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The Relationship Between High Ozone Days and Atmospheric Patterns in Atlanta, Georgia

Edward Eugene Unger

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The Relationship Between High Ozone Days and Atmospheric Patterns in Atlanta, Georgia

A Thesis

Presented in Partial Fulfillment of Requirements for the Degree of Master of Arts in the College of Arts and Sciences Georgia State University

2005

by

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ABSTRACT

Tropospheric ozone pollution is a world-wide problem, based on studies reported from locations as diverse as India, Hong Kong, Taiwan, South Korea, Germany, Spain, Greece, Canada, and the United States. Ozone is a serious pollutant in the troposphere due to its adverse effects on the health of plants, and on the respiratory systems, eyes, and mucous membranes of humans. Due to the seriousness of the issue, the ozone problem in the Atlanta, Georgia metropolitan area was investigated. A review of the literature revealed a research deficiency, since no environment-to-circulation analysis of the ozone problem in the Atlanta metropolitan area could be found. Therefore such a study was conducted, in order to determine how high ozone days in Atlanta were related to atmospheric patterns and meteorological variables. Statistical analysis of radiosonde data, and data from eleven air quality monitoring stations in metropolitan Atlanta, for the summer months of 2000-2003, revealed a relationship between high ozone days and both high- and low- pressure patterns, as well as between high ozone days and higher temperature and lower dew point temperature. The data revealed two groups of stations differentiated by geography, and also suggested transport of precursor chemicals as a factor at some stations. This research may assist policy-makers as well as policy-implementers in elucidating associations or mechanisms that can assist efforts to reduce tropospheric ozone concentrations in the Atlanta area.

Acknowledgements

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Finally, I wish to thank Gail C. Unger, my wife, for her patience and encouragement. Without her support, this thesis would never have been completed.

"There is a strangely waxing academic opinion, with roots in the 1960's, that holds all views to be equally arbitrary, and "true" or "false" to be a delusion. Perhaps it is an attempt to turn the tables on scientists who have long argued that literary criticism, religion, aesthetics, and much of philosophy and ethics are mere subjective opinion, because they cannot be demonstrated like a theorem in Euclidean geometry or put to experimental test. There are people who want everything to be possible, to have their reality unconstrained. Our imagination and our needs require more, they feel, than the comparatively little that science teaches we may reasonably be sure of. [...] Who dares to set limits on human ingenuity?

In fact, Nature does."

Carl Sagan: *The Demon-Haunted World: Science as a Candle in the Dark*. Chapter 15, pp 269-270. Random House. 1995.

TABLE OF CONTENTS

List of Figures

List of Tables

I Introduction

Because of its adverse effects on the health of humans, agriculturally important plants, and ecosystems such as forests, tropospheric ozone is an active subject of current research. Due to these effects of high ozone concentrations in the troposphere, the United States Environmental Protection Agency (USEPA) has designated ozone as an air pollutant to be monitored and controlled under the National Ambient Air Quality Standards (NAAQS) system (USEPA 1997). Primary standards are intended to protect \human health, while secondary standards are intended to protect “human welfare”, and take into account a pollutant’s impact on agriculture, ecosystems, and quality of life. The USEPA secondary NAAQS standard for ozone is presently the same as the primary standard (USEPA 1997).

Ozone in the lower troposphere is a significant concern, because it can seriously damage biological organisms, including humans and plants. In humans, ozone mainly affects the respiratory system, eyes, and mucous membranes of the nose and throat (Lippman 1989, Tilton 1989, McElroy 2002, Parmet *et al*. 2003,). Parmet *et al.* (2003) state that ozone irritates the eyes, nose, and throat, causes difficulty in taking deep breaths, and leads to increased requirements for asthma medications. Exposure to ozone reduces lung functioning in both healthy and compromised subjects, such as asthmatics or heart patients (Folinsbee *et al*. 1994, McMurdy 1994, Brauer and Brook 1997). In plants, ozone causes leaf mottling, accelerated leaf senescence (Mikkelson and Heide-Jørgensen 1996), and it can lead to leaf necrosis (Chappelka *et al*. 2003, Davison *et al*.

2003). Ozone can reduce crop yields (Chameides *et al*. 1999), and some authors attribute the major source of non-drought agricultural crop damage to high tropospheric ozone concentrations (Reiling and Davidson 1992, Musselman and Minick 2000), while other researchers cite ozone as a major threat to forest ecosystems, especially deciduous forests (Lefohn *et al.* 1997, Laurence *et al.* 2001).

Many urban areas in the United States have failed to meet the new NAAQS for ozone, which is defined as the fourth-highest 8-hour average ozone concentration over a consecutive three-year period, since implementation of the standard began. One of the noncompliant areas is the Atlanta, Georgia metropolitan area (St. John and Chameides 1997, Chang and Cardelino 2000, Cardelino *et al*. 2001). Therefore, this research will examine the atmospheric controls of high ozone levels in the Atlanta, Georgia metropolitan area.

2.0 Overview of Ozone

The formation, reactions, and destruction of ozone in the troposphere are in part a function of ozone's physical and chemical characteristics. Ozone is an allotrope of oxygen, with three oxygen atoms, which is formed when ultraviolet radiation of sufficient energy splits an oxygen molecule, allowing the freed oxygen atom to combine with another oxygen molecule (Fogg 2003). Ozone has long been known to be a powerful oxidant, meaning that it can remove electrons, or equivalently, hydrogen atoms, from other atoms or molecules (Fogg 2003). It follows that ozone can react with a number of organic compounds, such as hydrocarbons, which act as the reducing species in

oxidation-reduction reactions. Like oxygen, ozone can absorb light quanta of several different energies, or their wavelength equivalents, in the ultraviolet region of the electromagnetic spectrum, with a primary absorption peak around 0.250 μm (Matsumi and Kawasaki 2003). The high absorption of ozone in the ultraviolet is utilized by chemists to detect ozone, and is, of course, the reason for atmospheric ozone's ability to protect the planet's biosphere from harmful UV-B radiation (Herner *et al.* 2001, Matsumi and Kawasaki 2003, X. Wang *et al.* 2003). Because ozone is so reactive, it is unstable in the atmosphere, requiring a constant replenishment to maintain a significant concentration (McElroy 2002).

2.1. Ozone Precursor Species

In the unpolluted atmosphere, ozone can be formed by photolysis of oxygen by UV radiation with a wavelength of 0.240 μm or less (Seinfeld 1989, McElroy 2002), in the presence of a third molecule such as nitrogen that serves to absorb energy released by photolysis. The ozone rapidly photodissociates back into oxygen, but the forward and reverse reaction rates may vary slightly depending on ambient temperature, pressure, radiation intensity, and concentrations of trace constituents, so that a small background level of ozone (~20 ppbv) is always present in the troposphere (Sienfeld 1989, McElroy 2002).

In a polluted region of the troposphere, such as in many urbanized areas, ozone is formed by the conjunction of four ingredients: volatile organic compounds, NO_X

($NO + NO_2$), a neutral "third body" such as nitrogen (Seinfeld 1989, Sillman 1995, McElroy 2002, Chameides 2004), and ultraviolet radiation with a wavelength below 0.390 μm (Matsumi and Kawasaki 2003). Since nitrogen is abundant in the troposphere, it is often assumed, and left out of many equations.

NO_X, the sum of NO and NO_2 , is emitted by internal combustion vehicles, power plants, and other industrial and commercial sources (Duncan *et al*. 1995, Choi and Ehrman 2004). Biogenic sources are the second largest sources of NO_X , after fossil fuel combustion (Wang *et al.* 1998), with biomass burning equaling about 32 % of the burden from fossil fuel combustion and soil emissions equaling about 20 % of fossil fuel sources for the northern hemisphere as a whole(Wang *et al*. 1998).

The other major ozone precursor is a class of chemicals called volatile organic carbon compounds (VOCs), which include anthropogenic VOCs (AVOCs), and biogenic VOCs (BVOCs). Sources of AVOCs include fossil fuel combustion such as power plants and motor vehicles, and industry, while sources of BVOCs are primarily forests. Deciduous forests contribute most of the BVOCs (Chameides *et al*. 1988, Villanueva-Fierro *et al*. 2004). BVOCs include isoprene, terpenes, carbonyls, and other organics, which are often more reactive than many AVOCs (Chameides *et al*., 1988, Sillman 1999). Thus, according to Chameides *et al.* (1988*)* and Sillman (1999) in the works cited, low levels of a very reactive BVOC can have more of an impact on ozone production than high levels of a less reactive AVOC. Reinforcing this conclusion, Imhoff et *al*. (1995) found that higher ozone levels were associated with higher organic reactivity of VOCs, which the authors defined as the product of the concentration of a hydrocarbon

with its corresponding rate constant for the hydroxyl radical, OH, a species that is part of the ozone production mechanism. More recently, Kleinman derived a specific formula relating ozone production rates and NO_X concentration and VOC reactivity (Kleinman 2004). Russell *et al.* (1995) reached some of the same conclusions regarding organic reactivity as Imhoff *et al*. (1995), and suggested that regulatory control strategies should take organic reactivity into account.

When burned, plants can produce even more complex organics, such as organic acids, lipids, and chlorinated organic compounds (McKenzie *et al*. 1994, Simoneit *et al.* 1999), some of which can also act as ozone precursors. There are obvious policy implications considering the greater emissions of BVOCs and their greater reactivity compared to AVOCs.

2.2 Ozone-Production Sensitivity

The photochemical production of tropospheric ozone is sensitive to several factors, two of which are the concentrations of the two primary precursor species, NO_X and VOCs, and their concentrations relative to each other (Sillman *et al.* 1997, Sillman 1999). When VOC concentrations are much greater than NO_X concentrations, ozone production is sensitive to the NO_X concentration, and *not* sensitive to VOC levels; but when NO_X concentrations are greater than VOC concentrations, ozone production *is* sensitive to VOC concentrations and is *not* sensitive to levels of NO_X (Sillman *et al.* 1997, Sillman 1999). The reasons for this behavior include competing photochemical kinetics as well as

free radical chemistry, and will not be discussed further in this paper, but researchers must nevertheless be aware of the phenomenon.

2.3 Atmospheric Impacts on Ozone Levels

2.3.1 Ozone Production

Several meteorological variables such as cloud cover, ambient temperature, and relative humidity (or dew point temperature) can affect tropospheric ozone production (National Research Council 1991). Cloud cover is negatively correlated with high ozone levels (Wang *et al*. 2003), because ozone is photochemically produced, and cloud cover attenuates solar radiation (Chudzyński *et al.* 2001, Dani and Devara 2002). Temperature is positively correlated (Vukovich and Sherwell 2003, Wang *et al*. 2003), partly because most atmospheric chemical reaction rates increase with temperature (McElroy 2002), although temperature could also be a proxy for solar radiation intensity (Vukovich and Sherwell 2003). Relative humidity tends to be positively correlated with high ozone because it leads to an increase in radicals, which help initiate chain reaction mechanisms, and also tends to increase precursor BVOC emissions (Sillman 1999).

2.3.2 Ozone Ventilation

Low mixing heights tend to be associated with high ozone levels due to decreased ventilation of polluted air (Minoura 1999), although some researchers report no such relationship (T. Wang *et al.* 2000). Wind speed is negatively correlated with high ozone

levels, since ozone can accumulate faster with low winds), while high winds are more conducive to ventilation of polluted areas (Minoura 1999, Pissimanis *et. al.* 2000). Orography plays a role in ventilation, with mountains impeding ventilation (Pissimanis *et al.* 2000). A study of high and low ozone days over the eastern United States for the summer of 1995 concluded that high ozone days, where ozone concentrations were greater than 80 ppbv, had a weaker surface wind field, higher mixing heights, and a smaller ventilation coefficient [surface wind speed x mixing height] compared to low ozone days (Rao *et al*. 2003).

2.3.3 Ozone Transport

A number of studies have demonstrated that ozone can be transported within the troposphere (Diem 2004, Pissimanis *et al.* 2000, Rosenthal *et al*. 2003), and between the stratosphere and troposphere (Bithell *et al*. 2000, Oltsmans *et al*. 1996). In the eastern United States, Clark (2003) demonstrated that summertime polluted air from the Baltimore-Washington corridor was being transported to the north and northeast by low-level jets, so that downwind areas could suffer an increased ozone burden in addition to any local production. Pont *et al*. (2003) concluded data that ozone-laden air from the planetary boundary layer was breaking into the free troposphere, and being transported long distances.

2.3.4 Ozone and Synoptic-scale Atmospheric Circulation

Of the synoptic scale patterns, the anticyclone is most associated with high ozone concentrations (Pont *et al.* 2003, Schichtel and Husar 2001). The reasons for this are that anticyclones, or high-pressure systems, tend to produce clear, warm weather, providing

both abundant UV radiation needed for ozone production, as well as higher temperatures, and they tend to produce stagnant conditions with poor ventilation, allowing ozone to accumulate. Treffeison *et al*. (2002) concluded that source regions in central Europe had only a partial impact on the regional ozone content (~14%), while synoptic weather patterns were the primary determinant of high ozone levels (~50-70 %).

Synoptic patterns have been studied in relationship to ozone levels in other areas, such as west-central Taiwan (W. -L. Cheng *et al.* 2001). Cheng *et al*. (2001) found that high ozone levels in the study area could be correlated with two out of 13 synoptic patterns affecting the center of Taiwan. While one pattern was a high-pressure system to the northeast, the other pattern was a tropical low-pressure system with weak easterly winds, which were blocked by the transverse orography from the study area on the west (lee) side of the island. Both of these types resulted in a lee trough unfavorable for dispersion, and led to high ozone levels, defined as ozone concentrations greater than or equal to 80 ppbv. Cheng *et al*. (2001) found that ozone levels depended strongly on the regional synoptic pattern, but not on any one meteorological variable concentration.

In the study by Rao *et al*. (2003), another finding reached by the authors was that meteorological variables associated with high ozone levels were consistent with a synoptic-scale anticyclone centered over Kentucky and Tennessee. Their examinations of surface weather maps for the study period revealed frequent high-pressure systems over this area.

3.0 Ozone Pollution in Atlanta, Georgia

A considerable amount of research on ozone has been carried out for the Atlanta, Georgia area. This research can be roughly divided into studies of precursor influences and atmospheric influences.

3.1 Precursor Influences

In research related to organic precursor reactivity, Geron *et al*. (1995) estimated hourly BVOC emissions using data from the United States Department of Agriculture and the Forest Service Forest Inventory and Analysis, and an urban vegetation survey for an 11-county metropolitan Atlanta ozone nonattainment area for several periods from 1984 to 1988. When these data were compared to ozone levels, it was found that on high ozone days, BVOCs were estimated to be higher. In addition, the authors stated that BVOCs in the area have been underestimated by a factor of two in previous studies. It is noted here that Atlanta has a large forested area, both within the urbanized area and surrounding it, providing rich sources of reactive BVOCs, as Chameides and co-workers mentioned in their 1988 study cited previously.

Since NO_X plays such an important role in ozone formation, a survey of industries in Atlanta was taken in order to quantify these emissions (Chang *et al.* 1996). Of some 56 point sources, at least 85% of NO_X emissions were attributed to four fossil-fueled power plants located to the north and west of Atlanta, with one facility located within the metropolitan Atlanta nonattainment area. The resulting modeled effect on ozone levels was dependent on plant location and specific atmospheric conditions

downwind. In some cases, ozone levels would increase, or at least not decrease, if plant NO_X emissions were “turned off” or reduced in the model. This is related to the issue of ozone production rates and NO_X and VOC concentrations, or O_3-NO_X- VOC sensitivity (Sillman *et al.* 1997, Sillman 1999), since changing the relative concentrations of one precursor affected the sensitivity to the other.

The 1996 Summer Olympics that were held in Atlanta, Georgia from 19 July to 4 August were used by Friedman *et al.* (2001) to study the relationship between vehicular traffic, ozone levels, and acute health crisis visits to health care providers. Area governments had implemented a plan to reduce vehicular traffic in Atlanta during the Summer Olympics that reduced peak morning traffic during the time of the games. One-hour peak ozone levels decreased from as high as ~110 ppbv just before the games, to as low as ~25 during the Olympics, but increased in the immediate post-game period to as high as ~ 130 ppbv. Acute asthma attacks by children as measured by visits to health care providers dropped moderately during the two-week period of the games. The researchers reported no significant difference in weather between the period of the Olympics and immediately before and after, when both automobile traffic and ozone levels were higher, but they did not examine synoptic scale or mesoscale systems.

3.2 Atmospheric Influences

A seven-year study from 1987-1993 (St. John and Chameides 1997) found that Atlanta exceeded an 8-hour NAAQS standard up to five times as often as it did a

1-hour standard of 120 ppbv. The study determined that the most severe ozone episodes occurred when wind directed shifted, and polluted air parcels were recirculated back into the city where there was “recooking” of the air parcels. This meant that ozone precursor chemicals and radicals were given more time to react to further, sometimes resulting in multiple days of high ozone concentration. These were referred to as plume recirculation episodes, where a plume is an extended mass of polluted air driven downwind from the sources. These episodes appeared related to stagnant anticyclonic systems, but also seemed to require “subsynoptic” scale wind reversals. The mechanisms for these reversals were not examined or explained by the authors.

Somewhat contradicting the previous study, Lindsay and Chameides (1988) found that high ozone days in Atlanta were often associated with the transport of air into the region, with about half of high ozone days occurring when air had traveled into the Atlanta area over 600 kilometers, mostly from the northwest.

An airborne sampling of the Atlanta plume was conducted in 1992 (Imhoff *et al.* 1995). This sampling program tracked plumes of polluted air downwind and under different atmospheric conditions. The data indicated that the highest ozone concentrations were found approximately 17 kilometers downwind of the city center, a position that was also the location of the maximum production rate of ozone. In agreement with most studies elsewhere, the highest ozone levels were found on those days with a stagnant high-pressure system over the Atlanta area.

4 Research Question and Objectives

A review of the literature has found no studies of Atlanta that target atmospheric controls of high ozone concentrations in Atlanta, Georgia although it has been done for other areas, such as the Taiwan study by Cheng and co-workers discussed previously, Baton Rouge, Louisiana (Goldberg 1993), San Francisco, California (Ludwig *et al.* 1995) and Tucson, Arizona (Diem and Comrie 2001.) No study has been found to date that specifically attempts to investigate atmospheric controls of the highest daily maximum 8-hour ozone concentrations.

Consequently, the primary question addressed by this research is as follows:

- **How are high 8-hour ozone days in the metropolitan Atlanta, Georgia area related to multi-scale atmospheric phenomena?**

The major objective of this research is to carry out an environment-to-circulation analysis of high ozone days in Atlanta, in order to determine what, if any, upper-level atmospheric conditions are associated with high 8-hour ozone concentrations in the lower troposphere in the Atlanta metropolitan area. A second objective is to determine what associations, if any, exist between meteorological variables and high 8-hour ozone concentrations.

5 Data

The data used for this study includes ozone measurements, radiosonde data from the Peachtree City, Georgia airport, and spatially-interpolated upper-air data from NOAA for June-August for 2000-2003 inclusive. Hourly ozone concentrations at eleven of the

Georgia Environmental Protection Division (GEPD) monitoring stations in the Atlanta area (Figure 1), as measured by continuous ultraviolet spectrophotometry, were obtained, resulting in a four-year summer data set, June-August, from 2000-2003. All of the stations are monitored from a central location via computer datalink, and physically inspected and maintained by GEPD personnel and contractors. Station equipment includes standard air sampling precautions, such as particle and water traps and fine particle and moisture filters.

Figure 2 shows the Atlanta area and the southeastern United States. Table 1 lists the air quality monitoring stations used in this research, with their county and city locations. For brevity, stations were assigned a shorthand label used throughout the study.

Table 1. Air quality monitoring stations used in this research. "Label" is a unique shorthand ID for this study only, created by deleting the common FIPS code prefixes and any extraneous AIRS suffix codes.

FIPSAIRS	COUNTY	CITY	LABEL
1306700031	Cobb	Kennesaw	S067
1307700021	Coweta	Newnan	S077
1308900011	DeKalb	Decatur	S0890
1308930001	DeKalb	Tucker	S0893
1309700041	Douglas	Douglasville	S097
1311300011	Fayette	Fayetteville	S113
1312100551	Fulton	Atlanta	S121
1313500021	Gwinnett	Lawrenceville	S135
1315100021	Henry	McDonough	S151
1322300031	Paulding	Yorkville	S223
1324700011	Rockdale	Conyers	S247

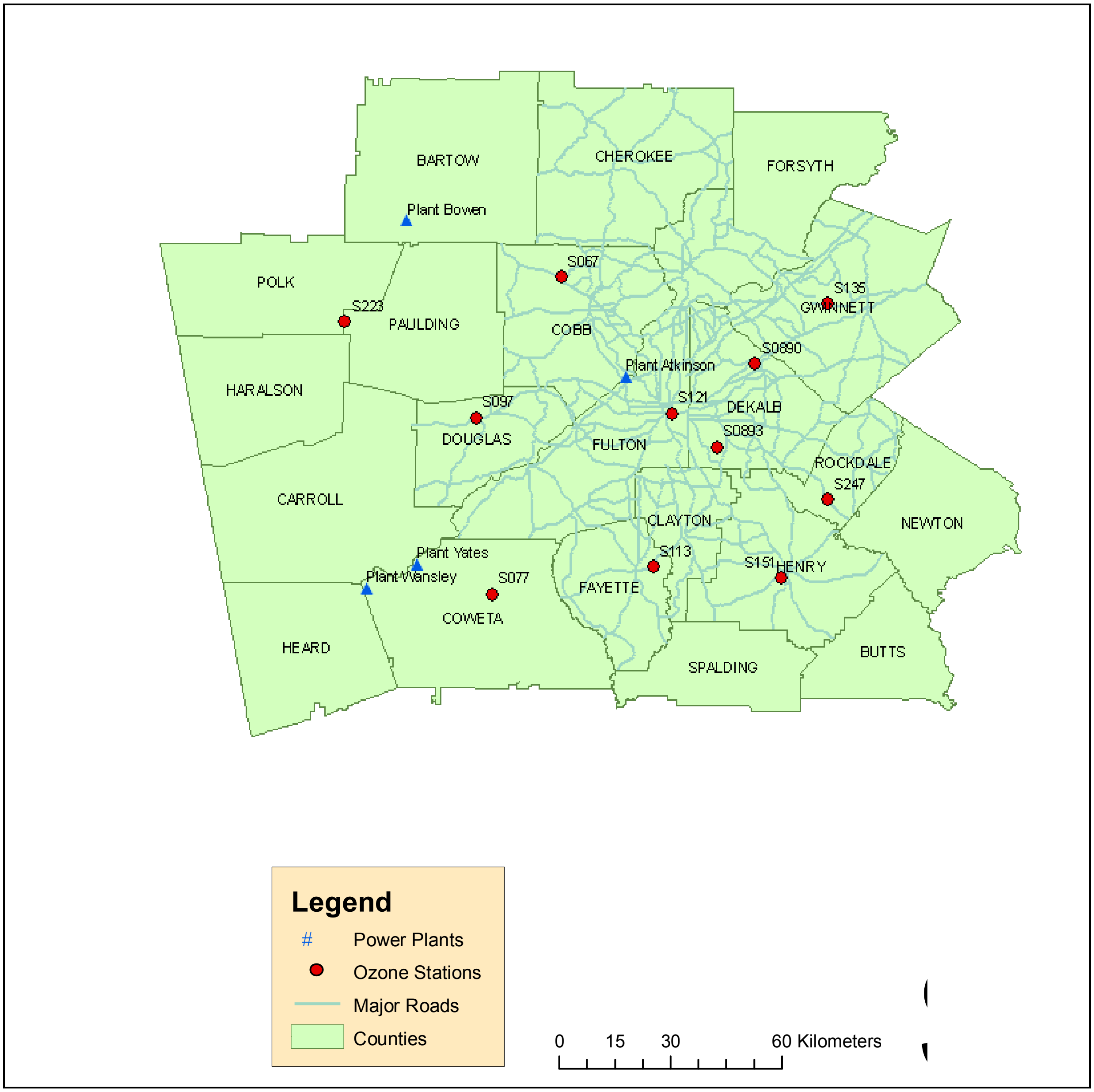

Figure 1. Metropolitan Atlanta study area.

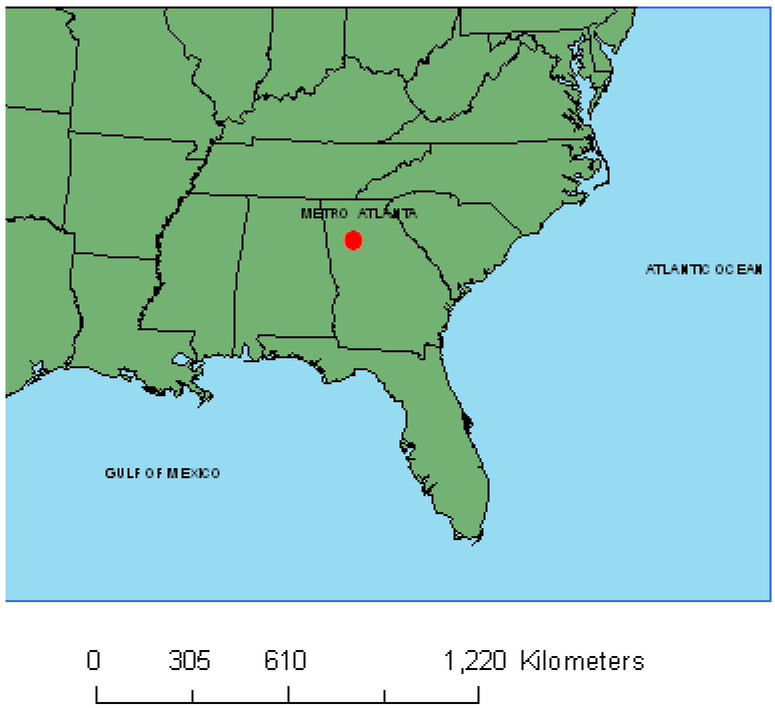

Figure 2. Atlanta metropolitan area in geographical context of the southeastern United States.

S067 is located at Kennesaw State University, in suburban Cobb County close to Interstate 75. S077 is located in semi-rural Coweta County. The GEPD lists S0890 as located in Decatur, but a site visit revealed it is actually located in Panthersville, in an isolated location over a kilometer from any Interstate highway. S0893 is located in an urbanized area in northern DeKalb County. S097 is located in Douglasville near Interstate 20. S113 is located in a small town in semi-rural Fayette County. S121 is located on Confederate Avenue in downtown Atlanta near Interstate 75. S135 is located

in a small city in suburban Gwinnett County, and S151 is located in a small city in suburban Henry County. S223 is located in a hamlet in rural northwest Paulding County. S247 is located in a monastery near the city of Conyers in Rockdale County, an urbanized area. Radiosonde data collected above the Peachtree City Airport were obtained for wind direction and speed, temperature, relative humidity, and geopotential height for 500, 700, 850, and 925 millibars, and geopotential height for 1000 millibars. Spatially-interpolated upper-air data were obtained from the NCEP/NCAR Reanalysis dataset of NOAA's Climate Diagnostics Center and the Cooperative Institute for Research in Environmental Sciences for the study period (Kalnay *et. al* 1996). All data were checked for obvious errors and completeness, and available metadata obtained for all datasets.

6.0 Methods

The methodology used in this study was an environment-circulation analysis (Winkler 1988, Yarnal 1993). High ozone days (HODs) were determined from the data by choosing the 90^{th} percentile of the daily maximum ozone concentrations, consisting of 38 cases per station. Atmospheric and meteorological conditions were examined for those days compared to the non-high ozone days (NHODs). Composite maps of geopotential heights were created for high ozone days, and hypothesis testing performed to compare variables for the high and non-high ozone cases to determine if there were statistically significant differences between the two cases. Since, in general, the data were not normally distributed, a nonparametric hypothesis test was required. The Mann-Whitney

U-test was selected since it assumes nothing about the distribution of data (von Storch and Zwiers 1999).

6.1 Ozone Calculations

The daily maximum 8-hour mean ozone concentration was calculated according to rules mandated by the USEPA (USEPA 2004b), which have been published in the Code of Federal Regulations, 40 Part 50. These rules require a running average of 8-hour averages to be calculated for 24 hours of each day that ozone is monitored. The daily maximum is defined as the highest of the 24 possible 8-hour average concentrations calculated for a given day. To be considered as a valid monitoring day, at least 8 out of 24 possible 8-hour averages must be available.

For purposes of this study, linear regression was used to estimate missing data from a station, using ozone values from a highly correlated station as the predictor variable. But if the 8-hour average ozone concentration is higher than a predicted value, the measured concentration was used. This resulted in a serially complete data set that follows the logic of the USEPA's methods for data completeness and computations.

6.2 Environment-to-Circulation Analysis

An environment-to-circulation analysis is based on choosing an environmental variable of interest at some concentration, then correlating that variable with atmospheric conditions for a relevant time period (Winkler 1988, Yarnal 1993). The specific method

used in this study is known as compositing, which includes the constructing of average maps, as well as statistical analysis of the chosen variables. From a spatial perspective, the result is a set of composite maps created from the high ozone days for all 38 cases representing HODs.

6.2.1 Circulation Patterns

In order to visualize the synoptic-scale atmospheric circulation for HODs, a composite 850-millibar geopotential surface was created for each set of 38 high ozone days, and compared with the mean surface during the study period. Such a composite map can reveal any circulation pattern difference between HOD and NHOD days, such as the presence of anomalous highs, systems conducive to transport of ozone into the area, or of lows bringing unstable air from the Gulf of Mexico, as hypothetical examples.

6.2.2 Radiosonde Analysis

Upper-level conditions impact ozone transport and ventilation. Therefore, mean upper-level atmospheric conditions were determined for the high ozone composites, and compared to the non-high ozone conditions. The Mann-Whitney *U*-test, at a significance level of 0.05, was used to test for differences between the two situations.

7 Results

7.1 Ozone Data

Histograms of ozone data revealed that, while data for some stations were normally distributed, not all were. Figures 3a through 14b show the histograms for all days and HODs. While the entire dataset was reasonably normally distributed, the data for HODs were often not normally distributed. One feature of the data is the high correlation of ozone values between stations. Correlation coefficients for ozone concentrations between different stations range from a low of 0.73 to a high of 0.98. Table 2 shows the median 8-hour ozone levels for the two cases for each station. Tables 3 and 4 in the appendix show the correlation matrices for ozone concentrations and HODs.

Table 2. Median 8-hour ozone concentrations in ppbv for all stations.

Station	HOD	NOD
S067	93.9	57.6
S077	86.1	50.7
S0890	90.5	55.1
S0893	90.3	59.9
S097	90.6	54.0
S113	85.4	52.4
S121	98.3	58.1
S135	88.6	58.4
S151	92.0	52.8
S223	84.3	53.0
S247	89.6	52.8

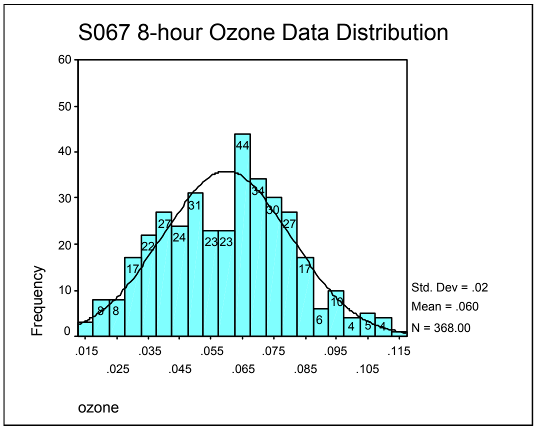

Figure 3a. S067 ozone data distribution.

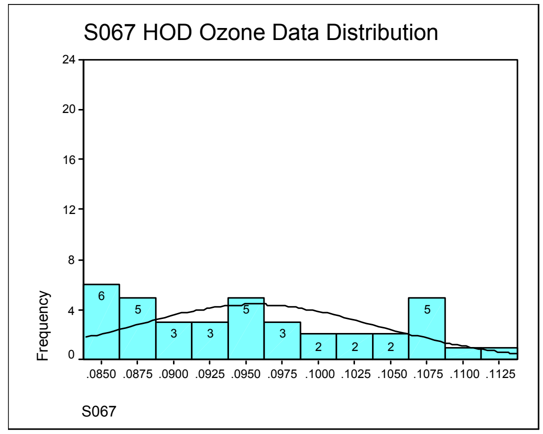

Figure 3b. S067 HOD ozone data distribution.

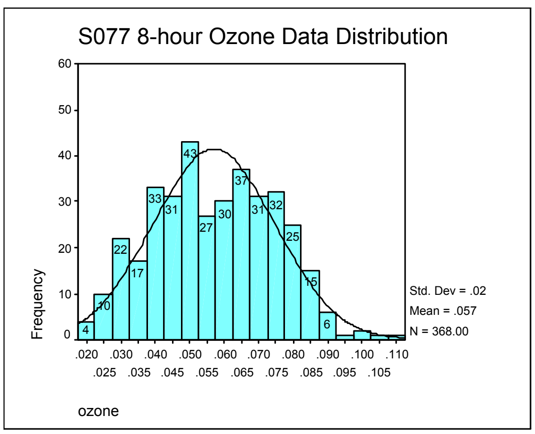

Figure 4a. S077 ozone data distribution.

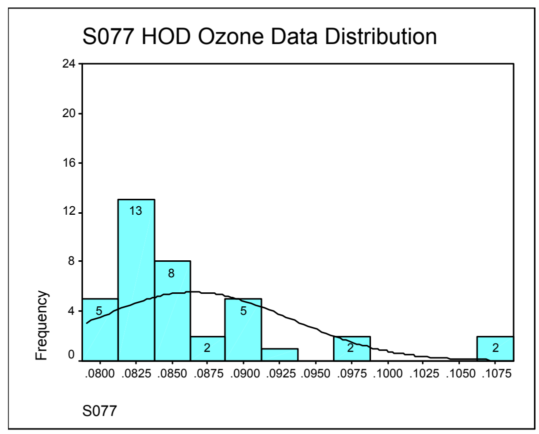

Figure 4b. S077 HOD ozone data distribution.

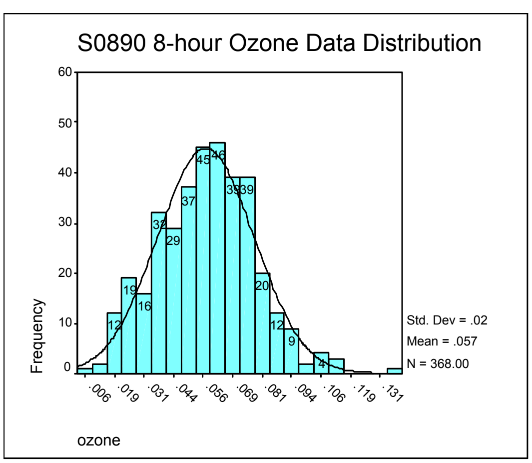

Figure 5a. S0890 ozone data distribution.

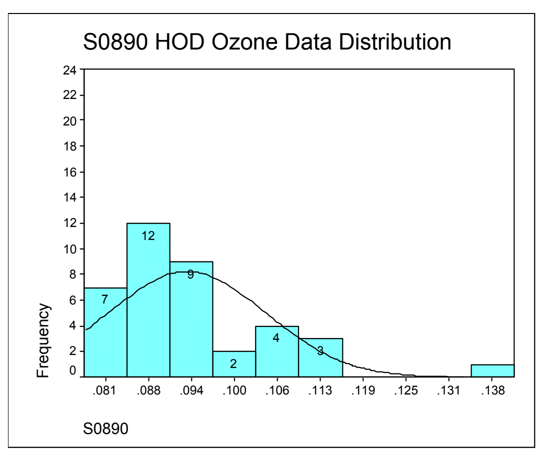

Figure 5b. S0890 HOD ozone data distribution.

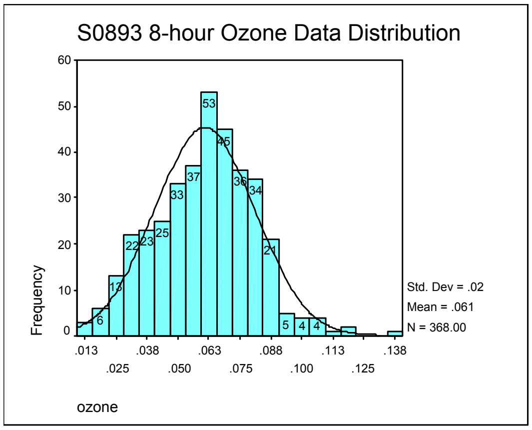

Figure 6a. S0893 ozone data distribution.

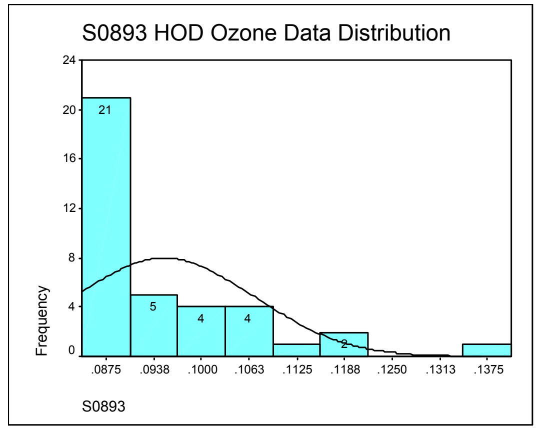

Figure 6b. S0893 HOD ozone data distribution.

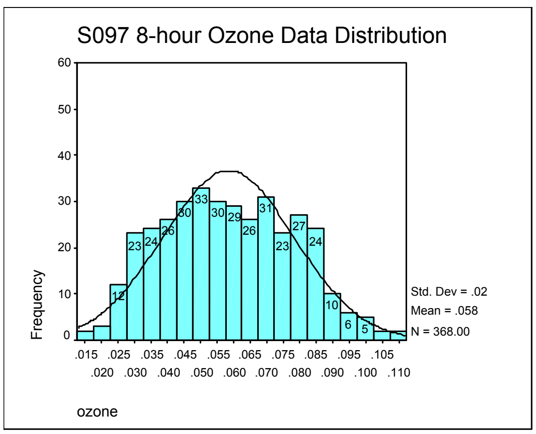

Figure 7a. S097 ozone data distribution.

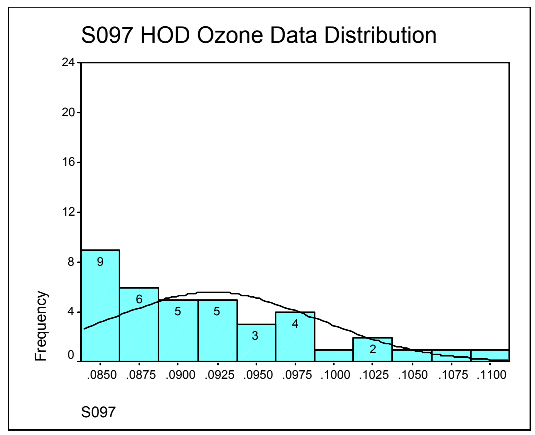

Figure 7b. S097 HOD ozone data distribution.

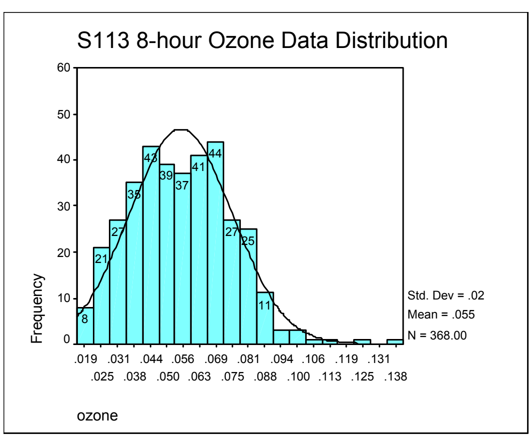

Figure 8a. S113 ozone data distribution.

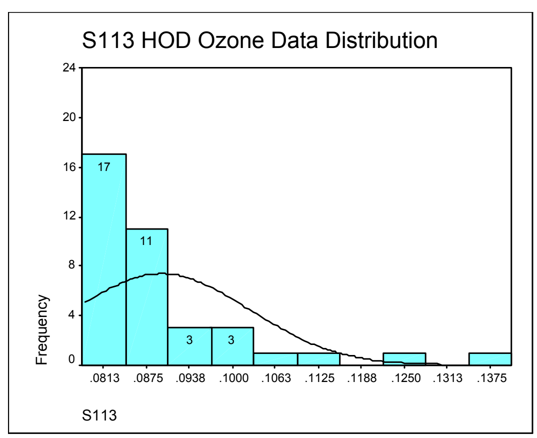

Figure 8b. S113 HOD ozone data distribution.

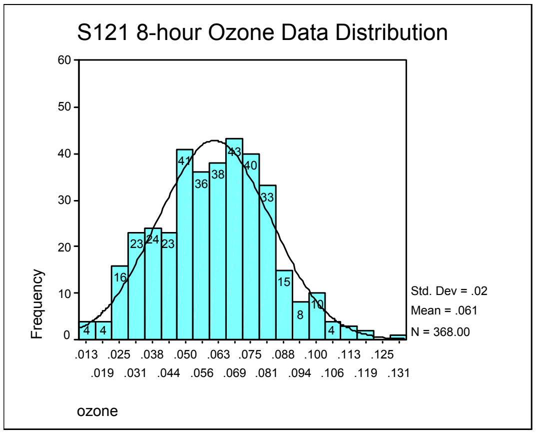

Figure 9a. S121 ozone data distribution.

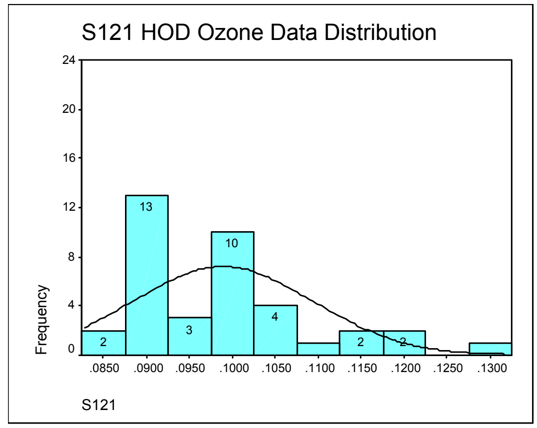

Figure 9b. S121 HOD ozone data distribution.

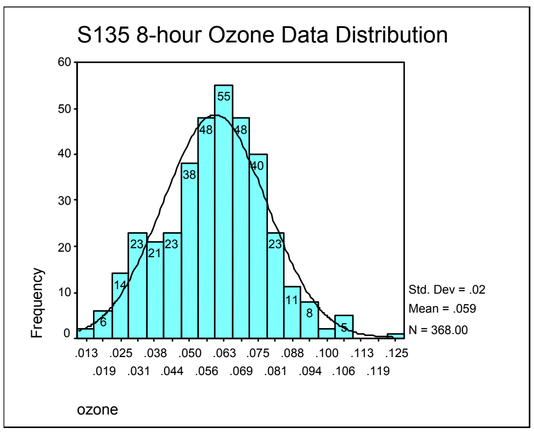

Figure 10a. S135 ozone data distribution.

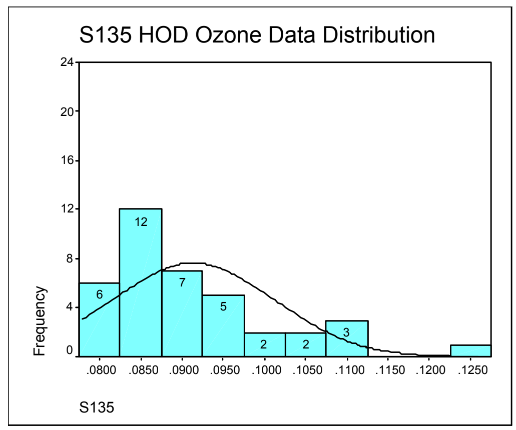

Figure10b. S135 HOD ozone data distribution.

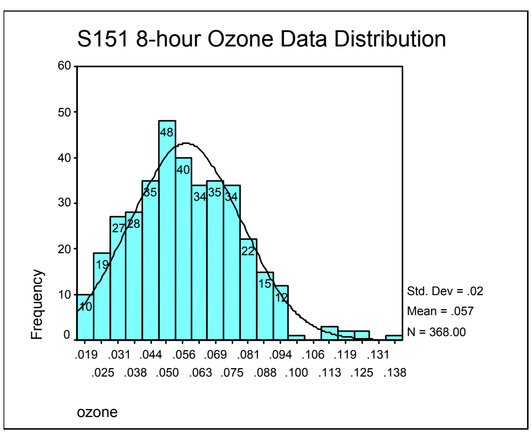

Figure 11a. S151 ozone data distribution.

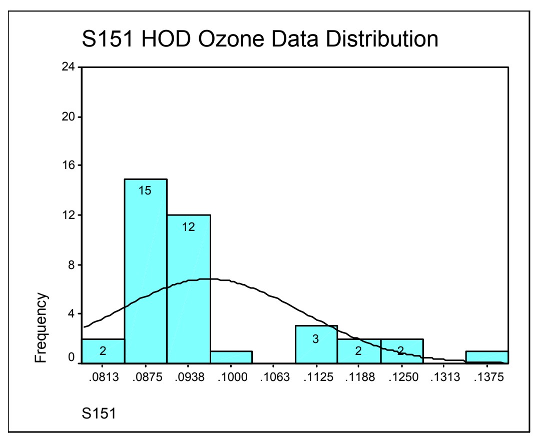

Figure11b. S151 HOD ozone data distribution.

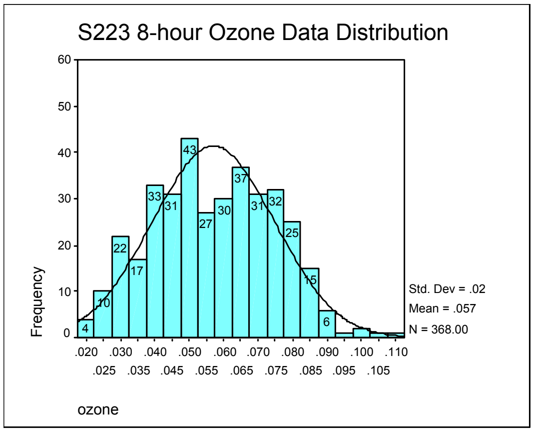

Figure 12a. S223 ozone data distribution.

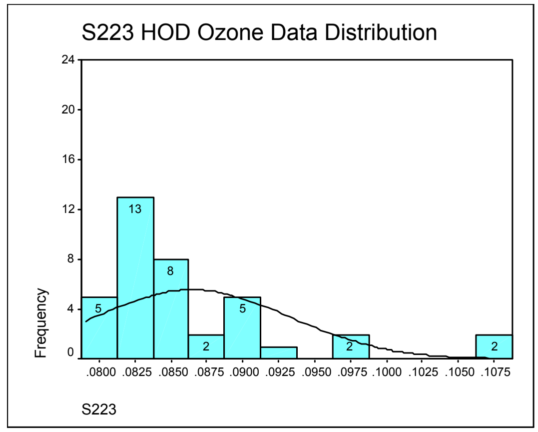

Figure 12b. S223 HOD ozone data distribution.

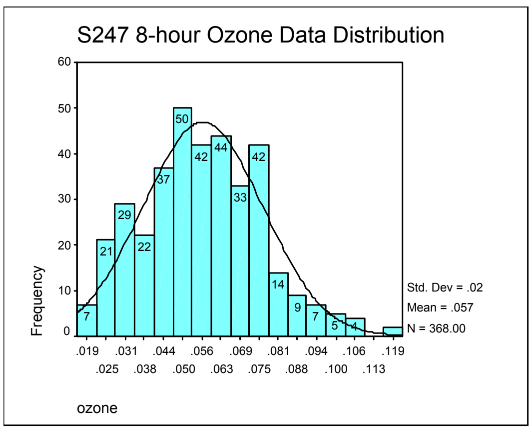

Figure 13a. S247 ozone data distribution.

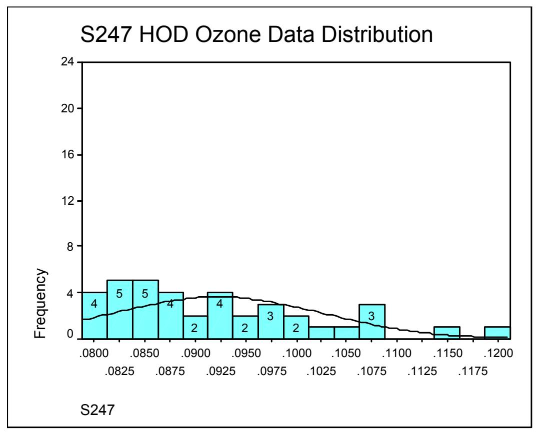

Figure 13b. S247 HOD ozone data distribution.

As the histograms indicate, some distributions for the entire dataset are leptokurtic, while the HOD distributions often are markedly platykurtic. Several distributions are highly skewed. The difference in sample size between the two cases, 330 versus 38, no doubt affects the shapes of the distributions.

7.2 Atmospheric Patterns

Atmospheric patterns are shown by maps for geopotential heights at 850 millibars, in Figures 14-24. These maps indicate the presence of three types of systems over the southeastern United States on HODs. One type has lower than mean geopotential heights over Atlanta, with some troughing evident, and a very weak Bermuda high off the east coast. A second pattern shows an anticyclone over Atlanta, and a near-normal or slightly weaker than normal Bermuda high off the east coast. The third type has an anticyclone over Atlanta, with Atlanta possibly in a trough or on the back of a trough, and a weak Bermuda high off the east coast, with higher geopotential heights over Louisiana and surrounding states. Stations will be grouped according to pattern and discussed in more detail.

In one pattern, Atlanta is not under an anticyclone, and is in a trough. This pattern includes S077 (Figure 15). The map for this station is the most unique of any. Atlanta is not under an anticyclone, but is located in the lee of a trough. There is a very weak Bermuda high off the east coast and higher than mean geopotential heights over Louisiana and Arkansas. S113 (Figure 19) is similar to this pattern, as is S151 (Figure 22), except that Atlanta could be on the back side of a trough.

In the second pattern, Atlanta is under an anticyclone, with a weak Bermuda high off the east coast. S067 (Figure 14) in this category shows an anticyclone over much of the southeast, including Atlanta, with a weak Bermuda high. The map for S0890 (Figure 16) is similar to S067, and suggests that Atlanta is on the back side of a trough. S097 (Figure 18), and S121 are similar to S067, as is S247 (Figure 24). This latter map shows

Atlanta under an anticyclone, with a moderately weak Bermuda high off the east coast, and possible troughing over Atlanta.

In the third pattern, Atlanta is under an anticyclone, and there is a near-normal Bermuda high. S0893 (Figure 17) falls into this category. The map for this station shows Atlanta under an anticyclone, with a near-normal Bermuda high off the east coast. S135 (Figure 21), and S223 (Figure 23) both show an anticyclone over Atlanta, with the Bermuda high only slightly weaker than normal off the east coast.

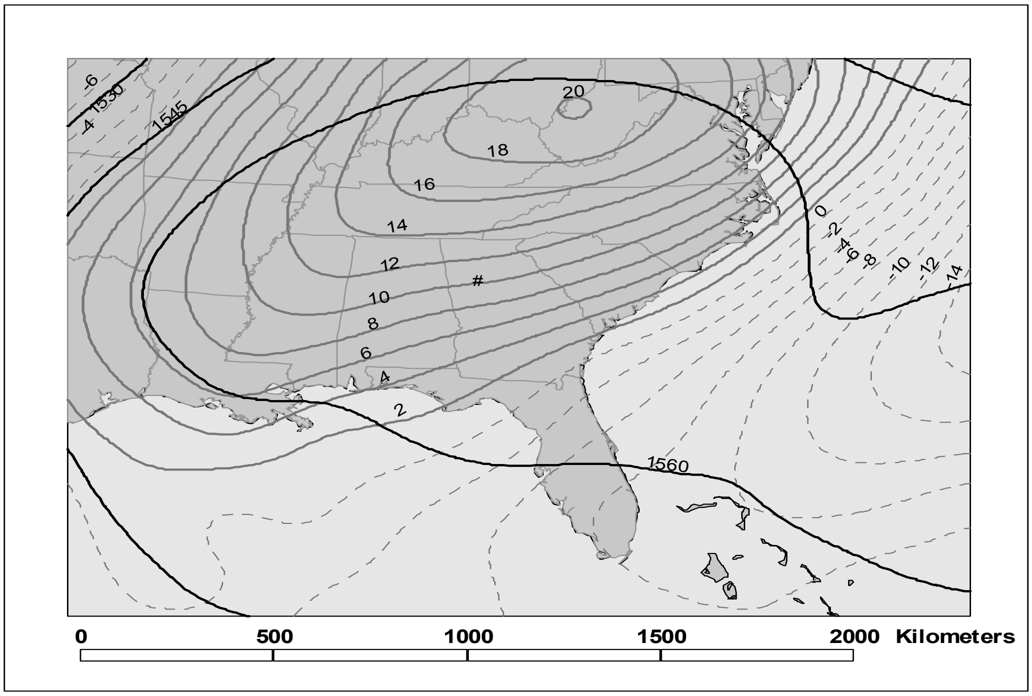

Figure 14. 850-millibar HOD pattern for S067. Dark solid lines indicate the geopotential height for HODs. Light solid lines indicate deviations from mean conditions for study period. Light dashed lines indicate negative deviations from mean conditions. All values are in meters.

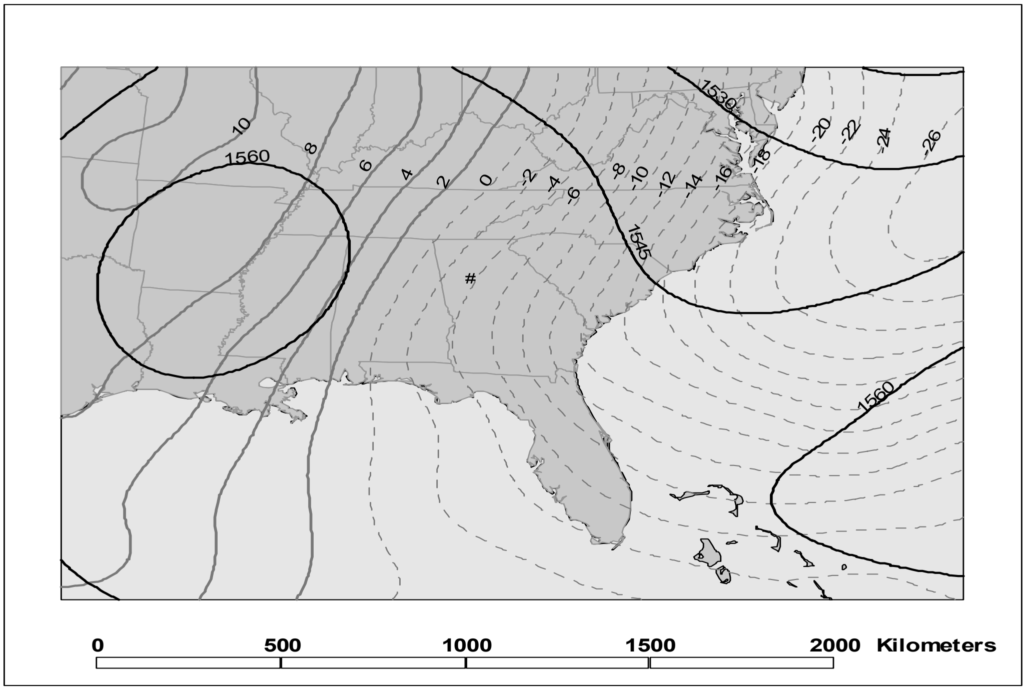

Figure 15. 850-millibar HOD pattern for S077. Dark solid lines indicate the geopotential height for HODs. Light solid lines indicate deviations from mean conditions for study period. Light dashed lines indicate negative deviations from mean conditions. All values are in meters.

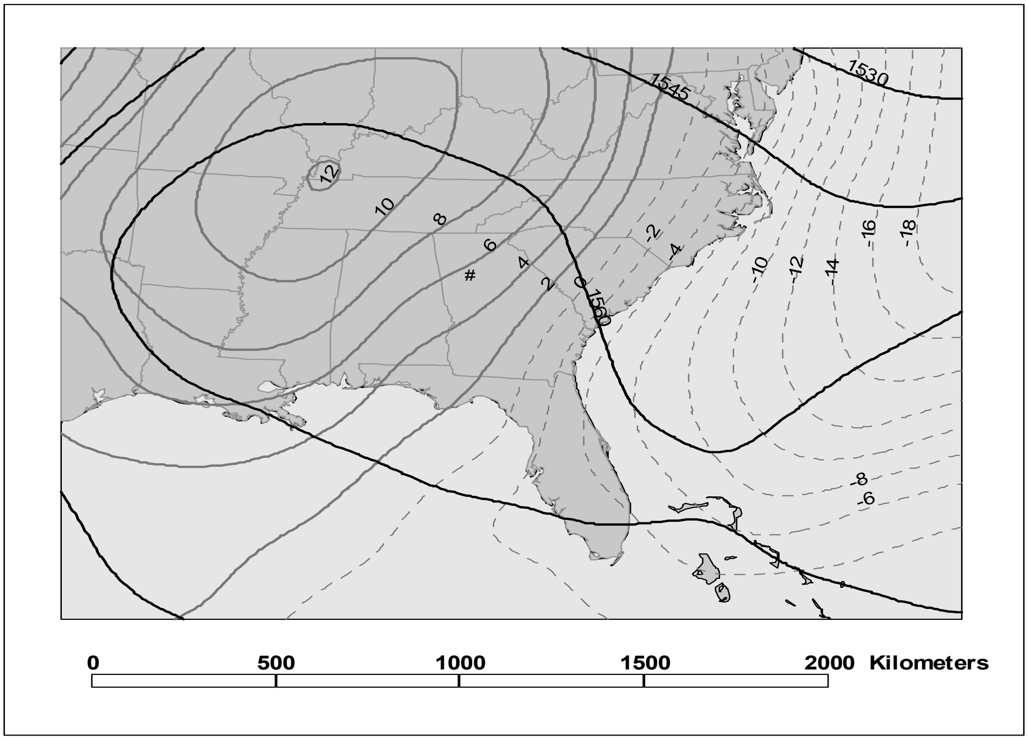

Figure 16. 850-millibar HOD pattern for S0890. Dark solid lines indicate the geopotential height for HODs. Light solid lines indicate deviations from mean conditions for study period. Light dashed lines indicate negative deviations from mean conditions. All values are in meters.

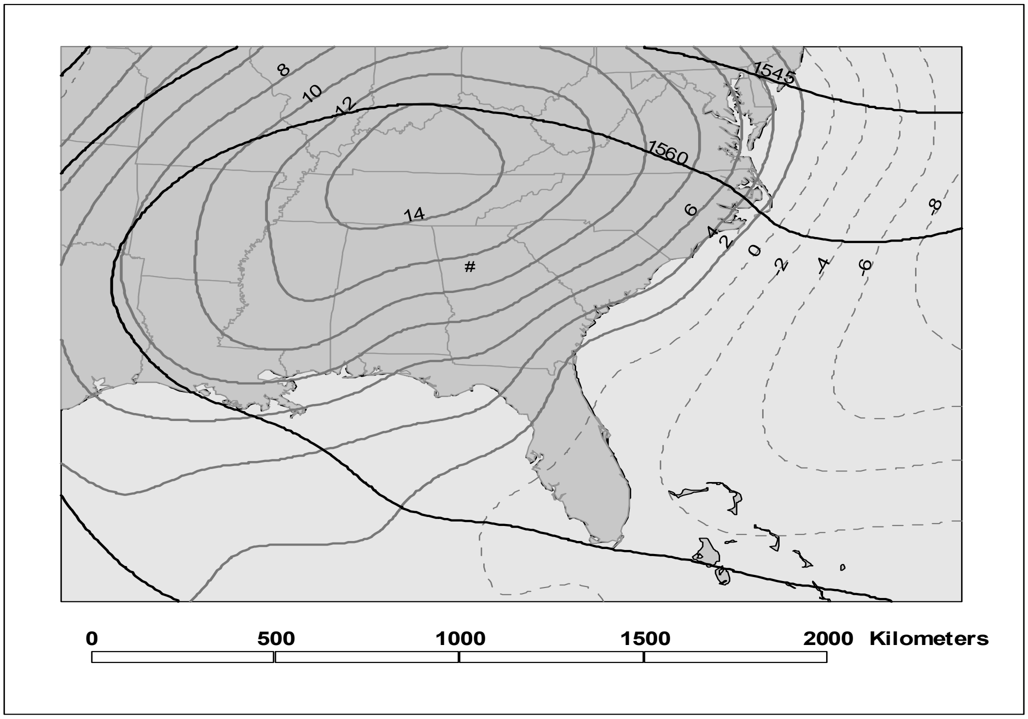

Figure 17. 850-millibar HOD pattern for S0893. Dark solid lines indicate the geopotential height for HODs. Light solid lines indicate deviations from mean conditions for study period. Light dashed lines indicate negative deviations from mean conditions. All values are in meters.

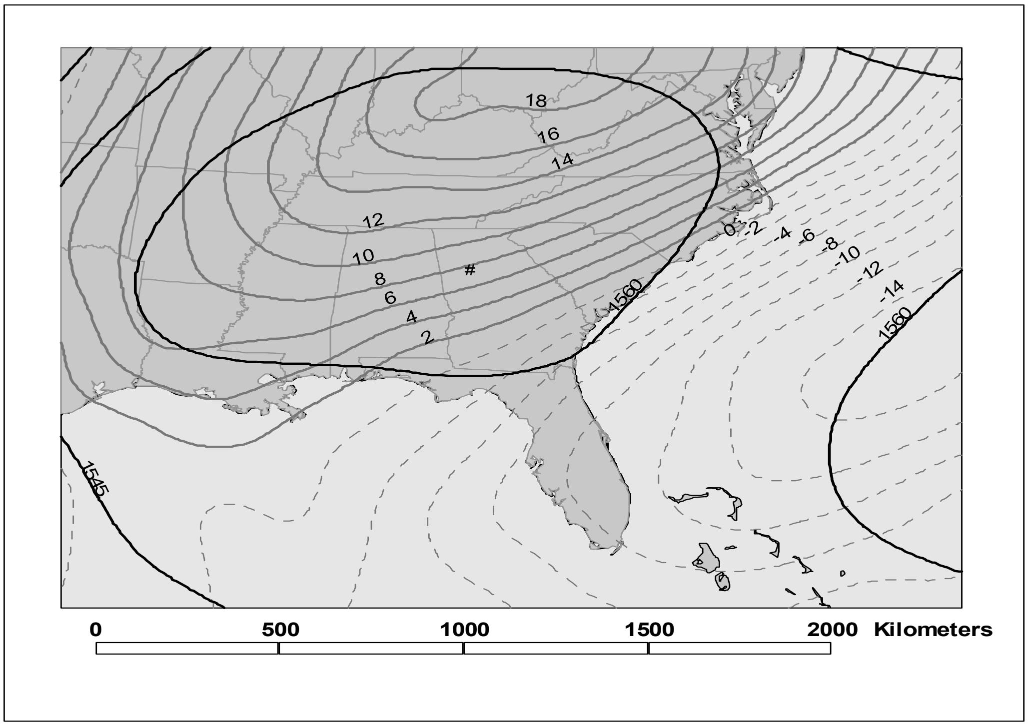

Figure 18. 850-millibar HOD pattern for S097. Dark solid lines indicate the geopotential height for HODs. Light solid lines indicate deviations from mean conditions for study period. Light dashed lines indicate negative deviations from mean conditions. All values are in meters.

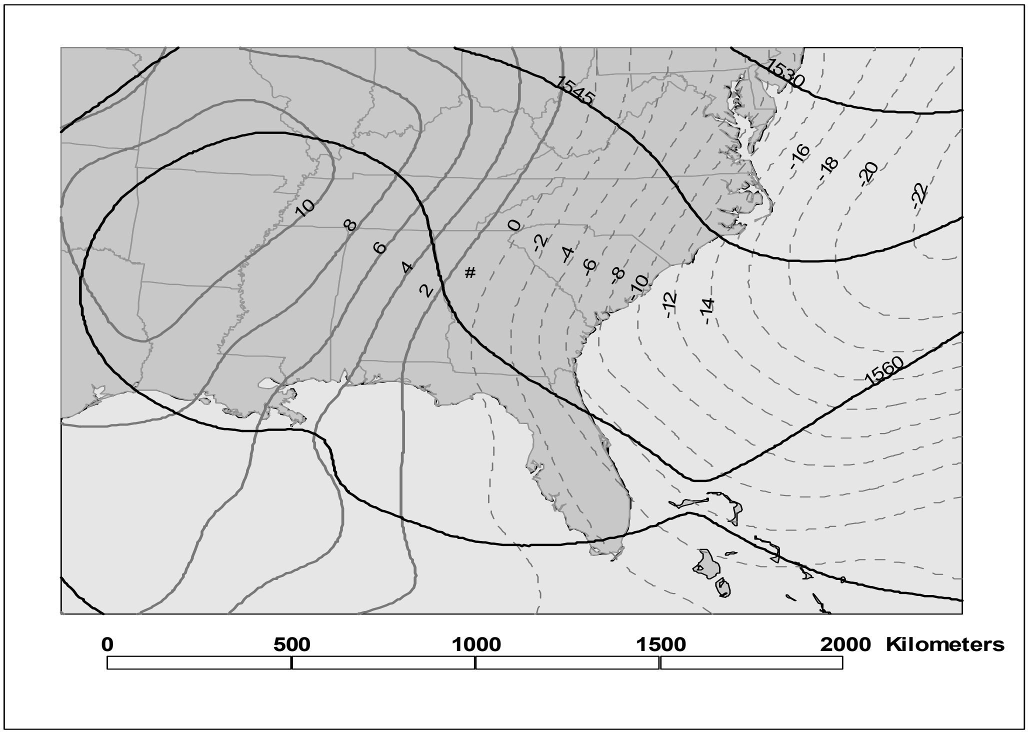

Figure 19. 850-millibar HOD pattern for S113. Dark solid lines indicate the geopotential height for HODs. Light solid lines indicate deviations from mean conditions for study period. Light dashed lines indicate negative deviations from mean conditions. All values are in meters.

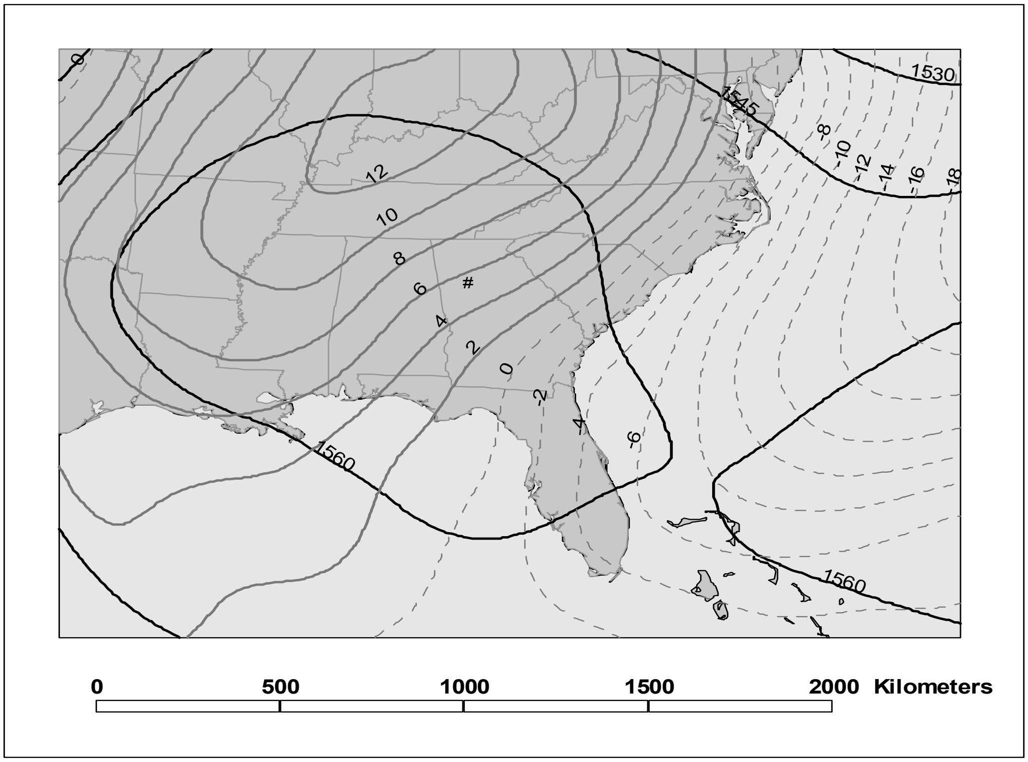

Figure 20. 850-millibar HOD pattern for S121. Dark solid lines indicate the geopotential height for HODs. Light solid lines indicate deviations from mean conditions for study period. Light dashed lines indicate negative deviations from mean conditions. All values are in meters.

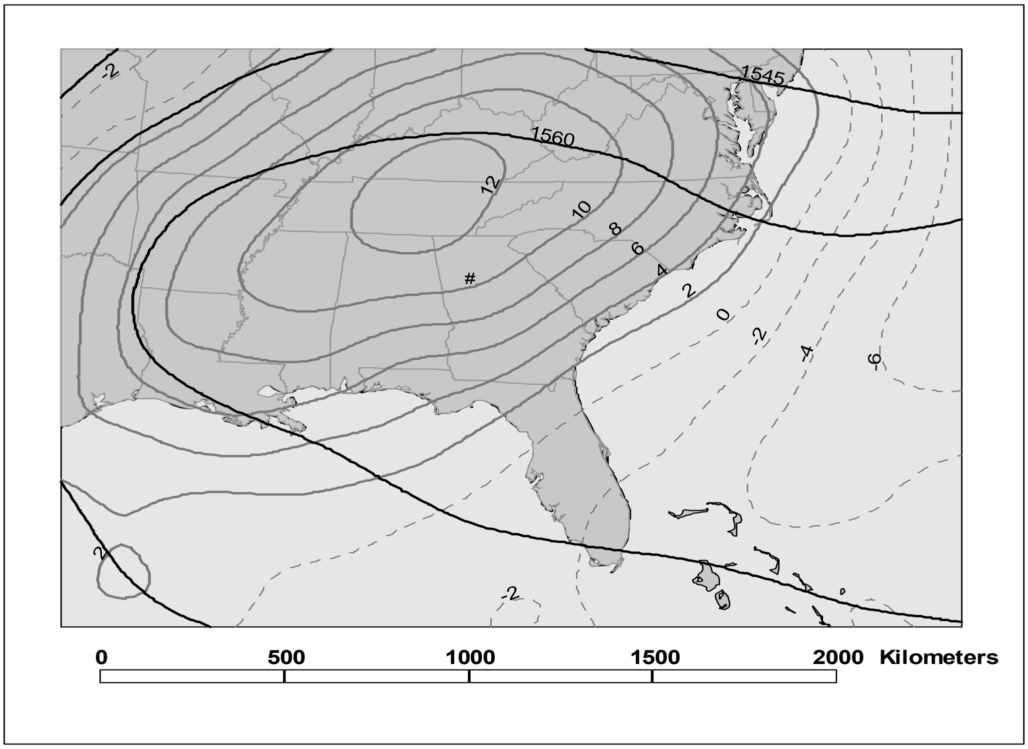

Figure 21. 850-millibar HOD pattern for S135. Dark solid lines indicate the geopotential height for HODs. Light solid lines indicate deviations from mean conditions for study period. Light dashed lines indicate negative deviations from mean conditions. All values are in meters.

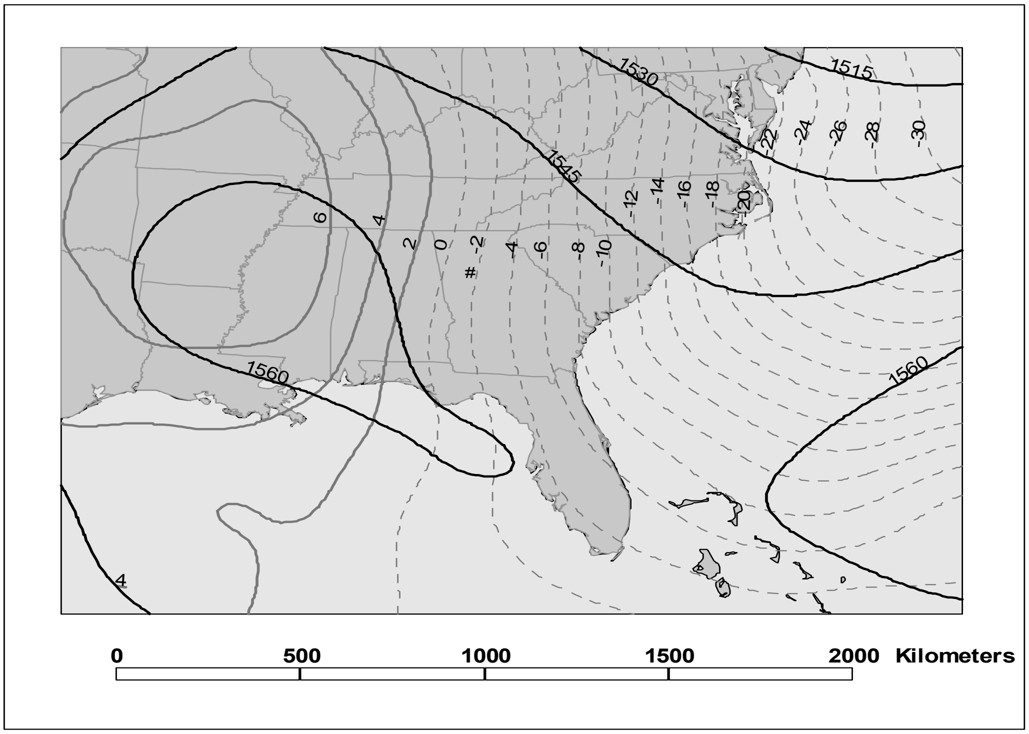

Figure 22. 850-millibar HOD pattern for S151. Dark solid lines indicate the geopotential height for HODs. Light solid lines indicate deviations from mean conditions for study period. Light dashed lines indicate negative deviations from mean conditions. All values are in meters.

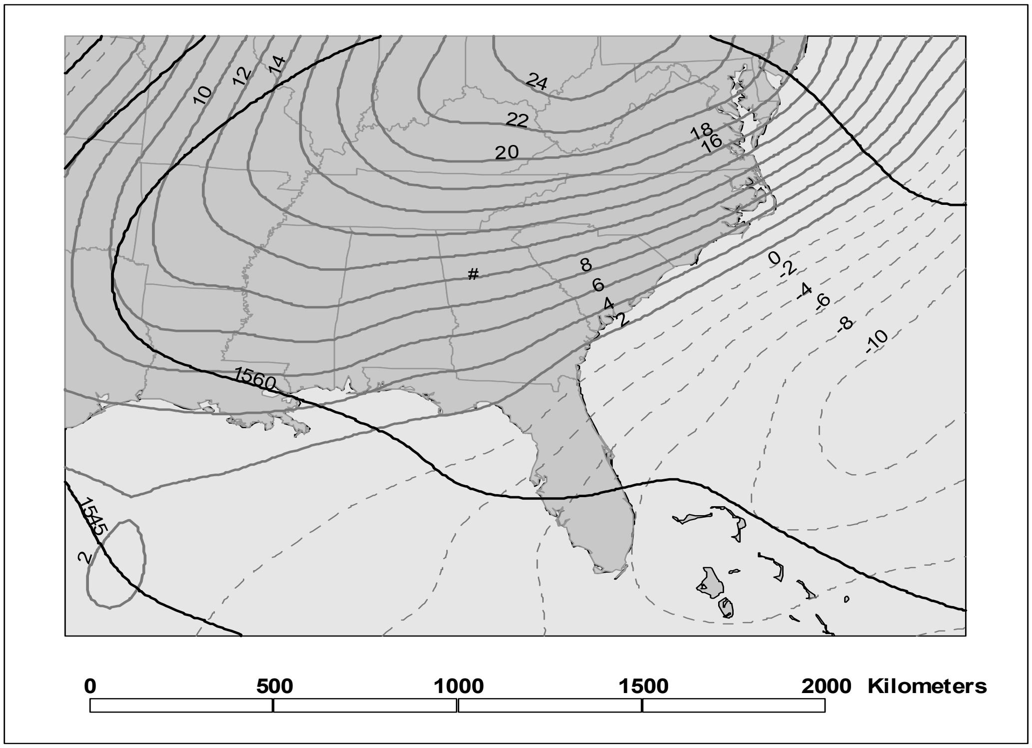

Figure 23. 850-millibar HOD pattern for S223. Dark solid lines indicate the geopotential height for HODs. Light solid lines indicate deviations from mean conditions for study period. Light dashed lines indicate negative deviations from mean conditions. All values are in meters.

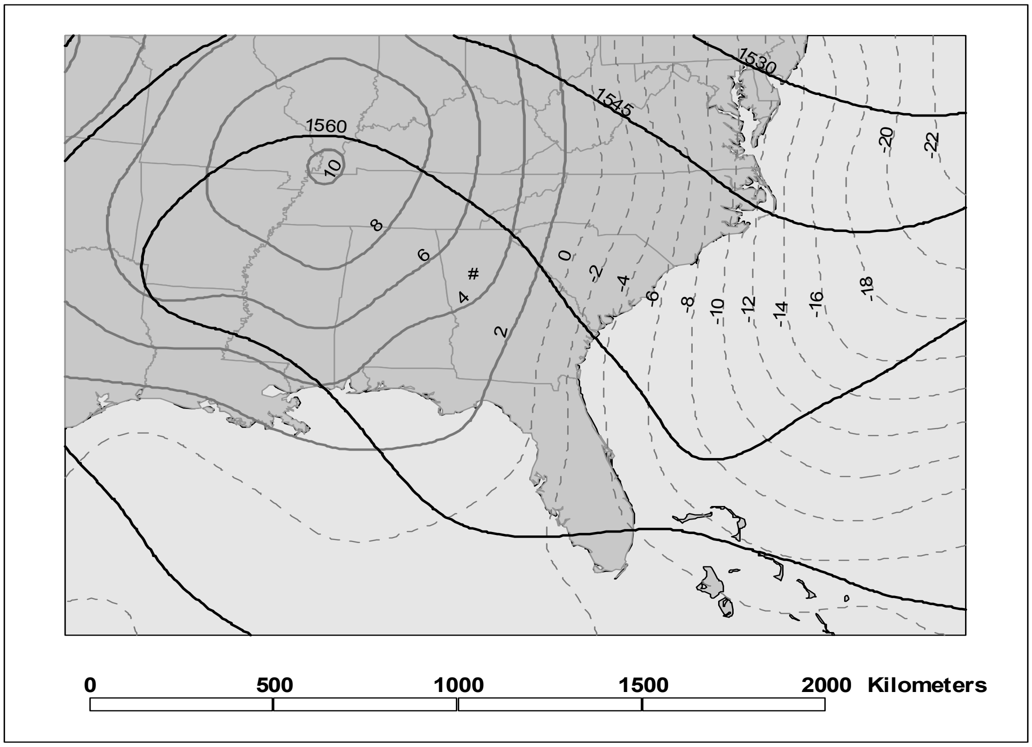

Figure 24. 850-millibar HOD pattern for S247. Dark solid lines indicate the geopotential height for HODs. Light solid lines indicate deviations from mean conditions for study period. Light dashed lines indicate negative deviations from mean conditions. All values are in meters.

7.3 Meteorological Variables

Table 5 displays the median values of all variables except wind direction for HODs and NODs. Wind direction is a circular variable, for which conventional statistical summaries and tests cannot be used (Mardia and Jupp 2000). The most obvious fact is that dew point temperature and temperature were important variables determining whether a day would be a high ozone day or a non-high ozone day. Higher air temperatures were associated with higher ozone values, while lower dew point temperatures were associated with higher ozone values. This is consistent with many other studies, and is consistent with a high-pressure system being present over the area. Weaker wind fields were associated with higher ozone levels at many but not all stations.

For S067, dew point temperature was lower for HODs than for NHODs for 500, 850, and 925 millibars. Also lower for HODs was wind speed for 850 and 925-millibars. S077 showed lower dew point temperature for 500, 700, and 925 millibars for HODs compared to NHODs, while showing higher air temperature for 700 and 925 millibars for HODs. S0890 displayed lower dew point temperature for 700 and 925 millibars, while showing higher air temperature for the same geopotential heights for HODs compared to NHODs. S0893 had more variables that were significant, with lower dew point temperatures for 700, 850, and 925 millibars, higher air temperature for 925 millibars, and lower wind speed for 700 and 925 millibars. S097 displayed only lower dew point temperature for 500 and 925 millibars for HODs compared to NHODs. S113 exhibited lower dew point temperature for 700, 850, and 925 millibars, and higher air temperature for 700 and 925 millibars for HODs. S121 displayed lower dew point temperature for 500, 700, and 925 millibars, higher air temperature for 700 millibars, and lower wind

speed for both 850 and 925 millibars. S135 exhibited lower dew point temperature for 700, 850, and 925 millibars, and higher air temperature for 700 and 925 millibars. This station also showed lower wind speed for 925 millibars.

S151 displayed higher air temperature for 700, 850, and 925 millibars, as well as lower dew point temperature for 925 millibars. S223 is unusual in that the geopotential height for 925 and 1000 millibars was significantly higher for HODs than NHODs, while dew point temperatures were lower for 500, 700, and 925 millibars for HODs. In addition, 850 millibar wind speed was lower for HODs. This station is located in rural northwest Paulding County. The last station, S247, showed lower 700, 850, and 925 millibar dew point temperatures for HODs, and higher 925 millibar air temperature.

Figures 25a-35b show wind direction histograms for each station for 850-millibar geopotential heights. The histograms often show considerable differences in wind direction between the HODs and NODs. NHODs tend to show some wind from all directions, but less from the north and northeast compared to southerly and westerly. Patterns were very similar from one station to the next, while HODs show more variation in wind direction between stations, and more variation in wind flow for any given station. Sample size is a possible complicating factor, since NHODs number 330, while HODs number only 38. Each station will be discussed in more detail.

S067 (Figure 25) HOD winds show a strong easterly tendency, with a secondary westerly to northerly trend. NHODs are southwesterly to northwesterly, with westerly winds dominating. This station is northwest of Atlanta, and would not be expected to be

downwind of the urban center frequently. S077 (Figure 26) HOD winds are more varied, but with most from the west to northwest. NHOD winds are very similar to S067.

Table 5. Median values of variables for all stations. Underlined bold numbers indicate the two cases are significantly different (α =0.05).

	H1000	H925	T925	DPT925	WS925	H850	T850	DPT850	WS850	H700	T700	DPT700	WS700	H500	T500	DPT500	WS500
S067																	
HOD	166	839	21.4	**11.6**	**3.6**	1563	16.0	**9.2**	**3.6**	3189	8.2	-13.2	5.7	5880	-8.1	**-30.1**	6.7
NHOD	151	830	21.2	**17.2**	**5.7**	1560	16.8	**12.8**	**6.2**	3189	7.4	2.0	6.2	5880	-7.9	**-18.7**	7.2
S077																	
HOD	135	817	**22.6**	**12.1**	5.1	1545	17.3	10.3	6.2	3179	**8.6**	**-4.0**	7.7	5880	-7.6	**-30.7**	8.2
NHOD	155	833	**21.2**	**17.1**	5.7	1561	16.6	12.8	5.7	3190	**7.4**	**2.0**	6.2	5880	-8.1	**-19.1**	6.7
S0890																	
HOD	153	832	**22.6**	**13.7**	3.6	1562	16.8	10.0	3.9	3190	**8.6**	**-7.9**	6.2	5890	-7.6	-27.6	6.2
NHOD	153	831	**21.0**	**17.1**	5.7	1560	16.6	12.8	5.7	3189	**7.3**	**2.0**	6.2	5880	-8.0	-19.0	7.2
S0893																	
HOD	162	841	**22.6**	**12.6**	**3.6**	1571	16.8	**9.8**	3.6	3200	8.2	**-2.0**	**5.7**	5900	-7.7	-26.5	5.7
NHOD	151	830	**21.0**	**17.0**	**5.7**	1560	16.6	**12.8**	5.7	3188	7.4	**2.0**	**6.2**	5880	-7.9	-19.1	7.2
S097																	
HOD	159	837	21.8	**15.2**	3.6	1565	17.1	10.2	4.6	3192	8.3	-4.6	5.2	5890	-7.7	**-28.3**	6.7
NHOD	152	830	21.2	**17.0**	5.7	1560	16.6	12.8	5.7	3189	7.4	2.0	6.2	5880	-7.9	**-19.1**	7.2
S113																	
HOD	143	822	**22.4**	**12.6**	3.6	1550	16.8	**9.8**	4.4	3183	**8.6**	**-6.8**	6.2	5880	-7.7	-26.3	8.2
NHOD	153	832	**21.2**	**17.1**	5.7	1560	16.6	**12.8**	5.7	3190	**7.4**	**2.0**	6.2	5880	-8.1	-19.1	6.7
S121																	
HOD	155	832	22.2	**13.4**	**3.6**	1562	16.8	10.0	**3.6**	3191	**8.6**	**-3.8**	5.7	5890	-7.9	**-29.9**	6.7
NHOD	152	831	21.2	**17.0**	**5.7**	1560	16.7	12.8	**6.2**	3189	**7.4**	**2.0**	6.2	5880	-7.9	**-18.9**	7.2
S135																	
HOD	161	837	**22.4**	**12.7**	**3.6**	1564	16.8	**9.6**	3.6	3195	**8.2**	**-1.6**	5.7	5890	-7.7	-27.9	6.2
NHOD	152	830	**21.0**	**17.1**	**5.7**	1560	16.7	**12.8**	5.7	3188	**7.4**	**2.0**	6.2	5880	-7.9	-19.1	7.2
S151																	
HOD	136	819	**23.0**	**15.0**	5.1	1548	**18.0**	10.2	5.7	3183	**8.6**	-2.0	6.2	5890	-7.5	-26.3	7.7
NHOD	154	832	**21.0**	**17.1**	5.7	1561	**16.6**	12.8	5.7	3190	**7.4**	1.9	6.2	5880	-8.1	-19.1	6.7
S223																	
HOD	**168**	**844**	21.2	**13.4**	4.4	1572	16.1	9.6	**4.1**	3202	8.1	**-6.4**	5.4	5890	-8.2	**-32.6**	6.7
NHOD	**150**	**829**	21.2	**17.1**	5.7	1560	16.8	12.8	**6.2**	3188	7.4	**2.0**	6.2	5880	-7.9	**-18.7**	7.2
S247																	
HOD	147	827	**22.6**	**14.4**	3.6	1561	17.6	**10.2**	4.6	3192	8.4	**-1.4**	6.0	5900	-7.7	-26.3	7.7
NHOD	153	832	**21.0**	**17.1**	5.7	1560	16.6	**12.8**	5.7	3189	7.4	**1.8**	6.2	5880	-7.9	-19.1	6.7

Definitions of the variables are given below. Wind direction was not analyzed, since it is a circular variable and requires specialized statistical tests. Tables 6a, 6b, and 7 in the appendix give summary statistics and z-scores for the variables.

Variable codes and definitions:

H500	500 millibar geopotential height in meters.
T500	500 millibar temperature in degrees Celsius.
DT500	500 millibar dew point temperature in degrees Celsius.
WD500	500 millibar wind direction in degrees.
WS500	500 millibar wind speed in meters per second.
H700	700 millibar geopotential height in meters.
T700	700 millibar temperature in degrees Celsius.
DT700	700 millibar dew point temperature in degrees Celsius.
WD700	700 millibar wind direction in degrees.
WS700	700 millibar wind speed in meters per second.
H850	850 millibar geopotential height in meters.
T850	850 millibar temperature in degrees Celsius.
DT850	850 millibar dew point temperature in degrees Celsius.
WD850	850 millibar wind direction in degrees.
WS850	850 millibar wind speed in meters per second.
H925	925 millibar geopotential height in meters.
T925	925 millibar temperature in degrees Celsius.
DT925	925 millibar dew point temperature in degrees Celsius.
WD925	925 millibar wind direction in degrees.
WS925	925 millibar wind speed in meters per second.
H1000	1000 millibar geopotential height in meters.

HOD winds for S0890 (Figure 27) are either easterly or westerly to northwesterly, while NHOD winds are similar to S067 and S077. S0893 (Figure 28) shows no main direction for HOD winds, with a slight east and northwesterly tendency, while NHOD winds are southwesterly to northwesterly, as with previous stations. S097 (Figure 29) HOD winds show no clear pattern except a relative lack of southeast to southwest flow. NHOD winds are similar to previous stations. S113 (Figure 30) shows HOD winds with westerly to northwesterly flow, and some easterly flow. NHOD winds are similar to previous stations. S121 (Figure 31) HOD winds tend to be either easterly or westerly to northwesterly. NHOD winds follow previous patterns. HOD winds for S135 (Figure 32) also tend to be either easterly, or westerly to northwesterly. NHOD winds follow

previous patterns. S151 (Figure 33) HOD winds exhibit a marked westerly to northwesterly flow, while NHODs followed the pattern of other stations.

HOD winds for S223 (Figure 34) show an easterly peak, with other directions represented fairly equally. NHODs follow the pattern of previous stations. S247 (Figure 35) HOD winds show a clear westerly to northwesterly flow, while NHODs were unremarkable in their similarity to other stations.

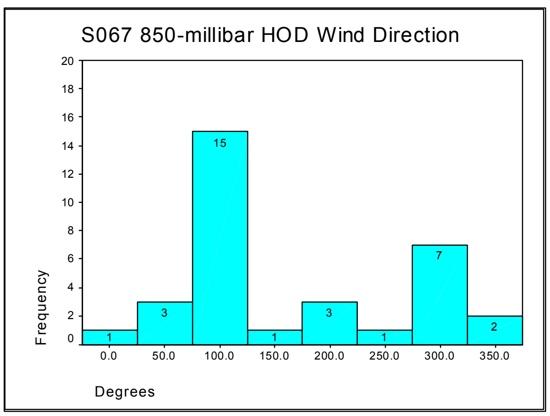

Figure 25a. 850 mb Wind Direction for S067 on HODs.

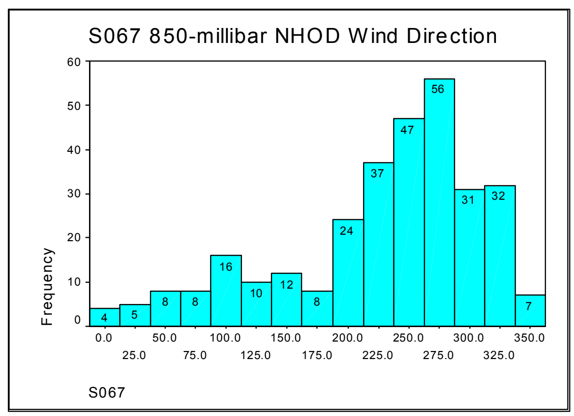

Figure 25b. 850 mb Wind Direction for S067 on NHODs.

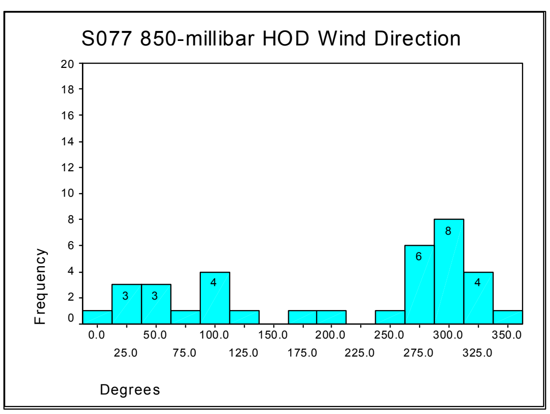

Figure 26a. 850 mb Wind Direction for S077 on HODs.

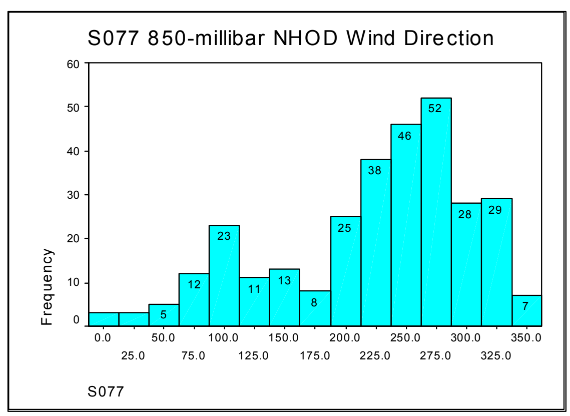

Figure 26b. 850 mb Wind Direction for S077 on NHODs.

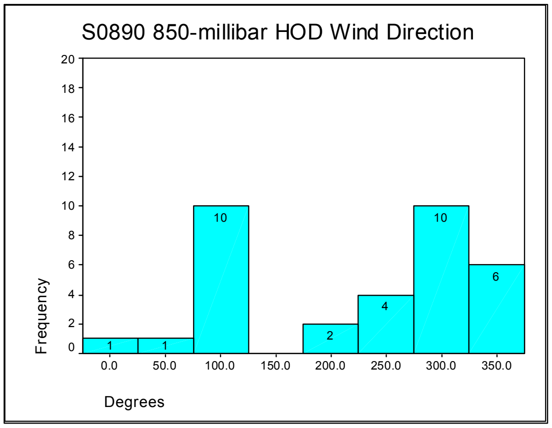

Figure 27a. 850 mb Wind Direction for S0890 on HODs.

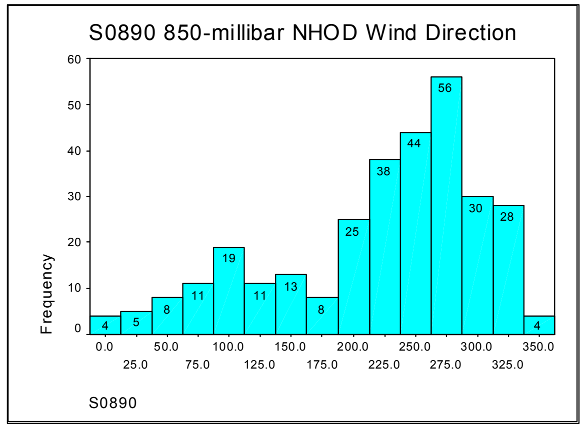

Figure 27b. 850 mb Wind Direction for S0890 on NHODs.

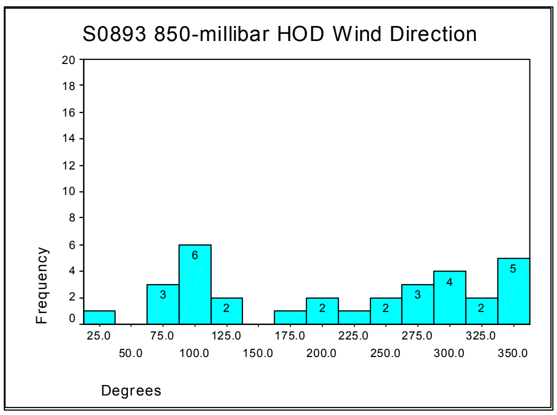

Figure 28a. 850 mb Wind Direction for S0893 on HODs.

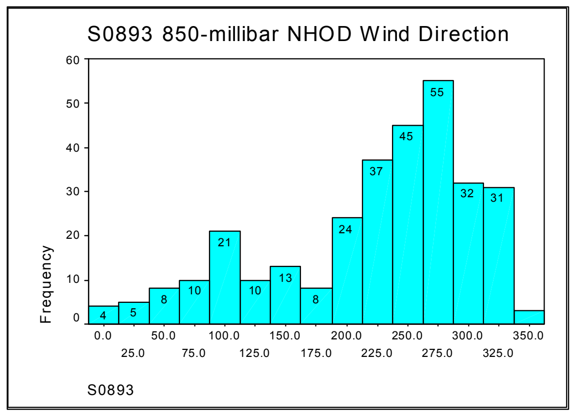

Figure 28b. 850 mb Wind Direction for S0893 on NHODs.

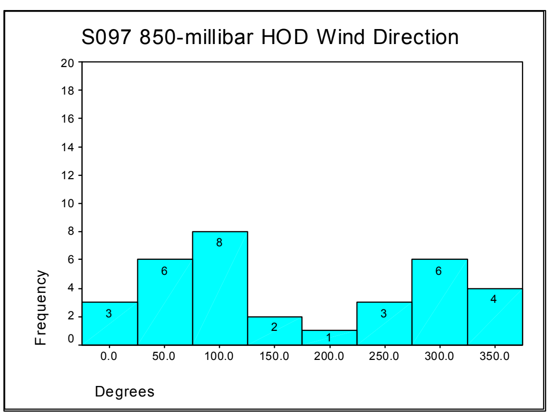

Figure 29a. 850 mb Wind Direction for S097 on HODs.

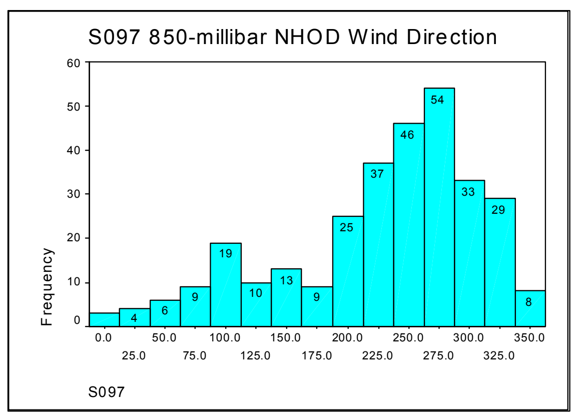

Figure 29b. 850 mb Wind Direction for S097 on NHODs.

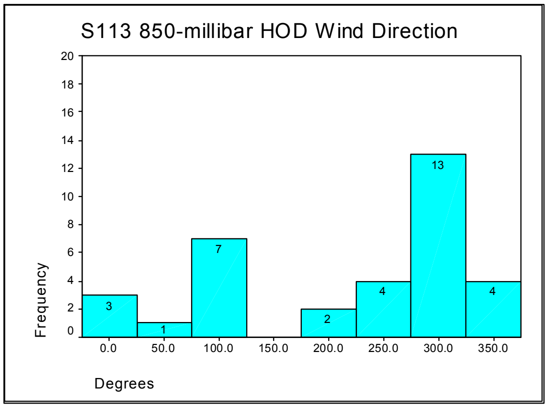

Figure 30a. 850 mb Wind Direction for S113 on HODs.

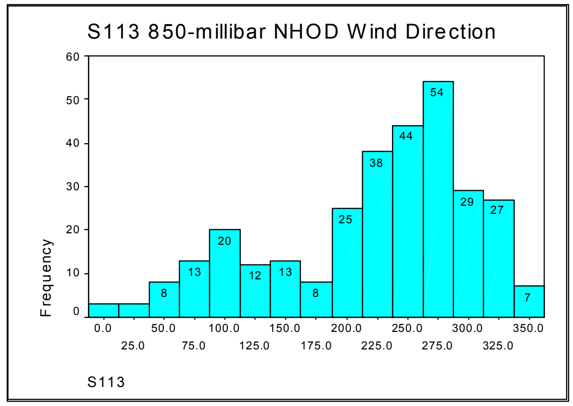

Figure 30b. 850 mb Wind Direction for S113 on NHODs.

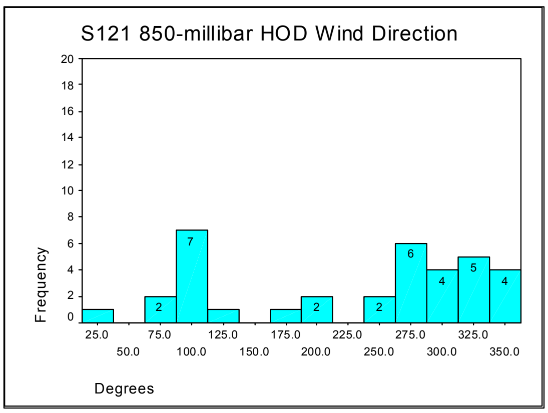

Figure 31a. 850 mb Wind Direction for S121 on HODs.

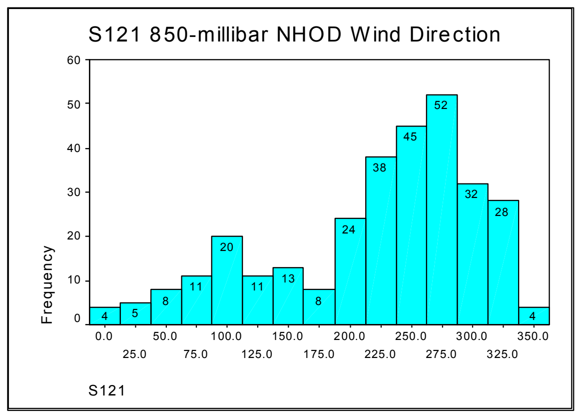

Figure 31b. 850 mb Wind Direction for S121 on NHODs.

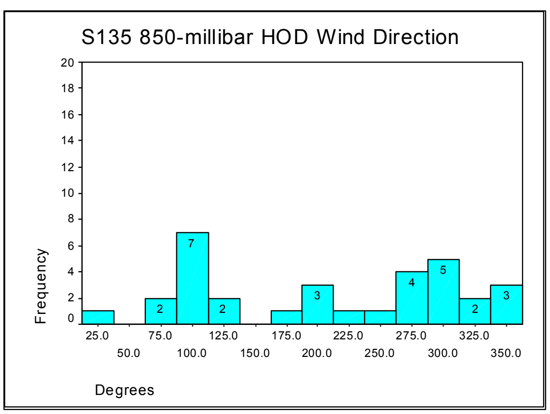

Figure 32a. 850 mb Wind Direction for S135 on HODs.

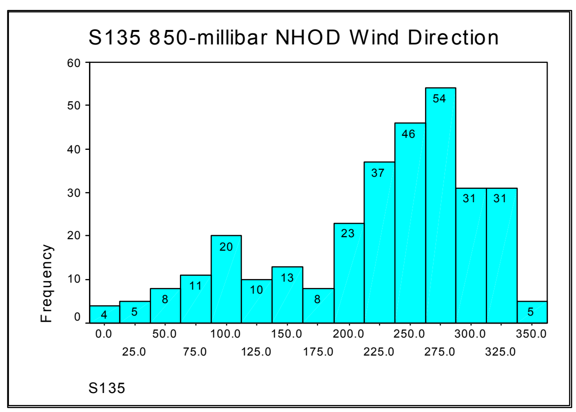

Figure 32b. 850 mb Wind Direction for S135 on NHODs.

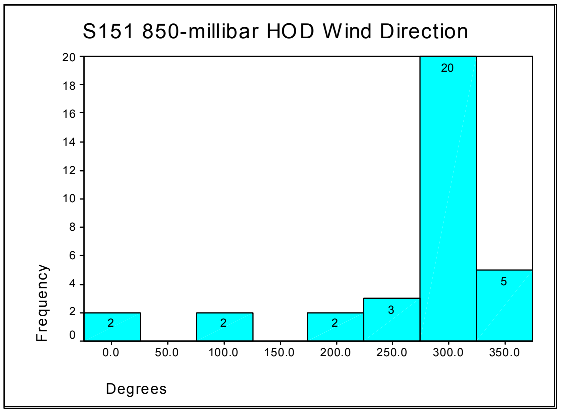

Figure 33a. 850 mb Wind Direction for S151 on HODs.

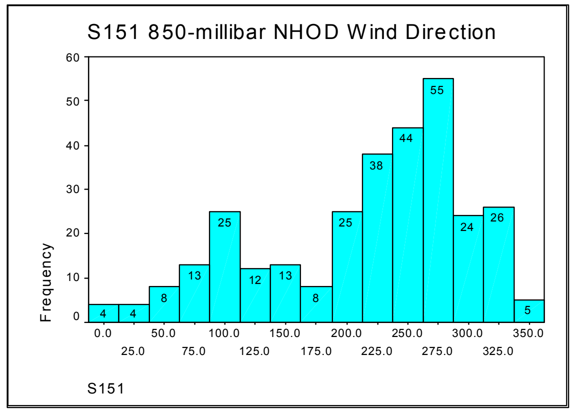

Figure 33b. 850 mb Wind Direction for S151 on NHODs.

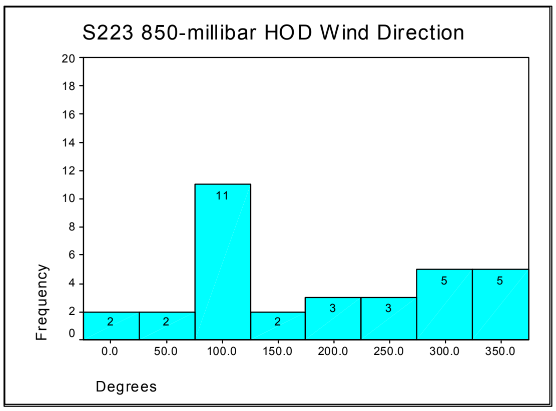

Figure 34a. 850 mb Wind Direction for S223 on HODs.

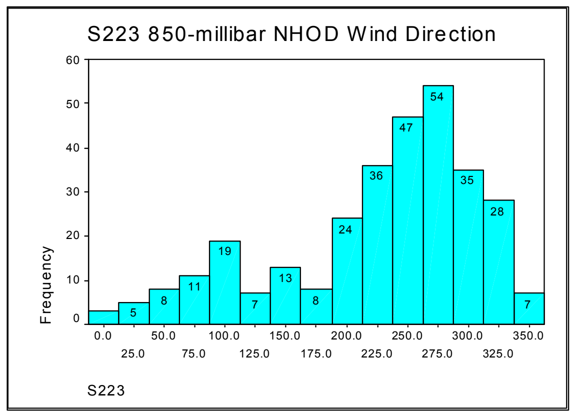

Figure 34b. 850 mb Wind Direction for S223 on NHODs.

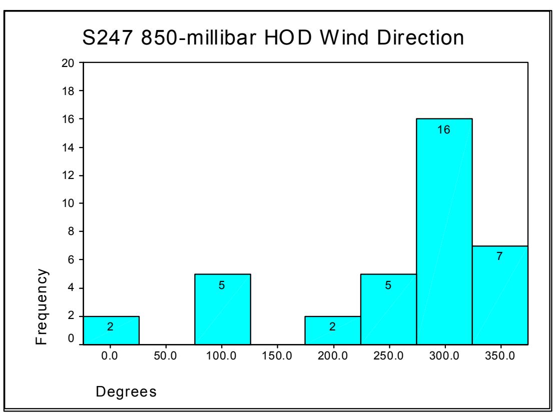

Figure 35a. 850 mb Wind Direction for S247 on HODs.

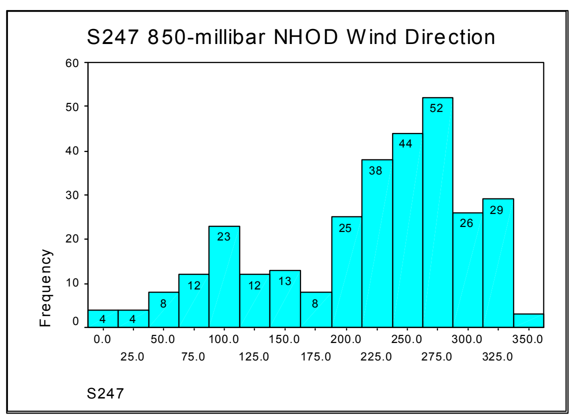

Figure 35b. 850 mb Wind Direction for S247 on NHODs.

8 Discussion

The results of this study show that high ground-level ozone concentrations in the Atlanta metropolitan area can be associated with three atmospheric patterns, and, with exceptions, several meteorological variables. Some results are consistent with other research, while some show differences with most, but not all research.

The relationship of lower dew point temperature with higher ozone concentrations is consonant with the presence of a high-pressure system over Atlanta, and with other research (Pont *et al.* 2003, Schichtel and Husar 2001). The association of higher air temperature with higher ozone concentrations, especially for the lower geopotential heights, though less uniform than that for dew point temperature, is also consistent with an anticyclone over Atlanta. Since anticyclones tend to exhibit weak wind fields, the association of lower wind speed with higher ozone concentrations is consistent with an anticyclone over Atlanta, and with other research (Minoura 1999, Pissimanis *et. al.* 2000).

The data show that for eight of the eleven stations studied in this research, Atlanta was under an anticyclone during HODs: S067, S0890, S0893, S097, S121, S135, S223, and S247. Stations S0890, S135 and S223 show an anticyclone over Atlanta, and a near-normal or slightly weak Bermuda high off the east coast during HODs. The only statistically significant meteorological variable that this set of stations share is dew point temperature for 925 millibars. There is no clear pattern for other meteorological variables for these stations. In addition, S223 showed higher geopotential heights for 925 and 1000 millibars for HODs.

Stations S067, S0893, S097, S121, and S247 show an anticyclone over Atlanta, and a weak Bermuda high off the east coast. These stations show no clear pattern of meteorological variables, except for lower 925-millibar dew point temperature and mostly higher 925-millibar air temperatures. Again, this is congruent with the presence of an anticyclone over the area.

The presence of an anticyclone over Atlanta, as in the two groups of stations discussed, would explain the higher 8-hour ozone concentrations found for these stations. Warm, dry, and stagnant air is conducive to the *in situ* production and build-up of ground-level ozone in the presence of the chemical precursors, VOCs and NO_X. (Minoura 1999, Pissimanis *et. al.* 2000).

The third group of stations consists of S077, S113, and S151, and are the most difficult to classify and explain. HODs for these stations did *not* show an anticyclone over Atlanta, with lower than mean geopotential heights, with a very weak Bermuda high off the east coast. These stations share lower 850 and 925-millibar dew point temperature and higher 700, 850, and 925-millibar air temperature for HODs, but otherwise show little commonality. S151, in Henry County, shows a marked westerly to northwesterly HOD wind flow for 850-millibars, which would put it downwind of Atlanta much of the time. S113 showed more variable flow, but with westerly to northwesterly wind flow predominate. Station S077 showed two-thirds of the HOD wind flow from the west to northwest, with the remainder from the east. All three stations appear to be in the lee or back of a trough. The probable subsidence in the trough would tend to inhibit ventilation, and is consistent with some research in Hong Kong and Taiwan, where some high ozone

episodes were found to be associated with low-pressure systems and troughing, as well as long-range transport of ozone (W.-L. Cheng *et al.* 2001, Lee *et al.* 2002).

Two of the stations, S077 and S113, share several geographical characteristics. They are on the south side of the metropolitan area, and are located in less urbanized counties. To the west-northwest of the stations are two fossil-fueled electrical power plants, which emit the precursor NO_X (Duncan *et al.* 1995). In a troughing situation, stack effluents from the power plants could be fumigated. With westerly to northwesterly wind flow, BVOCs could be collected as wind advects over forested areas and bring together the two ozone precursors species. Even with less than ideal meteorological conditions (still, warm, dry, and clear air), ozone could be produced in substantial quantities due to the amount of precursors entering the area. While somewhat speculative, this explanation accounts for some of the facts, but clearly more research is needed to clarify the reason(s) for the HODs at these two southern stations. Another possibility for S077 is that it is getting precursors from two directions. When wind is northeasterly, the Atlanta city center is approximately 60 kilometers upwind of the station, so that air could have several hours to react while being transported to the station. It is seems the best explanation for HODs at S151 is transport from Atlanta; some research reviewed supports this statement (Imhoff *et al*. 1995, St. John and Chameides 1997).

9 Conclusions

An environment-to-circulation analysis of the Atlanta ozone pollution problem was conducted for the summer months of 2000-2003 in order to address a research deficiency in relation to ground-level ozone pollution. Ozone data was obtained from **e**leven air quality monitoring stations operated by the Georgia Environmental Protection Division**,** and radiosonde data was provided by the Peachtree City, Georgia airport. Upper air data was obtained from NCEP/NCAR Reanalysis dataset. The results of this study indicate that high 8-hour ozone levels in the Atlanta, Georgia metropolitan area during the study period can be grouped into three classes. One class shows an anticyclone over Atlanta, with a weak Bermuda high off the east coast. A second class shows an anticyclone over Atlanta with a near-normal Bermuda high with some troughing. A third class shows normal geopotential heights over Atlanta (lack of an anticyclone), with a very weak Bermuda high, and troughing over Atlanta. Lower dew point temperatures at almost all stations for most geopotential heights studied were associated with high ozone levels, while higher air temperature was a significant determinant of high ozone concentrations for 700, 850, and 925 millibars for most, but not all, stations. Weaker wind fields were a significant factor at several stations at 850 and 925-millibar heights, but at only one station at 700 millibars, and none at 500 millibars. Geopotential heights were a significant determinant of high ozone concentrations at only one station, at 925 and 1000 millibars.

The first two classes of patterns are consonant with other studies that have found high ground-level ozone concentrations to be associated with high-pressure systems, or

anticyclones. These systems have drier air (lower dew point temperature), often higher air temperature, and weaker wind fields than other systems.

The third class found in this study is less common, but has been reported in other research. This pattern has normal or lower than normal geopotential heights, with Atlanta in or on side of a trough. The trough is not conduce to ventilation, but may be conducive to transport of precursor species into the area. The stations in this class are on the south side of the Atlanta region, with two power plants to the west-northwest, possible sources of NO_X, although Atlanta is to the northwest of one station, and to the northeast of another. Wind advecting over the abundant forests in the region can transport highly reactive BVOCs into the area, thus bringing together the two precursors needed for ozone production, while Atlanta could be exporting precursors to the area as well.

This study is the first environment-to-circulation analysis of the ozone pollution problem for the Atlanta area. Clearly, there is a need for more studies of this type, with more stations and more atmospheric and meteorological variables included, in order to provide a better understanding of the ground-level ozone problem in metropolitan Atlanta.

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Appendix

Table 3. Correlation matrix of ozone values between stations.

	S067	S077	S0890	S0893	S097	S113	S121	S135	S151	S223	S247
S067	1.00										
S077	0.82	1.00									
S0890	0.88	0.87	1.00								
S0893	0.87	0.83	0.95	1.00							
S097	0.91	0.90	0.86	0.82	1.00						
S113	0.83	0.93	0.90	0.85	0.88	1.00					
S121	0.89	0.89	0.98	0.95	0.88	0.91	1.00				
S135	0.85	0.80	0.90	0.97	0.81	0.81	0.91	1.00			
S151	0.78	0.88	0.90	0.83	0.80	0.94	0.89	0.79	1.00		
S223	0.90	0.84	0.82	0.78	0.94	0.85	0.84	0.77	0.77	1.00	
S247	0.75	0.82	0.89	0.84	0.76	0.86	0.87	0.79	0.92	0.73	1.00

Table 4. Correlation matrix of high ozone days between stations.

	S067	S077	S0890	S0893	S097	S113	S121	S135	S151	S223	S247
S067	1										
S077	0.90	1									
S0890	0.99	0.91	1								
S0893	0.98	0.91	0.97	1							
S097	0.91	0.76	0.90	0.89	1						
S113	0.90	0.97	0.91	0.91	0.76	1					
S121	0.98	0.92	0.99	0.96	0.87	0.92	1				
S135	0.97	0.93	0.98	0.97	0.88	0.94	0.97	1			
S151	0.88	0.97	0.88	0.91	0.73	0.93	0.89	0.92	1		
S223	0.94	0.82	0.93	0.92	0.96	0.82	0.92	0.91	0.79	1	
S247	0.95	0.87	0.94	0.93	0.91	0.86	0.93	0.93	0.83	0.95	1

Table 6a. Summary statistics for HODs.

STATION	STATISTIC	H1000	H925	T925	DPT925	WS925	H850	T850	DPT850	WS850	H700	T700	DPT700	WS700	H500	T500	DPT500	WS500
S067	MEDIAN	166	839	21.4	11.6	3.6	1563	16.0	9.2	3.6	3189	8.2	-13.2	5.7	5880	-8.1	-30.1	6.7
	MEAN	160	836	21.1	12.5	3.9	1563	15.8	9.1	4.2	3187	8.1	-11.6	5.9	5882	-7.9	-30.5	6.5
	MAX	208	884	25.6	19.1	8.2	1607	20.2	16.7	11.3	3234	10.6	6.6	14.4	5940	-4.1	-12.0	12.3
	MIN	102	779	10.6	-2.0	1.0	1503	5.0	-1.0	0.0	3097	4.2	-34.4	1.5	5780	-11.3	-46.9	1.0
S077	MEDIAN	135	817	22.6	12.1	5.1	1545	17.3	10.3	6.2	3179	8.6	-4.0	7.7	5880	-7.6	-30.7	8.2
	MEAN	139	818	22.4	12.6	5.5	1548	17.2	9.0	6.1	3179	8.4	-8.4	8.0	5876	-7.5	-30.0	8.5
	MAX	183	865	28.4	20.1	17.0	1597	22.2	16.7	13.4	3230	10.8	6.6	21.6	5930	-4.5	-8.0	20.1
	MIN	102	779	12.0	-2.0	1.5	1503	12.0	-22.2	0.5	3100	1.2	-35.4	2.6	5750	-11.3	-49.5	1.0
S0890	MEDIAN	153	832	22.6	13.7	3.6	1562	16.8	10.0	3.9	3190	8.6	-7.9	6.2	5890	-7.6	-27.6	6.2
	MEAN	149	829	22.3	13.6	4.5	1558	17.1	10.0	4.9	3190	8.7	-8.8	6.8	5888	-7.6	-28.7	6.5
	MAX	208	884	27.2	20.1	13.9	1607	20.8	16.3	11.8	3234	11.0	6.9	14.4	5950	-4.1	-8.0	14.4
	MIN	78	761	12.0	-2.0	1.5	1495	12.0	1.8	0.0	3128	5.6	-34.4	1.5	5810	-10.3	-48.7	1.0
S0893	MEDIAN	162	841	22.6	12.6	3.6	1571	16.8	9.8	3.6	3200	8.2	-2.0	5.7	5900	-7.7	-26.5	5.7
	MEAN	158	837	22.1	13.2	4.1	1566	16.8	10.1	4.4	3195	8.2	-7.2	6.0	5891	-7.7	-26.8	5.7
	MAX	208	884	25.6	19.6	9.3	1607	20.0	16.3	11.3	3234	10.6	6.6	14.4	5940	-4.1	-9.5	12.3
	MIN	102	779	12.0	-2.0	1.5	1503	12.0	1.8	0.0	3137	5.2	-33.8	1.5	5850	-10.5	-47.3	1.0
S097	MEDIAN	159	837	21.8	15.2	3.6	1565	17.1	10.2	4.6	3192	8.3	-4.6	5.2	5890	-7.7	-28.3	6.7
	MEAN	156	834	21.9	14.1	4.6	1563	16.7	10.1	4.7	3192	8.2	-9.6	5.8	5888	-7.6	-28.2	6.7
	MAX	199	876	27.2	20.1	13.9	1602	20.8	16.4	11.3	3229	10.8	6.6	21.6	5930	-4.1	-8.0	15.4
	MIN	109	792	10.6	5.6	1.0	1509	5.0	-1.0	1.0	3097	4.8	-34.4	1.5	5780	-10.5	-46.3	1.0
S113	MEDIAN	143	822	22.4	12.6	3.6	1550	16.8	9.8	4.4	3183	8.6	-6.8	6.2	5880	-7.7	-26.3	8.2
	MEAN	145	824	22.3	13.2	4.5	1554	17.1	9.8	5.1	3185	8.7	-8.7	7.1	5884	-7.6	-27.1	7.9
	MAX	183	865	28.4	20.1	9.3	1597	22.2	16.7	11.3	3230	11.0	6.6	21.6	5930	-4.1	-8.0	20.1
	MIN	102	779	12.0	-2.0	1.5	1503	12.0	-1.4	0.5	3137	4.8	-35.4	1.5	5830	-10.5	-47.3	1.0
S121	MEDIAN	155	832	22.2	13.4	3.6	1562	16.8	10.0	3.6	3191	8.6	-3.8	5.7	5890	-7.9	-29.9	6.7
	MEAN	153	832	21.9	13.6	4.3	1560	16.7	10.1	4.3	3190	8.4	-9.3	6.2	5885	-7.9	-29.4	6.5
	MAX	208	884	27.2	20.1	9.3	1607	20.8	16.3	11.3	3234	10.6	6.6	14.4	5940	-4.1	-8.0	20.1
	MIN	102	779	12.0	-2.0	1.5	1503	12.0	1.8	0.0	3137	4.8	-35.4	1.5	5830	-10.5	-47.3	1.0
S135	MEDIAN	161	837	22.4	12.7	3.6	1564	16.8	9.6	3.6	3195	8.2	-1.6	5.7	5890	-7.7	-27.9	6.2
	MEAN	155	834	22.1	13.0	4.2	1563	16.9	9.8	4.7	3192	8.2	-7.8	6.0	5888	-7.7	-27.7	6.1
	MAX	208	884	28.4	19.5	8.7	1607	22.2	14.6	11.3	3234	10.6	6.6	13.9	5940	-4.1	-9.5	15.9
	MIN	80	758	12.0	-2.0	1.5	1482	12.0	1.8	0.0	3103	5.2	-34.4	1.5	5790	-10.5	-47.3	1.0
S151	MEDIAN	136	819	23.0	15.0	5.1	1548	18.0	10.2	5.7	3183	8.6	-2.0	6.2	5890	-7.5	-26.3	7.7
	MEAN	138	819	22.7	14.1	5.2	1550	17.9	10.1	6.3	3184	8.6	-5.3	7.0	5883	-7.5	-28.0	7.5
	MAX	183	865	28.4	20.1	13.9	1597	23.6	16.7	17.5	3234	11.0	6.9	13.4	5950	-4.3	-8.0	20.1
	MIN	78	761	12.0	-2.0	1.5	1495	12.0	-0.4	2.1	3128	5.6	-25.2	2.1	5810	-10.5	-48.7	1.0
S223	MEDIAN	168	844	21.2	13.4	4.4	1572	16.1	9.6	4.1	3202	8.1	-6.4	5.4	5890	-8.2	-32.6	6.7
	MEAN	166	844	21.3	13.7	5.0	1571	16.3	10.0	4.5	3197	7.9	-10.3	5.8	5891	-8.2	-31.5	6.1
	MAX	228	905	26.2	19.1	13.9	1628	20.2	16.4	11.3	3241	10.8	6.6	21.6	5940	-4.1	-12.5	15.4
	MIN	126	807	16.0	7.6	1.0	1531	11.0	1.8	0.0	3140	2.4	-34.4	1.5	5800	-11.7	-46.3	0.5
S247	MEDIAN	147	827	22.6	14.4	3.6	1561	17.6	10.2	4.6	3192	8.4	-1.4	6.0	5900	-7.7	-26.3	7.7
	MEAN	148	828	21.7	13.1	4.5	1557	17.4	9.4	5.1	3190	8.4	-5.2	6.6	5887	-7.6	-26.4	7.5
	MAX	208	884	28.4	19.6	9.3	1607	22.2	16.3	11.3	3234	10.6	6.6	13.9	5950	-4.1	-8.8	20.1
	MIN	102	779	-3.3	-9.3	1.0	1503	12.0	-7.4	0.0	3131	5.6	-33.8	2.1	5810	-10.5	-47.3	1.0

Table 6b. Summary statistics for NHODs.

STATION	STATISTIC	H1000	H925	T925	DPT925	WS925	H850	T850	DPT850	WS850	H700	T700	DPT700	WS700	H500	T500	DPT500	WS500
S067	MEDIAN	151	830	21.2	17.2	5.7	1560	16.8	12.8	6.2	3189	7.4	2.0	6.2	5880	-7.9	-18.7	7.2
	MEAN	149	827	20.9	16.3	6.2	1555	16.7	11.5	6.5	3184	7.3	-1.5	7.0	5877	-8.0	-22.3	7.6
	MAX	228	909	28.4	20.8	18.0	1639	23.6	17.1	21.1	3276	11.0	7.8	21.6	5990	-3.9	-7.3	21.6
	MIN	74	750	-3.3	-9.3	0.0	1468	11.0	-31.0	0.5	3086	0.6	-39.6	1.0	5750	-16.1	-50.3	0.5
S077	MEDIAN	155	833	21.2	17.1	5.7	1561	16.6	12.8	5.7	3190	7.4	2.0	6.2	5880	-8.1	-19.1	6.7
	MEAN	151	830	20.8	16.3	6.0	1557	16.5	11.5	6.3	3185	7.3	-1.9	6.8	5878	-8.0	-22.4	7.4
	MAX	228	909	26.2	20.8	18.0	1639	23.6	17.1	21.1	3276	11.0	7.8	21.1	5990	-3.9	-7.3	21.6
	MIN	74	750	-3.3	-9.3	0.0	1468	5.0	-31.0	0.0	3086	0.6	-39.6	1.0	5760	-16.1	-50.3	0.5
S0890	MEDIAN	153	831	21.0	17.1	5.7	1560	16.6	12.8	5.7	3189	7.3	2.0	6.2	5880	-8.0	-19.0	7.2
	MEAN	150	828	20.8	16.1	6.1	1556	16.5	11.4	6.4	3183	7.2	-1.9	6.9	5876	-8.0	-22.5	7.6
	MAX	228	909	28.4	20.8	18.0	1639	23.6	17.1	21.1	3276	11.0	7.8	21.6	5990	-3.9	-7.3	21.6
	MIN	74	750	-3.3	-9.3	0.0	1468	5.0	-31.0	0.5	3086	0.6	-39.6	1.0	5750	-16.1	-50.3	0.5
S0893	MEDIAN	151	830	21.0	17.0	5.7	1560	16.6	12.8	5.7	3188	7.4	2.0	6.2	5880	-7.9	-19.1	7.2
	MEAN	149	827	20.8	16.2	6.2	1555	16.6	11.4	6.4	3183	7.3	-2.1	7.0	5876	-8.0	-22.7	7.7
	MAX	228	909	28.4	20.8	18.0	1639	23.6	17.1	21.1	3276	11.0	7.8	21.6	5990	-3.9	-7.3	21.6
	MIN	74	750	-3.3	-9.3	0.0	1468	5.0	-31.0	0.5	3086	0.6	-39.6	1.0	5750	-16.1	-50.3	0.5
S097	MEDIAN	152	830	21.2	17.0	5.7	1560	16.6	12.8	5.7	3189	7.4	2.0	6.2	5880	-7.9	-19.1	7.2
	MEAN	149	828	20.9	16.1	6.1	1555	16.6	11.4	6.4	3183	7.3	-1.8	7.0	5876	-8.0	-22.6	7.6
	MAX	228	909	28.4	20.8	18.0	1639	23.6	17.1	21.1	3276	11.0	7.8	21.1	5990	-3.9	-7.3	21.6
	MIN	74	750	-3.3	-9.3	0.0	1468	11.0	-31.0	0.0	3086	0.6	-39.6	1.0	5750	-16.1	-50.3	0.5
S113	MEDIAN	153	832	21.2	17.1	5.7	1560	16.6	12.8	5.7	3190	7.4	2.0	6.2	5880	-8.1	-19.1	6.7
	MEAN	151	829	20.8	16.2	6.1	1556	16.5	11.4	6.4	3184	7.3	-1.9	6.9	5877	-8.0	-22.7	7.5
	MAX	228	909	27.2	20.8	18.0	1639	23.6	17.1	21.1	3276	11.0	7.8	21.1	5990	-3.9	-7.3	21.6
	MIN	74	750	-3.3	-9.3	0.0	1468	5.0	-31.0	0.0	3086	0.6	-39.6	1.0	5750	-16.1	-50.3	0.5
S121	MEDIAN	152	831	21.2	17.0	5.7	1560	16.7	12.8	6.2	3189	7.4	2.0	6.2	5880	-7.9	-18.9	7.2
	MEAN	150	828	20.9	16.2	6.2	1556	16.6	11.4	6.5	3183	7.3	-1.8	7.0	5877	-8.0	-22.4	7.6
	MAX	228	909	28.4	20.8	18.0	1639	23.6	17.1	21.1	3276	11.0	7.8	21.6	5990	-3.9	-7.3	21.6
	MIN	74	750	-3.3	-9.3	0.0	1468	5.0	-31.0	1.0	3086	0.6	-39.6	1.0	5750	-16.1	-50.3	0.5
S135	MEDIAN	152	830	21.0	17.1	5.7	1560	16.7	12.8	5.7	3188	7.4	2.0	6.2	5880	-7.9	-19.1	7.2
	MEAN	150	828	20.8	16.2	6.1	1555	16.6	11.5	6.4	3183	7.3	-2.0	7.0	5877	-8.0	-22.6	7.7
	MAX	228	909	27.2	20.8	18.0	1639	23.6	17.1	21.1	3276	11.0	7.8	21.6	5990	-3.9	-7.3	21.6
	MIN	74	750	-3.3	-9.3	0.0	1468	5.0	-31.0	0.5	3086	0.6	-39.6	1.0	5750	-16.1	-50.3	0.5
S151	MEDIAN	154	832	21.0	17.1	5.7	1561	16.6	12.8	5.7	3190	7.4	1.9	6.2	5880	-8.1	-19.1	6.7
	MEAN	151	829	20.8	16.1	6.0	1557	16.4	11.4	6.2	3184	7.3	-2.3	6.9	5877	-8.0	-22.6	7.5
	MAX	228	909	27.2	20.8	18.0	1639	20.8	17.1	21.1	3276	10.8	7.8	21.6	5990	-3.9	-7.3	21.6
	MIN	74	750	-3.3	-9.3	0.0	1468	5.0	-31.0	0.0	3086	0.6	-39.6	1.0	5750	-16.1	-50.3	0.5
S223	MEDIAN	150	829	21.2	17.1	5.7	1560	16.8	12.8	6.2	3188	7.4	2.0	6.2	5880	-7.9	-18.7	7.2
	MEAN	148	827	20.9	16.1	6.1	1555	16.6	11.4	6.4	3182	7.3	-1.7	7.0	5876	-7.9	-22.2	7.7
	MAX	228	909	28.4	20.8	18.0	1639	23.6	17.1	21.1	3276	11.0	7.8	21.1	5990	-3.9	-7.3	21.6
	MIN	74	750	-3.3	-9.3	0.0	1468	5.0	-31.0	0.5	3086	0.6	-39.6	1.0	5750	-16.1	-50.3	0.5
S247	MEDIAN	153	832	21.0	17.1	5.7	1560	16.6	12.8	5.7	3189	7.4	1.8	6.2	5880	-7.9	-19.1	6.7
	MEAN	150	828	20.9	16.2	6.1	1556	16.5	11.5	6.4	3183	7.3	-2.3	6.9	5877	-8.0	-22.8	7.5
	MAX	228	909	27.2	20.8	18.0	1639	23.6	17.1	21.1	3276	11.0	7.8	21.6	5990	-3.9	-7.3	21.6
	MIN	74	750	10.6	2.8	0.0	1468	5.0	-31.0	0.5	3086	0.6	-39.6	1.0	5750	-16.1	-50.3	0.5

Table 7. Z-score results of Mann-Whitney *U*-test. Bold numbers indicate significant differences between HOD and NHOD cases. Wind direction not included.

	S067	S077	S0890	S0893	S097	S113	S121	S135	S151	S223	S247
H500	-0.264	-0.109	-0.810	-1.099	-0.935	-0.353	-0.483	-0.872	-0.313	-1.150	-0.788
T500	-0.019	-0.774	-0.691	-0.301	-0.490	-0.567	-0.025	-0.346	-0.724	-0.368	-0.627
DPT500	**-2.101**	**-1.781**	-1.635	-1.166	-1.435	-1.160	**-1.791**	-1.392	-1.405	**-2.335**	-1.047
WS500	-0.528	-0.935	-0.609	-1.212	-0.466	-0.447	-0.702	-0.928	-0.096	-0.939	-0.147
H700	-0.234	-0.610	-0.517	-1.053	-0.762	-0.091	-0.501	-0.797	-0.127	-1.296	-0.500
T700	-1.539	**-2.374**	**-2.743**	**-1.722**	-1.597	**-2.753**	**-2.235**	**-1.623**	**-2.366**	-1.123	**-2.222**
DPT700	-1.313	**-1.950**	**-2.102**	**-1.684**	**-2.432**	**-1.988**	**-2.149**	**-1.744**	-1.292	**-2.453**	-1.081
WS700	-0.764	-0.895	-0.083	-0.546	-1.108	-0.174	-0.389	-0.600	-0.293	-1.036	-0.029
H850	-0.667	-1.079	-0.220	1.079	0.667	-0.404	-0.399	-0.792	-0.701	-1.535	-0.021
T850	-1.130	-0.881	-0.754	-0.333	-0.471	-0.693	-0.030	-0.265	**-2.045**	-0.699	-1.364
DPT850	**-2.350**	-1.432	-1.638	**-1.655**	-1.425	**-1.764**	-1.526	**-1.955**	-1.478	-1.595	**-1.783**
WS850	**-1.924**	-0.110	-1.266	-1.634	-1.421	-0.993	**-1.830**	-1.297	-0.112	**-1.626**	-0.984
H925	-0.958	-1.318	-0.105	-1.033	-0.669	-0.510	-0.359	-0.731	-1.013	**-1.728**	-0.206
T925	-0.511	**-1.846**	**-2.005**	**-1.853**	-1.278	**-1.796**	-1.424	**-1.641**	**-2.625**	-0.250	**-1.938**
DPT925	**-2.881**	**-2.576**	**-2.094**	**-2.211**	**-1.805**	**-2.422**	**-2.065**	**-2.501**	**-1.827**	**-2.277**	**-2.212**
WS925	**-1.930**	-0.605	-1.531	**-1.775**	-1.277	-1.318	**-1.690**	**-1.689**	-0.739	-0.893	-1.414
H1000	-1.271	-1.376	-0.003	-0.950	-0.709	-0.535	-0.330	-0.670	-1.232	**-1.802**	-0.290

Table 8. 8-hour ozone data for all stations in ppbv.

Date	S067	S077	S0890	S0893	S097	S113	S121	S135	S151	S223	S247
20000601	104.5	83.8	106.0	121.5	78.7	86.1	107.4	105.1	93.6	76.3	91.3
20000602	87.3	79.9	81.0	102.8	83.0	80.4	86.0	93.6	88.1	81.0	76.8
20000603	81.1	80.5	85.9	86.0	82.8	81.8	89.3	78.4	90.0	77.6	74.0
20000604	42.5	45.5	36.4	40.1	42.9	48.3	40.9	50.3	55.9	41.8	43.1
20000605	34.0	40.1	19.6	28.3	40.9	36.1	31.3	33.6	31.4	41.1	29.8
20000606	50.0	56.8	45.9	49.5	53.8	56.1	50.6	51.9	56.4	52.8	44.5
20000607	73.0	72.4	67.8	68.8	74.8	68.6	71.8	68.3	64.1	78.0	50.4
20000608	93.0	76.4	71.4	80.5	81.9	74.4	77.3	76.9	78.6	81.9	55.8
20000609	108.0	76.1	90.3	107.9	93.5	74.8	101.0	108.9	82.3	79.5	62.5
20000610	107.1	71.6	74.0	79.0	87.1	72.0	80.1	77.0	74.6	80.6	56.0
20000611	105.1	62.0	68.4	85.1	84.9	63.0	76.9	82.9	65.8	72.6	49.4
20000612	88.0	51.4	64.1	85.2	68.8	72.6	73.6	83.0	65.6	65.8	45.8
20000613	48.3	39.9	48.3	59.0	45.4	45.1	50.3	58.8	43.5	41.0	36.1
20000614	46.6	39.4	50.5	66.2	47.5	43.5	53.6	75.1	41.0	44.9	35.1
20000615	39.8	31.5	38.4	44.8	34.6	34.9	39.6	47.4	36.0	37.5	32.6
20000616	26.9	25.9	28.5	33.6	28.3	27.6	31.0	33.3	26.9	26.3	24.1
20000617	42.3	29.8	31.8	40.0	33.3	25.1	33.0	42.6	31.9	30.5	26.5
20000618	31.4	28.0	47.0	49.0	34.3	31.4	42.1	56.4	30.8	30.8	30.4

20000619	39.9	33.9	43.6	36.5	44.9	48.9	42.3	38.3	42.5	40.9	33.4
20000620	35.8	42.6	46.3	45.4	48.0	55.7	47.9	52.0	55.1	41.0	43.8
20000621	48.6	46.5	61.6	68.6	51.1	52.0	67.1	59.4	52.5	54.8	46.4
20000622	50.0	37.9	40.1	51.5	49.8	48.0	48.3	50.1	48.1	44.3	42.3
20000623	68.0	95.8	75.9	74.4	79.0	82.6	84.1	70.8	68.0	70.1	54.5
20000624	97.0	68.3	74.0	78.4	73.1	74.9	79.6	77.6	69.6	78.6	56.8
20000625	59.6	51.0	46.4	60.3	56.0	55.0	57.0	55.0	51.5	61.8	46.0
20000626	51.3	43.3	61.0	77.1	55.3	51.4	66.1	83.0	50.5	48.9	50.3
20000627	66.9	48.5	53.0	67.8	56.5	42.0	57.1	67.0	47.6	44.6	43.3
20000628	35.4	29.5	26.8	37.6	38.5	36.3	34.6	38.6	31.6	38.9	28.9
20000629	34.5	43.8	17.0	27.3	46.6	43.5	29.0	31.4	43.3	43.9	32.4
20000630	73.0	86.6	73.4	79.3	81.1	100.1	92.4	77.5	74.4	72.1	59.6
20000701	67.5	96.0	75.8	80.1	82.5	101.8	89.1	75.5	111.9	77.0	84.8
20000702	99.1	75.9	62.4	80.5	85.5	73.9	78.5	77.3	76.5	79.5	61.6
20000703	83.3	74.0	77.1	103.4	89.3	70.8	99.5	100.8	67.5	82.6	54.4
20000704	72.1	69.4	71.8	82.9	60.9	70.3	83.0	67.0	87.1	59.6	74.0
20000705	59.6	68.0	55.9	70.0	62.5	64.5	67.9	66.3	71.5	60.5	65.3
20000706	69.6	66.0	85.7	67.0	66.5	71.9	85.6	68.5	90.6	66.9	74.0
20000707	65.6	95.3	79.6	70.4	80.8	98.6	79.1	73.3	93.9	82.1	67.6
20000708	74.5	69.4	60.9	62.4	77.5	71.5	63.6	62.6	74.9	85.0	46.1
20000709	73.1	52.8	62.6	75.1	71.3	54.1	68.5	75.1	57.9	55.8	46.3
20000710	66.1	70.5	75.7	72.1	69.4	72.6	76.6	76.5	74.4	65.8	61.4
20000711	74.9	65.9	72.0	81.4	70.7	67.9	76.4	77.8	81.6	68.5	72.3
20000712	77.1	51.7	65.0	68.1	62.5	53.0	65.3	65.9	60.3	64.6	57.3
20000713	83.3	81.8	89.6	84.1	89.2	86.3	92.1	75.9	111.1	77.0	77.4
20000714	84.4	79.4	79.3	72.0	78.1	86.4	84.0	69.0	93.8	73.3	69.0
20000715	66.8	69.9	65.9	60.0	69.8	71.3	70.3	58.5	76.8	74.0	54.3
20000716	68.9	74.4	81.3	66.1	76.4	74.6	81.5	61.4	86.1	70.8	68.0
20000717	73.1	77.9	78.1	66.9	80.0	80.4	77.3	66.5	93.0	77.0	71.0
20000718	92.5	94.6	111.3	104.0	87.5	111.0	109.4	96.3	122.8	84.3	84.1
20000719	73.0	84.4	76.9	81.5	76.4	86.4	81.5	79.1	82.8	69.1	69.8
20000720	79.4	73.1	78.5	72.4	66.5	76.6	80.6	67.3	83.9	66.6	72.6
20000721	82.8	76.8	85.6	81.0	79.3	84.5	83.3	77.5	92.1	76.6	77.0
20000722	78.5	79.6	91.5	88.0	69.9	77.6	91.5	83.8	81.4	74.8	81.9
20000723	57.6	61.8	51.0	56.6	69.0	62.3	56.5	53.8	57.9	62.4	45.5
20000724	65.0	75.0	69.8	75.4	78.9	71.0	77.4	69.5	61.5	69.0	49.6
20000725	41.1	42.3	32.4	36.0	30.0	36.8	38.5	38.1	39.0	42.5	33.1
20000726	64.8	62.6	69.4	64.6	78.5	69.6	75.3	61.5	58.8	82.3	48.4
20000727	110.0	72.6	78.6	82.1	97.6	81.0	92.3	78.5	75.3	88.0	55.7
20000728	93.9	95.0	107.6	110.9	91.3	88.8	113.1	96.4	84.8	78.1	71.9
20000729	64.0	63.0	68.0	65.8	64.0	61.3	63.3	70.9	69.6	65.5	48.0
20000730	52.3	51.1	57.3	62.9	53.3	54.3	57.4	66.9	57.9	47.6	49.3
20000731	38.8	37.1	37.4	41.8	36.9	36.6	38.9	43.8	38.6	36.3	32.9
20000801	35.5	32.6	36.0	43.1	37.6	31.6	35.4	44.0	32.9	31.9	31.1
20000802	27.9	25.1	29.1	35.6	28.6	29.0	28.6	38.1	30.9	33.3	26.6
20000803	57.6	39.0	43.9	55.4	53.1	40.1	46.0	57.9	44.0	49.6	39.4
20000804	66.8	56.5	55.8	67.8	68.3	58.6	67.4	63.6	53.1	67.9	42.9
20000805	76.3	70.9	85.1	76.0	74.4	72.3	90.1	68.0	89.9	68.9	75.8

20000806	69.0	67.5	66.8	90.0	75.6	64.4	81.6	91.4	59.3	65.9	50.0
20000807	40.5	28.3	45.1	59.8	35.3	40.9	52.5	68.9	31.4	42.8	33.1
20000808	42.5	37.6	57.1	65.1	46.0	47.9	63.1	67.6	47.4	43.9	49.2
20000809	65.9	52.5	61.3	61.0	64.9	67.3	67.5	67.9	80.3	58.4	56.7
20000810	83.8	69.4	110.5	93.5	82.5	68.3	120.4	72.8	74.5	77.0	97.2
20000811	69.6	71.6	63.4	63.0	72.6	75.0	74.9	63.3	61.8	68.8	79.0
20000812	63.1	79.0	66.1	62.0	69.9	72.4	70.3	62.5	70.1	67.9	67.9
20000813	65.3	85.6	71.9	64.5	74.8	66.5	78.1	61.0	70.4	65.9	67.9
20000814	71.8	77.6	87.1	85.5	82.3	87.0	92.6	81.4	94.5	71.1	102.5
20000815	72.9	97.0	81.5	76.8	103.5	81.1	85.9	71.3	87.5	82.3	88.9
20000816	87.5	101.4	91.8	85.5	107.9	137.7	94.6	82.3	118.9	92.9	108.4
20000817	107.8	113.8	135.3	136.5	98.6	127.0	132.1	123.4	138.9	91.0	116.1
20000818	82.0	89.6	80.1	81.8	82.6	83.9	85.3	90.0	89.8	76.6	96.3
20000819	98.4	79.0	103.8	90.6	83.3	78.6	115.1	85.6	88.0	80.2	80.0
20000820	69.6	68.3	61.5	61.4	74.4	64.6	66.9	61.6	66.9	70.8	62.0
20000821	41.3	43.3	46.3	47.6	34.1	44.1	47.9	49.8	45.8	44.6	49.8
20000822	77.1	63.8	67.0	67.9	82.9	66.1	70.1	71.9	60.5	89.4	64.3
20000823	87.0	71.0	87.3	88.5	70.6	70.1	90.1	86.8	82.6	65.4	87.6
20000824	79.0	80.0	79.1	85.0	70.5	80.3	86.5	81.8	86.4	73.5	95.4
20000825	67.4	75.5	62.1	64.6	75.1	75.1	68.4	62.7	81.1	73.8	82.7
20000826	90.0	83.5	83.6	80.5	82.6	80.9	84.6	77.1	85.5	77.1	99.1
20000827	53.9	44.6	38.1	46.3	52.3	44.5	44.3	46.2	48.3	53.0	47.6
20000828	74.4	71.4	73.4	80.8	72.1	70.0	84.0	86.8	75.6	71.9	92.3
20000829	79.6	95.9	72.1	74.5	91.9	81.0	83.1	71.7	71.9	85.9	74.1
20000830	62.0	71.3	61.3	59.3	71.9	65.5	65.5	57.6	60.4	64.4	60.5
20000831	26.5	36.9	26.6	30.7	28.4	30.8	21.9	31.1	32.0	41.3	33.1
20010601	21.8	20.8	13.0	31.6	30.8	25.1	12.4	33.0	22.3	33.3	22.4
20010602	49.4	48.6	50.1	51.1	51.0	52.9	53.5	50.6	55.0	50.9	55.4
20010603	54.4	43.9	53.4	58.9	53.6	46.4	54.5	57.6	45.8	53.0	46.4
20010604	30.4	20.5	25.9	32.6	27.1	22.8	26.8	33.9	21.8	26.5	25.3
20010605	40.6	37.0	30.0	30.6	42.1	53.0	33.8	32.1	43.0	33.4	43.3
20010606	30.8	35.8	34.9	35.5	35.8	41.3	40.5	36.5	40.1	31.8	41.0
20010607	20.5	31.9	16.1	23.8	25.8	33.5	20.9	25.9	31.9	25.8	30.4
20010608	37.5	23.0	24.1	31.9	36.8	25.0	31.3	33.2	21.4	35.6	28.1
20010609	64.0	43.5	53.5	60.3	56.6	50.8	60.9	58.8	47.4	55.9	57.1
20010610	75.8	66.3	78.8	82.3	70.1	74.6	80.0	78.6	77.9	62.9	83.1
20010611	21.5	13.9	16.0	16.3	18.6	20.4	17.6	19.2	16.0	23.7	16.4
20010612	25.0	18.0	7.0	13.4	27.0	16.8	15.1	16.5	16.1	29.4	18.3
20010613	82.3	54.1	69.4	88.9	56.8	64.9	72.4	84.6	69.3	61.1	76.9
20010614	44.6	30.8	37.1	51.8	39.0	49.0	40.2	51.1	50.8	40.8	43.2
20010615	26.3	30.9	29.4	37.0	30.9	28.4	32.3	37.8	26.3	30.4	28.9
20010616	53.4	58.4	49.1	50.8	53.6	57.3	54.5	50.2	60.1	50.8	55.6
20010617	65.6	85.1	64.4	68.1	71.0	66.3	71.3	65.9	65.9	65.3	64.4
20010618	93.8	70.0	72.3	76.4	97.6	84.1	77.1	73.4	72.5	91.1	66.6
20010619	82.0	60.8	65.4	70.5	75.6	67.9	67.8	68.0	64.1	86.5	66.0
20010620	95.0	49.1	72.9	81.9	76.1	57.9	77.1	78.3	51.8	84.3	68.6
20010621	53.0	38.8	52.4	63.6	44.9	47.8	55.1	61.8	42.2	53.9	48.8
20010622	41.3	42.0	27.8	31.3	43.8	36.9	35.8	32.6	36.5	48.1	39.3

20010623	60.5	63.8	54.3	54.1	59.8	63.9	60.6	53.3	64.1	58.9	62.1
20010624	62.9	67.8	59.3	64.0	68.1	72.0	67.6	62.2	64.6	66.8	62.5
20010625	52.9	51.5	50.1	57.3	51.3	54.1	52.8	56.1	51.9	56.6	52.8
20010626	66.4	55.0	54.6	62.5	60.9	58.5	56.0	60.8	52.1	63.5	53.8
20010627	83.5	55.5	62.1	71.7	67.0	66.9	62.3	69.1	59.8	79.9	59.3
20010628	66.5	41.4	51.0	60.6	52.0	53.1	55.5	59.1	44.4	50.3	50.3
20010629	42.0	25.1	41.6	42.1	31.9	35.1	38.1	42.5	36.5	40.5	33.5
20010630	41.9	25.3	33.9	37.9	34.6	29.1	32.5	38.6	27.8	31.8	29.0
20010701	55.4	50.4	43.8	57.4	39.6	39.5	49.3	51.3	33.1	35.3	46.5
20010702	61.5	43.6	62.1	68.4	60.3	47.6	59.3	60.3	53.3	50.8	60.6
20010703	33.1	28.3	28.5	34.3	32.0	28.5	32.0	35.4	26.6	32.5	32.4
20010704	38.0	30.5	26.8	34.4	35.5	33.3	33.0	34.6	31.1	38.0	32.6
20010705	46.3	47.3	52.4	55.3	50.1	58.4	55.9	63.9	59.9	47.4	59.0
20010706	71.5	61.4	55.3	59.1	60.9	72.3	66.5	59.0	73.1	58.3	66.9
20010707	66.4	58.6	62.4	74.5	60.6	60.8	66.5	63.0	72.9	54.9	73.4
20010708	73.6	64.8	77.5	74.3	53.3	63.3	80.4	59.3	76.1	52.5	79.8
20010709	68.1	54.6	64.9	73.9	60.0	62.9	70.9	69.1	72.2	53.3	74.4
20010710	61.9	56.0	59.8	70.6	49.8	58.1	65.4	68.8	73.6	51.3	78.0
20010711	70.1	77.6	68.4	70.0	77.1	76.9	77.1	63.3	86.3	62.6	65.5
20010712	88.8	79.3	93.0	88.0	80.6	96.4	98.6	82.1	114.9	78.0	91.9
20010713	75.0	75.3	71.0	76.5	78.5	84.9	79.5	73.1	83.1	71.6	75.0
20010714	73.4	66.1	64.8	71.5	80.4	68.3	69.1	69.5	61.9	68.1	62.5
20010715	76.9	60.0	66.5	78.3	67.3	58.1	65.3	68.4	66.5	67.0	61.6
20010716	77.0	58.9	75.8	79.4	64.1	71.1	79.1	70.0	70.5	64.1	64.4
20010717	88.5	63.1	74.4	87.6	70.8	65.6	79.5	76.9	65.9	74.1	61.4
20010718	63.3	79.1	82.5	93.1	71.3	81.1	81.4	94.0	80.0	59.3	94.5
20010719	68.8	65.3	68.0	82.6	58.9	71.8	74.0	75.8	77.8	59.1	93.0
20010720	51.3	62.8	53.1	61.0	57.6	58.9	58.9	54.6	54.5	64.6	61.2
20010721	66.1	49.0	54.3	57.9	64.3	51.9	55.1	57.6	48.0	69.3	50.9
20010722	70.1	58.6	58.6	61.0	83.3	56.3	58.4	62.0	51.6	68.0	52.1
20010723	77.8	86.8	72.9	77.0	85.6	74.4	78.1	70.9	61.0	72.6	65.4
20010724	39.5	37.8	32.8	32.5	40.9	34.0	33.1	26.9	23.4	48.0	27.3
20010725	20.5	20.3	20.5	20.6	24.1	23.0	18.6	14.0	19.8	27.9	16.6
20010726	41.8	32.5	36.5	43.1	32.3	27.9	33.0	43.8	28.8	25.3	30.4
20010727	36.9	31.0	46.1	46.1	32.9	37.5	47.3	48.4	29.9	31.5	36.0
20010728	34.5	23.5	25.3	28.1	23.6	26.9	27.3	28.8	25.0	28.4	25.3
20010729	28.0	29.1	29.5	30.1	30.9	28.3	29.5	27.8	26.0	28.6	27.3
20010730	63.5	44.5	61.6	59.9	56.1	55.8	65.5	56.6	55.1	52.6	63.0
20010731	60.5	52.1	46.8	47.4	58.0	53.1	47.8	44.8	46.9	71.6	44.4
20010801	62.3	48.9	50.6	53.4	64.3	52.1	51.1	49.3	45.8	66.4	47.0
20010802	71.4	63.3	59.8	64.8	78.9	61.1	61.1	61.9	54.5	68.3	54.8
20010803	81.4	62.4	77.0	79.8	81.0	62.3	79.3	72.9	58.8	68.9	50.6
20010804	63.3	53.1	57.5	69.8	55.5	59.6	62.5	70.8	55.8	56.5	60.3
20010805	51.5	44.5	37.4	40.4	46.9	45.6	39.6	40.3	43.1	52.3	39.3
20010806	28.8	20.4	34.8	28.1	24.8	31.8	32.9	19.4	31.5	32.0	33.5
20010807	42.1	29.4	35.5	50.4	24.8	35.8	44.4	49.3	34.1	32.4	40.1
20010808	50.6	45.3	55.6	59.3	42.9	55.1	53.6	56.9	56.1	42.4	64.8
20010809	44.6	35.5	45.8	52.8	49.1	45.5	51.5	48.9	49.7	46.8	58.1

20010810	49.0	40.4	54.7	57.1	45.3	46.0	54.5	59.3	48.3	42.1	47.9
20010811	51.0	47.6	56.3	58.6	51.5	51.0	57.0	56.8	51.3	51.8	49.5
20010812	35.6	37.3	38.0	41.8	38.3	36.0	38.4	38.8	33.5	31.0	29.1
20010813	36.4	33.4	23.3	31.9	36.6	30.3	32.0	33.9	23.6	36.5	20.4
20010814	58.9	72.8	64.4	65.4	66.5	82.9	73.1	62.9	64.9	67.9	55.6
20010815	77.3	57.8	65.6	62.6	69.3	61.3	64.6	57.0	52.8	75.9	56.5
20010816	61.0	52.5	55.0	61.6	61.4	46.9	56.9	55.1	50.5	58.3	44.1
20010817	69.0	65.0	63.5	74.1	58.5	64.8	70.9	80.1	45.1	59.9	58.0
20010818	68.3	66.4	73.8	69.9	61.4	69.1	70.6	79.8	74.1	61.8	77.1
20010819	50.9	47.3	49.4	53.4	53.9	49.5	48.0	55.1	46.4	52.4	48.5
20010820	66.5	57.0	60.6	65.9	62.5	59.5	68.3	61.8	64.5	64.0	68.8
20010821	63.3	68.3	72.0	65.6	70.0	78.3	72.1	58.3	78.4	67.8	74.9
20010822	84.3	101.4	87.0	86.4	99.9	80.6	99.0	72.8	70.1	73.4	71.3
20010823	81.6	74.9	103.4	103.1	92.5	88.8	103.8	108.1	92.8	81.4	108.3
20010824	77.5	90.1	79.4	72.6	94.4	94.4	81.5	64.1	96.1	75.6	85.8
20010825	82.0	72.9	67.0	64.1	87.5	66.9	68.8	58.9	59.5	90.8	58.5
20010826	77.6	71.5	70.0	77.0	72.4	64.1	71.6	65.6	57.6	65.6	50.3
20010827	53.4	49.8	66.1	68.3	62.8	59.8	67.8	68.6	55.3	53.3	65.3
20010828	43.5	43.6	32.0	28.4	45.3	46.8	40.5	23.5	48.9	44.1	44.8
20010829	47.6	56.6	50.5	51.6	59.8	60.3	52.6	38.8	52.1	50.9	57.3
20010830	30.6	25.9	21.5	25.8	33.4	30.1	27.4	26.5	29.9	30.1	24.3
20010831	25.0	29.4	23.9	21.4	32.5	35.9	24.6	24.8	36.1	28.0	41.6
20020601	68.9	67.4	72.5	67.6	68.9	67.5	73.9	69.6	85.6	66.0	82.3
20020602	71.0	62.9	77.9	71.8	72.0	71.4	76.5	67.3	91.9	68.1	88.0
20020603	78.4	77.4	97.4	86.0	76.3	90.4	100.6	79.4	121.3	74.8	108.1
20020604	94.0	70.1	80.3	81.8	87.0	80.3	83.4	73.9	67.6	98.0	79.5
20020605	74.5	50.1	71.6	74.1	57.5	59.8	74.6	60.3	66.1	67.5	66.6
20020606	50.4	46.4	52.7	50.6	51.3	39.3	48.6	55.5	42.4	51.3	50.3
20020607	66.8	72.1	54.8	57.9	76.9	60.0	58.9	58.8	56.9	73.3	55.1
20020608	67.3	48.3	53.5	60.1	63.1	49.6	56.0	65.5	52.1	67.8	55.6
20020609	74.1	65.0	63.6	65.4	80.9	61.6	64.8	66.9	60.1	80.6	62.4
20020610	91.1	64.3	71.5	72.9	90.8	67.3	75.4	74.5	65.4	107.9	68.0
20020611	112.8	72.3	81.6	81.3	104.1	75.9	88.8	82.8	71.0	82.8	77.9
20020612	106.9	95.6	114.6	120.0	109.6	104.5	117.6	103.9	127.9	107.3	119.3
20020613	84.2	88.4	95.6	102.6	86.3	85.9	98.0	99.8	96.8	77.8	105.6
20020614	35.1	47.0	34.0	37.3	45.6	42.9	41.4	38.5	49.1	44.1	46.6
20020615	55.3	57.3	53.4	53.5	58.1	53.1	56.1	54.9	62.4	57.0	62.0
20020616	62.6	63.5	65.3	60.9	62.8	62.8	70.3	55.9	77.1	61.6	73.4
20020617	66.5	84.0	61.6	67.1	71.9	70.6	69.5	65.3	68.4	67.4	65.4
20020618	77.9	72.6	69.4	69.8	82.0	71.5	71.5	67.6	69.6	98.1	68.5
20020619	66.4	51.4	56.5	60.0	65.1	53.1	59.6	62.1	52.8	77.8	54.3
20020620	70.5	70.9	66.4	72.6	81.5	65.5	73.0	77.5	65.0	75.3	67.8
20020621	77.5	61.0	60.0	65.0	76.3	58.4	65.4	73.5	56.8	79.0	59.8
20020622	54.8	36.6	36.6	49.8	47.0	31.0	45.9	52.5	35.9	63.9	37.1
20020623	31.5	25.9	27.5	25.5	31.9	26.0	28.3	24.4	22.8	36.4	27.9
20020624	40.4	27.1	35.0	30.3	45.1	32.9	37.0	29.0	29.6	54.3	30.9
20020625	22.0	23.1	31.6	32.3	28.6	33.8	28.1	28.4	31.3	38.3	34.1
20020626	41.0	29.3	36.5	34.8	34.5	26.0	30.4	35.0	27.9	37.6	26.4

20020627	34.1	37.3	38.8	45.9	39.3	37.0	42.3	46.8	39.9	41.0	45.6
20020628	21.6	19.9	25.3	27.1	27.8	21.9	28.1	26.8	27.1	26.9	31.1
20020629	37.5	36.4	36.3	39.8	35.8	31.4	39.9	50.0	40.3	33.8	43.1
20020630	49.6	54.0	61.4	58.3	54.3	43.4	64.3	58.1	53.6	48.6	52.8
20020701	67.8	62.9	58.5	67.4	90.0	61.5	68.8	65.3	56.8	77.6	58.5
20020702	82.1	72.0	94.5	88.4	83.0	79.9	99.2	79.1	91.9	77.9	99.4
20020703	57.1	69.8	56.9	62.3	66.5	67.1	67.3	76.8	72.0	64.4	77.5
20020704	76.3	74.0	74.0	74.4	96.3	69.6	80.6	76.8	73.8	74.1	71.3
20020705	84.3	92.1	91.3	90.6	85.8	79.9	101.0	91.3	75.5	73.9	78.0
20020706	81.1	84.1	82.3	78.9	102.3	78.8	90.1	75.8	75.3	72.9	77.3
20020707	67.9	58.6	57.9	60.1	74.4	51.5	60.4	62.6	55.6	74.5	60.6
20020708	80.0	63.6	69.1	64.5	85.3	62.1	71.5	64.5	64.1	85.0	68.1
20020709	56.8	41.3	53.3	72.6	61.5	33.9	59.5	77.8	40.3	52.1	49.3
20020710	52.3	38.1	57.1	69.1	55.4	41.1	62.8	71.1	41.1	51.8	54.1
20020711	61.1	29.8	32.9	41.3	50.4	39.9	39.8	43.1	38.9	57.9	47.7
20020712	50.1	42.6	47.3	48.9	47.1	44.1	48.6	52.8	45.9	55.5	50.4
20020713	32.4	29.3	34.8	36.3	32.0	32.4	33.8	37.1	36.3	37.6	36.3
20020714	49.3	55.9	53.0	55.1	50.6	47.9	53.9	62.9	54.1	50.5	61.3
20020715	61.4	57.5	68.6	71.9	52.5	58.3	66.2	69.8	67.1	53.4	81.9
20020716	64.8	54.0	70.4	69.6	54.3	56.6	72.1	65.6	81.4	52.8	87.6
20020717	71.9	65.1	84.6	78.9	68.5	74.6	82.0	75.5	102.5	66.8	98.5
20020718	47.3	44.3	55.1	55.0	44.9	46.1	56.6	50.1	61.0	43.3	69.4
20020719	44.5	47.8	49.3	48.9	43.3	41.0	50.1	57.9	48.6	43.9	59.0
20020720	67.9	54.4	70.6	77.1	54.9	50.0	70.4	68.1	59.8	55.9	78.0
20020721	66.3	66.3	72.1	69.0	67.9	70.3	78.0	69.5	67.8	75.6	59.5
20020722	84.4	62.9	71.9	65.4	85.6	71.0	74.0	60.8	69.8	84.5	64.9
20020723	79.4	62.9	66.8	89.3	67.3	58.1	76.8	87.2	57.9	58.5	64.9
20020724	48.4	41.6	40.9	45.9	48.6	42.4	40.8	43.3	52.3	45.5	58.6
20020725	54.0	39.9	51.6	52.3	47.8	39.3	48.4	47.3	49.6	42.3	54.3
20020726	47.3	41.5	46.9	50.0	42.4	38.1	46.3	44.9	44.8	47.9	49.5
20020727	42.0	38.4	46.0	58.3	44.8	42.4	47.0	61.8	52.0	39.5	52.0
20020728	42.1	45.0	45.6	52.3	39.6	44.4	42.8	54.6	44.5	42.8	52.5
20020729	35.8	42.5	51.6	58.0	41.1	41.5	49.8	57.1	49.0	36.5	62.8
20020730	46.4	31.8	46.3	58.9	38.0	35.5	48.5	56.0	45.6	40.0	52.8
20020731	51.4	53.9	58.0	60.0	49.3	52.0	62.8	46.9	65.0	46.9	65.3
20020801	75.0	106.6	80.8	81.6	84.8	76.0	90.5	78.1	71.3	74.6	75.5
20020802	85.9	67.8	74.1	78.6	94.7	65.4	76.3	80.0	63.9	91.1	68.4
20020803	69.1	58.9	59.8	60.3	77.6	51.3	60.1	63.3	52.1	75.3	53.9
20020804	59.3	61.8	57.1	60.0	76.6	50.6	59.8	63.8	49.0	59.1	51.6
20020805	78.6	76.1	91.5	81.4	74.5	95.0	99.6	68.6	90.0	83.3	85.6
20020806	80.5	95.9	71.0	69.3	90.4	80.3	80.9	72.9	93.9	75.8	90.4
20020807	83.3	80.9	75.1	77.0	92.4	63.4	82.8	74.9	67.0	83.4	71.5
20020808	100.9	75.8	98.0	97.8	86.1	82.1	107.3	89.6	80.6	81.8	83.9
20020809	101.4	66.0	87.3	87.5	82.3	69.3	88.4	81.3	81.4	85.4	80.6
20020810	96.5	74.9	77.5	78.1	87.0	69.8	80.1	76.9	72.0	77.0	76.5
20020811	93.9	68.8	75.4	79.3	74.6	65.1	81.3	79.4	72.5	71.8	73.8
20020812	74.3	56.1	73.1	85.0	62.1	57.8	74.3	81.8	71.8	64.8	67.9
20020813	81.8	72.4	64.0	68.0	67.1	59.6	63.5	56.6	75.5	62.5	67.8

20020814	52.6	34.5	50.3	58.8	43.4	40.6	52.9	60.3	51.1	48.0	49.1
20020815	44.1	26.1	40.1	40.3	41.1	28.0	40.3	43.8	39.1	46.5	42.4
20020816	45.9	33.8	49.9	50.0	40.1	36.0	47.5	47.6	41.1	41.8	45.8
20020817	32.6	32.1	36.6	39.1	34.9	30.4	44.5	37.9	34.8	37.5	39.0
20020818	36.3	45.6	48.6	55.4	40.9	41.8	47.6	50.3	47.8	37.9	55.0
20020819	51.8	46.6	47.5	48.1	50.6	55.6	50.9	40.5	67.1	48.8	67.5
20020820	47.6	62.3	64.4	64.6	56.5	68.9	68.4	57.0	76.5	61.0	69.4
20020821	83.3	69.6	71.4	74.0	82.3	68.3	73.5	70.1	75.4	81.9	75.9
20020822	67.8	51.4	58.9	62.0	55.4	43.1	59.1	57.8	48.9	48.4	49.4
20020823	60.3	74.8	78.6	78.9	58.9	63.8	76.0	71.4	78.4	49.6	74.2
20020824	52.5	58.5	51.6	58.4	47.5	44.6	51.5	64.3	53.5	49.6	53.3
20020825	55.3	56.0	58.0	59.5	53.4	49.8	57.9	55.8	59.1	53.4	58.1
20020826	72.9	67.0	53.8	65.4	64.8	52.1	55.5	64.8	57.0	60.3	56.3
20020827	57.3	53.4	51.1	57.6	58.1	47.9	54.4	58.4	48.5	52.1	51.9
20020828	57.6	48.8	46.4	52.3	53.6	41.3	48.4	51.5	44.8	53.3	44.9
20020829	44.0	42.3	40.8	43.1	43.4	37.4	39.4	43.4	40.3	48.4	40.9
20020830	33.4	26.1	21.3	28.5	29.4	22.8	26.4	28.0	24.8	37.0	26.1
20020831	27.5	28.1	21.0	24.1	26.3	22.8	23.0	25.6	25.3	30.4	27.4
20030601	62.8	62.8	61.6	62.8	61.0	64.3	65.5	56.6	70.6	59.0	71.8
20030602	76.5	62.8	74.8	70.0	78.3	74.1	78.5	68.9	75.8	78.1	65.0
20030603	32.4	28.6	38.5	35.6	35.8	40.9	38.9	28.3	32.6	46.8	39.5
20030604	54.5	52.1	56.8	58.6	47.3	54.4	57.1	66.0	58.1	50.5	63.6
20030605	67.8	73.0	73.8	76.4	75.3	79.9	75.9	74.6	82.5	70.9	88.5
20030606	38.8	21.3	39.0	37.5	30.6	31.8	37.9	41.6	35.3	48.4	43.0
20030607	32.1	24.1	26.8	28.5	30.3	22.5	27.3	28.8	22.0	36.9	23.5
20030608	44.4	46.9	45.4	52.1	46.0	43.4	48.8	49.9	42.9	46.6	47.3
20030609	56.9	59.3	58.5	64.3	54.9	57.6	62.9	67.4	61.9	60.3	66.4
20030610	66.3	54.9	68.3	82.0	59.4	59.6	67.8	85.8	62.0	63.9	73.0
20030611	38.4	22.3	40.1	45.3	33.3	31.6	39.3	47.3	35.4	33.4	39.0
20030612	24.4	15.8	22.0	28.1	23.8	18.5	25.5	27.3	17.5	25.8	20.8
20030613	15.8	15.0	19.4	17.9	14.3	18.3	17.6	18.4	21.6	18.1	28.8
20030614	31.6	21.5	26.8	31.5	29.0	17.9	27.5	28.8	21.4	29.5	25.8
20030615	34.3	27.8	37.5	46.1	35.1	27.1	41.3	47.4	28.1	33.0	32.5
20030616	30.5	31.0	57.5	46.8	36.1	41.0	60.6	42.4	45.0	33.3	49.5
20030617	44.1	37.8	37.8	32.5	41.6	40.9	39.3	33.1	31.9	51.5	37.3
20030618	26.3	18.3	25.6	21.4	25.1	25.5	25.9	24.5	28.3	27.4	28.8
20030619	37.5	46.1	34.8	44.9	40.4	44.6	44.0	45.0	52.5	38.1	47.5
20030620	62.3	72.3	63.3	66.6	69.1	74.3	73.0	64.8	82.0	62.1	74.9
20030621	64.4	67.9	72.1	67.4	63.0	72.1	72.6	60.5	80.8	59.1	77.5
20030622	65.1	84.8	62.1	64.1	71.6	65.1	68.9	69.3	60.5	66.3	58.8
20030623	103.4	62.0	80.6	81.9	77.9	67.6	91.8	79.4	65.9	83.0	65.0
20030624	93.6	75.3	90.8	103.3	79.0	79.0	107.0	108.3	69.9	65.9	73.8
20030625	108.1	69.6	84.9	79.0	94.5	81.6	93.0	88.3	71.8	84.8	76.6
20030626	67.8	66.8	83.8	91.6	71.1	70.4	84.3	94.9	67.1	64.0	74.5
20030627	53.3	47.0	60.9	63.9	47.8	56.6	65.1	65.0	50.1	49.9	54.6
20030628	58.0	48.0	54.5	52.0	50.4	51.5	55.9	50.6	45.6	46.3	47.8
20030629	66.5	35.8	54.0	42.5	54.0	41.4	48.6	47.6	36.0	49.5	40.5
20030630	13.0	14.3	15.6	12.1	16.9	23.1	13.1	20.0	23.0	23.1	20.1

20030701	15.8	19.8	16.3	13.4	18.9	18.1	14.0	12.1	17.9	20.6	17.8
20030702	29.1	28.0	26.4	32.5	28.0	27.3	30.1	30.8	30.3	29.1	32.0
20030703	68.9	54.3	64.9	66.5	49.6	55.0	65.0	56.6	71.0	57.1	73.8
20030704	59.6	33.9	41.4	47.5	36.9	29.6	43.6	44.5	36.3	44.0	38.5
20030705	27.6	22.4	25.3	24.5	23.3	20.0	24.6	22.8	23.0	21.8	24.5
20030706	25.3	21.0	21.5	27.9	20.5	19.4	25.4	28.8	20.9	20.5	22.9
20030707	34.5	36.4	41.5	41.8	31.0	39.5	44.5	37.6	46.3	31.5	50.1
20030708	50.1	40.1	64.1	72.8	48.9	55.5	64.4	60.8	60.0	41.4	72.0
20030709	36.4	33.5	43.1	50.8	40.7	35.9	43.8	49.3	41.3	42.4	47.6
20030710	21.8	32.0	17.1	21.1	28.9	29.3	22.5	17.6	34.3	33.4	28.4
20030711	38.6	38.5	36.8	44.8	37.9	40.8	43.5	42.8	40.3	40.3	42.4
20030712	52.6	49.4	66.9	77.5	50.8	51.8	68.3	76.3	52.5	46.8	60.0
20030713	64.5	47.4	57.3	67.9	49.8	46.3	60.3	70.5	49.9	45.1	48.5
20030714	46.9	39.6	51.5	46.3	41.3	41.4	51.5	47.9	47.8	40.0	52.6
20030715	53.9	49.4	52.5	62.9	50.1	39.3	51.0	72.3	47.4	44.8	51.5
20030716	36.0	46.4	46.6	47.3	36.4	48.3	48.0	48.5	57.0	39.8	57.1
20030717	77.8	69.1	73.1	83.3	65.3	67.6	84.9	71.4	82.6	68.6	78.5
20030718	72.6	70.3	77.5	95.0	77.5	72.3	83.0	91.1	54.1	67.0	66.9
20030719	63.3	60.6	65.1	72.3	55.1	58.6	65.3	72.9	57.6	60.0	65.3
20030720	59.0	58.3	67.4	71.3	59.0	57.8	67.6	61.5	56.8	53.3	52.0
20030721	47.0	45.9	51.3	58.6	46.4	43.9	54.4	55.4	45.8	46.1	46.0
20030722	34.1	38.1	34.8	34.9	37.8	38.3	38.1	32.5	37.0	41.4	40.5
20030723	50.5	43.9	46.1	49.6	47.3	42.5	51.6	51.6	42.1	48.8	48.3
20030724	68.0	59.8	70.5	64.9	59.1	65.8	66.4	62.3	72.8	59.8	78.8
20030725	69.0	51.5	57.4	58.1	74.5	53.4	62.3	61.5	48.1	83.4	54.4
20030726	40.3	31.5	31.3	32.1	47.4	29.6	36.4	33.3	26.0	48.8	27.4
20030727	45.1	47.8	52.6	52.6	39.0	45.6	54.1	44.4	57.9	36.0	56.4
20030728	55.6	40.3	60.9	67.1	49.3	55.8	64.3	59.9	67.4	49.6	71.8
20030729	65.5	60.1	66.4	69.9	61.0	64.5	70.1	64.3	73.5	60.4	76.6
20030730	52.8	57.1	68.6	67.8	59.0	58.5	68.3	46.8	68.5	49.6	68.8
20030731	38.1	40.0	47.9	46.3	39.5	46.0	46.0	49.1	44.9	42.8	45.9
20030801	46.3	44.3	57.0	58.5	47.1	45.9	56.3	58.4	45.3	44.3	48.6
20030802	65.1	37.8	53.4	52.3	51.3	40.1	52.8	53.6	42.4	51.8	38.6
20030803	50.1	39.5	51.4	52.8	45.4	36.1	53.1	50.8	36.6	43.5	35.1
20030804	43.4	38.9	38.3	46.8	40.9	39.5	47.0	46.1	36.0	41.0	38.6
20030805	45.9	34.6	42.5	51.8	44.6	39.3	48.3	51.3	40.4	46.6	45.8
20030806	31.1	32.5	23.4	25.8	34.3	35.5	31.6	30.9	38.6	37.9	32.9
20030807	49.4	51.9	49.6	52.1	48.4	54.5	57.8	52.5	56.3	48.5	60.9
20030808	69.3	67.9	63.9	65.4	69.4	71.0	75.1	56.3	80.3	68.9	75.5
20030809	75.3	65.8	65.6	77.4	62.4	71.4	75.3	64.3	82.4	65.0	74.4
20030810	62.5	65.6	68.8	68.1	56.4	63.6	74.4	58.0	72.0	57.3	74.5
20030811	48.9	55.9	54.3	62.8	47.3	65.1	63.4	65.0	63.0	50.0	63.8
20030812	55.5	42.1	43.5	39.9	49.6	42.6	47.1	40.8	37.9	57.0	44.4
20030813	35.8	28.6	24.9	29.1	37.4	30.1	31.4	28.5	32.9	42.5	34.7
20030814	51.9	43.9	39.3	41.9	60.6	39.5	46.6	45.4	38.6	49.1	37.4
20030815	66.1	65.9	53.8	55.0	73.1	53.4	65.8	59.6	55.1	62.5	54.5
20030816	58.6	42.1	42.6	55.8	45.1	40.1	49.9	52.9	47.6	49.9	47.1
20030817	62.8	56.8	60.6	70.5	53.0	51.5	69.0	63.0	50.8	53.3	59.8

20030818	78.6	51.9	71.9	72.5	64.5	58.0	76.6	69.8	56.5	64.4	64.8
20030819	82.5	52.8	68.6	61.8	85.5	66.3	73.0	61.9	64.3	76.0	61.1
20030820	52.0	41.8	41.0	38.4	53.8	47.4	43.5	35.3	47.1	67.3	39.9
20030821	73.4	47.3	49.7	50.0	60.5	52.1	52.9	50.9	54.1	69.3	46.8
20030822	78.8	34.1	55.2	60.3	54.9	44.9	58.8	64.9	44.8	58.5	43.5
20030823	59.5	63.3	68.1	74.6	54.0	52.8	72.5	74.5	60.3	53.0	71.3
20030824	67.6	64.9	57.6	54.9	67.1	61.1	61.3	56.0	54.1	58.9	55.8
20030825	73.1	58.9	61.4	55.5	86.0	53.8	65.4	58.0	46.6	67.9	51.8
20030826	84.3	77.9	93.5	93.3	70.8	71.4	99.8	84.6	72.5	62.4	77.0
20030827	69.3	59.3	74.1	88.0	65.0	68.0	79.4	88.9	58.5	57.9	69.8
20030828	62.8	39.5	45.7	56.0	48.3	39.1	48.5	64.8	47.1	48.8	51.0
20030829	43.8	32.5	49.6	42.4	40.6	35.5	45.9	38.5	43.4	41.1	43.5
20030830	20.8	29.4	28.3	34.4	26.5	22.1	32.6	39.0	30.3	22.8	27.6
20030831	0.0	23.4	34.9	26.4	27.9	23.6	35.8	23.8	31.8	29.4	28.0