2.3 **EXPLORATORY ANALYSIS OF THE POTENTIAL HEALTH IMPACTS OF CLIMATIC VARIABILITY AND AIR POLLUTION**

Adel Hanna,[1]* Aijun Xiu,[1] Karin Yeatts,[1] Peter Robinson,[1] Zhengyuan Zhu[1], and Joseph Pinto[2]

[1]The University of North Carolina at Chapel Hill, Chapel Hill, North Carolina 27599
[2]U.S. Environmental Protection Agency, Research Triangle Park, North Carolina 27711

1. INTRODUCTION

One of the most readily apparent contemporary factors linking climate to human health is air pollution. Important progress has been made in reducing U.S. air pollution since the first Clean Air Act was passed in 1970, but summer haze and its constituent particulate matter and photochemical air pollutants remain substantial ongoing problems across the U.S. Short-term meteorological effects on air pollution are readily observable but variably predictable. Furthermore, our understanding of longer-term climatological relationships to air pollution remains incompletely defined.

Exposures to air pollutants have serious public health consequences. Ground-level ozone (O_3) can exacerbate respiratory diseases, especially asthma, by damaging lung tissue, reducing lung function, and sensitizing the lungs to other irritants (Romieu, 1999). More recent epidemiologic studies have found significant associations of ambient O_3 levels with respiratory hospitalizations and premature death (U.S. EPA, 2006). Epidemiologic studies have also found that exposure to particulate matter can aggravate existing respiratory and cardiovascular diseases, alter the body's defense systems against foreign materials, damage lung tissue, and may cause cancer and premature death (Lambert et al., 1998; U.S. EPA, 2004). Health effects of exposures to carbon monoxide (CO), sulfur dioxide (SO_2), and nitrogen dioxide (NO_2) can include visual impairment, reduced work capacity, aggravation of existing cardiovascular diseases, effects on breathing, respiratory illnesses, lung irritation, and alterations in the lung's defense systems (Lambert et al., 1998).

Climate change may affect ambient air pollutants by (1) influencing weather and thereby local and regional pollution concentrations (Penner et al., 1989); (2) altering anthropogenic emissions, including adaptive responses involving increased fuel combustion for power generation (U.S. EPA, 1998); (3) affecting natural sources of air pollutant emissions; and (4) changing the distribution and types of airborne allergens (Ahlholm et al. 1998). Local weather patterns—including temperature, precipitation, clouds, atmospheric water vapor, and wind speed and direction—influence atmospheric chemical reactions. They can also affect atmospheric transport processes and the rate of pollutant exports from urban and regional environments into the global-scale environment (Penner et al., 1989). Climate change may further influence exposure to ambient air pollutants by modifying personal daily activities or behavior.

In this study we are analyzing climate trends and the associated weather in terms of eight identified air-mass/weather types. We hypothesize that such air masses and the corresponding air quality conditions will have differing health impacts on humans, which can be quantified based on statistical analyses of the correlates among the meteorological, climate, air quality, and health data. We focus on the links between gaseous air pollutants and asthma hospitalizations, and use Charlotte, NC, to demonstrate our analysis.

2. APPROACH AND DATA

Our approach will use time series methods to examine air quality data in relation to a health outcome. Ambient concentrations of O_3, NO_2, and CO are provided by the U.S. EPA AQS (formerly the Aerometric Information Retrieval System [AIRS]; http://www.epa.gov/ttn/airs/airsaqs/detaildata/downloadaqsdata.htm). We will use asthma hospitalizations data in the Charlotte area for the 9-year period (1996-2004)

Meteorological data are identified in terms of the daily maximum and minimum temperatures, precipitation, mean and maximum relative humidities (RH), mean wind speed and direction, and the air mass pattern. Air quality data include daily average O_3, NO_2, and CO. Health data, also identified on a daily basis, include the number of patients admitted to the hospital for asthma.

**Corresponding author address:* Adel Hanna, Carolina Environmental Program, UNC-Chapel Hill, 649 Bank of America Plaza, CB#6116, Chapel Hill, NC 27599-6116; e-mail: ahanna@unc.edu.

3. SYNOPTIC CLASSIFICATION AND AIR MASS TYPES

We classify daily air masses in the Charlotte area using the Spatial Synoptic Classification (SSC) system (Kalkstein and Greene, 1997; Sheridan, 2002; sheridan.geog.kent.edu/ssc.html). The SSC system takes in surface weather data for a given station and classifies each day into one of eight weather types or air masses. Figure 1 shows the regional surface pressure patterns for selected days in 2003 that are characteristic of the various air-mass types for Charlotte and stations in North Carolina. Locations elsewhere in the map may be assigned to a different air mass type.

The DM (dry moderate) air mass is mild and dry. It is typically found in the eastern and central U.S. associated with zonal flow aloft, when adiabatically-warmed and dried air moves eastward after crossing the Rocky Mountains; it may also be found in the southeastern U.S. The DP (dry polar) air mass is generally advected from Canada through circulation around a cold-core anticyclone, and is usually associated with the lowest temperatures observed in a region for a particular time of year, as well as clear, dry conditions. The DT (dry tropical) air mass represents the hottest and driest conditions found at any location. There are two modes of development for this air mass: either it is advected from the southwestern U.S. or Sonoran Desert of Mexico, or it is produced by rapidly descending air, such as the Chinook or Santa Ana winds. The MM (moist moderate) air mass is considerably warmer and more humid air than the MP (moist polar) air mass. The MM air mass typically appears in a zone south of MP air, still in an area of frontal overrunning but with the responsible front much nearer. This air mass may persist for many days if frontal movement is particularly lethargic. MP (moist polar) weather conditions are typically cloudy, humid, and cool. MP air appears either by inland transport from a cool ocean, or as a result of frontal overrunning well to the south of the region. The MT (moist tropical) air mass is warm and very humid. It is typically found in warm sectors of frontal cyclones or in a Gulf return flow on the western side of an anticyclone in the eastern and central U.S. The TR (transitional) air mass describes situation on days when one air mass gives way to another. MT+ is a subset of MT. It is defined as an MT day where both morning and afternoon temperatures are above specific daily means, and thus captures the most "oppressive" quarter or so of MT days. Figure 2 shows the percentage occurrence of the eight air mass types in Charlotte for 1996-2004.

The moist tropical, dry moderate, moist moderate, and dry polar air masses are the most frequent. The figure reveals a seasonal variability in most types of air masses; the MT and MM peak during summer, while the DP and DM maximum occurrences fall during autumn and winter.

4. ANALYSIS AND DISCUSSION

Figure 3 shows the seasonal pattern in terms of the mean, maximum, and minimum 9-yr monthly hospital admissions related to asthma based on the nine years of data. Asthma admissions clearly rise during fall and winter and decline during summer. Note that these patterns do not reveal the triggering cause of each medical condition (whether it is related to air pollution, extreme cold, or a patient's other medical conditions).

Table 1 shows correlations between air quality and meteorological parameters and asthma hospitalizations based on daily values for 1996-2004. The first three columns show the correlations between NO_2 and CO, O_3 and temperature, and O_3 and RH. The correlations between CO and NO_2 (ranging from 0.51 to 0.72) provide an indication of the commonality of sources (mainly traffic) for these pollutants. In the last three columns, correlations between ambient O_3 and cases of hospitalization for asthma are negative and very small. NO_2 and CO, however, always show positive correlations with asthma hospital admissions; some years exhibit larger correlations than others. We then isolated data for each air mass type during the nine years of analysis to examine the NO_2, CO, O_3 and asthma hospitalization relationships in the Charlotte area. Table 2 shows the relationships between NO_2 ambient concentration and asthma hospital admissions, CO ambient concentration and asthma hospital admissions, O_3 ambient concentration (above 80 ppb) and asthma hospital admissions, and the NO_2-to-CO correlations for each air mass type. The DM, DP, DT, and MM air masses generally show higher correlations for NO_2 and CO with hospitalizations for asthma than do the other air mass types. The correlation between O_3 ambient concentrations and asthma hospitalizations tends to be positive for MT and MT+ air masses.

We used a generalized linear model (GLM) to study the regression relationships between O_3, NO_2, CO, and asthma hospital admissions. We assumed that the number of asthma hospitalizations per day has a Poisson distribution with mean lambda, and that the logarithm of lambda is linearly related to some of the meteorological and air quality variables. Fitting such a GLM allows us to quantify the potential health effects of certain air pollutants after adjusting for meteorological variables. We can also include in the model the interaction effect between air mass types and air quality data to assess whether the health effects are dependent on air mass type.

Preliminary results indicate that higher levels of NO_2 are associated with increased asthma hospitalizations, with p-value of 0.028 and estimated regression coefficient of 5.441. This implies that an increase of 0.01 ppm in NO_2 corresponds to about a 5.6% increase in asthma hospitalizations. There is no evidence that this relationship changes with different air mass types. Similar results hold for CO, with p-value of 0.0195 and estimated regression coefficient of 0.066, which translates to a 6.8% increase in asthma hospitalizations with a 1 ppm increase in CO. There is also some evidence that the relationship between O_3 and asthma hospitalizations is different under DM, DT, and MT conditions. Further analysis is needed to confirm these findings. All the results above were obtained after adjusting for differences in the following meteorological variables: daily maximum RH, average daily pressure, departure from normal temperature, average daily dew-point temperature, and average daily wind speed.

5. SUMMARY AND CONCLUSIONS

We present preliminary results on possible links between gaseous air pollutants and asthma hospitalizations among the general population in the Charlotte area over a nine-year time span (1996-2004). Year-round asthma hospital admissions, air pollution, and meteorological data were used. NO_2 levels correlated strongly with CO for most air mass types, but NO_2 was independent of O_3. Increase in asthma hospital admissions could be linked to O_3 exposure for the MT and MT+ (moist tropical) air mass which is more frequent during summer. NO_2 and CO, on the other hand, were linked with increased hospitalizations with most types of air masses.

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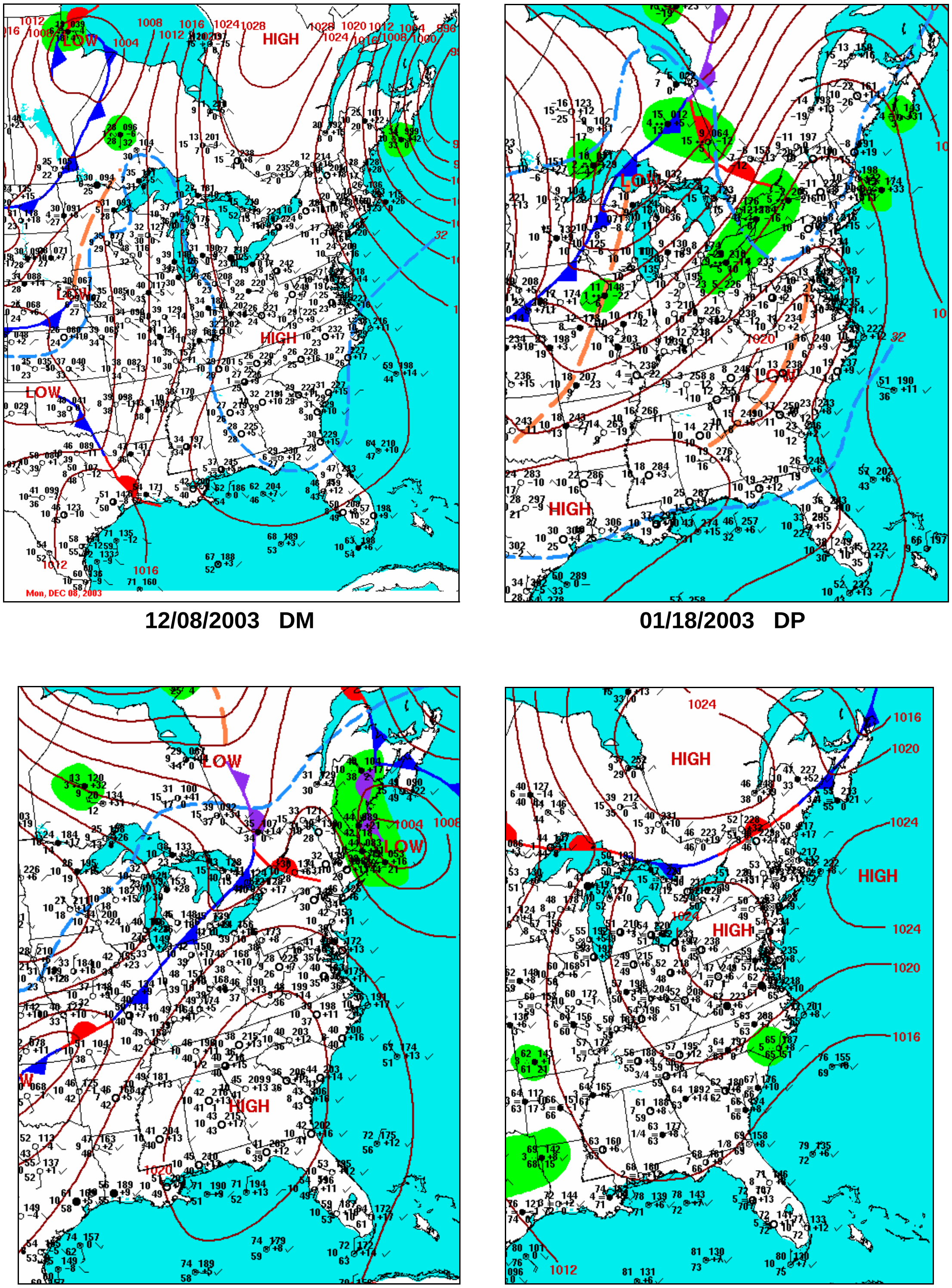

Figure 1a:Regional surface pressure maps associated with the DM, DP, DT, and MM air mass types for Charlotte, NC, for the dates indicated.

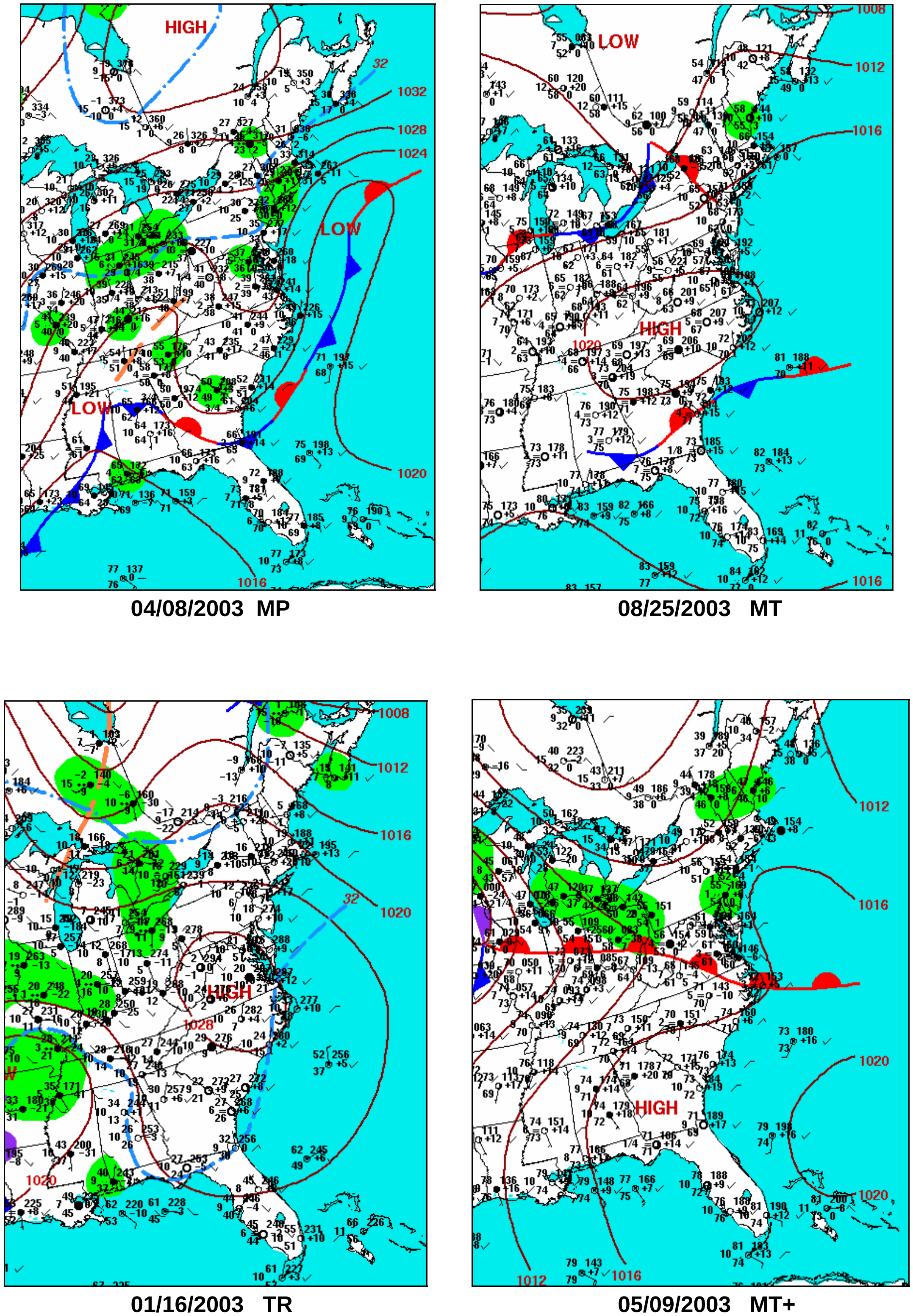

Figure 1b: Regional surface pressure maps associated with the MP, MT, TR, and MT+ air mass types for Charlotte, NC, for the dates indicated.

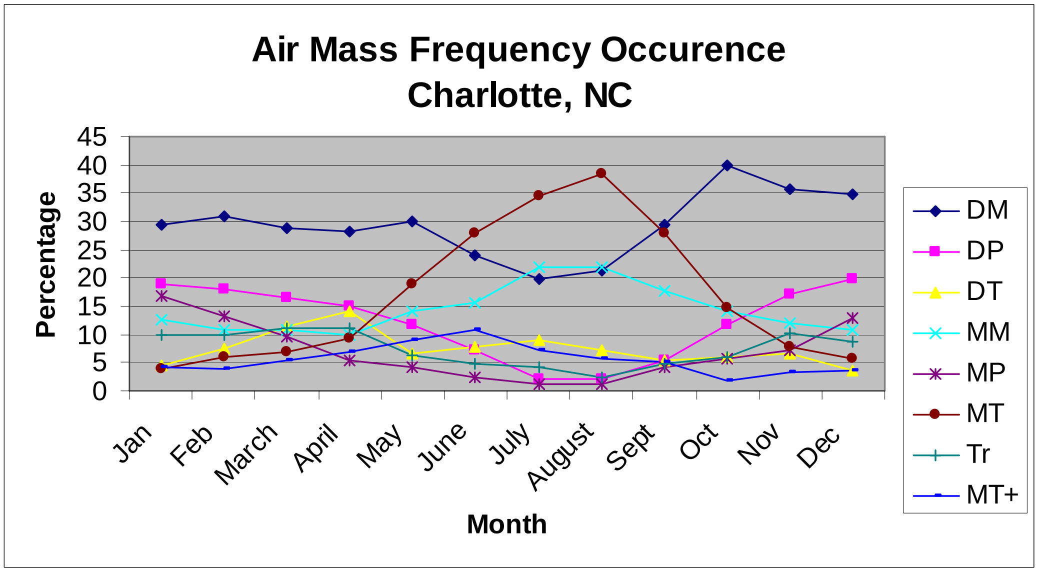

Figure 2: Percentage occurrence of air mass types in Charlotte, NC, based on meteorological observations from 1996 through 2004. DM: dry moderate; DP: dry polar; DT: dry tropical; MM: moist moderate; MP: moist polar; MT: moist tropical; TR: transitional; MT+: subset of MT that captures oppressive cases.

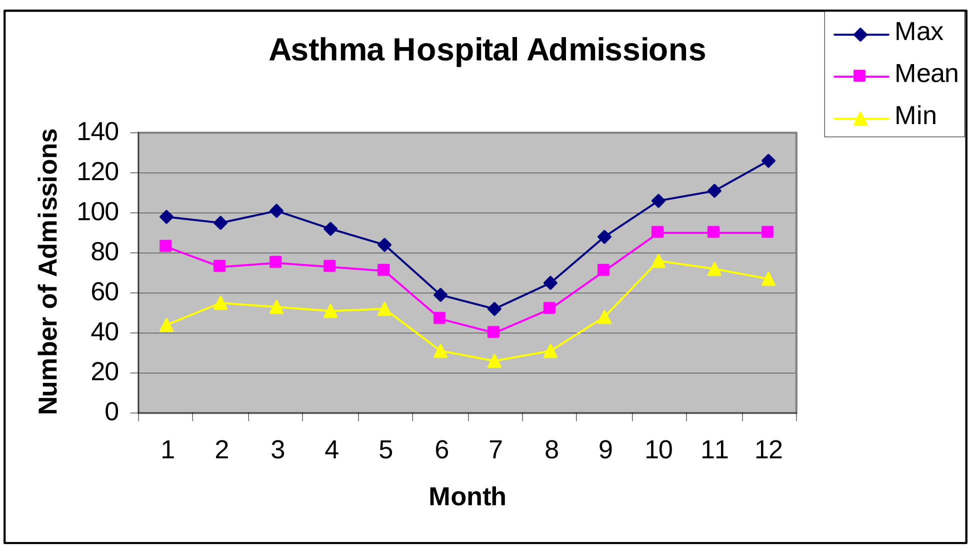

Figure 3: Mean, maximum, and minimum 9-yr monthly hospital admissions in the Charlotte area for asthma.

Year	NO_2/CO	O_3/temp	O_3/RH	Admiss/NO_2	Admiss/CO	Admiss/O_3
1996	0.67	0.59	-0.40	0.30	0.44	-0.24
1997	0.60	0.64	-0.32	0.17	0.22	-0.03
1998	0.51	0.61	-0.50	0.16	0.31	-0.16
1999	0.53	0.66	-0.42	0.23	0.40	-0.07
2000	0.69	0.68	-0.50	0.20	0.26	-0.22
2001	0.66	0.47	-0.42	0.34	0.36	-0.02
2002	0.56	0.59	-0.46	0.28	0.32	-0.20
2003	0.72	0.53	-0.64	0.30	0.17	-0.23
2004	0.66	0.48	-0.55	0.30	0.19	0.03

Table 1: Annual correlations between meteorology (temperature, relative humidity), air quality (O_3, NO_2, CO), and asthma hospital admissions (Admiss).

Air mass	DM	DP	DT	MM	MP	MT	TR	MT+
NO_2/Admiss	0.18	0.18	0.18	0.29	0.08	0.13	0.08	-0.14
CO/Admiss	0.22	0.19	0.24	0.26	0.10	0.21	0.27	0.01
O_3/Admiss	-0.08	*	0.0	*	*	0.10	*	0.32
NO_2/CO	0.53	0.52	0.65	0.61	0.52	0.50	0.39	0.27

Table 2: Correlation between gaseous air pollution and asthma hospital admissions, classified by air mass type (* indicates not enough data for O_3 ambient concentrations above 80 ppb).