ANALYSIS OF ASTHMATIC HOSPITAL ADMISSIONS IN MISSISSIPPI AS RELATED TO DEMOGRAPHIC AND ENVIRONMENTAL VARIABLES

A thesis submitted to Kent State University in partial fulfillment of the requirements for the degree of Master of Arts

by

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December, 2011
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PREFACE

The work in this thesis was conducted between September 2010 and May 2011. This project is an application of Geographically Weighted Regression on asthmatic hospital admissions in Mississippi for the time period ranging from 2003-2005.

I would like to thank a number of people for helping me along this long and difficult process. Without the help of the University of Mississippi Medical Center, this project would not have been possible. My advisor and the members of my committee have been extremely helpful in guiding me through the analytic and writing process. I’d also like to thank my colleagues for giving me ideas whenever I’d hit a roadblock. Lastly, thanks to my parents (and stepfamily!) for supporting me through this endeavor.
CHAPTER 1

INTRODUCTION

Studies of disease prevalence and spread have been a staple of the medical geography field. Understanding a disease’s progression through time is an important piece of knowledge that can save countless numbers of people. The use of improved computing and statistical techniques has been a key factor in such research, leading to increased preventative measures and policy making decisions. Geographers have been making great strides in studying various diseases within the last century or so, and their work continues to add to the general knowledge we have about disease origins and movements. This thesis is an analysis of asthma, a major respiratory disease that affects millions of people worldwide.

Asthma affects a large percentage of the population of the United States, with 16.4 million adults and 7 million children reporting asthmatic symptoms in 2008 (Office of Information Services 2009, 2). Within the adult population, it is estimated that asthma prevalence is 8.8% for women and 5.8% for men (McHugh et al. 2009, 759-766). The disease results from an inflammation of the airways, which swell and constrict airflow to the body. The disease is incurable, but with medication which includes prescription drugs and inhalers, it is controllable. Symptoms from the disease can occur whenever there is sufficient irritation in the airways from an outside source. Asthmatic prevalence
has been predicted to increase in the immediate future, making the need for understanding its distribution and correlating factors of prime importance (McHugh et al. 2009, 759-766).

In this work, I analyze the trends in asthmatic hospital admissions in Mississippi using Geographically Weighted Regression for the years 2003 – 2005. More specifically, I evaluated environmental, demographic, and socio-economic variables were analyzed in relation to hospital admissions. Mississippi is plagued with a number of health problems, including high amounts of obesity, diabetes, heart attacks, and low numbers of practicing physicians (Gregg et al. 2009, 1259-1263). It is imperative to understand how diseases are distributed through the study region, and to know about which factors most strongly increase or decrease hospital admissions.

The outcome of this study will have implications for policy-making considerations for public health. Once we have a better understanding of the effects of environmental, demographic, and socioeconomic factors on health issues such as asthma, strategies and policy may be devised to better respond to its spatio-temporal variations.

I have divided my thesis into several chapters which detail a number of relevant concepts regarding the project’s significance and methods. In the next chapter I outline previous research that has been conducted on asthma in other regions of the world. I discuss other studies that examined a number of relevant factors towards asthmatic hospital admissions. Following the literature review chapter I present the source data for this thesis and methods utilized to analyze asthmatic hospital admissions. In the analysis chapter I present the results of the study and provide explanations of trends where
applicable. Finally, I close with a short conclusion chapter in which I reiterate some of the findings, discuss limitations of the investigation, and propose future research.
CHAPTER 2

LITERATURE REVIEW

In this chapter I will discuss previous research that has been conducted on asthmatic hospital admissions in several regions of the world. More specifically, I present literature on hospital admissions as related to various independent variables that I analyzed in my study. The purpose of this chapter is to aid in justifying the choice of potential causative factors for severe asthmatic response in this research.

Air pollution is often cited as a cause of respiratory illness throughout the world. Pollutants can come in a variety of forms, ranging from windblown dust, ocean salts, and combusted materials from urban areas. These pollutants occur in various sizes, but for the sake of this study am concerned only with fine particulate matter (particles less than 2.5µm in size) (U.S. Environmental Protection Agency 2009, 1). Fine particulate matter are often determined to be the most dangerous of all air particles, because they can be deeply inhaled as opposed to larger materials (Laden et al. 2000, 941-947). Fine particulate matter also tends to occur in the most populated of areas, because it is created through the complete or incomplete combustion of some material, such as gasoline or wood.

In Seattle, Norris et al. (1999) wanted to better understand the trends in asthmatic hospital admissions in certain areas of the city. Within the inner cities of the metropolis
the admission rates for children are over six times that of other areas nearby. Fine particulate matter was shown to have a significant correlation with hospital admissions during the study. A large spike in fine particulate matter was observed on the 24th and 25th of December, hinting that holidays and other special events may have an impact on air composition and hospital admissions.

The association between asthma and fine particulate matter has not been found to be as clear cut in all cases. Lin et al. (2002) created correlations between asthmatic hospital admissions in children as related to both coarse and fine particulate matter between 1981 and 1993. Contrary to a number of other studies relating to these variables, Lin et al. (2002) found significant correlations between coarse particulate matter and asthma, but relatively low correlations with fine particulate matter. Something of note in this study regards the amounts of coarse and fine particulate matter in the air during the entire study period. From 1981 - 1993, coarse particulate matter never exceeded the standard set by the U.S. EPA, and fine particulate matter levels exceeded the standard only nine times (Lin et al. 2002, 575-581).

The effects of both fine and coarse particulate matter do not work independently however, some synergistic effects of the two particle types do occur. In 2009, researchers Chan et al. analyzed the effects of both fine and coarse particulate matter on emergency asthmatic admissions in Taipei City for the years 2000-2002. They specifically targeted both combustible pollutants and coarse particulate matter. Chan et al. (2009) found that a certain type of fine particulate matter, Nitrous oxide, was correlated the most strongly with increases in asthmatic hospital visits, with a 10%
increase in NO$_2$ equating to a 0.30% increase in hospital visits. Coarse particulate matter also was associated with hospital admission increase, with a 0.14% increase in hospital admissions for every 10% increase in PM$_{10}$.

Age has been shown to be a factor in asthmatic cases. By and large, children tend to be more affected by this disease than adults. Lin et al. (2002) cited increased outdoor activity and higher respiratory rates in children as compared to adults as reasons for these higher numbers of cases. The combination of these factors leads to increased exposure times to harmful pollutants in combination with higher amounts of inhalation. Children with the disease will often stop having asthmatic symptoms later in life if it is diagnosed early and medication is used as prescribed (Lin et al. 2002, 575-581).

Even with increases in the understanding of asthma and control of its symptoms, the prevalence of the disease is still increasing in some regions of the world. Gershon et al. conducted a study in Ontario, Canada which outlined the changes in asthmatic prevalence and incidence between 1996 and 2005. Between these years, the prevalence of the disease increased 70%, with the highest increases in incidence being among children (increasing 30%) (Gershon et al. 2010, 728-736). Within adults the disease remained relatively stable, and decreased in several years. This suggests that special attention must be taken in this region with regards to treating the disease in younger people.

Even though asthmatic prevalence is increasing worldwide, it is not increasing at the same rates in all locations. In Sweden, Kälvesten and Bråbäck theorize that childhood asthmatic prevalence has peaked, and may be stabilizing or even decreasing.
Using a questionnaire, Kälvesten and Bråbäck found that asthmatic symptoms and wheezing have decreased from 1985-2005, while the percentage of physician-diagnosed asthma cases have increased steadily during the same period. Increased usage of medication may account for the decreasing trend in wheezing and asthmatic symptoms in addition to the increasing of asthma diagnoses.

An interesting aspect of asthma prevalence with regards to age is also connected to gender distributions of the disease. By and large, higher prevalence of the disease occurs within males at younger ages. By the mid-teens to early twenties, most asthmatic cases reported are from females. The cause for this switch with age is unknown, but it is theorized that asthmatic symptoms may develop later in life for women than men (Thomas et al. 2003, 280-283). This has implications for areas of the world that have high female to male ratios and aging populations, as specialized care will need to be present in order to tend to those who need it.

The economic status of the population is another demographic factor to take into consideration when analyzing asthmatic prevalence. The amount of money available to a person afflicted with the disease will influence the types of treatment they receive in addition to how often they seek it. From a developmental perspective, children that live in poorer households for long periods of time may be higher at risk for developing the disease (Kozyrskyj et al. 2010, 540-546). Children that have been in households that are not chronically poor (family wealth increasing over time) were shown to have up to a 60% decreased risk for developing asthma in Australia. Similar results were found in the
United States in 2007, with lower incomes being correlated with higher morbidity and mortality from the disease (Moorman et al. 2007, 1-17).

The use of socioeconomic status as a proxy for asthma is a useful tool in determining relative access to care for the disease. Doctors and specialists may not want to be based in poorer inner city areas for a number of reasons, not limited to lower profits, higher crime, and higher traffic/longer commutes. As a result, the people that may need access to specialized care may not be able to receive it, and would need to use the general hospital instead (Flores et al. 2009, 392-398). If specialized care were to be somehow relocated to these areas, it may be possible to limit asthmatic outbreaks for those residents in the future.

Income also plays a factor in how asthma may be controlled for people suffering from the disease. Inhaled corticosteroids (ICS) are prescribed for people with asthma, which are used as an anti-inflammatory during an attack. These medicines are important in keeping the disease under control. Cope et al. (2008) analyzed whether income had an effect on keeping asthma under control for children in Canada. They examined whether children were able to keep their asthma under control based on the Canadian Pediatric Consensus Guidelines, a binary list detailing a number of scenarios which asthma sufferers face. Acceptable control was defined as successfully satisfying all of the conditions of the list, intermediate control being the failure of one condition, and unacceptable control being the failure of two of more conditions (Cope, Ungar, and Glazier 2008, 745-752). Over two thirds (69%) of the children surveyed had unacceptable control of their asthma. Typically, the children that had less control over
their symptoms came from poorer families. Higher levels of asthma control were seen in children from families with higher incomes.

The question of whether race has an effect on asthmatic prevalence has been posed several times before. The problem in determining whether race itself is a key factor in developing asthma is separating race from some other factor which may be a more telling cause (Litonjua et al. 1999, 394-401). Historically, it has been thought that African Americans and Hispanics are more prone to the disease, but this is difficult to separate from socioeconomic status. Many of the inner city urban areas where many of these groups live are poorly maintained, poorly constructed, and located near industries and businesses that may be greatly contributing to the pollution of the area.

Poor housing quality and socioeconomic status may be contributors to asthmatic prevalence within immigrant families. Often in the United States, immigrants’ wages are low, and they are forced to live in some of the unhealthiest regions in cities. These areas often consist of poorly constructed housing, low access to medical care, and high numbers of pests. Litt et al. (2010) describe Mexican communities in northern Denver that face these problems, where molds and fungi, pests, and poor ventilation in housing contribute to asthmatic symptoms in the population. Over two-thirds (67%) of the homes Litt et al. surveyed had one of these conditions, while multiple conditions existed in just under one-third (27%). Considering that immigrant children are one of the largest and fastest-growing sections of the youthful population (currently 20% of all children under eighteen), and are highly susceptible to respiratory illness, it is important to recognize
and work towards improving the conditions of these households (Litt et al. 2010, 617-625).

There is some evidence that there are differences in prevalence and incidence of asthma between minority populations and non-Hispanic whites that may not be socioeconomic. Other research conducted found significant difference in asthmatic hospital admissions between these two population groups, with the highest prevalence being in the African American, Puerto Rican, and American Indian populations (Canino, McQuaid, and Rand 2009, 1209-1217). Nationwide, Puerto Ricans exhibit the highest rates of prevalence among any racial group; however African Americans exhibit the highest asthma mortality. These racial and ethnic groups typically have less access and lower quality of health care than non-Hispanic whites in the country, necessitating better care provisions and understanding of the distributions of asthma among these groups.

This issue is not clear-cut however, as some research that has been conducted has found significant differences only in race in determining asthma prevalence. An odds ratio study conducted by Miller (2000) compared a number of variables as related to asthmatic prevalence and health care use across the nation. A key comparison that Miller studied was whether asthma prevalence increased or decreased based on increasing or decreasing income. For non-African American children in households with incomes increasing over time, asthma prevalence, hospitalizations, and emergency room usage decreased significantly (Miller 2000, 428-430). However for African American children in households with increasing income, none of these variables decreased in a similar manner. An explanatory mechanism has yet to be determined for this difference.
There may be a connection between weather effects and trends in asthma admissions, but the connection between the two has not been very well defined. Major variables that have been studied in relation to this disease have mainly been temperature, humidity, and precipitation (Mireku et al. 2009, 220-224) (Hanel 1976, 74-183) (Jerrett et al. 2008, 1433-1438) (Kaminsky, Bates, and Irvin 2000, 179-186). Fluctuations of these variables have been connected to outbreaks of asthmatic activity, but results are not uniform throughout the world. For example, asthma outbreaks occur in the Caribbean, where temperature, pressure, and humidity generally do not vary wildly throughout the year (Carey and Cordon 1986, 843-844). This implies that location is an important factor to consider when examining the population’s response to a weather event.

Temperature and humidity also have a secondary effect on the composition of the air itself. Increasing the temperature of the air reduces its density, which allows for higher amounts of some substance to be carried within it. Similarly, the addition of moisture to an air parcel achieves a similar effect, as nitrogen that is present in the air is replaced by less dense hydrogen (Hanel 1976, 74-183). Increases in air pollutants such as PM$_{10}$, NO$_2$, O$_3$, and SO$_2$ have been correlated with increases in temperature and humidity in other cases (Chan et al. 2009, 64-74). The combination of these two factors can create a number of different air masses, which can enhance or inhibit particle movement through an area.

Dewpoint in particular has been observed as a potential trigger for asthmatic response in several regions of the world. Jerrett et al. (2008) created a number of associations between meteorological variables, pollution and asthmatic response in
children ages 10-18 in southern California in 2008. These variables were analyzed seasonally, so that temporal trends could be observed. The researchers found that air pollution was a significant factor in asthmatic response in children of this age cohort, but that dewpoint was as well. Temperature had a lesser impact; however moisture was a significant contributor to asthmatic hospital admissions in all seasons through the study period (Jerrett et al. 2008, 1433-1438).

The mechanics of dewpoint on asthma are not universal across all seasons however. In the summer and spring months, dewpoint can contribute to the growth and proliferation of molds and fungi which can cause asthmatic response. In winter, dewpoint can act as an inhibitor of asthma by making cold air easier to breathe (Kaminsky, Bates, and Irvin 2000, 179-186). Cold dry air causes the throat to narrow and compress, which triggers the asthmatic response. By moistening the air, these compressions typically do not occur as frequently or severely. In addition, during cold, dry days, people may be forced indoors, where they may be exposed to indoor pollutants (such as the aforementioned molds and fungi) that may trigger their asthma as well.

Seasonal effects also seem to play a role in asthmatic response. During the colder months of the year, people may be inside more often than not, and must turn to various methods of keeping warm. The method in which a house is kept warm may be a factor in an asthmatic response, such as burning wood or some other material. In Seattle, Allen et al. found the major sources of fine particulate matter in wintertime arise from traffic and the burning of wood materials for heating. The burning of vegetative material during the winter months in this region makes up anywhere from 16%-37% of the total ambient fine
particulate matter count. Considering that there were strong correlations between the
counts of fine particulate matter and asthmatic response during this period, it is
necessary to examine further seasonal effects of these phenomena.

The seasonal effects on asthmatic hospital admissions are heavily dependent on
location however. In the northeastern United States, admissions for asthmatic patients
spike in September, and are generally higher in the fall months than any other time of the
year (Wang and Yousef 2007, 839-841). In this region of the country, the strongest
correlations with admissions were linked to high tree and weed pollen counts, low
temperatures, and low precipitation. The direct link between temperature, precipitation,
and asthmatic response is not clearly understood at this time; however pollen and its
interactions within the body are fairly well understood. Knowledge of the life cycles of
native vegetation can likely account for a large portion of respiratory illness in the region,
and should be taken into account in any study.

The southeastern region of the United States tends to experience extended
droughts during the summer months. By and large these droughts are the direct result of
a large expanse of high pressure aloft, which inhibits convection and limits rainfall (Zeng
and Qian 2005, L22709-1-L22709-4). A secondary result of these pressure systems lies
in the limited movement of pollutants away from ground level. For this region, asthmatic
breakouts may likely be higher during these months, as the populations of these states
will be constantly exposed to increased levels of pollution, in addition to other potential
health risks such as heat stroke and exhaustion.
Conversely, in other areas of the world, higher precipitation has been linked to increased asthmatic hospital admissions. Chavarría (2001) compared admissions to relative humidity and rainfall in San Jose, Costa Rica for a seven year span. Chavarría found significant links between higher precipitation and humidity and asthmatic hospital admissions (Correlation coefficients of 0.63 for precipitation and 0.65 for relative humidity) (Chavarría 2001, 514-515). Rainfall in Costa Rica is highly seasonal, with the wet season beginning in May and lasting until November. Highest correlations occurred in August, with admissions occurring 30% higher than normal. Chavarría suggested that the reasons for such increases include higher amounts of time spent indoors during a rain event, and that mold growth may be encouraged with high humidity and water availability.

The overall point that these climatic variable studies show is that the response of the population to differing levels of fine particulate matter in the air is not particularly clear. Different areas of the world seem to show differing responses to air pollution. People of different age groups and economic backgrounds show differences as well. The various races seem to experience differing trends in asthma prevalence, but whether this is a factor of socioeconomic status or some other factor has yet to be determined. Regional differences in admissions also exist throughout the country and the world. Specific weather events may have some link to asthma outbreaks, but weather’s effects are not uniform in all areas. Lastly, differences in air composition occur seasonally, and likely play a role in asthmatic outbreaks. In order to gain a better understanding of what the population’s response to environmental, socioeconomic, and ethnic variables may be,
it is imperative to understand all of these different factors, and what they specifically mean in the context of asthma outbreaks.
CHAPTER 3
DATA AND METHODS

In the preceding chapter I highlighted previous research that has been conducted on asthma in various regions of the world. Some triggers for asthma have been identified, however, many of the disease’s other causes are poorly understood. Certain trigger, such as air pollution, humidity, and precipitation affect different portions of the population in different ways at different times in different locations. Previous research indicates that environmental and demographic variables play a part in asthma’s prevalence. In this chapter, I outline the data sources and methodologies used in examining how several explanatory (independent) variables may affect asthmatic hospital admissions in a region (dependent variable) where analysis has not been conducted.

DATA

With the information available for this study, there were numerous ways that I could analyze hospital admissions. After reviewing the literature of asthma research I chose a number of sets of variables for this study. Previous research indicated that that more investigation was needed with regards to asthma and the factors I selected. A list of the initially chosen variables is detailed in Table 1.
Table 3.1: Listings of the initial variables chosen for this study

<table>
<thead>
<tr>
<th>Socioeconomic Factors</th>
<th>Environmental Factors</th>
</tr>
</thead>
<tbody>
<tr>
<td>Race (White, Black, Asian)/Ethnicity (Hispanic) (%)</td>
<td>PM2.5 (µg/m³)</td>
</tr>
<tr>
<td>Income ($)</td>
<td>Temperature (°F)</td>
</tr>
<tr>
<td>Sex (Male, Female) (%)</td>
<td>Dewpoint (°F)</td>
</tr>
<tr>
<td>Age (0-65) (%)</td>
<td>Precipitation (Inches)</td>
</tr>
</tbody>
</table>

A number of datasets were required before analysis could take place. The first major dataset I needed was provided by the University of Mississippi Medical Center. The dataset is a 10km x 10km grid comprising the entire state of Mississippi. Each grid cell contains a number of variables, including hospital admissions and estimated PM2.5 counts for each month throughout the study period. Hospital admission data was created by geocoding patient addresses and aggregating them to the statewide grid.

PM2.5 counts for each grid cell were determined by a combination of Moderate Resolution Imaging Spectroradiometer (MODIS) readings and confirmation at EPA ground stations. MODIS data is collected from two polar-orbiting satellites that cover the entirety of the Earth’s surface every one to two days (Brandon Maccherone 2011, 1). These satellites approximate PM2.5 counts by measuring aerosol optical depth, in which differences in visible and infrared light reflection and absorption rates are measured to determine particulate matter amounts in the atmosphere. Higher rates of reflection indicate that there is increased fine particulate matter in the atmosphere, and vice versa. I collected daily data and then averaged by it month for each grid cell for the entire study period.

I obtained population data from the United States Census Bureau 2000 decennial census. The data needed to be aggregated to the grid structure previously obtained. Population data was obtained at the census block level, and income information was used...
at the block group level. The census data were conterminous over the study area, allowing for the use of a method that calculates the centroids of each census block and weighting them by block group to be used. Other methods of aggregating this type of data typically involve obtaining the centroids of each block, and aggregating them directly. That type of coalescing is only suitable for nonconterminous data, and therefore was not used in this study. I normalized demographic and admission data by population to remove population bias from the study.

The last major dataset needed for this project was an interpolation of temperature, dewpoint, and precipitation data for the entire study area. These variables were first obtained from Weather Underground, a forecasting company in San Francisco. Their website contains historical National Weather Service monthly weather data for several cities across Mississippi and other neighboring states. The fifteen cities provided on the website were placed in a point dataset, and temperature, dewpoint, and precipitation values for each month were entered into its table.

The Mississippi cities on the aforementioned website did not provide total statewide coverage for interpolation, so cities from Louisiana, Arkansas, Tennessee, and Alabama were also included to improve the quality of interpolated estimates. Cities outside of the study area were selected based on their location to the study area, with the closest cities given priority. In total, thirty one cities were used for the interpolation, which can be seen in Figure 3.1.
Figure 3.1 - A map of the locations of the cities used for the environmental interpolation
A data error was observed for one of the cities included for the interpolation: New Orleans. When Hurricane Katrina made landfall in August 2005, the city’s NWS weather station was destroyed, and not replaced for several months, as indicated by a lack of data during this time period. As a result, environmental data for New Orleans was omitted from the study for the months of August 2005 – October 2005. Although there was extensive damage to areas in Mississippi as well, weather stations in cities along the coast continued to function, so they were included in this time period. The effects on the loss of data from this city should be minimal as New Orleans was included to extend the amount of environmental data available to only a small area in southern Mississippi.

I employed the Inverse Distance Weighted interpolation method to cover the portions of the study area where environmental data was not originally obtained. A major component of this interpolation method is the power used to interpolate the unknown points using the known points. Power is the emphasis placed on known points in the study area. Higher powers allow defined stations to exert more influence on the interpolation, and vice versa. I determined the power for each interpolation with the Geostatistical Wizard in ArcMap. By using this tool, the Root Mean Squared Errors were obtained and reduced for each variable, which generally called for a power from a range of between two and three.

The use of IDW for environmental data in this study is justified by the high amount of weight that nearby temperature, dewpoint, and precipitation values exert on nearby areas. The timeframe of this study is measured in months, and the use of IDW is appropriate because sharp changes in the environmental data should not exist over such
an extended period. Using monthly data averages out differences in temperature, dewpoint, and precipitation across the study area. A different method may have been necessary if there were significant terrain barriers across the state, however these features do not exist. The state is vastly comprised of lowland areas, with some higher elevations in the northeast.

After completing the interpolations for the point datasets, I needed to map the resulting environmental surfaces to the study area grid using the Table Statistics by Zone tool. This tool collected and averaged every pixel within a defined mask, which in this case is the grid structure. In this way, environmental data was coalesced into the same structure, the study area grid, as the hospital admission dataset.

METHODS

Geographically Weighted Regression (GWR) was the primary methodology for the analysis of this project. GWR is a relatively new type of statistical analysis that analyzes relationships between sets of variables at the local level. Using this method it is possible to see variations across a study area that might not otherwise be observed using a more traditional global model. It has been used in a numerous other studies in medical geography before, linking other diseases to potential causes (Yeshiwondim et al. 2009, 1-11).

As a modeling tool, GWR allows for higher reliability than conventional square regression models in cases where observations display high amounts of variability, such
as demographic data (Fotheringham, 2002). Conversely, when using data that does not vary greatly across the study area, a different model may be needed. Additionally, GWR is advantageous when using non-stationary data.

To better appreciate the advantage of using GWR, OLS can be used first to explore the global trends of the relationship between the dependent and independent variables. The OLS will provide an output detailing collinearity, model significance, residuals, and other statistics. It is also useful in determining where additional variables may need to be included or removed.

The residual map that the OLS generates shows where the global model over or underestimates the dependent variable. These residuals can be used to provide clues as to what may need to be included. For example, if the model were consistently underestimating in populated regions, it may indicate that another demographic factor needs to be included in the study.

When the necessary conditions of the OLS model are met, a GWR can be used. After the analysis is performed, a number of results are generated by the GWR tool, including local $R^2$, residuals (both regular and standardized), conditionality, intercepts, and errors. An important result of GWR analysis lies in the coefficients for each independent variable in the analysis, which shows how each independent variable affects the dependent variable. These coefficients can be positive or negative, implying that an increase of one unit of the independent variable will result in an increase or decrease in the dependent by the coefficient’s amount.
Collinearity

A common error that arises from the use of GWR is that if multicollinearity exists among the modeled variables. Multicollinearity between independent variables occurs when multiple variables strongly correlate with each other, as such, including collinear variables in the analysis offers no further explanatory power (Wheeler and Tiefelsdorf 2005, 161-187). A global OLS model can be used to determine which variables may be highly correlated with one another by calculating a statistic known as the variance inflation factor (ViF) for each variable. There is no official set number that is used to determine whether a variable is collinear or not, however, a good rule of thumb is that any number with a ViF greater than 7.5 is collinear (Wheeler and Tiefelsdorf 2005, 161-187). There are a number of remedies for multicollinearity, one of which being the use of z-scores for data input. Using the z-scores allows for comparisons to be made between many variables with differing numeric ranges. In the case of this study, variables differ from as little as a narrow range of PM2.5 values to changes in thousands of dollars for the income variable in each grid cell.

I averaged and analyzed all relevant factors (admissions, demographic, and environmental variables) by meteorological season so that the temporal effects of the differing independent variables could be measured. In this way I could examine the relative magnitudes of each variable in different portions of the year. Environmental factors are especially important in this regard, considering that weather patterns vary
throughout the year, and each physical variable may behave differently during these times. The seasons used in this study are defined in Table 3.2.

<table>
<thead>
<tr>
<th>Season</th>
<th>Definition</th>
</tr>
</thead>
<tbody>
<tr>
<td>Winter</td>
<td>December – February</td>
</tr>
<tr>
<td>Spring</td>
<td>March – May</td>
</tr>
<tr>
<td>Summer</td>
<td>June – August</td>
</tr>
<tr>
<td>Autumn</td>
<td>September - November</td>
</tr>
</tbody>
</table>

Originally, I considered including male and female populations as two independent variables for analysis. These two variables in Mississippi were highly collinear, displaying ViFs in excess of 450, so I excluded gender from this analysis. This collinearity arises from the fact that the total population of each grid cell can only consist of males and females. When the number of males compared to the total population in a cell is low, the number of females MUST be high, and vice versa. The use of these factors in addition to age (which is typically more indicative of asthma prevalence) is somewhat misleading; I could not obtain total numbers of males and females within certain age brackets.

White and minority populations showed similar trends in multicollinearity. Following the work of Flores et al. 2009, 392-398, Lintonjua et al., 1999: 394-401, and Miller, 2000: 428-430, who suggest that asthmatic hospital admissions may be affected by differences between white and minority populations, I created a new minority field by subtracting the white population from the total in each grid cell. OLS tests confirmed collinearity between the white population and the newly created variable, so the white
variable was excluded from the analysis due to previous literature stating asthma is typically more prevalent in minority populations (Flores et al. 2009, 392-398), (Lintonjua et al., 1999: 394-401), and (Miller, 2000: 428-430).

Lastly, temperature and dewpoint exhibited somewhat high amounts of collinearity (ViFs ~ 20). These correlations exist due to the presence of the Gulf of Mexico, which lends a moderating effect to the region’s climate. Temperatures and dewpoints near the coast do not vary greatly from each other in the same manner as they do further north. Collinearity still existed after converting the averaged temperatures and dewpoints to z-scores so temperature was eliminated from the analysis, because previous studies (Carey and Cordon, 1986: 843-844) (Mireku et al., 2009: 220 – 224) (Wang and Yousef, 2007: 839-841) link dewpoint more strongly with asthma prevalence.

After reducing the number of initial variables from the study, OLS tests resulted in significant models that would successfully run in GWR. The collinearity between my independent variables made it impossible to include every factor I initially wanted. The final list of used variables can be found below in Table 3.3.

<table>
<thead>
<tr>
<th>Socioeconomic Factors</th>
<th>Environmental Factors</th>
</tr>
</thead>
<tbody>
<tr>
<td>Minority Population (Percentage)</td>
<td>Dewpoint (ºF)</td>
</tr>
<tr>
<td>Age (0 – 15 years) (Percentage)</td>
<td>Precipitation (Inches)</td>
</tr>
<tr>
<td>Income ($)</td>
<td>PM2.5 (µg/m³)</td>
</tr>
</tbody>
</table>

Defining Urban Regions

After running the GWR model, I needed to narrow my study area to the regions I needed to study; urban areas. The first step in analyzing my data by urban counties was
to determine which counties were urban, and which were rural. The United States Census Bureau defines an urban county as one containing greater than 50,000 persons living within it (US Census, 2011). Using this definition, there are twelve urban counties within the state of Mississippi.

After determining which counties were urban, the next step was determining which grid cells fell within these counties. Grid cells which had their centroid within an urban county were determined to be within the county. Using this method, I obtained the number of urban grid cells, at 204. Figure 3.2 depicts the cells designated as urban or rural. An attribute was added to the grid shapefile, with a value of one being an urban cell, and a value of zero being a rural cell. With this new shapefile, the urban map was then multiplied with the resulting analysis maps, eliminating the rural cells, and leaving only the urban. From this it was possible to see how local $R^2$ values compared to the higher population areas of the state.
Figure 3.2 - Urban counties in Mississippi
Concluding Remarks

GWR was used in this project because this type of analysis is useful in assisting the identification of detail and localized trends between explanatory variables and the dependent variable. In addition, it has not been used to analyze asthmatic hospital admissions in Mississippi before so it can be a valuable test of how suitable such analysis is for such topics. The data largely supports its use; data throughout the state should vary, as the entire region is large and would not be uniform, both demographically and environmentally. The population is centered most heavily on a few major urban centers, and the climate varies from the Gulf Coast in the south to the somewhat higher, elevated regions in the north. Because the focus of this study is on urban areas within the state, localized results such as those obtained through GWR are vital; a global model would not provided the detail necessary.

The following chapter presents the results of the GWR analysis. I present maps detailing the distributions of various independent variables, hospital admissions, and statistical data used in this project. Each variable’s effects on asthmatic hospital admissions are presented for each season, and discussed where appropriate.
CHAPTER 4

ANALYSIS

In the previous chapter I indicated data sources and methodologies used in this project. Averaging all of the admissions, demographic and environmental variables by season gives an impression of patterns of severe asthmatic prevalence changes throughout the year. It is possible to observe local trends in the disease’s response to each variable by using GWR. It was necessary for me to convert each variable to a z-score so that the numerical variables with highly differing ranges could be compared using GWR.

Here I introduce the findings of the GWR analysis. I ran the analytical models using all of the variables listed in Table 3.3 of the Data and Methods chapter for each season of the year, and clipped the results to only show urban counties. The following maps reveal how the coefficients for each independent variable differ across the study area in each season. Because the variables had widely differing ranges, it was impractical to use a single classification scheme for the entire analysis. Using a single, somewhat wide classification scheme would have caused local variation for some coefficients to be generalized out. In an effort to keep each set of maps consistent with each other, classification schemes have been devised on a per-variable basis.

As a result of the variable conversions to z-scores before the analysis, the results of the GWR models may seem slightly different than what would normally be displayed.
The coefficients that were derived from the various model runs predict the amount of change in the dependent variable given a change of one unit in the z-score of the independent variable. That is to say, an increase of one standard deviation in the independent variable will produce \( x \) change of the standard deviation in the dependent variable. For ease of analysis, the various standard deviations, in their original data units, of the independent and dependent variables are presented below in Tables 4.1 and 4.2.

<table>
<thead>
<tr>
<th>Table 4.1 – Standard deviations of the demographic data</th>
</tr>
</thead>
<tbody>
<tr>
<td>Variable</td>
</tr>
<tr>
<td>Standard Deviation</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Table 4.2 – Standard deviations of the environmental data and admissions, classified by season</th>
</tr>
</thead>
<tbody>
<tr>
<td>Season</td>
</tr>
<tr>
<td>Spring</td>
</tr>
<tr>
<td>Summer</td>
</tr>
<tr>
<td>Fall</td>
</tr>
<tr>
<td>Winter</td>
</tr>
</tbody>
</table>

As stated in the Data and Methods Chapter, the diagnostic tools for GWR are relatively poor. I obtained the p-values of each independent variable using OLS regression to see which are statistically significant in which season. This was necessary because GWR is based upon the same principles as OLS, and statistical significance in an OLS should be applicable in a GWR. The only caveat is that GWR is supposed to be an improvement over global models, so there may be additional significant variables at the local level that are not observable at this time. Table 4.3 shows the p-values for each variable in each season using an OLS.
Table 4.3 – P-values for each independent variable in each season using an OLS. Bolded values indicate statistical significance at the $\alpha=0.05$ level.

<table>
<thead>
<tr>
<th></th>
<th>Youth</th>
<th>Minority</th>
<th>Income</th>
<th>Dewpoint</th>
<th>Precipitation</th>
<th>PM2.5</th>
</tr>
</thead>
<tbody>
<tr>
<td>Spring</td>
<td>0.49539</td>
<td><strong>0.02089</strong></td>
<td>0.36813</td>
<td><strong>0.00949</strong></td>
<td>0.50723</td>
<td>0.96042</td>
</tr>
<tr>
<td>Summer</td>
<td>0.11147</td>
<td>0.89388</td>
<td>0.60551</td>
<td>0.17685</td>
<td><strong>0.03346</strong></td>
<td>0.34766</td>
</tr>
<tr>
<td>Fall</td>
<td><strong>0.03042</strong></td>
<td><strong>0.03022</strong></td>
<td>0.14557</td>
<td>0.08942</td>
<td>0.54912</td>
<td><strong>0.00452</strong></td>
</tr>
<tr>
<td>Winter</td>
<td><strong>0.03827</strong></td>
<td>0.94006</td>
<td>0.15690</td>
<td><strong>0.03258</strong></td>
<td><strong>0.00835</strong></td>
<td><strong>0.00333</strong></td>
</tr>
</tbody>
</table>

For clarity and ease of comparison, I am including another copy of the map detailing the locations of the urban counties within the state (Figure 4.1). Please refer to this map any time I refer to a certain county or region of the study area. I did not label counties on each individual GWR coefficient map because it appeared to clutter the image, and inhibited showing some of my findings.
Figure 4.1 – Urban counties in Mississippi as defined by the U.S. Census Bureau.
Figure 4.2 depicts the urban minority population percentages across the entire study area. The highest concentrations of minority populations are located in northern Rankin County, southwestern Lowndes County, and northwestern Washington County. The southeastern regions of the state have fairly low numbers of minorities aside from one cell in southeastern Jackson County.
Figure 4.2 – Urban minority populations within the state as a percentage of the total population.
Figure 4.3 shows the distribution of the urban youth population percentages across the state. Much of the state has high percentages of youth in urban counties. Highest concentrations of this variable are located in northern Rankin County, northern Washington County, northwest Lowndes County, and northern Desoto County. The rest of the state tends to have youth populations between the ranges of 17-23%, except Lauderdale County, which has slightly fewer younger people.
Figure 4.3 – Youth population distributions within the state as a percentage of the total population.
Median household income distributions are shown in Figure 4.4. The highest incomes in the state are found in southern Rankin County/northern Madison County, where the state’s capital and largest city Jackson is located. Incomes are also relatively high in DeSoto County in the north. The lowest income region is Washington County in the west. The Gulf Coast counties have somewhat higher incomes than other urban counties in the state.
Figure 4.4 – Median Household Income for the entire study area
Figures 4.5 – 4.8 depict the normalized asthmatic hospital admissions for each season. Washington County in western Mississippi has two cells with very high numbers of hospitalization cases; one being in the northeastern portion of the county, and one in the west-southwest. In spring and winter, admissions are somewhat higher in the capital city region (Hinds, Madison, and Rankin counties). Forrest County has one cell in the winter months that shows somewhat elevated hospitalizations. For the rest of the state in all seasons, asthmatic hospital admissions remain fairly low, ranging between 0 – 25 for most cells.
Figure 4.5 – Monthly hospitalization data per 1,000 people for spring
Figure 4.6 – Monthly hospitalization data per 1,000 people for summer
Figure 4.7 – Monthly hospitalization data per 1,000 people for fall
Figure 4.8 – Monthly hospitalization data per 1,000 people for winter
GWR output provides a table that depicts a number of relevant variables to the analysis, including $R^2$, Adjusted $R^2$, Bandwidth, Effective Number, Akaike Information Criterion (AiCC), and Residual Squares. The adjusted $R^2$ is a value that signifies overall model explanatory power. The adjusted $R^2$ is presented for the model for each season in Table 4.4 below.

<table>
<thead>
<tr>
<th>Season</th>
<th>Adjusted $R^2$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Spring</td>
<td>0.0763</td>
</tr>
<tr>
<td>Summer</td>
<td>0.0815</td>
</tr>
<tr>
<td>Fall</td>
<td>0.1084</td>
</tr>
<tr>
<td>Winter</td>
<td>0.0929</td>
</tr>
</tbody>
</table>

Youth

Figures 4.9 – 4.12 display the results of the GWR analysis for the youth coefficient across all seasons. Figure 4.13 is a four-pane image of all of the seasons' results for this variable. Referring to Table 4.3, the youth variable was statistically significant in fall and winter.
Figure 4.9 – Map of spring GWR coefficients for the youth variable.
Figure 4.10 – Map of summer GWR coefficients for the youth variable.
Figure 4.11 – Map of fall GWR coefficients for the youth variable.
Figure 4.12 – Map of winter GWR coefficients for the youth variable.
Figure 4.13 – Four-pane map showing the GWR coefficients for the youth variable for each season. Values for each map are equivalent to those in Figures 4.8 – 4.11.
Higher youth populations in the central region of the state are associated with higher numbers of asthmatic hospital admissions in all seasons. Admissions are also positively related in every season except for spring for the southeastern portion of the state; however, these increases are lesser in degree in other regions than in the central regions. In spring (Figure 4.9), admissions in the southeast are negatively associated with elevated youth population. During the same season in the northeastern portion of the state (Lee and Lowndes counties), admissions decrease with higher percentages of youths. Finally, admissions are virtually unaffected by youth population percentage in the northwestern portion of the state (Desoto County).

Minority

Figures 4.14-4.17 display the results of the GWR analysis for the minority coefficient. A four-pane map of coefficients for all seasons is displayed in Figure 4.18. Minority status was statistically significant in spring and fall.
Figure 4.14 - Map of spring GWR coefficients for the minority variable.
Figure 4.15 - Map of summer GWR coefficients for the minority variable.
Figure 4.16 - Map of fall GWR coefficients for the minority variable.
Figure 4.17 - Map of winter GWR coefficients for the minority variable.
Figure 4.18 - Four-pane map showing the GWR coefficients for the minority variable for each season. Values for each map are equivalent to those in Figures 4.14 – 4.17.
Throughout the study period, Washington County in western Mississippi is a region with negative relationships between minorities and hospital admissions in contrast to other portions of the state. Besides Washington County, the remaining urban areas in spring (Figure 4.14) have positively related coefficients between minority populations and asthmatic hospital admissions. The highest relationships are in Rankin County at 0.1913.

Summertime (Figure 4.15) reveals a general weakening in the relationships between minorities and hospital admissions. The highest magnitude of increases exists in Jones County at 0.1451. For the other counties in the study area, except Washington County, minority population percentage is associated with only a slight increase to admissions, or relatively little effect in western Hinds County, and northwestern Madison.

Relationships between minority population and asthmatic hospital admissions in fall (Figure 4.16) are similar to those in summer. Most of the state only exhibits slight positive relationships between hospital admissions and increasing minority populations. The highest relationship is 0.1102. Admissions increase with minority populations in the southern, eastern, and northern areas of the state, but decrease in the west.

The southeastern portion of the state contains the highest increases of hospital admissions \textit{vs.} minority population percentages in winter (Figure 4.17). Relationships in the Gulf Coast region are slightly lower, and admissions decrease further north in the state.
Reasons for the changes in hospital admissions with minority population are difficult to ascertain. Definitive causes for severe asthmatic symptoms are not entirely understood in general, and transferring these causes to different races is difficult. Analyzing a different aspect of minority population, such as relative access to medical care may be a more telling cause of hospital admission increase or decrease, however this data was not available for this research.

Income

Figures 4.19 – 4.22 display the results of the GWR analysis for the income coefficient. A four-pane map of income coefficients across all four seasons is presented in Figure 4.23. Income was not found to be statistically significant in any season throughout the study period.
Figure 4.19 - Map of spring GWR coefficients for the income variable.
Figure 4.20 - Map of summer GWR coefficients for the income variable.
Figure 4.21 - Map of fall GWR coefficients for the income variable.
Figure 4.22 - Map of winter GWR coefficients for the income variable.
Figure 4.23 - Four-pane map showing the GWR coefficients for the income variable for each season. Values for each map are equivalent to those in Figures 4.19 – 4.22.
Along the Gulf Coast, near Biloxi, Pascagoula, and Gulfport, relationships between income and hospital admissions are negative, implying that having higher income in these areas may decrease the likelihood of being admitted to a hospital for asthma. This region of the state is heavily steeped in two industries, gambling and manufacturing. In fact, the state’s largest employer, Ingall’s Shipbuilding, is based out of Gulfport. In this area, the reason that having higher income levels might result in lower admissions stems from the fact that those with less money would have a tendency to be involved in relatively dangerous manufacturing work or less well maintained housing units. In these industries, workers are often exposed to harmful inhalants, as well as being exposed to body-stressing work environments.

The central regions of the state exhibit increased admissions with increasing income in the spring months (Figure 4.19). The areas of highest admission increase are located in the western portions of Hinds and Madison counties and in Lee County in the west. Desoto County in the north also shows elevated hospital admissions with increased income. Lee County in the northeast exhibits virtually zero increase or decrease in admissions compared to income changes.

There are large areas in the central regions of the state in summer (Figure 4.22) and fall (Figure 4.21) that exhibit very little change in hospital admissions as related to income levels. In both of these seasons, Desoto County in the northern region of the state exhibits somewhat strongly increased admissions with increasing income. The major difference between the two seasons is that Washington County becomes very strongly associated with increased hospital admissions with higher income in the fall months as
opposed to the summer, where admissions are virtually unaffected in the majority of the county.

Asthmatic hospital admission patterns in the winter months (Figure 4.22) vary more than those in the other seasons in the year. Relationships between admissions and income in the southeastern portion of the county are somewhat stronger in wintertime than in the other seasons. Admission coefficients remain positive in the central and western regions of the state, and slightly negative in the northeast.

As stated previously, $7,581 is required to increase the standard deviation of the income variable by one. The maximum positive value observed for this variable (0.1568) is in spring. The low amount of observable change combined with the high income level needed to increase or decrease admissions imply that income by itself is not a very significant factor in this study region. This is reinforced by the lack of statistical significance for this variable in any season.

Dewpoint

Figures 4.24-4.27 display the results of the GWR analysis for the dewpoint coefficients. A four-pane map of income coefficients across all four seasons is presented in Figure 4.28. Dewpoint was statistically significant for this region in the spring and winter months.
Figure 4.24 - Map of spring GWR coefficients for the dewpoint variable.
Figure 4.25 - Map of summer GWR coefficients for the dewpoint variable.
Figure 4.26 - Map of fall GWR coefficients for the dewpoint variable.
Figure 4.27 - Map of winter GWR coefficients for the dewpoint variable.
Figure 4.28 - Four-pane map showing the GWR coefficients for the dewpoint variable for each season. Values for each map are equivalent to those in Figures 4.24 – 4.27.
Dewpoint is particularly important for this study in the northern and central portions of the state. The northern areas of Mississippi are heavily forested, and dewpoint can have a profound effect on plantlife in this area. Especially in fall (Figure 4.26), higher dewpoints can contribute to the growth of molds and fungi, which have been shown to be triggers of asthmatic symptoms (Allen et al., 2008: 423-433, Kaminsky et al., 2000:179 -186). In the autumn months, fallen leaves combined with high dewpoints provide ideal breeding grounds for various airborne molds and fungi, which are a common irritant in the region. This is reflected in the summer (Figure 4.25) and fall months of the study, where coefficients appear to be fairly high in the northern portions of the state. Considering that this study focuses on urban counties, mold and fungus distributions may not be as high in some of the urban areas as compared to the rural areas; however, their effects can still be observed.

In spring (Figure 4.24), dewpoint for most of the state tends to be related to increased hospital admissions, with the highest incidents located in the northern regions. The northern areas of the state are primarily forest, and higher dewpoints will have effects on the flowering and blooming of both plantlife and fungi. In times of low water availability in the spring months, pollen and molds may not be able to flourish as readily as they would in wetter months, which may be a reason for these higher coefficients.

In the winter months (Figure 4.27), all urban counties in the state are inversely related between dewpoint and hospital admissions. In Lee and Desoto counties in the northern portions of the state, associations remain near zero. Cold, dry air is often cited as an asthma trigger (Mireku et al., 2009: 220-224). Cold, dry air causes the body to
increase mucus production, which inhibits airflow into the lungs. Increasing the amount of water content in cold air makes it easier to breathe, and results in fewer instances of severe asthma (Mireku et al., 2009: 220-224). Wetter winters, should in theory, reduce asthmatic admissions as supported by this analysis.

Precipitation

Figures 4.29-4.32 display the results of the GWR analysis for the precipitation coefficient. Figure 4.33 is a four-pane map depicting the previous four figures for ease of comparison. Statistical significance for precipitation was noted in summer and winter.
Figure 4.29 - Map of spring GWR coefficients for the precipitation variable.
Figure 4.30 - Map of summer GWR coefficients for the precipitation variable.
Figure 4.31 - Map of fall GWR coefficients for the precipitation variable.
Figure 4.32 - Map of winter GWR coefficients for the precipitation variable.
Figure 4.33 - Four-pane map showing the GWR coefficients for the precipitation variable for each season. Values for each map are equivalent to those in Figures 4.29 – 4.32.
In summer (Figure 4.30), the most negative coefficients as related to hospital admissions are observed at -1.9548 in Washington County. Precipitation in this season is especially important, because precipitation is an indicator of air stagnation. When air is highly stagnant and upward convective movement is not possible, precipitation values tend to be low. Stagnant air has been cited as a cause of asthmatic symptoms (Laden et al. 2007: 941 – 947). When precipitation values are higher, the air is typically less stagnant, and asthma may be less prevalent. In the summertime months in this region of the United States, persistent regions of high upper air pressure oftentimes exist, which restrict the amount of upward movement that air can take. During the other seasons, these air masses do not typically exist, which is reflected in the lesser magnitudes of coefficients for the other seasons.

Besides Washington County, coefficients for the rest of the state are generally contained within the range of -0.15 to 0.15. It does not appear that precipitation has much effect on admissions in the rest of the study area for this time. The rest of the state is highly forested as opposed to Washington County, which is comprised of corn cropland. Cropland has a tendency to erode and eject particulate matter (both fine and coarse) more readily than forested areas. Drier conditions may increase the amount of windborne particulate matter. Elevated precipitation levels may be a potential cause of the highly negative relationships in Washington County as opposed to the rest of the state.

Coefficients in the autumnal months (Figure 4.31) seem to follow the similar patterns observed in the spring and summer seasons. Relationships between precipitation
and admissions tend to remain between the -0.15 and 0.15 ranges. Only in Washington County do associations increase beyond 0.15.

In winter (Figure 4.32), coefficients appear to behave much differently than in the other seasons. The entire central and southern portions of the state exhibit slightly positive relationships between precipitation and asthmatic hospital admissions, with Washington County again being the location of the highest values (1.00).

**PM2.5**

Figures 4.34-4.37 display the results of the GWR analysis for the PM2.5 coefficient. Figure 4.38 is a four-pane image of all of the seasons’ results for this variable. Statistical significance for fine particulate matter was observed in fall and winter.
Figure 4.34 - Map of spring GWR coefficients for the PM2.5 variable.
Figure 4.35 - Map of summer GWR coefficients for the PM2.5 variable.
Figure 4.36 - Map of fall GWR coefficients for the PM2.5 variable.
Figure 4.37 - Map of winter GWR coefficients for the PM2.5 variable.
Figure 4.38 - Four-pane map showing the GWR coefficients for the PM2.5 variable for each season. Values for each map are equivalent to those in Figures 4.34 – 4.37.
In the spring months of this study (Figure 4.34), PM2.5’s affects on asthmatic hospital admissions hover near the zero point, never surpassing 0.1532 and never going any lower than -0.1114. Areas of positive and negative associations are mixed throughout the state, indicating no overarching pattern between this variable and admissions in this study period.

In summer (Figure 4.35), relationships are highly negative in the central regions of the state. Coefficient values increase farther north and south from the central region, and reach their maximum in Lee County. Washington County experiences a sharp transition from south to north in coefficient values (from -0.6330 in the south to 0.2336 in the north). This drastic change is not observed anywhere else in the state, and the land cover of this county does not change from north to south either. The land upwind of the county is the same; cultivated crops. It is difficult to theorize as to why the associations between PM2.5 and asthmatic hospital admissions change so dramatically in this area.

In fall (Figure 4.36) and winter (Figure 4.37), coefficients for asthmatic hospital admissions as related to PM2.5 have a largely negative showing across the entire study area. Considering that PM2.5 is an indicator of air pollution, a known cause of asthmatic symptoms, this is a somewhat puzzling outcome of the study.

A possible reason for these results lies in the resolution of the measured PM2.5 fields. Concentrations of air pollutants can change at very low scales depending on source areas, wind direction and speed, temperature, dewpoint, and other factors. For this project, I was only able to obtain PM2.5 at a fairly coarse resolution, and smaller pockets of admission increases or decreases may be occurring in regions with relatively little
change in air pollution concentrations. If a finer resolution in particulate matter were available the results may differ, however they were not available for this study area during this time period.

In the next chapter of this thesis, I will review some of the general findings and implications of this project. I will reiterate the overall hypotheses, methodologies, and results of the analysis. In addition I will discuss the limitations of this work as well as potential future research.
CHAPTER 5

CONCLUSIONS/DISCUSSION

In the previous chapter, I presented the results of the GWR analysis, and provided explanations of trends where applicable. It is difficult to explain the reasons why asthmatic hospital admissions exhibited positive or negative relationships with the independent variables, due to how little about asthma is currently known. However, this thesis provides some insight into the relationships between various independent variables and asthma using a method that has not been previously applied. It is impossible to theorize on why some of the trends’ behaviors considering how little we know about asthma. However, a number of observable patterns are made apparent:

• Youth associations with hospital admissions are greatest in the central and western portions of the state. Minor increases in hospital admissions with youth are also found in the southeastern regions.

• The greatest relationships between minorities and hospital admissions are typically found in the southern and central regions of the state. Conversely, Washington County in the west has negatively associated coefficients.
• Income has a very minimal impact on asthmatic hospital admissions considering that it was never statistically significant in any season, and changing the amount of income necessary to affect admissions is very high.

• Dewpoints have varying effects on asthmatic hospital admissions, however relationships between dewpoint and admissions in winter are all negative, agreeing with previous literature.

• The majority of precipitation’s relationships with asthmatic hospital admissions are largely minor, rarely being outside the range of -0.15 – 0.15.

• PM2.5 tends to have a low impact on asthmatic hospital admissions, and even has largely negative relationships with hospital admissions in fall and winter.

Limitations

With any project, there will be limitations with data, analytic techniques, and results. I tried to reduce the number of limitations encountered with this research, but some were unavoidable. Ideally, if more was known about asthma, then it would be possible to include more variables in my analysis. I tried to include independent variables that have been determined to have the greatest effects on asthma in other regions to see which ones had the most impact in my study area. There are other independent variables that could have been included in this analysis, but using the most prominent factors from other regions should have provided the greatest explanatory power. In this case, the explanatory power was quite limited.
Another limiting factor from this analysis was the resolution of the grid cell structure on which it was based. The 10km x 10km grid is relatively coarse when using certain variables that can be mapped at smaller scales, for example demographic data at block levels. However, the admission and PM2.5 data was from the period of 2003 – 2005, and more refined measurements from this time period were not available. This is somewhat offset with the inclusion of environmental data in the analysis. Temperature, dewpoint, and precipitation are not generally measured on a scale that fine. With improved monitoring techniques and instrumentation, better approximations for these environmental variables are possible, and the results of this analysis may change.

Lastly, the time period in which I analyzed my data has some limitations as compared to previous literature. Historically, asthma has been analyzed on a smaller time scale, especially with regards to environmental variables. Asthma is usually studied in terms of observing spikes in admissions days after some meteorological anomaly, such as a period of increased rainfall, higher temperatures, or increased PM2.5 counts (Laden et al., 2000, 941-947, Chavarría 2001, Chan et al., 2009). By analyzing asthma on a monthly scale, my research does not take these spikes into account. Future work in this region should take smaller time scales in relation to asthma triggers into account.

Youth populations exhibited varying associations with asthmatic hospital admissions. Youth populations are high in Washington County, where asthmatic hospital admissions are the highest in every season. These results agree with those of other studies linking severe asthma to younger populations, (Flores et al., 2009: 392-398) (Kälvesten and Bråbäck, 2009: 454-458) (Majkowska-Wojciechowska et al., 2007: 1044-
Negative relationships between youth population percentage and asthmatic hospital admissions were observed in every season in various regions of the state, which typically hasn’t been observed in previous research.

Minority percentage in this region had varying relationships with hospital admissions. The locations of increased and decreased associations with hospital admissions varied throughout the state, and varied throughout each season. Traditionally, studies have shown that increased percentages of minority populations correspond with increased asthmatic hospital admissions (Flores et al., 2009: 392-398, Litonjua et al., 1999: 394-401, Miller, 2000: 428-430), however the reasons for these increased admissions is not well-understood. Further analysis is needed in this region as we continue to discover the triggers of asthmatic symptoms within the various population groups.

Socioeconomic status was shown to have very limited relationships with severe asthma in this region. The amount of income needed to change the associations with asthma was rather high, and thus any associations observed would be very limited. In addition, the lack of any sort of statistical significance of income as related to hospital admissions reinforces the lack of influence that income has in this region. Other studies (Cope et al., 2008: 745-752; Kozyrskyj et al., 2010: 540-546; Miller, 2000: 428-430) have shown that socioeconomic status may be a secondary factor in asthmatic prevalence (through housing quality, medical care access, etc.). In my study, income levels did not have strong associations with asthmatic admissions directly, however other factors
related to income, such as accessibility to medical care may be more effective in predicting asthmatic prevalence.

Dewpoint’s associations with asthmatic hospital admissions seem to correspond well to findings in previous literature. Higher dewpoints in the winter months were universally related to reduced hospital admissions (Kaminsky et al., 2000: 179-186). Moister air is easier to breathe, and severe asthma cases are likely to be reduced in times of wetter winters.

Additionally, higher dewpoints in summer months correspond with increased admissions in the northern forested areas of the state. This finding is consistent with previous research which found that increased moisture in forested areas tends to promote the growth of fungi and allergenic molds, which may be the case in this study area.

Precipitation had relatively low associations with asthmatic hospital admissions in all seasons. Relationships between precipitation and asthmatic activity have not been shown to be uniform throughout the world, with low precipitation being linked to increased admissions in the northeastern United States (Wang and Yousef 2007, 839-841), and precipitation being independent of admissions in Caribbean nations (Carey and Cordon, 1986: 843-844). My results show that other variables besides precipitation may have stronger links with severe asthma in Mississippi.

PM2.5 did not associate with asthmatic hospital admissions in the manner that was initially predicted. Higher levels of fine particulate matter were related to reduced admissions throughout the study area, contrary to what has been found in a number of previously cited studies (Allen et al., 2008: 423-433), (Chan et al., 2009: 64-74), (Jerrett
et al., 2008: 1433-1438). However, it has also been shown that coarse particulate matter may be a more effective determinant of severe asthma in some cases (Lin et al., 2002: 575-581). These confictions indicate the need for additional research, and the associations between air pollution and asthma in this area may not be readily observable in a spatial context.

Future Research

Considering the fairly low overall explanatory power of the research presented, there is a vast amount of potential future research possible. Our understanding of asthma is improving with each passing year, and associated variables and triggers for the disease are being examined. It will be possible to include new spatially occurring variables in future models to further our understanding of this illness.

Future research might also focus on several of the individual fine particulate matters instead of using one variable for all of them. Studies cited in the literature review focused on several combusted gases, such as NO$_2$, O$_3$, and SO$_2$. Examining these individual gases in this region may give more insight as to what may be influencing asthma the greatest. Knowing these may lead to better preventative measures in the future.

This research can be useful in implementing strategies or policies to reduce the effects of asthma triggers in the future. For example, specialized weather monitoring could be more widely used in Mississippi to prepare asthmatics for high risks days.
Creating outreach programs for asthmatic sufferers could help in controlling symptoms, and spreading awareness of the disease. Building codes could be revised and updated to ensure housing and workplaces are well-built and have proper ventilation. These are just a few of the strategies that could be implemented to reduce asthmatic symptoms in the population.

My main goal of this thesis was to address the influence of my chosen independent variables on asthmatic hospital admissions. I was able to present numerous trends between my independent and dependent variables in my study region. Millions in the United States and other countries suffer from asthma, and understanding what triggers it will help people prevent and cope with asthmatic response. This project can be used as a stepping stone for further research into a disease which is understudied in this region of the country.


