Climate Change and Emergency Medicine: Impacts and Opportunities

Jeremy J. Hess, MD, MPH, Katherine L. Heilpern, MD, Timothy E. Davis, MD, MPH, and Howard Frumkin, MD, DrPH

Abstract

There is scientific consensus that the climate is changing, that human activity plays a major role, and that the changes will continue through this century. Expert consensus holds that significant health effects are very likely. Public health and health care systems must understand these impacts to properly pursue preparedness and prevention activities. All of medicine will very likely be affected, and certain medical specialties are likely to be more significantly burdened based on their clinical activity, ease of public access, public health roles, and energy use profiles. These specialties have been called on to consider the likely impacts on their patients and practice and to prepare their practitioners. Emergency medicine (EM), with its focus on urgent and emergent ambulatory care, role as a safety-net provider, urban concentration, and broad-based clinical mission, will very likely experience a significant rise in demand for its services over and above current annual increases. Clinically, EM will see amplification of weather-related disease patterns and shifts in disease distribution. In EM's prehospital care and disaster response activities, both emergency medical services (EMS) activity and disaster medical assistance team (DMAT) deployment activities will likely increase. EM's public health roles, including disaster preparedness, emergency department (ED)-based surveillance, and safety-net care, are likely to face increasing demands, along with pressures to improve fuel efficiency and reduce greenhouse gas emissions. Finally, EM's roles in ED and hospital management, particularly related to building and purchasing, are likely to be impacted by efforts to reduce greenhouse gas emissions and enhance energy efficiency. Climate change thus presents multiple clinical and public health challenges to EM, but also creates numerous opportunities for research, education, and leadership on an emerging health issue of global scope.

ACADEMIC EMERGENCY MEDICINE 2009; 16:782–794

Keywords: emergency medicine, emergency services, hospital, emergency medical services, disaster planning, climate, weather, greenhouse effect, health policy

There is abundant evidence and clear consensus among climate scientists that human activity is changing the world's climate. Lay opinion in the United States has begun to reflect this concern. Projections for future climate change include a global average surface temperature rise of 1.8 to 4.0°C, sea level rise of 0.18 to 0.59 m, and significantly increased weather variability.[1] These changes will very likely have net negative health effects through a range of direct and indirect exposures, both globally and in the United States, and place greater demands on acute care, disaster response, and public health services.[2,3] These increased demands are likely to burden health care generally and emergency medicine (EM) in several areas specifically. EM's clinical care mission is very likely to be influenced as the populations at greatest risk disproportionately rely on emergency departments (EDs) for care, EM sees many weather-sensitive diseases, and shifting disease distribution will bring new presentations to the ED. EM's prehospital, disaster response, and public health missions will almost certainly be affected, as the specialty has a primary role in emergency medical services (EMS) management, and EM-trained physicians have substantial roles in developing and managing the nation's disaster response capabilities. As a hospital-based, energy-intensive specialty, EM is also likely to be significantly influenced by climate change mitigation efforts. Other specialties are likely to bear substantial burdens, and systemwide preparation is required, but EM will face

From the Department of Emergency Medicine, Emory University School of Medicine (JJH, KLH, TED), Atlanta, GA; the U.S. Public Health Service, HHS/Office of the Assistant Secretary for Preparedness and Response (TED), Washington, DC; the National Center for Environmental Health and Agency for Toxic Substances and Disease Registry, Centers for Disease Control and Prevention (HF), Atlanta, GA.

Received January 9, 2009; revision received February 16, 2009; accepted February 17, 2009.

Address for correspondence: Jeremy J. Hess, MD, MPH; e-mail: jhess@emory.edu.

A related commentary appears on page 774.

ISSN 1069-6563
PII ISSN 1069-6563583

doi: 10.1111/j.1553-2712.2009.00469.x

several specific challenges, and specialty-specific preparation is indicated. Despite these projections, there is no EM-specific literature on climate change preparedness and prevention. The objective of this article is to identify climate change impacts on EM and chart appropriate actions to address those impacts.

HEALTH EFFECTS OF CLIMATE CHANGE

Climate change health effects in the United States have been extensively reviewed elsewhere.[3–7] The purpose here is to provide a brief overview as a segue to a discussion of impacts on EM's core services.

Expected health effects include heat-related illness such as heat stroke;[3,8–10] exacerbations of climate-sensitive cardiovascular and pulmonary disease, including acute coronary syndrome, asthma, and chronic obstructive pulmonary disease (COPD);[8,11] injuries from severe hurricanes and other extreme weather events;[5,12] water- and food-borne diseases causing gastroenteritis; and increased incidence of vector-borne and zoonotic diseases such as Lyme disease, hantavirus pulmonary syndrome, and dengue hemorrhagic fever.[7,13–18] Anxiety and depression associated with population displacement,[19,20] and indirect health effects from interruptions of medical and psychiatric care, are also significant concerns.[7]

Health effects will vary by region and will disproportionately affect certain populations.[21,22] Vulnerable groups include infants, elders, the overweight and obese, patients with chronic cardiovascular and pulmonary disease, those taking certain antipsychotic medications, and socially and economically marginalized.[23] Places at particular risk include urban areas, the coastal and low-lying areas and islands, the desert southwest, vector-border regions, and the Arctic.[26,27] While health consequences in the United States may be less severe than those in the developing world, burdens are likely to be significant for prevalent concerns.[4,7] Moreover, multisystem failures in major events, on a par with those that occurred in the aftermath of hurricane Katrina,[28] could have devastating effects on public health and the economy.[29]

The World Health Organization (WHO), using conservative estimates, believes that climate change already causes over 150,000 deaths a year globally, based on models of a study of health effects of thermal extremes, weather disasters, diarrhea, malaria, and malnutrition.[30] These impacts are expected to accelerate.[4,7,30–33] Preparing for these health effects has become a top priority both domestically and globally; the Centers for Disease Control and Prevention (CDC) has identified climate change as a top domestic health priority,[34] and WHO marks climate change as a key global health concern as well.[35] Both agencies have called for health system preparedness.

EFFECTS ON EM'S CLINICAL MISSION

Emergency medicine provides urgent and emergent care for the acutely ill and injured and acts as the nation's health care safety net. Table 1 highlights important characteristics of the specialty, its role, and its current patient base.[36–53] Climate change is important to EM clinically for several reasons, each of which is briefly elaborated on below.

1. Climate Change is Highly Likely to Increase the Incidence of Many Conditions Seen in the ED A host of diseases commonly seen in the ED exhibit climate sensitivity. Not all are equally sensitive, as detailed in Table 2.[3,5,10,17,54–63] Some, such as viral respiratory infections, are likely to be less prevalent as a result of climate change, but the net impacts are expected to be

Table 1
Characteristics of EM Relative to the U.S. Health Care System as a Whole

Descriptive Domain	Specifics for EM
Size and patient base	EM physicians constitute 5% of the U.S. physician workforce. There are an estimated 41,000 EM physicians in the United States (32,000 in 1999′ with 9,000 additional board certifications since[37]), compared with 720,000 physicians overall.[38]
Penetration	In 2005, there were a total of 115.3 million visits to hospital-based EDs,[39] and one-fifth of the U.S. population visited an ED.[40]
Growth	Annual ED visits increased 20% from 1995 to 2005, while the number of EDs declined from 4,176 to 3,795, resulting in an average census increase per ED from 23,119 to 30,388.[40]
Scope of practice	EM is responsible for all urgent and emergent conditions. In 2005, 35% of ED visits were for injuries, and 85% of visits were for acute concerns.[40] EM provides substantial mental health care: one-quarter of all patient transfers from EDs in 2005 were for psychiatric, mental health, or substance abuse care.[40]
Urgency of complaints	By triage category, over 85% of visits triaged at least semiurgent, requiring care within 1–2 hours, with 15% requiring immediate or emergent care.[40] 12% of ED patients were admitted to the hospital in 2005; of these, 16% went to an ICU.[40]
Populations seen and prevalence of care for underserved	EM is primarily urban: 85.5% of ED encounters occur in metropolitan statistical areas (MSAs).[40] Those at extremes of age (infants, nursing home residents) use EDs at significantly higher rates than the general population, as do African Americans.[40] Homeless people visited at nearly twice the national rate of other ambulatory care sites.[40]
Public health roles	Increasingly, EDs perform sentinel, syndromic, and other frontline, surveillance activities for outbreak detection.[41–48] EDs perform triage and serve as incident command posts and evaluation sites in disasters. EM providers are disproportionately represented among medical directors of EMS and in the National Disaster Medical System (NDMS).[49–53] EM professional organizations influence national health policy.

Table 2
Prevalent Climate Sensitive Diseases and Impacted Medical Specialties

Disease	Epidemiology	Primary Specialties	Climate Sensitivity	Climate Change Effect(s)	Confidence in Estimates*
• Heat illness • Heat-sensitive chronic conditions	• 240 hyperthermia deaths annually[54] • Increased excess mortality from approximately 7%–60% during heat waves • Increased ED admissions for respiratory and renal disease[10]	• EM • Pediatrics	Very high	• Increased heat wave frequency and severity • Increased incidence of heat-related illness • Persistent effect modification of morbidity and mortality from heat-sensitive chronic diseases	Very high[3]
• Weather-related injuries • Intentional injury associated with violent crime	• 29.6 million nonfatal injuries requiring ED care, including 1,314,000 intentional injuries; 161,000 fatal injuries in 2002[55] • 649 weather-related deaths per year 10-year average 1997–2006 and 3,849 direct weather-related injuries in 2006[56]	• EM • Family practice • Pediatrics	High for injuries related to extreme weather events and for intentional violence associated with violent crime[57]	• Increasingly frequent and severe weather, increased incidence of weather-related injuries • Increased heat wave frequency, severity and increased prevalence intentional violence	High[5]
Respiratory disease: • Asthma • COPD	• Average annual asthma prevalence 20 million (including 6.2 million children) 2001–2003 • Annual asthma attack rate approximately 55% in patients with active disease • 1.8 million asthma ED visits (including 0.7 million pediatric) • Annual average 4,210 asthma deaths[58] • COPD prevalence 10 million in 2000 • Annual average 1.5 million ED COPD visits • Annual average 119,000 deaths[59]	• EM • Family practice • Pediatrics • Internal medicine • Geriatrics • Pulmonary	• Asthma: high • COPD: moderate	• Increased aeroallergen production and higher ground-level ozone production • Increasing incidence of COPD and asthma exacerbations	High
Gastroenteritis	• Highly underreported • Estimated annual incidence 210 million cases • Estimated 900,000 hospitalizations annually • Estimated 6,000 annual deaths[60]	• EM • Family practice • Pediatrics • Internal Medicine	• Depends on pathogen • High for bacteria • Moderate for parasites • Relatively low for viruses[61]	• Increased incidence of water- and food-borne bacterial and parasitic gastrointestinal infection • Possible decrease viral infection incidence	Moderate[61]
Urolithiasis	• Lifetime prevalence of 12% in men • Lifetime prevalence 7% in women • Approximately 1% of ED visits • Total 1,140,000 ED visits in 2000[62]	• EM • Urology • Family practice • Internal medicine	Moderate	• Increased ambient temperature associated with dehydration and decreased urine volume • Higher stone incidence in populations not previously at risk	Moderate
Vector-borne and zoonotic disease	• Widely variable depending on disease • Lyme disease average annual prevalence 21,460 from 2003–2005[63]	• EM • Family practice • Pediatrics • Internal medicine • Infectious disease	• Depends on pathogen • Moderately high for vectors of: —Lyme disease —West Nile virus Western Equine encephalitis —Eastern Equine encephalitis —Bluetongue virus[61]	• Increased ambient temperatures and northward ecosystem migration associated with northward range expansion for *I. scapularis*[16]	Moderate[61]

*Confidence derived, where possible, from expert consensus as published in the literature, particularly the EPA's recent update of the health effects of climate change in the United States. Where expert consensus was not known, confidence was determined by the strength of the climate-health association as noted in the literature and by the number of studies predicting congruent effects.
COPD = chronic obstructive pulmonary disease; EPA = Environmental Protection Agency.

adverse,[61] and demand for EM's clinical services will likely rise as a result. Several examples are detailed below:

From 2001 to 2004, EDs provided 61.4% of acute care for dyspnea in the United States (personal communication, S. Pitts, National Center for Health Statistics, 2009). Higher temperatures are correlated with several common causes of dyspnea, including asthma, COPD, and allergic rhinitis. Of the three, asthma shows the clearest associations. Beggs and Bambrick[64] hypothesized that the global asthma epidemic is an early manifestation of climate change. Asthma is more prevalent in warm climates,[65,66] and asthma exacerbations show seasonality.[67] There is an association between asthma exacerbations and rainstorms,[68–71] which will increase in frequency in the northern half of the United States from climate change. There is also an association between asthma mortality and aeroallergen exposure.[72–74] Higher temperatures will result in greater ozone burdens (see Figure 1),[75] increasing the incidence of both asthma[76] and asthma exacerbations[77] and COPD hospitalizations.[78]

Aeroallergens, including pollen, trigger asthma and allergic rhinitis, both commonly seen in the ED. Higher pollen counts are another manifestation of climate change as a result of increased ground-level CO_2, higher plant metabolism, and longer growing seasons.[11,79,80] In a corollary concern, cases of contact dermatitis from poison ivy are likely to increase in incidence with climate change.[81] Wildfires, increasingly prevalent secondary to climate-related changes in the hydrologic cycle,[82] are associated with respiratory irritation and greater health system demand,[83] including a significantly higher rate of ED visits for respiratory symptoms, undifferentiated dyspnea, and asthma.[84]

Kidney stone incidence is also correlated with ambient temperatures. Kidney stone disease has an especially high prevalence in the Southeastern United States,[85] and urolithiasis is a common ED complaint.[62] The etiology of acute renal colic is multifactorial, but warm climate and dehydration leading to low urine volume are risk factors, and the incidence is geographically variable. Mean annual temperature has been estimated to account for 70% of the geographic variability in urolithiasis incidence.[86,87] A recent analysis concluded that there will be a climate-related increase of 1.6–2.2 million lifetime cases of nephrolithiasis by 2050, with a 25% rise in health system costs associated with this diagnosis.[88]

2. The Patients Who Rely Disproportionately on the ED Are Also Particularly Vulnerable to Climate Change Table 2 details the specialties that care for several prevalent climate-sensitive diseases in the United States. As noted in Table 1, EM provides disproportionate care for a number of marginalized groups, many of whom are also vulnerable to climate change health effects. The ED is also accessed disproportionately by individuals at the extremes of age, groups that are particularly vulnerable to climate change. Patients with mental health concerns, particularly exacerbations of psychiatric disease, are commonly seen in the ED and have multifactorial vulnerability to the hazardous exposures associated with climate change, not only from their diminished capacity but also as a result of increased psychotropic medication use, several classes

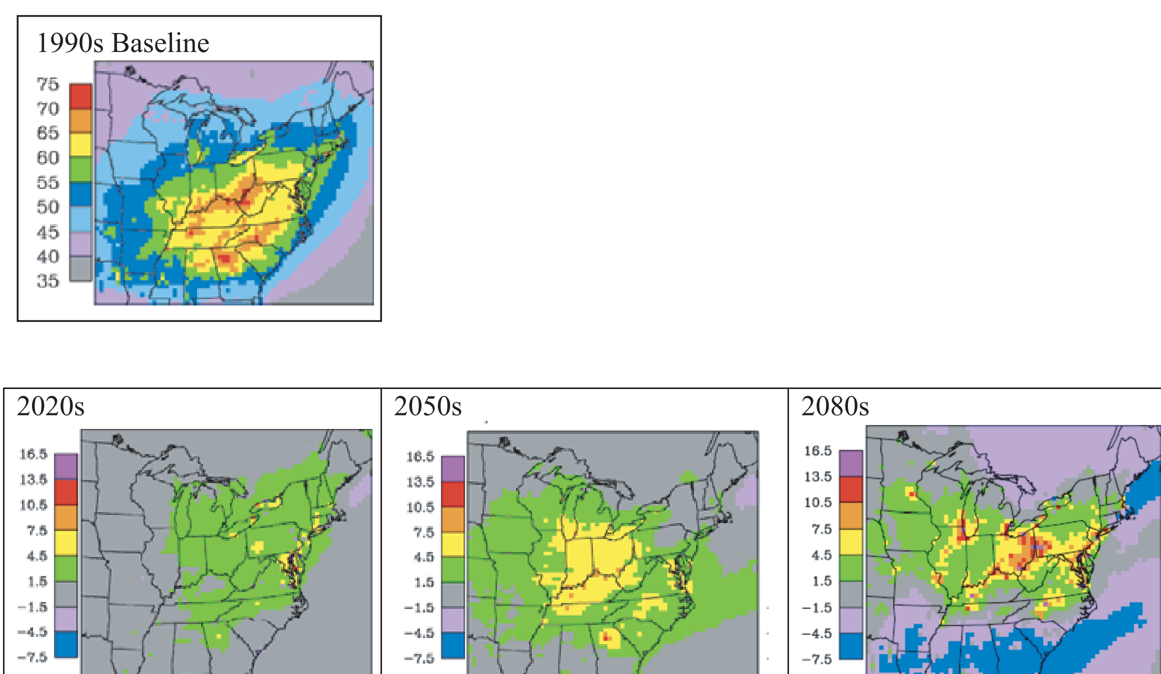

Figure 1. Ozone burdens. The first image depicts baseline summertime average daily ozone burdens from the 1990s, in which orange and red areas are at or over the upper exposure limit of 75 ppb (parts per billion) over 8 hours. The second three images are projected percentage changes for the 2020s, 2050s, and 2080s, based on the A2 CO_2 scenario (regionally oriented development at a moderate overall pace globally and continued population growth) relative to the 1990s. Changes are in relation to a baseline from the 1990s. Five consecutive summer seasons were simulated in each decade.[76]

of which predispose patients to heat-related illness and death via sweating impairment.[89]

3. Climate Change Is Almost Certain to Alter the Severity of Several Environmental Exposures Such as Heat and Ground-level Ozone, Increasing the Proportion of Disease Exacerbations Climate change will change the distributions of hazardous environmental exposures, with shifts in the measure of central tendency and variance. For example, the theoretical distribution of extreme heat events with climate change is detailed in Figure 2. For ozone, the shift in central tendency is most dramatic, as detailed in Figure 3[90] (which refers to Germany but similar patterns are expected in the United States[91]). For extreme precipitation, primarily variance will shift. Regardless of specifics, for each hazardous exposure more extremes are likely to result, increasing prevalence and severity of disease exacerbations. EM disproportionately cares for patients with severe disease and thus will very likely experience a higher demand for its services. Heat, precipitation, and storms serve as examples.

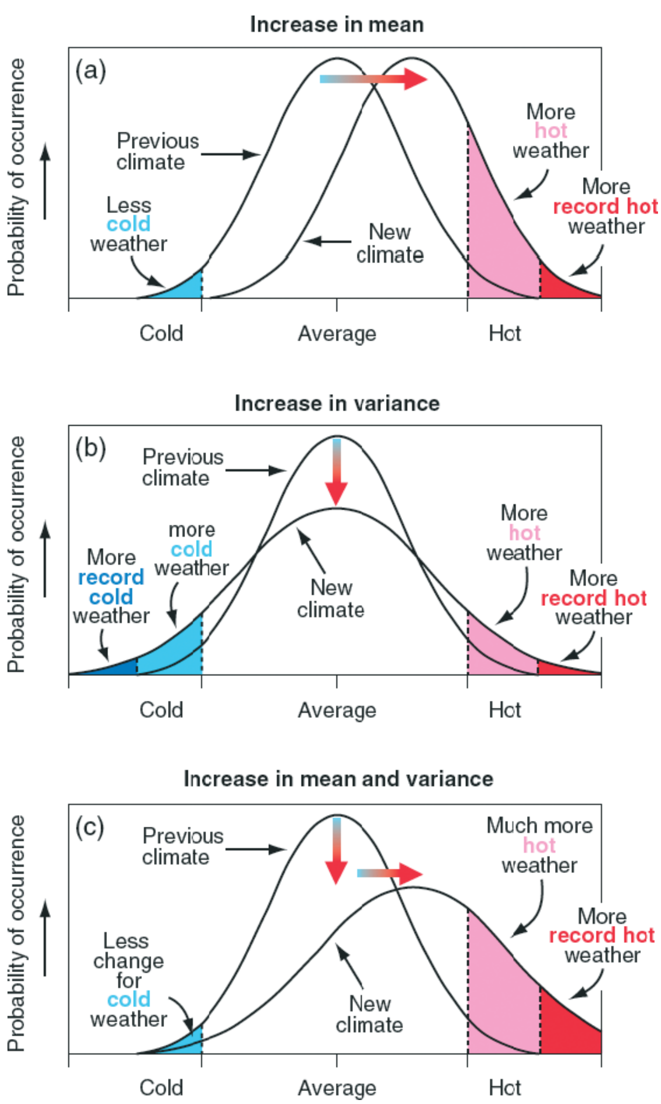

Figure 2. Theoretical shift in the distribution of extreme heat events with climate change. IPCC. Climate Change 2001: Synthesis Report. A Contribution of Working Groups I, II and III to the Third Assessment Report of the Intergovernmental Panel on Climate Change. Figure 4-1. Cambridge University Press.[33]

Heat waves are associated with increased ED visits over baseline,[92] and hospital admissions rise by roughly one-third during heat waves, primarily for the diagnoses of heat stroke, heat exhaustion, dehydration, acute renal failure, and degenerative neurologic conditions.[92,93] All-cause deaths also increase,[10] primarily among elders, the poor, and marginalized urban dwellers, typically from cardiovascular and cerebrovascular disease.[94–97] Death from cocaine overdose is more likely on hot days as well,[98] and ambient temperature and heat waves are strongly correlated with increases in violent crime and associated injuries.[57] Higher temperature and associated rises in ozone concentrations are also associated with increased ED visits for chest pain and other cardiovascular syndromes.[99]

Extreme precipitation is primarily associated with injury morbidity and mortality[100] and gastroenteritis outbreaks.[101,102] The mechanism(s) responsible for the observed findings are not known and require verification with additional study. Nevertheless, projections suggest that more frequent extreme weather events will increase outbreak incidence.[103] Higher ambient temperatures are likely to amplify this effect.[61] Outbreaks of gastrointestinal disease are associated with significantly increased demand for ED services.[104]

Severe storms are associated with injuries and often cause population displacement. Hurricane Katrina exemplifies typical health outcomes. Katrina made landfall in Mississippi on August 29, 2005, and by September 5, 2005, a total of 229,338 Gulf Coast residents had been displaced into Louisiana and several surrounding states[105]; ultimately the diaspora included more than 1 million evacuees.[106] The storm reduced New Orleans hospital capacity by 80%.[107] Morbidity and mortality followed patterns similar to those of other disasters.[108] Mortality, at 1,836 deaths,[109,110] was dwarfed by morbidity: there were 14,531 visits for health problems in evacuation centers in September 2005, mostly for chronic disease exacerbations, and 9,772 visits to health care facilities, most commonly for injuries.[105] In areas that received large numbers of evacuees, EDs did experience significantly increased service demands,[111,112] although off-site activities helped blunt the expected surge in hard-hit sites such as Houston.[113] Of note, emergency physicians (EPs) were the last to leave New Orleans during Katrina. Overall, EPs were pivotal in the response, from on-site triage and care, care during transport, triage and stabilization on the receiving end, and ongoing care for displaced populations in their new environs.[105,114,115]

4. Novel Diseases Frequently Present to the ED, and Climate Change Is Likely to Introduce Unfamiliar Vector-borne and Zoonotic Diseases Into New Geographic Areas Disease distribution is likely to shift as ecosystems migrate or are disrupted and as environmental exposures change. Certain infectious diseases that were rare or unknown may be introduced, while others that have been largely eliminated from the

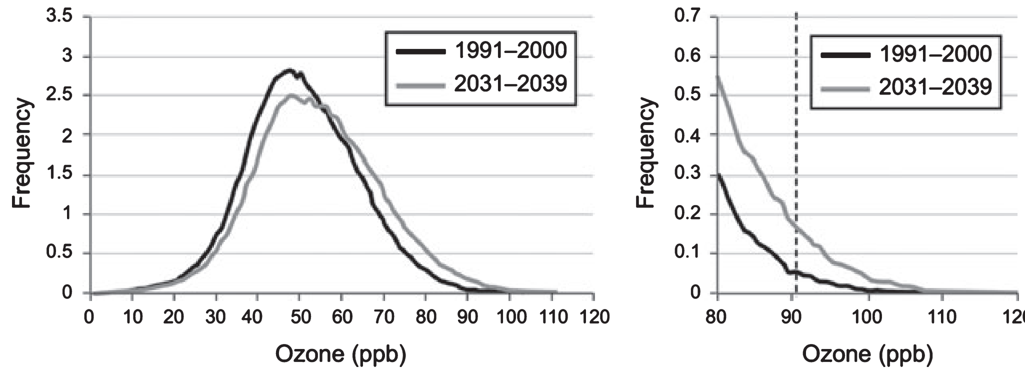

Figure 3. Projected ozone concentrations 2031–2039 relative to 1991–2000 for Germany.[90]

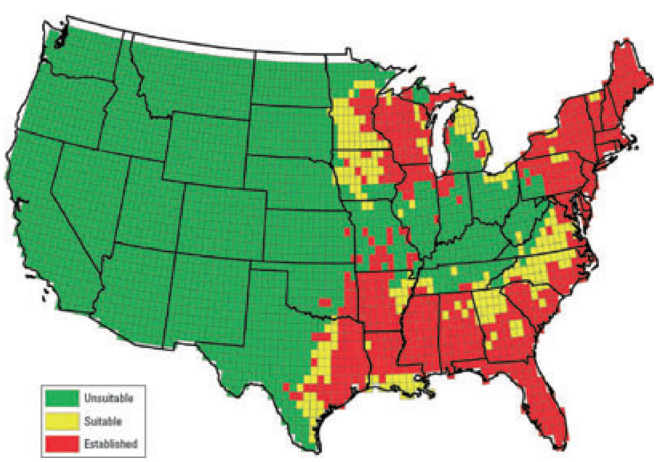

Figure 4. Range of suitable conditions for *Ixodes scapularis*, the Lyme disease vector. As the climate warms and there is increased precipitation in the northern latitudes, *I. scapularis*'s range is expected to expand northward. Yellow areas indicated projected suitable habitats.[95]

United States may return. These include but are not limited to Lyme disease, hantavirus pulmonary syndrome, plague, dengue, West Nile disease, Rocky Mountain spotted fever, and malaria.[13] Lyme disease migration illustrates the potential range expansion: as the climate warms, habitats suitable to *Ixodes scapularis* expand northward,[116] as illustrated in Figure 4. Ecosystem disruption, such as persistent droughts in the desert Southwest, may lead to increased burden of diseases such as Valley Fever, transmitted when *Coccidioides* spores are aerosolized in dust storms;[117] hantavirus outbreaks in the Four Corners region may become more frequent as precipitation patterns change, increasing food availability for the mice that transmit *Sin Nombre* virus.[118] Expansion of dengue in Central America has been observed, and there is concern it will extend into the Southeast as it is endemic on the United States-Mexico border[119,120] and shows significant climate sensitivity.[121]

Effective preventive measures are available for many climate-sensitive infectious diseases, but if these measures falter there is a high potential for significant outbreaks. Changes in disease distribution are likely to be gradual, and surveillance activities should detect changing patterns of disease distribution so ED personnel will be aware of emerging threats. However, the initial hantavirus outbreak caught the medical system largely unaware,[122] and the West Nile surveillance was initially hampered by lack of capacity,[123] although effective public health responses were initiated in both cases.

In conclusion, there are a host of potential effects on EM's clinical mission. EM's other core activities, including its prehospital and disaster response, public health activities, and hospital and EMS management activities, are likely to be affected as well. These are detailed below.

EFFECTS ON EM'S PREHOSPITAL MISSION: EMS AND DISASTER RESPONSE

At the local level, climate change is likely to bring increased EMS demands, while regionally and nationally it will likely heighten the need for disaster response and Disaster Medical Assistance Team (DMAT) deployments. Heat waves and other extreme weather conditions are associated with higher levels of EMS activity,[124] and multisystem failures such as power outages during heat waves dramatically increase EMS demand[125] and, potentially, the need for a regional disaster response. Disasters engage EM providers on a regional and national level, particularly those in the National Disaster Medical System (NDMS), through DMAT deployments, and in triage and care for evacuated patients. EM providers are heavily represented among medical directors of EMS agencies and in NDMS,[49–51] and EDs perform triage and serve as incident command posts and evaluation sites in disasters. In recent years, DMATs have been called on to respond to a growing number of water-related disasters, consistent with the climate change trend of more frequent severe precipitation events.[126] The NDMS's role was apparent in the response to Hurricane Katrina, as was the role of EM in general, as noted above.

EFFECTS ON EM'S PUBLIC HEALTH MISSION: LEADERSHIP, POLICY, ADVOCACY, AND SURVEILLANCE

Emergency medicine has a significant public health role including leadership, administration, policy formation, and advocacy.[127,128] Many leaders at the CDC and other agencies that coordinate disaster response are EM trained, and although the entire specialty is called upon to serve in times of disasters and severe resource constraints, these leaders help bridge the gap between clinical and public health concerns.

EM clinicians also play a role in public health activities in EDs, including surveillance and outreach. Increasingly, EDs perform sentinel, syndromic, and other front-line surveillance activities for outbreak detection.[41–44] ED surveillance will be increasingly common and important, as illustrated by a recent study of ED visits and wildfires in southern California.[84] There is also significant opportunity to couple early warning systems based on modeling and remotely sensed data, such as those administered by the National Weather Service, with community-based interventions to preempt disease outbreaks in susceptible populations and with ED surveillance. For heat-related concerns, vulnerability maps are becoming increasingly sophisticated, allowing vulnerable populations to be targeted with great specificity for home visiting programs, transport to cooling centers, and other strategies for preventing heat-related illness.

EFFECTS ON ED, HOSPITAL, AND SYSTEM MANAGEMENT

Mitigation activities will include all sectors of the economy. Efforts to reduce greenhouse gas emissions from the health care sector are likely to significantly affect EM, among other medical specialties. Health care, a large component of the economy, employs one in eight Americans directly or indirectly and accounts for approximately 16% of the Gross Domestic Product.[129] Hospitals and other health care–associated buildings rank second to food services in intensity of energy use[130] and account for more than $8.3 billion in annual energy expenditures.[131] Approximately half of hospital energy use is for shared systems such as heating and cooling, but energy-intense, continuously operating areas such as the ED, intensive care units, and operating suites require a disproportionate share of the remainder (personal communication, T. Leonidas, Seattle, WA, 2008). EM is thus one of many hospital-based specialties that will be affected by the larger climate change response, although all of health care will have to contend with sustainability issues and energy constraints.[132–134]

In addition to hospital-based energy use, EM also generates emissions through EMS, which provided 19 million patient transports in 2005. Emergency care consumes substantial amounts of fuel and is a significant source of transport-related greenhouse gas emissions from the health care sector.[40] There is great heterogeneity in the organization of EMS services nationally, with significant redundancy in some systems from overlap between EMS and fire and division of response and transport functions. Some systems rely more heavily on air transport, which is more fuel-intensive. Deployment strategies also vary widely: some EMS systems are dynamically deployed, increasing the need to idle in the field in exchange for reduced response times. Understandably, EMS systems have been organized around minimizing response time rather than limiting emissions, and there is little research regarding the impact of various parameters such as vehicle size and type, fuel mixture, deployment strategy, dispatch management, and related issues on EMS operations and emissions. Preliminary research suggests that some EMS systems have substantial carbon footprints, however, and that transport is the largest, but not the only, source of their emissions.[135] Dependence on petroleum for transport has also been identified as an important preparedness concern.[134] Strategies to reduce emissions and petroleum dependence are likely to garner increasing attention going forward.

HEALTH SYSTEM PREVENTION AND PREPAREDNESS

Minimizing dangerous climate change and preparing for its effects are significant challenges that require systemwide enhancements in both public health and health care.[29,136,137] Both prevention and preparedness activities are key. Prevention through reduction in greenhouse gas emissions can limit further climate change and is an imperative for all sectors of the economy, including health care, energy, and transport.[33,138] A number of other prevention activities have been discussed in the literature.[29]

Preparedness is equally important, as prior emissions have resulted in a climate change commitment.[139] Important preparedness measures include anticipation of increased clinical service and disaster response needs, scenario-based planning to prepare for multisystem failures, enhancing capacity for surveillance, predictive modeling, vulnerability mapping, early-warning systems, and improving health communication strategies.[136,137,140]

A dialogue on health system preparedness has started in earnest.[141–145] A recent review called for a robust national initiative, including emergency preparedness and provider training in affected medical specialties.[138] The primary care specialties of family practice, internal medicine, pediatrics, and geriatrics are all likely to be impacted.[145] Psychiatry, infectious disease, urology, pulmonology, and critical care are also likely to experience rising clinical demands.[146] Some of these specialties have begun preparation; the American Academy of Pediatrics recently acknowledged the import for its specialty in a policy statement.[147] There is no EM-specific literature on preparedness or prevention in relation to climate change.

EM'S ABILITY TO MEET PREPAREDNESS AND PREVENTION NEEDS

In many respects, EM is well equipped to meet the challenges posed by climate change. The all-hazards approach adapts well to the health threats climate change will bring, and EM enjoys a strong public health orientation. EM is a large specialty with national penetration, strong professional organizations, and established continuing medical education (CME) offerings to an engaged membership. Clinically, EPs are adept at offering timely interventions and risk communication. From a public health perspective, there are abundant opportunities for surveillance activities in the ED.

It is important, however, to acknowledge the specialty's vulnerabilities. More than any other specialty, EM is fundamentally dependent on hospital support systems and interactions with other medical specialties. This makes EM vulnerable during system failures, as evidenced by ED crowding, ambulance diversion, and prehospital care fragmentation as detailed in the Institute of Medicine report of 2006.[148] EM is hobbled by its unfunded mandate to sustain a health care safety net despite falling levels of health insurance coverage, and clinically, EM is a reactive specialty, although it exhibits significant proactive elements in its public health leadership. Finally, as a hospital-based, 24-hour, 7-day-a-week operation with a mobile component in EMS, EM is very energy dependent. With strains on the global petroleum supply,[134] and looming controls on carbon emissions, energy use is likely to become an increasingly significant cost center and ultimately a threat to EM preparedness.

Cost is a significant concern regarding both prevention and preparedness, for EM and other specialties anticipating increased service demands. While some prevention activities such as improved energy efficiency may bring substantial savings that can be applied to capital improvements, some preparedness activities may require new funding streams. Potential funding sources for specific response activities are noted in the discussion below.

PRIORITIES FOR THE EM RESPONSE TO CLIMATE CHANGE

In their discussion of general health system preparedness, Jackson and Shields[138] present several relevant recommendations, including CME, patient education, advocacy within the health community and with elected officials, and modeling of carbon literate behavior. They also recommend that hospitals undertake energy audits, pursue energy and water conservation and energy efficient construction, and plan for locally relevant disasters. While some EM providers and EDs may be pursuing components of this agenda, there is no national organized support for such activities in EM's professional organizations. No organization or specialty has initiated high-level interdisciplinary coordination of preparedness activities.

There are several other priorities for EM that reflect its unique role:

1. *Provide Health System Leadership*. Leadership will necessarily be interdisciplinary, but individual specialties can play a convening role, and as yet no specialty has taken the lead in coordinating the health system response. National EM organizations can provide leadership by authoring a position statement on EM and climate change, sponsoring relevant continuing education, and supporting members in developing carbon literacy.

2. *Green EMS*. EMS is fundamentally petroleum dependent and has significant emissions from electricity use and indoor climate control. Little is known about overall emissions from EMS or about preparedness threats from petroleum dependence; assessment of EMS's energy profile is a key first step. After assessing petroleum dependence, EM could develop and pursue a program to reduce EMS petroleum dependence and greenhouse gas emissions, reviewing a host of factors including vehicle types, deployment strategies, proportion of air transport, on-board technologies, and dispatch management. Funding for these activities could come from various quarters, including savings on operations from improved fuel economy; research funding from the Environmental Protection Agency (EPA), CDC, National Institutes of Health (NIH), and other federal sources; automakers; and foundation support.

3. *Green the ED*. A deeper understanding of EM's energy use, alternatives, and contingency plans will facilitate preparedness for events in which energy is scarce and demand for ED services are high, such as during an electricity blackout precipitated by a summer heat wave. As innovations are often pioneered in the ED before systemwide deployment, greening the ED could serve as a high-profile initiative to test a range of innovations and focus attention on green building overall. Many innovations are likely to pay for themselves over time: energy audits often identify significant energy efficiency opportunities in existing structures, and green new building routinely achieves significant cost savings in the long run. Federal and state tax credits are often available for increasing energy efficiency and green building initiatives.

4. *Model Carbon Literacy*. Approximately half of the world's greenhouse gases are emitted by 10% of the world's inhabitants.[149] Worldwide, physicians are major consumers of energy for professional and personal uses and are well-situated to affect public attitude. As an energy-intensive specialty, EM can model energy-efficient choices in management and purchasing decisions, in advocating for green building when facilities are built or upgraded, in its national and regional meetings, and in its research activities. Such choices offer the benefit of reduced energy costs in addition to decreased emissions.

5. *Engage Scenario-based Preparedness Planning*. Multisystem failures can have significant health consequences. Using scenarios, researchers should identify areas in which redundant systems are necessary to preserve operations in the case of blackouts during heat waves, water treatment failure during floods, fuel scarcity after storms, and other disasters more likely with climate change. In particular, EM should consider implications for ED crowding, EMS use, disaster response, and overall system demands. Funding for such research is available from federal agencies such as the CDC and foundations.

6. *Promote Local Climate Change Preparedness*. Effective climate change responses are often organized at the local level and include identification of relevant exposures, vulnerable populations, and intervention needs. EM providers are in a unique position to promote local preparedness given their community standing, professional authority as medical providers, and knowledge of local response systems. Partnering with

local emergency managers and health departments to develop and evaluate locally relevant scenarios would allow for leverage of scarce preparedness funds.

7. Leverage Concern Over Climate Change to Promote Safety-net Care. Climate change preparedness offers the possibility of *co-benefits* for the health system: predictive modeling and early warning systems can reduce health care demand and costs, surge capacity can reduce ED crowding, and energy efficiency can reduce costs and enhance preparedness. There is precedent for leveraging ancillary issues to effect policy changes related to ED crowding and ambulance diversion[150,151] and for removing toxins from the health care environment.[152] As public concern over climate change and its health effects increases, highlighting co-benefits of climate change prevention and preparedness may become an effective fulcrum for EM's other policy interests, particularly if health reform focuses attention on activities to promote population health.

8. Support Surveillance of and Research on Climate-sensitive Conditions. The ED is one of several places where surveillance for climate sensitive conditions should be deployed. To guide surveillance, much research is needed into several climate-sensitive clinical outcomes, particularly the extremes that present to the ED. Key priorities include specific dose–response relationships in climate-sensitive conditions, research into predictive health and early warning systems, the changing distribution of infectious diseases, health communication around climate change, and efficient fuel and energy use. Interdisciplinary research should be a priority. As with other activities, there are several potential federal funding sources, including EPA, CDC, NIH, and the National Oceanographic and Atmospheric Association (NOAA). Several prominent foundations have also identified climate change as an important priority for future programming.

CONCLUSIONS

The health system must prepare for the health effects of climate change. EM is one of several specialties that will be significantly affected. Climate change will generally enhance system stressors, resulting in both greater baseline system strain and periods of severe stress that may overwhelm an already burdened system. In the United States, the most concerning scenarios are those that include multiple system failures: blackouts during prolonged heat waves, levee failure during a severe storm, delayed evacuations of vulnerable populations, and interruptions in fuel supply during mass population movements. As recent history has shown, such systems failures can have dramatic consequences for our specialty. EM must anticipate and prepare for these eventualities to the extent possible so we can handle them effectively, with alacrity and grace.

References

1. Solomon S, Qin D, Manning M, et al. (eds). Climate Change 2007: The Physical Science Basis. Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change. Cambridge, UK: Cambridge University Press, 2007.
2. Haines A, Kovats RS, Campbell-Lendrum D, Corvalan CO. Climate change and human health: impacts, vulnerability and public health. Public Health. 2006; 120:585–96.
3. McGeehin MA, Mirabelli M. The potential impacts of climate variability and change on temperature-related morbidity and mortality in the United States. Environ Health Perspect. 2001; 109 Suppl 2:185–9.
4. Patz JA, McGeehin MA, Bernard SM, et al. The potential health impacts of climate variability and change for the United States: executive summary of the report of the health sector of the U.S. National Assessment. Environ Health Perspect. 2000; 108:367–76.
5. Greenough G, McGeehin M, Bernard SM, Trtanj J, Riad J, Engelberg D. The potential impacts of climate variability and change on health impacts of extreme weather events in the United States. Environ Health Perspect. 2001; 109 Suppl 2:191–8.
6. Rose JB, Epstein PR, Lipp EK, Sherman BH, Bernard SM, Patz JA. Climate variability and change in the United States: potential impacts on water- and foodborne diseases caused by microbiologic agents. Environ Health Perspect. 2001; 109 Suppl 2:211–21.
7. Ebi KL, Mills DM, Smith JB, Grambsch A. Climate change and human health impacts in the United States: an update on the results of the U.S. national assessment. Environ Health Perspect. 2006; 114:1318–24.
8. Kalkstein LS, Greene JS. An evaluation of climate/mortality relationships in large U.S. cities and the possible impacts of a climate change. Environ Health Perspect. 1997; 105:84–93.
9. Poumadere M, Mays C, Le Mer S, Blong R. The 2003 heat wave in France: dangerous climate change here and now. Risk Anal. 2005; 25:1483–94.
10. Kovats RS, Hajat S. Heat stress and public health: a critical review. Annu Rev Public Health. 2008; 29:41–55.
11. Beggs PJ. Impacts of climate change on aeroallergens: past and future. Clin Exp Allergy. 2004; 34:1507–13.
12. Mitchell JF, Lowe J, Wood RA, Vellinga M. Extreme events due to human-induced climate change. Philos Transact A Math Phys Eng Sci. 2006; 364: 2117–33.
13. Gage KL, Burkot TR, Eisen RJ, Hayes E. Climate and vector borne diseases. Am J Prev Med. 2008; 45:1160–4.
14. Epstein PR. Climate change and emerging infectious diseases. Microbes Infect. 2001; 3:747–54.
15. Hunter PR. Climate change and waterborne and vector-borne disease. J Appl Microbiol. 2003; 94 Suppl:37S–46S.
16. Ogden NH, Maarouf A, Barker IK, et al. Climate change and the potential for range expansion of the Lyme disease vector Ixodes scapularis in Canada. Int J Parasitol. 2006; 36:63–70.

17. Patz JA, Olson SH. Malaria risk and temperature: influences from global climate change and local land use practices. Proc Natl Acad Sci U S A. 2006; 103:5635–6.
18. Hurtado-Diaz M, Riojas-Rodriguez H, Rothenberg SJ, Gomez-Dantes H, Cifuentes E. Short communication: impact of climate variability on the incidence of dengue in Mexico. Trop Med Int Health. 2007; 12:1327–37.
19. Sondorp E, Patel P. Climate change, conflict and health. Trans R Soc Trop Med Hyg. 2003; 97: 139–40.
20. Morrissey SA, Reser JP. Natural disasters, climate change and mental health considerations for rural Australia. Aust J Rural Health. 2007; 15:120–5.
21. Patz JA, Kovats RS. Hotspots in climate change and human health. Br Med J. 2002; 325:1094–8.
22. Patz JA, Campbell-Lendrum D, Holloway T, Foley JA. Impact of regional climate change on human health. Nature. 2005; 438:310–7.
23. Kovats RS, Campbell-Lendrum D, Matthies F. Climate change and human health: estimating avoidable deaths and disease. Risk Anal. 2005; 25:1409–18.
24. Bunyavanich S, Landrigan CP, McMichael AJ, Epstein PR. The impact of climate change on child health. Ambul Pediatr. 2003; 3:44–52.
25. Kalkstein LS. Health and climate change. Direct impacts in cities. Lancet. 1993; 342:1397–9.
26. Longstreth J. Public health consequences of global climate change in the United States–some regions may suffer disproportionately. Environ Health Perspect. 1999; 1:169–79.
27. Hess J, Malilay J, Parkinson AJ. Climate change: the importance of place. Am J Prev Med. 2008; 35:468–78.
28. Franco C, Toner E, Waldhorn R, Maldin B, O'Toole T, Inglesby TV. Systemic collapse: medical care in the aftermath of Hurricane Katrina. Biosec Bioterrorism. 2006; 4:135–46.
29. Frumkin H, Hess J, Luber G, Malilay J, McGeehin M. Climate change: the public health response. Am J Public Health. 2008; 98:435–45.
30. McMichael A, Campbell-Lendrum D, Kovats RS, et al. Global climate change. In: Ezzati M, Lopez A, Rodgers A, et al., eds. Comparative Quantification of Health Risks. Geneva: World Health Organization, 2004.
31. Epstein PR. Climate change and human health. N Engl J Med. 2005; 353:1433–6.
32. McMichael AJ, Woodruff RE, Hales S. Climate change and human health: present and future risks. Lancet 2006; 367:859–69.
33. IPCC [Core Writing Team P, RK and Reisinger, A (eds.)]. Climate Change 2007: Synthesis Report. Contribution of Working Groups I, II and III to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change. Geneva: IPCC, 2007.
34. Krisberg K Climate change predicted to have dire effects on health: Experts urge action now to prevent deaths. April 2007. Available at: http://www.apha.org/publications/tnh/archives/2007/April2007/Globe/climateGLO.htm. Accessed Sep 9, 2008.
35. Chan M Climate change and health: preparing for unprecedented challenges. Bethesda, MD: 2007 David E. Barmes. Global Health Lecture, 2007.
36. Moorhead JC, Gallery ME, Hirshkorn C, et al. A study of the workforce in emergency medicine: 1999. Ann Emerg Med. 2002; 40:3–15.
37. American Board Medical Specialties. Member Board General Certificates Issued 1997–2006. ABMS. Available at: http://www.abms.org/News_and_Events/Media_Newsroom/pdf/ABMS_Certstats_tbl2.pdf. Accessed Jul 7 2008.
38. Weiner J. Expanding the U.S. medical workforce: global perspectives and parallels. BMJ. 2007; 335:236–8.
39. Centers for Disease Control and Prevention. Health, United States, 2007. Hyattsville, MD: National Center for Health Statistics, 2007.
40. Nawar EW, Niska RW, Xu J. National hospital ambulatory medical care survey: 2005 emergency department summary. Adv Data. 2007; 386:1–32.
41. Steiner-Sichel L, Greenko J, Heffernan R, Layton M, Weiss D. Field investigations of emergency department syndromic surveillance signals–New York City. MMWR Morb Mortal Wkly Rep. 2004; 53 Suppl:184–9.
42. Brillman JC, Burr T, Forslund D, Joyce E, Picard R, Umland E. Modeling emergency department visit patterns for infectious disease complaints: results and application to disease surveillance. BMC Med Inform Decis Mak. 2005; 5:4.
43. Carrico R, Goss L. Syndromic surveillance: hospital emergency department participation during the Kentucky Derby Festival. Disaster Manag Response. 2005; 3:73–9.
44. Balter S, Weiss D, Hanson H, Reddy V, Das D, Heffernan R. Three years of emergency department gastrointestinal syndromic surveillance in New York City: what have we found? MMWR Morb Mortal Wkly Rep. 2005; 54 Suppl:175–80.
45. Paladini M. Daily emergency department surveillance system — Bergen County, New Jersey. MMWR Morb Mortal Wkly Rep. 2004; 53 Suppl: 47–9.
46. Olson DR, Heffernan RT, Paladini M, Konty K, Weiss D, Mostashari F. Monitoring the impact of influenza by age: emergency department fever and respiratory complaint surveillance in New York City. PLoS Med. 2007; 4:e247.
47. Cohen AL, Budnitz DS, Weidenbach KN, Jernigan D, Schroeder T, Shehab DP. National surveillance of emergency department visits for outpatient adverse drug events in children and adolescents. J Pediatr. 2008; 152:416–21.
48. Waller AE, Ising AI, Deyneka L. Running the numbers. North Carolina emergency department visit data available for public health surveillance. N C Med J. 2007; 68:289–91.
49. Knouss RF. National disaster medical system. Public Health Rep. 2001; 2:49–52.
50. Moritsugu KP, Reutershan TP. The National Disaster Medical System: a concept in large-scale emergency medical care. Ann Emerg Med. 1986; 15:1496–8.

51. Stopford BM. The National Disaster Medical System–America's medical readiness force. Disaster Manag Respose. 2005; 3:53–6.
52. Brandt EN Jr, Mayer WN, Mason JO, Brown DE Jr, Mahoney LE. Designing a national disaster medical system. Public Health Rep. 1985; 100: 455–61.
53. Mahoney LE, Esch VH. The national disaster medical system. Emerg Med Serv. 1986; 15:13–9.
54. Centers for Disease Control and Prevention. Heat-related illnesses and deaths–United States, 1994–1995. MMWR Morb Mortal Wkly Rep. 1995; 44:465–8.
55. National Center for Injury Prevention and Control. CDC Injury Fact Book. Atlanta, GA: Centers for Disease Control and Prevention, 2006.
56. National Weather Service. Summary of natural hazard statistics for 2006 in the United States. National Weather Service of the National Oceanographic and Atmospheric Association; 2008. Available at: http://www.nws.noaa.gov/om/hazstats/sum06.pdf. Accessed Mar 23, 2009.
57. Anderson CA. Temperature and aggression: effects on quarterly, yearly, and city rates of violent and nonviolent crime. J Pers Soc Psychol. 1987; 52: 1161–73.
58. Moorman J, Rudd R, Johnson C, et al. National surveillance for asthma–United States, 1980-2004. MMWR Morb Mortal Wkly Rep. 2007; 56:1–14.
59. Mannino D, Homa D, Akinbami L, et al. Chronic obstructive pulmonary disease surveillance–United States, 1971-2000. MMWR Morb Mortal Wkly Rep. 2002; 51:1–16.
60. Mead P, Slutsker L, Dietz V, et al. Food-related illness and death in the United States. Emerg Infect Dis. 1999; 5:607–25.
61. Ebi KL, Balbus J, Kinney PL, et al. Synthesis and Assessment Product 4.6: Chapter 2, Effects of Global Change on Human Health. U. S. Climate Change Science Program, 2008. Available at: http://www.climatescience.gov/Library/sap/sap4-6/final-report/sap4-6-final-ch2.pdf. Accessed Mar 23, 2009.
62. Brown J. Diagnostic and treatment patterns for renal colic in US emergency departments. Int Urol Nephrol. 2006; 38:87–92.
63. Centers for Disease Control and Prevention. Lyme disease–United States, 2003–2005. MMWR Morb Mortal Wkly Rep. 2007; 56:573–6.
64. Beggs PJ, Bambrick HJ. Is the global rise of asthma an early impact of anthropogenic climate change? Environ Health Perspect. 2005; 113:915–9.
65. Hales S, Lewis S, Slater T, Pearce N. Prevalence of asthma symptoms in relation to climate in New Zealand. Environ Health Perspect. 1998; 106: 607–10.
66. Weiland S, Husing A, Strachan D, Rzehak P, Pearce N. Climate and the prevalence of symptoms of asthma, allergic rhinitis, and atopic eczema in children. Occup Environ Med. 2004; 61:609–15.
67. Johnston N, Sears M. Asthma exacerbations. 1: epidemiology. Thorax. 2006; 61:722–8.
68. Higham J, Venables K, Kupek E, Bajekal M, Kopek E. Asthma and thunderstorms: description of an epidemic in general practice in Britain using data from a doctor's deputising service in the UK. J Epidemiol Commun Health. 1997; 51:233–8.
69. Dales R, Cakmak S, Judek S, et al. The role of fungal spores in thunderstorm asthma. Chest. 2003; 123:745–50.
70. Marks G, Colquhoun J, Girgis S, et al. Thunderstorm outflows preceding epidemics of asthma during spring and summer. Thorax. 2001; 56: 468–71.
71. Grundstein A, Sarnat S, Klein M, et al. Thunderstorm associated asthma in Atlanta, Georgia. Thorax. 2008; 63:659–60.
72. Campbell M, Holgate S, Johnston S. Trends in asthma mortality. Br Med J. 1997; 315:1012.
73. Weiss KB. Seasonal trends in US hospitalizations and mortality. JAMA. 1990; 263:2323–8.
74. Targonski P, Persky V, Ramekrishnan V. Effect of environmental molds on risk of death from asthma during the pollen season. J Allergy Clin Immunol. 1995; 95(5 Pt 1):955–61.
75. Hogrefe C, Lynn B, Civerolo K, et al. Simulating changes in regional air pollution over the eastern United States due to changes in global and regional climate and emissions. J Geophysical Res. 2004; 109:D22301.
76. McConnell R, Berhane K, Gilliland F, et al. Asthma in exercising children exposed to ozone: a cohort study. Lancet. 2002; 359:386–91.
77. Schwartz J. Short term fluctuations in air pollution and hospital admissions of the elderly for respiratory disease. Thorax. 1995; 50:531–8.
78. Medina-Ramon M, Zanobetti A, Schwartz J. The effect of ozone and PM10 on hospital admissions for pneumonia and chronic obstructive pulmonary disease: a national multicity study. Am J Epidemiol. 2006; 163:579–88.
79. Ziska LH. Rising atmospheric carbon dioxide and plant biology: the overlooked paradigm. DNA Cell Biol. 2008; 27:165–72.
80. Ziska LH. Evaluation of the growth response of six invasive species to past, present and future atmospheric carbon dioxide. J Exp Bot. 2003; 54: 395–404.
81. Mohan J, Ziska L, Schlesinger W, et al. Biomass and toxicity responses of poison ivy (Toxicodendron radicans) to elevated atmospheric CO_2. Proc Nat Acad Sci USA. 2006; 103:9086–9.
82. Westerling AL, Hidalgo HG, Cayan DR, Swetnam TW. Warming and earlier spring increase western U.S. forest wildfire activity. Science. 2006; 313: 940–3.
83. Kunzli N, Avol E, Wu J, et al. Health effects of the 2003 Southern California wildfires on children. Am J Respir Crit Care Med. 2006; 174:1221–8.
84. Centers for Disease Control and Prevention. Monitoring Health Effects of Wildfires Using the BioSense System — San Diego County, California, October 2007. MMWR Morbid Mortal Wkly Rep. 2008; 57:741–7.

85. Pearle M, Calhoun E, Curhan G. Urologic diseases in America project: urolithiasis. J Urol. 2005; 173:848–57.
86. Soucie J, Coates R, McClellan W, Austin H, Thun M. Relation between geographic variability in kidney stones prevalence and risk factors for stones. Am J Epidemiol. 1996; 143:487–95.
87. Chen Y, Roseman J, DeVivo M, Huang C. Geographic variation and environmental risk factors for the incidence of initial kidney stones in patients with spinal cord injury. J Urol. 2000; 164:21–6.
88. Brikowski T, Lotan Y, Pearle M. Climate-related increase in the prevalence of urolithiasis in the United States. Proc Natl Acad Sci U S A. 2008; 105:9841–6.
89. Semenza JC, Rubin CH, Falter KH, et al. Heat-related deaths during the July 1995 heat wave in Chicago. N Engl J Med. 1996; 335:84–90.
90. Forkel R, Knoche R. Regional climate change and its impact on photooxidant concentrations in southern Germany: simulations with a coupled regional climate-chemistry model. J Geophys Res. 2006; 111:D12302.
91. Kinney PL. Climate change, air quality, and human health. Am J Prev Med. 2008; 35:459–67.
92. Semenza JC, McCullough JE, Flanders WD, McGeehin MA, Lumpkin JR. Excess hospital admissions during the July 1995 heat wave in Chicago. Am J Prev Med. 1999; 16:269–77.
93. Kovats RS, Hajat S, Wilkinson P. Contrasting patterns of mortality and hospital admissions during hot weather and heat waves in Greater London, UK. Occup Environ Med. 2004; 61:893–8.
94. Ellis FP, Prince HP, Lovatt G, Whittington RM. Mortality and morbidity in Birmingham during the 1976 heatwave. Q J Med. 1980; 49:1–8.
95. Ellis FP, Nelson F. Mortality in the elderly in a heat wave in New York City, August 1975. Environ Res. 1978; 15:504–12.
96. Ellis FP. Heat illness. I. Epidemiology. Trans R Soc Trop Med Hyg. 1977; 70:402–11.
97. Curriero FC, Heiner KS, Samet JM, Zeger SL, Strug L, Patz JA. Temperature and mortality in 11 cities of the eastern United States. Am J Epidemiol. 2002; 155:80–7.
98. Marzuk PM, Tardiff K, Leon AC, et al. Ambient temperature and mortality from unintentional cocaine overdose. JAMA 1998; 279:1795–800.
99. Turner RM, Muscatello DJ, Zheng W, Willmore A, Arendts G. An outbreak of cardiovascular syndromes requiring urgent medical treatment and its association with environmental factors: an ecological study. Environ Health 2007; 6:37.
100. Malilay J. Tropical cyclones. In: Noji E, ed. The Public Health Consequences of Disasters. New York, NY: Oxford University Press, 1997.
101. Curriero FC, Patz JA, Rose JB, Lele S. The association between extreme precipitation and waterborne disease outbreaks in the United States, 1948-1994. Am J Public Health. 2001; 91:1194–9.
102. Singh R, Hales S, de Wet N, Raj R, Hearnden M, Weinstein P. The influence of climate variation and change on diarrheal disease in the Pacific Islands. Environ Health Perspect. 2001; 109:155–9.
103. Patz J, Vavrus S, Uejio C, McLellan SL. Climate change and waterborne disease risk in the Great Lakes region of the U.S. Am J Prev Med. 2008; 35:451–8.
104. Del Beccaro MA, Brownstein DR, Cummings P, Goldoft MJ, Quan L. Outbreak of Escherichia coli O157:H7 hemorrhagic colitis and hemolytic uremic syndrome: effect on use of a pediatric emergency department. Ann Emerg Med. 1995; 26:598–603.
105. Centers for Disease Control and Prevention. Morbidity surveillance after Hurricane Katrina - Arkansas, Louisiana, Mississippi, and Texas, September 2005. Morb Mortal Wkly Rep. 2006; 55:727–31.
106. Lambrew JM, Shalala DE. Federal health policy response to Hurricane Katrina: what it was and what it could have been. JAMA. 2006; 296:1394–7.
107. U.S. Government Accountability Office. Status of the Health Care System in New Orleans. March 28 2006. GAO-06-576R. Available at: http://www.gao.gov/new.items/d06576r.pdf. Accessed Mar 23, 2009.
108. Gerrity E, Flynn B. Mental health consequences of disasters. In: Noji E, ed. The Public Health Consequences of Disasters. New York, NY: Oxford University Press, 1997.
109. Louisiana Department of Health and Hospitals. Reports of Missing and Deceased. Available at: http://www.dhh.louisiana.gov/offices/page.asp?ID=192&Detail=5248. Accessed Jan 14, 2008.
110. Anonymous. Deaths of evacuees push toll to 1,577. New Orleans Times-Picayune. Available at: http://www.nola.com/news/t-p/frontpage/index.ssf?/base/news-5/1148020620117480.xml&coll=1. Accessed Jan 14, 2008.
111. Mortensen K, Dreyfuss Z. How many walked through the door? The effect of hurricane Katrina evacuees on Houston emergency departments. Med Care. 2008; 46:998–1001.
112. Joy TL, Kemp HN. Managing the hurricane Katrina disaster in the Midwest. J Trauma Nurs. 2007; 14:70–2.
113. Eastman AL, Rinnert KJ, Nemeth IR, Fowler RL, Minei JP. Alternate site surge capacity in times of public health disaster maintains trauma center and emergency department integrity: hurricane Katrina. J Trauma. 2007; 63:253–7.
114. Blackwell T, Bosse M. Use of an innovative design mobile hospital in the medical response to Hurricane Katrina. Ann Emerg Med. 2007; 49:580–8.
115. Dunlop AL, Isakov AP, Compton MT, et al. Medical outreach following a remote disaster: lessons learned from Hurricane Katrina. Am J Disaster Med. 2007; 2:121–32.
116. Brownstein J, Holford T, Fish D. A climate-based model predicts the spatial distribution of the Lyme disease vector Ixodes scapularis in the United States. Environ Health Perspect. 2003; 111:1152–7.
117. Williams PL, Sable DL, Mendez P, Smyth LT. Symptomatic coccidioidomycosis following a

severe natural dust storm. An outbreak at the Naval Air Station, Lemoore, Calif. Chest. 1979; 76:566–70.
118. Gubler DJ, Reiter P, Ebi KL, Yap W, Nasci R, Patz JA. Climate variability and change in the United States: potential impacts on vector- and rodent-borne diseases. Environ Health Perspect. 2001; 109 Suppl 2:223–33.
119. Brunkard JM, Robles Lopez JL, Ramirez J, et al. Dengue fever seroprevalence and risk factors, Texas-Mexico border, 2004. Emerg Infect Dis. 2007; 13:1477–83.
120. Ramos MM, Mohammed H, Zielinski-Gutierrez E, et al. Epidemic dengue and dengue hemorrhagic fever at the Texas-Mexico border: results of a household-based seroepidemiologic survey, December 2005. Am J Trop Med Hyg. 2008; 78:364–9.
121. Barclay E. Is climate change affecting dengue in the Americas? Lancet. 2008; 371:973–4.
122. Centers for Disease Control and Prevention. Outbreak of acute illness–southwestern United States, 1993. MMWR Morb Mortal Wkly Rep. 1993; 42: 421–4.
123. Centers for Disease Control and Prevention. Guidelines for surveillance, prevention, and control of West Nile virus infection–United States. MMWR Morb Mortal Wkly Rep. 2000; 49: 25–8.
124. Dolney TJ, Sheridan SC. The relationship between extreme heat and ambulance response calls for the city of Toronto, Ontario, Canada. Environ Res. 2006; 101:94–103.
125. Rand DA, Mener DJ, Lerner EB, DeRobertis N. The effect of an 18-hour electrical power outage on an urban emergency medical services system. Prehosp Emerg Care. 2005; 9:391–7.
126. Mace SE, Jones JT, Bern AI. An analysis of Disaster Medical Assistance Team (DMAT) deployments in the United States. Prehosp Emerg Care. 2007; 11:30–5.
127. Hirshon JM, Morris DM. Emergency medicine and the health of the public: the critical role of emergency departments in US public health. Emerg Med Clin North Am. 2006; 24:815–9.
128. Bernstein E, Goldfrank LR, Kellerman AL, et al. A public health approach to emergency medicine: preparing for the twenty-first century. Acad Emerg Med. 1994; 1:277–86.
129. Levin D. Foreward, in Designing the 21st Century Hospital: Environment Leadership for Healthier Patients, Facilities, & Communities. Concord, CA: Center for Health Design, 2006.
130. U.S. Department of Energy (DOE). Buildings for the 21st Century. Washington, DC: U.S. Department of Energy, 2002.
131. Environmental Protection Agency. Energy STAR for healthcare. Available at: http://www.energystar.gov/index.cfm?c=healthcare.bus_healthcare. Accessed Jul 7, 2008.
132. Drodge WJ. Energy conservation and the responsibilities of health care institutions. Hosp Trustee. 1981; 5:19–20.
133. Applegath C, Wigle J. Turning green. Putting sustainable design concepts into practice in health care construction projects. Health Facil Manage. 2002; 15:22–7.
134. Frumkin H, Hess J, Vindigni S. Peak petroleum and public health. JAMA 2007; 298:1688–90.
135. Blanchard I, Brown L. Carbon footprinting of EMS systems: proof of concept [abstract]. Prehosp Emerg Care 2009; 13:129.
136. Ebi KL, Kovats RS, Menne B. An approach for assessing human health vulnerability and public health interventions to adapt to climate change. Environ Health Perspect. 2006; 114:1930–4.
137. Haines A, Kovats RS, Campbell-Lendrum D, Corvalan C. Climate change and human health: impacts, vulnerability, and mitigation. Lancet 2006; 367: 2101–9.
138. Jackson R, Shields KN. Preparing the U.S. health community for climate change. Annu Rev Public Health. 2008; 29:57–73.
139. Wigley T. The climate change commitment. Science 2005; 307:1766–9.
140. Epstein PR. Climate change: healthy solutions. Environ Health Perspect. 2007; 115:A180–1.
141. Blashki G, Butler CD, Brown S. Climate change and human health–What can GPs do? Austral Fam Phys. 2006; 35:909–11.
142. Coote A. What health services could do about climate change. Br Med J. 2006; 332:1343–4.
143. Stott R, Godlee F. What should we do about climate change? Health professionals need to act now, collectively and individually. Br Med J. 2006; 333:983–4.
144. Patz JA, Khaliq M. Global climate change and health: challenges for future practitioners. JAMA 2002; 287:2283–4.
145. Blashki G, McMichael T, Karoly DJ. Climate change and primary health care. Austral Fam Phys. 2007; 36:986–9.
146. Greer A, Ng V, Fisman D. Climate change and infectious diseases in North America: the road ahead. Can Med Assoc J. 2008; 178:715–22.
147. Shea KM. Global climate change and children's health. Pediatrics. 2007; 120:1149–52.
148. Committee on the Future of Emergency Care in the United States Health System. Hospital-based Emergency Care: At the Breaking Point. Washington, DC: National Academies Press, 2007.
149. Woodcock J, Banister D, Edwards P, Prentice AM, Roberts I. Energy and transport. Lancet. 2007; 370:1078–88.
150. Richardson L, Asplin B, Lowe R. Emergency department crowding as a health policy issue: past development, future directions. Ann Emerg Med. 2002; 40:388–93.
151. McConnell K, Richards C, Daya M, Weathers C, Lowe R. Ambulance diversion and lost hospital revenues. Ann Emerg Med. 2006; 48:702–10.
152. Health Care Without Harm. Healthcare Without Harm history. Available at: http://www.noharm.org/europe/aboutUs/missionGoals. Accessed Aug 31 2008.