When It Rains, It Pours: Future Climate Extremes and Health

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ABSTRACT

Background: The accelerating accumulation of greenhouse gases in the Earth's atmosphere is changing global environmental conditions in unprecedented and potentially irreversible ways. Climate change poses a host of challenges to the health of populations through complex direct and indirect mechanisms. The direct effects include an increased frequency of heat waves, rising sea levels that threaten low-lying communities, anticipated extremes in the global hydrologic cycle (droughts, floods, and intense storms), and adverse effects on agricultural production and fisheries due to environmental stressors and changes in land use. Indirectly, climate change is anticipated to threaten health by worsening urban air pollution and increasing rates of infectious (particularly waterborne and vector-borne) disease transmission.

Objective: To provide a state-of-the-science review on the health consequences of a changing climate.

Findings: Environmental public health researchers have concluded that, on balance, adverse health outcomes will dominate under these changed climatic conditions. The number of pathways through which climate change can affect the health of populations makes this environmental health threat one of the largest and most formidable of the new century. Geographic location plays an influential role the potential for adverse health effects caused by climate change, and certain regions and populations are more vulnerable than others to expected health effects. Two kinds of strategies are available for responding to climate change: mitigation policies (which aim to reduce greenhouse gas emissions) and adaptation measures (relating to preparedness for anticipated impacts).

Conclusions: To better understand and address the complex nature of health risks posed by climate change, interdisciplinary collaboration is critical. Efforts to move beyond our current reliance on fossil fuels to cleaner, more sustainable energy sources may offer some of the greatest health opportunities in more than a century and cobenefits beyond the health sector. Because the nations least responsible for climate change are most vulnerable to its effects, the challenge to reduce greenhouse gas emissions is not merely technical, but also moral.

Key Words: extreme weather events, global climate change, greenhouse gas emissions, health, vulnerable populations

 Annals of Global Health 2014;80:332-344

INTRODUCTION TO CLIMATE AND CLIMATE CHANGE

The overall energy budget of the planet, the balance between incoming shortwave radiation and outgoing longwave radiation, whether resulting from natural variability or from human activity, drive climatic change. This balance is mediated by the Earth's atmosphere, in much the same way that the glass of a greenhouse allows sunlight to enter and then traps heat energy inside. An atmosphere with higher levels of greenhouse gases will retain more of this heat and result in higher average surface temperatures than will an atmosphere with lower levels of these gases.

Greenhouse Gases

Since the mid-1800s, the composition of the Earth's atmosphere has changed dramatically from what it was in the preindustrial period. These changes include increases in atmospheric levels of carbon dioxide (CO_2), methane (CH_4), and nitrous oxide (N_2O) that now exceed the highest concentrations recorded over the past 800,000 years, with mean rates of increase over the past century being unprecedented (with very high confidence) in the past 22,000 years.[1] The concentration of CO_2, the most significant of the greenhouse gases, has risen by approximately 35%, from about 280 parts per million by

2214-9996/

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The authors have no conflicts of interest and all authors had access to the data and a role in writing the manuscript.

http://dx.doi.org/10.1016/j.aogh.2014.09.007

volume (ppmv) in the late 1800s to about 400 ppmv at present. This growth has accelerated over the past decade, as 2011 emissions were 43% higher than in 2005.[1] Higher greenhouse gas concentrations have contributed to warming of the Earth by absorbing and re-emitting infrared radiation toward the lower atmosphere and the Earth's surface. From 1880 to 2012, the global average temperature rose by 0.85°C according to multiple independently produced datasets. By the end of this century, the average global temperature is projected to rise between 1.5°C and 4°C.[2] The rate of change in global temperatures is faster now than during any period over the past thousand years.

Earth System Changes

Despite greenhouse warming being itself a dramatic effect across the Earth's surface, changing temperatures are only part of the story. Higher temperatures evaporate soil moisture more quickly (potentially leading to severe droughts); yet, warm air can hold more moisture than cool air and can trigger heavy precipitation events; such hydrologic extremes (e.g., floods and droughts), which are of substantial concern to public health professionals. Additionally, the Arctic and Antarctic ice caps are melting, releasing vast amounts of water into the oceans, raising ocean levels, and potentially altering the flow of ocean currents.

Increasing global temperatures are associated with corresponding Earth system changes. Between 1971 and 2010, sea levels rose on average by approximately 2 mm per year. Arctic perennial sea ice extent declined by about 11.5% per decade over this period, and snow cover and glaciers have diminished in both hemispheres.[3] According to the Intergovernmental Panel on Climate Change (IPCC), sea level will rise between 26 and 98 cm by 2100.

The potential exists for large-scale and potentially irreversible changes in Earth systems, such as slowing of the ocean circulation that transports warm water to the North Atlantic, large-scale melting of the Greenland and west Antarctic ice sheets, and accelerated warming due to positive feedbacks in the carbon cycle (such as the release of methane from thawing Arctic tundra). The probability of these events is unknown, but it is likely to be affected by how rapidly climate change evolves and its duration. Figure 1 shows the likelihood of these and other extreme events as determined by the IPCC's most recent report.[4]

CLIMATE CHANGE CONSEQUENCES ON HEALTH

Particularly Vulnerable Regions

Geographic location plays an influential role in the potential for adverse health effect linked to climate change.[5] Thus, certain regions and populations are more vulnerable than others to the health effects of climate change.[6] These vulnerable areas include:

1. Populations within or bordering regions with a high endemicity of climate-sensitive diseases (e.g., malaria).
2. Areas with an observed association between epidemic disease and weather extremes (e.g., El Niño–linked epidemics).
3. Areas at risk from combined climate effects relevant to health (e.g., stress on food and water supplies).
4. Areas at risk from concurrent environmental or socioeconomic stresses and with little capacity to adapt.

Earth system changes have direct and indirect implications for human health. The sections that follow address major categories of anticipated health effects of climate change. These include risks from weather extremes, natural disasters, air pollution, and infectious diseases, particularly those that are water-, food-, or vector-borne.

Direct Consequences on Human Health

Weather extremes

Heat waves. Extremes of both hot and cold temperatures are associated with rates of morbidity and mortality higher than rates in the intermediate, or comfortable, temperature range.[7] The relationship between temperature and morbidity and mortality is J-shaped, with a steeper slope at higher temperatures.[8] In the United States, extreme heat events cause more deaths each year than all other extreme weather events combined, and frequency of daily temperatures over 100°F is expected to increase substantially. Temperatures now occurring once in 20 years could happen every 2 to 4 years.[9] The previous decade was the warmest on record in the United States.[10]

In the United States, an average of 658 deaths are classified as directly attributable to heat-related causes annually.[11] The total population health effect of heat stress, however, is likely due more to the fact that heat-related deaths are routinely classified under other proximate causes.[12] An estimated 20,000 people were killed in the United States from 1936 through 1975 by the effects of heat and solar radiation (National Safety Council, Environmental Health Center, 2001), with more than 3,400 deaths occurring between 1999 and 2003. The 1995 Chicago heat wave took approximately 600 lives over 5 days.[13] The 2003 European heat wave is estimated to have killed more than 40,000 people in just 2 weeks, with more than 70,000 overall, while a Russian heat wave caused more than 15,000 deaths in 2010.[14] Researchers estimate that the probability of mega-heat waves (those that break centuries-long seasonal temperature records) will increase by a factor of 5 to 10 within the next 40 years.[15]

Reduced extreme cold. As an increase in summer temperature-related mortality is consistently anticipated in studies of climate change, so are at least partially compensating decreases in winter cold-related deaths. However, relatively milder winters attributable to climate change are unlikely to offset the more severe