The Effect of Nitrogen Oxide Emissions from Automobiles on the Concentration of Tropospheric Ozone in the Great Smoky Mountains National Park

James W. Herndon III[1], Rick D. Saylor[2], Joshua S. Fu[3]

[1]CSURE-REU Student New Mexico State University
[2]NOAA Air Resources Laboratory – Atmospheric Turbulence and Diffusion Division; Department of Civil Engineering, University of Tennessee
[3]Department of Civil Engineering, University of Tennessee

ABSTRACT

The Great Smoky Mountains National Park (GSMNP) is the most visited national park in the United States, drawing over 9 million visitors per year. Emissions of nitrogen oxides (NO_x) from the exhaust of automobiles transporting those visitors into and through the park combine with biogenic emissions of volatile organic compounds (VOCs) from the extensive park forests to form tropospheric (i.e., ground level) ozone, (O_3) which is harmful to plants, animals and humans. In this project, the National Oceanic and Atmospheric Administration's Atmospheric Chemistry and Canopy Exchange Simulation System (ACCESS) model is being used to estimate the impact of automobile NO_x emissions on O_3 within and downwind of GSMNP. The one-dimensional column model ACCESS utilizes a current state-of-the-science, near explicit atmospheric chemistry mechanism to simulate tropospheric O_3 from ground level to the top of the planetary boundary layer (PBL) (~2 km) and accounts for turbulent vertical atmospheric transport of trace species from within the forest canopy and up throughout the full depth of the PBL. NO_x emissions from varying levels of automobile traffic in the park will be simulated with ACCESS and the impact of the traffic on O_3 concentrations will be evaluated. Data from air quality monitoring sites within and around GSMNP will be used to assess ACCESS results.

OBJECTIVES

1. Run simulations that reflect realistic potential NOx levels from highway traffic and analyze the results of these simulations.
2. Gather data from detectors on the GSMNP site, and compare those results to our simulations. Potentially we will use those results to improve our initial conditions file and aid in future simulations.
3. Optimize ACCESS for an HPC platform.

AN ILLUSTRATION OF OUR PURPOSE: Ozone Levels in the Great Smoky Mountains as of July 31st, 2013

The National Park Service (NPS) has sensors all over the park to track the amounts of several air pollutants, including ozone (Figures 1 & 2). You can see that peaks in the park right now are on average quite high, with several high ozone days around Look Rock (Friday, July 26th, 2013, and Tuesday July 31st, 2013 having maxima in the yellow zone). ACCESS will be used to predict levels of ozone within the park when there is a given amount of traffic emissions within it. Once we have data from the simulations, we can compare it to actual values within the park, and see how similar (or dissimilar) the predictions are from actual recorded values. This could help us improve future ACCESS simulations and broaden its potential use in industry as a predictive tool.

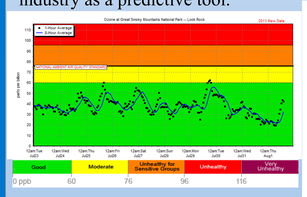


Figure 1: Ozone Concentrations at Look Rock, GSMNP
Image Source: National Park Service, "Great Smoky Mountains National Park: Air Quality 10-day Charts"
URL:http://www.nature.nps.gov/air/webcams/parks/grsmcam/grsm_datatimelines.cfm

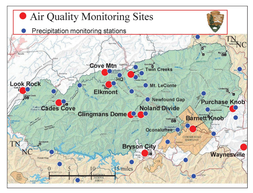


Figure 2: Map of Air Quality Monitoring sites at GSMNP
Image Source: Nancy Finley. Air Quality in the Great Smokey Mountains (PowerPoint Presentation). National Conference of State Legislatures Advisory Council on Energy. Oak Ridge, TN.

CHEMISTRY OF ACCESS

The following figures all describe the chemistry of the ACCESS program in detail. Figure 2 discusses the factors that are taken into an ACCESS simulation, such as emissions, different forms of turbulent mixing, deposition, and free tropospheric exchange within the planetary boundary layer to determine the photochemistry that is going on.

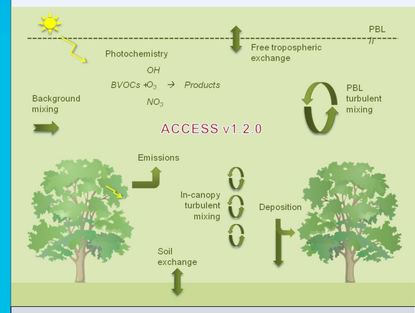


Figure 3: Diagram of ACCESS version 1.2.0
Image Source: Dr. Rick D. Saylor, Diagram of ACCESS.

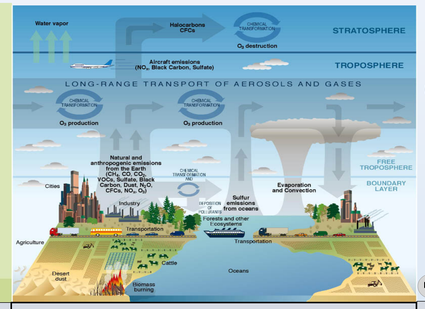


Figure 4: Diagram of the Chemistry of the Atmosphere
Image Source: ClimateScience.gov – "Schematic of chemical and transport processes related to atmospheric composition. These processes link the atmosphere with other components of the Earth system, including the oceans, land, and terrestrial and marine plants and animals.
URL: www.climatescience.gov/Library/stratplan2003/final/ccspstratplan2003-chap3.htm

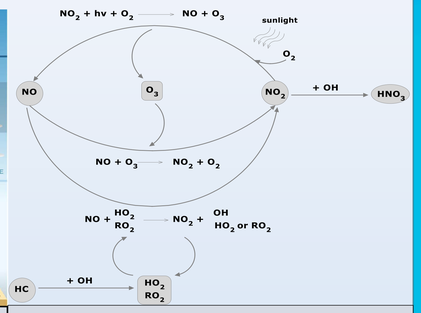
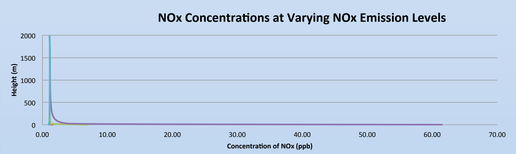


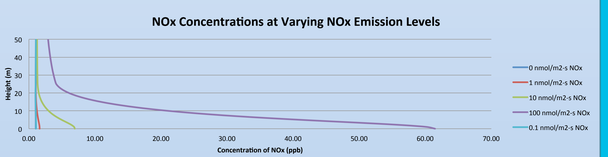
Figure 5 Schematic of atmospheric photochemical production of tropospheric ozone (a component of smog)
Image Source: Rick D. Saylor – NOAA. *Simplified diagram of reactions that take place in our atmosphere to create smog.*

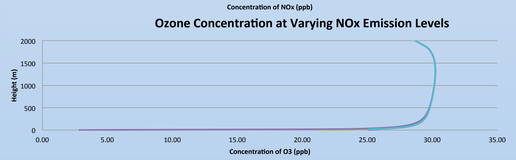
RESULTS

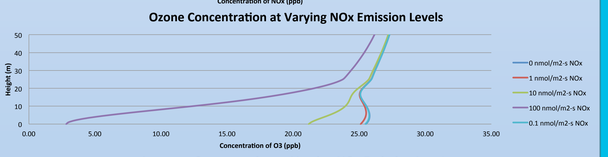
The following graphs constitute the results we have obtained thus far from the ACCESS simulations we ran. In the next column, we draw conclusions based upon these results.

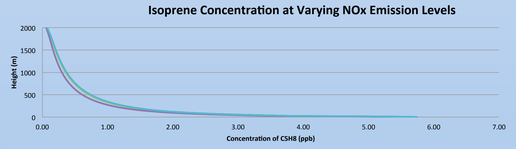
Graphs of Species Concentrations

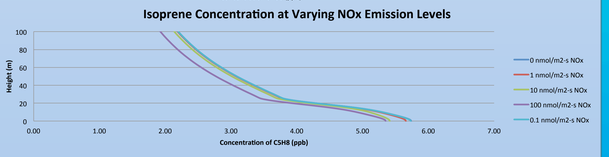


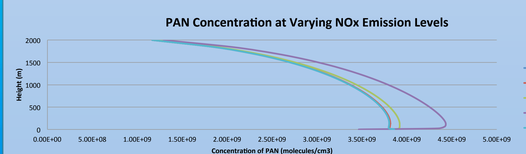


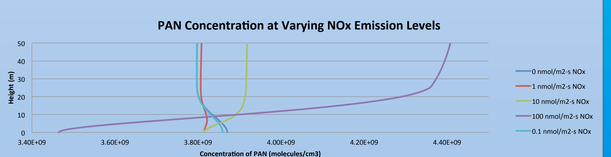


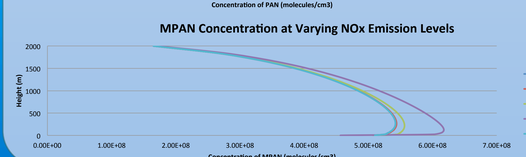


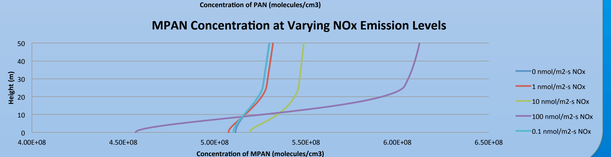






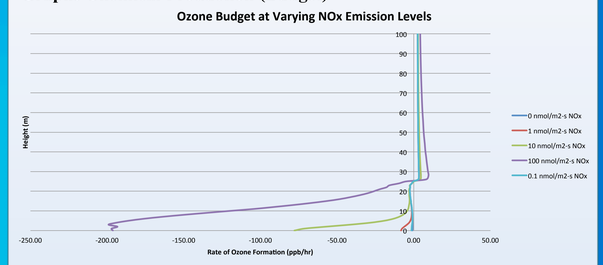


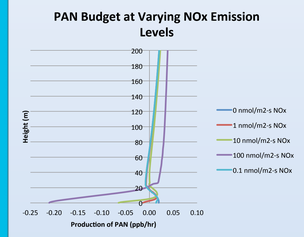


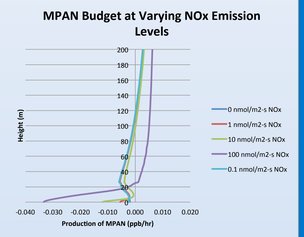


RESULTS (Cont.)

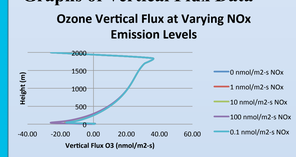
Graphs Chemical Production (Budget)

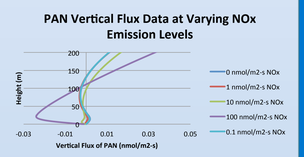


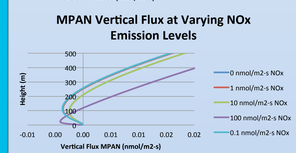


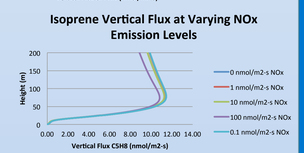


Graphs of Vertical Flux Data









FOR YOUR KNOWLEDGE: What is Isoprene (C_5H_8) and why is it important for our model?

Other than methane, isoprene is the largest single emitted hydrocarbon species from biological sources. On a global scale, isoprene emissions from vegetation are roughly 10x larger than hydrocarbon emissions from industrial and other human sources and thus have a major influence on tropospheric ozone production worldwide (via the chemistry depicted in Figure 5). Deciduous forests dominated by oak, hickory and poplar such as those prevalent in East Tennessee are primary emitters of isoprene.

CONCLUSION

Under the environmental conditions studied so far in our simulations, only minor amounts of local ozone production above the canopy are predicted. However, the simulation results suggest that the enhancements in PAN and MPAN formation from visitor traffic in the park may lead to increased ozone concentrations downwind from major highways within the park. Ozone data within and downwind of the park will be further analyzed to test the model prediction.

REFERENCES

Saylor, R. D. (2012). The Atmospheric Chemistry and Canopy Exchange Simulation System (ACCESS): model description and application to a temperate deciduous forest canopy. *Atmospheric Chemistry and Physics*, *12*(9). Retrieved from http://www.atmos-chem-phys.net/13/693/2013/acp-13-693-2013.pdf.