Part II

Defining the risk framework

2

Cities, disasters, and climate risk

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2.1 Introduction[1]

Cities are central to the climate change challenge, and their position is ever more important as the world's population is becoming increasingly urban. City governments can play an active role in attempting to mitigate climate change, as well as in sheltering their residents from the negative consequences of climate change. In this chapter, we examine the connections between cities and the management of these negative consequences of climate change.

Climate change affects hazard, vulnerability, and risk exposure in cities through a variety of direct and indirect relationships. Cities in many ways were first created as a means to more efficiently protect populations from hazards, whether they be physical (e.g., storms, droughts) or social (e.g., war, civil unrest) in origin. The very fact that cities are population centers illustrates the tension that city managers face with respect to hazards. They can be expected to help protect the populations that live within their cities' borders; while, at the same time, the concentration of population in cities means that when disaster strikes a large number of people could be adversely impacted.

City governments are beginning to put a greater focus on adapting their cities to the inevitable effects of climate change. In its 2007 Fourth Assessment Report (AR4), the Intergovernmental Panel on Climate Change (IPCC, 2007a) concluded that there is a greater than 90 percent chance that the average global temperature increase over the last century was primarily caused by human activity. However, in the context of cities, several climate-induced challenges, such as increased flooding potential and its impacts on water supply, are still largely understudied.

Climate change and increased climate variability will alter the environmental baselines of urban locales. Shifts in climate and increased frequency of extreme events have direct impacts on water availability and quality, flooding and drought periodicity, and water demand. These dynamic changes will affect system processes within multiple sectors in cities interactively, increasing the uncertainty under which urban managers and decision-makers must operate.

In turn, a central objective of this chapter is to review how this new information and uncertainty about climate risk is being integrated into effective and efficient adaptation planning at the city level. To address this issue, the chapter first focuses broadly on the connection between climate change adaptation and more established disaster risk reduction strategies. Derived from these connections, we then present a climate risk assessment-based analysis of adaptive capacity in a diverse set of four city-focused case studies.

2.2 Urban disasters and hazard dynamics in the context of climate change

At the global level, the IPCC Working Group I identified four major aspects of climate change relevant to cities (IPCC, 2007a). First, heat waves are very likely to increase in frequency over most land areas. Second, heavy precipitation events are very likely to increase in frequency over most areas; available data suggest that a significant current increase in heavy rainfall events is already occurring in many urbanized regions. The resulting risk poses challenges to urban society, physical infrastructure, and water quantity and quality. Third, the area affected by drought is likely to increase. There is high confidence that many semi-arid areas will suffer a decrease in water resources due to climate change. Drought-affected areas are projected to increase in extent, with the potential for adverse impacts on multiple sectors, including food production, water supply, energy supply, and health. Fourth, it is likely that intense tropical cyclone activity will increase. It is also likely that there will be increased incidence of extreme high sea levels (excluding tsunamis).

Further, the IPCC (2007b) Working Group II lays emphasis on conceptual issues regarding urban climate change with a focus on economic and social sectors in its Chapter 7 on Industry, Settlements, and Society. The review identifies four key findings with *very high* or *high* confidence. First, climate change effects can amplify the risks that cities face from non-climate stresses. These non-climate stresses include: large slum populations that live in low-quality housing lacking access to basic social services; city-wide lack of access to effective and efficient physical infrastructure; often poor quality of urban air, water, and waste disposal systems; lack of land use planning and other urban governance systems among others. Further, the climate change associated risks for cities stem primarily from extreme events – implying that cities need to assess risk for droughts, floods, storms, and heat waves, in order to plan and implement adaptation strategies. However, gradual changes such as a rise in mean temperature do affect cities in at least two significant ways: by increasing the frequency and intensity of extreme events and burdening existing infrastructure.

2.3 Climate risk and key urban sector impacts

Climate change and disasters affect critical socio-economic sectors in settlements (both formal and informal), water and energy supply and demand, and public health. Climate change impacts on these key sectors and the implications for disaster risk reduction effectiveness are presented in the following section. The impacts include (i) increased system variability and

1 The basic outline of the chapter was presented at the World Bank Fifth Urban Research Symposium, June 2009, Marseille, France. Case studies were adapted from an unpublished manuscript. Mehrotra *et al*. (2009) *Framework for City Climate Risk Assessment*.

potential instability, (ii) increased potential for declines in systems productivity, (iii) challenges to current system efficiency, and (iv) exacerbation of existing inequities.

In urban areas, inequities will become more apparent as populations will be differentially able to relocate away from highly vulnerable locations, leading to changes in the spatial distribution and density of both formal and informal settlements. Degradation of building materials is also projected to occur. As warmer temperatures extend into higher latitudes, diseases never before seen might appear, or diseases that had long been considered eradicated may re-emerge. The health ramifications in some areas could be disastrous, especially in densely populated informal settlements. Water supply and demand will be affected as areas under drought will expand. While precipitation is expected to increase in some areas, water availability is projected to eventually decrease in many regions, including those where water is supplied by meltwater from mountains. For energy supply and demand, climate change will put increased pressure on energy infrastructure via rising cooling demand, as well as greater likelihood of supply disruption from extreme event impacts.

Increased variability and instability of sector operation could in some cases lead to beneficial conditions. For example, future climate change could result in more favorable winter conditions in many northern-latitude cities. In most situations, however, the impacts will be more likely to be detrimental to sector operation, especially in poor countries that will be affected the most by climate change, and result in declines in system efficiency and production, e.g., decline in local agricultural productivity, more frequent drinking water shortages in cities, and loss of housing to flooding and storm surge. Even if these impacts are not evident in the short or medium term, enhanced climate change increases the potential for these types of losses, and potential secondary impacts such as increased rural-to-urban migration if rural agricultural systems become less viable. Local and national management regimes need to be ready to respond to these new possibilities. For example, the drought of record or similar baseline can no longer be seen as the most extreme and as the benchmark for disaster and hazard planning.

Sectoral impacts from climate change will reflect the underlying social and environmental conditions within cities. People and places that are most vulnerable and least resilient will be those most affected by climate change. Urban residents of already drought-prone and water-limited areas of cities will be more likely exposed to increased climate variability. Other urban poor already living in higher-risk sites in cities, such as floodplains or hill slopes, will be affected by more frequent and more severe floods or more massive landslides and mass wasting of hillsides.

In summary, climate change-related, sectoral impacts present a variety of challenges and opportunities for disaster risk reduction strategies. The challenges include a need for continuing reevaluation of existing plans and efforts to determine if they are to be responsive to the increased dynamism and changing baseline of the local environment; to the presence of increased numbers of more intensively marginalized and less-resilient populations and places; and to increased competition for limited funding and resources for climate change-related impacts (i.e., government funding and attention could be drawn away from disaster planning if the focus turns to address increasingly difficult economic and social stresses present in many cities).

The question of how to develop effective climate change adaptation strategies within the context of disaster risk reduction management approaches and a multitude of other demanding city-scale public policy pressures is discussed in the next section.

2.4 Climate change adaptation and disaster risk reduction: comparison, contrasts, and emerging synergies

The basic assumptions and institutional conditions under which climate change adaptation strategies and disaster risk reduction activities have emerged are reviewed here, as well as areas where additional potential opportunities for synergy within the urban context are starting to emerge.

Urban climate change adaptation strategy efforts have responded to increased awareness of the potential threat of climate change and enhanced climate variability. In the past decade, government and international organizations within cities have begun to assess how climate change could have a wide variety of primary and secondary impacts. The foundation for emerging climate change and adaptation policy has been science-based studies and assessments. Premier examples of such efforts are the four major assessment reports of the Intergovernmental Panel on Climate Change, which have been produced since 1990. These reports, along with a host of regional and national scientific reports as well as city-based assessments, serve as the basis for city-scale action. The administrative response to the emerging pressure of climate change impacts and associated scientific assessment, however, remains largely diffuse and uneven, often-times driven by a single agency or concerned officials within several agencies, without firm legislative mandates, and/or without financial or human resources to implement action plans. In many least developed country cities, if a climate change adaptation agenda exists it is often buried in environmental ministries or agencies that have very little voice and often even less influence.

In other managerial contexts, urban theorists and practitioners, with their emphasis on rational comprehensive planning as the primary tool to regulate city development, have evolved into a more bottom-up community-oriented approach of advocacy planning widely used in urban governance in the past decade (Campbell and Fainstein, 1996). Here as well, most city managers do not yet address climate change in their policy planning and strategies largely because city-specific risks remain undefined and more short-term problems, such as lack of basic services or overextended and aging infrastructure, take precedence.

Where climate change concerns are actually being recognized by policymakers and managers at the local level, climate risk literature looks predominantly at hazards – temperature, precipitation, and sea level trends and projections. This emphasis can be explained by the fact that in the near future most climate change impacts are likely to be in the form of enhanced climate variability, i.e., increased frequency and intensity of extreme events. While the observed and projected trends in climate parameters are a prerequisite to any assessment of climate risk and associated management strategies, in the context of cities two additional vectors are critical and often neglected – namely vulnerability and adaptive capacity. Vulnerability of a city is determined by a host of internal characteristics of the city set within a larger socio-environmental context. Adaptive capacity is a function of the ability and willingness of the city stakeholders to respond to and prepare for future climate-induced stresses.

In contrast to recent developments in climate change adaptation strategy action, disaster risk reduction planning developed out of much longer term efforts over the past half century in cities to provide emergency disaster response and recovery services for affected populations and economies (Blaikie *et al*. 1994; Helmer and Hilhorst, 2006; O'Brien *et al*., 2006). Previous to this, indigenous disaster resilience techniques were used. Disaster risk reduction planning and efforts in most cities emerged only after a major catastrophe occurred and where the potential for coherent local and national response efforts was possible. Prior to the past several decades, deficient communication and transportation infrastructure, political instability, and/or lack of governance structure made the response to disasters in cities quite limited. These challenges are still present in many less-developed countries' cities.

In further contrast to climate change adaptation, disaster risk reduction efforts typically grew out of public safety and civil defense mandates in the wake of a major event, instead of scientific study as with climate change and IPCC-style assessments. In its origin, urban disaster management focused largely on response and recovery to address the immediate pain and suffering of disaster aftermath rather than the underlying socio-economic foundations of vulnerability and adaptive capacity.

In the past two decades, as it became clear that disasters cannot be managed only as one-time events to be dealt with through humanitarian response and economic reconstruction, a significant amount of focus in disasters work has shifted toward a new approach that addresses the root causes of disaster vulnerability through either structural or non-structural adaptations (Blaikie *et al*., 1994). The new perspective has engendered considerable focus on risk assessment, institutional capacity building, risk mitigation investments, emergency preparedness, and catastrophe risk financing. Examples of significant improvements include development and implementation of building codes, early warning systems, drainage systems, hazard mapping, agricultural insurance, and financial risk pools.

Another central difference between climate change adaptation and disaster risk reduction as they are currently implemented in cities is the type of events they address and the implication of the events. Coupled with these distinctions are differing definitions and terminologies (for terms like hazard, risk, and sensitivity), which further divide the communities. For example, disaster risk reduction focuses on extreme events, the damage they cause, and short-term response. These extreme events often are conceptualized and defined as aberrant, isolated moments outside the norm, and the appropriate government response should to be bring the environment and social life in the affected zone "back to normal" as soon as possible. Climate change can exacerbate existing disaster risks and increase the potential for new risk levels, but in many cases causes gradual changes that are not typically associated with disasters – e.g., shifts in ecosystem zones that can affect local and regional hydrology, and spread of public health disease vectors, and changes in heating and cooling energy demand. Under climate change, extreme events and gradual shifts are seen as part of an increasingly variable and dynamic physical environment and that new "normal" conditions are constantly evolving.

While the origins and basic precepts are different, there is a large amount of common ground between climate change adaptation and disaster risk reduction planning in cities (Huq *et al*., 2004). They share a common goal: managing hazards, building resilience and adaptive capacity in vulnerable communities. Adaptation strategies and disaster risk reduction increasingly are connected by their dual focus on the significance and impact of extreme climate events; analysis of the root cause of exposure and vulnerability and integration of these concepts into planning and action; and the significant role of management. Both communities seek to mainstream their activities (i) through the development of management plans aiming to incorporate these into the local and regional development plans and strategies, and (ii) by having existing agencies and departments and local governments integrate key sectoral guidelines and issues into their planning and implementation activities. Both communities support local capacity building and have an increasing recognition of the importance of both expert knowledge and local knowledge in addressing their policy concerns. We further explore and assess this blending of the two sets of activities in the next section.

2.5 Convergence of climate change adaptation and disaster risk reduction in the urban context

Climate change and potential adaptation strategies are connected with existing disaster response and hazard management strategies in several ways (ICS, 2008; International Strategy For Disaster Reduction, 2010; Mercer, 2010). Disaster risk reduction management includes several phases such as risk assessment and preparedness planning; response, relief, and recovery; and structural hazard mitigation activities and non-structural hazard mitigation activities. Conditions of climate change and increased climate variability can affect the success and effectiveness of critical phases of disaster and hazard management. Such interactions are used as opportunities to more closely link climate risk adaptation and disaster risk reduction strategies and avoid the potential of the two remaining separate, become duplicative, fragmented, and overlapping risk assessments that do not well serve local decision-makers.

Climate change provides disaster risk reduction in cities several important opportunities for advancement, and vice versa (Pelling 2003, Pelling *et al.*, 2009; Prabhakar *et at*., 2009). The most important opportunity is that climate change raises the profile and importance of disaster risk reduction efforts. Climate change can help to connect disaster management to cutting-edge national and international policy issues, which are garnering the attention of governments at all levels and the NGO community as well. Conversely, since the disaster risk reduction agenda has often been built up over the past decade in the finance and planning agencies in many cities, this presence can help the climate change adaptation agenda to evolve from its current often-constrained situation in environment departments. Furthermore, disaster risk reduction planning frequently has well-developed platforms and coordination mechanisms, such as interagency task forces and mutual aid agreements, at the regional and city level to which climate change adaptation planning can be linked. Governments typically have plans, institutions, and policies already in place for disasters, while climate change adaptation planning is still very much under development.

The disaster management community also provides the main entry points to climate change adaptation for the general public. The public in cities often connect greenhouse gas reduction when hearing of climate change, but the questions “How do we deal with disaster impacts here and now?” and “What are the solutions to reduce the disaster impacts/vulnerabilities?” are questions that disaster management officials deal with on a regular basis. Thus, to incentivize officials at all levels to engage in the climate change agenda, disaster reduction can provide a key policy entry point.

City governments have begun to recognize the importance of disaster risk reduction at times other than during and just after a disaster event (Van Aalst, 2006; Van Aalst *et al*., 2007). Climate change heightens the awareness and concern for the potential of climate-related perturbations, such as cyclones, droughts, and floods. In many cities, the specter of increased intensity and frequency of extreme events is the primary policy concern associated with climate change. As this concern is raised, so is the focus on disaster risk reduction strategies and planning. Resilience initiatives emerge as one of the best “no regrets” actions that can be taken in the short term to reduce disaster vulnerability, from both current threats and those emerging from climate change. This increased interest not only presents opportunities for those promoting in disaster response and recovery, but also more importantly for long-term disaster risk exposure reduction and non-structural hazard mitigation strategies (e.g., promoting resettlement away from low-lying coastal sites that will affected by sea level rise, increased storm surge, and inundation).

Disaster preparedness planning is predicated on understanding the hazard and risk potential within the locale through analysis of historical hazard events and ongoing socio-physical shifts – e.g., increased urbanization and changing flood potential. Climate change increases the need for reassessment of disaster planning assumptions because of the potential for change of the environmental baselines (e.g., coastal evacuation plans need to be reevaluated because of heightened storm surge and flooding potential). Similarly, disaster recovery and reconstruction efforts will need to be reexamined, because in the future more-numerous climate-related disasters could have greater threat to life and property and be associated with more widespread and higher numbers of displaced people, homelessness, and property damage.

Structural and non-structural hazard mitigation policies will need to be reevaluated in the context of climate change (Thomalla *et al*., 2006). Additionally, the efficacy of large-scale infrastructure and capital improvement projects will need to be reevaluated. Projects possibly deemed as not cost-effective or overly ambitious, such as storm barriers or other flood-control devices in cities, might become feasible and needed as climate change impacts increase the possibility of more frequent disasters and greater losses per event. Non-structural approaches, which currently might seem as not appropriate or necessary, might need to be considered. Moving critical infrastructure out of highly vulnerable floodplains or coastal zones is just one example.

The interactions between climate change and disaster management provide opportunities to promote more structured coordination, planning, and communication, and eventually the effectiveness of both. The blending of initially diverse policy and research arenas is not without precedent within disaster management. During the 1980s, the previously disparate streams of natural hazards and technological hazards (including hazardous chemical releases and exposures) were effectively blended in an all-hazards management approach in some governments, such as the in USA through its Federal Emergency Management Agency (FEMA). Lessons learned from this experience can contribute to understanding how best to link climate change adaptation and disaster risk reduction.

The climate change community is now providing increasingly sophisticated climate models and scenarios that are enabling the disaster risk reduction managers in cities to better evaluate in terms of risks and vulnerabilities (World Bank, 2008). In turn, the disaster risk reduction community has brought to climate change planning a long history of experience and lessons learned and well-developed tools, such as probabilistic risk assessment techniques and frameworks for decision-making. For example, the disaster risk reduction community has developed the Hyogo Framework for Action 2005–2015 (HFA), an international agreement to build the resilience of nations and communities to disasters. The HFA provides the foundation for the implementation of disaster risk reduction. Agreed at the World Conference on Disaster Reduction in January 2005, in Kobe, Japan, by 168 governments, its intended outcome is the substantial reduction of losses from disasters in the next 10 years.

Critical components in this process of convergence include the development of common protocols for data gathering and reporting, and for assessment. Within the past half decade, climate change and climate variability studies increasingly have been able to utilize conceptual assessment frames present within the disaster risk reduction community. Critical concepts being explored include hazard, vulnerability, and adaptive capacity. In the next section, we detail these concepts and their emerging connections to climate change adaptation strategy development and risk assessment.

2.6 Climate risk in cities: assessing the nexus of disaster reduction and adaptation

A critical need for sector-specific analyses of climate hazards and vulnerabilities, and location-specific adaptive capacities and mitigation strategies, has been highlighted in the most recent IPCC Working Group III AR4 (IPCC, 2007c), and the World Resource Institute (Baumert *et al*., 2005; Bradley *et al*., 2007), and OECD (Hunt and Watkiss, 2007; Hallegatte *et al*., 2008). Several examples in the literature exist which highlight these omissions and deficiencies. For example, most analyses on climate impact assessments and cities have neglected non-coastal cities, and uncertainties in assessing the economic impacts need to be incorporated, particularly for developing-country cities where variances are likely to be higher (Hunt and Watkiss, 2007, and Hallegatte *et al*., 2008). Overall, there is a pressing call for understanding risks associated with climate change as they pertain to different types of cities – coastal versus non-coastal and developed versus developing; different sectors – physical infrastructure such as energy, transport, water supply, as well as social services such as health and environmental management (and the complex interactions among these sectors); and differential impacts on the poor or the young and old, who are more vulnerable than the rest of the urban population.

Furthermore, city-specific efforts should graduate from awareness raising to impact assessments – including costing impacts and identifying co-benefits-and-costs – and adaptation analysis so that "no-regret adaptation options" can be adopted to increase resilience of cities to climate change. Economic costs of climate change in cities should "bracket" for uncertainty and assess both intra- and inter-sectoral and systemic risks to address direct and indirect economic impacts.

Understanding how cities craft institutional mechanisms to respond to climate change is another important element of the urban risk assessment process. This has been briefly explored, where relevant, for detailed case studies on Quito and Durban (see Carmin and Roberts, 2009) and the eight-stage Risk, Uncertainty and Decision-Making Framework developed by the UK Climate Impacts Programme (2009), which aims "to help decision-makers identify and manage their climate risks in the face of uncertainty."

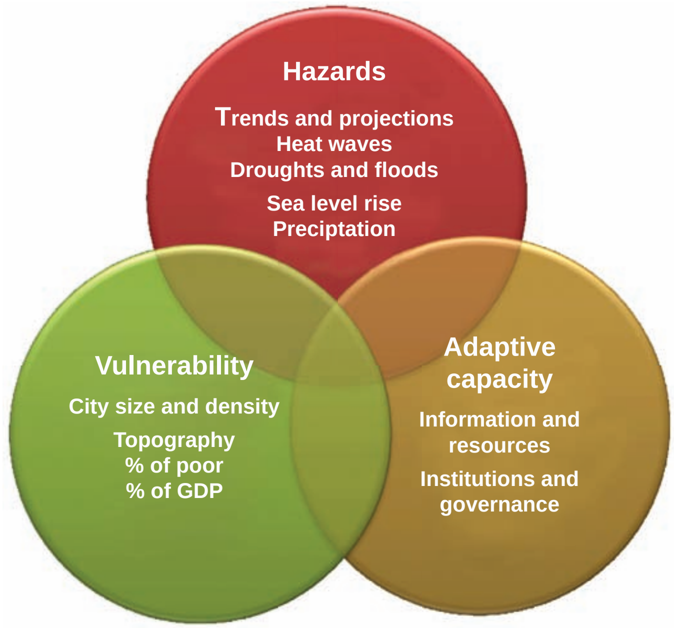


Figure 2.1: *Urban climate change vulnerability and risk assessment framework.*

Source: Mehrotra et al. (2009).

To further explore current practices and potential of urban climate risk assessment, we define and examine the characteristics and interplay of three basic risk elements in framework format: *hazards*, *vulnerability*, and *adaptive capacity* (see Figure 2.1). (Note: framework approach adapted from Mehrotra, 2003; Rosenzweig and Hillel, 2008; Mehrotra *et al*., 2009; also see Rawls, 1971; Shook, 1997; and Sen, 1999.) The challenge in the research community is to translate information on each and from climate science into knowledge that triggers a realistic assessment of the vulnerability of the city and its systems so as to facilitate the development of pragmatic adaptation strategies. In the remainder of this chapter we detail this challenge through the articulation of four city-level case studies around the three following objectives:

1. Characterize the hazards associated with climate change at the city-level;
2. Identify the most vulnerable segments (people, locations, sectors) of the city, and
3. Assess the city's ability to adapt to anticipated changes in climate.

2.6.1 Hazards

Hazards are defined in the framework as the climate-induced stresses and climate-related extremes and are identified through observed trends and projections derived from global climate models (GCMs) and regional downscaling (see Table 2.1). Extreme events affected by climate change include heat waves, droughts, inland floods, accelerated sea level rise, and floods for coastal cities. The variables examined to track these climate-related hazards are temperature, precipitation, and sea level (see Figures 2.2–2.22). In essence, the hazard element presents an array of climate change information and insights into the key stresses that potentially have the greatest consequence for any specific city. In this regard, it is critical to draw attention to both the variation in climate means and the change in frequency and intensity of extreme events. The latter offers opportunities for linkages with disaster risk reduction programs and has received perhaps more attention, while the former has critical long-term implications for city infrastructure and development, and tends to receive less attention because the mean changes are gradual.

Analysis of hazards specific to a particular city should include observed and projected data on key climate parameters – temperature, precipitation, sea level rise, among others. Further, each hazard needs to be analyzed for variance in climate parameters over the short and long term and, where relevant, for frequency as well as intensity of extreme events. Climate change scenarios provide a reasonable understanding of potential future climate conditions (Parsons *et al*., 2007). It is not expected that a single climate model will project exactly what will happen in the future, but by using a range of climate model simulations along with scenarios incorporating different atmospheric concentrations of greenhouse gases, a range of possible climate outcomes are produced and can be presented as projections that demonstrate the current expert knowledge.

Local climate change information for cities can be derived from the scenarios of greenhouse gas emissions and global climate model simulations described above. For the case-study cities that are examined below, quantitative projections are made for key climate variables such as the change in mean temperature that reflect a model-based range of values for the city-specific model grid boxes (see Table 2.5). Further, there is a need for a nuanced understanding of the complex interactions between hazards and the city. This is because the city can be both a producer as well as a receiver of these hazards. For instance, New York City alone contributes about 0.25 percent of global greenhouse gas emissions (The City of New York, 2007). On the other hand, increase in sea level also increases the city's susceptibility to flooding. In addition, while both urban heat island and global warming increase the ambient temperature of the city, one is internally generated while the other is externally induced.

2.6.2 Vulnerability

Vulnerability is defined as the physical attributes of the city and its socio-economic composition that determine the degree of its susceptibility. The variables affecting vulnerability include flood proneness (proximity to coast or river), land area, elevation, population density, percentage of poor, and quality of infrastructure. The OECD's work on city vulnerability in the context of climate change points to such variables as location, economy, and size as well (Hunt and Watkiss, 2007). More detailed indicators such as composition of the poor population – age, gender, labor force composition, and the like – need to be taken into consideration when in-depth city vulnerability analysis is conducted. For our evaluation here a more restricted set of variables that is readily available for most cities was utilized. These variables illustrate that such physical and socio-economic characteristics affect a city's risk.

Vulnerability is defined as the extent to which a city is predisposed to "adverse effects of *climate change*, including *climate variability* and extremes" (IPCC, 2007d). However, unlike the IPCC definition of vulnerability that includes adaptive capacity, we decouple the two here and address them individually, considering vulnerability to be determined by the physical and underlying social conditions of the city while adaptive capacity is determined predominantly by the change agents. In turn, vulnerability is a function of a host of city characteristics, including but not limited to the location of a city, particularly its proximity to a salt water coastline or other large water body, topography or any other physical attributes of the landscape or physical geography that make the city susceptible to climate variations.

Social factors that determine the degree of vulnerability of a city include its population size and composition, density, size of city, quality of infrastructure, type and quality of its built environment and its regulation, land use, governance structure and the like. A critical factor determining the vulnerability of the poor as opposed to the non-poor population of the city is the percentage of the population living in slums. These are households that lack access to one or more of the following: improved water supply, improved sanitation, sufficient living space, structurally sound dwellings, and security of tenure (UN-HABITAT, 2003). The contrast between the formally planned part of the city and the slums is stark and is a key determinant of the differential vulnerability of the poor as opposed to the non-poor (UN-HABITAT, 2008a).

2.6.3 Adaptive capacity

Adaptive capacity includes institutional attributes of the city and its actors that determine the degree of its capability to respond to potential climate change impacts. Thus they provide measures of the ability (institutional structure, caliber, resources, information, analysis), and willingness of actors (local governments, their constituent departments, private sector, civil society, NGOs, academics) to adapt to climate change. Variables that can determine the extent of a city's ability to adapt include the structure and capacity of institutions, presence of adaptation and mitigation programs, and motivation of change agents. Here it is critical to draw a distinction with the term "resilience" that the IPCC (2001b) Working Group II assessment defined as "amount of change a system can undergo without changing state." In contrast, adaptive capacity does not assume a steady state of a city and its integrated systems; rather it measures the ability and willingness to not only cope but to respond positively to the stresses that climate change imposes.

Adaptive capacity is the ability and willingness of the city's key stakeholders to cope with the adverse impacts of climate change and depends on the awareness, capacity, and willingness of the change agents. A quick measure of institutional awareness is the presence of a comprehensive analysis of climate risks for the city and corresponding adaptation and mitigation initiatives. Capacity here refers to the quality of institutions at various levels of governments – local, regional, and national – and within local government, across various departments. Further, the capacity of the private sector, non-governmental organizations, and community groups to respond also matters. Finally, the willingness to act is of the essence. In this regard, identifying in substantial detail the leading actors for climate response – government, private sector, and civil society – and mapping their initiatives is essential in estimating adaptive capacity of a city.

2.7 Climate risk assessment in selected case studies

We attempt to illustrate and assess the relative role of each of the three elements through a presentation of four major case studies for the metropolitan areas of Buenos Aires, Delhi, Lagos, and New York. These cities are located in four different global sub-regions and have a range of socio-economic conditions and vulnerability to climate hazards. A primary criterion for selecting these cities is that all four have leadership that is committed to addressing the issue of climate change and thus are exemplars for other cities within their respective region, and globally. Further, as these are all megacities and important national urban centers in their respective countries, not only do they constitute a significant share of the national GDP but also help to shape the direction of national urban development policies. See Table 2.1 for demographic parameters for the case study cities.

Most aspects of the risk case studies articulated in this chapter are equally applicable to small and medium sized cities, as in many cases time-series data on climate parameters are available. Smaller cities may have fewer resources to apply to the development of climate risk responses and thus may have additional needs for national and international guidance and support. However, the diverse urban conditions in the case study cities allow for some generalized lessons to be drawn regarding effective and efficient urban responses to climate change. The combination of city cases allows for a comparison among developing countries as well as contrasts between developed and developing country cities, their challenges and responses.

For each city, available knowledge is analyzed for various aspects of climate risks (including uncertainty). Background information from the case study cities has been evaluated and selected variables have been assigned to the framework components. The case studies allow for the understanding of the transferability of the climate risk framework to a variety of cities and what "climate services" of data analysis, access, and processing need to be provided at the international level.

To provide concrete examples of how climate risk information can be communicated, current trends in key climate variables (including temperature, precipitation, and the incidence of extreme events) for each of the case study cities have been determined, and recent IPCC 2007 projections (up to 16 models and three emissions scenarios) have been used to create city-focused downscaled climate model projections. The degree to which these models are able to replicate observed climate and climate trends in the past several decades is described. We also explore discrepancies, if any, between the identified risks, vulnerabilities, social capacities, and the current responses of cities to climate-related hazards. This addresses the important question of real-versus-perceived needs.

2.7.1 Buenos Aires, Argentina

Buenos Aires is the third largest city in Latin America, and is the political and financial capital of Argentina. The city is composed of several sub-jurisdictions that were added as the city expanded since its inception in the fifteenth century as a Spanish port. The Greater Buenos Aires Agglomeration (AGBA) has over 12 million inhabitants (National Population Census, 2001), with 77 percent of the population living in the surrounding provincial boroughs, and 23 percent in the central urban core of Buenos Aires City (Instituto Nacional de Estadística y Censos (INDEC), 2003). Buenos Aires City (CABA) is administered by an autonomous government elected directly by its citizens.

2.7.1.1 Hazards and vulnerability

Increases in sea and river levels, rising temperature and precipitation, along with increased frequency of extreme events such

Table 2.1: *Demographics for the case study cities (metropolitan area).*

Metropolitan area	Population	Area	Population density	Slum population as a percentage of national urban population
Buenos Aires	12.0 million	3,833 km^2	3,131 people per km^2	26.2 percent
Lagos	7.9 million	1,000 km^2	7,941 people per km^2	65.8 percent
Delhi	12.9 million	9,745 km^2	1,324 people per km^2	34.8 percent
New York	8.2 million	790 km^2	10,380 people per km^2	N/A

Sources: Authors' compilation from city, state, and national statistics and census bureaus of Argentina, Nigeria, India, and USA; slum data from UN HABITAT, 2008a,b.

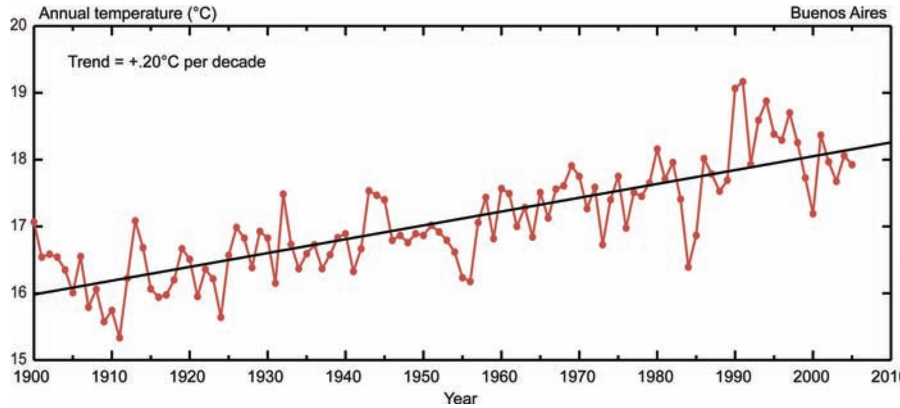


Figure 2.2: *Observed temperatures, Buenos Aires.*

as flooding caused by heavy (convective) rains and storm surges, as well as droughts, are the primary climate-induced hazards for Buenos Aires. The city has a humid subtropical climate with long hot summers, and winters with low precipitation caused by the central semi-permanent high-pressure center in the South Atlantic. This pressure system can cause strong south-southeast winds in the autumn and summer causing floods along the shores (Camillioni and Barros, 2008). For details on observed and projected temperature and precipitation trends for Buenos Aires see Figures 2.2, 2.3, 2.4, and 2.5. In regard to extreme events, there is an increase in frequency of extreme precipitation and associated city floods, see Table 2.2.

Further, occurrence of precipitation events of more than 100 millimeters within 24 hours has increased from 19 times between 1911 and 1970 to 32 times between 1980 and 2000. Such observed increases in the quantity and frequency of extreme precipitation not only adversely affect urban infrastructure, but also damage private property and disrupt the economic and social functioning of the city. With respect to sea level rise and drainage, the city is

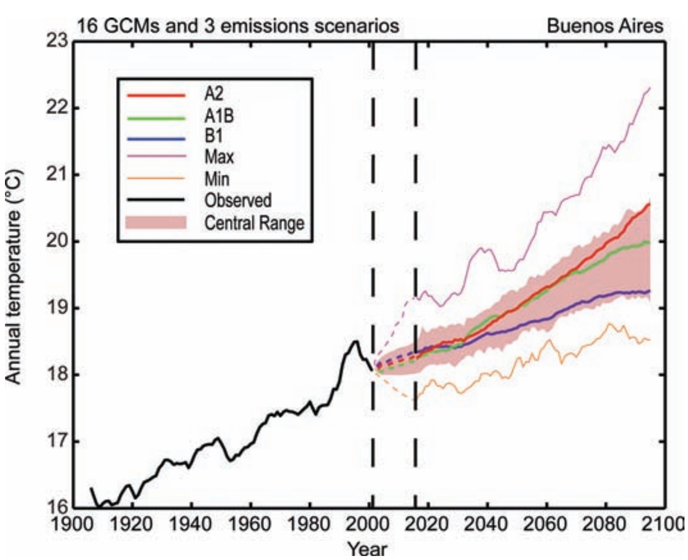


Figure 2.3: *Projected temperatures, Buenos Aires.*

located along the shores of the La Plata River and spreads over the *pampa*, a wide fertile plain, and adjoining the Paraná river delta. As a result, the entire metropolitan area is less than 30 meters above mean sea level. As the city grew, several rivulets that formed the natural drainage system were replaced with a system of underground stormwater drains (Falczuk, 2008).

Spatial distribution of poor versus non-poor

Over the 1990s the city experienced sprawl, with developers building gated communities on the periphery of the metropolitan area, extending the city over an area one-and-a-half times the size of the CABA (Pírez, 2002). With disparity on the rise and migration of the non-poor from the city center to the periphery, the city has been further spatially segregated by income groups. This condition was further intensified with the economic crisis of 2001, which created the "new poor" consisting of the newly unemployed middle class.

The precise distribution and enumeration of the slums is complicated by two additional factors. First is the process of "urban invasions" whereby squatter settlements crop up sporadically across the city. Second, like all other urban data for AGBA, information on the poor is parsed into 30 administrative units. For this research, data for slums and other dilapidated housing in the CABA were derived from an Ombudsman survey in 2006 (see Table 2.3 for quantification of low-income housing), which found that about 20 percent of all households in the urban core of the AGBA live in poor housing conditions.

Additionally, the survey identified 24 new settlements with 13,000 inhabitants located under bridges or simply "under the sky" (Defensoría del Pueblo de la Ciudad de Buenos Aires, 2006). However, unlike developing-country slums, most households have land tenure and property rights related to their homes due to a well-established public housing program in Argentina. Mapping the spatial distribution of differential vulnerability of the poor and non-poor to floods and other hazards is critical to crafting a climate-risk assessment of Buenos Aires (see Figure 2.6).

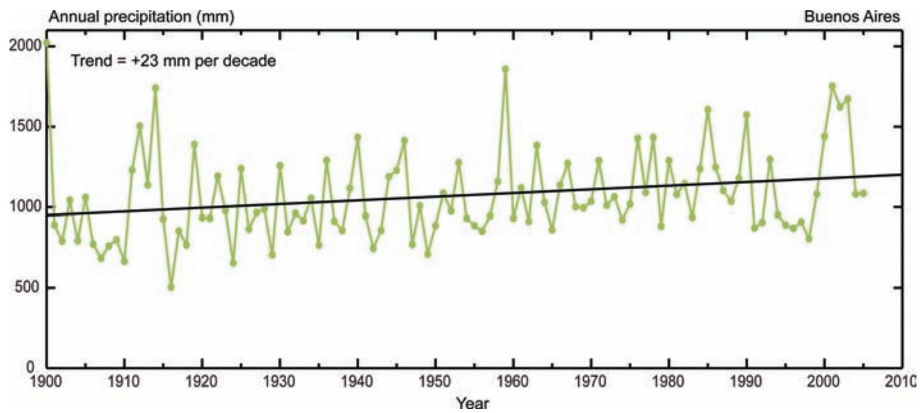


Figure 2.4: *Observed precipitation, Buenos Aires.*

Low elevation urban areas

In its present configuration, a quarter of the metropolitan area is susceptible to floods (Clichevsky, 2002; Menéndez, 2005). Urban expansion continues over the basins of the Matanza-Riachuelo, Reconquista, and Luján rivers, as well as the estuary of the La Plata River (see Figure 2.6). These areas consist of a combination of new gated communities, real estate speculation sites, as well as illegal plots in the flood plain targeted toward the housing needs of the poor. With a lack of regulation governing such urban development and the creation of unprotected infrastructure in the flood plain, the vulnerability of this part of the city is increasing (Ríos and González, 2005).

To assess the vulnerability of the low-elevation areas of the city, a review of past urban floods was undertaken. As reported in newspapers and official assessments, floods impaired all modes of public and private transportation, including domestic flights, road, and rail; disrupted energy supplies, telephone lines, and traffic lights; flooded buildings; and created an overall disruption of city life. Streets and cellars were waterlogged and people living in low-elevation neighborhoods in the suburbs were evacuated (González, 2005). In sum, the economic costs were high. Unlike urban disasters in other developing countries, the death toll in Buenos Aires related to flooding disasters tends to be low. The primary costs are the disruption of the economic activity of the city and damage to public and private property.

As the metropolitan area has been expanding into the flood plains, a simulation to quantify the population vulnerable to sea level rise was conducted. Barros *et al*. (2008) observed: "Assuming little change in population density and distribution, under the scenario of maximum sea-level rise during the 2070 decade […] the number of people living in areas at flood risk with a return period of 100 years is expected to be about 900,000, almost double the present at-risk population." The potential damage to public and private assets can be assessed from a recent survey that estimated that 125 public offices, 17 social security offices, 205 health centers, 928 educational buildings, 306 recreational areas, and 1,046 private industrial complexes are currently at risk of floods.

A conservative estimate by Barros *et al*. (2008) is that at present the damage to real estate from floods is about US$30 million per year. Assuming a business-as-usual scenario, which includes a 1.5 percent annual growth in infrastructure and construction and no adoption of flood-protection measures, the projected annual cost of damages is US$80 and US$300 million by 2030 and 2070 respectively. These estimates do not include the losses to gated communities of the non-poor being built in the coastal area, largely located less than 4.4 meters above mean sea

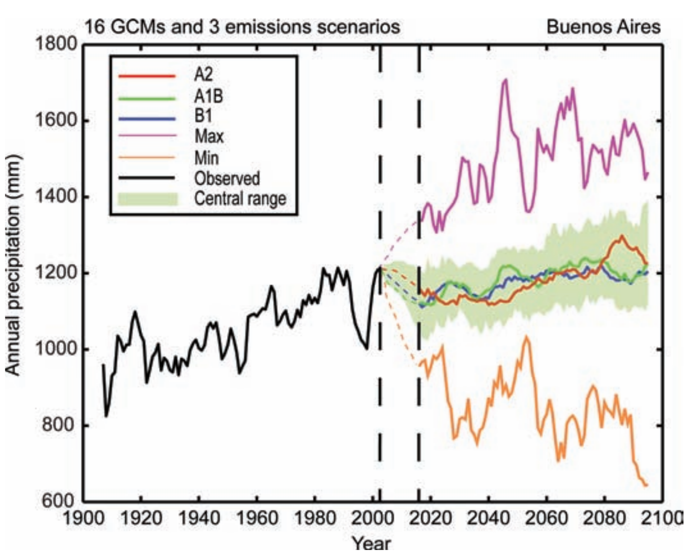


Figure 2.5: *Projected precipitation, Buenos Aires.*

Table 2.2: *Extreme events in Buenos Aires.*

City	Extreme temperatures	Extreme precipitation
Buenos Aires	January & February 1987; December & January 1988; December & January 1996–97; January & February 2001; January 2002; January 2003; January 2004; December 2004	March 1988; May 2000; February 2003

Table 2.3: *Slum population in Buenos Aires City (CABA).*

Housing types by building quality	Number of units
Slums (*villas miseria*)	< 120,000
Properties of other people (*inmuebles tomados*)	200,000
Tenement house (*casas de inquilinato*)	70,000
Lodges	70,000
Rooms in relatives' houses, rental rooms, or overcrowded houses	120,000

Source: Office of the National Ombudsman, Buenos Aires, 2006.

level. Nor does this account for the loss in productivity of the labor force, which can be significant given the size of the population likely to be affected. Thus, the costs of not responding to climate change in the course of urban development are projected to be significant and disruptive.

2.7.1.2 Adaptive capacity: current and emerging issues

The Argentinean government's response to global climate change has been dominated by mitigation efforts related to policies and programs to reduce greenhouse gas emissions (Pochat *et al*., 2006), with relatively little attention to adaptation. The lead national agency to address climate issues is the Secretariat for Environmental and Sustainable Development.

In 1993 Argentina became a signatory to the United Nations Framework Convention on Climate Change. In response, the federal government established the office for Joint Implementation, but in 1998 this was renamed the Office for Clean Development Mechanisms. Further, in 1999 Argentina adopted the objectives of the Greenhouse Gases Reduction Programme, and in 2001 signed on to the Kyoto Protocol. To institutionalize the response to climate change, in 2003 a Climate Change Unit was established within the Secretariat for Environmental and Sustainable Development. In 2007 this evolved into the Climate Change Office. In addition, the government has been supporting a range of research programs, such as the National Program on Climate Scenarios, which was initated in 2005. Through these institutional arrangements, first and second national reports were prepared in 1997 and 2006 respectively. The third version is under preparation (Pochat *et al*., 2006).

However, the roles and responsibilities of governmental agencies in regard to climate change remain fragmented, while adaptation responses, specifically at the city level, remain to be addressed. In addition, four ministries with a dozen departments

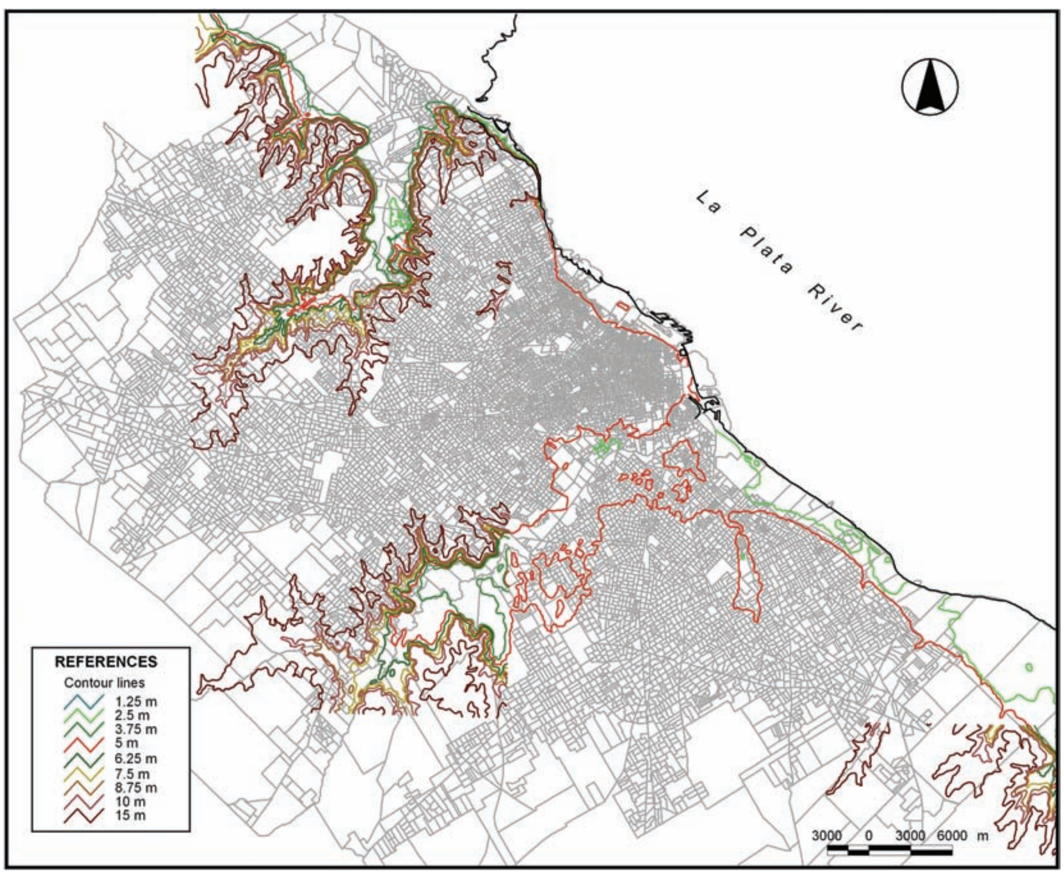


Figure 2.6: *Low-elevation land and land parcels in Buenos Aires.*

Source: Elaborated by S. Gonzalez. Based on AIACC Project, LA 26.

and institutions are involved in flood monitoring and broader disaster management systems (Natenzon and Viand, 2008). Gradually, lower levels of government such as the states and local authorities are taking an interest in addressing climate change mitigation and adaptation, and a range of stakeholders such as NGOs, the media, and citizen groups are participating.

Conflicting plans and multiple jurisdictions reduce the efficacy of climate change response plans at the city level as well (Murgida and González, 2005). For example, in 2007 an Office for Climatic Protection and Energy Efficiency was established within the Ministry for Environment of Buenos Aires City. With the arrival of a new administration in December 2007 this ministry was restructured into the Ministry of Environment and Public Space, with a new Environmental Protection Agency. The Office for Climatic Protection and Energy Efficiency was dismantled despite the fact that previously initiated programs and projects such as "Clean Production" and "Air Quality" continue to be implemented (Murgida, 2007).

The primary obstacles to institutional action at the metropolitan level are lack of actionable climate information, as well as vertical and horizontal fragmentation of jurisdictions with divergent interests and responses. Administrative units within the AGBA address flood management but lack an integrated strategy. For example, within Buenos Aires City two different plans – the Urban Environmental Plan and the Buenos Aires 2015 Strategic Plan – are being implemented simultaneously but with a lack of effective coordination. Further, in practice there are two critical legislative instruments to regulate urban development in the city – namely, the Building Code enacted in 1944 and the Urban Planning Code enacted in 1977. These are complemented by additional measures such as the Flood Control Plan, and post-2001 flood tax rebates for affected communities. However, these plans, codes and norms are inconsistent. For instance, the Urban Planning Code incentivizes the occupation of vulnerable low-lying areas within the city contradicting the flood prevention plans (González, 2005).

Moreover, constantly changing organizational roles and responsibilities of government agencies tasked to address climate change pose a challenge. For instance, in 2005 the Buenos Aires State Government created a unit to address climate change within the provincial Ministry for Environmental Policy. This office continues to be operational under the new local government that was elected in 2007, but the unit has been moved to the Ministry of Social Development and has a reduced mandate. This lack of action orientation is compounded by a general lack of public awareness of the risks associated with climate change (Assessment of Impacts and Adaptation to Climate Change, 2005).

Additionally, there is a mismatch in terms and scales. While the climate adaptation strategies such as flood prevention and management need to take a long-term view and plan for the metropolitan region as a whole, most planning interventions address short-term needs and do not take a citywide view (Murgida and Natenzon, 2007). "By analyzing who participated in the planning process and in which areas they did so, it becomes evident that the vast majority of interventions were partial, some were very specific, and a few encompass different areas and spheres" (Pírez, 2008). These issues become further complicated for the metropolitan region due to the overlap and aggregation of administrative units that lack a central governing authority.

The community of scientists and researchers has taken on an unusual task of coordinating climate-related programs and policies. A leading example of this effort was the launch of the Global Climate Change Research Program at Buenos Aires University (PIUBACC) in May 2007. The objective of this program is to map and link all research as well as city development projects within the metropolitan area so as to provide the government, civil society, and more-specifically interested groups directly involved in climate change programs with a holistic and scientific assessment of climate change risks. Additionally, the scientists are drawing transferable lessons from community knowledge on flood management along the La Plata River coast with a dual focus on the vulnerability of the poor and on adaptation to storm-surge floods (Barros *et al*., 2005).

2.7.2 Delhi, India

Metropolitan Delhi has a population of 16 million, and is rapidly urbanizing with a 3.85 percent annual growth rate over the 1990s amounting to half a million additional inhabitants each year. In 1901 Delhi had 400,000 inhabitants. Furthermore, rising per capita incomes are increasing energy consumption and over-stretching its infrastructure. Delhi is a city of wide income contrasts – in 2000, 1.15 million people were living below the National Poverty line. On the other hand, Delhi's Gross State Domestic Product at current prices was about US$27 billion during 2007 (Department of Planning, 2008).

Delhi has three distinct seasons – summer, winter, and monsoons with extreme temperatures and concentrated precipitation. Summers begin in mid March, lasting for three months, and are dry and hot with temperatures peaking at about 40 °C in the months of May and June. Monsoons are between mid June and September, during which period Delhi receives most of its 600 millimeters of annual rainfall, with July and August getting as much as 225 millimeters each, see Figures 2.7–2.10 for seasonal variation in temperature and precipitation. Winters are dry and last from November to mid March, with December and January being the coldest months with temperatures as low as 7 °C (Delhi, 2009).

2.7.2.1 Hazards and vulnerability

The National Action Plan for Climate Change and related analysis provides an overview of climate change issues confronting India as recognized by the federal government (see Government of India, 2002, 2008). Through a review of research on climate science, policy papers, and practitioner notes, five hazards are

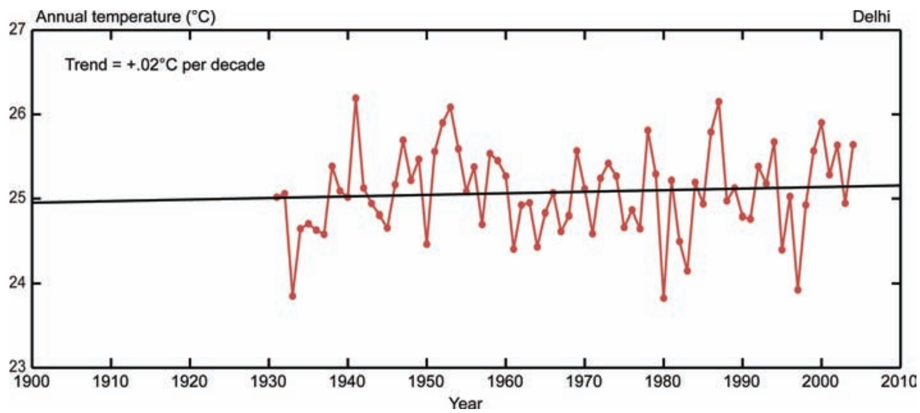


Figure 2.7: *Observed temperatures, Delhi.*

identified (Revi, 2007). First, although there are uncertainties with scaling down global models such that they reflect regional climate conditions such as the Indian monsoon, temperature, precipitation, and sea-level are likely to rise. For a summary of observed and projected temperatures for Delhi see Figures 2.7 and 2.8. Mean extreme temperatures, as well as maxima and minima, are expected to increase by 2 to 4 °C, likely to result in an average surface warming of 3.5 to 5 °C within this century.

Second, average mean rainfall is projected to increase by 7 to 20 percent due to the increase in mean temperature and its impact on the Indian monsoon cycles within the latter half of this century (see Figures 2.9 and 2.10). However, some drought-prone areas are expected to become drier and flood-prone areas will very likely experience more intense periods of precipitation. Third, 0.8 meters is the projected centennial rise in mean sea level. Fourth, extreme events like the Mumbai flood of 2005 are expected to be more frequent in western and central India. A combination of these hazards exposes the cities in this region to a range of other climate-induced extreme events such as droughts, temporary and permanent flooding, both inland and in coastal areas, and cyclones.

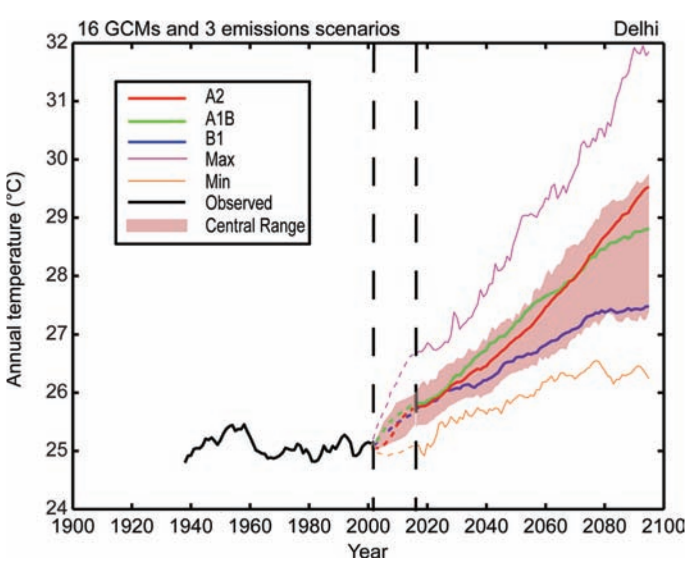


Figure 2.8: *Projected temperatures, Delhi.*

Delhi's physical infrastructure, social services, and slum populations make the city highly vulnerable. Demand for basic infrastructure services such as water, electricity, and public transport far exceeds supply (Delhi Development Authority, 2005). To add to the existing conditions, climate change-induced variability in rains could worsen the severe shortage of drinking water in summers and aggravate the floods in the monsoon season, thus making the existing energy shortage more challenging to address. With regard to transportation, Delhi has the highest per capita vehicular population in India – 5.4 million automobiles for 15 million people. This poses a challenge for a city with mixed land use and varying urban densities within the metropolitan region to introduce effective modes of public transport. Carbon emissions from vehicles, traffic congestion, and increasing particulate matter all pose challenges. These and other challenges create widespread public health risks to the inhabitants of Delhi. For example, lack of adequate sanitation facilities for the poor poses a problem for a rapidly growing city where a large proportion of the population lives in slums.

The hyper-dense nature of the slums, despite Delhi's relatively low population density and the centrality of the poor in provision of services – from household help to a range of labor-intensive and low-wage tasks – poses an enormous challenge. About 45 percent of the city's population live in a combination of unregulated settlements, including unauthorized colonies, villages, and slums. Further, three million people live along the Yamuna River, which is prone to flooding, where 600,000 dwellings are classified as slums.

Moreover, increasing competition for scarce basic services caused by the rapidly growing population of Delhi poses public health as well as quality-of-life challenges. For example, some poor settlements lack basic amenities resulting in open defecation. Although the extent of the impacts remains to be assessed, potential climate change impacts added to current local environmental stresses are likely to intensify this crisis. Moreover, the low quality of housing in slums and their proximity to

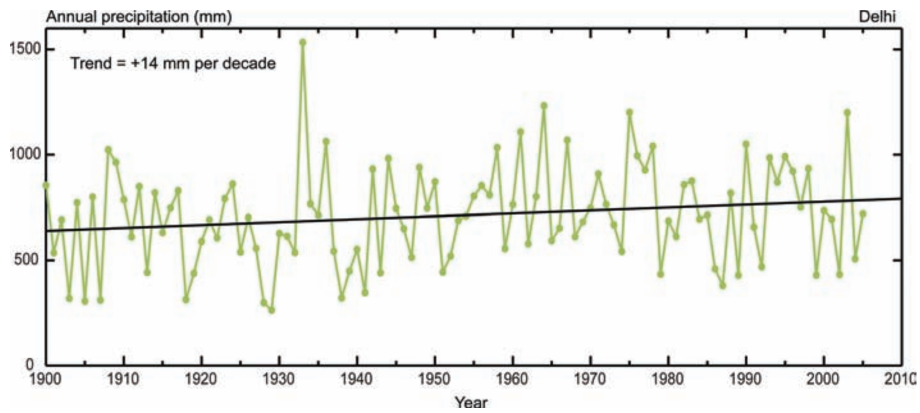


Figure 2.9: *Observed precipitation, Delhi.*

environmentally degraded land and flood-prone areas further exacerbate the vulnerability of the poor. Within the slums, climate-induced stress is likely to affect certain social groups more than others, particularly the elderly, women, and children.

2.7.2.2 Adaptive capacity: current and emerging issues

The government of Delhi has made many efforts towards climate change mitigation, but there is less emphasis on adaptation. In addition to the issues of energy, water, and transportation, mitigation projects also encompass public health and other social and economic development efforts. Climate change mitigation efforts by the government of Delhi were introduced first in the government departments and are being gradually expanded to include other stakeholders – schools, households, and firms. Most initiatives remain project-oriented (Department of Environment, 2008).

Some projects, such as the Bhagidari program, seek participation from neighborhood groups, private-sector associations, schools, and non-governmental organizations to enhance civil society engagement in environmental management, creating an expanded policy space for addressing climate change. Such collaboration holds the potential to address broader issues of climate adaptation by building awareness as well as capacity of stakeholders to respond. However, the most striking of all climate mitigation initiatives in Delhi so far is the establishment of the world's largest fleet of compressed natural gas (CNG) fueled public transport in response to a Supreme Court order. This has resulted in 130,000 CNG-powered vehicles, 145 CNG fuel stations, as well as improved vehicular emission standards like those adopted by the European Union. The greatest lesson from this initiative is in recognizing the diverse set of triggers and actors that can start adaptation and mitigation programs.

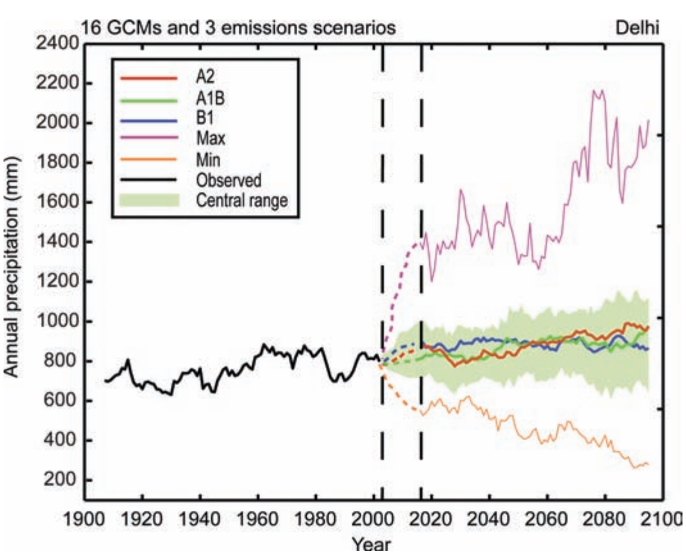


Figure 2.10: *Projected precipitation, Delhi.*

Some mitigation measures have co-benefits for adaptation. For instance, adoption of green building technology that is mandatory for the Public Works Department and the Airport Authority was introduced to address mitigation, but has adaptation benefits as well. Expected greenhouse gas emissions reductions are 35 to 50 percent in general energy consumption and up to 100 percent in energy for water heating. Moreover, the New Delhi Municipal Council aims to reduce other demand for energy and has set time-bound efficiency targets. The Municipal Corporation of Delhi is making efforts to install compact fluorescent lamps and capacitor banks to increase energy efficiency. Further, the government has a program that subsidizes electric vehicles and is encouraging the introduction of the Reva car, as well as battery-operated two- and three-wheelers.

Delhi also has expanded its forest cover over the past ten years. The cities greening program is considered to be one of the largest in the world. The forest cover has grown from 3 percent in 1998 to 19 percent in 2005. The city planted 1.7 million trees in 2007 and the forest cover grew to 300 square kilometers. To maintain the momentum, the city planned to plant 1.8 million saplings in the fiscal year 2009, increasing the greenery cover to a total of 326 square kilometers. The city also has a policy to plant ten trees for every tree chopped down. This project is done in collaboration with several stakeholders including school children, female homemakers, and neighborhood associations. The saplings are distributed *gratis* through a host of distributors. This afforestation effort is part of a Clean Development Mechanism (CDM) project proposal. To scale up mitigation efforts, the Delhi government has established a program with the aim to raise awareness about carbon credits and clean development mechanisms among various departments. The objective is to develop a holistic approach towards reducing greenhouse gas emissions and enable projects that can redeem carbon credits. In essence, these mitigation projects can prove vital for adaptive capacity as well. For example, green roofs and walls, and tree planting help to cool the urban environment and reduce heat island effects, as do many of the energy-efficiency projects related to buildings.

While the neglect of adaptation remains a concern, another co-benefit to mitigation efforts in Delhi is the climate change awareness and administrative capacity being built as a result of mitigation projects that may help as adaptation projects and policy measures are introduced. Not only is the government developing financial incentives to introduce programs and adopting a multisectoral approach that involves various departments within the city jusrisdiction, they are also learning to utilize mechanisms such as UNFCCC's CDM funds that are likely be equally relevant for adaptation. Illustrations of such efforts are the CDM projects and certified emission reductions (CERs) in the water sector.

While Delhi is making major efforts towards mitigation of climate change through carbon emission reductions and other environmental improvements, there is a significant lack of awareness about the need for adaptation to climate change. Therefore, the city has not yet planned for adaptation. Further, Delhi's response to climate change is often less than effective as well as piecemeal because its efforts are primarily project-oriented. In the experience of the Delhi government, incentives – subsidies and grants – have been effective for initiating projects, but operation and management frequently remain neglected. For instance, subsidies to install rainwater-harvesting systems have created demand, but subsequent maintenance is too often ignored and many systems fall into disrepair. Such experiences hold the potential to inform adaptation efforts as well.

Gradually the city is developing a programmatic approach, but there is a need to coordinate between departments and among levels of government. For example, while the Prime Minister of India has recently released the National Action Plan for Climate Change, Delhi's local efforts will need to be reconciled with regional and national priorities.

2.7.3 Lagos, Nigeria

Lagos is Africa's second most populous city and has grown explosively, from 300,000 in 1950 to an expected 18 million by 2010, ranking it as one of the world's ten largest cities. The metropolitan area, an estimated 1,000 square kilometers, is a group of islands surrounded by creeks and lagoons and bordered by the Atlantic Ocean. Lagos is the commercial and industrial hub of Nigeria, a country with a GDP three times larger than any other country in West Africa. Lagos is home to a large amount of commercial infrastructure, and has greatly benefited from Nigeria's natural resources of oil, natural gas, coal, fuel wood, and water. For an overview of the state of Nigerian cities see UN-HABITAT (2004).

The climate of Lagos is affected by Atlantic Ocean and atmospheric interactions both within and outside its environment, in which the Inter-Tropical Convergence Zone (ITCZ) plays a controlling factor. The movement of the ITCZ is associated with the warm humid maritime tropical air mass with its southwestern winds and the hot and dry continental air mass with its dry northeasterly winds. Maximum temperatures recorded during the dry season are high and range from 28 to 33 °C when the region is dominated by the dry northeast trade winds. Minimum temperature of about 26 °C is experienced during the wet season of May to September.

The city of Lagos experiences relatively high to very high temperatures throughout the year. The mean annual temperature is about 28 °C and the maximum and minimum temperatures are 33 °C and 26 °C respectively. High to very high monthly rainfall is also experienced between May and November, although significant variations in monthly rainfall peak values are experienced. For example, between 1950 and 2006, more than ten instances were recorded with a maximum rainfall of over 700 millimeters. Minimum monthly rainfall of less than 50 millimeters is experienced between December and March. Occasionally, extreme precipitation events are experienced in June. On June 17, 2004, for example, 243 millimeters of rain was experienced in Victoria Island and the Lagos environs. This resulted in flooding of streets and homes, collapse of bridges, and massive erosion of the main road linking Lekki to Lagos Island. About 78 percent of the total rainfall amount for the month was experienced in one day in June. The city was ill-prepared for that amount of rainfall.

2.7.3.1 Hazards and vulnerability

Ekanade *et al*. (2008) describe the nature and magnitude of the climate change hazards for the city level using different greenhouse gas emission scenario models. The IPCC (2001a) Special Report on Emission Scenarios A2 and B1 climate change scenarios were utilized to project 30-year timeslices for temperature and rainfall values for the City of Lagos and Port Harcourt and the coastal areas of Nigeria. This study did not, however, project sea level rise.

Records from the two stations (Ikeja and Lagos) used in this analysis show that monthly maximum temperature was increasing at about 0.1 °C per decade from 1952 to 2006, while monthly minimum was decreasing at about 0.5 °C per decade: since the 1900s average temperature has increased 0.07 °C per decade (see Figure 2.11). At the extremes, monthly maximum temperatures for Lagos have reached above 34 °C during seven of the last twenty years. The number of heat waves in Lagos has also increased since the 1980s (see Table 2.4). There have been very few incidences of unusually cold months of less than 20 °C

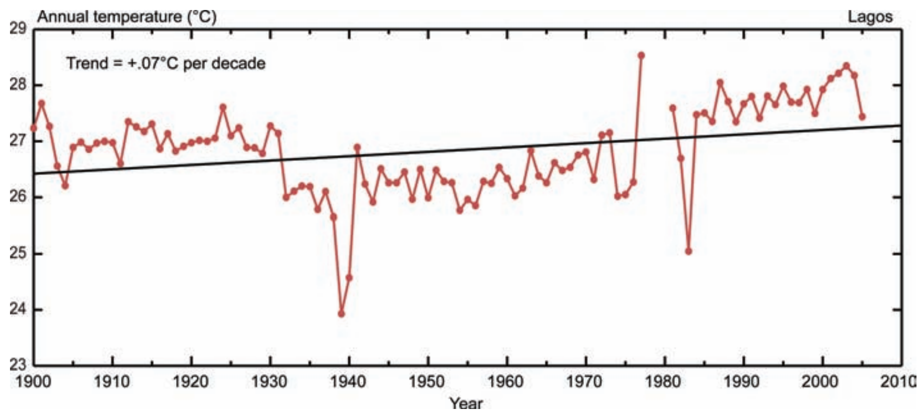


Figure 2.11: *Observed temperatures, Lagos.*

since 1995. Projected temperature for Lagos for the 2050s anticipates a 1 to 2 °C warming (see Figure 2.12).

According to historical records, the total annual precipitation in Lagos has decreased by 8 millimeters per decade since 1900 (see Figure 2.13). In keeping with the overall precipitation trends, most of Lagos has experienced decreases in rainfall amounts during the rainy season. For example, between 1950 and 1989 more than 20 months experienced rainfall amounts of over 400 millimeters. In the recent period between 1990 and 2006, however, very few (four) rainy months recorded over 400 millimeters of rain. In the twenty-first century, precipitation in Lagos is expected to be less frequent but more intense; projected precipitation for Lagos for the 2050s anticipates an uncertain 5 percent change in mean precipitation (see Figure 2.14; Table 2.4).

Coastal storm surge also is a concern. Lagos, as well as the entire Nigerian coast, is projected to experience more storm surges in the months of April to June and September to October annually. This increase in storminess is projected to be

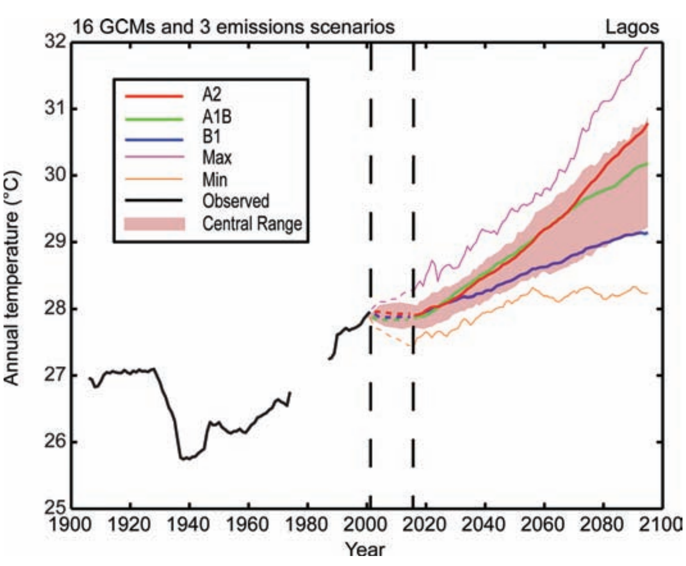


Figure 2.12: *Projected temperatures, Lagos.*

accompanied by greater extreme wave heights along the coasts. According to Folorunsho and Awosika (1995) the months of April and August are usually associated with the development of low-pressure systems far out in the Atlantic Ocean (in the region known as the "roaring forties"). Normal wave heights along the Victoria Beach range from 0.9 m to 2 m. However, during these swells, wave heights can exceed 4 m. The average high high-water (HHW) level for Victoria Island is about 0.9 m above the zero tide gauge with tidal range of about 1 m. However, high water that occurs as surges during these swells has been observed to reach well over 2 m above the zero tide gauge. These oceanographic conditions are aggravated when the swells coincide with high tides and spring tide.

An extreme event, which can be considered a case study for future threats, was observed between August 16 and 17, 1995, when a series of violent swells in the form of surges were unleashed on the whole of Victoria Beach in Lagos. The most devastating of these swells occurred on August 17, 1995, and coincided with high tide, thus producing waves over 4 m high causing flooding. Large volumes of water topped the beach and the Kuramo waters. A small lagoon separated from the ocean by a narrow – 50 m wide – strip of beach was virtually joined to the Atlantic Ocean. Many of the streets and drainage channels were flooded, resulting in an abrupt dislocation of socio-economic activities in Victoria and Ikoyi Islands for the period of the flood.

In addition, coastal erosion is very prevalent along the Lagos coast. Bar Beach in Lagos has an annual erosion rate of 25 to 30 m. Earlier IPCC scenarios have been used to estimate the effects of 0.2, 0.5, 1, and 2.0 m sea level rise for Lagos. Along with coastal flooding and erosion, another adverse effect of sea level rise on the Lagos coastal zone as earlier assessed by Awosika *et al*. (1993a, b) is increased salinization of both ground and surface water. The intrusion of saline water into groundwater supplies is likely to adversely affect water quality, which could impose enormous costs on water treatment infrastructure.

Lagos has an extremely dense slum population, many of whom live in floating slums. These are neighborhoods that extend out

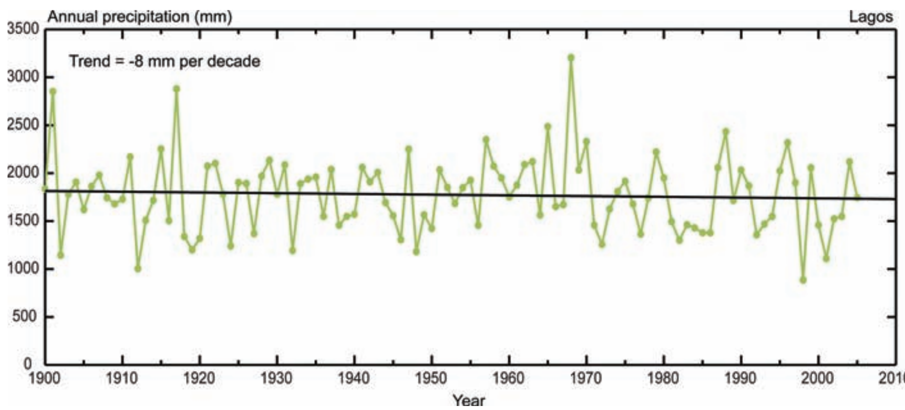


Figure 2.13: *Observed precipitation, Lagos.*

into the lagoons scattered throughout the city. The barrier lagoon system in Lagos, which comprises Lagos, Ikoyi, Victoria, and Lekki, will be adversely affected through the estimated displacement of between 0.6 and 6 million people for sea level rise of between 0.2 and 2 m (Awosika *et al*., 1993a) (see Table 2.5).

In their study of the impacts and consequences of sea level rise in Nigeria, French *et al.* (1995) recommended that buffer zones be created between the shoreline and the new coastal developments. A more generalized multisectoral survey of Nigeria's vulnerability and adaptation to climate change was funded by the Canadian International Development Agency (CIDA) through its Climate Change Capacity Development Fund (CCCDF). This study has served to create awareness of climate change issues and of the need for manpower development.

Even more worrisome is the general sensitivity of Lagos to climate change due to its flat topography and low-elevation location, high population, widespread poverty, and weak institutional structures. Many more vulnerabilities stem from these characteristics including the high potential for backing up of water in

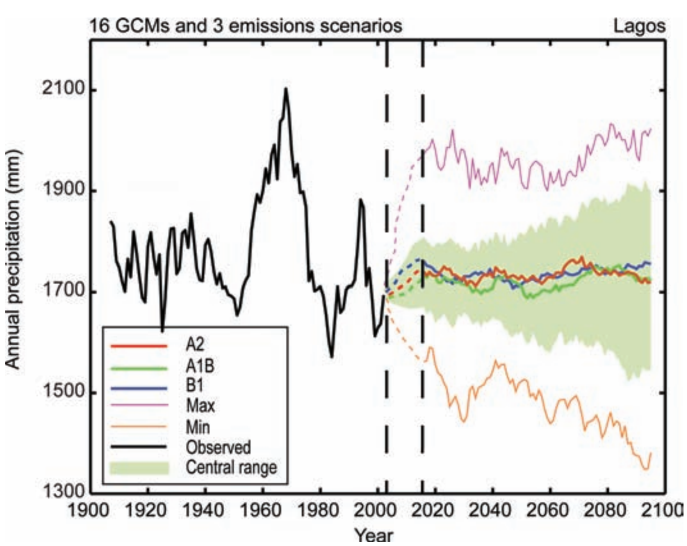


Figure 2.14: *Projected precipitation, Lagos.*

drainage channels, inundation of roadways, and severe erosion. The barrier lagoon coastline in the western extremity, including the high-value real estate at Victoria Island and Lekki in Lagos, could lose well over 584 and 602 square kilometers of land respectively from erosion, while inundation could completely submerge the entire Lekki barrier system (Awosika *et al*., 1993a, b). Moreover, flooding poses greater threats to the urban poor in several African cities (Douglas and Alam, 2006). See Figure 2.15 for topography identifying low-lying areas that overlap with built-up areas and are prone to flooding.

Intense episodes of heat waves will likely severely strain urban systems in Lagos, by inflicting environmental health hazards on the more vulnerable segments of the population, imposing extraordinary consumption of energy for heating and air conditioning where available, and disrupting ordinary urban activities.

It is very likely that heat-related morbidity and mortality will increase over the coming decades; however, net changes in mortality are difficult to estimate because, in part, much depends on complexities in the relationships among mortality, heat, and other stresses. High temperatures tend to exacerbate chronic health conditions. An increased frequency and severity of heat waves is expected, leading to more illness and death, particularly among the young, elderly, frail, and poor. In many cases, the urban heat island effect may increase heat-related mortality. High temperatures and exacerbated air pollution can interact to result in additional health impacts.

Table 2.4: *Extreme events in Lagos.*

City	Extreme temperatures	Extreme precipitation
Lagos	March 1988; March 1990; February 1998; March 1988; March 2001; March 2002; February 2003; March 2003; August 2004	May 1958; June 1962; July 1968; August 1998; November 1998

Source: Center for Climate Systems Research, Columbia University.

Table 2.5: *Estimation of internally displaced people by sea level rise scenarios in Lagos.*

Sea level rise scenarios	0.2 m	0.5 m	1.0 m	2.0 m
By shoreline types, number of people displaced (in millions)				
Barrier	0.6	1.5	3.0	6.0
Mud	0.032	0.071	0.140	0.180
Delta	0.10	0.25	0.47	0.21
Strand	0.014	0.034	0.069	0.610
Total	0.75	1.86	3.68	7.00

Source: Awosika et al. (1992).

Impacts are projected to be widespread, as urban economic activities will probably be affected by the physical damage caused to infrastructure, services, and businesses, with repercussions on overall productivity, trade, tourism, and on the provision of public services.

The degraded state of the urban form and poverty is indicative of the expected low resilience of most of the inhabitants of the city to external hazard stressors such as those often associated with climate extreme events. Most of the city's slums are located on marginal lands that are mainly flood-prone with virtually no physical and social infrastructure. Furthermore, some of the planned and affluent neighborhoods in many parts of the city still experience flooding during "normal" rainfall. This may be attributed to the little-to-no attention often given to the provision and maintenance of sewer and storm drains in these supposedly "planned" affluent neighborhoods. For instance, Ikoyi, one of the most highly priced neighborhoods in the city, was actually developed from an area originally covered by about 60 percent wetland.

2.7.3.2 Adaptive capacity: current and emerging issues

Even with active membership in the C40 Large Cities Climate Leadership network, Lagos megacity still does not have a comprehensive analysis of the possible climate risks facing it, especially with respect to inundation due to sea level rise. The implication is that there is an urgent need to address the obvious lack of awareness of the vulnerability of Lagos to climate change and the need to begin to plan adaptation strategies. Recently, tackling the problem of flooding and coastal erosion has been given more attention by the Lagos State government in the form of a sea wall along Bar Beach in Victoria Island. This activity, however, is evidence that local awareness appears to be lacking the full scope of the city's vulnerability to climate change.

Although the attention of the city managers is more focused on filling its long physical infrastructural gap due to years of neglect, the lack of concern or awareness of likely sea level rise in Lagos is worrisome. There continues to be sand-filling of both the Lagos Lagoon and the Ogun River flood plain in the Kosofe

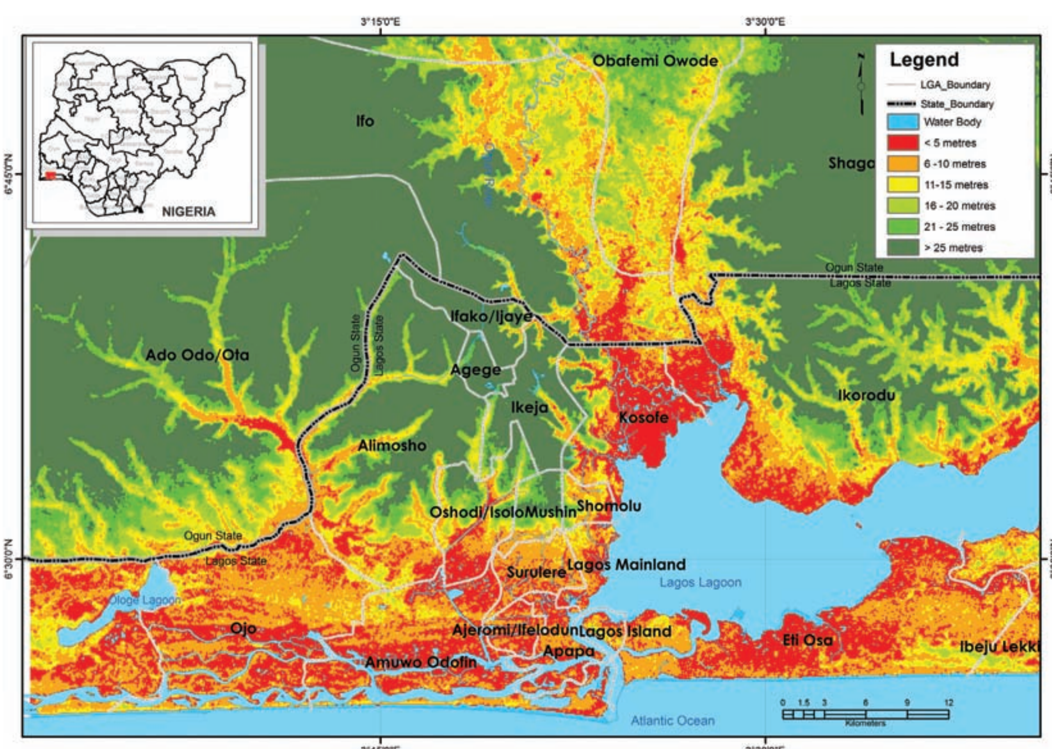


Figure 2.15: *Lagos topography.*

Source: Ademola Omojola – Author's analysis, derived from the Shuttle Radar Topography Mission (SRTM) Digital Terrain Model (DTM) data. The DTM data were color-coded, clipped for the study area, and the administrative map superimposed.

local government area to about 2 m above sea level for housing developments. Such activities need to be done with projections of sea level rise due to climate change as part of the planning process.

Currently, the leading actor on climate change issues in the city is the Lagos State government, which has been influenced by its membership of the C40 Large Cities Climate Summit. Some of the mitigation actions being pursued by the Lagos State government in the city include:

1. Improvement of the solid waste dump sites that are notable point sources of methane – a greenhouse gas – emissions in the city;
2. The new bus rapid transport (BRT) mass transit system is already shopping for green technology to power vehicles in its fleet;
3. Commencement of tree planting and city greening projects around the city; and
4. Proposed provision of three air-quality monitoring sites for the city.

The full picture of the nature of climate change and variability, its magnitude, and how it will affect the city is yet to be analyzed to support any informed adaptation actions. Thus, the climate risk reduction adaptation actions presently taken in the city are primarily spin-offs from the renewed interest of the city's management in reducing other risks and taking care of developmental and infrastructural lapses, rather than being climate change driven. Some of these adaptation activities include:

1. The sea wall protection at Bar Beach on Victoria Island to protect the coastal flooding and erosion due to storm surges;
2. Primary and secondary drainage channel construction and improvement to alleviate flooding in many parts of the city;
3. Cleaning of open drains and gutters to permit easy flow of water and reduce flooding by the Lagos State Ministry of Environment Task Force, locally referred to as "Drain Ducks";
4. Slum upgrade projects by the LMDGP project; and
5. Awareness and education campaigns such as the formation of Climate Clubs in primary and secondary schools in Lagos, and organization of training sessions and workshops on climate change issues.

Due to the increasing activity in the Ogun State sector of the city, a regional master plan for the years 2005–2025 (Ogun State Government, 2005) has been developed for its management. However, the issue of climate change risks to infrastructure and the different sectors such as water and wastewater (Iwugo *et al.*, 2003), health, and energy, is not yet reflected in the report.

"Normal" rainfall is known to generate extensive flooding in the city largely because of inadequacies in the provision of sewers, drains, and wastewater management, even in government-approved developed areas. Consequently, an increase in the intensity of storms and storm surges is likely to worsen the city's flood risks. Since the local governments work closely with the people and communities threatened by climate risks, there is a need to create awareness at the local government level. There is an urgent need to empower them intellectually, technically, and financially to identify, formulate, and manage the climate-related emergencies and disasters, as well as longer-term risks, more proactively.

2.7.4 New York City, United States

With 8.2 million people, a $1.1 trillion GDP (Bureau of Economic Analysis, 2008) and an operating budget of over $40 billion, New York City is the largest city in the USA both in population and in economic productivity (The City of New York, 2007, 2009). The distribution of wealth within the city, however, has been described as an "hourglass economy," where there is a shrinking of the middle class and growth in both the upper- and lower-income populations (Rosenzweig and Solecki, 2001).

New York City is an archipelago with five boroughs spread out over three islands – Long Island, Manhattan, and Staten Island – and the mainland of the USA. New York is one of the world's most important international financial hubs. As a coastal city, most of New York City sits at a relatively low elevation with approximately 1 percent of the city lower than 3 meters (10 feet) (Rosenzweig and Solecki, 2001). Much of Manhattan's very low-lying land is home to some of the most important economic infrastructure in the world.

New York City has a temperate, continental climate characterized by hot and humid summers as well as cold winters and consistent precipitation year round. Using a baseline period of 1971–2000, records show an average temperature of 12.7 °C with precipitation averaging 109 to 127 centimeters per year. Recent climate trends show an increase in average temperature of 1.4 °C since 1900 and a slight increase in mean annual precipitation (New York City Panel on Climate Change (NPCC), 2009) (see Figures 2.16 and 2.20).

2.7.4.1 Hazards and vulnerabilities

New York City is susceptible to mid-latitude cyclones and nor'easters, which peak from November to April. These storms contribute greatly to coastal erosion of vital wetlands that help defend areas of the city from coastal flooding. Tropical cyclones (hurricanes) also have the potential to reach New York City, usually during the months of August and September. There is some indication that intense hurricanes will occur more frequently in the future, but this is an area of active scientific research.

Based on climate model projections and local conditions, sea level is expected to rise by 4 to 12 centimeters by the 2020s and 30 to 56 centimeters by the 2080s (see Figures 2.18 and 2.19); when the potential for rapid polar ice-melt is taken into account based on current trends and paleoclimate studies, sea level rise projections increase to between 104 and 140 centimeters (NPCC, 2009). The possibility of inundation during coastal storms is greatly enhanced with the projected effects of sea level rise.

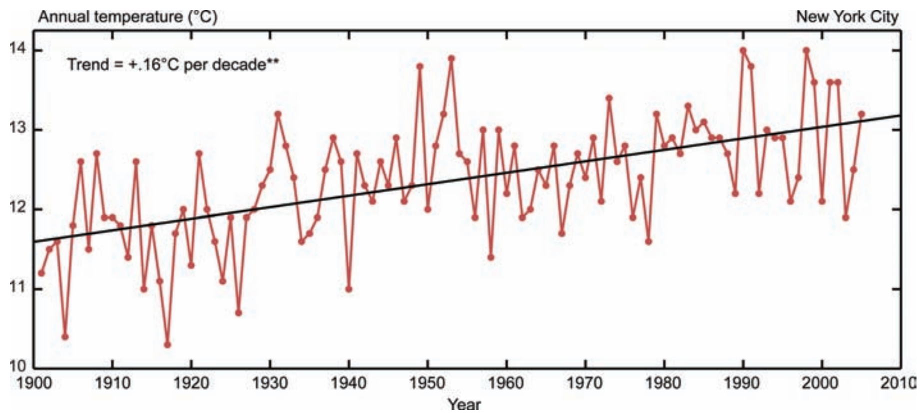


Figure 2.16: *Observed temperatures, New York City.*

Another hazard to impact New York City as a result of climate change is rising mean temperature, along with the associated increase in heat waves. The annual mean temperature in New York City has increased nearly 2 °C since 1900 (NPCC, 2009). Climate models predict that the average temperature will increase by between 1 and 1.5 °C by 2020 and 2 to 4 °C by the 2080s as seen in Figure 2.17 (NPCC, 2009). As defined by the New York Climate Change Task Force, a heat wave is any period of three straight days with a temperature over 32 °C. The frequency of heat waves is projected to increase as the number of days over 32 °C increases. These higher temperatures will also intensify the urban heat island in New York City, since urban materials absorb radiation throughout the daytime and release it during the night, causing minimum temperatures to rise (Rosenzweig and Solecki, 2001; Kinney *et al.*, 2008). These sustained, higher temperatures exacerbate the effects of heat on humans (Basu and Samet, 2002).

Inland floods and droughts are two more hazards that confront New York City. Climate models indicate that precipitation in New York City is likely to increase by up to 5 percent by the 2020s and between 5 and 10 percent by the 2080s, as seen in Figure 2.21 (NPCC, 2009). These increases are projected to come in the form of more intense rain events. This means more days without precipitation between larger and more intense storms. As extreme rain events are expected to increase in intensity while decreasing in frequency, many of the rivers and tributaries that flow through New York City and feed into the bodies of water that surround the city may breech their banks more frequently, as they will likely be unable to handle the volume of water flowing into them as runoff.

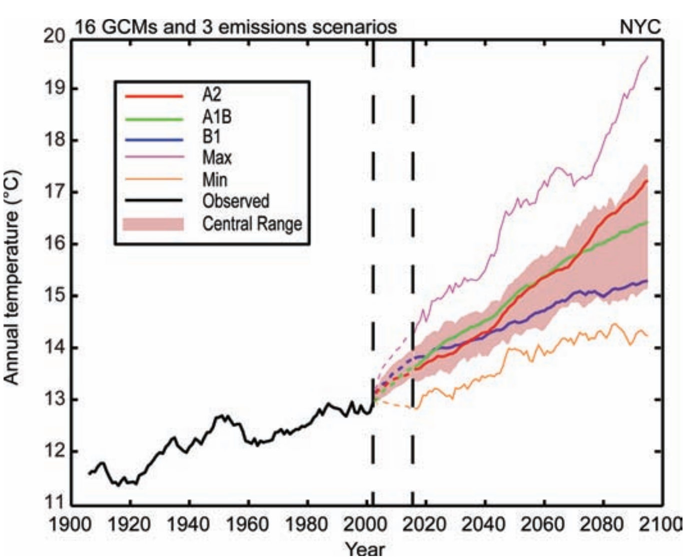


Figure 2.17: *Projected temperatures, New York City.*

Droughts may also prove to be a hazard as a result of climate change if the period between rain events increases. A major concern is the New York City water supply, which is drawn from up to 100 miles north of the city. The higher levels of precipitation associated with climate change are expected to be offset by the greater rates of evaporation associated with temperature increase, thus increasing the likelihood of drought (NPCC, 2009).

The impacts of these climate hazards are interconnected and affect many systems in New York City differently but simultaneously. Roadways and subways, as well as ferry ports, industries located along the coast, and wastewater treatment facilities are susceptible to inundation. More hot days will increase electricity demand to run cooling systems, thereby increasing CO_2 emissions. The erosion of natural defenses such as coastal wetlands increases the likelihood of flooding of nearby neighborhoods and industries.

Some populations are more vulnerable than others and these vulnerabilities are frequently differentiated along the lines of inland versus proximity to coast, young versus old, and rich versus poor. One key climate change vulnerability is related to air quality and human health, since degradation of air quality is linked with warmer temperatures. The production of ozone (O_3) and particulate matter with diameters below 2.5 micrometers ($PM_{2.5}$) in the atmosphere is highly dependent on temperature (Rosenzweig and Solecki, 2001). Therefore, increased temperatures are likely to make managing these pollutants more difficult. Both of these pollutants affect lung functioning,

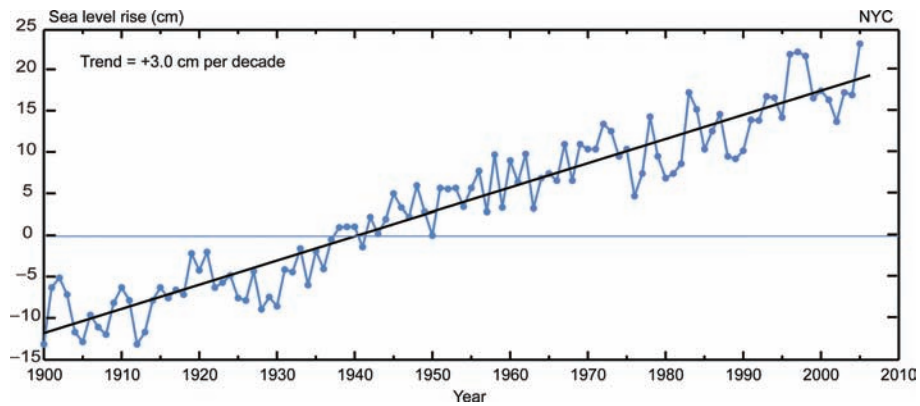


Figure 2.18: *Observed sea level rise, New York City.*

with higher ozone levels being associated with increased hospital admissions for asthma. Further, the elderly and those suffering from heart- and lung-related diseases have been shown to be more susceptible to the effects of heat, often resulting in death from heat stroke and heat-related causes (Knowlton *et al.*, 2007).

New York City is vulnerable to heat waves and, as an archipelago, is particularly vulnerable to the effects of storm surge as a result of sea level rise. Projected sea level rise of 30 to 58 centimeters – or 104 to 140 centimeters, if rapid polar ice-melt is considered – is not expected to inundate the city extensively; rather, the problem emerges when larger storms such as the 1-in-100 year storm, which are expected to become more frequent, produce a greater storm surge that will likely cause damaging floods (NPCC, 2009) (see Figure 2.22).

Certain populations are more vulnerable to the effects of heat and higher sea levels. Approximately 967,022 people in New York City are aged 65 or older and of those it is estimated

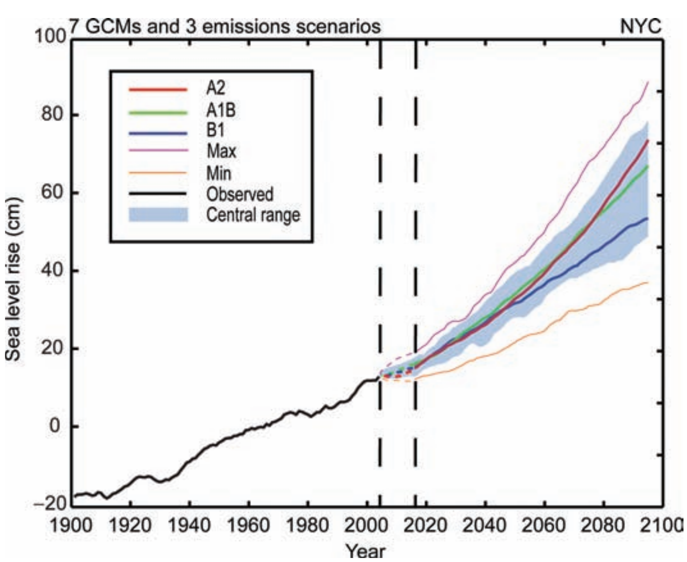


Figure 2.19: *Projected sea level rise, New York City.*

that 43 percent are living with some sort of disability (US Census Bureau, 2008). These two factors contribute to the extreme vulnerability to heat of the elderly (Basu and Samet, 2002). According to the Department of Health for the City of New York, during the heat wave of 2006 over half of those who died in New York City were over age 65 and all but five people were known to have suffered from some type of medical condition (Department of Health and Mental Hygiene (DOHMH), 2006).

New York City is a densely populated city with approximately 10,380 people in each of its 305 square miles or 790 square kilometers (Department of City Planning, 2009). Within this area there are clear pockets of wealth and poverty. The areas of low per capita income are in northern Manhattan, above Central Park, the borough of the Bronx and parts of Brooklyn. Sea level rise and coastal flooding are concerns for certain parts of these areas including Coney Island, Brighton Beach, and Jamaica Bay. One of the more recurring vulnerabilities for these populations is extreme heat and the diminished air quality that accompanies the heating trend that New York City has seen over the last 100 years and that is projected to continue. The US Census Bureau has estimated that for the period 2005–2007 about 20 percent of the people in New York City were living below the poverty line as established by the US Government (US Census Bureau, 2008). During the heat wave of 2006, 38 of those who died of heat stroke did not have functioning air conditioning in their apartment (DOHMH, 2006).

2.7.4.2 Adaptive capacity: current and emerging issues

The environment in which New York City makes climate change adaptation and mitigation decisions is highly complex. Due to shared regional transportation, water, and energy systems, the stakeholders in any decision include numerous local governments, multiple state governments, businesses, and public authorities.

The foundation for tackling the challenges of climate change in New York City began in the mid 1990s when the New York Academies of Science published *The Baked Apple? Metropolitan New York in the Greenhouse* in 1996. Shortly thereafter, the

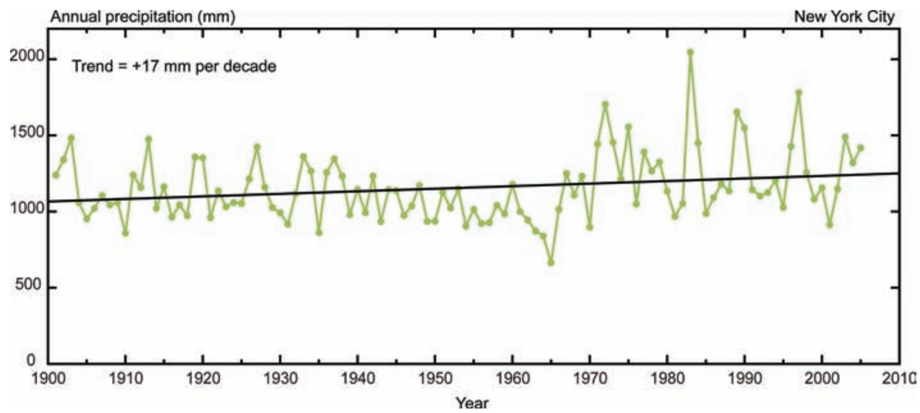


Figure 2.20: *Observed precipitation, New York City.*

Earth Institute at Columbia University, through the Center for Climate Systems Research (CCSR) released *Climate Change and a Global City: The Potential Consequences of Climate Variability and Change* (Rosenzweig and Solecki, 2001). This report covered the Metro–East Coast Region and served as the first assessment of climate change and cities in the USA. In 2008, CCSR worked with the New York City Department of Environmental Protection to develop a sector-specific climate assessment and action plan for New York City's water system (New York City Department of Environmental Protection, 2008).

The New York City administration through its Office of Long-Term Planning and Sustainability created the NYC Climate Change Adaptation Task Force in 2008, which is now working with local experts, city departments, and stakeholders to develop a comprehensive, integrated climate change risk assessment and adaptation plan for the critical infrastructure of the metropolitan region. The NYC Climate Change Adaptation Task Force is made up of representatives from over 40 city and regional departments and industries. The city administration also convened the New York Panel on Climate Change (NPCC) to provide expert information about climate change risks and adaptation. The NPCC is made up of climate change scientists and experts from the legal field, insurance, telecommunications, and transportation, and has provided the climate risk information needed to create actionable guidelines and plans for adapting the city's critical infrastructure for the projected effects of climate change (NPCC, 2009). The NPCC has also worked with the NYC Climate Change Adaptation Task Force to develop a common set of definitions for adaptation assessment.

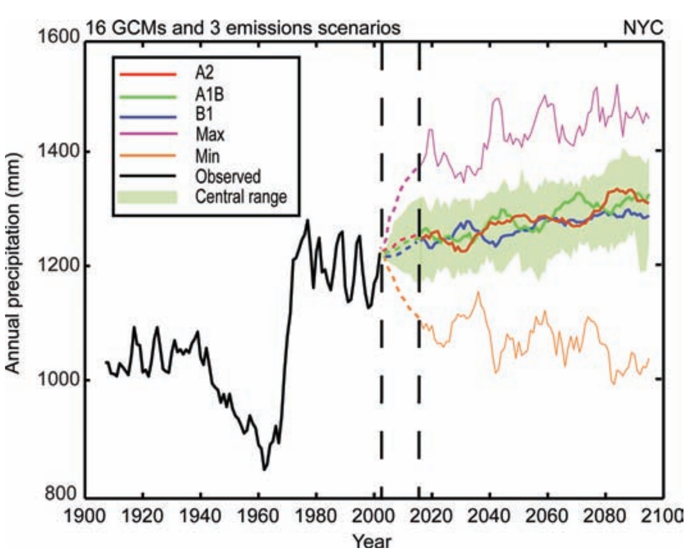


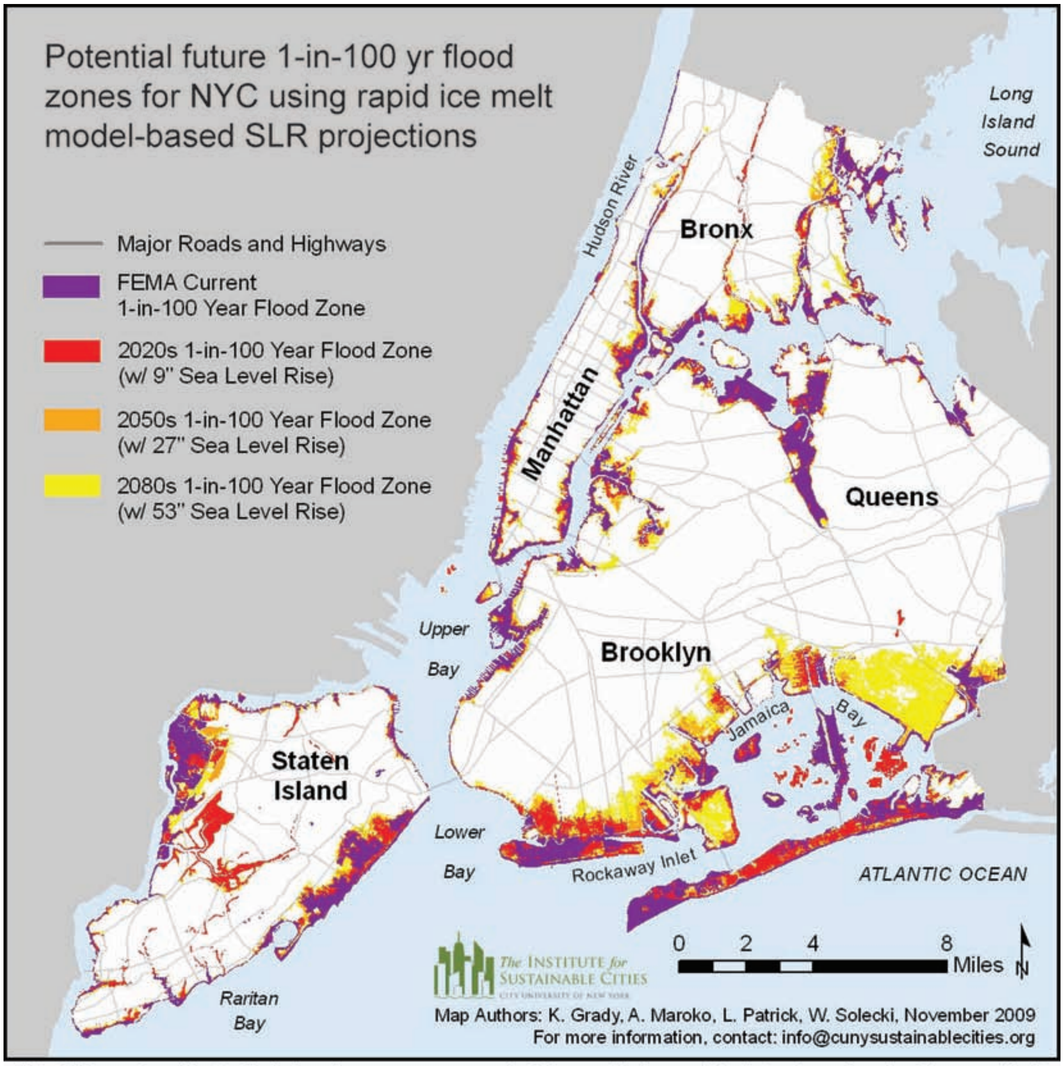
Figure 2.21: *Projected precipitation, New York City.*

The next step is to begin planning and making specific adaptation investments across the city. In the past in New York City, this has tended to be on a project basis and so has been less coordinated across sectors. Having brought decision-makers from all key departments in the city and from numerous sectors, the New York City climate change adaptation process is helping to facilitate more open avenues of communication and coordination within and among departments.

2.8 Cities, disasters risk reduction and climate change adaptation: critical observations and conclusions

The case study risk assessment process through the lens of the preceding disaster risk reduction and climate change adaptation strategy discussion produced several critical observations particularly important for understanding the challenges and opportunities for cities facing climate change. These include the following:

First, a multidimensional approach to risk assessment is a prerequisite to effective urban development programs that incorporate climate change responses. At present most climate risk assessment is dominated by an overemphasis on hazards. The application of the climate risk framework developed in this chapter provides more nuanced and more actionable insights into the differential risks. These insights reflect the exposure to hazards and the spectrum of vulnerabilities faced by urban households, neighborhoods, and firms. However, a critical issue



Note. This map is subject to limitations in accuracy as a result of the quantitative models, datasets, and methodology used in its development. The map and data should not be used to assess actual coastal hazards, insurance requirements or property values or be used in lieu of Flood Insurance Rate Maps issued by FEMA.

Interpretation. The floodplains delineated above in no way represent precise flood boundaries but rather illustrate three distinct areas of interest: 1) areas currently subject to the 1-in-100 year flood that will continue to be subject to flooding in the future, 2) areas that do not currently flood but are expected to potentially experience the 1-in-100 year flood in the future, and 3) areas that do not currently flood and are unlikely to do so in the timeline of the climate projection scenarios used in this research (end of the current century).

Figure 2.22: *Sea level rise projections.*

Source: The Institute of Sustainable Cities (2009).

that requires further research is identifying when strategic retreat may be more cost effective than adaptation and under what socio-economic conditions is it desirable and feasible.

Second, mismatches between needs and responses are occurring in regard to who should mitigate, how much to adapt, and why. Cities need climate change risk assessment, in addition to analysis of mitigation options, in order to decide for themselves what is the appropriate balance of mitigation and adaptation. Climate change risk frameworks, such as those described in this chapter, can help cities to address the issue of mismatches; that is, the difference between the city's response to climate change as opposed to the actual needs. For example, it appears that some developing countries may be over-focusing on mitigation when they could be addressing adaptation more due to the presence of critical climate risks in the near-term as well as in future decades. The 17 largest economies account for most of the greenhouse gas emissions, the root cause of climate change (US Department of State, 2009). And while many cities within these major economies have a significant role in mitigation, it may be prudent for cities in low-income countries with large populations of poor households to incorporate climate risk into ongoing and planned investments as a first step (Mehrotra, 2009). However, since cities play an important role in greenhouse gas emissions in both developed and developing countries, there is also motivation for cities to lead on mitigation activities as well. Emissions from cities everywhere burden the environment, which is a global public good, and thus can be regulated through a combination of market and non-market incentives at the urban scale.

Third, the vertically and horizontally fragmented structure of urban governance is as much an opportunity as an obstacle to introducing responses to climate change. While much has been researched about the need for an integrated and coordinated approach, the fragmented governance structure of cities is unlikely to change in the short term and offers the opportunity to have multiple agents of change. Examples in the case study cities show that early adopters on climate change solutions play an important role. As in the case of New York City, the city's early action has become a model for other cities within the USA and internationally. The broad spectrum of governmental, civil society, and private sector actors in cities encourages a broader ownership of climate change adaptation programs.

Further, gaps and future research for scaled-down regional and local climate models were identified. In addition to the difficulties global climate models have with simulating the climate at regional scales, especially for locations with distinct elevational or land–sea contrasts, they also continue to have difficulty simulating monsoonal climates. Such is the case for climate projections for some of the case study cities in this chapter, especially related to projected changes in precipitation. This is because simulation of seasonal periods of precipitation is challenging in terms of both timing and amount; in some cases the baseline values used for the projection of future changes are extreme – either too high or too low. Therefore, the percentage changes calculated vary greatly and can, on occasions, have distorted values. Especially for precipitation projections, the future trends may appear to be inconsistent when compared to observed data, because the averages from the baseline period to which the projected changes were added are inaccurate, either due to a lack of data or extreme values within the time period that are skewing the averages. The inability of the global models to simulate the climate of individual cities raises the need for further research on regional climate modeling.

However, what is important to focus on in these future climate projections is the general trends of the projected changes and their ranges of uncertainty. These refer to attributes such as increasing, decreasing, or stable trends, and information about the uncertainty of projections in particular due to climate sensitivity or greenhouse gas emission pathways through time. Information on climate model projections regarding the extreme values and the central ranges both provide useful information to city decision-makers.

Annex 2.1 Global institutional structure for risk assessment and adaptation planning[2])

Moving forward, there is a need for a programmatic science-based approach to addressing climate risk in cities of developing countries that are home to a billion slum dwellers, and quickly growing. These cities are most unprepared to tackle climate change-induced stresses that are likely to exacerbate the existing lack of basic urban services such as water supply, energy, security, health, and education, as well as of disaster preparedness and response. Most climate change adaptation efforts until now have focused on lengthy descriptive papers or small experimental projects, each valuable in their own right, but insufficient to inform policymakers. Further, there is little recognition of the need for a flexible strategy to adaptation; instead there are sporadic medium- and long-term project-oriented responses, often lacking analysis of basic climate parameters such as temperature variability, precipitation shifts, and sea level rise data. Three central elements of a comprehensive approach could include:

1. Establishment of a scientific body, which can verify as well as advise on technical matters of climate change science as it pertains to mitigation and impacts on cities;
2. A systematic approach to climate change adaptation;
3. Ongoing assessment of climate change knowledge for cities.

The most pressing needs for developing-country cities in low-income countries is to focus on adaptation, outlined here, but similar measures are essential for mitigation efforts as well.

For adaptation, there is a requirement for assessing risk, evaluating response options, making some politically complex decisions on implementation choices and implementing projects, monitoring process and outcomes, and continuously reassessing for improvements as the science and practice evolve. Further, in order to maximize impact, there is a need to leverage ongoing and planned capital investments to reduce climate-risk exposure, rather than to neglect potential climate impacts. Practitioners and scholars agree that a primary reason why cities neglect climate change risks is lack of city-specific relevant and accessible scientific assessments. Thus, to reduce climate risk in developing-country cities there is a demand for city-specific climate risk assessment as well as the crafting of flexible adaptation and mitigation strategies to leverage existing and planned public investments.

To inform action, the experience of the Climate Impacts Group at NASA's Goddard Institute for Space Studies and scholars at Columbia University and the City University of New York points to a need for at least a four-track approach.

Track 1: Addressing the need for a global progress assessment. This is an across-city global assessment that captures the state-of-knowledge on climate and cities. The First UCCRN Assessment Report on Climate Change and Cities (ARC3) is one of the only ongoing efforts that addresses risk, adaptation, and mitigation, and derives policy implications for the key city sectors – urban climate risks, health, water and sanitation, energy, transportation, land use, and governance. This assessment is an effort by more than 50 scholars located all over the world and offers sector-specific recommendations for cities to inform action. The aim is to continue assessments (on the order of every four years) and offer Technical Support after the UN Framework Convention on Climate Change COP16 has been held in December, 2010 in Mexico City.

2 Annex 2.1 is an excerpt from a White Paper authored by Shagun Mehrotra (April, 2009).

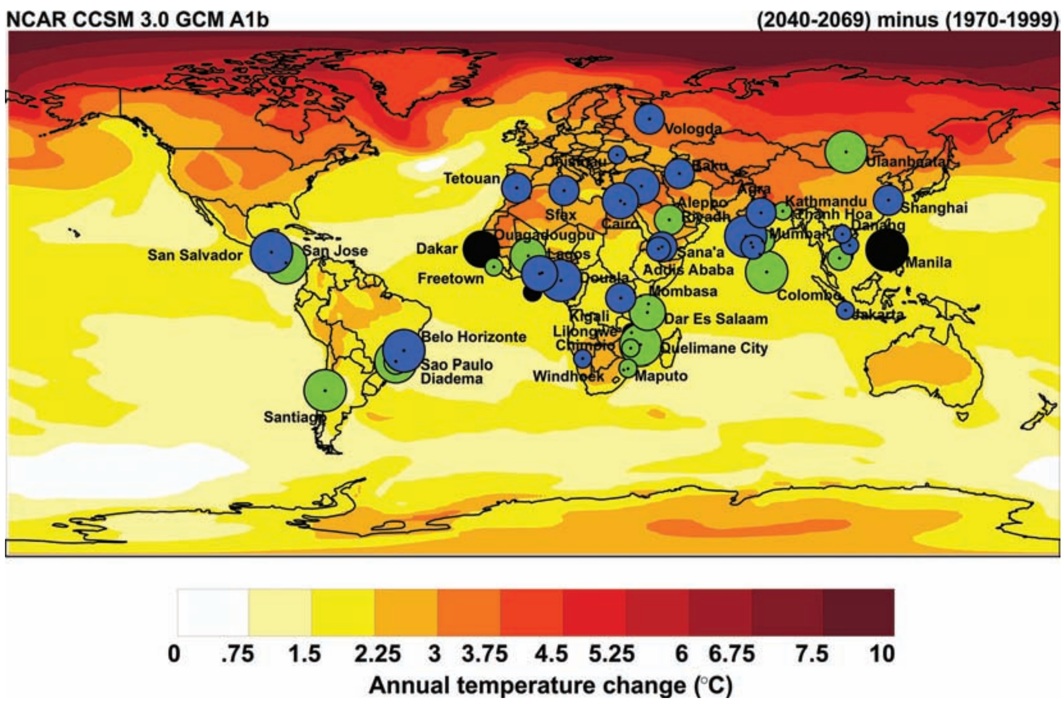


Figure 2.23: *Cities involved in Cities Alliance activities, 2008, and temperature projections for the 2050s. Green circles represent national slum upgrading plans: blue, city development strategies; and black, both.*

Source: This volume, chapter 1; data from Cities Alliance Annual Report 2008.

Track 2: Across-city rapid risk assessment. Mainstreaming climate risk assessment into City Development Strategies as well as pro-poor programs like Cities Alliance's citywide and nationwide slum upgrading. This effort is critical to inform ongoing large-scale capital investments in cities that often lack basic climate risk considerations (see Figure 2.23). For most cities illustrated in Figure 2.23, between 50 and 100 years of observed climate data are available but remain to be analyzed.

Track 3: City-specific in-depth sectoral assessment. General assessments are insufficient as many cities lack in-house expertise for technical analysis of city-specific climate impacts. To fill this gap, there is a requirement to craft city-specific risk and adaptation assessments for city departments (sector by sector) to redirect existing and planned investments. Cities like New York, London, and Mexico City have initiated this demanding, yet essential task. Such risk analysis needs to disaggregate risk into hazards (external climate-induced forcing), vulnerability (city-specific characteristics, such as location, and percentage of slum population), and agency (ability and willingness of the city to respond). The process will engage in-city experts and stakeholders in each city in the assessment process in order to develop local adaptive capacity.

Track 4: Learning from experience. This task involves deriving adaptation lessons from the early climate change

Table 2.6: *Four tracks with objectives, and related outputs.*

Track	Objective	Output
1. Global progress assessment	To provide state-of-knowledge	Providing a global First UCCRN Assessment Report on Climate Change and Cities (ARC3), a comprehensive assessment of risks, adaptation, mitigation options, and policy implications
2. Across-city rapid risk assessment	To inform ongoing urban investments that lack climate risk considerations	Integrate climate risk assessment into City Development Strategies and pro-poor programs
3. City-specific in-depth sectoral assessment	To redirect existing and planned investments	Crafting city-specific risk and adaptation assessments for each city department (sector by sector)
4. Learning from experience	To derive adaptation lessons from the early adopters	Detailed case-studies of implementation mechanisms from London, Mexico City, New York City, etc.

adopters like London, Mexico City, and New York City. It focuses on answering such questions as: How are London, Mexico City, and New York crafting a response to climate change? What are the institutional arrangements? What are the roles of mayoral leadership, public demand, offices of long-term planning, and civil society initiatives? How are assessments financed – for example foundations, scientist-volunteered, tax dollars? What are the positive externalities – such as establishment of the C40 Large Cities Climate Summit – of scaling-up both nationally and internationally? And what are transferable lessons? What can other cities learn from these experiences? Table 2.6 summarizes the four tracks along with their objectives and related outputs.

REFERENCES

Abosede, F. (2006). Housing in Lagos mega city: improving livability, inclusion and governance. Paper presented at the Social and Economic Rights Action Center's (SERAC) international conference: *Building Nigeria's Capacity to Implement Economic, Social and Cultural Rights: Lessons Learned, Challenges and the Way Forward*, Abuja, Nigeria, September 27–28, 2006.

Abosede, F. A. (2008). The challenges of slum upgrading: the Lagos experience. Paper presented at the International Policy Dialogue: *The Challenges of Slum Upgrade: Sharing Sao Paulo's Experience*, Sao Paulo, Brazil, March 10–14, 2008.

Aggarwal, D. and M. Lal (2001). *Vulnerability of Indian Coastline to Sea Level Rise*, New Delhi, India: Centre for Atmospheric Sciences, Indian Institute of Technology.

Assessments of Impacts and Adaptations to Climate Change (2005). *Informe final del proyecto LA 26* [LA 26 project, final report assessment]. Retrieved January 25, 2009, from www.atmo.at.fcen.uba.ar/~lcr/libros/Cambio_Climatico-Texto.pdf.

Awosika, L. F., G. T. French, R. J. Nicholls, and C. E. Ibe. (1993a). Impacts of sea level rise on Nigeria. In *Proceedings of IPCC Symposium: The Rising Challenge of the Sea*, Margarita, Venezuela, March 14–19, 1992.

Awosika, L. F., O. Ojo, T. A. Ajayi, *et al*. (1993b). *Implications of Climate Changes and Sea Level Rise on the Niger Delta, Nigeria, Phase 1*. Report, Nairobi, Kenya: UNEP.

Barros, V., A. Menéndez, C. Natenzon, *et al*. (2005). Climate change vulnerability to floods in the metropolitan region of Buenos Aires City. Paper presented at the *Assessments of Impacts and Adaptations to Climate Change (AIACC) Workshop: Climate Change*, Bellagio, Italy, May 7–12. Retrieved January 25, 2009, from www.aiaccproject.org/working_papers/working_papers.html.

Barros, V., A. Menéndez, C. Natenzon, *et al.* (2008). Storm surges, rising seas and flood risks in metropolitan Buenos Aires. In N. Leary *et al.* (Eds.), *Climate Change and Vulnerability*, London, UK: Earthscan, pp. 117–133.

Basu, R. and J. M. Samet (2002). Relation between elevated ambient temperature and mortality: a review of the epidemiologic evidence. *Epidemiologic Reviews*, **24**, 190–202.

Baumert, K., T. Herzog, and J. Pershing (2005). *Navigating the Numbers: Greenhouse Gas Data and International Climate Policy*, Washington, DC, USA: World Resource Institute.

Blaikie, P., T. Cannon, I. Davies, and B. Wisner (1994). *At Risk: Natural Hazards, People's Vulnerability and Disaster.* London, UK: Routledge.

Bradley, R., B. Staley, T. Herzog, J. Pershing, and K. Baumert (2007). *Slicing the Pie: Sector-based Approaches to International Climate Agreements*, Washington, DC, USA: World Resource Institute.

Bureau of Economic Analysis (2008). *News Release: GDP by Metropolitan for 2006 and Revised 2004–2005*. Retrieved January 25, 2009, from www.bea.gov/newsreleases/regional/gdp_metro/gdp_metro_newsrelease.htm.

Camillioni, I. and V. Barros (2008). Climate. In *Environmental Atlas of Buenos Aires.* Retrieved January 24, 2009, from www.atlasdebuenosaires.gov.ar/aaba/index.php?option=com_content&task=view&id=339&Itemid=188&lang=en.

Campbell, S. and S. S. Fainstein (Eds.) (1996). *Readings in Planning Theory*. Cambridge, UK: Blackwell Publishers.

Carmin, J. and D. Roberts (2009). Government institutions and innovations in governance for achieving climate adaptation in cities. *Fifth Urban Research Symposium*, Marselles, France. June, 2009.

City of New York (2007). *plaNYC: A Greener Greater New York*. NewYork, USA: The City of New York. Retrieved January 5, 2009, from www.nyc.gov/html/planyc2030/html/downloads/the-plan.shtml.

City of New York (2009). *Financial Plan, Summary: Fiscal Years 2009–2013*. New York, USA: Office of Management and Budget, May 1. Retrieved June 9, 2009, from www.nyc.gov/html/omb/html/publications/finplan05_09.shtml.

Clichevsky, N. (2002). *Pobreza y políticas urbano-ambientales en Argentina* [Poverty and urban-environmental policies in Argentina], Santiago de Chile: CEPAL – ECLAC, División de Medio Ambiente y Asentamientos Humanos.

Defensoría del Pueblo de la Ciudad de Buenos Aires (2006). *Informe de situación. Desalojos de "Nuevos Asentamientos Urbanos"* [Situation report. Eviction of "New urban settlements"]. Retrieved January 25, 2009, from www.defensoria.org.ar/institucional/doc/asentamientos.doc.

Delhi (2009). In *Encyclopædia Britannica*. Retrieved June 2, 2009, from Encyclopædia Britannica Online: www.britannica.com/EBchecked/topic/156501/Delhi.

Department of City Planning (2009). New York City: Department of City Planning. Retrieved January 15, 2009, from www.nyc.gov/html/dcp/.

Department of Environment (2008). *Delhi, Amongst the Greenest Capitals of the World*, New Delhi, India: Department of Environment, Government of National Capital Territory of Delhi.

Department of Health and Mental Hygiene (2006). *DOHMH Vital Signs: 2006 Heat Wave Investigation Report*. Retrieved from www.nyc.gov/html/doh/downloads/pdf/survey/survey-2006heatdeaths.pdf – 2006–11–15.

Department of Planning (2008). *Economic Survey of Delhi 2007–08*, New Delhi: The Government of the National Capital Territory of Delhi, Government of India. Retrieved January 05, 2009, from www.delhi.gov.in/wps/wcm/connect/doit_planning/Planning/Economic±Survey±of±Delhi/.

Delhi Development Authority (2005). *Master Plan for Delhi, 2021*, New Delhi, India: Development Authority, Government of National Capital Territory of Delhi, Government of India. Retrieved January 5, 2009, from www.dda.org.in/planning/draft_master_plans.htm.

Directorate for Statistics and Census (2007). *Anuario Estadístico 2006* [Statistical Yearbook 2006]. Gobierno de la Ciudad de Buenos Aires, Ministerio de Hacienda. Retrieved January 25, 2009, from http://buenosaires.gov.ar/areas/hacienda/sis_estadistico/anuario_2006/ cap_11.htm.

Douglas, I. and K. Alam (2006). *Climate Change, Urban Flooding and the Rights of the Urban Poor in Africa: Key Findings from Six African Cities*, London, UK: ActionAid International. Retrieved from www.actionaid.org.uk/doc_lib/urban_flooding_africa_report.pdf.

Ekanade O., A. Ayanlade, and I. O. O. Orimogunje (2008). Geospatial analysis of potential impacts of climate change on coastal urban settlements in Nigeria for the 21st century. *Journal of Geography and Regional Planning*, **1**(3), 49–57. Retrieved from www.academicjournals.org/JGRP.

Falczuk, B. (2008). Surface water. In *Environmental Atlas of Buenos Aires*. Retrieved January 24, 2009, from /www.atlasdebuenosaires.gov.ar/aaba/index.php?option=com_content&task=view&id=339&Itemid=188&lang=en.

Federal Republic of Nigeria (2006). *Report of the Presidential Committee on Redevelopment of Lagos Mega-city Region*, Lagos: Lagos Megacity Project.

Folorunsho, R. and L. F. Awosika (1995). Nigerian meteorological induced changes along the Nigerian coastal zone and implications for integrated coastal zone management plan. In *Proceedings of BORDOMER '95, International Convention: Rational Use of Coastal Zone*, Bordeaux, France, February 6–10, 1995.

French, G. T., L. F. Awosika, and C. E. Ibe (1995). Sea level rise and Nigeria: Potential impacts and consequencies. *Journal of Coastal Research*, **14**, 224–242.

González, S. (2005). Ciudad visible vs. ciudad invisible: la gestión del riesgo por inundaciones en la Ciudad de Buenos Aires. *Territorios*, **13**, 53–67.

Government of India (2002). *Climate Change and India*, New Delhi, India: Government of India. Retrieved January 12, 2009 from http://envfor.nic.in/cc/index.htm.

Government of India (2008). *National Action Plan for Climate Change*, New Delhi, India: Government of India.

Hallegatte, S., F. Henriet, and J. Corfee-Morlot (2008). *The Economics of Climate Change Impacts and Policy Benefits at City Scale: A Conceptual Framework* (Environment Working Papers No. 4), Paris, France: Environment Directorate, Organisation for Economic Co-operation and Development.

Helmer, M., and D. Hilhorst (2006). Natural disasters and climate change. *Disasters* **30**(1) 1–4.

Hunt, A. and P. Watkiss (2007). *Literature Review on Climate Change Impacts on Urban City Centres: Initial Findings* (ENV/EPOC/GSP(2007)10), Paris: Environment Directorate, Organisation for Economic Co-operation and Development.

Huq, S., H. Reid, M. Konate, *et al*. (2004). Mainstreaming adaptation to climate change in Least Developed Countries (LDCs). *Climate Policy*, 4(1) 25–43.

ICS (International Council for Science), Planning Group on Natural and Human-induced Environmental Hazards and Disasters (2008). *A Science Plan for Integrated Research on Disaster: Addressing the Challenge of Natural and Human-Induced Environmental Hazards*. ICSU.

Instituto Nacional de Estadística y Censos (2003). *¿Qué es el Gran Buenos Aires?* [What is Greater Buenos Aires?]. Retrieved January 25, 2009, from www.indec.gov.ar/glosario/folletoGBA.pdf.

International Strategy for Disaster Reduction (2010). Hyogo Framework for Action 2005–2015: Building the Resilience of Nations and Communities to Disasters. **http://www.unisdr.org/eng/hfa/hfa.htm**.

IPCC (2001a). *Special Report on Emissions Scenarios: A Special Report of Working Group III of the Intergovernmental Panel on Climate Change*. N. Nakicenovic, J. Alcamo, G. Davis, *et al.* (Eds.). Cambridge, UK: Cambridge University Press.

IPCC (2001b). *Climate Change 2001: Working Group II: Impacts, Adaptation and Vulnerability*. Assessment Report, Intergovernmental Panel on Climate Change.

IPCC (2007a). *Climate Change 2007: The Physical Science Basis. Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change*. S. Solomon, D. Qin, M. Manning, *et al.* (Eds.). Cambridge, UK and New York, USA: Cambridge University Press.

IPCC (2007b). *Climate Change 2007: Impacts, Adaptation And Vulnerability. Contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change*. M. L. Parry, O. F. Canziani, J. P. Palutikof, P. J. van der Linden, and C. E. Hanson (Eds.). Cambridge, UK: Cambridge University Press.

IPCC (2007c). *Climate Change 2007: Mitigation. Contribution of Working Group III to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change*. B. Metz, O. R. Davidson, P. R. Bosch, R. Dave, and L. A. Meyer (Eds.). Cambridge, UK and New York, USA: Cambridge University Press.

IPCC (2007d). *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 [Core Writing Team, R. K. Pachauri A. and Reisinger (Eds.)]. Geneva, Switzerland: IPCC.

Iwugo, O. K., B. D'Arcy, and R. Anoch (2003). Aspects of land based pollution of an African coastal megacity of Lagos. Paper presented at the *International Water Association International Conference*: *Diffuse Pollution and Basin Management*, Dublin, Ireland. August 17–22, 2003.

Kasperson, J. X. and R. E. Kasperson (Eds.) (2001). *Global Environmental Risk*, Tokyo, Japan: United Nations University Press.

Kinney, P. L., M. S. O'Neill, M. L. Bell, and J. Schwartz (2008). Approaches for estimating effects of climate change on heat-related deaths: challenges and opportunities. *Environmental Science and Policy*, **11**, 87–96.

Knowlton, K., L. Barry, A. G. Richard, *et al*. (2007). Projecting heat-related mortality impacts under a changing climate in the New York City region. *American Journal of Public Health*, **97**(11), 2028–2034. Retrieved January 31, 2009, from ABI/INFORM Global database.

Mehrotra, S. (2003). *Unfinished Promise: Institutionalising Local Knowledge for Risk Reduction in Earthquake-Prone Settlements of the Poor: Porbandar District, Gujarat, India*, ProVention Consortium, Applied Research Grant proposal, Washington, DC, USA: World Bank.

Mehrotra, S. (2009). *Climate and Cities: Crafting a Global Institutional Structure for Risk Assessment and Adaptation Planning*, White paper, New York, USA: Columbia University, and NASA Goddard Institute of Space Studies.

Mehrotra, S., C. E. Natenzon, A. Omojola, *et al.* (2009). *Framework for City Climate Risk Assessment, Buenos Aires, Delhi, Lagos, and New York*. Washington, DC, USA: World Bank.

Menéndez, A. (Ed.) (2005). Componente B1, Vulnerabilidad de la zona costera [B1 Component, Vulnerability of the coastal zone]. In *Cambio Climático: Segunda Comunicación Nacional Gobierno de la República Argentina Informe final*, Fundación Di Tella, Fundación Bariloche, Global Environment Facility, World Bank.

Mercer, J. A. (2010). Disaster risk reduction or climate change adaptation: Are we reinventing the wheel? *Journal of International Development* **22** 247–264.

Murgida, A. (2007). *Informe Final: Amenazas-Vulnerabilidad-Adaptación y Mitigación, Ciudad Autónoma de Buenos Aires* [Final Report Assessment: Threats-Vulnerability-Adaptation and Mitigation, Autonomous City of Buenos Aires], Buenos Aires, Argentina: Oficina de Protección Climática y Eficiencia Energética, GCABA, mimeo.

Murgida, A. M. and S. G. González (2005). Social risk, climate change and human security: an introductory case study in Metropolitan Area of Buenos Aires (Argentina). In *Proceedings of International Workshop: Human Security and Climate Change*, Oslo, Norway, June 21–23, 2005.

Murgida, A. M. and C. E. Natenzon (2007). Social 'downscaling': a few reflections on adaptation in urban environments. In *Proceedings of III Regional Conference on Global Changes, Round table 4: Urban aspects*. São Paulo, Brazil. November 4–8, 2007.

Natenzon, C. and J. M. Viand (2008). Gestión de los desastres en Argentina: instituciones nacionales involucradas en la problemática de las inundaciones [Disaster management in Argentina: national institutions involved in the flooding problem]. In A. I. Geraiges de Lemos, J. L. Sanches Ross, and A. Luchiari (Org.), *América Latina: sociedade e meio ambiente* (pp. 171–185), São Paulo, Brazil: Expressão Popular.

New York City Department of Environmental Protection (2008). *The Assessment and Action Plan: A Report Based on the Ongoing Work of the DEP Climate Change Task Force*, New York, USA: The New York City Department of Environmental Protection.

New York City Panel on Climate Change (2009). *Adaptation Assessment Guidebook*. Prepared for use by the New York City Climate Change Adaptation Task Force. Retrieved from www.nyc.gov/html/om/pdf/2009/NPCC_CRI.pdf.

NYSE Euronext (2009). *NYSE Euronext*. Retrieved June 9, 2009, from www.nyse.com/about/listed/1170350259411.html.

O'Brien, G., P. O'Keefe, J. Rose, and B. Wisner (2006). Climate change and disaster management. *Disasters*, **30**(1), 64–80.

Ogun State Government (2005). *Ogun State Regional Plan 2005–2025: Development Pressure Area, DPA report*.

Parsons, E. A., V. R. Burkett, K. Fisher-Vanden, *et al.* (2007). *Global-change Scenarios: Their Development and Use, Sub-report 2.1B of synthesis and assessment product 2.1 by the US climate change science program and the subcommittee on global change research*, Washington, DC, USA: Office of Biological & Environmental Research, Department of Energy.

Pelling, M. (2003). *The Vulnerability of Cities*. London, UK: Earthscan.

Pelling, M., A. Maskrey, P. Ruiz, L. Hall (Eds.) (2004). *A Global Report: Reducing Disaster Risk a Challenge for Development.* New York: United Nations Development Programme, Bureau for Crisis Prevention and Recovery.

Pírez, P. (2002). Buenos Aires: fragmentation and privatization of the metropolitan city. *Environment and Urbanization*, **14**(1), 58–76.

Pírez, P. (2008). Planning. In *Environmental Atlas of Buenos Aires*. Retrieved January 28, 2009, from www.atlasdebuenosaires.gov.ar/aaba/index.php?option=com_content&task=view&id=34&Itemid=30&lang=en.

Pochat, V., C. E. Natenzon, and A. Murgida (2006). Domestic policy frameworks on adaptation to climate change in water resources. Argentina country case study. In UNFCCC/OECD Global Forum on Sustainable Development: *Working Together to Respond to Climate Change: Annex I Expert Group Seminar*. Paris, France, March 27–28. Retrieved from www.oecd.org/dataoecd/29/2/36448827.pdf.

Prabhakar, S.V.R.K, A. Srinivasan, and R. Shaw (2009). Climate change and local level disaster risk reduction planning: need, opportunities and challenges. *Mitigation and Adaptation Strategies to Global Change*, **14**, 7–13.

Rawls, J. (1971). *A Theory of Justice*. London, UK: Oxford University Press.

Revi, A. (2007). *Climate Change Risk: An Adaptation and Mitigation Agenda for Indian Cities*, India Background Paper for Global Urban Summit, Bellagio, Italy, July 2007.

Ríos, D. and González, S. (2005). La aglomeración gran Buenos Aires [The greater Buenos Aires agglomeration]. In *Cambio Climático, Segunda Comunicación Nacional. Gobierno de la República Argentina. Informe final*, Fundación Di Tella, Fundación Bariloche, Global Environment Facility, World Bank.

Rosenzweig, C. and Hillel, D. (2008). *Climate Variability and the Global Harvest: Impact of El Niño and Other Oscillations on Agro-Ecosystems*. New York, USA: Oxford University Press.

Rosenzweig, C. and Solecki W. D. (Eds.) (2001). *Climate Change and a Global City: The Potential Consequences of Climate Variability and Change – Metro East Coast*. Report for the US Global Change Research Program, *National Assessment of the Potential Consequences of Climate Variability and Change for the United States*. New York, USA: Earth Institute at Columbia University.

Satterthwaite, D., Huq, S., Pelling, M., Reid H., and Lankao-Romero, P. (2007). *Adapting to Climate Change in Urban Areas: The Possibilities and Constraints in Low- and Middle-income Nations* (Climate Change and Cities Series, Discussion Paper, No. 1), London, UK: International Institute for Environment and Development (IIED).

Sen, A. (1999). *Development as Freedom*, New York, USA: Anchor Books.

Servicio Meteorológico Nacional (2008). *Informes estacionales* [Climate Data]. Retrieved January 24, 2009, from www.smn.gov.ar/?mod=clima&id=5

Shook, G. (1997). An assessment of disaster risk and its management in Thailand. *Disasters*, **21**(1), 77–88.

Thomalla, F., T. Downing, E. Spanger-Siegfried, G. Han, and J. Rockstrom (2006). Reducing hazard vulnerability: towards a common approach between disaster risk reduction and climate adaptation. *Disasters*, **30**(1), 39–48.

UK Climate Impacts Programme (2009). Retrieved from www.ukcip.org.uk/index.php.

United Nations Development Programme (2004). *Human Development Report*. Retrieved from www.hdr.undp.org.

UN-HABITAT (2003). *Slums of the World: The Face of Urban Poverty in the New Millennium*? Nairobi, Kenya: Global Urban Observatory, UN-HABITAT.

UN-HABITAT (2004). *State of the Lagos Mega City and other Nigerian Cities Report*. Lagos, Nigeria: UN-HABITAT and Lagos State Government.

UN-HABITAT (2006). A tale of two cities. In *World Urban Forum III, An International UN-Habitat Event: Urban Sustainability*, Vancouver, Canada, June 19–23, 2006.

UN-HABITAT (2008a). *The State of World's Cities 2008/2009: Harmonious Cities*, London, UK: Earthscan.

UN-HABITAT (2008b). *The State of African Cities 2008: Framework for Addressing Urban Challenges in Africa*, Nairobi, Kenya: UN-HABITAT.

US Census Bureau (2008). *State and County QuickFacts*. Retrieved January 25, 2009, from http://quickfacts.census.gov/qfd/states/36/3651000.html.

US Department of State (2009). *Major Economies Forum on Energy Security and Climate Change*. Retrieved from www.state.gov/g/oes/climate/mem/#.

Van Aalst, M.K. (2006). The impacts of climate change on risk of natural disasters. *Disasters*, **30**(1), 5–18.

Van Aalst, M.K., T. Cannon, and I. Burton (2007). Community level adaptation to climate change: The potential role of participatory community risk assessment. *Global Environmental Change*, **18**, 165–179.

World Bank, Global Facility for Disaster Reduction and Recovery (2008). *Climate Resilient Cities, 2008 Primer: Reducing Vulnerabilities to Climate Change Impacts and Strengthening Disaster Risk Management in East Asian Cities.* Washington, DC, USA: World Bank/International Bank for Reconstruction and Development.

World Bank (2009). *Glossary*. Retrieved June 9, 2009, from http://youthink.worldbank.org/glossary.php#ppp.