HAPI

Health
And
Places
Initiative

November 2015

Climate Change, Health, and Place

A RESEARCH BRIEF
VERSION 1.2

Photo by Ann Forsyth

The HEALTH AND PLACE INITIATIVE (HAPI) investigates how to create healthier cities in the future, with a specific emphasis on China. Bringing together experts from the Harvard Graduate School of Design (HGSD) and the Harvard School of Public Health (HSPH), it creates a forum for understanding the multiple issues that face cities in light of rapid urbanization and an aging population worldwide.

Health and Places Initiative
http://research.gsd.harvard.edu/hapi/
Harvard Graduate School of Design

The Research Briefs series summarizes recent research on links between human health and places at the neighborhood or district scale and provides background for a number of other forthcoming products—a set of health assessment tools, planning and urban design guidelines, urban design prototypes, and neighborhood cases. While the Research Briefs draw out implications for practice, it is these other tools that really provide specific, real-world guidance for how to create healthy places.

The following people were involved in the Research Brief Series:

Series Editors: Ann Forsyth and Laura Smead
Contributors: Laura Smead, with Yannis Orfanos, Joyce Lee, and Chuan Hao (Alex) Chen
Copy Editor: Tim Czerwienski
Layout Designers: Yannis Orfanos, with Laura Smead and Weishun Xu
Thanks to Heidi Cho, Lydia Gaby, Andreas Georgoulias, Joy Jing, Emily Salomon, and Dingliang Yang for assistance and to Joyce Rosenthal for helpful comments.

Suggested Citation:
Health and Places Initiative. 2015. Climate Change, Health and Place. A Research Brief. Version 1.2. http://research.gsd.harvard.edu/hapi/

Big Ideas

- Accelerated climate change has led to more extreme weather events that disrupt ecological and physical systems. Climate change effects, in conjunction with global population growth and urbanization, compromises public health.
- Potential health effects of climate change include (but are not limited to) heat related illnesses and deaths, extreme weather and air pollution–related health effects, increased rates of allergic and infectious diseases, malnutrition, stormsurge–related drowning and injuries, and health problems related to displaced populations.
- People with existing medical conditions, people without coping mechanisms (access to air conditioning or health care services, etc.), people without social networks, the elderly, women, lower income groups, and young children typically face the greatest climate change–related health risks.
- The effects of climate change can be assessed across a variety of metrics (e.g. sea level rise, air quality change, urban heat island effect, precipitation). Vulnerabilities are best assessed at the local level.
- Physical, programmatic, and policy changes at national, international, and local urban scales could help mitigate and adapt to the negative effects of climate change. Inclusive urban planning processes and interventions at the local scale include: urban greening, programs promoting better building insulation, creating awareness/warning programs (e.g. extreme weather, heat waves, and disasters), creating a climate change vulnerability assessment and adaptation plan (e.g. ensuring emergency road access, placing key city functions away from susceptible coastal areas, etc.), carbon emission reduction measures, and urban climate mapping.
- Disaster mitigation is closely related to climate change adaptation. Please see the disasters research brief for information on disaster related health impacts and mitigation strategies.

What the Research Says

Health Issues

Changing ecological processes brought on by climate change have led to premature mortality and increased morbidity already, and this is expected to continue due to the regional impacts of climate change and variability.

Example: Ebi (2008, 5) modeled population health impacts due to climate change. She describes, “Three broad categories of health impacts are associated with climatic conditions: impacts directly related to weather and climate variability; impacts resulting from environmental changes that occur in response to climate variability and change; and impacts resulting from consequences of climate-induced economic dislocation and environmental decline.”

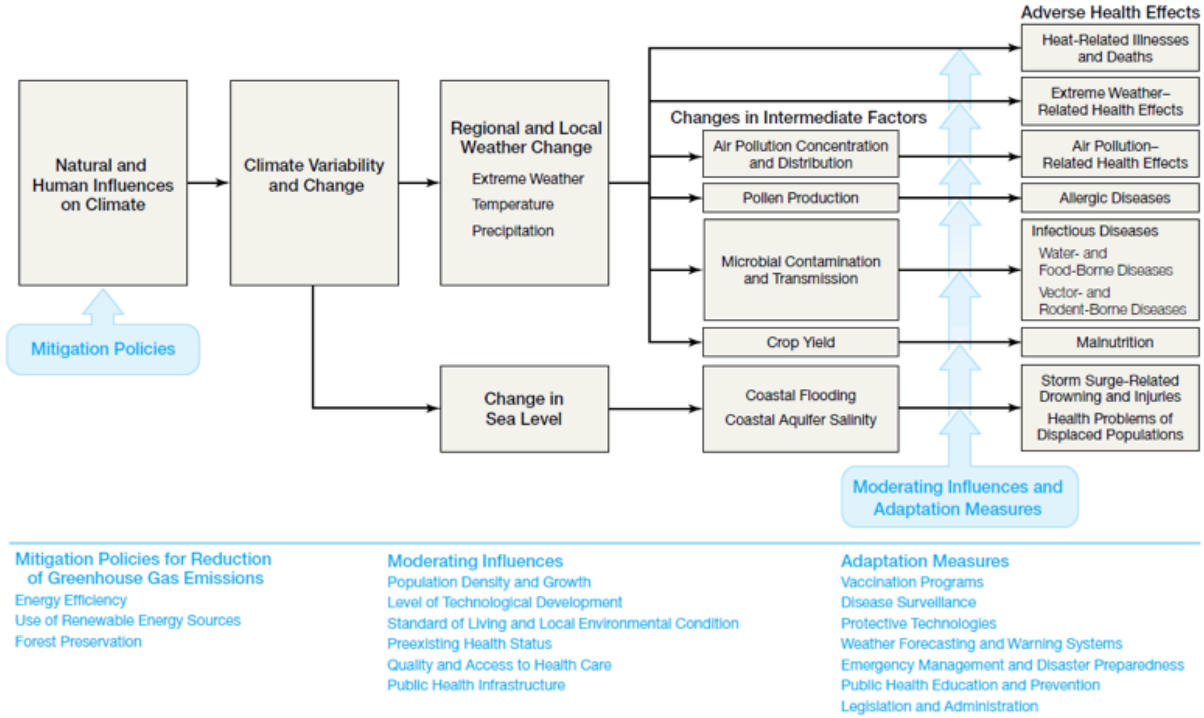
Figure 1 illustrates the pathways through which climate change affects health. Depending on the region, the process of climate change is increasing sea levels, temperatures, droughts, precipitation, and extreme weather events. In turn, these events affect intermediate factors like air pollution concentrations, pollen productions, microbial transmissions, crop yields, and coastal flooding (Haines and Patz 2004, Haines et al. 2006, Patz et al. 2005). Both the immediate and intermediate effects of climate change have an impact on health.

Health impacts include[1]:

- Air pollution–related health effects (both indoor and outdoor air quality)
- Allergic diseases
- Extreme weather–related health effects (both indoor and outdoor) (e.g. indoor: health effects due to building dampness, moisture, flooding, ventilation, weatherization, energy use)
- Health problems of displaced populations
- Heat-related illnesses, thermal stress, and deaths (both indoor and outdoor)
- Infectious diseases (water-borne, food-borne, and vector–borne, pests)
- Malnutrition
- Storm surge–related drowning and injuries

1. Haines and Patz 2004, Haines et al. 2006, I.O.M. 2011, Patz et al. 2005

Figure 1. Pathways through which climate change directly and indirectly affects health.



Source: Haines and Patz 2004, 101, used with permission.

As shown in Figure 1, climate change is closely related to air quality, water quality, and disasters. Please see the Air Quality, Water Quality, and Disasters briefs for discussion of those related health effects.

Heat is one of the climate change issues most relevant to planning and design, because strategies such as increasing vegetation are centrally within the toolkits of relevant professions. Therefore, this research synthesis focuses mainly on heat-related events and illness.

Elevated temperatures increase the risk of dying from cardiovascular, cerebrovascular, and respiratory diseases, above and beyond the moderating factor of air pollution.

Example: Basu (2009) reviewed epidemiological studies of the connections between temperature, air pollution and mortality between 2001 and 2008. Out of 36 included studies, 11 studies were conducted in U.S., 10 in Europe, 3 in Latin America, 3 in Australia, 2 in Canada, and 7 from elsewhere. He found, "The evidence suggests that particulate matter with less than 10 um in aerodynamic diameter and ozone may confound the association, while ozone was an effect modifier in the warmer months in some locations. Nonetheless, the independent effect of temperature and mortality was withheld. Elevated temperature was associated with increased risk for those dying from cardiovascular, respiratory, cerebrovascular, and some specific cardiovascular diseases, such as ischemic heart disease [insufficient blood supply to the heart], congestive heart failure, and myocardial infarction [heart attack]" (Basu 2009, 1).

Example: Planners and policy-makers need heat-related mortality data and estimates to evaluate public health and planning interventions. However, complex statistical modeling and extensive data sources are typically beyond the ability of health and planning departments. Hoshiko et al. (2010) created a simple method to assess heat-related mortality, without requiring statistical modeling. This model could easily be adopted by policymakers, health departments, or planners.

Place Issues

Climate change health effects (such as heat mortality) are compounded in urban areas, yet action on this scientific knowledge is lagging in the urban planning field.

Example: Huang et al. (2011) conducted a systematic review of 14 articles projecting future heat-related mortality due to climate change. They conclude that, "Urban areas, home to more than half of the world's population, can be particularly vulnerable to heat because of high concentrations of susceptible people, the urban heat island effect, poor urban design and planning, and the interaction between air pollution and heat" (Huang et al. 2011, 1681, citations removed).

Example: Mills et al. (2010) reviewed the literature (137 articles included) to compare urban climate science on a variety of different topics (e.g. air quality, climate planning, climate adaptation) and recommended urban policy and planning responses. They argue that "While a substantial body of knowledge on the science of urban climates has been developed over the past fifty years, there is little evidence that this knowledge is incorporated into urban planning and design practice" (Mills et al. 2010, 228). They describe how "Urban climate science is only now grappling with how climate change is likely to impact specifically on cities and their climates…Climate change models are not yet capable of generating predictions at a city scale. We do predictions for regional climate change that will perforce have implications for cities" (Mills et al. 2010, 231). The authors cite urban issues relating to urban heat island, airflow, and air quality — which can affect urban areas more negatively than more rural areas (e.g. heat mortality, snow dispersal impeding access, poor air quality from transportation, etc.) (Mills et al. 2010, 232).

Metropolitan areas with low-density, sprawling patterns of urban development may develop more frequent extreme heat events than the most compact urban regions, if regional forests and vegetative cover have not been preserved.

Example: Stone et al. (2010) analyzed the relationship between metropolitan region urban form using a sprawl index and historical rates of extreme heat events (EHEs) in the United States from 1956 to 2005. They conclude, "This analysis yields two principal findings. First the annual occurrence of EHEs continues to increase in large metropolitan regions …Second, the rate of increase in EHEs is higher in sprawling than in more compact metropolitan regions, an association that is independent of climate zone, metropolitan population size, or the rate of metropolitan population growth…This analysis further finds the rate of tree canopy loss to be significantly associated with the rate of increase in EHEs over time, when controlling for metropolitan population size and growth rate ($r=0.30$; $p< 0.05$). Based on this assessment, there is evidence to suggest that sprawling patterns of urban development may be influencing the frequency of EHEs through their effects on regional vegetative land cover" (Stone et al. 2010, 1427).

Vulnerable Groups

Table 1. Populations vulnerable to climate effects, particularly heat-related illness and mortality[2]

Populations	
Black racial/ethnic group (U.S.)	Low socioeconomic status
Existing medical conditions (e.g. diabetes, hypertension)	Older people (65+)
Heavy labor employees	Social isolation
Infants and young children	Without air conditioning
Inner cities	Women (in some locations)

2. Basu (2009), Basu and Samet (2002), Curriero et al. (2002), 85, Hajat and Kosatky (2009), Kovats and Hajat (2008), Reid et al. (2009), Romero-Lanko et al. (2012), Rosenthal et al. (2014), Shea (2007)

Things for Certain (or semi-Certain)

The effects of climate change vary across cultures, geographies, genders, and incomes. While negative health outcomes are typically more prevalent at extremely low temperatures or extremely high temperatures, the temperature thresholds that range from tolerable to detrimental differ from place to place.

Example: Romero-Lankao et al.'s (2012, 676) research synthesis of urban vulnerability to temperature-related hazards explains, "This lack of consensus across studies on the effects of gender, despite a large amount of evidence, likely indicates that the relationship between gender and vulnerability to heat-related hazards is context-specific. That is, it does not appear to be the case that women (or men) have a universal physiological susceptibility to heat, but rather that social conditions (e.g., occupation, gender equity in access to resources) are responsible for differential effects in some cases and not in others."

Example: Barnett, et al. (2010) used mortality data from 107 US cities from 1987–2000 to examine the relationship between temperature and mortality, using statistical methods to determine what temperature measure (e.g. maximum, minimum, mean, etc.) is the best predictor of mortality. They found, "Our results demonstrate that no temperature measure was consistently the best at predicting mortality in all age groups, seasons or regions. Instead we found marked variation in the best temperature measure across age groups, seasons and regions)" (Barnett et al. 2010, 608, references removed).

Marginalized populations are especially susceptible to the challenges brought on by climate change. Further, countries, cities, and people with more resources (financial, infrastructural) and capacity to adapt (time for acclimation, access to cooling mechanisms) will fare better in the face of challenges brought on by climate change.

Example: The Intergovernmental Panel on Climate Change's latest report for policy makers states, "People who are socially, economically, culturally, politically, institutionally, or otherwise marginalized are especially vulnerable to climate change and also to some adaptation and mitigation responses (medium evidence, high agreement). This heightened vulnerability is rarely due to a single cause. Rather, it is the product of intersecting social processes that result in inequalities in socioeconomic status and income, as well as in exposure. Such social processes include, for example, discrimination on the basis of gender, class, ethnicity, age, and (dis)ability" (Field et al. 2014, 6).

The world is warming up, however the rate is more pronounced in temperate regions. One should expect and plan for more heat-related illnesses and deaths in those areas.

Example: Shea's (2007, e1359) technical report for the American Academy of Pediatrics states, "According to the National Climatic Data Center, all records indicate that during the past century, global surface temperatures have increased at a rate near 0.6°C per century (1.1°F per century), but the trend has been 3 times larger since 1976." Paraphrasing National Climatic Data Center information, Shae states, "The climate in latitudes between 40°N and 70°N is warming more quickly than that in lower latitudes, and some areas (e.g., the southeastern United States) are actually cooling" (Shae 2007, e1359).

Risks of heat-related mortality increase above a certain temperature range that is a threshold (that varies by location). Humidity is also important to susceptibility and increases the risk of heat-related mortality.

Example: Curriero et al.'s (2002) time-series analysis for 11 large eastern US cities (1973–1994) analyzed cities' characteristics with variations in temperature-related mortality (using metropolitan area census data, national vital statistics data, and national climactic data). The authors found, "Current and recent days' temperatures were the weather components most strongly predictive of mortality, and mortality risk generally decreased as temperature increased from the coldest days to a certain threshold temperature, which varied by latitude, above which mortality risk increased as temperature increased. The authors also found a strong association of the temperature-mortality relation with latitude, which a greater effect of colder temperature on mortality risk in more-southern cities and of warmer temperatures in more-northern cities" (Curriero et al. 2002, 80).

Things up in the Air

There are many uncertainties and unknowns about the extent of climate change impacts, when they will be felt, and the best actions to protect health and well-being.

Example: According to the American Planning Association's Policy Guide on Planning and Climate Change (2011), "Planning to address climate change is particularly subject to time frames and levels of uncertainty that are unfamiliar to planners, policy makers and the general public. There may be a long time horizon before impacts are felt, there is some uncertainty about the extent of changes occurring in the global systems, and there are many unknowns about the costs and benefits of local action." (https://www.planning.org/policy/guides/pdf/climatechange.pdf)

Photo by Ann Forsyth

Urban tree canopies are one approach to protect urban areas from extreme heat events.

Implications

In these HAPI Research Briefs we aimed to find implications for planning and design at roughly the neighborhood level. These could include quantifiable standards, more qualitative but yet evidence-supported insights, and other good practices. Not every topic has a full complement of these implications.

Planners, designers, and policy makers can have a substantial effect on preventing and mitigating negative climate change-related health consequences through spatial reorganization, zoning, and other regulatory measures. However, only some of these are relevant at the neighborhood scale.

Standards and Insights

Conduct an inventory of the current housing stock and infrastructure to identify sites and groups that would be more at-risk in extreme weather events. For example, lower income communities.

Example: Romero-Lankao et al.'s (2012, 677) research synthesis of urban vulnerability to temperature-related hazards states, "The extent and quality of housing, infrastructure, and public services are potentially important—yet relatively unexplored—components of adaptive capacity, particularly in urban contexts."

Example: Rosenthal et al. (2014) assessed place-based characteristics associated with heat-related mortality for seniors (65 years or older) during heat events in New York City (1997–2006) for 59 Community Districts and 42 United Hospital Fund neighborhoods. They found, "Significant positive associations were found between the MMR_{65+} [mortality rate ratio among those 65 and older] and neighborhood-level characteristics: poverty, poor housing conditions, lower rates of access to air-conditioning, impervious land cover, surface temperatures aggregated to the area-level, and seniors' hypertension. Percent Black/African American and household poverty were strong negative predictors of seniors' air conditioning access in multivariate regression analysis" (Rosenthal et al. 2014, 45).

Table 2. Public health, policy and planning interventions for climate change health impacts[3]

Climate and Health Factors	Actions
Mortality and morbidity due to increased heat waves	• Landscaping for urban cooling: plant trees, increase urban green space • Forest preservation • Public-health education on what to do during heat waves, behavioral advice • Heat health warning systems • Emergency preparedness • Green building: better building insulation, material selection • Compact urban form (building placement, outdoor landscaping, materials, and surfaces, street dimensions and orientation can all affect outdoor comfort and health) • Urban climatic mapping and guidelines to inform urban planning and design • Vulnerability mapping and corresponding measures • Use of social care networks to reach vulnerable groups
Floods, Sea-level Rise, and Hurricanes	• Public-health education – e.g. boil water notices • Emergency preparedness • Checklist for post-flood activities • Ensure emergency access roads and other critical infrastructure (sewage, drainage) are in place for extreme events.(e.g. citywide drainage and sewage improvements) • Place key city functions and development away from disaster-prone, susceptible coastal areas. • Natural succession and ecosystem management (e.g. mangrove conservation, restoration, and replanting) • Stormwater management: maintenance of drainage systems • Well technologies to limit saltwater contamination of groundwater • Early warning systems and improved forecasting abilities (e.g. storms, flash floods, hurricanes) • Regional cooperation and risk pooling • Green infrastructure • Strengthening building design and regulation • Poverty reduction schemes
Air Quality	• Warnings for high pollution days • Increase renewable energy sources • Energy efficiency (all sectors: buildings, transportation, etc.) • Forest preservation • Transportation and parking policies • Mixed use development
Drought	• Rain and groundwater harvesting and storage • Water demand management and improve irrigation efficiency • Conservation agriculture, crop rotation, and livelihood diversification • Drought resistant crops • Early warning systems • Regional cooperation and risk pooling
Vector-borne diseases	• Public education, especially to avoid contact with ticks or mosquitoes • Programs to ensure adequate housing • Safe drinking water access and sanitation programs and infrastructure
Water-borne disease	• Risk assessment for extreme rainfall events • Risk assessment of health effects of algal blooms • Programs to ensure adequate housing • Safe drinking water access and sanitation programs and infrastructure • Sewage collection and treatment

3. APA (2011), Bowler et al. (2010), Ebi (2008), Haines (2004), Haines et al. (2006), Hajat and Kosatky (2009), IPCC (2012, 16-17), Huq et al. (2007), Mills et al. (2010, 233), Ren et al. (2011), Stone et al. (2010)

Other Good Practices

Promote synergy between smart growth, sustainability, hazard risk reduction, and climate change mitigation and adaptation.

In light of increasing evidence of climate change and urban vulnerability, planners and policy makers should **consider risk resiliency and ecological change in future plans** to better ensure the safety and health of all residents.

Example: According to the American Planning Association (2011), policy and planning responses to climate change should be based on the best possible science, be highly regional or local in nature, include adaptation measures as well as mitigation efforts, and communication with the public in original and creative ways. "By promoting the synergy between smart growth, sustainability and climate change mitigation and adaptation, planners can effect positive outcomes through a so-called 'no regrets' approach, whereby actions taken to adapt to or mitigate climate change are ones that should be done anyway for other reasons related to smart growth and sustainability" (APA 2011).

Example: The Intergovernmental Panel on Climate Change's (IPCC) Summary for Policymakers (2012) is a useful resource in describing the relationship between climate change, disasters, and implications for sustainable development. They advocate for an integrated approach between development, disaster mitigation, and climate change mitigation and adaptation, using an iterative and incremental approach toward adopting low-regrets measures. "Potential low-regrets measures include early warning systems; risk communication between decision makers and local citizens; sustainable land management, including land use planning; and ecosystem management and restoration. Other low-regrets measures include improvements to health surveillance, water supply, sanitation, and irrigation and drainage systems; climate-proofing of infrastructure; development and enforcement of building codes; and better education and awareness" (IPCC 2012, 14-15).

Photo by Ann Forsyth

Renewable energy sources, such as these solar panels, can reduce the impacts of climate change.

Sources

American Planning Association. 2011. "Policy Guide on Planning and Climate Change." American Planning Association. https://www.planning.org/policy/guides/pdf/climatechange.pdf.

Barnett, A.G., S. Tong, A.C.A. Clements. 2010. "What Measure of Temperature is the Best Predictor of Mortality?" *Environmental Research* 110: 604–611.

Basu, Rupa. 2009. "High ambient temperature and mortality: a review of epidemiologic studies from 2001 to 2008." *Environmental Health* 8:40.

Basu, Rupa and Jonathan M. Samet. 2002. "Relation between Elevated Ambient Temperature and Mortality: A Review of the Epidemiologic Evidence." *Epidemiologic Reviews 24(2): 190–202.*

Bowler, Diana E., Lisette Buyung-Ali, Teri M. Knight, and Andrew S. Pullin. 2010. "Urban Greening to Cool Towns and Cities: A Systematic Review of the Empirical Evidence." *Landscape and Urban Planning* 97:147–155. Accessed November 16,2013. doi:10.1016/j.landurbplan.2010.05.006.

Curriero, Frank C., Karlyn Heiner, Jonathan Samet, Scott Zeger, Lisa Strug, and Jonathan Patz. 2002. "Temperature and Mortality in 11 Cities of the Eastern United States." *American Journal of Epidemiology* 155(1): 80–87.

Ebi, Kristie, L. 2008. "Healthy people 2100: modeling population health impacts of climate change." *Climatic Change* 88:5–19.

Field, Chistopher, et al. 2014. "Climate change 2014: Impacts, adaptation, and vulnerability." IPCC WGII AR5 Summary for Policymakers.

Haines, Andy and Jonathan A. Patz. 2004. "Health Effects of Climate Change." *Journal of the American Medical Association* 291(1): 99–103.

Haines, Andy, R.S. Kovats, D. Campbell-Lendrum, and C. Corvalan. 2006. "Climate change and human health: impacts, vulnerability, and mitigation." *Lancet* 367: 2101–2109.

Hajat, Shakoor and Tom Kosatky. 2009. "Heat-related mortality: a review and exploration of heterogeneity." *Journal Epidemiology Community Health* 64:753–760. Accessed November 16, 2013. doi:10.1136/jech.2009.087999.

Hoshiko, Sumi, Paul English, Daniel Smith, and Roger Trent. 2010. "A simple method for estimating excess mortality due to heat waves, as applied to the 2006 California heat wave." *International Journal of Public Health* 55: 133–137.

Huang, Cunrui, Adrian Gerard Barnett, Xiaoming Wang, Pavla Vaneckova, Gerard FitzGerald, and Shilu Tong. 2011. "Projecting Future Heat-Related Mortality under Climate Change Scenarios: A Systematic Review." *Environmental Health Perspectives* 119 (12): 1681–1690.

Huq, Saleemul, Sari Kovats, Hannah Reid and David Satterthwaite. 2007. "Editorial: Reducing risks to cities from disasters and climate change." *Environment and Urbanization* 19: 3–15. DOI: 10.1177/0956247807078058.

Institute of Medicine. 2011. "Climate Change, the Indoor Environment, and Health." Report Brief. Washington DC: Institute of Medicine of the National Academies.

IPCC. 2012. "Summary for Policymakers." In: *Managing the Risks of Extreme Events and Disasters to Advance Climate Change Adaptation* [Field, C.B., V. Barros, T.F. Stocker, D. Qin, D.J. Dokken, K.L. Ebi, M.D. Mastrandrea, K.J. Mach, G.-K. Plattner, S.K. Allen, M. Tignor, and P.M. Midgley (eds.)]. A Special Report of Working Groups I and II of the Intergovernmental Panel on Climate Change. Cambridge University Press, Cambridge, UK, and New York, NY, USA, pp. 1–19.

Kovats, R. Sari and Shakoor Hajat. 2008. “Heat Stress and Public Health: A Critical Review.” *The Annual Review of Public Health* 29:41–55.

Mills, G., H. Cleugh, R. Emmanuel, W. Endlicher, E. Erell, G. McGranahan, E. Ng, A. Nickson, J. Rosenthal, and K. Steemer. 2010. “Climate information for improved planning and management of mega cities (needs perspective).” *Procedia Environmental Sciences* 1: 228–246.

Patz, Jonathan A., Diarmid Campbell-Lendrum, Tracey Holloway, and Jonathan A Foley. 2005. “Impact of regional climate change on human health.” *Nature* 438: 310–317.

Reid, Colleen E., Marie S. O’Neill, Carina J. Gronlund, Shannon J. Brines, Daniel G. Brown, Ana V. Diez-Roux, and Joel Schwartz. 2009. “Mapping community determinates of heat vulnerability.” *Environmental Health Perspectives* 117(11): 1730–1736.

Ren, Chao, Edward Yan-yung Ng, and Lutz Katzschner. 2011. “Urban climactic map studies: a review.” *International Journal of Climatology* 31: 2213–2233.

Romero-Lankao, Patricia, Hua Qin, and Katie Dickinson. 2012. “Urban vulnerability to temperature-related hazards: A meta-analysis and meta-knowledge approach.” *Global Environmental Change* 22:670–683.

Rosenthal, Joyce Klein, Patrick L. Kinney, and Kristina B. Metzger. 2014. “Intra-urban vulnerability to heat-related mortality in New York City, 1997-2006.” *Health & Place* 30: 45–60.

Shea, Katherine M. and the Committee on Environmental Health. 2007. “Global Climate Change and Children’s Health.” *Pediatrics* 120: e1359–e1367. DOI: 10.1542/peds.2007-2646.

Stone, Brian, Jeremy J. Hess, and Howard Frumkin. 2010. “Urban form and extreme heat events: are sprawling cities more vulnerable to climate change than compact cities?” *Environmental Health Perspectives* 118(10): 1425–1428.