Meteorologically Adjusted Ozone Trend Analysis in North Carolina

Adrienne Wootten
Kristen Gore
Timothy Brown
Jie Zheng

North Carolina State University
Department of Marine, Earth and Atmospheric Sciences
Department of Statistics

Submitted to the 11th Conference on Atmospheric Chemistry
Presented January 15th, 2009

Corresponding Author
Adrienne Wootten
wootten.adrienne@yahoo.com
amwootte@ncsu.edu

Extended Abstract

1. Introduction

Tropospheric ozone is a secondary pollutant formed by a reaction of volatile organic compounds (VOC's) and nitrogen oxides (NOx) in the presence of sunlight. Inhalation of tropospheric ozone can trigger a variety of health ailments, including chest pain, throat irritation and congestion, along with creating an increased risk of bronchitis, emphysema and asthma. In 2001, the EPA implemented the Nitrogen Oxides State Implementation Plan Call (NOx SIP Call) in an effort to mitigate the formation of tropospheric ozone concentrations by reducing NOx emissions which contribute to ozone formation. However, tropospheric ozone formation is also effected by variations in meteorological factors and biogenic emissions. Therefore, it has become necessary to determine a way to remove these effects in order to evaluate the impact of the NOx SIP Call and other control programs in individual states. While the main goal of the project was to determine the impact of the NOx SIP Call in North Carolina, this study also examines local sources of tropospheric ozone and its precursors, through several different exploratory methods using measured ozone concentrations and collocated meteorological data.

2. Trend Analysis

The data used in creating the meteorologically adjusted ozone trend was collocated hourly ozone and meteorological data from four Clean Air Status and Trend Network (CASTNET) Stations around the state of North Carolina for May through September 1997 through 2006. The locations of these four stations are displayed in

Figure 1. The first of these stations is BFT142, in Beaufort, NC. The second station is CND125, Candor, NC in Central North Carolina. The third station is COW137, Coweeta, NC in the southern mountains of the state. Finally, the last station is PNF126, Cranberry, at the border between North Carolina and Tennessee in the northwestern mountains. After performing quality control to remove all data that were poor quality, a correlation matrix was used to determine which meteorological variables measured by the CASTNET stations had the strongest correlation with the greatest significance. The variables that were more then 99% significant were used in the autoregressive model. This follows the method used by Wootten and Antczak (2008), however, 1 hour ozone concentration was used in place of log transformed 8 hour maximum ozone concentration. The variables allowed in were temperature, relative humidity, solar radiation, wind speed and precipitation. A day of the year variable was allowed along with the year variable in order to account for seasonality in the hourly ozone concentration resulting from NOx and VOC emissions from biogenic sources. This procedure allows follows the method used by Wootten and Antczak (2008), however, for this project we also determined the change in ozone over time considering only the year variable. This was done in order to compare the change over time of ozone produced by the model to the raw change in time. The meteorologically adjusted ozone trends showed a smaller change in ozone concentration over time compared to the raw ozone trend. For example, Figure 2 depicts boxplots of the ozone concentration for each year, showing the raw trend over time in ozone concentration for BFT142. Figure 3, depicts the mean values for each year from the meteorologically adjusted ozone trend connected by a smoothed curve for BFT142. A close examination shows that the mean adjusted trend

closely follows the raw trend, with both indicating a decrease that could be attributed to emissions controls such as the NOx SIP Call. However, without a method to eliminate variability in ozone concentration resulting from controls other then the NOx SIP Call, it remains a challenge to determine the full impact of the NOx SIP Call specifically. More results to be presented at the meeting.

3. Trajectory Modeling

Many models, such as the HYSPLIT model, are often used to trace parcels of air back in time 12 hours or more over multiple vertical levels. Generally, HYSPLIT can be used to determine long range sources of high ozone or its precursors. Since stagnation is a factor in high ozone concentration, it becomes necessary to determine local sources of ozone around a monitoring station. Using data from the same CASTNET stations measured previously and daily data from the North Carolina Division of Air Quality (NCDAQ) and North Carolina Environment and Climate Observing Network (NCECONET) on Frying Pan Mountain and in Waynesville, North Carolina (Figure 4), two different methods were developed for determining local sources. Finger plots depend on the ozone concentration and the wind speed or the maximum wind speed. The ozone concentration is multiplied by the wind speed and normalized by dividing by the standard error of the resulting values. When plotted by wind direction or the direction of the maximum wind speed they form fingers which can indicate the direction of local emitters which are potentially causing high ozone concentrations in an area. A second method, developed for determining local sources of ozone was the localized back trajectory. If one can assume that an area around a station has the same general wind speed and direction as at the station, then the wind conditions at a station can be used to trace an air parcel backwards for a small number of hours. The area that this assumption is accurate does depending strongly on the topography. For example, at PNF126 this scenario will not be as accurate as at CND125. For the purposes of this study only hourly data were considered with ozone values greater then 160ppb. The experiments with both of these methods will be presented.

Considering the data from Frying Pan Mountain, the maximum eight hour ozone concentration for a majority of the days of each ozone season predominantly occurred around midnight of each day. In an attempt to distinguish between an area where the eight hour maximum ozone concentration occurs during the day and an area where the eight hour maximum ozone concentration occurs during the night. Similarly to the Finger plot, the Bull's Eye plot indicates the timing of high ozone at a monitor using the time of the maximum wind speed. Initial results from the prototype plots suggest that these plots can be used to indicate a difference between stations more strongly affected by long range transport of ozone then by local sources. We hypothesize that monitors affected more strongly by long range transport would have a similar Bull's Eye plot pattern as at Frying Pan Mountain (Figure 5); that is, with the center of the Bull's Eye centered around midnight, not during the day as in the Waynesville plot (Figure 6). However, the current version of the plots does not distinguish between different groups of wind speed. Therefore, further development of the Bull's Eye plot should be centered on distinguishing between low wind speed and high wind speed ozone concentrations, in order to determine the impact of local and long range sources. Further results will be discussed briefly at the conference.

Figure 1. Terrain Map of North Carolina with the locations of the four CASTNET Stations used in this study.

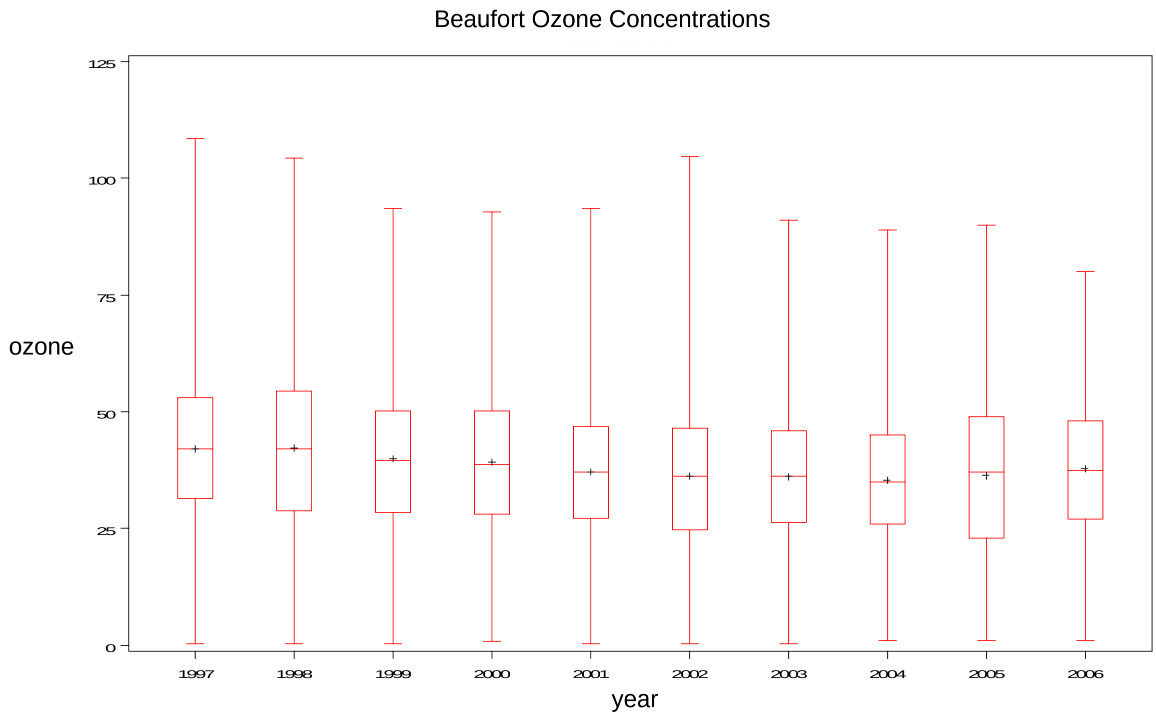

Figure 2. Boxplots of the ozone concentration for each season, 1997-2006 for BFT 142, Beaufort, NC – mean values for each season are signified by the black crosses in each boxplot

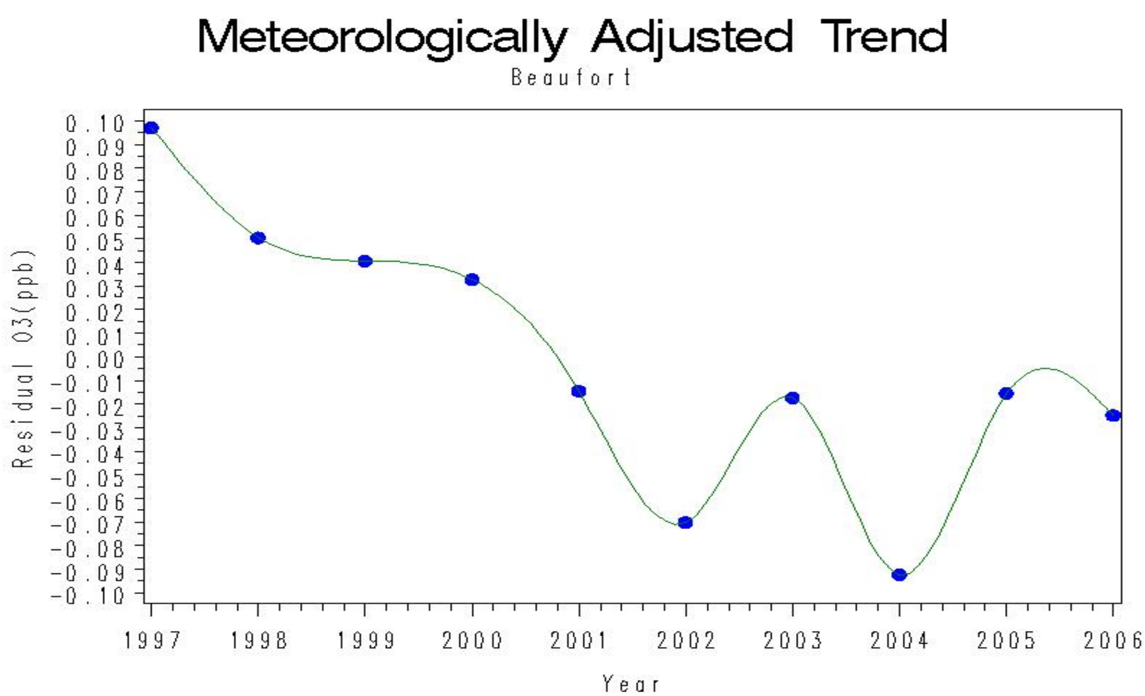

Figure 3. Meteorologically Adjusted Ozone Trend for Beaufort, NC – mean values for each season fitted with the modeled curve.

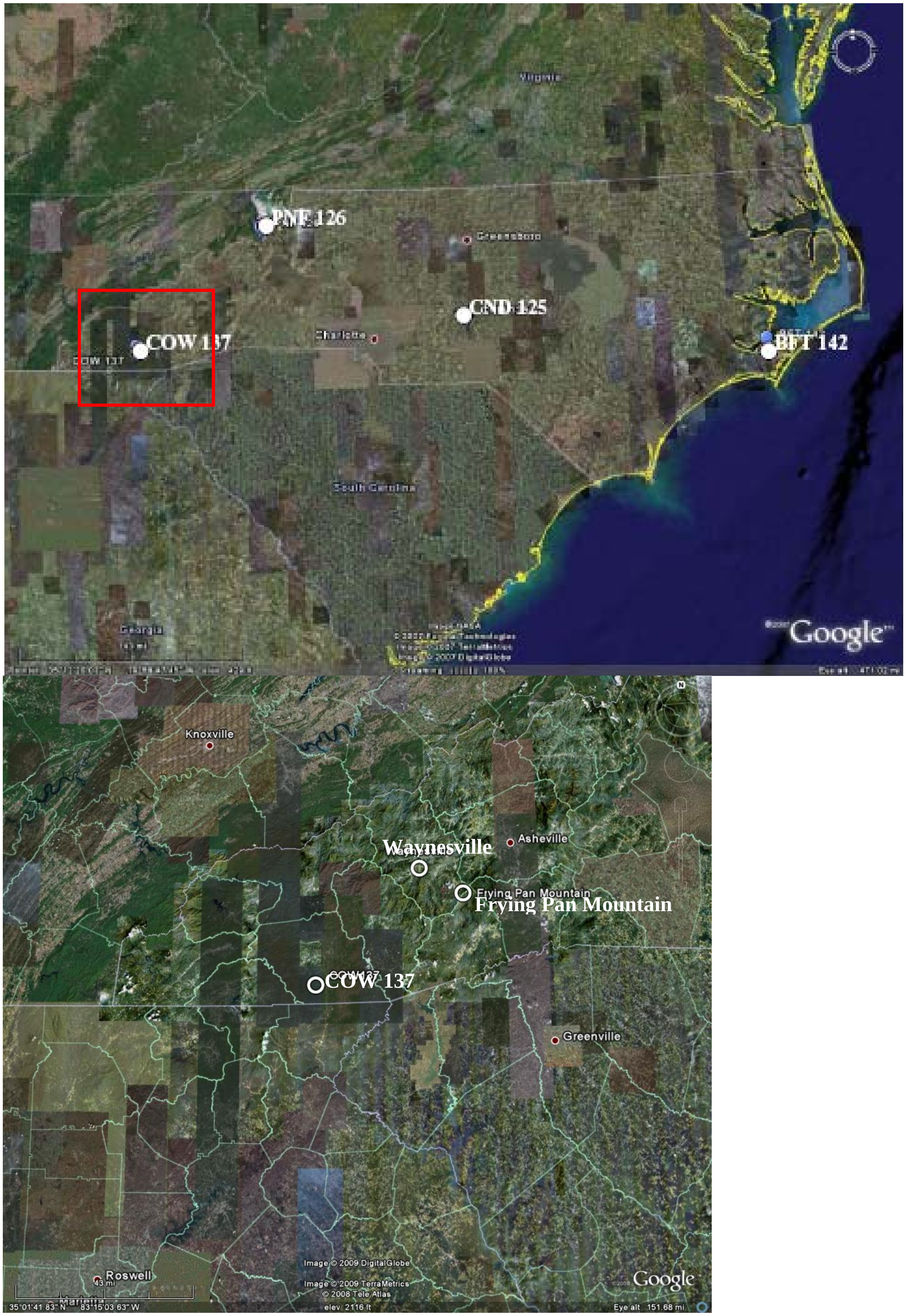

Figure 4. Terrain Map with close up map view of Frying Pan Mountain and Waynesville, NC.

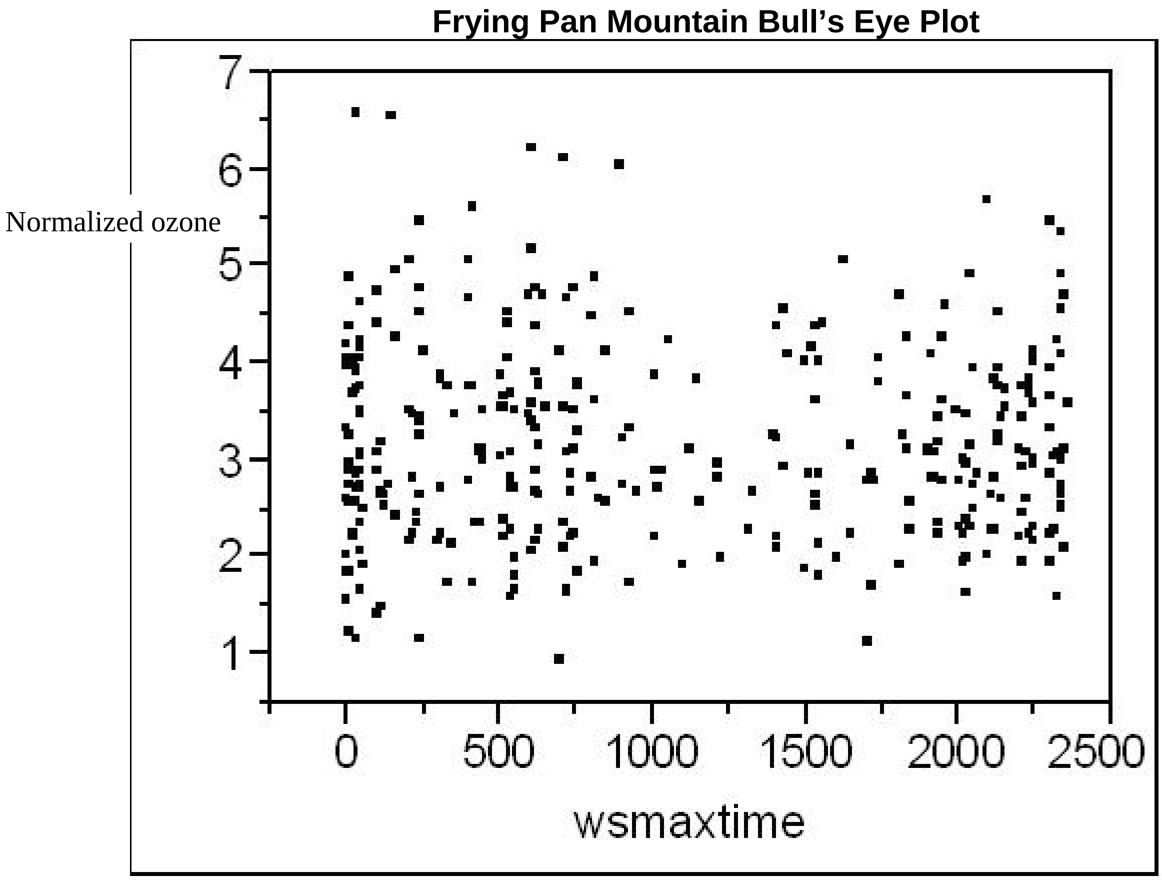

Figure 5. Frying Pan Mountain Prototype Bull's Eye Plot

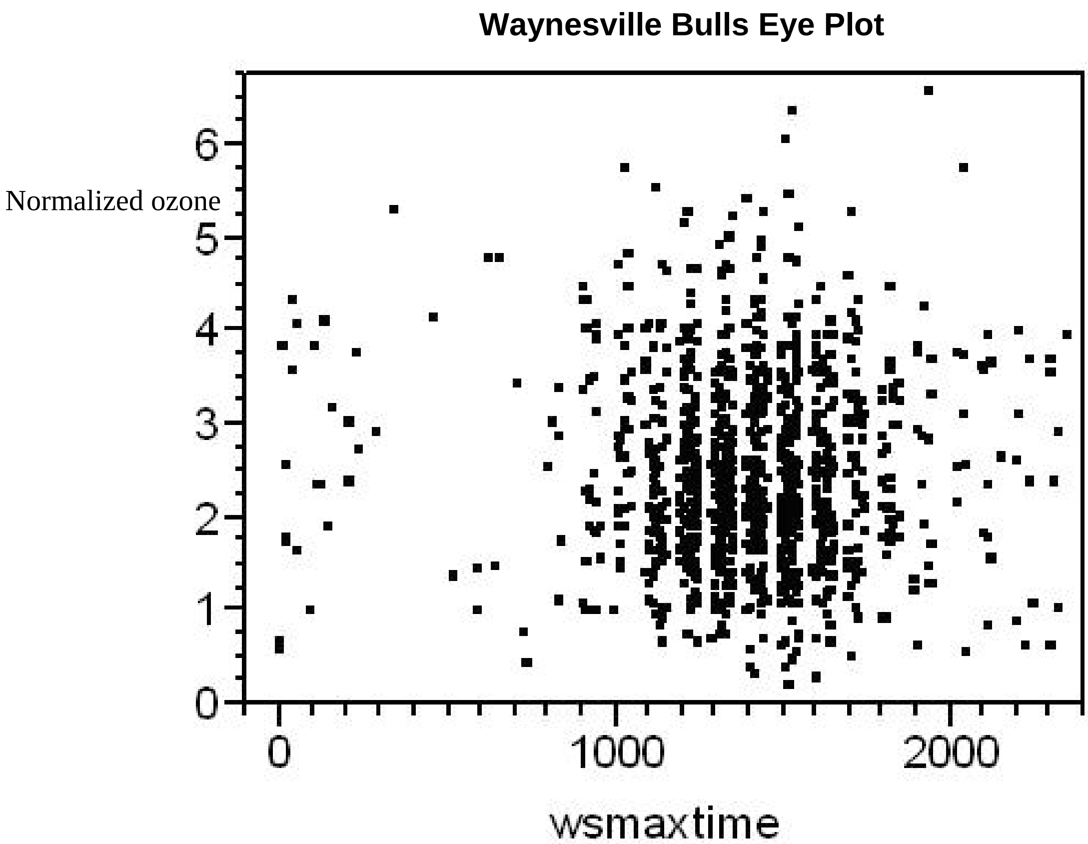

Figure 6. Waynesville Prototype Bull’s Eye Plot