Air Quality, Weather, and Visits to the Hospital for Asthma in Northern New England
Research Proposal

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Abstract

The scientific community has identified the human health consequences of climate change and variability as an issue of primary concern. The range of related morbidity and mortality effects include those resulting from extreme heat, storms, floods, vector-borne disease and poor air quality. The relationship of climate and health is complex and presents significant challenges to improving our understanding of relevant causal relationships. The focus of this study is Northern New England, a region that experiences considerable climate variability, both spatially and temporally. The region's air quality is strongly affected by emissions from upwind sources in the Mid-Atlantic, the Midwest, and eastern Canada and by local/regional emissions as well. New England also has a wide variety of landscapes ranging from densely-populated urban areas to largely-forested regions.

This proposal is an investigation into the relationship between air quality, weather, and respiratory admissions to the hospital and emergency room. Hospital and emergency room data from several northern New England cities will be gathered and condensed into a daily admission value. This series will be compared with air quality records (ozone, particulate matter, sulfur dioxide, nitrogen dioxide) in search of a relationship.

The project will rely upon the efforts of the AIRMAP (Atmospheric Investigations, Regional Modeling, Analysis and Prediction) research program funded by NOAA. The primary mission of AIRMAP is to develop a detailed understanding of climate variability and the source of persistent air pollutants in New England. AIRMAP's goals include identifying the causes of climate variability, predicting air quality changes as an addition to daily weather forecasts, and demonstrating new forecasting technologies. In addition, this project will serve as a background study for the New England Integrated Sciences and Assessments (NEISA). The NEISA project is seeking to increase understanding of the climate/human health relationship by studying the effects of climate variability and air quality on pulmonary function.

Introduction

The human-health effects of climate variability and change have been identified by the scientific community as an issue of concern (IPCC, 2001). The potential effects of a changing climate include mortality effects include those resulting from extreme heat, storms, floods, vector-borne disease and poor air quality. Knowing that each person inhales 20,000 liters of air a day, it is easy to understand that we are in intimate contact with the surrounding atmosphere and thus susceptible to airborne pollutants (Holgate, et al. 1995). Air pollution has been associated with acute reductions in lung function, aggravation of asthma, increased risk of pneumonia in the elderly, increased hospital admissions, and even death (Bates, 1999, Anderson, 1999). In addition, long term exposure to particulate matter has been associated with an increase in lung cancer and cardiopulmonary mortality (Pope, et al., 2002). In clinical studies, ozone, nitrogen dioxide, sulfur dioxide, and particulate matter have been shown to exacerbate asthma, primarily by augmenting airway inflammation (Peden, et al. 1999).

Affecting 26 million Americans, and costing over $12 billion annually, asthma has a significant impact on the American people, accounting for about 3 million lost work days and more than 10 million lost school days annually (CDC, 2001). Between 1970 and 1998, the death rate from asthma *increased* 55.6% even thought the death rate from all causes combined *decreased* 18%. In addition, the prevalence of asthma in the US has been increasing (Figure 1).

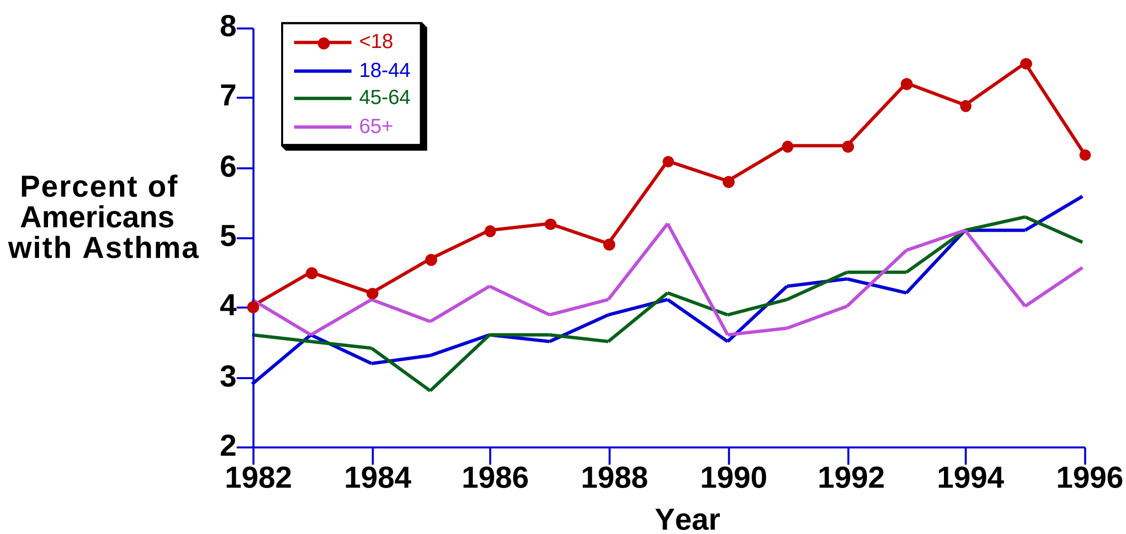

Figure 1: Percent of Americans with asthma by age group. Note that children under 18 years of age have the greatest prevalence. Data from Trends in Asthma Morbidity and Mortality, 2001, American Lung Association.

Among other factors, such as heredity and proximity of smokers, the risk of developing asthma is related to outdoor air quality. For example, one study estimates the relative risk of active children developing asthma in communities with high ozone as 3.3 (95% CI 1.9-5.8) (McConnell, et al. 2002). In contrast to understanding factors that increase the incidence of asthma, there are also factors that provoke it in individuals that have already contracted the disease. These provoking factors, including cigarette smoke, pollen, mold, pets, indoor air quality and outdoor pollution, are better understood than the causal factors (CDC, 2001).

The biggest challenge of resolving the human health/air quality relationship is a lack of good health data. For example, it is difficult to monitor individual asthma attacks, as most people deal with them without medical assistance. Instead of attempting to monitor individual responses, most studies have relied on institutional records for information. For example, for every 1.0 ppm CO and 50 ppb O_3 increase, the daily absenteeism rate in Nevada elementary schools was shown to increase 3.79% (95% CI 1.04 - 6.55%) and 13.01% (95% CI 3.41 - 22.61%), respectively (Chen, et al 2000). Another common source of respiratory data are records of hospital inpatient and emergency room (ER) visits. With detailed information of the number of people visiting the hospital every day and their diagnosis, it is possible to glean some information about the relative number of asthma attacks in a community. Many studies have used this methodology and virtually all found that the number of people that go to the hospital complaining of asthma increases after high pollution events (Dickey, 2000). For example, Burnett, et al. found that a 35% increase (95% CI 19-52%) in the daily hospitalization rate of children under two years of age was associated with an increase in the O_3 concentration (Burnett, et al. 2001). Another study investigated the impact of a massive policy intervention during the Olympic Games in Atlanta, GA in 1996. Policy initiatives resulted in citywide transportation changes resulting in an improvement in air quality (ozone decreased 27.9%) and a reduction in asthma events (19-44%)(Friedman, et al. 2001). One study has explored the role of air-mass type in asthma admissions and found that in New York City, pollution had a stronger correlation with hospital visits during the spring and summer and certain air mass types, while in the fall and winter, air mass had more of an effect (Jamason, et al. 1997).

While institutional records of hospitalization and absenteeism are readily available, they only reveal the most serious reactions to air pollutants (i.e. 'the tip of the iceberg'). Thurston (1997) has estimated the annual health impacts that could be avoided by meeting the U.S. EPA's air quality standards in New York City (Figure 2). This clearly illustrates that hospital admission are only represent a small proportion of the adverse affects of air pollution. The measure of lung function, such as forced vital capacity (FVC), one-second forced expiratory volume, (FEV_1), and peak expiratory flow rate (PEFR) can reveal the more subtle changes to human well being (i.e. the bottom level in Figure 2). Many studies have concluded that lung function is also related to air quality. For example, the California Children's Health study followed over 3,000 children from 12 southern Californian communities that fell along a gradient of air pollution levels for ten years. They found that diminished lung function was associated with living in communities with higher concentrations of pollutants (Peters, et al., 1999). In addition, the children from that study who moved during the study period to areas of lower PM_{10} showed increases in lung function, while those who moved to areas with higher PM_{10} showed decreases in lung function (Avol, et al. 2001). Another study found that ozone was associated with a decrease in lung function in

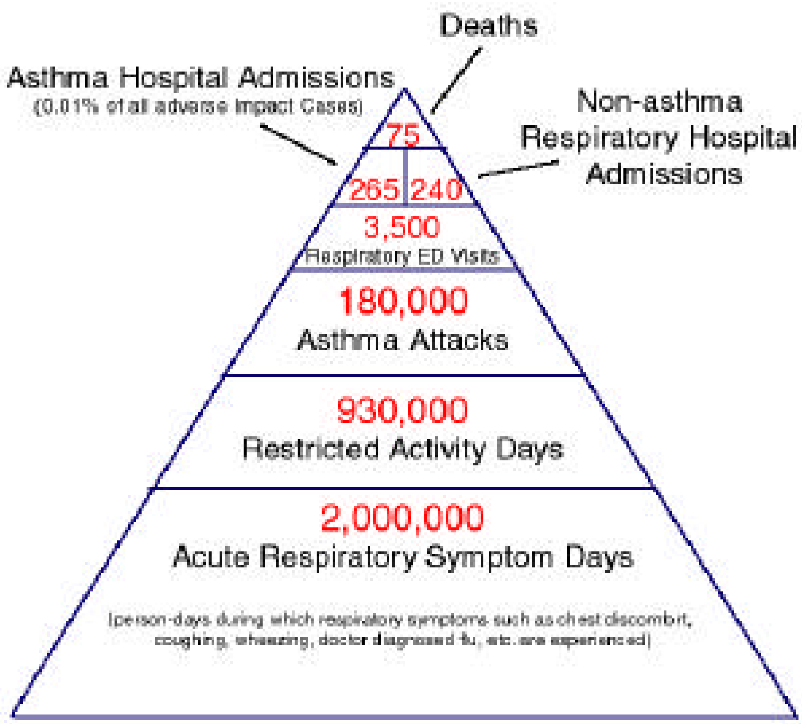

Figure 2. Present day adverse health effects that could be avoided every year by meeting the US EPA's (80 ppb 8-hour) daily maximum standard in New York, NY. Figure sections not drawn to scale. From Thurston, 1997.

hikers in the New England region. They found a 2.6% decline (95% CI 0.4-4.7) in FEV_1, a 2.2% decline (95% CI 0.8-3.5) in FVC, for each 50 ppb increment in ozone (Korrick, et al., 1998). A three-year prospective study in Austria followed over 1,000 children, measuring FEV_1 at the beginning and end of every summer. They found that summertime ozone was associated with a lesser increase in FEV_1, implying that ozone may affect lung function growth (Frischer, 1999).

In summary, research of the effects of air quality on mortality, hospital and ER visits, absenteeism, and lung function have confirmed that there is a significant connection between air quality and human health. However, there are several areas that still need research. Very few of these studies have been completed in New England, despite its dense population and unique air quality and weather phenomena. In addition, little is known about relationship of air mass characteristics and asthma morbidity.

Due to it's unique air quality and weather patterns, New England is an ideal location to conduct this research for several reasons. Lying downwind of several major urban and industrial centers in the eastern US, New England is susceptible to emissions from other regions. Even areas with little local emissions, such as the top of Mount Washington or Acadia National Park, sometimes suffer from dangerous levels of O_3 pollution (AIRMAP, 2002). While most of the studies on this topic have been completed in cities with primarily local pollution, New England receives much of its pollution from outside its borders. As a result, air pollution concentrations in this region are strongly tied to weather and transport processes, rather than local emissions. A high temporal resolution, multi-city study of hospital visits and weather / air quality events will provide a unique perspective on the relationship. For example, most of the O_3 that plagues cities in Northern New England is actually transported up the coast from other regions (AIRMAP, 2002). If a multi-city approach revealed similar relationships between hospital visits and air quality/weather events, it would suggest causation. This approach would be difficult in cities with consistently high O_3 levels that are dominated by local pollution.

The ultimate goal of this research is to increase our understanding of risks associated with pollution. If bad air quality leads to an increase in asthmatic suffering, it is directly affecting the quality of life in the region. Quantifying this relationship will assist efforts to improve the quality of life in the region, both by informing asthmatics of the risks of certain activities and by shedding light on the dangers of bad air quality. This study is funded by AIRMAP and will also serve as background information for the larger, longer-term research of the New England

Integrated Sciences and Assessment (NEISA). This project is building relationships with stakeholders in the region to better understand how people are affected by climate and air quality and how susceptible they are to the changing climate system.

The Question

Is there a relationship between **air quality, weather**, and the number of people who seek hospital care for **asthma** in cities in the Northeast?

- How strong is the relationship?
- Which pollutants are most important?
- What is the weather's role?

In this project I propose to investigate the relationship between air quality, weather, and emergency room (ER) visits to hospitals for asthma in several cities in the Northeast, such as Manchester, NH, and Portland, ME.

Methods

There are three distinct types of data I will be using for this study: air quality, weather and asthma. I will be working primarily with already existing datasets, though I will be modifying them to suit my needs. These datasets will come from a variety of sources as described below.

Asthma

Data Description:	Hospital Inpatient and visits to the ER	
	Date of admission	
	Reason for visit (ICD-9 code 493 - asthma)	
	Demographics (race, age, primary payer)	
Sources		
	Manchester, NH	Manchester Health department
	Portsmouth, NH	Manchester Health department
	Portland, ME:	American Lung Association
	Boston, MA:	Massachusetts Health Department
	Burlington, VT:	Vermont Health Department

The admission database will be summarized into a dataset consisting of total admissions per day. In addition, factors such as age, race, socioeconomic status (as approximated by primary payer) and sex will be separated for individual analysis.

Air Quality

Air quality is the chemical composition of the surrounding atmosphere. Air-quality data are collected by various agencies in New England, including the United States Environmental Protection Agency (US EPA), New Hampshire Department of Environmental Services (NH DES), the AIRMAP program at UNH, and the Maine Department of Environmental Protection (ME DEP). These data will be condensed as explained below into daily values**.**

Data	Ozone (O_3) - daily maximum 8-hour average Particulate Matter (PM_{10}) - daily average and maximum Nitrogen Dioxide (NO_2) - daily average and maximum Sulfur Dioxide (SO_2) - daily average and maximum Pollen and Mold - Daily average
Source:	UNH AIRMAP U.S. EPA NH Department of Environmental Services Maine Department of Environmental Protection National Allergy Bureau

There are a few problems raised by the use of these air quality data. Like other studies of this type, I will be relying on centrally located air-quality monitors to estimate personal exposure. It could be argued that central monitors do not represent actual exposure, since most people spend the majority of their time indoors. However, several studies have found that personal exposure to fine particles are highly correlated with ambient monitoring records (ALA, 2001; Janssen, H. et al. 1999; Mage D. et al. 1999). In addition, the National Morbidity, Mortality, and Air Pollution Study (NMMAPS) developed a model to systematically test if error between measured ambient air quality and personal exposure could be responsible for the relationship observed between particulate matter and mortality. Their analyses "refute the criticism that exposure measurement error could explain the associations between particulate matter and adverse health effects (Zeger, S.L. et al 2000)." Although imperfect, data collected at centrally located air-quality monitors do sufficiently represent personal exposure.

Weather

It has been shown that weather plays a role in aggravating asthma (Jamason, et al. 1997). Meteorological data from the cities will be included as potential factors in affecting asthma admissions. This data will be used to investigate any correlation with the asthma data, but also to build a synoptic weather type dataset. Larry Kalkstein, at the University of Delaware, has developed an automated system for identifying air mass types (a classification of bodies of air that are homogeneous in meteorological character) from the meteorological variables listed above. I will use existing classifications of air mass type (which have been completed for Concord and Boston) to construct a new system for the cities included in this project. In addition, I will also work with Barry Keim and the synoptic climatology that he has developed for New England. I will likely collaborate with Zack Irons and his thesis project on this part of the project.

Data Temperature, humidity, wind, pressure, dew point, thunderstorm, synoptic weather type

Source UNH AIRMAP

Analysis

The analysis of the three time series will be analyzed using a series of Poisson (log-linear) regressions to model the health outcome variables as a function of air pollution, weather, and temporal trends. The ultimate goal is to understand the association of increases in certain pollutants with increases in hospital admissions and ER visits (Figure 3). One outcome of this study will be to quantify any increase above the 'baseline' admissions that occurs in response to an increase in air pollution. One concentration-response (C-R) function commonly used to estimate the change in hospital admissions for asthma associated with daily changes in pollutants is (Lippman, et al. 2000):

$$\Delta \text{ Asthma Admissions} = - [\, y_o \bullet (e^{(-\beta \bullet \Delta \text{Pollutant})} - 1)] \bullet \text{pop}$$

Where:
y_o = Daily 'background' hospital admission rate for asthma per person
β = Coefficient of specific pollutant
Δ Pollutant = change in daily pollutant concentration
pop = estimated population exposed to pollutant

The Poisson regression will be used to find β (pollutant coefficient), which will be used with this model to estimate the number of admissions due to a certain increase in the concentration of a pollutant (Δ Asthma Admissions). This type of analysis will be completed for different seasons and during different airmass types to see how important weather is in the air quality / human health relationship.

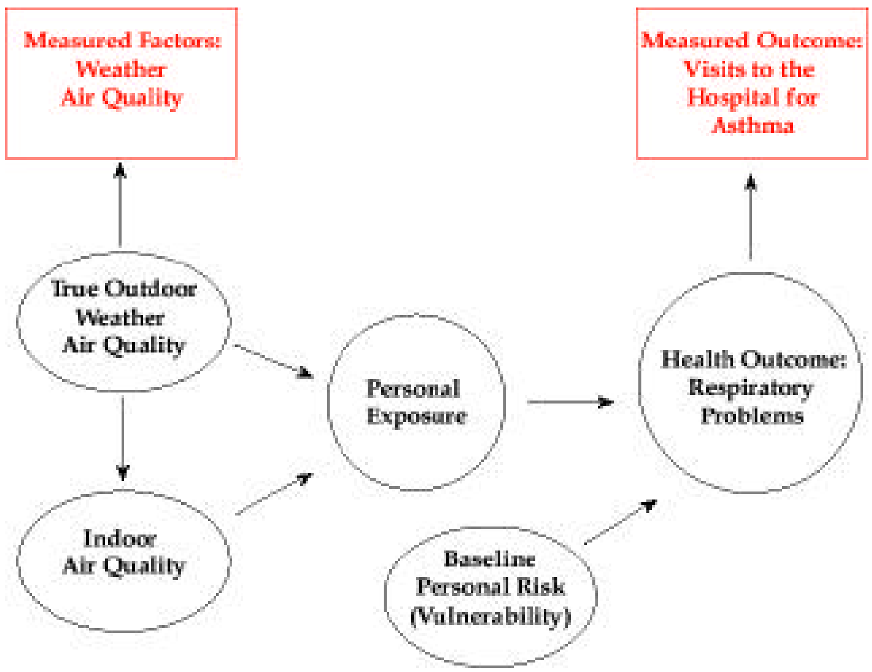

Figure 3: Relationship between the measured factors (weather and air quality) and the outcome (hospital visits).

This project is a continuation and expansion of previous work. Many similar studies have been completed, but this study has several unique characteristics (Table 1). First, it is the only one to be done in New England. Most of the previous work has been on the West Coast, which has very different air quality and weather phenomena. In addition, this study will include air-mass type as an additional variable that only one other study has used. This proposal also includes analyzing data from several cities independently but using exactly the same methods.

Summary

It has been shown in other places that air pollution and weather have a significant effect on human health. While it has been inferred to be important in New England, very little research has been completed to quantify the connection. This project will lead to an increased understanding of the relationship between human health and the climate (both chemical and

	Hospital Visit	ER Visit	O_3	PM_{10}	$PM_{2.5}$	NO_2	SO_4	SO_2	CO	TSP	Acid Aerosols	Mold	Pollen	Thunderstorms	Synoptic Weather	New England	Multi-City
This study	x	x	x	x		x		x				x	x	x	x	x	x
Hwang, 2002	x		x	x		x		x	x								
McConnell, 2002	x		x	x		x					x						
Wong, 2002	x		x	x		x		x									
Anderson, 2001		x	x									x	x				
Burnett, 2001	x		x	x	x	x		x	x	x							
Friedman, 2001	x		x	x		x		x	x								
Maynard, 2001			x	x			x				x						
Strachan, 2000			x	x		x		x				x	x				
Tolbert, 2000		x	x	x		x						x	x				
Koenig, 1999		x	x	x		x	x	x	x			x	x				
Lewis, 1999	x	x	x			x						x	x	x			
Norris, 1999		x		x		x		x	x								
Jamason, 1997		x	x	x		x		x					x		x		
Lipsett, 1997		x	x	x		x											
Stieb, 1996		x	x			x	x	x		x							
Weisel, 1995		x	x														

Table 1: A comparison of this study to previous work.

physical) system. The primary goals of this project and the encompassing New England Integrated Sciences and Assessments (NEISA) are to synthesize climate data, generate scientifically sound information, and communicate relevant research results. These results will address variability and uncertainty in the physical and chemical climate regimes in New England to meet the specific needs of policy makers, stakeholders, residents, and tourists. Determination of the most socially relevant climate issues for any region requires establishing a dialogue with public and private sectors, combined with an assessment of the regional vulnerability to climate fluctuations. Clearly, it is not sufficient to simply get the science right, but this science should also lead to informed decision-making (NRC, 1996). Experience with the ongoing National Assessments has highlighted the value of stakeholder involvement in helping bridge the gap between scientific research and the public (O'Connor et al., 2000; Rock et al., 2001).

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