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The impact of climate change on asthma and allergic-immunologic disease

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Abstract

Purpose: This review discusses climate change-related impacts on asthma and allergic-immunologic disease, relevant U.S. public health efforts, and healthcare professional resources.

Recent Findings: Climate change can impact people with asthma and allergic-immunologic disease through various pathways, including increased exposure to asthma triggers (e.g., aeroallergens, ground-level ozone). Climate change-related disasters (e.g., wildfires, floods) disrupting healthcare access can complicate management of any allergic-immunologic disease. Climate change disproportionately affects some communities, which can exacerbate disparities in climate-sensitive diseases like asthma. Public health efforts include implementing a national strategic framework to help communities track, prevent, and respond to climate change-related health threats. Healthcare professionals can use resources or tools to help patients with asthma and allergic-immunologic disease prevent climate change-related health impacts.

Summary: Climate change can affect people with asthma and allergic-immunologic disease and exacerbate health disparities. Resources and tools are available to help prevent climate change-related health impacts at the community and individual level.

Introduction

Climate change is one of the biggest public health threats of our time [1]. It has increased people's risk of experiencing temperature extremes, natural disasters, and climate-sensitive

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diseases (e.g., asthma, allergic rhinitis), each of which can result in far-reaching effects on short- and long-term health [2]. While climate change can affect everyone's health, various factors can influence individuals' risk for climate-related health effects [1–4]. People who have fewer resources to adapt to climate-related threats are more likely to experience adverse health outcomes; these individuals include children, older or socially isolated adults, people of some racial and ethnic groups, individuals experiencing poverty, and people with disabilities or underlying health conditions [1, 2, 4, 5].

This review highlights some impacts of climate change on asthma and allergic-immunologic disease, including examples of how these health impacts can disproportionately affect certain populations. Also, we discuss some U.S. public health efforts to reduce the health effects of climate change across the country. We conclude by describing selected climate-related resources that healthcare professionals can use to help patients with asthma or allergic-immunologic disease.

Examples of how climate change can affect people with asthma

Climate change can affect people with asthma through various pathways, including through increased exposure to asthma triggers [3] (Fig. 1). Each person with asthma has their unique asthma trigger(s) that can cause them to experience increased asthma symptoms, which might be severe enough to require emergency medical treatment for an asthma exacerbation [6–8]. Climate change-associated increases in ambient temperature can increase individuals' exposure to asthma triggers in several ways [3]. For example, levels of ground-level ozone and smog are projected to increase in some locations, because ground-level ozone is created by chemical reactions that occur in the presence of heat and sunlight [2, 3, 9–11]; these reactions occur between pollutants (oxides of nitrogen [NO_x] and volatile organic compounds) emitted by vehicle tailpipes, power plants, chemical plants, and other sources [2, 3, 9–11]. Results from a 2015 meta-analysis indicate that ozone is associated with increased risk of asthma-related emergency department (ED) visits and hospitalizations [12]. This finding is supported by results of more recent studies from various U.S. regions [13–15]. Also, heat waves are projected to become longer and more intense because of climate change [2]. Several studies have found relationships between increased ambient temperatures and asthma-related ED visits or hospitalizations [16, 17]. Besides the potential effect of heat as an asthma trigger, extreme heat can also adversely affect certain inhaled asthma medications; for instance, temperatures above 120° F can cause pressurized inhaler canisters to burst [3].

Warmer seasonal air temperatures, more frost-free days, alterations in rainfall patterns, and other effects of climate change can affect the onset and duration of "allergy season" for people with allergic asthma sensitized to seasonal aeroallergens (pollens and outdoor mold) [2, 3, 18, 19]. These changes also can affect how much pollen plants create and disperse which can, in turn, influence the intensity of seasonal allergy symptoms [2, 18, 19]. Several recent meta-analyses have reported positive associations between outdoor pollen exposure and asthma-related symptoms, ED visits, or hospitalizations [20–22]. For people with asthma symptoms triggered by exposure to outdoor aeroallergens, climate change-related

shifts in “allergy season” timing and intensity can adversely impact their asthma control [2, 3].

Climate change might increase levels of particulate matter in some locations [2, 3]. Particulate matter is the mixture of solid particles and liquid droplets found in the air, including visible dust and soot, as well as smaller particulate matter ≤2.5 μm in aerodynamic diameters ($PM_{2.5}$) [2, 11, 23]. Exposure to $PM_{2.5}$ can trigger respiratory symptoms in people with asthma [2, 3, 11, 24]. Meta-analyses published in 2016 reported positive associations between $PM_{2.5}$ concentrations and asthma-related ED visits and hospitalizations [25, 26]. These relationships have also been supported by more recent studies [13, 27].

Several types of climate change-related disasters are projected to increase in frequency, which can increase exposure to certain asthma triggers [2, 3]. For instance, shifts in global temperatures affect how heat and moisture move around the planet, which can result in drier conditions in some parts of the world [2, 18]. Changes to the frequency, duration, and geographic distribution of droughts can increase the risk of wildfires [2, 3, 18]. Epidemiologic studies conducted following numerous wildfires have reported positive associations between wildfires and asthma-related ED visits or hospitalizations [28–31]. While anyone’s health can be affected by wildfire smoke, people with asthma are at increased risk of experiencing respiratory symptoms triggered by wildfire smoke [2, 3].

Some climate change-related disasters are caused by extreme rainfall [2, 3, 18]. Increases in extreme rainfall and total rainfall have contributed to increases in severe flooding events in certain U.S. regions [2, 3, 18]. Moreover, the frequency of heavy rainfall events is projected to increase in all U.S. regions [2, 3]. In addition to immediate health hazards associated with flooding, water intrusion into buildings can lead to indoor mold growth, thereby increasing exposure to mold among people in affected buildings [3, 18]. For people with asthma symptoms triggered by inhaling mold, exposure to increased levels of indoor mold can adversely impact their asthma control [3, 32, 33].

Wildfires, floods, and other climate change-related disasters can affect mental health [2, 34]. At this time, limited research has focused on relationships between mental health conditions and asthma symptoms after wildfires or floods [35, 36]. Nevertheless, numerous studies have found these disasters can substantially impact symptoms of mental health (including posttraumatic stress disorder or depression symptoms) among individuals with or without previously diagnosed mental health conditions [2, 37–39]. Furthermore, extensive evidence has demonstrated that mental health symptoms can affect asthma control [7, 8, 34, 36].

Besides increasing human exposure to asthma triggers like mold and wildfire smoke, climate change-related disasters also can affect the medical management of asthma by disrupting usual access to asthma medications, medical care, and, in the event of a power outage, use of nebulizers that rely on electricity [3, 34, 40]. Moreover, disaster-related loss of electricity can affect the ability to follow recommended storage and handling instructions of some biologic agents for the treatment of severe asthma [41, 42]. For example, omalizumab, benralizumab, and reslizumab are stored under refrigerated conditions [42–44]. Dupilumab and tezepelumab are typically stored refrigerated but, if necessary, can be used while kept

at room temperature (up to 77°F) for certain periods of time [45, 46]. Dupilumab may be kept at room temperature for a maximum of 14 days; tezepelumab may be kept at room temperature for a maximum of 30 days [45, 46]. Prescribing information indicates that after these respective time intervals at room temperature, these two medications must be discarded [45, 46].

Examples of how climate change can affect people with allergic-immunologic diseases beyond asthma

Climate change can affect the health of people with allergic-immunologic diseases other than asthma. The aforementioned climate change-related effects on outdoor aeroallergens and flooding-associated indoor mold growth can increase symptoms among people with allergic rhinitis or allergic conjunctivitis who are sensitized to these aeroallergens and then exposed to higher levels of pollens or mold [2, 3, 19, 47]. For example, multiple studies have found that certain pollen seasons in some regions are starting earlier, lasting longer, or becoming more intense with increasing temperatures associated with climate change [2, 19, 48, 49]. Also, exposure to elevated levels of mold can affect people with hypersensitivity pneumonitis caused by mold inhalation [33, 50]. Conversely, exposure to indoor dust mite allergens can be lowered in homes with air conditioning, a climate-related adaptation measure, because air conditioning use lowers indoor relative humidity and thereby can reduce dust mite proliferation [51]. Data from several decades indicate the percentage of U.S. homes with air conditioning has steadily increased [51].

Management of any allergic-immunologic condition can be complicated by climate change-related disasters that disrupt usual access to medications or healthcare professionals, including emergency medical care needed to treat anaphylactic food allergy reactions [3, 52–55]. Also, for individuals and families affected by food allergy, disasters can impede usual access to allergen-safe foods [52, 53]. Furthermore, disaster-associated power outages can affect refrigeration of biologic agents indicated for treating certain allergic-immunologic conditions (e.g., omalizumab for chronic idiopathic urticaria, dupilumab for moderate-to-severe atopic dermatitis or chronic rhinosinusitis with nasal polyposis, ecallantide for hereditary angioedema, and some immune globulin products for treatment of primary humoral immunodeficiency) [43, 45, 56–58]. Storage of omalizumab and dupilumab are described in the previous section on asthma. Ecallantide should be kept refrigerated; vials of ecallantide removed from refrigeration should be stored below 85°F and used within 14 days or returned to refrigeration until use [56]. Two immune globulin products recommended to be stored under refrigerated conditions are Asceniv™ and Bivigam® [57, 58].

Examples of how climate change can disproportionately affect certain populations with asthma or other allergic-immunologic disease

Disparities in asthma and exposure to various asthma triggers have been well-documented. According to U.S. data from 2018–2020, asthma prevalence disproportionately affects certain groups, including children and adults who are non-Hispanic (NH) Black, American Indian/Alaska Native, or of Puerto Rican ethnicity [59–61]. Also, asthma is

disproportionately more common among people with lower household incomes than among people with higher household incomes [59, 62]. For example, asthma prevalence in 2020 was 11.0% (standard error, 0.75) among people with household incomes less than 100% of the federal poverty level but 6.7% (standard error, 0.28) among people with household incomes equal to or higher than 450% of the federal poverty level [59]. National mortality data indicate asthma deaths are also unequally distributed; the likelihood of dying from asthma in the United States is more than two times higher among NH Black Americans compared to NH White Americans [59–61]. Regarding disparities in exposure to asthma triggers, data at the national, state, and local level have shown that NH Black individuals, Hispanic individuals, and people with lower incomes are substantially more likely to reside in areas with higher levels of ozone or $PM_{2.5}$ [18, 63–69].

Disparities have also been identified for allergic-immunologic diseases beyond asthma [60, 62, 70, 71]. For instance, 2021 data from the National Health Interview Survey (NHIS) 2021 found that food allergy was more prevalent in NH Black children compared to NH White and Hispanic children [70]. Also, this survey reported the prevalence of atopic dermatitis was highest among NH Black children [70]. In addition to prevalence, other studies have identified racial or ethnic disparities in the severity of these allergic-immunologic diseases [60, 62]. For example, one analysis found NH Black and Hispanic children had higher odds of food allergy-related anaphylaxis and ED visits than NH White children [60, 72]. Other data indicate atopic dermatitis is more severe among NH Black adults and children compared to other racial groups [60]. For adults, data from the 2021 NHIS indicate that food allergy was more prevalent in NH Black adults than NH White, NH Asian, and Hispanic adults [60, 71]. For chronic rhinosinusitis, several studies involving adult patients have reported higher disease severity or morbidity among NH Black individuals, Hispanic individuals, and individuals receiving Medicaid insurance [73–77].

In addition to these documented disparities, climate change is a health equity issue [1]. Individuals with greater risk of exposure or fewer resources (e.g., children, individuals experiencing poverty, people with disabilities) to adapt to climate-related threats are more likely to experience negative effects on their physical and mental health [1, 5, 78]. For instance, extreme heat can disproportionately affect people with fewer resources to secure housing, including housing with air conditioners [3, 79, 80]. In another example, climate change-related urban flooding can impact low-lying areas with poor infrastructure, which disproportionately affects people with lower incomes and people of color [81, 82].

Contributors to disparate risk for climate-related health effects (such as economic and social factors, or the availability of individual and community resources to adapt to climate-related threats) could potentially add to existing disparities in climate-sensitive diseases including asthma. For instance, a 2022 report from the U.S. Environmental Protection Agency found that among all racial/ethnic groups studied, NH Black children are the most likely to live in Census tracts with the highest projected increases in pediatric asthma-related ED visits attributable to climate-driven changes in $PM_{2.5}$ levels [63, 81]. This report also found disparities by income level [63, 81, 83]. Specifically, children with from households with incomes less than two times the federal poverty level are more likely to live in areas with the highest projected increases in asthma-related ED visits attributable to $PM_{2.5}$ [63, 81, 83].

Examples of U.S. public health efforts to lessen the health effects of climate change

The U.S. Centers for Disease Control and Prevention's (CDC's) Climate and Health Program began in 2009 and has supported state, tribal, local, and territorial public health agencies as they prepare for and respond to the health impacts of a changing climate [3, 84]. This program's activities include conducting epidemiologic studies to build the scientific evidence base, providing technical assistance and funding to public health agencies, and creating tools and guidance to support communities to prepare for and respond to the health impacts of climate change [3, 84]. In 2022, CDC and the Agency for Toxic Substances and Disease Registry (ATSDR) developed and released a national CDC/ATSDR Agency-wide Climate and Health Strategic Framework [1]. This framework outlines more than 50 actions that CDC/ATSDR aspires to implement within the next five years [1]. These actions focus on addressing environmental justice and health equity, leveraging interdisciplinary partnerships, using innovative data practices and research to inform policy and decision-making, and building a climate-ready workforce [1].

Through these activities, CDC/ATSDR commits to embracing cross-cutting solutions, technological advances, and new partnerships to address the health impacts of climate change in the United States and abroad [1]. Furthermore, CDC/ATSDR will continue to include a health equity approach in its climate and health work to address health disparities and injustices [1]. This far-reaching, collaborative approach to address the health risks of climate change can help communities track, prevent, and respond to the public health threats of climate change, including impacts on asthma and allergic-immunologic diseases [1].

Selected resources healthcare professionals can use to help patients with asthma or other allergic-immunologic diseases

Everyone, including healthcare professionals, can participate in efforts to prepare for and reduce health effects associated with climate change, including impacts on asthma and other allergic-immunologic diseases [3]. Multiple clinically-oriented resources exist to help healthcare professionals learn more about this topic [3, 23, 85–88]. These materials include educational resources that can be shared with and used by patients, such as https://www.AirNow.gov or the AirNow app [89, 90], which both can help people with asthma and others learn when outdoor air pollution levels might be harmful in their area. When outdoor air pollution levels may be harmful in their area, these patients can try spending more time indoors (where outdoor air pollution levels are usually lower) or choose easier outdoor activities like walking instead of running [3, 89, 91]. For children with asthma, the American Academy of Pediatrics has endorsed publicly available activity books designed to help children learn about emergency preparedness for wildfires and flooding [92–96]. These activity books include information about asthma and are available in English and Spanish [92–96].

Certainly, discussions with patients about guidelines-based medical management, education on disease self-management, and reducing exposure to disease triggers (which vary among

individuals) continue to remain key to helping individuals achieve and maintain control of their asthma or other allergic-immunologic disease [6, 8, 24]. Conversations about climate change and health can be integrated into clinical care and examples of climate-related conversation strategies with patients and families are available in multiple publications [97–100]. These references include communication strategies tailored to patients with asthma or other allergic-immunologic disease [97–100].

For healthcare professionals involved in educating medical education, resources are available to inform teaching opportunities with medical students, residents, and fellows. For instance, asthma-related examples of how to provide climate change-related education for physicians-in-training can be found online or in the literature [54, 87, 88]. These resources include slide decks and problem-based learning cases that address both asthma and climate change [87].

Conclusions

Climate change is one of the biggest public health threats of our time, and its impacts on human health and wellbeing are far-reaching and worsening [1]. Climate change can impact asthma and other allergic-immunologic disease through various pathways. Climate change is a health equity issue; climate change-related health impacts can disproportionately affect certain populations, which could potentially add to existing disparities in climate-sensitive diseases such as asthma. U.S. public health efforts to reduce the health impacts of climate change include the development of the 2022 CDC/ATSDR Agency-wide Climate and Health Strategic Framework [1], which focuses on addressing health equity and can help communities track, prevent, and respond to the public health threats of climate change. For clinical care and medical training, numerous resources are available to help healthcare professionals provide education about preventing climate change-related health impacts. A collaborative, cross-sector approach can help individuals and communities be more prepared to prevent and respond to health effects associated with climate change, including impacts on asthma and other allergic-immunologic disease [1].

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Disclaimer:

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References

Papers of particular interest, published recently, have been highlighted as:

* Of importance

** Of major importance

1. Centers for Disease Control and Prevention. Agency-wide Climate and Health Task Force: FY 2022 Strategic Framework [cited 2023 Feb 9]. Available from: https://www.cdc.gov/climateandhealth/

docs/Agency-Climate-Health-External-Strategic-Framework-508.pdf.* This strategic framework was developed to guide the future of climate and health activities across the Centers for Disease Control and Prevention, in coordination with partners, to increase the capacity to prevent, prepare for, and respond to the ongoing and emerging health impacts of climate change.

2. Reidmiller DR, Avery CW, Easterling DR, Kunkel KE, Lewis KLM, Maycock TK, et al. USGCRP, 2018. Impacts, Risks, and Adaptation in the United States: Fourth National Climate Assessment, Volume II Washington D.C., U.S.A. [cited 2021 21 Oct]. Available from: https://nca2018.globalchange.gov/.** This report synthesizes information about the impacts of climate change in the United States. This report focuses on the human welfare, societal, and environmental elements of climate change and variability for 10 regions and 18 national topics, including chapters on air quality and human health.
3. Gillespie E, Schramm PJ, Hsu J. U.S. Public Health Response to Climate Change for Allergists-Immunologists. Ann Allergy Asthma Immunol. 2022;128(6):626–8. [PubMed: 35139427]
4. National Academies of Sciences, Engineering, and Medicine. 2023. Children's Environmental Health: Proceedings of a Workshop. Washington, DC: The National Academies Press. 10.17226/26848. [cited 2023 Mar 2]. Available from: https://nap.nationalacademies.org/catalog/26848/childrens-environmental-health-proceedings-of-a-workshop.
5. Lindsay S, Hsu S, Ragunathan S, Lindsay J. The impact of climate change related extreme weather events on people with pre-existing disabilities and chronic conditions: a scoping review. Disabil Rehabil. 2022:1–21.
6. Centers for Disease Control and Prevention. EXHALE Guide for Healthcare Professionals [cited 2023 Feb 6]. Available from: https://www.cdc.gov/asthma/exhale/documents/EXHALE-Healthcare-Professionals-Guide-508.pdf.* The Centers for Disease Control and Prevention's (CDC's) National Asthma Control Program created this guide to assist healthcare professionals in using CDC's EXHALE strategies to help people with asthma achieve better health outcomes. The EXHALE strategies are a set of six strategies; each of these strategies is proven to reduce asthma-related hospitalizations, emergency department visits, and healthcare costs.
7. Global Initiative for Asthma. 2022 GINA Report, Global Strategy for Asthma Management and Prevention Fontana, WI [cited 2023 9 Feb]. Available from: https://ginasthma.org/gina-reports/.
8. National Asthma Education and Prevention Program. Expert Panel Report 3 (EPR-3): Guidelines for the Diagnosis and Management of Asthma—Full Report 2007. NIH Publication No. 07-4051. Bethesda, MD: National Institutes of Health; 2007.
9. Fann NL, Nolte CG, Sarofim MC, Martinich J, Nassikas NJ. Associations Between Simulated Future Changes in Climate, Air Quality, and Human Health. JAMA Network Open. 2021;4(1):e2032064. [PubMed: 33394002]
10. U.S. Environmental Protection Agency. Ground-level Ozone Basics [cited 2023 Feb 28]. Available from: https://www.epa.gov/ground-level-ozone-pollution/ground-level-ozone-basics#formation.
11. HEI Panel on the Health Effects of Long-Term Exposure to Traffic-Related Air Pollution. 2022. Systematic Review and Meta-analysis of Selected Health Effects of Long-Term Exposure to Traffic-Related Air Pollution. Special Report 23. Boston, MA:Health Effects Institute. [cited 2023 Feb 28]. Available from: https://www.healtheffects.org/system/files/hei-special-report-23_4.pdf.
12. Zheng XY, Ding H, Jiang LN, Chen SW, Zheng JP, Qiu M, et al. Association between Air Pollutants and Asthma Emergency Room Visits and Hospital Admissions in Time Series Studies: A Systematic Review and Meta-Analysis. PLoS One. 2015;10(9):e0138146. [PubMed: 26382947]
13. Baek J, Kash BA, Xu X, Benden M, Roberts J, Carrillo G. Effect of Ambient Air Pollution on Hospital Readmissions among the Pediatric Asthma Patient Population in South Texas: A Case-Crossover Study. Int J Environ Res Public Health. 2020;17(13).
14. Byers N, Ritchey M, Vaidyanathan A, Brandt AJ, Yip F. Short-term Effects of Ambient Air Pollutants on Asthma-related Emergency Department Visits in Indianapolis, Indiana, 2007-2011. J Asthma. 2016;53(3):245–52. [PubMed: 26517197]
15. Castner J, Guo L, Yin Y. Ambient Air Pollution and Emergency Department Visits for Asthma in Erie County, New York 2007-2012. Int Arch Occup Environ Health. 2018;91(2):205–14. [PubMed: 29043427]

16. Winquist A, Grundstein A, Chang HH, Hess J, Sarnat SE. Warm Season Temperatures and Emergency Department Visits in Atlanta, Georgia. Environ Res. 2016;147:314–23. [PubMed: 26922412]
17. Soneja S, Jiang C, Fisher J, Upperman CR, Mitchell C, Sapkota A. Exposure to Extreme Heat and Precipitation Events Associated with Increased Risk of Hospitalization for Asthma in Maryland, U.S.A. Environ Health. 2016;15:57. [PubMed: 27117324]
18. Poole JA, Barnes CS, Demain JG, Bernstein JA, Padukudru MA, Sheehan WJ, et al. Impact of Weather and Climate Change with Indoor and Outdoor Air Quality in Asthma: A Work Group Report of the AAAAI Environmental Exposure and Respiratory Health Committee. J Allergy Clin Immunol. 2019;143(5):1702–10. [PubMed: 30826366]
19. Schramm PJ, Brown CL, Saha S, Conlon KC, Manangan AP, Bell JE, et al. A Systematic Review of the Effects of Temperature and Precipitation on Pollen Concentrations and Season Timing, and Implications for Human Health. Int J Biometeorol. 2021;65(10):1615–28. [PubMed: 33877430]
20. Kitinoja MA, Hugg TT, Siddika N, Rodriguez Yanez D, Jaakkola MS, Jaakkola JJK. Short-term exposure to pollen and the risk of allergic and asthmatic manifestations: a systematic review and meta-analysis. BMJ Open. 2020;10(1):e029069.
21. Shrestha SK, Lambert KA, Erbas B. Ambient pollen concentrations and asthma hospitalization in children and adolescents: a systematic review and meta-analysis. J Asthma. 2021;58(9):1155–68. [PubMed: 32419541]
22. Erbas B, Jazayeri M, Lambert KA, Katelaris CH, Prendergast LA, Tham R, et al. Outdoor pollen is a trigger of child and adolescent asthma emergency department presentations: A systematic review and meta-analysis. Allergy. 2018;73(8):1632–41. [PubMed: 29331087]
23. U.S. Environmental Protection Agency. Particle Pollution and Your Patients' Health [updated 2022 Aug 18; cited 2023 Mar 17]. Available from: https://www.epa.gov/pmcourse/learn-about-particle-pollution-and-your-patients-health-course.
24. Expert Panel Working Group of the National Heart L, Blood Institute a, coordinated National Asthma E, Prevention Program Coordinating C, Cloutier MM, Baptist AP, et al. 2020 Focused Updates to the Asthma Management Guidelines: A Report from the National Asthma Education and Prevention Program Coordinating Committee Expert Panel Working Group. J Allergy Clin Immunol. 2020;146(6):1217–70. [PubMed: 33280709]
25. Fan J, Li S, Fan C, Bai Z, Yang K. The Impact of PM2.5 on Asthma Emergency Department Visits: A Systematic Review and Meta-Analysis. Environ Sci Pollut Res Int. 2016;23(1):843–50. [PubMed: 26347419]
26. Lim H, Kwon HJ, Lim JA, Choi JH, Ha M, Hwang SS, et al. Short-term Effect of Fine Particulate Matter on Children's Hospital Admissions and Emergency Department Visits for Asthma: A Systematic Review and Meta-analysis. J Prev Med Public Health. 2016;49(4):205–19. [PubMed: 27499163]
27. Chang HH, Pan A, Lary DJ, Waller LA, Zhang L, Brackin BT, et al. Time-series Analysis of Satellite-Derived Fine Particulate Matter Pollution and Asthma Morbidity in Jackson, MS. Environ Monit Assess. 2019;191(Suppl 2):280. [PubMed: 31254082]
28. Stowell JD, Geng G, Saikawa E, Chang HH, Fu J, Yang CE, et al. Associations of Wildfire Smoke PM(2.5) Exposure with Cardiorespiratory Events in Colorado 2011-2014. Environ Int. 2019;133(Pt A):105151. [PubMed: 31520956]
29. Gan R, Liu J, Ford B, O'Dell K, Vaidyanathan A, Wilson A, et al. The Association between Wildfire Smoke Exposure and Asthma-Specific Medical Care Utilization in Oregon during the 2013 Wildfire Season. J Expo Sci Environ Epidemiol. 2022;30(4):618–28.
30. Reid C, Considine E, Watson G, Telesca D, Pfister G, Jerrett M. Associations Between Respiratory Health and Ozone and Fine Particulate Matter during a Wildfire Event. Environment International. 2019;129.
31. Delfino RJ, Brummel S, Wu J, Stern H, Ostro B, Lipsett M, et al. The Relationship of Respiratory and Cardiovascular Hospital Admissions to the Southern California Wildfires of 2003. Occup Environ Med. 2009;66(3):189–97. [PubMed: 19017694]

32. Mendell MJ, Mirer AG, Cheung K, Tong M, Douwes J. Respiratory and Allergic Health Effects of Dampness, Mold, and Dampness-Related Agents: A Review of the Epidemiologic Evidence. Environ Health Perspect. 2011;119(6):748–56. [PubMed: 21269928]
33. World Health Organization. WHO Guidelines for Indoor Air Quality: Dampness and Mould [updated 2023 Jan 1; cited 2023 Feb 9]. Available from: https://www.who.int/publications/i/item/9789289041683.
34. Cowan KN, Pennington AF, Gregory T, Hsu J. Impact of Hurricanes on Children With Asthma: A Systematic Literature Review. Disaster Med Public Health Prep. 2022;16(2):777–82. [PubMed: 33557998]
35. Arcaya MC, Lowe SR, Rhodes JE, Waters MC, Subramanian SV. Association of PTSD symptoms with asthma attacks among hurricane Katrina survivors. J Trauma Stress. 2014;27(6):725–9. [PubMed: 25470787]
36. Landeo-Gutierrez J, Forno E, Miller GE, Celedon JC. Exposure to Violence, Psychosocial Stress, and Asthma. Am J Respir Crit Care Med. 2020;201(8):917–22. [PubMed: 31801032]
37. Gao Y, Huang W, Yu P, Xu R, Yang Z, Gasevic D, et al. Long-term Impacts of Non-Occupational Wildfire Exposure on Human health: A Systematic Review. Environ Pollut. 2023;320:121041. [PubMed: 36639044]
38. Charlson F, Ali S, Benmarhnia T, Pearl M, Massazza A, Augustinavicius J, et al. Climate Change and Mental Health: A Scoping Review. Int J Environ Res Public Health. 2021;18(9).
39. Mirabelli M, Vaidyanathan A, Pennington A, Ye D, Trenga C. Wildfire Smoke and Symptoms Affecting Mental Health among Adults in the U.S. State of Oregon. Prev Med. 2022.
40. Centers for Disease Control and Prevention. Manage Your Asthma During Disasters [cited 2023 Mar 2]. Available from: https://blogs.cdc.gov/yourhealthyourenvironment/2022/08/03/manage-your-asthma-during-disasters/.
41. Brusselle GG, Koppelman GH. Biologic Therapies for Severe Asthma. N Engl J Med. 2022;386(2):157–71. [PubMed: 35020986]
42. U.S. Food and Drug Administration. Highlights of Prescribing Information: Fasenra (benralizumab) [cited 2023 Feb 9]. Available from: https://www.accessdata.fda.gov/drugsatfda_docs/label/2017/761070s000lbl.pdf.
43. U.S. Food and Drug Administration. Highlights of Prescribing Information: Xolair (Omalizumab) [cited 2023 Feb 15]. Available from: https://www.accessdata.fda.gov/drugsatfda_docs/label/2016/103976s5225lbl.pdf.
44. U.S. Food and Drug Administration. Highlights of Prescribing Information: Cinqair (Reslizumab) [cited 2023 Feb 15]. Available from: https://www.accessdata.fda.gov/drugsatfda_docs/label/2016/761033lbl.pdf.
45. U.S. Food and Drug Administration. Highlights of Prescribing InformationL Dupixent (Dupilumab) [cited 2023 Feb 15]. Available from: https://www.accessdata.fda.gov/drugsatfda_docs/label/2022/761055s044lbl.pdf.
46. U.S. Food and Drug Administration. Highlights of Prescribing Information: Tezspire (Tezepelumab-ekko) [cited 2023 Feb 15]. Available from: https://www.accessdata.fda.gov/drugsatfda_docs/label/2021/761224s000lbl.pdf.
47. Saha S, Vaidyanathan A, Lo F, Brown C, Hess JJ. Short Term Physician Visits and Medication Prescriptions for Allergic Disease Associated with Seasonal Tree, Grass, and Weed Pollen Exposure Across the United States. Environ Health. 2021;20(1):85. [PubMed: 34289856]
48. Manangan A, Brown C, Saha S, Bell J, Hess J, Uejio C, et al. Long-term Pollen Trends and Associations between Pollen Phenology and Seasonal Climate in Atlanta, Georgia (1992-2018). Annals of Allergy, Asthma & Immunology. 2021;127(4):471–80.e4.
49. Anderegg WRL, Abatzoglou JT, Anderegg LDL, Bielory L, Kinney PL, Ziska L. Anthropogenic Climate Change is Worsening North American Pollen seasons. Proc Natl Acad Sci U S A. 2021;118(7).
50. Barnes H, Lu J, Glaspole I, Collard HR, Johannson KA. Exposures and associations with clinical phenotypes in hypersensitivity pneumonitis: A scoping review. Respir Med. 2021;184:106444. [PubMed: 33991845]

51. Chew G, Saha S. Impacts of Climate Change on Indoor Allergens. In: Breggs P, editor. Impacts of Climate Change on Allergens and Allergic Diseases. Cambridge, UK: Cambridge University Press; 2016.
52. Centers for Disease Control and Prevention. Food for Thought: What Hurricane Sandy Can Teach Us about Food Allergy Preparedness [cited 2023 Mar 3]. Available from: https://blogs.cdc.gov/publichealthmatters/2019/05/food-allergies/.
53. Food Allergy Research and Education. Food Allergy Emergency and Disaster Preparedness [cited 2023 Mar 3]. Available from: https://www.foodallergy.org/resources/food-allergy-emergency-and-disaster-preparedness.
54. Philipsborn RP, Sheffield P, White A, Osta A, Anderson MS, Bernstein A. Climate Change and the Practice of Medicine: Essentials for Resident Education. Acad Med. 2021;96(3):355–67. [PubMed: 32910006]
55. Fonseca C, Philipsborn R. Climate Change, Extreme Weather & Children: What Families Need to Know [updated 2023 Jan 26; cited 2023 Feb 15]. Available from: https://www.healthychildren.org/English/safety-prevention/all-around/Pages/climate-change-extreme-weather-and-children-what-families-need-to-know.aspx.
56. U.S. Food and Drug Administration. Highlights of Prescribing Information: Kalbitor (ecallantide) [cited 2023 Mar 3]. Available from: https://www.accessdata.fda.gov/drugsatfda_docs/label/2014/125277s071lbl.pdf.
57. U.S. Food and Drug Administration. Highlights of Prescibing Information: Asceniv (immune globulin intravenous, human-sira) [cited 2023 Feb 15]. Available from: https://www.fda.gov/media/122525/download.
58. U.S. Food and Drug Administration. Highlights of Prescibing Information: Bivigam (immune globulin intravenous, human-sira) [cited 2023 Mar 6]. Available from: https://www.fda.gov/media/84782/download.
59. Centers for Disease Control and Prevention. Most Recent Asthma Data [cited 2023 Mar 17]. Available from: https://www.cdc.gov/asthma/most_recent_national_asthma_data.htm.
60. Davis CM, Apter AJ, Casillas A, Foggs MB, Louisias M, Morris EC, et al. Health Disparities in Allergic and Immunologic Conditions in Racial and Ethnic Underserved Populations: A Work Group Report of the AAAAI Committee on the Underserved. J Allergy Clin Immunol. 2021;147(5):1579–93. [PubMed: 33713767] ** This report reviews current evidence regarding health disparities in asthma, allergic rhinitis and other allergic-immunologic diseases, as well as primary immune deficiency disease.
61. Pate CA, Zahran HS, Qin X, Johnson C, Hummelman E, Malilay J. Asthma Surveillance - United States, 2006-2018. MMWR Surveill Summ. 2021;70(5):1–32.
62. Burbank AJ, Hernandez ML, Jefferson A, Perry TT, Phipatanakul W, Poole J, et al. Environmental justice and allergic disease: A Work Group Report of the AAAAI Environmental Exposure and Respiratory Health Committee and the Diversity, Equity and Inclusion Committee. J Allergy Clin Immunol. 2023;151(3):656–70. [PubMed: 36584926] ** This report was developed to improve allergy-immunology specialists' awareness of environmental injustice, its roots in systemic racism, and its impact on health disparities in allergic-immunologic disease.
63. U.S. Environmental Protection Agency. Climate Change and Social Vulnerability in the United States: A Focus on Six Impacts: Appendix D: Air Quality [updated 2022 Dec 6; cited 2023 Apr 17]. Available from: https://www.epa.gov/system/files/documents/2021-09/appendix-d_air-quality.pdf.
64. Liu J, Clark LP, Bechle MJ, Hajat A, Kim SY, Robinson AL, et al. Disparities in Air Pollution Exposure in the United States by Race/Ethnicity and Income, 1990-2010. Environ Health Perspect. 2021;129(12):127005. [PubMed: 34908495]
65. Collins TW, Grineski SE. Racial/Ethnic Disparities in Short-Term PM2.5 Air Pollution Exposures in the United States. Environ Health Perspect. 2022;130(8):87701. [PubMed: 35983969]
66. Colmer J, Hardman I, Shimshack J, Voorheis J. Disparities in PM(2.5) air pollution in the United States. Science. 2020;369(6503):575–8. [PubMed: 32732425]
67. Alexander D, Currie J. Is it who you are or where you live? Residential segregation and racial gaps in childhood asthma. J Health Econ. 2017;55:186–200. [PubMed: 28802746]

68. Maantay J. Asthma and air pollution in the Bronx: methodological and data considerations in using GIS for environmental justice and health research. Health Place. 2007;13(1):32–56. [PubMed: 16311064]
69. Martenies SE, Milando CW, Williams GO, Batterman SA. Disease and Health Inequalities Attributable to Air Pollutant Exposure in Detroit, Michigan. Int J Environ Res Public Health. 2017;14(10).
70. Zablotsky B, Black LI, Akinbami LJ. Diagnosed Allergic Conditions in Children Aged 0-17 Years: United States, 2021. NCHS Data Brief. 2023(459):1–8.
71. Ng AE, Boersma P. Diagnosed Allergic Conditions in Adults: United States, 2021. NCHS Data Brief. 2023(460):1–8.
72. Mahdavinia M, Fox SR, Smith BM, James C, Palmisano EL, Mohammed A, et al. Racial Differences in Food Allergy Phenotype and Health Care Utilization among US Children. J Allergy Clin Immunol Pract. 2017;5(2):352–7 e1. [PubMed: 27888035]
73. Konsur E, Rigg L, Moore D, Patel M, Batra PS, Mahdavinia M. Race and ethnicity define disparate clinical outcomes in chronic rhinosinusitis. Ann Allergy Asthma Immunol. 2022;129(6):737–41. [PubMed: 35623587]
74. Kuhar HN, Ganti A, Eggerstedt M, Mahdavinia M, Gattuso P, Ghai R, et al. The impact of race and insurance status on baseline histopathology profile in patients with chronic rhinosinusitis. Int Forum Allergy Rhinol. 2019;9(6):665–73. [PubMed: 30748100]
75. Levine CG, Casiano RR, Lee DJ, Mantero A, Liu XZ, Palacio AM. Chronic Rhinosinusitis Disease Disparity in the South Florida Hispanic Population. Laryngoscope. 2021;131(12):2659–65. [PubMed: 34254684]
76. Soler ZM, Mace JC, Litvack JR, Smith TL. Chronic rhinosinusitis, race, and ethnicity. Am J Rhinol Allergy. 2012;26(2):110–6. [PubMed: 22487286]
77. Duerson W, Lafer M, Ahmed O, Bandler I, Wang B, Lieberman S, et al. Health Care Disparities in Patients Undergoing Endoscopic Sinus Surgery for Chronic Rhinosinusitis: Differences in Disease Presentation and Access to Care. Ann Otol Rhinol Laryngol. 2019;128(7):608–13. [PubMed: 30832483]
78. Hrabok M, Delorme A, Agyapong VIO. Threats to Mental Health and Well-Being Associated with Climate Change. J Anxiety Disord. 2020;76:102295. [PubMed: 32896782]
79. Cardoza JE, Gronlund CJ, Schott J, Ziegler T, Stone B, O'Neill MS. Heat-Related Illness Is Associated with Lack of Air Conditioning and Pre-Existing Health Problems in Detroit, Michigan, USA: A Community-Based Participatory Co-Analysis of Survey Data. Int J Environ Res Public Health. 2020;17(16).
80. Guirguis K, Basu R, Al-Delaimy WK, Benmarhnia T, Clemesha RES, Corcos I, et al. Heat, Disparities, and Health Outcomes in San Diego County's Diverse Climate Zones. Geohealth. 2018;2(7):212–23. [PubMed: 32159015]
81. U.S. Environmental Protection Agency. Climate Change and Social Vulnerability in the United States: A Focus on Six Impacts [updated 2021 September; cited 2023 Feb 15]. Available from: https://www.epa.gov/system/files/documents/2021-09/climate-vulnerability_september-2021_508.pdf.
82. Centers for Disease Control and Prevention. CDC Environmental Health Nexus: Climate Change and Human Health Webinar [cited 2023 Feb 9]. Available from: https://www.cdc.gov/nceh/ehsp/ehnexus/learn/documents/climate-and-health-webinar_april-14-2021-508.pdf.
83. U.S. Environmental Protection Agency. Climate Change and Social Vulnerability in the United States: A Focus on Six Impacts: Appendix C. Inputs and Projections [cited 2023 Feb 15]. Available from: https://www.epa.gov/system/files/documents/2021-09/appendix-c_inputs-and-projections.pdf.
84. Schramm PJ CA, Berman PP, McCoy T, Gaines C, Svendsen E, Malilay J, Yip F, Sarisky J, Allwood P, Breysse P. Building a Comprehensive Approach in CDC's National Center for Environmental Health to Address the Health Effects of Climate Change. The Journal of Climate Change and Health. 2021;4:100071.
85. U.S. Environmental Protection Agency. Wildfire Smoke and Your Patients' Health [updated 2022 Aug 18; cited 2023 Feb 15]. Available from: https://www.epa.gov/wildfire-smoke-course.

86. The Medical Society Consortium on Climate and Health. For Health Professionals [cited 2023 Mar 17]. Available from: https://medsocietiesforclimatehealth.org/educate/healthprofessionals/.
87. Columbia Mailman School of Public Health. Global Consortium on Climate and Health Education [cited 2023 Mar 17]. Available from: https://www.publichealth.columbia.edu/research/global-consortium-climate-and-health-education.
88. Harvard TH Chan School of Public Health. Climate MD [cited 2023 Mar 17]. Available from: https://www.hsph.harvard.edu/c-change/research/climate-md/.
89. U.S. Environmental Protection Agency and Partners. AirNow [cited 2023 Feb 9]. Available from: https://www.airnow.gov/.
90. U.S. Environmental Protection Agency. AirNow Mobile App [cited 2023 Feb 15]. Available from: https://www.airnow.gov/airnow-mobile-app/.
91. Rosser F, Han YY, Rothenberger SD, Forno E, Mair C, Celedon JC. Air Quality Index and Emergency Department Visits and Hospitalizations for Childhood Asthma. Ann Am Thorac Soc. 2022;19(7):1139–48. [PubMed: 35394903]
92. Centers for Disease Control and Prevention. Ready Wrigley Prepares for Wildfires and Smoke [cited 2023 Feb 9]. Available from: https://www.cdc.gov/cpr/readywrigley/documents/CDC_CPR_RW_Prepares-for-Wildfires_FINAL.pdf.
93. Centers for Disease Control and Prevention. Ready Wrigley, CDC's Preparedness Pup, Inspires Our Youngest Partners [updated 2020 Oct 15; cited 2023 Feb 15]. Available from: https://www.cdc.gov/cpr/partnerships/readywrigley.htm.
94. Centers for Disease Control and Prevention. Flooding and Mold [cited 2023 Feb 15]. Available from: https://www.cdc.gov/cpr/readywrigley/documents/17_279940_Ready_Wrigley_mold_508_1.pdf.
95. Centers for Disease Control and Prevention. Listo Calixto Se Prepara Para Los Incendios Forestales Y El Humo [cited 2023 Feb 15]. Available from: https://www.cdc.gov/cpr/readywrigley/documents/CDC_CPR_RW_Prepares-for-Wildfires_FINAL_esp.pdf.
96. Centers for Disease Control and Prevention. Las iNundaciones Y El Moho [cited 2023 Feb 15]. Available from: https://www.cdc.gov/cpr/readywrigley/documents/17_279940_Ready_Wrigley_Mold_508_SP_1.pdf.
97. Senay E, Sarfaty M, Rice MB. Strategies for Clinical Discussions About Climate Change. Ann Intern Med. 2021;174(3):417–8. [PubMed: 33315471]
98. Wellbery CE, Lewandowski A, Holder C. Climate Change and the Local Environment: Communicating with Your Patients about Health Impacts. Am Fam Physician. 2021;104(5):526–30. [PubMed: 34783491]
99. Parker CL, Wellbery CE, Mueller M. The Changing Climate: Managing Health Impacts. Am Fam Physician. 2019;100(10):618–26. [PubMed: 31730308]
100. Ragavan MI, Marcil LE, Garg A. Climate Change as a Social Determinant of Health. Pediatrics. 2020;145(5).

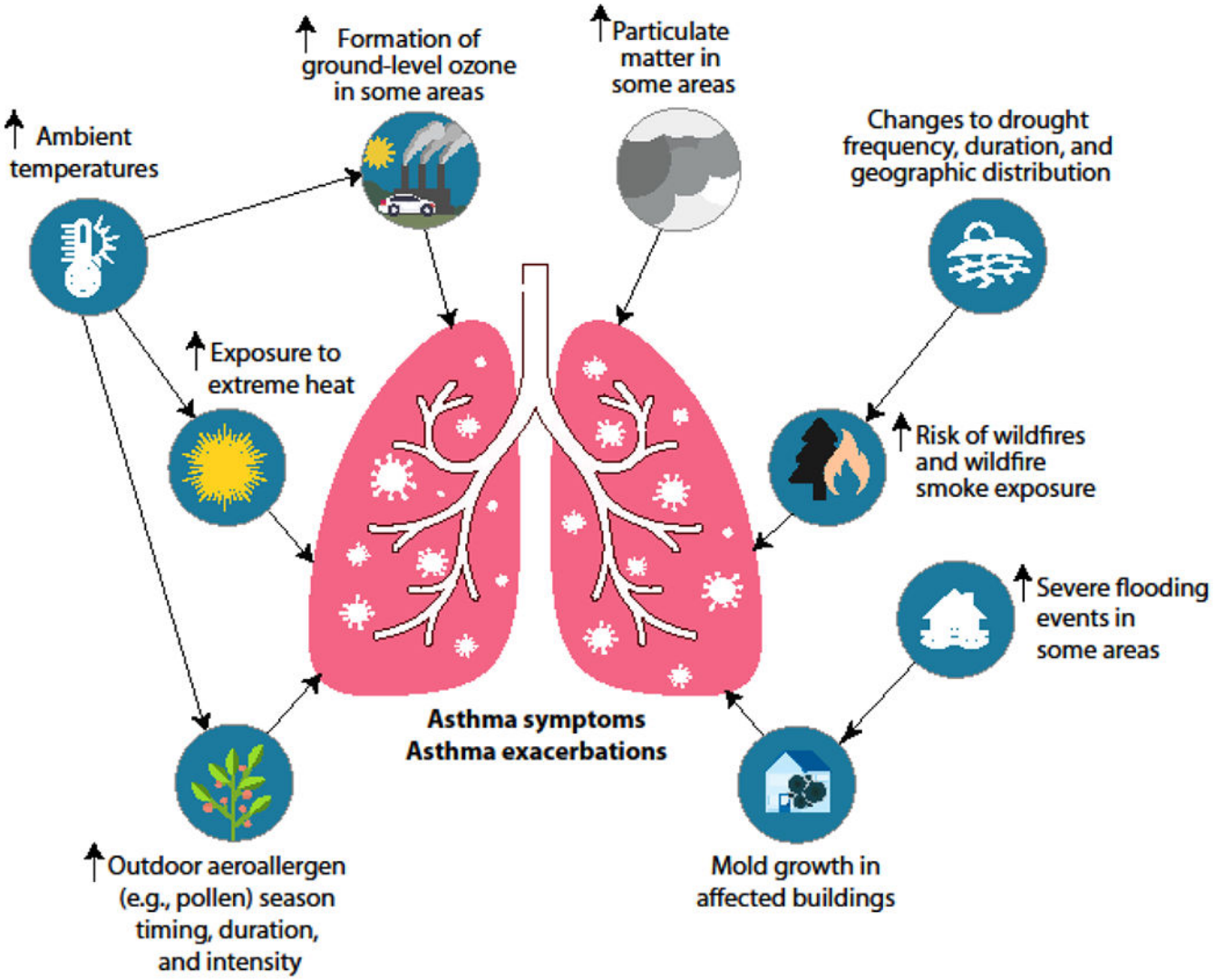

Fig. 1.
Examples of how climate change can increase exposure to asthma triggers