CHAPTER 4
OBSERVATIONAL BASED METHODS FOR DETERMINING VOC/NO\textsubscript{x} EFFECTIVENESS

4.1 INTRODUCTION

Observational based models (OBMs) represent a broad group of data analysis techniques, subject to many descriptions regarding their formulations and applications. Perhaps the distinguishing feature of OBMs is that they are driven principally by observed (or ambient) data as opposed to grid models which are driven by emissions estimates. Observational analysis methods include receptor models, regression techniques, ambient ratios (e.g., VOC/NO\textsubscript{x}), indicator species and the more semi-empirical based OBMs. This chapter is restricted to those methods which are capable of inferring control strategy effectiveness (e.g., NO\textsubscript{x} or VOC control preference). Source attribution and related methods for assessing emissions inventories are covered in Chapter 3.

This chapter follows a method (or method class) by method approach, starting with highly empirical\textsuperscript{1} ratio techniques and proceeding to the more semi-empirical OBMs which incorporate some degree of mechanistic-based chemistry formulations. All of the techniques discussed require “routine” data sources comparable to that available from a PAMS network, with certain exceptions in NO\textsubscript{x} measurements. Each methodology section provides case examples taken from the literature or developed from available data sources.

4.2 EMPIRICAL TECHNIQUES

4.2.1 VOC/NO\textsubscript{x} Ratios

Ratios based on the concentrations of VOC to NO\textsubscript{x} have been used for relating emission inventories to ambient data, as well as delineating NO\textsubscript{x} and VOC control requirements. Generally, the propensity of an area to be VOC- or NO\textsubscript{x}-limited is based on the measured (or predicted) ratio. Higher and lower ratios imply NO\textsubscript{x}- and VOC-limiting conditions, respectively. No specific cutoff ratios exist, since whether ozone formation is limited by VOC or NO\textsubscript{x} depends on other factors in addition to the VOC/NO\textsubscript{x} ratio. However, for the conditions often assumed in EKMA/OZIPM4 ozone isopleth diagrams ratios greater than 16 often were considered NO\textsubscript{x}-limited and ratios less than 6 were considered VOC-limited (U.S. EPA, 1989). The VOC/NO\textsubscript{x} ratio technique is based on well understood atmospheric chemistry processes, and represented in

\textsuperscript{1} All approaches have logical foundations in, or their behavior can be explained by, atmospheric chemistry principles.
ozone isopleth diagrams (Figure 4-1) derived from photochemical “box-type” models such as EPA’s EKMA/OZIPM4 (U.S. EPA, 1989).

As part of the evaluations of 1993 P AMS data from three sites in Houston, Texas and Baton Rouge, Louisiana, ratios were calculated from three hour averages of TNMHC and NO\textsubscript{x}, and TNMHC and CO for the three PAMS sites\textsuperscript{2}. The summary statistics for the ratios are presented in Table 4-1 (Stoeckenius et al., 1994). For Houston, the TNMHC/NO\textsubscript{x} ratios were found to be higher at the Clinton Drive than at the Galleria site, as might be expected given the dominance of petrochemical industry sources at Clinton Drive. The ratios at the Baton Rouge site are lower than at either Houston site. In contrast, morning (6–9 a.m.) ratios are very similar at all three sites. The Clinton site appears subject to higher evaporative emissions and fewer NO\textsubscript{x} sources during the day as compared to Galleria or Capitol.

Relationships between morning TNMHC/NO\textsubscript{x} ratios and daily maximum ozone concentrations may provide insight into the potential tradeoffs between VOC and NO\textsubscript{x} control strategies. Scatter plots of 6–9 a.m. TNMHC/NO\textsubscript{x} ratios with daily maximum ozone concentrations observed within the Houston non-attainment region and daily maximum temperature (as measured at the PAMS site) are presented in Figures 4-2 and 4-3 (Stoeckenius et al., 1994). At these sites, ozone concentrations above 0.10 ppm are associated exclusively with TNMHC/NO\textsubscript{x} ratios less than about 10. There is some hint in these data that the TNMHC/NO\textsubscript{x} ratio decreases with increasing ozone concentrations above 0.10 ppm. If this is confirmed by further analysis, it would suggest that Houston is in a NO\textsubscript{x} limited regime.

Nearly all of the TNMHC/NO\textsubscript{x} ratios above 10 at the Houston sites are associated with maximum ozone values substantially below 0.10 ppm. TNMHC/NO\textsubscript{x} ratios substantially above 10 may be associated with older air masses with very low NO\textsubscript{x} concentrations and a lower proportion of reactive NMHCs\textsuperscript{3}. This could be confirmed by further analyses comparing the reactivity weighted TNMHC on days with different TNMHC/NO\textsubscript{x} ratios and a more detailed examination of meteorological conditions. Figures 4-2 and 4-3 suggest that the meteorological conditions that place these aged air masses over the Houston site on certain mornings are not conducive to the formation of high ozone concentrations in the Houston area (Stoeckenius et al., 1994). As is typical of most urban areas, the daily maximum ozone concentrations in Houston are related to the daily maximum temperature with the highest ozone found on the warmest days. There are no obvious relationships between maximum temperature and 6 to 9 a.m. TNMHC/NO\textsubscript{x} ratios.

\textsuperscript{2}Ratios were set to missing for 3-hour blocks with two or more missing TNMHC or NO\textsubscript{x} concentrations.

\textsuperscript{3}High TNMHC/NO\textsubscript{x} ratios may also be associated with very low NO\textsubscript{x} concentrations that are not accurately measured. Investigation of this possibility was beyond the scope of the present study but must be conducted before any final conclusions can be drawn regarding the conditions leading to high TNMHC/NO\textsubscript{x} ratios.
While the VOC/NO\textsubscript{x} method is theoretically sound, application of the technique has several limitations:

1. Historically, applications have relied upon morning, center-city VOC and NO\textsubscript{x} measurements, yet the ratio varies widely in time and space. PAMS improves the spatial and temporal coverage of data, and therefore tempering this particular concern.

2. Assuming only limited measurement-related difficulties, the ratios delineating NO\textsubscript{x} and VOC-limited regimes vary with time and location, and are affected by vertical mixing processes that often are not accounted for in surface measurements. Additionally, the prevailing atmospheric chemistry (e.g., composition and age of air mass) can impart different control responses at the same VOC/NO\textsubscript{x} ratios.

3. Inconsistent and uncertain measurement techniques affect the ratio. These include various interpretations of total NMOC, measurement uncertainties and artifacts in NO\textsubscript{x} and NMOC, and the representativeness of observations (this latter issue is more problematic for emission inventory evaluation).

By themselves, VOC/NO\textsubscript{x} ratios probably cannot be used unambiguously to infer NO\textsubscript{x} or VOC control strategy effectiveness. However, in combination with other observational (and gridded models) techniques, the VOC/NO\textsubscript{x} method adds corroborative value.

4.2.2 Reactive (oxidized) Nitrogen (NO\textsubscript{y}, NO\textsubscript{z}) and Ozone Correlation Techniques

Several correlations relating ozone production to total oxidized nitrogen (NO\textsubscript{y}) or NO\textsubscript{z} (NO\textsubscript{y} - NO\textsubscript{x}) have been suggested as tools capable of implying VOC/NO\textsubscript{x} control effectiveness, as well as relative air mass aging. These correlations (e.g., Figure 4-4, Olszyna et al., 1994) are generally based on large quantities of averaged data covering multiple days, and limited to the midafternoon time period (1 - 5 pm).

NO\textsubscript{z} typically correlates better with ozone than NO\textsubscript{y}. This may reflect ozone scavenging by one of the NO\textsubscript{y} species (NO). Progressively higher slopes, \(\Delta O_3/\Delta NO_x\), reflect NO\textsubscript{x} limited regimes and negative or near zero slopes reflect VOC limiting conditions. The existing studies do not provide sufficient guidance to delineate clearly the range of slopes depicting NO\textsubscript{x} or VOC limiting regimes, although slopes greater than 8 appear to suggest NO\textsubscript{x}-limiting conditions. By themselves, the NO\textsubscript{z}-O\textsubscript{3} correlation does not provide a reliable NO\textsubscript{x}-VOC-limiting indicator. However, in combination with other observational approaches and photochemical modeling, the correlation can provide corroborative support for evaluating control effectiveness. Future applications with emerging data bases and cross analysis-method comparisons should provide
greater understanding of the utility of these correlation methods. Additional discussion on these techniques is found in Appendix A.

4.3 OBSERVATIONAL MODELS

The two semi-empirical OBMs discussed here, the Mapper-Smog Production Algorithm (SPA) and the Georgia Institute of Technology (GIT) model, rely on some level of mechanistic description of atmospheric chemistry (relative to correlation techniques) or produce explicit VOC and NO\(_x\) control effectiveness results and therefore are distinguished from other indicator and correlation techniques.

4.3.1 Smog Production Algorithm - MAPPER program

Figure 4-5 provides an example of MAPPER-SPA results. The map provides a visually-oriented time and space perspective of NO\(_x\)- (or VOC-) limitation. The circular elements are clocks reflecting hourly data at the monitoring site, the size of the diameter is in proportion to the maximum daily ozone observed at the site. Shading gradations are used to reflect extent, E, which is a indicator for degree of NO\(_x\)-limitation. Filled black reflects full extent of 1, situations clearly NO\(_x\)-limited; white reflects VOC limiting conditions with E < 0.5; and cross-hatched areas could be considered borderline NO\(_x\)-sensitive. The example is only illustrative, the shading forced to illustrate a full range of NO\(_x\)- and VOC-limiting conditions. Displays such as these can be used to corroborate control strategy results from gridded ozone models. Due to the potential for compensating errors, typical model evaluations limited to comparisons between observed and simulated concentrations do not necessarily provide confidence in the model’s response to emissions perturbations. The use of OBMs which rely on observations provide a unique corroborative check on the directional ability of EBM\(\)s to respond to emissions changes.

**Description**

The Smog Production Algorithms (SPA) and associated MAPPER software were derived from the Integrated Empirical Rate (IER) model of Johnson (1984) and later developed by Blanchard et al. (1994). The original IER was based on smog chamber experiments in Australia. Johnson (1984) defined smog produced (SP) as:

\[
SP(t) = O_3(t) - O_3(0) + NO(0) - NO(t)
\]

In simple terms, SP represents the cumulative oxidation of initial NO into ozone and other oxidized “smog” products (i.e., NO\(_y\) species), presumably accounted for in the change in NO over time. With sufficient NO, SP exhibits a linear relationship with cumulative light flux until a maximum, SP\(_{\text{max}}\), is reached. Over much of this linear period, SP can be thought of as being
VOC-limited. This maximum is related to initial NO\textsubscript{x} in the system by,

\[ SP_{\text{max}} = \beta[NO_x(0)], \]

where the parameter, \( \beta \), was assumed to be a constant of 4.1 based on the chamber experiments and reflects the potential maximum amount of smog produced per unit of NO\textsubscript{x} input. An extent of Reaction, \( E \), is defined as:

\[ E(t) = SP(t) / SP_{\text{max}} \]

where the extent, \( E \), represents the fractional movement toward maximum smog production. When the extent =1, virtually all the NO\textsubscript{x} in the system has been transformed to ozone and oxidized NO\textsubscript{x} products (NO\textsubscript{z}) and the system is NO\textsubscript{x} limited. Recalling that the linearized region of \( SP(t) \) is associated with VOC-limiting conditions, the value of \( E \) can be interpreted as a rough indicator of VOC or NO\textsubscript{x}-limiting conditions. That is, \( E \) with values very near or equal to 1 clearly reflect NO\textsubscript{x}-limiting conditions, and values of \( E \) far less than 1 (say less than .5) suggest VOC limiting conditions. Thus, the derivation of equations and associated algorithms which utilize measurements as independent variables directed toward the calculation of \( E \) forms the basis for MAPPER in delineating NO\textsubscript{x} and VOC limiting conditions. Details on the derivations and algorithms for \( E \) are found in Blanchard et al. (1994). More recent forms for \( SP \) include:

\[ SP(t) = O_3(t) + DO_3(t) - O_3(0) + NO(0) - NO(t), \]

and

\[ SP_{\text{max}} = \beta[NO_x(0)]^\alpha \]

where the term \( DO_3(t) \) accounts for the cumulative ozone lost to deposition from time zero to \( t \) (i.e., ozone that has been produced but deposited), and is parameterized as a function of observed ozone. Default values for \( \beta \) (19) and \( \alpha \) (.67) are empirical coefficients derived from numerous smog chamber studies.

**Measurement Requirements/Relation to PAMS**

MAPPER algorithms require hourly measurements of ozone, NO and either NO\textsubscript{x} or NO\textsubscript{y}, depending on the form of the MAPPER algorithm selected. Where available, true NO\textsubscript{x} or true NO\textsubscript{y} data should be used in MAPPER applications. The scarcity of such data will drive many applications toward routine NO\textsubscript{x} data. Since MAPPER operates in true NO\textsubscript{x} and true NO\textsubscript{y} modes and many of the available routine NO\textsubscript{x} overestimate afternoon NO\textsubscript{x}, the technique can provide a “bounding” associated with the positive NO\textsubscript{x} measurement biases. In addition, PAMS locations generally are weighted toward urban core areas and the results from PAMS alone are likely to be skewed toward the urban perspective, which in many cases will infer a VOC limiting
4.3.2 GIT Model

The Georgia Institute of Technology (GIT) OBM (Cardelino and Chameides, 1995) utilizes most of the data (speciated NMOC and NO$_x$) generated from a PAMS. The GIT-OBM quantifies the relative roles of various emission groups (e.g., natural and anthropogenic VOC, NO$_x$) on ozone production. Figure 4-6 illustrates a GIT-OBM application for Atlanta covering several monitoring locations.

Description

Cardelino and Chameides (1995) describe the use of a box model for calculating the sensitivity of ozone to VOC or NO$_x$ reductions, which they name the “Observation-Based Model” and is referred to here as the “GIT-OBM”. The model is an OBM because it uses ambient concentrations rather than emissions estimates to drive the calculations. The calculation is carried out separately for each monitoring location. Unlike a trajectory model, each box is fixed at the location of its monitor. The OBM utilizes some features of the OZIPM4 model to account for dilution and employs a modification of the CBM-4 (Cardelino and Chameides, 1995).

Cardelino and Chameides (1995) define a quantity, $P_{O_3-NO}$, which is the net ozone formed plus the net NO consumed over a 12-hour period (this quantity is similar to SP of the IER model but is computed as an integral over time rather than an instantaneous concentration). The fractional change in $P_{O_3-NO}$, divided by the fractional change in the “source strengths” of precursors, are used to define relative incremental reactivities (RIRs). For each measured species, instantaneous source strengths are calculated from the measurements and from production and loss terms. The RIRs for each site are (or can be) averaged to generate area-averaged RIRs. Cardelino and Chameides (1995) sum RIR terms so as to yield RIRs for NO, anthropogenic hydrocarbons (AHC), and natural hydrocarbons (NHC). The split between RIR-AHC and RIR-NHC is accomplished by summing RIRs for species arising from anthropogenic and biogenic emissions, respectively.

Limitation/Caveats

Numerous assumptions are made in the procedure. Some of the assumptions that appear to have a potentially substantial effect on the calculations are provided in Dmerjian et al. (1995) who suggest a potential bias toward overestimating the benefits of anthropogenic NO$_x$ reductions.

1. Nature and levels of uncertainty associated with the method. Analyses of uncertainty have not

---

4This description as well as the section discussing limitations and caveats of the GIT-OBM are taken from a review of OBMs conducted by Demerjian et al. (1995).
been carried out for the OBM. Taking into account the uncertainties deriving from factors such as those listed in the preceding section, as well as the inaccuracies and unavailability of data for typical nonattainment cities, there is a clear need to quantitatively characterize the resulting overall uncertainties in the model output. At present, some of the assumptions appear to generate biases that would enhance the apparent benefits of controlling anthropogenic NO\textsubscript{X}.

2. The type of output of the method and the degree of consistency between this output and the types of information needed for regulatory applications. The output consists of RIRs for NO, AHC, and NHC. RIRs can also be output for anthropogenic area and point sources, as well as for other disaggregations that would be of use. The form of the output, as RIRs, can be directly translated into qualitative control preferences. However, RIRs derived from 12-hour $P^\text{O_3-NO}$ terms may not be appropriate given the present form of the ozone standard, which requires compliance with a one-hour ozone average.

3. Availability of data needed as input to the method. The method requires measurements of NO that are accurate at sub-ppbv concentrations (Cardelino and Chameides, 1995), which appears to exceed the capabilities of most instrumentation that has been, or will be, deployed in routine monitoring networks. The OBM also appears to require continuous gas chromatograph (GC) measurements of hydrocarbon species.
4.4 REFERENCES


Johnson, G. "A Simple Model for Predicting the Ozone Concentration of Ambient Air." Proceedings of the 8th International Clean Air Conference Melbourne, Australia, May 2, 1984: 715-731.


Sillman, S.; and He, D. The Use of Photochemical Indicators to Evaluate Oxidant Models: Case Studies from Atlanta and Los Angeles. Presented at the 9th Joint Conference on the Applications of Air Pollution Meteorology with the Air and Waste Management Association, 1996.


Appendix 4A: DISCUSSION OF NITROGEN-BASED CORRELATION TECHNIQUES

Definitions:

\[ \text{NO}_x = \text{NO} + \text{NO}_2 \]
\[ \text{NO}_y = \text{NO}_x + \text{PAN} + \text{HNO}_3 + \text{ORGANIC-N plus AEROSOL-N} \]
\[ \text{NO}_z = \text{NO}_y - \text{NO}_x \]

Many of the observational based analysis methods applied over the last decade have relied on high quality NO\(_x\) and NO\(_y\) measurements. Several recent studies, designed to characterize air mass aging and the relationship of in-situ ozone production to NO\(_x\) or NO\(_y\) in rural environments, have produced strong correlations between ozone and various nitrogen groupings (Trainer et al., 1993; Olszyna et al., 1994). These correlations (e.g., Figure 1) generally are based on large quantities of averaged data covering multiple days, and limited to the mid afternoon time period (1 - 5 pm), to filter out the overwhelming negative impact of fresh NO\(_x\) titration of ozone. For the same reasons, NO\(_z\)-O\(_3\) regressions typically correlate better than NO\(_y\). Ozone should correlate positively with NO\(_z\) under NO\(_x\) and VOC-limiting conditions, since the radical processes associated with VOC reactions during VOC-limiting conditions coincidentally produce ozone and oxidized nitrogen (NO\(_z\)) products such as nitric acid. Collectively, the various studies as well as independent analysis of photochemical model results (Sillman, 1996) suggest that the slope of the regression line can be used as a qualitative indicator for delimiting NO\(_x\) and VOC limiting regimes. Progressively higher slopes, \(\Delta \text{O}_3/\Delta \text{NO}_z\), reflect NO\(_x\) limited regimes and lower slopes reflect a move towards VOC limiting conditions. The existing studies do not provide sufficient guidance to delineate clearly the range of slopes depicting NO\(_x\) or VOC limiting regimes, although slopes greater than 8 appear to suggest NO\(_z\)-limiting conditions. By themselves, the NO\(_z\)-O\(_3\) correlation does not provide a reliable NO\(_z\)-VOC-limiting indicator. However, in combination with other observational approaches and photochemical models, the correlation can provide corroborative support for evaluating control effectiveness. Future applications with emerging data bases and cross analysis-method comparisons should provide greater understanding of the utility of these correlation methods.

In addition to providing insight on control strategy effectiveness, the interpretation of NO\(_x\), NO\(_y\) and NO\(_z\) data can be interpreted to provide insights into air mass aging, ozone production efficiency, and other analyses. Air mass aging can be defined in many ways, but empirical indicators using NO\(_y\) and NO\(_z\) data are founded on basic, well-understood atmospheric chemistry principles. In simple terms, aging is reflected in observations by the relative amount of NO\(_x\) that is oxidized (aged) to various NO\(_z\) oxidation products (i.e., NO\(_z\)). The ratio, NO/NO\(_y\), is one indicator of air mass aging, and typically is normalized on a range from 0 to 1, with .6 used as a suggested indicator of “photochemically aged” air (Trainer et al., 1993):
AGE = 1 - (NO\textsubscript{x}/NO\textsubscript{y})

Ozone production decreases with aged air masses, and the NO\textsubscript{x}-limited conditions almost always associate with aged air masses. Aging analyses can provide guidance as to when to expect good NO\textsubscript{x}/NO\textsubscript{y}/O\textsubscript{3} correlations; poor correlations should be expected with “fresh” air masses. In turn, one might expect “good” correlations between VOC (or selected groups, species) and ozone during periods which are not NO\textsubscript{x}-limited, and poor (or coincidentally good) correlations during NO\textsubscript{x}-limited conditions. Again, the sum value of the collective use of several analysis techniques across multiple species is greater than the sum of individual analyses.

Data limitations/Relation to PAMS. PAMS will result in an enormous expansion of the VOC data base, and significant, but inadequate, improvements in nitrogen measurements. PAMS introduces additional spatial and temporal coverage of traditional NO\textsubscript{x} measurements. However, many of the NO\textsubscript{x} instruments are not capable measuring sub-ppb levels. More troubling is the lack of true NO\textsubscript{x} or NO\textsubscript{y} measurements. Many of the PAMS NO\textsubscript{x} instruments overestimate NO\textsubscript{x} (and therefore NO\textsubscript{x} as well), due to PAN and nitric acid interferences. This interference is stronger during daytime conditions, further compromising the utility of nitrogen-based data analysis techniques. NO\textsubscript{y} measurements are not required in the PAMS program. Finally, the majority of currently operating PAMS sites (mostly Type II) reflect urbanized conditions with relatively fresh air masses. One would expect these locations to produce poor correlations and infer VOC limiting conditions.

Model simulation derived methods

Various indicator techniques, which utilize absolute values of selected species or species ratio values, have been developed by analyzing photochemical model simulations. These include NO\textsubscript{y} (Milford et al., 1994; Sillman, 1995) along with nitric acid, HNO\textsubscript{3}, hydrogen peroxide, H\textsubscript{2}O\textsubscript{2} and formaldehyde, HCHO. Results from two different photochemical models suggested that ozone would be limited by VOC at ambient NO\textsubscript{y} levels exceeding a threshold level ranging from 10 to 25 ppb, and NO\textsubscript{x} controls would not result in increased ozone unless ambient NO\textsubscript{y} levels exceeded 20-30 ppb (Milford et al., 1994). Sillman (1995) reported similar results for NO\textsubscript{y}, but concluded that the ratios, HCHO/NO\textsubscript{y} < 0.28 and H2O2/NO\textsubscript{y} <0.4 were effective indicators for VOC limited regimes.
Relation to PAMS. Although these studies are based on model simulations, they provide direction toward the types of measurements useful for inferring control strategy directions. The potential value of NO\textsubscript{y} measurements is reinforced by these studies. As discussed above, NO\textsubscript{y} measurements are not required by PAMS but are considered an incremental improvement that gradually could be incorporated in the program. In combination with HCHO, which is measured in PAMS, another possible corroborative indicator, HCHO/NO\textsubscript{y}, could be available. Hydrogen peroxide is still considered a “research” level measurement. However, peroxide concentrations gradually are becoming standard components of field campaigns such as the SOS. In addition to an indicator application described here, peroxide measurement are extremely useful for model diagnosis and evaluation and should be given strong consideration as a PAMS species when and if monitoring technology allows for more routine H\textsubscript{2}O\textsubscript{2} measurements.
Figure 4-1. Isopleths developed from EPA’s EKMA to illustrate VOC/NOx ratios. (NRC, 1991).
Figure 4-2. Scatter plot matrix for 6-9 a.m. TNMHC/NOx, raio, daily maximum temperature at Galleria, TX site and regional daily maximum ozone
Figure 4-3. Scatter plot matrix for 6-9 a.m. TNMHC/NO\textsubscript{x} ratio, daily maximum temperature at Clinton Drive, TX site and regional daily maximum ozone.
Figure 4-4. Plot of ozone versus NOz for Giles County, TN (Olszyna et al., 1994).
Figure 4-5. Example MAPPER output for the Northeast U.S.
Figure 4-6. Results from GIT-OBM applied to Atlanta. The model provides a relative assessment of the role of emissions groups on ozone formation. (Cardelino and Chameides, 1995).
TABLE 4-1. Summary statistics for TNMHC/NO\textsubscript{x} ratios calculated from 3-hour average TNMHC and NO\textsubscript{x} concentrations.

<table>
<thead>
<tr>
<th></th>
<th>Min.</th>
<th>1st Qu.</th>
<th>Median</th>
<th>Mean</th>
<th>3rd Qu.</th>
<th>Max.</th>
<th>S.D.</th>
<th>NA's</th>
<th>N</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>All 3-Hour Values</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Clinton</td>
<td>3.857</td>
<td>11.2</td>
<td>19.22</td>
<td>22.76</td>
<td>29.86</td>
<td>141.2</td>
<td>15.648</td>
<td>297</td>
<td>736</td>
</tr>
<tr>
<td>Capitol</td>
<td>2.475</td>
<td>6.927</td>
<td>9.562</td>
<td>12.19</td>
<td>14.48</td>
<td>82.6</td>
<td>9.536</td>
<td>181</td>
<td>739</td>
</tr>
<tr>
<td><strong>6–9 a.m. Averages</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Capitol</td>
<td>3.738</td>
<td>7.558</td>
<td>10.2</td>
<td>12.51</td>
<td>14.66</td>
<td>45.28</td>
<td>7.798</td>
<td>22</td>
<td>92</td>
</tr>
</tbody>
</table>