



CME review

Climate change and allergic diseases

Gina Dapul-Hidalgo, MD, ^{*,†} and Leonard Bielory, MD, MS ^{‡,§}^{*} Center for Allergy and Asthma Research, Department of Medicine, State University of New York, Downstate Medical Center, Brooklyn, New York[†] Division of Allergy and Immunology, Department of Medicine, State University of New York Downstate Medical Center, Brooklyn, New York[‡] STARx Allergy and Asthma Center, Rutgers University, Springfield, New Jersey[§] Center for Environmental Prediction, Rutgers University, Springfield, New Jersey

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Release Date: September 1, 2012**Expiration Date:** August 31, 2014**Estimated Time to Complete:** 60 minutes**Target Audience:** Physicians involved in providing patient care in the field of allergy/asthma/immunology**Learning Objectives:**

At the conclusion of this activity, participants should be able to:

- Describe the potential effects of climate change on allergic diseases, including allergic rhinitis, allergic conjunctivitis, atopic dermatitis, and asthma.
- Recognize the impact of climate change on allergic diseases and the related need to minimize greenhouse gas emissions through various global and regional mitigation efforts.

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Leonard Bielory, MD, MS (Author)

Mitchell H. Grayson, MD (Deputy Editor)

Gailen D. Marshall, Jr, MD, PhD (Editor-in-Chief)

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CME Inquiries: Contact the American College of Allergy, Asthma & Immunology at education@acaai.org or 847-427-1200.

Reprints: Leonard Bielory, MD, MS, 400 Mountain Ave, Springfield, NJ 07081-2515; E-mail: Bielory@envsci.Rutgers.edu.

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Introduction

Although allergic diseases are the result of an interaction among genetics, the environment, and the immune system's interface at the mucosal surfaces, effects of climate change appear to already include changes in the distribution, amount, and quality of aeroallergens. The Intergovernmental Panel on Climate Change, a collaboration of more than 2,000 scientists from 100 countries, reported in 2007 that "most of the observed increases in global average temperatures since the mid-20th century is very likely due to the observed increase in anthropogenic greenhouse gas concentrations."¹ Temperatures have increased 0.7°C during the past 100 years and are projected to increase by 1.8°C to 4.0°C warmer from 1999 to 2099 in the coterminous United States and more than 5°C in northern Alaska.¹ The responsible greenhouse gases include carbon dioxide, methane, and nitrous oxide¹ and have apparently increased as a direct result of human activities² (Table 1).

One of the common errors associated with discussions of climate is that it is different from weather. Climate of a region is determined by long-term weather conditions, including seasonal changes. Weather represents the day-to-day occurrences of the climate. Another point that requires clarification is that climate change is not the same as global warming. Global warming is a misnomer because it depicts only one variable, temperature, whereas climate change means that regions may vary in their change with an increase or decrease in temperatures, precipitations (rain and snow), wind currents, and other meteorologic variables. Major global environmental changes are expected to significantly affect various aspects of human health from cardiovascular disease to infectious disease to respiratory disorders, including allergies and asthma (Fig 1).

Climate change is a worldwide event impacting human health, including infectious disease, nutrition, cardiovascular disease, respiratory disorders (including asthma), and allergies. We performed a PubMed search using the following medical subject heading terms: *climate change*, *global warming*, *temperature*, or *seasonal* together with *allergic disease*, *allergic rhinitis*, *allergic conjunctivitis*, *allergic rhinoconjunctivitis*, *atopic dermatitis*, *eczema*, *urticaria*, *food allergy*, *peanut allergy*, *wheat*, *asthma*, or *insect allergy*. Studies from 1990 to the present that emphasized the effects of climate change on allergic disease were selected for inclusion.

Effect of climate change on pollen, plant distribution, mold spores, and allergies

In general, it is well known that phenology (periodic phenomena that are related to climate change), such as pre-season temperature and precipitation, are important projectors of both tree and grass pollen production. Recent reviews have extensively discussed the topics of climate change, aerobiology, and aeroallergens.^{11,12} Changes attributable to the potential increase in aeroallergen concentration, distribution, dispersion patterns, and allergenicity with subsequent exposure of atopic individuals will have an effect on the incidence, severity, and prevalence of allergic disorders via longer, higher dosing and severity of the allergic inflammatory response (Fig 1),^{2,13} with warmer spring temperatures considered a primary variable of this effect. Increasing pollen concentrations and pollination seasons over time and increasing temperature have been reported, with several species of allergenic plants, including ragweed and other weeds (mugwort), grasses, and trees, including olive, cedar, birch, and alder (Table 2).

If the predicted climate conditions are correct, one of the most recognizable allergenic pollinating plants, ragweed, and potentially other allergenic plants, including molds, will increase significantly in various regions.¹⁴ The Global Change Research Program (<http://www.epa.gov/ncer/science/globalclimate/>) entitled Science to Achieve Results (STAR) initiated by the US Environmental Protec-

tion Agency is part of ongoing research investigating the effect of climate change on health.

Effect of climate change on allergic diseases

Increase in allergen exposure and long-distance transport of anemophilous allergenic pollens will generate increased symptoms to various species not commonly present in sufficient quantities to invoke symptoms.¹³ It can also generate potentially increased sensitization as various pollutants, and possibly oceanic toxins from increased algal blooms, will increase allergenicity by acting as immunogenic adjuvants.^{15,16} The results of the increased exposure and sensitization will potentially promote the "allergic march" in the pediatric population that would lead to a progression of multiple clinical atopic disorders, whereas in the adult population it will lead to persistence of symptoms or the development of new allergies later in life, affecting the geriatric population.

Allergic rhinitis

Coincident with climate changes during the past 30 years is the finding that allergic rhinitis in the US population has increased from 10% in 1970 to 30% in 2000. An example of increasing sensitization that may correlate with changes in pollen phenology and climate change may be the finding of the National Health and Nutrition Examination Survey (NHANES) III (1988–1994) that reflected that 26.9% and 26.2% of the US population was sensitized to perennial rye grass and ragweed, respectively, and the prevalence is at least 2 times higher than that from NHANES II (1976–1908).¹⁷ Similar rankings were found in Canada, although with a higher prevalence of grasses (51.9%), trees (47.2%), and ragweed pollens (44.9%).¹⁸

Increased humidity has been associated with 8- to 15-fold increases in eosinophil influx and eosinophil cationic protein levels during the late-phase allergic responses of the nasal mucosa, and with the regional predictions of climate change of increased temperatures and humidity, especially along various shorelines, one would also expect an increase in the intensity of the allergic inflammatory processes. Although other studies have demonstrated amelioration of nasal symptoms using humidified or saturated hot air in patients with perennial allergic rhinitis,¹⁹ cold air-induced rhinitis may also be seen to increase in those individuals with chronic allergic or nonallergic rhinitis in regions affected by colder climate changes.²⁰ Nasal mast cell activation, sensory nerve stimulation, and subsequent triggering of a cholinergic reflex can then lead to rhinorrhea.

Studies along the Pacific rim²¹ demonstrated that high nonsummer (September to May) warm temperatures were positively related to the prevalence of physician-diagnosed allergic rhinitis in both sexes (odds ratio, 1.10; 95% confidence interval, 1.02–1.19; in males; odds ratio, 1.09; 95% confidence interval, 1.01–1.19; in females). It is predicted that the number of individuals with hay fever in Japan will increase by 40% by 2050 because Tokyo's mean yearly temperature has increased by 3°C since 1890 and is set to increase up to 3.5°C by the end of the century.²² The International Study of Asthma and Allergies in Childhood (ISAAC), a study that was successfully completed in 155 centers in 56 countries on 6 continents, does not clearly support the observation²³ because the results did not show a consistent picture of an association between climatic conditions in the pediatric population and asthma, allergic rhinoconjunctivitis, and atopic disorders. Some associations were observed, but it is not clear whether they could be regionalized (ie, none of them was found more than once for another age group or region). As reflected above, this finding is not precluded to older aged cohorts with chronic allergic conditions beyond adolescence because climate conditions persist with continued allergenic expo-

Table 1
Summary of greenhouse gases comparing preindustrial revolution (baseline) and 21st century measurements

Greenhouse gas	Late 18th century	2001
Carbon dioxide, ppm	280	371
Methane, ppm	0.7	1.75
Nitrous oxide, ppb	288	315
Chlorofluorocarbons, ppt		
Chlorofluorocarbon 11	0	252
Chlorofluorocarbon 12	0	480

Abbreviations: ppb, parts per billion; ppm, parts per million; ppt, parts per trillion.

sure because the ISAAC study was not designed to specifically evaluate this question.

Allergic conjunctivitis

A study in Western Poland between 1995 and 2004 reported that the prevalence of atopic disorders consisted of rhinitis and conjunctivitis (45%), atopic dermatitis (AD) (28%), asthma (13%), and disseminated eczema (11%). Specific allergen sensitization to *Artemisia vulgaris* species (mugwort) pollen was reported in 12% of patients (10% with serum allergen specific IgE), mainly those with rhinitis and conjunctivitis (15%), AD (15%), and chronic urticaria (14%). The authors describe a strong advance in the seasonal pollen season start and end dates and the peak day.²⁴ Specific climatic variables, such as temperature, were positively correlated with daily *Artemisia* pollen concentrations, whereas rainfall and relative humidity were negatively correlated with daily pollen concentrations. In days when a high wind speed was recorded, the pollen

concentration was lower. The authors suggest that climate change is associated with an earlier onset and longer duration of the pollen season. Another European study, in Burgundy, during birch (*Betula*) pollination aimed to evaluate the influence of meteorologic conditions on pollen and pollinosis²⁵ and found that windy conditions, low relative humidity, precipitation below 2 mm, and temperatures above 6°C favored pollen dispersal. A decrease in temperature of 3°C and strong winds, owing to the irritant effect of cold or wind, were associated with the development of conjunctivitis symptoms. One of the confounding questions is whether these symptoms are solely allergic or whether they are conditions that increase inflammatory disorders of the anterior surface of the eye, such as dry eye syndromes, or are from a more toxic effect of local pollutants or the metalloproteinases that are found in grass pollen and are known to also promote mucosal inflammatory responses. However, none of the studies determined the changes of quantity, allergenicity, or distribution of allergenic pollen that are important climate change variables that affect the genetically predisposed allergic population.

Atopic dermatitis

Focusing on climatotherapy for AD, several studies have examined patients with AD traveling to different environments and determined the effect of such traveling on their AD. In an open, randomized, controlled, pediatric study (ages 4–13 years) objectively assessed by SCORing of Atopic Dermatitis (SCORAD) and quality of life,²⁶ study patients were randomized to a 4-week stay in a warm subtropic climate on Gran Canary (n = 30) or their home in Norway (n = 26). The extent, intensity, and subjective symptoms were significantly lower in the index compared with the control

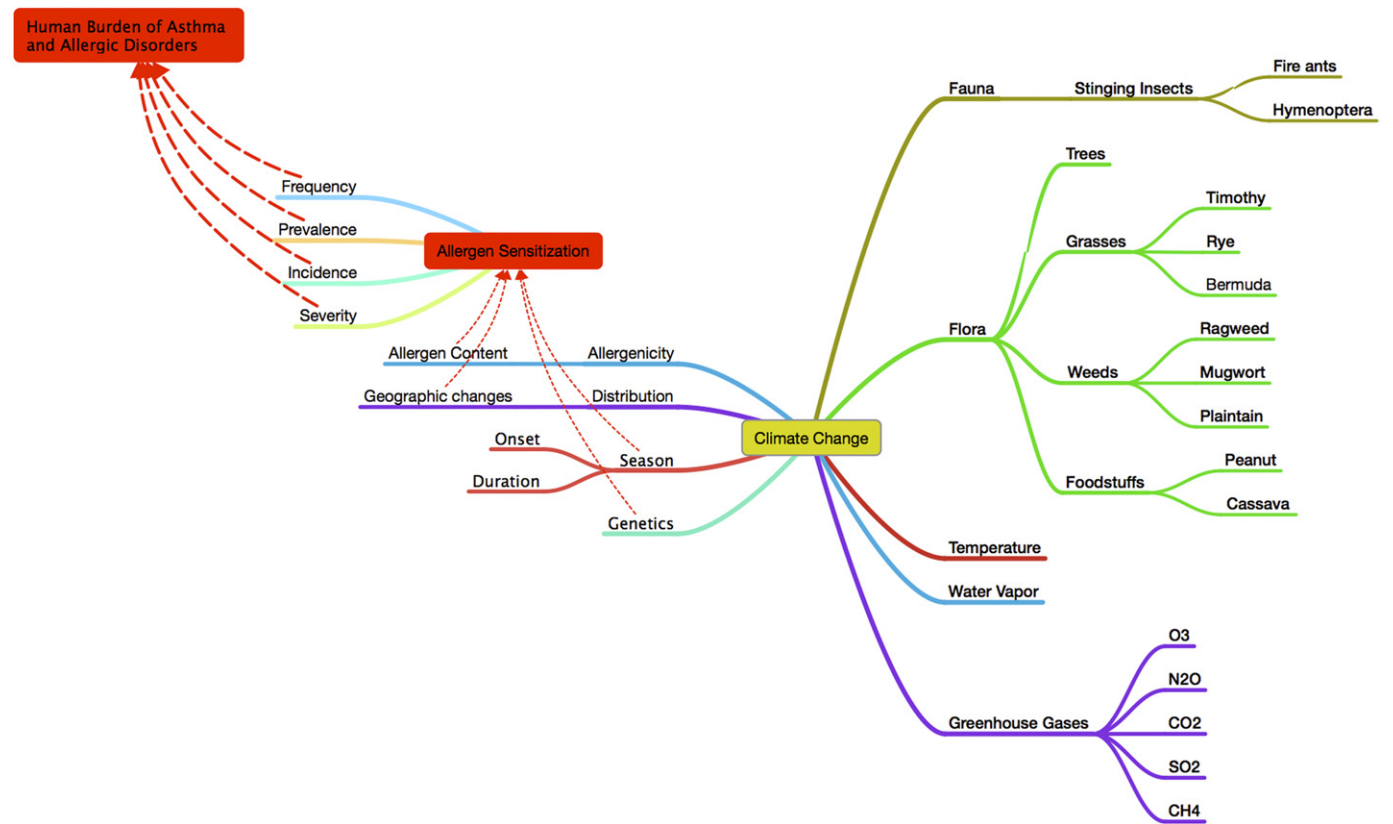


Fig 1. Climate change involves several environmental variables, including various greenhouse gases, temperature, water vapor, and plant (flora) and animal (fauna). The allergenic floras include trees, grasses, and weeds, as well as various plant-based foods (eg, peanut, cassava, corn, rice), and animals, particularly stinging insects. Although postulated by many, only a few experiments have demonstrated that the environmental variables have and will affect the allergenicity, season (onset, duration), and distribution of allergens. Depending on the human population's genetic propensity to develop a specific immune response toward the T_H2 lymphocytic allergic paradigm, an increase in prevalence, incidence, frequency, and severity of asthma and allergic disease can be seen, further increasing the human burden of asthma and allergic disorders.

Table 2
Correlation between air temperature and allergenic pollen in various countries

Common name	Latin name	Phenology	Location	Reference(s)
Japanese cedar	<i>Cryptomeria japonica</i>	Increased concentration	Japan	69,70
Birch	<i>Betula</i>	Increased concentration	Northwestern Poland	71
		Earlier flowering	Switzerland	72
Grass		Increased concentration	Australia	73
Mugwort	<i>Artemisia</i> spp	Increased concentration	Central Croatia	74
Alder	<i>Alnus</i>	Increased concentration	Northwestern Spain	75
		Increased duration	Worcester, United Kingdom; Poznań, Poland	76
Cedar	Cupressaceae	Increased concentration	Southern Spain	77
Ragweed	<i>Ambrosia</i>	Increased duration	A transect that ran from Texas to Canada	78
		Increased duration	Central Croatia	79
		Increased concentration	Northeastern Croatia	80
		Increased concentration	France	81
		Increased concentration	Italy	82
		Increased concentration	Poland	83
		Increased concentration	Slovakia	84

group after both 1 month and 4 months. The temperature during the children's stay at Gran Canary was higher and most of the days were sunny, whereas in Norway the days were mostly rainy with a colder temperature. Their finding supports a previous study²⁷ of the effect that climate therapy has on AD that lasts for several months. In a Dead Sea climatotherapy study of AD,²⁸ patients with stays longer than 4 weeks caused a clearance greater than 95% in the patient's skin score based on the area of the skin involved and its degree of inflammation. ISAAC also investigated climatic conditions and the prevalence of atopic eczema in children²³ and noted that, among the European centers, the prevalence of eczema symptoms in both age groups decreased with one primary climate variable, mean annual outdoor temperature.

A cross-sectional study involving 28,394 schoolchildren ages 6 to 7 years assessing the possible climatic influence on the prevalence of atopic eczema in 3 different climatic regions in Spain²⁹ noted that different atopic eczema prevalences were found: Atlantic, 32.9%; Mediterranean, 28.3%; and Continental, 31.2% (per 100 children studied) ($P < .005$). The results demonstrated the negative correlation of atopic eczema with the mean annual temperatures and the mean annual number of sunny hours and the positive correlation with precipitation and humidity. One of the major symptoms of cutaneous atopic disorders (AD and urticaria) is pruritus, which has been studied in relationship to weather and climate variables.³⁰ In the Swiss high-mountain area of Davos, the intensity of pruritus experienced by patients was compared with 15 single meteorologic variables recorded daily during a 7-year observational period.³⁰ Air temperature was the most important meteorologic variable that was negatively correlated with pruritus (ie, increasing air temperature decreased pruritus severity).

Although these studies found a negative association with temperature and AD symptoms, one cross-sectional study found that hot weather was 1 of the 3 most common causes of AD exacerbations in 12- to 14-year-olds with AD in Wales.³¹ Sweating from exercise, fabrics (especially wool), and hot weather were the 3 most common exacerbating factors, affecting 41.8%, 40%, and 39% of AD responders, respectively.

Urticaria

Studies on urticaria and climate change are limited. An entity called solar urticaria, which involves the induction of urticaria with direct exposure of the skin to sunlight,³² has been described. Damage to the Earth's stratospheric ozone layer will lead to an increase of solar UV radiation reaching the Earth's surface, with a consequent adverse effect on human health, especially to the skin and possibly associated with an increase trend in solar urticaria.³³ As reflected in the study performed in Poland regarding the impact of *Artemisia* species,²⁴ 14.3% of the patients had chronic urticaria. The

authors concluded that the earlier starts and the longer duration of the pollen season, perhaps caused by climate change, may affect the development of urticaria. Similarly, another study in Europe (Norwich, United Kingdom, and Heraklio in Crete, Greece) examined the influence of climate and geographic parameters on trends of acute childhood urticaria cases and found an inverse correlation with temperature and emergency department (ED) visits.³⁴ In addition, barometric changes were reported to have an association with episodic attacks of hereditary angioedema.³⁵

Food allergy

It was recently proposed that a link might exist between global climate change and plant food allergens, such as peanut, and the increase in associated allergic diseases.³⁶ The self-reported peanut allergy prevalence has increased from 0.4% in 1997 to 0.8% in 2002 and then to 1.4% in 2008,³⁷ but whether this increase is related to climate change warrants further investigation. What is known is that changes occur that involve the molecular, biochemical, and physiologic generating alterations in biomass, carbohydrate, and protein content that can clearly have an effect on human health and potentially allergies. Increased carbon dioxide and temperatures have been noted with above-ground biomass increases and underground biomass decreases that have been demonstrated to also affect plant-based foods. The net effects of higher carbon dioxide and climate change have been slightly positive for rice and soybean,³⁸ whereas cassava (*Manihot esculenta*), the third largest staple food worldwide, has been shown to generate toxic hydrogen cyanide when damaged, and a recent study revealed that increasing concentrations of carbon dioxide are associated with a linear decrease in total plant biomass and tuber yield (number and mass), thus clearly affecting the distribution of future food supplies.³⁹ Free-air carbon dioxide enrichment experiments have demonstrated enhanced carbon metabolism and yields on the foliage component of soybeans.⁴⁰ In addition, gradual temperature changes have had a measurable decrease trend on wheat crop yield.^{38,41} How these trends will affect the prevalence of food allergy, in general, is yet unknown.

Asthma

The influence of climate change on respiratory allergy in individuals is unpredictable because there are various factors on both sides of the scale, although most clinical experts expect that the scale is tipped toward increasing allergic airway disease. As previously described, possible negative effects on reversible airway disease include earlier start, increase of length and intensity of pollen season, increase of pollutant levels, and increase of heavy precipitation events. Warmer winter temperature could reduce susceptibility of asthmatic adults to upper respiratory tract infections that

Table 3
Pollen allergens suspected to be associated with specific epidemics of thunderstorm asthma

Location	Type of study	Dates of thunderstorm	Suspected contributory allergen	Reference(s)
Melbourne, Australia	Case-control study	November 8, 1987, and November 29, 1989	Rye grass pollen	61
London, England	Retrospective study	June 24–25, 1994	Grass pollen	46,62
Southeastern Australia	Case-control study	48 Epidemic case-days during January 1995 to December 1998	Rye grass pollen	63
Southeastern Australia	Case-control study	October 30–31, 1997	Rye grass pollen	64
Puglia, Italy	Case series	May 27–28, 2010	Olive tree pollen	65

play a key role in exacerbations of asthma⁴² but in its place may increase exposure to allergenic pollen.

Climate and various anthropogenic pollutants are known to alter the oxidant-antioxidant balance, adding to the underlying allergic inflammation of the conjunctiva,⁴³ eustachian tube (otitis),¹⁰ and upper and lower airways.⁴⁴

Several studies have indicated positive associations between ED visits for asthma and various weather conditions, including temperature, rainfall, humidity, and barometric pressure.^{45,46} Lower minimum (cold) temperature or a decrease in temperature was associated with asthma prevalence and exacerbation in adults^{47,48} and ED visits in children.⁴⁵ However, other studies have found no association between ED visits for asthma and several weather conditions.^{49,50}

On the other hand, warmer mean temperatures have also been associated with increases in asthma prevalence.^{51–53} An increase in mean temperature of 1°C was associated with an increase in asthma prevalence of almost 1% in a New Zealand study.⁵¹ In a study involving young adults living in 13 areas from 2 different Italian climatic regions, the Mediterranean climate with higher mean annual temperatures compared with the subcontinental climate (16.2°C vs 12.9°C) was associated with the prevalence of asthma attacks and asthma-like symptoms.⁵² Another study in Italy also supported the relationship between higher annual mean temperatures and asthma-like symptoms.⁵³

ISAAC also investigated the association of climatic factors and asthma, demonstrating that the lowest monthly means of temperature were positively related to asthma symptoms in European children.²³ However, mean annual outdoor temperature was not associated with the prevalence of asthma symptoms.

Epidemiologic data regarding allergenic pollen and asthma exacerbation are not entirely consistent. Several studies examined atmospheric pollen content and its effect on respiratory allergic diseases.^{45,46,54–57} Ambient concentrations of grass pollen had an increasing effect on asthma hospital admissions up to a threshold of 30 grains/m³, and the effect remained stable thereafter.⁵⁴ High grass pollen days were days when most sensitive individuals would experience allergic symptoms.⁵⁸ Hospital admissions for asthma or dyspnea related to respiratory diseases were significantly positively correlated with the monthly airborne pollen concentrations of *Acer negundo*, *Platanus occidentalis*, *Populus hybrida*, and *Quercus robur*⁵⁵ but more commonly associated with asthma exacerbations and ED visits several days after persistent exposure to high levels of pollen.¹⁰ Other studies have found no significant correlation on the actual day of peak pollen counts most likely due to the progressively inflammatory responses requiring several days to reach clinical significance in the lower airways.⁴⁵ Warmer and more humid weather patterns in the spring have been associated with aggravation of exercise-induced asthma during the spring birch pollen season.⁵⁹

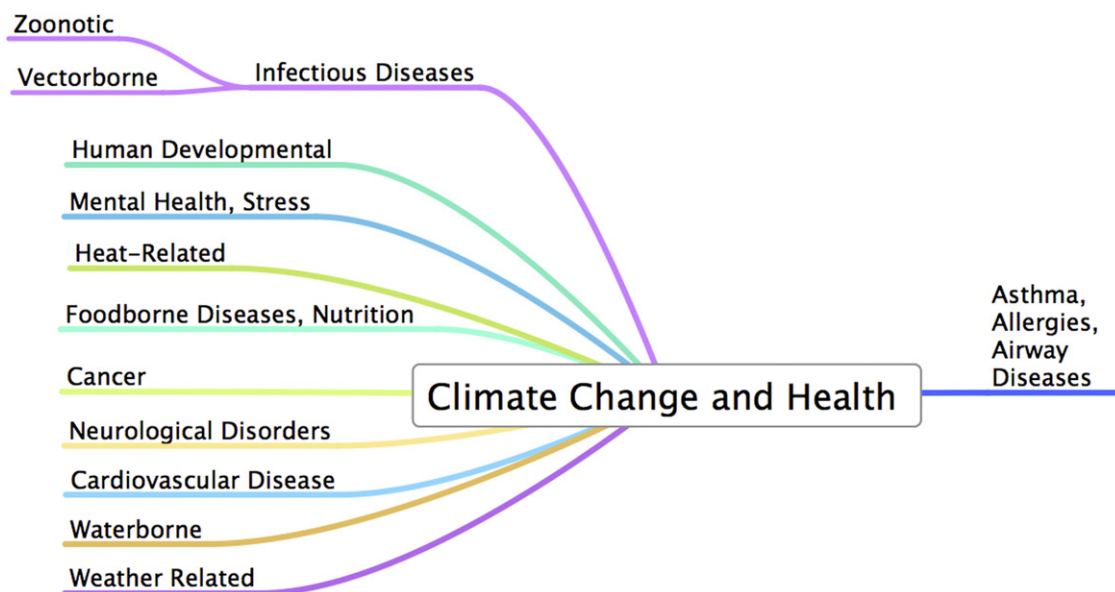


Fig 2. Impact of climate change on health in general. Major global environmental changes, including climate change, significantly affect human health³ in various ways, with potential effects on specific subpopulations, such as children, pregnant women, older adults, the poor, and people with chronic conditions due to heat stress, air pollution, extreme weather events, and waterborne, foodborne, and vectorborne illnesses.⁴ The same factors that affect allergenic plant growth, temperature, rainfall, and humidity are the same factors that strongly influence the ecology, development, and survival of arthropod vectors and hosts and the diseases they transmit,⁵ with temperature changes and plague in New Mexico,⁶ tickborne encephalitis in Central Europe,⁷ and West Nile virus in the United States.⁸ In cardiovascular disease, several studies have found a close association between increased temperature and mortality from ischemic heart disease⁹ and exposure to increased pollen counts.¹⁰

Thunderstorm asthma is a unique entity that occurs during the pollen season. The first reported asthma epidemic after a thunderstorm was in the United Kingdom in 1985,⁶⁰ and there have been other similar reports in different parts of the world (Table 3).^{46,61–65} A study in the Southeast United States observed an association between asthma ED visits and thunderstorm occurrence, with asthma visits 3% higher on days after thunderstorms.⁶⁶ There is evidence that during thunderstorms pollen grains may release allergenic particles by osmotic rupture and subsequently reach the lower airways and induce asthma exacerbations.⁶⁷

Insect allergy

Insect migration due to climate change has recently been noted. A retrospective review of 3 independent patient databases in Alaska compared temperature changes with increases in observed insect reactions in each region.⁶⁸ The study found a statistically significant trend in patients seeking care for insect reactions in each database, and the authors concluded that increases in annual and winter temperatures may be causally related to increases in insect reactions secondarily due to the expansion geographic distribution of insect habitats.

Conclusion

In summary, the evidence on how climate change will affect aeroallergens is limited because of the nature of the studies being focused on limited variables because they were not designed to encompass the broad subject of weather, aeroallergens, and complex gene-environment interaction in the individual predisposed to atopic disorders. Although unclear for food allergy, it appears that allergic rhinitis, allergic conjunctivitis (including other anterior inflammatory disorders, such as dry eye syndromes), AD, asthma, insect sting anaphylaxis, urticaria, and angioedema are associated with climate change in general. Overall, the evidence suggests that the projected trend will alter the lives of our atopic patients who are genetically predisposed to allergic diseases by increasing the prevalence, incidence, and severity of allergies and asthma (Fig 2). However, the effect of multiple variables occurring concomitantly will determine the *actual* climate change to a specific region. It is clearly recognized that asthma exacerbations and allergic disorders of mucosal surfaces are directly correlated with changes in exposure to pollen and mold concentrations, environmental pollutants, and temperature. Research should address the relationship between climate change and the composition of air pollutant mixtures (eg, how altered pollen counts and other effects of climate change affect the severity of allergies and asthma) to produce models to identify populations at risk. Such tools support the use of science in understanding disease risks and, as such, are an integral component of developing effective risk communication and targeting the messages to vulnerable populations while improving therapeutic interventions for these entities.

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