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Adaptation to Climate in Urban Areas: Identification of Research Needs

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Often located on coastlines and home to a rapidly growing percentage of the nation's people, cities are at the forefront of both vulnerability and adaptation to climate (Rosenzweig and Solecki, 2001a). The growing number and dominance of U.S. and world cities will play an increasingly large role in responding to environmental change. Yet, urban areas have been markedly understudied in regard to these vital issues (e.g., Aspen Global Change Institute, 1999; Miller and Small, 1999; U.S. National Assessment, 2000; IPCC WGII, 2001). The overall science questions motivating this new area of climate adaptation research are: How do climate, climate extremes, and projected climate change affect complex urban environments? and How can response capacity be most effectively developed? The following is a set of research needs that, if met, will facilitate the development of a fuller understanding of strategic adaptations to climate in urban places.

Comparative Urban Integrated Assessment Framework

Effects of climate in cities are significantly integrated. This integration fosters the development of secondary and tertiary effects and associated synergies. For example, extended heat waves cause peaks in energy demand that in turn cause electricity outages and air conditioning shutoffs, finally affecting heat stress and associated direct and indirect health impacts (Hill and Goldberg, 2001; Kinney et al., 2001). Another example is the integrated relationships among storm surges, infrastructure, and water supplies and outflows.

A fully defined yet flexible comparative framework for assessing the multi-dimensionality of urban climate is needed. Such a framework would allow for comparisons between similar and different-sized urban areas in geographically dispersed regions of the nation, and, with refinement, between developed country and less-developed country cities. The framework should focus on sectors (e.g. water supply, infrastructure) and basic quality-of-life measures and indicators, with mechanisms to examine synergistic impacts and to link natural and social science perspectives (Rosenzweig and Solecki, 2001b). This is crucial since climate extremes continue to occur within the context of the complex existing physical and socioeconomic systems that operate in urban regions. Such a research framework interleaves the three basic interlocking components in urban areas:

1. Biophysical systems (e.g., coastal estuaries, regional hydrology, ecosystems);
2. Socio-economic demographic conditions and institutions (e.g., age distribution, race/ethnicity, income distribution, social organization); and
3. Built environment (e.g., housing stock, infrastructure). A framework that links these components together is needed in order to make significant advances in understanding how climate interacts with the urban environment.

Urban Climate Scenarios

Previous research has used climate scenarios derived from coarse-scale (~2.5^{o}lat. x ~3.75^{o}long.) global climate models (GCMs). As many sub-grid scale climate variations relate directly to the local urban complexities (e.g., differential impacts on health and energy demand depending on proximity to the coast and on amount of vegetative cover), climate scenarios at finer resolutions would be useful in simulating such local scales directly. With recent advances in mesoscale climate modeling (e.g., Giorgi and Marinucci, 1996; Giorgi and Mearns, 1999), it is now possible to develop new enhanced climate scenarios at spatial resolutions more appropriate to urban regions. Needed in these finer-scale scenarios are projected changes in the variability as well as changes in mean climate parameters, information about the nature of regional storm tracks, and improved sea-level estimates.

Also needed is particular attention to the urban heat island effect and how it may change under changing climate conditions. The urban heat island effect, which tends to warm cities relative to surrounding areas particularly at night, could significantly increase the amount of warming in heavily urbanized sites and with it the level of secondary air pollutants and associated health effects. For example, it is recognized that increased warming causes heightened levels of atmospheric ozone in urbanized sites. Good projections of these interactions do not yet exist.

Spatial and Temporal Variations of Climate

Climate is manifested unevenly throughout the urban landscape with respect to both location and timing. For example, climate effects range from widespread to concentrated, from near-term to long-term, and finally, from acute to chronic events. The phenomenon of spatial and temporal unevenness of risk has been well documented within the risk and hazard literature (see Cutter, 1993, 1996; Blaikie et al., 1994). There is a need now to specify the methodologies needed to define the urban climate "riskscape."

For example, in the New York Metropolitan Region, many coastal communities have been identified as at high risk given their vulnerability to sea level rise and storm surges; these risks affect affluent and low-income communities in different parts of the region (Gornitz, 2001). Poor, inner city communities are more seriously affected by climate, particularly summer heat waves, because of the higher number of at-risk populations, e.g., the elderly poor (Kinney et al., 2001). A key objective is to more systematically define the spatial variation of climate effects and associated vulnerability across the urban regions through time. Geographic Information Systems (GIS) and remote sensing analyses will help to define these variations analytically (Miller and Small, 1999).

Valuation of Climate in Cities

The costs of climate extremes in urban regions are known to be significant. The economic costs of climate events such as droughts and floods can range into the billions of dollars. Estimating the costs of climate extremes is a critical element in regional decision-making in regard to preparing adaptations.

The costs to be examined include both market and non-market costs. Market costs are defined as those whose value or price can be quantitatively measured directly through a specification of expenditures and losses. Market value typically includes costs for materials, labor, and energy. These values are defined by prices that are set by supply and demand. A primary distinction is between present value costs and future costs. Present value costs are defined as those that are incurred in the short term, for example construction costs at a dam site. There are two primary ways to define the future value of these costs: discount rates and opportunity costs. Non-markets costs are assigned to goods and services that do not have defined market values. These include ecosystem functions of wetlands and recreational value of open space. There are several ways in which value can be quantitatively defined for these types of services (e.g., contingency pricing, proxy value estimation).

Another distinction between types of costs within sectors is added costs vs. new costs. Added costs are those that emerge as add-ons to current expenditures. For example, throughout the NY metro region, the U.S. Army Corps of Engineers has spent over $880 million for beach re-nourishment projects over the last 60 years. Under the conditions of further sea level rise, these costs are likely to rise as additional sand loss takes place (Gornitz, 2001). These supplemental costs are defined as added costs. New costs are those incurred when an individual or institution faces costs not dealt with previously. For example, previously unobserved public health conditions might occur in the region that would necessitate expenditures on new types of disease prevention activities.

Adaptation and Mitigation

Much research is needed to allow informed responses to climate change in cities. Urbanized areas typically are politically and socially fractured along jurisdictional, income, racial and ethnic lines. These complexities dramatically influence the process and conditions of adaptation to climate and considerations of mitigation of greenhouse gas emissions in urban areas.

Adaptations to climate are complex and diverse (Rosenzweig and Solecki, 2001a). They are likely simultaneously to include physical modification to infrastructure (e.g., seawalls and airport runways); changes in decision-making practices (e.g., use of management strategies with overlapping jurisdictions and longer timeframes); and far-reaching societal shifts (e.g., potential disinvestment in highly vulnerable coastal sites and increased support for at-risk populations of the poor and elderly).

Key questions related to climate adaptation research needs are: What is response capacity and capability in urban areas to climate? What conditions make particular sites, people, and systems in urban areas more vulnerable than others? How can these sites, people, and systems be made less vulnerable?

At the same time that urban decision-makers are evaluating adaptation options, they may be considering potential trajectories in energy usage, including possible mitigation options in terms of reductions in greenhouse gas emissions. Future research will serve a wider purpose of its stakeholders if adaptation and mitigation choices are studied jointly, for example taking into account how economic development, population growth, land-use planning (e.g., Smart Growth), and energy choices may interact.

Regional-to-Global Effects

By definition, urban areas are intimately connected with other places (Sassen, 1994; Crahan and Vourvoulias-Bush, 1997). Cities are locations in which materials, ideas and people are continually flowing in and out. These connections define to a significant degree the character of climate interactions in sites, as well as cities' response capacity to climate. First, second and third-order effects resulting from these interconnections are possible. For example, summer energy demand may require a readjustment of the national electric energy supply grid in order to meet the increased urban demands. (The recent blackout of July, 2003 is a case in point.) Another example is that strong hurricanes and greater storm damage in rural areas in Central America might result in the in-migration of large numbers of refugees to urban areas both in and outside the U.S. Thus, a key research need is the development of a fully integrated framework that includes such interconnections, both at the national and international levels.

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