# An Analysis of the Effect of Climate Change on Respiratory Ailments and Development of a Climate Change Health Model for Use in Community Adaptation Efforts

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July 22, 2011
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Table of Contents

## Introduction

The combination of contemporary human activities, most prominently the excessive burning of fossil fuels including oil, gas, and coal and unprecedented deforestation, has resulted in an abnormal increase in atmospheric greenhouse gases (GHGs), in particular, carbon dioxide, nitrous oxide, and methane (Solomon et al., 2007). These human activities, in turn, have resulted in an overall warming of our planet since these gases are slow to degrade and trap heat (Solomon et al., 2007). The effects of this overall warming of the planet are not linear and affect different areas in different ways. Increased temperatures affect precipitation because warmer air holds more moisture, and changes to temperature and precipitation patterns over long periods of time alter a location's climate. Some places may experience desertification, while others may become wetter; some may become hotter, others more temperate (Solomon et al., 2007). In each of these cases, there is the tendency for an increase in conditions that exacerbate respiratory ailments.

For example, in areas with increased dryness and desertification, more dust is likely to be in the air (Bernard, Ebi, Grambsch, Romieu, & Samet, 2001). Secondly, as a result of additional moisture on a regular basis or more frequent storms, mold becomes a problem (Gamble, Ebi, Sussman & Wilbanks, 2008). Thirdly, as a result of the climate being more temperate, along with an increase in carbon dioxide, the growing season is extended, and more pollen or more-potent pollen expelled into the air (Gamble et al., 2008). Lastly, increased temperatures alone can be a respiratory stressor (D'Ippoliti et al., 2010) as are increased temperatures combined with pollution (particulate matter) and sunlight, which form ground ozone (Bernard et al., 2001).

This investigative paper highlights some of the effects of anthropogenic (human-caused) climate change on respiratory ailments. In particular, this paper examines the rise in aeroallergens (pollen, mold, and dust), heat, and ground ozone, a climate-change consequence

that has been predicted by climate scientists around the world. Secondly, this paper analyzes methods of adaptation and mitigation for climate-change-exacerbated respiratory ailments. Thirdly, this paper presents a climate change health model, one that illustrates how community health practices and environmental efforts should go hand in hand.

This paper relates to the Bachelor of Individualized Studies concentration of Climate Change and Community Health, which combines the disciplines of Environmental Science and Community Health. Respiratory ailments are on the rise, but the general public may not be aware that one reason for this rise may be due to climate change. Some researchers are studying and reporting on the global security aspects of climate change (Rogers, 2009); others are studying the effects on our food and water supplies (Costello et al, 2009); many are focused on the outcomes for plant and non-human animal species (Montoya & Raffaelli, 2010). Health care is one of the most important issues of our time, yet alongside mass-media articles highlighting the dire consequences of obesity or smoking, for example, the health effects of climate change, unfortunately, are rarely reported.

Environmental courses are concerned with our (human) interactions with the natural world, yet they have typically relied on natural and social science disciplines such as chemistry, ecology, political science, and economics and have not included any disciplines in the health fields (Withgott & Brennan, 2009). Pubic health courses teach disease prevention and methods of achieving healthy lifestyles to those interested in working in the community health field, and although a public health curriculum includes courses in environmental health, they have traditionally been "concerned with the spread of disease through water, air, and food" and not the health effects brought about by climate change (Schneider, 2006, p. 10). By studying the issue of climate change and community health from an interdisciplinary viewpoint, one learns not only

about the science of climate change but also the effects on society of environmental health hazards—including climate change—and to avoid or adapt to climate-caused or climate-exacerbated ailments by using the public health model, focusing on prevention.

The audience for this project is the general public and those interested in the field of community health, particularly those who feel less informed about climate change and its health consequences. From an environmental science perspective, this project defines climate change, outlines the causes, and discusses the consequences, as well as examines the public's perception of climate change. From a health perspective this project defines respiratory ailments, outlines their causes, prevalence, costs, and prevention/treatment.

Included in the Background portion of the paper is a section regarding the public perception of climate change as well as the its perception of the effects of climate change on human health. This section supports the framework of this paper. By framing climate change from a health perspective, this paper aims to convey to readers the importance of mitigating climate change. If the public takes no mitigation actions, the only alternative is to learn to adapt, and the climate change health model aids in understanding adaptation measures.

## Background

This section is intended to provide readers with five basic knowledge bases: 1) climate change science, 2) general consequences of climate change, 3) respiratory ailments, 4) public perception of climate change and the health consequences thereof, and 5) respiratory health consequences of climate change.

### Climate Change Science

Using thermometers, humankind has recorded global temperatures since the mid-1800s. From 1860 to 2005, the average temperature rose approximately .76°Celsius (1°C = app. 1.8°F)

(Trenberth et al., 2007). In addition to natural processes that affect global temperature, such as variations in solar activity and volcanic eruptions, a majority of climate scientists have determined that a primary explanation for this temperature increase is human-produced greenhouse gases from the time of the industrial revolution forward (Schneider, Rosencranz, & Niles, 2002).

Historical records of the greenhouse gas carbon dioxide ($CO_2$) can be detected in air bubbles trapped in ice sheets. Ice cores drilled from Antarctica dated to 400,000 years ago have helped scientists connect the rise in temperatures to the rise in $CO_2$ (McManus, 2004). Greenhouse gases in our atmosphere are needed to maintain life on the planet, but an overabundance of these long-lived gases trap too much heat and affect the climate of different geographic regions.

The Intergovernmental Panel on Climate Change in its Fourth Assessment Report in 2007 asserted with "very high confidence" (p. 3) that anthropogenic climate change has been occurring since 1750 (Solomon et al., 2007). Figure 1 shows the connection between rising $CO_2$ and rising temperature levels in the northern hemisphere; graphs for the southern hemisphere are similar (Science Museum of the National Academy of Sciences, 2011).

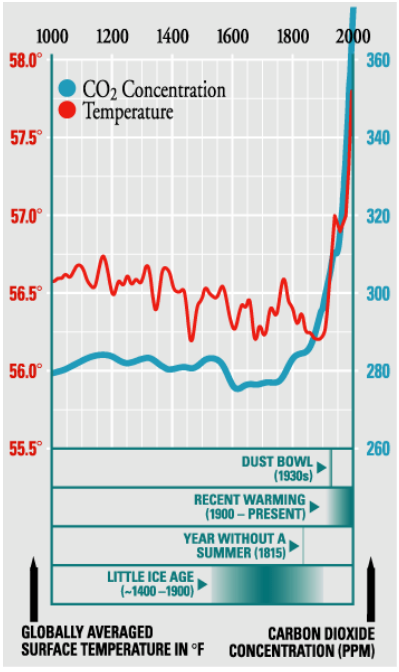



**Figure 1**

Graph showing concurrently rising $CO_2$ and temperature levels

## Climate Change Consequences in General

As a result of increased greenhouse gases, the overall average temperature of the earth has increased, which colloquially is termed "global warming." This warming is affecting the earth in a non-linear way, due to the temperature differences between the

poles and also the random dispersal of land and water bodies across the planet. This higher overall temperature of the earth means different things in different places and thus, the term "climate change" is a better description than "global warming." Because of the non-linearity of the earth system, some places are affected much more than others and some areas are getting colder while others get hotter. In the end, climate change will impact humans, plants, and animals in every part of the globe, although as mentioned, in different ways. Scientists have already observed sea level increases; altered precipitation patterns and variations in freshwater availability; changes in energy, transportation, and agriculture sectors; ecosystem disruptions; and health issues (Karl, Melillo, & Peterson, 2009). Although many people may not be seeing effects on a large scale at the present time, there are those around the planet who are indeed witnessing their way of life changing.

Inhabitants of the coldest environments on the planet, such as Siberia and Alaska, are experiencing climate change on an all-too-personal level, because warming and weather no longer allow them to grow or hunt traditional foods, build homes, travel, or secure fresh water (Crate, 2008; Crate & Nuttall, 2009). Newtok, Alaska, is one such community. The process of relocating the entire population because of sea and river erosion, thawing permafrost, storm surges, and increased temperatures began in 2006 and is expected to be completed this year (State of Alaska, n.d.). The 2,000-year-old community is being moved by the federal and state governments nine miles south of its present location at a cost of approximately $2 million per family, or a total of $80 to $130 million (State of Alaska, n.d.).

**Respiratory Ailments: Definitions, Susceptibility, Costs, and Treatment**

Indicative of the seriousness of respiratory ailments in our country, one of the goals of the U.S. Department of Health and Human Services' [HHS] Healthy People 2020 initiative is to:

> Promote respiratory health through better prevention, detection, treatment, and education efforts [because] the burden of respiratory diseases affects individuals and their families, schools, workplaces, neighborhoods, cities, and states. [Due to] the cost to the health care system, the burden of respiratory diseases also falls on society; it is paid for with higher health insurance rates, lost productivity, and tax dollars. (HHS, n.d., ¶s 1 & 6).

This initiative will be in force for the next 10 years, with respiratory disease one of 42 public health topics in Healthy People 2020 (HHS, n.d.).

Although there are over two dozen distinct lung diseases, there are three general categories of lung ailments: 1) Airway diseases, such as asthma, emphysema, and chronic bronchitis in which the breathing tubes are narrowed or blocked; 2) diseases that cause scarring or swelling of the lung tissue itself; and 3) ailments such as chronic obstructive pulmonary disease (COPD) that damage the blood vessels in the lungs (University of Maryland Medical Center [UMMC], 2011). Asthma and COPD will be examined in this paper, as will allergies, another respiratory ailment.

**Asthma**. Asthma is perhaps the most familiar pulmonary disease. Sufferers from this chronic condition become short of breath and cough or wheeze when having an attack (Health Canada, 2006). Triggers for asthma include stress, exercise, aeroallergens such as pollen, and other types of air pollution (Health Canada, 2006).

In the United States there are more than 24 million people with asthma: 17.5 million adults and 7.1 million children (U.S. Center for Disease Control and Prevention [CDC], 2009). In 2006 there were over 13 million doctor visits or outpatient hospital visits by those with asthma, and one-half million required inpatient hospital care, averaging three and one-half days

(figures as of 2006) (CDC, 2009.) Worldwide, there are approximately 300 million sufferers (figures as of 2007) (World Health Organization [WHO], 2011).

According to the CDC (2010), asthma is more prevalent among females, children, African Americans, and Puerto Ricans, as well as those living under the poverty level and in the U.S. Northeast and Midwest. Asthmatic children missed more than 10 million school days; adult employees missed more than 14 million workdays (Akinbami, 2011). Death rates are low (3,447 in 2007, the majority among adults), but treatment costs in addition to the financial cost of lost work- and school-days are high—a staggering $30 billion per year on average in the United States (CDC, 2010).

Medications are available to prevent an asthma attack and to ease an attack after the onset of symptoms, and physicians also work with patients to help them determine and avoid personal triggers to lessen the need for medications (UMMC, 2011). Although an asthmatic's quality of life can be impaired, a sufferer does not always experience symptoms. Unfortunately, there is no cure for asthma at the present time (UMMC, 2011).

**COPD**. COPD is another well-known pulmonary disease. Although most cases are attributable to tobacco smoke, pollution has been linked to the disease as well (Health Canada, 2006). Over 14 million American adults have been diagnosed with COPD, which includes two conditions: chronic bronchitis and chronic emphysema (CDC, 2011).

In the United States, COPD is the number four cause of death; in 2005 there were 715,000 hospitalizations of COPD sufferers (Brown, Croft, Greenlund, & Giles, 2010). Worldwide, there are at least 210 million people with COPD (2007 figure) (WHO, 2011). In 2006, there were 120,000 deaths caused by COPD; this number represents 53.6% of all deaths caused by lung diseases (U.S. Department of Health and Human Services, National Institutes of

Health, National Heart, Lung, and Blood Institute [NHLBI], 2009). In the past 10 years, COPD cases have almost doubled (Brown et al., 2010).

In 2006, the World Health Organization's Global Initiative for Chronic Obstructive Lung Disease released a report titled *Global Strategy for the Diagnosis, Management, and Prevention of Chronic Obstructive Pulmonary Disease*. According to the report, COPD is usually diagnosed in middle-aged or elderly people of both sexes (equally or perhaps favoring females slightly) and can severely restrict everyday activities as it progresses. Once diagnosed, treatment is almost always required for the rest of a sufferer's life, with the goal being to maintain quality of life and prevention of further deterioration. Treatment involves reducing risk factors, by advocating smoking cessation and indoor/outdoor air quality improvement. Additionally, there are many medications currently used to treat symptoms, but again, they cannot prevent progression of the disease. There are physical therapy, oxygen therapy, and nutritional regimes that can be undertaken, as well as several surgical procedures—although surgery is not a preferred method of treatment. The costs related to COPD in the United States in 2002 exceeded $32 billion (medical costs and lost-productivity costs) and are expected to rise greatly in the next 20 years. (WHO, 2006).

**Allergies.** In addition to asthma, COPD, and other lung diseases, millions of people (animals suffer too) are affected by airborne nasal and skin allergies, most of which are caused by dust, animal fur, mold spores, chemicals, and pollen (U.S. Department of Health and Human Services, National Institutes of Health, National Institute of Allergy and Infectious Diseases [NIAID], 2003).

In 2003, NIAID reported that 35 million Americans experience hay fever (seasonally or all year long) and that between 40 and 50 million Americans suffer from some sort of allergic

disease (of all types). The number afflicted with asthma and non-food allergies has risen substantially in the past 50 years, even taking into account better medical diagnosing (Isolauri, Huurre, Salminen, & Impivaara, 2004).

According to data gathered by the American Academy of Allergy, Asthma and Immunology (n.d.), not only are the number of allergy sufferers rising but the financial cost of treating allergic rhinitis (upper respiratory problems caused by aeroallergens) is rising as well. Over half of the $11.2 billion spent in 2005 (double that of 2000) was for prescription medications; also included in that figure were visits to physicians and hospitals (numbering over 12 million in 2006) and immunotherapy treatment, such as desensitizing allergy shots (American Academy of Allergy, Asthma & Immunology [AAAAI], n.d.).

Humans are susceptible to allergies in part due to their genetic predisposition but also because of environmental factors (NIAID, 2003). Avoidance of allergic triggers, another treatment method, is not always possible, as not everyone can avoid going outside for long periods of time or going to work, for example (NIAID, 2003).

**Public Perception of Climate Change and Its Health Consequences**

In June 2010, when polled by researchers from the Yale Project on Climate Change Communication and the George Mason University Center for Climate Change Communication, 61 percent of Americans thought that global warming was “happening” (p. 2), up slightly from 57 percent in January 2010 but down from 71 percent when the same question was asked in 2008 (Leiserowitz, Maibach, Roser-Renouf, & Smith, 2010). When pollsters followed by asking the same 61 percent to rate their confidence in that belief, only 20 percent were “extremely sure” and 37 percent were “somewhat sure” (Leiserowitz et al., 2010, p. 2).

In the same survey (2010), 50 percent of all respondents answered that climate change was "caused mostly by human activities" (p. 3), while 40 percent said that climate change was "caused mostly by natural changes in the environment" (Leiserowitz et al., 2010, p. 3). Interestingly, the number of those who believe in anthropogenic climate change dropped slightly from 2008, while those who believe climate change to be natural rose (Leiserowitz et al., 2010).

Media and public relations specialists hired by companies opposed to climate-change-mitigation legislation/regulations have made an impact on the American public's mind. In this regard, the poll (2010) also indicated Americans feel more scientists disagree than agree that global warming is occurring, a viewpoint strengthened since 2008 (Leiserowitz et al., 2010).

In short, the responses to the questions about belief in climate change, its cause, and disagreement by scientists about global warming indicate that the average American has not received current, correct information about climate change through the media.

The Intergovernmental Panel on Climate Change, the climate-change research organization formed by the United Nations Environment Programme [UNEP] and the World Meteorological Organization, is composed of over "2,000 scientists from 154 countries . . . [who] are independently nominated for participation in the Panel by their own governments. The fields of Earth system science, meteorology, ecology, economics, engineering, the social sciences and many more are represented" (Intergovernmental Panel on Climate Change [IPCC], n.d., p. Participants, ¶1). Current peer-reviewed studies from all over the world are gathered and analyzed by IPCC scientists who have been divided into three groups: The Physical Basis of Climate Change; Climate Change Impacts, Adaptation and Vulnerability; and Mitigation of Climate Change (IPCC, n.d., p. How the IPCC Works, ¶ 2). The best of this data are compiled into reports that are again reviewed by additional groups of scientists as well as by governments

participating in the process (IPCC, n.d., p. How the IPCC Works, ¶ 3). The next comprehensive reports are due in 2013 and 2014, but the most recent report in 2007, as has already been stated above, affirmed that anthropogenic climate change is occurring and that change will continue for at least 20 years, even if we are able to reduce greenhouse gas levels to what they were in 2000 (Solomon et al., 2007).

Of course, there are scientists who disagree that climate change is occurring, that it is human-induced, or that it requires action on the part of citizens and governments (CATO Institute, 2009). A study published last year in the Proceedings of the National Academy of Sciences sought to determine the credibility of climate change scientists (Anderegg, Harold, Prall, & Schneider, 2010). Publication and citation data for 1,372 climate scientists who had published at least twenty papers in the field were reviewed (Anderegg et al., 2010). Ninety-seven to 98% of them were in agreement with IPCC principles, i.e., consensus about anthropogenic climate change (Anderegg et al, 2010). Put another way, those researchers who were less prominent in their fields, with less expertise, composed the group who did not believe in anthropogenic climate change.

Of the many studies under consideration for the next set of IPCC reports, one published in 2008 by researchers from eight countries (including the United States) reported on data collected from physical and biological systems between 1970 and 2004 (Rosenzweig et al., 2008). Changes such as seasonal modifications, species distributions, and glacial melt were found to be occurring on every continent (Rosenzweig et al., 2008). The researchers deduced that the deviations could not be from natural forces alone, and that 90 to 95% of the 29,500 pieces of evidence tracked for over twenty years showed change due to anthropogenic climate change (Rosenzweig et al., 2008).

In so far as climate change and health are concerned, in 2010 Leiserowitz et al. queried just over 1,000 adult Americans about their level of concern regarding this issue (next page):

*Level of concern that climate change will affect personal health*
*(columns: # respondents June 2010 and Jan. 2010)*

| | June 2010 | Jan 2010 |
|---|---|---|
| Rating of Seven (Extremely concerned) | 8 | 7 |
| Six | 9 | 7 |
| Five | 14 | 14 |
| Four | 22 | 17 |
| Three | 9 | 12 |
| Two | 14 | 13 |
| Rating of One (Not at all concerned) | 25 | 29 |

The answers to this climate change and personal health question indicate that some Americans may be growing somewhat more concerned, although the change is not statistically significant (the same question was not asked in 2008).

The Yale and George Mason researchers joined other researchers in Malta and Canada to review studies about the public's perception of the effect of climate change on health (Akerlof et al., 2010). Of particular note, Americans tend not to believe climate change will affect them individually. Only 10 percent of those surveyed said that global warming would harm them personally; the top three responses were plants/animals, future generations, and less-developed nations (Akerlof et al., 2010). Overall, the researchers felt that, if the consequences of climate change were framed more from a health perspective, productive climate change mitigation and adaptation actions might get underway, and they encouraged additional study of this approach (Akerlof et al., 2010).

Americans should be concerned about the health consequences of climate change. In April 2009, the U.S. Environmental Protection Agency (EPA) issued the so-called Endangerment ruling under the Clean Air Act, declaring greenhouse gases harmful to human health (Proposed

Endangerment and Cause or Contribute Findings for Greenhouse Gases Under Section 202(a) of the Clean Air Act, 2009).

The American Public Health Association (APHA) in November 2007 issued a policy paper regarding climate change, a policy in which APHA members asserted the need for climate change adaptation and mitigation due to the seriousness of human health impacts. In 2008 they followed that policy paper with the beginnings of a plan for public health professionals, one that will help the American public recognize the dangers of climate change, prepare for its health consequences, and stop further environmental damage (APHA, 2008).

In 2008, the American Medical Association (AMA) also issued a policy paper, one that concurs with the IPCC's findings about anthropogenic climate change and the IPCC's conclusion that climate change will adversely affect human health. In the policy paper (2008) the AMA urged physicians to become involved in the effort to combat climate change, in ways similar to those stated in the APHA plan.

**Respiratory Health Consequences of Climate Change**

Climate change is expected to create a diverse set of health problems. Millions around the globe may experience malnutrition, suffer or die from heat waves, floods, storms, fires, and droughts, and succumb to illness brought about by an influx of infectious disease vectors (Parry, Canziani, Palutikof, van der Linden, & Hanson, 2007). The poor, the very young and the elderly, and those who are already sick or immunocompromised are at greatest risk. Aeroallergens (pollen, dust, mold) are known respiratory irritants, as are high temperatures and increased levels of ground ozone.

**Aeroallergens: pollen.** With regard to one of these human health consequences of climate change, Dr. Lewis Ziska of the U.S. Department of Agriculture in 2000 published data

gathered from studying ragweed in the laboratory to determine the effect of higher $CO_2$ concentrations. In February 2011, Ziska published additional ragweed data gathered from studying the length of its growing season.

In the first study, Ziska (2000) found that ragweed pollen, a common respiratory allergen, did indeed increase with more $CO_2$. Ziska (2000) determined that in the past 100 years, ragweed pollen counts had already doubled, and that within 75 years, if $CO_2$ levels double, as expected, ragweed pollen counts would also double--again.

In his 2011 study, Ziska confirmed that ragweed pollen counts in North America had risen in the last 15+ years due to higher temperatures. Ziska (2011) examined field data from all over the continent and determined that warmer temperatures have created a longer ragweed growing season due to an increase in the number of frost-free days and a delay of the first frost in higher-latitude areas of North America (e.g., Nebraska north). Specifically, Ziska noted, ragweed pollen was expelled 13 to 27 days longer (Ziska et al., 2011). What this may point to in the very near future, as researchers review patient health records of the recent past, is an increase in medical treatment for those with existing respiratory problems.

For example, in 2007, researchers studied the connection between pediatric asthma medical emergencies and increased aeroallergens, climate change (temperature and precipitation), and air pollution (Wang & Yousef). For the time period January 1, 2000, to December 31, 2003, in Wilmington, Delaware, they found that on days when tree and weed pollen counts were elevated, pediatric emergency room visits were also slightly elevated, indicative of a trend upwards (Wang & Youself, 2007). Of note, the latitude of Wilmington, Delaware, is 39.76°N, and the two pollen-counting stations used in Ziska's 2011 study closest to Wilmington were located at 41.15°N and 36.33°N. The median between these two numbers is

38.735, putting Wilmington closer to the 41.15°N location, one at which the ragweed season increased by 11 days in the last 15 years (Ziska, 2011).

**Aeroallergens: mold.** Mold is another aeroallergen, the production of which is affected by both temperature and precipitation. According to the EPA (2008), there are six types of mold commonly found in the United States that can adversely affect health, and that thrive in all but the coldest of conditions. Tiny mold spores can be present in large numbers in both indoor and outdoor environments when conditions are right. If humans are sensitive to a particular type of mold upon inhaling the spores, exposure can trigger allergic rhinitis or asthma attacks or even possibly prompt the development of asthma. Mold is the fifth leading cause of allergic reactions—the first being pollen; dust mites, second; pets, third; and cockroach excrement, fourth. (EPA, 2008).

Climate change is expected to cause conditions that will result in more severe weather events than in the past, some, perhaps on the magnitude of Hurricanes Katrina and Rita in 2005. The IPCC (2007) stated "[i]t is *very likely* that hot extremes, heat waves and heavy precipitation events will continue to become more frequent . . . [and that] it is *likely* that future tropical cyclones (typhoons and hurricanes) will become more intense" (p. 6). Two recent studies published in the February 2011 journal *Nature* indicated that such events can already be connected to climate change: floods in England and Wales in 2000 (Pall et al, 2011) and precipitation events in much of the northern hemisphere using data from 6,000 weather stations between 1951 and 2003 (Min, Zhang, Zwiers, & Hegerl, 2011).

The aftermath of Katrina and Rita presented ideal conditions for mold growth and, in fact, 44% of homes inspected by the Center for Disease Control in October 2005 had visible mold, with 19% of those homes heavily saturated with mold (Barbeau, Grimsley, White, El-

Dahr, & Lichtveld, 2010). Researchers at Tulane University's Schools of Public Health and Medicine (2010) studying the human health effects of Katrina's and Rita's aftermath, expected to find elevated numbers of medical visits by area residents as a result of the mold infestations. Instead they found that health care sought for allergy and asthma attacks did not increase significantly (Barbeau et al., 2010). They attribute that, however, to several factors, among them: limited access to healthcare because of the damage to medical infrastructure as well as the lack of health insurance; the fact that large numbers of homes were either abandoned or gutted so exposure was limited; a sense that mold reactions in allergic individuals might not have seemed serious enough to those affected to warrant medical treatment (Barbeau et al., 2010).

Another example of recent severe weather is the horrific flooding in the state of Iowa in 2008, flooding which particularly impacted Iowa City and Cedar Rapids (Iowa Climate Change Impacts Committee [ICCIC], 2011). One of the impacts was indoor mold growth. Researchers from three Iowa universities reported to the Iowa state legislature in the report *Climate Change Impacts on Iowa 2010* that temperatures and precipitation in the state have been on the rise (ICCIC, 2011). One of the report's contributors, Dr. Eugene Takle (2010), head of the Climate Science Program at Iowa State University, wrote in 2008 that the climate change pattern in Iowa over the last 30 years is consistent with that predicted by the IPCC. Dr. Peter Thorne, another contributor to the report to the legislature and also the director of the University of Iowa's Department of Occupational and Environmental Health as well as the university's Environmental Health Sciences Research Center, stated that the resulting mold from the aftermath of the floods resulted in "an increased burden of respiratory diseases including allergic rhinitis, asthma . . . and reports of a condition known colloquially as 'the flood crud' [that] . . . left victims suffering malaise, fatigue, and cough, often for many weeks" (ICCIC , 2011. p. 24). Flooding aside, Dr.

Takle noted in the report, Iowans should be aware that indoor mold may become a more frequent problem in the summer due to the trend of rising humidity levels (ICCIC, 2011).

**Aeroallergens: dust.** This section looks at inorganic dust (not dust mites), small inhalable particles that are created by soil or rock erosion. Dust levels can be increased by climate-change-caused or human-caused desertification and/or by altered wind patterns due to climate change (Confalonieri et al., 2007). The United Nations Environmental Programme (2006) reported climate-change-increased temperatures in the majority of deserts between 1976 and 2000 and forecast that average temperatures will continue to rise during this century. The UNEP report also projected less rain in the future for the Sahara desert due to climate change, which means there will be even less vegetation and greater dust emissions (Safriel, 2006).

In the past thirty years, increased amounts of dust from the Sahara region of northern Africa have been carried to the Caribbean, which some believe has resulted in an increase in asthma in the region (Gyan et al., 2004; Prospero & Lamb, 2003). The increased amount of dust carried by the trade winds is due both to changes in precipitation patterns and human agricultural practices, and unfortunately, increased amounts of dust can affect the climate even more by altering the warming of the ocean surface and the entire hydrological cycle (Multiza et al., 2010; Prospero & Lamb, 2003). In so far as agricultural practices are concerned, when commercial agriculture took off in northwest Africa in the mid-1800s, expansion of crops into forested and wooded areas was common, and this led to more field soil being open to wind dispersal (Multiza et al., 2010).

A 2004 study linked the increased African dust to escalations in treatment sought for pediatric asthma on the island of Trinidad (Gyan et al.). A more recent study, however, has debated that link, although the researchers cited other studies concerning the Middle East and

Australia in which asthma/dust connections were also claimed (Prospero, Blades, Naidu, Mathison, Thani, & Lavoie, 2007). The more recent study (2007) did not rule out the possibility that increased amounts of dust contribute to other respiratory illnesses, and another researcher, a prominent environmental geographer at Oxford University who studies dust storms, pointed out that other allergens can be carried by dust—fungal spores and chemical pollutants, for example—and that dust particles themselves, being so small (and thus able to penetrate deeply into the respiratory system), represent respiratory and cardiovascular health hazards (Kuehn, 2006).

**Excess heat.** The temperature of the human body need only rise slightly to suffer the ill effects of heat. The normal range for our body, on average, is 98.6°F to 100.4°F; above the range of 102.2°F and 104°F, the body becomes stressed (Hannah, McMichael, & Butler, 2011). The elderly, the poor, those already sick, pregnant women, children, and those whose job entails outside work are at greater risk for direct impacts of elevated heat levels, including heat stroke, cardiopulmonary distress, and even death (Hannah et al., 2011; Kjellstrom, Butler, Lucas, & Bonita, 2009; Sheffield & Landrigan, 2011). In addition, those living in urban areas may be exposed to slightly greater increased temperatures than non-urban dwellers, due to the "heat island effect," a well-known consequence of built-up areas holding more heat than rural areas with natural landscapes (Kjellstrom et al., 2009).

Since 1850 anthropogenic climate change has increased the global temperature on average .76°C, with the years 1995 to 2006 being the warmest years on record; and between now and 2030, global mean temperatures are expected to rise on average between 0.64°C and 0.69°C (if no greenhouse gas mitigation plans are put into place) and rise again as the century progresses

(even if some mitigation plans are put into place) (Solomon, et al., 2007). As has already been stated in this paper, the effect of climate change will vary from place to place.

The European summer of 2003 was the hottest on record in over five centuries, according to researchers at the Universities of Oxford and Reading (Stott, Stone, & Allen, 2004). They found with very high certainty that not only is Europe as a whole warming but that the cause is anthropogenic climate change, and they also assert that such extreme heat events will "increase 100-fold over the next four decades" (Stott et al., 2004, p. 613).

In France alone, which was the hardest hit, there were almost 15,000 deaths between August 4 and 18, 2003, when temperatures in some locations rose over 35°C (95°F) and over 40°C (104°F) in others; normal temperatures average between 24.8°C (76.64°F) and 37°C (98.6°F) (Poumadere, Mays, LeMer, & Blong, 2005). Middle-aged people of both sexes and elderly women were most affected; the greatest numbers of people died from dehydration and heat stroke, followed by renal and respiratory illness (Poumadere et al., 2005).

In the city of Essen, Germany, during approximately the same time period, researchers found that daily mortality rates due to the heat wave increased by 32%: a 61% increase in deaths due to respiratory causes; a 30% increase due to cardiovascular causes; cancer deaths were also up slightly (age/sex not reported in study) (Hoffman, Hertel, Boes, Weiland, & Jockel, 2008). Deaths due to respiratory ailments stayed elevated for a week following the end of the heat wave (Hoffman, et al., 2008).

Closer to home, in California, researchers examined hospital and emergency room visits during the heat wave of July 2006, when temperatures broke records and millions were affected (Knowlton et al., 2009). Emergency room visits increased by over 16,000, spread over all age groups; hospitalizations increased by a little over 1,000, with most admittances being elderly

patients (Knowlton et al., 2009). Heat-related ailments of all sorts were presented: electrolyte imbalance, renal issues, cardio/respiratory illness, and diabetes (Knowlton et al., 2009). Prolonged periods of excess heat not only cause illness and death, but also create environments in which accidents can occur more easily; mental health is affected; and learning in a school setting is curtailed (these topics will not be discussed in this paper) (Kjellstrom et al., 2009; Sheffield & Landrigan, 2011).

**Ground ozone.** There are two types of ozone: that in the upper atmosphere, which protects us from excess UV radiation; and that in the lower atmosphere, which in excess is harmful to living things. This section focuses on the latter: ground ozone--an air pollutant and health hazard.

Motor vehicles, industrial plants, and some natural sources, which by themselves are not enough to be a health hazard, emit nitrous oxide and volatile organic compounds, which in the presence of hot temperatures and sunlight create ozone (EPA, n.d.). Both urban and rural dwellers can be affected by ozone, because both the precursor pollutants and ozone can be blown "hundreds of miles away from their original sources" (EPA, n.d., p. 1, ¶2).

In humans, ozone is a respiratory irritant, the effects of which can be temporary, permanent, or life threatening with repeated exposure; ozone is especially dangerous for the young, the elderly, those with existing respiratory ailments, and those who work outdoors (EPA, n.d.). In addition to minor respiratory complications such as coughing and wheezing, ozone can cause an exacerbation of asthma, and "increase[s] susceptibility to respiratory illnesses like pneumonia and bronchitis" (EPA, n.d., p. Health and Environment).

In a 2009 report, EPA released findings showing that climate change is expected to increase summertime levels of ground ozone. The typical season of ozone formation (summer)

will be lengthened (spring and fall). Geographic areas affected would be those where temperatures rise, humidity decreases, and/or wind patterns shift (EPA, 2009).

The Royal Society of London (2008), an organization similar to the National Academy of Sciences, released findings about the danger of rising ozone levels due to climate change, the effects of which are already being felt in Europe. The report (2008) describes acute and chronic damage that can be inflicted by ozone inhalation, including the most serious effect (death notwithstanding): damage to the lining of the lungs, which impairs lung function. Due to cardio and respiratory problems caused by high levels of ozone, emergency room and hospital visits, medications prescribed for asthma, school absenteeism, and deaths have increased in Europe (Royal Society, 2008). The Royal Society (2008) predicted that if ozone levels rise unchecked until 2020, the United Kingdom could see as much as a 15% higher death rate (compared to that in 2003) from ozone/health complications.

A paper published in 2007 used modeling to predict various effects of climate-change-increased ozone mid-century in 50 American cities east of the Mississippi (Bell et al.). The researchers found that the number of elevated ozone days (above current the EPA standards) would increase 68%, which, in turn could result in .11% - .27% more human deaths. With 95% confidence they predicted rises in COPD and other respiratory ailments in the elderly and in asthma among the younger population. Richmond, Virginia, may see one of the largest increases in ozone levels in the 2050s (as compared to levels in the 1990s), with levels reaching into the purple zone (see Figure 2) of the Air Quality Index (Bell, et al., 2007). In 2009, there were 1,888 deaths in Richmond (Virginia Department of Health, 2011); therefore, an increase in deaths mid-century of .11% to .27% could result in an additional two to five deaths annually--from a rise in ozone alone.

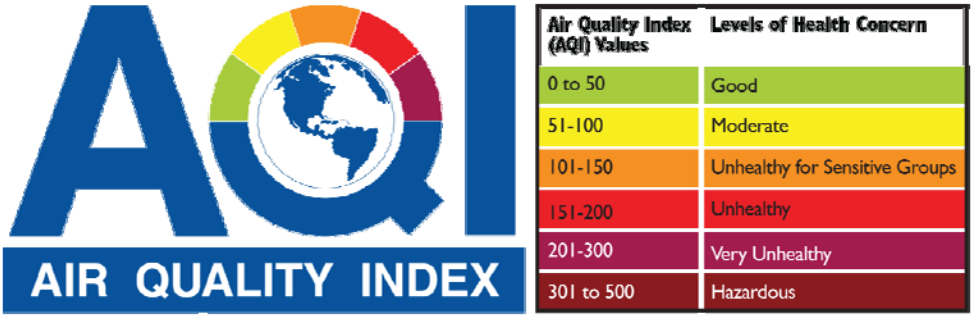



**Figure 2 EPA Air Quality Index, 2008**

## Methodology and Evidence

A critical analysis of current interdisciplinary literature and reports from reputable scientific organizations links climate change and respiratory ailments, provides evidence of adaptation and mitigation methods for climate-change-induced respiratory ailments, and contributes to creating a climate change health model.

Although predicted many years ago, sometimes with computer models (McMichael et al., 1995), researchers are beginning to look back through medical records, searching for evidence that points to the negative health outcomes of emitting greater amounts of fossil fuels (Wang & Yousef, 2007). Therefore, the cause-and-effect evidence linking climate change and respiratory ailments is in the form of studies in which researchers have reviewed increased hospitalizations, treatments, and deaths of patients suffering from respiratory ailments that have occurred at the same time as the appearance of climate-change stressors being studied in this project (pollen, mold, dust, excess heat, and ground ozone).

The adaptation methods presented consist of, for example, adjusting an individual's behavior to avoid distress. For some people this might mean staying indoors upon receiving via the media a high heat, ground ozone, or pollen warning provided by local environmental quality and public health departments (Confalonieri et al., 2007). An example of mitigation would be encouraging and/or mandating the use of renewable energy sources as a substitute for fossil-fuel-

based energy sources to reduce greenhouse gas emissions that add to and cause health problems in the first place (Confalonieri et al., 2007).

The final purpose of this project is to create a climate change health model. The IPCC in its fourth assessment suggested that to ensure the survival of as many natural systems (including humans) as possible, there needs to be "a portfolio or mix of strategies that includes mitigation, adaptation, technological development (to enhance both adaptation and mitigation) and research (on climate science, impacts, adaptation and mitigation)" (Parry et al., 2007, ¶14). These climate change strategies combined with the established public health model (U.S. Institute of Medicine [IOM], 1988) and the three public health interventions designed to keep populations healthy (primary, secondary, and tertiary prevention) (Schneider, 2006) were the guide for creating the climate change health model for this project. By visually representing the combination of these two concepts, the consequences of and need for adaption to climate change and strategies for protecting human health in a climate-changed world should be easier to understand. This final product may be the best evidence of the interdisciplinary nature of the topic of this paper.

## Analysis

### Mitigation of and Adaptation to Climate Change

The evidence heretofore presented points to the need to both mitigate and adapt to climate change—at an individual, community, and societal (government) level—to protect human respiratory health. What follows is a discussion of both mitigation and adaptation. Mitigation is discussed in general terms, and adaptations discussed are for the respiratory ailment triggers discussed in this paper.

**Mitigation**. The IPCC Working Group III (2007) reported that mitigation policies, historically, are most effective when they have taken into account "four main criteria…:

environmental effectiveness, cost effectiveness, distributional effects, including equity, and institutional feasibility" (Metz, Davidson, Bosch, Dave, & Meyer, p. 19). Climate change mitigation efforts must focus mainly on reducing the levels of fossil fuel emissions to lower the amount of greenhouse gases in the atmosphere and improving agricultural practices to both improve carbon uptake and reduce nitrogen and methane releases (Metz et al., 2007). Efforts should be made in the energy, transportation, buildings and industry, agriculture, forestry, and waste management sectors (Metz et al., 2007). Many of the mitigation recommendations in the IPCC report should by now be familiar to the public. Some efforts can be undertaken on an individual level but need to be implemented on a much larger scale, among them: using natural gas or renewable energy sources instead of coal, using mass transportation, buying energy efficient appliances and lighting, reducing fertilizer use, reforestation, and better waste management (composting, recycling, etc.) (Metz et al., 2007).

In so far as climate-change-induced health problems are concerned, mitigation efforts would create substantial health-cost savings in the long run as well (Metz et al., 2007). The British journal of medicine, *The Lancet*, did a survey of studies focused on climate change and health (Watts, 2010). The following findings are some of the climate change and health connections published in *The Lancet's* final report, the executive summary for which is titled "The Health Benefits of Tackling Change": more efficient household appliances, or in the case of less-developed countries, less-polluting cook stoves, minimize cardiopulmonary health burdens caused by poor air quality and increased heat; reducing dependency on personal vehicular use can lead to an increase in exercise via walking and cycling, resulting in multiple health benefits; cleaner energy generation improves air quality, which reduces cardiopulmonary

problems; and changing the way we eat—more plants, less meat—is not only good for the planet but for our bodies, in a cardiovascular sense (Watts, 2010).

Mitigation strategies are crucial because inaction in the short-term has far-reaching consequences. Although education is a key component of helping the public not only understand the ramifications of climate change but also how to adapt to and mitigate climate change, education must be followed by policy changes, to ensure that the public is protected from the effects of climate change—protection which entails modifying some of the ways in which we live, work, and play.

**Adaptation**. The IPCC Working Group II studies the effects on societies from climate change as well as societies' vulnerability from and adaptation to climate change. In the adaptation chapter of the Working Group II's 2007 report, the authors stated that societies have often sought ways to adapt to their environment (Adger et al.). The authors revealed findings that adaptation to climate change is occurring now, albeit on a small scale and not always to climate change specifically, for example: We adapt to a heat wave but not the underlying cause of climate change (Adger et al., 2007). Adaptations can be simple and low cost or very complicated, with a higher price tag, and adaptation capacity is not evenly spread among all societies or groups within societies (Adger et al., 2007).

**Aeroallergen adaptation: Pollen, mold, & dust.** Heavy pollen days and longer pollen seasons can be forecast—just as heat and ozone are forecast—and a search of Google.com reveals numerous Web sites offering daily notices sent to one's computer or cell phone. Advance warning is also available to those who live in areas prone to dust storms, from governmental and non-governmental agencies such as the National Weather Service and the World Meteorological Association (WMO) (U.S. Department of Commerce, 2011; WMO,

2011). In addition to being regularly informed about pollen and dust, maintaining communication with health-care providers is key, as is having on hand routine medicine and so-called rescue inhalers for sufferers of asthma or other respiratory ailments (Macquarie University, 2009; Schmier & Ebi, 2009; Sheffield, Weinberger, & Kinney, 2011). Several other adaptation methods were briefly mentioned or alluded to previously: avoidance of respiratory ailment triggers such as pollen and dust, for example, staying indoors or filtering air, allergy shots for pollen, and preparedness on the part of hospitals or other medical treatment facilities for higher-than-usual admissions.

Eliminating indoor moisture is crucial in adapting to a mold-prone environment, and de-humidifiers, air conditioners, and exhaust fans can help in this regard; indoor humidity should be between 30 and 50% (EPA, 2011; Storey et al., 2004). Water-damaged furnishings or building materials can begin to grow mold within 24-48 hours, so immediate cleaning and drying is critical (EPA, 2011). Hard surfaces that already have mold on them can be washed with detergent (recommended over bleach) and dried thereafter (EPA, 2011; Storey et al., 2004). Gloves, eye protection, and—in heavily mold-damaged buildings—personal respirators should be used by those undertaking the cleanup effort (Storey et al., 2004). Those with medical issues (especially those with respiratory ailments), should seek professional mold remediation (Storey et al., 2004).

On a broader level, governments must plan for and ensure that neighborhoods and/or entire cities are as safe as possible from climate-change-caused extreme weather events, a consequence of which may be mold (Costello et al., 2009). More severely restricting habitation in flood-prone areas and/or creating defense barriers, relocation, or developing more mold-resistant building materials are examples of such action. As is the case for other aeroallergens,

heat, and ozone, early warning of mold-inducing weather events, and access to health care are crucial (Costello et al., 2009).

**Heat adaptation.** Researchers at the Harvard and University of Michigan Schools of Public Health, in conjunction with the International Council for Local Environmental Initiatives (O'Neill, 2009), outlined possible strategies for adapting to climate-change-increased heat events. The researchers first acknowledged that susceptibility to heat depends on "age, race, sex, class, home characteristics, access to air conditioning, general health and living in an urban area versus a rural area" (O'Neill et al., 2009, p. 99). The researchers then suggested the following short- and long-term actions to adapt to periods of excess heat:

- ✓ High-heat alerts: "media announcements . . . home visits or telephone calls to vulnerable people, and website bulletins" (p. 99).
- ✓ Cooling centers and/or increased use of air conditioning, although there are pluses and minuses to both solutions.
- ✓ Planting additional vegetation (more trees for shade, roof-top plantings, etc.) and increasing solar reflectivity (asphalt and roves with reflective coatings, etc.) in urban areas (O'Neill, 2009).

Actions such as these are in practice in many major cities in the United States—Philadelphia, for example (Karl et al., 2009)—although as stated above when referencing the IPCC report on adaptation, the programs may have begun in response to heat waves alone, rather than in response to the possible underlying cause of climate change (Adger et al., 2007).

**Ozone adaptation.** High-ozone alerts are usually broadcast on radio and TV, but anyone can sign up for daily emails of the Air Quality Index (Figure 2) from www.airnow.gov (EnviroFlash) or follow EnviroFlash via social media sites such as Facebook (AIRNow, n.d.).

When ozone levels are at Code Orange or above (Figure 2), everyone needs to modify their behavior slightly, but those with respiratory ailments need to curtail their outdoor activities at the Code Orange level and avoid outdoor activities altogether at Code Red or above (EPA, n.d., EPA, 2008). Healthy people need to curtail their outdoor activities when the level is at Code Red or above (EPA, n.d.; EPA, 2008).

Because climate change may create longer and/or more intense ozone seasons in some regions, we also need to adapt to various lifestyle limitations intended to keep levels at the most moderate possible. On high-ozone alert days (orange and up, but can include yellow days), recommended adaptations include reducing the use of gas-powered vehicles, fueling such vehicles in the evenings, and temporarily cutting down on using "household, workshop, and garden chemicals until air quality is healthy again," due to the volatile organic compounds they emit which can add to ozone formation (EPA, 2008).

## Limitations

As in any project, there are limitations to what is presented in this paper. Firstly, not every scholarly paper on the topic of climate change and respiratory ailments has been researched, read, and reported on, due to the fact that this project is one of an undergraduate student and not a graduate student.

Secondly, the perspective of the author is that of one who has studied mostly in the fields of Environmental Science/Policy and Global/Community Health. These two disciplines are critical in understanding the specific topic of this project—climate change and respiratory ailments—but the two disciplines would also be important to those studying either climate change or 21st century community health issues (alone). Studies in other disciplines would certainly ensure a greater understanding of both the specific topic of this project and climate

change in general. Anthropology, Psychology, Communications, Economics, Philosophy, Urban Planning, and Conservation Biology are but a few of the disciplines that could provide insight for those studying the effect of climate change on community health. For example, although dollars and cents are briefly mentioned in several parts of this paper, courses in Economics would enable a climate change and health researcher to better understand the pros and cons of implementation of any number of regulations on this topic, as cost-effectiveness must be taken into account in all decision-making. However, a more thorough understanding of Philosophy (Environmental Ethics) might enable the researcher to come to the conclusion that no cost is too great to save a species, an ecosystem, or future generations because it was not within our rights as humans or Americans to degrade it/them in the first place. Also of note, many courses relevant to the topic are sometimes taught only at the graduate level.

Thirdly, this paper discusses mitigation briefly in the Analysis section, striving to create an awareness that mitigating climate change is critical to prevent having to adapt to the health consequences of climate change. It is recognized, however, that a single reader is limited in the actions he or she can take to make a difference in climate change mitigation. That said, perhaps a reader will be inspired to join others (community group, grass root campaign, etc.) in such a pursuit, or at the very least, feel better informed about mitigation and adaptation practices after reading this paper.

Lastly, as only briefly mentioned in this project, there are other climate change health consequences besides respiratory health consequences. A reader concerned about the consequences of climate change would do well to seek additional reading on the topic to fully educate themselves to the health dangers of a changing environment.

## Discussion

Public health professionals, working alongside climate scientists, are ideally suited to helping communities cope with climate change because of the way they address problems and because their focus is on prevention and early intervention. Visual representations can aid in understanding unfamiliar concepts, so four models follow that are intended to illustrate the connections between climate change and community health. The final model combines public health methodology with climate change adaptation and mitigation practices.

### Modeling

Figure 3 shows the connection between climate change and respiratory ailments. This simple model illustrates the chain of events set in motion by humankind's use of great amounts of fossil fuels, culminating with one of many outcomes: the rise in respiratory ailments.

Figure 4 is an example of the public health model that incorporates the field's three key methods of problem solving: assessment, policy development, and assurance (HHS, 2008). Assessment is equivalent to a doctor making a medical diagnosis or to a scientist seeking answers to an observation by using the scientific method (observe, form a hypothesis, test) (Schneider, 2006). Policy development is equivalent to a health practitioner's medical treatment plan or a climate scientist's proposal to government agencies to mitigate or adapt to climate change (Schneider, 2006). Assurance means ensuring in general that programs are in place to assist a population in living a healthy lifestyle, just as scientists continually test their own and one another's hypotheses to verify soundness and seek improvement (Schneider, 2006).

The preliminary climate change health model (Figure 5) takes a basic environmental health model (boxes/type in black) and adds (in red) the core public health functions (assessment, policy development, and assurance). Inserted into the model are the three types of

interventions at the core of public health's mission of keeping communities healthy: primary care, secondary care, and tertiary care. Primary care consists of preventative methods, for example, cancer prevention via anti-smoking media campaigns directed towards teens. Secondary care entails early diagnosis and intervention, for example, promotion of vision screenings in public schools. Tertiary care strives to curtail disability in those with existing conditions, for example, making available maternity care for pregnant women unable to afford it (Schneider, 2006). The purpose of this model is to show how climate change mitigation and adaptation fit into the public health model, generally.

The final climate change health model (Figure 6) includes mitigation and adaptation examples—some from the Analysis section of this paper—to more clearly illustrate how individuals and communities can understand and prepare for some of the health consequences of climate change.

**Figure 3** Establishment of causal relationship between climate change and ↑ respiratory ailments

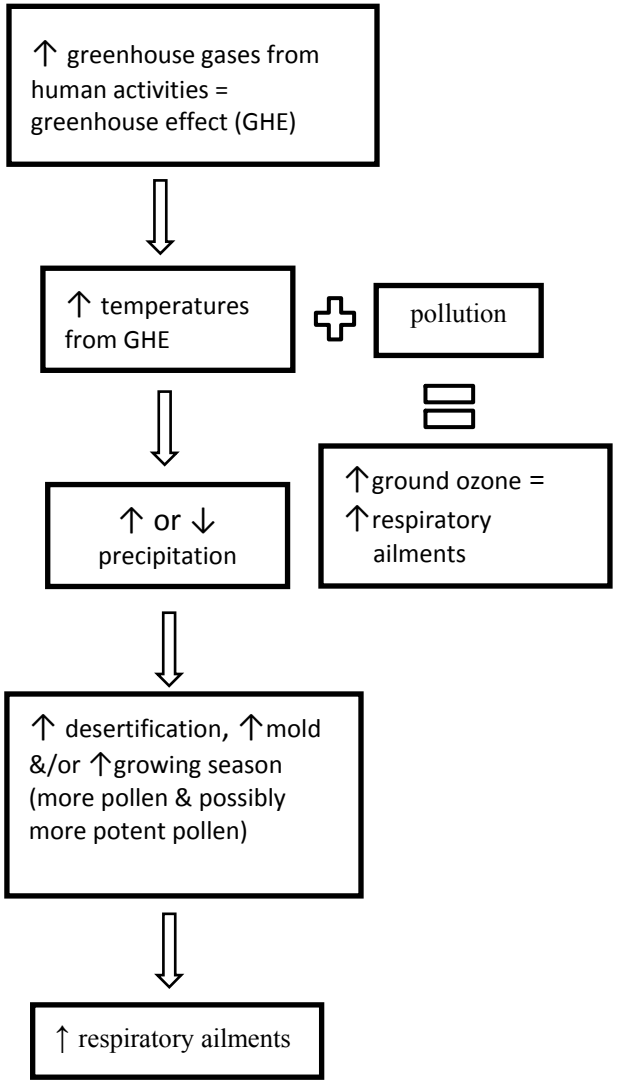
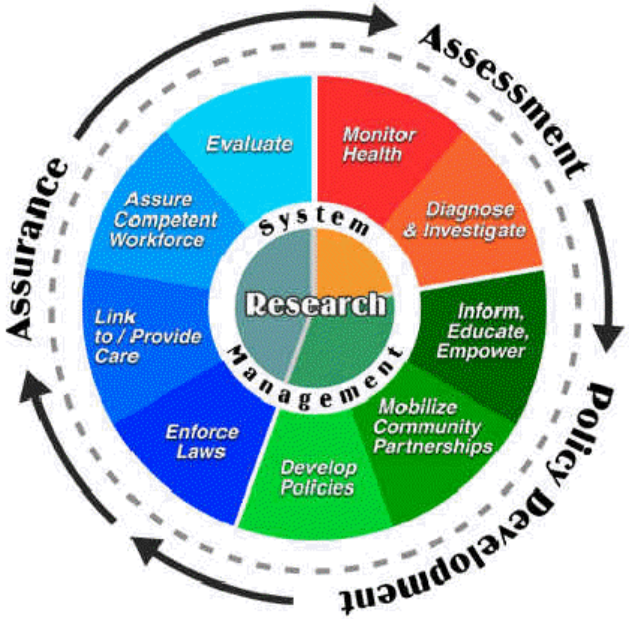
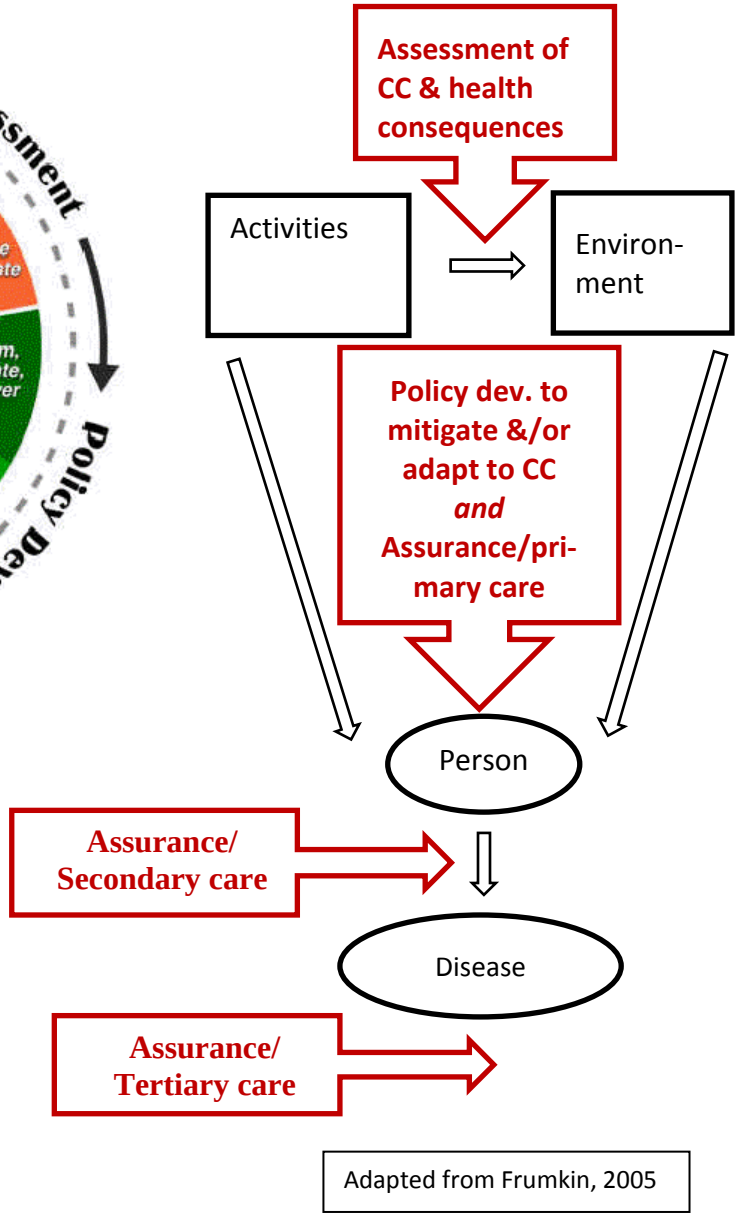



**Figure 4** Public health model: assessment, policy development, & assurance



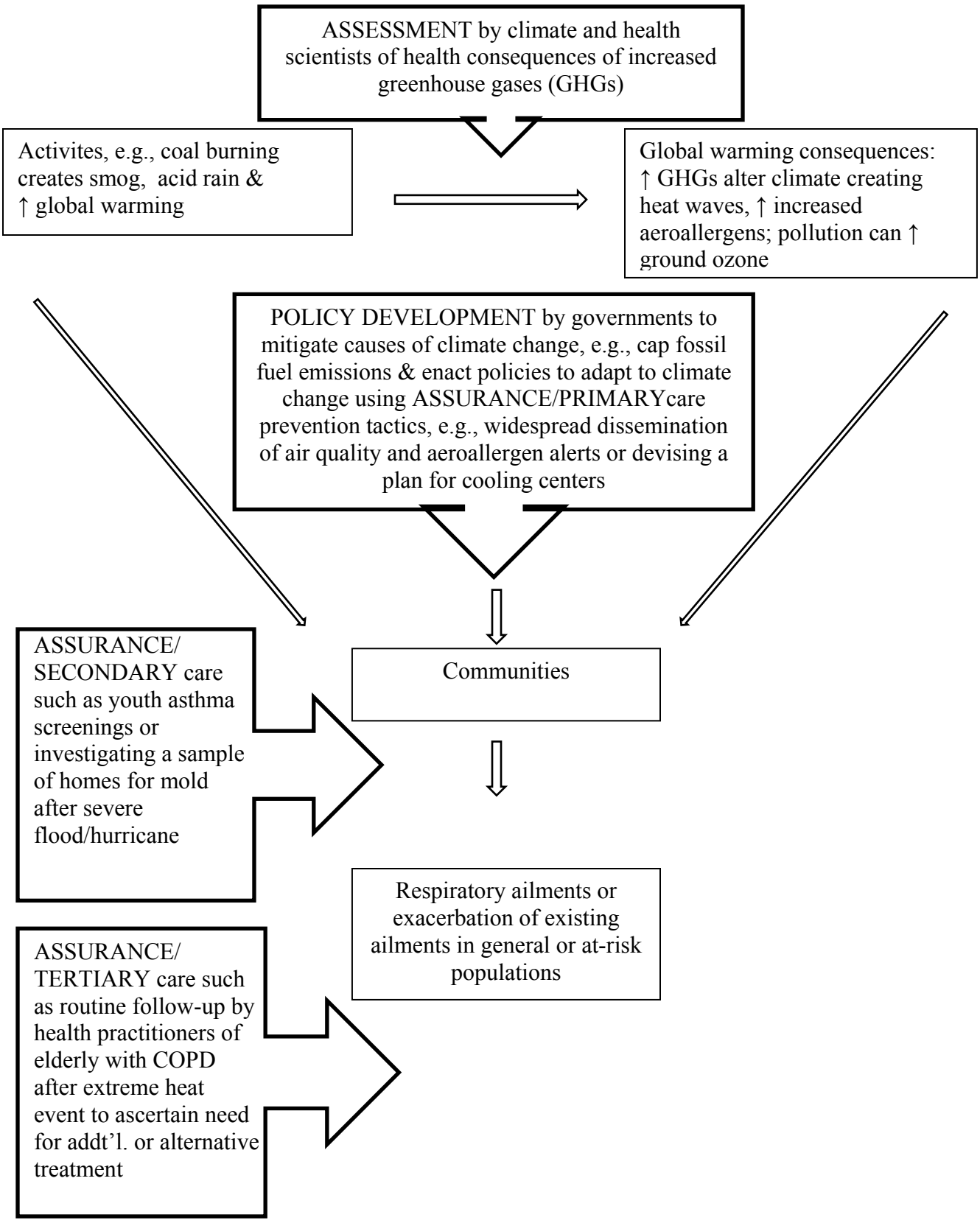

HHS, 2008

**Figure 5** Draft climate change health model




Adapted from Frumkin, 2005

**Figure 6** Final climate change health model



**A Theoretical Scenario Using the Climate Change Health Model**

To better understand the final climate change health model, imagine a community hospital. The hospital employs a Sustainability Engineer (SE) or Climate Change Officer (CCO). Working with local and state environmental scientists and public health experts, the SE or CCO assesses the health consequences of climate change that may occur in the hospital's geographic location, for example, higher temperatures, finding that higher temperatures, combined with increased air pollution due to recent population growth (cars, industry, etc.), will likely result in not only high-heat days but high-ozone days.

The public health department and hospital administration then work with local government officials to implement various climate change mitigation strategies. These policies may include offering free public transit rides, mandating that certain roadways be designated "High Occupancy Vehicles Only" on Code Red Days, or instituting a no-idling policy at the designated patient-pick-up area, to reduce local pollution from cars that add to greater levels of ozone on high-heat days.

As part of its commitment to assurance and prevention, the public health department would issue daily air quality and heat-index alerts. On its web pages it would also maintain information about climate change and health. The hospital would receive and broadcast the health department alerts on information monitors at its information and registration desks and in the waiting rooms. Hospital patrons would be able to use the interactive monitors (touch screen) to find out more about the air quality index, high-heat alerts, and the health consequences of both.

Hospital cardiologists, respiratory therapists, and pulmonary specialists would offer a web-based education program for patients newly diagnosed with respiratory ailments. The

program would be designed to help them understand both their illness and the effect climate change may have on their health. Each patient would submit an email address to receive daily air quality, heat index, and pollen alerts automatically. Existing patients at high risk for ozone and heat consequences, such as those with COPD, would be flagged in the hospital's and doctors' databases. On poor air quality or high-heat days when these patients are scheduled for routine appointments, they would receive an automated email offering to reschedule, along with a reminder about taking proper precautions, such as remaining indoors in air conditioning. This secondary assurance would be aimed at reducing the severity of their illness, by reducing their heat and ozone exposure.

The hospital's and the health department's Medical Reserve Corps volunteers would telephone elderly, high-risk respiratory patients or their caregivers on Code Red days or when the National Weather Service issues an Excessive Heat Advisory/Warning (National Oceanic and Atmospheric Administration, 2010). The volunteers would offer rides to the local cooling center or to deliver a portable fan, and encourage patients to call 911 if they become medically distressed. This tertiary assurance would help to prevent further disability in seriously afflicted individuals.

Traditional medicine and public health practitioners must work together to help the public combat the health effects of climate change. A climate change health model, such as that proposed here, is substantially similar to other disaster response models. It is hoped that through the implementation of such a model communities will be better able to address various and changing scenarios.

**What are Community Health Organizations Doing about the Climate Change & Health Connection?**

In 2008, the George Mason University Center for Climate Change Communication (4C) conducted a survey of community public health officials and discovered several things: Health consequences of climate change are occurring throughout the United States; health officials expect their communities to experience additional health consequences connected to climate change in the next two decades; communities lack the resources to cope with the issue (Maibach, Nisbet, & Weathers, 2011). George Mason's 4C advocated in their latest report (2011) that public health professionals be in the forefront of the effort to mitigate and adapt to climate change, echoing this paper's assertion that climate change should be framed from a community health perspective. The 4C report points to several states already beginning to tackle the issue from a public health standpoint: California, Minnesota, and New York (Maibach et al., 2011).

Another report for public health professionals was published this April, on the heels of a year's worth of webinars hosted by the American Public Health Association and the CDC. As does George Mason's 4C report, APHA's *Climate Change: Mastering the Public Health Role, a Practical Guidebook* (2011), is meant to further inform public health professionals, who in turn can help the public realize the connection between climate change and health and also take steps to protect community health. The APHA report (2011) noted the connections made in this paper between primary, secondary, and tertiary interventions and climate change adaptations.

To determine what, if anything, is being done on a very local level, three public health departments and two hospitals near George Mason University were contacted for this project: Health departments of Loudoun, Arlington, and Fairfax counties; Inova Health System and Virginia Hospital Center. The Fairfax County Health Department's Public Safety Officer, Glen

Barbour, on June 21, 2011, said he knew of nothing specific happening on the climate change and community health front in his department. The health department's web site has a page about air quality alerts (and the health implications), along with a few links to other sites discussing same, but there is nothing that specifically discusses climate change or the health consequences of climate change. Mr. Barbour said that the website is in the process of being completely redesigned, but he knew of no plan to incorporate information about climate change and/or the health consequences of climate change (Mr. Barbour is the webmaster) (Fairfax County Health Department, n.d.).

The director of the Loudoun County Health Department, Dr. David Goodfriend, on June 22, 2011, said that his department was not involved in climate change and/or climate change and health issues at the present time. Dr. Goodfriend pointed only to an air quality link on his department's home page that takes a reader to a page on the county's site. The county's page consists of a definition of ground ozone and several links to external sites concerning air quality (Loudoun County Government, n.d.).

On the Arlington County Public Health Division web pages there is no mention of climate change, although in a January 2009 report posted online—*Strategies for Building a Healthier Arlington*—global warming is mentioned as one of seven drivers of change that can affect citizenry health (Arlington County Public Health Division, 2011; Arlington County Public Health Division, MAPP Steering Committee, 2009). Arlington County Public Health Division Planning and Education Chief Josephine Peters in an email dated June 27, 2011, said that her division "is not planning to begin any public education about the health consequences of climate change."

Telephone calls and emails to the Inova Health System Office of Sustainability and Virginia Hospital Center went unanswered but brief reviews of their web sites are reported here. No mention of climate change, global warming, or environmental health was found on the Virginia Hospital Center web pages (Virginia Hospital Center, n.d.). Inova Health System has implemented numerous green iniatitives, including setting up Green Teams composed of hospital staff and volunteers at each Inova hospital in the D.C. area. Many of the initiatives, such as the promotion of eating locally grown farm goods, increasing wooded areas of their campuses by planting native trees, energy conservation and recycling, represent fine efforts in mitigating climate change. It is not apparent from their web site, however, that they are helping their staff and patients understand the connection between climate change and future health problems. (Inova Health System, n.d.).

## Conclusion

The natural systems on which we depend for food, water, and shelter are changing. Every day, the media bombards us with news about both natural and human-caused environmental tragedies. The earthquakes in Haiti and Japan, the oil spill in the Gulf of Mexico, and closer to home, the pollution-filled Chesapeake Bay are but a few examples of such tragedies. Although not receiving the same amount of media attention, at least in the United States, climate change too is one of those environmental tragedies.

What if we do nothing to mitigate or adapt to climate change? Tufts University researchers in a 2008 study answered that while "[i]t is difficult to put a price tag on many of the costs of climate change: loss of human lives and health, species extinction, loss of unique ecosystems, increased social conflict, and other impacts extend far beyond any monetary measure" (p. vii), doing nothing could cost the United States more than 3.6 percent of our GDP

by 2100, or $3.8 trillion dollars per year (2008 dollars) (Ackerman & Stanton). Likewise, a cost-benefit economic analysis commissioned by the British government in 2006 stated that while *acting* on climate change would annually cost 2% of the world's GDP, *not acting* would cost 5-20% annually (Costello et al., 2009).

By looking at climate change from a health perspective, more specifically, a respiratory health perspective, it is hoped that readers are better able to see the need for mitigating and adapting to climate change. Scientists, health professionals, and government agencies have previously worked together to solve some of our most pressing problems. In the 1960s, engineers and community health advocates worked together to improve automobile safety. The establishment of the National Traffic and Motor Vehicle Safety Act in 1966 led to the implementation of various automobile safety devices which have greatly reduced motor vehicle injuries and fatalities over the years (Schneider, 2006).

This interdisciplinary project strives to show that the health of our planet is directly connected to our own health, and that we should embrace ways in which we can clean up and improve both. If we instead ignore it, this tragedy may be the greatest challenge humankind has ever faced.

References

Ackerman, F., & Stanton, E. A. (2008). *The cost of climate change: What we'll pay if global warming continues unchecked*. Retrieved from National Resources Defense website: http://www.nrdc.org/globalwarming/cost/cost.pdf

Adger, W.N., Agrawala, S., Mirza, M.M.Q., Conde, C., O'Brien, K., Pulhin, J., . . . Takahashi, K. (2007). Assessment of adaptation practices, options, constraints and capacity. In M.L. Parry, O.F. Canziani, J.P. Palutikof, P.J. van der Linden and C.E. Hanson (Eds.), *Climate change 2007: Impacts, adaptation and vulnerability. Contribution of working group II to the fourth assessment report of the Intergovernmental Panel on Climate Change*. Retrieved from http://www.ipcc.ch/pdf/assessment-report/ar4/wg2/ar4-wg2-chapter17.pdf

AIRNow. (n.d.). *AIRNow – Homepage* [Web page]. Retrieved from http://airnow.gov/

Akerlof, K., DeBono, R., Berry, P., Leiserowitz, A., Roser-Renouf, C., Clark, K., . . . Maibach, E.W. (2010). Public perceptions of climate change as a human health risk: Surveys of the United States, Canada and Malta. *International Journal of Environmental Research and Public Health, 7*(6), 2559–2606. doi: 10.3390/ijerph7062559

Akinbami, L.J., Moorman, J.E., & Liu, X. (2011). Asthma prevalence, health care use, and mortality: United States, 2005–2009. *National Health Statistics Report, 32*, 1-16. Retrieved from http://www.cdc.gov/nchs/data/nhsr/nhsr032.pdf

American Academy of Asthma, Allergy & Immunology. (n.d.). *Allergy statistics* [Web page]. Retrieved from http://www.aaaai.org/media/statistics/allergy-statistics.asp

American Medical Association. (2008). *Report 3 of the Council on Science and Public Health (I-08): Global climate change and human health* [Web page]. Retrieved from http://www.ama-assn.org/resources/doc/csaph/csaph3i08-summary.pdf

American Public Health Association. (2007). *Addressing the urgent threat of global climate change to public health and the environment, APHA policy number 20078* [Web page]. Retrieved from http://www.apha.org/advocacy/policy/policysearch/default.htm?id=1351

American Public Health Association. (2008). *Blueprint: Recommendations for the public health community; climate change is a public health issue* [Web page]. Retrieved from http://www.nphw.org/nphw08/NPHW%202008%20Blueprint.pdf

American Public Health Association. (2011). *Climate change: Mastering the public health role, a practical guidebook.* Retrieved from http://www.apha-environment.org/pdf/APHA_ClimateChg_guidebook.pdf

Anderegg, W.R.L., Harold, J., Prall, J.W., & Schneider, S.H. (2010). Expert credibility in climate change. *Proceedings of the National Academy of Sciences of the United States of America*, *107*(27), 12107-12109. doi: 10.1073/pnas.1003187107

Arlington County Public Health Division. (2011). *Human services: Public health services* [Web page]. Retrieved from http://www.arlingtonva.us/Departments/HumanServices/services/health/HumanServicesServicesHealthPublicHealth.aspx

Arlington County Public Health Division, MAPP Steering Committee. (2009). *Strategies for building a healthier Arlington: Mobilizing for action through planning and partnerships [MAPP]*. Retrieved from http://www.arlingtonva.us/departments/HumanServices/PublicHealth/mapp/MAPPDocuments/file68225.pdf

Barbeau, D.N., Grimsley, L.F., White, L.E., El-Dahr, J.M., & Lichtveld, M. (2010). Mold exposure and health effects following hurricanes Katrina and Rita. *Annual Review of Public Health*, *31*, 165–178. doi: 10.1146/annurev.publhealth.012809.103643

Bell, M. L., Goldberg, R., Hogrefe, C., Kinney, P. L., Knowlton, K., Lynn, B., . . . Patz, J. (2007). Climate change, ambient ozone, and health in 50 US cities. Climatic Change, 82, 61-76. doi: 10.1007/s10584-006-9166-7

Bernard, S.M., Ebi, K.L., Grambsch, A., Romieu, I., & Samet, J.M. (2001). The potential impacts of climate variability and change on air pollution-related health effects in the United States. *Environmental Health Perspectives*, *109,* 199-209. Retrieved from http://www.jstor.org/stable/3435010

Brown, D.W., Croft, J.B., Greenlund, K. J., & Giles, W. H. (2010). Trends in hospitalization with chronic obstructive pulmonary disease—United States, 1990–2005 [Abstract]. *COPD: Journal of Chronic Obstructive Pulmonary Disease, 7*(1), 59-62. Retrieved from http://informahealthcare.com/doi/abs/10.3109/15412550903499548

CATO Institute. (2009). *Ad campaign takes on global warming myths* [Web page]. Retrieved from https://www.cato.org/pubs/policy_report/v31n3/cpr31n3-5.html

Confalonieri, U., Menne, B., Akhtar, R., Ebi, K.L., Hauengue, M., Kovats, R.S., . . . Woodward, A. (2007). Human health. In M.L. Parry, O.F. Canziani, J.P. Palutikof, P.J. van der Linden, & C.E. Hanson (Eds.), *Climate Change 2007: Impacts, Adaptation and Vulnerability. Contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change* (pp. 391-431). Cambridge, UK: Cambridge University Press.

Costello, A., Abbas, M., Allen, A., Ball, S., Bell, S., Bellamy, R., . . . Patterson, C. (2009). Managing the health effects of climate change. *The Lancet, 373*(9676), 1693-1733. doi:10.1016/S0140-6736(09)60935-1

Crate, S.A. (2008). Gone the bull of winter? Grappling with the cultural implications of and anthropology's role(s) in global climate change. *Current Anthropology, 49*(4), 569-595. doi: 10.1086/529543

Crate, S.A., & Nuttall, M. (Eds.). (2009). *Anthropology & climate change: From encounters to actions.* Walnut Creek, CA: Left Coast Press, Inc.

D'Ippoliti, D., Michelozzi, P., Marino, C., de'Donato, F., Menne, B., Katsouyanni, K., . . . Perucci, C. (2010). The impact of heat waves on mortality in 9 European cities: results from the EuroHEAT project. *Environmental Health, 9*, 37. doi: 10.1186/1476-069X-9-37

Frumkin, H., Ed. (2005). *Environmental health, from global to local*. San Francisco, California: John Wiley & Sons.

Fairfax County Health Department. (n.d.). *Community health and safety: Air quality* [Web page]. Retrieved from http://www.fairfaxcounty.gov/hd/air/

Gamble, J.L. (Ed.), Ebi, K.L., Sussman, F.G., & Wilbanks, T.J. (Authors). (2008). *Analyses of the effects of global change on human health and welfare and human systems. A report by the U.S. Climate Change Science Program and the Subcommittee on Global Change Research.* Retrieved from http://downloads.climatescience.gov/sap/sap4-6/sap4-6-final-report-all.pdf

Gyan, K., Henry, W., Lacaille, S., Laloo, A., Lamsee-Ebanks, C., McKay, S., . . . Monteil, M.A. (2004). African dust clouds are associated with increased paediatric [sic] asthma accident

and emergency admissions on the Caribbean island of Trinidad. *International Journal of Biometeorology, 49*(6), 371-376. doi: 10.1007/s00484-005-0257-3

Hannah, E. G., McMichael, A. J., & Butler, C. D. (2011). Climate change and global public health: Impact, research, and actions. In R. Parker, & M. Sommer (Eds.). *Routledge handbook of public health* [Googlebooks version]. Retrieved from http://books.google.com/books?hl=en&lr=&id=mrfGkSUNMv8C&oi=fnd&pg=PA133&dq=higher+rates+of+asthma+linked+to+greater+pollen+due+to+climate+change&ots=BWYtC3YT71&sig=M_7LQSaGUYCMVvpvhZVs80rlIlU#v=onepage&q&f=false

Health Canada. (2006). *Environmental and workplace health: health effects of air pollution* [Web page]. Retrieved from http://www.hc-sc.gc.ca/ewh-semt/air/out-ext/effe/health_effects-effets_sante-eng.php

Hoffman, B., Hertel, S., Boes, T., Weiland, D., & Jockel, K. (2008). Increased cause-specific mortality associated with 2003 heat wave in Essen, Germany. *Journal of Toxicology and Environmental Health, 71*, 759-765. doi:10.1080/15287390801985539

Inova Health System. (n.d.). *Our environmental commitment* [Web page]. Retrieved from http://www.inova.org/about-inova/sustainability/index.jsp

Intergovernmental Panel on Climate Change. (n.d.). *The facts surrounding the Intergovernmental Panel on Climate Change* [Web page]. Retrieved from http://www.ipccfacts.org/facts.html

Iowa Climate Change Impacts Committee. (2011). *Report to the Governor and Iowa General Assembly: Climate change impacts on Iowa 2010.* Retrieved from http://www.iowadnr.gov/iccac/files/completereport.pdf

Isolauri, E., Huurre, A., Salminen, S., & Impivaara, O. (2004). The allergy epidemic extends beyond the past few decades. *Clinical & Experimental Allergy, 34*: 1007–1010. doi: 10.1111/j.1365-2222.2004.01999.x

Karl, T. R., Melillo, J.M., & Peterson, T.C. (Eds.). (2009). *Global climate change impacts in the United States*. New York: Cambridge University Press.

Kjellstrom, T., Butler, A. J. Lucas, R. M., & Bonita, R. (2009). Public health impact of global heating due to climate change: potential effects on chronic non-communicable diseases. *International Journal of Public Health, 55*(2), 97-103. doi:10.1007/s00038-009-0090-2

Knowlton, K., Rotkin-Ellman, M., King, G., Margolis, H.G., Smith, D., Solomon, G., . . . English, P. (2009). The 2006 California heat wave: Impacts on hospitalizations and emergency department visits. *Environmental Health Perspectives, 117*(1), 61–67. doi:10.1289/ehp.11594

Kuehn, B. E. (2006). Desertification called global health threat. *Journal of the American Medical Association, 295*(21), 2463-2465. doi: 10.1001/jama.295.21.2463

Leiserowitz, A., Maibach, E., Roser-Renouf, C., & Smith, N. (2010). *Climate change in the American Mind: Americans' global warming beliefs and attitudes in June 2010.* Yale University and George Mason University. New Haven, CT: Yale Project on Climate Change Communication. http://environment.yale.edu/climate/files/ClimateBeliefsJune2010.pdf

Loudoun County Government. (n.d.). *Air quality information* [Web page]. Retrieved from http://www.loudoun.gov/Default.aspx?tabid=1045

Macquarie University. (2009). *Protect your health during the dust storm* [Web page]. Retrieved from http://www.announcements.mq.edu.au/hr/protect_your_health

Maibach, E., Nisbet, M., & Weathers, M. (2011). *Conveying the human implications of climate change: A climate change communication primer for public health professionals.* Retrieved from George Mason University Center for Climate Change Communication Web site: http://www.climatechangecommunication.org/images/files/4C%20Communication%20Primer%20-%20Conveying%20the%20Human%20Implications%20of%20Climate%20Change.pdf

McManus, J.F. (2004). Palaeoclimate: A great grand-daddy of ice cores. *Nature*, 429, 611-612. doi:10.1038/429611a

McMichael, A., Ando, M., Carcavallo, R., Epstein, P., Haines, J., Jendritzky, G., . . . Woodward, A. (1995). Human population health. In R.T.Watson, M.C.Zinyowera, & R.H.Moss (Eds.), *Climate Change 1995: Impacts, Adaptations and Mitigation of Climate Change: Scientific-Technical Analysis. Contribution of Working Group II to the Second Assessment Report of the Intergovernmental Panel on Climate Change* (pp. 561-584). Cambridge, UK: Cambridge University Press.

Metz, B., Davidson, O.R., Bosch, P.R., Dave, R., Meyer, L.A. (Eds.). (2007). IPCC, 2007: Summary for policymakers. In Climate Change 2007: Mitigation. Contribution of working group III to the fourth assessment report of the Intergovernmental Panel on Climate Change. Retrieved from http://www.ipcc.ch/publications_and_data/publications_ipcc_fourth_assessment_report_wg3_report_mitigation_of_climate_change.htm

Min, S., Zhang, X., Zwiers, F. W., & Hegerl, G.C. (2011). Human contribution to more-intense precipitation extremes. *Nature, 470*, 378-381. doi: 10.1038/nature09763

Montoya, J., & Raffaelli, D. (2010). Climate change, biotic interactions and ecosystem services. *Philosophical Transactions of The Royal Society of Biological Sciences, 365*(1549), 2013-2018. doi: 10.1098/rstb.2010.0114

Multiza, S., Heslop, D., Pittauerova, D., Fischer, H., Meyer, I., Stuut, J., . . . Schulz, M. (2010). Increase in African dust flux at the onset of commercial agriculture in the Sahel region. *Nature, 466*, 226-228. doi:10.1038/nature09213

National Oceanic and Atmospheric Administration, National Weather Service, Office of Climate, Water and Weather Services. (2010). *Heat: A major killer* [Web page]. Retrieved from http://www.weather.gov/om/heat/index.shtml

O'Neill, M.S., Carter, R., Kish, J.K., Gronlund, C.J., White-Newsome, J.L., Manarolla, X., . . . Schwartz, J.D. (2009). Preventing heat-related morbidity and mortality: New approaches in a changing climate. *Maturitas, 64*(2), 98-103. doi:10.1016/j.maturitas.2009.08.005

Pall, P., Aina, T., Stone, D. A., Stott, P. A., Nozawa, T., Hilberts, A., . . . Allen, M. R. (2011). Anthropogenic greenhouse gas contribution to flood risk in England and Wales in autumn 2000. *Nature, 470*, 382-385. doi:10.1038/nature09762

Parry, M. L., Canziani, O.F., Palutikof, J.P., van der Linden, P.J., & Hanson, C.E. (Eds.). (2007). IPCC, 2007: Summary for policymakers. In *Climate change 2007: Impacts, adaptation and vulnerability. Contribution of working group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change*. Retrieved from http://www.ipcc.ch/publications_and_data/ar4/wg2/en/spmsspm-d.html

Proposed Endangerment and Cause or Contribute Findings for Greenhouse Gases Under Section 202(a) of the Clean Air Act, 74 Fed. Reg. 18886 (proposed April 24, 2009) (to be codified at 40 C.F.R. chptr. 1).

Prospero, J.M., Blades, E., Naidu, R., Mathison, G., Thani, H., & Lavoie, M. C. (2007). Relationship between African dust carried in the Atlantic trade winds and surges in pediatric asthma attendances in the Caribbean. *International Journal of Biometeorology, 52*(8), 823-832. doi 10.1007/s00484-008-0176-1

Prospero, J.M., & Lamb, P.J. (2003). African droughts and dust transport to the Caribbean: Climate change implications. *Science, 302*(5647), 1024-1027. doi: 10.1126/science.1089915

Poumadere, M., Mays, C., Le Mer, S., & Blong, R. (2005). The 2003 heat wave in France: Dangerous climate change here and now. *Risk Analysis, 25*(6), 1483-1494. doi:10.1111/j.1539- 6924.2005.00694.x

Rogers, P. (2009). Climate change and security. *Clinical Medicine, Journal of the Royal College of Physicians, 9*(2), 108-109. Retrieved from http://www.ingentaconnect.com/content/rcop/cm/2009/00000009/00000002/art00004#expand/collapse

Rosenzweig, C., Karoly, D., Vicarelli, M., Neofotis, P., Wu, Q., Casassa, G., ... Imeson, A. (2008). Attributing physical and biological impacts to anthropogenic climate change. *Nature, 453*, 353-357. doi:10.1038/nature06937

Safriel, U. (2006). The physical tele-connections: climate, dust and rivers. In Ezcurra, E. (Ed.), *Global deserts outlook*. Retrieved from United Nations Environmental Programme website: http://www.unep.org/geo/gdoutlook/index.asp

Science Museum of the National Academy of Sciences. (2011). [Map depicting recent warming exceeds temperatures of the last several hundred years]. *Global warming facts and our future*. Retrieved from http://www.koshland-science-museum.org/exhibitgcc/historical03.jsp

Schmier, J.K., & Ebi, K.L. (2009). The impact of climate change and allergens on children's health. *Allergy and Asthma Proceedings*, *30*(3), 229-237. doi: 10.2500/aap.2009.30.3229

Schneider, S.H., Rosencranz, A., & Niles, J.O. (Eds.) (2002). *Climate change policy: A survey*. Washington: Island Press.

Schneider, M.J. (2006). *Introduction to public health.* Sudbury, MA: Jones and Bartlett Publishers.

Sheffield, P.E., & Landrigan, P. J. (2011). Global climate change and children's health: Threats and strategies for prevention. *Environmental Health Perspectives, 119*, 291-298. doi:10.1289/ehp.1002233

Sheffield, P.E., Weinberger, K.R., & Kinney, P.L. (2011). Climate change, aeroallergens, and pediatric allergic disease. *Mt. Sinai Journal of Medicine, 78*, 78-84. doi:10.1002/msj.20232

Solomon, S., Qin, D., Manning, M., Chen, Z., Marquis, M., Averyt, K.B., ... Miller, H.L. (Eds.). (2007). IPCC, 2007: Summary for policymakers. In *Climate change 2007: The Physical Science Basis. Contribution of working group I [physical science] to the fourth assessment report of the Intergovernmental Panel on Climate Change.* Retrieved from http://www.ipcc.ch/pdf/assessment-report/ar4/wg1/ar4-wg1-spm.pdf

State of Alaska Division of Community and Regional Affairs. (n.d.). *Newtok planning group* [Web page]. Retrieved from http://www.commerce.state.ak.us/dca/planning/npg/Newtok_Planning_Group.htm

Storey, E., Dangman, K.H., Schenck, P., DeBernardo, R.L., Yang, C.S., Bracker, A., & Hodgson, M.J. (2004). Guidance for clinicians on the recognition and management of health effects related to mold exposure and moisture indoors. Retrieved from University

of Connecticut Health Center, Division of Occupational and Environmental Medicine, Center for Indoor Environments and Health website: http://oehc.uchc.edu/images/PDFs/MOLD%20GUIDE.pdf

Stott, P. A., Stone, D. A., & Allen, M. R. (2004). Human contribution to the European heatwave of 2003. *Nature 432*, 610-614. doi:10.1038/nature03089

Takle, E.S. (2010). Was climate change involved? In C. Mutel, (Ed), *A watershed year: Anatomy of the Iowa Floods of 2008* (pp111-115). [Google books version]. Retrieved from http://books.google.com/books?hl=en&lr=&id=VYo_9Opq30wC&oi=fnd&pg=PA111&dq=Thorne:++A+Watershed+Year:+Anatomy+of+the+Iowa+Floods+of+2008&ots=5BmJ2QIX4B&sig=iDnSZK4bZNR1EwUDH9eAW2eRftw#v=snippet&q=climate%20change&f=false

The Royal Society. (2008). *Ground-level ozone in the 21st century: future trends, impacts and policy implications*. Retrieved from http://royalsociety.org/Ground-level-ozone-in-the-21st-century-future-trends-impacts-and-policy-implications-/

Trenberth, K.E., Jones, P.D., Ambenje, P., Bojariu, R., Easterling, D., Klein Tank, A. ,...Zhai, P. (2007). Observations: Surface and atmospheric climate change. In *Climate Change 2007: The Physical Science Basis. Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change*.

University of Maryland Medical Center. (2011). *Lung disease* [Web page]. Retrieved from http://www.umm.edu/ency/article/000066all.htm

U.S. Center for Disease Control and Prevention. (2009). *FastStats: Asthma* [Web page]. Retrieved from http://www.cdc.gov/climatechange/prevention.htm

U.S. Center for Disease Control and Prevention. (2011). *FastStats: Chronic Obstructive Pulmonary Disease* [Web page]. Retrieved from http://www.cdc.gov/nchs/fastats/copd.htm

U.S. Center for Disease Control, National Center for Health Statistics. (2010). *America breathing easier 2010: CDC's National Asthma Control Program* [Web page]. Retrieved from http://www.cdc.gov/asthma/aag/2010/ataglance2010.pdf

U.S. Department of Commerce, National Oceanic and Atmospheric Association, National Weather Service, Office of Climate, Water, and Weather Services. (2011). *Emergency alert system event codes* [Web page]. Retrieved from http://www.nws.noaa.gov/nwr/expand.htm

U.S. Department of Health and Human Services. (n.d.). *Healthy people 2020 topics & objectives: respiratory diseases* [Web page]. Retrieved from http://www.healthypeople.gov/2020/topicsobjectives2020/overview.aspx?topicid=36

U. S. Department of Health and Human Services, National Institutes of Health, National Institute of Allergy and Infectious Diseases. (2003). Airborne allergens: Something in the air (NIH Publication No. 03-7045). Retrieved from http://www.niaid.nih.gov/topics/allergicdiseases/documents/airborne_allergens.pdf

U.S. Department of Health and Human Services, National Institutes of Health, National Heart, Lung, and Blood Institute. (2009). *Morbidity and mortality:2009 chart book on cardiovascular, lung and blood diseases*. Retrieved from: http://www.nhlbi.nih.gov/resources/docs/cht-book.htm

U.S. Department of Health and Human Services, Public Health Functions Project. (2008). *Public health in America* [Web page]. Retrieved from http://www.health.gov/phfunctions/public.htm

U.S. Environmental Protection Agency. (n.d.). *Ground-level ozone* [Web page]. Retrieved from http://www.epa.gov/air/ozonepollution/

U.S. Environmental Protection Agency. (2010). *Our nation's air - status and trends through 2008 - download graphics* [Web page]. Retrieved from http://www.epa.gov/airtrends/2010/graphics/AQITextbox.gif

U.S. Environmental Protection Agency. (2011). *Mold and moisture*: *Mold resources* [Web page]. Retrieved from http://www.epa.gov/mold/moldresources.html#Health

U.S. Environmental Protection Agency, National Center for Environmental Assessment, Global Change Research Program. (2008). *A review of the impacts of climate variability and change on aeroallergens and their associated effects* ( EPA/600/R-06/164F). Retrieved from http://cfpub.epa.gov/ncea/cfm/recordisplay.cfm?deid=190306#Download

U.S. Environmental Protection Agency, Global Change Research Program, National Center for Environmental Assessment. (2009). *Assessment of the impacts of global change on regional U.S. air quality: a synthesis of climate change impacts on ground-level ozone* (EPA/600/R-07/094F). Retrieved from http://cfpub.epa.gov/ncea/cfm/recordisplay.cfm?deid=203459#Download

U.S. Institute of Medicine, Committee for the Study of the Future of Public Health. (1988). *The future of public health* [Adobe digital edition version]. Retrieved from http://books.nap.edu/openbook.php?record_id=1091&page=R1

Virginia Department of Health, Division of Health Statistics. (2011). *Statistical reports and tables: Vital events summary 2009*. [Web page]. Retrieved from http://www.vdh.virginia.gov/healthstats/documents/2010/pdfs/VitalEvents09.pdf

Virginia Hospital Center. (n.d.). Web site. Retrieved from http://www.virginiahospitalcenter.com/default.aspx

Wang, H.C., & Yousef, E. (2007). Air quality and pediatric asthma-related emergencies. *Journal of Asthma 44*, 839-841. doi:10.1080/02770900701751666

Withgott, J. H., & Brennan, S. (2009). *Essential environment: The science behind the stories.* San Francisco, CA: Pearson Education, Inc.

Watts, G. (2010, November) The health benefits of tackling climate change: An executive summary for *The Lancet* series. *TheLancet.com*. Retrieved from http://www.thelancet.com/series/health-and-climate-change

World Health Organization. (2011). *Chronic respiratory diseases* [Web page]. Retrieved from http://www.who.int/respiratory/en/

World Health Organization, Global Initiative for Chronic Obstructive Lung Disease. (2006). *Global strategy for the diagnosis, management, and prevention of chronic obstructive pulmonary disease*. Retrieved from http://www.who.int/respiratory/copd/GOLD_WR_06.pdf

World Meteorological Organization, Northern Africa-Middle East-Europe Regional Center. (2011). *WMO sand and dust storm warning advisory and assessment system overview and history* [Web page]. Retrieved from http://sds-was.aemet.es/about-us

Ziska, L., Knowlton, K., Rogers, C., Dalan, D., Tierney, N., Elder, M.E., . . . Frenz, D. (2011). Recent warming by latitude associated with increased length of ragweed pollen season in

central North America. *Proceedings of the National Academy of Sciences, 108(8)*, 1-4. doi: 10.1073/pnas.1014107108

Ziska, L.H., & Caulfield, F.A. (2000). Rising CO2 and pollen production of common ragweed (*Ambrosia artemisiifolia*), a known allergy-inducing species: implications for public health. *Australian Journal of Plant Physiology, 27*(10), 894-898.