocke	45.	24.	0.98
Cumberland	85.	40.	0.89
Grainger	26.	12.	1.02
Greene	91.	47.	0.98
Hamblen	79.	37.	1.02
Hamilton	306.	158.	0.72
Hancock	10.	5.	0.96
Hawkins	67.	35.	0.94
Jefferson	61.	28.	1.07
Johnson	32.	15.	1.22
Knox	535.	262.	1.10
Loudon	59.	29.	0.94
Marion	27.	13.	0.76
McMinn	57.	28.	0.81
Meigs	11.	5.	0.89
Monroe	42.	20.	0.82
Morgan	22.	10.	0.97
Polk	15.	8.	0.66
Rhea	32.	15.	0.82
Roane	75.	35.	0.89
Scott	23.	11.	0.96
Sevier	74.	35.	0.82
Sullivan	223.	112.	0.92
Unicoi	33.	19.	1.02
Union	20.	10.	1.05
Washington	152.	87.	1.02

RESPIRATORY DOCTOR VISITS USING OZONE_1hr

County	Expected	+/- SE	%Population
Anderson	473.	196.	0.86
Bledsoe	54.	22.	0.57
Blount	595.	245.	0.73
Bradley	326.	131.	0.49
Campbell	325.	138.	1.06
Carter	386.	162.	0.86
Claiborne	173.	72.	0.76
Cocke	222.	93.	0.86
Cumberland	241.	98.	0.66
Grainger	121.	50.	0.76
Greene	399.	166.	0.82
Hamblen	338.	140.	0.76
Hamilton	1331.	537.	0.56
Hancock	37.	15.	0.71
Hawkins	326.	136.	0.79
Jefferson	273.	113.	0.80
Johnson	127.	54.	0.90
Knox	2623.	1089.	0.88
Loudon	219.	90.	0.72
Marion	115.	47.	0.54
McMinn	233.	95.	0.62
Meigs	55.	22.	0.66
Monroe	175.	71.	0.60
Morgan	108.	44.	0.71
Polk	60.	24.	0.49
Rhea	123.	50.	0.57
Roane	266.	108.	0.66
Scott	114.	46.	0.73
Sevier	330.	135.	0.60
Sullivan	892.	373.	0.75
Unicoi	141.	60.	1.01
Union	108.	45.	0.82
Washington	848.	361.	1.01

RESPIRATORY DOCTOR VISITS USING OZONE_8hr

County	Expected	+/- SE	%Population
Anderson	489.	283.	0.89
Bledsoe	69.	35.	0.73
Blount	638.	365.	0.78
Bradley	386.	215.	0.58
Campbell	304.	188.	0.99
Carter	450.	236.	1.01
Claiborne	203.	107.	0.89
Cocke	224.	133.	0.86
Cumberland	287.	152.	0.78
Grainger	144.	75.	0.90
Greene	423.	241.	0.86
Hamblen	403.	209.	0.90
Hamilton	1495.	850.	0.63
Hancock	44.	23.	0.85
Hawkins	342.	198.	0.83
Jefferson	323.	168.	0.95
Johnson	153.	78.	1.09
Knox	2900.	1581.	0.98
Loudon	253.	136.	0.83
Marion	142.	75.	0.67
McMinn	266.	147.	0.71
Meigs	65.	34.	0.79
Monroe	211.	112.	0.72
Morgan	130.	67.	0.85
Polk	72.	40.	0.58
Rhea	157.	80.	0.73
Roane	318.	167.	0.79
Scott	133.	70.	0.85
Sevier	397.	210.	0.72
Sullivan	974.	547.	0.81
Unicoi	127.	81.	0.90
Union	123.	66.	0.93
Washington	763.	486.	0.90

+++++++ STATISTICS FOR EAST TENNESSEE ++++++++

Name for this simulation :

SCENARIO MOBILE 50% AND POINT 70% REDUCTION IN NOx

Total Expected Hospital admissions in East TN - O3 season

Due to short exposure: O3-1hr

Disease	Expected	±SE	5%	95%	%_Pop_Avg	%_Pop_5%	%_Pop_95%
Asthma	921.	109.	211.	1707.	0.057	0.013	0.105
Copd	3722.	296.	1764.	5768.	0.228	0.108	0.354
Copd65	2450.	249.	735.	4273.	0.833	0.250	1.453
Resp_DV	12157.	1442.	2789.	22536.	0.746	0.171	1.383

Due to medium exposure: O3-8hr

Disease	Expected	±SE	5%	95%	%_Pop_Avg	%_Pop_5%	%_Pop_95%
Asthma	1016.	161.	144.	1996.	0.062	0.009	0.123
Copd	5116.	566.	1840.	8591.	0.314	0.113	0.527
Copd65	2738.	376.	576.	5061.	0.931	0.196	1.721
Resp_DV	13408.	2122.	1904.	26351.	0.823	0.117	1.617

*** ECONOMIC VALUATION USING WTP/COI/COH ESTIMATION ***
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Name for this simulation : SCENARIO MOBILE 50% AND POINT 70% REDUCTION IN NOx

WTP ESTIMATION
COST (Million US$) OF AVOIDING ASTHMA HOSPITALIZATION (OZONE_1hr)
(Expected and 90% CI)

County	Cost_avg	Cost_L(5%)	Cost_U(95%)
Anderson	0.322	0.074	0.598
Bledsoe	0.037	0.009	0.067
Blount	0.406	0.093	0.750
Bradley	0.222	0.052	0.402
Campbell	0.222	0.050	0.419
Carter	0.263	0.060	0.493
Claiborne	0.118	0.027	0.220
Cocke	0.151	0.034	0.283
Cumberland	0.164	0.038	0.302
Grainger	0.082	0.019	0.152
Greene	0.272	0.062	0.507
Hamblen	0.230	0.053	0.426
Hamilton	0.907	0.212	1.649
Hancock	0.025	0.006	0.047
Hawkins	0.223	0.051	0.414
Jefferson	0.186	0.043	0.345
Johnson	0.087	0.020	0.164
Knox	1.789	0.409	3.326
Loudon	0.150	0.035	0.275
Marion	0.079	0.018	0.143
McMinn	0.159	0.037	0.291
Meigs	0.037	0.009	0.068
Monroe	0.119	0.028	0.218
Morgan	0.073	0.017	0.135
Polk	0.041	0.010	0.074
Rhea	0.084	0.019	0.154
Roane	0.181	0.042	0.332
Scott	0.077	0.018	0.142
Sevier	0.225	0.052	0.412
Sullivan	0.608	0.138	1.138
Unicoi	0.096	0.022	0.183
Union	0.074	0.017	0.137
Washington	0.578	0.130	1.097

COST (Million US$) OF AVOIDING COPD HOSPITALIZATION (OZONE_1hr)
(Expected and 90% CI)

County	Cost_avg	Cost_L(5%)	Cost_U(95%)
Anderson	1.992	0.944	3.087
Bledsoe	0.210	0.100	0.324
Blount	2.425	1.151	3.752
Bradley	1.229	0.589	1.884
Campbell	1.381	0.649	2.158
Carter	1.624	0.766	2.530
Claiborne	0.713	0.338	1.108
Cocke	0.922	0.435	1.435
Cumberland	0.973	0.463	1.500
Grainger	0.495	0.235	0.766
Greene	1.650	0.781	2.562
Hamblen	1.384	0.657	2.144
Hamilton	5.194	2.484	7.975
Hancock	0.151	0.072	0.234
Hawkins	1.353	0.640	2.101
Jefferson	1.125	0.533	1.744
Johnson	0.537	0.252	0.838
Knox	11.023	5.219	17.101
Loudon	0.896	0.426	1.383
Marion	0.447	0.214	0.687
McMinn	0.923	0.440	1.425
Meigs	0.220	0.105	0.339
Monroe	0.689	0.328	1.062
Morgan	0.437	0.208	0.675
Polk	0.227	0.109	0.349
Rhea	0.479	0.228	0.739
Roane	1.068	0.509	1.645
Scott	0.465	0.222	0.717
Sevier	1.299	0.619	2.004
Sullivan	3.685	1.739	5.738
Unicoi	0.601	0.282	0.942
Union	0.448	0.212	0.694
Washington	3.612	1.695	5.657

COST (Million US$) OF AVOIDING COPD65 HOSPITALIZATION (OZONE_1hr)
(Expected and 90% CI)

County	Cost_avg	Cost_L(5%)	Cost_U(95%)
Anderson	1.811	0.543	3.161
Bledsoe	0.143	0.043	0.247
Blount	1.932	0.581	3.362
Bradley	0.895	0.272	1.541
Campbell	1.122	0.333	1.977
Carter	1.299	0.387	2.281
Claiborne	0.539	0.161	0.942
Cocke	0.691	0.206	1.212
Cumberland	1.121	0.338	1.942
Grainger	0.347	0.104	0.605
Greene	1.345	0.403	2.352
Hamblen	1.040	0.312	1.813
Hamilton	4.277	1.297	7.375
Hancock	0.134	0.040	0.234
Hawkins	0.994	0.298	1.738
Jefferson	0.809	0.243	1.412
Johnson	0.418	0.124	0.737
Knox	7.594	2.274	13.269
Loudon	0.810	0.244	1.406
Marion	0.349	0.106	0.602
McMinn	0.778	0.235	1.350
Meigs	0.150	0.045	0.259
Monroe	0.547	0.165	0.947
Morgan	0.287	0.086	0.498
Polk	0.200	0.061	0.344
Rhea	0.396	0.120	0.687
Roane	0.982	0.296	1.701
Scott	0.309	0.093	0.536
Sevier	0.961	0.290	1.666
Sullivan	3.204	0.956	5.618
Unicoi	0.564	0.167	0.998
Union	0.278	0.083	0.486
Washington	2.630	0.779	4.650

COST (Million US$) OF AVOIDING ASTHMA HOSPITALIZATION (OZONE_8hr)
(Expected and 90% CI)

County	Cost_avg	Cost_L(5%)	Cost_U(95%)
Anderson	0.333	0.047	0.656
Bledsoe	0.047	0.007	0.092
Blount	0.435	0.062	0.849
Bradley	0.263	0.038	0.507
Campbell	0.207	0.029	0.409
Carter	0.307	0.043	0.614
Claiborne	0.138	0.020	0.274
Cocke	0.153	0.022	0.300
Cumberland	0.196	0.028	0.382
Grainger	0.098	0.014	0.193
Greene	0.288	0.041	0.567
Hamblen	0.275	0.039	0.541
Hamilton	1.020	0.147	1.969
Hancock	0.030	0.004	0.060
Hawkins	0.233	0.033	0.457
Jefferson	0.220	0.031	0.436
Johnson	0.104	0.014	0.211
Knox	1.977	0.279	3.910
Loudon	0.172	0.025	0.338
Marion	0.097	0.014	0.188
McMinn	0.181	0.026	0.355
Meigs	0.045	0.006	0.087
Monroe	0.144	0.021	0.279
Morgan	0.088	0.013	0.173
Polk	0.049	0.007	0.094
Rhea	0.107	0.015	0.209
Roane	0.217	0.031	0.422
Scott	0.090	0.013	0.176
Sevier	0.270	0.039	0.526
Sullivan	0.664	0.093	1.326
Unicoi	0.087	0.012	0.171
Union	0.084	0.012	0.166
Washington	0.520	0.073	1.030

COST (Million US$) OF AVOIDING COPD HOSPITALIZATION (OZONE_8hr)
(Expected and 90% CI)

County	Cost_avg	Cost_L(5%)	Cost_U(95%)
Anderson	2.468	0.887	4.146
Bledsoe	0.363	0.131	0.607
Blount	3.307	1.192	5.539
Bradley	2.150	0.780	3.580
Campbell	1.506	0.540	2.536
Carter	2.211	0.790	3.740
Claiborne	1.024	0.367	1.723
Cocke	1.137	0.409	1.910
Cumberland	1.490	0.537	2.495
Grainger	0.724	0.260	1.217
Greene	2.147	0.772	3.606
Hamblen	2.026	0.728	3.408
Hamilton	8.130	2.944	13.558
Hancock	0.226	0.081	0.379
Hawkins	1.746	0.628	2.932
Jefferson	1.611	0.578	2.713
Johnson	0.741	0.264	1.259
Knox	14.384	5.158	24.228
Loudon	1.295	0.466	2.173
Marion	0.763	0.276	1.274
McMinn	1.404	0.506	2.352
Meigs	0.339	0.122	0.567
Monroe	1.113	0.402	1.861
Morgan	0.661	0.238	1.108
Polk	0.398	0.144	0.663
Rhea	0.827	0.298	1.384
Roane	1.644	0.593	2.754
Scott	0.678	0.244	1.135
Sevier	2.090	0.755	3.495
Sullivan	4.882	1.746	8.244
Unicoi	0.635	0.228	1.071
Union	0.617	0.222	1.039
Washington	3.817	1.368	6.430

COST (Million US$) OF AVOIDING COPD65 HOSPITALIZATION (OZONE_8hr)
(Expected and 90% CI)

County	Cost_avg	Cost_L(5%)	Cost_U(95%)
Anderson	1.902	0.400	3.516
Bledsoe	0.185	0.039	0.339
Blount	2.102	0.444	3.869
Bradley	1.075	0.229	1.962
Campbell	1.070	0.225	1.983
Carter	1.535	0.320	2.868
Claiborne	0.640	0.134	1.187
Cocke	0.710	0.150	1.313
Cumberland	1.352	0.286	2.488
Grainger	0.419	0.088	0.776
Greene	1.448	0.305	2.676
Hamblen	1.255	0.264	2.325
Hamilton	4.867	1.035	8.903
Hancock	0.163	0.034	0.301
Hawkins	1.058	0.223	1.955
Jefferson	0.971	0.204	1.801
Johnson	0.510	0.106	0.958
Knox	8.508	1.785	15.789
Loudon	0.945	0.199	1.744
Marion	0.436	0.093	0.798
McMinn	0.902	0.191	1.662
Meigs	0.181	0.038	0.333
Monroe	0.668	0.142	1.227
Morgan	0.350	0.074	0.645
Polk	0.240	0.051	0.437
Rhea	0.513	0.108	0.943
Roane	1.188	0.251	2.185
Scott	0.366	0.077	0.674
Sevier	1.172	0.248	2.154
Sullivan	3.544	0.740	6.611
Unicoi	0.519	0.109	0.963
Union	0.322	0.068	0.598
Washington	2.417	0.507	4.489

COI ESTIMATION

COST (Million US$) OF ASTHMA HOSPITALIZATION (OZONE_1hr)
(Expected and 90% CI)

County	Cost_avg	Cost_L(5%)	Cost_U(95%)
Anderson	0.094	0.022	0.175
Bledsoe	0.011	0.002	0.020
Blount	0.119	0.027	0.219
Bradley	0.065	0.015	0.118
Campbell	0.065	0.015	0.122
Carter	0.077	0.017	0.144
Claiborne	0.035	0.008	0.064
Cocke	0.044	0.010	0.083
Cumberland	0.048	0.011	0.088
Grainger	0.024	0.006	0.045
Greene	0.080	0.018	0.148
Hamblen	0.067	0.015	0.125
Hamilton	0.265	0.062	0.482
Hancock	0.007	0.002	0.014
Hawkins	0.065	0.015	0.121
Jefferson	0.054	0.012	0.101
Johnson	0.025	0.006	0.048
Knox	0.522	0.119	0.971
Loudon	0.044	0.010	0.080
Marion	0.023	0.005	0.042
McMinn	0.046	0.011	0.085
Meigs	0.011	0.003	0.020
Monroe	0.035	0.008	0.064
Morgan	0.021	0.005	0.039
Polk	0.012	0.003	0.022
Rhea	0.024	0.006	0.045
Roane	0.053	0.012	0.097
Scott	0.023	0.005	0.041
Sevier	0.066	0.015	0.120
Sullivan	0.178	0.040	0.332
Unicoi	0.028	0.006	0.053
Union	0.022	0.005	0.040
Washington	0.169	0.038	0.321

COST (Million US$) OF COPD HOSPITALIZATION (OZONE_1hr)
(Expected and 90% CI)

County	Cost_avg	Cost_L(5%)	Cost_U(95%)
Anderson	0.908	0.430	1.408
Bledsoe	0.096	0.046	0.148
Blount	1.106	0.525	1.711
Bradley	0.560	0.268	0.859
Campbell	0.630	0.296	0.984
Carter	0.741	0.349	1.153
Claiborne	0.325	0.154	0.505
Cocke	0.420	0.199	0.654
Cumberland	0.444	0.211	0.684
Grainger	0.226	0.107	0.349
Greene	0.752	0.356	1.168
Hamblen	0.631	0.299	0.977
Hamilton	2.368	1.133	3.636
Hancock	0.069	0.033	0.107
Hawkins	0.617	0.292	0.958
Jefferson	0.513	0.243	0.795
Johnson	0.245	0.115	0.382
Knox	5.026	2.380	7.797
Loudon	0.408	0.194	0.631
Marion	0.204	0.098	0.313
McMinn	0.421	0.200	0.650
Meigs	0.100	0.048	0.154
Monroe	0.314	0.150	0.484
Morgan	0.199	0.095	0.308
Polk	0.104	0.050	0.159
Rhea	0.219	0.104	0.337
Roane	0.487	0.232	0.750
Scott	0.212	0.101	0.327
Sevier	0.592	0.282	0.914
Sullivan	1.680	0.793	2.616
Unicoi	0.274	0.129	0.429
Union	0.204	0.097	0.317
Washington	1.647	0.773	2.579

COST (Million US$) OF COPD65 HOSPITALIZATION (OZONE_1hr)
(Expected and 90% CI)

County	Cost_avg	Cost_L(5%)	Cost_U(95%)
Anderson	1.001	0.300	1.748
Bledsoe	0.079	0.024	0.137
Blount	1.069	0.321	1.859
Bradley	0.495	0.151	0.852
Campbell	0.620	0.184	1.093
Carter	0.719	0.214	1.262
Claiborne	0.298	0.089	0.521
Cocke	0.382	0.114	0.670
Cumberland	0.620	0.187	1.074
Grainger	0.192	0.058	0.335
Greene	0.744	0.223	1.301
Hamblen	0.575	0.173	1.003
Hamilton	2.366	0.718	4.079
Hancock	0.074	0.022	0.130
Hawkins	0.550	0.165	0.962
Jefferson	0.448	0.134	0.781
Johnson	0.231	0.069	0.407
Knox	4.200	1.258	7.339
Loudon	0.448	0.135	0.778
Marion	0.193	0.059	0.333
McMinn	0.431	0.130	0.747
Meigs	0.083	0.025	0.144
Monroe	0.302	0.091	0.524
Morgan	0.159	0.048	0.275
Polk	0.110	0.034	0.190
Rhea	0.219	0.066	0.380
Roane	0.543	0.164	0.941
Scott	0.171	0.052	0.297
Sevier	0.531	0.160	0.921
Sullivan	1.772	0.529	3.108
Unicoi	0.312	0.092	0.552
Union	0.154	0.046	0.269
Washington	1.455	0.431	2.572

COST (Million US$) OF ASTHMA HOSPITALIZATION (OZONE_8hr)
(Expected and 90% CI)

County	Cost_avg	Cost_L(5%)	Cost_U(95%)
Anderson	0.097	0.014	0.192
Bledsoe	0.014	0.002	0.027
Blount	0.127	0.018	0.248
Bradley	0.077	0.011	0.148
Campbell	0.061	0.009	0.120
Carter	0.090	0.013	0.179
Claiborne	0.040	0.006	0.080
Cocke	0.045	0.006	0.088
Cumberland	0.057	0.008	0.112
Grainger	0.029	0.004	0.057
Greene	0.084	0.012	0.166
Hamblen	0.080	0.011	0.158
Hamilton	0.298	0.043	0.575
Hancock	0.009	0.001	0.017
Hawkins	0.068	0.010	0.134
Jefferson	0.064	0.009	0.127
Johnson	0.031	0.004	0.062
Knox	0.578	0.082	1.142
Loudon	0.050	0.007	0.099
Marion	0.028	0.004	0.055
McMinn	0.053	0.008	0.104
Meigs	0.013	0.002	0.025
Monroe	0.042	0.006	0.082
Morgan	0.026	0.004	0.050
Polk	0.014	0.002	0.027
Rhea	0.031	0.004	0.061
Roane	0.063	0.009	0.123
Scott	0.026	0.004	0.052
Sevier	0.079	0.011	0.154
Sullivan	0.194	0.027	0.387
Unicoi	0.025	0.004	0.050
Union	0.025	0.003	0.049
Washington	0.152	0.021	0.301

COST (Million US$) OF COPD HOSPITALIZATION (OZONE_8hr)
(Expected and 90% CI)

County	Cost_avg	Cost_L(5%)	Cost_U(95%)
Anderson	1.125	0.404	1.890
Bledsoe	0.165	0.060	0.277
Blount	1.508	0.544	2.526
Bradley	0.980	0.356	1.632
Campbell	0.687	0.246	1.156
Carter	1.008	0.360	1.705
Claiborne	0.467	0.168	0.786
Cocke	0.519	0.186	0.871
Cumberland	0.679	0.245	1.138
Grainger	0.330	0.119	0.555
Greene	0.979	0.352	1.644
Hamblen	0.924	0.332	1.554
Hamilton	3.707	1.342	6.182
Hancock	0.103	0.037	0.173
Hawkins	0.796	0.286	1.337
Jefferson	0.735	0.263	1.237
Johnson	0.338	0.120	0.574
Knox	6.559	2.352	11.047
Loudon	0.591	0.213	0.991
Marion	0.348	0.126	0.581
McMinn	0.640	0.231	1.072
Meigs	0.154	0.056	0.258
Monroe	0.507	0.183	0.848
Morgan	0.301	0.109	0.505
Polk	0.181	0.066	0.302
Rhea	0.377	0.136	0.631
Roane	0.750	0.270	1.256
Scott	0.309	0.111	0.518
Sevier	0.953	0.344	1.594
Sullivan	2.226	0.796	3.759
Unicoi	0.290	0.104	0.488
Union	0.282	0.101	0.474
Washington	1.740	0.624	2.932

COST (Million US$) OF COPD65 HOSPITALIZATION (OZONE_8hr)
(Expected and 90% CI)

County	Cost_avg	Cost_L(5%)	Cost_U(95%)
Anderson	1.052	0.221	1.945
Bledsoe	0.102	0.022	0.188
Blount	1.163	0.246	2.140
Bradley	0.594	0.127	1.085
Campbell	0.592	0.124	1.097
Carter	0.849	0.177	1.586
Claiborne	0.354	0.074	0.656
Cocke	0.393	0.083	0.726
Cumberland	0.748	0.158	1.376
Grainger	0.232	0.049	0.429
Greene	0.801	0.169	1.480
Hamblen	0.694	0.146	1.286
Hamilton	2.692	0.573	4.925
Hancock	0.090	0.019	0.167
Hawkins	0.585	0.123	1.081
Jefferson	0.537	0.113	0.996
Johnson	0.282	0.058	0.530
Knox	4.706	0.987	8.733
Loudon	0.523	0.110	0.965
Marion	0.241	0.051	0.441
McMinn	0.499	0.105	0.919
Meigs	0.100	0.021	0.184
Monroe	0.369	0.078	0.678
Morgan	0.194	0.041	0.357
Polk	0.133	0.028	0.242
Rhea	0.284	0.060	0.522
Roane	0.657	0.139	1.209
Scott	0.203	0.043	0.373
Sevier	0.649	0.137	1.191
Sullivan	1.960	0.409	3.657
Unicoi	0.287	0.060	0.533
Union	0.178	0.037	0.331
Washington	1.337	0.280	2.483

COH ESTIMATION

HOSPITAL COST (Million US$) OF ASTHMA (OZONE_1hr)
(Expected and 90% CI)

County	Cost_avg	Cost_L(5%)	Cost_U(95%)
Anderson	0.033	0.008	0.062
Bledsoe	0.004	0.001	0.007
Blount	0.042	0.010	0.078
Bradley	0.023	0.005	0.042
Campbell	0.023	0.005	0.043
Carter	0.027	0.006	0.051
Claiborne	0.012	0.003	0.023
Cocke	0.016	0.004	0.029
Cumberland	0.017	0.004	0.031
Grainger	0.009	0.002	0.016
Greene	0.028	0.006	0.053
Hamblen	0.024	0.005	0.044
Hamilton	0.094	0.022	0.171
Hancock	0.003	0.001	0.005
Hawkins	0.023	0.005	0.043
Jefferson	0.019	0.004	0.036
Johnson	0.009	0.002	0.017
Knox	0.186	0.042	0.345
Loudon	0.016	0.004	0.029
Marion	0.008	0.002	0.015
McMinn	0.016	0.004	0.030
Meigs	0.004	0.001	0.007
Monroe	0.012	0.003	0.023
Morgan	0.008	0.002	0.014
Polk	0.004	0.001	0.008
Rhea	0.009	0.002	0.016
Roane	0.019	0.004	0.034
Scott	0.008	0.002	0.015
Sevier	0.023	0.005	0.043
Sullivan	0.063	0.014	0.118
Unicoi	0.010	0.002	0.019
Union	0.008	0.002	0.014
Washington	0.060	0.013	0.114

HOSPITAL COST (Million US$) OF COPD (OZONE_1hr)
(Expected and 90% CI)

County	Cost_avg	Cost_L(5%)	Cost_U(95%)
Anderson	0.341	0.162	0.529
Bledsoe	0.036	0.017	0.056
Blount	0.415	0.197	0.642
Bradley	0.210	0.101	0.322
Campbell	0.236	0.111	0.369
Carter	0.278	0.131	0.433
Claiborne	0.122	0.058	0.190
Cocke	0.158	0.075	0.246
Cumberland	0.167	0.079	0.257
Grainger	0.085	0.040	0.131
Greene	0.283	0.134	0.439
Hamblen	0.237	0.112	0.367
Hamilton	0.889	0.425	1.365
Hancock	0.026	0.012	0.040
Hawkins	0.232	0.110	0.360
Jefferson	0.193	0.091	0.299
Johnson	0.092	0.043	0.144
Knox	1.887	0.893	2.928
Loudon	0.153	0.073	0.237
Marion	0.077	0.037	0.118
McMinn	0.158	0.075	0.244
Meigs	0.038	0.018	0.058
Monroe	0.118	0.056	0.182
Morgan	0.075	0.036	0.115
Polk	0.039	0.019	0.060
Rhea	0.082	0.039	0.127
Roane	0.183	0.087	0.282
Scott	0.080	0.038	0.123
Sevier	0.222	0.106	0.343
Sullivan	0.631	0.298	0.982
Unicoi	0.103	0.048	0.161
Union	0.077	0.036	0.119
Washington	0.618	0.290	0.968

HOSPITAL COST (Million US$) OF COPD65 (OZONE_1hr)
(Expected and 90% CI)

County	Cost_avg	Cost_L(5%)	Cost_U(95%)
Anderson	0.385	0.115	0.671
Bledsoe	0.030	0.009	0.052
Blount	0.410	0.123	0.714
Bradley	0.190	0.058	0.327
Campbell	0.238	0.071	0.420
Carter	0.276	0.082	0.484
Claiborne	0.114	0.034	0.200
Cocke	0.147	0.044	0.257
Cumberland	0.238	0.072	0.413
Grainger	0.074	0.022	0.129
Greene	0.286	0.086	0.500
Hamblen	0.221	0.066	0.385
Hamilton	0.908	0.276	1.566
Hancock	0.029	0.009	0.050
Hawkins	0.211	0.063	0.369
Jefferson	0.172	0.052	0.300
Johnson	0.089	0.026	0.156
Knox	1.613	0.483	2.818
Loudon	0.172	0.052	0.299
Marion	0.074	0.022	0.128
McMinn	0.165	0.050	0.287
Meigs	0.032	0.010	0.055
Monroe	0.116	0.035	0.201
Morgan	0.061	0.018	0.106
Polk	0.042	0.013	0.073
Rhea	0.084	0.025	0.146
Roane	0.209	0.063	0.361
Scott	0.066	0.020	0.114
Sevier	0.204	0.062	0.354
Sullivan	0.680	0.203	1.193
Unicoi	0.120	0.035	0.212
Union	0.059	0.018	0.103
Washington	0.559	0.165	0.988

HOSPITAL COST (Million US$) OF ASTHMA (OZONE_8hr)
(Expected and 90% CI)

County	Cost_avg	Cost_L(5%)	Cost_U(95%)
Anderson	0.035	0.005	0.068
Bledsoe	0.005	0.001	0.010
Blount	0.045	0.006	0.088
Bradley	0.027	0.004	0.053
Campbell	0.022	0.003	0.042
Carter	0.032	0.004	0.064
Claiborne	0.014	0.002	0.028
Cocke	0.016	0.002	0.031
Cumberland	0.020	0.003	0.040
Grainger	0.010	0.001	0.020
Greene	0.030	0.004	0.059
Hamblen	0.028	0.004	0.056
Hamilton	0.106	0.015	0.204
Hancock	0.003	0.000	0.006
Hawkins	0.024	0.003	0.047
Jefferson	0.023	0.003	0.045
Johnson	0.011	0.001	0.022
Knox	0.205	0.029	0.406
Loudon	0.018	0.003	0.035
Marion	0.010	0.001	0.019
McMinn	0.019	0.003	0.037
Meigs	0.005	0.001	0.009
Monroe	0.015	0.002	0.029
Morgan	0.009	0.001	0.018
Polk	0.005	0.001	0.010
Rhea	0.011	0.002	0.022
Roane	0.022	0.003	0.044
Scott	0.009	0.001	0.018
Sevier	0.028	0.004	0.055
Sullivan	0.069	0.010	0.138
Unicoi	0.009	0.001	0.018
Union	0.009	0.001	0.017
Washington	0.054	0.008	0.107

HOSPITAL COST (Million US$) OF COPD (OZONE_8hr)
(Expected and 90% CI)

County	Cost_avg	Cost_L(5%)	Cost_U(95%)
Anderson	0.422	0.152	0.710
Bledsoe	0.062	0.022	0.104
Blount	0.566	0.204	0.948
Bradley	0.368	0.134	0.613
Campbell	0.258	0.093	0.434
Carter	0.379	0.135	0.640
Claiborne	0.175	0.063	0.295
Cocke	0.195	0.070	0.327
Cumberland	0.255	0.092	0.427
Grainger	0.124	0.044	0.208
Greene	0.367	0.132	0.617
Hamblen	0.347	0.125	0.583
Hamilton	1.392	0.504	2.321
Hancock	0.039	0.014	0.065
Hawkins	0.299	0.108	0.502
Jefferson	0.276	0.099	0.464
Johnson	0.127	0.045	0.215
Knox	2.462	0.883	4.148
Loudon	0.222	0.080	0.372
Marion	0.131	0.047	0.218
McMinn	0.240	0.087	0.403
Meigs	0.058	0.021	0.097
Monroe	0.191	0.069	0.319
Morgan	0.113	0.041	0.190
Polk	0.068	0.025	0.113
Rhea	0.142	0.051	0.237
Roane	0.282	0.102	0.471
Scott	0.116	0.042	0.194
Sevier	0.358	0.129	0.598
Sullivan	0.836	0.299	1.411
Unicoi	0.109	0.039	0.183
Union	0.106	0.038	0.178
Washington	0.653	0.234	1.101

HOSPITAL COST (Million US$) OF COPD65 (OZONE_8hr)
(Expected and 90% CI)

County	Cost_avg	Cost_L(5%)	Cost_U(95%)
Anderson	0.404	0.085	0.747
Bledsoe	0.039	0.008	0.072
Blount	0.446	0.094	0.822
Bradley	0.228	0.049	0.417
Campbell	0.227	0.048	0.421
Carter	0.326	0.068	0.609
Claiborne	0.136	0.029	0.252
Cocke	0.151	0.032	0.279
Cumberland	0.287	0.061	0.528
Grainger	0.089	0.019	0.165
Greene	0.307	0.065	0.568
Hamblen	0.267	0.056	0.494
Hamilton	1.034	0.220	1.891
Hancock	0.035	0.007	0.064
Hawkins	0.225	0.047	0.415
Jefferson	0.206	0.043	0.382
Johnson	0.108	0.022	0.204
Knox	1.807	0.379	3.353
Loudon	0.201	0.042	0.370
Marion	0.093	0.020	0.169
McMinn	0.192	0.040	0.353
Meigs	0.038	0.008	0.071
Monroe	0.142	0.030	0.261
Morgan	0.074	0.016	0.137
Polk	0.051	0.011	0.093
Rhea	0.109	0.023	0.200
Roane	0.252	0.053	0.464
Scott	0.078	0.016	0.143
Sevier	0.249	0.053	0.457
Sullivan	0.753	0.157	1.404
Unicoi	0.110	0.023	0.205
Union	0.068	0.014	0.127
Washington	0.513	0.108	0.953

CDV ESTIMATION

COST (Million US$) OF DOCTOR VISITS (OZONE_1hr)
(Expected and 90% CI)

County	Cost_avg	Cost_L(5%)	Cost_U(95%)
Anderson	0.132	0.030	0.246
Bledsoe	0.015	0.004	0.028
Blount	0.167	0.038	0.308
Bradley	0.091	0.021	0.165
Campbell	0.091	0.021	0.172
Carter	0.108	0.025	0.203
Claiborne	0.049	0.011	0.090
Cocke	0.062	0.014	0.116
Cumberland	0.068	0.016	0.124
Grainger	0.034	0.008	0.063
Greene	0.112	0.026	0.208
Hamblen	0.095	0.022	0.175
Hamilton	0.373	0.087	0.677
Hancock	0.010	0.002	0.019
Hawkins	0.091	0.021	0.170
Jefferson	0.076	0.017	0.142
Johnson	0.036	0.008	0.067
Knox	0.734	0.168	1.366
Loudon	0.061	0.014	0.113
Marion	0.032	0.008	0.059
McMinn	0.065	0.015	0.120
Meigs	0.015	0.004	0.028
Monroe	0.049	0.011	0.090
Morgan	0.030	0.007	0.055
Polk	0.017	0.004	0.031
Rhea	0.034	0.008	0.063
Roane	0.074	0.017	0.136
Scott	0.032	0.007	0.058
Sevier	0.092	0.021	0.169
Sullivan	0.250	0.057	0.467
Unicoi	0.040	0.009	0.075
Union	0.030	0.007	0.056
Washington	0.237	0.053	0.451

COST (Million US$) OF DOCTOR VISITS (OZONE_8hr)
(Expected and 90% CI)

County	Cost_avg	Cost_L(5%)	Cost_U(95%)
Anderson	0.137	0.019	0.269
Bledsoe	0.019	0.003	0.038
Blount	0.179	0.026	0.349
Bradley	0.108	0.016	0.208
Campbell	0.085	0.012	0.168
Carter	0.126	0.018	0.252
Claiborne	0.057	0.008	0.112
Cocke	0.063	0.009	0.123
Cumberland	0.080	0.012	0.157
Grainger	0.040	0.006	0.079
Greene	0.118	0.017	0.233
Hamblen	0.113	0.016	0.222
Hamilton	0.419	0.060	0.809
Hancock	0.012	0.002	0.024
Hawkins	0.096	0.014	0.188
Jefferson	0.090	0.013	0.179
Johnson	0.043	0.006	0.087
Knox	0.812	0.115	1.606
Loudon	0.071	0.010	0.139
Marion	0.040	0.006	0.077
McMinn	0.075	0.011	0.146
Meigs	0.018	0.003	0.036
Monroe	0.059	0.008	0.115
Morgan	0.036	0.005	0.071
Polk	0.020	0.003	0.039
Rhea	0.044	0.006	0.086
Roane	0.089	0.013	0.173
Scott	0.037	0.005	0.072
Sevier	0.111	0.016	0.216
Sullivan	0.273	0.038	0.544
Unicoi	0.036	0.005	0.070
Union	0.035	0.005	0.068
Washington	0.214	0.030	0.423

Statistics for East Tennessee

$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$

Name for this simulation : SCENARIO MOBILE 50% AND POINT 70% REDUCTION IN NOx

Total Expected Cost ($x10^6) per Respiratory disease in East TN - O3 season

WTP Total in ET (O3-1hr)

Disease	Cost_avg	±SE	Cost(5%)	Cost(95%)	Cost_avg/Pop
Asthma	8.29	0.98	1.90	15.37	5.09
Copd	49.88	3.96	23.64	77.30	30.62
Copd65	38.96	3.95	11.69	67.94	132.43

WTP Total in ET (O3-8hr)

Disease	Cost_avg	±SE	Cost(5%)	Cost(95%)	Cost_avg/Pop
Asthma	9.14	1.45	1.30	17.97	5.61
Copd	68.55	7.59	24.65	115.12	42.08
Copd65	43.53	5.97	9.16	80.47	147.99

COI Total in ET (O3-1hr)

Disease	Cost_avg	±SE	Cost(5%)	Cost(95%)	Cost_avg/Pop
Asthma	2.42	0.29	0.56	4.49	1.49
Copd	22.74	1.81	10.78	35.24	13.96
Copd65	21.55	2.19	6.46	37.58	73.25

COI Total in ET (O3-8hr)

Disease	Cost_avg	±SE	Cost(5%)	Cost(95%)	Cost_avg/Pop
Asthma	2.67	0.42	0.38	5.25	1.64
Copd	31.26	3.46	11.24	52.49	19.19
Copd65	24.08	3.30	5.07	44.51	81.86

COH Total in ET (O3-1hr)

Disease	Cost_avg	±SE	Cost(5%)	Cost(95%)	Cost_avg/Pop
Asthma	0.86	0.10	0.20	1.59	0.53
Copd	8.54	0.68	4.05	13.23	5.24
Copd65	8.27	0.84	2.48	14.43	28.13

COH Total in ET (O3-8hr)

Disease	Cost_avg	±SE	Cost(5%)	Cost(95%)	Cost_avg/Pop
Asthma	0.95	0.15	0.13	1.86	0.58
Copd	11.74	1.30	4.22	19.71	7.20
Copd65	9.25	1.27	1.95	17.09	31.43

```
 Statistics for this run
^^^^^^^^^^^^^^^^^^^^^^^^^^



Name for this simulation : SCENARIO MOBILE 50% AND POINT 70% REDUCTION
IN NOx


Operation                                       Flag
------------------------------------------------------
Generate output file with healt impact      :    OramKX_t.sal
Display Modeling Domain and Study Area      :    N
Display Relative Risk uncertainties         :    N
Display Hospital admissions by County in ET :    N
Display Summary graphs of Admissions in ET  :    N
Perform and Economic Valuation              :    Y
Perform Sensitivity analysis                :    N
Perform Monte Carlo simualation             :    N
Display Tornado graphs for Indep Variables  :    N
Display Scatter plots for var correlations  :    N
------------------------------------------------------


--->> Normal Completion of program ORAM
```

Appendix E

ORAM
USER'S GUIDE

E-1 General description

The description here is just for running ORAM system. It is assumed that the user has executed the exposure model (Models-3/CMAQ) in order to obtain the ozone concentration for the study area. Nevertheless, the total sequence of activities required for a complete run is shown as follows:

- Define the modeling domain
- Select the simulation days
- Define the emission scenarios
- Run Models-3/CMAQ
- Run Pre_ORAM
- Run ORAM

This User's guide presents the details for running the ORAM system.

ORAM system has two components (1) Pre_ORAM and (2) ORAM. The preprocessor Pre_ORAM must be run first in order to generate the exposure ozone metrics required by ORAM model. The system has been written in PV-WAVE™ and requires the compiler to execute the program.

Pre_ORAM perform the calculations of ozone metrics (1-hr and 8-hr ozone maximum per day) and the Models-3/CMAQ performance evaluation. After the output of Model-3/CMAQ has passed the EPA criteria for attainment test, Pre_ORAM generate the ozone metrics file that will be an input for ORAM. Pre_ORAM must be run for as many times as category day exists. The number of category days is calculated using CART analysis as is described in Chapter 2, section 2.5 of this document. If the particular day selected for running the exposure model does not pass the EPA criteria, then another day from its ozone category must be selected using the criteria as explained in Chapter 3, section 3.4 of this document.

ORAM needs the output from Pre_ORAM and socio-economic, epidemiological, and expansion factor files as well. ORAM must be run only when all category-day have been generated by Pre_ORAM since the calculation is made by the ozone season.

E-2 Pre_ORAM

Input data

Pre_ORAM requires four input files for each category-day run. See Table E-1.

File formats

IDBYCELL.INP:

An example of this file is as follows:

County	FIPS	Cell
Anderson	47001	150
Bledsoe	47007	103
Blount	47009	106
Bradley	47011	14
Campbell	47013	195
Carter	47019	200
Claiborne	47025	241
Cocke	47029	153
Cumberland	47035	148

Table E-1 Pre_ORAM input files

File	Description	Format
CCTM.OUT	Output from Models-3/CMAQ	NetCdf → ASCII
IDBYCELL.INP	Identification number for each county in the study area (County FIPS and cell number)	CSV
OBSO3_1HR.INP	Observed ozone maximum 1hr from the monitors in the study area	CSV
OBSO3_8HR.INP	Observed ozone maximum 8hr from the monitors in the study area	CSV

OBSO3_1HR.INP:

It is a file containing by column, the ozone maximum 1-hr for each of the 214 days (ozone season) for each of the monitors in the study area. An example of its structure is presented as follows:

Anderson	Blount1	Blount2	Hamilton1	Hamilton2
62	69	65	99	60
72	76	70	70	69
42	78	61	49	51
50	59	58	45	48
44	52	48	46	47
55	65	63	57	69
83	80	80	66	66

OBSO3_8HR.INP:

Is the same structure as OBSO3_1HR.INP, but the data correspond to ozone maximum 8-hr.

Output data

For each run of Pre_ORAM, nl+2 files are generated, where nl is the number of vertical layers according to Models-3/CMAQ run.

Table E-2 Pre_ORAM output files

File	Description	Format
CCTM.ly1 CCTM.ly2 …	Output from Models-3/CMAQ: O3 concentration for the 1st layer Output from Models-3/CMAQ: O3 concentration for the 2nd layer …. As many layer as Models-3/CMAQ has	ASCII
O3METRIC.INP	Ozone metrics (max-1hr and max-8h) by county in the study area	CSV
O3HOURLY.MPE	Hourly ozone concentration by county for model performance evaluation	CSV

File formats

CCTM.ly1:

Each column contains the information (ozone concentration) by cell of the modeling domain, and each row contains the time-step (hour). An example is shown as follows:

	Hour1	Hour2	Hour3	Hour4
Cell 1	35	29	24	21
Cell 2	35	34	33	32
Cell 3	35	34	33	33
Cell 4	35	34	33	33
Cell 5	35	34	34	33

O3METRIC.INP

This file gives for each county in the study area, the ozone maximum 1-hr and 8-hr for the target day. An example is shown as follows:

County	O_3_Max-1hr	O_3_Max-8hr
Anderson	93	83
Bledsoe	58	56
Blount	68	65
Bradley	54	51
Campbell	108	95
Carter	103	99
Claiborne	101	92
Cocke	94	88
Cumberland	78	72
Grainger	93	89
Greene	88	84

O3HOURLY.MPE

This file has the same structure as CCTM.ly1 but the data is for the study area rather than all the modeling domain. An example is as follows:

	Hour-1	Hour-2	Hour-3	Hour-4	Hour-5
Cell 1	37	35	33	32	30
Cell 2	45	44	42	41	39
Cell 3	49	47	46	44	43
Cell 4	35	32	30	29	28
Cell 5	60	58	56	55	53

E-3 ORAM

ORAM requires four input files plus as many as category-day used to represent the ozone season (see section 3.4 in the document). See Table E-3.

File formats

EPIDEM.INP

Disease	Beta-1hr	SE_B1	Beta_8hr	SE_B8
Asthma	0.00478	0.00185	0.0051	0.00221
COPD	0.00327	0.00086	0.00302	0.00097
COPD65	0.00315	0.00111	0.00341	0.00136

Table E-3 ORAM input files

File	Description	Format
O3METRIC1.INP O3METRIC2.INP ….	Output from Pre_ORAM (ozone metric category-day 1) Output from Pre_ORAM (ozone metric category-day 2) … as many files as category-days	ASCII
EPIDEM.INP	Epidemiological parameters by disease and ozone metric	ASCII
DEMOG.INP	Demographic file for each county in the study area (FIPS, Population by age group, Area, and Coordinates by county)	CSV
ECOFACTOR.INP	Economic factors for each respiratory disease (WTP,COI,COH)	ASCII
EXPANFACT.INP	Expansion factor by category-day	ASCII

DEMOG.INP

County	FIPS	Pop	Pop>20	Pop>64	Area	Long.	Latitude
Anderson	47001	71330	54781	11841	341.5282	-84.1951	36.09964
Bledsoe	47007	12367	9510	1410	406.7677	-85.1635	35.56938
Blount	47009	105823	81695	14921	569.0256	-83.9221	35.67021
Bradley	47011	87965	67117	10292	332.4901	-84.8522	35.17578
Campbell	47013	39854	30727	6018	495.5861	-84.1387	36.38629

ECOFACTOR.INP

Disease	WTP	COI	COH
Asthma	9000	2629	934
COPD	13400	6110	2294
COPD65	15900	8795	3377

EXPANFACT.INP

Cat-1	22
Cat-2	50
Cat-3	52
Cat-4	53
Cat-5	37

Output data

ORAM generates three output files. See Table E-4.

Table E-4 ORAM output files

File	Description	Format
ORAM.OUT	Hospital admission and Economic valuation by respiratory disease, county and ozone metric. Total hospital admission and economic valuation for the study area, by ozone metric and disease Sensitivity analysis Monte Carlo simulation results	ASCII
ORAM_HAV.OUT	Hospital admission by county, disease and ozone metric ready for spatial analysis in ArcView	ASCII
ORAM_EAV.OUT	Economic valuation by county, disease and ozone metric ready for spatial analysis in ArcView	ASCII

E-4 How to run ORAM System

First lunch the PV-WAVE™ program (see Figure E-1). Then by typing **“ .run pre_oram”**, and pressing enter, the main menu appears. See Figure E-2. There are seven tasks performed by Pre_ORAM.

After entering the title, the program will read the output from CCTM (Models-3/CMAQ) and it will begin to ask for each of the tasks from the main menu and the user must enter (1) for Yes (he or she likes to execute the task) or (0) No (he/she doesn’t like). See Figure E-3.

After the last user’s alternative the system stop automatically returning to the PV-WAVE™ prompt. See Figure E-4.

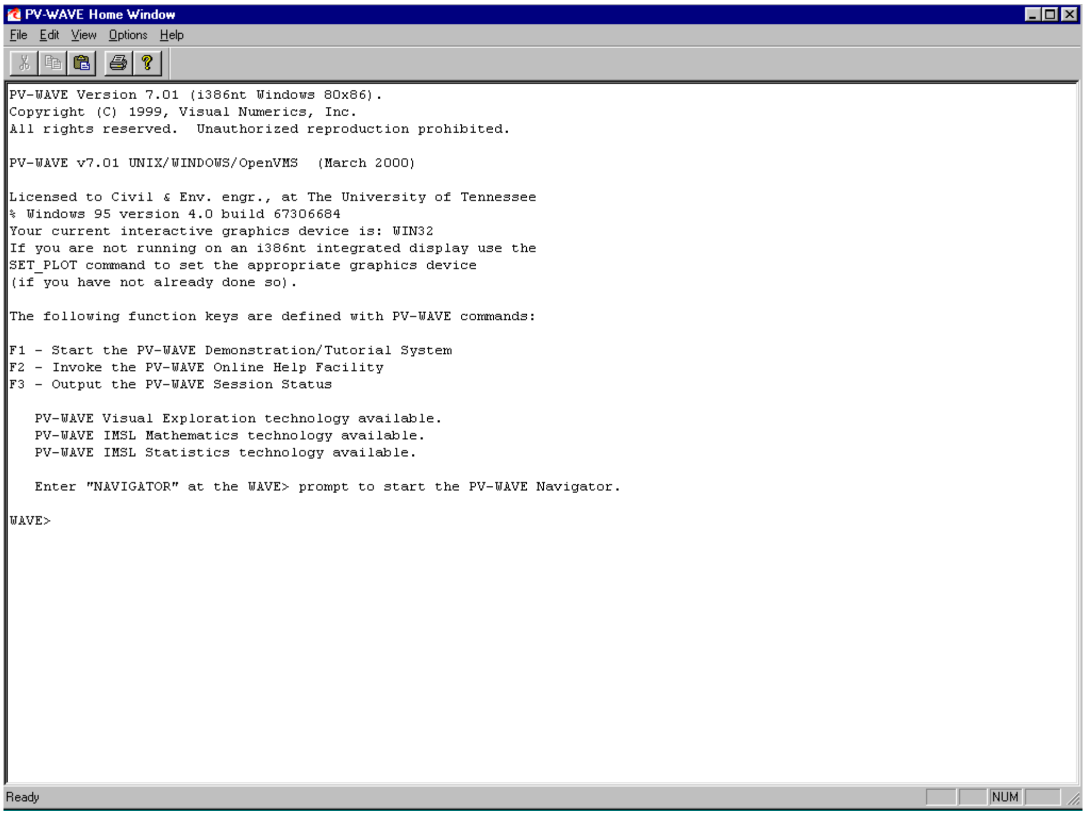

Figure E-1: PV-WAVE environment for running ORAM system

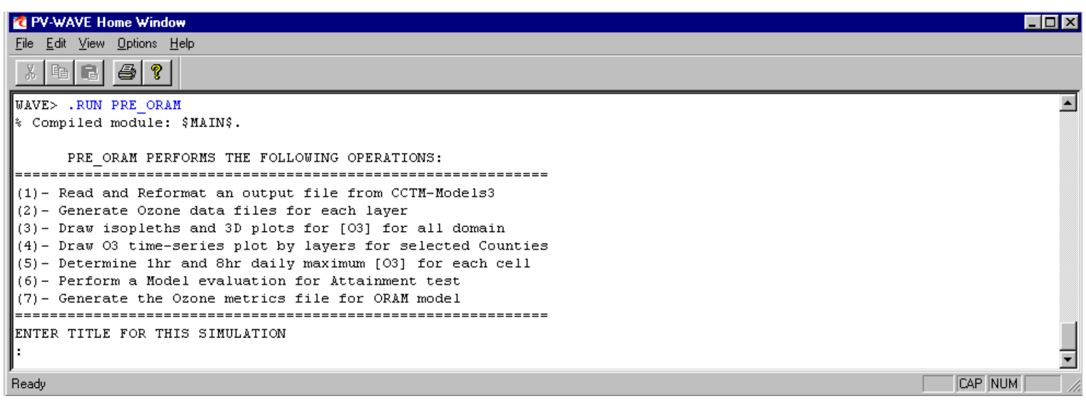

Figure E-2: Pre_ORAM main menu

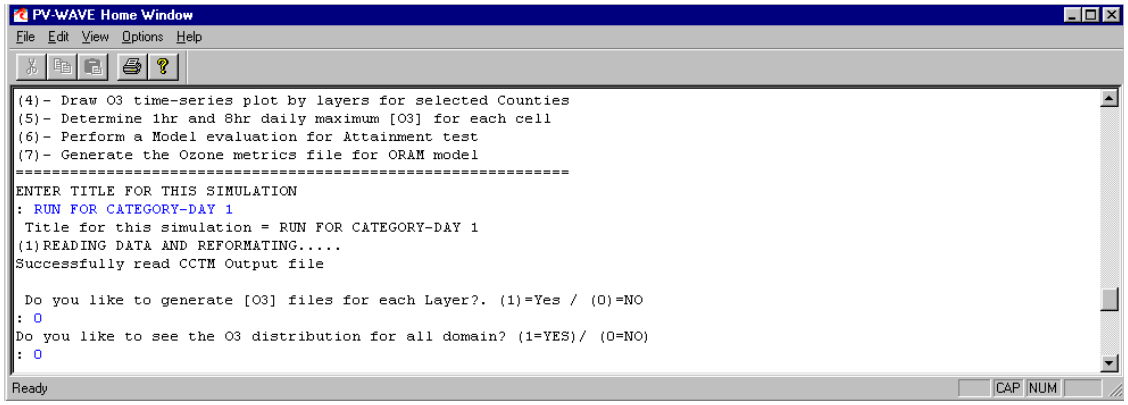

Figure E-3: Pre_ORAM User's running options

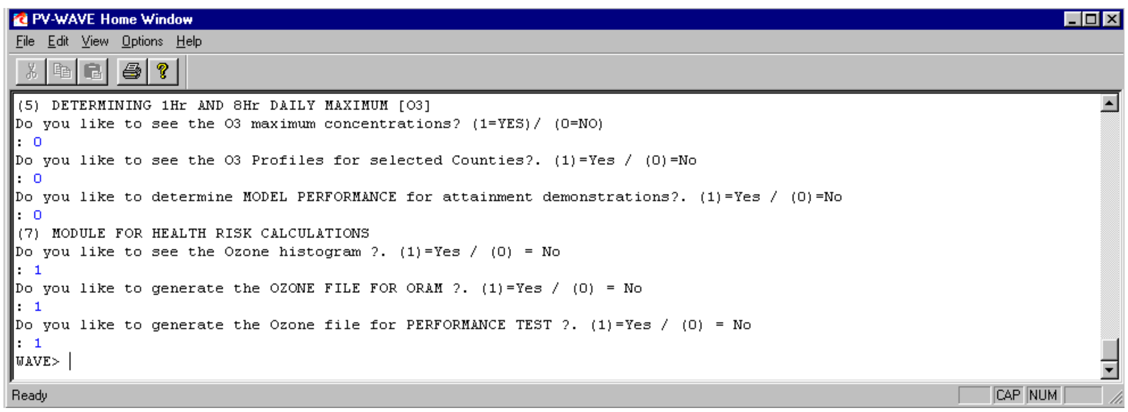

Figure E-4: Pre_ORAM end of running

After running as many times Pre_ORAM as category day exist, then the user must run ORAM as follow. In the same PV-WAVE^{TM} environment, enter the following command: **“.run oram”,** then the screen shown in Figure E-5 appears.

After entering the title for this run, ORAM read the input files detailed from 1 to 4 in the main menu. After reading the files, ORAM will begin to ask for each of the tasks from the main menu (5 to 10) and the user must enter (1) for Yes (he or she likes to execute the task) or (0) No (he/she doesn’t like). See Figure E-6.

After the last user’s alternative the system ask for entering 1 and press “enter” to close the windows and files, then return to the PV-WAVE^{TM} prompt. See Figure E-7.

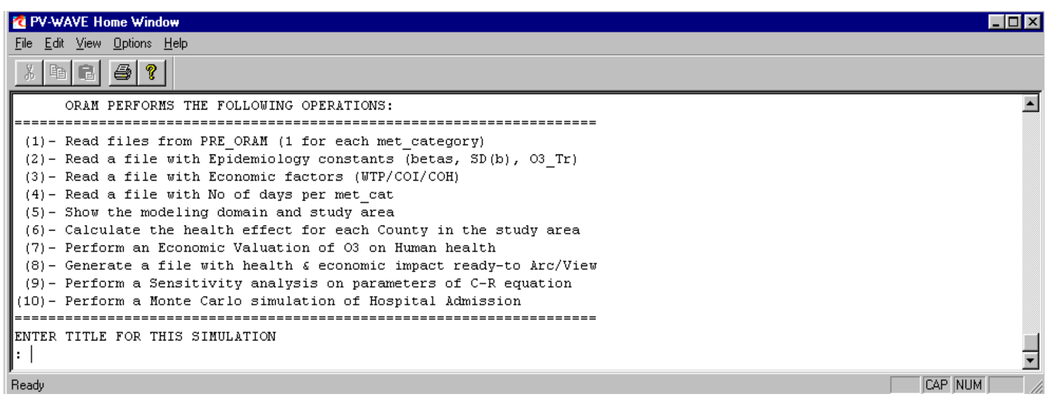

Figure E-5: ORAM main menu

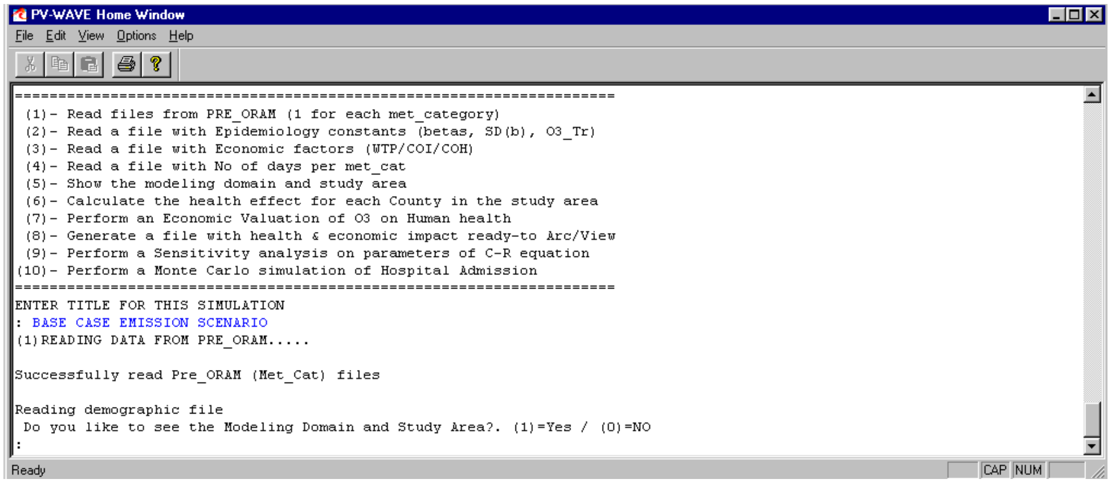

Figure E-6: ORAM user's running options

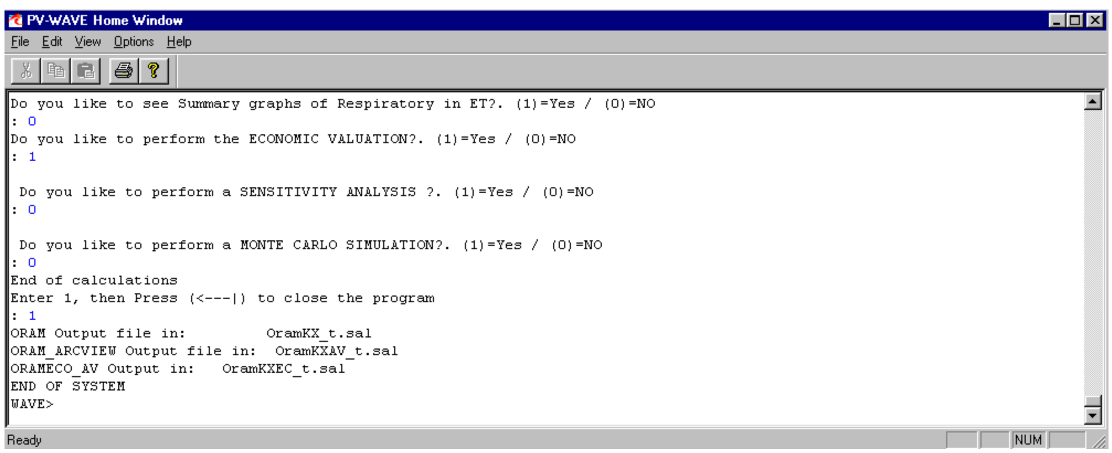

Figure E-7: ORAM end of system

VITA

Pedro A. Sanhueza H. was born in Santiago, Chile. In 1988 he received his title of Geographer engineer from the University of Santiago in Chile. In the same year he accept the position as Instructor professor at the University of Santiago, School of engineering. In 1993, he received his Master degree in Industrial Engineering from the Catholic University in Chile. In 1993 he went to Frankfurt, Germany to study Environmental Auditing. During his years as a professor, he taught Air quality management and Environmental statistics classes. He performed several research studies on air pollution and human health effects. He also worked as a consulting engineer expert in air pollution modeling. In 1999 he enrolled in the Environmental Engineering program at the University of Tennessee in Knoxville to study his PhD concentrating his studies in air quality modeling, health-effects, and policy implications. In 2002, he received the PhD in Environmental Engineering and his minor in Environmental policy, focusing his dissertation in the development of environmental decision-making tools. He will continue working in his area of interest (air quality modeling and heath risk assessment) as a faculty member of the University of Santiago in Chile and hopefully helping interested students in joining to this necessary and fascinating area of research and application.