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The Relationship Between Climate Social Vulnerability and Asthma

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THE RELATIONSHIP BETWEEN CLIMATE SOCIAL VULNERABILITY AND ASTHMA

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ABSTRACT

Asthma is a chronic respiratory disease that affects millions of people worldwide, the incidence and severity of asthma is influenced influenced by various factors, including air masses, and weather conditions. Asthma can also disproportionately affect different sociodemographics groups, leading to inequalities and injustices. This study used statistical analysis and GIS to analyze the spatial distribution of asthma calls and their relationship to sociodemographic traits in Wichita, KS, Tulsa, OK, and Oklahoma City, OK, and the seasonal distribution of asthma calls and their relationship to air masses. Results show that the relationship between asthma prevalence is higher among certain sociodemographic groups, such as those with lower income, and educational attainment, minorities, and young children. The study also found that exposure to certain air masses can correlate to an increase in emergency medical service-related asthma calls. This study provides valuable insight into the complex relationship between asthma, air masses, and sociodemographics and provides a basis for further research and interventions to improve public health.

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I would like to dedicate this work to my parents, brother, sister, nephew, and best friend; you are all my inspiration and motivation in life. To my parents- your hard work and sacrifices throughout my life made me the women I am today. Thank you for your love, support, and encouragement throughout my education. A huge thanks to my committee members: Dr. Richard Lisichenko, Dr. Todd Moore, Dr. Thomas Schafer for making this thesis possible and guiding me through to its completion. I would also like to extend my thanks Dr. Grady Dixon for allowing me to use his data and Dr. Keith Bremer for his guidance and support throughout my thesis process.

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CHAPTER I
INTRODUCTION

1.1 Research Problem

The human-health effects of climate change and variability have long been identified by the scientific community as an issue of concern (IPCC, 2001). Potential effects of climate change include mortality resulting from extreme heat, storms, and poor air quality (Rocque et al, 2021). The average person inhales 20,000 liters of air a day, making it easy to understand that we are in intimate contact with the surrounding atmosphere and therefore susceptible to airborne pollutants (Holgate, et al, 1995). Air pollution is associated with reduction of lung function, exacerbations of asthma, increased risk of respiratory pneumonia, increased hospital admissions, and even deaths in the most severe of cases (Bates, 1999, Anderson, 1999; D'Amato et al, 2015; Lee et al, 2012).

Affecting 26 million Americans, asthma is a chronic disease that can make breathing difficult (CDC, 2021). People with asthma can experience episodes of breathlessness, wheezing, coughing, chest tightness, and other symptoms when airflow is limited (Huang W, 2018). Asthma makes breathing difficult due to airway inflammation. However, the causes of this inflammation are unknown (Gillssen & Paparoupa, 2015). When the airways become inflamed, contraction of airway muscles occurs along with excessive mucus production and swelling of the airways that contribute to breathing difficulties and other asthma symptoms (Schiffman, 2018). An asthma attack can occur when air passages in the lungs become narrow after exposure to a pollutant (D'Amato et al, 2017).

Asthma can affect people of all ages, but certain sociodemographic factors can increase the risk of developing asthma or exacerbating symptoms (Cardet et al, 2018; Bacon et al, 2009). Age can affect people of all ages, but it is more common in children (Cardet et al, 2018; Ellison-Loschmann et al., 2007). Children with asthma may experience severe symptoms and have a higher risk of hospitalization compared to adults with asthma (Bacon et al, 2009; Eagan et al., 2004). Asthma prevalence and severity vary among different racial and ethnic groups (Cardet et al, 2018; Bacon et al, 2009). In the United States, Black and Hispanic individuals have higher rates of asthma compared to White individuals (George et al, 2022; Lugogo et al, 2022). This could be due to various factors, including environmental exposures, genetics, and healthcare disparities (Polosa & Thomson, 2012; Stapleton et al, 2011). People living in poverty or with lower socioeconomic status are more likely to have asthma and experience more severe symptoms (Eguiluz-Gracia et al, 2020). This could be due to factors such as exposure to indoor and outdoor allergens, pollution, and poor housing conditions (Eguiluz-Gracia et al, 2020). Geographical location plays a role in affecting the prevalence of asthma and severity (Nunes et al, 2017; Subbarao et al, 2009). People living in urban areas with high levels of air pollution may have a higher risk of developing asthma or experiencing more severe symptoms (Stapleton et al, 2011). In addition, climate, and weather conditions, such as high humidity or extreme temperatures, can trigger asthma symptoms (D’Amato & Gennaro, 2015; Dabrera et al, 2012).

Most climatological studies take an interest in the association of climate with individual weather variables, meanwhile, daily weather presents itself as a weather phenomenon composed of multiple variables and it is this weather situation which can cause an individual to become predisposed to asthma exacerbations (D’Amato et al, 2017; Gillssen & Paparoupa, 2015). Air masses are large bodies of air that have similar temperature, humidity, and density characteristics, with the help of prevailing winds air masses move around the atmosphere (Schultz et al, 2020; Thomas & Schultz et al, 2019). While known associations exist between asthma and temperature or humidity, the combined effects of temperature, humidity, wind, speed, cloud cover, precipitation, pressure, and other weather variables are unknown. Using air masses to capture numerous of these variables is therefore valuable to our understanding of links between weather and asthma.

The association of individual climatological variables, such as temperature, with climate outcomes, has been well researched, and while this approach can draw meaningful connections between weather and mortality, it can fail to capture the complex effect of interrelated weather factors on the human body (Lee et al, 2012).

Research on the effect of air mass morbidity, emergency rooms visit, and lung deterioration, confirmed a connection between air masses and human health (Hanna et al, 2011; Kurt et al, 2016; Lee et al, 2012). However, there are still several areas that still need to be researched. No studies have been carried out in Kansas and Oklahoma, despite the States of Kansas and Oklahoma being prone to severe weather, especially in the spring and the early summer. Despite the frequent sunshine throughout much of the state, due to their location on a climatic boundary they are prone to intrusions of multiple air masses, making the states vulnerable to strong and severe storms (Booth et al 2006).

The goal of this research is to increase our understanding of asthmatic exacerbations associated with air masses. If air masses lead to an increase in asthmatic suffering, it is directly affecting the quality of life in the cities of Wichita, Kansas, Tulsa, Oklahoma and Oklahoma City, Oklahoma. Assessing this relation will be of use to improve the quality of life in Wichita, Tulsa, and Oklahoma City by informing asthmatics of the risks of certain activities and by analyzing the dangers of air mass intrusions, to better understand how people are affected by climate, air masses and how susceptible they are to the changing climate system.

1.2 Purpose Statement

The purpose of this thesis is to investigate the impact of asthma on different sociodemographics and the relationship between air masses, sociodemographics and asthma calls in Wichita, Oklahoma City, and Tulsa from 2010 to 2015. The objectives and questions guiding this research are:

- Objective 1: Analyze the spatial distribution of asthma calls and their relationship to sociodemographics.
    - Question 1. Is race/ethnicity correlated with asthma calls.

- Question 2. Are children under the age of 5 correlated with asthma calls and are the elder above 65 years correlated with asthma calls.
- Question 3**.** Is educational attainment correlated with asthma calls.
- Question 4. Is lower income below $15,000 and greater than $24,000 correlated with asthma calls. Is middle income between $25,000 and $74,000 correlated with asthma calls. Is upper income between $75,000 and above $200,000 correlated with asthma calls.

- Objective 2: Analyze the seasonal distribution of asthma calls and their relationship to air masses.
    - Question 1. What is the seasonal distribution of asthma calls per region.
    - Question 2. What is the seasonal distribution of air mass types.
    - Question 3**.** What is the seasonal relationship between asthma calls and air mass types.

CHAPTER II

LITERATURE REVIEW

2.1 Introduction

The literature review focuses on the relevance of asthma in the cities of Wichita, Oklahoma City, and Tulsa. The chapter starts with the geography of asthma and how individuals from different sociodemographic backgrounds are affected by asthma prevalence. The next section discusses the dynamics behind air masses and asthma attacks. Importantly, this chapter demonstrates existing gaps regarding air mass and asthma prevalence, despite the well documented links between the two.

2.2 Asthma and Sociodemographics

The ability to link asthma and socio-demographics can provide several benefits, including the improved understanding of disease distribution (Bacon et al., 2009; Erickson et al., 2002). Table 2.1. provides common sociodemographic traits linked to asthma and have been used in other research articles. These variables are commonly used due to their accessibility, and prevalence in other literature such as topics ranging in hazards, injustices, climate, etc. However, it should be noted that this measure cannot fully capture the wide- range of individual level experiences within these geographies. It is important to note that sociodemographic factors are interrelated and can compound one another. For example, low income and poor living conditions can increase the risk of exposure to air pollution, which can exacerbate asthma symptoms (Cardet et al., 2018;

Bacon et al., 2009). Likewise, limited access to healthcare can make it more difficult to manage and treat asthma, which can lead to poor outcomes. By examining the relationship between socio-demographic factors and asthma, researchers can gain a better understanding of how the disease is distributed in different populations, which can inform public health policies and interventions (Bacon et al, 2009; Subbarao et al, 2009). Better identification of high-risk populations can help prioritize resources and interventions to reduce the burden of asthma (Cardet et al, 2018; Nunes et al, 2017; Bacon et al, 2009; Subbarao et al, 2009; Rona, 2000).

2.2.1 Geography of Asthma

Asthma is a chronic respiratory disease that affects individuals of all ages, races, and sociodemographic backgrounds (Cardet et al, 2018; Bacon et al, 2009; Ellison-Loschmann et al, 2007; Eagan et al, 2004). However, research has shown that certain socio-demographic factors such as low income, urban living, and minority race can increase the likelihood of developing asthma and exacerbate symptoms (Nunes et al, 2017; Eagan et al, 2004; Grant et al, 2000). Children from low-income families are more likely to have asthma and experience more severe symptoms due to exposure to environmental triggers such as air pollution and secondhand smoke (Nunes et al, 2017; Subbarao et al, 2009; Rona, 2000). Additionally, people living in urban areas are exposed to higher levels of air pollution which can increase the risk of developing asthma (Bacon et al, 2009; Grant et al, 2000; Rona et al,2000). Efforts to reduce socio-economic disparities in asthma outcomes and access to care are ongoing (Pessôa et al, 2021; Cardet et al, 2018; Melo et al, 2018; Nunes et al, 2017).

Forno et al (2010) found that African American and Hispanic populations in the United States were more likely to have asthma compared to other population groups (Braman , 2006; Rastogi et al, 2006). Many studies have found (Keet et al, 2017; Kurt et al, 2016; Sabit et al, 2012; Ekerljung et al, 2009; Neidell, 2004; Eisner et al, 2000) that individuals from lower income backgrounds were more likely to have asthma, and they experienced more severe symptoms and greater healthcare utilization. Exposure to environmental triggers, such as air pollution and secondhand smoke, was found to be an important contributing factor (Polosa & Thomson, 2012; Stapleton et al, 2011).

Watson et al (2007) found that individuals in Europe from lower socio-economic backgrounds are more likely to have asthma, and that they experience more severe symptoms leading to the rise of hospitalizations. This study found that individuals living in urban areas were more likely to have asthma compared to those living in rural areas, and that exposure to air pollution was a contributing factor (Grant & Wood, 2022; Watson et al, 2007; Braman et al, 2006).

Asthma affects a significant portion of Australia's population, (Cunningham, 2010; Jenkins, et al, 2009; Dawson, 2004). Factors such as exposure to air pollution and allergens, as well as limited access to quality medical care, and linguistic barriers can contribute to the high rates of asthma in these communities (Cunningham, 2010; Jenkins, et al 2009; Dawson, 2004).

2.2.2 Urban and Rural Cities

While asthma can occur in any part of the country, certain cities in the US have a higher prevalence of asthma cases due to environmental factors, pollution, and other triggers asthma (Bacon et al, 2009; Grant et al, 2000; Rona et al,2000). Rural and urban areas differ in various ways, including population density, demographics, environmental factors, and access to healthcare services (Bacon et al, 2009; Grant et al, 2000). For example, according to the New York City Department of Health and Mental Hygiene, asthma affects more than 1 million people in the city (Khan et al, 2021; Garg et al, 2010). The prevalence of asthma is particularly high in certain neighborhoods, such as the South Bronx, where the asthma rate is more than twice the national average (Walters et al, 2021; Khan et al, 2021). Air pollution, poverty, and inadequate access to healthcare are among the factors that contribute to high asthma rates in New York City (Khan et al, 2021; Walters et al, 2021; Garg et al, 2010).

These differences can affect the prevalence and management of asthma in patients. In rural areas, asthma prevalence is generally lower than in urban areas (Grant et al, 2000). This is partly due to the lower levels of pollution and environmental irritants in rural areas, such as traffic-related pollutants and industrial emissions (Bacon et al, 2009). Los Angeles has some of the worst air pollution in the country which can exacerbate asthma symptoms (Wolstein et al, 2010; Flore et al, 2003; Newacheck et al, 2000; AAFA SoCal, 2021). The prevalence of asthma is particularly high in low-income communities and communities of color (Wolstein et al, 2010; AAFA SoCal, 2021).

However, rural areas may have higher levels of indoor allergens, such as mold and dust mites, which can trigger asthma symptoms (Pattaun et al, 2021; Pate et al, 2021; Yu et al, 2013; Cooper et al, 2009). Urban areas have higher levels of pollution and environmental irritants, which can increase the risk of developing asthma and exacerbate existing symptoms (Pate et al, 2021; Yu et al, 2013; Cooper et al, 2009). Urban areas also tend to have a higher prevalence of socioeconomic risk factors, such as poverty and poor housing conditions, which can increase the likelihood of exposure to indoor allergens and other triggers (Pattaun et al, 2021; LaFave, 2020; Corburn et al, 2006). According to the Philadelphia Department of Public Health, asthma is a significant health concern in the city, particularly among children (Stephens et al, 2021; PDPH, 2017; PAAA, 2014). In some neighborhoods, the prevalence of asthma is more than 25%, which is much higher than the national average (LaFave, 2020; PAAA, 2014). Air pollution, poverty, and inadequate access to healthcare are among the factors that contribute to high asthma rates in Philadelphia (Pattaun et al, 2021; LaFave, 2020). Access to healthcare services can also differ between rural and urban areas (PDPH, 2017). In rural areas, there may be limited access to specialized medical care and asthma management resources, such as pulmonary specialists and asthma education programs (Corburn et al, 2006). In urban areas, there may be more access to these resources but also more barriers to access, such as long wait times and transportation issues (Pate et al, 2021; PDPH, 2017; Yu et al, 2013).

TABLE 2.1 : Socio-demographic Census Variables

Socio-demographic Variables	Rational	Sources
White Population	White Americans in the United States are more likely to have higher levels of income and educational attainment than other racial and ethnic groups, which can impact access to healthcare and environmental conditions that affect asthma.	(George et al, 2022), (Tran et al, 2022), (CDC, 2018) (Rozwadowski et al, 2019)
Black Population	According to the Center for Disease Control and Prevention (CDC), approximately 13.8% of African American children have asthma, compared to 7.7% of non-Hispanic white children. African Americans may be more likely to have a genetic predisposition to asthma, which can increase the likelihood of developing the condition.	(Correra-Agudelo et al, 2022), (George et al, 2022), (Lugogo et al, 2022), (Martin et al, 2 009)
Hispanic Population	Asthma prevalence is higher among Hispanic children and adults compared to non-Hispanic whites. Hispanics in the United States are more likely to live in poverty and have lower levels of educational attainment than non-Hispanic whites, which can impact access to healthcare and environmental conditions that affect asthma. Language barriers can make it difficult for Hispanics to access healthcare and asthma	(George et al, 2022), (Lugogo et al, 2022), (Llabre et al, 2017), (Washington et al, 2017), (Luz et al, 2006)

	management resources. Lack of access to information in Spanish can also be a barrier to managing asthma and accessing appropriate care.	
Education Attainment	Multiple studies have found that individuals with lower levels of education are more likely to have asthma than those with higher levels of education. Due to a lack of knowledge about asthma, poor understanding of asthma medication and many other factors.	(Cardet et al,2022), (Grant et al, 2022), (Li et al, 2021), (Pedersen, 2016)
Age < 5	Asthma is one of the most common chronic conditions in children in the United States, affecting an estimated 6.2 million children under the age of 18.	(Serebrisky & Wiznia, 2019), (Ferrante & La Grutta, 2018), (Akinbami et al, 2009)
Age > 65	As we age, our lung function naturally declines, and this can make it more difficult to manage asthma symptoms. Older adults may experience decreased lung capacity, reduced respiratory muscle strength, and decreased elasticity of lung tissue.	(Busse et al, 2020), (Nanda et al., 2018), (Battaglia et al, 2016), (Winer et al, 2012)
Upper Income	Upper income populations have access to healthcare, medication, and they tend to live in less densely populated areas.	(Grant et al, 2022), (Suri et al, 2022), (Janson et al, 2007)

Lower Income	People with lower incomes often live in places with higher concentrations of environmental asthma triggers. They may not have access to health care and are unable to receive the medical attention they may need.	(Grant et al, 2022), (Cadet et al, 2018), (Zahran et al, 2018), (Nurmagambetov et al, 2017)

2.3 Asthma and Climate

The link between climate and health is not a new concept; it is something that has long been known and studied by ancient civilizations like the Greeks, Romans, Egyptians, and Chinese. Nearly 2,500 years ago in an essay titled " *On Airs, Waters, and Places*", Hippocrates advised traveling physicians to "consider the seasons of the year, and what effect each of them produces." He went on to present the health implications of "the winds, the hot, and the cold," "the qualities of the waters", "rain, and drought, each city's unique setting in the landscape". These air pollution control measures advocated by Maimonides nearly 900 years ago are still appropriate in the 21st century (Rosner, 1981; Gea 2019). In the 17th-century English physician Sir John Floyer suffered from terrible asthma attacks. He kept diaries where he collected data not only of his symptoms but also those of his patients, where he observed seasonal cycles and increased intensity of asthma exacerbations frequently associated with storms. (Jackson, 2008; Thorax , 1984). During the 19th century, Hyde Salter was a physician who suffered from asthma exacerbations, and he understood the differences and the influence of asthma exacerbations. He reported the importance of heredity as well as the effects of exposure to allergens most notably those of a cat (Stephen Holgate, 2011; Ian D Pavord et al, 2017). Salter identified the immediate worsening of asthma during cold air from continuous asthma exacerbations caused by "taking cold"... The asthma consequent too cold on the chest (bronchitis) is of a most painful and distressing kind; unlike that produced by cold directly, it often lasts for days ' (Persson & Uller 2013).

The links between climate, weather, the environment, and asthma are complex and interrelated (D'Amato, Gennaro, 2015; D'Amato & Cecchi, 2008; Targonski et al, 1995). Poor air quality due to high levels of pollutants such as ozone, particulate matter, and nitrogen dioxide can irritate the airways and trigger asthma symptoms (Guarnieri & Balmes, 2014; Peden, 2005). Unexpected changes in temperature, humidity, and atmospheric pressure can impact air quality by affecting the dispersion and formation of pollutants, in the air such as pollen, mold, and dust mites (Eguiluz-Gracia et al, 2020). Exposure to these allergens can trigger symptoms in individuals who are sensitive to them. Climate change has led to an increase in the frequency and severity of extreme weather events, such as heat waves, heavy rainfall, and droughts (D'Amato & Gennaro., 2015; Sheffield et al., 201). These events can have a major impact on air quality, as well as increase allergen levels and disrupt daily routines, which can trigger asthma symptoms (Eguiluz-Gracia et al., 2020; D'Amato & Gennaro., 2015). For example, heavy rainfall can make allergens airborne, while heat waves can cause air pollution levels to rise due to increased energy consumption and vehicle usage (D'Amato & Gennaro., 2015; Dabrera et al., 2012).

Various studies have linked asthma and weather (Mireku et al., 2009; Hyrkas et al., 2016; Poole et al., 2019). Asthma prevalence has increased since the 1960s affecting children, and adults of different ethnicities, backgrounds, lifestyles, and locations (Chu & Drazen, 2005). Asthma exacerbations are increased due to faster plant growth, earlier plant maturity, longer growing seasons, earlier pollen seasons, increased season duration, and an increase in both pollen quantity and allergenicity with consequences leading to a rise in disease frequency (Harun, 2019). Small children are extremely at risk and their exposure to allergens induces susceptibility to asthma, and allergic rhinitis (Beggs & Bambrick, 2006).

In a study conducted in 2012 by Peterson et al. the medicals records of 294 patient's that went into the hospital experiencing asthma attacks noted weather-related asthma triggers at high frequencies: cold weather (74%), change in weather (66%), humidity (61%), hot weather (46%), and wind (45%). These reports were most notable when considering that 26 million Americans have asthma, 500,000 are hospitalized each year due to asthma attacks, and approximately 3,000 to 4,000 Americans die as a result of asthma each year (D'Amato et al, 2016; Louie et al, 2011; Pate et al, 2021). Increased hospitalization rates, emergency room visits, asthma exacerbation, and reduced lung function in the United States has been linked to exposure to air pollution, both naturally occurring, and human caused pollution.

In a study conducted by May et al. in 2011, the medical records of 554 patients were analyzed for those displaying asthma (symptoms) exacerbations. In an earlier study carried out two years prior to May et al (2011), carried out by Mireku et al. (2009) involved 25,401 pediatric emergency department admissions analyzed variations between temperature, barometric pressure, and relative humidity as predecessors of pediatric asthma attacks while controlling for airborne pollutants and allergens. Research revealed a strong correlation between temperature and relative humidity changes and pediatric asthma attacks, while barometric pressure changes were not significant. Unlike May et al, (2011) research that only considered relative humidity, (Areal et al, 2021; Bodaghkhani et al, 2019; Rossi et al, 1993; Vitkina et al, 2018). Researchers have found a relationship between asthma attacks when changes in relative humidity due to an increase or decrease of relative humidity were taken into consideration.

2.3.1 Asthma and Temperature Extremes

Extreme temperatures are the most studied climate variables in relation to health (Sarma et al, 2022; Ebi et al, 2021; Uejio et al, 2016; Kjellstrom & McMicheal, 2013; Dabrera et al, 2012; Zanobetti & Schwartz, 2008). Environmental heat stress is associated with increased morbidity and mortality (Sarma et al, 2022; Anderson & Bell, 2011; Ye et al, 2012). Heat stress occurs when the thermoregulation system is overstimulated and can't shed sufficient heat through sweating, causing the body's temperature to rise (Bodaghkhani et al, 2019; Han et al, 2022; Uejio et al, 2016). Heat stress can cause heat-related illness, which can manifest with symptoms, such as heat cramps, dizziness due to low blood pressure, and heat exhaustion (Becker and Stewart 2011, Lugo-Amado et al, 2004). Extreme heat wave events have been widely associated with an increased risk of emergency room visits (Basu, 2009; Rupa et al, 2012). Days that are hotter than average seasonal temperature in the summer can cause an increase in levels of illness and deaths by compromising the human body's ability to thermoregulate or by inducing direct or indirect health complications (Ebi et al, 2021; Sarofim et al, 2006). Heat exposure has been associated with the decrease of physical and mental capabilities, meanwhile poor air quality has been shown to have an impact on the respiratory system (Ebi et al, 2021; Weinberger et al, 2020). Buckley & Richardson (2012) found that temperature can have a direct effect on inflammation pathways or airway hyper-responsiveness causing asthma exacerbations. Exposures to high minimum temperatures may also reduce the ability of the human body to recover from high daily maximum temperatures (Zanobetti & Schwartz, 2008). Heat-related deaths and illnesses are expected to increase in the future, as circulation models of climate change projects increase in temperature and extreme heat events (Deng et al, 2023; Hu et al, 2022). Additionally, exposure to extreme weather events are associated with a range of adverse health effects (Bell's et al, 2016; Curtis et al, 2017; Ebi et al, 2021). Studies have examined weather patterns such as cold spells and relative humidity (Baaghideh & Mayvaneh, 2017; Kjellstrom & McMicheal, 2013). Prolonged exposure to cold temperatures can lead to hypothermia, a dangerous but preventable medical condition (Doung & Patelk, 2022; Lane et al, 2018). Mild cases of hypothermia develop when internal body temperature drops below 95°F, meanwhile severe cases of hypothermia occur when internal temperatures drop below 89.6°F (Jiang et al, 2005; Zi et al, 2003). Severe hypothermia cases can require emergency medical attention, and in the worst-case scenario can lead to death. When the temperature decreases, the human body becomes stressed as it struggles to return to homeostasis (Lane et al, 2018). The human body's initial response to cold weather is constricting blood vessels in the skin to reduce the heat loss and divert blood to vital organs (Cheung, 2015; Whitmer, 2021). Cold air is usually very dry, inhaling cold air lowers the temperature of the airways, and dries the mucosal membrane (D'Amato et al, 2018; Mäkinen et al, 2008).

2.3.2 Asthma and Thunderstorm

In addition to examining the specific effects of meteorological factors on asthma attacks, researchers have examined the relationship between asthma attacks and thunderstorms (Al-Rubaish, 2007; Andrew et al, 2017; D'Amato et al, 2021; D' Amato, 2016; Harun et al, 2019; Kevat, 2020; Thein et al, 2018). There have been cases of thunderstorm asthma that have occurred all over the world, including parts of the United States, South America, Europe, Australia, Canada, and other regions(Harun et al, 2019; D'Amato et al ., 2006). Thunderstorm asthma is broadly defined as an association between thunderstorms and asthma occurrence (Dales et al, 2003; D'Amato et al, 2007; Grundstein and Sarnat 2009; Dabrera et al, 2012). Since 1983, there have been 14 documented cases of epidemic thunderstorm-related allergy attacks (Grundstein and Sarnat 2009; D'Amato et al, 2016) affecting the health of thousands of people. Thunderstorm asthma is a complex phenomenon involving aspects of meteorology and climatology, plant and human biology, and public health (Nasser & Pulimood, 2009) .

The incidence of thunderstorm asthma may increase as the climate changes, affecting both the frequency of thunderstorms but also the concentration of allergenic bioaerosols in some areas (D'Amato & Cecchi, 2008; D'Amato et al, 2015; Hughes et al, 2022). The frequency and intensity of thunderstorms may increase across much of the United States, according to modeling results by Trapp et al. (2007) and Gensini and Mote (2014). Further, many studies indicate increases in the duration of pollen seasons and the production of pollen and fungal spores (Corden and Millington, 2001; Ziska et al, 2007; Cecchi et al, 2010; Ziska et al, 2011; D'Amato et al, 2015).

2.3.3 Asthma and Air Masses

Climate and weather are the manifestation of a range of atmospheric variables (IPCC, 2012). These atmospheric variables express themselves in the form of air masses which can be defined as large bodies of air that have the same temperature, humidity, and stability characteristics (Antokhina et al, 2019; Birmili et al, 2001). The short- and long-term air mass variability produces the climate and brings the daily weather changes that can be experienced in a location (Kunkel, 2003; McGregor, 1999; NOAA, 2001). The human body responds differently to contrasting air mass types or weather situations or combinations of these (Hajat et al, 2010).

Even though research on the effect of air mass on morbidity, hospital, emergency room visits, and lung deterioration, has been confirmed to have a strong connection between air masses and human health (Liu et al, 2019; Lee et al, 2021; Xing et al, 2016). There has been less research on air mass connection to asthma. In a study conducted by

Lee et al. in 2012 the application of synoptic weather types in New York allowed for the analysis of the entire weather situation to which an individual is exposed. Kassomenos et al, 2006 examines the associations between air mass types and mortality in Athens, Greece from 1987 to 1991. Kljakovic and Salmond (1998) found links between the number of asthma exacerbation consultations in New Zealand during a 5- year study. Garcia et al, 2005 examined the human health impacts of synoptic conditions associated with extreme temperatures experienced in the Iberian Peninsula.

2.4 Conclusion

Asthma is a significant health concern in many major US cities, particularly among low-income communities and communities of color (Grant & Wood, 2022; Pattaun et al, 2021; Cunningham, 2010). Factors such as air pollution, poverty, and inadequate access to healthcare contribute to high asthma rates in these cities (Grant & Wood, 2022; Subbarao et al, 2009). It is essential to address these underlying issues to reduce the prevalence of asthma and improve the overall health of affected communities.

While many studies have looked at the link between asthma prevalence and air mass distribution in globally and in many major US cities such as New York, Los Angeles, and Philadelphia, few studies have addressed the link between asthma prevalence and air mass distribution in the central plains of the United States. The cities of Wichita, Tulsa, and Oklahoma City experience hot and humid summers, severe weather, and cold winters. Their location in the mid- latitudes can lead them to experience many different air masses and transition between air masses. Despite all of these factors no studies have been carried out in Wichita, Tulsa, and Oklahoma City linking the prevalence of asthma calls to air masses. **In my thesis I propose to investigate the relationship between air masses and asthma exacerbations resulting in emergency calls in Wichita, Oklahoma City, and Tulsa.**

CHAPTER III

DATA AND METHODS

3.1 Data Sources

3.1.1 Census Data

Sociodemographic block group data were obtained from the 2010 United States Census for the cities of Wichita, Oklahoma City, and Tulsa. Block groups were used as they are preferred when dealing with neighborhood sociodemographic because they are small geographic area that are relatively homogenous in term of population characteristics (Kranjac et al, 2017; Eldeirawi et al, 2016; Keet et al, 2015).

Specific variables collected for this thesis were percent White, percent Black, percent Hispanic, percent under the age of 5 years old, percent over 65 years old, percent with high school diploma, percent with bachelor's degree, percent with low income $15,000 - $24,000, percent middle income $25,000- $74,000 and percent upper income $75,000 - $200,000, total population, and total household population. Table 2.1. provides a rational on why the above census variables were used as well as providing other research articles that have used the same variables.

3.1.2 Emergency Medical Service Data

Emergency medical service (EMS) data were obtained from First Watch for the years of 2010 to 2015 *(First Watch Helping the Helpers* . First Watch. (2023, April 12). Retrieved April 14, 2023, from https://firstwatch.net/). Specific attributes include date, city, longitude, latitude, and asthma code.

3.1.3 Air Mass Spatial Synoptic Classification

Spatial Synoptic Classification (SSC) is a weather-type classification system that depends on near surface weather observations to define air masses at a location from twice daily collected records (Hanna et al., 2011; Sheridan et al., 2008). The SSC provides air mass classification for the past 60 years for may sites across the United States, Canada, and Europe. The SSC combines six daily air mass types: Dry Moderate (DM), Dry Polar (DP), Dry Tropical (DT), Moist Moderate (MM), Moist Polar (MP), Moist Tropical (MT), and a Transition category (TR) marks a day when one air mass replaces another, such as when warm or cold front move through a region (refer to figure 3.1 which illustrates the air masses found in North America). One air mass is assigned to a site each day (Lee et al, 2012; Sheridan, 2002). The parameters utilized to determine air mass type are air temperature, dew point, wind velocity, pressure, and cloud cover. Table 3.1 breaks down the technical and verbal description of the air masses identified in this study.

3.2 Data Processing

Asthma data and census block data were aggregated to block group scale. By combining sociodemographic variables with asthma data, it may be possible to identify demographic or environmental factors that are associated with higher rates of asthma. A Spearman's *Rho* Rank Correlation was used to analyze association between asthma counts and each sociodemographic variable. Prior to analysis, asthma and air mass data was aggregated to the seasonal scale to analyze the distribution of asthma call counts across air masses. The initial step involved downloading air mass data from January 1st, 2010, to December 31st, 2015, which was obtained from Dr. Scott Sheridan's Spatial Synoptic Classification website (http://sheridan.geog.kent.edu/). This data was then organized in a Microsoft excel worksheet where it was sorted region, year, month, and date, and season. Seasons are defined by months as follows: spring as March, April, and May (MAM); summer as June, July, and August (JJA); fall as September, October, and November (SON); and winter as December, January, and February (DJF). Wichita had a total of 5,148 air mass occurrences, Oklahoma City had 2,9856 and Tulsa reported 2,189 air mass occurrences. The combined air mass and emergency medical service variables which include the following region, asthma code, longitude and latitude, air mass type, year, month, and date. The number of asthma and air mass days varied throughout the cities and increased in size as opposed to when only air mass days were accounted for. There was a total of 26,261cases in Wichita, 18,980 cases in Oklahoma City, and 43,379 cases in Tulsa.

3.2.1 Geographical Information Systems

Geographical Information Systems (GIS) provides the ability to analyze and display asthma data in a spatial way, the means to compare data with other socioeconomic factors, for example total household income, and population Hispanic in the same geographical domain (Kinghorn et al., 2019; Kelly., 2019). The creation of maps was to visualize and analyze the spatial distribution of asthma calls and their relationship to sociodemographic between Wichita, Oklahoma City, and Tulsa.

Census Data was prepared in ArcMap. City blocks were selected and exported as feature classes for Wichita, Tulsa, and Oklahoma City. Selected sociodemographic variables were spatially joined from the detailed tables to their respective city feature classes by their unique ID fields. Sociodemographic variables needed to be converted into percentages this was easily done in ArcPro by using the geometry calculator. To find the percent of population white, population black, population Hispanic population under the age of 5 years old, population over 65 years old, population with a high school diploma within each block group these variables were divided by the total population and multiplied by 100. To find the percentage of population with low income $15,000 - $24,000, middle income $25,000- $74,000 and upper income $75,000 - $200,000 within each block group these variables were divided by the total household population and multiplied by 100.

After the percentages were calculated the total count of asthma calls within each census block needed to be calculated, this was easily done by running the "summarize within tool". The summarize within tool calculated the number of asthma counts per block group in the three cities. There was a total of 26,261cases in Wichita, 18,980 cases in Oklahoma City, and 43,379 cases in Tulsa.

Sociodemographic data can be described in GIS using various symbology techniques in this thesis graduated symbols were used to visualize sociodemographic data. Graduated symbols are a commonly used symbology technique to represent different values of sociodemographic data. In this technique, the color of the symbol represents the magnitude of the data. For example, in this thesis red symbolizes larger sociodemographic values within each censused block group (e.g., percent White, Black, Hispanic, Age, Educational Attainment and Income) while the light shades of blue symbolize lower sociodemographic values within each census block group.

TABLE 3.1: Breaks down the technical and verbal description of the air masses identified in this study.

Air Mass Types in this Study		
Air Mass	**Technical Definition**	**Verbal Description**
10	Dry Moderate (DM)	Dry and humid air. Found in mid-latitudes, in lee of mountain ranges.
20	Dry Polar (DP)	Advected from polar regions, low temperature, and dry conditions.
30	Dry Tropical (DT)	Advected from desert regions, hottest and driest conditions.
40	Moist Moderate (MM)	Hot and humid air. Arise on hot days when high cloud cover suppresses temperature.
50	Moist Polar (MP)	Cloudy, humid, and cool conditions. Appear by inland transport from the ocean.
60	Moist Tropical (MT)	Warm and very humid, the air mass dominates near the tropics
70	Transitional (T)	Marks a day when one air mass replaces another, such as when warm or cold front move through a region

Figure 3.1 Illustrates the Air Masses found in North America. The selected cities of Wichita, Tulsa, and Oklahoma City were used to determine asthma and air mass distribution.

3.3 Statistical Analysis

Statistical techniques, specifically descriptive statistics, and chi-square tests were used to analyze data. The purpose behind these techniques was to examine the correlation between variables and to examine frequency distributions. Bar charts were primarily used to illustrate the distribution of air mass types across a region because they enable easy visualization.

Descriptive Statistics

Descriptive statistics were used to generalize and describe the characteristics of the datasets. Frequency distributions were used to examine the distribution of asthma calls per season and region, the frequency of the number of days per air mass and region not including asthma calls, and lastly the frequency of asthma calls per air mass type and region.

Spearman's Rho Rank Correlation Coefficient

The Spearman's Rho Rank Correlation Coefficient is a statistical measure that assesses the degree of association between two variables. It is a non-parametric measure, which means it does not assume that the data follow any distribution (Xiang et al, 2017; Zar, 2014) and instead, it focuses on the rank order of the data.

Spearman's Rank Correlation Coefficient can range from -1 to +1, with -1 indicating a perfect negative correlation, 0 indicating no correlation, and +1 indicating a perfect positive correlation (Rosińczuk et al, 2022; Uchmanowicz et al, 2022; Zar, 2014;

Apter et al, 2013). The coefficient is calculated based in the difference between the ranks of two variables.

In the context of the sociodemographic and asthma data, Spearman's rank correlation coefficient was used to examine the relationship between variables such as age, race, educational attainment, and income level (Uchmanowicz et al, 2022; Apter et al, 2013). Spearman's correlation was chosen for this thesis because it accounts for the difference in ranks for variables. For example, the Spearman's rank correlation coefficient was used to determine if there was a relationship between race/ethnicity and asthma, if there is a relationship between age and asthma, a relationship between educational attainment and asthma and if there is a relationship between income level.

To calculate Spearman's coefficient with sociodemographic data, one would typically rank the variables based on their values and then calculate the correlation between ranks. While Spearman's coefficient can provide insights into the strength and direction of the relationship between variables, it does not establish causality (Ma et al, 2020; Grażyna et al, 2018).

CHAPTER IV

RESULTS

4.1. Geography of Asthma

Asthma shows distinct differences in race/nationality, age, educational attainment, and income (American and Allergy Foundation of America et al., 2022). The main objective of this section is to **analyze the spatial distribution of asthma calls and their relationship to sociodemographics.** Focusing on by the questions outlined below:

- **Question 1.** Is race/ethnicity correlated with asthma calls ?
- **Question 2.** Is age correlated with asthma calls ?
- **Question 3.** Is educational attainment correlated with asthma calls ?
- **Question 4.** Is income correlated with asthma calls ?

4.1.1. Distribution of Asthma Calls

Figure 4.1 illustrates the number of asthma calls within block group boundaries in Wichita, Oklahoma City and Tulsa. Although asthma data can be sporadic, there are several block groups where asthma prevalence is high in Wichita, Tulsa, and Oklahoma City. Asthma calls concentrate where population is densest, which is in the downtown area of the cities.

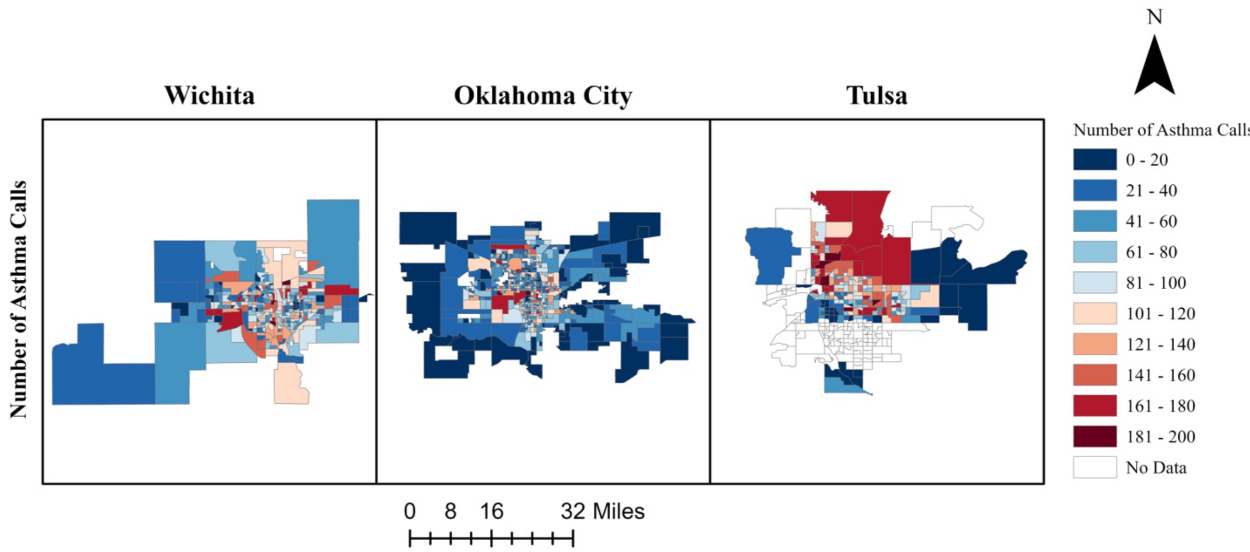

Figure 4.1. Number of asthma calls in Wichita, Oklahoma City, and Tulsa.

4.1.2. Distribution of Sociodemographics

Figure 4.2 illustrates race and ethnicity percentage within block group boundaries in Wichita, Oklahoma City and Tulsa. We can see that White populations tend to live on the out skirts of the cities. Tulsa, Wichita, and Oklahoma City have a high percent White population present. Meanwhile, Black and Hispanic populations are lower in these cities, and they tend to concentrate around the inner downtown area.

Figure 4.3. illustrates age percentage with block group boundaries, Wichita, Oklahoma City, and Tulsa. Children under the age of 5 and adults over the age of 65 are more susceptible to asthma than other age groups. The older populations live on the outskirts of the cities, away from environmental pollutants which can in turn lower their

chances of having an asthma attack. Meanwhile most of the young children live in clusters near the inner city.

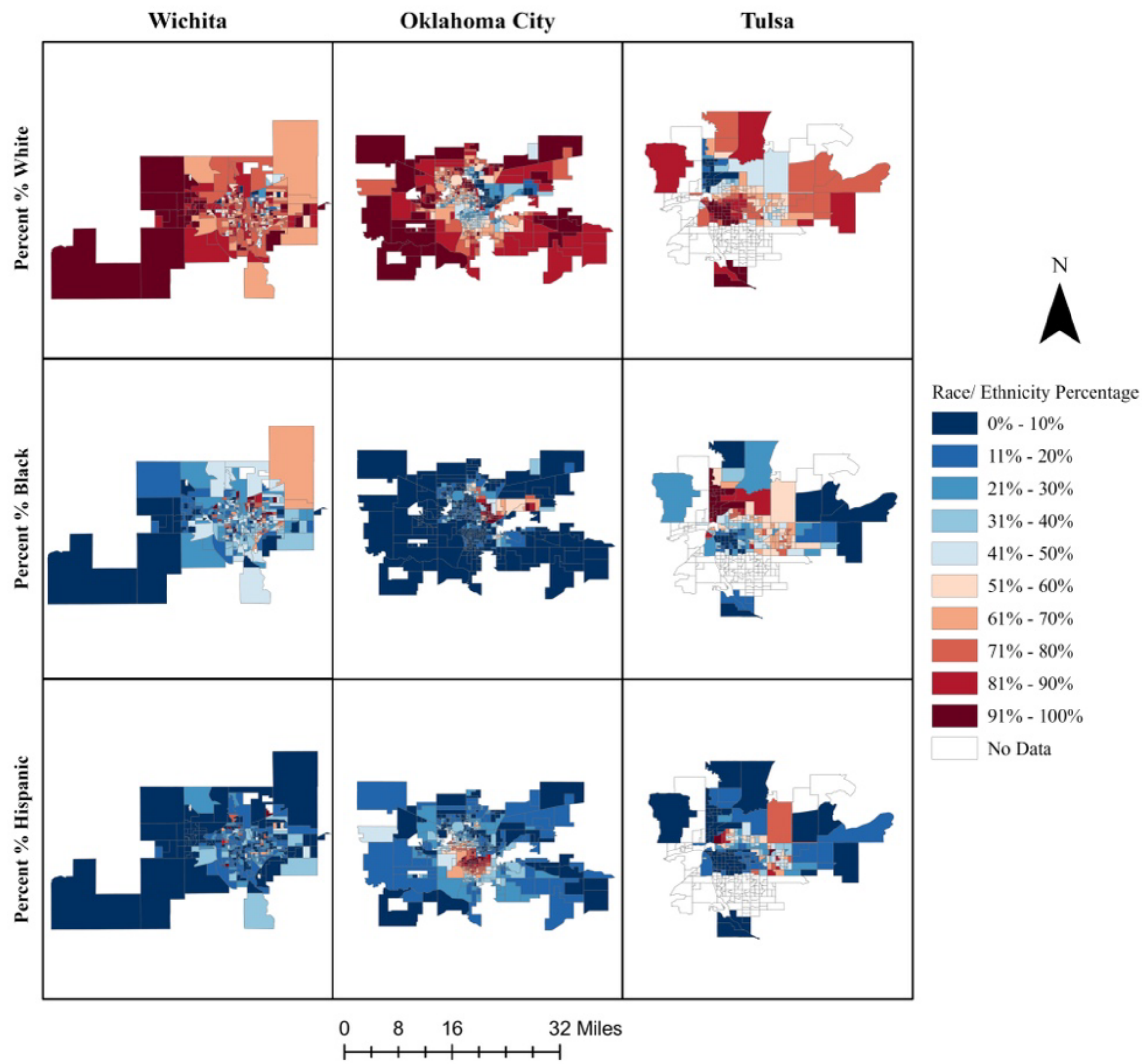

Figure 4.2. Race and ethnicity percentage in Wichita, Oklahoma City, and Tulsa.

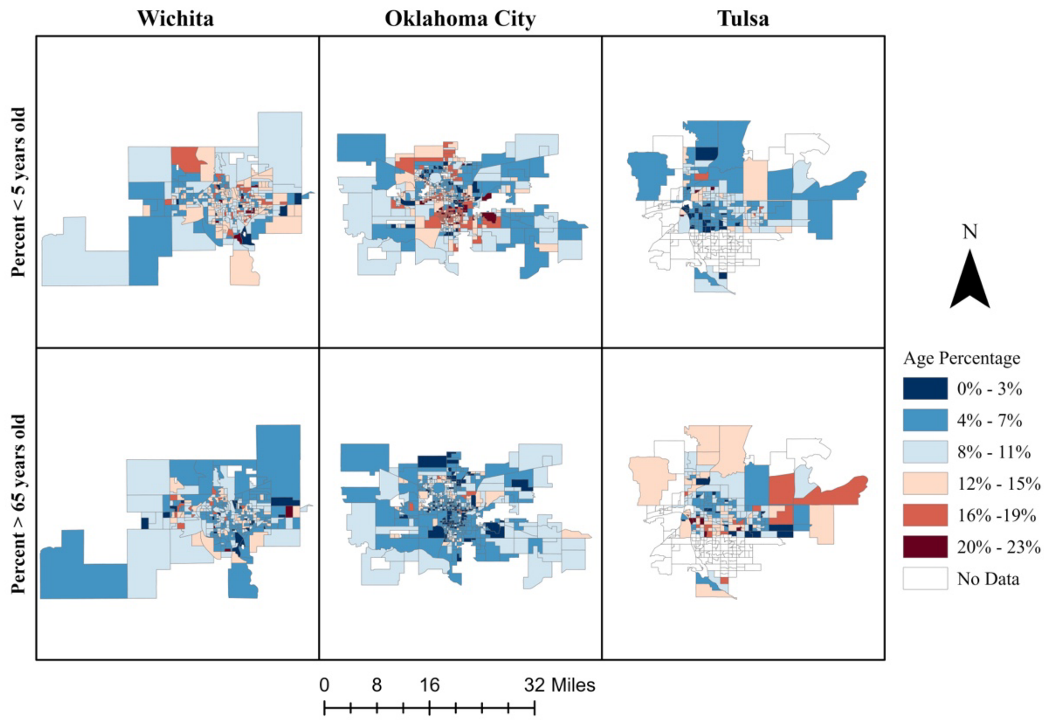

Figure 4.3. Age percentage in Wichita, Oklahoma City, and Tulsa.

Figure 4.4. Shows educational attainment percentage with block group boundaries, Wichita, Oklahoma City, and Tulsa. Education attainment is a critical factor in asthma prevalence, as individuals with a lower education level may have less access to healthcare and health information, leading to a higher risk of uncontrolled asthma. Educational attainment levels vary across all three cities. Oklahoma City and Tulsa's population have more bachelor's degrees than Wichita.

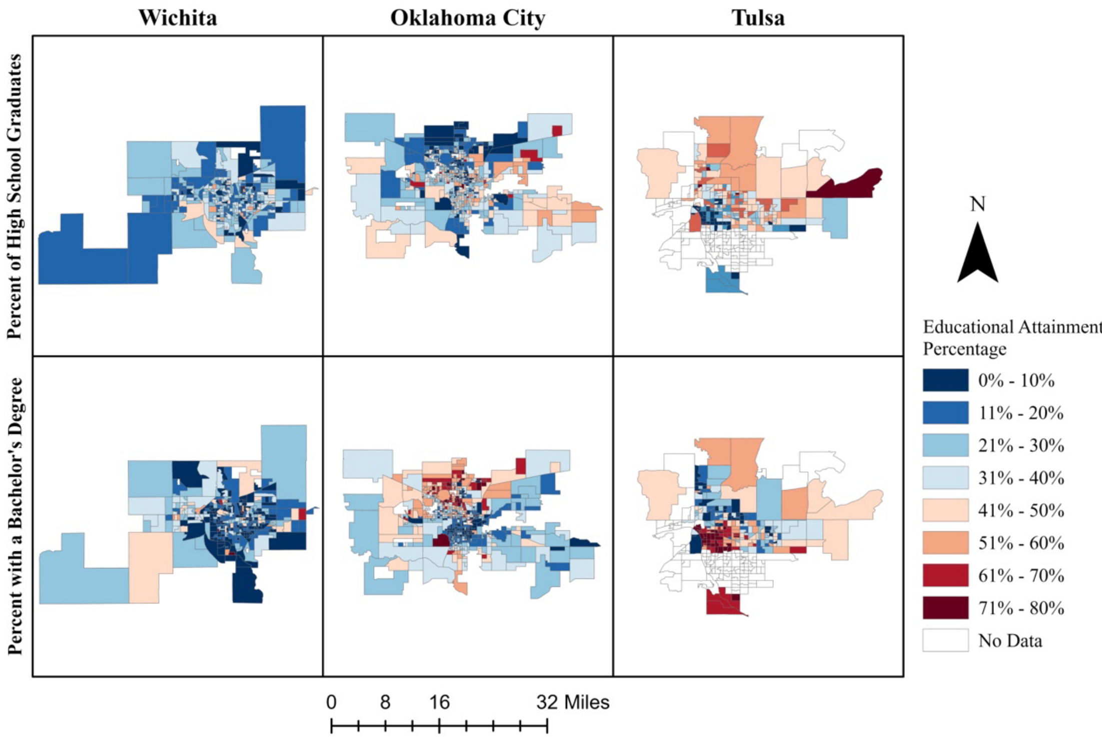

Figure 4.4. Educational attainment percentage in Wichita, Oklahoma City, and Tulsa.

Figure 4.5. illustrates income percentage with block group boundaries, in Wichita, Oklahoma City, and Tulsa. Lower income populations tend to cluster near inner urban area. Middle Income populations are more spread out between the inner city and the outskirts. Meanwhile it is important to point out that while Wichita and Tulsa's upper income population live near the outskirt, Oklahoma City's upper income population clusters in the inner city.

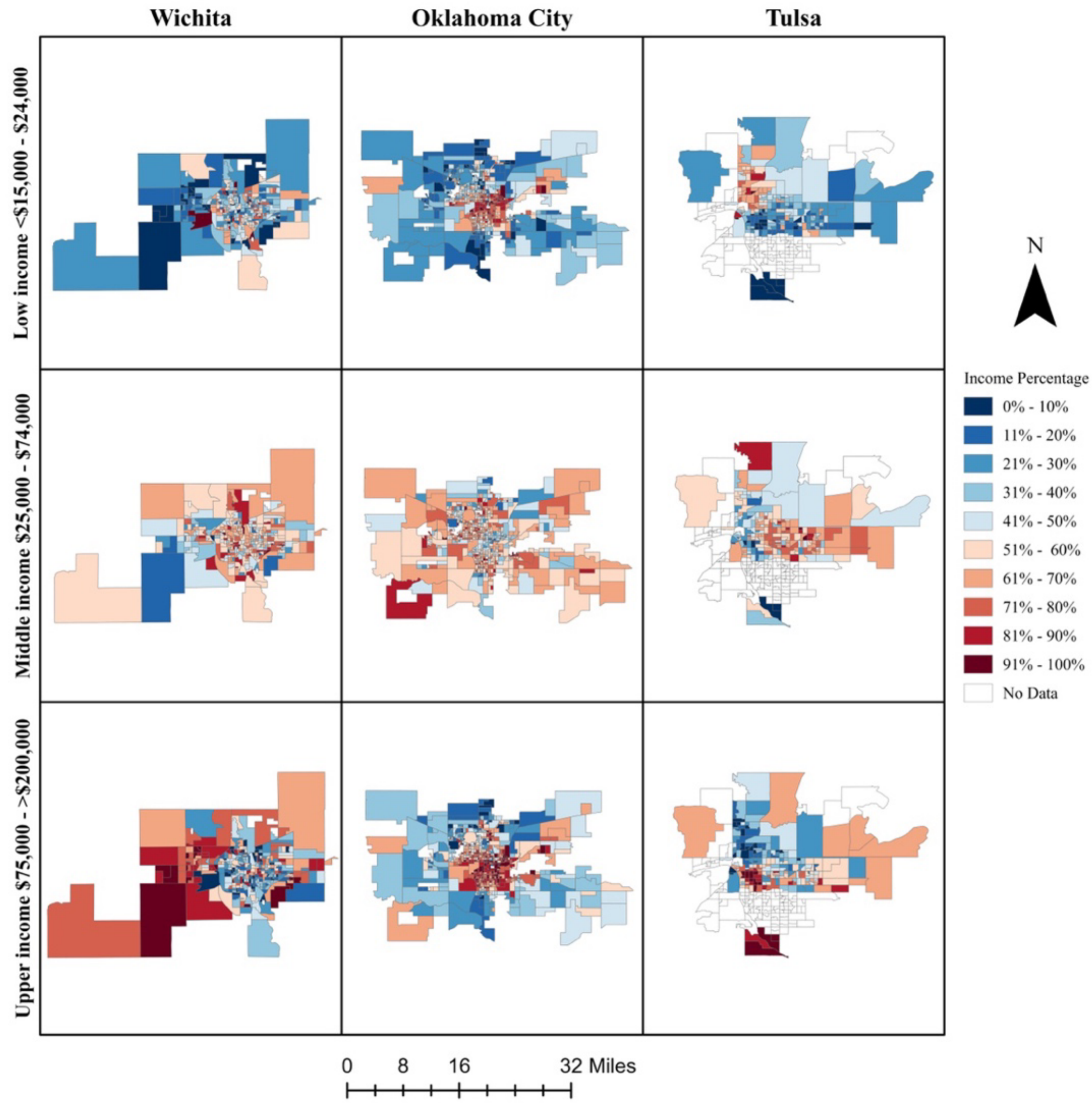

Figure 4.5. Income percentage in Wichita, Oklahoma City, and Tulsa

4.1.3. Correlation between Asthma Calls and Sociodemographics

Figures 4.6, 4.7, and 4.8 illustrate the correlation between all sociodemographics variables and asthma in Wichita, Oklahoma City, and Tulsa. The results of Spearman's tests indicate that five of the eleven sociodemographic variables were correlated with asthma for all three cities (see figures 4.6, 4.7 and 4.8).

The positive correlation means as the sociodemographic variables go up, so does the asthma count (Figures 4.6, 4.7, and 4.8). In all three cities asthma is positively correlated to percent Black, percent Hispanic, percent young, percent high school diploma only, and percent low income. The strength of correlation between sociodemographics varies between cities but are similar. For example, high school diploma only is strongest in Tulsa (0.336), and slightly weaker in Wichita (0.211), and Oklahoma City (0.142). Percent black and percent low income have the strongest correlation between the variables in the three cities, Tulsa correlation is strongest at (0.645) and the coefficients are less in Wichita (0.522), and Oklahoma City (0.413).

The negative correlation means that as the sociodemographic variables go up, the number of asthma count goes down (Figures 4.6, 4.7, and 4.8). In all three cities asthma is negatively correlated to percent white, percent college degree, and percent upper income. The strength of correlation between sociodemographics varies between cities but are similar. For example, upper income coefficient is strongest in Tulsa (-0.514), and the coefficient is weaker in Wichita (0.356), and Oklahoma City (-0.341). Another strong correlation is between percent Hispanic and percent college degree. In Wichita the correlation is the strongest with the coefficient being (-0.635), and weaker in Tulsa (0.583), and Oklahoma City (-0.535).

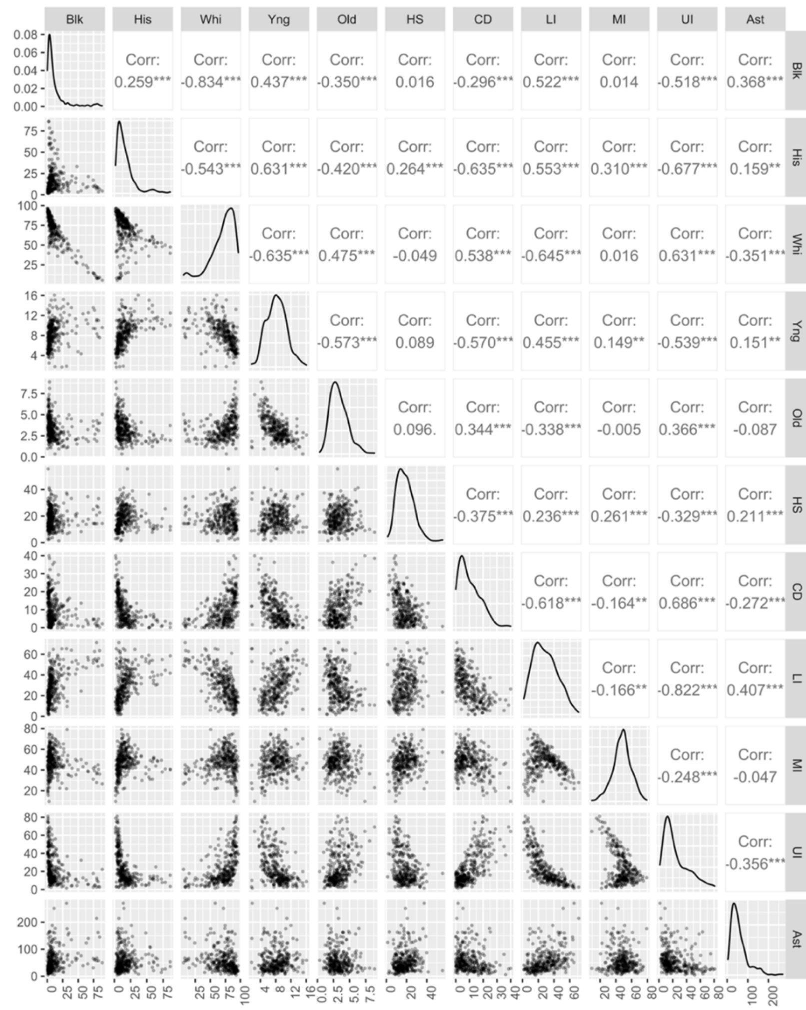

Figure 4.6. Sociodemographics and asthma correlation in Wichita. The abbreviations on the top of the page stand for sociodemographic variables used in this study. Blk means percent black, His is percent Hispanic, Whi is percent White, Yng is percent <5, Old is percent >65, LI is percent Lower Income <$15,000- $24,000, MI is percent Middle Income $25,000- $74,000 and UI is percent Upper Income $75,000 and >$200,000. If the correlation has a p value of <0.1 is not statistically significant. If the correlation has a p-value of <0.05 is significant. If the correlation has a p-value of <0.01 it is highly significant.

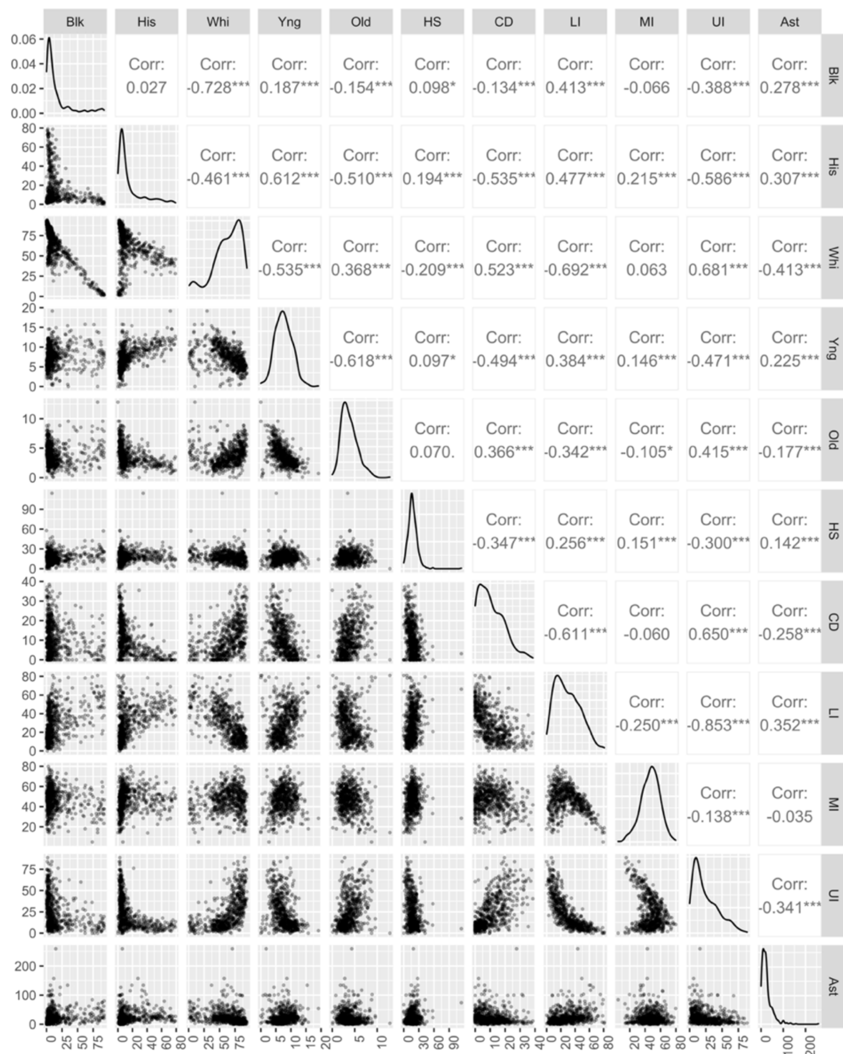

Figure 4.7. Sociodemographics and asthma correlation in Oklahoma City. The abbreviations on the top of the page stand for sociodemographic variables used in this study. Blk means percent black, His is percent Hispanic, Whi is percent White, Yng is percent <5, Old is percent >65, LI is percent Lower Income <$15,000- $24,000, MI is percent Middle Income $25,000- $74,000 and UI is percent Upper Income $75,000 and >$200,000. If the correlation has a p value of <0.1 is not statistically significant. If the correlation has a p-value of <0.05 is significant. If the correlation has a p-value of <0.01 it is highly significant.

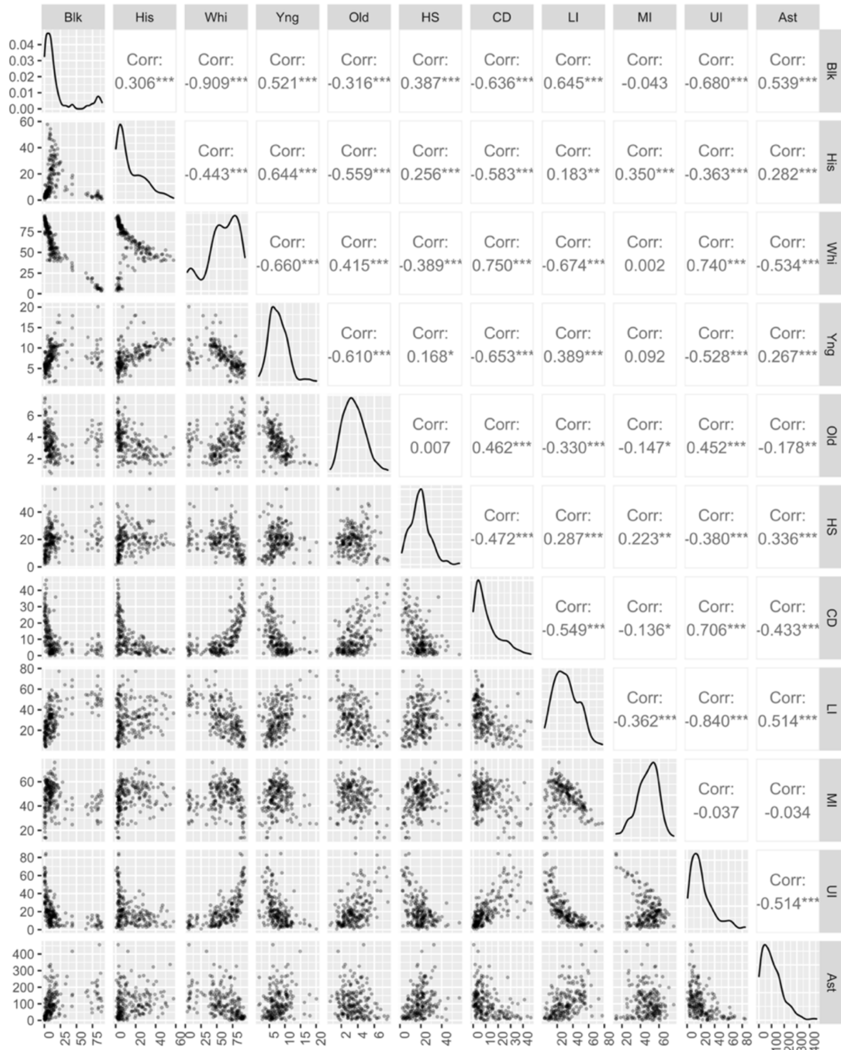

Figure 4.8. Sociodemographics and asthma correlation in Tulsa. The abbreviations on the top of the page stand for sociodemographic variables used in this study. Blk means percent black, His is percent Hispanic, Whi is percent White, Yng is percent <5, Old is percent >65, LI is percent Lower Income <$15,000- $24,000, MI is percent Middle Income $25,000- $74,000 and UI is percent Upper Income $75,000 - >$200,000. If the correlation has a p value of <0.1 is not statistically significant. If the correlation has a p-value of <0.05 is significant. If the correlation has a p-value of <0.01 it is highly significant.

4.2. Air Mass Climatology of Asthma Calls

Similarities between air mass climatology across Wichita, Oklahoma City, and Tulsa are expected, because they are mid-latitude cities known for hot and humid summers, severe weather, and cold winters. Exposure to these weather conditions can trigger asthma symptoms in people who are already sensitive to these factors. The main objective of this section is to **analyze the seasonal distribution of asthma calls and their relationship to air masses** which will be guided by the questions outlined below :

- **Question 1.** What is the seasonal distribution of asthma calls per region?
- **Question 2.** What is the seasonal distribution of air mass types?
- **Question 3.** What is the seasonal relationship between asthma calls and air mass types?

4.2.1. Seasonality of Asthma Calls

Figure 4.9. (A) illustrate the frequency of asthma calls per season and region. As expected, the distribution of all the asthma calls (A) and the days with many (> 90^{th} percentile) (B) and few (< 10^{th} percentile) (C) are similar across all three cities. When looking at Figure 4.9 (A) ICT, and OKC, follow the same kind of trend where it is highest in winter, and decreases in spring and summer, and it elevates back in fall. This cycle is less prominent in Tulsa. Where Tulsa has an increase of asthma call in the spring, but the number of asthma calls stays uniform across winter, summer, and fall. When looking at Tulsa and ICT Figure 4.9 (B) there are more asthma calls occurring it DJF, and MAM but when looking at figure 4.9 (C) there are more asthma calls in JJA and SON.

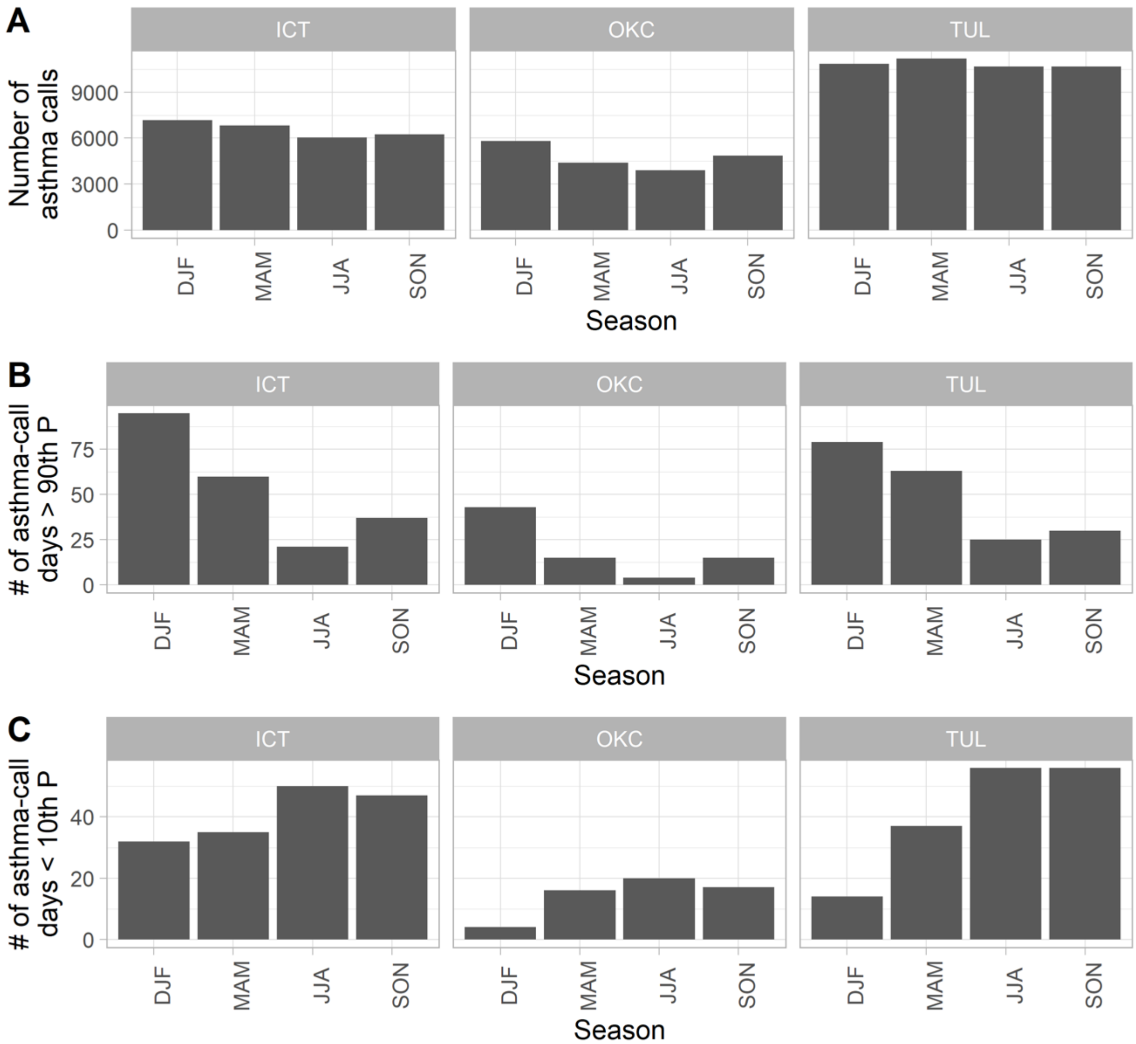

Figure 4.9 (A) Number of asthma calls per season and region. Figure 4.9 (B) Number of asthma calls days in the 90th percentile. Figure 4.9 (C) Number of asthma calls days in the 10th percentile.

4.2.2. Seasonality of Air Mass Types

Figure 4.10 (A) illustrates the frequency of the number of days and air mass types per region, while Figure 4.10 (B) illustrates the frequency of the number of days and air mass types per region and season. At the seasonal scale Dry Moderate overall increased asthma calls in Wichita except in summer when Moist Tropical causes more calls. The same reversal can be seen in Moist Tropical and Dry Tropical across Oklahoma City and Tulsa. At the annual scale, Dry Moderate is the most frequent air mass at ICT during the fall, winter, and spring, and OKC. Dry Moderate is also common in Tulsa, but Moist Tropical is also common during the summer.

4.2.3. Relationship between Asthma Calls and Air Mass Types

Figure 4.11 (A) illustrates the frequency of asthma calls and air mass types and region, meanwhile Figure 4.11. (B) illustrates the frequency of asthma calls and air mass types per region, and season. In both figures Dry Moderate maximum occurrence is during the fall and winter, during the spring and summer, and Moist Tropical are at their maximum occurrence. In Wichita (ICT) asthma calls are most likely to occur when DM air masses are present and less likely to occur when Moist Tropical, and Dry Tropical air masses are present.

Figure 4.12. (A) illustrates the frequency of asthma call days that are > 90^{th} percentile per air mass and region. Figure 4.12. (B) illustrates the frequency where asthma call days that are > 90^{th} percentile per air mass and season. Dry Moderate is the most prominent during the winter months (DJF). Big days are those most active asthma

call days with Dry Moderate increasing across seasons except in summer when Moist tropical is the most common.

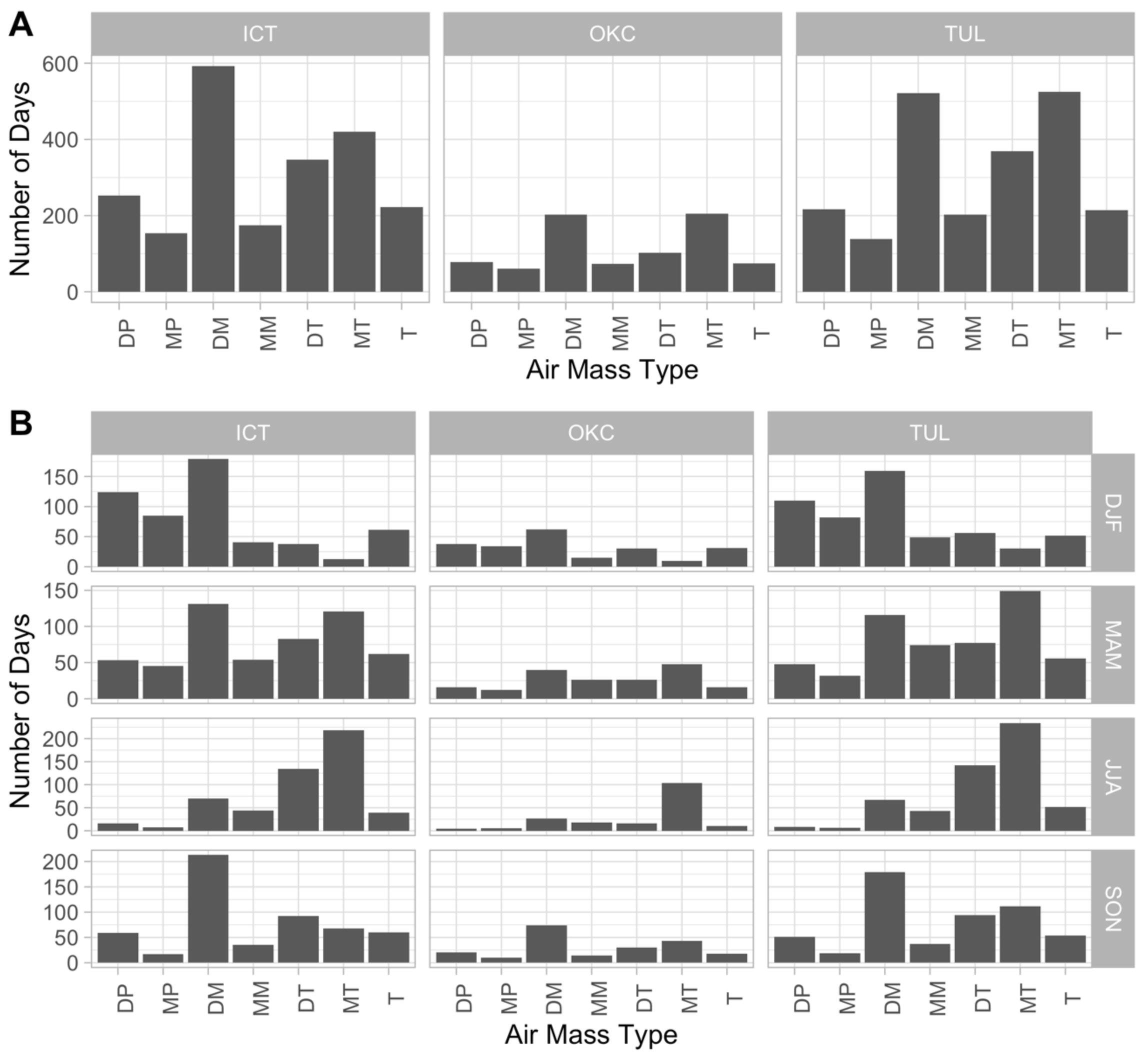

Figure 4.10. (A) Number of days and air mass types per region not including asthma calls. Figure 4.10.(B) Number of days and air mass types per region and season not including asthma calls.

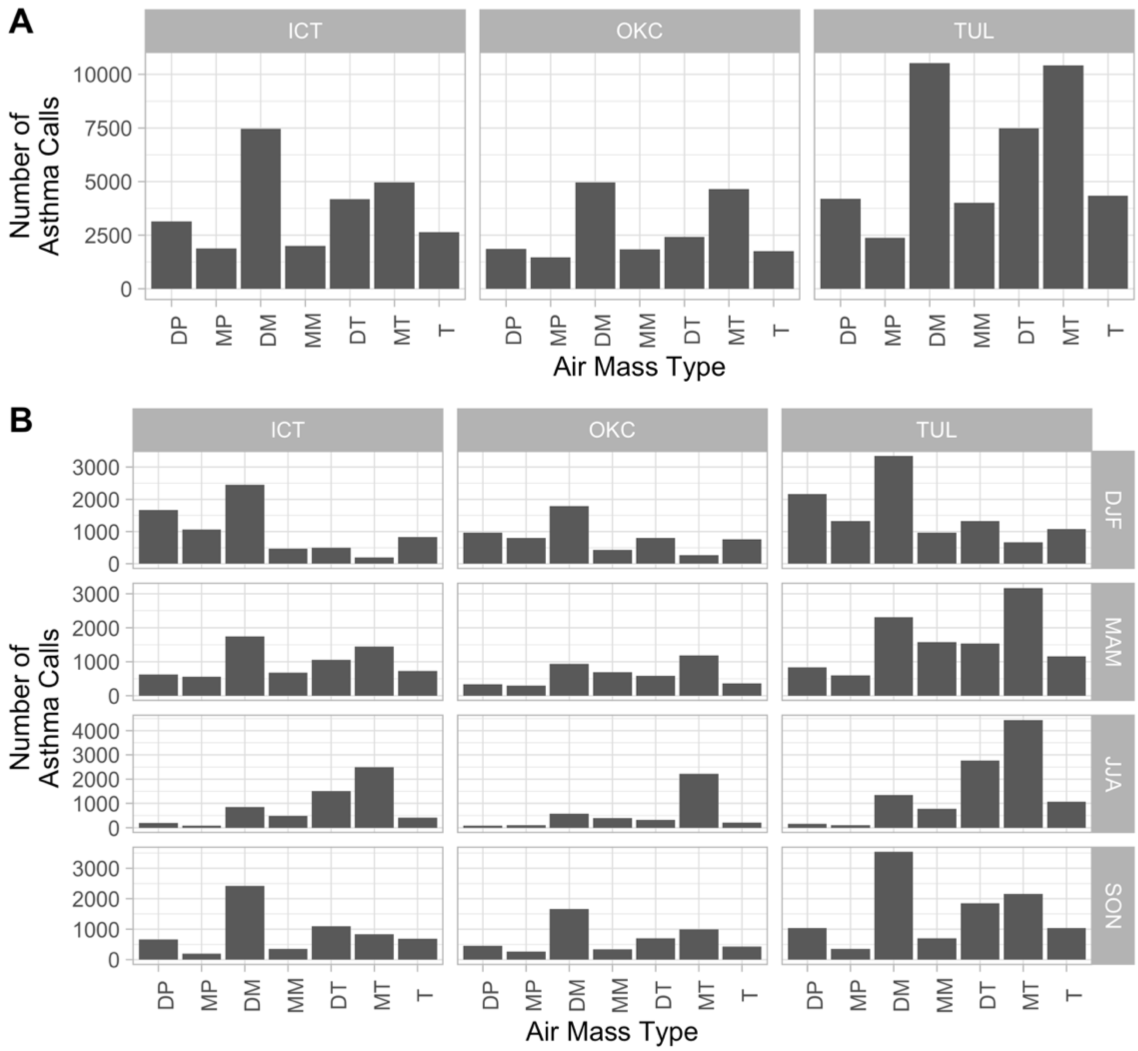

Figure 4.11. (A) Number of asthma calls and air mass types and region. Figure 4.11. (B) Number of asthma calls and air mass types per region, and season.

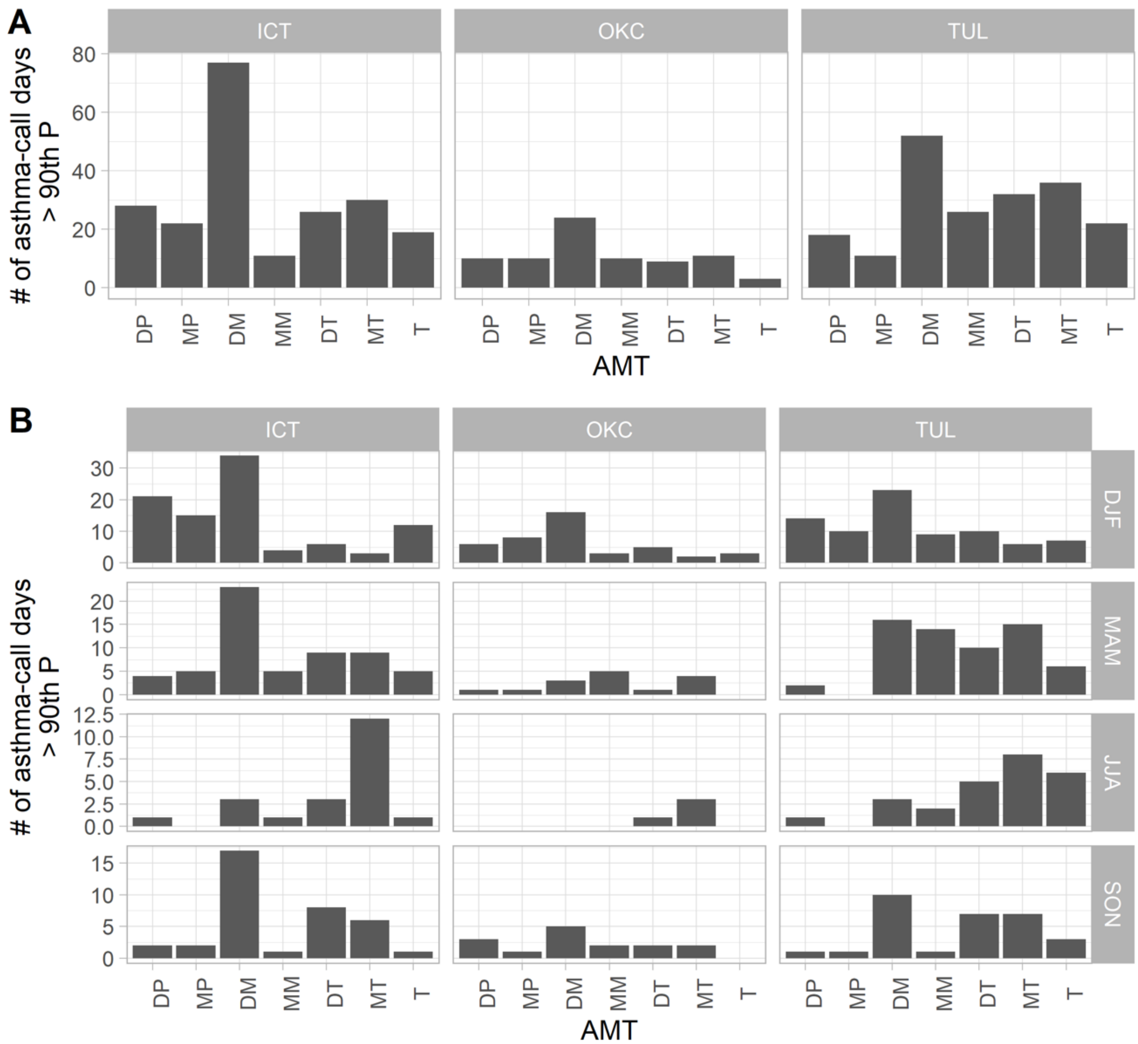

Figure 4.12. (A) Number of big days where asthma calls are in the 90th percentile per air mass and region. Figure 4.12. (B) Number of big days where asthma calls are in the 90th percentile per air mass and season.

Figure 4.13. (A) illustrates the frequency of asthma call days that are < 10^{th} percentile per air mass and region. Figure 4.13. (B) illustrates the frequency of asthma call days that are < 10^{th} percentile per air mass and season. In the summer small days asthma call in Tulsa are dominated by Moist Tropical air masses. If we look at Tulsa on figure 4.12(B) the occurrence of Moist Tropical asthma calls during the summer (JJA) shrinks in size comparison to figure 4.13. (B). Moist Tropical air masses are the leading cause of asthma calls that fall withing the 10^{th} percentile, and this is because there are more small days (< 10^{th} percentile) than big days (>90^{th} percentile), (figure 4.12 B) .

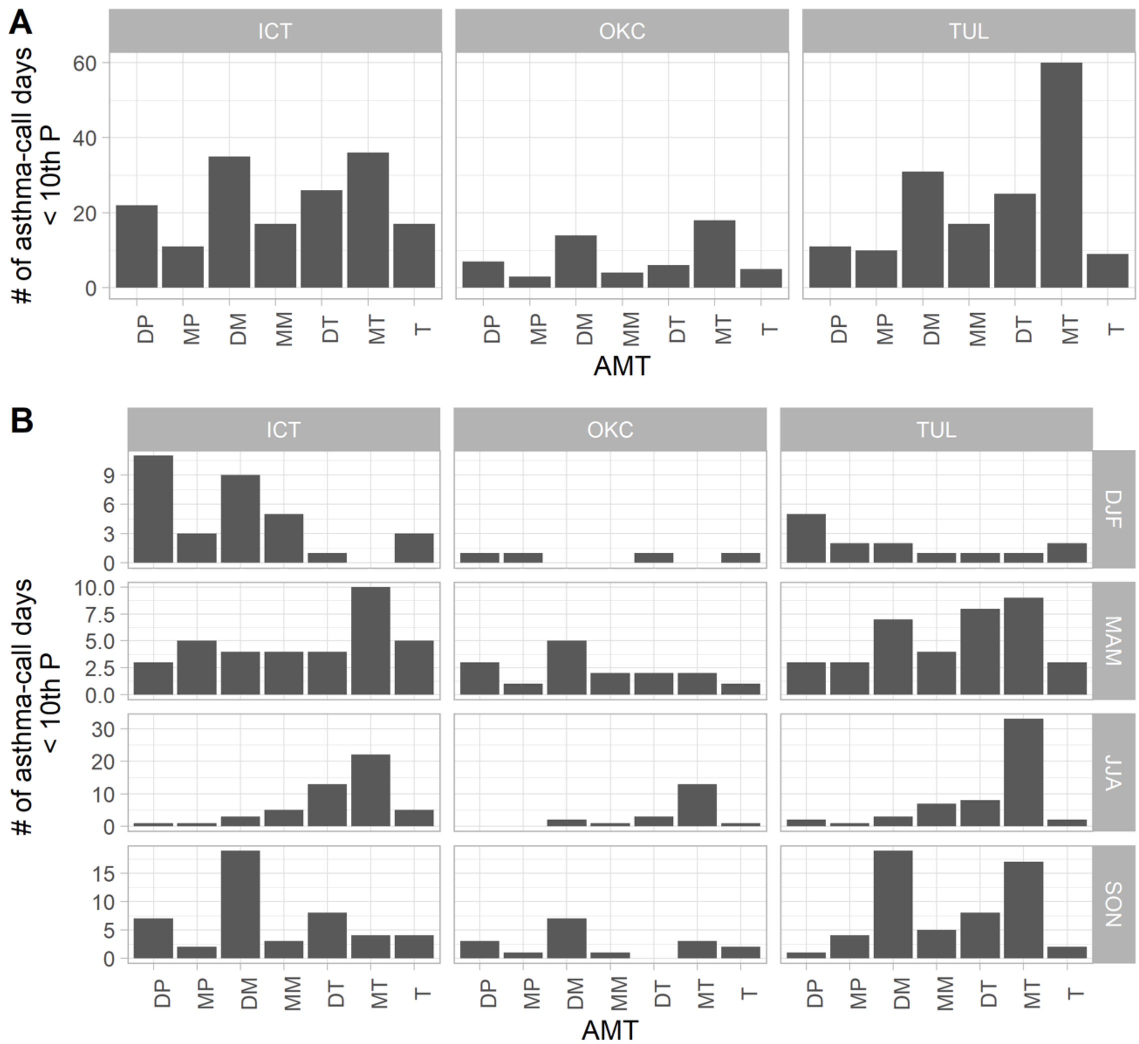

Figure 4.13. (A) Small days where asthma calls are in the 10th percentile per air mass and region. Figure 4.13. (B) Small days where asthma calls are in the 10th percentile per air mass and season.

CHAPTER V

DISCUSSION

5.1. Distribution of Sociodemographic Patterns

Like most health concerns, asthma occurrences follow spatial patters of systematic inequality across Wichita, Oklahoma City, and Tulsa. The distribution of vulnerable groups is commonly spatial in nature, geography plays an essential role in identifying spatial risk factors associated with negative health outcomes such as asthma. Where a person lives, and works can directly influence their health experiences and their access to social, built, and natural environments that affects a person's physical and mental health (Dummer, 2008).

This study builds upon results found in previous studies. In urban areas, asthma prevalence is often much higher due to the levels of air pollution, due to traffic congestion, industrial activity, which can cause an increase in the risk is developing asthma (Ferrante & La Grutta, 2018). Wichita, Oklahoma City, and Tulsa are no exception. The block groups that experience the most asthma calls are in the high-density populations and areas (Figure 4.1).

Question 1. Is race/ethnicity correlated with asthma calls ?

Studies have shown that asthma disproportionality affects minority populations, particularly Hispanics, and Blacks compared to Whites (Correra-Agudelo et al, 2022; George et al, 2022; Tran et al, 2022; Llabre et al, 2017; Washington et al, 2017). This study found a positive correlation of asthma in Wichita, Oklahoma City, and Tulsa

(Figures 4.7, and 4.8) between, African American populations and Hispanics populations and a negative correlation between White populations and asthma. Asthma is a complex disease with multifactorial ethology, meaning it arises from a combination of genetic, environmental, and social factors. Therefore, the vulnerability to asthma cannot be solely attributed to race.

Question 2. Is age correlated with asthma calls ?

There are multiple studies that suggest that age is correlated to asthma (Serebrisky & Wiznia, 2019; Ferrante & La Grutta, 2018 ;Akinbami et al, 2009). Studies have found that the number of asthma-related emergency department visits and hospitalizations tends to be highest among children and young adults and decreases in older age groups. Oklahoma City shows a positive correlation between asthma for both Hispanic children (0.612) and Black children (0.187) and a negative correlation between young white children (-0.535). This same positive correlation between Hispanic children and Black children can be seen in Wichita and Tulsa (Figures 4.6, and 4.8) and a negative correlation between young white children. Hispanic and Black children are more likely to live in high density block groups which only adds to their asthma exacerbations due to all the air pollution (figure 4.2). Some reasons that can explain why young white children are less vulnerable to asthma is because they may be less exposed to environmental triggers (figure 4.3), they are more likely to come from high -income families, which can provide better access to healthcare, and this access to healthcare allows for the early diagnosis and treatment of asthma.

Question 3. Is educational attainment correlated with asthma calls ?

Race and Ethnicity can play a role in determining educational attainment, or the level of education and individual achieves. This study showed that Hispanics with higher levels of education, such as a high school diploma, have lower rates of asthma than those with lower levels of education (figure 4.6, 4.7, and 4.8). The same pattern can be seen in the Black population, those who had a high school diploma experienced a negative correlation with asthma calls (figure 4.6, 4.7, and 4.8).

This study found a correlation between Hispanic and Black populations without a college degree (figure 4.6, 4.7, and 4.8) are more susceptible to asthma. As see in figure 4.5 Hispanics and Black population in Tulsa, Wichita, and Oklahoma City live near highly densely populated downtown areas.

Higher education levels are generally linked to better health outcomes, such as improved access to health care, better health literacy and upper income. One explanation for this correlation is that individuals with a college degree are more likely to have higher incomes and live in neighborhoods on the outskirts of the city (figure 4.5).

Question 4. Is income correlated with asthma calls ?

This study's findings that low income is positively associated with asthma, supports the well-documented association between asthma exacerbations and low income (Grant et al, 2022; Cremer & Baptist et al, 2020; Bacon et al, 2009). Low income Hispanic and Black populations may have limited access to asthma education programs and resources (figure 4.6, 4.7 and 4.8). Due to this lack of education about asthma management it can lead to poor asthma control and increased asthma exacerbation attacks. Limited access to health care services can lead to undiagnosed, or poorly managed asthma.

Upper-income white populations in Wichita, Oklahoma City, and Tulsa are associated with higher rates of asthma (figure 4.6, 4.7 and 4.8), and live in clusters in the inner city near highways, which can expose them to environmental pollutants (figure 4.5). Upper-income white populations may have higher levels of asthma exacerbations, but they also have access to healthcare that allows for earlier and a more precise diagnosis of asthma.

5.2. Air Mass Climatology of Asthma Calls

Location plays an essential role in exacerbating asthma calls. Kansas and Oklahoma are both located in the central region of the United States, which is known for its continental climate. This type of climate is characterized by temperature seasonality, low humidity, and high wind speeds. This section of the discussion will focus on analyzing the seasonal distribution of asthma calls and their relationship to air masses. Many studies focus on thunderstorm asthma and not in air masses and asthma, due to the lack of literature the results of this study are not directly comparable.

Question 1. What is the seasonal distribution of asthma calls per region?

This study showed that there were seasonal and regional difference of asthma call rates in Wichita, Tulsa, and Oklahoma City. At first glance when looking at the number of asthma calls and regions a noticeable trend between Wichita (ICT) and Oklahoma City is easy to see. The number of calls between the two regions have an increase in the number of calls followed by a gradual decrease. This trend is less obvious in Tulsa. An evident switch is seen in seasonality and the air masses that are the most prominent during big asthma call days (> 90^{th} percentile) and during low asthma call days (< 10^{th} percentile). Big asthma call days account for asthma calls occurring in December, January, February (DJF). Meanwhile low asthma days are the opposite which account for more asthma calls on June, July, August (JJA), and September, October, November (SON).

Question 2. What is the seasonal distribution of air mass types?

While annual air mass frequencies are helpful, in understanding the effect of air masses, the seasonality of air mass frequencies allows us to get a better picture of what is occurring (Sheridan, 2002). For instance, the warm temperatures of Moist Tropical (MT) have a greater potential to harm human health in the summer (figure 4.10), than in the winter because MT air masses, can create a hot, poor air quality day in the summer. This is can directly be seen in the spring and summer months of the three region, moist tropical air masses are responsible for all most of the asthma calls. During the fall and winter months when the temperature begins to drop Dry Moderate (DM) is most prominent throughout Wichita, Tulsa, and Oklahoma City. Figure 4.11 show the number of days and air mass types per region and season not including asthma calls. Wichita (ICT) and (TUL) have high counts of Dry Moderate and Moist Tropical intrusion occurring. In the winter and fall months DM is the most present airmass. When looking at spring and summer MT is the most abundant air mass type occurring in all three of the regions especially in Tulsa is Moist Tropical. We can see in an increase in asthma calls when that air mass is present.

Question 3. What is the seasonal relationship between asthma calls and air mass types?

When looking at the number of asthma calls and regions Dry Moderate and Moist Tropical are the most prominent, followed by Dry Tropical (figure 4.11). As mentioned on figure 4.11 an evident switch is seen in seasonality and the air masses that are the most prominent during big asthma call days ($>90^{th}$ percentile) and during low asthma call days ($< 10^{th}$ percentile), (figure 4.12 B & figure 4.13 B). During the summer months, Wichita, Tulsa, and Oklahoma City, are influenced by the Bermuda High, which is a high-pressure system that sits off the southeastern coast of the United States. This system causes warm, moist air from the Gulf to flow northwards into the three regions leading into the formation of MT. During low asthma call days MT air mass is the leading cause of asthma calls during the spring and summer (figure 4.13 B). During the winter months Wichita, Oklahoma City, and Tulsa, are affected by humidity, low moisture, and cold temperatures originating from the northwestern part of Canada. The combination of these factors results in Dry Moderate (DM) being the dominant air mass during winter and fall. Unlike Tulsa and Oklahoma, Wichita in the spring (MAM) during small asthma call days experienced five asthma calls related to DM air mass (figure 4.13 B). Meanwhile when looking at big asthma calls days the number of asthma calls related to DM increases almost four times (Figure 4.12 B). In Wichita (ICT) asthma calls are most likely to occur when DM air masses are present and less likely to occur when Moist Tropical, and Dry Tropical air masses are present.

5.3 Strengths & Limitations

This study aimed to identify whether air masses affected the number of asthma call in Tulsa, Oklahoma City and Wichita, while also looking at specific sociodemographic variables such as race/ethnicity, age, educational attainment, and income. We were able to identify statistically significant sociodemographic predictors of asthma. By conducting the analysis at the census block level for each city can provide a more insight for public health and Emergency Medical Services professionals in outreach methods that aim to decrease the burden of asthma.

There are a couple of considerations to keep in mind with this study when interpreting the results. When looking at spatial synoptic classification data there are days labeled as 80s meaning there is no data This was the case for Oklahoma City which had no recorded data from September 2008, until November 2013. Missing this amount of data can lead to a small data set which gives a limited scope of what the results could be if we did not have any missing data. The EMS Data did not account for asthma calls in several Tulsa, Oklahoma census blocks. When the EMS asthma calls were brought into ArcPro the points where not within bounds of the census blocks being analyzed so they were never counted. These points were in neighboring Tulsa counties that were not being analyzed in this study.

This study did not consider any environmental factors such as pollen counts. The Asthma and Allergy Foundation of America just released the 2023 allergy capitals in the United States (AAFA.,2023). Wichita ranks number one as the top worst metropolitan city to live in due to tree, grass, and weed score, over the counter medication, and availability of board-certified allergists and/ immunologists. Oklahoma City is number four on the list and Tulsa is number five on the list. Future research should incorporate additional asthma risk factors, such as environmental predispositions, to more comprehensively examine risk factors associated with air masses and pollen counts in Wichita, Tulsa, and Oklahoma City.

5.4 Future research

Future research still needs to be conducted to better understand the interconnection between air masses and asthma EMS calls across a broader spatial scale. The use of the spatial synoptic classification allows for the analysis of an entire weather type to which an individual is exposed too, opposed to individual weather variables. Synoptic climatological methods are becoming a valuable tool in climate change research (Lee and Sheridan., 2012; Sheridan and Lee., 2010; Knight., Davis., et al., 2008; Kalkstein., Sheridan., Graybeal., 1998; Green and Kalkstein., 1996). Before any accurate future projections of changes in asthma relation can be made research needs to be undertaken to better understand the correlation between air masses and asthma emergency medical services (EMS) across a spatial scale. Contemporary forecasting capabilities can provide an abundant warning for the public health officials in Wichita, Kansas, Tulsa, and Oklahoma City, allowing them to prepare for increased hospital admissions and other stressors, allowing vulnerable populations to take appropriate measures to decrease the exposure to severe environmental conditions. It is important to note that asthma is a complex condition and that there may be other factors at play as well. Further research is needed to fully understand the mechanisms behind these differences in susceptibility.

CHAPTER VI

CONCLUSIONS

Asthma can affect people of all ages, but certain sociodemographic factors can increase the risk of developing asthma or exacerbating symptoms (Cardet et al, 2018; Bacon et al, 2009). This study was conducted to determine whether air masses affect the number of asthma calls in Tulsa, Oklahoma City and Wichita from 2010 to 2015, while also looking at specific sociodemographic variables such as race/ethnicity, age, educational attainment, and income. This study found that asthma calls tend to be greatest where percent minority (black and Hispanic) population is greatest, where percent low-income is greatest and where percent high school only diploma is greatest. Asthma calls tend to be least where percent white is greatest, percent college degree is greatest, and where percent upper income is greatest. It is important to note that these disparities are not solely due to genetics or race itself but are the result of systemic inequalities that impact health outcomes (Uphoff et al, 2013; Stephens., 2009). Addressing these disparities requires a multifaceted approach that include improving access to healthcare, addressing environmental factors, and addressing social determinants of health such as poverty and discrimination.

According to the results of this study the most calls coincide with Dry Moderate in the cities of Wichita, Oklahoma City, and Tulsa, however seasonality is important in asthma calls. While most asthma calls coincide with Dry Moderate air masses at the annual scale and in the fall and winter, many of the calls in spring, and summer coincide with Moist Tropical. Days with many asthma calls are most common in winter, spring when DM is present. In the summer MT is the most common. Days with few asthma calls in the summer and fall the most common air mass type present in OKC and Tulsa is MT when DM is present in Wichita.

An important conclusion that can be drawn is that asthma is a complex disease with many contributing factors, and individual-level factors such as genetics, lifestyle, and exposure to intruding air masses play a role in asthma development and management.

This study benefits science by expanding the literature on climate and health impacts on Kansas and Oklahoma, providing a discussion on the applicability of a popular air mass classification system, and formulating the first asthma air mass study specifically concerning Kansas and Oklahoma.

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APPENDICES

Abbreviations

ICT – Wichita

TUL – Tulsa

OKC – Oklahoma City

DJF – December, January, February

MAM – March, April, May

JJA – June, July, August

SON – September, October, November

EMS- Emergency Medical Services

MT – Moist Tropical

MP – Moist Polar

MM – Moist Moderate

DT – Dry Tropical

DP – Dry Polar

DM – Dry Moderate

Links to Data Sources

http://sheridan.geog.kent.edu/ssc3.html - Spatial Synoptic Classification Data

https://www.census.gov/data/datasets.html - Census Data

ESRI Data for Educational Programs (CD) Copyright 2013

https://firstwatch.net/ - EMS Asthma Data

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