The Effects of Climate Change on the Health of Americans

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Introduction

Health is the human face of climate change. And climate change is here, affecting the health of all Americans.

Human activity, principally the release of greenhouse gasses (GHG), is the major contributor to climate change. There is strong and growing evidence that climate change is harming the health of the American people. The financial costs of these illnesses and harm to our healthcare infrastructure represent a strain on the budgets of governments, business, and individuals. Given this strong and growing body of evidence, rapid action on both mitigation and adaptation is needed to reduce the health effects and stem the large financial losses that will result from climate change if left unchecked.

Climate Pressure and Exposure Pathways

Climate change affects our health through four main mechanisms: rising temperatures, extremes of precipitation, more extreme weather events, and rising sea levels (see figure below). There is now clear and overwhelming evidence that all of these four phenomena are occurring, and there is little doubt that the climate effect caused by high levels of GHGs is a major contributor.

Since record keeping began in 1895, the average US temperature has increased by 1.3°F to 1.9°F.[1] The U.S. is experiencing more hot days than ever before. Across the US, record-breaking high temperatures are now outnumbering record lows by an average ratio of 2:1, where parts of Texas already have an additional month of temperatures above 100°F.[2,3]

The U.S. is also experiencing more extreme rainfall. Between 1958 and 2012, the amount of rain during heavy rainfall events in the Midwest increased by 37 percent, causing more severe floods.[4] The term "100-year event" is used to describe a weather event that has a 1 percent chance of occurring every year. Due to significantly higher rainfall frequency in Texas, the National Oceanic and Atmospheric Administration (NOAA) is redefining the amount of rainfall it takes to qualify as an 100-year or 1000-year event. The 100-year classification for areas around Houston, Texas increased from 13 inches to 18 inches, and the values previously classified as 100-year events are now more frequent 25 year-events.[5] Over the course of 30 years (life of the most common mortgage), a house in a 100-year floodplain has a 26 percent chance of being flooded at least once.[6] In the last seven years alone, NOAA has reported 25 separate 500-year flooding events nationwide.[7] By definition, these flooding events should be occurring far less often.

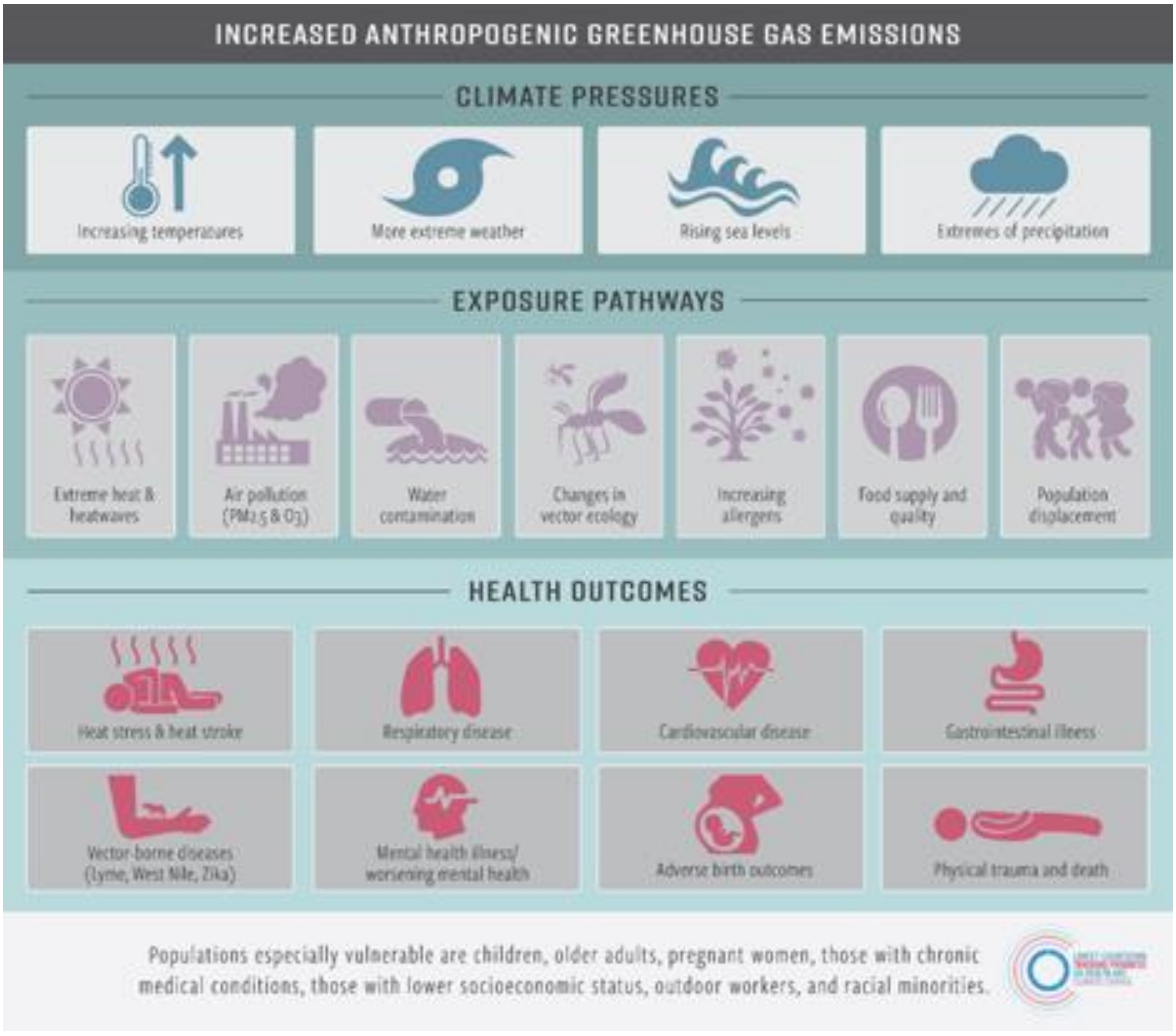
Alongside rising temperatures, lengthened droughts, and more extreme rainfall, climate change exacerbates the likelihood and severity of extreme weather events. Heat wave frequency has

increased from two per year on average in the 1960s to nearly six per year on average in the 2010s, while the overall length of the heat wave season has expanded from 20 days on average in the 1960s to 60 days on average in the 2010s.[8] A rise in heat waves has many effects, including a rise in the number of severe wildfires — estimated to have almost doubled since the 1980s.[8]

Climate change impacts more than just heat events. Tornados, hurricanes, blizzards, and extreme rainstorms all show a steady rise in severity over the last five decades, causing billions of dollars in damage and killing thousands of people each year.[8,9] The evidence suggests a link between these events and climate change, with growing damage to local populations and economies as the planet continues to warm.[10]

Thirty-nine percent of the American population live in counties directly on a shoreline, and millions of people already live in areas at risk of coastal flooding.[11,12] Over the last several decades, sea level trends in the Northeast Atlantic have risen at a rate higher than the global average, with a recent multiyear jump in sea level beginning in 2009.[12] The highest rising sea level trends are in the regions of Louisiana (8–10 mm/year), Texas (4–7 mm/year), and along the Northeast Atlantic from Virginia to New Jersey (3–5 mm/year). One study estimates that just 0.9 meters of sea level rise would permanently inundate 4.2 million Americans and a 1.8 meter rise would inundate 13.1 million Americans.[13]

The four climate pressures outlined above affect health via seven main exposure pathways: 1) extreme heat, 2) air pollution, 3) water contamination, 4) vectors, 5) increasing allergens, 6) food supply and quality, and 7) population displacement. Ultimately, these exposure pathways lead to a set of clinical manifestations – ways in which climate change harms the patients that I see as a clinician in the hospital.



Source: 2018 Lancet Countdown on Health and Climate Change Brief for the United State of America. Salas RN, Knappenberger P, Hess JJ. Lancet Countdown U.S. Brief

Health outcomes

In the following section, I outline some of the health effects of climate change. This section is not comprehensive, and various important clinical manifestations are not disucssed in detail. More detailed information about the health effects of climate change can be found in the Fourth National Climate Assessment of the U.S. government,[14] the Intergovernmental Panel on Climate Change,[15] and other sources.[9,16,17]

Allergies, asthma, and other respiratory diseases

One area where there is very clear evidence of the effects of climate change is on asthma and other related respiratory diseases. We know that the burden of asthma has increased over the past 20 years. The Centers for Disease Control and Prevention (CDC) found that the number of

Americans with asthma grew by 28% between 2001 and 2011.[18] While the increase in the burden is indeed multifactorial, pressures from climate change are a contributing factor.

The increasing temperatures and carbon dioxide (CO_2) levels associated with climate change can exacerbate allergies and asthma.[19] Warmer temperatures lead to an earlier start to pollen season in many types of plants.[14] In addition to increasing the duration of the pollen season, climate change also heightens pollen production, as well as the allergen content in some plant species — all of which contributes to asthma and hay fever.[14] Rising temperatures are also leading to higher levels of ozone, which contributes to the increase in asthma.[20]

Additionally, with climate change comes an increased frequency of wildfires, which decrease air quality and thus augment the burden of asthma and respiratory disease. Wildfires in the United States have been increasing in frequency and duration since the mid-1980s.[21] Longer and more frequent droughts lengthen the wildfire season and result in greater dust emissions.[14] Not only do the wildfires directly harm people and cause displacement, they also emit gases that contribute to ozone formation and are a major source of particulate matter (PM), which are hazardous air pollutants.[14] Exposure to wildfire smoke has been shown to increase the incidence of respiratory illnesses, including asthma, chronic obstructive pulmonary disease, bronchitis, and pneumonia.[14] There is strong evidence to suggest that hospitalizations and emergency department (ED) visits for respiratory diseases are greater during wildfires.[22–24] Young children are particularly susceptible. During one wildfire in San Diego, respiratory diagnoses went up by 70% in children ages 0-4, and asthma diagnoses increased by 243% in children under the age of 1.[25]

Cardiovascular Health

Climate change is significantly affecting the heart and vascular health of Americans through three mechanisms: higher temperatures, poor air quality, and extreme weather. First, we know that high temperatures are associated with increased coronary heart disease (CHD) hospitalizations, and long-term exposure to higher temperatures has been found to lead to doubled rates of ischemic heart disease and stroke admissions.[26,27] Heat exposure has also been linked to CHD in pregnant women.[28] Just a 1°C temperature increase is associated with a 1.1% increase in strokes, a 3.4% increase in cardiovascular deaths, and a 1.4% increase in cerebrovascular mortality.[29,30]

Second, poor air quality also contributes to cardiovascular disease. Both short- and long-term exposures to $PM_{2.5}$ are associated with increases in admissions for ischemic heart diseases and stroke.[26] These small particulate matters are released into the air with the burning of fossil fuels (among other sources) and they are associated with higher cardiovascular mortality.[31] The impact of these air pollutants is amplified at higher temperatures. That is, at any given level of air pollution ($PM_{2.5}$), higher ambient temperature leads to greater cardiovascular effects so even as

we continue to make progress on air pollution, we make that air pollution more deadly through climate change.[32] As climate change continues to impact our air quality, cardiovascular health will suffer.

Finally, during extreme weather events, cardiovascular disease has also increased. During Hurricane Sandy, stroke incidence increased by 7% and myocardial infarction incidence increased by 22%, with a 31% rise in 30-day mortality in high impact areas.[33] After Hurricane Katrina, cardiovascular hospitalization increased for two months, from 7.25 to 18.5 cases/10,000 adults per day in populations aged 65 or older.[34]

Vector-borne diseases

One of the ways in which climate change is harming our health is by exposing Americans to different and often a greater number of vector-borne diseases. Disease vectors (like mosquitoes that carry Zika or deer ticks that carry Lyme disease) have their own natural habitat and live in certain regions of the country. As the climate changes, these vectors can grow in range, changing their geographical distribution.

According to the CDC, vector-borne illnesses transmitted by mosquitoes, ticks, and fleas, including Lyme disease and West Nile virus, tripled between 2004 and 2016.[35] Tick-borne diseases specifically, of which Lyme disease accounts for 82% of reported cases, more than doubled during this period. The CDC pointed to warming temperatures as a major culprit. As the geographic range of vectors (and the diseases they carry) grows, it will expose new populations of Americans who may be unaware of these conditions and who lack natural immunity to these diseases.

In addition to increasing cases of more familiar illnesses, climate change has contributed to new ones in the U.S. From 2004 to 2016, there were nine new vector-borne human diseases reported in the United States.[36] One that received substantial attention was Zika, which used to be rare in the U.S. but spread through Puerto Rico, Florida, and Texas in 2016. Babies born from women infected with Zika when they are pregnant are at substantially increased risk of birth defects, often ones that are quite severe.

Indeed, when Zika hit Miami in 2016, it was the first time in modern history that the CDC had to place a travel warning for a part of the continental U.S.[37] Given climate change, it almost surely will not be the last. Aedis aegypti, the mosquito that carries Zika among other viruses, used to be rare in the U.S. just twenty years ago (found in 11 counties in 1999) but is becoming far more common (now found in 183 counties by 2016).[38] By all expectations, this number is likely to grow as well.

Other Health Effects

In addition to the health outcomes outlined in detail above, climate change affects many other aspects of health, including heat-related illness, birth outcomes, and mental health.

Extreme heat is the leading cause of weather-related deaths in the U.S.,[39] with children under the age of four and elderly populations being most vulnerable to heat-related illness.[40] One estimate predicts that 3,400 more Americans will die prematurely each year due to increased heat.[39] Heat waves can be deadly; for example, a 2006 heat wave in California caused 16,166 excess ED visits and 1,182 excess hospitalizations, mainly due to heat-related illness, acute renal failure, cardiovascular disease, diabetes, and electrolyte imbalance.[41]

Burning of fossil fuels has also been linked to poor birth outcomes, mainly through increasing levels of $PM_{2.5}$. Globally, 18% of all preterm births are associated with anthropogenic $PM_{2.5}$.[42] One study of mothers in Rhode Island found that a 2.5 µg/m3 increase in $PM_{2.5}$ was linked to a birth weight that was 15.9 grams lower.[43] In addition, prenatal exposure to $PM_{2.5}$ concentrations has been correlated with poor cognitive outcomes, decreased motor function, decreased IQ, and increased ADHD among babies born in the U.S.[44]

Finally, droughts, floods and other extreme weather events are proven to increase mental illness.[45,46] People directly affected by climate disasters have increased incidence of suicidal thoughts and behaviors.[4] This too has a direct impact on healthcare system utilization; for example, psychiatric ED visits increased significantly for 4-6 months after Hurricane Sandy.[47]

<u>The Financial Costs of Climate Change</u>

While the impact that climate change will have on health is critically important, we also must consider the financial burden that this will have on the healthcare system and, ultimately, on the American people.

High healthcare spending is obviously a huge concern for the U.S., and already chronic conditions like asthma, cardiovascular disease, and mental illness contribute substantially to our high spending. For example, in 2013, the total cost of asthma in the US was $81.9 billion, $50.3 billion of which was due to medical costs. This number will only increase as the burden of asthma continues to rise.[48]

Although the healthcare costs related to climate change are still being calculated, it is clear that climate change is already causing increased utilization of healthcare services and thus higher healthcare spending.

Hospitalizations due to heat-related illness cost the U.S. healthcare system over $390 million from 2001 to 2010.[49] The best estimates are that these numbers are likely to grow over time.[50]

Finally, the financial impact of increased utilization caused by severe weather events on the healthcare system is very large. One study found that six climate change-related extreme weather events caused $740 million in healthcare costs. This reflects almost 9,000 hospitalizations, over 21,000 ED visits, and over 734,000 outpatient visits associated with morbidity related to these events.[51] One heatwave alone led to an estimated $179 million in healthcare costs. Again, this is from only six events, a small sampling of the actual severe weather related to climate change.

This financial burden is expected to worsen in the future. Projections by The Climate Change Impacts and Risk Analysis (CIRA) provide insight into the financial benefits of health related climate mitigation. The annual costs of climate-driven, premature ozone-related deaths under a scenario with minimal mitigation are projected to be $9.8 billion in 2050, whereas if more intense mitigation is implemented, the projection drops to $6.9 billion. Annual damages associated with additional extreme temperature related deaths are estimated at $140 billion by the end of the century under minimal mitigation, whereas with more intense mitigation the cost would go down to $60 billion. While costs from oak pollen-related asthma ED visits increase in all scenarios analyzed, the increase in annual costs is projected to be $1.2 million with minimal mitigation, but only $0.52 million with more intense mitigation. These projections demonstrate the incredible financial benefit that mitigation can play in lowering the health costs of climate change.

<u>The financial and health benefits of addressing climate change are substantial.</u>

When the health co-benefits of mitigating climate change by reducing burning of fossil fuels are considered, optimal climate policy results in immediate net benefits, saving billions of dollars annually in health costs.[52]

Currently, government agencies have recognized the risks posed by climate change and have taken steps to encourage healthcare systems to prepare for the rise in extreme weather and other threats. In 2017, the Centers for Medicare and Medicaid Services established an Emergency Preparedness Rule, and compliance is required for participation in Medicare or Medicaid. The rule requires providers to make plans for both natural and man-made disasters, with a focus on risk assessment and emergency planning, communication plans, policies and procedures, and training and testing. Additionally, the Assistant Secretary for Preparedness and Response has created the Hospital Preparedness Program, which promotes collaboration between nearby healthcare facilities to improve their capacity to respond to emergencies, disasters, and medical surge events (including ones caused by climate change). Eighty-five percent of hospitals across the country participate in the program.[53] The Department of Health and Human Services has also

created a plan for climate adaptation.[54] However, resiliency is still not as embedded into regulatory systems as it could be; for example, accreditation agencies do not set climate resiliency requirements into their accreditation of healthcare facilities. They should.[54]

Extreme weather events can have large impacts on hospitals and patients. During Hurricane Irma, temperatures in a Florida nursing home soared to 99°F, leaving 12 people dead after Hurricane Irma knocked out the nursing home's central air conditioning. At the time, the city was under a boil-water advisory and the nursing home was using limited power from a generator to run lights and some equipment, but not the air conditioning.[55] When Superstorm Sandy hit New York, bed capacity was reduced by 8% and there was still a 5% reduction four weeks later. Nursing home staff were forced to live on-site for multiple days until their replacements could arrive. Thirty percent of hospitals reported personnel shortages, and some took to converting their lobbies into inpatient rooms. The storm led to the evacuation of 6,500 patients from hospitals and other healthcare facilities in New York and New Jersey.[56] One hospital, NYU Langone, had to evacuate all 322 of its patients, suspend surgery and admissions for 2 months, and close the ED for 18 months, leading to $400 million in lost revenue and $1.4 billion in total costs. Hospitals in the New Orleans area were still suffering a year after Hurricane Katrina, with the bed capacity in the city having fallen 79% and only a third of original hospitals even somewhat operational.[56]

Extreme weather can also lead to supply chain problems. For example, when Hurricane Maria hit Puerto Rico in 2017, it destroyed a factory that supplied a substantial proportion of the IV fluid bags used by the United States, causing IV shortages across the U.S. that continued for months.[57] During Hurricane Michael, Bay Medical Sacred Heart hospital was forced to send a tweet to the Florida Police Department as a desperate way to communicate that a truck carrying essential medical supplies needed to be let through a road closure. This is an example of how ill prepared hospital supply chains are for these events.

One population that is particularly vulnerable to healthcare infrastructure damage is patients with end stage renal disease who rely on dialysis. After one hurricane, many patients could not receive dialysis at their usual center, and many turned to the emergency room instead. Inpatient dialysis is significantly more expensive than outpatient dialysis, often costing three or four times as much.[58] Further interrupting usual outpatient care for this population could lead to greater healthcare spending.

Clearly hospitals need to prioritze making preparedness plans. Potential steps could include identifying and managing extreme weather risks; placing key patient areas, generators, and fuel above projected floodlines; making infrastructure more resilient to temperature changes; using on-site cogeneration plants rather than relying on the municipal power grid; keeping patient data in more than one place; and planning for transportation and access in the case of destruction of

nearby roads and bridges.[54,56] Yet most hospitals still are not doing enough. One study found that less than 1 in 5 hospitals surveyed reported that their disaster preparedness plan was "very sufficient" and did not need to be revised.[59] There are over 5,000 hospitals in the U.S. and over 15,000 nursing homes. There is little evidence that most are prepared for a world of more extreme weather events, storms, heat waves, and other challenges that will stretch these systems and make it difficult for them to provide the care Americans need.

The development of an adaptation strategy can be very beneficial. Texas Medical Center (TMC) was left with $5 billion in damages after a massive flood in 2001. In the aftermath, TMC invested millions of dollars to upgrade their infrastructure, and they also committed to making mitigation plans and creating flood management groups. They relocated all critical patient areas above projected flood levels and installed an on-site power plant. When Hurricane Harvey hit in 2017, all hospitals and emergency rooms on the campus stayed operational thanks to these measures.[56]

Climate change mitagation

Ultimately, although adaptation is critically important, mitigation is where the healthcare system can have the greatest impact on human health. The National Climate Assessment report estimates that 10% of all GHG in the U.S. come from the healthcare sector.[14] An upstream approach to tackling climate change— reducing CO_2 emissions and preventing severe weather events and extreme temperature rises before they even happen— would lead to immediate health benefits. Healthcare facilities must take active steps to assess and reduce their GHG footprint. Hospitals and other facilities should be more deliberate about measuring their GHG output, incorporating these measures into their cost-benefit analyses and making a plan with concrete goals around reducing reliance on carbon-based energy sources.

Mitigation is not just necessary for improving health in the far-off future; it also has immediate co-benefits. Currently, 1 out of every 8 deaths around the world are related to indoor and outdoor air pollution.[60] Reducing the use of fossil fuels would not only decrease CO_2 levels but also improve air quality immediately by lowering levels of other pollutants that are harming health now.[60] Additionally, many of the actions that would help tackle climate change— improving access to and incentivizing active transportation, for example— have benefits for population health today. The most recent evidence suggests that mitigation is financially beneficial when health impacts are taken into account. Considering these factors will signal to governments and other key players that it is time to take action, and that action now will have immediate benefits.

Healthcare systems are beginning to understand and act on the importance of climate change mitigation. In 2016, 130 facilities signed on to a climate change challenge or commitment working with the nonprofit Healthcare Without Harm to lower their GHG footprint. Professional

healthcare orgnaizations also stand united in asserting the negative affects that climate change is having on our health. The American Medical Assocaition (AMA) has adopted a policy ("Global Climate Change and Human Health," H-135.938) which emphasizes the reality and urgency of climate change and the vital role that physicians play in protecting the public against the impacts of climate change.[61] American College of Physicians (ACP) has developed a Climate Change and Health Action Plan to help its members take initiative by highlighting the substantial role physicians can play in advocating for climate change adaption and mitigation policies along with education themselves and their communities about the health threats that climate changes poses.[62] The American Academy of Pediatrics (AAP) states that Pediatricians are already seeing the effects of climate change on their patients. From more severe allergies and asthmatic symptoms, to impacts on children's mental health, AAP views a failure to take prompt substantive action as an act of injustice to all children.[63] Clearly, healthcare professionals and institutions are beginning to recognize the threat that climate change poses to the health of the people we care for -- and are ready to take mitigation action now, knowing that it will have a direct impact on the health of those who trust us to care for them.

Conclusion

As a clinician and a public health expert, I am deeply concerned, based on the latest evidence and data, that climate change is harmful to my patients and is harmful for the health of the American people. The most vulnerable among us are children and the elderly, who are most likely to suffer the health effects of climate change. While climate change is already here, there is much that we can do to mitigate its effects, primarily by reducing our dependence on fossil fuels. Adaptation is also important, but it will be both very expensive and not enough to protect the health of the American people. Further spending on healthcare caused by climate change will put more stresses on the budgets of the public and private sectors, including individual consumers. To improve the health of the citizens of our nation and to be wise stewards of the public purse, it is critical that Congress take action to mitigate the harmful health and financial effects of climate change.

1. U.S. Global Change Research Program. *The Impacts of Climate Change on Human Health in the United States: A Scientific Assessment*. Washington DC; 2016. doi:10.7930/J0R49NQX
2. Climate Nexus. Record High Temps vs. Record Low Temps. https://www.climatesignals.org/data/record-high-temps-vs-record-low-temps. Accessed May 10, 2019.
3. Climate Central. More Extremely Hot Days. http://medialibrary.climatecentral.org/resources/more-extremely-hot-days-2018. Published 2018. Accessed May 10, 2019.
4. U.S. Global Change Research Program. *Climate Change Impacts in the United States*.; 2014. https://nca2014.globalchange.gov/report/our-changing-climate. Accessed May 10, 2019.
5. National Oceanic and Atmospheric Administration. NOAA updates Texas rainfall frequency values. https://www.noaa.gov/media-release/noaa-updates-texas-rainfall-frequency-values. Published 2018. Accessed May 13, 2019.
6. US Geological Survey. *100-Year Flood- It's All About Chance*.; 2010. https://pubs.usgs.gov/gip/106/pdf/100-year-flood-handout-042610.pdf. Accessed May 13, 2019.
7. Douglas P. Flooding Frequency and Intensity are Increasing – Are You Factoring the Latest Trends?r. Aeris Weather. https://www.aerisweather.com/blog/2018/07/24/flooding-frequency-increasing/. Published 2018. Accessed May 10, 2019.
8. US Global Change Research Program. *Climate Science Special Report*. Washington, DC; 2017. doi:10.7930/J0J964J6
9. National Oceanic and Atmospheric Administration. Assessing the U.S. Climate in 2017. https://www.ncei.noaa.gov/news/national-climate-201712. Published 2018. Accessed May 13, 2019.
10. Barnes EA, Polvani LM. CMIP5 Projections of Arctic Amplification, of the North American/North Atlantic Circulation, and of Their Relationship. *J Clim*. 2015;28(13):5254-5271. doi:10.1175/JCLI-D-14-00589.1
11. National Oceanic and Atmospheric Administration. What percentage of the American population lives near the coast? https://oceanservice.noaa.gov/facts/population.html. Published 2018. Accessed May 13, 2019.
12. National Oceanic and Atmospheric Admistration. *Global and Regional Sea Level Rise Scenarios for the Untied States*. Silver Spring, MD; 2017. https://tidesandcurrents.noaa.gov/publications/techrpt83_Global_and_Regional_SLR_Scenarios_for_the_US_final.pdf. Accessed May 13, 2019.
13. Hauer ME, Evans JM, Mishra DR. Millions projected to be at risk from sea-level rise in the continental United States. *Nat Clim Chang*. 2016;6(7):691-695. doi:10.1038/nclimate2961
14. US Global Change Research Program. Fourth National Climate Assessment. 2018:1-470. https://nca2018.globalchange.gov/. Accessed May 13, 2019.
15. Intergovernmental Panel on Climate Change. *Special Report: Global Warming of 1.5 ºC.*; 2018. https://www.ipcc.ch/sr15/. Accessed May 13, 2019.
16. The Lancet Countdown 2018. *Lancet*. 2018.
17. Interagency Working Group on Climate Change. A Human Health Perspective On

Climate Change A Report Outlining the Research Needs on the Human Health Effects of Climate Change. 2010. doi:10.1289/ehp.1002272
18. Centers for Disease Control and Prevention. *Asthma Facts: CDC's National Asthma Control Program Grantees*. Atlanta, GA; 2013. https://www.cdc.gov/asthma/pdfs/asthma_facts_program_grantees.pdf. Accessed May 10, 2019.
19. Ebi KL, Paulson JA. Climate Change and Child Health in the United States. *Curr Probl Pediatr Adolesc Health Care*. 2010;40(1):2-18. doi:10.1016/j.cppeds.2009.12.001
20. Tolbert PE, Mulholland JA, MacIntosh DL, et al. Air quality and pediatric emergency room visits for asthma in Atlanta, Georgia, USA. *Am J Epidemiol*. 2000;151(8):798-810. http://www.ncbi.nlm.nih.gov/pubmed/10965977. Accessed May 10, 2019.
21. Westerling AL, Hidalgo HG, Cayan DR, Swetnam TW. Warming and Earlier Spring Increase Western U.S. Forest Wildfire Activity. *Science (80-)*. 2006. https://science.sciencemag.org/content/313/5789/940.full. Accessed May 13, 2019.
22. Centers for Disease Control and Prevention. Monitoring health effects of wildfires using the biosense system--San Diego County, California, October 2007. *MMWR Morb Mortal Wkly Rep*. 2008;57(27):741-744. http://www.ncbi.nlm.nih.gov/pubmed/18614992. Accessed May 10, 2019.
23. Silverman RA, Ito K. Age-related association of fine particles and ozone with severe acute asthma in New York City. *J Allergy Clin Immunol*. 2010;125(2):367-373.e5. doi:10.1016/j.jaci.2009.10.061
24. Reid CE, Jerrett M, Tager IB, Petersen ML, Mann JK, Balmes JR. Differential respiratory health effects from the 2008 northern California wildfires: A spatiotemporal approach. *Environ Res*. 2016;150:227-235. doi:10.1016/j.envres.2016.06.012
25. Hutchinson JA, Vargo J, Milet M, et al. The San Diego 2007 wildfires and Medi-Cal emergency department presentations, inpatient hospitalizations, and outpatient visits: An observational study of smoke exposure periods and a bidirectional case-crossover analysis. *PLoS Med*. 2018;15(7):e1002601. doi:10.1371/journal.pmed.1002601
26. Yitshak-Sade M, Bobb JF, Scwartz J, Kloog I, Zanobetti A. The Synergistic Effect of Short and Long Term Exposure to PM2.5 and Temperature on Hospital Admissions in New England. *Environ Health Perspect*. 2017. https://ehp.niehs.nih.gov/doi/abs/10.1289/isee.2017.2017-423. Accessed May 10, 2019.
27. Bai L, Li Q, Wang J, et al. Increased coronary heart disease and stroke hospitalisations from ambient temperatures in Ontario. *BMJ Hear*. 2018;104(8):673-679. doi:10.1136/heartjnl-2017-311821
28. Zhang W, Spero TL, Nolte CG, et al. Projected Changes in Maternal Heat Exposure During Early Pregnancy and the Associated Congenital Heart Defect Burden in the United States. *J Am Heart Assoc*. 2019;8(3). doi:10.1161/JAHA.118.010995
29. Lian H, Ruan Y, Liang R, et al. Short-Term Effect of Ambient Temperature and the Risk of Stroke: A Systematic Review and Meta-Analysis. *Int J Environ Res Public Health*. 2015;12(8):9068-9088. doi:10.3390/ijerph120809068
30. Bunker A, Wildenhain J, Vandenbergh A, et al. Effects of Air Temperature on Climate-Sensitive Mortality and Morbidity Outcomes in the Elderly; a Systematic Review and Meta-analysis of Epidemiological Evidence. *EBioMedicine*. 2016;6:258-268. doi:10.1016/J.EBIOM.2016.02.034
31. Newby DE, Mannucci PM, Tell GS, et al. Expert position paper on air pollution and

cardiovascular disease. *Eur Heart J*. 2015;36(2):83-93b. doi:10.1093/eurheartj/ehu458
32. Li J, Woodward A, Hou X-Y, et al. Modification of the effects of air pollutants on mortality by temperature: A systematic review and meta-analysis. *Sci Total Environ*. 2017;575:1556-1570. doi:10.1016/J.SCITOTENV.2016.10.070
33. Swerdel JN, Janevic TM, Cosgrove NM, Kostis JB, Group the MIDAS (MIDAS 24) S. The Effect of Hurricane Sandy on Cardiovascular Events in New Jersey. *J Am Heart Assoc*. 2014;3(6). doi:10.1161/JAHA.114.001354
34. Becquart N, Naumova E, Singh G, Chui K. Cardiovascular Disease Hospitalizations in Louisiana Parishes' Elderly before, during and after Hurricane Katrina. *Int J Environ Res Public Health*. 2018;16(1):74. doi:10.3390/ijerph16010074
35. Rosenberg R, Lindsey NP, Fischer M, et al. *Vital Signs: Trends in Reported Vectorborne Disease Cases — United States and Territories, 2004–2016*. Vol 67.; 2018. doi:10.15585/mmwr.mm6717e1
36. Rosenberg R, Lindsey NP, Fischer M, et al. Vital Signs: Trends in Reported Vectorborne Disease Cases — United States and Territories, 2004–2016. *MMWR Morb Mortal Wkly Rep*. 2018;67(17):496-501. doi:10.15585/mmwr.mm6717e1
37. Harvard T.H. Chan School of Public Health. Zika infections in Miami prompt CDC travel advisory. https://www.hsph.harvard.edu/news/hsph-in-the-news/zika-miami-cdc-travel-advisory/. Accessed May 13, 2019.
38. Hahn MB, Eisen RJ, Eisen L, et al. Reported Distribution of Aedes (Stegomyia) aegypti and Aedes (Stegomyia) albopictus in the United States, 1995-2016 (Diptera: Culicidae). *J Med Entomol*. 2016;53(5):1169-1175. doi:10.1093/jme/tjw072
39. Rose A, Porter K, Bouabid PBS J, et al. *Benefit-Cost Analysis of FEMA Hazard Mitigation Grants*.; 2006. http://econ.appstate.edu/RePEc/pdf/wp0602.pdf. Accessed May 10, 2019.
40. Centers for Disease Control and Prevention. *Picture of America: Heat-Related Illness Fact Sheet*. https://www.cdc.gov/pictureofamerica/pdfs/picture_of_america_heat-related_illness.pdf. Accessed May 10, 2019.
41. Knowlton K, Rotkin-Ellman M, King G, et al. The 2006 California Heat Wave: Impacts on Hospitalizations and Emergency Department Visits. *Environ Health Perspect*. 2009;117(1):61-67. doi:10.1289/ehp.11594
42. Malley CS, Kuylenstierna JCI, Vallack HW, Henze DK, Blencowe H, Ashmore MR. Preterm birth associated with maternal fine particulate matter exposure: A global, regional and national assessment. *Environ Int*. 2017;101:173-182. doi:10.1016/j.envint.2017.01.023
43. Kingsley SL, Eliot MN, Glazer K, et al. Maternal ambient air pollution, preterm birth and markers of fetal growth in Rhode Island: results of a hospital-based linkage study. *J Epidemiol Community Health*. 2017;71(12):jech-2017-208963. doi:10.1136/jech-2017-208963
44. Perera F, Ashrafi A, Kinney P, Mills D. Towards a fuller assessment of benefits to children's health of reducing air pollution and mitigating climate change due to fossil fuel combustion. *Environ Res*. 2018;172:55-72. doi:10.1016/j.envres.2018.12.016
45. Ginexi EM, Weihs K, Simmens SJ, Hoyt DR. Natural disaster and depression: a prospective investigation of reactions to the 1993 midwest floods. *Am J Community Psychol*. 2000;28(4):495-518. http://www.ncbi.nlm.nih.gov/pubmed/10965388. Accessed May 10, 2019.

46. Barreau T, Conway D, Haught K, et al. Physical, Mental, and Financial Impacts From Drought in Two California Counties, 2015. *Am J Public Health*. 2017;107(5):783-790. doi:10.2105/AJPH.2017.303695
47. He FT, Lundy De La Cruz N, Olson D, et al. Temporal and Spatial Patterns in Utilization of Mental Health Services During and After Hurricane Sandy: Emergency Department and Inpatient Hospitalizations in New York City. *Disaster Med Public Health Prep*. 2016;10(3):512-517. doi:10.1017/dmp.2016.89
48. Nurmagambetov T, Kuwahara R, Garbe P. The Economic Burden of Asthma in the United States, 2008-2013. *Ann Am Thorac Soc*. 2017. http://www.thoracic.org/about/newsroom/press-releases/resources/asthma-costs-in-us.pdf. Accessed May 10, 2019.
49. Schmeltz M, Petkova E, Gamble J. Economic Burden of Hospitalizations for Heat-Related Illnesses in the United States, 2001–2010. *Int J Environ Res Public Health*. 2016;13(9):894. doi:10.3390/ijerph13090894
50. Lin S, Hsu W-H, Van Zutphen AR, Saha S, Luber G, Hwang S-A. Excessive Heat and Respiratory Hospitalizations in New York State: Estimating Current and Future Public Health Burden Related to Climate Change. *Environ Health Perspect*. 2012;120(11):1571-1577. doi:10.1289/ehp.1104728
51. Knowlton K, Rotkin-Ellman M, Geballe L, Max W, Solomon GM. Six Climate Change–Related Events In The United States Accounted For About $14 Billion In Lost Lives And Health Costs. *Health Aff*. 2011;30(11):2167-2176. doi:10.1377/hlthaff.2011.0229
52. Scovronick N, Budolfson M, Dennig F, et al. The impact of human health co-benefits on evaluations of global climate policy. *Nat Commun*. 2019;10(1):2095. doi:10.1038/s41467-019-09499-x
53. Assistant Secretary for Preparedness and Response. *Hospital Preparedness Program*. https://www.phe.gov/Preparedness/planning/hpp/Documents/hpp-intro-508.pdf. Accessed May 13, 2019.
54. *HHS Climate Adaptation Plan*. https://www.hhs.gov/sites/default/files/about/sustainability/2014-climate-change.pdf. Accessed May 10, 2019.
55. O'Matz M. Inside the nursing home where 12 died during Hurricane Irma: 99 degrees. *South Florida Sun-Sentinel*. https://www.sun-sentinel.com/local/broward/fl-reg-nursing-home-dehydration-20171227-story.html. Published 2017. Accessed May 13, 2019.
56. Health Care Without Harm. *Safe Haven in the Storm*.; 2018. https://noharm-uscanada.org/sites/default/files/documents-files/5146/Safe_haven.pdf. Accessed May 13, 2019.
57. Wong JC. Hospitals face critical shortage of IV bags due to Puerto Rico hurricane. The Guardian. https://www.theguardian.com/us-news/2018/jan/10/hurricane-maria-puerto-rico-iv-bag-shortage-hospitals. Published 2018. Accessed May 13, 2019.
58. Hospital Charge Listing | Partners HealthCare. https://www.partners.org/for-patients/Patient-Billing-Financial-Assistance/Hospital-Charge-Listing.aspx. Accessed May 10, 2019.
59. Vick DJ, Wilson AB, Fisher M, Roseamelia C. Assessment of community hospital disaster preparedness in New York State. *J Emerg Manag*. 2018;16(4):213. doi:10.5055/jem.2018.0371
60. Hunter DJ, Dominici F. Honoring climate change agreements will save millions of lives.

STAT News. https://www.statnews.com/2016/11/14/climate-change-agreements/. Published 2016. Accessed May 13, 2019.
61. Norling A. The AMA Code of Medical Ethics' Opinions Related to Climate Change. *AMA J Ethics*. 2017;19(12):1183-1185. doi:10.1001/journalofethics.2017.19.12.coet1-1712
62. American College of Physicians. Climate Change Toolkit. https://www.acponline.org/advocacy/advocacy-in-action/climate-change-toolkit. Accessed May 13, 2019.
63. American Academy of Pediatrics. Climate Change and Children's Health. https://www.aap.org/en-us/advocacy-and-policy/aap-health-initiatives/climate-change/Pages/Climate-Change-and-Childrens-Health.aspx. Accessed May 13, 2019.